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A Wavelet Multiplexing to Reduce Phase Noise Effects in OFDM based DVB-t

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is a highly recommended multiplexing/modulation scheme for high data rate communications due to its high spectrum efficiency and robustness against Inter Symbol Interference (ISI). The OFDM is based on dividing the available spectrum into narrow band orthogonal subcarriers and modulating data on each subcarrier. Due to long symbol period, OFDM system is more sensitive to phase noise of the oscillator compared to single carrier systems. The Phase noise of oscillators used in the transmitters & receivers results in two effects, Common Phase Error (CPE) & Inter Carrier Interference (ICI). These effects results in increasing SNR requirement at the receiver to achieve certain BER. The design & simulation of OFDM based DVB-t system with wavelet multiplexing & demultiplexing and analysis of phase noise effects on BER is presented in this paper. The performance of simulated DVB-t system is analysed by considering SNR requirement to achieve certain BER in the presence of oscillator instabilities on AWGN & mobile radio channels. The modelled Wiener phase noise is generated for different 3 dB bandwidths of noise spectrum. The simulation results shows that, the SNR required to achieve a bit rate of 10^{-2} in wavelet multiplexing is around 6dB lower as compared to FFT counterpart. The result also reveal that PAPR is also less, however wavelet multiplexing computational intensive.

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Keywords: OFDM; Phase Noise; Wavelets; Mobile Radio Channel; Orthogonal; Biorthogonal; QAM; DWT; PAPR

1. Introduction

OFDM is parallel transmission scheme where data symbols are modulated over orthogonal complex exponential sub-carriers. OFDM is widely used in modern and next generation wireless communication systems like WiMAX, WLAN, Digital Television and Audio Broadcasting and 4G mobile applications.

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Due to its long symbol period, OFDM imposes strict constraints on the allowable impairments in RF oscillators used at transmitter & receiver. The low cost tuners used at the receiver, usually possess high phase noise characteristics. The multiplexing & demultiplexing in OFDM transmission scheme is traditionally realized using IFFT & FFT respectively. This paper presents a method to realize OFDM system by applying wavelet multiplexing and analysing BER performance in the presence of oscillator instabilities.

The oscillators phase noise in OFDM transmission scheme results in two effects: Common Phase Error (CPE) and Inter Carrier Interference (ICI). The CPE is common angular rotation of complex data symbols transmitted on all subcarriers in an OFDM symbol. Due to lack of orthogonality among the subcarriers, ICI results in increase of SNR degradation at the receiver.

Many authors have compared performance of OFDM realized using Fourier & Wavelets[1]. It was shown that, required E_b/N_0 to achieve certain BER in later is less. In papers[2, 3], the authors have shown that OFDM and Wavelet Packet Modulation (WPM) are equally affected by RF oscillators phase noise & frequency offset. The B.G. Negash, etal[4] have shown that, the multi carrier modulation realized using wavelet has stronger suppression towards ISI and ICI than the conventional OFDM scheme. In paper[5], authors have compared BER performance of FFT OFDM & Wavelet OFDM in the presence of oscillator phase noise. The results shows that wavelet OFDM performs better.

2. System Model

The different blocks of OFDM transmitter & receiver in baseband is shown in figure 1. The high speed serial binary data stream to be sent is converted to low speed parallel symbols. The constellation mapping block selects M-ary QAM, according to the needed data rate for the application. As shown in Fig. 1, the complex data symbols $Z_m(k)$ are generated by M-ary QAM modulator before multiplexing the symbols using IFFT, with N subcarriers. An OFDM symbol is generated by adding N_p pilots & N_{cp} cyclic prefix symbols. Where $N_{cp} \geq$ L, number of multipath taps of time varying fading channel. The baseband representation of the received signal $y_m(n)$ in time domain is given by,

$$y_m(n) = \left(h_m(n) * s_m(n)\right)e^{j\theta_m(n)} + w_m(n) \tag{1}$$

Where, $h_m(n)$ represents impulse response of multipath channel for m^{th} OFDM symbol. The $w_m(n)$ indicates zero mean complex Gaussians noise with variance σ_w^2. The $\theta_m(n)$ indicates phase noise at receiver for m^{th} OFDM symbol at time index n. The phase noise is considered at receiver, as the noise at the transmitter is very less. After removing cyclic prefix, the FFT demultiplexing is applied. The received symbol on k^{th} sub carrier is given by,

$$Z_m(k) = \left(\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1}\sum_{l=0}^{L-1} h_m(l)S_m(n-l)e^{-j\frac{2\pi kn}{N}}\right)e^{j\theta_m(n)} + \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} e^{-j\frac{2\pi kn}{N}} w_m(n) \tag{2}$$

3. Phase Noise Model

In an ideal oscillator, the phase transition over a given time interval is constant and the output signal is perfectly periodic. However in practical oscillators, the amount of phase increment is a random variable. This phase variation is called Phase Noise (PN) or phase jitter[6, 7]. The output of practical oscillator in time domain is given as,

$$a(t) = e^{j(2\pi f_0 t + \theta(t))} \tag{3}$$

Where, $\theta(t)$ denotes a random process of phase noise. The phase noise is often expressed as ratio of power in single side band spectrum at an offset frequency Δf from center frequency f to the total power P_{Total}[8].

$$\mathcal{L}(f) = 10\ \log\left(\frac{P_{SSB}(f + \Delta f)}{P_{Total}}\right) \tag{4}$$