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Design of Rectangular Microstrip Patch Antenna with Two Enhancements (Bandwidth and Gain)

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ABSTRACT

This electronic document introduces a design of a rectangular patch antenna with L-probe feed at frequency of 2.4 GHz and a design strategy using a dual-band frequency selective surface (FSS) consisting four arrays of double rectangular ring elements to improve the bandwidth and gain, and to optimize the onsets of two operating frequencies foe a U-slot patch antenna is presented. After implanting the FSS in the U-slot patch antenna, it is found that the bandwidth have been improved from 3.14 % to 5.51 % at resonant frequencies 2.4 GHz. The U-slot patch antenna implanted with a FFS consisting of double rectangular ring elements is capable of dual-band operations at 2.4 GHz. The radiation patterns are satisfied at this band. This paper aims to introduce an improvement of the gain parameter of a microstrip patch antenna with inset L-probe feed by using the four arrays double rectangular ring element. And aims to introduce an improvement of the bandwidth by using U-slot microwave patch antenna. This improvement will be investigated using the CST simulator. The design is performed at the frequency of 2.4 GHz.

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INTRODUCTION

Microstrip patch antennas are a type of antennas that is popular with wireless communication equipment because of its outstanding physical properties, such as light weight, low profile, low production cost, conformability, reproducibility, reliability, and ease in fabrication and integration with solid state devices and wireless technology equipment (Chakkrit Kamtongdee and NantakanWongkasem,2009), Required no cavity backing. Linear and circular polarizations are possible.

However, microstrip patch antennas have some drawbacks of low efficiency, low power, poor polarization purity and very narrow frequency bandwidth due to its small structure. Large ohmic loss in the feed structure of arrays. Poor end fire radiator except tapered slot antennas, extraneous radiation from feeds and junctions. Low power handling capacity Complex feed structures require high performance arrays. There is reduced gain and efficiency.

Therefore, how to enhance the bandwidth and frequency bands of a patch antenna has become an importance issue in the antenna design field.

The frequency selective surface (FSS) structure has a phenomenon with high impedance surface that reflects the plane wave in-phase and suppresses surface wave. Therefore, a microstrip patch antenna with one FSS structure can improve its radiation efficiency, bandwidth, gain, and reduce the side lobe and back lobe level in its radiation pattern.

The FSS has been widely applied in antennas, filters, reflectors, polarizers, absorbers, propagation, metamaterials, and artificial magnetic conductors (AMC) for more than four decades (R. Ulrich, 1967)-(B. A. Munk *et al*., 2007). Typical FSS geometric are designed by dipoles, rings, square loops, fractal shapes,...ect.

The transmission or reflection characteristic of a FSS depends on the shape, size, periodicity, and geometrical structure of FSS elements. Antenna gain is a measure of directivity properties and the efficiency of the antenna. It is defined as the ratio of the radiation intensity in the peak intensity direction

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to the intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The difference between the antenna gain and the directivity is that the antenna efficiency is taken into account in the former parameter (C. N. Chiu *et al*,. 2008).

In this paper, a dual-band FSS consisting of double rectangular ring elements was used to study its impact on the bandwidth and resonant friquencies of a U-slot patch antenna operating near 2.45 and 5.8 GHz. The frequency bands of 2.4~2.485 are regulated by IEEE802.11b/g (upper band) for Bluetooth and WLAN applications, respectively.

In simulations, the characteristics of U-slot patch antennas were obtained by using the CST Microwave STUDIO SUITE 2010. Simulation results of the return loss, radiation pattern, and gain of this U-slot patch antenna were validated by measurement data.

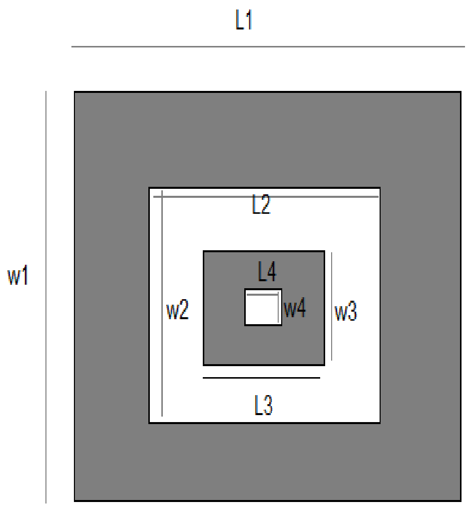

Fig. 1: Detail parameters of a double rectangular ring element.

Design of antenna:

The dimensions of patch antenna are 44.426 × 35.772 mm^2 and the thickness is 0.035 mm and there are two slots with 1.5 × 14.447 mm^2 and with same thickness. The PEC material is used for patch antenna. In our studies, a coaxial line with a characteristic impedance of 50 ohms is used as the L-probe feed of the patch antenna.

The FR4 material is used for the dielectric substrate with a thickness of 1.6 mm. The relative dielectric constant of the substrate is adopted to be 4.7 (M. Xu *et al*,. 2003). In order to improve the bandwidth, U-slot is used in the patch antenna. The length and the width of the U-slot are 24 and 14.25 mm, respectively. The width of the slot is 2.25 mm.

And to enhance the antenna gain, the four arrays of double rectangular ring elements is used. Detail dimensions of the double rectangular ring are W1=22 mm(exterior width of outer rectangular ring), W2=11.5 mm (interior width of outer rectangular ring), W3=6 mm (exterior width of inner rectangular ring), W4=3 mm (interior width of inner rectangular ring), L1=26 mm (exterior length of outer rectangular ring), L2=14.5 mm (interior length of outer rectangular ring), L3=9 mm (exterior length of inner rectangular ring), L4=3 mm (interior length of inner rectangular ring) as shown in Fig.1. The frequency that used is 2.4 GHz.

Equations of Patch Antenna:

$$W = \frac{c}{2f\sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-0.5} \quad (2)$$

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}} \quad (3)$$

$$\Delta L = 0.412h\,\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (4)$$

$$L = L_{eff} - 2\Delta L \quad (5)$$

W=width, ε_{eff}=effective dielectric constant, L_{eff}= effective length, h=thickness, L=length, ε_r = relative dielectric constant.

Measurements and simulation results:

The simulation results of first design of microstrip patch antenna with L-probe feed are obtained from the program CST Microwave Studio 2010 and as shown in Fig.2. The antenna gain for this design is 1.093 dB as shown in Fig.3. and the directivity is 2.836dBi as shown in Fig.4. The return loss and the bandwidth for patch antenna are -10 dB, 18.3 MHz and as shown in Fig.5.

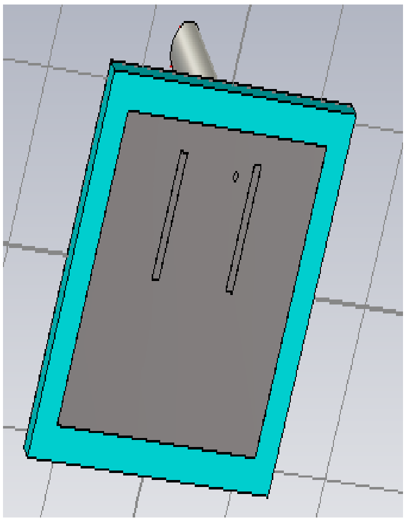

Fig. 2: CST patch layout.

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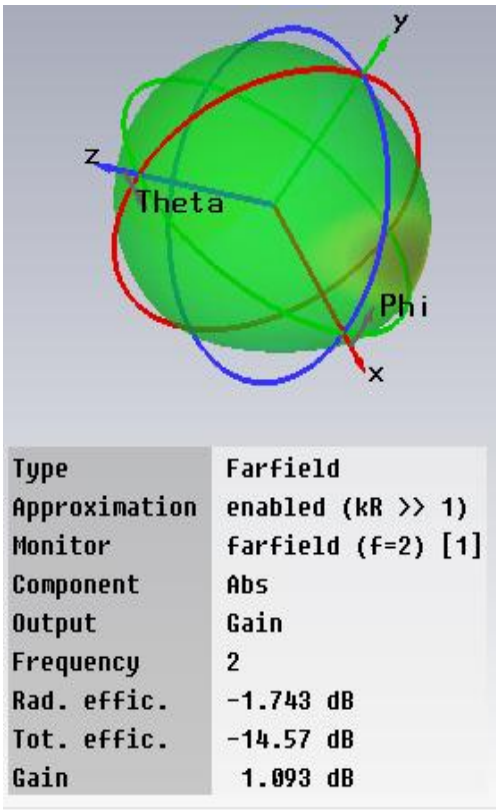

Fig. 3: The antenna gain.

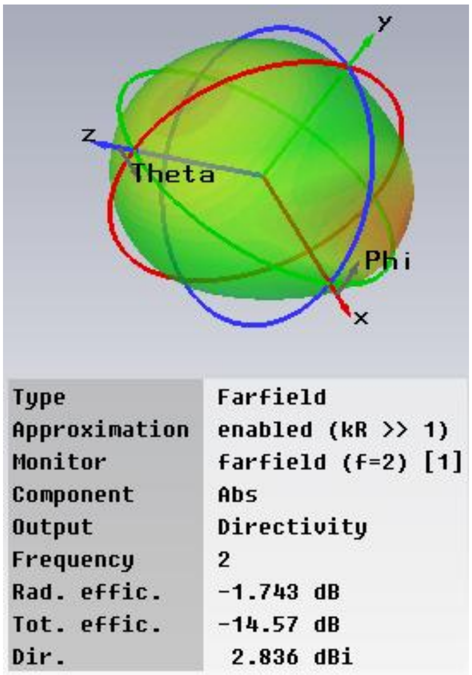

Fig. 4: Directivity of the antenna.

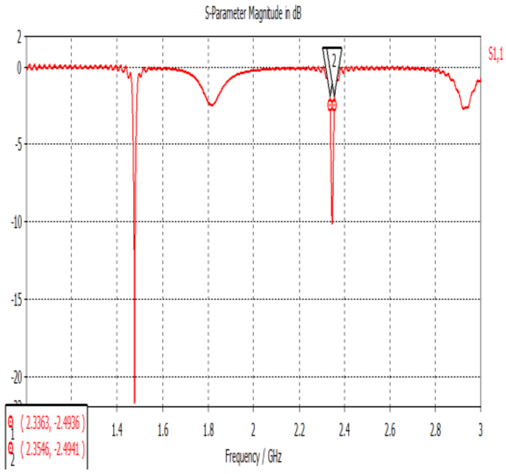

Fig. 5: Return loss and bandwidth.

The first enhancement is bandwidth enhancement and that was done after insert a U-slot patch antenna as shown in Fig.6. The bandwidth is improved and it is 165 MHz as shown in Fig.7.

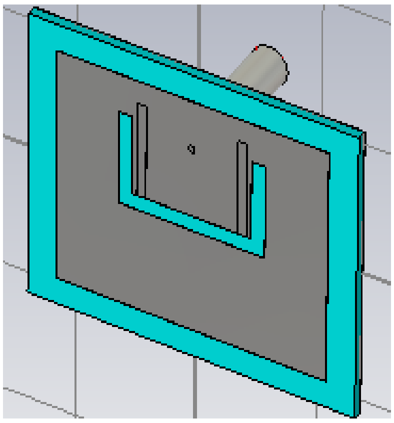

Fig. 6: CST U-slot patch antenna layout.

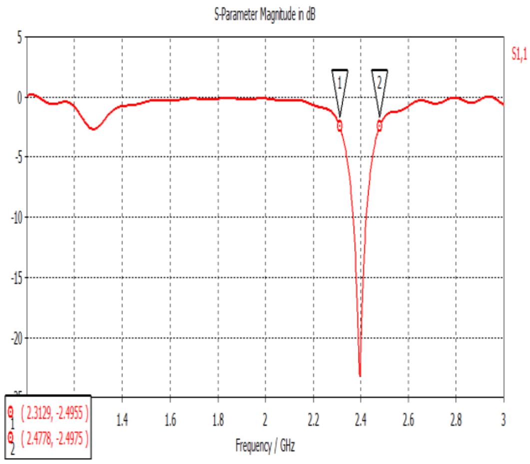

Fig. 7: Return loss and bandwidth after enhancement.

The second enhancement is antenna gain enhancement and that was done after insert double substrates, the first substrate with four arrays of double rectangular ring and the second substrate with U-slot patch antenna as shown in Fig.8. and Fig.9.

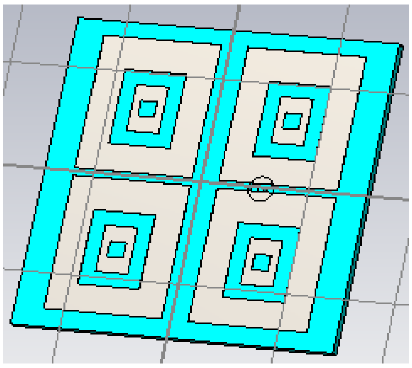

Fig. 8: CST four arrays of double rectangular ring antenna layout.

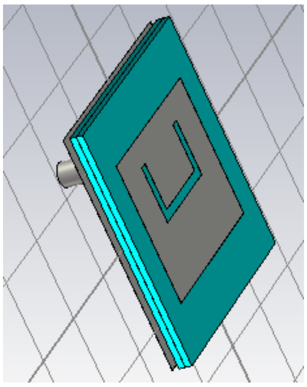

Fig. 9: CST double substrate patch antenna layout.

And the simulation result of antenna gain is 5.584 dB and as shown in Fig.10.And also the directivity is enhanced and become 5.818 dBi as shown in Fig.11.

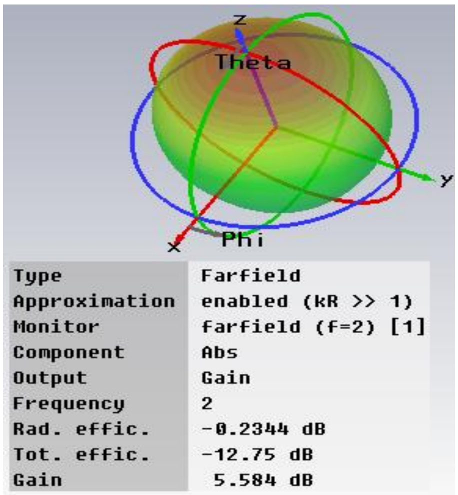

Fig. 10: The antenna gain after enhancement.

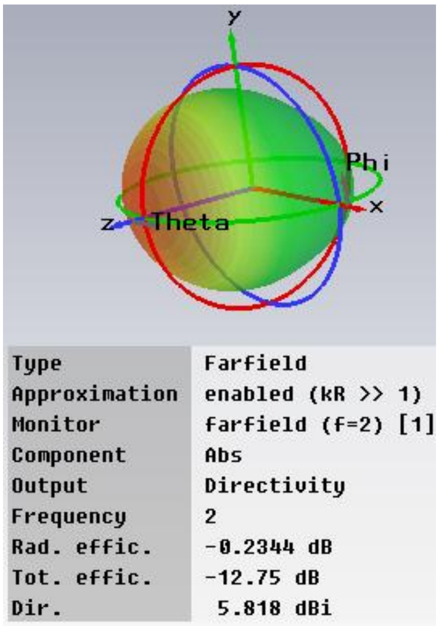

Fig. 11: Directivity of the antenna after enhancement.

Based on the above studies and observations, a FSS with new double rectangular ring elements implanted in the U-slot patch antenna was proposed to further improve the performance of the U-slot patch antenna. It is found that simulation results of return losses make good agreement data for the U-slot patch antenna implanted with the new FSS. It is very clear that much broader bandwidths are obtained by using the new FSS at 2.4 GHz.

The bandwidth has been improved from 18.3 MHz to 165 MHz at the frequency 2.4 GHz regulated by IEEE 802.11b/g. It is proved that the bandwidth is well improved from narrow band to wide band. The measured antenna gain of the array of double rectangular ring patch antenna and original patch antenna is also conducted.

Measurement data show that array of double rectangular ring patch antenna implanted produces better gains than the original patch antenna at resonant frequency 2 GHz. The higher gain obtained at frequency 2 GHz is 5.584 dB. And also the directivity with array of double rectangular ring patch antenna is better than the original patch antenna. The higher directivity obtained at frequency 2 GHz is 5.818 dBi.

Result analysis & discussions:

For the first enhancement, that's mean after insert the U-slot patch to the original antenna. The bandwidth of the U-slot patch antenna was increased from 18.3 MHz to 165 MHz at resonant frequency 2GHz.

The second enhancement after put double substrates, the first substrate FR4 with four arrays of double rectangular ring patch antenna and the second substrate FR4 with U-slot patch antenna.

The two substrates put them together to increase the bandwidth, the antenna gain, and the directivity at the same time. And the antenna gain was increased from 1.093 to 5.584 dB at the resonant frequency 2 MHz. And the directivity was increased from 2.836 to 5.818 dBi at the resonant frequency 2 MHz.

Conclusions:

In this paper, a dual-band FSS consisting of double rectangular ring elements was used to improve the bandwidths, gain, directivity, and onsets of operating frequencies for a U-slot patch antenna. From simulation results, it is found that the bandwidths have been improved near the operating frequency of 2.5 GHz for the U-slot patch antenna implanted with a FSS consisting of double rectangular ring elements.

However, the operating frequency of 2.5 GHz is not in the frequency band 2.4-2.485 regulated by IEEE 802.11b/g. For further improvement on the performance of the U-slot patch antenna, a FSS consisting of new parameters of the double rectangular ring elements was proposed to improve the performance of the U-slot patch antenna. It is demonstrated that the FSS consisting of double rectangular ring elements can successfully be used to improve the bandwidths, gains, directivities, and onsets of operating frequency for the U-slot patch antenna, respectively.

After implanting the FSS in the U-slot patch antenna, it is found that the bandwidths have been improved from 18.2 to 165 MHz at resonant frequency. The higher gains obtained at the frequency 2.4 GHz is 5.584 dB. The higher directivity obtained at the frequency 2.4 GHz is 5.818 dBi.The radiation patterns at the frequency 2.4 GHz is acceptable. The U-slot patch antenna implanted with the FSS has wide-band operation for Bluetooth and WLAN applications.

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