Investigation the Optimum Frequency Response of Transceiver Performances

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Abstract

In discrete multitone (DMT) transceivers an intelligent guard time sequence, called a cyclic prefix (CP), is inserted between symbols to ensure that samples from one symbol do not interfere with the samples of another symbol. The length of the CP is determined by the length of the impulse response of the effective physical channel. Using a long CP reduces the throughput of the transceiver, To avoid using a long CP, a short time-domain finite impulse response (FIR) filter is used to shorten the effective channels impulse response. This paper explores various methods of determining the coefficients for this time-domain filter. An optimal shortening and a least-squares (LS) approach are developed for shortening the channel's impulse response. To provide a computationally efficient algorithm a variation of the LS approach is explored. In full-duplex transceivers the length of the effective echo path impacts the computational requirements of the transceiver. A new paradigm of joint shortening is introduced and three methods are developed to jointly shorten the channel and the echo impulse responses in order to reduce the length of the CP and reduce computational requirements for the echo canceller

Keywords— **Discrete cosine transform (DCT), frequency-selective channel, guard sequence, multicarrier modulation (MCM),**

I. INTRODUCTION

MULTICARRIER modulation (MCM) based on the discrete Fourier transform (DFT) has been adopted as the modulation/demodulation scheme of choice in several digital communications standards. These include wire line systems such as digital subscriber lines (DSL), where it is commonly known as discrete multitone (DMT), and wireless systems such as digital audio and terrestrial video broadcast (DAB/DVB-T), local area networks (IEEE 802.11a/g/n), and metropolitan area networks (IEEE802.16a), where it is commonly known as orthogonal frequency-division multiplexing (OFDM). In this paper, we shall refer to it generically by DFT-MCM.. DFT-MCM divides the frequency response of a finite-impulse response (FIR) frequency-selective channel into parallel, decoupled, and memory less sub channels by adding a special guard sequence known as a *cyclic prefix* (CP) to each information block. This CP guard sequence (of length at least equal to the channel memory) is chosen as a *periodic* extension of the information sequence, causing the linear convolution performed by the FIR channel to resemble a circular convolution. This renders the equivalent channel matrix *circulate*, and hence, perfectly diagonalizable by the DFT. [1-4].

II. OPTIMUM TERMINAL FILTERS

Having abandoned rectangular pulses we must likewise abandon the conventional matched filter and reconsider the design of the optimum receiving filter that minimizes error probability. This turns out to be a relatively straightforward problem under the following reasonable conditions:[3-6].

1- The signal format is polar, and the amplitudes a_k are uncorrelated and equally likely.
2- The transmission channel is linear but not necessarily distortion less.
3- The filtered output pulse $p(t)$ is to be Nyquist shaped.
4- The noise is additive and has a zero-mean Gaussian distribution shown in figure .1

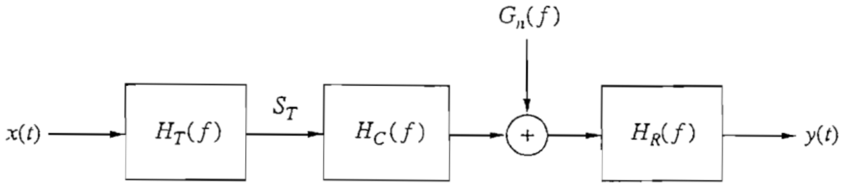

Figure .1. Noise additive and Gaussian distribution model

However may have a non white power spectrum the transmitted signal is given by

$$x(t) = \sum_{k=-\infty}^{\infty} a_k h_T(t - kT) \qquad (1)$$

Where $h_T(T)$is the impulse response of the transmitter filter that has the low pass transfer function $H_T(f) = \beth[h_T(T)]$. This signal passes through a bandlimited channel filter , after which Gaussian noise with power spectral density $G_n(f)$ is added to give the received signal [7, 8].

$$y(t) = x(t) * h_c(t) + n(t) \qquad (2)$$

Where $h_C(t) = \beth^{-1}[H_C(f)]$ is the impulse response of the channel . Detection at the receiver is accomplished by passing $y(t)$ through a filter with impulse response $h_R(t)$ and sampling is output at intervals of Tseconds . If we require that cascade of transmitter , channel and receiver filters satisfies Nyquistis pulse-shaping criterion , it then follows that output sample at time $t = t_d$ where t_d is the delay imposed by the channel and the receiver filters is

$$V = Aa_0 + N \qquad (3)$$

Where

$$Ap(t - t_d) = h_T(t) * h_C * h_R \qquad (4)$$

$$N = n(t) * h_R(t) \qquad (5)$$

We assume binary signaling ($a_m = 1\ or - 1$) so that the average probability of error is

$$P_\varepsilon = P(Aa_m + \geq 0\ given\ a_m = -1 \qquad (6)$$

$$P_E = P(N \geq A) = \int_A^\infty \frac{\exp\left(-\frac{u^2}{2\sigma^2}\right)}{\sqrt{2\pi\sigma^2}} du = Q\left(\frac{A}{\sigma}\right) \qquad (7)$$

Where

$$\sigma^2 = var(N) = \int_{-\infty}^{\infty} G_n(f)[H_R(f)]^2 \qquad (8)$$

Subject to the constraint in equation 4 by applying Schwarz's inequality. The result is given by

$$[H_R(f)]_{opt} = \frac{K[P(f)]^{\frac{1}{2}}}{G_n^{\frac{1}{4}}(f)[H_C(f)]^{\frac{1}{2}}} \qquad (9)$$

and

$$[H_T(f)]_{opt} = \frac{A}{K}[P(f)]^{\frac{1}{2}} G_n^{\frac{1}{4}}(f)/[H_C(f)]^{\frac{1}{2}}$$

Where K is an arbitrary constant and any appropriate phase response can be used A special case of interest occurs when

$G_n(f) = \frac{N_0}{2}$, all f (white noise)

and

$$H_C(f) = H_0, [f] \le \frac{1}{2T}$$

The minimum probability of error is simplified to

$$P_{E,min} = Q\left(\frac{\sqrt{2E_T}}{N_0}\right) \qquad (10)$$

Where

$$E_T = \int_{-\infty}^{\infty} [H_T(f)]^2 df$$

Is the average transmitted signal energy .This result is identical to that obtained previously for binary signaling in an infinite bandwidth baseband channel.[9, 10].

III. SIMULATION RESULTS

Optimum frequency responses ,$H_T(f)$ and $H_R(f)$,for an arbitrary data rate ,raised cosine pulse shaping , and an n th-order Butterworth frequency response for the channel is given in figure 1 .The simulation result of an optimum filter frequency response functions for raised- cosine signaling through a band limited channel is shown in figure .2.

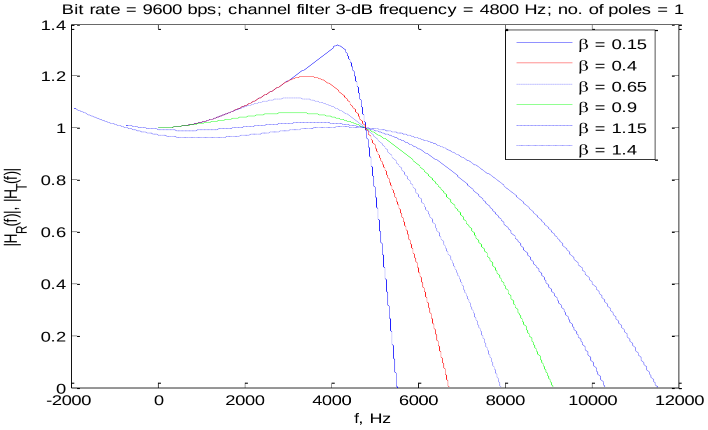

Figure. 2 Optimum filter frequency response functions for raised- cosine signaling through a band limited channel

IV. CONCLUSIONS

In summary, our results in this paper show that DCT-MCM is a viable multicarrier transceiver which can be competitive with DFT-MCM in some practical scenarios. An interesting topic for future research is to perform more extensive performance comparisons between DFT-MCM and DCT-MCM under additional real-world channel impairments, such as in-phase/quadrature phase imbalance, timing offset, multipath spread longer than CP leading to IBI and ICI effects, NBI, channel-estimation errors, amplifier nonlinearities, and Doppler (mobility) conditions leading to additional IBI/ICI degradation.

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