

## RECOMMENDATION ITU-R F.1093-2\*

**Effects of multipath propagation on the design and operation  
of line-of-sight digital fixed wireless systems**

(Question ITU-R 122/9)

(1994-1997-2006)

**Scope**

This Recommendation provides an introduction to propagation-related aspects of the design and operation of digital radio-relay systems, drawing on information from Radiocommunication Study Group 3 texts and measurements conducted by administrations. Annex 1 explains the role of multipath fading as the dominant propagation factor for digital radio-relay systems operating at frequencies below about 10 GHz. Further material discusses the roles of diversity techniques and adaptive equalization in reducing channel degradations.

The Radiocommunication Assembly,

*considering*

- a) that fading due to multipath propagation may distort and attenuate received signals on line-of-sight paths and thereby impair the performance of fixed wireless systems (FWSs);
- b) that Recommendation ITU-R P.530 provides data and methods for FWS propagation prediction and path planning;
- c) that countermeasures to reduce the effects of multipath fading on system performance, such as diversity reception and adaptive equalization, are available;
- d) that methods of analysing the effects of multipath fading on the error performance of FWS are needed for comparing alternative designs,

*recommends*

- 1 that multipath fading countermeasures should be incorporated in radio system design, as needed, to improve error performance;
- 2 that the methods in Annex 1 should be used for guidance in radio link planning.

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\* This Recommendation should be brought to the attention of Radiocommunication Study Group 3.

## Annex 1

### Effects of multipath propagation on design and operation of line-of-sight digital FWSs

#### 1 Introduction

The purpose of the present Annex is to furnish an introduction to propagation-related aspects of the design and operation of digital radio-relay systems, drawing on information from Radiocommunication Study Group 3 texts and measurements conducted by administrations. The first part of the Annex explains the role of multipath fading as the dominant propagation factor for digital radio-relay systems operating at frequencies below about 10 GHz. The following sections discuss the roles of diversity techniques and adaptive equalization in reducing channel degradations. Finally, the prediction of system performance depending on the foregoing factors is treated.

More detailed information on the application of the guidance contained here can be found in the Handbook on digital radio-relay systems.

#### 2 Propagation considerations

The texts established by Radiocommunication Study Group 3 contain a wealth of information on the propagation phenomena to be taken into account in the design and operation of radio-relay systems. In particular, Recommendation ITU-R P.530 is especially concerned with “propagation data and prediction methods required for line-of-sight radio-relay systems”. In that Recommendation, the information is arranged according to the propagation effects that must be considered. The relevant meteorological information concerning the propagation mechanisms is given in other Recommendations of the P series, notably Recommendations ITU-R P.834 and ITU-R P.676.

Propagation conditions vary from month to month and from year to year, and the probability of occurrence of these conditions may vary by as much as several orders of magnitude. It may therefore take some three to five years before drawing a proper conclusion on the results of a propagation experiment. However, for system application requirements, this time is often not available and models of this variability for some parameters have been examined in Recommendation ITU-R P.841.

From propagation data it was concluded that for a well-designed path which is not subject to diffraction fading or surface reflections, multipath propagation is the dominant factor in fading below 10 GHz. Above this frequency, the effects of precipitation tend increasingly to determine the permissible path length through the system availability objectives. The necessary reduction in path length with increase in frequency, reduces the severity of multipath fading. These two principal causes of fading are normally mutually exclusive. Given the split between availability and error performance objectives, precipitation effects contribute mainly to unavailability and multipath propagation mainly to error performance. Another influence of precipitation, e.g. back-scatter from rain, may influence the choice of radio-frequency channel arrangements.

Propagation effects due to various forms of precipitation tend not to be frequency dispersive, while multipath propagation caused by tropospheric layers can be, and this may cause severe distortion of information-bearing signals. The rapid development of digital communication systems has required an improved understanding of these effects and the means to overcome them.

### 3 Countermeasures to propagation effects

There are two countermeasures to propagation distortion commonly used: diversity techniques and adaptive channel equalizers, which attempt to combat attenuation and distortion caused by the propagation medium. The effectiveness of a fading countermeasure is usually expressed in terms of an improvement factor. On a single test path, the improvement factor is the ratio of the outage time observed for a system without the countermeasure, to that observed when the countermeasure is operative (see Note 1). The improvement factor depends on the outage threshold chosen.

NOTE 1 – Outage time is a general term to indicate the time duration over which the system exceeds a chosen bit-error ratio (BER) threshold.

#### 3.1 Diversity techniques

The most commonly used diversity techniques are frequency diversity and space diversity. For others, see Recommendations ITU-R F.752, ITU-R P.530 and the ITU-R Handbook on Digital Radio-Relay Systems (edition 1996).

##### 3.1.1 Space diversity

Space diversity is one of the most effective methods of combating multipath fading. For digital radio systems, where the performance objectives can be difficult to meet owing to waveform distortions caused by multipath effects, system designs must often be based on the use of space diversity.

In space diversity systems the signals received by two vertically separated receiving antennas rarely fade simultaneously when the fades are deep. The improvement factor that a system may achieve by using these two signals depends on both propagation factors and the radio system implementation, that is, its vulnerability to the power loss and multipath distortion of signals and its method of processing them. In evaluating the improvements achievable with space diversity, the accepted practice has been to use the single frequency fading improvement factor formulation in Recommendation ITU-R P.530, or similar formulations verified for regional application, particularly for thermal noise considerations in calculating outage probabilities (see § 4).

By reducing the effective incidence of deep fading, space diversity can reduce the effects of various types of interference. In particular, it can reduce the short-term interference effects from cross-polar channels on the same or adjacent channel frequencies, the interference from other systems, and from within the same system.

Linear amplitude dispersion (LAD) is an important component of waveform distortion and quadrature cross-talk effects, and can be reduced by the use of space diversity. Diversity combining designed specifically to minimize LAD (see Recommendation ITU-R F.752) is among the methods that are particularly effective in combating this distortion.

The improvement derived from space diversity will depend upon how the two signals are processed at the receiver. Two examples of techniques are “hitless” switching and variable phase combining (see Recommendation ITU-R F.752). The “hitless” switch selects the receiver which has the greater eye opening or the lower error ratio and the combiners utilize either co-phase or various types of dispersion-minimizing control algorithms. “Hitless” switching and co-phase combining provide very similar improvement factors.