Design of a Multiband Antenna with LTE B13 MIMO Characteristic in Mobile Handsets

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1. Introduction

The rapid growth in the application of mobile communication systems means that many functions are to be integrated into one mobile device. A single handset is now required to deal with multistandard services such as voice, data, video, broadcasting, and digital multimedia. This development had led to a great demand for compact multiband antenna designed specifically to handle multistandard services [1]. Furthermore, in modern wireless communication systems, high data rate is required over band limited channels. Multiple input multiple output (MIMO) systems having received a growing amount of interest in recent years. It can utilize to increase channel capacity without sacrificing additional spectrum or transmitted power [2]-[3]. For adopting these wireless devices, internal antennas are generally required to be capable of covering the frequency band of GSM850/900/1800/1900 and WCDMA B1/B2/B4/B5/B8. In addition, the ever increasing implementation of 4G devices further increases the bandwidth requirement in order to cover the LTE B13(746-787 MHz, USA). In the lower operating frequency of the LTE system, as compared to the WiFi and cellular standards, the antenna in handheld devices such as a smartphone must be electrically small.

In this paper, firstly a very compact and low-height small internal antenna is proposed for the GSM850/900/1800/1900 and WCDMA B1/B2/B4/B5/B8. The proposed antenna is a PIFA with three resonant elements in order to reduce the antenna's volume and to enhance its performance. The proposed antenna with a lower height (5mm) and smaller surface area in comparison to those of internal antennas proposed in [4]. Secondly, we designed the MIMO antenna for LTE B13. Finally, to demonstrate the MIMO characteristics, the envelope correlation coefficient (ECC), isolation characteristics have been investigated for the various LTE B13 Rx antenna arrangements.

2. Antenna Configuration and Results

2.1 Antenna Structure and Design

For limited height devices, a novel low profile version of the PIFA is presented in Figure 1. In case of the multiband antenna, as can be seen in Figure 1(b), it consists of three major parts to resonate three poles: the longest path (blue line) for low band (GSM850/900 and WCDMA B5/B8), a rectangular loop-type resonator (yellow line) and the shortest path (red line) for high band (GSM1800/1900 and WCDMA B1/B2/B4) to cover various wireless communication bands. The proposed antenna occupies a volume of 32 mm × 10 mm × 5 mm and is mounted on the top of a ground plane measuring 66 mm × 110 mm × 0.8 mm. The proposed antennas are fed by a cable that is directly soldered to the feed line and crimped to the ground plane. The schematic configuration of the proposed MIMO (LTE B13 R/Tx and Rx) antenna is shown in Figures 1(c) and 1(d). The proposed antenna size is small enough to be installed in practical mobile handsets. By folding the antenna lines, the dimension of the antenna can be further reduced. The distance between multiband antenna and LTE B13 R/Tx antenna is 12.5 mm. For the LTE B13 Rx antenna, the shape is almost similar to the LTE B13 R/Tx antenna. The proposed LTE R/Tx and Rx antennas occupy a volume of 21.5 mm × 10 mm × 5 mm. The optimized dimensions of the antenna are shown in Figure 1. The location of LTE B13 Rx antenna (location of the LTE B13 R/Tx antenna is fixed as shown in Figure

1(a)) with respect to the handset is a very important feature, as it influences many different performances. In our paper, the performance at seven different locations were compared : Top Left_vertical(TLv), Top Left_horizontal (TLh), Top Right_vertical(TRv), Top Right_horizontal (TRh), Top Center(TC), Middle Left(ML), and Middle Right(MR). The impedance matching over the low band can be tuned independently by L_{low}. Figure 3 shows the measured return loss for the proposed main antenna as a function of L_{low} for values between 11.5 and 16.5 mm. Although little difference is observed for the high band, the frequency range for the low band varies with L_{low}. As the total length of the L_{low} increases, the resonant frequency shifts down, thus enhancing the impedance matching around low band of interest. For the LTE B13 R/Tx and Rx antennas, when the length of the $L_{R/Tx}$ and L_{Rx} were increased, the resonant frequencies were lowered and the return loss characteristic was improved as illustrated in Figures 4(a) and 4(b). The following Figure 5 shows the measured scattering parameters (S_{11}, S_{12}, S_{21}, and S_{22}) for seven arrangements of the LTE B13 Rx antenna. The isolation characteristic (S_{12} and S_{21}) of the antennas in the straight position (TLv, TLh, and ML) is lower than those of the antennas in the diagonal position (TC, TRv, TRh, and MR) in respect of the LTE B13 R/Tx antenna.

2.2 ECC, Radiation Patterns, and Gain

The ECC is an important parameter in the calculation of the diversity performance. Multiple methods of calculating the ECC are available using far-field radiation pattern data. A simplified form of the expression is written in [5] as

$$\begin{aligned}
\rho_e &= \frac{N}{D_1 D_2} \\
N &= \left| \int_0^{2\pi}\int_0^{\pi} (\mathrm{XPR}E_{\theta 1}(\theta,\phi)E^*_{\theta 2}(\theta,\phi)P_\theta(\theta,\phi) + E_{\phi 1}(\theta,\phi)E^*_{\phi 2}(\theta,\phi)P_\phi(\theta,\phi)) \sin\theta d\theta d\phi \right|^2 \\
D_1 &= \left| \int_0^{2\pi}\int_0^{\pi} (\mathrm{XPR}EG_{\theta 1}(\theta,\phi)P_\theta(\theta,\phi) + G_{\phi 1}(\theta,\phi)P_\phi(\theta,\phi)) \sin\theta d\theta d\phi \right| \\
D_2 &= \left| \int_0^{2\pi}\int_0^{\pi} (\mathrm{XPR}EG_{\theta 2}(\theta,\phi)P_\theta(\theta,\phi) + G_{\phi 2}(\theta,\phi)P_\phi(\theta,\phi)) \sin\theta d\theta d\phi \right|
\end{aligned} \tag{1}$$

Computation of the ECC, as described equation (1), requires knowledge of the radiation pattern and involves integral calculation, which can be time-consuming to measure and calculate. To make this process easier, an alternate method for calculating the ECC from the *S*-parameters was calculated from the experimental complex-parameters using the following equation [6]:

$$\rho_e = \frac{\left| S_{11}^* S_{12} + S_{21}^* S_{22} \right|^2}{(1-(|S_{11}|^2 + |S_{21}|^2))(1-(|S_{22}|^2 + |S_{12}|^2))} \tag{2}$$

Table 1 summarized the measured and calculated ECC from the radiation patterns and S-parameters. The differently calculated results have acceptable agreement. From these results, the ECC of the straight Rx antennas is lower than those of diagonal Rx antennas. It can be seen that the results between ECC and isolation characteristic are relative. In other word, the ECC is lowed as the S_{12} and S_{21} between two antennas is improved. The proposed three-type antennas are measured in the far-field measurement system which 3D radiation patterns are obtained. It can be seen that antenna has patterns close to be omnidirectional pattern. Finally, the antenna average and peak gain are measured over the frequency bands of interest. For the low band of the main antenna, a peak gain variation within 1.1 dB between -2.1 and -3.2 dBi is measured. In the upper band, where antenna average gain varies from -0.7 to -2.9 dBi and the peak gain is better than 3.3 dBi. In case of LTE antenna, the measured peak antenna gain is more than -0.7 dBi. As can be seen, the antenna gains over the frequency bands of interest are reasonably good.

3. Conclusion

A compact and low profile antenna having LTE B13 MIMO characteristic has been designed and analyzed. For the multiband antenna, the measurement results clearly demonstrated that the antenna operates effectively in all the required GSM850/900/1800/1900 and WCDMA B1/B2/B4/B5/B8 wireless bands. By using different antenna position for LTE B13 Rx, it was possible to study about several performance metrics such as isolation and ECC in MIMO mode. At TLh get a best performance about ECC from radiation patterns and S-parameters that set the ECC goal under 0.5. As a general conclusion, it is important to remark that the compact size, simple structure, omnidirectional properties, multiband coverage, and reasonable MIMO characteristics can make the proposed antenna an attractive candidate for portable multistandard devices.

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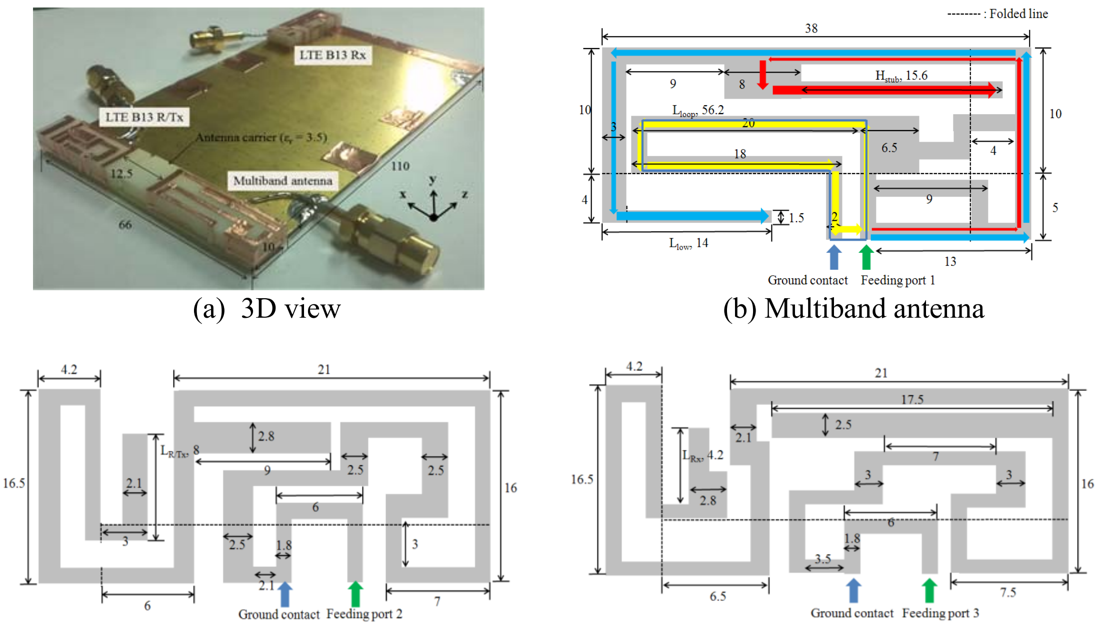
References

[1] C. W. Chiu and F. L. Lin, “Compact dual-band PIFA with multi-resonators”, *Electron Lett.*, vol. 38, pp. 538–554, 2002.
[2] T. Bolin, A. Derneryd, G. Kristensson, V. Plicanic, and Z. Ying, “Two antenna receive diversity performance in indoor environment”, *Electron. Lett.*, vol. 41, no. 2, pp. 1205–1206, 2005.
[3] Murch, R.D., and Letaief, K.B. “Antenna systems for broadband wireless Access”, *IEEE Commun. Mag.*, vol. 40, pp. 76–83, 2002.
[4] Wu, C.H., and Wong, K.L., “Hexa-band internal printed slot antenna for mobile phone application”, *Microw. Opt. Technol. Lett.*, vol. 50, pp. 35–38, 2008.
[5] S. Stein, “On cross coupling in multiple-beam antennas”, *IRE Trans.Antennas Propagat.*, vol. 10, no. 5, pp. 548–557. 1962.
[6] C. Blanch, J. Romeu, and I. Corbella, “Exact representation of antenna system diversity performance from input parameter description”, *Electron. Lett.*, vol. 39, no. 9, pp. 705–707, 2003.



(a) 3D view
(b) Multiband antenna
(c) LTE B13 R/Tx
(d) LTE B13 Rx

Figure 1: The Geometry of the Proposed Antennas [Unit: mm].

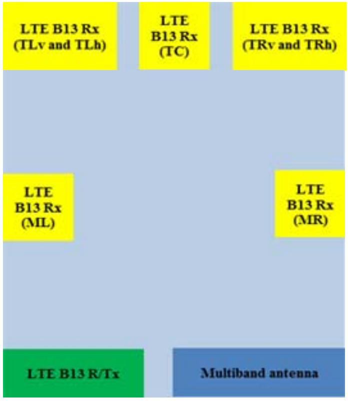


Figure 2: LTE B13 Rx Antenna Arrangements

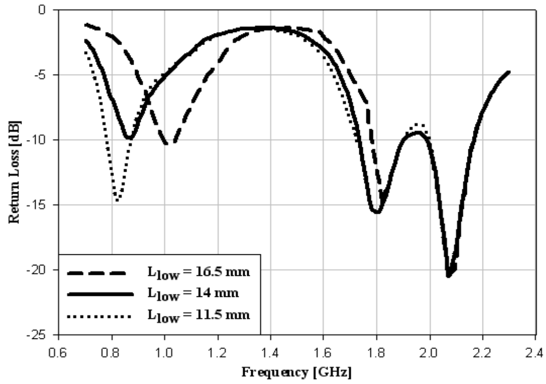
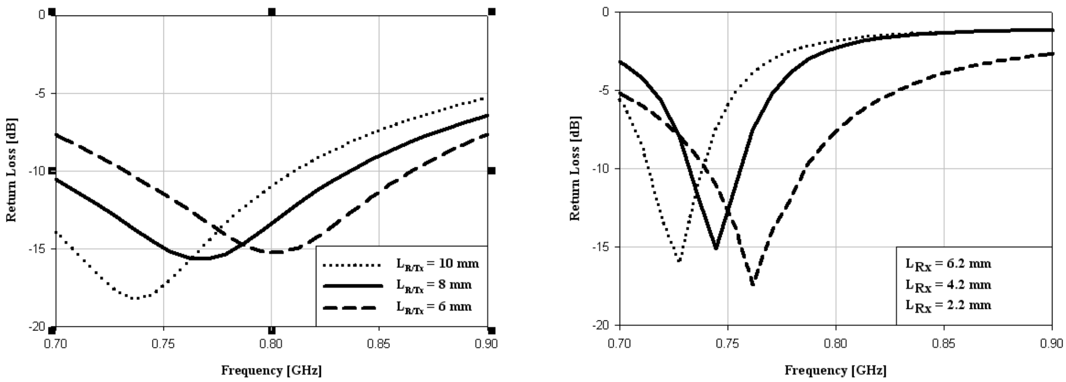


Figure 3: Measured Return Loss (L_{low})



(a) LTE B13 R/Tx ($L_{R/Tx}$) (b) LTE B13 Rx antenna (L_{Rx})

Figure 4: Measured Return Loss Characteristics

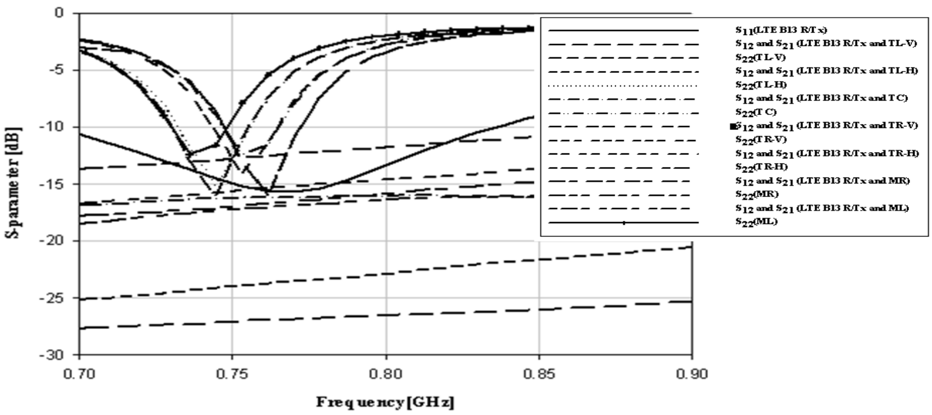


Figure 5: Measured S-parameters Characteristics between LTE B13 R/Tx and Rx antennas.

Table 1: Measured and Calculated ECC.

LTE B13 Rx antenna position	ECC from radiation patterns	ECC from S-parameters
TLv	0.48	0.52
TLh	0.35	0.47
ML	0.43	0.45
TC	0.57	0.69
TRv	0.92	0.89
TRh	0.87	0.92