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A decoupling method for MIMO antennas by using a short stub

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Abstract: In recent years, MIMO technology which uses multiple antennas has been introduced in mobile terminal to increase communication capacity. However, if MIMO antennas are put closely, a strong mutual coupling occurred. Then it causes decreasing radiation efficiency and channel capacity. Therefore, reducing the mutual coupling is required. In previous study, connecting MIMO antennas by inductor L or added branch elements to antennas instead of L. In this paper, we propose a novel decoupling method by using a short stub and confirm that proposed model performed decoupling, increased radiation efficiency.

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

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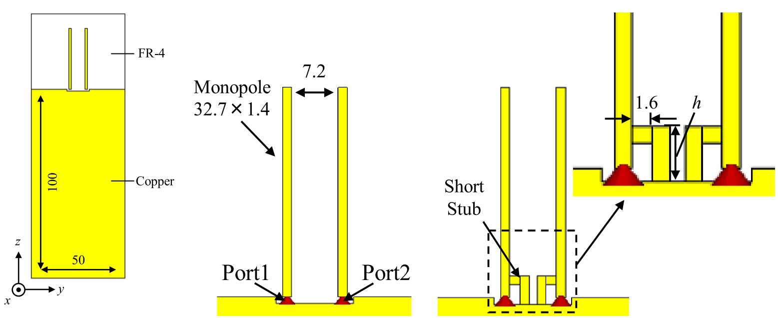
1 Introduction

In recent years, to communicate stably large capacity data such as high definition images is required in even small wireless communication terminals. Thus, MIMO (Multiple-Input Multiple-Output) technology is spreaded to increase channel capacity. If MIMO antennas are introduced to small terminals, multiple antennas are needed to put closely from the viewpoint of an installing space. However, a strong mutual coupling by putting multiple antennas closely causes deteriorating radiation efficiency, and channel capacity decreases [1]. Therefore, to reduce mutual coupling is required. Our purpose is proposing a decoupling method for putting closely MIMO antennas.

2 Antenna models and decoupling method

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 the desired frequency, decoupling can obtain [2]. In the previous study, connecting antennas by inductor L is proposed [3]. Fig. 2(a) shows Y_{21} of Fig. 1(a), and Fig. 2(b) shows Y_{21} of connecting the monopole antennas by 28 nH. Here, the frequency at which the real and imaginary part of Y_{21} change is defined as "resonance". Only monopole antennas (Fig. 2(a)) has one resonance at 1.6 GHz. The element length is relative to the frequency of appearing resonance each other. The shorter element length is, the higher resonance frequency is. In case of connecting by L, there are two current paths: monopole and another monopole via L. L lengthens the current path length, hence, one more resonance appears at the lower frequency 0 GHz (DC) than monopoles. Then, both real and imaginary parts of Y_{21} get to 0 between two resonances. Like this, there are many decoupling methods of connecting antennas via a decoupling connecting [4]. However, if the



(a) 2 elements monopole antennas (b) Proposed antenna with a short stub

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

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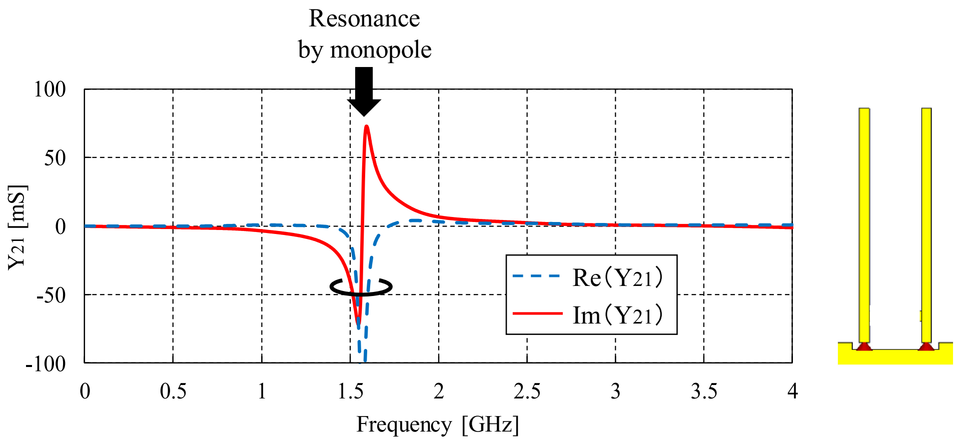
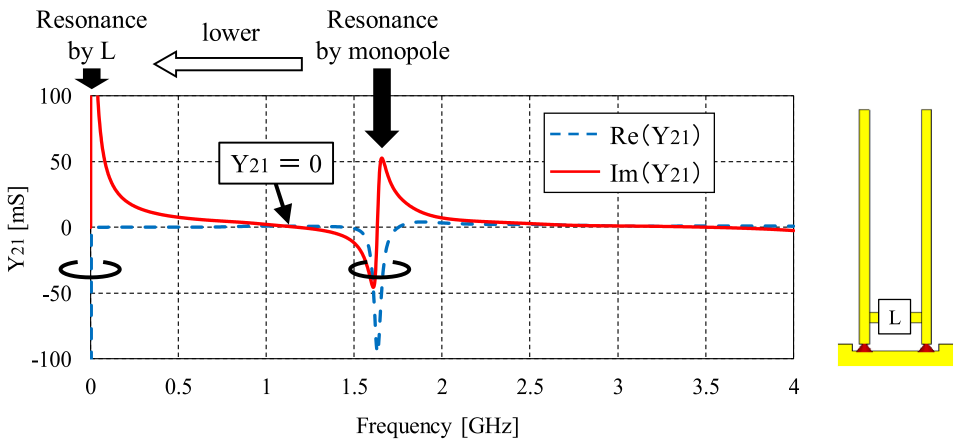
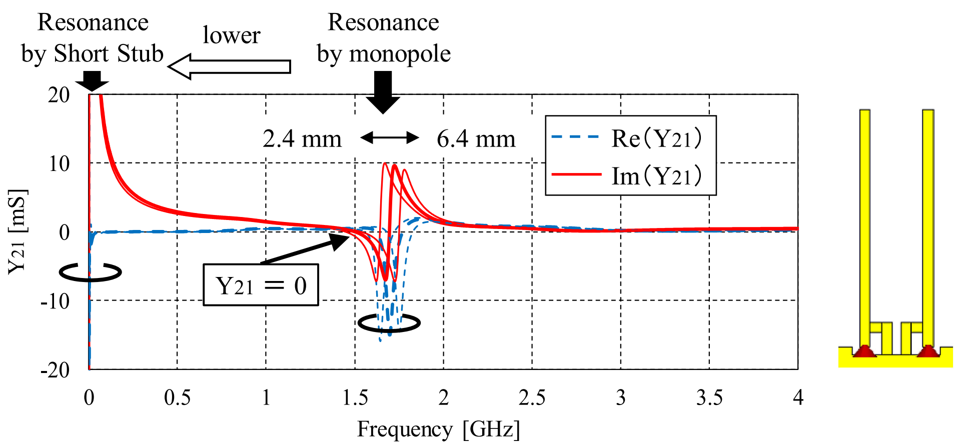


(a) Only monopole antennas



(b) Connecting antennas by L (28nH)



(c) Proposed model with short stub (Stub length *h* is 2.4, 4.4, 6.4 mm)

Fig. 2. Y_{21} of only monopoles, L connecting, and with short stub

decoupling network is used, the power loss due to resistance in the decoupling connecting occurs and radiation efficiency decrease. Besides, there are also some decoupling methods of connecting only antennas without the decoupling network [5]. Nevertheless, it is hard to connect antennas in a wireless terminal with a large number of parts.

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Moreover, adding meander branch element to monopoles instead of L is proposed [6]. This method is not needed to connect antennas and use decoupling connecting. As mentioned earlier, L lengthen the current path length, thus, to realize decoupling equivalent to L connecting is needed to add larger volume element to monopole antennas. Nevertheless, to insert mender branch element, antenna volume increases, thus, this method is not suitable for miniaturization.

3 Design by using a short stub

In this paper, we propose a short stub instead of the meander branch element to suppress antenna volume. The branch element is regarded as an open stub. Open stub must be from a quarter to a half of wavelength in order to exhibit inductivity. By contrast, if the short stub is used, the stub length must be less than a quarter of a wavelength. Hence, the short stub is more effective than the open stub to reduce antenna volume. The proposed antenna with the short stub attached to Fig. 1(a) is shown in Fig. 1(b). h is the length of the short stub. Fig. 2(c) shows Y_{21} of the proposed model whose h is changed 2.4 mm, 4.4 mm, and 6.4 mm. The desired frequency is 1.5 GHz. From Fig. 2(c), one more resonance is generated at 0 GHz (DC) in addition to resonance by monopoles. This operation is the same at decoupling by L connecting (Fig. 2(b)). Therefore, the short stub exhibit inductivity. Furthermore, $Y_{21} = 0$ is obtained at the desired frequency between two resonances at $h = 4.4$ mm.

The procedure of antenna design is shown below.

(a) The length of the monopole antenna is determined in order to resonate slightly higher than desired frequency which is wanted Y_{21} to be 0 (Fig. 1(a)).

(b) The short stub is attached to the monopole antenna. If the length of the short stub (h) is altered, the resonance of monopole is moved and the frequency of $Y_{21} = 0$ also changed.

(c) The length of short stub is adjusted so that the frequency of $Y_{21} = 0$ become desired frequency (in this paper, length is 4.4 mm).

In paper [7], the decoupling method of using capacitive loads for two inverted-F antennas is also proposed. Unlike [7], the novelty of proposed method is that there is no need to connect other stubs or capacitive loads to IFAs.

4 S-parameters and radiation efficiency

Fig. 3 shows S-parameter of each model with matching circuits. Lines indicate calculated by CST studio suite, markers indicate measured S-parameter. It is confirmed that the calculated value corresponds to the measured value. S11 shown in blue is less than −10 dB at the desired frequency in both only monopoles and proposed model. However, in only monopoles, S21 shown in red is −2.1 dB which is high mutual coupling. On the other hand, S21 of the proposed model is −10.4 dB. Therefore, S21 decreases 8.3 dB by attaching short stub.

In addition, we simulated radiation efficiency. Radiation efficiency of only monopoles is −5.1 dB. By contrast, in the proposed model, radiation efficiency is 3.4 dB. As a result, radiation efficiency increased 1.7 dB by using the short stub.

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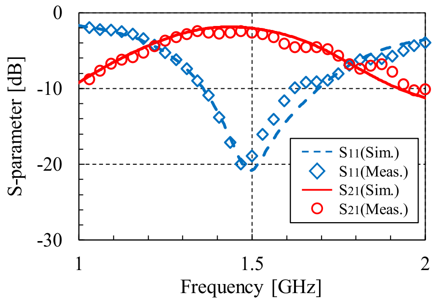
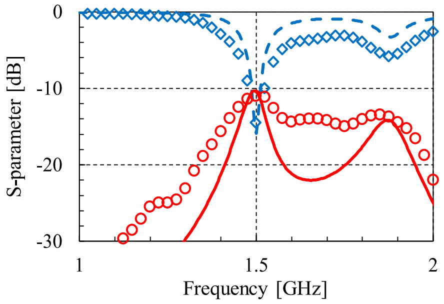


(a) Only monopoles



(b) Proposed model

Fig. 3. S-parameters

5 Conclusion

In this paper, we proposed the decoupling method of putting closely MIMO antennas by using the short stub to realize the method equivalent to L connecting. The proposed antenna model with the short stub can obtain the same operation of L connection. Moreover, the decoupling condition $Y_{21} = 0$ is obtained at the desired frequency. Therefore, compared with only monopole antennas model, mutual coupling S21 can be reduced 8.3 dB and simulated radiation efficiency improves 1.7 dB. Hence, it is confirmed that decoupling can perform by using a short stub.

As for future studies, corresponding to CA (Carrier Aggregation), dual-band decoupling method is required. Furthermore, the decoupling method for multiple antenna more than 2 elements is also a future task.

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