HIGH SENSITIVITY ANTENNA FOR WEARABLE HEADSET DEVICES

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Abstract- In this manuscript, high sensitivity antenna design technique for Bluetooth headset application is proposed. A planar inverted F antenna (PIFA) was designed on the top printed circuit board (PCB) of a two board PCB. Digital noise was designed as a loop type source on the bottom PCB, representing general noise derived from digital circuits and digital noise generated from the main cable line. The proposed antenna design was analyzed in simulation and verified in measurement. The result of the active measurement shows an increase in sensitivity of 2.23 dB and the simulation results show an increase in isolation of 25 dB.

Index Terms- Bluetooth Headset, Grounding Shorting Pin, PIFA, Sensitivity.

I. INTRODUCTION

With the advent of Bluetooth services, wireless headsets have become more common. However, designing a high sensitivity antenna in a small Bluetooth headset is a great challenge for antenna designers. The performance of a receiving antenna is affected by signal-to-noise ratio (SNR) and bit error rate (BER). The noise performance is an important factor affecting the minimum signal level recognized by the receiving antenna [1-3]. In a wireless system, the noise source affecting the antenna performance are usually man-made noises, which are derived from high speed digital circuits. In active measurements, total isotropic sensitivity (TIS) is strongly related to antenna efficiency, conductive sensitivity, and noise interference [1]. In order to increase the sensitivity of the receiving antenna, either the efficiency of the antenna has to be increased or the interference of the noise has to be reduced.

Many studies have been conducted [4-8], which use parasitic slot and characteristic mode for decoupling technique. However, these studies are conducted on a one board PCB and does not include a tunable and controllable design, which are applicable for commercial boards. In this manuscript, the concept of decoupling digital noise from the antenna is discussed. As an example, a two board Bluetooth headset is designed on a flame retardant substrate 4 (FR-4) and the impact of grounding shorting pin is studied. The simulation was conducted using full wave simulator and measurement data was verified using active measurements of Bluetooth headsets in a 6×6×3m3 three dimensional (3-D) CTIA OTA chamber by a TC-3000B Bluetooth tester.

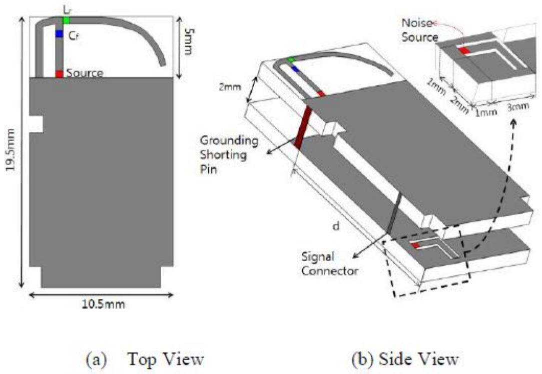

Fig. 1. Configuration of the proposed antenna design

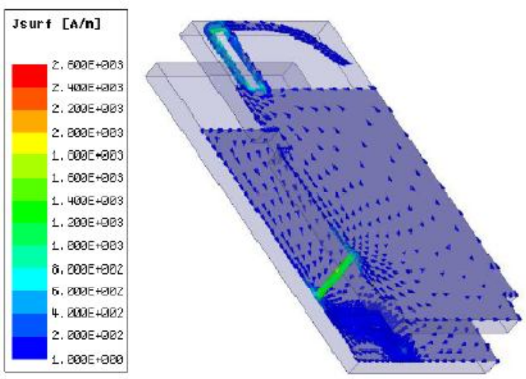

Fig. 2. Surface current field at 2.45GHz without grounding shorting pin

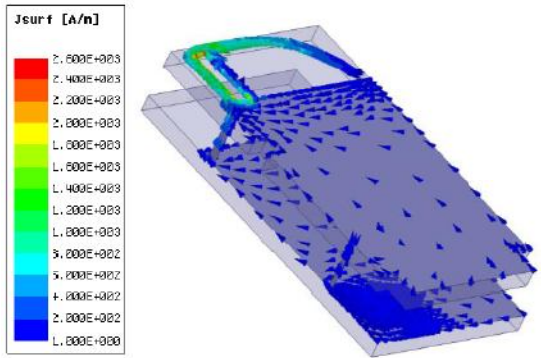

Fig. 3. Surface current field at 2.45GHz with grounding shorting pin

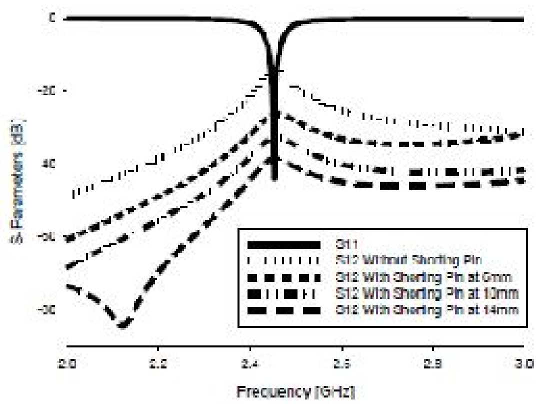

Fig. 4. Simulated return loss characteristics of the reference and proposed antenna

II. ANTENNA DESIGN AND OPERATING MECHANISM

As shown in Fig. 1, the proposed PIFA ($10 \times 5mm2$) was designed on the top PCB ($10.5 \times 19.5mm2$) ground plane of a Bluetooth headset. The PIFA takes a form of a bended radiator to be apt for actual commercial board application.

Top PCB is connected with the bottom PCB through a signal connector. The signal connector is usually a complicated board-to-board connector as shown in Fig. 5 (b), but for simulation the signal connector is simplified to a line connecting top and bottom PCB. For simulation, loop type resonator is formed on the bottom PCB ($10.5 \times 15mm2$) to represent digital noise. The digital noise occurring on commercial boards are mostly undefinable, but takes a form of a loop. Therefore, for simulation, it was simplified and designed as a loop type resonator on the bottom PCB. Digital noise is coupled to the antenna through the signal connector, degrading the antenna sensitivity. In order to reduce the coupling between the digital noise and the antenna, an additional grounding shorting pin was designed to distribute the current path. The resonant frequency of the antenna can be controlled by variation of the inductance value and the coupling of the antenna can be controlled by variation of the capacitance value. Fig. 2 shows the surface current of the reference antenna. It can be seen that the signal connector is strongly excited and thus the digital noise is strongly coupled to the antenna. Fig. 3 shows the surface current of the proposed antenna, and due to the distributed current path, the signal connector and the grounding shorting pin is relatively weakly excited. It is shown in Fig. 4 that when the position of the grounding shorting pin is changed, the effect of the digital noise on antenna sensitivity is changed. As the distance d is increased, the mutual coupling S12 between the antenna and the digital noise is reduced, thereby increasing the sensitivity of the antenna.

In a commercial board, noise sources are numerous and undefinable. However, the coupling between the noise sources and antenna can be analyzed through normal network theory. In the proposed design, the noise source is defined as port 1, and the antenna is defined as port 2. The decoupling loop formed of signal connector and the grounding shorting pin can be considered as another port, i.e. port 3. In this case, the mutual impedance between the noise and the antenna in the presence of a decoupling loop can be represented by [9]

$$Z'_{12} = Z_{12} - \frac{Z_{13}Z_{32}}{Z_{33}+Z_L} \quad (1)$$

where $Z12\ '$ and $Z12$ are the mutual coupling with and without grounding shorting pin, respectively. $Z33$ is the self-impedance observed at port 3, $Z32$ is the mutual impedance between port 2 and port 3, and $Z13$ is the mutual impedance between port 1 and port 3. ZL is the terminated load impedance at port 3. By adjusting the loop size of the decoupling loop, ZL term of ($Z33 + ZL$) can be controlled such that $Z12$ $'$ can be depressed.

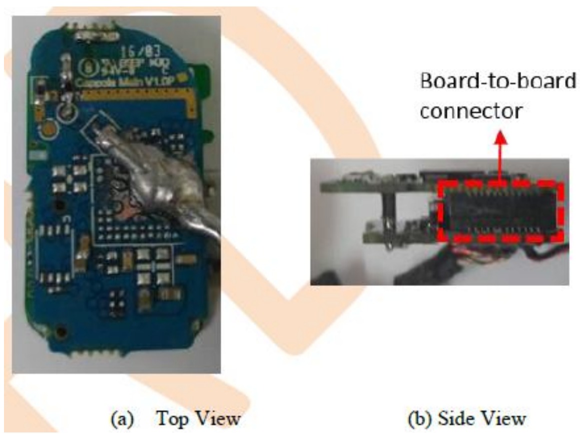

Fig. 5. Photographs of the proposed antenna in a commercial board

III. EXPERIMENTAL RESULTS

The measured average total isotropic sensitivity (TIS) values of the antenna with and without the grounding shorting pin shows significant difference as provided in Table. 1. It is shown that the reference design, without the grounding shorting pin, has the measured average TIS value of -77.81 dBm and the proposed design, with the grounding shorting pin, has the measured average TIS value of -80.04 dBm, indicating that the antenna is 2.23 dB more sensitive than that without the grounding shorting pin. Additionally the grounding shorting pin has an effect only on the antenna sensitivity and does not affect the total radiated power (TRP) of the antenna.

CONCLUSION

In this manuscript, a high-sensitivity antenna design using grounding shorting pin is proposed. It is found that the existence of grounding shorting pin has a significant effect on antenna sensitivity and when the position of the grounding shorting pin is changed, the effect of the digital noise on the antenna sensitivity is verified. Therefore, we can reduce the effect of digital noise on antenna sensitivity, increasing the antenna sensitivity and applying decoupling technique in practice. Further research may continue to apply the proposed decoupling technique without modifying the position of the grounding shorting pin.

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