Motorola Cognitive Radio White Space Device Reference Manual

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Acronyms

ATV	Analog TV
ATSC	Advanced Televisions Systems Committee
CR	Motorola Cognitive Radio / Motorola WSD
dBm	Decibels relative to 1 milliwatt
DTV	Digital TV
ESG	Electronic Signal Generator
GDB	Geo-location DataBase
GUI	Graphical User Interface
NTSC	National Television System Committee
UHF	Ultra High Frequency
WSD	White Space Device

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1 Introduction

This document provides a general reference manual for the Motorola Cognitive Radio / TV "White space" device (WSD) prototype provided to the FCC for testing. *The Motorola Cognitive Radio device is intended only as an experimental research prototype device, and should not be considered certification- or production-ready*. Several operational parameters and algorithms are under development for the device and are subject to change. The Motorola Cognitive Radio device is provided for experimental testing to introduce the concept of geo-location database enabled WSDs. Spectral sensing is performed in addition to refine the geo-location database results. The device also can be configured to perform testing of the sensing algorithms, but is not a normal operational mode.

2 System

The experimental Motorola WSD currently consists of the Cognitive Radio Rack and a laptop host connected to the rack via Ethernet. The rack consists of a UHF radio and 2 PRO-3500 carrier boards co-located in a Compact-PCI chassis. The Cognitive Engine for the Motorola WSD runs on the lower board as shown in Figure 1.

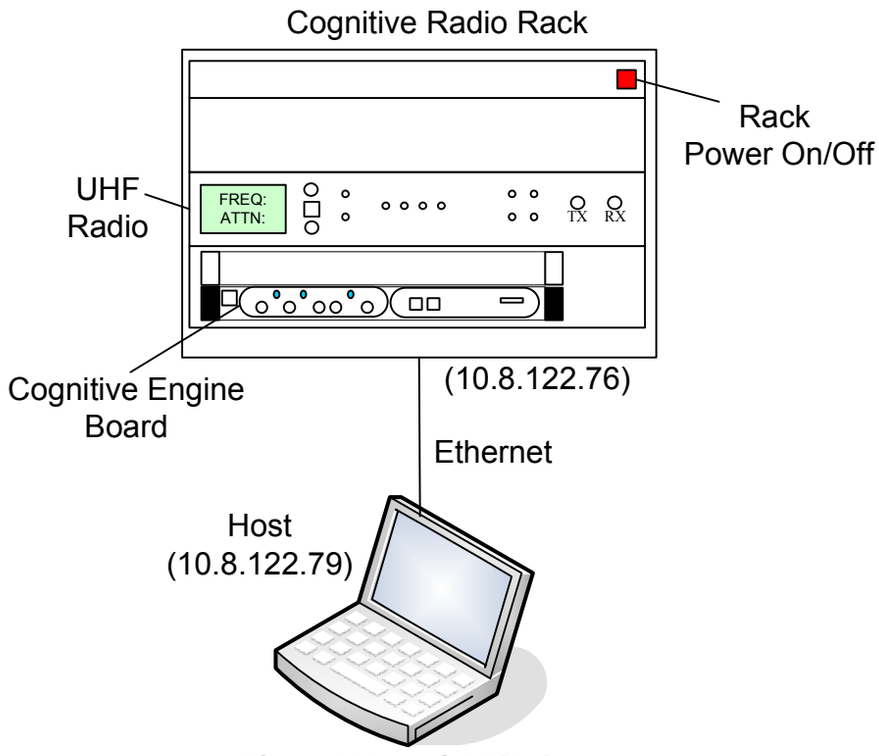


Figure 1 Motorola WSD System.

3 System Startup

The experimental Motorola Cognitive Radio is started up as follows (in order):

Step 1) Power on the host machine connected to the Cognitive Radio rack. A red Motorola Icon should show in the host system tray displaying "Cognitive Radio Booting …" as shown in Figure 2.

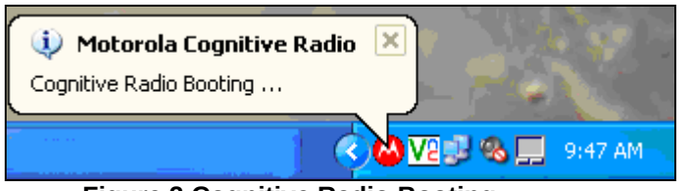


Figure 2 Cognitive Radio Booting.

Note: *If you do not see the red Motorola Icon* in the system tray click on the blue Motorola Icon in the taskbar as shown in Figure 3.

Figure 3 Taskbar Icon to start the Cognitive Radio.

Step 2) Power on the Motorola Cognitive Radio rack by toggling the red switch on the top right hand corner of the rack shown in Figure 1.

Step 3) On the host machine select whether you would like to start the Cognitive Radio in **Test Mode** or **Normal Mode**[1] in the pop-up window as shown in Figure 4.

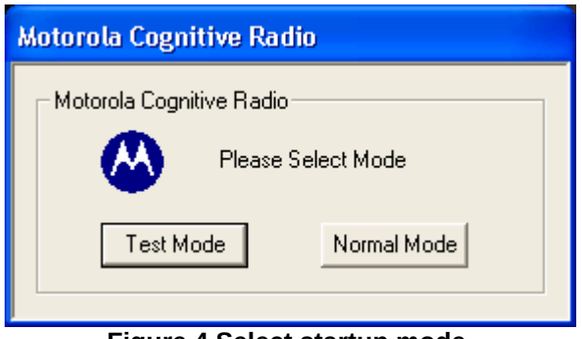


Figure 4 Select startup mode.

[1] Operation Modes are described in section 4.

After the Cognitive Radio rack is done booting, the host system tray Motorola Icon will turn red and *start rotating* indicating that the system is starting up in the selected mode as shown in Figure 5.

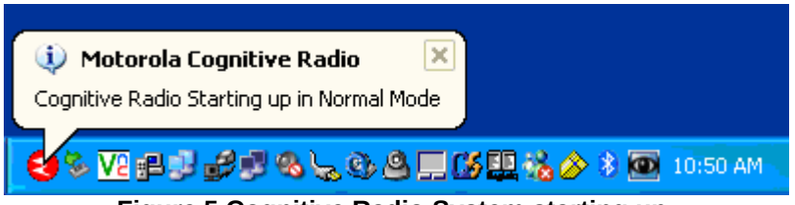


Figure 5 Cognitive Radio System starting up.

Step 4) **Wait** until the system tray Motorola Icon turns blue **(this usually takes around 2 minutes**[2]) as shown in Figure 6. This indicates that the system has started up in the selected mode. For details of startup in a specific mode please see section 4.

Figure 6 Cognitive Radio started up.

4 WSD Operational Modes

The Cognitive Radio can be started up in two modes from the host laptop:

1) **Normal Mode:** In this mode a geo-location database as well as sensing is used to select the best channel. A graphical user interface displays the active channel and the channel map. This is the normal operational mode of the Motorola Cognitive Radio.

2) **Test Mode:** In this mode a command shell is provided so that bench tests can be carried out.

Both modes can be chosen from the icon in the system tray[3] after startup. The modes are further described in the following sections.

4.1 Changing Modes

The user can switch between the two modes selecting the required mode on the icon in the system tray.

[2] This time allows the board to program the FPGA and boot the operating system. If the icon does not turn blue within three minutes please see appendix B.
[3] See section 4 for changing modes.

Step 1) Right click on the blue Motorola Icon in the system tray. A menu should pop up as shown in Figure 7. Select a mode that is not the current mode to change modes. The Motorola Icon will turn red and start rotating indicating that the system is starting up in the newly selected mode. This is shown in Figure 8.

Step 2) **Wait** until the system tray Motorola Icon turns blue **(this usually takes around 2 minutes).** This indicates that the system has started in the selected mode.

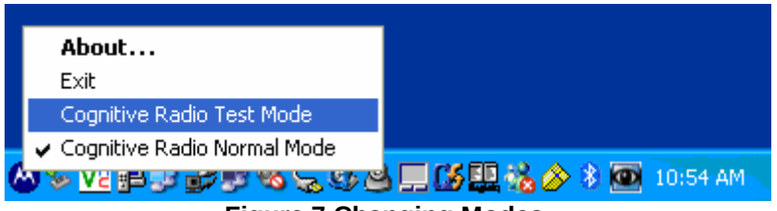


Figure 7 Changing Modes.

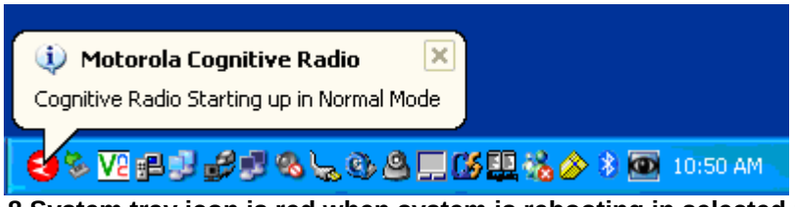


Figure 8 System tray icon is red when system is rebooting in selected mode.

Note: *The system will not allow you to change modes when the system it is starting up (Motorola icon is red)!*

5 WSD Normal Mode

In this mode of operation the experimental Cognitive Radio uses a geo-location database as well as sensing algorithms to find the best channel to operate on. Note that the device will select an operational channel, though the transmitter in the device is not enabled. The Motorola icon in the system tray will show that the CR has started up in Normal Mode as shown in Figure 9. ***The lower carrier board will light up the LEDs blue when the Cognitive Engine has been loaded***[4] (as shown in Figure 1). A GUI displaying all the channel information for the current location is shown when the system is started in this mode as shown below in Figure 10. A full description of the GUI can be found in Section 5.2 below.

[4] If the LEDs do not turn blue within three minutes please see Appendix B.

Figure 9 Cognitive Radio Up in Normal Mode.

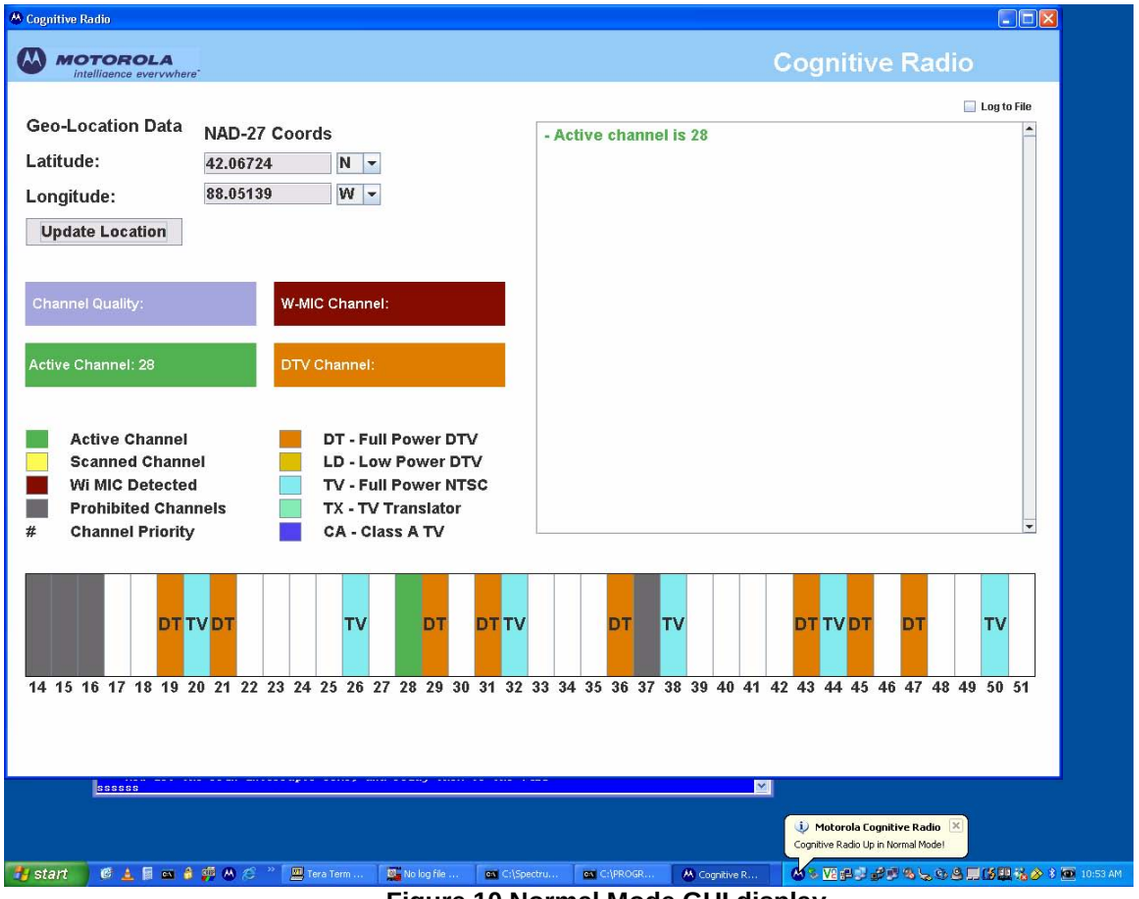


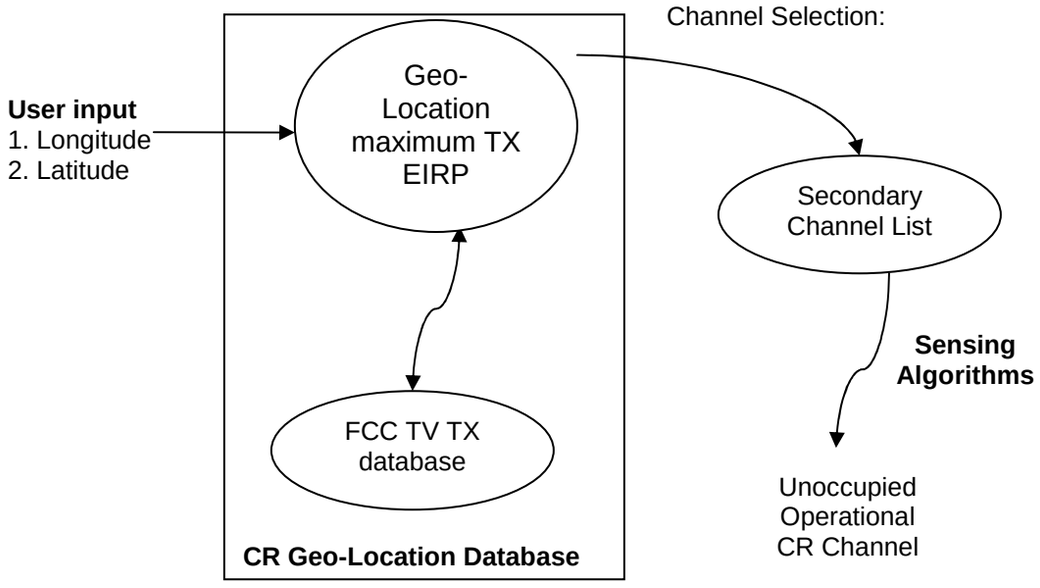
Figure 10 Normal Mode GUI display.

5.1 Operational Background

The experimental Motorola Cognitive Radio utilizes a geo-location database and sensing algorithms to determine which UHF channels are available for use. The geo-location database code also computes maximum allowed WSD transmit power levels per channel based on location. Currently, the Motorola WSD uses geo-location database techniques to identify protected incumbent TV stations (DTV and ATV stations of several types), and sensing techniques to rank the available channels and identify unexpected DTV signals. *In Normal mode, the sensing of unexpected DTV signals becomes more reliable as time progresses. The currently implemented sensing algorithms do not sense for the*

presence of NTSC TV or wireless microphone signals[5]. Below are descriptions of the geo-location database and the sensing based channel selection description.

The geo-location channel selection algorithm will utilize the current device location (GPS coordinates in NAD27 format) as an input, and output an initial Channel List to be used by the CR for final channel ranking and selection. The final channel ranking and selection is carried out by the sensing algorithms, using inputs from the geo-location database and channel measurements.



5.1.1 Geo-Location Database

The experimental Motorola WSD utilizes geo-location database techniques in order to determine available spectrum and the maximum allowed transmit power levels per channel (vs. location). *The unit does not rely on sensing techniques to determine open TVWS spectrum* (i.e., to determine if the unit is inside of a TV station's protected service contour) – it relies on geo-location database techniques for such information. The geo-location database incorporates known information about incumbent transmitters to protect licensed systems (see below). *The Motorola system will never select or transmit on a channel at a location that is determined to be within a licensed station's protected service contour.*

As mentioned above, the unit does perform sensing on a candidate channel list of (e.g., about six) potential operating channels obtained from the geolocation database code, in order to rank them for suitability of communications (see details in Section 5.1.2 below). The sensing in the experimental

[5] Other techniques, such as disabling beacon signals (e.g., IEEE 802.22.1 based) are available to provide protection to licensed wireless microphone deployments. Wireless microphone deployments may also be entered into incumbent databases to provide protection.

prototype unit is based on passive observations of the available spectrum. The Motorola system will only actively utilize the channel that is ranked the highest or most suitable for communications. In the unlikely event that the chosen channel becomes unusable (e.g., if a DTV incumbent signal is suddenly detected on the channel), the system will switch to the next highest ranked channel in the channel list. Therefore, while communication usually occurs on the highest ranked channel, it is possible though unlikely that communications may occur on the second-highest ranked channel. The system continually re-ranks the channel list, and any channel with unexpectedly detected incumbents is moved to the bottom of the list (making its use very highly unlikely).

The Motorola WSD geo-location database generator code runs in real-time on an embedded processor any time the unit's operating location is updated. The database code computes licensed TV stations' protected service contours[6], and applies a wide range of interference protection rules based on the unit's proximity to those service contours to derive maximum allowable WSD transmit power levels. *Note that location updates are currently manually entered (in NAD27 coordinate) format for the experimental prototype unit.* There are a wide variety of location determining methods available for WSDs (e.g., GPS, Time Difference of Arrival (TDOA) techniques, Time-of-Flight (TOF) techniques, various database means, etc.).[7] Most commercially available GPS units can be set to report the NAD27 latitude and longitude coordinate values required for the Motorola system[8]. The location accuracy level of commercial GPS units (e.g., of ~30m) is more than adequate for the purposes of the geolocation database code. Motorola has previously proposed requiring 300m (95% confidence) location accuracy requirements for WSDs.[9] Note that the GUI entered coordinates are in positive (N and W) decimal degree format. Once a location is entered into the Motorola WSD prototype (via the GUI), the database generator code runs in real-time to recompute protected service contours and the maximum allowed WSD transmit power levels (EIRP) for each channel for the given location. These calculations are based on a wide variety of incumbent interference protection requirements, largely proposed by the Commission[10] and in the Oct. 18th, 2007 Motorola ex-parte filing referenced above. The computations take into account WSD unit location, incumbent TV transmitter parameters (e.g., transmitter location, power level (ERP), antenna characteristics, etc.), TV receiver interference protection (D/U) ratios, and several WSD unit characteristics (e.g., transmit mask, antenna heights and gains). Currently, the calculations do not rely on detailed terrain databases, as was originally proposed by the Commission. The incumbent TV transmitter parameters are supplied to the program in text files ('*DC_FCCTVDBdata.txt*' and '*DC_FCCTVantdata.txt*') which are taken directly from the FCC's online TV transmitter database system (CDBS)[11]. All input and output files are typically contained in the *C:\spectrum\carnac\FCC\CE* directory. A shortcut to this directory is provided on the laptop desktop. Note that approximately 180 licensed/protected TV stations are considered in the geo-location database

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[6] Protected service contours are computed using average terrain models, as described in ET Docket No. 04-186, referenced below. Optionally, the unit may be configured to protect TV stations with "CP MOD" status. See the GDB configuration file details.

[7] See also IEEE 802.22-06/0159r10 "*Geolocation with Database Requirement Development*" document for a brief discussion of various location determining techniques and their associated accuracies.

[8] Otherwise, online tools are also available to convert the popular NAD83 coordinate reporting format to NAD27 format (e.g., see http://www.ngs.noaa.gov/cgi-bin/nadcon.prl)

[9] See Motorola ex-parte filing "*Recommendations on Cognitive Radio (CR) Operations in TV White Spaces (TVWS)*", Oct. 18th, 2007.

[10] The Commission's proposed rules for computing allowable CR system transmit power are described in ET Docket No. 04-186, "*Unlicensed Operation in the TV Broadcast Bands*", 5/25/04, pp. 14-18.

[11] The Commission's online CDBS TV transmitter database is available at: http://www.fcc.gov/mb/audio/tvq.html. (Both TV Short List and TV Query formats are utilized)

analysis for the Washington DC area. The accuracy of the geo-location database results is (of course) dependent on the accuracy of the input TV transmitter database. Once again, the intent with the experimental prototype device is to demonstrate geo-location database concepts. The actual implementation can be refined based on further testing results.

Note that the geolocation database input files that are supplied for Motorola WSD testing are suitable only for the Washington DC area (for generating geo-location database results over roughly a 140km x 140km area centered on the Washington monument). The results can be readily extended to other service regions if desired. If the Motorola WSD is tested outside of the above Washington DC area, additional TV transmitter data files will need to be downloaded from the FCC TV transmitter database (please contact Motorola for further information if such testing is desired). The geo-location database program can be operated over any region for which incumbent (TV transmitter parameter) databases are available.

Many of the geo-location database (GDB) code parameters are configurable, and some of those parameters are contained in the '*DC_GDBConfig.txt*' file. This file contains several configuration values for the GDB code. Note that the GDB code is typically set up to generate results for only one location (i.e., the updated location) when performing a location change scenario, though it may also be utilized to generate regional databases. (Analysis tools are also available to analyze geo-location database results- please contact Motorola for further details if desired.) The configuration file also contains several protected service contour levels and interference protection (D/U) ratios for various TV station and receiver types, as recommended by the Commission. These values could be altered to change the desired protection levels.[12] The configuration file also takes into account nominal WSD antenna height (*CR_BS_ANT_HT*), actual antenna gain per band (e.g., *UHF_BSANT_G*) and the maximum allowed transmit power amplifier output level (*MAX_CRTX_PWR*) for WSD testing. *Note that these parameters have been set specifically for FCC Motorola WSD testing, and may not reflect FCC proposed equipment limits (e.g., max. TX power limit is currently set to +20dBm, with 0dBi antenna gains).*

The configuration file also contains a flag (*INCL_CPMODS*) to treat TV stations with FCC "CP MOD" (construction permit – modification) status as fully licensed (and protected) stations, in addition to a flag (*INCL_ALTCHS*) to enable alternate channel interference modeling in the GDB code. *Note that CP MOD stations are currently treated as protected stations by default (since several of those stations are on the air, and were indicated as protected in past OET WSD testing reports).* Other station FCC status codes (e.g., CP) may optionally be protected, but such protection is not implemented here. Both the Motorola WSD unit's out-of-band emissions (OOBE) on adjacent *and* alternate channels, as well as the affected TV receiver's co-, adjacent, *and* alternate channel protection ratios are modeled by default (*INCL_ALTCHS=1)*. Note that modeling alternate channel interference levels is not required by the proposed TVWS operating rules contained in the Commission's 04-186 NPRM (referenced above), and will result in lower maximum allowed transmit power levels in certain geographic regions. Alternate channel interference modeling may be turned off (by setting *INCL_ALTCHS=0)* to obtain results considering only co- and adjacent channel interference levels, as originally proposed by the Commission. The *CR_ADJ_REJ* and *CR_ALT_REJ* configuration parameters model the WSD's transmitter splatter levels (in dBr/6MHz) and are determined by the device's transmit spectral mask. Devices with poor spectral emissions will be penalized with lower allowed transmit power levels by the

[12] Motorola has previously suggested the concept of "mirrored" incumbent databases and protection ratios, to allow protection data to be modified once WSDs are fielded. The same techniques can also be utilized to help adapt results for non-average terrain variations. See the Motorola Oct. 18th ex parte filing referenced above for further details.

geo-location database code. The maximum allowed TX splatter levels will ultimately be determined by regulations, and can greatly affect maximum allowed WSD transmit power levels, especially in major metro areas. The GDB code is configured by default to assume a *simple LP-DTV* WSD transmit mask (as previously proposed by Motorola), which reduces maximum allowed transmit power levels compared to a transmit mask based on Part 15.209(a). Changes in any of the GDB configuration parameters will generally produce different results (i.e., different max. allowed power levels) in the output files. Please contact Motorola if there is a desire to change any of the configuration file parameters. The platform is intended for experimentation, and may be utilized to help verify that the appropriate protection ratios are set. Currently, fairly conservative assumptions (e.g., alternate channel interference modeling, CP MOD protection, simple LP-DTV mask, etc.) are made in the geo-location database code.

When the Motorola geo-location database code is run (upon a manual unit location update/change), it produces several output files. *These files are overwritten with each GDB code run.* The first file is a '*CRDBtxpowersChange.txt*' (or '*CRDBtxpowers.txt*') data file. This file contains the entered unit location coordinates (i.e., NAD27 latitude and longitude), along with a channel listing of maximum allowable transmit power levels (EIRP in signed dBm) for that location. Generally, any value below -40dBm is inside of a TV station's protected service contour, and means that the channel will not be utilized for communications. The GDB code does allow operation (generally at lower power levels) within the protected service contour of adjacent channel TV stations (as described in the above-referenced 04-186 NPRM). Note that the actual WSD transmit mask is a strong determiner of maximum allowed transmit power levels in these cases. Recall that the supplied experimental Motorola WSD does not allow actual unit transmissions. The GDB code also produces a listing of FCC service codes (in the '*CRDBcodeoutChange.txt*' file) for stations for which the Motorola WSD is deemed to be inside of their protected service contours. Thus, this file provides a quick reference to channels on which a fully functional Motorola WSD would not operate on for the given location, and which types of stations are protected. (Example FCC service codes are DT (full power digital station), TV (full power analog station, CA (class A station), TX (TV translator station), etc.). The GDB code also produces a log file ('*CRDBlogoutChange.txt*'), which contains some of the configuration parameters utilized by the code and a listing of all of the licensed/protected TV stations in the incumbent database. The '*CRDBlogout.txt*' log file also contains distances to TV transmitters (& azimuths), along with a comparison to FCC database values (these values are only valid for databases centered on the default center coordinates). Please contact Motorola if further explanation is desired.

5.1.2 Sensing Based Operational Channel Ranking

The Motorola WSD initially senses all the channels in the candidate channel list (e.g., of six channels) obtained from the geo-location database to rank and select an unoccupied channel as the primary operational channel. *Normally, the channel ranking process may take a few seconds to complete upon changing device location.* Typically, the longer the observation time, the more reliable the sensing results. While operating on an unoccupied channel the WSD periodically performs sensing for channel ranking, incumbent detection and recovery. When the device detects a DTV signal, it also computes a confidence value in the detection result. The brief overview of operations performed by the WSD is as follows:

1. Arrive at scene – the WSD determines destination location (currently a manual operation for testing).
2. Based on location, the geo-location database generates the initial candidate channel list (through geo-location database lookup and computations) and their corresponding maximum allowed transmit power levels.
3. The WSD senses all the channels in the candidate channel list for unexpected services such as DTV.

4. The WSD periodically ranks the candidate channel list and chooses a primary operational channel (on the highest ranked channel). The WSD continuously schedules Quiet Periods and senses the channel list for in-band incumbent detection.
5. The WSD moves to the next highest ranked channel in case of incumbent detection on the active channel, or a significant change in the quality of the active channel.
6. For the location change/update case, the GUI notifies the WSD and the geo-location database program of the new coordinates.
    a. The WSD obtains the new candidate channel list from the geo-location database software, generated based computations for the new coordinates.
7. The WSD again senses and ranks all the channels in the new channel list to set up the primary operational CR channel.

5.2 Graphical User Interface (GUI)

The Cognitive Radio graphical user interface displays channel information and also displays the channel ranking for available channels as shown in Figure 11.

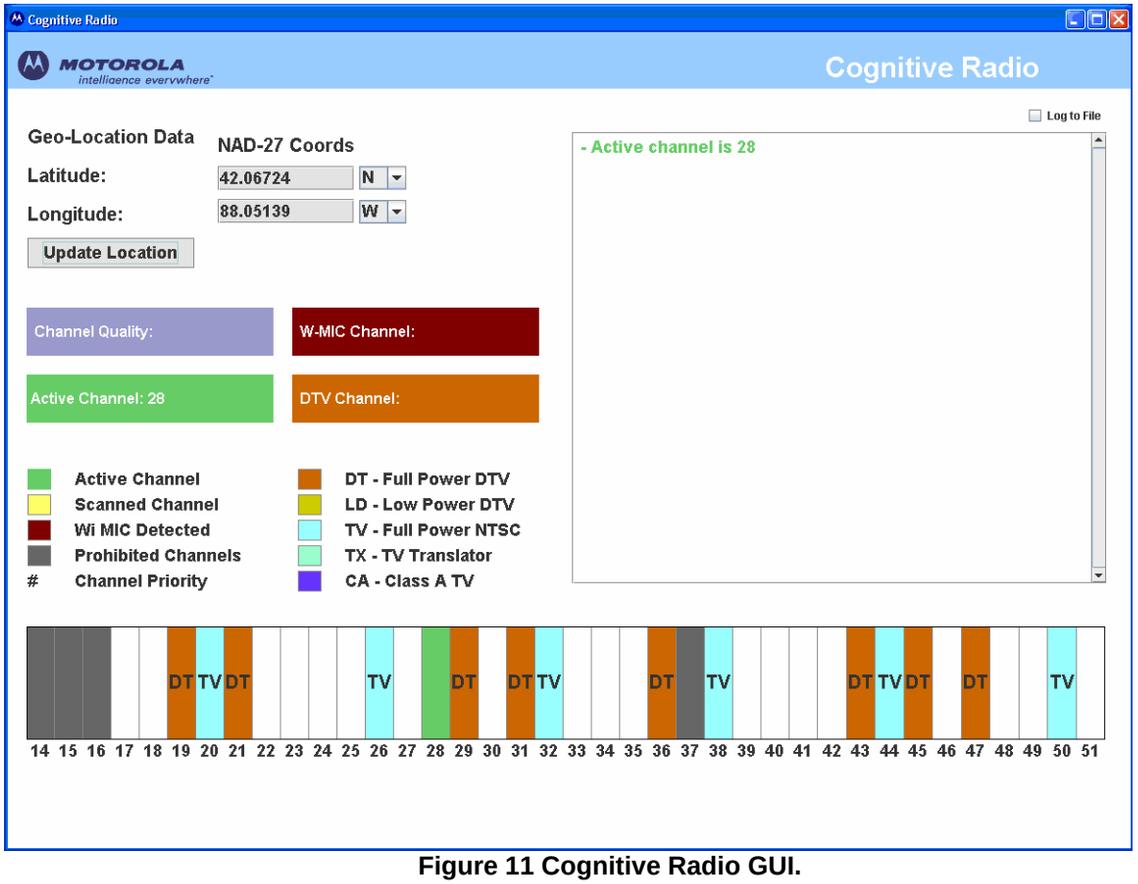

Figure 11 Cognitive Radio GUI.

The GUI provides the following functionalities and features:

- **Location Input**

- The Longitude and Latitude input fields allow a user to manually change the current geo-location. To update location
  Step 1. Input Longitude and Longitude (in NAD27 format)
  Step 2. Click “Update Location”.

  Note: The location input currently only allows the following inputs:
  - Allowable Min/Max Latitude is (38.25951N, 39.51939N)
  - Allowable Min/Max Longitude is (77.84200W, 76.22838W)
  Entering a location outside of this region will produce an error message and will not update the unit’s location (the previous valid location will be retained).

  The channel map at the bottom of the GUI screen should update to reflect the new location. A variety of different FCC service codes are displayed and color coded to indicate which types of TV stations that are serving the location (i.e., inside of protected service contours) – see below.

- **Service Codes**
  - The GUI displays the standard two-character FCC service codes for occupied channels from the geo-location database. Occupied channels are channels for which the specified location is contained within a protected service contour for the specific type of TV station. The GUI displays service codes for Full Power DTV, Low Power DTV, Full Power NTSC, TV Translator and Class A TV stations. Note that only licensed TV stations are displayed; unless the *INCL_CPMOD* flag is set in the geo-location database code configuration file (see above).

- **Active Channel**
  - The GUI displays the Active Channel (currently selected by the CR) in Green in the channel list. The Active Channel is 28 in Figure 11. The active channel is the only channel that would be utilized for communications by the Motorola WSD (if so enabled).

- **Scanned Channel**
  - The active channel changes color to yellow when it is scanned. The active channel is typically scanned during quiet periods. The channels in the candidate channel list are continually scanned during normal device operation.

- **Total Channel Power**
  - The GUI also displays a spectrum plot for any of the six ranked channels when the user clicks on the channel number. It also displays the total power and whether a DTV signal was detected on the channel.

- **Quiet Period Start and Stop**
  - The GUI displays when a Quiet Period has started and ended. This is the time the CR performs sensing.

- **Channel Ranking and Total Transmit Power**
  - The GUI shows the ranking of the six available channels (labeled 1 through 6 in the channel map) and lists the maximum allowed total transmit power in dBm (based on location) for each channel (shown in the text box).

The text box on the upper right side of the screen shows several operational messages (e.g., active operational channel, quiet period messages, location update messages, ranked channel lists, max.

allowed power levels, etc.). The text results can be logged to a user-specified file for later analysis by checking the 'Log to File' box.

6 WSD Test Mode

In this mode the Motorola Cognitive Radio does not use the geo-location database software to determine available channels. This mode of operation provides a command shell (telnet window) to allow the user to carry out bench testing of the sensing algorithms. This mode has been provided for testing purposes only, and is not a normal operational mode.

The Motorola Icon in the Host system tray will show that the CR has started up in Test Mode as shown in Figure 12.

Figure 12 System Tray showing Cognitive Radio started up in Test Mode.

A telnet window will pop up as shown in Figure 13. The telnet window allows the user to input test commands. The telnet window can be opened manually by typing in "Telnet 10.8.122.76" at a Windows command shell.

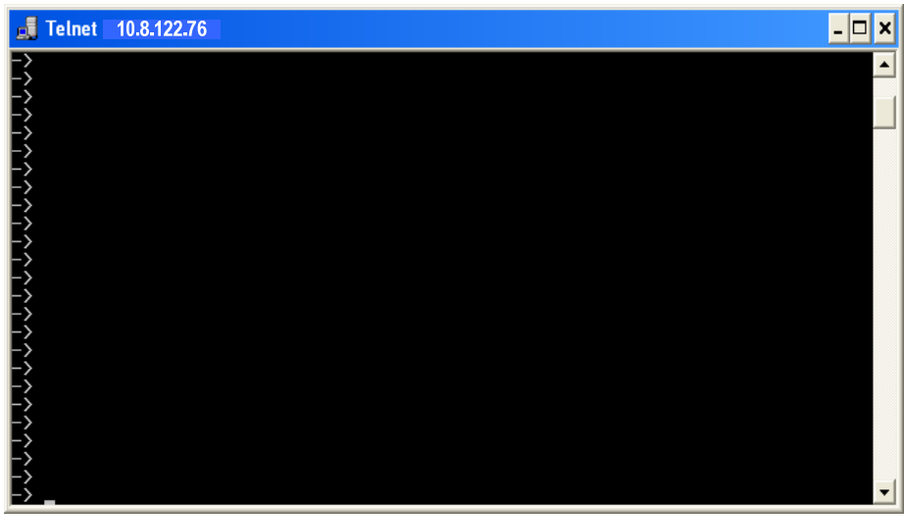

Figure 13 Telnet window for the Test Mode.

6.1 Background

The tests described in this section are used to evaluate DTV sensing capability of the Cognitive Radio (TV White Space Device). These tests allow assessing the ability of the CR:

1. To reliably detect DTV signals and
2. To determine the minimum level of DTV signals that can be successfully detected.

Combination of bench and field tests can be used to determine sensing capability of the devices.
At this time, Motorola does not provide NTSC or Wireless Microphones features detection.

6.2 Test Mode dtvSense() Command

In the Test Mode, a universal "***dtvSense()***" command is used to run the DTV scans in both bench and field testing. This command has the following optional arguments:

- **dtvSense(** [*start_channel* [,*stop_channel* [,*tries_number*]]] **)**

where: *start_channel* – first scanned UHF channel number, ≥14,
stop_channel – last scanned UHF channel number, ≤ 68,
tries_number – number of scans performed for each scanned channel, default = 100.

If no arguments are entered, **dtvSense()** scans UHF channels from 21 to 51[13], each channel 100 tries. If only one *start_channel* argument is used (i.e. in bench tests), only this one channel is scanned 100 times. Approximate duration of one scan try is 16 ms, so default 100 tries on one channel takes about 1.6 sec. Scanning channels from 21 through 51 will take around 50 sec. Increasing number of tries allows more precision in determining DTV signal presence probability.

The results of the scan are displayed in the telnet window, and also appended to the scan log file: **c:\spectrum\carnac\hwtest\sse_test\logs\sse_test.log**. An example of the command output for a few channels scan is shown below.

```
=============================================
      | DTV presence  | DTV    |  Ptotal
   UHF   | probability % | Detect |   dBm
 Channel | ( 100 tries)  |  > 50% | min max
---------+---------------+--------+---------
  27   |      30.0     |   No   | -86  -85
  28   |       0.0     |   No   | -89  -88
  29   |     100.0     |  Yes   | -78  -78
  30   |       0.0     |   No   | -89  -89
  31   |     100.0     |  Yes   | -81  -81
  32   |       0.0     |   No   | -79  -79
```

[13] Currently, channel 37 is excluded from scanning, since its use is prohibited.

6.3 Bench Tests

The bench tests are performed to determine the minimum DTV signal detection threshold of the CR device under test. Two separate bench tests can be defined:

1. **Single Signal Test**: This test utilizes a single unimpaired, laboratory-grade DTV signal as the test input.
2. **Two Signal Test**: This test utilized two unimpaired, laboratory-grade signals as the input, one on the detection channel and the other placed on one of two adjacent channels and held at constant amplitude.

6.3.1 Single Signal Test

The goal of this test is to baseline the detection threshold of the Device Under Test. Figure 14 and Figure 15 below show the test system set up and the spectral envelope of the laboratory grade ASTC (DTV) signal. Such signal can be generated by the Rohde & Schwartz SFU device, or produced from the Agilent ESG Signal Generator with downloaded DTV signal waveform.

Test Setup:

1. Generate a clean laboratory-grade DTV signal using a signal generator
2. Connect the signal generator output to the scanner antenna input of the prototype under test via coaxial cable through a bank of calibrated step attenuators.

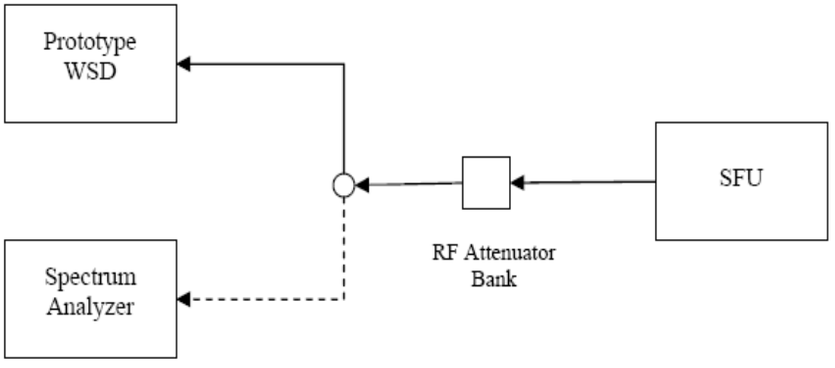

Figure 14. Single Signal Bench Test Connections

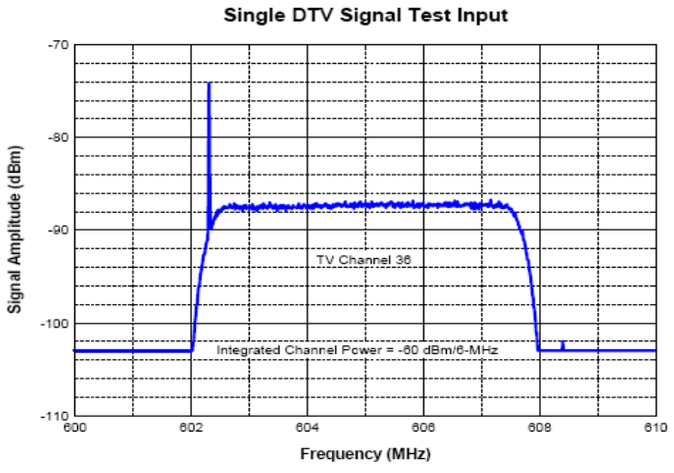

Figure 15. Single Signal Test DTV Spectrum

Test Procedure:

1. Set the DTV signal generator (SFU) to a desired channel N.
2. Set up the signal level at the DUT input to a low measurable level (i.e. -100 dBm) with 100% probability of detection.
3. Run the CR DTV scan using command: "**dtvSense(N)**". It will run 100 sensing tries, and output the resulting DTV Detection Probability, as described in section 6.2 above. If more precision is desired (for example, 500 tries per power level), the following command can be used: "**dtvSense(N,N,500)**".
4. Attenuate the signal by 1 dB step.
5. Repeat steps 3 & 4 till percentage of detections reaches close to zero.
6. Plot percentage of successful detections (DTV Detection Probability), observed at each attenuator step as a function of the input power level.
7. Repeat steps 1 to 6 for other desired channels. Choice of the tested channels can be: low, middle, high in the UHF band, i.e. 21, 36 and 51. Consistency of results between channels depends on the RF Receiver characteristics, and quality of related calibration.

A sample of the Single Signal Bench Test results is shown in Appendix A.1.

6.3.2 Two Signal Tests

The goal of this test is to determine sensing performance of the device in the presence of a strong DTV signal in the adjacent/alternate channel. This test is performed with an additional DTV signal placed:

1. On adjacent channel (N-1)
2. On alternate channel (N+2)

Figure 16, Figure 17 and Figure 18 below show the test system set up and the spectral envelope of the DTV signals used in the test. The signals can be generated by the Rohde & Schwartz SFU devices, or produced from the Agilent ESG Signal Generators with downloaded DTV signal waveform.

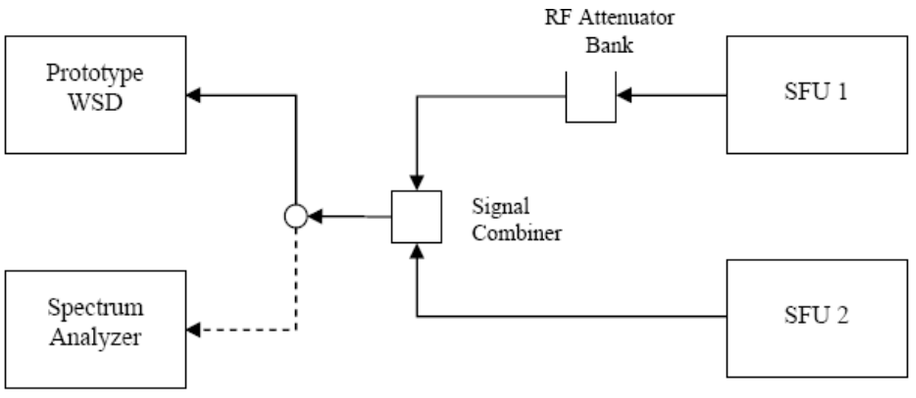

Figure 16 Two Signals Bench Test Connections

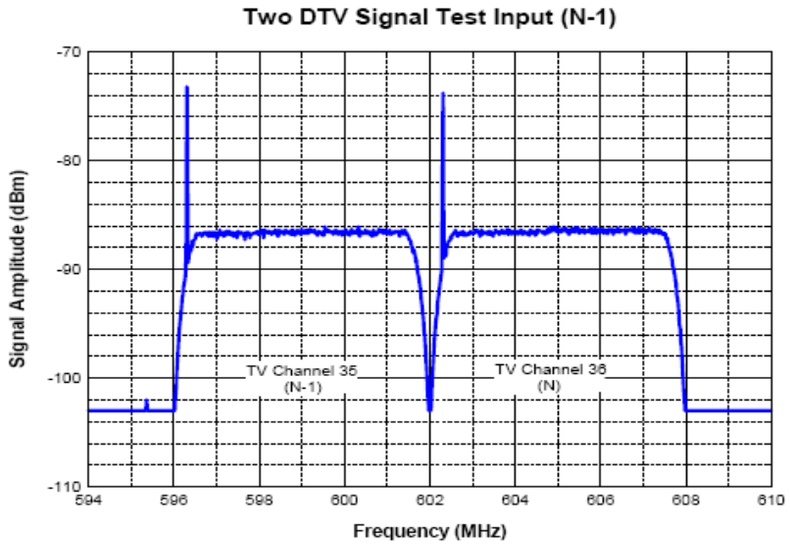

Figure 17 Two Signals Test DTV Spectrum (N-1)

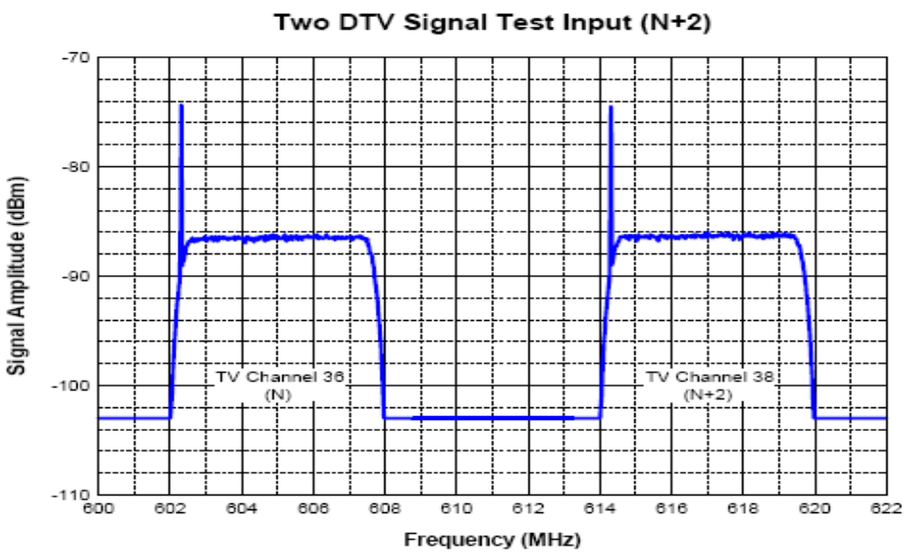

Figure 18 Two Signals Test DTV Spectrum (N+2)

Test 1 Procedure: ***Additional DTV signal placed on adjacent channel***

1. Set the DTV signal generator SFU1 to a desired channel N (i.e. 36).
2. Set the DTV signal generator SFU2 to adjacent channel 35 (N-1), and set the signal at constant power level of -60 dBm.
3. Using RF attenuator set up the SFU1 output signal level to the DUT input to a low measurable level (i.e. -100 dBm) with 100% probability of detection.
4. Run the CR DTV scan using command: "**dtvSense(36)**". It will run 100 sensing tries, and output the resulting DTV Detection Probability, as described in section 6.2 above. If more precision is desired (for example, 500 tries per power level), the following command can be used: "**dtvSense(36,36,500)**".
5. Attenuate the SFU1 signal by 1 dB step.
6. Repeat steps 4 & 5 till percentage of detections reaches close to zero.
7. Plot percentage of successful detections (DTV Detection Probability), observed at each attenuator step as a function of the input power level.

Test 2 Procedure: ***Additional DTV signal placed on alternate channel***

1. Set the DTV signal generator SFU1 to a desired channel N (i.e. 36).
2. Set the DTV signal generator SFU2 to alternate channel 38 (N+2), and set the signal at constant power level of -60 dBm.
3. Using RF attenuator, set up the SFU1 output signal level to the DUT input to a low measurable level (i.e. -100 dBm) with 100% probability of detection.
4. Run the CR DTV scan using command: "**dtvSense(36)**". It will run 100 sensing tries, and output the resulting DTV Detection Probability, as described in section 6.2 above. If more precision is desired (for example, 500 tries per power level), the following command can be used: "**dtvSense(36,36,500)**".
5. Attenuate the SFU1 signal by 1 dB step.
6. Repeat steps 4 & 5 till percentage of detections reaches close to zero.
7. Plot percentage of successful detections (DTV Detection Probability), observed at each attenuator step as a function of the input power level.

A sample of the Two Signal Bench Test results is shown in Appendix A.2.

6.4 Sensing Field Tests

This section describes a set of sensing field tests using live over the air TV signals, received over an omni-directional UHF antenna. Though the Motorola experimental WSD does not rely on sensing alone to determine operational channels, this section describes how to test the sensing portion of the radio. The goal of this test is that for those cases where the test site is located within the interior of a television broadcast station's service contour and where the station's signal can be successfully received by the existing DTV receive system, then that station's channel should be reliably identified by the scanning/sensing component as being occupied. Field sensing tests are in general much more challenging than bench test due to real-world channel effects.

At this time, Motorola does not provide NTSC or Wireless Microphones features detection.

1. To scan multiple channels for DTV detection in the Test Mode, use the following command: "**dtvSense(*start_chan*, *stop_chan*)**". It will run 100 sensing tries for each scanned channel, and will output the resulting DTV Detection Probability, as described in section 6.2 above. If more precision is desired (for example, 500 tries per channel), use: "**dtvSense(*start_chan*, *stop_chan*, 500)**".

2. To scan a single channel for DTV detection in the Test Mode, use the following command: "**dtvSense(*start_chan*)**". It will run 100 sensing tries for the scanned channel, and will output the resulting DTV Detection Probability, as described in section 6.2 above. If more precision is desired (for example, 500 tries), use:
"**dtvSense(*start_chan*, *start_chan*, 500)**".

7 Rebooting

The system can be rebooted using the following steps:

Step 1) Click "Exit" option on the host system tray.
Step 2) Click on the Motorola Icon in the host taskbar host desktop to restart the System as shown in Figure 3.

Note that the host laptop must always be powered on before the Cognitive Radio rack.

A Sample Test Results

This section shows the results of DTV sensing bench tests conducted by Motorola.

A.1 Single Signal Bench Test

The Figure 19 below shows a sample of the Single Signal Bench Test results. In general, excellent results should be obtainable in the lab.

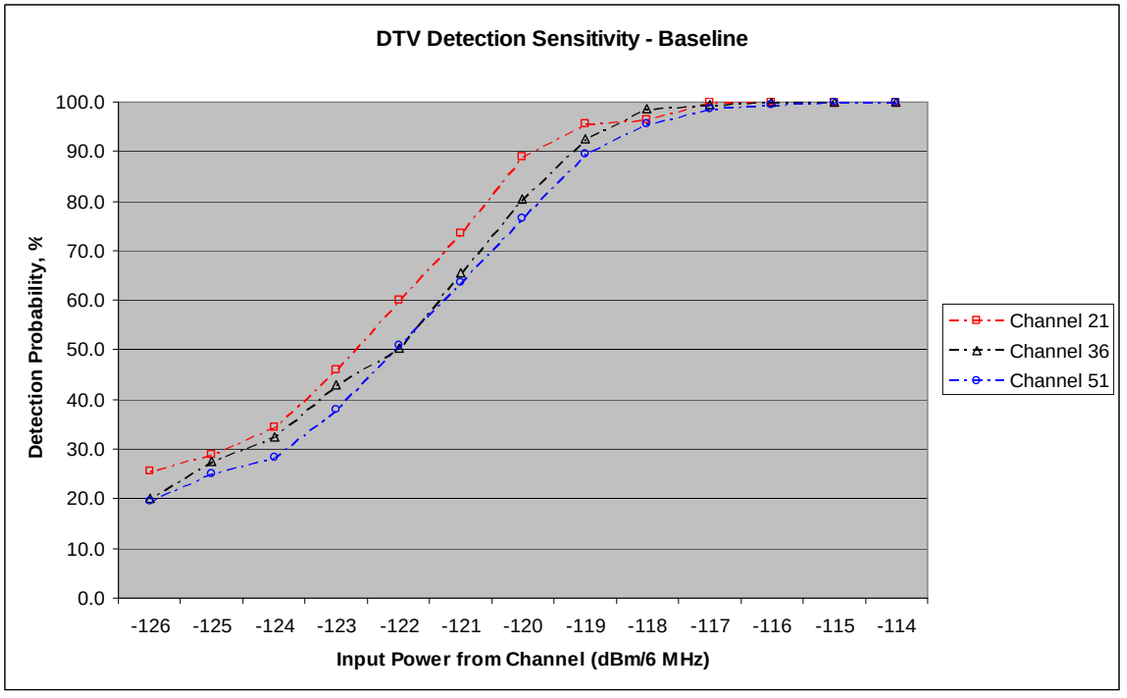

Figure 19 Single Signal DTV Detection Bench Test results

A.2 Two Signal Bench Test

The Figure 20 below shows a sample of the Two Signal Bench Test results. The reduced performance with two signals is due primarily to the relatively poor RF selectivity of the experimental unit's RF deck. The upper adjacent channel case should perform better than the lower adjacent channel case. Once again, recall that this WSD is only an experimental device, and should not be considered production-grade equipment.

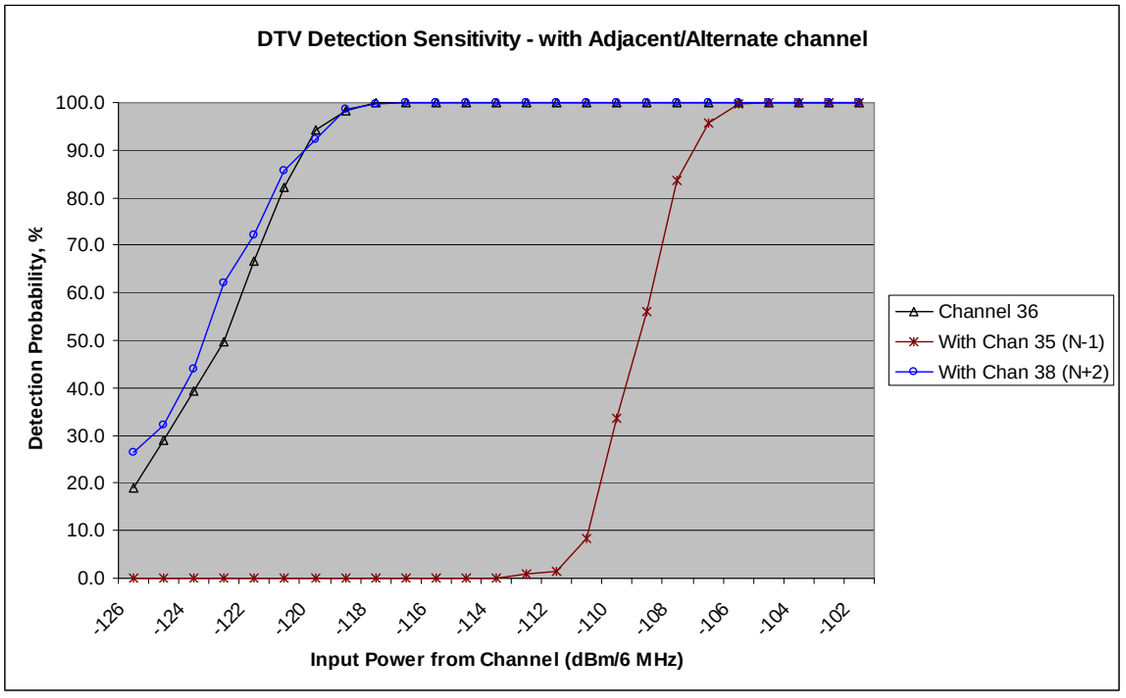

Figure 20 Two Signals DTV Detection Bench Test results

B Troubleshooting

This section covers some basic troubleshooting for the Motorola Cognitive Radio.

B.1 System Startup

Symptom:

Host System Tray Icon does not turn blue after 3 minutes of starting up / the Cognitive Engine board does not light up blue in Normal Mode.

Resolution:

As mentioned in section 3, startup usually takes around 2 minutes. During this time the FPGA code is downloaded by the board and the operating system boots and loads the Cognitive Engine module. It is possible that the board did not FTP the boot files correctly because of the third party FTP server used failed.

Step 1) Close the Motorola Cognitive Radio application by right clicking the system tray icon and selecting “Exit”.

Step 2) Exit the FTP Server by clicking on “WFTPD” Window -> File -> Exit.

Step 3) Double click on the desktop icon “FTP Server”

to start it again.

Step 4) Turn off the Cognitive Radio rack and turn it back on again.

Step 5) Start the Motorola Cognitive Radio application by clicking on the Motorola Icon in the host taskbar as shown in Figure 3.

C Contact Information

Please contact any of the following Motorola employees for further technical questions:

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