Ultra-Wideband Printed-Circuit Antenna in Coplanar Technology

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Abstract—**A new printed-circuit antenna in coplanar waveguide technology for ultra-wideband measurements is introduced. The frequency of operation is 3.1 GHz to 10.6 GHz with a VSWR < 2. Omni-directional characteristics in vertical polarization are demonstrated at selected frequencies. The analysis method is verified against previous measurements.**

Keywords - Printed-circuit antennas, ultra-wideband antennas (UWB), coplanar technology.

I. INTRODUCTION

The rapid development of components and systems for future ultra-wideband (UWB) technology has significantly increased measurement efforts within the electromagnetic compatibility community. Therefore, frequency- and time-domain testing capability for UWB compliance is at the forefront of research and development in this area, e.g. [1] – [4].

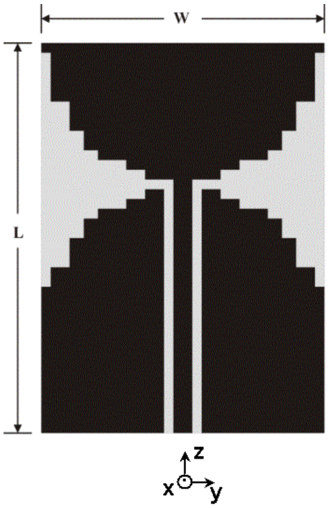

Figure 1. UWB antenna in coplanar technology.

Within such testing systems, the UWB antenna is a specific component whose transmitting and receiving properties differ from those for conventional narrowband operation. Several antennas have been developed. For localized equipment as, e.g., in chamber measurement setups, TEM horns can be used [1], [5]. For mobile testing, though, printed-circuit antennas are more appropriate. Therefore, several different planar UWB antennas have been proposed covering a variety of frequency ranges such as the 1-6 GHz band [6], the 3.1-10.6 GHz band [7], [8], the 5-20 GHz band [9] and even the 6-40 GHz band [10]. All these design use microstrip technology requiring processing on both substrate sides for fabrication.

Coplanar technology offers a number of advantages for the fabrication of printed-circuit UWB antennas, e.g. [11], [12]. Therefore, this paper presents a new design, which focuses on the 3.1-10.6 GHz band (Fig. 1). Stepped transitions in both the center conductor and ground plane are used to aid in providing a good UWB performance.

II. VALIDATION

The design of the coplanar UWB antenna follows basic principles outlined in [10] as far as the stepped configuration in Fig. 1 is concerned. The slots have been inserted on a rough trial-and-error basis. The entire antenna has then been fine optimized with respect to the input voltage standing wave ratio (VSWR) and pattern performances.

Since a major concern with using professional software packages such as HFSS is validation of the results, we present in Fig. 2 and Fig. 3 performance comparisons with existing UWB antennas.

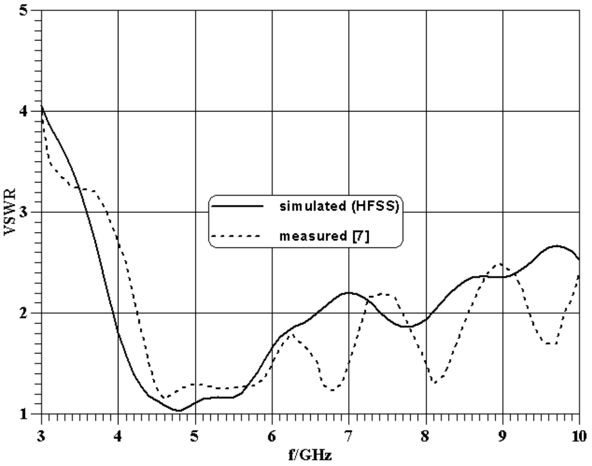

Figure 2. VSWR performance (simulated and measured) of the UWB antenna presented in [7].

Fig. 2 shows the VSWR (both simulated and measured) of the triangular monopole antenna presented in [7]. Although the agreement between theory and measurements is not ideal, the

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simulations agree well with measurements over the entire 3-10 GHz bandwidth.

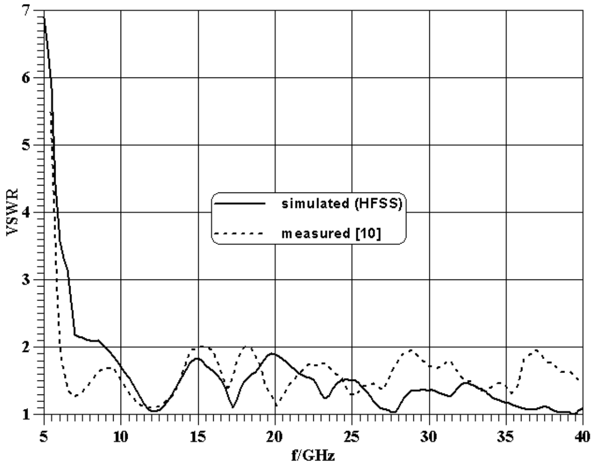

Figure 3. VSWR performance (simulated and measured) of the UWB antenna presented in [10].

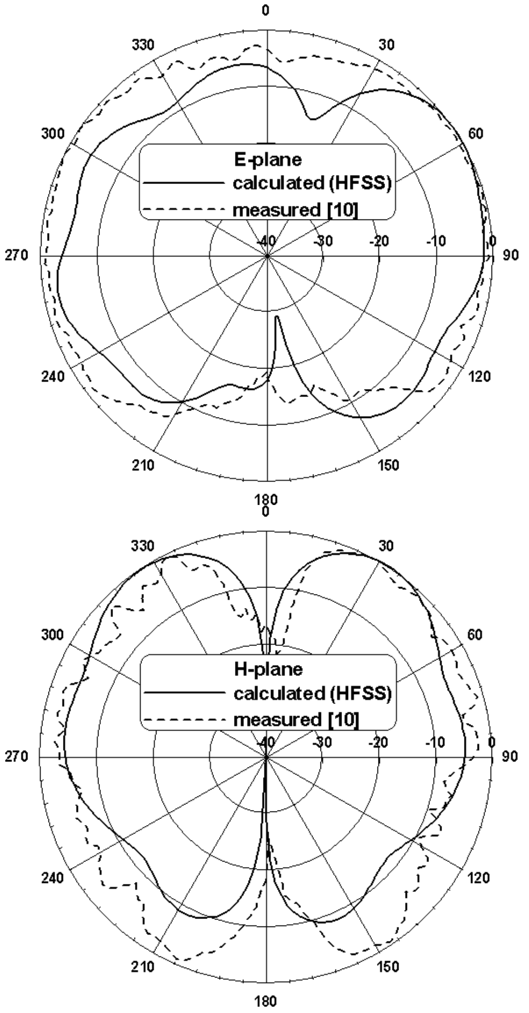

Figure 4. E- and H-plane radiation patterns at 10 GHz (simulated and measured) of the UWB antenna presented in [10].

A similar comparison for the multiple-resonance UWB antenna presented in [10] is shown in Fig. 3 for the VSWR performance in Fig. 4 for radiation patterns. Note that this design operates over a much larger bandwidth than that of Fig. 2. Nonetheless, the simulated performances agree well with measurements, thus validating the simulations with HFSS.

III. RESULTS

The ultra-wideband printed–circuit antenna in coplanar technology shown in Fig. 1 uses an FR4 substrate of 1mm thickness and 30mm x 40mm (W x L) substrate area. The permittivity parameters are ε_r=4.7 and tanδ= 0.018.

Fig. 5 demonstrates that the VSWR is below 2 between 3 GHz and 5.7 GHz, and between 6 GHz and 10.7 GHz. The maximum VSWR of 2.03 occurs at 5.83 GHz. Note that this result includes the effects of a coaxial (SMA) connector attached to the input of the coplanar waveguide. Therefore, compared to other UWB printed-circuit designs, this performance is excellent.

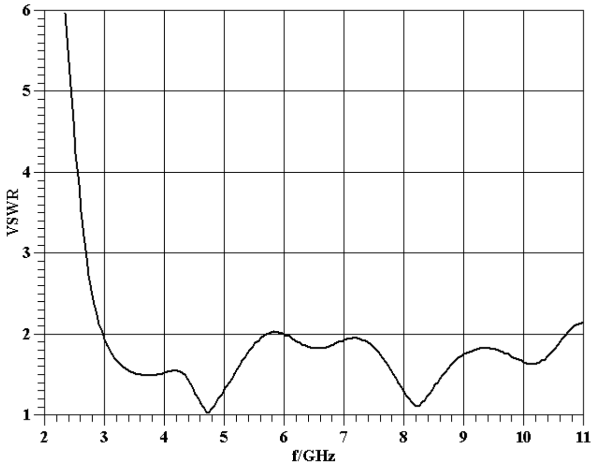

Figure 5. VSWR performance of the coplanar UWB antenna shown in Fig. 1.

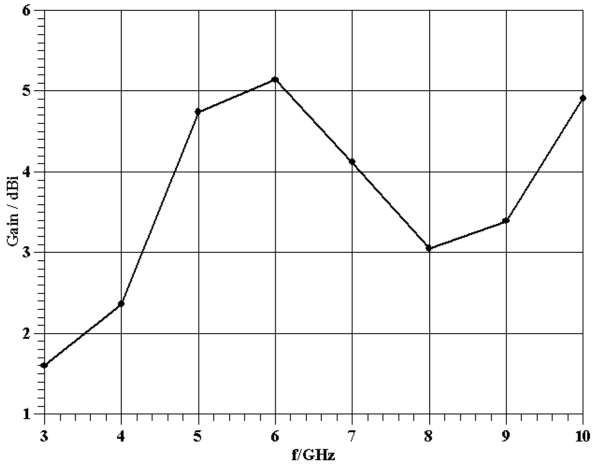

Figure 6. Maximum gain of the coplanar UWB antenna shown in Fig. 1.

Fig. 6 shows the maximum gain in the frequency range 3 GHz to 10 GHz. The variation over the frequency range is significant but compares well with other UWB antennas operating over similar frequency ranges.

In order to display the radiation patterns, we use the conventional definition of angles θ and ϕ with respect to coordinates x, y, z ($x/r=\sin\theta\cos\phi$, $y/r=\sin\theta\sin\phi$, $z/r=\cos\theta$). The normalized H-plane radiation patterns in the xy plane (c.f. Fig. 1) are shown in Fig. 7 and Fig. 8. The vertical polarization (Fig. 7) is mostly omnidirectional up to 8 GHz and starts to deteriorate slightly at 10 GHz. The reception in horizontal polarization, which is shown in Fig. 8 and normalized to the same values as in Fig. 7, is due to the direction of the field in the coplanar feed line. Therefore, these patterns are almost zero in ϕ=0 degrees and ϕ=180 degrees. Such property can be used in polarization sensitive measurements.

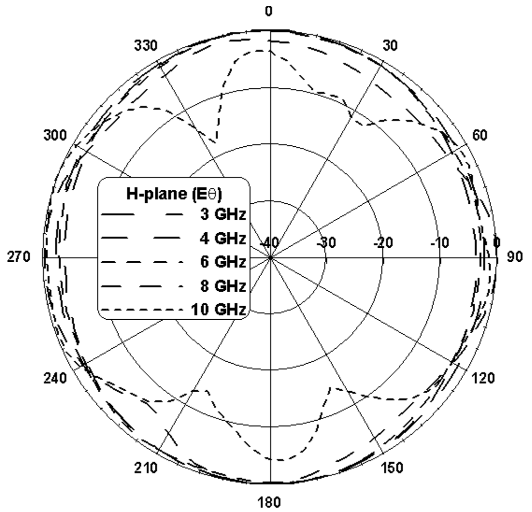

Figure 7. Normalized co-polarized H-plane (xy-plane) radiation patterns $E_\theta(\pi/2, \phi)$ of the coplanar UWB antenna for various frequencies.

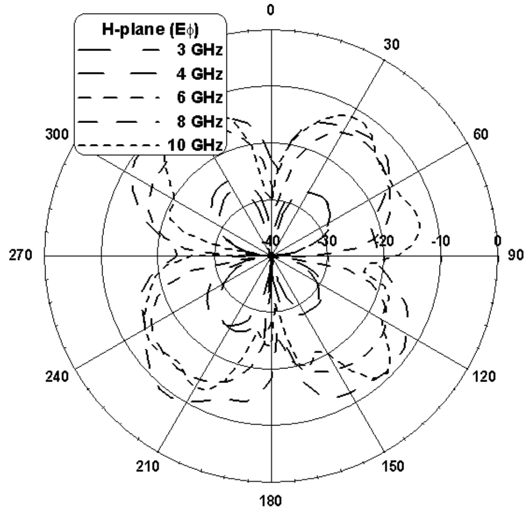

Figure 8. Normalized cross-polarized H-plane (xy-plane) radiation patterns $E_\phi(\pi/2, \phi)$ of the coplanar UWB antenna for various frequencies.

The co-polarized patterns in the E-plane are shown in Fig. 9 (yz plane) and in Fig. 10 (xz plane). It is demonstrated that the basic shapes of the patterns do not significantly change over the frequency band of operation and that – as expected – variation is larger towards the upper frequency limit. These results compare well with those of other printed-circuit UWB antennas. Note that in presenting these normalized radiation patterns, different normalization constants have been used. For example, the 90-degree values in Fig. 7 and Fig. 9 should be identical, but they differ by a few dB due to different normalization.

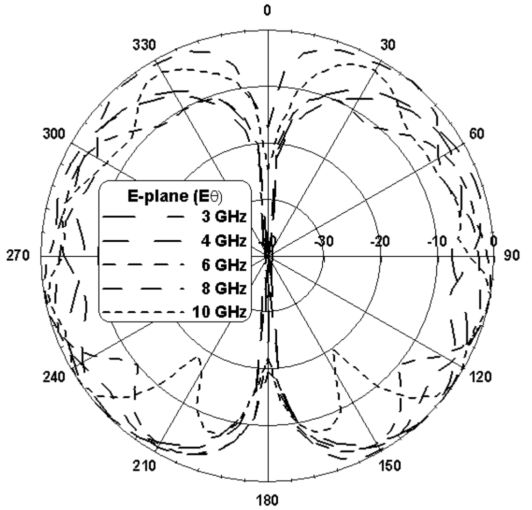

Figure 9. Normalized co-polarized E-plane (yz-plane) radiation patterns $E_\theta(\theta,\pi/2)$) of the coplanar UWB antenna for various frequencies.

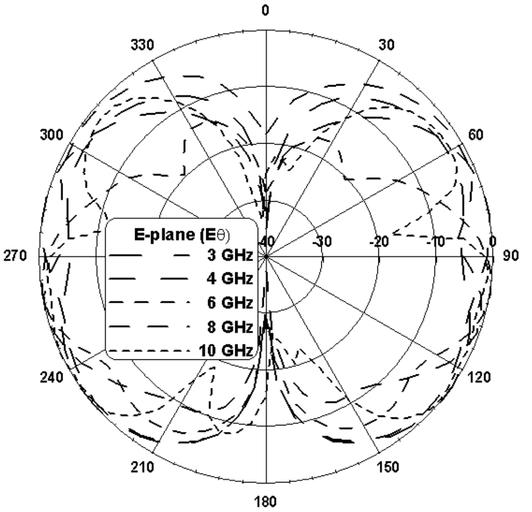

Figure 10. Normalized co-polarized E-plane (xz-plane) radiation patterns $E_\theta(\theta,0)$ of the coplanar UWB antenna for various frequencies.

IV. CONCLUSIONS

The ultra-wideband printed-circuit antenna in coplanar waveguide technology presents a viable option for EMC measurements in the 3.1 – 10.6 GHz frequency range. Nearly omni-directional characteristic is obtained for vertical polarization while the horizontal polarization shows possible applications for direction finding (nulling). The antenna shows excellent VSWR characteristics, and the radiation patterns vary within acceptable margins over the entire frequency range. The antenna is designed using a commercially available electromagnetic field solver, which is verified through measurements at similar ultra-wideband antennas.

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