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RESEARCH ARTICLE

ANALYSIS OF A NEW LEAKY-WAVE ANTENNA FOR W-BAND APPLICATIONS

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Abstract

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In this article, we present a dielectric leaky-wave antenna with periodic metallic patches in which the dielectric substrate contains periodic cylindrical holes. Its design is made using HFSS software. Analysis of the antenna's radiation pattern shows that one can control the direction of the main beam and the levels of minor's lobes from the diameters and numbers of the holes. This significantly reduces the weight of the antenna while improving its performance.

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Introduction:-

The development of space telecommunications in recent years has necessitated the design and construction of compact and efficient equipment, operating at increasingly high frequencies. Indeed, the use of high-precision radars in the field of military applications, the field of detection and for mobile communication systems is orienting research towards electronic scanning antennas [1]. Many electromagnetic modeling techniques have been developed to design miniature antennas [2-10].

In recent years, the field of research has been focusing on the study of scanning antennas, including leaky-wave antennas (LWA), which are essential components in much mobile or on-board equipments. Several studies are being developed with the aim of reducing side lobe levels and / or controlling the direction of the main beam [1] , [6] , [8] , [10] , [11].

This article therefore presents a dielectric leaky-wave antenna operating in the W-band, and whose particularity is to control the minor's lobes levels, the angular aperture and the direction of the main beam using the diameters, the number and /or the position of the holes in the substrate.

Theory:

The studied structure is a leaky-wave antenna based on a dielectric guide, on which rectangular metal patches have been placed periodically with a period l, to provide leaky-wave radiation. The dielectric guide is composed of rows of cylindrical holes of radius r and depth h, periodically arranged along the directions (oy) and (oz) as shown in figure (1).

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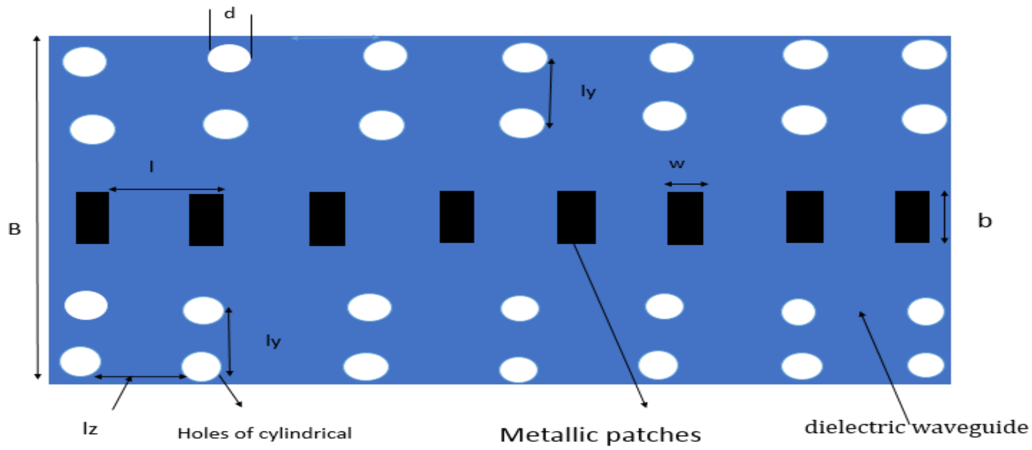

Figure 1: Dielectric leaky-wave antenna with periodic metallic patches

Leaky-wave antennas are generally periodic structures and have predetermined radiation characteristics where the main beam is scanned by frequency modification. Periodic LWA behaves as guiding of leaky-waves structure wich radiate energy in space as these waves propagate as shown in Figure 2.

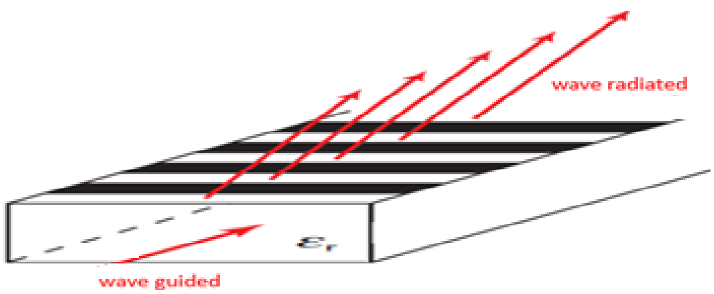

Figure 2:- Periodic leaky wave antenna.

With the periodic characteristics introduced into this structure, the propagated wave contains an infinity of modes. The electric field of the wave is expressed using Boch-Floquet theorem as an infinite sum of non-uniform plane waves [14], [15], [16].

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

where k_{zn} is the wave number of the n^{th} mode of Floquet is given by [1], [14], [16].

$$k_{zn} = k_z + \frac{2\pi n}{p} = \beta_z - j\alpha_z \qquad (2)$$

$\beta_{zn} = \beta_o + \frac{2\pi n}{p}$ is the phase constant the n^{th} harmonic ; β_o is the phase constant of the fundamental mode; α_z is the attenuation constant in z direction.

The corresponding radiation angle direction is given by:

$$\sin(\theta_{zn}) = \frac{\beta_{zn}}{k_o} \qquad (3)$$

The radiation harmonic n=-1 in the free-espace have an angle θ_{-1} who is given by:

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

In order to achieve the synthesis of LWA in microstrip technology

Ghomi, [1], T.N. Trinh and al [17] and F. Schwering, and al [18] showed that the parameters of a leaky-wave antenna obey the following conditions:

$$\begin{cases} \frac{\lambda_o}{\beta/k_o+1} \leq l \leq \frac{\lambda_o}{\beta/k_o-1} \text{ if } \quad \beta/k_o > 3 \\ \frac{\lambda_o}{\beta/k_o+1} \leq l \leq \frac{2\lambda_o}{\beta/k_o+1} \text{ if } \quad \beta/k_o < 3 \end{cases} \quad (5)$$

$$0,2\lambda_O \leq l \leq 0,4\lambda_O \quad (6)$$

$$b < \frac{\lambda_O}{(\varepsilon_{eff}-1)^2} \quad (7)$$

where λ_o is the free-space wavelength, β, the phase constant, $k_o = \frac{2\pi}{\lambda_O}$, the free-space wave number and ε_{eff}, effective dielectric constant of the structure.

Results and Discussion:

To demonstrate the effect of the degradation of the substrate on the radiation parameters of the dielectric leaky-wave antenna, we studied the dielectric leaky-wave antenna with a substrate composed of several rows of cylindrical holes of radius r and height h also regularly spaced with period lz.

The structure was designed and simulated using HFSS Simulation software. The characteristics of the LWA present are as follows:

Radiation patterns:

In order to check the influence of the degraded substrate on the performance of the antenna, we have plotted in figure (3) the field radiation patterns in the E-plane, with an antenna made up of two rows of holes each made up of 15 cylindrical shaped holes. We note that the main beam direction of the radiated with respect to the x axis tends slightly to the right as the radius of the holes increases, similarly of the Half-power beamwidth increases with the radius r of the holes. We also observe that this radiation patterns presents very low levels of minor lobes, less than -17 dB compared to the maximum radiated field and a very remarkable asymmetry of the lobe levels. Indeed, all the energy radiated is concentrated in the main lobes limiting radiation losses.

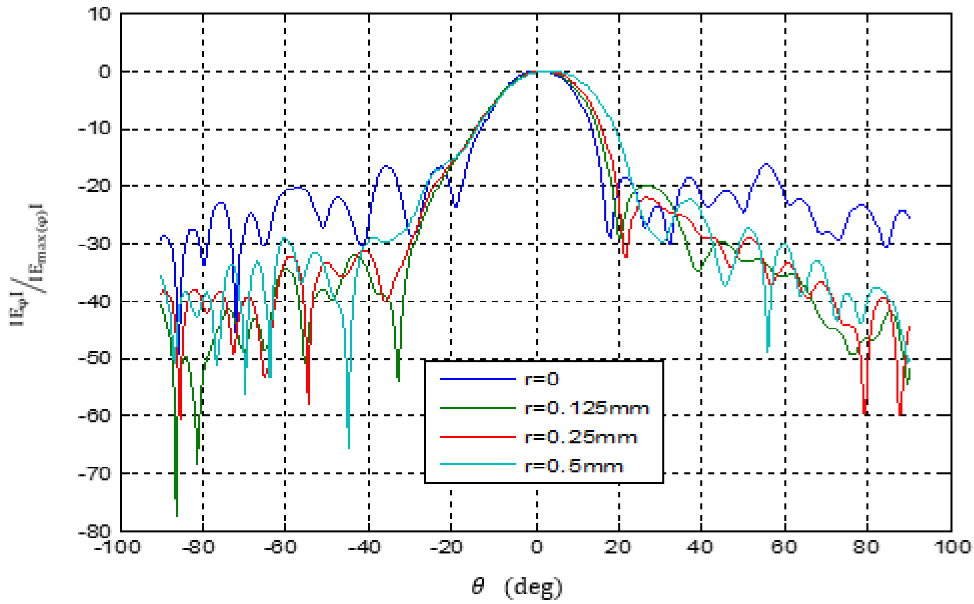

Figure 3:- Radiation patterns of the E-plane at F=80 GHz ; b=0,8λ_O ; N=11 , $\epsilon_r = 2{,}46$; w=0,3387λ_O ; B=8λ_O ; 2 rows of holes with 15 holes on each row ; lz=0,5λ_O.

In figure (4), a superposition of the radiation patterns in the E-plane is represented for a dielectric leaky-wave antenna with degraded substrate operating in W-band at F = 80 GHz for 4 rows of holes, each composed of 10 holes. As shown in this figure, it can be seen that an increase in the diameter of the cylinders leads to an increase in the levels of minor's lobes. The maximum of the radiated field is concentrated at the level of the main lobe. We note also that the direction of the main radiation beam with respect to the x axis tends to the right as the radius of the holes increases, it is 0.5 °, 2 °, 5.1 ° and 7.55 ° respectively for r = 0, 0.25, 0.5 and 0.75. One can affirm that the variation of the radius of the holes permits to control the direction of the main beam.

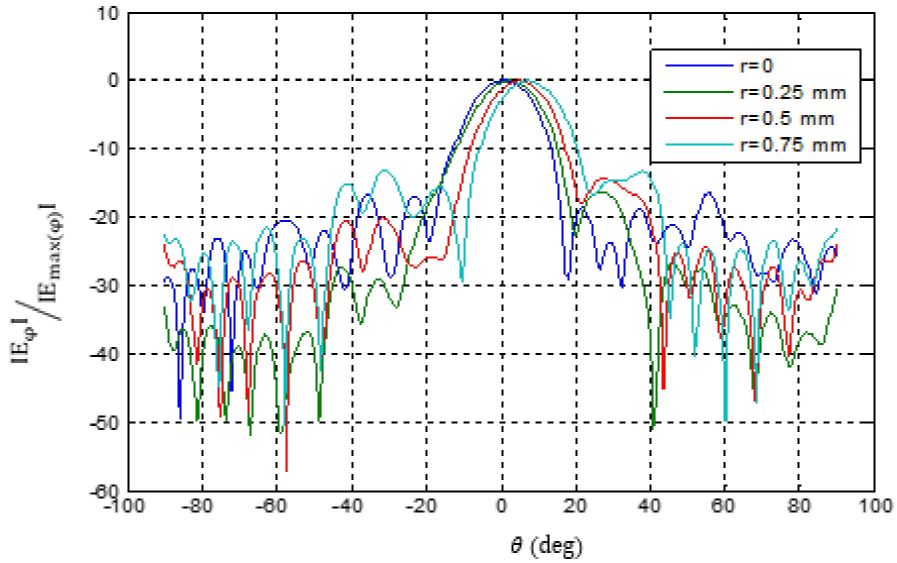

Figure 4:- Radiation patterns of the E-plane at F=80 GHz ; $b=0,8\lambda_O$; N=25 , $\epsilon_r = 2,46$; $w=0,3387\lambda_O$; $B=8\lambda_O$; 4 rows of holes with 10 holes on each row ; $lz=0,75\lambda_O$.

In figure 5, we represented the radiation patterns of the LWA for different values of lz at F=80 GHz for r=0.25 mm. We note that more the distance lz between the two rows of holes is important, more the levels of minor's lobes decrease. We also observe considerable asymmetric of minor's lobes levels. These are lower on the left than on the right of the scanning angle.

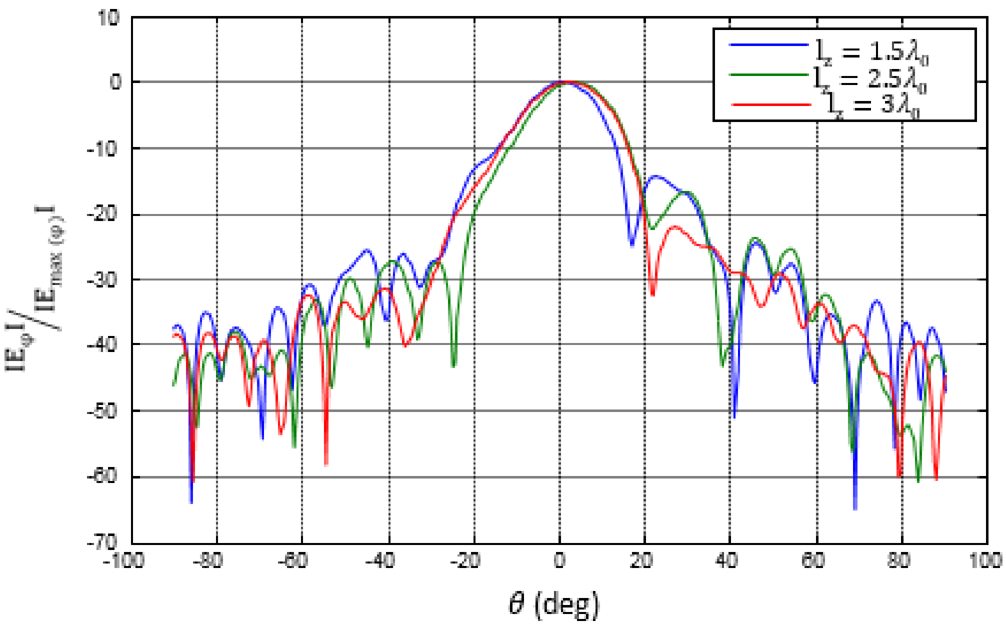

Figure 5:- Radiation patterns of the E-plane at F=80 GHz ; $b=0,8\lambda_O$; N=11 , $\epsilon_r = 2,46$; $w=0,3387\lambda_O$; $B=8\lambda_O$; 2 rows of cylindrical holes of 15 holes on each row ; r=0,25

Directivity:

To highlight the effect of the degraded substrate on the directivity of the antenna, we represent this quantity as a function of the frequency: in figure (6) for different values of the radius r of the cylinders holes and for lz=3λ_O, and in figure (7), for different values of the period of holes for r=0.25 mm. It can be seen that the directivity increases when the radius r of the holes increases.

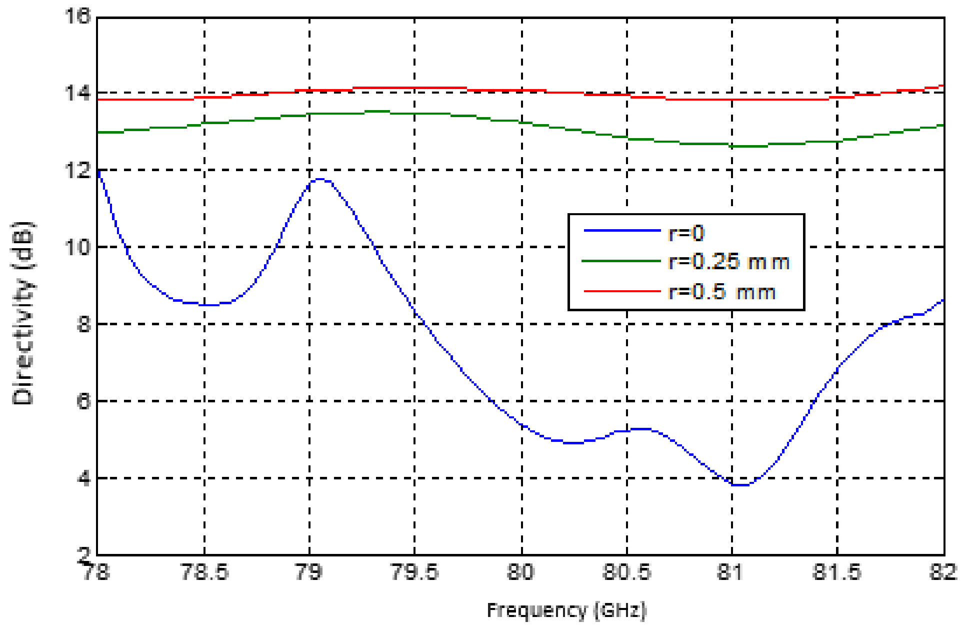

Figure 6:- Directivity of the defected substrate leaky-wave antenna b=0,8λ_O ; N=25 , $\epsilon_r = 2{,}46$; w=0,3387λ_O ; B=8λ_O ; lz=3λ_O

The distance between the holes lz plays an important role since it determines a good directivity and an interesting bandwidth [11]. It can be seen that the greater is this distance, the more the directivity in the operating frequency range decreases.

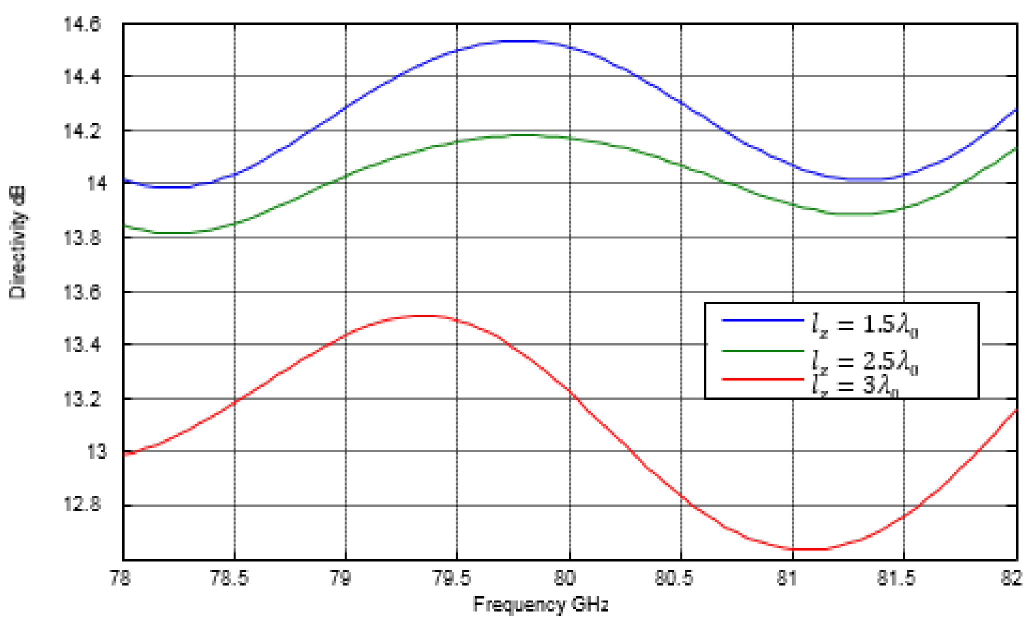

Figure 7:-Directivity of the defected substrate leaky-wave b=0,8λ_O ; N=25 , $\epsilon_r = 2{,}46$; w=0,3387λ_O ; B=8λ_O; r=0.25 mm

Conclusion:-

In this article, a dielectric leaky-wave antenna with periodic patches and with a degraded substrate has been proposed. The simulation results have shown that the direction of the main beam and the levels of minor's lobes can be controlled by adjusting the diameter of the holes in the substrate.

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