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Paper Authors **B. Sathish Kumar1, K. Ashwitha2, K. Ruchitha2, K. Lahari2, G. Supriya2**

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Enhancing Antenna Synthesis via Efficient Surrogate-Assisted Particle Swarm Optimization

B. Sathish Kumar[1], K. Ashwitha[2], K. Ruchitha[2], K. Lahari[2], G. Supriya[2]

[1]Assistant Professor, [2]UG Student, [1,2]Department of ECE
[1,2]Malla Reddy Engineering College for Women, Maisammaguda, Hyderabad, Telangana, India

ABSTRACT: By virtue of the prediction abilities, assisted evolutionary algorithm has been treated as an efficient solution for antenna design automation. This article presents an efficient ML-based surrogate-assisted particle swarm optimization (SAPSO). The proposed algorithm closely combines the particle swarm optimization (PSO) with two ML-based approximation models. Then, a novel mixed prescreening (mixP) strategy is proposed to pick out promising individuals for full-wave electromagnetic (EM)simulations. As the optimization procedure progresses, the ML models are dynamically updated once new training data are obtained. Finally, the proposed algorithm is verifed by three real-world antenna examples. The results show that the proposed SAPSO- mixP can find favorable results with a much smaller number of EM simulations than other methods

KEYWORDS: Antenna synthesis, machine learning (ML), particle swarm optimization (PSO), surrogate assisted evolutionary algorithm (SAEA), surrogate prescreening.

I.INTRODUCTION: Nowadays the wireless applications are focused towards high data rates. The concept of multi carrier transmission provides high data rates in communication channel. The OFDM is a special kind of multi carrier transmission technique that divides the communication channel into several equally spaced frequency bands. Here the bit streams are divided into many sub streams and send the information over different sub channels. A sub-carrier carrying the user information is transmitted in each band. Each sub carrier is orthogonal with other sub carrier and it is carried out by a modulation scheme. Data"s are transmitted simultaneously in super imposed and parallel form. The sub carriers are closely spaced and overlapped to achieve high bandwidth efficiency [2]. The main disadvantage of OFDM is high peak to average power ratio. The peak values of some of the transmitted signals are larger than the typical values [1]. High PAPR of the OFDM transmitted signals results in bit error rate performance degradation, inter modulation effects on the sub carriers, energy spilling into adjacent channels and also causes non linear distortion in the power amplifiers. The main work of this paper is to reduce the high peak powers in OFDM systems. Several methods are there to reduce PAPR effectively(15). In this study the concept of selective mapping (SLM)) technique is applied to the OFDM symbols to reduce high peak signals[11]. Coding and simulation were carried out for SLM, PSO and their effects on reducing the PAPR were analyzed.

In this article, a novel mixed prescreening (mix P) strategy is proposed by hybridizing a minimum surrogate predicted fitness (min SF) strategy and an EI in fling criterion. Then, an optimization algorithm for antenna synthesis is constructed by combining the mix P approach with a recently published SAEA. Overall, the main contributions of this article are summarized as

- First, a novel prescreening method called mix P is pro-posed or accelerating the optimization. It can release the computational cost of methods and improve the global exploration ability of the search engine
- Then, an efficient algorithm for antenna synthesis is introduced, called SAPSO- mix P. The effectiveness of the proposed SAPSO-mix P is verified on two antenna examples by comparing with other antenna synthesis is algorithms.
- Finally, the optimization of a medium-scale problem ,i.e., a feeding network structure with 27 design variables, is conducted by the proposed SAPSO-mix P

2. LITERATURE SURVEY

Recently, orthogonal frequency division multiplexing (OFDM) has been regarded as one of the core technologies for various communication systems. Especially, OFDM has been adopted as a standard for various wireless communication systems such as wireless local area networks, wireless metropolitan area networks, digital audio broadcasting, and digital video broadcasting. It is widely known that OFDM is an attractive technique for achieving high data transmission rate in wireless communication systems and it is robust to the frequency selective fading channels . However, an OFDM signal can have a high peak-to-average power ratio (PAPR) at the transmitter, which causes signal distortion such as in-band distortion and out-of band radiation due to the nonlinearity of the high power amplifier (HPA) and a worse bit error rate (BER) . In general, HPA requires a large back off from the peak power to reduce the distortion caused by the nonlinearity of HPA and this gives rise to a low power efficiency, which is a significant burden, especially in mobile terminals. The large PAPR also results in the increased complexity of analog-to-digital converter (ADC) and digital-to-analog converter (DAC). Thus, PAPR reduction is one of the most important research areas in OFDM systems.PAPR reduction schemes can be classified according to several criteria. First, the PAPR schemes can be categorized as multiplicative and additive schemes with respect to the computational operation in the frequency domain On the other hand, tone reservation (TR) [5], peak canceling, and clipping [6] are additive schemes, because peak reduction vectors are added to the input symbol vector.Although numerous schemes have been proposed to solve the PAPR problem, no specific PAPR reduction scheme can be considered as the best solution. Since the criteria involve trade-offs, it is needed to compromise the criteria to meet the system requirements. The aim of this paper is to review the conventional PAPR reduction schemes and the various modifications of the conventional PAPR reduction schemes for achieving a low computational complexity

3. EXISTING SYSTEM

3.1 SELECTIVE MAPPING TECHNIQUE (SLM): Many methods are there to reduce the PAPR , but both complexity and redundancy are high and only small gains in PAPR are achieved. When the phases of different sub-carriers add up in phase the possibility of PAPR being high is for sure. Hence one method to reduce the in-phase addition is to change the phase before converting the frequency domain signal into time domain. Hence before taking the N point IDFT each block of input is multiplied by an φ vector of length N. Now there is a possibility that the PAPR may turn low.

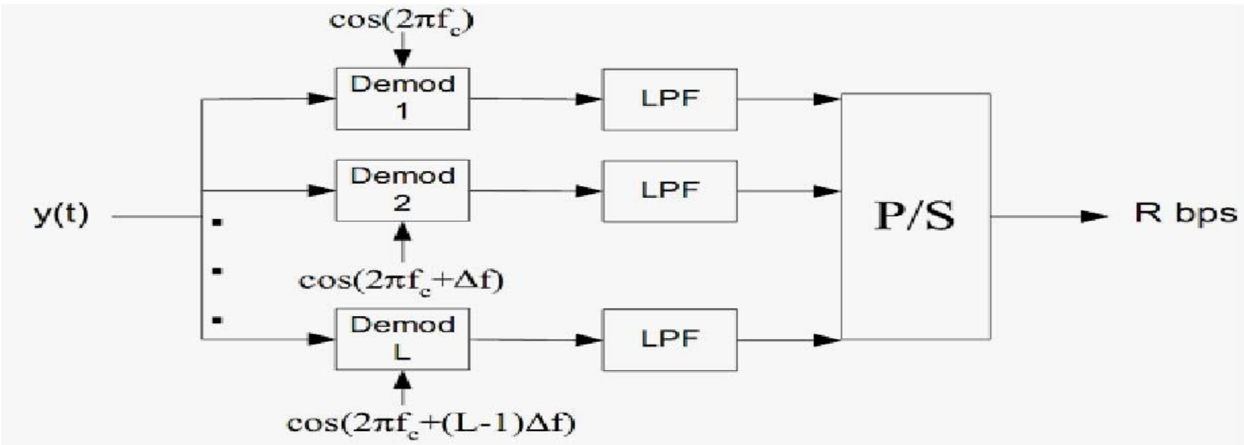

Fig 3.1: Scheme of a Modulator with Selective Mapping

3.2 REDUCED COMPLEXITY SLM In the case of reduced complexity SLM the φ vector is changed only of its odd components and the even components are assumed to be 1 for 1000 iterations. The other process remain the same.

3.2.1 ALGORITHM FOR REDUCED COMPLEXITY SLM

Step 1: Get the input vector(X) of length D and let N=integer

Step2: for i=1: N

Step 2.1: Generate φ (i) of length D

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Step 2.2: Multiply φ (i) with the input vector and get Z (Freq domain)

Step 2.3: Compute IDFT and get z (Time domain)

Step 2.4: Determine PAPR using the formula

$$\text{PAPR} = \frac{\max|x(t)|^2}{E\left[|x(t)|^2\right]}$$

Step 2.5: Increment the value of i

Step 3: Go-to Step 2

Step 4: PAPR of length N is obtained.

Step 5: Select a threshold Y. One with minimum PAPR is used for transmission

Step 6: If min of PAPR>Y then increment a count

Step 7: Perform Steps 1-6 M times

Step 8: Obtain final count

Step 9: Increment the value of N and repeat Steps1-8

Step 10: Plot Graph for various N values where

X axis: Threshold values

Y axis: Pr[PAPR low>Y]

Step 11: It could be inferred that as the value of N increases PAPR decreases (It is required to inform the phase information controlled for the data sub-carriers to the receiver as side information)

ISSUES IN CURRENT SYSTEM

- When the input signal passes through the inflexion threshold, transformed signal will have abrupt jump that degrades the power spectral density (PSD) of transformed signal.
- Design complexity

4. PROPOSED SYSTEM

4.1 Complexity of the proposed PSO

The time complexity of the proposed method is $O(I \times P)$, where I and P are the number of iterations and particles, respectively. After the first iteration of this algorithm, P evaluations will have been performed and after I iterations, the fitness will be evaluated $I \times P$ times. displays the overall process of the proposed PSO.

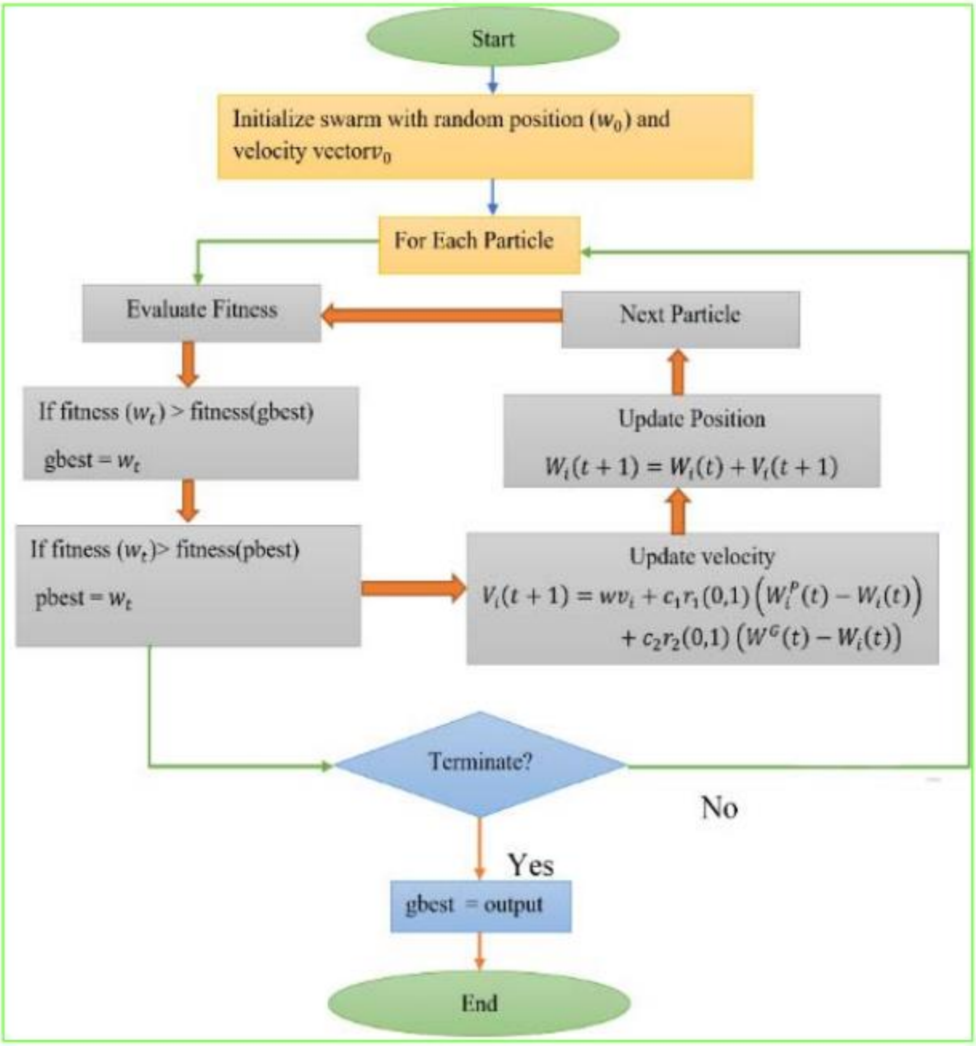

Fig 4.1: Block diagram of the PSO algorithm

the input data block is partitioned into disjoint sub blocks or clusters which are combined to minimize the PAPR . Define the data block,[Xn,n=0,1……N-1],as a vector ,X=[X0,X1……XN- 1] T . Then, partition X into M disjoint sets, represented by the vectors [Xm,m=1,2……M]. The objective of the PSO approach is to form a weighted combination of the M clusters,

$$X'(b) = \sum_{m=1}^{M} b_m X_m$$

Where [bm , m=1,2……..M] are weighting factors and are assumed to be pure rotations. After transforming to the time domain, the above equation becomes

$$\mathbf{x}' = \sum_{m=1}^{M} b_m \mathbf{x}_m$$

The vector xm, called the partial transmit sequence, is the IFFT of Xm. The phase factors are then chosen to minimize the PAPR of x ' .

In the case of reduced complexity PSO the „W" vector is changed only of its odd components and the even components are assumed to be 1 for 1000 iterations. The other process

4.2 ALGORITHM FOR REDUCED COMPLEXITY PSO:

The PSO scenario supported with mathematical expressions is summarized in the following steps:

1. The input data block X is divided and separated into M sub-blocks,

$$X_m = [X_{m,0}, X_{m,1}, \dots, X_{m,L-1}],\ m=1, 2,\dots M \qquad \text{----(1)}$$

2. That means if we recombine these sub-blocks, we would get the original data block X as the following,

$$\sum_{m=1}^{M} X_m = \mathrm{X} \qquad \text{--(2)}$$

3. The second step is to convert the sub-blocks to the time domain using inverse fast Fourier transform (IFFT) to form the signal from Xm as the following:

$$x_m = [x_{m,0}, x_{m,1}, \dots, x_{m,L-1}],\ m=1, 2,\dots M \qquad \text{---(3)}$$

4. To the purpose of minimizing PAPR, each sub-block in time domain is rotated by the phase factor

$$b = [b_0, b_1, \dots, b_{M-1}] \text{, where } b_m = e^{j\emptyset},\ 0 \leq \emptyset < 2\pi \qquad \text{---(4)}$$

5. The last step is to add all the sub-blocks up to form the final time domain signal which is

$$X'(b) = \sum_{m=1}^{M} b_m X_m \qquad \text{----(5)}$$

$$\text{Or, } X'(b) = [X_0'(b), X_1'(b), \dots, X_{NL-1}'(b)] \qquad \text{----(6)}$$

5. DISCUSSION OF SIMULATION RESULTS

An OFDM system is simulated under the following specifications: 10,000 OFDM symbols, 64 subcarriers, oversampling factor of 4, 16OFDM candidates, and QPSK modulation scheme. The simulation results of SLM and PSO algorithms are shown in Fig. 5.1 and 5.2, respectively, where the CCDFs are plotted for both schemes. In the previous comparison of SLM and PSO, It has been proven that PSO is more complex than the SLM is in most cases . Far away from the complexity metric used in the previous comparisons, we develop a PAPR

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reduction efficiency factor in this paper based on CCDF information for both SLM and PSO. Form CCDF information, we calculate the PAPR reduction at certain standard probabilities which are 10-4, 10-3, 10-2, and 10-1. At these probabilities we get the corresponding PAPR values for both SLM and PSO PAPR reduction systems. These PAPR values extracted from both systems will be compared to those values extracted at the same standard probabilities from the original OFDM signal. Comparing original OFDM PAPRs with those from SLM and PSO response we can calculate PAPR reduction values at the each of these standard probabilities. Therefore, the PAPR
reduction is:

$$\text{OFDM PAPR Reduction} = \text{Original PAPR} - \text{modified PAPR} \quad \text{---(7)}$$

Both the original and modified PAPRs should be at the same probability point. Finally, the proposed formula for the PAPR Reduction Efficiency is:

$$PAPR\ Reduction\ Efficiency = \frac{OFDM\ PAPR\ Reduction}{Original\ \ OFDM\ PAPR} \quad \text{---(8)}$$

After applying the proposed two formulas

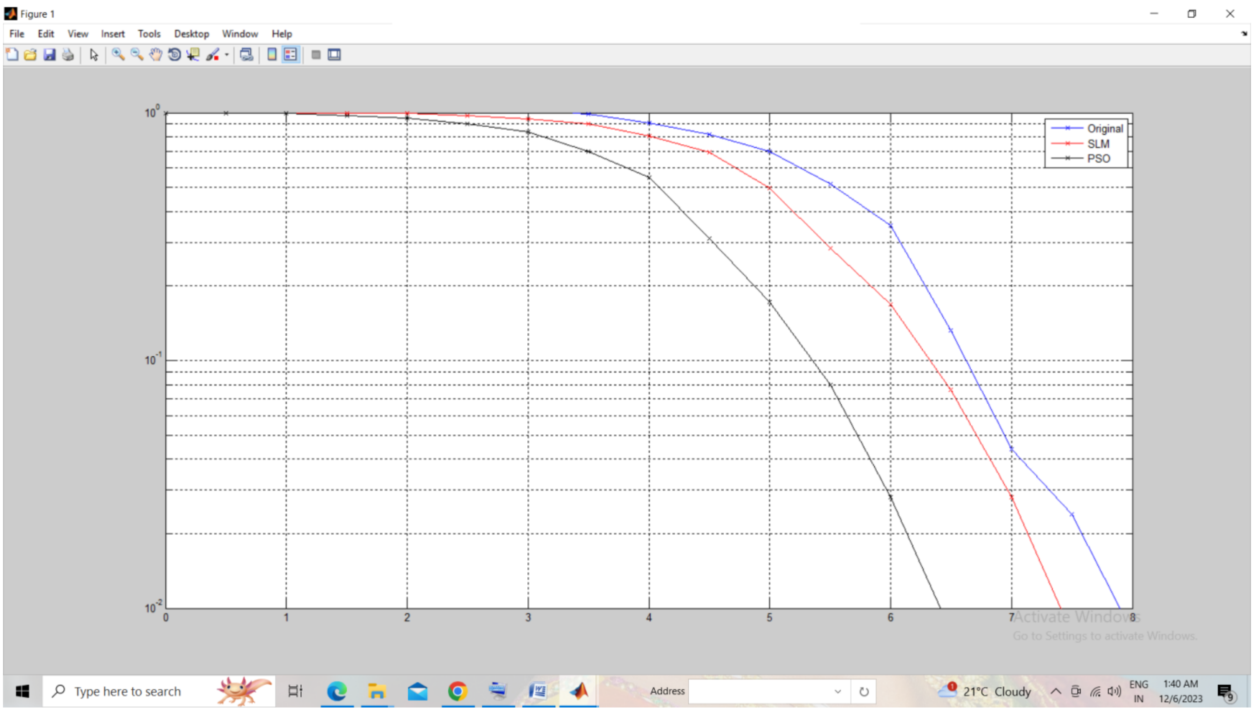

Fig 5.1: PAPR Reduction Analysis For Original OFDM, SLM AND PSO

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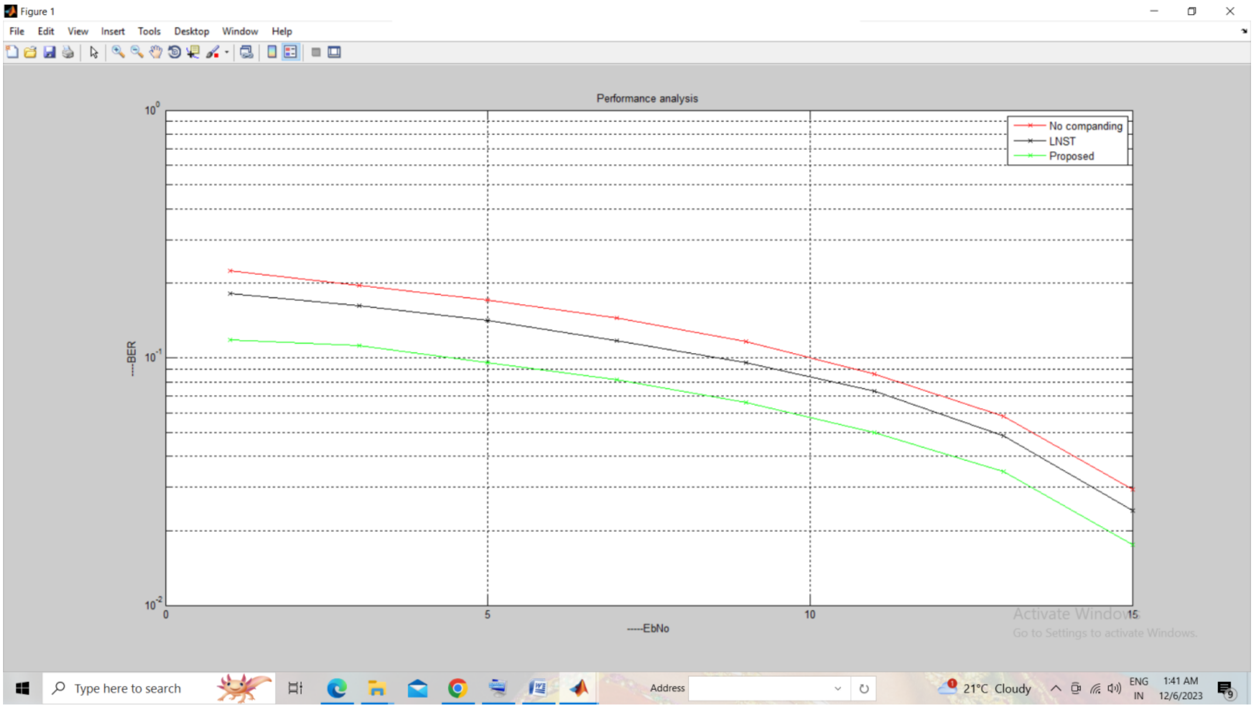

Fig 5.2 : BER analysis for existing and proposed systems

6.CONCLUSION

This article proposes a new SAEA, called SAPSO-mix P, by combining a novel prescreening strategy (mix P) with a recently proposed SAPSO framework. Three typical real-world cases of antenna design are employed to verify the performance of SAPSO-mix P. The experimental results show that the search efficiency is improved from 2 to 4 times by SAPSO-mix P compared with the state-of-the-art optimization algorithms (SA-QNEGO-NSM, SOGPR, and SADEA) for the SIW slot antenna case and the LAA case. In addition, the synthesis problem of an SR feeding network is solved by an automatic algorithm for the first time. Our future work is to enhance the proposed SAPSO-mix P framework by combining multi fidelity surrogate models for further improving the optimization efficiency. To cope with large scale antenna design problems, we plan to investigate more advanced PSO algorithms, such as CCPSO2 [35].To explore the antenna design space further, we plan to introduce the latest ideas in design space exploration [36] to our work

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