

RECOMMENDATION ITU-R S.1716*

Performance and availability objectives for fixed-satellite service telemetry, tracking and command systems

(Question ITU-R 262/4)

(2005)

Scope

This Recommendation resulted from multi-year studies within Radiocommunication Working Party 4B and provides guidance to the designers of fixed-satellite service systems on the technical and operational aspects of telemetry, tracking and command systems.

The ITU Radiocommunication Assembly,

considering

- a) that all FSS satellites have telemetry, tracking and command (TT&C) requirements;
- b) that TT&C operations are carried out on FSS satellites while in transfer orbit and for on-station operation on the geostationary-satellite orbit (GSO);
- c) that TT&C signal information originate and terminate under satellite operator control;
- d) that TT&C carriers need higher performance reliability objectives than normal traffic carriers;
- e) that loss of the uplink command carriers to the satellite and downlink telemetry and ranging carriers during orbital maneuvers or during solar eclipse periods could result in the loss of a satellite;
- f) that some satellites with service links in bands above 17 GHz may also operate service links in bands below 17 GHz;
- g) that some GSO FSS operators may co-locate their satellites operating above 17 GHz with satellites operating below 17 GHz;
- h) that GSO FSS operators should be given some flexibility to operate TT&C in the most appropriate frequency band;
- j) that the spectrum requirements for TT&C operations of satellites operating above 17 GHz may impact the satellite systems operating below 17 GHz,

recommends

- 1 that FSS satellite operators should design their TT&C systems based on the technical and operational considerations given in Annex 1.

NOTE 1 – Satellite operators are encouraged to provide further information on their TT&C operations.

* This Recommendation should be brought to the attention of Radiocommunication Study Group 6.

Annex 1

Technical and operational characteristics of FSS TT&C systems

1 Description of TT&C operations

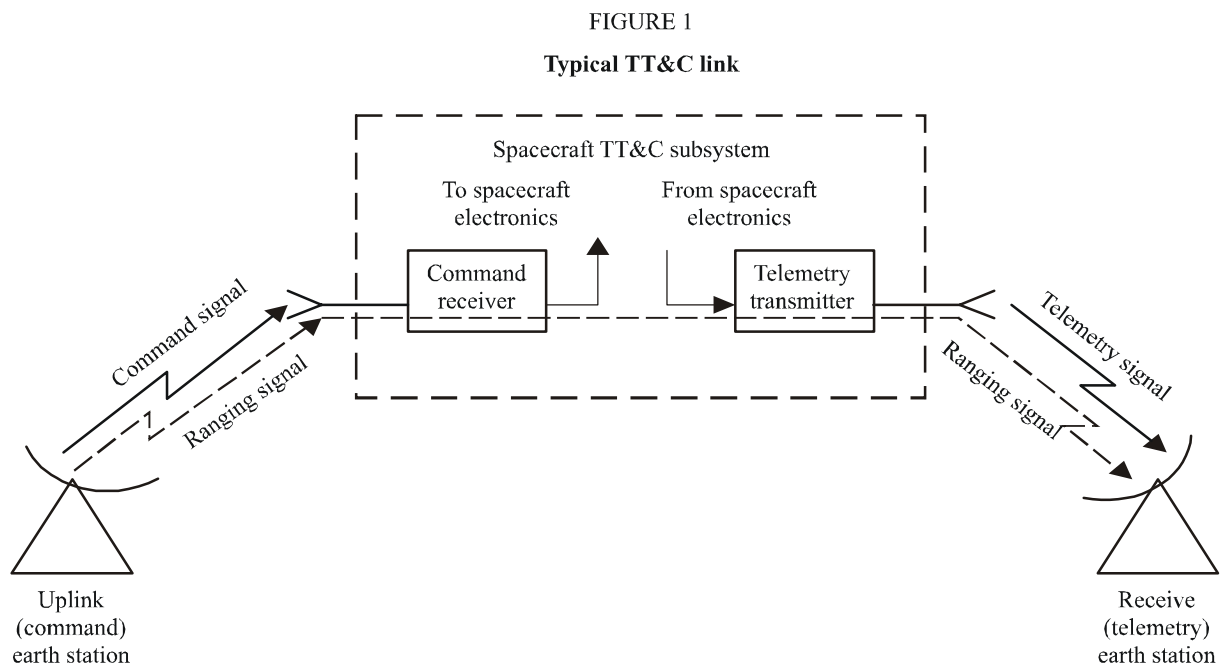
This Recommendation provides the technical and operational characteristics of FSS TT&C systems including their link performance and availability objectives that should be taken into account by a satellite operator. This Recommendation provides guidance to FSS operators on the design and choice of frequency for their TT&C systems based on their particular requirements.

It should be noted that in the commercial satellite industry the acronym TT&C has been replaced by TC&R which stands for telemetry, command, and ranging. Since space telemetry, space tracking and space telecommand are defined in Article 1 of the Radio Regulations, the acronym TT&C has been used in this Recommendation even if it is referring to telemetry, command and ranging (TC&R) type functions.

The TT&C subsystem of a spacecraft is designed to provide three primary functions:

- Telecommand to enable ground controllers to command the various electronic units aboard the spacecraft.
- Telemetry to enable ground controllers to monitor the operational health of the various electronic units aboard the spacecraft.
- Tracking/ranging to enable ground controllers to determine the location and orientation of the spacecraft.

A typical TT&C subsystem is shown in Fig. 1.



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For telecommand, a command signal is transmitted from the uplink earth station. This signal is in turn received and processed by the command receiver aboard the spacecraft and routed to the appropriate electronic units.

For telemetry, the designated spacecraft units provide a status signal to the telemetry transmitter. The transmitter in turn modulates and amplifies these signals onto the main telemetry carrier. From the transmitter, the modulated carrier signal is routed to the telemetry antenna, where it is transmitted to the ground for reception by the earth station.

For ranging, a command signal is uplinked to the spacecraft command receiver. This signal is then routed to the telemetry transmitter for transmission back to Earth. The distance from the ground station to the spacecraft is determined by simply measuring the change in phase between transmitted and received signals.

1.1 Transfer orbit and on-orbit operations

The TT&C subsystem of most satellites in use today have two modes of operation: on station mode and transfer orbit/emergency mode (hereafter referred to as emergency mode). The transfer orbit of a GSO FSS satellite is a critical phase in the life of a commercial satellite. As the satellite goes from low-Earth orbit to GSO, the command and telemetry channels must be continuously available, many operators have developed highly reliable networks of ground earth stations which can track a satellite during the launch and early orbit phase (LEOP) with at least two earth stations at all times.

In general, once the satellite reaches its on-orbit location in the GSO the TT&C receiver is switched from the omnidirectional antenna to a wide beamwidth horn antenna. As a result, the link requirements for on-station and emergency mode operations are usually different.

In order to determine the availability of a TT&C link, the operating parameters of both the ground earth station as well as the space station are required. On the command side, the location of the uplink earth station and its operating e.i.r.p. as well as the command threshold of the satellite are required in order to determine the actual link margin. Depending on the rain characteristic of the region in which the uplink earth station is located, the availability of the command link, signified as a percentage, can then be calculated.

For the telemetry, the location of the receive earth station and its associated receiver threshold as well as the spacecraft telemetry e.i.r.p. are required in order to determine the actual margin of this link. Again, depending on the rain characteristics of the region in which the receive earth station is located, the availability of the telemetry link can be determined.

2 6/4 GHz TT&C systems

The satellite TT&C carriers for one FSS satellite operator are located in an 18 MHz band in the range of 6 166-6 184 MHz and 3 941-3 959 MHz. Depending on the specific series of satellites there can be five TT&C carriers in this band, four being used for command and telemetry and one as a downlink beacon. Tables 1 and 2 contains further technical information on the link budgets and characteristics of the 6/4 GHz TT&C systems that are used on typical satellites. Because satellite operators often relocate their satellites to new orbital slots depending on the traffic and health of the satellites, the operational flexibility of maintaining a common set of baseline TT&C parameters has made the network more efficient and cost effective.

Each of the TT&C earth stations are normally connected via dedicated terrestrial and satellite facilities to a satellite control centre (SCC). The availability and quality of the TT&C signals is essential in maintaining the satellite's position and health (power, stability, temperature, etc.) and the data sent to and from the satellite must have the highest availability and performance, especially for the telecommand.

TABLE 1

Link budgets for a typical 6/4 GHz band telemetry carriers

Typical C-band transfer orbit telemetry and ranging	
<i>Parameter</i>	
Downlink carrier frequency	3 950 MHz
Tx power	13 dBW
Tx loss	−9.5 dB
Antenna gain	1.9 dBi
e.i.r.p. (typical)	1.6 dBW
Path loss (40 671 km) 10° elevation	−196.6 dB
Rx G/T	35 dB/K
C/N_0	68.2 dB-Hz
<i>Normal and dwell sub-carrier (S/C)</i>	
Available downlink S/C S/N_0	58.6 dB-Hz
Required S/N_0	50.2
Sub-carrier margin	8.4 dB
<i>Ranging S/C</i>	
Available downlink S/N_0	58.6 dB-Hz
Uplink S/N_0	60
Total S/N_0	56.2
Required S/N_0	41 dB-Hz
Ranging margin	15.2 dB

TABLE 2

Link budgets for a typical command and ranging carriers

Parameter	Transfer orbit	GSO	Units
Carrier frequency	6 175	6 175	(MHz)
e.i.r.p.	90	73.2	(dBW)
Spreading factor at GSO	−163.2	−163.2	(dB/m ²)
pfd at satellite	−73.2	−90	(dB(W/m ²))
Miscellaneous loss	−0.5	−0.4	(dB)
1 m ² gain	−37.3	−37.3	(dBi)
Incident isotropic power	−111	−127.7	(dBW)
Satellite antenna gain	−5.1	7.3	(dBi)
Feed and split loss	−6.5	−6.6	(dB)
Rx input power	−122.6	−127	(dBW)
Rx threshold power	−142	−142	(dBW)
Margin	19.4	15	(dB)

2.1 TT&C availabilities

6/4 GHz FSS operators can maintain their TT&C link margins to ensure the link availability to be between 99.99% to 99.999% of the time. These availabilities are comparable to the availability of the space segment for a satellite network. In the case of one satellite operator, the average transponder availability for their satellites was 99.9996% for the year 2000. Their TT&C earth stations have been able to achieve availabilities of better than 99.95% and with their wide beamwidth satellite antenna coverage there are usually two TT&C earth stations visible to each satellite. A redundant path terrestrial/satellite network infrastructure connects the SCC with the TT&C earth station. The network availability objective for this terrestrial/satellite path is 99.99%. Therefore, a TT&C link availability between 99.99% to 99.999% is a reasonable objective.

Typical TT&C link budget objectives for a 6/4 GHz satellite are given in Tables 1 and 2. Similar 6/4 GHz TT&C link performance has been specified for most of the satellite TT&C systems. It should be further noted that the uplink and downlink e.i.r.p. values are typical and can vary according to the TT&C earth stations that are operating with that satellite. These do not take into account the ageing of the satellite receivers and power amplifiers, and the uplink characteristics of the TT&C earth station. The availability for a TT&C link could be calculated according to the available margin and the operating elevation and rain climatic conditions for each TT&C earth station. Examples of availabilities that could be achieved with these typical link budgets, assuming the propagation attenuation probabilities for three TT&C sites, are given in Tables 3 to 5. From the above propagation attenuation data, one can see that to achieve a performance availability of better than 99.999% in the 6/4 GHz band, a minimum margin of 6.5 dB is required on the uplink, and a minimum margin of 1.9 dB is required on the downlink.

Propagation link margins at these locations for TT&C performance at the same percentages of time have been calculated for the 14/11-12 GHz, 30/20 GHz and 50/40 GHz bands. If satellite networks operating above 17 GHz wish to achieve similar objectives they will have to locate their TT&C earth station in dry regions and with higher elevation angles.

TABLE 3
Clarksburg TT&C site (elevation angle 23.2°)

<i>Clarksburg</i>					
Uplink frequency		Attenuation (dB)			
		6.17 GHz	14.50 GHz	30.00 GHz	50.00 GHz
Per cent of time					
	1	0.32	1.64	7.14	17.93
	0.1	0.68	5.49	22.92	47.84
	0.01	1.77	14.98	55.97	105.61
	0.001	4.17	29.9	98.05	171.73
Downlink frequency					
		3.95 GHz	11.70 GHz	20.20 GHz	40.00 GHz
Per cent of time					
	1	0.22	1.08	4.03	11.19
	0.1	0.35	3.61	12.01	34.7
	0.01	0.59	10.18	30.18	81.51
	0.001	1.17	21.12	55.88	137.36

TABLE 4
Raisting TT&C site (elevation angle 15.8°)

<i>Raisting</i>					
Uplink frequency		Attenuation (dB)			
		6.17 GHz	14.50 GHz	30.00 GHz	50.00 GHz
Per cent of time					
	1	0.38	1.35	5.32	16.07
	0.1	0.69	4.32	16.73	38.37
	0.01	1.56	11.94	41.59	83.06
	0.001	3.52	24.37	74.92	136.85
Downlink frequency					
		3.95 GHz	11.70 GHz	20.20 GHz	40.00 GHz
Per cent of time					
	1	0.28	0.92	3.22	8.77
	0.1	0.43	2.81	9.19	26.49
	0.01	0.67	7.95	23.27	63.05
	0.001	1.17	16.86	44.05	108.76

TABLE 5
Beijing TT&C site (elevation angle 13.5°)

<i>Beijing</i>					
Uplink frequency		Attenuation (dB)			
		6.17 GHz	14.50 GHz	30.00 GHz	50.00 GHz
Per cent of time					
	1	0.53	2.59	10.47	26.53
	0.1	1.13	8.5	32.04	66.45
	0.01	2.9	22.46	75.49	140.73
	0.001	6.5	43.11	128.06	221.49
Downlink frequency					
		3.95 GHz	11.70 GHz	20.20 GHz	40.00 GHz
Per cent of time					
	1	0.36	1.65	6.19	16.1
	0.1	0.58	5.39	17.35	47.61
	0.01	0.99	14.74	41.72	108.07
	0.001	1.9	29.5	74.5	176.64