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Titre : Lentille Rotman à guide d'ondes imprimé avec encoche pour applications en ondes millimétriques

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Résumé : Nous proposons un nouveau réseau de formation de faisceaux (BFN) basé sur un système de lentille Rotman utilisant la technologie du guide d'ondes imprimé avec encoche pour les applications en ondes millimétriques. Cette lentille est mise en œuvre avec la technologie du guide d'ondes imprimé avec encoche pour les ports de faisceau et de réseau. Un prototype de lentille est conçu avec onze ports de faisceau, seize ports de réseau et huit ports fictifs. En utilisant des guides d'ondes avec encoche et crête, la lentille proposée est placée dans l'air pour réduire considérablement les pertes par rapport à d'autres méthodes de conception. De plus, une transition efficace pour alimenter les ports de faisceau avec des guides d'ondes imprimés avec encoche est conçue et simulée. La lentille proposée est réalisée avec une plateforme multicouche pour respecter les règles du guide d'ondes avec encoche et balayer un angle de ($\pm 40^\circ$).

Mots-clés : Diagramme de rayonnement des antennes, Direction de propagation, Antennes dipôles à ondes millimétriques, Réduction du couplage mutuel, Surface ondulée à ondes millimétriques, lentille micro-onde plane, système d'antennes en réseau à formation de faisceaux, antenne en réseau Yagi-Uda alimentée par guide d'ondes intégré au substrat, antenne Bowtie alimentée par SIW non coplanaire, structure de guide d'ondes intégrée, réseau de formation de faisceaux, BFN, antenne linéaire en réseau Bowtie alimentée par SIW.

Printed Ridge Gap Waveguide Rotman Lens for Millimetre-wave Applications

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Abstract—We propose a new beam-forming network (BFN) based on Rotman lens system using printed ridge waveguide technology for millimeter-wave applications. This lens implemented with printed gap waveguide technology for the beam and array ports. A prototype lens is designed with eleven beam ports, sixteen array ports, and eight dummy ports. Using ridge-gap waveguides basis, the proposed lens take place in the air to reduce the loss significantly compared to other designed methods. In addition, an efficient transition to feed beam ports with MS to printed RGW is designed and simulated. The proposed lens is proposed with a multi-layer platform to realize gap waveguide rules and scans over ($\pm 40^\circ$) angle rang.

I. INTRODUCTION

In recent years, a new guiding medium to transmit electromagnetic waves was presented based on parallel plate waveguide theory with eliminating propagation in undesired direction using electromagnetic band gap (EBG) structures which is called ridge gap waveguide (RGW) technology [1]. The proposed EBG surface can be characterized by pins, or mushroom structures to form an artificial magnetic conductor medium to provide the proposed stopband. In this way, EBGs create a barrier to eliminate undesired direction propagated waves. Upon to this basis, the pins or mushrooms replace the walls in rectangular waveguides (RW), and this parallel plates can realize a TEM transmission line propagation with no electric contact, resulting in a much more straightforward assembly compared to RW. Furthermore, the loss of the dielectric-filled materials is avoided in this technology by using air as the propagation medium. In this case, distinct unit cells structures are designed to provide a wide range of frequency band gap. The printed gap waveguide has promising high fabrication freedom capabilities with ease of fabrication. In addition, the performance of loss for printed gap waveguide is significantly better than the microstrip transmission line which is so important for microwave industry. Indeed, the printed form of guiding structure in the air medium and capabilities of fabrication with conventional printed circuit board technologies are a step forward to design innovative microwave devices. Beam Forming Networks (BFNs), such as Blass, Nolen, Butler matrices [2], and microwave lenses [3]-[7], have a great potential to design with low loss platforms using printed gap waveguide technology to provide desired

radiation and pointing direction over the intended application bands.

This paper presents a novel printed ridge gap waveguide Rotman lens for millimeter-wave applications. It employs printed mushrooms to realize air-gap transmission to design air-based Lens as a beam-forming network (BFN) to scans over ($\pm 40^\circ$) angles.

II. DESIGN OF RIDGE GAP WAVEGUIDE UNIT-CELL

The printed ridge gap waveguide cell structure is shown in Fig.1. It consists of a semi-periodic mushroom cell that creates an EBG behavior in the desired frequency band. The width of guiding ridge determines the characteristic impedance of the waveguide. The air-gap between the proposed periodic mushrooms and the top plate plays the primary role to provide the required stopband for parallel plate modes and realize propagation in the desired direction. The performances of EBG structure unit-cells at parametric studies to cover the desired frequency band were investigated using commercial Ansoft HFSS (ver.11.1) software. At first, for clarifying the stop band process, the unit cell size with a via topped metallic plate with the circular patch is analyzed to provide sufficient stopband for desired operating frequency. The circular disk is shorted to the metallic ground plane using plated vias to block the wave propagation inside the substrate. In the second approach, the effect of the air-gap for stop bandwidth is analyzed which is a crucial factor for cell configurations and implementations. For this reason, the dispersion diagram of the single cell and guiding ridge in the center of EBG structures is analyzed. To determine the gap waveguide configuration, four parameters are imposed on the proposed design as follows: the gap height (g), the height ($H - h$) and radius of the plated pins (r), the pins physical distance from the center of circular patches, and the diameter of the circular disk (D). The calculated dispersion diagram (propagation constant versus frequency) for distinct propagation modes are shown in Fig.1, which shows a stop-band of 44-80 GHz for a single cell, and Q-TEM propagation for guiding ridge structure. The provided bandgap frequency by guiding ridge is narrower than the periodic unit-cell band gap as shown in Fig.2. As shown in the dispersion diagram, the complete design covers 43-68 GHz band gap, which is suitable to design a 60 GHz Rotman lens beamformer.

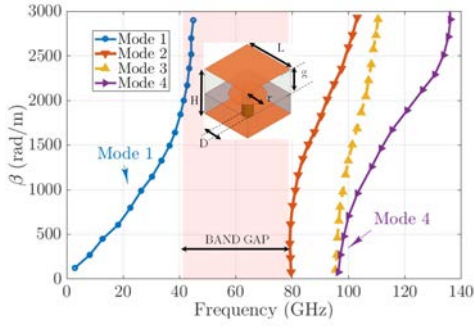


Fig. 1. Illustration of the dispersion diagram of different modes for the periodic printed mushroom like ridge with cell dimensions: $D = 0.25$, $r = 0.38$, $L = 1$, $H = 0.5$, $h = 0.25$ (All in: mm).

III. ROTMAN LENS THEORY AND DESIGN

Fig. 3 shows the geometry of a conventional Rotman lens and PRGW rotman lens, which consists of an inner lens contour (also called inner receiver contour), the circular focal arc (also called feed contour), and an outer lens counter. In this scheme, C_2 is the inner lens contour and defined by the set of $P(X, Y)$ points. G_0 is the axial focal point and located on the central axis, and off-axis focal points (F_1, F_2) are symmetrically located on a circular focal arc [3]. The outer lens contour is a straight line and determines the position of the radiating elements. To determine the Rotman lens configuration in this design, we imposed four crucial parameters on the system as follows: the axial focal point as G_0 , a straight front face and two off-axis focal points as (F_1, F_2). During the lens design process, these ideal focal points effect on outgoing beams at the angles of $\pm\alpha$, and 0° is considered [4].

IV. RESULTS AND DISCUSSION

The proposed Rotman lens based beam forming network was designed for sixteen radiation elements based on printed gap waveguide [6]. Eleven beam ports with microstrip to gap waveguide transition were implemented in the proposed design to steer sixteen radiating beams at 0° , $\pm 7.5^\circ$, $\pm 15^\circ$, $\pm 23^\circ$, $\pm 31^\circ$, and $\pm 39^\circ$. In this scheme, as shown in Fig.2, respect to the longitudinal direction of B_6 port the beam and array ports are placed in symmetrical position. Fig.2 shows the geometry of the proposed printed ridge gap Rotman lens system. The transmitted power amplitude and phase distribution from B_1 and B_8 port to all the array ports ($A_1 - A_{16}$) ranges from -10 to -20 dB. The designed lens can offer 0° to $\pm 150^\circ$ phase differences with acceptable rate of error. The isolation between all beam ports is simulated, and it is better than 16 dB while for array ports the proposed isolation is better than 10 dB. The simulated retrun loss for the B_1 and B_8 are better than -28 dB with wide impedance bandwidths for V-band applications. This prototype is also compared to previous works cover more angles, and it has larger impedance bandwidth [7] with good impedance matching.

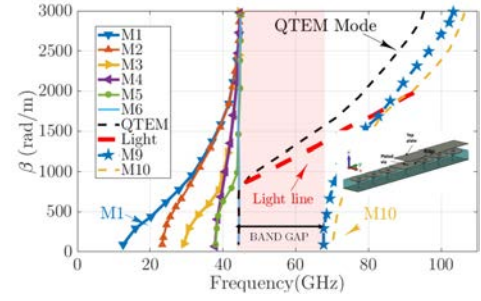


Fig. 2. Illustration of the dispersion diagram for the proposed PRG waveguide, and structure configuration.

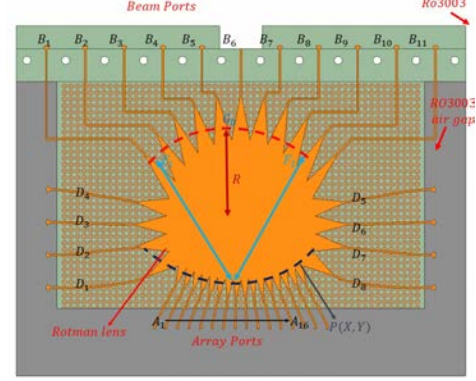


Fig. 3. The 60GHz beam forming network based on rotman Lens in PRGW. Only the PRGW section and lens prototype is shown without top plate.

V. CONCLUSION

In this paper, a novel 60-GHz beam-forming system using a printed ridge gap waveguide has been presented. This beamforming network with eleven beam ports can be cascaded with sixteen array antenna. This multi-layer planar layout can be manufactured by a conventional PCB process. With these features, the proposed design can be used for a retro directive applications with PRGW structures.

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