Performance Analysis of a Synchronized Receiver over Noiseless and Fading Channels

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Abstract – *This paper presents a baseband communications system that implements the data phase transmission using a single-tone waveform. In our contribution, the behavior of received signal when transmitted over a noiseless channel and a fading frequency selective channel with AWGN is analyzed in-terms of the output power spectrum, estimate of the cross-spectral phase between the equalizer input and its output, control signal used to drive the Farrow fractional delay, scatter plot of the equalizer input, output and descrambler output.*

Key Words: AWGN, Equalization, Fading, Phase modulation, RLS.

1. INTRODUCTION

Wireless communication is turned out to be one of the greatest endowments from the telecommunication industry for the development of one's nation. The continually expanding interest for high data rates in wireless networks requires the productive use of the restricted data transfer bandwidth available, while supporting a high review of portability in differing propagation conditions [1]. The limit and the achievable integrity of correspondence frameworks are to a great degree subject to the system's knowledge concerning the channel conditions experienced. Consequently, the arrangement of an exact and strong channel estimation system is an essential figure accomplishing a high performance. The estimation is finished by equalizing the channel [2]. The equalization alludes to expelling the impacts of the channel. In multipath propagation the signal data goes through a diverse way and may bring fading of the signal, in this manner there comes a delay in achieving the destination. At the point when the delay spread (Td) is lesser than a symbol period, the contortion is called flat fading, if the delay spread is more than a symbol period called as frequency selective fading. Data exchange is seriously constrained at the deep fade frequencies [3]. The channel conditions are assessed and its belongings are evacuated by channel equalization. It monitors the movement in the channel by creating updates of the channel estimates utilizing equalizing algorithms (RLS) and at long last tries to limit those estimated errors [4]. The Equalizer is set at the recipient front end to evacuate the channel impairments by refreshing the weights.

The synchronization writing is so incomprehensible as to involve more than 1000 technical papers with applications in differing territories, for example, communications, telemetry, time and frequency control, and instrumentation frameworks. This colossal accumulation of information has been incorporated and expounded in brilliant books like those by Viterbi [5], Stiffler [6], Lindsey [7], Lindsey and Simon [8], Gardner [9], Meyr and Ascheid [10], and in the ESA specialized report by Gardner [11]. Digital synchronization strategies, which implies that to recover timing, phase and carrier frequency by working just on signal tests taken at appropriate rate. This is interestingly with the recognizable analog methods which work on continues time waveforms. On the other-hand, continues phase modulation (CPM) strategies have turned into a serious research territory in the eighties, around with the production of the book by Anderson et al [10].

2. SYSTEM MODEL

The received signal from a transmitter is processed through RLS Equalizer to avoid the noise introduced by the channels. RLS equalizer is designed as shown in Figure 1. The extra delay is introduced to align the Randomizing sequence with the Equalized signal. The Equalizer introduces a delay equal to the length of a frame. An extra delay is intended in Frame Alignment block to align the signal to the beginning of the interleaver frame [12]-[14]. This block collects a block of data equal to size of the interleaver matrix depending on the data rate and interleaver length. The function of Symbol Extraction block is to convert the tribit that results from the modulation into one, two or three bit channel symbols depending on the data rate. Finally the deinterleaved data is passed to the FEC decoder and the data is decoded. The input signal and received signals are given as inputs to BER block to analyze the performance of various blocks and will be discussed more in Section.

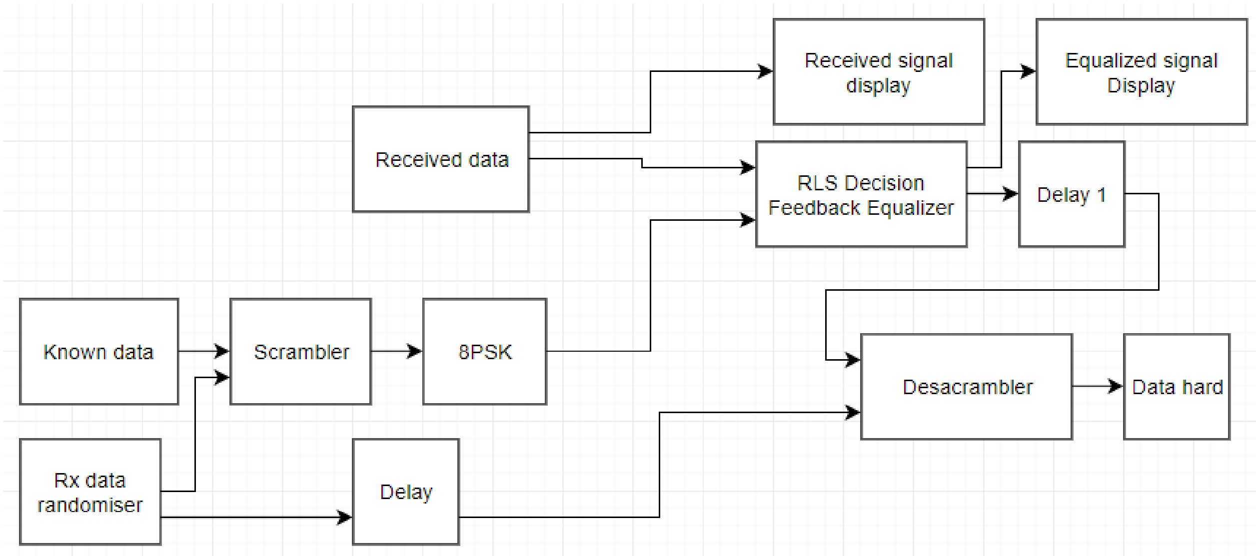

Figure 1: RLS Equalizer.

3. NUMERICAL ANALYSIS

In basic linear model, let us consider estimation of vector θ in model that is linear in θ. Classical linear form can be defined as

$$Y_i = ({h_i}^T\theta + n_i) \qquad (1)$$

where Y_i is i th measurement, h_i is corresponding "design vector," and n_i is unknown noise value. This model is used extensively in control, statistics, signal processing, etc. However, many estimation/optimization criteria based on "squared-error"-type loss functions which leads to criteria that are quadratic in θ and Unique (global) estimate θ. This Criterion (loss function) has form

$$\frac{1}{2n}\sum_{i=1}^{k}(Y_i - h_i^T\theta)^2 = \frac{1}{2n}(Y_k - h_k\theta)^T - (Y_k - H_k\theta) \qquad (2)$$

where $Y_k = [y_1 y_2,.....,y_i$] and H_k is $k \times p$ concatenated matrix of h_i^T row vectors. Classical *batch* least-squares estimate is

$$\hat{\theta}_k = ({H_k}^T H_k)^{-1}{H_k}^T Y_k \qquad (3)$$

Popular recursive estimates (LMS, RLS, Kalman filter) may be derived from batch estimate. However, *batch* form may not be convenient in many applications, for example, data arrive over time and want "easy" way to update estimate at time i to estimate at time k+1.

Least-mean-squares (LMS) method is very popular recursive method which is a Stochastic analogue of steepest descent algorithm and LMS recursion can be written as

$$\hat{\theta}_{(i+1)} = \hat{\theta}_i - a h_{i+1}(h_{i+1}^T\hat{\theta}_i - Y_{i+1}) \ \forall a > 0 \qquad (4)$$

Suppose process is modeled according to autoregressive (AR) form:

$$Y_{(i+1)} = \alpha_0 Y_i + \alpha_1 Y_{i-1} + \cdots + \alpha_m Y_{i-m} + \gamma u_i + n_i \tag{5}$$

where x_i represents state, γ and α_i are unknown parameters, u_i is control, and n_i is noise. Let target ("desired") value for x_i be d_i, Optimal control law known (minimizes mean-square tracking error) as

$$u_i = \frac{d_{i+1} - \alpha_0 Y_i - \alpha_1 Y_{i-1} - \cdots - \alpha_m Y_{i-m}}{\gamma} \tag{6}$$

An alternative to LMS is Recursive Least Squares (RLS) which is a stochastic analogue of Newton-Raphson ("second order" method) and faster convergence than LMS in practice. The two recursions of RLS algorithm are

$$P_{i+1} = P_i - \frac{P_i h_{i+1} h_{i+1}^T P_i}{1 + h_{i+1}^T P_i P_{i+1}}$$

$$\hat{\theta}_{(i+1)} = \hat{\theta}_i - P_{i+1} h_{i+1} (h_{i+1}^T \hat{\theta}_i - Y_{i+1}) \tag{7}$$

It is common to have the underlying true θ evolve in time (e.g., target tracking, adaptive control, sequential experimental design, etc.). Prototype recursive form for estimating θ_i is

$$\hat{\theta}_{(i+1)} = A_i \hat{\theta}_i - I_{i+1} (h_{i+1}^T A_i \hat{\theta}_i - Y_{i+1}) \tag{8}$$

where choice of A_i and I_i depends on specific algorithm.

4. RESULTS AND DISCUSSION

The full receiver which shown in Figure 2 mainly comprises of four blocks such as Acquired Passband Waveform, Frequency Translator and Channel, Receiver and Byte Error display [15], and the internal operations of the receiver is shown in Figure 3.

Figures 4, 5 show the behavior of received signal when transmitted over a noiseless channel and a fading frequency selective channel with AWGN, respectively. Figure 4 depicts the plots for a noiseless channel (a) The channel output power spectrum (b) Estimate of the cross-spectral phase between the equalizer input and its output (c) Control signal used to drive the Farrow fractional delay (d) Scatter plot of the equalizer input (e) Equalizer output (f) Descrambler output. It can be observed that a distortion in the signal due to the effect of the noise in the fading channel [15] - [20].

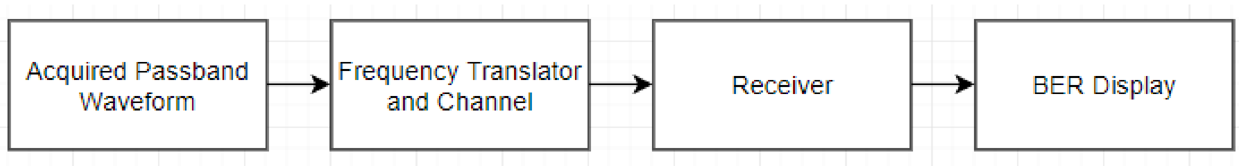

Figure 2: Basic block diagram of receiver.

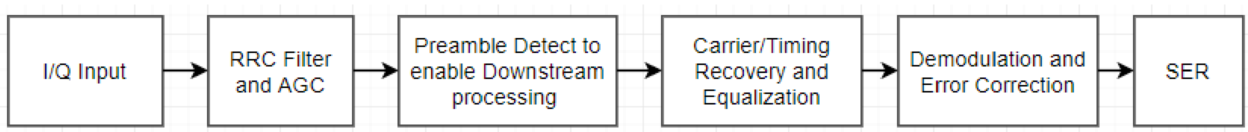

Figure 3: Synchronization operations involved in receiver.

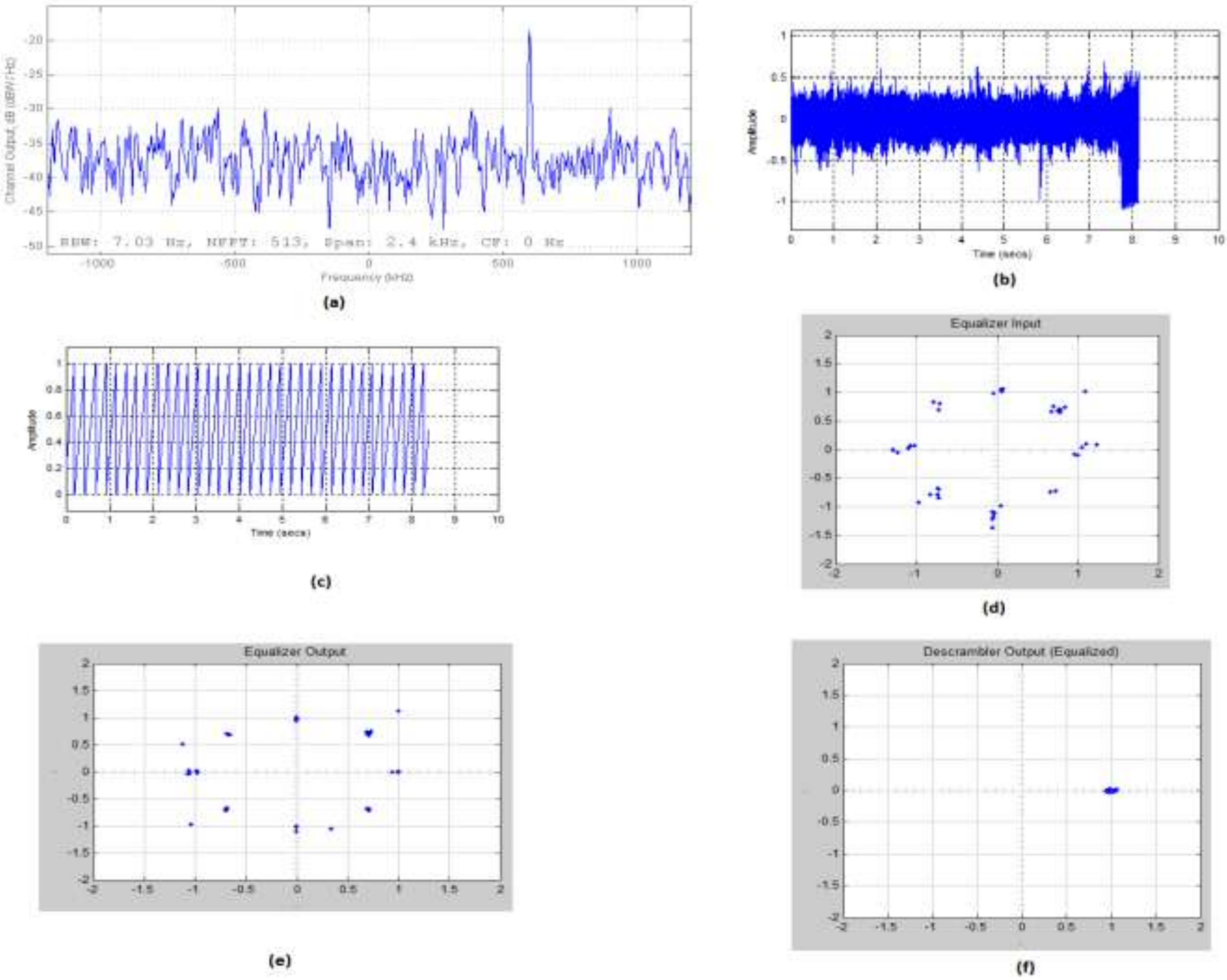

Figure 4: Plots for a noiseless channel (a)The channel output power spectrum (b)Estimate of the cross-spectral phase between the equalizer input and its output (c) Control signal used to drive the Farrow fractional delay (d) Scatter plot of the equalizer input (e) Equalizer output (f) Descrambler output.

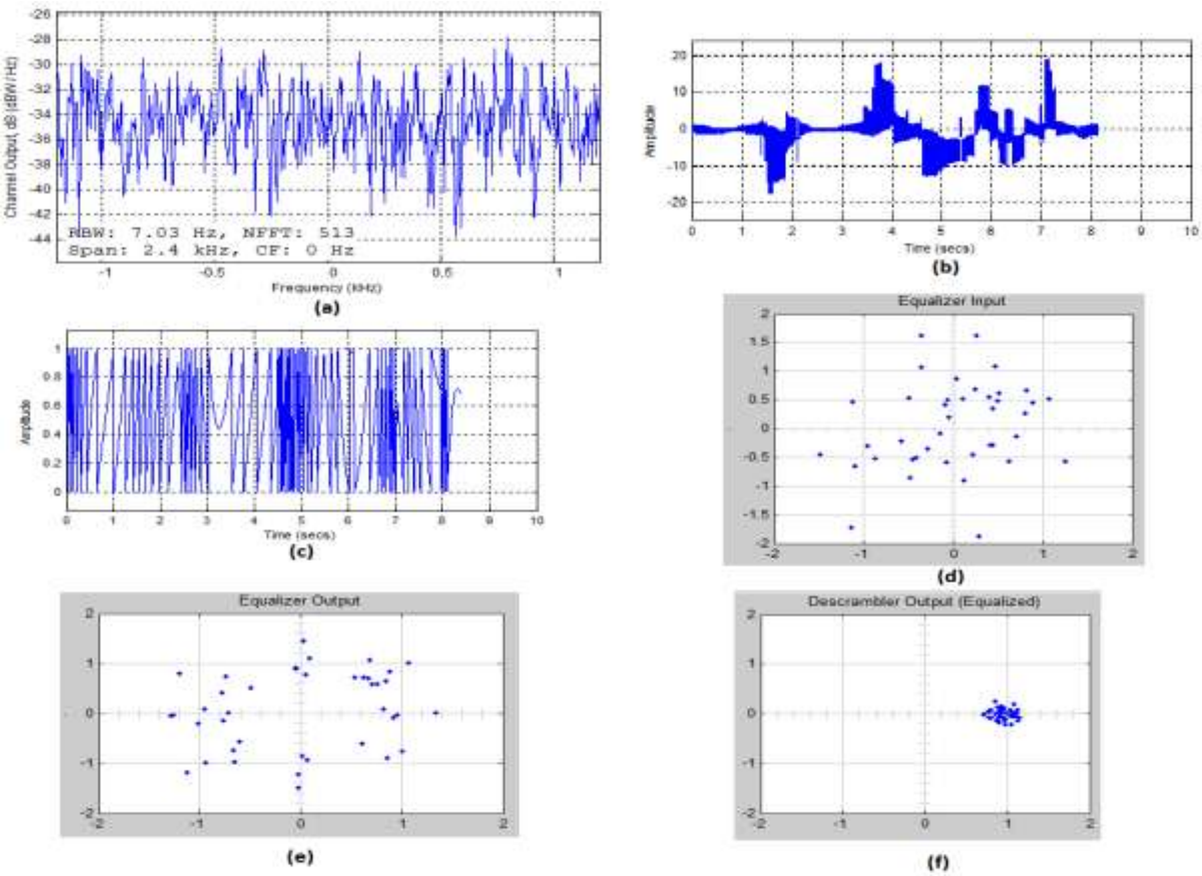

Figure 5: Plots for a fading frequency selective channel with AWGN (a)The channel output power spectrum (b)Estimate of the cross-spectral phase between the equalizer input and its output (c) Control signal used to drive the Farrow fractional delay (d) Scatter plot of the equalizer input (e) Equalizer output (f) Descrambler output.

5. Conclusion

This paper presented the receiver with RLS equalization properties and also analyzed the behavior of a signal over various channels. The mathematical analysis is also presented with relevant expressions. It is observed that a distortion in the signal due to the effect of the noise in the fading channel. In future, different equalizers will be analyzed for various fading channels.

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