Application of Dielectric Resonator Antenna in Implantable Medical Devices

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***Abstract*—Wireles biomedical telemetry through Implantable Medical Devices (IMD) has been one of the major interest of human kind in present times due to life supporting advantages. As sensors, actuators, battery and antenna comprises the IMD and role of efficient radiator describes the quality of implantable device. However, Dielectric Resonator Antennas (DRA) have been proved more efficient in comparison to their contemporaries in different applications due to its inherent properties, but application of DRA in implantable devices is not proposed yet. In this paper, a rectangular DRA resonating at 2.45 GHz excited by coplanar waveguide feed has been proposed for in depth implantable applications.**

***Index Terms*—Dielectric resonator antenna (DRA), implant antennas, SAR, IMD.**

I. Introduction

An exponential growth has been experienced by wireless technologies in the past few decades due to rapid development in the field of antennas. Transition from wired to wireless communications has been distinguished in outer space communication but it is in growing phase when looked into in-body communication for biomedical applications. There are two operating bands reserved for biomedical applications which are Medical Implant Communication Service (MICS) band (402-405 MHz) to Industrial, Scientific and Medical (ISM) band (902-928 MHz, 2400-2483.5 MHz and 5.725 - 5.875 GHz). If looked electrically, human body is combination of dielectric materials with varied minor conductivity like skin, muscle, fat are equivalently represented as dielectric material with conductivity, in [1].

In [2], [3] authors reviewed significant microstrip patch antennas proposed in recent times for ingestible and implantable body antennas. Microstrip patch antennas have been preferred choice by researchers due to its various advantages like low profile and possible miniaturization. But human body is very lossy in nature and metallic patch antenna experience low gain and high loss there. DRAs have advantages like high gain and design flexibility which may be a better choice in dielectric environment of human body. An Ultra Wide Band (UWB) frequency band 3.1-10.6 GHz hemispherical Dielectric Resonator Antenna (DRA) for medical capsule endoscope applications has been proposed in [4].

In this paper, a novel concept of using DRA in implantable application such as in human arm, has been proposed. To the author's knowledge, no other muscle implantable DRA work has been reported in the literature yet.

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II. Antenna Design

Designing an implantable antennas requires biocompatibility and body radiation condition to be met with existing standards. Taking biocompatiblity into considerations, DRA is made up of TiO_2 with ϵ_r=80 which is a biocompatible ceramic. This DRA with dimensions 23.5mm×23.5mm×5 mm has been placed on biocompatible substrate made up of PVC plastic ϵ_r=2.7 with dimensions 40mm × 40mm × 0.5mm. Initial dimensions of DRA has been calculated using Marcatili's approximation method [5], [6] at 2.45 GHz for $TE_{11\delta}$ mode, which were further optimized by EM simulator. Overall thickness of antenna is 5.5 mm which is considerable for implantable antenna applications. The microstrip feedline dimension are 25.3 mm×2.2mm with 0.5mm gap between ground and feedline. To avoid ground plane at the bottom side of substrate which can lead to losses and high power requirement to achieve desired results inside body environment, a CPW (Coplanar Waveguide) feed is used to excite RDRA. Geometry of antenna is shown in Fig. 1.

III. Result Analysis

A simulation analysis has been performed on 3D Canonical right arm tissue model in HFSS EM simulator. Upper

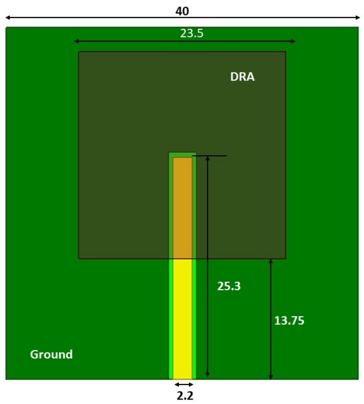

Fig. 1: Geometry of the Antenna

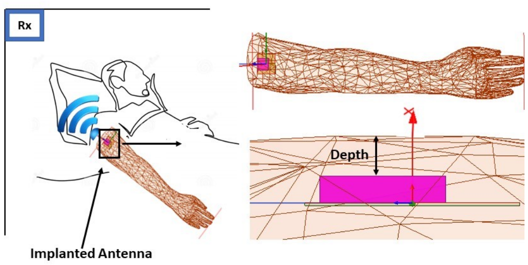

Fig. 2: 3D Canonical right arm tissue model in HFSS

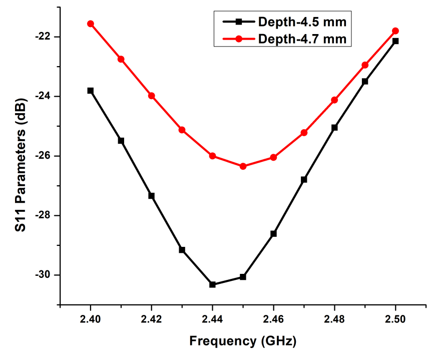

Fig. 3: S_{11} Parameters of RDRA in 3D Canonical right arm tissue model in HFSS

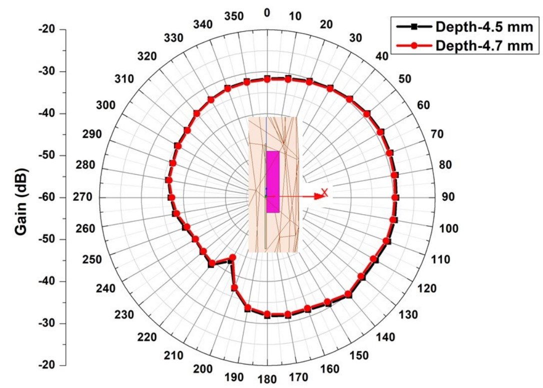

Fig. 4: Simulated gain of RDRA in 3D Canonical right arm tissue model in HFSS at 2.45 GHz and $\phi = 0$, here broadside is $\theta = 90^o$ for Human Arm Model

human arm was chosen because it has thick muscle and fat which resembles chest and thighs. Simulation time per iteration heavily depends upon configuration of computer so a 16 GB RAM computer with 3.2 GHz processor was used in the analysis.

S_{11} parameters and simulated gain at 2.45 GHz, $\phi = 0$ are shown in Fig. 3 and Fig. 4 for two implant antenna depths i.e. 4.5 mm and 4.7 mm. Simulated gain for these two implant depths is shown in Fig. 4. Maximum gain of −29.5 dB is achieved in the broadside direction (here at $\theta = 90^o$ and $\phi = 0$) due to change in inclination of human arm model in HFSS. Inside body radiation is majorly characterize by surface absorption rate (SAR). The IEEE C95.1-1999 standard restricts the SAR averaged over any 1 g of tissue to be less than 1.6 W/kg [7], and the IEEE C95.1-2005 SAR averaged over any 10 g of the tissue be less than 2 W/kg [8]. Maximum value of SAR field are 388.38 W/kg and 53.97 W/Kg for 1-g avg and 10-g avg cases. Maximum allowed net input power of proposed DRA for both the standards are 2.25 mW and 37 mW which are more than required when input power is less than 1 mW provided by internal battery. A link budget analysis revealed that this antenna can be useful for upto 5 meters out-body communication with data rate of 1 Mbps when base station antenna is considered as omnidirectional dipole antenna with gain of 2.45 dBi.

IV. Conclusion

In this paper, a novel concept of application of DRA in implantable devices has been presented. Exploiting advantages of DRA over microstrip patch antenna in the in-body to out-body communication is possible and demonstrated with the help of biocompatible rectangular DRA excited by coplanar waveguide feed. SAR and link budget analysis supports its candidature for high data rate biomedical telemetry applications.

References

[1] S. Gabriel, R. W. Lau, and C. Gabriel, "The dielectric properties of biological tissues: II. Measurements in the frequency range 10 Hz to 20 GHz," Phys. Med. Biol., vol. 41, no. 11, p. 2251, 1996. [Online].

[2] A. Kiourti and K. S. Nikita, "A Review of Implantable Patch Antennas for Biomedical Telemetry: Challenges and Solutions [Wireless Corner]," in IEEE Antennas and Propagation Magazine, vol. 54, no. 3, pp. 210-228, June 2012.

[3] A. Kiourti and K. S. Nikita, "A Review of In-Body Biotelemetry Devices: Implantables, Ingestibles, and Injectables," in IEEE Transactions on Biomedical Engineering, vol. 64, no. 7, pp. 1422-1430, July 2017.

[4] Q. Wang, K. Wolf and D. Plettemeier, "An UWB capsule endoscope antenna design for biomedical communications," 2010 3rd International Symposium on Applied Sciences in Biomedical and Communication Technologies (ISABEL 2010), pp. 1-6,2010.

[5] E. A. J. Marcatili, "Dielectric rectangular waveguide and directional coupler for integrated optics," Bell Syst. Tech. J., vol. 48, pp. 2071-2102, 1969.

[6] R. K. Mongia and P. Bhartia, "Dielectric resonator antennas - A review and general design relations for resonant frequency and bandwidth," Int. J. RF Microw Millim. Comput.-Aided Eng., vol. 4, no. 3, pp. 230-247, 1994.

[7] IEEE Standard for Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 KHz to 300 GHz, IEEE Standard C95.1-1991, 1999.

[8] IEEE Standard for Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 KHz to 300 GHz, IEEE Standard C95.1-2005, 2005.