November 5, 2007

Office of Engineering and Technology
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Unlicensed Operation in the TV Broadcast Bands, ET Docket No. 04-186

In response to OET's Public Notice DA 07-4179, Adaptrum, Inc. prepares to submit a white-space device (WSD) prototype system for field testing by FCC. Adaptrum believes flexible FCC rules based on sound technical evidence will be essential to the commercial viability of the white space devices as well as gaining widespread acceptance among different parties. To this end, Adaptrum plans to submit the WSD prototype system and provide necessary technical assistance in FCC's investigation on the unlicensed operation in the TV bands. Adaptrum's WSD prototype is capable of both sensing and transmit in the UHF TV bands. Further details of the prototype system are discussed in the attached document.

Adaptrum plans to deliver two prototype units to FCC in the week of 11/26/07 or later. In addition to the prototypes, Adaptrum plans to submit test results and field data on the prototype system when they are available. Adaptrum is also prepared to provide any technical assistance to facilitate the testing process on the prototypes.

Sincerely,

/s/ *Haiyun Tang*

Haiyun Tang
Adaptrum, Inc.

cc: Rashmi Doshi
Patricia Goff

Adaptrum Cognitive Radio Platform

1. System overview

Adaptrum Cognitive Radio (CR) Platform is an integrated hardware and software development system that allows effective exploration, design, evaluation, and demonstration of cognitive radio technologies.

Specifically designed for TV white spaces, the system is capable of various forms of TV signal sensing including waveform/signature sensing, spectral identification, signal power estimation, and network-level cooperative sensing. The system is also capable of signal transmission in the TV bands with flexible waveform, modulation, and signal bandwidth construction, transmit power control, and transmit chain linearization to reduce adjacent channel interference.

Key components of the development platform include:

1. A wide-band high dynamic-range RF transceiver operating over the frequency range 400 MHz – 1000 MHz. Small modification of the transceiver front-end filter structure will extend the lower edge of operating frequency range down to about 100 MHz, covering both VHF and UHF TV bands.
2. An FPGA-based hardware development board with integrated high-speed ADCs and a high-density FPGA where CR baseband and protocol-layer functions are implemented.
3. Matlab-based integrated development environment (IDE) where the CR hardware functions are controlled using Matlab GUI and Matlab scripts.

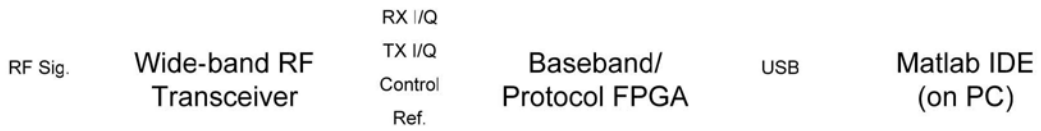

Figure 1: Adaptrum TV-band CR development platform.

2. System functions and specifications

2.1 RF transceiver

The CR wide-band RF transceiver supports tunable carrier frequency from 400 to 1000 MHz with 30 MHz signal bandwidth. Small modification of the front-end bandpass filter will extend the lower edge of the frequency range down to about 100 MHz so that both VHF and UHF TV bands are supported. The transceiver employs a novel 2-step heterodyne up/down conversion architecture to achieve a spur-free dynamic range (SFDR) in excess of 70 dB – essential to support high dynamic range operation needed by TV-band cognitive radios. Table 1 shows the key transceiver specifications.

Carrier frequency tuning range	400 – 1000 MHz (Optional 100 – 1000 MHz)
Minimum tuning step size	1 MHz

1 dB 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 stage) 22.5 dB in 1.5 dB steps (Baseband stage)
Maximum TX output power	0.5 W
TX gain control range	30 dB in 0.5 dB steps (Additional gain control provided by baseband DACs)
Supply	12 V, ~350 mA
I/O 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.

2.2 Baseband/protocol

CR baseband and protocol-layer functions are implemented on a high-density FPGA on a hardware development board with integrated high speed ADCs and DACs. The WSD-related functions implemented in the current revision of the system include: ATSC and NTSC signal sensing, flexible OFDM signal construction, transmit power control, and transmit chain linearization. The FPGA also has an embedded soft-core MIPS processor which handles real-time hardware configuration and control and CR protocol-related processing. Table 2 shows the main baseband/protocol layer functions. Table 3 shows the baseband/protocol FPGA board specifications.

Function	Status for the current submission	Description
Baseband anti-aliasing and channel selection filter	Included	Allow 6 MHz channel selection within 30 MHz RX signal band.
Automatic Gain Control (AGC)	Included	Receive chain gain control.
FFT/IFFT	Included	Real-time spectral analysis and OFDM signal construction. Flexible 1 to 16384-point FFT over 30 MHz (1.8 kHz minimal subcarrier spacing).
ATSC and NTSC signal sensing	Included	Combination of waveform/signature sensing, spectral identification, and signal power estimation.
Microphone signal sensing	Not included	
Geo location based	Not included	

sensing		
OFDM transmit signal construction	Included	Arbitrary OFDM signal construction with flexible bandwidth, modulation, and window parameters.
Transmit power control	Included	Transmit power control to minimize potential interference.
Transmit chain linearization	Included	Transmit chain linearization through signal pre-distortion to reduce adjacent channel interference.
Complete baseband transmit and receive chains	Not included	Allow communication sessions between WSD units through white space TV channels.
Network-level cooperative sensing	Not included	Cooperative sensing by multiple WSD units to improve sensing reliability against shadowing and fading.

Table 2: CR platform baseband/protocol layer functions.

ADC	Dual, 12-bit, 125 MHz
DAC	Dual, 14-bit, 165 MHz
PC interface	USB 2.0 daughter card
RF 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 3: CR platform baseband/protocol FPGA board specifications.

3. System interface and software

The baseband/protocol board interfaces a PC through a USB 2.0 interface. A special USB driver is required. System control software and GUI are built in Matlab. Direct integration of the control software with Matlab takes advantage of Matlab's extensive signal processing, graphics, and scripting capabilities and allows effective data capturing, analysis, and algorithm exploration during CR system development and evaluation. Figure 2 shows a screen-shot of the Matlab-based CR development environment.

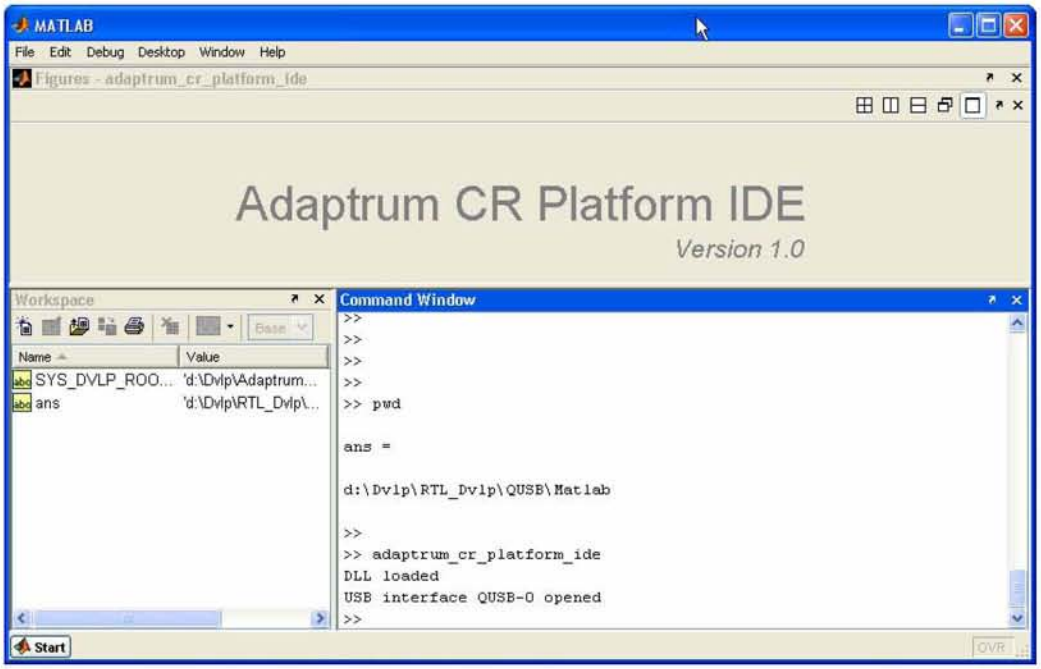

Figure 2: Matlab-based CR platform integrated development environment.

4. System picture and example measurement result

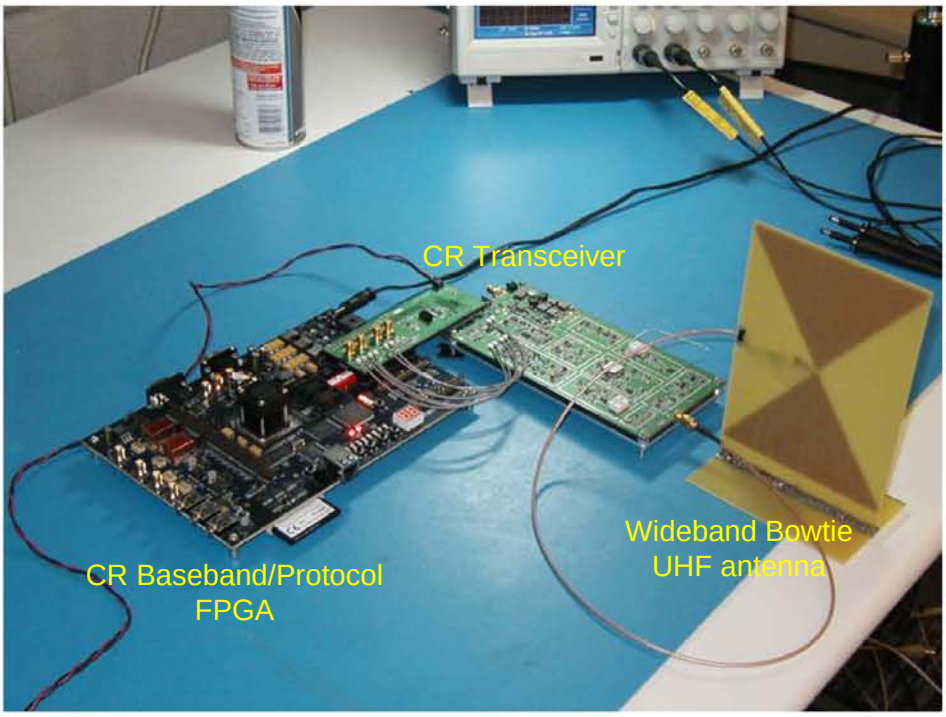

Figure 3: Adaptrum CR platform lab picture.

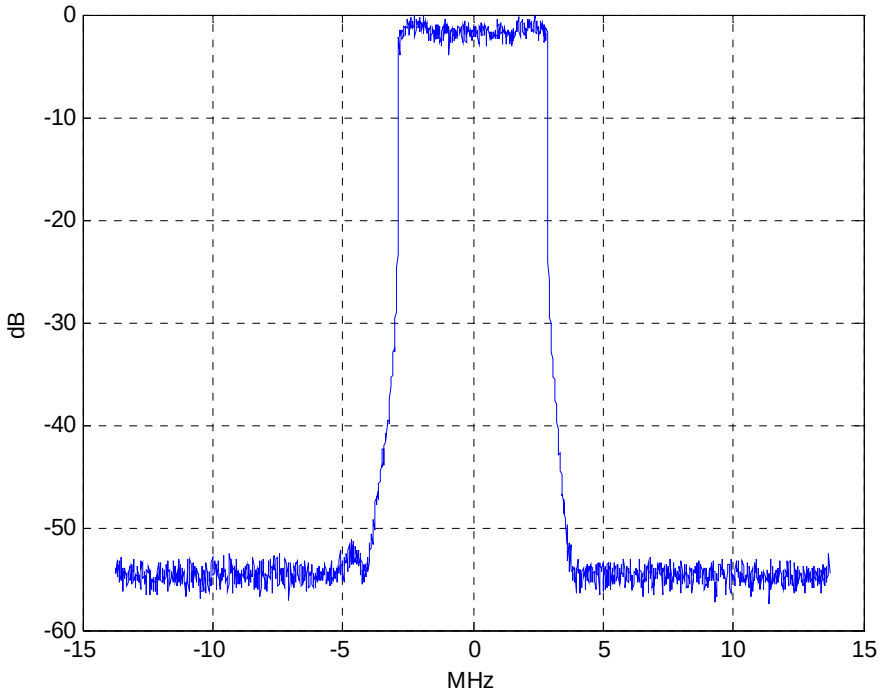

Figure 4: Example measured OFDM signal spectrum through Adaptrum CR Platform.