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Printed Multi-Turn Loop Antenna for RF Bio-Telemetry

Rainee N. Simons
Glenn Research Center, Cleveland, Ohio

David G. Hall
ZIN Technologies, Inc., Cleveland, Ohio

Félix A. Miranda
Glenn Research Center, Cleveland, Ohio

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Rainee N. Simons,[1] David G. Hall,[2] and Félix A. Miranda[1]

[1]NASA Glenn Research Center, Cleveland, Ohio 44135
[2]ZIN Technologies, Inc., Brook Park, Ohio 44142

Abstract—**In this paper, a novel printed multi-turn loop antenna for contact-less powering and RF telemetry from implantable bio-MEMS sensors at a design frequency of 300 MHz is demonstrated. In addition, computed values of input reactance, radiation resistance, skin effect resistance, and radiation efficiency for the printed multi-turn loop antenna are presented. The computed input reactance is compared with the measured values and shown to be in fair agreement. The computed radiation efficiency at the design frequency is about 24 percent.**

I. Introduction

The biological and physical sciences program at NASA seeks to develop telemetry based implantable sensing systems to monitor the physiological parameters of humans during space flights [1]. This focus is rather unique when compared to efforts by other investigators, which have been mainly in the area of RF/microwave applications in medical treatment and biological effects [2].

In this paper, we present the development of a printed multi-turn loop antenna for contact-less powering and RF telemetry to acquire data from implantable bio-microelectromechanical systems (bio-MEMS) based capacitive pressure sensors. This effort is part of a U.S. patent that has been recently granted [3]. Several researchers in the past [4–6] have demonstrated RF antennas for telemetry reception from implantable sensors, and table I summarizes the type and dimensions of these antennas. However, the unique aspects of our approach are as follows: first, we make use of a multi-turn loop antenna printed on a dielectric substrate with a central annular region. The central annular region facilitates housing of signal processing circuits and thus lowers the height profile of the packaged hand-held unit. Second, the diameter of our loop antenna is significantly smaller which makes the hand-held unit very compact.

II. RF Telemetry System

The contact-less powering and telemetry concept, is illustrated in figure 1(a). To obtain a pressure reading, a pulse emitted by the external hand-held unit initially interrogates the implanted sensor. The pulse induces a voltage in the implanted sensor inductor thus implementing contact-less powering. The waveform of this induced voltage is a decaying sine wave. Since the inductance is fixed, the frequency of the decaying sine wave is mainly determined by the capacitance of the pressure sensor. The energy radiated by the inductor during these oscillations is picked up as a telemetry signal by the receiving antenna in the hand-held unit. The notional wireless RF telemetry system [3] is illustrated in figure 1(b).

Table I: The diameter and the type of antenna used in RF biotelemetry systems

Type of antenna	Antenna diameter, mm	Reference
Planar spiral	80	Von Arx and Najafi [4]
Disk coils	90	Hamici, Itti, and Champier [5]
Solenoid coils	100 to 150	Troyk and Edgington [6]
Printed multi-turn loop	51	This paper

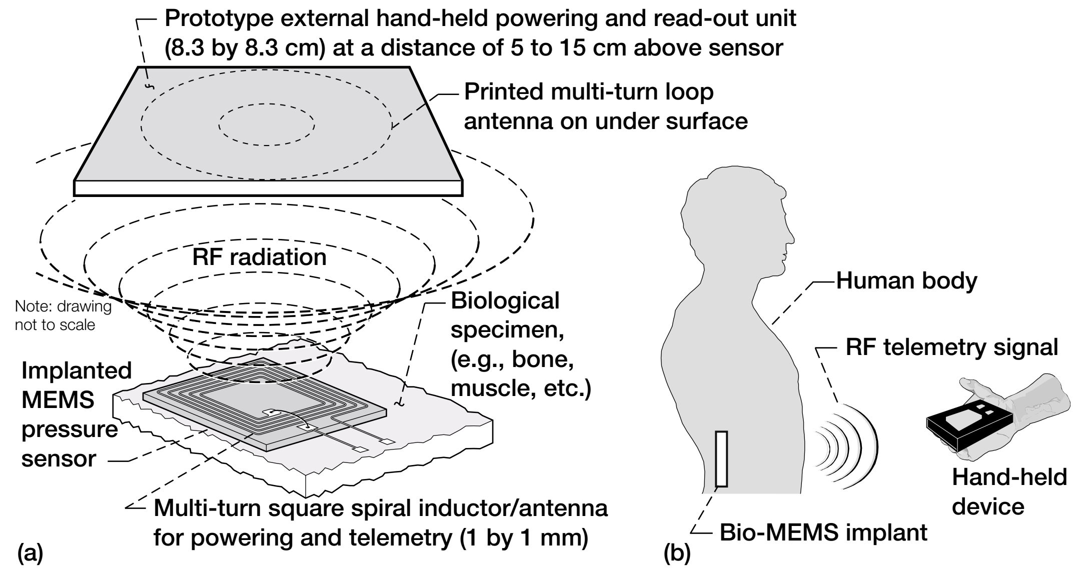

Figure 1.—Contact-less powering and telemetry. (a) Concept. (b) Application in biosensors.

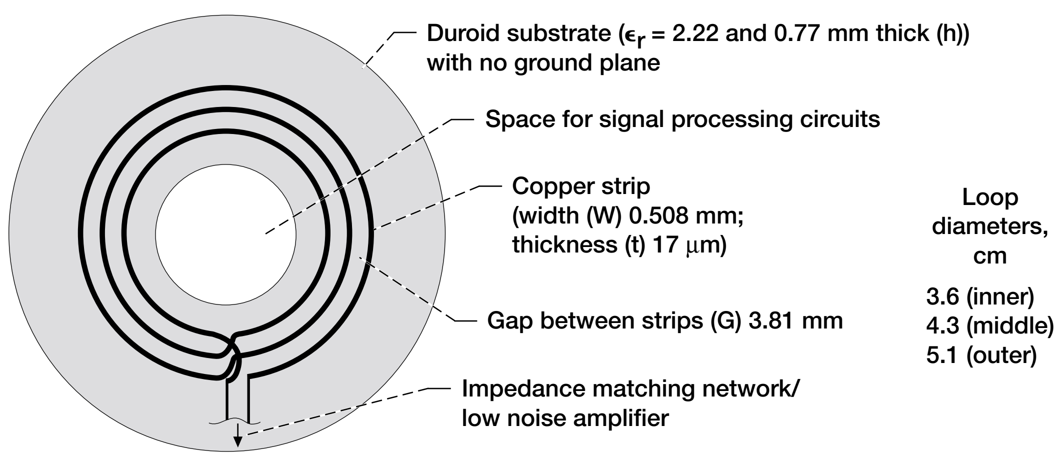

Figure 2.—Printed multi-turn loop antenna on a dielectric ring.

III. Multi-Turn Loop Antenna on a Dielectric Ring

A. Input Reactance, Radiation Resistance, and Skin Effect Resistance

The multi-turn loop antenna is illustrated in figure 2. The presence of a dielectric substrate of relative dielectric constant ε_r is taken into consideration in the computer model by assuming that the loop is embedded in a medium of effective dielectric constant equal to $(\varepsilon_r + 1)/2$, [7]. In addition, the loop strip conductor of width W and thickness t is replaced by an equivalent wire of diameter $d = 0.25\ W$ [8]. Under these assumptions, the multi-turn loop with total perimeter P is modeled as an equivalent lossless shorted transmission line of length $l = P/2$ [9]. The input reactance of the loop is then equal to the transmission line input reactance. The skin effect resistance and the radiation resistance of the loop are determined using equations in [7] and [10], respectively.

IV. Computed/Measured Results and Discussions

The computed and measured reactive part of the input impedance (Z_{in}) is shown in figures 3(a) and 3(b), respectively. To measure the Z_{in} of the antenna in figure 2, a short length of a coax is soldered to the circuit and the data acquired using a microwave network analyzer (Model HP 8510C). The computed and measured results are in fair agreement. The discrepancy is because of the phase introduced by the short length of coax that is needed for interface with the test instruments, which is not trivial to calibrate out. The computed skin effect and the radiation resistances are presented in figures 4 and 5, respectively. From these results the radiation efficiency is calculated and shown in figure 6. The radiation efficiency at the design frequency of 300 MHz is about 24 percent.

V. Conclusions

The paper demonstrates a novel printed multi-turn loop antenna for contact-less powering and RF telemetry from implantable bio-MEMS sensors at 300 MHz. In addition, computed values of input reactance, radiation resistance, skin effect resistance, and radiation efficiency for the loop antenna are presented. The computed input reactance is compared with the measured values and shown to be in fair agreement. The computed radiation efficiency of the loop antenna at 300 MHz is about 24 percent.

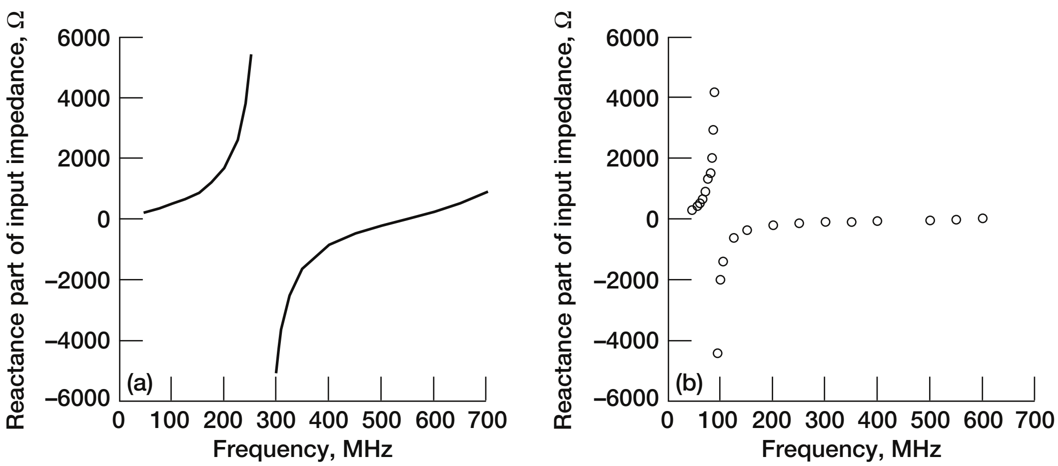

Figure 3.—Input reactance. (a) Computed. (b) Measured.

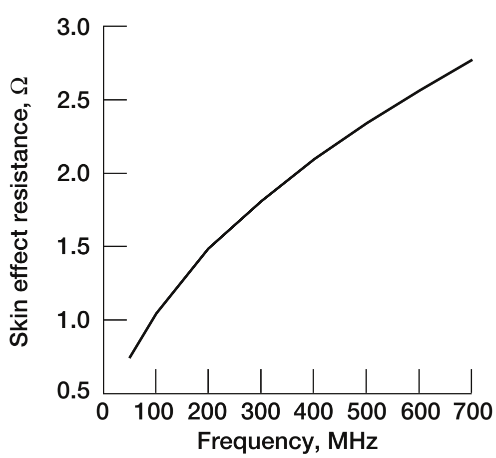

Figure 4.—Computed skin effect resistance.

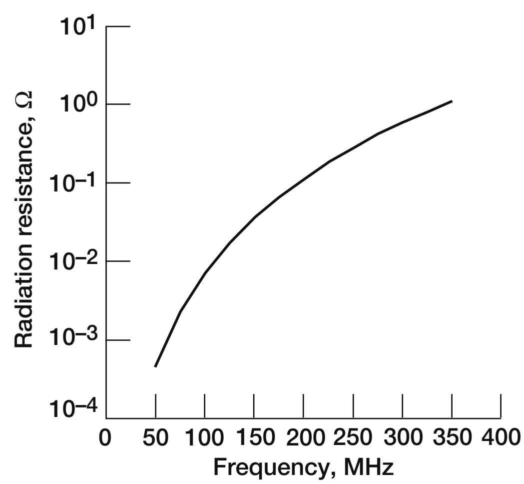

Figure 5.—Computed radiation resistance.

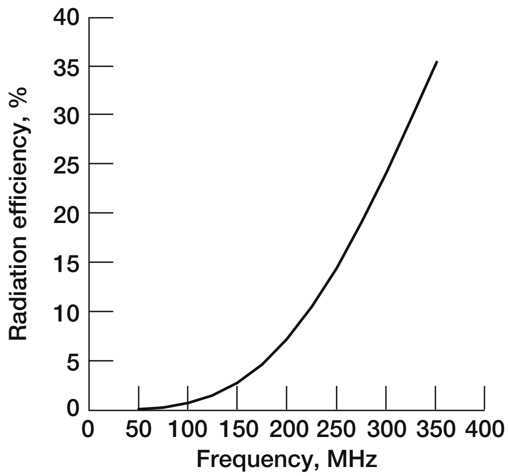

Figure 6.—Computed radiation efficiency.

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13. ABSTRACT ***(Maximum 200 words)***
In this paper, a novel printed multi-turn loop antenna for contact-less powering and RF telemetry from implantable bio-MEMS sensors at a design frequency of 300 MHz is demonstrated. In addition, computed values of input reactance, radiation resistance, skin effect resistance, and radiation efficiency for the printed multi-turn loop antenna are presented. The computed input reactance is compared with the measured values and shown to be in fair agreement. The computed radiation efficiency at the design frequency is about 24 percent.

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