

RECOMMENDATION ITU-R S.1425

**TRANSMISSION CONSIDERATIONS FOR DIGITAL CARRIERS USING
HIGHER LEVELS OF MODULATION ON SATELLITE CIRCUITS***

(Questions ITU-R 73/4 and ITU-R 230/4)

(2000)

The ITU Radiocommunication Assembly,

considering

- a) that the radio spectrum and geostationary orbit are limited resources;
- b) that there is spectrum congestion in certain frequency bands allocated to the FSS;
- c) that due to the rapid development of different radio services, sharing conditions in many frequency bands are becoming increasingly difficult;
- d) that the spectral efficiency of satellite networks can be increased through the use of higher level modulations such as 8-PSK and 16-QAM as compared to QPSK;
- e) that the power efficiency of satellite networks can be improved through the use of appropriate encoding techniques;
- f) that there is a continuous need to update the information available on the characteristics of satellite transmissions and their related performance;
- g) that different transmission techniques can be implemented to transport the same information stream,

taking into account

- a) that satellite circuits transmitting higher level modulations and in particular QAM such as 16-QAM are more sensitive to linear and non-linear distortion than those transmitting QPSK signals;
- b) that satellite circuits transmitting higher level modulations such as 8-PSK and 16-QAM are more sensitive to phase noise than those transmitting in QPSK format;
- c) that use of higher level modulation techniques improve the bandwidth efficiency for a given E_b/N_0 at the cost of more transmitter power or higher earth station G/T and greater earth station e.i.r.p.,

recommends

- 1** that the information contained in Annex 1 be used as a guide for implementation of transmission quality for satellite circuits using higher level modulations such as 8-PSK and 16-QAM.

* This Recommendation should be brought to the attention of Radiocommunication Working Parties 4 SNG and 10 HSS.

Transmission considerations for carriers using higher levels of modulation on satellite circuits

1 Introduction/purpose

This Annex provides information regarding the development of new technologies intended for use on, but not limited to, FSS networks. The initial purpose of these developments are to increase the throughput capacity of the available spectrum that is allocated to that service. This could be achieved by utilizing more efficient modulation processes for the transmission of information.

2 Background

2.1 Purpose/objective

With the increased satellite transponder power and concatenated error correction techniques, higher modulation schemes such as 8-PSK and 16-QAM have become feasible for implementation in geostationary satellite orbit (GSO) satellite communication systems. These high order modulations significantly improve the transponder bandwidth efficiency which suits the needs of broadband format structures and applications, such as asynchronous transfer mode (ATM), frame-relay and HDTV. In order to achieve acceptable quality of service as characterized by low BER and higher data rates with the higher order modulations, there is a requirement for not only a higher C/N ratio at the input of the demodulator, but also a need to control interference and limit distortion within the satellite transmission circuit.

This Recommendation describes the nature of the higher order modulations considered applicable to geostationary-satellite networks and details the reasons for their susceptibility and increased sensitivity to transmission impairments. It will also describe the tests and results of 8-PSK and 16-QAM circuits implemented to determine their operational requirements in a typical satellite network.

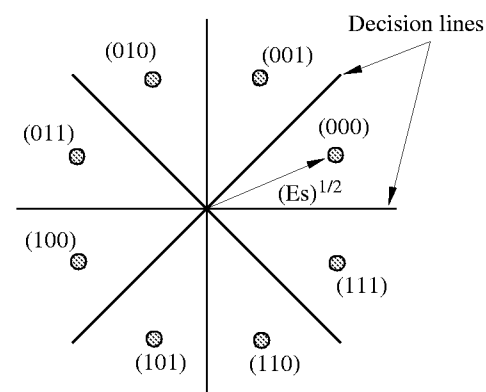
2.2 8-PSK and 16-QAM modulations

In 8-PSK the transmitted symbol is a sinusoidal carrier with eight equally spaced phases. The signal-space diagram is shown in Fig. 1.

Every 8-PSK modulated symbol represents three user bit occupancies, as opposed to 2 bit occupancies for QPSK modulation, thereby improving bandwidth utilization by 50%. On the other hand, each symbol is 45° closer to each other in phase compared to the QPSK symbols which introduces more difficulty to the decision-making processes of the receiver. Theoretical calculations shows that without any error correction techniques, 8-PSK requires 7 dB more energy per bit than QPSK in order to achieve 1×10^{-8} BER.

Figure 2 is an example of a 4×4 QAM (16-QAM) signal-space. Each symbol represents four information bits and requires that the receiver distinguish between the different combinations of both the phase and amplitude modulation process. As shown in Fig. 2, the receiver must distinguish between the possible 12 phases and four amplitudes in order to make a decision. As the separation between the signal states are even closer together than for 8-PSK, both amplitude noise and phase noise will have a more pronounced affect in the decision-making process. However, although more vulnerable to transmission impairments than 8-PSK, the bandwidth utilization is improved by 100% compared to QPSK.

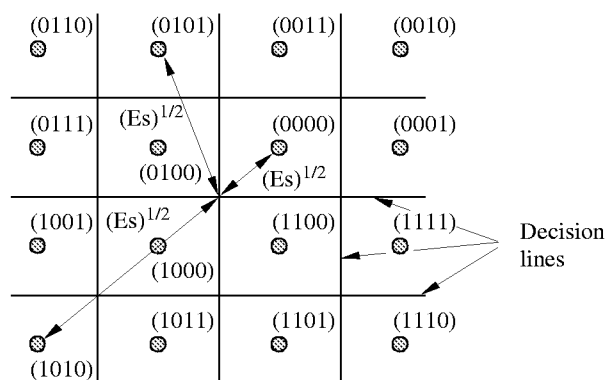
FIGURE 1
Signal-space for 8-PSK



E_s : Energy per symbol

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FIGURE 2
Signal-space for 16-QAM



E_s : Energy per symbol

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3 Transmission test methods and measurements

3.1 Description of test facility

Tests were conducted to investigate the capability and circuit limitations necessary for 16-QAM broadband transmissions in a satellite network. To that purpose a flexible test configuration was implemented which also allowed the determination and optimization of intermediate transmission level points associated with the non-linear transmission elements in the network. Figure 3 presents a block diagram representation of the test configuration used. The switch points indicated in this Figure are shown to convey the variety of the test configurations used.