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Packaging Technique for Gain Improvement of Multi resonance CPW-fed Antenna for Satellite Applications

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ABSTRACT

A suitable technique for gain improvement of multi-resonance CPW-fed antenna for satellite application at Ku-, K- and Ka-bands for user terminals is presented in this paper. New concept of stacking numerous layers with different dielectric material has been also presented. The conventional antenna design consists of a CPW-fed patch antenna with modified CPW elements printed on Rogers TMM4 substrate. In order to improve the antenna performance in term of gain and bandwidth, we propose two different configurations. The first one consists of designing a stacked structure by adding on the top of the single antenna an additional layer with parasitic elements. The dielectric added consists in Rogers RO3010 substrate with a high permittivity of 10.2. The proposed antenna is formed by two layers separated by an air gap; this new configuration provides major reduction on antenna beam width and allows gain enhancement. The second one implement the design of 2×1 and 4×1 series feed antenna arrays based on the conventional CPW-fed antenna. These array configurations are used to achieve higher gain in comparison with stacked solution. Finally we combined both techniques yielding the stacked 4×1 series feed antenna array. Fabricated CPW-fed antenna and the achieved results demonstrate the performance of presented techniques for gain improvements.

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1. INTRODUCTION

The demand of low cost, low volume, low profile, and planar configuration for the antenna to be integrated on the user terminals of mobile systems has increased the interest of research work technologies [1-3]. The miniaturization of antennas is essential in radio communication devices such as wireless LAN, RFID, and MIMO, and extensive studies are made of an electrically small antenna [4-6]. The main idea of this paper is to design new antennas with small shape, enhanced gain and larger bandwidth for satellite communications. Many works have been developed with the same end in the past few years, but the antenna design is still a discreet component for the highly system in package. CPW-fed antennas have many attractive features like low radiation loss, easy integration for monolithic integrated circuits, and low dispersion [7], [8]. Therefore, CPW-fed antenna is widely considered a good candidate for satellite application. This paper presents a multi-band CPW-fed antenna for satellite applications. The antenna structure was designed and fabricated using Rogers TMM4 substrate to covers the Ku-band (11.75-16.83GHz), K-band (22 GHz) and

Ki-band at (28-34 GHz). Suitable techniques for gain improvement with new concept of stacking numerous layers with different dielectric material have been also presented. In order to improve the antenna performance in term of gain and bandwidth, we proposed two different configurations. The first one consists of designing a stacked structure by adding on the top of the single antenna an additional layer with parasitic elements. The dielectric added consists in Rogers RO3010 substrate with a high permittivity of 10.2. The proposed antenna is formed by two layers separated by an air gap; this new configuration provides major reduction on antenna beam width and allows gain enhancement. The second one implement the design of 2×1 and 4×1 series feed antenna arrays based on the conventional CPW-fed antenna. These array configurations are used to achieve higher gain in comparison with stacked solution. Finally we combined both techniques yielding the stacked 4×1 series feed antenna array. The array solutions proposed offers good improvement of antenna gain, respect to other work [9], [10]. Fabricated CPW-fed antenna and the achieved results demonstrate the performance of presented techniques for gain improvements.

2. ANTENNA DESIGN AND ANALYSIS

2.1. CPW-fed Antenna Configuration

The geometrical configuration of the proposed antenna is shown in Figure 1. It consists of a simple rectangular radiator fed by a 50 Ω coplanar wave-guide (CPW) transmission line. Since both the patch and the feed line are implemented on the same plane, only one layer of substrate with single-sided metallization was needed. The designed antenna is low cost and very easy for manufacturing process. A detailed study has been employed to perform the design and the optimization process. As shown in Fig. 1, the final parameters for the CPW-fed antenna printed on the Rogers TMM4 with dielectric constant of 4.5, loss tangent of 0.002 and thickness of 0.762 mm, are: W_1=5.4 mm, W_2 =7 mm, W_3=5.5 mm, W_4=2.1 mm, W_f=3.8 mm, L_1=4.5 mm, L_2=5.5 mm, L_3=8.5 mm, L_f=9 mm, t=0.5 mm and t_1=0.8mm.

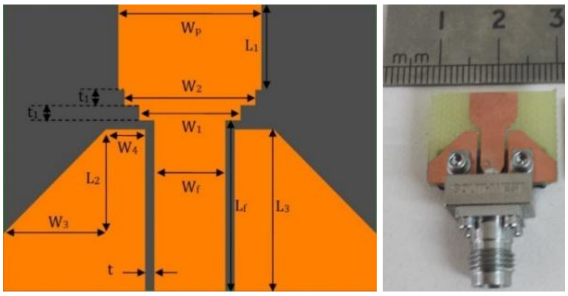

Figure 1. Geometry of the proposed CPW-fed antenna (antenna 1) with photograph of the fabricated prototype

2.2. Results and discussion

In Figure 2, measured and simulated S_{11} of the CPW-fed antenna are plotted. It is observed that the antenna covers the Ku-band (11.75-16.83GHz), K-band (22 GHz) and Ka-band at (28-34 GHz).

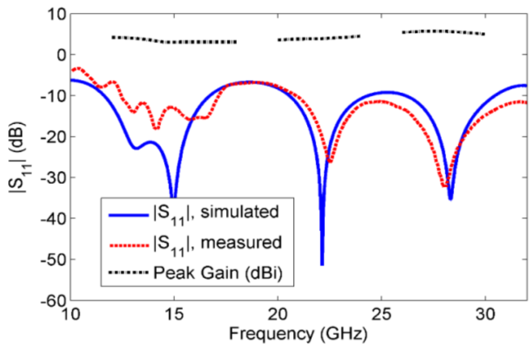

Figure 2. Simulated and measured S_{11} with peak gain values of the proposed antenna 1

A good agreement is shown between simulation and measurement results. A small shifting was observed in the first band for the measured response that might be due to manufacturing imperfections and performance measurement process. The antenna peak gain is shown in Fig. 2 indicating a stable gain performance overs 4 dBi at the three selective satellite bands.

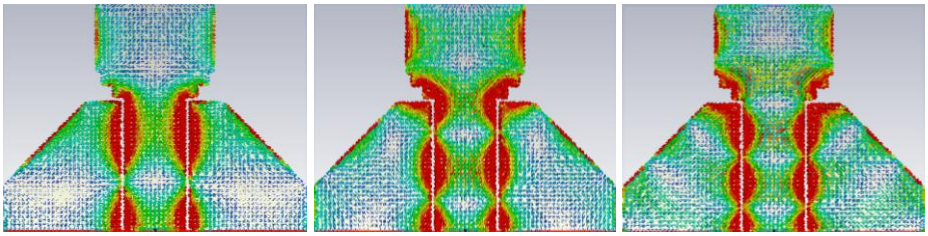

Figure 3. Current distribution of the proposed antenna at 15GHz (left), at 22.15 GHz (middle) and at 28.3 GHz (right)

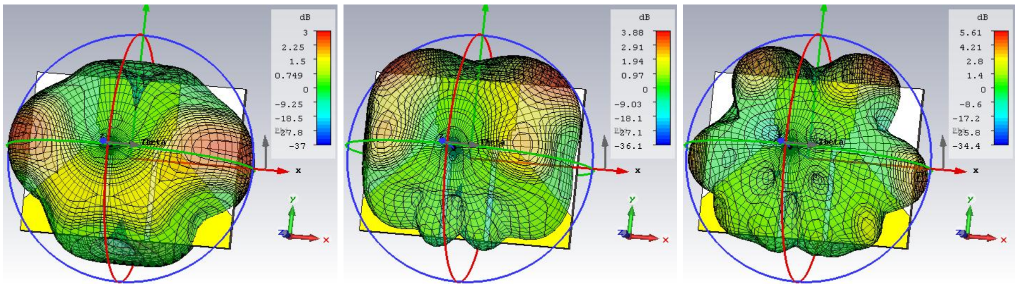

Figure 4. 3D gain pattern of the proposed antenna at 15GHz (left), at 22.15 GHz (middle) and at 28.3 GHz (right)

Figure 3 and Figure 4 show respectively the simulated current distributions and 3D total gain pattern at 15 GHz, 22.15 GHz and 28.3 GHz. It can be evidently seen from Fig. 3 that the current distribution at the three resonant frequencies is different. Concerning the first mode (15 GHz), the current distribution is mainly distributed along coplanar feeding while we observe more concentration of current distribution for the high resonance modes at 22.15 GHz and 28.3 GHz. From Figure 4, it is indicated the shape of simulated 3D radiation pattern at 28.3 GHz is not stable with important side lobes due to the presence of high propagation modes. However, for other frequency bands 11.6–16.5 GHz and 20.5–24.3 GHz, the simulated 3-D radiation pattern is bidirectional, stable, and with low side lobes. Following we describe the proposed techniques with the aim to perform the presented CPW-fed antenna in terms of gain enhancement.

3. ANTENNA GAIN IMPROVEMENT

To enhance the gain of the proposed antenna, we propose tree different techniques. The first technique is based on a stacked antenna designed with the CPW-fed antenna presented in the last section. The second one is based on series-feed antenna array based also in the same antenna. The third technique combines the first and the second techniques in one antenna. As we will see, the fourth antenna provides major gain enhancement.

3.1. Stacked Antenna: Results and Discussion

In order to enhance the CPW-fed antenna gain presented above, we add a second layer with air gap on the top of the single antenna designed previously. The design of the new stacked antenna can be shown in Figure 5. The thickness of air gap is fixed at 5 mm for real manufacturing process. The effect the permittivity of the second layer on the antenna response illustrated in Figure 6 demonstrates that the frequency response of the stacked antenna is not affected by increasing the permittivity value of the second layer. However, it is clearly indicated that the antenna gain increases when the dielectric constant increases. For the second layer, we choose the Rogers RO3010 with higher dielectric constant of 10.2, tangent loss of 0.003 and thickness of

1.27 mm. The resulting antenna responses in terms of gain and return loss compared to single CPW-fed antenna are shown in Figure 7. Regarding the return loss behavior, the stacked antenna presents a small shifting in the first band compared to the antenna 1. While this technique demonstrates a good improvement of antenna gain of about 72.39 %, 44.29 % and 21.88 % at the three successive frequency bands respectively, compared to the basic CPW-fed antenna.

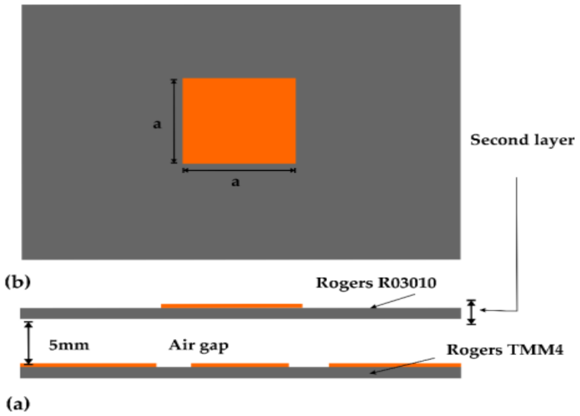

Figure 5. Configuration of the new stacked antenna (antenna2): (a) top view (b) front view

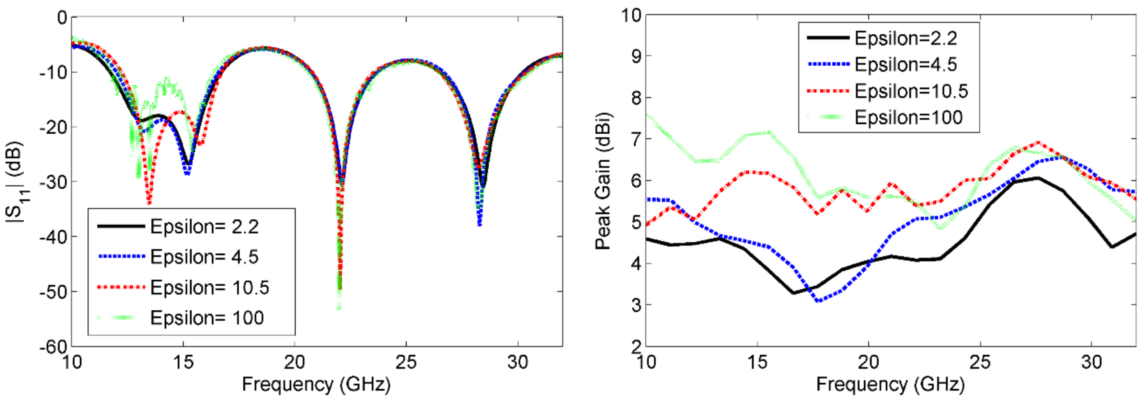

Figure 6. Return loss (left) and gain (right) performances of the proposed stacked antenna for different values of the second layer dielectric constant (Second layer thickness is fixed to 1.4 mm)

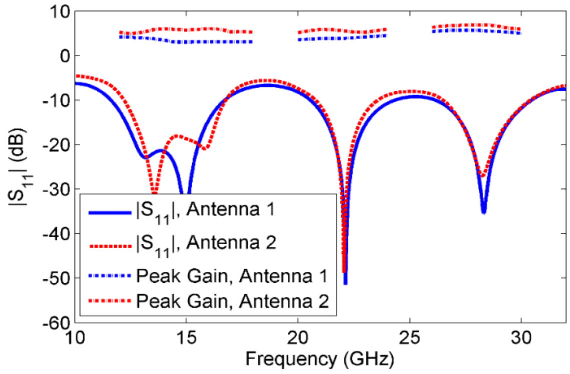

Figure 7. Return loss (left) and gain (right) performances of the proposed stacked antenna for different values of the second layer dielectric constant

In the next step, we propose the design series-feed antenna arrays based on the same CPW-fed antenna described previously for two and four elements. After comparison of both gain improvement techniques stacked and array configurations, we will combine these two methods in one structure, offering stacked series-feed antenna array on the base of coplanar fed antenna.

3.2. Series-feed antenna array: results and discussion

Figure 8 illustrates the schematic of the proposed series-feed antennas formed by two and four elements. For both cases, the antenna is feeding by the first element. This method of feeding is very widely used because it is very simple to design and analyze, also very easy to manufacture. The distance d_1 between two closed radiated elements is 0.45 λ, while the total length of the cell unit is equal to 0.75λ. The 4×1 series-feed antenna array is named antenna 3 in the rest of the paper description.

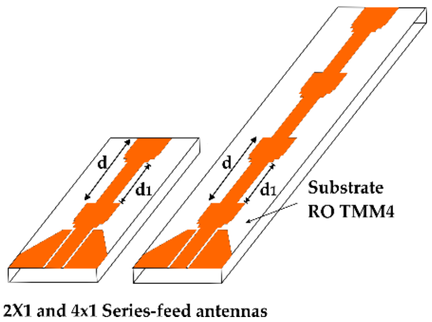

Figure 8. Schematic of the proposed series-feed antenna arrays

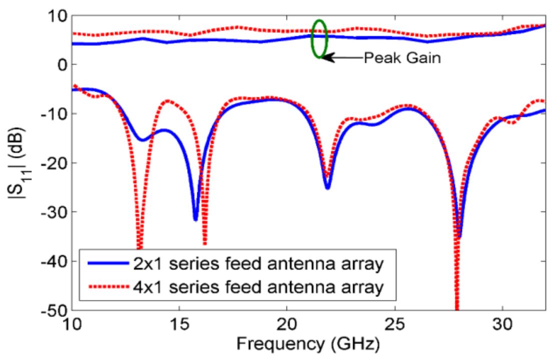

Figure 9. Return loss of the proposed series-feed antenna arrays

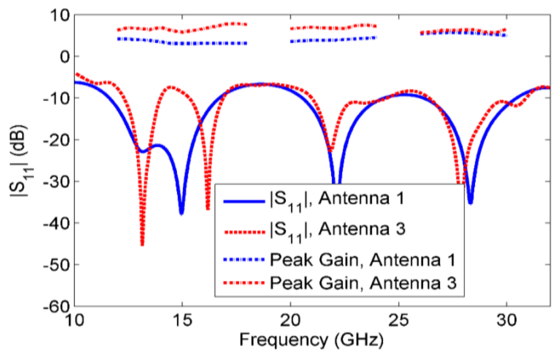

Figure 10. Return loss of the proposed antenna design cases

According to Figure 9, the antenna gain depends on the number of elements in the series-feed antenna array configuration. Then we observe a high antenna gain for the case 4×1 series feed array. These configurations offers 65.67 %, 76.56 % and 11.48 % of gain enhancement for the three successive resonance modes, compared to antenna 1as shown in Figure 10.

3.3. Stacked series-feed antenna array: results and discussion

Figure 11 illustrates the configuration of the proposed stacked series feed antenna formed by two layers separated by the air gap. The first consists of a 4×1 series feed CPW-fed antenna with the same specification described in the previous section. In the second layer, we print four parasitic conductors on the Rogers RO3010 substrate having permittivity of 10.2. This configuration combine both stacked and array solutions.

The simulated return loss of all proposed designed antennas in this paper are depicted in Figure 12. As can be seen, a very small shifting in frequency is noted between all proposed antennas. However, the antenna gain was increased using three different configurations. According to Figure 13, we observe that, the stacked array structure (antenna 4) represents high gain values of 8dBi for all covered frequency bands in comparison with to the rest of the designed antenna.

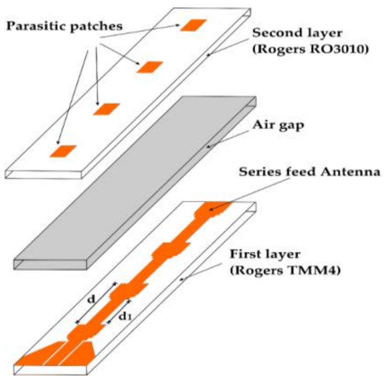

Figure 11. Configuration of the proposed stacked Series-feed antenna array (antenna 4)

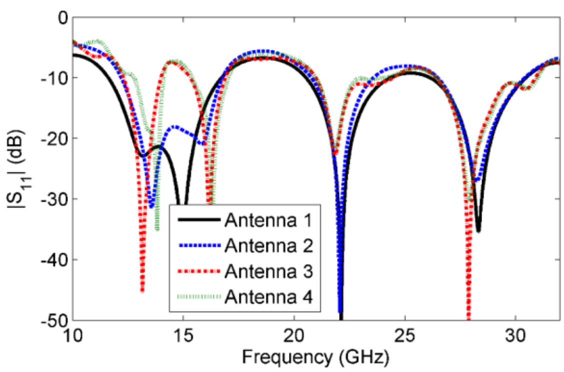

Figure 12. Simulated Return Loss of stacked Series-feed antenna array

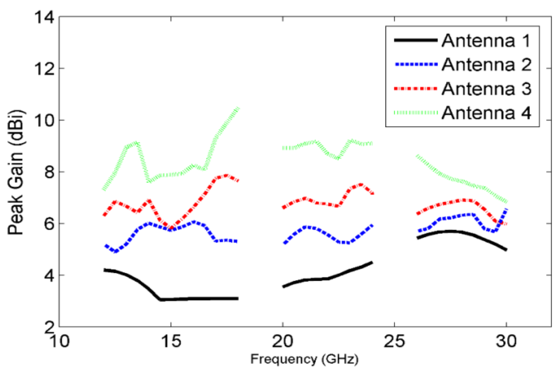

Figure 13. Simulated gain for all proposed design antennas

In addition, the stacked array solution presents a compact size and reduces the CPW-fed antenna beam with additional advantage on the vertical stacking to control the take-off angle together with the gain; on the other hand, an expected gain can be achieved at specific radiation pattern angle. The last technique demonstrates an average of 47% and 26 % gain improvement for CPW-fed antenna and the series feed antenna array respectively.

4. CONCLUSION

In this paper a compact CPW-fed antenna with gain improvement technique is proposed and multi-resonances for satellite application are described. Measurement results demonstrate a good agreement with simulations. To improve antenna performances, the stacked solution technique has been used, a second layer with high dielectric constant and air gap separation are introduced on the top side of the single layer antenna. A high performance in term of gain improvement with compact size has been achieved. For more gain enhancement, array technique is also introduced. Finally, both stacked and array techniques are combined into the stacked series-feed antenna array to allow more and more gain enhancement. Comparison studies between the previous antennas prove that both CPW-fed single layer and the stacked antennas are good candidates for future packaging systems.

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