Spring 2022 CCSDS SLS-RFM Working Group Meeting Minutes

Issue 1.0

1. Introduction

The Spring 2022 RFM WG meeting took place on May 17, 2022 by videoconference due to COVID-19 restrictions. A joint meeting with C&S and SLP WGs was also held on May 12. The minutes for the joint meeting can be found in the Spring 2022 meeting minutes for the C&S WG, and are not repeated in this document.

There was a total of 21 participants in the Spring RFM WG meeting, representing CNES, ESA, NASA, and EUMETSAT. The list of the attendees is shown in the Annex 1.

2. Meeting Agenda

The RFM meeting agenda for Spring 2022 (see Annex 2) was approved by the WG with no changes.

3. Action Item Review

The action items from the previous RFM meeting were reviewed. There were 9 action items from the Fall 2021 RFM meeting. Eight of the action items have been closed, with AI_21-05 remaining open. The status of the Fall 2021 action items is shown below.

Table 1. Action Items from Previous RFM WG Meeting (Fall 2021)

AI #	AI description	Status
AI_21-01	W. Fong to define the worst case scenario to analyze and repeat his comparison at the same loop SNR. M. Lanucara would perform hardware tests for the same configuration using available ESA GMSK modulator and demodulator	Closed by SLS-RFM_22-02 and Powerpoint presentation from M. Lanucara
AI_21-03	Convert draft rec 2.2.9 into a similar recommendation 2.2.10 for space-to-space forward links at 22 GHz (leave open phase noise spec)	Closed by SLS-RFM_22-04
AI_21-05	Review the draft rec 4.1.8 and provide comments (including addition of amplitude/phase imbalance)	Open. No comments received so far.
AI_21-07	Review draft rec 2.2.10 (space-to-space forward links at 22 GHz) resulting from AI_21-03	Closed during Spring 2022 meeting

AI_21-08	Review draft recommendation 2.4.25 (space-to-space return links at 26 GHz)	Closed during Spring 2022 meeting
AI_21-09	Contact NAV WG chair on possible joint activities for lunar PNT	Closed by email to NAV WG chair (D. Berry)
AI_21-10	Review draft charter	Closed. No comments received
AI_21-11	Submit approved charter	Closed. Revised charter was sent
AI_21-12	Create new project for prox-1 PL BB (211.1-B-4)	Closed. Replaced by AI_22-05 from joint C&S/RFM/SLP meeting

4. Discussion of Input documents

4.1 Extension of CCSDS 211.1-B-4 Prox-1 Physical Layer for Lunar Region

Input paper **SLS-RFM_22-03** was presented by F. Davarian regarding proposed modifications to the Prox-1 standard to support future Lunar S-band Proximity links. The concept paper proposed several enhancements of the Prox-1 protocol in the lunar region, including the addition of S-band frequency bands (2025-2110 MHz and 2200-2290 MHz) for the forward and return links, the addition of GMSK and Filtered OQPSK/PM modulations for bandwidth efficiency, use of LDPC rate ½ and 2/3 codes to improve power/bandwidth efficiency, and the addition of USLP transfer frames for increased flexibility. The concept paper also proposed including PCM/PM/Bi-phase-L modulation at S-band for cases where a residual carrier was needed, but limited only to data rates below 64 kbps.

During the ensuing WG discussion of the document, it was agreed to that the Ka-band proximity frequencies (23.15-23.55 GHz and 27-27.5 GHz) should also be included along with the S-band frequencies in the update of the Prox-1 standard. There was discussion among the WG whether 64 kbps was the appropriate data rate limit for PCM/PM/Bi-phase-L, and it was agreed to leave this as a TBD to be resolved after further study. S. Rodriguez mentioned that the IOAG Lunar Communication Architecture study did not include GMSK modulation for the proximity link. However it was remarked that the IOAG study was based on the existing CCSDS standards, and that any changes to the CCSDS Prox-1 standard (e.g., addition of GMSK or Filtered OQPSK/PM) would likely be incorporated in future IOAG lunar communication architecture studies.

An action item on A. Modenini and D. Lee was created during the joint C&S/RFM/SLP meeting to create a CWE project regarding extensions of the Prox-1 standard use in the lunar region. As there was already an action item issued during the joint meeting, a separate RFM action item for this activity was not created.

4.2 High Rate Doppler Effect on GMSK Receiver Tracking Performance

Input **SLS-RFM_22-02** was presented by W. Fong which provided additional simulation results of the GMSK receiver tracking loop performance in the presence of high rate Doppler. The paper noted that a high Doppler frequency ramp resulted in an increasing loop phase error for a second order tracking loop which ultimately caused a loss of lock. The Doppler rate in this paper (and also input **SLS-RFM_22-06**) was defined by the parameter gamma, which is the frequency ramp rate in rad/sec normalized by the square of the natural frequency of the loop ($\gamma = 2\pi \dot{f_d}/{\omega_n}^2$). Simulations were run using a casual loop delay of a single sample to be compared with a single symbol delay previously used. Results showed that the shorter causal delay improved the GMSK receiver tracking of Doppler rate, but tracking loop would still lose lock for a high enough gamma (e.g., gamma = 0.3). The paper recommended that users limit the maximum gamma to 0.02.

M. Lanucara presented **SLS-RFM_22-06** showing tracking results of additional hardware tests using the ESA GMSK receiver with input frequency ramps. The presentation provided the maximum gamma values that were successfully tracked by the GMSK receiver under different conditions. One set of tests were conducted under "noise free" conditions with Es/No > 9 dB. Tests were also run with Es/No = -3 dB for GMSK BT_s=0.25 and PN ranging, and Es/No = -5 dB for GMSK BTs=0.5 and PN ranging. In general, the paper indicated that the GMSK tracking loop bandwidth setting had to be large enough to track the frequency ramp, but small enough to limit the phase error jitter. The document also noted that there was a 2 dB Es/No difference between the tracking performance of GMSK BT_s=0.25 and BT_s=0.5. The tracking performance for both values of BT_s was roughly the same once the 2 dB difference was adjusted for. ESA noted that the tracking results of the GMSK BT_s=0.25 and BT_s=0.5 receiver tests matched expectations based on the model.

AI_22-01 was assigned M. Lanucara and W. Fong to provide material regarding GMSK receiver tracking performance with Doppler rate and selection of the appropriate tracking loop parameters for inclusion in the 413.1-G-2 Green Book (Simultaneous Transmission of GMSK Telemetry and PN Ranging). During the WG discussion, NASA proposed that GMSK BT_s=0.5 be used instead of GMSK BT_s=0.25 for Category A missions due to its better Doppler rate tracking performance. ESA disagreed and pointed to the difference in bandwidth efficiency between the two. As a consensus agreement on this issue could not be reached during the meeting, an offline discussion between the interested parties (G. Sessler, M. Arza, M. Lanucara, W. Fong, V. Sank, S. Rodriguez, D. Lee) was proposed to resolve the issue.

4.3 Filtering of SP-L/PM for Space-to-Earth Links

SLS-RFM_22-01 was presented by A. Modenini regarding filtering options for SP-L/PM modulation needed to comply with the SFCG emissions mask for Cat. A space-to-Earth links. Two different filtering configurations were considered in the document. In the first option, the filter is applied at the output of the telemetry phase modulator with a separate phase modulator used for the ranging signal, before combining the outputs of the two phase modulators. The second option is to filter the SP-L signal before adding the ranging signal, followed by a single phase modulator. As shown by the document, the second option has less complexity than the first option but introduces spectral spikes

in the output spectrum. Both filtering options were simulated, with comparison plots of the filtered SP-L/PM spectrum and the bit error rate performance using both options provided in the document. The simulation results showed that using a 3rd order Butterworth filter with frequency cutoff of $4R_s$ to $4.5R_s$ could meet the Rec SFCG 21-2R4 emissions mask, while having only 0.5 dB loss at 1E-5 BER compared to the unfiltered SP-L modulation.

During the ensuing discussion of the document, D. Lee observed that the Option 1 configuration would produce an output signal with non-constant envelope and that the resultant spectrum would be a function of the SSPA model. **AI_22-2** and **AI_22-3** was assigned to the author to clarify the SSPA model used in the simulations and to propose a draft 401.0 Recommendation for SP-L/PM filtering for Cat. A downlinks, respectively.

4.4 Draft New Recommendation 2.2.10 on Modulations for 22 GHz space-to-space links, Cat. A

Input **SLS-RFM-22-04** was presented by A. Modenini with a proposed draft of a new Recommendation 2.2.10 on modulations for Cat A. space-to-space links in the 22.55-23.15 GHz band. During the WG discussion, a comment was made that the maximum symbol rate for lunar 22 GHz space-to-space links in the IOAG lunar architecture study was 200 Msps, which was consistent with the value in the draft Recommendation. Some editorial corrections were suggested by the WG, including adding a footnote reference to the relevant phase and amplitude imbalance recommendation in the 401.0 Blue Book. The WG chair agreed to make these editorial corrections and provide a clean version for the Fall 2022 RFM meeting. In addition, **AI_22-04** was assigned to W. Fong to review the phase noise mask in the Annex of proposed Recommendation 2.2.10.

4.5 Draft New Recommendation 2.4.25 on Modulations for 26 GHz space-to-space links, Cat. A

Input **SLS-RFM-22-04** was presented by D. Lee with a proposed draft of a new Recommendation 2.4.25 concerning modulations for Cat A. space-to-space links in the 25.25 – 27.5 GHz band. The Recommendation had been introduced and discussed at the Fall 2021 meeting. During the WG discussion of this document, NASA proposed the addition of GMSK BT_s=0.5 to the recommendation based on the results from document **SLS-RFM-22-02**. ESA did not agree, and this proposal was deferred to the offline GMSK discussion (see Section 4.2).

There were also comments from the WG regarding editorial changes, including fixing the version numbers for SFCG Recommendations in the footnotes. The Chairman agreed to make these editorial revisions offline and provide a clean version for the RFM meeting. There was WG agreement to add a phase noise mask to draft Rec. 2.4.25 based on the one in the 22 GHz recommendation, pending the outcome of **AI_22-04**. The WG also agreed to change the coded symbol rate from 10 Msps to 5 Msps in *recommends* (1) and (2).

5. Resolutions

The WG agreed to publication of updates to the RFM charter.

6. Action Items for Next RFM Meeting

The action item list from the Spring 2022 RFM meeting is shown in Annex 4.

Annex 1– Spring 2022 CCSDS RFM WG Meeting Participants

Name	Agency
Marie Vialard	CNES
Andrea Modenini	ESA
Ignacio Aguilar Sanchez	ESA
Maite Arza	ESA
Marco Lanucara	ESA
Nicola Maturo	ESA
Ricard Abello Puyuelo	ESA
Gunther Sessler	ESA
Jorge Quintanilla Sanchez	ESA
Luca Milani	ESA
Salvador Marti	ESA
Xavier Enrich	EUMETSAT
Jon Hamkins	NASA
Ken Andrews	NASA
Victor Sank	NASA
Wing Lee	NASA
Dennis Lee	NASA
Wai Fong	NASA
Shannon Rodriguez	NASA
Faramaz Davarian	NASA
David Ni	NASA

CCSDS SLS-RFM WG MEETING

Spring 2022 Meeting, 17 May 2022

Annex 2 – Spring 2022 RFM Agenda

Date	Item		Comments / Input Papers
May 17	1	Action items review	Minutes of meeting
	2	Existing recommendations	
16:00 – 19:30 (CET)	2.1	Updates to CCSDS 211.1-B-4 Prox-1 Physical Layer	SLS-RFM_22-03
	3	High Rate Doppler Effect on GMSK Receiver	SLS-RFM_22-02
	4	Filtering for SP-L/PM	SLS-RFM_22-01
	5	New recommendations	
	5.1	Modulations for 22 GHz space-to-space links	SLS-RFM_22-04
	5.2	Modulations for 27 GHz space-to-space links	SLS-RFM_22-05
	6	Charter discussion	Oct-20 charter
May 12	7	Joint RFM/C&S/SLP meeting (**)	
16:00 – 18:30 (CET)	7.1	Open ISL	SLS-CS_22-07
	7.2	Lunar S-band Proximity link (*)	SLS-CS_22-05

(*) Same document (SLS-RFM_22-03) for in-depth analysis by RFM WG

(**) Session followed by C&S meeting. C&S inputs available at https://tinyurl.com/v9kc68hm

CCSDS SLS-RFM WG MEETING

Spring 2022 Meeting, 17 May 2022

Annex 3 - List of Input Papers

Document No. (SLS-RFM_22-XX)	**Radio Frequency and Modulation: Paper Title**	**Available/ Distributed**	**Author**
01	SP-L/PM for Space-to-Earth (Category A) Applications: Guidelines for Filtering	Y/Y	A. Modenini
02	Action AI-21-01: Update to Worst-case Doppler Scenario for GMSK BTs=0.25	Y/Y	W. Fong, W. Lee
03	Concept Paper Concerning Lunar S-band Proximity links	Y/Y	F. Davarian
04	Proposed New Recommendation 2.2.10 on Suppressed Carrier Modulations for High Rate Space-to-Space Links in the 22 GHz Band	Y/Y	A. Modenini, V. Sank
05	Proposed New Recommendation 2.4.25 on High Coded Symbol Rate Transmissions in the 25.25-27.5 GHz Band, Space-to-Space	Y/Y	D. Lee
06	AI 21-01 - Additional Tests with Frequency Ramps	Y/Y (**)	M. Lanucara, M. Menapace, G. Sessler
SLS-C&S_22-YY	**C&S WG papers for joint meeting/of interest to RFM WG**		
05 (**)	Concept Paper Concerning Lunar S-band Proximity links	Y/Y	F. Davarian
07	Open ISL – Standardization of Intersatellite Links and Issue of a CCSDS Recommended Practice	Y/Y	A. Modenini

(*) Same document as SLS-RFM_22-03

(**) Document was distributed during the RFM meeting

CCSDS SLS-RFM WG MEETING

Spring 2022 Meeting, 17 May 2022

Annex 4 – Spring 2022 RFM Action Items

AI #	AI description	Actionee	Due date
AI_21-05	Review the draft rec 4.1.8 and provide comments (including addition of amplitude/phase imbalance)	All WG members	(1)
AI_22-01	Provide material regarding GMSK receiver tracking performance with Doppler rate, and selection of the appropriate loop parameters for inclusion in the 413.1-G-2 Green Book (based on inputs SLS-RFM_22-02, SLS-RFM_22-06, SLS-RFM_21, SLS-RFM_21-21, and SLS-RFM_21-22)	M. Lanucara and W. Fong	(1)
AI_22-02	Clarify what SSPA model was used to generate the SP-L/PM spectra in document SLS-RFM_22-01	A. Modenini	(1)
AI_22-03	Provide draft Recommendation on filtering for SP-L/PM modulation for space-to-Earth links to meet the SFCG emissions mask	A. Modenini	(1)
AI_22-04	Review the 22 GHz phase noise mask in the proposed Recommendation 2.2.10, and comment on its applicability for use in the draft Recommendation 2.4.25	W. Fong	(1)
AI_22-05	Provide clean versions of draft Recommendations 2.2.10 and 2.4.25 with editorial corrections agreed upon during the Spring 2022 RFM meeting	D. Lee	(1)

(1) 2 weeks prior to the Fall 2022 RFM meeting.
All inputs should be announced 4 weeks prior to the meeting.