

# Array Antenna for Synthetic Aperture Radar Operating in X and Ku-Bands: A Study to Enhance Isolation Between Radiation Elements

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**Abstract-** Modern synthetic aperture radars (SAR) require a system bandwidth of greater than 1 GHz. Waveguide slot antennas are popular for use in SAR applications because of their inherent advantages, namely high efficiency and power handling capability, but such antennas have a limited bandwidth. Although the bandwidth of slot antennas can be broadened by using ridge waveguides however this approach introduces manufacturing complexity and is costly. A novel solution is presented in this paper to realise a large bandwidth by using 2x3 array antenna where the mutual coupling between the radiating elements is suppressed by inserting an isolation wall between the radiating elements. The isolation wall comprises three intercoupled U-shaped microstrip transmission-lines. With this technique the antenna's bandwidth for VSWR<1.5 is greater than 2 GHz inside the X- and Ku-bands.

**Keywords-** Synthetic aperture radar (SAR), decoupling, meander lines, array antennas.

## I. INTRODUCTION

Synthetic aperture radars are extensively used for high-resolution spaceborne and airborne applications for monitoring the weather, climate change, earth resource mapping, and military systems. SAR systems take advantage of the long-range propagation characteristics of radar signals and the complex information processing to provide high resolution imagery. Slant-range spatial resolution ( $\rho_r$ ) of SAR systems is a function of the system bandwidth, given by [1][2]:

$$\rho_r = c/2B \quad (1)$$

where  $c$  is speed of the light, and  $B$  is the system bandwidth. It is evident from this equation that when the slant-range spatial resolution is required to be

better than 0.2m, the system bandwidth needs to be greater than 1 GHz.

Numerous SAR satellite programs including RadarSAT-1, X-SAR, and ERS-1/2 have adopted waveguide slot array antennas because of their inherent advantages of high efficiency, mechanical strength, high power handling capability, and ease of fabrication. Conventional waveguide slot array antennas unfortunately have a limited bandwidth. To overcome this deficiency several approaches have been investigated in the past to enhance the bandwidth of such antennas. In one method the array is divided into sub-arrays that are fed through power dividers, but the associated loss is considerably high. Although the bandwidth using ridged waveguide can be improved it is considerably difficult to manufacture the ridges, which exacerbates the antennas cost [3]-[5].

Other than bandwidth requirements mutual coupling between the antenna needs to be minimal, which could significantly degrade the antenna's radiation pattern and gain performance, as well as contribute to crosstalks between neighboring antenna elements. Mutual coupling is higher for antenna elements which are spaced less than half-wavelength. Ideally, antenna elements should be highly isolated from each other to achieve desired performance from array antennas. Various techniques have previously been proposed to minimize the mutual interference between the antenna elements and to improve the isolation between the elements [6]-[11]. The basic principle is to involve embedding between the array antenna elements various structures, namely: (i) defected ground; (ii) electromagnetic bandgap; (iii) parasitic element; (iv) neutralization line; (v) metamaterial, etc. The structures reported to-date can suffer from

fabrication complexity, having a large resonant frequency mismatch between  $S_{11}$  and  $S_{22}$ , degraded antenna radiation patterns and efficiency, not having acceptable isolation over the whole system bandwidth, or narrow frequency bandwidth.

In this paper, a  $2 \times 3$  array antenna is presented that has a wide bandwidth for high-resolution synthetic aperture radar applications. The proposed array antenna is a symmetrical configuration with six radiation elements separated edge-to-edge by only  $0.37\lambda_0$  (10 mm) whose bandwidth is within X- and Ku-bands, i.e. 11.2 to 13.5 GHz, corresponding to 18.62% fractional bandwidth. Isolation between the adjacent antenna elements is improved by inserting an isolation wall between the radiating elements. The isolation wall is implemented with three intercoupled U-shaped transmission-lines. Parametric study on the effects of the isolation wall was conducted to optimise the antenna's performance. The results show by applying this simple isolation technique the level of decoupling between all array elements have dramatically improved.

## II. PROPOSED MUTUAL COUPLING BASED ON TRANSMISSION LINE ISOLATION WALL

Fig.1 shows  $2 \times 3$  array antenna which is implemented with six standard patch antennas. Mutual coupling between the patches is reduced by inserting an isolation wall between the patch antennas. The isolation wall is three intercoupled U-shaped microstrip transmission-lines that behaves essentially as an electrical resonator resulting from oscillation of currents induced within the structure. In fact, the isolation wall increases the slow wave factor to thereby perturb the current that flows through the microstrip structure. This creates a bandgap that blocks the surface currents at its resonant frequency. This structure when employed as a decoupling unit acts like a band reject filter whose fundamental resonant frequency is controlled by the length of the three U-shaped microstrip transmission-lines. The array antenna and isolation wall were constructed on FR-4 substrate material with height of 1.6 mm, dielectric constant of 4.3, and loss tangent of 0.025. The antenna's performance with and without the isolation wall was analysed using CST Microwave Studio (Version 2016). The array antenna was excited simultaneously through the six designated waveguide ports in the yz-plane, shown in Fig.1. The reflection and transmission characteristics of the simulation analysis are as shown in Fig.2, where the bandwidth is defined for  $S_{11} < -10\text{dB}$ . The proposed mutual coupling isolation

wall exhibits a sharp rejection at a frequency of 12.7 GHz when the width of the U-shaped transmission-lines is 0.5mm and the gap between the lines is 1mm. These dimensions result in band reject function between 11.2 and 13.5 GHz for isolation greater than -15dB between the ports.

With no wall the maximum isolation between elements #1 and #2; #1 and #3; #1 and #4; #1 and #5; #1 and #6; #2 and #3; #2 and #5; #3 and #4; #3 and #5; #4 and #5; #4 and #6; #5 and #6 is -26, -17, -36, -17, -36, -36, -36, -31, -33, -34.5, -31, and -30.3, respectively. After applying the isolation wall the maximum isolation between corresponding elements as above significantly improve to: -33, -33, -55, -33, -55, -58, -66.5, -71, -60, -56.3, -66, and -70.3, respectively. It is noted in each case the isolation has improved by a factor of at least two. In other words, the isolation improvements between aforementioned elements is: -7dB, -16dB, -19dB, -16dB, -19dB, -22dB, -30.5dB, -40dB, -27dB, -22dB, -35dB, and -40dB, respectively.

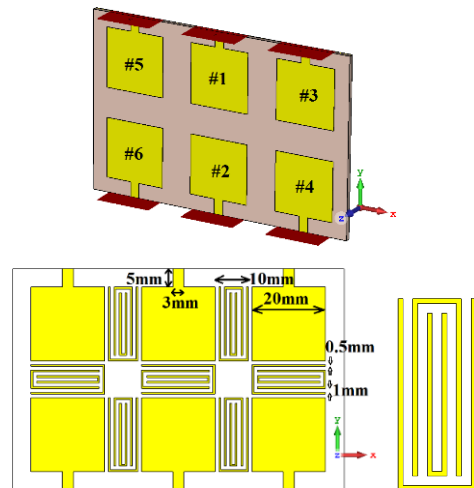
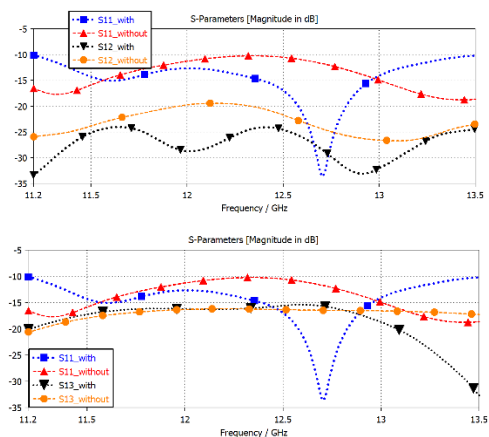


Fig.1. Proposed array antenna without and with isolation wall.



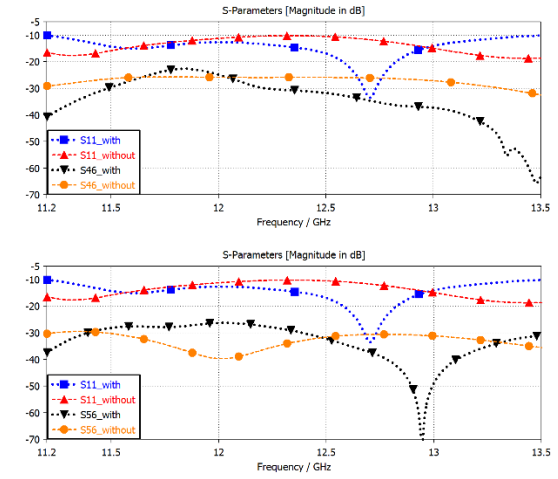
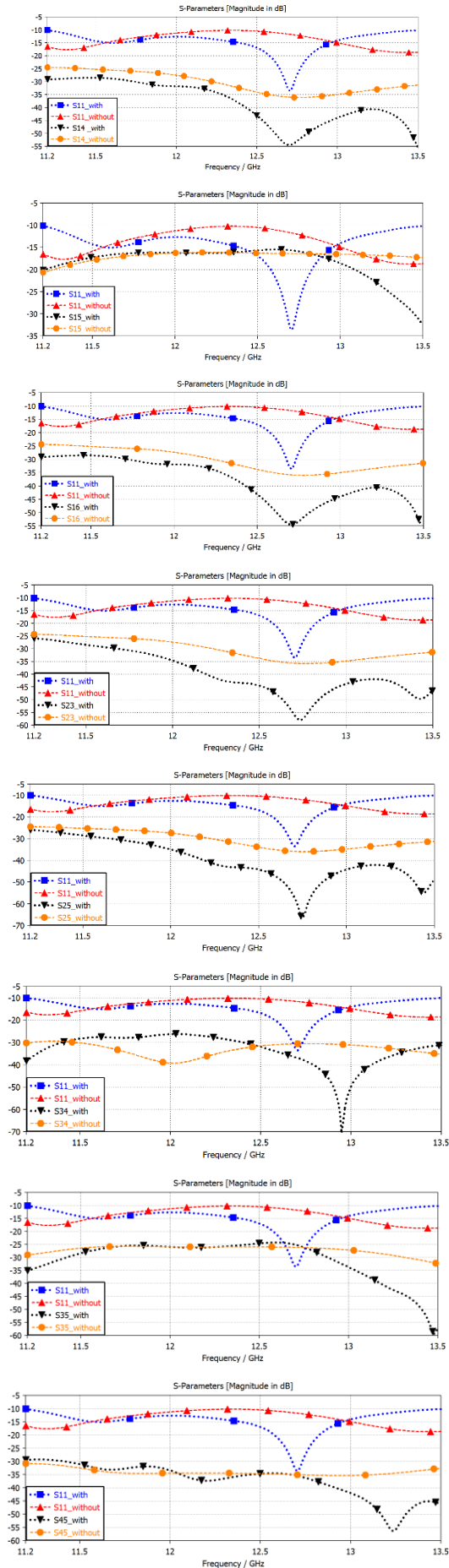


Fig.2. Reflection and transmission response where the bandwidth is defined for  $S_{11} < -10$ dB. Other corresponding S-parameters are identical due to the symmetrical configuration of the array antenna.

The array antenna's radiation patterns for both cases with and without the isolation wall at the antenna's resonance frequency of 12.7 GHz are plotted in Fig.3. These results show no obvious degradation in the radiation characteristics of the array radiation without and with the isolation wall. In fact, this implies the isolation wall could be inserted retrospectively to reduce mutual coupling in planar antennas.

The array antenna's radiation gain without and with the isolation wall varies from 3.91dBi to 6.80dBi, and from 4.45dBi to 8.5dBi, respectively.

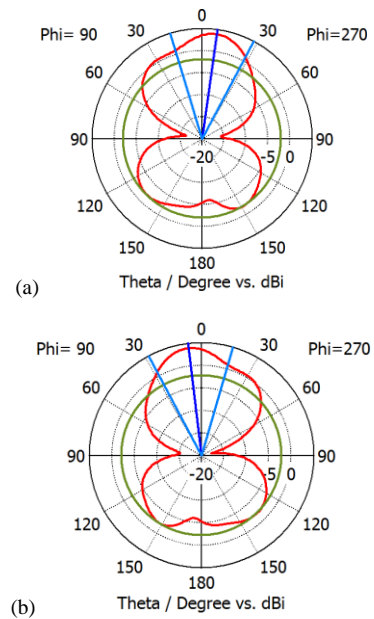


Fig.3. Radiation patterns at the resonance frequency of 12.7 GHz, (a) without isolation wall, and (b) with isolation wall.

The array antenna's performance is compared and validated with other recent mutual coupling reduction techniques in Table I. The results, shows that the proposed array antenna has a wide bandwidth of more than 2 GHz from 11.2 – 13.5 GHz (18.62% fractional bandwidth) to support part of X- and Ku- bands. The other antennas in Table I apply mutual coupling reduction to just 1×1 array antenna, whereas here we have applied the proposed isolation wall to 2×3 array antenna configuration. The results show with the proposed isolation wall a higher isolation between antennas is achieved, and the radiation pattern remains essentially intact. The proposed isolation wall is of a simple construction, which can be applied retrospectively to existing planar array antennas. In addition, unlike other techniques the proposed technique does not require any via holes and/or defected ground plane.

TABLE I. Proposed Array Antenna Characteristics Compared with Recent Works

Ref.	Method	Max. isolation improvement	BW	Rad. pattern deterioration	No. of elements
[12]	EBG	4 dB	Narrow	Yes	2
[13]	UC-EBG	10 dB	Narrow	Yes	2
[14]	Compact EBG	17 dB	Narrow	Yes	2
[15]	DGS	17.43 dB	Narrow	Yes	2
[16]	U-Shaped Resonator	10 dB	Narrow	Yes	2
[17]	Slotted Meander Line Resonator	16 dB	Narrow	Yes	2
[18]	I-Shaped Resonator	30 dB	Narrow	Yes	2
[19]	Slot in Ground plane	40 dB	Narrow	Yes	2
[20]	SCSRR	10 dB	Narrow	Yes	2
[21]	SCSSRR	14.6 dB	Narrow	Yes	2
[22]	W/g MTM	20 dB	Narrow	No	2
[23]	W/g MTM	18 dB	Narrow	No	2
[24]	Meander Line Resonator	10 dB	Narrow	No	2
[25]	Fractal load with DGS	16 dB	Narrow	No	2
This work	Triple U-Shaped Coupled Lines	S12: 7 dB S13: 16 dB S14: 19 dB S15: 16 dB S16: 19 dB S23: 22 dB S25: 31 dB S34: 40 dB S35: 27 dB S45: 22 dB S46: 35 dB S56: 40 dB	Wide	No	6

### III. CONCLUSION

A novel technique is shown to significantly enhance isolation between radiating elements in a 2×3 array antenna. This is achieved by simply inserting an isolation wall comprising three intercoupled U-shaped microstrip transmission-lines. The proposed technique offers a wide bandwidth operation greater than 2 GHz inside the X- and Ku-bands, which is necessary for SAR systems, and has minimal affect

on the antenna's radiation patterns. The isolation wall is simple to fabricate and does not require any via-holes or defected ground plane.

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