Sonobuoy Position Location using the Military P(Y) Code

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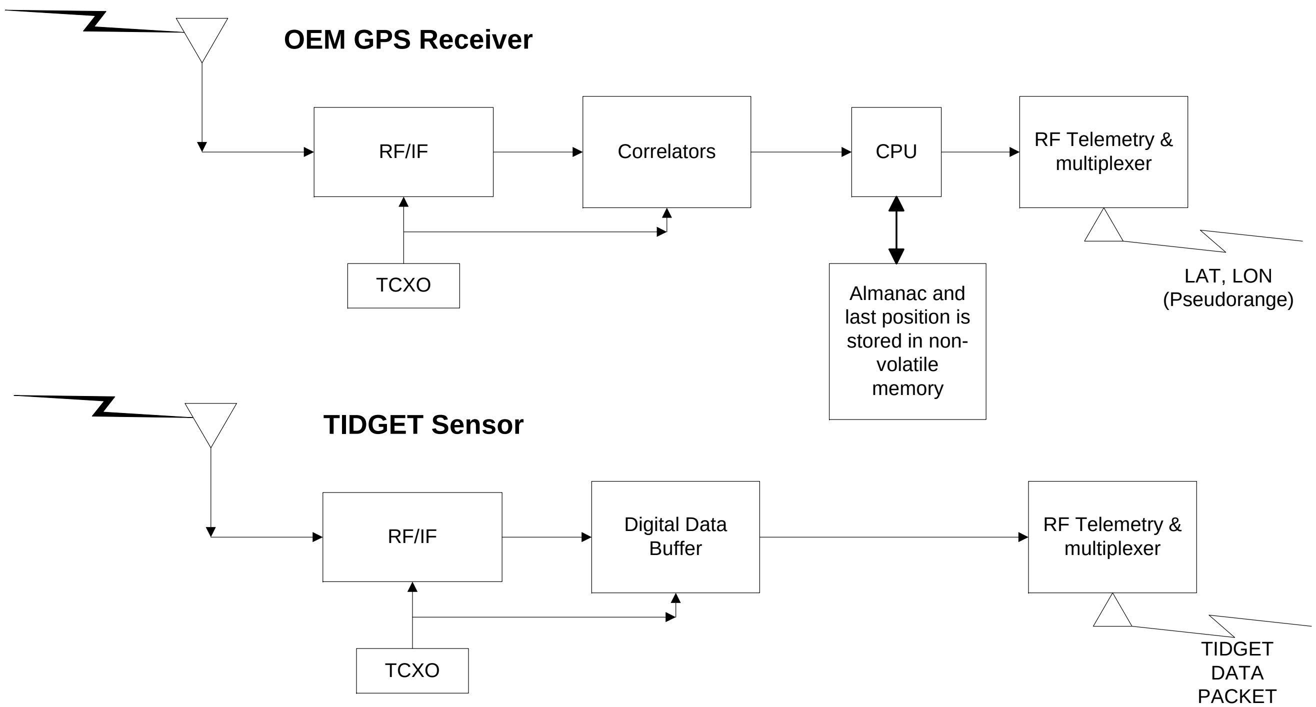
What is the Problem

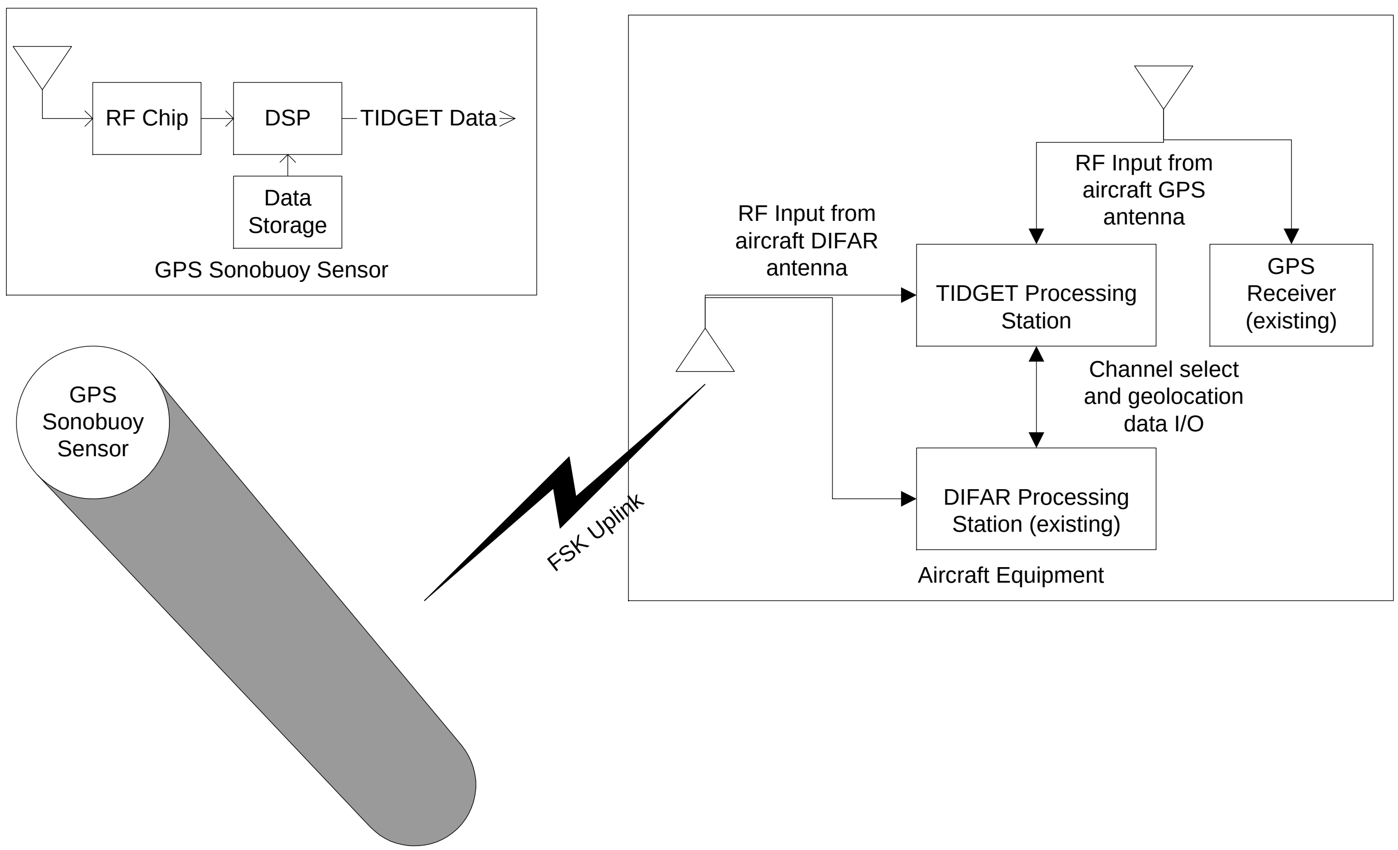
- Sonobuoys could benefit from precise GPS location to improve operations
  - Improve accuracy and reduce aircraft vulnerability
  - Allows networked sonobuoy positioning and stand-off operation
- OSD policy requires use of secure P(Y) code for GPS military applications
  - C/A code GPS can be easily spoofed or denied in a tactical environment
  - Current military GPS UE (SAASM) are too expensive for sonobuoy operation
- Conventional GPS solutions do not operate well in the challenging sonobuoy environment
  - High degree of masking due to antenna's low elevation above the sea surface
  - Long Time-To-First-Fix when coming out of storage. TTFF is also aggravated by high sea-states and/or high winds (up to hours!)
  - RF interference from 1 watt of power adjacent to antenna

Alternative GPS Architecture



- TIDGET allows use of commercial GPS chips on buoy with secure P(Y) code signal processing performed in aircraft
- Client/Server architecture facilitates operation in high sea-states and challenging sonobouy environment

P(Y) TIDGET Sonobuoy System Architecture



Desired GPS Sonobuoy Performance

- Position accuracy of < 100 meters
- Position refresh rate of < 3 minutes per buoy
- Uplink data link rate of 1200 bps

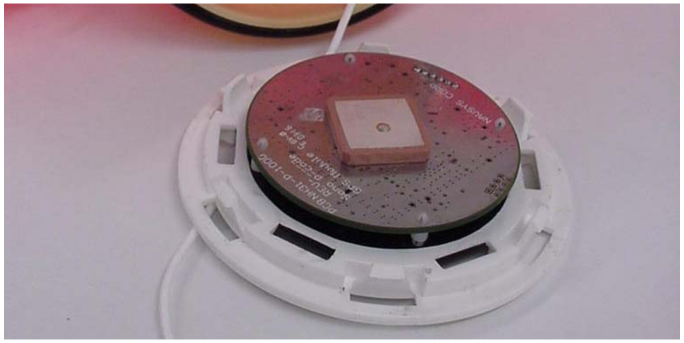
DIFAR SSQ-53-F Buoy

NAWC-AD funded an SBIR to build and test 5 prototype GPS DIFAR sonobuoys

P(Y) TIDGET Sonobuoy Design

- Sparton DIFAR Sonobuoy and Acoustic Processor.
  - Integrated P(Y) TIDGET sensor
  - Modified with GPS uplink data.
  - Design is backwards compatible with the existing DIFAR aircraft acoustic processor.
- TIDGET P(Y) Code Sensor mounted in the buoy float bag
  - Power supply regulation and switching
  - Low-cost P(Y) compatible RF front-end with integrated GPS patch antenna.
  - TIDGET data buffer and state-control functions
  - Sparton-designed GFSK (Gaussian Frequency Shift Keying) modulation circuit, outputting the modulation signal to the buoy electronics.

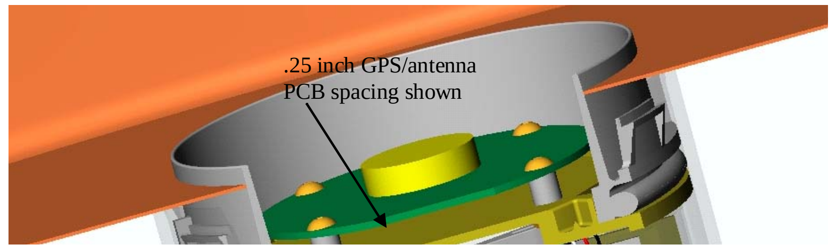
TIDGET assembly uses all Commercial Components

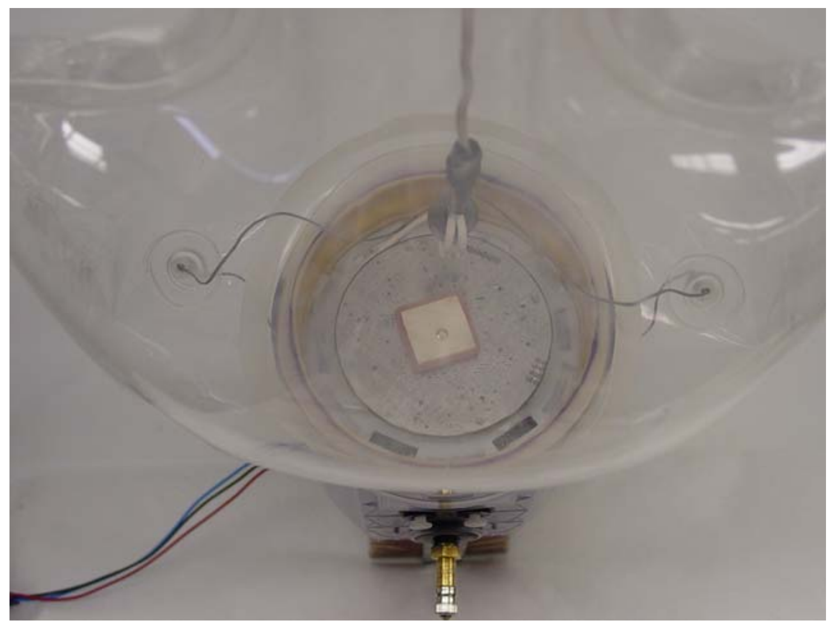


- TIDGET circuit board mounted in surface unit
- Includes GFSK modulation circuit

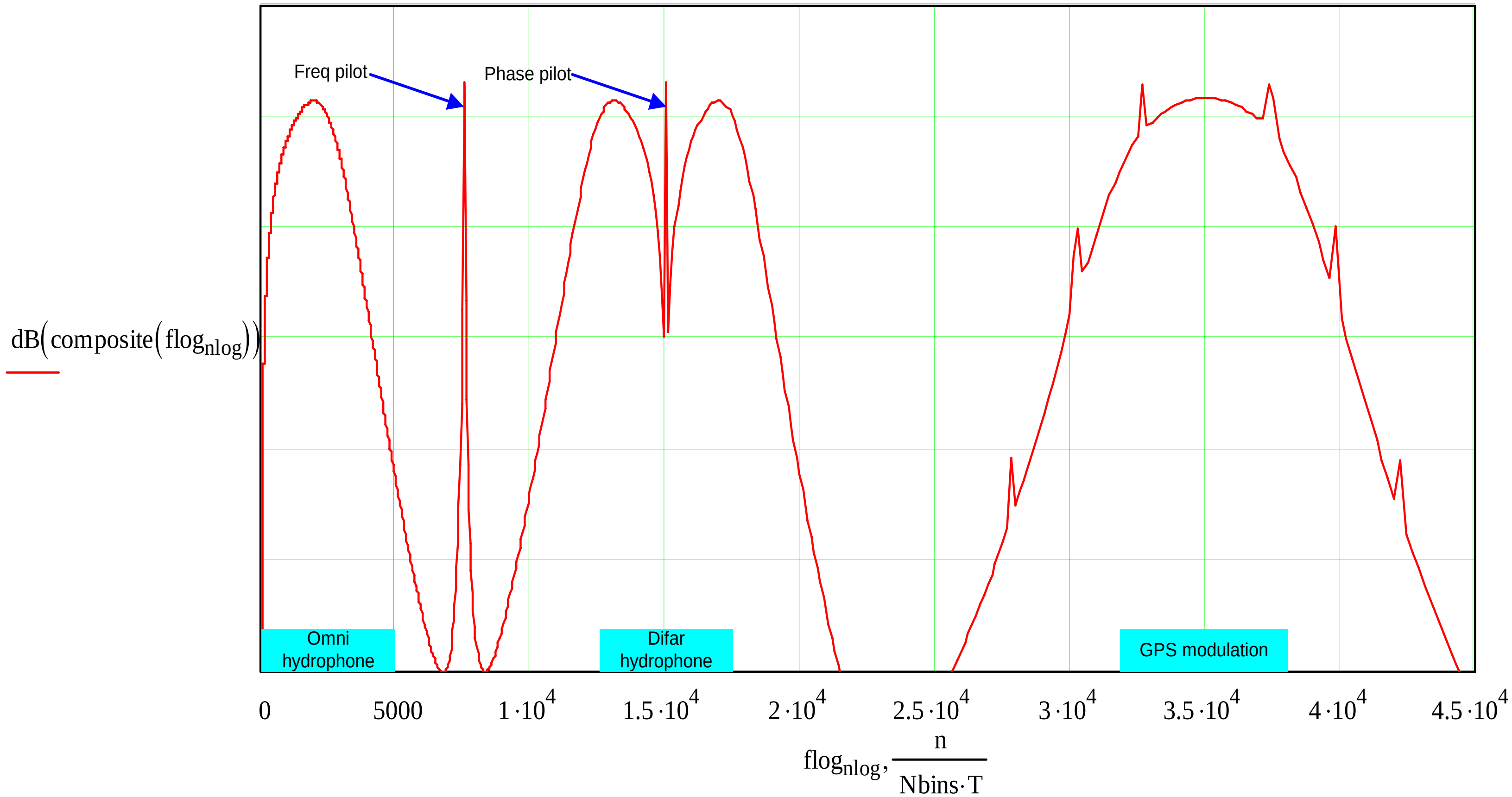
Q-53F Buoy with TIDGET Card

- The weight and overall form factor of the Q-53F buoy with added GPS capability remain unchanged.
- The bare buoy weighs 18.6 lbs and the buoy with sonobuoy launch container (SLC) weighs 23.6 lbs.





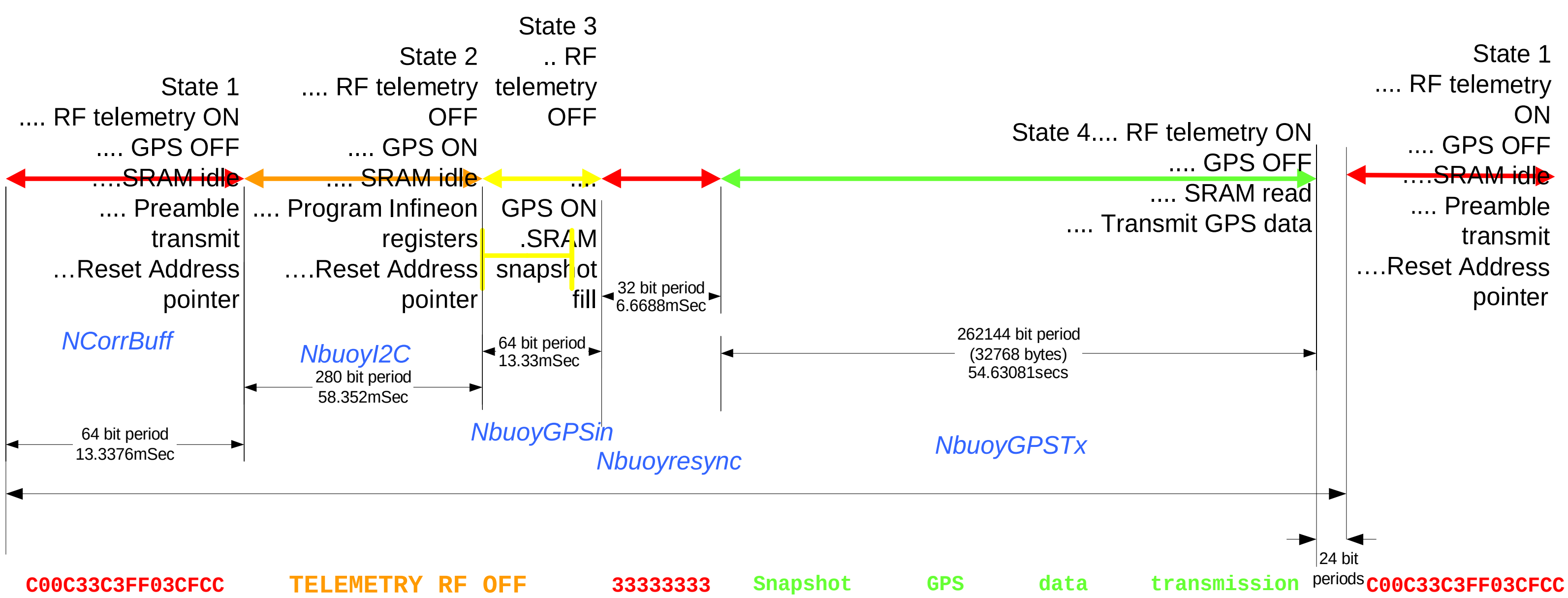
DIFAR Composite Spectrum



GPS Modulation added as a 4800 Baud GFSK Pseudo-Random Bit Stream

Does not affect existing Sono Data demodulation as above current channel pass-band

Telemetry Sequence



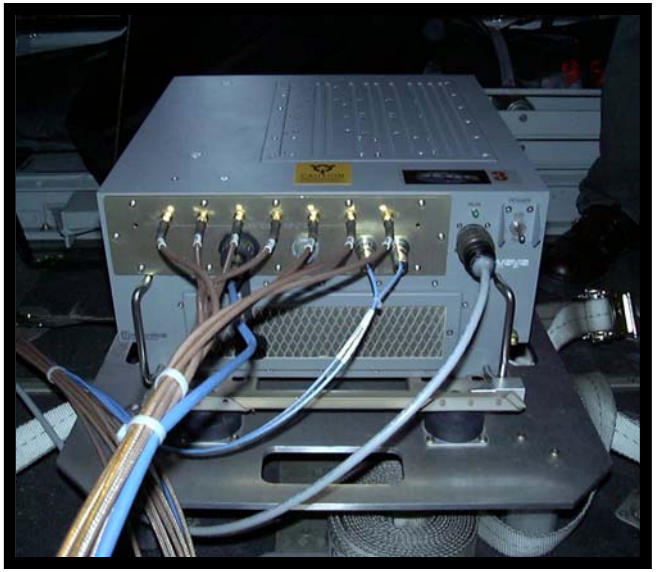
- Data rate = 40000000/8336 =4798.4644913 bps
- Snapshot = 6.55 mSecs
- Frame Length = 262608 bit period = 54.7275seconds

Telemetry uplink briefly gated off during GPS snapshot collection to avoid interference

Aircraft Processing Unit

Sonobuoy Software Defined Radio Processing uses 3 Waveforms

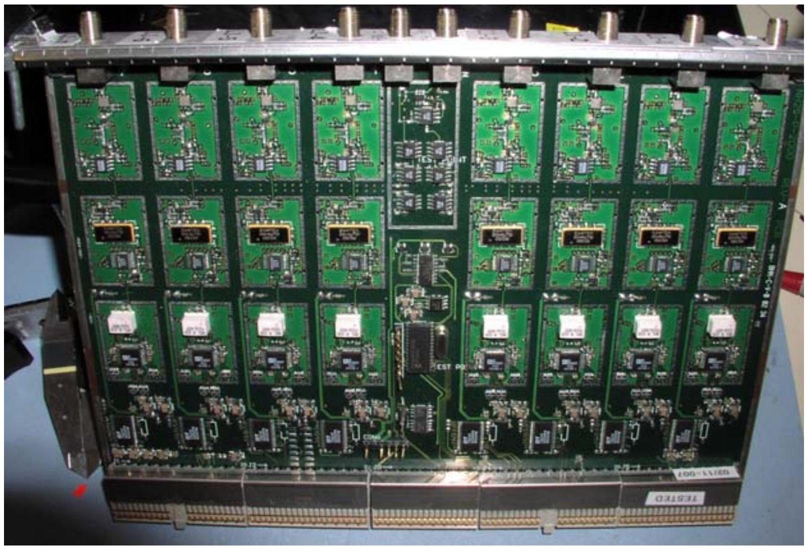
- GPS Waveform
  - GPS L1 P(Y) Code
  - Includes PPS-SM Security Processor
  - Provides GPS reference data
- Sonobuoy Telemetry Waveform
  - Data Processing for GFSK demodulation
  - Acquisition, Tracking, Data demodulation and Frame Sync
- TIDGET Processing Waveform
  - P(Y) Correlation on TIDGET data
  - Computes Sonobuoy navigation solution



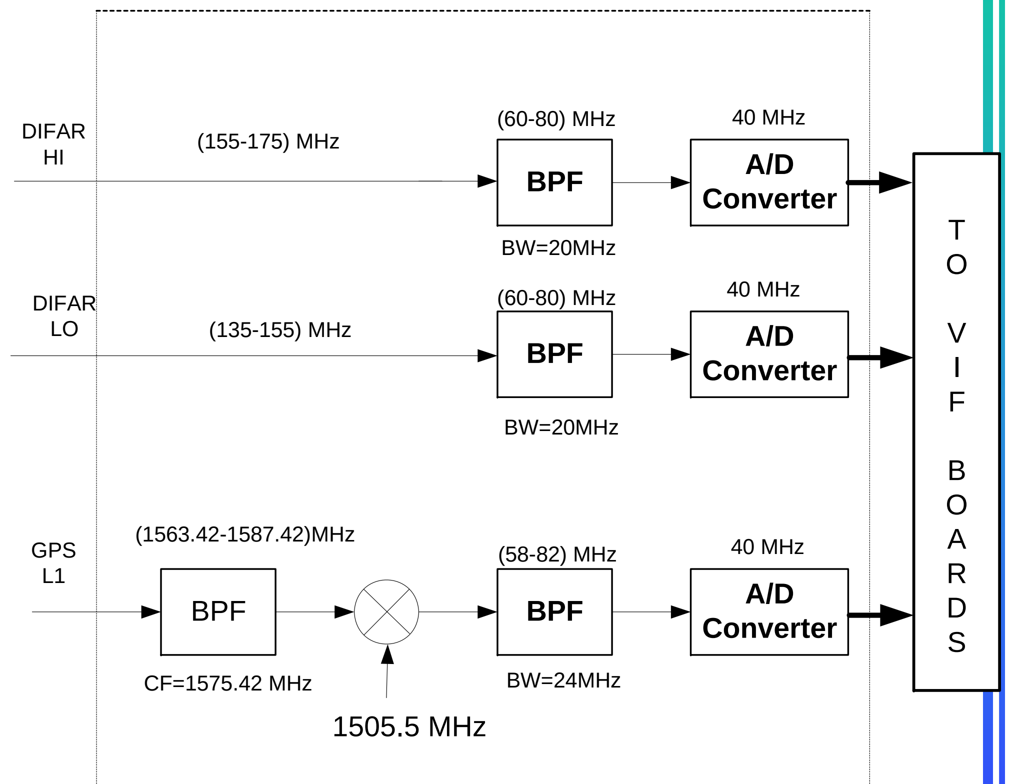
Sonobuoy Test-Bed used a Compact PCI Software Defined Radio (SDR)

1 ½ ATR Aviation SDR has now been purchased by NAVAIR

Software Defined Radio DIFAR/GPS Digital Front-End

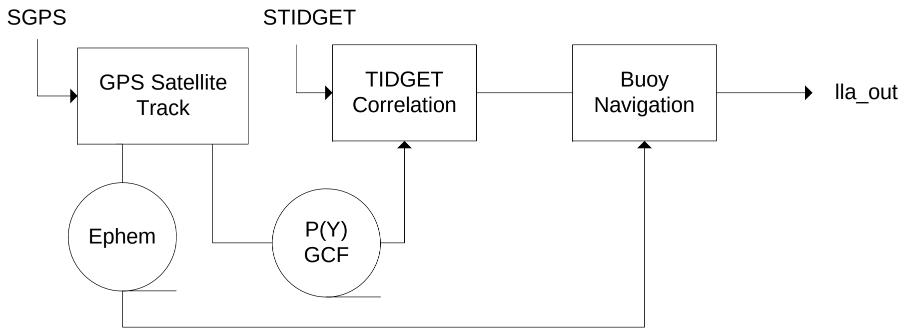


- Receives both GPS and DIFAR uplinked signals
- DIFAR Channel selectable through software control



TIDGET Waveform Processing

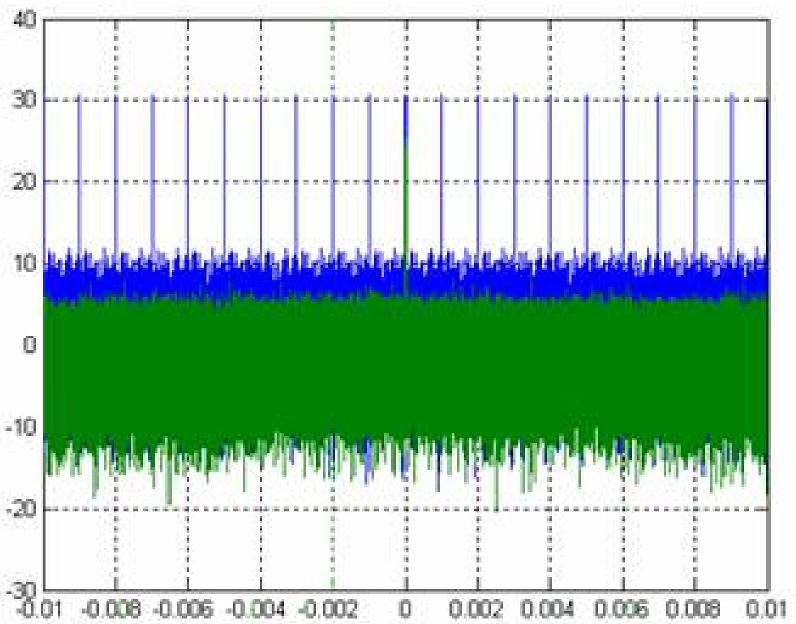
- TIDGET data provided by Telemetry Waveform
- TIDGET Correlation generates pseudo-ranges
- Buoy Navigation computed using Kalman Filter



- P(Y)-code (10.23Mbps) recorded by GPS Waveform
- Ephemeris data provided by GPS Waveform

TIDGET Waveform Results

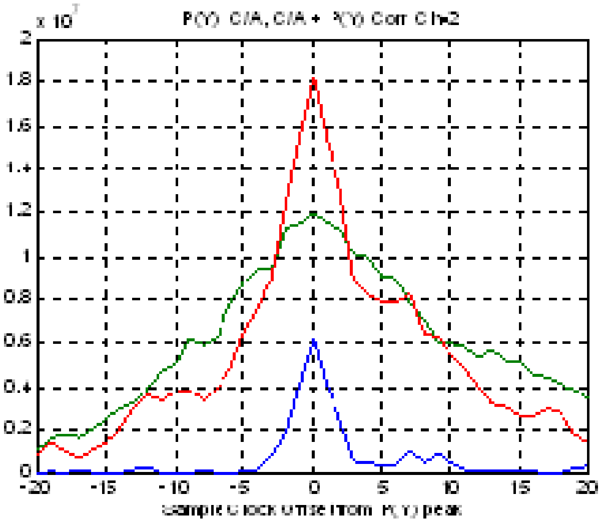
- C/A and P(Y) Correlations are computed for all visible satellites
- P(Y)+C/A correlation peaks used to detect which satellites can be tracked
- Sonobuoy mask angle and wave motion will cut-off some satellites

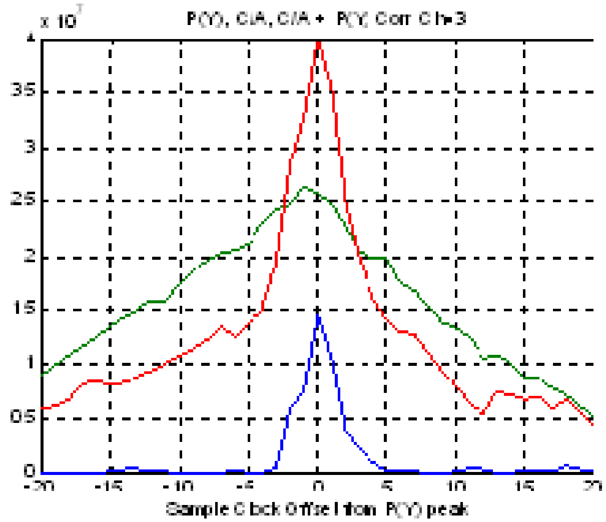


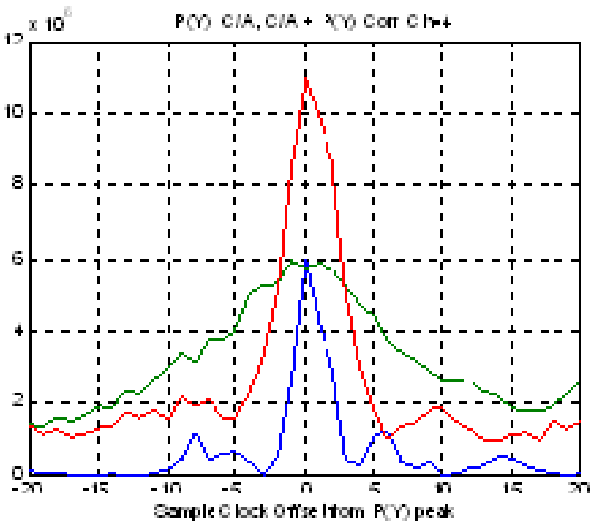
C/N0 (dB-Hz) for Channels 0 through 7

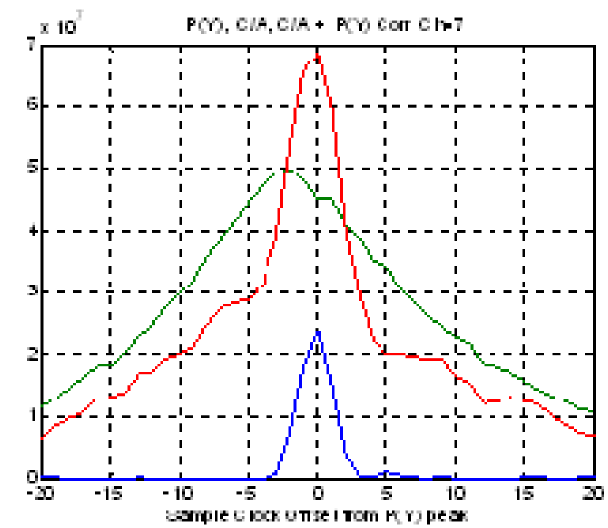
C/A	23.4448	17.3604	38.4201	41.7175	35.2154	15.8219	18.9964	44.1526
P(Y)	32.2919	30.8377	35.5640	39.2597	35.3738	32.2720	32.0136	41.4152
P(Y)+C/A	27.8612	25.9788	40.2327	43.6369	38.0287	28.8691	29.0887	45.9957

Channels where SV Signal Detected

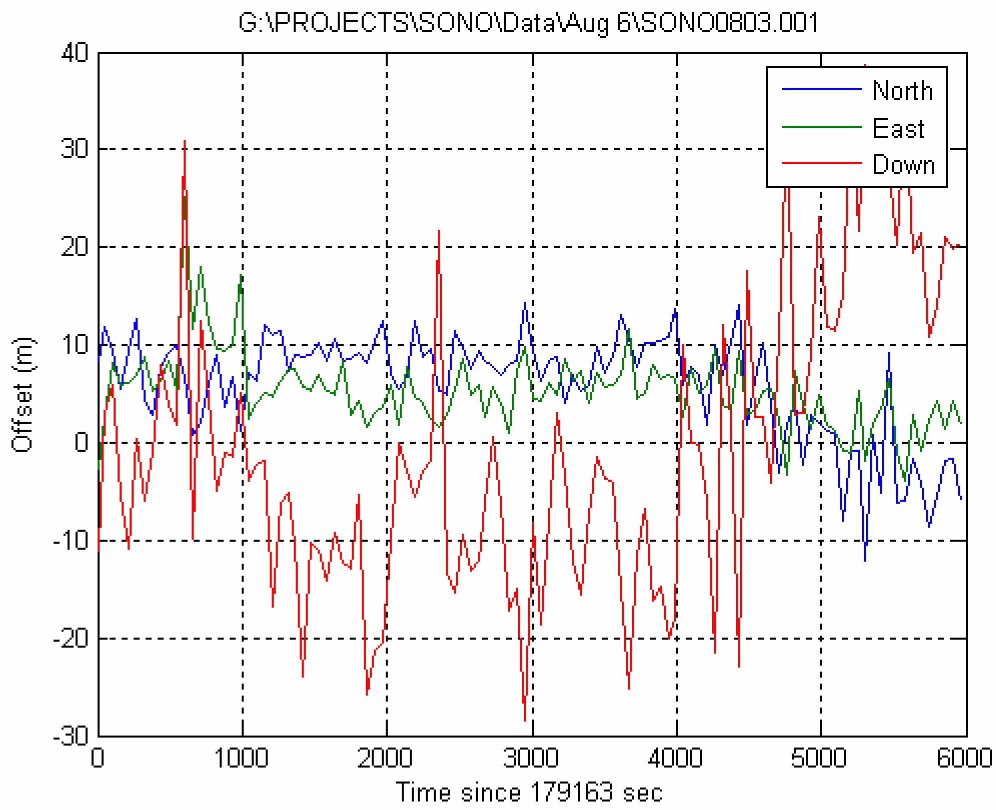








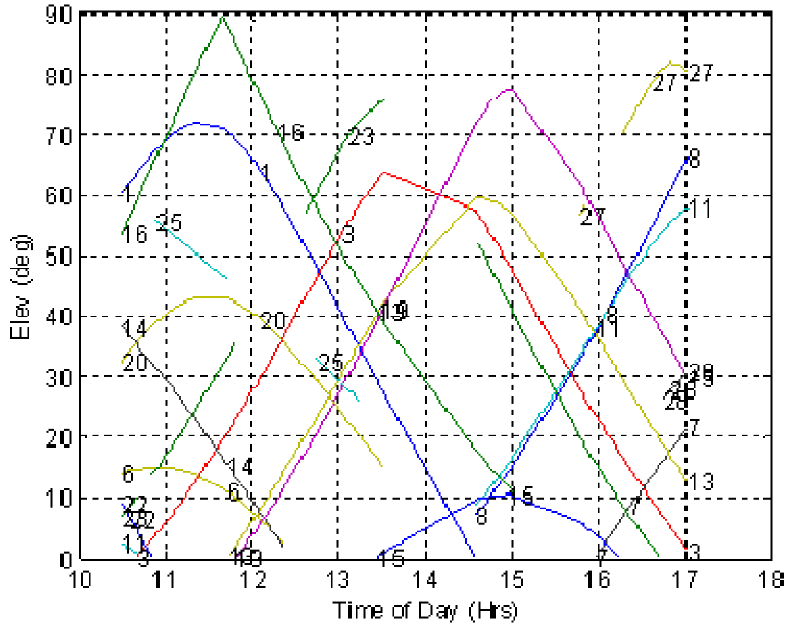
Lab Test - Sonobuoy Navigation Data

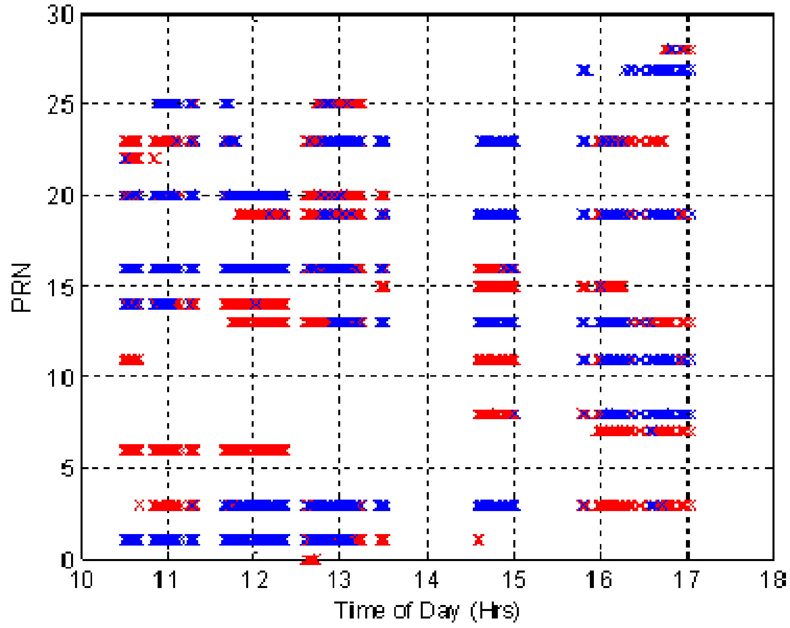


Sea Trial at New Smyrna Beach, FL

- Five Buoys were deployed between 10:25 am to 5 pm on October 26, 2004
- The sea state through the trial was 4-5 with a 6-8 foot swell
- After each buoy deployment the boat was allowed to drift several hundred meters downwind before being motored back into the buoy field.

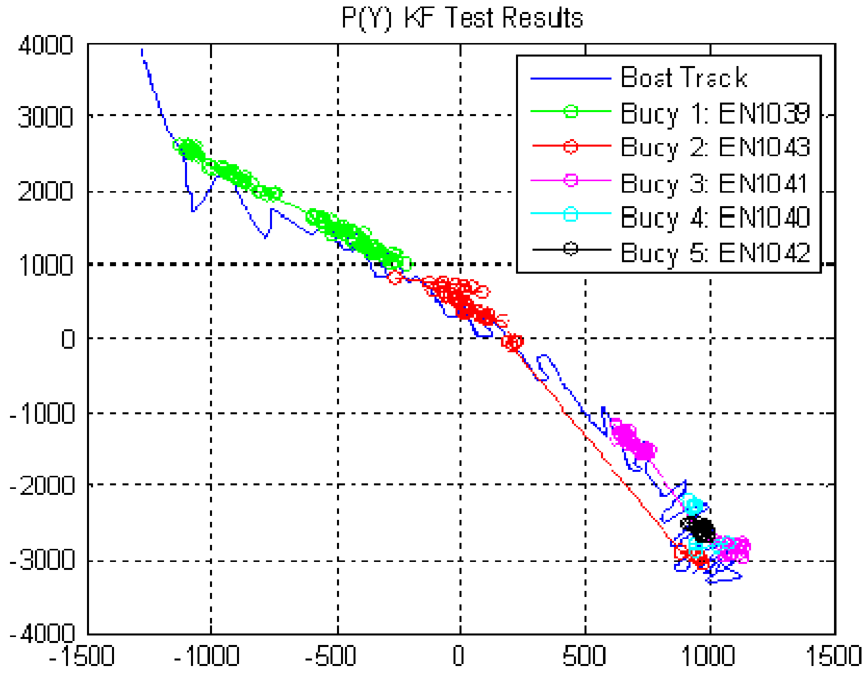
Satellites Tracked during Sea Trials





Satellites below 30 degrees in elevation were rarely tracked (Predicted mask angle was 18.5 degrees). The additional masking may be due to wave obscuration or the buoy may be sitting lower in the water than was assumed

Boat Tracks and Buoy Tracks (units in meters)



Test successfully demonstrated Client/Server P(Y) code Sonobuoy operation in Sea State 4-5 using a Software Defined Radio for the GPS signal processing

GPS Sensor Trade Study Summary

Sensor Type	C/A GPS Engine	SAASM Engine	P(Y) TIDGET
Provides PPS solution	No	Yes	Yes
Does not require Buoy Initialization pre-launch	No (Initialization needed to reduce TTFF in high sea state)	No (Both keying and initialization needed)	Yes
Data-Link bandwidth requirements	Low	Low	Medium (4800 bps)
Security requirements	Not compliant with GPS Security policy for combat support	Security device is on Buoy - Must be zeroized prior to mission end	None – all security devices on aircraft
Estimated Cost	<$150 (including telemetry uplink)	$2800 (+ telemetry uplink)	<$180 (with telemetry uplink and in large volume production)
Modifications to aircraft	Buoy initialization device required	Buoy initialization device required	Software Defined Radio required (could use JTRS on aircraft)

Conclusion

- P(Y) TIDGET provides low cost, secure solution for sonobuoy positioning using GPS
- SBIR project resulted in a design for embedding GPS sensor into existing DIFAR sonobuoys
- Software Defined Radio was used to perform DIFAR Telemetry, GPS and TIDGET processing
- Sea Trials have demonstrated capability to provide secure P(Y) code GPS positioning capability for sonobuoys in sea-state 4-5
- Parts for additional sonobuoys have been purchased to allow for further sea-trials and operational evaluation
  - NAWC-AD POC: Rich Sensenig, Pax River