Simulation and Measurements of Ultra-Wideband Antenna Radiation Efficiency

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***Abstract*—The present paper compares the simulated and measured radiation efficiency of a dielectrically loaded microstrip-fed Ultra-Wideband (UWB) monopole. The antenna was designed to operate inside a Universal Serial Bus (USB) dongle.**

Wideband efficiency measurements were conducted using the reverberation chamber technique and a cavity-based approach, called the source-stirred method. Both procedures yield close results, although the source-stirred method is still in development. The reverberation chamber allowed for radiation efficiency to be measured with the antenna connected to a laptop computer. The source-stirred method is a convenient extension of the widely used narrowband Wheeler cap approach.

The simulations resorted to the commercial computational electromagnetics code CST Microwave Studio™. It was confirmed that radiation efficiency simulations are computationally demanding, requiring large calculation domains with special attention to numerical absorbers and accurate material modeling.

***Index Terms*—Antenna measurements, Radiation efficiency, Reverberation chamber, Source-stirred method, Ultra Wideband antennas, Universal Serial Bus.**

I. Introduction

An Ultra-Wideband (UWB), coaxial-fed monopole antenna integrated into a Universal Serial Bus (USB) device has been previously simulated, built and tested. The effects of loading the antenna with a commercial substrate sandwich were investigated. The technique has shown to provide a slight bandwidth extension in the lower frequencies and increased resilience upon connection to a laptop computer. The whole system (antenna, USB dongle, dielectric loading sandwich, feed) was modeled in CST Microwave Studio™ [1].

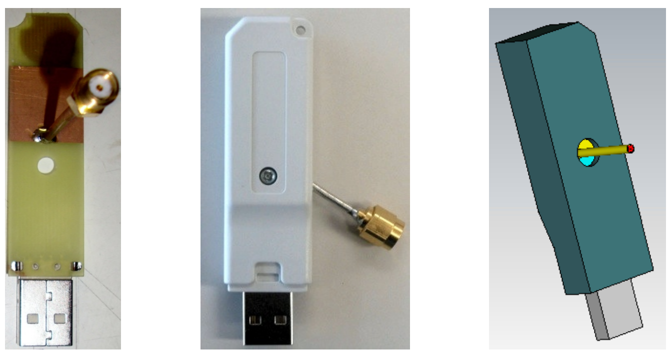
Essential to the actual feasibility of this UWB dielectric loading technique is its impact on antenna efficiency, as a decrease of this parameter is expected. To assess this effect, an UWB radiation efficiency measuring campaign was set [2]. More recently [3], a microstrip-fed version of the UWB monopole antenna was designed, as shown in Fig. 1, for which the measurements were repeated.

II. Efficiency measurements

Two measuring procedures were used: the reverberation chamber [4], [5] and the source-stirred method [6], [7].

Reverberation chamber measurements resorted to the University of Liverpool's setup detailed in [3]. The dimensions of the chamber allow the antenna efficiency to be tested in realistic deployment scenarios. The efficiency results for the antenna in free-space and connected to a laptop computer, as shown in Fig. 2, are plotted in Fig. 3.

The source-stirred method is being developed at the University of Liverpool and measurements were conducted at Instituto de Telecomunicações/Instituto Superior Técnico of the Technical University of Lisbon. It improves on the modified Wheeler cap method, proposing the use of the antenna as a mode stirrer by placing it in several positions and orientations inside the cavities. The UWB antenna radiation efficiency is then estimated by considering the joint peak values of the several efficiency curves calculated by the classical narrowband approach, but severely contaminated by cavity resonances. The setup used is described in detail in [3]. The results for the dielectric loaded prototype with USB case are plotted in Fig. 3. Shown are the joint peak values of eight measurement positions and a piecewise curve joining the local maxima wider apart than ≃312 MHz, as a peak smoothing algorithm for this technique is still being developed.



(a) (b) (c)

Fig. 1. Improved, microstrip fed, UWB antenna: (a) picture of antenna, (b) USB case, and (c) CST Microwave Studio™ model.

Fig. 2. Reverberation chamber setup for measuring the radiation efficiency of the antenna connected to a laptop computer.

III. Efficiency simulation

The dielectrically loaded UWB antenna was simulated in CST Microwave Studio™ inside the USB case using the Time Domain solver. The complete feeding arrangement, including a coaxial-microstrip transition, was modeled as pictured in Fig. 1(c). The simulations assume the USB case to be made of PVC, as there was no information on the actual material. All dielectrics of the the simulation model are listed in Table I. A constant fit loss tangent value across the operation bandwidth was used. The copper used in the coaxial and microstrip lines and antenna was considered lossy with an electrical conductivity of 5.96×10^7 S/m.

The simulation results for two different problem meshing densities are shown in Fig. 3 compared to the measurements. The values are close to the experimental results, especially to those obtained by the source-stirred method above 4 GHz. Below this frequency there is some oscillation in the simulation outcome, particularly severe in the $\simeq$6M meshcells case as the efficiency even unmeaningly exceeds 100%.

IV. Conclusions

This paper presents recent developments in comparing measurements and simulation of the radiation efficiency of a UWB antenna. The experimental and numerical results exhibit a close agreement, considering the complexity of the problem, possible fabrication deviations and different measurement methods used. Some issues persist in the low-frequency accuracy of radiation efficiency simulation.

The source-stirred method is a very convenient cavity-based approach with the possibility of allowing UWB efficiency estimations using a simple and very common setup. It was shown that the reverberation chamber is adequate to measure the efficiency of an antenna inside a USB dongle and connect to a laptop computer.

V. Ongoing and future work

A comprehensive study on the impact of model parameters such has mesh density, material characteristics and PML configuration is being pursued to evaluate the impact on efficiency calculations. Other commercial tools are being investigated.

For the source-stirred method it is currently being investigated how to increase accuracy both in low and high frequencies. For the latter case the effect of cavity losses is being considered. For the former situation, where the cavity dimensions can't be disregarded with respect to the wavelength, it is planned to study how impedance measurements could benefit the procedure. Furthermore, a peak smoothing algorithm is being developed.

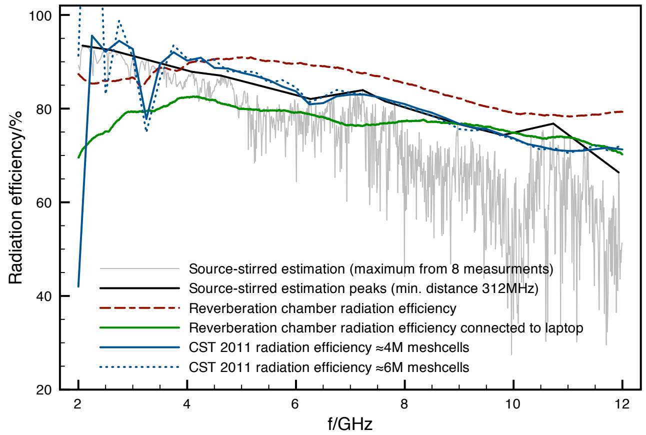


Fig. 3. Microstrip-fed loaded prototype radiation efficiency: comparison between the simulation and measurement.

Material	ε_r	$\tan\delta \vert f = 10$ GHz
Teflon™(coaxial line dielectric)	2.1	0.0002
PVC (casing)	2.3	0.035
Rogers RO3003™(dielectric sandwich)	3	0.0013
FR4 (antenna substrate)	4.5	0.03

TABLE I
Relative electric permittivity and loss tangent of the different dielectric materials used in the simulation.

Acknowledgments

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