Bayesian Equalizer for Inter-symbol and Co-channel Interference using Mamdani Fuzzy System

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***Abstract*—Linear and Non-linear distortion influenced data transmission rate in communication system. In the presence of White Gaussian Noise linear distortion occurs in form of inter-symbol interference (ISI) and co-channel interference (CCI). Amplifiers, modulator and demodulator subsystems are caused for Non-linear distortions along with nature of the medium. Different techniques are used to equalized and mitigate these effects. We present a mamdani fuzzy system of a Bayesian equalizer to eliminate the CCI using mamdani fuzzy logic system. With the help of mamdani fuzzy system we can simulate results that the equalizers based on FAFs (Fuzzy Adaptive Filters) perform better where co-channels are more than one.**

***Keywords*—Co-channel interference, Inter-symbol interference, Bayesian equalizers, adaptive filters, fuzzy logic system.**

I. Introduction And Background

The demand for cellular mobile communication for users is to reduce cell size, increasing frequency reuse. The users of one cell to the users in other cell using the same frequency are called co-channel interference (CCI). In transmission channel each received pulse is affected by adjacent pulses. This is called Intersymbol interference (ISI). Intelligent allocation and reuse of channels throughout a coverage region in a cellular mobile communication system. The reuse of channel means reuse of frequency. In a given coverage area there are many cells that use the same set of frequencies. The interference between signals of these cells is called Co-channel interference (CCI) and these cells are called Co-channel cells.
Overcome Co-channel Interference an adaptive (RBF) radial basis function network is used. After that an adaptive fractionally spaced decision feedback equalizer (DFE) is used to eliminate CCI in a multipath fading environment.

A Bayesian DFE was used for CCI. Recently a fuzzy adaptive filter (FAF) type-1 is used to eliminate CCI.
The fuzzy adaptive filter (FAF) is model free approach but Bayesian decision is based on a probability model. If the data is not according the model signal processing results will not be good and if the data according with the model the then statistical signal processing result will be good.

Linguistic uncertainties handle by fuzzy set, as typified by the adage “words can mean different things to different people.” Karnik and Mendel established a complete Type-2 fuzzy logic systems theory to handle linguistic and numerical uncertainties, Liang and Mendel proposed a type-2 FAF and applied it to time-varying channel equalization.

In this we apply Mamdani Fuzzy FAFs Bayesian equalizer to a decision feedback equalizer (DFE) for eliminating CCI and ISI. The equalizer present in the receiver should be capable of compensating ISI and CCI effects with limited computational complexity. We interpret in this paper that CCI as an uncertain disturbance added to the channel states. Theoretical analysis shows that the interpretation matched the reason of existence.

II. System Model

A. Communication Interference

High speed data transmits over the channels in communication systems. During this process the transmitted data is corrupted due to the effect of linear and nonlinear distortions.
Linear distortion includes inter-symbol interference (ISI), co-channel interference (CCI), and adjacent channel Interference (ACI) in the presence of additive white Gaussian noise (AWGN). The nonlinear distortion occurs in the system by impulse noise, modulation, demodulation, amplification

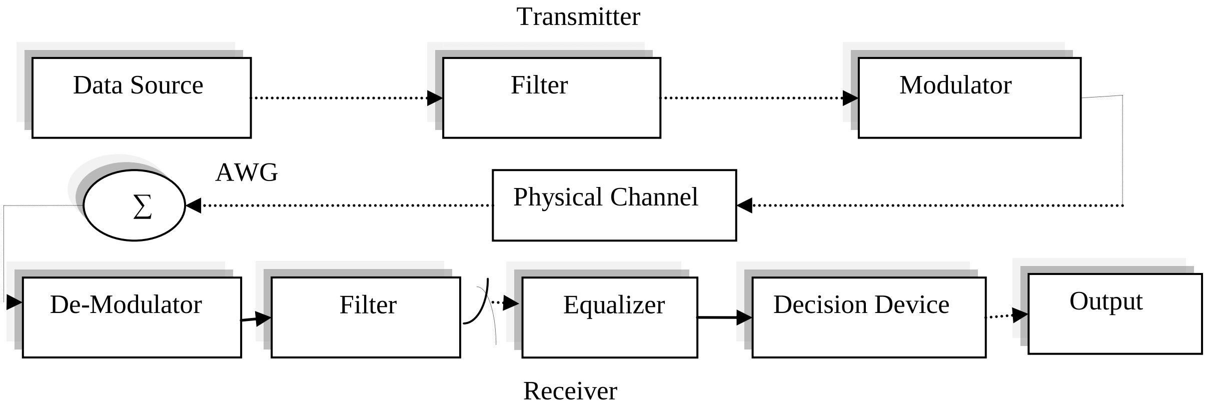

Fig: Block Diagram of Digital Communication System

The following sections briefly describe the linear and nonlinear interferences.

B. *Inter Symbol Interference (ISI)*

Inter-symbol interference (ISI) arises when the data transmitted through the channel is dispersive, in which each received pulse is affected somewhat by adjacent pulses and due to which interference occurs in the transmitted signals.

C. *Co-Channel Interference and Adjacent Channel Inteference*

Co-channel Interference (CCI) and Adjacent Channel Interference (ACI) occur in communication systems due to multiple access techniques using space, frequency or time. CCI occurs in cellular radio and dual-polarized microwave radio, for efficient utilization of the allocated channels frequencies by reusing the frequencies in different cells.

A digital communication system model where s(t) is the transmitted symbol sequence, is additive white Gaussian noise, is a received signal sequence sampled at the rate of the symbol interval Ts, is an estimate of the transmitted sequence s(t) and d denotes the delay associated with estimation. The received signal is additionally corrupted by n co-channel interference

sources. The receiver has a copy of the training signal transmitted by the transmitter.

D. *Burst Noise Interference*

Burst noise is a high intensity noise which occurs for short duration of time with fixed burst length means a series of finite-duration Gaussian noise pulses.

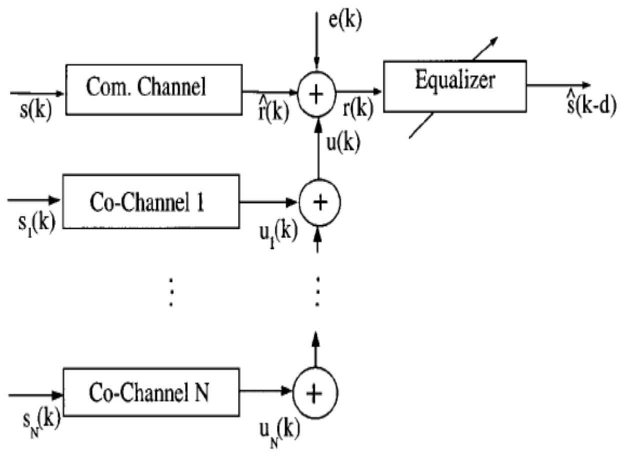

Figure: discrete time model of communication system subject to ISI, CCI and AGN ref-[1].

III. EXPERIMENTAL SETUP

A. *Features of Equalization*

Intersymbol interference distortion causes symbols to overlap in Time-dispersive channels and become in distinguish by the receiver. For example, in a multipath scattering environment, the receiver sees delayed versions of a symbol transmission, which can interfere with other symbol transmissions. An equalizer attempts to mitigate ISI and improve receiver performance.

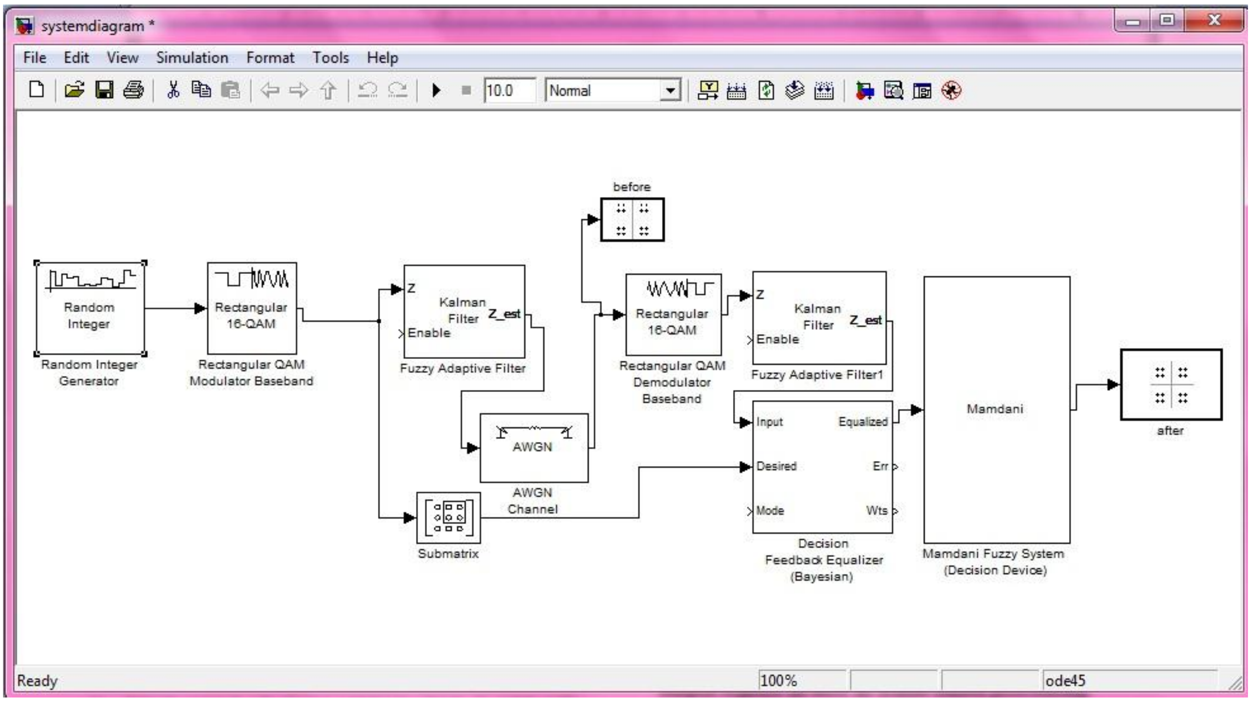

Fig: Proposed system model for Bayesian equalizer using Mamdani neuro fuzzy system

B. Random Integers

Generate random uniformly distributed integers in the range [0, m-1], where m is the m-ary number.

C. Rectangular QAM Modulator Baseband

Modulate the input signal using the rectangular quadrature amplitude modulation method. The m-ary number must be an integer power of two.

D. Submatrix

Return selected portion of input matrix 1-D input signals are treated as 2D column vectors. The output is always 2-D.

E. Kalman Filters

Estimate the state of a dynamic system from a series of incomplete and / or noisy measurements. This block can use the previously estimated the state to predict the current state. It can also use the current measurement and the predicted state to estimate the current state value.

All filters have the same state transition matrix; measurement matrix, initial conditions and noise covariance, but their state measurement enable and MSE signals are unique. Within the state, measurement, enable and MSE signals, each column corresponds to a filter.

F. AWGN (Add White Gaussian Noise)

AWGN to the input signal. The input and output signal can be real or complex. This block supports multichannel input and output signals as well as frame based processing.

When using either of the variance modes with complex inputs, the variance values are equally divided among the real and imaginary components of the input signal.

G. Decision Feedback Equalizer (Bayesian)

Equalized modulated signal through a dispersive channel using a Bayesian (DFE) equalizer and the Baye's theorem.

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)},$$

Where *A* and *B* are events.

- *P* (*A*) and *P* (*B*) are the probabilities of *A* and *B* without regard to each other.
- *P* (*A* | *B*), a conditional probability, is the probability of observing event *A* given that *B* is true.
- *P* (*B* | *A*) is the probability of observing event *B* given that *A* is true.

The leakage factor must be in the range 0 and 1.

H. Mamdani Neuro Fuzzy System

Mamdani's method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani [14] as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani's effort was based on Lotfi Zadeh's 1973 paper on fuzzy algorithms for complex systems and decision processes [15]. Although the inference process described in the next few sections differs somewhat from the methods described in the original paper, the basic idea is much the same.

After find out the data from demodulation we will pass that data through mamdani neuro fuzzy system and then we will find out our desired result.

The choice of neuro fuzzy system is of mamdani neuro fuzzy system rather than takagi sugeno model because mamadani based system are human friendly and easily understandable. Mamdani type fuzzy inference gives an output that is a fuzzy set.

E.g. Mamdani:

If A is X1, and B is X2, then

C is X3. (X1, X2, X3 are fuzzy sets).

IV. Conclusion and Future Work

The key objective of the paper is to develop novel artificial neural network equalizer (trained with linear, nonlinear) to reduce the linear and nonlinear distortion like ISI, CCI and burst noise interferences occurs in the communication channel and can provide minimum bit-error-rate plot for extensive assortment of channel condition.

Using DFE with Mamdani based neuro fuzzy system (decision device) reduces computational complexity, and increases the performance. BER performance will be minimizing and better using this system. Mamdani handles linguistic errors efficiently with interpretability. We will use Matlab 7.6 for simulation. System model has been prepared. The implementation is carrying out in Matlab 7.6 (R2008a) and NeuCom.

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