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Reflect Array Using Multi Segment Circular Fractal Unit Cell With Isoflux Pattern For C-Band Application

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Abstract-*in this paper with using novel fractal structure which is composed of multi segment circular fractal. A unit cell and then reflectarray antenna have been designed. The unit cell of reflect array has been designed in 4.4 GHz with 24*24*1 mm^3 dimension. The reflectarray is consist of 400 (20* 20) elements that even element is placed in the locus has been calculated. Maximum gain of antenna is 12.9 dBi.*

Introduction

Since the revolutionary breakthrough of printed circuit technology in the 1980's, microstrip reflectarrays have emerged as the new generation of high-gain antennas for long distance communications. They are similar in principal to parabolic reflectors, while the bulky curved surface of the parabolic reflector is replaced with a planar antenna array, which results in a low-profile, low-mass, and low-cost antenna. The concept of the reflectarray was initially introduced using waveguide technology in the 60's [1]. Later in the 70's the spiral phase reflectarray was developed [2], but the reflectarray didn't receive much attention until the development of microstrip reflectarrays in the late 80's [3]. The elements of the reflectarray are designed to reflect the EM wave with a certain phase to compensate for the phase delay caused by the spatial feed. The phase shift of the elements is realized using various methods such as variable size elements, phase-delay lines, and element rotation techniques. The infinite array approach is used to calibrate the element phase versus element change [4]. Due to the very large number of elements involved in a reflectarray, full-wave simulation of the entire reflectarray antenna is still challenging. On the other hand, different theoretical models have been developed for the analysis of reflectarrays, such as the array theory formulation and the aperture field analysis technique, which show a good agreement with measured results. Moreover, implementing the spectral transform in these calculations allows for fast calculation of the radiation characteristics of the antenna, which is a considerable advantage for synthesis design problems using iterative procedures. Single and multi-layer reflectarrays have been designed to achieve broad band and multi-band performance from microwave frequencies up to the THz range [5]. Considerable improvements have been made to these designs over the years and many practical designs have been demonstrated. One of the main challenges in reflectarray designs is improving the bandwidth of the antenna, which is the major drawback of all printed structures [6]. Different bandwidth improvement techniques such as using multi-layer designs [7], true time-delay lines [8], and sub-wavelength elements [9] have been studied and bandwidths of more than 20% have been reported. On the other hand, the direct control of the phase of every element in the array allows multi-beam performance with single or multiple feeds [10]. The design of contoured beam reflectarrays is also a challenging field [11]. A phase-only synthesis process is used to obtain the required element phase shift from any given mask. Multi-feed multi-beam contoured beam designs have been demonstrated [12]; however, the performances of these designs are slightly inferior to the shaped beam parabolic reflectors. Another advantage of reflectarrays is the ability of the antenna to scan the main beam to large angles off broadside. Beam scanning reflectarrays are designed by using low-loss phase shifters in every element of the array [13]. These beam scanning reflectarrays require a switch board to control the main beam direction and are well suited for radar applications and some models have been demonstrated; however, considerable challenges lie in improving the performance of these beam scanning antennas. In addition to the numerous capabilities and potentials reflectarray antennas have demonstrated, a great deal of interest now is the practical implementation of reflectarray antennas for space applications. Since the common considerations for space antennas are size, weight, and power, because of limitations imposed by the satellite launch

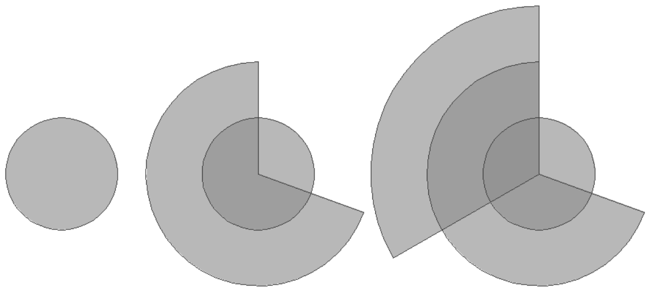


Fig. 1. Iterations of proposed fractal

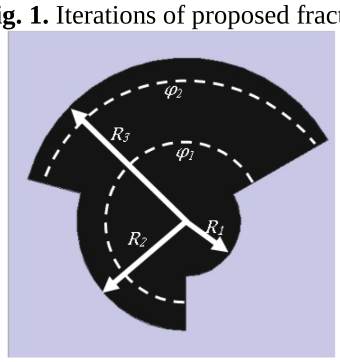


Fig. 2. Configuration of proposed fractal

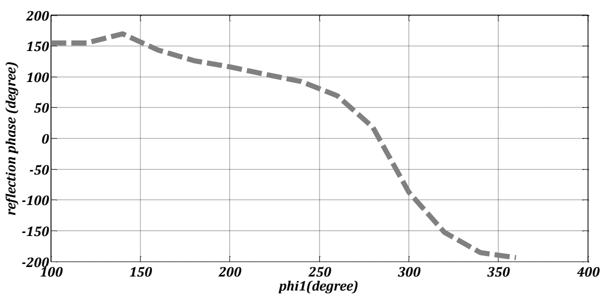


Fig. 3.Reflection phase of the variable size of φ_1

Multi-segment circular fractal configuration, result and discussion

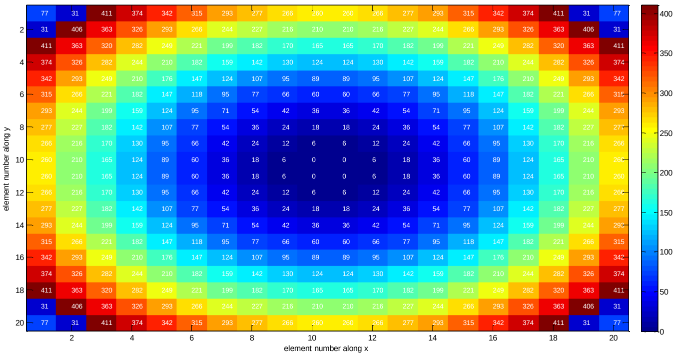
The proposed circular fractal is a two dimensional (2D) fractal constructed from multi-segment circles. The construction of the proposed fractal begins with an iterative process at odd numbered iterations *km, m=1, 3… 2M+1*, where *M* is a positive integer number. As shown in Fig.1, the proposed fractal initiator is partitioned into three non-overlapping segments with different radius. The same procedure is then applied recursively to the other remaining layer with iterated function transformations, ad infinitum. In the proposed fractal, all the segments angle have M=2π/n constant value and different radius r=R, 2R… nR. Fig.1 shows illustration of the first four iterations in the construction process. As seen in fig 2, R_1, R_2 and R_3 are fixed in 4, 8 and 12 mm, respectively and φ_2 is fixed at 120°.

The techniques presented in this section are applied to C-band reflectarrays for comparison of these methods. We consider a C-band reflectarray with a circular aperture and a diameter of 678.8mm. The phasing elements, used in this study, are variable size of φ_1 with R_2 fixed at 8 mm. the unit-cell periodicity of 0.35λ at the design frequency of 4.4 GHz and are fabricated on a 1 mm FR4 epoxy substrate. The reflection phase response (S-curve) of the phasing elements obtained using the infinite array approach, is generated using High Frequency Structure Simulation (Ansoft HFSS v.15) [15], and is given in Fig. 3.

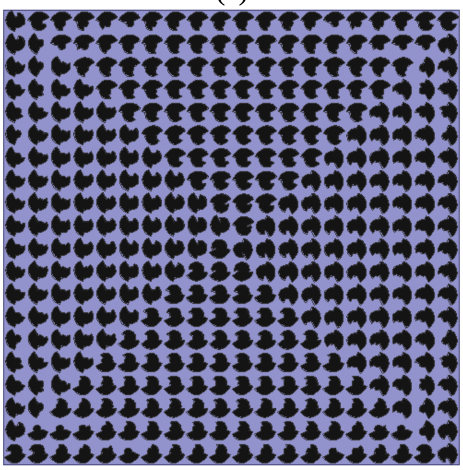
The variable size of φ_1 are selected from the S-curve in Fig. 3 to match the required phase distribution on the aperture. The mask of the reflectarray antenna and the obtained reflection phase of the elements are given in Fig. 4(a) and 4(b).

It can be seen the phase distribution obtained from the variable size of φ_1 shows a close agreement with the ideal phase, i.e. Fig. 2-15 (b). The principal plane radiation patterns of the reflectarray antenna, is given in Fig. 5 at 4.4 GHz. It should be noted that with this design the cross-polarized pattern obtained using the aperture field formulation is almost zero in the principal planes. The maximum cross-polarization level for this system is -18.5 dB.

Using the FR4 substrate with high loss tanσ=0.02 is caused increasing the side lobe level and X-polarization.

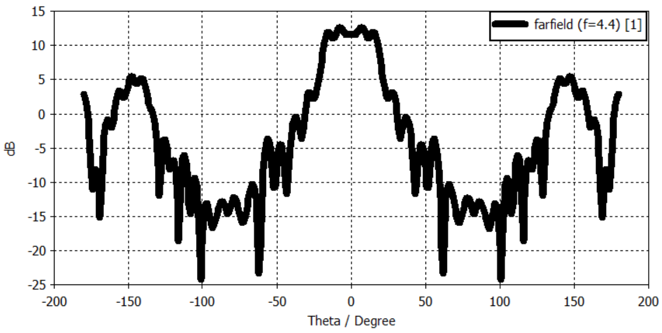


(a)

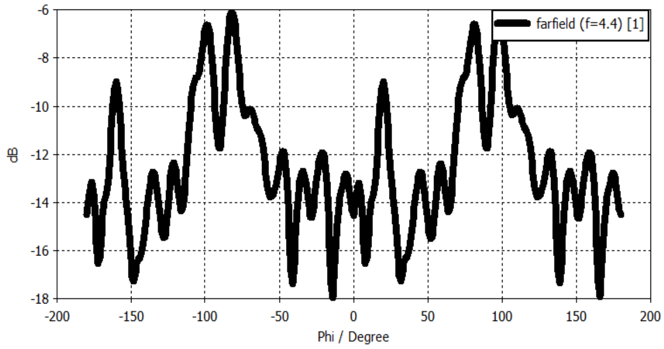


(b)

Fig. 4. The mask of the reflectarray antenna and the obtained reflection phase of the elements



(a)



(b)

Fig. 5. Pattern of proposed antenna at 4.4GHz (a)co-polarization (b)cross polarizarion

Reflectarray antenna result and discussion

In this design, the reflectarray phasing elements are designed to generate a beam in the broadside direction. The reflectarray aperture is circular and has a diameter of 678.8mm. The x-polarized prime-focus feed horn is positioned with an F/D ratio of 0.9, in the array theory calculations, the polarization of the feed horn is not modeled. For the horn model used in this study, the gain of the horn is 6.5dBi at 4.4 GHz. the ideal phase requirement for the reflectarray elements is given in Fig. 4.

Conclusion

In this paper the design of reflectarray with 400 elements each of the elements by changing the angle of the circular fractal parameters were placed in selected locations. All structures on FR4 substrate with loss tangent of 0.02 and permittivity of 4.4 were designed. The unit cell of reflectarray was consist of Multi-segment circular fractal. Reflection phase of unit cell of reflectarray that designed with infinite array approach has 380 degree that suitable for broadside application. F/D ratio was 0.9 and gain of antenna at 4.4GHz (center frequency) was equal with 12.9dBi.

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