SPLINE-SHAPED ULTRA-WIDEBAND ANTENNA OPERATING IN THE ECC RELEASED FREQUENCY SPECTRUM

F. Viani, L. Lizzi, R. Azaro, and A. Massa

January 2008

Technical Report # DISI-11-055
Spline-shaped ultra-wideband antenna operating in the ECC released frequency spectrum

F. Viani, L. Lizzi, R. Azaro, and A. Massa

A spline-shaped antenna for Ultra-Wideband (UWB) communications that operates in the Electronic Communications Committee (ECC) released band from 6 GHz up to 8.5 GHz is described. Selected simulated and measured data are reported to assess the achieved impedance matching over the whole band of interest, and the distortionless behavior as well as to show the omni-directional radiation properties.

Introduction: In correspondence with the increasing demand of high transmission data-rate, low power consumption, and wider bandwidth of wireless communication systems, the UWB technology has attracted a growing attention. Since 2002, when the Federal Communication Commission (FCC) released the use of the frequency band 3.1-10.6 GHz for communications [1], non-negligible research efforts have been devoted to the development of efficient and reliable UWB systems. Concerning the European situation, the ECC considers that “the higher maximum power densities in frequency spectrum 6 - 8.5 GHz without additional mitigations will facilitate the UWB operations” [2]. As regards to UWB antenna design, many geometries and shapes have been studied and proposed for different purposes and applications. As an example, small-size and omni-directional antennas have been presented in [3][4] for short-range indoor communications. Generally
speaking, several antenna configurations are usually synthesized starting from a parameterization of reference shapes (e.g., planar triangular patch [5], circular disc [6] or rectangular slot [7]).

In this letter, a spline-shaped antenna is proposed in order to fit the last ECC UWB standard (July 2007) in the frequency range 6-8.5 GHz. Likewise [8], where a generic UWB radiator has been optimized to preliminary assess the proposed approach, the antenna prototype is synthesized by further exploiting a spline-based procedure, but taking into account different and more realistic constraints. Unlike other parametric synthesis methods, the antenna geometry comes from the modification of a spline contour that describes the perimeter of the radiator. The result is a simple and easy-to-build configuration that satisfies both dimensional and electric requirements. To assess the fitting with project constraints, both simulated and measured performance indexes are presented and compared.

**Spline-shaped antenna design:** According to the ECC guidelines for UWB devices, the spline-shaped antenna has been designed in order to efficiently operate within the frequency spectrum 6-8.5 GHz. Towards this end, in order to guarantee a distortionless transmission of time-domain UWB pulses, the following constraints have been imposed over the whole operating bandwidth: $s_{11}$ amplitudes lower than -10 dB, flat behavior of $s_{21}$, and linear dependence of the phase of $s_{21}$ on the frequency. The constrained parameters are the input reflection coefficient ($s_{11}$) and the forward transmission coefficient ($s_{21}$) of the two-port system composed by a pair of identical UWB antennas. As far as the geometric constraints are concerned, the antenna has been required to belong to a square area of side length of 80 mm. Figure 1 shows the
geometry of the UWB antenna resulting from the synthesis process. More in
detail, $\varphi_1 = 67.5 \text{ mm}$ is the substrate length, $\varphi_2 = 12.3 \text{ mm}$ is one half of the
substrate width, $\varphi_3 = 6.0 \text{ mm}$ is one half of the feedline width, and
$\varphi_4 = 35.0 \text{ mm}$ is the metallic plane length on the back side of the substrate.
Furthermore $\{P_i = (x_i, y_i), i = 1, \ldots, 4\}$ are the control points, located at
$(x_1 = 6.0 \text{ mm}, \ y_1 = 39.6 \text{ mm})$, $(x_2 = 8.5 \text{ mm}, \ y_2 = 40.3 \text{ mm})$, $(x_3 = 4.7 \text{ mm}, \ y_3 = 54.6 \text{ mm})$, and $(x_4 = 0.0 \text{ mm}, \ y_4 = 46.8 \text{ mm})$, which unequivocally define
the contour of the antenna. Finally, the feeding port has been located at
$(x_F = 0.0 \text{ mm}, \ y_F = \varphi_4)$. These values have been determined at the
convergence of an iterative procedure [8] aimed at updating the spline-based
contour until a suitable matching with the user-defined requirements is
reached. Such a procedure is based on the integration of a Method of
Moment (MoM) electromagnetic simulator [9], able to estimate the electric
parameters of the antenna, and a particle swarm optimizer (PSO) [10] used to
define an evolution strategy for the trial antenna shapes.

**Numerical and experimental results:** A prototype of the antenna has been built
to experimentally assess the reliability and efficiency of the synthesized shape
(Fig. 1). The prototype has been printed on a Arlon dielectric substrate
($\varepsilon_r = 3.38$) of $0.78 \text{ mm}$ thickness with a photolithographic technology.
Moreover, it has been equipped with a SMA connector and fed with a coaxial
line. The electrical parameters ($s_{11}$ and $s_{21}$) have been measured by means of
an Anritsu Vector Network Analyzer in a non-controlled environment.
Concerning the $s_{21}$, it has been evaluated by considering a two-port system
composed by a pair of identical prototypes. A comparison between simulated
and measured data is summarized in Fig. 2. As it can be noticed, the electric behavior of the synthesized antenna fits the project guidelines. More in detail, a good impedance matching over the whole ECC released frequency bandwidth (6 - 8.5 GHz) has been achieved (Fig. 2a). Moreover, as far as the $s_{21}$ parameter is concerned, the flatness of $|s_{21}|$ (Fig. 2b) and the linear trend of $\angle s_{21}$ (Fig. 2c) assure a distortionless behavior of the system when UWB pulses are in transmitted and received. For completeness, Figure 2d shows the plot of the group delay $\tau$ computed as the $\omega$-derivative of the phase of $s_{21}$. As it can be observed, a variation lower than 0.7 ns verifies in the measured data although they have been collected in a non-controlled environment. Finally, the radiation patterns computed at $f_1 = 6.0$ GHz, $f_2 = 7.25$ GHz, and $f_3 = 8.5$ GHz are displayed in Fig. 3 to show the omnidirectional behavior in the horizontal plane ($x-z$ plane). On the hand, as expected, the antenna behaves as a monopolar radiator in the vertical plane ($x-y$ plane).

**Conclusions:** The design of a spline-shaped planar antenna for UWB applications and operating in the ECC released 6 - 8.5 GHz frequency spectrum has been proposed. Simulated and measured electrical parameters over the whole band of interest as well as the radiation patterns confirm the effectiveness of the synthesized antenna prototype.
References:


Authors’ affiliations:
F. Viani, L. Lizzi, R. Azaro, and A. Massa
ELEDIA Research Group
Department of Information and Communication Technology,
University of Trento, Via Sommarive 14, 38050 Trento – ITALY

Corresponding Author:
A. Massa
ELEDIA Research Group
Department of Information and Communication Technology
University of Trento
Via Sommarive 14
38050 Trento
ITALY
E-mail: andrea.massa@ing.unitn.it
Figure captions:

Fig. 1 - Antenna prototype
   (a) Front view
   (b) Back view

Fig. 2 - Comparison between simulated and measured values over the ECC frequency band:
   (a) Magnitude of $s_{11}$
   (b) Magnitude of $s_{21}$
   (c) Phase of $s_{21}$
   (d) Group delay

Fig. 3 - Simulated radiation patterns at $f_1 = 6.0$ GHz, $f_2 = 7.25$ GHz, and $f_3 = 8.5$ GHz:
   (a) Horizontal plane ($x - z$)
   (b) Vertical plane ($x - y$)
Figure 1
Figure 2
Figure 3