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AM Technical Improvement: A report prepared by the AM Improvement Subcommittee of the Engineering Advisory Committee

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NAB
NATIONAL ASSOCIATION OF BROADCASTERS

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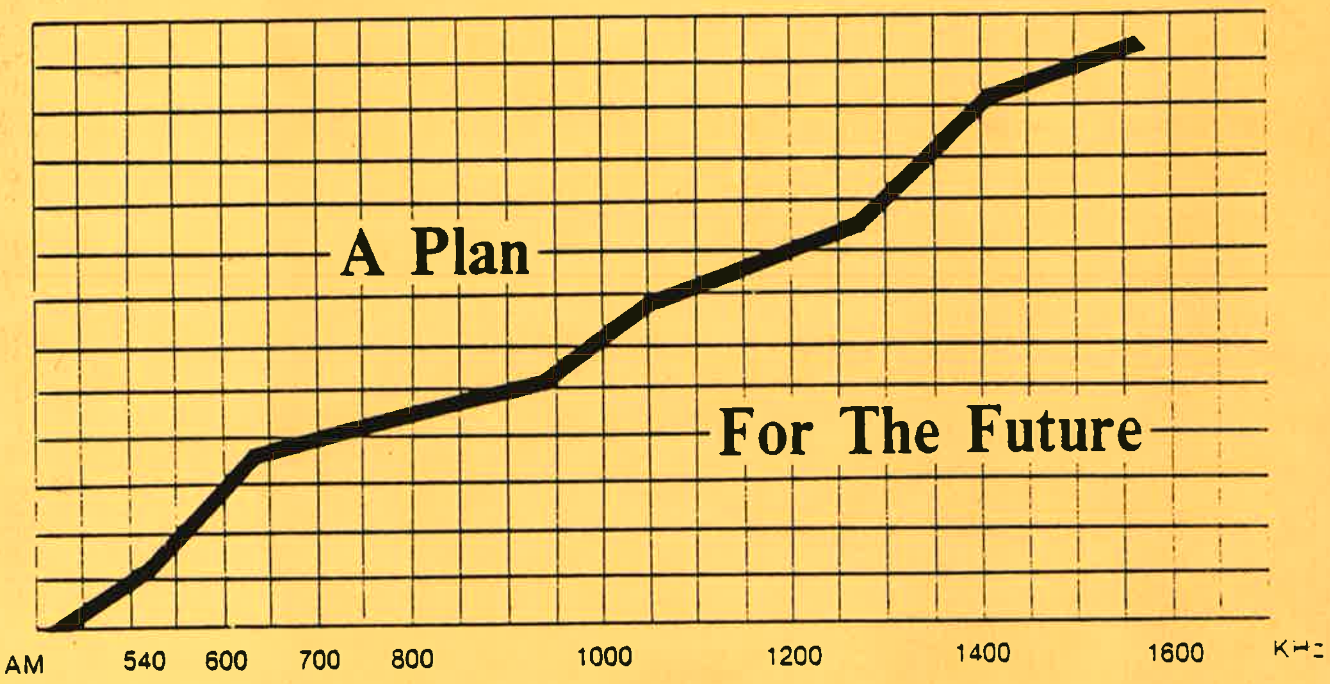
AM TECHNICAL IMPROVEMENT:

A report prepared by the AM Improvement Subcommittee of the Engineering Advisory Committee.



A Plan For The Future

National Association of Broadcaste

AM TECHNICAL IMPROVEMENT

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AM Improvement Report[1]

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[1] Note to Reader: This report has been organized with the needs of several different audiences in mind. As such, the report is repetitious if read from cover to cover. A reader only interested in a one-page summary should read page 3. A reader interested in a little more information should read Sections I and II only. In depth treatment of each subject is found in Sections III and IV.

I. Purpose

This report summarizes eight meetings of NAB's AM Improvement Subcommittee. The Subcommittee was formed under the aegis of the NAB Engineering Advisory Committee with a mandate to study ways that new technology, industry efforts, and/or FCC regulation (or deregulation) can improve the technical quality of AM transmission and reception. The Subcommittee's formation was prompted by the need to meet the technical challenges facing today's AM broadcasters and the accompanying opportunity to increase the listenership of AM radio. Because we view the study of AM improvement as a proper responsibility to be undertaken by NAB, the time is ripe to carefully analyze the current technical challenges of AM broadcasting and offer our best ideas for AM Improvement.

AM stereo is specifically not considered in this report. Although AM Stereo is without doubt an AM improvement, the controversial nature of AM stereo within the industry precludes arriving at a useful consensus of views.

This report summarizes the Subcommittee's suggestions for improvement of the AM broadcast service.

II. Introduction and Executive Summary.

The Subcommittee was chartered to explore the technical state of AM broadcasting today with a view toward improvements. We have examined some of the most vexing challenges of AM transmission and reception during our meetings and conversations with industry experts. Many of these issues are enormously complex and in some cases highly technical; often generating controversy among even the most experienced and objective engineers.

In response to the current state of AM transmission and reception, the Subcommittee urges our industry to (1) commence an industry-wide AM Promotion campaign; (2) establish a "Technical Reference Center" at NAB to collect and disseminate available AM technical information; (3) limit the boost of transmitting audio frequencies above 12 kHz; (4) improve AM broadcast antenna performance through broadbanding; (5) undertake research of supplementary antenna designs that offer the potential to significantly attenuate skywave in chosen, specified directions; (6) undertake research of Transmitter Transient Distortion ("TTD") which can cause interference with no apparent compensating benefit; (7) encourage, and consider underwriting, the development of a high-quality, useful and inexpensive Integrated Circuit ("chip") for use in AM radios; and (8) work to mitigate existing and potential interference from radio-frequency electrical equipment especially radio-frequency lighting devices.

These ideas and suggestions are treated in more detail in Section IV of this report.

A. Background.

Commercial AM broadcasting is generally considered to have begun on November 2, 1920, when KDKA in Pittsburgh began broadcasting election returns to only a few listeners with crystal sets. Radio was a big hit; the idea that one could "hear" over a great distance was irresistable. People rushed to buy the first RCA radio receiver. By 1927, the number of AM stations increased to 733 and over six million radio receivers had been manufactured.[2]

In the absence of federal regulation, chaos on the spectrum prevailed. Stations switched frequency and power at will. To preserve order and control interference, and to provide for the orderly establishment of new stations, the Federal Radio Commission was formed in 1927, the predecessor to the Federal Communications Commission, formed pursuant to the Communications Act of 1934.[3]

Today, there are over 4,750 operating AM stations. Roughly half of these stations operate daytime-only and nearly half of all AM stations operate with directional antennas. AM Broadcasting may be headed for further growth: in 1986, the U.S. will participate in a Regional Administrative Radio Conference ("RARC")

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[2] "The Evolution of Radio," **Radio Programs Sourcebook**, 1st ed., 1982 pp. VIII-XXII. "First broadcast" claims are also made by WWJ, Detroit, on August 20, 1920; and WBZ, Springfield, MA, the first station be be issued a regular broadcasting license by the U.S. Department of Commerce (September 15, 1921). Hilliard, Robert L., Ed., Radio Broadcasting, An Introduction to the Sound Medium. New York: Hastings House, 1974 at 16.

[3] Bittner, John R., Broadcast Law and Regulation. New Jersey: Prentice-Hall Inc., 1982, at pp.7-11.

looking toward development of a plan for broadcast use of the 1605-1705 kHz spectrum -- a potential increase of 10 channels for new AM broadcast stations.[4]

B. AM Challenges.

The major challenge confronting AM broadcasting is to maintain and increase its share of the national radio listening audience.[5] We do not believe that the improvements necessary to meet this challenge are entirely technical.[6] Because FM is now considered to be the "benchmark" of broadcast quality, it seems that a worthwhile goal for NAB and the AM industry is to strive for technical comparability with FM. Here is a summary of each technical area for improvement the Subcommittee has identified:

1. Because of the presence of skywave at night the AM broadcast frequency band is susceptible to interference from other stations. In addition, the nature of electromagnetic noise is AM; this is the principal reason that electrical devices, such as hairdryers, fluorescent lamps, and automobile ignition systems

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[4] Federal Communications Commission First Notice of Inquiry in General Docket No. 84-467, released May 16, 1984 (FCC 84-195) at para. 1.

[5] According to a Statistical Research, Inc. ("SRI") study, FM's spring 1984 share stands at 68%, up from 65% one year ago, and 66% in the fall, 1983. Broadcasting Magazine, June 18, 1984 at 66. Television/Radio Age, June 25, 1984, at 20. FM's share was 61% in the spring, 1982. Inside Radio, May 31, 1982 at 3. The younger the person, the more likely they are to use FM. Broadcasting Magazine, Id. By comparison, for persons 18-34, FM's share was **34%** in 1973 and **58%** in 1978. Broadcasting Magazine, January 22, 1979, at 33.

[6] Still, it is common to characterize FM as "hi-fi" and "interference-free". See, e.g., Media Decisions, April 1976 at 56.

tend to interfere with AM reception.[7] Compounding the inherent interference susceptability of AM reception is the nature of FCC interference-prevention standards, especially at night. Several classes of nighttime service are not protected from adjacent channel skywave interference.[8]

2. Traditionally, the AM broadcast industry has seen the AM receivers now in widespread use as one of AM's principal obstacles for improvement. Receiver manufacturers generally dispute this view for many reasons. For one thing, there are significant economic factors that must be considered when a given AM radio design is proposed, tested, or manufactured.[9] For another, receiver manufacturers view the AM broadcast reception environment as generally hostile to wideband receivers; not only because of interference from distant signals that is more prevalent at night, but also partly because of the "boosting" of high frequencies done by AM stations in an effort to improve their reception on response-limited receivers. These problems are, to

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[7] Interference from electrical devices may become an even greater problem for AM broadcasting in the future. See Notice of Inquiry in Gen. Docket No. 83-806 (In the Matter of FCC regulations concerning RF Lighting Devices), released August 5, 1983. "In controlled laboratory tests, AM radios received objectionable interference...from the RF light bulbs tested." Id. at para. 14.

[8] See 47 C.F.R. 73.182(v) and 73.182(w) of the Commission's Rules. Specification of adjacent channel nighttime skywave protection requirements is absent.

[9] E.g., Delco Electronics, an automobile radio receiver manufacturer, typically produces 22,000 radios per day. (Subcommittee interview with Chris Payne, Motorola, Inc., February 22, 1984.) Ford Motor Co. produces approximately 6800 radios per day (interview with Bill Goldes, Ford Motor Co., (313-594-2600).

a degree, interdependent: broadcasters boost high frequencies to compensate for narrowband receivers; the boost degrades the reception environment of adjacent channels and helps to promulgate additional reluctance to build cost-effective wideband receivers.

3. When communities begin to grow or change, they often "spread" beyond the intended interference-free service area of a local AM station's facilities. As the community spreads, a higher population concentration can occur in weak local signal areas, degrading AM service even though there has been no change in the radio station's technical facilities.

4. The Subcommittee sees a need for a "Technical Reference Center" to collect and distribute AM technical information. Currently, technical sources are scattered; it can be difficult for an engineer (especially an engineer new to our industry) to find pertinent and up-to-date reliable information when it is needed.

5. Correspondence to the Subcommittee noted that under certain modulation conditions, AM transmitter instability can occur thereby producing spurious emissions and/or distortion. Apparently, this distortion is not present under "static" or "proof" conditions, but only under the "dynamic" conditions of actual modulation. The implication, however, is that "cures" for the distortion might be found relatively easily if the necessary research were performed. Such research would benefit the AM industry. The presence of this distortion, denoted "Transmitter Transient Distortion" ("TTD") contributes interference with

apparently no compensating benefit.

Each of these challenges to AM improvement is treated in depth in Section III of this report.

C. AM Suggestions.

The Subcommittee offers a number of suggestions designed to help the technical state of AM broadcasting and reception. These recommendations are summarized below and treated in depth in further sections of this report.

1. <u>Begin an Industry-wide AM Promotion Campaign</u>. After careful consideration, we believe that one of the best ways to improve the transmission and reception of AM is by skillful use of promotion. Specifically, a promotion campaign focusing on the quality aspects and potential quality of AM radio receivers would be beneficial for the AM industry.

2. <u>Establish a Central Source for AM Technical Information</u>.

AM transmission can be improved through the spreading of technical knowledge and industry experience regarding AM station design and maintenance. Toward this end, the Subcommittee urges the establishment of a "Technical Reference Center" ("TRC") for the purpose of consolidating available AM technical information into a simple, centralized source.

3. Urge AM Broadcasters to Limit Boost of Frequencies Above 12 kHz. The Subcommittee recommends a roll-off of transmitted high frequencies above 12 kHz. Audio frequencies above 12 kHz contribute to interference at distant locations. Many engineers, however, believe it is not necessary to excessively boost these frequencies to realize good quality AM reception. A ceiling on transmitted frequencies above 12 kHz could produce significant interference-reducing benefits to the listenability of AM stations.

4. Improve AM Transmitting Antenna Fidelity. The antenna system of a radio station acts not only as the radiator of the signal but also as a "final filter" on the transmitter output. Too narrow a bandpass in the antenna system, as is prevalent in older designs, will not only reduce harmonics of the carrier but will also reduce transmitted high-frequency response, resulting in muddy, lifeless sound. We urge improvement of AM transmitting antennas. Many AM broadcasters can measurably improve transmission quality of their broadcast signal by incorporating antenna improvements.

5. Research New Antenna Designs. It has come to the Subcommittee's attention that there are theoretical antenna designs which, if constructed together with the existing station's antenna system, could significantly attenuate interfering skywave in chosen, specified directions. If viable, there would be less need for directional antennas to have deep "nulls" in their patterns for the purpose of protecting distant stations.

6. Research Transmitter Transient Distortion ("TTD"). TTD Research is an area brought to our attention through Subcommittee correspondence and should begin with help from AM transmitter manufacturers. The Subcommittee recognizes that the largest benefits for AM broadcasters would occur if, as a result of our research, knowledge of TTD could be brought to bear on existing tranmitters, possibly resulting in modifications that would both improve AM transmission and reduce spurious interference.

7. Work Closely with Receiver and Integrated Circuit Manufacturers. Knowledge about AM transmission and reception should be continuously exchanged between the Broadcast and Receiver industries. The Subcommittee urges a reactivation of the National Radio Systems Committee ("NRSC") for this purpose. The participation of Integrated Circuit Manufacturers, who produce the "heart" of modern radios, will be especially invited. A copy of this report will be sent to all.

8. Work to Mitigate Existing and Potential Interference From Electrical Devices. Electrical equipment manufacturers are on the verge of beginning a marketing and production effort to sell high-efficiency "RF Lighting Devices" (e.g. light bulbs that use RF to produce light) if FCC approval is secured. Currently, the FCC is conducting a proceeding (General Docket No. 83-806) to determine whether interference-control standards for RF light bulbs should be voluntary or mandatory. The AM industry must work to insure that any developed standards do not further degrade the listenability of AM transmissions; in the absence of

such work, there is the likelihood of RF light bulbs would become popular and cause interference wherever they are operated.

III. Discussion of AM Improvement Subject Areas.

Many of the impediments to AM improvement are interdependent to a great extent. The most serious issue facing AM broadcasters today, and certainly one which is capable of being at least partially solved, is the reception of received sound which makes competition with FM on a technical basis extremely difficult. This arises in part from the need for AM receivers to exclude reception of cochannel and adjacent channel interference, and therefore is related to the problem of achieving proper coverage within the predicted service area.

For years now, broadcasters and receiver manufacturers have been blaming each other for the deterioration in the sound quality of AM. Broadcasters have claimed that extreme preemphasis was necessary in order to partly overcome the narrow bandwidths of common AM radios. Radio receiver manufacturers have claimed that broadcasters transmitted such excessively broadband and splattering signals that relatively narrow radio bandwidths are needed in order to keep down adjacent channel interference. In considering these matters, the Subcommittee has come to believe that the most accurate answer to these claims and counterclaims is that both are correct, and both transmission and reception systems must be considered to solve this problem. Here is the Subcommittee's assessment of the technical challenges facing AM broadcasting:

A. AM Interference

Interference-causing splatter can be caused by excessive audio bandwidth and by highly compressed audio entering the nonlinear components of a broadcast transmitting and antenna system, which causes transmitter overmodulation in a way that may not appear on the station modulation monitor but which could still "win" an FCC citation for overmodulation or spurious emissions.

These possiblities are important because of the relative ease with which spurious emissions as a result of overmodulation can cause interference, especially at night. AM broadcasting is more susceptible to interference than the FM or the television bands. In AM, the industry has to contend with the presence of skywave signals at night, resulting in the requirement that AM stations operating full-time protect other stations on the same channel, often located a great distance away. Further, the characteristics of our AM allocations system allow for continual "shoe-horning" of AM full-time stations if certain threshold requirements of a policy nature are first met.[10] Since there is an absence of adjacent channel skywave protection requirements for nighttime AM operation, it is inevitable that each additional AM station incrementally increases interference to reception on

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[10] *See* Section 73.37(e) of the Commission's Rules.

adjacent channels. Further congestion of the AM spectrum, therefore, generally leads to increased interference even though all stations are complying with FCC protection requirements.

B. AM Receivers

The AM Broadcast industry has traditionally viewed the improvement of AM receivers now in widespread use as one of AM's principle challenges. The industry characterizes these radios as "inferior" chiefly because, if presented with a clear, hi-fidelity AM signal, many AM radios exhibit poor fidelity. One "typical automobile receiver" had an audio response 3 dB down at 1.7 kHz and 7 dB down at 3 kHz.[11] In a survey conducted in 1976, the National AM Stereo Radio Committee ("NAMSRC") found that the mean 6 dB Intermediate Frequency ("IF") bandwidth of (1) "hi-fi" AM radios was 7.2 kHz (low of 5 kHz and a high of 10.5 kHz); (2) automotive radios was 7.3 kHz (low of 6 kHz and a high of 8.7 kHz); (3) console, compact, and modular radios was 8.5 kHz (low of 5.5 kHz and a high of 11 kHz); and (4) pocket portables was 6.8 kHz (low of 4 kHz and a high of 11 kHz).[12] It should be recognized that the audio frequency response is at most one-half the IF bandwidth, and is usually less due to post-detection audio

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[11] Payne, C. AM Preemphasis and Transmission Bandwidth, NAB, 1979.

[12] Rau, Michael C. A Review of Past Efforts and Research, NAB, January 10, 1984.

filtering.[13]

These data reveal the difficulty that most AM radios have in receiving a hi-fidelity AM signal.

Receiver manufacturers see the characteristics of AM receivers as symptoms of the many trade-offs and compromises that need to be made when AM receivers are designed and manufactured. These compromises are economic (cost of added circuits and their manufacture) as well as technical (intrinsic to AM reception is a trade-off between bandwidth and selectivity). Still, it is generally true that better quality radios can be built; it is, however, an evolutionary process.[14]

Virtually all AM radios made and sold today still use the envelope detector. There are other forms of detectors that could enhance the radio's capability to reduce adjacent channel interference problems.

A newer generation of AM radios uses ceramic filters in the IF with narrow bandwidths and very steep skirts. These filters have become common due to their stability and low cost. Unfortunately, a filter with a sharp cutoff in the middle of the audio frequency range "rings" in the presence of program material, and sounds poor compared with a more gentle rolloff. While some manufacturers have introduced radios with 6 dB audio

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[13] For example, a 7.2 KHz bandpass has, at best, a 3.6 KHz audio response.

[14] See, e.g., Giles, Martin, Advances in AM Radio Design, Broadcast Engineering, September 1984 at 192; and Orban, R. and Oganowski, G., Two Evaluate AM Stereo Tuners, Radio World, July 15, 1984.

bandwidths approaching 6 kHz, this response has sometimes been achieved with a sharp cutoff filter. Even though manufacturers expect the number of wider bandwidth radios to increase, our interviews have appeared to reveal that there is not much awareness of, or concern for, the audio effects of sharp cutoff filters.

C. Availability of Technical Information.

It is axiomatic that improving the technical quality of AM transmission requires the necessary knowledge and expertise to upgrade an AM station's transmitting facilities. Radio-frequency upgrading, particularly, requires a great deal of experience especially for the important task of antenna broadbanding.

A major challenge for an engineer who is new to a technically-based industry such as broadcasting, is where to learn the techniques and industry practice necessary to solve technical problems. The Subcommittee also recognizes that economic factors at times have a major, if not determinative, influence on whether a particular station is or is not to be improved. But many technical improvements need only modest expenditures; it is only necessary for the appropriate expertise and information to be available. If an AM station decides to improve its technical facilities, the station should not be unable to do so because of an absence of readily available technical guidelines and information.

Much of the necessary information is presently available.

Unfortunately, however, these materials are not located in a central source available to anyone upon request. If such a central source for technical information existed, we believe that the technical improvement of AM station transmission facilities would more readily achieved.

D. Other Issues.

Many antenna systems do not have the characteristics necessary to handle highly compressed audio or large percentages of high frequencies. The case was, we think, adequately made over the past several years that transmitter plants need to be upgraded for today's audio. However, instead it appears that many stations have replaced transmitters and inserted "magic boxes" into the audio without making the expenditures necessary to improve their antenna systems. The result of improvements to the audio and processing chain ahead of the AM antenna is that the antenna (and transmitter, in some cases) is "force-fed" quality audio. Spurious emissions are often produced as a result. In any case, the audio actually detected by an AM receiver may not resemble the audio that was initially fed to the AM transmitter.

Additional problems include community spreading and interference from electrical devices. Of the two, community spreading is the more difficult, and is perhaps unsolvable. The problem occurs when communities, over time, outgrow and "spread" beyond the AM service contours of local AM stations. Because AM stations can be essentially unmovable due to antenna allocation considerations, the result of community spreading is to create areas of population concentration served by potentially weak AM signals, thereby degrading AM service over time even if the location of the AM station(s) have remained unchanged. If the spreading is due to population shifting, rather than growth, the service degradation realized by listeners can become even more pronounced. The spreading of communities into weak signal areas of AM stations is difficult to remedy because of the large expense incurred by a relocation of an AM station. Moreover, relocation may not even be possible due to interference or other technical constraints.

Interference from electrical devices such as power lines, hairdryers, "dimmers," and vacuum cleaners is a bothersome problem likely to get worse before it gets better. Of immediate concern are efforts by the lighting industry to begin marketing radio-frequency lighting devices ("RF light bulbs"). RF light bulbs are claimed to be three to four times more energy efficient than conventional incandescent lamps, and substantially more efficient than conventional fluorescent lighting using electromagnetic ballasts.
In controlled laboratory tests, RF light bulbs objectionably interfered with reception of AM broadcasts. The FCC is conducting a <u>Notice of Inquiry</u> to determine whether, and to what extent, RF lighting devices should be regulated under Commission Rules. Naturally, the lighting industry maintains that "voluntary" interference-prevention standards are preferable to FCC regulations. NAB, on the other hand, believes that the lighting

industry has little incentive, if any, to adopt and abide by voluntary standards to reduce harmful interference to AM reception. RF lighting is an emerging technology whose regulatory status has yet to be determined. It is clear, however, that the AM reception environment will be further degraded if the use of RF light bulbs causes interference and if they enjoy the widespread use the lighting industry expects.[15]

V. Discussion of Specific Suggestions.

A. Controversial Issues

1. Standardizing AM Preemphasis and Deemphasis.

Preemphasis is the boosting of high audio frequencies prior to transmission. Deemphasis is not necessarily a complementary process of high frequency rolloff at the AM receiver.

Those who support implementation of standard preemphasis curve argue that such a standard would provide the millions of narrow-band radios now in use with increased high frequency response intended to compensate for the generally limited quality of present-day AM receivers. New wideband radios could be equipped with deemphasis filters subjectively optimized to complement the

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[15] For further information, see, generally, Notice of Inquiry in Gen. Docket No. 83-806 (FCC 83-360), adopted July 28, 1983, 48 Fed. Reg. 37235 (August 17, 1983); Comments of the National Association of Broadcasters filed in Gen. Docket 83-806, October 31, 1983; and Reply Comments of NAB filed December 16, 1983.

standard preemphasis curve. Such deemphasis filters would also reduce the objectionableness of man-made interference and naturally-occurring static. After widespread implementation of the standard, all radios, new and old, would have the same potential to sound <u>good</u>. Stations not conforming to the standard would sound "dull"; there would then be a "marketplace" incentive to upgrade the processing and improve the physical plant of these stations.

Other arguments in favor of introducing standardized preemphasis curves have to do with the wide variety of AM receivers now on the market. Since AM receivers exist with such varying electrical characteristics, it is difficult, if not impossible, to find an "average" AM receiver that can be trusted enough to to adjust the transmitted audio processing in a manner that would sound good on all AM receivers. The theory is that introduction of some standardization in preemphasis and deemphasis would result in future AM receivers exhibiting more uniform electrical characteristics so that, in turn, AM received sound eventually would be subject to less variability among receivers. Engineers, managers, and programmers could thus be more certain that the AM receiver used in station processing setup would be more likely to sound the same as other AM receivers.

There are several arguments espoused by those who are generally opposed to introduction of some standardization of preemphasis and deemphasis curves. One reason is that any "standard" preemphasis would have to be voluntary and thus would probably have little impact. Broadcasters have traditionally done whatever processing and equalization is necessary to sound the way they want to on their own chosen radios. Often, the chosen sound is format dependent as well. With respect to deemphasis there are some receivers now being produced that would not benefit from receiving a preemphasized signal. A receiver response that is flat to 6 kHz requires no preemphasis below 6 kHz. Any such boost would serve merely to increase adjacent channel interference.

Another factor is that preemphasis curves are by definition static, but appear dynamic because they can be present anywhere within in a program chain. The location of a preemphasis curve in the processing chain makes a great deal of difference in station output. The high-frequency content of a broadcast may have little relation to the amount of high frequency boost actually employed. And many common audio processing techniques such as limiting and compression essentially serve to "destandardize" any curve that could be implemented. To be effective and uniform, not only would a preemphasis curve have to be standardized, but its place within the processing chain would have to be standardized as well; and for the reasons above, we feel it is unlikely that broadcasters would agree to a preemphasis curve that might not sound right (in the station's view) for their station.

Moreover, the nature and details of the curve remain controversial. We asked "experts" in areas of audio and AM system design and they did not agree on the nature of a specific preemphasis/deemphasis standardized curve. Finally, boosting high frequencies in AM has the result of exacerbating adjacent channel interference, particularly at night. It is not known if standardizing pre-emphasis would serve to generally reduce such interference, or increase it, if radio stations were to adhere to the standard. Because high frequency boost is used today, there is now more interference at night that there would be if all broadcasters transmitted a "flat" response. The problem would still exist, however, because the FCC has not promulgated allocations standards to control nighttime interference.

After carefully considering this issue, we believe that there is little to gain by recommending a standardized preemphasis curve. We generally agree that introduction of a greater degree of standardization into the AM transmission and reception system would, as a strictly technical matter, bring improvement to the resulting sound. But it is not a strictly technical matter. There is no guarantee, nor should there be, that radio stations would adhere to the new standard; and, as mentioned, the AM station's entire processing chain -- from studio to antenna -- would have to be standardized in order for the standardization to bring the desired beneficial effect. There is also no guarantee that receiver manufacturers would significantly alter either their existing narrowband AM radio designs or future wideband designs (that would incorporate deemphasis) unless it could be shown that there is economic benefit to do so.

Interestingly, high frequency boost will improve the tonal quality with only the older designs, for the reasons discussed below. As time goes on, the population of these radios is expected to decrease, with the other two classes of radios becoming more prevalent, thus rendering preemphasis both less useful and more objectionable.

We do not propose any standard for preemphasis. The number of radios which can be helped by preemphasis is decreasing in the marketplace, being replaced either with wider bandwidth radios, for which a different preemphasis standard is necessary, or radios using ceramic filters with sharp cutoffs, for which no reasonable amount of preemphasis makes any difference. As a strictly technical matter, AM is unlike FM in that no significant noise improvement will be gained by preemphasis (noise improvement with preemphasis, however, depends on program spectral characteristics). Preemphasis, therefore, appears useful only to overcome radio IF and audio response limitations. Since the problems of preemphasis in FM, especially the modulation restrictions, are legend, we would prefer to see AM preemphasis gradually disappear along with the older radios. In the interim, it is essential to not discourage attempts to sell wider bandwidth radios, and excessive preemphasis can sound objectionable on those radios. Knowing that some highly successful major-market stations have reached a compromise and are satisfied with their sound on both narrowband and wide band radios, we suggest that station preemphasis should be tailored specifically with better radios in mind. This reduced preemphasis will permit greater loudness than is presently available to some stations (subject to the characteristics of the station's audio processor), without the extremely objectionable consequences of overmodulation.

There may, however, be some benefit to recommending a rolloff of transmitted high frequencies, perhaps above 12 kHz. Audio frequencies above 12 kHz are severely attenuated in typical AM radios. It is a difficult task, at best, to perceive the presence of audio frequencies above 12 kHz if they exist in the AM receiver. But they do cause interference at night, because these audio frequencies, when transmitted, fall into the passband of AM receivers listening on adjacent channels. We believe a roll off of transmitted high frequencies above 12 KHz would yield significant interference-reducing benefits to the listenability of AM stations. Some of the most popular AM audio processors contain such filters.

2. Use of Filters.

Filters pass desired frequencies and attenuate undesired frequencies. Many kinds of filters exist. By "5 kHz" low pass filter, we mean a filter installed or switched in (only at night) after all audio processing at the station, and before the AM transmitter. This filter has the general property of attenuating audio frequencies higher than 5 kHz.

The proclaimed advantage for use of 5 kHz filters at night is the reduction of nighttime AM interference levels due to transmission of sidebands arising from AM modulation of high audio frequencies. The amount of RF energy appearing in adjacent channels that could interfere with reception of distant adjacent channel stations would be attenuated. Proponents of the use of 5 kHz filters also believe that receiver manufacturers would be more likely to widen their IF bandwidths once the AM band is "cleaned up".[16]

There are a number of disadvantages to this idea. For one thing, the Subcommittee does not believe that AM stations will voluntarily install 5 kHz low pass filters. Installation of the filter would result in a noticeable diminution of sound quality in many receivers. Even though existing narrowband receivers have 3 dB bandwidths of less than 5 kHz, many such receivers roll off gently above the 3 dB point. A sharp cutoff 5 kHz filter inserted in the audio chain would introduce unnatural coloration of the audio in these radios.[17]

In addition, it is not clear that manufacturers would act to improve the quality of their receivers if broadcasters installed the filters. If they didn't, the possibility exists that broadcasters would install the filters in partial expectation of

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[16] It should be noted that the carrier of an adjacent channel AM station is generally about 8 dB above its accompanying sidebands. Thus, the carrier has a greater potential to interfere than the sidebands, and installation of a low pass filter will not attenuate a station's carrier, only its high-frequency sidebands.

[17] See Orban, R. and Ogonowski, G., A Recommended Preemphasis Characteristic and Deemphasis Characteristic for AM and Stereo Broadcast, April, 1983, available through the authors, or NAB, at 4.

new and improved receivers only to find that the manufacturers have no monetary incentive to build them. Finally, use of a 5 kHz filter appears to preclude other system refinements that hold greater promise for improvement of AM transmission and reception.

For these reasons, we are not convinced that the idea of using 5 kHz nighttime filters on AM transmitters is a viable means to reduce nighttime interference.

3. Receiver Improvements.

There are a number of receiver improvements that we believe could be beneficial. Not an exhaustive analysis, several are considered below.

a). Synchronous Detectors.

Synchronous detection is an alternative demodulation technique useful in recovering audio from an AM signal. Most AM radios in existence today use envelope detection, a simpler, generally less expensive, and more well known detection technique. Based on careful analysis, the use of synchronous detectors wherever possible ought to bring improvement to the sound quality of received AM signals. However, a good quality envelope detector with well-designed RF, IF and audio stages can also bring improved performance. Use of synchronous detection in such a radio would provide additional benefits especially in poor signal areas.

(1) High Q Effects. The envelope of a modulated AM carrier is the waveform of the modulating audio. Undistorted envelope detection is possible as long as neither the top nor

bottom audio waveform ever crosses the zero carrier axis.

In a sharp null of a directional AM antenna, in the presence of re-radiation from power lines or high-rise building, or in a station's fringe area where there is interference between groundwave and skywave, the carrier may become reduced in amplitude compared to the sidebands. This results in the situation where the top and bottom audio waveforms now cross the zero axis and each other, resulting in a distorted envelope detected output. These same reception situations may also cause asymmetry between the upper and lower sidebands, which will result in distortion in an envelope detector.

A synchronous detector does not depend on the presence of the carrier or symmetrical sidebands for undistorted detection. Therefore, high Q effects such as reduction of carrier amplitude or sideband asymmetry will not cause distortion in a synchronous detector.

While this is a theoretical advantage of synchronous detectors, some receiver manufacturers believe that by the time the receiver is 2-3 blocks from the transmitter in a deep, sharp null, the desired signal is often so weak, or the co-channel signal being protected by the DA null so strong, that either the station is unlistenable or the synchronous detector is also adversely affected (see below for a discussion of co-channel interference). If sideband asymmetry occurs in a strong signal area due to a null, re-radiation, or groundwave/skywave interference, a synchronous detector does provides better reception. Receiver manufacturers, however, believe such occurences are not common or severe enough to justify a change in detector design. Many broadcasters disagree with this conclusion. They believe these situations to be quite common and the resulting degradation in an envelope detector to be a significant deterrent to AM listening.

(2) IF filtering. Because an envelope detector recovers the envelope of whatever signal is fed to it, the signal it sees must be the desired station only. Stations on other frequencies present in the front end of the receiver must be filtered out before the detector. In other words, filtering to provide the required selectivity must be done at radio frequencies, generally at the receiver's intermediate frequency (IF).

Al Resnick's paper on Envelope Detector Performance explains what will happen if there is insufficient IF filtering and the envelope detector is presented with undesired signals.[18] A low level adjacent channel signal will be heard as a 10 kHz whistle along with "monkey-chatter," because the adjacent channel sidebands overlap the sidebands of the desired signal. As the undesired signal increases in amplitude, the non-linearities of the envelope detector come into play, and gross distortion of the desired modulating signal occurs.

The whistle and monkey-chatter are inherent in amplitude modulation and the existing system of channel spacing and alloca-

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[18] Available from Al Resnick, Chief Engineer, WLS Radio, 360 North Michigan Avenue, Chicago, Illinois 60601 (312) 984-0890.

tions, and occur in all AM detectors. They can be eliminated with either IF or post-detection audio filtering. The only advantage of synchronous detection here is the greater freedom it gives the receiver designer in IF characteristics. It may be advantageous, for example, to develop an asymmetrical IF passband that could reduce interference coming from one sideband. This is possible with a synchronous detector, but not with an envelope detector due to its distortion of signals with asymmetrical sidebands.

In addition, use of a synchronous detector would minimize, in new radios, two attributes of many existing AM radios. First, there would be no distortion due to mistuning a manually-tuned radio. Second, distortion arising from asymmetrical response of the IF stages (caused by drift, time, temperature, or factory misalignment, etc.) would be minimized.

The distortion problems due to envelope detector nonlinearity in the presence of large unwanted signals do not exist when using a synchronous detector. A synchronous detector is, in effect, a frequency shifter. If shifts radio frequencies down to the audio frequency range where they can be amplified and heard. If a 1000 kHz station were being detected, its audio would appear in the synchronous detector's output at normal audio frequencies. Other stations would also appear in the output, but at higher frequencies. (A station 30 kHz away from the desired would appear centered at a supersonic frequency of 30 kHz.) The presence of these additional frequencies at the detector's input does not degrade the desired signal as it does in an envelope detector (as long as the undesired signals do not exceed the detector's linear range). Thus, filtering can be employed after the detector, at audio frequencies, instead of, or in addition to, IF filtering.

If distortion is to be avoided in an envelope detector, the IF bandwidth must be narrow enough to protect against the largest adjacent channel signals expected to be encountered. In a mobile environment, an adjacent channel signal may be significantly above the desired signal. No practical amount of IF filtering can deal with this kind of adjacent channel dynamic range, so the synchronous detector will provide better performance under these conditions. In practice, however, front end stages of receivers are often unable to deal with large adjacent channel signals, and intermodulation products that degrade the desired station are created before the signal reaches the detector.

Until now, receiver manufacturers have not felt that envelope detector nonlinearities in the presence of large undesired signals gave sufficient reason to use synchronous detectors, and the two detectors perform equally as far as weak adjacent channel interference is concerned. If audio filtering becomes cheaper than IF filtering, however, then synchronous detectors will have an advantage. Digital detection techniques that would detect the signal, provide proper selectivity, and provide other useful features such as adaptive bandwidth under varying adjacent channel interference conditions, are several years away from being cost effective for receiver use. When the price drops to $4-5, down from approximately $30 now, this synchronous detector advantage may become significant.

(3) Signal-to-Noise Improvement. When an AM signal has a low carrier-to-noise (C/N) ratio, a synchronous detector will provide an audible improvement in audio signal-to-noise (S/N) ratio compared with an envelope detector.[19]

Receiver manufacturers generally consider a 26 dB audio signal-to-noise ratio to be the threshold of entertainment. Below 26 dB, a consumer would be expected to switch to another station rather than put up with the noise. There has been little interest by receiver manufacturers in improving what they consider to be very bad signal. This is not to say that such an improvement is insignificant; it may be very important to some stations or listeners.

Synchronous detectors are particularly effective in reducing the audibility of impulse noise. The detector converts the often asymmetrical impulses into a symmetrical audio waveform. While the measured noise level is not significantly different from an envelope detector, it becomes less annoying to a listener.

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[19] Note: knowledgeable engineers appear to disagree on this subject. Some say there is no S/N difference until the C/N drops below approximately 20 dB, at which point the synchronous detector begins to have an advantage, with the difference between detectors reaching 3 dB at a C/N of 10 dB and below. Others say a synchronous detector has a 3 dB advantage at all signal levels, but the advantage begins to be noticed only when the C/N ratio is low and the noise, therefore, is more apparent. It is generally agreed, however, that the synchronous detector's advantages are significant only in high noise areas.

(4) Implementation Effects. Synchronous detectors used to hold the promise of lower distortion levels than envelope detectors. Although both envelope and synchronous detection is theoretically distortion-free, envelope detection was traditionally accomplished with diodes that were non-linear at high modulation percentages or with low input voltages. Synchronous detectors do not have this problem; if the detector's reference oscillator is stable the detection is distortion-free.

Newer envelope detector designs, however, have virtually eliminated the old diode distortion problem. One new envelope detection technique, the "MacArio decoder," has only 0.1% total harmonic distortion ("THD") at 95% modulation, which is as good or better than existing synchronous detectors.[20]

It is important to distinguish between the theoretical limitations in a detector's performance, and limitations caused by imperfect implementation. For example, "overshoots" in sharp-cutoff IF stages can result in overmodulation within the receiver that would cause distortion in a radio using an envelope detector, but would not cause distortion in a radio using a synchronous detector. As technology advances, we can expect continued improvement in both envelope and synchronous detector design, so that performance will reach closer to the detector's theoretical capabilities.

(5) Co-channel Interference. Synchronous detectors may

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[20] Under laboratory conditions that do not account for propagation effects.

be more or less subject to co-channel interference than envelope detectors. A strong co-channel signal will result in the carrier amplitude of the desired station rising and falling at the beat rate between the two signals. As discussed above in the High Q Effects section, this causes apparent overmodulation of the desired signal, and distortion in the envelope detector. This phenomenon would occur in the ground-wave fringe area of a station, where a co-channel station might be fading in and out. During the co-channel signal peaks, the interfering signal might be as large as the desired signal, causing high distortion in an envelope detector. A synchronous detector would be free of this distortion. It should be noted, however, that the sidebands of the interfering signal would also be as large as those of the desired signal, and it is doubtful that many listeners would be interested in listening to the station under these conditions.

If the co-channel signal is not strong enough to cause significant envelope-detector distortion, but still strong enough to beat with the desired station, the envelope detector may have the advantage. The frequencies of most AM stations are held to close tolerances, typically +/- 2 Hz. The beat frequency between two co-channel signals is therefore likely to be less than the automatic phase control (APC) loop bandwidth of the synchronous detector's phase-locked loop (which is usually above 5 Hz). The reference oscillator will then follow the low frequency beat, and the amplitude of the desired signal will flutter at twice the frequency of the beat.

This problem is another result of existing synchronous detector implementation. Theoretically, with a stable reference oscillator, there will be no amplitude flutter. More sophisticated circuitry may be developed in the future which would do a better job of reconstructing the reference phase. The detector would then be less susceptible to low frequency phase instability in the received signal.

(6) Other Issues. Synchronous detector radios must be muted until the detector has locked onto the received signal. Lock-up time is only approximately 150 milliseconds, so an electronically tuned radio (ETR) can just remain muted as the frequency is changed. A manually tuned radio (MTR), however, must remain muted so the user knows when the station is tuned in. Thus, even if a MTR is to use a synchronous detector, an envelope detector must be used as a tuning aid between stations. This increases the complexity and cost. As a practical matter, most manufacturers are unlikely to ever use synchronous detectors detectors in MTR's. Inexpensive radios, which are likely to remain MTR's, will probably continue to be designed with envelope detectors.

Manufacturers have also been reluctant to design synchronous detector radios due to the uncertain nature of low frequency phase modulation in AM broadcasting. Existing synchronous detector implementations are sensitive to any low frequency phase information, as discussed under co-channel interference, above. Incidental carrier phase modulation in transmitters, AM stereo pilot tones and recently permitted ancillary AM carrier services, all present synchronous detectors with problems. It has been easier to avoid the problems by continuing to use envelope detectors.

(7) The Future of Synchronous Detectors. The reception quality advantages to be gained from synchronous detectors are considered to be negligible by manufacturers. However, other considerations may presage greater use of synchronous detectors in the coming years. The issue of cost, discussed above, is central. Synchronous detectors, when combined with other receiving functions, are likely to become widespread as a result of new techniques in FM receiver design. Engineers are working on FM synchronous detector demodulation techniques that can be more easily implemented using integrated circuits than present detector designs. Eventually, a synchronous detector chip may be able to demodulate both FM and AM signals, at a lower price than either can be demodulated now.

(8) Recommendations. The only negative performance aspects of synchronous detectors are increased susceptibility to some forms of co-channel interference, sensitivity to low frequency phase modulation in AM transmitters, and muting problems in manually tuned radios. In all other respects, their performance is equal or superior to envelope detectors. Cost has been the primary deterrent to synchronous detector use by receiver manufacturers.

While we advocate synchronous detector use wherever possible, it is clear that it is far less critical to AM quality than improvements in frequency response and distortion. A good quality envelope detector with properly designed RF, IF and audio stages can provide vastly superior performance to most radios today. Use of synchronous detection in such a radio would provide significant additional benefits.

b) Filters in Receivers.

Many AM reception problems can be ameliorated by sophisticated filtering in either the IF or audio stages of a receiver. In areas where the desired signal is strong and adjacent channel signals are weak, a wide IF bandwidth and wide audio bandwidth will provide quality audio without difficulty. If the IF and/or audio filter bandwidths could be selectively raised or lowered in the presence of adjacent channel signals, interference could be reduced to desirable levels, with audio frequency response reduced only when necessary.

A 10 kHz notch filter would also greatly improve receiver quality. The 10 kHz "whistle" is the dominant manifestation of adjacent channel interference. Not only is the carrier power of an AM signal generally at least 6-7 dB above the total power in both sidebands, but the program-modulated sidebands are spread out, while the carrier is a spectrally pure tone not easily masked.[21] Thus, though "monkey-chatter" from the adjacent channel sidebands never can be completely eliminated, a 10 kHz filter will eliminate the whistle and greatly reduce audible interference.

Such a filter would also permit high frequency response to be substantially increased. The primary reason for the sharp high frequency rolloff in AM radios is to make the response at 10 kHz low enough so the whistle is not objectionable. If the whistle were eliminated by a notch filter, the frequency response could be improved up to the point where monkey-chatter became excessive.

Because the FCC requires AM carrier frequencies to be held within 20 Hz of the assigned frequency, the best frequency between two AM stations is within 40 Hz of 10 kHz, and can be removed with a sharp notch filter that would have virtually no audible effect on the program material.

Variable-bandwidth IF and audio filters, and sharp 10 kHz notch filters, are not new technologies, and could have been included in AM radios for some time. However, until recently there was no way to construct stable, precise RC networks in integrated circuit form. Thus the cost and complexity of such circuitry was too high for most manufacturers to include in AM

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[21] Orban, R. and Ogonowski, G., A Recommended Preemphasis Characteristic and Deemphasis Characteristic for AM Stereo Broadcast, supra, at 2.

radios.

A recent circuit design development promises to make sophisticated filtering much easier to accomplish. The "switched-capacitor" filter uses capacitors and high-speed transistor switches to simulate most types of filters. These filters can be built with a single integrated circuit chip, and can also be combined with other receiver functions on the same chip. As integrated circuit manufacturers develop new receiver chips, this technology is likely to be included in new AM receivers.[22]

Because the 10 kHz whistle is such a significant audible contributor to adjacent channel interference, we advocate inclusion of 10 kHz notch filters in receivers wherever possible. Such filters could be left in the circuit without degrading the program material, and would allow improved high frequency response at all times. We also urge the development and use of switched-capacitor filters as part of new integrated circuit designs for receivers.

B. Non-Controversial Issues

1. Enhancing Technical Knowledge.

The Subcommittee believes that AM transmission can be improved through the spreading of technical knowledge and industry experience regarding AM station design and maintenance. Toward this

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[22] See, generally, Broderson, R.W., et al., MOS Switched-Capacitor Filters, Proceedings of the IEEE, Vol. 67, No. 1, January, 1979, at 61.

end, the Subcommittee urges the establishment of a "Technical Reference Center" ("TRC") for the purpose of consolidating available AM technical information into a simple, centralized source. Once the TRC is established, it should be promoted by NAB to stimulate use.

For the near term, the Subcommittee envisions two projects. The first of these is to assemble a bibliography of useful technical articles and similar materials addressing the typical problems encountered by AM Chief Engineers. The second is to take a sampling of these articles and materials and publish a "Primer" on AM station radio-frequency maintenance. The detailed nature of the Primer would depend on the nature of NAB's new edition of the Engineering Handbook, forthcoming in early 1985.

(a) The Bibliography. Initially the bibliography would contain materials limited to the subject of radio-frequency problems; for example, directional antenna maintenance, coupling networks, impedance matching, tower maintenance, and other similar problems. For the time being, we suggest other problem areas -- such as studio design, station wiring, equipment maintenance, and acoustics -- not be included in the bibliography.

The bibliography would be assembled by a search through past magazines and newspapers likely to contain useful articles and by investigation of computer databases that list and summarize general technical reference materials.[23] Each entry in the bibliography should be numbered and available to an NAB member, without charge, who calls in to request a copy.[24] A form has been created which organizes AM technical material into nine categories.[25] The form can be used to "update" the bibliography at periodic intervals, perhaps every three months.

Two desired additional features of the bibliography are the inclusion of (1) a code (A, B, or C) to reflect the degree of mathematical complexity, and (2) an asterisk ("*") to indicate the presence of a calculator or computer program. Because industry chief engineers have varying mathematical backgrounds, not all technical articles on a particular subject would be understandable or useful. Inclusion of a suitable code, therefore, should help a chief engineer to choose only those articles on a particular

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[23] Trade press would include such magazines as BM/E, Broadcast Engineering, Radio World, and others. Computer databases include INSPEC, BRC, and NTIS. Much of this work has already been completed.

[24] The Subcommittee anticipates few copyright difficulties with this strategy because many materials will be several years old or more. If there are any problems, the TRC would still be able to publish the bibliography, but perhaps would not be able to provide copies of all entries upon a member request.

[25] These categories are (1) Transmission Lines, (2) Phasors, (3) Measurement Techniques, (4) Operational Monitoring, (5) Coupling (or "matching") Networks, (6) Towers, (7) Ground Systems, (8) Directional Antennas, and (9) FCC Compliance and Proofs. Many technical articles overlap and thus could be included in multiple categories.

subject at a comfortable level of math.[26] The second additional feature of the bibliography, the possible presence of an asterisk, would exist to indicate whether a particular article contains a calculator or computer program. The Subcommittee believes that this is important information to include in a technical bibliography. As an example, a moderately complex article on Directional Antenna design (category 8), with a calculator program, would be accompanied by a technical indicator of "B*", and would appear on the bibliography with a code of "8B*".

(b). The Primer. In order to help the process of spreading AM technical knowledge throughout the industry, and especially to help newcomers to AM broadcasting, the Subcommittee believes that publication of a basic "Primer" on AM Station maintenance would be a useful NAB task.[27]

2. Antenna Improvements.

Many AM antennas can be improved. We urge AM broadcasters to measure their antennas and optimize the antenna's performance.

The antenna system of a radio station acts not only as the radiator of the signal but also as a "final filter" on the

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[26] We envision an "A" article to contain complicated mathematics such as calculus or involved algebra. A "B" article would contain simple algebra, no calculus, and graphs. A "C" article contains no mathematics and would be primarily a qualitative treatment of a specific subject. The Subcommittee recognizes that no "rating system" is perfect and there will be occasions where a reader will disagree with the indicated rating.

[27] The Primer should not "compete" with NAB's Engineering Handbook. It would be written and compiled for a different purpose: an in depth treatment of AM RF maintenance and design.

transmitter output. Almost all antenna systems and coupling networks are designed to help reduce the level of out-of-band emissions (especially second and higher order harmonics). In the early years of radio, many transmitters did not contain sufficient filtering to meet the harmonic radiation limits and thus required extra filtering from the antenna circuits. More recent transmitters, as a rule, do not have this problem, and the additional protection supplied by the antenna circuits is helpful but not essential.

A narrow bandpass in the antenna system will not only reduce higher harmonics of the carrier but will also reduce transmitted high-frequency response, resulting in muddy, lifeless sound. An antenna system having an impedance characteristic that varies greatly across the audio passband (+/-15 kHz from carrier frequency) poorly matches the output impedance of the transmitter, as measured at the plate of the final amplifier. Such a system may be perfectly matched at the carrier frequency but mismatched at the sideband frequencies. When the amplifier load varies, the efficiency of the power transfer into the antenna is reduced; as a result, the "quality" audio going <u>into</u> the transmitter <u>never leaves the antenna</u>. Also, different antenna characteristics at frequencies above and below the carrier frequency will result in asymetrical sidebands, which causes the received signal to be distorted in an envelope detector (quadrature distortion).

There are additional complexities in directional antenna systems which may add to the problem such as high "Q" antenna circuits, high circulating currents, sharp nulls in the pattern where the carrier is attenuated to a greater extent than the sidebands, and so forth. Sometimes these problems can be reduced by a simple redesign of the input sections of the phasing system; sometimes a complete phasor redesign is necessary for significant improvement, and in some cases no complete solution is possible without completely redesigning the pattern -- often not possible or desirable. One study estimates 66% of directional stations and almost all non-directional stations can be improved by some attention to the design of the antenna phasing and coupling networks.

Importantly, the problems caused by the antenna must be fixed at the antenna. Merely adding preemphasis will often overload the transmitter or cause spurious emissions. Additionally, using excessive preemphasis wastes modulation capability (loudness) because transmitter modulation is used on sound that never gets out of the antenna. With asymetrical sidebands and heavy processing used to compensate for a poor fidelity antenna, it is possible to overmodulate an AM signal even if the station monitor, watching the transmitter output, shows all is well.

Possibly the clearest test is to run the audio response portion of the annual proof into both the antenna system and into a good, nonreactive dummy load. If the audio response into the antenna falls off at higher frequencies (5000-7500 Hz) but the response into the dummy does not, the antenna is limiting the station sound. In severe cases, it may not even be possible to make 100% modulation at 7500 Hz in the antenna, while it is easily done in the dummy. Excessive modulator current (or modulator overload) at higher frequencies in the antenna but not in the dummy is another good indication (problems at low frequencies, 100 Hz and below, are more likely to be transmitter-related than antenna-related). A somewhat reactive dummy (like the typical resistor bank built into lower power transmitters) is also usable, since it is the difference between the two responses that is important.

Another way to tell if antenna work should be considered is to examine the load impedance seen by the transmitter output. This impedance can be determined at a directional station by reviewing the common-point impedance plots contained in the most recent directional antenna proof of performance. Non-directional stations also measure impedances, but such measurements are usually made at the tower base, and do not reflect bandwidth problems of antenna tuning equipment. A non-directional station should obtain impedance measuring equipment and measure the entire antenna system at the transmitter output point.

It has been suggested that the impedance should be measured looking toward the antenna at the plate of the final RF amplifier for the most meaningful results. Measurements should be made at least every 5 kHz over a range of at least ± 20 kHz from carrier.

Solutions to antenna bandwidth problems improvement in the bandwidth of a non-directional antenna generally requires the design of a matching network in which the impedance slopes (resistive and reactive) of the network oppose the impedance slopes of the antenna, resulting in a flat response. This is a fairly simple job for a qualified consulting engineer specializing in AM antenna design, and there are computer programs which assist in such work.[28] Almost any antenna system, unless designed specifically with broadbanding in mind, is capable of at least some improvement, usually resulting in a noticeable improvement in the air sound.[29]

3. Transmitter Research.

The Subcommittee is convinced that the interference problems which arise from heavy processing of audio signals can be mitigated through research together with transmitter manufacturers. The goal is to determine the types of signal inputs that give use to instabilities in the transmitter modulation and output circuits. While many transmitters pass audio proofs easily, dynamic modulation conditions can induce distortions and instabilities that result in production of harmonic content, intermodulation products and transient oscillations. The Subcommittee has denoted this set of distortions caused by the

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[28] The Technical Reference Center should have a sizeable collection of articles useful in "Broadbanding" AM antennas.

[29] With directional antennas, network broadbanding can affect control of the antenna's pattern. Caution should be exercised. Employing a technical consultant to improve an antenna deficiency would be money well spent.

dynamic characteristics of highly processed input audio, "Transmitter Transient Distortion," or "TTD".

In the words of one of the Subcommittee's correspondents, TTD is

> ....usually due to the transmitter going open-loop in the modulation circuit, where the dense, clipped, high- amplitude high frequency audio modulation is forcing the modulation output to [attempt to] slew faster than it is able, and thus there is no effective audio feedback to keep the modulation linear. The effect is known as transient intermodulation distortion ["TIM"] in solid state op-amp technology.... In the world of AM transmitters, there are no TIM measurement standards, or established measurement techniques. In AM transmitters, TIM effects are multiplied by poor supply predictable phase shifts, ... [and] radio frequency feedback into audio processing equipment....[30]

The Subcommittee urges investigation of these problems. Like the case of TIM in audio solid state circuits, investigation and research into TTD could lead to suggestions for design improvements in all transmitters, new and old, that, if implemented, would noticeably improve the fidelity of the transmitted AM signal.[31] The knowledge gained from research would result in the development of testing and measurement procedures enabling industry engineers to make improvements to their stations to reduce TTD. The Subcommittee intends to begin

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[30] Werrbach, Donn R., Correspondence to Subcommittee, January 24, 1984 at 6.

[31] See, e.g., Otala and Leinonen, Theory of Transient Intermodulation Distortion, IEEE Transactions on Acoustics, Speech, and Signal Processing, February 1977.

this research effort by collecting available technical information and distributing this report to interested transmitter manufacturers and other appropriate engineers.

4. AM Antenna Research.

It has come to the Subcommittee's attention that there are theoretical antenna designs which, if constructed with an existing AM station's antenna system, could significantly attenuate interfering skywave in chosen, specified directions.

The implications for such antenna designs are significant. When an AM station's directional antenna is used to protect distant AM co-channel station, at night, the radiation in the direction of the distant station is reduced. These are the "nulls" of the directional antenna pattern. The nulls occur at the azimuths in the directions of the protected AM stations. Nulls are engineered to minimize radiation not only at the specified azimuths, but also at the proper vertical, or elevation angles, of the protected stations. Radiation emitted along the ground will not interfere with a distant station; it is the skywave, the radiation emitted at critical elevation angles, that causes interference. The promise of AM antenna research, therefore, is to develop a practical way to minimize interfering radiation at critical azimuths and elevation angles, but not at the expense of suppressing radiation along the ground. The result of implementation would be generally higher groundwave field strengths with no increase in skywave interference.

Currently, a computer-model of the theoretical antenna design is being formulated. The next step logically would be a model antenna built on a relatively small scale, followed by a working prototype at broadcast frequencies. The computer-model provides for the typical limitations on the land that each AM antenna station occupies. The "supplementary" antennas would, in effect, be small-scale antenna structures strategically located on the antenna premises.

The Subcommittee highly recommends research into these matters.

5. Additional Suggestions.

(a) Working with Receiver and Integrated Circuit Manufacturers. The Subcommittee urges the industry to encourage AM Receiver and Integrated Circuit Manufacturers to develop a high-quality integrated circuit chip for AM radios. We urge reactivation of the National Radio Systems Committee ("NRSC") to include participation of IC Manufacturers. It is important to begin a coordinated effort toward the development of an orderly evolutionary process for improving AM transmission and reception technology.

Today, design of the IC is likely to be more determinative of the AM radio's performance than other components assembled by a receiver manufacturer. For this reason, if a "quality' IC could be developed on a cost-effective basis, receiver quality would naturally follow. It may be desirable, therefore, for AM broadcasters to begin participating in the development of the next generation of IC's.

For now, the Subcommittee urges NAB to invite technical papers from the receiver and IC industries to be presented at the 1985 NAB Engineering Conference. An "award" for best radio design of the year may also be worthwhile. These matters will be presented to NAB's Engineering Conference Committee for use in planning the 1985 and future conferences.

(b) Reducing Electrical Interference.

The Subcommittee urges NAB participation in on-going FCC proceedings looking toward minimizing the creation of additional interference. Unfortunately, such participation requires considerable time and effort, in order to achieve meaningful results. With respect to RF Lighting Devices, the lighting industry has invested tremendous resources in developing these devices, and in preparing technical reports and memoranda for use in evaluating their interference potential. Responding competently to these reports is a large task.

The risk to AM broadcasters is not so much the immediate effect of FCC authorization of RF lighting devices, but that continual authorizations will, over a period of time, cumulatively degrade the AM reception environment. It is very difficult to gather empirical data to conclusively demonstrate actual interference caused by RF lighting devices, and even more difficult to show how the AM environment is degraded.

The most promising solution to electrical interference problem may be "noise blankers" incorporated in AM radio receivers. The Subcommittee urges investigation of noise blanking, together with AM receiver manufacturers.

C. Marketing and Promotion Issues.

After careful consideration, the Subcommittee has come to believe that an industry-wide AM promotion campaign could bring significant benefits to the AM industry. AM broadcasters can do much to help themselves through promotion; the ideas and suggestions for specific promotions could originate at NAB or RAB. During Subcommittee meetings, several ideas for AM promotion were discussed and appear worthy of consideration:

1. Promotion of "Quality" Receivers. In theory, receiver manufacturers will not build quality radios unless those radios are successful in the marketplace.[32] Broadcasters could, under a rigorous and carefully structured standards-setting organization, establish specified quality criteria in an attempt to encourage the manufacture and sales of quality AM radios. The obstacles are formidable, however, for beginning a nationwide program of this nature. A major problem, of course, is the nature of the organization that could undertake the necessary administation and due process requirements such a standards-setting effort would

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[32] See Norberg, Eric G., "An AM Stereo Commentary," Broadcasting, March 5, 1984 at 30. In New Orleans, Louisiana, six local AM broadcasters incorporated the "New Orleans Quality Broadcasters AM Stereo Association," devised a plan (that included over $25,000 of prime-time advertising spots), pooled funds to purchase 1000 Sony SRF-A100 AM Stereo Receivers and began to promote sales of the Sony radios. See "Stations Unite for AM Stereo," Radio World, August 1, 1984, at 6.

entail.[33] Although the idea of quality receiver promotion has a certain amount of intuitive appeal, the realities of administering such an effort on a large scale seem to preclude its serious consideration.

2. Other Promotion Ideas. One idea is a promotional campaign which attempts to raise the "quality consciousness" of the general public with respect to AM radio. Such a campaign could be formulated in a central location, with the goal of preparing and mailing of promotional "kits" to AM radio stations. Each kit could contain a number of distinct alternatives for AM promotion.

Because this is a technical report, the Subcommittee does not believe an in depth treatment of promotional issues would be appropriate at this time. Yet, in most of the Subcommittee's meetings, it was clear that the AM broadcast industry can and should do much to help itself through promotion. AM Improvement is not a strictly technical matter; while broadcast engineers can greatly improve the technical quality of AM transmission and reception, these efforts alone will not be sufficient to successfully meet AM's challenges.

V. Conclusion.

The study of AM Improvement has been a taxing and difficult

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[33] Large standard-setting committees are possible to establish but consume considerable time, financial and personnel resources. And there is no assurance that such a committee would be succcessful in its endeavors.

project. It is ironic that the oldest form of broadcasting, Amplitude Modulation, remains, after many years, technologically so complex. Not in TV or FM broadcasting do we find current technical issues as resistant to objective analysis and as controversial as the issues addressed in this report. Accordingly, it cannot be said that the Subcommittee has finished the job; instead, it appears that we have just begun. If the conclusions and suggestions contained herein stimulate the resources of the AM broadcasting industry to work toward self-improvement, the Subcommittee would consider the report to have accomplished its purpose. In whatever form the industry's efforts take, the NAB AM Improvement Subcommittee has pledged its efforts to work toward improving the technical quality of AM transmission and reception.

Comments on the report are welcome. Drop a letter in the mail to NAB AM Improvement Subcommittee, National Association of Broadcasters, 1771 N. St., N.W., Washington, D.C. 20036.

VI. Appendices.[34]

A. *List of References: Technical Papers and Reports*

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B. *Correspondence, Memos and Letters*

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[34] These documents are available on request from NAB. (202) 293-3557.

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Harris, Bill, Chief Engineer, KNUS Radio, Denver, Colorado. Letter to Subcommittee (opposing 5 kHz nighttime filters and believing that a standard AM pre-emphasis curve will be "at best" a trade-off), January 4, 1984.

Hoke, James H., VP and Director of Engineering, Harte-Hanks Radio, Winston-Salem, N.C. Letter to Subcommittee (opposing nighttime 5 kHz filters and standardized pre-emphasis, but suggesting "an upper limit" on transmitted high frequency boost), January 23, 1984.

Hubert, David L., Chief Engineer, KIRO, Seattle, Washington. Letter to Bill Wisniewski (opposing standardized pre-emphasis and 5 kHz nighttime filters), January 16, 1984.

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Mann, Thomas L., NBC Radio. Memo to Subcommittee (reporting on survey of AM antenna bandwidths at 1300 kHz), March 27, 1984.

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Resnick, Al, WLS Radio Engineering, Chicago, Ill. Memo to Ken Brown, ABC, with references and technical papers on Transient Intermodulation Distortion, April 5, 1984.

Serafin, John, ABC Engineering, New York. Memo to Subcommittee (ABC position paper on AM and draft report; Al Resnick studies on synchronous detectors at WLS and AM receiver selectivity characteristics; various technical attachments), March 26, 1984.

Werrbach, Donn R., Broadcast Engineer, Honolulu, Hawaii. Letter to Bill Wisniewski (opposing AM standard pre-emphasis; opposes nighttime filters; sees some interference resulting from unstable transmitters at high modulation levels (together with transmitter intermodulation distortion); suggest 8 ways to improve AM), February 7, 1984.

Wood, J. Robert, General Manager, CHUM Radio, Toronto, Canada (some AM interference is attributable to "small amounts" of overmodulation; urges careful monitoring and use of a "soft clip"), February 7, 1984.

White, James P., VP and General Manager, WSPD Radio, Toledo, Ohio, Letter to Subcommittee (opposing 5 kHz filters; supporting the Orban/Gregg standard pre-emphasis curve; supporting Kann's receiver variable sideband filter circuit), December 2, 1983.

C. Conversations and Discussions

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