Parallel-Strip-Fed Antenna designs in Ultrawideband applications

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Introduction

Since the Federal Communications Commission (FCC) approved rules for the commercial use of ultrawideband (UWB) radio applications, a wide number of UWB antenna structures have been proposed in order to satisfy the spectrum requirements of this technology. Among them, monopole-like and printed single side dipoles have received much more attention compared to double side structures. In this paper, a set of different shape radiators fed with parallel-strip transmission lines (UWB-PS antennas) are proposed and studied, taking into account not only the return losses metric, but also the Copolar Fidelity factor defined on a single antenna [1] . This metric will allow to choose the best geometry based on the minimum angular distortion introduced by the antenna considered as a linear system.

UWB-PS antenna geometries

Fig. 1 shows the typical structure of a UWB-PS antenna related to that proposed in [2]. 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 [3], avoiding the asymmetrical radiation patterns showed in the same article. The simplest shape already used comprises a linear-rectangular patch, printed in a double sided fashion. Here it will be referred as triangular-rectangular parallel strip antenna (TR-PS), and it will be used as reference to compare with our proposals. 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).

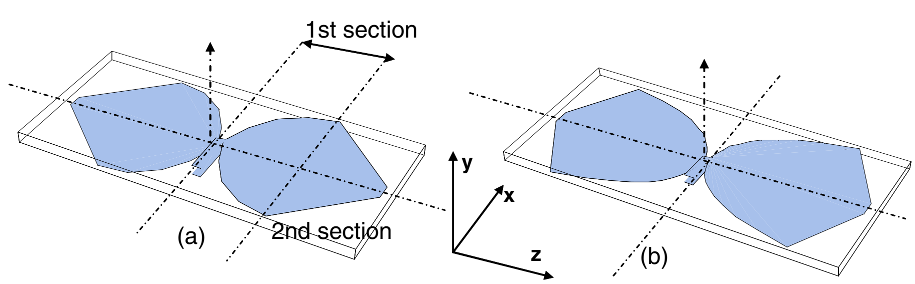

Figure 1: Antenna geometries without balun.(a) CL-PS structure. (b) EL-PS structure

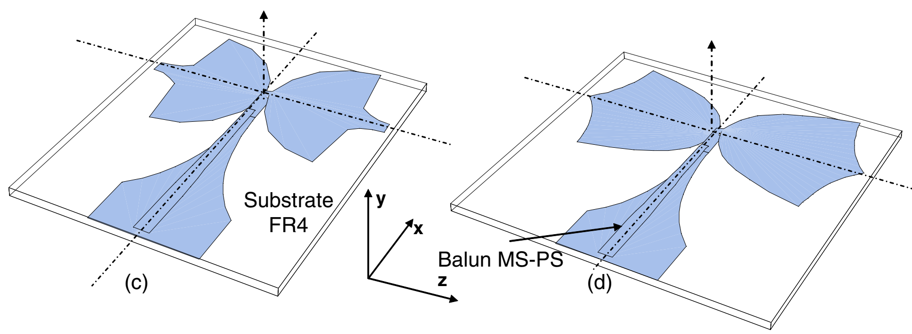

Figure 2: Antenna geometries with balun.(c) CC-PS structure. (d) EE-PS structure

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: $h = 1.6mm, \epsilon_r = 4.55, \tan\delta = 0.02$. 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), based on the next fitness function:

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

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. The computed size of the structures is slighty higher than λ_g referred to the lower frequency (3.1 GHz). Table 1 shows the best fitness obtained in this optimization for the eight configurations.

Table 1: Best Fitness obtained though SGA optimization

Fitness Value	Candidates				Refused				
Geometry	*CL*	*CC*	*EL*	*EE*	*CE*	*EC*	*LC*	*LE*	*LL*
Value (dB)	-15.28	-11.80	-14.25	-13.27	-10.06	-12.53	-8.25	-8.76	-9.25

Analysis of Results and Copolar Fidelity Factor

Based on Table 1, it is possible to discard some of the 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. Fig. 3 shows the frequency response of the stuctures and the reference TR-PS when the balun is included. As it will be seen later, although strictly speaking not all of them are below -10 dB, the fidelity factor determined from the radiation pattern response (see Fig. 3) might be better, so all are considered as possible candidates.

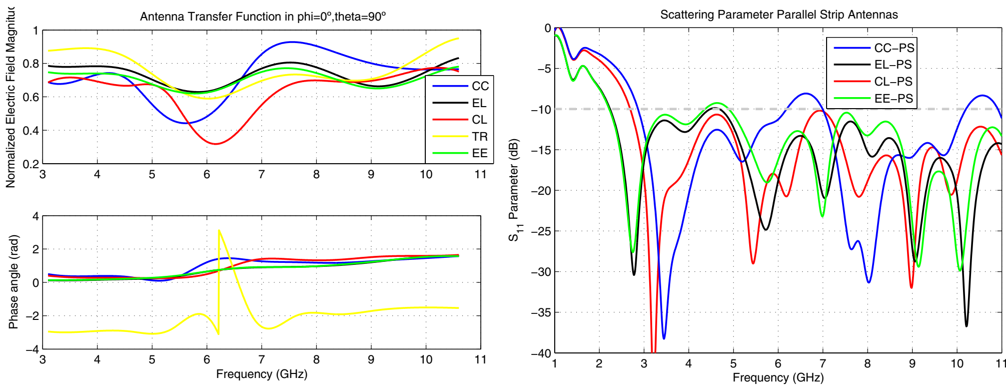

Figure 3: (a) Transmit Antenna Transfer Function. (b) Return Loss comparison of PS-antennas.

The Copolar Fidelity Factor (CFF) defined for an transmitting antenna is given by [1] :

$$F(\theta,\phi)=\max_{\tau}\left[\frac{\int_{-\infty}^{+\infty}s_i(t)E_{cp}(t+\tau,\theta,\phi)dt}{\sqrt{\int_{-\infty}^{+\infty}s_i^2(t)dt\int_{-\infty}^{+\infty}E_{cp}^2(t,\theta,\phi)dt}}\right] \tag{2}$$

where $s_i(t)$ is the input signal to the antenna (here considered antenna and balun) and E_{cp} is the copolar component of the electromagnetic field radiated by the antenna when fed with $s_i(t)$. Different input signals will lead to different correlations. Fidelity Factor here will be figured out using the fourth derivative gaussian signal which satisfies the FCC indoor emission mask [4] :

$$s_i(t)=A\left(3-6\left(\frac{4\pi}{T_{au}^2}\right)t^2+\left(\frac{4\pi}{T_{au}^2}\right)^2t^4\right)\exp\left\{-2\pi\left(\frac{t}{T_{au}}\right)^2\right\} \tag{3}$$

where A=0.1 and $T_{au}=0.175ns$. Fig. 4 shows the temporal waveform and the radiated copolar field when $\theta=\pi/2,\phi=0$. This field has been obtained using a convolution between the input signal and antenna transmit transfer function as [5]:

$$E_{cp}^T(t)=-\eta s_i(t)*\mathcal{F}^{-1}\left\{\left(\hat{r}\times\hat{r}\times\int_{V'}\vec{J}(r',\omega)e^{j\mathbf{k}\cdot\mathbf{r}}dV'\right)\cdot\widehat{\mathbf{cp}}\right\}(t) \tag{4}$$

where η is a constant related to the physical medium $\mathcal{F}^{-1}$ denotes the Inverse Fourier Transform, $\widehat{\mathbf{cp}}$ represents the unitary copolar vector and $\vec{J}$ is the current density on the antenna.

Besides Fig. 4 shows the Fidelity Factor for the four proposals and the reference antenna in the E plane $\phi=0$. These results reveals that, as supposed, the distortion depends on the transmission angle and that the best antenna in the E plane corresponds to the Exponential-linear Parallel Strip structure (EL-PS). It has not only the highest CFF value, but also the more stable regarding the elevation angle.

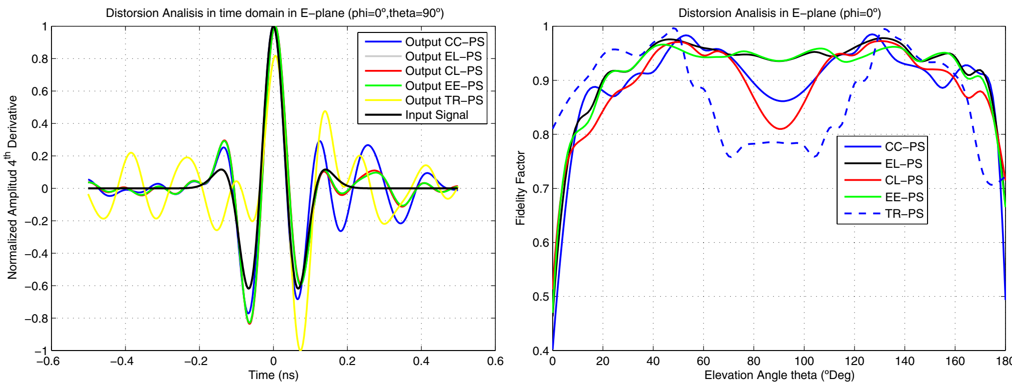

Figure 4: Time domain normalized electric field and Fidelity Factor in E-plane

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. From those results and a correlation analysis between the radiated fields and the generator signal, transmission distortion has been analyzed leading to dependent-angle best geometry.

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