Update on Two-Way Development

Presented by

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Two-Way Update – Over-the-Air Summary

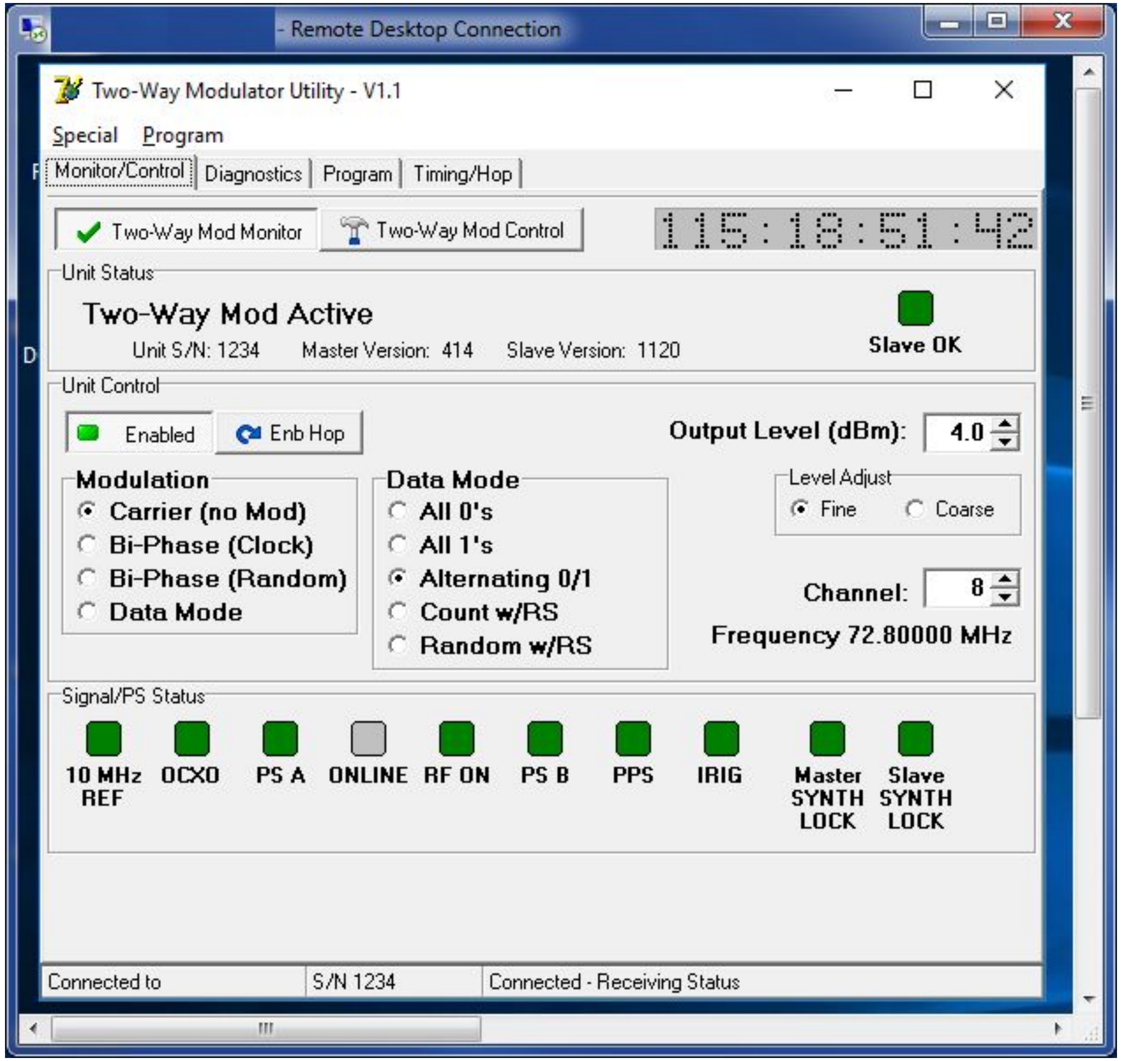
- Project consisted of thee major tasks:
  - Verify operation of the Two-Way Modulator installed at WCDA.
  - Measure the BER of the Two-Way signal at the allowed PSD.
  - Demonstrate the ability to synchronize and advantages of synchronizing transmitted Two-Way signal to UTC at the satellite.
- Modulator install completed November 22ND 2019.
- Two-Way Over-the-Air BER testing - on hold.
- Hop synchronization can be manually adjusted, but will ultimately need automatic alignment and tracking.
- Reliably receiving data at expected SNR at the correct PSD.
- Received signal level is in agreement with the calculated link margin analysis.

Two-Way Update – Modulator Install

- Instillation was successfully completed in one day and the Two-Way Modulator was allowed to provide the DCPC (aka Two-Way) uplink signal for GOES-East.

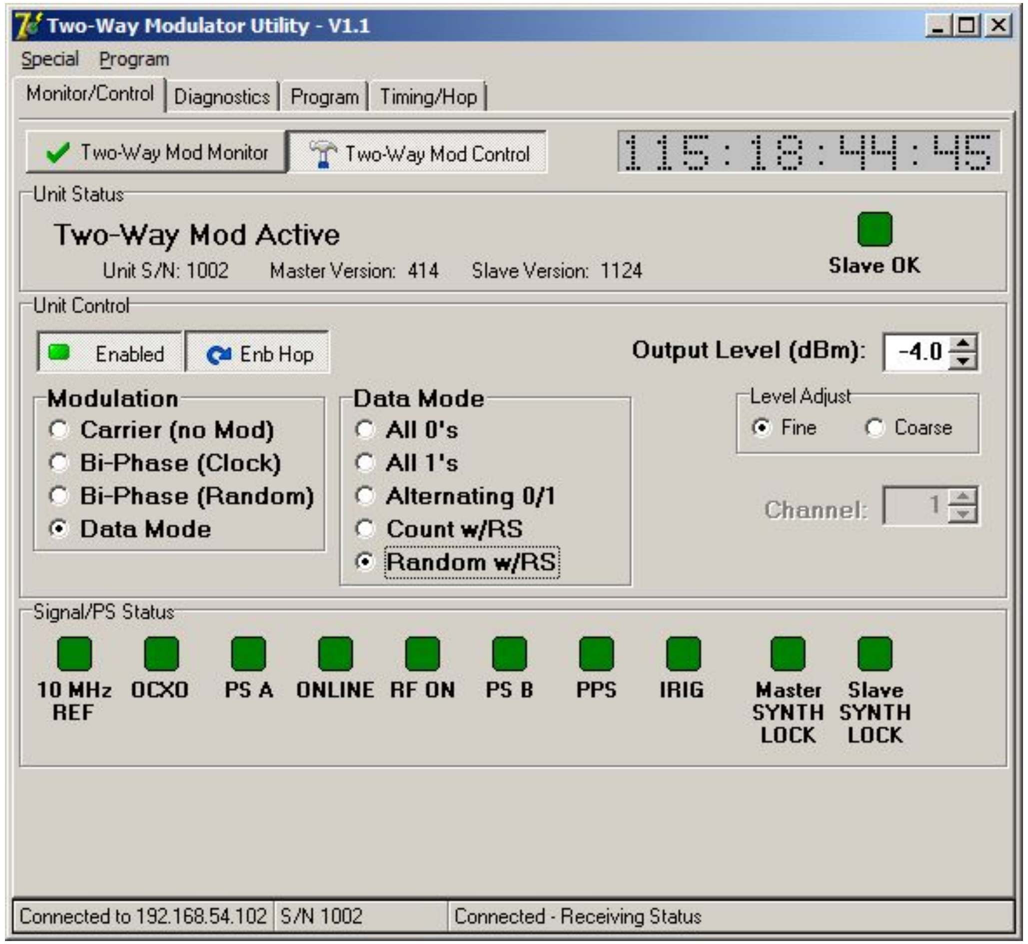
Two-Way Update – Modulator Install

- Microcom has been able to reliably connect to the Two-Way Modulator installed at WCDA using remote desktop.
  - When not testing the modulator is configured to not hop and make carrier at 72.8 MHz, which correlates to a 468.8 MHz downlink signal.



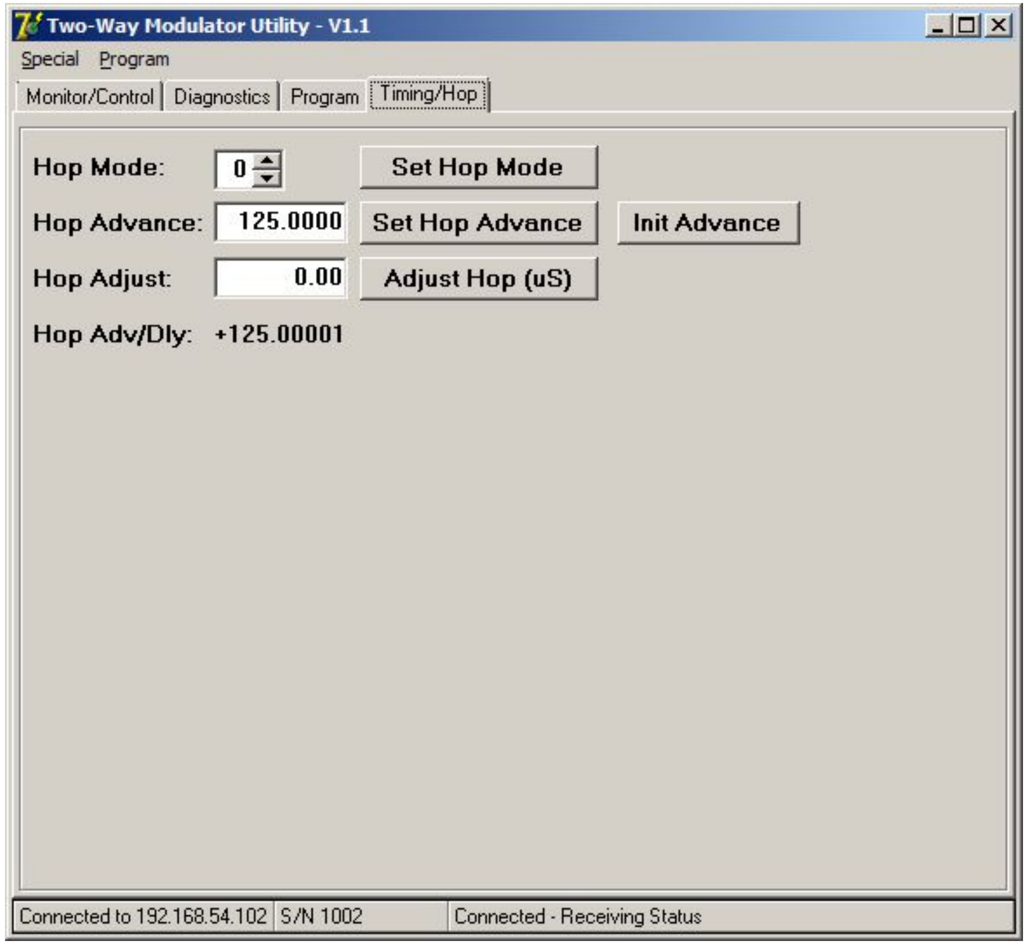
Two-Way Update – Modulator Updates

- The following features were added to the modulator PC program which were necessary for testing:
  - Power level adjustment
  - Channel adjustment
  - 10MHz OCXO lock algorithm
  - Modulation modes
  - Remote programming
  - Hop timing delay adjustment



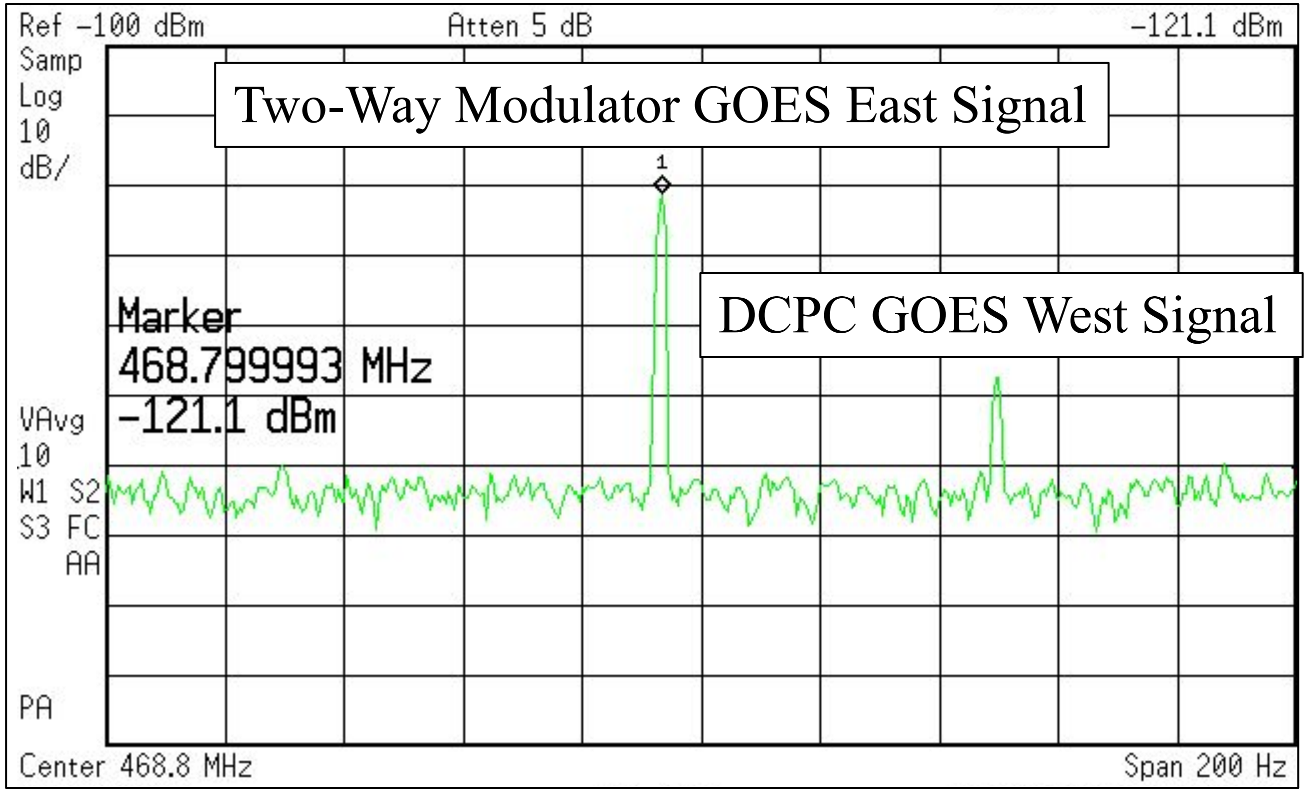
Two-Way Update – Modulator Updates

- Hop timing can be adjusted while hopping.
  - Allows for fine adjustments to facilitate hop alignment.
  - The monitor reports the current advance/delay amount.



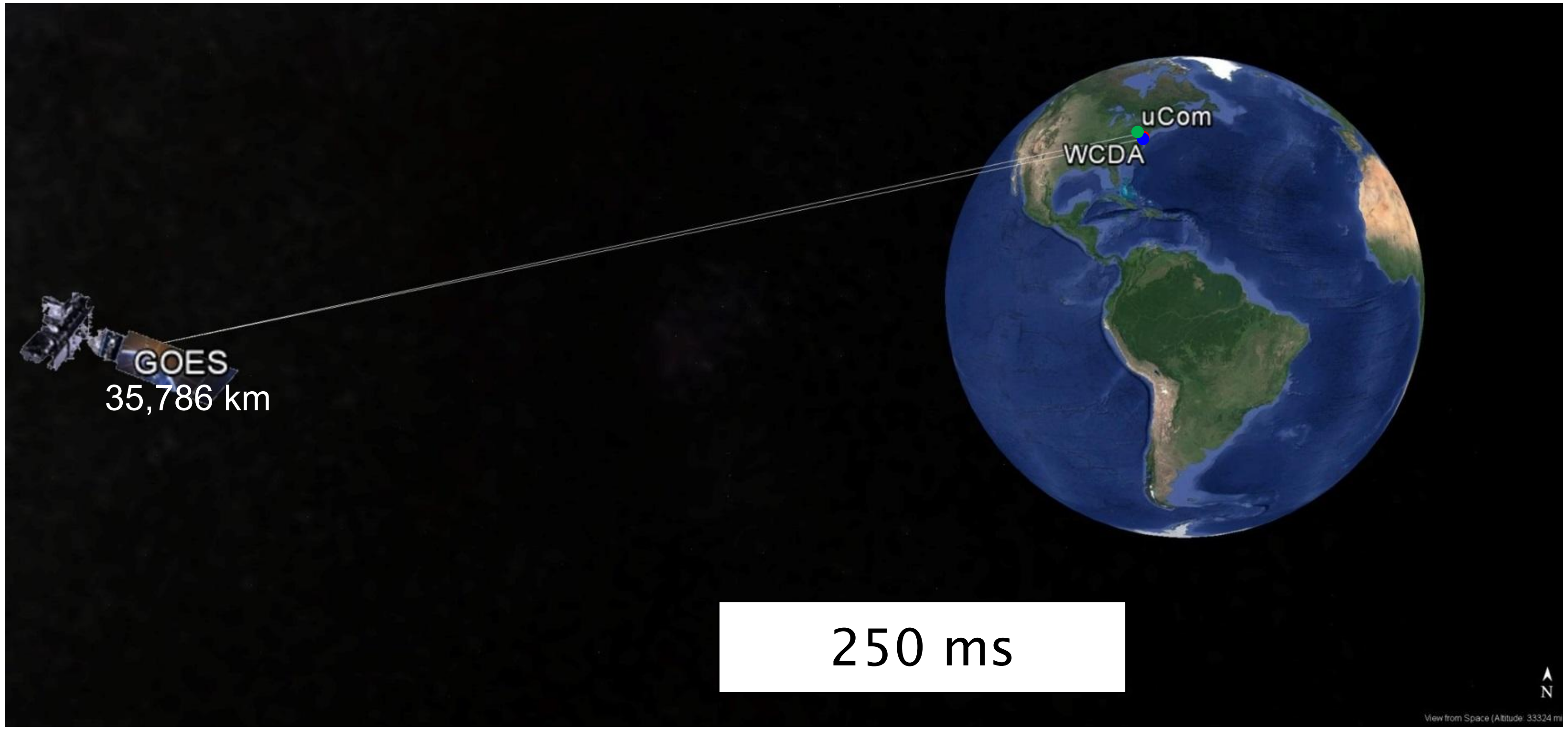
Two-Way Update – Modulator Install

- Screen capture is using a 468 MHz cross Yagi receive antenna pointed at GOES East. The Two-Way Modulator is making the carrier for GOES-East and a signal generator is making the DCPC signal for GOES-West.



Two-Way Update – Link Overview

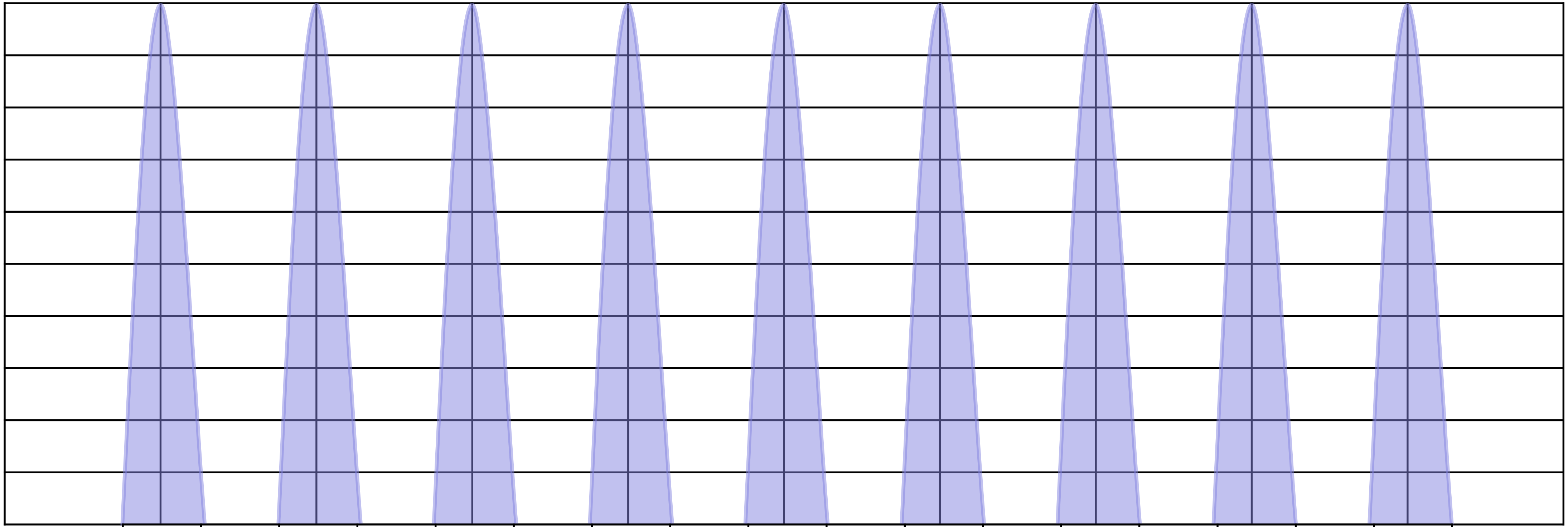
- Modulator needs to advance by 125 ms so the hop will reach the satellite on time
- Demodulator needs to delay by 125 ms so the locally generated hopping mix down signal and received hopping signals will align.




WCDA
Google earth

Two-Way Update – Channel Overview

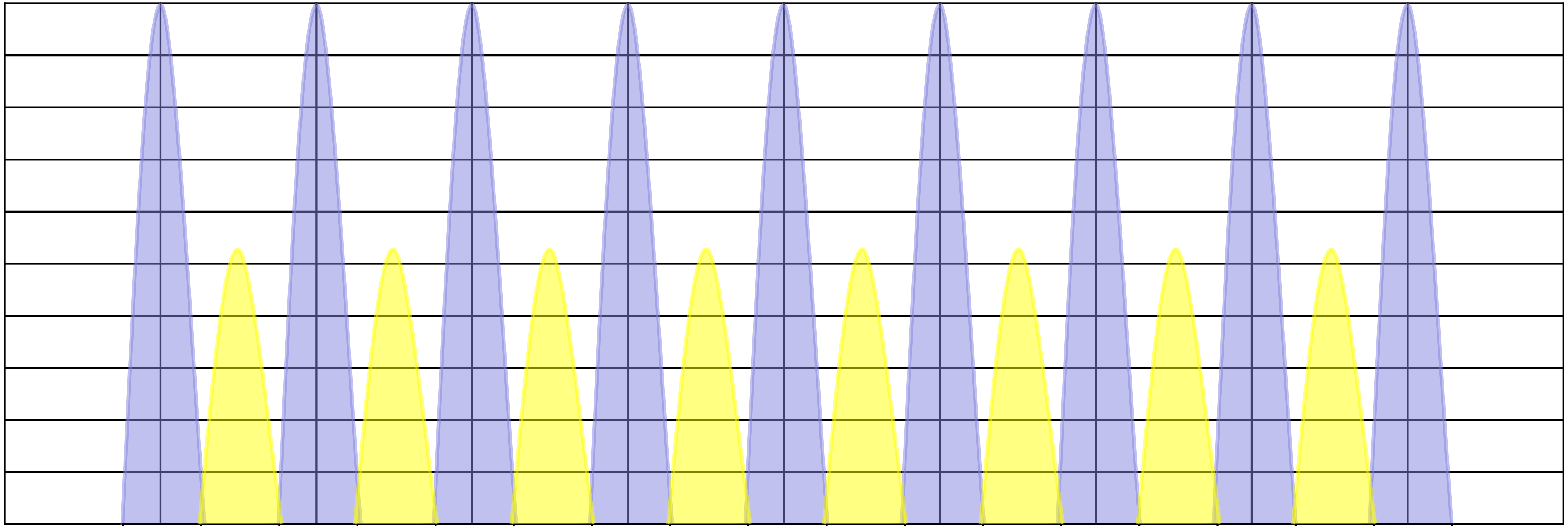
- LMRs are the primary users of this frequency band



468.750 000 MHz	468.756 250 MHz	468.762 500 MHz	468.768 750 MHz	468.775 000 MHz	468.781 250 MHz	468.787 500 MHz	468.793 750 MHz	468.800 000 MHz	468.806 250 MHz	468.812 500 MHz	468.818 750 MHz	468.825 000 MHz	468.831 250 MHz	468.837 500 MHz	468.843 750 MHz	468.850 000 MHz

Two-Way Update – Channel Overview

- The Two-Way signal hop in the interstitial frequencies



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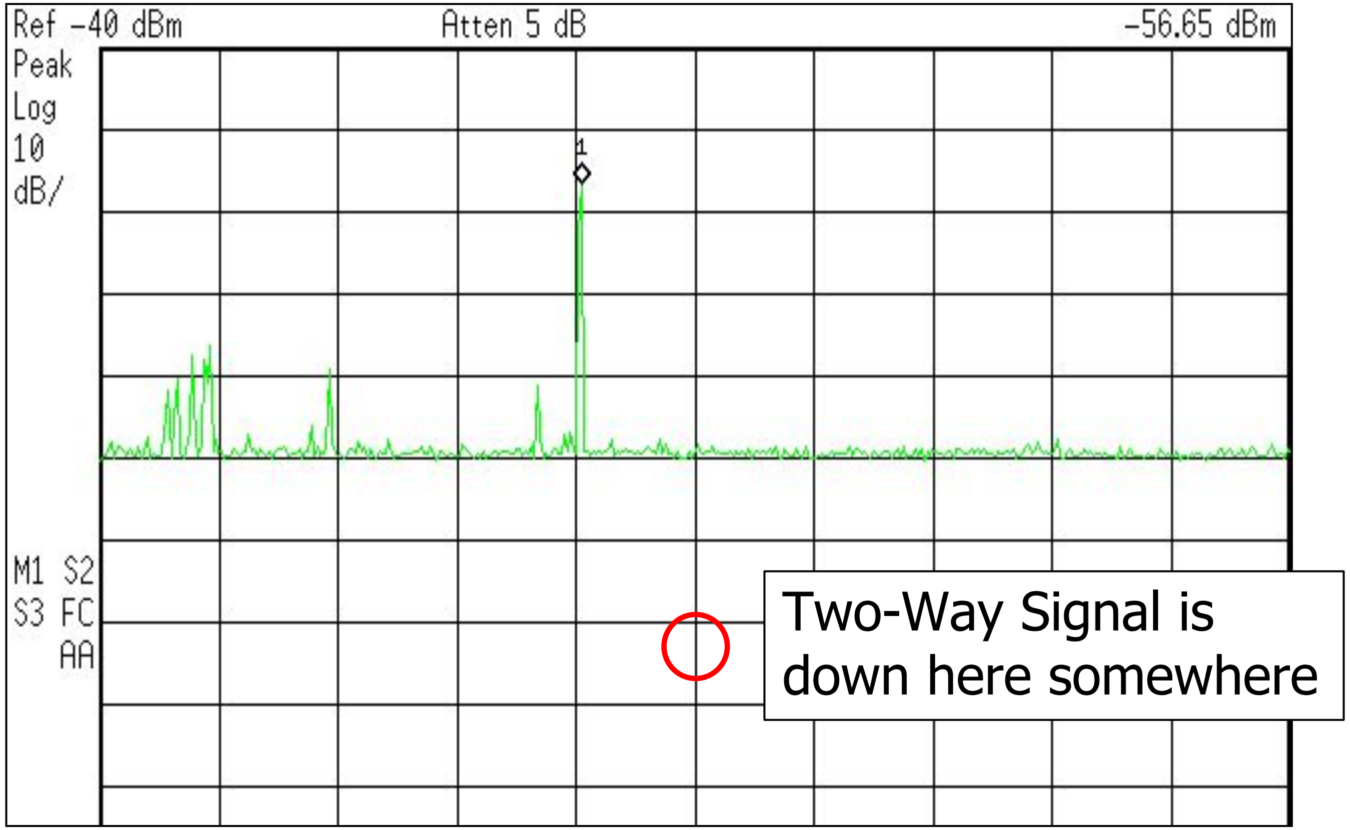
Two-Way Update – BER Measurements

- BER measurement task was delayed and is on hold due to unforeseen complications.
  - Strong interfering emitter
    - RF front end was damaged by an LMR transmitter.
  - February 19th to March 4th GOES operations were moved from WCDA to CBU.
    - This move caused significant project delays due to the DCPC signal being uplinked from the CBU instead of WCDA.
    - Two-Way Modulator installed at WCDA not at CBU.
    - This could be resolved by installing a second Two-Way Modulator at CBU allowing full fidelity during any subsequent switchover.
  - Adjustable power level from GOES
    - DCPC transponder on GOES is using AGC.
    - The AGC feature is thwarting attempts to lower the output power of the Two-Way signal needed to perform BER measurements.
  - Satellite movement
    - Minor satellite movement causing major hop timing misalignments

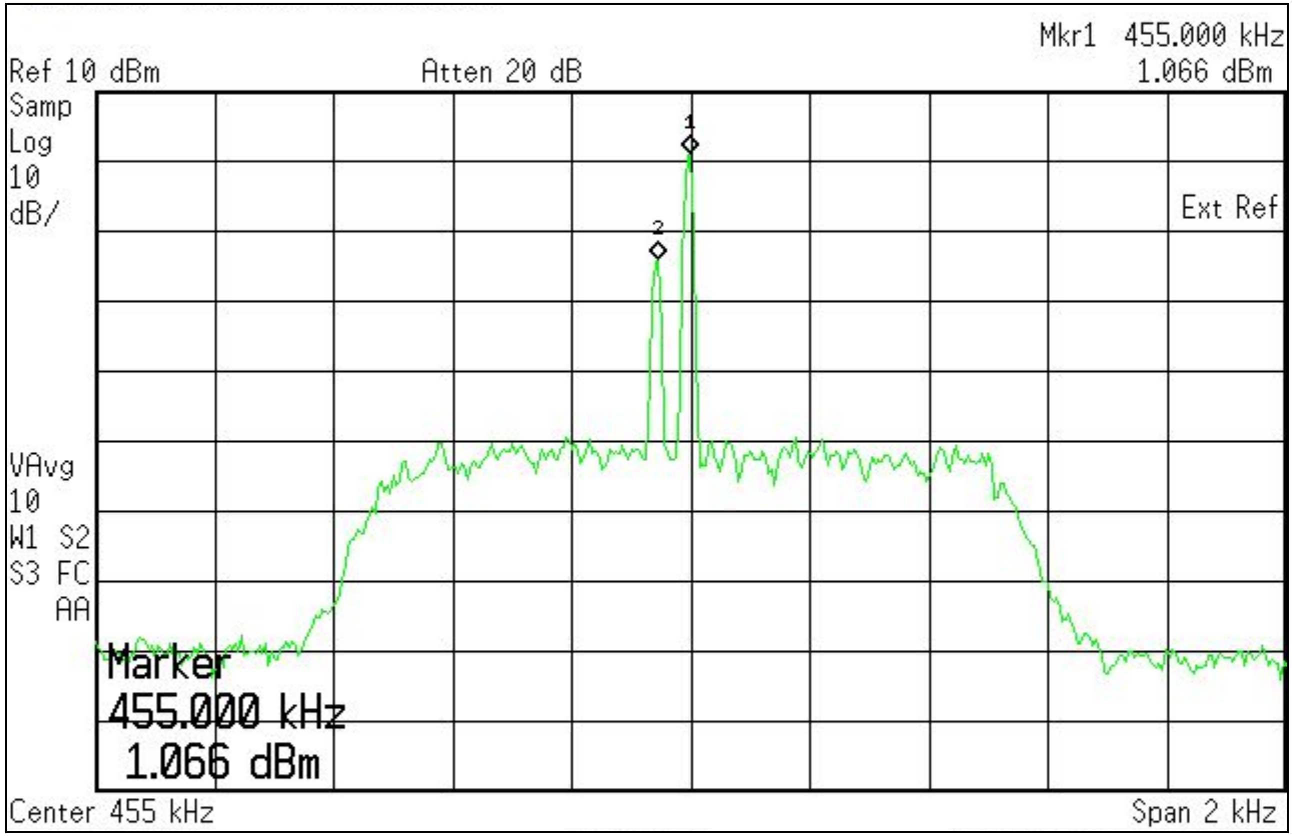
Two-Way Update – Interfering Emitter

- LMR signal +65 dB stronger then Two-Way
- 4 MHz away
- Damaged RF front end amplification stage



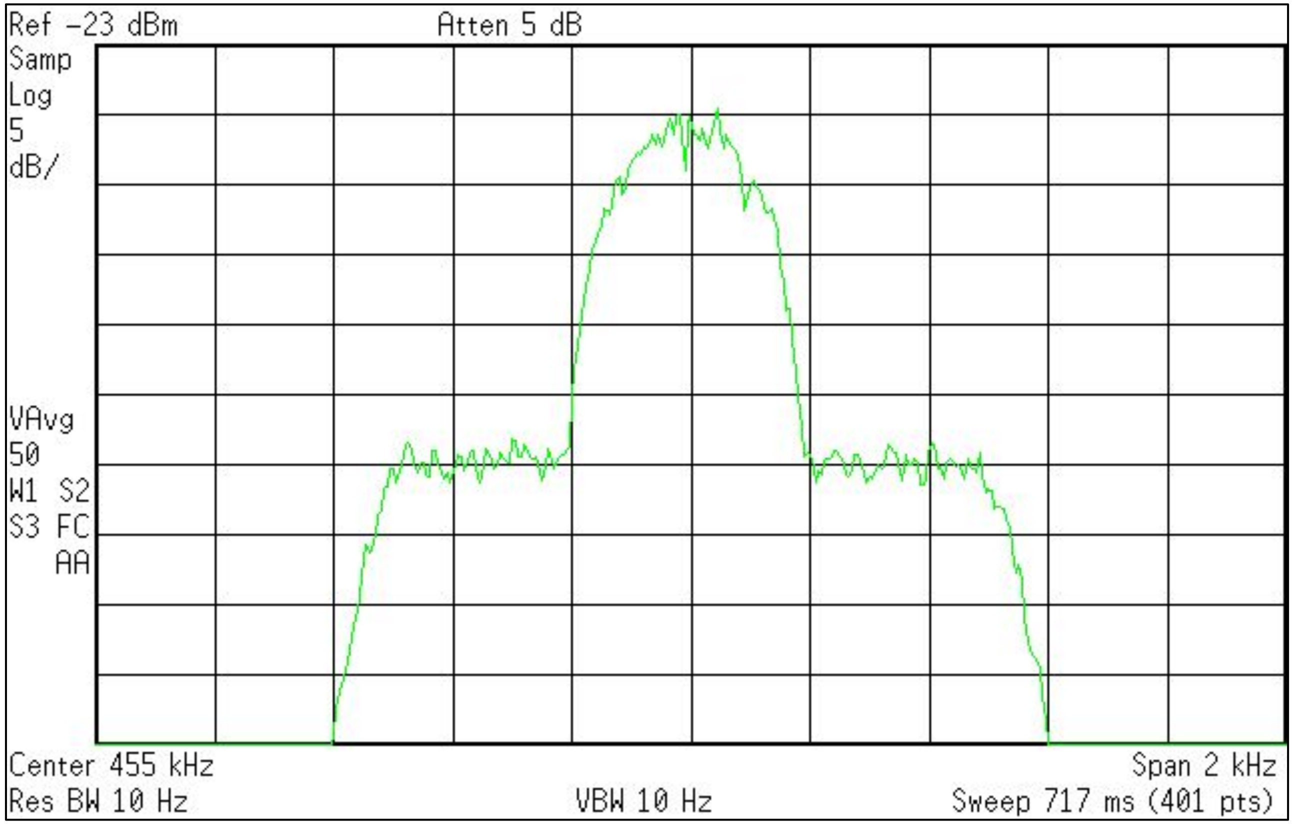
Two-Way Update – Interfering Emitter

- The RF front end was hardened against strong interfering emitters.
- RF front end is shown here successfully mixing the Two-Way 468.8 MHz signal to 455 kHz where it can be digitized and demodulated.



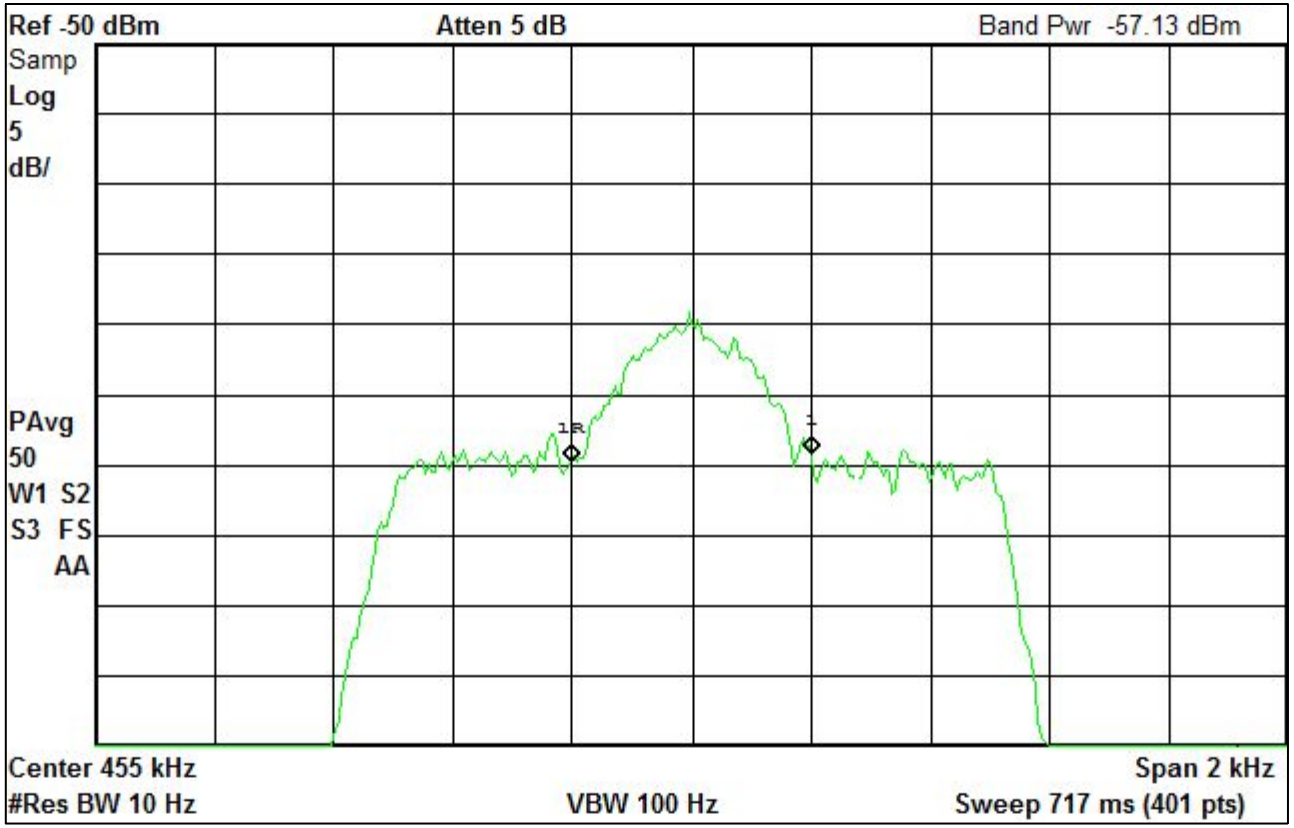
Two-Way Update – Interfering Emitter

- Shown here is the Two-Way Modulator successfully making 200 bps signal with RF front end down converting to 455 kHz.
- Microcom is reliably receiving over-the-air data with hopping at an SNR of 25 dB.



Two-Way Update – BER Measurements

- The signal level needs to be brought down closer to the existing noise floor to ensure BER through the GOES agree with the measurements taken during bench testing.
- Bench test screen shot at a BER $1.6e^{-4}$ with a SNR of 9 dB.



Two-Way Update – Power Level

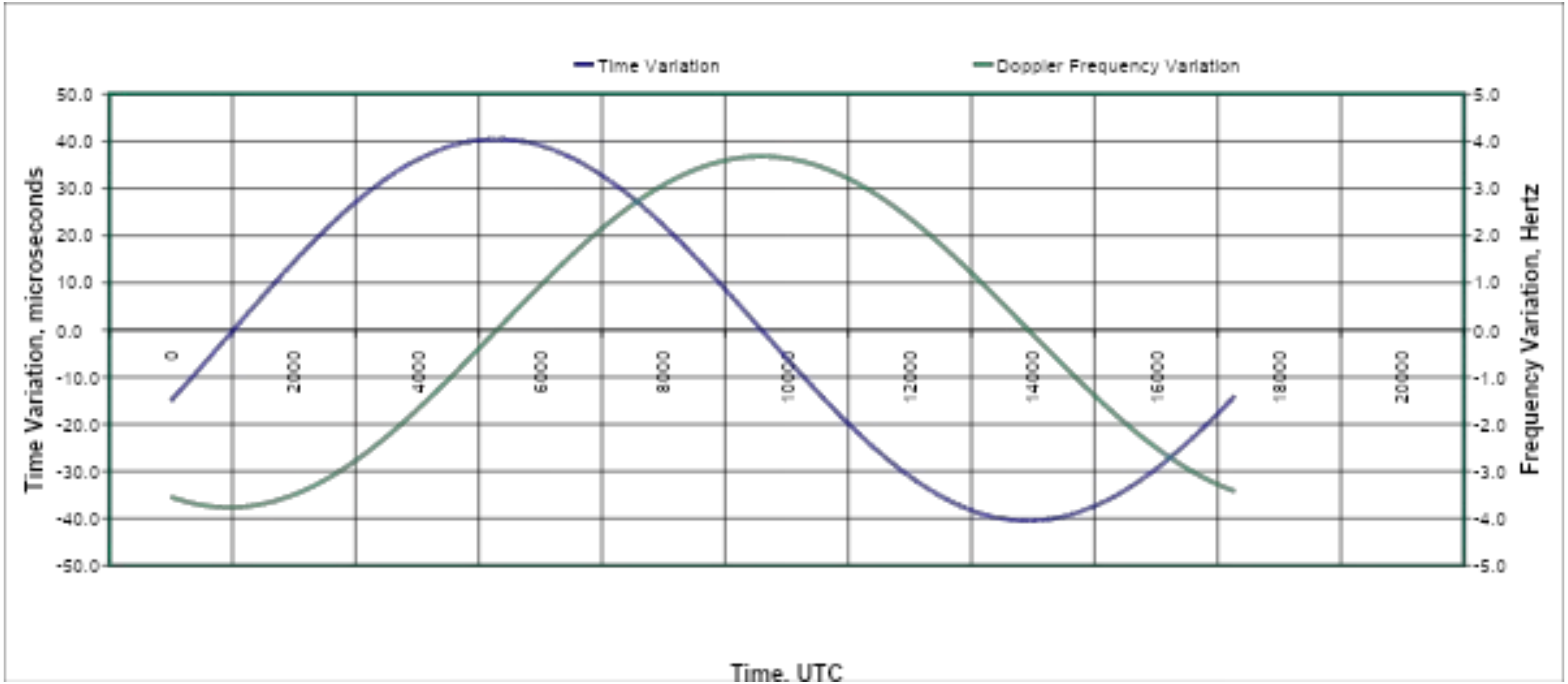
- On March 6th the inability to adjust the power level coming from the satellite was discovered.
- Down Link Power Level Solution
  - Two options have been discussed:
    - Add a secondary carrier which would keep the AGC active while testing the Two-Way signal.
    - Place the satellite in fixed gain mode.
  - Both potential solutions were thwarted by the ongoing pandemic.
  - WCDA personnel were restricted to working on only critical operations which excluded a secondary carrier from being uplinked.
  - NSOF personnel would be needed to turn off the AGC but were also restricted from working on non-critical operations.
  - Either solution will allow for accurate and repeatable BER measurements.

Two-Way Update – Satellite Movement

- Satellite movement issue was found and research began on determining the impacts to the system on March 6th.
- Small satellite movements impacts BER measurements.
  - Two-Way hopping requires timing accuracy better then 0.5 µs.
  - This equates to GOES moving of less then 300 meters.
  - Currently GOES-East moves 12000 meters per day.
  - Un-tracked movement causes increased phase noise due to hop misalignment.
  - Large hop timing misalignments will cause the demodulator to break lock.
  - Satellite movement must be tracked out before BER measurements can be made.
  - Satellite movement causes a 7 Hz shift Doppler shift in 468.8 MHz over 24 hours.

Two-Way Update – Satellite Movement

- 80 µs travel time variation and 7 Hz frequency variation over 1 day



Two-Way Update – Satellite Movement

- Satellite Movement Solution
  - Movement is approximately sinusoidal.
  - Hand calculations are currently being performed to correct for movement.
  - Any station keeping maneuver preformed by GOES will alter the hopping timing.
  - Further investigation is need to find a robust solution.

Two-Way Update – Next Steps

- Near Term
  - Complete BER measurements once power control is addressed.
  - Utilize manually predicted motion to account for time variability.
  - Prepare and submit report for this phase.
- Longer Term (depending on NOAA approval)
  - Develop automated hop alignment and tracking mechanisms.
  - Implement DCP communication protocol.
  - Demonstrate DCP control and possibly DCP feedback.