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Mutual Coupling Optimization of Compact Microstrip Array Antenna

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Abstract

As we all know, traditional compact microstrip array antenna has low accuracy. So in this paper, we perfect the mutual coupling of compact microstrip array antenna by designing a new defected ground structure. When the resonant frequency is 2.45GHz, array element spacing is 0.1 times of free space wavelength, we introduce new defected ground structure into antenna array. Then we use HFSS to make simulation and compare the changing of antenna's parameters before and after adding defected ground structure. The results demonstrate that the parameters representing mutual coupling in new model can reduce by 30dB, which effectively perfects the mutual coupling of compact microstrip array antenna.

Keywords*: compact microstrip array antenna, defected ground structure, mutual coupling.*

1. Introduction

Microstrip antenna [1-2] has a simple structure. It is easy to product, manufacture and install. It can realize a multi-polar or multiple frequency work. At the same time feed network can be integrated with microstrip antenna in the same dielectric substrate. Compared with the single microstrip antenna, the microstrip array antenna has a higher gain and can realize the beam scan or beam control, which has been used in multiple input-output system [3], radar system [4], satellite communication system [5], navigation system [6] and individual wireless communication system [7]. Different to the input impedance of isolated antenna array, the mutual coupling in array antenna will result in changes of input impedance and impedance mismatch, which can cause reduction of array element radiation efficiency and deterioration of antenna polarization characteristics. Antenna cannot reach at the best design effect, and even can't work normally. For the high-integration large-scale circuit, microstrip antenna and other components are integrated in a relatively narrow space, the effect of coupling between microstrip antenna and other components on antenna performance cannot be ignored.

Three factors cause mutual coupling: surface wave, near-field coupling and far-field coupling [8]. When dielectric layer size and material are different, the three coupling mechanisms are likely to play a leading role. Reference [9] studied the relationship between mutual coupling and array element distance. With the increase of distance, the effect of the three coupling mechanisms on antenna decreases. When the distance between array elements increases by two times, surface wave decreases 3dB, far-field coupling reduces 6dB, near-field coupling reduces more than 12dB. So for compact microstrip array antenna with a small array distance, mutual coupling restrain is very important. Ghahramani [10] proposed a uniplanar compact electromagnetic band-gap (UC-EBG) structure in order to reduce mutual coupling between substrate integrated waveguide (SIW) slot array antennas, decreased side lobe level and increased antenna gain by suppressing the surface waves. Wu [11] presented a novel ultracompact two-dimensional (2D) waveguide-based metasurface, it exhibited a bandgap with two transmission zeros attributing to the negative permeability in the vicinity of magnetic resonance and the negative permittivity in the vicinity of electric resonance.

Defected ground structure (DGS) carves defected pattern on the circuital earth plate to change the effective dielectric constant of circuit substrate material, which changes the distributed inductance and distributed capacitance of microstrip antenna based on that dielectric and then forms frequency band elimination effect. Compared electromagnetic band gap (EBG),

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DGS only needs simple geometric shapes, it can form the EBG. DGS has been used in microwave circuit discrete components, such as microstrip antenna, filter, resonator, amplifier and oscillator etc. Therefore, we design a new defected ground structure to perfect mutual coupling of compact microstrip array antenna.

2. New Design of Defected Ground Structure

As we all know, DGS is fit for proving mutual coupling of array antenna with a big distance of antenna array element. There are enough apace in two antenna array elements to carve defected structure and reduce the mutual coupling between array elements. If the compact antenna array and other devices are integrated in a large scale integrated circuit in the same substrate, it is very strict to the size of DGS. Some proposed structures are not suitable for compact array. Rawat [12] designed a new circular patch antenna having defected ground structures. First, a geometrically complex domain of problem was represented as a collection of geometrically simple sub domains, called finite elements. Second, over each finite element, approximation functions were derived using the basic idea that any continuous function could be represented by a linear combination of algebraic polynomials. For this antenna structure, it has a great effect on antenna radiation patterns, not suitable for the improvement of the array antenna mutual coupling.

Typical dumbbell DGS has been used in filter, resonator and microwave devices. Because of the requirements of antenna size, dumbbell DGS is restricted seriously. In this paper, we design the new defected ground structure based on dumbbell DGS. We decrease the rectangular aperture in both ends and change it as a continuous periodic. This design will greatly reduce the geometrical scaling of DGS making it suitable for compact array antenna. Figure 1 and Figure 2 shows the original dumbbell DGS and new DGS respectively when stop-band frequency is 2.45GHz. In Figure 1, $x_0 = y_0 = 15$mm. In figure2, $x_1 = 2$mm, $y_1 = 4$mm, $x_2 = 3$mm, $y_2 = 1$mm, $x_3 = 20$mm.

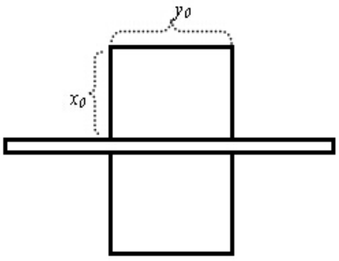

Figure 1. Original Dumbbell DGS

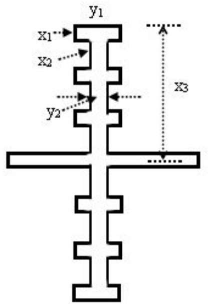

Figure 2. New Dumbbell DGS

Table 1. Detailed S_{12} value.

Name	X	Y
m1	0.88	-11.08
m2	3.33	-7.84
m3	2.45	-24.26
m4	2.25	-8.25
m5	2.88	-6.87
m6	2.45	-18.57

Figure 3 is the comparison of microstrip antenna filter with DGS when characteristic impedance is 50. For the original dumbbell DGS, the value of insertion loss S_{12} is below -10dB when frequency is in 1.88-3.29GHz. Center frequency is 2.45GHz, S_{12} reaches to -24.26dB. For the new dumbbell DGS, the value of insertion loss S_{12} is below -10dB when frequency is in 2.14-2.82GHz. Center frequency is 2.45GHz, S_{12} reaches to -18.57dB. Table 1 is the detailed value of m1-m6.

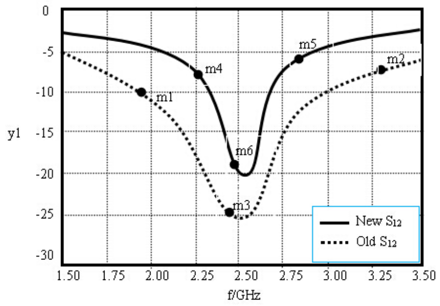

Figure 3. Insertion Loss S12

3. Improved Compact Microstrip Array Antenna Design and Analysis

Microstrip array antenna is as Figure 4. We select the FR4 with dielectric constant 4.4 as substrate. Loss tangent tanδ= 0.02, dielectric thickness H= 1.6mm. Patch width W_0= 37.26mm, length L_0= 30.2. It connects a quarter wavelength impedance converter and 50Ω microstrip antenna to feeding. The distance of two array elements is 0.1 times of free space wave length.

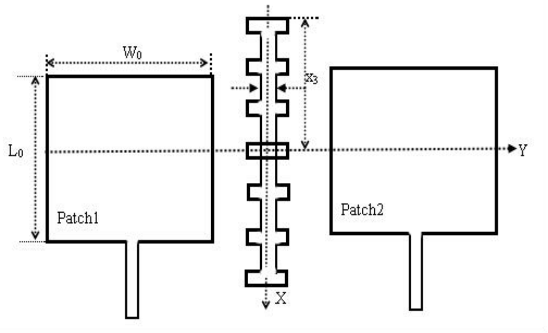

Figure 4. Array Antenna Structure.

Compared to original microstrip antenna structure, the distribution of antenna surface current in new structure is more complex. After optimization, the shape of new DGS is: x_1 = 5mm, y_1 = 7mm, x_2 = 3mm, y_2 = 0:45mm, x_3 = 24mm. That has a obvious optimization effect for antenna mutual coupling.

Figure 5 shows the S_{11} and S_{12} comparison before and after adding DGS into antenna. After adding DGS, resonant frequency has a little skewing. At 2.45GHz, return loss S_{11} is almost unchanged. S_{12} decreases to -46.4dB, which illustrates that our DGS structure can effectively reduce mutual coupling of Compact microstrip array antenna.

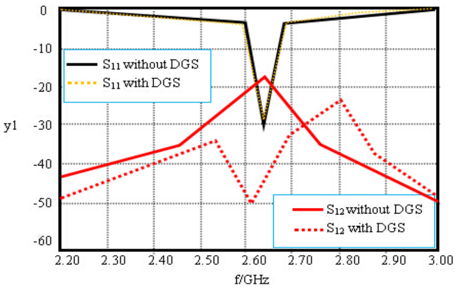

Figure 5. S_{11} and S_{12} comparison.

Figure 5 gives the antenna directional pattern in E-plane before and after adding DGS. we can see that DGS cannot change the direction. So we adopt new DGS to perfect the mutual coupling which is a feasible solution.

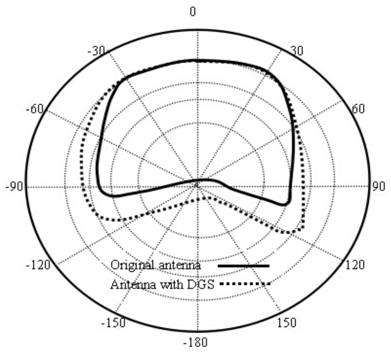

Figure 6. Directional Pattern in E-plane

4. Conclusion

In this paper, we design a defected ground structure used for compact array antenna. Under the conditions of fixed return loss and radiation pattern of antenna, the restrain exceeds 30dB for insertion. Loss S_{12}, it has a obvious improvement for antenna mutual coupling. Lateral compact structure makes it not only be applied to array antenna elements, but also be apply to large scale circuit integrated by antenna and other devices. That can reduce the effect of mutual coupling on antenna performance. The new structure in the inhibiting antenna coupling design has a good application prospect.

References

[1] Rafique U, Ali S A. Ultra-Wideband Patch Antenna for K-Band Applications. *Telkomnika Indonesian Journal of Electrical Engineering.* 2014; 12(12).

[2] Wahab A, Xu J. U-slot Circular Patch Antenna for WLAN Application. *Telkomnika Indonesian Journal of Electrical Engineering*. 2015; 14 (2).

[3] Ojaroudi N. *Design of Microstrip Antenna for 2.4/5.8 GHz RFID Applications*. Microwave Conference. VDE. 2014; 1-4.

[4] Kim DJ, Kim SH, Kim YK, et al. Switched *Microstrip Array Antenna for RFID System.* Microwave Conference. EuMC. 38th European. IEEE, 2008: 1254-1257.

[5] Park D, Kwak Y. Design of an Aperture-Coupled Microstrip Array Antenna for Millimeter-wave Radar System. *International Journal of Control & Automation*. 2015; 8(1): 317-324.

[6] Zulkifli FY, Rahardjo ET. Circularly Polarized Microstrip Array Antenna for Ground Segment in Quasi-Zenith Satellite System. Makara Seri Teknologi. 2012: 16(1).

[7] Madany YM, Elkamchouchi HM, Ahmed AE. Analysis and design of microstrip array antenna using SPDT-T/R Switch for MIMO antenna system applications. Antennas and Propagation in Wireless Communications. *IEEE*. 2015.

[8] Misran N, Tariqul Islam M, Jiunn NK. Design and development of broadband inverted E-shaped patch microstrip array antenna for 3G wireless network. *American Journal of Applied Sciences*. 2008: 5(4).

[9] Li H, Yin S. An improved TEM antenna designing used in electromagnetic pulse directed radiation. *Progress in Electromagnetics Research Letters.* 2015; 57: 17-22.

[10] Nikolic MM, Djordjevic AR, Nehorai A. Microstrip antennas with suppressed radiation in horizontal directions and reduced coupling. *IEEE Transactions on Antennas & Propagation*. 2005; 53 (11): 3469-3476.

[11] Ghahramani E, Sadeghzadeh RA, Boroomandisorkhabi B, et al. *Mutual coupling reduction in waveguide-fed slot array antenna using uniplanar compact EBG (UCEBG) structure*. Antennas and Propagation Conference. 2013: 634-636.

[12] Wu GC, Wang GM, Liang JG, et al. Novel ultra-compact two-dimensional waveguide-based metasurface for electromagnetic coupling reduction of microstrip antenna array. *International Journal of RF and Microwave Computer-Aided Engineering*, 2015: 25: n/a-n/a.

[13] Rawat S, Sharma KK. A compact broadband microstrip patch antenna with defective ground structure for C-Band applications. *Open Engineering.* 2014; 4 (3): 287-292.