International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.7 September - October – 2023
DOI:10.46647/ijetms.2023.v07i05.055 ISSN: 2581-4621

Influence Of Patchs Shape On The Radiation Performance a Microstrip Leaky-Wave Antenna

Charmolavy G. L. Nkouka Moukengue[1], Ronelle Gogom[2]
[1]*Assistant Professor, Electrical and Electronic Engineering Laboratory, National School of Polytechnic Studies, Marien Ngouabi University, Congo*
[2]*Doctoral student, Electrical and Electronic Engineering Laboratory, National School of Polytechnic Studies, Marien Ngouabi University, Congo*

ABSTRACT
In this article, we present microstrip leaky wave antennas designed using HFSS software. These microstrip antennas differ in the shape of the patches on the substrate. To this Effect, three shapes have been studied and the analysis of the radiation parameters of these antennas shows that the T-shape patches have low levels of minor's lobes and good the scanning angle in the E- and H-plane compared to the other studied shapes. This study of the influence of the patches shape on the performance of microstrip leaky wave antennas shows the impact on the radiation pattern and directivity of the antenna. Through a comparative study of three patch shapes H, inverted T and L, simulations show that inverted T patches have low the levels of minor's lobes and good the scanning angle in the E and H planes compared to the other shapes studied. However, the L-shape present a better directivity compared to the other shapes.
Keywords: leaky wave antenna, microstrip, HFSS, patchs, radiation parameters.

1. Introduction

The remarkable developments in millimeter band technologies, has allowed the design of communication systems of small rigid dimensions and best resolution.
The high frequency circuits, which are used in all spheres of telecommunications that are often heavy and imposing [1].
In addition, patch and slot antennas are widely used in various applications, such as those encountered in space telecommunications, radar, mobile telephony, traffic control [1-4] etc. However, these antennas have very high feed losses contributing to a degradation of performance at these operating frequencies.
To overcome to these problems, microstrip leaky wave antennas are suitable solutions[5-6]. They overcome some problems associated with resonant structures since they provide wider band performance and reliable electronic scanning capabilities.
The radiation angle of these antennas can be scanned by a frequency change technique or by mechanical means [3-12] .
Another way to control the scanning of these antennas is to modify the shapes of the patches or slots [13-14]. It is in this perspective that we propose to study the influence of the shape of these patches on the radiation performance of a leaky wave antenna (LWA).

2. Theory approach

Leaky wave antennas are designed to radiate in a specific direction and to scan within a certain angular opening. The scan is limited as a result to the $0 < \theta < 90°$ quadrant. They vary depending on the type of source of use. Figure 1 shows the principle schematic of the scan aperture of a leaky wave antenna.

DOI:10.46647/ijetms.2023.v07i05.055 ISSN: 2581-4621

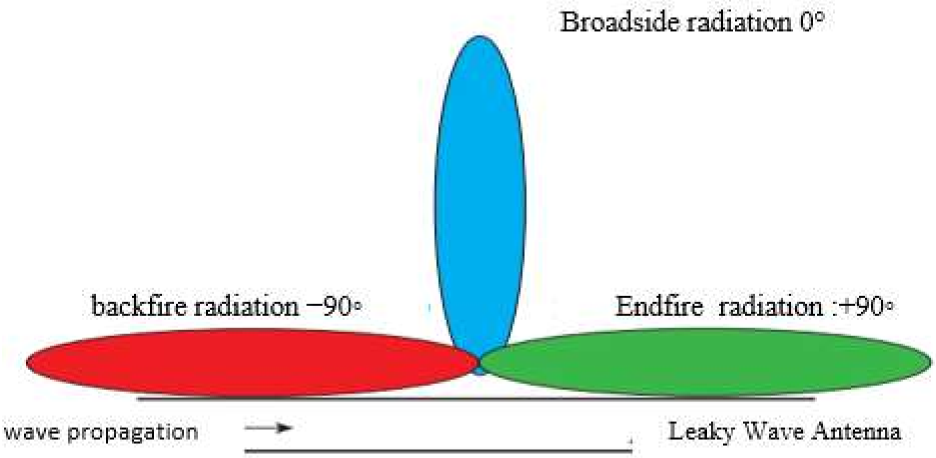

Fig 1. Antenna radiation convention: backfire radiation −90◦, Broadside radiation 0 ◦, Endfire radiation :+90◦ [15]

In the case of a periodically charged structure (figure 2) with a spatial periodicity p along the axis (Oz) is the direction of propagation of the guided wave, the configuration of the fields at a point of coordinates (x,y,z) will be the same as that which will exist at the point (x, y, z+p). Moreover, Floquet's theorem [16-18] states that the fields at two homologous points differ only by a complex constant.

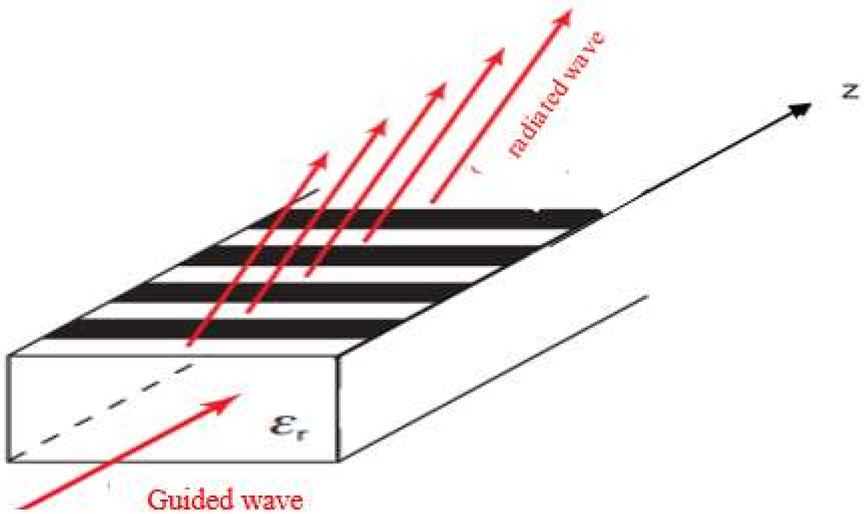

Fig 2. leaky wave antenna [19].

$$E(x, y, z + d) = E(x, y, z)e^{-jk_z z} \qquad (1)$$

In this case, the pseudo-periodic field is decomposed into a fourier series, giving rise to a fundamental term (n=0) and spaces harmonics (n=±1,±2....) given by :

$$E(x, y, z) = \sum_{-\infty}^{+\infty} A_n(x, y)e^{-jk_{zn}z} \qquad (2)$$

Where

$$A_n(x, y) = \frac{1}{p}\int_0^p E(x, y, z)e^{+jk_{zn}z}\, dz$$

$$k_{zn} = k_z + \frac{2\pi n}{p}$$

$$= j\alpha_z - \left(\beta_z + \frac{2\pi n}{p}\right)$$

With $\beta_{zn} = \beta_o + \frac{2\pi n}{p}$, the phase constant of the n[th] harmonic of LWA along (Oz), βo is the phase constant of the fundamental mode (n=0); αz is the attenuation constant in z direction. The coefficient A_n of the considered space harmonic decreases in general with the rank n of the harmonic and the series converges quickly so as to retain only the fundamental term (n=0).
The knowledge of k_{zn} and in particular its real part makes it possible to determine whether we are dealing with a slow or a fast wave. We can define for each space harmonic n, the angle corresponding to the direction of radiation. It is given by the following relation:

$$\sin\theta_n = \frac{\beta_{zn}}{k_0} \quad (3)$$

- Si $|\beta_z n| > k_0$, the angle is located in the so-called invisible region there is no radiation;
- Si $|\beta_z n| < k_0$, the angle indicates the direction of radiation which varies according to each space harmonic considered.

In practice, to avoid spurious lobes, it is advisable to work with only one fast harmonic; the n=-1 mode is then chosen to be radianting mode [9],[18],[20].
The angle θ_{-1} in this case, is given by:

$$\theta_{-1} = sin^{-1}\left(\frac{\beta_{z-1}}{k_o}\right) \quad (4)$$

$k_o = \frac{2\pi}{\lambda_o}$ is the wave number and λ_o is the length of the wave in free space.
the sign θ_{-1} determines whether the resulting radiation is forward or backward. We can immediately see that the radiation condition is given by the following equation:

$$-1 < \frac{\beta_{zn}}{k_o} < 1 \quad (5)$$

3. antenna design

It is proposed to design microstrip leaky wave antennas, constituted of a dielectric substrate of relative permittivity ε_r, width B, thickness a and length Lo. Metallic patches of several shapes of width w, with length b, with a periodicity l following (Oz), are printed on the top face of the substrate, as shown in Figure (3). These antennas are designed for operation at the frequency of 80GHz.

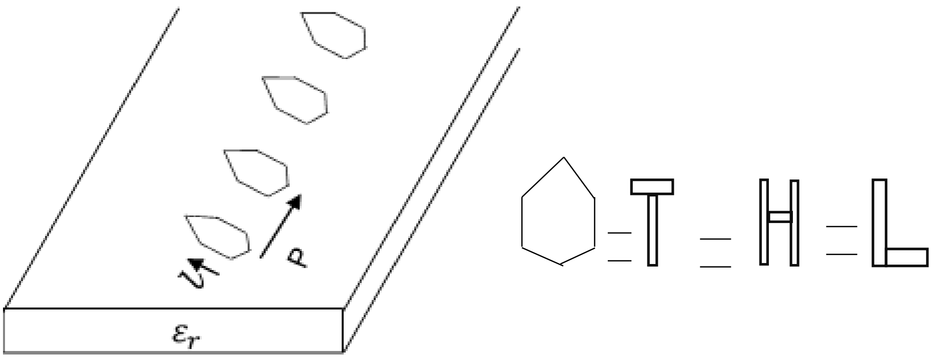

Fig 3. Leaky-wave antenna with patches of any shape

The antenna dimensions calculated from formulas [20],[21] (6), (7) and (8) at the operating frequency of 80 GHz are recorded in Table 1.

$$\begin{cases} \dfrac{\lambda_o}{\beta/k_o + 1} \le l \le \dfrac{\lambda_o}{\beta/k_o - 1} & \text{if} \quad \beta/k_o > 3 \\ \dfrac{\lambda_o}{\beta/k_o + 1} \le l \le \dfrac{2\lambda_o}{\beta/k_o + 1} & \text{if} \quad \beta/k_o < 3 \end{cases} \quad (6)$$

$$0{,}2\lambda_O \le l \le 0{,}4\lambda_O \quad (7)$$

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.7 September - October – 2023
DOI:10.46647/ijetms.2023.v07i05.055 ISSN: 2581-4621

$$b < \frac{\lambda_0}{(\varepsilon_{eff} - 1)^2} \quad (8)$$

Table 1: Dimensions of the antenna structure

Désignation	w	d	l	p	B	ε_r
Dimensions	0.27mm	1mm	3mm	2.5mm	30mm	2.46

4. Analysis of antenna performance as a function of patch shape

Using the software (HFSS), we have simulated this antenna with H, T and L shaped patches. Let's analyze the results obtained on the radiation characteristics of the antenna.

a. Radiation patterns

Figure 4 present the H-plane radiation pattern plotted for different shapes of the patches at the operating frequency. We note a weak shift of the the scanning angle $\theta°_{-1}$ to the right.

T-shaped patches have a lower levels of minor's lobes compared to other patch shapes in this plane.

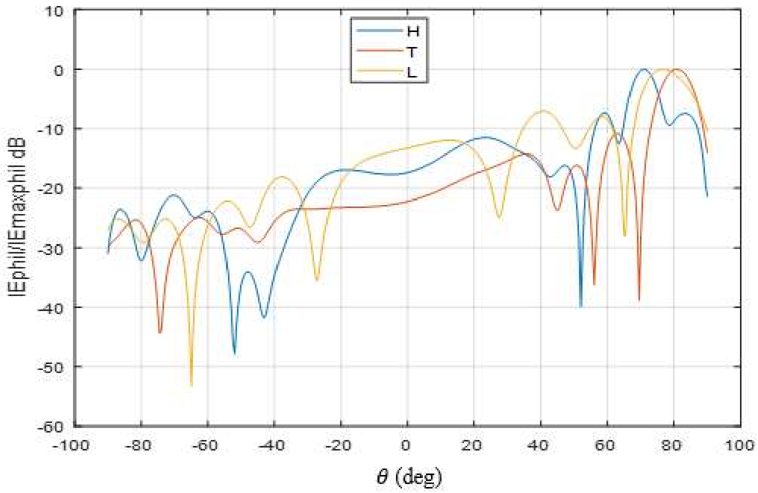

Fig 4. H-plane radiation pattern for LWA, p=2,5mm, F=80GHz, b=0,8λ_o, $\varepsilon_r = 2,46$, N=11 ,w=0,338λ_o, B=8λ_o

Figure 5 shows the radiation patterns in the E-plane of the antenna, for different shapes of the metal patches at the operating frequency. We note enough displacement of the main beam $\theta°_{-1}$. Thus, the shape of the patches influences the beamwidth. We also note a remarkable asymmetry of the levels of minor's lobes lower on the left of the scanning angle than on the right of the scanning angle.

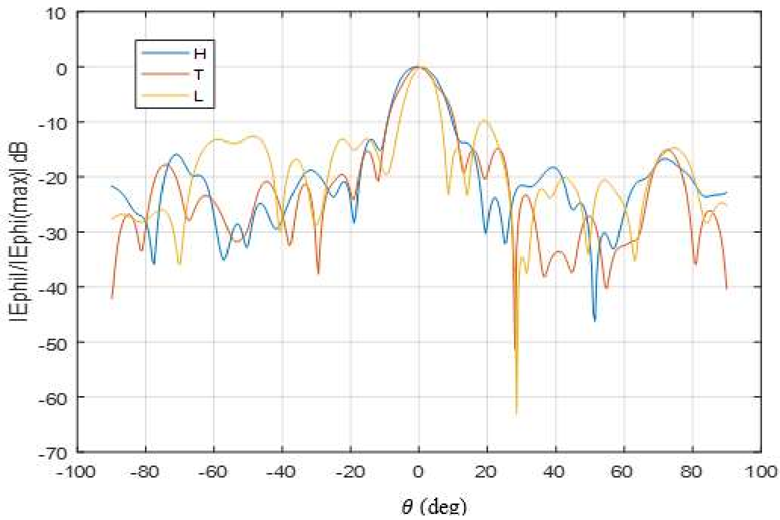

Fig 5. E-plane radiation pattern for LWA, p=2,5mm, F=80GHz, b=0,8λ_o, $\varepsilon_r = 2,46$, N=11 , w=0,338λ_o, B=8λ_o

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.7 September - October – 2023
DOI:10.46647/ijetms.2023.v07i05.055 ISSN: 2581-4621

b. Directivity

In figure 6 we have plotted the variation of the directivity as a function of frequency. We can see that the shape of the patches has a considerable influence on the directivity. At the operating frequency, the L-shaped patches have a good directivity and its value is 14.02dB.

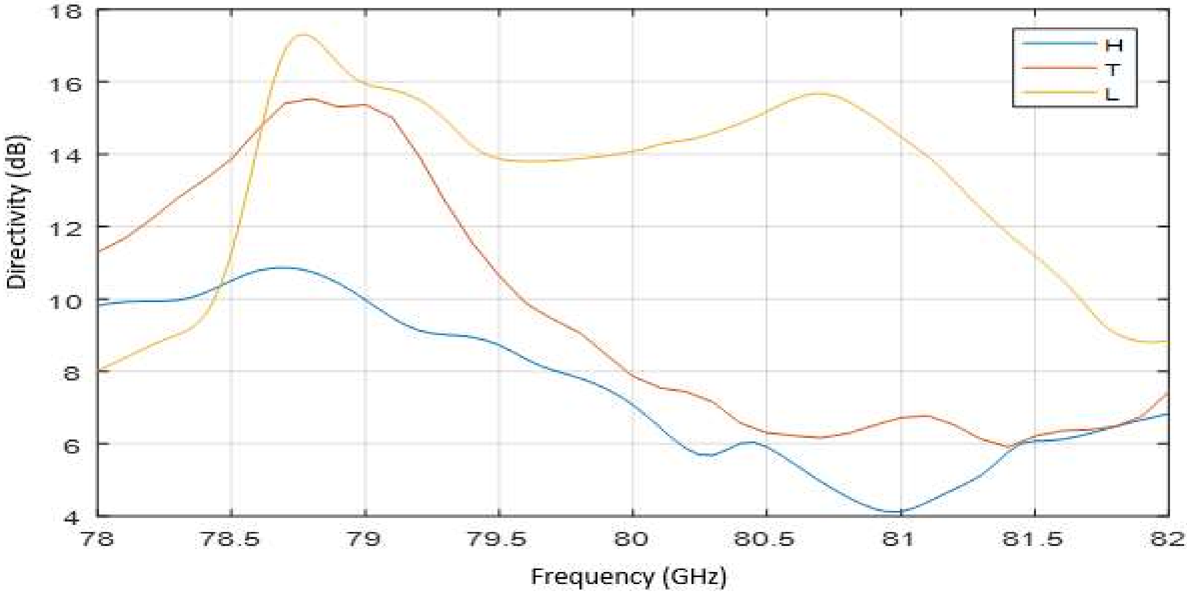

Fig 6. Leaky-wave antenna directivity with H, inverted T and L shaped patches L ; p=2,5mm, F=80GHz, b=0,8λ_o, $\varepsilon_r = 2,46$, N=11 ,w=0,338λ_o, B=8λ_o

CONCLUSION

The study of the influence of the patches shape on the performance of microstrip leaky wave antennas has shown the impact on the radiation pattern and directivity of the antenna. Through a comparative study of three patch shapes H, inverted T and L, simulations show that inverted T patches have low the levels of minor's lobes and good the scanning angle in the E and H planes compared to the other shapes studied. However, the L-shape present a better directivity compared to the other shapes.

References

1. Zahéra Mekkioui, H. Baudrand et B. Benyoucef " Caractéristiques de rayonnementet performances d'antennes micro-rubans à ondes de fuite à couche diélectrique superposées en revêtement"

2. Zahére Mekkioui et H Baudrand "Analyse d'antenne diélectrique à ondes de fuite chargée de motif métallique quelconque" Anales des télécommunications 62, n°5-6, pp 663-689 2007.

3. Mekkioui Z., ''Analyse rigoureuse d'antennes diélectrique micro-ruban à ondes de fuite'', Thèse de Doctorat d'Etat Université de Tlemcen, 2004.

4. Charmolavy Goslavy Lionel Nkouka Moukengue , Rostand Martialy Davy Loembe Souamy , Nzonzolo , Aristide Mankiti Fati , Désiré Lilonga-Boyenga and Junwu Tao '' Analysis Of A New Leaky-Wave Antenna For W-Band Applications'' Int. J. Adv. Res. 8(12), 358-363, ISSN: 2320-5407, December 2020

5. Hicham AzizP , Mahmoud MoubadirP, Naima Amar TouhamiP, Abdelkrim Farkhsi '' Planar leaky-wave antenna at 6GHz" 11th International Conference Interdisciplinarity in Engineering, INTER-ENG 2017, 5-6 October 2017, Tirgu-Mures, Romania, pp: 527–532

6. Bin Xi, Yuanxin Li , and Yunliang Long " A Miniaturized Periodic Microstrip Leaky Wave Antenna with Shorting Pins" Hindawi International Journal of Antennas and Propagation Volume 2019, pp:1-7

7. Charmolavy G. L. Nkouka Moukengue, Franck Moukanda Mbangou, Nzonzolo and D. Lilonga-Boyenga ‘’ A 80 GHz Microstrip Leaky-Wave Antenna with Degraded Ground Plane Design ,‘’ Journal of Scientific and Engineering Research, 2019, 6(8):97-101

8. Mauro Ettore ”Analysis and design of planar leaky-wave antennas” Tesi di dotorato diUniversit à DegliStudi Di Siena 2007-2008

9. GHOMI M. “ Contribution à l’étude des antennes micro-ruban à ondes de fuite “, Thèse de Doctorat INPT Toulouse, 1992

10. Juhua Liu Tang, al ‘’ Substrate Integrated waveguide leaky-wave Antennas with H-shaped sots ‘’ IEEE Transaction on Antennas and propagation vol 60, N° 8, August 2012

11. Juhua liu, David R Jackson, al ‘’ Substate Integrated Waveguide SIW eaky-wave Antenna with Transverse slot’’ IEEE Transactions on antennas and propagation, vol 60, N°1, January 2012

12. Ghayath El Hal, Ronan Souleau ‘’ Antenne à ondes de fuite à balayage angulaire à fréquence fixe à 77 GHz,” 17é Journée Nationale micro-ondes 18, 19, 20 Mai 2011 Brest.

13. Rahul AGRAWAL, Pravesh BELWAL, Suresh GUPTA “ Asymmetric Substrate Integrated Waveguide Leaky Wave Antenna with Open Stop Band Suppression and Radiation Efficiency Equalization through Broadside” RADIOENGINEERING, VOL. 27, NO. 2, JUNE 2018, pp: 409-416

14. Sajad Mohammad-Ali-Nezhad and Alireza Mallahzadeh “Periodic Ridged Leaky-Wave Antenna Design Based on SIW Technology” IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 14, 2015, pp: 354-357

15. T. Tamir and A. A. Oliner. "guided complex waves, part ii : Relation to radiation patterns". In Proc. Inst. Elec. Eng., volume 110, pages 325–334, February 1963.

16. Robert E. Collin, “Theory of Guides Waves”, 2nd Ed., OEEE Press, 1991

17. Lilonga-Boyenga D ”Contribution à l’étude du couplage par onde de charge d’espacedans les structures interdigitale et bigrille” Thèse de doctorat 3e cycle INP-Toulouse 1984

18. Visser H.J., “Array and phased array antenna”, John Wiley & Sons, 2005

19. R. C. Honey. "a flush-mounted leaky wave antenna with predictable patterns". IRE Trans. Antennas Propagat., vol. AP-7 :320–329, October 1959.

20. T. N. Trinh, R. Mittra, et al. (1981). Horn Image-guide Leaky-wave Antenna. IEEE Trans. Microwave Theory and Tech. vol. 29: 1310-1314.

21. Schwering F. Oliner A.A. et al. (1988). Millimeter-wave antennas, ch.17, Antenna Hand book, New York