A Decoupling Method of Two Planar Inverted-F Antennas by Using Parasitic Element

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***Abstract-* In this study, we investigate a simple method to reduce the mutual coupling between two planar inverted-F antennas (PIFAs). When two antenna elements are located at a very close spacing, the mutual coupling between them become strong. By using a parasitic element (PE), which is linked with a bridge line (BL), and loaded above the PIFAs, the size of the PIFA elements are not need to be adjusted to help them have a good impedance matching and low level of mutual coupling at 2 GHz. In the future, this method is expected to be an easier method to reduce mutual coupling of the array PIFAs, which have more than two antenna elements.**

I. Introduction

In recent years, multiple-input multiple-output (MIMO) application are considered as the potential technology for enhancing the performances, capacity with a high speed transmission rate and have a major role for realizing the next generation communication. Therefore, the integration of multiple antenna on a mobile handset terminal becomes one of most important prerequisite, because the handset only has small space for installing multiple antenna elements on it. Moreover, when the antennas are located at a very close spacing on the same ground plane of a mobile handset terminal, improving their isolation is still remains a problem, since the mutual coupling occurring between the radiators adversely affect the total antenna efficiency [1].

So far, many decoupling solutions have been proposed using various arrays of conventional antenna element. Amongst them, the decoupling method using the well-known BL is an effective method, which provided significantly good isolation and efficiency for multiple antenna [2,3]. However, after linking directly two antennas with the BL, resonant frequency usually shifts to higher frequency. Therefore, the antenna size has to be increased in size for the resonant frequency shifting to the desired frequency. Moreover, when the number of antenna element increases as in MIMO, it is difficult to design when all of them have to be linked one by one directly with the BLs.

In this study, firstly, we study about the coupling reduction effect of BL, when it is linked directly between two PIFAs. Subsequently, we investigate another decoupling method using PE, which is loaded above the two element PIFAs and linked with a BL. Finally, instead of changing the size of PIFAs, the size of the PE is adjusted to help PIFAs have a good impedance matching and low level of mutual coupling at 2 GHz. So that, the size of the PIFA elements are not need to be changed.

II. Configuration of Antenna

A. Configuration of PIFA

Fig. 1(a) shows the configuration of the two PIFA elements mounted on a rectangular ground plane of size 120 mm×45 mm; the ground plane represents a shielding plate in a mobile handset. The size of PIFAs have been adjusted so that it resonates at a frequency of around 2 GHz by the size 20 mm×19 mm. Two PIFA elements are symmetrically mounted with respect to the centerline of ground plane and separated by a very small spacing 7 mm. The height of these antennas is 7 mm. Each PIFA element is fed by a 50 Ω source at feeding strip and the spacing between feeding strip and shorting strip is 11 mm. The PIFA elements and ground plane are made of copper with thickness 0.3 mm and 0.5 mm, respectively.

B. Configuration of PIFA with bridge line

Fig. 2(a) shows the configuration of PIFAs with a BL. We use the BL with the length l = 14 mm and wide 0.5 mm to link two PIFA elements. The point of contact between two PIFA elements and BL is at feeding strip.

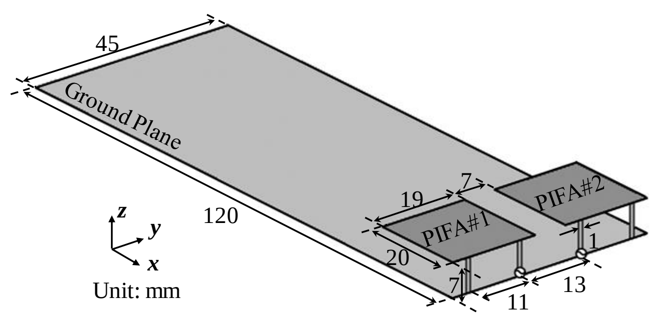
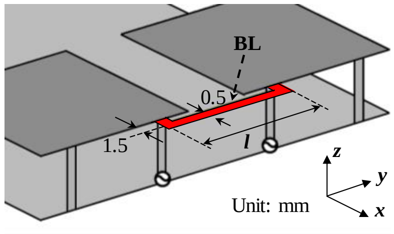
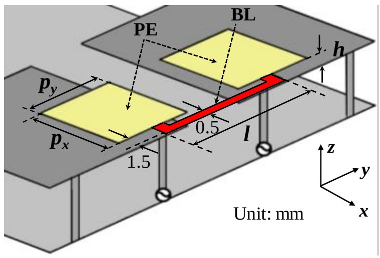


Fig. 1 Two elements PIFA on ground plane



(a)



(b)

Fig.3 Configuration of PIFAs with (a) BL linking directly, (b) PE and BL loading above

C. Configuration of PIFA with PE and BL

Fig. 2(b) shows the initial PE loading above PIFAs. We utilize the PE, which have the initial size of 1/4 size of PIFA (p_x =10 mm, p_y=9.5 mm) and loaded on the top edge of PIFAs with the air gap between PE and PIFAs h = 0.6 mm. A BL with the length l = 14 mm and wide 0.5 mm is used to link two PE. Moreover, the point of contact between two PE and BL is right above feeding strip.

III. EFFECT OF BL AND PE TO PIFAS

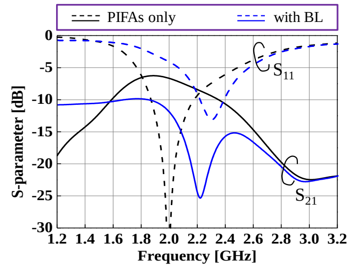
A. S-parameter when linking PIFAs with BL and loading PE

Fig. 3(a) shows the S-parameter of the PIFAs only and PIFAs with BL. In the case of PIFAs only, a good impedance matching is obtained at 2 GHz. However, due to the small spacing between two PIFAs, it can be observed that the S_{21}, which presents the level of mutual coupling, is approximately − 6 dB at the desired frequency 2 GHz. From this results, we know that the mutual coupling between two PIFAs is very strong. However, in the case of PIFAs after linking with BL, the mutual coupling is strongly reduced at frequencies around 2.2 GHz.

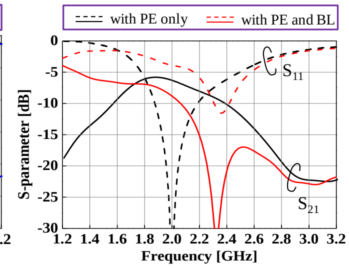
Fig. 3(b) shows the S-parameter of PIFAs after loading PE only and PE with BL linking. In the case of PE only, there is almost no change compared to S-parameter of PIFAs only in Fig. 3(a). However, in the cases of PE with BL linking, the mutual coupling is strongly reduced at frequencies around 2.3 GHz. This result is almost similar to the result when PIFAs were linked directly with the BL as shown in Fig. 3(a)

B. Changing the size of PIFAs

In the both case shown in Fig. 3(a) and (b), as can be seen, the resonant frequency shifted to higher frequency and the impedance matching is significantly deteriorated compared to PIFAs only. Therefore, it is necessary to adjust some parameters



(a)



(b)

Fig.3 S parameters of (a) PIFAs only and PIFAs with BL, (b) PIFAs with PE only, and, PIFAs with PE and BL

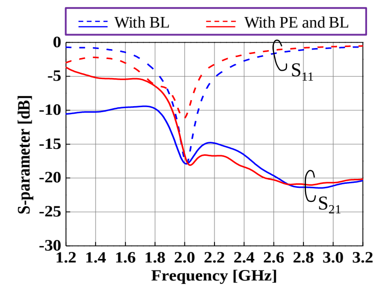


Fig.4 S parameters after changing PIFAs size

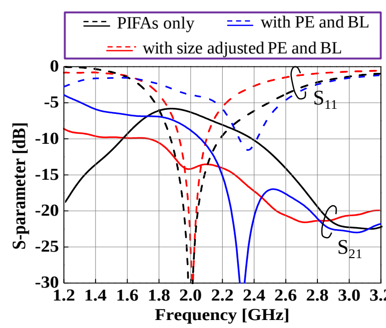


Fig.5 S parameters of PIFA after changing PE size

in size of PIFAs to do three works: shifting the resonant frequency to 2 GHz, improving impedance matching at 2 GHz, and maintain the low level of mutual coupling less than −10 dB.

Fig. 4 shows the S-parameter after adjusting the size of PIFAs. The size of them are changed from 20 mm×19 mm to 24 mm×19 mm for the case of PIFAs with BL, and to 25 mm×19 mm for the case of PIFAs with PE and BL. In both cases, the lowest mutual coupling is reduced to −17.8 dB and the impedance matching is observed at 2 GHz. However, the impedance matching is significantly deteriorated compared to PIFAs only.

C. Changing the size of PE

In order to propose a simple decoupling method, which is no need to change the size or shape of antenna, instead of changing PIFAs as shown in Fig.4, we changing the size of PE. Fig. 5 shows the S parameters of PIFAs when the length p_x of

PE is changed from 10 mm to 26 mm. As a result, a good impedance matching is observed at 2 GHz and the level of mutual coupling between two PIFAs is reduced to −14.1 dB compared to the PIFA only.

IV. Conclusion

In this study, we proposed a simple method to reduce the mutual coupling of two PIFAs. By using PE loading above on the PIFAs, it is not need to change the size of the antenna, and a low level of mutual coupling is observed at the desired frequency. In the future, this method is expected to be an easier method to reduce mutual coupling of the array PIFAs, which have more than two antenna elements.

References

[1] [1] P.-S. Kildal, and K. Rosengren, "Correlation and capacity of MIMO systems and mutual coupling, radiation frequency, and diversity gain of antennas: simulation and measurements in a reverberation chamber", *IEEE Commun. Mag*., vol.42, no.12, pp.104-112, Dec. 2004.

[2] [2] A. Diallo, C. Luxey, P. Thuc, R. Staraj, and G. Kossiavas, "Study and reduction of the mutual coupling between two mobile phone PIFAs operating in the DCS1800 and UMTS bands", *IEEE Trans. Antennas Propag*., vol.54, no.11, pp.3063-3073, Nov, 2006.

[3] [3] Y. Kim, T. Hayashi, Y. Koyanagi, and H. Morishita, "Compact built-in handset MIMO antenna using L-shaped monopole antennas", *IEICE Trans. Commun.*, vol.E91-B, no.6, pp.1743-1751, Jun. 2008.