# Gnu Radio Based Cognitive Signal Identification and Classification Platform

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**Abstract--In the US the commercial dawn of unlicensed wireless products based on cognitive radio technology is anticiapted to begin in 2008 when the Federal Communications Commission (FCC) issues rules and regulations for low power operation in the UHF TV Spectrum. Viable products will undergo a rigorous regime of testing to demonstrate their ability to coexist on a non-interfering basis with existing over-the-air (OTA) Digital, Analog TV and none-TV services. High reliability algorithmic processes for incumbent signal identification and classification are core to an effective and dynamic local area spectrum utilization plan. In this papert he authors will describe their experience in developing, implementing, and field testing a GNU radio based cognitive radio platform recently presented to the FCC for testing the viability of reliably detecting and identifying low level North American 8VSB DTV and wireless microphone signals. The authors will also discuss energy based detection systems for EU DVB and Chinese DVB formats.**

**Index Terms--Cognnitive radio, incumbent, sensing, spectrum agility, IEEE 802.00, coexistence**

## I. Introduction

Radio devices that forage and hut for operating spectrum in existing commercial and military bands will be commercially marketed within a year. Initial applications will range from providing gap filler transport infrastructure for a wide range of business and residential networked based devices. The concept of scanning, evaluating and automatically selecting an operating frequency plan or regime is not new. A precusror to cognitive radio is the adaptive radio concept used by radio amateurs and goverments alike to establish high reliability HF links. Called ALE, stations have the capability to make contact, or initiate a circuit, between itself and another specified radio station(s), without human intervention and usually under processor control within a predetrimined band using a well define protocol. Nominally ALE techniques include automatic signaling, selective calling, and automatic handshaking. Other automatic techniques that are related to ALE are channel scanning and selection, link quality analysis (LQA), polling, sounding, message store-and-forward, address protection, and anti-spoofing.

http://hflink.com/automaticlinkestablishment/

## II. COGNITIVE RADIO CONCEPT

At it's most basic level the purpose of a cognitive radio based communications stem is to provide point-to-point and/or multi-point communications networks ultilizing locally clear spectrum – where, in simple terms, is defined as a metrics set by regulatory, radio engineering and economic and market factors.

The core subcomponets of a cognitive radio system are:

1. Regulartory – operating spectrum and conditions set by a a national or intra-national agency In the US the FCC has jusristrition over comercial entites that market transmission and receiving devices. In the UK this agency is Ofcom. Each of these national agencies are undertaking processes that will free-up spectrum in thier respective UHF TV bands due to the scheduled change over from analog-to-digital television transmissions. In the US the transistion from analog to digital is scheduled for February 2009, in the UK the transistion is scheduled for 2012.

   In the US the FCC is considering allowing cognitive radio operation, on a non-interfering shared basis with on-the-air Digital TV transmissions within the UHF TV Channels 21 (512 MHz) to 51(698 MHz).

   The UK's approached, as shown in figure 1 is to define spectum into two catagories, Clear and Interleaved. Clear spectrum, 112 MHz, is proposed to be allocated to a wide variety of services including, cogitive radio, emergency services, etc.

   Interleaved spectrum, 256 MHz, is occupied by

Digital terrestrial television (DTT) services, DTV transmitters, relays, etc. The free space between incumbent users, is termed White Space

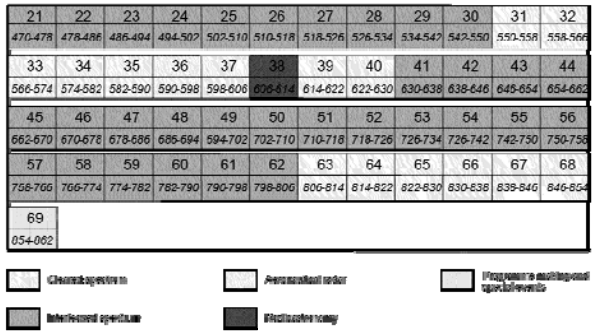



Figure 1. Channel Numbers and Frequencies for UK TV bands IV and V.

Lastly FCC requirements, will require that when transmitting the cognitive radio transmitter minimize the potential of interference to DTV receivers

Basic Cognitve Radio Components

1. A fast scanning system that can scan, anaylize, catagorize spectrum to allow dynamically select canidate operating frequency channels in a changing spectral space
2. A transmitter/receiver suite capable of dynamically adapting channeling, modulation, coding and power to maximize information transfer use given the results of the scanning sub-system. It is expected that some these techniques would include:

   a. Dynamically agile non-contiguous modulation frequency plans.

   b. Code morphing techniques to balance power and application information requirements.

   c. Rule base modulation shifting, much like the 802.11xx devices currently do, to adapt to varying spectrum enviroments and signal processing $E_b/N_o$ requiements

3. An effective wide-band high-dynamic range low-noise antenna. A practical cognitive radio will need to operate in a dynamic range of over 134 dBm. In the US the maximum Receive DTV signal can be as high a + 10 dBm. The lowest signal level requied is nominally -124 dBm. Industrial

The balance of this paper will

To maintain a non-interferring protocol the spectrum band would be declared clear or available if the aggregate power over the DTV transmission bandwidth of 6 MHz was -114 dBm or less. In addition to accurate energy detection of DTV signals a high probability detection of professional wireless microphones is required. The strict regulatrory requirements for meeting DTV, Analog and Wireless microphones detection do not nessacerly indicate that a channel is clear for transmission. Measurement tests for noise level and potential interfers to the cognitive radio must be located and classified.

http://www.gnu.org/software/gnuradio/doc/exploring-gnuradio.html

Purpose of the Metric Systems Cognitive radio or White Spaces Device is to demonstrate to the US FCC the practical ability of a device to scan a predetermined segment of the UHF TV section to scan and identivie spectrum segment available for link use.

The USRF along with was sufficient to to act as a hardware core for the basic demonstration platform GNU Radio software provides a library of signal processing blocks. To this end we publicly express appreciation to Matt Ettus and Eric Bloom and the many USRP developers.

Our goal was to build the simplest-thing-that-possibly-could-work.

Called the White Spaces Device it's technical object was tree fold:

1. Unequivocally demonstrate that an automated device can reliabley detect the present of incumbent DTV/NTSC

GNU Radio provides a library of signal processing blocks and the glue to tie it all together.

Graphical interfaces for GNU Radio applications are built in Python. Interfaces may be built using any toolkit you can access from Python; we recommend wxPython to maximize cross-platform portability. GNU Radio provides blocks that use interprocess communication to transfer chunks of data from the real-time C++ flow graph to Python-land.

Hardware Requirements

GNU Radio is reasonably hardware-independent. Today's commodity multi-gigahertz, super-scalar CPUs with single-cycle floating-point units mean that serious digital signal processing is possible on the desktop. A 3 GHz Pentium or Athlon can evaluate 3 billion floating-point FIR taps/s. We now can build, virtually all in software, communication systems unthinkable only a few years ago.

System-level frequency management and control

automatic link establishment (ALE)

Contemporary Cognitive radio Architecture and functionality

Purpose of radio.

Architecture and basic functionality

Basic components in a systems

Core spectrum function identification and feature analysis

1. Quick

2. Accurate -99.9 percent over a period of time

3. reliable

4. Low cost

5. Upgradeable to handle new modulation screens

Overview of existing incumbent spectrum users

UHF TV Band in US is shared by multiple users

1. Main TV users – Digital (Imag)

2. Analog TV users

3. narrow band users (Wirless microphones, two way radio, telemetry)

4. specialized users

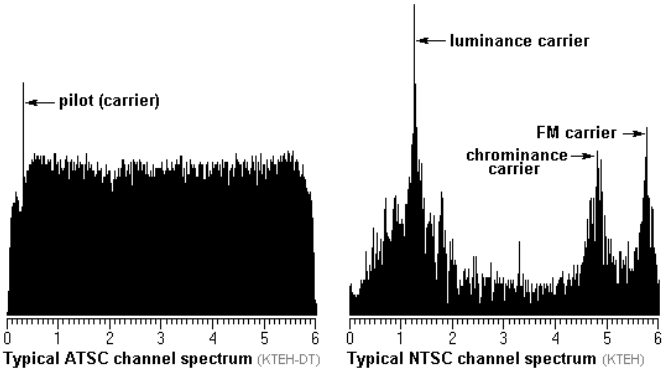
Signal Analysis approach (hardware, software, hybrid)

Hardware

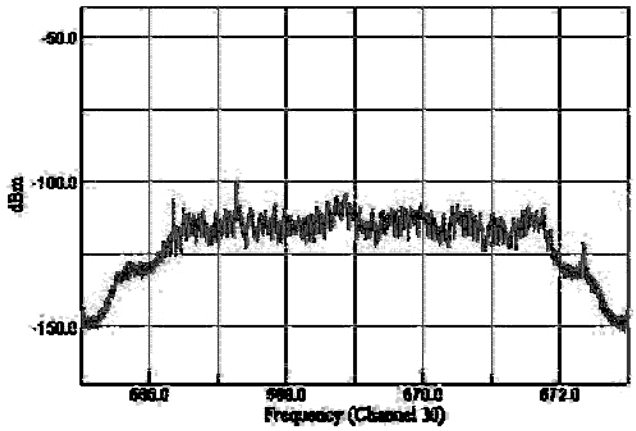
Software tools (GNU Radio components)

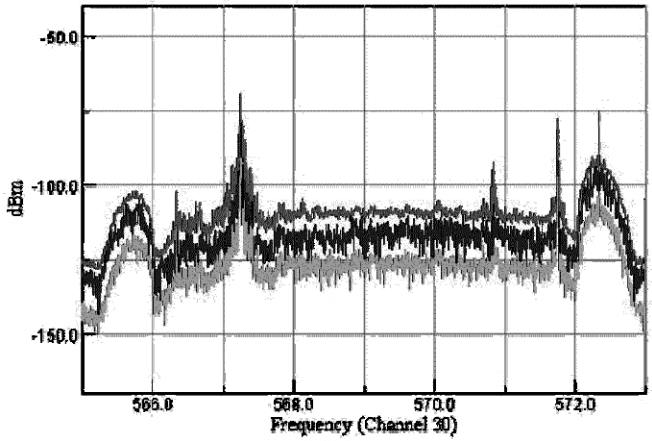
Signal processing Process

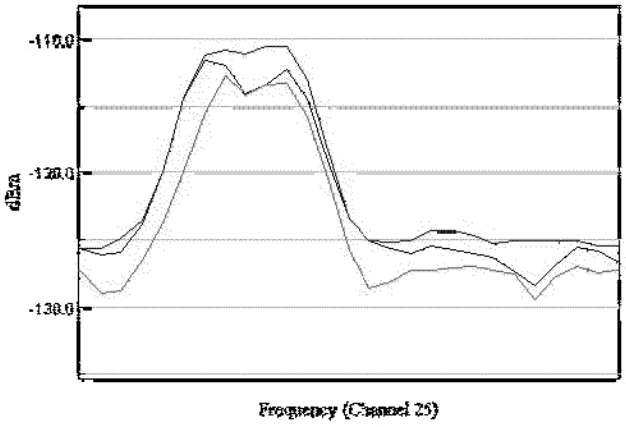
Scan, anal



Typical ATSC channel spectrum (KTEH-DT) Typical NTSC channel spectrum (KTEH)


-50.0
-100.0
-150.0
dBm
668.0
670.0
672.0
Frequency (Channel 30)


-50.0
-100.0
-150.0
dBm
566.0
568.0
570.0
572.0
Frequency (Channel 30)


-110.0
-130.0
dBm
Frequency (Channel 25)