Highly power-efficient wide band antenna for LTE base station application

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Abstract

A new feeding mechanism is proposed to enhance the bandwidth of an efficient air-gap antenna designed for LTE base station. By optimally tapering the feed, the bandwidth is enlarged to fully cover the 250 MHz required for LTE operation while maintaining radiation performance and a high efficiency of 90%.

Keywords: Efficient antennas Base station Wide band antennas

1. Introduction

A substantial reduction in power consumption over current wireless communication networks is aimed at by the Mobile VCE Green Radio Programme [1] of which the antenna at the base station (BS) is an integral part. It was shown in [2] that a dual polarised air-gap antenna, also known as Suspended Plate Antenna (SPA), achieved a high efficiency of 95% due to the presence of an air substrate between ground plane and the main patch. However, due to the large inductance caused by the probe feed, although the transmission bandwidth was good, the impedance bandwidth for this antenna was not sufficient to cover the LTE band between 1920 MHz and 2170 MHz with reflection coefficients below -10dB.

Much research has been presented in the literature to enhance the bandwidth of microstrip antennas, the main techniques consisting of enlarging the substrate thickness and modifying the main radiator with a complicated shape [3]. Some publications have appeared to address the bandwidth enhancement for SPA by modifying the feed rather than the patch itself [4-7]. A coplanar configuration was used in [4], a loop loaded feed arrangement was utilised in [5] and a microstrip offset rectangular loop feed was designed in [6]. In [7], the centre portion was made concave in a “V” shape to enlarge the bandwidth of the SPA. However, a groove was manufactured along the central part of the radiator on the whole length and the antenna was singly polarised. Together with the manufacturing constraints of maintaining a precise groove over the whole length of the patch, this configuration is likely to increase coupling to unrealistic levels when a dual feed is inserted for polarisation diversity in Multiple Input Multiple Output (MIMO) systems. Moreover, although [2] showed the advantage of using air as the main substrate in SPA for efficiency purposes, the efficiency of the antenna was not considered in [4-7]. However this is crucial for *green* communications.

In this contribution, a novel approach is taken to achieve a wider bandwidth for the SPA antenna presented in [2], whereby the inner part of the coaxial feed is locally tapered in a fan-like manner between the ground plane and the patch. The antenna is designed using the Finite-Difference Time-Domain (FDTD) software developed at the University of Bristol. A second feed is added for dual polarisation. Full antenna characteristics were measured and are presented in this report, including input bandwidth, full radiation patterns, polarisation, coupling between ports and radiation efficiency. The rigorous method established in [2] to determine antenna efficiency is applied again here to derive the efficiency of the designed antenna.

2. Tapered-feed air substrate antenna prototype

The geometry of the antenna is shown in Fig. 1. Brass was used as the patch and ground plane material and an air substrate is employed. The dimension of the square patch was determined by FDTD simulations for a resonance around 2GHz. A tapered feed, displayed in Fig. 1, was used to excite the antenna for broadband purposes. The height of the patch element, as well as the dimensions and locations of the feeds were determined by optimization through many FDTD simulations to give a broad bandwidth for LTE usage. This antenna has two orthogonal feeds, with the centre of each feed placed at 90 degrees to the other feed to enable polarisation diversity at the BS end and therefore increase system capacity.

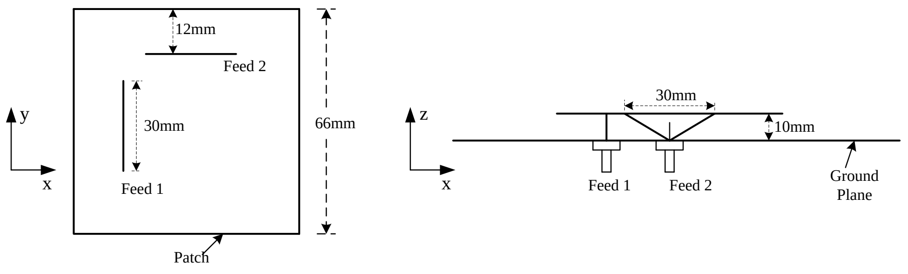
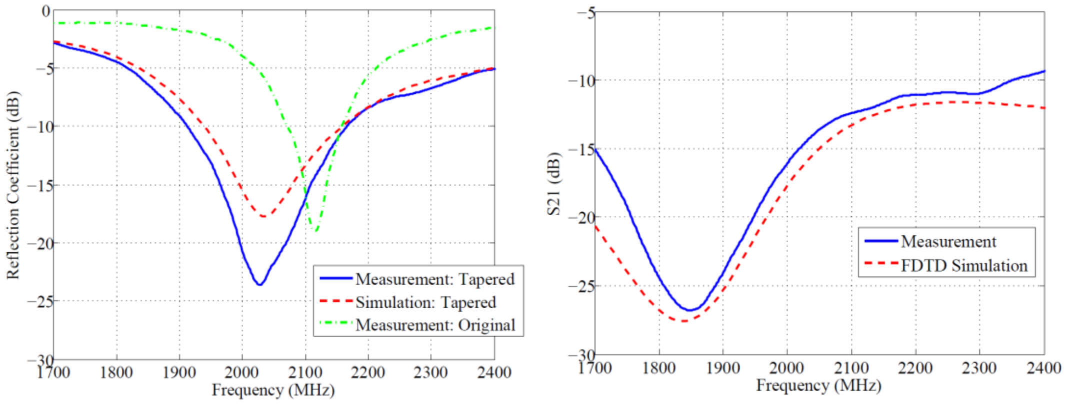


Figure 1: Configuration of the designed antenna.

3. Validation results

The input response of the tapered-feed antenna is shown in Fig. 2 (a), when excited by Feed 1, with Feed 2 terminated on a matched load. The response for Feed 2 excitation is not shown in the paper because it was found to be identical to the response with Feed 1 excitation. The measured result is in good agreement with the FDTD simulated result. Fig. 2 (a) also shows the measured response for the antenna manufactured in [2] which incorporates a traditional coaxial feed and is narrow-band. It can be appreciated that the input response bandwidth is significantly enlarged by tapering the feed as proposed in this design. A reflection coefficient below -10 dB is now achieved from 1910MHz to 2165MHz by measurements. With slight adjustment of the patch size, the full 250 MHz LTE band from 1920MHz to 2170MHz can easily be covered within a reflection coefficient of -10dB.

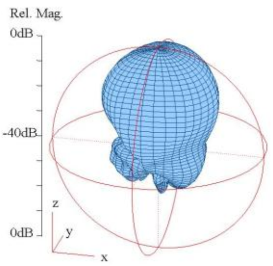
The coupling between the two feeds is displayed in Fig. 2 (b), showing the excellent prediction of the FDTD method as differences between simulation and measurement are within 1dB in the LTE band. The coupling between feeds is low at 1920 MHz (-23dB) rising with frequency to about -12dB in the higher part of the LTE band at 2170 MHz. Average value for the coupling is -16dB in the LTE band.



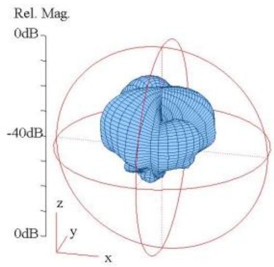
(a) (b)

Figure 2: (a) Measured and simulated input response of the antenna; (b) Measured and simulated coupling between the two orthogonal feeds of the antenna

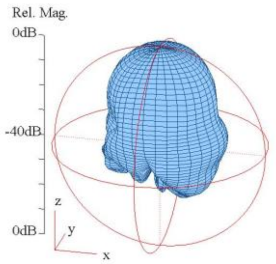
The radiation patterns were measured across the bandwidth using a 30×30 mm ground plane . The full three-dimensional patterns measured at both ends of the bandwidth are shown in Fig.3. Only the patterns for Feed 1 excitation are shown, as patterns for Feed 2 are virtually identical but rotated by 90 degrees. The polarisation purity at 1920MHz is 88%, derived from the 3-D pattern data, which means that 88% of the total input power is transmitted in co-polarisation. The polarisation purity at 2170MHz is 78%.



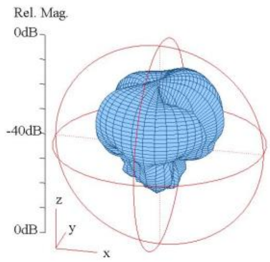
(a) Co-polarisation pattern at 1920MHz



(b) Cross-polarisation pattern at 1920MHz



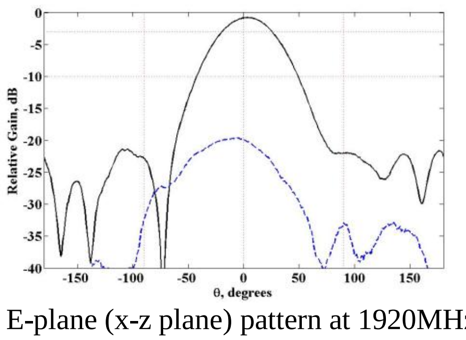
(c) Co-polarisation pattern at 2170MHz



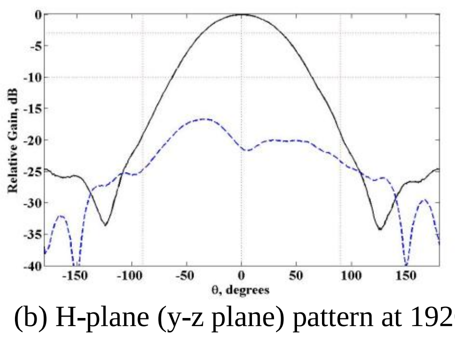
(d) Cross-polarisation pattern at 2170MHz

Figure 3: 3-D measured radiation patterns

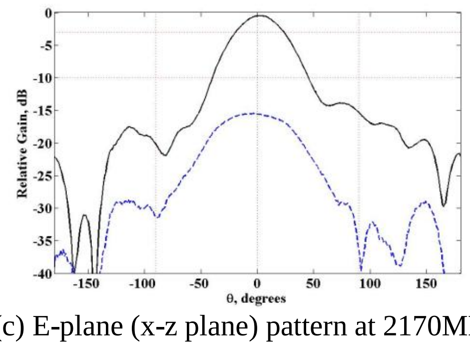
The two-dimensional patterns in two principal planes at both ends of the bandwidth are shown in Fig.4. The cross polarisation levels are low at -18dB below the co-polarised component at 1920MHz. The cross polarisation levels are somewhat higher with -16dB in the E-plane and rising up to -11dB in the H-plane at 2170MHz. However these higher levels are on the outside edge of the main beam and the cross-polar at boresight is lower with levels of -16dB.



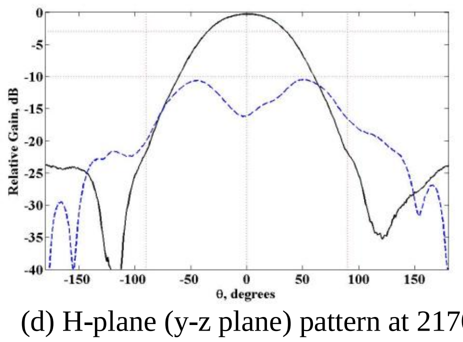
(a) E-plane (x-z plane) pattern at 1920MHz



(b) H-plane (y-z plane) pattern at 1920MHz



(c) E-plane (x-z plane) pattern at 2170MHz



(d) H-plane (y-z plane) pattern at 2170MHz

Figure 4: Measured 2-D radiation patterns (solid line: Co-polar; dotted line: Cross-polar)

The broadside directivity derived from the 3-D pattern data and the half-power (3dB) beamwidth for both E and H planes are shown in Table 1. These remain fairly constant across the band.

Table 1: Directivity and 3dB beamwidth

Frequency (MHz)	Directivity (dBi)	E-plane 3dB beamwidth (degrees)	H-plane 3dB beamwidth (degrees)
1920	10.2	46	72
2170	9.7	44	70

At 2170MHz, the 3 dB beamwidth in the E-plane is reduced from 53 degrees for the original narrow-band antenna in [2] to 44 degrees. However, the H-plane 3dB beamwidth is unchanged at 70 degrees compared to original antenna in [2].

The efficiency of the tapered-feed antenna is measured to be 90% across the bandwidth using the robust and repeatable method developed in [2].

4. Conclusion

A novel feeding mechanism resulting in bandwidth enhancement for a base station antenna in the LTE band was examined in the paper. The antenna was probe fed and the inner part of the coaxial feed was tapered from ground plane to the upper resonating patch in a fan-like manner. This resulted in a measured bandwidth enlarged to 12.5 % from 4% for the original antenna in [2]. The dual polarised antenna is capable to fully cover the 250 MHz requirement for LTE operation from 1920 MHz to 2170 MHz. The -3dB beamwidths were slightly reduced from 53º to 44º in the E plane and unchanged at 70º in the H plane relative to the original antenna in [2]. The cross polar radiation increases slightly with frequency from -18 dB to -11 dB but stays below -16 dB at boresight. Overall, radiation patterns remain relatively constant across the band and the polarisation purity is good with 78% at 2170 MHz and 88% at 1920 MHz. Most importantly, the efficiency of the antenna is high at 90% across the whole LTE band due to the air substrate which is key to achieving high antenna efficiency.

References

[1] MVCE Executive Summary of Core-5 Research Area: Green Radio. [online]. Available: http://www.mobilevce.com/core5research, 2010.

[2] Lingjian Li, G.S. Hilton, D.L. Paul, “High efficiency LTE band base station antenna array for MIMO system evaluation,” Proc. LAPC 2010, Loughborough, UK, pp. 273-276, 2010.

[3] Kin-Lu Wong, Compact and Broadband Microstrip Antennas, Wiley Series in Microwave and Optical Engineering, New-York, pp.1-288, 2002.

[4] Z.N. Chen, M.Y.W. Chia, "Broadband suspended plate antenna with probe-fed strip," IEE Proceedings of Microwaves, Antennas and Propagation, vol.148, no.1, pp. 37-40, 2001.

[5] M.R. Ranjith, P.H. Rao, R. SivaRamaKrishnan, "Microstrip line fed broadband suspended plate antenna," IEEE Antennas and Propagation Society International Symposium, vol.1, pp. 755-758, 20-25 June 2004.

[6] P.H. Rao, M.R. Ranjith, L. Naragani, "Offset fed broadband suspended plate antenna," IEEE Transactions on Antennas and Propagation, vol.53, no. 11, pp. 3839- 3842, November 2005.

[7] Z.N. Chen, "Broadband suspended plate antenna with concaved center portion," IEEE Transactions on Antennas and Propagation, vol.53, no. 4, pp. 1550-1551, April 2005.

Acknowledgments

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