

RECOMMENDATION ITU-R F.1106

**EFFECTS OF PROPAGATION ON THE DESIGN AND OPERATION
OF TRANS-HORIZON RADIO-RELAY SYSTEMS**

(Question ITU-R 103/9)

(1994)

The ITU Radiocommunication Assembly,

considering

- a) that the effects of propagation are crucial in the design and operation of trans-horizon radio-relay systems;
- b) that transmission characteristics can be determined in terms of the amplitude and phase properties of a received signal;
- c) that amplitude variation as a function of time consists of a rapid variation superimposed on a slow change;
- d) that rapid variations, which are basically caused by multipath phase interference phenomena, can be mitigated in many cases by diversity techniques;
- e) that the effects of slow variations of received power may be minimized through the use of high-power transmitting equipment, high-gain antennas, e.i.r.p. automatic level control, very low-noise receiving systems, low-loss feeders, adaptive message-loading techniques, and improved detection and other practices for system optimization, which are associated with the choice of radio-frequency carrier, bandwidth and modulation,

recommends

- 1. that the guidance contained in Annex 1 should be taken into consideration in the design and operation of trans-horizon radio-relay systems (see Notes 1 and 2);
- 2. that, in particular, the following factors should be taken into consideration in the design and operation of digital trans-horizon radio-relay systems:
 - 2.1 the combined gain of the transmitting and receiving antennas may be less than the sum of their plane-wave gains as described in § 2 of Annex 1; this apparent drop in gain is termed “gain degradation” or “antenna-to-medium coupling loss”;
 - 2.2 Recommendation ITU-R F.698 should be referred to for the preferred frequency bands for trans-horizon radio-relay systems;
 - 2.3 diversity techniques, such as space diversity, frequency diversity and angle diversity are effective for mitigating adverse effects caused by rapid variations of a received signal, as described in § 4.1 of Annex 1;
 - 2.4 transmission bandwidth of a system utilizing diversity techniques can be estimated by the methods described in § 4.2 of Annex 1;
 - 2.5 in order to mitigate the effects of multipath dispersion on digital trans-horizon radio-relay systems, order of diversity, adaptive equalization and selection of effective modems should be taken into consideration as described in § 5 of Annex 1;
 - 2.6 in order to mitigate the effect of interference to other systems, caused by side lobe and overshoot signals under conditions of enhanced propagation, the use of automatic level control of the transmitter power, from the level received at associated distant receivers, should be considered.

Note 1 – This Recommendation applies to trans-horizon systems using tropospheric scatter but not necessarily to trans-horizon systems using other modes of propagation (diffraction, etc.).

Note 2 – Recommendation ITU-R PN.617 should also be referred to for the propagation data required for the design of trans-horizon radio-relay systems.

Factors concerning effects of propagation on the design and operation of trans-horizon radio-relay systems

1. Introduction

This Annex is based on consideration of systems carrying a relatively small number of voice channels or a television signal.

Transmission characteristics can be defined in terms of the amplitude and phase properties of a received signal. Given a tropospheric-scatter path, both amplitude and phase transmission characteristics vary with frequency and time.

Amplitude variation as a function of time consists of a rapid variation superimposed on a slow change. Rapid variations, which are basically caused by multipath phase interference phenomena, can be mitigated in many cases by diversity techniques. The effects of slow variations of received power may be minimized through the use of high-power transmitting equipment, high-gain antennas, very low-noise receiving systems, low-loss feeders, adaptive message-loading techniques, and improved detection and other practices for system optimization, which are associated with the choice of radio-frequency carrier, bandwidth and modulation.

2. Drop in antenna gain

The combined gain of the transmitting and receiving antennas may be less than the sum of their plane-wave gains. This apparent drop in gain is termed “gain degradation” or “antenna-to-medium coupling loss”. Theoretical analyses state that the amount of loss is dependent on the antenna gain and scatter angle.

The path antenna gain or total effective antenna gain over a trans-horizon system has been observed experimentally to be practically independent of distance between about 150 and 500 km. According to these experiments, the total effective gain (see Fig. 1) may be assumed to depend only on the sum of the free-space antenna gains, without large corrections provided that neither of the free-space antenna gains exceeds about 50 dB, and the gains of the two antennas do not differ greatly.

Further studies indicate that the drop in antenna gain is related to the slope of the refractive index gradient-altitude curve within the common volume, consequently the variations of drop in antenna gain as a function of distance depend slightly on the climate. These studies also show that, with increasing antenna gain, the slope of the curve in Fig. 1 tends asymptotically to 1/4.

3. Choice of frequency band

The choice of a frequency band for a trans-horizon radio-relay link depends on:

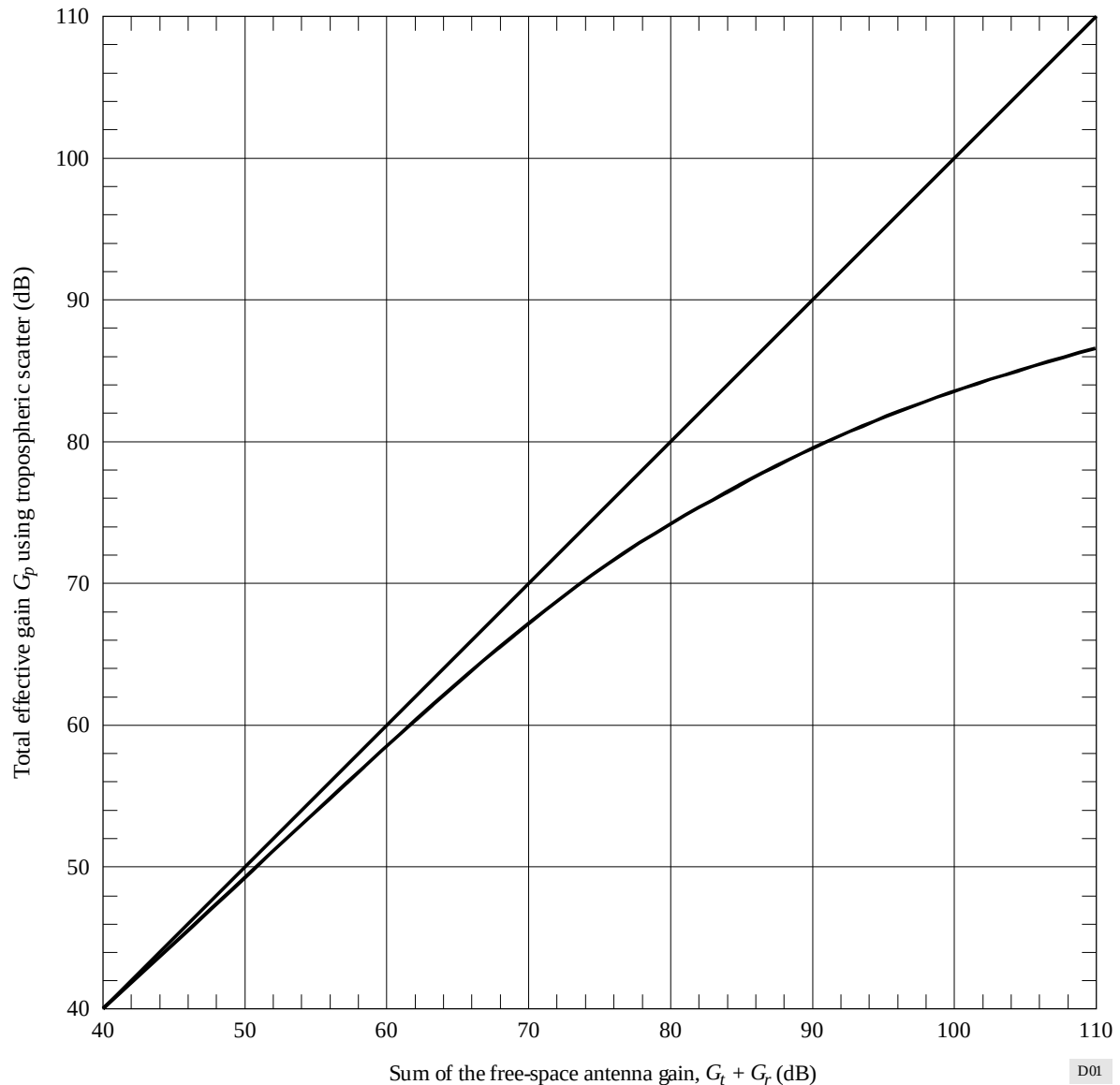
- propagation considerations, to obtain a sufficient received level and an adequate transmitting bandwidth;
- frequency sharing considerations, in relation with the usual high transmitting power trans-horizon systems.

These problems are described in Recommendation ITU-R F.698.

4. Diversity reception in trans-horizon radio-relay links

Most trans-horizon systems are designed to minimize the adverse effects of fluctuations due to propagation by making use of the partially correlated properties of the transmitted signal through diversity reception and/or transmission. Diversity techniques are also very useful for trans-horizon digital radio-relay systems because they can lead to a reduction of short-term outages which are caused by multipath fading.

FIGURE 1
Relations between antenna gains (tropospheric scatter)



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4.1 Methods of obtaining diversity signals

4.1.1 General

The most commonly used methods are frequency and space diversity, i.e., simultaneous transmission of the same signal over two or more channels (frequency diversity) and utilizing two (or more) antennas for reception and/or transmission (space diversity). Some operational systems have used a combination of frequency and space diversity. Diversity reception, making use of relatively uncorrelated properties of the direction of arrival, has been also demonstrated to be beneficial in minimizing not only the rapid-fading problem, but also in lessening antenna-to-medium coupling loss.

To realize substantial operational benefits from diversity reception, low orders of correlation coefficient are not required.