Telemetry Ranging – Concept Paper Summary

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Background

- Previous CCSDS meetings:
  - Spring 2015: Telemetry ranging technique was described.
  - Fall 2015: A comparison to GMSK+PN ranging was made.

- How telemetry ranging works:
  - The spacecraft tracks the phase of the uplink PN ranging signal.
  - Receive-time of downlink telemetry frame provides timing information.
  - No downlink ranging signal is used.

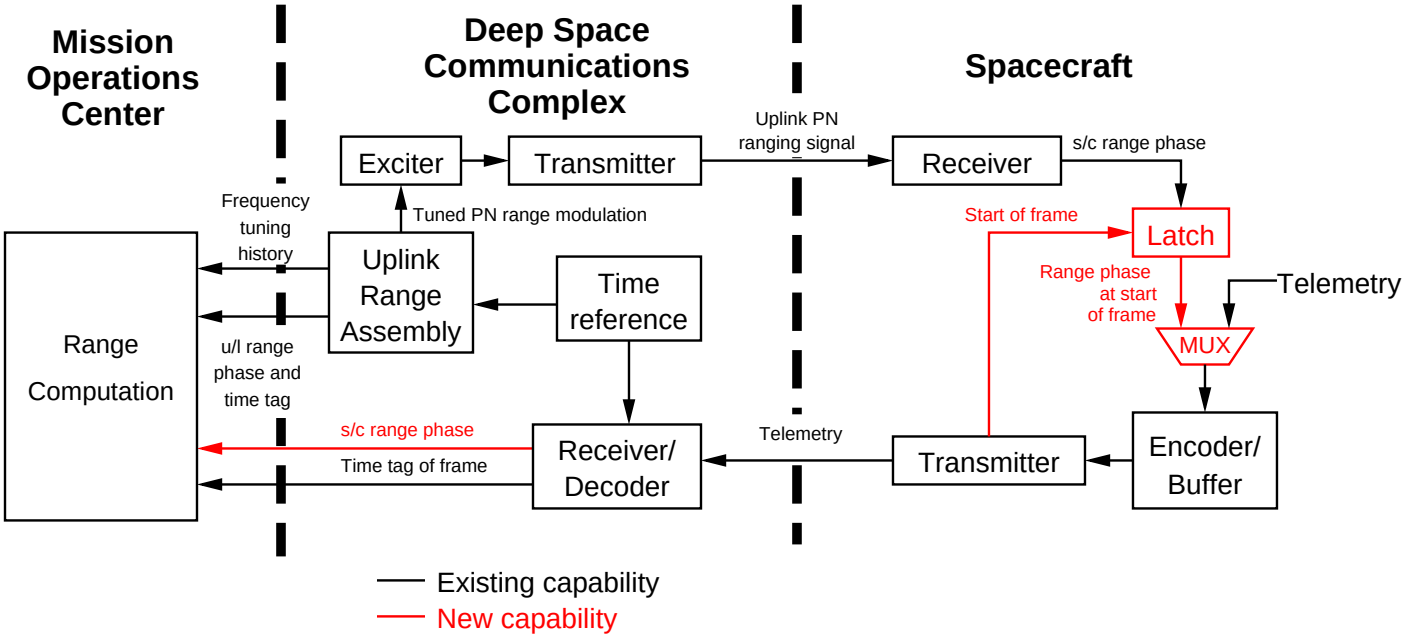
- This presentation:
  - Summarizes the telemetry ranging concept paper

Purpose

The purpose of the concept paper is to propose that the RFM Working Group consider telemetry ranging for inclusion as a recommended method for two-way ranging in the 401.0-B Blue Book.

Description of the key technical features

Top Level Implementation:



<u>Data flow and range computation</u>

1.PN ranging signal is sent on uplink; as it is transmitted, its phase is periodically recorded and time-tagged on ground (as usual with 2-way PN ranging).

2.Spacecraft records phase of acquired uplink PN signal *at moment when telemetry frame is transmitted. There is no downlink PN range signal.*

3.Range is computed from known uplink frequency tuning history, time-tagged PN phase from uplink range assembly, PN phase recorded on spacecraft, and time tag of telemetry frame. The range computation algorithm remains nearly unchanged.

Expected benefits

The adoption of telemetry ranging as a recommended standard is expected to provide the following benefits:

- Elimination of data rate limitation for simultaneous telemetry and ranging
  - The maximum telemetry rate is not expected to be limited by or tied to the chip rate of the uplink PN ranging signal
  - This enables an “always on” ranging system
- 100% of transmit power can be used to send high rate telemetry
  - No power will be used for a dedicated ranging signal
  - 2-10% more power will be available for telemetry
- Timing resolution will be based on full power of telemetry signal
  - This is 10-20 dB more ranging power
- There will be no interference between ranging and telemetry signals.
- There will be no need for telemetry-cancelling in the receiver.
- The system would be compatible with low-rate telemetry modulations.

Requirements of prospective missions

- All space missions have requirements to provide both telemetry and ranging functions
  - Minimum data rates are generally derived from Level I requirements related to the scientific goals of the mission
  - Ranging products are required as needed to perform the functions of the mission (e.g., orbit insertion, stabilization, trajectory maneuvers)

- Specifically, Solar Probe Plus and Europa missions have considered the telemetry ranging system in technology development efforts
  - Link budgets at certain mission phases had insufficient margin; the telemetry approach could help reduce their need for residual carrier during these phases, and improve link margin
  - This outreach led to the successful laboratory demonstrations of telemetry ranging on APL's Frontier Radio, which will fly on these missions.

- CCSDS has previously identified simultaneous high rate telemetry and ranging as a needed capability

Relationship to existing standards

- CCSDS 414.1-B-2 defines a two-way, regenerative PN ranging system.

- CCSDS 401.0-B-25 defines a method for high rate telemetry and ranging, based on GMSK+PN.
  - GMSK+PN uses the sequences defined in 414.1-B-2, and simply allows for high-rate telemetry modulation to be an additive phase modulation.

- A new telemetry ranging standard would be appear as a new section of 401.0-B-25. It would provide an alternate mechanism to provide simultaneous high rate telemetry and ranging.

Identified deficiencies, flaws, and limitations in existing standards*

- Symbol rate limitation
  - The maximum telemetry rate must be less than the uplink PN chip rate
  - The only PN chip rates identified in 414.1-B-2 for international cross support are 2 Mcps and 4 Mcps; currently, in the DSN only 2 Mcps is supported.
  - Thus, DSN users cannot transmit ranging and telemetry at more than 2 Msps
  - Missions capable of exceeding 2 Msps will likely not use “always on” ranging
- Power efficiency of telemetry signal
  - 2 – 10% of power is not available for telemetry, since it is dedicated to ranging
  - In addition, the in-band PN signal interferes with the GMSK signal
  - This amounts to a loss of 0.3 to 1.4 dB with respect to a telemetry-only signal
- Power efficiency of ranging signal
  - 90 – 98% of power is not available for ranging, since it is dedicated to telemetry
  - In addition, imperfect GMSK symbol wiping degrades ranging performance
  - This amounts to a loss of 10 – 20 dB with respect to a ranging-only signal
- Complexity
  - A signal canceling receiver is needed on the ground to wipe the GMSK signal before the PN ranging signal can be processed.

* The existing standard provides one recommended method for high rate telemetry and ranging: GMSK+PN ranging (401.0-B-25, section 2.4.22).