RILDOS: A Beaconing Standard for Small Satellite Identification and Situational Awareness

Thomas Rivers
Kratos Technology and Training Solutions
thomas.rivers@kratosdefense.com

John Heskett
RT Logic, Inc.
jheskett@rtlogic.com

Marco Villa
Tyvak Nano-Satellite Systems Inc.
marco.villa@tyvak.com

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Overview

- Rapid increase in number of small satellites and CubeSats deployed presents a challenge to identify and locate them
- There is no unified approach to solve this problem
- Identity and location information broadcast unencrypted from satellite would be most direct approach to resolve issue
- **RILDOS** – **R**adio with **I**dentity and **L**ocation **D**ata for **O**perations and **S**SA – is an approach to solve this problem using data broadcast from the satellite

RILDOS Approach

- *Goal:* Develop a beacon standard that is low power for cubesat and small satellite missions
  - ***Solution: Very low data rate to easily close link budget; message cycles every 10 seconds***
- *Goal:* Re-use the primary downlink frequency to avoid need for secondary transmitter and additional frequency deconfliction
  - ***Solution: Broadcast under primary downlink using spread spectrum with PRN to get processing gain***
- *Goal:* Allow quick orbit determination
  - ***Solution: Time tagged position data in message***

RILDOS Approach

- *Goal:* Use message for emergency status, operator specific data, and allow future changes
  - ***Solution: Inserted standardized emergency flags, areas for user defined data, and "bit margin" budget***
- *Goal:* Enable broad and quick adoption
  - ***Solution: Make it an open standard vice a proprietary solution that dictates radios used***
- *Goal:* Make the signal usable for community SSA as well as for the owner and operator
  - ***Solution: The signal is unencrypted and uses published, well defined format***

Message Frame

- RILDOS message data must be precise and allow clear identification of satellite and orbit
  - Message is 500 bits long, and allows each message frame to contain full orbit position and timestamp as well as flags
  - Room for future expansion as well as proprietary use by operator
  - Strikes balance between content and repeat cycle at low data rate
- RILDOS version included to allow use of multiple versions

Message Area	Content	Start Bit	End Bit	Total Bits
Sync Code	Sync Code	0	23	24
Header Data	S/C ID, timestamp, RILDOS version, coordinate system	24	101	78
Navigation Data	Position, Velocity, Accel (Geo); Position and Velocity (Helio)	102	347	246
Emergency Flags	Predefined flags for S/C emergency - e.g., EPS or OBC flags	348	355	8
RILDOS Use	Reserved for future message content by RILDOS standard	356	419	64
Vehicle Use	Area for owner proprietary format and content	420	467	48
Checksum	IEEE 802.3 32 bit CRC Standard	468	499	32

RILDOS Message Frame Structure and Bit Mapping

Message Content

- Geocentric orbital data uses ECI, J2000 coordinate system
  - 8 bits of GNSS flags allow for definition of data source and some initial “quality” characteristics to be provided
- Emergency flags pass data on source of anomaly
  - Spacecraft operators define what an anomaly is for them

Item	Range	Units	Example	Start Bit	End Bit
GNSS Flags	00000000 to 11111111	--	10111101	102	107
x	` +/- 85899345.91	m	711572.99	108	144
y	` +/- 85899345.91	m	456852.99	145	181
z	` +/- 85899345.91	m	1254790	182	218
x dot	` +/- 10485.75	m/s	5245.99	219	242
y dot	` +/- 10485.75	m/s	7550.99	243	266
z dot	` +/- 10485.75	m/s	6548.99	267	290
x dot dot	` +/- 655.35	m/s^2	-11.99	291	309
y dot dot	` +/- 655.35	m/s^2	125.99	310	328
z dot dot	` +/- 655.35	m/s^2	325.01	329	347
	Total Bits (Geocentric)	***246***			

Geocentric Orbit Navigation Fields

Bit	Flag
348	Loss of Attitude Control
349	Unable to Receive Commands
350	Power Subsystem Anomaly
351	Propulsion Subsystem Anomaly
352	On Board Processor Anomaly
353	Thermal Anomaly
354	Payload Anomaly
355	Other Vehicle Anomaly
For all flags, "0" is for Nominal status, while "1" is for Emergency status	

Pre-defined Vehicle Emergency Flags

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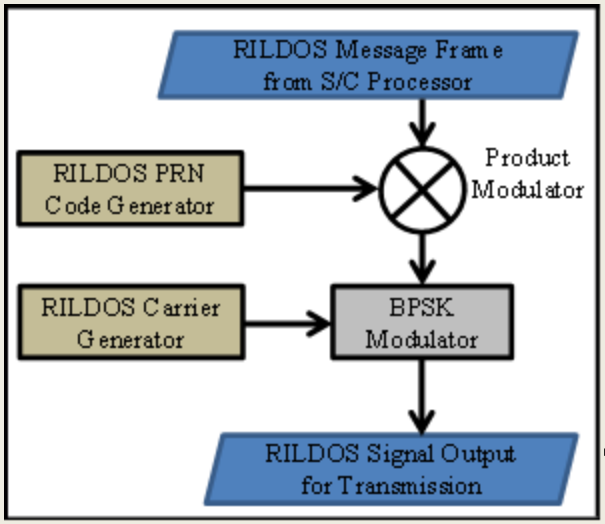
Modulation

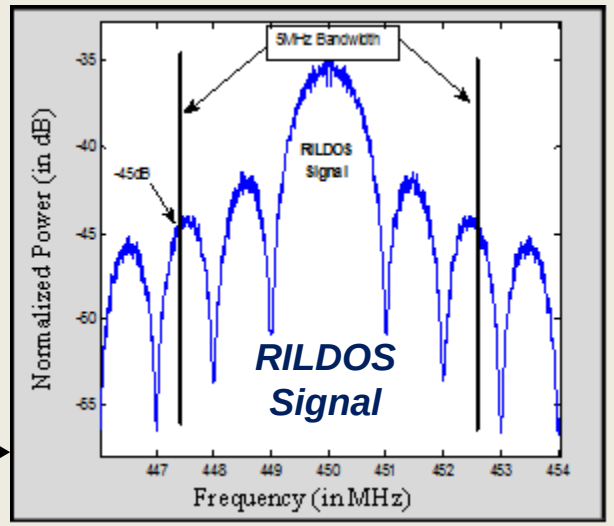
- RILDOS signal is broadcast at 50 bps using BSPK, Direct Sequence Spread Spectrum (DSSS), chipping at 1 Mcps
  - Null-to-Null bandwidth of 2 MHz and resultant secondary sidelobes are within 5 MHz UHF channel with no pulse shaping required
- NASA Return Mode 2 Short PRN Codes from *451-PN CODE SNIP (Rev 1)* libraries are used as the PRN codes
  - Allows 400+ unique PRNs for deconfliction and separation



Spread Spectrum Processing Gain

$$Gain = 10 * log_{10} (C_r/B_r)$$
$$Gain = 10 * log_{10} (1000000/50)$$
$$Gain = 43\ dB$$

Where C_r is the Chipping rate of the RILDOS Standard and B_r is information data rate of the RILDOS Standard



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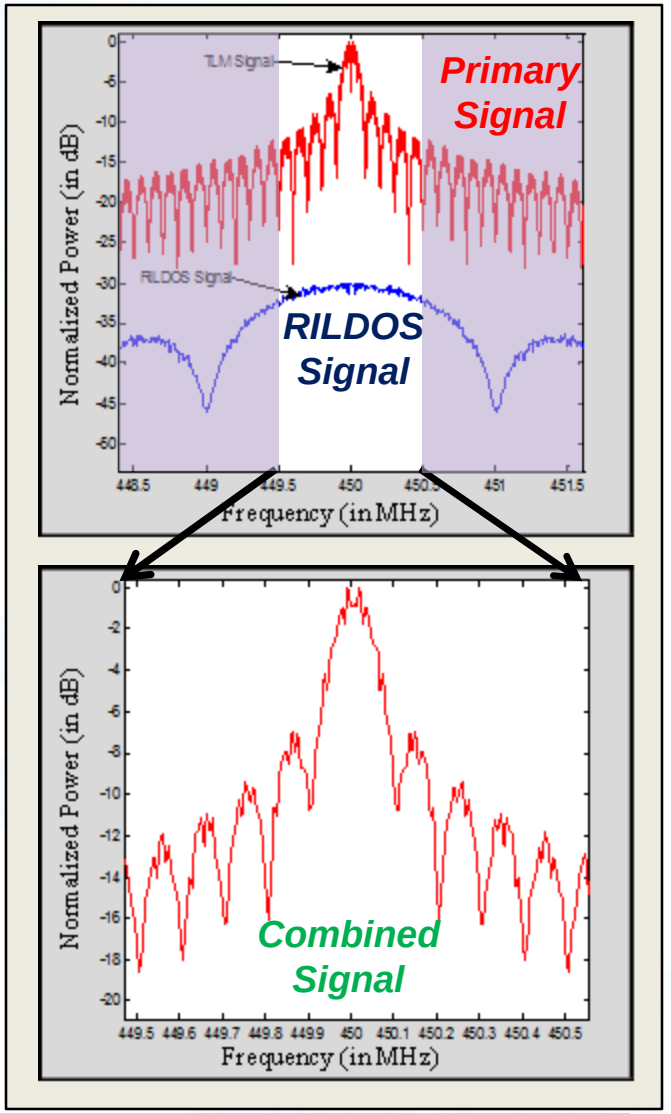
Integration with Primary Downlink

- RILDOS broadcast at the same center frequency as primary downlink
  - RILDOS signal must not interfere with primary downlink signal
- RILDOS transmit power is a function of the primary link's symbol rate
  - Incorporates gain from DSSS (+ 43 db)
  - No FEC is used, must be 15 db of Eb/No for error free data
- RILDOS can be transmitted with 30 db less than primary signal
  - May vary slightly, but will not need to be broadcast at more than 25 db below
  - Paper provides details for this calculation



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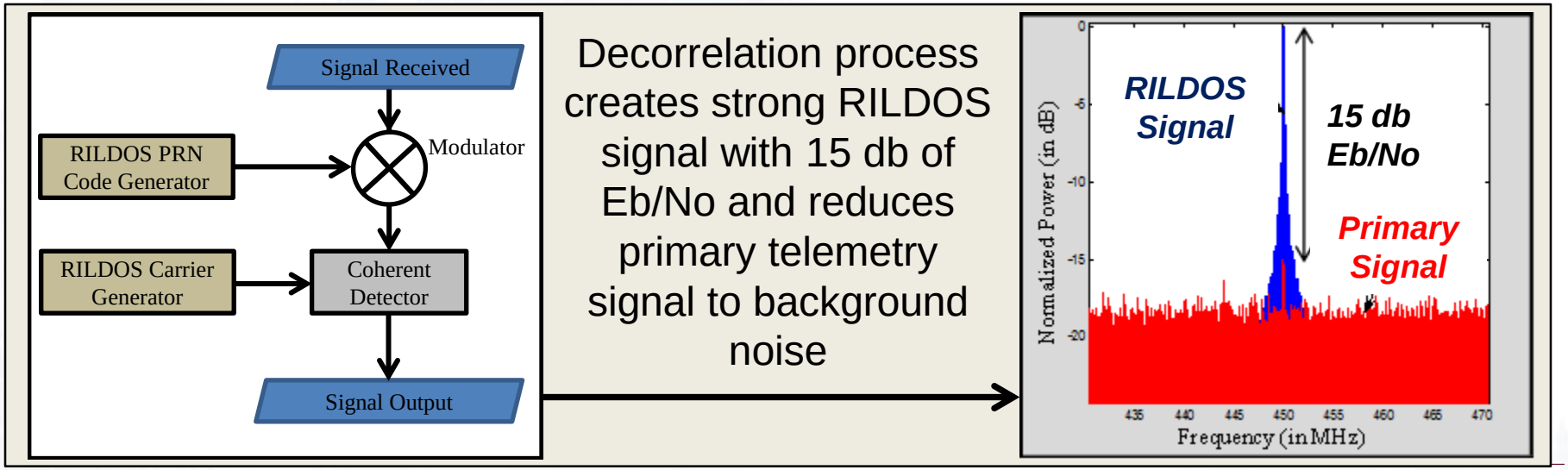
Receipt and Processing

- Receiver uses well proven DSSS techniques to decode RILDOS signal
  - Ground generated PRN time shifted via iterative process
- With known PRN, code acquisition is less than 2 seconds
  - Worst case time to full data frame is not greater than 20 seconds
- RILDOS and telemetry receiver can be in same modem
  - Independent receivers see the other signal as noise



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Operational Concepts

- Satellite Operator
  - Have RILDOS signal turn on at deployment and use on the first contact to determine which satellite in a cluster is belongs to them
  - Use the vehicle area in message as low power option for continuous low rate downlink to update users if RILDOS is left on to transmit
- Neighborhood
  - Orbital information from RILDOS can help confirm or rule out conjunction concerns from nearby or transiting satellites
  - Non-RILDOS enabled satellites could rule out RILDOS satellites as not theirs in a cluster
- Overall Space Situational Awareness
  - RILDOS monitoring can aid overall Space Catalog maintenance and provide unique data source for comparison to SSN

Next Steps

- Solicit Feedback from Small Satellite community
- Post complete RILDOS message and signal definitions
- Investigate IRAD for RILDOS radio system
  - Software defined space radio
  - Software defined ground modem
- Look for opportunities to integrate RILDOS on new mission
  - Find mission willing to add RILDOS radio as proof of concept