Analysis to Find Optimum Value of Threshold to Improve Detection in Energy Based Spectrum Sensing Technique in Cognitive Radio

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Abstract: Cognitive radio has been proposed to utilize the available spectrum to its optimum level. Sometimes licensed spectrum is not in used because of unavailable user in that area, at that time in place of making it waste, it has been used by unlicensed user and in this way, it is optimally utilized. But the unlicensed user has to make sure that the spectrum band is not in use or in requirement, for this spectrum sensing techniques are used. Energy based detection (EBD) technique is one of the popular technique due to its simplicity and less computation. But due to the presence of noise, sometimes it leads to false detection. In order to improve it, it is studied with different value of threshold and it is found that if threshold is changed with change in SNR then optimum results in terms of probability of detection can be achieved.

Keywords: Cognitive Radio (CR), Energy Based Detection (EBD) Technique, Integrator, Secondary Users (SU), Primary Users (PUs), Spectrum Sensing, Squaring device, Threshold value, Probability of detection (Pd), Probability of false alarm (Pf), Signal to Noise Ratio (SNR).

1. INTRODUCTION

Radio spectrum is available in limited amount therefore every new application cannot be allotted with a new spectrum. Cognitive Radio (CR) is a possible solution to fulfil the demand of radio spectrum as the applications are increasing day by day [1]. The purpose of CR is to make available a dynamic access of spectrum by the secondary user (SU) without causing any unwanted interference to the primary user (PU). In CR, everything depends on the efficiency of SU to successfully detect the Spectrum Holes (SH) and make use of these unused holes without interfere with the functioning of PU [3]. Cognitive radio has two primary objectives: 1) highly reliable communications whenever and wherever needed. 2) Efficient utilization of the radio [5].

Energy-based sensing (EBS) is one of the simplest and easiest spectrum sensing technique and the main advantage of EBS is that it does not required any a priori knowledge of primary user signal. CR technology is an efficient solution to the under-utilized licensed spectrums. This increases the spectrum utilization and subsequently reduces the spectrum white spaces. Where the white spaces are actually an unused spectrum bands in the temporal and/or spatial domain [2].

In EBS, there is a requirement of threshold value which decides whether spectrum is available to use by SU or not. If this threshold value is kept constant then it may be possible that some available spectrum will not be detected due to low SNR of the signal or presence of noise. Therefore in our proposed work, variation of threshold value VS probability of detection is studied for different value of threshold.

2. ENERGY DETECTION

In EBS spectrum sensing technique, the energy of the radio frequency is measured with the help of a wireless device to determine whether channel is busy or idle. EBS technique has very low computational complexity and therefore it is easy to implement [10]. The disadvantage of this method is it only detects the PU signal if it is above specified threshold, separate noise level detection is not possible [9].

The working principle behind energy based detection technique is as shown in the Fig. 1. The energy detector consists of three parts – Pre-filter, squaring device and a finite time interval integrator [4]. Pre-filter is used to select the desired band spectrum and limit the noise bandwidth. The squaring device's input has a band limited and flat spectral density. The output of the squaring device is given to the integrator. The output of the integrator is the energy of the input to the squaring device over the interval T.

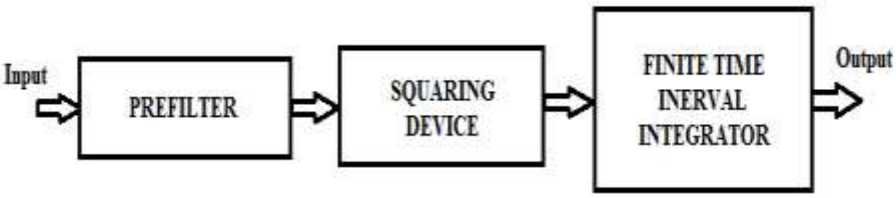

Fig. 1: Working principle of energy detection technique.

Mathematically, the signal at the receiver y(t) in the CR is given by:

$y(t)=x(n)+w(n)$ (1)

Where,
x(n) = the signal to be detected,
w(n) = the White Gaussian Noise.

Then the equation matric can be written as:

$M=\sum_{i=1}^{N} |y(n)|^2$ (2)

Where n is the sample index and N is the observation space. Two states will result due to comparing the metric M with the predefined threshold δ.

when, $y(n) = w(n)$ $(M < \delta)$ (3)

when, $y(n)=s(n)+w(n)$ $(M > \delta)$ (4)

This threshold parameter δ must be selected in order to get the optimum performance so that the power of the signal and noise can be detected [3] [5].

3. PROPOSED WORK

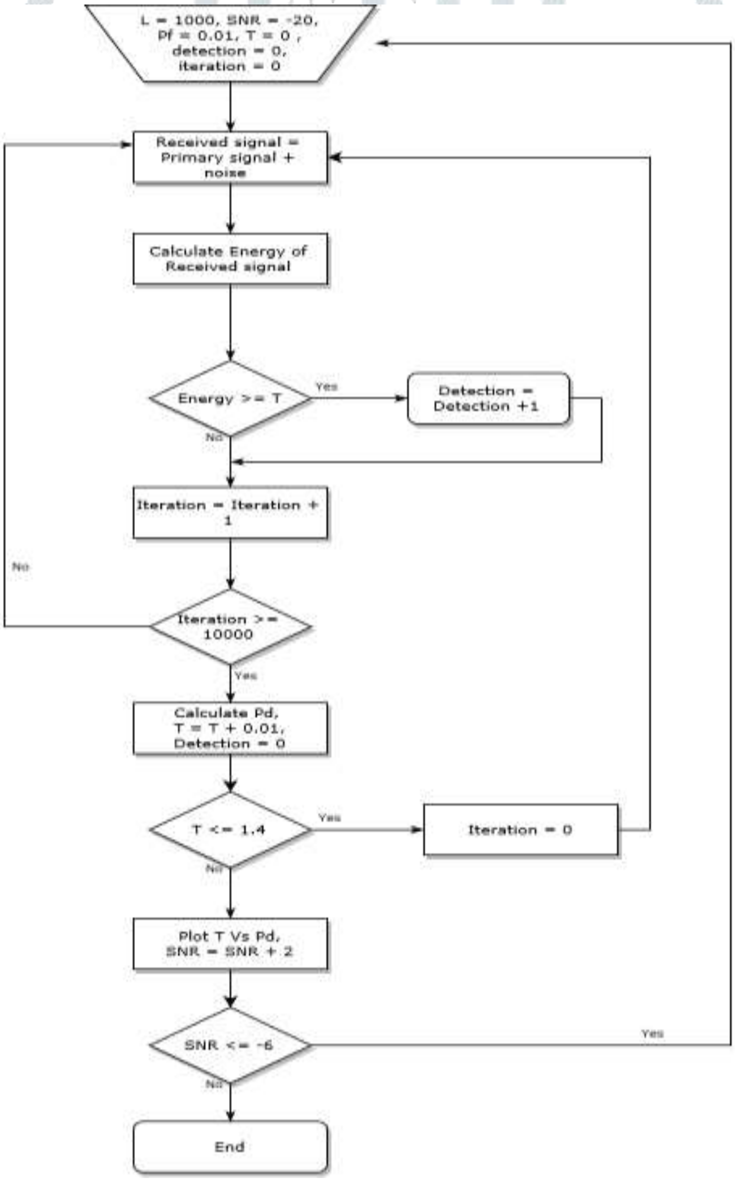

Fig. 2: Flowchart of proposed Analysis

Fig. 2 shows the flowchart of proposed analysis. In proposed analysis T (Threshold) Vs Pd (Probability of detection) is plotted by changing T value from 0 to 1.4 in the increment of 0.01 at fixed SNR value. The above procedure is repeated for SNR value from

– 20dB to -6 dB for the fixed value of Pf = 0.01 and L =1000. At last a comparison graph is plotted as shown in Fig. 3 to compare plots of all SNR values.

4. SIMULATIONS & RESULTS

TABLE 1: Pd vs Threshold value for Pf=0.01 and SNR=-6 dB

SNo	Threshold value	Pd (Probability of detection)
1	0.873	1
2	0.883	1
3	0.893	1
4	0.903	1
5	0.913	1
6	0.923	1
7	0.933	1
8	0.943	1
9	0.953	1
10	0.963	1
11	0.973	1
12	0.983	1
13	0.993	1
14	1.003	1
15	1.013	1
16	1.023	1
17	1.033	1
18	1.043	0.999900000000000
19	1.053	1
20	1.063	0.999900000000000
21	1.073	0.999200000000000
22	1.083	0.999500000000000
23	1.093	0.999000000000000
24	1.103	0.997600000000000
25	1.113	0.993300000000000
26	1.123	0.992500000000000

27	1.133	0.984200000000000
28	1.143	0.977000000000000
29	1.153	0.962300000000000
30	1.163	0.945000000000000
31	1.173	0.918400000000000
32	1.183	0.888000000000000
33	1.193	0.849100000000000
34	1.203	0.804100000000000
35	1.213	0.749800000000000
36	1.223	0.683700000000000
37	1.233	0.620600000000000
38	1.243	0.552500000000000
39	1.253	0.475500000000000
40	1.263	0.401400000000000
41	1.273	0.340100000000000

TABLE 2: Pd vs Threshold value for Pf=0.01 and SNR=-8 dB

SNo	Threshold value	Pd (Probability of detection)
1	0.873	1
2	0.883	1
3	0.893	1
4	0.903	1
5	0.913	1
6	0.923	1
7	0.933	1
8	0.943	1
9	0.953	1
10	0.963	1
11	0.973	1
12	0.983	1

13	0.993	0.9999
14	1.003	0.9997
15	1.013	0.9997
16	1.023	0.9992
17	1.033	0.9991
18	1.043	0.9969
19	1.053	0.9932
20	1.063	0.9885
21	1.073	0.9804
22	1.083	0.9675
23	1.093	0.9540
24	1.103	0.9284
25	1.113	0.8958
26	1.123	0.8533
27	1.133	0.8129
28	1.143	0.7494
29	1.153	0.6886
30	1.163	0.6088
31	1.173	0.5311
32	1.183	0.4566
33	1.193	0.3874
34	1.203	0.3065
35	1.213	0.1936
36	1.223	0.1065
37	1.233	0.0773
38	1.243	0.0521
39	1.253	0.0315
40	1.263	0.0247
41	1.273	0.0162

TABLE 3: Pd vs Threshold value for Pf=0.01 and SNR=-10 dB

SNo	Threshold value	Pd (Probability of detection)
1	0.873	1
2	0.883	1
3	0.893	1
4	0.903	1
5	0.913	1
6	0.923	1
7	0.933	0.9999
8	0.943	0.9997
9	0.953	0.9993
10	0.963	0.9987
11	0.973	0.9971
12	0.983	0.9928
13	0.993	0.9883
14	1.003	0.9760
15	1.013	0.9624
16	1.023	0.9408
17	1.033	0.9108
18	1.043	0.8764
19	1.053	0.8259
20	1.063	0.7634
21	1.073	0.6981
22	1.083	0.6333
23	1.093	0.5341
24	1.103	0.4669
25	1.113	0.3818
26	1.123	0.3186
27	1.133	0.2457
28	1.143	0.1896
29	1.153	0.1422

30	1.163	0.0971
31	1.173	0.0722
32	1.183	0.0509
33	1.193	0.0264
34	1.203	0.0179
35	1.213	0.0114
36	1.223	0.0075
37	1.233	0.0040
38	1.243	0.0017
39	1.253	0.0014
40	1.263	0.0008
41	1.273	0.0005

TABLE 4: Pd vs Threshold value for Pf=0.01 and SNR=-12 dB

SNo	Threshold value	Pd (Probability of detection)
1	0.873	1
2	0.883	1
3	0.893	0.9997
4	0.903	0.9995
5	0.913	0.9995
6	0.923	0.9988
7	0.933	0.9978
8	0.943	0.9937
9	0.953	0.9916
10	0.963	0.9859
11	0.973	0.9729
12	0.983	0.9537
13	0.993	0.9290
14	1.003	0.8962
15	1.013	0.8487
16	1.023	0.7957

17	1.033	0.7393
18	1.043	0.6581
19	1.053	0.5813
20	1.063	0.4906
21	1.073	0.4099
22	1.083	0.3266
23	1.093	0.2532
24	1.103	0.1937
25	1.113	0.1413
26	1.123	0.1003
27	1.133	0.0690
28	1.143	0.0484
29	1.153	0.0303
30	1.163	0.0199
31	1.173	0.012
32	1.183	0.0073
33	1.193	0.0037
34	1.203	0.0018
35	1.213	0.0014
36	1.223	0.0006
37	1.233	0.0002
38	1.243	0
39	1.253	0.0002
40	1.263	0
41	1.273	0

TABLE 5: Pd vs Threshold value for Pf=0.01 and SNR=-14 dB

SNo	Threshold value	Pd (Probability of detection)
1	0.873	1
2	0.883	0.9996
3	0.893	0.9996

4	0.903	0.9988
5	0.913	0.9979
6	0.923	0.9954
7	0.933	0.9913
8	0.943	0.9826
9	0.953	0.9739
10	0.963	0.9557
11	0.973	0.9241
12	0.983	0.8871
13	0.993	0.8369
14	1.003	0.7810
15	1.013	0.7153
16	1.023	0.6295
17	1.033	0.5556
18	1.043	0.4673
19	1.053	0.3778
20	1.063	0.3010
21	1.073	0.2403
22	1.083	0.1709
23	1.093	0.1247
24	1.103	0.0910
25	1.113	0.0599
26	1.123	0.0365
27	1.133	0.0214
28	1.143	0.0127
29	1.153	0.0101
30	1.163	0.0054
31	1.173	0.0025
32	1.183	0.0012
33	1.193	0.0004

34	1.203	0.0006
35	1.213	0.0002
36	1.223	0.0002
37	1.233	0
38	1.243	0
39	1.253	0
40	1.263	0
41	1.273	0

TABLE 6: Pd vs Threshold value for Pf=0.01 and SNR=-16 dB

SNo	Threshold value	Pd (Probability of detection)
1	0.873	1
2	0.883	0.9995
3	0.893	0.9989
4	0.903	0.9976
5	0.913	0.9932
6	0.923	0.9903
7	0.933	0.9802
8	0.943	0.9661
9	0.953	0.9453
10	0.963	0.9149
11	0.973	0.8702
12	0.983	0.8235
13	0.993	0.7531
14	1.003	0.6817
15	1.013	0.5880
16	1.023	0.5101
17	1.033	0.4190
18	1.043	0.3400
19	1.053	0.2666
20	1.063	0.1991

21	1.073	0.1392
22	1.083	0.1065
23	1.093	0.0682
24	1.103	0.0479
25	1.113	0.0313
26	1.123	0.0155
27	1.133	0.0118
28	1.143	0.0053
29	1.153	0.0027
30	1.163	0.0014
31	1.173	0.0006
32	1.183	0.0005
33	1.193	0.0004
34	1.203	0
35	1.213	0.0001
36	1.223	0.0001
37	1.233	0
38	1.243	0
39	1.253	0
40	1.263	0
41	1.273	0

TABLE 7: Pd vs Threshold value for Pf=0.01 and SNR=-18 dB

SNo	Threshold value	Pd (Probability of detection)
1	0.873	0.9993
2	0.883	0.9987
3	0.893	0.9955
4	0.903	0.9902
5	0.913	0.9833
6	0.923	0.9674
7	0.933	0.9426

8	0.943	0.9178
9	0.953	0.8763
10	0.963	0.8259
11	0.973	0.7534
12	0.983	0.6756
13	0.993	0.5987
14	1.003	0.5191
15	1.013	0.4178
16	1.023	0.3472
17	1.033	0.2699
18	1.043	0.1999
19	1.053	0.1446
20	1.063	0.1033
21	1.073	0.0668
22	1.083	0.0519
23	1.093	0.0298
24	1.103	0.0169
25	1.113	0.0105
26	1.123	0.0069
27	1.133	0.0037
28	1.143	0.0014
29	1.153	0.0011
30	1.163	0.0007
31	1.173	0.0003
32	1.183	0.0004
33	1.193	0.0002
34	1.203	0
35	1.213	0
36	1.223	0
37	1.233	0

38	1.243	0
39	1.253	0
40	1.263	0
41	1.273	0

TABLE 8: Pd vs Threshold value for Pf=0.01 and SNR=-20 dB

SNo	Threshold value	Pd (Probability of detection)
1	0.873	0.9993
2	0.883	0.9986
3	0.893	0.9960
4	0.903	0.9919
5	0.913	0.9842
6	0.923	0.9714
7	0.933	0.9559
8	0.943	0.9369
9	0.953	0.8990
10	0.963	0.8470
11	0.973	0.7898
12	0.983	0.7174
13	0.993	0.6333
14	1.003	0.5501
15	1.013	0.4639
16	1.023	0.3771
17	1.033	0.3018
18	1.043	0.2231
19	1.053	0.1686
20	1.063	0.1209
21	1.073	0.834
22	1.083	0.0535
23	1.093	0.0318
24	1.103	0.0224

25	1.113	0.0127
26	1.123	0.0076
27	1.133	0.0042
28	1.143	0.0025
29	1.153	0.001
30	1.163	0.0004
31	1.173	0.0002
32	1.183	0
33	1.193	0
34	1.203	0
35	1.213	0
36	1.223	0
37	1.233	0
38	1.243	0
39	1.253	0
40	1.263	0
41	1.273	0

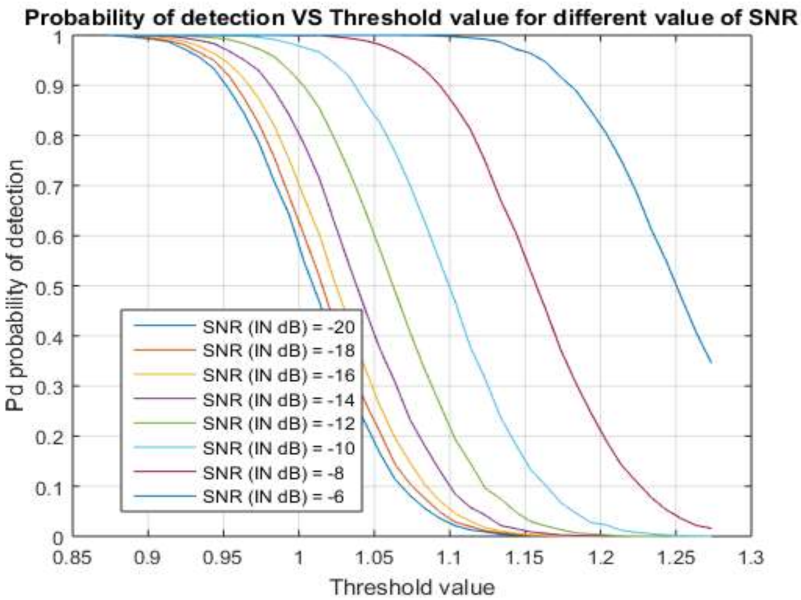

Fig. 3: Pd vs Threshold value for Pf=0.01 and SNR=-20 to -6 dB

Table 1 to 8 contains the data of Probability of detection for different threshold values at probability of false alarm Pf=0.01 and SNR varies from -20 dB to -6 dB. Fig. 3 shows the plot for individual value for comparison.

TABLE 9: SNR vs Threshold value for Pd=0.9

SNo	Threshold value	SNR
1	0.943	-20
2	0.953	-18
3	0.963	-16
4	0.973	-14
5	0.993	-12
6	1.033	-10
7	1.103	-8
8	1.173	-6

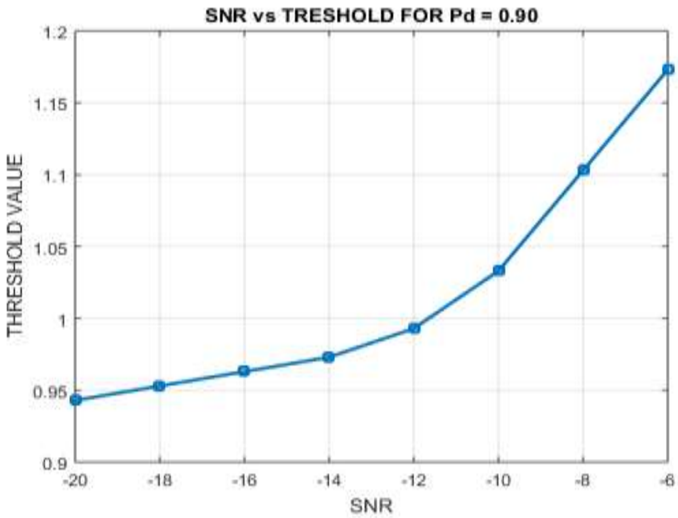

Fig. 4: Plot of SNR vs Threshold value for Pd=0.9

Table 9 shows the data of optimum value of threshold for each SNR (-20dB to -6dB) value decided by the best value probability of detection (considered Pd=0.9). It can be concluded from the fig. 4 that threshold value increases with increase in SNR value as at -20 dB, threshold value is 0.943 and at -6 dB, threshold value is 1.173.

5. CONCLUSION

EBS has less computation; simple to implement as well as it doesn't required prior knowledge of signal. Therefore EBS has been studied in our proposed work so that its efficiency can be increased. In this paper we studied the different threshold values for different SNR values, we take the SNR from -20 to -6 dB. The optimum value of threshold for each SNR (-20dB to -6dB) value decided by the best value probability of detection (considered Pd=0.9). It can be concluded from the results that threshold value increases with increase in SNR value. It means for the system with high SNR value, it is suggested to use high threshold values while for the systems with low SNR value is suggested to use low threshold value. An adaptive system can be created on the basis of this analysis. In that system, firstly signal SNR is estimated and if it is found high then threshold value will automatically be selected high as per table in results and same will be with other values of SNR. In this way, output will always have better probability of detection with this adaptive change in threshold value as compared to a fixed value of threshold.

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