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Neutrosophic data formation using Gaussian filter based costas coding for wireless communication systems

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Abstract

Outstanding advantages of OFDM helps high data rate communication systems such as Digital Video Broadcasting (DVB) and mobile worldwide interoperability for microwave access (mobile Wi-MAX). But, OFDM system grieves from grave issue of high PAPR. In OFDM system data output is superposition of multiple sub-carriers and leads to big data. In this case some instantaneous power output might increase greatly and become far higher than the mean power of system. In order to make Neutrosophic data for less PAPR criteria, Gaussian filter based Costas coding is proposed. This paper also proposes feeding the Orthogonal Frequency Division Multiplexed signal (OFDM) into a phase accumulator to obtain frequency modulation, with the aim of reducing the peak to average power ratio (PAPR). For associated radar with modulated waveform mentioned here can be used to enhance the performance. It is widely used to analyze the variation of the output waveform further, the implementation results using MATLAB show that the ratio of average power to peak power is reducing considerably in comparing with the conventional method. Consequently; the signal can assume to fade in a frequency selective channel without an equalizer.

Keywords: Neutrosophic data; Costas codes; Ambiguity function in radar; Low papr OFDM; Pulse compression radar; Doppler frequency; Constant amplitude modulation; Side lobe level; Radar channel equalization; Gaussian filter; Phase accumulator

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1. Introduction

The Neutrosophic set model is an important tool for dealing with real scientific and engineering applications because it can handle not only it can handle not only incomplete information but also the inconsistent information which exists in common real situations. The technique of solving the minor lobe problem associated with pulsed radar had done partially by using Pulse Compression based Linear Frequency Modulation [LFM] (Rajeswari et al., 2002). Therefore suitable coding is the best alternative; Costas is a kind of time-frequency coded waveform to improve the radar performance with no side lobes (Farnane, Minaoui, Rouijel, & Aboutajdine, 2015). Consequently here in this paper, the coding which we had to set up and the Doppler frequency approaches combined with coding to generate Constant amplitude continuous phase coding (Design of frequency-coded waveforms for target detection, 2007). Henceforth the coding of Costas sequences which are carrying out there and thus the phase information is updating during each cycle by the phase accumulator, also the Doppler frequency approaches

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which we merged herein coding with OFDM to generate pre-modulation Gaussian Filter based Costas coding for Cognitive Wireless Networks.

Furthermore, Costas is a coding approach which is a time-based frequency coded waveform which has compared here with pulse compression based radar with low side lobes (Farnane et al., 2015; Li, Zhao, & Qiao, 2014). By MATLAB, results show that the ratio of average power with peak reduced considerably as compared with the conventional method. In modulation, when an operation to select the right frequency for the channel, without an equalizer, the baseband signal can assumed to fade during differential coding (Krysik, Gajo, Kulpa, & Malanowski, 2014).

Wireless Networks are considered to be the cradle of future technology. Much advancement are being incorporated in wireless technologies, one of such concepts is the concept of Cognitive Wireless Networks. A continuous series of computations that includes sensing, reasoning, advertising and reacting is referred to as cognition. The principles of cognition and wireless networking together form the Cognitive Wireless Networks, which are aware of their capabilities, internal structure and radio resources. The average transmitted power of conventional radar will increase with the increasing the transmitted pulse duration (Cook, 1960; Qadir, Kayani, & Malik, 2007). However, this technique decreases the range resolution ability of the radar by decreasing the bandwidth of the received signal. In order to give increased pulse width without compromising range resolution, a technique we use that provides for transmitting of a long pulse that has a bandwidth corresponding to the short pulse duration in the receiver (Qadir et al., 2007). Then, the received echo will processed using a compression filter to give a short pulse response to the main lobe of width 1/B that does not depend on the pulse width of the transmitted pulse (Qadir et al., 2007). Pulse compression technique enables radar to detect targets with sufficiently fine range resolution while remaining within the peak power limitations of the transmitter (Qadir et al., 2007). For a pulse Doppler radar to track a target, the target amplitude following Doppler filtering must exceed that of the clutter residual. Thus, the pulses which may occur within an interval must choose a right integer value as the blind speed for effective design of the Costas coding.

$$\text{Blind speed} = \frac{\text{Wavelength of the transmitted pulse}}{2(\text{Pulse Repetition Interval})}$$

The above relation defines that the blind speed will depend on transmitted pulse width and pulse repetition interval. By coding the pulse accordingly using Costas method, the range ambiguity and thus the Doppler approaches could be solved considerably.

In Costas coding, N number of sub-pulses are formed by dividing any transmitting pulse with a long duration of width T, whose frequencies constitute a finite set of equally spaced frequency signals that form a time-frequency-coded waveform (Sadkhan, Mohsin, & Hutahit, 2014).

Here we use pre-modulation Gaussian filtering on the transmitter side to get satisfactory prior efficiency and constant envelope properties. By applying of the above-mentioned technique offers coherent detection capability better BER performance and efficiency. This filter produces an efficient output but from the impulse response of this system is a sharp peak with relatively negligible overshoot.

However, an OFDM signal can be modulated either in phase or frequency for radar applications, which increases power and amplifier efficiency (Li, Wu, Tseng, Tang, & Chang, 2009). Thus, the amplifier operates in the region near to saturation and fading in multipath also increases. This will result in poor range resolution for radar with OFDM.

The primary drawback of OFDM is that there will be high amplitude variations of the modulated waveform and this produces high peak-to-average power ratio (PAPR) (Misaridis and Jensen, 2005). The reduction in peak-to-average power ratio (PAPR) problem associated with radar with modulated waveform mentioned it can be used to enhance the performance.

When the signal is passed through a pre-modulation filter with 0.5 modulation index then it is called as GMSK modulation (Sadkhan et al., 2014). This helps in suppressing high-frequency components. In a radar system, it consists of a transmitter and a receiver, having a fair SNR by using a GMSK filter with a name as a pre-modulation filter (Sadkhan et al., 2014). The reason is that this filter produces better accuracy and increased efficiency while filtering the signal components. In this paper, the same filter design will also use in the receiver section and is equally proportioned in the form of matched filter. Pulse shaping is an important task performed on the transmitter side and to reduce the effective bandwidth during transmission suitable Gaussian low pass filter were used (Nguyen, Salt, Nguyen & Berscheid, 2016).

The choice of bandwidth B and bit-rate T is a compromise between spectrum efficiency and BER performance (Rajeswari et al., 2002). Hence, smaller BT leads to compact spectrum and more ISI. Hence, these parameters suitably were chosen to reduce ISI while doing this paper. The above mentioned Gaussian filter introduces overlapping of the transmitted signal, and this causes the degradation and it is small if the 3 dB bandwidth bit duration product (BT) is greater than 0.5 values (Sadkhan et al., 2014). This ISI occurred by the channel can be controlled by filtering the shaped pulses (Nguyen et al., 2016). Earlier initially, the input data is in the form of NRZ, data and it is given to a pulse shaping filter (Gaussian filter) before feeding them to the LFM modulator. Digital phase modulation system involves sending information through channel either by varying the physical quantities and it is smoothed by using pulse shaping filter. The requirement of pulse shaping filter is effective to nullify the spectral leakage, reducing ISI and channel width (Nguyen et al., 2016). These result in a very compact signal spectrum and better utilization of available bandwidth. At the receiving end, the matched filter elimi-

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nates the reflected echo to overlap with a subsequent symbol period (Misaridis and Jensen, 2005).

2. System description

In this section, we give the details of Costas coding technique and how the modulation is undergone on the transmitter side. Here constant amplitude based OFDM is used to provide a constant amplitude with a relatively low PAPR value. This method explained here which involved a signal transformation from the frequency domain to time domain prior to amplification and an inverse process will be at the receiver during demodulation. Costas coding offers better correlation capabilities and is better suited for spectrum analysis. The signal transformation which is done in the time domain converts these variations of the signal with time into a constant mean power called as Constant Amplitude. This method offers a very low peak to average power ratio (Thompson, Ahmed, Proakis, Zeidler, & Geile, 2008) reduction for the conventional OFDM. This requires two steps of algorithm design.

Step 1: Time domain signals from OFDM source block having several subcarriers which are super positioned using pre-coding.
Step 2: The pre-coding weights are optimized to minimize the amplitude variations.

Here the phase accumulator will produce a sequence of phase signal. This phase signal is transformed into equivalent sine waveform by using a look-up-table. The premodulation filter helps to convert in suppressing the high-frequency components to a smooth signal. The filter output is either frequency or phase modulated to an LFM signal and then converts this signal to an analog waveform.

In Fig. 1 the phase accumulator along with D/A converter will generate a sine wave. The phase accumulator that adds each pulse to generate a sine wave signal having a frequency *Fout*.

Fout is given by

$$Fout = \left(\frac{N}{2^M}\right) \times f_c \tag{1}$$

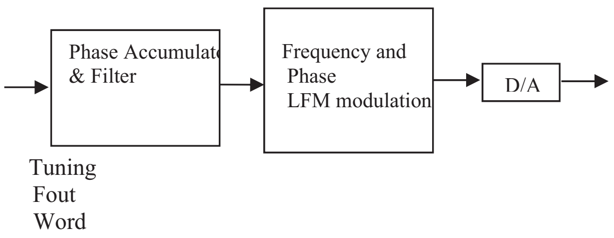

Fig. 1. Frequency generation using phase accumulator.

where M is the resolution of phase accumulator f_c is the clock frequency and N is the number of pulses that count by the accumulator.

We collectively define that M is the resolution of the tuning word (24–48 bits, depending on DDS design), and N is the number of pulses in f_c, matching the smallest incremental phase change of the phase accumulator's output word. Therefore, the tuning word is defined the output frequency as a fraction of the reference clock frequency.

The encoder here used to code the binary data sequence that can be used into its equivalent Costas code of length N. This helps the receiver to overcome the effect of noise and interference encountered in the transmission. Especially Costas coding technique is used to enable unambiguous range and Doppler measurement and at the same time minimizing crosstalk between frequencies for a particular range.

In order to reduce the ISI problems occur during transmission suitable cyclic prefix codes are inserted between the blocks. The resulting part of the peak signal is clipped off in order to avoid the higher PAPR values to the smallest value. This maintains the peak to the average ratio to a low value.

However, an OFDM signal can be modulated either in phase or frequency for radar applications, which increases power and amplifier efficiency (Li et al., 2009). Thus, the amplifier operates in the region near to saturation and fading in multipath also increases. This will result in poor range resolution for radar with OFDM.

The primary drawback of OFDM is that there will be high amplitude variations of the modulated waveform and this produces high peak-to-average power ratio (PAPR) (Misaridis and Jensen, 2005). The reduction in peak-to-average power ratio (PAPR) problem associated with radar with modulated waveform mentioned here can be used to enhance the performance and is widely used to analyze the variation of the output waveform.

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In this paper, the same filter design will also use in the receiver section and is equally proportioned in the form of matched filter. Pulse shaping is an important task performed on the transmitter side and in order to reduce the effective bandwidth during transmission suitable Gaussian low pass filter is used (Nguyen et al., 2016). The choice of bandwidth B and bit-rate T is a compromise between spectrum efficiency and BER performance (Said, El-Henawey, & El-Kouny, 2013). Hence, smaller BT leads to compact spectrum and more ISI. Hence, these parameters suitably are chosen to reduce ISI while doing this

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paper. The pre-modulation Gaussian filtering introduces ISI in the transmitted signal, but the degradation is small if the 3 dB bandwidth bit duration product (BT) is greater than 0.5 value (Sadkhan et al., 2014). This ISI occurred by the channel can be controlled by filtering the shaped pulses (Nguyen et al., 2016).

Earlier initially, the input data is in the form of NRZ data, and it is given to a pulse shaping filter (Gaussian filter) before feeding them to the LFM modulator. Digital phase modulation system involves sending information through channel either by varying the physical quantities and it is smoothed by using pulse shaping filter. The requirement of pulse shaping filter is effective against eliminating spectral leakage, reducing the channel width and also to eliminate the ISI (Nguyen et al., 2016). This result in a very compact signal spectrum and better utilization of available bandwidth. At the receiving end, the matched filter eliminates the reflected echo to overlap with a subsequent symbol period (Misaridis and Jensen, 2005).

3. Using gaussian filter

The present OFDM technique with varying envelope characteristics leads to low spectral and power efficiency. An alternative way to improve the efficiency and to give constant envelope properties is to reduce PAPR, leading to a pre-modulation Gaussian filtering technique. This will act as a front-end for an LFM modulator. The method outlined in (Sadkhan et al., 2014) as GMSK modulation for digital mobile radio telegraphy, is used for pulse compression based radar. Here the last mentioned method pulse radar by using binary NRZ input data is applied here. This is shown in Fig. 2, NRZ as data input and after Gaussian filtering, the width of the spectrum reduced from the actual width.

This paper also describes the use of pre-modulation LPF (pre-modulation Gaussian filter) which offers the following properties such as constant envelope characteristics, coherent detection capability, better BER performance and better efficiency (Sadkhan et al., 2014). Gaussian LPF can act as an excellent digital modulation technique for this method. In addition to that, LFM based pulse compression method is included with the above method results reduced the number of side lobes with the main lobe compared with the conventional pulse compression based radar. At the receiver end reducing the side lobe is to be done by using the filtering technique. Pulse compression is based on matched filtering, which basically uses the complex conjugate of the actual radar signal to filter the received signal.

Here this shows that by the application of the mentioned method with LFM technique the side lobes are reduced drastically.

The auto-correlation function of LFM with Gaussian envelope is given by (Said et al., 2013)

$$A_{GLFM}(\tau) = exp\left[\frac{-\pi\tau^2}{2\tau_{pt}^2}[1 + r_0\tau_{pt}^4]\right] \quad (2)$$

τ_{pt} represent the effective pulse duration, r_o is the rate of frequency at time $t = 0$ and τ is the pulse width.

The effective pulse duration is

$$\tau_{pt} \equiv \frac{\left[\int_{-\infty}^{+\infty} |\mu(t)|^2 dt\right]^2}{\int_{-\infty}^{+\infty} |\mu(t)|4_{dt}} \quad (3)$$

By considering Eqs. (2) & (3) we understand that autocorrelation function depends on pulse duration, pulse width and here in LFM at the demodulator side the pulse width is compressed.

Thus, by compressing the pulse width, the autocorrelation function $A_{GLFM}(\tau)$ reaches close to the unity. Fig. 3 shows the autocorrelation for an LFM pulse with a pre-modulation Gaussian filter. And this implies that this technique offers positive correlation at the receiver compared with the conventional based LFM design (Cook, 1960). Here there are no side lobe arrays for three targets. This shows definitively that the above-mentioned method is

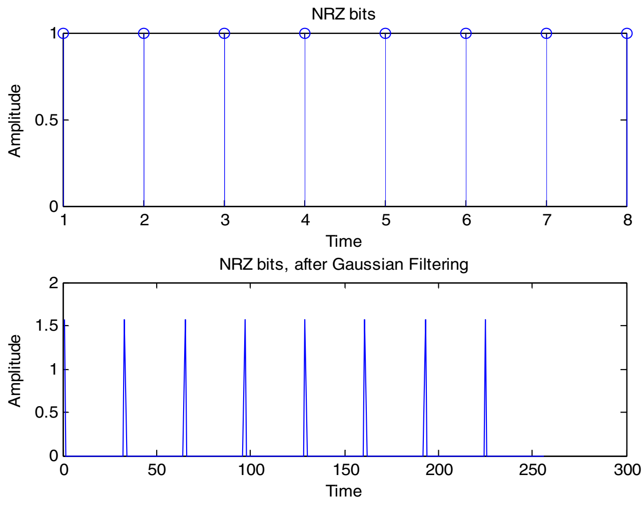

Fig. 2. NRZ as input data and after Gaussian filtering.

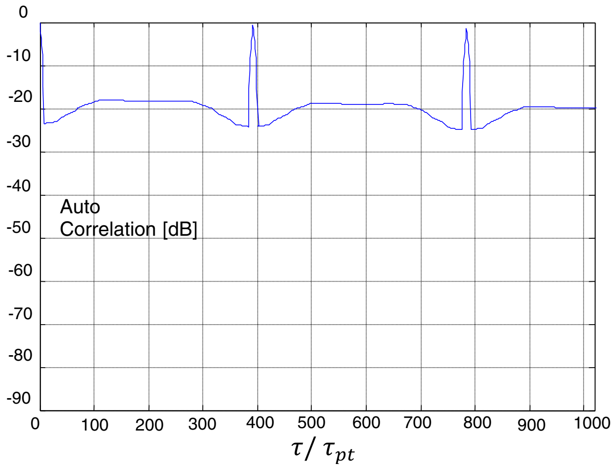

Fig. 3. Autocorrelation function from a pre-modulation Gaussian filter based Costas coding.

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perfectly suitable to reduce side lobe by the use of a Gaussian filter as a pre-modulation filter.

Also, the matched filter at the receiver results $\tau_{pt}$from the auto-correlated signals obtains less pulse width as compared to reference sinusoidal pulse waveform.

Autocorrelation function serves radar to detect two closely similar, near and far target signals delayed by it. In this paper, the autocorrelation function is shown in Fig. 3 specifies during each lag the signal exactly matches. For t = 0 the signal is correlated, one and two-period lagging intervals, during t = 400 and t = 800 respectively the signal matches exactly. This will improve the spectral efficiency of LFM based Costas coded radar with a filter design. These signify that the energy spectrum for each N number of sub-pulses is almost identical. Fig. 4 shows the autocorrelation for an LFM pulse without a filter. Here side lobe arrays are visible with the amplitude of −65 dB level with main lobe amplitude of −17 dB.

If there is a pre-modulation filter in the transmitter, then the power spectral density of the side lobe can be suppressed considerably (A New Pulse Shaping Technique to Reduce Spectral Side Lobe Level of QPSK Spectrum for Space Communications, 2004). Fig. 5 shows the autocorrelation of the same LFM pulse with Costas coding. This shows better correlation but exists side lobes with side and the main lobe of amplitude −65 and −17 dB respectively. There is no spectral leakage and thus no discontinuity in waveform compared with Fig. 4.

Also, the shape of the waveform of the correlation function depends on the autocorrelation function $A_{GLFM}(\tau)$ for the pulse shape having pulse duration τ_{pt}. By matched filtering, this basically uses the complex conjugate of the real radar signal to filter the received signal. The conjugate property eliminates range side lobes considerably during the nonzero integer time period (Said et al., 2013).

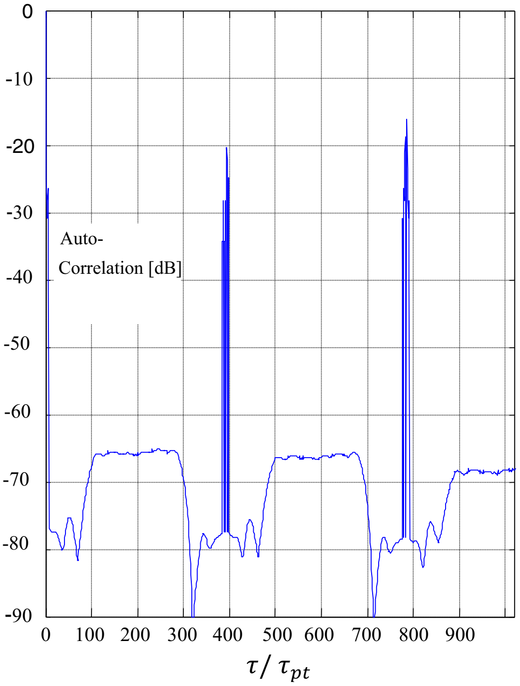

Fig. 4. Autocorrelation plot for an LFM pulse using three targets without filter.

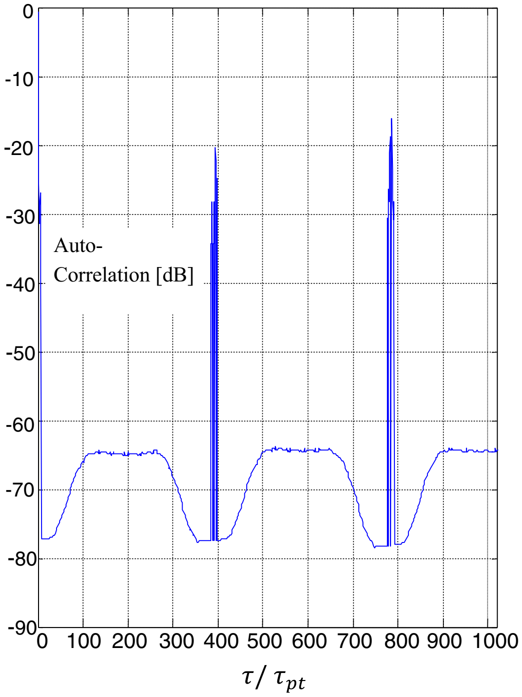

Fig. 5. Autocorrelation plot for an LFM pulse using. Costas coding with three targets without filter.

By verifying these figures, it is clear that the side lobes are efficiently suppressed with the application of Gaussian filter based pre-modulated Costas coded LFM. These results are compared with the other techniques with necessary simulated waveforms. There is no spectral leakage, and this improves the spectral efficiency of this system.

This second objective of this paper is to measure the theoretical importance of BER performance and efficiency of the conventional radar with constant envelope properties of the coherent receiver. By matched filtering in the receiver, except with additive white Gaussian noise assumption matched filter maximizes the SNR. The BER performance of the above-mentioned method can be evaluated by using the BPSK modulation is shown in Fig. 6. The performance is improved by a coded based GMSK filter as shown in Fig. 7 and it is analyzed by the measured modem, here the BER reduced by a large amount considerably, generally it is quantified by measurement of the signal-to-noise ratio (SNR) versus BER.

The theoretical bit error rate in the case of GMSK filter with coherent receiver is given by

$$Pe = \mathrm{P_e}\frac{1}{2}erfc(\sqrt{Eb/No}) \tag{4}$$

where Pe is the energy per transmitted bit and N is the noise power spectral density. The equation to find Eb is given by (Krysik et al., 2014) is

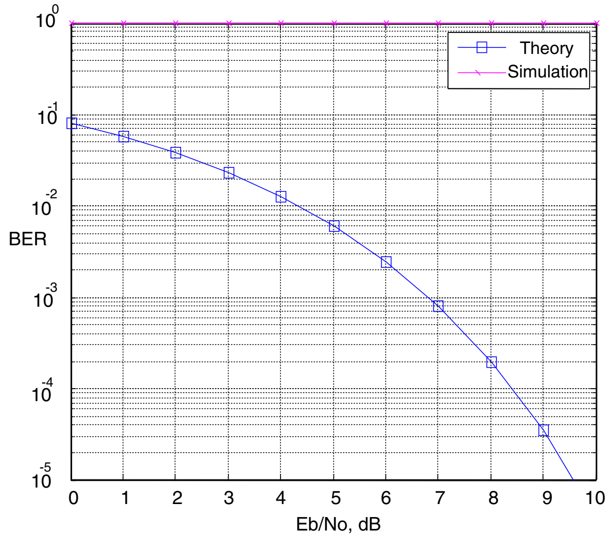

Fig. 6. SNR versus BER over BPSK modulation.

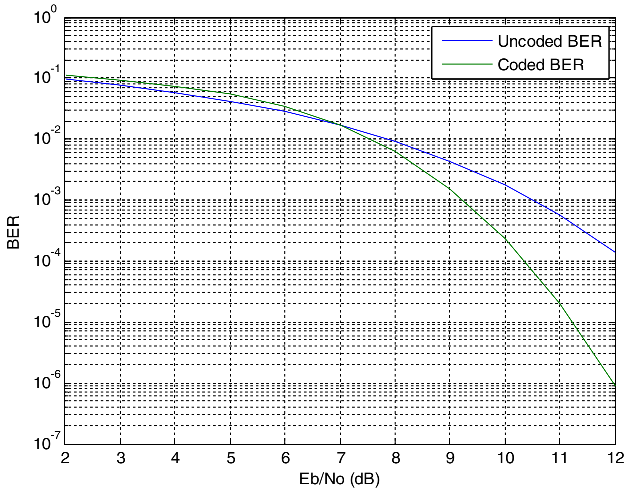

Fig. 7. SNR versus BER for coded AWGN channel.

$$Eb = \frac{1}{2}\int_0^T |U_H(t)|^2 dt = \frac{1}{2}\int_0^T |U_L(t)|^2 dt \tag{5}$$

where $U_H(\mathrm{t})$ and $U_L(t)$ are the complex signal waveforms corresponding to binary 1 and binary 0 transmissions, respectively. This Eq. (5) indicates that the error probability is dependent only on the energy contents of the signal that is *Eb* as the energy increases, value of error function *erfc* decreases and the value of *Pe* will reduce.

Since in pulse compression the energy content of long duration, low-power pulse which will be comparable to that of short duration, high power pulse. Thus, the energy content will increase by the use of pre-modulation Gaussian filter followed by LFM. Also, BER reduces considerably by a large amount compared with the conventional pulse compression technique. This is shown in Fig. 7, SNR versus BER for coded AWGN channel.

4. Basic theory of costas coding

Costas coding is an encoding technique which is frequency coded. In Costas coding a long transmitting pulse of width, T is divided into N number of sub-pulses. These are a class of time-frequency-coded waveforms. A Costas signal is of the frequency-coded waveforms having better correlation capabilities and is better suited for fading channel with additive noise. In Costas code, a group of a pulse is equally spaced by a frequency called a burst. These codes are un-coded pulse waveforms with a definite range of frequency and thus it is processed by using a coherent receiver. This code offers high Doppler resolution and can be able to detect multiple targets with a separation of short distance. In Costas code, the discrete time signals of the sampled waveform which is a carrier will be encoded by the transmitted pulse of order ‘N.’ This order of N is called a burst of duration ‘T’ and at each frequency, the signal is chosen as $\{F_1,F_2,F_{3,}\ldots F_n\}$ of varying frequencies with a time period of $\{t_{1,}t_{2,}t_3\cdots t_n\}$ interval and these intervals are equal.

An ideal Costas signal or pulse has a duration T seconds with constant amplitude, a centre frequency f_{centre} Hz, and a characteristic phase component θ (t), which varies with time in a specific manner for linear frequency modulation, the phase is a quadratic function of time.

Complex form of this signal is given by (Chan and Lim, 2008)

$$\mathrm{s(t) = rect(t/T)exp}\{\mathrm{j}\pi kt^2\} \tag{6}$$

where t is the time variable in seconds, while k is the linear FM rate in hertz per second.

In the above equation, each of the real and imaginary part oscillates as a function of time, and this oscillating frequency increases away from the time origin. On the other hand, the phase of this pulse is given by the magnitude of the exponential function expressed in radians.

$$\varphi(t) = \pi kt^2 \tag{7}$$

This equation is a quadratic function of time. Where time expressed in Hz, implying that the frequency is a function of time t, with the slope k expressed in hertz per second.

$$f = kt \tag{8}$$

The bandwidth is defined as the range of frequencies spanned by the significant energy of the chirp, or the frequency excursion of the signal and the bandwidth is the product of the chirp slope and the chirp duration, expressed in Hertz, and it governs the obtainable resolution.

$$\mathrm{BW} = |\mathrm{K}|\mathrm{T} \tag{9}$$

Another signal parameter is the time-bandwidth product (TBP) (Chan and Lim, 2008), which presents the product of the bandwidth |K|T and chirp duration T (a dimensionless parameter).

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$$\mathrm{TBP} = |\mathrm{K}|\mathrm{T}^2 \quad (10)$$

The TBP of the basic Costas signal can be measured by counting the number of zero crossings of the real or imaginary part of the time-domain signal. In short, a Costas signal has a quadratic phase, where its frequency is a function of time.

The pulse width is divided into a number of sub-pulses. Whereas a linear FM signal is often called a chirp. When the slope is positive, then, the signal is called an up-chirp; whereas, for a negative slope, the signal is called a down-chirp. Yet the direction of the chirp, which is embedded in the sign of k, will not affect the analysis. In a linear-FM waveform, the phase samples follow a quadratic pattern and can be generated by two cascaded digital integrators. The input digital command to the first integrator defines this quadratic phase function. The digital command to the second integrator is the output of the first integrator plus the desired carrier frequency. This carrier may be defined by the initial value of the first integrator. The desired initial phase of the waveform is the initial value of the second integrator.

Binary data will be the input of an 2^{N} to N output encoder here after coding; the inter-leaver will rearrange the signal in such a way that if any repetition in the code can be eliminated. Next step involved is the mapping of a signal technique which is a digital modulation technique. Here the block of data is modulated at two frequencies levels. These two frequency levels are converted into equivalent N sub-carriers by using the IFFT block. Then by using a demodulator, the Costas equivalent coding is produced. Here keeping the peak to average power to a constant level by using a pre-modulation filter. The coding of Costas sequences which are carried out and thus the phase information is updated during each cycle by the phase accumulator, also the Doppler frequency approaches which we merged herein coding with OFDM to generate pre-modulation Gaussian Filter based Costas coding. The phase information from the phase accumulator drives the DAC.

5. Simulation result

In this paper, we have presented the simulated results used to evaluate CCDF versus PAPR reduction capability as shown for Costas array. Here in this simulation, an OFDM with a symbol size of N = 1024 and modulation was considered. The performance estimation of a channel with low PAPR, OFDM offers a very good performance in association with a non-linear amplifier. Here with CE-OFDM, the amplifier does not show any non-linearity due to its constant peak. Also, we will discuss the analysis by using constant amplitude modulation, which maintains a constant mean power with the help of an equalizer (Krysik et al., 2014). In this coding, we used Constant Envelope OFDM symbols for reducing the PAPR at the receiver before demodulation.

Here the coding was done in MATLAB software, PAPR reduction technique was done by using Constant amplitude modulation (Krysik et al., 2014). The simulation obtained is evaluated several times by using three transmitting antennas and modulating techniques. Here the binary input is developed and modulated by a number of iterations by using this modulation. Here the number of transmitting antenna is three and is evaluated when Mt = 3, where Mt represents number of antennas. This algorithm generates Multiple Input Multiple Output OFDM when the number of antennae is Mt = 3. Due to the phase change in the sub-carrier with constant amplitude, this method will provide low PAPR.

After the above-mentioned modulation scheme at the transmission end for a generation of OFDM, IFFT blocks are utilized, and at the receiving end, the inverse transform (FFT) is taken to reproduce the original signal. In this, we present the results of the simulation, and this is used to evaluate PAPR reduction capability and BER of the proposed scheme. Here in this simulation, an OFDM with a sub-carrier of N = 1024 and linear frequency modulation with Costas coding is considered. The performance estimation of a channel with low PAPR OFDM offers well in the presence of a power amplifier. As expected, the performance is worse for non-linear Travelling Wave Tube Amplifier (TWTA) as compared to the Solid State Power Amplifier (SSPA) case. However, CE-OFDM is not affected by amplifier non-linearity due to its constant envelope.

In this paper, we will discuss the performance analysis results of Constant Envelope OFDM with Pulse Width Compression for reducing the PAPR prior to data transmission using different coding scheme. Here the PAPR reduction technique is done using Linear Frequency based Gaussian Modulation, developed by using MATLAB 2011 software and using MATLAB programming. The simulation obtained is evaluated several times for two types of transmitting antennas and modulating techniques.

Here the binary input is developed and modulated by a number of iterations by using above-mentioned scheme. Here the number of transmitting antenna is changed from Mt = 1 and Mt = 3, where Mt represents the number of antennas. This algorithm generates Single Input Single Output System When Mt = 1 and generates Multiple Input Multiple Output OFDM When the number of antennae is Mt = 3.

In Fig. 8, we have shown the conventional method of PAPR reduction for MIMO-OFDM data transmission over the binary data. Here the PAPR value is 5.392 for CCDF is 0.2222 with the existing CMA algorithm. This states that the peak to average ratio for power having more nonlinearity. This nonlinearity generates low efficiency and also improves the performance of power amplifier. However, the CE-OFDM method is not affected by amplifier non-linearity due to its constant envelope.

The above-mentioned modulation due to phase change in sub carrier makes the data become more complex. Due

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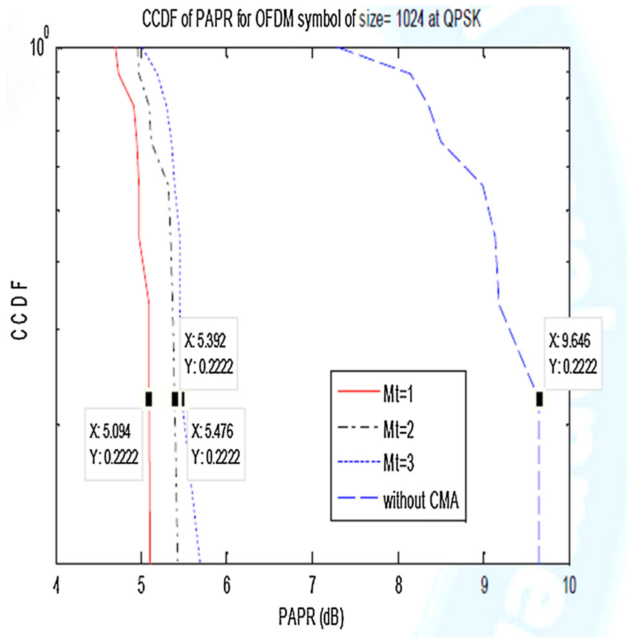

Fig. 8. Conventional methods of PAPR reduction for Mt = 1 & Mt = 3.

to the phase change in subcarrier, this method with constant amplitude will provide low PAPR. In Fig. 9 we have shown the ability to reduce the PAPR to a lower value. Here the binary data is in the form of NRZ data based Constant Envelope OFDM, with LFM modulation scheme. At CCDF = 10^{-1}; the PAPR of this technique is less than 3 dB smaller than the conventional method. Here the PAPR value is 2.196 for CCDF is 0.2222, reduced by approximately 3.196 dB when compared with conventional method shown in Fig. 8.

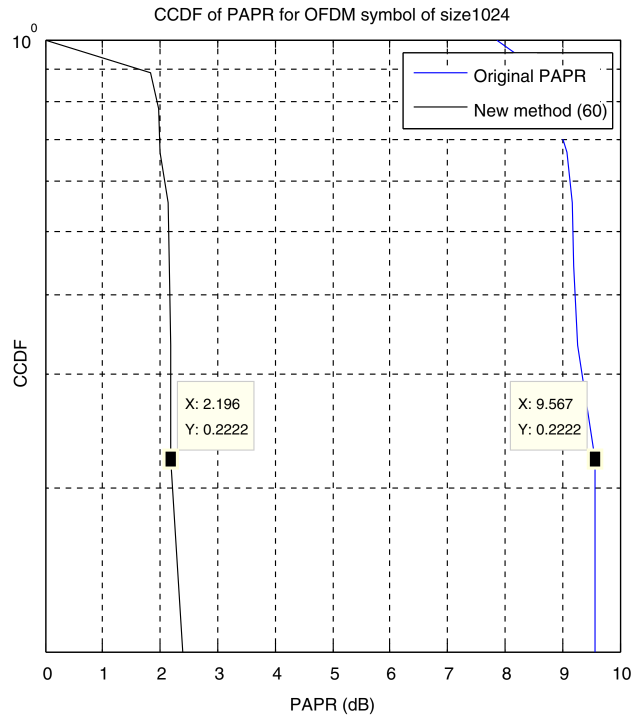

Fig. 9. CCDF versus PAPR for Costas with GMSK, Mt = 3.

Fig. 14 shows the ambiguity diagram of the above-mentioned method is also shown. From the ambiguity diagram, it is clear that there are absolutely no side lobes and this gives improved range resolution. Here we are using 13 bit Costas coded LFM and is evaluated. This method provides better correlation and range resolution. Also, Costas coded LFM with Gaussian filter offers less spectral leakage hence efficiency is more.

Fig. 10 also evaluates another technique involved with low PAPR. Here we had selected Costas coding without Gaussian filter method and at CCDF = 10^{-1} the PAPR of this technique is less than 3 dB, smaller than the conventional method, but compared with LFM the PAPR value is 2.246 for CCDF is 0.2222 a 'little' more.

In Fig. 15, the ambiguity diagram of the above-mentioned method is also shown. From the ambiguity diagram, it is clear that there are some side lobes and this gives ambiguity in range measurement and also the range resolution. Here we are using Costas array of order 8 is used.

In Fig. 11, the PAPR value of LFM pulse train is shown. Here the value is less than 3 dB at 10^{-1}, the graph shows the details. Figs. 16 and 17 shows the simulation of the ambiguity function for an LFM pulse train. Also the PAPR value of the simulated waveform by using Barker code is in Fig. 12 and an un-modulated pulse with its corresponding ambiguity function was shown. Fig. 18 shows peak-to-average power ratio reduction for OFDM using Costas coded LFM with Gaussian filter is shown. In this, we can see that after ten iterations the performance is improved.

In Fig. 13 shows the PAPR versus CCDF value of un-modulated pulse train as shown. Here the value is 2.578 dB at CCDF of 0.2222. Fig. 7 is its ambiguity function. Fig. 8 shown is the conventional graph of Constant Modulus Algorithm of PAPR reduction for OFDM (CMA).

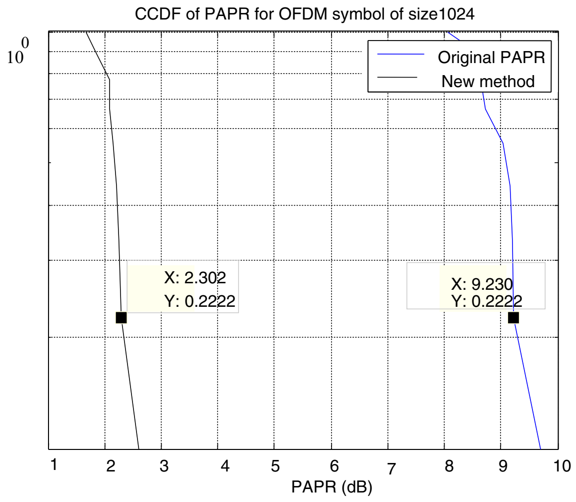

Fig. 10. CCDF versus PAPR reduction for Costas Array, Mt = 3.

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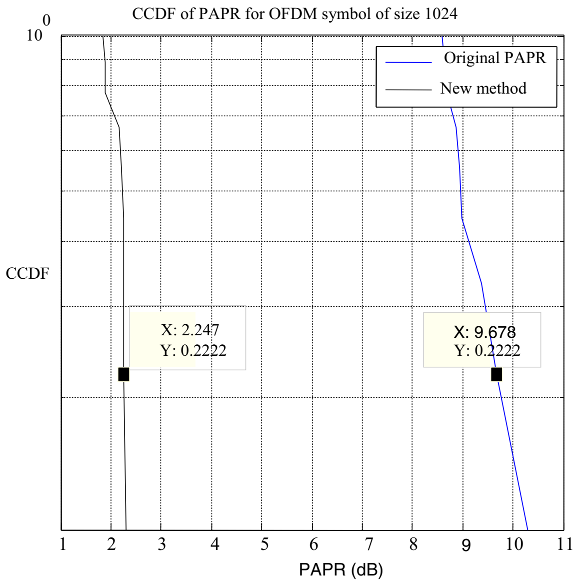

Fig. 11. CCDF versus PAPR reduction for LFM, Mt = 3.

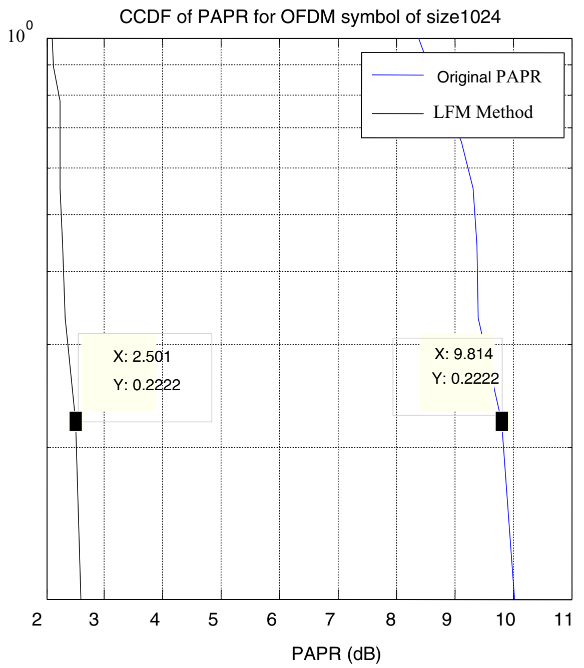

Fig. 12. CCDF versus PAPR reduction for Barker Code, Mt = 3.

In Fig. 14 the ambiguity diagram of Costas method is also shown. From the ambiguity diagram, it is clear that there are absolutely no side lobes and this gives improved range resolution.

Here we are using Costas array of 13 pulses. In other methods shown, it visualizes that the ambiguity diagram and it is clear that there is more side lobes present and this gives ambiguity in range measurement also the range resolution for multiple targets. Here we are using Costas array of order 13 is used. Costas coding is to offer targeted pulse detection by providing both unambiguous Doppler and ideal range information. PAPR reduction in the receiver is evaluated by the amount of CCDF reduction achieved.

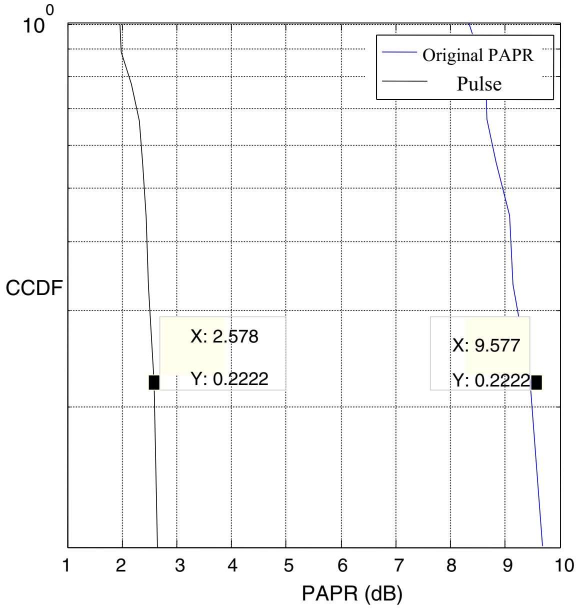

Fig. 13. CCDF versus PAPR reduction for Un-modulated Pulse, Mt = 3.

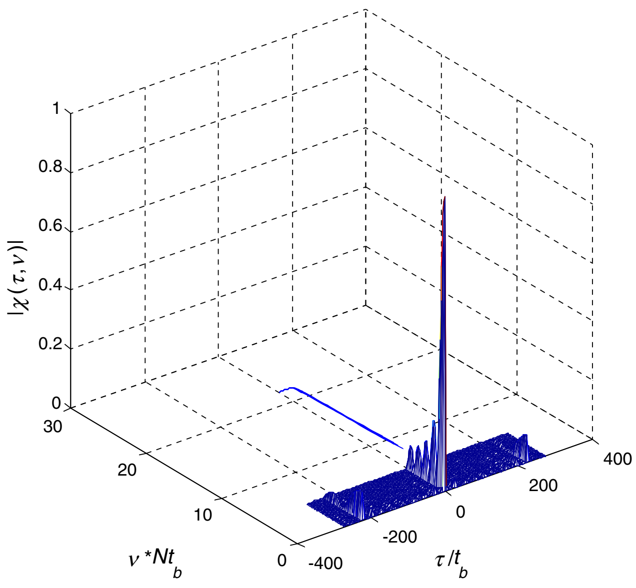

Fig. 14. Ambiguity diagram for Costas Array with Gaussian filter.

In this coding, we used constant modulus algorithm based on a scheme of Constant Envelope OFDM symbols for reducing the PAPR at the receiver before demodulation.

6. Discussion

Costas Frequency coding is an alternative to provide improved low PAPR value and an ambiguity function with less number of side lobes. In this paper, a PAPR reduction scheme for the OFDM signal with Costas coding, Barker

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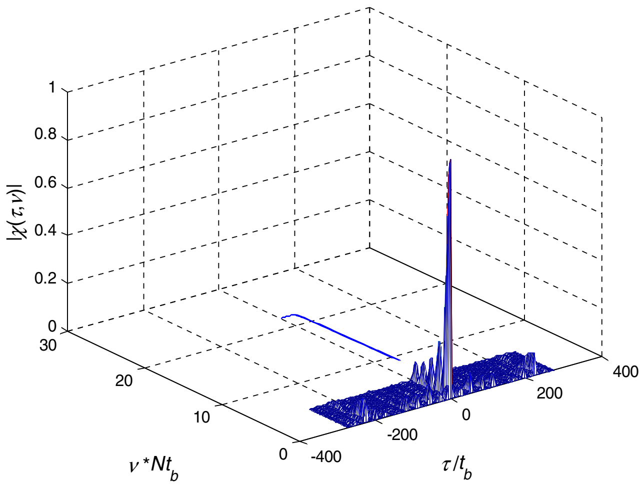

Fig. 15. Ambiguity diagram for an LFM pulse.

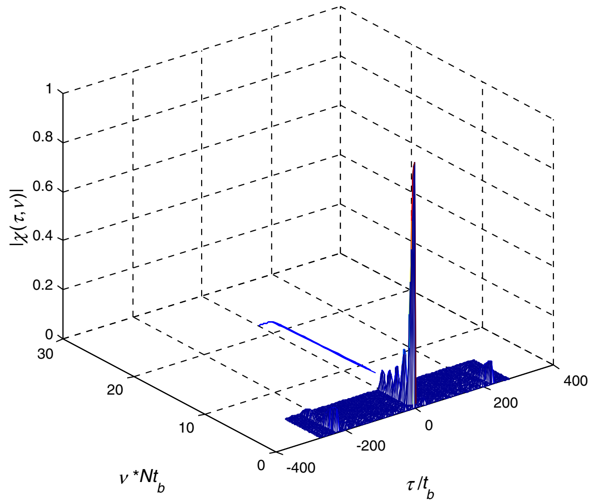

Fig. 16. Ambiguity diagram for Barker coded pulse.

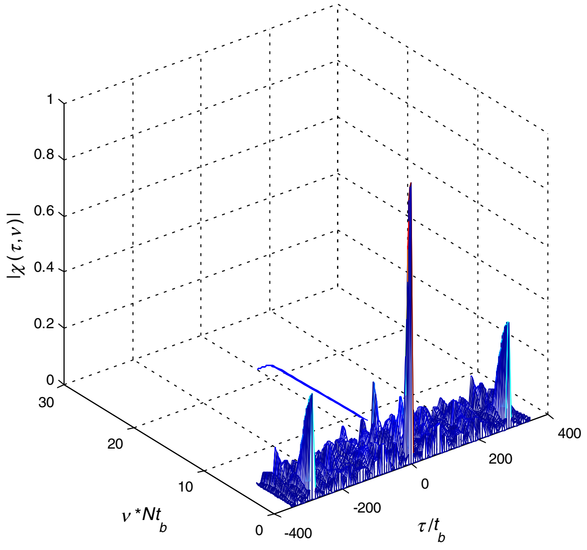

Fig. 17. Ambiguity diagram for an un-modulated pulse.

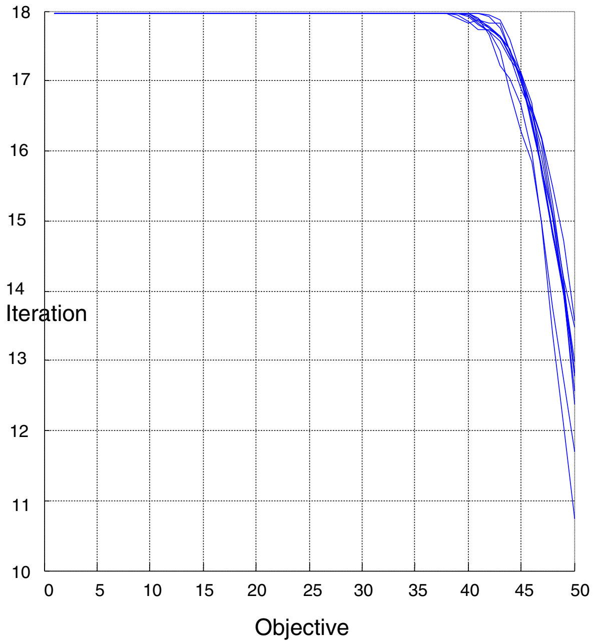

Fig. 18. Constant Modulus Algorithm of PAPR reduction for OFDM.

code, un-modulated pulse was examined. This paper explains Constant Envelope OFDM with phase accumulator based Costas code which simulates a better result in PAPR value, a reduction of 7.3 dB. The PAPR versus CCDF reduction, CMA convergence and its ambiguity function for all the above-mentioned coding have been evaluated by MATLAB simulation.

Simulation results show that the PAPR reduction is improved to a low value by using the proposed scheme as compared with the conventional method. This PAPR reduction technique produces a constant envelope signal which provides a nearly 0 dB PAPR and thus it is well suited for efficient power amplification purposes. This is also to improve the range resolution for multiple numbers of closely spaced targets. The ambiguity diagram shows clearly that there are less no side lobes in the case of CE-OFDM based Costas coding and this gives an enhanced resolution for distinct targets. Constant Envelope OFDM (CE-OFDM) alleviates the high peak-to-average power ratio (PAPR) problem in OFDM. In OFDM, the constant envelope peak and multipath propagation produce fading in a frequency selective channel permitting operation without an equalizer especially when differential data encoding is used.

This method offers a low peak-to-average power ratio (PAPR) (Li et al., 2009) for the conventional OFDM-based radar; therefore to cut the undesirable effects due to side lobes of an OFDM signal. Results show that Costas coding is best suited for low side lobes and low PAPR in OFDM with improved ambiguity function for LFM based radar. Results show that Costas coding is best suited for low side lobes and low PAPR in OFDM with improved ambiguity function for LFM based radar.

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By the addition of pre-modulation Gaussian filter in the transmitter side along with Costas coding achieves better PAPR and obtain satisfactory prior efficiency and constant envelope properties in future. This PAPR reduction technique produces a constant envelope signal which provides a nearly 0 dB PAPR and thus it is well suited for efficient power amplification purposes.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cogsys.2018.09.030.

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