RADIO ENGINEERING
MICROWAVE RADIO
PROPAGATION
RAIN FADING

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1. INTRODUCTION

1.01 Rainfall can severely attenuate microwave radio signals. Its effect on the 4- and 6-GHz bands is small in comparison with other causes of fading. The 11-GHz band and above, however, is particularly vulnerable to rain. This is because radio energy is absorbed and scattered by rain drops and these effects become more pronounced at the higher microwave frequencies where the wavelength approaches the diameter of the raindrops.

1.02 This section presents data on average rainfall in the various areas of the United States, the amount of attenuation that rainfall of varying severity will cause, and a method of predicting the probable rain outage time a given radio path will experience. The majority of the information in the section is based on studies of propagation in the 11-GHz band.

2. EFFECT OF RAIN ON PROPAGATION

2.01 The transmission of radio signals in regions of rainfall will cause the radiation to scatter in all directions. If the size of the rain particles is large enough and sufficiently concentrated, the scattering will result in appreciable attenuation of the radio signal. In addition, as the rain particles comprise a lossy dielectric, energy will be absorbed from the signal and converted into heat. Both phenomena are entirely negligible at frequencies below 3 GHz but, as the wavelength decreases, the scattering and absorption become important until, at frequencies above 10 GHz, they place a limitation on transmission through rain over appreciable distances.

2.02 The theoretical excess path loss per mile for the three common carrier frequency bands, 4, 6, and 11 GHz, is shown in Fig. 1.

3. REGIONAL PERFORMANCE PREDICTIONS

3.01 The amount of attenuation caused by rain is a function of droplet size and the intensity of the rain storm. Therefore, system outages should be treated on a probability basis by geographical area. The rate of rainfall and not total rainfall is the determining factor. Areas with high annual rainfall accumulations may seldom experience rainfall of a rate sufficient to interrupt service on a well-engineered system. Also, in most parts of the country, heavy rainfall rates are likely to accompany thunderstorms which are generally confined to a small area (1 to 2 miles). In these cases the heavy rainfall may not extend over a sufficient distance along the path to cause the fading margin to be exceeded. Studies on the size, severity, and distribution of rainstorms have tended to confirm this. Measurements, taken simultaneously at approximately 100 points in a 50-square-mile area, indicate that heavy rainfall is not evenly distributed over an area but is formed in cells of varying intensity and size. Figure 2 is one of many plots of rainfall rate contours obtained in the study. The plot points up the spatial variability of rainfall rates. In most areas, the total system outage because of rain is expected to consist of short periods which will be most frequent when thunderstorms are prevalent.

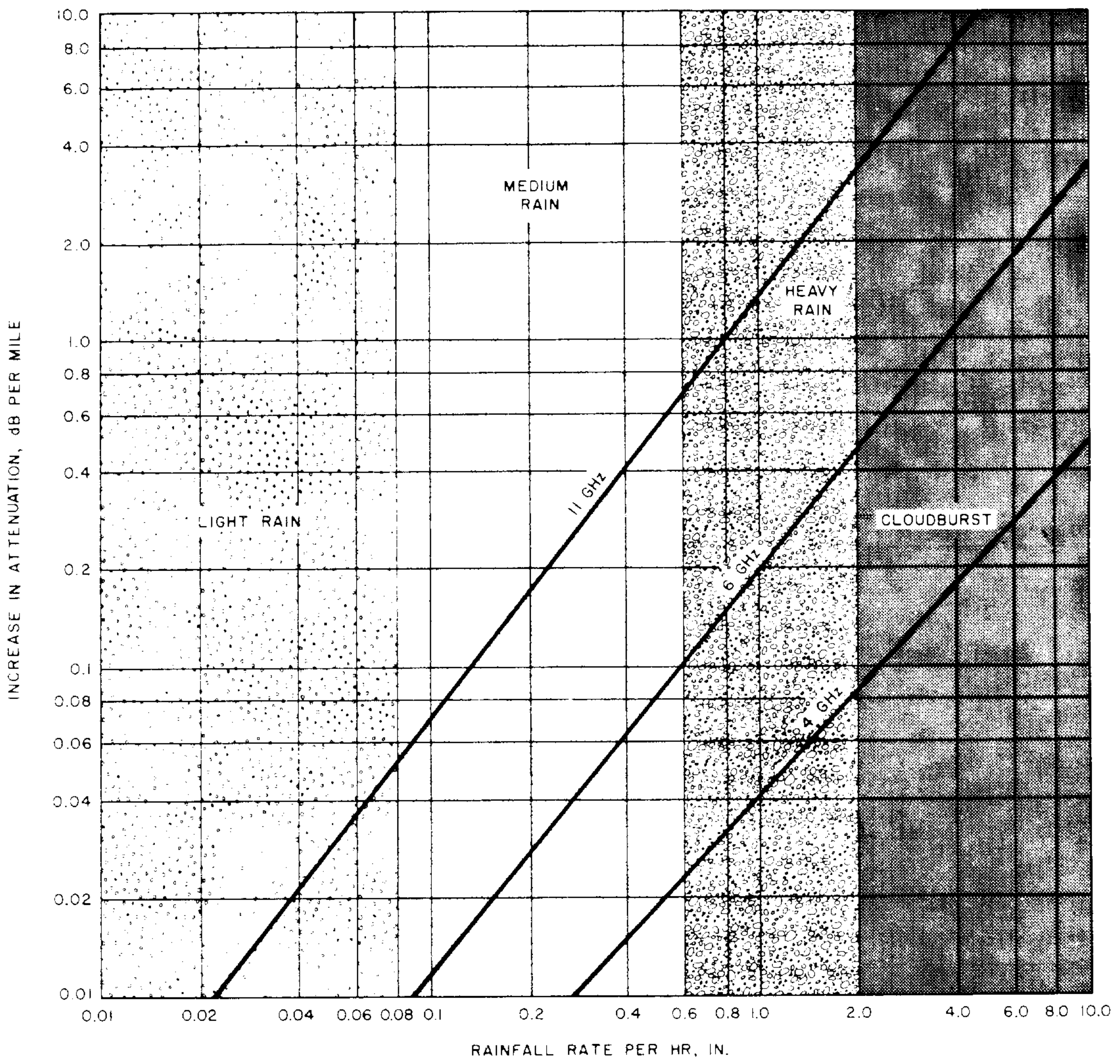

Fig. 1—Rain Attenuation Versus Rainfall Rate (Theoretical, After Ryde and Ryde)

3.02 Figure 3 is a map of the continental United States. The contour lines are boundaries of areas of equal expected rain outage. To determine the radio hop lengths that will provide acceptable reliability from the standpoint of rain attenuation, refer to Fig. 3 and find the contour line with the lowest alphabetical letter bounding the area in which the hop is located. (Consider the letter A the lowest letter on the map.) Then refer to Fig. 4 to estimate the expected annual rain outage. For example, if a 15-mile path is assumed in the western part of South Carolina, the expected annual rain outage would be 0.6 hours per year as read from contour C. Note that the expected outage increases rapidly as the hop length is increased.

3.03 Figure 4 is based on a fading margin of 40 dB. The rain outage determined from Fig. 4 should be modified to reflect the actual fading margin on a hop. Figure 5, though based on limited data, may be used to make the correction. Thus, if the system of interest has a fading margin of 30 dB, the expected rain outage becomes approximately one hour per year (0.6 x 1.65, from Fig. 5). The estimated annual outage for the system will be the sum of the individual hops.

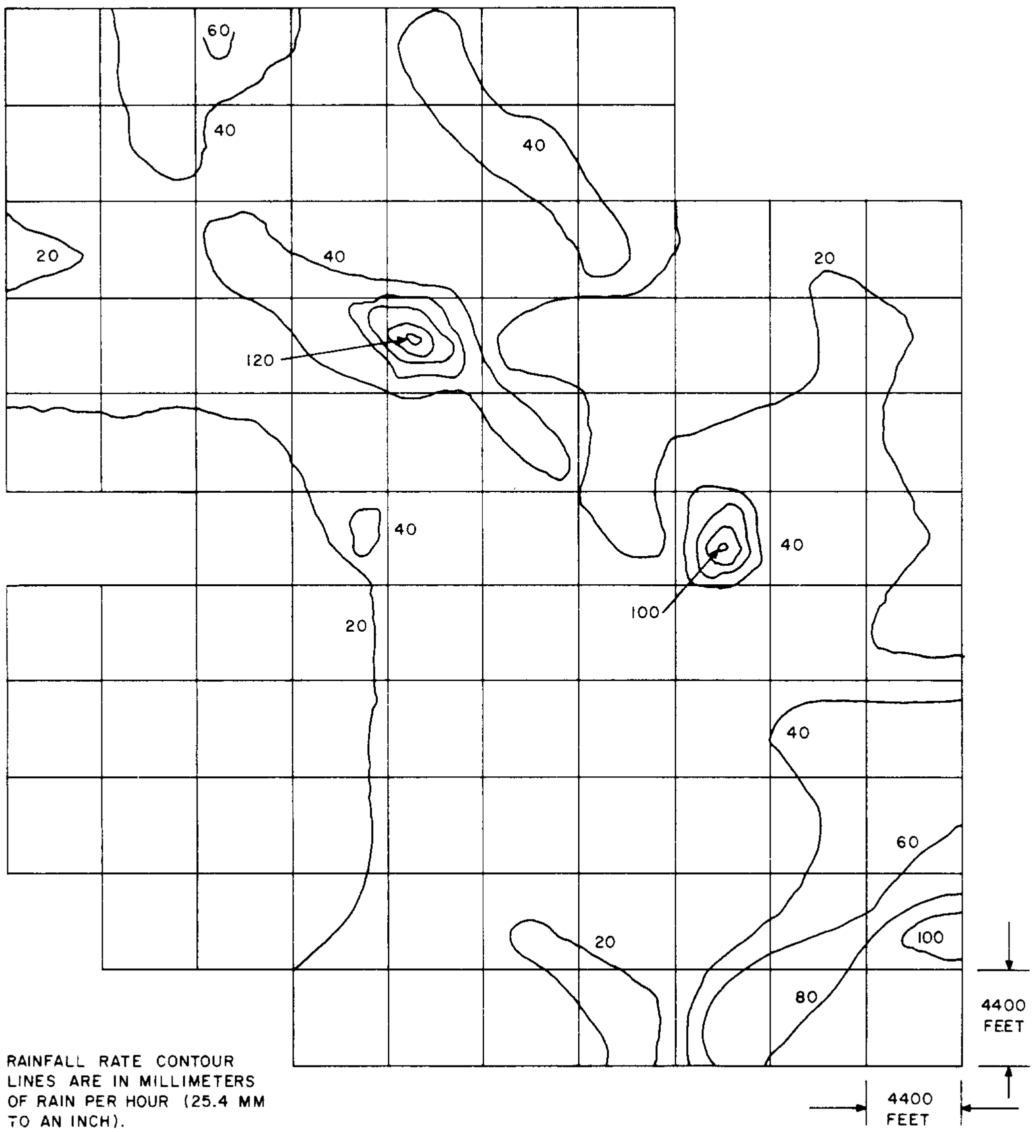

Fig. 2—A 10-Second Example of Rainstorm Data

4. CONCLUSIONS

4.01 The method of estimating annual rain outage for a system (Part 3) should enable an average hop length to be determined which will result in an estimated total outage that will meet the objective chosen for a particular system. If one or more hops must be longer than this average, it will be necessary to shorten one or more of the remaining hops to keep the outage time within the system objective.

4.02 It should be evident from Fig. 3 and 4 that the average path lengths will vary with the area, the number of hops in the system, and the reliability required. Average hop lengths in areas bounded by contours A and B in Fig. 3 (Gulf Costal areas) will, of necessity, have to be very short, but longer hops should be feasible in areas of the country having less intense rainfall.

4.03 Since vertical space diversity and frequency diversity do not protect a system against rain fading (rain attenuation over an individual microwave band is almost independent of frequency), it is important that good fading margins be obtained in areas where rain appears to be a problem. It should also be noted that reducing the hop length not only reduces the probability of severe rain fading, but also increases the fade margin.

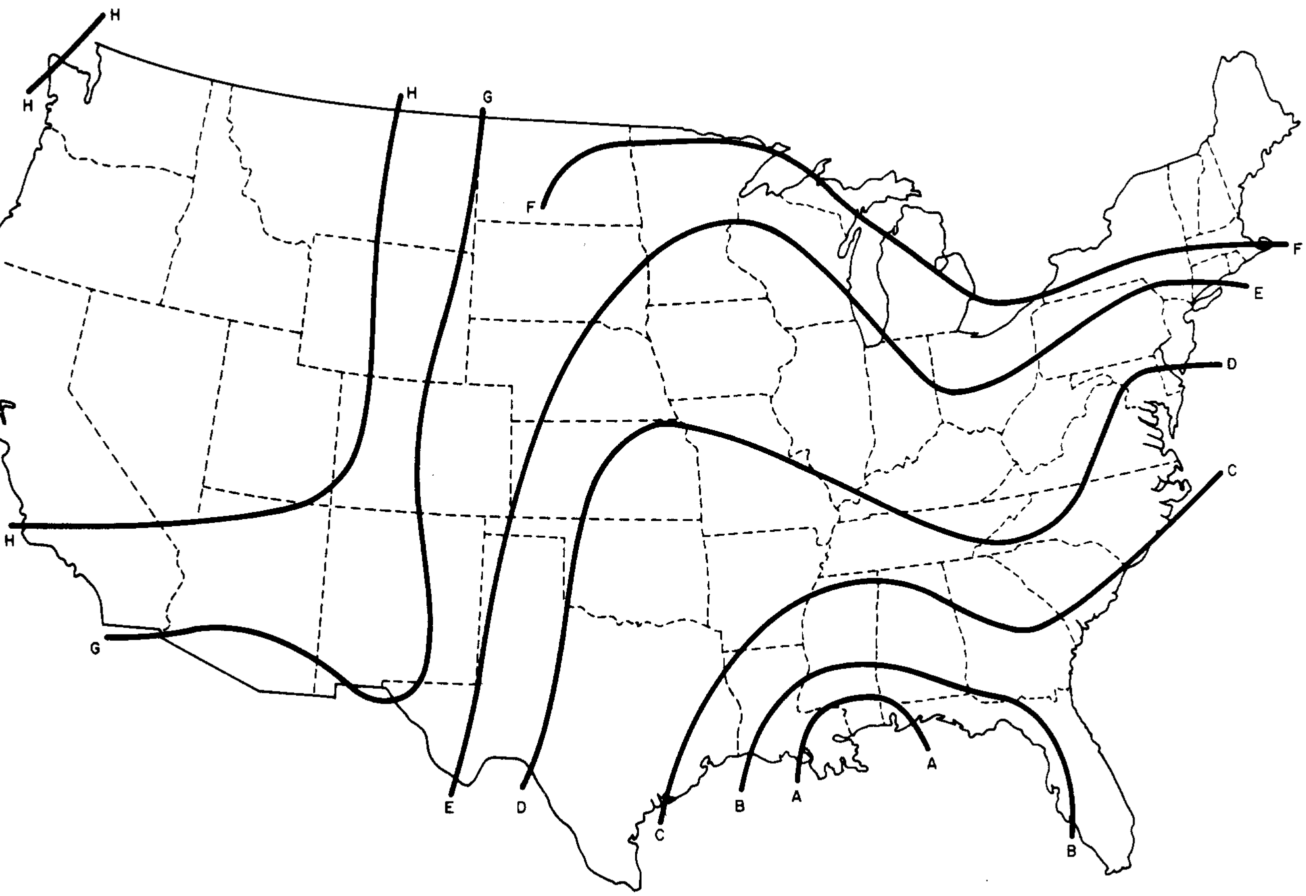

Fig. 3—Contours of Areas with Expected Equal Outage Time

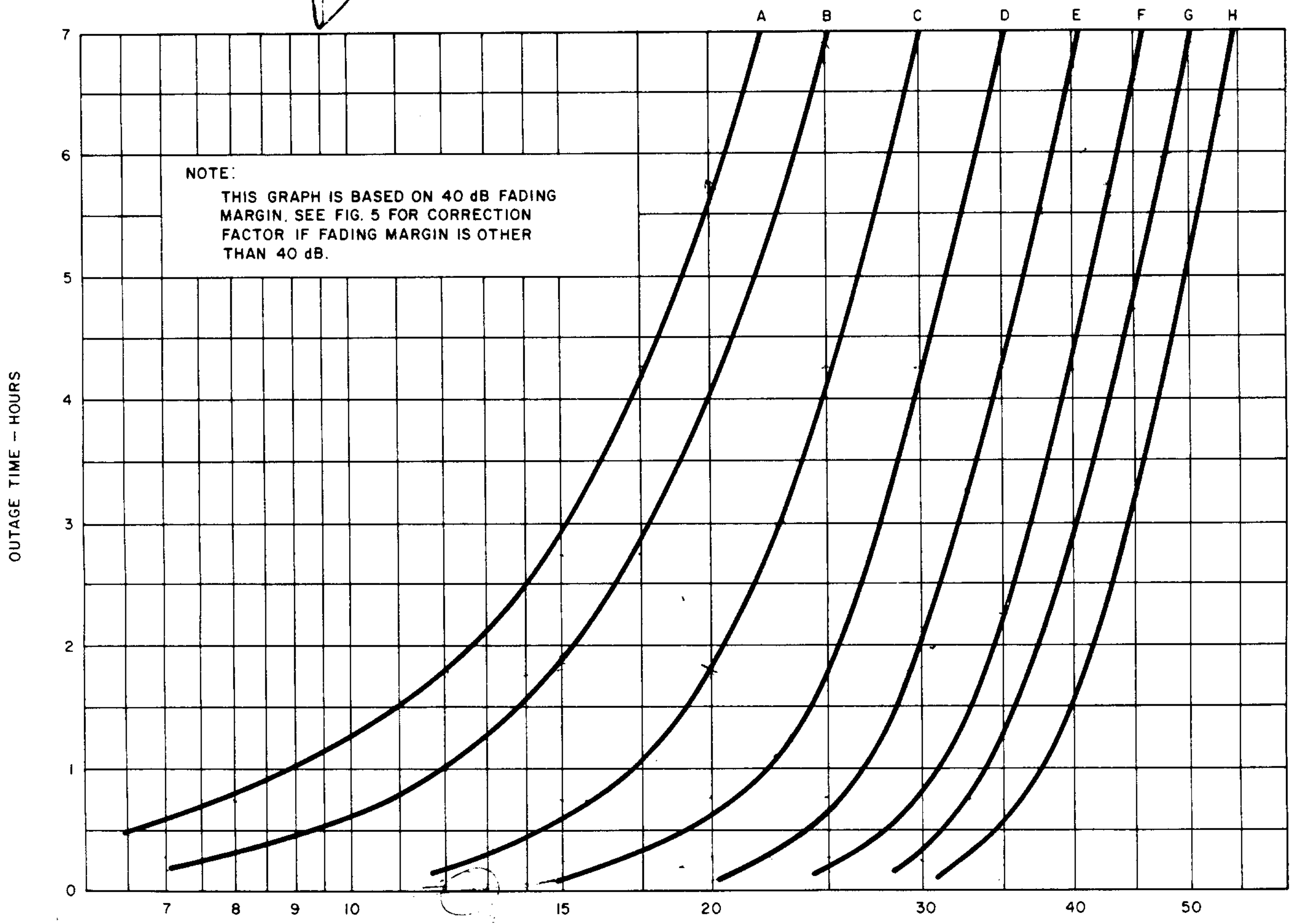

Fig. 4—Expected Outage Time in Hours Per Year Versus Path Length in Miles for Various Areas of the United States

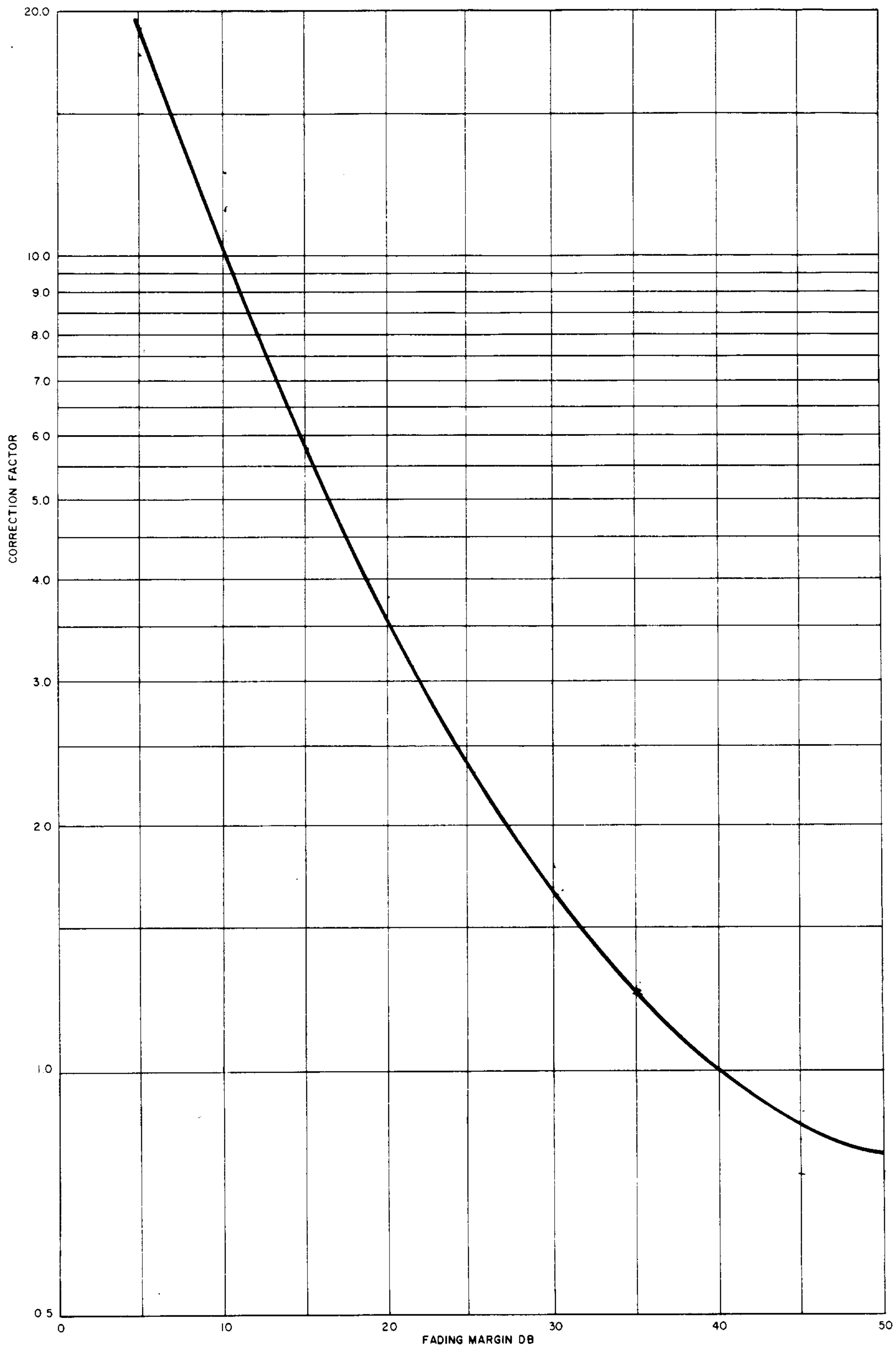

Fig. 5—Estimated Correction Factor to be Applied to Fig. 4 for Fading Margin of Less Than 40 dB