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DESIGN OF H-PLANE SECTORAL HORN ANTENNA FOR MICROWAVE APPLICATIONS USING MATLAB

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Abstract: Wireless communications has become more essential in our life, as well as considered as the one of fastest growing segment in the communication business. The antenna was and still the main component of any wireless communication system. In other word the antenna is the eyes and ears of any wireless communication system. Many recent research has carried out designing of H-sectoral horn antenna but yet H-plane horn antenna with a very high gain and narrow radiation pattern while keeping up its compact size is not been completely delivered. Consequently, H-plane sectoral horn operates on c-band (6GHz) has clarified and successfully designed using MATLAB with an optimum compact size. In addition, the power pattern of E-plane and H-plane have drawn using MATLAB simulation. In conclusion, the designed H-sectoral horn antenna is promising a directive, narrow and intense radiation in the direction of a selected path to support high coverage distances. Besides, a very high power of 21dB of gain is achieved. This antenna is perfectly suitable to use in numerous microwave applications such as, feed element in large radio astronomy, satellite tracking, feed for various lenses and reflectors antenna, and gain measurement for other transmitting antenna.

Keywords: *Horn Antenna, H-Sectoral Horn antenna, Microwave Antenna and Microwave applications.*

تصميم هوائي البوق القطاعي للموجات الدقيقة باستخدام الماتلاب

الخلاصة:الاتصالات الاسلكية اصبحت اكثر فاكثر جزء اساسي في حياتنا، وتعتبر ايضا الاسرع نموا في مجال الاتصالات. الهوائي كان ومازال المكون الاساس في اي نظام من انظمة الاتصالات الاسلكية. بعبارة اخرى ، الهوائي هو العين و الاذن لاي نظام لاسلكي. العديد من البحوث قد اجريت على تصميم هوائي البوق القطاعي لكن هوائي مع ربح جدا عالي وقوة اشعاع ضيقة ومركزة مع المحافظة على حجم صغير لم يوفر بالكامل. لذلك هوائي البوق القطاعي يعمل على حزمة الترددات c وبتردد 6 جيجا هيرتز قد وضح وصمم باستخدام برنامج الماتلاب بحجم اصغر مايمكن. بالاضاقة الى رسم قوة الشعاع باتحاه H , E باستخدام الماتلاب. خلاصة القول هوائي البوق القطاعي المصمم يوفر اشعاع موجه ومركز في الاتجاه المرغوب لدعم مسافات بعيدة. اضافة الى ربح عالي جدا يساوي 21 دي بي.هذا الهوائي المصمم ملائم تماما للكثير من تطبيقات الموجات الدقيقة مثل ، عنصر تغذية لمحطات الراديو الفلكية الكبيرة، تتبع الاقمار الصناعية، عنصر تغذية للكثير من هوائيات العدسية و العاكسة و لقياس الربح لهوائيات الارسال.

1. Introduction

Wireless communications is extremely crucial in our life, also deliberated as the fastest developing section in the communication business [1]. Furthermore, wireless communications is regarded as one of our utilities nowadays. Wireless technology was invented for more than 200 years ago with the significant benefit of the antenna [2]. In

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other word, the antenna was and still the main and the most important player in any wireless system. Likewise, the antenna is the eyes and ears of any wireless communication system. The antenna is a device aimed at transmitting and/or receiving signals [3, 4]. It's clear to say that, a good antenna is intended to be "in tune", or in other words is designed to transmit or receive a signal that seeking for. Horn antenna is used regularly as a microwave antenna [3, 5].

In addition, there are several typical electromagnetic horn antenna configurations, which are E-plane, H-plane, conical and pyramid [3]. Numerous research claimed that, there are only two types of horn antenna pyramid and conical, and extra alteration such as; septum, ridged, exponential corrugated and sectoral (E &H) [5, 6]. Furthermore, the horn antenna is simply a hollow pipe taking different type of cross sections with a large opening [4, 5]. In this research, one of the classical types of microwave antenna has selected to design, which is H-plane sectoral horn antenna. H-plane sectoral is selected due to its compact size, simple construction, preferred radiation, high gain and suitable for microwave applications [3, 4, 5].

To design and fabricate H-plane sectoral antenna, various parameters should be carefully taking into consideration; Such as, anticipated operating frequency, bandwidth, gain and radiation pattern [5, 6]. Therefore, in this proposed design, H-plane sectoral is intended to meet the following constraints; operation frequency 6GHz, maintain a high power gain about 20dB over the entire range of the operating frequency and directive and narrow beamwidth in the direction of transmitting or receiving to support high distances. Additionally, after extensive survey, few recent researches have carried out designing Horn antenna using different type of approach and simulation.

In paper [7], the practical and simulation design is aimed to support tunable bandwidth using balanced screws. Which is successfully completed while maintain a compact size but with a very wide radiation beamwidth in the direction of H- field, that cause low antenna directivity and less radiating distance for high distance radiation. In paper [8], an H- plane sectoral is designed also using different sized, then it analyzed depending one each approach. It is found that the radiation pattern is almost acceptable in compare with [7] but with a very low power gain, which makes this antenna is not suitable for middle and high range of microwave applications.

In paper [9], H-sectoral has designed operate on x-band (8-12GHz) using acceptable size and optimum 16dB of gain but again a very wide radiation pattern with a large side loop in compare with [8]. In addition, a Substrate integrated waveguide technology is studied, which is widely used in antenna and microwave [10, 11]. In brief, a design of an H-plane horn antenna with a very high gain and narrow radiation pattern while keeping up its compact size is not been provided.

2. H-plane Sectoral Horn

Basically, the H-plane sectoral is feed by a rectangular waveguide and keep the other side open with a rectangular dimensions in the direction of the H-field [3,5,6]. The waveguide is commonly a transmission line used to collecting or feeding signals from or into the antenna, its conductive wall connected to a coaxial cable [3,4,5,10,11]. H-plane sectoral horn antenna is shown in Figure 1 below.

The construction design of the H-sectoral horn antenna is clarify in the coming section.

Figure.1 H-Plane Sectoral Horn

3. Design of H-Plane Sectoral Horn Antenna

To begin with, the microwave frequency band start with 300MHz up to 300GHz [4]. In this design, 6GHz is been selected among various frequency at c-band by reason of this antenna is work at optimum level, besides most of H-sectoral antennas designed do not support this band due to gain limitations [7,8,9]. Moreover, the suitable waveguide size is selected based on the operating frequency of the antenna [5,6,10,11]. Therefore the waveguide standards based on 6GHz (c-band) are as follows [4,5,6]:

- USA STANDARD:
  WR-137 this waveguide has size of a=1.37inch and b=0.622inch.
- EUROPE STANDARD:
  WG-14 this waveguide has size of a=1.37inch and b=0.622inch.

In this design, numerous factor are carefully examined, such as maintaining a compact size H-sectoral horn with a high power gain to support high coverage distance as well as directive and narrow radiation beamwidth. This inspiring requirements is subjected to shape and size of the waveguide and the antenna body alike.

Consequently, waveguide and antenna body sizes are tested and examined cautiously to make an optimum H-sectoral horn antenna. Hence, the optimum design of H-Plane sectoral antenna is found and exposed as follows:

- Waveguide optimum design (WR-137):
  a=1.37 Inch (0.6958λ) and b=0.622 Inch (0.3159λ).
- Other important parameters:

λ=C/F = 0.05m (f=6GHz), β=2π/λ =2π/0.05=125.6637.

- H-sectoral Horn antenna optimum design:
  A=8.66 Inch (4.4λ) and R_0=11.81 Inch (6λ).

The power gain of this design is calculated using the following formula also using a simulation plot [3,4,5]:

$$G = \frac{32}{\pi}\left(\frac{A}{\lambda}\sqrt{\frac{50}{\frac{R_1}{\lambda}}}\right) \qquad (1)$$

Where

A is the aperture length which is equal to 8.66 Inch.

$R_1$is can be found using the following formula $R_1 = \lambda\sqrt{(6)^2 + (\frac{4.4}{2})^2} = 6.3906\lambda$ which is equal to 12.5799 Inch.

The antenna power gain of this H-sectoral horn antenna is 21dB, which is extremely promising and appreciated.

The optimum waveguide and H-sectoral body design is drawn in Figure 2 below.

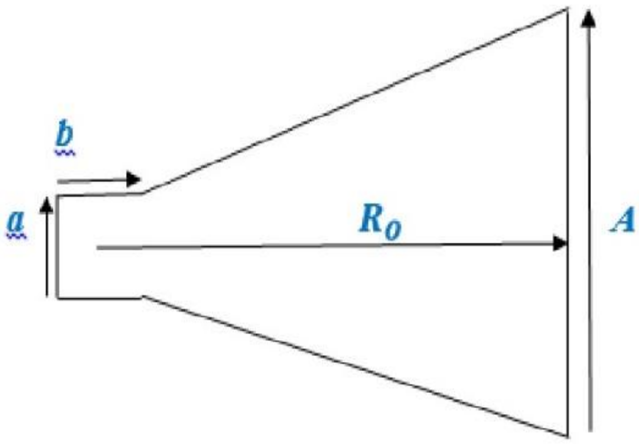

Figure.2 Design of H-sectoral horn and rectangular waveguide

4. Plotting The Power Pattern Using Matlab

The power pattern $(\mathbf{E_\theta}, \mathbf{E_\emptyset})$ of the H-plane sectoral horn antenna operates on frequency equal to 6GHz at C-band is plotted using MATLA. The equations of the power pattern and other parameters are as follows:

1) E-Plane (yz-Plane) ($\emptyset=\frac{\pi}{2}$,$E_\emptyset = E_r = 0$):

$$\boldsymbol{\lambda}= \frac{c}{f}= 3*10^8/6*10^9=0.05 \qquad (2)$$

$$b=.3159*\lambda = 0.015795 \qquad (3)$$

$$\phi = 90^o$$

$$\beta = \frac{2\pi}{\lambda} \qquad (4)$$

$$F_E(\theta) = \frac{1+\cos\theta}{2}\frac{\sin[(\beta b/2)\sin\theta]}{(\beta b/2)\sin\theta} \quad (5)$$

2) H-Plane (xz-plane) (Ø=0,$E_\theta = E_r = 0$):

$$\lambda = \frac{c}{f} = 3*10^8/6*10^9=0.05 \quad (6)$$

$$\phi = 0^o$$

$$\beta = \frac{2\pi}{\lambda} \quad (7)$$

$$F_H(\theta) = \frac{1+\cos\theta}{2}\frac{I(\theta,\phi=0)}{I(\theta=0,\phi=0)} \quad (8)$$

$$I(\theta,\phi) = e^{j(R_1/2\beta)(\beta\sin\theta\cos\phi+\pi/A)^2}[C(s_2') - jS(s_2') - C(s_1') + jS(s_1')]$$
$$.e^{j(R_1/2\beta)(\beta\sin\theta\cos\phi-\pi/A)^2}[C(t_2') - jS(t_2') - C(t_1') + jS(t_1')] \quad (9)$$

When (Ø=0) then:

$$I(\theta,\phi) = e^{j(R_1/2\beta)(\beta\sin\theta+\pi/A)^2}[C(s_2') - jS(s_2') - C(s_1') + jS(s_1')]$$
$$.e^{j(R_1/2\beta)(\beta\sin\theta-\pi/A)^2}[C(t_2') - jS(t_2') - C(t_1') + jS(t_1')] \quad (10)$$

5. Results of the Power Pattern Plots (E & H)

The power pattern E-plane and H-plane plots are indicate the radiation of the electromagnetic in free space. Constantly, changing the size of both the waveguide and the antenna itself has a substantial effect on the beamwidth. Thus, the optimum size of the waveguide is a=1.37 Inch and b=0.62 Inch. While, the body of the H-sectoral size is A=8.66 Inch and R_o=11.81 Inch. The electromagnetic radiations of the compact H-sectoral horn design both E-plane and H-plane are shown in figure 3 & 4 (respectively) below.

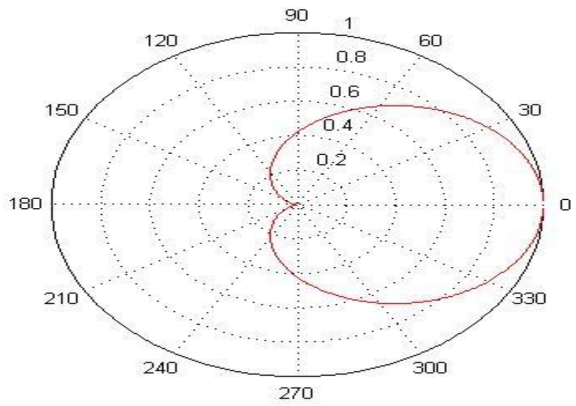

Figure.3 E-Plane of the H-plane Sectoral Horn Antenna

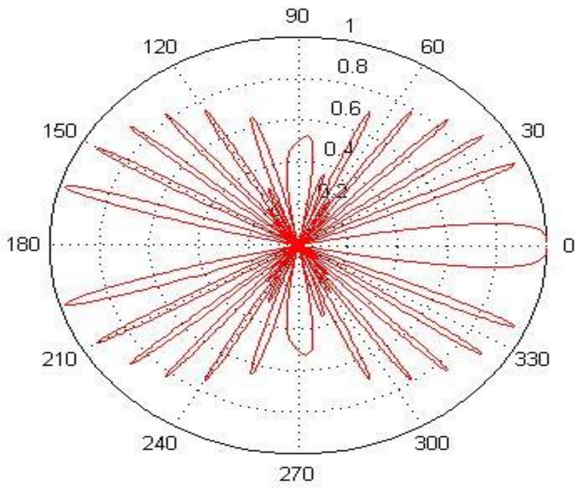

Figure.4 H-Plane of the H-plane Sectoral Horn Antenna

From the plots, the main lobe of the E-plane is narrow and very directive in the direction of H field. This beamwidth promises a very sharp and intense transmitting or receiving signals, as well as a very high power gain of 21dB, which is normally not found especially at c-band where most of the antennas design have a limited power gain.

6. Applications Zone

The designed compact size H-sectoral horn antenna with a concentrated and narrow radiation pattern as well as a very high power gain of 21dB is perfectly suitable for several microwave applications, such as; added as a Feed element for radio astronomy, Satellite tracking, Communication dishes and lenses and Gain measurement.

7. Conclusions

To sum of all, in this paper, H-plane sectoral horn operates on 6GHz is illuminated and successfully designed using MATLAB. In addition, constantly manipulating the size of the waveguide and the H-sectoral antenna body and testing the optimum sizes resulting a compact size antenna. Similarly, promising a directive, narrow and intense radiation in the direction of a selected path to support high coverage distances. Besides, a very high power of 21dB of gain is delivered by the designed antenna. Furthermore, the power pattern of E-plane and H-plane plots have drawn and illustrated using MATLAB simulation. In conclusion, this H-sectoral horn antenna is seamlessly proper for numerous microwave applications such as, feed element in large radio astronomy, satellite tracking, feed for various lenses and reflectors, and gain measurement for other transmitting antenna.

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