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A Radial Glide-Symmetric Corrugated Sectorial Leaky-Wave Antenna

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***Abstract*—A fully-metallic periodic corrugated sectorial leaky-wave antenna is proposed, for application to direction-of-arrival (DoA) estimation. This application requires the scanning of the field-of-view (FoV) with beams having high diversity. For this reason, the presence of mirror symmetries in the antenna should be avoided. The antenna presented here consists of a sectorial waveguide with radial glide-symmetric corrugations in the bottom plate and radiating slots in the top plate. The aim of this paper is to investigate how radial glide-symmetric corrugations in a sectorial waveguide can introduce an asymmetric field distribution across the azimuthal direction. Moreover, in the paper the azimuthal-dependent properties of the leaky-wave antenna are studied, where concentric slots with different radial periods can avoid ambiguities in ϕ by further breaking the symmetry of the azimuthal-independent pattern. This will be important in the use of such a passive structure with a bi-dimensional and azimuthal-dependent field-of-view (FoV) in flat technologies.**

***Index Terms*—Waveguides, metasurfaces, higher symmetries, radial glide symmetry, leaky-wave antennas.**

I. Introduction

METASURFACES, an emerging class of 2D engineered materials, offer significant potential for advancing antenna design, especially in millimeter-wave (mmWave) communications and sensing. Passive metasurfaces provide a cost-effective means to control the phase and amplitude of guided and radiated waves, as well as the frequency dispersion of electromagnetic structures without the need for active components or inhomogeneous materials. For instance, periodic corrugations and slots in waveguide structures enable frequency-selective energy leakage, enabling frequency-dependent beam scanning [1]–[5]. This principle underlies leaky-wave antennas (LWAs), which present a compelling alternative to traditional mechanically steered systems by eliminating active elements. Their frequency dispersion properties define their beam-scanning properties and can be modified with a suitable geometric symmetrical or asymmetrical arrangement of the periodic slots.

Glide and twist symmetries are particular cases of higher symmetry [6], [7]. Among these, polar glide symmetry has recently been introduced as a novel extension [8], [9]. It can be viewed as the cylindrical-coordinate counterpart of conventional (Cartesian) glide symmetry. In Cartesian glide-symmetric structures, each unit cell is obtained by translating a reference element by half the period along the direction of periodicity, followed by a reflection across a so-called glide plane. This glide plane is a flat surface that contains the periodic axis and can be oriented either parallel or perpendicular to the structure's surface. When the reflection is instead performed with respect to a cylindrical surface with circular cross-section, the resulting configuration exhibits polar glide symmetry [9].

The use of higher symmetries into periodic structures can significantly modify their electromagnetic behavior. Recent studies [11] have highlighted the unique properties and emerging applications of glide-symmetric configurations. In particular, polar glide and twist symmetries are typically applicable only to structures conforming to cylindrical coordinate systems, such as coaxial lines. However, these geometries often involve high manufacturing complexity and cost, and are incompatible with planar fabrication technologies. To address these limitations, [10] explores the feasibility of replicating the effects of twist symmetry in flat, planar structures.

The corrugated sectorial LWA introduced in [1] features a flat configuration where corrugations follow a cylindrical coordinate system. Building upon this concept, the present work explores the design of a metasurface-based sectorial waveguide incorporating glide-symmetric corrugations, employed as LWA by inserting slots with different periods in the top plate. These features lead to an azimuthal-dependent radiation pattern which avoids ambiguities in ϕ.

The paper is organized as follows. Section 2 describes the geometry of the sectorial waveguide with glide-symmetric corrugations on the bottom plate and the dispersion diagram is obtained. In Section 3 the LWA is designed by etching concentric slots on the top plate and simulated results are presented. In Section 4, conclusions are drawn.

II. Radial glide symmetric corrugated waveguide

We propose the design of a leaky-wave antenna (LWA) having a directional pattern along two main planes and exhibiting different scanning rates depending on the azimuthal plane of observation. In this section, we describe the closed structure with (radial) glide-symmetric corrugations on the bottom plate, and in the next section we design the LWA by opening radiating slots on the top plate.

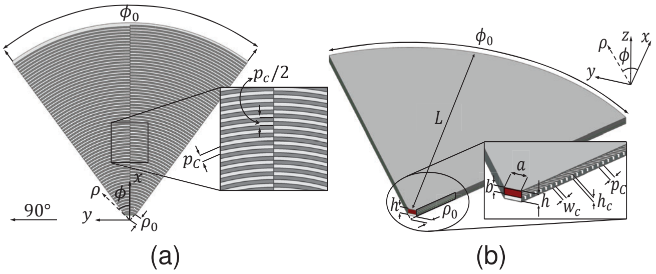


Fig. 1. Radial glide-symmetric corrugated waveguide studied in this paper with the feeding in red. Sectorial waveguide with concentric radial glide-symmetric corrugations in bottom plate: (a) top view, (b) isometric view. The geometric parameters are $\phi_0 = 73°$, $L = 131.5\,\text{mm}$, $\rho_0 = 4.8\,\text{mm}$, $a = 7.112\,\text{mm}$, $b = 2.556\,\text{mm}$, $h_c = 1.6\,\text{mm}$, $p_c = 2\,\text{mm}$, $w_c = 1\,\text{mm}$ ($h = b + h_c$).

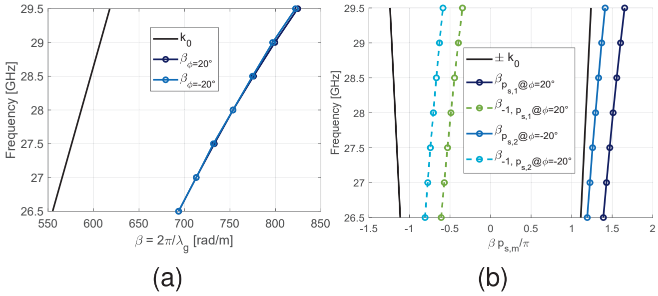


Fig. 2. (a) Dispersion diagram for sectorial waveguide with concentric radial glide-symmetric corrugations at $\phi = \pm 20°$. (b) Normalized (respect the slot period $p_{s,m}$) dispersion diagrams for the radial glide-symmetric corrugated sectorial waveguide at $\phi = 20°$ with $p_{s,1} = 6.3\,\text{mm}$ and, $\phi = -20°$ and $p_{s,2} = 5.4\,\text{mm}$. The curves are obtained by (1a) and the results in Fig. 2a. Fundamental harmonic β (*solid dark blue line*) and visible harmonic β_{-1} (*dashed green line*) at $\phi = 20°$ with $p_{s,1} = 6.3\,\text{mm}$. Fundamental harmonic β (*solid light blue line*) and visible harmonic β_{-1} (*dashed light blue line*) at $\phi = -20°$ with $p_{s,2} = 5.4\,\text{mm}$. Lines of the light $\pm k_0$ (*black lines*).

The structure analyzed here is a sectorial waveguide (Fig. 1). It has an angular aperture ϕ_0 and a radial length L, and is fed by a rectangular waveguide placed at a distance ρ_0 from the sector center. The waveguide is completely shielded with top, bottom and lateral PEC boundaries (radiating slots on the top plate will be considered in the next section). The values of the geometric parameters are: $\phi_0 = 73°$, $L = 131.5$ mm and $\rho_0 = 4.8$ mm. The waveguide height is chosen equal to $b = 2.556$ mm, lower of standard WR28 waveguides, to increase LWA leakage in the next section [3]. We use a cylindrical coordinate system (ρ, ϕ, z) centered at the sector center, with ρ and ϕ the radial and azimuthal variables, respectively. The waveguide has a mirror-symmetric plane at $\phi = 0°$. A TM^z polarized wave is excited in the waveguide [1], travelling along the $+\rho$ direction with a radial dependence represented by Hankel functions of the second kind and order q, $H_q^{(2)}(k_\rho \rho)$, and a sinusoidal azimuthal behavior to fulfill boundary conditions on side walls [12]. $k_\rho = \beta - j\alpha$ is the radial wavenumber, where β and α are the radial phase and attenuation constants, respectively. The frequency dispersion of the structure (β vs. frequency) can be enhanced by inserting periodic corrugations in the bottom plate and suitably varying their height. We work in a region where $\alpha = 0$ (lossless passband), so $k_\rho \equiv \beta$.

In this paper, we design corrugations on the bottom plate and, differently from the concentric and mirror-symmetric corrugations in [1], here we design concentric (radial) glide-symmetric corrugations. The radial glide symmetry is defined as it follows. The local periodicity of corrugations is here p_c taken along the radial ρ axis. In the proposed radial glide symmetry, one part of corrugation in $\phi \geq 0°$ is locally translated along the radial direction of $p_c/2$ (more rigorously, it is transformed with a homothetic operation) and it is mirrored with respect to the plane xz (or $\phi = 0°$). The resulting lattice is shown in the inset of Fig. 1a.

The design presented here being meant for mmWave sensing applications, the chosen operational bandwidth is $[26.5, 29.5]$ GHz. By varying the height of the corrugations h_c, we evaluated if the waveguide is effectively in passband in this frequency band with the analytical model for a linearized parallel-plate waveguide having straight corrugations in [13]. We used that model for soft polarization [14], i.e. for a wave propagation direction perpendicular to the corrugations. Using Ansys HFSS software and Adjacent-Zeros Method (AZM) [1], we select corrugation height $h_c = 1.6\,\text{mm}$, period $p_c = 2\,\text{mm}$ and width $w_c = 1\,\text{mm}$. To analyze the dispersion with AZM, a traveling wave behavior is enforced by terminating the structure with absorbing boundary conditions.

In Fig. 2a, AZM-calculated dispersion diagrams are shown for two ϕ directions in each of the two half of sector respect the glide plane, that is, $\phi = 20°$ and $\phi = -20°$. As shown in Fig. 2a, for both ϕ angle of propagation we have a superposition of the (solid light and dark) curves. This means that the radial glide-symmetric corrugated sectorial waveguide possesses an isotropic dispersion in ϕ, as is expected from the assumption of local periodicity: a wave traveling along the radial direction at a given $\phi > 0°$ experiences a local periodicity which is not dependent on the glide configuration in $\phi < 0°$, and vice versa. The *dispersion* behaviour in the waveguide is therefore the same along any constant-ϕ line, as the corrugation parameters are the same everywhere.

However, the radial glide symmetry has an impact in the *excitation* of the structure. In Fig. 3, the top view of electric field magnitude distribution at 28 GHz, obtained with the Ansys HFSS software is illustrated. The glide configuration of corrugations enables an unequal splitting of the electric field magnitude distribution in the two halves within the structure respect the glide plane at $\phi = 0°$. This feature is important to create a diversity between the fields radiated along symmetric directions across the xz plane.

III. Sectorial Leaky-Wave Antenna

In this section, concentric slots are etched on the top plate of the radial glide-symmetric corrugated sectorial waveguide. The slot radial distance is chosen such that one single beam is radiated and in order to observe a directional pattern on the H-plane (yz plane) and E-plane (xz plane), having an azimuthal-dependent angular scanning with frequency.

A. Dispersion design

As shown in Fig. 2a, in the corrugated waveguide the guided modes are in the slow-wave region, i.e., $\beta > k_0$, for both

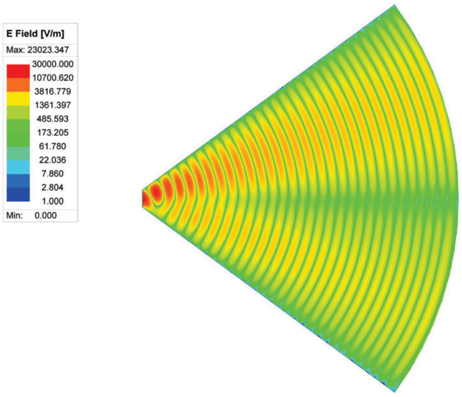


Fig. 3. Electric field distribution at 28 GHz of the radial glide-symmetric sectorial waveguide.

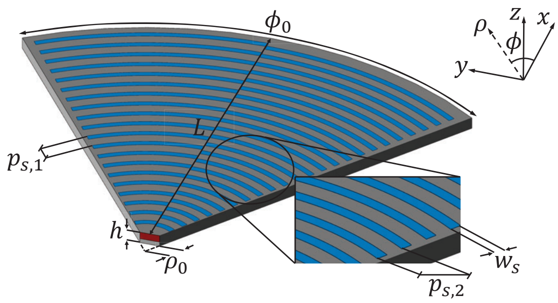


Fig. 4. Radial glide-symmetric corrugated LWA studied in this paper with feeding in red: sectorial LWA with concentric radial glide-symmetric corrugations in the bottom plate and concentric slots in the top plate with two different radial period $p_{s,1}$, $p_{s,2}$. The geometric parameters are $\phi_0 = 73°$, $L = 131.5$ mm, $\rho_0 = 4.8$ mm, $p_{s,1} = 6.3$ mm, $p_{s,2} = 5.4$ mm, $w_s = 2.14$ mm.

positive and negative ϕ values. In order to radiate, the approach chosen here is to etch on the top plate two series of concentric slots as shown in Fig. 4, a first one in the positive ϕ region (region 1) and a second one in the negative ϕ region (region 2), having the same radial width w_s. In each region the slots have radial distance $p_{s,m}$ between them: $p_{s,1}$ in region 1 and $p_{s,2}$ in region 2. The presence of annular slots creates a radial periodicity along each radial line and produces higher harmonics β_n possibly radiating (if in the fast region $-k_0 \leq \beta_n \leq k_0$) at an elevation angle θ_n [15]:

$$\beta_n = \beta + \frac{2\pi}{p_{s,m}} n, \qquad n = 0, \pm 1, \pm 2, ... \tag{1a}$$

$$\theta_n = \sin^{-1}(\beta_n / k_0), \tag{1b}$$

where $m = 1, 2$, depending on the half sector and, β is the radial phase constant of the fundamental harmonic, assuming it is the same as the phase constant of the guided modes in the closed structure computed in Fig. 2a. This is a common hypothesis and is confirmed by the following results of radiation properties.

Selecting the radial distance $p_{s,m}$, fast (visible) harmonics can be generated in the forward and backward ranges, i.e. $0 < \beta_n < k_0$ and $-k_0 < \beta_n < 0$, respectively. In this paper, we choose two different values of $p_{s,m}$ to obtain one visible harmonic with different frequency-scanning properties in each half of the structure respect the glide plane. This increases the diversity in the radiation pattern with respect to the plane xz. We select $p_{s,1} = 6.3$ mm and $p_{s,2} = 5.4$ mm.

In Fig. 2b, the normalized dispersion diagram of the fundamental harmonic (solid lines) and the backward -1 visible harmonic (dashed lines) obtained using (1a) for two radial periods of the slots $p_{s,m}$ are displayed. In particular, the fundamental harmonics (solid dark blue curve) and the visible harmonic (dashed green curve) at $\phi = 20°$ and with $p_{s,1} = 6.3$ mm and, the fundamental harmonics (solid light blue curve) and the visible harmonic (dashed light blue curve) at $\phi = -20°$ and with $p_{s,2} = 5.4$ mm are shown. The higher harmonics β_{-1} are in backward region.

Following our hypothesis that the elevation angle (θ_n) for a given ϕ mainly depends on the phase constant experienced

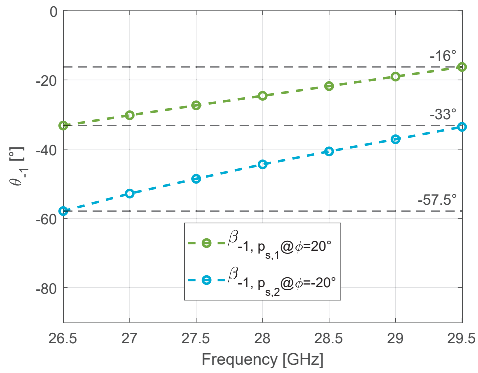


Fig. 5. Predicted elevation angles for radial glide-symmetric corrugated sectorial waveguide obtained from the backward beam β_{-1} (a) at $\phi = 20°$ with $p_{s,1} = 6.3$ mm and, (b) at $\phi = -20°$ with $p_{s,2} = 5.4$ mm of Fig. 2b.

by the guided wave along that same ϕ, the θ_n is estimated using (2b) and the backward -1 visible harmonics of Fig. 2b. The corresponding results are shown in Fig. 5. Although the radiated pattern along each direction depends on the entire aperture field, it is shown later that this assumption is relevant when predicting the elevation angle and its frequency variation. Fig. 5 shows that the radial glide corrugated sectorial waveguide exhibits different frequency variation depending on the two ϕ, i.e. $\Delta\theta = 17°$ at $\phi = 20°$ and $\Delta\theta = 24.5°$ at $\phi = -20°$, but also different elevation angles. This latter feature is due to the different values of chosen $p_{s,m}$.

B. LWA radiation features

In this section, we discuss the radiating properties of the radial glide corrugated sectorial leaky-wave antenna. 20 and 23 slots are etched on the top plate in each half of the structure respect to the glide plane, all of them with the same radial width $w_s = \lambda_0/5$, where λ_0 is the free-space wavelength at central frequency of 28 GHz. The geometry of the periodic leaky-wave antenna is shown in Fig. 4.

The reflection coefficient $|S_{11}|$ of the LWA is shown in Fig. 6. In the bandwidth considered, the antenna is well matched with values lower than -15 dB without needing initial tapering of corrugations or slots.

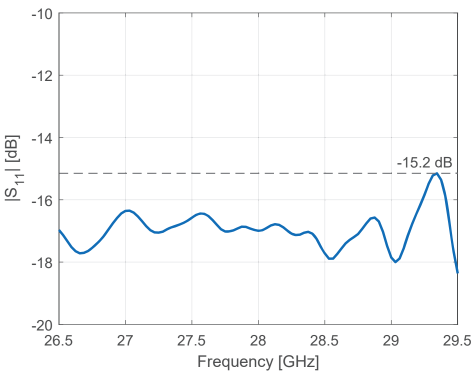
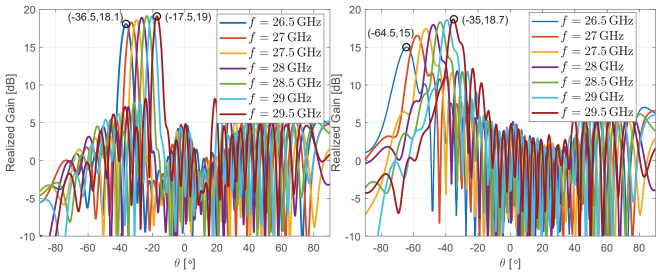


Fig. 6. Reflection coefficient $|S_{11}|$ of the proposed leaky-wave antenna.



(a) (b)

Fig. 7. Realized gain of the radial glide-symmetric sectorial leaky-wave antenna (a) at $\phi = 20°$ with $p_{s,1} = 6.3$ mm and (b) at $\phi = -20°$ with $p_{s,2} = 5.4$ mm.

The realized gain for the LWA is shown in Fig. 7 for 7 frequencies in the considered bandwidth. To compare with the elevation angles of Fig. 5, we show the realized gain at the same ϕ-directions, i.e. $\phi = \pm 20°$. The corresponding θ are in good agreement with the theoretical predictions shown in Fig. 5, in which θ angular scanning within $[26.5, 29.5]$ GHz is $\Delta\theta = 19°$ for $\phi = 20°$ and $\Delta\theta = 29.5°$ for $\phi = -20°$. This good agreement between theoretical prediction and simulated results confirms that the values of $p_{s,m}$ were well chosen on the basis of the dispersion properties along different radial lines. Based on these simulated results, the radiation pattern is azimuthal-dependent, as opposed to a canonical sectorial structure having mirror symmetry with respect the xz plane. This aspect is fundamental for direction-of-arrival (DoA) applications, since it allows to avoid ambiguities due to mirror-symmetric pattern when estimating the DoA of sources placed at $\pm\phi$.

IV. Conclusions

We have proposed a novel fully-metallic periodic leaky-wave antenna based on sectorial waveguide with radial glide-symmetric corrugated metasurface and periodic slots for leakage. The glide-symmetric corrugations are placed on the bottom plate and radiating periodic slots with different radial periods are etched on the top plate. The azimuthal-dependency of the LWA radiation will be fundamental in further work for direction-of-arrival (DoA) applications.

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References

[1] M. Perrone, J. Sarrazin, G. Valerio and G. Lombardi, "Leaky-wave Analysis and Design of a Corrugated Sectoral Waveguide," in *International Conference on Electromagnetics in Advanced Applications (ICEAA)*, Lisbon, Portugal, pp. 662–666, 2024.

[2] A. Attar and A. R. Sebak, "High Gain Periodic 2-D Leaky-Wave Antenna With Backward Radiation for Millimeter-Wave Band," *IEEE Open Journal of Antennas and Propagation*, vol. 2, pp. 49–61, 2021.

[3] Z. Liu, H. Lu, J. Liu, S. Yang, Y. Liu and X. Lv, "Compact Fully Metallic Millimeter-Wave Waveguide-Fed Periodic Leaky-Wave Antenna Based on Corrugated Parallel-Plate Waveguides," *IEEE Antennas and Wireless Propagation Letters*, vol. 19, no. 5, pp. 806–810, 2020.

[4] J. Sarrazin and G. Valerio, "H-plane-scanning Multibeam Leaky-Wave Antenna for Wide-Angular-Range AoA Estimation at mm-Wave", *17th European Conference on Antennas and Propagation (EuCAP)*, Florence, Italy, pp. 1-4, 2023.

[5] M. Perrone, J. Sarrazin, G. Valerio and G. Lombardi, "Leaky-Wave Sectorial Antennas for Passive Bidimensional DoA Applications," *IEEE Antennas and Wireless Propagation Letters*, pp. 1–5, *submitted*, 2025.

[6] P. J. Crepeau and P. R. McIsaac, "Consequences of symmetry in periodic structures," *Proceedings of the IEEE*, vol. 52, no. 1, pp. 33–43, 1964.

[7] A. Hessel, M. H. Chen, R. C. M. Li and A. A. Oliner, "Propagation in periodically loaded waveguides with higher symmetries," *Proceedings of the IEEE*, vol. 61, no.1, pp. 183–195, 1973.

[8] O. Dahlberg, R. C. Mitchell-Thomas, and O. Quevedo-Teruel, "Reducing the Dispersion of Periodic Structures with Twist and Polar Glide Symmetries," *Scientific Reports*, vol. 7, no. 10136, 2017.

[9] F. Ghasemifard, M. Norgren, and O. Quevedo-Teruel, "Twist and Polar Glide Symmetries: an Additional Degree of Freedom to Control the Propagation Characteristics of Periodic Structures," *Scientific Reports*, vol. 8, no. 11266, 2018.

[10] F. Ghasemifard, A. Salcedo, M. Norgren and O. Quevedo-Teruel, "Mimicking Twist Symmetry Properties in Flat Structures", *13th European Conference on Antennas and Propagation (EuCAP)*, Krakow, Poland, pp. 1–3, 2019.

[11] O. Quevedo-Teruel, Q. Chen, F. Mesa, N. J. G. Fonseca and G. Valerio, "On the Benefits of Glide Symmetries for Microwave Devices," *IEEE Journal of Microwaves*, vol. 1, no. 1, pp. 457–469, 2021.

[12] R. F. Harrington, "Cylindrical wave functions" in *Time-harmonic electromagnetic fields*, ch. 5, Wiley-IEEE Press, 2001.

[13] M. Bosiljevac, Z. Sipus and P.-S. Kildal "Construction of Green's functions of parallel plates with periodic texture with application to gap waveguides–a plane-wave spectraldomain approach," *IET Microw. Antennas Propag.*, vol. 4, no. 11, pp. 1799–1810, 2010.

[14] C. Balanis, "Rectangular cross-section waveguides and cavities" in *Advanced engineering electromagnetics*, ch. 8 and ch. 9, 2nd ed., Wiley, 2012.

[15] A. A. Oliner, "Leaky-wave antennas" in *Antenna Engineering Handbook*, J. L. Volakis, ch. 8, 4th ed., McGraw-Hill Education, 2007.