

RECOMMENDATION ITU-R P.1060*

**PROPAGATION FACTORS AFFECTING FREQUENCY SHARING IN
HF TERRESTRIAL SYSTEMS**

(Question ITU-R 219/3)

(1994)

The ITU Radiocommunication Assembly,

considering

- a) that frequency sharing at HF is difficult in practice because of the nature of the ionosphere and ionospheric propagation;
- b) that models of both short- and long-term variability in ionospheric propagation may facilitate improved frequency sharing;
- c) that modern frequency agile communications systems provide new techniques for increasing frequency sharing,

recommends

1. that the propagation factors indicated in Annex 1 should be taken into account when designing, planning and operating radiocommunication services or systems in the HF band.

ANNEX 1

1. Introduction

Limitations on the sharing of radio frequencies in the HF spectrum are dependent on the propagation characteristics of ionospheric radiowaves. Frequency sharing at HF has been found to be extremely difficult because radiowaves propagating via the ionosphere do not attenuate quickly. Any attempt at frequency sharing must consider the facts that at HF,

- radiowaves normally propagate in all directions;
- radiowaves are refracted and reflected by the ionosphere and the ground and will continue until dissipated.

In the highly congested HF band the occupancy of individual channels and possible co-frequency allocation vary with the type of service, frequency, time-of-day, season, angle of arrival, type of receiving antenna, bandwidth, service threshold, geographic location and solar activity.

Recommendation ITU-R M.831 addresses the technical factors to be taken into account when preparing studies relating to sharing between fixed and other services at frequencies below 30 MHz. Of the factors highlighted, that of circuit predictability concerns the propagation of ionospheric waves.

2. Signal strength

The possibilities of co-frequency assignment at HF hinge on the signal intensities of wanted and unwanted signals at the receiving site. Because the signal intensity is dependent on the propagation path, reduction of the unwanted signal requires separation by geographic distance (assuming transmissions cannot be interleaved in time) between the receiver and the unwanted transmitter. Transmitted powers should be kept to the minimum necessary to provide a satisfactory service.

* Radiocommunication Study Group 3 made editorial amendments to this Recommendation in 2000 in accordance with Resolution ITU-R 44.

Propagation via the ionosphere is governed by the frequency of the signal relative to the plasma density of the ionosphere. Variations in the ionization density of the ionosphere will affect the propagation characteristics such as signal intensity (through transmission losses), polarization and Doppler shift.

Ionospheric density and structure vary with time of day, season, solar cycle and location, and must be taken into account when determining transmission characteristics so as to maintain the minimum required signal strength at the receiver.

3. Signal attenuation

To optimize frequency sharing, radio services need to restrict their transmissions to their zone of interest. Because HF signals continue to propagate past the receiver site, it is important to limit the signal intensity at the receiver to the minimum required by optimizing characteristics that cause the signal to decay swiftly beyond the receiving location, such as frequency, and antenna vertical radiation angle.

The signal attenuation loss over a propagation path is made up of free-space loss, ionospheric loss, ground reflection loss and polarization loss. From this one can expect the signal to attenuate fastest when:

- the frequency is close to the LUF;
- the elevation angle is higher than optimum for the path (many small hops);
- the ray path is long;
- the circuit is over lossy ground.

To cause the signal to decay rapidly beyond the receiving site, it is desirable to operate at a frequency close to the lower limit of the available frequency range for the particular circuit. However this can be in conflict with signal quality which generally increases as the frequency approaches the MUF. Optimizing the signal requires a clear definition of the necessary service margins at the receiver and a knowledge of the behaviour of the signal under various ionospheric conditions.

4. Skip zone

At a distance close to the transmitter but beyond the limit of ground waves, there can be a zone where sky waves from the transmitter cannot reach because they exceed the MUF and pass through the ionosphere.

Theoretically this provides a zone in which frequency sharing can operate. However, in practice measurements have indicated that signals can penetrate into the skip zone by sidescatter.

5. The use of propagation models

Radio propagation prediction models such as that of Recommendation ITU-R P.533 can provide guidance on the expected characteristics of circuits. This information can be used to indicate where there may be possibilities for the sharing of frequencies.

These models are based on average behaviour and should not be expected to give results beyond their statistical capabilities. For example they do not predict well the behaviour of ionospheric propagation in the equatorial region where the anomaly can cause transient variations from the normal modes of propagation and high signal intensities can be transmitted over long distances. Again, sporadic-E propagation can cause interference which will not be predicted by the models. In the high latitude regions there are irregularities and transient phenomena which cannot be accounted for by the models.

6. Variations in propagation

While models can provide a statistical guide to circuits that may share frequencies, the effect of real variations in the ionospheric propagation needs to be considered. Variations in propagation and the reality of signal strength fading should be accounted for by making allowance for the expected variation. Report ITU-R P.266 provides the background information on the nature of these variations while Recommendations ITU-R F.339 and ITU-R BS.411 give values for fading allowances for fixed and broadcasting service applications.

Unwanted signals can propagate beyond their intended reception area to an unpredictable extent when sporadic-E layers are present (Recommendation ITU-R P.534 provides occurrence statistics for sporadic E), when tilts are prominent near the ionospheric reflection point or when irregularities in the ionospheric density give rise to sidescattered signals.

Most of these phenomena occur at certain times of the day, season or solar cycle and there is a case for dynamic assignment of frequencies where the use of shared frequencies would be withdrawn during the periods of abnormal propagation.

7. Frequency agile systems

Dynamic frequency sharing or real-time frequency management is a useful tool for providing communication circuits that are not otherwise possible because of interference constraints. Dynamic sharing implies operation on a secondary basis where there is no possibility of a claim for interference-free communication. This type of sharing is possible with frequency-agile transmitting and receiving equipment made feasible by modern technology. Dynamic frequency sharing is particularly effective when one service operates with high power on known or published frequencies, such as the broadcasting service and the dynamic service operates with low power involving two-way communications such as in the fixed, mobile and amateur services.

Real-time channel evaluation (RTCE) systems, which test the quality of a specific circuit over a set of channel frequencies in real-time, provide the means of matching current propagation conditions over the circuit with the frequencies available. Radio systems incorporating RTCE are becoming available and use of such techniques is likely to increase.

RTCE can provide a means of automatically selecting the best frequency and simultaneously indicating stand-by channels. Often the best frequency is chosen to be that which maximizes the ratio of signal-to-background-noise-plus-interference. Consideration should be given to the selection of working frequencies which are sub-optimum but which are less likely to interfere with other users of the spectrum. Some RTCE equipped communication links may also have the capability to adapt transmitter power levels so that an acceptable grade of service is achieved with the minimum radiated power. Techniques such as this, which can maximize the opportunity for frequency sharing, should be encouraged.

When using RTCE systems it should be recognized that the optimization of one circuit may give rise to interference on another.

Intelligent control systems which can respond rapidly to null out interfering signals by means of adaptive antennas give the promise of increasing the chances of frequency sharing and are recommended in the situation of a few strong interferers.

8. Summary

The feasibility of frequency sharing in a particular scenario depends on compatibility, that is, meeting the specified protection ratio for the required percentage of time (recommended protection ratios for use in sound broadcasting and for the fixed services appear respectively in Recommendations ITU-R BS.560 and ITU-R F.240). Transmitted power and propagation loss are paramount factors in determining whether or not there is compatibility between emissions. For this reason there are particular advantages in having like services with comparable radiated powers sharing the same bands. Propagation loss depends to a first order on distance so that sharing is more likely to be possible where the geographical separations between co-channel and adjacent channel emissions are greatest. With the crowded nature of the spectrum, sharing must be adopted and each case of potential harmful interference needs to be assessed separately.
