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Machine Learning Based Identification of Digitally Modulated Signals

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ABSTRACT
The automatic identification of the modulation type of a signal at the receiver is a major task of an intelligent receiver, such as software defined radio (SDR), which is used in different communication systems. With no knowledge of the transmitted data, recognition of the modulation type is a difficult task. A communication system, in which receiver is designed based on Machine learning is trained to detect the message using statistical parameters. In this work, machine learning algorithm is developed for identifying 6 different modulated signal types at the receiving end. MATLAB tool is used to generate different modulated signals. Identification of modulation type is done by analyzing different statistical features such as normalized PSD, kurtosis and sum-fft which are calculated using the sampled version of received signal. The algorithm is tested for different frequency and amplitude signals at the receiving end and results are tested for correctness.

I. Introduction

Digital communication has evolved to become major way of distance communication today. Statistical analysis and machine learning have taken very important role in digital communication. Statistical analysis is a science of collecting and exploring large amounts of data in order to discover essential patterns and trends in the data. A modulation classification algorithm using statistical pattern recognition uses statistical moments of both the modulated signal and the signal spectrum as the modulation identifying parameters. The basis for the classification routine is a set of formulated probability distributions which were developed by statistically analyzing a large set of numerically simulated signals. Development of automatic modulation recognition system is receiving a great interest over the past two decades, because of increased demand for avoiding underutilization of allotted spectrum as significant portion of the licensed spectrum is not effectively utilized.

Among these, most of the papers deal with Automatic Modulation Recognition (AMR). Paper [1, 2] presents methods for the automatic recognition of digital modulations without a priori knowledge of the signal parameters. Paper [3] presents a method based on support vector machines (SVMs) for recognizing digital modulation signals in the presence of additive white Gaussian noise. Automatic classification of analog and digital modulation signals is proposed in [5] which use autoregressive spectrum modeling. The authors of paper [6] introduce a new AMR method based on time-domain and spectral features of the received signal. In paper [7], authors include a variety of modulation types for recognition, e.g. QAM16, V29, V32, QAM64 through the addition of a newly proposed statistical feature set. In papers [8,9], authors have evaluated problems related to automatic recognition of digital modulation signals by using maximum likelihood algorithm. Paper [4] considers Multiple-Input-Multiple-Output (MIMO) detection using deep neural networks.

Work in this paper considers only 3 statistical parameters to develop an algorithm which differentiates different modulation schemes at the receiving end. Part II of this paper deals with the statistical parameters used in this work, Part III describes algorithm development by analyzing the statistical values for different modulation system and part IV gives results and conclusion.

II. Statistical Parameters

A modulation classification algorithm using statistical pattern recognition techniques has been developed in this work. Pattern recognition (PR) method here employs algorithm designed on the basis of statistical features. This algorithm uses minimum number of features. Feature extraction is a process, where an initial set of raw variables is reduced to more manageable features for processing, which describes accurately and completely the original data set.

Pattern recognition used in this work is based on 3 important features γ_{max}, kurtosis and sum_fft.

Normalized Power Spectral Density $\gamma_{max:}$

It is the primary feature parameter used which gives the peak value of the PSD(*Power Spectral Density*) of the normalized data and further centered instantaneous amplitude of the approached signal segment.

$$\gamma_{max} = \frac{\max |DFT(a(i))|^2}{N} \tag{1}$$

In the above equation N is the number of samples per block of received data, a(i) represent input samples. γ_{max} is constant for PSK and FSK techniques as they are constant envelope modulations while it varies with ASK where amplitude varies with message.[1]

Kurtosis:

Kurtosis is the next feature parameter used in the algorithm. It is mathematically defined as.

$$\text{kurtosis} = \frac{E\{a^4(i)\}}{E\{a^4(i)\}^2} \tag{2}$$

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The shape of the tails of the distribution on the far left and the far right is given by Kurtosis. Kurtosis is the measure of the thickness or heaviness of the tails of a distribution. As M value varies, PSK samples will have different kurtosis values.

Sum_fft:

Sum_fft is third feature in this algorithm which is used to distinguish between BFSK and 4-FSK. It is the net value of the frequency components of the modulated signal. This count is more for 4-FSK signal as compared to BFSK signals, since it has more peaks because of 4 different frequencies rather than 2 in case of BFSK.

III. Algorithm development

In order to compute the statistical parameters, the samples of modulated signals are considered. Development of algorithm is done based on these parameters.

- Take samples of the received modulated signal at sampling rate greater than Nyquist rate.
- Compute $\gamma_{max,}$ Kurtosis, sum-fft parameters with these sample values.
- Repeat the calculations for different frequencies and amplitude of the modulated signal and compare the results to develop algorithm.
- It is found that γ_{max} is always greater for ASK compared to PSK and FSK as shown in fig1(a) so that we can differentiate between ASK and PSK, FSK.
- By analysing the values of kurtosis, it is evident that there is difference between BASK and 4ASK, so BASK and 4ASK can be differentiated by computing the value kurtosis, always the value of kurtosis is greater for BASK than 4ASK as shown in fig1 (b).
- As frequency components in FSK will be more than PSK, by taking the FFT of input signal one can find the difference between FSK and PSK i.e sum_fft is greater for BFSK compared to BPSK, as shown in fig1(c)
- Sum_fft is also useful to differentiate between the BFSK and 4FSK (fig1(d))
- For the differentiating PSK signals, γ_{max} is considered, because the PSD of the QPSK will be more compared to BPSK.(fig1(e))

Fig(1) shows variation of 3 statistical parameters γ_{max}, kurtosis, sum_fft with respect to change in frequency and amplitude of the modulated signals. It is observed from the plots in fig(1) that the difference in the values of γ_{max}, kurtosis, sum_fft is maintained even if carrier frequency of modulated signal or amplitude of modulated signal varies.

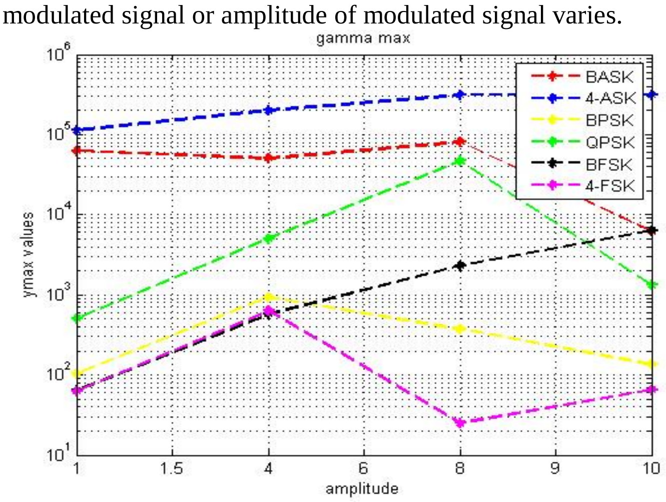

Figure 1(a)

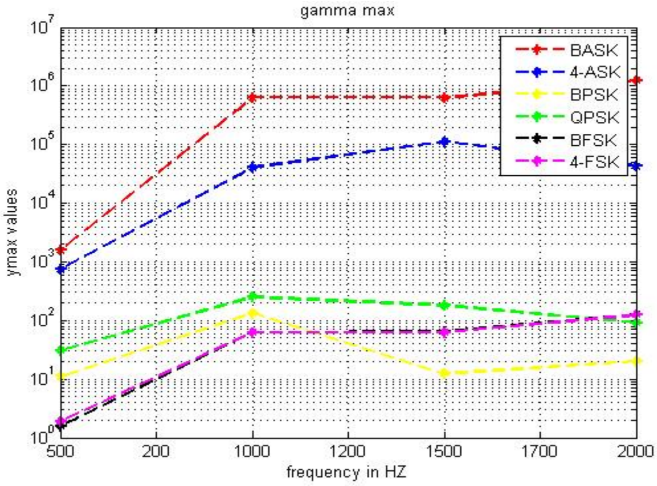

Figure 1(b)

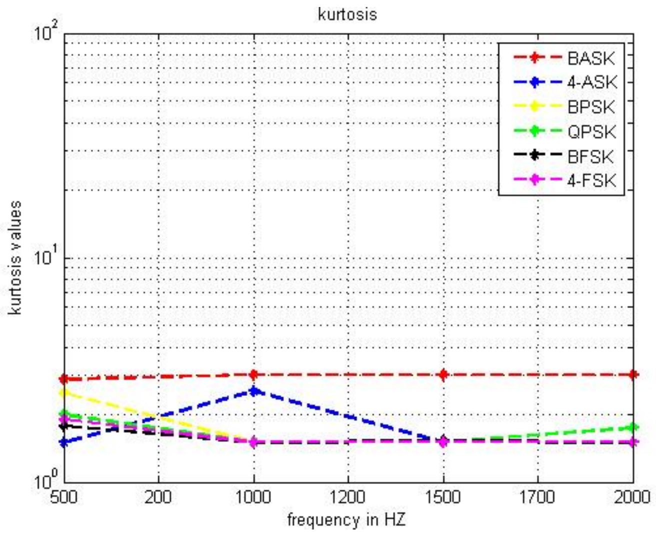

Figure 1(c)

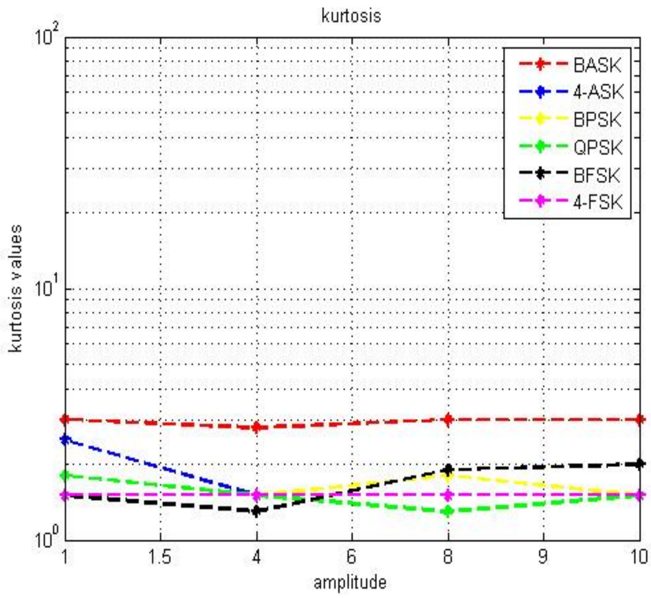

Figure 1(d)

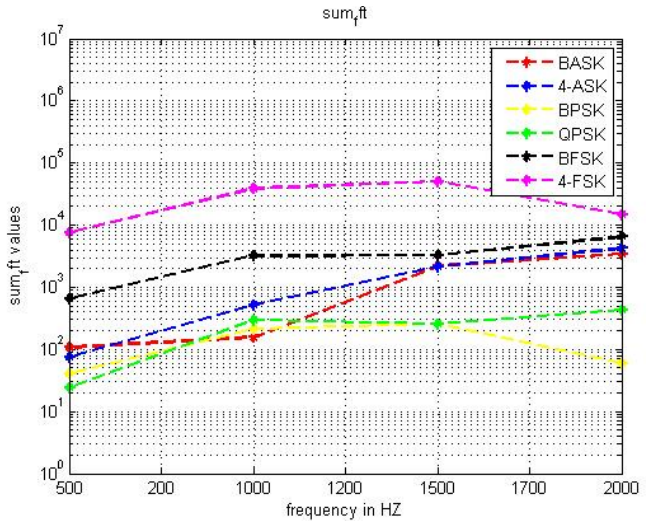

Figure 1(e)

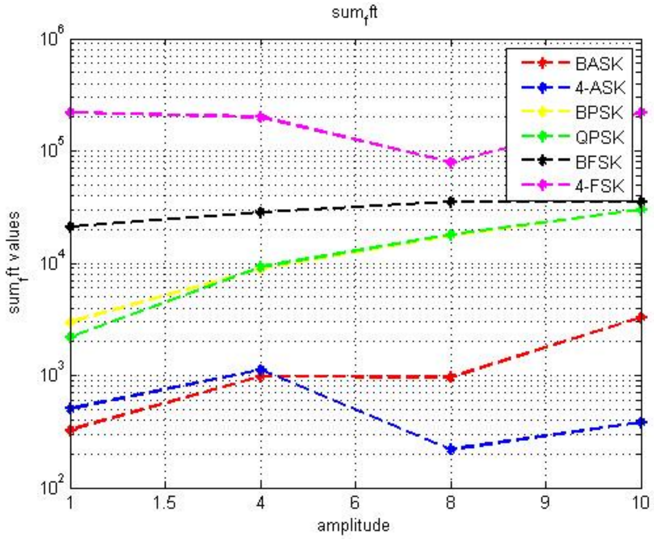

Figure 1(f)

Figure 1.Variation in 3 features (γ_{max}, kurtosis and sum_fft with frequency and amplitude.

In fig(1) shows that γ_{max} is always greater for BASK and 4ASK than other 4 modulated signals for different frequency and different amplitude, so we can fix the threshold to differentiate between BASK, 4ASK and other signals. By analysing the value of kurtosis we can fix the value between BASK and 4ASK, and the value of kurtosis is always greater for BASK than 4ASK.the 3rd parameter sum_fft will differentiate between PSK and FSK signals, the frequency component will be more in FSK signals. And also the sum_fft will differentiate between BFSK and 4FSK,sum_fft will always greater for 4FSK.finally to differentiate between BPSK and QPSK again the γ_{max} is used because the PSD of the QPSK will be more compare to BFSK.

Based on the value of (γ_{max}, kurtosis , sum_fft), for the received signal frequency and amplitude, threshold values (TH1, TH2,TH3,TH4, TH5) for the identification of the different modulated signals are fixed and algorithm is developed. Flow chart for the algorithm is given in fig(2).

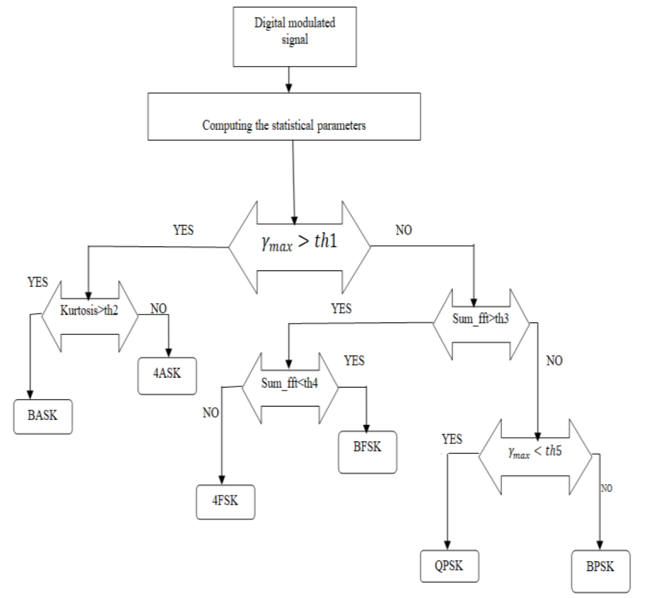

Figure 2. Flow chart to identify modulation from signal's statistics

Simulation results

MATLAB program is written to generate randomly one of the modulated signals which is considered as input to the developed modulation identification algorithm. The samples are taken for the randomly received modulated signal and are given as input to the developed algorithm. Results prove that the type of modulation is identified correctly by the algorithm. MATLAB command window showing correct identification of modulation type is shown in fig(3)

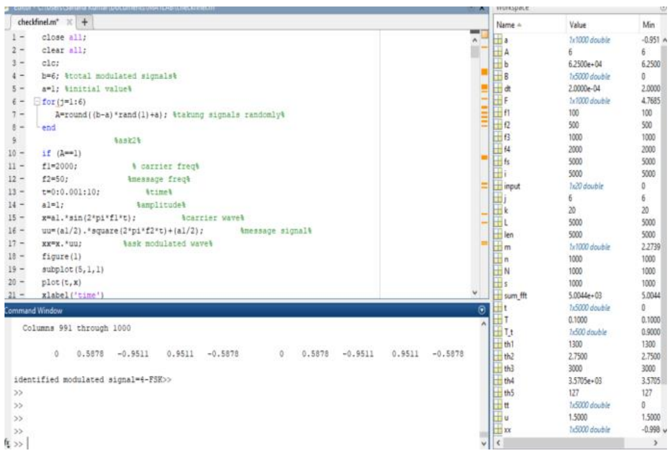

Figure 3. MATLAB command window showing correct identification of modulation type.

IV. Conclusions

Machine learning algorithm to identify different modulated signals using statistical parameters $\gamma_{max,}$ Kurtosis, sum-fft is developed in this paper. Input considered for the calculation of statistical parameters is sampled values of modulated signal. Irrespective of modulated signal frequency and amplitude, the algorithm is able to distinguish between different modulated signals in ideal conditions. Real time scenario where in noise added with modulated signal as input to the algorithm is the future work to be carried out.

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