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FOREWORD

NRSC-R39, Final Report – 1990 FM Technical Study, details technical work done by the broadcast consulting engineering firm of Lahm, Suffa & Cavell Inc. (now Cavell, Mertz & Associates, Inc.) on behalf of the National Association of Broadcasters (NAB), to examine the FCC rules for regulating interference between FM broadcast stations and fundamental standards from which they were derived. This report was submitted to NAB on October 23, 1990.

The NRSC is jointly sponsored by the Consumer Electronics Association and the National Association of Broadcasters. It serves as an industry-wide standards-setting body for technical aspects of terrestrial over-the-air radio broadcasting systems in the United States.

Final Report

1990 FM TECHNICAL STUDY

prepared for
National Association of Broadcasters
Washington, D.C.

23 October 1990

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EXECUTIVE SUMMARY

This Final Report concludes the 1990 FM Technical Study. The focus of this Study has been the technical standards utilized by the Federal Communications Commission (FCC) to regulate interference between FM broadcast stations. Both that agency's rules and the fundamental standards from which they were derived have been examined. Improvements directed toward improving FM service and preventing increases in interference between FM stations are presented.

The FCC's technical and procedural rules which govern FM broadcasting have not been thoroughly re-examined since the Docket 14185 proceeding of the early 1960s. FM broadcasting was, at that time, an emerging medium. The present rules and standards hail from a bygone era of few FM stations, vacuum tube receivers connected to rooftop antennas, and manual engineering techniques.

Although those standards were appropriate when adopted, they may not be sufficiently effective in an era of crowded spectrum, Walkman™ receivers, stereophonic listening, and digital storage of terrain data for the entire country in a space the size of a sandwich. Now that the FM service is mature, the regulatory scheme employed should be designed therefor. The Commission should be petitioned to initiate a wide-ranging review of its technical and procedural rules, along with the fundamental engineering standards and assumptions upon which its rules are based.

All existing interference regulatory mechanisms are based on a radio wave propagation model which assumes (1) a receiving antenna elevation of 30 feet (9.1 meters) above foreground terrain, (2) a certain "correction" for terrain "roughness" in the its derivation, and (3) a presumed nominal value of "roughness correction" in its application. The typical FM listener is not utilizing the home rooftop antenna which the 30 foot elevation is correlated to. The "correction" for "roughness" has little to do with terrain irregularity at all, is mostly based on UHF-TV data, and was roundly criticized upon its proposal. Use of that "correction" in predicting coverage was suspended almost immediately after its adoption. However, the technique continues to impact service and interference predictions because the propagation model was developed from data "corrected" in accord with presumed "roughness" effects.

Accordingly, a new generalized propagation model should be adopted for FM planning purposes which is not contaminated by inappropriate "roughness correction" assumptions and which facilitates the specification of lower receiving antenna elevations. The Rice 1990 formula model, described in Appendix E, is believed to represent, at the worst, a good starting point for such an effort.

Desired-to-undesired signal ratios define interference at a station's recognized service boundary. Present co-channel and first adjacent channel D/U ratios were developed for monaural service. Fresh analysis of D/U ratio requirements utilizing contemporary receivers, particularly for the second and third adjacent channel cases, is considered a necessary part of developing revised technical standards. Multiple-signal interference is also in need of contemporary study.

Assumption of a more realistic receiving antenna elevation, 6½ feet (2 meters), is shown by Appendix B to necessitate greater separation distance standards if the present desired-to-undesired (D/U) signal ratios are to be achieved. This is because lower receiving heights cause more loss of within-the-horizon desired signals than beyond-the-horizon interference. Protection of stations by means of field strength contour location is also more stringent for a lower receiving height. To better protect FM stations from interference, assumption of a lower receiving antenna elevation is recommended.

The existing allotment standards and procedures facilitate crowding of the FM band because (1) technical standards designed for evaluation of *specific* station placements (assignments) are employed to make a frequency *generally available* near the community to which it is alloted and (2) the allotment and application proceedings are not adequately coordinated as to filing and cut-off dates. By the time applications are filed for an allotment, no fully-spaced transmitter sites may be available. It is recommended that consideration be given to combining these proceedings to eliminate timing problems. If the two-step process of allotment and later assignment is to be retained, it is recommended that allotment proponents be required to demonstrate the availability of adequate transmitter sites and that such siting areas be protected from encroachment by later allotment proposals and, perhaps, other applications.

Because implementation of technical standards premised on lower receiving heights and field strengths will require more stringent interstation separation distance standards, it is believed that most stations will become short spaced. The administration of existing short spacings has caused a great administrative headache for the FCC over the years. Therefore, it is believed that administrative efficiency favors use of contour protection as the interference evaluation technique for *applications*, where specific knowledge of the transmitter site and propagation environment is available. Modern desktop computer technology greatly facilitates implementation of such a procedure. Such a method will better protect stations whose service areas extend beyond the normal range due to favorable terrain and will lessen overprotection where unfavorable terrain limits service and interference ranges, facilitating service in an overall sense.

It has long been recommended that a less approximate propagation model be adopted for predictions of service and interference. Various propagation models are described in Appendix D. There does not exist a complete, empirically verified model for point-to-area (broadcast) service at FM frequencies that considers important factors such as diffraction over irregular terrain, atmospheric refractivity, and terrain cover/clutter in a specific way. Neither adjustments to simple propagation models, use of the CCIR broadcast propagation model, nor implementation of the Area Mode of the NTIA's Irregular Terrain Model improved field strength predictions for the 30 sample FM stations studied, as detailed in Appendices E and F. Some guidance on development of an improved model is available in the literature. Personal computer technology facilitates more detailed evaluation of terrain effects and the use of refractivity and cover/clutter data. There may be sufficient interest in government and industry to convene a joint effort at development of such a technique.

Improved interference standards will be ineffective if stations radiate excessive power in directions critical to protection. Side-mounted FM antennas, supposedly "omnidirectional", render directional coverage to one extent or another due to the interaction of the antenna with the support/feed structure. The Commission's rules should be revised to prevent abuse of side-mounted antennas, while accomodating small antenna radiation variations that have limited interference impact, if any.

When the station proposing a short-spaced transmitter site and processing of its application under §73.215 of the Commission's Rules is of a lower class than the station to which it is short spaced, any interference that results is likely to affect the proponent station more than the existing station. The foregoing station class relationsip is the situation for a majority of the §73.215 filing cases studied, as detailed in Appendix H. Therefore, it appears that applications filed under the "contour protection" provisions of §73.215 present little or no greater interference threat to existing stations than do stations with barely sufficient spacing, evaluated under §73.207. Most §73.215 proposals involve Class A proposals, many for 6 kW upgrades. The second most prevalent group of filings under §73.215 are applications for new stations. This is believed to reflect the crowding of allotments and inability of the allotment technical and procedural standards to assure and maintain fully spaced site location zones of adequate size.

This study demonstrates the need for a wide-ranging overhaul of the technical and procedural rules governing FM stations' service and the interference they can potentially cause each other. Now that the band is mature, allotment and assignment standards should facilitate maintenance of service and avoidance of interference over the addition of more and more allotments, many of which may be barely viable from an engineering point of view.

INTRODUCTION

This 1990 FM Technical Study concerns the effectiveness of the Rules and Regulations promulgated by the Federal Communications Commission (FCC) in controlling interference between U.S. FM stations. Such interference is presently regulated by two sets of standards: a primary means, based on interstation separation distance requirements, and a secondary method, which requires that contours of certain predicted field strength values not overlap (intersect).

The validity and effectiveness of interference protection standards, be they based on separation distances or contour protection, is dependent upon the pertinence of the assumptions underlying their derivation and implementation. The contour distances which form the basis of the separation standards are determined from propagation prediction techniques which, in turn, are based on certain assumptions as to terrain conditions, receiving antenna height, and other details. The contour values at which such distances are determined are derived from minimum usable field strength and desired-to-undesired (D/U) signal ratio considerations. If there exist flaws in the contour field strengths specified or if the propagation prediction method is erroneous or based on impertinent assumptions, the protection of FM stations from interference may be ineffective or partially flawed.

Therefore, this 1990 FM Technical Study will focus primarily on the assumptions and methods upon which the FCC's interference protection standards for FM stations are based. This Study will review the derivation of separation distances and suggest interim changes therein. The application of those distances at the allotment stage will be described and changes in procedures will be offered that should slow the crowding of FM stations. The possibility of improving the propagation model that underlies contour definition and protection techniques is evaluated, along with recommendations for direction of emphasis in efforts to improve such models. Finally, this Study will present an evaluation of those FM proposals filed under §73.215 of the Commission's Rules prior to 30 April 1990, determining their interference potential.

This Final Report incorporates much material submitted in six Draft Reports previously submitted as part of this Study.

Part I: PRESENT FCC FM ASSIGNMENT SYSTEM

North American FM broadcasting utilizes the frequency band from 88 to 108 Megahertz (Mhz), with channel assignments made every 0.2 Mhz, starting at 88.1 Mhz. One hundred channels are thus available. The lower 20 are reserved for noncommercial broadcasting; the remaining 80 available for commercial or noncommercial use.

The system currently used by the FCC in creating commercial FM stations is a two-step process in which (1) a vacant frequency is determined to be available for use in a particular community and is *allotted* thereto, followed by (2) the acceptance of applications proposing *assignment* of specific uses for that allotment.[1] The original purpose of this approach was to permit stations to be planned and assigned nationwide in an orderly and equitable manner, so as to maximize efficiency of frequency reuse without overly disrupting operations existing at the time the procedure was adopted. A complete history of the development of FCC FM technical standards and procedures is contained in Appendix A.

Virtually every allotment made during nationwide rule making proceedings (e.g., Dockets 14185 and MM 84-231) now has a licensed station assigned to it or application for its use pending. New allotments currently result from petitions proposing single station class upgrades or allotment of one particular channel to a community. Multiple-community proposals ordinarily occur only when it is necessary to change existing allotments or assignments in order to accommodate a desired upgrade or new allotment.

Allotment of Frequencies to Communities

A party desiring to introduce new FM service on a frequency (channel) not already assigned for use at the community of interest must first file a Petition for Rule Making to allot the channel to that place. Section 1.401(c) of the FCC's Rules requires that the petitioner submit "all facts, ... , and data deemed to support the action requested." There is no specific technical showing required by the rules, although the Commission staff may declare petitions to be incomplete if the supporting technical details are not included therewith.

Proposed allotments are evaluated based on minimum distance separations between the specified community of allotment, or a (usually arbitrary) reference point located near that community, and (a) licensed, authorized, or proposed stations and (b) other communities at which allotments have been made but do not yet have proposed uses.[2] Distances are computed and evaluated for assignments and allotments made on the same frequency as that which is proposed to be allotted and for those operating on the first, second, and third adjacent channels,

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/1 Section 73.203 of the Commission's Rules establishes this approach for FM stations.

/2 The distance separation standards are set forth in §73.207 of the Commission's Rules.

along with those FM channels 10.7 MHz above or below the proposed channel. If the computed distances exceed the minimum requirements of §73.207, and there is no conflict with any other timely-filed allotment proposal, the frequency desired (or a non-conflicting substitute selected by the FCC staff) is allotted to the specified community.

Assignment of Uses to Allotments

Applications proposing the assignment (specific use) of an allotted frequency are primarily evaluated under the same technical criteria as are proposed allotments, except that the specific transmitter site proposed is used instead of a "reference" site in determining interstation distances. FM station applications are presently reviewed for compliance with allocation standards primarily on the basis of the transmitter site distance separation minima set forth in §73.207 and §73.213(c)(1) of the FCC's Rules. If the proposal is not in compliance with either of the aforementioned technical standards, the *applicant* may request evaluation of its proposal under the standards set forth in §73.215 of the Commission's Rules. That section permits the acceptance of short-spaced proposals where it is demonstrated that interference is not likely to exist because certain field strength contours do not overlap.

Separation Distance Requirements

The minimum separation distances between stations are presently based on the idealized distances to protected and interfering signal strength ranges for the station relationship involved, assuming that each allotment or assignment operates with the maximum power and height permitted for its class. No consideration is made with regard to the interference between the proposed allotment and existing stations that might be predicted for the actual physical situation involved, unless processing of the application under the provisions of §73.215 was specifically requested by the *applicant*.[3]

Contour Definition and Protection

The FCC has traditionally defined service areas for all broadcast services through the administratively simple concept of a boundary defined by a specific signal strength contour.[4] The contour is the locus of points where a reasonable signal strength level is predicted, sufficient to overcome noise in the absence of interference. For administrative purposes, it is assumed that service is adequate within this boundary but is deficient outside it. The signal strength level

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/3 Interference protection is disclaimed in §73.209 of the Commission's Rules.

/4 See the Table of §73.182(s) of the Commission's Rules for AM, §73.215(a)(1) and §73.509 for FM, and §73.683(a) for TV signal strength contour definitions.

definition of service area often does not result in establishment of a uniform (i.e., purely circular) coverage boundary; that effect is inherent in the methods used.

Interference is said to occur when the potentially interfering signal strength exceeds a fraction of the desired signal strength at a given receiving location (e.g., the service boundary), said fraction being defined as the desired-to-undesired (D/U) signal ratio. Different D/U ratios are established for different frequency assignment relationships, such as co-channel and first, second, and third adjacencies.[5] D/U ratios are derived fundamentally from subjective studies of listener annoyance by undesired signal or noise interference.

Just as service boundaries were defined by contours of specified field strength, interference boundaries may be established based on those service field strength values plus the D/U ratios. Where the service and interference boundaries overlap, interference may result. This method of interference regulation has been used in the AM, noncommercial FM, and low-power television (LPTV) services.[6] This is an administratively simple "go/no go" evaluation technique which speeds proposal processing. It is implemented both ways, i.e., a proposed station assignment cannot cause interference to, nor accept interference from, previous assignments.

The validity and effectiveness of interference protection standards, be they based on separation distances or contour protection, is dependent upon the pertinence of the assumptions underlying their derivation and implementation. These details will be considered in the remainder of this document.

Part II: SEPARATION DISTANCE REQUIREMENTS

Both prospective allotments and actual station assignments are initially evaluated for acceptability using the interstation distance separation tables set forth in §73.207 and §73.213(c)(1) of the FCC's Rules. The distances contained within those tables were generally derived as follows. First, distances to pertinent normally protected and potentially interfering contours were determined by means of the propagation graphs of §73.333, Figures 1 (F{50,50}) and 1a (F{50,10}). These contour distances presume use of the maximum permitted facilities for the pertinent station classes. Those critically related contour distances are then added to yield the separation required.

/5 Section 73.215(a)(2) of the Commission's Rules establishes D/U ratios for the pertinent channel relationships in the FM broadcast band.

/6 Contour protection standards are set forth in §73.37 and the Table to §73.182(s) for AM stations, §73.215(a) and §73.509 for FM stations, and §74.705/6 for LPTV stations.

The separation distances adopted when this method of interference protection was chosen were quite approximate.[7] In some cases, distances established at earlier times have been maintained, despite changes in the propagation graphs during intervening years or adoption of more precise rounding procedures. Such retention of obsolete standards enhances interference protection in some cases and lessens it in others. In one case involving a pre-existing insufficient spacing,[8] the interference situation was determined from the previously specified separation. The criteria so defined were then used to establish contour and D/U ratio values for use in determining a new separation distance for a higher operating power. This approach effectively perpetuated a substandard interference criterion.

Determination of idealized contour ranges from a generalized propagation prediction method was designated by the Television Allocations Study Organization (TASO) as a *Type I* approach to interference control (TASO, 1959). The three types of interference administration and service prediction methods described by the TASO will be discussed later in this Final Report.

Receiving Antenna Height Effects

The propagation graphs of §73.333 were derived for a receiving antenna elevation of 30 feet (9.1 meters), typical of residential rooftop receiving antenna installations. In the early days of FM broadcasting, many FM receivers were connected to rooftop antennas, which were also used for television reception. Furthermore, such a receiving antenna elevation has long been considered to be necessary to limit the contamination of field strength measurements by ground reflections. Correlation of field measurements and predictions is facilitated by the use of identical receiving elevation assumptions.

Modern FM receiving situations are, typically, automotive, portable, and desktop. Few involve the use of well-elevated or directional (gain) receiving antennas. A realistic receiving antenna elevation is 6½ feet (2 meters). The pertinence of the curves shown in §73.333 to the environment and use experienced by typical FM receivers today is, therefore, questionable. Therefore, the adequacy of the interstation distance separation standards is doubted.

Adjustment factors have been used over the years to equate signal strengths at lower receiving antenna heights to those measured or predicted for the "standard" 30 foot elevation. In some cases, field strength measurements have been taken at relatively low elevations (such as 10

/7 Initially, separation distances were rounded to the nearest 5 miles (8 kilometers) from underlying contour distance ranges. *see* Footnote 15 to the First Report and Order, cited at note 15 herein.

/8 Specifically, the situation involving the first adjacent channel relationship between Class A and Class B stations feet / 3 meters) and adjusted to "30 foot equivalent" values by assumption of a linear receiving antenna height gain function (9.5 dB for the 10 foot example). Similarly, field strengths predicted for a receiving elevation of 30 feet are sometimes adjusted downward to predict signal strength at lower receiving elevations.

The literature generally supports assumption of a linear height gain function at clear locations within the radio horizon (Norton, et.al., 1947; FCC, 1949, p.4). For beyond-the-horizon paths, the gain function departs from linear; some data suggest that it follows a square root function (Egli, 1957). The FCC's rules, proceeding documents, and technical reports contain no guidance as to how field strengths should be adjusted for receiving heights departing from those assumed by the agency in deriving its propagation graphs.

It stands to reason that the relationship between received signal strength at 30 feet and that at lower antenna elevations will be different inside and beyond the radio horizon. At particularly long distances, well beyond the horizon, the dominant propagation mechanism is tropospheric scatter, which is atmosphere-dependent and has little to do with the geometry of the path. The linear relationship predicted for within-horizon paths where field strength is primarily a function of path geometry cannot be expected to hold for the scatter-dominated case. Within the diffraction region, just beyond the horizon, a transition from a linear relationship to something else is a logical assumption.

Because the receiving antenna height gain function is expected to vary with distance from the transmitter site, the use of a constant adjustment factor is considered improper and the use of two discrete factors, one for within-the-horizon paths and another for beyond-the-horizon paths, is problematical. The CCIR Recommendation 370-5 (CCIR, 1986) and P.L. Rice 1990 formula (Rice, 1990) propagation models permit adjustment received signal strength for receiving antenna elevations departing from the 30 foot (10 meter) norm. The CCIR model uses one constant factor below 31 miles (50 kilometers), another above 62 miles (100 kilometers), and a smooth transition in between. The Rice formulas yield a continuously varying relationship between signal strength and receiving antenna height. The difference between field strengths predicted using the Rice formulas for receiving heights of 30 and 6½ feet ranges from approximately 7½ dB within the horizon to 4 dB well beyond the horizon.

From the foregoing discussion, it is apparent that predicted field strengths for lower receiving antenna elevations will be less than those predicted for the "standard" elevation currently assumed. The reduction will be less for beyond-the-horizon paths than for within-the-horizon paths. It must be kept in mind that adequate reception occurs within the coverage boundaries conventionally defined for FM stations, despite the lower field strength values predicted for reduced receiving antenna heights. However, the D/U ratios found to be necessary for satisfactory service may not be realized at lower receiving antenna elevations, because undesired, distant (over-the-horizon) signals are attenuated less then the desired (within-the-horizon) signal. To achieve the desired D/U ratios at lower receiving elevations, increased separation distances appear to be necessary. Appendix B describes re-derivation of separation distance requirements based on a lower receiving antenna height assumption.

Presumed Terrain Roughness Effects

As discussed in Appendix A, revised propagation graphs for §73.333 of the FCC's rules were proposed in 1965. These graphs did not incorporate any "correction" for terrain "roughness". The revised graphs, completed in 1966, incorporated into the rules in 1976, and still in use today, presume "roughness" effects and account for them by incorporating a 2 dB reduction in field strength below "smooth earth" values.

As is set forth with more specificity in Appendix D, the applicability of that method of "roughness correction" to low band VHF facilities and the FM service in particular is questioned. The limited amount of FM data used in deriving the "correction" and the dominance of high band VHF and UHF data in the derivation process raises a question as to the validity of the correction technique. This is because terrain undulations are much more significant in terms of wavelengths at UHF frequencies than at FM frequencies.

It is not appropriate to presume smooth earth conditions for all FM stations and simply add 2 dB to the field strengths otherwise predicted, nor to extend that result to further revision of the separation tables at this time. What is suggested is that new propagation formulas be derived from available measured data *without "correction" for presumed "roughness"* and that separation distance tables be further revised based on that work.

Revised Separation Tables

Appendix B describes the construction of new interstation separation distance tables using the CCIR and Rice propagation models in conjunction with an assumed receiving antenna elevation of 2 meters. That data shows markedly increased co-channel separation requirements for all class relationships except between co-channel 3 kilowatt Class A stations. Application of the CCIR model suggests an average increase in separations of approximately 47 kilometers for the co-channel case, 13 kilometers for first adjacent channel relationships, and 9 kilometers for second adjacent channel situations. Data derived using the Rice model suggests an average increase in co-channel separations of 18 kilometers for the co-channel case, 5 kilometers for first adjacent channel situations, 11 kilometers for second adjacent channel relationships, and a *decrease* of 3 kilometers for the third adjacent channel cases. The increase in second adjacent channel separations is primarily due to the use of a -20 dB desired-to-undesired (D/U) ratio for that channel relationship. The existing separation distances are generally based on use of a D/U ratio of -40 dB, which was established for the third adjacent channel case in Docket 80-90 and results in reduced interstation separation requirements.

The conclusion drawn from the data presented in Appendix B is that the present FM station separation distances are probably inadequate to achieve the desired service radii and D/U ratios for typical receiving antenna elevations.[9] The worst spacing shortfalls are for co-channel relationships, but significant deficiencies are noted for first adjacent channel relationships, particularly those involving Class B, C1, and C stations. It is believed that the reason why deficiencies are concentrated in those classes is that first adjacent interfering contours fall beyond the radio horizon for those cases, whereas the same contours fall within or closer to the horizon for other classes.

Table I presents the separation distances recommended at this time. These distances were derived using the Rice 1990 propagation formulas. If the wisdom of reducing separation standards before further review of those formulas takes place is questioned, the existing separation distances could remain in effect temporarily.

Sample Station Separations Under Revised Table

The 30 "sample" FM stations described in Appendix C have been evaluated under the revised separation standards derived for a receiving antenna height of 6½ feet (2 meters). Table II details the number of short spacings for each station under the current FCC rules and under the recommended separation requirements.

In constructing Table II, short spacings which arise from the use of the distances effective for Class A stations as of 2 October 1989 were identified. Short spacings resulting solely from the presumption of 6 kW Class A operation by stations originally authorized as 3 kW Class A stations are tallied in the "6 kW A" columns of Table II. To include those situations with short spacings arising from grandfathered sites and waivers would distort the analysis. Most of the short spacings identified under the current FCC rules involve Class B stations, either the station

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/9 This discussion is premised upon the assumption of ideal transmission and reception conditions, e.g., uniform, gently rolling terrain and limited local clutter. In actuality, desired service or interference freedom may or may not result. It also accepts as valid the FCC's present D/U ratios and protected field strength values equivalent to those which establish the protected contour location. Any change in either D/U ratios or protected contour standards would necessarily change the separations determined, likely increasing separations even more.

studied or the short-spaced facility not explicitly identified herein. These situations mostly result from policies and rules in effect prior to 1964.

Under the existing rules, 47 percent of the stations studied are short spaced to at least one Class A station if 6 kW Class A operation is presumed. Other short spacings are identified for 37 percent of the stations at present. There are 19 short spacings arising from the 6 kW Class A separation standards and 20 short spacings resulting from grandfathered situations, waivers, etc.

For the recommended separation standards, 20 percent of the stations studied are short spaced solely due to the presumption of 6 kW Class A operation. Short spacings arising from grandfathered facilities, waivers, and the stricter separation standards recommended involve 77 percent of these stations. Ten short spacings exist due to 6 kW Class A operation that would not exist if 3 kW operation is presumed for those stations. A total of 47 short spacings results for all other situations.

Analysis of the results of Table II reveals that the recommended separation standards double the number of stations experiencing short spacings not solely resulting from 6 kW Class A operation. The increase in total number of short spacing instances increases by a slightly larger amount. It is concluded that the existing separation standards are inadequate and, under improved standards, most existing stations are short spaced.

Part III: ALLOTMENT OF COMMERCIAL FM FREQUENCIES

It is important to review the FCC's method of allotting FM stations, because the number and nature of allotments made influences allotment/station density. In a densely populated medium, the probability of interference increases greatly. It is not enough to simply review technical standards. Procedures followed in the allotment process, i.e., the means of implementing those technical standards, have a profound impact on the interference result produced by the adopted engineering principles.

The technical acceptability of a proposed allotment is presently evaluated based on minimum distance separations between the specified community of allotment and (a) licensed, authorized, or proposed stations and (b) other communities at which allotments have been made but do not yet have proposed uses.[10] Distances are computed and evaluated for assignments and allotments made on the same frequency as that which is proposed to be allotted and for those

/10 The distance separation standards are set forth in §73.207 of the Commission's Rules.

operating on the first, second, and third adjacent channels, along with the two FM channels adjacent to a frequency 10.7 MHz above or below the proposed channel.

The reference point of a proposed *new* allotment, used in determining compliance with the minimum distance separation standards, is ideally that defined by the geographic "reference coordinates" of the community, which usually defines a location near the primary business district, road intersections, seat of local government, or main Post Office. If the point so defined does not meet the distance separation requirements, a proponent can still request the allotment.[11] If the proposal is adopted, the Commission staff will often place the allotment at a mathematically defined location which meets the distance separation standards and from which the minimum required signal strength over the community is anticipated to be achieved, based on idealized service radii determined for the maximum facilities permitted for the class.

Proposed class *upgrades* of existing station assignments, whether involving a change in frequency or not, are first evaluated using the station's existing transmitter site or a prospective site specified in its Petition as the reference point. If the existing site does not meet the separation requirements and no alternative site has been specified, the proposal can still be considered under the same scheme that applies to new allotment proposals which do not meet separation requirements at the principal community reference point.

Upon initial examination, one might fault the allotment technical criteria on the grounds that particular coverage characteristics toward other stations are not accounted for by the nominal contour distance concept embodied by the distance separation standards. Interference caused to or received from other stations will be a function of all stations' transmitting powers and antenna elevations, along with intervening terrain between transmitter sites. However, at the allotment stage, there is seldom any specific information known about potential transmitter sites.[12] An applicant seeking an assignment of the allotment could propose operation anywhere within a

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/11 §73.208(a)(2) of the Commission's Rules provides that proponents should demonstrate the availability of a fully spaced and "suitable" transmitting site when distance separation requirements are not met at the community reference point. When the proposed allotment might affect other allotments which do not yet have stations assigned to them, the Rule states that the applicant should also demonstrate that adequate spacing results between "suitable" transmitter sites at all locations.

No definition of what constitutes a "suitable" site is stated. The Commission's staff seldom requires demonstration of specific site availability and suitability. Although some proponents may file such information, the FCC routinely accepts proposals where the proponent demonstrates nothing more than an area of some size wherein a transmitter site might be located. The staff may put a proposal out for public comment even when the proponent has demonstrated nothing concerning site availability for any allotment. The staff often specifies a mathematically determined "reference site" for the allotment without any apparent determination of the size of the remaining permissible site zone(s).

/12 Specific information can be known where the permissible site location area is small and/or terrain characteristics throughout the general area of the proposed allotment and potentially affected stations is homogeneous and "gently rolling" to flat.

wide area, with any one of many different propagation environments realized. Consequently, the high degree of generalization inherent in the separation distances is appropriate at the allotment stage, when only the most general planning considerations arise and nothing is known about the specific use that might be proposed.

Analysis of Allotment Technical Criteria

The present technical standards for allotting a new FM frequency to a community are usually identical to those under which a specific usage, or assignment, is evaluated.[13] These two types of proceedings are inherently different, as the purpose of the allotment proceeding is to make a channel *generally* available and the purpose of the assignment proceeding is to assign a *specific* use. Therefore, it is appropriate for them to be governed by different technical standards, but the present procedures do not provide any distinction between these dissimilar situations.[14]

Hardly ever does any party construct an FM broadcast station at the reference coordinates for the community to which that station is allotted. Most local zoning restrictions, to say nothing of economic considerations, preclude construction at such sites. In the uncrowded environment that existed when the present FCC allotment/ assignment scheme was adopted in 1962,[15] there was usually a moderate amount of space about a community within which a new station's transmitter site might be located. At worst, one or two other stations might restrict the area wherein a site could be placed. In today's increasingly crowded allocation environment, it is often difficult for new station applicants to propose practical transmitter sites which fully meet the distance separation standards and principal community coverage requirement, particularly when the initial evaluation used the allotment reference point, which may or may not be within the principal community.

The FM band has become crowded in many parts of the country in recent years as a result of the adoption of intermediate classes of FM stations under Docket 80-90,[16] the allotment of

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/13 An exception to this is where the applicant has requested processing of its specific usage proposal under the "contour protection" standards of §73.215.

/14 Were the allotment and assignment actions combined into one unified proceeding, one set of technical criteria could be used.

/15 First Report and Order, "Revision of FM Broadcast Rules, Particularly as to Allocation and Technical Standards ...", Docket No. 14185; 40 FCC 2d 662 (1962)

/16 Report and Order, "Modification of the FM Broadcast Station Rules to Increase the Availability of Commercial FM Station Assignments", BC Docket No. 89-90; FCC 83-259, 48 FR 29486; adopted 26 May 1983 approximately 689 new FM services under MM Docket 84-231,[17] upgrade proposals from existing stations, and demand brought on by the exceptional increase in FM station sale prices during the early to middle 1980s. Consequently, new allotment proposals do not involve as much freedom in transmitter site location as they did prior to 1980.

It is our experience that few new allotments can be made at the community reference coordinates. A study of the 44 FCC Report and Order documents granting new station allotments[18] released during the first six months of 1990 reveals that 50 percent involved reference geographic coordinates other than those corresponding to principal community reference point. Even more revealing was a similar review of Notices of Proposed Rule Making released by the FCC during the first half of this year. Out of 43 new FM station allotments proposed, 65 percent involved restricted sites. Significant restrictions in siting freedom are now the norm, not the exception.[19] Even if the allotment can be made at the community reference coordinates, there is no guarantee that substantial restrictions on site location will not exist.

Analysis of Allotment Procedures

The separation of allotment and assignment proceedings leads to coordination problems that complicate the consideration of both proposed allotments and applications for actual station uses. Proposed allotments and applications which conflict are not subject to the same filing and opposition deadlines. In noncommercial educational FM, low power television, and AM actions, the allotment and assignment processes are unified into one proceeding where all proposals are subject to the same filing and response deadlines; they involve the specification of actual transmitting sites, avoiding permissible site location zone adequacy problems.

Applications are not protected from conflict by rule making proposals until they are actually granted; an allotment petition filed the day before the application is finally acted on could hold up or prevent its grant. Applicants are often unaware of previously filed Petitions for Rule Making which propose allotments in conflict with their applications, simply because the FCC's Allocations Branch has not yet issued Notices of Proposed Rule Making in response to

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/17 Report and Order, "Implementation of BC Docket No. 80-90 to Increase the Availability of FM Broadcast Assignments", MM Docket No. 84-231; 49 FR 11213; 14 March 1984

/18 Frequency substitutions and existing station class upgrades were not counted.

/19 Site restrictions may exist in some cases due to a proponent of a new allotment in a given area picking the community which would receive preference in a new allotment proceeding rather than the community where service is primarily intended. Channels and/or communities may also be specified in odd ways for strategic reasons, such as to minimize chances of counterproposals or to block existing stations' site relocations.

such petitions.[20] It appears that these situations occur because Commission feels an obligation under §307(b) of the Communications Act to withhold action on applications pending comparative analysis of the conflicting allotment proposals or resolution of the allotment proceeding.[21]

During the processing of new allotment requests, little consideration is apparently given by the FCC staff to the practicality of locating a transmitter site where the allotment might be used. This is particularly true when the reference point is defined by the community's reference coordinates. Establishment of a singular reference point, within or without the principal community, does nothing to assure that a suitable transmitter site will be available. If a proponent happens to specify a practical site in its Petition for Rule Making, the FCC's Allocations Branch staff may not adopt that site as the reference point for the allotment, although it often does.[22]

In practice, the potential site location area for the prior (but not yet operating) allotment is not necessarily protected from encroachment by subsequently filed proposals. Between the time the allotment is made final and the time applications to use it are granted, other allotments may be made which could, in the extreme, reduce the permissible site location zone to a circular area of 0.3 mile (0.5 kilometer) radius, which encompasses only 186 acres. Similarly, minor change applications by existing stations filed prior to applications for use of the allotment could place significant restrictions on the site location area, constraints on usage not considered when the allotment was approved.

Only the reference point of the earlier allotment is protected from encroachment by later-filed allotment requests. The applicants' sites are considered to be "mere preferences" of site location. It is apparently presumed, absent submission of a convincing showing otherwise by an aggrieved party, that an adequate site location area remains despite whatever dislocation might be caused by the later allotment proposal to the applications filed to make use of the earlier allotment. The Commission staff may attempt to find a non-conflicting frequency for use by the allotment, but it is difficult to resolve conflicts in this manner in a crowded allocation environment. Those sites are protected only from later-filed (assignment) applications for

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/20 It is especially difficult for applicants to be aware of those allotments advanced as counterproposals in other rule making proceedings.

/21 Analysis of the FCC's 1 July 1990 "Blocked FM Facilities-Change Applications" list reveals that 41 pending FM station minor change applications are being withheld from grant or dismissal until conflicting rule making proceedings are resolved.

/22 See n.11, *supra*

specific facilities - existing station minor changes, changes to cover an approved upgrade, and proposals to use new allotments.

The present FCC's present two-step method of allotting and assigning FM stations fails to ensure that the allotments made are viable and, in effect, encourages further crowding of the FM band. Although the preference of new allotment or upgrade proposals over pending applications is supposed to place a priority on new service, it has the opposite effect when it dislocates applications being prepared or pending for allotments made several weeks or months earlier. The preference favors a *mere expression of interest* in a new allotment proposal over a *proven commitment* by an applicant *ready, willing, and able* to provide new service to the public on an allotment recently granted.[23] In effect, the allotment proposed last could have the most potential site location freedom, an inequity with respect to similarly situated but earlier granted allotments, for which there appears to be no logical public interest rationale. The freedom of minor change applications to restrict the uses of a new allotment for which applications are not yet being accepted seems quite at odds with the policy of new service preference. The introduction of "valued" new service at one location may be delayed, not speeded, because applications to make use of that service may require amendment when in conflict with later filed proposals.

Modification of Technical Standards

If the present two-step processing of FM station assignments is to be retained, it is recommended that the FCC require proponents of new FM station allotments to adequately demonstrate site availability. This will lessen the number of new station applicants forced to request interstation separation distance standard waivers or file their applications under "contour protection" rules, due to the unavailability of fully spaced sites. It is expected that implementation of such procedures will slow the tendency of the FM band to become crowded. This recommendation is independent of any suggested changes in propagation prediction and station assignment standards discussed elsewhere in this Final Report.

Proponents of new station allotments should be required to demonstrate that sites are available where the station can be constructed so as to achieve adequate coverage of the community of license without being likely to cause interference to other stations. This may be

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/23 Allotments proponents are not required to apply for the channel if it is adopted; they are merely required to express a continued interest in doing so. Some allotments have been proposed not by would-be broadcasters interested in constructing stations, but by (a) entrepreneurs interested in promoting the allotment and their application filing services to "investors" who might become interested in applying for the allotment, (b) other broadcasters attempting to delay grant of the upgrade of a competing station or the allotment of a new station through complication of the proceeding, or (c) entities filing a proposal solely to reach a settlement with other parties which is financially beneficial to the proponent. Recent changes in Commission policies regarding abuse of the Commission's processes may deter the latter practices.

done by adding any or all of three provisions to the rules. The first provision involves the use of "buffer zones" to provide an administratively simple manner of promoting siting flexibility. The second is based on the establishment of minimum site location area sizes that cannot be further restricted by later allotment proposals or existing stations' minor change applications. The last suggested modification of the rules would permit allotment proposals to be advanced based on the presumed use of specific transmitter sites for which FAA and local approval can reasonably be expected.

The simplest means of assuring new allotment viability would be to require new allotment proposals to meet the traditional distance separations plus a "buffer zone" radius, the latter distance being chosen to permit adequate flexibility in site selection. The Commission has done this before. In reclassifying FM stations pursuant to BC Docket 80-90, a "buffer zone" of 10 miles (16 kilometers) was established for a short time about each Class C station potentially subject to downward reclassification. This was done to assure such stations an adequate possibility of relocating, if necessary, in order to apply for at least minimum Class C facilities. The use of "buffer zones" is administratively simple in that it is readily implemented by adding fixed distances to the separations already programmed into channel study computer programs. The following table presents an initial suggestion of the pertinent "buffer zone" radii. It is based on a smooth transition from half the principal community coverage radius for Class A to the distance specified for Class C stations in BC Docket 80-90.

Class	**Zone Radius** mi (km)	**Site Area** mi^2 (km^2)
A	5 (8)	80 (200)
B1	6 (10)	120 (310)
C3	6 (10)	120 (310)
B	7½ (12)	175 (450)
C2	7½ (12)	175 (450)
C1	10 (16)	310 (800)
C	10 (16)	310 (800)

Should the proponent of the new allotment be unable to demonstrate compliance with the spacing plus buffer zone requirements from the community reference coordinates, it could demonstrate that such clearances can be attained at an arbitrary reference site, provided that it is also shown that the required coverage of the principal community can be achieved from locations within the buffer zone.

A new allotment proponent could demonstrate that an area exists wherein a site might be located, having a size equal to, or greater than, the pertinent value shown in the table above. The location area would be constructed by drawing the pertinent spacing arcs, without a buffer zone, and arcs defining the boundaries for the principal community service contour, extended from the most distant official boundaries of the community to be served.[24] Sites would be assumed to be available throughout the location area bounded by those arcs, absent a convincing showing to the contrary by an allotment opponent.

The final alternative recommended is the specification of a particular transmitter site where availability and suitability can be demonstrated. It is recommended that site availability be based on the present "reasonable assurance" criterion used in the application process. A site should be considered "suitable" only if (a) the FAA has indicated that an FM installation at the site would not cause a hazard to air navigation, (b) the required principal community coverage is achieved, and (c) local land use regulations do not expressly prohibit the use of the site for broadcast transmitting purposes.[25] This burden would be easy to meet for many existing station proponents requesting upgraded facilities, since FAA and local zoning clearances already exist at their present sites and, if relocation is necessary, such approvals are often in hand before the upgrade is proposed. Many such proponents would file under this provision.

Modification of Allotment Procedures

It was noted earlier in this Part that not only a lack of rigid technical criteria concerning site availability, but also the structure of allotment and application procedures can lead to the adoption of substandard allotments. Accordingly, it is recommended that consideration also be given to modification of existing procedures to lessen such problems.

This could be done by combining allotment and assignment proceedings to simplify the processing and coordination of both. The filing and opposition dates for the proceedings might be coordinated but separate consideration of each could be retained. The Table of Allotments concept could be eliminated and an open "window" filing system similar to that used in the low power television service could be adopted, except that mutually exclusive proposals would be resolved through the comparative hearing process. The streamlining of the process is not necessarily limited to the foregoing possibilities.

/24 Areas over large bodies of water and those located within military reservations, airport boundaries, wildlife refuges, wilderness preserves, national parks, and state parks, where it is reasonable to presume that sites are not available, should be discounted from the site location area otherwise determined. Allotment proponents could be permitted to offer evidence rebutting the presumption of site non-availability within such areas.

/25 Assurance that the Commission would have a multitude of applicants to choose from in assigning a specific use to the allotment would not necessarily exist. To assure a possibility of multiple applicants, the proponent could be required to demonstrate that the site is available to any and all comers. However, not adopting such a requirement could make it more difficult for other parties to "ride the coattails" of the allotment's proponent, sometimes effectively giving the party proposing the allotment a significant advantage at the application stage or limiting the number of applicants. Some parties believe that such an "effective preference" is justified.

Coordination problems might be solved by simple eligibility restrictions. Allotment petitions which conflict with applications submitted during a "filing window" period might be accepted only if they are received on or before its closing date. Allotment petitions which conflict with minor change applications might be rejected if they are not filed prior to 30 days after the FCC issues a Public Notice of the application's acceptance. Petitioners and applicants in mutual conflict could be formally notified, so that they might resolve that conflict voluntarily. Regulatory incentives to conflict resolution might be constructed, such as threat of comparative hearing, proposal dismissal, etc.

Another possible approach to proceeding coordination might be to combine the allotment and assignment steps into one unified proceeding. Minor change applications or combined petitions/applications for new stations could be filed within universal "open windows" such as those used in LPTV. Petitions would be evaluated and adopted before review of the companion application. Counterproposals that expand the number of new or upgraded mutually exclusive allotments above the number filed during the window period might be prohibited. This procedure would inherently limit the number of competing applicants, because only those proponents actively searching for channels would file in a timely manner.

Even if coordination of the allotment/application process is not substantially improved, some changes to existing procedures can still be made which will slow the crowding of FM stations. For instance, from the time an allotment is adopted until the closing of its related application filing window, later proponents of other allotments should be required to meet one of the site location area criteria detailed earlier in this Part with respect to both their own and the prior allotment proposals with which they might conflict. Those proposing otherwise-conflicting class upgrade rule making petitions or facility modification applications for existing stations should be required to demonstrate that the previously granted allotment remains viable, using one of the criteria described above.

Once the allotment filing window has closed, other new allotments should not be permitted in conflict with any of the prior applicants' transmitter sites for the new service allotted earlier, unless the proponent of the later-filed allotment demonstrates the availability and suitability, as defined above, of a transmitter site available to all applicants and agrees to reimburse the costs of amendment to be borne by the ultimate grantee. Minor change applications (site relocations, tower height or power modifications, etc.) filed between time of allotment grant and close of the corresponding application filing window can be designated for comparative hearing with the new station's applicants if they conflict with any applications filed for use of the new allotment.[26] Conflicting applications for facility upgrades filed during that same transitional period could be considered to be mutually exclusive and compared under traditional criteria with the proposed use of the new allotment at a comparative hearing. Alternatively, the applicant for use of a new allotment whose transmitter site conflicts with an earlier filed upgrade application could be required to relocate its transmitter site or affirmatively demonstrate that the upgrade can still be implemented by showing the existence of a remaining permissible site zone of pertinent size or the availability of a specific, suitable site for the upgraded facility.

Finally, if the application filing window for a new allotment closes without any applications being filed, there appears to be little public interest benefit in preserving the site location flexibility of applicants who have not yet stepped forward. However, some may take their chances on filing their applications on a "first come, first served" basis after the closing deadline. To allow time for the Commission staff to place applications received during the filing window on Public Notice, it is recommended that the special restrictions on separations with respect to new allotments be maintained until 60 days after the allotment filing window closes. Thereafter, the site location zone can be freely restricted without prejudicing any party having a timely interest in the allotment. In addition, there may be some merit to adopting an automatic "sunset" provision to delete new allotments if more than six months passes from the close of the application filing window without any proposal being received.[27]

Part IV: CONTOUR PREDICTION

The concept of service area has always been defined by a specified signal strength level, determined using the propagation model designated by the Commission for the particular type of service involved. The locus of a constant predicted field strength level is referred to as the field strength contour. Fixed distance service radii, unique to different FM station classes, were never used for coverage representation or service definition. Similarly, service area has never been

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/26 Such applicants could avoid risk by specifying sites that would not impact the new allotment's permissible site location area or, more simply, waiting until applications for use of the new allotment are on file before submitting their minor change proposals.

/27 Where the applications filed within or just after the window are later found to be defective, the expiration of the siting flexibility restrictions on other stations should be adjusted to 60 days after the dismissal of the last remaining applicant and the "sunset" date for the allotment set to six months after that dismissal.

established on a desired-to undesired (D/U) signal ratio basis, independent of absolute received field strength.

Factors pertinent in the prediction of contour location are (a) the signal strength defined as necessary for service, (b) the effective radiated power (ERP) transmitted in that direction, and (c) the appropriate propagation model and the parameters pertinent to its use.

Service Boundary Definition

The service area of early FM stations was defined as that "area in which the signal is not subject to objectionable interference or objectionable fading."[28] In effect, early FM stations had only one class of service. Coverage of "city areas near factories, car lines or busy streets" was expected to require a median field intensity of 1 mV/m. In "rural areas away from highways" 0.05 mV/m was considered usable. The absolute basis for these levels was not explicitly found in the literature.

When the FM service was relocated to the 88-108 MHz band after World War II, signal strengths describing service area boundaries were slightly redefined. A median field intensity of 3 to 5 mV/m was to be placed over the principal city to be served. Later, in 1962, the Commission slightly modified its service definitions, requiring a predicted field strength of 3.16 mV/m over a station's principal community and showings of the 1 mV/m and 50 µV/m service contours to be included with applications.[29] These contours were disclaimed as being only indications of the approximate extent of coverage, over average terrain and in the absence of interference.

In 1967, the use of the 50 µV/m contour was abandoned as a meaningful coverage contour in the commercial FM service.[30] The minimum interstation distance separation adopted in 1963 effectively permitted interference to the 1 mV/m contour for Class A and C stations and to the 0.5 mV/m (approximate) contour for Class B operations,[31] so there was no reason to

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/28 Code of Federal Regulations, 1940 Supplement, Title 47, Part 3, Section 3.206

/29 First Report and Order, *supra* n.15

/30 Order, "Amendment of Section 73.311, Field strength contours, FM Broadcast Stations"; FCC 67-920; adopted 2 August 1967

/31 Third Report, Memorandum Opinion and Order, "Revision of FM Broadcast Rules, Particularly as to Allocation and Technical Standards ...", Docket No. 14185; FCC 63-735, 40 FCC 2d 747, 28 F.R. 8077; effective 12 August 1963 continue consideration of an unprotected contour. This decision notwithstanding, many station operators continue to show the location of that contour on promotional maps.[32]

The foregoing definitions of service, 3.16 mV/m for the principal community and 1.0 mV/m elsewhere, remain in use today, with two exceptions. Class B FM stations are effectively protected from co-channel interference to approximately their 0.5 mV/m contours and from first adjacent channel interference to their 0.7 mV/m contours, by virtue of the separation distances required in those cases. Class B1 stations are protected from interference to their 0.7 mV/m contours. These protected contour specifications may be considered *de facto* definitions of service boundaries for such stations.

Research efforts uncovered no solid linkage between the field strength values established as measures of service and the sensitivity of receivers, attenuation of buildings and similar structures, receiving antenna performance, and similar important characteristics. FM receiver technology has improved dramatically since the use of solid-state devices became widespread. Contemporary research into minimum signal level standards is considered appropriate.

FM station service and interference areas are defined for Federal regulatory purposes by contour lines, which represent boundaries along which x percent of the nearby locations are expected to exhibit the desired field strength or greater for y percent of the time. This statistical definition of service was developed for television stations in the early 1950s and has been in use in the FM service since the early 1960s.

To increase either of the figures used to statistically establish service would necessarily shrink predicted service areas; to decrease either would expand such areas. Both actions would be controversial. The existing standard is well established and does not appear to have been subjected to much criticism over the years. We do not consider it ripe for revision at this time.

Effective Radiated Power

ERP is defined as the transmitter power, less combiner and/or transmission losses, plus antenna power gain. The combiner/line loss is reliably defined for almost every installation. Transmitter power is reasonably well defined and regulated, although power meters can be mis-calibrated or the transmitter operated at a higher level than what is authorized. The antenna power gain is not always established with certainty.

/32 It is the experience of many stations that, in favorable terrain and in the absence of interference, acceptable service can be rendered beyond the range of the protected service contour. With the adoption of Docket 80-90, more spectrum crowding is occurring, conceivably lessening the "interference free" area of existing stations.

Antenna gain is the product of the elevation pattern gain and the azimuthal power gain. The elevation power gain is the square root of the ratio of the maximum radiation in the elevation (vertical) plane to that radiation which obtains for a half-wave dipole theoretical antenna, assuming identical power input to both. Where only one radiating bay is used, power gain is a function of the difference in element elevation patterns of the actual antenna and the half-wave dipole. Where multiple bays are used, outward radiation is enhanced by the performance of the antenna as a stacked array. The azimuthal power gain is the square root of the ratio of radiation at whatever bearing it is maximum with respect to the root-mean-square (RMS) value of the radiation in all azimuthal directions. For a truly nondirectional antenna, the azimuthal power gain is equal to one. When the azimuthal power gain is not unity in all directions (or within a reasonably tight tolerance of that value), the antenna is considered to be directional, since signal is enhanced over the nondirectional case in some directions and suppressed in others.

Any metallic object located within several wavelengths of an FM radiating element has the potential to distort the elevation and azimuthal radiation patterns of that element, depending upon the dimensions and location of said metallic object. The support pole or tower and the transmission line feeding the antenna are metallic objects of significant dimensions which are obviously located close to the radiating elements, so they may well have an effect on the elevation and azimuthal radiation patterns.

The effect of such structures on the azimuthal pattern is well documented.[33,34] Azimuthal radiation patterns otherwise assumed to be omnidirectional can exhibit marked directional characteristics. The measurement work performed by Canada revealed that ERP error could range from -20 to +5.4 dB for side-mounted antennas, with 50 percent of the measured ERPs falling between -2.7 and +1.3 dB relative to the ideal omnidirectional value. The error was ± 2 dB for panel-type antennas, which completely surround the mounting structure and feed lines, with 65 percent of the cases within $\pm$ 1 dB. It is clear that the ERP of stations employing side-mounted antennas can depart substantially from the omnidirectional ideal, whether intended or not.

The effect of structures on elevation patterns is not well documented. The primary reason for this appears to be the difficulty of achieving accurate antenna range measurements of such patterns at FM frequencies, due to ground reflections and related phenomena. Nevertheless, it is

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/33 Request for Declaratory Ruling, Hammett & Edison, Inc.; 12 September 1989; FCC DA 90-1467; dated 18 October 1990

/34 "FM Broadcast Antenna Radiation Pattern Characterization", Canada; CCIR JIWP 8-10/1 Document CAN 3; 22 July 1988 logical for the presence of metallic objects such as tower members in the antenna aperture to affect elevation patterns. This matter deserves serious study.

Based on Canada's study data, it appears that a maximum radiation limitation of +2 dB over the RMS value would accommodate 100 percent of the stations employing panel antennas and approximately 82 percent of the stations employing side-mounted antennas not "intentionally" directionalized. In the interest of interference protection, it is recommended that all FM stations installing new side-mounted antennas be required to either (a) certify in their license applications that the antenna is mounted such that in no direction would its maximum radiation exceed the horizontal plane RMS value by more than 2 dB or (b) submit a measured pattern for the antenna and mounting configuration employed and an Application for Modification of Construction Permit specifying directional operation and demonstrating no interference to be caused to other stations.

At present, the maximum ERP achieved in any direction is limited to the maximum specified for the station class. A directional antenna cannot be used to increase service in one direction beyond that which would result from maximum ERP omnidirectional operation while reducing service elsewhere. This makes sense under a separation distance scheme of regulating interference. However, if station assignments are to be evaluated entirely on the basis of contour protection, a modification of the Commission's restrictions on directional antennas might be considered that would permit some expansion of service by stations operating with directional antennas, where such operation would not cause interference.

Under a contour protection assignment scheme, ERP limitations could be established based on the root-mean-square (RMS) field of the directional antenna. Ideally, use of a directional antenna would not require an overall loss of coverage area. Instead, gains would be permitted to offset losses. This approach would eliminate the present disadvantage placed on stations using directional antennas that are officially acknowledged as such. It would also serve to lessen the assignment of "substandard" facilities and coverage whenever it is necessary for siting reasons to specify directional operation.

Propagation Models

Field strengths are predicted by means of models of radio wave propagation, which may be based on theory, empiricism, or both. A complete presentation on propagation models is included as Appendix D. The propagation model employed by the FCC in determining service and interference contour locations is described by §73.313 and §73.333 of that agency's Rules.

The TASO Report identified three particular categories of propagation curves and models (TASO, 1959, pp. 405-412). *Type I* curves and their results were to be "average empirical propagation curves to be applied on a country-wide basis," to be used in developing overall allocations plans. *Type II* curves or methods were to "take into account average large area effects" in predicting field strengths and were to be based on additional characteristics of the path. It was recommended that such methods be utilized in predicting service and interference (TASO, 1960, p.54). *Type III* methods were to facilitate the prediction of field strengths in small areas, such as coverage of particular locations, under very specific conditions, i.e., precise and complete knowledge of terrain along the path, land use and cover, etc.

The propagation prediction method outlined in the FCC's rules is, in essence, a TASO *Type I* method. Field strength is predicted solely on the basis of the distance of interest from the transmitter site and the effective antenna height (EAH) of the transmission system. The model does include a provision for adjusting field strength predictions based on roughness of terrain, on which basis it could be claimed that the FCC procedure constitutes a TASO *Type II* method, but the use of that provision has been indefinitely suspended.[35] No method for adjusting the assumed receiving antenna height is reported in any of the relevant documents.

The method of predicting field strength adopted internationally is CCIR Recommendation 370-5 (CCIR, 1986a). The CCIR propagation model is very similar to the FCC method, utilizing a slightly different terrain averaging segment for determination of EAH and incorporating a distance-dependent terrain "roughness" correction factor. Although no specific graph or formula is provided, the CCIR method does contain information regarding the adjustment of field strengths for reduced receiving antenna elevations. This information can be extrapolated to an approximate adjustment formula useful over a limited range of data. Because of the latter two factors some might consider the CCIR method to be a TASO *Type II* method. We consider it to fall into the TASO's *Type I* category, due to its use of highly generalized statistics, i.e., average terrain and delta h determined over a long distance.

P.L. Rice has developed one set of formulas with frequency-dependent terms which approximate the FCC's generalized propagation curves for FM, VHF TV, UHF land mobile, and UHF TV (Rice, 1990). Used only with the input data developed for the FCC curves, Rice's formulas should be considered to constitute a TASO *Type I* technique. However, the formulas facilitate parametric adaptation for such considerations as density of terrain cover and the elevation assumed for the receiving antenna. When variability is introduced into such

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/35 Order, "Temporary suspension of Certain Portions of Sections 73.313, 73.333, 73.684, and 73.699 of the Commission's Rules and Regulations"; FCC 77-304; adopted 28 April 1977 (this Order continued indefinitely a suspension of the referenced rule provisions which originally commenced on 28 August 1975) parameters, the method enters the TASO *Type II* category. Rice's formulas and further information concerning them is presented in Appendix E.

We have found two methods reported in the literature reviewed which clearly meet the TASO *Type II* definition. The first is Okumura's method, which was developed in Japan for use in mobile radio service area predictions (Okumura, 1968). However, this method is useful only for frequencies above 150 MHz and much of its development is described for UHF frequencies. The second is the technique of Blomquist and Ladell, which was developed in Sweden for VHF and UHF transmission based on limited data in rough terrain (Ice, ed., 1975). A detailed comparison of measured versus predicted field strengths, conducted at 93.8 MHz in Germany's Black Forest, concluded that the Blomquist & Ladell method yielded the closest overall correlation to measured values (Grosskopf, 1987). Unfortunately, this method has been empirically validated only for mountainous terrain conditions.

An early, classic method which meets the TASO *Type III* definition is the use of Bullington's nomograms. This approach considers the effects of smooth-earth (cylindrical) and knife-edge diffraction, but does not present a complete solution for multiple knife-edge conditions (Bullington, 1947). It may be considered to be the forerunner of many of the more sophisticated methods developed later.

The Irregular Terrain Model (ITM) of the Commerce Department's National Telecommunications and Information Administration (NTIA) has been recommended from time to time for use in predicting broadcast service. The ITM permits two operational modes, the Area Mode and the Point-to-Point mode. The Area Mode (Hufford, et. al., 1982) predicts field strengths by characterization of terrain over large areas. As such, it could be considered to be a TASO *Type II* model. However, due to the large size of the areas over which it is sampled, this categorization is questionable and we believe that it can be alleged that the ITM Area Mode is a *Type I* model. The point-to-point mode of the ITM, generally referred to as the Longley-Rice model (Longley & Rice, 1968), is a true TASO *Type III* method, since it considers terrain, ground conductivity/permittivity, horizon angles, and other precise details in the prediction of field strengths.

Alternative Prediction Analysis

Several prediction techniques were applied to the sample station set described by Appendix C. Results of numerical comparisons of the FCC, CCIR, ITM/Point mode, and the Rice 1990 formula (with three different EAH definitions) models are presented in Appendix G. Graphical comparisons of the FCC, CCIR, ITM (both modes) and Rice 1990 formulas (with conventional EAH data input and 2 meter receiving height assumed) are presented for five representative stations from the sample in Figures 1-5.

Overall, the numerical correlation of the FCC method results to the ITM/Point baseline data, as described in Appendix G, was fairly consistent ... the average standard deviation of prediction differences was 3.3 dB. The five coverage illustration maps show that the 60 dBμ contour determined under the FCC method generally falls near the boundary computed using the ITM/Point mode. For flat and gently rolling terrain situations, such as those present about WMVY and KGRS, the FCC technique appears to slightly underestimate coverage. In hilly terrain, such as that about WKDQ, the method approximates more sophisticated results surprisingly closely. Even in the West Virginia mountains surrounding WKKW, the FCC technique seems to define a reasonable coverage boundary, especially when it is remembered that the technique is intended to predict statistical results, i.e., for 50 percent of the locations. However, where terrain sharply changes from one sort (valley) to another (mountains), the method is less successful, as can be seen for the case of KVVA (Figure 4).

The statistical comparison of the CCIR method indicates somewhat less consistent difference results than was noted for the FCC method, although the standard deviation of variance, 3.4 dB, is not of any significance. For stations in terrain Groups 1 (flat) and 2 (gently rolling), the CCIR method results correlated significantly better to the ITM/Point mode baseline than did the FCC method results. However, for terrain Group 3 (hilly), the correlation was worse, extremely so for the case of KUDA, Pahrump, NV. The correlation in Group 4 (mountains) was not as good as that determined for the FCC method.

It is believed that the improvements apparent in terrain Groups 1 and 2 for the CCIR method are attributable to the fact that the method's terrain roughness correction increases predicted field strength in relatively flat terrain areas, whereas the FCC's propagation curves contain a built-in 2 dB attenuation factor attributable to the median terrain roughness assumed in its derivation. The deterioration in CCIR method performance in hilly and worse terrain is a direct result of applying the same field strength adjustment; a downward figure based upon terrain roughness exceeding the nominal value assumed for the propagation curves. Use of the CCIR method is not recommended because (1) there is no significant overall improvement in results and (2) for stations located in hilly terrain, the accuracy of service area prediction is believed to be diminished significantly.

Station coverage areas were also evaluated under the Area Mode of NTIA's Irregular Terrain Model. The Area Mode generally characterizes terrain in a region by a composite roughness factor derived from many criss-crossed paths and utilizes that value to predict propagation conditions. Area Mode studies were conducted only for the five stations depicted by Figures 1-5. The concept of this Report was to present a comparative analysis of line mode coverage prediction techniques statistically and a limited graphical presentation of area-based techniques, so the Area Mode results are included only with the latter presentation. As it turns out, the analysis results presented in Appendix F suggest that area-based results are effectively obtained for averaged line-specific terrain data, so no change to an area-based scheme was warranted to prepare Figures 1-5 for the FCC, CCIR, and Rice formula methods.

Examination of Figures 1-5 reveals that the ITM Area Mode approximates coverage reasonably well only for the flattest terrain case, WMVY (Figure 1). The complete failure of the ITM Area Mode to adequately address local terrain is best illustrated for the two mountainous examples, KVVA (Figure 4) and WKKW (Figure 5). The ITM Area Mode coverage contour prediction lies far beyond any reasonable interpretation of its location under the ITM Point mode.

It is concluded that the ITM Area Mode is inappropriate for use in predicting FM station service and interference. The areas utilized in defining terrain parameters are apparently much too large. The generalized result obtained using the method approximates reality only where terrain is relatively flat. Time and resources did not permit an evaluation of the ITM Area Mode using granular terrain data.

Coverage areas bounded by the 53 dBμ, 6½ foot (2 meter) receiving elevation contour reasonably approximate the present coverage boundaries, overall. The service area differences shown result primarily from the fact that the 7 dB contour adjustment figure is an average value, based on equivalence factors slightly higher for Class C, C1, and B stations and slightly lower for Class A stations. Were the underlying raw adjustment factors used for each station class, somewhat better correlation would result.

Even though the contours shown for the Rice formula model at lowered receiving elevation may, for higher class stations, fall slightly short of the current FCC method predictions, use of the alternative approach is not expected to increase interference to these stations. Potentially interfering co-channel contours are effectively extended by the same prediction method, so the resulting interference, within and just beyond the service contour defined, would be better protected from interference.

Improvements in Propagation Models

Today, some 30 years after the TASO Supplemental Report was issued, we still evaluate FM service and interference boundaries by means of what that organization called a *Type I* method, usable only for nationwide planning purposes, not specific situations. Deficiencies in the present propagation curves, adopted in Docket 16004, were thoroughly documented as early as 1966.[36] Use of the terrain "roughness correction" factor incorporated into the FCC model was "temporarily" suspended 15 years ago; its deficiencies have yet to be addressed. The FCC has not yet adopted a TASO *Type II* propagation model, even though we understand that Congress effectively directed it to do so.

We suggest that the time has come (indeed, it is overdue) to develop (1) a revised *Type I* propagation model to replace the existing FCC procedure, for use in general allocation planning work, (2) develop a true *Type II* model for use in determining service and interference boundaries, and (3) adopt an existing or newly developed *Type III* method as a standard for resolving disputes as to the field strengths realized in small areas. These models should yield reasonable results for a range of receiving antenna elevations. When applied to FM service and interference predictions, the realistic FM receiving antenna elevation of 6½ feet (2 meters) should be assumed.

Terrain data for a *Type I* method need only be the average elevation determined along a line following the bearing of interest. As explained in Appendix F, it is believed that averaging of all terrain samples extracted out to a point where the incremental change in EAH is less than the incremental change in distance will avoid the arbitrariness of the present 2 to 10 mile (3-16 kilometer) averaging segment while keeping data analysis to a minimum. Rice's 1990 formulas provide an excellent starting point for the development of a new *Type I* propagation model using revised terrain data.

For a *Type II* method, we recommend that terrain elevations be developed using a sector area technique; i.e., terrain is sampled on an equal area basis, all points within uniform azimuth-by-distance increment sector averaged, and a composite terrain profile constructed from such averaged data points. It may be possible to utilize line-sampled data, averaged within distance increments, in lieu of the sector area data, with little loss of accuracy if the separation between bearings is sufficiently small. However, present data is not considered sufficient to reach a definite conclusion in this regard for a *Type II* method.[37]

The use of more sophisticated terrain analysis routines is facilitated greatly by the availability of topographic data bases and personal computer technology. The workload concerns that surrounded use of such methods for 40 of the last 50 years are now virtually moot. It is

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/36 Affidavit of Howard T. Head, 21 November 1966, submitted with the Comments of the Association of Maximum Service Telecasters in MM Docket No. 16004; *see also* Engineering Statement of A. Earl Cullum, Jr., & Associates; 26 June 1971; submitted in the same proceeding

/37 The analysis and conclusion reported in Appendix F applies only to determination of a single overall terrain average figure for a particular direction.

suggested that those who might express concerns about method complexity not compare computer execution times between the present techniques and those postulated, but rather the time required for manual extraction of 2-10 mile data from topographic maps with the execution speed of the methods suggested, because it is the manual technique that was the level of effort accepted for this service.

In developing a new *Type I* method, we believe that the data presented both herein and in the literature clearly establishes that the presumptions used in adjustment of method results or underlying data for terrain "roughness" area inappropriate. Raw field strength measurement data should be correlated to EAH without correction. However, it is recommended that more sophisticated methods of defining EAH, such as the diminishing difference criterion described above or fitting of a line to the data, be employed both in correlation analysis and method application. The resulting method should be described primarily by formula so that it may be readily implemented in various computing environments with close agreement of results. The Rice 1990 formula model, with coefficients re-established based on a reanalysis of measured data, is suggested as a good "starting point" for developing a new *Type I* method.

A *Type II* method to be developed for broadcast use should be based on a more rigorous, but area based, approach to terrain effect analysis, as described above. It should permit consideration of the effects of land use and cover. Such data is now available for much of the United States. The data can be organized into a regular polygon structure, with pertinent values assigned to each element thereof. Desktop computer technology facilitates the consideration of composite "clutter attenuation" values along paths crossing elements of differing values. Such an approach permits particularizing field strength estimates to thickly forested paths, such as exist in the southern pines or Allegheny Mountains, and open areas, such as overwater paths or the western deserts. Although the *Type II* method should permit adjustment of receiving antenna elevation, it should not utilize specific information about the immediate foreground of the receiver, because the purpose of the method is to evaluate average conditions over areas of moderate size, not field strengths at specific locations. In developing a *Type II* approach, the work of Blomquist and Ladell appears to be particularly interesting, although it must be verified for a wider variety of terrain situations. It also appears to require the addition of "clutter attenuation" terms and other refinements. Perhaps that technique could be combined with attributes of Rice's 1990 formulas to describe a more particularized propagation model by incremental changes to the more general *Type I* method.

A TASO *Type III* method should be formally adopted for use in resolving disputes as to coverage of small areas, particularly compliance with principal community coverage standards. Although several methods meeting the *Type III* definition are reported in the literature, the FCC has not provided any formal guidance as to which is to be used and what input assumptions are to be made. It is our experience that the Commission's FM Branch accepts showings based on use of the ITM/Point mode, but we have been told that the Propagation Analysis Branch will only accept showings based on the use of Bullington's nomographs in contested TV proceedings referred to it by the TV Branch. Because these methods have existed for some time and a number of engineers are familiar with them, it is suggested that the FCC be urged to conduct a formal Inquiry into the matter.

These recommendations may involve some controversy. The FCC has sometimes been reluctant to adopt propagation models that substantially differ in results in the "average" case from existing techniques, with many of its fears concerning the establishment (or maintenance) of administrative precedents. However, if an inadequate engineering technique has been used for 25 years, its longevity of use does not make it correct. Recently, the agency has adopted and proposed substantial alteration of fundamental technical standards in the AM service to better predict service and interference, despite considerable quarrel with the proposals made. That action may signal a preference of technical pertinence over fear of establishing or violating precedents. These recent actions suggest that the agency may be quite open at the present time to changes such as those recommended herein.

Part V: CONTOUR PROTECTION

Adequate station service areas exist when interference is minimized along those boundaries. Interference between stations is considered to exist when a specified ratio of desired (service) to undesired (interfering) signals (D/U ratio) is not achieved at points along nor within the service boundary. Service and interference field strengths and the distances at which they are achieved are predicted for different time and location statistics.

The FCC has administered interference protection in the AM, noncommercial FM, and LPTV broadcast services by prohibiting the overlap (intersection) of contours defined by specific service and interference field strengths; the interfering contour being defined by the service contour field strength value less the D/U ratio. Commercial FM applicants who request processing of their proposals under §73.215 of the Commission's Rules can avail themselves of this method of interference analysis, in lieu of the fixed distance separation standards of §73.207 of the FCC's Rules.

Protection (D/U) Ratios Employed by the FCC

The earliest FM interference standards were established based on a primitive time/location criterion set forth in the 1940 Standards of Good Engineering Practice for the 50 MHz FM band. Objectionable interference was considered to exist "when the signal for 50% of the distance in any sector on a radial exceed 0.005 mV/m at the 0.05 mV/m contour of the desired station."[38] In the case of a station protected to the 1 mV/m contour; objectionable interference was said to occur when "the signal for 50% of the distance in any sector exceeds 0.1 mV/m."

With the shift to the 100 MHz band in 1945-46, the D/U ratios were clearly stated as 10:1 (20 dB) for the co-channel case and 2:1 (6 dB) for first adjacent channel stations. By 1956, D/U protection ratios of 20 dB for co-channel, 6 dB for first adjacent, 1:10 (-20 dB) for second adjacent and 1:100 (-40 dB) for third adjacent channels had been adopted. These D/U ratios were not reexamined until the consideration of Docket 14185 in the early 1960's, at which time they were reaffirmed. Indeed, they remain in the Commission's Rules to this day.

Signal Nature Underlying D/U Ratios

The transmission mode always assumed for regulatory purposes when reviewing the pertinence of D/U ratios was monaural. Although FM multiplex transmission was mentioned, even at the inception of FM, scant attention was paid to the differing protection ratios needed for satisfactory multiplex or stereophonic reception.

The first acknowledgement of this fact came near the time when the FM multiplex system was first approved. The need for higher protection ratios for multiplexed operations was discussed, but the record suggests that little supporting information had been submitted to the Commission at that time.[39] Some commenting parties had specifically urged that the adjacent channel D/U ratios be increased to protect stereo and SCA operations. Zenith pointed out, on the basis of its own receiver measurements, that the signal-to-noise ratio for stereophonic broadcasting was about 23 dB poorer than that for monophonic broadcasting. It recommended that the cochannel D/U ratio be increased to 40 dB, and that the first adjacent ratio be increased to 26 dB (no change was suggested for second or third adjacent ratios). The subsequent rejection of more stringent protections was based primarily on the perceived need to provide a sufficient number of allotments and the supposed lack of justification for tighter standards. It was also stated that the service area of stereo FM is less than that of monaural FM service, so "ratios ...

/38 Code of Federal Regulations, supra n.16, "Standards of Good Engineering Practice Concerning High Frequency Broadcast Stations", Section 2 (the wording of the procedure may seem confusing, but that is the way the standard was crafted in 1940)

/39 First Report and Order, *supra* n.15, at ¶15-18 affording adequate protection to regular service will also afford appropriate protection to these other types of service."

The issue of increased protection for multiplexed transmission was raised again in Docket 80-90.[40] Comments were received that the existent minimum separations were insufficient for stereophonic broadcasting and subsidiary communications operations. For example, the American Broadcasting Companies submitted studies by A.D. Ring & Associates that suggested that, in the absence of interference, a signal level of 0.063 mV/m would provide satisfactory stereo service. The Advisory Committee on Radio Broadcasting also urged protection of stereophonic service and submitted three supporting studies.[41] A study of the radio listeners (Bruskin, 1982) showed that approximately half of all radio receivers were capable of stereo reception, that stereo listening was roughly twice as prevalent as mono listening. A psychoacoustic study of audio signal-to-noise (interference) ratios (Middlekamp, 1982) demonstrated that a 50 dB AF signal-to-noise ratio (SNR) was needed for satisfactory stereo reception; i.e., an interfering signal only "slightly annoying". A study of FM interstation separation distances (Cohen, 1982) determined that the average co-channel separation between stations yielded a 34 to 40 dB RF D/U protection ratio. As referenced in the Technical Subgroup Report, the National Radio Systems Committee (NRSC) Report concluded that to achieve a 50 dB AF SNR, RF protection ratios of 40 dB cochannel, 25 dB first adjacent and -20 dB second adjacent would be required.[42]

In response to the comments filed, the Commission again examined the desirability of revising the protection requirements. NRSC receiver data were used in their studies to establish the expected service ranges for mono and stereo reception under the existing rules. A 30 dB AF SNR was employed for the monophonic service (the figure generally assumed to be the basis of the existing protection ratios) while 50 dB AF SNR was used for stereo.

The Commission that, to provide the 40 dB RF D/U ratio needed to obtain a 50 dB AF SNR, the separation requirements would have to be vastly increased. For example, the separation between cochannel Class C stations would increase to 255 miles from 180 miles. The agency concluded that to fully protect stereo broadcasts, it would have to effectively preclude many new allotments. The FCC determined that the protections put into place in 1963 permitted

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/40 Report and Order, *supra* n.16, at ¶32

/41 The Advisory Committee was formed by the FCC to advise the Commission's staff on technical and spectrum allocation matters (See Memorandum Opinion and Order, FCC 80-537, 22 September 1980)

/42 The NRSC is an entity co-sponsored by the Electronic Industry Association (EIA) and the NAB. It is composed of persons from the broadcasting and electronics manufacturing industries to provide agencies with information on technology.

the existence of adequate service areas while serving the mandate of Section 307(b) of the Communications Act for the fair, equitable and efficient distribution of service. Additionally, the Commission felt that stereo broadcasting was an "optional enhancement" of stations' entertainment programming. Thus protection ratios tied to the stereophonic service were rejected and the use of ratios derived for monaural service remained.

There is no doubt that better protection of FM stations' stereophonic service would result if RF D/U ratios were improved, resulting in lower AF S/N ratios. Analysis of changes in D/U ratios based on stereophonic service is believed beyond the scope of this project.

Location/Time Interference Criteria

The first interference standards were based on a primitive location/time criteria, described under Protection Criteria above. The 1949 Engineering Conference called in the matter of Dockets 8736, 8975 and 9175 appears to have been the genesis of the current location/time statistical contour parameters (F{50,50} and F{50,10}). Both the F{50,50} and F{50,10} propagation prediction curves were adopted in September 1962 as part of Docket 14185.[43] Service (F{50,50}) field strengths are predicted for 50 percent of the locations and 50 percent of the time. Interfering (F{50,10}) field strengths are predicted for 50 percent of the locations and 10 percent of the time. The notion here appears to be that, at 50 percent of the locations receiving an adequate signal strength, interference will not occur more than 10 percent of the time. The other 50 percent of the locations will have an inadequate field strength interfered with for 10 percent or more of the time. There has been no change proposed to these criteria over the years. These time percentage critera are identical to those used for many years in evaluating skywave service and interference in the AM band.

Multiple Interfering Signals

Although different approaches to consideration of multiple interfering signals are described in early literature, a generally accepted method of evaluating the cumulative effects of those signals does not exist for the FM broadcast service. Recommendations were offered to the Commission on standards by committees but not without considerable dissention from the participants. It appears that the FCC, perhaps due to a lack of data and the complexity involved, has not chosen to further address the multiple interference issue at any point in time since the early 1950s. Evaluation of such effects using modern receiver technology is warranted.

Interference Between Short-Spaced Stations

/43 First Report and Order, *supra* n.15, ¶12

The standards for assignment of stations that do not meet the mininum separation standards of §73.207 of the Commission's Rules are set forth in §73.213 and §73.215 thereof. Section 73.213 concerns stations that became short spaced solely by changes in the rules. Stations which purposely request inadequately spaced transmitter sites are now considered under §73.215.

When the original separation standards were adopted in Docket 14185, stations that were short spaced at that time (prior to 16 November 1964) and remained so thereafter were permitted to relocate transmitter sites and/or improve facilities based on a complicated alternative separation table set forth in §73.213. Directional antennas were often used to suppress ERP toward a short-spaced station while increasing it to the pertinent class maximum in other directions.

In MM Docket No. 86-144, the continued use of that table was suspended. In its place, a simpler standard was adopted. "Grandfathered" short spaced stations are only permitted short-spaced facility changes where they demonstrate that the predicted 1 mV/m service contour for the proposed facility will not extend beyond the same contour of the licensed station over the sector(s) of bearings toward any short spaced station(s). This document will not present any analysis of this procedure on FM broadcasting.

Technical Provisions of §73.215

The technical provisions of §73.215 are identical to the contour protection standards in use for many years in the noncommercial educational FM service. However, they are premised on different fundamental standards than is the separation distance table of §73.207.

Under §73.207, Class B stations are protected from idealized interference caused by first adjacent channel Class A stations to the former stations' 57 dBμ (0.7 mV/m) contours, whereas the Class B station's 54 dBμ (0.5 mV/m) contour is the service protection standard for all other relationships. Section 73.215 requires protection of the 54 dBμ contour of Class B stations in all situations. The second and third adjacent channel D/U ratios used in constructing the tables of §73.207 are identical, -40 dB. Under §73.215, a -20 dB D/U ratio, far more stringent, is applied to the second adjacent channel relationship.

The foregoing situations point out a curious anomaly in the Commission's technical standards: a site that might be fully spaced and acceptable under §73.207 could, if the provisions of §73.215 were applied to it, be found to cause or receive impermissible contour overlap. For example, a station critically spaced (say, clear by 0.1 mile) to a second-adjacent channel facility might have to relocate slightly due to highway construction. Were it to become short spaced, it would have to file its relocation application under §73.215. It could be required to reduce its ERP toward the critical second adjacent channel station by 20 dB. A relocation "across the street" triggering a 20 dB signal suppression requirement makes little sense.

The underlying bais of technical standards should be consistent throughout the Commission's rules for a given communications service. Otherwise, anomalous situations result, as described above for a contour protection example. The lessening of the protected contour definitions of §73.215 is not necessarily recommended here. What is recommended is that whatever standards are adopted be applied consistently throughout all rules for the service involved.

Administration of §73.215

When demonstrating compliance with the terms of §73.215, the actual facilities of existing or proposed stations are not necessarily used to determine the location of their normally protected nor potentially interfering contours. If the station operates with the maximum facilities for its class, the actual facilities are used. Otherwise, use of class maximum facilities must be presumed.

Even where facilities are equivalent to the maximum, but ERP is below and HAAT above the nominal limit, the use of nominal maxima is required. This can lead to absurd facility assumptions. For example, a Class C2 station located atop a mountain might have an ERP of 2 kW and HAAT of 2000 feet, achieved by use of a 100 foot tower. However, under §73.215, it would be assumed that the station operates with 50 kW at 492 feet, which would mean that one assumes the antenna to be 1400 feet underground!

This is not an unimportant matter. The co-channel 40 dBµ interfering contour for 2 kW at 2000 feet extends 78 miles, whereas it extends 85 miles for the nominal Class C2 maximum facility. This makes physical sense, because the relationship between transmitting EAH and predicted field strength is not linear for over-the-horizon paths, the case here. The lower ERP that results from higher HAAT reduces the interference radius more than the higher HAAT stretches it.

Continuing the example, Class A stations must locate so as to avoid reception of interference from the higher class station, as well as avoiding interference caused to other stations. Their freedom in site location and/or service area toward the Class C2 station changes by 7 miles depending upon what assumption is used in determining the higher class station's interfering contour. Were the Class A station located 96 miles from the Class C2 station, its operation at full facilities (6 kW at 328 feet) would not cause interference to nor receive interference from the actual operation of the Class C2 station. Under the "class maximum" assumption, that Class A station would have to reduce its ERP to less than 1 kW toward the Class C2 station.

The requirement that all stations be assumed to operate at their class maxima makes administrative sense, but can have obtuse results in yet another way. The interstation separation distance requirement between higher and lower class stations is primarily determined by the separation required to prevent the lower class station from *receiving* interference from the higher class station. Our study of proposals filed under §73.215 reveals the majority to involve the lowest class of stations, Class A. Many of these stations have filed directional antennas to avoid being interfered with by higher class stations, often not by the present operation of the latter stations but by their future, potential operation. In other words, they must avoid the *reception* of "phantom" interference that may never occur.

For example, the required separation between co-channel Class A and C stations is 226 kilometers, necessary to avoid the reception of interference by the Class A station. To protect a Class C station operating with 100 kW at 1968 feet from interference, a separation of 178 kilometers is necessary. Let us assume that the Class C station involved actually operates with 100 kW at 1000 feet, a fairly typical combination for such stations. The Class A station would not actually receive interference if it is located at least 201 kilometers from the Class C station, in which case it would cause interference to neither the existing nor potential operation of the Class C station. In other words, for this example, §73.215 requires that the Class A station protect *itself* from what the Class C station *might* do in the future.

And protect itself severely, at that. Under §73.215, the a Class A station with a HAAT of 100 meters cannot be spaced any closer than 208 kilometers from the Class C station and, so spaced, must reduce ERP in the direction of that Class C station to 100 watts. Its maximum ERP elsewhere is limited to no more than 3.2 kW due to the 15 dB maximum-to-minimum ratio provision for FM directional antennas. However, because its proposal was filed under §73.215, other stations need only protect its actual contours. A first adjacent channel station located between the Class C and Class A stations could take advantage of this situation by moving closer to the Class A station, causing interference to an area where service was suppressed solely to avoid *future* interference. This effectively hastens the date when such interference will occur.

The desire of the FCC to preserve the flexibility of over-height stations to reduce HAAT and sub-maximum stations (especially Class C) to improve facilities, without causing interference to voluntarily short-spaced stations in both cases, seems laudable. But service potentially provided *now* by the lower class station must be limited in order to avoid a slight *future* degradation of service caused by a *potential* facilities improvement by the higher class station. Even with that interference, the service rendered by the lower class station would be greater than it is permitted under §73.215, because the pertinent D/U boundary is defined between overlapping contours, not along the interfering contour. Although some small segment of the public is spared interference at some unknown time in the future, a larger segment is denied service forever.

Revision of §73.215

It is recommended that §73.215 be revised to avoid unnecessary restriction of service under anomalous situations such as those described above. First, each overheight station should be evaluated assuming its licensed antenna elevation and the maximum ERP permitted for their class at that elevation, if higher than the ERP at which it is authorized. Second, stations not achieving the maximum facilities for their respective classes should be afforded a reasonable opportunity, such as 2 to 3 years, to file improvement applications. Thereafter, those stations not achieving maximum facilities for their respective classes should be considered on the basis of their actual facilities for contour protection purposes, not their hypothetical future facilities.

There exists no provision within §73.215 relating to existing contour overlap. While reducing interference by foreclosing the maintenance of existing contour overlap is a laudable goal, the lack of any mention of these situations in the rules could lead to interpretations that do not support such an objective. For example, if the staff were to determine that, as a matter of policy, stations are entitled to the overlap area magnitudes (square miles or kilometers) presently achieved and that minor change proposals can propose relocation of overlap areas as long as the total area remains the same, interference could be caused where it does not presently exist. A better approach would be to explicitly prohibit any overlap where it does not already exist at the time the minor change proposal is tendered.

Administration of Interference Protection

Interference between FM stations has been regulated since the early 1960s primarily by means of the separation distance table of §73.207 of the Commission's Rules. Until §73.215 was adopted, any situation not in compliance with §73.207 or subject to the alternative provisions of §73.213 had to request a waiver of the latter rule. Waivers are inconvenient to administer consistently and consume limited FCC staff resources.

The separation distance standards make a lot of sense for the population of the spectrum by new allotments, where nothing specific can be known about a potential future operation. However, they do not afford the flexibility often found to be necessary in making (and, especially, changing) assignments. Transmitter site locations are constrained not only by the FCC's separation standards, but also by land availability, local land use regulations, air navigation hazard considerations, and interservice radio interference situations not expressly recognized in the rules. Site leases can expire, with renewal either refused or priced exhorbitantly. As discussed in Part III, the administration of the separation standards in allotment proceedings does nothing to assure that a practical transmitter site or alternative remains available.

The separation standards approximate interference between stations reasonably well where terrain is flat or gently rolling. In hilly or mountainous terrain, the contour locations which underlie the separation standards vary considerably from the ideals assumed. Service or interference contours may be extended beyond the distances assumed, in which case interference could be caused even though the stations are fully spaced. The same contours could be reduced below the distances assumed, in which case facilities can be located closer together without interference. The separation standards, when applied to actual station uses, are effective only for relatively flat terrain.

A considerable problem with the use of the separation standards at the assignment stage is their inability to handle short-spacings that come about not by applicant choice, but by changes in technical standards. Stations became short-spaced as a result of the replacement of the propagation curves in the early 1960s, the adoption of higher power limits in Docket 14185, the "metrication" of the FCC's rules in the early 1980s, and the recent increase in ERP limit for Class A stations. As the nature of these situations is highly variant, it is very difficult to construct "alternative" separation tables or standards of similar generality to deal with them without having to contend with waiver requests. In Part II of this document, changes in separation standards have been recommended. Adoption of such standards would create many new short spacings. The administration of separation requirements would become more complex, because it would become even more necessary to identify the genesis of each short spacing.

Adoption of universal contour protection standards at the application stage would inherently resolve the complexity of the present "hybrid" technical standards. Existing overlap situations, caused by "grandfathering", changes in separation standards over the years, or inconsistency of assumptions underlying separation and contour protection standards, can be handled by a simple provision that overlap cannot be caused anywhere it does not now exist. Now that terrain databases are available for use on desktop computers, there is little difficulty in implementing contour protection for all application situations.

Based on the discussion above, it is concluded that the time has come to evaluate station assignments (applications) based on contour protection only. This will not facilitate the immediate "shoehorning in" of new, substandard allotments, because no permissive change in allotment standards is recommended. The allotment stage changes recommended in Parts II and III of this document are generally restrictive in nature. With time, migrations by existing stations might open up some allotment opportunities, but such situations are expected to be limited in number.

Part VI: ANALYSIS OF SECTION 73.215 PROPOSALS

Section 73.215 of the FCC Rules describes the technical requirements an applicant must meet if the proposed FM transmitter site does not satisfy the minimum distance spacing requirements contained in Section 73.207 of the Rules ("short spacing"). These requirements, also known as the "contour protection rules", generally require that a short spaced proposal not cause or receive objectionable interference[44] with respect to the any stations, allotments or applications to which distance separation requirements are not met.

Provisions of Section 73.215

Section 73.215 applies to new short spacings and decreases in the actual separation between stations currently short spaced, except for those stations qualifying under §73.213 of the FCC Rules ("grandfathered" short spaced stations). The provisions of §73.215 became effective on April 14, 1989.[45,46] They permit use of terrain characteristics (but not terrain shielding), directional antennas, reduced power, or reduced antenna height as means of achieving the required desired to undesired ratios at the appropriate station contours. Stations operating on frequencies 53 or 54 channels apart (IF-related stations) must meet minimum distance separation requirements; contour protection is not permitted for these situations.

Section 73.213 of the FCC's Rules applies to 1) short spacings which existed prior to 1964, and 2) short spacings involving class A stations operating with facilities equivalent to 3 kilowatts at 100 meters above average terrain. Other short spacings which were created or

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/44 As defined by the FCC's desired to undesired signal ratios in §73.215

/45 Later delayed until form approval was obtained

/46 Report and Order, "Amendment of Part 73 of the Commission's Rules to Permit Short-Spaced FM Station Assignments by Using Directional Antennas"; MM Docket No. 87-121, FCC 88-406, released February 22, 1989 authorized prior to April 1989, either through waiver or changes in the spacing tables, do not fall under the situations described in Section 73.213. Proposed changes to those facilities must meet the current spacing requirements, lessen the degree of short spacing to any station not meeting separation requirements, or meet the requirements of Section 73.215.

One of the most controversial provisions of Section 73.215 is the allowed use of directional antennas for short spaced situations. In the past, directional antennas had been permitted on a case-by-case basis. Along with Section 73.215, the FCC codified existing policies and modified rules governing directional antennas by amending Section 73.316 of its Rules.

Although the FCC's rules are not clear as what affect a proposal filed under §73.215 has on the station being short spaced to, the current staff policy considers such a station as "fully, but minimally" spaced. Any future modification of that facility must not decrease the separation between the stations, unless it too is proposing the processing of its application under §73.215. It is recommended that this policy be clarified and codified within the rules.

Identity and Nature of Section 73.215 Proposals

FM applications requesting processing under §73.215 were identified using the FCC's FM Engineering Database of 30 April 1990. This database is released monthly by the FCC through the National Technical Information Service (NTIS). A proprietary database access system was used to extract all records within the database for which an FCC-defined indication was present that the application requested §73.215 processing. A total of 132 records were found which had the §73.215 flag set. Pertinent data for these records were stored and analyzed. Each proposal so identified is listed in Appendix H, along with a detailed breakdown of the analysis results.

The data were analyzed to characterize the nature of each proposal, first by class, and then by the reason for short spacing. The data were further separated to identify the number of proposed short spacings, the amount (distance) of short spacing, whether directional antennas were proposed, and the directional suppression.

Over half of the Section 73.215 proposals involved short spacings *proposed by* Class A stations. The lowest percentage of proposals is attributed to Class B and C3 facilities (3 stations, 2.3 percent each). Likewise, Class A facilities were most likely to be affected by proposals filed under §73.215. Of the 153 stations that would become short spaced[47] as a result of the proposals analyzed, 52 (34 percent) are Class A facilities. The Tables contained in Appendix H detail the short spacings as they relate to the class of station.

/47 No attempt was made to extract grandfathered short spacings, except for 3 kilowatt class A stations.

Nearly 65 percent of the proposals involve only one short spacing. An additional 24 percent involve two short spacings, although some of these appear to be grandfathered situations. Few (less than 6.0 percent) involve 3 or more short spacings. The remainder were experimental proposals or had no identifiable short spacings. In a number of cases, either the applicant or protected facility is involved in a rule making proposal which would affect the proposed short spacing.

The amount of short spacing proposed is minimal for most proposals. Almost half of the proposals are located such that the greatest short spacing is less than 5 kilometers. Approximately 10 percent involve short spacings of 15 kilometers or more. The majority of the 10 percent group involve grandfathered facilities. In only one instance, it was noted that a short spacing proposed involved IF related stations. Since contour protection of IF related station is not permitted, this application may be subject to dismissal or other administrative action. The tabulation contained in Appendix H shows only the most severe short spacing, regardless of whether the proposal is grandfathered.[48]

When possible, the reason for requesting processing under §73.215 was determined.[49] The largest group, with 28 percent of the total requests, are Class A stations proposing six kilowatt operation. Applications for new facilities account for 26.5 percent; 21.2 percent were class upgrades; and 18.2 percent involve site relocations (exclusive of 6 kilowatt requests). Three percent had no identifiable reason for requesting section 73.215 processing. It is speculated that, in one case, the short spacing had been removed by amendment of another application. Figure H-2 of is a graph showing the breakdown of reasons as a portion of all station classes. Figure H-3 is a similar graph for class A stations.

A total of 80 directional antennas have been proposed. Excluding 4 experimental proposals at Charlotte, NC, which request 30 dB of antenna suppression, only 1 proposal specifies antenna suppression of more than 15 dB, the limit permitted under Section 73.316 of the FCC Rules. Minimal suppression of 6 dB or less is proposed for 42.5 percent of the proposals, with 57 percent proposing less than 9 dB.

The database contains four proposed stations in Charlotte, North Carolina which are classified as "experimental". Those stations have been specified within the database as "Section 73.215" applications, although by their experimental nature they do not meet the traditional

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/48 For grandfathered facilities, §73.213 requires only that the 60 dBμ contour extend no farther toward the short spaced station. In instances of grandfathered short spacings, it was not possible to identify whether the request met §73.213 requirements.

/49 In some instances it was not possible to identify the reason for the short spacing from the database records.

definition of short spaced facility. These have been included in this report for completeness, although some data (notably, short spacing distances and counts) excludes these proposals.

As noted above, a number of the facilities requesting processing under §73.215 and a number of protected facilities and allotments are affected by rule making requests. Several Class A facilities have applied for 6 kilowatt operation under these rules pending action on upgrade requests to class C3. Similarly, several Section 73.215 applications protect current rule making proposals, including proposed new allotments and proposed facility deletions (frequency move or upgrade). Absent a §73.215 request to protect these proposed allocations, the facility changes would not be permitted or would be held in abeyance pending resolution of the rule making proceedings.

The data also reveals that 7 protected facilities are proposed for modification (either an upgrade, or frequency change) in rule making proceedings. Conversely, 10 applicants which have filed under §73.215 are involved in upgrade, or other, rule making proceedings. These numbers represent 4.6 percent and 7.6 percent of the total, respectively.

A review of the data reveals that 19 of the required protections are to pending applications for vacant allotments, while 9 protections involve short spacings to proposed or vacant allotments for which applications have not yet been accepted. This raises the distinct possibility that no fully spaced site will exist for these allotments when and if they are granted, and applications are accepted. Vacant allotments having no fully spaced site zones as a result of one, or more, of these 73.215 proposals may require all new applicants for the allotment to file under Section 73.215, further crowding the distribution of FM stations.

Short Spacings Under Revised Separation Table

A comparison of the number and magnitude of short spacings was made between the current FCC separation tables, and the revised separation table set forth herein. The comparison revealed that use of a spacing table based on a two meter receive antenna height and modified contour levels would increase the number of short spacings at nearly all facilities studied. Use of propagation algorithms employing the same modified contour levels and 2 meter receive antenna height would create an apparent increase in the amount of prohibited contour overlap in approximately 56 percent of the 132 situations studied.

Table I-I of Appendix I presents a summary of the separation analysis results, along with the corresponding results obtained in the earlier study. These results show that both the number of short spacings and the degree of short spacing increases when the newly derived distance separation tables are employed. In only four situations did the number of short spacings decrease when the new tables were employed. Three situation showed a decrease in the amount of short spacing between the proposed facility and the most severely short spaced existing facility.

Analysis of Contour Overlap

A computation was made for each proposal filed under §73.215 of the amount of area affected by prohibited contour overlap using proposed and current FCC methods. All contour overlap calculations were made using only the station parameters listed in the FCC's FM Engineering Database. Calculations for vacant and proposed allotments were made using the class maximum facilities at the specified reference point. Where a directional antenna was specified *and the directional antenna parameters were contained in the database,* the distances to contours were computed with the directional antenna radiation values. Use of the licensed facilities was believed to give a better representation of the actual impact of the 73.215 proposals on existing stations. Except where obvious, no attempt was made to identify overlap areas falling over water, foreign countries or otherwise uninhabitable area.

Of all the proposals filed under §73.215, the majority had no prohibited contour overlap when the FCC method was employed. When the method proposed in this report was used, however, over 56 percent of the proposals showed at least some contour overlap. In many of the situations where contour overlap was determined to exist regardless of the propagation method employed, later FCC engineering data shows the applications as returned, dismissed or amended. Likewise, several situations involve grandfathered short spacings, thus the computed overlap cannot be attributed to the Section 73.215 proposal.

The overlap data were reviewed and analyzed to allow comparison of results for the two methods. Data for non-existent allotments were eliminated, and in those cases where overlap was shown to multiple facilities for one station (i.e. the existing facility has a licensed facility and a construction permit facility), the "newest" facility was used. A cumulative overlap factor was obtained for each §73.215 proposal under each propagation method by summing the individual overlap factors for each facility pair.

Four §73.215 facilities were selected for a graphical comparison of the comparative impact of the two propagation methods. Contour overlap maps are presented in Appendix I which show the protected and interfering contours of each short-spaced station. The contours were determined along 10 degree radial increments, using the actual facilities for each station, including directional antenna, where appropriate.

Table I-2 of Appendix I presents summary results of the overlap study. A substantial increase in predicted overlap when the Rice 1990 formula propagation model is employed along with modified protected contour levels. Further investigation reveals that the overlap increases dramatically for those cases where the interfering contour falls over the radio horizon, which is expected in co-channel situations.

Implementation Difficulties

The validity of all data extracted and analyzed is limited to the accuracy of the FCC database as of 30 April 1990. Errors have been noted in the FCC data on previous occasions. No attempt was made to fully investigate each station by means other than the FCC database. There was no attempt made to include any stations other than those flagged therein as requesting processing under §73.215. Likewise, no exclusion was made for those showing §73.215 processing which did not appear to need it. A significant effort was required to determine which facilities met the old (3 kilowatt) class A criteria, entitling use of the separation distance table set forth in §73.213(c)(1).

Although the methods used for the contour overlap study are believed sufficient to perform a comparative analysis, certain limitations exist regarding use of the data. Therefore, only broad, general conclusions should be drawn from the data presented herein. No conclusions should be drawn with respect to the acceptability of any specific proposals studied.

In conducting the review of study results, later FCC data were used to determine the current status of various applications. In 12 of the 29 situations where overlap would occur using the FCC propagation method, later data shows these applications as dismissed, returned or amended. Two situations were readily identified as involving pre-1964 grandfathered short spacings in addition to the newly proposed spacing deficiencies, and several other situations appear to include overlap resulting from other short spacing situations. It was also noted that the directional antenna data were missing for some existing stations, and found to be incorrect for at least one §73.215 proposal.

A limitation on the conclusions which may be drawn from the overlap data results from the use of actual station facilities. Actual station facilities were used to depict the interference which would occur if all proposals were granted as specified, without consideration of future actions by existing stations. This is not in strict conformance with the literal provisions of §73.215, which specifies use of maximum facilities for the class of station involved, regardless of whether the facility were overheight or overpower. The approach used here is believed to more realistically depict the actual impact of these proposals.

The contour overlap processing routine employed cannot detect whether a facility contour is crossed twice, as may occur for large overlap areas. Likewise, automated determination of overlap areas which fall over water or foreign countries was not considered feasible for this project. Although exact values of overlap area are not obtained, a good relative indication of overlap area was obtained.

The other major limitation in these results is that a determination of *contour overlap* was made, rather than actual interference area. This choice was made since the FCC uses contour overlap as its guideline for authorization purposes. Further, contour overlap calculations minimized program size and speed. In those cases where the overlap area is very small (a few square miles, or less), little or no actual interference area is likely to exist, and the impact of the proposal should be negligible. In cases where the contour overlap is large, significant interference can be expected to occur.

Part VII: OVERALL STUDY RESULTS

The purpose of this comprehensive study is to evaluate the effectiveness of the FCC's Rules and Regulations in controlling interference between U.S. FM stations and to recommend specific changes in rules or areas for further study, the intent of both being to protect FM stations from interference increases. Conclusions have been drawn from the information presented in this document and the related appendices. Recommendations are made based on those conclusions and the supporting studies. Finally, the impact of these recommendations on the FM broadcast community is discussed.

Conclusions

1. The FM facility separation distance standards of §73.207 are not based on consistent service and interference criteria. For example, the 54 dBμ "normally protected" contour of a Class B station is not fully protected from first adjacent channel interference from Class A stations. Instead, the 57 dBμ contour is so protected.

2. Technical standards are based on an unrealistic receiving antenna elevation assumption. The 30 foot (9.1 meter) assumption, which facilitates field strength measurement and is a good approximation of outdoor television receiving antenna heights, is not an elevation typical of FM listeners' receiving antennas.

3. The propagation characteristics described by the FCC's current curves are contaminated by questionable terrain "roughness" assumptions, utilized in the curves' derivation but subsequently suspended from use in the application of the curves.

4. The table of separation distances does not adequately protect stations from interference because it was derived on the basis of techniques having deficiencies noted in (1), (2) and (3) above.

5. Application of revised separation distances, which implement consistent technical criteria within each station class and are based on a more realistic 2 meter receiving antenna elevation assumption, to a representative nationwide station sample reveals that 77 percent of the stations would become short spaced thereby.

6. The existing allotment procedures facilitate crowding of the FM band because the technical standards used in such proceedings are those developed for specific station assignments, not the generalized facilities that must be assumed at the allotment stage. Actual facility proposals may not be able to comply with the same technical standards because of changes in circumstances between the times of allotment and application consideration.

7. The signal strength boundaries which define protected FM service areas appear to have been developed from administrative considerations; they do not appear to have been derived from studies of receiver performance.

8. Interference may be caused if antennas assumed to be omnidirectional are, due to their installation, actually directional. The Commission's present rules effectively permit the installation of radiating systems having directional characteristics without requiring them to be disclosed and authorized as such.

9. The present approximate, single-parameter method of propagation analysis is appropriate for overall planning purposes. Analysis of specific service and interference situations requires a multi-parameter model which relies upon better description of the propagation environment within the *area* of interest. Signal strengths realized at particular locations require the use of propagation models which take into account even more specific environmental data.

10. Although redefinition of the means of determining effective antenna height results in significant individual changes in that parameter, no marked overall improvement in field strength prediction accuracy was observed when such changes were applied in conjunction with a single-parameter propagation model to a representative nationwide sample of FM stations. Use of the NTIA's Irregular Terrain Model (Area Mode) or the propagation model described by the CCIR's Recommendation 370-5 would not improve service nor interference prediction.

11. The protection (D/U) ratios adopted for the FM service have not been validated for contemporary receiver technology and listener expectations, particularly for the second and third adjacent channel situations.

12. The effects of multiple interfering signals on FM reception have not been meaningfully addressed in any formal FCC proceeding.

13. The provisions of §73.215 of the FCC's Rules require, in some cases, unrealistic evaluations of interference. These situations result under two circumstances, (a) where "overheight" operation is authorized but lower "class maximum" antenna elevations are required to be assumed and (b) for those cases where higher class (particularly Class C) stations operate with less than maximum facilities but it must be demonstrated that no *future* interference would be received from such maximum facilities. These two provisions unnecessarily limit service and facilitate the creation of interference by other stations in those areas where service is prohibited due to unrealistic evaluations of interference received.

14. Analysis of the proposals filed under §73.215 of the Commission's Rules as of 30 April 1990 reveals that over half involve Class A stations, 28 percent involve Class A ERP upgrades, 27 percent involve applications to use new allotments, 21 percent involve class upgrades, only 18 percent involve site relocations, and 6 percent were filed for other reasons.

15. Adoption of a propagation prediction method incorporating a more reasonable assumption for receiving antenna height will extend interfering contours for trans-horizon paths. This will increase predicted co-channel (and, occasionally, first adjacent channel) overlap where it now exists and result in some cases of predicted overlap where none now exists.

Recommendations

A. A new TASO *Type I* (generalized) propagation model should be adopted for FM band planning purposes. It should be based on improved (convergent) effective antenna height (EAH) definition, no consideration of terrain "roughness correction", and permit use of realistic receiving antenna elevation assumptions. The Rice 1990 formulas provide an excellent starting point for such propagation prediction method development.

B. A realistic receiving antenna elevation, 6½ feet (2 meters), should be adopted as a basis for determining FM service and interference areas. Because service appears to be generally sufficient at lower receiving elevations within the contour boundaries now defined, it is suggested that the field strength values defining such boundaries be adjusted downward so that the present service radii are closely approximated by the redefined contours. Alternatively, service contour field strength definitions could be related to the performance of contemporary receivers.

C. Changes to allotment and application filing and evaluation procedures should be adopted to lessen conflicts between such proceedings. If the two-step allotment/assignment process is to be continued, demonstration of the availability of truly viable transmitting sites should be formally required at the allotment stage and protection of a reasonable site location area should be afforded until the filing deadline for applications to use the allotment passes. This will lessen the crowding of the FM band by allotments that become deficient by the changing events between the time of allotment and application review.

D. New interstation separation distance standards should be adopted based on the propagation model adopted under (A) and the contour redefinition resulting from assumption of a lower receiving antenna elevation, as described in (B) above. Such standards should be based on the same protected contour values and D/U ratios as contour overlap standards arise from. Uniform contour values and D/U ratios should apply within each station class.

E. Allotments for which no applications are filed within a reasonable time should be automatically deleted, since they needlessly restrict the site relocation freedom of operating stations.

F. Applicants for FM station license should be required to certify that the transmitting antenna, feed system, and support structure does not exhibit a maximum radiation in any direction of more than 2 dB above the RMS azimuthal radiation value for each polarization employed. Where such certification cannot be made, the filing of an application for directional operation should be required.

G. A TASO *Type II* propagation model, taking into account terrain, its cover, average atmospheric conditions, and receiving antenna height should be developed for evaluation of service and interference areas of FM stations. Terrain data should be comprised of uniform sector averages or averages taken from multiple radials, either based on ten degree sector widths. The method of Blomquist and Ladell should be examined closely in this regard, along with modifications to the Rice 1990 formulas to account for better descriptions of terrain diffraction and tropospheric scatter.

H. A complete re-evaluation of necessary D/U ratios should be made based on current receiver technology, particularly for the second- and third-adjacent channel cases. It is recommended that stereophonic reception be assumed in any studies conducted and recommendations made. This is a task appropriate for study under the auspices of the National Radio Systems Committee.

I. The method developed under (H) above should be used in conjunction with the revised service and interference contour definitions of (B) above for the administration of FM station assignments. A universal contour protection procedure will eliminate many of the anomalous problems inherent in the Commission's current "hybrid" system of administration.

J. Section 73.215 should be revised immediately to specify the use of maximum ERP at the authorized HAAT for overheight stations, prohibit received contour overlap only where caused by actual authorized facilities, and explicitly permit maintenance (or require a slight reduction) of overlap where it is now effectively authorized.

K. Section 73.213 of the Commission's Rules can be eliminated once contour protection is adopted as the sole standard for evaluating the acceptability of FM minor change and new station applications and pre-existing overlap is provided for.

Impact on Broadcasters

All in all, it is believed that the changes in the FCC's technical standards, or the study thereof, both recommended herein, will serve to slow FM band crowding and minimize increases in interference sufferred by FM broadcast stations. Any changes made may affect some existing broadcasters wishing to modify their facilities and would-be broadcasters desiring to propose new FM station allotments.

Revision of propagation models, particularly as to receiving antenna height assumptions and service boundary field strengths, will change service and interference predictions, as well as modify interstation distance separation requirements. While there is always a chance that opening the topic to discussion could lead to undesired results (i.e., adoption of standards that cause further crowding of the FM band), it is anticipated that revision in accord with the suggestions provided herein will result in improved interference protection between stations.

An inevitable result of tightening these technical standards is greater potential restriction on the freedom stations have in facility selection. By evaluating new allotment proposals using stricter separation standards, the crowding of the band can be lessened, but this may also limit the possibilities of upgrading existing stations to higher classes. Stricter standards would compress somewhat the permissible site location areas, which, in turn, might affect existing stations seeking transmitter site moves. However, if applications are evaluated on the basis of contour protection rather than distance separation standards, site location freedom might be enhanced.

Implementing more stringent interstation separation distances and stricter site availability criteria (or "buffer zones") would obviously create difficulty for the proponents of new station allotments. Also affected might be those few broadcasters seeking channel substitutions at other stations in order to clear the way for their own class upgrades, depending on whether contour protection criteria can be applied to justify channel substitution requests. However, the resulting restriction of new allotments and substitutions will slow the tendency of the band to become crowded, controlling the potential for interference to existing stations.

Changes in allotment proceedings to lessen conflicts with applications is also expected to lessen FM band crowding and limit the adoption of "substandard" allotments, generally benefitting existing FM broadcasters. Stations which find their facilities change proposals sidetracked by conflicting rule making proposals, filed at the "eleventh hour", would certainly benefit. However, some stations would find their options restricted by changes in allotment procedures. For example, timely filing of upgrade proposals would be essential; stations could not sit back indecisively until a competing proposal forces them to step forward. Creative use (some might say abuse) of the rule making process by existing stations to delay or prevent the allotment of new stations or upgrade of competing stations could be significantly restricted if more streamlined and coordinated procedures are adopted. But these and other stations would benefit from the FCC's processes being less clogged when they submit their own modification proposals.

Combining the allotment and application processes could significantly affect existing broadcasters, depending on how it is done. If the existing LPTV filing procedure is used as a model, with filing periods one month long, spaced roughly six months apart, FM stations seeking minor changes would be overly restricted, because they can presently file at any time. One alternative is to consider each calendar month to be a filing period for comparative purposes, which would permit continuous application acceptance.

"Substandard" allotments could result if contour protection and use of less-than-class-maximum facilities is permitted at the allotment stage, continuing the "crowding" of the FM band. Such possibilities are lessened if ERP is based on the directional RMS and allotments are evaluated on the basis of class-maximum facilities, from practical transmitter sites.

Interference may result under the present standards when "omnidirectional" antennas are installed so as to cause highly directional coverage and the achievement of otherwise-forbidden

ERP increases in particular directions. Requiring broadcasters to certify in their license applications that their antennas are reasonably non-directional would focus attention on such matters and, in the long run, lessen existing interference situations, particularly where they result from inadvertance.

The many broadcasters who seek truly omnidirectional performance of their antennas would not be significantly affected by requirements that newly installed nondirectional antennas be certified as such, because they already bear the costs of pattern modeling and testing. However, those who do not presently care about the performance of their antennas would face increased hardware costs when constructing new stations or implementing facility modifications. These costs would be in the antenna type or mounting arrangement necessary to achieve omnidirectional operation, range measurement of the antenna to demonstrate pattern performance for "nonstandard" mounting arrangements, and the preparation and filing of modification applications to specify directional operation, when range tests show that the required omnidirectional performance is not attained. Those broadcasters who represent their antennas to the FCC as nondirectional, while seeking instruction from the antenna manufacturer as to the best way of achieving maximum radiation in a particular direction (through adjustment of the mounting of the antenna on its support structure), would be particularly affected by the proposed certification requirement. The industry, as a whole, would benefit.

Evaluating facility compliance with the class maxima ERP/HAAT combinations set forth in §73.211 on the basis of the directional pattern RMS would allow directional FM stations to achieve the maximum coverage area idealized for their respective classes; i.e., there would be no coverage penalty inherent in directional operation. Expansion of these stations' service areas in non-critical directions would help protect those stations from future interference within such regions.

Use of contour protection as the sole interference evaluation mechanism at the application stage would better protect stations from interference. It would facilitate service where no interference would occur. Confusing regulations and "Catch-22" situations that existing "short-spaced" broadcasters find themselves in, when considering site relocations and related minor changes, could be eliminated through universal application of contour protection criteria at the application stage. This will be particularly true if provision is made for the swapping of *de minimis* overlap areas. Siting flexibility is likely to be greater in most cases than that which results under fixed separation distance requirements, particularly if uniform technical criteria underlie both the separation and contour protection standards.

While broadcasters proposing their own facility changes can already avail themselves of contour protection methods, they cannot use the same methods to protest applications which might cause them interference when such proposals are "fully spaced". Adoption of universal contour protection would level the playing field.

Station migrations, under any set of regulatory criteria, might open some "holes" for new or upgraded allotments. It is not believed that adoption of contour protection as the sole interference evaluation criterion at the application stage will result in many migrations that, in turn, may facilitate new allotments which "crowd" the FM band. This is because the opening of "holes" would be quite gradual, and perhaps offset by other relocations that serve to close up those "holes". The present situation, where the applicant can submit its proposal under whichever criteria benefit it, is the worst of both worlds.

Implementation of revised propagation models and universal contour protection at the application stage will impact those who prepare FM broadcast applications, including stations and groups that perform such work in-house. With the proliferation of desktop computers, appropriate software, and the availability of time-shared remote-access broadcast computing services, implementation of better propagation models and contour protection methodology is facilitated, for both engineering professionals and station technical staffs alike.

In summary, the establishment of improved technical standards and assignment procedures will involve change for the broadcasting community, particularly for engineering professionals. However, the end result of the changes recommended is expected to be slowed "crowding" of the band, better protection from interference, and an authorization process that is less complicted for both the broadcaster and the FCC. Consistent, sensible rules based on sound technical criteria will better serve the industry than does the present patchwork of procedures which have evolved to serve different, and sometimes conflicting, regulatory objectives over the years.

23 October 1990

Respectfully Submitted,

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Table I

SEPARATION DISTANCES BASED ON RICE MODEL AT 2 METERS

prepared for
National Association of Broadcasters
Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	29	35	64	102
	B1	47	55	87	154
	B	66	75	112	182
	C3	41	48	85	154
	C2	52	59	105	182
	C1	73	80	143	228
	C	92	99	169	249
A6	A6	33	41	74	120
	B1	47	57	94	157
	B	66	78	120	188
	C3	42	50	89	157
	C2	53	61	109	185
	C1	73	81	145	223
	C	92	101	172	253
B1	B1	49	63	112	189
	B	69	84	143	224
	C3	49	63	112	189
	C2	55	69	136	215
	C1	75	86	175	252
	C	94	105	203	281
B	B	71	92	170	249
	C3	69	84	143	224
	C2	71	92	170	249
	C1	77	108	211	286
	C	96	121	240	315
C3	C3	43	55	98	166
	C2	55	66	118	194
	C1	75	86	154	232
	C	94	105	181	261
C2	C2	56	72	129	205
	C1	77	92	165	243
	C	96	111	192	273
C1	C1	80	104	185	264
	C	99	123	213	293
C	C	102	133	232	312

Table II

SAMPLE STATION SHORT SPACINGS

prepared for
National Association of Broadcasters
Washington, D.C.

Station	Class	Location	Short Spacings: FCC Rules 6 kW A	Short Spacings: FCC Rules Other	Short Spacings: Recommended 6 kW A	Short Spacings: Recommended Other
WSGL	A	Naples, FL	0	0	0	0
WKRE	B	Exmore, VA	1	0	0	1
WMVY	A	Tisbury, MA	1	0	0	1
WXXL	C1	Leesburg, FL	0	1	0	2
WMDH	B	New Castle, IN	2	1	3	1
WDZQ	B	Decatur, IL	2	0	1	1
WZTR	B	Milwaukee, WI	1	3	0	4
WBCH	A	Hastings, MI	2	1	2	2
KGRS	C1	Burlington, IA	0	0	0	1
WWYN	C1	McKenzie, TN	1	0	0	4
WTOJ	A	Carthage, NY	0	*	0	1*
WRJH	A	Brandon, MS	1	0	1	1
WBCN	B	Boston, MA	1	2	0	3
WCME	B1	Boothbay Harb, ME	1	0	0	1
WKDQ	C	Henderson, KY	0	2	0	4
KWYR	C1	Winner, SD	0	0	0	0
WDEN	C	Macon, GA	0	0	0	0
WEZZ	A	Clanton, AL	2	0	1	1
WWNK	B	Cincinatti, OH	1	2	0	3
WGTY	B	Gettysburg, PA	0	4	0	4
KVVA	A	Apache Junct, AZ	0	0	0	0
KUDA	C	Pahrump, NV	0	0	0	1
WANB	A	Waynesburg, PA	2	0	0	2
WAGI	C	Gaffney, SC	0	1	0	4
KNJO	A	Thousand Oaks, CA	0	1	2	1
WKKW	B	Clarksburg, WV	0	0	0	0
KVFM	C1	Logan, UT	0	0	0	1
WREL	B1	Buena Vista, VA	1	2	0	3
WIMZ	C	Knoxville, TN	0	0	0	0
KTNY	A	Libby, MT	0	0	0	0
	Total			37%		77%

* Specially negotiated short spacings to Canadian stations not included

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Appendix A

HISTORY OF FCC FM ASSIGNMENT STANDARDS AND PROCEDURES

prepared for
National Association of Broadcasters
Washington, D.C.

The idea for a system of FM radio broadcasting was brought to the attention of the Federal Communications Commission in 1936 by Major Edwin H. Armstrong. However, the advantages of frequency modulation (FM) were not recognized until proof thereof was presented in the late 1930's, through the endeavors of some 20 experimental stations operating on what were then termed "the high frequencies" (25 Megahertz and up).

Early FM Stations

Formal authorization of the FM broadcast service was made on May 20, 1940, utilizing frequencies between 42 MHz and 50 MHz. The expansion and development of the FM stations was curtailed by restrictions on the use of electronic components and equipment during World War II. By October 1944, 46 commercial stations had been licensed and 7 construction permits were outstanding. The number of pending applications had reached 405 by May of 1945.

FM assignmments were first administered under a "demand" systen similar to that utilized in AM broadcasting at the time. Assignments were related only to the characteristics of the area and population to be served. No orderly allotment scheme, as such, existed. While it was preferable that applications be crafted on a non-interference basis, proposals could be granted under conditions of limited interference where it could be demonstrated that the service gained was greater than the service lost.

When regular FM operations were first authorized, service to local populations and trade centers was emphasized,[1] with wide area coverage to remain the domain of the AM service. Grants were made on the basis of serving a specified area (in square mile terms).[2] A system of station classes evolved based on service to a particular type of area with a corresponding population density. Essentially, stations were to serve either a small community, a large metropolitan city, or large rural area.[3] Three groups of channels were thus established for these classes, each group reserved for a particular station class. Six channels were designated (initially) for stations serving cities or towns of less than 25,000 persons, with service generally not to exceed 500 square miles (1300 square kilometers) of area. Twenty-two were specified for service to populations of 25,000 or more within a 3000 square mile (7,800 square kilometer) maximum service area. Seven were set aside for service to larger areas.

Early FM stations had only one class of service. The service area was that "area in which the signal is not subject to objectionable interference or objectionable fading."[4] Coverage of "city areas near factories, car lines or busy streets" was expected to require a median field intensity of 1 mV/m. In "rural areas away from highways" 0.05 mV/m was considered usable. These values were based, according to Commission documents, on the absence of objectionable fading, noise encountered in the cited environments and objectionable interference. An absolute basis for these levels could not be found in the available literature.

/1 Report on Frequency Modulation, Docket 5805; 39 FCC 29; 20 May 1940

/2 Code of Federal Regulations, 1940 Supplement, Title 47, Part 3, Section 3.321

/3 Code of Federal Regulations, *supra* n.2, Section 3.222

/4 Code of Federal Regulations, *supra* n.2, Section 3.206

Predicting coverage during the early years was uncertain, since actual experience with FM service in the 40-50 MHz band was very limited. It appears that the original prediction method evolved from the ground wave theory developed largely by Kenneth A. Norton of the Federal Communications Commission (Norton, 1941). Tropospheric transmission was known to occur, but little experimental data were available to quantify its effects.

Coverage predictions incorporated the effects of terrain features by use of the familiar concept of average terrain taken from eight evenly spaced (45°) radials extending from the transmitter site. However, elevations were taken and analyzed along the *entire path* from the transmitter site to the signal strength boundary of interest. The Standards of Good Engineering practice which accompanied the 1940 Supplement to the Code of Federal Regulations specified that elevations be taken from the site out to the estimated location of the contour of interest (1.0 or 0.05 mV/m) and the average elevation determined for that entire segment. If the initial estimate of distance to the desired contour was found to be in error after the terrain average was determined, the process was repeated. This iterative process continued until acceptable agreement between results was attained.

Interference was apparently determined based on distances between stations and the percentage of such distances where the signal strength exceeded a pertinent threshold value. At other field strength levels, D/U ratios were established for co-channel and first adjacent channel relationships. This may be viewed as a primitive approach to consideration of signals on a statistical basis. In the case of a station protected to the 1 mV/m contour; objectionable interference was said to occur when "the signal for 50% of the distance in any sector exceeds 0.1 mV/m".[5] The desired to undesired (D/U) signal strength ratios were established at 10:1 (20 dB) for co-channel stations and 2:1 (6 dB) for first adjacent channel stations.

Startup of the Present FM Band

The FM broadcasting service was relocated to its 88-108 MHz, where it remains to this day, as a result of the extensive hearings involved in the reallocation of the spectrum in Docket 6651. In that proceeding, the Commission proposed three alternative locations for the FM broadcasting service, 50-68 MHz, 68-86 MHz, or 84-102 MHz.[6] The Commission intended that the selection of frequency band and adoption of technical standards governing its use would be derived from extensive tests and measurements, for which sufficient time was thought to be available during the closing days of World War II. When the war rapidly drew to an end, the test and measurement plan was abandoned and hearings concerning FM broadcasting were quickly held. The Commission reserved the 88 to 92 MHz span for non-commercial educational FM stations and the 92 to 106 MHz group for commercial broadcasting.[7] The commercial frequencies were extended to 108 MHz shortly thereafter.

For general allocation purposes, the United States was divided into two areas. Area I was primarily the heavily populated, industrialized northeastern portion of the country, while the remainder comprised Area II. Classes of stations were specified, again defined by their coverage areas. Class A stations were local stations with limited power and height. Class B stations were designated to serve large metropolitan or wide rural areas.

The system of alloting frequencies to communities and then assigning specific uses to those allotments was initiated domestically in the FM broadcast service at this time. Frequencies were allocated for the existing licensees

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/5 Code of Federal Regulations, *supra* n.2, "Standards of Good Engineering Practice Concerning High Frequency Broadcast Stations", Section 2 (the wording of the procedure may seem confusing, but that is the way the standard was crafted in 1940)

/6 Report, "In the Matter of Allocation of Frequencies to the Various Classes of Non-Governmental Services in the Radio Spectrum from 10 Kilocycles to 30,000 Kilocycles", Docket No. 6651; 39 FCC 68, 25 May 1945; section 8

/7 Report, "Allocation of Frequencies to the Various Classes of Non-Governmental Services in the Radio Spectrum from 10 Kilocycles to 30,000,000 Kilocycles", Docket No. 6651; 39 FCC 222; 27 June 1945, at p. 226

and permittees on September 12, 1945, with a "tentative allocation plan" announced by December 19, 1945. Specific allotments of stations to communities were made by the Commission, with particular attention to ensure an "equitable distribution" of Class B stations, especially in the heavily populated markets. Until mid-1947, in areas where at least 5 Class B stations had already been assigned, one out of every 5 Class B channels tentatively indicated as available to those areas was to be withheld from assignment. Also, for a limited time, four channels were withheld from Class A assignment and no authorizations would be made for central cities of metropolitan districts having four or more AM stations. Channels reserved for Class A operation were dispersed somewhat uniformly throughout the band.[8]

Since the Class A station was intended to render service primarily to a community,[9] the maximum permitted effective radiated power (ERP) was 1 kW, at a antenna height above average terrain (HAAT) of 250 feet (76 meters). Class B stations were required to achieve a minimum ERP of 10 kW at an HAAT of 300 feet (91 meters), but not exceed an ERP of 20 kW ERP at an HAAT of 500 feet (152 meters) within Area I. In Area II, a minimum ERP of 2 kW at an HAAT of 300 feet and maximum ERP of 20 kW at an HAAT of 500 feet were specified for Class B stations. Class B stations could be authorized for greater power and antenna height upon a showing of need and lack of interference caused.

The "ground wave" field strength deemed necessary for service was redefined slightly. A median field strength of 3 to 5 mV/m was to be placed over the principal city to be served. Curiously, Class A stations were not initially required to determine the distance to their service contours. However, Class B stations were to determine the extent of their 1 mV/m and 50 μV/m contours and, if they served rural areas, the 20 μV/m contour location was also to be found. The last requirement was soon dropped. Again, the basis for these contours was not readily apparent from the literature.

The use of terrain elevations over the entire propagation path in determination of contour location was discontinued in 1945 as a result of an informal committee decision (TASO, 1959, p.331). The committee concluded that the terrain in the vicinity of the antenna might be as effective a parameter for calculating coverage as those methods previously employed. Its decision was apparently based on the analysis of 10 to 12 field strength surveys on FM stations operating in the 42-50 MHz band. Terrain information within two miles of the antenna was to be excluded "because many antennas would be located on hills or mountains which might not be representative of the surrounding terrain." From that time forward, terrain from two to ten miles from the transmitting antenna has been the standard.

By 1945, mobile field strength measurement was the preferable method of determining interference between stations. Alternatively, interference predictions could be made based on theoretical contour predictions and prescribed desired to undesired (D/U) field strength ratios. The protected service area of the desired station was defined by the pertinent median "ground wave" signal strength. For undesired signals, the tropospherically propagated signal intensity (for 1% of the time) was to be determined, but no tropospheric propagation graph then existed. Therefore, ground wave charts were "temporarily" used for establishing the interfering contour's location.

No change was made in the protection ratios established earlier for co-channel and first adjacent station relationships. Interference was not considered to exist at channel separations of 400 kHz (second adjacent) or

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/8 Order, "Promulgation of Rules and Regulations and Standards of Good Engineering Practice for FM Broadcasting Other Than Non-Commercial Educational Broadcast Service", Docket 6768; 12 June 1947

/9 To a city or town other than the "principal city" of a region and its surrounding rural area greater, but the assignment of stations separated in frequency by 10.6 to 10.8 MHz in the same general area was to be avoided, in order to avoid interference to receivers' intermediate frequency (IF) stages.

Television Proceedings of 1949-1950

A joint government/industry Engineering Conference was called in conjunction with Dockets 8736, 8975 and 9175, the proceedings which established the basis for our present television service, to consider wave propagation phenomena at VHF and UHF frequencies (FCC, 1949 and 1950). Among the subjects considered were: (1) improvement of the prediction of "service field intensities", (2) evaluation of the random field strength variations due to terrain and buildings, (3) tropospheric propagation curves and (4) methods of combining spatial and time variations of the desired signal and one (or more) interfering signals.

Propagation curves were developed which presented, for the first time in the broadcast services, measures of signal strength level defined statistically.[10] Data from field strength measurements and studies of location/time statistical treatment were published. However, the *ad hoc* committee which developed these methods felt that the data underlying these new graphs were too scant for them to be more than a rough approximation of propagation conditions throughout the United States. The resulting methods adopted for television service and interference prediction were not extended to the FM service at that time.

Serious consideration was given to alternatives to the 2-10 mile terrain averaging segment. Although individual investigations conducted by several members of the conference indicated improvement through one or more alternative methods, it was decided that the improvements were not sufficiently "systematic" nor of a high enough magnitude to warrant recommendation of any new method at the time. The conference did, however, stress that the decision to use the 2-10 mile terrain segment in studies should not be taken as a recommendation that an alternative method of determining antenna height should not be permitted. In the event that an alternative technique were chosen, it was cautioned that consideration be given to its effects with respect to the statistical predictions discussed in the report. Norton hoped that further studies of such data would lead to the development of "methods for estimating the departure of the median field along a particular radial in terms of some quantitative measure of the roughness along a radial..." He also thought that such studies might include a transmitting height above average terrain different from that obtained by the 2-10 mile rule that perhaps would vary with the distance along the radial.

The subject of how to handle multiple interference sources appears to have had its first serious examination during the Engineering Conference of 1949. A discussion of some substance was contained in the subsequent Report of the Ad Hoc Committee. Referenced therein were detailed reports on possible analysis methods written by Wilmotte, Fine and Blum.[11] In short, although different approaches were examined, a generally accepted method of evaluating the cumulative effects of multiple interfering signals had not been found at the time of the issuance of the Report. Recommendations were offered to the Commission on standards but not without considerable dissention from the participants. As far as can be determined, the FCC did not choose to further address the multiple interference issue in any subsequent proceeding, perhaps due to a lack of data and/or the complexity involved.

/10 i.e., at a defined percentage of receiving locations for a specified percentage of time

/11 Wilmotte, Raymond M., Report No. 748, "Report on Interference Caused by More Than One Signal"

Fine, Harry; FCC TID Report 4.2.3, "Combination of Several Interfering Signals in the VHF Range"

Fine, Harry; FCC TRR Report 4.2.4, "An Abbreviated Method for Calculating Multiple Interference"

Staras, Harold, and Blum, Marvin; "A Statistical Analysis of Multiple Radio Interference to Television Service", unpublished report of the Central Radio Propagation Laboratory, National Bureau of Standards

Experimentation with Demand Assignments

Along with the establishment of the present FM broadcast band in 1945, the FCC adopted a tentative Table of Allotments which reserved specific FM frequencies to particular cities. In August of 1958, the Table of Allotments principle was abandoned.[12] This resulted in a demand assignment system similar to that existing then (and now) in AM broadcasting. Simply put, if a qualified applicant proposed a new frequency usage at a community, and its application satisfied the pertinent technical standards, the proposal would be approved. The interference protection standards could be waived if, on balance, the benefits of the new service outweighed the service losses caused by interference.

Adoption of the Current Allotment/Assignment Scheme

The experimentation with demand-based station assignments ended when Docket 14185 was opened in 1961.[13] Sweeping changes in the manner of handling FM assignments resulted from that proceeding. Adoption of the present assignment scheme, the cornerstones of which are the Table of Allotments and interference evaluation by interstation separation distances, was completed in 1962.[14]

The new Table of Allotments specified particular channels (and classes thereof) to specific communities, based on "grandfathering" of existing assignments and the use of the interstation distance separation standards for new allotments.[15] Areas I and II were redefined as Zones I (the northeast), I-A (most of California), and II (the remainder of the country).

The propagation curves proposed for low band VHF television use were adopted for the FM service. Despite the expected improvement in service and interference area prediction, the contour-based definition of interference was abandoned in favor of a simpler interference regulation scheme based on minimum separation distances based on station class and frequency relationship, which remains in use to this day. The existing protection ratios were retained in the noncommercial FM technical standards, but existed for commercial stations only to the extent that they formed the basis for the separation table. The use of field strength measurements in evaluations of FM service and interference was henceforth disallowed.

The table of separation distances approach regulates interference between stations solely by requiring them to be separated by distances which are reasonable in a nationwide, general application sense. The distances set forth in the table were based on the maximum facilities permitted within each station class and non-overlap of the normally protected and potentially interfering field strength contours predicted for those ideal facilities. The distance separation table interference regulation technique provides administrative convenience and certainty. These facts, plus the difficulties inherent in administering contour protection under the technology of the day in 1963, are believed to have formed the rationale for the adoption of this technique for commercial FM station interference analysis. However, under this scheme, actual service contours may be over or underprotected from interference.

The Commission very slightly modified its service definitions, requiring a predicted field strength of 3.16 mV/m over a station's principal community and showings of the 1 mV/m and 50 μV/m service contours to be

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/12 Order, Docket No. 12461; FCC 58-777; released 5 August 1958

/13 Notice of Inquiry, Notice of Proposed Rule Making and Memorandum Opinion and Order, "Revision of FM Broadcast Rules, Particularly as to Allocation and Technical Standards ...", Docket 14185; FCC 61-833, 26 FR 6130; 8 July 1961

/14 First Report and Order, "Revision of FM Broadcast Rules, Particularly as to Allocation and Technical Standards ...", Docket 14185; FCC 62-866, 40 FCC 2d 662; effective 10 September 1962, at ¶32 and 37

/15 These allotments were loosely based on the priorities set forth in a Further Notice of Proposed Rule Making in the proceeding which was released in July of 1962. The Table itself was the subject of a Second Further Notice of Proposed Rule Making; FCC 62-1340, 40 FCC 2d 728; (1962)

included with applications.[16] These contours were disclaimed as being only indications of the approximate extent of coverage, over average terrain and in the absence of interference. The minimum interstation distance separation adopted in 1963 effectively permitted interference to the 1 mV/m contour for Class A and C stations and to the 0.5 mV/m (approximate) contour for Class B operations.[17] The 50 µV/m contour was no longer protected from interference. Therefore, in 1967, that contour was abandoned as a meaningful definition of FM service.[18]

Station power and height limitations were revised in the early 1960s. Acceptable ERP ranges were established as 0.1 to 3 kW for Class A stations, 5 to 50 kW for Class B stations, and 25 to 100 kW for the newly established Class C stations. Maximum HAAT limits were set at 300 feet (91 meters) for Class A stations, 500 feet (152 meters) for Class B stations, and 2000 feet (610 meters) for Class C stations. For ERP/HAAT combinations not falling within the ranges defined for a given station class, stations were categorized based on the Zone in which they were located and the distance to the predicted 1 mV/m service contour.

The need for higher protection ratios for multiplexed (stereophonic, SCA) operations was discussed, but the record suggests that little supporting information had been submitted to the Commission in Docket 14185.[19] Some commenting parties had specifically urged that the adjacent channel D/U ratios be increased to protect stereo and SCA operations. Zenith pointed out, on the basis of its own receiver measurements, that the signal-to-noise ratio for stereophonic broadcasting was about 23 dB poorer than that for monophonic broadcasting. It recommended that the cochannel D/U ratio be increased to 40 dB, and that the first adjacent ratio be increased to 26 dB (no change was suggested for second or third adjacent ratios). The subsequent rejection of more stringent protections was based primarily on the perceived need to provide a sufficient number of allotments and the lack of justification that the Commission claimed. It was also stated that the service area of stereo FM is less than that of monaural FM service, so "ratios ... affording adequate protection to regular service will also afford appropriate protection to these other types of service."

Revision of Propagation Curves

Docket 16004 was opened in May 5, 1965 to consider improving the reliability of the propagation curves.[20] Prior to the initiation of that proceeding, consultations were held between members of the Commission's staff, its former Radio Propagation Advisory Committee, industry engineers, and members of the CCIR study groups. Specifically considered was the incorporation of factors related to the nature of the terrain surrounding the transmitter site and data obtained from new, "standardized" field strength measurements following the technique adopted by the Television Allocations Study Organization (TASO, 1959). The extensive measurements collected during the TASO project, in addition to subsequent measurements provided the Commission with what it believed to

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/16 First Report and Order, *supra* n.14

/17 Third Report, Memorandum Opinion and Order, "Revision of FM Broadcast Rules, Particularly as to Allocation and Technical Standards ...", Docket No. 14185; FCC 63-735, 40 FCC 2d 747, 28 F.R. 8077; effective 12 August 1963

/18 Order, "Amendment of Section 73.311, Field strength contours, FM Broadcast Stations"; FCC 67-920; adopted 2 August 1967

/19 First Report and Order, *supra* n.14, at ¶15-18

/20 Notice of Proposed Rule Making, "Sections 73.333 and 73.699, Field Strength Curves for FM and TV Broadcast Stations", Docket No. 16004; FCC 65-383; adopted 5 May 1965 be sufficient data to revise the propagation curves.[21] The derivation of the new curves was described in FCC/OCE Report No. R-6502 (Damelin & Daniel, 1965).

The Commission's proposal was not accepted as it stood. Further studies were submitted by industry engineers, the Association of Federal Communications Consulting Engineers (AFCCE), and others which included additional data and critical commentary. In view of the importance of the matter, an Engineering Conference was held in the fall of 1965 to discuss the proposed curves. Additional information and refinements in the methods employed led to the revision of the material, detailed in FCC/OCE Report No. R-6602 (Damelin, et.al., 1966). Despite the considerable controversy which developed during this proceeding, the Commission became firmly convinced that the revised proposed curves represented a substantial improvement in prediction precision and felt justified to adopt them as an allocations tool on May 29, 1975.[22] The method included a procedure for the "correction" of field strength values based on terrain "roughness", but the implementation of that technique was indefinitely stayed.[23] The adoption and use of the revised curves had the effect of slightly reducing the distances predicted to FM stations' service contours.

BC Docket 80-90

BC Docket 80-90, which commenced in March of 1980,[24] proposed numerous rule changes to increase the availability of FM stations within the existing assignment structure. The changes proposed were rooted in the elimination of restrictions on class assignments to certain channels, and the addition of intermediate classes.

The proposed new community assignments were made on the basis of social criteria, as evidenced by the proceeding's Notice of Proposed Rule Making.[25] Class B and C stations were intended to serve large areas or population centers while Class A stations were designated for smaller communities. The NPRM for the proceeding illustrates this in the discussion of class versus community assignment criteria. For example, the Commission considered that service to populations of less than 10,000 was possible with Class A stations. Similarly, service was considered to be feasible to communities of 10,000 to 300,000 with a Class A, B, or C stations. Communities with populations greater than 300,000 could be served minimally with B1 or C1 stations or with B and C stations.

Ultimately, only four of the proposals were adopted.[26] The restriction of certain frequencies within the commercial (nonreserved) band to certain classes of stations was lifted. Three new classes of stations were added, B1 (25 kW at 328 feet), C1 (100 kW at 983 feet), and C2 (50 kW at 492 feet). Any stations not meeting the

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/21 The writers of this document find it most curious that the FCC relied greatly on the TASO data in developing its proposed propagation curves, but failed to follow the TASO's recommendations concerning propagation prediction methods. Its Supplementary Report (TASO, 1960) cites three propagation models, Types I, II, and III. The method proposed by the FCC was, in essence, a TASO Type I method, which the TASO's Supplementary Report found to "have limited value for allocation or assignment purposes because they fail to take into account many important influences on propagation." (p. 52) The TASO recommended use of a Type II method for assignment purposes (p. 54), which included substantial changes in the processing of terrain data.

/22 Report and Order, "Amendment of Sections 73.333 and 73.699, Field Strength Curves for FM and TV Broadcast Stations ...", Docket No. 16004; FCC 75-636; adopted 29 May 1975

/23 Order, "Temporary Suspension of Certain Portions of Sections 73.313, 73.333, 73.684, and 73.699 of the Commission's Rules and Regulations"; FCC 77-304, adopted 28 April 1977 (this Order continued indefinitely a suspension of the referenced rule provisions which originally commenced on 28 August 1975)

/24 Notice of Proposed Rule Making, "Modification of FM Broadcast Station Rules to Increase the Availability of Commercial FM Broadcast Assignments", BC Docket No. 80-90; 78 FCC 2d 1235, 45 FR 17602; adopted 28 February 1980

/25 Notice of Proposed Rule Making, *supra* n.24, at ¶5

/26 Report and Order, "Modification of the FM Broadcast Station Rules to Increase the Availability of Commercial FM Station Assignments", BC Docket No. 80-90; FCC 83-259, 48 FR 29486; adopted 26 May 1983 minimum facility standards for their existing classifications were given three years to file applications proposing to do so or face reclassification to the category describing their actual facilities. Finally, the metric system of measurement was adopted as the dimensional standard in the FM service.

The resulting availability of new (mostly Class A) allotments, generally on frequencies previously reserved for Class B and C use, was organized in MM Docket No. 84-231, wherein some 684 new allotments were proposed in one nationwide proceeding.[27]

The issue of increased protection for multiplexed transmission was raised again in Docket 80-90.[28] Comments were received that the existent minimum separations were insufficient for stereophonic broadcasting and subsidiary communications operations. For example, the American Broadcasting Companies referenced studies provided by the A.D. Ring & Associates consulting engineering firm that suggested that, in the absence of interference, a signal level of 0.063 mV/m would provide satisfactory stereo service. Others espousing a need for increased protection cited the CCIR's 50 dB audio frequency (AF) signal to noise ratio (SNR) standard. It was argued that to provide for this level of quality, the distance separation requirements should be increased to provide greater radio frequency (RF) protection ratios.

The Advisory Committee on Radio Broadcasting also urged protection of stereophonic service and submitted three supporting studies.[29] A study of the radio listeners (Bruskin, 1982) showed that approximately half of all radio receivers were capable of stereo reception, that stereo listening was roughly twice as prevalent as mono listening. A psychoacoustic study of audio signal-to-noise (interference) ratios (Middlekamp, 1982) demonstrated that a 50 dB AF SNR was needed for satisfactory stereo reception; i.e., an interfering signal that was only "slightly annoying". A study of FM interstation separation distances (Cohen, 1982) determined that the average co-channel separation between stations yielded a 34 to 40 dB RF D/U protection ratio. As referenced in the Technical Subgroup Report, the National Radio Systems Committee (NRSC) Report concluded that to achieve a 50 dB AF SNR, RF protection ratios of 40 dB cochannel, 25 dB first adjacent and -20 dB second adjacent would be required.[30]

In response to the comments filed, the Commission again examined the desirability of revising the protection requirements. NRSC receiver data were used in their studies to establish the expected service ranges for mono and stereo reception under the existing rules. A 30 dB AF SNR was employed for the monophonic service (the figure generally assumed to be the basis of the existing protection ratios) while 50 dB AF SNR was used for stereo.

It was found that to provide the 40 dB RF D/U ratio needed to obtain a 50 dB AF SNR, the separation requirements would have to be vastly increased. For example, the separation between cochannel Class C stations would increase to 255 miles from 180 miles. It was thus concluded that to fully protect stereo broadcasts, the Commission would have to effectively preclude many new allotments. The agency determined that the protections put into place in 1963 permitted the existence of adequate service areas while serving the mandate of Section 307(b) of the Communications Act for the fair, equitable and efficient distribution of service. Additionally, the Commission

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/27 Notice of Proposed Rule Making, "Implementation of BC Docket No. 80-90 to Increase the Availability of FM Broadcast Assignments", MM Docket No. 84-231; FCC 84-66; adopted 1 March 1984

/28 Report and Order, *supra* n.26, at ¶32

/29 The Advisory Committee was formed by the FCC to advise the Commission's staff on technical and spectrum allocation matters (See Memorandum Opinion and Order, FCC 80-537, 22 September 1980)

/30 The NRSC is an entity co-sponsored by the Electronic Industry Association (EIA) and the NAB. It is composed of persons from the broadcasting and electronics manufacturing industries to provide agencies with information on technology.

felt that stereo broadcasting was an "optional enhancement" of stations' entertainment programming. Thus protection ratios tied to the stereophonic service were rejected and the use of ratios derived for monaural service remained.

Limited Adoption of Contour Protection Assignment Standards

Faced with many requests for waivers of the interstation distance separation standards as a result of the "crowding" of FM station assignments spawned by BC Docket 80-90, the astronomical increase in FM station values during the early and mid 1980s, increasing local restrictions on land use, and air navigation obstruction/interference problems, the Commission initiated Docket 87-121 to examine the possibility of routinely permitting short-spaced transmitter sites where the proponent could, by utilizing a directional antenna, demonstrate no interference caused nor received under the contour protection standards then existing only in the noncommercial FM rules.[31] The Commission ultimately adopted its proposal, expanding it to include short-spaced applications which could demonstrate, due to favorable terrain between stations, contour protection without resorting to the use of a directional antenna.[32]

The Commission's stated intent was to allow greater flexibility in transmitter site selection, presumably lessening its waiver request burden. Contour protection was not envisioned as an allocations tool nor were such techniques to be permitted with respect to spacing deficiencies on "IF-related" frequencies (separated by 10.6 or 10.7 MHz). This Commission decision is now the subject of petitions for reconsideration.

Establishment of Class C3 and Increased Class A ERP

Responding to several petitions for rule making, the Commission proposed and ultimately adopted, one year ago, a new Class C3 with facilities identical to those previously adopted for Class B1.[33] Class A broadcasters' groups had petitioned for a universal increase in the maximum Class A ERP to 6 kW, regardless of the interference that might be caused to each other and to other classes of stations, based on their claims of economic hardship and public interest benefit. The Commission responded by permitting power increases for (a) all Class A stations which are fully spaced using distance separation standards based on 6 kW operation, (b) all Class A stations which meet such standards with respect to stations of other classes, are short spaced to other Class A stations, agree to mutually waive objections to those short spacings, demonstrating a public interest benefit in such an arrangement, and (c) those stations which, due to their use of low antenna heights, could increase power without extending their idealized interfering contours beyond the distances underlying the separation standards.[34] Class A power increases may also be sought under the alternative contour-based interference protection standard cited above.

Conclusion

/31 Notice of Inquiry, "Amendment of Part 73 of the Commission's Rules to Permit Short-Spaced FM Station Assignments by Using Directional Antennas", MM Docket No. 87-121; 2 FCC Rcd 3141 (1987), 53 FR 20430 (1 June 1987)

/32 Report and Order, "Amendment of Part 73 of the Commission's Rules to Permit Short-Spaced FM Station Assignments by Using Directional Antennas", MM Docket No. 87-121; 4 FCC Rcd 1681 (June 1989)

/33 First Report and Order, "Amendment of Part 73 of the Rules to provide for an additional FM station class (Class C3) and to increase the maximum transmitting power for Class A FM stations", MM Docket No. 88-375; FCC 89-107, 4 FCC Rcd 2792 (1989)

/34 Second Report and Order, "Amendment of Part 73 of the Rules to provide for an additional FM station class (Class C3) and to increase the maximum transmitting power for Class A FM stations", MM Docket No. 88-375; FCC 89-232; adopted 13 July 1989

The total effect of Commission actions in recent years has been to increase station population density nationwide. This will, increasingly, require the accurate prediction of service and interference areas in the FM broadcasting service during the coming years, if degradation of existing service is to be prevented.

Appendix B

REVISED SEPARATION DISTANCES

prepared for
National Association of Broadcasters
Washington, D.C.

FM stations' service areas are now protected from interference primarily based on fixed interstation distance separation standards. Those distances, set forth in §73.207 and §73.213(c)(1) of the Commission's Rules, were primarily derived by assuming use of the maximum facilities permitted for each station class and determining distances to pertinent protected and interfering field strength contours by means of the propagation curves of §73.333. It is presumed that, where the required separation distances are met, harmful interference will not occur.[1]

The propagation curve families were developed based on an assumed receiving antenna elevation of 30 feet. While such a height is a realistic assumption for television antennas commonly mounted atop houses and may have been indicative FM reception techniques many years ago, it is not typical of most FM receiving installations today. FM reception ordinarily involves automotive/mobile, portable, and desktop receivers and antennas. Assumption of a receiving antenna height of 6½ feet (2 meters) is considered to be more realistic for modern FM reception situations.

The separation distance requirements set forth in §73.207 and §73.213(c)(1) were evaluated for adequacy in light of these concerns relating to the assumed receiving antenna elevation.[2] The evaluation procedure employed and results obtained are described herein.

General Procedure

The procedure for evaluating the adequacy of the FCC's separation standards involves the determination of pertinent separation distances under different sets of assumptions. To best illustrate the procedure itself, it is useful to evaluate the current separation standards using the same method outline that will be employed in examination of alternative methods. This approach will provide a basis for better understanding the results obtained using alternative techniques.

The adequacy of the existing separation distances may be evaluated "within the four corners" of the FCC's existing technical standards in the following manner. For each station class, the maximum permitted effective radiated power (ERP) and antenna height above average terrain (HAAT) are assumed. The distance to the nominally protected contour (60 dBμ for Classes A and C, 57 dBμ for Class B1, and 54 dBμ for Class B) is determined. The distances to potentially interfering contours for the co-channel case (40, 37, and 34 dBμ), first adjacent relationship (54, 51, and 48 dBμ), second adjacent channel situation (80, 77, and 74 dBμ), and third adjacent channel instance (100, 97, and 94 dBμ) are also found. Each pertinent separation distance is found by adding the normally protected contour distance and the matching interfering contour distance for the class and frequency (channel) relationship involved. The matching of protected and interfering field strength values is based on the desired-to-undesired (D/U) ratios set forth in §73.215(a)(2) of the Commission's Rules.

/1 This presumption is sometimes false, due to the many environmental factors that affect the propagation of both desired and undesired signals in the real world.

/2 There are several other concerns relating to the adequacy of the separation standards, including the normally protected field strength contour magnitude and desired-to-undesired (D/U) signal ratio standards. Those topics are addressed elsewhere in this document. The purpose here is to consider the effects of the receiving height assumption in isolation, so those other concerns will not be considered in this Appendix.

Table B-I presents the resulting separation distances based on the FCC's current normally protected contour, D/U ratio, and propagation prediction definitions. Table B-II presents the difference between the actual separation distances of §73.207 and §73.213(c)(1) and the values set forth in Table B-I. A negative number indicates that a shorter separation was determined than that found in the Commission's Rules; i.e., the current standards may be overprotective. A positive number indicates a potential inadequacy in the present standards. Differences of one kilometer are attributable to the rounding off of data.

Several inadequacies in the present distance separation table result from the continuation of separations based on obsolete propagation curves or substandard separations established and maintained for policy reasons. For example, the first adjacent channel separation distance for Class A to B relationships and the co-channel Class B to A relationship only provides idealized protection to the Class B station's 57 dBμ contour. The current separation table is based on use of a -40 dB D/U ratio for second adjacent channel relationships, even though a -20 dB ratio has long been part of the rules for such situations. For relationships where separations are presently deficient, alternative methods can be expected to continue to show deficiencies.

The existing separation distance tables can be evaluated for other technical standard assumptions in a similar manner. The protected service boundary is defined in both field strength and distance terms, the potentially interfering contour is similarly described, and the distances added to find the separation necessary.

CCIR Propagation Model at Conventional Receiving Height

CCIR Recommendation 370-5 (CCIR, 1986) contains the international standard propagation curves, based on an assumed receiving height of 10 meters (33 feet). The table of separation distances for FM stations was constructed using the CCIR's propagation prediction method.

The CCIR propagation curves do not extend to distances under 10 kilometers (6 miles). Since several pertinent interfering contour distances fall within that range, a means of extrapolating the curves to lower distances was necessary. This was accomplished by determining the curve slope at the shortest defined distance, 10 kilometers, and projecting the field strength at the distance of interest from that slope and its 10 kilometer intercept. Free space field strength was computed at the same distance. The lesser of either the extrapolated CCIR curve or the free space field strength was selected as the result, avoiding unrealistic results. Both the FCC and CCIR curves are constrained not to exceed free space values within the ranges for which field strength - distance - height relationships are defined, so the limiting procedure described is considered to be appropriate.

Table B-III sets forth the calculated separation distances determined using this method. Table B-IV presents differences between this method and the separations currently specified in §73.207 and §73.213(c)(1) of the FCC's Rules. The average changes in separations with respect to the present standards are tabulated below.

Station Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
3 kW A	-1	+6	-6	+4
6 kW A	0	+7	-7	+2
B1	-2	+8	-7	+5
B	-1	+14	-4	+11
C3	-1	+8	-10	+3
C2	-1	+10	-9	+6
C1	+1	+15	-2	+15
C	-1	+13	-10	+17

Both the data shown above and that contained in Table B-IV suggest deficiencies in co-channel spacing for Class B, C1, and C2 stations. This is because the CCIR curves estimate higher field strengths at far distances than do the FCC curves. As was the case for the earlier evaluation using the present FCC standards, the differences for the second adjacent channel case largely result from the fact that the FCC's separation distances for both second and third adjacencies are based on a -40 dB D/U ratio, while -20 dB was used for the second adjacent channel case here. The data developed also suggests that it might be feasible to slightly reduce first adjacent channel separtion requirements.

Rice 1990 Formula Model at Conventional Receiving Height

Well known propagation physicist P.L. Rice has developed a set of formulas which approximate the FCC's F{50,50} and F{50,10} propagation curves for low VHF, high VHF, and UHF frequencies reasonably well (Rice, 1990). Mr. Rice's formulas are continuous with frequency, permitting them to be applied for any frequency band between 40 and 1000 MHz without modification. The difference between field strengths determined from the FCC's curves and the Rice formulas is generally less than 2 dB and often 1 dB or less.

Table B-V sets forth the calculated separation distances determined using this method. Table B-VI presents differences between this method and the separations currently specified in §73.207 and §73.213(c)(1) of the FCC's Rules. The average changes in separations with respect to the present standards are tabulated below.

Station Class	**Third Adjacent**	**Second Adjacent**	**First Adjacent**	**Co-Channel**
	(km)	(km)	(km)	(km)
3 kW A	-1	+7	+3	+8
6 kW A	-1	+8	+2	+6
B1	-2	+10	0	+4
B	-3	+16	0	+4
C3	0	+11	-1	+5
C2	-2	+12	-2	+6
C1	-2	+15	+4	+12
C	-6	+11	-1	+18

As was the case for the earlier evaluations using the present FCC and CCIR standards, the differences for the co-channel case are attributable to lower attenuation estimates well beyond the horizon and the second adjacent channel differences are attributable to the FCC's use of a -40 dB D/U ratio for both third and second adjacent channel situations. The data developed supports a modest increase in first adjacent and co-channel separation distances, with substantial increases appropriate for co-channel relationships involving Classes C and C1.

Adjustment for Lower Receiving Antenna Height

The FCC and CCIR propagation graphs are based on assumed receiving antenna elevations of 30 feet (9.1 meters) and 10 meters (33 feet), respectively; the latter method providing an adjustment factor for an elevation of 3 meters (10 feet) only. The Rice 1990 formula model permits entry of any assumed receiving antenna elevation. The general procedure to determine separation distances for reduced receiving elevations is described below.

In practice, a field strength of 60, 57, or 54 dBμ (depending on station class) at a receiving elevation of 30 feet is considered to yield an acceptable field strength at lower, more realistic receiving antenna heights. This should come as no surprise, since almost all FM receivers achieve full quieting at threshold levels far below the signal magnitudes present in such receiving situations. For administrative purposes, service is presently recognized at the normally protected contours of FM stations, regardless of receiving antenna height. There seems to be general consensus within the industry that, in gently rolling or relatively smooth terrain, service is realized to and often beyond the distances corresponding to the normally protected contours. Therefore, it makes sense to provide interference protection at or near those distances.[3]

Distances to the normally protected contours were determined using each alternative propagation relationship and a "conventional" receiving antenna elevation (10 meters for CCIR, 30 feet for Rice). The field strengths at those distances were then determined using a lower receiving antenna elevation assumption. Differences between the FCC's normally protected contour value and the lower elevation field strengths were calculated for each station class. Those results were averaged when using Rice's formulas and rounded off when using the CCIR curves. Next, field strength values which define normally protected contours were adjusted downward in accordance with the average (Rice) or specific (CCIR) difference found for each alternative. The distances to the resulting "adjusted" normally protected contours were then found for each station class using the alternative models. These distances are slightly different than the present nominal distances for each class.

Pertinent D/U ratios were applied to the "adjusted" protected contour values to find the interfering field strength levels. Distances to those interfering contours were then found for each station class using the alternative models. Tables of separation distances were then constructed by adding the normally protected and potentially interfering distances determined for a receiving elevation of 6½ feet (2 meters).

Rice 1990 Formula Model at 2 Meters

Rice's formulas take into account receiving height throughout the field strength estimation process rather than as absolute adjustments to the result. The differences between the FCC's normally protected contour and the 2 meter Rice 1990 formula values, determined at distances first found using the formulas at 30 feet (9.1 meters), ranged from -6.9 dB for Class C stations to -7.7 dB for 6 kilowatt Class A stations. The average difference was -7.3 dB. Rounding this value off, normally protected contours were reduced by 7 dB for all station classes. For the Rice 1990 formulas at 2 meters, the protected contour values become 53 dBµ for Class A and C stations, 50 dBµ for Class B1 stations, and 47 dBµ for Class B stations.

Potentially interfering contour values must, therefore, also be adjusted downward by 7 dB. For example, the co-channel interfering contours become 33, 30, and 27 dBµ.

Table B-VII sets forth the calculated separation distances determined using this method. Table B-VIII presents differences between this method and the separations currently specified in §73.207 and §73.213(c)(1) of the FCC's Rules. The average changes in separations with respect to the present standards are tabulated below.

/3 Separation distance tables could be constructed based on the use of the present "normally protected" field strength values but assuming a receiving elevation of 2 meters. The distances to idealized protected service contours would diminish greatly due to the additional signal attenuation attributable to reduced receiving antenna elevation. Similarly, the distances to idealized potentially interfering contours would shrink dramatically. The separation table constructed from such data would be far less restrictive than the existing FCC separation standards. Although parties interested in alloting more FM stations might cite such an analysis in urging lessening of the separations, we point out that the present "normally protected" field strength values at 30 feet are not the basis for present receiver designs nor are they related in any way to noise thresholds. We believe there is no solid technical basis for determining separation standards in such a manner; the sole reason to do so is to permit further crowding of the band.

Station Class	Third Adjacent	Second Adjacent	First Adjacent	Co-Channel
	(km)	(km)	(km)	(km)
3 kW A	-1	+6	+4	+18
6 kW A	-1	+8	+4	+16
B1	-3	+10	+3	+15
B	-4	+15	+6	+16
C3	-1	+10	+1	+17
C2	-3	+11	+2	+17
C1	-2	+14	+11	+22
C	-6	+11	+6	+26

The differences for the second adjacent channel case were explained earlier in this Appendix. A need to substantially increase the separation of co-channel stations is evident from the summary data shown above, particularly since it is quite consistent.

CCIR Propagation Model at 2 Meters

CCIR Recommendation 370-5 (CCIR, 1986) contains suggested adjustment factors for field strength estimation at 3 meters (10 feet). An adjustment factor of 9 dB is to be used for distances under 50 kilometers (31 miles), the factor is to be halved for distances in excess of 100 kilometers (62 miles), and the modification is to be linearly interpolated between those levels at distances from 50 to 100 kilometers (31 to 62 miles).

It is our intent to evaluate field strengths not at 3 meters, but at 2 meters. The relevant literature indicates general agreement that the receiving antenna height versus field strength function is approximately linear within the radio horizon. Therefore, the adjustment factor was linearly extrapolated from 3 meters to 2. An adjustment factor of approximately 12 dB was used within 50 kilometers, 6 dB was employed beyond 100 kilometers, and the value interpolated linearly for distances in between.

The differences between the FCC's normally protected contour and the 2 meter adjusted CCIR curve values, determined at distances first found using the unadjusted (10 meter) CCIR curves, was -7 dB for Class C stations, -9.4 dB for Class C1 stations, -10.6 dB for Class B stations, and -12 dB for all other classes. The average difference was -10.9 dB. However, use of a rounded average value (-11 dB) for all station classes would result in slightly substandard separations for Class A, B1, C2, and C3 stations and overly restrictive separations for Class C and C1 stations. Therefore, protected contours were adjusted by figures pertinent to the class involved. For the CCIR curves, the protected contour values, assuming a 2 meter receiving height, become 53 dBμ for Class C stations, 51 dBμ for Class C1 stations, 43 dBμ for Class B stations, 45 dBμ for Class B1 stations, and 48 dBμ for Class A, C2, and C3 stations.

Potentially interfering contour values must be less than the protected contour values specified above by the pertinent D/U ratio. For example, the co-channel interfering contours corresponding to the protected contours just described are 33, 31, 23, 25, and 28 dBμ, respectively.

Table B-IX sets forth the calculated separation distances determined using this method. Table B-X presents differences between this method and the separations currently specified in §73.207 and §73.213(c)(1) of the FCC's Rules. The average changes in separations with respect to the present standards are tabulated below.

Station Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
3 kW A	-1	+5	+8	+42
6 kW A	-1	+6	+6	+41
B1	-2	+7	+10	+47
B	-1	+14	+18	+51
C3	-1	+8	+5	+43
C2	-1	+9	+18	+48
C1	0	+12	+25	+49
C	-3	+10	+16	+55

Both the data shown above and that contained in Table B-X reveal wide variations in first adjacent channel spacing differentials. It is believed that these variations result from the fact that the first adjacent channel potentially interfering contour for several station classes falls between 50 and 100 kilometers, where the receiving antenna elevation adjustment factor is a variable function of distance. The second adjacent channel distances are extended for the reasons cited earlier.

The most striking result of this analysis is the apparent need to greatly increase the separation of co-channel stations. A much greater increase results here than under the Rice 1990 formula model study. That increase is attributable to the difference in receiving antenna elevation adjustment factors. An "interference gain" of 6 dB exists under the CCIR model, whereas the similar figure for the Rice 1990 formula model is less than 4 dB. Small dB variances translate to large distance differentials when low-valued field strengths are being predicted.

Conclusion

Redetermination of required separation distances based on the assumption of a lower receiving antenna elevation reveals that the interference protection ideally achieved by the FCC's current interstation separation distance standards may not be realized, particularly for the co-channel case. This is because the desired, within-the-horizon, field strength is attenuated more by lowered receiving antenna elevation than is the undesired, beyond-the-horizon signal, worsening the D/U ratio. Such a result is expected from the fundamental nature of VHF propagation, because the dominant factor in desired signal attenuation is classically determined from the optical path, which is quite sensitive to receiver height, but the undesired signal attenuation is largely determined by atmospheric (tropospheric) scatter effects, which have been shown to be less dependent upon antenna height and far more a function of the effective radiated power employed.

Distance separation tables need to be based on realistic receiving antenna heights if they are to be effective. Contour protection methods, if used in lieu of separation tables or as an adjunct thereto, should also be based on realistic assumptions of receiver antenna heights. Normally protected contour values should be redefined downward based on the assumption of lowered receiving elevations in order to maintain protection of existing service areas.

Separation distance revisions, based on the Rice formula model and presented in Table B-VII, are tentatively recommended.[4] The average results obtained using this technique are more consistent and well-behaved than those using the CCIR model. The fact that the CCIR model is not sensitive to relative location of the radio horizon reduces its accuracy. If reliable adjustments to the FCC's FM propagation model for lower receiving heights can be developed, the existing FCC propagation curves could be used as an alternative means to develop improved separation distance tables.

/4 Additional factors, such as protected contour field strength redefinition based on receiver performance data or changes in D/U ratios, could be incorporated into a more comprehensive review and modification of the separation distance tables.

Table B-I

SEPARATION DISTANCES BASED ON FCC D/U STANDARDS

prepared for

National Association of Broadcasters

Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	26	32	61	100
	B1	48	54	89	138
	B	68	76	116	163
	C3	41	47	84	138
	C2	54	60	102	162
	C1	75	80	131	204
	C	94	99	161	222
A6	A6	31	38	72	115
	B1	48	56	96	143
	B	69	78	125	177
	C3	42	48	89	142
	C2	55	61	107	166
	C1	75	82	133	201
	C	94	101	165	226
B1	B1	50	61	114	175
	B	71	84	145	211
	C3	50	61	114	175
	C2	56	68	133	200
	C1	77	86	161	233
	C	96	105	193	259
B	B	74	93	164	237
	C3	71	84	145	211
	C2	74	93	164	237
	C1	79	112	195	270
	C	98	133	225	297
C3	C3	43	52	99	153
	C2	56	65	117	177
	C1	77	86	144	211
	C	96	105	176	237
C2	C2	58	72	130	190
	C1	78	92	157	224
	C	98	111	189	250
C1	C1	82	106	177	245
	C	102	125	209	270
C	C	106	142	228	289

Table B-II

SEPARATION DIFFERENCES BASED ON FCC D/U STANDARDS

prepared for
National Association of Broadcasters
Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	-1	5	-3	-5
	B1	0	6	1	0
	B	-1	7	11	0
	C3	-1	5	0	0
	C2	-1	5	-3	-1
	C1	1	6	2	8
	C	0	5	0	0
A6	A6	0	7	0	0
	B1	0	8	0	0
	B	0	9	12	-1
	C3	0	6	0	0
	C2	0	6	1	0
	C1	0	7	0	1
	C	-1	6	0	0
B1	B1	0	11	0	0
	B	0	13	0	0
	C3	0	11	0	0
	C2	0	12	-1	0
	C1	-1	9	0	0
	C	-9	0	0	0
B	B	-1	19	-5	-4
	C3	0	13	0	0
	C2	-1	19	-5	-4
	C1	0	33	0	0
	C	-7	28	8	23
C3	C3	0	9	0	0
	C2	0	9	0	0
	C1	1	10	0	0
	C	0	9	0	0
C2	C2	0	14	0	0
	C1	-1	13	-1	0
	C	-7	6	1	1
C1	C1	0	24	0	-1
	C	-3	20	0	0
C	C	1	37	-13	-1

Table B-III

SEPARATION DISTANCES BASED ON CCIR MODEL AT 10 METERS

prepared for
National Association of Broadcasters
Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	27	33	56	91
	B1	46	53	79	137
	B	67	75	106	167
	C3	40	46	76	137
	C2	54	59	94	167
	C1	76	81	131	219
	C	96	101	151	235
A6	A6	31	38	65	107
	B1	47	54	86	141
	B	68	77	114	175
	C3	40	47	79	141
	C2	54	61	97	171
	C1	76	83	132	213
	C	96	103	155	238
B1	B1	48	59	103	174
	B	70	82	134	215
	C3	48	59	103	174
	C2	56	66	125	206
	C1	78	87	161	249
	C	98	107	184	275
B	B	73	90	160	248
	C3	70	82	134	215
	C2	73	90	160	248
	C1	80	107	197	291
	C	100	121	221	320
C3	C3	42	51	88	150
	C2	56	65	106	180
	C1	78	87	141	223
	C	98	107	164	247
C2	C2	58	71	120	194
	C1	80	93	155	236
	C	100	113	178	261
C1	C1	85	106	177	258
	C	105	126	200	283
C	C	110	139	219	303

Table B-IV

SEPARATION DIFFERENCES BASED ON CCIR MODEL AT 10 METERS

prepared for
National Association of Broadcasters
Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	0	6	-8	-14
	B1	-2	5	-9	-1
	B	-2	6	1	4
	C3	-2	4	-8	-1
	C2	-1	4	-11	4
	C1	2	7	2	23
	C	2	7	-10	13
A6	A6	0	7	-7	-8
	B1	-1	6	-10	-2
	B	-1	8	1	-3
	C3	-2	5	-10	-1
	C2	-1	6	-9	5
	C1	1	8	-2	13
	C	1	8	-11	12
B1	B1	-2	9	-11	-1
	B	-1	11	-11	4
	C3	-2	9	-11	-1
	C2	0	10	-10	6
	C1	1	10	0	16
	C	-8	2	-9	16
B	B	-1	16	-9	7
	C3	-1	11	-11	4
	C2	-1	16	-9	7
	C1	1	28	2	21
	C	-5	16	4	46
C3	C3	-1	8	-11	-3
	C2	0	9	-11	3
	C1	2	11	-3	12
	C	2	11	-12	10
C2	C2	0	13	-10	4
	C1	1	14	-4	12
	C	-5	8	-11	12
C1	C1	3	24	-1	13
	C	0	21	-10	13
C	C	5	34	-22	13

Table B-V

SEPARATION DISTANCES BASED ON RICE MODEL AT 30 FEET

prepared for
National Association of Broadcasters
Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	30	37	66	99
	B1	47	56	88	141
	B	66	76	112	170
	C3	42	49	85	141
	C2	53	60	103	170
	C1	73	80	138	219
	C	92	99	162	241
A6	A6	34	42	75	114
	B1	48	58	95	145
	B	67	78	119	175
	C3	43	51	89	145
	C2	54	62	107	174
	C1	74	82	140	214
	C	92	101	166	245
B1	B1	50	64	110	176
	B	69	85	138	211
	C3	50	64	110	176
	C2	55	71	131	204
	C1	75	87	167	243
	C	94	106	196	274
B	B	72	93	162	238
	C3	69	85	138	211
	C2	72	93	162	238
	C1	77	108	201	275
	C	96	121	230	306
C3	C3	44	56	97	154
	C2	55	67	116	183
	C1	75	87	148	223
	C	94	106	175	254
C2	C2	57	73	126	194
	C1	77	93	159	234
	C	96	112	186	265
C1	C1	81	104	179	254
	C	99	123	206	285
C	C	102	133	225	303

Table B-VI

SEPARATION DIFFERENCES BASED ON RICE MODEL AT 30 FEET

prepared for
National Association of Broadcasters
Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	3	10	2	-6
	B1	-1	8	0	3
	B	-3	7	7	7
	C3	0	7	1	3
	C2	-2	5	-2	7
	C1	-1	6	9	23
	C	-2	5	1	19
A6	A6	3	11	3	-1
	B1	0	10	-2	2
	B	-2	9	6	-3
	C3	1	9	-0	3
	C2	-1	7	1	8
	C1	-2	7	7	14
	C	-3	6	1	19
B1	B1	0	14	-4	1
	B	-2	14	-7	-1
	C3	0	14	-4	1
	C2	-1	15	-3	4
	C1	-2	10	6	10
	C	-11	1	3	15
B	B	-2	19	-7	-3
	C3	-2	14	-7	-1
	C2	-2	19	-7	-3
	C1	-2	29	6	5
	C	-9	16	13	32
C3	C3	1	13	-2	1
	C2	-1	11	-2	6
	C1	-1	11	4	12
	C	-2	10	-1	17
C2	C2	-1	15	-4	4
	C1	-2	14	1	10
	C	-9	7	-2	16
C1	C1	-2	22	2	9
	C	-6	18	-3	15
C	C	-3	28	-17	13

Table B-VII

SEPARATION DISTANCES BASED ON RICE MODEL AT 2 METERS

prepared for
National Association of Broadcasters
Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	29	35	64	102
	B1	47	55	87	154
	B	66	75	112	182
	C3	41	48	85	154
	C2	52	59	105	182
	C1	73	80	143	223
	C	92	99	169	249
A6	A6	33	41	74	120
	B1	47	57	94	157
	B	66	78	120	188
	C3	42	50	89	157
	C2	53	61	109	185
	C1	73	81	145	228
	C	92	101	172	253
B1	B1	49	63	112	189
	B	69	84	143	224
	C3	49	63	112	189
	C2	55	69	136	215
	C1	75	86	175	252
	C	94	105	203	281
B	B	71	92	170	249
	C3	69	84	143	224
	C2	71	92	170	249
	C1	77	108	211	286
	C	96	121	240	315
C3	C3	43	55	98	166
	C2	55	66	118	194
	C1	75	86	154	232
	C	94	105	181	261
C2	C2	56	72	129	205
	C1	77	92	165	243
	C	96	111	192	273
C1	C1	80	104	185	264
	C	99	123	213	293
C	C	102	133	232	312

Table B-VIII

SEPARATION DIFFERENCES BASED ON RICE MODEL AT 2 METERS

prepared for
National Association of Broadcasters
Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	2	8	0	-3
	B1	-2	7	-1	16
	B	-4	6	7	19
	C3	-1	6	1	16
	C2	-3	4	0	19
	C1	-1	6	14	27
	C	-2	5	8	27
A6	A6	2	10	2	5
	B1	-1	9	-2	14
	B	-3	9	7	10
	C3	0	8	0	15
	C2	-2	6	3	19
	C1	-2	6	12	28
	C	-3	6	7	27
B1	B1	-1	13	-2	14
	B	-2	13	-2	13
	C	-1	13	-2	14
	C2	-2	13	2	15
	C1	-2	9	14	19
	C	-11	0	10	22
B	B	-3	18	1	8
	C3	-2	13	-2	13
	C2	-3	18	1	8
	C1	-2	29	16	16
	C	-9	16	23	41
C3	C3	0	12	-2	13
	C2	-2	10	1	17
	C1	-1	10	10	21
	C	-2	9	5	24
C2	C2	-2	14	-1	15
	C1	-2	13	7	19
	C	-9	6	4	24
C1	C1	-2	22	8	19
	C	-6	18	4	23
C	C	-3	28	-9	22

Table B-IX

SEPARATION DISTANCES BASED ON CCIR MODEL AT 2 METERS

prepared for

National Association of Broadcasters

Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	27	33	56	110
	B1	46	53	79	177
	B	68	76	117	209
	C3	40	46	77	177
	C2	54	59	117	209
	C1	74	79	162	256
	C	94	99	182	281
A6	A6	31	38	65	139
	B1	47	54	86	180
	B	69	76	120	212
	C3	40	47	80	180
	C2	54	61	120	212
	C1	75	80	162	250
	C	95	100	186	284
B1	B1	48	59	111	217
	B	71	82	155	254
	C3	48	59	111	217
	C2	56	66	155	250
	C1	76	84	195	293
	C	96	104	218	324
B	B	74	90	189	287
	C3	71	82	153	254
	C2	74	90	189	287
	C1	80	106	230	331
	C	98	123	253	364
C3	C3	42	51	89	189
	C2	56	65	130	221
	C1	77	86	171	259
	C	98	107	195	293
C2	C2	58	71	143	235
	C1	78	89	185	273
	C	98	108	209	307
C1	C1	82	100	190	278
	C	103	121	213	304
C	C	104	130	224	310

Table B-X

SEPARATION DIFFERENCES BASED ON CCIR MODEL AT 2 METERS

prepared for
National Association of Broadcasters
Washington, D.C.

Proposed Class	Protected Class	Third Adjacent (km)	Second Adjacent (km)	First Adjacent (km)	Co-Channel (km)
A3	A3	0	6	-8	5
	B1	-2	5	-9	39
	B	-1	7	12	46
	C3	-2	4	-8	39
	C2	-1	4	12	46
	C1	0	5	33	60
	C	0	5	21	59
A6	A6	0	7	-8	24
	B1	-1	6	-10	37
	B	0	7	7	34
	C3	-2	5	-9	38
	C2	-1	6	14	46
	C1	-1	5	29	50
	C	0	5	21	58
B1	B1	-2	9	-3	42
	B	0	11	10	43
	C3	-2	9	-3	42
	C2	0	10	21	50
	C1	-1	7	34	60
	C	-9	-2	25	65
B	B	0	16	20	46
	C3	0	11	8	43
	C2	0	16	20	46
	C1	1	27	35	61
	C	-7	18	36	90
C3	C3	-1	8	-10	36
	C2	0	9	13	44
	C1	1	10	27	48
	C	2	11	19	56
C2	C2	0	13	13	45
	C1	-1	10	27	49
	C	-7	3	21	58
C1	C1	0	18	13	33
	C	-2	16	4	34
C	C	-1	25	-17	20

Appendix C

SELECTION OF SAMPLE STATIONS

prepared for
National Association of Broadcasters
Washington, D.C.

In order to evaluate alternative methods of coverage and interference prediction for FM broadcast stations, it is necessary to utilize a sample of stations that is representative of the types of environments in which FM stations normally operate. Terrain characteristics have long been recognized as the single most important environmental characteristic in FM propagation. Accordingly, representative diversity of terrain is important in testing the performance of service and interference prediction mechanisms. The terrain characteristics surrounding transmitter sites were used as a measure for categorizing licensed FM stations nationwide and picking a 30-station representative sample of those situations.

Four methods were used to calculate the terrain characteristics near each licensed FM station in the 48 contiguous states using data contained in the April 30, 1990 FCC FM Engineering Data Base. Detailed results are presented herein for three of those methods. Two methods used raw terrain data throughout the nominal service area to compute the rate of change in the terrain between data points and the variation in that rate of change at each point. The third method made use of the standard FCC/CCIR terrain roughness factor, *delta h*, along the 8 standard cardinal radials from each station.

It was found that the vast majority of licensed domestic FM radio stations operate in areas where there are relatively small amounts of elevation change, with most stations having a terrain "roughness" factor below 20 percent of the maximum value computed for all stations studied. A comparison was made between data obtained using traditional terrain roughness deviations and the alternative methods used for this study.

Methods of Analysis

The traditional FCC/CCIR definition of terrain "roughness" may be used to categorize stations. However, that only measures the absolute difference in terrain elevations within a station's entire coverage area. Land sloping uniformly from one side of the service area to another will have a large FCC/CCIR *delta h* value, but is not "rough" because large variations in terrain elevation do not occur over short distances. Therefore, it is reasonable to also evaluate terrain in terms of terrain slope and the rate of change thereof.

Conventional *delta h* Roughness Factor

The "conventional" FCC/CCIR method of defining terrain "roughness" involves computation of the interdecile difference in terrain elevation between 6.2 miles (10 kilometers) and the point where the signal strength is to be determined, but never more than 31 miles (50 kilometers), along a given radial going outward from the transmitter site. The interdecile difference is that between the terrain elevation exceeded for 10 percent of the sampled points and the elevation exceeded by 90 percent of the sampled points. It is really a measure of elevation diversity along a path, not the rate of change in elevation over incremental distances.

Characterizatoin of terrain in this fashion has the advantage of computational ease; the determinations can be performed graphically or mathematically. The terrain characteristic is only calculated between the transmitter site and a distance of interest. When using this method for locating coverage contours, the terrain factor is determined only within the coverage area of the facility, except when the contours extend beyond 31 miles (50 kilometers).

Furthermore, this method of terrain characterization calculation is direction sensitive; that is, it provides individual data on the terrain characteristics in the directions of the radials used.

This method has disadvantages, however. It considers only a two dimensional surface along each radial: elevation as a function of distance. Something closer to a three dimensional surface will be obtained only with a substantial number of radials. Furthermore, for higher classes of station, the outer portions of the coverage area lie beyond the 50 kilometer segment limit. Thus, the characteristic developed may not represent the terrain throughout the entire coverage area. Use of this method may not be entirely adequate in categorizing terrain throughout the coverage area of broadcast stations.

Three Dimensional Measures

With the availability of digitized terrain data, an alternative method of characterizing the terrain is to construct a three dimensional model of the terrain within the nominal coverage area[1] of each station. From this model, various computations can be made to establish the character of the terrain. Three separate computations were made to characterize the terrain using this model. The first computation was an average slope between the data points, providing a first derivative function. The second method of computation was to determine the average rate of change in the slope at each data point. This provides a second derivative function. The third computation was simply the statistical mean and standard deviation of the elevations within the service area. These methods of computation are valid only for a broad characterization of the terrain in a wide area. Such methods do not account for terrain variations in different directions, nor can they provide data for specific paths.

The N.G.D.C. 30 arc second and U.S. Geological Survey Defense Mapping Agency 3 arc second terrain databases provide three-dimensional models of terrain. The elevation at each point is indexed by the latitude and longitude of the point. When employed for traditional methods of terrain averaging, a two-dimensional model is constructed as a subset of this three-dimensional data by taking a "slice" of data along one radial from the transmitter site, using linear interpolation between latitude/longitude coordinate data points. When terrain characteristics are desired over a wide area, the required statistics can be obtained directly from the data points themselves, without interpolation.

<u>Average Slope Characteristic</u>

The average magnitude of elevation difference versus distance (slope) between data points was computed simply by taking the elevation of the data point in question and subtracting the elevation of the next northerly point, and also subtracting the elevation of the next westerly point. The absolute value of each of these differences were computed, and the average calculated to obtain the average slope at each point. This process was repeated over the entire service area. For the entire defined coverage area, the mean of all point averages was computed.

<u>Average Change in Slope</u>

The average rate of change in elevation difference was similarly computed. For each point, the difference was determined to the next easterly and next westerly point, and the difference between these two differences was computed to obtain the rate of change between the two elevation differences. A similar process was performed for points in a north-south direction. The average of the absolute values of these

/1 Defined as the F(50,50) 60 dBu contour distance for the maximum power/height combination for the class of station.

rates of change were computed to produce the average rate of change at each point. This process was repeated over the entire service area, and the average was found.

In addition to the foregoing meausres, the mean and standard deviation of terrain elevations within each station's coverage area were determined directly from the raw data points sampled near each facility.

Computation of Terrain Factors for Stations

The previously defined quantities were computed for each licensed station contained in the FCC's 30 April 1990 FM Engineering Data Base. N.G.D.C. 30-second terrain data was used for this phase of the project. Since the N.G.D.C. 30-second data does not contain information for Alaska, Hawaii, Puerto Rico, or other U.S. possessions, no categorization was attempted for stations located outside the coterminous 48 States. No weighting of the results was employed to account for earth bulge or other effects related to distance from the transmitter site, nor was any correction applied to correct for distance differences in latitude or longitude. Further, no attempt was made to ferret out and correct erroneous station information contained in the FCC's database.

Coverage Areas

The nominal coverage area of an FM station is defined as a uniform radius circle surrounding the transmitter site. For purposes of the terrain characterization, that circle represents the nominal 60 dBu coverage based on the F{50,50} propagation curves. To minimize computation complexity and time, the terrain calculations were computed for square areas equivalent to the nominal circular coverage area. This choice was made due to the orthogonal structure of the terrain data. An additional advantage of use of a square area is that interpolation between data points is not required.

The uniform radius and length of the side of the square used for terrain extraction for various classes of station were defined as follows:

Class	Uniform Circle Radius (km)	Equivalent Square Side (km)
A	24	42.5
B1	39	69.1
B	52	92.2
C3	39	69.1
C2	52	92.2
C1	72	128
C	92	163

Data Processing Procedure

The proprietary in-house database employed by this office incorporates a feature to search the FCC's engineering database for records meeting certain criteria. The entire database contains approximately 25,000 records, with one record each for licensed station, construction permit, application, translator, booster, and allotment proposal. Minor changes were made to the retrieval routine to call programs which process and compute the terrain data in order to facilitate the task at hand.

Each record in the database was checked to determine whether the facility status flag indicated a licensed station. For each record meeting this condition, the call sign, city and state of license, channel, facility class and geographic coordinates were extracted. The class and geographic coordinates were passed to the terrain retrieval routine. The terrain calculations were conducted, and the data was stored in a disk file for later processing. The terrain routine determined the lowest and highest latitude and longitude which formed a box with side length as defined above around the site. Proprietary routines were used to extract the terrain points from the database, which were then used to compute the terrain data for each station. Identifying data for each station and the results were stored in an intermediate data file, and processed using a commercially available spreadsheet package.

For the three dimensional models, the terrain results used to determine "roughness" are based on the elevation differences, or rate of change in those differences, between data points. These data points are indexed by latitude and longitude. It is noted that the distance between these points varies with latitude.[2] There is a variation of approximately 17 percent in distance between the elevation points for latitudes at the northern most boundary of the 48 contiguous states as opposed to the lowest latitude in Florida. The terrain data studies conducted here averaged elevation change in the north-south, and east-west direction. Therefore, the expected margin of error for the overall average is expected to be approximately 8.5 percent. Some error might also be expected for differences in distance between latitude points and longitude points. The random nature of the data tends to minimize the effect of these potential errors.

For the conventional terrain *delta h* interdecile difference characteristic, the uniform circle coverage radius was used to determine the outer distance boundary of the terrain retrieval segment. If the distance exceeded 50 kilometers, 50 kilometers was used. Elevations were determined every 0.1 miles along each radial using the FCC-specified linear interpolation method. These computed elevations were sorted, and the interdecile difference was computed.

Potential errors which arise from use of digitized terrain data include the elevation resolution of data points (20 feet for the 30 second terrain data), the latitude and longitude resolution (30 seconds of latitude and longitude, for the database used herein), and the accuracy of the terrain data. In regard to the latter, it is noted that the 30 second terrain data is a subset of the 3 second data. The 3 second data originated from digitization of 1:250,000 topographic maps. Currently available versions of the 3 second data incorporate added points and a greater elevation resolution than the 30 second data. Numerous comparisons of terrain data has found that the error between use of 3 second data and 30 second data over a large number of data points averages 5 percent. This is considered insignificant in the context of categorization of stations.

Analysis of Data

The data obtained from the above calculations were sorted and grouped to allow various forms of analysis to be conducted. The data was ordered by the first derivative (average elevation difference between points), the second derivative, or average rate of change in the elevation difference at each point, and interdecile difference magnitude. A commercial spreadsheet software package was used to perform data manipulation and processing.

Study Results

For each set of studies, the stations were grouped by terrain elevation characteristics. An analysis of the results showed that, although the sequence of individual stations varied, depending on which data were being analyzed, the same general grouping of stations occurred for both slope and rate of change. Twenty-three even divisions were made between zero and the maximum recorded for each terrain characteristic. The number of stations within each group was counted for each characteristic.

/2 The distance between data points also varies slightly with longitude, but the variation is negligible.

Figure C-1 is a graph showing the relative number of stations in each group for the first and second derivative characteristics. Table C-I lists these results in tabular form. It is readily apparent that at least 50 percent of the licensed FM stations fall in the lower two groups for this form of analysis. Clearly, the terrain within most coverage areas can be characterized as relatively smooth or slightly rough. The bunching of stations near the lower roughness factors was not expected.

Figure C-2 is a graph showing a similar count of stations within 26 groups, based on the maximum interdecile elevation difference (defined by the FCC and CCIR as *delta h*) for any radial from any station. The three sets data represent the lowest radial *delta h* for any radial at the station, the average *delta h* for all 8 radials at the station, and the highest radial *delta h* for any radial at the station. Table C-II contains the data used for preparation of this graph. This study validated the findings of the three dimensional model: most stations are described by low-valued terrain characteristics.

An additional calculation was made of the average *delta h* factor for all stations studied. For only those radials having the greatest *delta h* at all stations, the average roughness factor was 235 meters. For the average of all radials at all stations, the average *delta h* was 117 meters. For only those radials having least *delta h* at all stations, the average roughness factor was 39.7 meters. The median value of *delta h* for the 8 radial roughness average at all stations sampled was 53 meters. The FCC propagation curves are based on an assumed *delta h* for the United States of 50 meters.

Selection of Sample Stations

From the body of data derived herein, four categories of terrain were established, based on the second derivative terrain function. Within those four categories, 30 stations were selected for further study. It was desired to select stations based on terrain categories, while still maintaining a sample distribution relative to the portion of stations within each category. The distribution of raw data made selection of categories difficult. Several attempts were made without success to divide the terrain roughness values into linearly even categories, while still retaining a statistically significant number of stations in each category.

The method ultimately chosen for use was to categorize the stations based on the logarithm of the second derivative terrain characteristic. The approximate median of the body of data had a logarithmic terrain characteristic of approximately 1.5, with the highest logarithmic value being slightly less than 3.0. Each category had a range of 0.75 logarithmic units, with the lowest category encompassing all lower values of terrain. Table C-III is a tabulation of the terrain categories chosen.

Within each terrain category, stations were selected for study. The number of stations chosen in each category was determined by using the percentage of all stations which fell within the category. The minimum number of stations in any category was two. Thirty stations were selected for study. Two were in the lowest category, 11 in the second category, 13 in the third category, and 4 in the highest category. Table C-IV is a listing of the stations chosen for study and their representative terrain characteristics.

Table C-I

TERRAIN CHARACTERISTIC DATA

prepared for

National Association of Broadcasters

Washington, D.C.

Percentage of Maximum	Delta Feet	First Derivative Number of Stations	First Derivative Percent	$Delta^2$ Feet	Second Derivative Number of Stations	Second Derivative Percent
0	0	18	0.4	0	1	<0.1
4	20	1611	38.4	25	1426	34.0
9	40	989	23.5	50	1042	24.8
13	60	348	8.3	75	391	9.3
17	80	252	6.0	100	286	6.8
22	100	182	4.3	125	171	4.1
26	120	161	3.8	150	189	4.5
30	140	152	3.6	175	155	3.7
35	160	116	2.8	200	132	3.1
39	180	111	2.6	225	123	2.9
43	200	91	2.2	250	84	2.0
48	220	41	0.9	275	56	1.3
52	240	34	0.8	300	30	0.7
57	260	29	0.7	325	35	0.8
61	280	10	0.2	350	17	0.4
65	300	10	0.2	375	16	0.4
70	320	9	0.2	400	10	0.2
74	340	3	0.1	425	9	0.2
78	360	9	0.2	450	4	0.1
83	380	3	0.1	475	2	<0.1
87	400	2	<0.1	500	1	0
91	420	1	<0.1	525	2	<0.1
96	440	2	<0.1	550	2	<0.1
100	460	0	0	575	0	0

Table C-II

FCC/CCIR TERRAIN ROUGHNESS (*delta h*)

prepared for

National Association of Broadcasters

Washington, D.C.

Delta h	Average Stations	Average Percent	Minimum Values Stations	Minimum Values Percent	Max. Values Stations	Max. Values Percent
0	46	1.1	674	16.1	46	1.1
350	2920	69.5	3146	74.9	2303	54.8
700	526	12.5	273	6.5	614	14.6
1050	262	6.2	52	1.2	286	6.8
1400	179	4.3	28	0.7	228	5.4
1750	100	2.4	16	0.4	154	3.7
2100	76	1.8	3	0.1	95	2.3
2450	56	1.3	1	0	98	2.3
2800	10	0.2	0	0	81	1.9
3150	7	0.2	0	0	61	1.5
3500	6	0.2	0	0	64	1.5
3850	4	0.1	0	0	39	0.9
4200	0	0	0	0	33	0.8
4550	1	0	0	0	18	0.4
4900	0	0	0	0	25	0.6
5250	0	0	0	0	11	0.3
5600	0	0	0	0	15	0.4
5950	0	0	0	0	5	0.1
6300	0	0	0	0	1	0
6650	0	0	0	0	12	0.3
7000	0	0	0	0	0	0
7350	0	0	0	0	0	0
7700	0	0	0	0	1	0
8050	0	0	0	0	1	0
9100	0	0	0	0	2	0.1

Table C-III

TERRAIN CATEGORIES

prepared for

National Association of Broadcasters

Washington, D.C.

Log of Second Derivative	**Category**	**Description**
-10 to 0.75	1	Flat Terrain
0.75 to 1.50	2	Slightly Rough
1.50 to 2.25	3	Moderately Rough
2.25 to 3.00	4	Very Rough

Table C-IV

SAMPLE STATIONS SELECTED FOR STUDY

prepared for
National Association of Broadcasters
Washington, D.C.

Call	City/State	First Derivative (ft/deg)	Second Derivative (ft/deg/deg)	Delta H Average (ft)	Delta H Min (ft)	Delta H Max (ft)
Group 1						
WSGL	Naples, FL	0.4	0.7	2.5	0	20
WKRE	Exmore, VA	0.9	1.6	7.7	0	38
Group 2						
WMVY	Tisbury, MA	4.4	6.8	33	0	131
WXXL	Leesburg, FL	5.1	9.1	58	20	100
WMDH	New Castle, IN	7.3	10.0	105	44	150
WDZQ	Decatur, IL	8.2	13.9	53	25	75
WZTR	Milwaukee, WI	11.8	17.7	106	0	346
WBCH	Hastings, MI	16.4	24.3	92	40	192
KGRS	Burlington, IA	17.3	27.5	153	79	235
WWYN	McKenzie, TN	19.0	28.6	105	42	169
WTOJ	Carthage, NY	25.9	28.6	188	16	340
WRJH	Brandon, MS	20.0	29.7	100	69	145
WBCN	Boston, MA	20.2	30.9	142	0	378
Group 3						
WCME	Boothbay Harbon, ME	23.1	35.3	114	0	264
WKDQ	Henderson, KY	24.4	38.2	84	20	124
KWYR	Winner, SD	30.5	41.9	266	181	371
WDEN	Macon, GA	28.9	44.4	172	120	237
WEZZ	Clanton, AL	41.0	61.7	194	130	269
WWNK	Cincinatti, OH	41.2	63.2	307	152	486
WGTY	Gettysburg, PA	54.6	78.5	380	170	990
KVVA	Apache Junct, AZ	71.8	96.5	489	56	1563
KUDA	Pahrump, NV	132	137	1366	955	1889
WANB	Waynesburg, PA	81.1	139	211	159	283
WAGI	Gaffney, SC	100	142	551	140	1447
KNJO	Thousand Oaks, CA	115	155	826	273	1848
WKKW	Clarksburg, WV	96.6	164	335	143	740
Group 4						
KVFM	Logan, UT	161	192	2095	94	4057
WVLI	Buena Vista, VA	175	228	1037	350	2161
WIMZ	Knoxville, TN	171	243	509	192	822
KTNY	Libby, MT	358	436	2349	1161	4010

Appendix D

AVAILABLE PROPAGATION MODELS

prepared for
National Association of Broadcasters
Washington, D.C.

All broadcast station assignment methods presently used in the United States are fundamentally based on "normally protected" signal strength contours along which "potentially interfering" signal intensities do not exceed certain values relative to the levels of the "protected" signal. These signal strengths are determined through the use of analytical models of radio wave propagation.

A basic factor in station assignment administration is the nature of the propagation model to be used, because any method of predicting FM station service or interference necessarily involves estimating the signal levels at a given point or within a given region. The effectiveness of all other factors is driven, to a large extent, by the appropriateness of the propagation model employed to the task at hand.

General Types of Propagation Models

There exist four fundamental types of propagation models, (1) area, (2) point-to-point, (3) point-to-line, and (4) point-to-area. Each of these will be generally described as follows.

Area Models

Area models are designed to estimate the signal strength on essentially a statistical basis over a variety of transmitter-receiver paths throughout a given region. True area models have been developed primarily to estimate the parameters of service for land mobile communications systems, with randomly sited transmitters and receivers, both having low antenna elevations. They inherently evaluate terrain effects for random paths within the region of interest. There is a high degree of generalization and approximation inherent in true area models, which limits the precision with which they may be used to estimate received signal strengths and service areas. Much of the data from which empirical relationships utilized in area models were derived is for mobile-to-mobile service using short antennas, quite unlike the broadcast case, which involves high transmitting antennas and low receiving antennas. The only true area model known is the Area Mode of NTIA's Irregular Terrain Model (Hufford, et. al., 1982).

Point-to-Point Models

Point-to-point models are designed to predict the signal strength over a specific path from transmitter to receiver. Point-to-point models were developed primarily to predict received signal strengths for fixed link radio facilities, such as microwave relay systems, etc. It is feasible to predict the nature of the terrain and its cover between transmitter and receiver to a very detailed extent and thus predict signal strength with specific knowledge of almost all pertinent factors. However, the particularity of point-to-point methods is also their major drawback, in that the signal strength predicted has only limited validity at any other receiving location. Examples of point-to-point methods are the Bullington nomographs (Bullington, 1947), the Longley-Rice point-to-point mode of NTIA's Irregular Terrain Model (Longley & Rice, 1967), and the BBC method (Causebrook & King, 1974).

Point-to-Line Models

We consider a propagation model which evaluates the average effects of terrain on received signal strengths in a specific radial direction from the transmitter to constitute a point-to-line model. The point-to-line model may be considered to be somewhat pertinent to the broadcast case in that it considers terrain along the line in a generalized fashion. The average value of the actual terrain elevations over a specific radial path from the transmitter site is used to predict signal strengths along that line. However, terrain off each line is not considered in any way unless it is cut by the elevation/radial distance plane of another radial bearing. In this latter respect, the point-to-line model is not entirely adequate for the three-dimensional reality of broadcast transmission and reception. The FCC and CCIR propagation models for broadcast services are examples of point-to-line models.

Point-to-Area Models

Broadcasting is inherently a point-to-area service, since there is a single transmitter location, usually selected with some care, but an infinite variety of receiving locations. As such, it does not fit neatly into the model types discussed above, although they may be based on data accumulated for broadcast frequencies and may be presently used in planning broadcast service. Research conducted to date has not identified any method applicable to FM frequencies which we consider a true point-to-area propagation model. A point-to-area model considers the effects of terrain and its cover about a specific transmitter site in an average manner, using methods based on equal area sampling. Such a model takes into account the fact that terrain either side of a particular direction may vary considerably; the model develops results for a particular sector of area going outward from the transmitter site on an equal area basis. Okumura's propagation model is an example of this type, but it was developed for higher frequency bands, particularly UHF (Okumura, et. al., 1968).

TASO Categorization of Propagation Models

Thirty years ago, the Television Allocations Study Organization (TASO) released its report to the Federal Communications Commission, Engineering Aspects of Television Allocations (TASO, 1959). That document contains the most thorough overall treatment of propagation prediction for VHF/UHF broadcast services written to date. Because low band VHF television occupies the same general part of the electromagnetic spectrum as FM, the work of the TASO is considered pertinent to the improvement of FM station assignment standards.

The TASO Report proposed three particular categories of propagation curves and models. *Type I* curves and their results were to be "average empirical propagation curves to be applied on a country-wide basis." *Type II* curves or methods were to "take into account average large area effects" in predicting field strengths. *Type III* methods were to facilitate the prediction of field strengths in small areas under very specific conditions. (TASO, 1959, pp. 405-412)

The TASO Report classified the FCC propagation curves as *Type I* curves, noting that, although the curves were used for (a) the establishment of an allocation plan, (b) estimating the coverage of individual assignments, and (c) estimating coverage of the principal community from a specific site, the Commission had originally intended them for application *only* to purpose (a). (TASO, 1959, p. 406) Relatively small modifications have been made to the low band VHF/FM curves since the issuance of the TASO Report, so that organization's conclusion in this regard is considered to remain valid.

Proceeding from the TASO's characterization of techniques, the use of propagation curves or mathematical relationships similar to the Commission's propagation graphs, with non-specific input,[1] may be described as TASO *Type I* methods. The separation distance approach to frequency allotment and/or interference regulation may also be considered to be a TASO *Type I* approach. Such methods are suitable for use in allocation planning on a country-wide

/1 e.g., the nominal antenna height above average terrain in all directions, not the effective antenna height in a specific direction basis. We agree with the TASO's conclusion (as well as the FCC's original intent, as the TASO perceived it) that such procedures are less than adequate for prediction of service areas and evaluation of specific assignments.

The TASO Supplement recommended the adoption of a *Type II* method for television station assignment purposes (TASO, 1960, p.54). The present method of determining FM station coverage prescribed by §73.313 of the FCC' Rules and the interference evaluation method prescribed by §73.215 could be claimed to represent a *Type II* method. However, because the determination of EAH involves only the terrain along a *limited segment* of a *line*, rather than *"average large area effects"*, we do not consider the present FCC method to involve what the TASO had in mind. Furthermore, the TASO recommended that the 2-10 mile (3-16 kilometer) EAH determination terrain segment be replaced by a more sophisticated method used over most of the distance of interest, which the FCC's present method does not do. For the purposes of predicting the field strengths over large areas (i.e., coverage contours) or evaluating the interference potential of assignments, improvement of the FCC's method of predicting service and interference requires the development of a technique generally consistent with the TASO *Type II* definition.

For more specific situations involving small areas, such as evaluating the adequacy of principal community coverage, the TASO recommended the use of *Type III* prediction curves and methods. Such procedures were to take into account terrain and clutter/foliage details of specific paths. The TASO tentatively recommended the use of a complicated technique described by Professor A.H. LaGrone.[2] A contemporary method of propagation prediction which meets the TASO *Type III* definition is the point-to-point mode of the Longley-Rice model (Longley & Rice, 1968). For assignment evaluation purposes, the data obtained from *Type III* methods is too detailed to be conveniently used.

FCC FM/TV Propagation Model

The propagation model required by the FCC to be used in the prediction of FM (and TV) service and interference was most recently refined in Docket 16004, which commenced in May of 1965[3] and concluded some ten years later.[4] It is based primarily upon empirical data and designed to yield estimates of approximate mean signal strength in fairly large areas, based on average terrain characteristics determined along radial bearings. As such, we classify the model as being a point-to-line, TASO *Type I* technique.

History of the FCC Propagation Model

The present model has its roots in the 1949-1950 Engineering Conference held in association with (primarily television) Dockets 8736, 8975 and 9175. Data from field strength measurements and studies of location/time statistical treatment were merged into subsequently published reports (FCC, 1949 and FCC, 1950). Public comment was received and the issues explicitly addressed (for the FM service) in the early 1960s in Docket 14185, with the immediate predecessor of the current procedure finally adopted in September of 1962.

Docket 16004 was opened in May 5, 1965 to consider improving the reliability of the curves. Prior to the initiation of that proceeding, consultations were held between members of the Commission's staff, its former Radio Propagation Advisory Committee, industry engineers, and members of the CCIR study groups.

/2 Attachment A to Report of Committee 5.4, "Empirical Method for Determining the Effect of Uneven Terrain on the Television Signal at a Given Location"; A.H. LaGrone; 1 July 1959 (TASO, 1960, p.56)

/3 Notice of Proposed Rule Making, "Field Strength Curves for FM and TV Broadcast Stations", Docket No. 16004; FCC 65-383, released 10 May 1965

/4 Report and Order, "Field Strength Curves for FM and TV Broadcast Stations" and "Amendment of Part 73 of the Rules regarding field strength measurements for FM and TV Broadcast Stations", Dockets Nos. 16004 and 18052; FCC 75-636, released 27 June 1975

Specifically considered was the incorporation of factors related to the nature of the terrain surrounding the transmitter site and data obtained from new, "standardized" field strength measurements.

Efforts at standardizing field measurement techniques had been made in conjunction with the Television Allocations Study Organization project (TASO, 1959). The extensive measurements collected during that project, in addition to subsequent measurements provided the Commission with what it believed to be sufficient data to revise the propagation curves.[5]

With respect to the VHF/FM curves, the proposed F{50,50} graph was in essential agreement with the curves previously adopted, out to a distance of 20 miles (32 kilometers). Beyond the horizon, the proposed curves indicated higher field strengths. At distances beyond 80 miles (129 kilometers), the revised curves were in good agreement with the CCIR graphs. Field strength measurement data were used to determine the fading ratios which were then applied to the F{50,50} curves in order to obtain the F{50,10} graphs. These fading ratios ranged from roughly 1 dB at 10 miles (16 kilometers) to about a 9 dB maximum at progressively greater distances as the antenna height increased. The particular details of the new curve development were provided in FCC Report R-6502 (Damelin & Daniel, 1965).

The Commission's proposal was not accepted as it stood. Further studies were submitted by industry engineers, AFCCE and others which included additional data and critical commentary. In view of the importance of the matter, an Engineering Conference was held in the fall of 1965 to discuss the new curves. Additional information and refinements in the methods employed led to the revision of the material, detailed in FCC/OCE Report No. R-6602 (Damelin, et.al., 1966).

In spite of the considerable controversy which developed during this proceeding, the Commission became firmly convinced that the revised proposed curves represented a substantial improvement in prediction precision and felt justified to adopt them as an allocations tool on May 29, 1975.[6]

The exact relationships between field strength, distance, and antenna height described by the R-6602 curves have become somewhat "fuzzy" in practical application in recent years, due to the digitization of the graphs for internal FCC staff use and then the conversion of those charts to the metric system of units. The first departure from the R-6602 curves was reported in 1976, when the Commission staff developed a computer program to simulate the determinations otherwise carried out graphically using the propagation curves.[7] The next departure from the R-6602 curves came in 1984, when the printed graphs contained in §73.333 of the Rules were replaced with "equivalents" scaled in the metric system of units. Although these "metric" curves are alleged to be equivalent to the R-6602 curves, they are not. Differences between the curves and their computer approximations are tabulated in Tables D I-III. It is understood that the Commission staff relies heavily on various computer programs based on "TVFMFS" and its related data files for day-to-day studies of

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/5 The writers of this document find it most curious that the FCC relied greatly on the TASO data in developing its proposed propagation curves, but failed to follow the TASO's recommendations concerning propagation prediction methods. The TASO's Supplementary Report (TASO, 1960) cites three propagation models, Types I, II, and III. The method proposed by the FCC was, in essence, a TASO Type I method, which the TASO's Supplementary Report found to "have limited value for allocation or assignment purposes because they fail to take into account many important influences on propagation." (p. 52) The TASO recommended use of a Type II method for assignment purposes (p. 54), which included substantial changes in the processing of terrain data.

/6 Report and Order, "Amendment of Sections 73.333 and 73.699, Field Strength Curves for FM and TV Broadcast Stations ..."; Docket No. 16004, FCC 75-636; adopted 29 May 1975

/7 G.S. Kalagian, Report No. RS 76-01, "Field Strength Calculation for TV and FM Broadcasting (Computer Program TVFMFS)"; Federal Communications Commission, Office of the Chief Engineer, Research and Standards Division; January 1976

FM and TV service and interference contours, effectively making such computer routines the *de facto* standard for propagation analysis.

Derivation of R-6602 Propagation Curves

The R-6602 propagation curves were based on an analysis of the VHF and UHF field strength measurement data available in the mid-1960s. This included data from the Television Allocations Study Organization work, government research, and private station measurement activities. Radial measurements were used for collecting data over paths generally less than 100 miles in length, while long-term, fixed location measurements were utilized for longer distances.

Measured data were modified to account for terrain "roughness" before it was used in deriving propagation graphs. Terrain "roughness" values were determined for many paths along which measurements were taken. From such data, "correction factors", in dB, relative to a nominal "roughness" of 164 feet (50 meters, see section on Terrain Roughness Correction, below, for more information), were determined for each measurement set. These factors were then added to the measured field strength values.

Modifications to measured data were also made to "normalize" the EAH to 1000 feet (305 meters). The EAH was determined for each measurement path, *where available*, based on the 2-10 mile (3-16 kilometer) terrain evaluation segment. Another "correction factor" was determined based on the ratio of the EAH to 1000 feet, assuming a linear relationship between field strength and EAH. This second "correction factor" was also added to each measured field strength value. For example, measured field strengths along a path where an EAH of 500 feet obtained were increased by 6 dB to yield values equivalent to those for 1000 feet.

Another modification made to measured data involves so-called "preferred location bias". It was assumed that long-term measurements at fixed locations were conducted at "advantageous" sites relatively free of local clutter and terrain obstruction. Therefore, an adjustment of 4 dB was deemed appropriate and subtracted from all measured data obtained under such circumstances.

Measured field strength values, modified using the factors described above, were plotted for each frequency group (channels 2-6 and FM, channels 7-13, and channels 14-83) as a function of distance for two conditions: within the horizon and beyond the horizon path segments. For each segment type within a given frequency group, a smooth "median" curve was drawn through the data distributions plotted. Each such curve constitutes a 1000 foot "base" curve.

The R-6602 propagation curves were obtained primarily by scaling the 1000 foot base field strength versus distance curves to heights of interest, assuming a linear height versus field strength relationship. However, exceptions to this procedure were a limitation on field strength not exceeding theoretical free-space values and the sketching of a smooth transition between points just within and beyond the horizon.

Field strength prediction graphs were developed for 10 percent of the time (F{50,10}) by adjusting the mean values shown on the 50% graphs (F{50,50}) by the fading ratios determined for the distances involved. Fading ratios represent the difference between measured field strength threshold values exceeded for 50 and 10 percent of the time. It is notable that no "corrections" were used in establishing fading ratios, since the only variable at each measurement site was time.

Application of the FCC Propagation Model

The first step in applying the Commission's propagation model to a given situation is to evaluate the terrain conditions. The EAH is determined for the 2-10 mile (3-16 kilometer) terrain segment, while a segment range of 6 (10 kilometers) to 32 miles (50 kilometers), or the location of the field strength contour of interest, applies for the determination of terrain "roughness" (*delta h*). From *delta h*, the appropriate "roughness" correction factor is found by means of Figure 5 of §73.333 of the FCC's Rules, but use of that factor has been indefinitely suspended.[8]

The preliminary field strength value is then read off the pertinent 50% or 10% of time propagation graph (Figures 1 and 1a of §73.333 of the Rules). Added to that value is the "roughness" correction factor, yielding the predicted field strength value.

Factors Employed in the FCC Propagation Model

The principal factors used in the FCC propagation model are the effective (transmitting) antenna height (EAH), assumed receiver antenna height, and terrain roughness definition. Each of these factors has been defined in unique terms by FCC action; we consider those definitions to be part of the FCC propagation model. Terrain has long been known to affect the propagation of FM broadcast signals. However, technical standards adopted over the years treat terrain effects only in the most general way. During the early years, there was apparently little research information available. Later, notions of administrative convenience may have precluded critical examination of terrain and incorporation of data derived from it in service and interference prediction. However, the scientific community and the military continued their studies into propagation phenomenon.

<u>Effective Antenna Height</u>

Effective antenna height has been classically defined as the ratio of the lumped induced voltage to the field strength (Terman, 1955). The preceding not withstanding, "effective antenna height" has become an accepted term which is defined slightly differently by different engineers. Typically, it is considered to be either the antenna radiation center height above average terrain or the antenna radiation height above a particular radial. We shall assume the latter definition throughout this and other reports.

It should be noted that the FCC does not employ the term "effective antenna height" in its FM rules. It refers instead to the "antenna height above average terrain" or HAAT (See §73.310(a)). HAAT refers either to the transmitting antenna radiation center height above the average terrain within two to ten miles of the antenna site as determined in accordance with §73.313 of the rules or the antenna radiation center height above the average elevation along a particular radial in question.

However, the continued common usage in the broadcast industry, its similar common use in communications systems design (as height above a path) and direct utilization by luminaries such as Okumura, Rice and others, (in the context of antenna height above the average terrain around a transmitting system), have legitimized the term "effective antenna height" as it is construed today.

As a practical matter, general agreement has been that increased height yields increases in coverage. Egli asserted that his review of propagation data, for practical purposes, indicated that received signal strength increases linearly with transmitting antenna height (Egli, 1957). Of related interest is the statements in earlier FCC documents that, "an increase in height increases service area more than it increases interference, whereas

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/8 <u>Order</u>, "Temporary suspension of Certain Portions of Sections 73.313, 73.333, 73.684, and 73.699 of the Commission's Rules and Regulations"; FCC 77-304; adopted 28 April 1977 (this <u>Order</u> continued indefinitely a suspension of the referenced rule provisions which originally commenced on 28 August 1975) an increase in power increases interference more than it does service."[9] Thus "effective height" has been considered to be the more important indicia in coverage predictions, as opposed to interference concerns.

The 2-10 Mile Terrain Averaging Segment

The history of the 2-10 mile "average terrain" segment seems to have evolved from the distinguishing nature of the high frequency services (VHF and above) and their unique propagation characteristics from those factors described for the medium wave and/or short wave bands. In point-to-point VHF/UHF systems, the exact nature of the terrain along the narrow path of interest is generally known to a reasonable degree of confidence. In broadcasting, a point-to-area service, an alternative way for estimating coverage was developed.

The TASO Report (TASO, 1959, p. 331) summarizes the evolution of the 2-10 mile (3-16 kilometer) terrain segment for use in predicting broadcast station coverage. In 1945, an informal committee established the segment as the standard for terrain evaluation henceforth. It was agreed that it would be appropriate to exclude terrain information within two miles of the antenna "because many antennas would be located on hills or mountains which might not be representative of the surrounding terrain." The committee's consideration of some 10 or 12 field strength surveys in the 42 to 50 MHz band indicated to them that the contour predictions based only on terrain within the first two to ten miles of the antenna "compared as least as accurately with the measured data" as when all terrain within a given contour were included. The segment definition was subsequently adopted by the FCC for FM use on September 20, 1945. Other than minor distance changes resulting from the "metrication" of the rules in 1983, no changes have been made to the 2-10 mile terrain averaging segment since 1947 and no serious "official" reconsideration has (apparently) occurred since the TASO work of the late 1950s. It should be noted that the use of the 2-10 mile (3 to 16 km) method has been embraced for some time by our coterminous neighbors, Canada and Mexico.

Assumed Receiving Antenna Height

The height of the receiving antenna has been assumed to be 30 feet (9.1 meters) from the inception of the FM service. A report prepared by K. Norton in early 1940, prior to the formation of the FM broadcast band was premised entirely upon a 30 foot receiving antenna height.[10] The subsequent Annex I to the 1940 Supplement to the Code of Federal Regulations implies an adoption of a 30 foot receiving antenna standard by stating that the prediction graph (chart) may be used "for determining for a 30 foot receiving antenna the distance to the ....contour." However, the height to be used for the receiving antenna in the then required RF field intensity proof-of-performance was not specified.

In FCC Exhibit No. 593, submitted as part of the mid 1940s Docket No. 6651, theoretical "ground wave" coverage ranges were computed for various types of stations.[11] "Broadcast stations", in this case specifically FM and TV, were assumed to have receiving antennas elevated by 30 feet. The measurements

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/9 First Report and Order, "Revision of FM Broadcast Rules, Particularly as to Allocation and Technical Standards ...", Docket 14185; FCC 62-866, 40 FCC 2d 662; effective 10 September 1962; at ¶79

/10 K.A. Norton, "A Theory of Tropospheric Wave Propagation", Hearing in the Matter of Aural Broadcasting on Frequencies Above 25,000 Kilocycles, FCC Mimeo 40003, 18 March 1940

/11 E.W. Allen, Jr., Exhibit No. 593, "Very High Frequency and Ultra-High Frequency Signal Ranges as Limited by Noise and Co-channel Interference", submitted in "Allocation of Frequencies to the Various Classes of Non-Governmental Services in the Radio Spectrum from 10 Kilocycles to 30,000,000 Kilocycles", Docket 6651; 39 FCC 202 reported in Exhibit No. 4 to that same proceeding also were premised on a 30 foot receiving antenna.[12] This use of the 30 foot receiving height assumption continued as the FM band was shifted to 88-108 MHz.

The effects of receiving antenna height were explored, especially in regions with rough terrain, by the National Bureau of Standards' Central Radio Propagation Laboratory (Norton, et. al., 1947). That analysis indicated that the median field increased directly in proportion with the height and the distribution of the field relative to the mean is not significantly different at 30 feet than at lower receiving antenna heights (8-12 feet in this case). It was opined that, "there is no present justification except in mountainous terrain for separating from a linear height-gain relationship..." The topic was raised because a large portion of the available data were taken from mobile field surveys at antenna heights from 8 to 12 feet. Therefore, "in order to relate the field intensities measured at this level to the field intensities to be expected at housetop level, at a nominal height of 30 feet, it was necessary to evaluate the variation of field intensity with receiving antenna height." (FCC, 1949, p. 4) The 1949-50 Ad Hoc Committee considered the subject of receiving antenna height, but apparently did not consider the CRPL's paper.

In contrast, Egli suggested that the data does not appear to support any definite variation with field strength with change in receiving antenna height (Egli, 1957). Specifically, where receiving antennas are clear of surrounding features, it was found that the height gain was linear. On the other hand, where receiving antennas do not clear surrounding terrain features, no orderly pattern was discernable. Statistically analyzed data indicated that the field strength was a square root height gain variation between six to thirty feet. Above thirty feet, the gain appeared to be linear.

However, in the later Notice of Proposed Rule Making (NPRM) for Docket 16004, it was stated that the majority of the data available prior to 1958 was taken a the 10 foot (3 meter) level and that "abnormal variations" were observed, apparently with respect to the *UHF* data. This raised questions as to the validity of such measurements. Rather than considering the environments in which the measurements were taken, it was apparently assumed that all the data were suspect.

Methods for making measurements were standardized with the TASO (television) project, specifically using 30 foot receiving antenna elevations. The 30 foot height for measurement purposes was incorporated into the rules in Docket 18052.[13] It was noted in the Report and Order that Jansky & Bailey had proposed the use of a receiving antenna height of 10 feet, the purpose of which was to accumulate data for a height representative of indoor antennas (and, coincidentally, might permit reference to the existing body of 8-10 foot measurement data). The Commission rejected this proposal, stating that it found no support for the proposal by others, and that it could "needlessly" complicate a method which had general industry support.

The 30 foot receiving height standard was the basis for the propagation curves described in Report R-6502 (Damelin, 1965) and Report R-6602 (Damelin, et.al., 1966), the latter of which describes the propagation curves in use today. No explicit reason for its adoption could be found. We surmise that the assumption is rooted in field strength measurement concerns. Measurements taken at low elevations can be distorted by ground reflections. Early measurements were conducted to (a) establish service and interference areas and (b)

/12 FCC Engineering Department, Exhibit No. 4, "VHF Radio Field Strength Measurements 1943-1944", submitted as part of "Allocation of Frequencies to the Various Classes of Non-Governmental Services in the Radio Spectrum from 10 Kilocycles to 30,000,000 Kilocycles", Docket 6651; 39 FCC 171; 28 September 1944

/13 Report and Order, "Amendment of Part 73 of the Rules regarding field strength measurements for FM and TV Broadcast Stations", Docket No. 18052; FCC 75-686, released 27 June 1975 provide raw data for use in constructing propagation prediction techniques. The need for uncontaminated data is fairly obvious in both cases. Presuming a receiving elevation of 30 feet encouraged measurements at a reasonable elevation and facilitated correlation of predicted and measured results. Finally, 30 feet was a good approximation of the elevation of rooftop television receiving antennas. FM propagation analysis seems to have been a "stepchild" to the more glamorous and economically valued TV projects conducted over the years.

Terrain "Roughness" Correction

The Central Radio Propagation Laboratory found that terrain correction factors could be used in calculating field strengths in connection with allocations work (Norton, et. al., 1947). These factors were based on a "semi-empirical" study of the field strength measurements made on eighteen FM and TV stations in the eastern part of the country. The corrections were to be applied to field strength predictions based on smooth earth ground wave propagation theory. This early work found that, for all values of distance, frequency and receiver antenna height for which data were available, the measured fields could be satisfactorily represented by log-normal distributions with an eight dB standard deviation. The logarithmic mean (or median) fields at fixed distances were found to approximate what would be expected over a smooth spherical earth. However, departures from the smooth-earth theory were greater at the higher frequencies studied. Coincidentally, it was found that the departures of median received fields from the smooth earth theoretical values were substantially greater in the summer. Theories were separately presented in this paper on the general effects of terrain roughness on propagation.

The U.S. Army Signal Engineering Labs analyzed approximately 1400 measurements in the VHF bands and additional data at the UHF frequencies (Egli, 1957). This work was premised on the assumption of plane earth rather than curved since, at that point, the best median data fit for distances up to about 40 miles showed that the inverse distance squared trend is better for the plane earth case at lower antenna heights. Measured data was compared to expected results over plane earth and it was determined that the median field intensity can be described by the theoretical plane earth field intensity, less the median deviation (terrain factor). It was also found that, empirically, while the theoretical received field over plane earth increases with frequency, the median received field over irregular terrain is frequency independent above 40 MHz. Also, while theoretical received power between half wave dipoles is frequency independent, the median received power varies inversely with the frequency squared. In sum, it was concluded that field strength, statistically derived median values and received power are frequency independent over irregular terrain.

The terrain "roughness" correction method incorporated into the FCC propagation model, but later suspended, was not included for FM station propagation analysis when FCC/OCE Report R-6502 was released at the commencement of Docket 16004. "Roughness" corrections were proposed only for UHF television propagation modeling at that time; the correction suggested was very coarse. The terrain segment used in determining the "roughness" of terrain (*delta h*) was imported from CCIR Recommendation 370, that body's equivalents of §73.313 and §73.333 of the Commission's Rules, which contained such a correction factor at the time.

The correction factor to be used, in dB, was determined from a gross analysis of U.S. measured data. Within each frequency group (channels 2-6 and FM, channels 7-13, and channels 14-83), measured field strengths, "normalized" to an EAH of 1000 feet (305 meters), were plotted versus distance. A median line was drawn through each set of plotted measured data. The deviation of each measurement point, for each station radial, above or below that median line was determined. The interdecile terrain "roughness" (delta h) was found for each radial from path profiles drawn.

One master graph of deviations versus delta h, with no dependency on channel (frequency), nor distance from the transmitting site, was constructed from the intermediate data described above. A first order "best fit" equation was then derived to approximate the median relationship between delta h and measurement deviation. From examination of Figure 2 of FCC/OCE Report R-6602, it appears that approximately 24 FM data points were used in derivation of the "roughness correction" factor, but 38 high band VHF and 43 UHF points were included. In other words, only 23 percent of the data utilized in deriving the "roughness correction" factor came from FM measurements.

The coefficients of the equation were picked such that zero correction occurred for a *delta h* value of 167 feet (50 meters). For FM broadcasting, the range of correction extends from +2 dB to -14 dB. FCC/OCE Report R-6602 noted that the RMS improvement in field strength prediction error resulting from the employment of this terrain "roughness" correction was only 1.4 dB for all low-band VHF data (including FM), an improvement that is not by any means substantial.

The correlation of predicted and actual field strengths is substantially influenced by the incorporation of presumed "roughness corrections" in the normalization of raw measurement data. Simply suspending the use of the correction factor does not completely remove the influence of the procedure from the propagation graphs, since it was applied to the underlying raw data used in their development. Complete suspension of "roughness corrections" requires that the propagation curves be derived anew from the raw measurement data *without "correction" in the normalization process*.

CCIR Propagation Model

CCIR Recommendation 370-5 is the current international propagation prediction standard for FM and television broadcasting (CCIR, 1986a). The overall approach to the subject is very similar to the FCC propagation model, involving average terrain over a short segment near the transmitter and a "roughness" correction term. Like its FCC counterpart, the CCIR method constitutes a point-to-line model which could be categorized under either TASO *Type I* or *Type II*. Because the method relies heavily on the single terrain average parameter, we believe that a *Type I* categorization is more appropriate.

The terrain segment specified by the CCIR for determining the antenna EAH extends from 1.9 to 9.3 miles (3 to 15 kilometers) from the transmitter site, which is 0.6 mile (1 kilometer) shorter than the FCC segment. The CCIR propagation graphs illustrate signal strength versus distance, with families of curves drawn for different EAH values. In contrast, the FCC curves illustrate the field strength versus height function, with curves drawn for various distances.

The CCIR graphs include plots for several different and distinct climactic conditions, whereas the FCC does not recognize climactic differences. The CCIR terrain "roughness" correction factor is based on *delta h*, defined for the 6 to 32 mile (10 to 50 kilometer) terrain segment, without segment truncation by shorter contour distances. It is zero within 6 miles (10 kilometers) of the transmitter site. From 6 to 32 miles (10 to 50 kilometers), the correction factor increases to its maximum value. From 62 to 124 miles (100 to 200 kilometers) distant from the transmitter site, the factor decreases to a lower value, which remains constant for greater distances. The range of the correction value extends from +7 to -19 dB, 10 dB wider than the FCC correction term.

An additional adjustment term is noted in Recommendation 370-5 for the assumed receiving height. The CCIR propagation curves were developed for a receiving height of 33 feet (10 meters). To estimate field strengths for receiving elevations of 10 feet (3 meters), an adjustment of -9 dB should be added to the field strength otherwise determined for points located within 31 miles (50 kilometers) of the transmitter site. The adjustment factor is halved for distances in excess of 62 miles (100 kilometers). Between 31 and 62 miles (50 and 100 kilometers), linear interpolation of the transition of the adjustment factor from 9 to 4.5 dB is to be employed.

CCIR Report 239-6 discusses the technical bases for Recommendation 370-5 and supplemental factors that might be used to further refine propagation predictions (CCIR, 1986b). It presents the path-to-path variability equation derived by the NTIA's A.G. Longley, which is dependent upon the *delta h* to wavelength ratio. It also notes a method of adjusting the estimated received signal strengths based on the terrain clearance angle, which is the elevation angle of the receiving antenna to the highest obstruction in the receiver foreground. Either or both of these factors may be used to refine predicted field strengths determined using the graphs of Recommendation 370-5, transforming that procedure toward the TASO *Type II* category.

Okumura's Propagation Model

Another of the better known propagation models is that developed by the Electrical Communication Laboratory of Japan's Nippon Telephone and Telegraph Company in 1968, commonly referred to as the Okumura Model (Okumura, et. al., 1968). This model is oriented specifically to the case of land-mobile communications systems, particularly base-to-mobile links, operating at or above 200 MHz. However, it involves a number of topics that are of interest to those considering the modeling of broadcast propagation, for it deals with well-situated transmitters and randomly located receivers. It is, therefore, the only true TASO *Type II* propagation model identified from the research conducted.

Okumura's method embodies, in essence, a hybrid of point-to-line and point-to-area techniques. The technique is empirical in that field strength versus distance graphs for various EAH values were derived from the medians of many measured runs. However, this method introduced several other important factors into the estimation of field strength.

EAH is determined in the CCIR (point-to-line) manner, using a terrain segment extending 1.9 to 9.3 mile (3 to 15 kilometer) along radial bearings of interest. Field strength relationships are separately described for different types of terrain, which Okumura categorized as urban, suburban, and open. The nature of the path is considered, with one approach employed if it is flat or rolling and another to be used if a single obstruction, such as a tall ridge or mountain, obstructs the signal path. Adjustment terms are introduced for the elevation angle from the receiving antenna to the most critical terrain elevation within the foreground of the receiving site and the terrain slope. Formulas for location variability are also presented. The foregoing factors give the model its point-to-area characteristics.

One of the most important discussions in Okumura's paper is that concerning terrain "roughness" effects. Unlike the CCIR and FCC approaches, Okumura does not employ a unipolar adjustment factor derived from what are really bipolar error data. His "roughness" adjustment factor is used to describe the variation of field strength with respect to the mean value determined. In addition, the *delta h* value used in variability factor estimation is determined over the terrain segment within 6.2 mile (10 kilometer) foreground of the receiving antenna.

The NTIA Irregular Terrain Model

The Irregular Terrain Model (ITM) of the Commerce Department's National Telecommunications and Information Administration (NTIA) contains the classic Longley-Rice propagation model point-to-point and area modes. The ITM is popular for use in predicting the performance of both fixed link and mobile/portable communications systems in both commercial and governmental applications.

Longley-Rice Point-to-Point Model

The Longley-Rice model (LRM) was the first computer implementation of detailed propagation prediction methods to gain wide acceptance (Longley & Rice, 1968). The LRM contains both point-to-point and area modes, largely based on procedures described in the National Bureau of Standards' Technical Note 101 (Rice, et. al., 1967). Its point-to-point mode, discussed in this section, utilizes terrain characteristics along specific paths to particular points in order to predict the field strength with a fair amount of exactitude at such points. It is considered to be a TASO *Type III* model.

The LRM differs from the FCC, CCIR, and Okumura models in that its primary focus is the estimation of transmission loss (attenuation) along the transmitter-receiver path. This is a difference only in the manner of presentation, since received field strength can be readily determined from the radiated field of the transmitting antenna and the transmission loss. The attenuation computed is based on two-ray theory and extrapolated diffraction attenuation for radio line-of-sight paths. For paths beyond the radio horizon, the smaller of either the diffraction or forward scatter attenuation determines the transmission loss.

The LRM defines effective antenna height (EAH) in a manner completely different from the FCC and CCIR. Fundamentally, EAH is defined under the LRM as the height of the antenna above the dominant reflecting plane between transmitting and receiving locations. The basis for this definition is that such terrain will result in the reflections that dominate signal attenuation within line of sight of the transmitting facility. The elevation in what is effectively the receiver foreground, rather than the transmitter foreground, is what is important for propagation prediction purposes within the LRM.

For the broadcast case of high transmitting and low receiving antennas, this definition effectively means the height of the transmitting antenna above a plane passing through the terrain penetrating a first Fresnel zone drawn between the antennas. Where detailed path data is available, EAH (and "roughness") parameters are calculated precisely. Where detailed data is not available, these parameters are estimated in a general manner.

For detailed terrain data, the EAH determination is conducted as follows. The distances where the first Fresnel zone initially falls below and finally rises above terrain are found. A line is fit to the terrain elevations within that distance range by the method of least squares. Using the equation parameters defined for that line, its elevation intercepts at transmitting and receiving distances are computed. The EAH at either end is determined by subtracting the computed intercept elevation at each site from the actual antenna elevation. This technique can sometimes cause unreasonable results, such as modifying EAH to place the antenna underground or the terrain projection well below ground level, even below sea level, at either site.

Where detailed terrain data is unavailable or terrain is exceptionally rough, EAH is estimated from the terrain "roughness", as the LRM defines that parameter, and the antenna heights above ground at their respective transmitter sites.

Also of interest at FM frequencies is the fact that the LRM can account for the refractivity of the atmosphere along the surface of the earth. That factor strongly influences the distance to the radio horizon, an important parameter in the LRM model and also in the original derivations of the FCC and CCIR models.

Several parameters within the LRM are influenced by its estimate of terrain "roughness". The LRM estimate of "roughness" is based on the interdecile deviation of terrain values from a straight line fitted to the terrain profile. This avoids the obvious mis-definition of "roughness" where a substantial interdecile difference in terrain elevations results primarily from uniform slope characteristics. Unlike other models, the LRM *delta* *h* value used in its formulas is distance dependent. It is exponentially related to the distance from the transmitter site, reaching its maximum value at the greatest distance of interest.

ITM (Longley-Rice) Area Mode

The Area Mode of the ITM (ITM-Area), is a modification of the Longley-Rice area mode designed for use where exact path terrain information is not available (Hufford, et. al., 1982). This technique was originally derived to model tactical radio communications systems for the U.S. Army. It is based primarily on measurements for portable and/or mobile transmitters and receivers, both employing low antenna heights, which is typical for this sort of service. The NTIA has recommended use of the ITM Area Mode for predictions of broadcast station coverage. The ITM Area Mode would fit within the TASO *Type II* category, were the terrain data applied to it not overly generalized.

Most of the empirical relationships forming the basis of the model were developed for low transmitting and receiving antennas, from 3 to 100 feet (1 to 30 meters) above ground level. In contrast, the broadcast case involves high transmitting antennas, well above the highest elevations forming the basis for ITM/Area, and low receiving antenna elevations, near the lower limit of the data underlying the ITM/Area. Much of the measured data used in relating secondary parameters to terrain "roughness" was obtained in rural areas where the transmitting and receiving antenna foregrounds were relatively open. In contrast, the "fringes" of broadcast coverage areas often fall in well-populated areas.

ITM/Area does not define EAH in the same way as the LRM point-to-point mode. Instead, an arbitrary value, never more than 33 feet (10 meters) is added to the antenna elevation above ground. For broadcast sites located on (relatively) short structures placed atop tall mountains or hills, this presents obvious problems. To avoid such problems, the ITM/Area documentation recommends including natural elevation above surrounding terrain in the structural height input to the model. However, no specific, verified method of adjusting structural height is described or recommended. The FCC's 2-10 mile (3-16 kilometer) segment terrain average is merely mentioned as one way of adjusting antenna structural height.

Perhaps the most useful information presented in the ITM/ Area Mode documentation, from a broadcast perspective, is the extensive discussion of the statistics of propagation prediction included therein. That report expands upon the fundamental presentation of propagation statistics presented in Appendix 1 to the Longley-Rice model report.

Blomquist & Ladell Model

In 1987, a comparison of field strength predictions with FM band data measured in Germany's Black Forest was presented (Grosskopf, 1987). The best correlation between measured and predicted data was reported for the method of Blomquist and Ladell. As Grosskopf noted, "the essential part of [the] method is an empirically developed formula with no apparent theoretical explanation from the propagation point of view. The total attenuation is a weighted sum of free space loss, plane earth loss, and multiple knife-edge loss after Epstein and Peterson." The Blomquist & Ladell method appears to be a TASO *Type II* procedure. Time constraints have prevented obtaining and reviewing a copy of Blomquist & Ladell's paper,[14] but it is expected to arrive shortly and it may be reported on in the future.

/14 A. Blomquist & L. Ladell, "Prediction and Calculation of Transmission Loss in Different Types of Terrain", NATO AGARD Conference Publication CP144, 1974

Rice 1990 Formula Model

Well-known propagation physicist Philip L. Rice has published a new approach to propagation prediction involving mathematical description of the FCC's propagation curves, where many factors pertinent to the prediction of field strength are based on theory and slight adjustments are made to conform the result to a close approximation of the FCC curves (Rice, 1990). His method yields results reasonably close to those obtained using the present FCC curves. As such, it is essentially a TASO *Type I* method whose parameters may be specified to transform it into a *Type II* technique.

Rice's approach facilitates the consideration of additional factors in propagation, such as the assumed receiving antenna height, the effects of terrain cover, and location variability. Another advantage is that it is fundamentally rooted in the methodology of NBS Technical Note 101, which is regarded domestically a the definitive treatise on the details of wave propagation. This method can provide a means of incrementally moving from the present FCC model to more sophisticated means of propagation analysis. A more comprehensive description of Rice's model is presented in Appendix E.

Table D-I

Propagation Coordinate Comparison

Ex Parte Comments of Karl D. Lahm, P.E.
MM Docket No. 88-56, June 1988

Low Band Metric VHF, 50 Percent

	50 meters			70 meters			100 meters		
Read Distance (km)	**Comp. F.S.** (dBu)	**Read F.S.** (dBu)	**Comp. Dist.** (km)	**Comp. F.S.** (dBu)	**Read F.S.** (dBu)	**Comp. Dist.** (km)	**Comp. F.S.** (dBu)	**Read F.S.** (dBu)	**Comp. Dist.** (km)
1.5	97.8	97.7	2.9	99.7	99.5	2.3	101.0	100.9	2.0
2	92.6	93.1	2.1	95.0	95.2	2.0	96.7	97.1	2.1
3	85.3	85.4	3.0	88.2	88.1	3.0	90.7	90.8	3.0
4	80.4	80.5	4.0	83.4	83.3	4.0	86.2	86.3	4.0
5	76.5	76.6	5.0	79.6	79.5	5.0	82.6	82.7	5.0
6	73.2	73.3	6.0	76.3	76.2	6.0	79.5	79.5	6.0
7	70.6	70.6	7.0	73.6	73.5	7.0	76.7	76.8	7.0
8	68.3	68.4	8.0	71.3	71.2	8.0	74.4	74.4	8.0
9	66.2	66.5	9.2	69.3	69.3	9.0	72.4	72.4	9.0
10	64.4	64.7	10.2	67.4	67.5	10.1	70.5	70.6	10.0
15	57.3	57.4	15.1	60.4	60.2	14.9	63.5	63.4	14.9
20	52.2	52.7	20.6	55.3	55.6	20.3	58.4	58.8	20.4
30	44.9	45.1	30.3	48.0	47.9	29.9	51.1	51.1	30.0
40	39.1	39.5	40.7	42.1	42.4	40.5	45.2	45.5	40.6
50	34.3	34.5	50.4	37.2	37.3	50.1	40.3	40.4	50.3
60	29.8	29.9	60.3	32.4	32.5	60.2	35.5	35.6	60.3
70	26.0	26.0	70.1	28.3	28.3	70.0	31.2	31.4	70.4
80	22.6	22.6	79.9	24.6	24.6	79.9	27.3	27.3	80.1
90	19.4	19.2	89.5	20.9	20.7	89.6	23.1	23.1	90.1
100	16.7	16.6	99.7	17.9	17.8	99.7	19.7	19.5	99.2
110	14.6	14.5	109.6	15.5	15.5	110.0	16.9	16.8	109.5
120	12.4	12.4	119.9	13.3	13.2	119.7	14.5	14.5	119.8
130	10.3	10.3	130.2	11.2	11.1	129.6	12.3	12.3	130.1
140	8.7	8.6	139.4	9.4	9.3	139.6	10.4	10.4	140.1
150	6.9	6.9	149.9	7.7	7.6	149.7	8.7	8.6	149.6
Maximum Deviation		0.5	0.9		0.3	0.5		0.4	0.6
Maximum Percent			3.0			1.5			3.0

Notes: Computed distances assume read field strength shown.

Errors at 1.5 and 2.0 kilometers were disregarded due to transition from free-space to F(50,50) propagation characteristics.

Table D-II

Propagation Coordinate Comparison

Ex Parte Comments of Karl D. Lahm, P.E.
MM Docket No. 88-56, June 1988

Low Band Metric VHF, 50 Percent

	150 meters				210 meters				300 meters		
Read Distance (km)	**Comp. F.S.** (dBu)	**Read F.S.** (dBu)	**Comp. Dist.** (km)		**Comp. F.S.** (dBu)	**Read F.S.** (dBu)	**Comp. Dist.** (km)		**Comp. F.S.** (dBu)	**Read F.S.** (dBu)	**Comp. Dist.** (km)
1.5	102.	101.8	1.8		102.6	102.3	1.6		102.8	102.6	1.6
2	98.4	98.6	2.0		99.4	99.6	2.0		99.8	100.0	2.1
3	93.2	93.2	3.0		94.9	94.9	3.0		95.7	95.7	3.0
4	89.1	89.2	4.0		91.2	91.2	4.0		92.4	92.5	4.0
5	85.9	85.9	5.0		88.1	88.1	5.0		89.9	89.9	5.0
6	82.9	82.9	6.0		85.4	85.4	6.0		87.6	87.7	6.0
7	80.3	80.2	7.0		83.0	83.0	7.0		85.5	85.6	7.0
8	78.0	77.9	8.0		80.9	80.8	8.0		83.7	83.7	8.0
9	75.9	75.9	9.0		78.8	78.9	9.1		81.7	81.9	9.1
10	74.1	74.1	10.0		77.0	77.1	10.1		79.8	80.2	10.2
15	67.1	66.9	14.9		70.0	69.9	14.9		73.0	73.0	15.0
20	61.9	62.2	20.4		64.8	65.1	20.3		68.0	68.2	20.2
30	54.6	54.5	29.9		57.5	57.5	30.0		60.7	60.7	30.1
40	48.8	49.1	40.5		51.7	52.0	40.6		54.8	55.1	40.6
50	44.0	44.1	50.2		46.8	46.9	50.3		49.9	50.0	50.3
60	39.2	39.3	60.2		42.0	42.2	60.4		45.2	45.4	60.4
70	34.8	34.9	70.2		37.4	37.7	70.6		40.8	41.0	70.5
80	30.7	30.7	80.0		33.3	33.3	80.0		36.7	-	80.1
90	26.3	26.4	90.3		28.9	29.1	90.4		32.3	32.5	90.5
100	22.4	22.3	99.8		25.1	25.1	100.0		28.3	28.4	100.1
110	19.2	19.1	109.6		21.7	21.7	110.0		24.6	24.7	110.2
120	16.4	16.4	119.9		18.6	18.5	119.7		21.3	21.3	120.0
130	14.0	14.0	130.0		15.7	15.7	129.9		18.3	18.3	130.0
140	12.0	11.9	139.5		13.4	13.3	139.7		15.7	15.6	139.8
150	10.1	10.0	149.7		11.4	11.4	150.1		13.5	13.5	150.2
Maximum Deviation		0.3	0.5			0.3	0.6			0.4	0.6
Maximum Percent			2.0				1.5				2.0

Notes: Computed distances assume read field strength shown.

Errors at 1.5 and 2.0 kilometers were disregarded due to transition from free-space to F(50,50) propagation characteristics.

Table D-III

Propagation Coordinate Comparison

Ex Parte Comments of Karl D. Lahm, P.E.
MM Docket No. 88-56, June 1988

Low Band Metric VHF, 50 Percent

Read Distance (km)	420 meters Comp. F.S. (dBu)	420 meters Read F.S. (dBu)	420 meters Comp. Dist. (km)	600 meters Comp. F.S. (dBu)	600 meters Read F.S. (dBu)	600 meters Comp. Dist. (km)	800 meters Comp. F.S. (dBu)	800 meters Read F.S. (dBu)	800 meters Comp. Dist. (km)
1.5	102.9	102.7	1.6	103.0	102.9	1.6	103.0	103.0	1.5
2	100.1	100.4	2.1	100.3	100.6	2.1	100.4	100.7	2.1
3	96.5	96.5	3.0	96.7	96.7	3.0	97.0	96.9	3.0
4	93.6	93.6	4.0	94.0	94.0	4.0	94.2	94.2	4.0
5	91.1	91.2	5.0	91.8	91.8	5.0	92.0	92.2	5.1
6	88.9	88.9	6.0	90.0	89.9	6.0	90.4	90.4	6.0
7	87.0	87.0	7.0	88.2	88.2	7.0	88.8	88.8	7.0
8	85.5	85.5	8.0	86.7	86.7	8.0	87.4	87.4	8.0
9	83.7	84.1	9.2	85.2	85.4	9.2	86.1	86.2	9.1
10	82.1	82.6	10.3	83.9	84.1	10.2	84.9	85.1	10.2
15	75.8	75.9	15.1	78.6	78.7	15.2	80.3	80.5	15.2
20	70.9	71.0	20.1	74.1	74.5	20.4	76.2	76.7	20.7
30	63.8	63.8	29.9	67.2	67.3	30.1	69.8	69.9	30.2
40	58.0	58.3	40.6	61.8	62.1	40.8	64.7	65.1	40.9
50	53.3	53.4	50.2	57.4	57.6	50.4	60.4	60.5	50.3
60	48.7	48.8	60.3	53.0	53.2	60.5	55.8	56.1	60.6
70	44.4	44.6	70.5	48.8	49.1	70.7	51.7	51.9	70.5
80	40.4	40.5	80.3	45.0	45.0	80.1	47.8	47.9	80.2
90	35.9	36.1	90.5	40.6	40.8	90.4	43.6	43.8	90.4
100	31.8	31.8	100.0	36.7	36.8	100.0	39.8	39.9	100.1
110	28.1	28.1	109.9	33.1	33.1	110.1	36.3	36.5	110.6
120	24.8	24.8	119.9	29.7	29.7	120.0	32.8	33.0	120.5
130	21.8	21.8	129.9	26.4	26.4	130.0	29.4	29.5	130.3
140	19.1	19.1	140.0	23.2	23.3	140.2	26.1	26.2	140.4
150	16.6	16.6	150.1	20.3	20.2	149.7	23.0	23.1	150.2
Maximum Deviation		0.5	0.6		0.4	0.8		0.5	0.9
Maximum Percent			3.0			2.0			3.5

Notes: Computed distances assume read field strength shown.

Errors at 1.5 and 2.0 kilometers were disregarded due to transition from free-space to F(50,50) propagation characteristics.

Appendix E

RICE'S GENERALIZED PROPAGATION FORMULAS

prepared for
National Association of Broadcasters
Washington, D.C.

In 1989, propagation physicist Philip L. Rice first described a formula-based approach to approximating the FCC's generalized propagation curves for low and high band VHF, UHF land mobile, and UHF television services. These formulas were refined and updated in March of this year (Rice, 1990).

The formulas provide continuous results from about 40 MHz through 2 GHz, although their validity is restricted at the extremes of this range due to built-in limiting factors. There are no changes in formula coefficients with frequency band.[1] The input parameters to the formulas are the frequency (in MHz), height of transmitting and receiving antennas above average terrain (in feet), and distance to the point at which it is desired to determine field strength (in miles). A terrain cover density factor is provided internally, although that parameter could be defined externally if desired.

Preliminary Processing

In implementing Rice's generalized formulas, basic parameters are computed from the input data:

$$d_{ls} = \sqrt{2h_t} + \sqrt{2h_r} \tag{E.1}$$

$$w_l = .001 + e^{-\left(\frac{d}{d_{ls}}\right)^{1.2}} \tag{E.2}$$

$$\lambda' = 0.1 + \frac{300}{f+20} \tag{E.3}$$

where:
d = distance, miles
d_{ls} = smooth-earth horizon range, miles
f = frequency, megahertz
h_r = receiver EAH, feet
h_t = transmitter EAH, feet
λ' = limited wavelength, meters
w_l = horizon proximity weighting factor

The wavelength is adjusted to prevent unreasonable extrapolation of results to frequencies beyond the range for which the method was designed.

Clutter/Cover Attenuation

Next, the terrain cover density factor t_k is defined:

$$t_k = 0.8 + 0.25w_l \tag{E.4}$$

Without modification, this factor varies from 0.55 well within to 0.80 far beyond the smooth-earth horizon. The cover attenuation factor A_c is defined:

$$A_c = 4.5\lambda^{-1.2} - w_l\,[\log_{10}f + \log_{10}(h_t\,h_r)] + 8 \tag{E.5}$$

and is constrained to a maximum value of 30 dB. For the FM band (97.5 MHz), h_t of 500 feet and h_r of 30 feet, the cover attenuation at is 4.3 dB at 10 miles (¼ the smooth-earth horizon range) and 9.4 dB at 160 miles (4 times the

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/1 In a private conversation, Mr. Rice noted that better correlation to FM measured data could be attained with adjusted coefficients, but his intent was to create a universal model, so compromises had to be made and the formulas do not yield as close a correlation as might otherwise be possible in any particular frequency band.

smooth-earth horizon range). The effective cover attenuation for average terrain, K_{at}, is simply the product of the cover attenuation factor A_c and the cover density factor t_k:

$$K_{at} = t_k A_c \tag{E.6}$$

and is constrained to values greater than -1.5 dB.

Path Attenuation

The attenuation below free space is determined from distance, within-horizon, beyond-horizon terms, and a constant. The within-horizon term is:

$$A_{ls} = w_l [10.4 q_l \log_{10} d - 12 \log_{10}(h_t h_r)] \tag{E.7}$$

$$\text{where: } q_l = w_l w_l e^{-\frac{K_{at}}{2.8}} \tag{E.8}$$

The beyond-horizon term is:

$$A_{ds} = (1 - w_l) [\frac{d}{9} - 6 \log_{10}(h_t h_r)] \tag{E.9}$$

The complete path loss equation is:

$$A_p = 10 \log_{10} d + \frac{d_{ls}}{6.3 d} + A_{ls} + A_{ds} + 44.5 \tag{E.10}$$

and is constrained to values between -3dB and 150 dB.

Field Strength

The basic field strength for 50% of the time is the calculated free space value, less path and clutter losses:

$$FC_{50} = 102.79 - 20 \log_{10} d - A_p - K_{at} \tag{E.11}$$

To determine field strengths for 10% of the time, the fading ratio is calculated and added to the basic 50% field strength. First, a term X_e is computed:

$$X = d_{ls} + \frac{65}{1.609} \left(\frac{100}{f}\right)^{0.333} \quad \text{(E.12)}$$

Next, an "effective distance" term, described in NBS Technical Note 101, is defined:

$$\text{if } d \le X_e \text{ then } d_e = \frac{130}{1.609} \frac{d}{X_e}$$

$$\text{if } d > X_e \text{ then } d_e = \frac{130}{1.609} + d - X_e \quad \text{(E.13)}$$

The standard deviation of time variability is then estimated:

$$\text{if } d_e \le \frac{200}{1.609} \text{ then } \sigma_t = \frac{8}{0.8} \left(\frac{1.609\ d_e}{100}\right)^2 e^{-\left(\frac{1.609\ d_e}{100}\right)^2}$$

$$\text{if } d_e > \frac{200}{1.609} \text{ then } \sigma_t = \frac{4.2 + 16.5\ e^{-.77\left(\frac{1.609\ d_e}{100}\right)}}{0.8} \quad \text{(E.14)}$$

The 10% of time field strength is:

$$FC_{10} = FC_{50} + 1.282\ \sigma_t \quad \text{(E.15)}$$

Application of These Formulas

The fundamental input parameters to these formulas are frequency, transmitting EAH, receiving EAH, and distance. It is recommended that, for FM service, frequency be set to 97.5 MHz, the logarithmic midpoint of the 88-108 MHz band. The remaining parameters should be defined in the conventional manner.

A substantial effort was made to evaluate the results of redefining the transmitting EAH. That work is reported in Appendix F to this Final Report. It was found that redefinition of EAH resulted in significant differences in predicted field strengths in particular situations. However, using a nationwide station sample, significant overall improvement with respect to the method currently prescribed by the FCC was not realized. Some more work in this area is suggested, but it is anticipated that redefinition of a single parameter - the averaged EAH - will not result in significant improvements in prediction error.

An approximate equation relating field strength to receiving antenna height is presented in Rice's paper. It is valid at 76 MHz (the midpoint of 54-108 MHz) for receiving antenna elevations from 3 to 30 feet and transmitting antenna elevations between 100 and 2500 feet.

$$\Delta FC_{hr21} = \left(12.2 - \frac{d}{7.44} + \frac{d^{1.2}}{27.4}\right) \log_{10}\left(\frac{h_{r2}}{h_{r1}}\right) \quad \text{(E.16)}$$

Comparison of Results

Tables E-I and E-II present a comparison of field strengths computed using Rice's formulas with the field strength data points used by the FCC computer program "TVFMFS". Table E-I applies to the F{50,50} curves; table E-II applies to the F{50,10} curves. Root-mean-square (RMS) differences were computed for each antenna height column and the complete data set. The differences are largest for the extremes of antenna height. Overall, the RMS differences are less than 2 dB.

The data points used by TVFMFS were read directly from large-scale copies of the R-6602 propagation curves. They are necessarily different than what would be read off the metric propagation curves now placed in §73.333 of the FCC's Rules, as discussed in some detail in Appendix D and documented in the tables contained therein. Several points in this data set have been adjusted by one or two tenths of a decibel in order to better match the R-6602 curves in critical places.

Extension of the Procedure

The work performed indicates that a major shortcoming of the present method of predicting propagation is its underestimation of field strength in flat terrain and open areas. Fit of the parameters A_c and t_k to measured results and terrain use/cover data defined by a suitable data base may well improve correlation of predicted and measured field strengths in all types of environments.

We have not dismantled the formulas any further than Rice's paper presents them. Tropospheric scatter and diffraction terms should underly these summary formulas. If diffraction and scatter terms can be isolated, terrain input data could be developed for more specific estimation of diffraction loss and atmospheric input data might be used in estimating scatter phenomena.

Table E-I

RICE FORMULA COMPARISON TO FCC DATA
50% CURVES

prepared for

National Association of Broadcasters

Washington, D.C.

	Height in meters												
Distance (km)	**30** (dB)	**61** (dB)	**122** (dB)	**183** (dB)	**244** (dB)	**305** (dB)	**381** (dB)	**457** (dB)	**533** (dB)	**610** (dB)	**914** (dB)	**1219** (dB)	**1524** (dB)
1.6	1.8	-1.2	-1.3	-0.9	-0.6	-0.2	0.1	0.3	0.4	0.3	0.2	-0.1	-0.5
3.2	4.9	2.1	0.2	-0.4	-0.4	0.0	0.2	0.5	0.9	1.2	2.1	2.0	2.0
4.8	5.9	3.3	0.9	-0.2	-0.5	-0.5	-0.3	-0.2	0.2	0.5	1.7	2.4	2.5
6.4	6.4	4.2	1.6	0.3	-0.4	-0.8	-0.7	-0.5	-0.4	-0.2	0.8	1.6	2.2
8.0	6.6	4.5	2.2	0.7	-0.3	-0.9	-1.1	-1.1	-0.9	-0.7	0.1	0.9	1.6
16.1	6.1	4.6	2.9	1.8	1.0	0.3	-0.4	-0.9	-1.5	-2.0	-2.3	-2.0	-1.6
32.2	2.6	1.9	1.4	1.1	0.8	0.4	-0.2	-0.5	-1.1	-1.6	-3.0	-3.8	-4.4
48.3	-0.0	-0.6	-0.4	-0.4	-0.0	-0.1	-0.4	-0.8	-1.4	-1.9	-3.0	-3.4	-3.5
64.4	-2.2	-1.5	-1.5	-1.1	-0.7	-0.6	-0.7	-0.9	-1.5	-1.8	-2.1	-2.1	-2.2
80.5	-3.0	-2.0	-1.8	-1.2	-0.6	-0.6	-0.6	-1.1	-1.5	-1.6	-1.3	-0.9	-0.7
96.6	-3.4	-1.8	-0.8	-0.5	-0.1	0.1	0.4	0.0	-0.5	-0.5	-0.3	0.3	1.1
112.7	-3.7	-2.4	-0.8	-0.2	0.3	0.7	1.0	0.7	0.1	-0.1	0.2	1.3	2.1
128.7	-3.8	-2.5	-1.2	-0.0	0.6	1.0	1.1	0.9	0.6	0.4	1.3	2.6	3.5
144.8	-3.7	-2.7	-1.5	-0.5	0.4	0.8	0.9	0.8	0.9	0.9	2.1	3.3	4.3
160.9	-3.4	-2.8	-1.9	-1.1	-0.2	0.2	0.6	0.6	1.2	1.4	2.6	3.8	4.7
177.0	-3.3	-2.7	-2.1	-1.2	-0.6	-0.2	0.2	0.7	0.9	1.1	2.5	3.5	4.5
193.1	-2.9	-2.4	-2.0	-1.7	-1.2	-0.6	-0.2	0.4	0.8	1.2	2.3	3.5	4.2
209.2	-2.6	-2.1	-1.9	-1.5	-1.1	-0.7	-0.3	0.1	0.5	0.9	2.1	3.0	4.0
225.3	-2.5	-1.6	-1.4	-1.5	-1.3	-1.0	-0.6	-0.3	-0.1	0.3	1.3	2.2	3.2
241.4	-2.2	-1.5	-1.3	-1.2	-1.2	-1.0	-0.8	-0.5	-0.2	0.0	0.9	1.4	2.3
257.5	-1.6	-1.0	-0.9	-1.1	-1.0	-0.9	-0.7	-0.6	-0.4	-0.3	0.3	0.9	1.5
273.6	-1.1	-0.6	-0.5	-0.5	-0.6	-0.7	-0.6	-0.5	-0.5	-0.5	-0.1	0.4	1.1
289.7	-0.9	-0.2	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5	-0.1	0.1	0.6
305.8	-0.6	0.1	0.4	0.2	-0.0	-0.1	-0.2	-0.3	-0.3	-0.2	-0.2	0.1	0.4
321.9	-0.4	0.5	0.9	0.8	0.6	0.4	0.2	0.1	-0.1	0.0	-0.3	-0.3	0.0
RMS	3.5	2.4	1.4	1.0	0.7	0.6	0.6	0.6	0.8	1.0	1.7	2.2	2.7

Total RMS Difference = 1.7 dB

<u>Table E-II</u>

RICE FORMULA COMPARISON TO FCC DATA
10% CURVES

prepared for
National Association of Broadcasters
Washington, D.C.

Distance (km)	30 (dB)	61 (dB)	122 (dB)	183 (dB)	244 (dB)	305 (dB)	381 (dB)	457 (dB)	533 (dB)	610 (dB)	914 (dB)	1219 (dB)	1524 (dB)
	Height in meters												
1.6	1.9	-1.1	-1.2	-0.8	-0.5	-0.1	0.2	0.4	0.5	0.5	0.3	0.0	-0.4
3.2	5.0	2.2	0.3	-0.4	-0.4	0.1	0.3	0.6	1.0	1.3	2.1	2.1	2.1
4.8	6.0	3.3	1.0	-0.1	-0.4	-0.4	-0.3	-0.2	0.2	0.5	1.7	2.5	2.6
6.4	6.5	4.2	1.6	0.3	-0.4	-0.8	-0.7	-0.5	-0.4	-0.2	0.7	1.6	2.3
8.0	6.8	4.6	2.3	0.8	-0.2	-0.8	-1.1	-1.1	-0.9	-0.7	0.1	0.9	1.6
16.1	6.5	4.7	3.0	1.7	0.8	0.2	-0.5	-1.3	-1.6	-2.2	-2.8	-2.5	-1.9
32.2	2.6	2.2	1.4	0.9	0.4	0.0	-0.6	-1.3	-1.8	-2.4	-3.7	-4.8	-5.4
48.3	-1.3	-0.9	-0.4	-0.2	-0.5	-0.8	-1.4	-1.9	-2.5	-2.8	-3.8	-4.5	-5.2
64.4	-3.3	-2.3	-1.1	-0.9	-0.8	-1.0	-1.6	-2.1	-2.8	-3.0	-3.6	-4.1	-4.5
80.5	-3.7	-2.4	-1.2	-0.8	-0.7	-0.7	-1.3	-2.0	-2.4	-2.8	-3.3	-3.4	-3.9
96.6	-2.9	-1.6	-0.5	-0.0	0.0	-0.1	-0.6	-1.4	-1.9	-2.2	-2.6	-2.9	-2.8
112.7	-2.0	-1.1	0.0	0.5	0.9	1.0	-0.1	-0.8	-1.5	-1.8	-1.7	-1.8	-1.7
128.7	-1.3	-0.7	0.2	0.8	1.2	1.3	0.6	-0.1	-0.8	-0.8	-0.8	-0.3	-0.3
144.8	-0.9	-0.3	0.7	1.1	1.4	1.8	1.4	0.8	0.2	0.2	0.4	0.6	0.8
160.9	-0.8	-0.1	0.6	1.1	1.6	2.0	1.6	1.4	1.2	1.2	1.4	1.6	1.8
177.0	-0.7	-0.1	0.7	1.2	1.6	2.1	2.1	2.2	2.1	2.3	2.3	2.6	2.6
193.1	-0.6	0.1	0.5	1.2	1.8	2.2	2.3	2.5	2.7	2.7	2.7	2.8	2.9
209.2	-0.7	-0.3	0.2	0.8	1.4	1.9	2.3	2.6	2.8	3.1	2.9	3.0	3.2
225.3	-0.4	-0.2	0.3	0.9	1.0	1.3	1.9	2.3	2.7	2.9	3.2	3.0	3.2
241.4	-0.5	0.2	0.5	0.6	0.9	1.2	1.7	1.8	2.0	2.5	3.3	3.4	3.3
257.5	-0.2	0.2	0.5	0.8	0.9	1.0	1.1	1.3	1.6	1.9	2.7	3.5	3.9
273.6	-0.2	0.5	0.7	0.9	0.9	0.9	1.1	1.2	1.5	1.7	2.3	3.1	3.8
289.7	-0.1	0.4	0.9	1.1	1.0	1.1	1.2	1.3	1.3	1.3	1.9	2.6	3.6
305.8	-0.0	0.6	1.1	1.2	1.1	1.2	1.2	1.1	1.1	1.2	1.6	2.3	3.2
321.9	-0.3	0.6	1.2	1.4	1.2	1.4	1.4	1.3	1.2	1.2	1.1	1.9	2.8
338.0	-0.2	0.6	1.3	1.5	1.4	1.3	1.3	1.2	1.1	0.9	0.9	1.3	2.2
354.1	-0.0	0.7	1.3	1.5	1.4	1.2	1.1	1.0	1.0	0.9	0.6	1.1	1.6
370.1	0.1	0.9	1.5	1.6	1.5	1.4	1.3	1.1	0.8	0.8	0.7	0.8	1.4
386.2	0.3	1.0	1.5	1.7	1.6	1.5	1.3	1.2	1.1	1.1	0.9	0.7	1.2
402.3	0.4	1.1	1.7	1.9	1.7	1.6	1.4	1.2	1.1	1.0	0.7	0.7	0.8
418.4	0.6	1.3	1.9	2.0	1.9	1.6	1.6	1.4	1.3	1.3	0.6	0.7	0.7
434.5	0.8	1.5	2.1	2.3	2.1	1.9	1.7	1.4	1.1	1.2	0.7	0.5	0.5
450.6	1.0	1.7	2.2	2.2	2.2	2.2	1.8	1.7	1.4	1.3	0.5	0.3	0.3
466.7	1.3	2.0	2.5	2.6	2.4	2.5	2.1	1.8	1.5	1.4	0.6	0.3	0.1
482.8	1.5	2.4	2.6	2.7	2.6	2.4	2.2	1.8	1.5	1.3	0.8	0.3	0.1
RMS	2.7	1.9	1.4	1.3	1.3	1.4	1.4	1.5	1.6	1.8	2.1	2.4	2.7

Total RMS Difference = 1.9 dB

Appendix F

EFFECTIVE ANTENNA HEIGHT DETERMINATION

prepared for
National Association of Broadcasters
Washington, D.C.

Because variations in terrain elevation are significant in comparison to the wavelength of signals in the FM broadcast band, terrain characteristics have a marked effect on the service provided by and interference caused to FM broadcast stations. Methods of predicting FM signal strength levels have always been sensitive to terrain effects. Even though the present measure of terrain is essentially arbitrary and bears little relation to the actual physics of wave propagation, its results are generally reasonable and no statistically significant improvement was obtained by making adjustments to it, as detailed in Appendix G.

In its simplest form, effective antenna height (EAH) is the elevation of the radiation center point above surrounding terrain. Where terrain rises outward from the site, EAH can be and often is negative. The definition of EAH presently used in broadcast station planning and assignment administration is the height of the antenna above the foreground terrain near the transmitter site. Average terrain elevation is determined over a radial line segment commencing 2 miles (3 kilometers) from the transmitter site and terminating 9½ miles (CCIR, Okumura; 15 kilometers) or 10 miles (FCC; 16 kilometers) therefrom.

History of EAH Definition

FCC-specified coverage predictions in the FM and TV services have always incorporated the effects of terrain features by use of the familiar concept of average terrain taken from eight evenly spaced (45°) radials extending from the transmitter site. However, prior to 1945, elevations were taken and analyzed along the *entire path* from the transmitter site to the signal strength boundary of interest. The Standards of Good Engineering practice which accompanied the 1940 Supplement to the Code of Federal Regulations specified that elevations be taken from the site out to the estimated location of the contour of interest (1.0 or 0.05 mV/m) and the average elevation determined for that entire segment. If the initial estimate of distance to the desired contour was found to be in error after the terrain average was determined, the process was repeated. This iterative process continued until acceptable agreement between results was attained.

The TASO Report (TASO, 1959, p. 331) summarizes the evolution of the 2-10 mile (3-16 kilometer) terrain segment for use in predicting broadcast station coverage. In 1945, an informal committee established the segment as the standard for terrain evaluation henceforth. It was agreed that it would be appropriate to exclude terrain information within two miles of the antenna "because many antennas would be located on hills or mountains which might not be representative of the surrounding terrain." The committee's consideration of some 10 or 12 field strength surveys in the 42 to 50 MHz band indicated to them that the contour predictions based only on terrain within the first two to ten miles of the antenna "compared as least as accurately with the measured data" as when all terrain within a given contour were included. The segment definition was subsequently adopted by the FCC for FM use on September 20, 1945. Other than minor distance changes resulting from the "metrication" of the rules in 1983, no changes have been made to the 2-10 mile terrain averaging segment since 1947 and no serious nor official reconsideration appears to have occurred since the TASO work of the late 1950s. It should be noted that the use of the 2-10 mile (3 to 16 km) method has been embraced for some time by Canada and Mexico.

The Ad Hoc Committee Report (FCC, 1949) gave serious consideration to alternatives to the 2-10 mile terrain averaging segment. Some of the concepts considered include the determination of an equivalent ground plane, use of a residual height where intervening high terrain is encountered, and an equivalent earth's radius through the transmitter and receiver sites. Although individual investigations conducted by several members of the Committee indicated improvement through one or more of the alternative methods, the Committee itself agreed that the improvements were not sufficiently "systematic" nor of a high enough magnitude to warrant recommendation of any new method at the time. The Committee did, however, stress that the decision to use the 2-10 mile terrain segment in their studies should not be taken as a recommendation that an alternative method of determining antenna height should not be permitted. In the event that an alternative technique were chosen, the Committee cautioned that consideration be given to its effects of the statistical predictions discussed in its report. Norton hoped that further studies of such data would lead to the development of "methods for estimating the departure of the median field along a particular radial in terms of some quantitative measure of the roughness along a radial..." He also thought that such studies may include a transmitting height above average terrain different from that obtained by the 2-10 mile rule that perhaps would vary with the distance along the radial.

Egli also criticized the 2 to 10 mile rule, saying that "it has not proven as reliable as one might expect, since it does not take into account terrain within 2 miles or beyond 10 miles." (Egli, 1957) For the purposes of his analysis of terrain effects on propagation, he employed the antenna height above plane earth.

The TASO Supplementary Report ultimately concluded that better approaches than the 2-10 mile segment were available (TASO, 1960). The referenced method, authored by Howard T. Head,[1] recommended the sampling of terrain elevations at uniform distance intervals over the central 80 percent of the distance from the transmitting antenna to its radio horizon, fit of a line to that terrain by the method of least squares, and determination of the effective antenna height as the elevation of the antenna above the intercept of that line with the zero-distance axis. This method tends to adjust effective antenna height for the slope of terrain, which was considered to an improvement over the 2-10 mile technique.

The "Final Report of Committee 4.4" in the TASO Report acknowledged that the 2-10 mile rule had been recognized "all along" as a "purely empirical procedure, a more-or-less rule-of-thumb device." (TASO, 1959, p. 332)

Description of Terrain Effects

FM signal strength calculation methods are generally based on free space transmission loss plus additional attenuation factors. These factors relate to reflective effects along the path between transmitting and receiving antennas, as well as diffraction, tropospheric scattering, and other phenomena.

Within line of sight of the transmitter, one of these additional attenuation factors is a direct function of path geometry. At least two signals arrive at the receiving antenna: the direct signal from the transmitting antenna and one or more secondary signals reflected off terrain between the two antennas. These signals will not usually be in phase. Some attenuation (or apparent gain, depending on the phase relationship) is attributable to the vector addition of these two signal components.

The effective antenna height (EAH) is a measure of the relative clearance of the path between transmitting and receiving antennas over relatively smooth terrain. EAH primarily affects the mean (average) received signal strength within a homogeneous area of interest, under the physical situation described herein.

/1 Final Report of Committee 5.4, "Theoretical Studies - Supplemental Final Report", p. 54; and its Attachment C, "A Method of Predicting Average Field Strengths at Television Broadcast Frequencies", H.T. Head; 31 December 1959; p. 84

Where terrain is not smooth, diffraction is more of a factor in path attenuation than the "outphasing" predicted by two-ray theory. Diffraction loss is most pronounced close to but well below an obstacle which "shadows" the receiving location from the transmitting antenna. As the receiving distance is increased, the diffraction attenuation lessens. "Holes" in coverage can result from diffraction losses behind large obstacles, such as mountains and ridges.

Terrain roughness affects the "spread" of data from the average value. In statistical terms, terrain roughness has been correlated to the standard deviation of the received signal strengths within a homogeneous area of interest. However, the signal variations correlated to roughness effects are caused by two separate mechanisms. Under two ray theory, (a) the elevation of a point of reflection directly affects both the magnitude and phase of the reflected signal component and (b) the slope of terrain at the point of reflection affects that component's phase, both of which influence total attenuation. A rough path may be comprised of many diffracting surfaces, each of which causes losses that affect the variability of measured or predicted field strength. Thus, empirical correlation of field strength variations to roughness describes the combined effect of variances attributable to two distinct phenomena.

For intermediate distances beyond the horizon, attenuation is primarily attributable to diffraction over smooth earth, irregular terrain, multiple peaks, or rounded obstacles. At greater distances, the attenuation is primarily attributable to tropospheric scatter, which is a function of atmospheric characteristics, not terrain.

Clearance Over Terrain

For VHF/UHF/SHF transmission systems, it is well known that propagation conditions near free space can be realized. Signal attenuation will not significantly exceed the computed free space value if the clearance above ground and obstacles of the direct line-of-sight path from the transmitting antenna to the receiving antenna is sufficient. However, if the clearance is insufficient, additional loss is likely and service reliability decreases.

The criterion for adequate clearance in fixed-link service (microwave/STL, for example) is based on the first Fresnel zone between transmitter and receiver. Should the ground elevation, corrected for "bulge" attributable to the curvature of the earth, intercept the first Fresnel zone boundary, additional signal attenuation is likely. It is common to assume that adequate path clearance exists if the clearance between terrain and the ray between antennas exceeds 60 percent of the first Fresnel zone height, but much of the literature points to a full first Fresnel zone clearance criterion, ensuring a further safety margin.

This same analysis applies for all services operating on frequencies in excess of roughly 30 MHz. When an unblocked line-of-sight path exists, at least 60 percent first Fresnel zone ground and obstacle clearance is necessary for free-space (minimum loss) field strengths to be realized. For lesser clearance, additional attenuation may be quite significant. Therefore, the segment of terrain intercepted by a first Fresnel zone drawn about the direct transmitter-receiver elevation-distance path is significant in predicting received signal level. Whether 60 or 100 percent of the first Fresnel zone should be used appears to be a matter of diverse opinion, but that consideration is somewhat irrelevant to this discussion.

Figure F-1 illustrates the smooth-earth path profile to a radio horizon located 50 kilometers from the transmitter site.[2] The effect of earth curvature, demonstrated by the "bulge" in surface terrain in the middle of the graph, is drawn for an effective earth's radius of 4/3 the actual value, to make allowance for atmospheric refraction. The clearance between either Fresnel zone boundaries and ground level can be determined by scaling the difference

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/2 Such a distance is attained for a transmitting antenna height above smooth earth of 139 meters and is similar to the horizon path for Class B and C2 FM stations.

between the pertinent Fresnel zone curve (opening upward) and the earth bulge curve (opening downward). The 100% first Fresnel zone boundary intersects smooth earth 4.8 kilometers from the transmitter site; the 60% boundary intersects the earth at 9.5 kilometers. Neither Fresnel zone boundary "surfaces" until the immediate foreground of the horizon is reached. Of particular note is the fact that the point of least Fresnel zone clearance (greatest depth of zone boundary *below* terrain) occurs at approximately 32 kilometers, *far beyond* the 3-16 kilometer segment specified for terrain evaluation by §73.313 of the Commission's Rules.

It is the terrain segment commencing where the Fresnel zone boundary intersects terrain and ending at the receiving site that is most pertinent in predicting received field strength. Based on this evaluation, the terrain closer to the receiver is most important in the prediction of field strength. The transmitter foreground terrain in general, and the terrain within the FCC's 3-16 kilometer segment in particular, has little to do with the field strength achieved at expected FM station service boundaries.

Analytical Segment Definition

The points of intersection of the Fresnel zone boundary and uniformly smooth (flat) terrain, in the foreground of the transmitter, will vary with distance to the radio horizon. Horizon distance varies directly with the square root of antenna elevation above smooth earth, according to the following equation.

$$d_h = \sqrt{2\,h_e} \qquad \text{(F.1)}$$

where: h_e is the effective antenna height (in meters)
d_h is the horizon distance (in kilometers).

The radio horizon distance and corresponding transmitter foreground distances to the points of intersection of Fresnel zone boundaries with the earth ("start distances" hereafter) have been computed for different antenna elevations above smooth earth. In preparing the following table, the traditional assumptions of the effective earth's radius being 4/3 the actual value and the receiving antenna elevation of 30 feet (9.1 meters) above ground were employed. The receiver foreground Fresnel zone boundary intersection with terrain will occur very close to the receiving antenna; its distance from the receiver may be assumed to be negligible. For a given antenna effective antenna height and smooth earth conditions, the terrain segment analytically determined to be pertinent to the estimation of received field strength will start at the distances set forth in the table above and terminate at the radio horizon distance. In other words, for a transmitting antenna height of 200 meters, terrain from perhaps as little as 8.4 kilometers from the transmitter site but commencing at least at 15.3 kilometers and extending to 60 kilometers (ideally) may impact received signal strength at the radio horizon.

Effective Antenna Height (meters)	Radio Horizon Distance (km)	Transmitter Foreground Fresnel Zone Intersections 60 percent (km)	100 percent (km)
50	30	1.9	0.77
75	37	3.8	1.65
100	42	6.0	2.75
125	47	8.3	4.0
150	52	10.6	5.4
175	56	13.0	6.9
200	60	15.3	8.4
225	64	17.6	10.0
250	67	19.9	11.6
275	70	22.2	13.3
300	73	24.4	15.0
350	79	28.7	18.3
400	85	32.9	21.6
450	90	36.9	24.9
500	95	40.8	28.1
550	99	44.6	31.3
600	104	48.3	34.5

Figure F-2 presents these data in graphical form. The relationship between antenna elevation and first Fresnel zone earth intersection is approximately linear, so first order equations may be fit to these data with minimal errors resulting. For a transmitting antenna height h_e (in meters) and a distance to the Fresnel zone intersection point d_s (in kilometers), the relationships are described by the following equations:

$$d_s = 0.086\ h_e - 2.0 \qquad \text{for 60\% clearance} \qquad (F.2)$$

$$d_s = 0.063\ h_e - 3.7 \qquad \text{for 100\% clearance} \qquad (F.3)$$

Logic suggests that, as the total distance to the point where it is desired to estimate signal strength is reduced below the horizon distance, the point of interception of the Fresnel zone boundary and terrain should be reduced also. The variances in start distance as a function of path length are tabulated below, again assuming a receiving elevation of 30 feet.

Effective Antenna Height (meters)	Distance Range (km)	60% Start Distance Average (km)	60% Start Distance Variance (km)	100% Start Distance Average (km)	100% Start Distance Variance (km)
100	10-40	5.9	0.8	2.75	0.2
150	25-65	10.6	0.6	5.4	0.2
300	40-85	24.4	1.1	15.0	0.5
600	55-100	47.6	3.4	34.6	1.2

Figure F-3 illustrates the situation for an EAH of 139 meters, full first Fresnel zone clearance, and receiving locations of 25, 30, 35, 40, 45, and 50 kilometers. It is apparent that the starting intersection point of the Fresnel zone ellipse and smooth earth terrain changes little as the receiving antenna distance range is varied, especially when that variation is compared to the total segment distance involved and particularly for the full first Fresnel zone case.

Analytical Evaluation of FCC Terrain Segments

Section 73.313 of the FCC's Rules requires that terrain averages used in computing EAH be determined over a segment commencing 3 kilometers from the transmitter site and terminating 16 kilometers therefrom. CCIR Recommendation 370-5 and the Okumura propagation model begin the segment at the same point and terminate it at 15 kilometers.

Applying the approximate equations stated above, the 60 percent smooth earth intersection elevation occurs at 3 kilometers for an EAH of 58 meters; a transmitting antenna height in excess of 209 meters has a smooth earth intersection commencing beyond the FCC terrain segment termination distance. For 100 percent first Fresnel zone clearance, the 3 kilometer intersection EAH value is 106 meters; any antenna height in excess of 313 meters will cause the relevant terrain segment to start after the FCC segment terminates.

This information suggests that there is little physical basis for the selection of the 3 to 15/16 kilometer range as the terrain segment applicable to all FM stations, since the starting distance infers an atypically low EAH value and the termination distance infers a rather low-powered facility (or, conversely, the termination distance infers an unusually high level of desired signal strength). Although deficiencies in the use of the specified terrain segment used in EAH determination have long been acknowledged, no serious effort has been made to suggest a relevant means of redefining that distance interval. It is suspected that the difficulty of retrieving terrain data manually from topographic maps discouraged both government and industry engineers from suggesting any change in procedure.

Alternative Methods of Terrain Segment Definition

In an era of readily available terrain data bases, it is now convenient to sample terrain over longer distances, facilitating the consideration of different segment definitions. This was not possible in earlier eras, when all terrain data had to be manually extracted from topographic maps, many of which had not yet been published. Based on the foregoing analysis, it appeared that better approximation of station service and interference areas might be obtained if the corresponding contour distances are determined using EAH values computed from alternative terrain segments. Prospective new methods of EAH determination were tested using the 30 station sample set described in Appendix C.

Terrain Segment Determined by Class EAH

Alternative terrain segments were first defined by fixing the EAH at the nominal maximum value for each station class and computing the horizon and Fresnel zone intersection points from that EAH figure. The terrain segments shown in the following table resulted:

Class	**Maximum EAH** (m)	**Start Distance** (km)	**End Distance** (km)
A, B1, C3	100	3	42
B, C2	150	6	52
C1	300	15	73
C	600	34	104

The disadvantage of an approach like this is that, in reality, the relationship between EAH and horizon distance is realized only for those situations where terrain is homogeneous, about the transmitter site, out to the horizon, and beyond. That is, terrain variations are randomly and uniformly distributed (Iowa) or the terrain is simply flat (northwestern Ohio). Although coverage based on EAH figures determined in this manner is evaluated herein, the EAH figures themselves will not be discussed further.

Iterative Determination of EAH

The distance segment over which terrain averages are determined and EAH computed might be changed to dynamically correlate with the physical situation at hand. The starting distance under such a method would be the point where the first Fresnel zone boundary is predicted to intercept terrain in the foreground of the transmitter site. The termination distance should, ideally, be the location at which it is desired to determine field strength (i.e., the city boundary or contour of interest).

While such an ideal approach to EAH determination does offer theoretical advantages over fixed distance segments (i.e., the FCC 2-10 mile segment), it may well be seen as impractical for generalized use in the regulatory environment. FM service boundaries have been traditionally defined by contours corresponding to particular field strength values. Were this method used in contour distance determination, a succession of distance guesses, segment definitions, and field strength predictions would have to be made until the field strength value of interest was obtained.

Implementation of such an ideal procedure would involve several complications. First, the resulting iterative solution procedure must be constrained not to extend the terrain evaluation distance beyond the radio horizon. Second, the propagation model must be included within the iterative determination loop. Third, in particularly rough terrain, it is possible that several distances, or no distances at all, would be found using such a iterative procedure. Lastly, this situation is considered not to be administratively convenient and lacks the certainty that the FCC usually seeks adopting rules of general applicability.

In the interest of simplicity, a compromise approach was taken, whereby terrain characteristics were determined independently of predicted field strength. The terrain segment termination point was simply set at the radio horizon distance, assuming smooth earth conditions.[3] The segment start distance was readily determined by assuming the same conditions and that termination distance.[4] This still required an iterative determination of EAH, start distance, and horizon distance, since EAH defines horizon distance, which defines the terrain segment start distance. However, the determination was made less complicated by the exclusion of a field strength prediction model from the iterative procedure. As is discussed below, the remaining iterative solution situation is not believed to be unduly complex or burdensome.

To perform the initial retrieval of terrain, to be used in establishing EAH values by iterative procedures, the distance to the farthest possible radio horizon was computed based on the transmitting antenna radiation center elevation above mean sea level. Terrain data points were retrieved along the path of interest. The point distance was rounded to the nearest radial distance increment (kilometer) and the point elevation added to the running total for that radial distance and sector azimuth. Average elevations were computed for each distance increment along each bearing. The result of this process is a path profile of mean terrain for each sector bearing.

Terrain data need only be retrieved once and stored in a two-dimensioned array, indexed by sector central distance and azimuth. The iterative determination of EAH may be conducted by decrementing distance and sequentially deleting data from the running terrain sum by retrieving incremental data from array storage and subtracting it, saving execution time.

/3 A case can be made that the actual radio horizon, defined as the distance at which the ray elevation angle from transmitter to receiver is least negative (downward), should be used in lieu of the smooth earth horizon. However, propagation models developed for average conditions are based on smooth-earth horizon distances. To be internally consistent, the terrain data input to such models should be based on similar parameters. Therefore, use of the smooth-earth horizon distance is appropriate.

/4 A case can be made that the start point ought to be based on the intersection of the Fresnel zone ellipse with the actual terrain profile. That adds an undesirable level of complication, with little improvement in results likely. Furthermore, a smooth earth assumption is consistent with the propagation relationship definition to be used, as discussed above. Therefore, use of a start point defined using a smooth earth assumption is considered valid.

The use of antenna elevation above sea level as an initial guess of EAH to determine horizon distance is considered to be valid. Only near California's Death Valley and Salton Sea, neither of which are desirable broadcast markets, is the EAH likely to exceed the antenna elevation above mean sea level. In highly elevated areas, such as the Rocky Mountains, this assumption might result in retrieval of excessive amounts of terrain data over unreasonably large distances, but (1) those areas comprise such a small portion of the U.S. FM station distribution that they are not nationally significant and (2) the minimum elevation found within a large range of the transmitting site could be used to provide an initial limit on terrain elevation searching. Practically, a horizon distance limit was imposed based on the EAH limit of the propagation curves, 5000 feet (1524 meters).

In implementing this technique, terrain was initially retrieved from the N.G.D.C. TPG-0050 topographic data base over a long segment and stored as described above. Trial values of horizon (segment termination) distance were established. Terrain samples were averaged from the transmitter site to this distance to redefine EAH, which, in turn, redefines the horizon distance. The trial value of horizon distance was adjusted and the process repeated, continuing until the solution converged within a one kilometer tolerance. At that point, an inner segment boundary was established in accordance with the intersection of the first Fresnel zone with assumed smooth earth. Terrain was averaged within the segment so defined and EAH computed as the difference between transmitting antenna elevation above sea level and the average terrain elevation. It should be noted that this method requires initial knowledge of the antenna radiation center elevation above mean sea level; the average terrain elevations cannot be determined independently, as they can under the FCC/CCIR methods.

Consideration of Terrain Slope

The slope of terrain can markedly affect coverage range. Upward slopes departing the transmitter site lessen the effect of earth curvature, improving reception above "flat earth" conditions. Downward slopes have an opposite impact, effectively reducing the radius of the earth such that the horizon is encountered at a distance closer to the transmitter site than would ordinarily be expected. EAH definition methods sensitive to terrain slope are cited in Technical Note 101 (Rice, et. al., 1967), the Longley-Rice propagation model (Longley & Rice, 1968), and the TASO Supplement.[5] These techniques evaluate EAH as the transmitting antenna elevation above the point of intersection with the zero distance axis of a straight line fitted to the terrain over the pertinent path.

Definition of EAH was attempted based on an iterative determination of (1) terrain segment start and end points, (2) fit of a straight line to the terrain within the segment so defined, and (3) projection of that line back to the transmitter site to determine EAH. However, problems were encountered in obtaining convergence and reasonable results when using this comprehensive, complex procedure.

Where pertinent segments commenced well away from transmitter sites and a terrain slope was fit to data within the segment of interest, effective terrain elevation projected back to the transmitter site could (and did) sometimes fall below sea level, which makes little sense. This problem was partially resolved by evaluating the effective terrain elevation at the segment start point rather than at the transmitter site, but situations still occurred, in mountainous terrain, where EAH values were grossly and unreasonably modified when slope was considered.

/5 A method of this sort, adaptable to the technology of the time, was described by H.T. Head, "A Method of Predicting Average Field Strengths at Television Broadcast Frequencies", pp. 84-86, TASO Supplement (TASO, 1960)

The physical impact of terrain slope is to extend the radio horizon distance when rising terrain overcomes the apparent terrain depression resulting from the curvature of the earth and to reduce the horizon distance when falling terrain effectively accelerates the earth curvature. Therefore, EAH gain should not increase further from rising terrain situations once the curvature of the earth has been overcome. Accordingly, a limit on terrain slope was established, based on the slope of the earth at the midpoint of the terrain segment, relative to plane established at the transmitter site. Upward slopes were permitted to modify (increase) EAH values until they equalled the slope of a line tangential to the curvature of the earth at the terrain segment midpoint. Downward slopes were limited symetrically. This modification, in conjunction with the aforementioned determination of EAH at the segment commencement point, appeared to resolve excessive slope modification of EAH data, yet maintained a sensitivity to terrain slope.

Area Based Terrain Sampling

FM broadcasting is, by its nature, a point-to-area service. Propagation models seeking to provide mean estimates of FM signal strength in regions and/or coverage areas must necessarily have their input data defined on an area basis. Terrain data, one of those necessary input parameters, must also be defined on an area basis. A sector area based terrain sampling approach was used to construct a composite terrain profile from which EAH was determined.

First, the outermost boundary of the area of interest was defined, as described earlier. The geographic coordinate boundaries of a square which that radius inscribes were then determined. Terrain data points at 30 arc second (or lesser) intervals were retrieved for the square so defined, from the N.G.D.C. terrain data base. The distance and bearing of each such point from the transmitter site was computed. If the point lay within the idealized maximum service range defined above, the point distance was rounded to the nearest radial distance increment, the azimuth angle rounded to the nearest sector azimuth interval, and the point elevation added to the running total for that radial distance and sector azimuth. Figure F-4 illustrates a uniform terrain data point grid and the sectors which could be used for terrain data retrieval and processing.

For example, assuming a one kilometer distance increment and ten degree sector width, terrain elevations were sorted by round-kilometer (1, 2, 3, ... , 17, 18, 19, ... , etc.) distance and decile radial bearing (0, 10, 20, ... , 340, 350 degrees). After the entire "box" of terrain data was scanned, average elevations were determined for each radial distance and sector interval central bearing coordinate pair. Where no points fall within the sector distance and bearing limits, average elevation values could be interpolated from adjacent sectors of identical center distance or the coordinate pair excluded from use in EAH determination. The result of this process was a path profile of mean terrain for each sector central bearing, based upon an equal area sampling process throughout the zone of interest.

EAH Data Comparison

For each of the 30 sample FM stations, EAH was computed by several methods, including the existing FCC procedure and the iterative method described above, along each of the 8 evenly spaced "cardinal" radial bearings. The first numerical column of Table F-I presents the percentage change of the iteratively determined EAH with respect to the conventionally determined EAH. The value shown for each station is actually the average of the absolute values of individual radial changes, to show the average variability, rather than the overall average difference, with respect to the current method.

Differences between iterative and conventional EAH determinations are noticable for Group 2 (gently rolling terrain, 9%) facilities, significant for Group 3 (hilly terrain, 22%) stations, and substantial for Group 4 (mountainous terrain, 58%) stations. Both Group 1 (flat terrain) stations show one percent or less difference in EAH results. These results should not be surprising, since increasing the sampling range in uniform, gently rolling or flat terrain, would not ordinarily be expected to change the result obtained by a somewhat limited, but still representative, sample.

The second numerical column of Table F-I illustrates the difference in EAH value computed by the iterative method with and without slope sensitivity. There was no change in the iterative determination of horizon distance. The differences in EAH shown result from the final processing of the terrain data, commencing at the computed segment start distance and terminating at the horizon distance, once an iterative solution thereof has been obtained. The data shown in Table F-I reveals little change in EAH resulting from slope consideration for terrain Groups 1 (flat, 1%) and 2 (gently rolling, 10%). The difference is significant within terrain Group 3 (hilly, 18%) and pronounced for Group 4 (mountainous, 30%).

A fundamental theoretical difficulty in the application of any technique sensitive to terrain slope in conjunction with the existing propagation curves is that the technique was not applied in the *derivation* of such curves. A truly proper analysis would involve the use of slope effects in developing baseline empirical field strength versus *apparent* (slope-sensitive) EAH graphs, followed by the use of *apparent* EAH values with the resulting curve family to predict field strength. Without reference to and correction of the EAH values for the raw measured data underlying the propagation curves, the success of predicting field strengths using slope-modified EAH values is problematical. It is believed that the failure to achieve any significant improvement in prediction results where EAH values are modified by terrain slope, as reported in the body of this Final Report, is in part attributable to this fact.

The third numerical column of Table I describes the results for sector widths of 45 degrees. There is virtually no change in EAH by virtue of area-based terrain sampling for terrain Groups 1 (0%) and 2 (3%). The change for Group 3 is small (7%) with the exception of one station.[6] Significant changes (20%) are apparent for Group 4; that is expected for mountainous terrain areas. The data appearing in the fourth numerical column of Table F-I is based on sector widths of 10 degrees. Only in the most hostile terrain (Group 4) is a difference of any significance apparent.

The conclusion drawn is that, for a propagation model based on one defining terrain parameter (EAH), linear sampling of terrain provides an adequate approximation of terrain characteristics within areas (sectors), in all but the most mountainous regions. However, this situation obtains only when the separation of adjacent sampling paths is kept small (15 degrees or less). Although an area-based method appears outwardly to have theoretical advantages, those improvements are not realized when data is used to define a single average terrain value for the direction involved.

Additional Statistical Parameters of Interest

The numerical approaches to terrain retrieval in common use today facilitate ready determination of additional statistics important in describing the nature of FM service. The field strength determined based on the average EAH figure is a mean value. The variability of that field strength is a function of the undulations of terrain (and secondary factors). Terrain variability can be readily found by determining the deviation of terrain from the

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/6 KVVA, Apache Junction, AZ, which is located at the edge of a substantial mountain range on one side and valley elsewhere; see Figure 4 of the Final Report. Data is not presented for KUDA and KVFM because a convergent result was not obtained with the present algorithm.

average or from a line fitted to it. Knowing the mean terrain value and the average deviation therefrom, the signal strength at a given distance may be expressed in terms of a nominal level and plus/minus average tolerance by running the three EAH values (mean, mean plus variance, and mean minus variance) through the field strength - distance - height propagation model used.

It is suggested that the development of tolerance statistics provides an objective means of determining whether a generalized, TASO *Type II* method is appropriate when predicting critical field strengths in limited areas, such as determining the extent of principal community coverage. For example, where terrain variability is such that an average deviation of 3 dB is forecast for predicted field strengths, it might be desirable for applicants to provide supplemental showings of principal community coverage based on TASO *Type III* methods, such as point-to-point grid modeling using the Longley-Rice method or other suitable techniques.

Terrain Shielding

The recommended approach to determination of EAH does not encompass any adjustment factor for paths where a large terrain discontinuity, such as an intervening mountain range, exists. The existing FCC propagation prediction method also fails to consider the effects of distant obstructions. Along such paths, additional attenuation caused by diffraction over the large obstacle in the path is to be expected. This effect is often referred to as "terrain shielding".

That term is considered to be a misnomer in that, while obstacle effects severely attenuate signal levels at receiving points located just beyond its peak (i.e., in its "shadow"), the effect moderates as distance beyond the obstacle increases, whereas a "shield" effect involves a fixed amount of attenuation that is not distance nor receiving elevation dependent.

The use of an EAH figure developed for average terrain data does not accommodate estimation of the impact of terrain shielding. While there may be considerable interest in such matters,[7] the details of signal blockage effects are believed to be beyond this project's scope of work. The stated goal of this project is to define ways of preventing future *increases* in interference to FM stations. Ignoring terrain blockage effects is consistent with that goal in that it will sometimes result in *overprotection* of stations. Therefore, detailed consideration of shielding effects and derivation of appropriate means of modeling such phenomena were not considered herein.

Recommendation for Further Study

The present work demonstrates that, for the majority of situations, little improvement in overall results is obtained for the averaging of terrain over long segments. There are, of course, some situations where that is not true ... use of a longer segment occasionally yields better correlation of results. The experience gained suggests that it might be worthwhile to explore the possibility of evaluating terrain first from the transmitter site out to the conventional 10 mile (16 kilometer) segment limit, then extending the search range until the point is reached where the percentage change in average terrain elevation is less than the percentage change in retrieval distance.

This technique is likely to achieve valid results in most cases. The inclusion of terrain within 2 miles of the transmitter site will not produce anomalous results. Where the transmitter sites are located atop hills or mountains, the technique will extend the retrieval segment a sufficient distance to "wash out" the distorting effects of high terrain about the site. In those cases where the transmitter site is located in a valley but surrounded by hills, the

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/7 It is understood that the FCC plans to issue a contract to derive a new propagation prediction method incorporating greater sensitivity to intervening terrain in response to Congressional concern about the consideration of such effects in the low power television service.

segment is likely to stretch out a distance sufficient to estimate the effect of such terrain. Where terrain is uniform about the site, excessive data retrieval would not take place. Unfortunately, time constraints do not permit complete development and evaluation of such a technique at present.

It may not be entirely valid to apply EAH values determined in such a manner to the present propagation curves. These curves were derived for field strength data correlated to EAH figures determined using the 2 to 10 mile average. To the extent that the terrain within that segment is indicative of terrain along the entire path, the redefined EAH value may be used with a reasonable probability of success. Where the terrain average for the convergent segment departs markedly from the 2-10 mile average, the predicted field strength may not be as reliable.

The appropriate solution to the problems noted above is to reconstruct the average propagation curves based upon redefined terrain parameters, such as EAH defined by result convergence and/or slope. Modern terrain databases readily facilitate the consideration of such factors in the correlation of empirical models to measured data.

Table F-I

Summary of Effective Antenna Height Data

prepared for
National Association of Broadcasters
Washington, D.C.

Station	Location	Iterative Segment Change (%)	Slope Adj. Change (%)	45° Area Mode Change (%)	10° Area Mode Change (%)
WSGL	Naples, FL	0	0	0	0
WKRE	Exmore, VA	1	2	0	0
Group 1	Averages	1	1	0	0
WMVY	Tisbury, MA	5	7	5	2
WXXL	Leesburg, FL	4	4	1	0
WMDH	New Castle, IN	8	8	2	1
WDZQ	Decatur, IL	3	3	1	0
WZTR	Milwaukee, WI	17	15	2	1
WBCH	Hastings, MI	8	11	5	1
KGRS	Burlington, IA	13	20	4	1
WWYN	McKenzie, TN	4	3	2	1
WTOJ	Carthage, NY	27	19	8	3
WRJH	Brandon, MS	8	11	6	2
WBCN	Boston, MA	8	10	2	1
Group 2	Averages	9	10	3	1
WCME	Boothbay Harb, ME	9	17	5	2
WKDQ	Henderson, KY	11	11	3	1
KWYR	Winner, SD	18	21	4	1
WDEN	Macon, GA	9	11	3	1
WEZZ	Clanton, AL	24	25	7	4
WWNK	Cincinatti, OH	11	19	5	2
WGTY	Gettysburg, PA	12	17	6	2
KVVA	Apache Junct, AZ	16	16	24	
KUDA	Pahrump, NV	55	16		
WANB	Waynesburg, PA	12	19	9	2
WAGI	Gaffney, SC	20	20	9	2
KNJO	Thousand Oaks, CA	70	21	4	5
WKKW	Clarksburg, WV	17	26	9	3
Group 3	Averages	22	18	7	2
KVFM	Logan, UT	47	27		55
WREL	Buena Vista, VA	98	63	31	23
WIMZ	Knoxville, TN	24	23	6	2
KTNY	Libby, MT	64	5	22	8
Group 4	Averages	58	30	20	22

ALTERNATIVE PROPAGATION MODEL COMPARISON

prepared for
National Association of Broadcasters
Washington, D.C.

FM station service and interference areas are defined for Federal regulatory purposes by contour lines, which represent boundaries along which *x* percent of the nearby locations are expected to exhibit the desired field strength or greater for *y* percent of the time. Service may be inadequately protected if the predicted service contours fail to completely encompass the entire area where field strength generally exceeds the minimum value considered necessary for service. The same holds true when interfering signal strength contours are not projected with reasonable reliability.

In this phase of the 1990 FM Technical Study, various means of predicting service field strengths were applied to the 30 sample stations identified as representative of the nationwide diversity of station situations, for the purpose of identifying whether or not any method(s) offer significant advantages over the technique mandated by the present FCC rules.

Numerical Analysis

It is difficult, if not impossible, to visually inspect a number of graphical coverage comparisons and draw any quantitative conclusions as to the advantages or disadvantages of alternative means of predicting FM service and interference contour location. Any qualitative judgements rendered are inherently subjective in nature. Therefore, a numerical approach to method comparison was employed for the 30 sample stations.

Baseline field strength data was computed using the ITM/Point (Longley-Rice) model for 10 to 14 evenly spaced distances ranging from 50% to 150% of the nominal contour radius for the pertinent station class, along the 8 "cardinal" radials of each station. The ITM/Point results are well known and widely accepted as being more representative of reality that the approximate results yielded by the prediction method mandated by the FCC's rules. Although the use of measured data would be preferred over any predicted values, such an analysis is believed to be beyond the scope of this project. Moreover, measured data may not be available for a sufficient, fully representative sample of FM operating environments nationwide.

For each alternative propagation prediction method, field strengths were also determined at the same points and statistically compared to the ITM/Point results. The field strength values utilized throughout this analysis were those determined for 50 percent of the locations and 50 percent of the time.

No attempt was made to evaluate in detail the magnitudes of potentially interfering signals occurring 10 percent of the time. Those signal levels are determined by applying fading ratios to the 50 percent signals. They are no more valid that are the 50 percent results which underlie them. The 50% of time coverage boundary nominally corresponds to the radio horizon distance for several FM station classes (B, B1, C1, C2, and C3). If that boundary is well defined, so is the horizon location. By the nature of the propagation models evaluated, the locations of potentially interfering signal strength levels are fixed by the horizon distance to he greatest practical degree, within the confines of each method.

Additionally, the outermost distance at which field strength was computed is just short of the location of the first adjacent channel interfering contour in most cases. The second- and third-adjacent channel interfering contours are almost always determined using 50% of time field strength graphs, because those contours fall quite close to the transmitter site. Accurate depiction of service should also result in valid prediction of second- and third- adjacent channel interference. The co-channel interfering signal generally falls well beyond the horizon, thereby becoming largely influenced by tropospheric scatter, not intervening terrain anomalies. Given these considerations, application of conclusions drawn from service contour comparative analysis is believed to be appropriate and technically valid.

For the purpose of this comparative study, the receiving antenna elevation was fixed at the conventionally assumed value, 30 feet (9.1 meters). This was done because the FCC's propagation prediction method assumes that height and there is no accepted manner of adjusting results to any other value of receiving antenna elevation. To present an "apples and apples" comparison with respect to the current FCC-mandated technique, use of the "standard" receiving elevation was necessary. It is expected that the conclusions drawn would be similar had the comparative analysis been conducted for lower receiving elevations.

Along each of the eight radial bearings for each station, the difference between the ITM/Point and other method predicted field strength values was determined. All field strength differences along each radial bearing for particular station were averaged to find the difference for that radial. The magnitude of such differences were than averaged to determine the overall correlation.

In addition, the standard deviation of the radial differences were determined for each station and propagation model. These figures give a sense of the consistency of method error from radial-to-radial. A method which consistently errs but does so by about the same magnitude from bearing-to-bearing is to be preferred over one which achieves less error overall but varies substantially with direction.

Table G-I presents the average field strength prediction differences with respect to the ITM/Point model results for each station and alternative method studied. Table G-II presents the standard deviations of field strength errors for those same situations.

Graphical Illustration

Statistics alone cannot illustrate the situation. It is difficult to relate a table of field strength differences to station reach and ratings diary penetration. But it would be a monumental task to prepare 30 comparative service area maps as part of this study, and an even more daunting task to examine all such maps and draw some conclusions therefrom. Accordingly, coverage comparison maps have been prepared for five stations, evenly distributed throughout the 30 station sample, in the interest of being illustrative but not overwhelming.

Figures G 1-5 illustrate the predicted coverage contours for the alternative propagation prediction methods studied. The baseline ITM/Point data is represented by red radial lines drawn over those distance segments where the predicted signal strength level fell below the 60 dBμ (1.0 millivolt per meter) field strength value commonly considered to represent the boundary of acceptable FM service and ideally protected from interference. ITM/Point mode computations were conducted along uniformly spaced 2 degree bearings.

FCC Method

The FCC-mandated method of predicting FM service contours was, of course, evaluated. Overall, the correlation of the results to the ITM/Point baseline data was fairly consistent ... differences of 15 - 21 dB were typical. The total average difference was 13.9 dB; the average standard deviation of prediction differences was 3.3 dB.

The five coverage illustration maps show that the 60 dBμ contour determined under the FCC method generally falls close to the boundary computed using the ITM/Point mode. For flat and gently rolling terrain situations, such as those present about WMVY and KGRS, the FCC technique appears to slightly underestimate coverage. In hilly terrain, such as that about WKDQ, the method approximates more sophisticated results surprisingly closely. Even in the West Virginia mountains surrounding WKKW, the FCC technique seems to define a reasonable coverage boundary, especially when it is remembered that the technique is intended to predict statistical results, i.e., for 50 percent of the locations. However, where terrain sharply changes from one sort (valley) to another (mountains), the method is less successful, as can be seen for the case of KVVA (Figure G-4).

CCIR Method

The propagation prediction method described by CCIR Recommendation 370-5 is similar to the FCC technique except that (a) no propagation characteristics are depicted for distances less than 6 miles (10 kilometers) and (b) a field strength correction term is included which is dependent upon distance from the transmitter site and the interdecile magnitude of terrain "roughness" between 6 and 32 miles (10 and 50 kilometers) from the transmitter site.

The statistical comparison of the CCIR method indicates somewhat less consistent difference results than was noted for the FCC method, although the overall average difference, 14.1 dB, and standard deviation of variance, 3.4 dB, are not of any significance. For stations in terrain Groups 1 and 2, the CCIR method results correlated significantly better to the ITM/Point mode baseline than did the FCC method results. However, for terrain Group 3, the correlation was worse, extremely so for one case: KUDA. The correlation in Group 4 was not as good as that determined for the FCC method.

It is believed that the improvements apparent in terrain Groups 1 and 2 for the CCIR method are attributable to the fact that the method's terrain roughness correction increases predicted field strength in relatively flat terrain areas, whereas the FCC method contains a built-in 2 dB attenuation factor for the median terrain roughness assumed in its derivation. The deterioration in CCIR method performance in hilly and worse terrain is a direct result of the same factor ... a downward adjustment in predicted field strength based upon terrain roughness. The FCC's Rules contain a procedure for correcting predictions for terrain roughness, but the effectiveness of that procedure has been indefinitely stayed, almost since the day of its adoption fifteen years ago. The CCIR and FCC roughness correction procedures are reasonably similar; the results shown herein demonstrate that there is good reason for the FCC not to utilize the roughness "correction".

Use of the CCIR method is not recommended because (1) there is no significant overall improvement in results and (2) for stations located in hilly terrain, the accuracy of service area prediction is diminished significantly.

Rice 1990 Formula Adaptations

Three different approaches to using the propagation prediction formulas developed earlier this year by Philip L. Rice were studied. They differ only in the manner under which EAH was determined for input to Mr. Rice's formulas.

A. Class EAH Definition of Terrain Averaging Segment

The first method of determining EAH for use with the Rice formula propagation model was to establish the segment starting and ending distances based upon the nominal maximum EAH for the station class. That figure defines a horizon distance, used as the segment termination point, and a first Fresnel zone smooth terrain intercept point, used as the segment commencement distance. The actual distance segments used are identical for all radial bearings at all stations of the same class. The segment distances actually used were described earlier in this Appendix.

This method yielded no significant improvement in predicted field strength correlation to the ITM/Point mode results. It yielded the greatest range of radial-to-radial variations for each station data set. Because no improvement in results was noted and the method is a gross simplification of theory, the results obtained using it were not plotted on Figures G 1-5.

B. Iterative Determination of Horizon Distance

The second approach to EAH definition involved iterative determination of the horizon distance along each radial bearing. The procedure was described earlier in this Appendix. It results in different horizon distances for each direction when terrain is not homogeneous.

While slightly better results for terrain Groups 1 and 2 are apparent from Table G-I for this method, there is no overall improvement in Group 3 and the Group 4 results at first appear to be significantly worse. However, the errors noted within Group 4 result from (1) a sharp change in terrain nature in the vicinity of KVFM and (2) overprediction of the KTNY service area. The latter effect is not detrimental if the purpose of adopting a new propagation prediction procedure is to improve freedom from interference between stations.

Figures G 1-5 illustrate the 60 dBμ coverage contour predicted for five sample stations using this method. Little change with respect to the current FCC method contour location is seen except for rough terrain areas, and the visual correlation to the ITM/Point mode predictions is better than the FCC approach.

C. Slope Adjustment of Iteratively Determined Terrain Segment

The EAH figure was also determined by a slope-based analysis of the terrain segment derived under the immediately preceding method. The technique was described in more detail earlier in this document. Where terrain generally rises going outward from the station, EAH is increased somewhat. Where terrain falls, EAH is lessened.

This method incorporates all means of improving EAH definition identified in research work performed during this study, with the exception of area-based terrain analysis. However, no significant improvement in overall results over the FCC method was obtained. A slight improvement in prediction correlation for terrain Groups 1 and 2 is offset by a significant decrease for Group 4. There is no significant difference in the radial-to-radial error consistency described by Table G-II. There is little change in service area predictions depicted on Figures G-2 and G-3; for the rough terrain situations of Figures G-4 and G-5, there are both improvements and deteriorations in correlation to the ITM/Point mode results.

Significant deteriorations in prediction correlation are apparent in Tables G-I and G-II for all three such approaches when applied to KTNY. This station has negative EAH values in all direction, necessitating the classic assumption of a 100 foot (30 meter) transmitting height. Predictions using Rice's formulas depart from the FCC's propagation curves most significantly at the extreme lower and upper ranges of EAH values, so significant differences for very low or high EAH values are expected.

ITM Area Mode

Station coverage areas were also evaluated under the Area Mode of NTIA's Irregular Terrain Model. The Area Mode generally characterizes terrain in a region by a composite roughness factor derived from many criss-crossed paths and utilizes that value to predict propagation conditions.

Area Mode studies were conducted only for the five stations depicted by Figures G 1-5. The concept of this part of the study was to present a comparative analysis of line mode coverage prediction techniques statistically and a limited graphical presentation of area-based techniques, so the Area Mode results are included only with the latter presentation. As it turns out, the analysis suggests that area-based results are effectively obtained for averaged line-specific terrain data, so no change to an area-based scheme was warranted to prepare Figures G 1-5 for the FCC, CCIR, and Rice formula methods.

Examination of Figures G 1-5 reveals that the Area Mode approximates coverage reasonably well only for the flattest terrain case, WMVY (Figure G-1). The complete failure of the Area Mode to adequately address local terrain is best illustrated for the two mountainous examples, KVVA (Figure G-4) and WKKW (Figure G-5). The Area Mode coverage contour prediction lies far beyond and reasonable interpretation of its location under the ITM/Point mode.[1]

It is concluded that the ITM Area Mode is inappropriate for use in predicting FM station service and interference. The areas utilized in defining terrain parameters are apparently much too large. The generalized result obtained using the method approximates reality only where terrain is relatively flat.

Overall Results

This study has revealed no simple method or incremental adjustment to existing simple methods that yields consistently and significantly better field strength prediction results when compared to data derived from sophisticated methods. The suggestions that have been made over the years concerning definition of EAH and roughness effects have been implemented and statistically compared to more sophisticated prediction results, with little improvement noted. Visual analysis provides a similar result.

It is believed that extension of the segments over which terrain is averaged does not significantly improve prediction correlation because (1) within most regions, there is a point reached where adding more data to the averaging set yields no substantial change in the result obtained and (2) within hilly or mountainous areas, the prediction is likely to be erroneous regardless of the method of terrain sampling used.

Substantial improvement of propagation methods based on the redefinition of but a single determining parameter, the effective antenna height (EAH), has been conclusively proven to be impossible. While a slightly better approach to EAH definition that the 2-10 mile (3-16 kilometer) terrain segment might be obtained by extending the segment based on incremental percentage change criteria, that is expected to result in only a subtle improvement in nationwide results.

Recommendations for Improvement

The results of this study do, however, suggest that the 2 dB downward bias in field strength prediction to accommodate terrain roughness results in the underprediction of service and interference areas for most U.S. FM stations. It is tempting to recommend that the adjustment factor be removed. However, the FCC propagation curves themselves were derived from measured field strength data that had been adjusted based upon terrain roughness considerations. To completely remove this residue of roughness analysis from the prediction method, new propagation relationships must be defined on the basis of the original, uncorrected measured data. That effort is beyond the scope of this project.

/1 In the case of KVFM, the Area Mode 60 dBμ contour ranges beyond the search distances at which field strengths were predicted, for bearings from 100 through 350 degrees True. Therefore, no contour is plotted over that range of azimuths.

It is concluded that FM service and interference in quite hilly and mountainous areas cannot be approximated reasonably well by any prediction method dependent upon a single governing parameter. A multiple-parameter technique is obviously required, although it need not be as complicated as sophisticated point-to-point propagation models are.

Parameters that deserve investigation in conjunction with development of an improved model appear to be losses attributable to terrain cover/clutter in the desired coverage area, upward and downward adjustment of predicted field strength depending upon diffraction characteristics over a given path, and sampling of terrain on a sector area basis so that predictions apply for the average case within a region of modest size. It is noted that the FCC has been directed by Congress to investigate more specific methods of propagation analysis that the agency has prepared (but not issued) a Request for Proposal to derive a new propagation model from a large measured field strength data base established under an earlier contract.

Table G-I

Summary of Field Strength Prediction Differences

prepared for
National Association of Broadcasters
Washington, D.C.

Station	FCC Rules Method (dB)	CCIR Method (dB)	Class EAH Segment (dB)	Iterative EAH Segment (dB)	Slope Adjusted EAH (dB)
WSGL	7.3	4.6	5.2	5.2	5.1
WKRE	16.8	12.5	17.3	17.3	17.4
Group 1	12.0	8.6	11.2	11.2	11.3
WMVY	18.2	16.7	15.4	15.4	15.8
WXXL	18.3	13.8	18.4	18.5	18.7
WMDH	6.9	5.5	7.0	6.9	6.9
WDZQ	19.1	15.6	19.6	19.6	19.6
WZTR	18.3	16.9	19.5	17.9	16.8
WBCH	19.2	18.8	16.2	16.1	16.8
KGRS	15.2	15.8	17.4	17.1	16.3
WWYN	21.5	19.0	21.8	21.9	21.8
WTOJ	18.8	19.7	16.8	17.3	17.2
WRJH	18.8	18.5	15.8	15.8	16.2
WBCN	21.1	20.1	21.4	22.1	21.4
Group 2	17.8	16.4	17.2	17.1	17.1
WCME	18.6	18.2	18.3	18.2	17.8
WKDQ	19.4	16.8	21.4	20.7	20.7
KWYR	20.1	23.8	20.2	20.1	20.5
WDEN	19.5	20.2	20.1	19.9	19.7
WEZZ	19.1	20.4	14.6	14.8	16.9
WWNK	20.0	24.3	20.9	21.0	20.2
WGTY	8.6	12.4	9.2	9.0	9.3
KVVA	14.4	16.4	12.5	12.2	12.4
KUDA	4.4	15.8	3.2	3.1	3.5
WANB	7.7	9.1	7.9	7.3	6.8
WAGI	6.9	3.5	3.3	4.6	6.4
KNJO	4.7	6.0	10.0	9.6	8.4
WKKW	4.5	5.2	5.0	4.6	4.6
Group 3	12.9	14.8	12.8	12.7	12.9
KVFM	5.8	13.2	16.0	10.7	10.8
WREL	5.2	8.2	9.7	9.3	7.0
WIMZ	11.8	6.4	8.5	8.5	10.3
KTNY	6.2	5.6	9.1	9.1	9.1
Group 4	7.3	8.3	10.8	9.4	9.3
Total Averages	13.9	14.1	14.1	13.8	13.8

Table G-II

Summary of Field Strength Prediction Error Variance

prepared for

National Association of Broadcasters

Washington, D.C.

Station	FCC Rules Method (dB)	CCIR Method (dB)	Class EAH Segment (dB)	Iterative EAH Segment (dB)	Slope Adjusted EAH (dB)
WSGL	0.1	0.1	0.1	0.1	0.1
WKRE	0.7	0.6	0.7	0.6	0.7
Group 1	0.4	0.3	0.4	0.4	0.4
WMVY	0.8	1.2	0.7	0.7	0.9
WXXL	1.3	2.5	1.0	1.0	1.0
WMDH	1.0	1.2	1.0	1.2	1.0
WDZQ	1.3	1.6	1.2	1.2	1.2
WZTR	0.8	2.7	1.0	2.1	1.5
WBCH	0.9	1.1	0.9	0.9	0.8
KGRS	2.2	2.2	2.1	1.3	2.6
WWYN	1.5	1.9	1.4	1.4	1.4
WTOJ	3.9	5.5	4.3	4.3	3.2
WRJH	0.9	1.1	1.4	1.4	0.5
WBCN	1.8	4.2	1.8	2.4	1.6
Group 2	1.5	2.3	1.5	1.6	1.4
WCME	2.0	2.1	0.8	0.8	1.6
WKDQ	1.4	1.5	1.3	1.5	1.5
KWYR	2.6	3.5	4.9	3.7	2.5
WDEN	2.0	2.1	2.3	1.9	2.0
WEZZ	2.5	2.8	2.5	2.3	1.8
WWNK	1.6	3.2	1.5	1.5	1.8
WGTY	5.8	4.6	5.0	5.0	5.4
KVVA	2.8	2.4	3.4	3.6	3.5
KUDA	4.6	6.1	4.5	4.5	4.6
WANB	8.7	3.5	2.7	3.4	2.9
WAGI	8.4	3.1	3.2	5.7	7.7
KNJO	6.2	7.3	11.1	10.7	9.7
WKKW	4.8	5.6	6.3	5.3	4.9
Group 3	4.1	3.7	3.8	3.8	3.8
KVFM	6.8	10.1	14.5	12.2	12.4
WREL	4.5	4.3	10.0	9.4	7.1
WIMZ	11.1	8.7	9.0	9.3	10.3
KTNY	6.6	6.6	6.6	6.6	6.6
Group 4	7.3	7.4	10.0	9.4	9.1
Total Averages	3.3	3.4	3.6	3.5	3.4

Appendix H

INVENTORY OF PROPOSALS FILED UNDER §73.215

prepared for
National Association of Broadcasters
Washington, D.C.

An analysis was performed of all proposals contained in the FCC's Engineering Data Base of 30 April 1990, for which an indication was present that the applicant requested processing of its proposal under the provisions of §73.215 of the Commission's Rules. That Section contains alternative technical standards for proposals that do not meet the minimum interstation distance separations of §73.207. The analysis encompassed a review of each such proposal to determine the number of short spacings, the reason for short spacing, whether a directional antenna was used, the degree of directional antenna suppression (if used), and the maximum short spacing proposed.

The data presented herein represents the most feasible analysis of the available data. The work performed revealed that some confusion appears to remain regarding the necessity of requesting application processing under §73.215. In addition, some errors or omissions appear to exist in the FCC FM Engineering Data Base. No apparent reason could be found for §73.215 processing requests in a number of cases. In one case, it appears that such processing was unnecessarily requested with respect to a short spaced Canadian facility. Likewise, four experimental proposals were flagged as requesting this alternative approach to interference analysis.

A significant factor in these filings (and the analysis thereof) is *proposed modifications to the table of allotments*. In a number of cases, it appears that the protected facility was a proposed new allotment or upgrade, or the requested facility was involved in an upgrade or channel change proceeding. Under current FCC policy, the allotment proposal must be protected as if it were a facility of class maximum located at the reference point.

A total of 132 proposals were found to request processing under §73.215, representing 116 different prospective or operating stations. The most common reasons identified for such proposals were, in order, 6 kilowatt class A operation, pending applications for new allotments, pending applications for upgraded allotments, site relocation, and experimental operation. A small number had no identifiable reason for requesting processing under §73.215.

Directional antennas were specified in 80 applications, representing 60.6 percent of the total. Class A stations most frequently requesting processing under §73.215. The majority of proposals involved only one short spacing.

Method of Analysis

The data set used for this analysis was extracted from the FCC's FM Engineering Data Base. This database is released monthly by the FCC through the National Technical Information Service (NTIS). A proprietary database access system is used to maintain the data in a format compatible with a desktop computer. This proprietary system allows retrieval of records within the database which match defined characteristics. The database system is capable of performing allocation studies according to the various distance separation requirements contained in the FCC's rules. Minor modifications were made to the computer code to allow computation of the minimum directional antenna (DA) radiation (if a DA was used) and to write only the specific data required for study to an intermediate computer data file for later processing.

The database was searched and all records extracted which were flagged by the FCC to indicate that processing under §73.215 was requested by the applicant. This flag is entered and maintained by the FCC staff for processing convenience. A total of 132 records were found which had the §73.215 flag set. For each record, an allocation study was performed and printed to show the short spaced situations. The following data was stored on disk for later analysis: call, channel, class, geographic coordinates, FCC File number, directional antenna (if any), maximum directional suppression (if directional), power, and effective antenna height.

A detailed review of each allocation study was conducted to determine how many short spacings were new, and, therefore, within §73.215 criteria. A significant effort was required to determine which seemingly short-spaced facilities met the old (3 kilowatt) class A criteria, entitling use of the §73.213 separation table and requiring no contour overlap analysis under §73.215. A further check was then performed to determine if other grandfathered short spacings existed, and, if possible, the extent of change requested. It was also necessary to identify any rule making proposals which no longer required protection. Once the allocation studies had been reviewed, all the data was placed into a commercially available spreadsheet program to analyze the results.

The validity of all data extracted and analyzed is limited to the accuracy of the FCC database as of the 30 April 1990. Errors have been noted in the FCC data on previous occasions. No attempt was made to fully investigate each station by means other than the FCC database. There was no attempt made to include any stations other than those flagged as being §73.215 requests. Likewise, no exclusion was made for those unnecessarily requesting such processing. In any cases where questions remained, engineering judgement was used in the analysis.

Analysis of Short Spacings

The entire body of data was analyzed to characterize the nature of each proposal. A summary was prepared of various proposal characteristics, such as class and the reason for short spacing. Where the reason was not readily apparent, engineering judgement was used to categorize the proposal. For example, a new application proposing 6 kilowatt operation was considered as a "new facility" if no call letters had been assigned, but would be considered a "6 kilowatt request" if the station had been authorized to begin operation. The data were further separated to identify the number of proposed short spacings, the amount (distance) of short spacing, whether directional antennas were proposed, and the directional suppression.

Number of Short Spacings

A total of 132 proposals were flagged as having requested processing under §73.215. Table H-I shows the numbers and percentages of the total attributed to each class of station proposing short spacing. Figure H-I shows this data graphically. Table H-II is the converse, showing the number and percentages of each class of station to which short spacing was proposed. Table H-III shows the number of short spacings per application attributed to the class proposing the short spacing.

Excluding the experimental facilities and multiple applications, the 132 proposals cover 116 different FM allotments. For categorization purposes, all applications were considered. Over half of the proposals involved short spacings proposed by Class A stations. The lowest percentage of proposals were attributed to Class B and C3 facilities (3 stations, 2.3 percent each). Likewise, Class A facilities were most likely to be affected by short-spaced proposals. Of the 153 station that would have short spacings[1] as a result of the proposals analyzed, 52 (34 percent) are Class A facilities. Most proposals (84, or 63.6 percent) involve only one short spacing. An additional 32 (24.2

/1 No attempt was made to extract grandfathered short spacings, except for 3 kilowatt class A stations.

percent) involve two short spacings, although some of these are believed to involve grandfathered situations. Only 8 (6.0 percent) involve 3 or more short spacings. The remainder were experimental proposals or had no identifiable short spacings. In a number of cases, either the applicant or protected facility is involved in a rule making proposal which would affect the proposed short spacing.

Reasons for Proposing Section 73.215 Processing

When possible, the reason for requesting processing under §73.215 was determined. Table H-IV is a breakdown by class of station showing the reasons for proposing short spacings under these rules. Clearly, the largest group, with 28 percent of the total requests, are class A stations proposing six kilowatt operation. Applications for new facilities account for 26.5 percent; 21.2 percent were class upgrades; and 18.2 involve site relocations (exclusive of 6 kilowatt requests). Three percent had no identifiable reason for requesting section 73.215 processing, although in one case it was noted that a recent amendment had been filed for a new application which was close to the minimum separation requirements. It is speculated that, in this case, the short spacing had been removed by amendment of another application. Figure H-2 is a graph showing the breakdown of reasons as a portion of all classes of station. Figure H-3 is a similar graph for Class A stations.

Degree of Short Spacing

Each short spacing proposal was checked to determine the distance by which the proposal would not meet the requirements of §73.207 (or §73.213, if appropriate) of the Commission's Rules. Table H-V and Figure H-4 describe the greatest amount of short spacing which will result for each proposal. If the facility was grandfathered with respect to one or more stations, the short spacing shown is the full short distance, regardless of the amount of change.[2] This data only includes the greatest short spacing for each proposal.

Almost half (47 percent) of the proposals have the greatest short spacing at 5 kilometers or less. 10.3 percent involve short spacings of 15 kilometers or more. It is believed that some of these greater short spacings involve grandfathered facilities. In one instance, it was noted that one proposed short spacing involved IF related stations. Section 73.215 does not permit short spacings on an IF related basis; this application may be subject to dismissal or other administrative action.

Directional Antennas

Table H-VI is a breakdown of the number of directional antenna proposals by class of facility. A total of 80 directional antennas have been proposed. Table H-VII and Figure H-5 provide information related to the amount of directional antenna suppression proposed. These charts include the four experimental proposals at Charlotte, NC, which request 30 dB of antenna suppression. Excluding those four applications, only one proposal specifies antenna suppression of more than 15 dB, the limit permitted under Section 73.316 of the FCC Rules. Minimal suppression of 6 dB or less is proposed for 42.5 percent of the proposals, with 57 percent proposing less than 9 dB.

Experimental Proposals

The database contains four proposed stations in Charlotte, North Carolina which are classified as "experimental". Those stations have been specified within the database as §73.215 applications, although by their experimental nature they do not meet the traditional definition of short spaced facility. These have been included in

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/2 For grandfathered facilities, Section 73.213 requires only that the 60 dBu contour extend no farther toward the short spaced station. In instances of grandfathered short spacings, it was not possible to identify whether the request met Section 73.213 requirements.

this report for completeness, although some data (notably, short spacing distances and counts) excludes these stations.

Upgrades and Allotments

As noted above, a number of the facilities requesting processing under these rules, and a number of protected facilities and allotments are currently the subject of rule making requests. Several class A facilities have applied for 6 kilowatt operation under these rules, while having a pending upgrade to class C3 awaiting action in the FCC's Allocations Branch. Similarly, several applications filed under §73.215 protect current rule making proposals, including proposed new allotments and proposed facility deletions (frequency move or upgrade). Absent a §73.215 request to protect these proposed allocations, the facility changes would not be permitted or would be held in abeyance pending resolution of the rule making proceedings.

A review of the data reveals that 19 of the required protections are to pending applications for vacant allotments, while 9 protections involve short spacings to proposed or vacant allotments for which applications have not yet been accepted. This raises the distinct possibility that no fully spaced site will exist for these allotments when and if they are granted, and applications are accepted. Vacant allotments having no fully spaced site zones as a result of one, or more, §73.215 proposals will require all new applicants to file under §73.215. The data also reveals that 7 protected facilities are proposed for modification (either an upgrade, or frequency change) in rule making proceedings. Conversely, 10 applicants which have filed under Section 73.215 are involved in upgrade, or other, rule making proceedings. These numbers represent 4.6 percent and 7.6 percent of the total, respectively.

Table H-I

DISTRIBUTION OF SECTION 73.215 PROPOSALS
by Class of Proponent Station

Class	A	B	B1	C	C1	C2	C3	Total
Number	68	3	13	9	8	28	3	132
Percent	51.5	2.3	9.8	6.8	6.1	21.2	2.3	100.0

Table H-II

DISTRIBUTION OF SECTION 73.215 SHORT SPACINGS
by Protected Station Class

Class	A	B	B1	C	C1	C2	C3	Total
Number	52	36	7	22	19	11	6	153
Percent	34.0	23.5	4.6	14.4	12.4	7.2	3.9	100.0

Table H-III

NUMBER OF SHORT SPACINGS PER §73.215 PROPOSAL

Number of Proposals

Class	A[3]	B	B1	C	C1	C2	C3	Total
Short Spacings								
0	1	0	1	0	1	0	1	4
1	43	1	5	6	6	21	2	84
2	16	1	7	3	0	5	0	35
3	3	1	0	0	1	2	0	7
4	1	0	0	0	0	0	0	1

Percentage of Proposals

Class	A	B	B1	C	C1	C2	C3	Total
Short Spacings								
0	1.6	0	7.7	0	12.5	0	33.3	3.0
1	67.2	33.3	38.5	66.7	75.0	75.0	66.7	63.6
2	25.0	33.3	53.8	33.3	0	17.9	0	26.5
3	4.7	33.3	0	0	12.5	7.1	0	5.3
4	1.6	0	0	0	0	0	0	0.8

/3 Experimental operations omitted.

Table H-IV

CLASSIFICATION OF §73.215 PROPOSALS BY TYPE AND CLASS

Number of Proposals

Class	A	B	B1	C	C1	C2	C3	Total
6 kW Class A	37	0	0	0	0	0	0	37
New App.	18	1	7	0	0	9	0	35
Upgrade	0	0	3	3	5	15	2	28
Site Move	8	2	2	6	2	4	0	24
Experiment	4	0	0	0	0	0	0	4
Unknown[4]	1	0	1	0	1	0	1	4
Total	68	3	13	9	8	28	3	132

Percentage of Proposals

Class	A	B	B1	C	C1	C2	C3	Total
6 kW A	54.4	0	0	0	0	0	0	28.0
New App.	26.4	33.3	53.4	0	0	32.1	0	26.5
Upgrade	0	0	23.1	33.3	62.5	53.6	66.7	21.2
Site Move	11.8	66.7	15.4	66.7	25.0	14.3	0	18.2
Experiment	5.9	0	0	0	0	0	0	3.0
Unknown	1.5	0	7.7	0	12.5	0	33.3	3.0
Total	51.5	2.3	9.8	6.8	6.1	21.2	2.3	100.0

/4 Not identified as requiring Section 73.215 processing.

Table H-V

DEGREE OF SHORT SPACING
(Maximum Distance Per §73.215 Proposal)

Number of Proposals

Class	A[5]	B	B1	C	C1	C2	C3	Total
Distance (km)								
0-2.5	12	0	1	3	3	4	0	23
2.5-5.0	16	0	2	5	1	11	0	35
5.0-7.5	15	0	4	0	2	7	1	29
7.5-10.0	8	1	3	1	1	2	0	16
10.0-12.5	4	0	1	0	0	1	1	7
12.5-15.0	2	0	0	0	0	1	0	3
>15.0	6	2	1	0	0	1	0	10

Percentage of Proposals

Class	A	B	B1	C	C1	C2	C3	Total
Distance (km)								
0-2.5	19.0	0	8.3	33.3	42.8	14.8	0	18.6
2.5-5.0	25.3	0	16.6	55.5	14.2	40.7	0	28.5
5.0-7.5	23.8	0	33.3	0	25.0	25.9	50.0	23.6
7.5-10.0	12.7	33.3	25.0	11.1	14.3	7.4	0	13.0
10.0-12.5	6.3	0	8.3	0	0	3.7	50.0	5.7
12.5-15.0	3.2	0	0	0	0	3.7	0	2.4
>15.0	9.5	66.7	8.33	0	0	3.7	0	8.1

Greatest short spacing per proposal used, including any grandfathered short spacings.
Amounts may not total to previous tables, as some proposals have no short spacings.

/5 Experimental operations omitted.

Table H-VI

DISTRIBUTION OF DIRECTIONAL ANTENNA PROPOSALS
by Station Class

Class	A	B	B1	C	C1	C2	C3	Total
				Number				
DA	44	3	12	3	3	14	1	80
				Percent				
Of DA	55.0	3.8	15.0	3.8	3.8	21.2	1.25	100.0
Of Total	64.7	100	92.3	33.3	37.5	50.0	33.3	60.6

Table H-VII

DIRECTIONAL ANTENNA SUPPRESSION
(per §73.215 Proposal)

Number of Proposals

Class	A	B	B1	C	C1	C2	C3	Total
Suppression (dB)								
> 15	5[6]	0	0	0	0	0	0	5
12-15	5	2	1	0	1	1	0	10
9-12	5	0	1	1	0	1	0	8
6-9	11	0	7	2	1	0	0	21
3-6	14	0	1	0	1	5	1	22
0-3	4	1	2	0	0	7	0	14

Percent

Class	A	B	B1	C	C1	C2	C3	Total
Suppression (dB)								
> 15	11.4	0	0	0	0	0	0	6.25
12-15	11.4	66.7	8.3	0	33.3	7.1	0	12.5
9-12	11.4	0	8.3	33.3	0	7.1	0	10.0
6-9	25.0	0	58.3	66.7	33.3	0	0	26.3
3-6	31.8	0	8.3	0	33.3	35.7	100.	27.5
0-3	9.1	33.3	16.7	0	0	50.0	0	17.5

/6 Includes 4 experimental proposals at 30 dB, each.

ALTERNATIVE OVERLAP ANALYSIS for §73.215 Stations

prepared for
National Association of Broadcasters
Washington, D.C.

The change in propagation prediction method postulated for general use in in this report[1] were applied to pending applications and granted authorizations filed with the Federal Communications Commission under the provisions of §73.215 of that agency's Rules. Appendix H identifies the 132 proposals in the April 30, 1990 FCC Engineering Data Base for which an indication was present that the applicant had requested Section 73.215 processing. Our analysis involved a computation of the number and maximum amount of short spacing which would occur if the proposed methods were adopted and a comparison of these data against similar data for current FCC standards. A further computation was made of the amount of area affected by prohibited contour overlap using postulated and current FCC methods.

A detailed engineering review of each proposal, as would be conducted by the applicant or the FCC, was not made. The limitations of database-only studies described in Appendix H applies equally to this study. All contour overlap calculations were made using only the station parameters listed in the FCC's FM Engineering Database. Calculations for vacant and proposed allotments were made using the class maximum facilities at the specified reference point. Where a directional antenna was specified *and the directional antenna parameters were contained in the database,* the effective radiated power incorporated the directional antenna radiation values. Use of the licensed facilities was believed to give a better representation of the actual impact of the 73.215 proposals on existing stations. Except where obvious, no attempt was made to identify overlap areas falling over water, foreign countries or otherwise uninhabitable area.

Of the proposals requesting processing under §73.215, the majority had no prohibited contour overlap when the present FCC contour overlap analysis method was employed. When the method postulated in this project was employed, however, over 56 percent of the proposals showed at least some contour overlap. In many of the situations where contour overlap was determined to exist (regardless of the propagation method employed), later FCC engineering data shows the applications as returned, dismissed or amended. Likewise, several situations involve grandfathered short spacings, and the computed overlap cannot be attributed to the §73.215 proposal.

In general, the proposed methods showed *increased* numbers and degree of short spacings. The proposed methods increased the calculated contour overlap area where the interfering contour extended beyond the radio horizon. Within the radio horizon, the calculated overlap area appears to be reduced somewhat for the method postulated.

Method of Analysis

The FCC FM Engineering Data Base contains entries for each licensed station, construction permit, application, and allotment. Each entry (or record) contains the channel, station class, location and site coordinates. Antenna height data and power are included for all authorized facilities and pending applications, but not for allotments. Although an indication is present as to whether the application requested processing under §73.215, no

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/1 Use of the Rice 1990 propagation formulas in conjunction with a receiving antenna elevation of 2 meters and service contours defined 7 dB below the present values, with interfering values reduced accordingly such flag is included to indicate whether the facility is grandfathered under §73.213 (including pre-1964 and 3 kilowatt class A facilities), or whether the facility is a "superpower" station. The FCC data also includes an indication of whether a directional antenna has been specified by the applicant. For recent applications (since August, 1989) the database also contains the directional antenna pattern. Some, but not all, patterns filed prior to that date have been entered into the database.

To allow automated processing of this data, it was concluded that the actual station facilities included in the database should be used. In the event that no power and height parameters were shown in the FCC data, the program assumed power and height values equivalent to maximum facilities for the indicated station class. If a directional antenna pattern was present in the data base, it was employed in conducting the analysis.

The use of actual facilities presents a more realistic picture of the impact of each §73.215 facility on existing stations, but does not necessarily provide an indication that the application complies with the FCC's rule, which calls for use of class maximum facilities, even in those situations where overheight or overpower facilities may be authorized. A comprehensive determination of FCC rule compliance was not made. Instead, this Appendix presents a comparison of prediction methods on station contour protection.

Calculation Procedure

The same routine described in Appendix H was employed to determine the number and degree of short spacings which will occur if the prospective spacing tables are employed. The prospective spacings were those shown detailed in Table B-VIII of Appendix B.

A comparison was also made of the amount of interference which might occur for each §73.215 proposal. An existing proprietary computer routine was slightly modified to allow calculation of amount of area contained between overlapping contours. The figure obtained, an "overlap factor", is relatively accurate for small areas of contour overlap, but loses accuracy for larger areas, and those cases where the one contour encompasses another. The results do in all cases provide a good relative indication of the extent to which contour overlap occurs for two different propagation prediction methods. A more accurate routine could be designed, but such a routine would require significantly increased processing time.

The overlap computation routine first obtains the station data for each facility or application filed under §73.215. The distance spacings to other pertinent facilities (for simplicity, these will be called "existing facilities", even if they are proposed or authorized under §73.215) were computed as if a traditional spacing study were being performed. If the §73.215 facility was found to be short spaced to an existing facility, the overlap routine then computed the protected and interfering contour distances for each station along the direct bearing between sites. No distinction was made for "grandfathered" facilities as it is not possible to readily distinguish grandfathered short spacings. A computation was also made of the start bearing, end bearing, and bearing increment which will be used to compute the contour distances from the §73.215 facility under study. These bearings were determined mathematically as a function of the greatest single radial height above average terrain for the existing station, the existing station power, and the distance between the two stations. The program then sequentially computes the distances to the pertinent contour from the new facility site along the incremental bearing from new station to the protected station.[2] The geographic coordinates of the contour location along the radial were computed, and the distance and bearing to this point from the existing station was then computed.

/2 This differs from the FCC's computer study method which analyzes the proposed station operation along fixed 1 degree bearing increments.

The contour distance for the existing station is determined along this computed bearing. If the existing station contour distance exceeds the distance to the new station contour, overlap exists, and an incremental area calculation is made assuming that both the existing station contour and the proposed station contour are arc segments over the incremental distance span. These incremental areas were summed for each bearing within the specified bearing span to determine the "overlap factor" for the particular facility pair. A similar computation was made for each short spaced situation.

Two propagation methods were used for these computations: the propagation curves of §73.333 of the Commission's rules and the Rice 1990 propagation model, the latter assuming a 2 meter receive antenna height and protected/interfering contour values 7 dB below those defined under §73.215. Contour distances between facility pairs showing short spacings under the FCC's current spacing tables were computed using the existing FCC propagation prediction method. The Rice 1990 formulas are fully described in Appendix E. All facilities to which a given 73.215 proposal did not meet the prospective spacings, Table B-VIII of Appendix B, were calculated using the Rice model.

For all contour calculations, the antenna height above the average terrain elevations along each radial was determined using 30 second N.G.D.C. digitized terrain data from database TPG-0050. The traditional 3 to 16 kilometer terrain segment was used, with elevations determined at 0.16 kilometer increments.

The overlap data were reviewed and analyzed to allow comparison of results for the two methods. Data for non-existent allotments were eliminated, and in those cases where overlap was shown to multiple facilities for one station (i.e. the existing facility has a licensed facility and a construction permit facility), the "newest" facility was used. A cumulative overlap factor was obtained for each 73.215 proposal under each propagation method by summing the individual overlap factors for each facility pair.

Four facilities filed under §73.215 were selected for a graphical comparison of the comparative impact of the two propagation methods. A contour overlap study map was prepared to show the protected and interfering contours of each short-spaced station. The contours were determined along 10 degree radial increments, using the actual facilities for each station, including directional antenna, where appropriate.

Study Limitations

Although the methods used for this study are believed to be sufficient to perform a comparative analysis, certain limitations exist regarding use of the data. Therefore, only broad, general conclusions should be drawn from the data presented herein. No conclusions should be drawn with respect to the acceptability of any specific proposals studied.

One significant factor limiting the conclusions which may be drawn from these results is the information contained within the FCC database itself. This study was conducted using the April, 1990 FCC/FM engineering Data Base in order to properly compare results to the previous study of §73.215 processing requests. In conducting the review of study results, later FCC data were used to determine the current status of various applications. In 12 of the 29 situations where overlap would occur using the FCC propagation method, later data shows the applications as dismissed, returned or amended. Two situations were readily identified as involving pre-1964 grandfathered short spacings in addition to the new §73.215 short spacing, and several other situations appear to include overlap resulting from other conditions. It was also noted that the directional antenna data were missing for some existing stations, and found to be incorrect for at least one proposal requesting processing under §73.215.

A further limitation on conclusions which may be drawn from this data results from the use of actual station facilities. Actual station facilities were used to depict the interference which would occur if all proposals were granted as specified, without consideration of future actions by existing stations. The FCC's rules specify use of maximum facilities for the class of station involved, regardless of whether the facility were overheight or overpower. In several situations, the existing station was grandfathered as a "superpower" facility, and contour overlap was computed to occur with respect to the §73.215 proposal.

The contour overlap processing routine employed was a compromise, and was chosen for execution speed. The routine cannot detect whether a facility contour is crossed twice, as may occur for large overlap areas. Likewise, no automated determination of overlap areas which fall over water or foreign countries was not considered feasible for this project. However, a good relative indication of overlap area is obtained.

The other major limitation in these results is that a determination of *contour overlap* was made, rather than actual interference area. Two reasons drove the choice to use overlap area as a guideline, rather than interference area. First, the FCC uses contour overlap as its guideline for authorization purposes. Second, as with the processing routine, contour overlap was used to minimize programming effort, and maximize program speed. In those cases where the overlap area was very small (a few square miles, or less), little or no actual interference area will exist, and the impact of the proposal is negligible. In cases where the contour overlap is large, significant interference can be expected to occur.

Study Results

Table I-I presents a summary of the separation study results, along with the corresponding results obtained in the earlier study reported in Appendix H. These results show that both the number of short spacings and the degree of short spacing increases when the newly derived distance separation tables are employed. In only four situations did the number of short spacings decrease when the new tables were employed. Three situation showed a decrease in the amount of short spacing between the proposed facility and the most severely short spaced existing facility.

Table I-II presents summary results of the overlap study. A substantial increase in predicted overlap occurs in the majority of cases when the Rice model is employed along with modified protected contour levels. Further investigation reveals that the overlap increases dramatically for those cases where the interfering contour falls over the radio horizon, which is expected in co-channel situations.

Figures I-1 through I-4 present allocation studies for four specific §73.215 proposals. The chosen proposals are: the South Ocean application for Channel 289B1, Manahawkin, New Jersey; an application for WFMR, Menominee Falls, Wisconsin; an application for KXFX, Santa Rosa, California, and the application by Port Saint Lucie Broadcasting Corporation for Channel 267A, Port Saint Lucie, Florida.

<u>Manahawkin, New Jersey</u>

The South Ocean proposal for Manahawkin, New Jersey is short spaced to 2 facilities (WNWK, Newark, NJ, and WQSR, Catonsville, MD) under the current FCC rules. Under the prospective standards there would 4 short spacings, involving those two stations as well as WBNJ, Cape May Courthouse, NJ, and WQXA, York, PA. WQSR and WQXA employ directional antennas; however, only the WQSR antenna was entered in the FCC database. The South Ocean proposal requests authorization of a directional antenna. The September, 1990 FCC database shows a different antenna pattern for South Ocean then does the April, 1990 database.

Use of the Rice propagation method, along with 2 meter receive antenna height and modified contour levels, will result in reduced predicted contour overlap between the proposal and WNWK. Additional clearance will be obtained to WBNJ. With respect to WQSR, however, additional contour overlap will occur. Figures 1A and 1B show the results.

WFMR, Menominee Falls, Wisconsin

WFMR has proposed to improve its class A facilities to 6 kilowatts. Under the current FCC rules, WFMR is short spaced only to WMGN, Madison, Wisconsin. Under the newly derived spacing table, WMGN will remain as the only short spaced station. The overlap factor for WFMR is 888 for the current FCC propagation methods, and 132 for the Rice method and revised contour levels. Figures 2A and 2B show the results. In this case, less overlap occurs when the proposed methods are employed. This is likely the result of the overlap area falling within the radio horizon for both stations.

KXFX, Santa Rosa, California

KXFX is a class B1 facility seeking to relocate. The proposed facility is short spaced to KKIQ, Livermore, California under the current FCC spacing tables. Under the prospective tables, the facility will also be short spaced to KDFC, San Francisco. The proposed facility will have contour overlap within its protected contour from KKIQ's interfering contour for both the FCC and Rice methods. The KXFX interfering contour will overlap KDFC's protected contour for the Rice method (the FCC method for KDFC was not studied since the distance separation requirements were met).

Port St. Lucie, Florida

The Port St. Lucie proposal which was studied is slightly short spaced to WAVW, Vero Beach, FL under the FCC spacing table. Under the prospective spacing table, the facility would also be short spaced to WSTF, Cocoa Beach, Florida. There is no contour overlap when the protected and interfering contours are computed using the current FCC method, however, substantial contour overlap will occur if the Rice method is used with the revised receive antenna height and contour levels. Figures 4A and 4B depict the contours for the pertinent stations.

Table I-III is a listing of the short spacing comparison data and overlap factors for each of the 132 stations which were studied. The table shows the number and maximum amount of short spacing for each facility, along with the overlap factors derived as described herein.

Conclusion

The results of this study reveal that a change to the contour calculation methods and distance separation tables derived as part of this project will result in a substantial change in both the number and amount of short spacings which will occur for facilities authorized under the provisions of §73.215 of the FCC's rules. There will also be an increase in the amount of contour overlap (and interference) predicted to occur if these facilities are authorized.

Although a study of the contour overlap which currently exists between stations meeting the current separation table was not conducted, it is believed that such a study will show that many stations currently receive interference within their protected contours as a result of the inadequate protection offered by that table.

Table I-I

COMPARISON OF SHORT SPACINGS

Short Spacing Distance (km)	**Number of Short Spacings** (FCC Table)	**Number of Short Spacings** (Prospective Table)
0.0 - 2.5	23	1
2.5 - 5.0	35	4
5.0 - 7.5	29	8
7.5 - 10	16	10
10.0 - 12.5	7	15
12.5 - 15.0	3	22
More than 15	10	65

Number of Short Spacings per 73.215 Proposal	**FCC Table**	**Prospective Table**
0	4	3
1	84	16
2	32	51
3 or more	12	62

Table I-II

COMPARISON OF CONTOUR OVERLAP

Contour Overlap Factor	**Number of 73.215 Facilities (FCC Method)**	**Number of 73.215 Facilities (Prospective Method)**
(No Overlap)	103	75
0 - 10	9	16
10 - 50	5	11
50 - 100	4	5
100 - 500	6	27
500 - 1000	2	7
More than 1000	3	9

Appendix J

FCC RULES POTENTIALLY AFFECTED BY RECOMMENDATIONS

prepared for
National Association of Broadcasters
Washington, D.C.

A number of provisions of the FCC's rules and regulations will need revision in order to implement the improvements recommended by the 1990 FM Technical Study. This Appendix notes each such rule, provides a description of it, and explains what sort of change might be necessary. Specific language is not provided, because the recommendations suggest further study be made.

§1.420 Additional Procedures in Proceedings for Amendment of the FM, TV, or Air-Ground Table of Allotments: This rule sets forth the procedures to be followed in considering FM allotment petitions.

If filing and cut-off dates are coordinated between allotment and application proceedings or allotment petition and application filing are simultaneous, changes in this section of the rules will be necessary.

§73.207 Minimum Distance Separations Between Stations: The interstation separation distances required for allotments and assignments are explained and tabulated in this section.

Revised separation distance requirements based on the assumption of a lower receiving antenna height assumption are recommended. This will necessitate revision of Table A. In addition, use of contour protection as the sole interference regulation tool for applications has been recommended. If that is done, references to applications contained in this section should be deleted so that it pertains only to allotment proposals.

§73.208 Reference Points and Distance Computations: This section specifies the locations to be used when determining compliance of an allotment proposal or application with the minimum interstation separation distance requirements of §73.207.

The provisions of subsection (a)(2) need to be strengthened to define more precisely what the phrases "a transmitter site is available" and "suitable transmitter sites for all communities" mean. It is recommended that this subsection be revised to require that allotment proponents demonstrate existence of a minimum area wherein transmitter sites might be located or, alternatively, the true availability and feasibility of a particular location.

If contour protection is adopted as the universal interference regulation tool for applications, subsection (b) of this rule can be deleted.

§73.209 Protection From Interference: This section disclaims protection of interference to stations other than what results from the interstation separation distance requirements of §73.207.

If contour protection is adopted as the sole interference regulation tool for applications, the present provisions of this rule should be deleted and the provisions of §73.215, appropriately modified, should be relocated to this section.

§73.211 Power and Antenna Height Requirements: This section establishes the maximum effective radiated power (ERP) premitted for each FM station class.

If contour protection is adopted for interference evaluation at the application stage, the ERP limitation of subsection (b)(1) can be changed from "maximum ERP in any direction" to simply "ERP", with the definition of ERP for directional antennas handled elsewhere.

§73.213 Grandfathered Short-Spaced Stations: This section concerns stations that became short-spaced as a result of changes in the rules, not voluntary actions on their part.

This section may be deleted in its entirety if contour protection is adopted as the inteference evaluation standard for applications.

§73.215 Contour Protection for Short-Spaced Assignments: The technical standards under which short-spaced applications can be considered are set forth in this section.

If any change is made to protected contour values (as has been recommended in conjunction with a change in the receiving antenna height assumption), subsection (a)(1) will need revision. Any changes in the D/U ratios determined to be warranted through a contemporary study of receiver performance will necessitate revision of subsection (a)(2). The cross-references to contour location procedures of §73.313 will need to be changed if improved propagation models are adopted and that section is extensively revised.

It is recommended that the provisions of subsections (b)(2)(ii) and (iii) be revised. On an interim basis, where HAAT exceeds the nominal maximum for the station class, the ERP to be used shall be determined in accordance with §73.211(b)(1) and (2). Ultimately, presumption of the use of class maximum facilities for authorized facilities should be subject to a reasonable "sunset" date. Thereafter, authorized ERP and HAAT values, including directional antenna characteristics, if used, should be employed in predicting contour locations. ERP should be limited to the equivalent of the class maximum at the stations' HAATs, where so-called "grandfathered super-power" operation is involved.

Appropriate editorial changes are necessary throughout this section if contour protection is to be adopted for all application proceedings and this section is relocated to §73.209.

§73.310 FM Technical Definitions:

Antenna Height Above Average Terrain (HAAT): Any change in the manner of determining HAAT will necessitate changes to this section. Flexibility would be assured by replacing the specific language defining average heights with a cross-reference to the method specified in §73.313.

Effective Radiated Power: If use of the separation table for interference analysis of applications is suspended, it is recommended that this section be revised to note that the ERP for stations using directional antennas is that computed from the azimuthal RMS power gain of the antenna, not the peak power gain.

<u>Effective Antenna Height</u>: A definition for this parameter should be added to this section.

§73.311 Field Strength Contours: This section sets forth restrictions on the use of field strength contours.

Revision is necessary if universal application of contour protection principles at the application stage is adopted as the interference evaluation standard.

§73.312 Topographic Data: This section informs the public of the topographic data to be used in conjunction with HAAT determination, service predictions, and interference projections.

If a propagation prediction method based on terrain sampling within areas is used, the requirement of subsection (d) that data be processed along radial lines and by linear interpolation may require deletion or revision.

§73.313 Prediction of Coverage: This section describes the FCC's propagation model and the procedures to be employed in its use.

Extensive revision is necessary if any significant change is made to the propagation prediction technique.

§73.316 FM Antenna Systems: This section primarily defines directional antennas, sets forth filing requirements for applications proposing their use, and establishes limitations on pattern characteristics.

It is recommended that a new subsection concerning nondirectional antennas be added which directly addresses the issue of antenna pattern modification by side-mounting.

§73.333 FM Engineering Charts:

Changes to propagation prediction methods may necessitate revision of Figures 1 and 1a of this section. It is recommended that such methods be primarily defined by formula, but the inclusion of charts in the rules may be useful for illustrative purposes.

NRSC Document Improvement Proposal

If in the review or use of this document a potential change appears needed for safety, health or technical reasons, please fill in the appropriate information below and email, mail or fax to:

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