OPTIMIZED HORN DESIGN FOR RADIOMETER APPLICATION

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Abstract

A rectangular horn antenna is designed by March Microwave System B.V. and analyzed for its radiation pattern. The antenna is part of a radiometer which is used to measure the temperature inside baked food samples when they leave the oven. The horn antenna frequency was selected at 3.2 GHz, as a compromise between the shortest wavelength possible for optimal distance resolution and on the other hand the need for a long wave to achieve the desired depth of measurement. Calculations by CST Microwave Studio are done to simulate performance and to complete the analysis these are validated against the experimental results. The rectangular horn antenna is measured inside an anechoic chamber.

Key: horn, radiometer, CST, anechoic chamber.

Abstrak

Antena Horn Persegi Panjang dirancang oleh March Microwave System B.V. dan dianalisa untuk pola radiasi. Antena merupakan bagian dari radiometer yang digunakan untuk mengukur suhu di dalam sampel makanan panggang ketika mereka melewati oven. Frekuensi antenna horn yang digunakan 3,2 GHz sebagai kompromi antara panjang gelombang sesingkat mungkin untuk resolusi jarak optimal dan disisi lain panjang gelombang dibutuhkan untuk mencapai kedalaman yang diinginkan dalam pengukuran. Perhitungan diselesaikan oleh CST Microwave Studio untuk mensimulasi kinerja dan untuk melengkapi analisis tersebut divalidasi terhadap hasil percobaan. Antena Horn Persegi Panjang diukur dalam ruang anechoic.

Kunci : horn, radiometer, CST, anechoic chamber.

1. Introduction

Microwave radiometry is a remote sensing technique for resolving thermal energy in matter by measuring electromagnetic radiation in the microwave spectrum. Originally microwave radiometers have been used for variety of applications within radio astronomy and earth observation by satellite. More modern uses include through-wall sensing, detection of fire, and temperature control in food industry as well as industrial processes. In this case the interest of the research is the antenna part which receives the radiation emission for temperature control in food industry.

The relative distribution of radiated power as function of direction in space is the radiation pattern of the antenna. This radiation or antenna pattern is one of various parameters to describe the performance of an antenna. The radiation of antenna is closely related to the directivity. Directivity defined as the ratio of maximum radiation intensity with that averaged over all direction. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π.

Directivity calculation and analysis of the radiation pattern in the near distance are necessary to perform the horn design for radiometer applications with specific use for temperature control in food industry around a working frequency of 3.2 GHz. In general a horn antenna is used for transmission and reception of microwave signals. The flare portion can be square, rectangular, or conical. Its maximum radiation and response corresponds with the axis of the horn. It has connection with waveguide for guidance of the electromagnetic waves from feed to free space along the horn in a uniform distribution.

Using CST Microwave studio 2008 the existing antenna can be simulated and parameters, such as radiation pattern, calculated. Afterwards, these simulation results can be compared with measurement data. The measurements were done by far-field rotation and near-field scanning measurement methods in an anechoic chamber. The results from simulation and measurements were analyzed to decide the best configuration for the radiometer application.

COMPANY PROFILE

MARCH MICROWAVE SYSTEMS B.V. is an international manufacturer and developer of microwave products. Specialization of the company is the indoor measurement and evaluation of microwave antennas and radar cross section. The company concentrates on research and development as well as software and hardware production. Its hardware products mainly consist of indoor measurement facilities such as Compact Antenna Test Ranges (CATR) and Single Plane Collimating Ranges (SPCR). Accessory equipment for these indoor measurement facilities such as microwave antennas and horns are also produced. Furthermore, the company develops fully automated data-acquisition systems for indoor antenna and radar cross section measurements which include sophisticated software packages. These products have applications for customers in the industrial, laboratory and government markets.
MARCH MICROWAVE SYSTEMS B.V. was founded on 5 May 1984. The company is originally a research and consultancy firm. Since 1985 it started to produce hardware and develop software packages for creation of fully automated indoor test facilities for antenna and radar cross section measurements. At present, the company's main business is the design and delivery of turn-key facilities.

The company is located in Nuenen, the Netherlands where it has its main office, research and manufacturing facilities. The research facilities consist of an anechoic chamber with CATR and SPCR reflectors supported by automated data acquisition systems and software packages to process and analyze the measurement results. MARCH MICROWAVE SYSTEMS B.V. has a broad experience in the design and installation of advanced turn-key facilities for antenna tests and RCS measurements. The most important products and services are:

1. Anechoic chamber design
2. Compact Antenna Test Range
3. Single Plane Collimating Test Range
4. RF instrumentation
5. Positioning Equipment
6. Software for antenna and RCS measurements
7. System Integration and evaluation

3. The Assignment

Characterization and analysis of an aperture horn antenna at a frequency of 3.2 GHz. Optimization of the directivity and radiation pattern as well as the illumination in the near field region to maximize the performance for a close range radiometer application.

3.1 Initial Condition

A microwave radiometer is a passive remote sensing instrument, which is used to measure thermal electromagnetic emission from material. It has been widely used in atmosphere measurements, ocean observation, biomedical, and other domains. This b research is focused around the part that collects the radiometry signal: a horn antenna and its design. In this case the horn antenna and radiometer are used in the field of food production. The motivation is to design the ideal horn antenna with homogenous radiation over the measuring surface to obtain accurate temperature measurement data with minimal disturbance from the environment.

3.2 Objectives

The objectives of the work described here is to analyze, improve and evaluate the technology used by March Microwave B.V for designing a horn antenna for radiometer applications. Of specific interest is an antenna used to measure the temperature inside baked food samples when they leave the oven. The horn antenna frequency was selected at 3.2 GHz, as a compromise between the shortest wavelength possible for optimal distance resolution and on the other hand the need for a long wave to achieve the desired depth of measurement. Initial tests showed that the used antenna was too sensitive for disturbances from the surrounding, specifically TL lights, and could not be accurately focused. A new antenna is designed and its performance must be measured and simulated to prove that the both the effects from the surrounding are minimized and the sensitivity over the aperture is homogenous.

3.3 Description of Assignment

This paragraph will focus on the problem definition and strategies that were set up for this research project. The assignment of this project is proving that the performance of the designed horn antenna is meets the radiometer application demands. Strategies to accomplish the project goals are:

- **Theoretical study**

The theoretical study will improve the basic knowledge about antenna performance and bring it to the level needed to analyze the project problem. Starting points are the radiation pattern, definition of directivity and its calculation for a rectangular horn antenna. This indicates how much an antenna concentrates energy in one direction in preference to radiation in other directions.

- **Software implementation**

CST Microwave Studio is a tool for computation of electromagnetic designs. As such it can calculate the parameters of interest in antenna design. In this case it is the antenna radiation pattern.

- **Measurement antenna**

This part will describe the radiation pattern as obtained from the measurement as well as the measurement itself. It is divided into two configuration measurements. They are

1. Configuration 1 is the normal design.
2. Configuration 2 is obtained by rotating part of the horn 90 degrees to change its principal polarization.

These measurement results will identify which configuration has an optimum radiation pattern and directivity for the radiometer application.

- **Analysis**

The last part of the assignment is to analyze and compare the simulation and measurements of the two configurations. Finally, the recommendations for improving the horn antenna design will be given.

4. Antenna Radiation Properties

4.1 Radiation Pattern

The radiation pattern or antenna pattern is defined as graphical representation of the radiation properties of the antenna as a function of space coordinates. For a linearly polarized antenna, performance is described in terms of its principal E- and H-plane patterns.

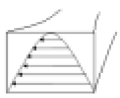

(a) (b)


Figure 4.1 Principal E- and H-plane patterns for rectangular horn.

The part of radiation pattern are referred to as lobes, which is sub classified into main, minor, side, and back lobes. A radiation lobe is a portion of the radiation pattern bounded by regions of relatively weak radiation intensity. A major lobe (main beam) is defined as the radiation lobe containing the direction of maximum radiation. In Fig 4.2 the major lobe is pointing in the *θ = 0* direction. Minor lobes divided into side lobe and back lobe, the radiation lobe in any direction other than intended lobe.

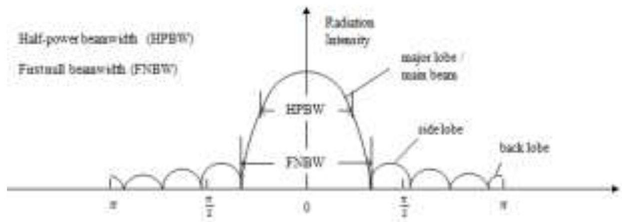


Figure 4.2 Linear plots of power pattern and its associated lobes and beams [1].

4.2 Radiation Intensity

Radiation intensity in a given direction is defined as the power radiated from an antenna per unit solid angle. The radiation intensity is a far-field parameter, and it can be obtained by simply multiplying the radiation density by square of the distance.

$$U = r^2 W_{rad}$$

where

U = radiation intensity (W)

W_{rad} = radiation density (W/m^2)

The radiation intensity is also related to the far-zone electric field of an antenna, referring Figure 4.3, by

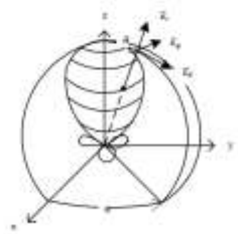


Figure 4.3 Amplitude field pattern

The total power is obtain by integrating the radiation intensity, as given by (4-3), over the entire solid angle of 4π. Thus [1]

$$P_{rad} = \oiint_{\Omega} U \, d\Omega = \int_0^{2\pi} \int_0^{\pi} U \sin\theta \, d\theta \, d\phi \quad (4\text{-}3)$$

Where dΩ = element solid angle = sin *θ dθ dΦ*

For an isotropic source U will be independent of the angles *θ* and *Φ*, as was the case for W_{rad}. Thus (4-4) can be written as

$$P_{rad} = \oiint_{\Omega} U_0 \, d\Omega = U_0 \oiint_{\Omega} d\Omega = 4\pi U_0 \quad (4\text{-}4)$$

The radiation intensity of an isotropic source as

$$U_0 = \frac{P_{rad}}{4\pi} \quad (4\text{-}5)$$

4.3 Directivity

An important description of an antenna is how much it concentrates energy in one direction in preference to radiation in other directions. This characteristic of an antenna is called its directivity, which is measure of the concentration of radiated power in a particular direction. It is defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all direction. The averaged radiation intensity is equal to the total radiated power P_{rad} or P_t divided by 4π. If the direction is not specified, the direction of maximum radiation intensity is implied. In mathematical the directivity (dimensionless) can be written as

$$D = \frac{U}{U_0} = \frac{U(\theta,\phi)}{U(\theta,\phi)_0} = \frac{4\pi U(\theta,\phi)}{P_{rad}} = \frac{4\pi U}{P_{rad}}$$

where
D = directivity (dimensionless)
P_{rad} = total radiated power (W)
U = radiation intensity (W/unit solid angle)

4.3.1 Horn Antenna Geometry

Rectangular waveguide is transmission line which is guiding the electromagnetic wave from source to the horn. The rectangular waveguide has the lateral dimensions a (width) and b (height), see Figure 4.4.

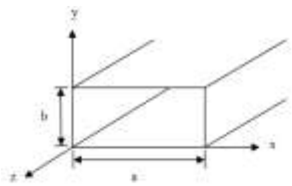


Figure 4.4 Rectangular Waveguide with its dimensions.

Horn antennas are extremely popular antennas in the microwave region above 1 GHz. A horn antenna is used for transmission and reception of microwave signals to produce a uniform phase front larger than that of the wave guide and hence greater directivity. It derives its name from the characteristic flared appearance. The flared portion can be square, rectangular or conical.

4.3.2 Rectangular Horn Directivity

Provided that the aperture in both planes of a rectangular horn exceeds 1 , the pattern in one plane is substantially independent of the aperture on other plane. In general, the H-plane pattern of an H-plane sectoral horn is the same as the H-plane pattern of a pyramidal horn with the same H-plane cross section. Likewise, the E-plane pattern of an E-plane sectoral horn is the same as the E-plane pattern of pyramidal horn with the same E-plane cross section.

Figure 4.6 shows the total flare angle in the E-plane is θ_E and the total flare angle in the H-plane is θ_H. The input waveguide is rectangular. The axial length of the horn from throat to aperture is and the radial length is .

(a) E-plane cross section **(b) H-plane cross section**

Figure 4.6 E-plane and H-plane cross sections [2].

The directivity (or gain, assuming no loss) of a horn antenna can be expressed in terms of its effective aperture. Thus,

$$D = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi \varepsilon_{ap} A_p}{\lambda^2}$$

wher
A_e = effective aperture (m^2)
= physical aperture (m^2)
ε_{ap} = aperture efficiency = $\frac{A_e}{A_p}$
λ = wavelength (m)

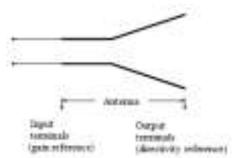
For a rectangular horn $A_p = \alpha_E\, \alpha_H$ and for the conical horn $A_p = \pi r^2$ with
R = aperture radius
α_E = E-plane aperture in
α_H = H-plane aperture in

4.4 Antenna Efficiency

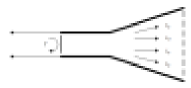
When the antenna has connected with the input power in the terminal input, the power is not all will be radiated by antenna to free space. The losses factor are influence the radiation of antenna.

The total antenna efficiency ε or e_0 *is used to take into account losses at the input terminals*, losses within the structure of the antenna and those coming from polarization mismatch. Polarization efficiency is normally defined separately. Referring to Figure 4.7,

1. Reflection because of the mismatch between the transmission line and the antenna.
2. Losses (conduction and dielectric).



(a) Antenna reference terminal



(b) Reflection, conduction, and dielectric losses

Figure 4.7 Reference terminals and losses of an antenna [4].

The overall efficiency can be written as,

$$e_0 = e_r e_c e_d$$

e_0 = total efficiency (dimensionless)
e_r = reflection (mismatch) efficiency = (1- $|\Gamma|^2$) (dimensionless)
e_c = conduction efficiency (dimensionless)
e_d = dielectric efficiency (dimensionless)
Γ = voltage reflection coefficient at the input terminals of the antenna
[Γ = ($Z_{in} - Z_0$) / ($Z_{in} + Z_0$) where Z_{in} = antenna input impedance,
Z_0 = characteristic impedance of the transmission line]
VSWR = voltage standing wave ratio

Usually e_c and e_d are very difficult to compute, but they can be determined experimentally. Even by measurement they cannot be separated, and it is usually more convenient to write as,

$$e_0 = e_r e_{cd} = e_{cd}(1 - |\Gamma|^2)$$

where $e_{cd} = e_c\, e_d$ = antenna *radiation efficiency*, which is used to relate the gain and directivity.

5. Measurement Methods

The understanding of physical phenomena involves a balance of theory and experiment. Experimental measurements determine the actual performance of a horn antenna. In this chapter methods and techniques are discussed for measurements of antenna radiation patterns. Both near-field $(R \geq 0.62\sqrt{D^3/\lambda})$

and far-field $(R > 2D^2/\lambda)$
measurement methods are used to completely characterize both configuration of the antenna.

5.1 Far-field

An accurate far-field measurement of an antenna has as first requirement that is made at a sufficient large distance so that the field illuminating the antenna under test closely approximates a uniform plane wave.

The far-field *(Fraunhofer)* [1] region is defined as “that region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. If the antenna has largest dimension , the far-field region is commonly taken to exist at distances greater than $2D^2/\lambda$ from the antenna”.

Suppose the physical size of the target is D. At an infinite distance, the electromagnetic field will arrive in the same phase at the target. But at the finite distance R, the edge of the field must travel a distance R + α, and by using Pythagoras theorem ba: this formula the phase different is 0 when R is in $R \approx \frac{D^2}{8\delta}$ Afterwards the recommendation.

$\delta \leq \lambda/16$ the value of δ which still can be tolerated. In this condition, the maximum phase error of the incident field from an ideal plane wave is about 22.5°.

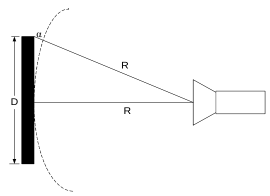


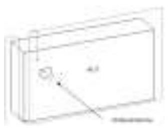
Figure 5.5 Phase error at antenna edge.

5.2 Near-field

Near field is divided into two sub regions. The reactive near-field region is closest to the antenna and dominates over the radioactive fields, this region extend at the distance 0 to $0.62\sqrt{D^3/\lambda}$ The radiating near-field (*Fresnel*) region is defined as “that region of the field of an antenna between the reactive near-field region and the far-field region” or *when the distance R is* or ± 1.13 m. Near-field measurement data, usually amplitude and phase to obtain the ability to transform it to the far-field is obtained by scanning the field close to the AUT on a known surface with a known probe antenna. The probe is placed in the radiating near-field at least a few wavelengths from the AUT.

The basic system coordinates are planar, cylindrical, and spherical (Figure 5.6). For the planar system the AUT is fixed and the probe moves. The cylindrical system, the AUT rotates and the prove moves on a linear track. The calculation to get to the far-field is more complicated than for a planar system. For a spherical system where the AUT rotates and the probe is fixed, the calculations are quite complex.

Acquisition of planar near field data is usually conducted over a rectangular x-y plane.



(a) Planar scanning geometry.

(b) Cylindrical scanning geometry.

(c) Spherical scanning geometry.

Figure 5.6 Near-field scanning geometries for close-up measurements of an aperture antenna.

The samples are weighted equally by the receiver, providing uniform amplitude and phase across the test antenna as required measurements. Radiation properties such as the pattern are then computed using Fourier transform methods [7].

The complexity of the analytical transformation is increasing from the planar to the cylindrical and from the cylindrical to spherical surfaces.

Together the three near-field scanning surfaces are permitting convenient data acquisition for all antenna sizes.

6. Measurement System

The near-field method is chosen to describe the performance of horn antenna using for radiometer application. The measurements were taken in near-field region in an anechoic chamber at a distance 0 to

$0.62\sqrt{D^3/\lambda}$

6.1 Antenna Configuration

The two configurations of the antenna measured in the anechoic chamber are:

- First configuration of the rectangular horn

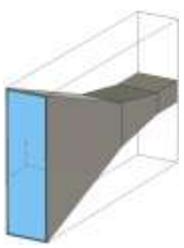


Figure 6.1 Horn configuration 1

- Second configuration is with the polarization of the launcher 90 degrees rotated.

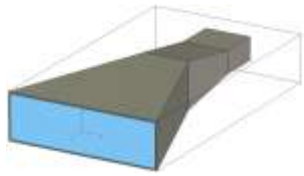


Figure 6.2 Horn configuration 2

The dimensions of the rectangular horn are given in Figure 6.3.

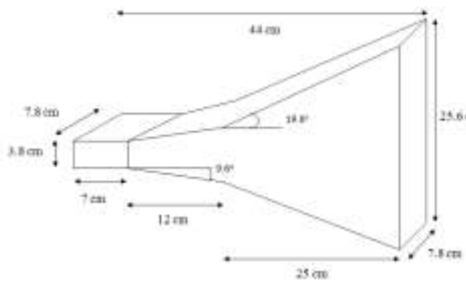


Figure 6.3 Horn dimension in configuration 1

6.2 Computational System

Accurate data from calculation is important for presentation and comparison with measurement results. Several software packages were used to calculate some parameters and for the antenna measurement data acquisition and presentation.

6.1.1 ARCS

ARCS (Antenna and Radar Cross Section) Software is designed by March Microwave B.V System company, the software allows the operator to define a set of test parameters for the antenna, after which all remaining parameters required for the test are automatically configured. The ARCS software consist of ARCS acquisition, ARCS analysis, and graphics software program menu-5D.

The measurement system is a menu controlled program package to acquire process and display data for all common antenna and RCS measurements.

6.1.2 CST

Rectangular horn design and performance simulation uses the program Computer Simulation Technology (CST) Microwave Studio 2008. This process includes the dimensions and shape of the horn antenna and calculation of its radiation pattern, directivity, etc.

CST software is one of the computational tools in electromagnetic designs especially for accurate simulation of high frequency problems. CST MWS has three solver types available concerning high frequency electromagnetic field problems, they are: transient solver, frequency domain and eigenmode solver. The transient solver is used for simulation of the horn antenna because allows the simulation behavior in a wide frequency range in single computation run for large dimensions. Both horn antenna configurations will be simulated with CST and results compared with measurement results. Afterwards an informed decision can be made over which of the two configurations is better.

6.3 RF Subsystem

The RF subsystem used planar scanning methods is shown in Figure 6.4 Schematic of near-field measurement system. The vector analyzer is ZVA 24 model, offer coupled generators and multichannel receivers, integrated mixer control, synchronized sweep functions and much more. They are available in the 0.01 GHz to 8 GHz, 24 GHz, 40 GHz and 50 GHz frequency ranges.

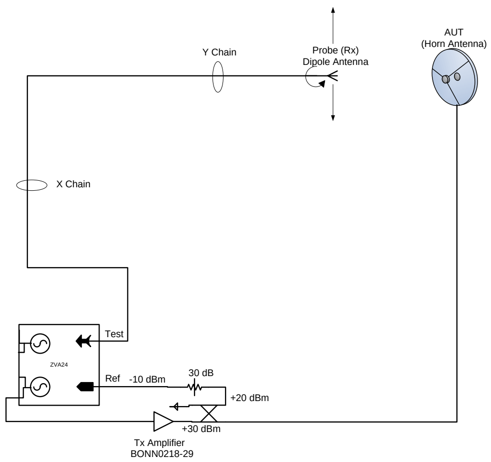


Figure 6.4 Schematic of near-field measurement system.

6.4 Polarization

An important feature of an electromagnetic wave is polarization. The polarization of an antenna is the polarization of the wave radiated in a given direction by the antenna when transmitting. It describes the instantaneous E-field at a fixed observation point when it leaves the antenna. The polarization in microwave communications is divided into horizontal polarization, vertical polarization, and circular polarization. In horizontal polarization the E-field moves in horizontal direction and similar for vertical polarization.

In the radiometer application the antenna receives in co-polarization. Co-polarization is achieved when the electric field is received 0^o (0 degrees) different from the transmit feed. Measurement systems write this as symbol VV (vertical to vertical) and HH (horizontal to horizontal). If the antenna receives in cross polarization, this is when the electric field is received 90^o (90 degrees) different from the transmit feed, is written as VH (vertical to horizontal) and HV (vertical to horizontal).

7. Result And Analysis

To prove that the optimized horn design has homogenous radiation pattern over the aperture results will be presented in this chapter. These results give comparisons from measurement and simulation between two configurations of the designed horn and considered radiation pattern.

Configuration Antenna in Radiometer Application

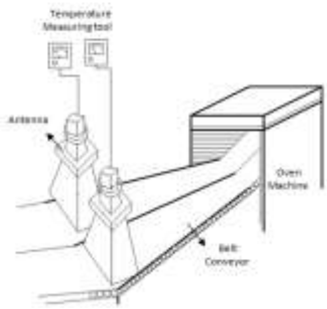


Figure 7.1 Antenna in radiometer measurement system.

Two antennas with complete temperature measurement equipments are placed above the belt at certain distance. The belt carries baked food straight out of the oven, passed the antenna. Function of this antenna is to receive radiation emissions from the baked objects for measuring the temperature. Then from the measured temperature inside the object, data will be saved and used as parameter to know and decide that all bacteria died and it is decent for food consumption. As next step the production process can be optimized. Before an antenna can be used in this application, its performance should be known and proved. Parameters like radiation pattern, directivity, and radiation intensity will be used to prove the performance which is calculated and measured in two regions: close to the antenna and far away.

7.1 Far-field Comparison Result

The analysis is validated by calculating E- and H-plane radiation pattern of a rectangular horn carrying TE_{10}-mode in free-space at 3.2 GHz using CST analysis and comparing it with experimental results.

▪ **Configuration 1**

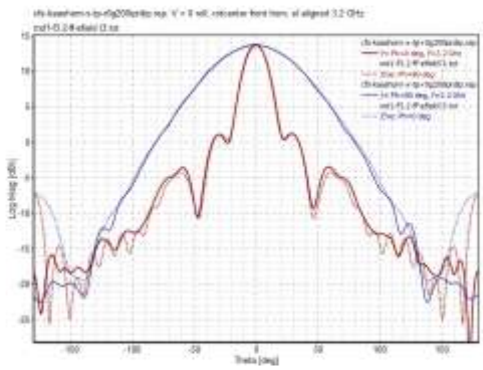


Figure 7.2 Cartesian plot E-and H-plane radiation pattern configuration 1 frequency 3.2 GHz.

The plots of the E-and H- field radiation pattern in the first configuration as seen from Figure 7.2 at frequency 3.2 GHz. In all cases the material was Aluminum, both in measurements and calculations. Results of calculations at 3.2 GHz are a gain value of 13.64 dBi and total efficiency 0.99.

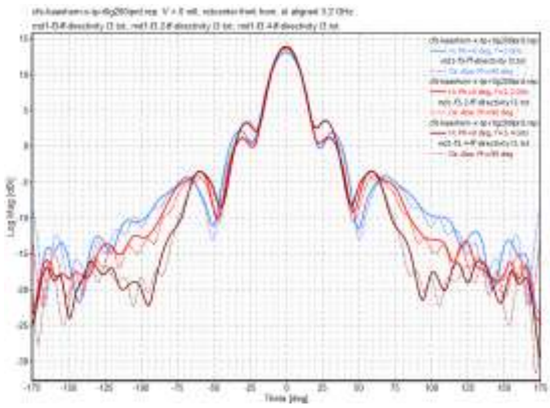


Figure 7.3 Cartesian plot of directivity for configuration 1.

Figure 7.3 shows an overview of the V-polarization patterns at all three frequencies, both for measurements (solid) and calculation (dashed). In table 7.1 the first configuration of the rectangular horn antenna calculation and is compared with measurements for HPBW of E-and H-plane, side lobe level and directivity from the antenna.

Table 7.1 HPBW E-and H-plane and directivity comparison result configuration 1.

Frequency (GHz)	HPBW in E-plane (degree)		HPBW in H-plane (degree)		Directivity (dBi)	
	measurement	calculation	measurement	calculation	measurement	calculation
3.0	20.5	20.3	72.1	69.5	13.2	13.3
3.2	19.4	19.6	67.2	67.8	13.7	13.6
3.4	18.4	18.5	66.1	65.6	13.9	13.9

The SLL of the measured and calculated pattern is shown in table 7.2. The SLL of the E-plane measurement is lower when compared to the SLL of calculation between ± 0.6 dB and the H-plane SLL measurement result is also lower when compared to the calculation with value around ± 3 dB.

Table 7.2 E-and H-plane SLL comparison result configuration 1.

Frequency (GHz)	E-plane SLL (dB)		H-plane SLL (dB)	
	measurement	calculation	measurement	calculation
3	-11.22	-11.86	-22.04	-19.37
3.2	-17.29	-17.82	-23.84	-20.83
3.4	-17.45	-17.95	-25.28	-23.26

7.2 Near-Field Comparison Result

In the application under study, performance of the aperture antenna at close distance is of major interest. To know the radiation pattern over aperture, the comparison exhibited here is limited to the aperture region at several nearby distances. Please refer to Figures 7.6 for configuration 1 at frequency 3.2 GHz and Figure 7.7 for the configuration 2. Each of the four plots compares a planar near field measurement with a calculation at one distance and both principal planes.

▪ **Configuration 1**

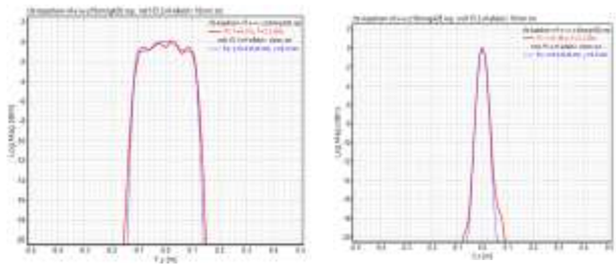


Figure 7.6 Cartesian plot E-and H-plane of near-field radiation pattern configuration 1 frequency 3.2 GHz and distance (a) 10 mm,

The difference between measurement and calculation is ± 0.5 dB. Even though the pattern from measurement has ripple wave which is most likely caused by antenna probe interaction. At larger distance (50 and 100 mm), the measured radiation pattern in E-plane is the same as theory. The size of the horn aperture is 250 mm in length and 72 mm in width. The E-plane of radiation pattern should have a pattern in accordance with the length of the aperture antenna. The result from Figure 7.6 shows the illumination over the aperture with a size of approximately 250 mm.

- **Configuration 2**

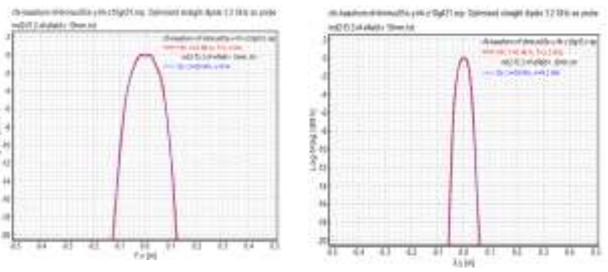


Figure 7.7 Cartesian plot E-and H-plane of near-field radiation pattern configuration 2 frequency 3.2 GHz and distance (a) 10 mm,

The second configuration of the antenna is obtained by rotating the field in the horn 90 degrees. The idea is that this would lead to a more tapered distribution suitable for focusing the radiation on a single object. Therefore the horn antenna has a middle section with square aperture.
The purpose of this section is to make the radiation of the antenna more flexible and configurable before all practicalities of the complete system of the complete system are known. Results for this configuration are less uniform over the aperture antenna but the beam is more concentrated, because the E-plane has a smaller aperture than in the first configuration on the other hand H-plane does not have different distributions for both configurations

8. Conclusions

From the simulations and the measurements of the antenna radiation pattern, both in far-field and near-field region for specified frequency of 3,2 GHz, the following conclusion can be drawn:

1. In the far-field and for configuration 1 the antenna has directivity of 13.70 dBi with gain 13.66 dBi and an efficiency of 0.99. The configuration 2 has 12.83 dBi for directivity, 12.77 dBi gain and an efficiency of 0.99. This high efficiency means that the antenna is made of good conducting material and has low polarization losses.
2. Configuration 1 is suitable for specific function in the radiometer application for its field uniformity over the aperture. Near-field analysis is used to determine the radiation pattern close to the aperture. Measurement result is agreed well with the predicted patterns. The E-plane radiation pattern is uniform over the complete horn aperture of 250 mm in length.
3. Configuration 2 is matched when applied in far-field region base on side lobe level of -32.62 dBi while for configuration 1 this is -17.82 dBi. In other hand, when it is related with near field the result leads to more tapered distribution suitable for focusing the radiation on a single object.
4. Some factor contributed make some different result with calculation is coming from
   - Reflection signal in surrounding equipment by object inside anechoic chamber.
   - Measurement setting equipment, shadowing from positioned antenna and bend scanning probe.
5. Taken into consideration the results in far-field and near-field it can be said that first configuration best satisfies the application demands. This because it has uniform radiation over the aperture and thus all objects contribute to the aperture measurement.

Recommendations

After all of the measurements and conclusion, some recommendations can be given for further research in the future:

1. Optimizations for the horn antenna design to achieve spot temperature measurements lay into increasing its aperture dimension.
2. Alternatively one can also create a linear antenna array where the main beam of radiation can be steered with polarization phase.
3. The higher side lobe in configuration 1 can be reduced by using absorber nearby the antenna.

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