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DRAFT

1.1 Purpose

This document proposes a non-regenerative ranging scheme be added to the regenerative schemes in the CCSDS 415.1-B- document. These schemes are to be used over space-to-space, ground-to-space and space to ground communications links by space missions using signals in the 2 GHz S-band flowing from: 1) Ground Station to User, 2) Ground Station through relay to user, and 3) Provider Satellite directly to user. This proposal might be added as an appendix intended for lunar applications and may be extended to the X-band.

1.2 Scope

This document covers only the addition of non-regenerative ranging to the CCSDS 415.1-B- recommendation. No new PN patterns are added.
This addition to the existing Recommended Standard defines CDMA spread spectrum modulation schemes in terms of:

a) the services provided to the Users of this specification
b) spreading code formats; and
c) the procedures performed to generate and process the code formats.

1.3 Background

The CCSDS 415.1-B-1 document specifies a different range pattern for the forward (up) link from the one in the return (down) link. The patterns are of equal length and the return (downlink) pattern is synchronized to the uplink pattern. This requires "re-generation" in that the receiver must synchronize the internally generated return link pattern to the received forward link pattern. This kind of system has the advantage that noise in the forward link is not conveyed to the return link signal. The result is that the return link signal received at the original sending node is of higher signal to noise then if the forward link was simply turned around (non-regenerative).

With strong signals or high signal to noise systems, a simple remodulation of the forward link pattern on the return link carrier can result in sufficient signal quality at the original sending node to meet the required ranging needs. The CCSDS 414.1-B- document allow for this non regenerative ranging using ranging patterns that were developed for deep space missions where the spectrum has spikes due to the high "clock" (10101010…) component of the pattern. This document proposes a similar non regenerative method for the CCSDS 415 type signals which are appropriate for near Earth systems since the spectrum does not have spikes. The high "clock" component of the CCSDS414 patterns has a small advantage in range measurement accuracy.

1.4 Rationale

CCSDS has a recommendation for CDMA via a relay satellite which limits how the schemes are applied. Lunar and other missions may desire to use the same schemes but without the requirement for regeneration to simplify the radio hardware and cost.

Nomenclature and terminology shall be the same as in the CCSDS 415.1-B- recommendation except as noted. In an attempt for CCSDS to standardize on how PN generators and associated polynomials are shown, if this document includes PN pattern shift register figures, it does not use the same convention for cell numbering as the CCSDS 415.1-B- document. <The figures have not had the cell numbers updated yet>

2.1 OVERVIEW

The *Sending Node* transmitter accepts spacecraft command symbols from the MOC, PN spreads them and modulates them on the I, command channel. A second, Q channel (range channel), contains the Ranging PN code but no data symbols, and the two are combined into a QPSK channel with unequal power, UQPSK. The ranging PN code is also available for the User Spacecraft Clock Calibration System (USCCS) time transfer service. Figure 4-1 of CCSDS 415.1-B- (copied here for convenience) shows the generation of the forward I, command channel, PN GOLD code. The initial value for register A depends on the assigned PN code set in the CCSDS PN code library. This pattern has a length of 1023 chips.

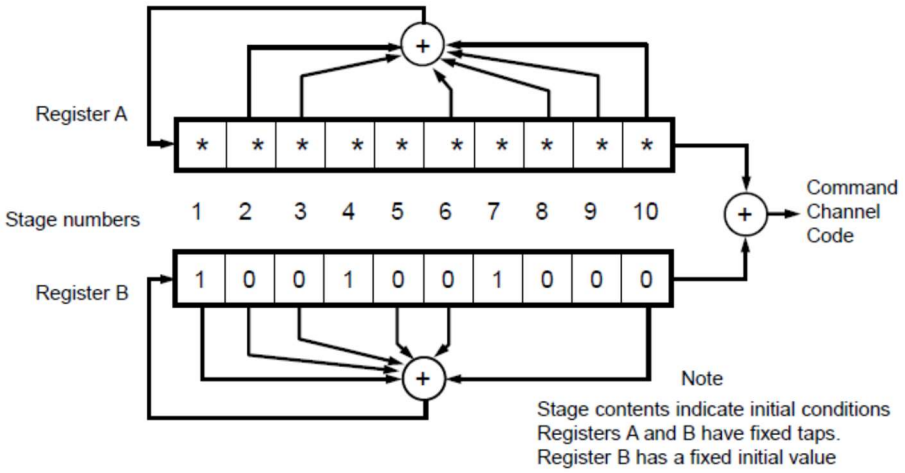


Figure 4-1: CCSDS Command Link Gold Code Generator (I channel)

The forward link range channel is a longer PN 18 pattern as shown in figure 4-2.

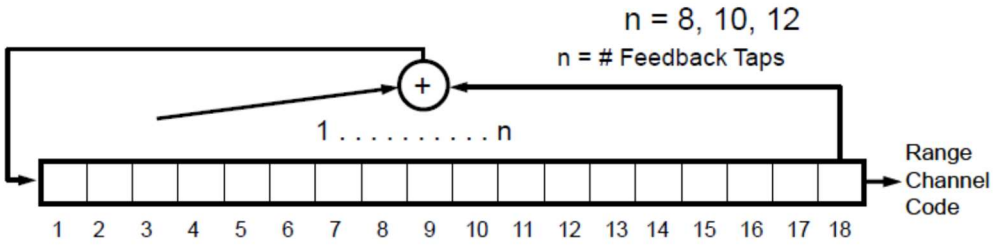


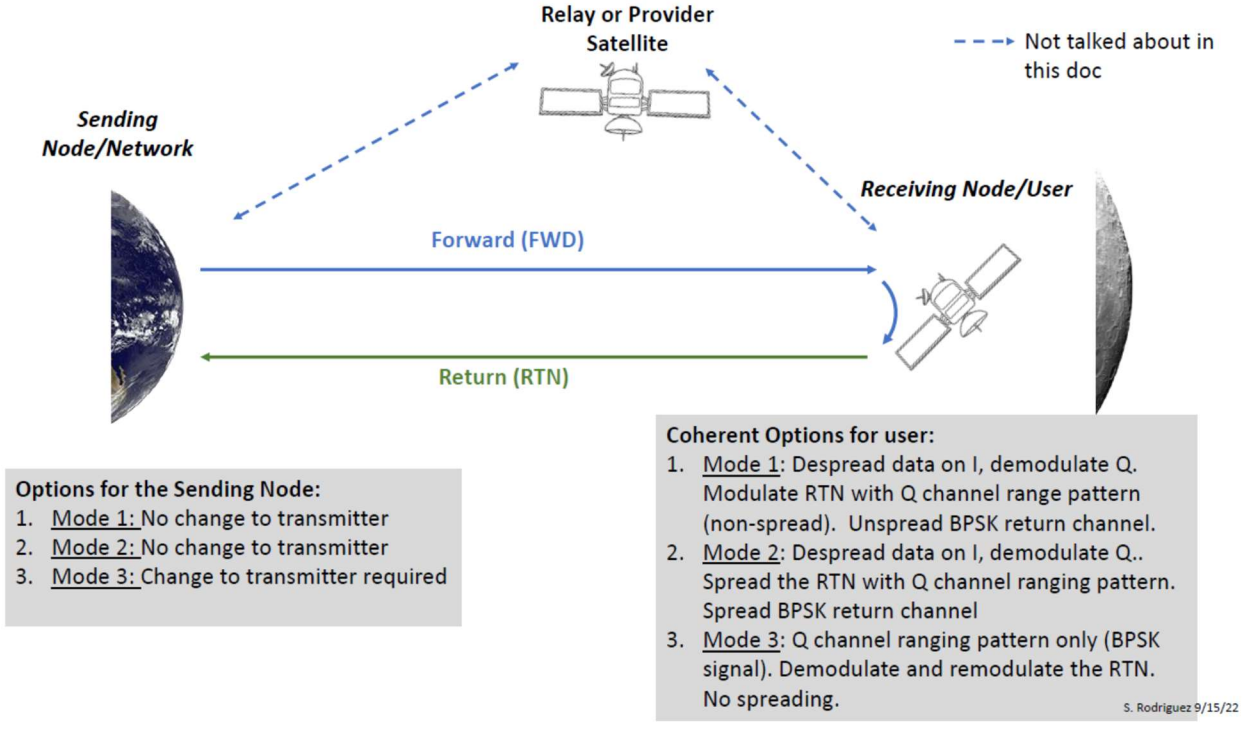
Figure 4-2: CCSDS Range Channel Code Generator (Q channel)

This pattern has a length of $2^{18} - 1 = 262{,}143$, but in keeping with the scheme in the CCSDS 415.1-B- it is truncated to a length equal to 256 times the I channel pattern, 256 x 1023 = 261.888 chips, 255 chips shorter than the full PN18 pattern.

2.2 Proposal for Non-Regenerative Ranging

For links where the return roundtrip signal quality is weak, regenerative ranging is required. For links where the return roundtrip signal quality is deemed strong enough to meet the ranging (or timing) requirements, the *User* receiver does not need to de-spread or correlated with the received signal and generate an equal length, synchronous and noise free pattern for the return link. In this scenario, there are three possible non-regenerative ranging modes available to the *User*. The first two modes require no change to the forward link, as described in the CCSDS 415.1-B- and a third mode has a small change in that there is no command data, and only the range channel is used.

1. Mode 1: The I command channel data, as stated in the CCSDS 415.1-B- book, gets spread with the short 1023 length pattern. The Q channel contains only the range pattern. The *User* receiver despreads the data on the I channel and demodulates the forward Q, range channel, and uses this Q channel data to modulate the return channel.
2. Mode 2: The I command channel data is as stated in the CCSDS 415.1-B- book, it gets spread with the short 1023 length pattern. The Q channel contains only the range pattern. The User receiver despreads the data on the I channel and demodulates the forward Q, range channel, and uses the I-channel spreading code to spread the down link data to result in a spread spectrum signal.
3. Mode 3: The I channel is eliminated resulting in a BPSK link with only what was the Q channel range pattern modulated on it. This signal is demodulated and remodulate on the return link carrier. The result is BPSK on forward and return.



When the time transfer service is also used, a pulse is output to the *User* spacecraft upon detecting the PN pattern all 1s epoch.

In all cases the forward carrier frequency and the return carrier frequency are RF coherent using the forward to return ratio of 221:240. Both the short and range PN patterns are coherent with the carriers with the same ratios as specified in the CCSDS 415 document.

In all cases, the ranging channel uses the truncated ranging PN18 pattern as described in the 415 document. When using any of these schemes proposed above, the return channel PN pattern generator shown in CCSDS 415.1-B-, Figure 5-1: Coherent Return Modes PN Code Generator, is not used.

The chip rates considered in this standard are designed to be coherent with the carrier with chip rates that are approximately 3 Mchips/s.

Note: The design where the range pattern is 256 times the length of the command pattern was set in the late 1970s to ease the design of the space receiver by reducing the required number of tracking loops. At least one spacecraft receiver vendor has said that with today's FPGAs, they have separate tracking circuits and do not take advantage of this. Missions with small low-cost transponder may use this feature.

Forward Link I/Q Channel Power

The scheme in the existing CCSDS 415 book has the I Command channel at a power that is 10 times the power on the Q ranging channel (10:1). There are two options for this forward link that could be considered for Mode 1 and Mode 2 above:

1. This configuration can be maintained exactly as it currently is, which provides the benefit of no change. Or,
2. The power ratio can be changed, for example to a 1:1 ratio. This would allow for a more robust ranging signal when used in a non-regenerated fashion.

END OF PROPOSAL

Differences and similarities between the CCSDS 414 patterns and the 415 patterns

	CCSDS 414	CCSDS 415
Length	1,000,000	2^18 – 1 = 262,143 Truncated to 261,888
Chip rate	~ 1, 2, Mcps coherent with Fwd link carrier $fc = i\ f_{fwd} /(128 \times 2^k)$	coherent with the Fwd link carrier $fc = f_{fwd} * 31/(221*96) \approx 3$ Mcps
Modulation	residual carrier	direct on carrier (BPSK or QPSK)
Used for Spread Spectrum	No	Yes
Used for Ranging	Yes	Yes
Spectrum	High density spikes	No high density spikes
Appropriate for Deep space	Yes	No
Appropriate for Near Earth	No	Yes
Appropriate for GPS like ranging	No	No
Maximal pattern	No	Truncated maximal
Gold pattern	No	No

Requirements for GPS like patterns (some different from above patterns)

Repeat on 1 second interval

Many patterns with good cross correlation Gold patterns or similar

Modulation BPSK, QPSK, BOC

End