SR-Based Printed Antenna Array with Reduced Size

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***Abstract*—Array of antenna with reduced size is required for wireless and mobile communications due to the portability properties. This paper presents a printed antenna array based on spiral resonator (SR) with reduced size. The proposed antenna array is configured by use of 2×2 patches of SR structure on two layers of FR4 epoxy dielectric substrate with each thickness of 1.6 mm. The characterization result of proposed printed antenna array provides the reflection coefficient (S_{11}) value of –23 dB at the frequency of 2.4 GHz with the working bandwidth of 95 MHz for the S_{11} value less than –10 dB. Meanwhile, the gain of proposed printed antenna array achieves around 7 dB. The simulation result is verified with the measurement one which shows a good agreement. Moreover, the size of proposed SR-based 2×2 printed antenna array is reduced up to 27% compared to the one of 2×2 printed square patches antenna array.**

***Index Terms*—antenna array, size reduction, spiral resonator (SR), square patch**

I. Introduction

As is already known, antennas employed for wireless and mobile communications should have compact size and light weight. To fullfill these demands, the miniaturization or size reduction of antenna is sometimes necessary. Many researches emphasizing in miniaturization and size reduction have been conducted for single antenna as well as for array of antenna [1]– [3]. Numerous techniques have been proposed and demonstrated recently for minimizing the size of antenna which range from using artificial materials/metamaterials [4]–[5], electromagnetic band gap substrate (EBG) [6], fractal Koch and patch geometry [7]–[8], multiple spilt ring resonator (MSRR) and spiral resonator (SR) [9]–[10].

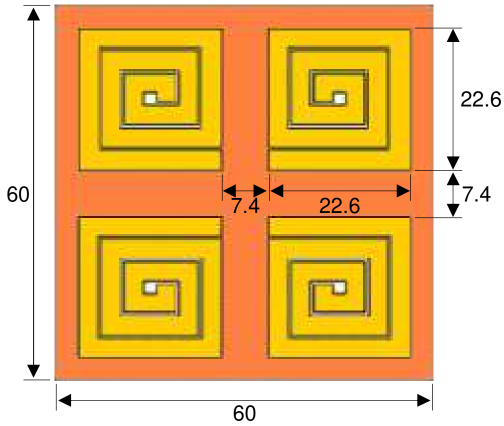
In the latter mentioned techniques above, the SR structure has more smaller compared with MSRR structure through the observation of resonant frequency [9]–[10]. The use of MSRR and SR structure could reduce linearly the size of antenna up to $\lambda_0/30$–$\lambda_0/40$ and $\lambda_0/65$–$\lambda_0/250$, respectively, showing the reduction factor of SR structure greater than the MSRR structure. The measurement result of SR shape deployed on the dielectric substrate has indicated the reduction factor of approximately 40%–70% with the efficiency of 20%–30% [11]–[12]. Furthermore, an enhanced SR structure in a square spiral patch has been investigated as an antenna radiator with a proximity feeding system to observe its radiation performance and size reduction [13]– [15]. The investigation result has produced an antenna without impedance matching circuit working at the frequency of 2.43 GHz with the bandwidth of 30 MHz and the size reduction up to 53%.

By taking the advantage of enhanced SR structure, in this paper, a printed antenna array composed of 2×2 patches of SR structure is presented to improve the radiation performance as well as to reduce the size. The proposed antenna array is designed on two layers of 1.6 mm thick FR4 epoxy dielectric substrate. An array of 2×2 patches of SR structure which has a functions as an antenna radiator is deployed on the first layer. Whilst the second layer has a microstrip line used as the feeding system which is electromagnetically coupled to the antenna array and groundplane. To investigate the potency of size reduction of printed antenna array based on SR structure, the design of antenna array using 2×2 square patches is also performed with the same treatment in which the result will be analyzed in comparison to the proposed SR-based printed antenna array. The proposed SR-based 2×2 antenna array is then fabricated and characterized experimentally to be compared with the design result.

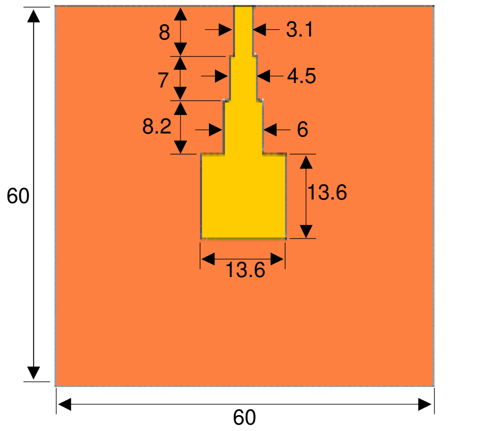
II. Brief Overview of Antenna Array Design

The proposed printed antenna array is designed using 2×2 patches configuration with the SR structure taken for each patch. The overall size of proposed SR-based 2×2 printed antenna array is 52.6 mm × 52.6 mm which is deployed on two layers of FR4 epoxy dielectric substrate with the thickness of 1.6mm for each layer. As discussed in [13], each SR patch has the dimension of 22.6 mm × 22.6 mm made of a spiral shape with the number of turn of 3, whereas the width of strip, the width of gap, and the inner radius are 3.1 mm, 0.5 mm, and 1 mm, respectively. The separation between patches which is set to be equal in all directions is 7.4 mm to achieve a good radiation characteristic. As shown in Fig. 1, the configuration of SR-based 2×2 patches is placed on the top side of first layer of dielectric substrate. This configuration is functioned as the radiator of antenna array. Meanwhile, to excite the radiator, a microstrip feeding line is placed on the second layer of dielectric substrate which is electromagnetically coupling the antenna and the groundplane.

Furthermore, to investigate the potency of size reduction of proposed antenna array, the antenna array configured by 2×2 printed square patches is also designed. As depicted in Fig. 2, the antenna array is configured by using two layers of 1.6 mm

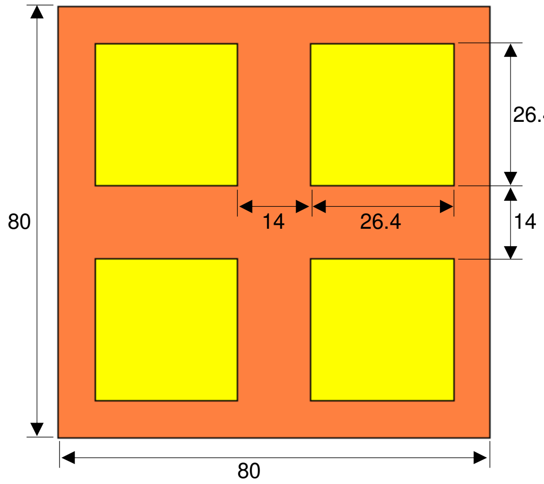


(a) SR-based 2 x 2 patches on first layer

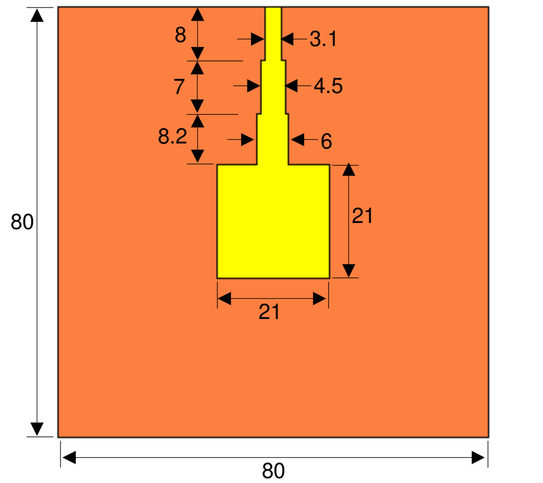


(b) proximity coupled feeding system on second layer

Fig. 1. Configuration of proposed SR-based 2×2 printed antenna array on two layers of FR4 epoxy dielectric substrate (unit in mm).



(a) 2 x 2 square patches on first layer



(b) proximity coupled feeding system on second layer

Fig. 2. Configuration of 2×2 printed square patches antenna array on two layers of FR4 epoxy dielectric substrate (unit in mm).

FR4 epoxy dielectric substrate, in which the top side of first layer is for deploying the 2×2 printed square patches and the top side of second layer is for placing the proximity coupled feeding system of microstrip line. To resonate at the same frequency of 2.4 GHz, each square patch has the dimension of 26.4 mm × 26.4 mm. The separation between square patches is set to be 14 mm yielding the overall size of antenna array to be 80 mm × 80 mm.

III. Result and Discussion

A. Simulation Result

The simulation result of SR-based 2×2 printed antenna array is plotted in Fig. 3 with the result of 2×2 printed square patches antenna array are depicted together as comparison. The result shows that the proposed SR-based 2×2 printed antenna array has radiation performances which are coincided with the 2×2 printed square patches antenna. The resonant frequency of SR-based 2×2 printed antenna array is 2.4 GHz with the value of reflection coefficient (S_{11}) of –23 dB, gain achievement of 7 dBi, and the –10 dB working bandwidth of 95 MHz in the frequency range of 2.366 GHz – 2.461 GHz. Meanwhile at the same resonant frequency, the 2×2 printed square patches

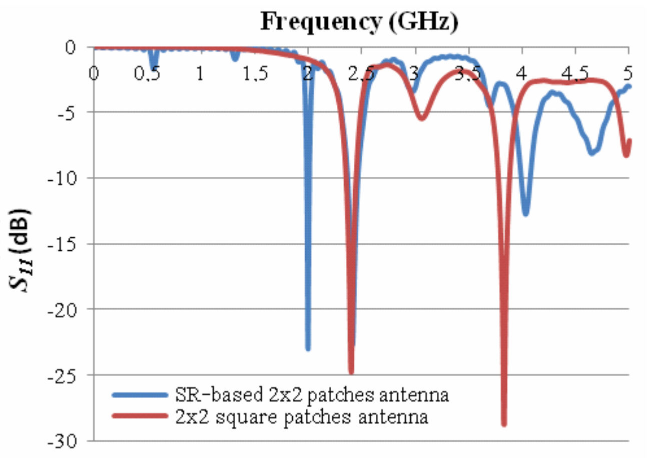
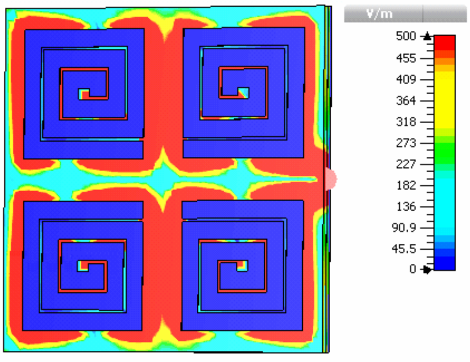
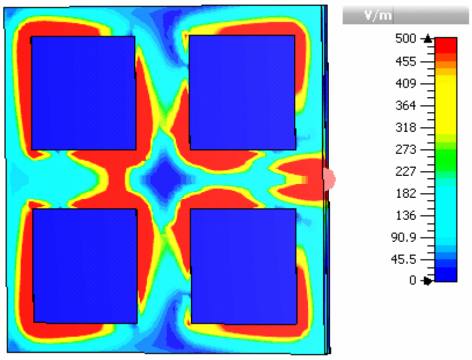


Fig. 3. Result comparison of simulated reflection coefficient (S_{11}) for both printed antenna arrays.



(a) SR-based 2 x 2 patches



(b) 2 x 2 square patches

Fig. 4. Electric field distributions on patches for both printed antenna arrays.

antenna array has the S_{11} value of 24.7 dB, gain achievement of 7 dBi, and the -10 working bandwidth of 92 MHz in the frequency range of 2.351 GHz – 2.443 GHz.

Furthermore, the use of SR structure for proposed printed antenna array has reduced the size up to 27% compared to the 2×2 printed square patches antenna array. This means that the SR structure is very potential to minimize the size of printed antenna array which is advantageous for wireless and mobile communications. Fig. 4 shows the electric field distributions on patches for both printed antenna arrays which were taken at the frequency of 2.4 GHz. Both of electric field distributions have similarity in theirs patterns, hence it can be inferred that 2.4 GHz resonant frequency for SR-based 2×2 printed antenna array is in the same mode with the one of 2×2 printed square patches antenna array.

B. Realization and Discussion

As shown in Fig. 5, the proposed SR-based 2×2 printed antenna array is deployed on two layers of FR4 dielectric substrate with each thickness of 1.6 mm. The realized printed antenna array is then characterized experimentally. The comparison of measured and simulated reflection coefficients (S_{11}) for SR-based 2×2 printed antenna array is plotted in Fig. 6. It can be observed that the measured result has good agreement with the simulated result. A slight difference of

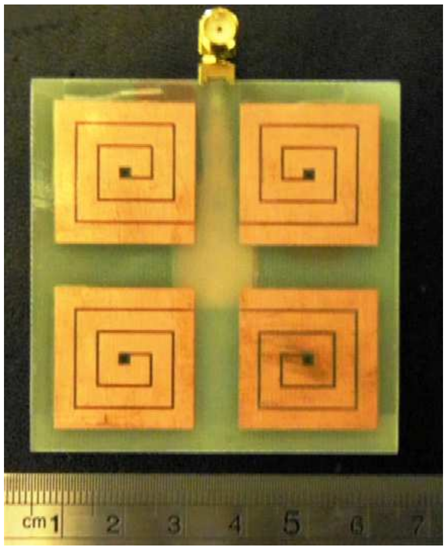


Fig. 5. Realized SR-based 2×2 printed antenna array on two layers of FR4 dielectric substrate.

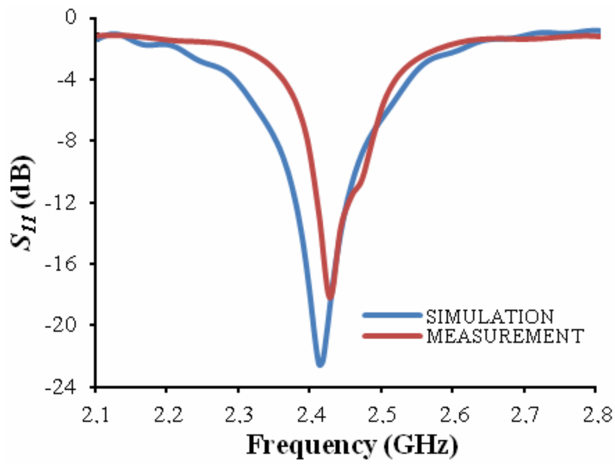


Fig. 6. Measured and simulated reflection coefficient (S_{11}) for SR-based 2×2 printed antenna array.

resonant frequency in the measured result is probably caused by the value of relative permittivity of dielectric substrate which is lower than in the simulation.

IV. Conclusion

The development of printed antenna array configured by 2×2 patches of SR structure has been presented. The proposed SR-based printed antenna array has been designed and analyzed to demonstrate the potency of size reduction compared to the 2×2 printed square patches antenna array. It has been shown that the proposed SR-based printed antenna array could provide better radiation performance compared to the 2×2 printed square patches antenna array. In addition, the use of SR structure for the antenna array configuration has also increased the -10 dB working bandwidth up to 3 MHz and reduced the size up to 27%.

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