Progress Report on Signal Generation of Ultrawideband Signals

Task 1 Report of "A Study to Define Metrics that Determine the Interference Potential of Various Ultrawideband Waveforms"

Michael Cotton, Robert Achatz, Jeffery Wepman, Brent Bedford

On March 22, 2004, the Institute for Telecommunication Sciences (ITS) entered a Cooperative Research and Development Agreement (CRADA) with Motorola/Freescale, Incorporated. Under the CRADA, measurement methods will be developed and actual measurements made of ultrawideband (UWB) interference. A primary goal is to identify those characteristics of various UWB signals that correlate with performance degradation of legacy victim receivers. Specifically, this CRADA focuses on C-band satellite television receivers. To date, ITS has generated a set of signals relevant to existing and proposed UWB systems. These signals include: (1) Direct Sequence UWB (DS-UWB), (2) Multi-Band Orthogonal Frequency-Division Multiplex (MB-OFDM), (3) gated and non-gated Gaussian noise, and (4) dithered pulses. All signals were measured with a vector signal analyzer (VSA), a spectrum analyzer, and a high-speed digital oscilloscope. Block diagrams, pictures of equipment, and examples of measured data are given in this brief paper. A comprehensive test plan will be completed in the near future. It will contain information on measurement equipment and procedures for characterizing UWB signals and evaluating their effects on C-band satellite television receivers.

Figure 1. ITS engineer Brent Bedford with signal generation rack (left) and measurement equipment rack (right).

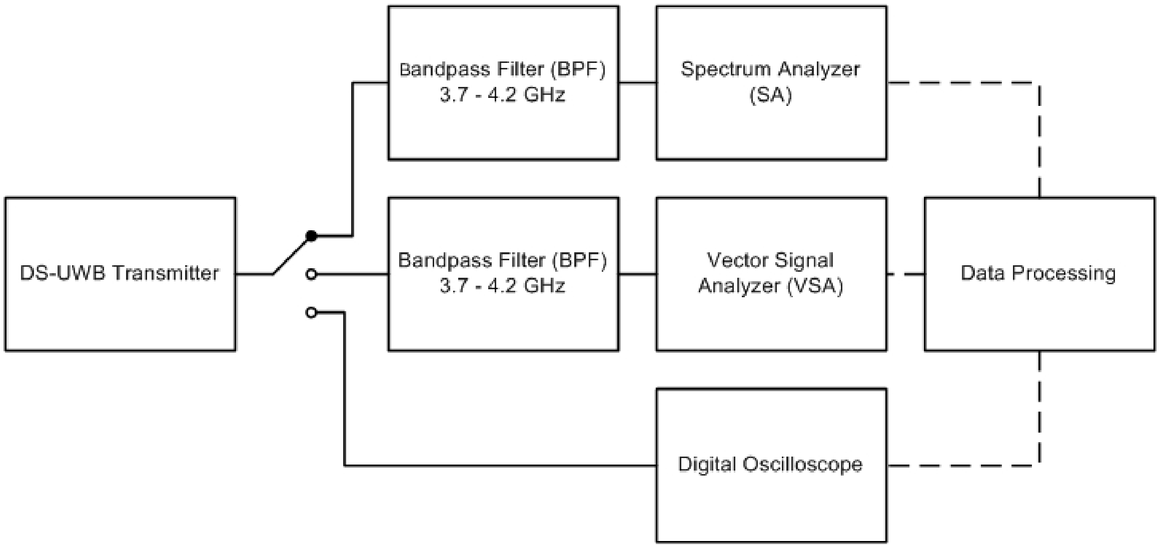

Figure 2. Block diagram for signal generation and measurement of DS-UWB signal. The DS-UWB transmitter operates in the lower band (from 3.1 to 4.85 GHz) and uses BPSK modulation with a spreading code length of 12.

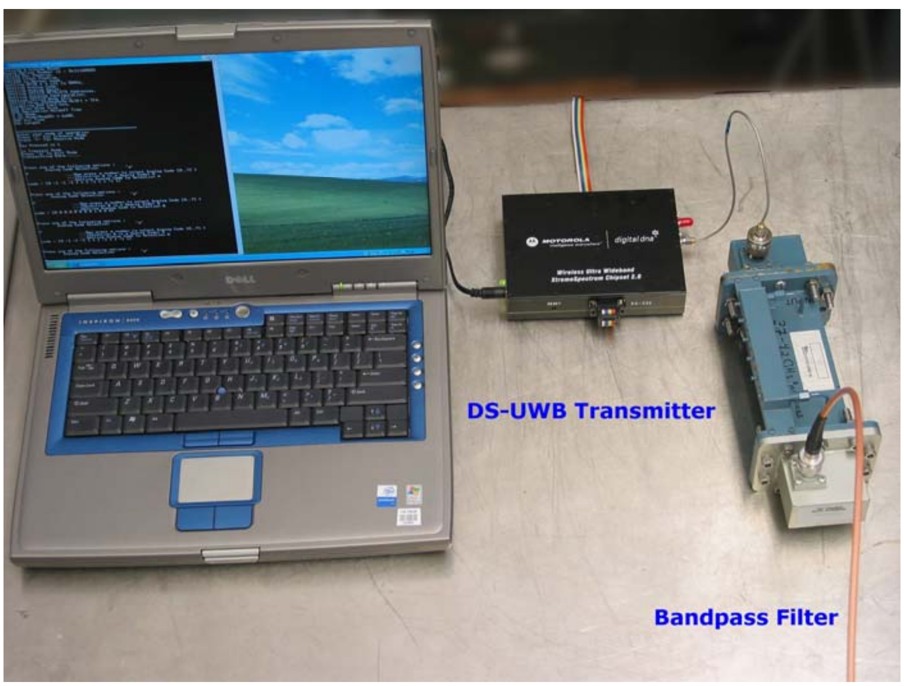

Figure 3. Equipment for signal generation and measurement of DS-UWB signal.

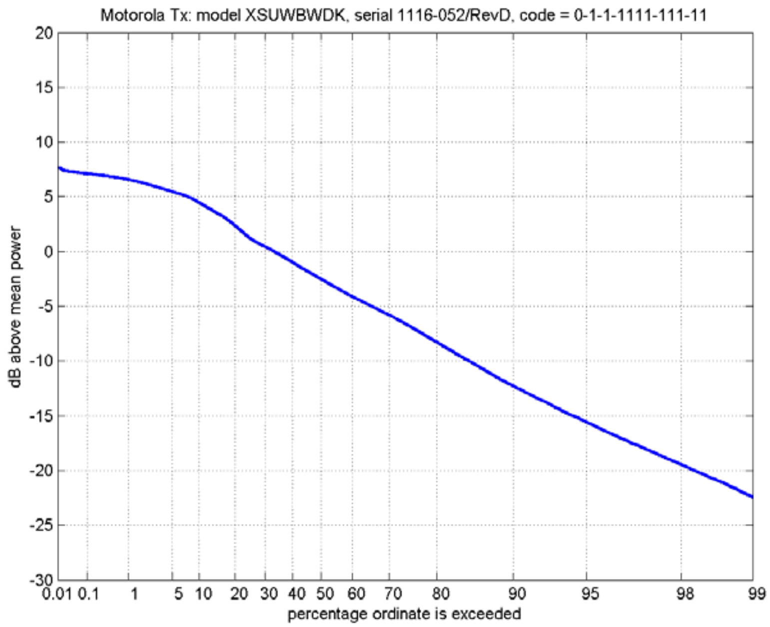

Figure 4. Amplitude Probability Distribution (APD) in 36-MHz bandwidth of DS-UWB emission described in Figure 2. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 36 MHz.

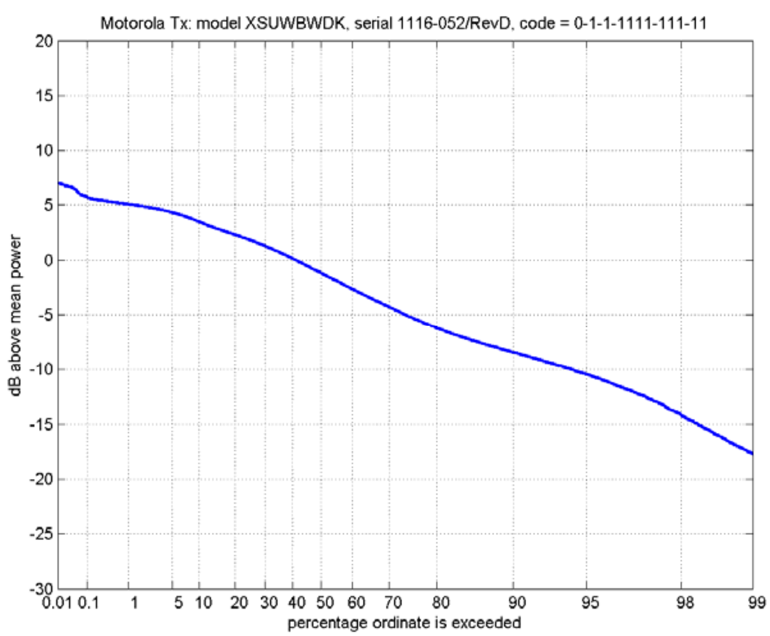

Figure 5. APD in 3-MHz bandwidth of DS-UWB emission described in Figure 2. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 3 MHz.

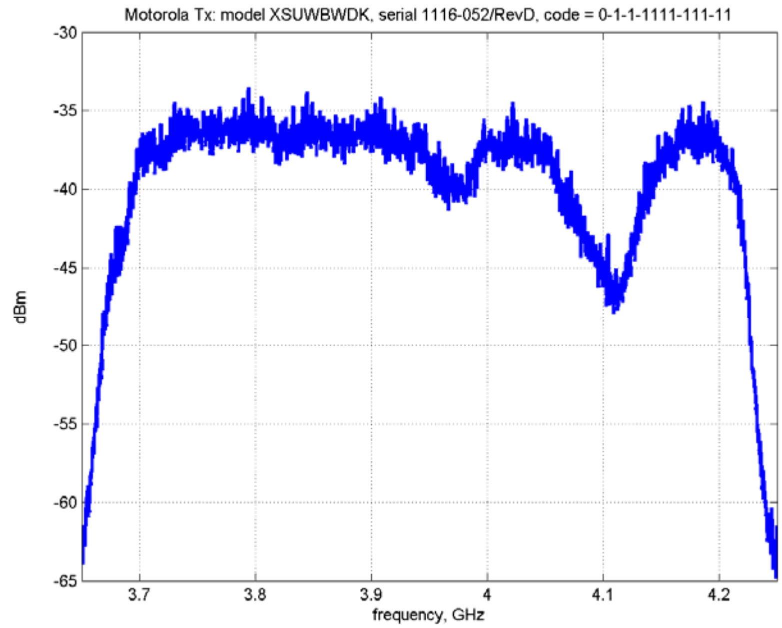

Figure 6. Spectrum plots of DS-UWB emission in the 500-MHz band used for C-band satellite television broadcast. Spectrum analyzer settings: center frequency = 3950 MHz, span = 600 MHz, resolution bandwidth = 1 MHz, video bandwidth = 50 MHz, frequency step size = 0.167 MHz, detection = peak, sweep time = 3.6 s.

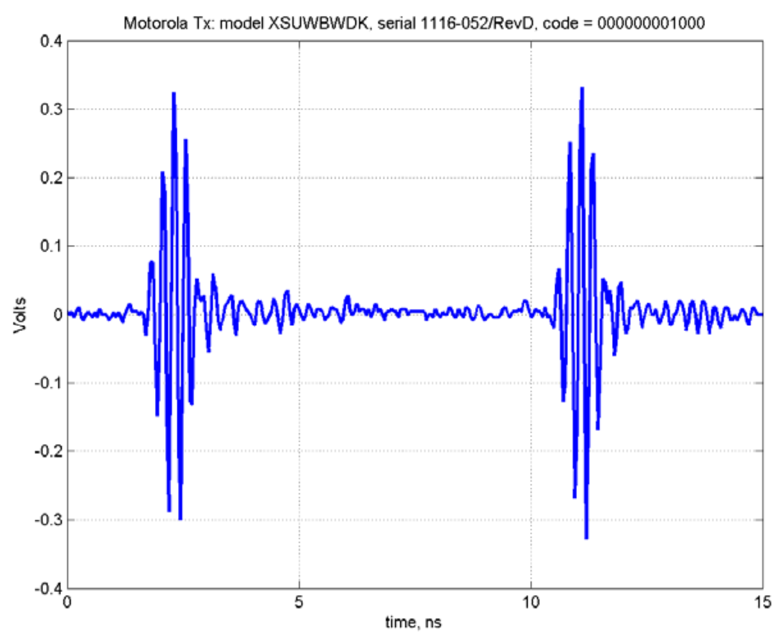

Figure 7. Digital oscilloscope measurement of DS-UWB emission. Oscilloscope settings: samplerate = 20 GS/s.

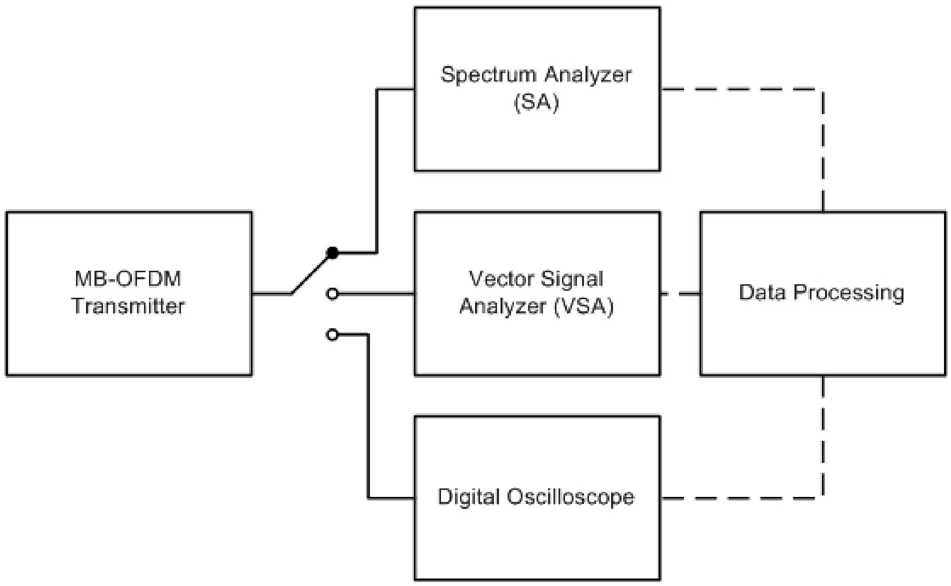

Figure 8. Block diagram for signal generation and measurement of MB-OFDM signal. The Wisair MB-OFDM transmitter hops within the first band group between bands F1, F2, and F3. Transmitted signal was offset by 264 MHz from frequency specifications in "Multi-band OFDM physical layer proposal for IEEE 802.15 Task Group 3a" (March 2004). For example, center of F2 was 4224 MHz rather than 3960 MHz.

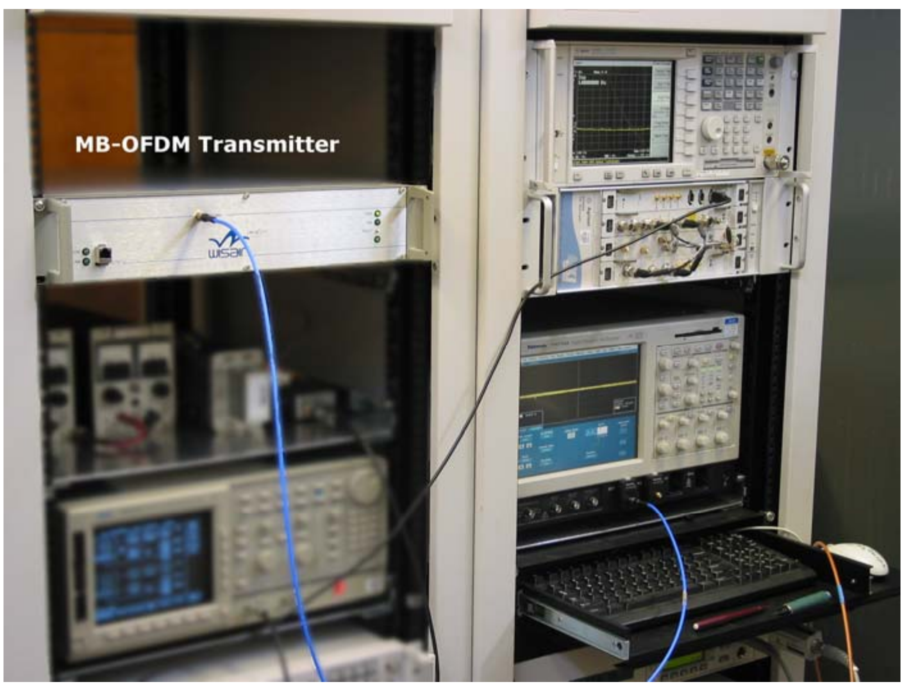

Figure 9. Equipment for signal generation and measurement of Wisair MB-OFDM signal.

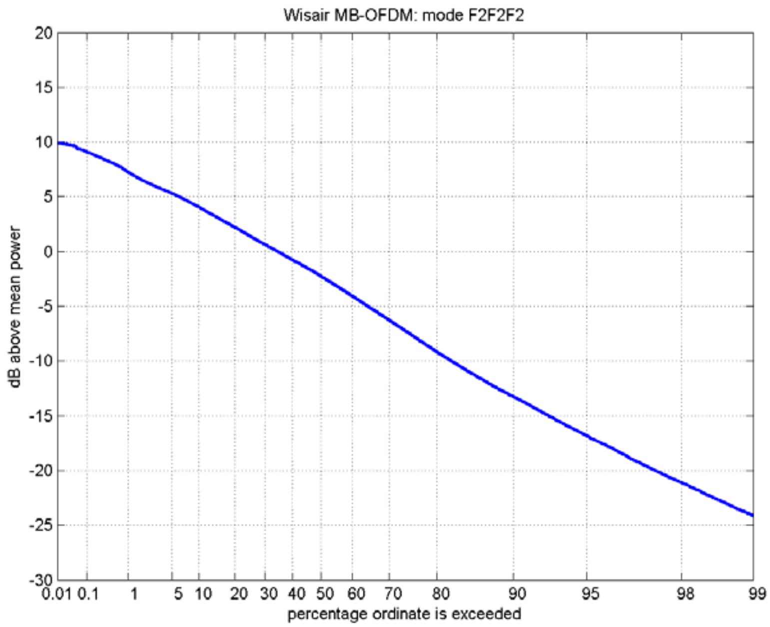

Figure 10. APD in 36-MHz bandwidth of Wisair MB-OFDM in a non-hopping mode. APD is built from 65,536 samples. VSA settings: center frequency = 4.084 GHz, span = 36 MHz.

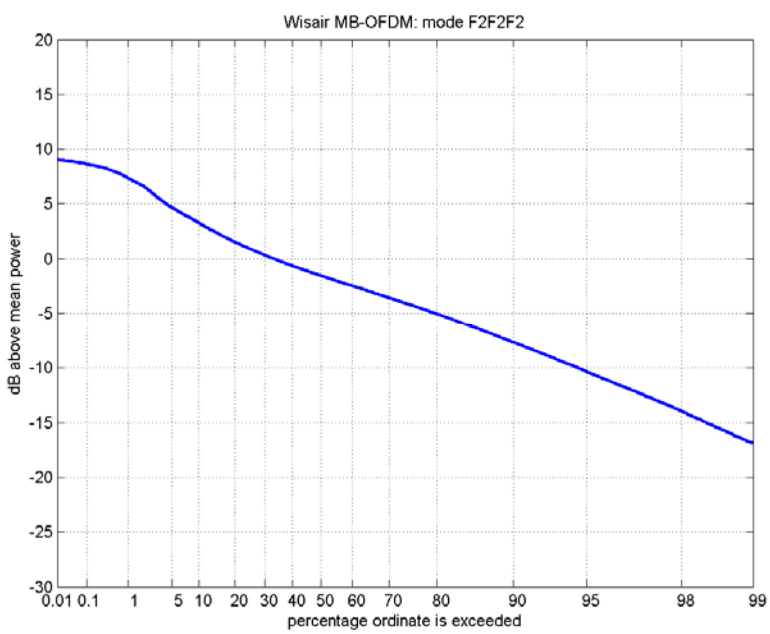

Figure 11. APD in 3-MHz bandwidth of Wisair MB-OFDM in a non-hopping mode. APD is built from 65,536 samples. VSA settings: center frequency = 4.084 GHz, span = 3 MHz.

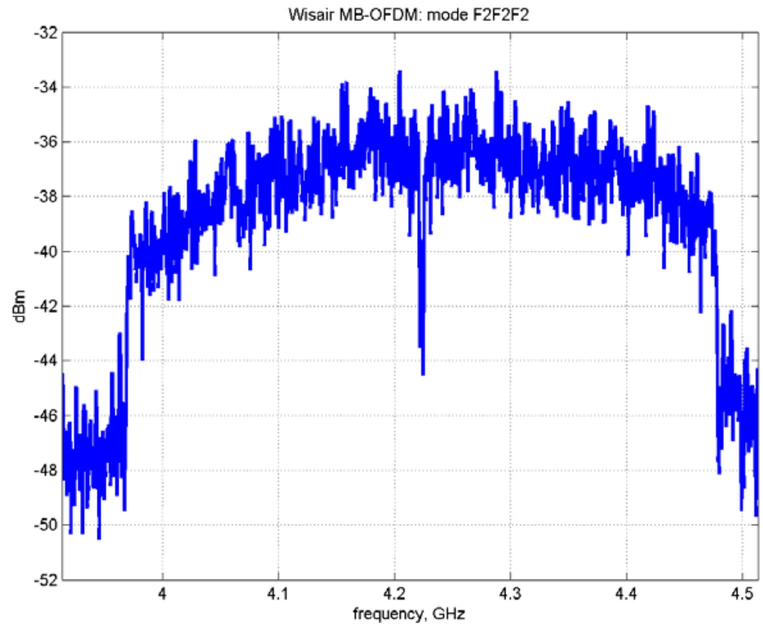

Figure 12. Spectrum plot of Wisair MB-OFDM in a non-hopping mode. Spectrum analyzer settings: center frequency = 4214 MHz, span = 600 MHz, resolution bandwidth = 1 MHz, video bandwidth = 50 MHz, frequency step size = 0.167 MHz, detection = peak, sweep time = 3.6 s.

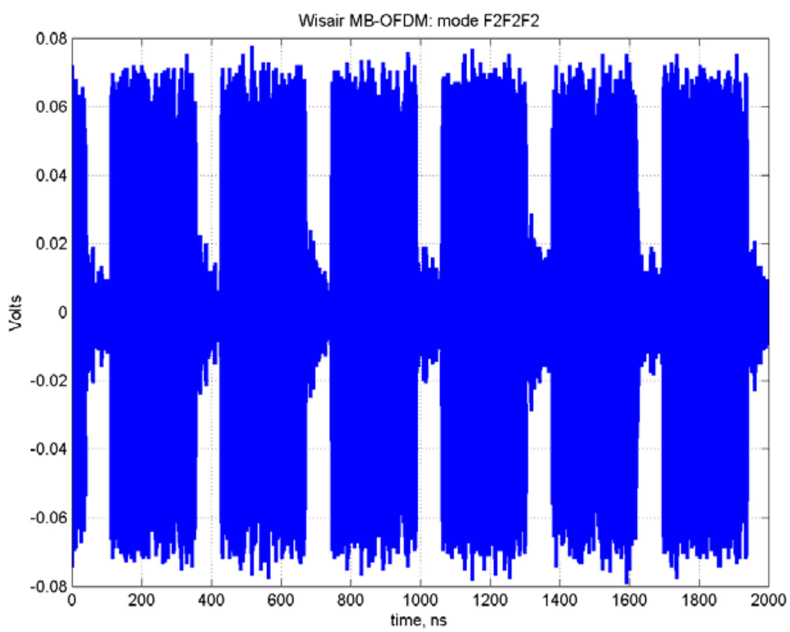

Figure 13. Digital oscilloscope measurement of Wisair MB-OFDM in a non-hopping mode. Oscilloscope settings: samplerate = 20 GS/s.

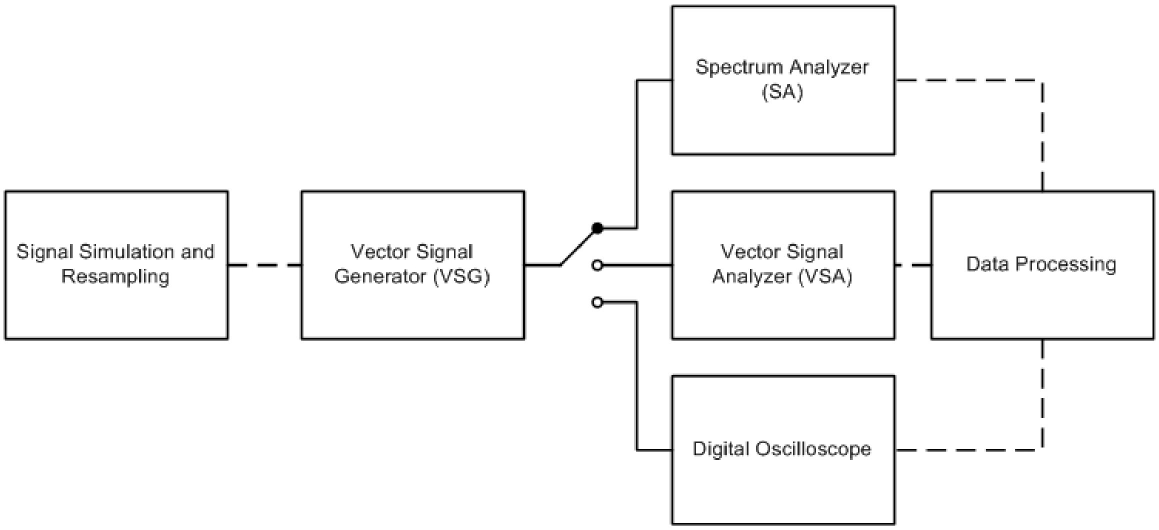

Figure 14. Block diagram for signal generation and measurement of gated/non-gated OFDM. OFDM parameters were taken from "Multi-band OFDM physical layer proposal for IEEE 802.15 Task Group 3a" (March 2004). The OFDM signal is comprised of 128 QPSK-modulated tones 4.125 MHz apart. An OFDM-symbol includes a 60.6-ns prefix, 242.4 ns of data, and a 9.5-ns guard interval. The 528-MHz OFDM waveform was software simulated, resampled to the sample rate of the vector signal generator (100 MS/s), and implemented on the vector signal generator.

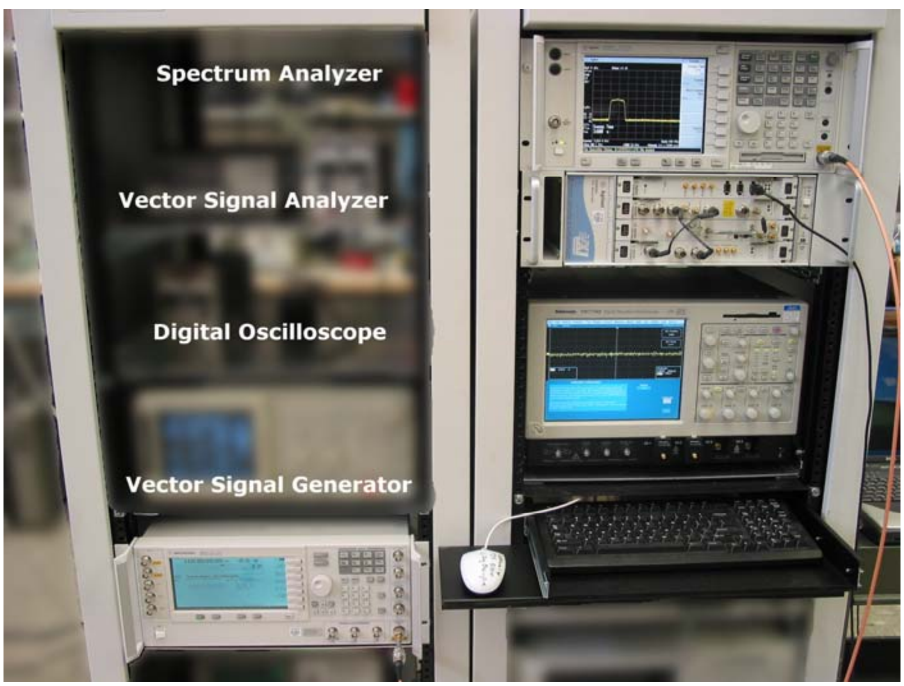

Figure 15. Equipment for signal generation and measurement of gated/non-gated OFDM signal.

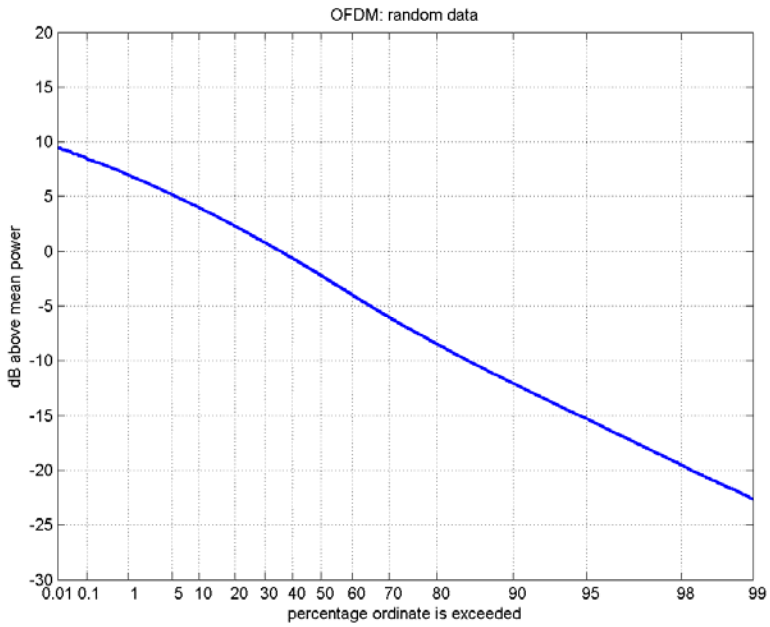

Figure 16. APD in 36-MHz bandwidth of OFDM signal described in Figure 14. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 36 MHz.

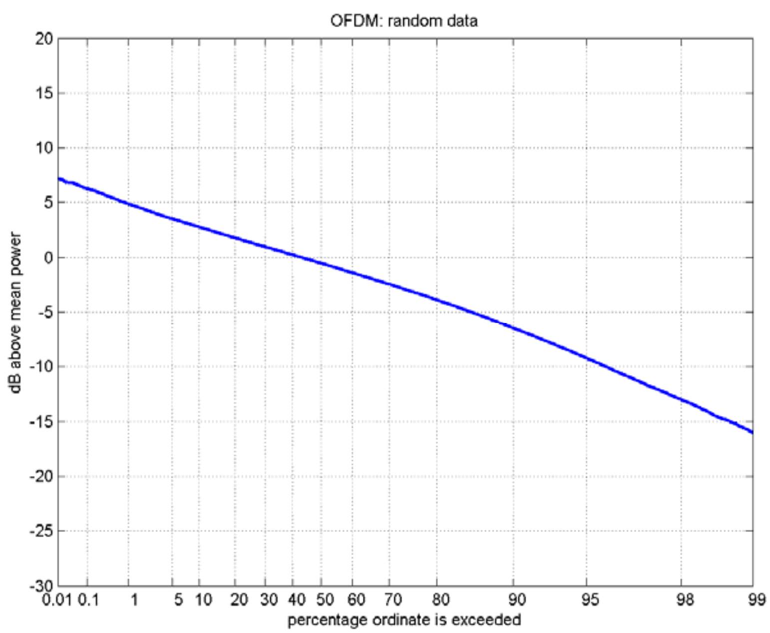

Figure 17. APD in 3-MHz bandwidth of OFDM signal described in Figure 14. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 3 MHz.

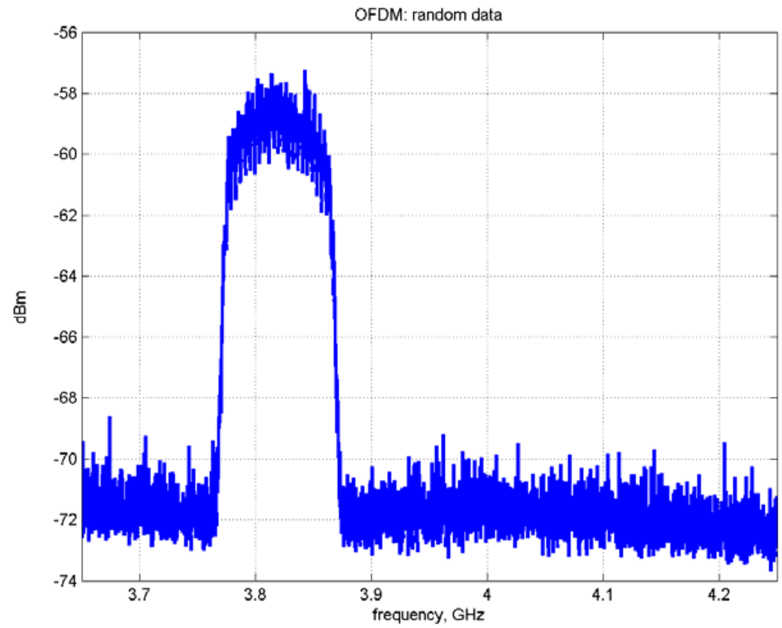

Figure 18. Spectrum plot of OFDM signal described in Figure 14. Spectrum analyzer settings: center frequency = 3950 MHz, span = 600 MHz, resolution bandwidth = 1 MHz, video bandwidth = 50 MHz, frequency step size = 0.167 MHz, detection = peak, sweep time = 3.6 s.

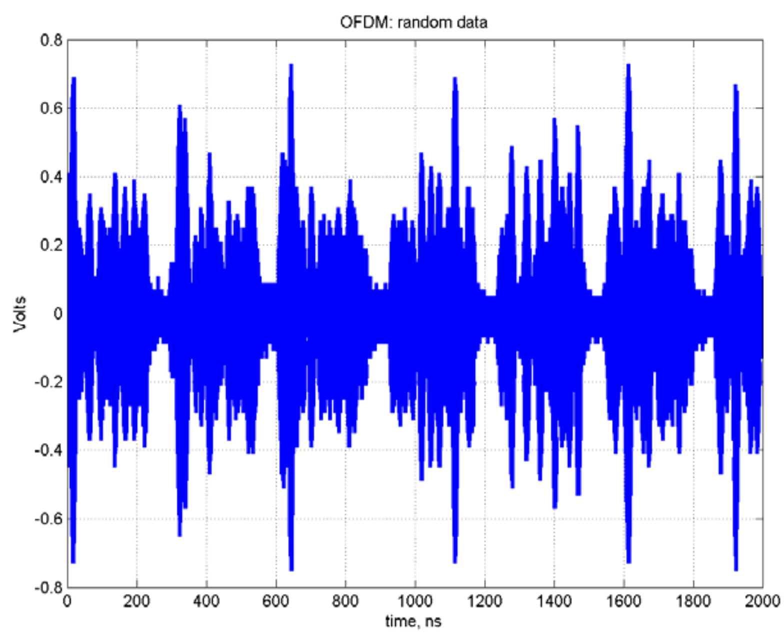

Figure 19. Digital oscilloscope measurement of OFDM signal described in Figure 14. Output power of the VSG was increased to observe signal on the oscilloscope. Oscilloscope settings: samplerate = 20 GS/s.

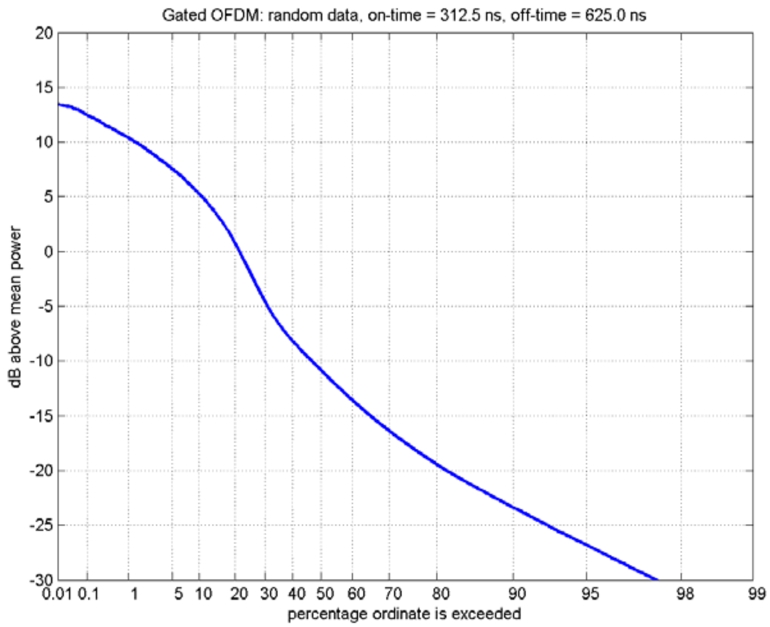

Figure 20. APD in 36-MHz bandwidth of gated (on for one 312.5-ns OFDM-symbol, then off for two symbols) OFDM signal described in Figure 14. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 36 MHz.

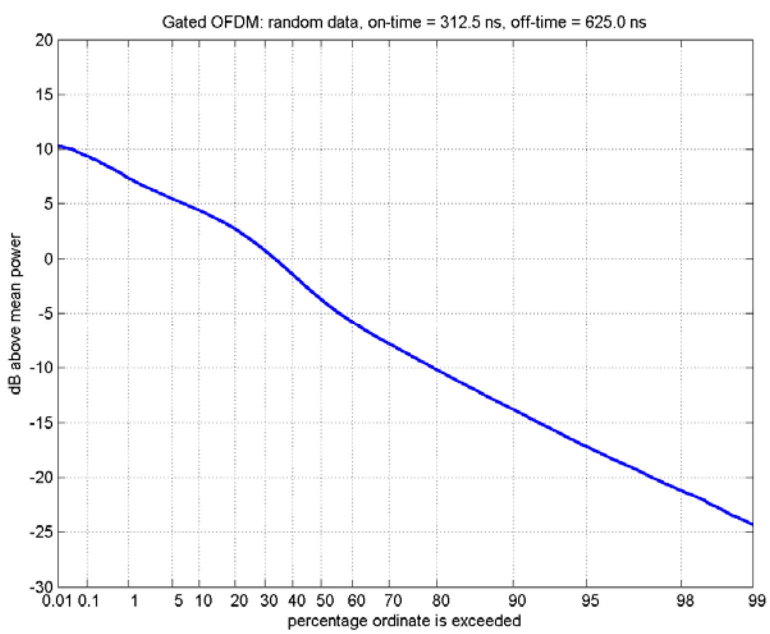

Figure 21. APD in 3-MHz bandwidth of gated (on for one 312.5-ns OFDM-symbol, then off for two symbols) OFDM signal described in Figure 14. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 3 MHz.

Figure 22. Spectrum plot of gated (on for one 312.5-ns OFDM-symbol, then off for two symbols) OFDM signal described in Figure 14. Spectrum analyzer settings: center frequency = 3950 MHz, span = 600 MHz, resolution bandwidth = 1 MHz, video bandwidth = 50 MHz, frequency step size = 0.167 MHz, detection = peak, sweep time = 3.6 s.

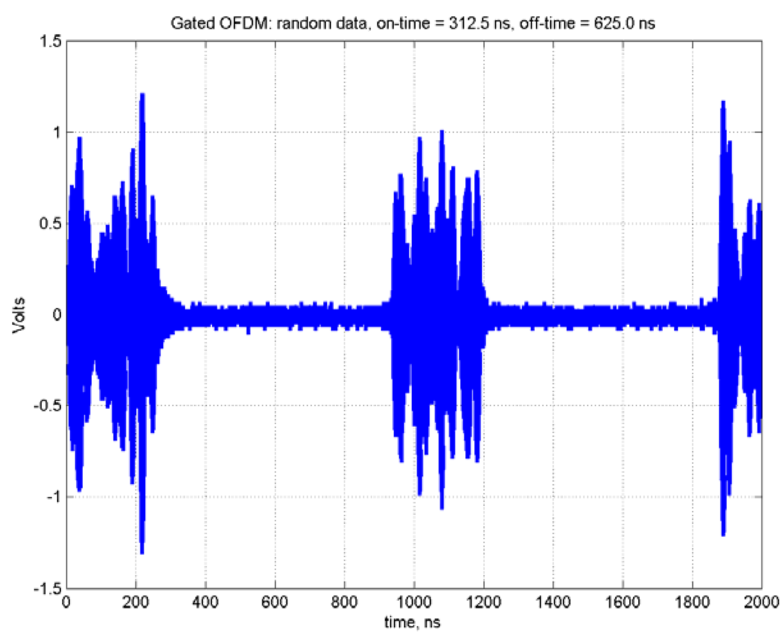

Figure 23. Digital oscilloscope measurement of gated (on for one 312.5-ns OFDM-symbol, then off for two symbols) OFDM signal described in Figure 14. Output power of the VSG was increased to observe signal on the oscilloscope. Oscilloscope settings: samplerate = 20 GS/s.

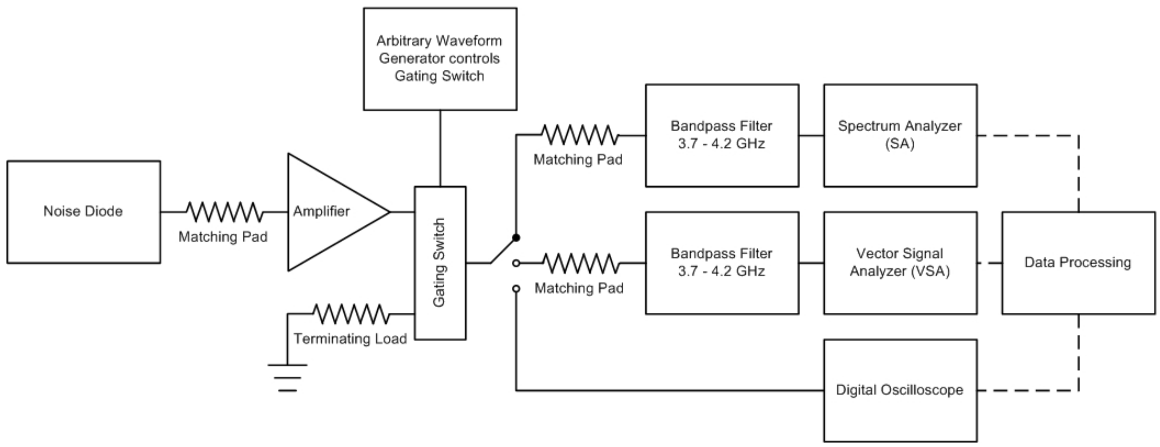

Figure 24. Block diagram for signal generation and measurement of gated/non-gated noise. The noise signal was generated by a noise diode (ENR = 27 dB) and gated with a high-speed electronic switch.

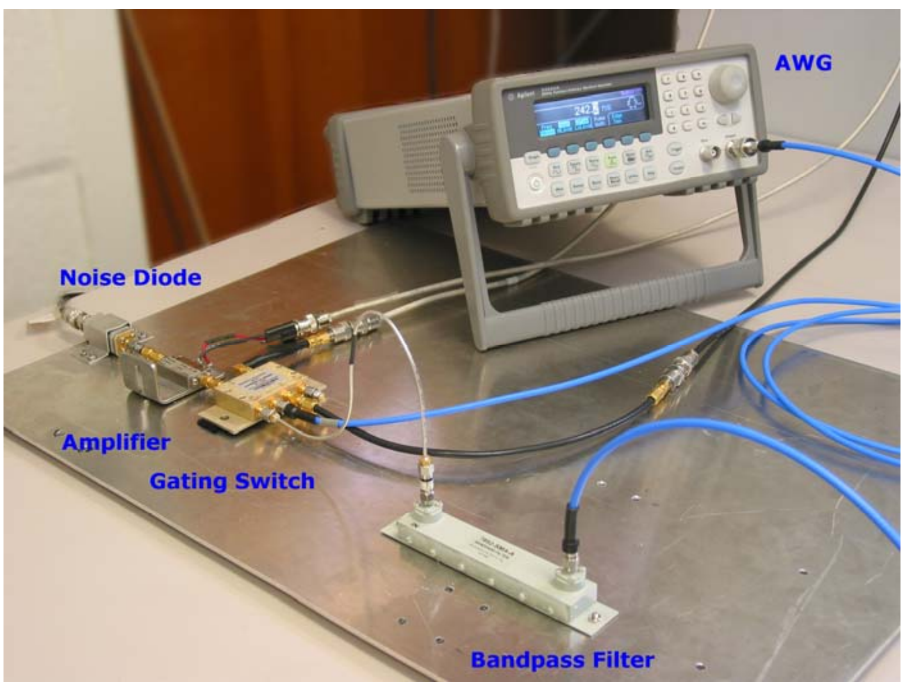

Figure 25. Equipment for signal generation and measurement of gated/non-gated noise.

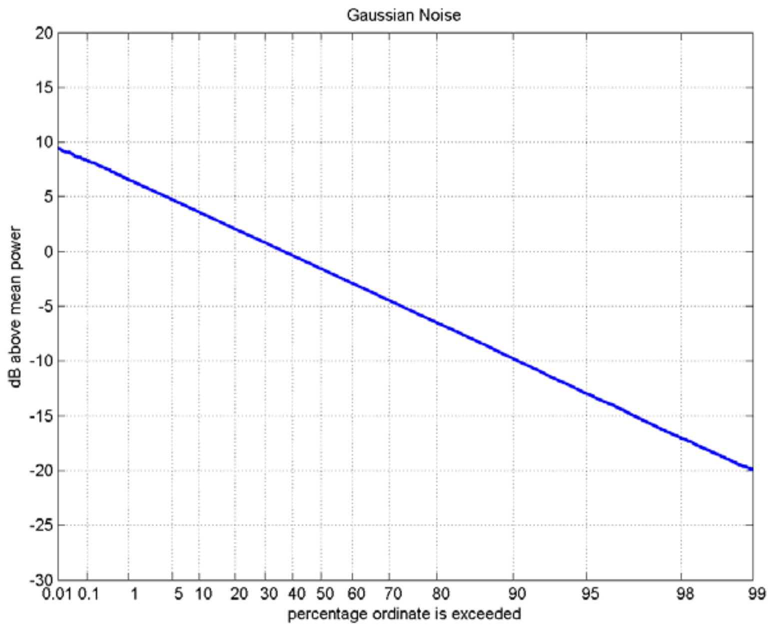

Figure 26. APD in 36-MHz bandwidth of Gaussian noise. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 36 MHz.

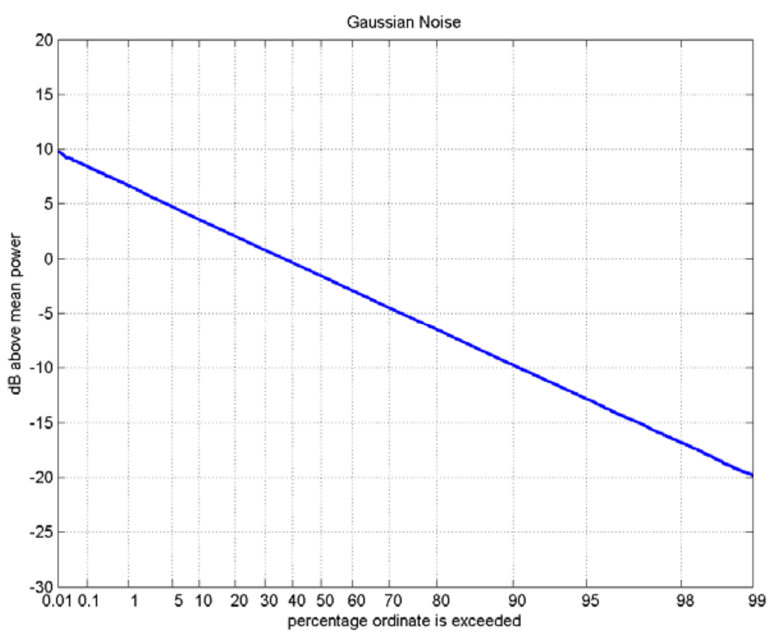

Figure 27. APD in 3-MHz bandwidth of Gaussian noise. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 3 MHz.

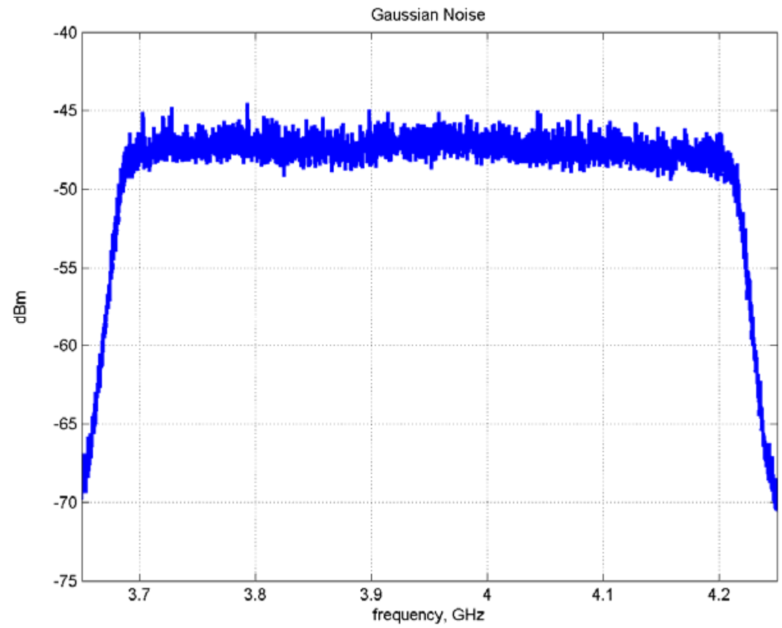

Figure 28. Spectrum plot of Gaussian noise in the 500-MHz band used for C-band satellite television broadcast. Spectrum analyzer settings: center frequency = 3950 MHz, span = 600 MHz, resolution bandwidth = 1 MHz, video bandwidth = 50 MHz, frequency step size = 0.167 MHz, detection = peak, sweep time = 3.6 s.

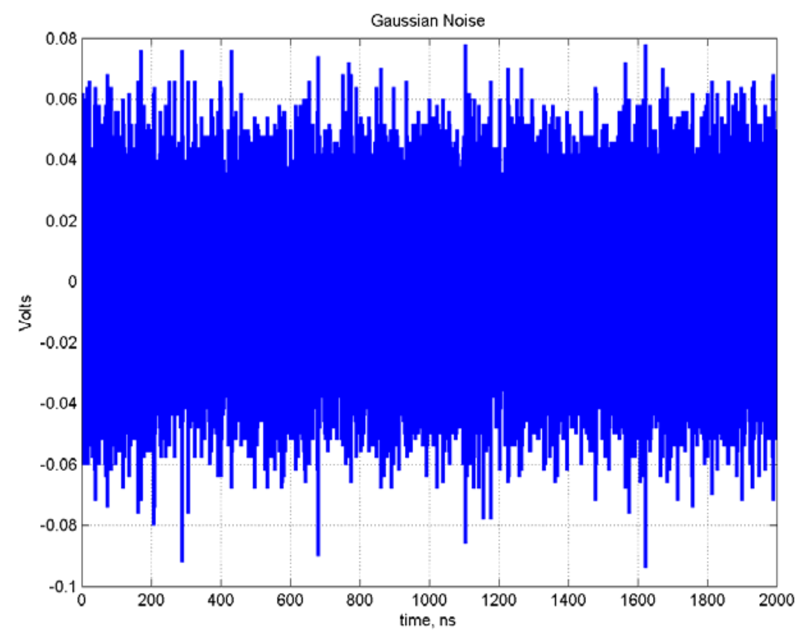

Figure 29. Digital oscilloscope measurement of Gaussian noise. Oscilloscope settings: samplerate = 20 GS/s.

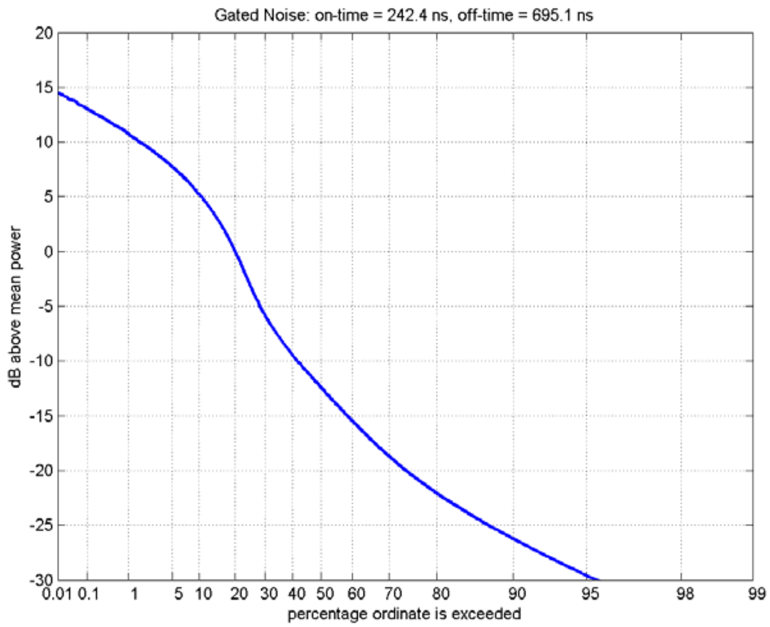

Figure 30. APD in 36-MHz bandwidth of gated noise. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 36 MHz.

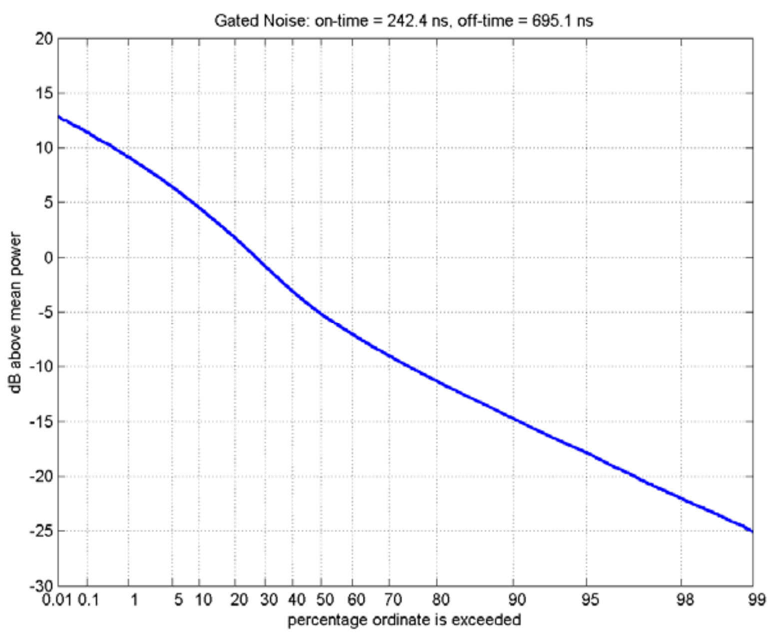

Figure 31. APD in 3-MHz bandwidth of gated noise. APD is built from 65,536 samples. VSA settings: center frequency = 3820 MHz, span = 3 MHz.

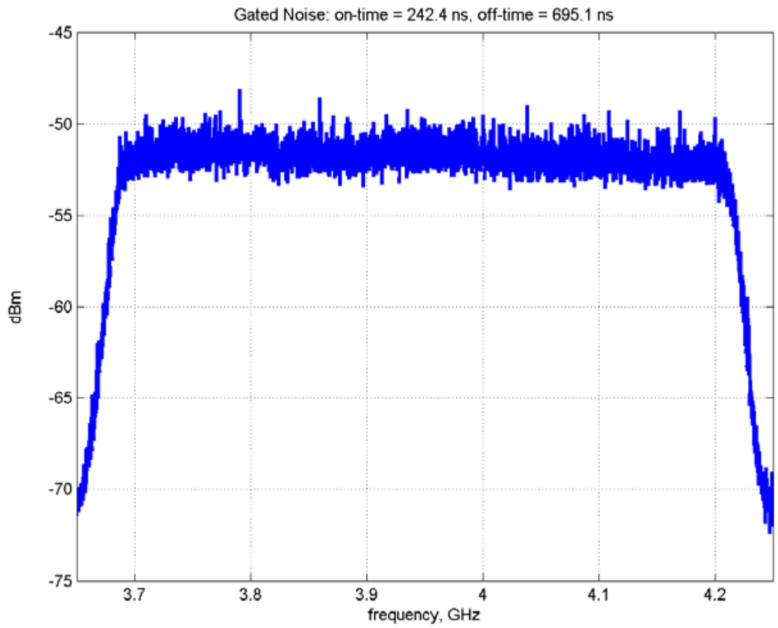

Figure 32. Spectrum plot of gated noise in the 500-MHz band used for C-band satellite television broadcast. Spectrum analyzer settings: center frequency = 3950 MHz, span = 600 MHz, resolution bandwidth = 1 MHz, video bandwidth = 50 MHz, frequency step size = 0.167 MHz, detection = peak, sweep time = 3.6 s.

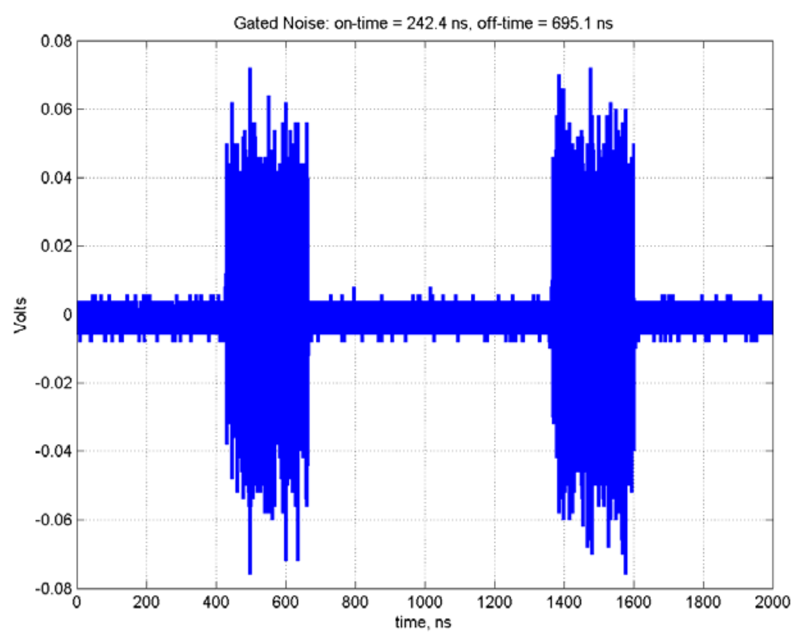

Figure 33. Digital oscilloscope measurement of gated noise. Oscilloscope settings: samplerate = 20 GS/s.

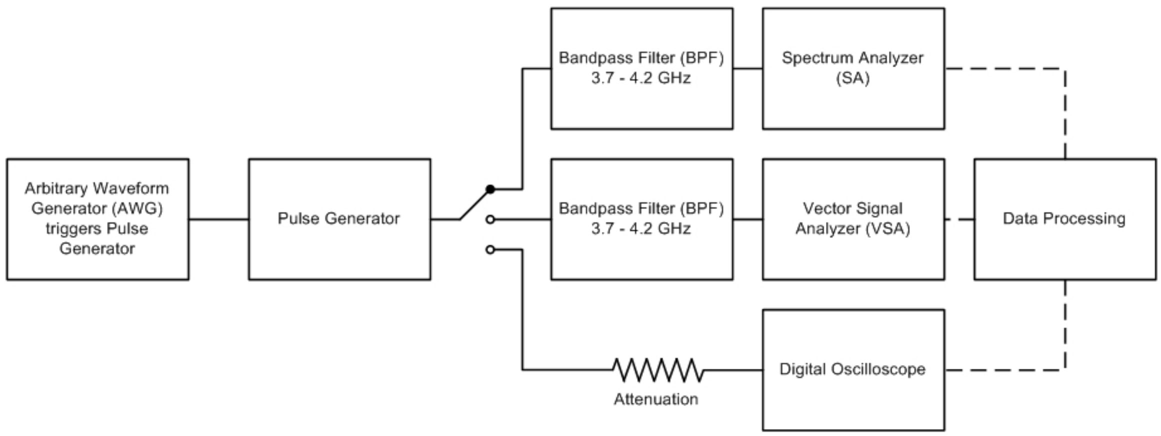

Figure 34. Block diagram for signal generation and measurement of 18-MHz PRF (pulse repetition frequency), 50%-ARD (absolute-referenced dithered) pulses. The signal was generated by a pulse generator (pulse width ≈ 245 ns) triggered by an Arbitrary Waveform Generator (AWG).

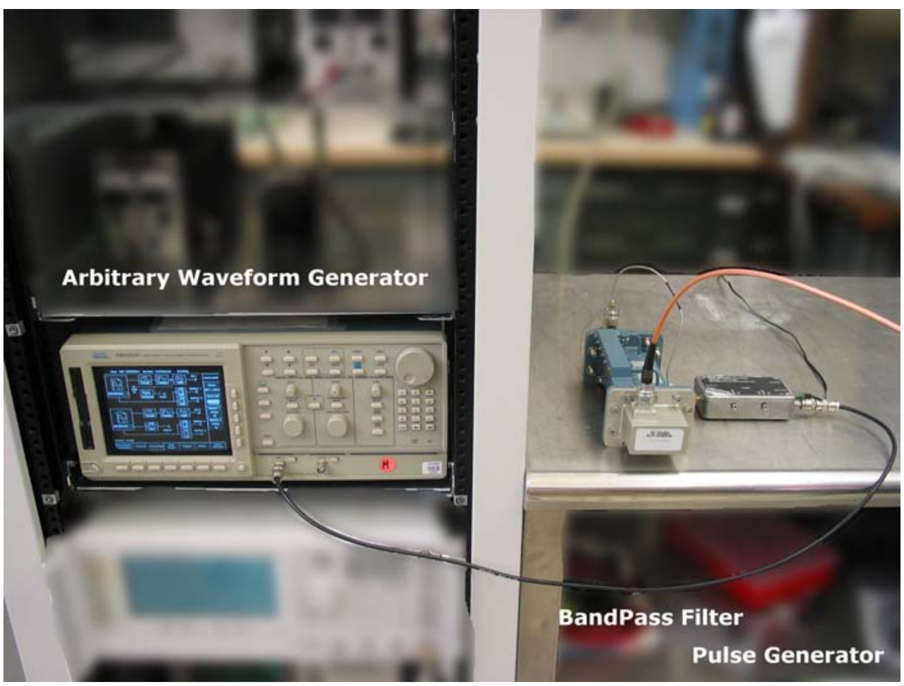

Figure 35. Equipment for signal generation and measurement of dithered pulses.

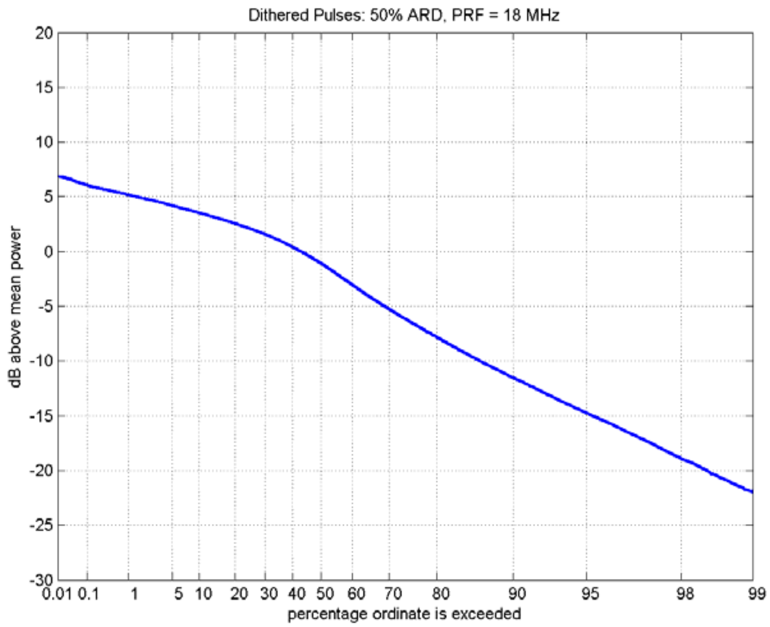

Figure 36. APD in 36-MHz bandwidth of dithered pulses described in Figure 34. APD is built from 65,536 samples. VSA settings: center frequency = 3.820 GHz, span = 36 MHz.

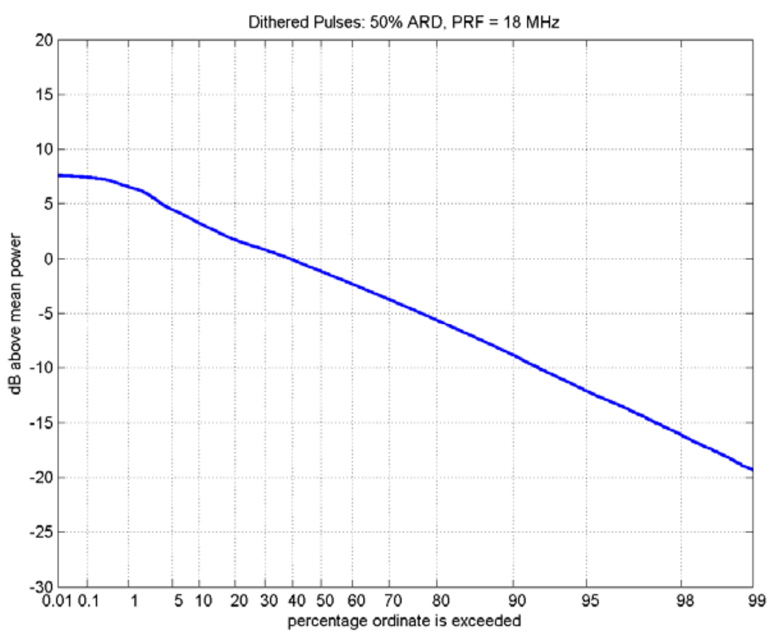

Figure 37. APD in 3-MHz bandwidth of dithered pulses described in Figure 34. APD is built from 65,536 samples. VSA settings: center frequency = 3.820 GHz, span =3 MHz.

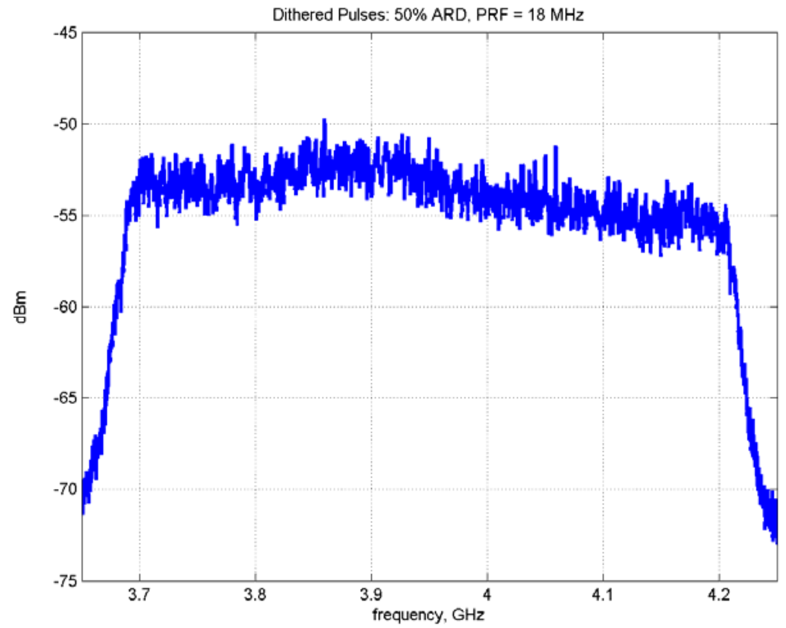

Figure 38. Spectrum plot of dithered pulses in the 500-MHz band used for C-band satellite television broadcast. Spectrum analyzer settings: center frequency = 3950 MHz, span = 600 MHz, resolution bandwidth = 1 MHz, video bandwidth = 50 MHz, frequency step size = 0.167 MHz, detection = peak, sweep time = 3.6 s.

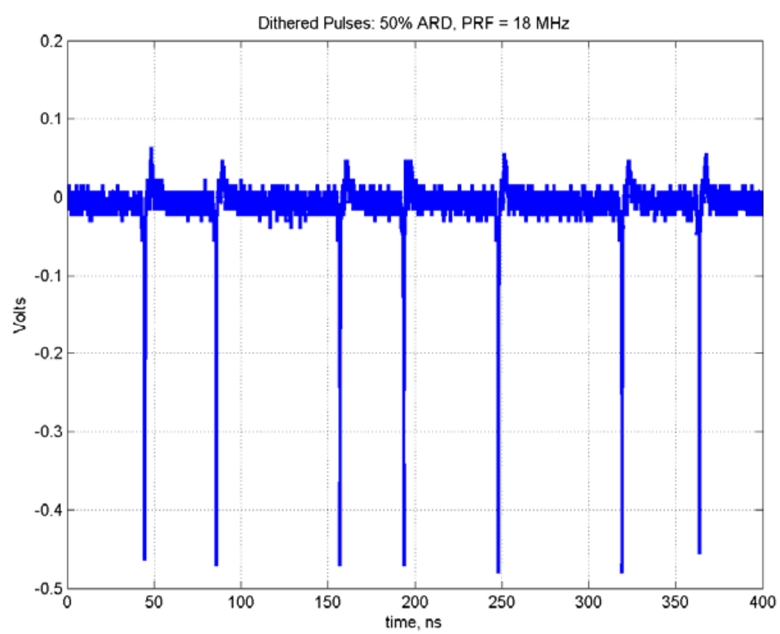

Figure 39. Digital oscilloscope measurement of dithered pulses described in Figure 34. Oscilloscope settings: samplerate = 20 GS/s.

Figure 40. ITS engineer Brent Bedford at the measurement rack that holds (from the top): spectrum analyzer, VSA, high-speed digital oscilloscope, and power meter.

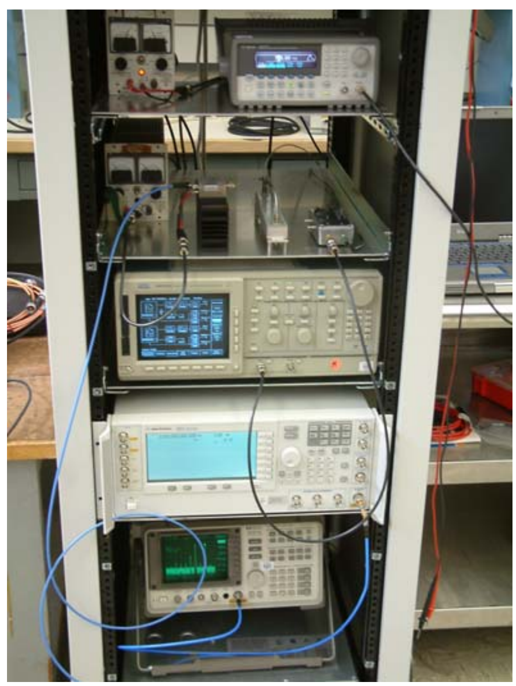

Figure 41. (Left) ITS engineer Jeff Wepman using spectrum analyzer to monitor OFDM signal generated by the vector signal generator (VSG). (Right) Signal generation rack: top level contains power supply for noise diode and arbitrary waveform generator for gating the noise, levels two and three hold components necessary to generate dithered pulses, and level four holds the VSG.

Figure 42. ITS engineer Mike Cotton connecting pulse generator, bandpass filter, and amplifier for dithered pulse generation.

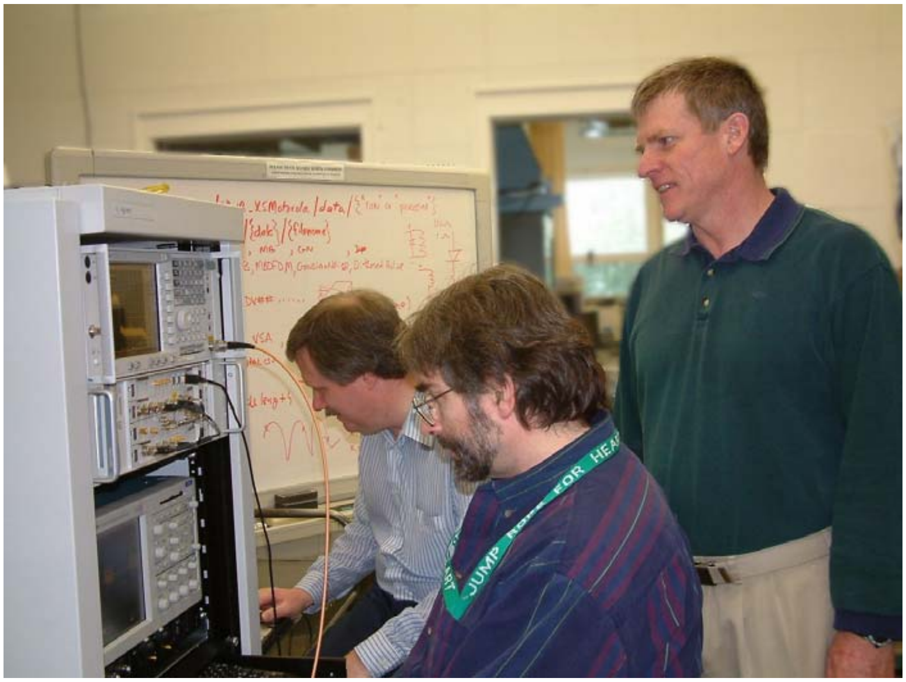

Figure 43. ITS engineers Brent Bedford, Jeff Wepman, and Bob Achatz at the measurement rack.