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A triple-band decoupling method for MIMO antennas without connection

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Abstract: In recent years, MIMO technology is used in many mobile terminals to increase channel capacity. MIMO uses multiple antennas, however, if MIMO antennas are put closely such as a small terminal, a strong mutual coupling occurred. Then it causes decreasing radiation efficiency and channel capacity.

Besides, CA technology which uses multiple frequencies is also utilized. Therefore, reducing the mutual coupling at multiple frequencies is required corresponding to CA. In the previous study, a method of adding a branch element connecting by inductor L and capacitor C has been proposed. In this paper, focusing on the relationship between the number of decoupling frequencies and current paths, we propose a novel triple-band decoupling method without connecting and confirm that the proposed model performed decoupling and increased radiation efficiency.

Keywords: MIMO, CA, decoupling, short stub
Classification: Wireless Communication Technologies

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1 Introduction

MIMO (Multiple-Input Multiple-Output) technology which uses plural antennas and CA (Carrier Aggregation) which operates multiple frequencies are introduced in many mobile terminals to increase channel capacity. If MIMO antennas are inserted to small terminals, plural antennas are needed to put closely from the viewpoint of an installing space and designability. However, a strong mutual coupling by putting plural antennas closely causes deteriorating radiation efficiency, and channel capacity decreases [1]. Therefore, to reduce mutual coupling at multiple frequencies is required corresponding to CA. In the previous study, a method of making antennas branch structure and connecting antennas by inductor L and capacitor C is proposed [2]. However, this method needs to connect antennas, hence, wiring routing is troublesome, and power loss by L and C is occurred. In this paper, focusing on the relationship between the number of decoupling frequencies N_{fd} and current paths, we propose a non-connected triple-band decoupling method.

2 Antenna models and decoupling method

We use simulator CST MW-Studio 2018 [3]. In this paper, 2 elements monopole antennas are a base model assuming 2×2 MIMO shown in Fig. 1(a). This antenna array is implemented on a $140 \times 50 \times 0.8$ mm one-side 35 µm copper plate FR4 substrate whose relative permittivity is 4.3, a ground plate is 100×50 mm. If admittance between antennas Y_{21} set to 0 at desired frequencies, decoupling can be obtained [4]. Fig. 2(a), (b) show S_{11} and Y_{21} respectively of Fig. 1(a). From Fig. 2(a), the downtrend of S_{11} is obtained at around 1.9 GHz, the resonance of Y_{21} also generated at around the downtrend of S_{11} (1.9 GHz). Here, the frequency at which the real and imaginary part of Y_{21} change is defined as "resonance". The downtrend of S_{11} and the resonance correspond to each other, if the downtrend of S_{11} moves higher frequency, the resonance also moves higher. Hence, the frequency of the resonance can be adjusted because of altering monopole element length.

Fig. 1(b) shows the proposed antenna model to decouple at 3 frequencies: 800 MHz, 1.7 GHz and 2.1 GHz. This model is constructed by attaching the long branch element, the short branch element and the short stub to the monopole of Fig. 1(a). The long branch is a meander structure because the antenna volume to z-direction is reduced [5]. Fig. 2(c) shows Y_{21} of eliminated the short branch and the short stub of the proposed model. From this figure, one more resonance is generated at 900 MHz in addition to the resonance of monopole. Then, $Y_{21} = 0$ is obtained 1.3 GHz between two resonances. Therefore, to get $Y_{21} = 0$, engendering two resonances is required. Fig. 2(d) shows Y_{21} of eliminated only the short stub of the proposed model. One more resonance is generated at 2.1 GHz. $Y_{21} = 0$ is obtained at two frequencies 1.3 GHz between resonances of meander (900 MHz) and monopole (1.7 GHz), 1.9 GHz between resonances of the monopole (1.7 GHz) and the short branch (2.1 GHz). Fig. 2(e) shows Y_{21} of the proposed model. The resonance of the short stub added at DC (0 Hz) [6], a total of four resonances appear. At 900 MHz, 1.7 GHz and 2.1 GHz, decoupling condition $Y_{21} = 0$ is achieved.

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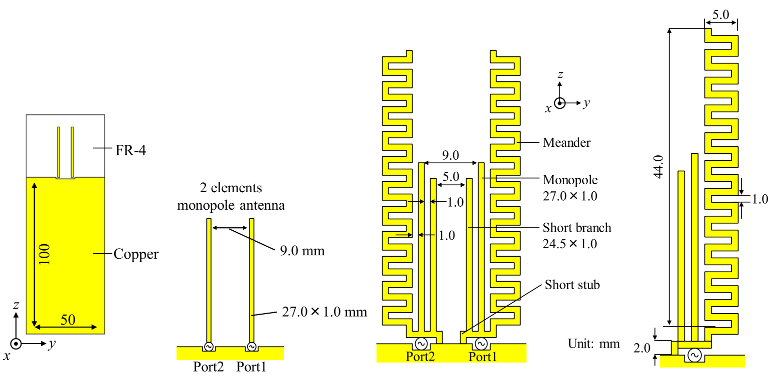
As a result, to decouple at three frequencies, four resonances should be generated. In the proposed model, current paths are assumed four: the monopole, the short branch, the meander, the short stub. Thus, by preparing one more current path than N_{fd}, decoupling at multiple frequencies can be realized. Moreover, to decouple at three frequencies, we propose a trifurcation structure with the short stub. In fact, four branch elements without the short stub are also realized. However, the number of branches can be reduced by using the short stub, we adopt the short stub. In summary, to perform decoupling at multiple frequencies, preparing branch elements same at N_{fd}, the short stub is added. The branch element and the short stub is not needed to connect antennas, hence, decoupling without connection is performed.

3 S-parameters and radiation efficiency

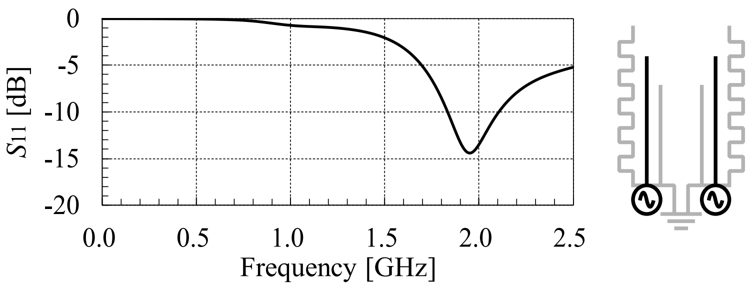
Fig. 3 shows S-parameter of each model with matching circuits. S_{11} shown in blue is less than −10 dB at the desired frequencies in both models. However, in only monopoles, S_{21} shown in red is −2.0 dB at 800 MHz, −3.2 dB at 1.7 GHz, −5.7 dB at 2.1 GHz. On the other hand, S_{21} of the proposed model is −6.3 dB at 800 MHz, −10.3 dB at 1.7 GHz, −15.7 dB at 2.1 GHz. Therefore, S_{21} decreases 4.3 dB, 7.1 dB and 10.0 dB respectively.

In addition, radiation efficiency of only monopoles is −8.6 dB at 800 MHz, −3.9 dB at 1.7 GHz, −2.0 dB at 2.1 GHz. By contrast, in the proposed model, radiation efficiency is −3.0 dB at 800 MHz, −3.3 dB at 1.7 GHz, −1.5 dB at



(a) 2 elements monopole antennas (b) Proposed antenna

Fig. 1. Base and proposed antenna models (Unit: mm)



(a) S_{11} of only monopole antennas

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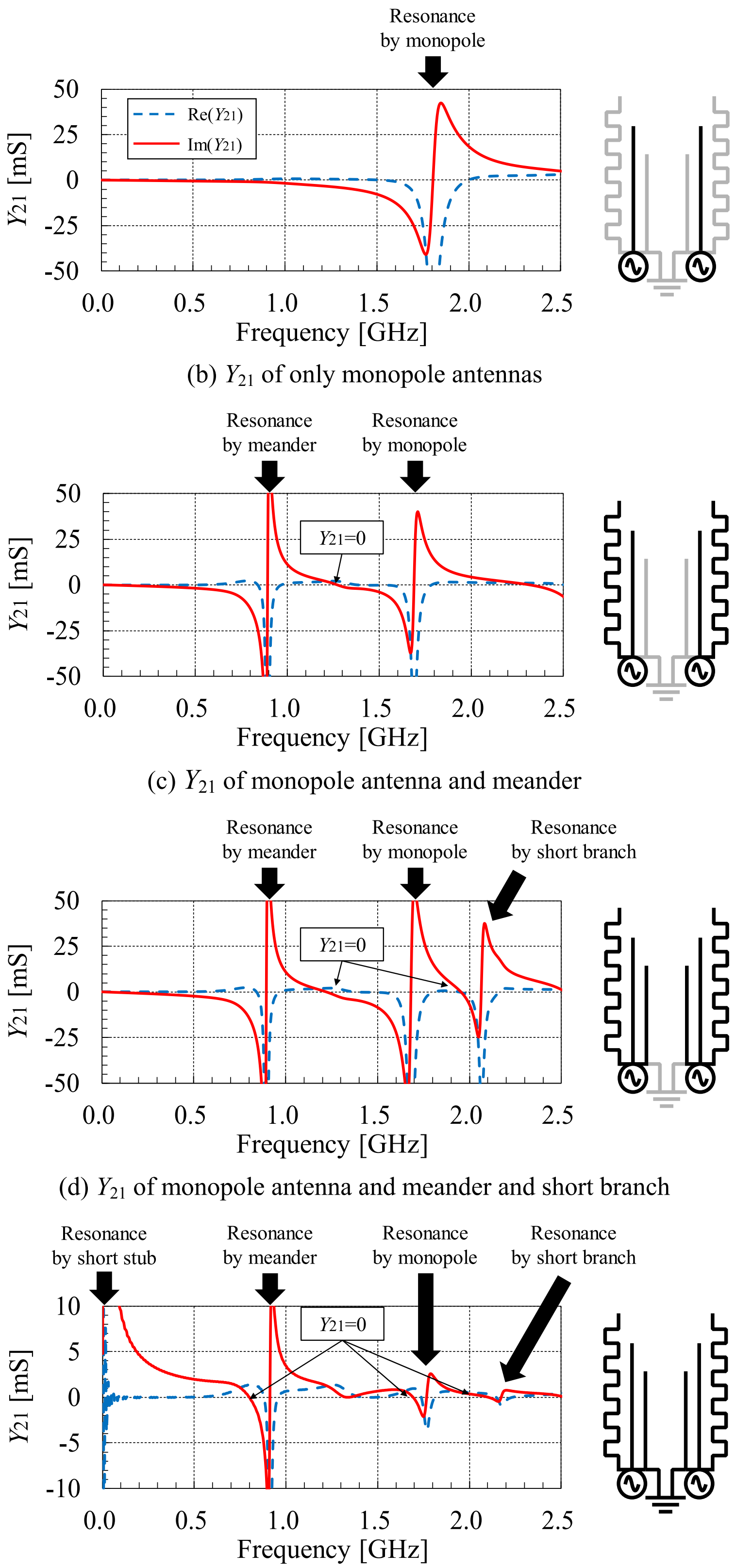

(b) Y_{21} of only monopole antennas

(c) Y_{21} of monopole antenna and meander

(d) Y_{21} of monopole antenna and meander and short branch

(e) Y_{21} of the proposed model

Fig. 2. Relationship between resonances and decoupling frequencies

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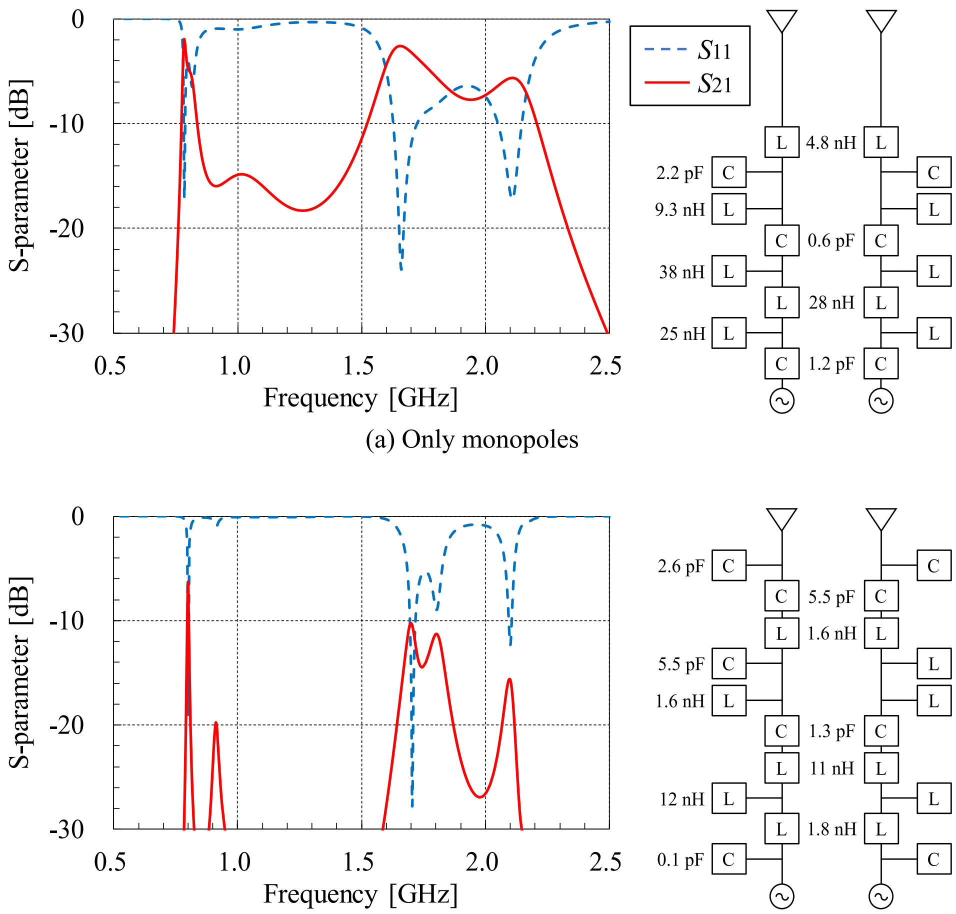

(a) Only monopoles

(b) Proposed model

Fig. 3. S-parameters and matching circuit of each model

2.1 GHz. As a result, radiation efficiency increased 5.6 dB, 0.6 dB and 0.5 dB respectively.

4 Conclusion

In this paper, we proposed the multiband decoupling method focused on the number of resonances of Y_{21} and N_{fd}. In an arbitrary number of decoupling frequencies, if one more current path than N_{fd} is prepared, decoupling can be realized ($Y_{21} = 0$ is obtained).

Based on this theory, we make the triple-band decoupling model by using the trifurcation element and the short stub. As a result, resonances of Y_{21} corresponding to each current path are generated by the proposed model, then, $Y_{21} = 0$ can get at desired frequencies.

Compared with only monopole antennas model, mutual coupling S_{21} can be reduced 4.3 dB, 7.1 dB and 10.0 dB respectively and radiation efficiency improves 5.6 dB, 0.6 dB and 0.5 dB respectively. Hence, it is confirmed that decoupling can perform at triple-band frequencies.

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