An Electrically Small Layered Meander Line Antenna with Multiple Resonances

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1. Introduction

Recently, wireless communication technology has advanced rapidly. Along with it, mobile terminals have become smaller and advanced. For such reasons, mobile terminals have required multiband antennas for various applications of electrically small antennas with very small size to the wavelength.

Introducing meander line is typical method to miniaturize antennas [1]-[3]. And, multi band antennas and electrically small antennas have been widely studied [4]-[8]. An electrically small meander line antenna has been reported [9]. This antenna is an electrically small antenna (ka < 0.5, k: wave number, a: radius of a sphere surrounding the antenna), and is formed with meander line on the same plane. Moreover, the antenna can easily control the impedance. However, this antenna has a single resonance and a narrow bandwidth. A multiband antenna with two elements of meander line has been reported [10]. Two elements are on the same plane. So, the dimension of the antenna is large compared to the resonant frequency. Moreover, the antenna has wide bandwidth, and multiple resonances.

In this paper, an electrically small layered meander line antenna with multiple resonances is presented. Simulated and measured results in S_{11} and radiation patterns are discussed with good agreements.

2. Antenna Structure

Figure 1 shows the proposed antenna structure. This antenna uses RT/Duroid 5880 substrate with a permittivity (ε_r) of 2.2 and a dielectric loss (tanδ) of 0.001, and the metal (copper) thickness is 35 μm. The dimension of the substrate layer and the ground is 22.5 mm × 14 mm. The antenna has five metallic layers with the dielectric substrates, and some of ends of the metallic elements are connected to another neighboring element by a metallic side wall. Both ends of the meander line are opened. The feed point is fabricated between the first (ground plane) and the second metallic layers at one of the open ends as shown in Fig. 1 (b). The width of the meander line is ml_w.

In the proposed antenna, resonances can be observed at the frequencies in cases that the total length of the meander line corresponds to half wavelength, a wavelength, and 3/2 wavelength.

3. Simulated and measured results

The structure is simulated using Ansoft HFSS13.0. Figure 2 (a) shows the simulated S_{11} characteristics with an increase in ml_w from 1 mm to 14 mm. Three resonances depend on the ml_w. It is noticed that the first (the lowest) resonance is shifted to a higher frequency and the second resonance is not shown regularity and the third (the highest) resonance is shifted to a lower frequency with an increase in the ml_w. And, this is because the first resonance is strongly affected by the inductance of the metallic side walls with the substrates, and the third resonance is strongly affected by the capacitance between the metallic layers.

Figure 3 shows the fabricated antennas for ml_w= 2 mm, 8 mm, 14 mm. The measured results of the S_{11} characteristics are also shown in Fig. 2 (b). The measured results also show the same behavior as the simulated results. However, it is noticed that the measured third resonance is shifted to a higher frequency by 200 MHz compared to the simulated result. This is due to fabrication errors and the gap between the dielectric substrates. Figure 4 and 5 show the radiation patterns of the antenna at the first and third resonance in the z-x and y-z plane (ml_w= 8 mm). At the first resonance, the main lobe of the antenna in the y-z plane is tilted by 60° (θ = 60°) from +z direction. This is because the radiation is affected by the part of the connecting element of layers forming the inductance. At the third resonance, the main lobe of the antenna is not tilted. This is because the current for the radiation exists weekly on the metallic side walls. The second resonance does not contribute to the radiation. So, this paper omits the results.

4. Conclusion

The paper has proposed an electrically small antenna design with multiple resonances by forming a layered meander line. The first resonance is strongly affected by the inductance, and the third resonance is strongly affected by the capacitance in the meander line, and both of the resonances can be controlled with the meander line width. The measured results show good agreements with the simulated results.

References

[1] O. Calla, A. Singh, A. K. Singh, S. Kumar, and T. Kumar, “Empirical Relation for Designing the Meander Line Antenna,” in Proc. Recent Advances in Microwave Theory and Applications, 2008. MICROWAVE 2008, pp. 695-697, Nov. 2008.

[2] A. Khaleghi, “Dual Band Meander Line Antenna for Wireless LAN Communication,” Antennas and Propagation, IEEE Transactions, vol. 55, No. 3, pp. 1004-1009, March. 2007.

[3] Hong-Kyun. Ryu and Jong-Myung. Woo, “Small-sized Square Loop Antenna Using Meander line for RFID tag Applications,” in Proc. Antennas and Propagation Society International Symposium, 2007 IEEE, pp. 2463-2466, June. 2007.

[4] D. Liu, B. Gaucher and T. Hildner, “A Dualband Antenna for Cellular Applications,” in Proc. Antennas and Propagation Society International Symposium 2006, IEEE, pp. 4689-4692, July. 2006.

[5] D. Liu, “A Dual-band Antenna for Cellular Applications,” in Proc. Antennas and Propagation Society International Symposium, 1998. IEEE, vol. 2, pp. 786-789, June. 1998.

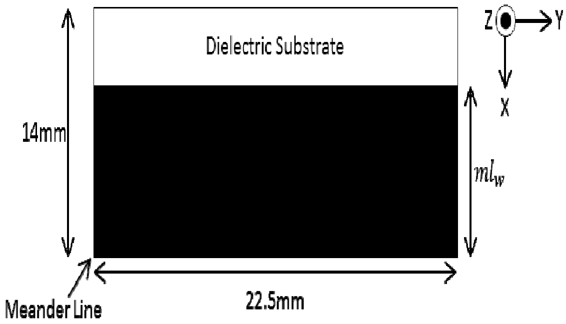
[6] Jong-Ho. Jung and I. Park, “Electromagnetically Coupled Small Broadband Monopole Antenna”, Antennas and Wireless Propagation Letters, IEEE, vol. 2, No. 1, pp. 349-351, 2003.

[7] S. R. Best, “A Discussion on the Properties of Electrically Small Self-Resonant Wire Antennas”, Antennas and Propagation Magazine, IEEE, vol. 46, No. 6, pp. 9-22, Dec. 2004.

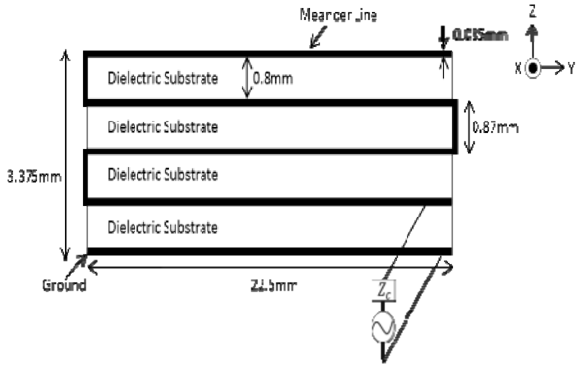
[8] D. Liu, "A Multi-branch Monopole Antenna for Dual-Band Cellular Applications," in Proc. Antennas and Propagation Society International Symposium, 1999. IEEE, vol. 3, pp. 1578-1581, Aug. 1999.

[9] K. Ide and T. Fukusako, “Low-profile, electrically small meander antenna using a capacitive feed structure” Microwave and Optical Technology Letters, vol.52, No.10, pp. 2269-2274, Oct. 2010.

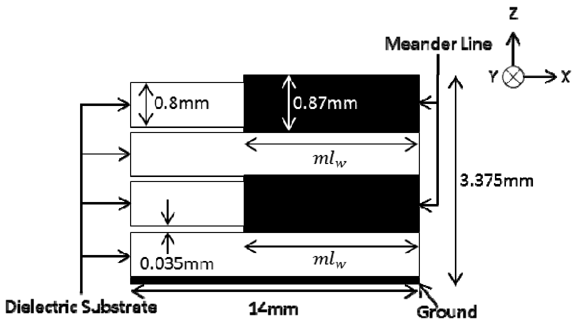
[10] J. W. Ha, C. Cho, and J.W. Lee, “A Triple-Band Antenna using CPW-Fed and Meander-line for PCS/IMT-2000/Bluetooth Applications,” in Proc. Antennas and Propagation Society International Symposium, 2005 IEEE, vol. 1A, pp. 434-437, July. 2005.



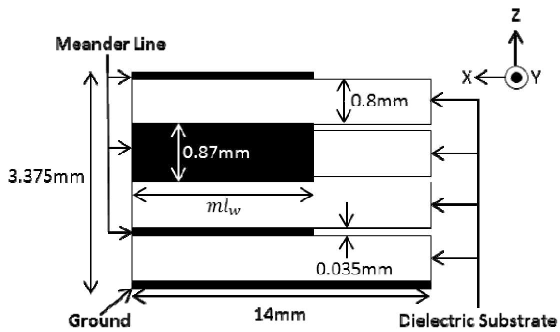
(a) top view



(b) front view

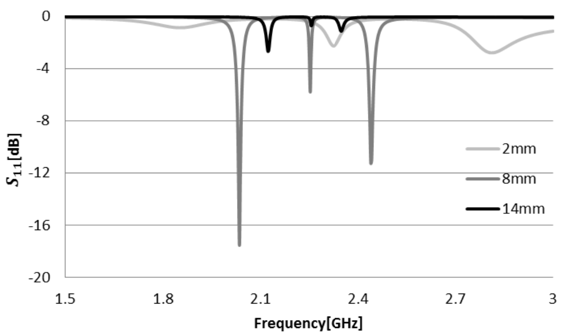


(c) side view seen from –y

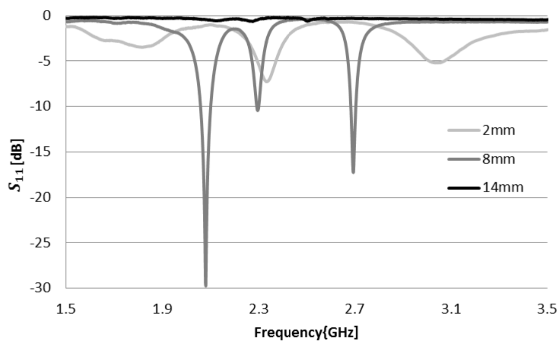


(d) side view seen from +y

Figure 1: Proposed antenna structure



(a) Simulated S_{11} characteristics



(b) Measured S_{11} characteristics

Figure 2: Variation in S_{11} characteristics with the ml_w

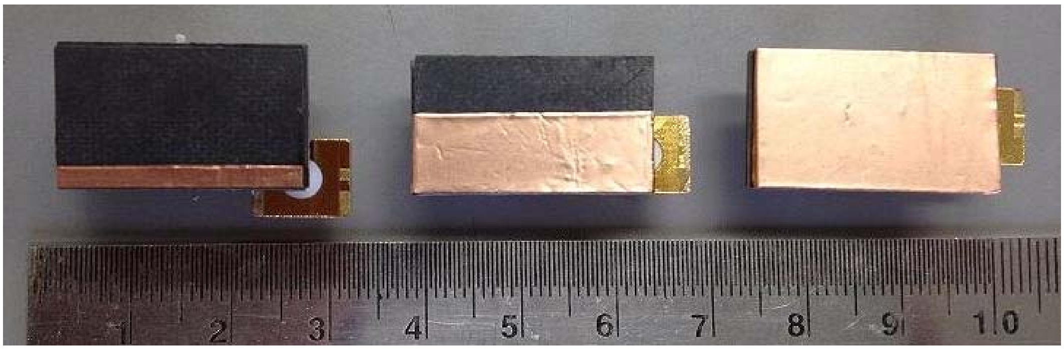
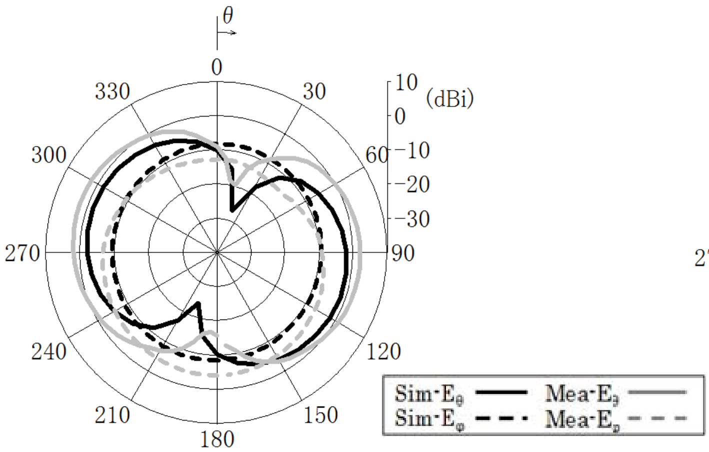
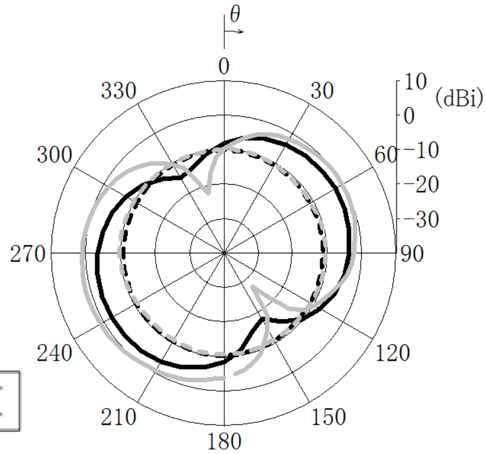


Figure 3: Photograph of fabricated antennas (ml_w= 2mm, 8mm, 14mm)

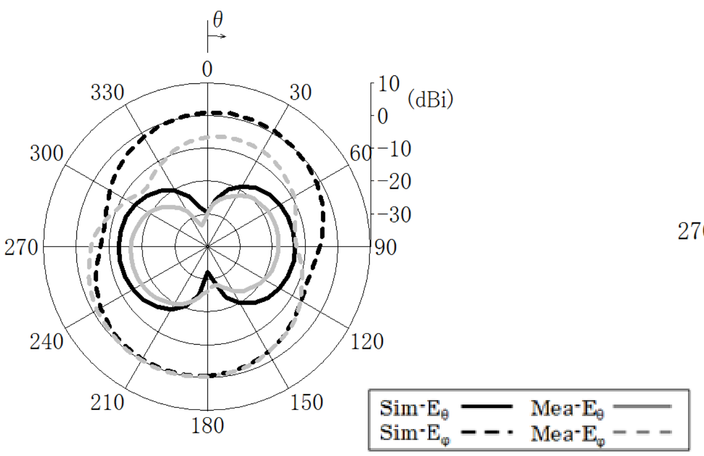


(a) z-x plane

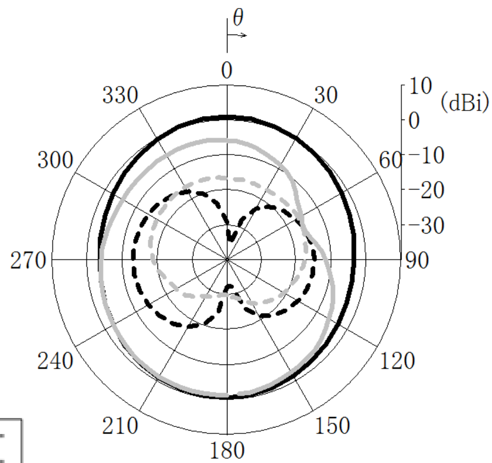


(b) y-z plane

Figure 4: Radiation pattern (First resonance)



(a) z-x plane



(b) y-z plane

Figure 5: Radiation pattern (Third resonance)