

RECOMMENDATION ITU-R S.1522-1

**Impact of loss of synchronization recovery time on availability in
hypothetical reference digital paths**

(Question ITU-R 73/4)

(2001-2005)

Scope

Service restoration time is an important factor that must be taken into consideration when determining the performance requirements of the service. This Recommendation gives the typical $C/(N+I)$ level when considering the loss of synchronization, the typical recovery times and sync loss threshold.

The ITU Radiocommunication Assembly,

considering

- a) that the unavailability of a hypothetical reference digital path (HRDP) is determined by the combined effects of equipment and link availability;
- b) that in some instances equipment unavailability is not due to equipment failure;
- c) that Recommendation ITU-R S.521 specifies that HRDPs can include functions such as: demodulation/modulation, error correction, buffer and processing which may be implemented in customer terminal or earth station equipment;
- d) that HRDPs may support such applications, as MPEG-2, which contain sequentially layered coding schemes that may include among other things: address security, data compression, and error correction;
- e) that HRDPs may also include digital applications employing other modulation and coding techniques such as quadrature phase shift keying (QPSK), octaphase shift keying (8-PSK), quadrature amplitude modulation (QAM), 1/2, 3/4 rate forward error correction (FEC), Reed-Solomon (RS), turbo coding etc.;
- f) that such applications, after loss of signal, may take a significant time to recover after signal restoration;
- g) that Recommendation ITU-R S.579 indicates that a link is considered to be unavailable when the received digital signal timing alignment (or synchronization) is lost for 10 consecutive seconds or more. Those 10 s are considered to be unavailable time and that period continues until timing alignment (or synchronization) is restored for 10 consecutive seconds;
- h) that Recommendation ITU-R S.579 defines availability and unavailability of an HRDP (which may include elements of *considering* c) above);
- j) that synchronization in the satellite HRDP may also affect the loss of synchronization and recovery time of higher protocol layers in the hypothetical reference connection (HRX);
- k) that freeze frame degradation to MPEG-2 receivers occur when error blocks appear in the video image and can be considered as unavailability,

recommends

- 1 that recovery times should be taken into account when determining availability requirements for digital decoders with complex synchronization schemes which are susceptible to short periods of signal degradation due to propagation or interference (see Annex 2);
- 2 that sensitive digital decoders, that are configured as in *recommends* 1, should be used in links which have been designed to ensure that statistical sources of interference will not cause additional equivalent link noise temperature increases resulting in loss of synchronization;
- 3 that the $C/(N+I)$ levels given in Table 1 should be used when considering the loss of synchronization for typical digital demodulator/decoders employing various modulation and coding techniques for systems with data rates of 34 Mbit/s or less;

TABLE 1

Typical $C/(N+I)$ levels when considering the loss of synchronization*

Modulation and coding	$C/(N+I)$ (dB)
QPSK rate 1/2	3.5
QPSK rate 3/4	5.3
QPSK rate 7/8	6.0
8-PSK	8.1
16-QAM	11.0

* Taking into account the measured data in Annex 4.

- 4 that in cases where the minimum performance objectives are below the values indicated in *recommends* 3, the threshold for loss of synchronization is assumed to be 1 dB below the degraded performance objective;
- 5 that for digital demodulator/decoders, recovery times given in Table 2 should be used when determining the unavailability due to loss of synchronization in an HRDP employing such digital demodulator/decoders;
- 6 that for applications using MPEG-2 receivers, error blocks will occur in the video image at threshold level higher than the level for synchronization shown in Table 1 by 0.3 dB for QPSK 1/2-RS rate coding and 0.6 dB for QPSK 3/4-RS and 7/8-RS rate coding (see Annex 1).

NOTE 1 – The time duration and frequency of occurrence of interfering signals can contribute to the determination of the allowable maximum interference level. It is observed that multiple short interference events can result in periods of unavailability of longer duration than those periods caused by fewer long events (see Annex 3). This effect and the results of short duration (< 1 s) interference events are subjects of further study.

NOTE 2 – The impact of the loss of synchronization in the satellite HRDP on the higher layer protocol levels in an HRX is a subject of further study.

NOTE 3 – Table 2 is derived from the latest available, limited set of data as given in Annex 4 and is provisional pending further studies.

TABLE 2
(see Note 3)**Maximum of measured recovery times**

Modulation and coding	Carrier bit rate	Recovery time (s)
QPSK rate 1/2 FEC	64 kbit/s	40
	2 Mbit/s	4.5
QPSK rate 3/4 FEC	64 kbit/s	19.8
	2 Mbit/s	6
	8 Mbit/s	9.3
	34 Mbit/s	2.3
8-PSK rate 2/3 FEC with (201,219) RS coding	2 Mbit/s	3.1
	8 Mbit/s	9.1
	34 Mbit/s	4.0

Annex 1

**Considerations for HRDPs when implemented for providing services
whose availability are sensitive to recovery time
after loss of synchronization**

1 Introduction and purpose

The synchronization behaviour of several different classes of receivers were examined based on measurements performed or information supplied by earth station receiver manufacturers. The objectives of the investigation were to determine the interference duration and the power level required to cause the receiver to lose synchronization. For each receiver investigated, the degradation level and length of time necessary to cause loss of synchronization were determined. Additionally, the amount of time to reacquire synchronization for each receiver was determined. The results were then quantified so as to determine the threshold for loss of synchronization that could be applicable for all geostationary-satellite orbit (GSO) fixed-satellite service (FSS) earth station receivers.

2 Digital video and audio receivers

A typical MPEG-2 digital video and audio receiver is described in Annex 2 along with its performance and discussion of the test results. The test results indicate that a satellite channel of the type tested above and implemented, using QPSK concatenated 1/2 RS or 7/8 RS convolutional coding and operating at a 1×10^{-10} bit error ratio (BER) would lose synchronization if the noise is increased 2.2 dB for a period of 1 to 2 s. Assuming nominal $C/(N+I)$ levels were restored after loss of synchronization, the equipment would require an additional 4 to 8 s to return to normal operation.

It was noted that error blocks occur in the received image at a threshold level higher than the synchronization loss level. MPEG-2 video is considered to be unavailable when error blocks are seen in the video image. For the QPSK 1/2 rate coded MPEG-2 signal, error blocks occurred at a threshold C/N that was 0.3 dB above the threshold for loss of synchronization. For the QPSK 7/8 rate coded MPEG-2 signal, error blocks occurred at a threshold C/N that was 0.6 dB above the threshold for loss of synchronization.

3 Data receivers

Performance results for digital receivers operating at various data rates show that the margin for loss of synchronization is of the same order as discussed in § 2.1. When the E_b/N_0 falls below threshold and remains below it for a period of 1 to 2 s, it loses lock both frequency and data synchronization. The time duration to reacquire depends on the particular algorithm used, and on the bandwidth that it must sweep in order to reacquire synchronization. Generally this is a function of the data rate, modulation method (binary PSK (BPSK), QPSK, etc.), coding/decoding method and the coding rate used. The total time to reacquire frequency and data synchronization varies for moderate and high bit rates up to the Mbit/s range, test results illustrating the range of recovery times are given in Table 8.

4 Packet services

Packet data service may be affected for much longer periods even when a system abnormality lasts for a short duration.

ITU-T considers a system to be unavailable after a service is unavailable for 10 s or more. The routing information for the packet service is updated every 30 s, and up to two cycles of such updating may be affected by a short abnormality and its after-effects. Thus, it may be concluded that although the receiver loses synchronization for only 1 to 15 s, the overall effect including the time for service restoration may be to make the service unavailable for much longer period.

5 On-board processing satellite networks

With the advent of on-board processing satellites, consideration of loss of synchronization on the uplink of such networks must also be taken into account when evaluating the effects of interference from non-GSO and other interference sources into GSO FSS systems. Further analysis will be necessary to determine the durations and levels of interference necessary to cause loss of synchronization at satellite receivers employing on-board processing.

6 Summary and conclusions

Test results of performance and interference susceptibility for several types of receiver-demodulators operating or planning to operate in the 30/20 GHz and 14/11 GHz bands have been completed. Additional information on other configurations and improvements in the state of the art is required.

Tests performed on typical receivers used for digital video, digital audio, and data service and voice applications indicate that noise or interference levels exceeding C/N thresholds in Table 1 for short periods of time will cause the receiver to lose synchronization. The tests demonstrate that when signals are returned to nominal $C/(N + I)$ levels, after loss of synchronization, the recovery times of the receiver are a function of modulation, coding and bit rate as shown in Table 2. Further study on the time duration and frequency of occurrence of interference sources is required in order to fully quantify their effects on services with imbedded synchronization implementations.

For the systems tested it is apparent that service restoration time is an important factor that must be taken into consideration when determining the performance requirements of the service. Several factors affect the total time for which service restoration is required including: demodulator and bit synchronization, frame synchronization, error correction decoding, security synchronization, restoration of connection for voice circuits and re-initiation of transmission protocols for data circuits.

Annex 2

Loss of synchronization due to short-term interference in an MPEG-2 digital video and audio receiver

1 Introduction

In this Annex, the synchronization behaviour of a digital video receiver is examined that is commonly used for satellite news gathering (SNG) and for video distribution by broadcasters. Similar complex receivers are also used for direct to home and broadcasting-satellite service (BSS) applications, data distribution, file transfer, broadcast of data, etc. This class of receiver was chosen for testing and evaluation because the video data is heavily coded and compressed where the loss of synchronization could cause long-term outages. Other receivers designed for different types of service will perform similarly with different outage times.

2 Objective and approach

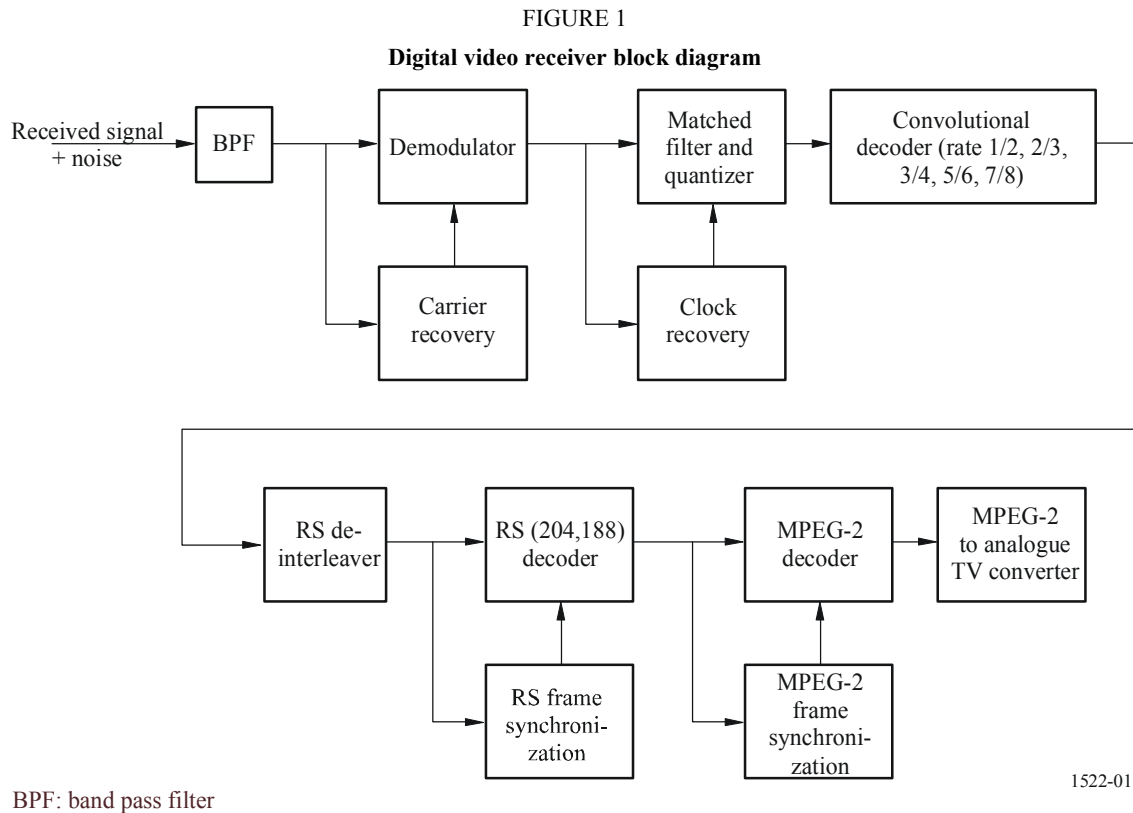
The objectives of the investigation were to determine the interference duration and the power level required that cause the receiver to lose synchronization and also to characterize the receiver outage time. For these measurements the interference is modelled as Gaussian noise. This is consistent with accepted test procedures that treat interference from digital sources. Measurements were obtained by raising the noise level to simulate the interference source. Initial tests were designed to characterize the BER performance of the receiver and were compared to the manufacturer's specifications in order to ensure that the system under test was performing properly. Additional tests were performed to determine the mean time to loss of synchronization, and the time for reacquisition. Tests were also conducted to determine the impact of noise bursts on receiver performance.

3 Receiver description

The digital video receiver under test integrates MPEG-2 digital video and MPEG-2 digital audio decoders into a single channel per carrier. That configuration allows direct reception of digitized video, audio, and data from satellite network transmissions. For this implementation the received signal was set as QPSK modulated where the receiver can handle data rates from 2.5 Mbit/s to 15 Mbit/s.

Figure 1 is a block diagram showing the receiver processing chain. The received signal is demodulated, matched filtered and the detected symbols are quantized. The quantized symbols are convolutionally (Viterbi) decoded. The system can be set-up for rate 1/2, 2/3, 3/4, 5/6, and 7/8 codes. The symbols then enter an RS decoder, and a de-interleaver that protects the RS decoder

from burst errors generated by the Viterbi decoder. The RS decoder outputs MPEG-2 frames. These frames are decoded, demultiplexed and the MPEG-2 signal is converted to analogue TV format.



As seen in Fig. 1, the receiver has many levels of synchronization from initial carrier recovery to MPEG-2 frame synchronization preceding conversion to analogue TV. In general, higher level synchronization functions are more susceptible to loss of synchronization than the lower level functions. Therefore, frame and code synchronization will be lost before carrier synchronization. Loss of synchronization and reacquisition are primarily software functions. Thus the behaviour of the receiver can depend on the specific software implementation.

Figure 2 shows typical performance curves for the RS decoder for several different convolutional code rates. The clear sky performance threshold is usually set to the $\text{BER} = 1 \times 10^{-10}$. This corresponds to an $E_b/N_0 = 4.7$ dB for a rate 1/2 code and an $E_b/N_0 = 7.5$ dB for a rate 7/8 code.