Adaptrum White Space Field Study:

FCC STA Request 1

Supplement to Application

April 28, 2008

File 0241-EX-ST-2008

1. Introduction

Adaptrum is a Silicon Valley based company developing cognitive radio technologies to make efficient use of sub 1 GHz spectrum. Adaptrum's cognitive radio technology applies directly to the TV white space. Last year, Adaptrum has submitted its cognitive radio prototype for the second phase of the FCC TV White Space Testing. The prototype is currently being evaluated at the FCC Laboratory.

To further characterize the technology in the real world environment, Adaptrum plans to conduct a white space field study in multiple test sites in the San Francisco Bay Area. The goal of this study is two fold. First, through the study, we want to evaluate and explore the cognitive radio technology and its application to the TV white space in real world settings to further understand the issues and facilitate innovations in this area. Second, through field experiments, we want demonstrate the feasibility of using TV white space for broadband wireless communications on an interference free basis in real world environment. Adaptrum will provide all relevant test results to FCC and we hope such data will provide useful feedback to the further rulemaking regarding the TV white space.

For this field study, Adaptrum plans to apply for an experimental license to operate on the TV channels listed in Table 1 in the range of channels 7 – 51 at certain test sites in the San Francisco Bay Area over a course of six months to a year. (The list avoids the Radio Astronomy allocation on Channel 37 and the §90.303 TV/Land Mobile sharing on Channels 16 and 17 in the San Francisco area.)

TV Channels	Frequency (MHz)
7-13	174-216
14-15	470-482
18-36	494-608
38-51	614-698

Table 1: Frequencies requested

In this initial phase of this study, Adaptrum seeks an STA to operate on the above TV channels at multiple temporary fixed sites and mobile sites on Adaptrum's campus in Milpitas, California and within 2 km of the licensed location. Adaptrum will then apply for a follow-on authorization to operate at other test sites as more operational experience is acquired about mitigating the risk of interference to terrestrial TV receptions around the test sites.

Adaptrum will provide necessary hardware and software to be used in the field study as well as logistics support for establishing and maintaining the test sites. As such, Adaptrum will allocate a significant amount of resources to carry out this project. Adaptrum urges the Commission to take quick action on approving the experiment license for this study so that the knowledge acquired and experience learned will be useful in time.

2. Hardware description

We will use Adaptrum cognitive radio (CR) prototype system for the white space field study. Adaptrum cognitive radio prototype system is an integrated hardware and software development platform for effective exploration, design, evaluation, and demonstration of cognitive radio technologies. The key components of the development platform are:

1. A wide-band high dynamic-range RF transceiver operating over the frequency range 400 – 1000 MHz, which can be modified to operate over the frequency range 100 – 1000 MHz.
2. An FPGA-based hardware development board with integrated high-speed ADCs and DACs and a high-density FPGA where cognitive radio signal processing and protocol layer functions can be implemented.
3. Matlab-based integrated development environment (IDE) for system control and data I/O.

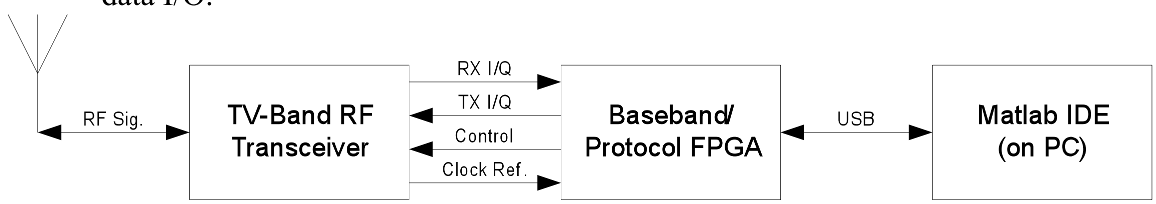

Figure 2: Adaptrum TV-band CR Development Platform.

The wide-band RF transceiver supports carrier frequency from 400 to 1000 MHz with 30 MHz signal bandwidth and with a modified front-end bandpass filter, it supports carrier frequency from 100 to 1000 MHz. The transceiver employs a novel 2-step heterodyne up/down conversion architecture to achieve a spur-free dynamic range (SFDR) of more than 70 dB. Table 1 shows the key transceiver specifications.

Carrier frequency tuning range	400 – 1000 MHz (Extendable to 100 – 1000 MHz)
Minimum tuning step size	1 MHz
1 dB baseband signal bandwidth	30 MHz
Noise Figure	3.5 dB
SFDR	70+ dB
Image rejection	80+ dB
Maximum RX input power	30 dBm
RX gain control range	52.5 dB total 30 dB in 0.5 dB steps (IF) 22.5 dB in 1.5 dB steps (Baseband)
Maximum TX output power	1.0 W
TX gain control range	30 dB in 0.5 dB steps
Supply	12 V, ~ 2A
I/Q connections	RF input: SMA female RX baseband I/Q output: 2 x SMA female TX baseband I/Q input: 2 x SMA female Reference clock output: SMA female Control: 2 x 40-pin header

Table 1: Adaptrum CR RF transceiver specifications.

While this is the essentially the same hardware now undergoing testing at the FCC Laboratory, a new revision of the transceiver board may be used in testing. An additional external power amplifier may also be used to provide up to 1 W transmission power.

Cognitive radio baseband signal processing and protocol-layer functions are implemented on a high-density FPGA on a hardware development board with integrated high speed ADCs and DACs.

ADC	Dual, 12-bit, 125 MHz
DAC	Dual, 14-bit, 165 MHz
PC interface	USB 2.0 daughter card
Transceiver interface	RX I/Q input: 2 x SMA female TX I/Q output: 2 x SMA female Reference clock input: SMA female Control: 2 x 40-pin header

Table 2: CR platform FPGA board specifications.

Error! Reference source not found. shows a lab picture of the prototype system which includes the RF transceiver board and the FPGA board. A similar unit has been submitted to FCC for white space device testing [1]. Figure 3 shows measured sensitivity curves for DTV (ATSC) signal sensing using the prototype system. Detailed description of the DTV sensitivity measurement can be found in [2]. Figure 4 shows a typical transmit signal spectrum from the prototype system.

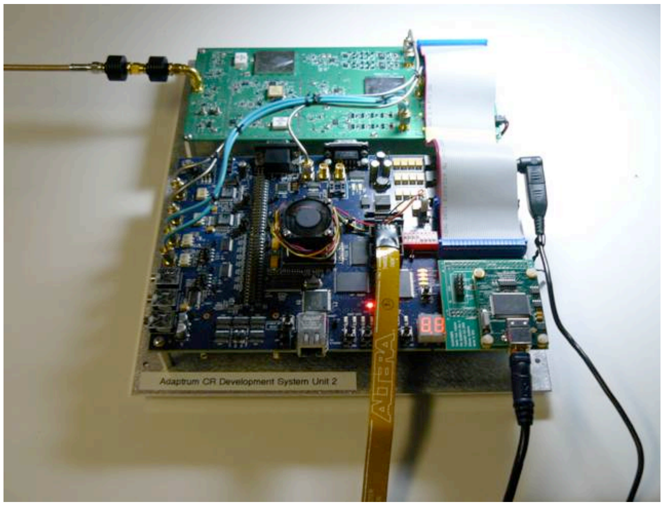

Figure 2: Lab picture of Adaptrum CR prototype system.

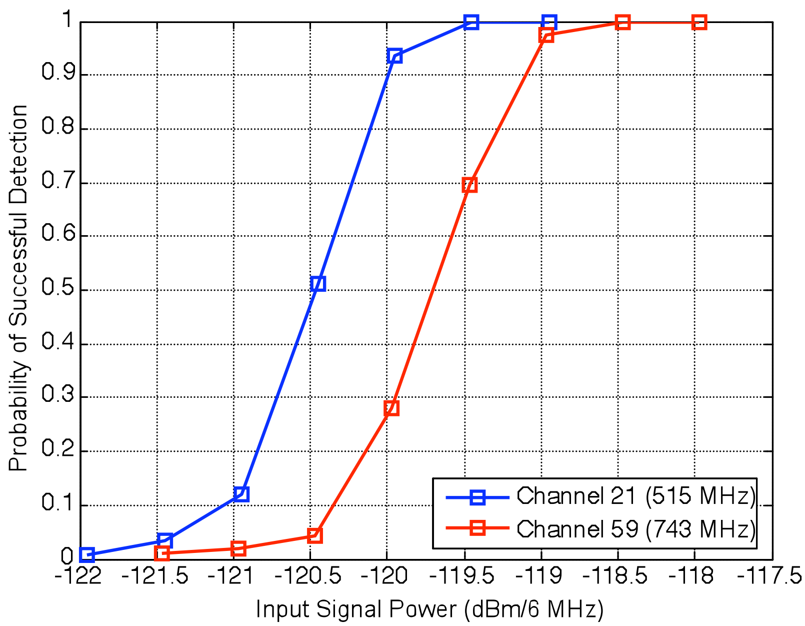

Figure 3: Measured ATSC spectrum sensing results.

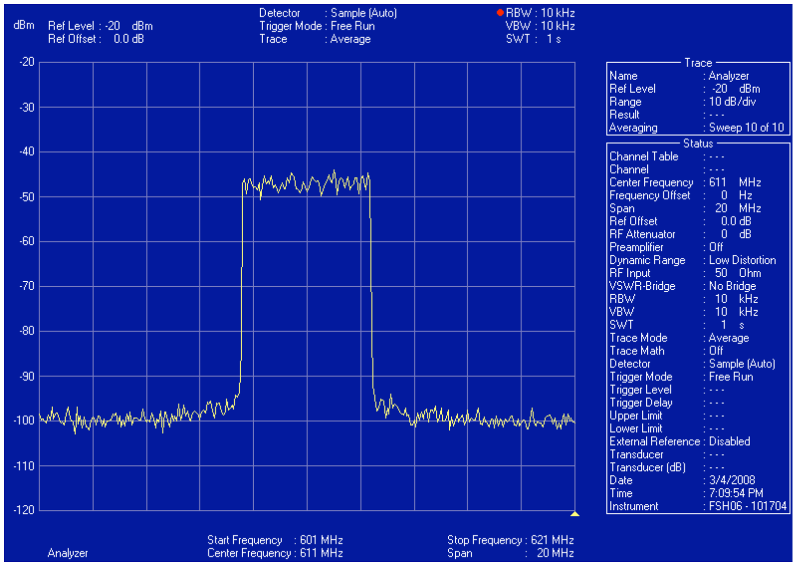

Figure 4: Example measured transmit spectrum from Adaptrum cognitive radio prototype (signal attenuated before being measured by the spectrum analyzer).

3. Test site description

Each test site is 2 km in radius and centered around a fixed outdoor antenna structure about 40 feet above the ground. As specified in the FCC NPRM, we define two types of white space devices to be used within each test site: fixed white space device and personal/portable white space device. A fixed white space device will be connected to an outdoor antenna structure and will have a max conducted output power of 1 W and EIRP of 2 W. There will be only one fixed white space device per test site. A number of personal portable white space devices may be deployed at random outdoor or indoor locations within each test site. These devices can also roam in a test site or across connected test sites. Personal/portable white space devices are ground based and will have a maximum transmission power of 100 mW. Both fixed and personal/portable devices will use the same prototype system described in the last section.

An example personal/portable white space device test unit is shown in Figure 5. The unit consists of a Bowtie UHF antenna, Adaptrum CR prototype system, and a laptop. The Adaptrum CR prototype system can be powered by a 12 V DC battery so the whole test unit can be made portable.

Each test site is centered around one fixed white space device connected to an outdoor antenna at a known location. The fixed white space device uses the same prototype system described before and the outdoor antenna is usually elevated well above ground. Figure 6 shows a picture of the outdoor antenna structure at a planned test site in Milpitas, California. In this case, a wideband discone antenna is attached to a fiber glass pole that is installed on the roof of an office building. Considering the height of the building and pole, the antenna is approximately 40 feet above the ground.

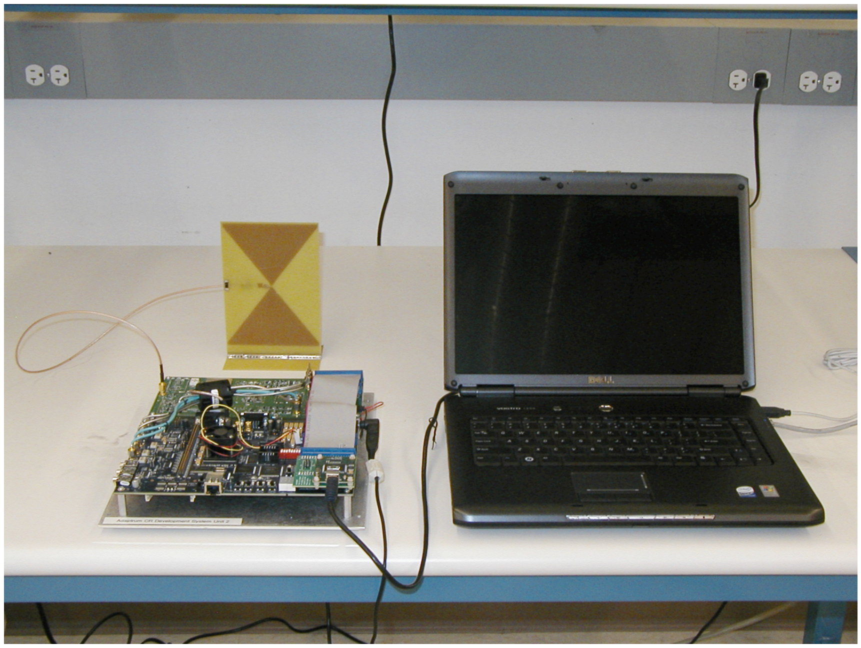

Figure 5: Personal/portable white space device test unit.

Figure 6: The outdoor rooftop antenna structure in a planned test site.

Various tests will be conducted to evaluate the potential interference to TV reception due to white space operations. We will sample popular TV sets from different manufacturers for these tests. **Error! Reference source not found.** shows a typical TV receiver setup used in the interference test where a Sharp AQUS digital TV is receiving over-the-air ATSC broadcast using a discone antenna (or alternatively, as shown, a

Bowtie antenna). **Error! Reference source not found.** shows a typical setup used to test the interference from personal/portable white space devices.

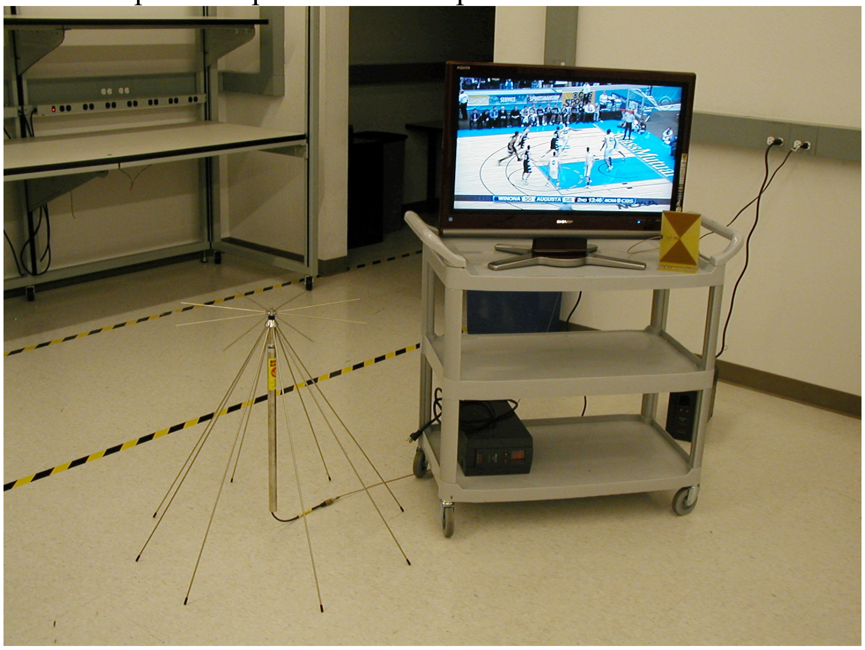

Figure 7: A digital TV set and antennas used for interference test.

Figure 8: Personal/portable white space device interference test setup.

4. Test scenarios and interference prevention

The following is a list of example tests we plan to perform. This list is not intended to be exhaustive and we will add additional experiments as the study progresses.

- *Concurrent and correlated sensing*. We will perform concurrent sensing at different locations within the test sites using indoor and outdoor ground-based antennas as well as fixed rooftop antennas. The sensing results will be compared to determine their correlation and explore how cooperative sensing may help improve spectrum sensing reliability.

- *Continuous sensing*. We will perform continuous sensing at certain outdoor and indoor locations over a period of days or weeks. Sensing results will be recorded and analyzed to determine channel availability as a function of time.

- *Adjacent channel interference threshold as function of distance*. We will conduct over-the-air (OTA) adjacent channel interference test on a typical digital TV set. The interference signal will be transmitted on either the lower or upper adjacent channel to the channel where the TV is actively receiving ATSC broadcast. The transmitter antenna will be placed at progressively larger distance from the TV. The quality of the TV reception will be monitored to determine when harmful interference has occurred.

- *Adjacent channel interference threshold as function of signal bandwidth and power*. At a fixed distance to the TV set (within which adjacent channel transmission may cause interference), the signal bandwidth and power of the adjacent channel transmission are varied to determine the DTV reception threshold of visibility (TOV) as a function of the interference signal bandwidth and power.

- *Demonstration of video transmission through white space channel*. We plan to demonstrate real-time video transmission between two personal/portable white space devices and from a fixed white space device to a personal/portable white space device over TV white space channels, while randomly placed digital TV sets are simultaneously receiving OTA TV broadcasts in the test sites.

To reliably sense the white space channels and avoid cochannel interference to consumer terrestrial TV receivers in the vicinity of the test sites, we will use a combination of geolocation and spectrum sensing (through both rooftop antennas and ground based personal/portable antennas) to determine the available white space channels at each test site. Once a set of white space channels are identified, we will perform a reassurance test in which we will take a typical TV receiver to randomly selected locations within 4 km radius of the test site and verify that TV reception is indeed not possible at these locations on these white space channels. Such white space channel sensing and reassurance test will be performed periodically to ensure that the sensing results are consistently reliable.

To ensure no adjacent channel interference, we will place TV sets within a specified radius from the fixed rooftop antenna in all directions within a test site. We will verify that there are no signs of reception degradation on a TV channel when we are transmitting a white space signal from the fixed rooftop antenna on an adjacent white space channel. Since any consumer TV receivers in the vicinity of the test site are far beyond the specified radius and likely to receive far less interference signal power, we expect such measure will prevent any potential adjacent channel interference from the fixed rooftop antenna. Transmission between personal/portable white space devices have lower power and are ground based and local to the test sites, which is unlikely to create adjacent channel interference to TV receivers outside the test sites.

In addition to the preventive measures, we will log all white space transmission activities including time, location, transmit power, signal bandwidth, etc. We will also log all spectrum sensing results along with the corresponding time, location, and antenna information. If interference does occur, such records will provide useful clues about the cause of such interference and how our methods can be improved to prevent such incident from reoccurring. We will immediately cease transmitting if we receive reports of interference that correlate with our actual transmissions until we can take corrective action. We will inform the local FCC Enforcement Bureau office of contact information for personnel involved in the testing.

References

1. http://www.fcc.gov/oet/projects/tvbanddevice/Welcome.html
2. http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6519821091

Appendix A: Description of test sites in the initial phase of the study

The initial phase of the white space study is limited to locations on and within 2 km of Adaptrum's campus in Milpitas, CA, located at 37° 24' 20.52"N, 121° 53' 58.95" W. Each test site is centered around a fixed rooftop antenna about 40 feet above the ground.

A sketch of the vertical profile of the rooftop antennas used for the temporary fixed transmissions is shown in Figure 9.

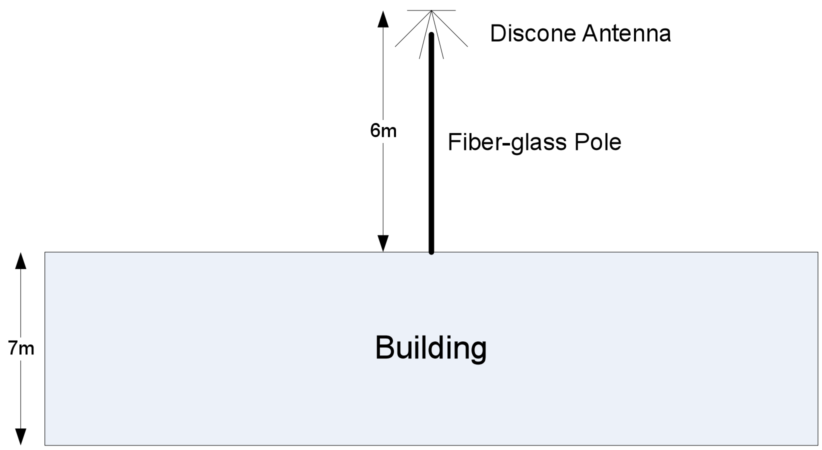

Figure 9: Antenna structure vertical profile sketch.

The minimum distance of the antenna structures to the nearest airport SJC (San Jose Airport) is approximately 3 miles. Nearby utility poles are higher than the antenna structures and will shield the antenna structures from any aeronautical hazard.

Two types of antennas – wideband discone and bowtie – are generally used in the testing. Fixed white space devices will use the discone antenna while personal/portable white space devices will use either the discone or the bowtie antenna. Both antennas are omini-directional. The discone antenna has a flat response from 150 MHz to 1300 MHz. The bowtie antenna has a flat response from 400 MHz to 1000 MHz.

The white space devices will operate on TV channels listed in Table 1. Fixed white space devices will have a maximum conducted transmission power of 1 W and EIRP of 3 W. Personal/portable white space devices will have a maximum conducted transmission power of 100 mW. The frequency stability of the white space device is 10 ppm, equivalent to a frequency offset of 6 kHz for a 600 MHz carrier.