Fabrication and Testing of Pyramidal X- Band Standard Horn Antenna

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Abstract

Standard horn antennas are an important device to evaluate many types of antennas, since they are used as a reference to any type of antennas within the microwave frequency bands. In this project the fabrication process and tests of standard horn antenna operating at X-band frequencies have been proposed. The fabricated antenna passed through multi stages of processing of its parts until assembling the final product. These stages are (milling, bending, fitting and welding). The assembled antenna subjected to two types of tests to evaluate its performance. The first one is the test by two port network analyzer to point out S & Z parameters, input resistance, and the voltage standing wave ratio of the horn, while the second test was done using un-echoic chamber to measure the gain, side lobes level and the half power beam width. The results of testing come nearly as a theoretical value of the most important of antenna parameters, like; gain, side lobe level, -3 dB beam width, return loss and voltage standing wave ratio "VSWR", input Impedance.

Keywords: - Horn antenna, VSWR, Reflection loss.

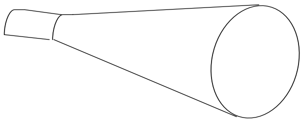
الخلاصه

يعتبر الهوائي البوقي القياسي من الهوائيات المهمة التي تستخدم في تقييس الهوائيات التي تعمل ضمن نطاق أو حزمة الترددات المايكروية إذ أن الهوائي القياسي يعتبر كمرجع لجميع الهوائيات العاملة ضمن نطاق الترددات المايكروية. في هذا البحث تم تصنيع وفحص هوائي بوقي قياسي يعمل ضمن حزمة الترددات المايكروية (X-Band).ان الهوائي الذي تم تصنيعه مر خلال مراحل تصنيعية كثيرة ابتدأت من تصنيع أجزائه قطعة قطعة انتهاءا إلى مرحلة التجميع النهائي وهذه المراحل هي التفريز والثني ومطابقة الأجزاء وأخيرا تجميعها بعملية اللحام. تم فحص الهوائي بمرحلتين للفحص لغرض التأكد من صلاحيته للعمل ، اذ تم في المرحلة الأولى فحصه بجهاز محلل الشبكات ذي القناتين لتقييم أدائه من خلال احتساب معالمه الأساسية مثل نسبة الموجة المتوقفة وقيمة الخسائر الراجعة او المنعكسة أما في المرحلة الثانية فتم فحص الهوائي في الغرفة عديمة الصدى لغرض رسم المخطط الإشعاعي للهوائي لاحتساب الكسب وعرض الفص الرئيسي ومستوى الفصوص الجانبية و كانت نتائج مرحلتي الفحص قريبة لقيم الحسابات النظرية لتصميم الهوائي (مثل الكسب ومستوى الفصوص الجانبية وقيمة الخسائر الراجعة او المنعكسة ونسبة الموجة المتوقفة.

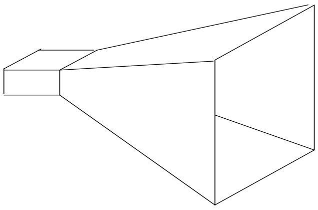
الكلمات المفتاحية :- الهوائي البوقي، VSWR ، وفقدان الانعكاس.

1-Introduction

Horns are among the simplest and most widely used microwave antennas employing the frequency band (above 1 GHz), with a variety of uses, from small-aperture antennas to feed reflectors to large-aperture antennas or used by themselves as medium-gain antennas(Milligan,2005). The area of applications that employing horn antennas covering wireless communications, electromagnetic sensing, radar systems, RF heating and biomedicine(Daniyan *et.al.*,2014) . Horn antennas are characterized using several parameters like gain, side lobes, voltage standing wave ratio (VSWR), half-power beam width, return loss, frequency of operation, polarization, and geometry. There are two mostly types of horn antennas which are rectangular horn antenna and conical horn antenna as shown in Fig. 1.



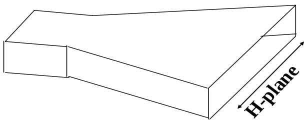
(a) Conical horn antenna



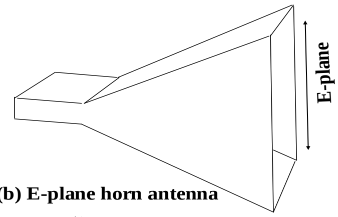
(b) Rectangular horn antenna

Fig 1 Main types of horn antenna

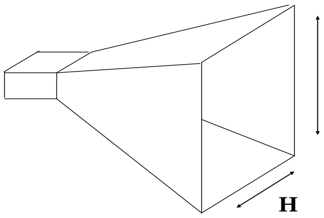
Rectangular horn antenna can be classified into three types according to the flare of its side walls, the first two types are: E-Plane, where two of its sides are flared in E- plane and the rest are parallel, H-plane, where two of its sides are flared in H-plane while the rest sides are parallel, both of these two types are called sectoral horn antenna, whereas the third type is called pyramidal horn antenna where the sides of the horn are flared in both E and H planes. Fig. 2 show the types of rectangular horn antenna.



(a) H-plane horn antenna



(b) E-plane horn antenna



(c) Pyramidal horn antenna

Fig. 2. Types of rectangular horn antenna

the decision of fabrication the standard pyramidal horn antenna comes from that it is used as a reference to many types operating within microwave frequencies because it has some specifications which are: directional radiation pattern, ability to achieve high gain and directivity, slowly varying input impedance.

The aim of the research is to fabricate a pyramidal standard horn antenna operating at X-band GHz (8-12 GHz), maintain the following parameters:

- The gain ≥ 15 dB.
- Side lobe level $\leq$ -13 dB,
- Half power beam width $\leq$ 20 degrees.
- Voltage standing wave ratio (VSWR) $\leq$ 2.
- return losses as high as possible (negative value).

The research is arranged as follows: Introduction, related works, theory, practical work, results and conclusions, and references.

2-Related works.

Many researches have been proposed to design and fabrication of standard pyramidal horn antenna also there are some of companies presenting its products with various types of horn antenna covering the ranges of microwave frequency bands in order to satisfy the requirements of the markets of RF products. In(Constantine,2005) the authors propose a set of standard pyramidal horn design with the aid of WIPL-D software. This software used to design and simulated a group of pyramidal standard horn antennas covering some ranges of popular standard horns. They got an encourage results from simulated antennas. In(Roy and Puri) the authors presenting a method for design and simulation of pyramidal horn antenna operating in X-band for navigation and surveillance applications using CST software. They got a directivity of ranges from 15.18 dB to 18.55 dB and beam width ranges from 20.9 deg to 30.0 deg. In(Pereira and Terada,2011) the authors introduce a procedure for determining the optimum design of pyramidal horn antennas. The efficiencies and phase errors in the optimum design are variables and depend on the design requirements. Also they propose new equations for the optimum design, which can be solved numerically or analytically. In(Maybell and Simon,1993) a design and fabrication of pyramidal horn antenna operating at 9.5 GHz have been proposed. the researchers got results close to pre calculated theoretical value of gain and directivity after using approximations to dimensions of proposed horn.

from most of the previous works (except "6") it can be seen that these researches uses the simulators to get the results for the performance of pyramidal horn antenna. In(Maybell and Simon,1993) the tests do not cover the most important parameters of antennas like VSWR, and side lobes. In our work we tried to fabricate a pyramidal standard horn antenna working at X-Band frequencies in order to study its performance through the gain, VSWR, HPBW, input impedance, side lobes, and return losses.

3-Theory of horn antenna

The design of horn antenna depends on the values indicated in figure 3, like *A*, *RH*, *R*1, *RE*, *R*2 and *B*, and these are related by(Maybell and Simon,1993) :

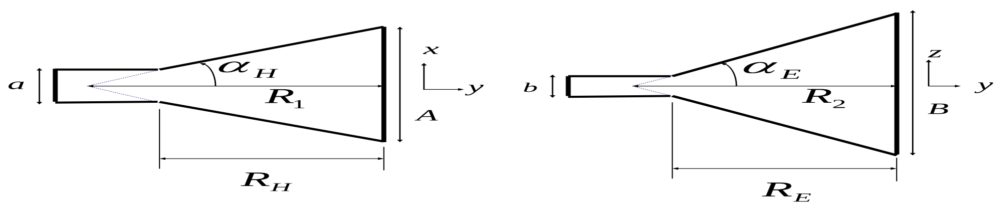


Fig. 3 Geometry of a pyramidal horn

$$R_H^2 = R_1^2 + (\frac{A}{2})^2$$

$$R_E^2 = R_2^2 + (\frac{B}{2})^2$$

$$R_E = R_H = R_P$$

Where *A* is the H-plane dimension of the aperture, *RE* is the distance from the input of the waveguide to the aperture of the horn in E-plane, *RH* is the distance from the input of the waveguide to the aperture of the horn in H-plane, and *B* is the E-plane dimension of the aperture.

In this work the waveguide geometry is standardized (width, height) and the size of the pyramid is selected from reference document(Ohlsson *et.al.*, 2001) for this application as shown in table 1.

Table 1 Geometry of standard gain pyramidal horn antenna

Frequency range (GHz)	E (mm) "B"	H (mm) "A"	L (mm) with waveguide	Connector type
8.2 – 12.4	80	60	160	Flange

4 Practical work and testing

Horn antenna could be made from aluminum, copper, or brass. The used metal for fabrication may be in the form of powder or sheet metal, so the fabrication of horn antenna may be performed by casting or by forming sheet metal to make horn antenna. The casting method is more preferable method to fabricate horn antenna that it is produce high quality with high précised inner walls product. This method called precision casting, i.e. the surface of the horn walls has high accuracy, because of using plaster and wax during the process of fabrication to maintain the desired inner surface accuracy. But this method of fabrication is not economic to fabricate horn antennas for experimental use, because of the highly cost of the design and fabricate metal punch and die used for casting to form the shape of the horn, in addition to the cost of plaster and wax used in casting, so this method is used for mass production of horn antennas. For experimental purposes that need more than one sample with different dimensions of horn antennas, the researchers prefer the use of sheet metals made from any of the pre mentioned metals to fabricate horn antennas, because they need to implement more than one sample of horn antenna according to design requirements. These sheets can be shaped in many methods to fabricate horn antenna. Performing of the process of fabrication of horn antenna from sheet metals passing through many steps which are:

1- **Metal selecting:** there are three most common metals used to fabricate horn antenna which are; copper, aluminum, and brass. In this work the decision comes for using aluminum sheets of 3 mm in width, because of its availability in markets, and its capability for shaping in different forms.

2- **Choosing the desired shape of horn antenna:** according to the aim of research, it has been choosing the pyramidal horn antenna with the geometry specifications depicted in table 1.

3- **Designing of waveguide, and horn sides and flanges:** according to the dimension specified in table 1, three drawings had been done accordingly as shown in figures 4-5.

4- **Milling:** the shaping of sheet metals process starts with milling process where the sheets are milled to the shapes of pre specified dimensions. as depicted in figures 4-5.

5-**Bending:** in this step the shaped pieces from step (4) is bended according to flaring angle of the horn sides.

6- **Assembling by welding:** the bended pieces are fitting and assembling by welding using a technique so called "Tig welding"

7- **Finishing by milling:** the assembled horn is milled to get final product which is pyramidal horn antenna.

Figure 6 indicating the technological path for fabricating horn antenna, while figure 7 indicating the final product of horn antenna.

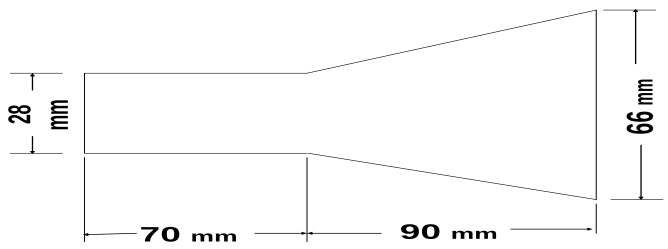


Fig. 4 H-plane flared side of pyramidal horn antenna

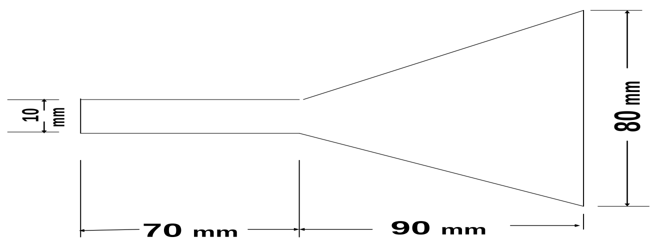


Fig. 5 E-plane flared side of pyramidal horn antenna

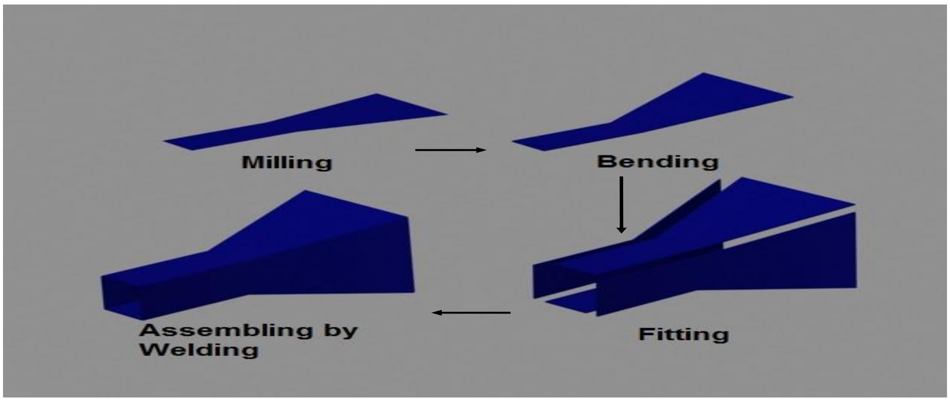


Fig. 6 Technological path for horn antenna fabrication

Fig. 7 Assembled pyramidal horn antenna

4 Testing

The most significant parameters related to the performance of the horn antenna are; gain, side lobes, voltage standing wave ratio, losses or return losses, -3 dB beam width, and input resistance. Using of the two port network analyzer facilitate the getting of S & Z - parameters to have the data of voltage standing wave ration (VSWR), return losses, and impedance. To get radiation pattern of the antenna, anechoic chamber has been used in order to extract the side lobe level, gain, and half power beam width. The results are shown in figures (8-11)

5 Results

The results of testing the antenna is coming as follows:

1- the gain of the antenna is (16 dB) with no backlobe.
2- maximum side lobe level is about (-21 dB).
3- half power beam width "-3 dB beam width" is about (20 degrees).
4- voltage standing wave ratio (1.019) at the operating frequency (8.64 GHz).
5- reflection loss is (-39.9457 dB) at the operating frequency (8.64 GHz).
6- input resistance is (49.594 Ω) at the operating frequency (8.64 GHz).

6 Discussion, and Conclusions

After fabricating and assembling the pyramidal horn antenna it is passed through many tests to decide how it is valid or how it has a satisfactory performance. These tests are performed in the laboratories using network analyzer to gate the S & Z parameters to indicate the VSWR, reflection loss, and impedance. And using anechoic chamber to get the radiation pattern of the antenna to point out the values of gain, side lobe level, and half power beam width. From the extracted results, it can be concluded that there is an ability to fabricate many samples of horn antenna in different frequency bands according to pre-defined dimensions of the designed geometry.

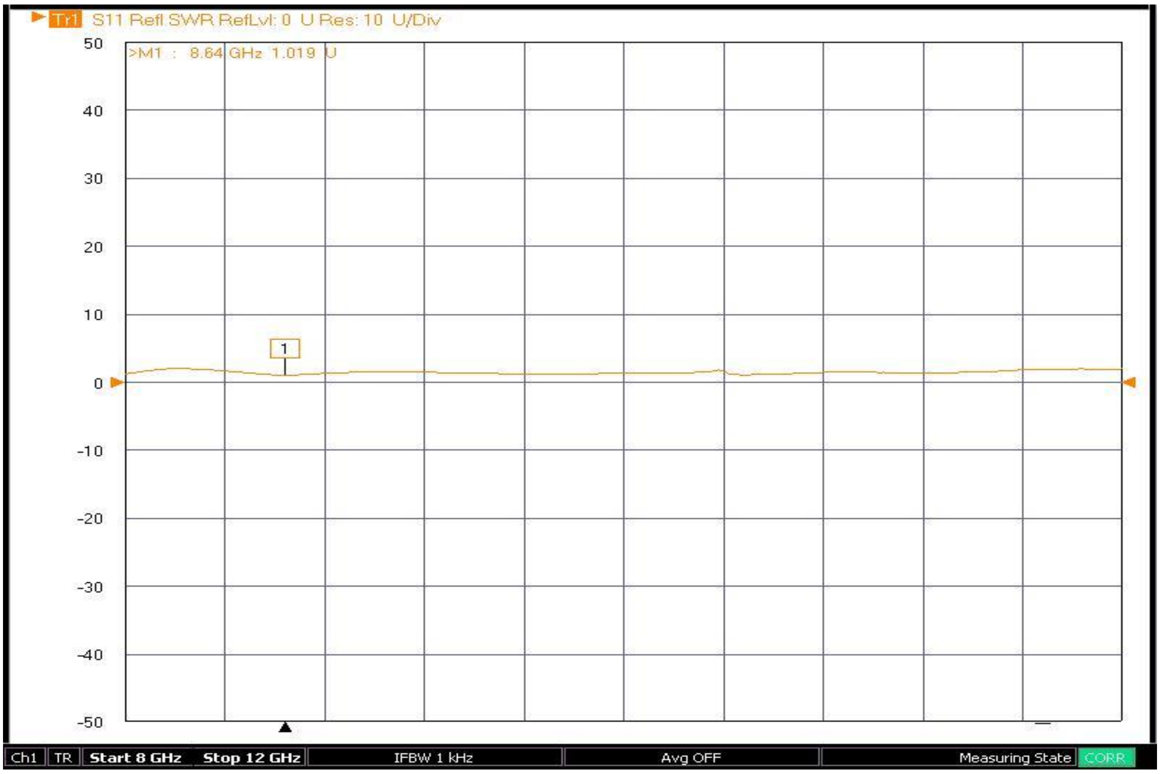


Fig. 8 Voltage Standing Wave Ratio (VSWR) result

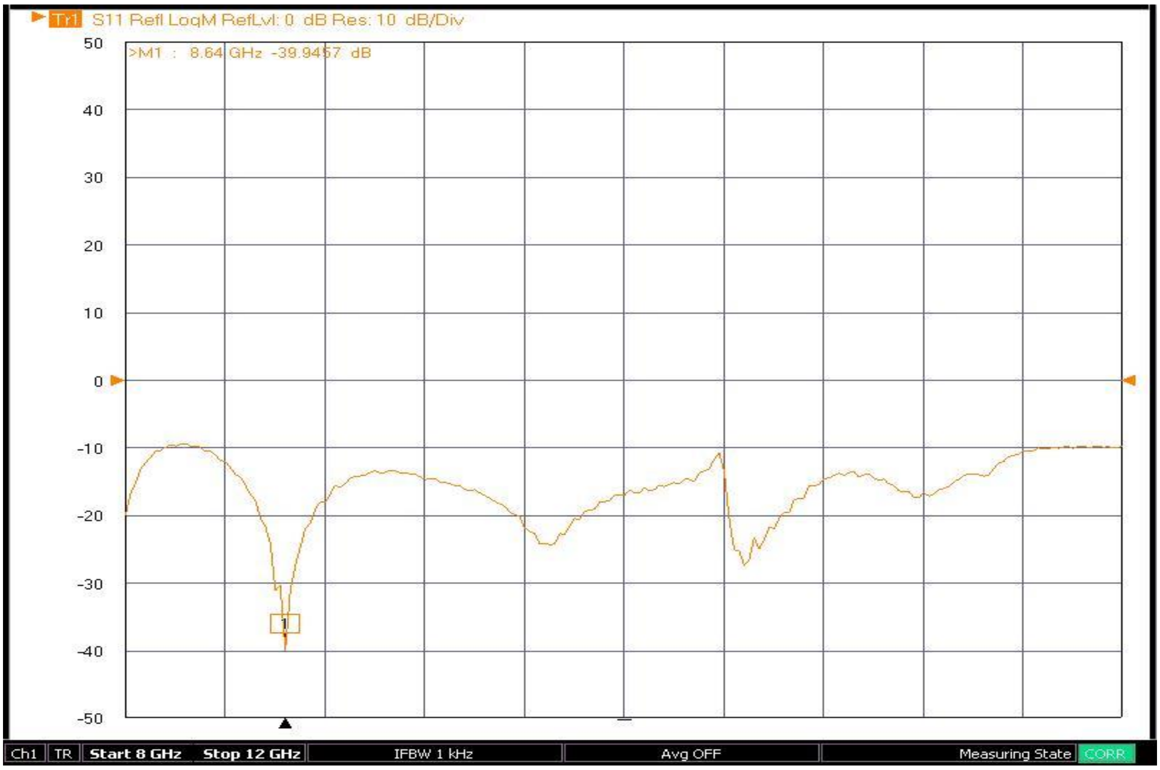


Fig. 9 Return losses results

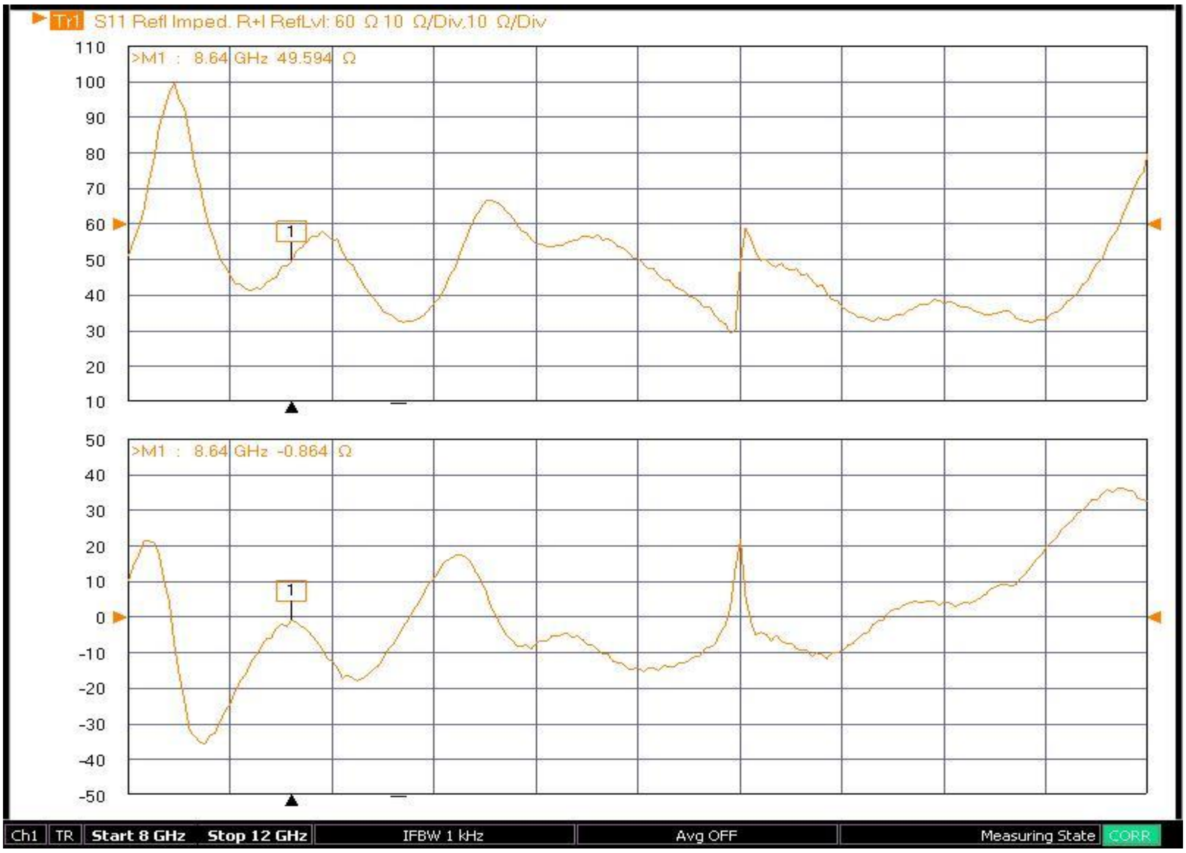


Fig. 10 Reflection impedance results

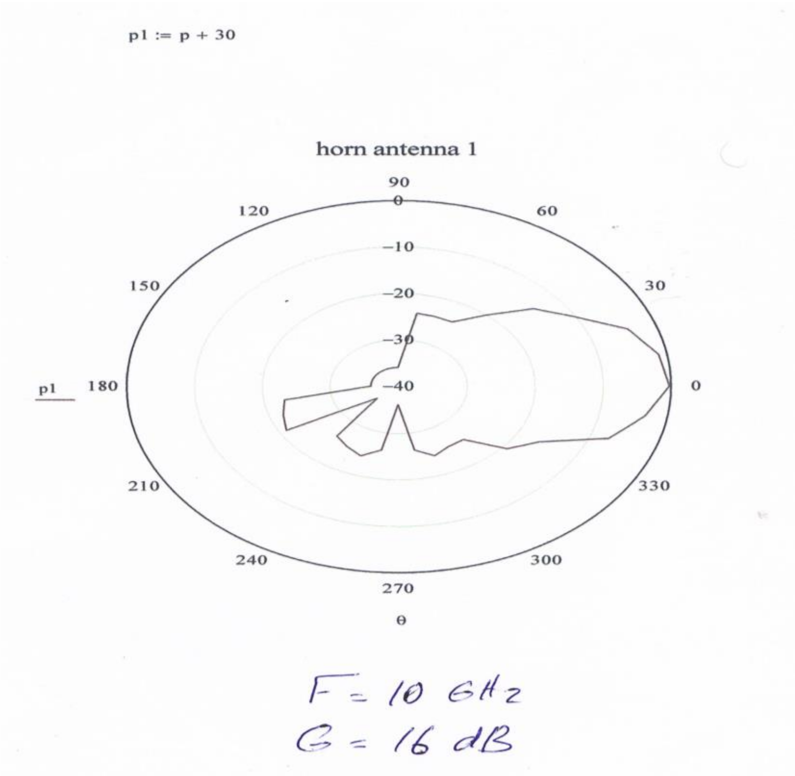


Fig. 11 Radiation pattern of the pyramidal horn antenna, indicating the values of gain, side lobes level, and Half power beam width.

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