Reprint from the Proceeding
1981 IEEE Int'l Symposium o
Electromagnetic Compatibili
Boulder, CO August 18-20

# PROPOSED TECHNIQUES FOR ADDING FM BROADCAST STATIONS IN A MAJOR MARKET

Eldon J. Haakinson
Institute for Telecommunication Sciences
National Telecommunications and Information Administration
U.S. Department of Commerce
325 Broadway
Boulder, Colorado 80303.

## Summary

An investigation of the FM Broadcast spectrum's utilization shows that more assignments are possible if some or all of the following recommendations are adopted:

1. protection to existing facilities rather than to maximum facilities is granted,
2. the effects of terrain are considered,
3. directional antennas are used,
4. reasonable changes to the signal-to-interference protection ratios for cochannel and adjacent channel operation are adopted, and
5. cositing of second- and third-adjacent channel transmitters with existing transmitters is permitted.

By way of demonstration of the techniques in a saturated market, the number of FM broadcast stations in Dallas-Ft. Worth could be increased from the present 21 stations to 38 stations.

## Introduction and Background

Under the current FCC rules, the top fifty FM broadcast radio markets in the United States are saturated; that is, nearly all of the slots in the Table of Assignments are assigned. 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 desired signals and undesired; these improvements and techniques could allow many new FM broadcast assignments in the major markets.

The FM broadcast band extends from 88 MHz to 108 MHz. In this 20 MHz band, there are 100 channels; each channel is 200 kHz wide. Due to interference concerns, no market has all 100 channels available for its own use. Instead, if all of the station separation rules as specified by the FCC were strictly followed, the maximum number of stations in any location would be 25.

The FM frequency assignment structure allows four different classes of FM stations. The four classes are defined to provide different levels of service to the public. Each class has been assigned a particular range of operating characteristics, i.e., minimum to maximum allowed transmitted power, and a maximum allowed antenna height. Assuming that all stations would eventually operate at their maximum allowed power and antenna height (maximum facilities), the FCC defined the minimum required distance separation between the classes of FM stations. The minimum distances, given in Table 1, were intended to ensure that any particular class of station could provide at least a minimum signal over a specified service area without objectionable interference.

Table 1. FCC Minimum Distance Separation for FM Broadcast Transmitters

| Class of Station | Required Spacing (miles) Class A Coch. | Class A 200 kHz | Class A 400 kHz | Class A 600 kHz | Class B Coch. | Class B 200 kHz | Class B 400 kHz | Class B 600 kHz | Class C Coch. | Class C 200 kHz | Class C 400 kHz | Class C 600 kHz | Class D Coch. | Class D 200 kHz | Class D 400 kHz | Class D 600 kHz |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class A | 65 | 40 | 15 | 15 | -- | 65 | 40 | 40 | -- | 105 | 65 | 65 | -- | 30 | 15 | 15 |
| Class B | -- | -- | -- | -- | 150 | 105 | 40 | 40 | 170 | 135 | 65 | 65 | -- | -- | 40 | 40 |
| Class C | -- | -- | -- | -- | -- | -- | -- | -- | 180 | 150 | 65 | 65 | -- | -- | 65 | 65 |

Note: Stations or assignments separated in frequency by 10.6 or 10.8 MHz (53 or 54 channels) will not be authorized unless they conform to the following separation table.

| Class to Class | Required Spacing in Miles |
|---|---|
| A to A | 5 |
| B to A | 10 |
| B to B | 15 |
| C to A | 20 |
| C to B | 25 |
| C to C | 30 |

Table 2. FM Protected Signal Distances and Field Strengths

| Class | Protected Service Radius (mi) | Full Facility Parameters Power (kw) | Full Facility Parameters Antenna Height (HAAT, ft) | Protected Field Strength (μV/m) | Protected Field Strength (dBμ) |
|---|---|---|---|---|---|
| A | 15 | 3 | 300 | 927 | 59.3 |
| B | 40 | 50 | 500 | 562 | 55.0 |
| C | 65 | 100 | 2000 | 944 | 59.5 |

In Paragraph 62 of the First Report [1], the FCC stated that FM assignments would be made so that each class of FM station would be provided with a protected signal service radius as given in Table 2. Paragraph 62 also gives the field strength for that protected distance, assuming a full facility station. In Table 2 we have listed the full facility parameters and their protected field strength for each class.

In Paragraph 15 of the First Report [1], the FCC defined that objectionable cochannel interference exists whenever the undesired rf signal level exceeds one-tenth of the desired rf signal level. Thus, the desired-to-undesired signal ratio must be 20 dB or greater if cochannel interference is to be avoided. Data gathered from consumer audio and hi-fi magazines indicate that good quality FM receivers available in the early 1960's had capture ratios of about 8 dB or less. Paragraph 66 of the First Report states that the assignment plan (and the FM rules) should be based on "receivers of reasonably good quality." Thus, it appears that the FCC had built in a safety factor of about 12 dB when the 20 dB cochannel S/I ratio is compared with the performance available in 1962 good quality receivers. Today's good quality receivers have capture ratios of 2 dB or less. Assuming all else equal, if the cochannel separations were based only on the performance of good quality receivers, today's cochannel separation rules could be relaxed by 6 dB, while maintaining the 12 dB safety ratio.

In Paragraph 15 of the First Report [1], objectionable first-adjacent-channel (200 kHz removed) interference is defined to exist whenever the undesired signal voltage exceeds one-half of the desired signal voltage; second-adjacent-channel (400 kHz removed) interference exists if the undesired signal voltage is more than 10 times the desired signal voltage; and third-adjacent-channel (600 kHz removed) interference exists if the undesired signal voltage is more than 100 times the desired signal voltage. Table 3 gives the protection ratios between cochannel and adjacent channel stations specified by the FCC.

Table 3. FM Protection Ratios

| Channel Relationship | Frequency Separation (kHz) | Required Desired Signal-to-Undesired Signal Ratio (dB) |
|---|---|---|
| Cochannel | 0 | 20 |
| First-Adjacent | 200 | 6 |
| Second-Adjacent | 400 | -20 |
| Third-Adjacent | 600 | -40 |

We can describe some of the reasons why first-adjacent-channel protection is required. Although the FM channel width is 200 kHz, the FCC allows the broadcast FM signal to have spectrum occupancy limits which exceed 200 kHz. The allowed occupancy is 40 kHz greater than the channel width. With an audio frequency of 15 kHz (the upper baseband frequency for monaural FM) and a deviation of 75 kHz (100 percent deviation in broadcast FM), the principal Bessel function sidebands are located at 15, 30, 45, 60, 75, 90, 105, and 120 kHz from the carrier. Receiver manufacturers, in turn, have designed their IF bandwidths to be about 265 kHz if less than 1 percent distortion is desired, or 225 kHz if less than 3 percent distortion is desired. Because of the allowed spectrum occupancy and associated receiver designs, it is obvious that the first-adjacent channels on either side of an assigned carrier are unavailable for future use in that market. Unfortunately, first-adjacent-channel selectivity is not usually reported by receiver manufacturers, so we are unable to tell how this performance factor has changed since 1962.

Receiver manufacturers do report second-adjacent-channel selectivity, called alternate-channel selectivity. In 1962, good quality receivers had alternate-channel selectivity values ranging from less than 20 dB to greater than 50 dB. Today's good quality receivers have alternate-channel selectivity values which exceed 50 dB, an improvement of as much as 30 dB. The second- and third-adjacent-channel separations are the rules that we believe could be relaxed with least additional interference while providing for the greatest increase in FM broadcasting capacity.

## Ways of Increasing the Number of FM Stations

### Improve FM Equipment

Improved FM equipment could allow a relaxation of the protection ratios and lead to more FM band assignments. Obviously, if receivers can be improved to discriminate against interference, then they are more capable of selecting a desired FM station in a dense FM environment.

### Relax FCC Rules on FM

In order effectively to increase the number of FM stations, the FCC rules would have to be changed. Such changes would:

1. allow locating second- and third-adjacent-channel stations near existing FM stations,
2. allow locating stations that can cause IF response signals near existing FM stations,
3. allow use of directional antennas,
4. allow terrain features to be used in computing signal and interference coverage, and
5. consider actual facilities rather than maximum facilities.

These are independent recommendations; each one could increase the assignment capacity without significantly decreasing the coverage of existing stations. Recommendations 1 and 2 would not require case-by-case engineering calculations. Recommendations 3, 4, and 5 would require a change in philosophy from that of developing a Table of Assignments to specific-situation engineering.

## Example of Increasing FM Broadcast Capacity

A proposed assignment [2] in the saturated Dallas-Ft. Worth market will be on channel 209 with potential interference to a cochannel station (KGCC) and an adjacent channel station (KSHU). Figure 1 shows the coverage from the proposed facility, a 20-kW ERP, 500-ft (152.4 m) height-above-average-terrain (HAAT) transmitter with an omnidirectional antenna. Figure 2 shows the coverage by, and the interference to, the existing stations. The upper solid contour shows the coverage from station KGCC to a population of 107,600 people and an area of 4768 $km^2$ or 1841 $mi^2$. The dashed contour (S/I = 20 dB) shows the interference region with a population of 15,500 and an interference area of 864 $km^2$ or 110 $mi^2$.

Figure 3 shows the proposed facility's coverage if a directional antenna pattern is used. An alternative to using a directional antenna would be merely to reduce the power and antenna height of the proposed facility until the interference regions in Figure 2 disappeared. However, this also would result in a significant reduction in the area and population covered by the proposed facility. The directional antenna provides a means of reducing the signal in the directions where potential interference may occur, while maintaining the full signal strength (of an equivalent omnidirectional antenna) in those directions where interference is not likely to occur. Figures 4 and 5 show the corresponding coverage by, and the interference to, the existing stations. Using the directional antenna and the new criteria for interference (S/I = +14 dB for cochannel interference and S/I = -50 dB for second-adjacent-channel interference), Figure 5 shows there is no unacceptable interference to the existing stations from the proposed Channel 209 station. Note that the proposed Channel 209 transmitter is cosited with the existing facility on Channel 207. We will want to cosite as many of the proposed facilities as are possible in order to control the interference areas.

In a similar manner, other proposed stations could be added to the Dallas-Ft. Worth market. By using

1. less than maximum-allowed power and antenna heights,
2. directional antennas,
3. terrain-effects on propagation, and
4. modern FM receiver performance characteristics,

we can increase the number of stations in Dallas-Ft. Worth from 21 to 38 stations.

## Conclusions

An examination of the background on the FM broadcast spectrum capacity 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 facilities allowed for their class,
3. the rules disallowed the use of terrain-dependent propagation algorithms, and
4. the rules disallowed the use of directional antennas for assignment purposes.

Using these guidelines, the FCC adopted a Table of Assignments for FM broadcast stations based on <u>minimum mileage</u> 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 paper, 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 Dallas-Ft. Worth region could be increased from the present 21 stations to 38 stations. This was accomplished by using existing facilities rather than maximum facilities, cositing of second- and third-adjacent channel transmitters with existing transmitters, terrain-dependent propagation algorithms, and directional antenna patterns when required and/or otherwise helpful. Additional material can be found in several NTIA reports [2,3].

## Recommendations

We make several recommendations regarding the FM broadcast band:

1. the FCC should use techniques such as shown in this report to examine easily 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 Dallas-Ft. Worth area),
3. directional antennas should be allowed,
4. cositing 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 current, good quality receivers.

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

## References


[1] FCC (1962), Revision of FM broadcast rules, Docket No. 14185, First Report and Order.

[2] Haakinson, E.J. (1980), Proposed Techniques for Adding FM Broadcast Stations in a Major Market, NTIA Report 80-44, NTIS Accession No. PB81-108433. (NTIS, 5285 Port Royal Road, Springfield, VA 22161).

[3] Hufford, G.A. (1977), Techniques for the evaluation of proposed VHF TV drop-ins, OT Report 77-112, NTIS Access. No. PB 271212/AS.


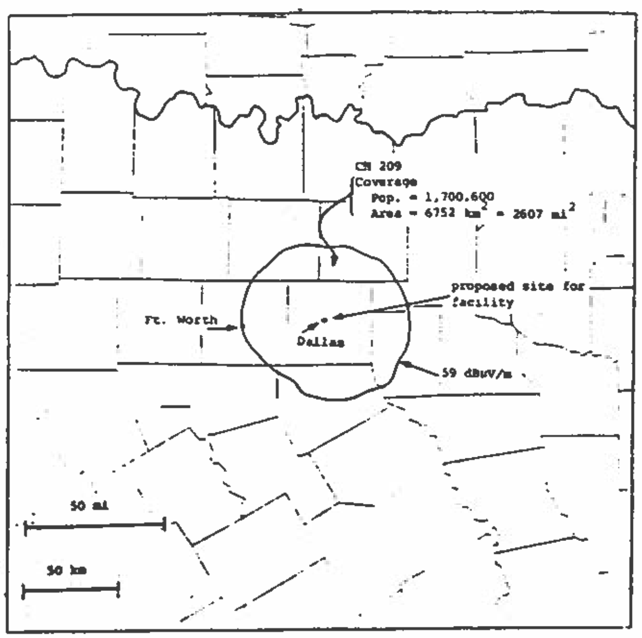


Figure 1. The solid contour shows the 59 dB$\mu$ V/m coverage of a proposed station in Dallas on FM Broadcast Channel 209 with a 20 kW effective radiated power and an antenna center of radiation at 500 ft (152.4 m) above average terrain.

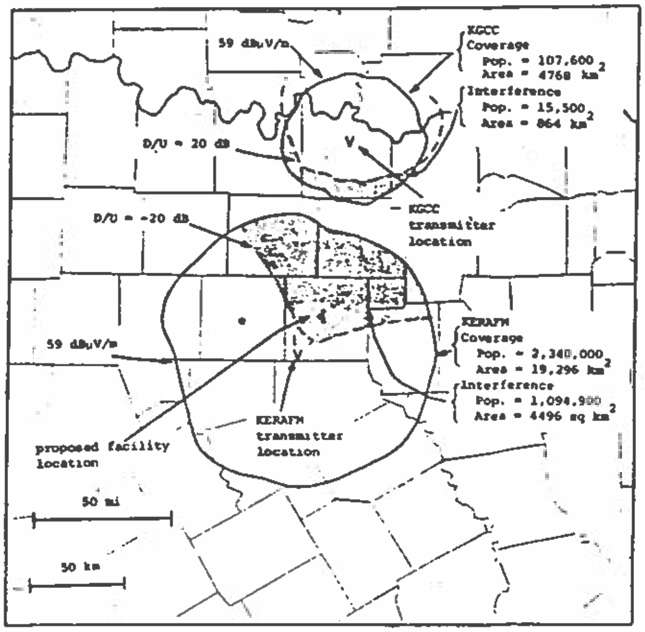


Figure 2. Solid contours show the 59 dB µV/m coverage from stations KERAFM and KGCC. The dashed contours and shaded areas show regions of interference exceeding the allowed 20 dB desired-to-cochannel interference (to KGCC) and -20 dB desired-to-second-adjacent-channel interference (to KERAFM) from the station proposed in Figure 1.

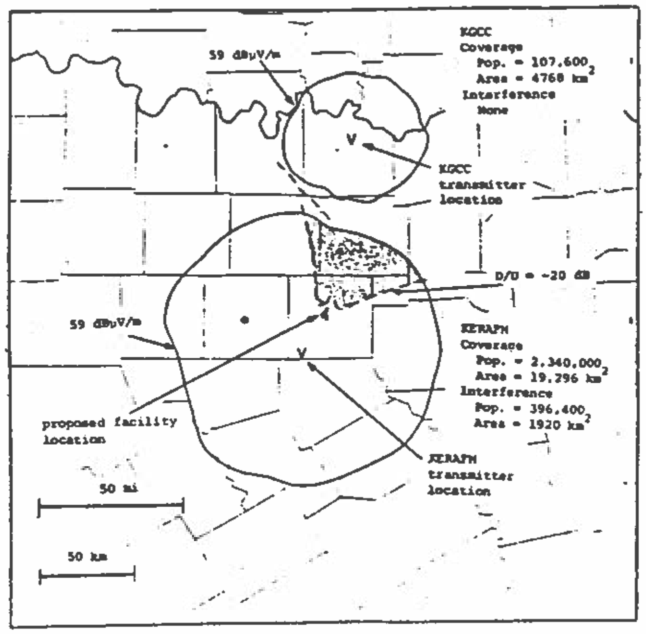


Figure 4. The dashed contours and shaded areas show regions of interference to KERAFM and KGCC from the proposed station using a directional antenna. The existing protection standards of 20 dB for cochannel and -20 dB for second-adjacent-channel interference are assumed.

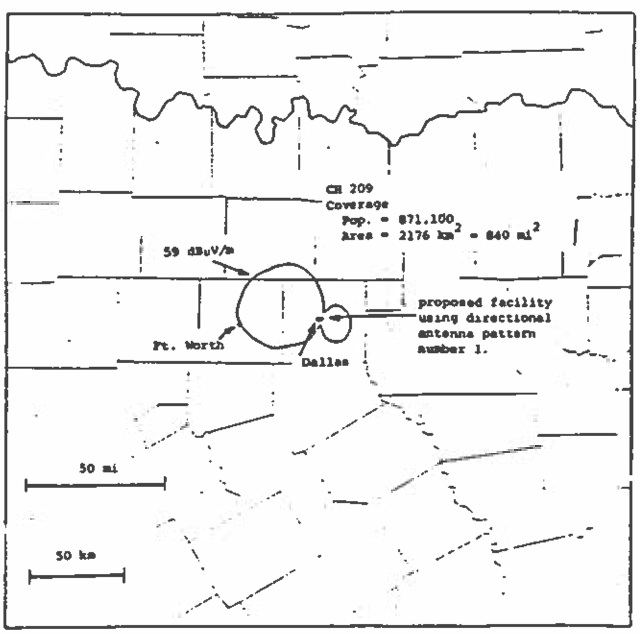


Figure 3. The solid contour shows the 59 dB µV/m coverage from the proposed station when a directional antenna is used. As before, the effective radiated power is 20 kW and the antenna height above average terrain is 500 ft (152.4 m).

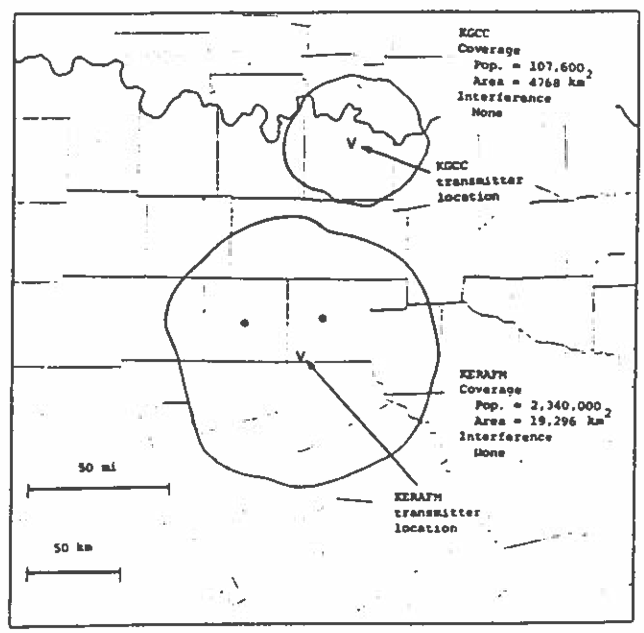


Figure 5. The dashed contours and shaded areas show regions of interference to KERAFM and KGCC from the proposed station using a directional antenna. Proposed protection standards of 14 dB for cochannel and -50 dB for second-adjacent-channel interference are assumed.