PART 5D – TECHNICAL AND OPERATING CHARACTERISTICS OF MOBILE-SATELLITE SERVICES

RECOMMENDATION ITU-R M.1188

IMPACT OF PROPAGATION ON THE DESIGN OF NON-GSO MOBILE-SATELLITE SYSTEMS NOT EMPLOYING SATELLITE DIVERSITY WHICH PROVIDE SERVICE TO HANDHELD EQUIPMENT

(Question ITU-R 88/8)

(1995)

Summary

This Recommendation provides the factors to be taken into account for designing a non-GSO MSS handheld system not employing satellite diversity. The consideration of propagation impairments are given in Annex 1.

The ITU Radiocommunication Assembly,

considering

a) that a mobile-satellite service (MSS) system design must take account of propagation characteristics;

b) that non-geostationary (non-GSO) satellite propagation paths have characteristics different from those in terrestrial mobile systems;

c) that to provide reliability and quality in handheld communications requires adequate link margin in the system to combat propagation impairments;

d) that determination of required link margin is heavily influenced by the nature of propagation impairments and system implementation details;

e) that there is strong influence of elevation angle on fading;

f) that rate of change of signal level (fading bandwidth) due to changing geometry between the two communication end-points appears to vary at rates up to 200 Hz;

g) that considerable fading may be encountered both in clear line-of-sight, and in heavily shadowed conditions due to user motion and user head or body interference;

h) that Recommendation ITU-R P.681 provides propagation prediction methods for land-mobile satellite systems, and that work is continuing within Radiocommunication Study Group 3 under Question ITU-R 207/3 to expand this information;

recommends

1 when designing a non-GSO MSS handheld communication system not employing satellite diversity for operation in the 1-3 GHz band (see Note 1):

– that the effects of varying rate of fade be taken into account in design of receiver acquisition times;

– that link margins and system design be adequate under considerable fading due to user motion and user head or body interference as well as the effects of shadowing, and system designs must compensate for channel impairments;

– that the information in Recommendation ITU-R P.681 be used as reference for propagation information. The propagation impairment information in Annex 1 relates to one proposed system;

– that data interleaving and forward error correcting techniques be used in combating fading conditions.

NOTE 1 – The data available and the propagation model given in Recommendation ITU-R P.681 are valid at low elevation angles for frequencies below 1.5 GHz, and for elevation angles above 30° the 1-3 GHz frequency range is applicable. Further measurements and contributions would be welcome in order to complete the model for low elevation angles (below 30°) and at frequencies higher than 1.5 GHz.

ANNEX 1

Propagation impairments of non-GSO mobile-satellite systems providing personal communication services not using satellite diversity

1 Introduction

To achieve optimal and efficient communication system performance, the system design must consider and mitigate against propagation path impairments.

2 Summary of applicable propagation effects

The appropriate propagation data for these applications are given in the latest revision of Recommendation ITU-R P.681. This Recommendation gives details of the expected fading statistics on paths obstructed by trees and in urban areas for various elevation angles and also discusses the effects of head blockage. Azimuth may affect head blockage. In many cases, flat fading with respect to frequency will be observed.

Thus, narrow-band signal formats should anticipate some fade effects across their operating bandwidth.

It may also be expected that fading in this band will have a burst characteristic, whether clear line-of-sight (LOS) or shadowed which is due to satellite motion and user movement. A system design, when specifying a signal structure and baseband structure, must carefully consider these fading characteristics.

2.1 Clear line-of-sight fading

A clear LOS condition is one where no obstacle blocks the satellite signal. A portable communication terminal operating under these conditions must contend with two impairment effects which may require additional margin. These are ground reflection and interference by the body. The latter can also be described as head blockage or head interference when the handheld mobile earth station (MES) with integral antenna is used in telephone hand-set fashion.

Lower elevation angle geometries introduce more pronounced impairments. For arbitrary aspect angles of the source, the probability is relatively high that the head will partially shadow either the antenna’s direct line-of-sight or the ground multipath direction.

Fading maximum rate of change, also referred to as fading bandwidth, is determined by the varying geometry between the two communication end points and also by object types which give rise to fades, e.g., trees, hills, etc. For example, where one end point is a non-GSO satellite and the other a stationary handheld MES, the fading bandwidth will be low and influenced by the relative motion of the satellite. Alternatively, where the two points are a moving MES and a non-GSO satellite, the fading bandwidth will be higher and influenced primarily by mobile terminal speed. Examination of previous data has shown that fade bandwidth varies between 20 Hz and 200 Hz. The higher values of fading bandwidth will affect receiver acquisition design and the design of systems with dependency on power control.

2.2 Impairment due to shadowing by trees

There is likely to be little difference in fade impairments between intermediate and high elevation angle ranges in tree-shadowed conditions, since the shadowing effect, rather than elevation, dominates (refer to Recommendation ITU-R P.681, Annex 1, § 4.1 to 4.4).

2.3 Effects due to multipath from structures

Where tall structures are present, as in suburban or urban environments, two additional signal impairment effects are possible:

– almost total blockage of the direct LOS signal component;

– multipath (other than ground specular) from large structures, e.g., buildings or water towers relative to the direct LOS signals.

In personal satellite communications, multipath, if present at a significant power level, is very significant if multipath delay is long relative to symbol duration. The implication would be that fading may be frequency selective and that equalizers may be required in a receiver design. The effect is significantly different from that in terrestrial cellular or terrestrial trunk communication systems, where both have been designed to overcome this impairment by use of high transmitted power in relation to slant range.

There is very little quantitative data on multipath for the geometry of satellite transmission paths. However, one data set from measurement campaign in a dense urban environment showed that the multipath signal components recorded in this measurement campaign all have either a low power level or a very low probability level, or both, compared to that of the LOS component. Thus, these measurements lead to the conclusion that structure induced multipath will not be deleterious in non-GSO MSS LOS communication.

Appendix 1 describes an example of TDM/FDM system design taking the above into consideration.

APPENDIX 1

TO ANNEX 1

1 Propagation impairments on non-GSO mobile satellite systems providing personal communication services not using satellite diversity

1.1 Performance in a vocoded narrow-band channel

Using the limited propagation data collected during the design of this particular system (referred to hereafter in this Appendix as the “test data”), the performance capability of narrow-band, TDMA burst communication was evaluated for single non-GSO satellite service to a handheld MES. The burst format implemented time compression by a factor of 11 in forming 8 ms transmission packets to communicate each 90 ms of vocoded data. Results of an example evaluation summarize link margin requirements for acceptable quality of vocoded voice communication. Impairments are characterized by the 90th percentile dB fade level. The impairments include either tree shadowed or clear line-of-sight conditions. The data depicts a form of signalling robustness. That is, in an environment where 90% of the fades are below a specific level and in a link with a defined bit-error rate (BER), the vocoder-required margin for quality voice communication is significantly less than the maximum fade depth. For example, 8 dB of link margin will accommodate a link where 90% of the fades are less than 10 dB. Acceptable quality of vocoded voice communication has been determined, using simulation techniques, as equal to at least 90% of the vocoder's ideal-channel quality score (e.g., mean opinion value – MOS value).

The link margin values are dB values in excess of that E_b/N_0 which would be required to maintain a given BER for QPSK signalling in a static Gaussian channel. This was determined in this example by application of channel fade measurements to a vocoded voice link with selective, rate 2/3 coding. The vocoder used in this determination was VSELP 4800. A well-designed vocoder/error protection scheme will permit quality communication in a 1% BER channel. The 1% BER line of the data is the least mean square error, linear fit of the data values. It is possible, by theoretical means, to project required performance capability for higher per cent BER conditions and these are also depicted in Fig. 1. Specifically, referring to a standard BER curve for QPSK signalling, the increase from 1 to 5% BER is equivalent to a decrease of signal power by 3 dB. Therefore, to maintain constant voice quality at a given fade level the link margin must increase in proportion to the BER increase. This condition applies also to non-Gaussian faded channels. In general, communication channel induced fade levels exceeding the 1 to 3% BER conditions introduce a requirement for additional vocoder data protection. The most efficient way this can be achieved is by excess link margin.

Several factors other than link margin also affect communication quality in a vocoded link. Specifically, channel impairment statistics, vocoder rate, error protection coding and bit-interleaving all can affect quality of communication. Evaluation of the effect of channel impairments, if based on actual time-domain data, allows more accurate conclusions. Also, evaluation based on actual data requires no assumption as to the statistical nature of the channel, e.g., stationary, non-stationary, Rayleigh, Rician, log-normal and thus avoids the need for additional justification. An example of the test data for TDMA communication is illustrated by Fig. 1. This shows test results for the 90th percentile significance level of fades. The 90th percentile level was used for higher confidence in the conclusions. The figure shows that 16 dB of impairment margin suffices for quality communication with the particular MSS system design considered here, where the 90th percentile fade level is 18 dB. If similar results were shown for the 50th percentile (median) level, fade depth itself would be lower and so would the required link margin to offset such fade level.

In general, higher rate vocoders are more robust in impaired channels. Also, the coding rate can be adjusted to provide greater error protection. But in both latter cases higher rates imply less channel capacity in a bandwidth limited channel. Thus, a trade between link margin and vocoding rate or link margin and coding rate becomes necessary. To date, such trades have shown to favour preserving higher link margins. Relatively long duration bit-interleaving is known to enhance quality, however, this technique imposes a distinct disadvantage in voice channels, i.e., increased communication delay. Thus, whereas the quality of data communication would be enhanced, the quality of voice communication would be degraded.

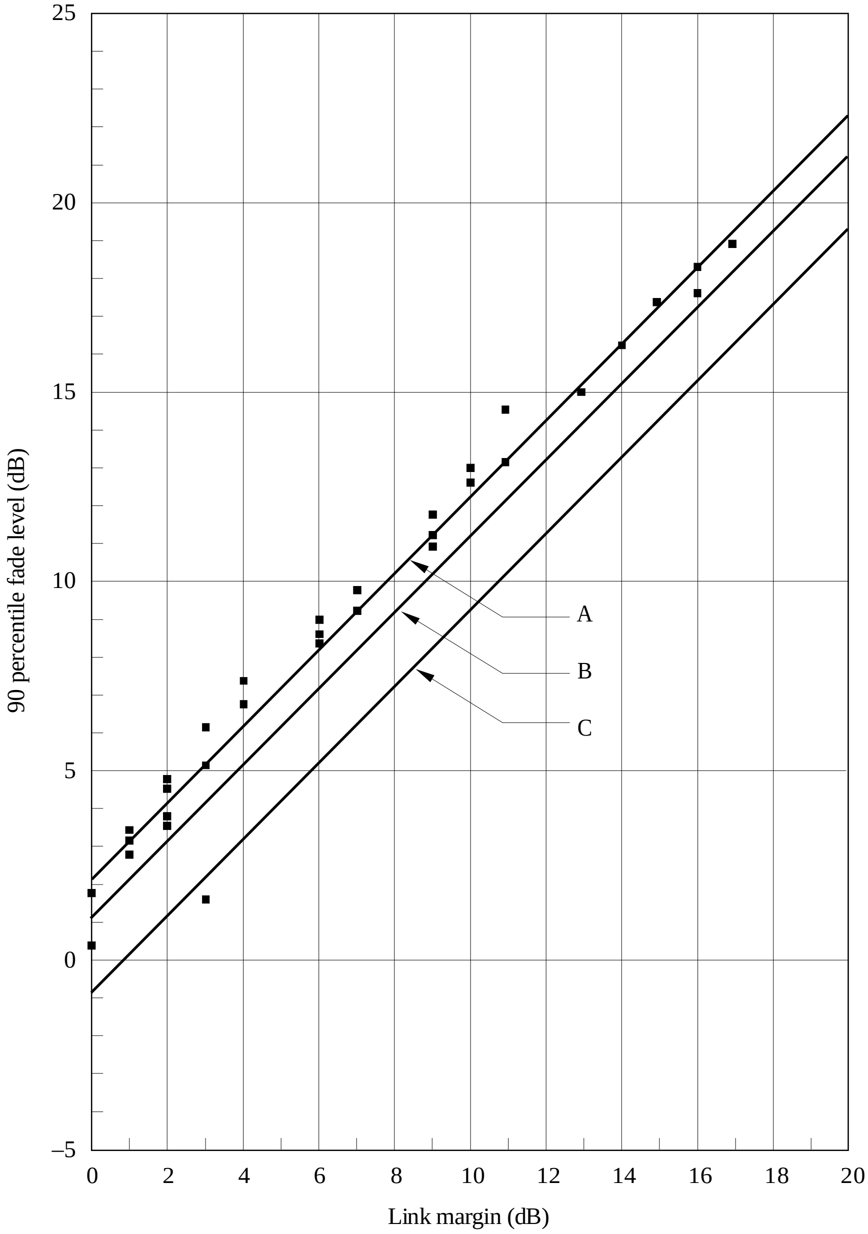
1.2 Link margin

Non-GSO satellite-based handheld MSS systems, designed for single satellite at one time service, may have to contend with low elevation angle scenarios. Under these conditions, propagation impairments may give a fading depth at between 6 dB and 12 dB depending on the antenna position relative to the head, the azimuth, the elevation angle and the propagation environment.

Now, referring to Fig. 1, taking a worst case value of 12 dB (on the ordinate), a link with a static BER of 1% requires at least 10 dB of link margin in order to provide quality voice communication.

FIGURE 1

Link margin required for acceptable voice quality



Uncorrected channel error rate:
A: 1% BER
B: 2% BER
C: 5% BER

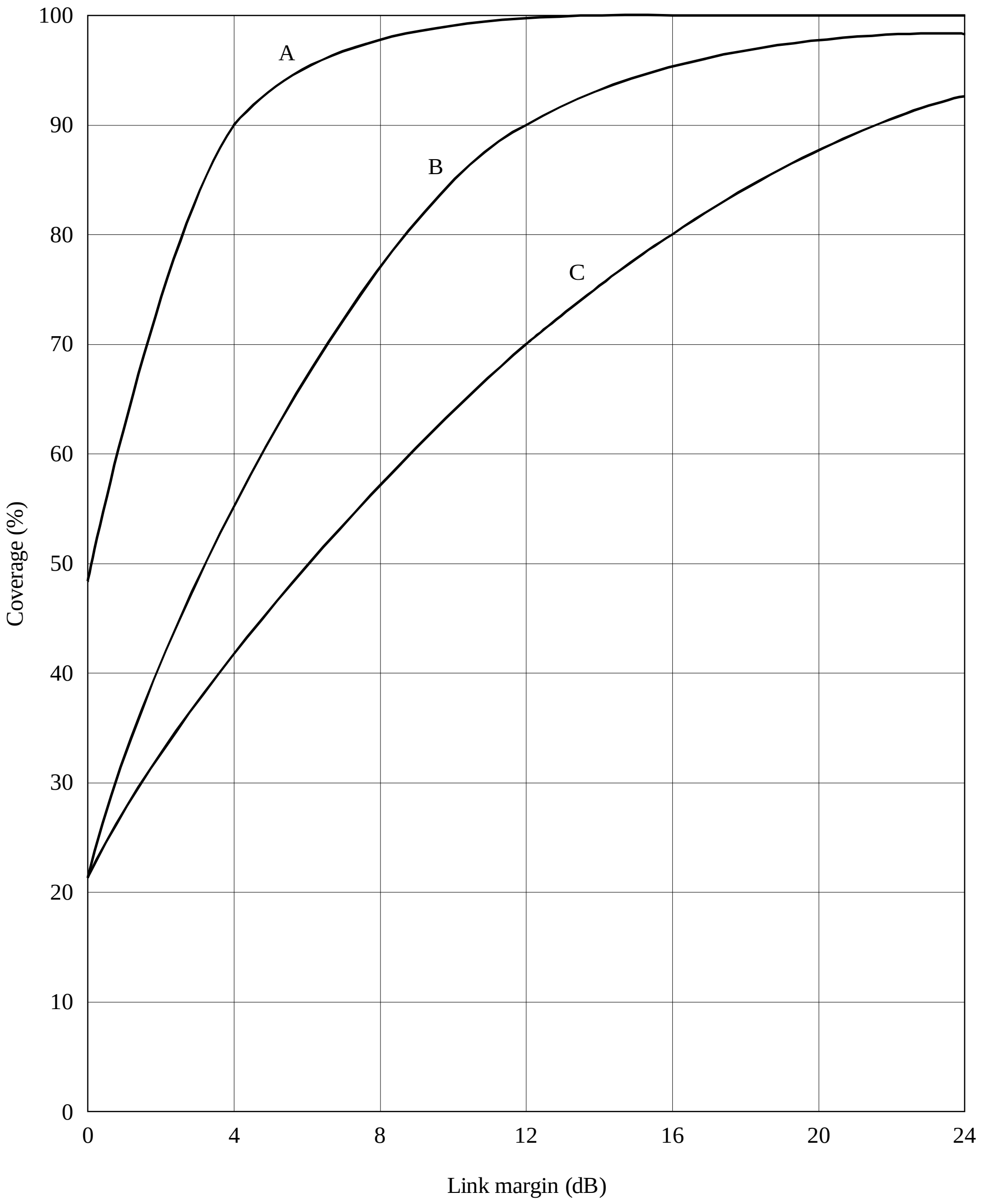
D01

1.3 Coverage as affected by shadowing

A 1.6 GHz band propagation data set was used to determine coverage estimates for different shadowing conditions and fading margin for the particular MSS system design considered here. This is depicted in Fig. 2. The data was characterized as heavy, moderate, or light shadowing. The characterization for each set was based on both the probability of shadowing and the mean fade depth when shadowing was present. Voice quality degradation was then estimated as a function of fade margin, assuming an ideal QPSK modem with 2 dB of implementation loss. Fade margin is defined to be excess margin over the LOS component assuming a 4.3 dB E_b/N_0 reference. Degradation numbers are calculated using the VSELP 4800 bit/s vocoder and rate 2/3 hard decision block channel coding. Voice quality degradation was estimated using a relationship between voice quality and channel BER and frame erasure rate. This relationship was derived through multiple listening tests. Using this relationship, voice quality was determined for each second of time series fade data. Greater than a 10% degradation from a no error condition was considered unacceptable and coverage was considered inadequate. The coverage numbers shown in Fig. 2 represent the percentage of 1 s windows in which voice quality degradation was less than 10%. Coverage numbers were calculated for heavy, moderate and light shadowing conditions.

FIGURE 2

Coverage for <10% degradation from ideal condition



Curves A: light shadowing
B: moderate shadowing
C: heavy shadowing

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2 Conclusion

This Appendix has described some of the propagation impairments affecting a non-GSO MSS system at 1.6 GHz. It also shows how these impairments can be accommodated in the design of non-GSO MSS systems. Key findings regarding propagation effects in these non-GSO satellite paths are:

– the temporal dynamic nature of received signal levels which is due to satellite motion, handheld subscriber MES usage and physical environment;

– the presence of significant and time-varying fading under clear LOS conditions between non-GSO satellite and handheld terminal. (This fading is caused by ground specular reflection in the subscriber’s vicinity and interference or shadowing introduced by the subscriber’s head and body);

– the existence of significant fades in propagation paths that are shadowed by trees;

– it is necessary to confirm that if non-frequency selective (flat) fading is likely then link margin could be used to overcome it to promote quality communication;

– some measurements in a dense urban environment indicate that, for such an environment, structure induced multipath reflections with long delay are low in power relative to the LOS component and are statistically infrequent in occurrence.

The characteristics of these non-GSO propagation impairments are different than those encountered in terrestrial personal communication network services. Therefore, some system solutions used in terrestrial mobile communications, such as increased transmitter power or decreased slant range, are not appropriate for cost-effective non-GSO satellite system implementation.

Based on the characteristics of this non-GSO propagation information, it appears that appropriate link margins are necessary in a narrow-band TDM/FDM system for quality communication under a broad array of possible propagation conditions with a direct LOS to the non-GSO spacecraft. It has shown, furthermore, that a narrow-band FDMA/TDMA signal format can overcome the propagation impairments of non-GSO channels in the 1.6 GHz band through use of appropriate link margin.