CCSDS SLS-RFM WG MEETING

Spring 2024 Meeting, 29 April – 03 May 2024

Spring 2024 SLS-RFM Working Group Meeting Minutes

Issue 1.0
July 17, 2024

1. Introduction

The Spring 2024 RFM WG meeting took place on Tuesday April 30 in Washington DC, USA. It was a hybrid meeting with both in-person and remote participants.

A joint meeting with the RFM, C&S, and SLP working groups was held on Thursday May 2, followed by a joint meeting with just the RFM and C&S WGs. The minutes for the joint meetings are provided in the C&S WG meeting minutes.

2. Meeting Participants

There was a total of 17 participants in the Spring 2024 RFM WG meeting, representing 6 different space agencies (CNES, DLR, ESA, JAXA, NASA, and EUMETSAT). The list of the attendees is shown below.

Table 1. Spring 2024 CCSDS RFM WG Meeting Participants (30 April)

	Name	Agency
1	Marie Vialard	CNES
2	Jean-Luc Issler	CNES
3	Antonio Miraglia	ESA
4	Andrea Modenini	ESA
5	Klaus-Jergen Schulz	ESA
6	Nicola Maturo	ESA
7	Rebecca Giuliani	Università Politecnica delle Marche (ESA)
8	Gunther Sessler	ESA
9	Jorge Quintanilla Sanchez	ESA
10	Xavier Enrich (virtual)	EUMETSAT
11	Victor Sank	NASA
12	Wing Lee	NASA
13	Dennis Lee	NASA
14	Wai Fong	NASA
15	Shannon Rodriguez	NASA
16	Amanuel Geda	DLR
17	Nakadai Mitsuhiro (virtual)	JAXA

3. Meeting Agenda

The RFM meeting agenda for Spring 2024, as shown in Annex 1, was approved by the WG.

4. Action Item Review

The action items from the previous RFM meeting were reviewed. There were 9 action items from the Fall 2023 RFM meeting. One action item remains open (AI_23-05), while the others have been closed. The status of the RFM action items from the previous meeting is shown below.

Table 1. Action Items from Previous RFM Meeting

AI #	AI description	Actionee	Status
AI_21-05	Review the draft rec 4.1.8 and provide comments (including addition of amplitude/phase imbalance)	All WG members	Closed with **SLS-RFM_24-04**
AI_23-02	Incorporate GMSK tracking performance material into 413.1-G-2 Green Book, and verify notation, Figure/Table numbering, references, etc. are consistent with the rest of the document	D. Lee	Closed
AI_23-04	Provide pink sheets for update of 415.1 CDMA Blue Book to include non-regenerative ranging and lunar relay	V. Sank/S. Rodriguez	Closed with **SLS-RFM_24-01**
AI_23-05	Draft white recommendation for low data rate MFSK communications	J. Quintanilla, D. Lee	Open
AI_23-06	Provide feedback on feasibility of including PCM/PM/NRZ in 401.0 Blue Book for symbol rates between 150 ksps and 2 Msps	G. Sessler	Closed with inter-meeting emails
AI_23-07	Provide guidance in 414.1 Blue Book on the selection of the chip rate when PN ranging is used simultaneously with data transmission	D. Lee	Closed with **SLS-RFM_24-09**
AI_23-08	Create a new project in CWE to begin development of the 401.0 Part 2 Blue Book.	D. Lee	Closed with **SLS-RFM_24-10**
AI_23-09	Review the proposed draft updates to 415.1 Blue Book in document SLS-RFM_23-09 and provide comments to V. Sank	All RFM WG members	Closed
AI_23-10	ESA to check if they can support independent verification of proposed non-regenerative ranging in 415.1 book as described in document SLS-RFM_23-09	A. Modenini	Closed

5. Discussion of Input documents

5.1 PCM/PM/NRZ for Residual Carrier Telemetry

Document **SLS-RFM_23-05** was presented by W. Fong regarding a NASA proposal to add PCM/PM/NRZ modulation to Recommendations 2.2.7 (Medium rate telecommand) and 2.4.7 (PCM waveforms for residual carrier telemetry) in the 401.0 RFM Blue Book. This modulation could be used to fill the gap for medium rate links between 150 ksps to 2 Msps. ESA had expressed concerns

with (1) the high spectral bandwidth usage of PCM/PM/NRZ at 2 Msps; (2) having too many modulation options in the 401.0 Blue Book; (3) the benefits of using PCM/PM/NRZ are unclear; and (4) GMSK+PN could be used at symbol rates down to 256 ksps as an alternative to PCM/PM/NRZ. NASA responded that the maximum symbol rate could be limited to just 1 Msps to address the high bandwidth usage concern. NASA also noted that GMSK+PN is not available as a LunaNet Initial Operations Capability (IOC), while PCM/PM/NRZ modulation is. In addition, the benefit of using PCM/PM/NRZ is that it is a residual carrier modulation which allows for simultaneous telemetry/telecommand and ranging signals while being more bandwidth efficient than PCM/PM/Bi-phase. During the WG discussion, ESA and DLR noted that their existing ground station receivers already have the capability to demodulate PCM/PM/NRZ.

The RFM WG agreed in principle to include PCM/PM/NRZ modulation in the Recommendations 2.2.7 and 2.4.7. Action item **AI_24-01** was assigned to NASA to perform a follow-on study to determine the appropriate filter type and parameters for PCM/PM/NRZ, taking into consideration the spectrum with PN ranging and losses due to the filtering.

Document **SLS-RFM_23-06**, also from NASA, provided a draft revision of Recommendation 2.4.7 with the addition of PCM/PM/NRZ. The RFM WG agreed to some additional edits to the revised Recommendation, including a *recommends* to use the CCSDS randomizer to the draft Recommendation, and a *considerings* to define the meaning of direct modulation. The WG also agreed to limit the use of PCM/PM/NRZ to a maximum of 1.024 Msps as discussed earlier.

The WG agreed to add the modulation index and filter parameters for PCM/PM/NRZ to the draft Recommendation 2.4.7 when the NASA study (see **AI_24-01**) is completed.

5.2 Proximity-1 S-band Phase Noise Analysis

Input document **SLS-RFM_24-07** was presented by W. Lee with analysis of the 401.0 phase noise mask when applied to the S-band Prox-1 hailing channel. Specifically, the analysis looked at the phase lock loop tracking and bit error rate performance at a coded symbol rate of 1 ksps. It was clarified during later discussion that the Prox-1 hailing symbol rate agreed upon at the Spring 2023 CCSDS meeting in Huntsville, was 2 ksps after coding instead of 1 ksps. The analysis results indicated that the 401.0 phase noise mask was not adequately specified at frequencies less than 10 Hz for the case where the symbol rate is low (1 ksps) and the operating Es/No is also low (-1.25 dB). In addition, under worst case S-band Doppler conditions specified in the current draft revision of the Prox-1 physical layer standard, maintaining carrier tracking on the Prox-1 receiver would be challenging for the hailing channel for a conventional 2nd order loop.

The NASA proposal was to use the phase noise mask from the Lunar Pathfinder (LPF) mission rather than the classical 401.0 phase noise mask. Action item **AI_24-02** was assigned to A. Modenini to provide the Lunar Pathfinder transmitter phase noise mask and a simple block diagram of the transceiver identifying the oscillator location(s).

5.3 High-Order Modulations for X-band Scientific Missions

Document **SLS-RFM_24-02** was presented by A. Modenini regarding use of high order modulations, up to 64-APSK, for X-band Category A science missions in the 8450-8500 MHz band. The document

provided end-to-end simulations of the BER performance of high order modulations in a nonlinear channel using SCCC coding in conjunction with different ACM modes (e.g., ACM17 with 16-APSK, ACM22 with 32-APSK, and ACM27 with 64-APSK). The effect of the carrier suppression was also simulated using values of -30 dBc, -35 dBc, and -38 dBc. The results indicated that for a carrier suppression of -38 dBc, the demodulation losses are less than 0.1 dB. This carrier suppression level was also met by the 3 ESA transmitter prototypes, so it is achievable with realistic hardware.

The accompanying document **SLS-RFM_24-03**, also from ESA, provided a draft revision of 2.4.17A to include the addition of high order modulations SRRC-16APSK, SRRC-32APSK, and SRRC-64APSK for Category A missions downlinks (space-to-Earth) for symbol rates greater than 10 Msps. The draft revision also included specification of a minimum carrier suppression when using these high order modulations and addition of SRRC-QPSK.

The RFM WG agreed to delete section A1.5 from the ESA proposed revision of the Recommendation, and replace it with the wording from Recommendation 2.4.23. The WG also agreed to add a copy the constellation diagrams from Rec. 2.4.23 into the Annex. During the WG discussion, other modifications to the draft revision of Rec. 2.4.17A including changing the carrier suppression limit from -38 dBc to -35 dBc for SRRC-32APSK and SRRC-64APSK.

Action item **AI_24-03** was assigned to D. Lee to provide an updated version of the modified Recommendation 2.4.17A with the agreed upon changes incorporated.

5.4 Amplitude and Phase Imbalance in 26 GHz Channel Model

Input document **SLS-RFM_24-04** was presented by W. Fong (NASA) which provided end-to-end simulation results with LDPC coding using the 26 GHz channel model. The results indicated that the uncoded and coded BER performance was consistent within the simulation tolerance, while uncoded simulations could be performed much quicker than coded simulations. Without predistortion and a 5 dB input backoff on the power amplifier, an amplitude of 0.5 dB and a phase imbalance of 3 deg resulted in an error floor for 32-APSK and the decoder threshold for LDPC 4/5 was not achieved. However with centroidal predistortion, the effects from the transmitter amplitude and phase imbalance on the BER performance was almost entirely mitigated.

The RFM WG agreed to add an amplitude imbalance of 0.5 dB and phase imbalance of 3 degrees to 26 GHz channel model in draft Recommendation 4.1.8, and to add a note that with predistortion the effects of the amplitude and phase imbalance (0.5 dB and 3 degrees, respectively) are negligible. With these changes, the RFM WG agreed to approve and request agency review for Rec. 4.1.8.

5.5 Updates to 415.1 CDMA Blue Book

Input document **SLS-RFM_24-04** was presented by V. Sank (NASA) which provided updates to draft revision of the 415.1 CDMA Blue Book. The revision includes expanding the scope of the CDMA standard to include lunar missions and a non-regenerative turnaround ranging option. This version of the draft document provided an Annex D which specified how the CDMA codes would be assigned and distributed to the CCSDS space agencies.

5.6 Ranging for Lunar Proximity Links

Document **SLS-RFM_24-08** was presented by NASA regarding radiometric requirements planned for lunar proximity links. During the ensuing WG discussion, it was clarified that the presentation was intended to cover all lunar proximity links, and not just those using Prox-1. The document provided information on various Doppler and ranging requirements applicable for lunar proximity links, as well as the messaging requirements needed to enable such radiometric measurements. NASA indicated in the presentation that there was a desire for a pseudorange (or one-way ranging) capability for lunar proximity links, which is currently not specified in the RFM standards. The document also provided a recommendation on the oscillator stability needed for the Doppler measurements.

The WG noted that the existing PN Ranging Blue Book is for Earth-to-space and space-to-Earth ranging links only, and does not include recommendations for space-to-space ranging links. The WG also noted that the performance of PN ranging for space-to-space ranging links will likely be different than for direct-to-Earth ranging links, and this will require additional study.

Action item **AI_24-04** was assigned to D. Lee to create a draft CWE project to update the 414.0 PN Ranging Blue Book for space-to-space PN ranging and one-way pseudorange.

5.7 Other Documents

There were two other inputs documents **SLS-RFM_24-09** and **SLS-RFM_24-10** which were submitted after the deadline, and therefore were provided for information only and not discussed during the WG meeting.

SLS-RFM_24-09 provided a paragraph to be added to the 414.1 PN Ranging Blue Book with guidance on selecting the PN chip rate when there is simultaneous telemetry on the carrier.

SLS-RFM_24-10 showed the draft CWE project created for creation of a new 401.1 Blue Book for space-to-space physical layer recommendations that are not specific to the Prox-1 or CDMA Blue Books.

6. Review of RFM Charter

There were no time left at the end of the meeting session to review the RFM charter. However the WG will review and revise the RFM charter as needed at the next meeting.

7. Resolutions

The WG agreed to creation of a new project for an update of the 414.1 PN Ranging Blue Book with physical layer recommendations for space-to-space and one-way PN ranging.

The WG also agreed to request agency review for 401.0 RFM pink sheets for Recommendations 2.2.9, 2.5.7B, and 4.1.8.

8. Action Items for Next RFM Meeting

The action item list for the next RFM meeting (Fall 2024) is shown below.

Table 1. Action Items for Fall 2024 RFM Meeting

AI #	AI description	Actionee	Due Date
AI_23-04	Draft white recommendation for low data rate MFSK communications	J. Quintanilla, D. Lee	(1)
AI_24-01	Perform a study to determine the appropriate filter type and parameters to recommend for PCM/PM/NRZ, taking into consideration the spectrum with PN ranging and losses due to the filtering.	W. Fong, W. Lee	(1)
AI_24-02	Provide the Lunar Pathfinder transmitter phase noise mask for inclusion in the updated Prox-1 physical layer Blue Book, and a simple block diagram of the transceiver clarifying the oscillator location where the phase noise mask is specified.	A. Modenini	(2)
AI_24-03	Send out an updated version of the modified Recommendation 2.4.17A with the agreed upon changes to the working group	D. Lee	(1)
AI_23-04	Create a CWE project to modify the 414.0 PN Ranging Blue Book to include space-to-space PN ranging and one-way pseudorange.	D. Lee	(2)

(1) 2 weeks prior to Fall 2024 RFM Meeting

(2) Intersessional Prox-1 meeting in July

Annex 1 – Spring 2024 RFM Agenda

Date	Item		**Input Papers**
Apr 30 AM **08:45 – 12:30 (UTC -4:00)**	1	Action items review	Minutes of meeting
	2	PCM/PM/NRZ for Residual Carrier Telemetry (Recommendation 2.4.7)	SLS-RFM_24-05 SLS-RFM_24-06
	3	High Order Modulations for Space Research Category A (Recommendation 2.4.17A)	SLS-RFM_24-02 SLS-RFM_24-03
	4	Realignment of 401.0 Blue Book (Parts 1 and 2)	SLS-RFM_24-10
Apr 30 PM **13:30 – 17:30 (UTC -4:00)**	5	Amplitude and Phase Imbalance Recommendation for High Order Modulations	SLS-RFM_24-04
	6	CDMA for Non-regenerative Ranging and Lunar Relay (415.1-B Blue Book)	SLS-RFM_24-01
	7	PN Ranging Chip Rate	SLS-RFM_24-09
	8	Proximity-1 Physical Layer Extension for S-band and Lunar	SLS-RFM_24-07 SLS-RFM_24-08
	9	Review of WG Charter	RFM Charter
May 02 AM	10	**Joint RFM/C&S/SLP meeting**	
	10.1	Proximity-1 Session Control and Directives	SLS-SLP_24-02 SLS-SLP_24-03
	10.2	Draft Extension of Prox-1 Blue Books	SLS-SLP_24-01 SLS-CS_24-08
May 02 PM	11	**Joint RFM/C&S meeting**	
	11.1	VCM Green Book	SLS-CS_24-01
	11.2	Orange Book for Link Budget Digital Format	SLS-CS_24-05 SLS-CS_24-07

(*) Input papers are available at:
https://cwe.ccsds.org/sls/docs/Forms/AllItems.aspx?RootFolder=%2Fsls%2Fdocs%2FSLS%2DRFM%2FMeeting%20Materials%2F2024%2FSpring

CCSDS SLS-RFM WG MEETING

Spring 2024 Meeting, 29 April - 03 May 2024

Annex 2 - List of Input Papers

Document No.	Paper Title	Available/ Distributed	Author
SLS-RFM_24-XX	**RFM WG Meeting**		
01	Draft CCSDS 415.1-B-2 Data Transmission and PN Ranging for 2 GHz CDMA Links, Including Relay and Lunar	Y/Y	V. Sank
02	High-Order Modulations for Scientific Missions	Y/Y	A. Modenini, J.D. Ferris
03	Proposed Revision to Recommendation 2.4.17A for High-Order Modulations	Y/Y	A. Modenini, J.D. Ferris
04	Amplitude and Phase Imbalance Study for New Rec. 4.1.8 (action item AI_21-05)	Y/Y	W. Fong, W. Lee
05	Proposed Update to Recommendation 2.4.7 to Include PCM/PM/NRZ (part 1)	Y/Y	W. Fong, W. Lee, S. Rodriguez, V. Sank
06	Proposed Update to Recommendation 2.4.7 to Include PCM/PM/NRZ (part 2)	Y/Y	W. Fong, W. Lee, S. Rodriguez, V. Sank
07	Phase Noise Analysis on S-band Proximity-1 Hailing Channel	Y/Y	W. Lee, W. Fong
08	Radiometrics for Lunar Prox-1	Y/Y	J. Crenshaw, C. Gramling
09	Proposed Update to 414.1-B on PN Chip Rate Selection	Y/Y	D. Lee
10	Draft Realignment of RFM 401.0 Blue Book Parts 1 and 2 (for information)	Y/Y	D. Lee
SLS-YY_24-XX	**Joint RFM – C&S – SLP Meeting**		
SLS- SLP_24-01	Draft Updates to 211.0 Proxity-1 Data Link Layer	Y/Y	G. Kazz
SLS- SLP_24-02	Default Session Access Control Parameters for Space Enterprises	Y/Y	G. Kazz
SLS-SLP_24-03	Lunar Prox-1 Directives	Y/Y	G. Kazz
SLS-CS_24-08	Proximity-1 – RFM and C&S Blue Books Open Points	Y/Y	N. Maturo, B. Dellandrea
SLS-RFM_24-07 (also SLS-CS_24_09)	Phase Noise Analysis on S-band Proximity-1 Hailing Channel	Y/Y	W. Lee, W. Fong
	Joint RFM – SLP – C&S WG Meeting		
SLS-CS_24-01	Proposed Table of Contents for VCM Green Book	Y/Y	A. Modenini
SLS-CS_24-05	A New Link Budget Processing Method	Y/Y	CNES
SLS-CS_24-07	Draft Orange Book for the Link Budget Digital Format	Y/Y	ESA/ESTEC

(*) RFM and Joint Meeting Input Papers are available at: https://cwe.ccsds.org/sls/docs/Forms/AllItems.aspx?RootFolder=%2Fsls%2Fdocs%2FSLS%2DRFM%2FMeeting%20Materials%2F2024%2FSpring