MOBILE RADIO COMMON CARRIER COCHANNEL INTERFERENCE ANALYSIS

Background

The Domestic Public Land Mobile Radio Service consists of hundreds of small radio common carriers (RCC's) who offer two way mobile radio and paging services to the public. These RCC's are regulated by the FCC (Part 21 of the FCC Rules and Regulations) and are frequently in competition with each other for radio channels. The method used to analyze and protect these operations from cochannel interference is the subject of this article. First the method for determining a reliable service area for the individual stations will be discussed. This will be followed by a method for determining interference areas. Although the system parameters for both base-to-mobile and mobile-to-base communications are important, the controlling factor for assignment purposes is considered to be the link from the base station to the mobile receiver.

The frequency bands where these systems are operated are 35-44 MHz, 152-162 MHz and 454-460 MHz. The two way systems operate in a full duplex mode with frequency separation between transmit and receive frequencies of 5 to 6 MHz.

Propagation Curves

The curves used to determine the propagation loss for this service are based on CCIR data (CCIR Recommendation No. 370, Geneva, 1963). This data is based on measurements performed in the U.S.A. and Western Europe. The antenna heights are defined as the height of the antenna above the average level of the ground between distances of 3 km and 15 km from the transmitter, in the direction of interest. The CCIR data is expressed in terms of dB relative to 1 µv/m for 1 kW effective radiated power from a half-wave dipole. Specifically, the CCIR VHF curves for a land sea path and a transmitting antenna height of 300 meters were used for the 35-162 MHz curves and the CCIR UHF curves for a land path with a transmitting antenna height of 150 meters and a roughness factor of $\Delta h = 50$ meters (difference between highest and lowest elevations along the path) were used for the 450-460 MHz curves. The CCIR VHF and UHF curves for other antenna heights were found to be unusable due to unexplained anomalies. The CCIR curves considered an antenna height of 10 meters. The standard height for mobile antennas is considered to be six feet. A 9 dB antenna height gain adjustment was therefore incorporated to modify the data. The curves were extrapolated for different antenna heights using a linear height gain assumption. The resulting curves are found in the FCC Rules and Regulations, Part 21.504 and reproduced in Figures 1 and 2.

Minimum Required Field Strength

The curves discussed above present field strength as a function of distance and 1 kW transmitter power using half wave dipole antennas. The form of analysis used therefore is expressed in terms of received field strength (dBu, V/M or dBuV/M), and transmitted power above a KiloWatt (dBK). Antenna directivity gain is expressed as dB above a dipole. In order to determine interference, it is first necessary to determine a protected service area or signal level that must be protected. This factor will be developed below. One assumption is that a typical sensitivity level for FM communications receivers is 0.5 microvolts in the 33-44 MHz and 152-162 MHz bands. This would provide about a 12 dB S/N ratio. This equals -143 dBW for a 50 ohm load. Similarly, because of their higher noise figure, receivers in the 450-460 MHz band are assigned a typical sensitivity level of -138 dBW. The equivalent field strength is calculated assuming lossless transmission line and a half-wave dipole antenna.

Figure 1

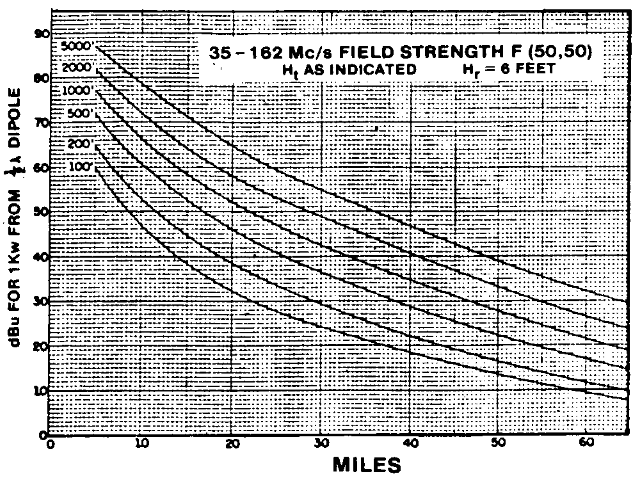
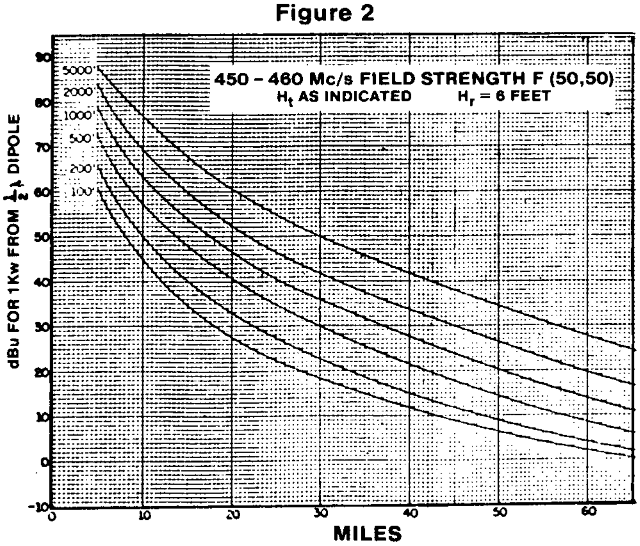


Figure 2



$$Pr = pA,$$

where
Pr = input received power
p = power density (W/M^2)
A = antenna operative (M^2)
$p = E^2 (10)^{-12}/120\pi$

where E = field strength, ($\mu V/M$)

$$A = \frac{1.64\lambda^2}{4\pi}, \quad \lambda = \frac{300}{f_{MHz}}$$

for a half-wave dipole, therefore,

$$P_r = \frac{3.12(10)^{-11}E^2}{f^2_{MHz}}$$

and $$E = \left[P_r f^2_{MHz}/3.12(10)^{-11}\right]^{1/2}$$

or $$E_{dBu} = 105+10\log P+20\log F_{MHz}$$

Since most RCC's are in urban areas, the systems are external noise limited. The following values are used, based on a 1952 survey, using 50 kHz bandwidth receivers, in the suburbs of New York City. For 150 MHz signals the minimum acceptable median required signal was found to be -122.5 dBW. For 450 MHz signals it was found to be -133 dBW. There were no measurements at 40 MHz but a value 5 dB below the 150 MHz required level was assumed. This data is the basis for the present regulations. Using the above values in the field strength equation,

E (35-44 MHz) = 20 dBu

E (152-162 MHz) = 26 dBu

E (450-460 MHz) = 25 dBu

Reliable Service Field Strength

The CCIR-derived propagation curves discussed above are F (50,50) curves, i.e., they represent the field strength exceeded at 50% of the location for at least 50% of the time. The standard for reliable service in the Domestic Public Land Mobile Radio Service is 90%. Therefore, this additional factor has to be taken into account. The statistical variability for VHF and UHF were developed in independent studies.[3,4] Based on these studies 90% probability factors were developed. For VHF the factor is 11 dB and for UHF, 14 dB. These factors have to be added to the required field strengths calculated above. The service field strengths for 90% reliability are therefore:

35-44 MHz = 31 dBu

152-162 MHz = 37 dBu

450-460 MHz = 39 dBu

For pagers, the level of reliable operation used is 43 dBu for all bands.

Cochannel Interference Analysis

The method used to determine cochannel interference is to first determine a required ratio of desired to undesired signal. Based on an analysis developed by Bullington[5], this ratio is computed as follows:

$$R = A+K\left(L_d^{\,2}+L_\mu^{\,2}+T_\mu^{\,2}\right)^{1/2}$$

where

R = required ratio between the desired and undesired fields

A =acceptance ratio (assumed to be 6 dB).

I_d =90% terrain variability factor for the desired field,
=11 dB for 35-162 MHz
=14 dB for 450-460 MHz.

L_μ =10% terrain variability factor for the undesired field,
=11 dB for 35-162 MHz.
=14 dB for 450-460 MHz.

T_μ =Time fading factor for the interfering signal (90%)

K =1 for 90% probability.

The time fading for the desired signal, due to the short ranges involved, is considered to be negligible. Once this ratio is determined, it is possible to draw iso-service and iso-interference contours based on the propagation curves and thresholds developed above.

Example Problem

Assume a one-way (paging) station operating at 152.84 MHz with an omni-directional antenna. The effective radiated power is 500 watts (-3.01 dBk). The antenna height above average terrain (2-10 mile range) is given. The service contour can be calculated based on the F (50, 50) propagation curves and the required field strength (43 dBu). The interference contour requires calculation of the desired to undesired field ratio by the equation described above. The determination of the value $T\mu$, the undesired signal time fading can be performed by taking the difference between the F (50, 50) curve and the F (50, 10) curve. The value of $T\mu$ as a function of distance is shown in Figure 3. Note that the distance required is the distance to the interference contour. The calculation of the ratio R therefore required iteration. A typical value is chosen for a first approximation and subsequent calculations converge on the actual value. Once the value of R is determined, the field strength at the interference contour can be determined based on the fact that this frequency is received for paging operations and that all the other stations on this frequency will therefore require 43 dBu signals. The field strength at the interference contour is therefore (43-R) dBu. The example results are tabulated below. The time facing $T\mu$ is about 3.5 dB at the interference contour. The ratio R is therefore 21.9 dB. The field strength at the interference contour is therefore 43 dBu - 21.9 dB or 21.1 dBu. This will be slightly different for each radial but the variations are small enough to be negligible.

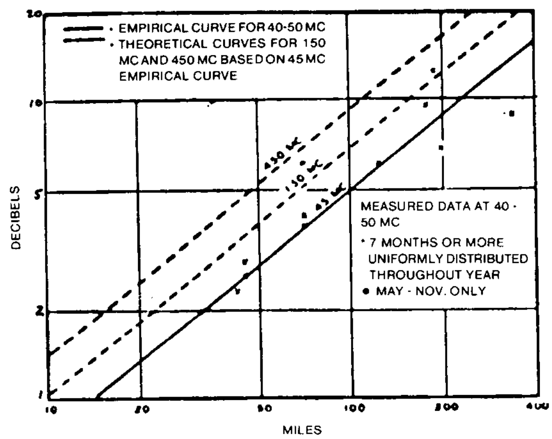


Figure 3. Atmospheric fading; ratio of field intensity exceeded 10 per cent of time to field intensity exceeded 50 per cent of time.

Bearing	Radiation Center Above Average Terrain	43 dBu Service Contour	21.1 dBu Interference Contour
0°	500'	20.1 mi.	46.2 mi.
45°	400'	18.4 mi.	43.4 mi.
90°	300'	16.5 mi.	39.9 mi.
135°	350'	17.5 mi.	41.8 mi.
180°	400'	18.4 mi.	43.4 mi.
225°	450'	19.3 mi.	44.9 mi.
270°	475'	19.7 mi.	45.5 mi.
315°	500'	20.1 mi.	46.2 mi.

The results are plotted in Figure 4. Note that this procedure provides a cochannel interference contour based on the type of service assigned to this frequency, without actually considering any other cochannel station. Assume that another cochannel station does exist about 55 miles away at a bearing of 90°. Assume that this other station has a side-mounted antenna, providing a directional antenna pattern. The characteristics of this second station are tabulated below. The time fading, Tμ is about 3.3 dB and R therefore is 21.9 dB as before.

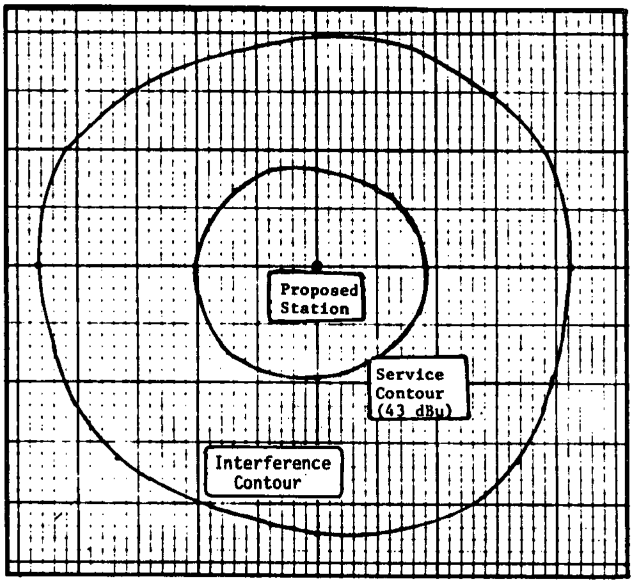


Figure 4. Service and Interference Contours

Bearing	Radiation Center AAT	E.R.P. (dBk)	43 dBu Service Contour	21.1 dBu Interference Contour
225°	300'	-4.5	15.4 mi.	38.0 mi.
270°	350'	-4.0	16.7 mi.	40.9 mi.
315°	400'	-3.5	18.0 mi.	43.3 mi.

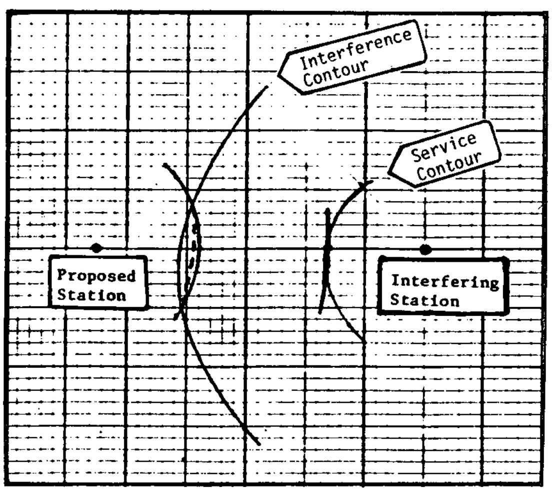


Figure 5. Cochannel Interference

The cochannel interference situation is plotted in Figure 5. Note that there is an overlap of the interference contours and the service contours. This indicates that there is an area within the reliable service contour where the required signal-to-interference ratio R is not sufficient. The intersections of the contours are the points at which this ratio is exactly the calculated value (21.9 dB). The dashed line indicates the iso-interference contour (locus) at which this ratio occurs. These points have to be calculated by iterative techniques. The area within the service contour and outside this locus is the area of unacceptable interference.

Implementation Considerations

The form of analysis described above, while based on many assumptions is the standard approach relied upon for the Domestic Public Land Mobile Radio Service. The analysis is usually submitted to the FCC along with the license application. Since the interference analysis usually concerns competition between profit oriented companies, there are usually opposition reports filed taking issue with any assumptions made or any possible errors found. If agreement cannot be reached between the parties the next step is a formal hearing before an administrative law judge. Among the more common objections are the specific characteristics of the terrain being different than that for which the propagation curves were derived. The original CCIR data was based on terrain exhibiting 50 meter variations from high points to low points. Other terrain would exhibit other shadow loss characteristics. Another point of contention is the threshold value selected, since it is based on noise data gathered in the suburbs of New York City in 1952, and may not be representative of other areas at other times. The basic analysis relied upon, however, is as described above.

REFERENCES

1. Documents of the Xth Plenary Assembly, *Propagation*, Vol. II, Recommendation No. 370, C.C.I.R., Geneva, 1963.
2. Carey, Roger B., *Technical Factors Affecting the Assignment of Facilities in the Domestic Public Land Mobile Radio Service*, Report No. R-6406, F.C.C., June 24, 1964.
3. FCC Report of the Ad Hoc Committee for the Evaluation of the Radio Propagation Factors Concerning the Television and Frequency Modulation Broadcasting Services in the Frequency Range Between 50 and 250 Mc., Volume I, May 31, 1949.
4. Fine, Harry, FCC T.R.R. Report No. 2.4.12, UHF Propagation Within Line of Sight, June 1, 1951.
5. Bullington, K., Radio Propagation Variations at VHF and UHF, Proceedings of the I.R.E., January, 1950.

This article was prepared for ITEM *by Ernest R. Freeman, President, Sachs/Freeman Associates, Inc., Bowie, MD 20715*