Two-Way Update

Presented by

Microcom Design, Inc.

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General Two-Way History

- Long been a desire of the DCS community to have a communication link to the remote DCPs.
  - The addition of two way communications would considerably enhance the value of the entire DCS system.
  - Also known as DCPI (interrogate) and DCPC (command).
- Original 1965 design was based on Interrogate Operation
  - DCPI was never widely utilized due to limited capability and cost of receivers.
  - DCPI link terminated around 2005 since it did not meet NTIA Power Spectral Density (PSD) requirements.
- Work by NOS/Sutron (circa 2007-2009) proved feasibility of a spread spectrum approach to meet PSD.
  - DCPC utilized Direct Sequence Spread Spectrum (DSSS).
  - Never fully implemented by NOAA.
- Two-Way transponders have always been available.
  - GOES-R series satellites include DCP I/C transponder, but may be removed from future satellites if not utilized.

2015 Two-Way Study

- In 2015, NOAA tasked Microcom with performing comprehensive study on resurrecting the Two-Way
- Two-Way Link Concerns:
  - DCS is an NTIA Secondary Licensee on non-Interference basis with FCC Primary Licensees
  - Primary Licensee is Land Mobile Radio (LMR).
- Study results presented at April TWG and formal report submitted to NOAA In July.
- 2015 Study Key Recommendations:
  - Frequency Hopping Spread Spectrum (FHSS) instead of DSSS.
    - FHSS will perform better in busy LMR environment.
  - NOAA to fund and provide reference receiver design.
  - Utilize DADDS to provide secure User interface for sending commands, confirming receipt, and delivering response.
  - Synchronize hop pattern, packet structure and error correction (Reed-Solomon) to UTC.
    - Quicker acquisition when time known, allows time sync when not.

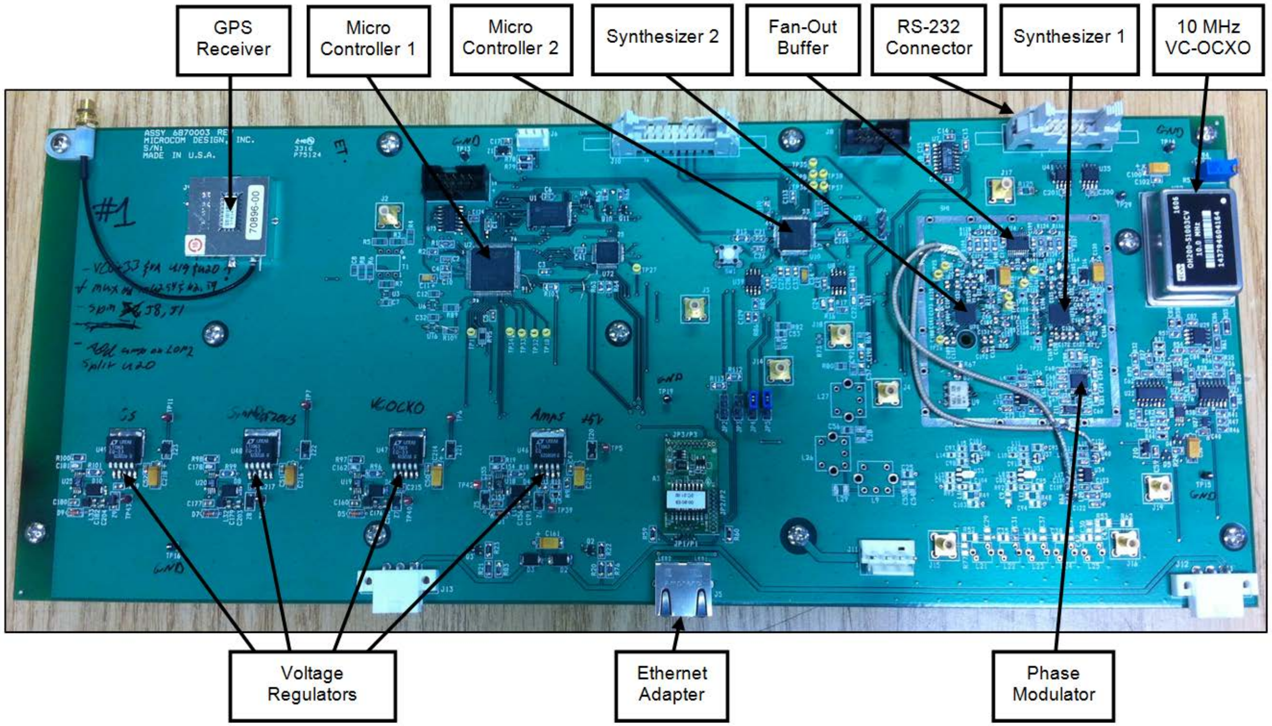
2016 Two-Way Study

- In 2016 NOAA authorized Microcom to perform a follow-on study to further confirm the FHSS recommendation.
- 2016 Study Goals
  - Extend simulation models to better confirm FHSS performance in presence of LMR interference.
  - Evaluate impact on Bit Error Rate (BER) with truncated RS (250,218).
- Study results presentation at May TWG.
- 2016 Study Key Results
  - Simulations confirmed only minor BER degradation in the presence of two simulated, 20 dB stronger LMR signals.
  - Negligible performance difference for shortened RS (250,218) versus (255,233); shortened code showed slight improvement.
- Following 2016 TWG, NOAA requested proposal to build prototype modulator and demodulator for bench test.
- Bench prototype work began in the fall of 2016.

Two-Way Project Status

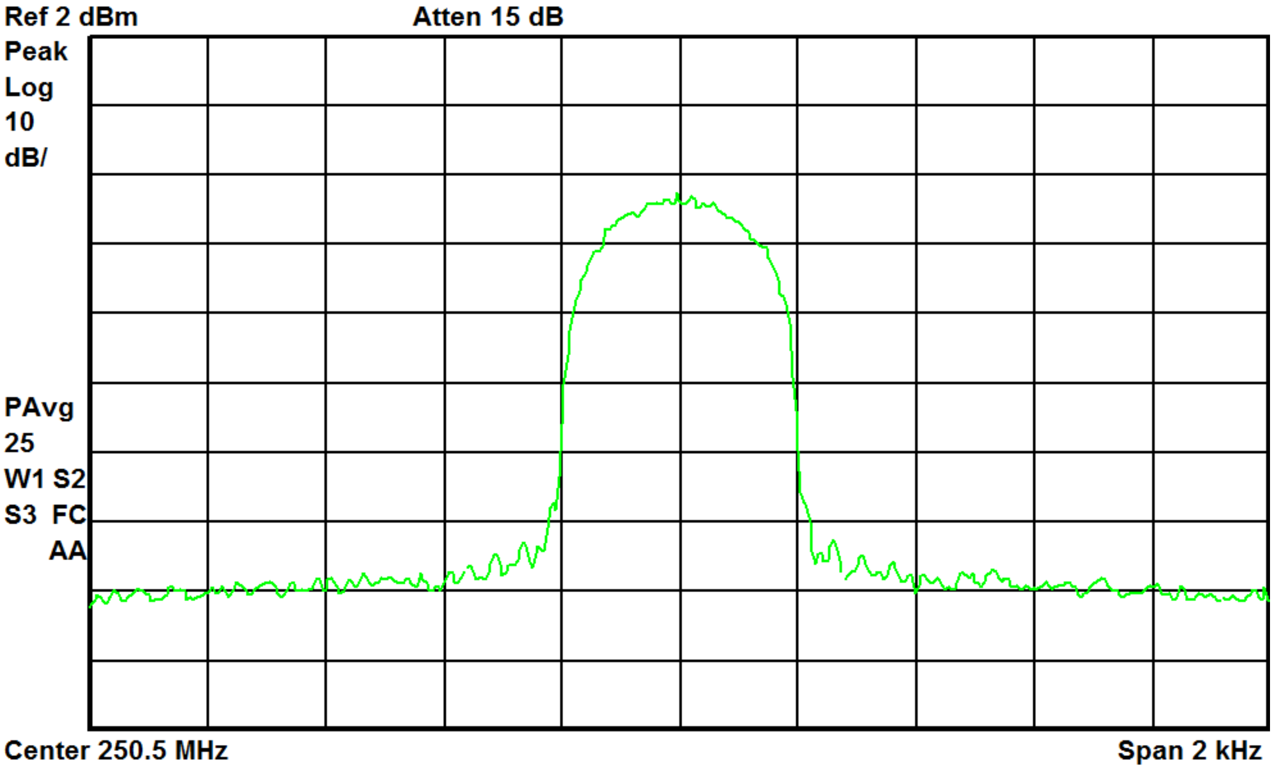
- Two-Way bench prototype put on hold due to budget and priority concerns in early 2017.
- Unexpected DCS Management change and focus on GOES-16 further delayed resuming project.
- In early October 2017, NOAA authorized resumption of work on bench prototype.
- Progress has been good, but running slightly behind target schedule.
  - Changed from TI TM4C123 ARM processor to TI AM3358 ARM due to CPU utilization concerns.
  - Performance of AM3358's integral ADC proved not as good as TM4C123 and required integrating external ADC into prototype design.
- Prototype modulator and demodulator have been mated, and Microcom is getting close to performance testing.

Bench Prototype – Modulator



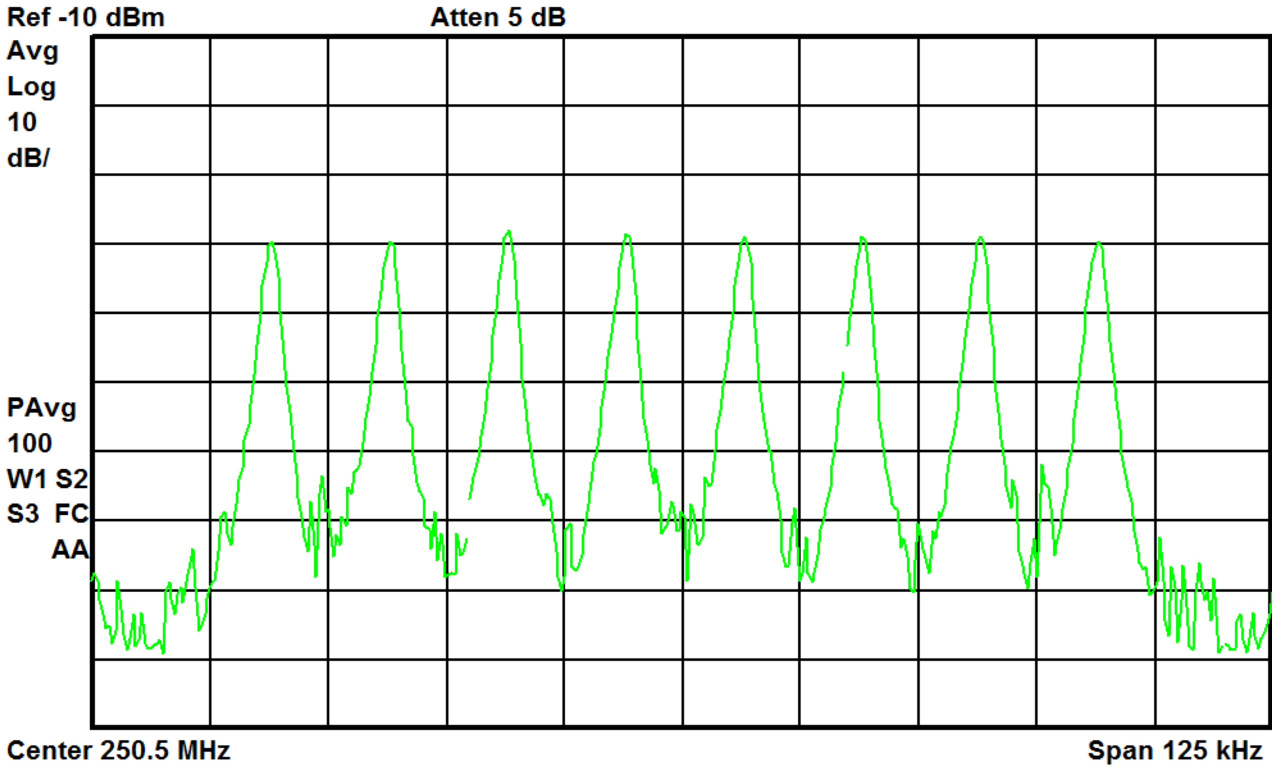
- Modulator completed in 2016; custom design based on DCS Pilot/Test Transmitter previously designed for NOAA.
- Can produce a variety of test signals to support the demodulator development; including desired FHSS BPSK signal at 200 bps with pseudo-random data.

Modulator – Un-hopped Output Spectrum



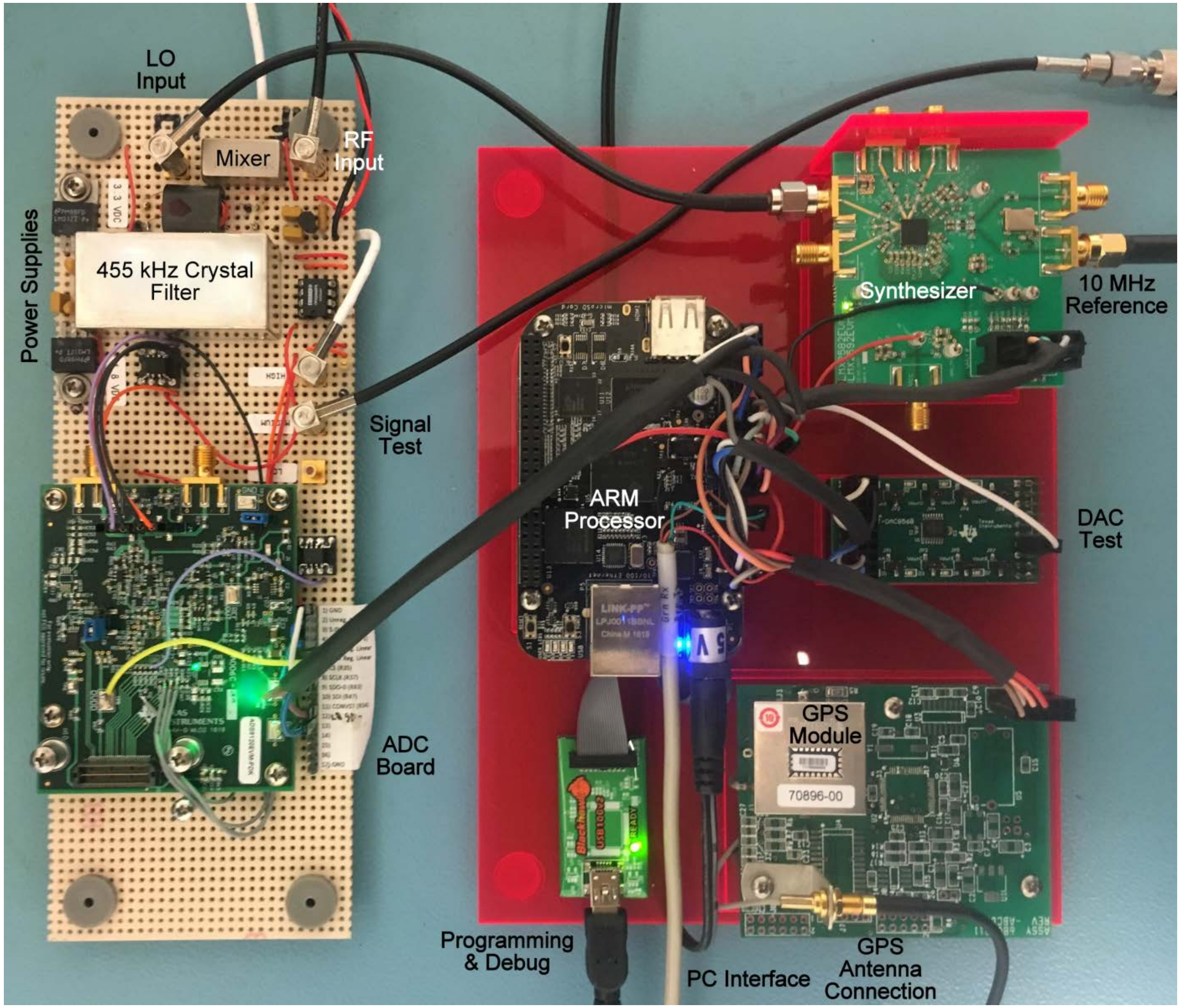
- Modulated signal from un-hopped output.
- Biphase random data at 200 symbols per second (sps).

Modulator – Hopped Output Spectrum



- Modulated FHSS output with long-term average.
- Eight frequency hops spaced at 12.5 kHz.
- LMR signal would appear at vertical divisions.

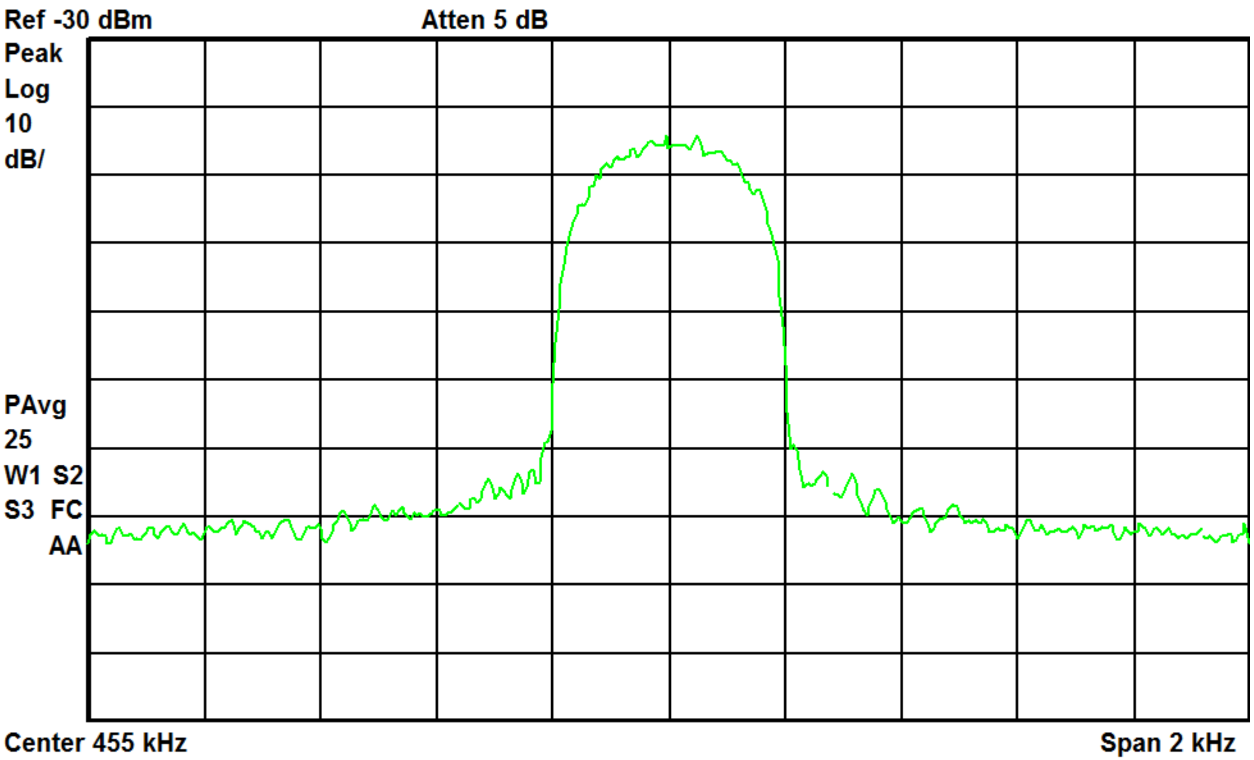
Bench Prototype – Demodulator



Bench Prototype – Demodulator Functionality

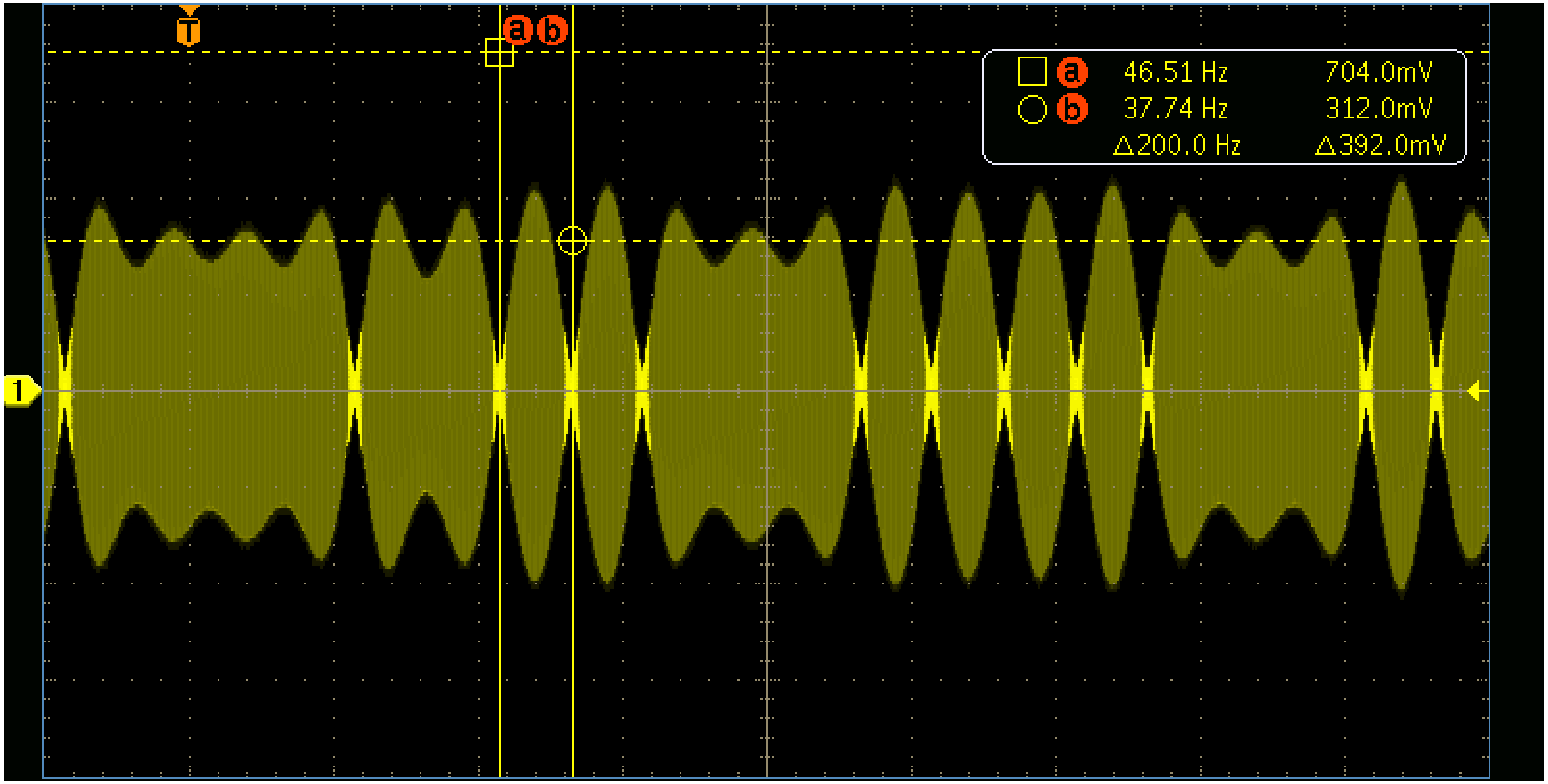
- Demodulator built from several off-the-shelf evaluation boards along with custom breadboard circuits.
- Demodulator Hardware Functions Implemented:
  - Precision synthesizer to produce Local Oscillator (LO) for both single frequency and hopping pattern.
  - Mixer stage to produce 455 kHz IF.
  - Narrowband (~1kHz) crystal filter for noise and LMR signal rejection.
  - Pre-ADC IF amplifier stages.
  - GPS module for time synchronization.
  - High sample rate Analog to Digital Converter (ADC).
- Demodulator Software and Digital Signal Processing (DSP)
  - ADC sampling of a 455 kHz IF with …
  - Direct digital down conversion to 5 kHz IF and digital 5 kHz LO.
  - Costas loop phase lock on both un-hopped and hopped input.
  - Baseband filtering, bit recovery, and byte framing.
  - LO Hop pattern synchronized to GPS/UTC.

Demodulator – 455 kHz IF Spectrum



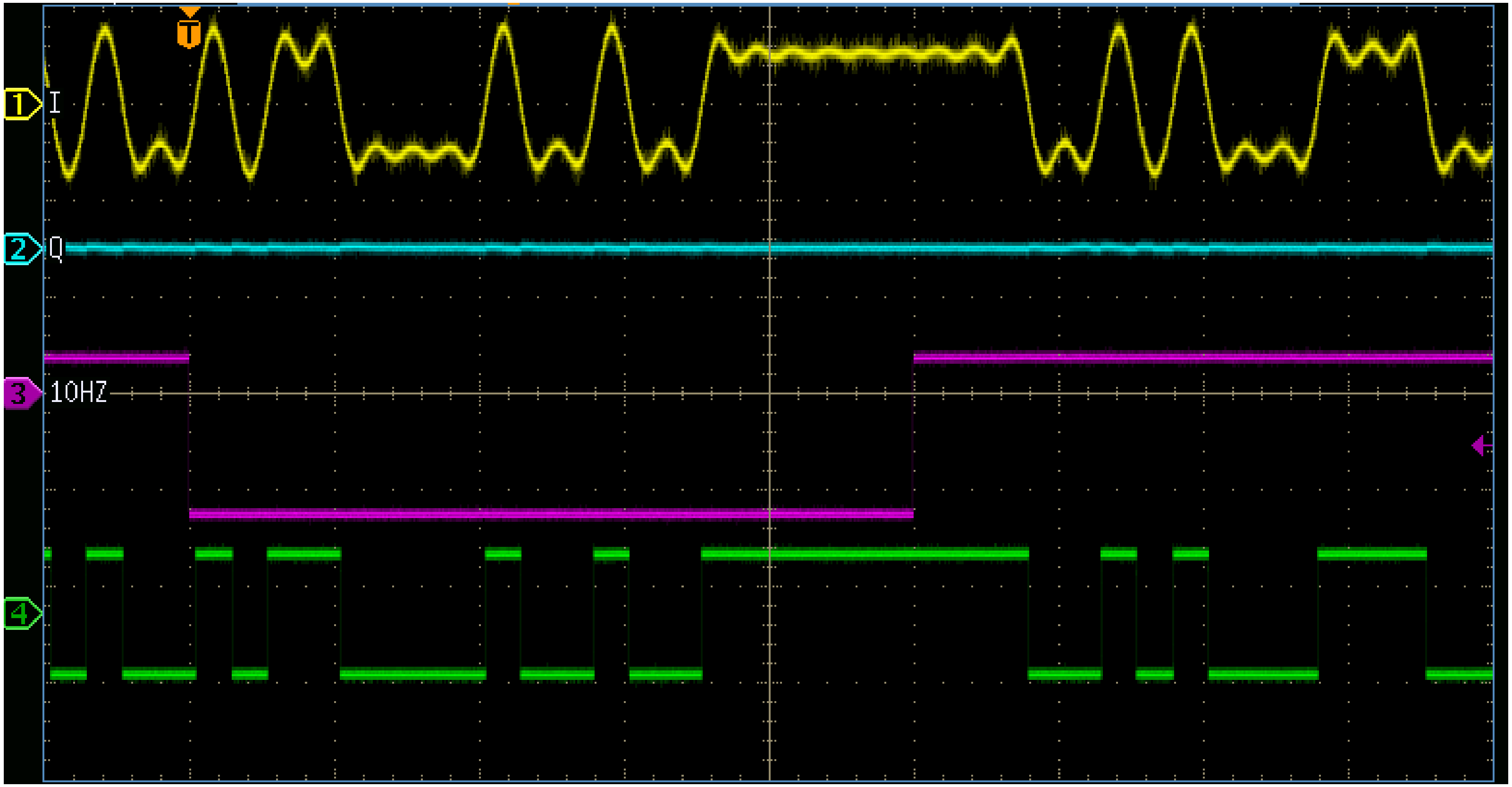
- De-hopped 455 kHz IF produced from mixing FHSS modulated signal with hopped LO.
- No significant signal/hopping noise outside RRC lobe.

Demodulator – 455 kHz IF Scope Trace



- **IF signal just before ADC sampling.**
- **Biphase random data present at 200 sps.**
- **Root Raises Cosine (RRC) envelope readily apparent.**

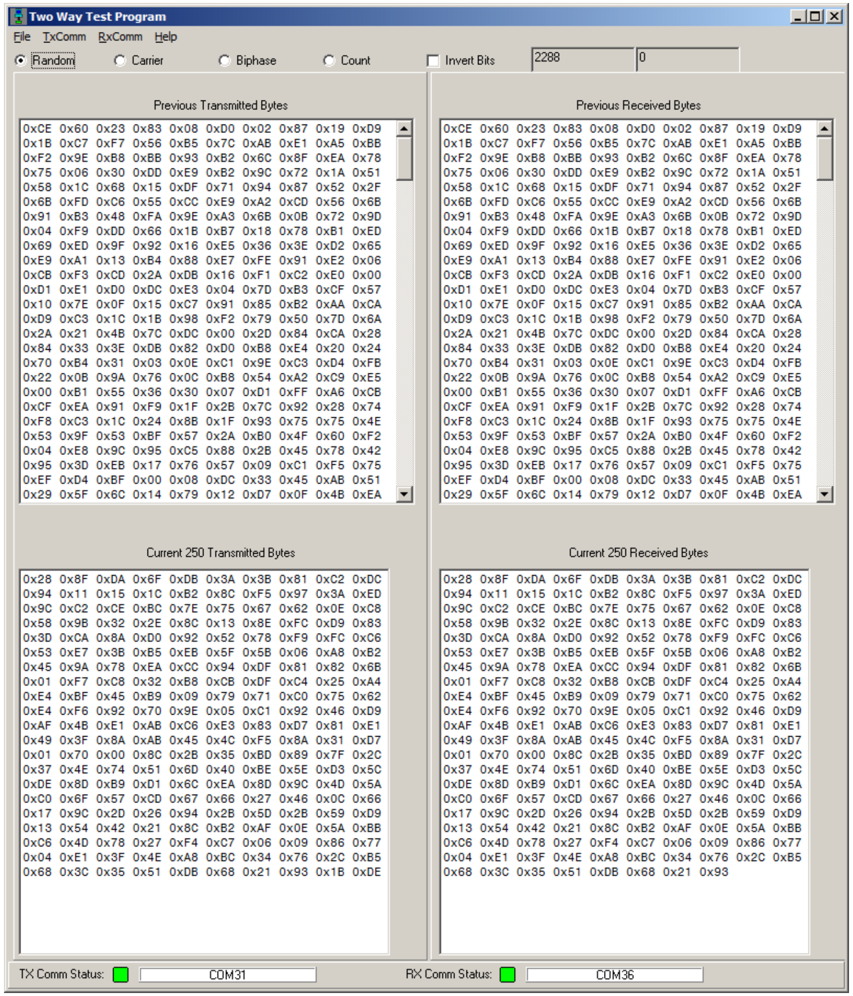
Demodulator – Baseband I/Q and Bit Sync



- Costas loop allows phase modulated data to be recovered; In-Phase (1) component carries data and Quadrature (2) component indicates stability.
- Bit timing synchronized to 0.1 second hops (3).
- Bits (4) extracted and formatted into bytes for capture by …

Bench Prototype – Test Utility

- Interfaces to both modulator and demodulator.
- Supplies Modulator with pseudo-random data in Reed Solomon encoded blocks.
- Ingests framed data from Demodulator.
- Will score both raw Bit Error Rate (BER) and corrected BER (still in process).
- Performance tests will be done with Additive White Gaussian Noise (AWGN) and simulated LMR signals.



Bench Prototype – Next Steps

- Bench Prototype.
  - Finalize Test Utility
  - Initial performance tests.
  - Demodulator fine tuning.
  - Final performance testing.
  - Prepare summary report with findings and submit to NOAA.
- Possible Future Tasks – Subject to NOAA Approval
  - Over-the-Air Test/Demonstration
    - Extend bench prototypes to prototype Transmitter and Receiver.
    - Will need to account for ~0.24 second travel delay at receiver.
    - Possibly implement packet protocol to include time information.
    - Confirm performance results in Over-the-Air test using GOES-16.
  - Data Rate and Error Coding Evaluation
    - Possibly consider alternative error coding schemes.
    - Evaluate the potential for increase in data rate.
  - System Demonstration
    - Tie Over-the-Air prototypes to DADDS to demonstrate Two-Way command initiation, DCP response, and DADDS acknowledgement.