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A Miniaturized UWB Microstrip Antenna Structure

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ABSTRACT

This paper focuses on the design of an ultra-wide band (UWB) printed circuit antenna of enhanced performance in terms of gain and radiation patterns with the aid of meta-material (MTM) structures. The antenna patch is shaped as a miniaturized open mouth flower backed with a partial ground plane to provide a significant enhancement in the antenna bandwidth. To provide a stable antenna radiation pattern over the entire frequency band, a MTM structure is introduced at the edge of patch structure. The proposed MTM unit cell is constructed from three arrays of H-resonators. Such arrays are provided to focuses the antenna radiation patterns toward the end fire of the antenna. The MTM characterizations in terms of effective constitutive parameters are retrieved with in the frequency band of interest. Numerical simulations are conducted using CST MWS and HFSS software packages to arrive to the optimal antenna design based the proposed MTM structure. Finally, the optimal antenna design is fabricated and tested experimentally for validation.

Keywords: Keywords: UWB, MTM, Partial ground

INTRODUCTION

In the last two decades, wireless communication technologies have changed our lives [1]. Without counting the home and office areas, the wireless handsets free us from the short phone leashes and provide us more freedom to communicate with others at any time and in any place [2]. For example, wireless local area network technologies help us to obtain the internet access without the need for cables with a large number of services [1]. In the first- mobile communication generation, the analogue voice communication was allowed, while, the second generation realized the digital voice communication [3]. The third generation provided video telephony, internet access, video/music download services as well as digital voice services [4]. Then, in the fourth generation, on-demand high quality audio and video services are provided [5]. Recently, more efforts have been conducted into the wireless personal area networks to provide a reliable wireless connection between personal computers and portable devices within a short range with [6]. Moreover, such technology accomplishes a fast data storage and exchange between the portable devices [7]. This technology requires a high data rate for the optimal band-limited additive white Gaussian noise (AWGN) channel that is related to the bandwidth and signal-to-noise ratio (SNR) by Shannon-Nyquist criterion [8].

$$C = B \log2 (1+SNR) \qquad (1)$$

where C denotes the maximum transmit data rate and B stands for the channel bandwidth. Equation 1 indicates that the channel capacity can be increased rabidly by increasing the bandwidth occupation or transmission power [9]. However, the transmission power, i.e., SNR, must not be increased significantly because many portable devices are battery powered and the potential interference consolation [10]. Therefore, a large frequency bandwidth would be the feasible solution to achieve a high data rate [8]. The Federal Communications Commission adopted the commercial operation of ultra-wideband (UWB) technology [3].

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Therefore, UWB technology became one of the most promising wireless technologies to revolutionize a high data rate transmission to enable the personal area networking industry leading to new innovations with great service quality [4].

AN UWB ANTENNA BASED MTM STRUCTURE DESIGN

In this section, a numerical study based on Computer Simulation Technology Microwave Studio (CST MWS) formulations [11] is invoked to optimize the antenna performance and the MTM characterizations. In the first, the antenna structure is optimized to provide the maximum antenna bandwidth match with maximum gain. Next, the MTM is designed and characterized numerically in terms of S11 spectrum. Then, the antenna structure is integrated to the MTM to realize the obtained enhancements on the antenna performance.

A partial ground plane micro strip antenna of a flower-shaped patch with an open mouth cut is designed for the UWB applications. The patch structure is fed with a micro strip line of a varied width from 1 mm up to 2 mm following a binomial transformer [12,13].

The patch layer is mounted on an FR-4 substrate of 30 mm × 60 mm with 1 mm thickness. The partial ground plane is introduced to obtain the maximum bandwidth coupling over the entire band of interest. Therefore, the antenna bandwidth is found to cover the frequencies from 2.4 GHz up to10 GHz with maximum gain of 5.9 dBi. However, the antenna radiation patterns would be mostly scattered toward different directions that limits the antenna use in portable and compact handsets devices. In **Figure 1**, the antenna design based on MTM structure is presented.

AN UWB ANTENNA BASED MTM STRUCTURE DESIGN

The unit cell structure is characterized in terms of S-parameters to retrieve the constitutive parameters in terms of relative permittivity (εr) and relative permeability (μr). As seen in **Figure 2**, the S-parameters are evaluated from CST MWS, than, they are compared the HFSS results. This comparison is performed to validate the obtained results from the CST MWS software package.

Now, the ε_r and μ_r spectra of the proposed MTM are retrieved using Nicholson-Ross-Weir formulations [14] as seen in **Figure 3**. It is found that the proposed unit cell shows no negative part, however, the unit cell shows ε_r=8 at 3.8G Hz and 7 at 7.5 GHz, while, the value of μ_r is found to be 6.7 at 3.6G Hz and 8 at 7.8 GHz.

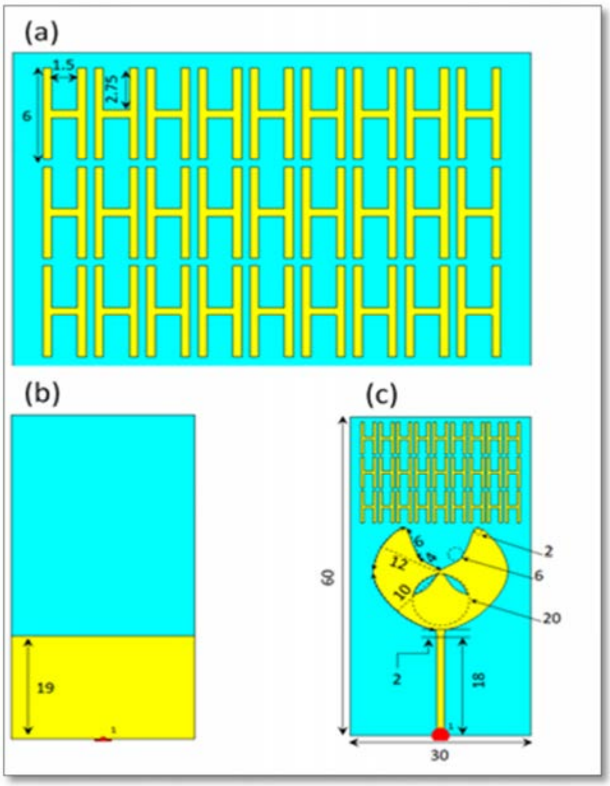

Figure 1. Antenna design details in mm; (a) MTM based H-resonator, (b) back view, and (c) front view.

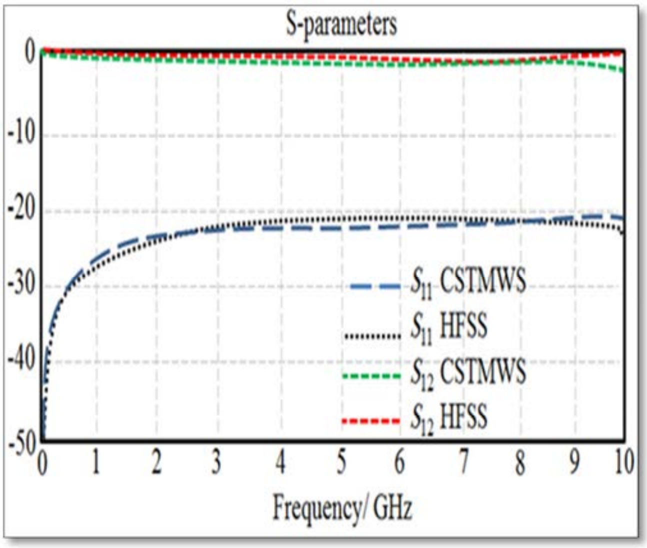

Figure 2. The evaluated S-parameters from both numerical and analytical techniques.

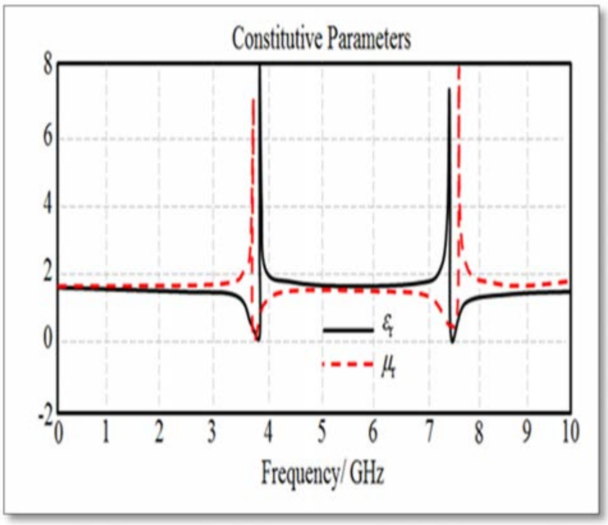

Figure 3. The retrieved constitutive parameters.

THE OPTIMAL ANTENNA DESIGN

The antenna structure is based on a partial ground plane to obtain significant bandwidth enhancements. In **Figure 4**, the effect of the ground plane length on the matching impedance is realized with the S11 spectra. It is found that the antenna shows the best matching bandwidth at 7 mm from the antenna centre. This is due to the effects of fringing from the ground plane edges with respect to the patch edges.

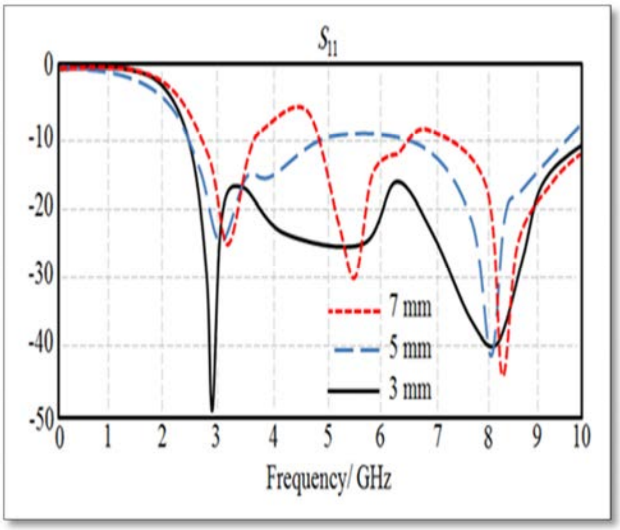

Figure 4. S_{11} spectra with different ground plane lengths.

The effect of introducing the MTM structure arrays to the antenna performance is evaluated in terms of S11 and gain. It is found that the antenna shows a wideband from 2.45 GHz up to 10 GHz with excellent matching, |S11|<-10 dB, as seen in **Figure 5**.

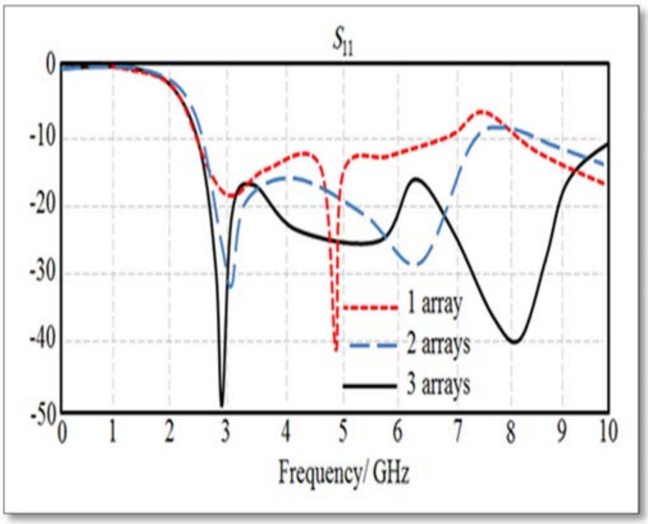

Figure 5. S_{11} spectra with different MTM arrays.

ANTENNA PERFORMANCE VALIDATION AND MEASUREMENTS

The proposed antenna performance is validated numerically before realize the prototype fabrication and perform the experimental measurements. Then the proposed antenna is fabricated using chemical etching processing. The fabricated antenna is shown in **Figure 6a** with MTM structure. The numerical validation is conducted with HFSS software package [15] to evaluate the S11 spectrum and the radiation patterns at 2.45 GHz and 5.8 GHz. As seen in **Figure 6b**, the obtained results from the CST MWS software package agree excellently with those obtained from the HFSS simulations. It is found that the proposed antenna shows excellent matching, |S11|<-10 dB, for the entire band from 2.38 GHz up to 10 GHz. When the experimental measurements are conducted with a Vector Network Analyzer (VNA) of Vector star MS4642A Series, the antenna shows excellent matching with entire band from 2.4 GHz up to 10 GHz.

The antenna radiation patterns are evaluated, based on CST MWS and HFSS, at two frequency bands of 2.45 GHz and 5.8G Hz only for Wi-Fi applications. It is found that the proposed antenna shows a gain of 4.4 dBi at 2.45 GHz and 5.4 dBi at 5.8 GHz from both of the software packages. This gain enhancement as motioned previously is attributed to the introduction of the MTM structure. The antenna radiation patterns are presented in **Figure 7**. Finally, the radiation patterns of the fabricated prototype are measured inside a microwave anechoic chamber at the E- and H-planes. The measurements are performed after calibrating the free space losses inside the chamber using the VNA. Later on, the proposed antenna is mounted on a rotary mount, while, the reference antenna is located in the line of sight from the antenna under the test. It is found excellent agreement between the simulated and measured results at the two frequency bands of interest.

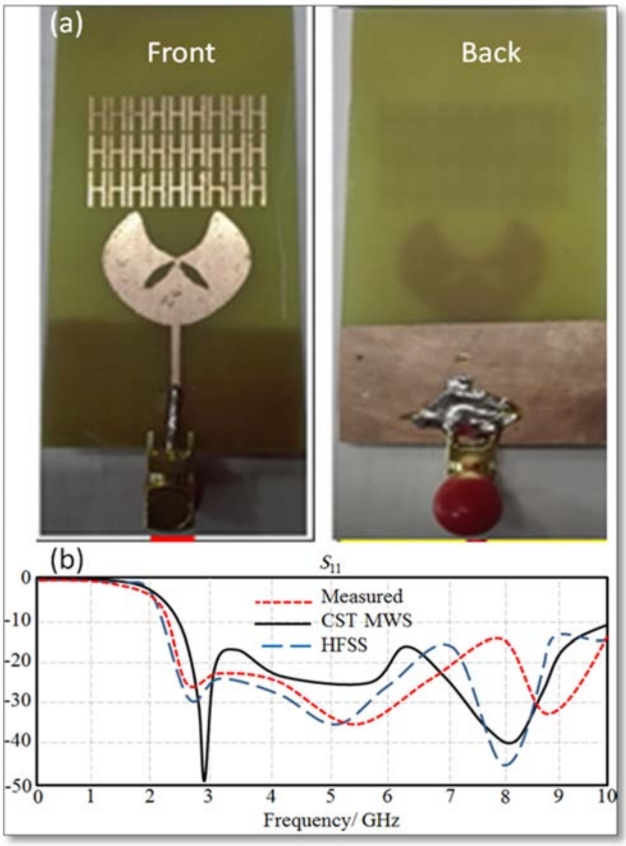

Figure 6. (a) The fabricated prototype and (b) Comparison of the simulated S11spectra with respect to the measurement.

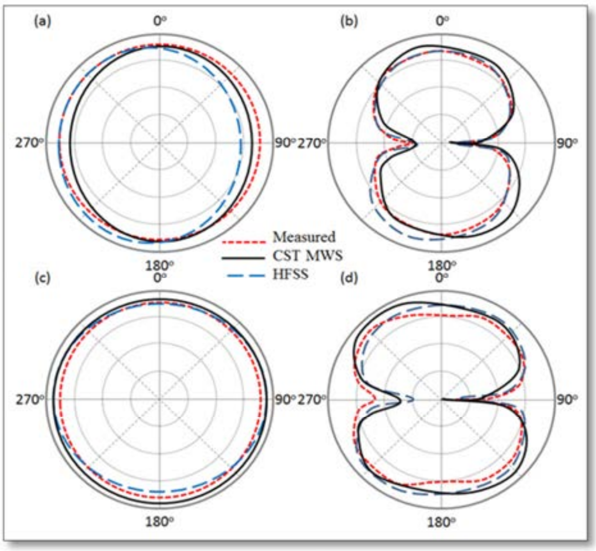

Figure 7. Radiation patterns measurement in comparison to simulated results; (a) E-plane at 2.45 GHz, (b) H-plane at 2.45 GHz, (c) E-plane at 5.8 GHz, and (d) H-pane at 5.8 GHz.

CONCLUSION

In this work, an UWB miniaturized micro strip antenna based of slotted flower profile has been designed, simulated, and implemented on a range of frequency from 3 GHz to 10 GHz. The purpose of this design is to illustrate the effect of adding the MTM cells in H-resonators shapes for bandwidth and enhancements. The resulted antenna has the advantage of small dimensions (60 mm × 30 mm) and a bandwidth smaller than that required by the standard FCC UWB. The UWB antenna based MTM is altered to enhance its specifications and produce a wideband frequency range which can be used for biomedical applications. The design has been optimized and verified using CST MWs and HFSS software packages. Then, it has been fabricated and tested successfully. The measurements of the fabricated antenna are almost similar to the simulation results but they are not typically the same due to the limited fabrication defects. For the proposed UWB antenna based MTM, the radiation patterns within the operating frequency bands are relatively acceptable.

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