CCSDS 2004 FALL MEETING

NASA/JPL, Pasadena, USA

October 18-22, 2004

SLS Ranging Working Group - Minutes of the Meeting

1. Action items review

Discussion took place on the 'old' action item AI_03-04 (review summary of available ranging techniques): the meeting agreed that such action was not needed anymore. A Green Book would do a better job and should be proposed as soon as the Red or Blue Book is approved.
AI_04-01 through AI_04-05 were all completed with results in the provided input documents. The same is true for AI_04-07, AI_04-09 and AI_04-11.
The work on AI_04-06 and AI_04-08 is progressing but did not result in the required input document. It was agreed to delay completion of these actions to the Spring 2005 meeting whereas AI_04-10 was already foreseen for completion in Spring 2005. Moreover, AI_04-06 was slightly redrafted to reflect the changes of ESA's document RNG_04-07 compared to ESA's initial proposal contained in RNG_04-03.

2. PN (regenerative) ranging

Paper RNG_04-07 on PN ranging was presented by ESA. Such paper develops a normalized acquisition time for acquiring the phase of the PN code (clock component acquisition not considered) and compares such normalized time for different PN code implementations. The derived formulas are based on a search for the maximum correlation value. It is to be noted that certain practical approaches (like the first implementation of BepiColombo transponder bread-board[1]) are based on a threshold comparison and as such yield a 3-dB degradation compared with the correlation maximum. For comparing JPL results provided at the previous meeting and included in the current 810-05 document, the Pr/No ratio was set to 27 dBHz corresponding to Ec/No = -33 dB for a 1 Mchip/s clock. Similarly, the acquisition probability was set to 99.9%.
The current JPL proposal, called JPL1999, has a very strong clock component and can be seen to approach a square wave. JPL1999 is based on the family of Titsworth codes. The paper presents two variations of the Titsworth family obtained by weighting the clock component with 2 or 4 votes and shows that compared to JPL1999 Titsworth V=2 halves the acquisition time with just a slightly reduced clock component while V=4 can be acquired 32 times faster at the expenses of 3.8 dB reduction of the clock.
The paper also considers the weighted-scrambled Stiffler codes family obtained with a 20-bit counter that only needs 20 probing sequences as compared to 75 for the Titsworth family (therefore including JPL1999.) Of particular interest to the applications being discussed are the codes obtained with voting V=6 and V=8. Scrambling can actually be implemented by a simple decimation rule and is necessary to avoid the bad spectral characteristics of the Stiffler sequences.

[1] The design shown during the Spring Meeting 2004 in Paris was implemented using the “Threshold Comparison”. Recently the design has been updated including the optimum detection algorithm based on the “Maximum Selection”.

The following recap table gives the acquisition performance of the 5 codes considered:

PN Sequence	Normalized ACQ Time $t_{acq-tot}$	Clock component $10 * Log_{10}(x^2)$
JPL 1999	**22081 sec (note 1)**	**-0.4 dB**
Titsworth V4	**10196 sec (note 1)**	**-0.6 dB**
Titsworth V2	**697 sec (note 1)**	**-4.2 dB**
Stiffler V8	**4681.6 sec (note 2)**	**-0.57 dB**
Stiffler V6	**998.5 sec (note 2)**	**-1.59 dB**

Note 1: 5 parallel correlators assumed as in BepiColombo breadboard
Note 2: 4 parallel correlators assumed.

Discussion followed. ESA stated that the BepiColombo breadboard[2] can be programmed for both the JPL1999 as well as the Titsworth V=2 and V=4 sequences. It was not known if also the Stiffler sequences could be easily accommodated[3]. JPL mentioned that New Horizon to be launched in January 2006 may embark regenerative ranging and may have selected JPL1999 regeneration scheme. It was suggested to continue the current investigation and try to reach a conclusion on which ranging standard(s) to recommend next year based on technical facts only leaving it up to the Agencies to review programmatic aspects.
Completion of action items AI_04-06 and AI_04-08 will allow deciding which system(s) to recommend in the foreseen white book.

Document RNG_04-09 by ESA was introduced, presenting the results obtained so far on the BepiColombo breadboard. Due to the selected codes (JPL1999 and Titsworth) with strong clock component a PLL can be used to acquire and track the chip rate via a mid-phase integrator (DTTL-like). Presented measurement results encompass spectral plots and tracking jitter for JPL1999 and Titsworth V=2 and V=4. No major difference seems to be evident concerning spectral characteristics and therefore suitability for simultaneous telecommand and telemetry transmission. Tracking jitter depends as expected on the clock component.
A theoretical computation of the ranging jitter is also given. However, such computation (equation 5.2-14-b) differs from JPL's formula (J. Berner et alt)[4] by a factor 4. ESA was not able to understand this difference. An action item was taken by JPL (AI_04-12) to try and align ESA's and JPL's equations.

The section on regenerative ranging contained in document RNG_04-10 was reviewed. JPL stated that the ranging clock to uplink carrier frequency ratio can only be as given in 810-05 and that the uplink PN clock is always coherent with the carrier. The downlink can either be coherent or not coherent.
ESA took action AI_04-13 to check if JPL ratios, which are different from the ones proposed by ESA, can be accepted by ESA.

[2] Programmability at transponder level will be analyzed (not included in the current spec for the EM).
[3] Implementation of Stiffler PN ranging in the BepiColombo BB will require additional funding.
[4] TMO Progress Report 42-137, “Regenerative Pseudo-Noise Ranging for Deep Space Applications”, May 15, 1999, formula (29).

Document RNG_04-10 also confirmed that the spectral plots in 810-05 assume sinewave ranging. ESA's spectral plots are instead based on squarewave ranging.

In order to meet the charter deadline for a first white book on PN (regenerative and transparent) ranging next Spring, AI_04-14 was taken by the chairman in cooperation with D. Lee, W. Martin and G. Boscagli. An outline of the white book is to be prepared by December 2004 for an initial round of comments. Document RNG_04-04 will be used as template.

3. Delta-DOR recommendation

Document RNG_04-08 by ESA was presented showing simulation of filtered delta-DOR squarewave tones at the output of the saturated amplifier (TWTA). Comparisons with ideal sinewaves as well as quantized sinewaves with 8 samples per tone were also presented. It is shown that the occupied bandwidth at the TWTA output is rather large for squarewave tones while quantized sinewave are as good as ideal sinewaves and do not suffer from saturation effects. Since the impact on the transponder of quantized sinewaves is minimal, ESA's approach is to use such implementation when ideal sinewaves cannot be generated. It is shown that the impact (in terms of spectral re-growth) of the squarewave tones can be properly minimized by using the proper modulation index[5], HPA input back-off and tone frequency; this allows to use squarewaves as well, provided that the emission at the Earth surface is compliant with the requirement on the maximum allowable power flux density.

Document RNG_04-11 by NASA/JPL was presented showing measured delta-DOR spectra at the output of the MRO TWTA during RF compatibility tests at JPL. MRO embarks the small deep space transponder (SDST) and 35W/100W Ka/X-band TWTAs. Since ideal sinewaves are generated by the SDST and no filtering is implemented, no spectral regrowth is visible. Tones at 19.2 and 76.7 MHz can be simultaneously generated at Ka-band. The use of 76 MHz tones is in compliance with the revised 2.5.6B recommendation (see sections 4 and 5).

4. Current ranging recommendations

The input papers on the action items concerning recs. 2.5.4A and 2.5.4B were discussed and as result no changes were deemed necessary for these two recommendations. It was noted that the required inputs had been already received in May and used for the drafting of the ECSS standard on ranging.

5. Discussion of agency's review RIDs on 2.5.6B (delta-DOR)

No RIDs have been received. As result the WG resolve to raise the modified recommendation to blue status.
It was noted that the changes to 2.5.6B were based on ESA's inputs from BepiColombo and Rosetta/Mars-Express as well as on discussions between ESA and the (NASA/JPL) author of the current 2.5.6B recommendation with the aim to clarify this recommendation and bring it up to latest practice (for instance, NASA's MRO etc.). Other than ESA and NASA, no other agency is currently using delta-DOR.

[5] At present several transponders allow in-flight flexibility for the modulation index.

6. Resolutions

The ranging WG resolve to raise modified recommendation 2.5.6B to blue status.

7. Charter

Discussion of the charter concluded that no changes were needed.
A white book (Issue 1) on PN ranging is due July 2005. Only regenerative ranging will be included in full. Sections for transparent ranging will be inserted as place holders in Issue 1. Transparent channel specifications and systems will be included in Issue 2 of the white book, due July 2006.
A draft white book will be made available for discussion at the Spring 2005 meeting so as to meet the deadline of the charter.

Annex 1 - Action Item List

AI #	AI description	Actionee	Due date
AI_04-06	Review the four ESA's proposed codes of paper SLS-RNG_04-07	D. Lee	(1)
AI_04-08	Analyze the RFI of all proposed PN ranging schemes with TC/TM	D. Lee G. Boscagli	(1)
AI_04-10	Proposed figures for XPND linearity, gain flatness, 3dB bandwidth and group delay variation for the selected PN ranging scheme(s)	D. Lee G. Boscagli	(1)
AI_04-12	Align ESA's (doc. RNG-04_09) and JPL's (J. Berner) formulas on PN ranging jitter	D. Lee	(1)
AI_04-13	Check if JPL ratios for PN code clock/carrier can be accepted by ESA	G. Boscagli	(1)
AI_04-14	Prepare an outline for the PN ranging white book and circulate for comments	E. Vassallo + G. Boscagli, D. Lee, W. Martin	(2)

(1) 2 weeks prior to Spring 2005 meeting
(2) 15 December 2004

Annex 2 - List of Participants

Name	Affiliation	e-mail
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Annex 3 - List of Input Papers

	Ranging WG: Paper Title	Distributed	Author
RNG_04-XX			
07	PN ranging-code schemes - past & future (AI_04-07)	y	J. Massey, G. Boscagli
08	Simulation of filtered square-wave DOR tones (AI_04-01)	y	G. Boscagli et al.
09	Regenerative ranging breadboard results (AI_04-11)	y	G. Boscagli et al.
10	JPL response to AI_04-03, AI_04-04 and AI_04-09	y	D. Lee
11	Simulated delta-DOR spectra through saturated power amplifier (AI_04-01)	y	D. Lee
12	RIDs to Agency Review from Spring 2004 meeting	y	CCSDS secretariat

Annex 4 - Agenda

Date	Item		AI/REC	Actionnee / Author	Comments / Input Papers
Thu 6, a.m.	1	RNG action items review		All	
	2	Regenerative ranging	AI_04-07 AI_04-11 AI_04-09 AI_04-04	G. Boscagli G. Boscagli D. Lee D. Lee	RNG_04-07 RNG_04-09 RNG_04-10 RNG_04-10
Thu 6, p.m.	3	Ranging and delta-DOR	AI_04-01 AI_04-01 AI_04-03	G. Boscagli D. Lee D. Lee	RNG_04-08 RNG_04-11 RNG_04-10
	4	RIDs from Agency Review		All	RNG_04-12
	5	Charter discussion		All	
Fri 7		Contingency/RFM&RNG wrap-ups			