



XVIIth PLENARY ASSEMBLY
DÜSSELDORF, 1990



INTERNATIONAL TELECOMMUNICATION UNION

REPORTS OF THE CCIR, 1990

(ALSO DECISIONS)

ANNEX TO VOLUME IV – PART 1

FIXED-SATELLITE SERVICE

CCIR INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

Geneva, 1990

I61
1990
V.4/V/Ann.

9360029



XVIIth PLENARY ASSEMBLY
DÜSSELDORF, 1990



INTERNATIONAL TELECOMMUNICATION UNION

REPORTS OF THE CCIR, 1990

(ALSO DECISIONS)

ANNEX TO VOLUME IV – PART 1

FIXED-SATELLITE SERVICE



E9360029



CCIR INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

**INDEX OF TEXTS WHICH HAVE BEEN DELETED
AT THE END OF THE STUDY PERIOD 1986-1990**

(In order to facilitate the retrieval of a given text, the page number of Volume IV of the XVth Plenary Assembly, Dubrovnik 1986, is indicated.)

ANNEX TO VOLUME IV

Text	Title	Page No. Vol. IV Dubrovnik, 1986
Report 204-6	Terms and definitions relating to space radiocommunications	1
Report 205-4	Factors affecting the selection of frequencies for telecommunications with space stations in the fixed-satellite service	5
Report 383-4	The effects of transmission delay in the fixed-satellite service	15
Report 385-1	Feasibility of frequency sharing between systems in the fixed-satellite service and terrestrial radio services. <u>Criteria for the selection of sites for earth stations in the fixed-satellite service</u>	208
Report 559	The effect of modulation characteristics on the efficiency of use of the geostationary-satellite orbit in the fixed-satellite service	440
Report 707-1	Digital interface characteristics between satellite and terrestrial networks	122
Report 711-1	Criteria of efficiency of use of the geostationary-satellite orbit	448
Report 871-1	Calculation of the equivalent satellite link noise temperature and the transmission gain	335

ANNEX TO VOLUME IV
FIXED-SATELLITE SERVICE
 (Study Group 4)

TABLE OF CONTENTS

	Page
Plan of Volumes I to XV, XVIIth Plenary Assembly of the CCIR (See Volume IV - Recommendations)	
Distribution of texts of the XVIIth Plenary Assembly of the CCIR in Volumes I to XV (See Volume IV- Recommendations)	
Table of contents	I
Numerical index of texts	VII
Index of texts deleted	IX
 <u>Section 4A - Definitions</u>	 1
There are no Reports in this Section.	
 <u>Section 4B - Systems aspects - Performance and availability - Susceptibility to interference</u>	
<u>4B1 - Systems aspects</u>	
Report 552-4 Use of frequency bands above 10 GHz in the fixed-satellite service.....	3
Report 1139 General system and performance aspects of digital transmission in the fixed-satellite service.....	37
Report 1134 Digital satellite dedicated networks.....	56
Report 451-3 Factors affecting the system design and the selection of frequencies for inter-satellite links of the fixed-satellite service.....	76
Report 1237 Satellite news gathering (See Annex to Vol. XII).....	89
 <u>Section 4B2 - Performance and availability</u>	
Report 208-7 Form of the hypothetical reference circuit and allowable noise standards for frequency-division multiplex telephony and television in the fixed-satellite service.....	91

Report 997-1	Characteristics of a fixed-satellite service hypothetical reference digital path forming part of an integrated services digital network.....	97
Report 706-2	Availability of circuits in the fixed-satellite service.....	130
Report 214-4	The effects of Doppler frequency-shifts and switching discontinuities in the fixed-satellite service.....	135
 <u>Section 4C - Earth station and baseband characteristics - Earth station antennas - Maintenance of earth stations</u>		
Report 391-6	Radiation diagrams of antennas for earth stations in the fixed-satellite service for use in interference studies and for the determination of a design objective.....	143
Report 390-6	Earth-station antennas for the fixed-satellite service.....	159
Report 998-1	Performance of small earth-station antennas for the fixed-satellite service.....	182
Report 868-1	Contributions to the noise temperature of an earth-station receiving antenna.....	202
Report 875-1	A survey of interference cancellers for application in the fixed-satellite service.....	206
Report 212-3	Use of pre-emphasis in frequency-modulation systems for frequency division multiplex telephony and television in the fixed-satellite service.....	216
Report 384-6	Energy dispersal in the fixed-satellite service.....	220
Report 553-3	Operation and maintenance of earth stations in the fixed-satellite service.....	248
Report 554-4	The use of small earth stations for relief operation in the event of natural disasters and similar emergencies.....	255
Report 869-2	Low capacity earth stations and associated satellite systems in the fixed-satellite service.....	264

Section 4D - Frequency sharing between networks of the fixed-satellite service - Efficient use of the spectrum and geostationary-satellite orbit

4D1 - Permissible levels of interference

Report 455-5	Frequency sharing between networks of the fixed-satellite service.....	279
Report 710-3	Interference allocations in systems operating at frequencies greater than 10 GHz in the fixed-satellite service.....	322
Report 867-2	Maximum permissible interference in single-channel-carrier and intermediate rate digital transmissions in networks of the fixed-satellite service.....	333
Report 1001-1	Off-axis e.i.r.p. density limits for fixed-satellite service earth-stations.....	356
Report 555-4	Discriminations by means of orthogonal circular and linear polarizations.....	367
Report 1141	Polarization discrimination in interference calculation.....	398

Section 4D2 - Coordination methods

Report 453-5	Technical factors influencing the efficiency of use of the geostationary-satellite orbit by radiocommunication satellites sharing the same frequency bands. <u>General summary</u>	419
Report 454-5	Method of calculation for determining if coordination is required between geostationary-satellite networks sharing the same frequency bands.....	455
Report 870-2	Technical coordination methods for communication-satellite systems.....	494
Report 1000-1	Spectrum utilization methodologies.....	507
Report 1135	Optimization methods to identify satellite orbital positions.....	515
Report 1003	Methods for multilateral coordination among satellite networks.....	532
Report 1137	Stochastic approach in the evaluation of interference between satellite networks.....	537
Report 557-2	The use of frequency bands allocated to the fixed-satellite service for both the up link and down link of geostationary-satellite systems.....	567
Report 999	Determination of the bidirectional coordination area...	575

	Page
Report 1140	Satellite networks for more than one service in one or more frequency bands..... 589
Report 1138	Intra-service implications of using slightly inclined geostationary orbits for fixed satellite service networks. <u>Operational, sharing and coordination considerations</u> 596
Report 1004-1	Physical interference in the geostationary-satellite orbit..... 617
<u>Section 4D3 - Spacecraft station keeping - Satellite antenna radiation pattern - Pointing accuracy</u>	
Report 556-4	Factors affecting station-keeping of geostationary satellites of the fixed-satellite service..... 623
Report 1002-1	Flexibility in the positioning of satellites..... 627
Report 558-4	Satellite antenna patterns in the fixed-satellite service..... 640
Report 1136	Geostationary satellite antenna pointing accuracy..... 697
<u>Section 4E - Frequency sharing between networks of the fixed-satellite service and those of other space radiocommunications systems</u>	
Report 560-2	Sharing criteria for the protection of space stations in the fixed-satellite service receiving in the band 14 to 14.4 GHz..... 711
Report 872	Sharing criteria between inter-satellite links connecting geostationary satellites in the fixed-satellite service and the radionavigation service at 33 GHz..... 713
Report 561-4	Feeder links to space stations in the broadcasting-satellite service..... 717
Report 712-1	Factors concerning the protection of fixed-satellite earth stations operating in adjacent frequency band allocations against unwanted emissions from broadcasting satellites operating in frequency bands around 12 GHz..... 729
Report 873-2	An analysis of the interference from the broadcasting-satellite service of one region into the fixed-satellite service of another region around 12 GHz..... 740

	Page
Report 713-1 Spurious emissions from earth stations and space stations of the fixed-satellite service.....	746
Report 874 Frequency sharing between the inter-satellite service when used by the fixed-satellite service and other space services.....	754
 <u>Decisions</u>	
Decision 2-7 Frequency sharing between radiocommunication satellites. <u>Technical considerations affecting the efficient use of the geostationary-satellite orbit</u>	757
Decision 64-1 Updating of the handbook on satellite communications (<u>Fixed-Satellite Service</u>).....	761
Decision 70-1 Implementation of digital satellite systems.....	762
Decision 76-1 Satellite news gathering (SNG).....	763
Decision 87 Determination of the coordination area. <u>Appendix 28 of the Radio Regulations</u> . (See Annex to Vols. IV/ix-2)..	766

NUMERICAL INDEX OF TEXTS

ANNEX TO VOLUME IV

	Page
SECTION 4A: Definitions (There are no Reports in this Section)...	1
SECTION 4B: Systems aspects - Performance and availability susceptibility to interference.....	3
4B1: Systems aspects.....	3
SECTION 4B2: Performance and availability.....	91
SECTION 4C: Earth station and baseband characteristics - Earth station antennas - Maintenance of earth stations.....	143
SECTION 4D: Frequency sharing between networks of the fixed- satellite service - Efficient use of the spectrum and the geostationary satellite orbit	
4D1: Permissible levels of interference.....	279
SECTION 4D2: Coordination methods.....	419
SECTION 4D3: Spacecraft station keeping - Satellite antenna radiation pattern - Pointing accuracy.....	623
SECTION 4E: Frequency sharing between networks of the fixed- satellite service and those of other space radiocommunications systems.....	711

REPORTS	Section	Page	REPORTS	Section	Page
208-7	4B2	91	868-1	4C	202
212-3	4C	216	869-2	4C	264
214-4	4B2	135	870-2	4D2	494
384-6	4C	220	872	4E	713
390-6	4C	159	873-2	4E	740
391-6	4C	143	874	4E	754
451-3	4B1	76	875-1	4C	206
453-5	4D2	419	997-1	4B2	97
454-5	4D2	455	998-1	4C	182
455-5	4D1	279	999	4D2	575
552-4	4B1	3	1000-1	4D2	507
553-3	4C	248	1001-1	4D1	356
554-4	4C	255	1002-1	4D3	627
555-4	4D1	367	1003	4D2	532
556-4	4D3	623	1004-1	4D2	617
557-2	4D2	567	1134	4B1	56
558-4	4D3	640	1135	4D2	515
560-2	4E	711	1136	4D3	697
561-4	4E	717	1137	4D2	537
706-2	4B2	130	1138	4D2	596
710-3	4D1	322	1139	4B1	37
712-1	4E	729	1140	4D2	589
713-1	4E	746	1141	4D1	398
867-2	4D1	333	1237	4B1	89

Note. - Decisions which already appear in numerical order in the table of contents, are not reproduced in this index.

SECTION 4A: DEFINITIONS

There are no Reports in this Section.

SECTION 4B: SYSTEMS ASPECTS - PERFORMANCE AND AVAILABILITY
 - SUSCEPTIBILITY TO INTERFERENCE
 4B1: SYSTEMS ASPECTS

REPORT 552-4

USE OF FREQUENCY BANDS ABOVE 10 GHz IN THE
 FIXED-SATELLITE SERVICE

(Study Programme 27C/4)

(1974-1978-1982-1986-1990)

1. Introduction

This Report makes a preliminary examination of some of the technical factors which should be considered in the design of systems of the fixed-satellite service which are intended for use in frequency bands above about 10 GHz. Since the allocated bandwidth is generally wider at frequencies above about 10 GHz, the use of these frequencies would facilitate the design of high-capacity systems. The use of the 30/20 GHz bands, would facilitate the design of very high capacity systems employing spot beam antennas.

The factors considered in this Report are:

- analogue system performance,
- system configuration strategies,
- frequency sharing with terrestrial systems,
- design considerations for systems in the fixed-satellite service.

2. Analogue system performance

CCITT Recommendation G.222 (see sections 1.2.1, 1.2.2 and 1.2.3) states the required design objective for an analogue telephony HRC of 2,500 km as:

- 10,000 pWOp for 20% of any month
- 50,000 pWOp for 0.1% of any month
- 1×10^6 pW0 for 0.01% of any month.

Reference to satellite systems is made by citation of Recommendation 353 of the CCIR which is:

"that the noise power, at a point of zero relative level in any telephone channel in the hypothetical reference circuit as defined in Recommendation 352 should not exceed the provisional values given below:

- 1.1 10 000 pWOp psophometrically-weighted one-minute mean power for more than 20% of any month;
- 1.2 50 000 pWOp psophometrically-weighted one-minute mean power for more than 0.3% of any month;
- 1.3 1 000 000 pW0 unweighted (with an integrating time of 5 ms), for more than 0.01% of any year; "

CCIR Recommendation 353 has been developed to be in compliance with the requirements of the CCITT, although there are some small differences. However, the concept of availability is not contained in the current version of the Recommendation and the following analysis shows the impact of its inclusion. The analysis is limited to 14/11 GHz systems since the performance of 6/4 GHz systems is not generally affected by propagation fades.

Performance of 14/11 GHz systems compliant with Recommendation G.222

The 10,000 pWOp requirement for 20% of any month is interpreted as applying to the worst month*, i.e., for the poorest propagation month. The same interpretation is applied to the 50,000 pWOp clause.

A standard link concept is used for the analysis to correspond to the current practice of other terrestrial systems of allowing 1 pWOp/km for design, or a link of 10,000 km. The operational locations for such links are typically at 40 degrees latitude and 25 degrees elevation angle. The climates for these latitudes exhibit rain rates, for 0.01% of the time, between 30 and 60 mm/hour. A value of 50 mm is chosen for the analysis. Calculations of the rain attenuation are then made in accordance with the methods of Study Group 5.

Propagation availability factor (as defined in Report 997) is taken as 10% of the duration of fade which results in reaching the system threshold. Two cases are shown in Figure 1, one at 50,000 pWOp and one at 100,000 pWOp. The margin in the first case is 7 dB and is 10 dB for the second.

The performance for the path expressed in terms of the available time will meet all of the G.222 performance objectives for the climate and latitudes assumed in this study. For low antenna elevation angles and higher rain rates, it may be more difficult to meet G.222. Further studies are required for such cases.

* The definition of the worst month is provided in Recommendation 581.

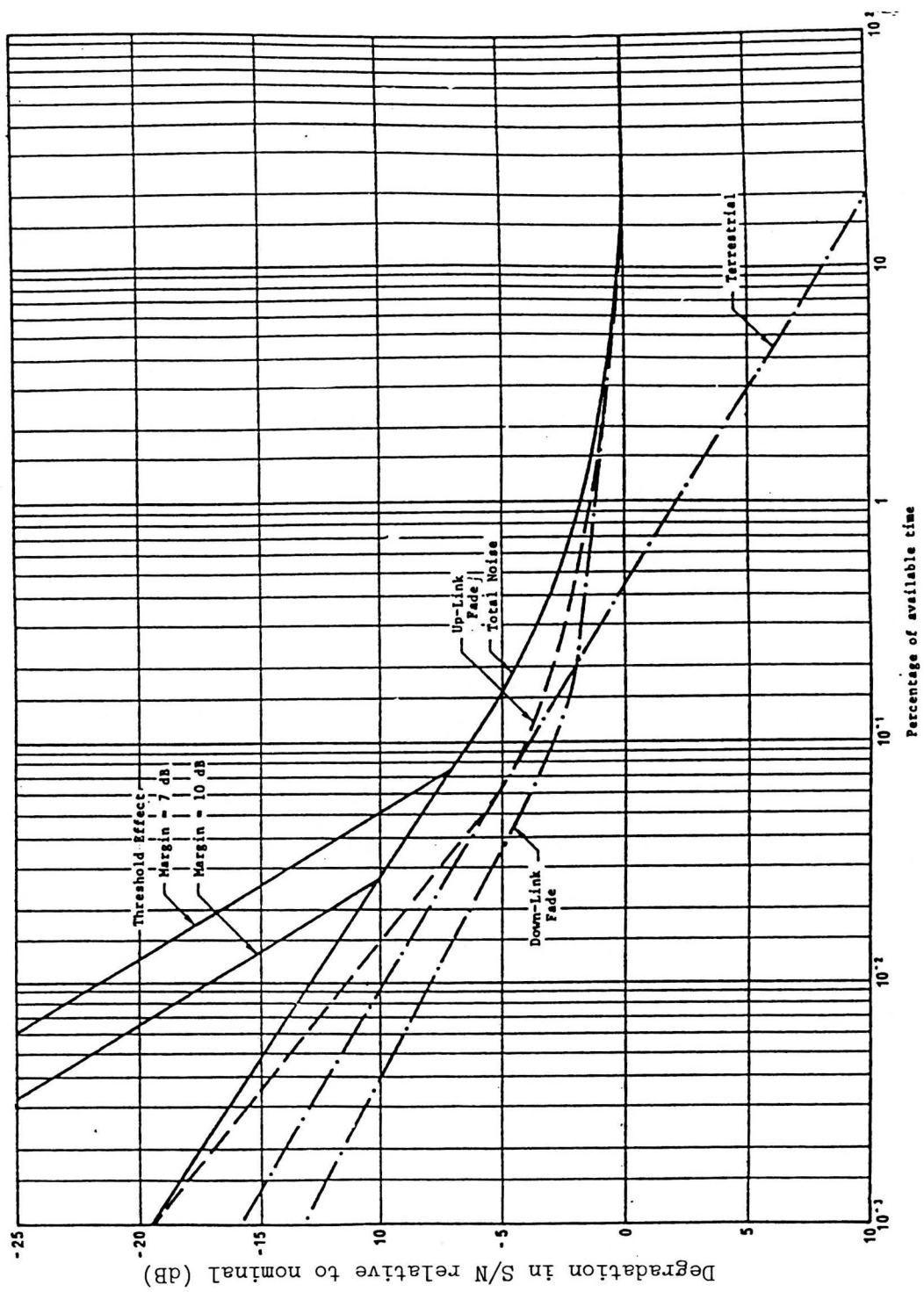


FIGURE 1
14/11 GHz noise performance as a
function of available time

3. System configuration strategies

Scatter and absorption by cloud and precipitation increase rapidly at frequencies above about 10 GHz, and this adds considerably to the problems of designing such systems. Without the use of special techniques it may be quite impracticable to provide the large rain margins necessary to meet the required standards of performance.

Four possible ways in which the severe effects of precipitation at the higher frequencies can be overcome are:

- (a) the use of site diversity;
- (b) the use of a lower alternative frequency band to that normally used, and which is much less affected by precipitation;
- (c) the use of adaptive systems which alter the transmission parameters during changing propagation conditions;
- (d) the use of multiple narrow beam on-board antennas with possible extension to the single station per beam (SSPB) concept.

In the first approach referred to in (a) above advantage can be taken from the fact that for earth stations spaced a suitable distance apart (i.e. 10 to 30 km) the correlation of precipitation between them is almost negligible and the probability that both stations will be affected simultaneously by heavy rain is likely to be very small. The technique is to connect the two earth stations providing the diversity, by a transmission line free from the effects of precipitation, and select for operational use the earth station which is least affected. Diversity operation is discussed in detail in Annex I.

In the second approach referred to in (b) above, the assumption is that a number of earth stations within a system normally operate at frequencies which can be severely affected by precipitation, i.e. above about 10 GHz. However, since the probability of more than one station at a time being affected is likely to be small, the technique of switching into use a lower frequency band at the earth station badly affected by precipitation, can be employed [Mori *et al.*, 1978]. To make a better utilization of the normally unused lower alternative frequency band, it may be possible to normally carry the traffic in the lower frequency band and interchange the operating frequency bands between stations operating in the lower frequency and those operating in the higher frequencies under adverse weather conditions [Kosaka, 1978]. Based on this concept, an experimental system using 30/20 GHz and 6/4 GHz bands was constructed [Kosaka *et al.*, 1982].

In the third approach, referred to in (c) above, system performance of digital systems may be improved by reducing the information rate transmitted or increasing the transmitted power (up-link power control) during poor propagation conditions. Examples of this approach are given in Annexes II, III and IV.

Adaptive fade countermeasure (FCM) techniques give selective enhancement to carriers undergoing fading. Some FCM methods require that the user is prepared to accept a lower data rate during fading, as in Annex II, but other methods allocate part of a shared resource overhead (eg. power, frequency, time) to any fading carriers within the network, and thus maintain the user rate (see Annex III and IV). Adaptive methods use the shared resource efficiently by apportioning resource to carriers according to the depth of fading.

In the 30/20 GHz frequency range, even in temperate zones, fade depths for significant portions of time are too great for simple fixed fade margins to be a practical solution, so some FCM is essential if the bands are to be exploited. For applications requiring high availability in the wetter climatic zones, stations will suffer even more frequent and severe fading, and there is a practical limit to the fade depth which can be countered by an adaptive system, the deeper fades requiring unacceptable high levels of shared resource. Although further propagation studies are required, indications are that it is practical to operate a shared resource adaptive scheme for an availability corresponding to Recommendation 522 in climatic zone E, but for greater availability in the wetter regions, the diversity methods, which are not adaptive and may be expensive in the earth sector, seem the only suitable option for trunk satellite services.

In the fourth approach referred to in (d) above, the objective is to avoid complications of design and operation of earth stations, even at the expense of making the satellite more complicated due to the use of complex multiple beam on-board antennas with several narrow beams which however provide for both high satellite e.i.r.p. and high satellite G/T to compensate for the propagation effects.

Examples of various existing and planned system implementations in the 30/20 GHz frequency bands are given in Annex V.

4. Frequency sharing with terrestrial systems

At frequencies above about 10 GHz variations in the level of the wanted and unwanted signals due to precipitation, and the effects of scatter, have a greater influence on the minimum separation distance obtainable between earth stations of the fixed-satellite service, and terrestrial stations of the fixed service.

The effect of scatter can be overcome by careful site selection to avoid beam intersection of the two systems, and by using cross-polarization in the case of linearly polarized waves and, since the basic transmission loss over a given path increases with frequency, the separation distance between stations of the two systems can be less at the higher frequencies. By arranging that the separation angle between an earth station and terrestrial stations is more than about 20 to 30 degrees, the minimum separation distance can be reduced to a few kilometres and the effect of the fluctuation of the wanted and unwanted signals caused by differential rain attenuation of the two systems can be avoided to some extent.

5. Design aspects of systems in the fixed-satellite service at frequencies above 10 GHz

For systems in the fixed-satellite service which use frequency bands above 10 GHz, the effects of hydrometeors, especially rainfall, are particularly important and must be taken into account when the systems are designed. The most reliable calculation of the effects of hydrometeors may be made on the basis of experimental distributions of attenuation due to hydrometeors against time. This distribution varies with the frequency and the time of the year and depends on climatic conditions at the site of the earth station and the angle at which the satellite is visible.

It should also be borne in mind that the correlation between attenuations on the paths of the satellite link declines with the distance between earth stations and increased intensiveness of precipitations. A further de-correlating factor is the frequency difference between the up-link and the down-link.

The relevant data on propagation can be found in Reports 564 and 565. In addition to that, since 1969, continuous rain attenuation experiments on earth-satellite paths have been carried out at various locations in the United States of America. The measurement frequencies include 11.7, 13.6, 15.5, 17.8, 19 and 28.5 GHz. Interim results of the 10 year (1969-1978) experiments have been published in various technical journals and conference proceedings. [Lin, *et al.*, 1980] summarizes new results and the previously published results and discusses radio communication systems. The summary includes the geographic dependence, the frequency dependence, the diurnal, monthly, and yearly variations of rain attenuation statistics, the diversity improvement factors, the fade duration distributions, the dynamic rain attenuation behaviour, the long-term (20 years) rain rate distribution for United States of America locations and a simple empirical model for rain attenuation.

The data indicate that the 28.5 GHz earth-satellite radio link, assuming 20 dB fade margin, will require site-diversity protection for most United States of America locations to meet the conventional long-haul reliability objective. Operation in this or higher frequency bands would, therefore, probably require new network operation procedures.

On the other hand, the site-diversity protection may be avoidable for frequencies at or below 14 GHz where the antenna elevation angle is relatively high.

The earth-station satellite link at 19 GHz may or may not require site-diversity protection, depending on earth-station location and satellite orbital position. Other major findings are:

- Rain-induced outages on earth-satellite radio links have higher service impact than multipath-fading-induced outages on terrestrial (6/4 GHz) radio relays even if the two systems are engineered for equal total outage time. This is because multipath fading occurs mostly during the early morning hours of low telephone activity. Furthermore, multipath fading is frequency selective and interrupts only a fraction of the frequency band at a time. By contrast, about 35% of rain outages will occur during telephone busy hours, and the outage will interrupt all traffic on an earth-satellite radio link at the same time.
- Site-diversity protection can reduce the rain outage time by at least one order of magnitude if site separation exceeds 20 km. Orbital diversity protection, although effective against sun-transit outages, reduces rain outage time by less than 20%.