GNU Radio Project Report

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May 3, 2016

1 Introduction

The increasing demand of wireless connectivity has made many research over the world on the cognitive radio. Cognitive radio is an adaptive, intelligent radio and network technology, which can be used to automatically detect the available channels in a wireless spectrum. Then more communication could be transmitted concurrently and the spectrum could be used more efficiently through changing transmission parameters[1].

Cognitive radio depends on many technologies like Adaptive Radio and Software Defined Radio (SDR). The Adaptive Radio could monitor its own performance and vary the operating characteristics including the frequency, power and data rate. And SDR is a different concept from the traditional hardware based radio devices. It implements the radio's operating functions through modifiable software or firmware operating on programmable processing technologies. So it is more flexible and low-cost.

2 Background

The Digital Video Broadcasting – Terrestrial (DVB-T) standard is used as the TV broadcasting in Europe. It can transmit compressed digital audio, digital video and other data in an MPEG transport stream, using coded orthogonal frequency-division multiplexing (COFDM or OFDM) modulation. It offers three different modulation schemes, including QPSK, 16QAM and 64QAM. And the occupied bandwidth is designed to accommodate each single DVB-T signal into 5, 6, 7, or 8 MHz wide channels[2]. There are five

DVB-T Multiplexer operators which are concurrently operating in Delft as Table 1 presented.

Table 1: DVB-T MUX operator and frequency in Delft

MUX Operator	Tx Location	Center Freq. (MHz)	Channel No.	Bandwidth (MHz)	ERP (kW)
RTS Bouquet 1	Delft	722	52	8	1
NTS1 Bouquet 2	Delft	698	49	8	1
NTS2 Bouquet 3	Delft	762	57	8	1
NTS3 Bouquet 4	Delft	498	24	8	1
NTS4 Bouquet 5	Delft	522	27	8	1

There will have some unused frequency bands called white space in the television broadcasting system with DVB-T standard, which will make the spectrum inefficient. In fact, these white space in spectrum can be used by a secondary user. And it can be found by SDR devices. In order to achieve SDR, the GNU Radio, a free software development toolkit, is used to get the signal source and signal process. It can connect to external RF hardwares to create SDR[].

3 Implementation

In this experiment, a mini digital TV stick is used as a receiver to obtain the signals from different places and these signals are processed and presented through GNU. In this way, we can test detector under varying conditions and change the parameters to get different signal.

3.1 Hardware

The specification of the mini digital TV stick is shown in table 2.

Table 2: Specification of the RF hardware

Input terminal	75 Ohm Din
Receiving Frequency	48.25-863.25 MHz
Bandwidth	6/7/8 MHz Auto Select
USB	2.0 port

The most important thing of this digital TV stick is that it is fully DVB-T compliant.

3.2 Software

The received signal is processed in GNU Radio. In GNU Radio, the unused spectrum should be founded. So many functions are needed like FFT and changeable threshold to find the signal in the frequency band.

There are two approaches which could be used to detect the present signal in the frequency band. The first one is signal demodulation, which is able to extract the original digital signal into the video channel. The television broadcast system is in the DVB-T standard, so the signal in particular frequency could be detected. But when there is an analog signal or the signal which is modulated by different methods. Sequentially, it is possible that the signal miss the detection. If the miss detection happened, the secondary user might use this channel to transfer signal, which will interfere the original signal from the first user. Another one is energy detection which is also what we used in this experiment. The level of the signal is obtained and compared with the threshold. When the level of the received signal is above the threshold, we believe that there presents a signal. Otherwise, there is no signal. This method is independent on the types of the modulation, but it will be significantly influenced by the noise from the environment. When the level of noise is above the threshold, it will regard the noise as a real signal, which is false alarm and will cause the secondary user cannot use this frequency band. The process of the energy detection is shown in figure 1.

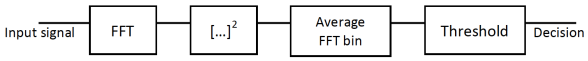


Figure 1: Implementation of energy detector in frequency domain

The input signal is transferred from the time domain into frequency domain by FFT block. Then the magnitude square is used to amplify the magnitude, finally the threshold is used to decide whether there is a signal.

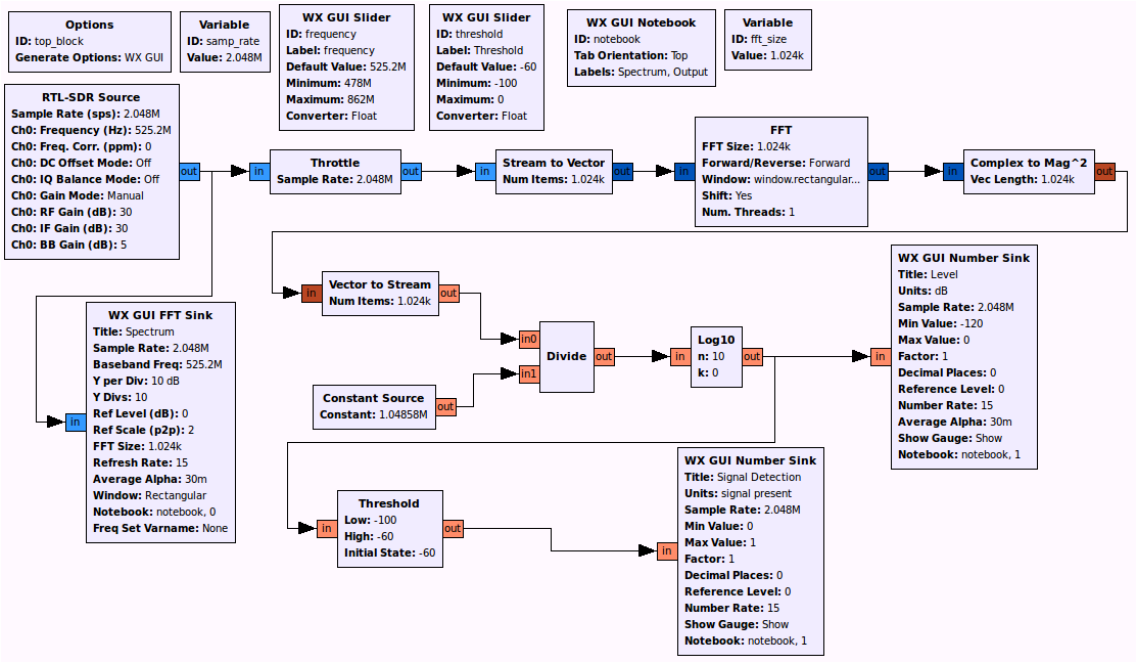


Figure 2: The implementation in GNU

4 Results

The signals with different frequency are detected by energy detector in EWI and Rotterdamseweg and the threshold is set to be 80dB.. The testing results are listed in table 3.

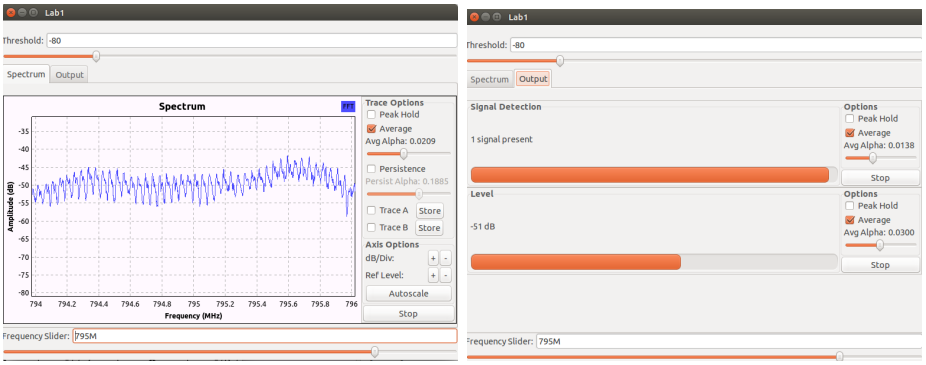
Table 3: The measurement of GNU

Frequency			TU Delft(EWI)		Rotterdamseweg	
Frequency User	Center Freq (MHz)	Freq Range(MHz)	Detection (Y for Yes, N for No)	Average Level(dB)	Detection	Average Level(dB)
RTS Bouquet1	722	718-726	Y	-71	Y	-55
NTS1 Bouquet2	698	694-702	Y	-72	Y	-54
NTS2 Bouquet3	762	758-768	Y	-74	Y	-60
NTS3 Bouquet4	498	494-502	Y	-66	Y	-56
NTS4 Bouquet5	522	518-526	Y	-57	Y	-47
Unknow1	480	1carrier	N	-78	Y	-69
Unknow2	600	1carrier	Y	-75	N	75
Unknow3	795	791.5-800.5	Y	-51	Y	-49
Unknow4	805	801.5-810.5	Y	-70	Y	-58
Unknow5	815	811.5-820.5	Y	-62	Y	-63
Empty1	550	-	N	-78	N	-72
Empty2	650	-	N	-78	N	-76
Empty3	750	-	N	-77	N	-76
Empty4	850	-	N	-78	N	-78
Empty5	478	-	N	-78	N	-71
Empty6	479.2	-	N	-78	Y	-64
Empty7	489.6	-	N	-77	Y	-73
Empty8	504	-	N	-77	N	-71
Empty9	506	-	N	-76	N	-70
Empty10	604.8	-	N	-78	N	-78

From the results of the measurement, it is obvious that there are some frequency band without any signal. This frequency band can be used by secondary user to enhance the efficiency of the wireless network.

4.1 Signal detection

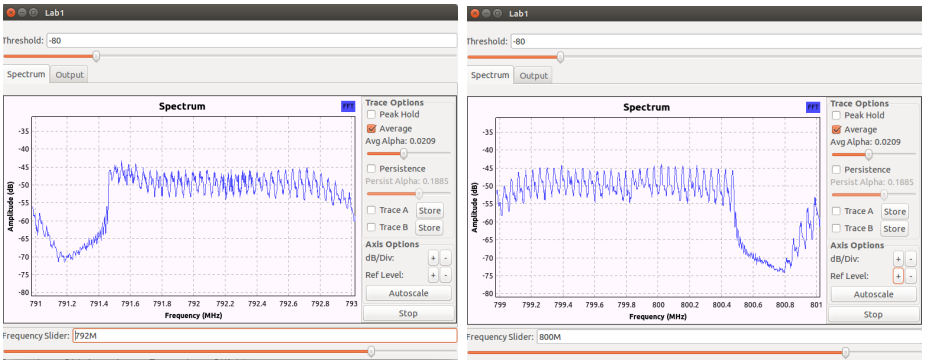
The signal is detected in some frequency by the energy detector. The figure 3 presented the detected signal with center frequency of 795MHz.



(a) a (b) b

Figure 3: The detected signal

The range of the signal frequency can also be measured by GNU as shown in figure 4. There is a sharp decrease in frequency 791.5 MHz and 800.5 MHz. So the bandwidth of this signal is about 9MHz.

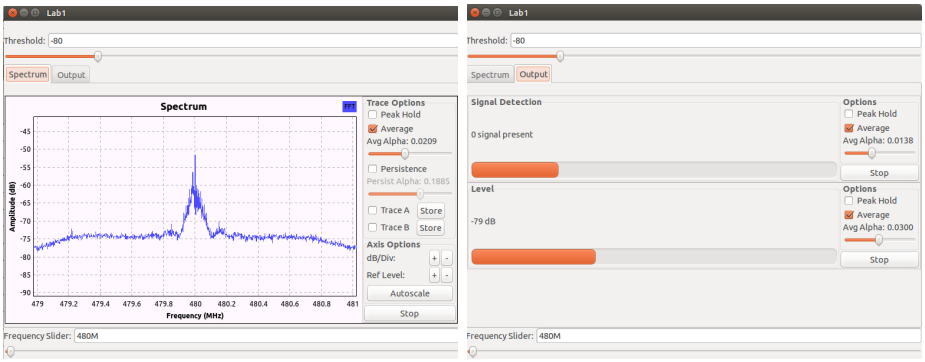


(a) a (b) b

Figure 4: The edges of signal

4.2 Signal missed detection

The signal missed detection is that there is a signal but it could not be detected by the detector. In this way, the secondary user will think this frequency is empty and try to send signal in this frequency. Consequently, the original signal will be interfered. Thus the signal missed detection should be avoid in cognitive radio. The figure 5 shown the situation of signal missed detection. The probability of missed detection can be reduced by reducing the threshold.

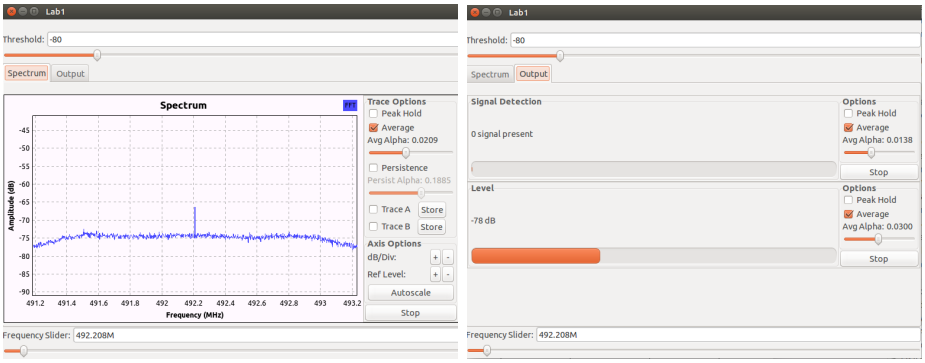


(a) a (b) b

Figure 5: The detected signal

4.3 No signal presence

When there is no signal in some frequency, the energy detector can indicate there is no signal in this frequency and measuring the level of the environment noise. As shown in figure6.



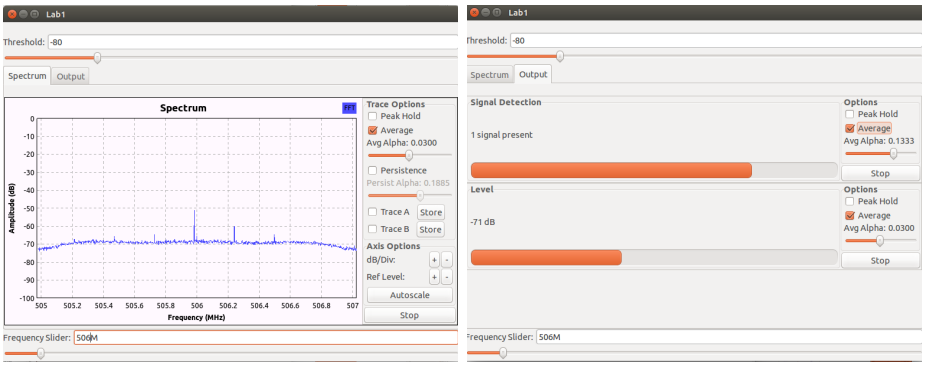
(a) a (b) b

Figure 6: No signal

4.4 False Alarm

The false alarm will lead to lower efficiency of the wireless network. It will indicate there is a signal but in fact there is no signal in this frequency. So the secondary user will not try to send signal in this empty frequency. As shown in figure 7. At the 506MHz frequency, there is no signal, but the

energy detector alarm the presence of a signal. This may happen when the level of noise is high. It can be sovled to some extend by increasing the threshold value.



(a) a (b) b

Figure 7: The false alarm

5 Conclusion

Cognitive radio technology needs to detect the signal to find the empty frequency. In this assignment, the energy detector is used and the signals with different frequency are measures. There is a large range of frequency without any signal. These frequency can be used for secondary user.

However, some situation will cause the missed detection and false alarm. To improve the efficiency as much as possible, these two situations should be avoid by enhance the accuracy of the detector. For this purpose, the threshold should have a trade-off when detection the system.

References

[1] https://en.wikipedia.org/wiki/Cognitive_radio

[2] https://en.wikipedia.org/wiki/DVB-T

[3] https://en.wikipedia.org/wiki/GNU_Radio

[4] http://gnuradio.squarespace.com/gr-tutorial/