

Study on Band-notched Characteristic Inheritance in UWB MIMO Antenna Array Design

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Abstract—In this paper, the band-notched characteristic inheritance in ultra-wide band (UWB) multiple input multiple output (MIMO) antenna array design is studied. First, the structure parameters and return loss of a monopole antenna are optimized to obtain desired UWB property. Then, the band-notched characteristic is realized in 7.9-8.4GHz by using the rectangle split ring resonator (r-SRR). Furthermore, this UWB antenna is utilized to form a MIMO antenna array based on quasi-self-complementary antenna technique. Finally, the simulation results show that on the one hand, the band-notched property of the unit antenna can be inherited by the antenna array; on the other hand, the bandwidth of the stop band for antenna array is increased by about 66% compared with that of the antenna unit.

Keywords- UWB antenna; MIMO antenna array; band-notched characteristic; inheritance

I. INTRODUCTION

With the rising and rapid development of the wireless communication, the increasing demands are moving towards large channel capacity, high transmission speed and stable mobile radio link. In order to adapt to this tendency, many novel techniques are developed in the past few decades. Among which, ultra-wide band (UWB) technique and multiple input multiple output (MIMO) concept have aroused wide interest in both academia and industry^[1-2]. Hence, as one of the most important component in the new generation wireless communication system, the UWB antenna and the MIMO antenna have evolved so quickly and become one of the hottest field in the forefront of antenna design.

For any UWB antenna, there is always a great possibility that its operation frequency band will overlap with that of many other wireless systems, which might lead to undesired interference between different devices. To overcome this problem, the band-notched characteristic, which can achieve band-stop property in a particular frequency band to filter transmission signal from interference system directly, has been introduced to UWB antenna. Another major problem for a UWB system is that the limited output power makes it difficult to achieve long-distance transmission. Since MIMO technology can decrease channel fading and improve the transmission quality of the mobile terminals, the combination of UWB characteristic and MIMO property can further improve the performance of the wireless devices. Based on the above analysis, it is reasonable to conclude that the design of UWB MIMO antenna array with band-notched characteristic is of

significance in both theoretical research and practical engineering.

Until now, many scientists and engineers have devoted themselves to the studies of UWB antenna, UWB antenna with band-notched characteristic and MIMO antenna array^[3-4]. According to these studies, the general design process for UWB MIMO antenna array with band-notched characteristic can be divided into four steps: UWB antenna unit design; band-notched characteristic design for antenna unit; MIMO antenna array design; band-notched characteristic adjustment for antenna array. To the best of our knowledge, most of relative researches usually present their MIMO antenna array directly and rarely analyze how the MIMO array inherit the band-notched characteristic from its UWB antenna unit. This is the starting point of this work.

Hence, the band-notched characteristic inheritance in UWB MIMO antenna array design is studied in this paper. First of all, a monopole antenna unit is optimized to obtain desired UWB property. Second, the rectangle split ring resonator (r-SRR) is used to realize the band-notched characteristic in 7.9-8.4GHz for the UWB antenna unit. Then, a UWB MIMO antenna array with four antenna unit is presented by using quasi-self-complementary antenna technique. Finally, the simulations discover that the antenna array can inherit band-notched characteristic directly from its antenna unit and the main change is the increase in stop band bandwidth. Specifically, the stop band width of the array is increased by about 66% compared with that of the unit here.

II. SIMULATION AND ANALYSIS

A. UWB Antenna Unit

The geometry of the UWB antenna unit, as shown in Fig.1, has one planar monopole element^[5]. The three-dimensional size of this antenna is 25mm×25mm×1.6mm. The substrate is FR4 with relative permittivity 4.6 and loss tangent 0.019. According to the reference, the S_{11} of this UWB antenna unit is very close to -10dB at 4GHz frequency point. Hence, the structure parameters are optimized to obtain better return loss property. The optimized geometry parameters are $L=25\text{mm}$, $L_1=3\text{mm}$, $L_2=3\text{mm}$, $L_3=2.5\text{mm}$, $L_4=2\text{mm}$, $L_5=6\text{mm}$, $L_6=3\text{mm}$, $L_7=1\text{mm}$, $L_8=3\text{mm}$, $L_9=6\text{mm}$, $W=25\text{mm}$, $W_1=2\text{mm}$, $W_2=11\text{mm}$, $W_3=3\text{mm}$, $W_4=2\text{mm}$, $W_5=8.8\text{mm}$, $W_7=5\text{mm}$, $W_8=4\text{mm}$, $W_9=7.8\text{mm}$. Fig.2 displays the comparison between the S_{11} curves before and after optimization. It can be found that the return loss property satisfies the Federal Communications

Commission requirement in the whole 3.1-10.6GHz frequency band and the S_{11} value in 4GHz frequency point decreases from -9.8dB to -10.9dB.

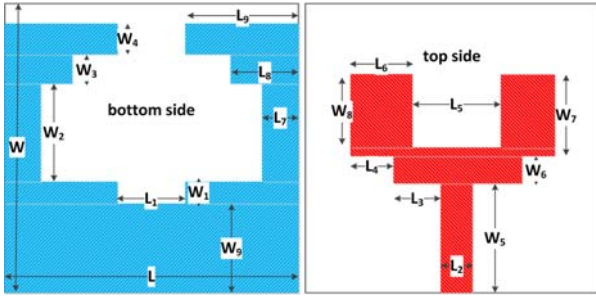


FIGURE I. GEOMETRY OF UWB ANTENNA UNIT

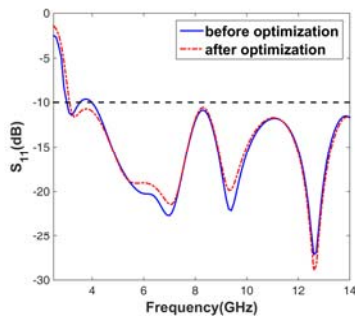


FIGURE II. DIFFERENT S_{11} CURVES

B. Band-notched Characteristic

The r-SRR is used here to generate band-notched characteristic for UWB antenna, as shown in Fig.3. The stop band design objective is chosen to be in the uplink frequency band for X-band satellite communication, i.e., 7.9-8.4GHz.

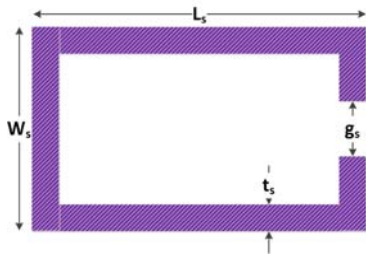


FIGURE III. STRUCTUE OF r-SRR

The resonant frequency f_{res} of this resonator can be estimated approximately by the following expression

$$2(L_s + W_s - 2t_s) = \frac{c}{2f_{res}\sqrt{\epsilon_{eff}}} \quad (1)$$

where

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + \frac{12h}{w_f} \right)^{-0.5} \quad (2)$$

here ϵ_r is the relative permittivity of the substrate, h is the height of the substrate and w_f is the width of the feed line.

Two resonant rings are placed on both sides of the feed line to achieve desired band-notched characteristic. The geometry parameters of each resonator are $L_s=5\text{mm}$, $W_s=2.4\text{mm}$, $g_s=0.8\text{mm}$, $t_s=0.3\text{mm}$. At the same time, an antenna structure parameter is also adjusted to obtain better return loss property, i.e., $L_9=5\text{mm}$ here. Fig.4 shows the obtained S_{11} curves.

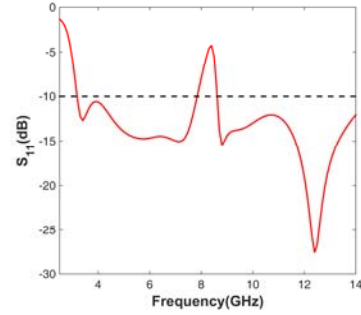


FIGURE IV. BAND-NOTCHED CHARACTERISTIC

As shown in the figure, the band-notched characteristic can be found in the 7.9-8.5GHz, which is basically consistent with the design objective. The bandwidth of the stop band is about 0.6GHz.

C. MIMO Antenna Array with Band-notched Characteristic

Based on the quasi-self-complementary antenna technique^[5-6], a MIMO antenna array with band-notched characteristic is presented. The layout of this UWB MIMO antenna array, which is illustrated in Fig.5, includes four antenna units. Each unit has a 7.9-8.5GHz stop band generated by the application of r-SRR. The whole size of the MIMO array is 50mm×50mm×1.6mm.

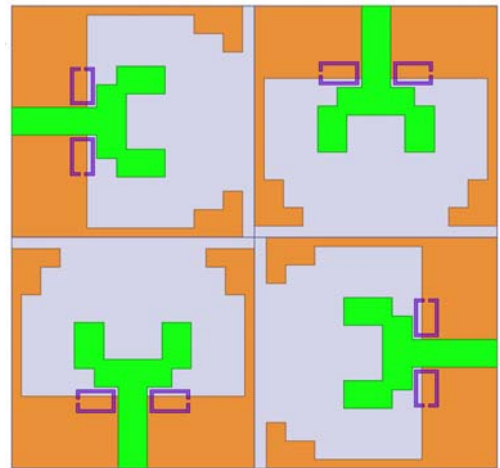


FIGURE V. LAYOUT OF UWB MIMO ANTENNA ARRAY

For convenience, the UWB antenna in the top left is denoted as unit 1; the top right antenna is denoted as unit 2; the

bottom left antenna is unit 3; the bottom right antenna is unit 4. The orientation of each unit is orthogonal to each other.

The correlation coefficient is a key parameter to determine whether MIMO antenna can be applied to MIMO system. For two antenna units, for example, unit 1 and unit 2, their correlation coefficient is given by

$$\rho = \frac{|S_{11}^* S_{12} + S_{11}^* S_{12}|^2}{(1 - |S_{11}|^2 - |S_{21}|^2)(1 - |S_{22}|^2 - |S_{12}|^2)} \quad (3)$$

Fig.6 gives the calculated correlation coefficients for the presented MIMO antenna array.

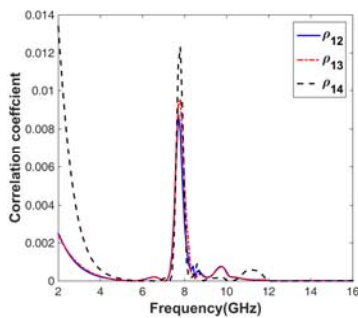


FIGURE VI. CALCULATED CORRELATION COEFFICIENTS

According to the figure, the correlation coefficients between different antenna units are less than 0.014 in the whole UWB operation frequency band. Since the correlation coefficient should not be greater than 0.5 in MIMO technique, this demonstrates the rationality of the presented MIMO antenna array.

Last but not least, the band-notched property inheritance is studied in Fig.7. It is obvious that both the UWB property and the band-notched characteristic of the antenna unit is inherited by the MIMO antenna array. What's more, it is worth noting that the stop band is 7.5-8.5GHz for the MIMO antenna array, i.e., the bandwidth is increased by about 66% compared with that of the antenna unit. Hence, when designing an UWB MIMO antenna array with band-notched characteristic, one needs to consider the inheritance and variability of the stop band. Otherwise, some useful signals might be rejected by the UWB MIMO system.

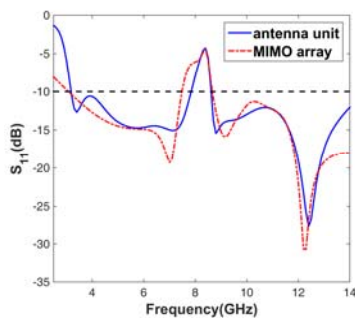


FIGURE VII. BAND-NOTCHED PROPERTY INHERITANCE

III. CONCLUSIONS

In summary, the band-notched characteristic inheritance in UWB MIMO antenna array design is studied in this paper. Through four design steps, we present a UWB MIMO antenna array with band-notched characteristic. The simulation results show that the stop band width is 0.6GHz for UWB antenna unit and 1.0GHz for MIMO antenna array, which means that the bandwidth is increased by about 66%. Such phenomenon suggests us to consider the band-notched characteristic inheritance and variability in this four-step design process.

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