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Implementation of Blind Modulation Detection for Software defined Radio

Patel Harsha Sumanbhai
Guide Name: Mrs.Chandani Maheshwari
Department of Electronics& Communication
Silver Oak Collage of Engineering &Technology,Ahmedabad
Gujarat Technological University,Ahmedabad

Abstract- **Rising development in software Defined Radio(SDR) systems has led to rapid development in Blind Modulation Detection (BMD) techniques. Different order modulations combined with different coding schemes allow sending more bits per symbol, thus achieving higher throughputs and better spectral efficiencies by the use of BMD. A generalized Digital Modulation Identification algorithm for adaptive demodulator has been implemented. The algorithm is verified using Wavelet Transform and histogram computation to identify BPSK QPSK, M-ary PSK, 16-QAM and GMSK signals. The proposed method is implemented using MATLAB Simulink tool and the simulations are also carried out in the same.**

Index Terms- **SDR, BPSK, QPSK, QAM, PSK, GMSK**

I. INTRODUCTION

A Cognitive Radio (CR) is an SDR that additionally senses its environment, tracks changes, and reacts upon its findings. A CR is an autonomous unit in a communications environment that frequently exchanges information with the networks it is able to access as well as with other CRs. From our point of view, a CR is a refined SDR.SDR is thus a collection of hardware and software technologies that enable reconfigurable system architectures forwireless communications. SDR provides an efficient and comparatively inexpensive solution to the problem of building multi-mode, multi-band, multi-functional communications devices that can be enhanced using software upgrades.

Using the SDR with programmable hardware like FPGA the reconfigurable radio can adapt various standards and provide benefits such as multi functionality, compactness, ease of upgrades etc. Thus the problem of incompatibility of general hardware radio for different operations is eliminated.

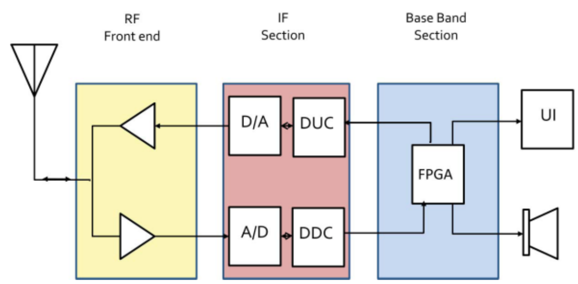

Fig. 1.1: Block Diagram of a SDR

In Fig. 1.1, shows the overall block diagram of SDR. It consists three sections viz. RF Front end section, IF Section and Base Band section. In this paper the part of concern is the third section, that is, the Base Band Section which houses the FPGA chip. The FPGA can be used to implement the Blind Modulation Detection.

BMD involves estimation of any modulation scheme at the receiver generally followed by its demodulation using relevant technique. The receiver does not have any prior knowledge of the modulation scheme the transmitter is using. Based on certain parameters of the received bit stream the modulation scheme is estimated. Adaptive modulation systems improve rate of transmission, and/or bit error rates, by exploiting the channel information that is present at the transmitter. A Simulink model is designed for BMD based on Wavelet transform technique which identifies BPSK and QPSK at very high accuracy. The model can be implemented on a reconfigurable platform like FPGA (Base Band Section) in order to realize the benefits stated above. Thus, Software Defined Radio is the base of this project and the concept is BMD on basis of which the model is designed.

II. COMPARISON OF VARIOUS BMD SCHEMES

Before coming to the conclusion that Wavelet Transform is the most feasible technique to be implemented, following techniques have been studied thoroughly and their advantages and disadvantages have been compared.

- Feedback based technique
- Mean Square Error based technique
- Least Mean Square Difference based technique
- Wavelet transform based technique

[A]. Feedback Based Technique

In the feedback based technique a single software defined circuit for BPSK, QPSK, 16QAM, and 64QAM or even future coming techniques based on SDR is used. When the basic system is successfully built and tested, a cognitive engine (CE) must develop to automatically direct the SDR to load and execute the appropriate profile based on the response obtained through the feedback. The CE refers to predefined polices, while continuously sensing the channel situation. Then, it performs its logic to pick up the suitable configuration to execute it in the SDR system. In the model, the receiver evaluates received packets (i.e. SNR or BER) to estimate the Channel Quality Indictor (CQI) module, then feedback the transmitter to reconfigure itself for the next packet to be sent. It is diagrammatically explained in the figure shown below.

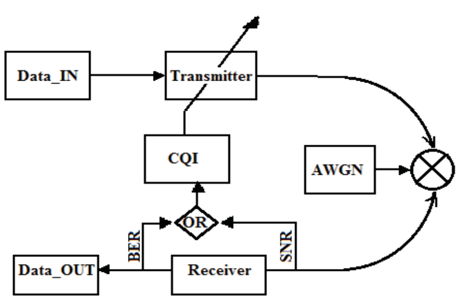

Fig. 2.1: Adaptive System [1]

For this technique, the advantage is that the scheme is simple and easy to implement and variety of modulation schemes can be used, but the disadvantages are far higher. One requires accurate channel estimation at the receiver and reliable feedback path through which receiver reports channel state information. But this cannot be achieved practically because the mobile channel is not constant but time varying; moreover it's not practical for the receiver to send channel state information to the transmitter via feedback. Hence this technique is ruled out for practical implementation.

[B]. Mean Square Error Based Technique

The second technique is based on Mean Square Error. This method recognizes the modulation scheme utilizing Mean Square Error decision rule to recognize and differentiate M-ary PSK modulated signals in both AWGN and Rayleigh fading channels [2]. First of all different PSK schemes are simulated after which Mean Square Error is calculated on whose basis appropriate Mean Square Error Difference Threshold is used to finally differentiate M-ary PSK schemes. The accuracy of this scheme is reported to be very high. The received band pass signal in the kth signalling interval may be expressed as as

$$\mathbf{r(t, k) = S_m(t, k) + n(t, k)}$$
$$\mathbf{kTs < t < (k + 1)\ Ts}$$

where, Ts is symbol duration, $S_m(t)$ is the message waveform corresponding to the M-PSK symbol S_m, m=1,2,3,…M.

Assuming perfect carrier synchronization and timing recovery, we employ I-Q demodulation to get

$$\mathbf{r(k) = r_I(k), r_Q(k)]}$$
$$\mathbf{=[S_{mI} + n_I(k), S_{mQ} + n_Q(k)]}$$

These sequences of N signal samples are collected at demodulator output. Then it is checked how closely they match with the prototype ideal constellations. This degree of closeness is measured in terms of Mean Square Error power defined as:

$$MSE(M) = \left(\frac{1}{N}\right)\sum_{k=1}^{N} D_{k,M}^2 , \qquad M=2^q,\ q=1, 2\ldots$$
$$\text{Where, } D_{k,M} = \min\{|r(k)-s_m|\},\ m=1,2,..M$$
$$= \min\{|d_{k,M}|\}$$

Now, Lower-order PSK constellations are sub-sets of the higher order PSK schemes; therefore, when lower-order PSK symbols are transmitted, the received signal sequence r(k) will find a match not only with the corresponding constellation, it will also match with the higher-order constellation (with more or less the same degree of accuracy).

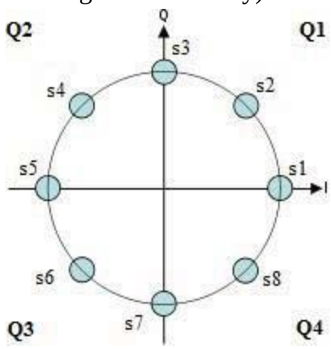

Fig. 2.2: Constellation Diagram [2]

Case I: BPSK is transmitted Here, the received signal points will be scattered around the symbols S2 and S6 shown in Fig 2.2.

a) Majority of the points will be confined in the first and the third quadrants (Q1 and Q3) especially at high SNR. The contribution of these points towards MSE power will be the same in both BPSK and QPSK, i.e. MSE(2) = MSE(4), where r(k) ϵ Q1 U Q3. However, this same set of points will result in a slightly lower MSE when matched to 8-PSK as some of these points will have closer match to 8-PSK symbols s1 or s3 and s5 or s7. Thus, MSE(8) < MSE(2), MSE(4), where r(k) ϵ Q1 U Q3.
b) For a small fraction of the received points which lie in Q2 and Q4, their 'match' with the BPSK prototype will be proper (the nearest symbols being s2 and s6) as compared to QPSK prototype (nearest symbols S4 and s8) and 8-PSK (nearest symbols s3, s4, s5 and s7, s8, s1). Thus, MSE(8) < MSE(4) < MSE(2), where r(k) ϵ Q2 U Q4.

Finally, the observation of this case can be drawn as follows:

I. When BPSK is transmitted, at any SNR, we shall find MSE(8) < MSE(4) < MSE(2)
II. At high SNR, the differences in MSE are negligibly small; only at low SNR, the differences are distinguishable.

Case II: QPSK is transmitted Now, r(k)s are scattered around the four symbols s2, s4, s6, s8 It follows that r(k) will match well with QPSK and 8-PSK prototypes while there will be large mismatch with BPSK prototype. Thus, MSE(2) > MSE(4) and MSE(8) at all SNR, MSE(8) ~ MSE(4) at high SNR and MSE(8) < MSE(4) at low SNR.

Case III: 8-PSK is transmitted Following Similar reasoning one can conclude:
MSE(2) >MSE(4) > MSE(8) at all SNR.

Algorithm

Step 1:

Compute:

$D_{k,2} = |r(k)-S_m|$
  m=2 if r(k) ϵ Q1
  m=6 if r(k) ϵ Q3

$D_{k,2} = \min\{|r(k)-S_m|\}$
  m=2,6 if r(k) ϵ Q2 or Q4

$D_{k,4} = |r(k)-S_m|$
  m=2 if r(k) ϵ Q1
  m=4 if r(k) ϵ Q2
  m=6 if r(k) ϵ Q3
  m=8 if r(k) ϵ Q4

Dk,8 = $\min\{|r(k)-S_m|\}$
  m=1,2,3 if r(k) ϵ Q1
  m=3,4,5 if r(k) ϵ Q2
  m=5,6,7 if r(k) ϵ Q3
  m=7,8,1 if r(k) ϵ Q4

Step 2: Compute:

$$\mathrm{MSE(M)} = \left(\frac{1}{N}\right)\sum_{k=1}^{N} D^2{}_{k.M}, M = 2,4,8$$

Step3: Compute Mean Square Error Difference (MSED):

$MSED_{2-4}$=MSE(2)-MSE(4)
$MSED_{4-8}$=MSE(4)-MSE(8)

Step 4: Decision Rule

If $MSED_{2-4} < \lambda_{2-4}$, BPSK is transmitted.
If $MSED_{2-4} > \lambda_{2-4}$, then check if $MSED_{4-8} < \lambda_{4-8}$, QPSK is transmitted.
If $MSED_{4-8} < \lambda_{4-8}$, then 8-PSK is transmitted.

In order to determine the thresholds λ_{2-4} and λ_{4-8}, distribution of MSED and frequency of its occurrence which is approximately Gaussian for both AWGN and Fading channels is plotted and thus the threshold value as the sum of the mean and standard deviation is set as $\lambda_{2-4}=\sigma_{2-4}+\mu_{2-4}$. This is shown in the following figure of distribution of $MSED_{2-4}$ at SNR=10dB in an AWGN channel.

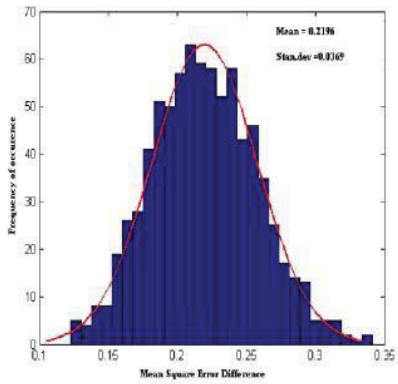

Fig.2.3: Frequency of Distribution v/s Mean Square Error Difference curve [2]

Similarly such distribution can be found out for MSED4-8, and thus one can find the corresponding threshold value. With these thresholds, the recognition capability is reported to be quite accurate for both AWGN and fading channels. For this technique based on the mean square error, the recognition accuracy is predicted to be quite high for even lower SNR values. But the main disadvantage is that the technique can distinguish only between M-PSK schemes and the phase of the transmitted signal needs to be known. Hence this technique is ruled out too.

[C]. Least Mean Square Error Difference Based Technique

The third technique studied is based on least mean square error difference in amplitude, phase and frequency. This procedure has an ability to adapt to mostly all possible schemes dynamically and the ability to recognize even continuous phase modulation (CPM) signals like Gaussian Minimum Shift Keying (GMSK) too. The central frequency *fc* and the bandwidth *B* of a significant part of the received signal is estimated from a digitized and down-converted signal.

Thus on the basis of advantages and disadvantages it is seen that all the techniques discussed above have some disadvantages, which prove to be a fetter to be implemented on a reconfigurable platform like FPGA. The technique based on Wavelet Transform which has been discussed in next chapter wins over the above techniques and hence its model is developed in this project.

[D]. Wavelet transform Based Technique

This technique of which a model has been designed for BMD in this project is based on Wavelet Transform. Before getting further into this technique it is essential to know about Wavelet Transform.

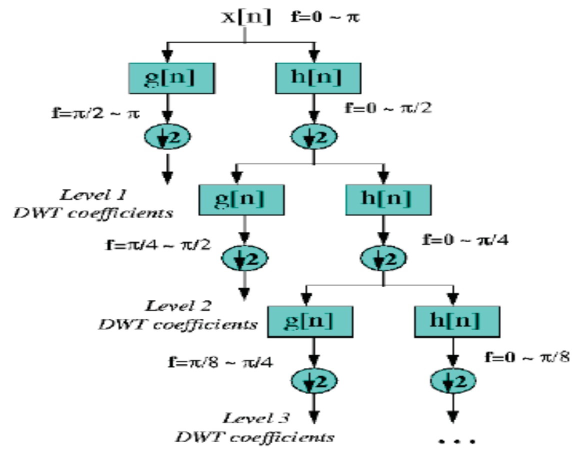

Fig. 2.4: Discrete Wavelet Transform [7]

Explanation of the Technique

The model of the technique designed is based Wavelet Transform. The implementation procedure for the proposed BMD algorithm is shown in the figure below. The received modulated signal with AWGN is wavelet transformed and the detailed coefficients are processed to classify QPSK signals.

The histogram is computed for the detailed wavelet coefficients and the number of peaks is recorded. If the number of peak is 1 then the identifier identifies that the received signal is QPSK The QPSK demodulation is done by means of coherent in-phase and quadrature phase demodulation. The output of the demodulator is passed through the decision circuits and output of the decision circuits is multiplexed to get original message signals.

III.PROPOSED ALGORITHM

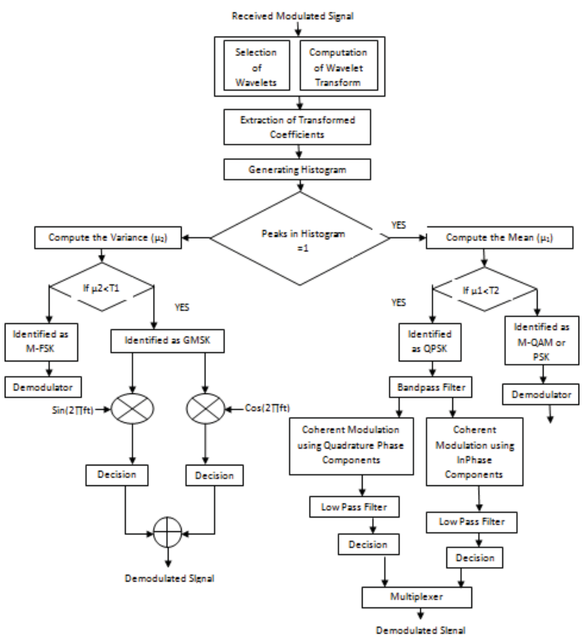

Fig. 3.1: Algorithm for Wavelet Transform based Technique.

IV.SIMULINK MODEL

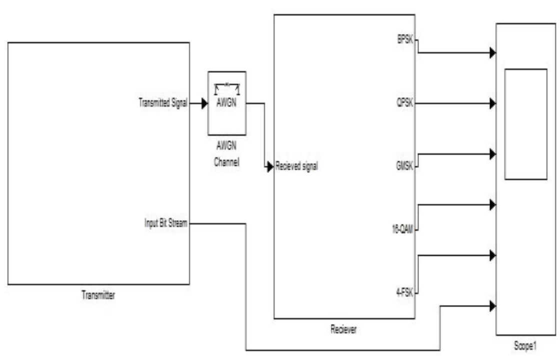

fig. 4.1: Overall Simulink Model

As shown in the figure above, this is the overall system which consists of the following parts:

- Transmitter
- Receiver
- AWGN Channel
- Scope

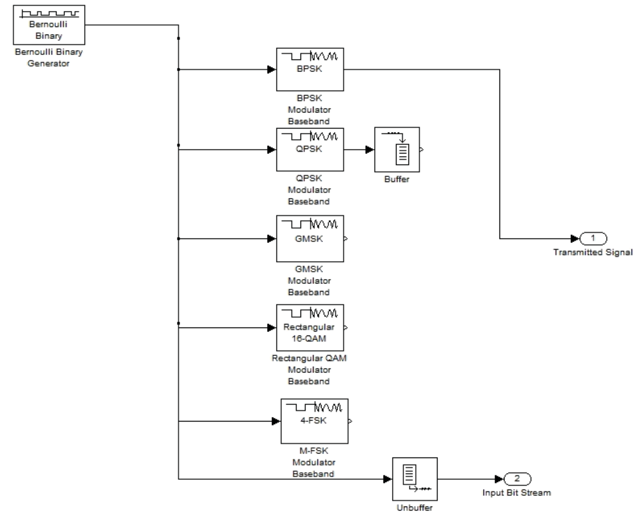

Fig.4.2: Transmitter in the Simulink Model

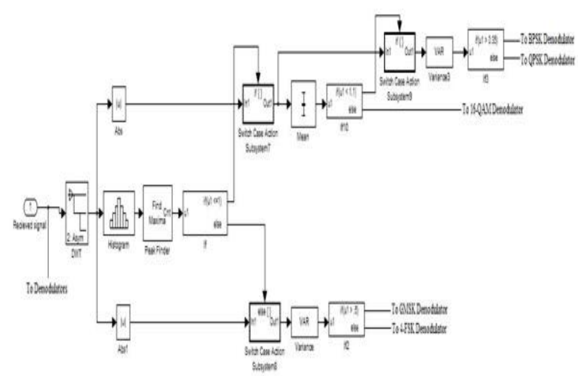

Fig.4.3: Receiver in the Simulink Model

The model is step by step practical implementation of the algorithm explained. As the AWGN noise infested signal is received at the receiver it passes through the system and is redirected to the concerned demodulator following the algorithm, i.e. based on the parameters of the signal, the system selects the appropriate demodulator and the signal is sent through that path to the demodulator.

Computation of Threshold

The calculation of the thresholds is done with the help of the codes (Appendix 1). However it is known that the modulated signals will pass through the channel with Additive White Gaussian Noise (AWGN). To add practicality to the threshold values, the effect of noise needs to be added to the model. Only then can a tentative practical value be obtained for differentiating any two modulation schemes. A new Simulink model was prepared. This model has the same transmitter and the channel as the main model. Instead of a receiver system, here the mean and variance has been calculated for all the schemes further used in mathematical calculations. The innovation of adding the effect of SNR and AWGN to the modulated signal has been applied here. The formula for calculation the threshold for distinction between QPSK and BPSK, GMSK and 4- FSK, and QPSK and 16-QAM respectively is given as follows:

- $T_1 = \dfrac{\mu_{1,QPSK}\,\mu_{2,BPSK} + \mu_{1,BPSK}\,\mu_{2,QPSK}}{\mu_{2,QPSK} + \mu_{2,BPSK}}$
- $T_2 = \dfrac{\mu_{1,GMSK}\,\mu_{2,M\text{-}aryFSK} + \mu_{1,M\text{-}aryFSK}\,\mu_{2,GMSK}}{\mu_{2,GMSK} + \mu_{2,M\text{-}aryFSK}}$
- $T_3 = \dfrac{\mu_{1,QPSK}\,\mu_{2,QAM} + \mu_{1,QAM}\,\mu_{2,QPSK}}{\mu_{2,QPSK} + \mu_{2,QAM}}$

Here, T1, T2, T3 are the respective threshold values. μ1 and μ2 are the mean and variances of the subscripts mentioned.

As it is seen from the fig, the information is generated at the Bernoulli binary generator. The bit stream is then passed through all the transmitters. The modulated bit stream is then simulated through the AWGN channel. Then the modulated bit streams undergo discrete wavelength transform. The coefficients generated are then passed into mean and variance blocks after their absolute values have been calculated. Now the values at each mean and variance is multiplied and divided according to its formula. This finally gives the required value of threshold which becomes the starting point for separating the modulation schemes with an average error of 23%. This is a small error which is expected between practical and theoretical values.

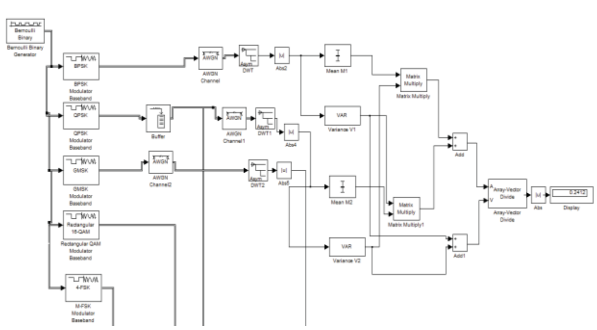

Fig. 4.4: Model for Separating BPSK and QPSK

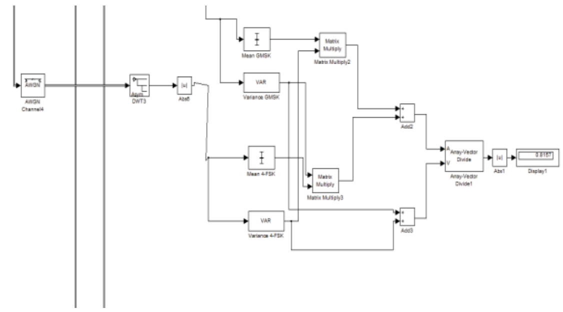

Fig. 4.5: Model for Separating GMSK and 4-FSK

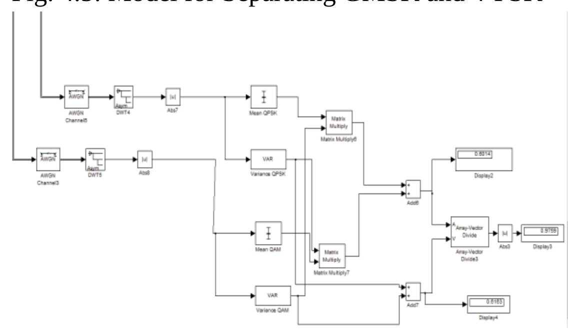

Fig. 4.6: Model for Separating QPSK and 16-QAM

V. RESULTS

The proof of concept is presented using the MATLAB tool. MATLAB provides a powerful tool like Simulink, which allows the block level implementation of various systems. The discussed systems were implemented using MATLAB Simulink and the transmitted and received signal are observed and compare for the correctness. The Simulink model has been run successfully and it is observed that for each Modulation Scheme 100% accuracy is obtained. This means that the model is successful in calculating the DWT and the peaks of the histogram to direct the received signal to the appropriate path for demodulation. This is shown as follows for every scheme one by one.

BPSK

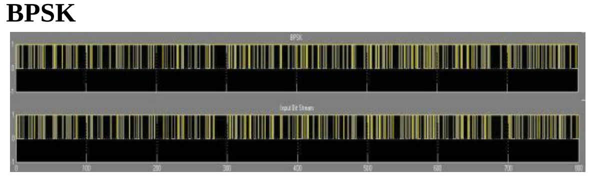

Fig. 5.1: Result for BPSK Modulation

Here the signal at the bottom is the Input Bernoulli random bit stream while the one on the top is the BPSK signal that is received after passing through the signal and after being demodulated. As stated above the accuracy here is 100%.

QPSK

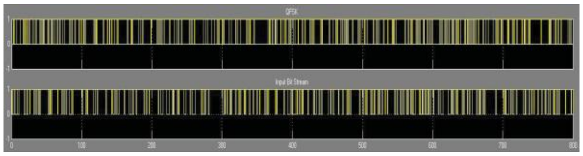

Fig. 5.2: Result for QPSK Modulation

Here too it is seen that the signal are matching with 100% accuracy of the received signal.

The delay may have arose because GMSK modulation is tad more complicated and the signal has to pass through the system.

16-QAM

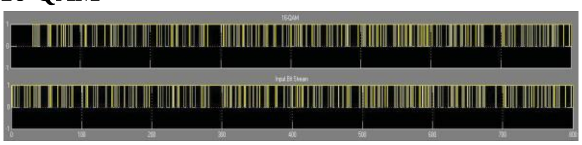

Fig. 5.3: Result for 16-QAM Modulation

Like GMSK, here too after some delay the signals are matching totally.

4-FSK

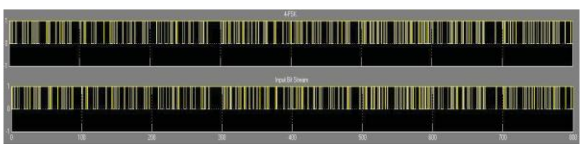

Fig. 5.4: Result for 4-FSK Modulation

As stated, here too the accuracy of 100% is successfully achieved.

Thus the model designed can be used practically by implementing on reconfigurable platforms like FPGA and it will run successfully at SNR of 12 dB.

VI. CONCLUSION

The DWT technique for blind modulation detection has been studied thoroughly and its advantages and disadvantages have been compared with other techniques to come to the conclusion that it is the best technique to be implemented. Thus it is observed that of all the techniques discussed, the technique based on Wavelet Transform is most feasible and practical to be implemented with least disadvantages that are a fetter in other techniques. Also this technique provides highest accuracy of 100% which is not possible in other techniques.

REFERENCES

[1] Sami H. O. Salih, Mamoun M. A. Suliman, “Implementation of Adaptive Modulation and Coding Techniques using Matlab” Sudan University of Science and Technology, 53rd International Symposium ELMAR-2011, 14-16 September 2011, Zadar, Croatia.

[2] M.VastramNaik, A.Mahata, R.Bhattacharjee and H.B.Nemade, "An Automatic Blind Recognition Algorithm for MPSK Signals Based on MSE Criterion," International Conference on E-Bussiness and Telicommunicalion, Networks, ICETE '05, UK, 2005.

[3] Ferdinand Liedtke, “Adaptive procedure for automatic modulation recognition”, Journal of Telecommunications and Information Technology.

[4] P.Prakasam and M.Madheswaran, “Reconfigurable Automatic Modulation Identification Hardware Module for Software Defined Radio Receivers”, International Journal of Computer Theory and Engineering, Vol. 1, No. 5, December, 2009.

[5] P. Prakasam and M. Madheswaran, “Automatic Modulation Identification of QPSK and GMSK using Wavelet Transform for Adaptive Demodulator in SDR” IEEE - ICSCN 2007, MIT Campus, Anna University, Chennai, India. Feb. 22-24, 2007. pp.507-511.

[6] P. Prakasam and M. Madheswaran, “Modulation Identification Algorithm for Adaptive Demodulator in Software Defined Radios Using Wavelet Transform”, International Journal of Information and Communication Engineering 5:1 2009.

[7] O. A. Dobre and S. Rajan and R. Inkol, “A Novel Algorithm for Blind Recognition of M-ary Frequency Shift Keying Modulation”, IEEE WCNC proceedings, 2007

[8] Kam-Tim Woo and Chi-WahKok , “Clustering based distribution fitting algorithm for Automatic Modulation Recognition”,12th IEEE Symposium on Computers and Communications, 2007

[9] The Wavelet Tutorial by RobiPolikar.