Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [UWB Interference Comparison]
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Source: [Gadi Shor] Company [Wisair]

Address [24 Raul Wallenberg, Tel-Aviv, Israel]
Voice:[+972-3-7676605], FAX: [+972-3-6477608], E-Mail:[gadi.shor@wisair.com]

Abstract: [Contribution on UWB interference comparison]

Purpose: [For discussion by IEEE 802.15 TG3a]

Outline

- UWB interference comparison
- Analysis, simulations and measurements
- Measurement set-up and calibration procedure
- Conclusions

UWB interference comparison

- MBOA members performed analysis, simulations and measurements
- Measurements, analysis and simulation results match each other
- Results show difference of up to 1.5 dB for realistic operating scenarios of C-Band victim receivers

Operating conditions for C-Band receivers

- The operating condition (I/N) is related to the allowed isolation between the UWB device and the C-Band receiver (e.g. distance, side-lobe attenuation, etc.)

- C-Band receivers have 1.5-2 dB link margin above the sensitivity level
  - Expected fading due to rain is about 1 dB
  - Leftover margin for total interference from other sources is 0.5-1 dB
- This means that $I_{uwb}/(N+Isat)<=-6$ dB

Operating conditions for C-Band

- NTIA in their analysis of the UWB systems assumed an I/(N+Isat) of -13.5 dB
- XSI in their FCC petition filing in September, 2003 proposed an I/(N+Isat) of – 9.5 dB
- FCC has studied cases of I/(N+Isat) < -3.5 dB
- Remark: Isat = adjacent satellite interference of about 1 dB above the thermal noise
- Demonstration by Motorola/XSI was done at an unacceptable operating condition of I/(N+Isat) greater than zero in which the interference from the UWB device is even stronger than the other noise sources

Operating conditions for C-Band

To justify the proposed I/N = -9.5 dB XSI in their FCC petition filing in September, 2003 states the following:

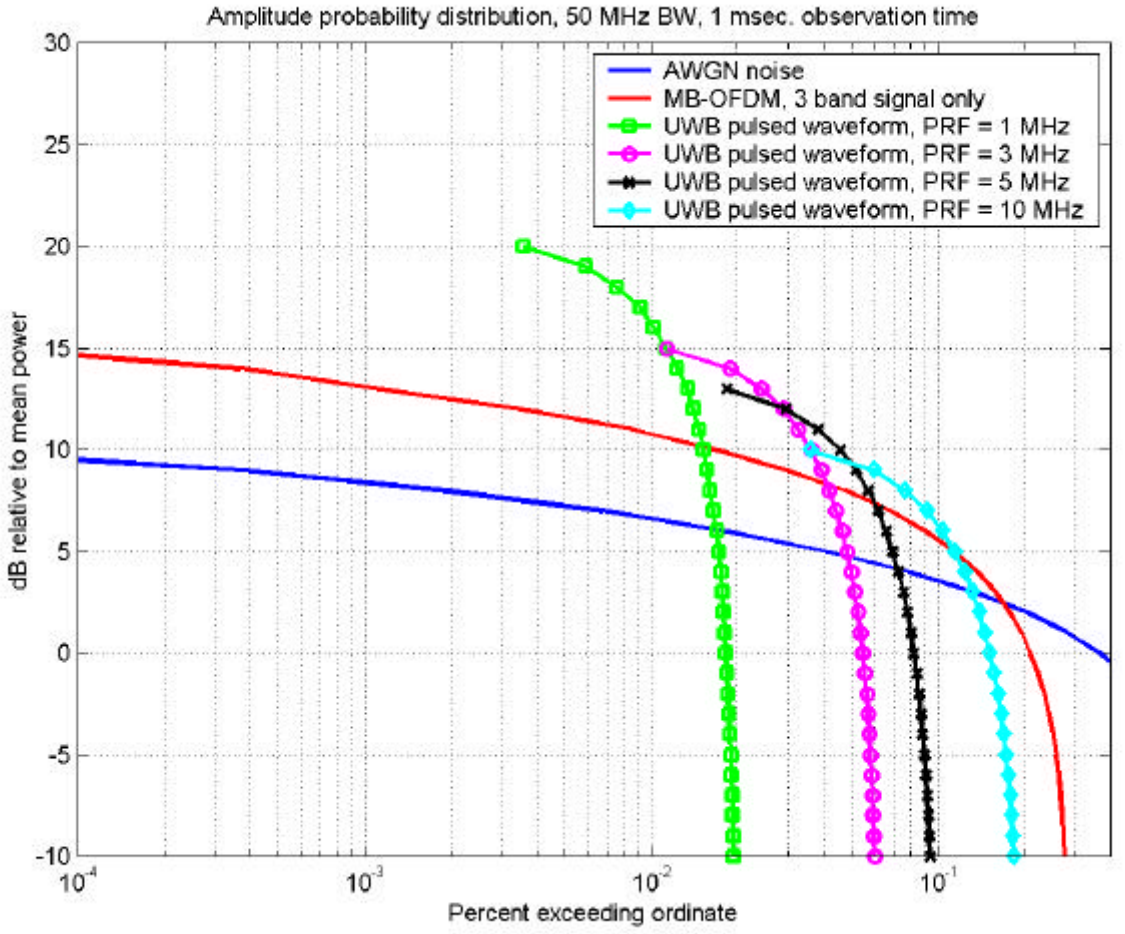
"The vanishingly low probability of harmful interference depends on the joint probability that a handheld UWB device is actively transmitting, is close enough to a low-elevation earth station, is in the susceptible azimuth region, has its antenna oriented in the worst case direction, has the antenna aligned with a linearly polarized earth station antenna, lies along the bore site azimuth of the earth station antenna, has no other intervening people, fences, berms or foliage, and all at a moment when the earth station is suffering a fade deep enough to eat away its margin. The actual probability of all this occurring is essentially zero.“

Analysis based on APD

- It has been suggested that the Amplitude Probability Distribution (APD) is a way to analyze the effect of a non Gaussian noise on a victim receiver
- It has been argued that the APD for MB-OFDM is not compliant with the FCC regulations [IEEE 802.15-03/334r5].
- We show that
  - APD for the MB-OFDM is similar to the APD of pulsed systems already allowed by FCC.
  - APD for the noise plus interference as seen by the C-Band receiver in realistic operating conditions is very close to AWGN (up to 1.5 dB of difference)
  - APD for narrow band receivers is almost identical to AWGN regardless of the operating conditions

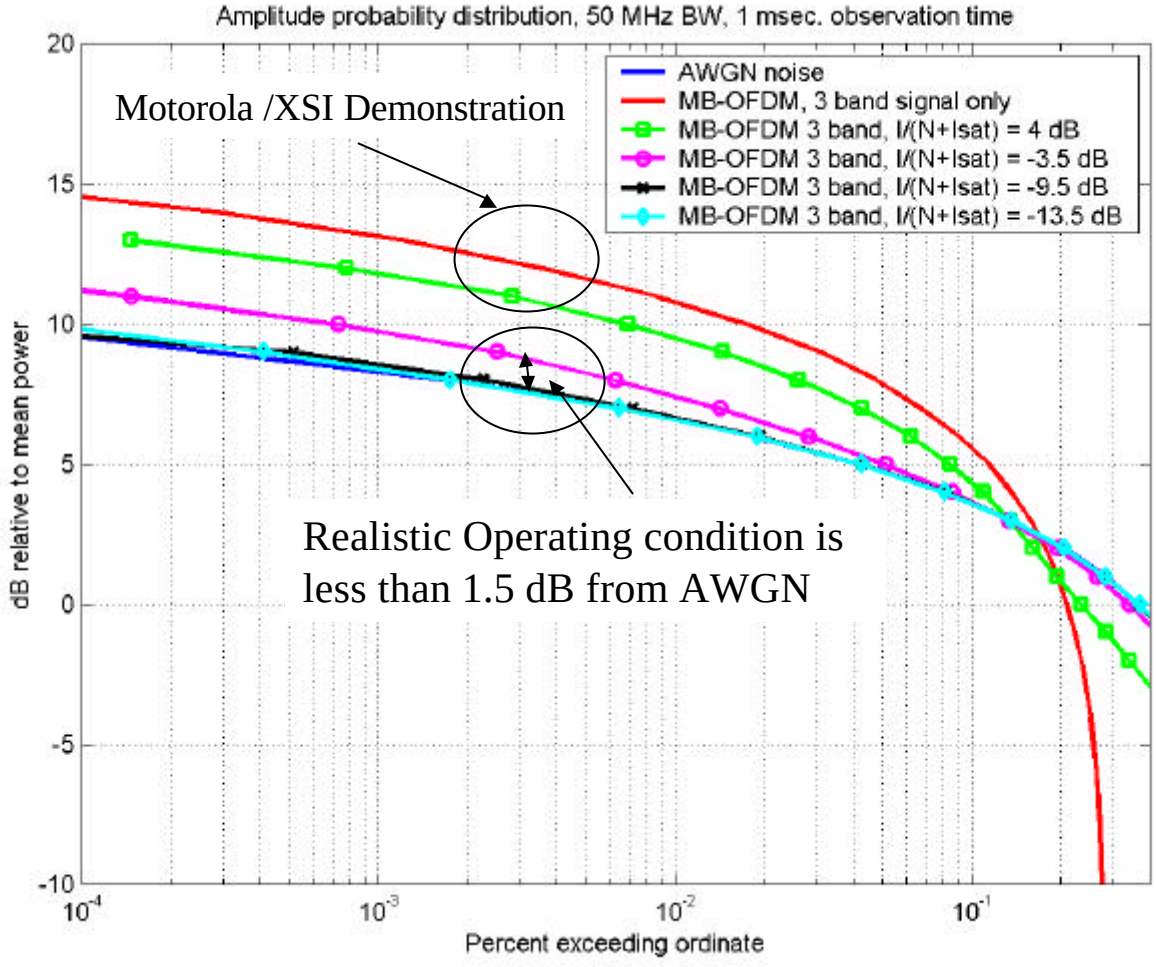
MB-OFDM and Pulsed UWB APD

- MB-OFDM APD is similar to pulsed UWB systems already allowed by FCC even with 50 MHz resolution bandwidth.



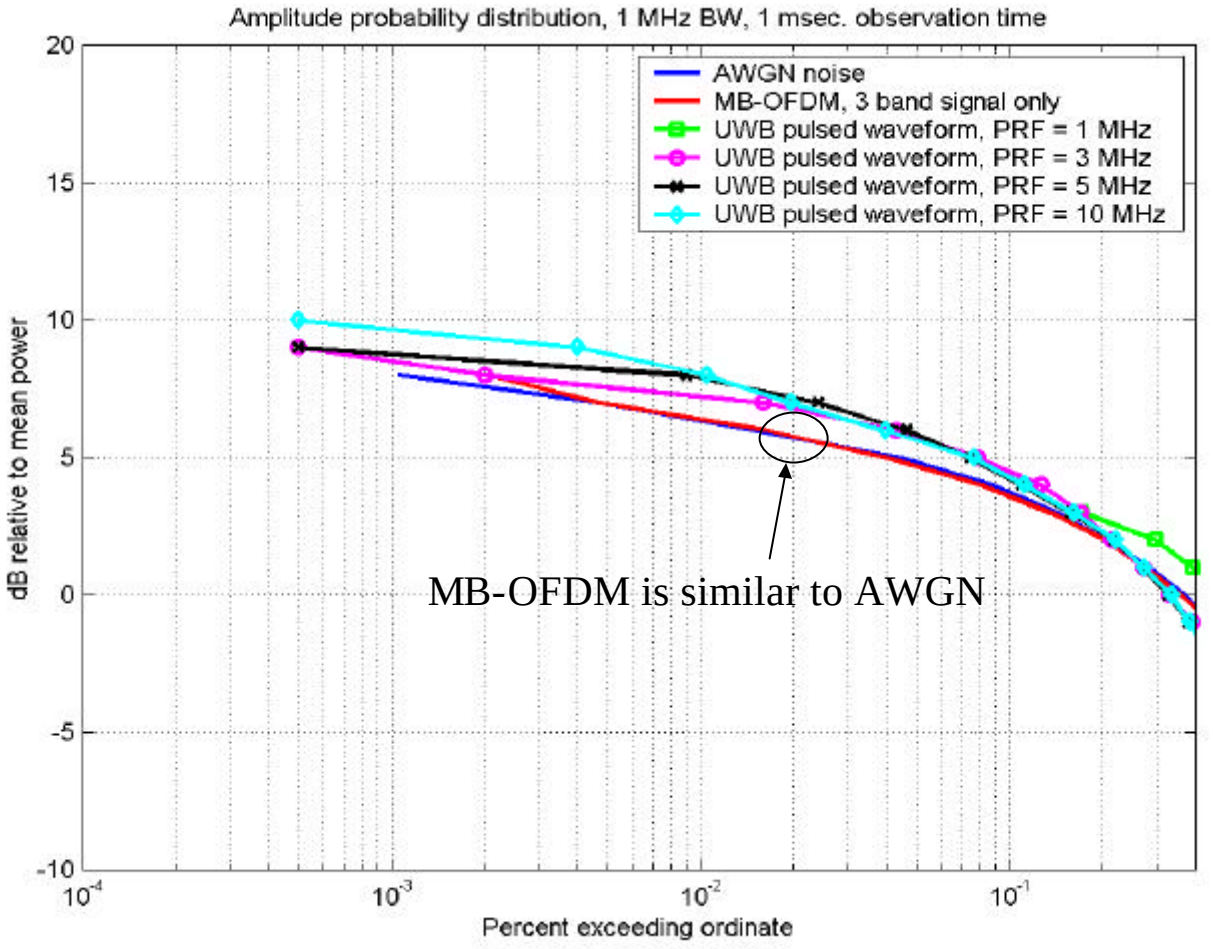
APD for MB-OFDM with different I/(N+Isat)

The APD of MB-OFDM with I/(N+Isat) = -3.5, -9.5, -13.5 is less than 1.5 dB from AWGN.



APDs for narrow band receivers

- MB-OFDM APD is similar to AWGN with a 1 MHz resolution bandwidth.



Link simulations for C-Band receivers

- C band DVB-S system parameters
  - 30 Msps
  - convolutional code (133,171) rate 3/4, outer RS code (204,188)
  - convolutional interleaver between inner and outer codes
  - no channel interleaving before Viterbi decoder
- We show that the difference between interference from DS-CDMA and MB-OFDM to C-Band receivers is very small (below 1.5 dB) for realistic operating conditions

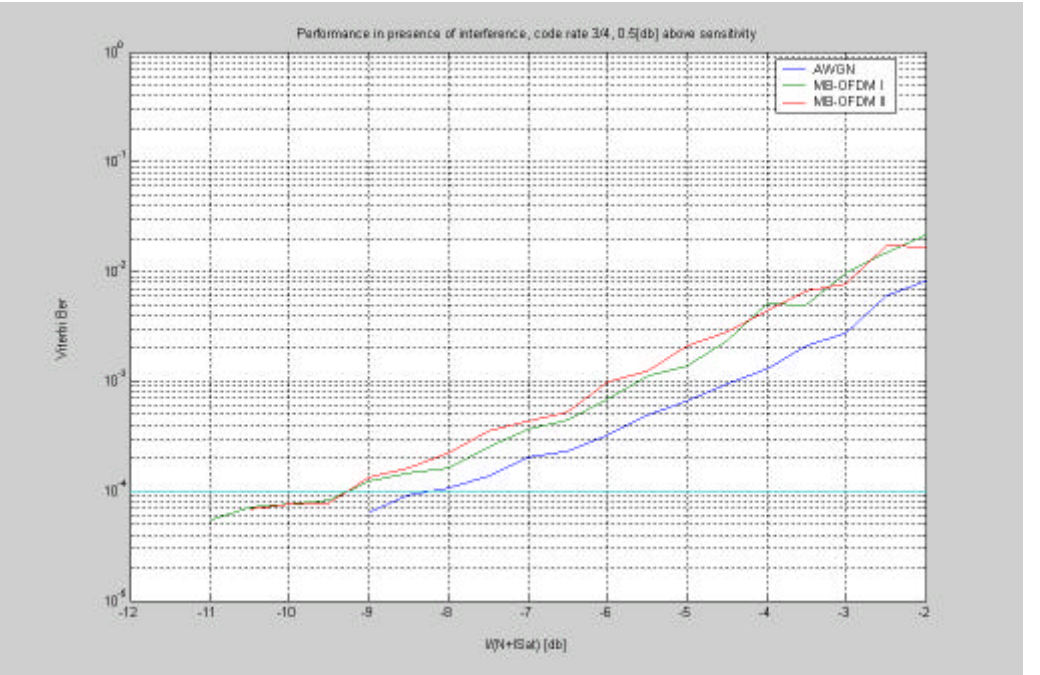
Signal of 0.5 dB above sensitivity Equivalent to I/(N+Isat) = -8.5 dB

B-OFDM I =

f2 f3 f1 f2 f3

B-OFDM II =

f1 f2 f2 f3 f3



Remarks: Ber represent Ber at the Viterbi output. Threshold is set according to RS decoder threshold

Signal of 1 dB above sensitivity Equivalent to I/(N+Isat) = -5.5 dB

B-OFDM I =

f2 f3 f1 f2 f3

B-OFDM II =

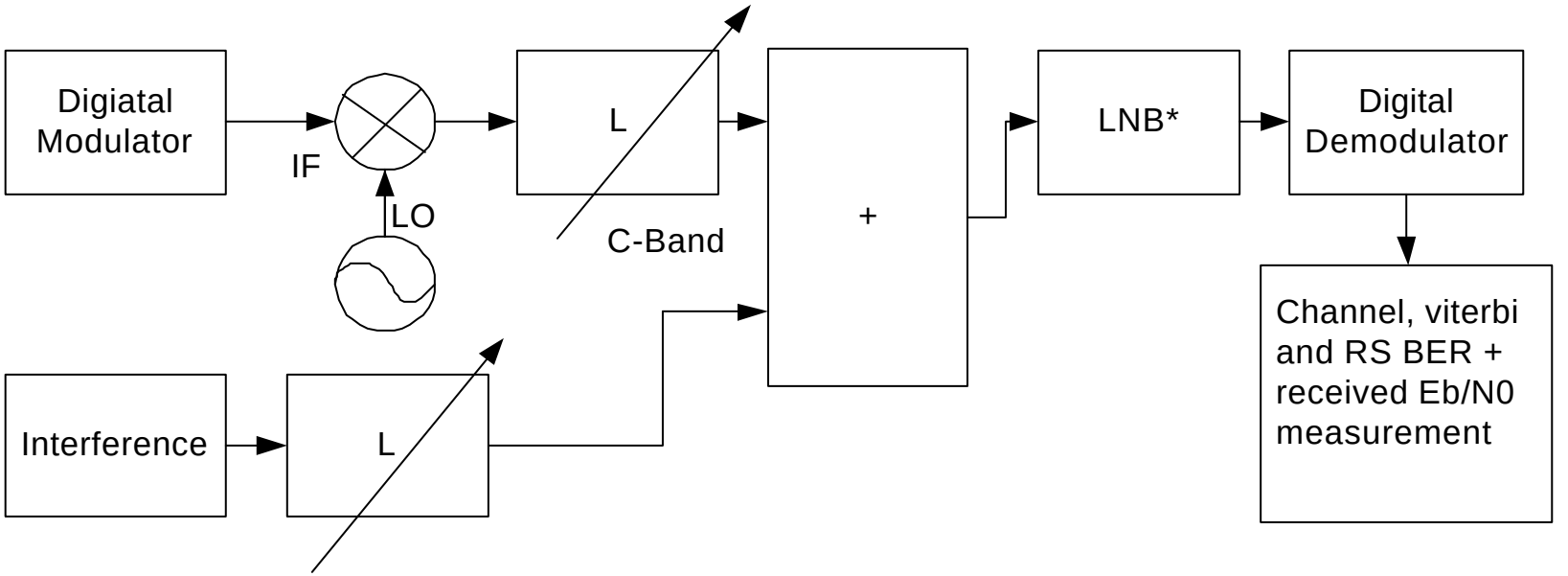
f1 f2 f2 f3 f3

Remarks: Ber represent Ber at the Viterbi output. Threshold is set according to RS decoder threshold

Measurements

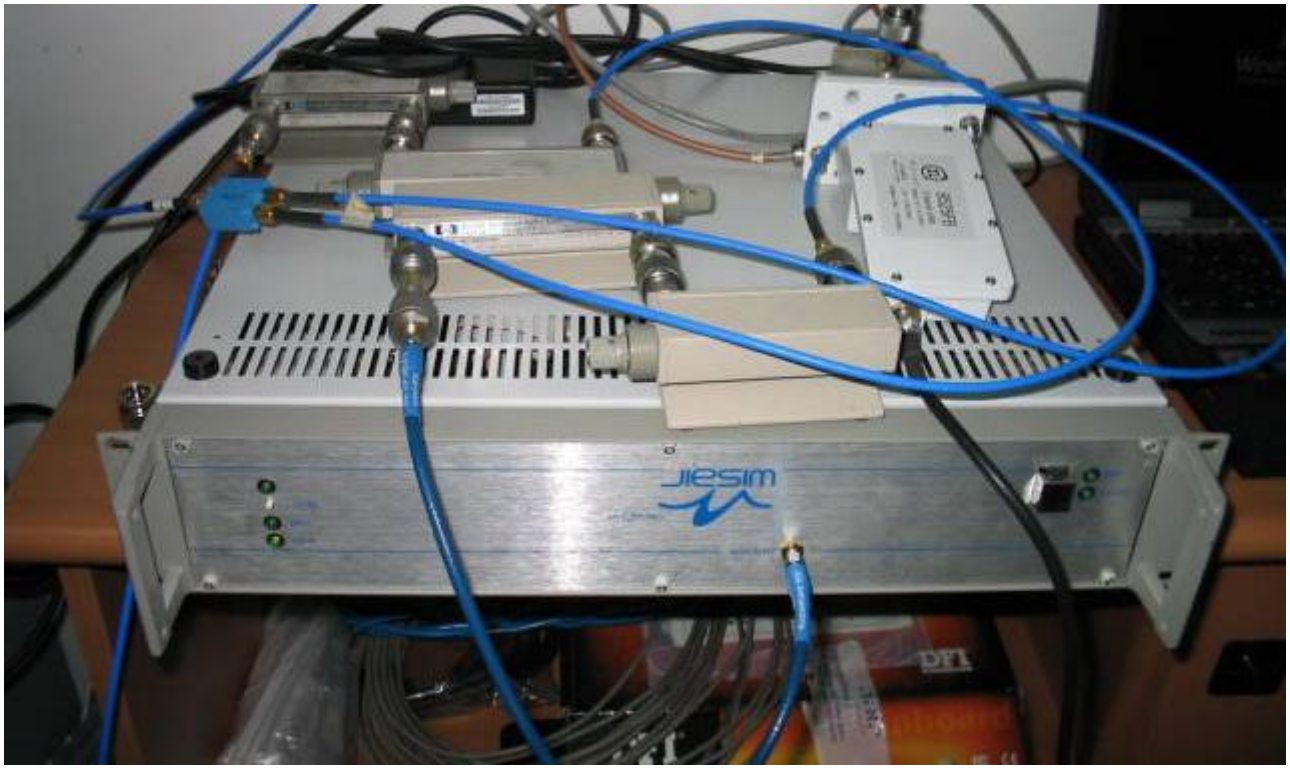
- Measurements were taken with a digital C-Band victim receiver in a carefully calibrated laboratory environment
- Performed preliminary testing with 2.5 Msps and 30 Msps including combinations of convolutional and RS encoders
- Initial measurement results match simulation results when considering measurement accuracy and implementation degradation
  - Less than 1.5 dB difference between MB-OFDM and DS-CDMA for 30 Msps receivers under realistic operating conditions similar to simulation and analysis results
  - No difference between MB-OFDM and DS-CDMA for 2.5 Msps receivers

Digital Test Setup (1)



*LNB sets the initial noise level. Interference is added on top.

Digital Test Setup (2)



Digital Test Setup (3)

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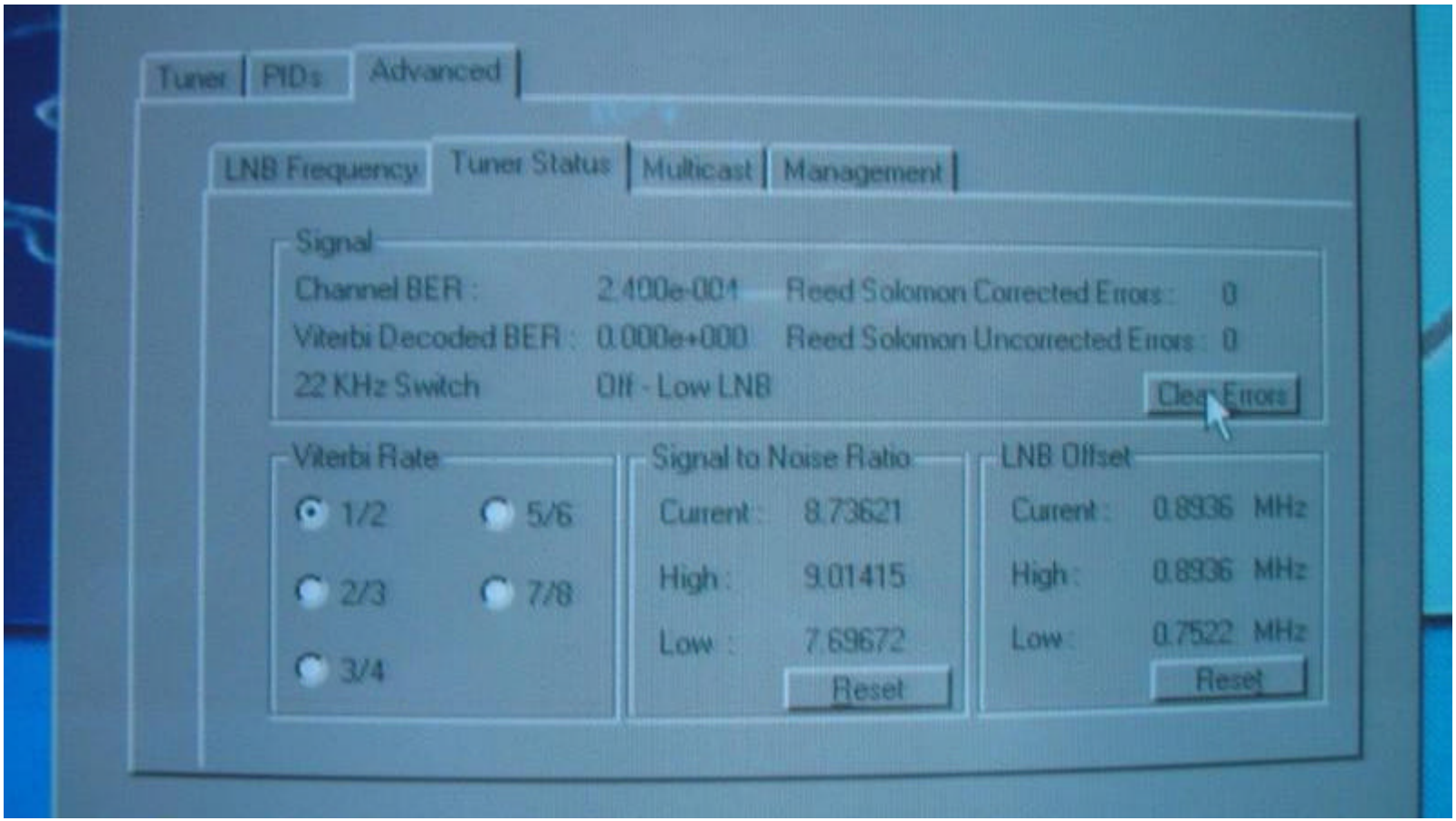

Calibration

- Calibration is a very critical part of the measurement procedure
- For each data point, N, C+N, I+N and C+I+N were measured using a spectrum analyzer with a RMS channel power measurement capability in a 40 MHz bandwidth
- Accurately calculated C, N and I
- Compared results to attenuators readings
- Performed all measurements relative to actual sensitivity level of the C-Band receiver
- Repeated tests and were able to duplicate results to within several tenths of a dB

Conclusions

- Analysis based on APD, bit error rate simulations and measurement results match each other
  => this gives us confidence in our results
- For realistic operation conditions (with interference below the noise and not above it) difference between MB-OFDM and DS-CDMA is smaller than 1.5 dB
- This difference does not apply for more narrowband receivers
- Analysis, simulation and measurement activities will continue
- We believe Motorola/XSI findings are flawed and are willing to work with them to find the measurement error here in ABQ.