Design of a Ka-Band Dual Polarized SIW Slot Array Antenna with Low Mutual Coupling

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***Abstract*-The ±45° dual polarized standing-wave slot array antenna design method for mutual coupling and grating lobes suppression is proposed. The antenna is realized using substrate integrated waveguide (SIW) technology for Ka-band operation. The relative permittivity of a printed circuit board (PCB) and the width of radiating SIWs are chosen to meet orthogonalized arrangements between dual polarized radiators, and reduce the slot spacings in both longitudinal and transverse directions, simultaneously. As a result, the isolation and cross polarization levels for 4 × 4 dual polarized slot array antenna were obtained better than 30 dB and 15 dB at center frequency of 35 GHz, respectively.**

I. Introduction

The polarization diversity has been suggested to several communication and radar systems in order to enhance the channel capacity and clear the target image from the glint angle noise [1-3]. The dual linear polarization was realized by shunt and series radiating slots on broad and narrow walls of radiating waveguides, respectively, for X-band SAR with somewhat complex 3-dimensional feeding structure [2]. In addition, ±45° crossed radiating slots with individual open-ended cavities above the ridged feeding waveguides are arrayed using multi-layered metal sheets and operate for dual polarized Ka-band monopulse tracking with high isolation and cross polarization levels [3]. The most important design issue for these dual polarized array antenna is to suppress the mutual coupling between crossed radiators within a common aperture area. Besides, the grating lobe reduction is also crucial for efficient radiation.

In this paper, the simple ±45° dual polarized slot array antenna design method is proposed and realized using the substrate integrated waveguide (SIW) technology for Ka-band. In addition, the design method for suppression of mutual coupling and grating lobes are presented and verified using a full-wave simulation.

II. Design Considerations for Dual Polarization

The ±45° series slot array antennas are designed using alternating reactance slot pairs as a basic radiating unit [4]. The SIW transmission lines consist of via arrays with a diameter (d) and a spacing (s) of 0.4 mm and 0.75 mm, respectively, for minimum radiation, conduction losses for 35 GHz operation [5]. In order to design a dual polarized SIW slot array antenna with suppressed mutual coupling and grating lobes, orthogonalized radiating slot arrangements with

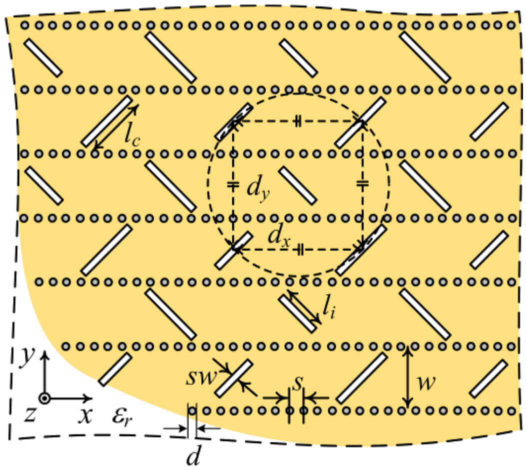

Fig. 1. The arrangement of ±45° dual polarized radiating slots on each radiating SIWs.

proper slot spacings are required. Fig. 1 shows the arrangement of orthogonalized and dual polarized radiating slots that are etched on each radiating SIWs. Under the orthogonal condition, four adjacent cross-polarized radiating slots are orthogonalized to a centered slot with a constant radius.

A. *The width of radiating SIWs*

The slot spacings along the x- (d_x) and y-directions (d_y) are determined by the width (w) of the radiating SIWs in reverse proportion, as shown in Fig. 1. In order to satisfy the orthogonal condition, two times of the width of the radiating SIW should be equal to one half guided-wavelength of the corresponding SIW in accordance with [4]. In addition, the guided-wavelength of the SIW is a function of the relative permittivity (ε_r) of a dielectric material.

B. *The relative permittivity of PCBs*

In order to satisfy the orthogonal condition between dual linear polarizations, the width and the dielectric constant of radiating SIWs should be deliberated simultaneously. Also, the slot spacings should be less than one wavelength in free space to avoid grating lobes in both directions. The orthogonal conditions are verified with a RT/Duriod5880 that has the dielectric constants of 2.2. When, the width of the radiating SIWs are set as 3.42 mm (= $0.8\cdot\lambda_0$), the grating lobes can be suppressed under the orthogonal condition. In addition, these

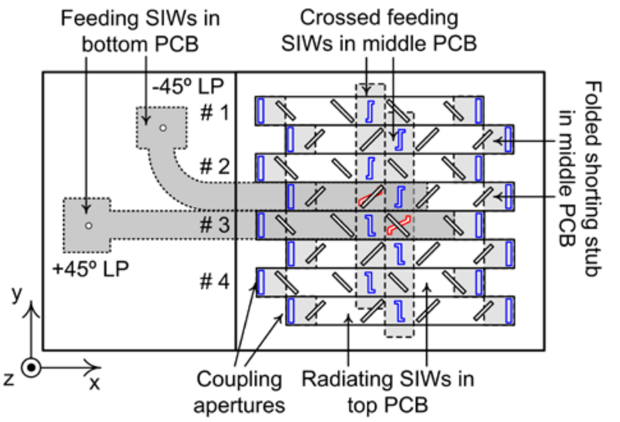

Fig. 2. The configuration of a 4 × 4 dual polarized slot array antenna (SIW transmission lines that are consisted with metallic via arrays are replaced with equivalent conventional rectangular waveguides).

radiating SIWs operate over cut-off frequency with a fundamental TE_{10}-mode.

III. APPLICATION FOR DUAL POLARIZED 4 × 4 SLOT ARRAY ANTENNA

A 4 × 4 dual polarized slot array antenna is designed under the orthogonal condition on multi-layered RT/Duroid5880 laminates, as shown in Fig. 2. The input powers are injected through two coax-to-SIW transitions and pass along feeding SIWs on a bottom PCB for each polarizations. All radiating SIWs are fed by centered shunt-to-series coupling slots etched on crossed feeding SIWs in a middle PCB for in-phase and uniform distributions.

The proposed antenna is simulated and optimized using full-wave EM simulator, CST MWS 2012. Each reflection coefficients for ±45° polarizations with isolation are depicted in Fig. 3. Both impedance bandwidth is over 480 MHz when VSWR < 2.0, and the isolation (i.e. S21 or S12) is better than 30 dB at operating frequency range. In addition, the radiation patterns for each polarizations and cutting planes are shown in Fig. 4. It is found that cross polarization and sidelobe levels of –15 dB and –10 dB can be achieved from orthogonal arrangement and a uniform field distributions, respectively.

IV. CONCLUSIONS

The ±45° dual polarized SIW slot array antenna is proposed under the orthogonal condition in order to suppress mutual coupling and avoid grating lobes, simultaneously. It is important to decide the width of the radiating SIWs and relative permittivity of a PCB. A 4 × 4 dual polarized slot array antenna is designed using the proposed design method, and resulted in low mutual coupling and high purity of co-polarized radiation.

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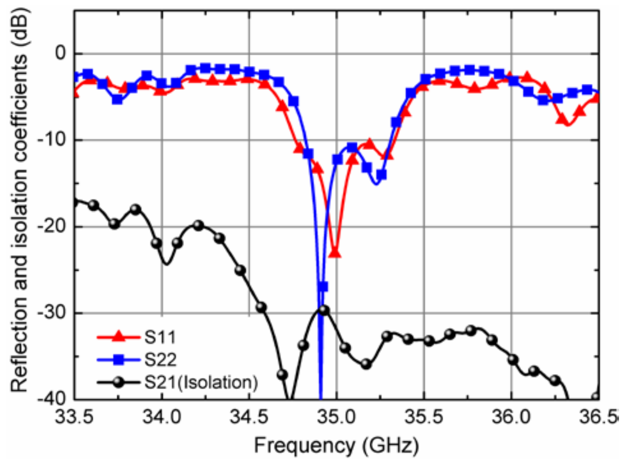

Fig. 3. The simulated reflection coefficients and isolation results for 4 × 4 dual polarized slot array antenna.

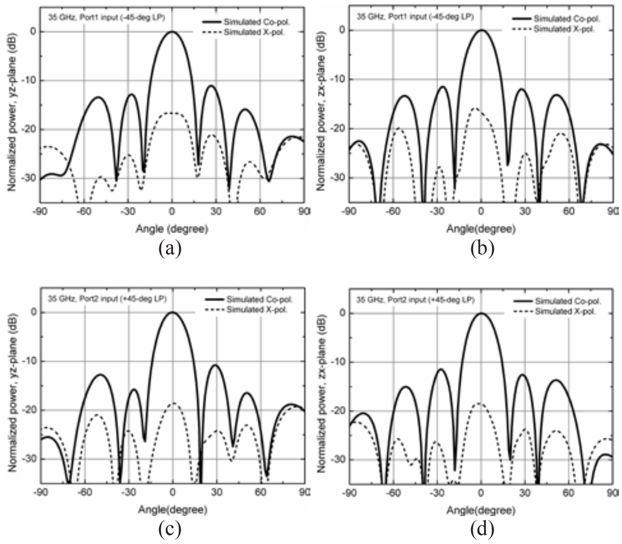

Fig. 4. The simulated radiation pattern results of a 4 × 4 dual polarized slot array antenna at 35 GHz for –45° polarization (a) *yz*-plane and (b) *zx*-plane, for +45° polarization (c) *yz*-plane and (d) *zx*-plane.

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