RECOMMENDATION ITU-R F.1705

Analysis and optimization of the error performance of digital fixed wireless systems for the purpose of bringing into service and maintenance

(Question ITU-R 235/9)

(2005)

Scope

This Recommendation provides analysis for optimization of the error performance of digital fixed wireless systems (FWSs) for the purpose of practical maintenance work prior to bringing into service. Annex 1 presents the guidance and systematic methods for the maintenance of both point-to-point (P-P) and point-to-multipoint P-MP systems.

The ITU Radiocommunication Assembly,

considering

a) that many factors including fading due to multipath effects may distort and attenuate received signals on line-of-sight paths and thereby impair the performance of FWSs;

b) that countermeasures such as diversity reception and adaptive equalization are available to reduce the effects of multipath fading on system performance;

c) that methods for the analysis and optimization of the error performance degradation of digital FWSs due to many factors are needed for the bringing into service (BIS) and/or maintenance of FWSs and for radio equipment development;

d) that the performance limits and the technical guidance on BIS or maintenance for FWSs are given in Recommendations ITU-R F.1330 (Performance limits for bringing into service of the parts of international plesiochronous digital hierarchy and synchronous digital hierarchy paths and sections implemented by digital radio-relay systems) and ITU-R F.1566 (Performance limits for maintenance of digital fixed wireless systems operating in plesiochronous and synchronous digital hierarchy-based international paths and sections), respectively;

e) that it is often necessary to optimize the performance of FWSs after they are installed, in particular during the maintenance work before BIS,

recommends

1 that the guidance and the systematic method for the analysis and optimization of digital FWS error performance detailed in Annex 1 should be applied in cases of sub-optimal performance.

Annex 1

Analysis and optimization of the error performance of digital FWSs for the purpose of bringing into service and maintenance

1 Introduction

The purpose of this Annex is to provide guidance on the availability of methods for fault analysis and optimization of the performance of digital FWSs. Detailed information on propagation aspects of the design of fixed wireless systems is contained in Recommendation ITU-R P.530 (Propagation data and prediction methods required for the design of terrestrial line-of-sight systems).

ITU-R error-performance Recommendations (e.g. Recommendation ITU-R F.1668 – Error performance objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections) place requirements on the design and operation of FWSs to meet the performance objectives of these Recommendations. In view of these requirements, this Recommendation seeks to provide guidance for commissioning and operating FWSs in situations where difficulties are experienced due to poor error performance. Guidance on performance limits for systems BIS is given in Recommendation ITU-R F.1330. This Recommendation may also serve to provide maintenance trigger points for operational systems. Furthermore it is noted that error cause assessment can basically be triggered by the performance limits given in Recommendation ITU-R F.1566.

There has been a great deal of development of systems and techniques to provide high quality FWSs. Measurement technologies and software are now available for the analysis of digital FWSs in the laboratory and in field operation.

In view of these developments it is recommended that where system analysis for fault rectification or optimization for the purpose of meeting the required performance objectives is necessary, then measuring instruments and software may be applied to achieve the above aims.

More detailed general information on FWS operations can be found in the ITU-R Handbook on digital radio-relay systems.

2 Link analysis

There are many potential causes of errors on FWSs. The analysis of system errors is thus complex and potentially time-consuming. To progress the analysis and optimization of systems it is necessary to adopt a systematic approach to understanding the nature of the errors and their relationship to the environment in which the FWS operates.

In the absence of a systematic approach to error performance analysis, it is easy for the system operator to ascribe all errors to fading and do nothing to rectify the problem. The purpose of this guide is to simplify the process of system analysis and optimization by giving directions that assist in the improvement of system performance. Measurement and analysis tools are available to assist this process even in the face of seemingly severe error-performance problems.

A basic flow chart is shown in Fig. 1 for assessing the potential causes of system errors, which are observed in P-P FWSs with multi-hop connection. There are many branches in this flow chart each of which requires some special knowledge about the system and its environment. To gain the necessary knowledge, specific measurements or analyses are required at each branch of Fig. 1. Following such measurements, further application software may be required to assist in evaluating the measurements and to derive an optimum solution.

For FWSs used in the access portion, in particular for P-MP systems operating in different propagation environments, another flow chart in Fig. 2 could be used.

The following sections set out guidance for each decision point, the numbering of each section corresponding to a decision in the flow charts of Figs. 1 and 2.

FIGURE 1

Flow chart for assessing the causes of link errors observed in P-P FWS wih multi-hop connection

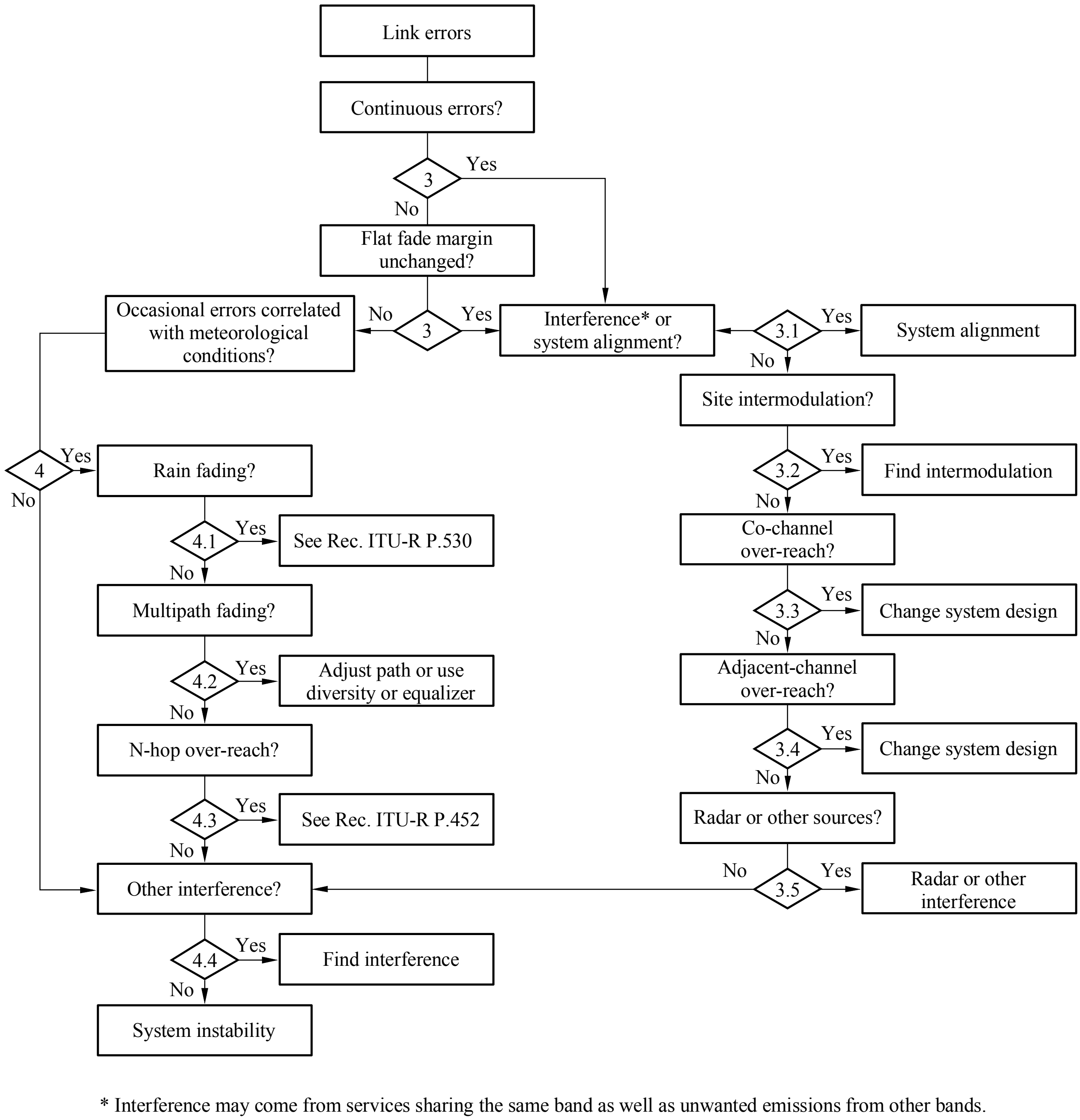

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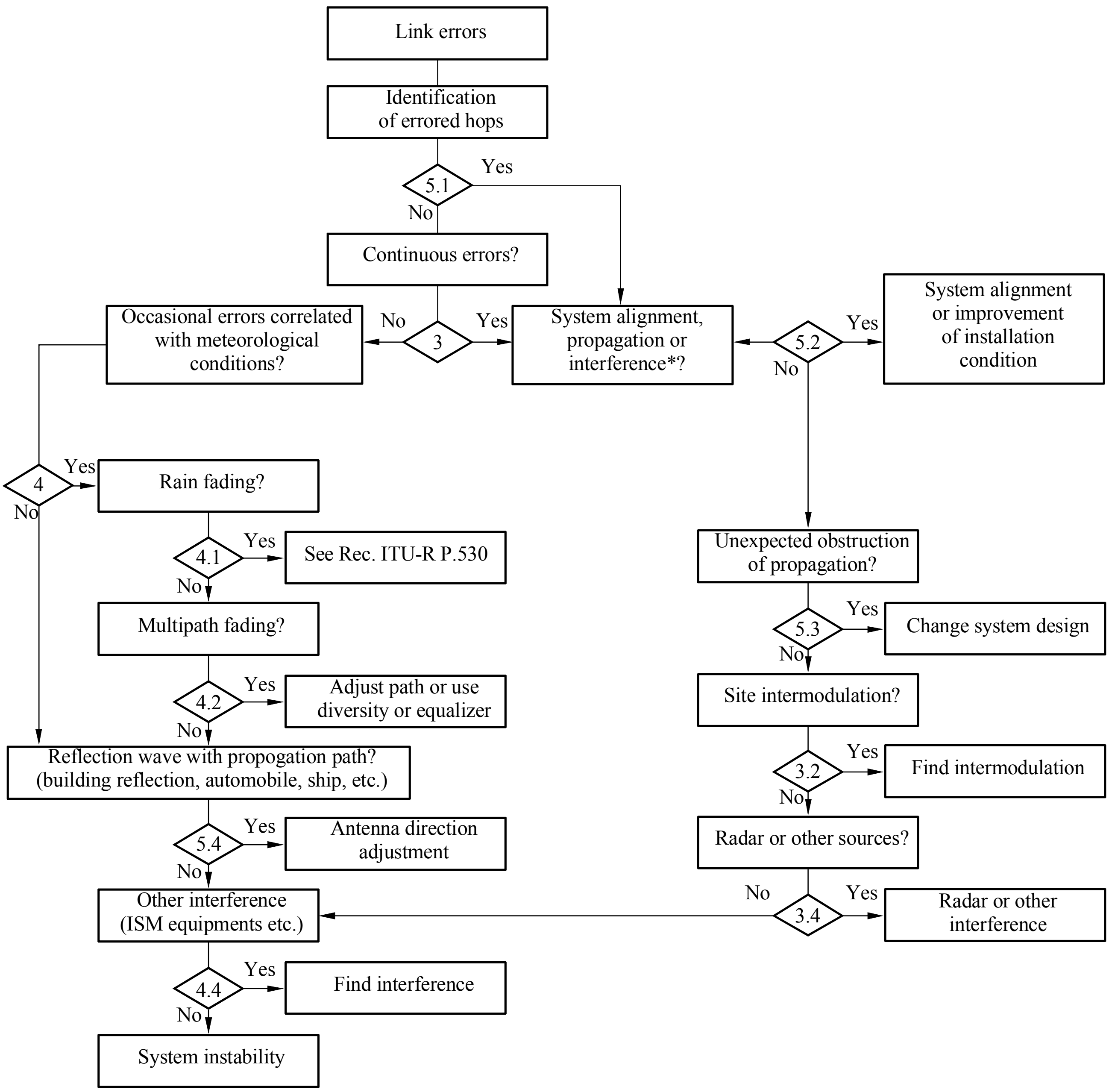
FIGURE 2

Flow chart for assessing the causes of link errors observed in the P-MP FWS



* Interference may come from services sharing the same band as well as unwanted emissions from other bands.

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3 Link error analysis for P-P FWS in multi-hop connection

The initial decision is to determine how often the errors are occurring. The errors may be at a low level but always be there, for example a system may have in excess of 100 errored seconds (ESs) every month, these would be classed as “continuous errors”. If the system has less ESs, e.g. 50 even including severely errored seconds (SESs), in most months, they would be classed as “occasional errors”.

Even when occasional errors are observed, there may be a case that these errors are due to certain reduction of flat fade margin caused by impairment of the equipment or the feeder system. If the flat fade margin of the system is reduced by several dB (or more), a small effect of multipath fading which would not normally produce any bit errors may result in apparent occasional errors. Therefore, by inspecting flat fade margin, the cause of the occasional errors may be found in system alignment or site intermodulation and so on, which are generally considered as factors relating to continuous errors.

3.1 Interference or system alignment

To make this decision it is necessary to determine whether the errors are caused by interference, arriving via the antenna, or if there is a fault internal to the system. An effective method to see whether interference is present is to attach a spectrum analyser to the RF branching filter output to the receiver and closely examine the spectrum. This approach works well for high-level interferers but can be compromised for lower-level wideband interference that is below the spectrum analyser noise floor (see the next paragraph for an alternative approach). For this measurement to be most effective the far end transmitter should be turned off. If there is no interference evident then the errors are most likely due to system alignment. This assumes that the errors are continuous and that a measurement of the received spectrum will show the offending interferer.

The received spectrum can also be measured at the output of the receiver IF amplifier as the system receiver has sufficient gain and excellent noise figure to ensure that any interference will be evident. This alleviates the need for microwave spectrum analysis tools and yields much greater sensitivity for measuring low-level interference.

Generally, interference should be preventable through prudent frequency planning. In practice, interference from unknown sources does occur. Interference can also be aggravated by abnormal propagation conditions and should not be dismissed as a source of errors without appropriate system level investigation.

The system alignment issues are complex and diverse. Key issues include antenna alignment, fade margin, wave-guide and branching filter loss, group delay and amplitude distortion, diversity equalization, channel frequency, cabling and connector quality and of course basic equipment faults. Each item requires detailed checking to ensure that the system is correctly aligned and potential error sources minimized.

3.2 Site intermodulation

Local site intermodulation products can arise from the mixing products of co-located transmitters. Such mixing products can result from poor mechanical connections; for example the elements of an antenna tower can act as a non-linear "diode" mixer to produce in-band interference products.

The potential cure for these problems is to shift the frequency of the offending transmitter or to locate and correct the mechanical/electrical structure that produces the mixing. Spectrum analysis of the received signal should be made with the far end transmitter turned off. The received spectrum analysis can easily be facilitated at the output of the receiver IF amplifier. Mixing products can be evaluated by calculation.

3.3 Co-channel over-reach interference

Co-channel over-reach under normal propagation conditions will propagate typically over three hops or two hops further away than the wanted transmitter for standard frequency arrangements. In design it is normal to ensure that paths are correctly offset so that the antenna discrimination will minimize any over-reach interference. If over-reach interference is suspected, then it may be detectable by spectrum analysis of the received signal with the wanted transmitter turned off. It is also possible that the next hop transmitter facing away from the affected receiver may be the cause of co-channel interference. This can occur if the next hop antenna front-to-back ratio is poor or the angle of the next hop is such that a sidelobe of the next path antenna directs sufficient co-channel signal to cause interference (see Recommendations ITU-R F.1096 (Methods of calculating line-of-sight interference into radio-relay systems to account for terrain scattering) and ITU-R F.1095 (A procedure for determining coordination area between radio-relay stations of the fixed service)).

3.4 Adjacent-channel over-reach interference

Adjacent-channel over-reach interference will have similar issues to those of co-channel interference. Spectrum analysis at RF or IF with the wanted transmitter off is required to determine the amount of interference (see Recommendations ITU-R F.1191 (Bandwidths and unwanted emissions of digital fixed service systems) and ITU-R SM.328 (Spectra and bandwidth of emissions)).

3.5 Radar or other interference

Pulse-type interference can rise from a variety of sources such as radar, electrical arcs and motor vehicle ignition systems. The radar signature can usually be determined from an analysis of the error bursts. As a qualitative estimate, a radar that causes continuous interference will generally be located within line-of-sight of the affected receiver. It may also be close to the boresight of the antenna unless the radar is very close (see Recommendations ITU-R F.1097 (Interference mitigation options to enhance compatibility between radar systems and digital radio-relay systems) and ITU-R F.1190 (Protection criteria for digital radio-relay systems to ensure compatibility with radar systems in the radiodetermination service) for detailed guidance on radar interference). Pulse interference can occur from other sources located close to the affected receiver. Comprehensive error analysis tools are required to evaluate the effects of pulse interference.

Information and guidance concerning interference from other services sharing the same frequency bands is contained in several F-Series Recommendations and the ITU-R Handbook on digital radio-relay systems.

4 Occasional errors correlated with meteorological conditions

Meteorological conditions can play a significant role in causing errors on FWSs. In many cases, errors can be correlated with stable air in high-pressure systems, fronts, cold, hot or even windy conditions. To determine which meteorological conditions are related to poor error performance may take some effort in meteorological observation. Having determined that the errors are related to particular meteorological conditions further effort is required to isolate the particular issue. If occasional errors are not correlated with meteorological conditions then the errors could be due to other interference sources (see § 4.4).

4.1 Rain attenuation

Loss of signal due to rain attenuation will clearly be correlated with higher rainfall rates. Poorly designed systems will fade out at low rain rates. In such cases Recommendation ITU-R P.530 should be consulted to determine the rain margin of the system and this checked against the actual margin. Causes of poor rain margin could be insufficient transmit power, poor antenna alignment or the incorrect selection of antennas, and frequency for the given path length.

4.2 Multipath fading

Multipath fading can be caused by meteorological conditions as well as reflections from objects and surfaces or a combination thereof (see Recommendation ITU-R P.530). To determine whether multipath fading is the cause of system errors requires detailed measurements of several system parameters. The best results are obtained from correlated measurements of signal level, amplitude dispersion and error characteristics made during fading. For diversity systems the correlated measurement of signal level and dispersion at the input to the combiner may yield sufficient information to allow the optimization of diversity operation.

Further analysis of measurements using software and/or simulation of the measured effects may be of assistance in determining the nature of the fading. Once an understanding of the nature of the fading is obtained adjustments can be made to individual systems to improve error performance.

If multipath fading is not the cause of the errors correlated measurements of signal level, dispersion and errors will show at normal unfaded signal levels. In such cases multipath fading should be ruled out.

Multipath signal enhancement can result in a substantial increase in received signal level. At such times overload of the receiver can occur resulting in errors.

The mechanisms that produce multipath fading and the individual path remedies are complex but reasonably well understood. If multipath fading is deemed to be the cause of the errors then the link design should be reviewed. One effective method to overcome multipath fading effect is to implement an adaptive equalizer in the receiver. Today many equalizers are available as elaborated in ITU-R Handbook on digital radio-relay systems or Recommendation ITU-R F.1101 (Characteristics of digital fixed wireless systems below about 17 GHz). Another method is to optimize the radio propagation path. Detailed analysis of each path using measurement and simulation may be required before any objective conclusions can be made about remedies. Adjustments to individual paths by way of changing antenna positions, shifting towers, splitting paths or adjustments to vegetation along the path without such analysis is not recommended.

4.3 *N*-hop over-reach interference

In addition to co-channel or adjacent channel over-reaches producing continuous errors as discussed in § 3.3 and 3.4, long distance over-reach from co-channel or adjacent channel interferers can sometimes arise during periods of stable atmospheric conditions particularly related to high-pressure systems. During such conditions ducts can cause interference to be propagated from several hundred kilometres away. Such long-distance interference will generally be the result of distant antennas being closely aligned. The interference may also traverse intervening ranges of hills that may normally block most of the interference. The potential for interference from all possible licensed sources can be calculated using the fixed service interference model contained in Recommendation ITU-R P.452 (Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz).

The conditions that produce long distance over-reach interference can also produce multipath fading effect mentioned in § 4.2. Thus, it can sometimes be very difficult to separate the individual effects. Separation of the effects of over-reach and multipath fading may be carried out by making correlated measurements of signal level, dispersion and error characteristics. Analysis of the received signal intermediate frequency spectrum during periods of high error rate will also assist in separating out the problems.

4.4 Other interference

Interference from a variety of sources can occur over long distances during abnormal propagation conditions. Such interference will usually be correlated with stable high-pressure conditions. Errors may also be correlated with signal fading that can occur at the same time. In such cases it is necessary to carry out signal level, dispersion and error correlations to determine if the robustness of the system has been compromised by interference.

Interference can occasionally occur from temporary installations or even from occasional testing of high-power transmitters. This type of interference will not necessarily be correlated with any particular meteorological conditions. Interference from temporary installations can be very difficult to locate. In all cases the best result will be obtained from detailed analysis of the errors using high sampling rate signal level and/or error measurement systems (see § 3.5 for references on radar interference).

Occasional errors can result from random events of interference and are very difficult to locate. It is recommended that correlated measurements of signal levels, dispersion and errors are made to assist in eliminating other potential causes of errors. Interference may come from a variety of mobile or fixed transmitter harmonics or even from electrically conducted interference.

Random system instability can be caused by poor connectors, poor earthing, broken/corroded wiring, vibration or electrically induced noise from switch contacts. Once again these effects are very difficult to isolate and a systematic approach is required to first eliminate all other causes.

Interference from other sources such as trans-horizon radio-relay systems and mobile radio systems is also possible (see Recommendations ITU-R F.302 (Limitation of interference from trans-horizon radio-relay systems) and ITU-R F.1334 (Protection criteria for systems in the fixed service sharing the same frequency bands in the 1 to 3 GHz range with the land mobile service)).

System instability can occur due to meteorological conditions such as wind, hot or cold weather or even rain. There could be a wide variety of causes such as oscillator stability, instability of external components such as towers, antennas and wave-guides or even electrical interference from air conditioners running in hot weather.

5 Link error analysis for FWS used in access networks

Also in case of fixed wireless systems used in the access portion or back-haul links to the core network, the technical and operational guidance given in § 3 and 4 could generally apply to the analysis of the link errors. It should be noted that the number of radio hops for such FWSs is limited, in many cases, to one or very few. Therefore, over-reach interferences discussed in § 3.3, 3.4 and 4.3 may be excluded from the analysis. There are, however, several issues to be considered in these systems as explained below.

5.1 Identification of the station or the radio hop causing link errors

It is firstly necessary to investigate which radio hop or station is causing link errors. If the error is observed in all the wireless links to the user stations operating in P-MP mode, there should be a problem in the radio equipment in the hub-station. Otherwise a specific radio hop or the corresponding user terminal equipment may be affected by a certain error cause, e.g. system misalignment, unfavourable propagation or interference.

5.2 Installation condition

Among a number of user stations it might happen, especially in case of a very short hop, that the antenna is not exactly facing toward the hub-station. Such insufficient adjustment may jeopardize the receiving antenna to undesired reflection waves or other interference sources. Also it is important for the waterproof purpose to confirm all the physical connections in the radio equipment or to protect the antenna surface from being covered by snow.

The above factors in the system alignment should be carefully investigated during the error analysis process.

5.3 Unexpected obstruction of propagation

In case of FWS links constructed in urban areas, radio equipment (antenna and transmit/receive devices) is usually installed on a building rooftop. In such environments, it often occurs that the radio propagation path is obstructed by unexpected factors, e.g. a new building or trees, after the initial installation. Thus resulting in certain reduction of the fade margin, receiving power fluctuation associated with continuous errors may be observed more frequently. Such a situation could be improved by raising the antenna height. However, if it is physically difficult, the site of the antenna has to be changed.

5.4 Reflection wave over the propagation path

In fixed wireless access links, fluctuation of the propagation condition causing occasional errors occurs not only due to multipath or rainfall fading, but also due to other factors, e.g. moving automobile, trains or ships. It is generally difficult to find and identify the cause of such kind of occasional errors. It may be necessary to adjust the location of the victim antenna to resolve the problem.

6 Summary

The continued use and development of FWSs combined with evolution of system performance requirements places considerable burden on the design and operation of wireless systems to ensure that systems provide a consistent high quality of service. The causes of errors on FWSs include the issues of propagation, interference, equipment and link design, installation and maintenance. For the approach to resolving poor performance to be successful, careful consideration must be given to measurements of system signal levels and error performance parameters.

Analysis and optimization of the error performance of digital FWSs considered in this Recommendation requires a systematic approach combined with the performance limits specified in other Recommendations (i.e. for maintenance in Recommendation ITU-R F.1566 and for BIS in Recommendation ITU-R F.1330) as well as an intimate knowledge of the relevant system structure. Accordingly, this Recommendation provides the guidance necessary to ensure that FWSs can continue to be developed and deployed to meet ITU-R performance requirements.