

Response to AI 22-05: Draft Recommendation 2.2.10 on Suppressed Carrier Modulations for the 23.15-23.55 GHz Band

1. Introduction

AI 22-05 was assigned to provide an updated version of draft Recommendation 2.2.10 to the Fall 2022 RFM meeting, which incorporates the revisions agreed to at the Spring 2022 meeting.

2. Summary of Revisions to Rec. 2.2.10

The following revisions agreed to at the Spring 2022 meeting have been made with track changes:

- Added footnote reference to Rec 2.4.12A regarding maximum phase/amplitude imbalance
- Corrected space-to-space frequency band in title and *recommends* (1) from 22.15-23.15 GHz to 23.15-23.55 GHz to match SFCG Recommendation 32-2R4
- Updated version number for SFCG Rec. 32-2R4 and CCSDS 131.0-B-4
- Corrected numbering of Figure 2.2.10-3
- Minor editorial corrections in *considerings* (1) and (2), and *recommends* (4)

In addition a different wording for *considerings* (4) is proposed for clarity, noting that 23.15-23.55 GHz is only one of the frequency bands recommended by SFCG Rec 32-2R4 for lunar orbit-to-orbit and orbit-to-surface links.

Earth Stations and Spacecraft

2.2.10 USE OF SUPPRESSED CARRIER MODULATIONS FOR HIGH RATE SPACE-TO-SPACE LINKS, SPACE RESEARCH AND INTER-SATELLITE, AT ~~23.15~~23.55-23.55 GHz

The CCSDS,
considering

- (a) that the frequency band 22.55-23.15 GHz is allocated to ~~to~~ the Space Research Service (Earth-to-space) and the band 22.55-23.55 GHz is allocated to the Inter-Satellite Service;
- (b) that ~~L~~ lunar missions in the near future will require high-rate space-to-space links, up to 200 coded Msymbol/s, for functions other than telecommand;
- (c) that the SFCG has ~~approved a R~~ recommendation¹ 23.15-23.55 GHz as one of the frequency bands to be used specifying that for intersatellite links from space between lunar orbiters and for communications from to the Lunar orbit ~~or to the L~~unar surface ~~shall use the frequency allocation 23.15-23.55 GHz~~;
- (d) that it is important to limit the occupied bandwidth at high rates to reduce out-of-band interference;
- (e) that GMSK² and baseband filtered OQPSK³ modulations have only a small performance degradation as compared with ideal unfiltered suppressed carrier systems;
- (f) that since GMSK² modulation is inherently differential in nature, the use of GMSK with precoding is necessary to optimize bit error rate performance;
- (g) that a phase imbalance of less than 5 degrees and an amplitude imbalance of less than 0.5 dB should result in acceptable performance degradation⁴;
- (h) that recommended maximum values of phase noise is needed to ensure small end-to-end losses;

recommends

- (1) that GMSK² or baseband filtered OQPSK³ modulations be used for high data rate transmissions with coded symbol rate in the range 5-200 coded Msymbol/s⁵ in communications systems operating for high rate space-to-space links in the ~~23.15~~23.55-23.55 GHz band;

¹ See SFCG ~~R~~ recommendation 32-2R42 or latest version.

² Gaussian Minimum Shift Keying ($BT_s = [0.25/0.5]$), with pre-coding as in Figure 2.2.10-1 (see CCSDS 413.0-G-4). B refers to the one-sided 3-dB bandwidth of the filter.

³ Filtered (Square Root Raised Cosine $\alpha = 0.5$) Offset QPSK; Butterworth 6 poles, $BT_s = [0.25/0.5]$; agencies may also utilize filtered OQPSK modulation with other types of bandpass filters provided that the equivalent baseband BT_s is not greater than 0.5 and they ensure interoperability with the cross-supporting networks. B refers to the one-sided 3-dB bandwidth of the filter.

⁴ See CCSDS Recommendation 401 (2.4.12A) B-5

⁵ For the purpose of this Recommendation, the coded symbol rate is defined in Figure 2.2.10-2.

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2.2.10 **USE OF SUPPRESSED CARRIER MODULATIONS FOR HIGH RATE SPACE EARTH-TO-SPACE LINKS, SPACE RESEARCH AND INTER-SATELLITE, AT 22.55-23.15 GHz**
 (Continued)

- (2) that CCSDS agencies use a data randomizer as specified in the CCSDS telemetry synchronization and channel coding blue book, CCSDS 131.0-B-3 (or latest edition);
- (3) that the modulator's phase imbalance shall not exceed 5 degrees, and the amplitude imbalance shall not exceed 0.5 dB between the constellation points;
- (4) that the phase noise for oscillators in the communication chain-link should be limited according to the mask in the Annex.

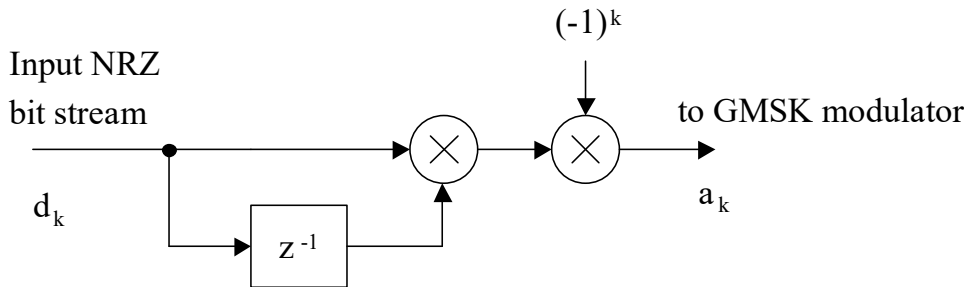


Figure 2.2.10-1: GMSK Precoder

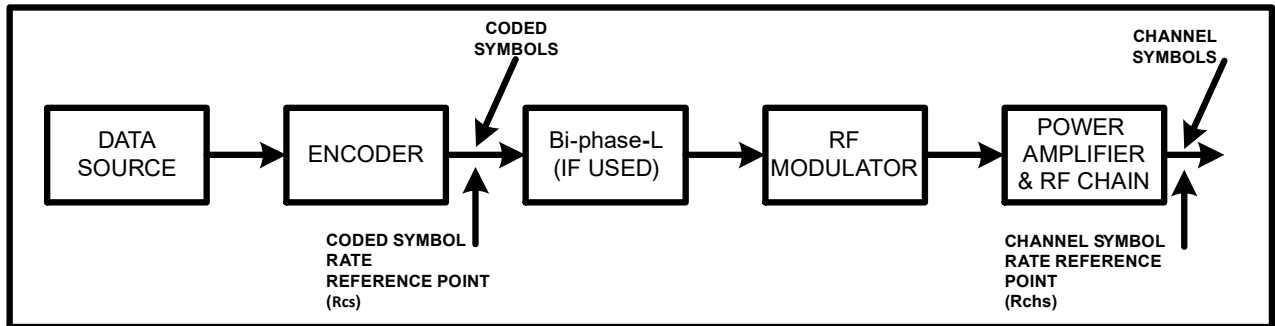


Figure 2.2.10-2: Telemetry Rates Definition

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2.2.9 **USE OF SUPPRESSED CARRIER MODULATIONS FOR HIGH RATE EARTHSPACE-TO-SPACE LINKS, SPACE RESEARCH AND INTER-SATELLITE, AT 22.55-23.15 GHz (Continued)**

ANNEX

PHASE NOISE

(Normative)

The phase noise for all the oscillators of the communication chain shall be limited according to the mask given in Figure 2.2.10-3.

-NOTE – The figure shows the double-sided phase noise mask $2L(f)$ in dBc/Hz versus frequency in Hz.

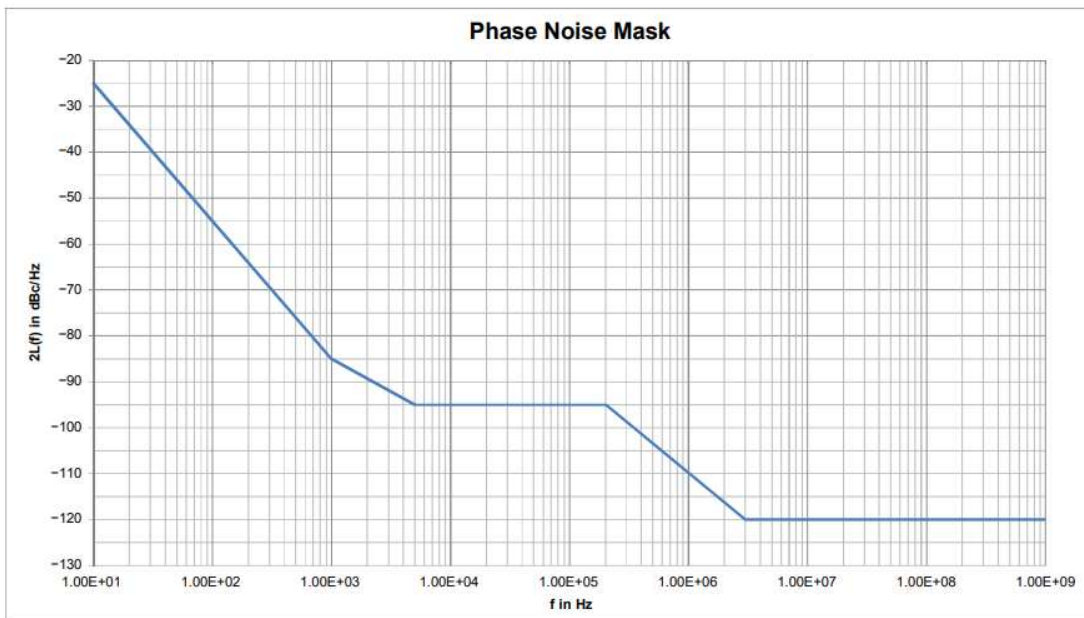


Figure 2.2.10-3: Phase noise mask recommendation