

International Telecommunication Union

ITU-R
Radiocommunication Sector of ITU

Recommendation ITU-R S.2099-0
(12/2016)

**Allowable short-term error performance
for a satellite hypothetical
reference digital path**

S Series
Fixed-satellite service



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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

Electronic Publication
Geneva, 2016

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RECOMMENDATION ITU-R S.2099-0

**Allowable short-term error performance for a satellite
hypothetical reference digital path**

(Question ITU-R 277/4)

(2016)

Scope

This Recommendation provides definition on *short-term* in satellite communication systems, by considering up-to-date technical trend on satellite communication systems and standards, and specifies error performance objectives depending on the service and information.

Keywords

Error performance objectives, satellite hypothetical reference digital path, short-term

Abbreviations/Glossary

3GPP	3 rd generation partnership project
ACM	Adaptive coding and modulation
BBE	Background block error
BER	Bit error rate
bit/s	bits per second
CQI	Channel quality information
DVB	Digital video broadcasting
DVB-S2	Second generation digital video broadcasting via satellite
DVB-RCS	DVB-return channel via satellite
EB	Errored block
EN	European standard
ES	Errored second
ETSI	European Telecommunications Standards Institute
FER	Frame error rate
GEO	Geostationary earth orbit
LTE	Long term evolution
PER	Packet error rate
SES	Severely errored second
SNR	Signal-to-noise ratio
TR	Technical report
TS	Technical specification
L_b	Length of a block
L_p	Length of a packet

N_{bit_allow}	Allowable number of bit errors
N_{packet_allow}	Allowable number of packet errors
R_b	Information bit rate expressed in bit/s
R_p	packet rate, number of packets per second
P_{b_req}	Required BER
P_{p_req}	Required PER

Related ITU Recommendations, Reports and Resolutions

Recommendation ITU-R S.614-4	Allowable error performance for a satellite hypothetical reference digital path in the fixed-satellite service operating below 15 GHz when forming part of an international connection in an integrated services digital network
Recommendation ITU-R S.1061-1	Utilization of fade countermeasure strategies and techniques in the fixed-satellite service
Recommendation ITU-R S.1062-4	Allowable error performance for a satellite hypothetical reference digital path operating below 15 GHz
Recommendation ITU-R S.1323-2	Maximum permissible levels of interference in a satellite network (GSO/FSS; non-GSO/FSS; non-GSO/MSS feeder links) in the fixed-satellite service caused by other codirectional FSS networks below 30 GHz
Recommendation ITU-R SF.1006	Determination of the interference potential between earth stations of the fixed-satellite service and stations in the fixed service
Recommendation ITU-T G.826	End-to-end error performance parameters and objectives for international, constant bit-rate digital paths and connections

The ITU Radiocommunication Assembly,

considering

- a) that developments in satellite communications have required the specification of short-term interference criteria;
- b) that short-term performance objectives can be used to develop short-term interference criteria;
- c) that satellite link performance must be sufficient to allow compliance with overall end-to-end performance objectives and end-user requirements;
- d) in defining error performance criteria, it is necessary to take into account all foreseeable error-inducing mechanisms, especially time-varying propagation conditions and interference,

recognizing

- a) that long-term error performance objectives have been provided in Recommendations ITU-R S.614 and ITU-R S.1062;
- b) that information on adaptive transmission and power control techniques which can be used to counteract time-varying attenuation has been provided in Recommendation ITU-R S.1061;

c) that information on the time-allowance for the bit error rate (BER) specified in the short-term performance objectives, due to interference in a satellite network has been provided in Recommendation ITU-R S.1323;

d) that information on the short-term interference criteria applicable for interference between fixed-satellite service earth stations and stations in the fixed service has been provided in Recommendation ITU-R SF.1006,

recommends

1 that the number of bit errors during the short-term period, N_{bit_allow} be no greater than $R_b \times P_{b_req}$, when the service-dependent required performance is specified by bit error rate (BER) (see Note 1);

2 that the number of packet errors during the short-term period, N_{packet_allow} be no greater than $R_p \times P_{p_req}$, when the service-dependent required performance is specified by packet error rate (PER) (see Notes 2 and 3);

3 that the short-term period is defined as 1 second for “bent-pipe” geostationary satellite links using adaptive coding and modulation (ACM);

4 that the short-term period can be shorter depending on the satellite orbit or the satellite transponder configuration, e.g. on-board processor (the minimum short-term period would be the end-to-end transmission time of one-hop);

5 that compliance with the N_{bit_allow} or N_{packet_allow} objective may be determined at the output of any functional blocks which are used to enhance error performance such as decoders and deinterleavers;

6 that the following Notes should be regarded as part of this Recommendation.

NOTE 1 – R_b is the information bit rate expressed in bits per second (bit/s) and P_{b_req} is the required BER of the service provided by the satellite system.

NOTE 2 – The term “packet” may be used as the same meaning as “frame” if the service-dependent required performance is specified by frame error rate (FER).

NOTE 3 – R_p is the number of packets per second and it is the same as R_b divided by the number of bits per packet, and P_{p_req} is the required PER of the service provided by the satellite system.

NOTE 4 – The P_{b_req} and P_{p_req} are service and application dependent values, and to achieve one of these values a suitable power margin should be used.

NOTE 5 – The relationship between N_{bit_allow} or N_{packet_allow} and the definitions of the terms used in Recommendation ITU-R S.1062 (Recommendation ITU-T G.826), including severely errored seconds and background block error rate can be found in § 1.3 of Annex 1.

Annex 1

Short-term error performance objectives for satellite communication systems

1 Background

1.1 Definition of short-term in satellite systems

Satellite systems may be equipped with adaptive coding and modulation (ACM) scheme and/or power control scheme to suitably counteract channel fading. Especially if they are operated in the frequency range over 10 GHz, adoption of ACM may be considered as a mandatory option to counteract severe rain fading.

As detailed in Recommendation ITU-R S.1061 – Utilization of fade countermeasure strategies and techniques in the fixed-satellite service, an adaptive rain fade compensation system is required to predict in advance the amount of rain attenuation or the signal quality taking into account the round-trip delay. Assuming the round-trip delay of 0.25 second of the geostationary earth orbit (GEO) satellite system, the updating period of changing the modes (or estimating period of channel quality information (CQI)) should not be much less than a second assuming the use of a “bent-pipe” transponder. The minimum interval will be 0.5 second in the case of GEO satellite. Fading or interference factors longer than this period can be suitably detected and compensated with proper means.

For satellite links not employing ACM, the short term interval can be defined as the transmission time for one hub-to-node link or approximately 0.25 second, for a geostationary satellite. A “hub” denotes a central station and a “node” denotes a remote station.

Non-geostationary satellites will have reduced short-term intervals depending on the altitude of the satellites in the constellation.

Therefore, if we limit our interests to popular GSO satellite systems, the period of short-term needs to be defined as 1 second. In addition, by referring to a recent satellite transmission specification by European Telecommunications Standards Institute (ETSI), a timing recovery loop is considered to have a response time on the order of 1 second, in the receiver terminal (see ETSI TR 102 768 V1.1.1 (2009-04), “Digital Video Broadcasting (DVB); Interaction channel for Satellite Distribution Systems; Guidelines for the use of EN 301 790 in mobile scenarios”).

1.2 Short-term error performance objectives in terms of number of bit errors or packet errors

By defining the short-term as 1 second, the performance objectives need to be defined by service dependent bit error rate (BER) or packet error rate (PER) performance, by considering prevailed multimedia services over satellite systems in the future. For example, the typical required BER performance for voice and data services are 10^{-3} and 10^{-6} , respectively. More specific examples of service dependent performance objectives can be found in Table 17 of the user guidelines for mobile users of DVB-RCS, ETSI TR 102 768 V1.1.1 (2009-04), and Table 6.1.7 of 3GPP LTE-Advanced system specification, 3GPP TS 23.203 v.11.12.0 (2013-12). The error rate requirements of the second generation digital video broadcasting via satellite (DVB-S2) is defined by PER, and a number of PER estimation results with various coding and modulation schemes are in the ETSI TR 102 376-1 V1.2.1 (2015-11).

If the period of short-term is set to 1 second, the BER performance due to fading or interference will be dependent upon the information rate. The higher the information rate is, the larger will be the number of bits that will be received that are corrupted by the interference or fading during a fixed interval. In order to maintain the required BER during the short-term period, the allowable number of bit errors, N_{bit_allow} can be estimated as follows:

$$N_{bit_allow} = R_b \times P_{b_req} \quad (1)$$

where R_b is the information bit rate expressed in bits per second (bit/s) and P_{b_req} is the required BER defined by a specific service in the satellite system. Table 1 shows examples of the estimated N_{bit_allow} according to R_b and P_{b_req} , when the short-term period is defined as 1 second.

TABLE 1
Allowable number of bits in error during the short time period,
1 second, according to the required BER

Information rate, R_b	Required BER, P_{b_req}	Allowable number of bits in error, N_{bit_allow}
9.6 kbit/s	10^{-3}	9
	10^{-6}	0
1.5 Mbit/s	10^{-3}	1.5×10^3
	10^{-6}	1
155 Mbit/s	10^{-3}	1.5×10^5
	10^{-6}	1.5×10^2
1 Gbit/s	10^{-3}	1.0×10^6
	10^{-6}	10^3

If the system performance requirement is defined by PER (or FER), the allowable number of packet errors, N_{packet_allow} , in order to maintain the required PER during the short-term period can be estimated as follows:

$$N_{packet_allow} = R_p \times P_{p_req} \quad (2)$$

where R_p is the number of packets per second and it is $R_p = R_b/L_p$, where L_p is the length of a packet in number of bits. P_{p_req} is the required PER defined by a specific service in the satellite system. A typical size of MPEG packet is 188 bytes.

1.3 Relationships between the terms used in this Recommendation and those used in Recommendation ITU-R S.1062

Recommendation ITU-R S.1062 used performance parameters which were originally defined in Recommendation ITU-T G.826. Each of the parameters can be expressed in terms of the performance measures, N_{allow} , R_b , and P_{b_req} used in this Recommendation.

1.3.1 Error performance events for paths

- An errored block (EB) is defined as a block in which one or more bits are in error. General definitions and examples of the blocks are found in Table 1 of Recommendation ITU-T G.826. The length of a block is in the range of 800 to 30 000 bits depending on the service rate.

If the length of a block is defined by L_b , then an EB is a block in which $L_b \times P_{b_req}$ or $L_b \times P_{p_req}$ is greater than or equal to 1, for a 1 second short-term interval.

- An errored second (ES) is defined as a 1 second period with one or more EBs.
During an ES, N_{bit_allow} or N_{packet_allow} is always greater than or equal to 1, for a 1 second short-term interval.
- A severely errored second (SES) is defined as a 1 second period which contains 30% or more EBs or at least one defect (see Recommendation ITU-T G.826 for definition of defects).
Note that SESs are a sub-set of ESs.
- A background block error (BBE) is defined by an EB not occurring as part of an SES.

1.3.2 Error performance events for connections

- An errored second (ES) is defined by a 1 second period in which one or more bits is in error or during which a loss of signal or alarm indication signal is detected.
During ES, N_{bit_allow} or N_{packet_allow} is always greater than or equal to 1, for a 1 second short-term interval.
- Severely errored second (SES) is defined by a 1 second period which has a BER of greater than or equal to 10^{-3} .
During SES, N_{bit_allow} is always greater than or equal to $R_b \times 10^{-3}$.

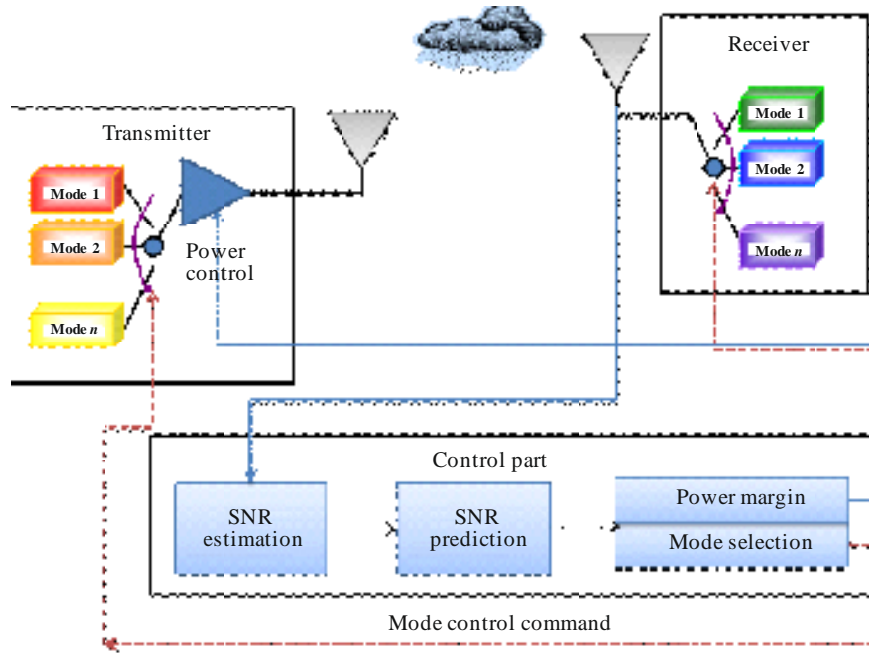
2 Operational principles of ACM

Due to time-varying characteristics of wireless channels, ACM schemes are considered in most of the modern satellite communication systems. Employing ACM greatly affects the ability of a satellite link to satisfy the error performance objectives. This effect is reflected in the link budget. The purpose of this section is to provide basic operational principles of ACM, which would help satellite system engineers to utilize the specified error performance objective. Additional material on the use of ACM for point-to-multi-point applications can be found in Recommendation ITU-R S.1061.

Figure 1 shows a block diagram of one example of an ACM operating concept for point-to-point links. The adaptive transmission technique using ACM and power control may be used to compensate short-term fading or interference that may occur in the link. The adaptive technique employs spectrally efficient transmission schemes in normal conditions and switches over to power-efficient schemes to counteract fading or interference. Since the switching operation involves investigating the history of the received signal quality or signal-to-noise ratio (SNR) and predicting the SNR at the next transmission period, a control part is required.

The control mechanism consists of SNR estimation, SNR prediction, and mode selection. SNR prediction, on the receiving side, must consider the round trip delay over a satellite link. The updating interval of the mode allocation can be no lower than two times of one-hop delay. Mode selection adaptively allocates suitable transmission schemes, such as coding and modulation, to both the transmission and receiving sides. Additionally, a power margin may be adaptively applied to compensate for any error that may occur due to SNR estimation, SNR prediction, or mode selection errors.

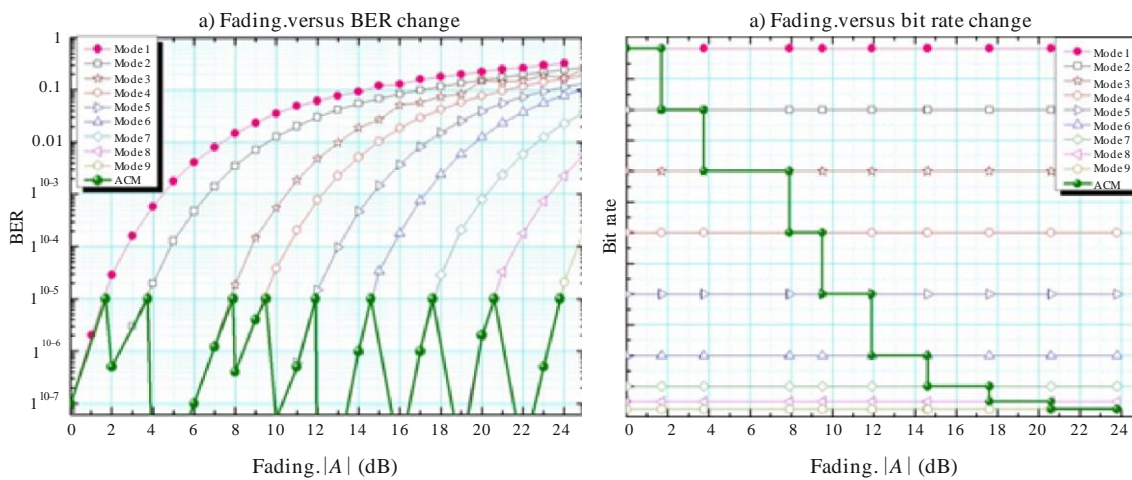
FIGURE 1
Operating concept of ACM



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Figures 2(a) and (b) illustrate the relationship between fading (or interference) versus BER, and fading versus bit rate, respectively, depending on whether or not ACM is used. In the example shown in Fig. 2, it is assumed that nine ACM modes, Mode 1 to Mode 9, are employed to compensate for fading, and that the required BER is 10^{-5} . It is also assumed that the system SNR is set to a value that produces a 10^{-5} BER with Mode 1.

FIGURE 2
Impact of fading on BER and bit rate using ACM



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More information on ACM operation over forward link with DVB-S2 can be found in the ETSI TR 102 376-1 V1.2.1 (2015-11), and its operation over return link with DVB-RCS2 can be found in the ETSI TR 101 545-4 V1.1.1 (2014-04).
