Decoupling Method for Two-element MIMO Antenna Using Meander Branch Shape

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***Abstract*—Recently, MIMO (Multiple-Input Multiple-Output) technology is introduced in various small wireless applications. If MIMO antennas are mounted on such terminals, a strong mutual coupling is occurred because a distance between antenna elements is close. To solve this problem, a decoupling method for 2x2 MIMO connecting between two antenna elements by inductors has been developed. However in this method, the inductors caused loss and this is the factor of deterioration in radiation efficiency. In this paper, a new decoupling method without connecting between two antenna elements is proposed.**

Keywords—MIMO; mutual coupling; decoupling; admittance

I. INTRODUCTION

In recent years, MIMO technology is introduced in various small wireless terminals for the purpose of an increase communication speed and communication capacity. However if MIMO antenna is mounted on limited space such as mobile phones and USB Wi-Fi adapters, a strong mutual coupling occurs because a distance between antenna elements is close. The strong mutual coupling causes lower radiation efficiency and a higher correlation coefficient. Therefore throughput of MIMO communication is decreased. If the mutual coupling can be reduced, antennas obtain high throughput because of high radiation efficiency and lower correlation coefficient. Moreover, if MIMO antennas can be arranged closely, the terminals obtain small volume, and a good appearance.

A lot of decoupling methods for 2x2 MIMO have been developed. The decoupling method connecting between two antenna elements was utilized inductors [1]. It is known that the mutual coupling is reduced at the frequency of $|Y_{21}| \approx 0$. In this method, antennas were obtained $|Y_{21}| \approx 0$ at desired frequency by utilizing inductors. However in this traditional method, increase of cost and loss power by inductors is concerned. This loss is the factor of deterioration in radiation efficiency, it is desirable that the loss of inductors be free to obtain high radiation efficiency.

This paper proposes a new decoupling method without connecting between two antenna elements by inductors. A decoupling principle is the same as the traditional one [1] and to obtain a decoupling condition at desired frequency without using inductors, the branch shape is proposed.

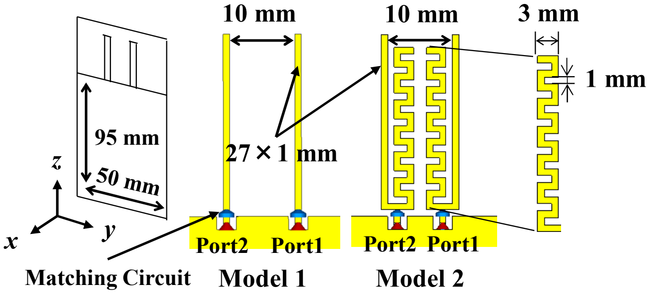

Fig.1. Antenna models. (Model 1 and Model 2)

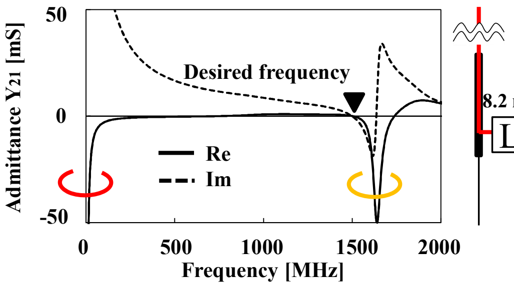

Fig.2. Y_{21} and electrical path (Model 1 with previous decoupling method).

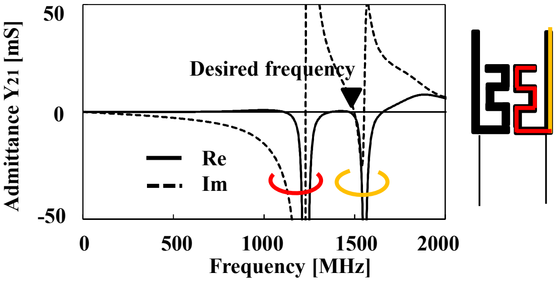

Fig.3. Y_{21} and electrical path (Model 2).

II. PROPOSED MODEL

Fig.1 shows two models of 2-element MIMO antenna. These models can operate at 1.5 GHz. Model 1 shows 2-element monopole antenna of 27×1 mm is placed in 10 mm (0.05λ) in the closest distance. Model 2 shows a proposed antenna which is the same antenna further distance as Model 1. The proposed antenna line width is 1 mm. These models are implemented on 130×50×1.6 mm one side copper plate FR4 substrate, the ground plate size is 95×50 mm.

Fig.2 shows Y_{21} and electrical path of Model 1 with traditional decoupling method. This antenna is disposed 8.2 nH inductor between two antenna elements, two types of Y_{21}

resonance are generated as sandwich between 1.5 GHz. Therefore the antenna is obtained $|Y_{21}| \approx 0$ at 1.5 GHz. It may be suspected that the inductor produced two different electrical paths as Fig.2 because two types of Y_{21} resonance are generated after the inductor is disposed. In Fig.3, Y_{21} and electrical path of Model 2 is shown. Model 2 is a branch shape which has two different electrical paths the same as Model 1. The branch shape can obtain two types of Y_{21} resonance and the antenna is satisfied with the decoupling condition at 1.5 GHz. When the branch antenna is selected to satisfy with the decoupling condition at 1.5 GHz, the antenna length is long. Therefore, to achieve small antenna, the proposed antenna is used meander shape partially.

III. PROPOSED ANTENNA PERFORMANCES

A. *S-parameters*

S-parameters of Model 1 are shown in Fig.4. Murata's LQG15 inductors and capacitors are used in matching circuits. S_{11} is less than -10 dB at 1.5 GHz. On the other hand, S_{21} is -2.2 dB at 1.5 GHz. This is because strong coupling is occurred due to closely spacing of two monopole antenna elements. Fig.5 shows S-parameters of Model 2. S_{21} is -16.8 dB at 1.5 GHz. For this reason, decoupling is performed at 1.5 GHz, the antenna length is selected to satisfy with $|Y_{21}| \approx 0$ at 1.5 GHz.

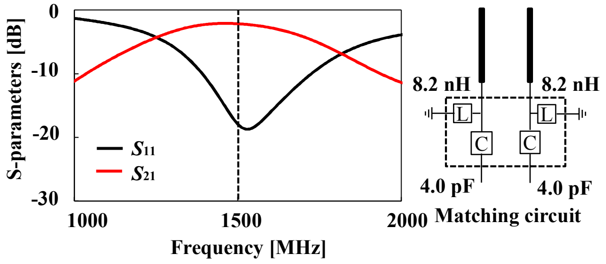

Fig. 4: S-parameters (Model 1).

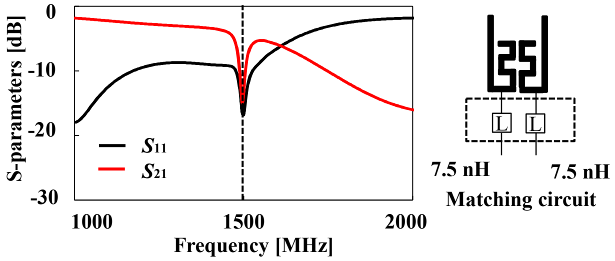

Fig. 5: S-parameters (Model 2).

B. *Correlation coefficient*

Correlation coefficient ρ is a figure of merit for MIMO performance and a measure for the similarity between two radiation patterns. Using equation (1), correlation coefficient is calculated from both antennas of amplitude and phase radiation pattern E in all angles. In TABLE I, correlation coefficient of both Models and computational condition are shown. From the TABLE I, the correlation coefficient of Model 2 is reduced at 1.5 GHz.

$$\rho = \frac{\left|\int_0^{2\pi}\int_0^{\pi}\left(XPR\cdot E_{\theta1}\cdot E_{\theta2}^*\cdot P_\theta + E_{\varphi1}\cdot E_{\varphi2}^*\cdot P_\varphi\right)d\Omega\right|^2}{\left\{\int_0^{2\pi}\int_0^{\pi}\left(XPR\cdot E_{\theta1}\cdot E_{\theta1}^*\cdot P_\theta + E_{\varphi1}\cdot E_{\varphi1}^*\cdot P_\varphi\right)d\Omega \times \int_0^{2\pi}\int_0^{\pi}\left(XPR\cdot E_{\theta2}\cdot E_{\theta2}^*\cdot P_\theta + E_{\varphi2}\cdot E_{\varphi2}^*\cdot P_\varphi\right)d\Omega\right\}} \qquad (1)$$

TABLE I. CORRELATION COEFFICIENT AND COMPUTATIONAL CONDITION.

Model 1	0.28
Model 2	0.16

XPR=1,
$P_\varphi = P_\theta = 1$

C. *Radiation pattern*

A radiation pattern of the proposed antenna has also been evaluated. With the Port 1 excited while the other port is terminated with 50 Ω matching loads, the radiation patterns of the both Models at 1.5 GHz in *xy*-plane are given in Fig.6, 7. In comparison Fig.6 and Fig.7, E_φ radiation pattern of Model 2 leans outside. It may be suspected that a low correlation coefficient of Model 2 is due to these changes in radiation pattern.

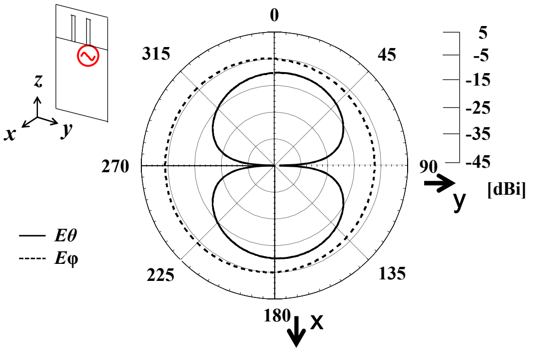

Fig. 6: Radiation pattern at 1.5 GHz in *xy*-plane (Model 1).

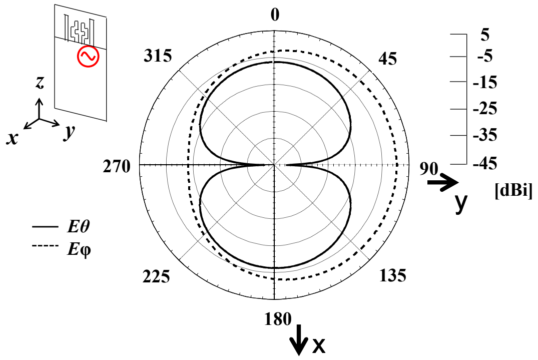

Fig. 7: Radiation pattern at 1.5 GHz in *xy*-plane (Model 2).

IV. CONCLUSION

This paper presented the new decoupling method without connecting between two antenna elements using the meander branch shape. Compared to the 2-element monopole antenna (w/o decoupling), mutual coupling was reduced 14.6 dB at 1.5 GHz in the meander branch antenna (with decoupling). Moreover, the proposed antenna obtained a low correlation coefficient. Based on these results, it confirmed that the proposed method can reduce mutual coupling without connecting between two antenna elements by inductors.

REFERENCES

[1] H. Sato, Y. Koyanagi, K. Ogawa, M.Takahashi, "A Method of Dualfrequency Decoupling for Two-element MIMO Antenna," PIERS Proceedings, 1853 - 1857, August 12-15, Stockholm, 2013.