NRSC REPORT

NATIONAL RADIO SYSTEMS COMMITTEE

NRSC-R200
NRSC Noise Report
November 2001

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FOREWORD

NRSC-R200, NRSC Noise Report, was prepared by iBiquity Digital Corporation to describe analyses done on the level of noise in the FM broadcast band. The DAB Subcommittee chairman at the time of adoption of NRSC-R200 was Milford Smith; the NRSC chairman at the time of adoption was Charles Morgan.

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.

NRSC Noise Report

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Noise Levels in the FM Band

From the earliest days of FM IBOC research and development, efforts were made to determine existing noise levels in the FM band. In preparation for the CCIR Study Group Meeting, January 1993, USA Digital Radio, USADR, contacted Hammett and Edison, H&E, consulting engineers to produce coverage maps of the proposed IBOC system. In this CCIR filing, USADR relied upon the H&E recommendation of 30,000 K as representative of urban noise levels.

In early 1998 field testing performed by USADR it was discovered that the noise levels in the Northeast region of the US were well in excess of 30,000 K. The field test crews typically observed noise levels of 200,000 K in the Baltimore, Washington area. In these tests the crews found that the noise in the FM spectrum was 10 dB higher than in the adjacent Channel 6 and VHF aircraft bands.

Investigations were conducted to determine if these effects were caused by out of band emissions from the FM transmitters operating in the FM band. iBiquity testing and discussions with the FM transmitter manufacturers determined transmitters were not the source of the elevated noise levels in the FM band.

Careful observations of the noise spectra indicated the noise was actually the accumulation of a finite number of non-coherently added FM interferers. To test that theory a study was conducted with MLJ, Moffett, Larson, and Johnson, Consulting Engineers. A second study with further refinements and differing criteria was conducted by H&E to confirm the noise levels in the FM Band.

MLJ Noise Study

In this theoretical study field strengths were calculated from potentially interfering co-channel stations within a desired station's protected contour. To consider location variation, sample receiving locations were considered throughout a station's protected coverage area. Calculations of field strength were made at a series of receiving locations consisting of "cells" or "bins" of two minutes of latitude and longitude. Terrain between an interfering station and a receiving location can affect field strength. As in other cases such as Digital Television (DTV) interference studies, the Longley-Rice propagation model was used to take the effect of terrain into account. At a given receiving location, multiple co-channel stations can contribute to the ambient signal level. To consider multiple stations, calculated field strength was converted to received power and the power from individual stations was added. This procedure is comparable to that used in AM nighttime interference calculations.

The results of computer calculations for multiple stations were checked with calculations considering one station at a time and adding the interfering powers. Time fading, as considered in the Longley-Rice and FCC propagation models, is long term fading which is affected by tropospheric weather prevailing in an area. Thus, multiple signals are expected to be correlated so that adding 10 percent of the time powers is reasonable. Total received power was then converted to field strength to yield equivalent ambient co-channel noise level. Calculations were performed for a receiving antenna height of 1.8 meters above ground. A height of 9 meters (30 feet) is standard for FM, however the lower height is more representative of actual reception height used by listeners.

There are 100 FM channels. To gain understanding of the distribution of co-channel interference levels, ten channels were selected for study. The channel allocation procedure is not constant across the FM band. The twenty lowest channels in frequency are reserved for non-commercial educational use; these channels are allocated on the basis of avoiding the overlap of predicted interfering and coverage contours. Directional antennas are often used and there tends to be great disparity in the facilities of stations in the same class. Allotments in the non-reserved band are made on a distance separation basis, although there are many instances of short spacings between stations. Many of these arose before the present distance spacings were adopted. Only Class A operation originally was permitted on twenty of the eighty non-reserved channels. While higher class operation is now permitted on these channels, the distribution on the stations is generally much different than on the other commercial channels. Only stations in the conterminous 48 states were included. Channels across the band were to represent a regular distribution of the allotments.

The program calculated summed co-channel interfering signals at each cell and reported the minimum, maximum and median of the results for each station. When all potential interfering stations are distant from a desired station, calculated noise level may be less than thermal noise. A value of 0 dBu is approximately equivalent to noise expected at "quiet' rural locations. In this case the total noise figure (receiver plus ambient) was assumed to be 4 dB. The results are presented in Table 1.

The MLJ Study concluded that the median co-channel noise level (field strength exceeded 10% of the time) within the protected contour for FM stations is approximately 25 dBu, which is about 25 dB above the noise level of a rural location in the absence of significant FM interference. The co-channel noise level in the northeast region is approximately 4 dB higher.

Dataworld Maps

The data from the MLJ study was used by Dataworld to create maps depicting the noise levels in the US. In these maps the desired signal is removed within its protected contour leaving only the sum of the co-channel interferers. Examining the areas of the map contained within the protected contour of each station one can see the levels of the total co-channel interference. Three sample maps are included in this report. The first map is of 104.9 MHz, representing a channel that was formerly reserved for Class A stations. The second map is of 91.1 MHz, representing a channel in the reserved band. The last map 100.7 represents a Former Class B/C channel.

H&E Noise Study

iBiquity requested that Hammett & Edison take an independent approach in the preparation of its study model, but in a way that would be comparable to the MLJ data presentation. There were four major differences in methodology employed by Hammett & Edison in conducting the study project, the results of which are presented in this report. First, a "channel mask" model was employed to evaluate the anticipated characteristics of actual co- and adjacent-channel stations within a selected 200 kHz study bandwidth operation. Second, all calculated data points in station coverage areas were used in median calculations. Third, a calculated theoretical minimum (kTB) noise floor, that being about -9 dBu for a 200 kHz-wide channel was assumed in the calculations. Finally, vertical polarization was selected in the Longley-Rice propagation calculations, since that mode is predominant in mobile FM reception, although actual differences for the polarization employed were found to be slight.

To study "real world" channel characteristics, a series of statistical occupied spectrum analog masks were developed as shown in Figures 1A, and 1 B.

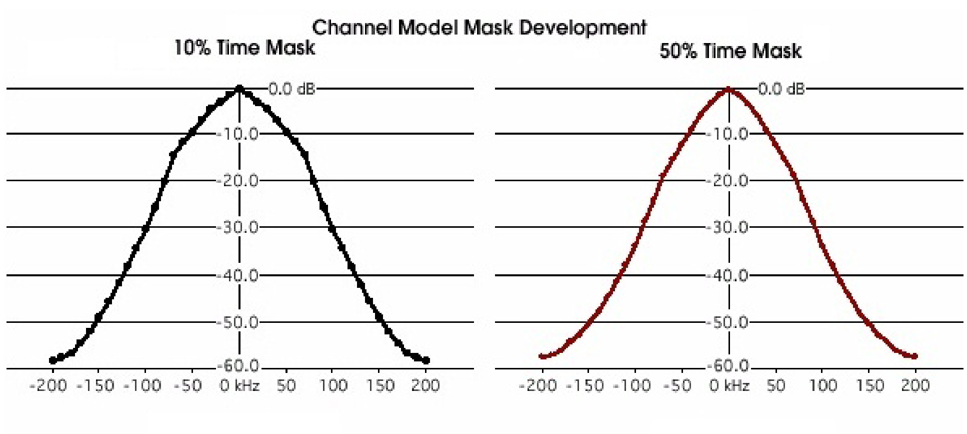

Figure 1A Figure 1B

The analog masks were developed using measurements and statistical analysis of 7 strong local FM signals in the San Francisco radio market. The signals included two non commercial public stations, one classical-format station, and four popular music/oldies/rock-format stations. Each station was observed on an RF spectrum analyzer using 3 kHz resolution bandwidth in swept mode, with one sweep per second over a 500 kHz total bandwidth, centered on the observed station carrier frequency. Each station was observed for five minutes, yielding approximately 300 trace sweeps per station.

The H & E study retained use of the Longley-Rice model and the MLJ method for determining the study grid point locations, as well as the specific channels studied. Reserved band Channels 203, 214, 216, and 218 were included, as well as former Class A Channels 232, 280, 285, and 288, along with former Class B/C Channels 222, 229, 239, 241, 253, 260, 264, 273, 281, 294, 297, and 300. The results data, described below, was provided in an expanded but similar and comparable format to the MLJ report.

In initial operation of the noise floor calculation program, the mask data was read from external files, allowing a single run to consider both masks. When the program read in a mask, it interpolated three sets of scalar power multipliers for the co-, upper-, and lower-adjacent-channel cases. Each set has an interpolated value at 10 kHz frequency increments, over which power will be summed across the main channel band.

The main study procedure was as follows: Given an FM channel, the program searches the FCC FM database for co- and adjacent-channel stations. All stations are included, regardless of distance, along with translators and Canadian and Mexican stations; FM boosters and low power FM stations are ignored. During the search, license records are preferred, but construction permit (CP) records are used for facilities that do not have a license. If azimuth pattern data does not exist in the database for a directional facility, a nondirectional pattern was assumed. Transmitting antenna elevation patterns are not applied; the antenna gain at horizontal was always used. Since Canadian and Mexican records in the FCC database normally do not have an indication of status (licensed, CP, application, etc.), all are assumed to be notified and licensed facilities if the technical parameters appear valid.

The study, for each station in the 10 studied channels began by predicting the coverage contour[1] using FCC F(50,50) curves, defining the study area. A grid of points across the study area was created using a latitude and longitude increment of 120 arc-seconds. In the next step each co-channel station in the continental United States was considered as potential contributors to the composite interference. However stations not meeting a level representing 5% of the field of the highest interferer were excluded

The contribution of an undesired source was determined at each point in the grid, at every 10 kHz increment in the studied channel bandwidth. First, the receiver terminal power was determined at a point using the Longley-Rice propagation model. Then the power contribution was summed across the bandwidth of the channel, using the mask data. The power sum accumulators at each point are initialized to a power level computed for "kTB" background noise. Once all undesired sources were accumulated using the study masks, the peak and average result were computed for each point and each mask, and these values are converted back to an equivalent "noise-like" field strength in dBu. Overall statistics for the grid are determined for use in a summary table written to a text output file. The histogram data used to compute the statistical numbers in the final output table was written to a spreadsheet file. The study then proceeds to the next co-channel station in the list.

The study results are presented in Figures 2 A & 2B for one sample single-channel run, Channel 273 (102.5 MHz), and in Figures 3A & 3B, combined for all 20 channels studied. An examination of analog mask graphs for the combined 20 channels shows that the noise levels center about 15 dBu for the 10% case and similarly for the 50% case.

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[1] The coverage contour is 54 dBu for Class B stations, and 57 dBu for Class B1 stations. All other stations have a 60 dBu coverage contour.

Conclusions

Comparing results to the MLJ study, the data under the "analog 10% mask" heading would be most comparable, since a 10% time variability was assumed in that study. Using the MLJ methodology a median noise level was determined to be 25 dBu. (300,000 K). While the H&E methodology showed the level to be closer to 15 dBu. (30,000 K) An examination of the maps confirms that the noise levels in the FM band are within the bounds of both studies. Therefore it is reasonable to assume that on average the noise levels in the FM band, as a consequence of the FCC' allocations is between 15 dBu and 25 dBu

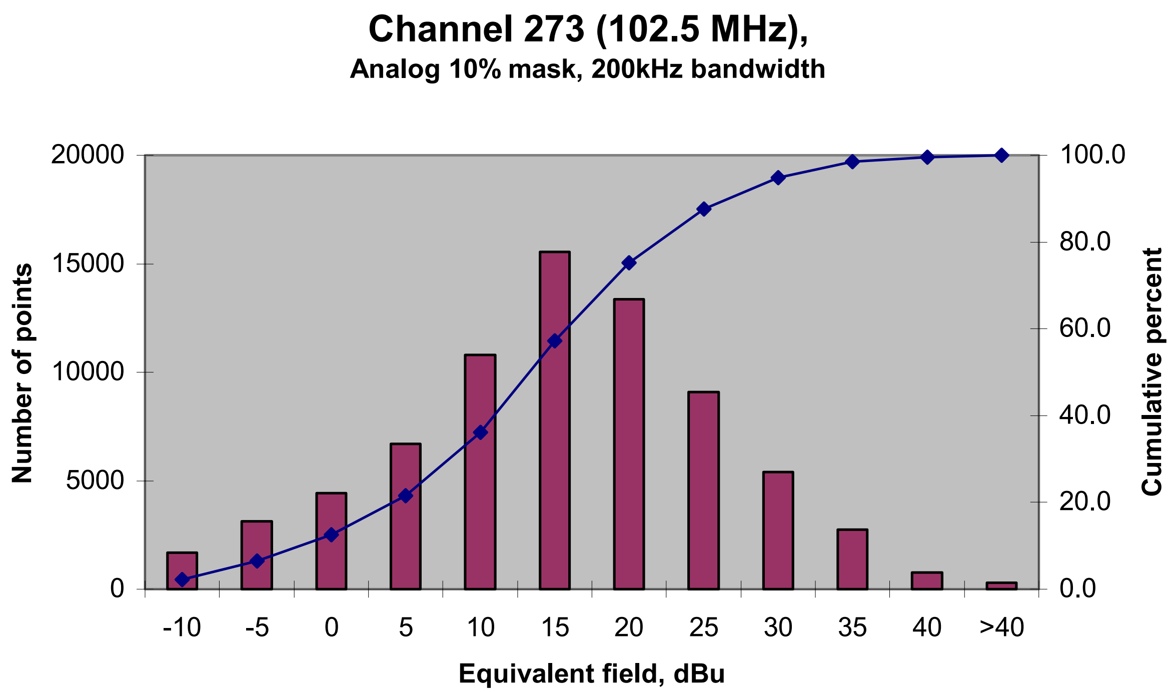


Figure 2A

Channel 273 (102.3 MHz)
Analog 10% 200 kHz bandwidth

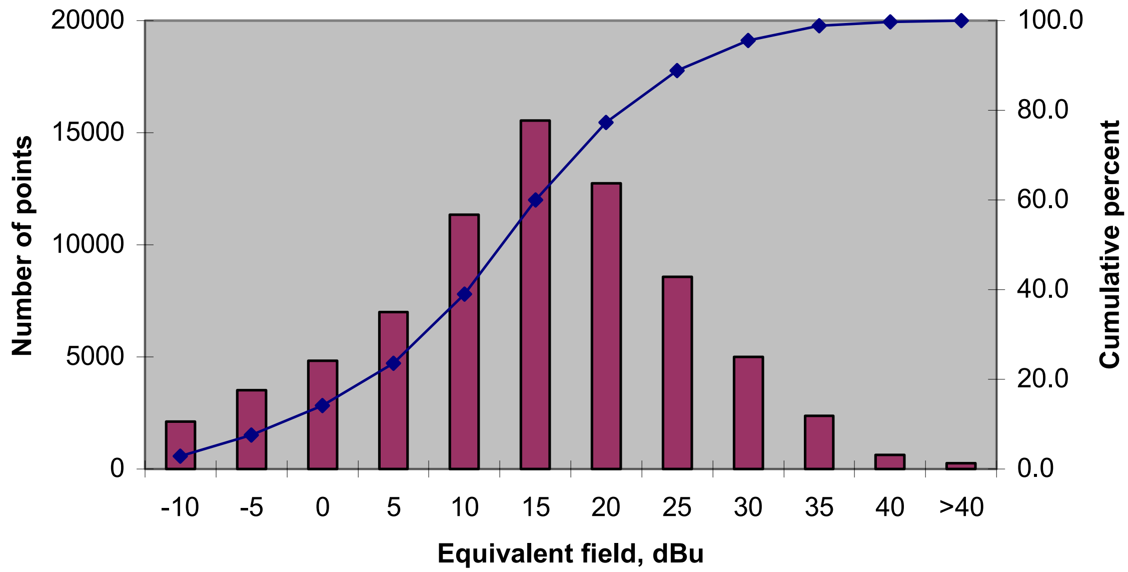


Figure 2B

20 Channels Average
Analog 10% mask, 200kHz bandwidth

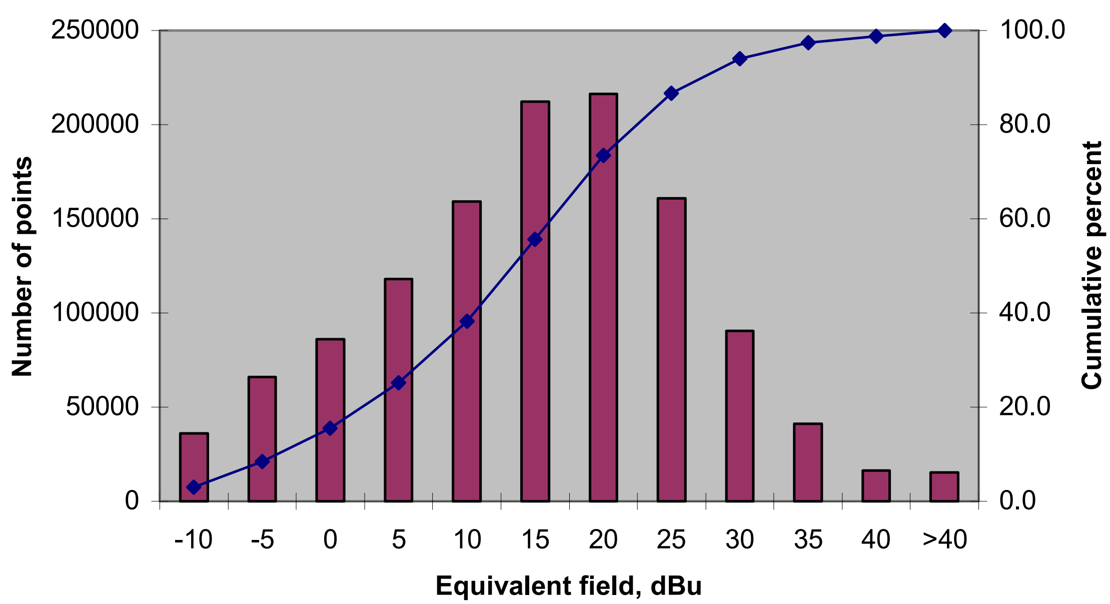


Figure 3A

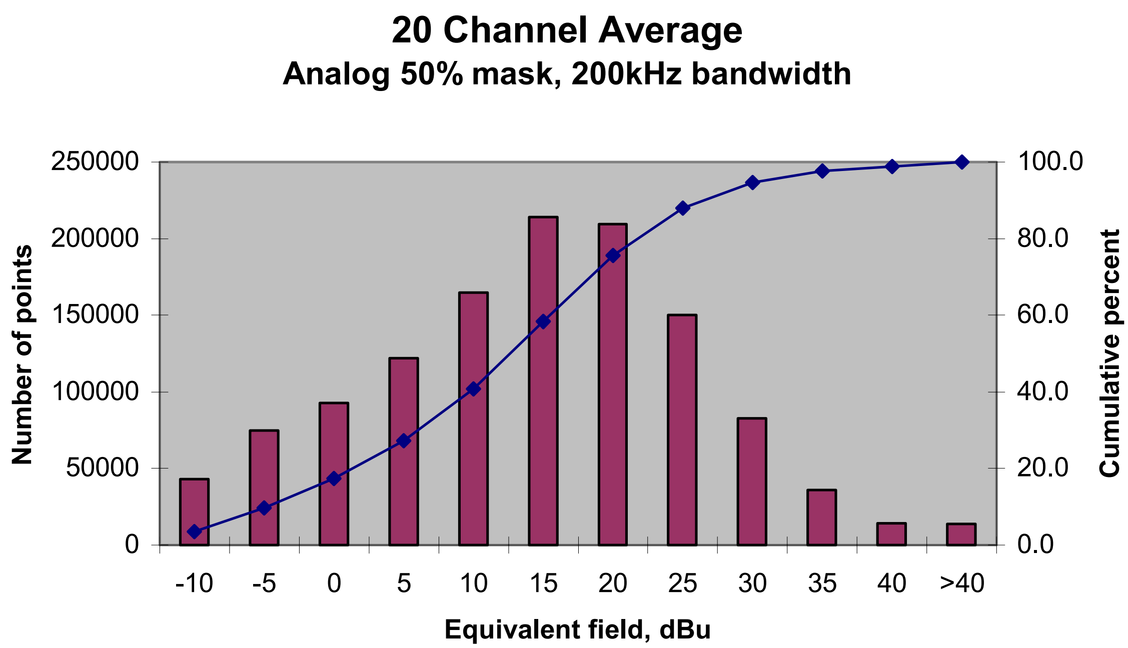
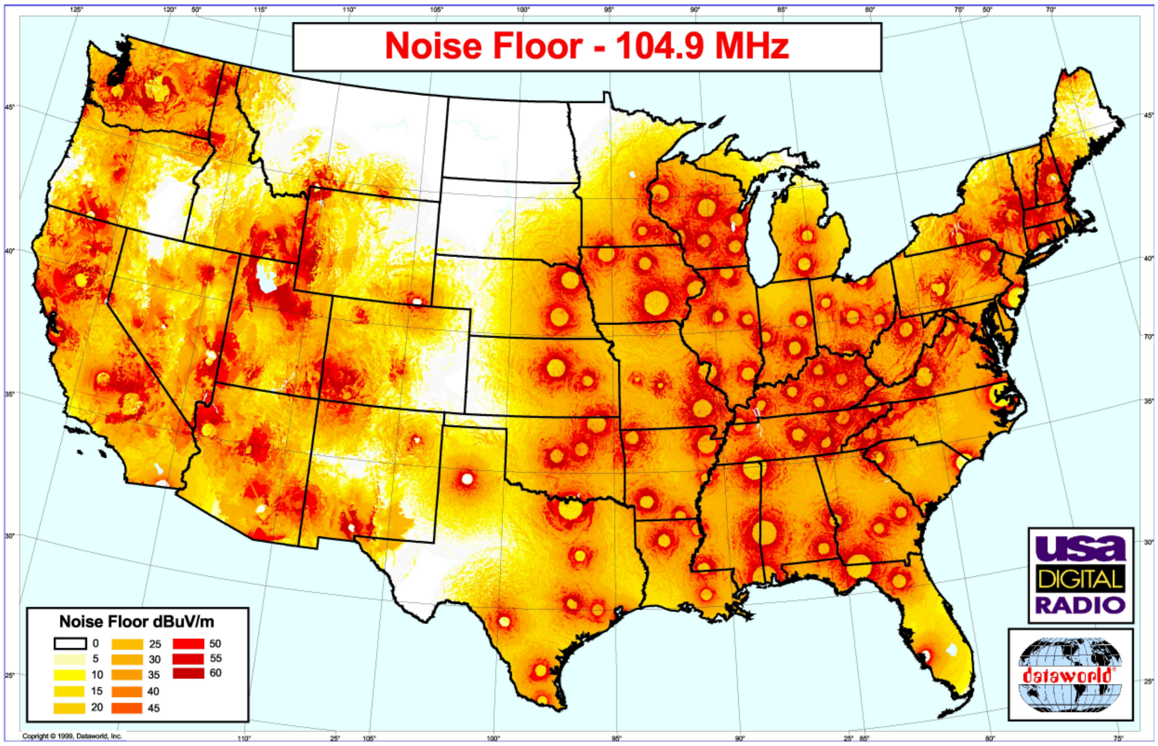

20 Channel Average
Analog 50% mask, 200kHz bandwidth
250000
200000
150000
100000
50000
0
Number of points
100.0
80.0
60.0
40.0
20.0
0.0
Cumulative percent
-10
-5
0
5
10
15
20
25
30
35
40
>40
Equivalent field, dBu

Figure 3B

Table 1
All Channels

Channel	Frequency (MHz)	Field Strength (dBu) 48 States	Northeast
	Reserved Channels		
203	88.5	24.9	31.1
214	90.7	25.5	27.7
216	91.1	26.2	31.7
218	91.5	26.9	33.0
	Median	25.9	31.4
	Former Class A Channels		
232	94.3	25.3	29.4
280	103.9	27.2	29.0
285	104.9	29.6	31.6
288	105.5	27.4	30.3
	Median	27.3	30.8
	Former Class B/C Channels		
222	92.3	23.3	29.4
229	93.7	25.3	28.7
239	95.7	22.2	25.9
241	96.1	24.1	27.7
253	98.5	23.8	26.2
260	99.9	25.2	28.9
264	100.7	24.4	31.3
273	102.5	25.1	27.9
281	104.1	23.7	28.8
294	106.7	23.6	27.0
297	107.3	21.7	27.6
300	107.9	24.5	29.8
	Median	23.8	28.3
	Median - All Channels	25.0	28.9


Noise Floor - 104.9 MHz
Noise Floor dBuV/m
0
5
10
15
20
25
30
35
40
45
50
55
60
usa DIGITAL RADIO
dataworld
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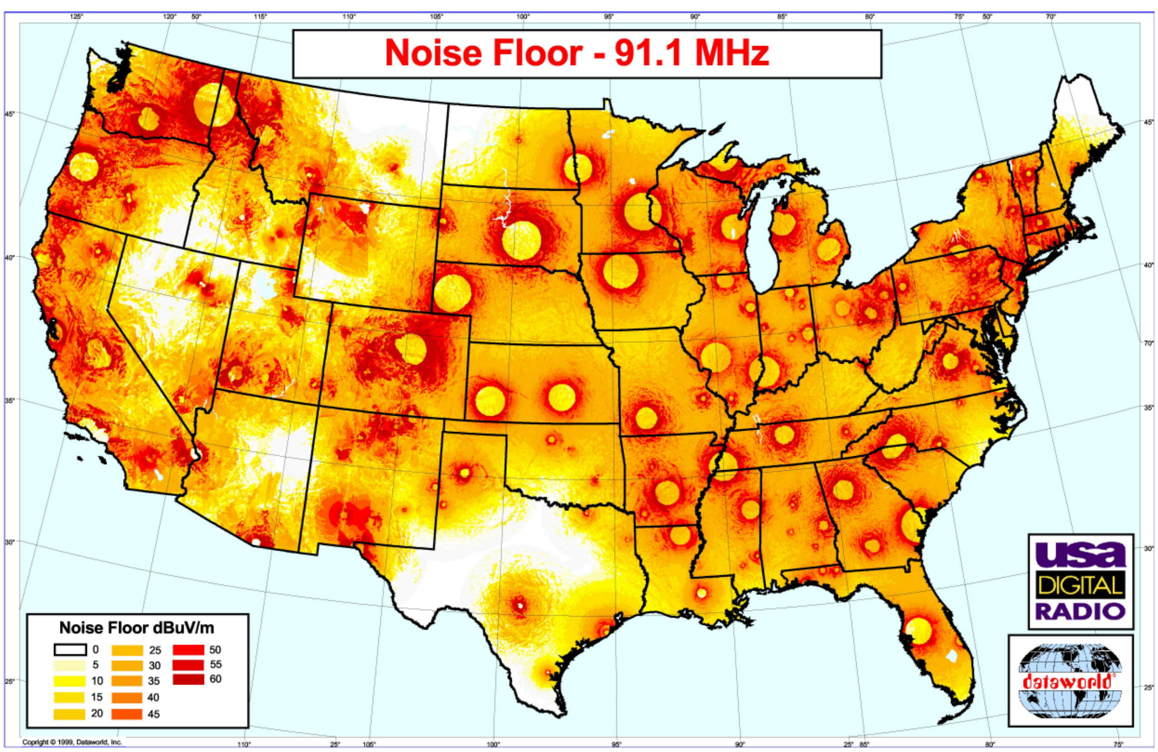
Noise Floor - 91.1 MHz
Noise Floor dBuV/m
0
5
10
15
20
25
30
35
40
45
50
55
60
usa DIGITAL RADIO
dataworld
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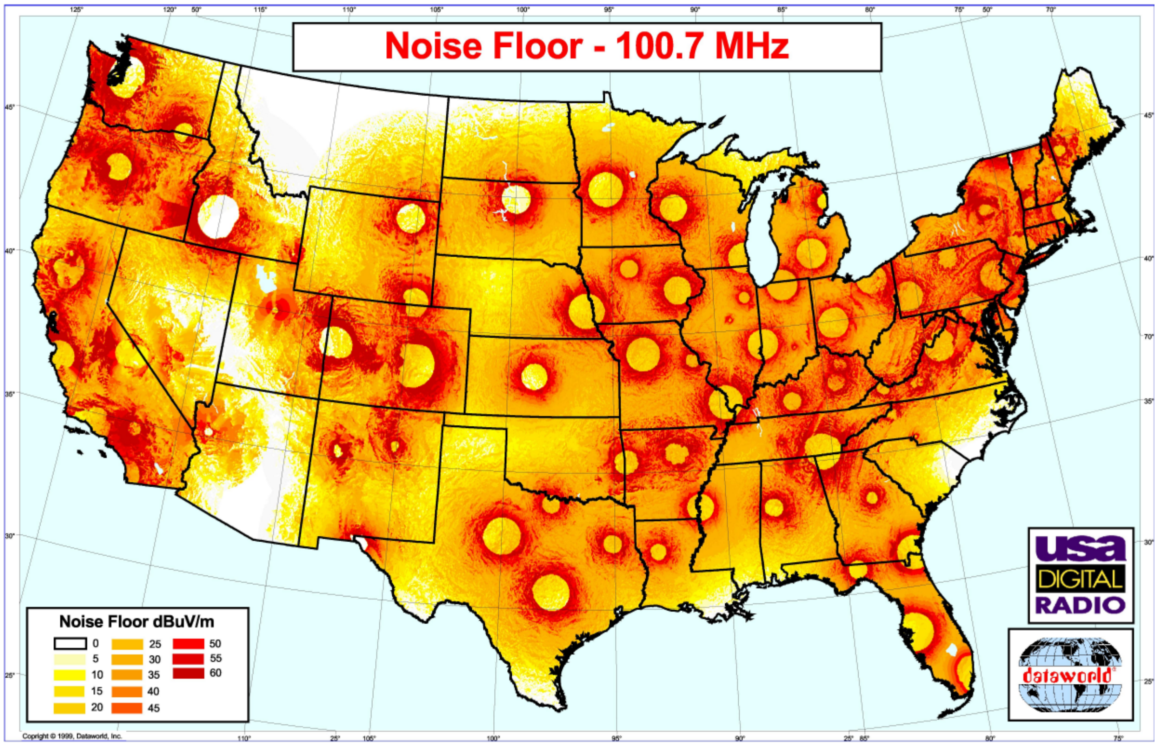

Noise Floor - 100.7 MHz
Noise Floor dBuV/m
0
5
10
15
20
25
30
35
40
45
50
55
60
usa DIGITAL RADIO
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