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Proposed Techniques for Adding FM Broadcast Stations in a Major Market

Part II

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PROPOSED TECHNIQUES FOR ADDING FM BROADCAST STATIONS IN A MAJOR MARKET, PART II

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This is a companion document to another NTIA Report, "Proposed Techniques for Adding FM Broadcast Stations in a Major Market". Increasing the number of assignments is possible if: 1) co-siting of second- and third-adjacent-channel transmitters is allowed, 2) directional antennas to control both signal coverage and interference are used, 3) reasonable changes to the signal-to-interference protection ratios for co-channel and adjacent-channel operation are adopted, 4) protection to existing facilities rather than maximum allowed antenna height and transmitter power is granted, and 5) the effects of terrain on coverage and interference are considered. To demonstrate the approach of adding assignments to a saturated major market, this second report shows how the number of FM broadcast stations in the Washington, DC, market could be increased from the present 13 commercial and non-commercial stations to 21 assignments.

Recommendations are made which, if adopted, could increase significantly the number of FM broadcast stations in almost all markets.

Key words: co-sited transmitters; directional antennas; FM broadcast; spectrum utilization; terrain

1. INTRODUCTION

1.1 Purpose

Under the current FCC rules, the top 50 FM broadcast radio markets in the United States are saturated; that is, nearly all of the slots in the Table of Assignments (FCC, 1980) are assigned. However, the FM band in these markets is "filled to capacity" only because of the FM rules (FCC, 1962) which establish the Table of FM Assignments. There have been many improvements, over the past 20 years, in the FM broadcasting and receiving equipment and in our ability to predict FM broadcast coverage including both signals and interference; these improvements and techniques could allow many new FM broadcast assignments in the major markets.

The purpose of this study is to investigate the technical capacity of the FM broadcast spectrum and determine if today's equipment and techniques would

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allow utilization of the FM spectrum to be increased, without decreasing the listening quality of FM radio. To bring about the increased capacity, we will consider:

1. the co-siting of second- and third-adjacent-channel transmitters,

2. the use of directional antennas to control both coverage and interference,

3. the effects of reasonable changes to the signal-to-interference protectional ratios for co-channel and adjacent channel operations,

4. the consideration of actual facilities rather than maximum allowed antenna height and transmitter power, and

5. the effects of terrain on signal coverage and interference.

1.2 Objectives

The study's objectives were listed in the first report (Haakinson, 1980). In this report we will use the same approach as outlined in the first report to determine how many new FM broadcast stations could be introduced in another major market.

2. ANALYTICAL APPROACH

We will use computer-based analytical tools (Hufford, 1977) to compute the area and population covered by the desired signals and by the interference. The tools allow us to analyze all of the stations (both existing and proposed), using the same rules, the same data base, and the same methodology. The approach[1] is:

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[1] In a fully developed system for analyzing FM applications or for engineering new facilities, the selection of the best facility/coverage alternative will involve the station owners. For the new owner, "best" may be limited by:

1) how much he/she is willing to pay for site selection with terrain features, transmitter power, antenna tower height, directional antennas, etc., or

2) where or what size of audience he/she is trying to reach.

Using tools such as proposed here, the new owner can analyze for himself/herself the trade-offs between transmitter antenna site, transmitter power, antenna height, directional antenna patterns, and coverage area.

1. To define the signal level to be protected for each class,

2. To define the minimum allowed signal-to-interference (protection) ratio required at the protected signal contour,

3. To compute the protected signal contour for an existing station,

4. To evaluate facility alternatives for a proposed new station or a modified existing station, and

5. To compare area and population of coverage for the alternatives.

3. DEMONSTRATION

In this section we will choose a major FM market to demonstrate how we propose to increase the capacity of the selected market's "saturated" FM broadcast band. We will use the approach as described in Section 2. After selecting the market, we will determine from the FCC data base the locations and station characteristics of the existing assignments in the region. We propose to increase the number of stations by adding second- and third-adjacent-channel stations, by adding IF-response-channel stations, by using directional antennas, and by using terrain effects to determine actual coverage and interference contours. Finally, for each proposed channel assignment, we will demonstrate what potential area and population are covered for proposed values of transmitter site location, power, antenna height, and directional antenna pattern.

3.1 Selection of Market

We have chosen the Washington, DC, region, one of the top 10 radio markets (see Table 1 for comparative ranking), to demonstrate the addition of new assignments to a major market.

3.2 Current Assignments

We have searched for and considered in the study all of the FM assignments[2] in the FCC data base within 150 mi (241.4 km) of our Washington, DC, reference location (38.9400 deg north, 77.1000 deg west). The 150-mi range includes all stations that could be co-channel with proposed

[2] The complete list is available from the author.

Table 1. Commercial and Non-commercial Radio Stations in Large Markets, 1979 (From FCC (1979) Table 3)

Total # Stations	Market	Commercial # AM	Stations # FM	Noncommercial # NPR	Stations # Other
64	Los Angeles	29	28	4	3
59	Chicago	22	24	1	12
54	New York	23	22	3	6
42	San Francisco	18	16	3	5
40	Boston	16	15	2	7
37	Dallas-Fort Worth	16	15	1	5
36	St. Louis	14	11	1	10
36	Seattle	19	12	1	4
36	Washington, D.C.	18	13	2	3
35	Detroit	15	18	1	1
35	Pittsburgh	18	12	2	3
34	Philadelphia	15	14	1	4
31	Atlanta	18	8	1	4
31	Houston	14	12	1	4
31	Miami-Miami Beach	13	14	1	3
30	Norfolk-Portsmouth-Newport News-Hampton	14	11	1	4
30	Minneapolis-St. Paul	15	7	3	5
29	Tampa-St. Petersburg	18	9	1	1
28	Cleveland	11	13	1	3
28	Phoenix	19	8	1	0
28	Portland	15	10	3	0
28	San Diego	13	12	1	2
28	Denver	17	10	1	0
27	Baltimore	13	10	2	2
25	Cincinnati	11	8	1	5
25	Kansas City	11	10	1	3
24	Hartford-New Britian	9	10	0	5
24	Milwaukee	10	11	1	2
24	San Antonio	13	9	0	2
23	Honolulu	17	5	0	1
23	Jacksonville	14	7	1	1
22	Albany-Schenectady-Troy	9	8	2	3
22	Louisville	11	7	3	1
22	Memphis	10	7	1	4
22	New Orleans	11	8	1	2
22	Oklahoma City	9	12	0	1
22	Orlando	9	9	0	4
21	Fresno	12	7	1	1
21	Indianapolis	8	6	1	6
21	Riverside-San Bernardino-Ontario	9	8	1	3
21	Albuquerque	12	6	0	3
20	Birmingham, Ala.	11	7	1	1
20	Buffalo	8	9	3	0
20	Raleigh-Durham	10	6	0	4
20	Salt Lake City	14	6	0	0
20	Spokane	10	6	0	4
19	San Juan	12	6	1	0
19	Nashville	10	6	1	2
19	Sacramento	9	9	0	1
19	Scranton	10	5	1	3
18	Richmond, Va.	11	5	1	1
18	Columbus, Ohio	7	6	3	2
18	Springfield-Chicopee-Holyoke	9	3	0	6
18	Syracuse	8	8	1	1
17	Colorado Springs	8	7	0	2
17	Portland, Maine	6	10	1	0
17	Greensboro, N.C.	8	5	0	4
17	Tucson	10	5	2	0
17	West Palm Beach	9	6	1	1
17	El Paso	10	6	1	0
16	Chattanooga	8	6	0	2
16	Columbia, S.C.	6	6	1	3
16	Rochester, N.Y.	6	7	1	2
15	Allentown, Pa.	7	5	0	3

Table 2. Channel Assignments and Facility Characteristics of the Washington, DC, FM Broadcast Stations

Channel	Call Sign	Class	Power ERP (kW)	Antenna Height Above Average Terrain (ft)	(m)	Location Latitude (deg N)	Longitude (deg W)
203	WAMVFM	B	50	500	152.4	38.9358	77.0925
207	WPFM	B	50	410	125.0	38.9358	77.0925
211	WGTBFM	B	7	440	134.1	38.9358	77.0925
215	WETAFM	B	75	610	185.0	38.8917	77.1319
230	WKYS	B	50	480	146.3	38.9400	77.0817
242	WHURFM	B	24	670	204.2	38.9503	77.0797
246	WASH	B	23	690	210.3	38.9558	77.0825
254	WMZQ	B	50	490	149.6	38.8867	77.2014
258	WGAYFM	B	21	770	234.7	38.9636	77.1050
262	NEW	B	20	485	147.8	38.8867	77.2014
266	WWDCFM	B	50	500	152.4	39.0003	77.0578
278	WGMSFM	B	47	510	155.5	38.9358	77.0925
297	WRQX	B	36	590	179.8	38.9503	77.0797

Washington, DC, Class B stations. Table 2 lists the channels assigned to Washington, DC, and the stations' characteristics. There are 10 non-commercial and commercial assignments serving Washington, DC, whose transmitters are located within 1.5 mi (2.4 km) of one another. In addition, 4 transmitters are co-sited at one location (channels 203/207/211/278), and 2 transmitters are co-sited at two other locations (channels 242/297 and channels 254/262). In total, there are 17 transmitters clustered within 7 mi (11.3 km) of one another serving Washington, DC, and other communities. All of the Washington, DC, assignments are separated by at least 4 channels; Baltimore's 10 Class B stations have been given assignments that alternate in the every-fourth-channel assignment pattern with Washington, except for Baltimore's Channel 205 which is a second-adjacent-channel assignment to Washington's Channels 203 and 207. Other assignments in the every-fourth-channel pattern have been given to Takoma Park, Bethesda, Arlington, Woodbridge, etc. Thus, by the FCC's current separation rules, the Washington, DC, FM broadcast band has reached capacity.

3.3 Potential New Assignments

Our first step in deciding whether new assignments may be introduced is to determine what signal level is to be protected. For this example, we will stay with the present rules and use the equivalent field strengths at 40 mi (64.4 km) for Class B stations and at 15 mi (8.05 km) for Class A stations. We will use 55 dB V/m (sometimes shortened to dBu) for Class B (the signal strength at 40 mi for a full facility class B station) and 59 dB V/m for Class A as the signal levels to be protected. Our next step is to decide what signal-to-interference protection ratios should be used. Table 3 shows what we believe to be reasonable ratios based upon today's good quality receivers and compares the ratios with the current requirements given by the FCC (1962). These proposed values are based on measurements of receivers as reported in popular audio magazines and by Quadracast Systems, Inc. (1979). From these data, today's receivers provide 30 dB of audio signal-to-interference ratio when the rf signal-to-co-channel interference ratio is 1 to 2 dB and when the rf signal-to-second adjacent channel interference ratio is -50 dB.

Table 3. Signal-to-Interference Protection Ratios for New Assignment Demonstration

Interference Condition	Proposed Required Signal-to-Interference Protection Ratio (dB)	Current Required Signal-to-Interference Protection Ratio (dB)
Co-channel	14	20
Adjacent channel		
First	0	6
Second	-50	-20
Third	-50	-40
IF Response	-50	---

Assuming that we are now free to test vacant channels for new assignments, Table 4 shows where we will attempt to bring new stations to Washington, DC. If all could be successfully introduced, the total number of FM broadcast stations assigned to Washington, DC, would increase from 13 to 24.

3.4 Alternatives for Proposed Facilities

In this section we will provide some possible facility characteristics for the proposed assignments given in Table 4. All of the assignments will be made to serve Washington, DC, although in practice we probably would want some of the stations to cover surrounding communities. To keep the interference to manageable and acceptable levels, we will co-site (wherever it is feasible) the facilities with existing second- and third-adjacent-channel transmitters, and we will use directional antennas for the proposed facilities. Finally, we will adjust transmitter power, antenna height, and the directional pattern to give acceptable levels of coverage and interference. When we compute the interference contours, we will use both sets of interference thresholds as given in Table 3; i.e., plots will be given with the current interference thresholds and plots will be given with the proposed interference thresholds.

For this study when directional antennas are used to reduce interference effects, we will utilize one of three simple dipole arrays for demonstration. Directional antenna 1 is a single dipole with a reflector to give the pattern

Table 4. Proposed New Washington, DC, FM Broadcast Assignments

Proposed Station Channel	Proposed Station Location and Antenna Pattern (If Different From Omni-directional)
209	Co-site with channels 207 and 211's transmitter
213	Co-site with channel 211's transmitter, near 215's transmitter
232	Co-site with channel 234's transmitter, near 230's transmitter
244	Co-site with channel 242's transmitter, near 246's transmitter
248	Co-site with channel 246's transmitter, directional antenna needed with null towards 250's transmitter
252	Co-site with channel 254's transmitter, directional antenna needed with null towards 250's transmitter
260	Co-site with channel 258's transmitter, near 262's transmitter
264	Co-site with channel 266's transmitter, near 262's transmitter
268	Co-site with channel 266's transmitter, directional antenna needed with null towards 270's transmitter
276	Co-site with channel 278's transmitter directional antenna needed with null towards 274's transmitter
284	Co-site with channel 286's transmitter, directional antenna needed with null towards 282's transmitter

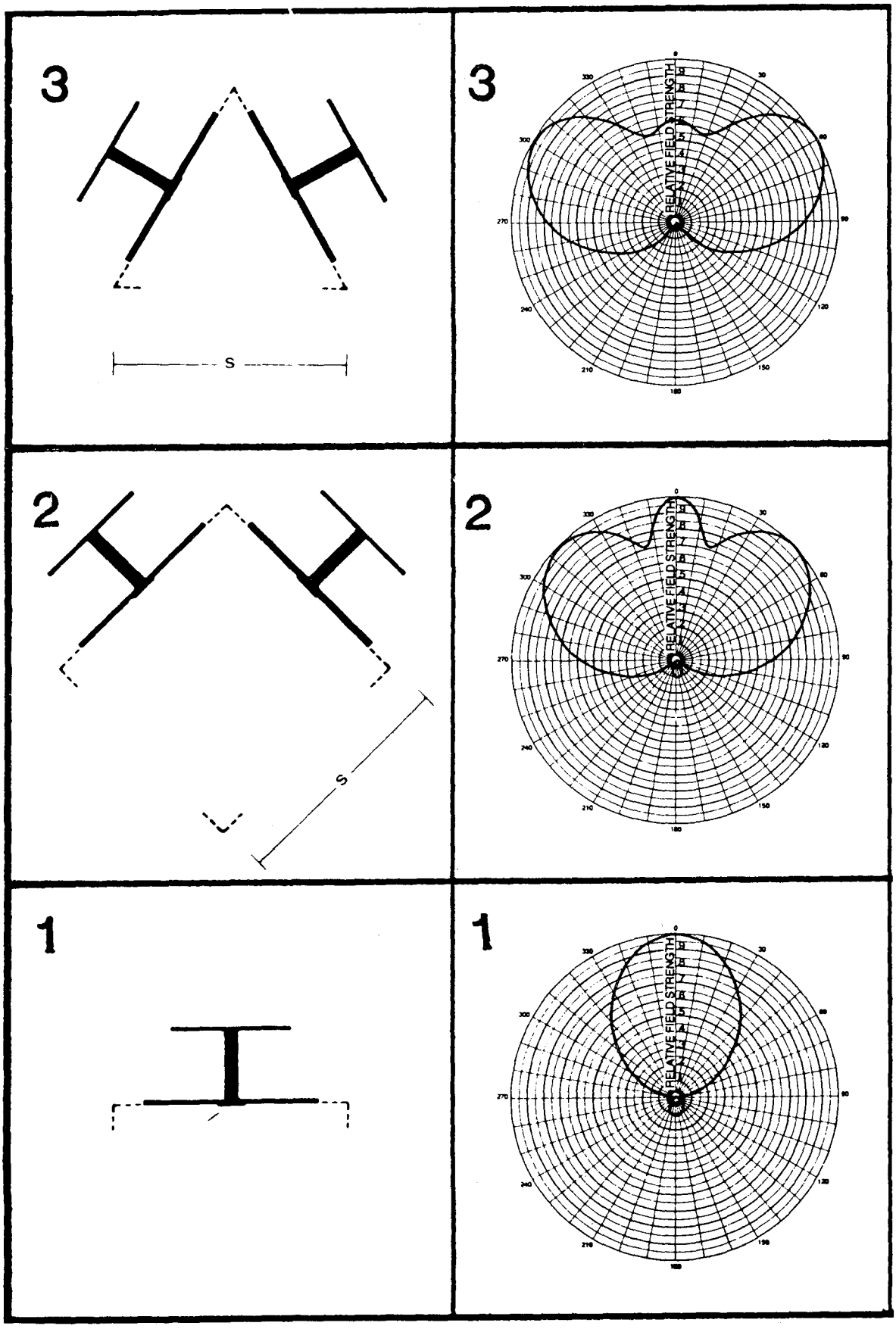

Figure 1. Commercial directional antennas and patterns for FM broadcast band. Patterns are shown on a voltage scale.

shown in Figure 1. Directional antenna 2 has two dipoles, with reflectors, offset 90 deg to give the second pattern shown in Figure 1. directional antenna 3 has two dipoles, with reflectors, offset by 120 deg to give the third pattern shown in Figure 1. Of course, there are many other patterns that are possible and could be used in place of these three.

As an example, we will consider a proposed assignment on Channel 268. From the FCC's FM data base, there are two co-channel assignments, i.e., WFVAFM located in Fredericksburg, VA, and WAYZFM located in Waynesboro, PA, and one second-adjacent channel assignment, i.e., WLIF located in Baltimore. We propose to site the new transmitter near either channel 266 or 272 (whose transmitter's are located less than 0.8 mi (1.3 km) from each other). This follows our recommendation to co-site new transmitters with existing second- and third-adjacent channel transmitters. The coverage from a 10 kW, 300 ft (91 m) HAAT (height above average terrain) transmitter, located at 39.0003 deg north and 77.0578 deg west, to the 55 dB μV/m contour is shown in Figure 2. The number of people within this contour is estimated to be 2,760,800 and the area served is 1699 mi^2 or 4400 km^2. The method of computing the signal coverage uses the FCC curves F(50,50) as modified by the local terrain (Hufford, 1977).

To compute the effects of interference, we will use the FCC curves F(50,10) and the current set of interference criteria as given in Table 3. The results are plotted and shown in Figure 3. The solid contours are the coverage contours from the existing co-channel and second-adjacent-channel stations (WAYZFM, WFVAFM, and WLIF). The dashed contours indicate where the interference criterion has been met and the cross-hatched areas indicate regions of unacceptable interference within the coverage contour. For each assignment, we have listed the computed estimate of population and area within the service (solid) contour. Below that, we have listed the population and area that is within the coverage contour but that also receives interference above the stated criterion (dashed contour). Figure 4 illstrates how the interference regions change when the proposed interfernce criterion of Table 3 is used.

To remove the interference outside of the coverage contours, we could reduce the proposed transmitter's power or antenna height. Instead, we propose to use a directional antenna.

Figure 5 shows the coverage from a directional antenna with a slight modification from that shown for antenna number 3 in Figure 1 (we have

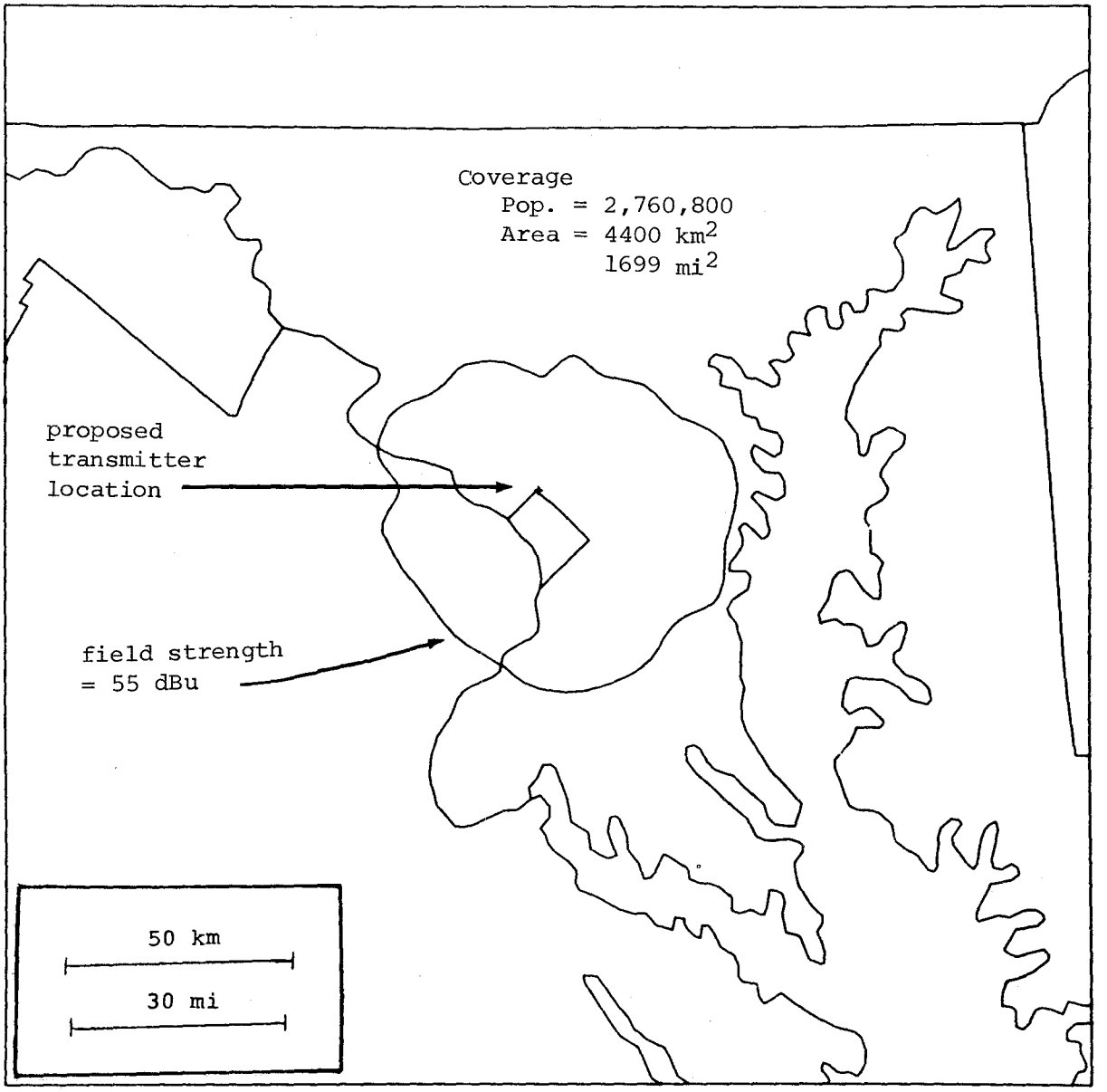

Figure 2. Proposed channel 268 at 10 kW, with a 300 ft (91.4 m) HAAT omni-directional antenna.

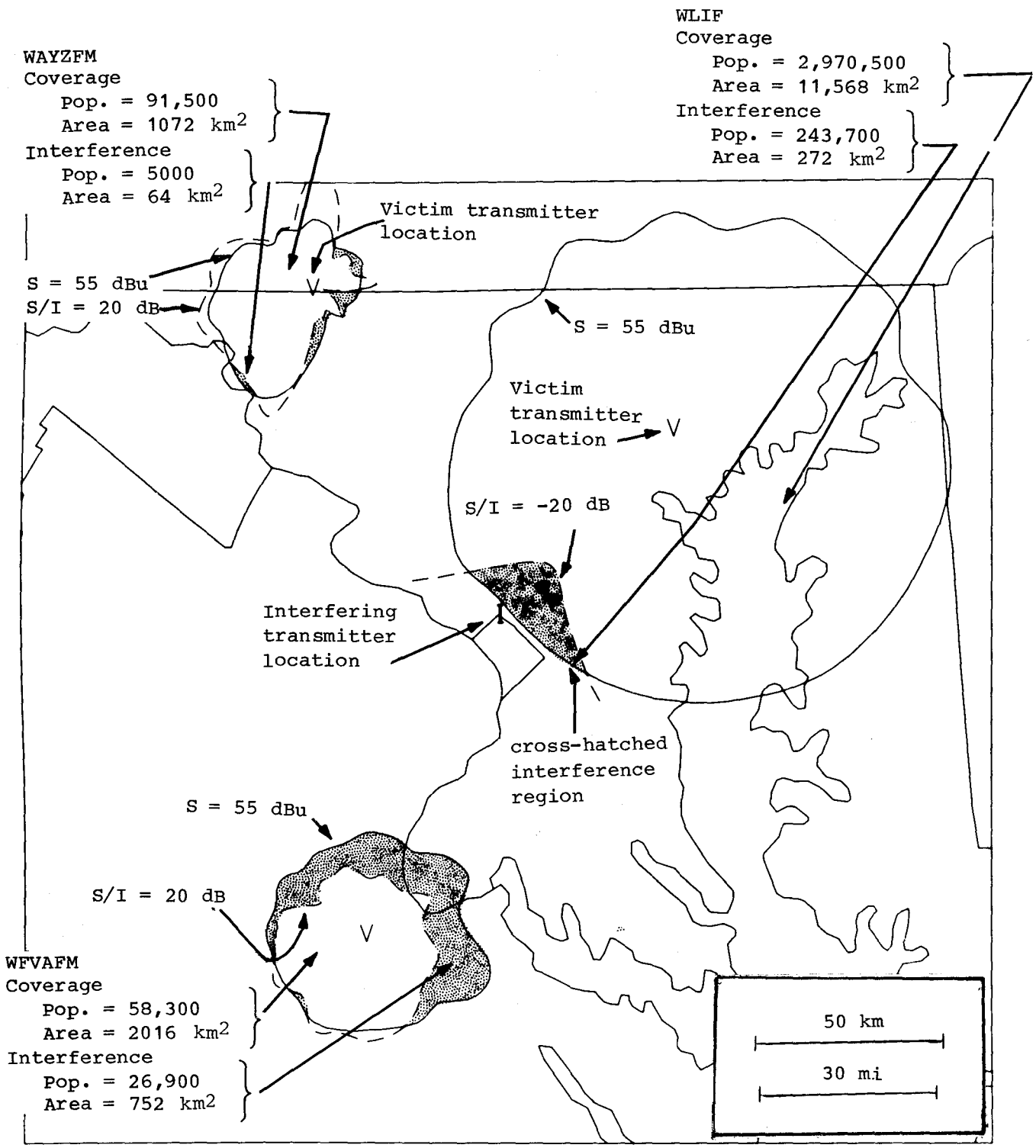

Figure 3. Interference as calculated by using existing protection standards to co-channel and second-adjacent-channel stations on channels 268 and 270 from a proposed facility on channel 268.

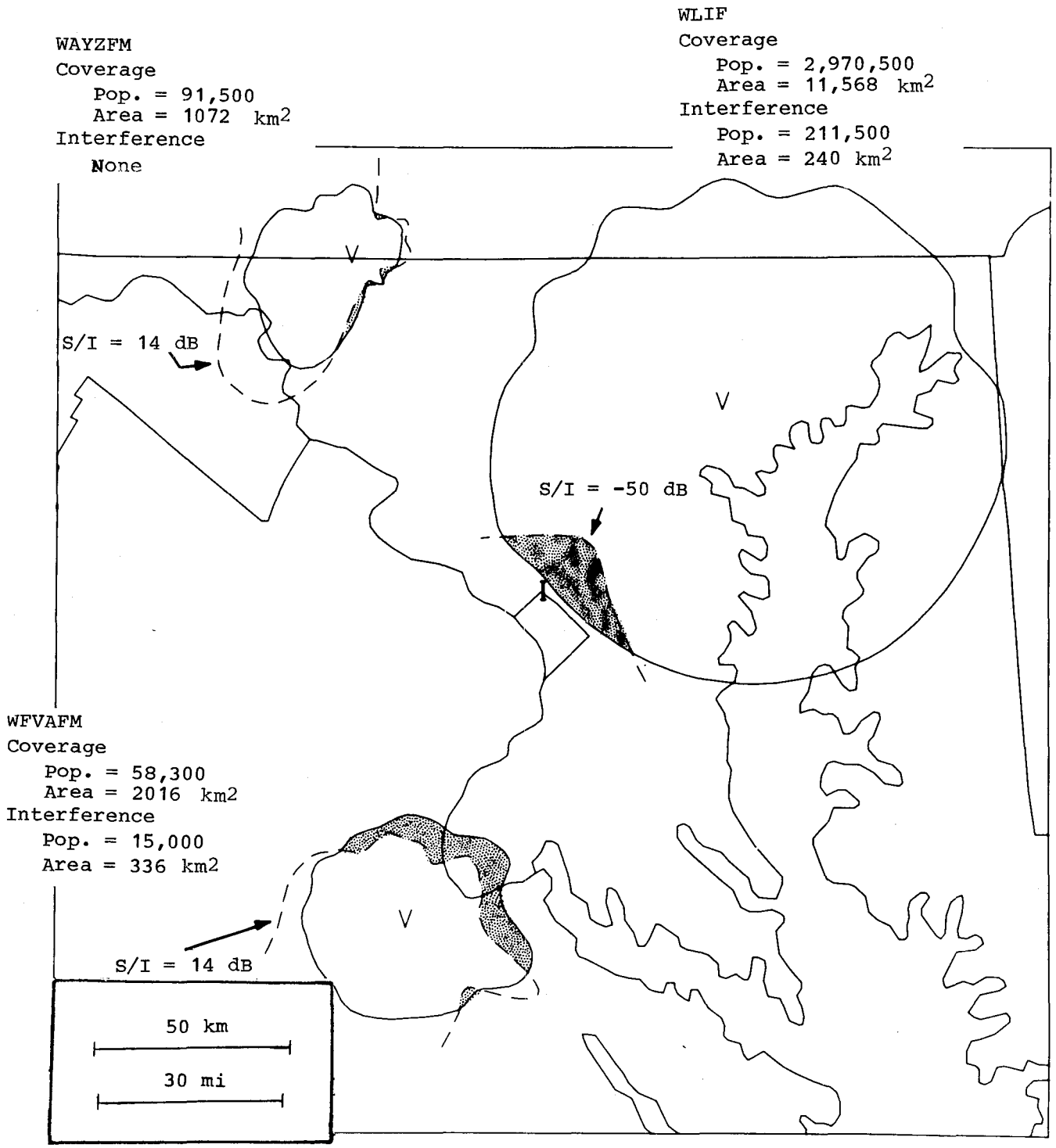

Figure 4. Interference as calculated by using proposed protection standards to co-channel and second-adjacent-channel stations on channels 268 and 270 from a proposed facility on channel 268.

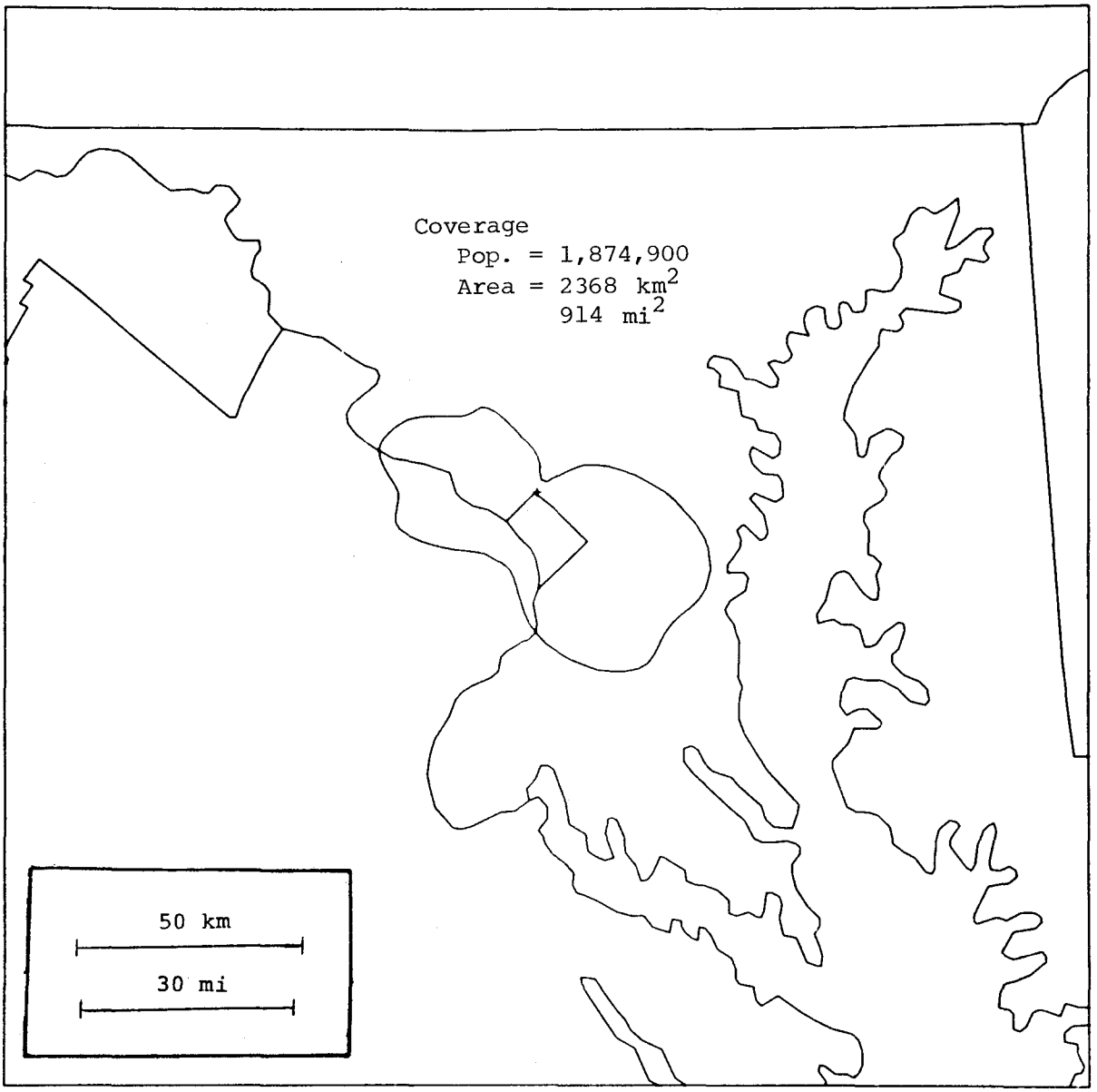

Figure 5. Proposed channel 268 at 10 kW, with a 300 ft (91.4 m) HAAT, directional antenna.

suppressed the small lobe appearing at 0 deg in the pattern). The population served has now dropped to 1,874,900 (a loss of 32 percent of the population compared to that covered by an omni-directional antenna) and the area to 2368 km^3 (a loss of 46 percent). Figure 6 shows the coverage and interference by the existing stations using the current interference criteria; Figure 7 shows the results using the proposed criteria. Note in the latter case, there is no predicted interference within the existing service contours.

For this example, we have 1) used existing characteristics for each station to compute its coverage contour, 2) co-sited our proposed station with existing second- and/or third-adjacent channel transmitters, 3) used a proposed set of interference criteria, 4) utilized a directional antenna for the proposed station, and 5) utilized terrain effects in the calculation of both signal coverage and interference. A similar set of plots[3] for the other proposed stations were computed.

In Table 5, we have summarized the results of locating new stations in Washington, DC.

4. CONCLUSIONS

An examination of the background on the FM broadcast spectrum capacity (Haakinson, 1980) has uncovered some reasons why today's major markets are "saturated":

1. the FCC rules were developed around good quality receivers of the late fifties' technology,
2. the rules assumed that all stations eventually would have the maximum allowed antenna height and transmitter power (maximum facilities) for their class,
3. the rules disallowed the use of terrain-dependent propagation algorithms, and

[3] A complete set of the plots for the other proposed stations is available from the author.

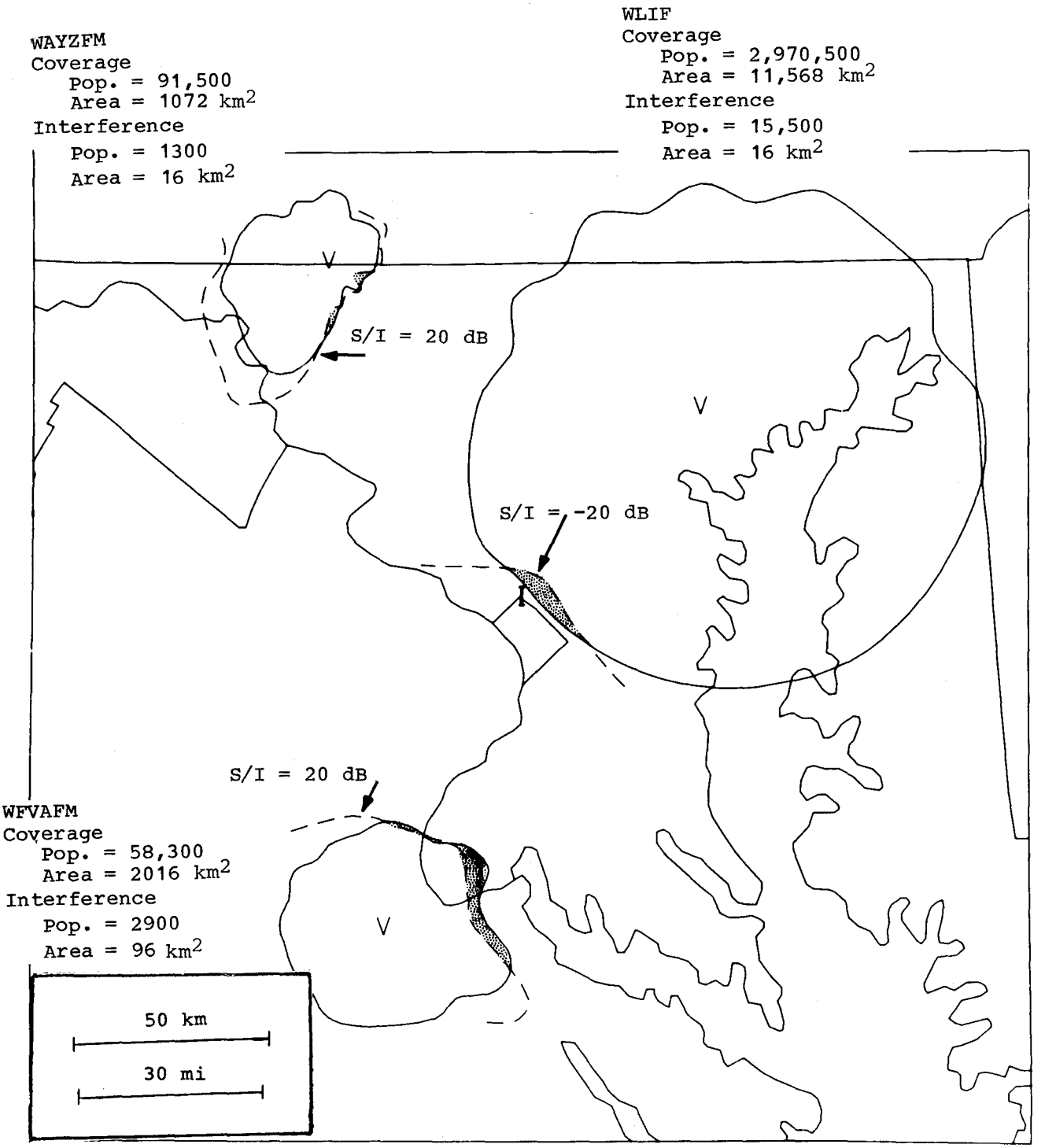

Figure 6. Interference as calculated by using existing protection standards to co-channel and second-adjacent-channel stations from a proposed facility having a directional antenna.

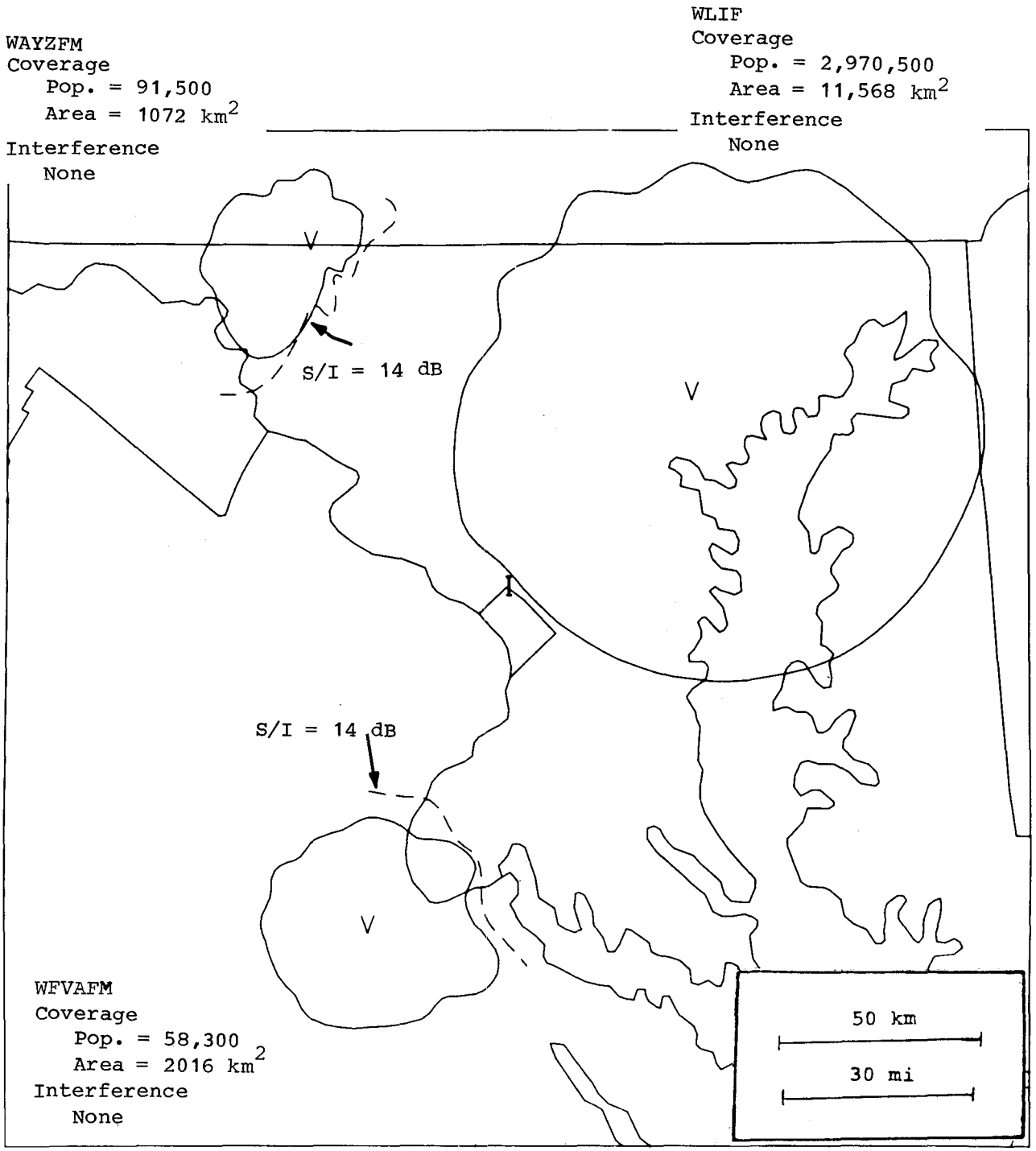

Figure 7. Interference as calculated by proposed protection standards to co-channel and second-adjacent-channel stations from a proposed facility having a directional antenna.

Table 5. Proposed Facilities for Potential FM Stations in Washington, DC

Channel Number	Power ERP (kW)	Antenna Height Above Average Terrain (ft)	(m)	Directional Antenna Pattern No.	Co-located with 2nd Adjacent Channel Transmitters	Requires New S/I Receiver Thresholds	Estimated Population Within 55 dBμ contour
209	10	400	121.9	1	yes	no*	1,791,700
213	50	500	152.4	none	yes	yes	3,311,900
232	25	300	91.4	1	yes	yes	2,984,700
244	20	500	152.4	1	yes	yes	1,783,800
248	10	300	91.4	3	yes	yes	2,144,800
252–260	Unavailable; too much second-adjacent-channel interference						
264	10	300	91.4	3	yes	yes	2,261,800
268	10	300	91.4	3 (modified)	yes	yes	1,874,900
276	Unavailable; too much second-adjacent-channel interference						
284	10	300	91.4	2	yes	no*	1,601,500

* less than one percent of population receives interference with present protection standards

4. the rules disallowed the use of directional antennas for assignment purposes.

Using these and other guidelines, the FCC adopted a Table of Assignments for FM broadcast stations based on minimum mileage separations between transmitters. As a consequence, there are at most 25 out of a possible 100 channels assigned in any one location, when the FCC rules are strictly followed.

In this report, we have selected one of the ten most saturated FM broadcast markets and have demonstrated what we believe are reasonable methods for increasing that market's number of FM stations. In particular, we have shown that the number of FM stations operating in the Washington, DC, region could be increased from the present 13 stations to 21 stations, given the conditions set forth in this report. This was accomplished by using existing facilities rather than maximum facilities, co-siting of second- and third-adjacent channel transmitters with existing transmitters, terrain-dependent propagation algorithms, and directional antenna patterns when required and/or otherwise helpful.

5. RECOMMENDATIONS

We make several recommendations regarding the FM broadcast band:

1. the FCC should use techniques such as those shown in this report to examine easily the new applications for coverage and interference,

2. the effects of terrain should be included in the prediction of signal coverage and interference (although terrain did not have a significant influence in the relatively flat Washington, DC, area),

3. directional antennas should be allowed,

4. co-siting of second- and third-adjacent-channel transmitters with existing transmitters should be encouraged,

5. service area protection should be granted to stations based upon their present (or seriously proposed) facilities rather than protection to the maximum facility allowable for the station's class, and finally,

6. the FM broadcast receiver protection standards should be developed around present-day, good-quality receivers.

We believe that if these recommendations were adopted, the number of FM stations could be increased significantly in almost all markets.

6. REFERENCES

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This is a companion document to another NTIA Report, "Proposed Techniques for Adding FM Broadcast Stations in a Major Market". Increasing the number of assignments is possible if: 1) co-siting of second- and third-adjacent-channel transmitters is allowed, 2) directional antennas to control both signal coverage and interference are used, 3) reasonable changes to the signal-to-interference protection ratios for co-channel and adjacent-channel operation are adopted, 4) protection to existing facilities rather than maximum allowed antenna height and transmitter power is granted, and 5) the effects of terrain on coverage and interference are considered. To demonstrate the approach of adding assignments to a saturated major market, this second report shows how the number of FM broadcast stations in the Washington, DC, market could be increased from the present 13 commercial and non-commercial stations to 21 assignments.

Recommendations are made which, if adopted, could increase significantly the number of FM broadcast stations in almost all markets.

16. Key Words *(Alphabetical order, separated by semicolons)*

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