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PROPOSAL OF NEW PULSE SHAPING METHOD FOR SIDE LOBES REDUCTION IN OFDM SYSTEM

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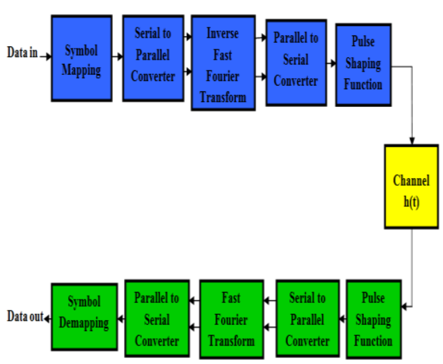
Graphical abstract



Abstract

In this paper, we propose a new pulse shaping method namely scale alpha for orthogonal frequency-division multiplexing (OFDM) system. The suggested pulse shape is designed and simulated using Matlab software. The results show that scale alpha has a better impulse response in both time and frequency domains with minimum side lobes compared to Franks, raised cosine, and double-jump pulses.

Keywords: OFDM, pulse shaping, scale alpha, Nyquist pulse

1.0 INTRODUCTION

In the last few years, multicarrier transmission techniques like orthogonal frequency-division multiplexing (OFDM) has emerged as one of the leading candidates for higher data rate transmission. OFDM is a potential technique for the wideband wireless communication systems especially in fourth generation (4G) applications [1]. This technique has been originally deployed in scenarios where time-selectivity can be effectively ignored. It has been employed for various wireless standards, including IEEE 802.11a and HiperLAN2 [2]. The need for the application of multicarrier system in high mobility channels has become important. OFDM also has its own advantages and disadvantages. The most important advantage of the OFDM system is its capability of converting a frequency selective fading channel into different nearly flat fading subchannels as the entire available spectrum is classified into a number of narrow band subchannels [3]. The high spectral efficiency of OFDM system is obtained by overlapping the orthogonal frequency responses of the subchannels. Nonetheless, one of the major drawbacks of OFDM is the sensitivity versus carrier frequency offset that causes attenuation and rotation of subcarriers, and inter-carrier interference (ICI) [3]. There are several mitigation methods of ICI in OFDM systems which include maximum likelihood (ML), extended Kalman filter (EKF), self-cancellation (SC), and pulse shaping. Maximum likelihood approach provides the same level of redundancy but offers an enhanced bit-error rate (BER) performance because it accurately estimates the frequency offset. Self cancellation method does not need a complex hardware or software for implementation. EKF implementation is more complex than the maximum likelihood (ML) method but provides an improved BER performance. For very small frequency offset, it does not perform well, as it hardly improves the BER performance. For high frequency offset, the EKF does perform extremely well. The main advantage of EKF method is that it does not reduce bandwidth efficiency as in SC method [4]. The pulse shaping approach is another method for reducing ICI and thereby allowing for higher mobility in OFDM. Pulse shaping also reduces out-of-band emissions, the sensitivity to narrowband interference and synchronization errors [5]. The pulse shaping filter has two properties; the first one is a high stop-band attenuation to reduce the ICI as much as possible and the second one is to minimize intersymbol interference (ISI) in order to accomplish a BER as low as possible. The first Nyquist criterion states that in order to achieve an ISI-free transmission, the impulse response of the shaping filter should have zero crossings at multiples of the symbol period.

In this paper, we focused on pulse shaping method. Pulse shaping filters are utilized at the heart of many modern data transmission systems such as mobile phones and high-definition television (HDTV) to keep a signal in an allotted bandwidth, maximize its data rate, and minimize transmission errors. In the pulse shaping method, there are six Nyquist pulseswhich are double-jump pulse, second order continuous window (SOCW) pulse, polynomial pulse, raised cosine pulse, "Better than" raised cosine pulse and Franks pulse[6]. In this work, we used three important and popular Nyquist pulses namely double-jump, raised cosine and Franks pulses. From the references [6 - 8], it was stated that Franks pulse has the best performance among the other pulses. Here, we have presented a new pulse shaping method named scale alpha to improve the impulse response in both time and frequency domains through reducing the side lobes compared to other reported pulses.

2.0 EXPERIMENT

The received signal$r(t)$ at the receiver can be represented as:

$$r(t) = x(t) \otimes h(t) + n(t) \qquad (1)$$

In (1), the convolution is denoted by $\otimes$,$h(t)$ is the channel impulse response and the additive white Gaussian noise is represented by $n(t)$ [8].

Each carrier in the OFDM spectrum is represented by main lobe with number of side lobes having lower amplitudes. Since peak power is associated with main lobe and ICI power is associated with side lobes, so the motive of pulse shaping function is to increase the width of main lobe and reduce the amplitude of the sidelobes [9, 10]. In this section, some most commonly used pulse shaping functions have been introduced. These functions are raised cosine, double-jump, Franks pulse and the new scale alpha pulse. The Fourier transform of the raised cosine, $p_{rc}(f)$ is defined as [6]:

$$p_{rc}(f)=\mathrm{sinc}(fT_u)\frac{\cos(\pi\alpha fT_u)}{1-(2\alpha fT_u)^2} \qquad (2)$$

where T_u is the time spacing and α is the roll-off factor.

The Fourier transform of the double jump, $p_{dj}(f)$ is given by [6]:

$$p_{dj}(f)=\mathrm{sinc}(fT_u)\cos(\pi\alpha fT_u) \qquad (3)$$

where,

$$\mathrm{Sinc}(x)=\begin{cases} 1, & x=0 \\ \frac{\sin(\pi x)}{\pi x}, & x\neq 0 \end{cases}$$

The Fourier transform of Franks pulse, $p_f(f)$ can be represented as [6]:

$$p_f(f) = \mathrm{sinc}(fT_u)[(1-\alpha)\cos(\pi\alpha fT_u + \alpha sinc(\alpha fT_u)] \quad (4)$$

The time domain equation of the new scale alpha pulse can be written as:

$$p_{s-a}(t) = \mathrm{phi} \times \mathrm{Cos}\theta_p \times \mathrm{Sinc}\theta_p \qquad (5)$$

where,

$$\mathrm{Phi} = (1-(t/2s)^2)\exp(-(t/2s)^2)/2 \qquad (6)$$

$$\mathrm{Cos}\theta_p = \frac{Cos\ (\alpha\pi t)}{1-(2\alpha t)^2} \qquad (7)$$

$$\mathrm{Sinc}\theta_p = \frac{Sin\pi t}{\pi t} \qquad (8)$$

$\theta_p$is the phase theta, and s is the number of scale.

By inserting (6), (7), and (8) into (5), (5) can be rewritten as:

$$p(t)_{s-\alpha} = \{(1-(t/2s)^2)\exp(-(t/2s)^2)/2\} \times \left\{\frac{Sin(\pi t)Cos(\alpha\pi t)}{\pi t - 2\pi\alpha t^2}\right\} \qquad (9)$$

Note that there are two brackets in (9) where the first one is called phi.

3.0 RESULTS AND DISCUSSION

Figure 1 shows the graph for phi and the time domain response of the proposed pulse shaping method against the time when s= 2 and different values of α. It can be observed that the new pulse has a big bend which looks better than phi. This is because the multiplication of phi with the second bracket of (9).

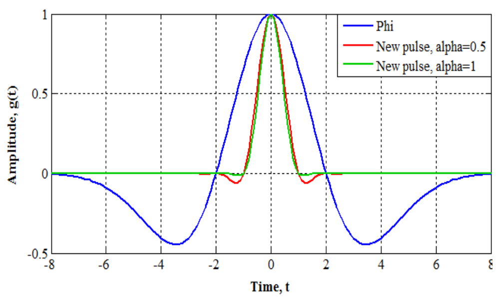


Figure 1 Phi, and the new pulse response versus time

The simulation results have been conducted using Matlab software to assess the performance enhancement of pulse shaping for the OFDM system using the various pulse shaping functions which have been mentioned in Section 2. Figure 2 compares the impulse response for different pulse shapes considered in this work, such as double-jump, raised cosine, Franks pulse, and new scale alpha pulse when *a* = 0.5. It is observed that the new scale alpha pulse shape has lesser side lobes amplitude compared to other existing pulses. So, our proposed scale alpha pulse shape has a reduced ICI power in comparison with other pulse shapes as the side lobes contain the ICI power. Moreover, the impulse response in the frequency domain is shown in Figure 3 when*a* = 0.5. Figure 4 and Figure 5 show the impulse response for *a* = 1 in time and frequency domains, respectively. It can be clearly seen that when *a*increased from 0.5 to 1, the side lobes have lower amplitudes for all pulses under investigation, which results in better system performance in terms of ICI reduction.

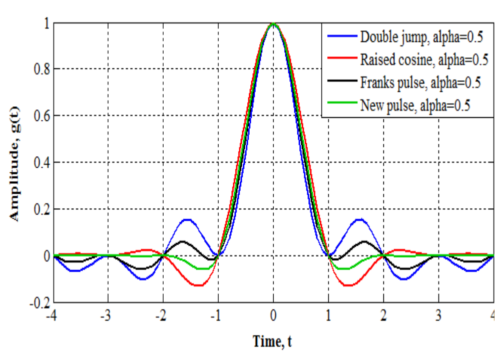


Figure 2 Comparison of impulse response in time domain when *a* = 0.5

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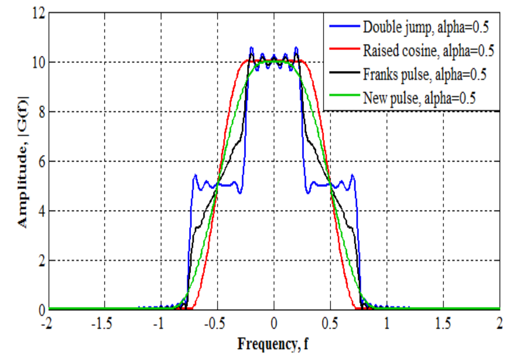

Figure 3 Comparison of impulse response in frequency domain when *a* = 0.5

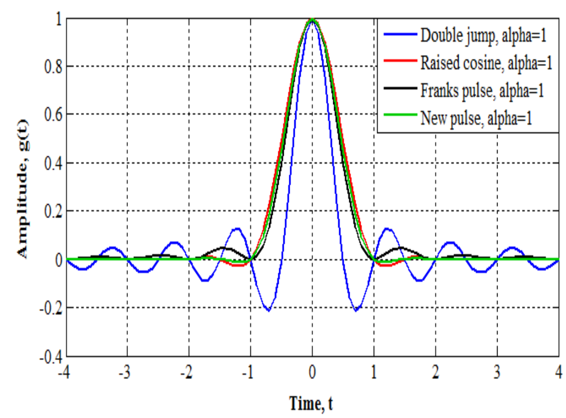

Figure 4 Comparison of impulse response in time domain for all pulseswhen *a* = 1

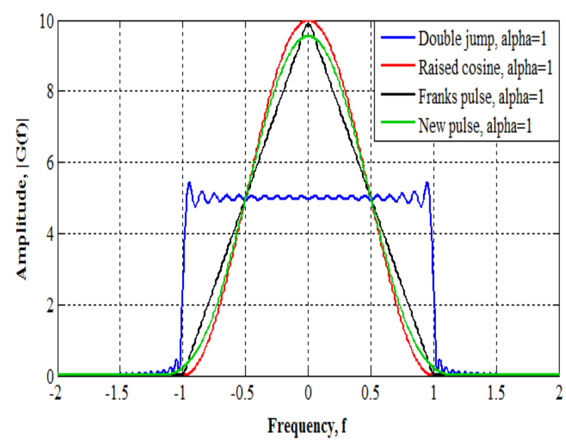

Figure 5 Comparison of impulse response in frequency domainfor all pulseswhen *a* = 1

4.0 CONCLUSION

In this work, simulation results have been presented to compare different shaping methods in OFDM system. It can be observed that our proposed scale alpha pulse has lesser side lobes amplitude compared to double-jump, raised cosine, and Franks shaping pulses. This property may help in providing better performance owing to ICI alleviation.Future work will be devoted to evaluate the ICI power reduction in OFDM system.

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