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A Novel Iterative Methodology for Monitoring OFDM-MIMO Radar

Ambati Sravani, A.V.N. Tilak

***Abstract*— The distributed orthogonal frequency division multiplexing (OFDM) based multiple input and multiple output (MIMO) radar system can shorten the processing time due to spatially accumulation using coordinate transformation. As OFDM is a multi-carrier technology, multi-carriers with large number of sub carriers have high peak to average power ratio (PAPR), which is a measure of the amplitude fluctuations. In order to improve PAPR values and other performance parameters such as tracking error and detection probability a modified iterative clipping and filtering (MICF) algorithm is proposed in the present work for the design of OFDM pulses. With the use of MICF an improvement of about 37% in PAPR, 25% in root mean square error (RMSE), 3% in average root mean square error (ARMSE) and 49% in detection probability is observed as compared to state model method.**

***Index Terms*— MICF, MIMO, OFDM and PAPR.**

I. INTRODUCTION

Track before detect (TBD) [1]-[2] is a detection technology based on tracking. It performs the correlation processing of the radar data scans with almost no information loss and the detection result and target tracks are obtained simultaneously. Distributed multiple input and multiple output (MIMO) radar [3], due to its widely distributed architecture, can obtain separated echoes from multi aspect angles. It is possible to obtain spatially accumulation echo of multi channels in single pulse duration by utilizing the orthogonal frequency division multiplexing (OFDM) waveforms. This provides some feasibility for high speed weak target tracking. However, it is difficult to track the high speed weak target [4] using traditional radar with long-time mechanical scanning. Due to omnidirectional radiation, MIMO [5]-[6] radar can increase the data rate via spatial distribution of antennas [7]. OFDM is characterised by higher PAPR values [8]-[9] due to interference of large number of sub carriers. The large PAPR leads to in-band distortion and out-of-band radiation [10].

State model method [3] was used to evaluate the performance of OFDM-MIMO radar. State model method [3] was used to evaluate the performance of OFDM-MIMO radar. In order to improve further the performance parameters, an algorithm, namely, modified iterative clipping and filtering [MICF] is proposed in this work.

Simulations are carried out using Matlab to demonstrate the tracking performance and detection probability superiority of MICF method compared to state model method.

The paper is organized as follows. In section II, the background of present work is given. Section III presents the details of MICF algorithm. Simulation results are provided in section IV and finally section V concludes the paper.

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***Ambati Sravani**, Department of Electronics & Communication Engineering, Gudlavalleru Engineering College, Gudlavalleru, A.P. - 521356, India, Phone: +91-9502607135*

***A.V.N.Tilak**, Department of Electronics & Communication Engineering, Gudlavalleru Engineering College, Gudlavalleru, A.P. - 521356, India, Phone: +91-9441085622.*

II. BACKGROUD

The performance parameters of radar and state model method to evaluate these parameters are briefly described.

A. PAPR of OFDM Signals

The PAPR is the relation between the maximum powers of a sample in given OFDM transmit symbol divided by the average power of that OFDM symbol. PAPR occurs in a multicarrier system. PAPR is defined as

$$\mathrm{PAPR} = \frac{\max|x(t)|}{\mathrm{E}[x(t)]} \qquad (1)$$

where E[.] denotes the expectation operator.

The input symbol stream of the IFFT should possess a uniform power spectrum, but the output of the IFFT results in a non-uniform or spiky power spectrum. Most of transmission energy would be allocated for a few instead of majority subcarriers. This problem can be quantified as the measure of PAPR. The large peaks introduce a serious degradation in performance when the signal passes through a non-linear high power amplifier (HPA). The non-linearity of HPA leads to in-band distortion which increases bit error rate (BER) and out-of-band radiation that causes adjacent channel interference, leading to a negative impact on the detection probability.

B. Tracking Error

Tracking error is measured in the form of root mean square error (RMSE) and average root mean square error (ARMSE). RMSE is defined as

$$\mathrm{RMSE} = \sqrt{\frac{\sum(|x_{sig} - y_{sig}|)}{\sum(|x_{sig}| + E_{sig})}} \qquad (2)$$

where x_{sig} = estimated signal, y_{sig}= transmitted signal, and E_{sig}= mean value.

The RMSE values at every scan moment are considered to evaluate overall tracking error as ARMSE.

C. Tracking Detection Probability

Tracking detection probability is defined as the probability of more than two real target cells existing in backtracking trajectory.

D. State Model Method

This method exploits second order Markov target state model, which fully considers the relativity of target states between multi scan.

III. MICF ALGORITHM

In order to obtain lower PAPR, increment in detection probability and reduction in tracking error of radar MICF algorithm is used. By this method amplitude fluctuations above the threshold value will be clipped off and the unwanted signals will be filtered.

The MICF technique involves the following steps.

Step 1: Number of maximum iterations and threshold value A for the peak amplitude of transmitted signal are set.

Step 2: IFFT of the transmitted signal is performed.

Step 3: The transmitted signal amplitude that exceed threshold is clipped, which is done in time domain. The clipping can be expressed as

$$C(x) = \begin{cases} x, & x < A \\ A, & x > A. \end{cases} \qquad (3)$$

where C(X) = transmitted signal, x = signal amplitude.

Step 4: The clipped time domain signal is then converted to frequency domain by applying FFT.

Step 5: The in-band as well as out-of-band distortions [11] are filtered in frequency domain.

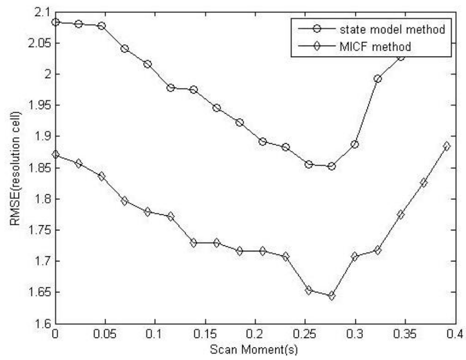
This distortion, if not eliminated, may degrade BER. The filtering action causes peak to re-grow beyond the original clipping threshold thus increasing the signal PAPR.

Steps 3 to 5 are repeated 10 times in order to obtain lower PAPR.

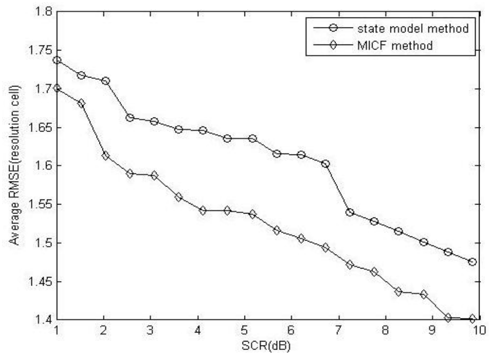
IV. SIMULATION AND PERFORMANCE ANALYSIS

To verify the performance parameters of OFDM- MIMO radar, simulations are carried out in Matlab. In this work an OFDM system with 1024 FFT size, QPSK modulation, MIMO of size 2*2, oversampling factor of 1 and threshold value for clipping as 4dB is considered. Kroon function [3] is used to generate the transmitted signal. The simulation results of present MICF method are compared with those of state model method.

The tracking root mean square error with time or SCR is analysed. Fig. 1(a) gives the root mean square error of the radar with an SCR of 6dB. For comparison, the RMSE evaluated using state model method is also given in figure. With MICF method the RMSE is reduced by 25%. The variation of the average RMSE with SCR is shown in Fig. 1(b). The average RMSE found using MICF and state model methods are 1.47 and 1.58 respectively during the whole tracking process.



(a)



(b)

Fig 1. Tracking error a) RMSE vs scan moment (SCR = 6dB) b) ARMSE vs SCR

The complementary cumulative distribution function (CCDF) is one of the most frequently used performance metric to measure the probability of signal PAPR exceeding certain threshold [7], PAPR0, i.e. Pr[PAPR>PAPR0].

Fig. 2 gives the PAPR values obtained using the two methods. It can be noted that the PAPR value is lowered by 35.1% when found using MICF method.

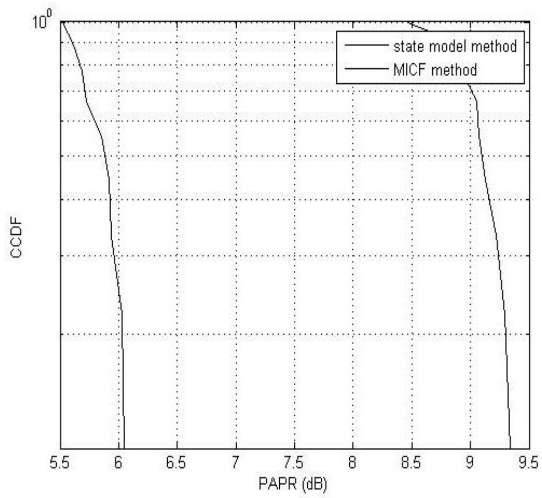


Fig 2. Peak to average power ratio

The detection capability of the radar found for different SCR values is depicted in Fig 3. For an SCR of

6dB an improvement in detection probability of 49.08% is observed with MICF technique as compared with state model method.

Table I gives the comparison of performance parameters of OFDM-MIMO radar evaluated using state model and MICF methods.

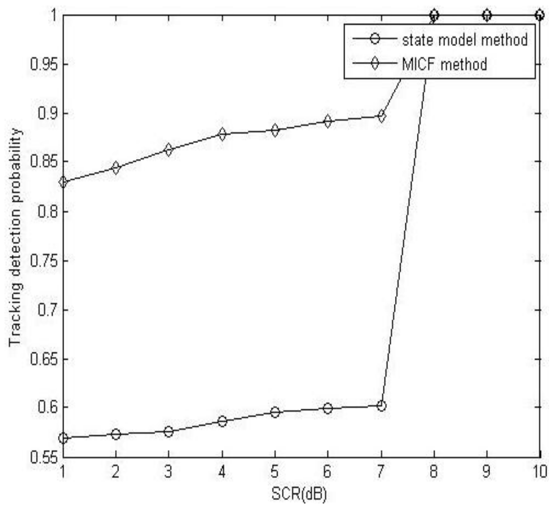


Fig 3.Tracking detection probability

Table I. Comparision of performance parameters of OFDM-MIMO radar

Parameter	State model method [2]	MICF method	Percentage Improvement
PAPR (dB)	9.4	6.1	35.10
RMSE	2.2	1.65	25.0
ARMSE	1.53	1.48	3.26
Detection Probability	0.599	0.893	49.08

V. CONCLUSION

State model method was used to evaluate the performance of the OFDM-MIMO radar. In order to improve the performance of radar MICF algorithm is proposed in this work. Simulations are carried out using Matlab for estimating the performance parameters. The MICF method lowers the PAPR, RMSE and ARMSE by 35.10%, 25% and 3.26% respectively as compared to state model method. The tracking detection probability increases by 49.08% with MICF technique.

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Ambati Sravani has obtained her B.Tech from VLITS, Vadlamudi. Pursuing M.Tech in Gudlavalleru Engineering College, Gudlavalleru. Her areas of interest are Digital and VLSI Design.

A. V. N. Tilak has obtained his B.E, M.Tech, and Ph.D from MIT Manipal, IIT Kanpur, and IIT Madras respectively. His areas of interest are Microelectronics, Digital Design, and Low Power VLSI Design. Dr. Tilak is a member of IEEE, Fellow IETE, Fellow IE(I), and Life member of ISTE.