Towards an Implantable Wireless Module with a Bandwidth-enhanced Antenna Manufactured using Inkjet-printing Technology

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Abstract— Intra-body electromagnetic propagation through dispersive tissue and studies of wireless power transmission have tended to focus on MHz frequencies due to relatively lower tissue absorption loss in this frequency range. Other studies have focused on the 2.4GHz frequency. The Medical Implant Communication Service, a standard specified by the U.S. Federal Communications Commission, allows bi-directional radio communication between implantable devices using 401 and 406 MHz. Recent studies, however, have shown that frequencies in the low GHz range can be used for both bi-directional communication and wireless power transfer with the lowest absorption loss. This paper presents a preliminary study towards the development of an implantable module at 1.86 GHz. A Planar Inverted-F Antenna (PIFA) has been considered as the modules' antenna and in order to increase the inherently narrow bandwidth, a ground slot is used. The module demonstrates omni-directional radiation pattern, it is well matched at 1.86 GHz and it has 1.5 dBi gain. The module's antenna can be easily inkjet-printed on conformal materials such as paper and bio-compatible LCP.

I. Introduction

Research has been conducted in creating low cost and durable wireless modules in biomedical applications using inkjet printing technology [1]. These wireless modules have been intended as wearable sensors, but recent projects have created sensors that can be implanted into human body or animal tissue [2].

Implantable antennas have traditionally suffered with decreased efficiency operating in the environment of highly dispersive material such as living tissue. As a result, the communication link through this environment is very noisy. [3]. Designing an antenna implanted in dielectric material has been demonstrated to decrease this effect [4]. Researchers have also attempted to reduce the human tissue–antenna interaction by introducing printed electromagnetic band-gap structure (EBGs) arrays that effectively isolate wearable antennas from the dispersive human body. However, most of the reported antennas have used rather large EBG structures. [5][6].

Many of these wearable and implantable wireless modules utilize planar inverted-F antennas (PIFAs) due to their high front-to-back ratio and the relatively superior performance, when operating within dispersive tissue environment, compared to other types of antennas [7]. However, PIFAs generally have very narrow bandwidths causing more problematic interaction between the tissue and the antenna that deteriorates the performance of the system significantly. Researchers have been able to increase the bandwidth of PIFAs by etching away an area of the ground plane [8].

We describe the possibility of manufacturing low cost wearable and implantable modules with bandwidth-enhanced PIFAs in the low GHz frequencies using inkjet-printing technology. Previous research has shown that the optimal operating frequency of these implantable antennas has been shown to be in the low GHz range [9]. Our module will incorporate an antenna operating at 1.86 GHz, a frequency for which researchers have demonstrated the relatively lowest absorption loss, while achieving successful data and power transmission for a small loop antenna [10].

II. Antenna Design and Sensor Module

The wireless module has a standard architecture consisting of an embedded microprocessor, a matching network, a transceiver, an antenna, and a battery as shown in Fig.1.

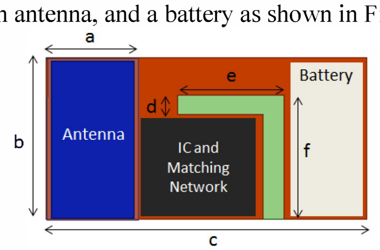

Figure 1. Wireless module layout and dimenstions.

The antenna lays on top of a ground plane as shown in Fig.2. The antenna consists of a stack of non-conductive layers with a dielectric constant of εr=3.4 in the HFSS simulations. Common substrates used in inkjet printing technology such as paper or Kapton have dielectric constants of εr=3.3 [11] and εr=3.4 respectively. The top layer of the antenna must be conductive and connected to the ground plane through the shorting pin(s) near the end of the antenna. Additionally, the top layer must be connected to the matching network through a separate pin, located 2mm away from the shorting pin(s). The shorting pins are 400 µm in diameter in the simulations.

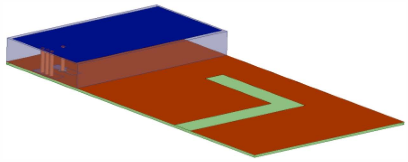

Figure 2. PIFA antenna in HFSS with ground slot.

The total size of the module is 19.5mm by 39mm, and the antenna is 11mm by 19.5mm. Parametric HFSS simulations determined that the slot geometry shown in Fig. 2 can be used to enhance the antenna's bandwidth; its dimensions and the dimensions of the module are found in Table 1.

TABLE I. MODULE CONFIGURATION DIMENSIONS

Part	Dimension
a in Fig. 1 is the width of the antenna	11mm
b in Fig. 1 is the length of the antenna	19.5mm
c in Fig. 1 is the length of the module	39mm
d in Fig. 1 is the width of the ground slot	2.3mm
e in Fig. 1 is part of the ground slot	13mm
f in Fig. 1 is part of the ground slot	15mm
Antenna height, substrate thickness	2.5mm, 250µm

III. RESULTS

The return loss of the wireless module can be seen in Fig. 3. The antenna's resonant frequency is 1.86GHz and it has been bandwidth-enhanced using the ground slot shown in Fig. 2.

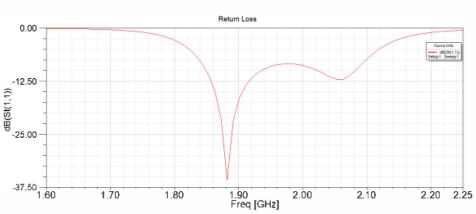

Figure 3. Wireless module return loss.

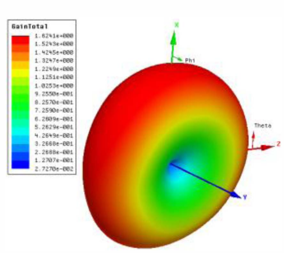

Figure 4. Wireless module radiation pattern.

Fig. 4 shows the the radiation pattern of the module with an efficiency of more than 90%, and 1.5dBi realized gain.

IV. CONCLUSIONS AND FUTURE WORK

This paper presents a preliminary study towards a future implementation of compact, biocompatible and implantable wireless modules. The preferred 1.86 GHz frequency allows for a more compact antenna design. More frequencies in the same range will be also studied. The antenna can be inkjet printed directly on the substrate and every lumped component can be developed on bio-compatible LCP using system on package (SOP) technology. LCP can allow the creation of cavities to embed the lumped components, the IC, and using multilayer technology and thermobonding the whole wireless sensor system can be packaged in a compact solid module. For this future module development, a PIFA with enhanced bandwidth has been considered. Preliminary simulations indicate that it can be a competitive candidate for the module's antenna.

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