### PAPER • OPEN ACCESS

# Leaky wave antenna for millimeter wave utilization

To cite this article: Ruchi Agarwal et al 2021 J. Phys.: Conf. Ser. 1921 012026

View the article online for updates and enhancements.

# You may also like

al.

- Review of graphene for the generation, manipulation, and detection of electromagnetic fields from microwave to terahertz David A Katzmarek, Aiswarya Pradeepkumar, Richard W Ziolkowski et
- Leaky wave antenna with backfire to endfire beam-scanning capability based on even mode spoof surface plasmon polaritons

Min Wang, Gao Wei, Kangkang Han et al.

 Simple method to suppress n = 2 harmonic for periodic leaky-wave antennas with open-stopband suppression Siyuan Lei, Gao Wei, Kangkang Han et al.





DISCOVER how sustainability intersects with electrochemistry & solid state science research



This content was downloaded from IP address 3.21.233.41 on 02/05/2024 at 01:03

# Leaky wave antenna for millimeter wave utilization

Ruchi Agarwal<sup>1,2</sup>, Ayushi Agarwal<sup>1,3</sup>, Aman Dwivedi<sup>1,4</sup> and Ashutosh Sharma<sup>1,5</sup>

<sup>1</sup>Department of Electronics and Communication Engineering, Galgotias College of Engineering and Technology, Greater Noida, India

<sup>2</sup>ruchi.agarwal1987@gmail.com, <sup>3</sup>ayushiashu.agarwal06@gmail.com <sup>4</sup>dwivediaman113@gmail.com <sup>5</sup>anashutoshsharma111@gmail.com

Abstract. The simulation of planar periodic leaky-wave antenna for ultra-wideband application is introduced here. The antenna proposed here comprises 15 matched unit cells with high directivity which provides a backward to forward beam scanning range of 80° with frequency from 24.4GHz to 27.5GHz and has filtering capability making the design simpler. The calculated efficiency is 90% which is the gain to the directivity ratio of the designed antenna. The bandwidth range is between 24.4 GHz to 27.5GHz. The work is outlined and assembled on Roger's substrate (particularly good for 5G applications) and has a gain of 13.92dB which represents an excellent choice for communication systems.

Keywords—LWA (Leaky wave antenna), PLWA (Periodic LWA), SIW (Substrate integrated waveguide), OSB (Open Stop Band), UC (Unit Cell).

### **1. Introduction**

Among the advancements in the growth of 5G, which are currently undergoing, the demand for a highgain antenna is increasing. Furthermore, the antennas which work in the millimeter-wave region will play a pivotal function in the future of communication systems [1]-[4]. A very compact size, low loss leaky-wave antenna with a very wide bandwidth has been presented in [5], which has a direct relation with planar circuits. The planar 2-D LWA which have high transmission at the main side has been proposed, had a circular Substrate Waveguide (SW) feed and segmented ring-shaped strip, a partially reflected surface (PRS) line can also be realized, the auxiliary openings of the given SWL source of data help in obtaining propagation of unilateral SW, yet at the expense of radiation in the far-field which is cross-pol, thus it had some drawbacks such as different radiation patterns. A new method to suppress OSB is presented in [6], in which an open stub that is radiating is used to give UC having distinct impedance, the structure is very simple, low profile, and compact, thus making it a proper contender for high-frequency purposes, however, the given antenna has a very low scanning range.

Planar antennas are one of the most important antennas because of their ease of realization, integrability with active circuits, low profile, and cost-effectiveness [7][8]. One of the most prominent features of LWAs is their frequency scanning. These types of antennas can be used as a lucrative solution for 5G communication and also suppress unwanted signals [9]. The main advantages of 5G are more improved latency, high resolution, and bi-directional large bandwidth shaping, greater capacity of remote execution, a larger number of connected devices, providing more adjusted connectivity to essential needs [10][11]. That's why a substantial amount of work was done in the previous years for the development of 5G systems for commercial applications. In our work, we improved the previously proposed LWA, which has high gain, planar-structure, and simple-feeding LWAs are made by cascading

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd 1

ICASSCT 2021		IOP Publishing
Journal of Physics: Conference Series	<b>1921</b> (2021) 012026	doi:10.1088/1742-6596/1921/1/012026

unit cells (UCs). A very low-loss periodic antenna is proposed in which shows good results in the band 38-41GHz and also has high efficiency of 90%, but it has a low beam scanning range.

The increase in remote (data)information usage as of now is currently restricted by the present remote network organizations [12]. They are low profile, are compact in size and their radiation scanning can be driven just by varying the input signal frequency. The designed antenna is a PLWA antenna containing fifteen UCs. Adding all UCs makes it a periodic antenna and uniform. Each UC is composed of a circular ring in the center with a characteristic impedance of Z0. A ring-shaped design is cut in the center of the substrate, which helps in increasing the gain of LWA from 9.89 dB to 13.92 dB. The substrate is made up of Roger's Material RO3006(lossy) because of its durability, low-cost, performance, and electrical properties. The design is very detailed and efficient, and the array of UCs is composed of two ports. Our proposed antenna also provides high directivity which gives high backward to forward beam scanning of 80 degrees.

#### 2. Antenna Structure

Fig. 1 shows the proposed 5G antenna. The antenna contains fifteen sections, in which every section consists of a square patch that has two concentric rings cut inside. The input of the antenna is given by a microstrip line configuration. Two waveguide ports are connected on either side of the antenna. These unit cells are connected uniformly to get high directivity and contain a periodic recurrence towards the propagation direction. This array method helps each unit cell in representing that element of the array that has high impedance matching and radiation patterns. The 5G array is outlined on the RO3006(lossy) having  $\mathcal{E}r=6.15$ , height= 0.250mm. Rogers RO3006 provides circuit materials a stable dielectric constant (Dk). These are intended to use in commercial microwave and RF applications. The width and length of the proposed antenna are 15.0 mm and 89.0 mm respectively.



Figure 1. Presented PLWA (measurements: millimetre)

#### 3. Unit Cell Characteristics and Dispersion Diagram

As shown in the Fig.1, the antenna is realized by cascading 15 unit cells in the direction of propagation. Compared to the structure proposed in [11], this UC has concentric rings made in the center of the UC. Distinct Parameters of the UC will have various impacts on the dispersion properties. Fig.2 shows a Unit Cell (UC) of the designed antenna whose dimensions are mentioned in Table 1. It has 3 layers Ground, Substrate, and Patch. Their dimensions are shown in Table 2. The array is provided with feed at both ends.

A dispersion diagram shown in Fig. 3 is a plot of propagation  $constant(\beta)$  versus frequency(f). This diagram tells you how much phase shift a material has given at a given frequency.  $\beta$ (beta) shows the phase constant which gives the amplitude/phase of the sinusoidal signal along a transmission line, at a constant time. Its units are radians/meter and degrees/meter.

$$\beta_{eff} = \frac{1}{p} Re \left[ cos^{-1} \left( \frac{1 - S_{11}S_{22} + S_{21}S_{12}}{2S_{21}} \right) \right]$$

**1921** (2021) 012026 doi:10.1088/1742-6596/1921/1/012026

# Where,

 $\beta_{eff}$  is the effective phase constant *p* is unit-cell length



Figure 2. Unit Cell Structure

 Table 1. Proposed Antenna Dimensions (Unit: mm)

Parameter	L	Lm	Wm	Wh	Wsh	Ls	Lu	Wu	X	Y
Value	3.8	1.6	0.8	1.0	0.4	2.0	1.5	0.3	89.0	15.0

 Table 2. Unit Cell properties (Unit: mm)

Parameter	Material Used	Dimensions(L*W*H)
Ground	PEC	5.8*3.8*0.035
Patch	PEC	5.8*3.8*0.035
Substrate	Rogers(RO3006 Lossy)	5.8*3.8*0.25
Holes	Nickel	0.4*0.3





Figure 3. Dispersion diagram (center frequency at 25 GHz)

## 4. Result and discussion

In Fig 4. the S parameter portrays the information yield connection between the two ports. Subscripts describe the responding and incident ports respectively. Thus, S21 signifies the reply at port 2 because of the port 1 signal. The antenna proposed here is a 2 port network. An antenna's bandwidth shows the frequency range over which the antenna can operate correctly. The best frequency range of the given antenna is between 24.4 GHz to 27.5 GHz.

Gain graph shows the strength of a signal that an antenna can send/receive in a particular direction. Higher gain signifies that the signal gets focused over a smaller beamwidth. This is suitable for linear applications that need isolating a specific signal to prevent external signals from interfering. From Fig. 5 it can be observed that the antenna's maximum gain is 13.92 decibel at 25.5 Gigahertz. Gain to the directivity ratio of the antenna is called efficiency. It shows the conversion of power of given accepted radio frequency signals into radiated signals. The efficiency of the antenna proposed here is 90%. Fig. 6 shows the total efficiency presented in the designed antenna.

Given antenna's Beam steering or beam scanning is shown in Fig. 7,8,9,10,11,12,13. The diagram clearly shows that the principle main lobe direction of the antenna shifts persistently back and forward with dynamic frequency. Beam steering is seen at different continuous frequencies and can be noticed that the standardized example of the radiation of far-field directivity at 24.5 GHz, 25 GHz, 25.5GHz, 26GHz, 26.5 GHz, 27.5GHz is sequential and therefore the antenna is radiating backward to forward. The designed antenna shows that the main lobe direction at 24.5 GHz is -26 degrees, at 25 GHz is 0 degrees, at 25.5 GHz is 22 degrees, at 26 GHz is 27 degrees, at 26.5 GHz is 32 degrees, at 27.5 GHz is 54 degrees so the total beam scanning range is 80 degrees.

Table 3 shows the comparison between the proposed antenna and the recently reported work on LWAs in [6] and [11].

**1921** (2021) 012026 doi:10.1088/1742-6596/1921/1/012026



Figure 4. S Parameter of the Antenna



Figure 5. Maximum Gain Graph



Figure 6. Total Efficiency of the antenna

**1921** (2021) 012026 doi:10.1088/1742-6596/1921/1/012026



Theta / Degree

Figure 7. Far-field directivity at frequency 24.5 GHz is -26 degrees

0 30 30 Phi=180 Phi=360 60 60 90 90 10 5 n 120 120 150 150 180

Theta / Degree

Figure 8. Far-field directivity at frequency 25 GHz is 0 degree

Farfield Directivity Abs (Phi=180)

**1921** (2021) 012026 doi:10.1088/1742-6596/1921/1/012026





Figure 9. Far-field directivity at frequency 25.5 GHz is 22 degree Farfield Directivity Abs (Phi=180)



Theta / Degree

Figure 10. Far-field directivity at frequency 26 GHz is 27 degree

**1921** (2021) 012026 doi:10.1088/1742-6596/1921/1/012026





Figure 11. Far-field directivity at frequency 26.5 GHz is 32 degree Farfield Directivity Abs (Phi=180)



Theta / Degree

Figure 12. Far-field directivity at frequency 27 GHz is 40 degree

**1921** (2021) 012026 doi:10.1088/1742-6596/1921/1/012026



Farfield Directivity Abs (Phi=180)

Theta / Degree

Figure 13. Far-field directivity at frequency 27.5 GHz is 54 degree

Property	Ref. [6]	Ref. [11]	Proposed Antenna
Number of unit cell structure	16	16	15
Bandwidth range	63GHz to 75GHz	38GHz to 41GHz	24.4 GHz to 27.5Ghz
Beam Scanning	38 Degrees	18 Degrees	80 Degrees
Gain	11.2 dB	15.6 dB	13.92 dB
Efficiency	90%	90%	90%

 Table 3. Proposed Antenna and recent reported works on LWAs comparison table

## 5. Conclusion

The paper presents a high-gain periodic leaky-wave antenna with better beam-steering and a wide scanning range of 80°. The Gain and efficiency of the proposed PLWA are improved by making a winding ring in the substrate and impedance was expanded by lessening the size of the port connection on the sides of the substrate. The proposed antenna has a 90% efficiency from 24.4GHz to 27.5GHz with a complete gain of 13.92 dBi. The uncomplicated antenna structure makes it good for the use in applications of high-frequency and radars.

#### 6. References

- [1] Feng Xu, Ke Wu, and Xiupu Zhang, "Periodic Leaky-Wave Antenna for Millimeter-Wave Applications Based on Substrate Integrated Waveguide", in IEEE Transactions on Antennas and Propagation on, vol. 58, pp 340-347, 2010.
- [2] Priyanka Mondal and Ke Wu, "A Leaky-Wave Antenna Using Periodic Dielectric Perforation for Millimeter-wave Applications", in IEEE Transactions on Antennas and Propagation on, vol.64, pp 5492-5495, 2016.
- [3] Rahmani, M.H., Deslandes, D.: 'Backward to forward scanning periodic leaky-wave antenna with wide scanning range', IEEE Trans. Antennas Propag., 2017, 65, (7), pp. 3326–3335.
- [4] Xingying Huo, Junhong Wang, Zheng Li, Yujian Li, Meie Chen and Zhan Zhang, "Periodic leaky-Wave Antenna with Circular Polarization and Low SLL Properties" in IEEE Antennas and Wireless Propagation Letters on, vol.17, pp 1195-1198, 2018.
- [5] Junfeng Xu, Wei Hong, Hongjun Tang, Zhenqi Kuai, and Ke Wu, "Half-Mode Substrate Integrated Waveguide (HMSIW) Leaky-Wave Antenna for Millimeter-Wave Applications", in IEEE Antennas and Wireless Propagation Letters on, vol.7, pp 85-88, 2008.
- [6] Mohammad H. Rahmani, Dominic Deslandes, "A Novel Periodic Microstrip Leaky-Wave Antenna with Backward to Forward Scanning" in 2015 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC), 2015.
- [7] Mohammad A Matin, "Review on Millimeter-Wave Antennas- Potential Candidate for 5G enabled Applications", in Advanced Electromagnetics on, vol.5(3), pp 98-105, 2016.
- [8] Muhammad Saqib Rabbani, James Churm and Alexandros Feresidis, "Millimetre-Wave Beam Steerable Leaky-Wave Antenna for 5G Systems", in 12th European Conference on Antennas and Propagation (EuCAP 2018).
- [9] Ka Ming Mak, Kwok Kan So, Hau Wah Lai and, Kwai Man Luk, "A Magneto-Electric Dipole Leaky Wave Antenna for Millimeter-Wave Application" in IEEE Transactions on Antennas and Propagation on, vol.65, pp 6395-6402, 2017.
- [10] José Luis Gómez-Tornero, Fernando Daniel Quesada-Pereira, and Alejandro Álvarez-Melcón, "Analysis and Design of Periodic Leaky-Wave Antennas for the Millimeter Waveband in Hybrid Waveguide-Planar Technology", in IEEE Transactions on Antennas and Propagation on, vol. 53, pp 2834-2842, 2005.
- [11] Daniel Sanchez-Escuderos, Miguel Ferrando-Bataller, Jose I. Herranz and Vincent Miquel Rodrigo-Penarrocha, "Low-loss Circularly Polarized Periodic Leaky-Wave Antenna", in IEEE Antennas and Wireless Propagation Letters on, vol.15, pp 614-617, 2015.
- [12] Youssef El Gholb, Miguel Poveda-Garcia, José Luis Gómez Tornero, Jose Maria Molina-Garcia-Pardo and Najiba El Amrani El Idrissi, "A Mobile Terminal Leaky-Wave Antenna for Efficient 5G Communication", in IICEAA-IEEE APWC 2019, Granada, Spain, 2019.