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Isolation Enhancement in Microstrip Antenna Arrays

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ABSTRACT

Slotted Meander-Line Resonator (SMLR) is implemented by creating defect in the microstrip structure. This resonator is designed to block the surface current at the resonant frequency of the two patch antennas coupled along H-plane operating at 3.6 GHz. The proposed configuration provides an improvement in isolation by 10 dB (measured value) with a reduced edge-to-edge spacing of 7 mm ($\lambda_0/9$). This resonator has been designed, simulated, and validated experimentally.

***Keywords*- Antenna array, isolation enhancement, meander lines, mutual coupling reduction, resonators.**

1. Introduction

Isolation enhancement in array antenna applications poses complicated result in the antenna community. In antenna arrays, multiple antenna elements designed to operate at the same frequency share a common substrate, so that mutual coupling occurs. It reduces antenna gain, operational bandwidth, and radiation efficiency which may significantly interfere with neighboring antenna unit cells. Therefore, it is necessary to overcome this coupling effect between antenna elements and to improve the performance of the antenna array.

In existing system, several configurations like Multiple dielectric substrates (MDS), Electromagnetic band-gap (EBG) structures and Defected ground plane structures (DGS) have been investigated to reduce the mutual coupling effects between the antenna elements. In EBG structures, surface current reduction are proposed to be to overcome the mutual coupling effects. However, to incorporate these periodic structures in between the radiating elements, the separation between the antenna elements should be large, essentially greater than one third of the free-space wavelength (λ_0).

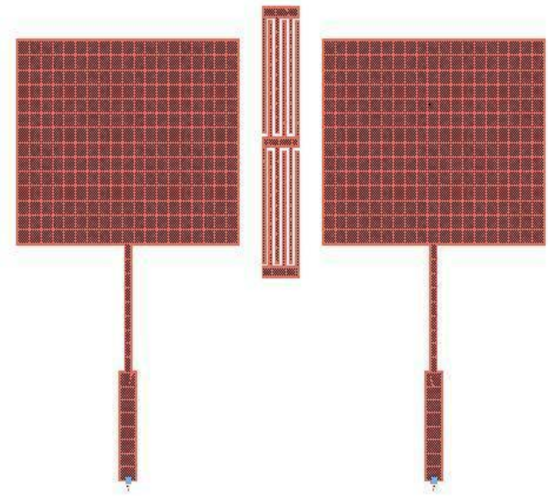
EBG-based solutions are not an attractive solution due to electrical loss incurred while using the vias and intricate fabrication. The use of planar EBG without vias increases the complexity and cost for being multilayer in nature. DGS structures, by disturbing the ground plane as a result back-radiation is increased, and in Multilayer dielectric substrates, each element uses separate substrate so it lead to increased weight of the antenna arrays.

In slotted meander- line resonators (SMLRs) are proposed to be the decoupling unit that occupies less space when compared to EBG structures and uses a single standard substrate. Packing density can increased due to the reduction in the spacing of the radiators in the antenna aperture, resulting in antenna array miniaturization. The decoupling unit has two sections of slotted meander lines cascaded and sandwiched between two patch antennas designed to work at 3.6 GHz. These SMLR structures act as a bandstop resonator that stops the surface current from one unit cell to another unit cell. The patch antenna is excited using 50- Ω microstrip lines through a quarter-wave transformer.

In Section 2 describes the characterization of the proposed SMLR decoupling unit In Section 3, the implementation of SMLR in between radiating patch and its effect on isolation has been detailed with results from simulation.

2. Design and Characterization Of SMLR

Fig. 1 shows the SMLR sandwiched between two microstrip patch antennas. The slotted meander line structure as shown in Fig. 2 is an electrical resonator because of the oscillation of currents induced within the slot. The SMLR is constructed by creating defects in the conventional microstrip structure. By introducing the folded slots, the slow wave factor over the microstrip increases, thereby perturbing the current that flows through the microstrip structure. This creates a band-gap that blocks the surface currents at resonant frequency. This structure acts as a decoupling unit by which fundamental resonant frequency is controlled by the length of the slot line and function as a band reject filter. To analyze the performance of the SMLR, a substrate material with height 1 mm and dielectric constant 4.4 is chosen. The SMLR is printed over this standard Substrate (FR4) and the simulations are carried out using ADS software. The proposed decoupling unit exhibited a sharp rejection at a frequency of 3.6 GHz when the length of the slot (l) is 11 mm. The design achieves a band reject function at 3.6 GHz enhances isolation for 10 dB. Increase in slot length decreases the resonant frequency. To improve the isolation between the radiating patch resonating at 3.6GHz, this SMLR with a slot length of 11 mm has to be sandwiched between the unit cells.



3. Isolation Enhancement Using SMLR

To verify the isolation enhancement in microstrip patch antenna arrays, a two- element array is constructed using microstrip patch antennas fed through a quarter-wave transformer.

The patch antenna operating frequency of 3.6 GHz.The antennas are printed over a standard FR4 substrate of height 1 mm having a dielectric constant of 4.4 and loss tangent 0.025. The antenna elements are separated by an edge-to-edge distance of 7 mm ($\lambda_0/9$).The total size of the antenna array is 54×45 mm. The isolation between two antenna elements is determined through the computation of S_{21}.

The measured S-parameters of the antenna array are depicted in Fig. 4. The measurement is done using Agilent's RF Vector Network Analyzer. At resonant frequency (3.6 GHz), an isolation improvement of 10 dB is achieved. Furthermore, from the measured results, it was evident that an improvement of isolation from 6 to 10.0 dB is realizable within the 10-dB operational bandwidth of the antenna array.

4. Figures and Table

Fig. 1. Proposed SMLR decoupling unit sandwiched between two patch antenna elements.

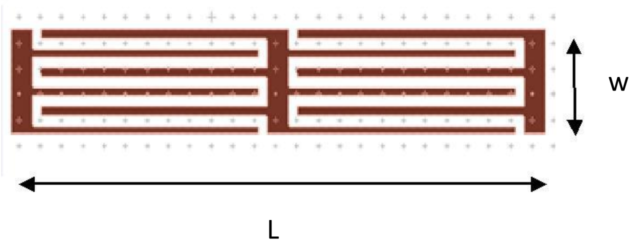


Fig. 2. Two- element cascaded SMLR decoupling unit (l_s , Length of the slot =11mm; l_S Width of the slot =0.375mm;w_S, Width of the defected

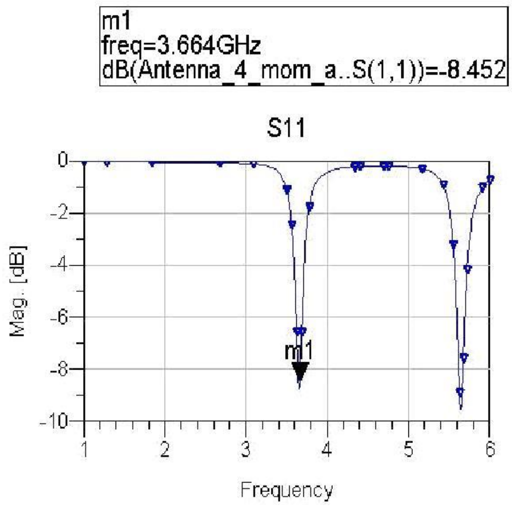


Fig. 3. Return loss Response without SMLR

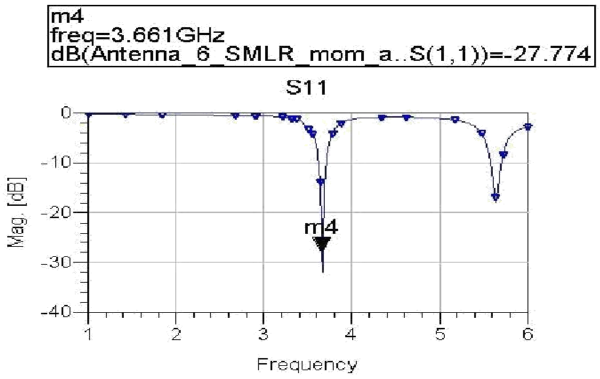


Fig.4 Return Loss Response with SMLR

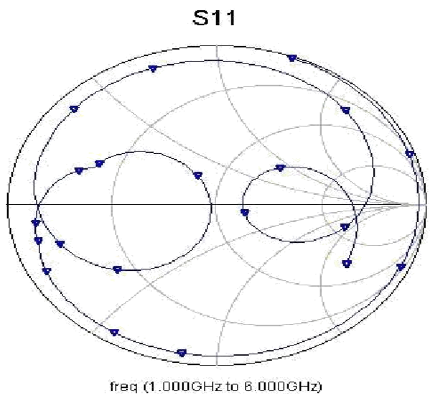


Fig.5. Smith chart

4.1. Performance of the Proposed SMLR and Other Configuration in Literature

S.NO	Ref.No	Approach	Size of array in mm	Freq(f_o) in GHz	-10dB percentage Bandwidth	Edge to edge spacing	Center to Center Spacing	Improvement in S_{21} (dB)
1	[2]	Multilayer Dielectric Substrate	130×130	3.0	7.67	0.40 λ_0 (40mm)	0.75 λ_0 (75mm)	10.00
2	[3]	Uniplanar EBG over superstrate	78.3×78.3	5.75	1.74	0.50 λ_0 (26.0mm)	0.63 λ_0 (32.9mm)	10.00
3	[4]	EBG	Not reported	8.0	15.63	Not reported	0.60 λ_0 (22.5mm)	5.00
4	[5]	DGS	63.5×40	9.2	3.26	<0.33 λ_0 (8.6mm)	0.70 λ_0 (23.6mm)	16.50
5	[6]	Slotted CSRR	78.0×60.0	5.0	3.00	0.25 λ_0 (15.0mm)	0.50 λ_0 (30.0mm)	10
6	[7]	Wave Guide metamaterial	76.0×91.0	3.5	1.43	<0.125 λ_0 (10.0mm)	0.36 λ_0 (31.0mm)	6.00 to 9.00
7	Proposed	Slotted meander line	54.0×45.0	3.6	5.21	0.11 λ_0 (7.0mm)	0.38 λ_0 (23.9mm)	10.00

5. Result

The SMLR sandwiched between the antenna elements has a minor effect on the resonant frequency causing a small shift. This is due to fact that the SMLR characterization and design of patch antenna array have been done independently. The surface current distribution of the configuration is depicted in Fig, from which suppression of surface current due to SMLR unit cell is evident.

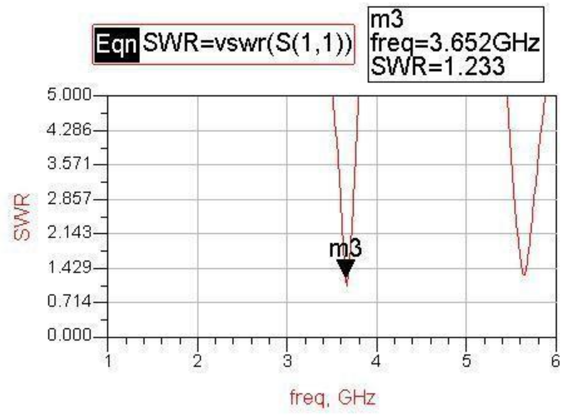


Fig.6. VSWR measurement

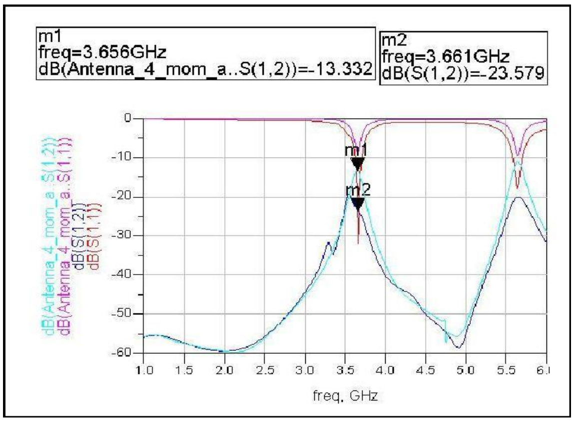


Fig.7. Simulated S-Parameter characteristics of the Antenna Array with one antenna excited and another antenna terminated by 50Ω

Furthermore, to analyze the effect of SMLR on radiation Characteristics, the unit cell in the antenna array is de-fined to work in transmit and receive mode by exciting one antenna element with RF waveguide port, while the other element is terminated by a 50- Ω load. The reflection characteristic under this simulation setup the VSWR results shown in fig.6 VSWR value is 1.2:1 for 3.6 GHz resonance frequency. The smith chart is also shown in fig.5

The SMLR in between the elements of the antenna array has a little influence on the radiation characteristics in terms of gain, front-to-back ratio, and cross polarization. A 6% improvement in the radiation efficiency is achieved through the simulated results, owing to effect of enhancement in isolation.

Table 4.1 shows the results of the various solutions that were adopted for enhancing the isolation between individual elements in a microstrip patch antenna array. The array has been designed, simulated, and tested for minimum spacing and found suitable for applications like array applications.

6. Conclusion

In this paper, a new configuration using slotted meander lines has been proposed to enhance the isolation between two antenna elements in microstrip patch antenna arrays. The properties of SMLR are verified using band- gap analysis. The design achieves an improvement of 10 dB at the operating frequency with edge -to-edge spacing of 7 mm. A comparison between the proposed configuration and those reported earlier has been described in Table . The measured results justify the effect of the proposed SMLR on isolation enhancement and array size.

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