6. main-lobe widths (3 dB) at 3.5 GHz: 36° (XZ-plane), 26° (YZ-plane).

Although the original specifications are given for the 3.4–3.6 GHz band, it can be observed that the above-mentioned characteristics extend beyond 3.7 GHz (more than 8.5% bandwidth).

4. CONCLUSIONS

Two robust low-cost 4 × 4 arrays of microstrip antennas on foam substrates have been designed to operate between 3.4 and 3.6 GHz. Their bandwidths have been enhanced by means of two different techniques: a stacked layer and a coplanar set of parasitic patches. Prototypes are currently under test.

REFERENCES


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A NOVEL PRINTED MICROSTRIP WINDOW ANTENNA FOR SIZE REDUCTION AND CIRCUIT EMBEDDING

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ABSTRACT: A printed microstrip window antenna is proposed in this paper. The window antenna is obtained by perforating a conventional microstrip patch antenna into a window-like geometry. This perforation not only induces a size reduction of more than 50%, but also makes it possible for antenna and RF circuits to be integrated into a unified subsystem by embedding passive and active circuits into the windows of the antenna. The 10 dB return-loss bandwidth of the window antenna is 1.7%, with a gain of 3.7 dBi. © 2002 John Wiley & Sons, Inc.

Key words: microstrip; patch antenna; microwave integrated circuit

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I. INTRODUCTION

As microstrip and printed antennas are low profile, conformal to their mounting bases, and compatible with integrated circuits, they are rapidly finding their way into commercial and consumer products [1–4]. To make microstrip antennas more suitable for mobile communication applications, much effort has been devoted to the size reduction of conventional patch antennas [5–7]. For a given substrate, the shorting pin and shorting wall are the main approaches for size reduction [6–7]. Recently, we have demonstrated that suitable perforations on a microstrip line can achieve a remarkable size reduction [8]. The perforation pattern on the microstrip line is restricted by the width of the line. If the same perforation technique is used in a microstrip patch antenna, much more space is available for designing the perforation pattern, and a better size reduction can be expected.

In this paper, we propose a microstrip window antenna for size reduction. The so-called window antenna is constructed by introducing perforations on a conventional microstrip patch antenna, giving the patch a window-like geometry. A remarkable size reduction has been achieved. This window structure also allows the integration of passive and active circuits into the antenna to form a compact integrated microwave front end for mobile application.

II. ANTENNA DESIGN

Figure 1 shows the proposed window antenna. It is constructed by perforating a conventional microstrip patch antenna to a window-like pattern. The antenna is probe fed. There are four apertures in the antenna. The larger two are used to control the resonance. The size difference between these two large apertures makes the real part of the input impedance matched to 50 Ω. The two symmetric small apertures are used for the compensation of the imaginary part of the input impedance. The size of the antenna for 4.09 GHz are W = 18 mm, W1 = 0.2 mm, W2 = 2.0 mm, W3 = 5 mm, L = 11 mm, L1 = 1.5 mm, L2 = 2.0 mm, L3 = 3.3 mm, and L4 = 5.3 mm. The diameter of the feeding probe is 1.2 mm. The substrate thickness is 3.15 mm, with a relative permittivity of εr = 2.33. On the same substrate and at the same frequency, the size of the conventional square patch antenna should be 22 × 22 mm². The size of the window antenna is less than 50% of that of a conventional patch antenna at the same operating frequency. Considering the area of the conductive part of the antenna, the area reduction of the antenna is 90%.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The window antenna with the parameters given above was fabricated and measured. Figure 2 shows that the 10 dB return-loss bandwidth of the window antenna is about 1.7%, which is about 40% of that of the conventional patch antenna. Figure 3 shows the H-plane and E-plane radiation patterns at 4.09 GHz. It can be observed that the 3 dB beamwidths in the H- and E-plane are 75 and 101°, respectively. Both copolarization and cross-polarization patterns are
Figure 2  Measured return loss of the window antenna

Figure 3  Measured radiation patterns in two orthogonal planes at 4.09 GHz. (a) H-plane. (b) E-plane

given in the same chart. They are similar to that of a patch antenna. The antenna gain is about 3.7 dBi. This is physically sound as the size and conductive area of the antenna are smaller than that of a conventional one by 50 and 90%, respectively.

When the two larger apertures are modified by incorporating some conductor patterns as shown in Figure 4, the shift of the center frequency of the antenna is less than 0.5%, and the patterns almost remain unchanged if the incorporated patterns are one-third the substrate thickness away from the window frame. This implies that passive and active circuits can be embedded within the holes to form a compact integrated microwave front end with both circuits and antenna. The antenna is probe fed for the convenience of measurement. For circuit embedding in the apertures, it can be microstrip-line fed at the same point.

IV. CONCLUSION

A novel microstrip window antenna is proposed and implemented in this paper. The antenna size and conductive area can be reduced to 50 and 10% of those of a conventional patch antenna, respectively. In addition to the reduction, the proposed antenna can also be integrated with passive and active circuits to form a compact integrated microwave front end. The bandwidth of the proposed antenna is less than that of a conventional patch antenna, however.

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SIDELOBE REDUCTION IN SPARSE LINEAR ARRAYS BY GENETIC ALGORITHMS

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ABSTRACT: A numerical procedure based on a genetic algorithm is proposed in order to synthesize a linear, sparse, and aperiodic array to be used in a beamforming processor. The method is aimed to minimize the sidelobe peak of the beam pattern acting on the elements’ positions and weights. Obtained results also confirm the effectiveness of the approach in comparison with other techniques in the related literature. © 2002 John Wiley & Sons, Inc. Microwave Opt Technol Lett 32: 194–196, 2002.

Key words: linear array; beamforming; beam pattern; genetic algorithms DOI 10.1002 / mop.10128

1. INTRODUCTION

In order to investigate a 2-D area by means of a beamforming system, a linear array should be used to generate and/or receive the wave field. To prevent grating lobes in the beam pattern (BP) due to spatial undersampling, a half-wavelength (λ/2) spacing between the elements of the array should not be exceeded. However, an aperiodic element placement also allows us to avoid grating lobes using an average spacing much larger than λ/2. Unfortunately, a higher sidelobe peak (SLP) results.

In this paper, a stochastic method based on a genetic algorithm (GA) is proposed in order to reduce the SLP of the BP generated by a linear array of 25 elements over a fixed aperture of 50A (discretized into intervals equal to λ/2). As indicated in [1], the addressed test case is a recognized baseline to evaluate the effectiveness of array optimization methods. In more detail, the SLP reduction is obtained by varying the positions and weights of the array elements, according to an evolutionary strategy and allowing the synthesis of an aperiodic and sparse array. The main innovations of the proposed approach with respect to other methods [2, 3] are: 1) both weight coefficients and positions are optimized at the same time, 2) a hybrid integer-real coding is used, 3) the method has been hybridized with a local search algorithm, and 4) a priori knowledge-augmented operators have been considered. To the best of the authors’ knowledge, the best result on the considered baseline problem has been reported in [1], where the simulated annealing (i.e., another stochastic optimization method) has been exploited. However, the high suitability of GAs in exploring complex search spaces and the computational effectiveness (when the attraction basin of the global minimum is localized) of gradient-based search algorithms (GSs) have allowed the authors to yield better results.

2. THE OPTIMIZATION ALGORITHM

GAs are optimization algorithms based on the Darwinian theory of evolution. Standard GAs [4, 5] consider a population of P trial solutions coded into binary strings called chromosomes, and ranked according to the value of a suitable objective function (called “fitness function”). The best solutions are selected, and undergo crossover and mutation operators in order to generate a new population. The iterative procedure is stopped when a fixed threshold for the fitness function or a maximum number of generations has been reached.

In the problem considered here, the unknown parameters are positions X and weights W of the array elements. To optimize, at the same time, both positions and weights, the fitness function \( f(X, W) \) is defined as follows:

\[
\max_{u_{\text{start}} \leq u \leq u_{\text{end}}} \left( g(p(u)) \right) = f(X, W) \tag{1}
\]

where \( p(u) \) is the normalized BP [1] computed by considering current vectors \( X \) and \( W \), and \( u = \sin \theta - \sin \theta_0 \) is related to the arrival direction of the wave \( \theta \) to the steering direction \( \theta_0 \), and ranges between \(-2\) and \(2\). Owing to the symmetry properties of \( p(u) \), the investigation and visualization of the BP in \( u \in [0, 1] \) are completely sufficient [1]. Therefore, \( u_{\text{end}} = 1 \), and \( u_{\text{start}} \) is chosen equal to 0.04 in order to take into account the main-lobe region.

To maximize (1), a customized GA has been considered. Hereafter, we point out the main features of the iterative process with respect to standard implementations. A hybrid coding has been used in order to accurately represent the unknown parameters. The positions and weights of the array elements have been represented with integer and real coding, respectively. Moreover, in order to decrease the worst individuals’ fitness and raise the best ones, a heuristically chosen fitness scaling has been applied as follows:

\[
f' = (f - f_{\text{avg}})^5 - (f_{\text{worst}} - f_{\text{avg}})^5.
\]

As far as the genetic operators are concerned, because of the low effectiveness of conventional crossover and mutation, a real coding crossover [6] has been applied, and the standard mutation has been modified by considering the a priori knowledge, allowing a reduction of the search space and an increase of the convergence rate. In more detail, if an array element is picked up for mutation, its position is forced to randomly vary within the range imposed by the second and the next to the last element’s position. This choice is due to some heuristic reasoning about the layout of highly optimized arrays, which always presents elements’ accumulations. Moreover, the gigabit improvement procedure [4], adapted to integer-real coding, has been included in the main loop of the GA.