Miniature WideBand Stacked Microstrip Patch Antenna based on the Sierpinski Fractal Geometry

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Abstract- The main interest in the design of a miniature Microstrip Patch Antenna (MPA) is its small size in conjunction with the well-known advantages of a MPA (cost, profile, weight). However there is a big constraint on the bandwidth limitation either in a miniature antenna or in a MPA. The proposed solution to overcome such problem is to couple a miniature parasitic resonator to the miniature active patch forming a wideband small stacked microstrip patch antenna.

I.-INTRODUCTION

The actual demand on mobile communication systems (GSM900, GSM1800, PCS...) requires small terminals and consequently a reduced-size antenna. MPA have been widely studied recently to achieve this goal [1,2].

The limitations of small antennas has been studied [3,4] concluding that the smaller the size relative to the wavelength, the smaller the bandwidth and also the smaller radiation efficiency. According to [4], a classical MPA wouldn't be an optimum miniature antenna because it does not fill properly the radian sphere.

In this communication, a method to design Miniature Stacked MPA (MSMPA) is presented as a possible solution to obtain enhanced BW and also an acceptable radiation efficiency value.

The Stacked MPA (SMPA) has been widely analysed [5]. An example of this structure is depicted in figure 1.

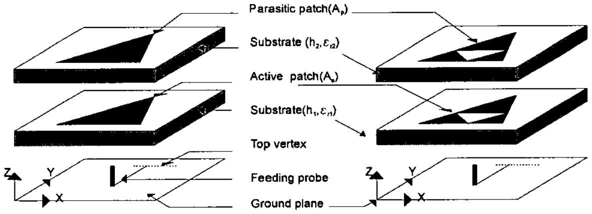

Fig. 1. Stacked triangular microstrip patch antenna (left) and the proposed miniature stacked microstrip patch antenna (right).

The SMPA is formed by an active patch placed near the ground plane ($0.01\lambda_o$-$0.02\lambda_o$) and a parasitic path over the active patch (fig. 1).

To miniaturize the traditional SMPA of fig.1(left) it is necessary to miniaturize both patches: the active and the parasitic patch. A simple technique consists on impressing a triangular slot on the triangular active and parasitic patches such as the resulting structures inspires the first iteration of the fractal-shaped Sierpinski antenna [6]. Strictly speaking, the resulting three-triangle structure is not fractal though, and the names multi-triangular and multilevel antennas are preferred to describe these kind of geometries [7,8]. This slot forces the electrical current to change its electrical patch resulting a diminution on the resonant frequency. In this case the slot shape is triangular (fig.1 right).

II.- DESIGN METHODOLOGY

Due to the fact that this multilayer structure has a lot of design degrees of freedom (active and parasitic dimensions (A_a, A_p), dielectric constants (ε_{r1}, ε_{r2}), feeding position, gap between patches (h_2-h_1)), a design rule is required to avoid a costly trial and error simulation or experimentation process.

The proposed design rule is based on an electrical model presented in [9]. In this case this design rule is modified to take into account the new degrees of freedom: the slot on active and parasitic patches.

To reduce the size dimensions of the stacked traditional antenna once a traditional SMPA has been designed is to practice a perturbation on the active patch. Then a second perturbation is practiced on the parasitic patch . The resulting input BW is lightly smaller then the traditional stacked BW. The central resonant frequency is lowered depending on the perturbation size. Following this process iteratively, several antennas have been designed to study the evolution of electrical and radiation parameters between each perturbation.

III.- NUMERICAL RESULTS

Following the design rule proposed in section II, a set of different MSMPA have been simulated and compared with the original SMPA using the IE3D software tool (fig. 2). The return loss has been calculated for each antenna and results are represented in figure 3 .

From figure 3 can be observed as expected, a diminution of the resonant frequency and also a reduction of the BW. However this BW is quite high (see table I) due to the wideband behaviour of the stacked configuration.

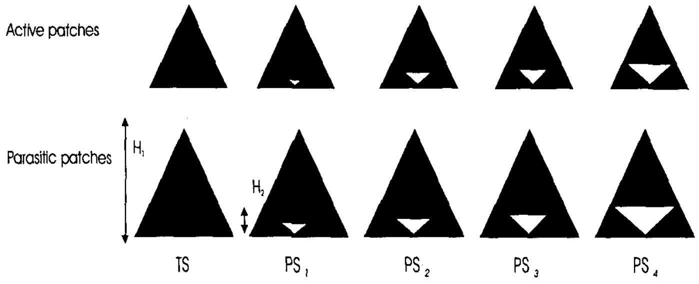

Fig. 2.- Set of different antennas simulated for BW and radiation parameter comparisons

Antenna Label	H_1/H_2
PS_1	6.8
PS_2	5.7
PS_3	5
PS_4	4.4

Table I.- Geometrical characteristic of the antennas presented in fig.2

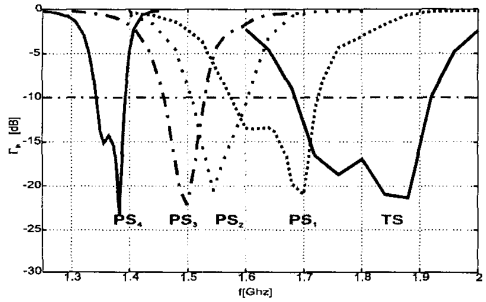

Fig. 3 Simulated return loss of different perturbed stacked antennas.

The table II represents the antenna size reduction with respect the traditional SMPA.

Antenna Label	f_o[GHz]	f_{i-1}/f_i	BW[%,SWR=2]	BW_{i-1}/BW_i	Size reduction[%]
TS (0)	1.8	-	13	-	-
PS_1 (1)	1.65	1.09	9	.7	5
PS_2 (2)	1.55	1.16	6	.46	14
PS_3 (3)	1.5	1.2	4.6	.35	17
PS_4 (4)	1.37	1.3	3.6	.37	24

Table II.- Electrical parameters comparison between the traditional stacked and different perturbed stacked microstrip antennas. TS: traditional stacked, PS_i i-perturbed stacked antenna

To study how the stacked structure improves the BW, the single active miniature elements (fig.2 top) have been also simulated to calculate the BW. A figure of merit F is defined as the relation between the stacked patch and the single active patch BW (table III).

#Perturbation	BW active patch[%,SWR=2]	BW Stacked[%,SWR=2]	F
TS (0)	1.13	13	11
PS_1 (1)	0.43	9	20
PS_2 (2)	0.38	6	15
PS_3 (3)	0.19	4.6	24
PS_4 (4)	Difficult to match	3.6	-

Table III.- BW comparison for the single element and the enhanced BW when adding the parasitic patch

Finally the radiation patterns have been calculated to estimate the basic radiation parameters: directivity (D) and radiation efficiency (η) . The directivity and radiation efficiency when increasing the perturbation size are quite constant and with very acceptable values (D=9dB and η>93%).

IV-CONCLUSIONS

A novel method has been presented to design MWSPA. This systematic method allows an easy way to design the MWSPA once a standard SMPA has been designed.
The proposed antenna configuration has a wide BW and also good level of efficiency because this structure fills betters the radian sphere than a single miniature patch.
Increasing the perturbation size a bigger reduction in antenna size is achieved.

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REFERENCES

[1] R. Waterhouse, "Small Microstrip Patch Antenna", Electron. Lett. 13th April 1995, vol.31, n°8.

[2] Chia-Luan Tang, Hong-Twu Chen and Kin-Lu Wong, "Small circular microstrip antenna with dual-frequency operation", Electron. Lett. 19th June 1997,vol.33, n°13.

[3] H. A. Wheeler, "Small Antennas", IEEE Transaction on Antennas and Propagation, vol. 23, n°4, pp.462-469, July 1975.

[4] R.C. Hansen, "Fundamental Limitations in Antennas", Proceeding of the IEEE, vol.69, n°2, Feb. 1981.

[5] D.M. Pozar and D.H. Schaubert, "Microstrip Antennas: The Analysis and Design of Microstrip Antennas and Arrays", IEEE Press 1995

[6] C.Borja, C.Puente, A.Medina, "Iterative network model to predict the behaviour of a Sierpinski fractal network", Electrón. Lett 23rd July 1998, vol.34 n°15.

[7] C.Puente, J.Romeu, M.Navarro, C.Borja, J.Anguera, "Dual Multi-Triangular Antennas for GSM and DCS cellular telephone", patent app. n° P9800954.

[8] C.Puente, J.Romeu, C.Borja, J.Anguera, J.Soler, "Multilevel Antennas", patent app. n° PCT/ES99/002296.

[9] J.Anguera, C.Puente, C.Borja, "A Procedure to Design Wide-Band Electromagnetically-Coupled Stacked Microstrip Antennas Based on a Simple Network Model", IEEE Antennas and Propagation Society International Symposium , vol. II, pp.944-947, Orlando July 1999.