



Near Field Radiation Characteristics of Implantable Square Spiral Chip Inductor Antennas for Bio-Sensors

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Introduction

NASA's Exploration Vision initiative calls for the completion of the International Space Station (ISS) by 2010 and the return of human beings to the Moon by 2018, with a subsequent exploration initiative to Mars called for 2030 and beyond [1]. The challenges and risk for humans involved in the different stages of the Exploration Vision have been summarized in NASA's Bioastronautic Roadmap [2]. For example, the prolonged stay of astronauts either in the ISS, the Moon or Mars, will induce biological changes that must be carefully monitored to guarantee the astronauts' well being and safety. Therefore, development of crew physiological monitoring devices for autonomous medical care is an area of high interest for NASA. Although novel health monitoring concepts have been developed to ensure astronaut safety during space flight related activities, these are generally electrode and wireline-based, and hence limited to external use [3]. On the other hand, development of space-qualified implantable sensors, that could be used to monitor recovery from injuries or chronic but treatable conditions of crew members during extended presence in space (e.g., one-year ISS mission; 30 month journey to Mars, etc.) are yet to be fully developed. Consequently, development of wireless, versatile monitoring techniques for embedded bio-sensors are highly desirable. In previous work, the authors have studied thoroughly the fundamental components (i.e., the embedded as well as the hand-held subsystems) of a wireless telemetry system for Bio-Sensors [4-10]. In this work, we present the experimental characterization of implantable square spiral chip inductor antennas (SSCIA) in free space. Our results indicate that the measured near field relative signal strength of the SSCIA agrees with simulated results and confirm that in the near field region the radiation field is fairly uniform in all directions [8]. The results show the applicability of SSCIA's for the intended application.

Implantable Square Spiral Chip Inductor Antenna

A schematic and photomicrographs of the circuit and ground plane sides of the fabricated miniature printed SSCIA on high resistivity silicon wafer ($\rho > 2500 \Omega\text{-cm}$ & $\epsilon_r = 11.7$) are shown in Figs. 1(a)-(c), respectively. Several designs of these antennas were step-and-repeated across the wafer and fabricated using photolithography techniques [4-6]. Results of the near field characterization for four such antennas are reported in this paper.

Measurement Setup

GRC's Planar Near-Field Probe Station Scanner (PNFPSS) was utilized to measure the near field relative signal strength emitted by the antenna under test (AUT), i.e., the SSCIA. A block diagram and a photo of the experimental set-up are shown in Figs. 2(a) and (b), respectively. Since the antennas were not designed with a 50Ω impedance match at their operating frequency of 330 MHz, two sets of amplifiers were implemented to ensure a measurable signal was obtained. Power amplification of the 0 dBm power

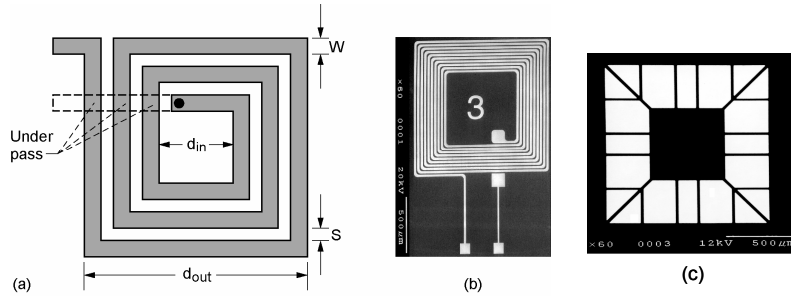


Figure 1 – (a) Schematic of the SSCIA, $d_{in} = 0.5\text{mm}$, $d_{out} = 1.0\text{mm}$. Photomicrograph of (b) SSCIA and (c) Serrated ground plane (1mm x 1mm).

from an HP 8510C Vector Network Analyzer (VNA) was provided via a Medium Power Amplifier (MPA). The MPA provided 20 dB power amplification, and hence nearly 20 dBm of power was input to the AUT, since RF cable losses were negligible. At a 5 cm distance above the antenna, a dipole probe was used to scan a planar field from boresight to a 45° semi-cone angle to measure the relative radiated power coupled from the AUT to the probe. On the receive end, a Low Noise Amplifier (LNA) supplied another 15 dB of gain to the signal. An S_{21} measurement conducted over a 5cm x 10cm scan plane thus provided the spatial dependence of the relative signal strength from the AUT.

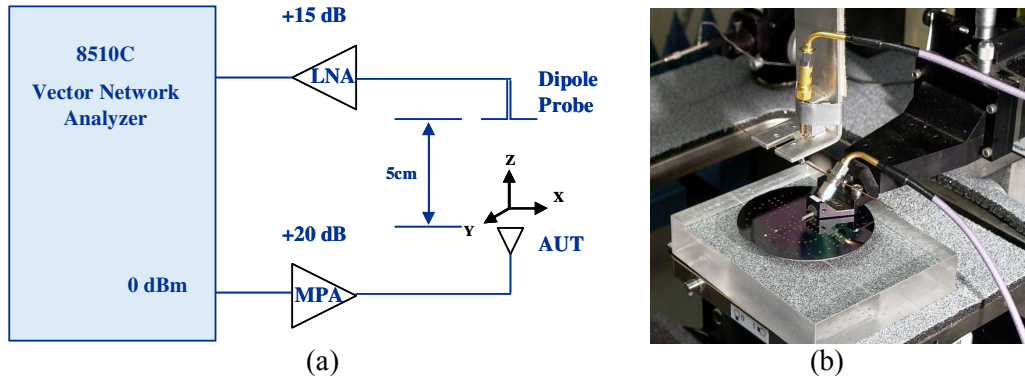


Figure 2 – (a) Block diagram of the setup implemented for the measurement of the SSCIA. (b) Photo of the on-wafer SSCIA mounted in the PNFPS.

Results and Discussions

Multiple wafers with and without a ground plane were characterized in the near field. Table I summarizes the geometrical parameters of four of these antennas investigated in this paper. Antenna A-VI was fabricated on a wafer with a serrated ground plane and was measured to investigate the performance of the SSCIA as fabricated for the intended application. Antennas A1, A3, and A6 were fabricated on a second wafer, with no ground plane, to study the effects of strip/gap width and number of turns on the near-field radiation properties of the SSCIA. A-VI is identical in electrical design to antenna A6, except for the presence of a serrated ground plane. Previous results [5] have indicated that the serrated ground plane suppressed the eddy currents and hence improved the loss characteristics of the antenna. Thus, this configuration was the only antenna with ground plane measured in this paper. Fig. 3 compares the relative signal strength of each antenna as coupled to the probe in the near field.

Table I: Characteristics of SSCIA Antennas

Antenna	Inner Strip(W)/ Gap(S) Width (μm)	Outer Strip(W)/ Gap(S) Width (μm)	No. of Turns	Bottom side of wafer
A-VI	15/10	15/15	10	Serrated ground
A1	10/10	10/10	13	No ground
A3	15/10	15/10	10	No ground
A6	15/10	15/15	10	No ground

Conductor thickness: A-VI 1.5 μm (top), 1.8 μm (bottom). A1/A3/A6 2.56 μm (top).

Substrate thickness: A-VI 400 μm . A1/A3/A6 326 μm

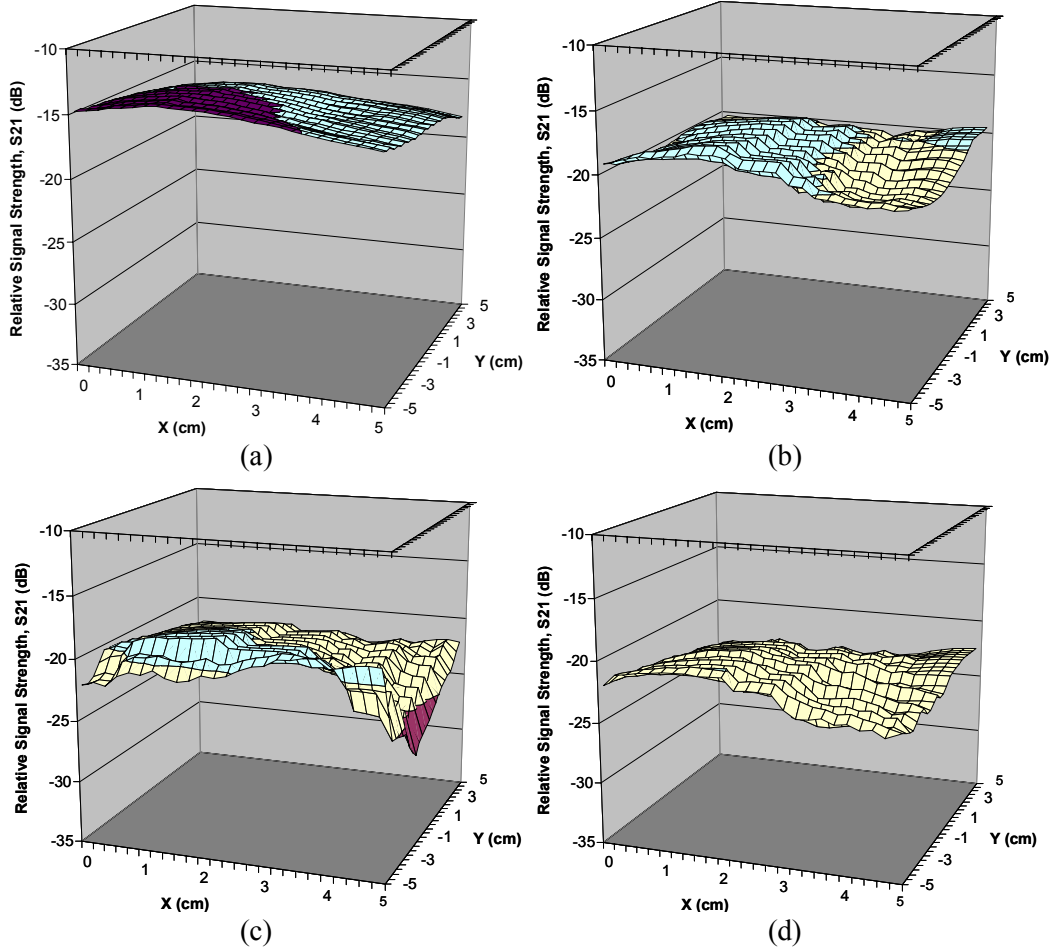


Figure 3 – Measured relative signal strength, S_{21} (dB), over a 5cm x 10cm planar field at a height of 5cm and frequency of 330 MHz. The origin of the coordinate system coincides with the geometric center of the SSCIA (a) A-VI, (b) A1, (c) A3, and (d) A6.

The following observations can be made based on the experimental measurements of the different types of SSCIA. Fig. 3(a) shows that the SSCIA with serrated ground plane produces a broad radiation pattern with a relative signal strength detectable at distances typical of hand held devices for self-diagnosis. In addition, the broad radiation pattern would reduce the requirement of placing the hand-held device at a specific location or orientation while reading the data from the embedded Bio-Sensor. Although a direct comparison of the absolute signal strength radiated by antennas A-VI and A6 is not

possible, due to the fabrication differences, the effect of other parameters on the performance of the SSCIA's could be observed from the other antennas studied in this paper. Antennas A3 and A6 possess the same number of turns with slightly different gap widths (10 vs. 15 μm in the outer loops of the antenna). Comparing Fig. 3(c) with Fig. 3(d) indicates that a wider outer gap width tends to decrease relative signal strength. Also, increasing the number of turns from 10 (A3/Fig. 3(c)) to 13 (A1/Fig. 3(b)) increased relative signal strength by approximately 1-2dB.

Conclusions

The near field radiation characteristics of implantable Square Spiral Chip Inductor Antennas (SSCIA's) for Bio-Sensors have been measured. Our results indicate that the measured near field relative signal strength of these antennas agrees with simulated results and confirm that in the near field region the radiation field is fairly uniform in all directions. The effects of parameters such as ground-plane, number of turns and microstrip-gap width on the performance of the SSCIA were presented. Furthermore, the SSCIA antenna with a serrated ground plane produces a broad radiation pattern, with a relative signal strength detectable at distances within the range of operation of hand-held devices for self-diagnosis.

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