



**CCSDS**

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-27.1**

**RED/PINK SHEETS**

**August 2017**



**CCSDS**

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-27.1**

**RED/PINK SHEETS**

**August 2017**

# CCSDS RECOMMENDATIONS FOR RADIO FREQUENCY AND MODULATION SYSTEMS

## Earth Stations and Spacecraft

### DOCUMENT CONTROL

CCSDS 401.0-B	Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft, Draft Recommended Standard, Issue 27.1	August 2017	Current draft update: <ul style="list-style-type: none"><li>– updates recommendations 2.1.4A and 2.1.4B;</li><li>– deletes recommendations 2.1.8A and 2.1.8B;</li><li>– adds new recommendation 2.6.11A (note).</li></ul>
---------------	--	-------------	---

NOTE – Because recommendation 2.6.11A is new, it is presented without markup.

Earth Stations and Spacecraft

**2.1.4A TRANSMITTER FREQUENCY SWEEP RATE ON EARTH-TO-SPACE LINKS, CATEGORY A**

The CCSDS,

considering

- (a) that the rate of change of the Doppler frequency shift on the Earth-to-space link, resulting from relative motion between Earth stations and Category A spacecraft, is smaller than:

3 kHz/s at 2 GHz  
10 kHz/s at 7 GHz;

- (b) that most of the spacecraft receivers have a phase-locked loop with a bandwidth ( $2 B_{LO}$ ) in the range 200 Hz to 800 Hz at their threshold;
- (c) that the maximum permissible rate of input frequency variation for most types of spacecraft receivers is between 2 kHz/s and 30 kHz/s at their threshold;
- (d) that the frequency sweep rate on the Earth-to-space link should be chosen such that the total rate of frequency variation, resulting from both the transmitter's sweep rate and the orbital Doppler rate, does not unlock the spacecraft's phase-locked loop;
- (e) that the acquisition time should be kept to a minimum for each mission phase;

recommends

- (1) that the Earth station's transmitter should have a minimum frequency sweep rate capability of:

500 Hz/s

and a maximum frequency sweep rate capability of at least:

50 kHz/s;

- (2) that the Earth station's transmitter RF phase continuity be maintained at all times, which will ensure that the spacecraft's receiver remains locked following acquisition.

Earth Stations and Spacecraft

**2.1.4B TRANSMITTER FREQUENCY SWEEP RATE ON EARTH-TO-SPACE LINKS, CATEGORY B**

The CCSDS,

considering

- (a) that the rate of change of the Doppler frequency shift on the Earth-to-space link, resulting from relative motion between Earth stations and category B spacecraft, is smaller than:

70 Hz/s at 2 GHz  
240 Hz/s at 7 GHz  
1200 Hz/s at 34 GHz;

- (b) that most of the spacecraft receivers have a phase-locked loop with a bandwidth ( $2 B_{LO}$ ) in the range 10 Hz to 100 Hz at their threshold;
- (c) that the maximum permissible rate of input frequency variation for this type of spacecraft receiver is between 6 Hz/s and 1 kHz/s at its threshold;
- (d) that the maximum permissible rate of input frequency variation for signals above the receiver's threshold can be as much as 10 kHz/s;
- (e) that the frequency sweep rate on the Earth-to-space link should be chosen such that the total rate of frequency variation, resulting from both the transmitter's sweep rate and the orbital Doppler rate, does not unlock the spacecraft's phase-locked loop;
- (f) that the acquisition time should be kept to a minimum for each mission phase;

recommends

- (1) that the Earth station's transmitter should have a minimum frequency sweep rate capability of:

1 Hz/s

and a maximum frequency sweep rate capability of at least:

10 kHz/s;

- (2) that the Earth station's transmitter RF phase continuity be maintained at all times, which will ensure that the spacecraft's receiver remains locked following acquisition.

Earth Stations and Spacecraft

**2.1.8A MINIMUM EARTH STATION TRANSMITTER FREQUENCY RESOLUTION FOR SPACECRAFT RECEIVER ACQUISITION, CATEGORY A**

[This recommendation has been deleted \(CCSDS resolution \[TBD\]\).](#)

~~The CCSDS,~~

~~considering~~

- ~~(a) that Category A spacecraft receivers typically have phase-locked-loop bandwidths ( $2 B_{LO}$ ) in the range of 200 to 800 Hz at their thresholds;~~
- ~~(b) that, for spacecraft receivers having a second-order phase-locked-loop with the threshold bandwidths shown in (a), the frequency lock-in range is typically 267 to 1067 Hz;~~
- ~~(c) that steps in Earth station's transmitter frequency which exceed the spacecraft receiver's lock-in range can result in long acquisition times or complete failure of the spacecraft to acquire the signal;~~
- ~~(d) that some margin should be included to ensure proper acquisition of the Earth station's signal by the spacecraft receiver's phase-locked loop;~~
- ~~(e) that the spacecraft's receiver may fail to acquire or remain locked to the Earth station's transmitted signal if abrupt phase discontinuities in that signal occur during the acquisition of that signal;~~

~~recommends~~

- ~~(1) that the Earth station transmitter's frequency be adjustable over its specified operating range in increments (step size) of 100 Hz or less;~~
- ~~(2) that the Earth station transmitter's RF phase continuity be maintained at all times during tuning operations, using frequency sweep rates that are in accordance with Recommendation 401 (2.1.4A) B-1, which will ensure that the spacecraft's receiver remains locked following acquisition.~~

**2.1.8B MINIMUM EARTH STATION TRANSMITTER FREQUENCY RESOLUTION FOR SPACECRAFT RECEIVER ACQUISITION, CATEGORY B**

[This recommendation has been deleted \(CCSDS resolution \[TBD\]\).](#)

~~The CCSDS,~~

~~considering~~

- ~~(a) that Category B spacecraft receivers typically have phase locked loop bandwidths ( $2 B_{LO}$ ) in the range of 10 to 100 Hz at their thresholds;~~
- ~~(b) that for spacecraft receivers having a second order phase locked loop with the threshold bandwidths shown in (a), the frequency lock in range is typically 13 to 133 Hz;~~
- ~~(c) that steps in Earth station's transmitter frequency which exceed the spacecraft receiver's lock in range can result in long acquisition times or complete failure of the spacecraft to acquire the signal;~~
- ~~(d) that some margin should be included to ensure proper acquisition of the Earth station's signal by the spacecraft receiver's phase locked loop;~~
- ~~(e) that, with certain Category B missions, it is desirable to continuously tune the Earth to space link's transmitter frequency to maintain its value, at the spacecraft, at a single, optimal frequency;~~
- ~~(f) that the spacecraft's receiver may fail to acquire or remain locked to the Earth station's transmitted signal if abrupt phase discontinuities in that signal occur during the acquisition of that signal;~~

~~recommends~~

- ~~(1) that the Earth station's transmitter frequency be variable over its specified operating range in increments (step size) of 5 Hz or less;~~
- ~~(2) that the Earth station transmitter's RF phase continuity be maintained at all times during tuning operations, using frequency sweep rates that are in accordance with Recommendation 401 (2.1.4B) B-1, which will ensure that the spacecraft's receiver remains locked following acquisition.~~

**2.6.11A TRANSPONDER TURNAROUND FREQUENCY RATIOS FOR THE 7190–7250 MHz AND 8025–8400 MHz BANDS, CATEGORY A**

**The CCSDS,**

**considering**

- (a) that Earth Exploration Satellite Service (EESS) missions can use Earth-to-space links in the 7190–7250 MHz band in conjunction with space-to-Earth links in the 8025–8400 MHz band;
- (b) that these EESS missions may require coherency between Earth-to-space and space-to-Earth links for development of navigational data;
- (c) that for space missions which require coherency, a Transponder Turnaround Frequency Ratio (TTFR) must be defined;
- (d) that the two frequency bands under consideration differ regarding the available bandwidth;
- (e) that multiple TTFRs are needed to allow almost full access of the entire 8025–8400 MHz band while maintaining coherency between the space-to-Earth link and the Earth-to-space link in the 7190–7250 MHz band;
- (f) that for reasons of similarity of on-board receiver design, a TTFR should be chosen in such a way as to contain 749 as the numerator of the ratio for the 7 GHz uplink / 8 GHz downlink system, to be consistent with the existing TTFR recommendation for the 7145–7235 MHz and 8400–8500 MHz bands;<sup>1</sup>
- (g) that an odd number (749) has been selected as an uplink factor (numerator of the TTFR), and thus an even number should be selected as the downlink factor (denominator of the TTFR) to prevent downlink harmonic interference with uplink signals;
- (h) that for reasons of simplicity of on-board transmitter design, a TTFR which can be divided down to small integers should be selected;
- (i) that TTFRs resulting in coherent downlink carrier frequencies close to 8400 MHz should be avoided, in order to protect Earth stations of Space Research Service (Category B) missions using the adjacent 8400–8450 MHz band allocation;

**recommends**

- (1) that CCSDS agencies use the TTFRs<sup>2</sup> in Table 2.6.11A-1 for EESS systems operating in the 7190–7250 MHz and 8025–8400 MHz bands;
- (2) that these TTFRs are only necessary for those space missions which require both cross support from other agencies' Earth stations and coherency between the Earth-to-space and space-to-Earth links.

---

<sup>1</sup> See CCSDS Recommendation 401 (2.6.2) B-1.

<sup>2</sup> 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.



Earth Stations and Spacecraft

**Table 2.6.11A-1: Transponder Turnaround Frequency Ratios for 7190–7250 MHz and 8025–8400 MHz Bands**

Transponder Turnaround Frequency Ratio (E-S/S-E)	Allocated Earth-to-Space Band (MHz)	Available Earth-to-Space Coherent Band (MHz)	Allocated Space-to-Earth Band (MHz)	Available Space-to-Earth Coherent Band <sup>3</sup> (MHz)
749/836	7190–7250	7190–7250	8025–8400	8025.154–8092.123
749/840	7190–7250	7190–7250	8025–8400	8063.551–8130.841
749/846	7190–7250	7190–7250	8025–8400	8121.148–8188.919
749/850	7190–7250	7190–7250	8025–8400	8159.546–8227.637
749/854	7190–7250	7190–7250	8025–8400	8197.944–8266.235
749/858	7190–7250	7190–7250	8025–8400	8236.342–8305.073
749/864	7190–7250	7190–7250	8025–8400	8293.939–8363.151

---

<sup>3</sup> The available coherent band refers to the range of frequency which are coherent with the corresponding Earth-to-space or space-to-Earth band in the opposite direction.