

RECOMMENDATION ITU-R S.1779

**Characteristics of fixed-satellite service systems using
wideband spreading signals**

(Question ITU-R 270/4)

(2007)

Scope

This Recommendation provides example approaches on the use of wideband spreading signals in fixed-satellite service (FSS) systems. The three annexes to this Recommendation present an overview of the techniques and implementation approaches of transmission schemes for the benefit of network operators and users.

The ITU Radiocommunication Assembly,

considering

- a) that new transmission techniques using wideband spreading signals may be used in fixed-satellite service (FSS) uplinks and/or downlinks;
- b) that FSS systems using such technologies may address new applications and new services;
- c) that the applications of FSS systems using wideband spreading signals have different features from other FSS systems;
- d) that the characteristics of FSS systems using wideband spreading signals are different from those FSS systems currently deployed;
- e) that the interference effect of the emissions from a FSS system using wideband spreading signals needs to be defined;
- f) that it would be useful for network operators and users to have a source of information on the characteristics of FSS systems using wideband spreading signals,

recommends

1 that the system models and the technical characteristics contained in Annexes 1 through 3 should be used as example approaches for implementation of transmission schemes using wideband spreading signals for FSS systems.

NOTE 1 – Materials in Annexes 1 to 3 correspond to the following approaches, respectively:

Annex 1 – Transmission of additional information overlaid on the conventional FSS frequency-division multiple access (FDMA) signals.

Annex 2 – Improvement of the effective channel capacity in a FSS system with a number of narrow spot beams.

Annex 3 – Reduction of the off-axis e.i.r.p. density level to meet the values in the associated ITU-R recommendations.

Annex 1

A satellite system with wideband spreading signals (direct sequence (DS) technology)

1 Introduction

This Annex provides a description of transmission techniques using wideband spreading signals, referred to as a wideband satellite system, that can be used to transmit additional information without changing the operational frequency plan of the existing FSS system.

One of the applications of the system would be for the transmission of emergency traffic, such as earthquake information, tsunami warnings, etc. Figure 1 illustrates this type of application. For the purposes of emergency signal transmission, user terminals should be compact and inexpensive, so that most people can install and use such receivers at any time. Therefore, those with small (low-gain) antennas would be convenient, which would also facilitate installation and maintenance. Antennas in conventional FDMA FSS systems are usually higher gain and must be oriented towards the satellite direction, due to antenna directivity, and the antenna orientation is easily subject to change by accidental force, such as earthquakes or tropical cyclones.

In contrast to the above advantages, user terminals with low-gain antennas are affected by interference from adjacent satellites. The use of spreading signals is expected to mitigate this deterioration due to inter-system interference because of its spreading gain. This is the reason the spreading signal is used for this type of application.

The following applications have been evaluated to apply the technique:

- A satellite system with wideband spreading signals overlaid on the conventional FSS FDMA signals.
- A satellite system with dedicated bandwidths for both FDMA signals and wideband spreading signals.

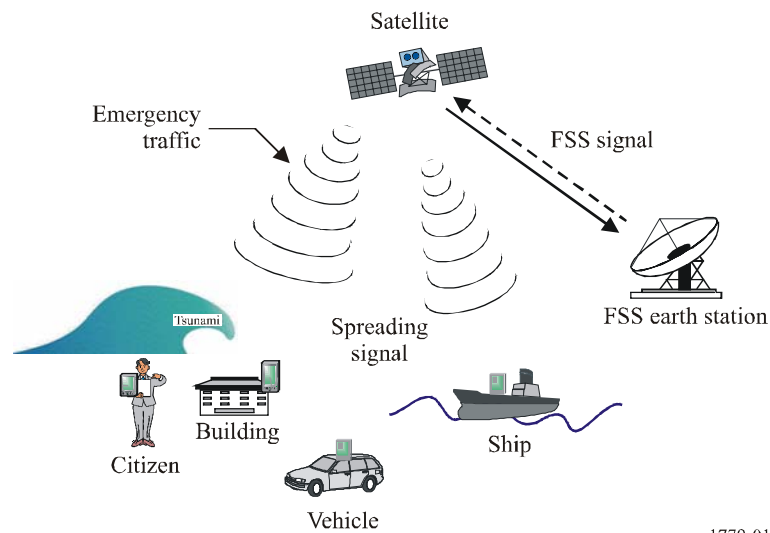
In the following section, the link budget analysis in this application is presented using various parameters of the existing FSS system with evaluation results in terms of the data rate. Note that the DS technology is assumed in this analysis.

2 Application 1 – A satellite system with wideband spreading signals overlaid on the conventional FSS FDMA signals

2.1 System models

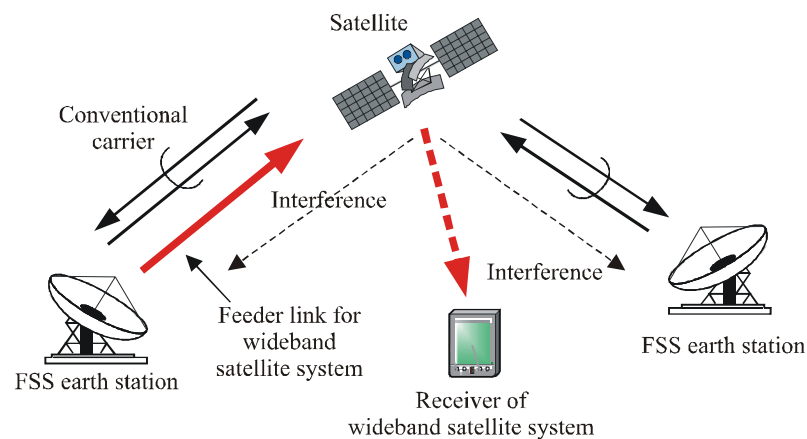
The conceptual view of the system is shown in Fig. 2. Two system models, Model 1 and 2, are assumed for a preliminary analysis on the wideband satellite system, which is summarized in Table 1. Model 1 is applied to a new satellite system using a regenerative type transponder, and Model 2 is applicable to the existing satellite system with a non-regenerative type one. The following scenarios are also assumed for this analysis.

FIGURE 1
Application of wideband spreading signals for emergency traffic transmission



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FIGURE 2
System model for satellite systems using wideband spreading signals



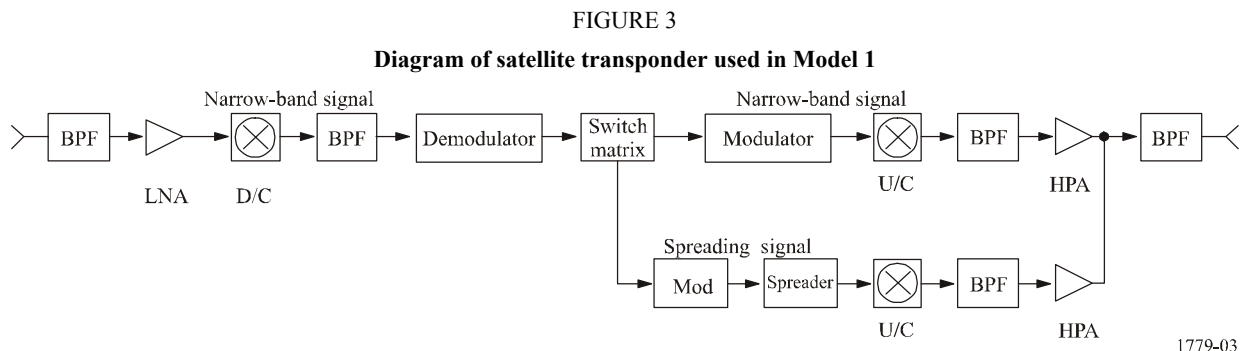
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TABLE 1
Assumed link models in a wideband satellite system

	Model 1	Model 2
Transponder type	Regenerative	Non-regenerative
Bandwidth (uplink/downlink)	36/240 MHz	36/36 MHz
Transmission scheme (uplink/downlink)	FDMA/ FDMA and spreading signal	FDMA and spreading signal/ FDMA and spreading signal

2.1.1 The wideband spreading signals are overlaid onto the existing FSS spectrum within the FSS allocation. The bandwidth of the wideband spreading signals is identical to the transponder bandwidth of the FSS, in which multiple FDMA carriers are allocated. Therefore the spread signals would be co-frequency with several adjacent FDMA signals of the same FSS networks, causing intra-system interference.

2.1.2 In Model 1, a conventional narrow-band type transmission is utilized for the uplink. For the downlink, the wideband spreading signals are transmitted through a transponder with very wide bandwidth, designed for the wideband satellite system, while the narrow-band signals are channelled through conventional narrow-band transponders. Figure 3 provides a diagram of a portion of the satellite payload in Model 1 which explains how the uplink signals are processed on board.



2.1.3 In Model 2, for the uplink the wideband spreading signals are overlaid onto the existing FDMA spectrum; both the FDMA signals and the wideband spreading signals are transmitted through a conventional transponder. For the downlink, just as for the uplink, both type signals are processed through a conventional transponder.

2.1.4 The space segment consists of a single satellite. Both the wideband and the narrow-band signals are processed at a single space station, and a single antenna is shared to transmit them into a single satellite beam. On the other hand, a new type of terminal, receiving only the spreading signals from the satellite, is assumed. The technical parameters of the wideband satellite system receiver can be independent from those of the existing FSS systems.

2.1.5 For ease of calculation, for the uplink both the FSS FDMA signals and the wideband spreading signals are transmitted from the same earth station; the two types of receivers are located at the same position at the Earth's surface, avoiding the need to take satellite antenna patterns into consideration.

2.2 Link budget analysis and performance estimation

The achievable data rate is estimated by the link budgets in the 14/12 GHz bands. Since a conventional transponder and transmission scheme are used for the uplink, the data rate of the wideband satellite system is obtained considering downlink parameters. The calculation is carried out by implementing the following steps:

Step 1: Using typical parameters in FSS systems and the required C/I value for FDMA carriers, the downlink e.i.r.p. in the wideband satellite system is derived, which, accordingly, provides the received C/T at the wideband signal receiver.

Step 2: Using the determined received C/T , an ideal data rate is obtained as the first step of the data rate analysis, assuming a condition where no FDMA carriers exist.

Step 3: Just as in Step 2, the achievable data rate is derived taking the interference from FDMA carriers into the wideband satellite system into consideration.

The procedures of the above steps are presented in more detail in the following sections.

2.2.1 Step 1

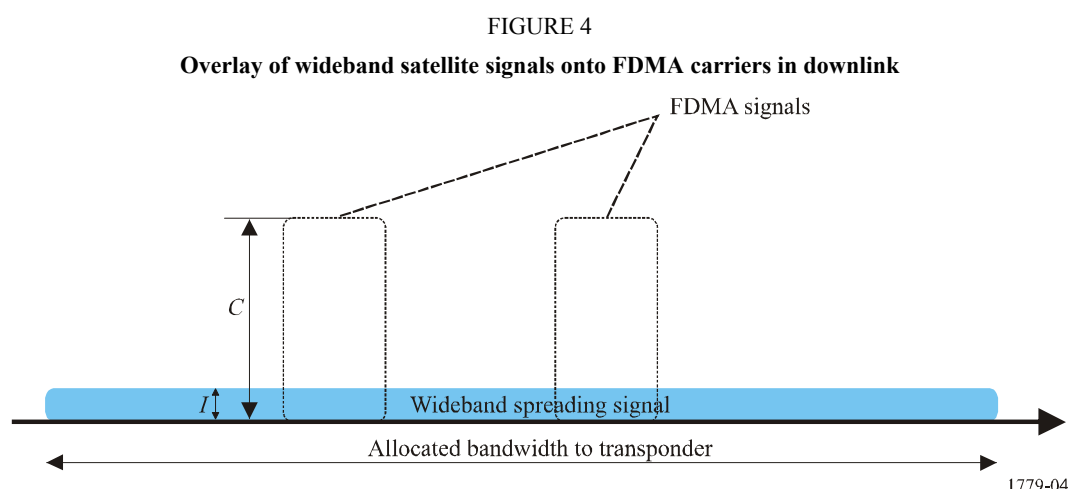
As shown in Fig. 4, the conventional FDMA carriers are transmitted in certain portions within the transponder bandwidths while the signals of the wideband satellite system are overlaid within the whole transponder bandwidth.

First, the required C/I value for the FDMA carriers is given where C and I represent the output power of one of the FDMA carriers and that of the wideband satellite system, respectively. A C/I of 20 dB is employed in this analysis.

Once the required C/I is given, the permissible e.i.r.p. on the space station for the wideband satellite system is derived with the occupied bandwidth taken into consideration. Hence, the received C/T in the system, Rx C/T , is expressed by the following equation:

$$\text{Rx } C/T = e.i.r.p. - L_p - M_{rain} + G/T \quad \text{dB} \quad (1)$$

where L_p , M_{rain} and G/T represent the free space path loss between the satellite and the receiver on the Earth's surface, the rain margin and the receiving antenna G/T , respectively.



2.2.2 Step 2

When Rx C/T is given, the attainable information rate R is calculated by:

$$R = \text{Rx } C/T - (E_b/N_0)_{req} + 228.6 \quad \text{dB} \quad (2)$$

where $(E_b/N_0)_{req}$ and “228.6” are the required E_b/N_0 and Boltzmann's constant, respectively.

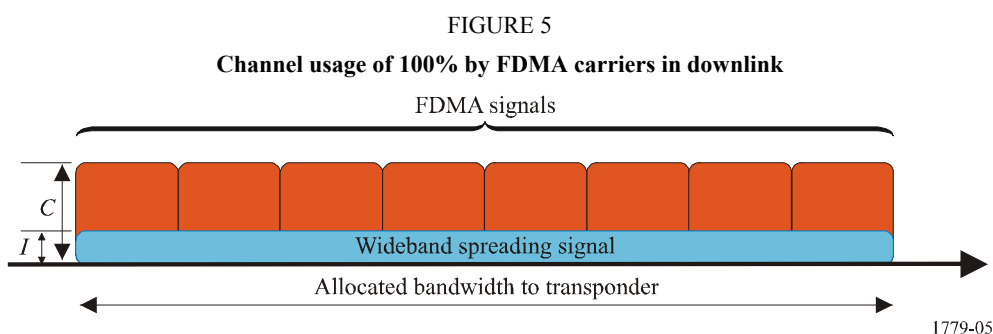
The above information rate is the ideal data rate estimated under the condition assuming the absence of narrow-band FDMA carriers.

2.2.3 Step 3

Finally, an achievable data rate is calculated for the wideband satellite systems, considering multiple narrow-band FDMA carriers within the transponder bandwidth. In this case the downlink Rx C/I of the FDMA carriers is regarded as the interference with the wideband satellite system. The overall C/I in the case of Model 1 is obtained by summing up the downlink receiver C/I value of the wideband satellite system and the degradation of the downlink wideband receiver C/I value due to the interference caused by FDMA carriers. This procedure can be also applied to the case of Model 2.

The channel usage of FDMA carriers is modelled for the analysis as shown in Fig. 5 with usage of 100% defined as the whole spectrum in the transponder bandwidth being used by multiple narrow-band FDMA carriers, and a usage of 50% showing half the bandwidth occupied by the FDMA carriers. When the channel usage is 100%, for example, the wideband satellite system requires a higher spreading gain by 20 dB than in Step 2. Note that the guardbands are not considered here for ease of calculation.

The way to calculate the data rate is the same as that presented in Step 2.



2.3 Results of link budget analysis

Typical parameters of the FSS system and e.i.r.p. values in the wideband satellite system are summarized in Tables 2 and 3. Taking a C/I value of 20 dB into account, the e.i.r.p. density of the spreading signals would be 14.4 dB(W/MHz), as shown in Table 3.

TABLE 2
Typical FSS system parameters

Parameter	Uplink	Downlink	Note
Bandwidth per carrier	72.0 MHz	36.0 MHz	
e.i.r.p. per carrier	70.0 dBW	50.0 dBW	
e.i.r.p. density	51.4 dB(W/MHz)	34.4 dB(W/MHz)	

TABLE 3
e.i.r.p. values in wideband satellite system

FDMA system	Uplink	Downlink	Note
e.i.r.p. density of FDMA	51.4 dB(W/MHz)	34.4 dB(W/MHz)	From Table 2
Required C/I (FDMA/wideband satellite system)	20.0 dB	20.0 dB	
e.i.r.p. density of wideband satellite system	31.4 dB(W/MHz)	14.4 dB(W/MHz)	

To consider a link budget in more detail, take the example of Models 1 and 2 with the summary shown in Tables 4 through 7.

From Table 2, a bandwidth of 72.0 MHz together with an e.i.r.p. value of 70.0 dBW gives an e.i.r.p. of 67.0 dBW in a 36 MHz bandwidth in Model 1. In Model 2, since the spreading signal level is suppressed 20 dB lower than that of the FDMA signal, an e.i.r.p. value of 47.0 dBW is obtained.

The uplink Rx C/T is calculated by equation (1), deriving an uplink Rx C/T value of -134.5 and -154.5 dB(W/K) for Models 1 and 2, respectively.

TABLE 4
Link budget – 1 (uplink)

Wideband satellite system	Mode 1 (Regenerative)	Model 2 (Non-regenerative)	Note
Bandwidth	36 MHz	36 MHz	
Earth station e.i.r.p.	67.0 dBW	47.0 dBW	From Tables 2 and 3
Path loss	206.5 dB	206.5 dB	Operating frequency: 14 GHz
Rain attenuation	0 dB	0 dB	
Rx antenna G/T	5.0 dB/K	5.0 dB/K	
Uplink Rx C/T	-134.5 dB(W/K)	-154.5 dB(W/K)	

With an e.i.r.p. density of spreading signals of 14.4 dB(W/MHz) given in Table 3 and a downlink bandwidth of 240 MHz in Model 1, it follows that the satellite e.i.r.p. value is 38.2 dBW. Similarly, a satellite e.i.r.p. value of 30.0 dBW is obtained in Model 2. Using equation (1), the downlink Rx C/T is calculated: -171.9 and -180.2 dB(W/K) for Models 1 and 2, respectively.

TABLE 5
Link budget – 2 (downlink)

Wideband satellite system	Model 1	Model 2	Note
Bandwidth	240 MHz	36 MHz	
Satellite e.i.r.p.	38.2 dBW	30.0 dBW	From Table 3
Path loss	205.2 dB	205.2 dB	Operating frequency: 12 GHz
Rain attenuation	0 dB	0 dB	
Rx antenna G/T	−5.0 dB/K	−5.0 dB/K	10 cm dish antenna (19.8 dBi), $T_{sys} = 300$ K
Downlink Rx C/T	−171.9 dB(W/K)	−180.2 dB(W/K)	

User terminals with low-gain antennas could be affected by interference from adjacent satellites, resulting in C/T degradation. However, those effects are neglected in order to evaluate an ideal value in this link budget analysis, which will be discussed in § 2.4.2.

Therefore, an overall C/T is the same as the downlink Rx C/T of −171.9 and −180.2 dB(W/K) for Models 1 and 2, respectively.

TABLE 6
Link budget – 3 (overall)

Wideband satellite system	Model 1	Model 2	Note
Intra-system overall C/T	−171.9 dB(W/K)	−180.2 dB(W/K)	from Tables 4 and 5
C/T degradation due to interference from adjacent satellites	0 dB	0 dB	
Overall C/T	−171.9 dB(W/K)	−180.2 dB(W/K)	

Finally, using equation (2), the estimated data rate is derived, as shown in Table 7.

TABLE 7
Available data rate in wideband satellite system

Wideband satellite system	Model 1	Model 2	Note
Overall C/T	−171.9 dB(W/K)	−180.2 dB(W/K)	
Required E_b/N_0	4.0 dB	4.0 dB	
Boltzmann's constant	−228.6 dB(W/(K · Hz))	−228.6 dB(W/(K · Hz))	
Estimated data rate	52.7 dB(bit/s) 184.8 kbit/s	44.4 dB(bit/s) 27.7 kbit/s	

From the viewpoint of FSS carrier operation, the above value gives I_0/N_0 of −1.3 dB, assuming 1.2 m antenna (41.3 dBi) and the system temperature of 120 K at an earth station.

2.4 Summary of available data rate

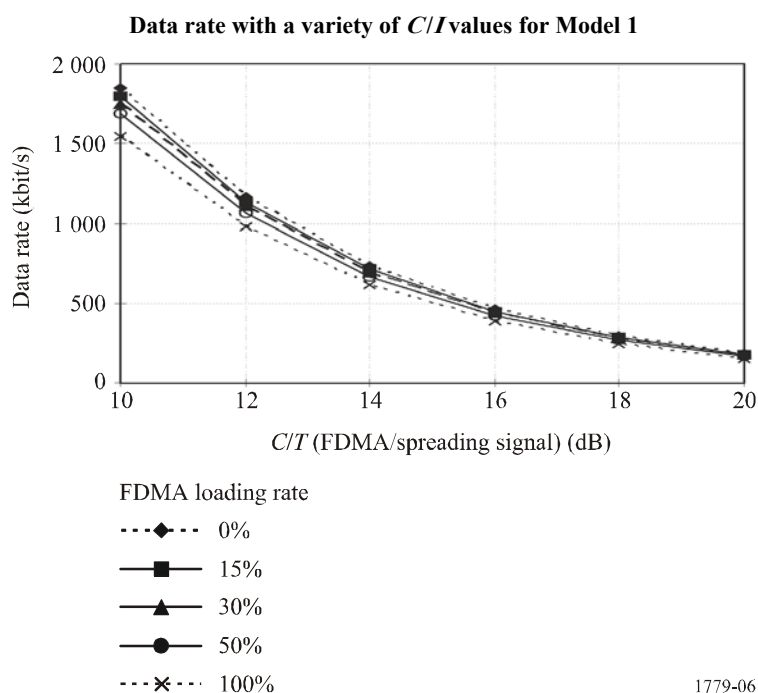
2.4.1 Data rate with a variety of C/I values

Data rates are given with a variety of C/I values in the downlink as shown in Table 8 and Fig. 6 for Model 1, where C and I represent the output power of one of the FDMA carriers and that of the wideband satellite system, respectively. Antenna gain and C/T degradation due to interference from adjacent satellites are set to be 19.8 dBi and 0 dB (an ideal case), respectively. From the result, with the loading rate of 100% and the C/I value of 20 dB, the achievable data rate is 154.9 kbit/s, for example.

TABLE 8
Data rate (kbit/s) with a variety of C/I for Model 1

C/I (dB)	Loading rate of FDMA carriers (%)				
	0	15	30	50	100
10	1 848.0	1 795.9	1 746.7	1 685.1	1 548.5
12	1 166.0	1 133.2	1 102.1	1 063.2	977.0
14	735.7	715.0	695.4	670.8	616.5
16	464.2	451.1	438.7	423.3	389.0
18	292.9	284.6	276.8	267.1	245.4
20	184.8	179.6	174.7	168.5	154.9

FIGURE 6



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