Novelty Journals

International Journal of Novel Research in Electronics and Communication
Vol. 3, Issue 2, pp: (74-80), Month: September 2016 - February 2017, Available at: www.noveltyjournals.com

Design of Vivaldi Antenna Array with Enhancement of Radiation Characteristics for 5G Mobile Applications

[1]A. A. El Badawy, [2]Y. M. Abdulmaqsoud, [3]F. Z. Amer

[1,2]October University for Modern Sciences and Arts
[3]Faculty of Engineering, Helwan University

Abstract: **In this paper, a compact size antenna for fifth generation of mobile applications is introduced. The antenna is antipodal Vivaldi antenna with ellipse patch in the effective aperture area to enhancement the radiation characteristics. The proposed antenna is designed with size 5 mm ×15 mm on Fr-4 substrate with $\epsilon_r = 4.5, h = 0.4$ and $\tan_\delta = 0.025$. The antenna operates from 26GHz to 32 GHz. The antenna meets three challenging parameters: the compact size, the wide bandwidth and high gain across the operating band. The antenna not only has a compact size but also supports a low SAR radiation at all the operating frequencies. The proposed antenna is tested using the four recommended test positions of the CTIA association where the proposed antenna reveals good performance in all test cases; in talking position, and in standby position. Good agreement is found between the experimental and the simulated results.**

Keywords: **Fifth Generation (5G), Specific Absorption Rate (SAR), Millimeter Wave, Vivaldi Antenna, Mobile Applications.**

I. INTRODUCTION

The future development of the personal communication devices will aim to provide image, voice, highly reliable networks, massive machine type communications and data communication at any time. Nowadays, the fifth generation of mobile communications, is expected to deliver multimedia services anywhere, anytime. So, Fifth Generation (5G) is a new high –performance air interface standard for cellular mobile communication systems in millimeter wave (mmW) range to increase the capacity and speed of mobile networks. It will most likely use millimeter-wave frequencies [1-3].

Several studies have been performed to solve the problem of inherent propagation losses, shadowing, large-scale attenuation of materials and human bodies, and atmospheric absorption in mmW [2]. So, different methods are presented to solve these problems highly directional beam forming antennas at both the base station and the mobile device should be deployed. Antenna arrays are usually applied to overcome the inherent high path loss at the mmW frequency band [4-6].

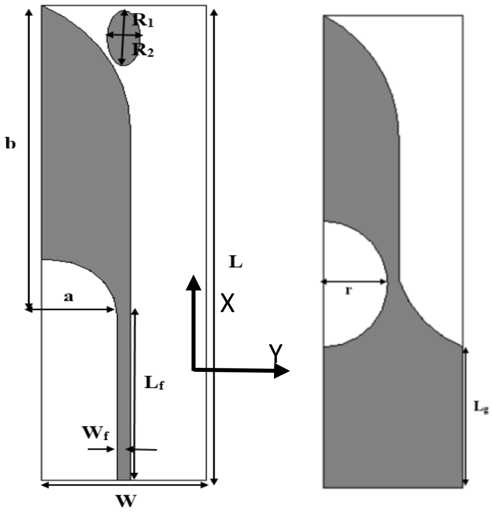
The continuous growth of wireless mobile services has forced the worldwide mobile handset manufacturers to consider the mutual interactions between the mobile terminals and the human body. While part of the electromagnetic wave radiated by the antenna is absorbed by the human head, some mobile handset antenna characteristics, such as radiation pattern, radiation efficiency, bandwidth, and return loss are altered due to the proximity of the human head. The mutual effects of the human head and the antenna have been introduced by many research works [7-9].

In this paper, the proposed antenna is Antipodal Vivaldi antenna with enhancement of gain, it is introduced to achieve wide impedance bandwidth with compact size 5 × 15 mm^2 compared to the previous techniques. The UWB antenna is fabricated on a FR4 substrate with relative permittivity of 4.5, and thickness of 0.8 mm.

The paper is organized as follows: section II describes the design of antenna. Section III explains the antenna performance and compare between simulated and measured results. The SAR calculations are introduced in section IV. Finally, section V presents the conclusions for this research.

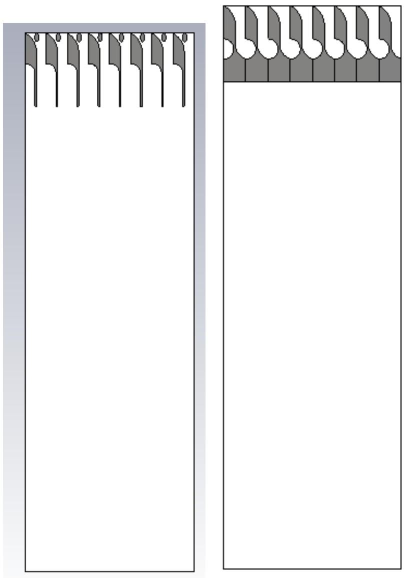
II. ANTENNA DESIGN

The proposed antenna is a planar micro strip antenna with compact size (5 × 15 × 0.4) mm^3. The geometry of the proposed antenna is shown in Fig. 1. All the labeled dimensions are tabulated in Table I. The antenna is physically compact with an exponentially tapered opening slot used to achieve directivity in one direction. The configuration of the proposed Vivaldi antenna consists of two tapered arms which lie on the opposite sides of the substrate and ellipse parasitic patch to increase directivity in the proposed direction. The tapered-arm used on the top layer of the substrate is fed by a 50 Ohm microstrip-line. The arm on the bottom layer is connected with an exponentially tapered ground plane feed. Fig. 2 shows the structure of antenna array; the proposed design consists of eight antipodal Vivaldi antenna elements which are used along the upper edge of the mobile PCB.



(a) Front View **(b) Back view**

Fig 1: Geometry of the proposed antenna



(a) Front View **(b) Back view**

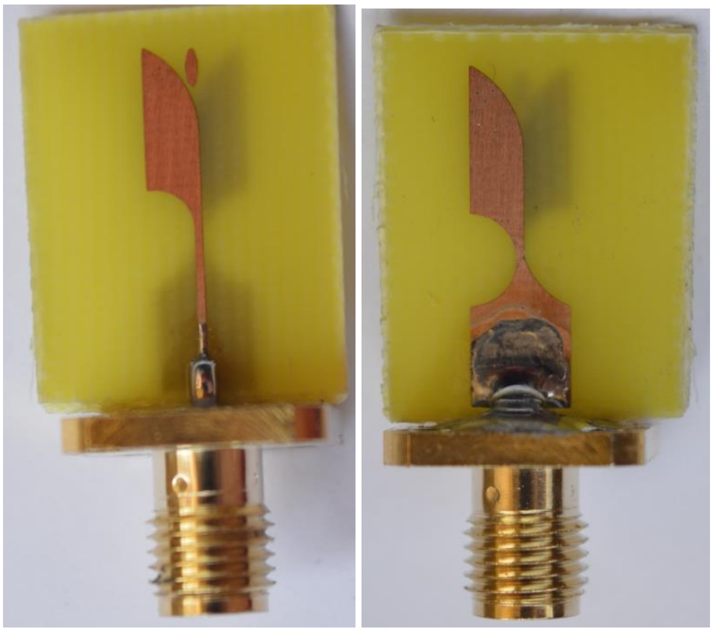
Fig 2: Geometry of Antenna array

Table I: Antenna Parameters (all dimensions in mm)

Parameter	R_1	R_2	L	W	L_f	a	b	W_f	r	L_g
Value	2	1	15	5	7	2.3	8	0.7	2.1	5

III. SIMULATION AND MEASUREMENT

The antenna is fabricated on FR4 substrate and the prototype of the antenna is shown in Fig. 3. The proposed antenna is simulated using the CST Microwave Studio 2016. The good agreement between simulated and measured reflection coefficient are shown in Fig. 4. Fig. 5 shows the appreciable gain of the antenna over the operating band and the efficiency. Fig. 6 illustrates the simulated radiation patterns in both the E- plane and H-plane at 28 GHz. A discrete-port feeding technique has been used to feed the antenna in the simulations. The distance between elements is half wavelength from center frequency. The mutual coupling between elements is -18 dB. Fig. 7 shows the radiation pattern of antenna array and the gain of the antenna array is 16 dB.



(a) Front **(b) Back**

Fig 3: prototype of the antenna

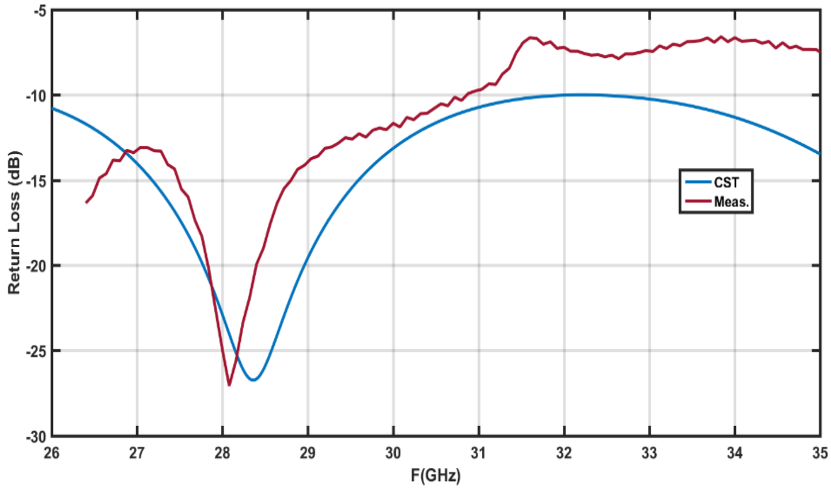


Fig 4: Return loss of the antenna

Novelty Journals

International Journal of Novel Research in Electronics and Communication
Vol. 3, Issue 2, pp: (74-80), Month: September 2016 - February 2017, Available at: www.noveltyjournals.com

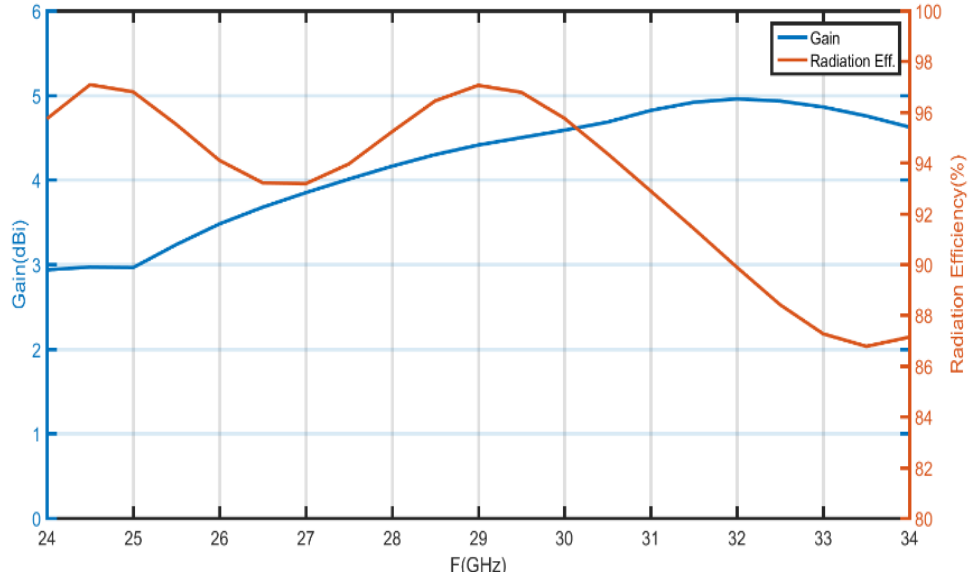
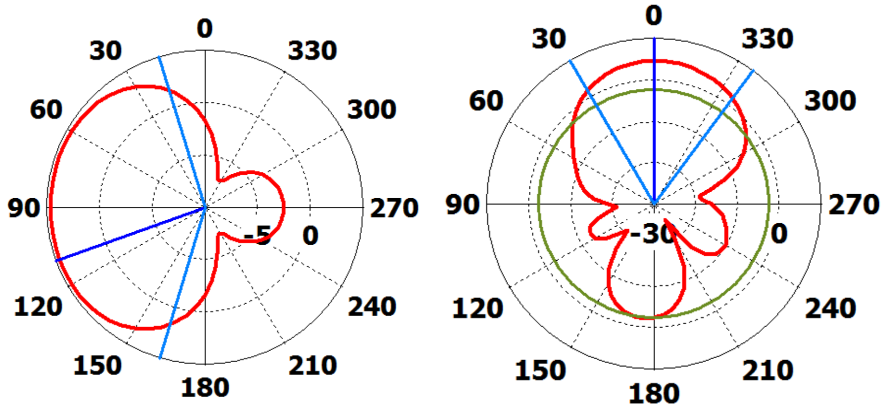
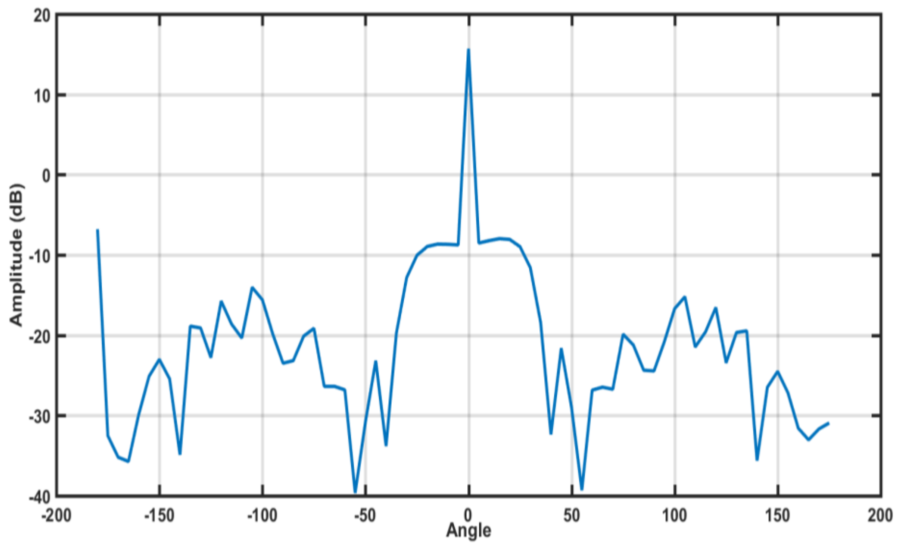


Fig 5: Gain and radiation efficiency of antenna



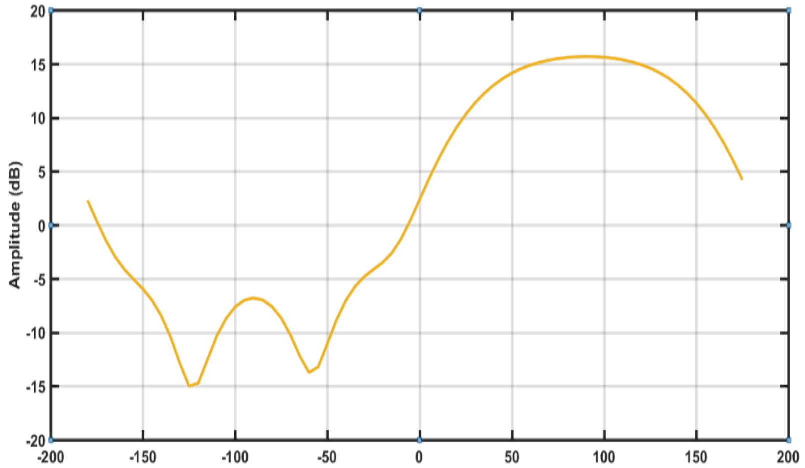
(a) XZ Plane **(b) XY Plane**

Fig 6: Radiation pattern of antenna at 28 GHz



(a) XY Plane

International Journal of Novel Research in Electronics and Communication
Vol. 3, Issue 2, pp: (74-80), Month: September 2016 - February 2017, Available at: www.noveltyjournals.com

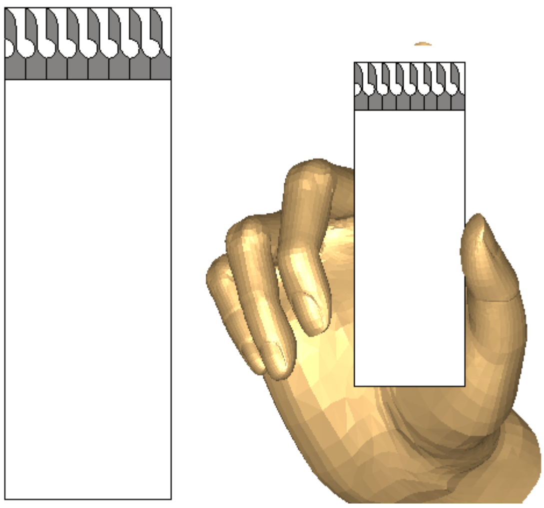


(b) XZ plane

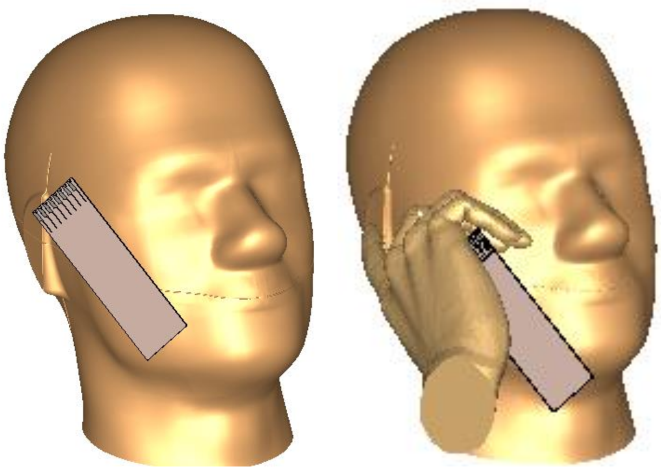
Fig 7: Radiation pattern of the antenna array at 28 GHz

IV. SAR CALCULATIONS

Cellular Telecommunication and Internet Association (CTIA) has proposed several body test cases for a mobile phone as shown in Fig. 8, namely, mobile handset in free space, browsing mode, talking position, and talking position with hand [10]. Fig. 9 shows the return loss of the antenna in the 4 different cases. The primary effect of the hand and head has little shift and degradation in the impedance matching. As the use of the mobile phone is increased, the research on the health risk due to the electromagnetic (EM) fields generated from wireless terminals is widely in progress. Many factors may affect the EM interaction while using cellular handset in close proximity to head and hand. One of the most widely used parameters for the evaluation of exposure is SAR, specific absorption rate. Therefore, some regulations and standards have been issued to limit the radiation exposure from the mobile handsets not only to decrease the SAR but also to increase the antenna systems efficiency. The SAR limit specified in IEEE C95.1-2005 has been updated to 2W/kg over any 10 g of tissue [11], which is comparable to the limit specified in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines [12].In this paper, The SAR is tested at 28 GHz when the antenna is close to the human head and the output power of the cellular phone is set to 500mW. The SAR calculations are done using the CST2016 commercial package with SAM model CST Microwave Studio [13]; the tissues that are contained have relative permittivities and conductivities, according to [14]. Table 2 shows the maximum SAR at the aforementioned operating frequencies when the antenna is close to the body, the radiation efficiency and gain.



(a) **(b)**



(c) (d)

Fig.8: CTIA-defined four different test positions: (a) free space, (b) browsing mode, (c) talking position, and (d) talking position with hand

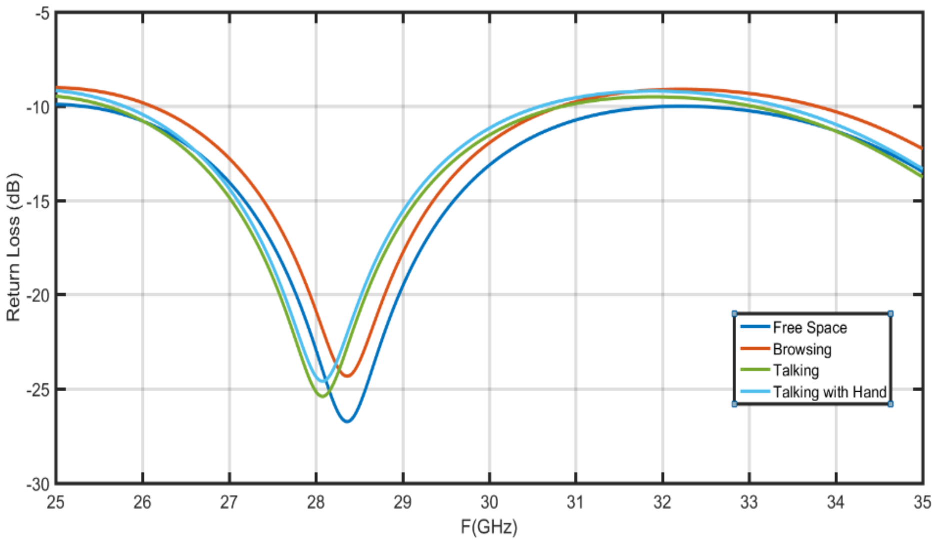


Fig 9: The simulated return loss of antenna in four different test positions

Table 2: SAR values and the effects of human model on antenna properties

F (GHz)	SAR (W/kg) (10g)	Position	$\|S_{11}\|$ (dB)	Gain (dB)	Radiation Efficiency (%)
28	0.472	Free Space	-24	16	93
		With human model	-25	15.6	89
29	0.323	Free Space	-20	16.5	95
		With human	-16.5	16.2	93

V. CONCLUSION

A compact planar antenna is designed to support 5 G applications. The antipodal Vivaldi antenna is introduced with ellipse to increase the gain. Furthermore, the antenna array is designed on the top edge of mobile PCB. The antenna has compact size 5 ×15 × 0.8 mm^3 on Fr-4 substrate with dielectric constant 4.5. The antenna is simulated using the CST simulator and fabricated using the photolithographic technique. Very good results are obtained in both the simulated and the experimental data.

International Journal of Novel Research in Electronics and Communication
Vol. 3, Issue 2, pp: (74-80), Month: September 2016 - February 2017, Available at: www.noveltyjournals.com

REFERENCES

[1] Osseiran, et al., “Scenarios for 5G mobile and wireless communications: the vision of the METIS project,” IEEE Commun.Mag., vol. 52, pp. 26-35, 2014.

[2] I. Sulyman, et al., “Radio propagation path loss models for 5Gcellular networks in the 28 GHZ and 38 GHZ millimeter-wave bands,” IEEE Commun. Mag., vol. 52, pp. 78-86, 2014.

[3] S. Rajagopal, S. Abu-Surra, Z. Pi and F. Khan, “Antenna array design for multi-Gbps mmWave mobile broadband communication,” Proc. IEEE GLOBECOM’2011, Houston, Texas, USA, pp.1-6, 2011.

[4] W. Hong, K. Baek, Y. Lee, and Y. G. Kim, “Design and analysis of alow-profile 28 GHz beam steering antenna solution for future 5Gcellular applications,” IEEE international microwave symposium, 1-6June 2014, Tampa Bay, Florida, 2014.

[5] P. J. Gibson, “The Vivaldi aerial,” Proc. 9th Eur. Microwave Conf.,Brighton, pp. 101-105, 1979.

[6] N. Ojaroudiparchin, M. Shen, and G. F. Pedersen “Design of Vivaldi Antenna Array with End-Fire Beam Steering Function for 5G Mobile Terminals” 23rd Telecommunications forum TELFOR , pp. 587-590, Nov. 2015.

[7] K. S. Sultan, H. H. Abdullah, E. A. Abdallah, and E. A. Hashish, “Low SAR, miniaturized printed antenna for mobile, ISM, and WLAN services” IEEE, Antennas and Wireless Propagation Letters, Vol. 12, pp. 1106-1109, 2013.

[8] K. S. Sultan, and H. H. Abdullah, “Multiband Compact Low SAR Mobile Hand Held Antenna” PIER, Vol. 49, PP. 65-71, 2014.

[9] K. S. Sultan, H. H. Abdullah, and E. A. Abdallah “Comprehensive study of printed antenna with the handset modeling” Microwave and Optical Technology Letters, Vol. 58, No. 4, pp. 974-980, April 2016.

[10] CTIA Certifcation Department Program, Test Plan for Mobile Station over the Air Performance Method of Measurement for Radiated RF Power and Receiver Performance,http://www.ctia.org/.

[11] IEEE C95.1-2005, IEEE Standards for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, Institute of Electrical and Electronics Engineers, New York, NY, USA, 2005.

[12] International Non-Ionizing Radiation Committee of the International Radiation Protection Association, “Guidelines on limits on exposure to radio frequency electromagnetic fields in the frequency range from 100 kHz to 300 GHz,” Health Physics, vol.54, no. 1, pp. 115–123, 1988.

[13] “CST Microwave Studio Suite 2016 User’s Manual,” http://www.cst.com.

[14] S. Gabriel, R. W. Lau, and C. Gabriel, “The dielectric properties of biological tissues: II. Measurements in the frequency range10 Hz to 20 GHz,” Physics in Medicine and Biology, vol. 41, no. 11, pp. 2251–2269, 1996.