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# Microstrip fractal patch antenna for multi-band communication

R.V. Hara Prasad, Y. Purushottam, V.C. Misra and N. Ashok

A novel square microstrip fractal patch antenna in a Sierpinski carpet is proposed for three-band operation. Measured results indicate that the return loss is better than 10dB and that the gain is greater than 7dB in each band. This antenna is an attractive candidate for wireless, satellite and mobile communication applications.

*Introduction:* A 'fractal' is a recursively generated structure having a fractional dimension. Recently, the concept of 'fractal' has been extended to the design of antennas to obtain multi-band frequency operation. Puente *et al.* [1] described a Sierpinski multi-band fractal antenna in which the multi-band behaviour was achieved for both the Sierpinski monopole and dipole. The fractal volume antenna concept [2] was introduced in order to increase the degree of design freedom associated with fractal antenna elements and hence to improve their input matching characteristics. More recently the multi-band and wide-band properties of printed fractal branched antennas have been reported by Sindou *et al.* [3].

In conventional microstrip patch antennas, dual- or multi-frequency operation can be obtained by employing multiple radiating elements [4] or reactively loaded patch antennas [5] or multi-frequency dielectric resonator antennas [6]. In this Letter, the concept of a 'fractal' has been applied for the first time to the geometry of a square microstrip patch antenna to obtain multi-band frequency operation. Both impedance matching and radiation pattern characteristics are studied and the measured results are presented. This antenna is useful in wireless, satellite and mobile communication applications.

*Antenna configuration:* A schematic diagram of the square microstrip fractal patch antenna in a Sierpinski carpet is indicated in Fig. 1. A scaling factor of 1/3 was chosen so as to maintain the perfect geometrical symmetry of the fractal structure. To establish the multi-band frequency operation, initially the order $n$ of the antenna was limited to three ($n = 3$), which enabled the antenna to operate in three different frequency bands with corresponding resonant frequencies of $f_1$, $3f_1$ and $9f_1$ (where $f_1$ is the resonant frequency of the driven element i.e. $n = 1$). The radiating elements were printed on a copper clad material Rogers RT - Duroid 5880 ($\varepsilon_r = 2.2$) of 1/16" thickness using a photolithographic process. The dimensional details of the antenna are indicated in Table 1. The driven element ($n = 1$) is fed by means of a 0.141" co-axial semi-rigid cable at 50Ω impedance point which was at a distance of 22.86mm from the edge of the patch. The other end of the cable was provided with a 50Ω SMA connector. Energy was coupled parasitically from the driven element to the parasitic elements for multi-band operation of the antenna.

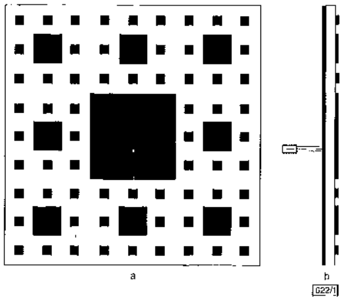

**Fig. 1** *Schematic diagram of square microstrip fractal patch antenna*

*a* Top view
*b* Cross-sectional view

**Table 1:** Dimensional details of square microstrip fractal patch antenna

| Order | Resonant frequency | Element size | Number of elements | Excitation |
|---|---|---|---|---|
| | GHz | mm | | |
| 1 | 1.5 | 65.33 × 65.33 | 1 | Co-axial probe |
| 2 | 4.5 | 21.78 × 21.78 | 8 | Parasitic coupling |
| 3 | 13.5 | 7.26 × 7.26 | 64 | Parasitic coupling |

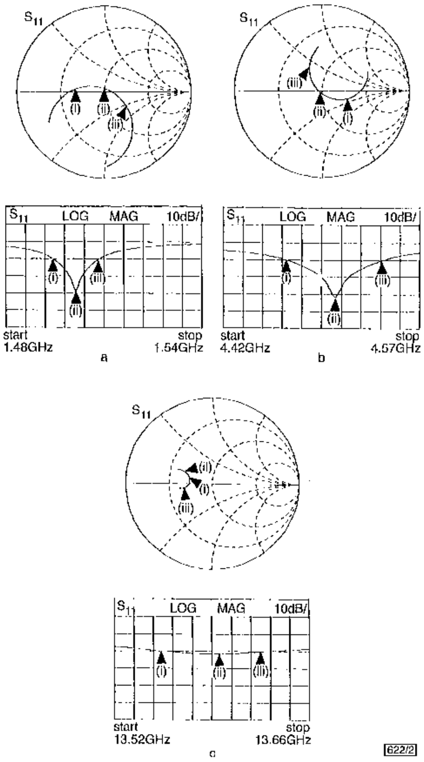

**Fig. 2** *Impedance and return loss measurements for square microstrip fractal patch antenna*

*a* Band 1
Marker: (i) 1.49GHz: 26.19 + *j* 1.96Ω; –10dB
(ii) 1.50GHz: 50.67 + *j* 3.28Ω; –29dB
(iii) 1.51GHz: 78.72 – *j* 30.29Ω; –10dB
*b* Band 2
Marker: (i) 4.46GHZ: 90.36 – *j* 18.91Ω; –10dB
(ii) 4.50GHz: 48.37 – *j* 1.81Ω; –32dB
(iii) 4.54GHz: 32.29 + *j* 19.68Ω; –10dB
*c* Band 3
Marker: (i) 13.56GHZ: 26.71 + *j* 6.94Ω; –10dB
(ii) 13.59GHz: 29.14 + *j* 1.59Ω; –11.5dB
(iii) 13.63GHz: 26.20 – *j* 2.28Ω; –10dB

*Test results:* Impedance and return loss measurements were carried out on the antenna in all three bands and the measured plots are shown in Fig. 2. The impedance bandwidth in each frequency band was measured for a minimum return loss of 10dB. The ratio of the highest to lowest operating resonant frequencies $(f_3/f_1)$ was equal to 9.06.

Radiation pattern and gain measurements in all three bands of the antenna were also carried out in an anechoic chamber. The typical measured co-polar and cross-polar radiation patterns at the resonant frequencies of each band are illustrated in Fig. 3. The top row shows the H-plane radiation patterns while the bottom row shows the E-plane radiation patterns. The multiple lobes of the E-plane radiation patterns in bands two and three are due to the geometrical asymmetry of the fractal structure in the E-plane with respect to the feed point location. A minimum gain of 7dB was achieved in each frequency band of the antenna.

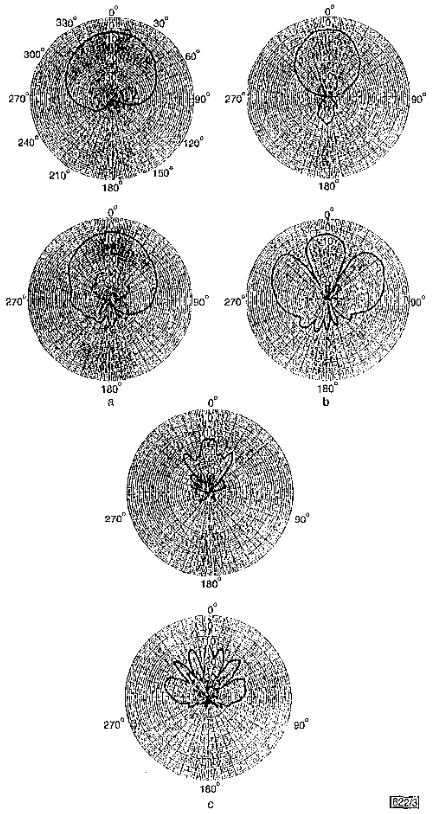

**Fig. 3** *Co-polar and cross-polar radiation patterns of square microstrip fractal patch antenna*

——— co-polar
-•-•- cross-polar
*a* 1.50GHz
*b* 4.50GHz
*c* 13.59GHz

**Table 2:** Measured performance characteristics of square microstrip fractal patch antenna

| Band | Measured resonant frequency | 3dB beamwidth |  | Boresight cross polarisation level |  | Gain | Bandwidth for 10dB return loss |
|---|---|---|---|---|---|---|---|
|  |  | H-plane | E-plane | H-plane | E-plane |  |  |
|  | GHz | deg | deg | dB | dB | dB | % |
| 1 | 1.5 | 74 | 60 | –26 | –23 | 7.5 | 1.33 |
| 2 | 4.5 | 41.5 | 32.5 | –22.8 | –23.5 | 9.2 | 1.78 |
| 3 | 13.59 | 18 | 8 | –16 | –15.5 | 10.4 | 0.51 |

The measured performance characteristics of the antenna at the resonant frequencies of each band are indicated in Table 2.

*Conclusion:* The concept of a 'fractal' has been extended for the first time to the domain of microstrip patch antennas to obtain multi-band frequency operation. A square microstrip patch antenna was constructed using fractal geometry for three-band operation. The measured results indicate that the antenna exhibits good radiation and impedance matching characteristics in all three bands. The same concept can be extended to any number of bands taking into account the fabricational criticality and also to the domain of triangular microstrip patch antennas. Antennas of this type are attractive candidates for wireless, satellite and mobile communication applications.

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# Shaped beams from circular apertures and arrays with uniform amplitude

A. Trastoy-Rios, M. Vicente-Lozano and F. Ares-Pena

It is shown that shaped beam patterns with acceptable ripple and sidelobe levels can be obtained from circular apertures or arrays with uniform excitation amplitude.

*Introduction:* It is often easier and less expensive to control the phase of an antenna excitation distribution than to control its amplitude, especially in the case of dynamic control. We therefore recently developed a general method for the synthesis of radiation patterns by controlling the phase distribution of apertures with fixed amplitude distributions [1, 2]. Of all amplitude distributions, the simplest is uniform distribution, which in the case of an active feed array also allows for maximum efficiency at the feed amplification stage [3]. In this Letter, we report the results of applying our method to the synthesis of patterns exhibiting flat-topped beams with controlled ripple surrounded by ring sidelobes with controlled heights to be produced by a circular aperture with an excitation distribution of uniform amplitude, and of adapting the result to a circular grid planar array, likewise of uniform excitation amplitude distribution.

*Description of method: Continuous apertures*: We assume an excitation distribution $h_0 = I_0\exp\{j\psi_0\}$, where $I_0$ is the desired amplitude distribution and $\psi_0$ is arbitrary (for example, identically zero). We assume that the complex zeros $(u_{0n} + jv_{0n})$ of the corresponding radiation pattern $F_0$ are known. We seek to synthesise a desired radiation pattern $F$ by iterative perturbation of the $u_{0n} + jv_{0n}$. In

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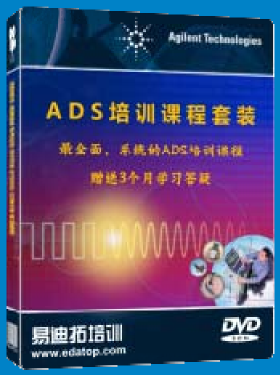

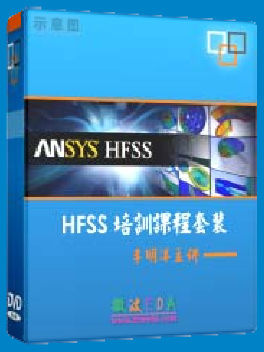

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