GNU Project Report

Qiaoqiao Li
4508300
ET4394 Wireless Networking
Embedded Systems
TU Delft

May 1, 2016

1 Introduction

DVB-T (Digital Video Broadcasting Terrestrial) is the DVB European-based consortium standard for the broadcast transmission of digital terrestrial television. Frequencies assigned to broadcast television channels lies from 478 MHz to 862 MHz. Based on Nederland Radio and TV database, there are five DVB-T Multiplexer operators that are currently operating in Delft area. Frequencies and channels assigned to DVB-T Multiplexer operators that are currently operating in Delft area is shown in figure 1. In telecommunications, frequencies allocated to a broadcasting service but not used locally are so- called white spaces [1]. In particular, the switchover to digital television frees up wide spectrum between about 50 MHz and 700 MHz. The radio spectrum which has never been used is free for use in order to improve spectrum utilization. The use of TV White Spaces on a secondary, unlicensed basis has been of great interest recently in academia, industry and regulatory bodies worldwide. In order to find a white space, there are currently two ways. One of them is database approach. Directly querying of databases gives vacant channels. This approach has gradually dominated the market because it is more reliable. Another approach is spectrum sensing, including three types, namely local detection based on signal observation, cooperative methods and feature detection. In this project, we will experiment with local detection. The detector decides whether there is a signal or not by comparing the received level of signal with the threshold. If the received level is above the threshold, then it deduces a signal presence and vice versa. However, a noise that is above the threshold may be detected as a real signal and a

Figure 1: DVB-T MUX Operator & Frequency in Delft [2]

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

signal that is below the threshold may not be detected, hence, diminishing the performance of the detector.

2 Project Description

2.1 Objective

This project creates a DVB-T signal detector. The objective of this project is to use this detector to see whether a signal exists based on a certain signal threshold, under varying channel conditions. As a consequence, the empty channels should be observed and the receiver operating characteristics of the detector should be shown.

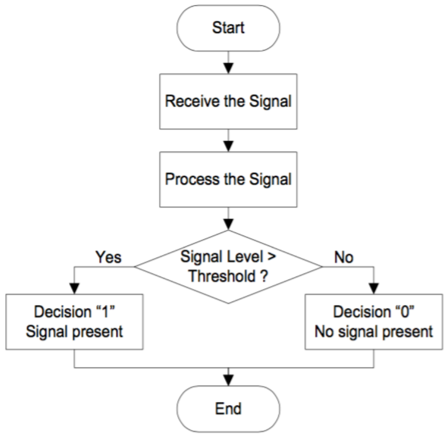
2.2 Hypothesis

The performance of the detector is related to the threshold value. An optimal threshold value should filter out as much noise as possible while detect as much real signals as possible. If the threshold is set too low, a noise signal would be considered as a real signal by the detector. In contrast, if the threshold is set too high, a real signal would be considered as noise signal and hence would be missed by the detector.

3 Implementation

A flowchart in figure 2 depicts the whole detection process. The detector comprises two main blocks: signal collection and signal processing. Signal collection is done by a hardware called RTL2832U Dongle [4]. The dongle filters the signals on the antenna with a frequency range of 24 - 1766 MHz and converts the analog signals to digital signals. The output from the Dongle is then processed by an open source software development toolkit called GNU

Figure 2: Signal Detection Process [3]



radio [5]. The block diagram of the GNU radio is shown in figure 3. The parameters are shown in Appendix A. What it does is simplied in figure 4. In general, the output from the Dongle is processed into FFT block, which transforms the signal from time domain to frequency domain. Subsequently, the signal is amplified by a magnitude square block. After the average FFT bin block, a moving average block is used to smooth out the noisy signal. Next, a threshold is provided to make a decision on whether there is a signal in a certain frequency and channel or it is noise.

4 Results and Analysis

The measurement is performed in Vossenlaan Delft. In this measurement, the threshold is set to be -70 dB. Every channel with a center frequency is checked. Appendix B lists the measurement results. The duration of measurement for each frequency is about 10s in order to wait for the signal to be stable every time the frequency changed. The average signal level is the average of detected signal, which is -68.5 and the standard deviation is 2.51. The aver- age of noise level is indicated by the level where no signal present. Therefore, the receivers average noise level is -74.67 dB and the standard deviation is 0.72.

The detector outputs can be categorized to four cases. The first case is that a real signal is detected. The second case is that there is only noise, and therefore no real signal is detected. The third case is that there is a real signal but the detector fail to detect it, which is the so-called missed detection. The last case is that there is only noise but the detector report

Figure 3: Block Diagram of Signal Processing in GNU Radio

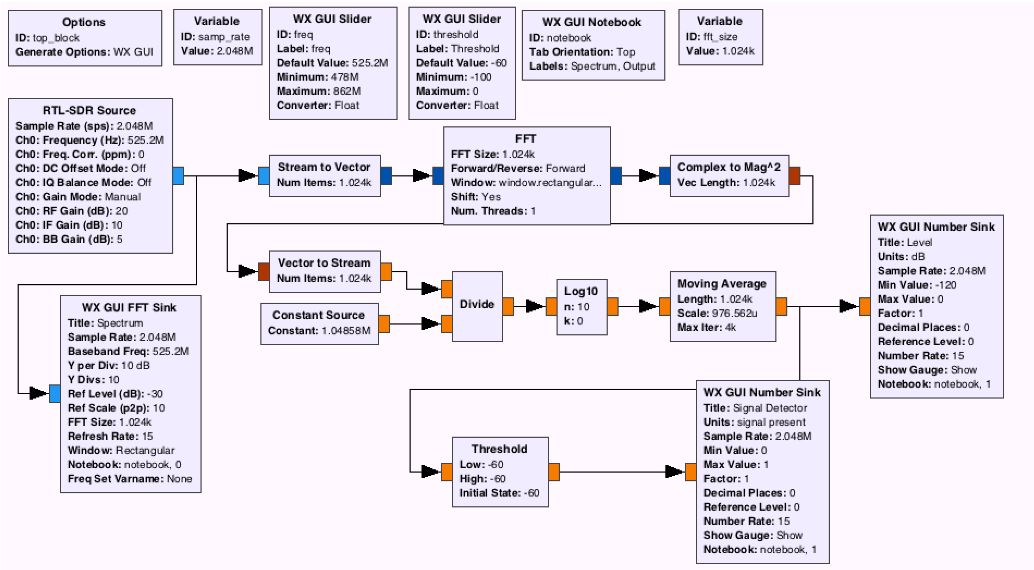
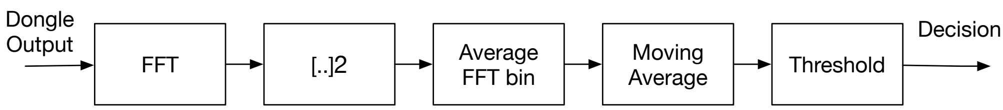
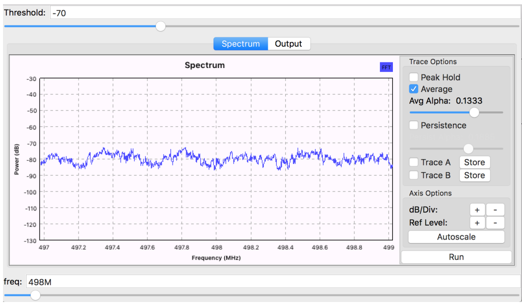


Figure 4: Block Diagram of Signal Processing

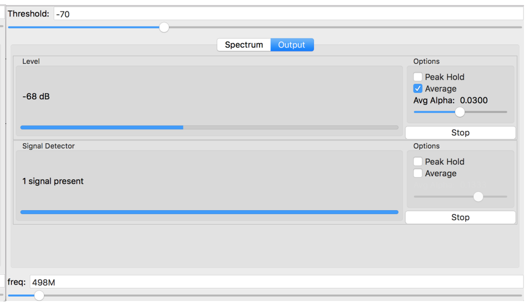


that there exists a real signal by mistake, which is the so-called false alarm. The former two cases are good performance of the detector, while the latter tow cases are bad performance. In terms of missed detection, the user may choose to use that channel which is not empty, leading to interference with the primary user. In terms of false alarm, a channel that can actually be used will be left empty, and hence the utilization is not improved. For each case, we plot the signal spectrum from the Dongle output. The signal level and the decision on whether there is a signal in a certain channel after the processing of the GNU radio are also shown.

4.1 First Case



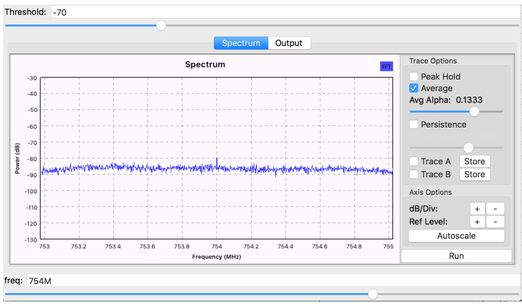
(a) Spectrum



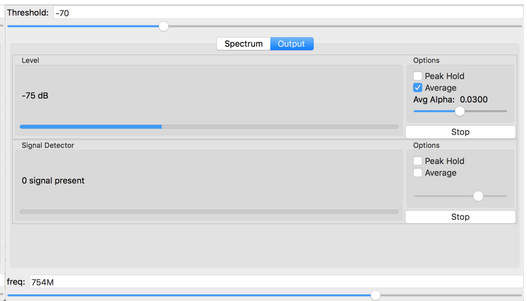
(b) Signal Level and Decision

Figure 1: Detection of Signal in Frequency 498 MHz

4.2 Second Case



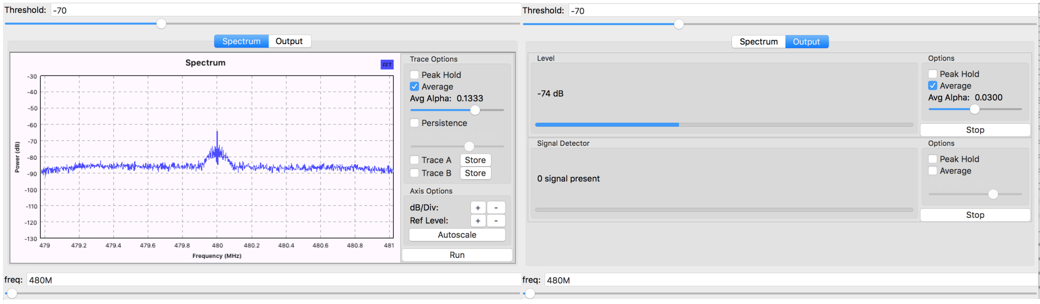
(a) Spectrum



(b) Signal Level and Decision

Figure 2: Detection of Signal in Frequency 754 MHz

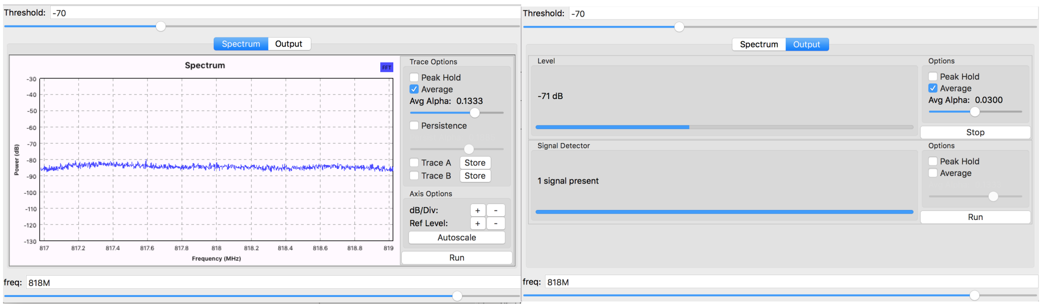
4.3 Third Case



(a) Spectrum (b) Signal Level and Decision

Figure 3: Detection of Signal in Frequency 480 MHz

4.4 Fourth Case



(a) Spectrum (b) Signal Level and Decision

Figure 4: Detection of Signal in Frequency 818 MHz

5 Conclusion

The performance of the receiver is related to the threshold value. An optimal threshold value would result in best signal to noise ratio and hence gives the best detector performance. Based on good local detection, users are able to take advantage of an empty channel without interfering with the primary user.

References

[1] Ray, Bill (April 22, 2011). How to build a national cellular wireless network for 50m. The Register. Retrieved February 4, 2012.

[2] http://radio-tv-nederland.nl/dvbt/digitenne-kpntv.html

[3] Rizqi H. GNU Radio Project Report.

[4] http://www.dx.com/nl/p/rtl2832u-r820t-mini-dvb-t-dab-fm-usb-digital-tv-dongle-black-170541?tc=EUR&gclid=CMOlhtrNtswCFdIV0wodG4Jaw#.VyTFz6N94p8

[5] http://gnuradio.org/

A Appendix

Block Name	Description	Parameter
RTL-SDR Source	Getting the input of signal from RTL2838 dongle	Sample Rate : 2.048 M Samples/s RFGain:20dB, IFGain:10dB, Baseband Gain : 5 dB
Throttle	Limiting the sample per sec (sampling rate)	Sample Rate : 2.048 M Samples/s
Stream to Vector	Converting stream data into vector in order to be processed in FFT	Num Items : fft_size (1024)
FFT	Fast Fourier Transform process	FFT Size : 1024 Window : Rectangular
Complex to Mag^2	Calculating magnitude squared value of FFT sample output	Vector Length : fft_size (1024)
Vector to Stream	Converting Vector to Stream after FFT process. (The opposite of Stream to Vector block)	Num Items : fft_size (1024)
Constant Source	Generating (FFT size)2 value as a divisor	$(\text{fft\_size})^2$
Divide	Getting the average bins of FFT Result (Complex to Mag^2) by (FFT size)2 in order to get the power	
Log10	Converting the power level into dB $P_{(dB)} = 10*\log^{10}(P_{Watt})$	
WX GUI FFT Sink (Spectrum)	Displaying FFT results of spectrum	Sample Rate : 2.048 M Samples/s Baseband freq : freq FFT Size : fft_size (1024) Window : Rectangular
WX GUI Number Sink (Level)	FFT Size : fft_size (1024) Window : Rectangular	Sample Rate : 2.048 M Samples/s Min value : -120, Max value : 0, Average Alpha : 0.01
Threshold	Setting the threshold with upper limit -70 dB	threshold
WX GUI Number Sink (Signal Detection)	Displaying the signal detection based on threshold set. "1" if there is a signal present and "0" if there is no signal present	Sample Rate : 2.048 M Samples/s Minvalue:0, Maxvalue:-3
V ariable Sampling Rate	Define the sampling rate	samp_rate : 2.048 M Sample/s
Variable FFT Size	Define the FFT Size	fft_size : 1024
WX GUI Slider Frequency	Define the frequency	req, freq. min : 478 MHz, freq. max : 862 MHz
WX GUI Slider Threshold	Define the threshold. It will give "1" if the signal level is above -70 dB and will give "0" if the signal level is below -70 dB.	threshold, default = -70 dB, min : -100 dB, max : 0 dB
Moving Average	Implements a basic moving average filter. Can be used as a simple way to smooth out a noisy signal.	fft_size: 1024, scale: 1.0/fft_size, Max later: 4000

B Appendix

				Vossenlaan Delft (51.985308, 4.359877)	
Channel	Frequency User	Center Freq. (MHz)	Freq. Range (MHz)	Detection	Average Level (dB)
22	Empty	482	478-486	×	-75
23	Empty	490	486-494	×	-75
24	NTS3 Bouquet 4	498	494-502	✔	-69
25	Empty	506	502-510	×	-74
26	Empty	514	510-518	×	-75
27	NTS4 Bouquet 5	522	518-526	✔	-66
28	Empty	530	526-534	×	-73
29	Empty	538	534-542	×	-74
30	Empty	546	542-550	×	-73
31	Empty	554	550-558	×	-73
32	Empty	562	558-566	×	-74
33	Empty	570	566-574	×	-75
34	Empty	578	574-582	×	-75
35	Empty	586	582-590	×	-75
36	Empty	594	590-598	×	-75
37	Empty	602	598-606	×	-75
38	Empty	610	606-614	×	-75
39	Empty	618	614-622	×	-75
40	Empty	626	622-630	×	-75
41	Empty	634	630-638	×	-75
42	Empty	642	638-646	×	-75
43	Empty	650	646-654	×	-75
44	Empty	658	654-662	×	-75
45	Empty	666	662-670	×	-75
46	Empty	674	670-678	×	-75
47	Empty	682	678-686	×	-75
48	Empty	690	686-694	×	-75
49	NTS1 Bouquet 2	698	694-702	×	-72
50	Empty	706	702-710	×	-75
51	Empty	714	710-718	×	-75
52	RTS Bouquet 1	722	718-726	×	-74
53	Empty	730	726-734	×	-75
54	Empty	738	734-742	×	-75
55	Empty	746	742-750	×	-75

Channel	Frequency User	Center Freq. (MHz)	Freq. Range (MHz)	Vossenlaan Delft (51.985308, 4.359877)	
				Detection	Average Level (dB)
56	Empty	754	750-758	✖	-75
57	NTS2 Bouquet 3	762	758-766	✖	-74
58	Empty	770	766-774	✖	-75
59	Empty	778	774-782	✖	-75
60	Empty	786	782-790	✖	-75
61	Unknown	794	790-798	✔	-65
62	Unknown	802	798-806	✔	-69
63	Unknown	810	806-814	✔	-71
64	Unknown	818	814-822	✔	-71
65	Empty	826	822-830	✖	-75
66	Empty	834	830-838	✖	-75
67	Empty	842	838-846	✖	-75
68	Empty	850	846-854	✖	-75
69	Empty	858	854-862	✖	-75