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Javad Pourahmadazar, Reza Karimian, Tayeb Denidni. 8–12-GHz beam-shaping/steering phased antenna array system using SIW fed nonplanar director Yagi-Uda antenna. 2016 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, Jun 2016, Fajardo, United States. pp.1145-1146, 10.1109/APS.2016.7696280 . hal-04116007

**HAL Id: hal-04116007**

**<https://hal.science/hal-04116007>**

Submitted on 2 Jun 2023

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# Radio Frequency Laboratory (LRF)

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Titre :

Système de réseau d'antennes à commande de formation de faisceau/de direction à 8-12 GHz utilisant une antenne Yagi-Uda avec alimentation par guide d'ondes intégré à substrat

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Résumé :

Cet article présente un nouveau système de réseau d'antennes à commande de formation de faisceau utilisant une antenne Yagi-Uda avec alimentation par guide d'ondes intégré à substrat (SIW). Cette structure utilise une lentille intégrée en guide d'ondes comme réseau de mise en forme de faisceau (BSN). La lentille micro-ondes proposée est une lentille intégrée de type Rotman dans le substrat. Un système de réseau d'antennes prototype est conçu avec 7 ports de faisceau, 9 ports de réseau et 8 ports fictifs. Une antenne Yagi-Uda alimentée par SIW de 10 GHz est proposée avec un élément directeur non planaire comme éléments rayonnants ayant une capacité de balayage sur un angle de  $(-24^\circ, +24^\circ)$ . Tout au long de cet article, le processus de conception du système de réseau d'antennes à phase de 8-12 GHz proposé est démontré en détail.

# 8–12-GHz Beam-Shaping/Steering Phased Antenna Array System Using SIW Fed Nonplanar Director Yagi-Uda antenna

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**Abstract**— This paper presents a novel beam shaping/steering phase array system using substrate integrated waveguide (SIW) fed Yagi-Uda array antenna. This structure employs an integrated waveguide structure Lens as a beam shaping network (BSN). The proposed microwave lens is Rotman type integrated lens in substrate. A prototype phase array system is designed with 7 beam ports, 9 array ports, and 8 dummy ports. A 10 GHz SIW-fed Yagi-Uda antenna is proposed with nonplanar director element as radiating elements with scanning capability over  $(-24^\circ, +24^\circ)$ . Throughout this paper, the design process of the proposed 8-12 GHz phase array system has been demonstrated in details.

**Keywords**-Substrate Integrated Waveguide (SIW), Beam forming network (BFN), Rotman Lens, Multibeam antenna

## I. INTRODUCTION

In recent years, Beam Forming Networks (BFNs) techniques such as Blass, Nolen and Butler matrices [1], Luneburg, R-KR and Rotman lenses [1-5], using substrate integrated waveguides for providing desired far field radiation pattern and pointing direction over the application bands have been developed to produce phase array antennas [1-6]. This paper presents a novel steerable 8-12 GHz Yagi-Uda array antenna using substrate integrated waveguide (SIW) [6]. It employs an integrated waveguide structure microwave Lens as a beam forming network (BFN) [2-5]. The proposed microwave lens is Rotman type integrated lens in substrate. A prototype lens is designed with 7 beam ports, 9 array ports, and 8 dummy ports. A 10 GHz SIW-fed Yagi-Uda antenna is proposed with nonplanar director element as radiating elements [2-5]. The simulated results around the center frequency for X-band application validate the proposed design and scanning capability over  $\pm 24^\circ$  [3-5]. The full design process of the proposed phase array antenna is integrated with SIW technology. In this work, an X-band lens with SIW technology is proposed to feed nine non-planar director Yagi-Uda antenna to generate multiple beams. The proffered steerable array antenna, which is comprised of seven beam ports, eight dummy ports and nine array ports, was designed to operate at

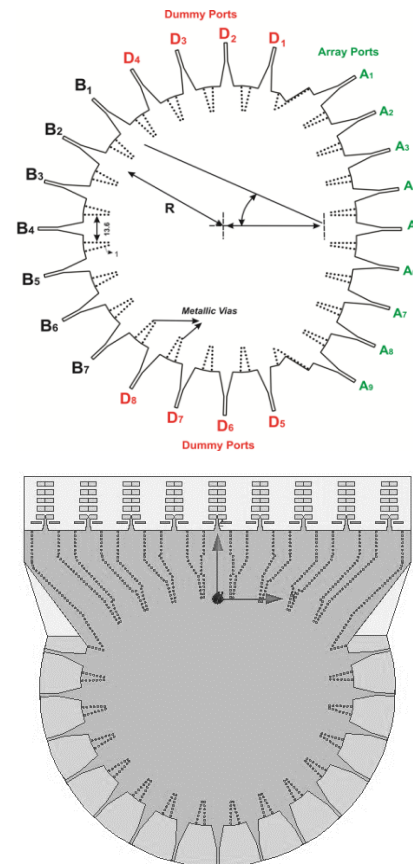


Fig. 2. Geometry of the proposed steerable Rotman lens array antenna

the center frequency of 10-GHz, on an RO5880 substrate with electric permittivity of 2.2 and thickness of 0.508mm. The proposed Rotman lens based steerable array antenna is designed for a nine linear non-directive Yagi radiation elements [3-5]. Seven beam ports were implemented in the proposed design to steer seven radiating beams at  $0^\circ, \pm 8^\circ, \pm 16^\circ$  and  $\pm 24^\circ$ , respectively. In all previous lenses, the transverse electromagnetic (TEM) propagation

incorporated in the design. One of possible solution for that is to adopt the principle of a non-TEM parallel-plate propagation mode. Due to utilizing a non-TEM parallel-plate mode, it is anticipated that impedance bandwidth will decrease but throughout its structure incorporating rectangular waveguide or dielectric slab feeds around the lens periphery will be possible. Respect to the longitudinal direction of B4 port the array and beam ports are placed in symmetrical position as shown in Fig.1 [3-5]. Fig.2 shows the geometry of the proposed SIW-fed Yagi-Uda array. Compared to other reported Yagi antennas, the proposed array antenna director element is not a single microstrip line on similar plan. The directors divided into two separate part on the upper and lower surfaces of the substrate, which could improve the maximum gain of antenna. The simulation results for amplitude variation and the phase slope validate the linearity of these parameters over the operating band (X-band; 8 to 12 GHz) as shown in Figs. 3, and 4. Fig.3 shows the transmitted power amplitude from  $B_1$  and  $B_4$  port to all the array ports ( $A_1 - A_8$ ) ranges from  $-10$  to  $-20$  dB. The proposed SIW lens can offer  $0^\circ$ ,  $\pm 40^\circ$ ,  $\pm 80^\circ$ ,  $\pm 120^\circ$  phase differences with acceptable rate of errors. It is noted that using phase shifter will limit the operation bandwidth. However, from the simulated results as shown in Figs. 3 and 4, the influence on the proposed lens is small. By inserting of additional feed taper for beam ports much better return losses for  $B_2 - B_6$  ports less than  $-15$  dB are achieved. The 2-D patterns for  $B_2$  ( $+16^\circ$  beam port),  $B_4$  ( $0^\circ$  beam port),  $B_5$  ( $-8^\circ$  beam port) beam ports are calculated at 10 GHz from  $-100^\circ$  to  $100^\circ$  theta angles for each input ports and are shown in Fig. 5. The calculated E-plane radiation patterns at 9.5, 10 and 10.5 GHz are shown in Fig. 5 at B1-B4 ports, respectively. These results reveal that the beam directions are  $0^\circ$ ,  $15.5^\circ$ , and  $27.6^\circ$ , respectively and the 3-dB beam widths are 13.2, 13.1, 12.6, 13.7, and 13.2.

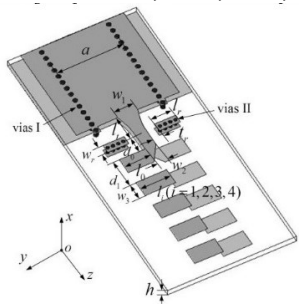


Fig. 2. Geometry of the proposed Single element Yagi-Uda,  $a=10.4$ ,  $h=0.508$ ,  $w_1=3.1$ ,  $w_2=1.7$ ,  $r=12$ ,  $d_1=4.6$ ,  $l_0=4$ ,  $l_1=4.75$ ,  $l_2=4.65$ ,  $l_3=4.55$ ,  $l_4=4.45$ ,  $l_r=3.3$  (All in mm).

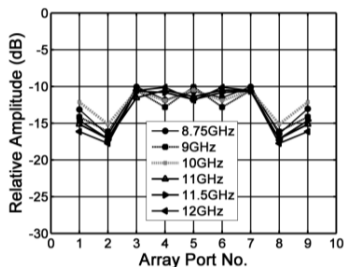


Fig. 3. Relative amplitude distribution across the array ports excited by  $B_4$  beam port ( $0^\circ$  beam port) of the SIW Rotman lens at 8.75, 9, 10, 11, 11.5 and 12 GHz, respectively.

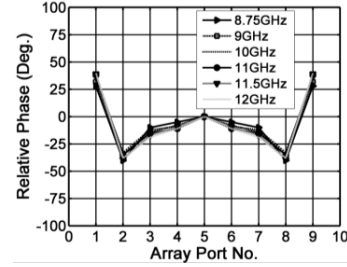


Fig. 4. Relative phase distribution across the array ports excited by  $B_4$  beam port ( $0^\circ$  beam port) of the SIW Rotman lens at 8.75, 9, 10, 11, 11.5 and 12 GHz, respectively.

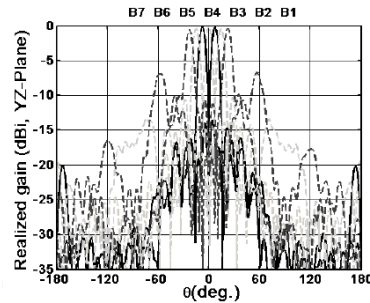


Fig. 5. Simulated 2-D gain patterns spectrum corresponding to  $B_1$  ( $+24^\circ$  beam port),  $B_2$  ( $+16^\circ$  beam port),  $B_3$  ( $+8^\circ$  beam port),  $B_4$  ( $0^\circ$  beam port),  $B_5$  ( $-8^\circ$  beam port),  $B_6$  ( $-16^\circ$  beam port) and  $B_7$  ( $-24^\circ$  beam port), beam ports at 10 GHz.

Due to path length error and propagation dispersion, there is a beam angle deviation, especially at the edge ports. The maximum gain of the proposed design is 18 dBi at central beam port.

#### IV. CONCLUSION

In this paper, a novel 8–12-GHz beam-shaping/steering phased antenna array System using SIW-fed nonplanar director Yagi-Uda antenna is presented. This steerable antenna with seven beam ports is cascaded with nine Yagi array antennas. This layout can be constructed by a standard PCB process. The proposed steerable design presents a full planar structure operating at 10 GHz, with high gain, and low loss.

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