FEDERAL COMMUNICATIONS COMMISSION
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## TECHNICAL FACTORS AFFECTING THE ASSIGNMENT OF FACILITIES IN THE DOMESTIC PUBLIC LAND MOBILE RADIO SERVICE

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Summary

This report concerns the technical factors involved in the assignment of facilities in the 35-44 Mc/s, 152-162 Mc/s and 450-460 Mc/s bands allocated to the Domestic Public Land Mobile Radio Services. System parameters such as radiated power, transmitting antenna height, receiver performance, ambient external noise level and location of co-channel operations may be combined with the average radio propagation curves presented herein for the calculation of service areas. Many of the procedures set forth in the FCC Technical Research Report No. 4.3.8 are incorporated in this document. However, the basic propagation curves are of more recent derivation and are believed to be more representative of the actual field behavior in most instances.

## Introduction

The Domestic Public Land Mobile Radio Service treated in this report is the two-way service with mobile units, employing separate frequencies for the base station and the mobile transmitters. Although the system parameters in both directions are important from an operational standpoint, only the reception of a base station by a mobile unit is considered, since this is the controlling factor for assignment purposes. The one-way signalling or paging service requires somewhat different parameters because of reduced receiving sensitivity and different modulation techniques and should be given separate consideration.

## Propagation Curves

Figures 1 and 2 are median, F(50,50), and tropospheric, F(50,10), propagation curves for the 35-44 Mc/s band and the 152-162 Mc/s band. Figures 3 and 4 are median, F(50,50), and tropospheric, F(50,10) propagation curves for the 450-460 Mc/s band. Both sets of curves were derived from the curves in CCIR Recommendation No. 370, Geneva, 1963. Specifically, the CCIR VHF (Bands I, II, and III) curves for a land-sea path and a transmitting antenna height of 300 meters were used as bases for the 35-162 Mc/s curves and the CCIR UHF (Bands IV and V) curves for a land path with a transmitting antenna height of 150 meters and a roughness factor for $\Delta h = 50$ meters were used as bases for the 450-460 Mc/s curves. The CCIR VHF and UHF curves for other transmitting antenna heights were abandoned due to unexplained anomalies which became apparent when field strength was plotted as a function of transmitting antenna height. The basic curves which considered a receiving antenna height of 10 meters were adjusted downward by 9 dB to reflect the 6 foot receiving antenna height prevalent in the mobile service. Within the horizon, curves for different transmitting antenna heights were computed from the basic curves by assuming a linear height gain. These curves were then merged into beyond-the-horizon curves by assuming $F + 10 \log d = \phi (d - d_{LS})$ in the manner set forth in FCC Technical Research Report No. 2.4.15,[1] dated October 7, 1955 and revised November 15, 1955.

F = field strength (dBu) from CCIR UHF curve for $H_t$ = 150 meters or 492 feet

d = path length in miles

$d_{LS}$ = combined radio horizon distance in miles (smooth earth)

$$= \sqrt{2 H_t} + \sqrt{2 H_r}$$

where $H_t$ and $H_r$ are transmitting and receiving antenna heights in feet.

$\phi (d - d_{LS})$ = function of the distances between the radio horizons.

Minimum Field Strength Required for Service

An efficient allocation plan for a Domestic Public Land Mobile Radio Service depends upon several factors aside from the propagation characteristics at the assigned frequencies. Inasmuch as the assignments generally have a protected service area, an important parameter is the minimum input signal power level required by the receiver for a commercially acceptable output speech-to-noise ratio. Ideally, the ultimate limitation would be imposed by the usable sensitivity of the receiver which is principally a function of bandwidth, noise figure and input noise temperature. Contemporary FM communications receivers for the 35-44 Mc/s and the 152-162 Mc/s bands have a 12-14 dB speech-to-noise ratio with input signal power levels on the order of -143 dBw (0.5 microvolt across a 50 ohm input). Because of their higher noise figure, receivers operating in the 450-460 Mc/s band require an input signal power level of approximately -138 dBw. The input power levels required to override "set" noise are usually accepted as the requirement for remote rural areas free from man-made noise. The field strengths required for these input signal power levels may be easily calculated by assuming that there is no loss in the receiving antenna transmission line and that the receiving antenna has an effective area equal to that of a half-wave dipole.

(1) $P_r = pA$

where $P_r$ is the receiver input power, p is the power density at the receiving antenna and A is the effective area of the antenna.

(2) $p = \dfrac{E^2 \times 10^{-12}}{120\pi}$

where E is the field strength in microvolts per meter

(3) $A = \dfrac{1.64\ \lambda^2}{4\ \pi}$

where λ is the wavelength in meters, or

(4) $\lambda = \dfrac{300}{f_{mcs}}$

Substituting (2), (3) and (4) in (1)

(5) $P_r = \dfrac{3.12 \times 10^{-11} \times E^2}{f_{mcs}^2}$

The field in microvolts per meter may then be obtained by

$$(6) \quad E = \left( \frac{P_r \times f^2_{mcs}}{3.12 \times 10^{-11}} \right)^{1/2}$$

or in dBu by

$$(7) \quad F = 20 \log E = 105 + 10 \log P_r + 20 \log f_{mcs}$$

A receiver input of -143 dBw at 40 Mc/s is equivalent to a field strength of

$$F = 105 - 143 + 20 \log 40 = -6 \text{ dBu}$$

The same input power at 157 Mc/s is equivalent to

$$F = 6 \text{ dBu}$$

and an input power of -138 dBw at 455 Mc/s is equivalent to

$$F = 20 \text{ dBu.}$$

In practice most Domestic Public Land Mobile Radio Systems are ambient or external noise limited (man-made plus cosmic noise) in all areas in the 35-44 Mc/s band and the 152-162 Mc/s band and in all except rural areas in the 450-460 Mc/s band.

A 1952 survey in the suburban areas near New York City indicated that the median receiver input signal power level at 150 Mc/s required to provide a commercially acceptable output speech-to-noise ratio (12 dB) was -122.5 dBw./2 The requirement for acceptable service at 450 Mc/s was -133 dBw. The survey did not include measurements at a frequency near 40 Mc/s but the ambient noise level at that frequency is generally considered to be about 5 dB worse than that at 150 Mc/s./3 The 1952 survey was made with receivers having a 50 kc/s bandwidth and a system modulation with 10 kc/s deviation. Although the need has been apparent for a number of years, there are no new data nor have there been appreciable efforts to obtain new data concerning representative ambient external noise levels in the VHF and UHF spectrum. The field strengths required for reliable service must therefore be based upon the 1952 data. The median field strengths required for commercially acceptable service are calculated from equation (7) to be:

35 - 44 Mc/s = 20 dBu

152 - 162 Mc/s = 26 dBu

450 - 460 Mc/s = 25 dBu

Service Field Strength

Figures 1 and 3 are F(50,50) curves for various transmitting antenna heights above the average terrain in the interval between 2 and 10 miles from the station. F(50,50) curves represent the field strength exceeded at 50 percent of the locations for at least 50 percent of the time. In the Domestic Public Land Mobile Radio Service the reliability should be at least 90 percent. The F(50,50) curves must therefore be modified with a reliability factor R(L). In a mobile service messages may be received while a unit is in motion. This means that the time and terrain variations, although they may be independent of each other, cannot be statistically separated. The reliability factor cannot distinguish between the time variability and the terrain variability. However, at the distances involved in the Domestic Land Mobile Radio Service, the time variability of the desired signal is insignificant compared with the terrain variability. A reasonable reliability factor for the VHF calculations may be obtained from the VHF Ad Hoc Committee Report, /4 and a factor for UHF was developed in FCC T.R.R. Report No. 2.4.12./5 Both factors were presented in Figure 10 of FCC T.R.R. Report No. 2.4.16./6 An adaptation of the latter presentation appears as Figure 5 from which may be obtained reliability factors for modifying median curves to provide increased reliability up to 99 percent. Figure 5 indicates that in the VHF service there is a 90% probability that the received signal in a given area will be at least 10 dB below the average median value for the area. Other authorities have indicated that this factor is minus 11 dB at 150 Mc/s in vehicular communication services. /7 In the UHF service there is a 90 percent probability that the signal in a given area will be at least 14 dB below the average median value for the area. Therefore, for 90 percent reliability, the reliability factors must be added to the local median values before the required field strengths for satisfactory service can be specified.

| Band | F for 90% Reliability |
|---|---|
| 35 - 44 Mc/s | 31 dBu |
| 152 - 162 Mc/s | 37 dBu |
| 450 - 460 Mc/s | 39 dBu |

Evaluation of Co-channel Interference

In considering co-channel interference between two stations it is necessary to consider the terrain and time variations of the desired ($F_d$) and the interfering ($F_u$) fields and the minimum acceptable ratio of desired to undesired signals (acceptance ratio or A). At the distances usually involved in the Domestic Public Land Mobile Radio Service the time variability of the desired field is negligible compared with the time variability of the undesired field and the factors introduced by terrain variations. For co-channel interference an acceptance ratio (A) of 6 dB is commonly used in the FM communications service. The acceptance ratio can be combined with the reliability factors in a manner developed by K. Bullington[8] and presented as follows:

$$(8) \quad R = A + K\left(L_d^2 + L_u^2 + T_u^2\right)^{1/2}$$

where R = required ratio between desired and undesired fields

A = acceptance ratio (assumed to be 6 dB)

$L_d$ = R(L) = Desired field terrain factor from Figure 5. (L = 90 in this case.)

$L_u$ = R(L) = Interfering field terrain factor from Figure 5 (L = 10 in this case.)

$T_u$ = Time fading of the interfering signal

This is a function of distance and is equal to the difference between the F(50,10) and the F(50,50) curves.

K = 1 for 90 percent probability.

By straightforward geometrical construction it is possible to draw iso-service contours based on the limitation by ambient external noise at the distance where $F_d(50,50)$ = 31 dBu, 37 dBu or 39 dBu depending upon operating band or interference limited contours where the distance is that at which $F_u(50,50)$ + R where R was determined by (8).

The problem of calculating the cumulative effects of two or more interfering signals was afforded extensive consideration by the VHF Ad Hoc Committee; however, the report of their findings was by no means conclusive as to the most acceptable method to be used and was not fully endorsed by the committee.[9]

Conclusion

Under average terrain conditions, the methods set forth in this report will facilitate the calculation of service areas in the Domestic Public Land Mobile Radio Service. However, it should be pointed out that the use of average propagation curves for prediction on a point-to-point basis will result in standard deviations in the order of 8 dB at VHF and 12 dB at UHF. Individual deviations for specific paths in both frequency ranges may be much greater.

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4. 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.

5. Fine, Harry, FCC T.R.R. Report No. 2.4.12, UHF Propagation Within Line of Sight, June 1, 1951.

6. Fine, Harry and Taff, John M., FCC T.R.R. Report No. 2.4.16, Propagation Data and Service Calculation Procedures Used for the Rescinded Appendix A of Report and Order (Docket 11532), Released June 26, 1956.

7. Egli, J. J., Vehicular Transmission PGVC-11, July, 1958.

8. Bullington, K., Radio Propagation Variations at VHF and UHF, Proceedings of the I.R.E., January, 1950.

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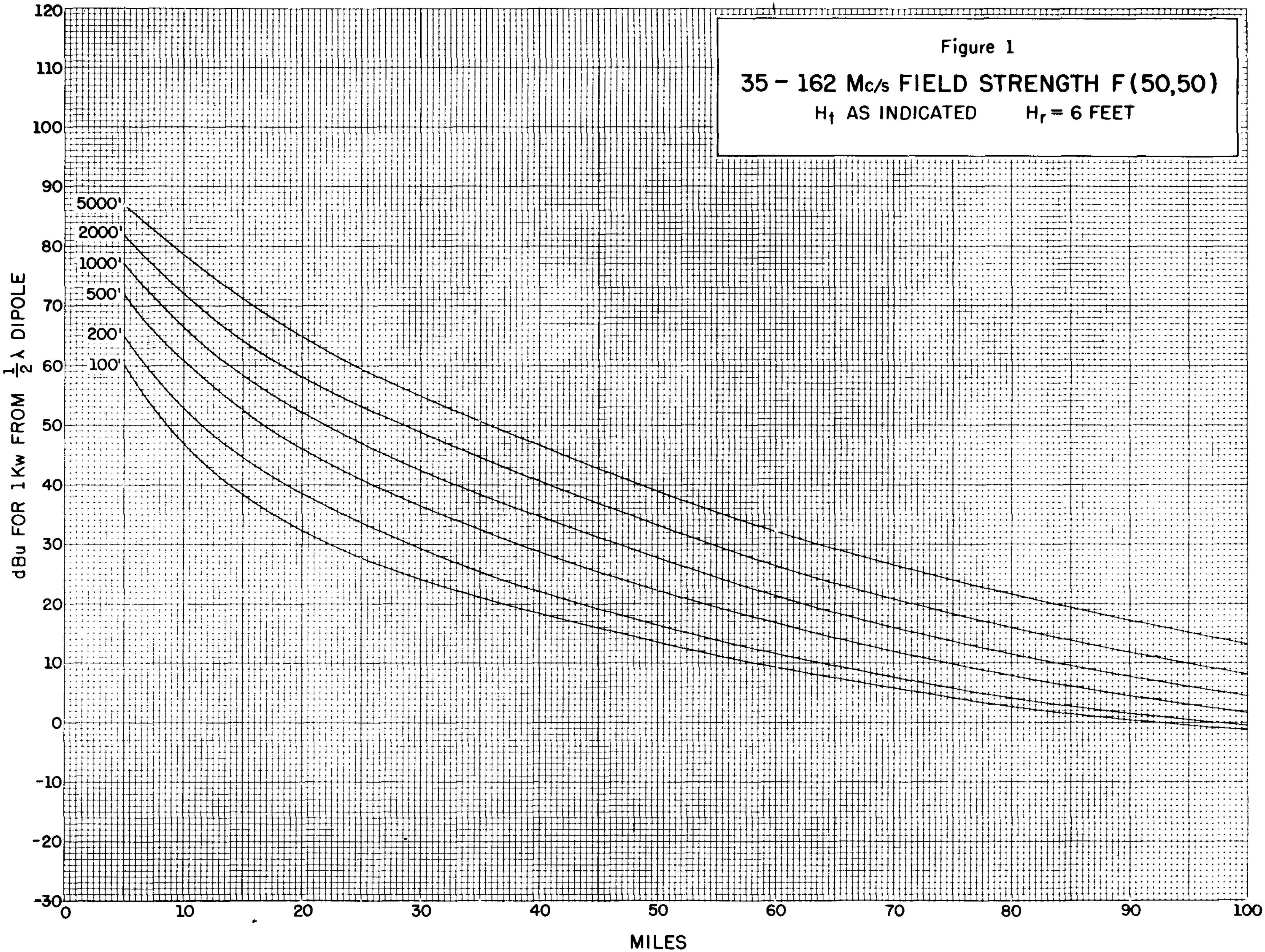

Figure 1
35 – 162 Mc/s FIELD STRENGTH F(50,50)
H_t AS INDICATED H_r = 6 FEET
dBu FOR 1 Kw FROM ½ λ DIPOLE
MILES
5000'
2000'
1000'
500'
200'
100'
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

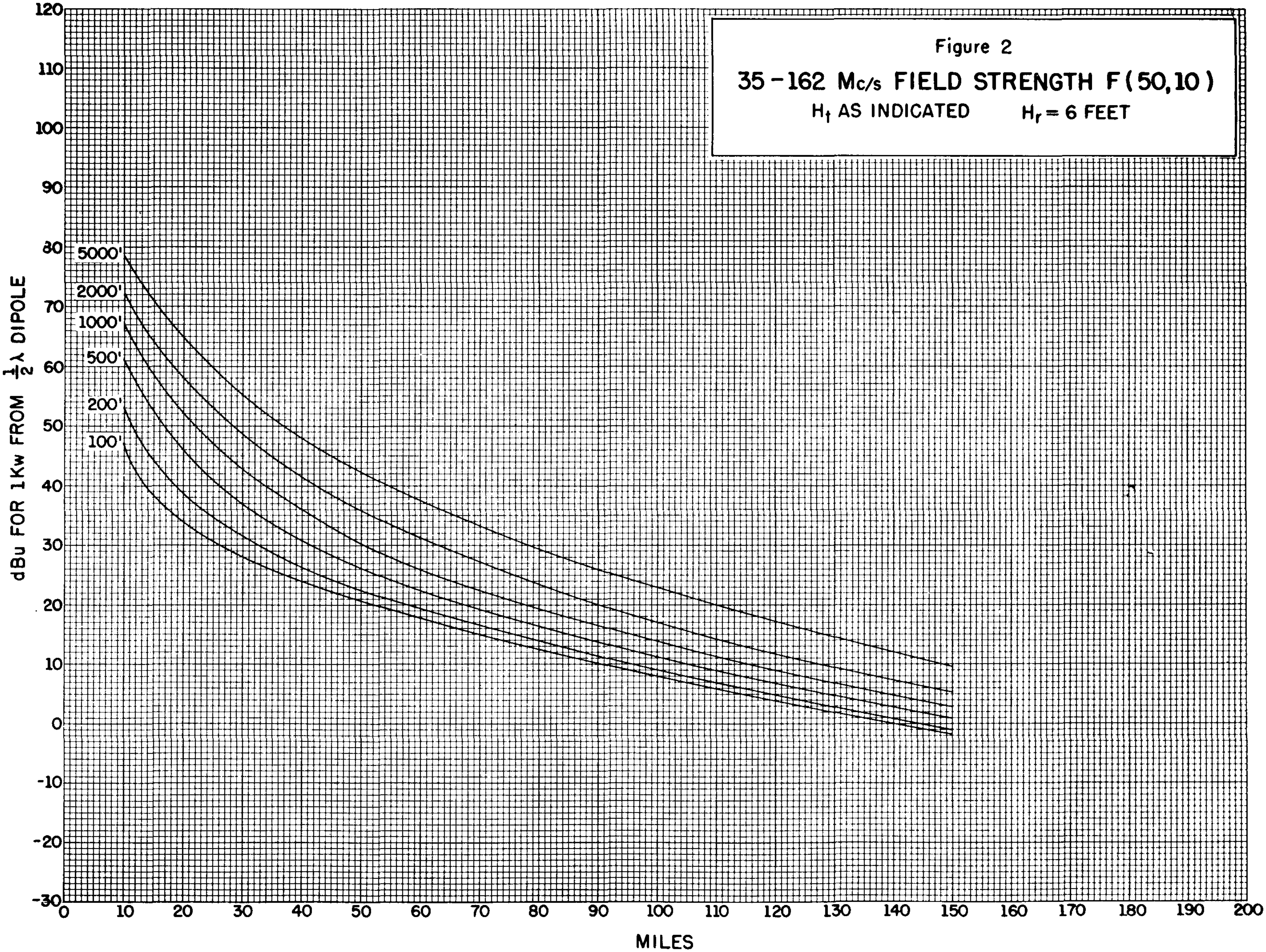

Figure 2
35 - 162 Mc/s FIELD STRENGTH F(50,10)
Ht AS INDICATED Hr = 6 FEET
dBu FOR 1 Kw FROM ½λ DIPOLE
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
5000'
2000'
1000'
500'
200'
100'
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
MILES

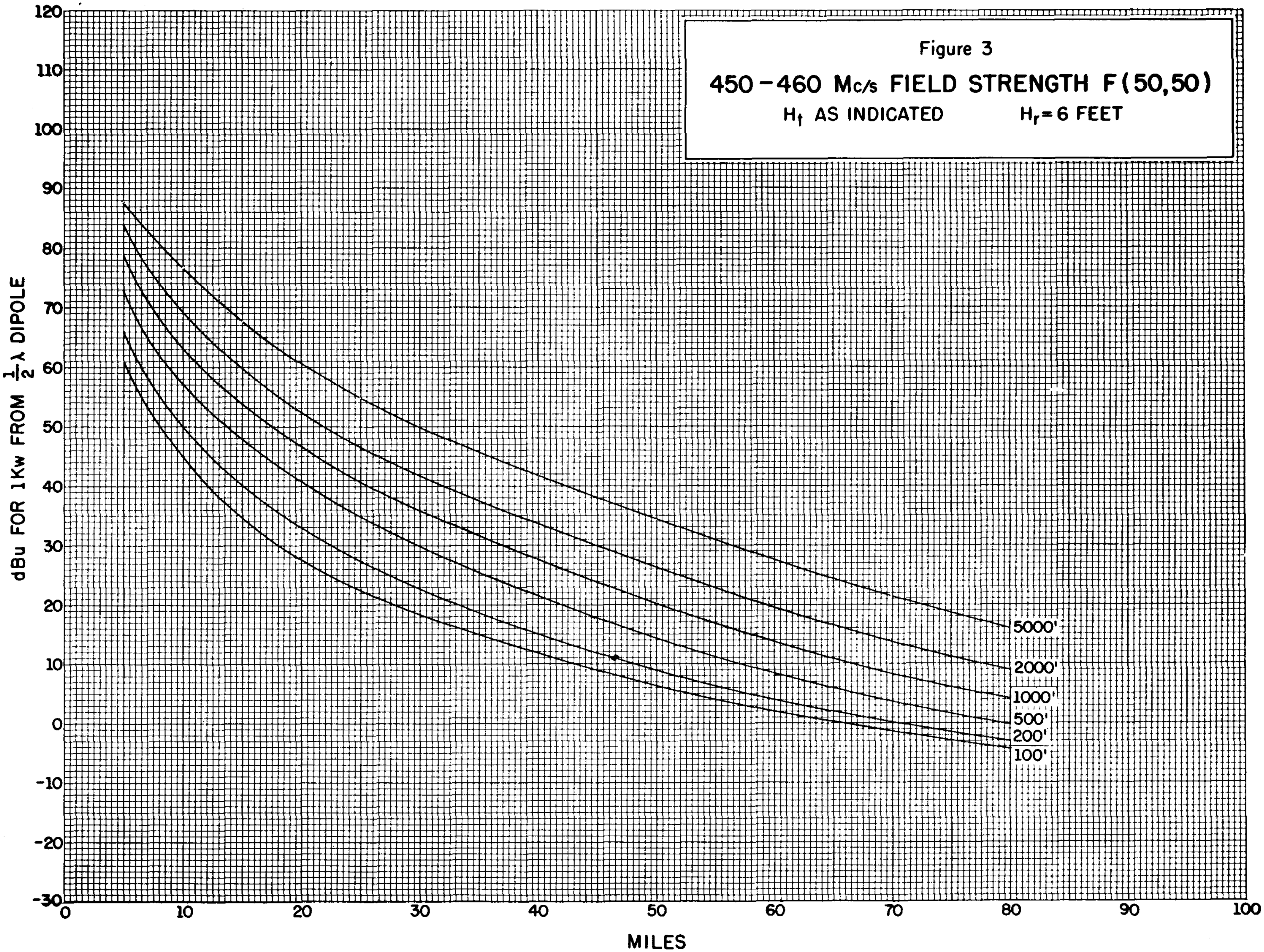
Figure 3
450 - 460 Mc/s FIELD STRENGTH F(50,50)
$H_t$ AS INDICATED
$H_r$ = 6 FEET
dBu FOR 1 Kw FROM $\frac{1}{2}\lambda$ DIPOLE
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100
MILES
5000'
2000'
1000'
500'
200'
100'

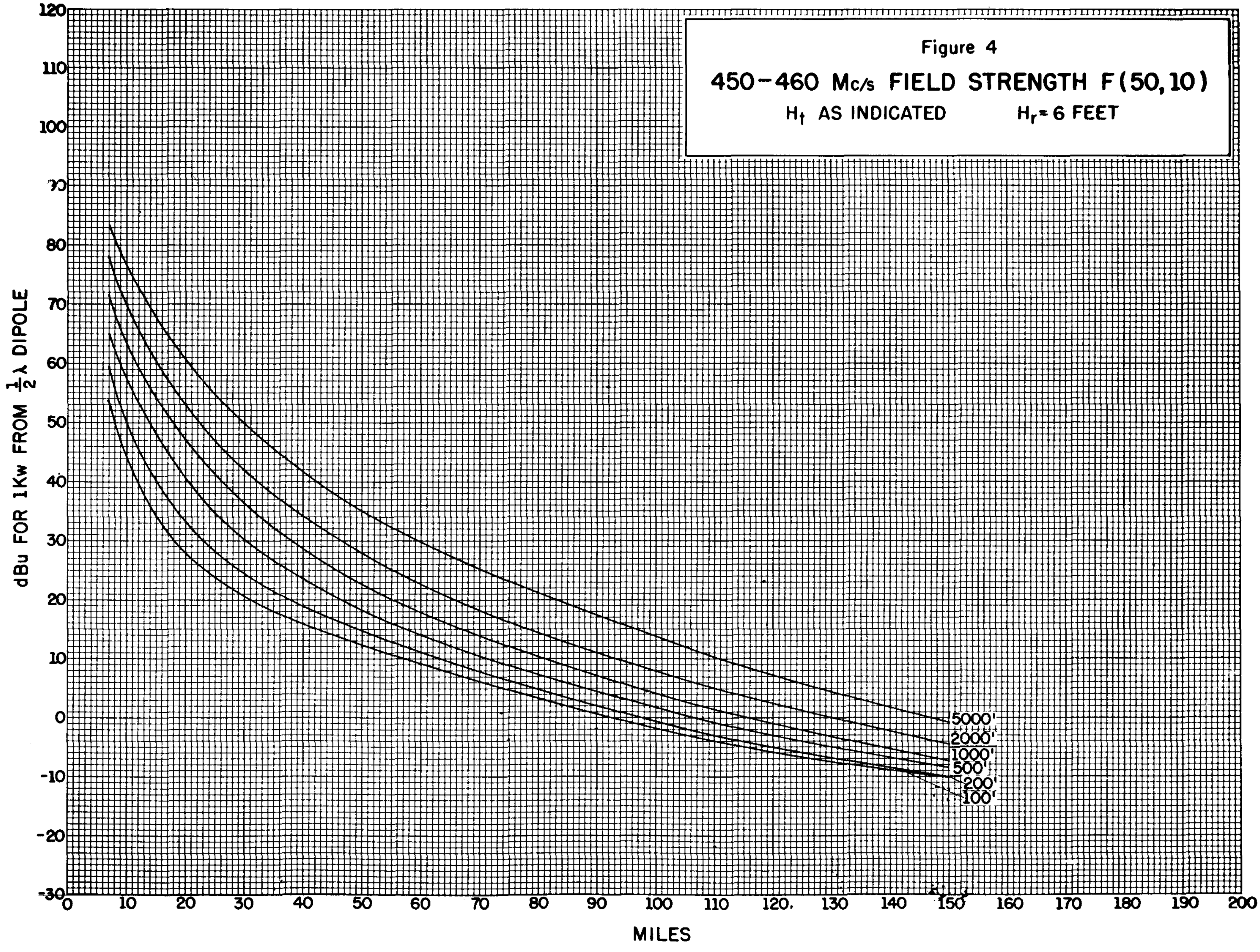

Figure 4
450-460 Mc/s FIELD STRENGTH F(50,10)
Ht AS INDICATED
Hr = 6 FEET
dBu FOR 1Kw FROM ½λ DIPOLE
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
MILES
5000'
2000'
1000'
500'
200'
100'

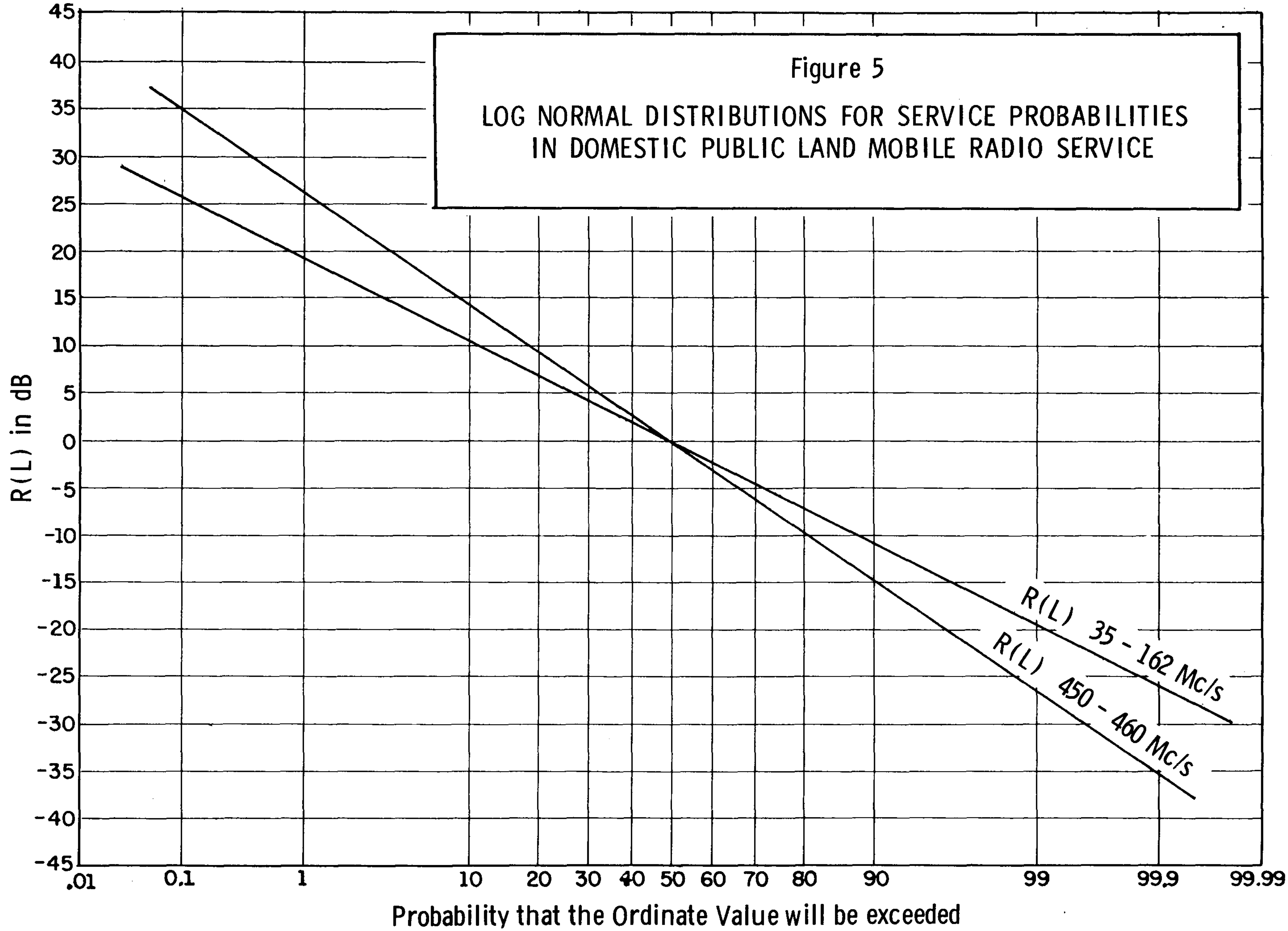

Figure 5
LOG NORMAL DISTRIBUTIONS FOR SERVICE PROBABILITIES IN DOMESTIC PUBLIC LAND MOBILE RADIO SERVICE
R(L) in dB
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
.01
0.1
1
10
20
30
40
50
60
70
80
90
99
99.9
99.99
Probability that the Ordinate Value will be exceeded
R(L) 35 - 162 Mc/s
R(L) 450 - 460 Mc/s