Design of traveling wave slotted waveguide array antenna with high efficiency

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ABSTRACT

The slotted waveguide antenna is one of the most important antennas used in high-frequency applications, in radars, navigation systems, remote sensing systems and communications because of its efficiency and high gains. In this paper, the slotted waveguide antenna was designed and simulated with suitable specifications with a working frequency range of 2-2.45 where this antenna was checked by plotting S parameters in the designed frequency band and we got a very good reflection coefficient for the designed antenna (S11) at the operating frequency, draw and illustrate the three-dimensional radiation pattern of the designed antenna that shows the gain and bandwidth at the operating frequency. The performance of a 9-element slotted waveguide array antenna with an operating frequency of up to 12 GHz was also investigated by plotting the S11 parameters and illustrating the designed antenna directivity diagram. We obtained the reflection coefficient of the designed array antenna (S11) below -23 dB at the operating frequency, and the SWG antenna directivity pattern with a maximum value of=13.2 dB and a minimum value of=-23 dB.

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1. INTRODUCTION

Slotted waveguide antennas contain a multi-slot waveguide, and these antennas do not include reflectors, but emission occurs directly through the slits. The value of the distance between the slits is a multiple of the wavelengths used for reception and transmission. In a rectangular waveguide antenna having dimension a>b it is usually at TE10. The slits are either placed in a wide wall of the waveguide antenna or narrow and in a basic position TE10, which depends on the polarity of the required field. We note that the transverse openings in the narrow wall have a horizontal field polarization, but the longitudinal apertures in the wide wall have a vertical field polarization [1], [2]. One of the most important applications of split waveguide antennas is radar, because the design specifications need mechanical strength and high gains. The signal transmitted by the radar antennas is of very high peak power, and for this reason, the waveguide antennas are a suitable alternative to planar arrays [3]-[6]. The slotted waveguide array (SWA) is used in remote sensing and radar applications because it has a high radiation efficiency [7], [8]. We can perfectly and accurately control the aperture distribution of aperture arrays when an exact input match is achieved by relying on carefully designed techniques and advanced full wave analysis programs. In these antennas, energy is radiated by apertures located on a narrow or wide wall in the waveguide. That is, the radiation elements are part of the feeding system, i.e. the waveguide itself. Thus, the design is simple and does not need feeding networks, and other useful advantages of these antennas are small size, light weight and high efficiency, so they are considered an ideal preferred solution in high-energy communications, radar, microwave and navigation systems [9]-[11].

One of the most important applications of edge aperture array antennas, or the so-called transverse tilted aperture antennas, is in radars, digital warfare, and communications, for its ease of manufacture and its distinction of low cost, high gain and little loss [12], [13]. On the other hand, it is equally difficult to analyze theoretically precisely because of the effects of its thick wall and the mutual coupling between its hole [14]-[16]. Nowadays, we notice that many applications of image sensing or in medical equipment and devices adopt focus in near fields to focus beams at a certain distance, which is called the focal distance of the antenna such as planar antennas, the slotted rectangular waveguide antennas, in addition to the dielectric lens antennas, but all of these antennas have a two-dimensional focus of radiation. But sometimes the antenna is in one plane, and the antenna beam can be two-dimensional, as we can see in the applications of microwaves and optics. An antenna whose focus is on one plane and whose beam is wide in an orthogonal plane is one of the important antennas found in optical systems for testing long material of small width, or in the application of a microwave to feed the reflective linear antenna. In such applications, the antenna is highly efficient and capable [17]-[27].

2. WAVEGUIDE ANTENNA METHOD

The waveguide is a transmission line of electromagnetic waves, and it consists of a single piece of metal tube with a rectangular or circular cross-section. Note that the conditions inside the waveguide depend mainly on the excitation as well as the frequency, when the frequency is the value of the (cut-off frequency) fc is low than the basic fc (ie TE10 of the standard waveguide). There is no propagation mode, so the operating frequency must be higher the cut-off frequency. So, the waveguide is considered a high-pass filter and the larger its size, the lower the value of the cut-off frequency, a waveguide has width (a) and height (b) [26]-[30].

The electric field can be expressed as:

$$E_y = E_0 \sin(\frac{\pi}{a} x)\, e^{j(\omega t-\beta z)} \tag{1}$$

$$E_x = E_c = 0$$

the magnetic field can be expressed in the following:

$$H_x = H_1 \sin(\frac{\pi}{a} x)e^{j(\omega t-\beta z)} \tag{2}$$

$$H_y=0$$

$$H_z = H_2 \cos(\frac{\pi}{a} x)e^{j(\omega t-\beta z)} \tag{3}$$

we can express the cut-off wavelength for TE_{mn} and TM_{mn}:

$$\lambda c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}} \tag{4}$$

the cut-off frequency is given by the following:

$$fc = \frac{21}{2\sqrt{\varepsilon\mu}} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \tag{5}$$

at TE_{10} mode, the λc=2a, and the wavelength of the waveguide given by the (6),

$$\lambda_g = \lambda \Big/ \sqrt{1 - \left(\frac{\lambda}{\lambda c}\right)^2} \tag{6}$$

λ represents the wavelength of free space and λc represents the cut-off wavelength. We can express the characteristic impedance of TE_{10} mode:

$$\lambda_g = \lambda \Big/ \sqrt{1 - \left(\frac{\lambda}{\lambda c}\right)^2} \tag{7}$$

$$Z_{TE10} = 120\pi \Big/ \sqrt{1 - \frac{\lambda}{2a}} \quad (8)$$

Figure 1 shows the proposed rectangular slotted waveguide with 9 slots. In this work, the slotted waveguide antenna was designed and simulated using MATLAB programs within the specifications shown in Table 1.

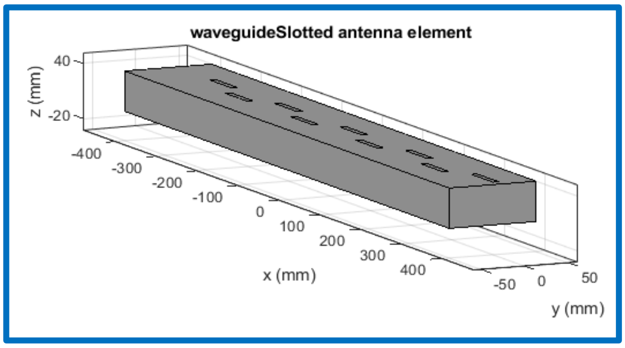

Figure 1. Rectangular waveguide

Table 1. Properties of slotted wave guide antenna

Parameter description	Value (mm)
Waveguideslotted length	800
Waveguideslotted width	100
Waveguideslotted height	44
Slot length	53
Slot width	6.5
Slot spacing	80.6

3. RESULTS AND DISCUSSION

This paper presents a proposal for a traveling–wave slotted waveguide antenna with a working frequency of 2-2-45 GHz, having the dimensions are length=800 mm, width=100 mm, height=44 mm, hole length=53 mm, hole width=6.5 mm, hole spacing=80.6. The designed antenna was tested by plotting the parameters of S in the mentioned frequency range. From figure 2 we can see that the reflection coefficient of the designed antenna is very good (S11) at the working frequency. Figure 3 shows the 3D radiation pattern of the designed antenna, which shows the most important antenna properties such as gain and bandwidth. The performance of a 9-element slotted waveguide array antenna with a working frequency of up to 12 GHz was also investigated by plotting the S11 parameters and illustrating the designed antenna directivity diagram. From Figure 4 we can see that the reflection coefficient of the designed array antenna (S11) is less than -23 dB at the working frequency, while Figure 5 shows the directivity scheme of the SWG antenna with a maximum value=13.2 dBm and a minimum value=-23 dB

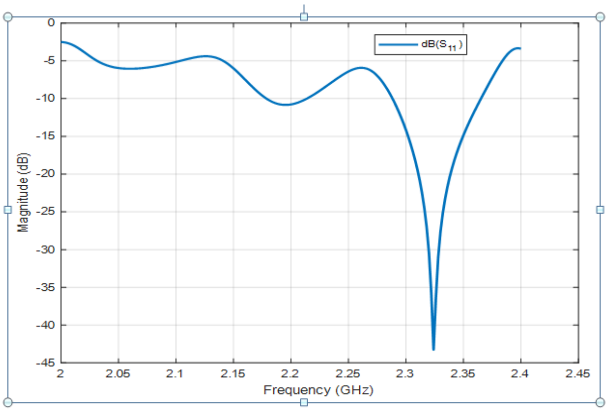

Figure 2. The S-parameters of slotted wave guide antenna

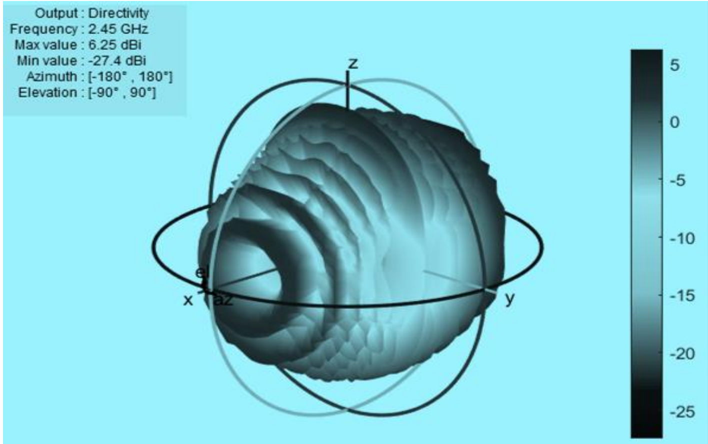

Figure 3. Radiation pattern of slotted wave guide antenna

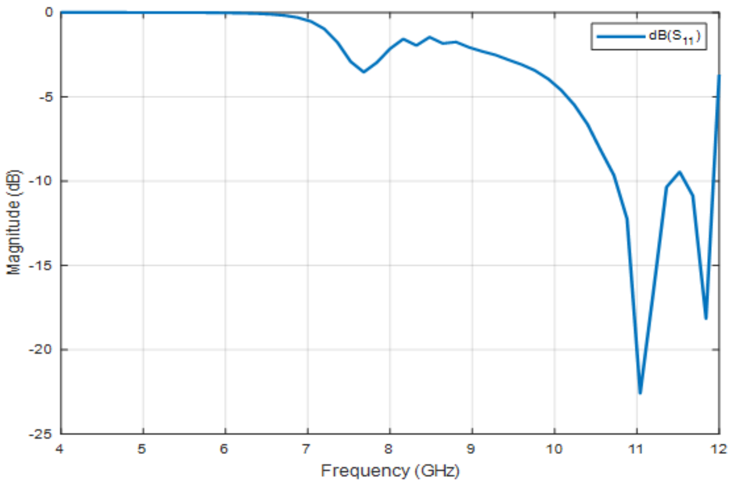

Figure 4. The S-parameters of slotted wave guide array antenna

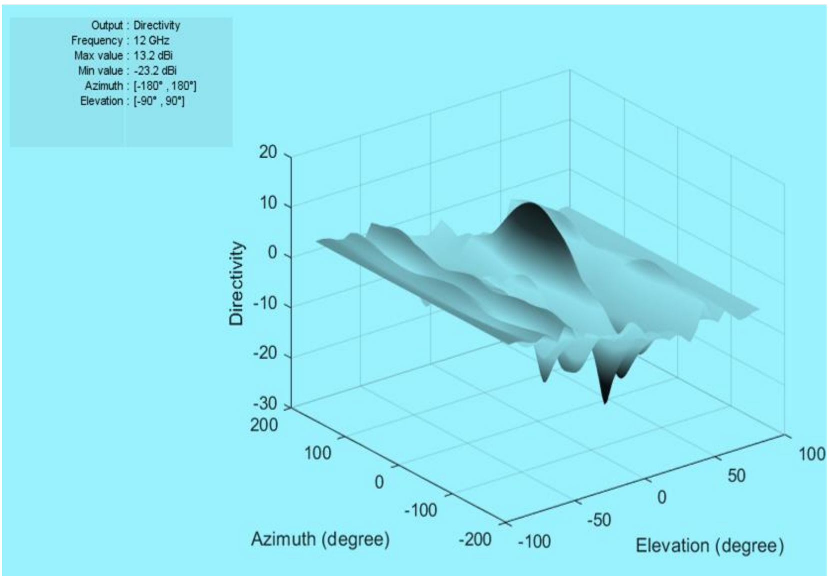

Figure 5. Directivity diagram of slotted wave guide array antenna

4. CONCLUSION

The traveling wave slotted waveguide antennas are characterized by high gain and high efficiency, which made these antennas have wide applications in the field of communications, navigation, satellites, radars, etc. In this paper, the traveling wave slot waveguide antennas are designed and simulated with appropriate specifications to achieve good gain, high efficiency and working frequency range 2-2.45. The proposed antenna was tested with a number of apertures=9 by drawing and calculating the reflection coefficient S at the operating frequency. The antenna achieved good values for the reflection coefficient and with high gain and efficiency. Also in this paper, the design and simulation of a 9-element slit waveguide array antenna with an operating frequency of 12 GHz and plotting the S11 coefficients, the value of the reflection coefficient was less than -23 dB, in addition to the drawing of the directivity diagram, which has a maximum value of=13.2 dB and a minimum value of=-23 dB.

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