Dual and Linearly Polarized SIW Series Slot Array Antenna for Ka Band

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Abstract

In this paper, the prototype of a dual and linearly polarized series slot array antenna, using substrate integrated waveguide (SIW) technology, is proposed. The ±45° dual polarized slot arrays share a common aperture of 62.4 × 55.04 mm. The uniform field distribution and impedance matching are realized by alternating reactance slot pairs at 35 GHz. These radiating slot elements and coupling slots are placed in double-layered substrates having a dielectric constant 3.5 with a thickness of 1.52 mm and 0.75 mm. Moreover, the coordinate systems of radiating and coupling slots are designed to realize in-phase field excitation and eliminate grating lobes for all cutting planes. The proposed antenna can be fabricated using a standard PCB process, such as drilling and etching, for low cost and light weight features. By using the full-wave simulator, CST MWS, we checked the electrical performance, including bandwidth, realized gain, and side lobe level (SLL), with 1 GHz, 24.2 dBi, and −13.6 dB, respectively.

Keywords : Alternating reactance slot pair Dual polarization Slot array antenna Substrate Integrated Waveguide (SIW)

1. Introduction

Dual polarization is required to increase the resolution of images and acquire the tolerance to the environment for radar applications such as synthesis aperture radar (SAR). Until now, dual polarization has been developed using microstrip patch radiating elements [1]. However, the feeding network that consists of microstrip transmission lines can be inevitably affected by external interferences and surface wave energy coupling. As a result, the radiation patterns are easily distorted. Additionally, for a dual polarized waveguide slot array antenna the grating lobe suppression is an important issue. In [2], the excellent dual and linearly polarized slot array antenna was proposed using a broad wall shunt slot array and narrow wall series slot array combination within a common aperture to eliminate the grating lobes. Furthermore, the travelling wave type 45° inclined narrow wall slot array antenna was suggested in [3].

In this paper, the standing wave type series slot array antenna is proposed for ±45° linear polarization using a standard PCB process to create a low-cost, light-weight antenna structure. All radiating elements are realized by the alternating reactance slot pair, which is suggested by the authors [4]. Using half guided-wavelength spacing, these radiating units allocate themselves, even though these radiating slots are centered-inclined series slots with the same tilt angle of ±45°.

2. Proposed antenna structure

As shown in Figure 1, the proposed antenna has an alternative arrangement between orthogonal polarizations with an offset parameter, d_{offset}, as published in [5]. Each planar slot array is also composed of 16 × 8 elements and etched on the top metal plate of the upper PCB. Additionally, the coupling slots are etched on the bottom metal plate of the upper PCB and the top metal plate of the lower PCB and are aligned with Taconic bonding film of dielectric constant 3.5. Furthermore, wideband coax-to-SIW transitions are employed, using 2.92 mm connectors for port 1 and port 2.

2.1 **Radiating element coordinate system**

The linear slot array antenna is designed using eight pairs of alternating reactance slots [4]. All of these radiating elements can be separated by a half guided-wavelength (d_x) of radiating SIW. This is because the slot length is shorter and longer than the resonant slot length represented by inductively loaded and capacitively loaded impedance, respectively. As a result, it is easy to suppress the grating lobes in the *zx* cutting plane, as shown in Figure 2. Moreover, the element spacing (d_x and d_y) is primarily affected by the width of the radiating SIW of the linear slot arrays. Therefore, the width of the radiating SIW must be set so as not to create an excess of a wavelength in free space for d_x and d_y, simultaneously. As a result, the proposed antenna has a spacing of 3.34 mm (d_x) and 6.88 mm (d_y) which corresponds to $0.39\lambda_0$ and $0.8\lambda_0$, respectively. Furthermore, in order to minimize the isolation between the linear polarizations, the offset spacing was determined to be $3/4\lambda_{gr}$ [5].

2.2 **Coupling slot and wideband coax-to-SIW transition**

We adopted the soft coupled type series-to-series coupling slots in the feeding SIW, as shown in Figure 1 and Figure 2. In order to inject the power into every radiating SIW with uniform and in-phase excitation, the coupling slots are separated by a guided-wavelength in the feeding SIW with the same tilt angle (p) and length (cl). The thickness and dielectric constant of bonding film are additional concerns with regard to minimum reflection in full-wave simulation. Meanwhile, a wideband coax-to-SIW transition was designed using an inductive junction structure, as shown in Figure 1, to create a dual resonance characteristic.

3. Results

Figure 3 shows the s-parameter results of the proposed dual polarized slot array antenna. The center frequency is 35 GHz and the bandwidth of S11 and S22 are evaluated by 1 and 0.78 GHz, respectively. However, the isolation results of S21 and S12 are approximately −12 dB, which is a significant amount of coupling between orthogonal linear polarizations even with the use of offset distance, d_{offset}. The radiation patterns and realized gain for each polarization and cutting plane are depicted in Figures 4 and 5. The realized gains are obtained with 24 dBi and 24.2 dBi for ±45° polarization slot arrays, respectively, which corresponds to 43% aperture efficiency in a given aperture area. The side lobe levels were also checked for each polarization and found to be −13.6 dB and −12.8 dB at *zx* planes, respectively. As a result, we confirmed that the radiation patterns show symmetric features without any grating lobes.

4. Conclusion

The dual and linearly polarized SIW planar series slot array prototype antenna is proposed for Ka band. The linear slot arrays are designed by the alternating reactance slot pairs periodically, for uniform excitation and impedance matching, simultaneously. With the help of the above-stated arrangement, the grating lobes can be avoided and the radiation efficiency can be enhanced. At the same time, the proper value of the radiating SIW width can suppress the grating lobes at a different cutting plane. We designed the uniform excitation in the common aperture area and checked the simulated radiation patterns with −13.6 dB and −12.8 dB side lobe levels. We expect that the proposed antenna can be used for radar applications with improved isolation characteristics in future work.

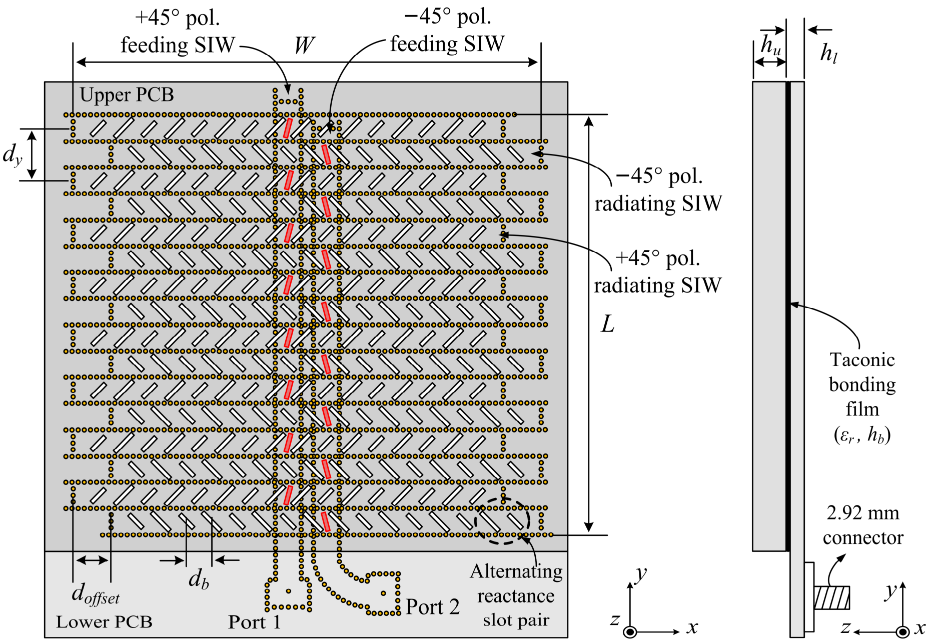


Figure 1: The perspective and lateral view of the proposed antenna.

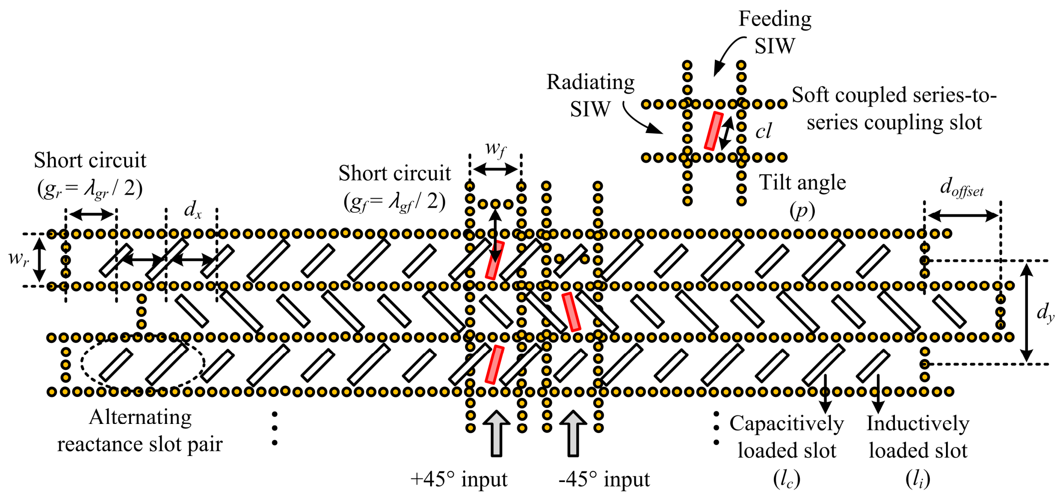


Figure 2: Dual polarized slot array antenna coordinate system.

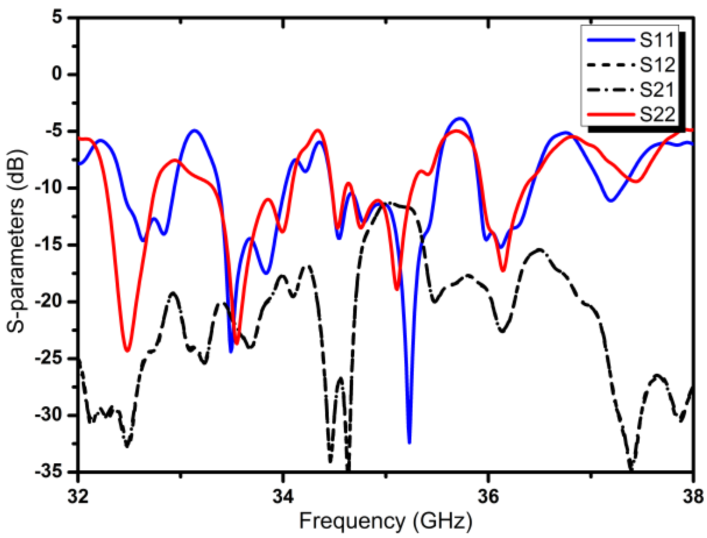
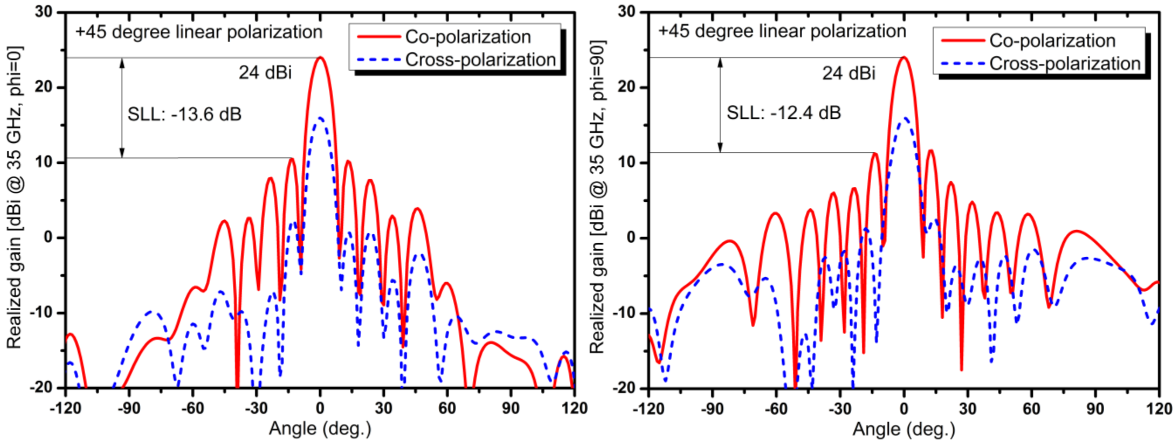
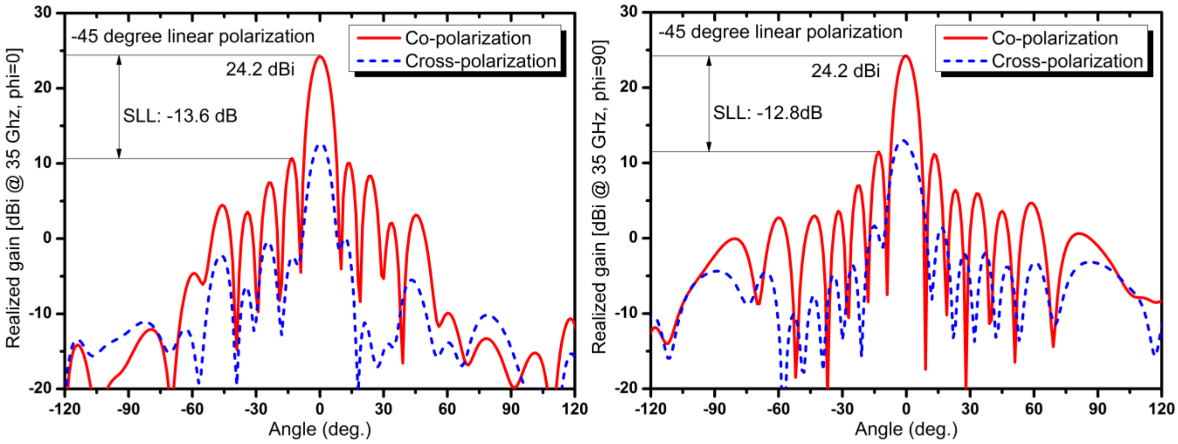


Figure 3: Simulated S-parameter results.



(a) (b)

Figure 4: Simulated +45° linear polarized radiation patterns at 35 GHz (a) *zx* plane (b) *yz* plane.



(a) (b)

Figure 5: Simulated −45° linear polarized radiation patterns at 35 GHz (a) *zx* plane (b) *yz* plane.

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Acknowledgments

This work was supported by LIG Nex1 Co. LTD.