Investigating the Dependency Between Navigation and Reflectometry Receivers in GNSS-R Instruments

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**MOTIVATION**
- Spaceborne GNSS-R receivers can logically be separated into a "navigation" receiver and a "reflection" receiver.
- Currently, reflection receivers are highly dependent on the navigation receiver to provide delay and Doppler information.
- There are potential benefits to decoupling the navigation and reflection receivers.
- Simplifying interface between receivers can yield important savings in power and reduce operational complexity.

**CURRENT CYGNSS REFLECTOMETRY RECEIVERS**
- Current GNSS-R receivers (such as CYGNSS and TDS-1) require the direct-path signal in order to produce Delay Doppler Maps (DDM).

**PROBLEMS WITH CURRENT DESIGN**
- As new GNSS constellations continue to fill out, many more specular reflections become available.
- We want to track more reflections than direct path signals.
- More reflections measured increases global coverage.
- Tracking so many direct path signals will cost too much processing power on small-satellite platform.
- With new wideband GNSS signals coming online, the effects of tracking these direct path signals amplifies.
- There are also other benefits to decoupling the navigation and reflection receiver.
- Feasibly we can lose lock on direct path due to ionospheric phenomena, undergo a restart, or switch to cold load for calibration purposes.
- Possibly want to track low elevation reflections where no direct path signal is realistic.
- Best reflection transmitter choice is not the best for navigation.

**PROPOSED DESIGN**
- Utilize assistance data uplinked from the ground in the form of an extended ephemeris (EE).
- Replace the absolute delay/Doppler measurements from direct path signal with accurate model estimates.
- Extended Ephemerides would contain Keplerian parameters and corrections as inputs to an on-board orbital model.
- Current EEs can provide 500m accuracy or better for 72 hours with a graceful degradation afterwards (e.g. Walker/Garrison).
- EE errors can be viewed in satellite body frame components:
  - Radial
  - Along-track (in-track)
  - Cross track
- There will be many possible specular reflections to track in the future.

**INITIAL RESULTS**
- The EEs must maintain a certain level of accuracy for each error component over the chosen period.
- The reflection receivers estimate of specular location in delay and Doppler must be within a small number of chips and a few Doppler bins.
- The different components of error manifest as errors in delay and Doppler separately.
- With a robust specular reflection targeting algorithm, periods between assistance data uplinks could be more than a week.

**FUTURE WORK**
- Verify DDM specular point targeting algorithms using extended ephemeris assistance data.
- Examine range and Doppler errors metrics for wideband GNSS signals.

**CONCLUSIONS**
- There are significant opportunities to improve next generation GNSS-R receivers.
- Separating the navigation and reflection components of the instrument has numerous benefits, including the ability to track more reflections than direct path signals.
- Extended Ephemerides will allow accurate tracking of specular reflections for periods up to a week or more.