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RESEARCH PAPER

Design of CPW-fed tapered MIMO antenna for ISM band applications

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In this paper, an implantable coplanar waveguide-fed tapered monopole antenna for industrial scientific and medical band (2.4–2.48 GHz) applications is proposed. This proposed design has an overall dimension of 44 × 44 × 0.5 mm³. The designed antenna is made compatible for implantation on human tissues such as skin, fat, or muscles by embedding it on the RT Duroid substrate and the 10 dB return loss bandwidth is 6.12% ranging from 2.35 to 2.5 GHz. This proposed antenna can be significantly used in implantable medical devices and radio frequency (RF), because of its merits such as conformability, flexibility in design and shape, biocompatibility, patient safety, miniaturization, power consumption, etc.

Keywords: Antennas, Industrial, scientific and medical (ISM) band, Coplanar waveguide structure

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I. INTRODUCTION

In patient care systems nowadays, to communicate exceptionally well with external environment antennas are implanted to the human body. These antennas are called implantable antennas and it assures better quality of life. This contrived the researchers to firmly work on them and the results lead to various innovations in biomedical engineering [1].

This system may be an exceptional stand-in for the patients in close observation over a period of time and they need not visit the hospital or stay for days together. Here we install a Home Care Unit at the patient's residence [2] and these units, along with networking device, send the required data regarding patient's condition on a formal basis to the medical examiner [3]. Medical implant devices are magnetically coupled to external equipment such that, it is in close proximity to the external monitoring device [4, 5].

Medical implants require more time for data transfer because of sluggish data rate due to inductive communication. Usage of Medical Implant Communication Services (MICS) has bolstered up the data rate in [6]. The antenna required is designed either in air or dielectric of the body and if designed in air, it performs well when air surrounds the implant or if designed using dielectric, it works fine when inculcated to the body [3, 7]. Consequently, the implantable antenna should be placed in the medium in which it operates. In this attempt, we have contemplated an implantable antenna for industrial scientific and medical (ISM) band applications which is of compact size, reasonable return loss insensitive to the discrepancies of electrical properties of the human body. To curtail wave devitalization in complex human environment, MICS band operating electrically with very small antenna is preferred [8, 9]. All these days, dielectric-covered Microstrip or planar inverted F antenna (PIFA) were used for implantable devices [10] and not many implantable antennas were evaluated for the ISM band. This design is mainly for ISM band applications because, use of large implants, reduce the transmission stretch and since our skin and body fluids greatly attenuate signals, we are enforced to construct compact antennas for adequate use in ISM band.

This paper presents a depiction of an implantable antenna that will operate in the 2.45 GHz ISM band, recommended by the European Radio Communications. This is an ultra-low-power circular slot antenna. To be valuable for implantable applications, the antenna is nested in the RT Duroid ceramic substrate and the reflection coefficient was simulated in a human tissue to study the radiation characteristics at 2.45 GHz. When simulations were carried out on different human tissues, the antenna was found to work without any complications.

II. GEOMETRY OF THE PROPOSED ANTENNA

A. Antenna design

The proposed antenna design compresses of a radiating patch fed by a coplanar waveguide (CPW) transmission line and bottom patch to reduce the human body effect on the antenna performance.

Figure 1 shows the geometry of Implantable CPW-fed monopole hybrid antenna for 2.45 GHz ISM band biomedical applications. The antenna is printed on an RT Duroid substrate with dimensions 44 × 44 mm². Thickness and relative permittivity are 0.5 and 4.4 mm, respectively. A 50 Ω CPW transmission line with strip width 3 mm and with a gap of

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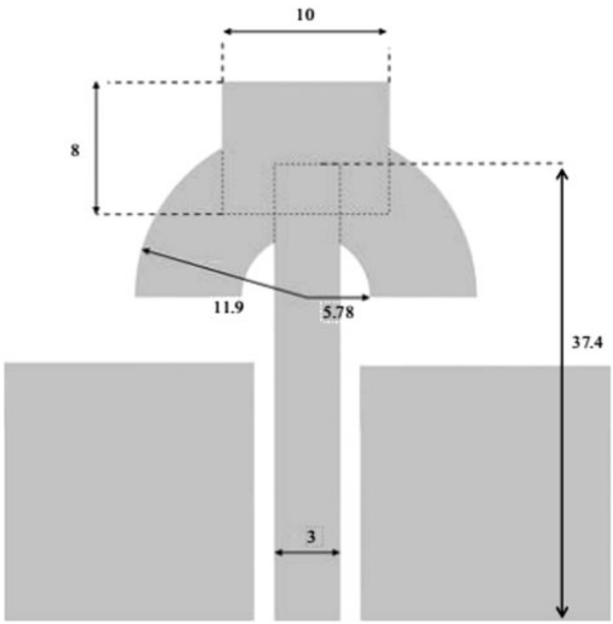

Fig. 1. Proposed antenna structure (all dimensions are in mm).

1 mm between the strip and the coplanar ground plane is used to feed the antenna.

III. RESULTS AND DISCUSSION

Since, experimental research is crucial to justify the simulation results of CPW-fed antennas investigations that were carried out using laboratory-fabricated prototypes as measuring over human body is hardly possible. Because of the unavailability of biocompatible materials, the RT Duroid substrate was procured from Electronics Pvt. Ltd.

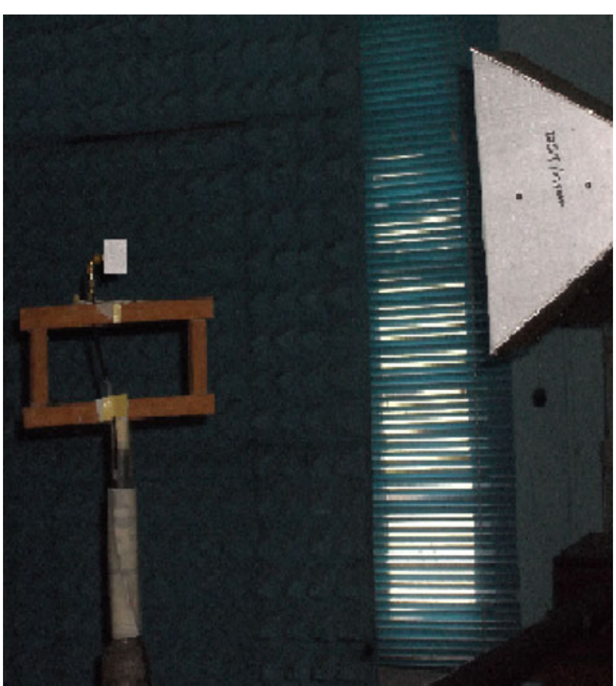

Fig. 2. Photograph for measurement setup model.

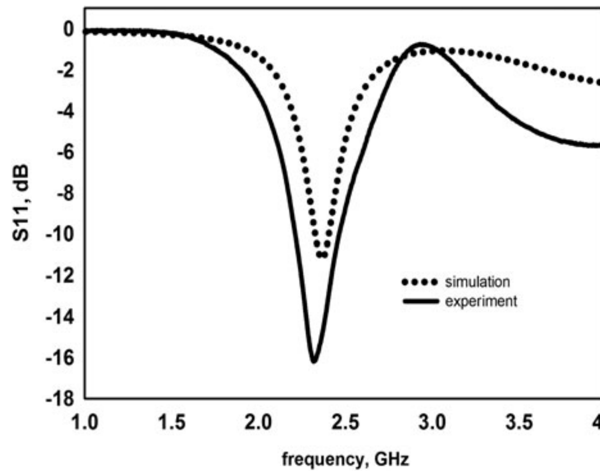

Fig. 3. Return loss versus frequency.

Dielectric measurements were taken using Network analyzer between 300 and 3000 MHz with a test tissue of dimensions 250 × 250 × 80 mm^3 as shown in Fig. 2. Figure 3 shows the comparison of measured and simulated return loss of the proposed antenna. Simulations were performed using Mentor Graphics IE3D simulator. As it is a three-dimensional (3D) simulator, the finite size of size typically results in a shift of the resonance frequency to lower frequencies; the antenna is designed to resonate at 2.45 GHz. Once fabricated and measured, the design ensures that the antenna will cover the requested bandwidth. The required −10 dB impedance bandwidth of the antenna is 200 MHz (2290–2490).

Radiation characteristics of the antenna placed inside the liquid simulating muscle, fat, skin tissues are determined in terms of radiation pattern and gain. Antenna that is directed toward the surface of the gel (muscle, fat, and skin) along the *z*-direction and at a distance of 10 mm in the *xy*-direction is positioned to the center of the surface of the body phantom liquid. Computed radiation patterns at 2.45 GHz, 7 m reference distance, and 1.6 W input power in the *yz, xz*, and *xy* are shown in Figs 4–6, respectively.

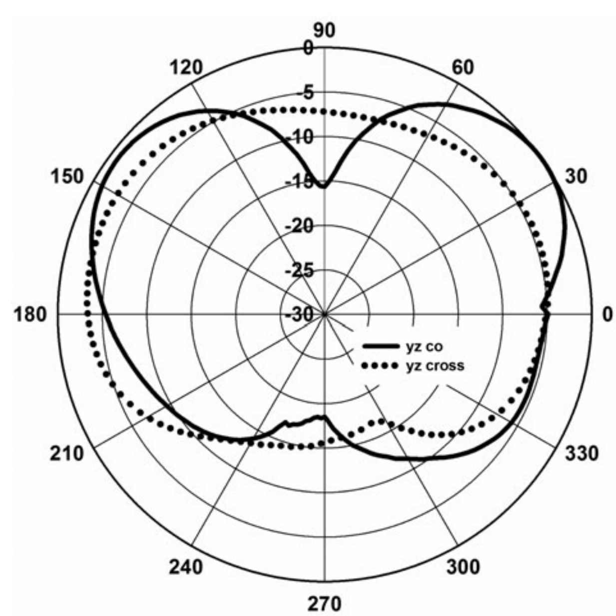

Fig. 4. Radiation pattern for the *yz*-plane.

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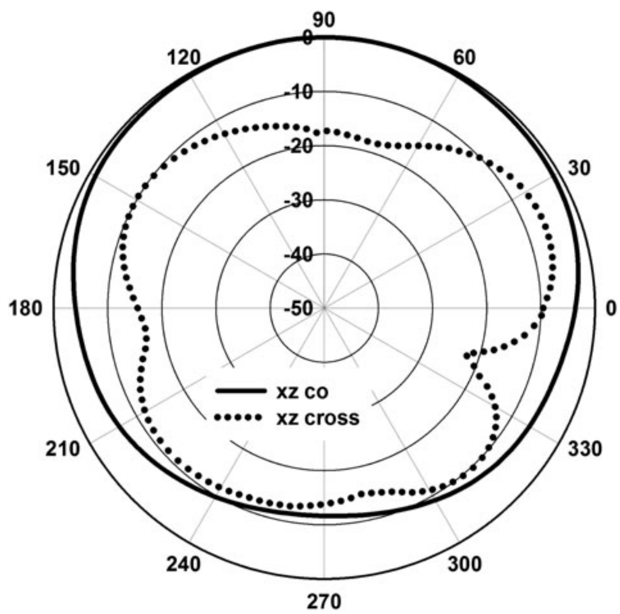

Fig. 5. Radiation pattern for the *xz*-plane.

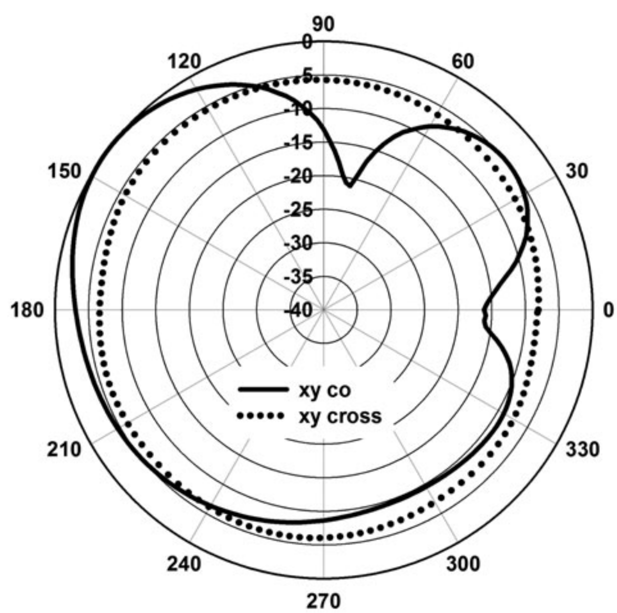

Fig. 6. Radiation pattern for the *xy*-plane.

In this work, a CPW-fed tapered antenna for ISM band applications is proposed and presented at a compact size of $44 \times 44\ mm^2$. Solutions and suggestions regarding the design and experimental outcome of the proposed antenna for biomedical telemetry are given.

IV. CONCLUSION

The design of the CPW-fed antenna is mainly emphasized on miniaturization and compatibility. Energy conservation that extends the lifespan of implantable medical devices is also significant. ISM band antennas that wake up only when there is a need of information are designed to defend this issue.

There are many homogenous antenna models, but we need a design that is more sensible and clear to provide us the exact results required. Owing to the better dielectric constant, the implantable antenna designed using the RT Duroid substrate exhibits low return loss, good VSWR, better impedance matching, high gain, and is suitable for miniaturization. Hence, the proposed CPW-fed antenna design will be the most suitable for 2.45 GHz ISM band applications.

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