Broadband Characteristic of Dual-Band Decoupling for closely spaced antennas

Keita Kuriyama[1], Hiroshi Sato[2], and Masaharu Takahashi[1]
[1]Graduate school of Engineering, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba, Japan
[2]Panasonic Corporation, 600 Saedocho, Tsudukiku, Yokohama, Kanagawa, Japan

***Abstract*—Recently, the technology of MIMO (Multiple-Input Multiple-Output) using multiple antennas and CA (Carrier Aggregation) using multiple frequency bands are introduced in a mobile terminal. If plural MIMO antennas are installed closely, mutual coupling between the antennas must be reduced to suppress deterioration of radiation efficiency and increase of the correlation coefficient. In previous studies, a decoupling method for dual-band using trifurcation elements has been confirmed. This paper proposes a broadband technique with branch elements.**

***Index Terms*— MIMO antenna, Dual-band, Mutual coupling, Decoupling, broadband**

1. Introduction

In recent years, the technology of MIMO (Multiple-Input Multiple-Output) using multiple antennas and CA (Carrier Aggregation) using multiple frequency bands are introduced in a mobile terminal. If multiple antennas of multiband are installed, channel capacity is improved in proportion to increasing the number of antennas and operating frequencies. However, a strong mutual coupling is caused between closely spaced antennas. Hence, throughput of MIMO transmission is decreased. Therefore, if MIMO introduce in a small limited space such as mobile terminals, countermeasures for mutual coupling must be devised.

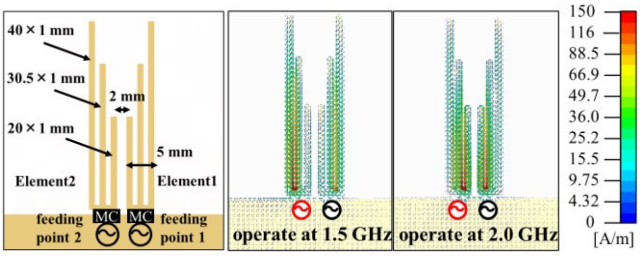
To solve this problem, a decoupling method between two element MIMO antennas for dual-band using branch elements has been proposed [1]. However, in previous study, the fractional bandwidth that S11 and S21 are less than -10 dB are narrow at 1.5 and 2.0 GHz. The reason is because a bandwidth of S21 at 1.5 GHz, and a bandwidth of S11 at 2.0 GHz are narrow.

This paper proposes a broadband technique in decoupling method using branch elements.

2. Broadband Characteristic

(1) Broadening bandwidth of S_{11}

It is known that the operating frequency bandwidth of monopole antenna can be enhanced by expanding a width of antenna elements. This approach can also be used in the branch elements. Fig. 1 shows the design of previous models of closely spaced two element MIMO antennas using trifurcation elements and current distribution at 1.5 and 2.0 GHz. The feeding point 2 is stimulated 1 W while



(a) Previous model (b) Current distribution

Fig. 1. Previous model and Current distribution at 1.5 and 2.0 GHz

the other point is in 50 Ω terminal condition. If the previous model operates at 1.5 GHz, the current flows concentrated to a part of the long and middle length branches. On the other hand, if at 2.0 GHz, the current flows to a part of the short and middle length branches. Hence, by expanding middle length branch or trifurcation elements width, the operating frequency bandwidth at 1.5 and 2.0 GHz can be widened.

(2) Broadening bandwidth of S_{21}

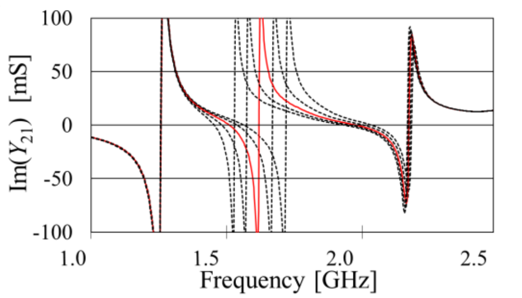
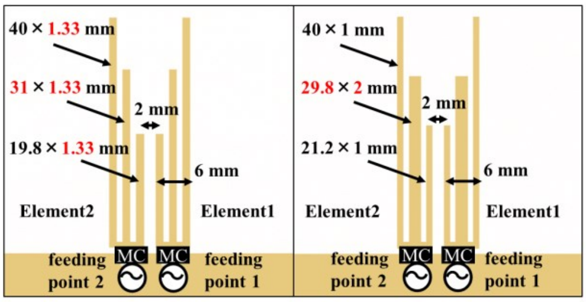


Fig. 2. Imaginary parts of admittance Y_{21}

Previous study shows that the mutual coupling is reduced at the frequency of admittance $Y_{21} \approx 0$ between feeding points [2]. By the trifurcation structure of different length, three types Y_{21} resonance frequencies are generated. Between two resonance frequencies, Re (Y_{21}) is close to 0, and Im (Y_{21}) is also close to 0. Fig. 2 shows imaginary parts of Y_{21} in the trifurcation model without matching circuits. The length of the long branches is fixed at 40 mm and short branches is fixed at 20 mm. The length of middle branches varies in the range of 30 ± 2 mm at 1 mm intervals. If the middle length branches are shorter, the interval between the resonances are spread across the 1.5GHz. Therefore, the slope of Im (Y_{21}) around 1.5 GHz becomes gentle, and the range of $Y_{21} \approx 0$ can be widened. Because of this, the decoupling bandwidth can be enhanced around 1.5 GHz.

3. Antenna Design



(a) Model 1 (2) Model 2

Fig. 3. Analysis models

In Fig. 3, two models of closely spaced two element MIMO antennas are shown. These models are designed the trifurcation length to perform decoupling at 1.5 and 2.0 GHz. In the previous model, the width of the each branch elements are 1 mm. In the Model 1, the width of the each branch elements are expanding to 1.33 mm. Because of this, the bandwidth of S_{11} can be widened than the previous model. In the Model 2, the width of the only middle length branch is 2 mm, and the others are 1 mm. In addition, the middle length branch is shorter than the model 1. Therefore, in particular at 1.5 GHz, the bandwidth of S_{11} and S_{21} can be widened. These trifurcation elements that have occupied 40 mm × 6 mm areas are symmetrically arranged in 2 mm in the close distance. The distance of 2 mm is one-hundredth of wavelength at 1.5 GHz. These antennas are installed on one side copper plate FR4 substrate and the ground plate size is 90 mm × 50 mm. In all models, matching circuits are installed in feeding points to operate at 1.5 and 2..0 GHz

4. Results and Discussion

(1) S-parameters and Fractional bandwidth

S-parameters of analysis models with matching circuits are shown in Fig. 4. In these models, S_{11} and S_{21} are less than -10 dB at the desired two frequencies. Hence, It is confirmed that decoupling is performed at 1.5 and 2.0 GHz. Table I shows the fractional bandwidth that S_{11} and S_{21} are less than -10 dB of all models. In previous model, the fractional bandwidth is 1.7 % at 1.5 GHz and 2.6 % at 2.0 GHz. In the Model 1, 1.9 % at 1.5 GHz and 3.9 % at 2.0 GHz. This is because that S_{11} is widened by expanding antenna radiation elements. In model 2, in addition to S_{11}, S_{21} is also widened at 1.5 GHz by spreading the range of $Y_{21} \approx 0$. Therefore, the fractional bandwidth is improved to 2.5 % at 1.5 GHz and 3.8 % at 2.0 GHz.

(2) Radiation Efficiency

Fig. 5 shows the radiation efficiency at desired two frequency bands of all models. In two frequency bands, the Model 2 has the highest radiation efficiency in the wider frequency band. This is due to the fractional bandwidth of S_{11} and S_{21} is improved.

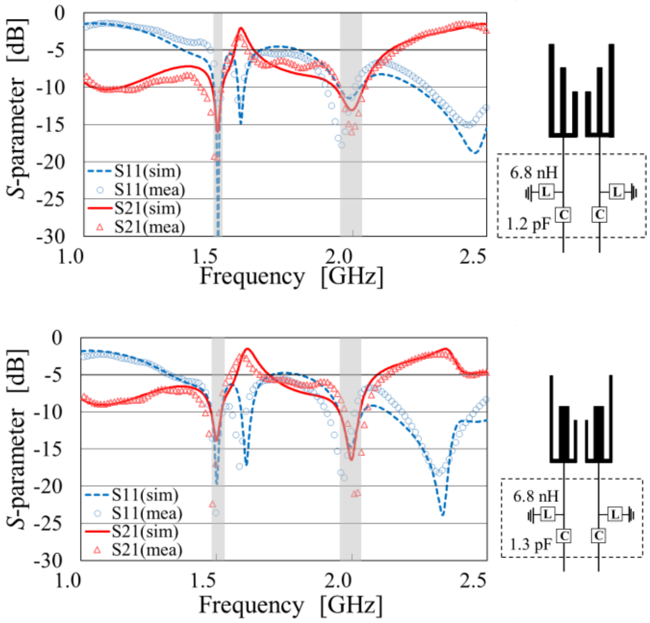
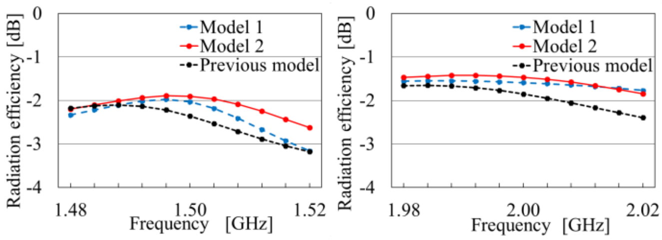


Fig. 4. S-parameters with matching circuits

TABLE I. FRACTIONAL BANDWIDTH

Fractional bandwidth[%]	Previous model	Model 1	Model 2
1.5 GHz	1.7	1.9	2.5
2.0 GHz	2.6	3.9	3.8



(a) 1.5 GHz (b) 2.0 GHz

Fig. 5. Radiation efficiency

5. Conclusion

This paper proposes a broadband technique with branch elements. In this method, by expanding the branch width of the current flows concentrated, the frequency bandwidth of S_{11} can be enhanced. In addition, by optimizing the branch length to spread the range of $Y_{21} \approx 0$, S_{21} can be enhanced. Moreover, the radiation efficiencies are improved. As a result, these techniques can obtain the broadband characteristic in decoupling method using branch elements.

References

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