Our results show that the mean value of the input impedance (both real and imaginary parts) remains relatively unchanged with frequency in the range from $C/\lambda = 0.95$ to $C/\lambda = 1.8$, different from that computed in [2]. We notice from Fig. 5 that the computed and the measured impedance for the 7-turn spherical helical antenna differ more significantly with increasing frequencies. This is due to the use of a fixed number of divisions for the antenna wire in the numerical computation which gives less accurate results at higher frequencies. This error can be reduced by proportionately increasing the number of divisions at higher frequencies but at the expense of a longer computation time.

The measured antenna gains (with respect to an isotropic circularly polarized source) for a 3-turn and a 7-turn antennas are shown in Fig. 6. It can be seen that a relatively stable gain (within 1 dB) can be obtained for the 3-turn antenna from $C/\lambda = 1.1$ to $C/\lambda = 1.3$. On the other hand, the gain of the 7-turn antenna changes more rapidly with frequency. The maximum gain of the 3-turn antenna is 11.1 dB measured at $C/\lambda = 1.28$ and that of the 7-turn antenna is only 9.9 dB at $C/\lambda = 1.18$. The generally smaller gain of the 7-turn antenna is due to its deeper mismatched impedance (Fig. 5) when compared with that of the 3-turn antenna (Fig. 3).

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Generalized Sierpinski Fractal Multiband Antenna

Jordi Romeu and Jordi Soler

***Abstract*—A new set of fractal multiband antennas called $\mathrm{mod} - p$ Sierpinski gaskets is presented. $\mathrm{Mod} - p$ Sierpinski fractal antennas derive from the Pascal triangle and present a log-periodic behavior, which is a consequence of their self-similarity properties. $\mathrm{Mod} - p$ Sierpinski fractal antennas constitute a generalization of the classical Sierpinski antenna.**

***Index Terms*—Antennas, fractals, multifrequency antennas.**

I. INTRODUCTION

The multiband behavior of the fractal-shaped antennas and of the Sierpinski gasket dipole has been described in [1], [2]. The multiband properties of the Sierpinski gasket dipole are a consequence of its self similarity. Self similarity is a property common to many fractals, but in order to become a useful radiator it is necessary that the fractal antenna meet the specifications at the desired frequencies. The Sierpinski gasket in a monopole configuration has a good matching to 50 Ω at the resonance frequencies, a log-period band spacing of 2, and a fairly invariant radiation pattern in all bands, which is very similar to the pattern of a monopole. The Sierpinski gasket dipole reported in [2], is just one special case of a more general class of fractal objects called Pascal–Sierpinski gaskets [3]. Furthermore, the geometry of the Sierpinski dipole can be altered by changing the flare angle [4]. It is even possible to modify it in order to obtain a desired log-period band spacing [5]. In this paper the properties of these generalized Sierpinski gasket antennas are presented. Their main advantage is the possibility to obtain log-periodic behavior with values of the log-period larger than 2.

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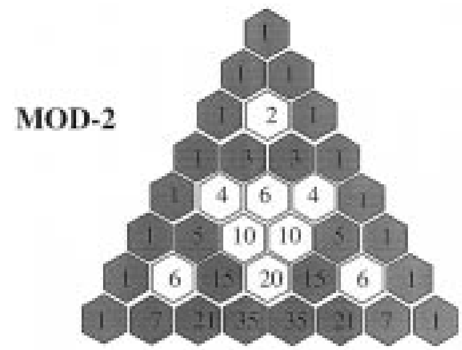

Fig. 1. Derivation of the Sierpinski gasket from Pascal's triangle. When those numbers divisible by 2 are deleted, the $\mathrm{mod} - 2$ Sierpinski gasket is obtained.

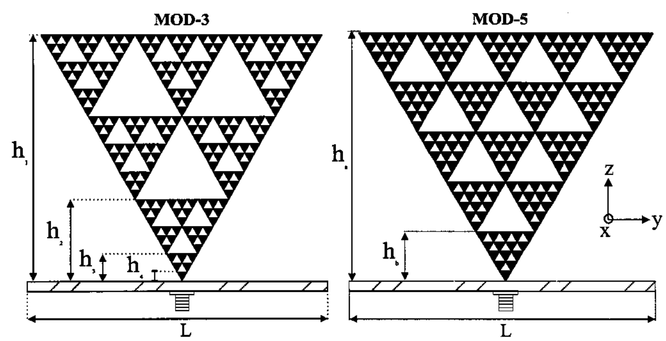

Fig. 2. Two Sierpinski gaskets (a) $\mathrm{mod} - 3$ Sierpinski gasket, (b) $\mathrm{mod} - 5$ Sierpinski gasket.

II. THE SIERPINSKI GASKET AND ITS VARIATIONS

The Sierpinski gasket is a well known fractal. The way it can be constructed and its main properties can be found in [1], [2], and [6]. In [3] it is shown that the Sierpinski gasket is a special case of a wider class of fractals that can be derived from the well known Pascal's triangle. This class of fractals can be derived in the following way. Consider an equiangular triangular grid whose rows shall be labeled by $n = 1, 2, 3, \ldots$. Each row contains n nodes and to each node a number is attached. This number is the coefficient of the binomial expansion of $(x + y)^{n-1}$. Now delete from this grid those nodes that are attached to numbers that are exactly divisible by p, where p is a prime number. The result is a self-similar fractal that will be referred as the $\mathrm{mod} - p$ Sierpinski gasket [3]. In Fig. 1, this process is shown for the $\mathrm{mod} - 2$

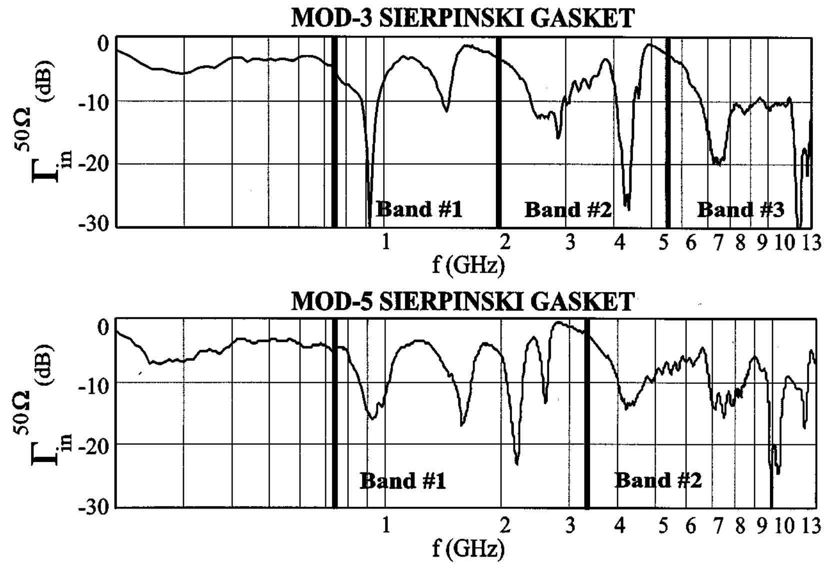

Fig. 3. Input reflection coefficient for the $\mathrm{mod}-3$ and $\mathrm{mod}-5$ Sierpinski monopoles. VSWR is minimum for the $\mathrm{mod}-3$ antenna at 0.29, 0.92, 1.46, 2.74, 4.32, 7.46 and 12.37 GHz, and for the $\mathrm{mod}-5$ monopole at 0.26, 0.91, 1.58, 2.18, 2.6, 4.24, 7.5, 10.11 and 12.08 GHz.

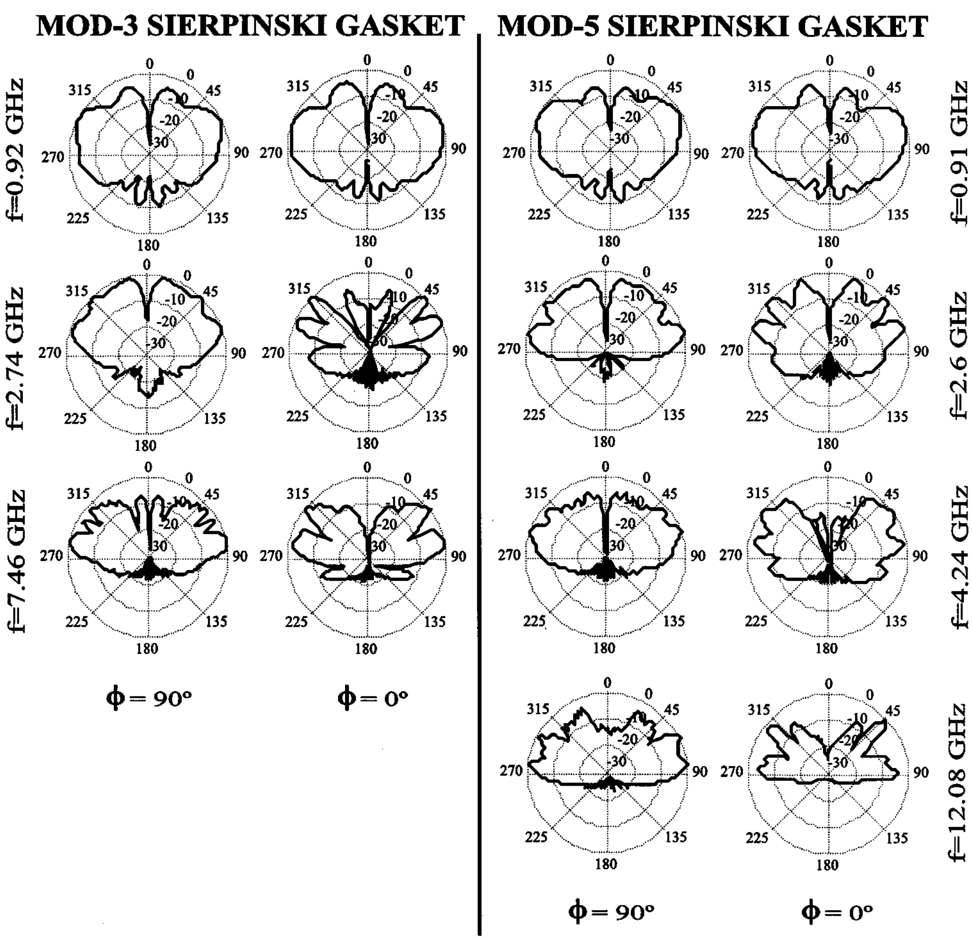

Fig. 4. Main radiation pattern cuts for the $\mathrm{mod}-3$ and $\mathrm{mod}-5$ monopole antenna.

Sierpinski gasket and the blank nodes represent those deleted from the grid. To obtain the $\mathrm{mod}-3$ and $\mathrm{mod}-5$ Sierpinski gaskets, those nodes attached to numbers divisible by 3 and 5 should be deleted from the Pascal's triangle. In Fig. 2 , three-iteration $\mathrm{mod}-3$ and $\mathrm{mod}-5$ Sierpinski gaskets are shown. In this case it is clear that the scaling of the different replicas is p.

III. Analysis and Results

The different Sierpinski configurations presented in the previous section have been analyzed. The experimental results have been obtained by building the antennas in the similar way as described in [2].

The $\mathrm{mod}-3$ and $\mathrm{mod}-5$ Sierpinski monopoles are printed over a thin dielectric substrate ($\epsilon_r = 3.38, h = 0.8$ mm), mounted over a 800×800 mm^2 square conductor ground plane, and fed using a coaxial probe. The scale factor is p in both cases; in particular, 3 for the $\mathrm{mod}-3$ antenna and 5 for the $\mathrm{mod}-5$ monopole. Since the triangular-like shape appears at different scales for $\mathrm{mod}-p$ antennas, it is expected that they behave similarly to a triangular antenna but at different bands. Besides, it is also expected that the log-period (d) matches the scale factor (p).

The input reflection coefficient of the antennas relative to 50 Ω was measured using an HP8510B from 0.2 to 13 GHz for the $\mathrm{mod}-3$ and $\mathrm{mod}-5$ antennas (see Fig. 3). In both antennas, the resonant frequencies are log-periodically spaced by a factor (d), which matches the log-period p. The $\mathrm{mod}-3$ antenna has been built after three iterations; therefore, the antenna exhibits three bands. Each one contains two resonances spaced by a factor 1.6. Each band is separated from the other by a factor of 3. This log-periodic behavior also occurs for the $\mathrm{mod}-5$ antenna, where two bands can be identified with four resonances inside each one. For this antenna, at each new iteration the size of triangles that make up the structure is reduced by a factor of 5. Due to technological reasons of the etching process only a two-iteration antenna was built. The spacing between the two bands also match the scale factor 5. The presence of multiple resonant frequencies inside each band is caused by the multiple triangles that appear between fractal iterations.

The main cuts $(\phi = 0, \phi = 90)$ of the radiation patterns of the novel designs were measured in an anechoic chamber at the first resonance of the three bands for the $\mathrm{mod}-3$ antenna, and at the first and last resonances for the two bands in the $\mathrm{mod}-5$ antenna (see Fig. 4). The patterns keep a notable degree of similarity among bands, especially in the $\phi = 90$ plane. At the highest bands a slight increase of ripples due to the diffraction at the edges of the ground plane is observed.

IV. Conclusion

A novel set of fractal multiband antennas called $\mathrm{mod}-p$ Sierpinski gaskets has been introduced. Experimental results show that the spacing between bands is related to the characteristic scale factor of the fractal structure. Moreover, the number of iterations that the structure contains is related to the number of bands at which the antenna keeps the same behavior in both the input impedance and the radiation patterns. Although, multiple resonances are observed within each band; a log-periodic behavior is clearly observed. Thus, $\mathrm{mod}-p$ Sierpinski gaskets constitute a new set of fractal multiband antennas where log-periods larger than 2 can be obtained.

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Magneto Optical Technique for Beam Steering by Ferrite Based Patch Arrays

N. Das and A. K. Ray

***Abstract*—An improved technique is presented to scan a beam of a phased antenna array on a ferrite substrate through use of time delays instead of phase shifts provided by nonlinear transmission lines coupled to elements of the array. A coplanar transmission line loaded with a varactor diode when subjected to varied optical illumination offers bias dependent time delays to the elements of the arrays over a wide range of tunable operating frequencies at lower UHF without scan blindness effect. This method results in a broadband ferrite based phased antenna array with reduced weight, loss and complexity of the integrated system. This technique has proved to have a special application potential in case of beam steering by ferrite based microstrip antenna arrays at lower UHF (800 MHz–2 GHz).**

***Index Terms*—Dynamic scanning, ferrite based patch array, magneto optical.**

I. Introduction

A phased antenna array consists of a number of elements patched on a dielectric or ferrite substrate. The elements of the array fed with variable phase or time delay can cause beam steering. The use of phase shifters, however, restrict the operating frequency bandwidth of the antenna array, besides being bulky and costly. A nonlinear transmission line (NLTL) using varactor diodes has been reported [1] to provide 1.1 ns true delay at 2 GHz, with less than 4 dB insertion loss to the elements of a phased antenna array to cause beam steering. The delay could be achieved through a coplanar transmission line loaded with a single varactor diode when the diode is subjected to optical illumination under intensity control [2]. This is accompanied by enhanced range of capacitance variation of the varactor diode beyond the saturation value under optical illumination. The intensity variation of the optical beam results in wide range variation of the dark current capacitance of the varactor diode at different operating frequencies (800 MHz to 7 GHz). This has a special application in a ferrite based array; as such arrays could be tuned to resonate over (800 MHz to 2 GHz) [3] by applying magnetic bias to the substrate. Thus, the range of the achievable time delay by the NLTL method could be gainfully exploited over the operating frequency bandwidth at lower UHF, resulting in a beam scanning with sufficient scan angle and without scan blindness.

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