On-the-Air Demonstration of a Prototype LWA Analog Signal Path

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Contents

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1 Summary

We have demonstrated in field conditions an analog signal chain consisting of an ETA active antenna, an ETA analog receiver (ARX) modified for 20–80 MHz bandpass, and the 12-bit LWA prototype A/D board described in LWA Memo 127 [1]. The test was conducted near Blacksburg, VA and valid data were obtained despite the presence of strong RFI in the form of an ATSC (digital TV) signal and other broadcast signals. This represents a significant milestone in demonstrated performance of a direct sampling receiver operating in the LWA frequency regime in terms of sample rate (200 MSPS) and fractional bandwidth (ratio of bandwidth to center frequency = 110%). For comparison, the corresponding values for LWDA (60–88 MHz) are 100 MSPS and 38%, and for ETA (29–47 MHz) are 120 MSPS and 47%. The raw A/D output data file from this field experiment is freely available to those interested in analyzing or experimenting with the data. This setup is portable and easily reproducible, and we describe how it could be extended into a system capable of array capture. With the replacement of the ETA antenna with an LWA candidate antenna (such as the "big blade"), this setup is well-suited to LWA development tasks including evaluation of LWA prototype antennas, front end electronics (FEE), ARX, array experiments, and sensitive RFI surveys capable of detecting impulsive interference (not practical with a spectrum analyzer).

2 System Description

Figure 1 shows a block diagram of the system. The ETA active antenna is described in detail in LWA Memo 60 [2], and is shown in Figure 2. This design uses an active balun which is similar to the LWDA active balun and is open to the entire LWA "desired" tuning range. The antenna portion of the active antenna uses thin aluminum dipole arms and as a result is Galactic noise-dominated only over 29–47 MHz. However, any antenna design could be used in this arrangement using either the ETA active balun or an LWA prototype active balun.

The active antenna is connected to the ARX via 150 ft of RG-58 coaxial cable. The ARX is an ETA ARX which has been modified for 20–80 MHz bandpass, as described in LWA Memo 82 [3], and can be seen in Figure 3. The ARX was operated in it's maximum gain configuration, in which it provides 54 dB of gain with 6 dB noise figure and input third-order intercept point equal to −16 dBm. The ARX output is connected to the 12-bit LWA prototype A/D board described in LWA Memo 127 [1]. (A more detailed evaluation of the A/D board at 196 MSPS can be found in LWA Engineering Memo (EM) ARX0001 [4].) The output of this board is captured by the Analog Devices, Inc. HSC-ADC-EVALC digital capture board (also described in [1]) which interfaces to a laptop PC via USB. The capture board comes with software for MS-Windows which allows up to 8192K (8388608) contiguous samples to be captured on the board and then transferred to a disk file. At 200 MSPS, this amounts to 42 ms of continuous capture. The software is designed primarily for evaluation of A/D boards, and thus has many additional features related to that application. The +7 dBm 200 MHz clock signal is provided by a small module cannibalized from another project, and requires a 10 MHz reference which is provided in this case by an inexpensive Novatech 408A DDS unit. Additional details are available in LWA EM ARX0001 [4].

In future realizations of this setup, a suitable clock could be obtained compactly and inexpensively in a variety of methods. For example, the SignalForge SF1000 Synthesized Signal Generator (∼$1000) is a very compact device which includes an internal reference oscillator. Also, coherent capture from multiple antennas can easily be accomplished using multiple copies of this setup with a single clock coherently replicated into as many copies as needed. The ETA project has had success using the inexpensive Analog Devices, Inc. AD9510/PCBZ evaluation boards (∼$150) for clock generation and coherent fan-out. Synchronization of the data streams should be possible as a post-processing operation either by direct correlation of an RFI-free portion of the spectrum from each antennas, if they are closely spaced (since the noise is nominally Galactic noise-dominated); or by embedding signals in the RF inputs if the separation between antennas is more than a few wavelengths. Synchronized triggering might be possible, but would require a careful examination of the A/D capture board in order to determine.

3 Field Demonstration

The field experiment was conducted in the afternoon of March 13, 2008 at Pandapas Pond, a U.S. Forest Service facility located a few miles from the Virginia Tech main campus in Blacksburg, VA. Brush Mountain (actually, a ridge line) provides a useful degree of isolation from the significant levels of RFI associated with the nearby population centers and industry in Blacksburg, Christiansburg, and Radford. The antenna setup and test equipment setup are shown in Figures 2 and 3, respectively. First, we acquired 64K (65536) samples, resulting in the spectrum shown in Figure 4. The bandpass of the ARX is clearly visible, and an ATSC signal is prominent at about 63 MHz. A few NTSC (analog TV) carriers and the usual forest of HF and FM broadcast signals are visible.

Next, 42 ms seconds of contiguous raw A/D data were acquired. This dataset is freely available by contacting the authors. In post-processing, this data was organized into frames of length 651 samples (326 μs/frame). Each frame was individually FFTed without windowing, and the resulting spectra were averaged to obtain the result shown in Figure 5. It should be noted that due to the limited bandwidth of the ETA antenna, this result is expected to be Galactic noise-dominated only for a few MHz around the primary resonance of the antenna, which is 38 MHz. We see a slight hint of this in the result, however due to time constraints (and the fact that this was not the primary goal of the experiment) we did not attempt to improve on this result. The entire effort including planning, construction, field activity, and data analysis was completed in less than one week.

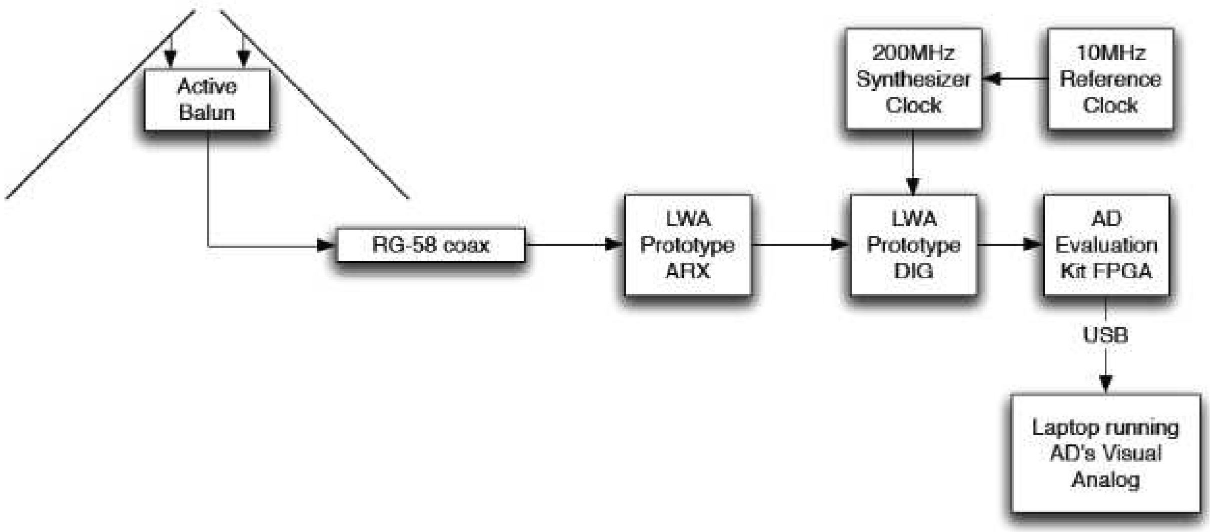

Figure 1: Block diagram of the system.

Figure 2: Illustration of the ETA active antenna setup.

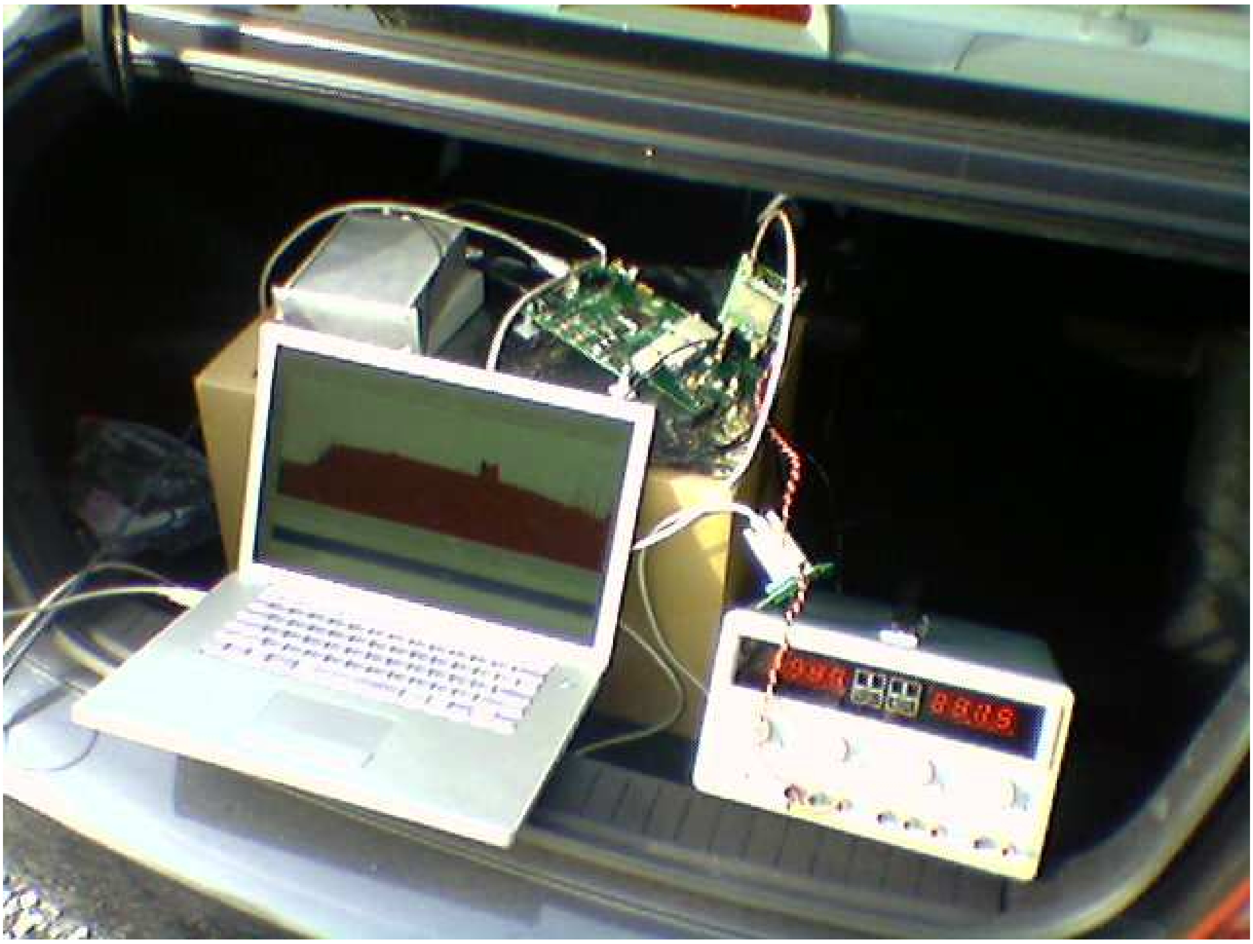

Figure 3: The remainder of the setup, located for this experiment in the trunk of a rental car. The ARX is the small aluminum box in the upper left, and the 200 MHz clock module is the circuit board extending vertically from the A/D board.

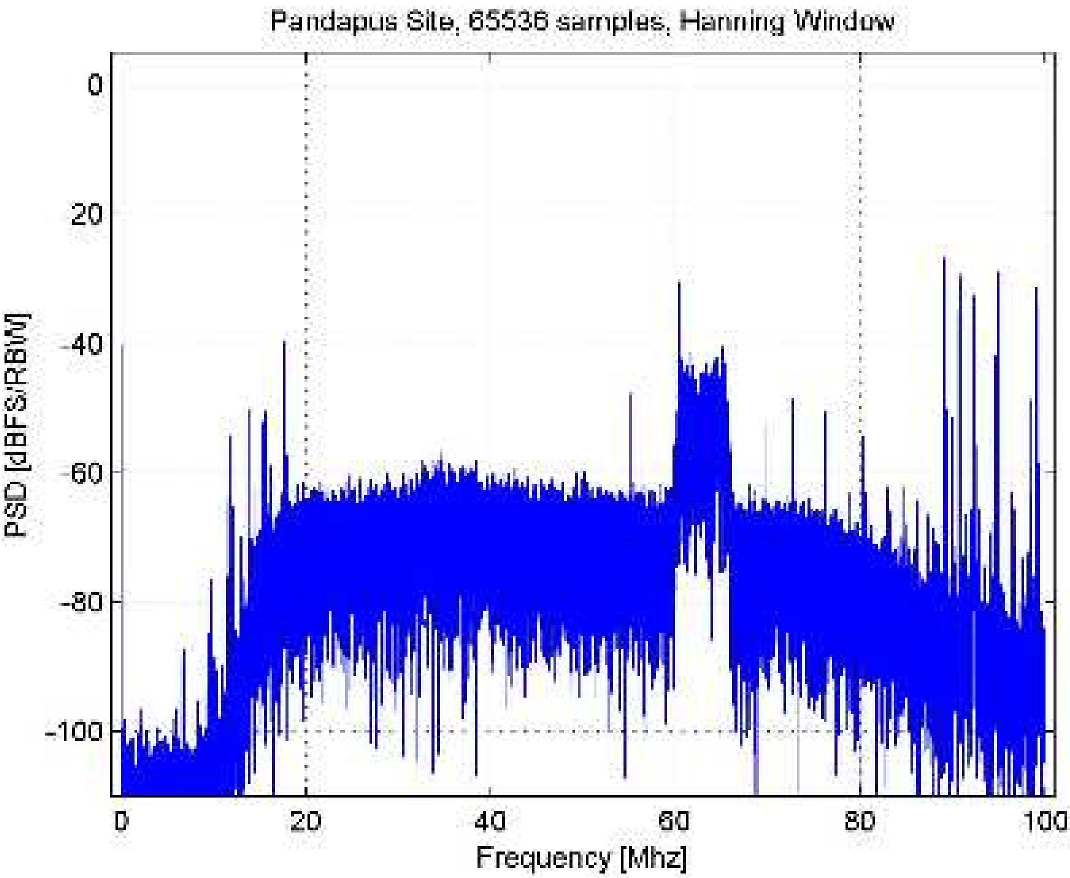

Figure 4: FFT of 65536 samples (328 μs) of contiguous data with Hanning window; resulting spectral resolution of about 6 kHz.

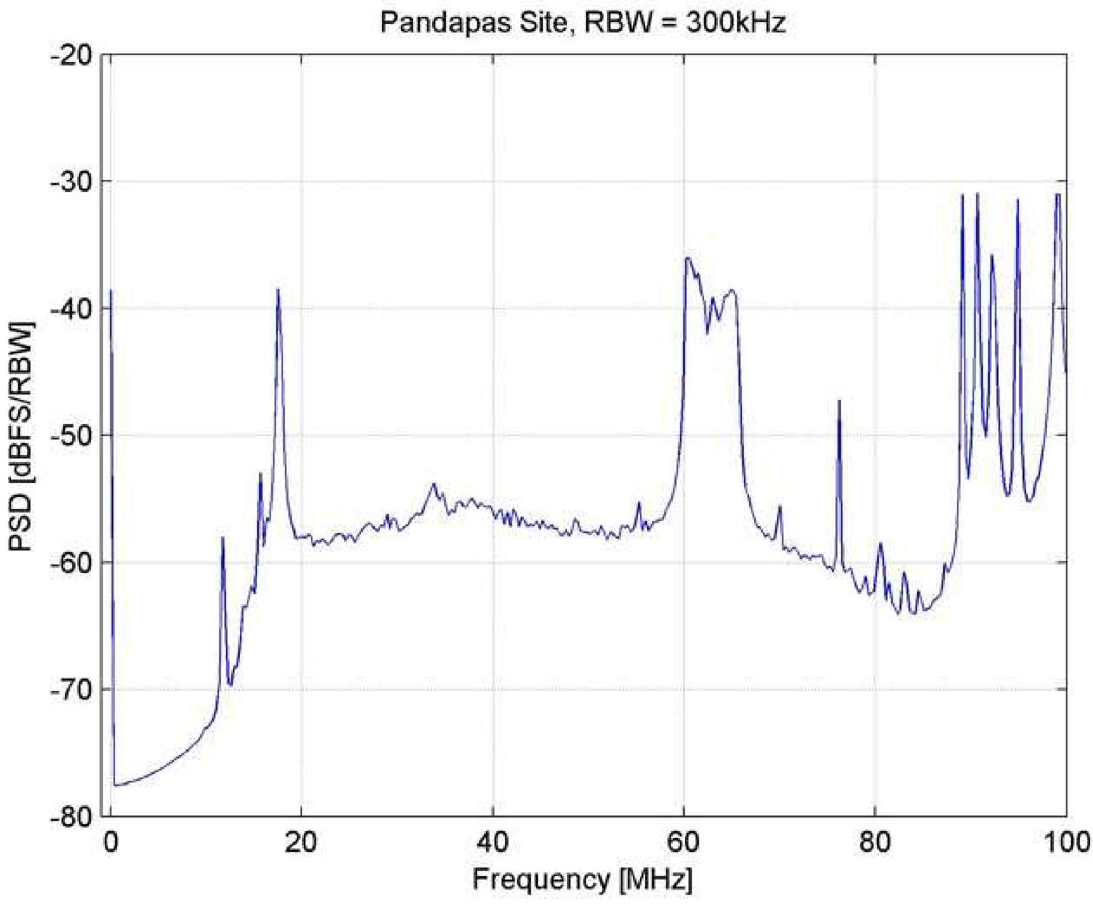

Figure 5: Integrated spectrum. Integration over 42 ms of contiguous data with ~ 300 kHz spectral resolution.

References

[1] M. Harun and S. Ellingson, "Design and Development of a Prototype ADC for LWA," Long Wavelength Array Memo 127, Mar 4, 2008. http://www.phys.unm.edu/∼lwa/memos.

[2] S. Ellingson, J. Simonetti, and C. Patterson, "Design and Evaluation of an Active Antenna for a 29-47 MHz Radio Telescope Array," Long Wavelength Array Memo 60, http://www.phys.unm.edu/∼lwa/memos. Also available as *IEEE Trans. Ant. and Prop.*, Vol. 55, No. 3, March 2007, pp 826-831.

[3] M. Harun and S. Ellingson, "A Prototype Analog Receiver for LWA," Long Wavelength Array Memo 82, March 28, 2007. http://www.phys.unm.edu/∼lwa/memos.

[4] J. Craig, "March 10-14, 2008 Virginia Tech Trip Report," Long Wavelength Array Engineering Memo ARX0001, March 21, 2008. (closed web site; direct inquiries to author.)