PRINTED STRAIGHT F ANTENNAS FOR WLAN AND BLUETOOTH

H.Y. David Yang

Dept. of Electrical and Computer Engineering, Univ. of Illinois at Chicago
Chicago, IL 60607, Emails: hyang@ece.uic.edu

Abstract Miniaturized printed-circuit-board antennas are proposed in PCMCIA cards for WALN and Bluetooth applications. The proposed antenna is a straight F in shape printed on a FR4 substrate together with the rest of the circuit components, providing a low-cost antenna solution. The straight F antenna resembles a printed inverted F antenna, but the inductive tuning arm is in the same side of the capacitive arm, resulting in further reduced overall antenna area. The proposed antenna occupies an area of about 9mm by 7mm. Several prototype antennas are designed and fabricated. Reasonable impedance bandwidth and good range of coverage are found.

Introduction

Recently there is tremendous demand for the development of wireless communication systems for local access networks (WLAN) including bluetooth, IEEE 802.11a, and 802.11b. This demand has stirred significant renewed interest in antenna design particularly at the ISM bands. Many novel antenna structures for single, dual, or multiple bands have been proposed [1-2]. Among them, printed circuit antennas are desirable for their low cost, low profile, and conformality. Furthermore, the material substrate provides substantial antenna size reduction. A drawback is the narrow bandwidth, when a conductor backing is presented. Parasitic elements may be used to provide multiple resonances to enhance the bandwidth. Recently, inverted printed F antenna was proposed that provides much wider bandwidth and smaller size [3]. Inverted antenna is similar to a freestanding quarter-wave monopole above a ground plane, rather than the usual half-wave printed antennas. Much larger bandwidth is a result of lower Q factor as compared to the resonant microstrip elements. In WLAN or Bluetooth applications, either the PCMCIA bus card or dogle allows very small area for an antenna. There is a demand that the antenna area be even less than 10mm by 10mm. The inductive and capacitive arms of a printed inverted F antenna add up to the total antenna length much larger than what is desired for. In this paper, a modified inverted F antenna named as a straight F antenna is proposed. The design and test results show that this antenna is much smaller that the usual F antenna with sufficient bandwidth for ISM band.

Design Considerations

An example of a usual printed inverted F antenna is shown in Figure 1. A truncated ground plane is on the surface of the bottom substrate. The protrusion of the F over the ground plane edge determines the antenna characteristics and the operation band. The upper part of the F is for inductive tuning and the lower part of the F together with the microstrip line protrusion forms a capacitively loaded monopole. A quarter-wave monopole on a FR-4 substrate is about 17mm long. As a result, the overall length of the F antenna is about 15~ 20 mm depending on the microstrip protrusion length.

Figure 1. A printed inverted F antenna on a FR-4 substrate.

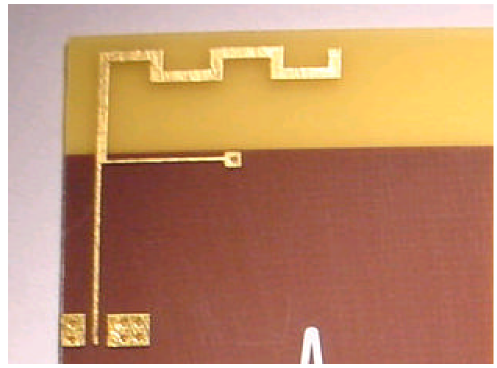

Figure 2. A printed straight F antenna on a FR-4 substrate.

In WLAN or Bluetooth applications, overall board space for antennas are limited. It is often necessary to further reduce the antenna area from the usual inverted F antenna. A modified F antenna structure that provides significant area reduction is shown in Figure 2. It utilizes both antenna corners and moves the inductive arm into and around the edge of the ground plane covered area. Meandering further reduces the capacitive arm. The resulting overall antenna area is down to below 9mm by 8 mm for a 4-layer stack-up FR-4 substrate of 18 mil overall thickness for 2.4 GHz band operation.

A Design Example

An example of the design of IEEE 802.11b PCMCIA card antenna is given here. The substrate is a four-layer stack-up with truncated ground plane on the second and the bottom layers indicated in the dark brown area in Figure 2. Antenna is built on the upper-left corner of the board with 7 mm extension of board beyond the ground plane. The top sandwiched substrate is 5mil thickness so that 50ohm line trace is about 10mil wide. Overall antenna area is 9mm long and 8 mm deep (7mm board extension over ground plane and 1mm for the tuning inductance). Return loss measurement is performed with a network analyzer. The lower the return loss, the less the matching loss will be. A 10 dB return loss at antenna corresponds to 10% power loss (or 0.46 dB) due to matching. The matching test result for the antenna shown in Figure 2 is shown in Figure 3. For IEEE 802.11b WLAN, the required bandwidth is 80 MHz. It is seems that the present antenna has bandwidth over 120 MHz, sufficient for the required applications. Additional loss will be at the substrate, which is usually a fraction of a dB. In MIC, vias are usually built around the circuits to reduce the surface-wave loss and undesired cross coupling between components. The same antenna is tested with vias built around. The return loss test result is shown in Figure 4. The effect of vias is to lower the in-band frequency and it shows the designed antenna is useful for the WLAN band at 2.4-2.48 GHz.

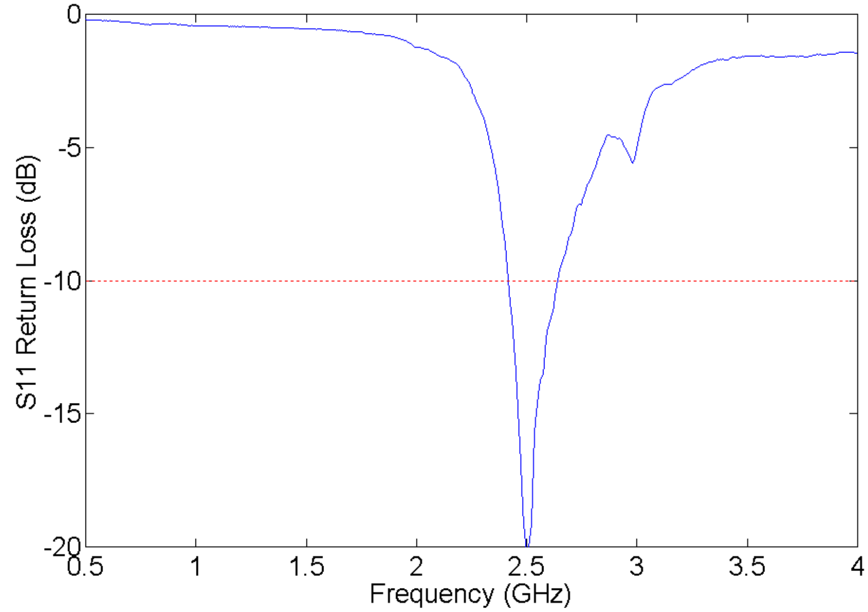

Figure 3. Measured return loss for the straight F antenna shown in Figure 2.

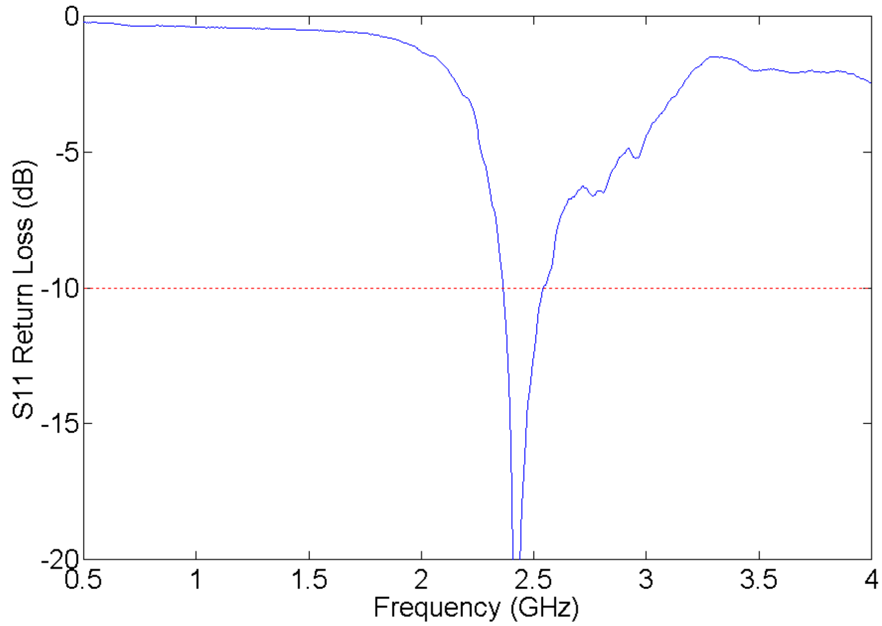

Figure 4. Measured return loss for the straight F antenna shown in Figure 2, but with vias built around the antenna in the ground plane covered area.

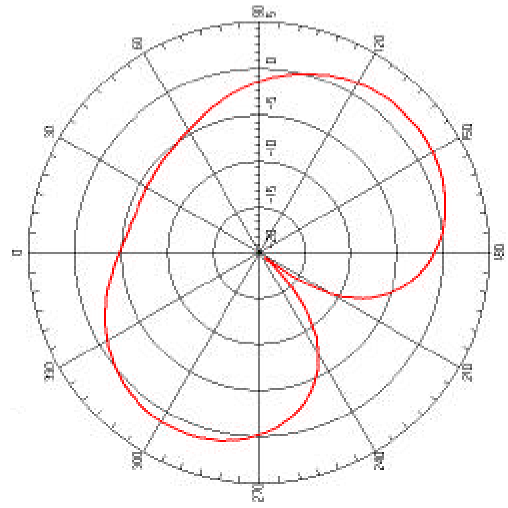

Figure 5. Computed radiation pattern in the plane of a PCMCIA card. Note that the pattern angle is aligned with the antenna layout in Figure 2.

Antenna gain patterns provide the information of the signal receptability at a particular direction relative to the antenna. HFSS simulation (Ansoft 3D simulator) result for the antenna in Figure 2 is shown in Figure 5 for the plane parallel to the circuit board. The lower half of the circle is radiation into the board-side inserted into a computer and is less important. The gain in the front of the board about –2dB and maximum radiation is at about 45 degrees from the front. Significantly less radiation (-5 to –10 dB gain) is seen at the left side corner of the board, indicating that a diversity antenna or antenna arrays are probably needed to cover more area at a larger distance. This observation is common for a line-type (or linear) antenna due to the nulls of magnetic field.

Conclusions

This paper described a printed straight-F antenna, a modification of the inverted-F antenna. It is demonstrated that the antenna area is reduced significantly with the proposed structure by moving the inductive tuning arm into the ground-plane covered area. The proposed antenna structure should find useful applications in WLAN or Bluetooth.

Reference

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