Boundary-Based Optimization Strategy for Fragment-Type Isolation Structure Designs

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***Abstract*—Fragment-type structures are potential for acquiring high isolation for a compact MIMO (multiple-input and multiple-output) system. A novel boundary-based median filtering operator is proposed to increase the number of optimized candidates. For example, fragment-type isolation structures of a compact MIMO PIFAs (planar inverted-F antennas) system operating at 2.345GHz-2.36GHz and having a center-to-center interval of 15mm are designed. Comparison results show that more alternative designs could be found at the expense of searching speed, and both better front-back-ratio and wider impedance bandwidth are observed.**

Keywords—fragment-type structure; isolation; MIMO; multi-objective optimization; optimization method

I. INTRODUCTION

Multiple-input and multiple-output (MIMO) technique has been widely used in wireless communication. To achieve high isolation between closely-packed MIMO antenna elements is a key point in MIMO design. Many structures, such as electromagnetic band-gap structures [1], slots [2], resonator structures [3], meta-surface [4], and meta-material structures [5], have been proposed to improve the isolation among MIMO antenna elements. In [6], fragment-type isolation structures have been designed through MOEA/D-GO (multi-objective evolutionary algorithm based on decomposition combined with the enhanced genetic operators). In [7], MOEA/D-GO-II (MOEA/D-GO combined with median filtering operator) is proposed to speedup searching.

However, MOEA/D-GO-II converges too fast at the expense of population diversity, which might make the algorithm converge to local optimal or reduce the number of alternative designs. In order to overcome this problem, a boundary-based median filtering operator, metalizing the edge cell when it is bounded by metal, and non-metalizing the edge cell when it is bounded by air, is proposed here. Boundary-based filtering operator has more possibility to maintain the connectivity of the boundary of the metal conductor, thus

1) more metalized cells are remained to maintain the population diversity and to reduce backward radiation, and

2) it is beneficial for trapping the current into the isolation structure through conductor to obtain perfect return loss and isolation, and to increase the overall loss [7], and thus obtain wider impedance bandwidth.

Therefore, boundary-based median filtering operator is expected to obtain more alternative optimization designs, better front-back-ratio, and wider impedance bandwidth.

II. BOUNDARY-BASED FILTERING OPERATOR

A novel boundary-based median filtering operator is proposed in this section. During the implementation of boundary-based median filtering operator, each cell is assigned with “1” or “0” according to the following equation,

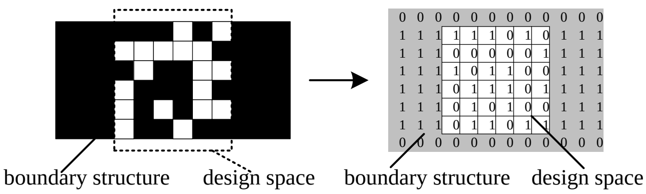
$$H(i,j)=\begin{cases}1 & (\ if\ \ d(i,j)\ \ >=\ \dfrac{|\mathrm{FM}|}{2}\ ) \\ 0 & (\ otherwise\ )\end{cases} \tag{1}$$

$$d(i,j)=\sum_{m=-1}^{1}\sum_{n=-1}^{1}H(i+m,j+n)\times \mathrm{FM}(m,n)\,, \tag{2}$$

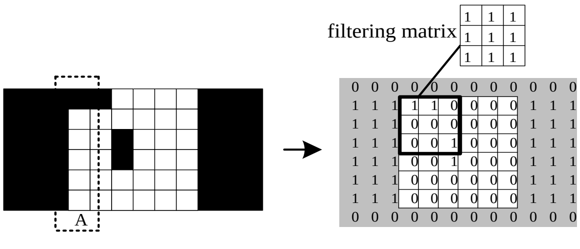
$$(i=1,2,\cdots,M;\ \ j=1,2,\cdots,N)$$

where $|\mathrm{FM}|$ represents the sum of all elements of the filtering matrix, $M\times N$ denotes the size of the fragment-type structure, and $H(i,j)$ denotes the value of each cell of the fragment-type structure. The difference between the proposed boundary-based filtering operator and the original median filtering operator [7] is the index of the calculation of $d(i,j)$.

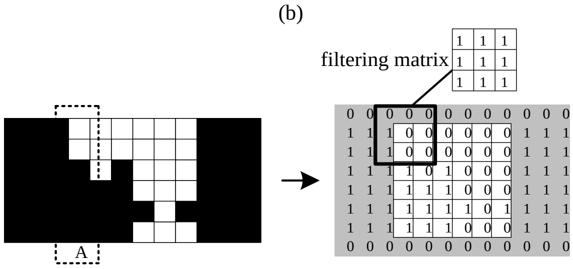
Fig. 1(a) shows the original fragment-type structure and its boundary conditions, along with their 0/1 design matrix. Fig. 1(b)-(c) illustrate the obtained fragment-type structures through different filtering operators, along with their filtering matrices (FM). It is obviously observed that the edge (region A) of the fragment-type structure maintains the connectivity of the boundary, and the overall metalized cells assigned with “1” is more than that generated by the original median filtering operator.



(a)



(b)



(c)

Fig. 1. (a) Original fragment-type structure, (b) fragment-type structure after median filtering used in [7], and (c) fragment-type structure after boundary-based median filtering

III. FRAGMENT-TYPE ISOLATION STRUCTURE DESIGNS

The proposed boundary-based median filtering operator is introduced into MOEA/D-GO to design the fragment-type isolation structures. The basic configuration of a compact MIMO PIFAs with an overall size of 43mm×43mm×6mm and a center-to-center interval of 15mm, operating at 2.345GHz-2.36GHz, is the same as that in [7]. Meanwhile, the objective functions are also the same as those in [7].

After optimization, several candidate designs are obtained. The design with the widest bandwidth, along with its current distribution at 2.35GHz, is illustrated in Fig. 2. Its prototype is shown in Fig. 3(a), and both simulated and measured return loss and isolation are given in Fig. 3(b).

From Fig. 2, it is clearly seen that the current at 2.35GHz could be well trapped into the isolation structures through metal conductor. From Fig. 3(b), good agreement between simulated and measured results is observed. The antenna operates at 2.26GHz-2.36GHz with return loss of more than 10dB and isolation of more than 20dB. The isolation at 2.35GHz could achieve 24dB.

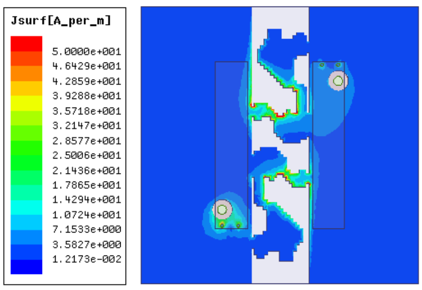
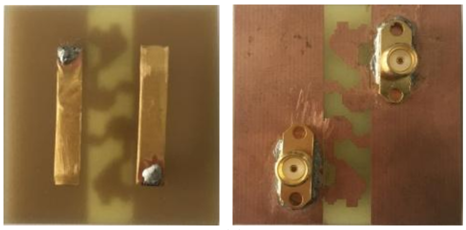
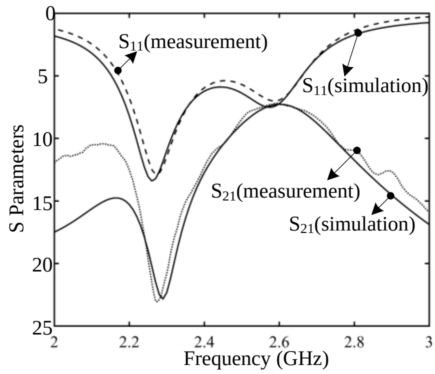


Fig. 2. Optimized ground plane by using MOEA/D-GO combined with boundary-based median filtering operator and its current distribution at 2.35GHz.



(a)



(b)

Fig. 3. (a) Prototype of MIMO PIFAs by using MOEA/D-GO combined with boundary-based median filtering operator and (b) simulated and measured *S* parameters

IV. COMPARISON

For demonstration, those designs reported in [6], reported in [7], and given in Fig. 3 of this paper are denoted as design#1, design #2, and design #3, respectively.

Table I exhibits the comparison on optimization results, including electric characteristics, the number of alternative designs, and computational cost. The computational cost corresponds to the emergence of the simulated isolation with more than 20dB at 2.345GHz-2.36GHz while return loss is larger than 10dB for the first time.

From Table I, it is obviously observed that MOEA/D-GO combined with boundary-based median filtering operator could generate more satisfied designs at the expense of computational cost.

TABLE I. COMPARISON ON THE OPTIMIZATION RESULTS AND THE COMPUTATIONAL COST

Design	**Electric Characteristics**				**Number of Designs**	**Computational Cost**	
	***S_{11}* (dB)**	***S_{21}* (dB)**	***Relative bandwidth (%)***	***Front-back-ratio***		***Iteration number***	***Time (days)***
#1	16.3	47	2.8	1.39	11	46	8
#2	10.5	46	0.6	1.18	2	10	2
#3	10.6	24	4	2.53	8	21	7

V. CONCLUSIONS

In this paper, a novel boundary-based median filtering operator is proposed to design the isolation structures of two closely-packed MIMO PIFAs. Comparison on the number of obtained designs and the electric performances of the designs shows that more alternative designs could be found at the expense of the searching speed, and both better front-back-ratio and wider impedance bandwidth are observed. The proposed operator is promising for the design of the fragment-type structure of other kinds of antennas and microwave components.

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