Ultrawideband Parallel Strip Antennas designed by Genetic Algorithms

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***Abstract*— Since the Federal Communications Commission (FCC) approved rules for the commercial use of ultrawideband (UWB) radio applications, UWB antenna structures have been a intensive research field in order to satisfy the spectrum requirements of this technology. Different kind of UWB radiators like monopole-like and printed single side dipoles have received more attention compared to double side structures. In this paper, a set of different shape antennas fed with parallel-strip transmission lines (UWB-PS antennas) are proposed and studied, taking into account the return losses metric. The geometrical parameters have been computed using a Genetic Optimizer linked to a Method of Moment (MoM) simulator like IE3D Zeland. The main advantage of the designed geometries lie in the fact they do not include ground plane, radiating in almost the whole space. Measurements of two candidates with circular and exponential profiles have been carried out, showing a good frequency behaviour in the frequency band from 3.1GHz to 10.6 GHz.**

I. Introduction

The emergence of ultrawideband (UWB) technologies have provided an intense research over the last few years. This also applies to the antenna field, since this element is considered one of the bottle-necks in a UWB wireless communication systems. Broadband applications require the radiating structure to have a good impedance matching and high radiation efficiency in the whole band. The Federal Communication Commission (FCC) has stablished a frequency range from 3.1 GHz to 10.6 GHz for UWB, that is, a bandwidth ratio around 3.3:1. In spite of achiving all UWB antenna requirements is extremely difficult, some geometries have been proposed [1-5]. Typicall examples include printed monopoles and dipoles on substrates. These antennas include ground planes in their geometries, and therefore, strictly speaking, they are unable to provide omndirectional radiation patterns, which are preferred for point-to-multipoint communications. Another important issue is related to the integration of this part with modern low-cost MMIC's. In most cases, grounded circuits are used, and therefore in the case differential antennas, balanced-to-unbalanced structures (baluns) have to be considered. However, in some differential circuits they can be connected directly, making easier the integration with those circuits.

In this paper, genetic algorithms (GA) are used to optimize a differential geometry based on parallel strip dipoles proposed originally by Tefiku and Grimes [6] and used originally in mobile communication systems. Several canonical shapes have been combined and used to build the geometries. Afterwards, a simple genetic algorithm has been used to perform the parameter computation in order to achieve a UWB frequency behaviour. The computed antennas are a good choice since they lack in ground plane, providing nearly omnidirectional coverage. Finally, best geometries are selected and implemented, together with a parallel strip tapered balun with additional matching purpose and a comparison between simulations and measurements is carried out.

This paper is organized as follows. The antenna geometries are presented in the next section. Then, the genetic algorithm results are presented choosing some possible candidates. Finally, electromagnetic performances computed for those antennas including the balun structure are presented and compared with experimental results.

II. UWB-PS antenna geometries

Fig. 1 shows the typical structure of a UWB-PS antenna related to that proposed in [7]. It consists in a double sided bow-tie shape, printed on a dielectric substrate. In this case the antenna is fed using a UWB balun [8], avoiding the asymmetrical radiation patterns showed in the same article. Examples of the analysed geometries are shown in Figs. 1 and 2. Three different profiles have been used to build these geometries: circular (C), exponential (E) and linear (L).These profiles may be combined in the different subsections (in this case two) in which the antenna is divided. Therefore, this approach leads to 3^2 different geometries that should be studied (CC-PS,CE-PS,CL-PS...LL-PS).

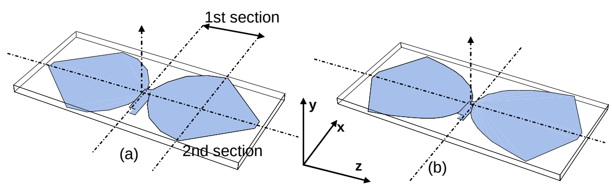

Fig. 1. Antenna geometries without balun.(a) CL-PS structure. (b) EL-PS structure

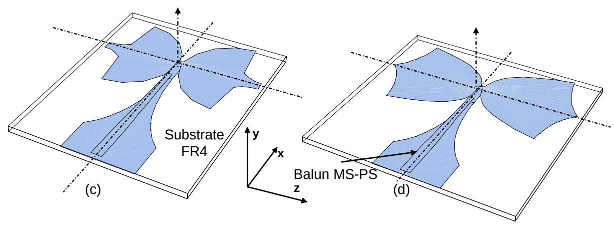

Fig. 2. Antenna geometries with balun.(c) CC-PS structure. (d) EE-PS structure

TABLE I
BEST FITNESS OBTAINED THOUGH SGA OPTIMIZATION

	GEOMETRY	FITNESS VALUE
	CL	-15.28
	CC	-11.80
	EL	-14.25
	EE	-13.27
	CE	-10.06
	EC	-12.53
	LC	-8.25
	LE	-8.76
	LL	-9.25

III. PARAMETER COMPUTATION USING GENETIC ALGORITHMS

The nine structures have been simulated and their electrical parameters have been obtained using the electromagnetic simulator IE3D, which is a MoM code. In order to obtain an easy and cheap-manufacture antenna, the selected substrate was the FR4, with the following electrical parameters: $h = 1.6\ mm, \epsilon_r = 4.55, \tan\delta = 0.02$. Several critical points were defined as optimization parameters and afterwards the edges were computed using those points. The optimization method performed was a Simple Genetic Algorithm (SGA) [9-10], based on the next fitness function:

$$C = \max\left\{S_{11}(\omega)\right\}_{\omega \in BW} \quad (1)$$

where BW is the UWB frequency band, 3.1-10.6 GHz, and S_{11} corresponds to the return losses obtained by IE3D, normalized to a reference impedance of 100 Ohm. Thus, this function has to be minimized in order to achieve an ultrawideband antenna. It should be noticed that the balun has not been included in the optimization process. Therefore, it must be designed to match the 100 Ohm antenna reference impedance to 50 Ohm. The GA parameters were set to $p_{cross} = 0.65$, $p_{mut} = 0.01$, population size 25 and it was let to evolve during 40 generations. A binary codification using 32 bits has been used for each chromosome. The computed size of the structures is slightly higher than λ_g referred to the lower frequency (3.1 GHz). Table 1 shows the best fitness obtained in this optimization for the nine configurations.

Based on Table 1, it is possible to discard some geometries, considering a typical constrain of $S_{11} = -10$ dB for UWB antennas or larger size (as EC antenna). Therefore selected candidates will be these four configurations: CC-PS, CL-PS, EE-PS, EL-PS. They fulfill, o nearly so, the imposed constrain.

IV. ELECTROMAGNETIC STUDY OF CANDIDATES

The frequency response of the structures when the balun is included have been obtained by means of IE3D . The balun consists in a tapered exponential transition from a microstrip line to a parallel strip line, matching the impedance from 50 to 100 Ω. It has been placed directly behind the candidate input ports, and thus, fitness values are degraded due to the balun perfomance, which has not been optimized. Because of that, a bound of the return losses will be obtained instead of the actual antenna return losses. Fig 3 shows the scattering parameter at the balun input obtained by the moment method.

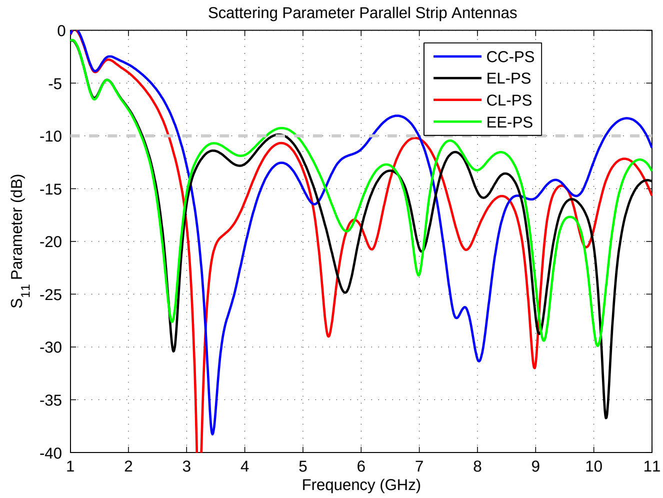

Fig. 3. Return loss of PS-antennas.

As presented, these results are close in the whole frequency to the usual constrain of -10dB and fulfill the requirement of $VSWR < 2$ (equivalent to $S_{11} < -9.5dB$).

Regarding the radiattion pattern, two of these candidate field patterns are presented: the CC-PS antenna and the EL-PS (see Figs 4-5) .

These patterns shows omnidirectional behaviour in the lower frequencies for both antennas. However, the directivity increases the higher the frequency, degrading the omnidirectional performance. This phenomena is typical in most UWB antennas [11]. The main difference is, then, that since there is no ground plane, the antennas radiate in the whole space. It is also important to notice that the performance is worse in the feeding direction.

V. EXPERIMENTAL PERFORMANCE

Fig 6 and 7 show two antenna test-beds, corresponding to the CC-PS and EL-PS structures, manufactured in FR4 substrate. The dimensions, included the balun are $1.138\lambda \times 0.91\lambda$ in the case of the CC-PS and $1.133\lambda \times 1.17\lambda$ in the case of the EL-PS antenna, being λ the guide wavelength in the lower frequency. The balun is approximately $\lambda/2$ in length.

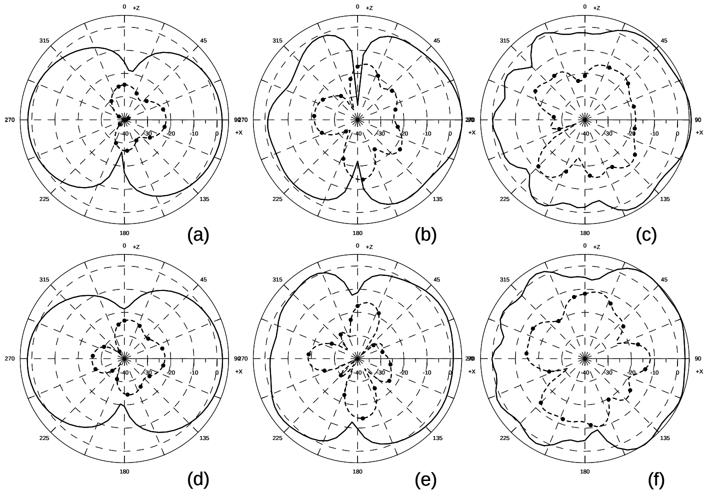

Fig. 4. E-plane copolar and crosspolar(dashed) field pattern (a) CC-PS at 3.1 GHz (b) at 6.85 GHz (c) at 10.6 GHz (d) EE-PS at 3.1 GHz (c) at 6.85 GHz (d) at 10.6 GHz

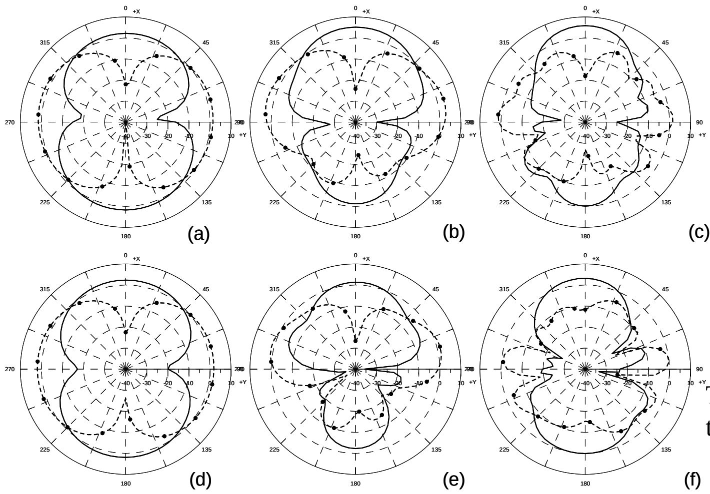

Fig. 5. H-plane copolar and crosspolar(dashed) field pattern (a) CC-PS at 3.1 GHz (b) at 6.85 GHz (c) at 10.6 GHz (d) EE-PS at 3.1 GHz (c) at 6.85 GHz (d) at 10.6 GHz

Scattering parameters have been measured using the network analyzer ANRITSU 37247D. They have been obtained in a frequency band from 1GHz to 11GHz, using 1601 points in the measure.

Measurements results and their comparison to simulated results are presented in Figs. 8 and 9. It has been also pointed the usual constrain of $VSWR < 2$ in the UWB frequency band.

As expected, the performance of both antennas are slightly worse than simulations. Besides, there are some differences between experimental results and simulations, although they show the overall tendency. Despite, the agreement is good in lower frequencies than in higher. Since the simulation model does not include the coaxial connector, authors believe that differences might be due to this influence, specially taking into account the closeness to actual values in low frequencies.

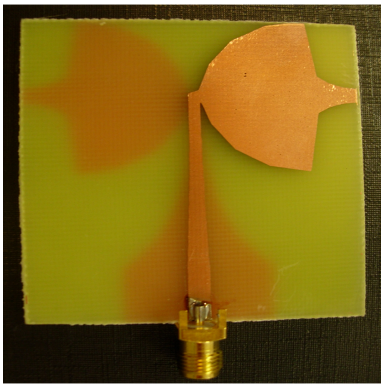

Fig. 6. CC-Parallel Strip Antenna in FR4 substrate

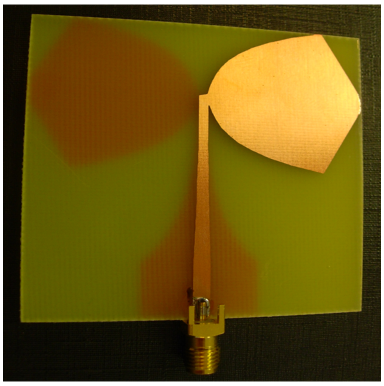

Fig. 7. EL-Parallel Strip Antenna in FR4 substrate

Indeed, the antennas nearly fulfill the VSWR constrain. Table 1, shows the worst cases, and the frequency where they take place.

TABLE II
BEST FITNESS OBTAINED THOUGH SGA OPTIMIZATION

GEOMETRY	WORST MEAS. (DB)	VSWR	FREQUENCY (GHZ)
CC	-8.97	2.10	7.494
EL	-8.1	2.29	4.204

VI. CONCLUSIONS

A systematic analysis of different parallel-strip UWB antennas with mixed canonical shapes have been proposed. These antennas have been optimized and four possible suitable designs have been selected. Radiation patterns are introduced, showing a typical omnidirectional pattern in low frequencies which degrades as the frequency increases. Nevertheless, both antennas are radiating in the whole space since no ground plane is defined. Return loss measurements carried out for CC-PS and EL-PS geometries agree in tendency with simulations and shows that the structures are suitable in UWB frequency band from 3.1 GHz to 10.6 GHz.

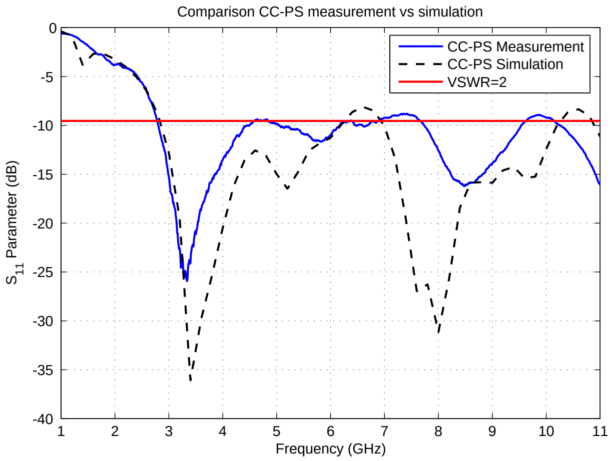

Fig. 8. CC-Parallel Strip Antenna simulation versus experimental results

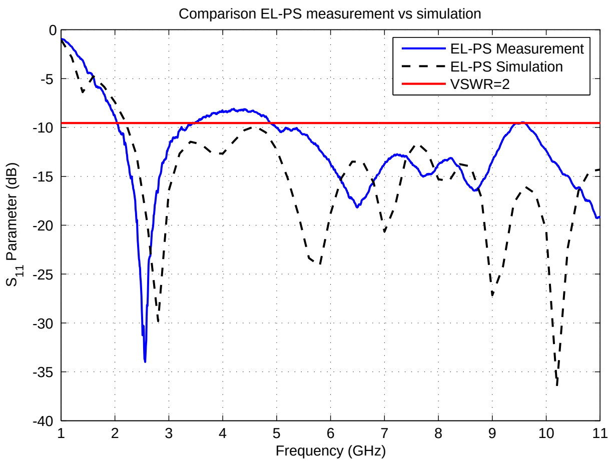

Fig. 9. EC-Parallel Strip Antenna simulation versus experimental results

VII. Acknowledgement

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