Update on Two-Way Work

Presented by

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μcom

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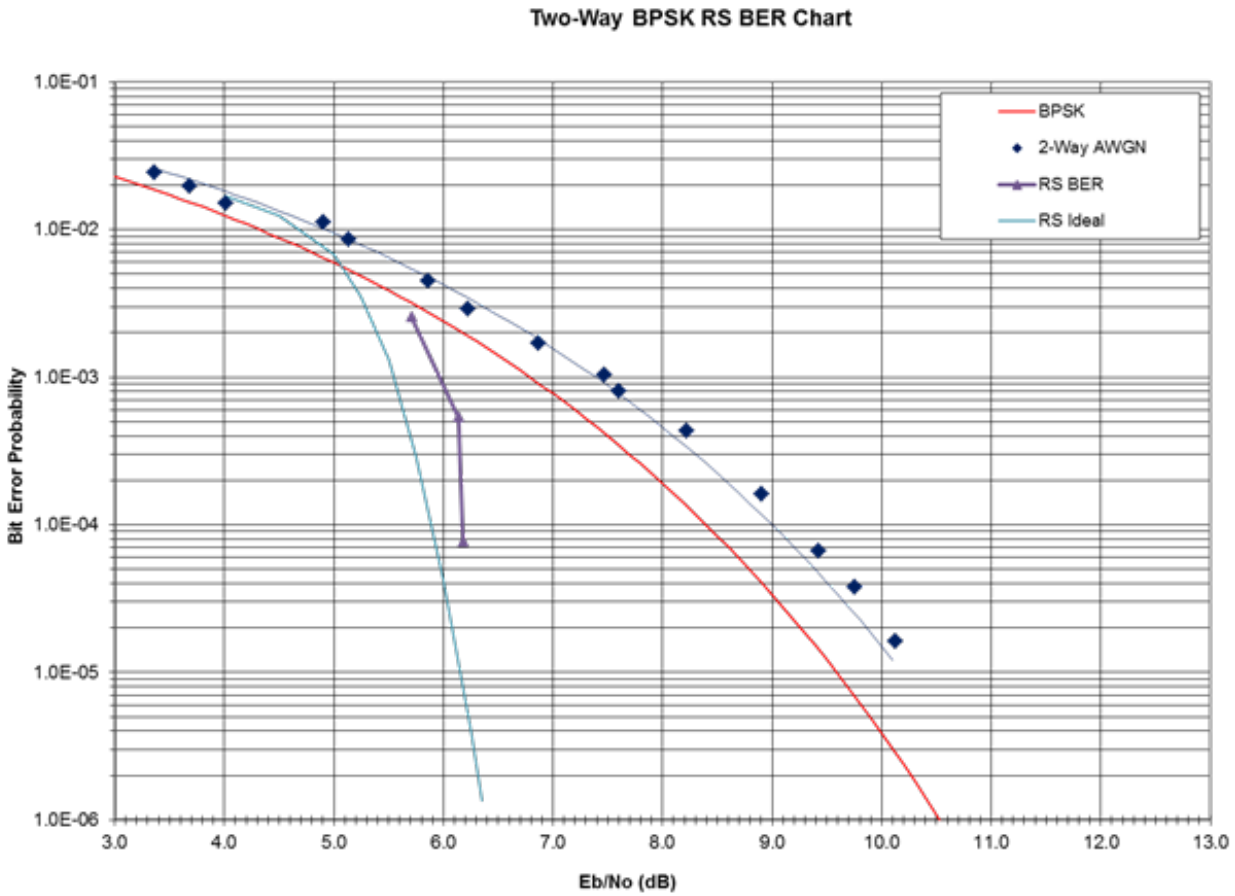
Two-Way Update – Summary since 2018 TWG

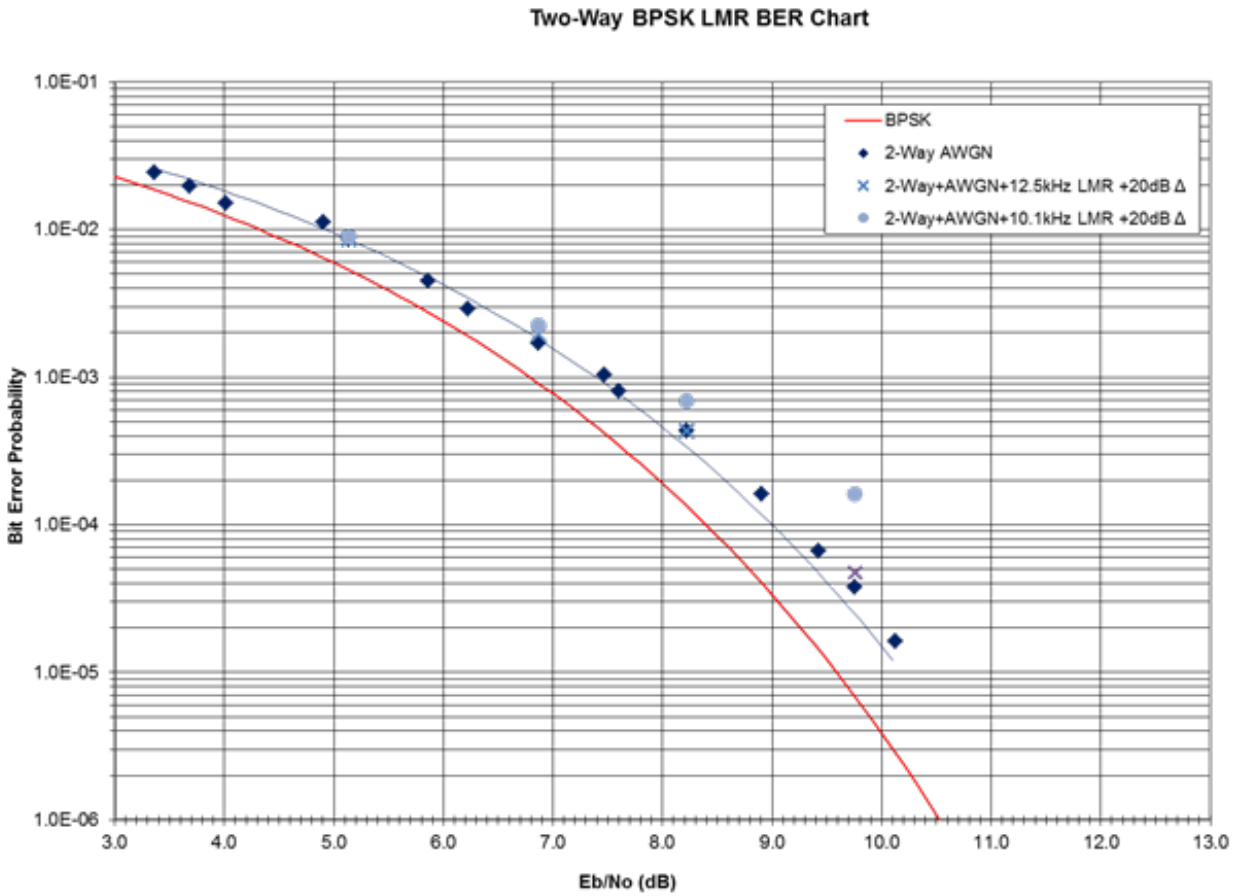
- Bench Prototype Testing Completed in May 2018.
  - Final report submitted to NOAA in early June 2018.
  - BER testing confirmed expected performance .
- After reviewing Bench Prototype report and other project status, NOAA requested proposal for Two-Way Over-the-Air Prototype in July 2018.
  - Initial proposal submitted in early August 2018.
  - Review of initial proposal held later in August.
  - As a result of the review, Microcom requested to make some modifications.
  - Final proposal submitted in September 2018.
  - Project authorized in late September 2018 and work on first task began in October 2018.
- Additional initial task requested to study bandwidth expansion to 1 MHz.
- Phase Reversal Investigation

Two-Way Update – BER Results AWGN



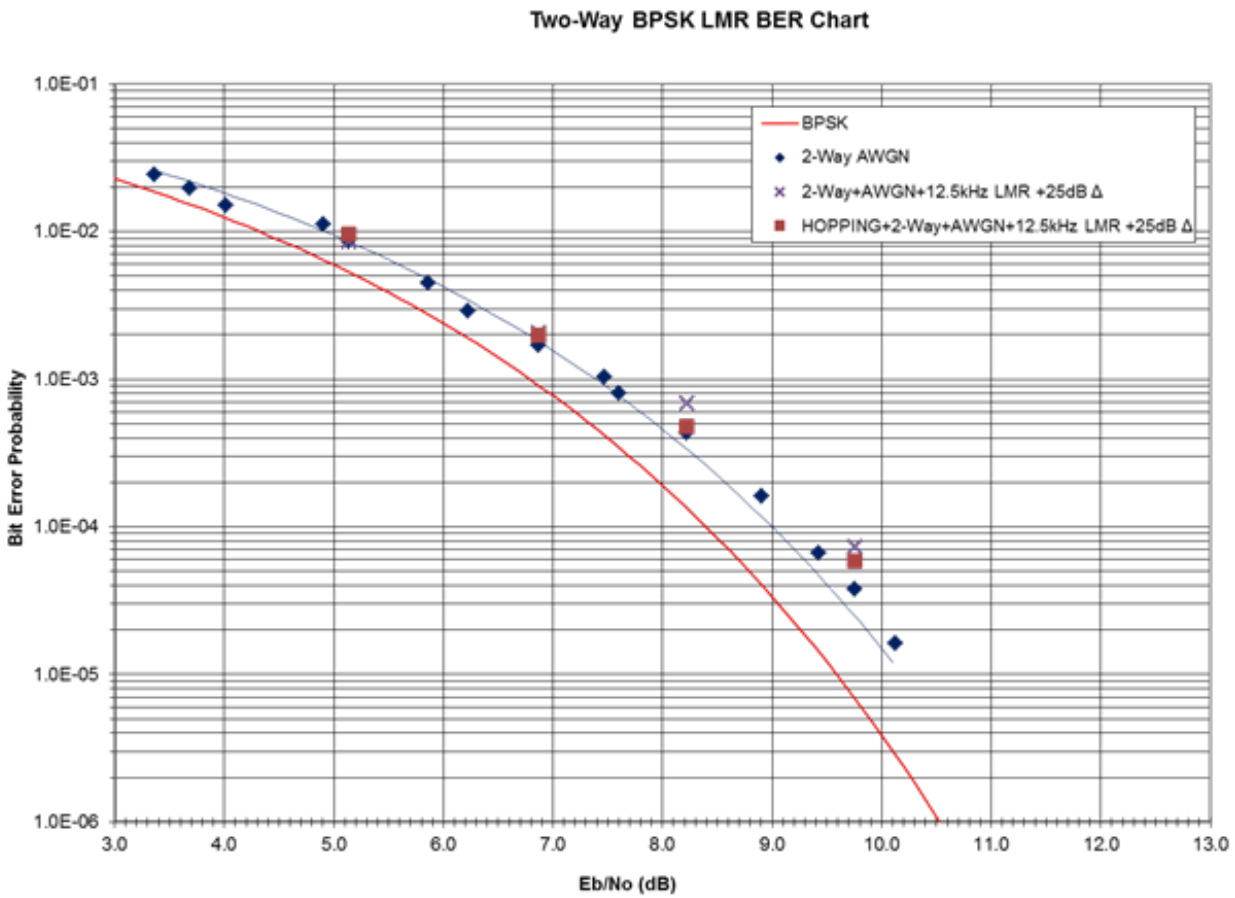
- Bench Prototype showed good correlation to theory for AWGN.
- BPSK BER better than $4x10^{-3}$-$2x10^{-3}$ will yield overall BER below 10^{-6}.

Two-Way Update – Static BER Results LMR



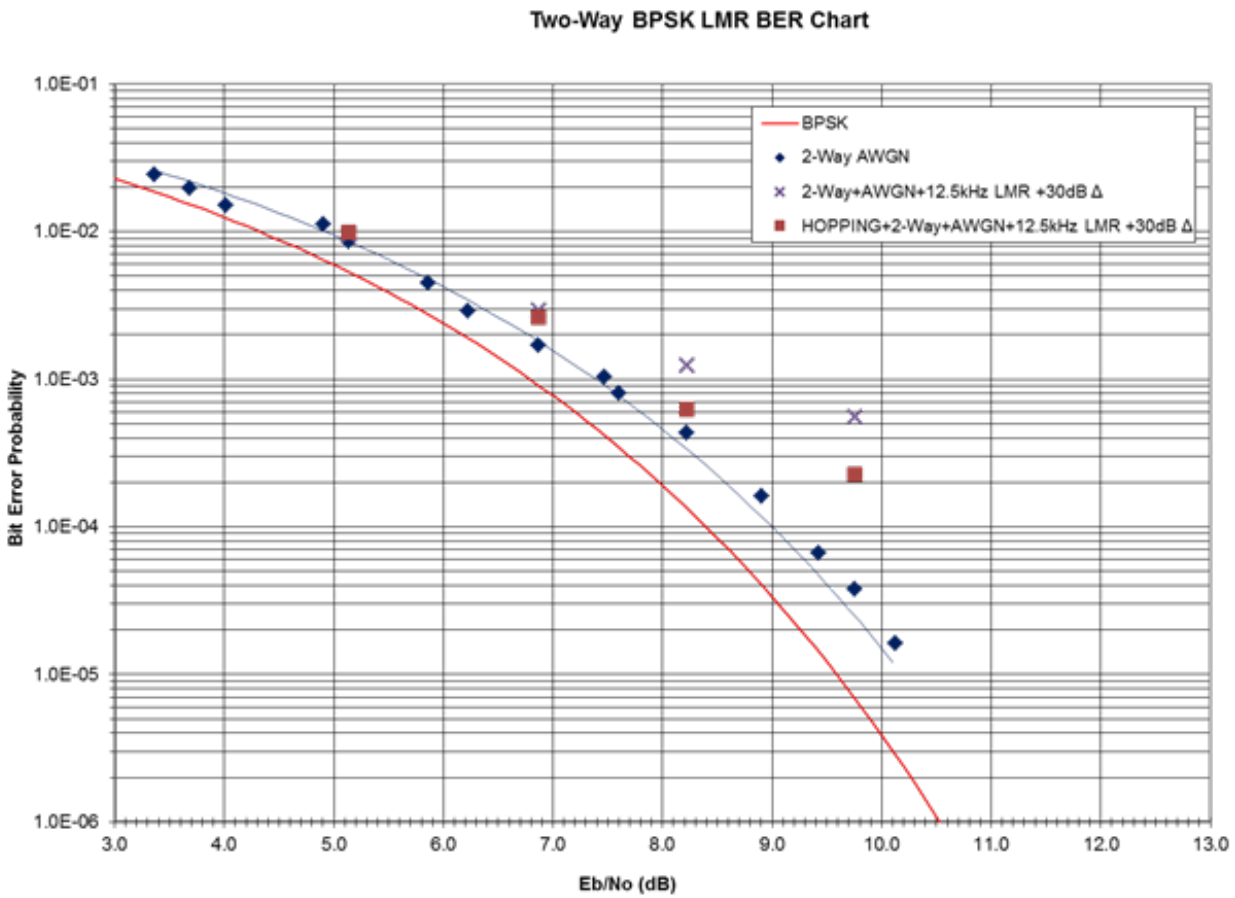
- Un-hopped Bench Prototype showed good immunity to LMR.

Two-Way Update – Hopped BER Results



- Hopped results with excessive (+25 dB) LMR signals present.

Two-Way Update – BER under Extreme Case



- Hopped results with extreme (+30 dB) LMR signals present; hopping improvement more readily apparent.

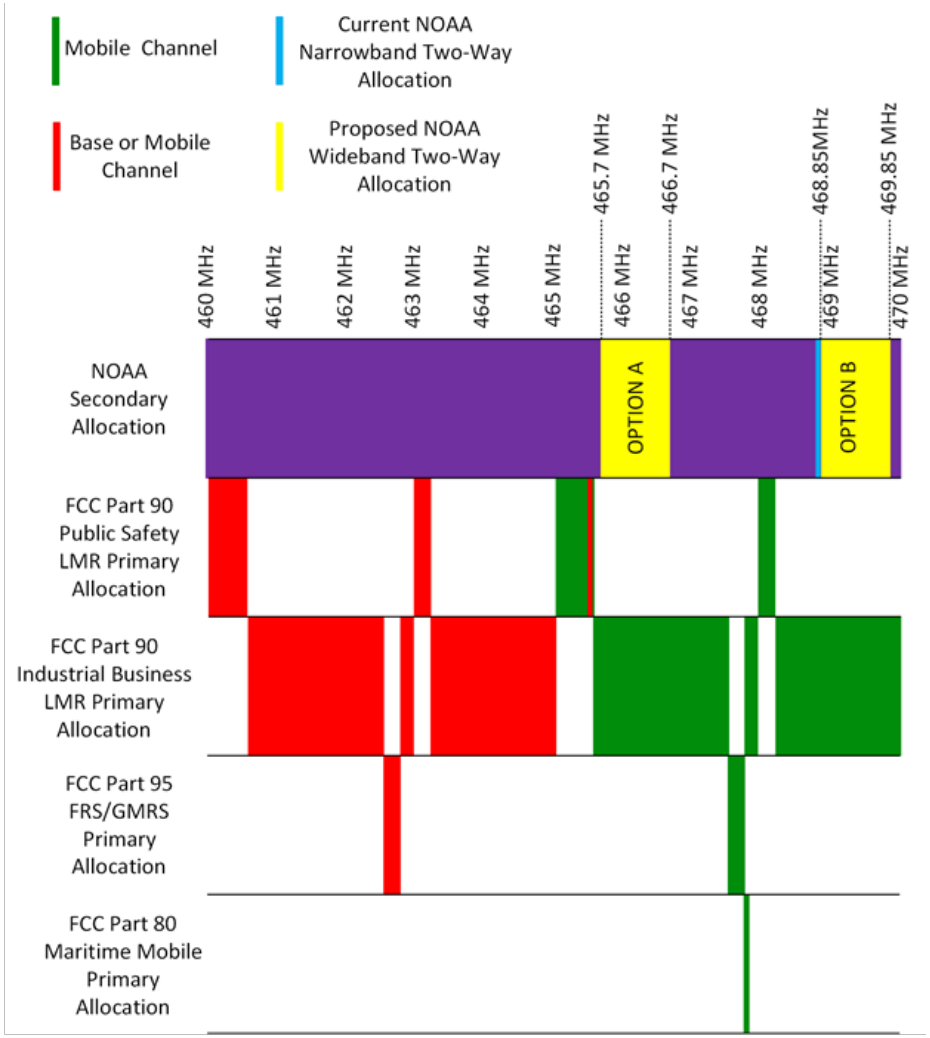
Two-Way Update – Possible ITU Changes

- In late April 2018, Peter Woolner notified NOAA and Microcom that the ITU is considering lowering the allowable Power Flux Density (PFD) of the Two-Way downlink.
  - Change could be as little as a few dB to as much as 10 dB.
  - To address this change, either the power has to be lowered or the signal has to be spread over a wider bandwidth.
- Other Considerations:
  - Reducing downlink power will degrade performance so only option is to expand bandwidth up to 1 MHz.
  - Current 100 kHz bandwidth is determined by the transponder, and cannot be altered until the next generation of GOES.
  - It is believed the existing PFD would be grandfathered on current series of GOES satellites.

Two-Way Update – 1 MHz Bandwidth Study

- While the change is not definite, during the Two-Way Over-the-Air proposal review, NOAA and Microcom realized:
  - Any potential change would most likely further delay the realization of the Two-Way system.
  - Users would not want to purchase and deploy 100 kHz units, only to have to replace or upgrade them once a new 1 MHz system is in place.
- As a result of the potential changes, NOAA asked Microcom to revise its Two-Way Over-the-Air Proposal to do a formal study of the possibility of increasing the Two-Way bandwidth to 1 MHz.
- Final report submitted to NOAA in November 2018.

Two-Way Update – LMR Spectrum Allocation



- First step in 1 MHz BW study was to identify possible locations for wider Two-Way downlink signal.
- Preferred spectrum is with mobile versus base stations due to:
  - Lower transmit power.
  - Lower antenna elevation.
  - Base stations often operate as repeaters ⇒ higher use.
- Based on number of FCC licenses, two specific areas identified.
  - A: 465.70-466.70 MHz
  - B: 468.85-469.85 MHz

Two-Way Update – 1 MHz BW Design Impacts

- Uplink Modulator:
  - Current implementation at NOAA is to produce Uplink Two-Way signal at a lower frequency IF (~75 MHz), which gets translated up to S-Band (2032.8 MHz).
  - Ignoring hopping, signal is very narrow-band, which results in a minimal impact, simply need to hop over wider range. Can be done with existing prototype modulator.
- Receiver/Demodulator:
  - From a demodulator perspective change is similar to modulator – just need to de-hop over wider range.
  - From a receiver perspective, need to be certain front-end elements compatible with new frequency and wider bandwidth.
    - Initial band-pass filtering would be inherently wide enough to accommodate 1 MHz BW (i.e. a 100 kHz wide bandpass filter centered at ~468 MHz is not readily achievable or practical).
    - Downstream IF filters narrower than 1 MHz would not be of much benefit since final filter bandwidth after de-hopping is ~1 kHz.
  - Just need to ensure new center frequency is close to current frequency.

Two-Way Update – 1 MHz BW Conclusions

- Should be relatively easy to adapt existing hopping design to cover 1 MHz wide bandwidth – could actually provide some additional immunity to LMR since signal would spend less time near a particular channel.
- High confidence that it is possible to design Two-Way receivers for current 100 kHz range and switch to 1 MHz with no hardware or firmware modifications if designed in at outset – units would just need to be re-configured for 1 MHz operation.
- Units could be deployed for operation on GOES-R series satellites and switchover to future series spacecrafts with minimal user intervention – could even be commanded through Two-Way at a specified date/time.
- Recommended using 1 MHz portion of the spectrum (468.85 - 469.85 MHz) just above existing Two-Way frequency assignment (468.75 - 468.85 MHz).
  - Ensures compatibility with front-end filters.
  - No overlap to avoid 100 kHz and 1 MHz signals interfering with each other during satellite transition period.
  - Number of LMR assignments roughly equivalent.

Two-Way Update – Phase Coherence Study

- NOAA reviewed 1 MHz BW report and authorized Microcom to proceed to next step in Over-the-Air Project – Phase Coherence Study.
  - During final testing of Bench Prototype, Microcom observed very intermittent phase reversals during long-term testing.
  - While phase reversals did not prevent Microcom from finalizing BER testing, any operational system needs to ensure these do not happen or can be reliably mitigated.
- First step was to re-visit original testing performed by Dr. Brian Kopp and Duane Preble to confirm that two synthesizers hopping at simultaneous rate would maintain phase coherence.
  - Both synthesizers operating on common circuit board with common oscillator and driven in sync by single microcontroller.
  - This was completed in January and early February.
  - Improved synchronization algorithm in microcontroller code.
- Second step was to repeat synchronization testing with synthesizers on two different modulator circuit boards.
  - This is where problems were observed and needed to be addressed.

Two-Way Update – Issue with Synthesizer

- After identifying issue with multiple synthesizers on separate circuit boards, Microcom investigated several possible “obvious” issues that could be causing the problem.
- Once these were eliminated, Microcom investigated the synthesizer circuit itself and found that some of the synthesizers were randomly unlocking even at a stable frequency.
- After trying numerous fixes, Microcom ultimately replaced the problematic units and determined a problem was simply a fault in the synthesizer itself that could not be readily explained.
- Once the faulty synthesizers were replaced with new devices, Microcom was able to successfully complete the two circuit board synchronization test.
- Microcom is presently applying similar fixes to the demodulator prototype to confirm that the random phase reversals seen during the bench prototype testing has been fully addressed.

Two-Way Update – Next Steps

- Once Microcom has successfully demonstrated phase coherence can be maintained with the bench modulator and demodulator, work will proceed to the required tasks to complete the Over-the-Air demonstration and testing:
  - Enhancing Two-Way Modulator for deployment at WCDA.
  - Developing Two-Way Receiver Front-End and Antenna system.
  - Cleaning up and finalizing Two-Way Demodulator.
  - Mating Demodulator to Receiver Front-End.
- Hope to be sending and receiving signals through satellite by end of summer of 2019.
- If all goes well, by fall 2019 Microcom should be performing Over-the-Air Prototype Operational and Performance Testing.