

Wideband Loop-type Antenna by Controlling Resonance Frequencies

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1. Introduction

In recent years, many small internal antennas have been designed for mobile handsets in [1, 2]. Many monopole-type antennas have been investigated because they operate at the lowest resonant mode which helps to reduce their size. A loop-type antenna, on the other hand, has rarely been applied to small antenna design because the lowest resonant mode is a parallel resonance (anti-resonance). Certain types of monopole antennas can be designed to operate on a low frequency band [3], but the overall size of the monopole antenna sets a rough limit of the bandwidth. In [4], multi-resonant elements were utilized to widen the bandwidth, but this technique makes antenna rather than large. To extend the operation bandwidth without changing the size of the antenna, this paper proposes a wideband loop-type antenna that is tuned from a conventional loop-type antenna by simply adding a spiral inductance and a gap capacitance. This method provides an ability to effectively control resonance frequencies. It differs from conventional antenna design methods in utilizing the concept of a resonant perturbation. This design mechanism is analyzed in this paper by observing voltage and current distribution as a function of resonant modes at a transmission line. The design goal in this paper is to present a dual band for a wide global system for mobile communications (GSM) and Bluetooth.

2. Antenna Design

The conventional loop-type antenna and the proposed loop-type antenna are illustrated in Figure 1 (a) and Figure 1 (b), respectively. The proposed antenna is distinguished from the conventional loop-type antenna by two structures: a spiral inductor and a gap capacitor. Antenna resonance is perturbed by inserting an inductance between beginning and ending points of the loop-type antenna. The degree of the perturbation at beginning and ending points is determined by resonant modes, and this phenomenon provides the solution to control resonance frequencies. The input reactance curve shown in Figure 2 indicates that the parallel resonances are shifted upward and the series resonance is almost fixed. As a result, a very smooth curve is obtained by simply adding the spiral inductance. The gap capacitance is employed to match the input reactance that is a little higher than zero around 1GHz. Figure 3 shows that adding spiral inductance and the gap capacitance effectively enhances the bandwidth. Note that this technique does not change the antenna size and it presents a very wide bandwidth.

3. Analysis

The perturbation theory was used to analyze a design method used to control the resonance frequencies in this paper. Because resonance frequency changes considerably when a disturbance occurs at maximum electric field or minimum magnetic field [5], a shift of resonance frequencies depends on the points at which the perturbation of a resonator is artificially made. To simplify the analysis, electric field and magnetic field are replaced with voltage and current, respectively, in this paper. We use a shorted transmission line model equivalent to the loop-type antenna for observing voltage and current at each resonant mode. Figure 4 shows voltage and current distribution in the shorted transmission line. Voltage difference between beginning and ending points of the transmission line is maximum value at parallel resonances and minimum value at series resonances. The parallel resonances have one minimum current point and the series resonances have no

minimum current point. Based on these characteristics, we estimate that the perturbation effect between beginning and ending points is larger at the parallel resonance than at the series resonance. This phenomenon is also observed when a spiral inductance is inserted between beginning and ending points of the loop-type antenna in Figure 2. Therefore, the proposed antenna can have very wide bandwidth merged the first parallel resonance with the first series resonance by adjusting the degree of perturbation.

4. Results

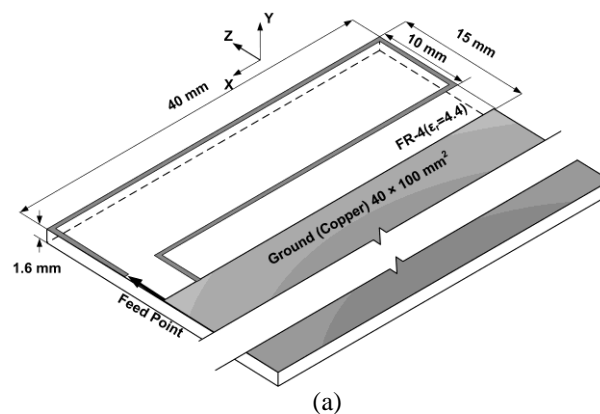
For simulation and measurement, this paper uses the ground of size $40 \times 100 \text{ mm}^2$, which is the same size as a practical mobile handset. Figure 5 shows that simulated VSWR has a good agreement with the measured VSWR. The measured bandwidth under $\text{VSWR} = 2.5$ is 530 MHz (975–1505 MHz) and 150 MHz (2410–2560 MHz) which sufficiently cover the required bandwidth at GSM and Bluetooth bands. This wideband contributes to the tolerance with a resonance frequency shift by peripheral components. As shown in Figure 6, the measured radiation patterns at H (x-y), E1 (z-x), and E2 (y-z) planes have 2.02 dBi and 2.25 dBi at the middle of each bandwidth and is almost omni-directional in the azimuthal plane (H-plane). We found that the proposed antenna can be effectively used for mobile handsets based on its wide bandwidth and good radiation characteristics.

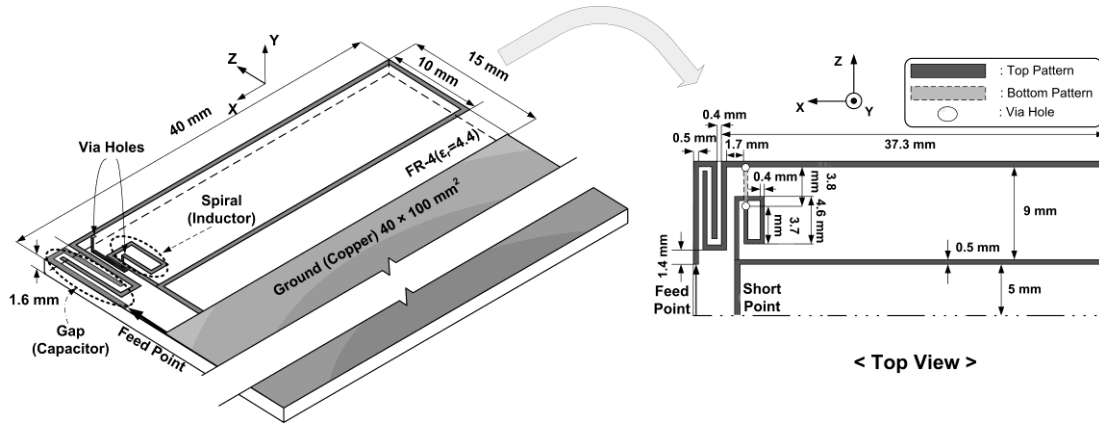
Acknowledgments

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References

- [1] K. L. Wong, *Planar antennas for wireless communications*. Hoboken: Wiley-Interscience, 2003.
- [2] Z. N. Cheng and M. Y. W. Chia, *Broadband planar antennas*. Hoboken: John Wiley & Sons, 2005.
- [3] S. Best, "On the resonant properties of the Koch fractal and other wire monopole antennas," *IEEE Antennas and Wireless Propagation Letters*, vol. 1, 2002.
- [4] F. Shyh-Tirng, Y. Shih-Huang, and W. Kin-Lu, "Planar inverted-F antennas for GSM/DCS mobile phones and dual ISM-band applications," in *Antennas and Propagation Society International Symposium, 2002. IEEE, 2002*, pp. 524-527 vol.4.
- [5] R. F. Harrington, *Time-harmonic electromagnetic fields*. New York Wiley-Interscience, 2001.





(b)
 Figure 1: Geometries of (a) conventional loop-type antenna and (b) proposed loop-type antenna

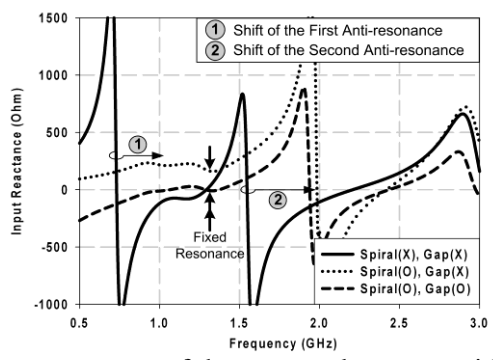


Figure 2: Simulated input reactance of the proposed antenna with/without the spiral and with/without the gap

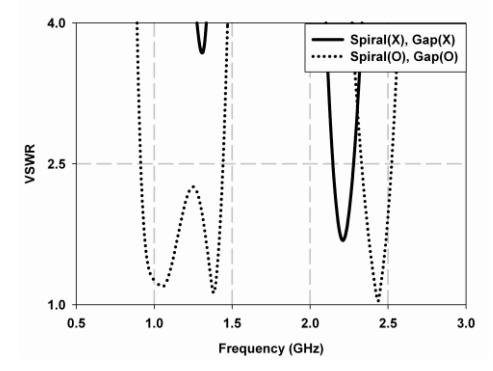
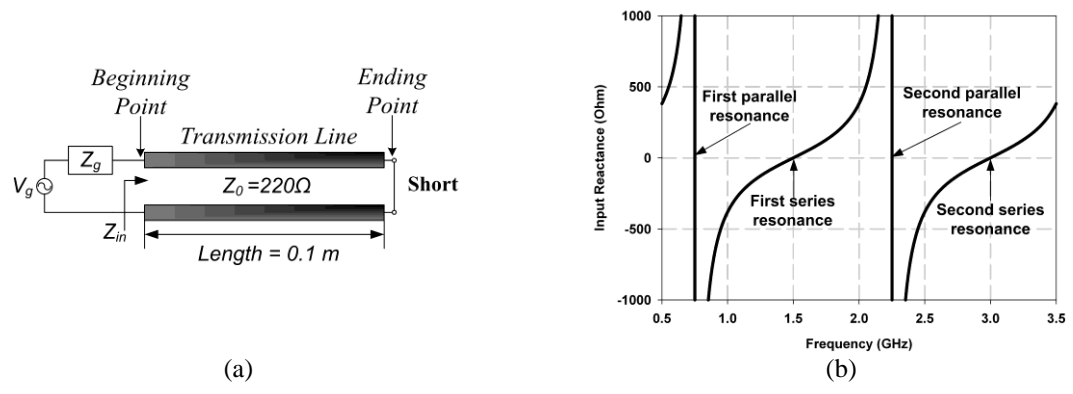


Figure 3: Simulated VSWR of the proposed antenna with/without a spiral and a gap



(a) (b)
 Figure 4: (a) Shorted transmission line and (b) input reactance of the shorted transmission line

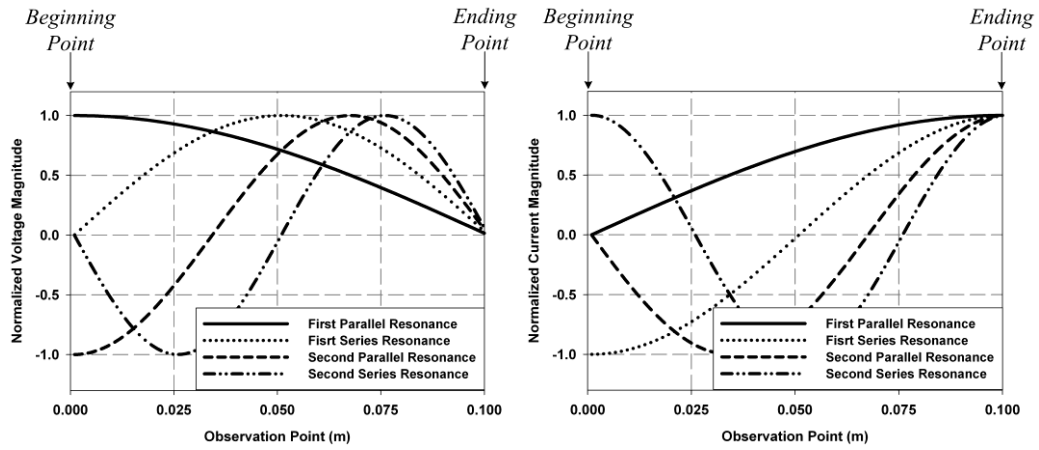


Figure 5: Normalized voltage and current distribution of the shorted transmission line at resonances

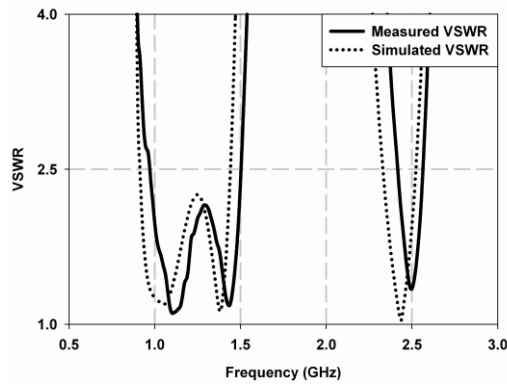


Figure 6: Simulated and measured VSWR of the proposed antenna

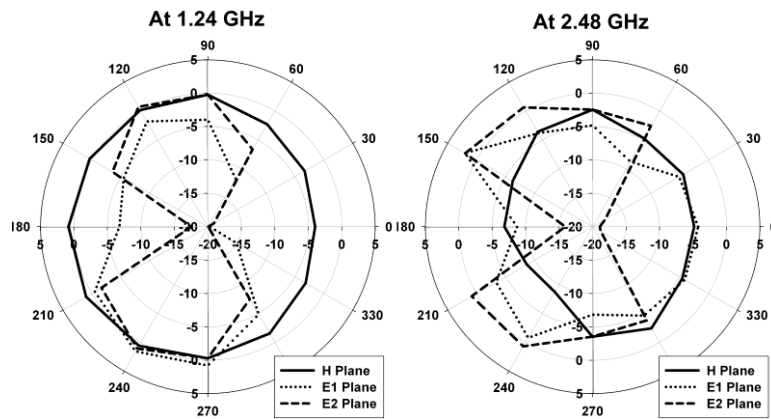


Figure 7: Measured radiation patterns