

2013-09-23

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Abraham Loutridis

Technological University Dublin

Matthias John

Trinity College Dublin, matthias.john@tudublin.ie

Max Ammann

Technological University Dublin, max.ammann@tudublin.ie

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Recommended Citation

Loutridis, A. John, M. & Ammann, M.J. (2013) "Dual Band LTE Planar Inverted-F Antenna for M2M Applications", *Microwave and Optical Technology Letters*, vol. 55, issue 12, pp. 2925–2929, doi:10.1002/mop.27980

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DUAL BAND LTE PLANAR INVERTED-F ANTENNA FOR M2M APPLICATIONS

Abraham Loutridis^{1,2}, Matthias John², Max J. Ammann^{1,2}

¹ Antenna & High Frequency Research Centre, Dublin Institute of Technology, Dublin 8, Ireland

²The Telecommunications Research Centre (CTVR) Trinity College Dublin, Dublin 2, Ireland
 abraham.loutridis@mydit.ie

ABSTRACT: A Planar Inverted-F Antenna for M2M applications is presented. The antenna is located on a rectangular ground plane and operates across both LTE frequency bands (690-960 MHz) and (1710-2690 MHz). The low cost antenna has omni-directional characteristics. The efficiency is better than 80% in both bands and the average gain is more than -2.1 dBi across the whole frequency range. A parametric study of key geometrical parameters is reported.

Key words: PIFA; LTE; M2M applications.

1. Introduction

Long Term Evolution (LTE) communication systems have been introduced recently, promising to provide greater capacity, throughput rates and better quality of service. For a variety of machine-to-machine (M2M) applications [1] many types of antennas have been reported, such as Planar Inverted-F Antenna (PIFA) antennas [2-5] and monopoles [6-8]. A broadband antenna is required to cover the whole frequency range of the lower and upper band of the LTE standard [8-10]. The performance of any broadband antenna is dependent on its geometrical characteristics and also the size and shape of the ground plane [11, 12] which is a criterion which strongly effects the broadband performance.

In this paper a PIFA structure which operates in the LTE bands (690-960 MHz)/ (1710-2690 MHz) is presented for M2M applications. The proposed antenna provides a dual band operation with omnidirectional radiation characteristics, good impedance matching and high efficiency and gain. The effects of the geometrical characteristics of the antenna are studied.

2. PIFA Antenna

Figure 1 shows the geometry of the PIFA antenna, which is located on a ground plane of a single sided FR-4 substrate ($\epsilon_r=4.3$, thickness=1.5 mm) with dimensions 178 mm \times 247 mm with metallization thickness=0.035 mm. The front and the back part of the PIFA antenna (Fig 1(a)

and (b)) are printed on FR-4 layers ($\epsilon_r=4.3$, thickness=1.5 mm) with dimensions $l=67$ mm \times $h=30$ mm. The top part of the PIFA antenna consists of a thin brass layer (thickness=0.13 mm) with dimensions $l=67$ mm \times $w=33$ mm. The PIFA is fed via a 50 Ω SMA connector through the ground plane to a feeding strip of 2.7 mm width which is located $a=20.5$ mm from the left edge of the antenna.

The fold-over metallization lengths for the front and back sections are $d=23$ mm and $b=12$ mm respectively. The shorting strip is printed on a thin FR-4 layer (thickness=0.2 mm) and touches the inner part of the FR-4 back side layer (Fig. 1(d)). It connects to the top face of the antenna. The shorting strip width is 7.4 mm and is positioned $s=20$ mm from the edge of the antenna. The antenna was modeled in CST Microwave Studio.

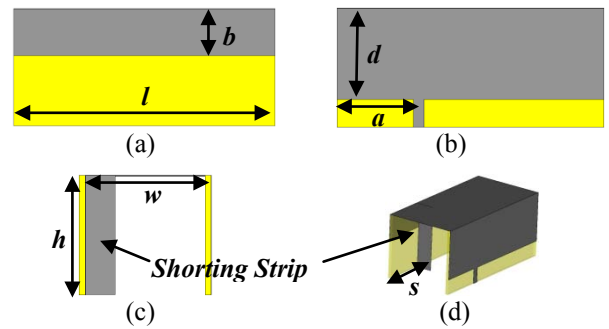


Figure 1 Rear view (a), Front view (b), Left view (c), General view.

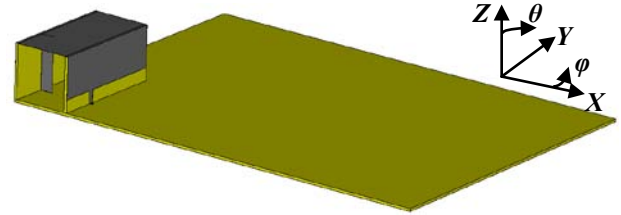


Figure 2 CST simulation model and the coordinate system.

3. Parameter Study

A parametric study of the four key parameters was made. Fig. 3 shows the simulated S_{11} as a function of the length (l) of the PIFA antenna. From the graph it is seen that increasing the length of the PIFA antenna shifts the resonances downwards. The proposed value of the length l for the proposed antenna is 67 mm.

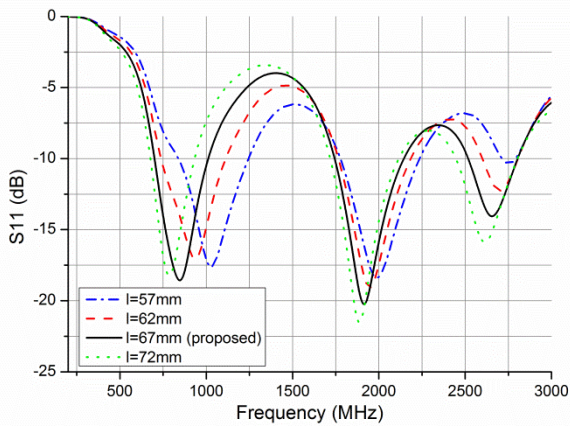


Figure 3 The simulated S_{11} as the length (l) of the PIFA is swept.

Fig. 4 shows the variation of the height (h) of the PIFA antenna. As the height of the antenna increases, the impedance matching at the first resonance improves. On the other hand, for the second and third resonance as the height of the antenna increases the impedance matching deteriorates. The optimized value of the height h for the proposed antenna is 30 mm, providing good matching for both LTE bands.

In Fig. 5 simulated results for the width (w) of the antenna are shown. As the value of width (w) increases from 12 mm to 40mm, the low band degrades while the second band matching improves. A suitable value of the width w of the antenna was chosen to be 33 mm.

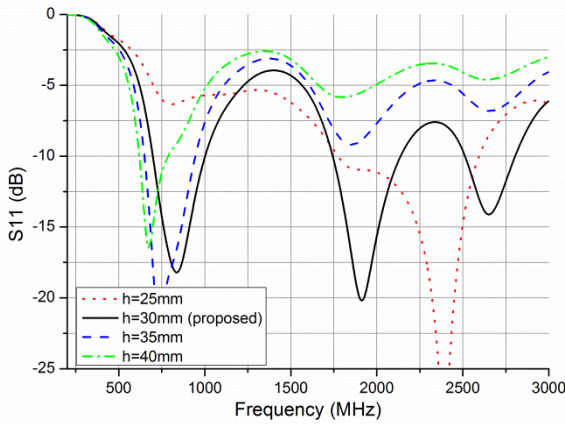


Figure 4 The simulated S_{11} as the height (h) of the PIFA is swept.

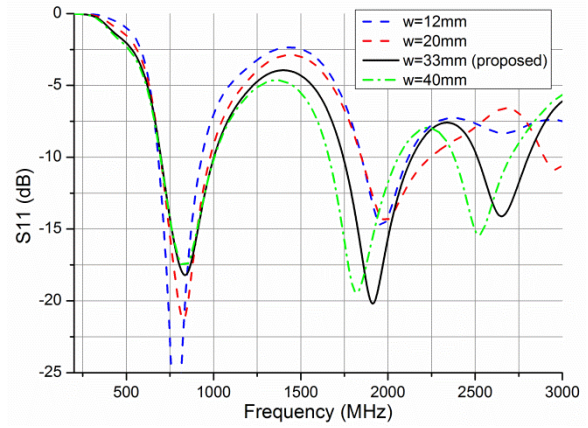


Figure 5 The simulated S_{11} as the width (w) of the PIFA is swept.

Finally, in Fig. 6 the simulated S_{11} results of the variation of the position s of the shorting strip are shown. The obtained results clearly show that all resonant frequencies can be controlled (impedance matching and frequency shifting) by varying the parameter s . By considering the results of Fig. 6 the best value of the length s is 20 mm.

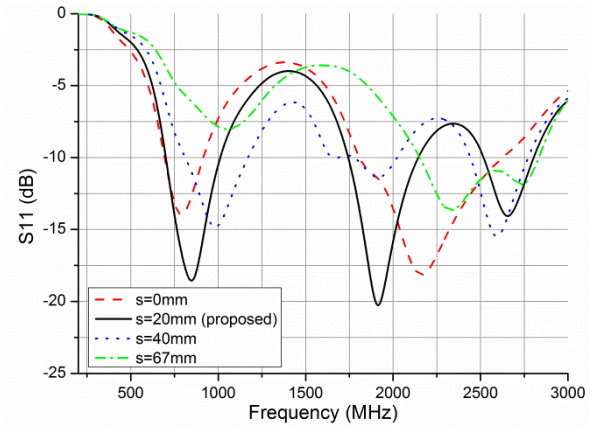


Figure 6 The simulated S_{11} showing the dependence on the shorting strip position s .

4. Results

The measured and simulated S_{11} are in good agreement as seen in Fig. 7. The S_{11} was less than -10 dB over the range 688.5 MHz - 1009.8 MHz, 1736.3 MHz - 2121.5 MHz and 2459 MHz - 2698 MHz giving fractional bandwidths of 40.6%, 20.87% and 9.31%, respectively the frequency range for $S_{11} \leq -6$ dB is 623.5 MHz - 1111.8 MHz and 1621.74 MHz - 3007.04 MHz, (62% and 75%, respectively).

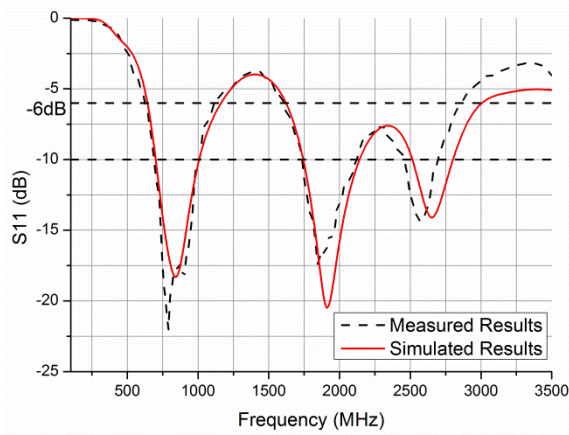


Figure 7 S_{11} of the simulated and measured PIFA antenna.

In Figs. 8-13 the simulated and measured radiation patterns for XZ , YZ and XY planes at the LTE centre frequencies of 825 MHz and 2200 MHz are illustrated.

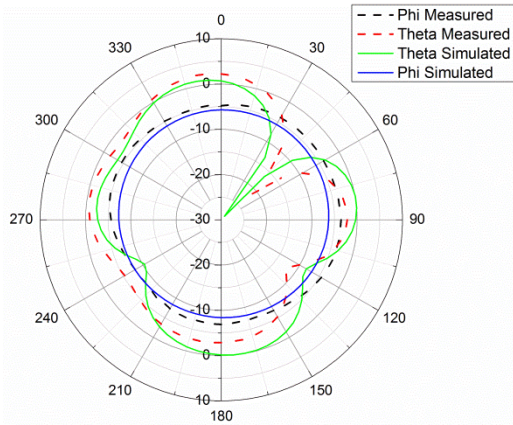


Figure 8 Measured and simulated XY -plane patterns at 825 MHz.

At the three planes of 825 MHz it is observed that the Phi (ϕ) component provides good omnidirectional characteristics, which is also observed at the XY -plane of 2200 MHz for the Theta (θ) component. Moreover, at 825 MHz in the ZY -plane good discrimination between the Phi (ϕ) and Theta (θ) component is provided.

The measured maximum gain for the lower and upper band is 4.5 dBi and 6.4 dBi, respectively. The measured gain, averaged over the principle plane cuts (XZ , YZ and XY) was -1.1, -1.2, and -2.1 dBi for the low band and -1.4, -1.7 and -1.6 dBi for the high band. The simulated total efficiency is more than 82% and 80% for the first and for the second frequency band, respectively. The maximum total efficiency is 97.5% at 1915.4 MHz.

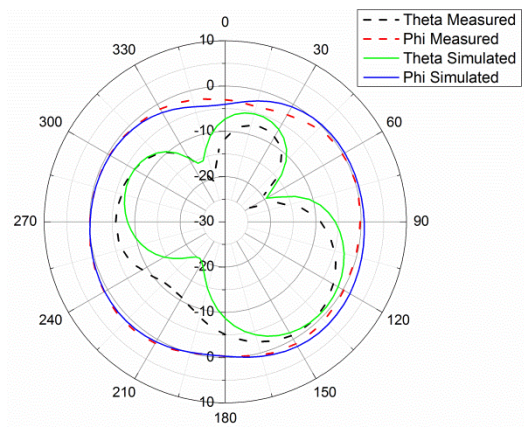


Figure 9 Measured and simulated YZ -plane patterns at 825 MHz.

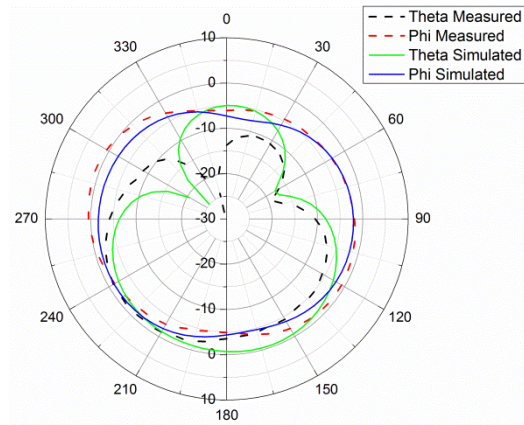


Figure 10 Measured and simulated ZX -plane patterns at 825 MHz.

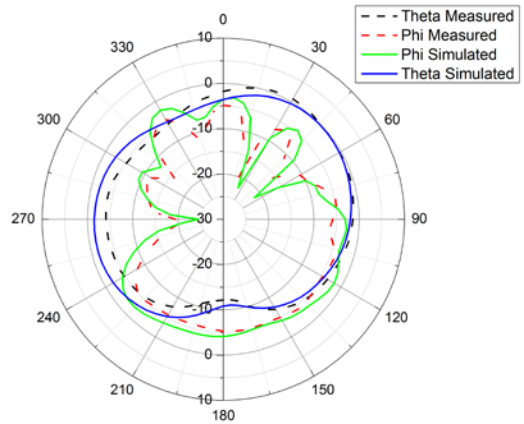


Figure 11 Measured and simulated XY -plane patterns at 2200 MHz.

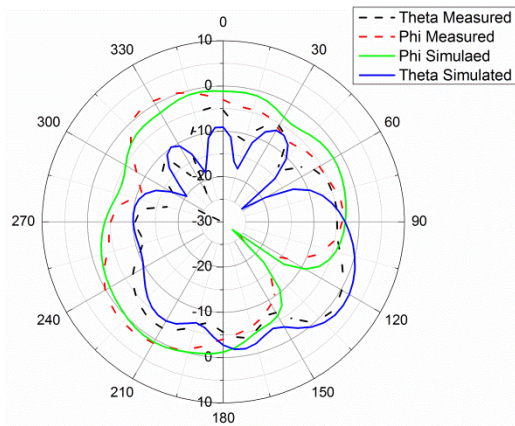


Figure 12 Measured and simulated ZX-plane patterns at 2200 MHz.

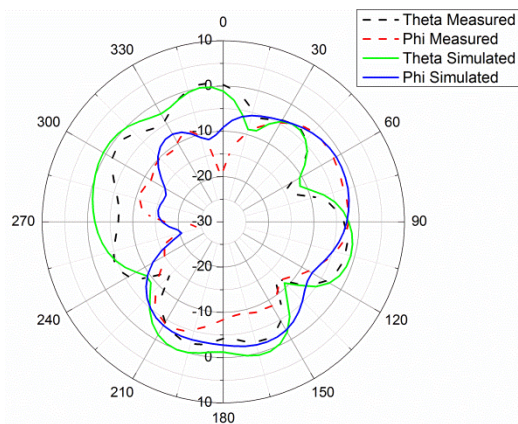


Figure 13 Measured and simulated YZ-plane patterns at 2200 MHz.

5. Conclusion

In this paper a parameter study of a dual-band Planar Inverted-F Antenna (PIFA) for the LTE frequency range is presented. The proposed antenna which is suitable for M2M applications provides dual band operation, omnidirectional radiation characteristics, and high total efficiency in both bands and also good gain across the whole frequency range.

6. Acknowledgements

This material is based upon works supported by the Science Foundation Ireland under Grant No. 10/CE/I1853.

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