Minimized Dual-Band Coupled Line Meander Antenna for System-In-a-Package Applications

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Abstract: A novel low-profile planar coupled line meander antenna for dual-band operation is presented. The design is based on meandered line principle with a coupled line to achieve two different radiation modes for GSM and DCS applications. Because of the effect of the coupled line, total dimension of the proposed antenna is greatly deduced. With a compact size of 14 x 17 mm^2; this prototype is suitable for System-In-a-Package (SIP) applications. The antenna is fabricated on a Rogers Corp. TMM4 substrate with a relative permittivity of 4.50. The experimental results have good agreement with the simulated data.

Introduction: Dual-band planar monopole antennas with low-profile are previously studied and demonstrated [1-7] because the topic of small antennas for mobile handset applications is very attractive recently due to the increasing demand of wireless communication devices. In addition, the idea of integration antennas inside SIP is currently receiving much attention to further reduce the size and lower manufacturing costs. In order to produce compact antennas, different methods have been investigated. In previous studies, to achieve dual-band operation, two separate radiation paths are implemented [1] [4-7], and each path occupies the area equivalent to half-wavelength or quarter-wavelength. A compact meander-type slot antenna with non-uniform slot line widths to yield lower operating frequency has also been reported [2]. In another study, dual-frequency antenna has been designed by using a tapered meander slot antenna with a short-ended microstrip line feed and fabricated on a high permittivity substrate [3]. However, these designs are not suitable for the applications of SIP because of their large dimensions. Moreover, high dielectric constant can possibly produce small size antennas, but the idea cannot be applied in SIP applications as thin and low dielectric constant substrates are usually used in such applications.

In this paper, we present a novel dual-band meander line antenna with a coupled line to achieve two separate resonant frequencies for GSM and DCS applications. The meander line antenna subjects to reduce the physical dimension of the overall antenna size while still maintain the required electric length. Moreover, a single couple line is designed next to the main antenna can possibly generate additional resonant frequency with a very tiny space. Therefore, it leads to the compactness in size of the proposed antenna. Details of the proposed dual-band meander antenna with a coupled line are described, and the simulated as well as experimental results of the antenna are presented and discussed.

Antenna Configuration and Design: Fig. 1(a). illustrates the detail geometry and dimensions of the proposed low-profile meander antenna with a coupled line. The antenna is successfully fabricated on a Rogers Corp. TMM4 substrate with a relative permittivity ε_r = 4.50, dissipation factor tan δ = 0.002, and thickness of 0.76 mm as shown in Fig. 1(b). A 50 Ω microstrip line is printed on the same microwave substrate to serve for the purpose of exciting the antenna. For simplicity and ease in the fabrication and measurement of this research, 50 Ω microstrip line feeding is used through a SMA connector. However, it is possible to integrate this antenna into a SIP via hole connection. A ground plane is printed on the back of the substrate as a ground plane for the microstrip feeding line, and it does not cover the antenna portion. The proposed antenna has an overall size of only 14 x 17 mm^2; thus it is very promising to integrate this antenna within a package. The proposed antenna consists of two major parts: the meandered portion is mainly designed to achieve a resonant frequency of

about 900 MHz, and the coupled line is used to generate upper operating band of about 1800 MHz. The main strip meandered part dimension is calculated corresponding to a resonant length of quarter-wavelength with the given frequency at 900 MHz. As the meandered section is increased in length, the resonant frequency of the antenna drops accordingly. However, because of the corner effects between adjacent meandered sections, the actual length of the prototype is larger than a quarter-wavelength simple monopole patch. The detail dimensions of the antenna are shown in Fig. 1, and these dimensions are optimized by using the simulation software Ansoft HFSS. Next, the small coupled strip line is designed to achieve the second resonant frequency. This line is effectively coupled through the main meandered section to resonate at the center frequency of about 1800 MHz. The correct resonant frequencies and impedance matching of the proposed antenna can be established by adjusting the length of the coupled line and the distance between the coupled line and the main meandered portion. The optimum length of the coupled line is designed to be equal to 6 mm. In addition, non-uniform spaces between two adjacent meandered lines are used to lower operating frequency in order to minimize the total size of the antenna. The distances between adjacent meandered lines are chosen to be 0.3 mm and 0.5 mm.

Analysis and Experimental Results: Fig. 2 shows the simulated and measured return loss of the proposed meander antenna. The simulated return loss is obtained from the HFSS software version 8 to predict the resonant frequencies of the proposed antenna. It can be seen that two separate radiation frequencies with good impedance matching are obtained. The lower bandwidth, which covers the GSM band at the center frequency of 900 MHz, and the upper bandwidth, which covers the DCS band at the center frequency of 1800 MHz are determined by 2.5:1 VSWR (about -7.3 dB return loss), which is acceptable for practical applications. The experimental results reasonably agree with the simulated data. However, due to some limitations of etching technique processes, a slightly difference between the simulated and measured results have been observed. This can be taken care of by carefully considering constrains in fabrication processes. Although the prototype has a small dimension, reasonable impedance bandwidths are observed.

The radiation characteristics of the proposed antenna have also been investigated in the x-y plane, y-z plane, and x-z plane. Fig. 3 and 4 plot measured radiation patterns at center operating frequencies of about 900 MHz and 1800 MHz, respectively. For both frequencies, the results show a good omni-directional radiation patterns in the y-z plane (elevation direction). The proposed antenna also exhibits omni-directional-like radiation patterns in other planes. Radiation characteristics within operating frequency bands are also studied, and they are shown to be stable across interest frequency bands.

Conclusion: A novel low-profile meander antenna with coupled line has been proposed, and the prototype covers the dual-band operating of 900 MHz GSM band and 1800 MHz DCS band. A basic meandered line antenna is modified with a compact strip through effective electromagnetic coupling effects to achieve a dual-band frequency operation with much smaller in the overall dimension. The constructed antenna is low-profile with the size of 14 x 17 mm^2; and it is successfully fabricated on a low permittivity dielectric constant substrate. Therefore, it is very promising for internal antenna in a package integrated application. Reasonable return loss and radiation characteristics of the proposed antenna have also been observed.

References:

[1] K. Wong, Planar Antennas for Wireless Communications, John Wiley & Sons, New Jersey, 2003.

[2] J. Kim, J Yook, W. Song, J. Yoon, J. Park, and H. Park, “Compact meander-type slot antennas,” *IEEE Antenna Propagation Symp Proceedings*, pp 724-726, 2001.

[3] C M. Allen, A Z. Elsherbeni, C E. Smith, C P. Huang, and K. Lee, "Tapped Meander Slot Antenna for Dual Band Personal Wireless Communication Systems," *Microwave and Optical Technology Letters*, vol. 36, No. 5, pp 381-385, March, 2003.
[4] K. Wong, G. Lee, T. Chiou, "A Low-Profile Planar Monopole Antenna for Multiband Operation of Mobile Handsets," *IEEE Trans. Antenna Propagation*, vol. 51, No. 1, pp 121-125, January 2003.
[5] G. Lee, H. Chen, K. Wong, "A Low-Cost Surface-Mount Monopole Antenna for GSM/DCS Operation," *Microwave and Optical Technology Letters*, vol. 37, No. 1, pp 2-4, April 2003.
[6] F. Hsiao, K. Wong, "Compact Planar Inverted-F Patch Antenna for Triple Frequency Operation," *Microwave and Optical Technology Letters*, vol. 33, No. 6, pp 459-462, June 2002.
[7] F. Chang, K. Wong, " Planar Monopole Folded Into a Rectangular-Disk-Like Structure as Surface-Mountable Antenna for 2.4/5.2 GHz Dual-Band Operation," *Microwave and Optical Technology Letters*, vol. 34, No. 3, pp 166-169, August, 2002.

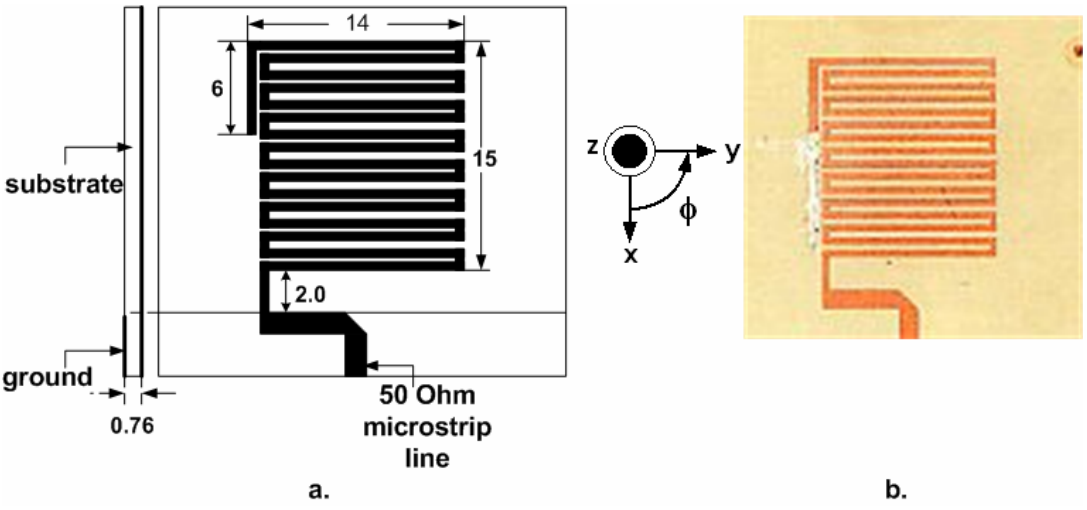

Fig. 1. Geometry of the proposed low-profile meander with a coupled line antenna (a) Detail geometry and dimensions and (b) Fabricated antenna,

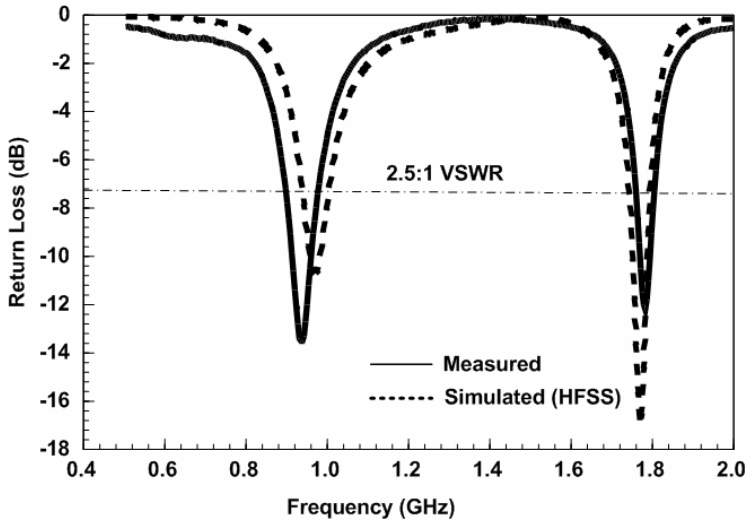

Fig. 2. Simulated and measured return loss for the proposed antenna,

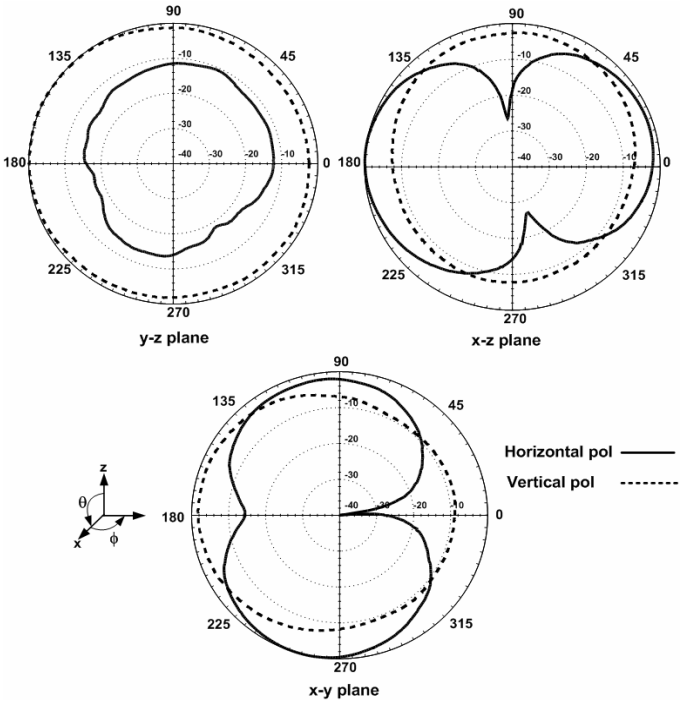

Fig. 3. Measured radiation patterns for the proposed antenna at 900 MHz,

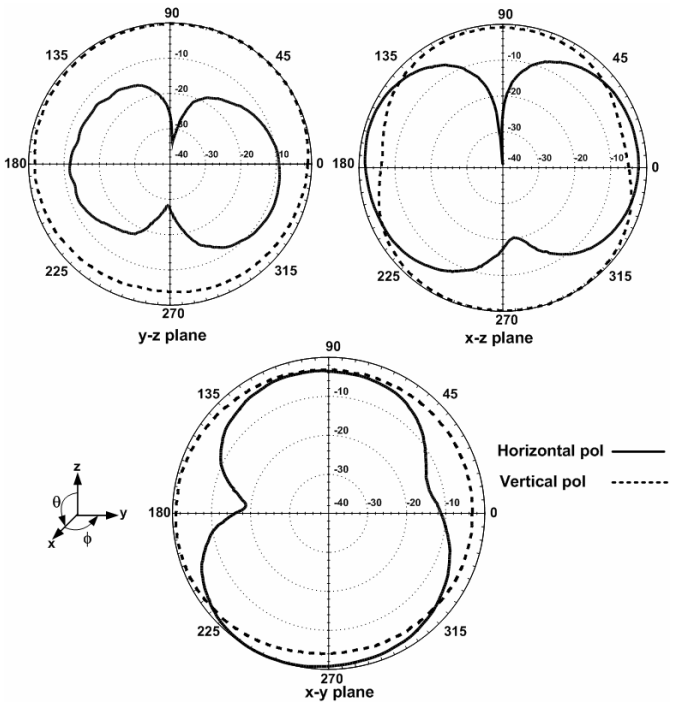

Fig. 4. Measured radiation patterns for the proposed antenna at 1800 MHz.