The Consultative Committee for Space Data Systems

Draft Recommendations for
Space Data System Standards

RADIO FREQUENCY AND MODULATION SYSTEMS—
PART 1
EARTH STATIONS AND SPACECRAFT

DRAFT RECOMMENDED STANDARD

CCSDS 401.0-B-29.1

RED/PINK SHEETS

August 2019

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DOCUMENT CONTROL (Continued)

DOCUMENT	TITLE	DATE	STATUS/REMARKS
CCSDS 401.0-B	Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft, Draft Recommended Standard, Issue 29.1	August 2019	– Updates recommendation 2.3.7; – adds new recommendations 2.1.9 and 2.6.14.

NOTE – Recommendations 2.1.9 and 2.6.14 are new recommendations and are thus presented without markup.

2.1.9 MULTIPLE UPLINK CARRIERS FOR SPACE RESEARCH EARTH STATION SUPPORT OF MULTIPLE SPACECRAFT PER APERTURE

The CCSDS,

considering

(a) that there are several methods,[1] broadly called Multiple Spacecraft Per Aperture (MSPA), whereby a single Earth station antenna can be used to support multiple spacecraft located within its antenna beamwidth;

(b) that several space agencies have already used MSPA to simultaneously receive downlink telemetry from multiple spacecraft using a single Earth station antenna, in cases where each spacecraft is transmitting on a different frequency;

(c) that there are various approaches[1] for MSPA on the uplink, which have their own relative merits and drawbacks in terms of implementation complexity and operational impacts;

(d) that the preferred approach[1] for MSPA may be different depending on the timeframe being considered;

(e) that some space agencies have the need for simultaneous uplink and downlink MSPA but do not want to pursue changes to the existing spacecraft transponder;

(f) that transmission of multiple uplink carriers through the Earth station High Power Amplifier (HPA) results in intermodulation products, which could cause interference to other missions or exceed spurious emission limits;

(g) that the use of a linearizer or HPA back-off can reduce the intermodulation products significantly;

(h) that the installation of a linearizer requires changes in the current CCSDS space agencies' stations;

(i) that the use of HPA back-off reduces the link margin of the uplink;

(j) that the spurious level for space services Earth stations cannot be above −60 dBc as per ITU Radio Regulations;

recommends

(1) that CCSDS agencies' Earth stations transmit multiple uplink frequencies[2] simultaneously through the high power amplifier to all spacecraft in its antenna beam when supporting two or more spacecraft using a single Earth station antenna;

(2) that a linearizer and some HPA back-off be used to reduce uplink intermodulation products;

(3) that the linearizer and the HPA back-off shall be designed or dimensioned to meet the maximum spurious level of −60 dBc referred to the maximum transmitter power in the station license.

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[1] See CCSDS 401 (3.1.7).

[2] Each spacecraft has a different uplink and downlink frequency, related by the standard CCSDS turnaround ratios applicable to the bands being used.

2.3.7 EARTH STATION OSCILLATOR REFERENCE FREQUENCY STABILITY

The CCSDS,

considering

(a) that most of the space agencies use a reference frequency standard to which the Earth station's receiver and transmitter local oscillators are locked;

(b) that the short term frequency stability of the local oscillator substantially determines the range rate measurement's accuracy for Category A missions;

(c) that the long term frequency stability of the local oscillator substantially determines the range rate measurement's accuracy for Category B missions;

~~(d) that it is desirable for many missions to determine range rate with an accuracy of 1 mm/s or better;~~

~~(e) that the oscillator's frequency shall be sufficiently stable such that its effect upon the range rate measurement's error shall be significantly less than 1 mm/s;~~

(d) that it is desirable for many Cat. A missions (except lunar missions) to determine range rate with an accuracy[1] of 1 mm/s or better, and that it is desirable for Cat. B missions as well as Cat. A lunar missions to determine range rate with an accuracy[2] of 0.1 mm/s or better;

(e) that the oscillator's frequency shall be sufficiently stable such that its effect upon the range rate measurement's error shall be an order of magnitude smaller than the required range rate accuracy;

(f) that, in addition to the foregoing, the long term stability of the local oscillator is also determined by the drift permitted in the Earth station's clock which should not exceed 10 microseconds per month;

recommends

~~(1) that the short term frequency stability (Allan Variance) shall be better than $\pm 5 \times 10^{-13}$ for time intervals between 0.2 s and 100 s;~~

~~(2) that for Category B missions and for timekeeping, the long term frequency stability shall be better than $\pm 2 \times 10^{-12}$ for any time interval greater than 100 s.~~

(1) that for Category A missions except lunar missions the Earth station oscillator reference frequency stability (Allan deviation) shall be better than the values in curve A[3] of figure 2.3.7-1;

(2) that for Category B3 missions as well as lunar missions the Earth station oscillator reference frequency stability (Allan deviation) shall be better than the values in curve B of figure 2.3.7-1.

[1] Typical measurement integration time is 10 s.
[2] Typical measurement integration time is 60 s.
[3] The sample time for computing the range rate bias is the signal round-trip light time. The sample time for computing the range rate jitter is the duration over which the measurement is integrated.

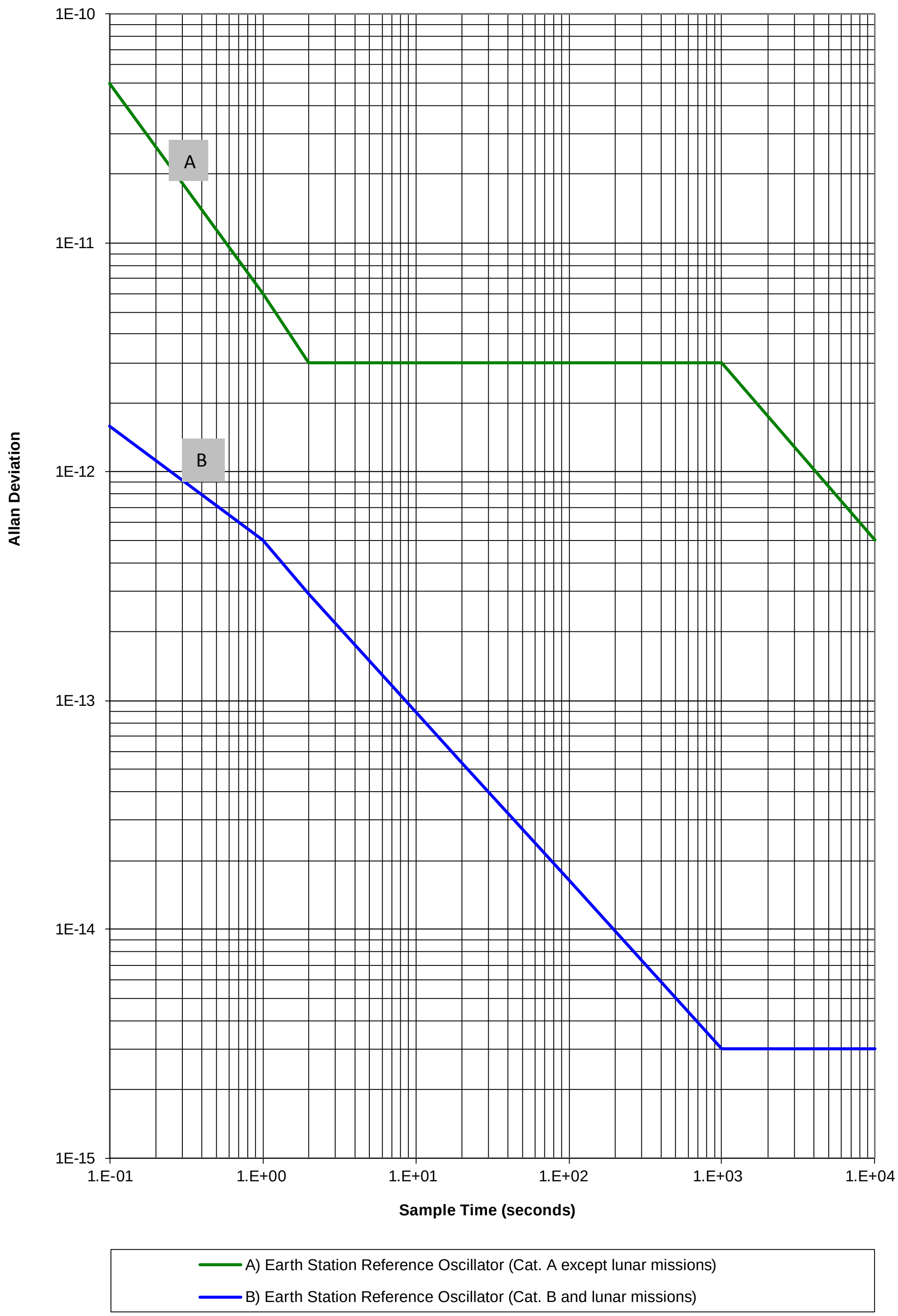

Figure 2.3.7-1: Frequency Stability Requirements

2.6.14 TRANSPONDER TURNAROUND FREQUENCY RATIOS FOR THE 22.55–23.15 GHz AND 25.5–27.0 GHz BANDS, SPACE RESEARCH, CATEGORY A

The CCSDS,

considering

(a) that future space missions may choose to use Earth-to-space links in the 22550–23150 MHz band in conjunction with space-to-Earth links in the 25500–27000 MHz band, particularly for high data rate applications;

(b) that these space missions may also require coherency between Earth-to-space and space-to-Earth links for development of navigational data such as ranging and Doppler;

(c) that for space missions that require coherency, Transponder Turnaround Frequency Ratios (TTFRs) must be defined;

(d) that for these two frequency bands, a minimum of three TTFRs are needed to cover the entire frequency range of the 25.5–27.0 GHz band;

(e) that the TTFRs should be chosen so as to minimize the possibility of self-interference from harmonics of the on-board transmitter intermediate frequencies to the on-board receiver;

(f) that for reasons of simplicity of the on-board transmitter design, turnaround ratios that can be divided down to small integers are preferable;

recommends

(1) that CCSDS agencies use TTFRs[1] in table 2.6.14-1 for systems operating in the 22550–23150 MHz and 25500–27000 MHz bands;

(2) that these TTRFs are only necessary for those space missions that require both cross support from other agencies' Earth stations and coherency between the Earth-to-space and space-to-Earth links.

Table 2.6.14-1: Recommended TTFRs for the 22.55–23.15 MHz and 25.5–27.0 GHz Bands

Transponder Turnaround Frequency Ratio (E-S/S-E)	Allocated Earth-to-Space Band (MHz)	Available Earth-to-Space Coherent Band[2] (MHz)	Allocated Space-to-Earth Band (MHz)	Available Space-to-Earth Coherent Band[1] (MHz)
2407/2720	22550–23150	22550–23150	25500–27000	25500.000–26160.366
2407/2760	22550–23150	22550–23150	25500–27000	25857.084–26545.077
2407/2816	22550–23150	22550–23150	25500–27000	26381.720–27000.000

[1] On-board implementations may result in deviations from these values and in a significant delay of the downlink carrier relative to the uplink carrier; mission designers have to take these factors into consideration when computing the orbit determination performance.

[2] The available coherent band refers to the range of frequencies that are coherent with the corresponding Earth-to-space or space-to-Earth band in the opposite direction.