

RECOMMENDATION ITU-R F.752-2*

Diversity techniques for point-to-point fixed wireless systems

(1992-1994-2006)

Scope

This Recommendation provides diversity techniques for point-to-point fixed wireless systems. The diversity techniques include those considered in the domain of space, angle, frequency or their combinations. Basic methods for choice of diversity, obtaining or processing the diversity signals are presented in the Annex, which also gives practical diversity effects based on propagation data. Diversity techniques using alternative transmission media or route/site diversity which may be applied to improve system availability are not handled in this Recommendation.

The ITU Radiocommunication Assembly,

considering

- a) that frequency-selective fading may distort and reduce the strength of received signals on line-of-sight and trans-horizon paths and thereby impair the performance of a fixed wireless system;
- b) that the application of diversity techniques is useful in reducing the effects of fading on system performance;
- c) that the provision of diversity reception is necessary to achieve satisfactory performance on diffraction and trans-horizon paths;
- d) that various techniques for implementing diversity on line-of-sight, diffraction and trans-horizon paths have been studied and are in use;
- e) that the application of diversity techniques can provide high performance in line-of-sight systems that make efficient use of the radio spectrum;
- f) that further information regarding the use and application of diversity techniques can be found in Recommendations ITU-R P.530 and ITU-R F.1093,

recommends

- 1 that the information presented in Annex 1 should be used when applying diversity techniques to fixed wireless systems (see Note 1).

NOTE 1 – The ITU-R Handbook – Digital radio-relay systems also contains relevant material on the application of diversity techniques to fixed wireless systems.

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

Annex 1

Diversity techniques for point-to-point fixed wireless systems

1 Methods of obtaining diversity signals

The most common methods are generically described as frequency diversity and space diversity. In frequency diversity, the same information is transmitted over more than one radio channel. In space diversity, the signal reaches the receiver through more than one transmit/receive antenna path. A description of diversity implementation in different systems operating in distinctive propagation regimes requires a more detailed description of space diversity methods.

Trans-horizon systems have used diversity on both transmit and receive. They use multiple diversity with full, three-dimensional, flexibility in the placement of antennas, and sometimes use angle diversity in which multiple beams or directivity patterns are formed with a single antenna. Angle diversity provides relatively uncorrelated signals by taking advantage of the variations in the angle of arrival of the scattered energy at the receiver.

On line-of-sight paths, space diversity is usually implemented using two antennas at the receiver with a large enough vertical separation to provide two signals in which the impairments due to multipath fading are sufficiently decorrelated, where the impairments are signal distortion and loss of signal power. Concerns for the performance of digital radios, for which signal distortion is the dominant propagation impairment, have led to the introduction of diversity methods that rely on the non-uniform structure of the incident electromagnetic field near the main receiving antenna, instead of large spatial separations, to decorrelate the signal impairments.

In these methods, which are called pattern diversity or angle diversity, the diversity signal is derived from a second antenna or beam that has a different directivity pattern or angular beamwidth in the vertical dimension and/or a different boresight elevation angle. These diversity methods, which can be implemented with antennas that are at the same, or nearly the same, height or with multiple feeds within a single antenna, allow diversity to be added to an existing hop without requiring tower height extensions to obtain path clearance for diversity reception. Although some studies attempt to distinguish between angle and pattern diversity, others use the terms interchangeably.

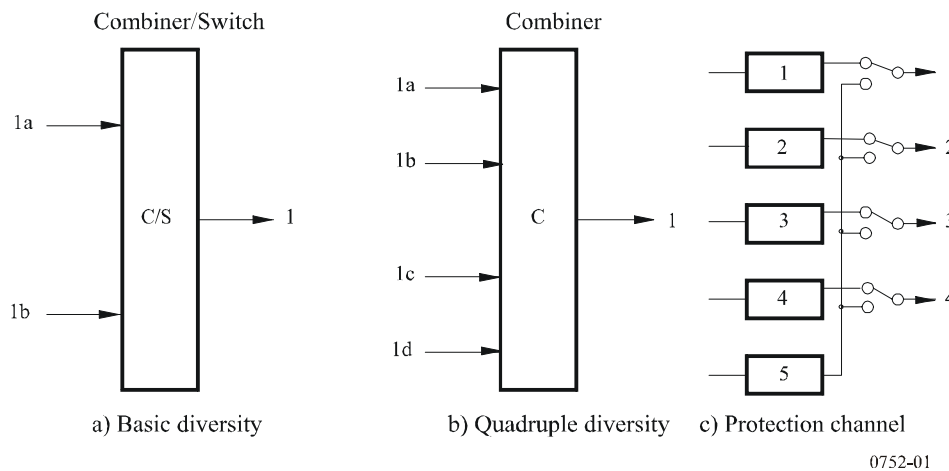
Since the effectiveness of any diversity system depends on the correlations of the impairments in the signals, the displacements in space, pointing angles, and frequency are fundamental in determining system performance.

2 Methods of processing signals

2.1 Arrangements

Figures 1a) and 1b) show the basic arrangements in which two or four signals are used to derive a common output or decision, in the case of some digital systems. Although systems in line-of-sight paths often use frequency diversity to implement 1 + 1 protection switching with the arrangement of Fig. 1a), it is more common to use one or sometimes two protection channels for several working channels. Figure 1c) shows the arrangement for a 1 + 4 operation. Such protection is often applied in tandem with space diversity operation on the individual channels. Under extreme conditions, such as those sometimes encountered on reflecting line-of-sight paths, space diversity is used in conjunction with 1 + 1 frequency protection. Difficult long or over-water paths have also used quadruple diversity, either in the form of quadruple space diversity or in a combination of dual space and dual frequency diversity.

FIGURE 1
Arrangements for diversity combining



2.2 Implementation considerations

Current systems implement diversity operation by using combiners at radio, intermediate, or baseband frequencies, or by using switches at intermediate or baseband frequencies. These combiners may employ equal gain, maximum power, or minimum dispersion control algorithms. Because the differences in the transmission performance are small, the equipment design choice between these alternatives is usually based on convenience or simplicity. Whether diversity is needed on a given link is determined by the expected severity of propagation conditions and by the characteristics of the transmitted signal.

The actual improvement which can be obtained from diversity depends upon many parameters, which include the influence of in-band amplitude dispersion and inter-system interference on channel performance, and the algorithms which are used in the implementation of diversity.

In high speed digital fixed wireless systems, use has been made of minimum dispersion combining devices (MID) and also of dual reception receivers in which the diversity signals are processed by maximum power combining (MAP) and the aggregate signal by adaptive equalizing (EQ). The use of MAP + EQ produces a synergistic effect, i.e. a considerable decrease in the bit error rate. The methods used for combining space diversity signals on the basis of the maximum power principle which are used in receivers with MAP + EQ can be classified into the following three categories:

- MAPEG or maximum power equal gain combining. This method which uses linear addition has the following drawback: in the case of complete fading of one of the diversity signals, the signal/noise ratio at the combiner output is 3 dB worse than with an ordinary receiver.
- MAPEG/SW or maximum power equal gain/switch combining. This method uses linear addition and there is no signal/noise ratio loss at the combiner output when the input signal from the first receiver is switched off when it becomes $(\sqrt{2} + 1)$ times weaker than the input signal from the second receiver. This method has the following drawback: when switching takes place, a transient process occurs which gives rise to an increase in the error ratio in high speed digital systems.
- MAPOPT or maximum power optimized combining. This method does not suffer from the drawbacks inherent in the MAPEG and MAPEG/SW systems. In the MAPOPT system, the diversity branches in front of the combiner contain electronic attenuators, the attenuation of which varies automatically in proportion to the ratio of the powers of the space diversity signals received. In a MAPOPT combiner, linear addition occurs when there is a

strong/weak signal power ratio of $\gamma < 7.7$ dB; if further fading occurs, smoothly varying attenuation proportional to the parameter γ is introduced into the weak signal path. The signal/noise ratio gain for MAPOPT in comparison with that of an ordinary receiver is practically equal to the gain as defined by an optimum addition combiner (maximum ratio combining or MAR).

With reference to the minimum dispersion combining devices (MID) also used for combining space diversity signals, the following method can be considered:

2.3 Minimum BER or weighted strategy

This method is based on a proper weighting of the received IF (or BB) signals and in-band dispersion in order to minimize the bit error ratio (BER).

The BER function can be estimated in real time from the received level and in-band power dispersion (IBPD) of the signal. Optimization of the estimated BER is equivalent to optimization of the radio link hop outage.

3 Applications in trans-horizon systems

3.1 Types of diversity

Existing systems use space diversity, angle diversity, and frequency diversity, either singly or in combination, to obtain sufficiently decorrelated replicas of the transmitted signal. For more detailed information on the application of these techniques and the calculation of their performance, reference should be made to Recommendation ITU-R F.1101.

3.2 Types of combiners

Trans-horizon systems have commonly employed combiners following demodulation. The types of combiners in order of decreasing efficiency are maximal-ratio, equal-gain, and selector. Equal-gain combining can result in equipment and maintenance simplification over maximal-ratio combining, at only a modest sacrifice (about 1 dB for quadruple diversity) in performance. A further narrowing of this gap can be achieved by combining equal-gain with selector diversity-combiners. With equal-gain combining, if the signal levels differ greatly, a receiver in a weak signal leg can actually degrade overall performance; however, if it is switched off under these conditions, the overall performance closely approximates an ideal maximal ratio combiner.

4 Applications in line-of-sight systems

Multipath fading on line-of-sight paths results in a loss of power which may vary selectively within a radio channel. These two aspects, loss and dispersion, can be considered separately in some applications. For FM and narrow-band digital signals, performance is controlled by narrow-band, or single-frequency, power loss; for many high capacity digital systems, dispersion controls performance. Because of the rapid evolution of high capacity digital radio systems, it is difficult in a given application to identify which systems are sensitive only to loss, which only to dispersion, and which to both. Although higher multi-state modulations are inherently more sensitive to dispersive effects, equipment design advances, such as those obtained with improved equalizers, make systems less sensitive to dispersion.