SIMULATION OF FREQUENCY SELECTIVE RAYLEIGH FADED HF CHANNEL FOR DATA TRANSMISSION USING DECISION FEED BACK EQUALIZER

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Abstract

Communication using the High Frequency (HF) band has been a primary means of beyond line of sight communication. Despite the advent of several other kinds of transmitting media it continues to be used extensively owing to the fact that it is economical and flexible.

The use of a channel simulator for evaluating the performance of a data transmission system offers several advantages. The HF channel model is simulated and degree of accuracy between input and output is observed. Efficiency of this model derived from the decision feedback equalizer is good even under severe distortion.

Unlike cables, whose properties can be accurately defined and reproduced, Ionosphere channel properties can’t be reproduced easily, transmission conditions vary uncontrollably and it is not possible to test a system repeatedly for the same channel conditions. This simulator is accurate and a large range of channel conditions can be produced in a controlled manner. It is possible to compare the performance of several systems under the same channel conditions using a channel simulator. And tests can be repeated any number of times with consistent channel transmitting conditions.

Index Terms: Channel modeling, DPSK, Decision feedback equalizer

1. INTRODUCTION

Communication using High frequency (HF) band between 2 Hz and 30 MHz has been a primary means of beyond line of sight communication. In this paper the design and implementation of channel model over a frequency selective Raleigh fading HF channel is dealt with. The proposed model is based on Differential Phase Shift Keying (DPSK) modulation in which Synchronization and Doppler correction are made with the inclusion of preamble and a special sub carrier in the transmitted signal. In particular the channel is modeled for the transmission of data at 2400bps or at any speed as per the requirements.

When a complex valued signal is transmitted through a frequency selective fading channel with low – pass equivalent, the time variant channel impulse response will have two components viz., Direct component and a Dispersive Rayleigh faded component. The received signal will consist of a number of time variant phasors, which the vector sum of different waves received after reflections by Ionosphere layers from a number of paths. It can be expected that due to randomly varying delays associated with different paths, the received signal can be modeled as random process. When the impulse response of channel is modeled as zero mean complex valued Gaussian process, the envelope of it at any instant’ is Rayleigh distributed. Due to its correspondence with the observed characteristics of High Frequency and a troposcatter channels, the Rayleigh fading model is widely accepted.

DPSK is used for transmitting the bits in which information is encoded into phase differences between two successive signaling intervals. The phase corresponding to a pair of bits is added to the phase shift corresponding to the previous pair to get phase shift to present pair. In doing so, the effect of multi-path, which causes phase errors, will be reduced. Comparing the phase of the received signal between two successive intervals does the demodulation.
The computer simulation of HF channel model using C showed good degree of accuracy between input and output. It can be shown that the efficiency of the model derived from the decision feedback equalizer is good even under severe distortion. The signal to noise ratio increases with bit duration but it is within the limits for good to worst channel conditions. The minimum bit error rates are in the 0.01 to 0.001, which can be further increased by using Hamming code techniques. The radiation and insertion losses are varying exponentially with frequency and these losses are well within ± 6.5 dB range with an average value of 32.607 dB. Further the simulation of HF channel model exhibits excellent response viz., uniform response throughout the message of lengths of 1 to 140,000 characters.

2. DATA GENERATION

The signals leaving the transmitter reach the distant receiving points. After reflection from the ionized regions they may arrive the receiver following different paths leading to time dispersion. The signal received at any instant at the receiver is vector sum of all the waves received. This results in different distortions being introduced. Multipath propagation is one of the factors, which introduces the fading causing undesirable change in intensity and loudness of the received signals.

Figure (1) shows the model of data transmission system using DPSK. The input to the system is the message of ‘L’ number of characters. Represented by

\[ S(t) = \{ U(t) \exp (j2\pi f_c t + \theta) \} \] \hspace{1cm} (2.1)

The model converts the given text into ASCII code and supplies the bit stream to DPSK encoder. The general representation for a set of M-ary phase signaling waveform is

\[ S(t) = \{ U(t) \exp j(2\pi f_c t + 2\pi (m-1)/M + \theta) \} \] \hspace{1cm} (2.2)

In practice we seldom have prior knowledge of the exact channel characteristics. The net result is that there will be some residual distortion like ISI like a limiting factor on the data of the system. To compensate for the intrinsic residual distortion we can use Equalization process. Decision Feedback Equalization is the better one among the available equalizers. It yields good results ever in the presence of severe ISI and noise.

The impulse response of base-band channel be denoted by \( h_n = h(nT) \). The response of t channel to an input sequence \( \{X_n\} \), in the absence of noise is

\[ y_n = \sum h_k x_{n-k} \] \hspace{1cm} (2.3)

Where

1st term = Desired data symbol
2nd term = Precursors of the channel impulse response that occur before the sample associated with the desired data symbol
3rd term = Post cursors of the channel impulse response that occur after the sample.
The idea of decision feedback equalization is to use data decision made on the basis of precursors of the channel impulse response to take care of the post cursors.

A decision feedback equalizer consists of a feed forward section and a decision device shown in fig (2).

![Fig(2) Decision Feedback Equalizer](image)

The feed forward section consists of a tapped delay line filter, whose taps are spaced at reciprocal of the signaling rate. The data sequence to be equalized is applied to this section. The feedback section consists of another tapped delay line filter, whose taps are also spaced at the reciprocal of the signaling rate. The input applied to the feedback section consists of the decision made on the previously detected symbols of the input sequence. The function of the feedback section is to subtract out that portion of the ISI.

3. DATA TRANSMISSION

When \( S(t) \) is fed into a single Rayleigh fading HF channel, the output would be

\[
X(t) = S'(t)q_1(t) + S^*(t)q_2(t)
\]

Where \( q_1(t) \) and \( q_2(t) \) are random processes.

Filtering the zero mean white Gaussian noise signals through a Bessel filter has generated the random processes. The frequency and impulse response of Bessel filter approaches Gaussian when the order of the filter is sufficiently large.

\[
S^*(t) = S'(t) * f(t)
\] (3.2)

Where \( f(t) \) is the impulse response of Hilbert Transform filter

\[
S^*(T) = \{ \sum S_i g(t-iT) + \sum S_i^* g(t-iT) \} * f(t)
\]

\[
= \sum S_i g(t-iT) * f(t) + \sum S_i^* g(t-iT) * f(t)
\]

(3.3)

(3.4)

Where \( S_i^* \) is complex conjugate of \( S_i \). For the simplicity sake let us consider that the HF channel has three independent Rayleigh-fading sky waves. The same logic can however be extended to any number of sky waves. The relative delay of the two sky waves from direct path is \( \tau \) seconds and \( \tau_1 \) seconds respectively. The output from the channel is \( X(t) \).

While passing through the channel, the signal is modified as a result of random noise \( n(t) \) added to it. The noisy signal \( X'(t) \) is then passed through receiver filter \( C(t) \). The receiver filter’s output is \( Y(t) \). The output of the matched filter \( d(t) \) is given to the demodulator where the signal splits into inphase (I) and quadrature (Q) channels. The input to the matched filter is given by \( Y'(t) \). \( n(t) \) is the noise produced at the output of receiver filter due to Additive White Gaussian Noise AWGN at the receiver input. This can be written as

\[
Y'(t) = \{ \mu \sum a_i p(t-kT) n(t) \} \exp (-j2\pi f_c t)
\]

(3.5)

\[
\mu p(t) = X(t) * C(t) * d(t);
\]

\[
Y'(t_i) = \mu a_i + \mu \sum k# a_k p((i-k)T) + n(t_i)
\]

(3.6)

4. DATA RECOVERY

In the absence of noise, in the \( i^{th} \) signaling interval, the received signal can be simply represented as

\[
R_c(t) = \sin (2\pi f_c t + \theta + \phi_1)
\]

(4.1)

The inphase (I) channel of demodulator gives

\[
X_c = \int_{T_1}^{T_2} S_i(t) \cos (2\pi f_c t) dt
\]

(4.2)

Where \( T_1 - T_2 \) corresponds to a time period in which \( f_c \) has an integral number of cycles.
Xp = X\(_{i-1}\) = XC in the previous signaling interval.

\[
Xp = \frac{1}{2} \cos (\theta + \phi_{L-1})
\]

Assuming path delay is constant for two successive signaling intervals. Similarly the quadrature phase (Q) channel of demodular will give.

\[
Yc = \int_{T_1}^{T_2} S_i(t) \cos (2\pi f_c t) dt
\]

(4.3)

Yp = Y\(_{i+1}\) = YC in the previous signaling interval.

\[
Yp = \frac{1}{2} \cos (\theta + \phi_{L-1})
\]

The final outputs of the system are R and Q signals.

\[
R = Xc \times Xp + Yc \times Yp
\]

And \(Q = Xc \times Yp - Yc \times Xp\)

The decision is now made on the basis of the signs of ‘R’ and ‘Q’ signals. The period of integration \(T_2-T_1\) makes it possible to avoid the use of bandpass filters to separate out noise (if any) from received signal.

REFERENCES


