ET4394 - Wireless Networking
GNU Radio Project

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Abstract

This report depicts the work done for the GNU radio project for the Wireless Networking course. This report is organized as follows:
Some basic theory is provided in the first section. In the second section the results are presented. Next is the conclusion section, followed by the references and appendix section.

Theory

[1, 2] White space frequency is the empty spectrum, consisting of unused frequencies at a particular band. For example, in digital tv broadcasting band there may exist frequencies, which are not used in a particular area. This means that the band utilization is less efficient. Therefore, secondary users should be able to use these frequencies in order to optimize the utilization of that band. If the primary user needs to broadcast at those frequencies, the secondary user should switch to some other empty frequency. This procedure is called dynamic spectrum access. A user can dynamically access the spectrum by applying cognitive radio property. The spectrum sensing technique is a common way to do that. The system uses spectrum sensing in order to detect the presence or not of a primary user, at a particular frequency.

In this project a signal detector for DVB-T (Digital Video Broadcasting - Terrestrial) signals is given. The DVB-T band is from 478MHz to 862MHz. The goal is to test this detector both in some frequencies where is known that DVB-T signals are transmitted and in some random frequencies where there should not be any signal transmitted.

It should be noted that this detector uses the energy detection approach. It just senses a signal and if the signal level is above a threshold value it deducts that there is a signal. If not, it deducts that there is not a signal. Therefore, the threshold value should be chosen carefully as there may be mis-detections or false alarms as it will be explained later.

To create that kind of detector a receiver is needed, in order to sense the signal. Then the signal is processed and transformed in the frequency domain where it is amplified by the magnitude square block. Based on the threshold value chosen, the detector decides if what it senses is a signal or not. The given detector consists of a Realtek RTL-SDR dongle which is used as a receiver. The dongle receives the signal and after performing A/D conversion it sends the signal to the block diagram constructed through the GNU radio software. In Figure 1 this block diagram is presented.

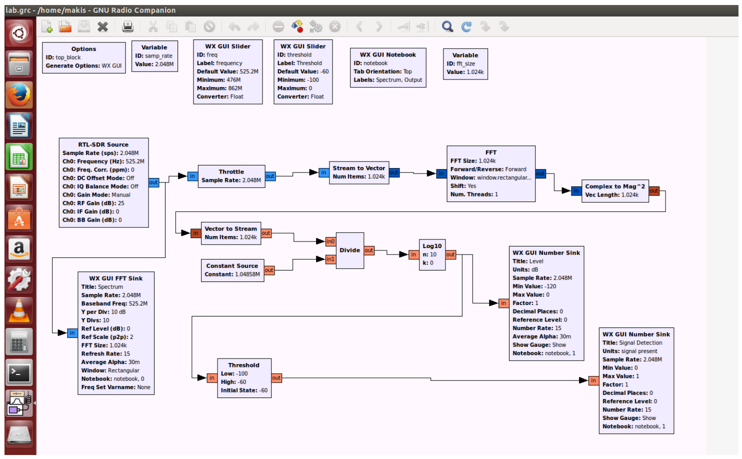

Figure 1: Energy detector block diagram

In the following table the frequencies where DVB-T signals are broadcasted in Delft area is given [3]:

Operator	Center Frequency(MHz)	Bandwidth(MHz)
RTS Bouquet 1	722	8
NTS1 Bouquet 2	698	8
NTS2 Bouquet 3	762	8
NTS3 Bouquet 4	498	8
NTS4 Bouquet 5	522	8

Measurements and Results

The detector was tested in two different locations: EWI buliding 2nd floor and Roland Holstlaan area in Delft.In the next table the measurement results are presented for those frequencies where a signal is detected.

Center Frequency(MHz)	Bandwidth(MHz)	Detection	Level(dB)	Detection	Level(dB)
722	8	Yes	-53	Yes	-57
698	8	Yes	-56	Yes	-53
762	8	Yes	-59	Yes	-60
498	8	Yes	-55	Yes	-59
522	8	Yes	-52	Yes	-56
480	200KHz	Yes	-73	Yes	-75
795	8	Yes	-47	Yes	-49
805	8	Yes	-51	Yes	-54
815	8	Yes	-56	Yes	-51

The average level is found equal to **-56.44 dB** and the standard deviation equals to **6.87**.

Next table depicts the measurement results for those cases that no signal was detected:

Center Frequency(MHz)	Detection	Level(dB)	Detection	Level(dB)
640	No	-77	No	-76
780	No	-72	No	-73
565	No	-76	No	-77
482	No	-79	No	-78
840	No	-72	No	-74
750	No	-77	Yes	-75
680	No	-75	No	-76
510	No	-73	No	-74
530.2	No	-73	No	-77

The average level is found equal to **-75.05 dB** and the standard deviation equals to **1.99**.

It should be noted that except for the five frequencies where the DVB-T signals are broadcasted, signals are also detected in four additional frequencies. At 480 MHz a carrier signal is detected (Figure 2). In addition, at center frequencies 795MHz, 805MHz and 815MHz, signals with 9MHz bandwidth are detected.

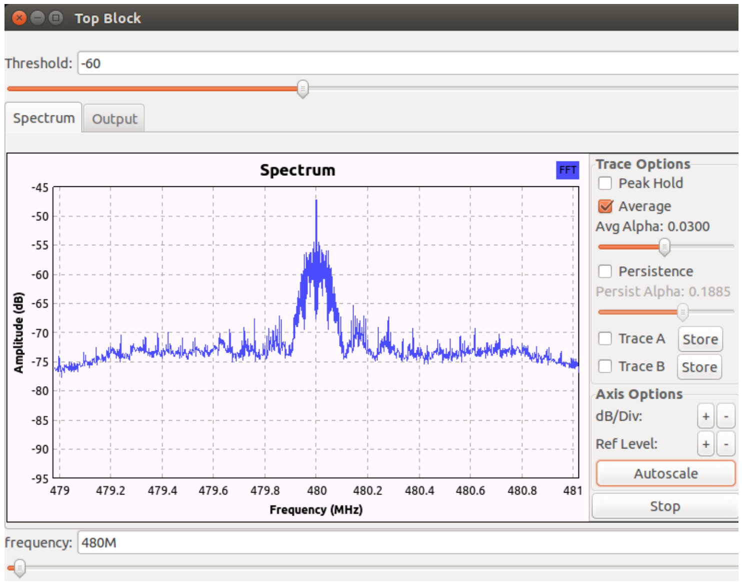

Figure 2: One carrier signal

Looking at the measurements, it is concluded that there is no mis-detection. Mis-detection of the signal is the incapability of the detector to sense a signal that is present in a particular frequency. In our case, all signals that were detected at the first location were also detected in the other as well. The average level of the detected signals was above the threshold value, so a misdetection didn't occur.

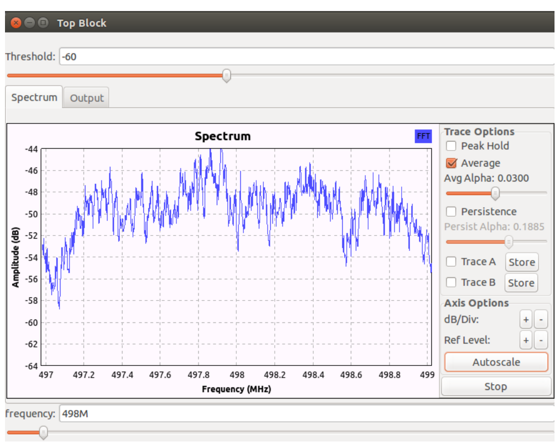

Figure 3: Signal at 498 MHz

In Figures 3, 4 and 5 the detection of a signal is given. Specifically, the signal found at the 498MHz center frequency is depicted. Since the FFT is visualized for only 2 MHz, the two additional figures, confirm that its bandwidth is almost 8MHz, starting from the 494MHz and ending at the 502MHz.

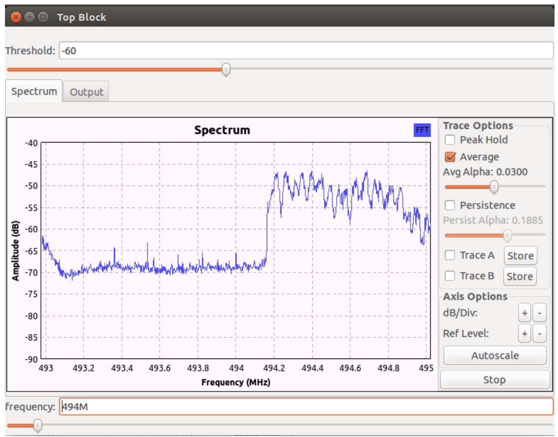

Figure 4: Signal at 498 MHz

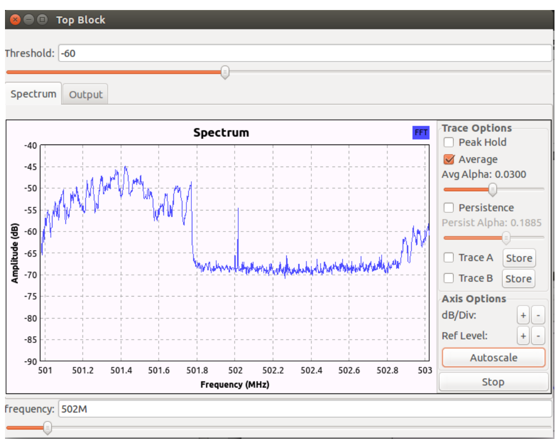

Figure 5: Signal at 498 MHz

In addition, as observed both in the measurements and the Figures 6 and 7. A false alarm occurred. When the system decides that a signal is present in a particular frequency, where there exists nothing but noise, it is said that false alarm occurs. The main problem that can lead to false alarm is the narrow signal observed in the center frequency of measurement. That signal is not real but it is produced by the baseband processing of the RTL-SDR source. Its level is a bit above the noise level and sometimes this may lead to false alarm.

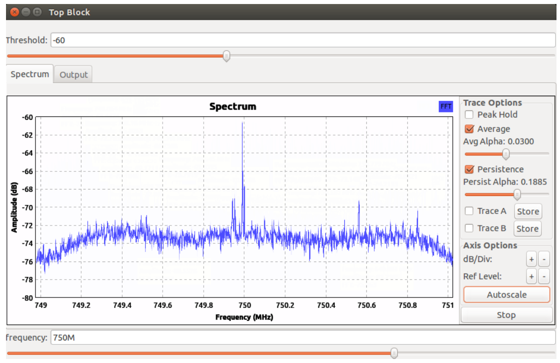

Figure 6: False alarm at 750 MHz

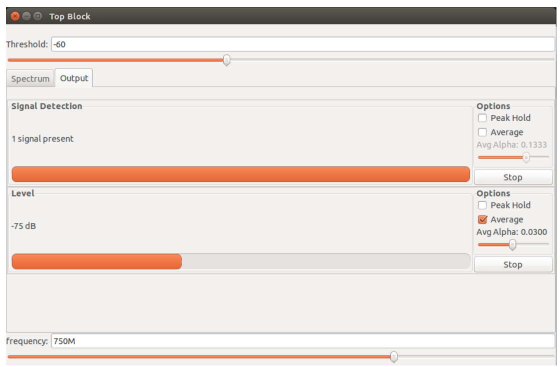

Figure 7: False alarm at 750 MHz

Finally at Figure 8 a no signal presence example is given for the 840 MHz frequency.

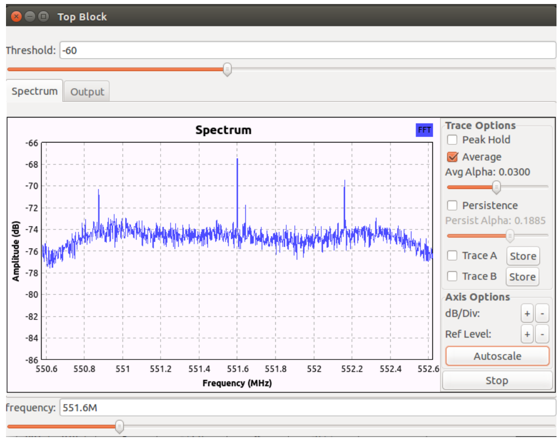

Figure 8: No signal presence at 840 MHz

Next the detection probabilities for three different threshold values are presented.

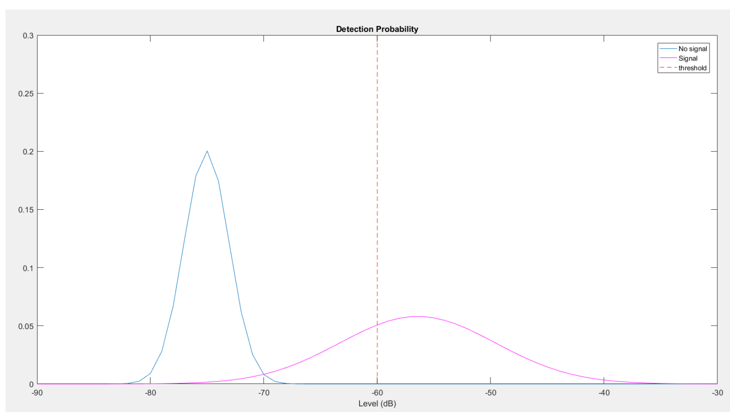

Figure 9: Threshold = -60 dB

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>> Untitled

Pfa =

   1.9762e-14


Pd =

    0.6978


Pmd =

    0.3022
```

Figure 10: Probabilities of detection, mis-detection and false alarm for -60dB threshold

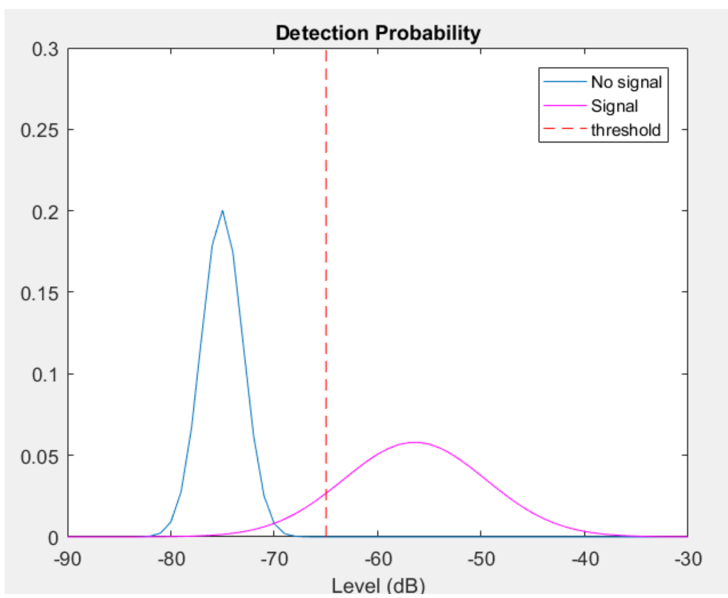

Figure 11: Threshold = -65 dB

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>> Untitled

Pfa =

   2.2061e-07


Pd =

    0.8936


Pmd =

    0.1064
```

Figure 12: Probabilities of detection, mis-detection and false alarm for -65dB threshold

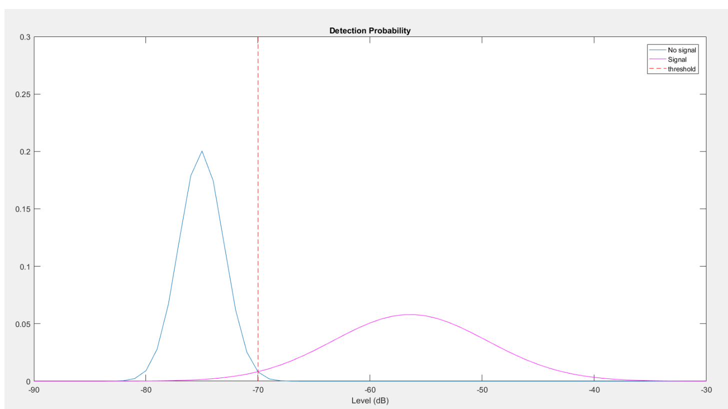

Figure 13: Threshold = -70 dB

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>> Untitled

Pfa =

    0.0056


Pd =

    0.9758


Pmd =

    0.0242
```

Figure 14: Probabilities of detection, mis-detection and false alarm for -70dB threshold

As observed in the previous figures the lower the threshold the higher is the probability of false alarm, the higher is the probability of detection and the lower is the probability of mis-detection.

Conclusion

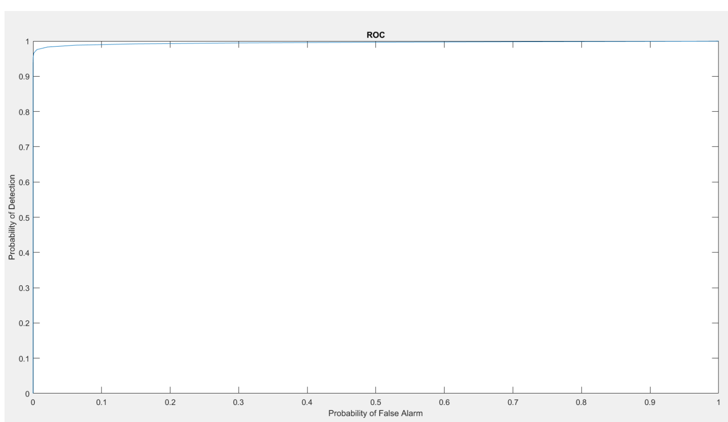

Figure 15: ROC

It is concluded that the given detector behaves efficiently enough. In Figure 15 the receiver operating characteristic of this detector is plotted. It is deducted that there is high detection probability whereas the probability of false alarm remains low. Determining the threshold value is what affects the detector efficiency, giving a trade-off between false alarm and detection probability.

References

[1] Rizqi Hersyandika. GNU Radio Project Report - 2015.

[2] Przemysław Pawełczak. Wireless Networking Course, TU Delft.

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

Appendix

Here is the Matlab script for producing the different plots.

```
Pnosignal = makedist('Normal','mu',-75.05,'sigma',1.99);
Psignal = makedist('Normal','mu',-56.44,'sigma',6.87);
threshold = -65 ;
Pfa = 1-cdf(Pnosignal,threshold);
Pd = 1-cdf(Psignal,threshold);
Pmd=1-Pd;
display(Pfa);
display(Pd);
display(Pmd);
figure(1);
Level = -90:1:-30;
plot(Level,Pnosignal.pdf(Level));
hold on
plot(Level,Psignal.pdf(Level),'m');
title('Detection Probability')
hold on
Y =0:0.1:0.3;
X = threshold * ones(size(Y));
plot(X, Y,'r--')
legend('No signal','Signal','threshold')
xlabel ('Level (dB)')

Pfa_ROC = 1-cdf(Pnosignal,Level);
Pd_ROC = 1 -cdf(Psignal,Level);

figure(2);
plot(Pfa_ROC,Pd_ROC);
title('ROC')
ylabel ('Probability of Detection')
xlabel ('Probability of False Alarm')
```