ET4394

Wireless Networking

GNU Radio project

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Challenge the future

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Chapter 1

Introduction

1.0.1 Software defined radio

Software defined can be defined as Radio in which some or all of the physical layer functions are Software Defined. In other words, the software is used to determine the specification of the radio and its functionality. Unlike traditional hardware based radio systems, software defined radio is not designed for a specific modulation/demodulation scheme, the signal processing processes can be completely defined in the software implementation. Re-configurability and reprogrammability are key aspect of this kind of wireless communication systems

1.0.2 RTL-SDR

RTL-SDR is a custom driver software that operates a USB digital TV tuner to function as a software defined radio receiver. It is an open source software developed by Osmocom. The driver works on digital TV tuners based on the Realtek RTL2832U data acquisition chip. It was found that the signal I/Q data could be accessed directly, which allowed the DVB-T TV tuner to be converted into a wide band software defined radio via a new software driver.The basic configuration of the dongle is as shown in figure 1.1.

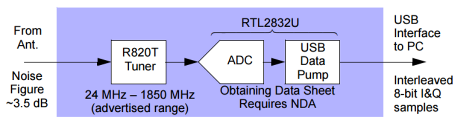

Figure 1.1: RTL-SDR high level block diagram

This essentially paved way for a highly inexpensive TV tuner dongle to be used as computer based software scanner. RTL-SDR is widely used by the academic community for research purposes, students and hobbyists alike. There are a multitude of interesting projects using the dongle. Some of them include listening to unencrypted Police/Ambulance conversations, decoding pager traffic, sniffing GSM signals, listening to broadcasts from satellites and ISS to name a few.

Chapter 2

Cognitive radio

2.0.1 Basics of cognitive radio

Electromagnetic radio spectrum is a highly valuable resource, careful studies of the current usage of the radio spectrum have shown that a large portion of the radio spectrum is inadequately utilized. Some parts of the spectrum are overcrowded, while others are rarely used. Main objective of cognitive radio is to improve spectrum usage efficiency and 0minimize the problem of spectrum over-crowdedness. In a cognitive-radio environment, one must thus identify two types of users: primary users and secondary users. The primary users are already assigned to specific and fixed parts of the channel, and have the right to freely access it at any given time. Since primary users are not active all the time, a cognitive-radio system should also support the secondary users. These users are allowed to use parts of the channel that are not occupied by primary users. For a cognitive-radio device to function properly, it should follow the closed-loop cycle shown in 2.1

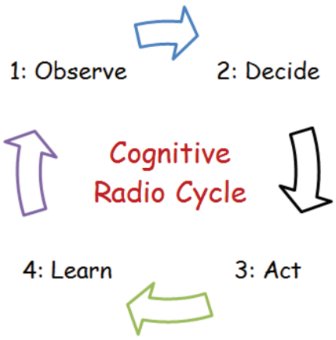

Figure 2.1: Cognitive cycle.

This observe-decide-act-learn cognitive cycle is based on

- Observing the channel activity.
- Deciding which part of the spectrum is suitable for communication.
- Acting appropriately to achieve the required mode of communication.

- learning from previous channel activity.

This cycle allows the cognitive-radio device to self-decide and optimally self-reconfigure its hardware to physically realize the selected mode of communication [1].

2.0.2 TV white space and cognitive radio

Broadcast television services operate in licensed channels in the VHF and UHF portions of the radio spectrum. TV White Space refers to the unused TV channels between the active ones in the VHF and UHF spectrum. This unused spectrum can be used by cognitive radio networks for wireless communications. Spectrum sensing is done to confirm the emptiness of these channels. Using these white spaces for wireless communication can have significant advantage in terms of range and portability

In the Netherlands only band from 470 MHz to 862MHz is used for transmission of digital TV. The following table provides an overview of operators around Delft with a bandwidth of 8MHz.

Operator	Frequency (MHz)	Channel number
RTS Bouquet 1	722	52
NTS Bouquet2	698	49
NTS Bouquet3	762	57
NTS Bouquet4	498	24
NTS Bouquet5	522	27

Table 2.1: DVB-T operators in Delft
source : https://nl.wikipedia.org/wiki/DVB-T-frequenties

Chapter 3

Energy detector

3.0.1 Spectral sensing in cognitive radio

The main objective of a cognitive radio system is to be able to scan the electromagnetic spectrum for white spaces and reconfigure its communication mode. Spectrum sensing is a process of discovering white spaces that can be allocated to secondary users. Reliability of cognitive operation entirely depends upon how effectively the task of spectrum sensing has been performed. Energy detection is widely considered method due to its simplicity. However, due to noise and interference the performance of energy detector may not be very reliable.

The basic block diagram of an energy detector is shown in figure 3.1. The ADC is used to convert the received signal to its digital form. Then the square magnitude of the digitized signal is calculated by using the Fast Fourier Transform (FFT) and magnitude square function respectively. To make the measurement more accurate, an average of N samples is taken. value of the samples is compared with predetermined threshold to decide if signal is present or not.[2] [3]

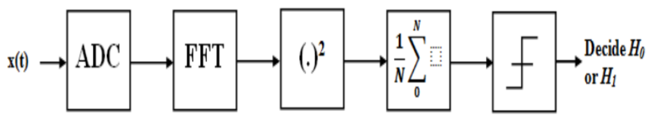

Figure 3.1: Basic energy detector

3.0.2 Implementation

The energy detector as explained previously is implemented by means of `gnuradio-companion` in a Linux machine. It is graphical tool for creating signal flow graphs and generating flow-graph source code for software defined radios. The tools drag and drop style of implementation makes it very easy to realize the system and configure it. The flow graph used to realize the energy detector in `gnuradio-companion` is as shown in figure 3.2.

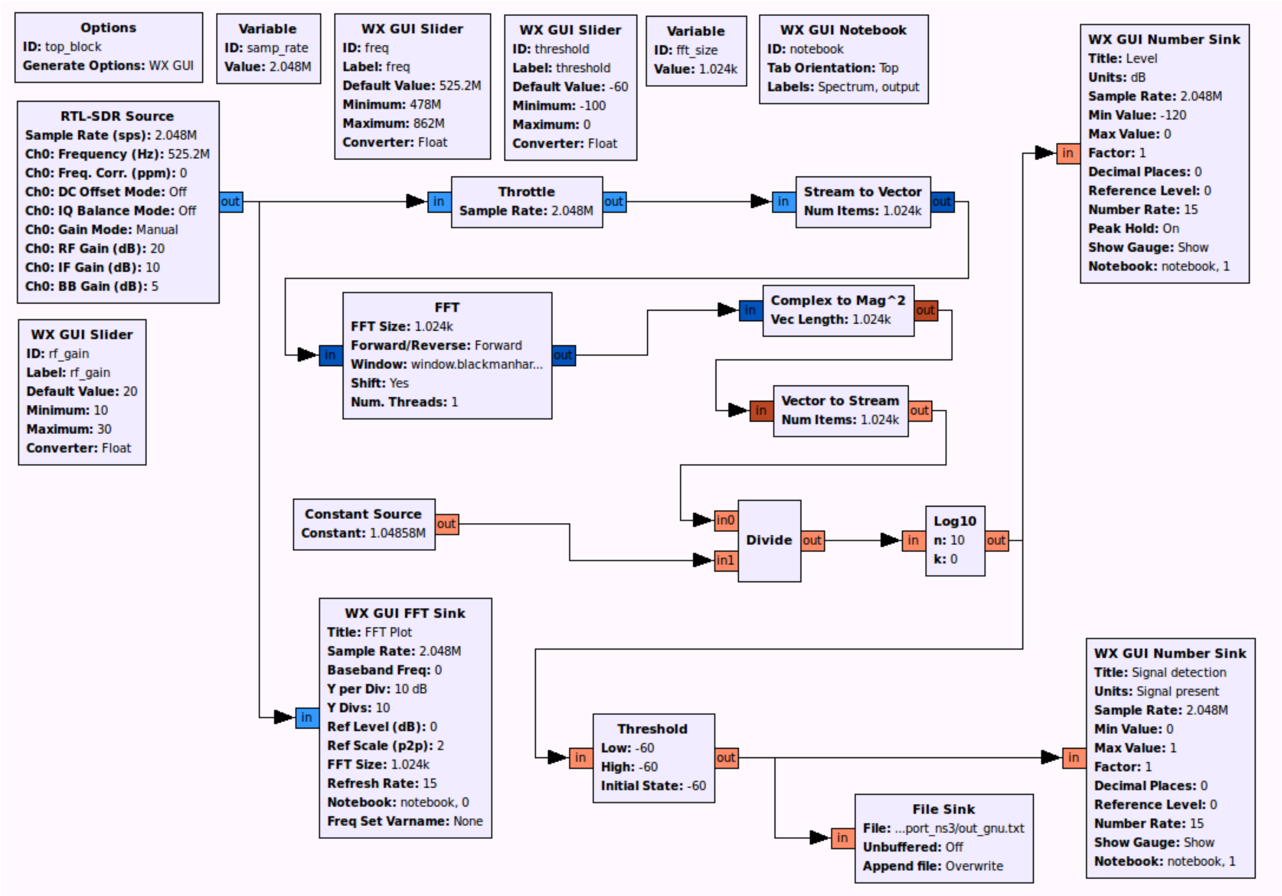

Figure 3.2: Energy detector flow graph in gnuradio-companion

Chapter 4

Analysis of results

Signal measurements are taken at two different locations to validate the performance of the energy detector. At each location parameters like signal level in dB and detection capability (Yes or No) is recorded. The signal measurement is done for approximately 10-12 seconds in order to get a stable signal. Readings at places where signals exists and don't not exist are taken. Table 4.1 contains values of the measurement taken at TU Delft, EWI and Willem Dreeslan 2623JT Delft with a threshold value of -60dB.

Table 4.1: Signal Measurements

			Melkeweg, Delft		Willem Dreeslan 2623JT Delft		Average & standard deviation(dB)
Operator	Center Frequency	Range	Detection	Signal Level (dB)	Detection	Signal Level (dB)	
RTS Bouquet 1	722	718-726	Yes	-50.65	NO	-69.47	Deviation : 6.54 Mean : -53.72
NTS1 Bouquet 2	698	694 -702	Yes	-51.87	Yes	-50.46	
NTS2 Bouquet 3	762	758 - 768	No	-61.45	Yes	-55.70	
NTS3 Bouquet 4	498	494 - 502	Yes	-53.94	Yes	-53.71	
NTS4 Bouquet 5	522	518 - 526	Yes	-55.23	Yes	-57.42	
Unknown - 1	796.15	791.7 - 800.6	Yes	-37.45	No	-61.84	
Unknown - 2	805.7	801 - 810.4	Yes	-58.13	Yes	-46.31	
Unknown - 3	815.7	812-819.5	Yes	-48	Yes	47.90	
Empty - 1	710	-	No	-68.13	-	-68.08	
Empty - 2	625	-	No	-66.51	-	-73.26	Mean: -70.72 Standard deviation:1.375
Empty - 3	510	-	No	-68.78	-	-71.20	
Empty - 4	770	-	No	-71.20	-	-72.76	
Empty - 5	862	-	No	-67.96	-	-74.66	
Empty - 6	550	-	No	-69.82	-	-74.16	
Empty - 7	630	-	No	-70.31	-	-73.64	
Empty - 8	580	-	No	-68.48	-	-72.73	

4.0.1 Signal detection

A signal is said to be present when the value of the signal obtained after processing through the energy detector is greater than the chosen threshold level. Consider the example shown in figure 4.4, the value of signal obtained after processing is -46dB. Therefore a decision is made that the signal exists as its higher than the threshold value of -60dB.

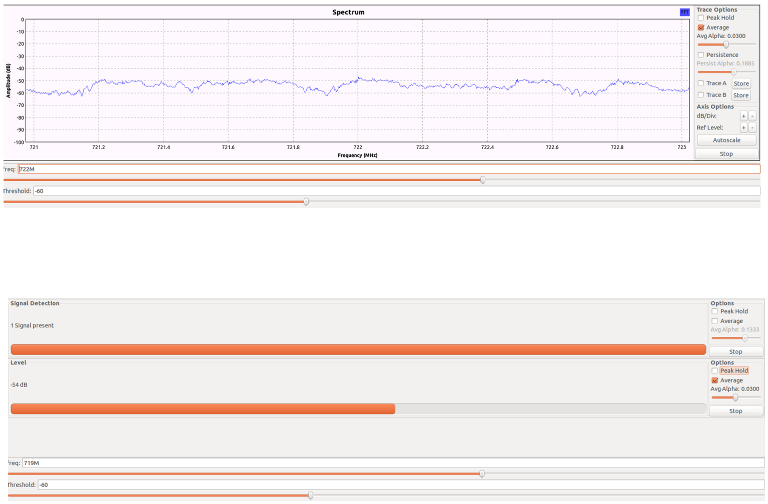

Figure 4.1: Signal missed detection

4.0.2 Signal Missed detection

This scenario occurs when the energy detector fails to identify the presence of a legitimate signal. As seen in figure 762MHz is a valid signal present in well known bouquet 3 but still the detector fails to identify its presence.

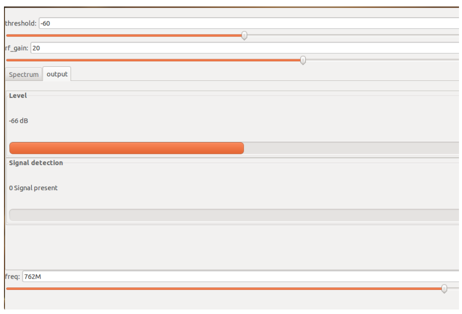

Figure 4.2: Signal missed detection

There might be several reasons that might cause this. It has been observed that several factors such as location, time of the day and even weather(especially rains in Delft) can cause subtle disturbance in measurement and introduce noise. To combat these scenarios it is very

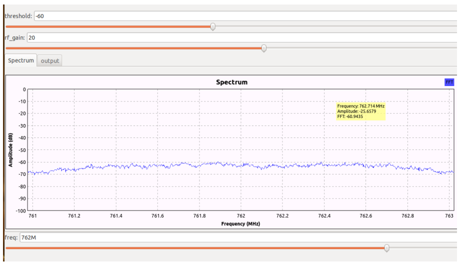

Figure 4.3: Missed detection of 762MHz signal

important to have the threshold reconfigured depending on the present conditions to have a stable detection.

4.0.3 No signal presence

When the detector receives a high amount of noise much lower than threshold a decision is made that there is nothing valid present in that frequency range. This can be seen in figure where the level of signal received is -75dB and thus a decision is made that nothing is present at 710MHz.

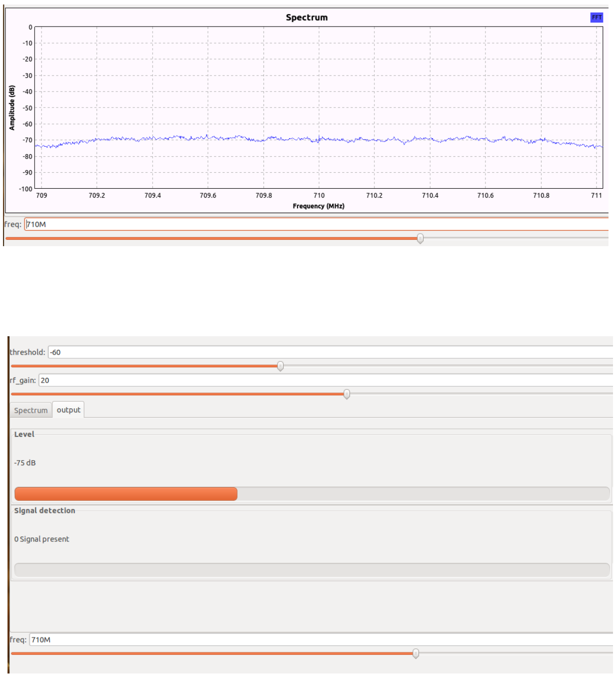

Figure 4.4: No signal present

4.0.4 False alarms

This scenario occurs when a decision is made about presence of a signal although there is nothing valid present. These false alarms are usually caused by the unstable variations in the input signal. Figure 4.5 shows an example of such kind of situation

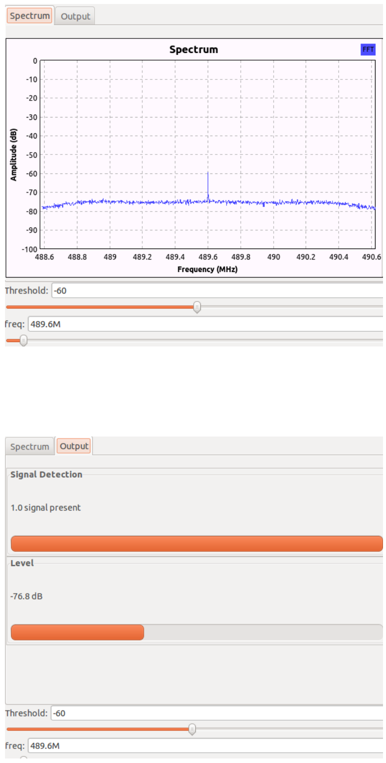

Figure 4.5: False Alarm from the detector

4.0.5 Performance of the detector

The signal measurements were taken at -60dB threshold. Average and standard deviation from the table was used to generate a distribution of signal present and signal absence. Figure 4.6 shows performance of the detector.

The probability of false alarm was found very close to 0%. The probability of detection and missed detection were found to be 83.15% and 16.85% respectively. These values may not be very accurate as in a practical situation the probability of false alarm and missed detection will be high. The figure 4.7 shows ROC of the detector which looks very close to the ideal theoretical value however this should not be considered valid in a practical situation.

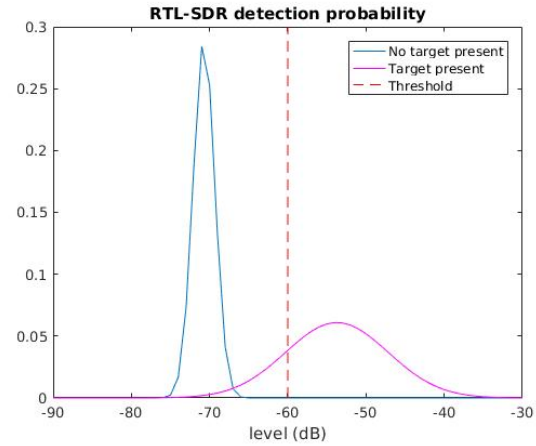

Figure 4.6: Detector performance

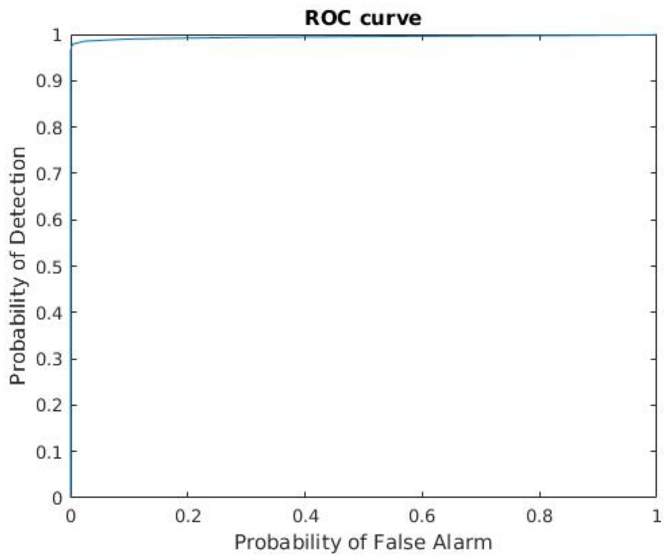

Figure 4.7: Detector performance

Chapter 5

Conclusion

Spectral sensing using a simple energy detector has been implemented by means of a software radio dongle. It was observed that probability of detection and missed detection depends on a variety of factors such as location, height at which readings are taken and interference from structures etc.
Selection of threshold used for detection also plays a vital role. An optimal value should be chosen so as to not trigger too many false positives or incur missed detection. It would also be a good measure to dynamically reconfigure decision threshold as signal intensities may not be constant over a period of time and operating conditions.

Reflection

Getting our hands dirty using the SDR dongle was a wonderful experience. Understanding the basics of cognitive networks and spectral sensing by means of practical project helped me in understanding the topics better.

Bibliography

[1] J. C. Y. Tawk and C. G. Christodoulou, "Cognitive-radio and antenna functionalities: A tutorial."

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[3] P. J. Zhai Xuping, "Energy-detection based spectrum sensing for cognitive radio."