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A Loop Antenna with Uniform Current Distribution for Mobile Handsets

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I. INTRODUCTION

Mobile handsets are popular but their antenna performance degrades when operators hold cellar phones at talk positions. The performance necessary to consider is radiation efficiency and average gain on horizontal plane especially when vertical incoming waves are assumed. We consider two major factors that degrade the antenna performance at talk positions. They are polarization mismatch and vicinity of operator heads. The first factor is polarization mismatch. Tilting mobile handsets change their radiation patterns and cause polarization mismatch between mobile handsets and cellar phone base stations. Polarization loss factor is significant especially when a simple rod antenna is tilted and a base station radiates vertical electric field. It is true for most of all antennas like as rod, fixed helical and inverted F and so on. These antennas are typically mounted on PCB grounds containing unbalanced type RF amplifiers. When a PCB ground acts as a part of antenna and is tilted, it also tilts its radiation patterns. Tilt angle varies from user to user and it becomes one reason of unstable wireless communication quality. The second factor is vicinity of operator heads. This factor is hard to avoid and results as lower radiation efficiency than in free space. To reduce effects of these degrading factors agreeably, an antenna should have following characteristics. 1) Stable average gain of vertical electric field on horizontal plane at all talking angles. 2) Radiation suppression toward an operator side. About second issue, some authors study radiation pattern control toward operator side [1], [2] by array or single antenna. Purpose of this paper is to propose a useful loop type antenna which satisfies these requirements without introducing complicated field pattern control system. Investigation is done by numerical calculation and measurements.

II. PROPOSED ANTENNA

One approach to meet these characteristics seems a small loop antenna of 0.1 λ circumference. A plane made by loop antenna conductor is located parallel to a plane of main liquid crystal display of a mobile handset. This arrangement gives radiation null toward an operator and opposite sides. Although its radiation patterns satisfy above two characteristics, its radiation resistance and physical size are too small to put it in use [3]. Apparently, these defects of a small loop antenna arise from its own size. To increase its electrical antenna size or cross sectional area, phases of current flowing on its conductor should be kept in phase at all positions so as to avoid radiation null on antenna plane. The proposed antenna includes

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several gap structures which are distributed equally along antenna conductors and acts as capacitors to pull back current phase. The proposed antenna satisfies above two characteristics. A pair of one conductor element and a gap structure gives minimum phase shifts. Current distribution obtained by numerical calculation is similar to a small loop one, and its physical loop size is basically independent of its resonance frequency.

III. ANTENNA CONFIGURATION, CALCULATION AND MEASUREMENTS

Fig.1 (a) shows square antenna fed at one corner marked point O. In Fig.1 (b), series capacitors are added at point A, B and C. Fig.1(c) shows planar gap structures to make capacitances. Fig.2 (a) and (b) show current amplitude distribution along antenna conductors for each of Fig.1 (a) and (b) respectively. In Fig.2 (a), each of lines shows current distribution for different loop circumference lengths. It is clear loop antenna of 0.1λ circumference length has uniform current distribution and stronger current amplitude than others. In other words, input impedance is quite low. In Fig. 2 (b), circumference length is fixed to 0.5λ. As shown in bottom line of Fig.2 (b), no capacitor case has the largest variance of current amplitude along conductor. In the second from the bottom line, one capacitor is inserted at point B. In the third, value of capacitance is reduced to half. Different capacitance gives different current variance. Top line shows three distributed capacitors case at points A, B and C. All three capacitors have same capacitance that is chosen to make current amplitude uniform. This current distribution is similar to 0.1λ loop antenna in Fig. 1(a). At feed point O, current amplitude is larger than no capacitor case. As 0.5λ loop antenna is quite high impedance, distributing capacitors act to decrease its input impedance. Fig. 3 shows calculated and measured input resistance. Circumference length is L. MoM NEC2 code is used to calculate input impedance of square antenna. Dotted line shows calculated input impedance of circular loop antenna which has ideally uniform current distribution. Measured value is larger than both of calculated values. Because thin wire and soldering discrete capacitances increase series resistance. Choosing larger L/λ ratio is desirable to ease matching adjustment and to reduce component loss relatively.

IV. RADIATION CHARACTERISTICS

Fig.4 shows coordinate system and antenna. Tilt angle at talk position is defined as α. The main square loop antenna measured at Fig. 3 is located approximately 10mm away from a 40 x 120 mm rectangular ground plane. To adjust input impedance to 50 Ω, an additional matching loop is added to couple with the main loop antenna. Incoming wave is assumed vertical electrical field or Ez in Fig. 4. Fig. 5 shows measured radiation pattern on XY plane or horizontal plane. Vertical field Ez has figure 8 shaped radiation pattern. Horizontal field Ex should be ideally zero strength. However, current unbalance and other conductive components produce horizontal field but it is small. Fig. 6 shows measured average gain vs. tilt angle α. Average gain is measured on XY plane in Fig.4 configuration. Loop circumference size is 0.54λ. A dipole antenna is used as reference. Measurement errors are approximately ±0.5dB or less. Dipole antenna at α= 0 degree shows highest average gain of Ez, while Ex is under -15 dB. When α increases, Ez decreases while Ex increases. At α=90 degree, Ez is under -20 dB but Ex can't reach 0 dB, then total power on horizontal plane decreases at large tilt angle. On the other hand, the proposed loop antenna with distributed capacitors shows almost no change of Ez and total power.

V. CONCLUSION

In this paper, a new antenna concept for cellar phones is proposed. A loop type antenna with distributed capacitors makes uniform current distribution and is suitable for mobile handsets especially at talk positions. As is expected, measured results tell that average of vertical field on horizontal plane is independent from its tilt angle and radiation toward operator side is suppressed.

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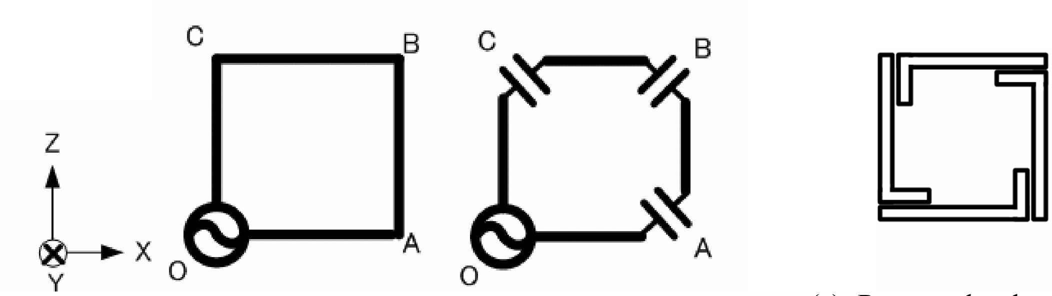
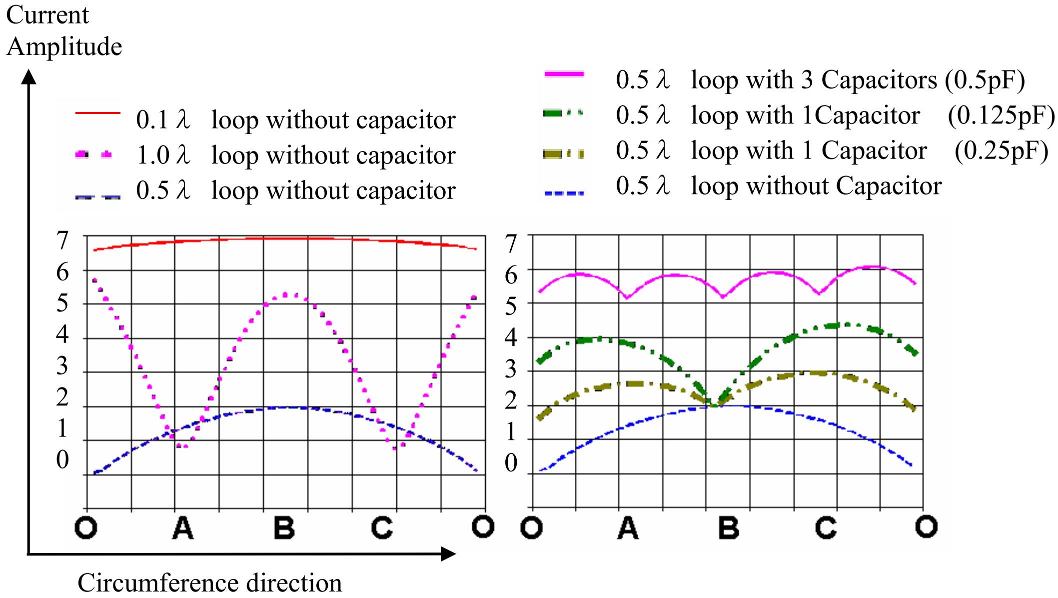


(a) Rectangular loop (b) Rectangular loop with distributed capacitances (c) Rectangular loop with flat gap structure

Fig.1 loop antenna



(a) 0.1, 0.5, 1λ rectangular loop antenna (b) Effect of distributed capacitance at 0.5 λ

Fig.2 Current distribution along rectangular loop conductor

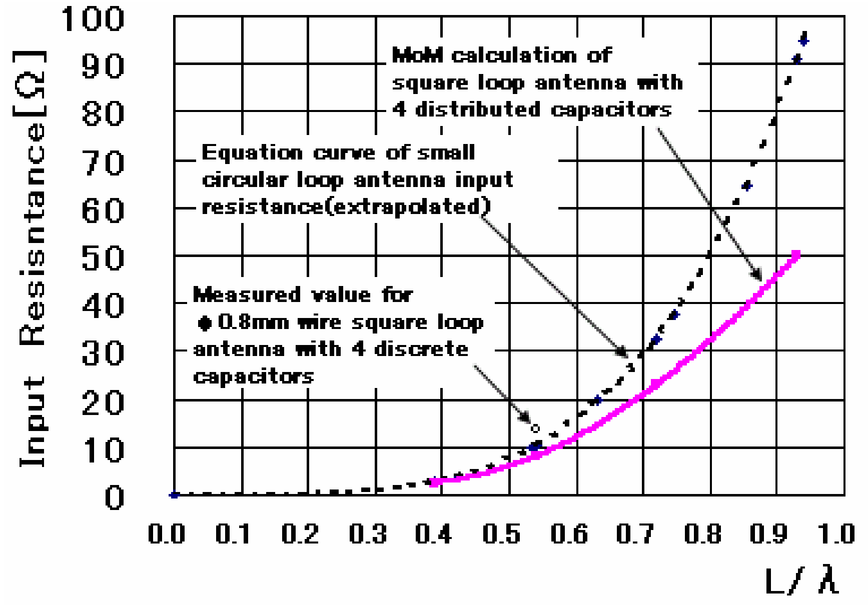


Fig. 3 Calculated and measured input resistance

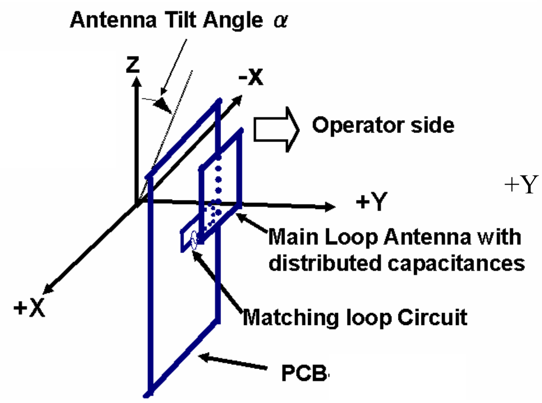


Fig.4 Antenna orientation and tilted angle α at talk position

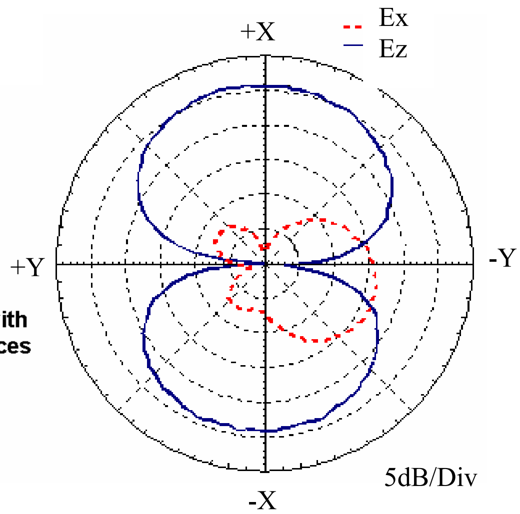


Fig. 5 Measured Radiation Pattern

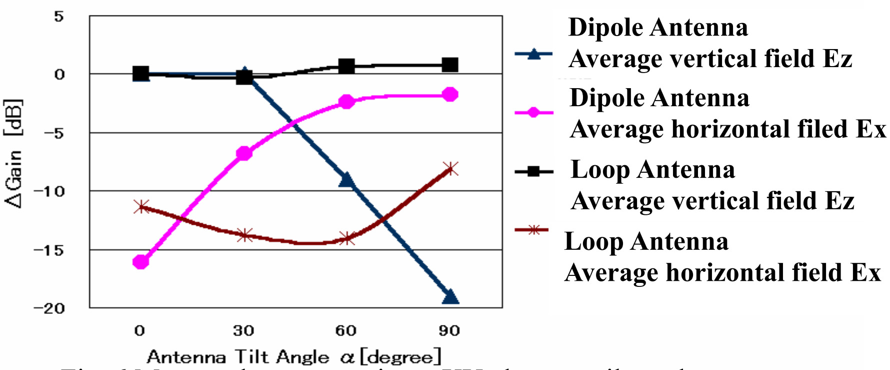


Fig. 6 Measured average gain on XY plane vs. tilt angle α