

# BLIND EQUALIZATION FOR MODULATION IDENTIFICATION TECHNIQUES

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## ABSTRACT

Recently, the concept of software defines radio (SDR), which has adaptability to variance of application, and environment has been thoroughly investigated. Specially, there have been reports about the modulation scheme estimation algorithms, which can be a key technique of SDR. In the conventional blind modulation estimation algorithms, there is no report about blind equalization. Therefore, we propose the system, which include the blind modulation estimation algorithm and blind equalization. The blind modulation estimation algorithm can estimate the 2PAM(Pulse Amplitude Modulation) and 4PAM, and in the equalization, the SATO algorithm is used. In conclusion, we evaluate the proposed system with the numerical evaluations.

## 1. INTRODUCTION

Software Defined Radio, attracted great attention of the research community due to its capability of reconfiguring itself by simply changing its software, in order to adapt to the environment and user's application. Another advantage of the SDR is that a multimode terminal for any number of communication schemes. However, there is a problem when the transmitter of an SDR changes its specifications, because it is then necessary that the receiver recognize such a changing of specifications. There are two approaches to solve the specifications estimation problem: non-blind and blind. The non-blind scheme uses supplementary (thus redundant) information, to inform the receiver side about the changing of specifications. In the blind scheme, on the other hand, such supplementary information is not necessary at all so that its flexibility exceeds the one of the non-blind scheme. Recently, for such problem the blind modulation identification techniques are proposed. This technique has a possibility to realize the blind receiver. However, in the modulation identification technique there is no reports and discussions to devise a countermeasure for multi path with any blind equalizer. In this paper the blind equalizer for blind modulation identification technique is discussed. The conventional blind equalizers assume that they do not

have knowledge about data, but the modulation schemes of received signals are known. However, in the blind modulation identification technique the modulation scheme is unknown, therefore such measure is necessary. Specially, there are a few reports about multi modulation schemes which have difference amplitude levels blind equalization. In this paper the blind equalization schemes for PAM (Pulse Amplitude Modulation schemes) is discussed with SATO algorithm [1]. In the SATO algorithm the update equality is decided by the modulation scheme, especially amplitude characteristics. In this report, there are two proposed systems. In the first proposed scheme, blind equalizers are set at the same number of modulation schemes. Therefore the equalization is realized and if the received signals modulation scheme and the equalizer are not matched the received signal's amplitude characteristic will be changed. This is an advantage of blind modulation identification techniques. Since the modulation schemes are identified by the amplitude characteristic, the blind equalizers perform to aid the blind modulation identification. On the other hand, in second proposed scheme, only one equalizer has been used. In the equalization processing, if the modulation scheme and the blind equalizer are not matched, the output signals of equalizer amplitude characteristic is changed. Therefore in the modulation identification processing, the secondly proposed scheme considers such changing to identify the modulation scheme effectively. In this report, the output of filter is discussed when there is one equalizer, and the possibility of secondly proposed system is shown.

The proposed scheme is evaluated by computer simulation; the parameter to evaluate the identification is denoted as "Modulation Estimation Error Rate (MEER)". Using this parameter both proposed schemes and the conventional scheme have been compared.

## 2. SYSTEM MODEL AND ASSUMPTIONS

The system model is shown in Figure. 1. Transmitted signals are denoted as  $s(k)$  where  $k$  is unit of symbol time value. The modulation schemes are 2PAM and 4PAM. If the modulation schemes are  $M$ -array PSK, it is possible to

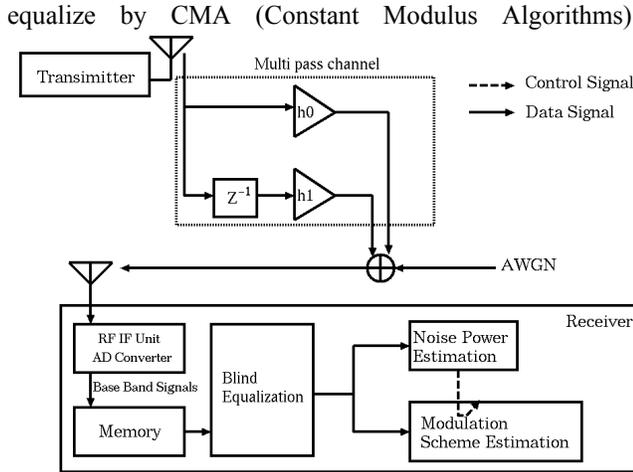


FIG. 1 System block diagram

without knowledge of  $M$ . Therefore, in this report, multi amplitude levels modulation schemes are focused. SATO algorithm considers multi level amplitudes modulation schemes, for example M-array PAM. In this case, transmitted signal  $s(k)$  is denoted as following.

$$s(k) = \{\pm(M-1)d, \pm(M-3)d, \dots, \pm 3d, \pm d\} \quad (1)$$

where  $M$  is an even number and  $d$  is unit amplitude value which is set as the average power has to be 1. Multi path channels have two paths, then the received signals are denoted as following.

$$r(k) = h_0 s(k) + h_1 s(k-1) + n(k) \quad (2)$$

$$h_1 = \sqrt{1 - h_0^2}$$

Where  $n(k)$  is a AWGN. At the receiver side, firstly, the blind equalizer equalizes received signals. In second step, noise power is estimated to aid the modulation identification processing, and finally the modulation scheme is recognized at the modulation identification block. The modulation identification processing is referred from [2]. Therefore, in this report noise estimation algorithm is abbreviated.

### 3. M-PAM MODULATION SCHEMES IDENTIFICATION ALGORITHM

Block diagram of  $M$ -PAM modulation scheme algorithm is shown in Figure. 2. This process assumes that after equalization, ISI (Inter Symbol Interference) is canceled. At first,  $N$  symbols which are received signals are stored in memory. As a preprocessing the amplitude value  $a(k)$  is

obtained by  $r(k)$ . In feature extraction processing, the

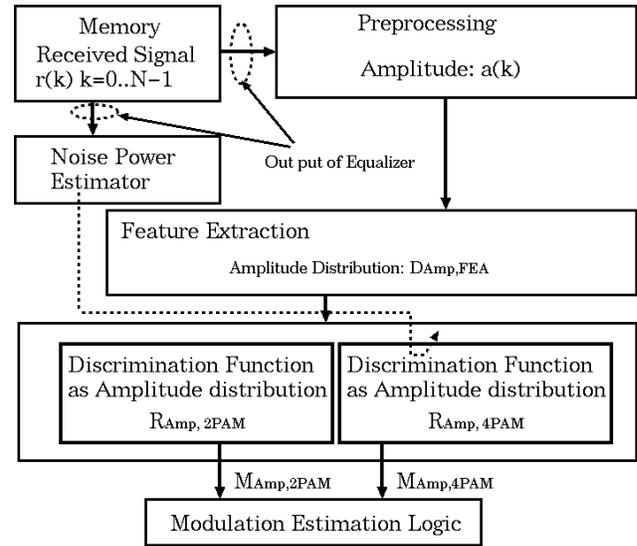


FIG. 2 Block diagram of modulation identification

amplitude distribution is obtained. This distribution is a feature vectors  $D_{AMP,FEA}$ . At the receiver, there are discrimination functions  $R_{AMP,MOD}$  which are suitable for prototypes of each modulation schemes. In the identification logic block, the correlation of  $D_{AMP,FEA}$  and  $R_{AMP,MOD}$  are calculated in each modulation schemes. Each correlation results is denoted as  $M_{AMP,MOD}$ . Where  $MOD$  is a type of modulation scheme. The modulation scheme is recognized by selecting the maximum value among the each  $M_{AMP,MOD}$ .

### 4. BLIND EQUALIZATION WITH SATO ALGORITHM FOR M-ARRAY PAM

In this section, at first SATO algorithm is introduced in the next place, the first proposed system which responds to 2PAM and 4PAM is shown.

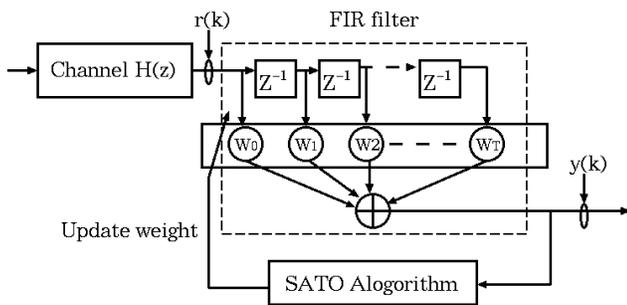
#### 4.1. SATO algorithm

The block diagram of FIR filter with SATO algorithm is shown in Figure. 3. In this report the number of taps in FIR filter is 20. The weight vector is denoted as  $W$  and is updated via

$$W(k+1) = W(k) - u[y(k) - R_M \text{sgn}(y(k))]x(k) \quad (3)$$

Where  $u$  is step size,  $y(k)$  is output of FIR filter, and  $x(k)$  is input vector of FIR filter, respectively.  $R_M$  is denoted as following

$$R_M = \frac{E[s(k)^2]}{E[|s(k)|^2]} \quad (4)$$



**FIG. 3 Block diagram of FIR filter with SATO algorithm**

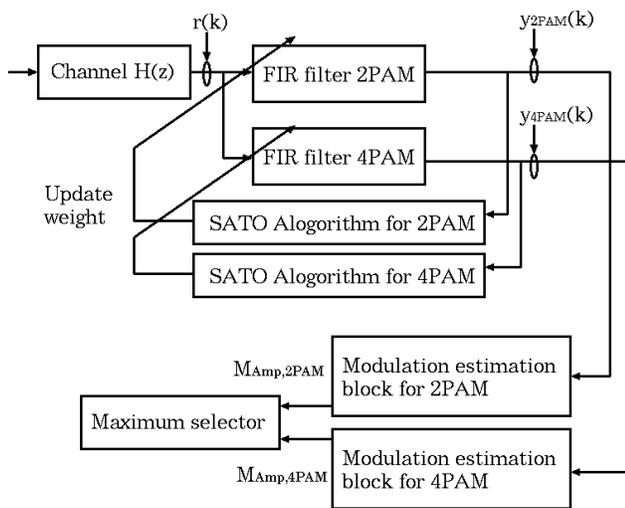
It is clear that  $R_M$  depends on  $M$ . Therefore, if there is no information of the modulation scheme at the receiver, it is difficult to equalize.

#### 4.1. Equalization for 2PAM and 4PAM

When received signal's modulation scheme is 2PAM or 4PAM, three methods are considered.

- Scheme1: Equalizer is implemented as 2PAM type
- Scheme2: Equalizer is implemented as 4PAM type
- Scheme3: Two type equalizers are implemented

In scheme 1 and 2, there is only one equalizer. However, in scheme 3 the equalizers are implemented in parallel. The block diagram of scheme3 is shown in Figure. 4 and this scheme is a first proposed scheme.



**FIG. 4 Block diagram of multimode FIR filter with SATO algorithm**

In this scheme, if there are  $L$  types modulation schemes, at the receiver  $L$  types equalizers are necessary. This is a weak point. In scheme 3, the modulation estimation block is suitable for the processing that is from preprocessing to discrimination block in Figure. 3.

## 5. NUMERICAL EVALUATION

The assumptions of the numerical evaluations are shown in Table. 1.

Modulation scheme	2PAM, 4PAM
Channel	2 paths AWGN
Step size $u$	$0.0001 < u < 0.001$
Identification period $N$	50symbols

The parameter of evaluation of modulation identification ability is denoted as "Modulation Estimation Error Rate (MEER)".

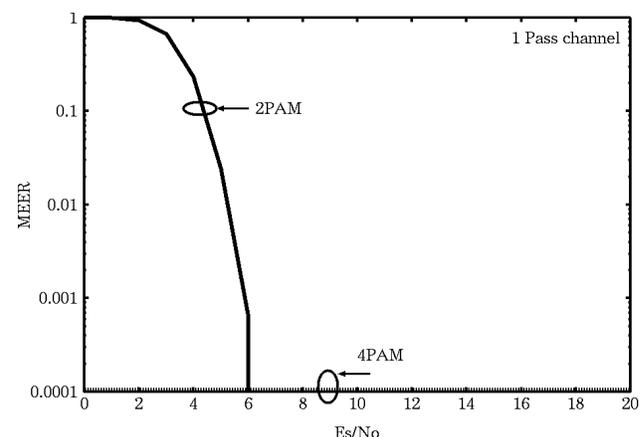
Where  $Err$  and  $Est$  are the number of estimation errors and the number of estimations trials, respectively.

$$MEER = \frac{Err}{Est} \quad (5)$$

**TABLE. 1 Assumptions of numerical evaluation**

### 5.1. 1 path channel

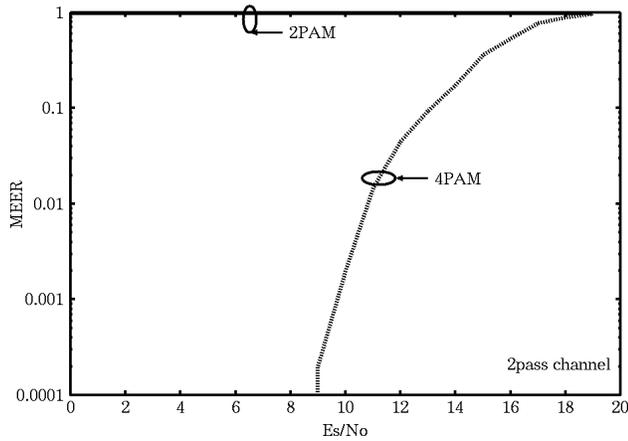
At first the modulation identification algorithm is evaluated with simple body. In this case there is no multi path, therefore, it is not necessary to equalization. The two cases are evaluated, one is that modulation scheme is 2PAM and other is 4PAM. This simulation result is shown in Figure. 5.  $E_s/N_0$  is more than 6dB, the MEER is less than 0.001 in both modulation schemes.



**FIG. 5 MEER vs.  $E_s/N_0$ , 2PAM and 4PAM, channel: 1path AWGN**

## 5.2. 2 paths channel

In next, the 2-multi paths are assumed. At first, the case that there is no equalizer in receiver is evaluated. This result is shown in Figure. 6.



**FIG. 6 MEER vs. Es/No, 2PAM and 4PAM, channel: 2path AWGN. Receiver dose not have equalizer**

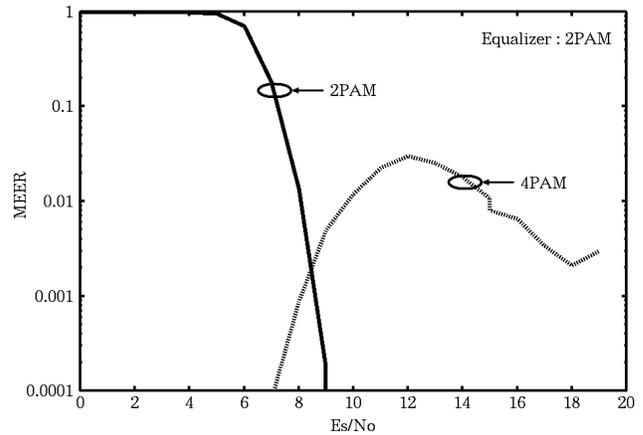
If there is no equalizer, the reason of ISI, modulation identification is difficult. It can be said that it is necessary to compensate ISI.

In next time, 3 schemes are evaluated in 2paths channel. Each result is shown in Figure. 7-9. The worst case is scheme1 that equalizer is set as 2PAM. However in scheme2 equalizer is set as 4PAM the 2PAM is equalized, too. Comparing scheme2 and scheme3, scheme3 is better than scheme2. The reason is that in scheme3, the modulation scheme and equalizer type is matched.

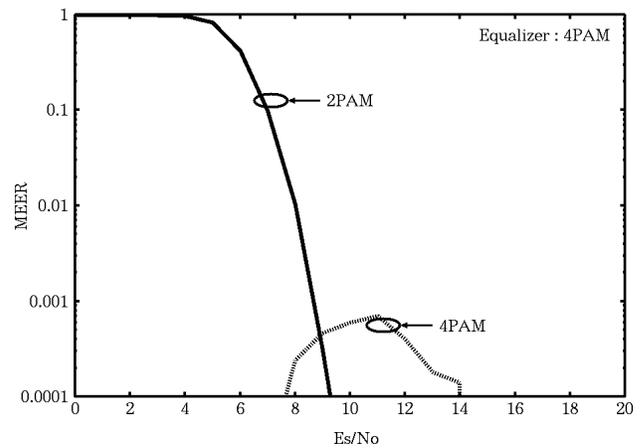
## 6. INVESTIGATION OF UNIVERSAL EQUILIZER

This section is discussed about second proposed system which aims the universal equalizer. In first proposed system which is scheme3, if number of the modulation schemes is increased, the number of the modulation scheme is increased, too. This is a big weak point for scheme3. On the other hand if the equalizer is design for 4PAM, it is possible to equalize. It can be guessed that there is a possibility of universal equalizer for multi amplitude levels. The necessary conditions for modulation identification are two issues.

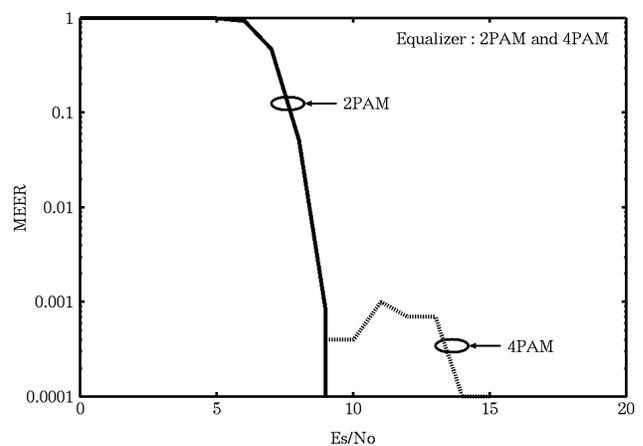
- 1: Filter output amplitude probability is steady state.
- 2: Amplitude probabilities of each modulation scheme are different.



**FIG. 7 MEER vs. Es/No, 2PAM and 4PAM, channel: 2path AWGN. Receiver has equalizer scheme1**

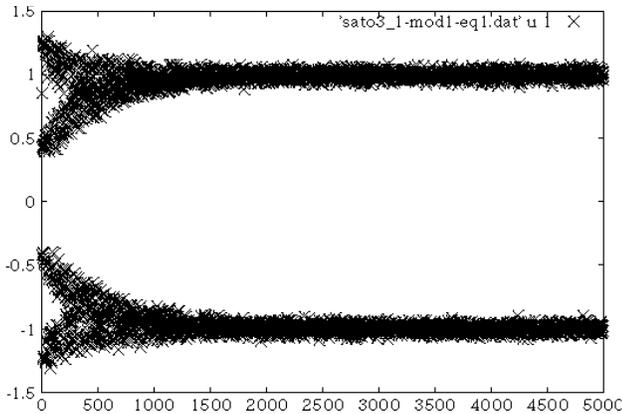


**FIG. 8 MEER vs. Es/No, 2PAM and 4PAM, channel: 2path AWGN. Receiver has equalizer scheme2**

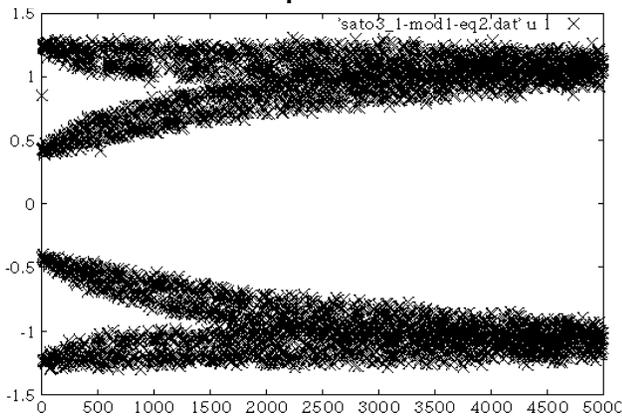


**FIG. 9 MEER vs. Es/No, 2PAM and 4PAM, channel: 2path AWGN. Receiver has equalizer scheme3**

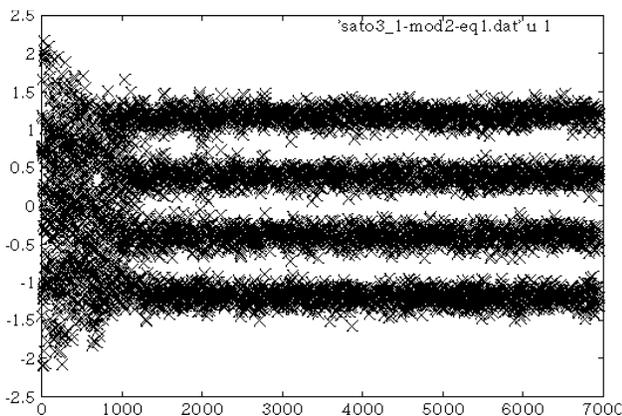
For investigation this problem, the convergence characteristics are shown in Figure10-13. In these figures, x-axis is time domain, and y-axis is amplitude of filter outputs.



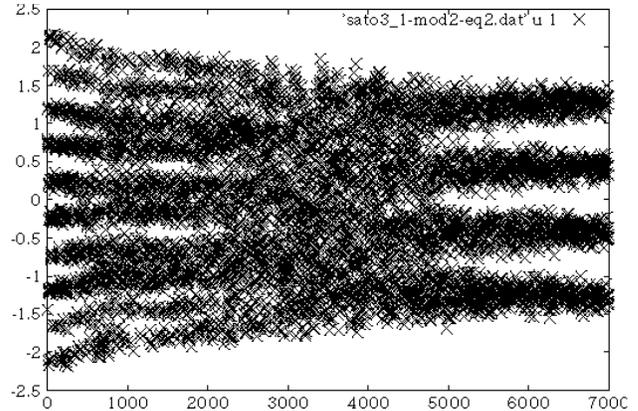
**FIG. 10 time vs. Filter output  $E_s/N_0=30\text{dB}$ ,  
 $MOD=2\text{PAM}$  Equalizer is 2PAM**



**FIG. 11 time vs. Filter output  $E_s/N_0=30\text{dB}$ ,  
 $MOD=2\text{PAM}$  Equalizer is 4PAM**



**FIG. 12 time vs. Filter output  $E_s/N_0=30\text{dB}$ ,  
 $MOD=4\text{PAM}$  Equalizer is 2PAM**



**FIG. 13 time vs. Filter output  $E_s/N_0=30\text{dB}$ ,  
 $MOD=4\text{PAM}$  Equalizer is 4PAM**

It can be said that if the equalizer type and sending signal's modulation scheme is not matched, the filter output can converge certain value. The difference of convergence speed depends on step size. In these simulations, the step sizes of 2PAM and 4PAM are 0.001 and 0.0005, respectively. The convergence value is depend on the combination of transmitted signal's modulation scheme and equalizer type. If the transmitted modulation scheme is 2PAM, the convergence value of 2PAM and 4PAM equalizers is not same. When the universal equalizer will be discussed these characteristic will be used. This is a main future investigation.

## 6. CONCLUSION

In this report, the equalizer for multi amplitude level modulation schemes is discussed. The proposed scheme uses some blind equalizers for each modulation scheme in the receiver side. It can be said that the modulation scheme is identified. However, this method has a weak point that the device scale has to be very big. Therefore the one type equalizer for the modulation identification is discussed and a guideline for this problem is shown

## 10. REFERENCES

- [1] Y. Sato , "A method of self-recovering equalization for multi-level amplitude modulation" IEEE Trans. Commun, vol. 23, pp.679-682 April 1998
- [2] K.Umeybayashi, S.Ioshii, R.Kohno "Blind Algorithm of the Modulation Scheme Estimation Adapt to Noise Power Based on a Concept of Software Defined Radio" WPMC 2001 Aalborg Denmark pp.1559-1564 September 2001