Proceedings of the 2023 Design of Medical Devices Conference
DMD2023
April 17-19, 2023, Minneapolis, MN, USA

DMD2023-2982

ON THE DESIGN OF ULTRA-WIDE BAND ANTIPODAL VIVALDI ANTENNA FOR BIOMEDICAL SENSORS

Poulami Samaddar
Microwave Engineering & Imaging Laboratory (MEIL), GIH Division, Mayo Clinic, Rochester

Tasin Nusrat
Dept. of Electrical Engineering, South Dakota Mines, Rapid City South Dakota, USA

Sunil Gaddam
Microwave Engineering & Imaging Laboratory (MEIL), GIH Division, Mayo Clinic, Rochester

Cadman L. Leggett
Microwave Engineering & Imaging Laboratory (MEIL), GIH Division, Mayo Clinic, Rochester

Shuvashis Dey
Dept. of Electrical Engineering, NDSU, Fargo, North Dakota, USA

Dipankar Mitra
Dept. of Computer Science, University of Wisconsin, La Crosse Wisconsin, USA

Sayan Roy
Dept. of Electrical Engineering, South Dakota Mines, Rapid City South Dakota, USA

Shivaram P. Arunachalam
Microwave Engineering & Imaging Laboratory (MEIL), GIH Division, Mayo Clinic, Rochester

ABSTRACT

Designing an effective antenna is very important to utilize microwave imaging. A high gain antipodal antenna designed with ultra-wideband frequency range is presented here. The simulated results are validated with measured data. The antenna can operate within the Ultra band frequency range of 3 to 8 GHz. The maximum gain of 2.96 dBi is obtained at 4 GHz. An experiment with biological tissues is also done to show the effectiveness of the antenna using as a resonator.

Keywords: Microwave Imaging, Antipodal Vivaldi Antenna, Ultrawide band (UWB), gain, biomedical sensor

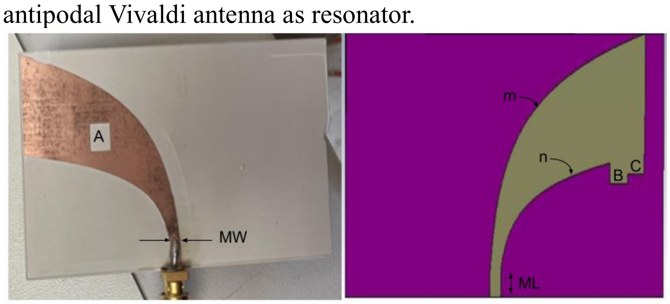
1. INTRODUCTION

Microwave Imaging (MI) is gaining a lot of interest in biomedical field due to its fast, non-invasive, non-ionizing and potentially low-cost nature. The rapid growth of microwave engineering, advances in signal processing and addition of growing advantages of machine learning (ML) techniques created a perfect environment to develop microwave sensor based clinical diagnostic tools [1, 2]. Various research works using this technology are documented for cancer detection like breast cancer, skin cancer and stroke detection systems etc [3]. The difference between the dielectric characteristics of tissues is the main motivation behind the MI technology [4]. Recent work for blood flow velocity mapping and gastrointestinal tissue classification using dielectric spectroscopy technique offers promise towards viable clinical applications [3,5]. Electrical properties like electric permittivity (ε) and conductivity (σ) of the material under test (MUT) significantly control the electromagnetic (EM) propagation through them. EM signal transmitted by an antenna penetrates through the MUT and the scattered signal then received by a receiver antenna. This received signal using nonlinear inverse scattering approaches reconstruct the dielectric property distribution in MI technology [2]. It can be established that one of the key components of MI technology is suitable antenna. Ultra-wide band (UWB) and high gain antennas provide better resolution and accuracy for MI system [1]. The simple structure of the antenna is important as that is computationally less challenging and easy to feed in forward solver during image extraction [2].

There are many ultra-wide band antennas (UWB) documented throughout the literature like spiral, log-periodic, fractal bow-tie, vivaldi antenna etc [6]. Slot line fed Vivaldi antenna operates under the tapering travelling wave principle. This type of antenna is used for biomedical application due to its simple structures, high gain and UWB characteristics [7]. The purpose of this work was to design a slot fed antipodal Vivaldi antenna operating at UWB frequency range with a 2.96 dBi gain at 4 GHz, which is suitable for biomedical sensing.

2. MATERIALS AND METHODS

Antipodal Vivaldi antenna was modeled using commercial EM solver CST microwave studio (simulation tool). The simulated and fabricated antenna structure (75 mm * 85 mm) is shown in figure 1 and the dimensions are added in table 1. Antenna was designed to have initial resonating harmonic at 4 GHz (fr). Microstrip length (ML) and width (MW) were calculated considering available substrate's (Rogers TMM 4), thickness (1.524 mm), dielectric constant (4.7), thickness of the perfect electric conductor (PEC, 0.035 mm) and fr. The equation for the exponential curve m, and n are shown in table 1 and the constant values (4.7 and 0.1 for 'm' curve and 2 and 0.2 for 'n' curve) mandated the width of the antenna as 75 mm which is the wavelength for the frequency 4 GHz. This indicates that the initial design had the first harmonic at 4 GHz while a consecutive second order harmonic at 6 GHz was also evident. After addition of 'A' slot on patch and metallic extension of 'B' and 'C' (figure 1) part on the ground plane, the bandwidth and the impedance matching were improved. This slot loaded antenna was then measured in an anechoic chamber to validate the simulated results. An experiment with store bought chicken breast was performed to show the difference of received signal in the presence and absence of the antipodal Vivaldi antenna as resonator.



(a) (b)

Figure 1: STRUCTURE OF ANTIPODAL VIVALDI ANTENNA (a) FABRICATED TOP (PATCH) VIEW AND (b) SIMULATED BOTTOM (GROUND PLANE) VIEW

Table 1: Dimension of the antenna

ML	4.16 mm
MW	2.7 mm
B (box1 at ground plane)	2.99 mm * 4.16 mm
C (box2 at ground plane)	4.5 mm * 3.17 mm
A (box slot at patch)	5 mm * 5 mm
m (curve)	f(t) = 4.7 - exp (0.1*t)
n (curve)	f(t) = 2 - exp (0.2*t)

3. RESULTS AND DISCUSSION

Comparison between simulated and measured s-parameter (S11) is shown in figure 2. The experimental setup with chicken breast and measured S21 is shown in figure 3. Chicken breast piece (with/without Vivaldi antenna) was suspended using a non-reflecting wooden frame between two horn antennas by which EM signal was transmitted and received. All the measurements are done inside anechoic chamber to eliminated outside noise.

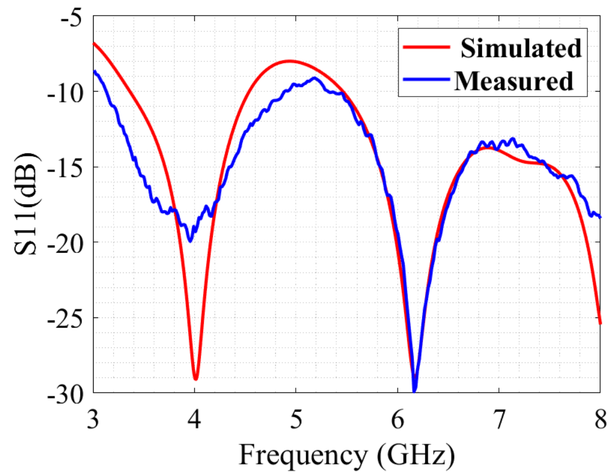
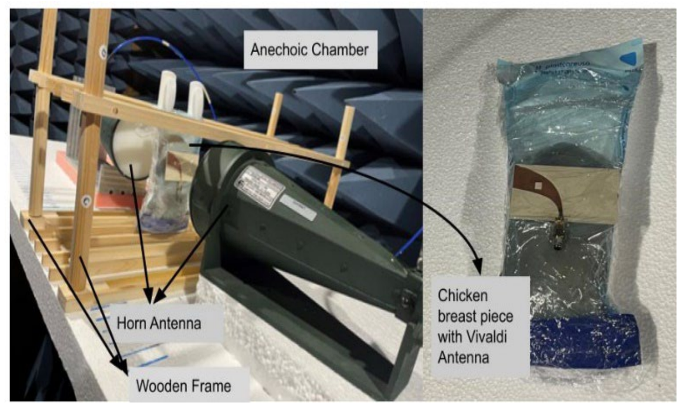
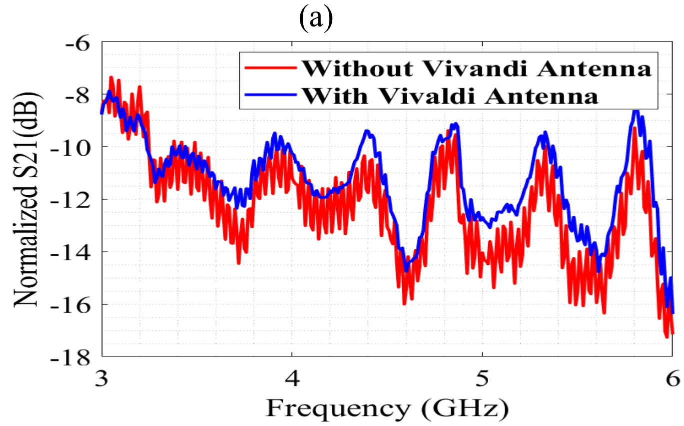


Figure 2: SIMULATED AND MEASURED S-PARAMETERS



(a)



(b)

Figure 3: (a) MEASUREMENT SETUP INSIDE ANECHOIC CHAMBER AND (b) S21 PLOT WITHOUT AND WITH VIVALDI ANTENNA

4. CONCLUSION

Slot loaded Antipodal Vivaldi antenna was designed and measured for MI application. Experimental results showed that the antenna can reduce noise significantly. This initial study offers significant potential to extend the work for designing UWB-antenna based bio sensors.

REFERENCES

[1] M. S. Mahalingam, et al., “An ultrawideband balanced antipodal vivaldi antenna for medical imaging applications with performance analysis for different surface finish materials,” *Analog Integrated Circuits and Signal Processing,* vol. 112, pp. 103–113, 2022.

[2] J. Kowalewski, et al., “Vivaldi Antenna with improved Directivity for Medical Applications,” in German Microwave Conference, Nürnberg, Germany, 2015.

[3] H. M. Fahmy, et al., “Dielectric spectroscopy signature for cancer diagnosis: A revieew” in *Microw. Opt. Technol. Lett*., vol. 62, pp. 3739-3753, 2020.

[4] P. Samaddar et al., “On the Dielectric Characterization of Biological Samples for Microwave Imaging Reconstruction,” in 2022 IEEE AP-S/URSI, Denver, CO, USA, 2022, pp. 1082-1083.

[5] S. Gaddam, et al., “On the Non-invasive Sensing of Arterial Waveform and Hematocrit using Microwaves,” in 2022 IEEE AP-S/URSI, Denver, CO, USA, 2022, pp. 1082-1083.

[6] A. Mehdipour, et al., “Complete Dispersion Analysis Of Vivaldi Antenna For Ultra Wideband Applications,” in *Progress In Electromagnetics Research*, vol 77, pp. 85–96, 2007.

[7] A. Lazaro, et al, “Design of tapered slot Vivaldi antenna for UWB breast cancer detection,” *Microwave and Optical Technology Letters,* vol. 53, no. 3, pp. 639-643, 2011.