Reduction of Head Effect in Mobile Devices

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***Abstract*- This paper compares two types of antennas for Bluetooth applications in mobile handsets in the presence and absence of a human head. A Planar Inverted F Antenna (PIFA) and a three dimensional Loop Type Antenna were designed to fully cover Bluetooth services. The antennas are designed on a Frame Retardant Type 4 (FR-4) substrate ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$) with the size of 140 mm × 45 mm Printed Circuit Board (PCB) with 1 mm thickness.**

***Index Terms* – Bluetooth Service, Mobile Device, Head Effect, Printed Circuit Board (PCB), Frame Retardant Type 4 (FR-4), Planar Inverted F Antenna, Three Dimensional Loop**

I. INTRODUCTION

Modern mobile devices currently on the market are evolving to be smart and wearable devices to enhance the quality of living. These devices are closely located to the human body and the performance of the antenna is affected by the human body. In addition to the market requirements in the past that were wide bandwidth capability and a high realized efficiency, they also require the antennas to be highly immune to the effects of the human body. Thus, it is becoming more important that the performance of the antenna are strongly immune to the effects of the human body.

It is well known from 'Chu-Harrington limit' [1, 2, 3, 4] that the radiation quality factor of an ideally small antenna is approximately inversely proportional to the volume of the antenna in wavelength and its impedance bandwidth is limited by the size of the antenna. Hence, it has become a great challenge for antenna designers to develop an antenna with small size having good radiation performance. Many types of antennas have been analyzed in many papers that there has to be sufficient height in the antenna to reduce the head and body effects [5, 6, 7, 8, 9, 10].

In this paper, a three dimensional loop type antenna is proposed to reduce the size of the antenna and to reduce the head effects compared with conventional PIFA over Bluetooth band (2.4 GHz – 2.5 GHz). Measurement data was obtained using network analyzer and three dimensional anechoic chamber.

	2.44GHz	
Materials	**Permittibity**	**Conductivity**
Blood	58.28	2.54
Bone Marrow	10.31	0.46
Cancellous Bone	18.56	0.8
Cartilage	38.79	1.75
Cerebellum	44.82	2.09
Cerebro Spinal Fluid	66.26	3.45
Cortical Bone	11.39	0.39
Eye Cornea	51.63	2.29
Eye Sclera	52.64	2.03
Fat	5.28	0.1
Grey Matter	48.93	1.8
Lens Cortex	44.64	1.5
Lens Nucleus	33.98	1.08
Muscle	54.43	1.87
Nerve Spine	30.16	1.08
Skin	38.01	1.46
Vitreous Humor	68.21	2.47
White Matter	36.18	1.21

Table 1. Permittivity and Conductivity of Materials inside the Human Head at 2.44 GHz

	2.44 GHz		
Materials	**Permittivity**	**Conductivity**	**Density(App.)**
Avg. Brain	42.55	1.51	1030
Avg. Skull	14.97	0.6	1850
Avg. Muscle	53.59	1.8	1040

Table 2. Permittivity, Conductivity and Density of Brain, Skull and Muscle at 2.44 GHz

II. ANTENNA DESIGNS AND ANALYSIS

Two types of antennas were simulated and designed to observe the head effects on the performance of the antenna. For modeling of head in the simulation, the data given in Table. 1 and 2 are used. The antennas were etched on a 140 mm × 45 mm FR-4 substrate with a thickness of 1 mm. PIFA was designed with the width of the top radiator 1.5mm, located

2mm above the ground plane, and the three dimensional loop type antenna was designed with the width of the top radiator 5mm, located 2mm above the ground plane. For both PIFA and three dimensional loop type antenna, the values of inductors used for L1 and L2 are 1 nH.

In the case of conventional PIFA, the parallel electric current (z-direction) is formed near the antenna and when it is placed close to the human head, the image current in the human head is formed in the opposite direction, degrading the performance of the antenna. On the other hand, the proposed three dimensional loop type antenna forms a parallel magnetic current (z-direction) and when it is placed close to the human head, the image current in the human head is formed in the same direction, and has less head effect compared to PIFA as shown in Fig. 6[11].

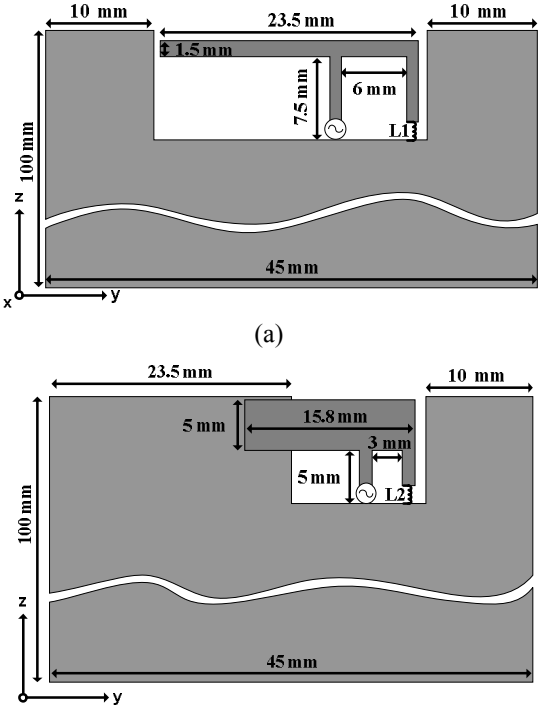

Figure 1. Geometry of the Antennas (a) PIFA; (b) Three Dimensional loop type antenna

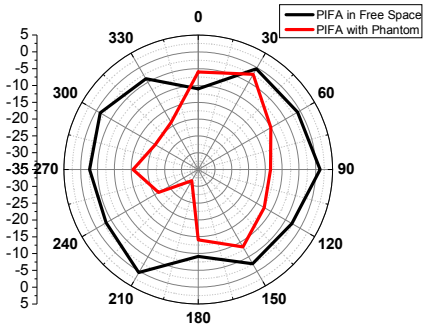

Figure 2. Measured Radiation Patterns of PIFA at 2.44 GHz

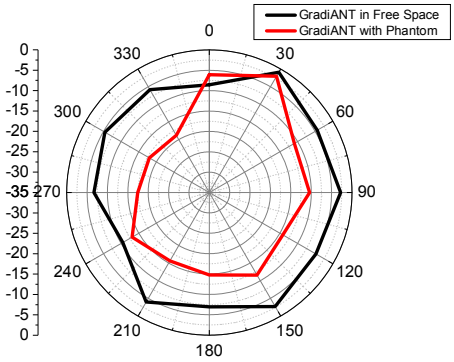

Figure 3. Measured Radiation Patterns of Three Dimensional Loop type Antenna at 2.44 GHz

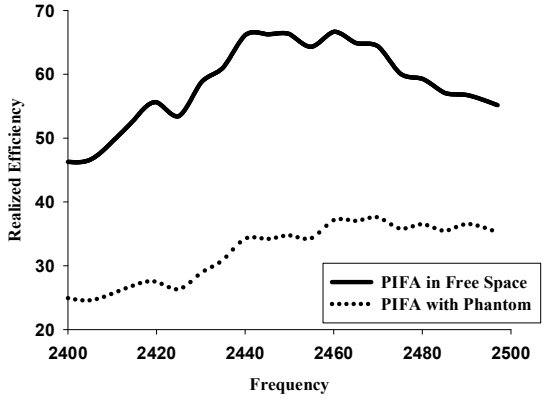

Figure 4. Measured Realized Efficiency of PIFA

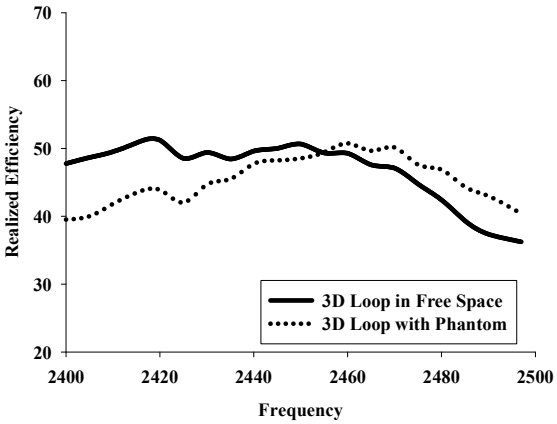

Figure 5. Measured Realized Efficiency of Three Dimensional loop type antenna

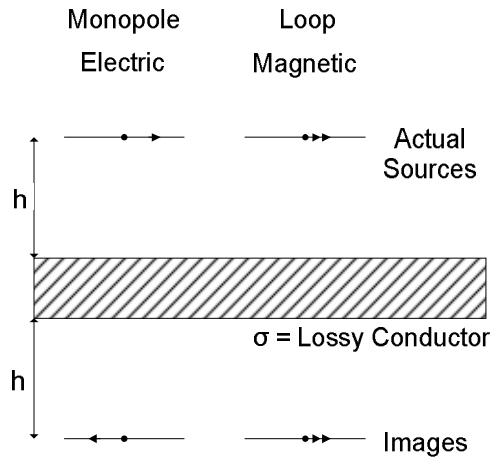

Figure 6. Concept of PIFA and Three Dimensional Loop

III. EXPERIMENTAL RESULT AND DISCUSSION

The proposed antennas have been successfully simulated and constructed. The proposed antennas were simulated and measured. It can be seen from Figures. 2 and 3 that the proposed three dimensional loop type antenna has less head effect than PIFA. The overall realized efficiency at 2400 MHz to 2500 MHz of PIFA has dropped from 58.57% to 32.23% in the presence of human head whereas three dimensional loop type antenna has dropped from 46.91% to 45.38%.

IV. CONCLUSION

The proposed antenna was designed and achieves sufficient gain in the direction of a human head to operate at Bluetooth band. Three dimensional loop type antenna not only occupies a smaller space, but also achieves better radiation performance in the presence of a human head.

ACKNOWLEDGMENT

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