Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

6th International Conference
on Electrical Engineering
ICEENG 2008

Implementation of digital modulation identification on signal processing platform for software defined radio

By

Ahmed M. Bakhraiba * Sabira Khatun * Nor Kamaria Noordin *
Alyani Ismail* Borhanuddin Mohd Ali*

Abstract:

Software Defined Radio (SDR) has been used by many military and commercial communication applications. The need to identify the digital modulation type of an incoming radio signal is important in order to design an intelligent system that can be used for different applications. This paper describes an approach to extract the transient characteristics of the digital modulated signal using the wavelet transform technique, allowing a simple identification process. A method for identify the modulated signal scheme from the wavelet transform is described, and the performance of the identifier is investigated through simulation for different signal to noise ratio (SNR) values, showed that the system identification performance is improved more than 95% when SNR more than 9dB for all the proposed modulated signal in the system.

Keywords:

Adaptive detection, SDR and wavelet transform

---

* Department of Communication and Computer system Engineering, Faculty of Engineering, University Putra Malaysia (UPM)

1. Introduction:

Lots of effort have been given now a days to reduce hardware and software development cost. Many of today's military and commercial communication systems use software defined radio (SDR) technology to create various different hardware combinations in terms of software control.
The term software defined radio was coined in 1990s to overcome these problems. A software defined radio is a communications device whose functionality is defined in software. Defining the radio behavior in software removes the need for hardware alterations during a technology upgrade.
Digital modulation schemes such as amplitude shift keying (ASK), frequency shift keying (FSK) and binary phase shift keying (BPSK) are commonly used in modern communication systems, in commercial and military application. There is a need to identify digital modulation types of an incoming signal [1]. Many of today's applications and systems use automatic system recognition for digital modulation, e.g., civilian applications such as signal conformation, interference identification, spectrum management and traffic management system; and military application such as: electronic warfare, surveillance, threat detection and analysis, warning and target acquisition and jamming.
Digital modulation waveform is a cyclostationary signal that contains transit in amplitude, frequency and phase. The wavelet transform (WT) is quite suitable for extracting transient information, beside that it is capable to be computed using fast algorithm and hence allowing identification in real time [2]. To extract the features of the signal there are two ways: the first one called multi resolution analysis, decompose the signal at different level, and the other way is to look for the local maximum of the magnitude by continuous wavelet transform (CWT) [3].
Many researches have been done using wavelet transform techniques. Lin and Kuo [4] applied morlet Wavelet to detect the phase change, and used the likehood function based on the total number of detected phase change as a feature to classify M-ary PSK signal. Ho and Chan [5] on the other hand proposed a method to identify PSK and FSK signal using the Haar WT (HWT) without the need of any communication parameter of a modulated signal. Liedt Ke [6] applied amplitude and frequency variances to differentiate ASK, FSK and PSK signal.
The modulation identification plays an important role in signal verification and interference identification, since the SDR systems has the ability to convert hardware functions to software realization, whereas SDR technique has been widely used to design an adaptive system to detect the modulation type and tune between different modulation schemes.
This paper propose the use of wavelet transform for ASK, FSK and BPSK digital

modulation based on the principle that the ASK modulation depend on the amplitude changes, where as the FSK depend on the frequency change, and the BPSK modulation changes in the phase, hence by compute the variance of the HWT, can distinguished all of them by the combination the continuous wavelet transform and the Haar family.

The paper is organized as follows. The method to identify digital modulation using HWT is presented in next section, followed by the simulation results, and finally the conclusion.

2. Discrimination of the digital modulation by wavelet:

The wavelet transform has the ability to extract the transient information of different signals detected at the front end of the receiver. It uses a simple identification process and algorithm that take place to discriminate between different schemes.

The continuous wavelet transform (CWT) is defined as the sum of the signal multiplied by scaled and translation versions of the wavelet function Ψ over time. This process produces wavelet coefficients that are functions of scale and position; hence Any discussion of wavelets begins with Haar wavelet, the first and simplest. Haar wavelet is discontinuous, and resembles a step function. It represents the same wavelet as Daubechies db1.

In the SDR receiver system, a common hardware front end may be used. Signal from the antenna will be amplified; filtered if required and digitized using an analog to digital converter (ADC). Then the digital signal can be processed by a general purpose processor or dedicated DSP processor in terms of software [7]. The modulation detection is an intermediate step between the signal detection and signal demodulation.

A received waveform r(t) is described as r(t) = s(t) + n(t) where n(t) is the complex white Gaussian noise , the signal s(t) can be represented in complex form as :

$$S(t) = \overline{S}(t)e^{j(w_c t+\theta_c)} \quad (1)$$

As ASK, FSK and BPSK are considered to be identified by the system algorithm; hence ideal signals are generated as reference signal in order to match with the unknown modulated signal. The ideal signal for the ASK, FSK and BPSK are as follows also shown in Figure 1:

$$\overline{s}_{ASK}(t) = aA\cos(\omega_0 t + \varphi) \quad (2)$$

$$\overline{s}_{FSK}(t) = \sqrt{s}\sum_{i=1}^{N} e^{j(w_i t+\theta_i)}u_t(t-iT) \quad (3)$$

$$\overline{s}_{PSK}(t) = \sqrt{s}\sum_{i=1}^{N} e^{j\varphi_i}u_t(t-iT) \quad (4)$$

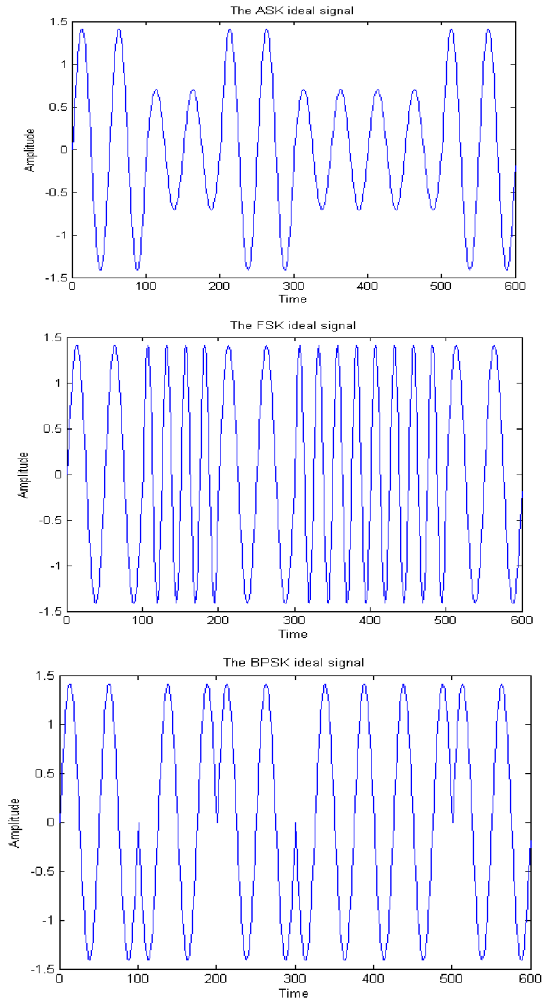


***Figure (1)**: Ideal signal for ASK, FSK and BPSK respectively*

The unknown modulated signal which needs to be matched with the ideal signals in order to identify the type of the modulation is the received signal at the receiver with noise and the noise level varies depending on the channel signal to noise ratio (SNR) as shown in Figure 2.

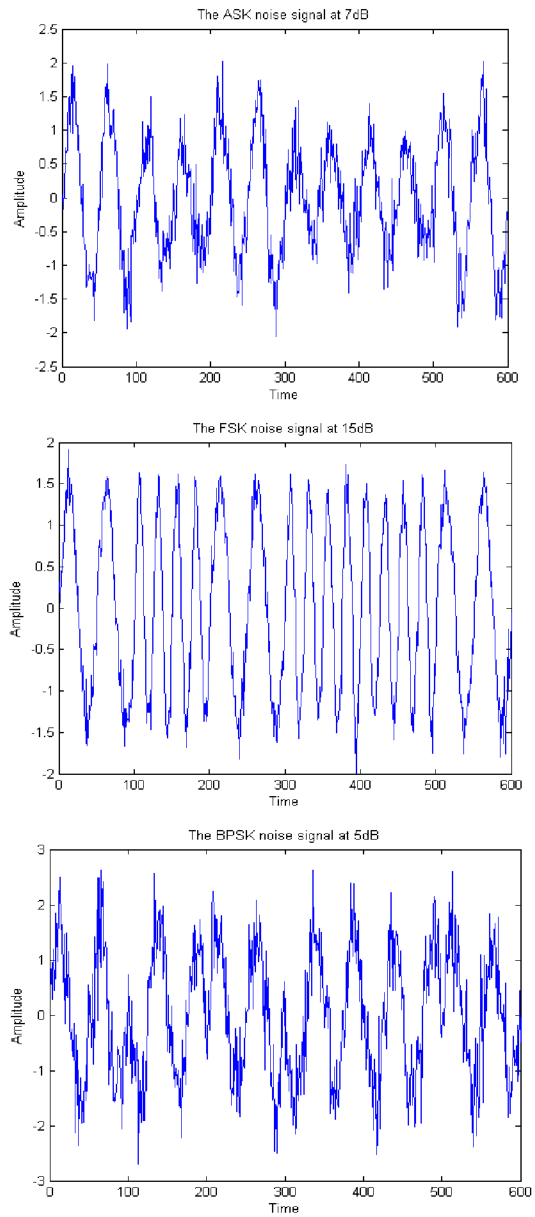


***Figure (2)**: Noise signals for ASK, FSK and BPSK at 7dB, 15dB and 5dB respectively*

It can be seen from equations 2, 3 and 4 that symbol changes will raise the transient in the modulated signal. The transits are created independently due to the change of amplitude, frequency and phase respectively. WT can characterize these transients effectively and allow simple method for discrimination of the two signals. The continues WT of any signal s(t) is defined as:

$$CWT(a,\tau) = \int s(t)\Psi_a^*(t)dt$$
$$= \frac{1}{\sqrt{a}}\int s(t)\psi^*(\frac{t-\tau}{a})dt \quad (5)$$

As we use the CWT to analysis the signal we chose the Haar wavelet to analyze the ASK, FSK and PSK signal:

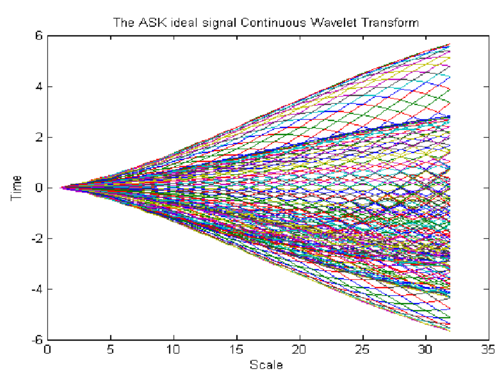
$$|CWT_{ASK}(a,\tau)| = \frac{\sqrt{s}}{\sqrt{a}(\omega_0)}\cos^2(\omega_0+\varphi) \quad (6)$$

$$|CWT_{FSk}(a,\tau)| = \frac{4\sqrt{s}}{\sqrt{a}(\omega_c+\omega_i)}\sin^2\left[\frac{(\omega_c+\omega_i)a}{4}\right] \quad (7)$$

$$|CWT_{PSk}(a,\tau)| = \frac{4\sqrt{s}}{\sqrt{a}(\omega_c)}\sin^2\left[\frac{\omega_c a}{4}\right] \quad (8)$$

The result of the Haar wavelet transform is the coefficient of the signal as shown in Figure 3, and then the filter function is used to filter the data sequence using a digital filter that works for both real and complex inputs. It filters the data signal by numerator and denominator coefficient vector as shown in Figure 4. Apparently the difference between the ASK, FSK and BPSK signals makes the identification easier.

To differentiate ASK, FSK and BPSK signals, it is needed to find a common features and select a criterion based on the differences, hence in this paper, the identification system is designed based on multi-steps analysis and variance that finally implies the statistical approach to differentiate between the different modulation schemes.



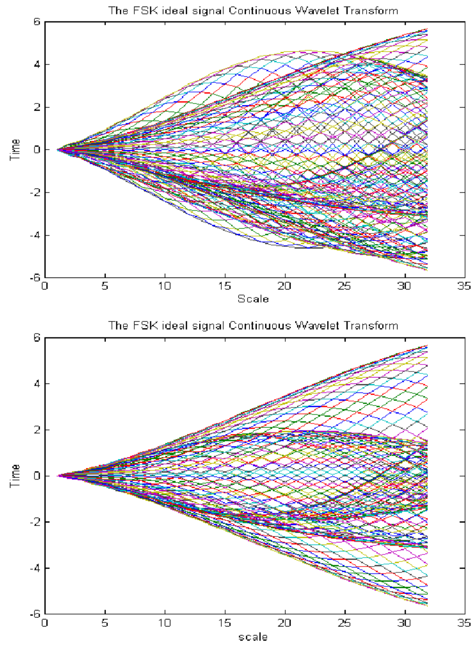
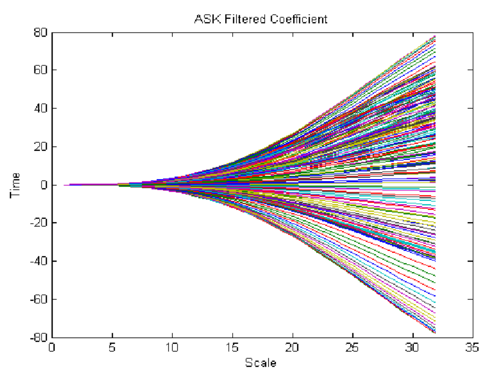


***Figure (3)**: ASK, FSK and PSK coefficient signal*

The WT magnitude of BPSK has one DC level and many levels of peaks, whereas that of FSK has several DC levels and peaks. After filtering, the FSK WT magnitude still contains different DC levels, whereas there is only one in PSK. Thus the median filter output for FSK shows a higher variance, and the variance test is a simple method to separate the two [3].



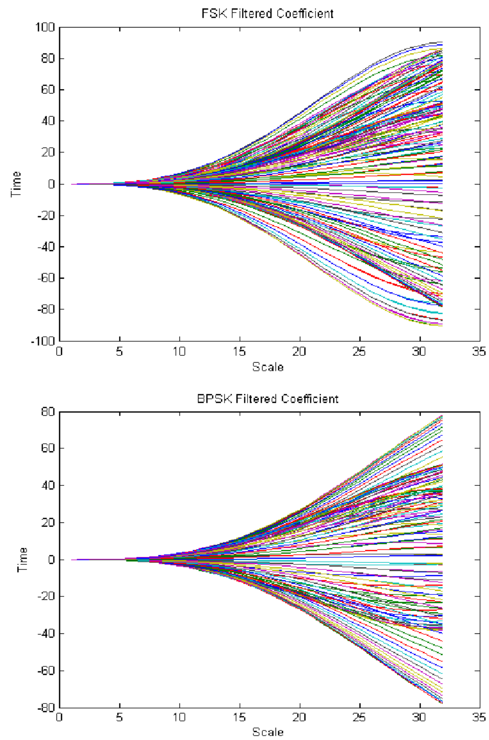


Figure (4)*: ASK, FSK and BPSK filtered coefficient*

2.1 The Block Diagram of the Identification System:

The design of the identification procedure shown in Figure 5 based on four steps:(I) First step is to analysis the signal by the CWT using Haar family technique, then (II) apply the digital filter for the coefficient result to remove the peaks of the signal. After applying the median filter, at the third step (III) the identifier compute the first step variance of the digitally filtered signal, followed by (IV) compute the second step variance and finally (V) threshold matching with the unknown modulated signal.

The justification for the multi step is to identify the type of the modulated signal easily and simply. For example, the coefficient of ASK signal analyzed by Haar WT is a constant while the Haar WT analysis for the FSK signal is a multi-step function since the frequency is variable [1].

For the BPSK signal, the theoretical variance of the median filter output can be calculated because the output is constant with random noise. On the other hand for the FSK signal, the theoretical variance of the median filter output is not constant.

The double steps variance computation for the signal is used to generate the fixed number for reference signal in order to match the unknown modulated signal with the reference signal (the ideal signal).

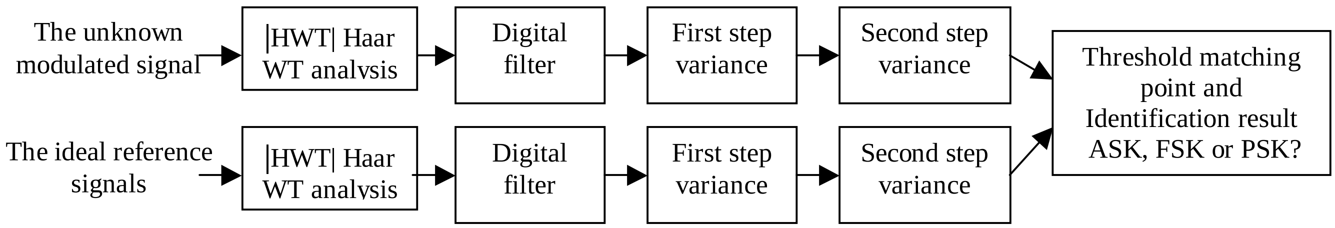


Figure (5)*: Block diagram of the digital modulation identifier.*

3. The Simulation:

In this section, the results of the proposed digital modulation identifier shown in Figure 5 are presented.

Figure 6 shows the comparison between the variance of both ASK ideal signal and the unknown modulated signal, the first graph is the ideal signal that was generated by the system as a reference, and the second one is the unknown modulated signal after it has been identified by the system as ASK signal.

The different SNR values included in the unknown modulated signal gives some alteration to the variance than the variance of the ideal signal, which finally after calculating the second variance for both ideal and unknown modulated signals; resulting in a fixed threshold value for the ideal signal, whereas show different values for the unknown modulated signal depending on the noise level in the signal.

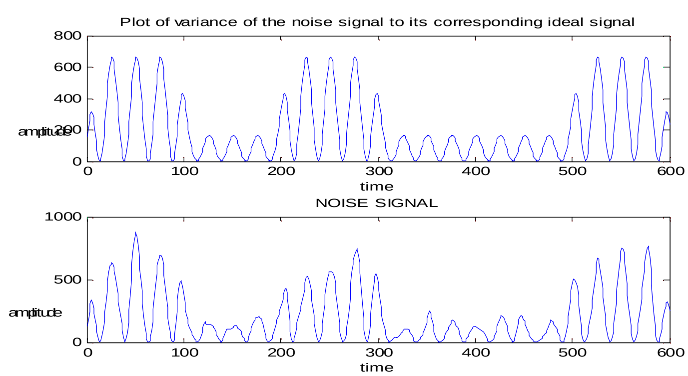


Figure (6): *Comparing ASK signal with unknown modulated signal after processing*

Figures 7 and 8 shows the same concept of the comparison between the FSK and BPSK respectively with the unknown modulated signal, this comparison mainly depend on the threshold value of the ideal signal calculated by the second variance step, and this threshold has been used to identify the unknown modulated signal.

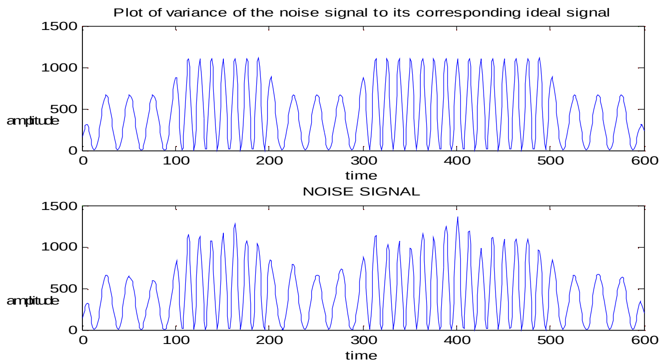


***Figure (7)**: Comparing FSK signal with unknown modulated signal after processing*

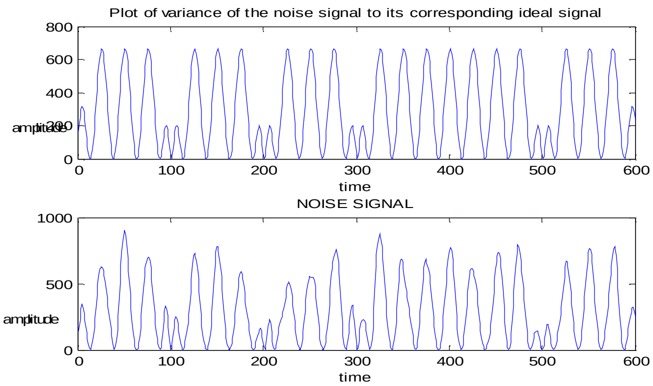
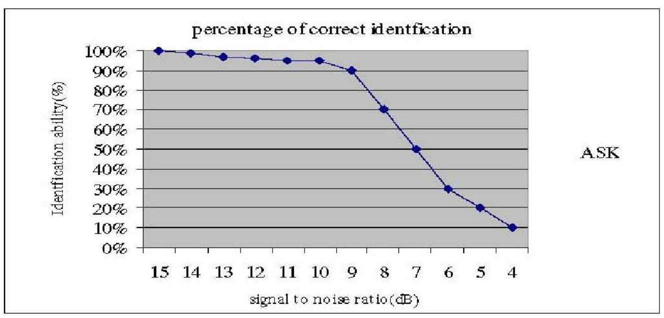
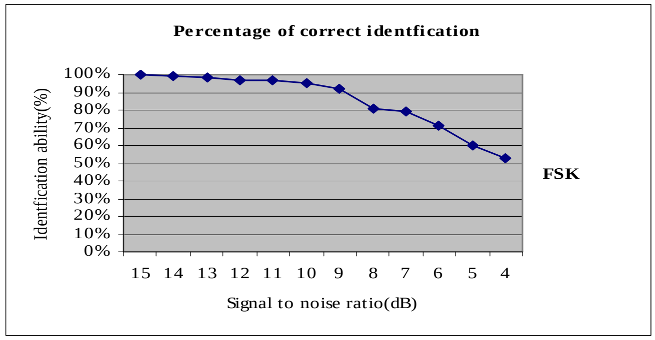


***Figure (8)**: Comparing BPSK signal with unknown modulated signal after processing*

The simulation perform all the analysis process on the unknown modulated signal as mentioned before on the identification block, and finally match the result of the variance to the ideal signal on the system.

The threshold for separation between different types has been determined according to the ideal signal that was generated in the experiment and simulation, and this threshold may vary for different systems and different environments; which means it is not a fixed standard for all the systems but the concept is fixed.





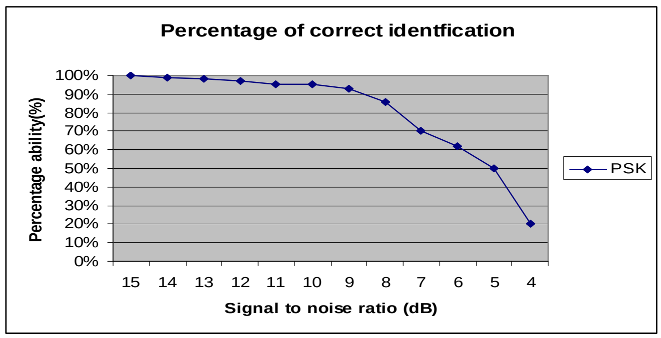


Figure (9)*: Graph percentage of the identification system for ASK, FSK and BPSK signal respectively.*

Figure 9 showed the correct identification percentage of the system. From the graphs, for higher SNR values, the system can identify the type of the modulation scheme correctly, beside that it has the ability to identify the FSK signal better then ASK and BPSK signal for lower SNR values. The result show that, the system's accuracy (identification ability) is approximately 95 to 100% if SNR > 9dB.

4. Conclusions:

In this paper, modulation identification has been implemented for SDR approach. The approach based on statistical analysis method using the Haar wavelet transform and matching the variance of an unknown modulated signal with reference ideal signals (which considered as a threshold point in the system).
The identification system has been applied for the ASK, FSK and BPSK signals. The identification process states that the WT magnitude of ASK, FSK and BPSK are easily identifiable in terms of DC levels and peaks. In general, the system's identification ability is approximately 95% and above for SNR > 9dB. Hence the efficiently of the system is apparent.

References:

[1] C. Huang and A. Polydoros, "Likelihood method for MPSk modulation classification", IEEE Trans. Commun., vol. 43, no.2/3/4, pp.1439-1504, Feb. /Mar. /Apr. 1995.
[2] K. C. O, W. Prokopiw, Y. T. Chan, "Modulation identification of digital signals by the wavelet transform", IEEE Trans. Commun. In Aug. 1995.
[3] Jian Chen, Yonghong Kuo, Jiandong Li, Fenglin Fu, Yubao Ma, "Digital Modulation Identification by Wavelet Analysis" the IEEE sixth international conference on computational intelligence and multimedia applications (ICCIMA'05) 2005
[4] Y.C. LIN and C.-C. Jay Kuo, " Modulation Classification using Wavelet Transform", in SPIE, vol.2303, pp. 260-271.
[5] K.C. Ho, W. Prokopiw and Y.T. Chan, "Identification of M-ary PSK and FSK signals by the Wavelet Transform", IEEE Military Communication Conf., pp. 886-889, California, November 1995.
[6] Liedtke, F.F, "Computer Simulation of an Automatic Classification Procedure for Digitally Modulated Communication signals with Unknown Parameters", Signal Process.vol .6, pp. 311-323, 1984.
[7] J. Eyre, "the Digital Signal Processor Derby", IEEE, Spectrum, vol. 38, no. 6, pp. 62-68, Jun. 2001

Nomenclatures:

w_c … Carrier frequency
θ_c … Phase frequency
S … Signal power
N … Number of observed symbols
T … Symbol duration
u_t … Standard unit pulse of duration T
φ_i … $\varphi_i \in \left\{ \frac{2\Pi}{M}(m \approx 1), m = 1,2,\ldots, M \right\}$
ω_i … $\omega_i \in \{\omega_1, \omega_2, \ldots, \omega_m\}, \theta_i \in (0.2\Pi)$
α … The scale of the coefficient
τ … Translation
$*$ … Complex conjugates
$\psi(t)$ .. Mother wavelet
Ψ_a .. Baby wavelet