

CHOKED-GAUSSIAN CORRUGATED HORN ANTENNA DESIGN SMALL GLOBAL COVERAGE HORN ANTENNA FOR TT&C WITH EXTREMELY LOW SIDELOBE LEVEL

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Abstract

Extremely low sidelobe horn antennas are often required for the actual technology. This type of horn antennas are important to avoid interference with other systems.

In this paper we describe a new design implementing a radical change in the current technology. It consists in attaching together a choked-waveguide antenna with a classical pure gaussian output corrugated horn. A really impressive radiation pattern with very low sidelobes and crosspolar levels in a very short antenna is obtained.

This antenna shape was firstly presented in [1]. In this paper an improvement in size, weight, bandwidth and crosspolar level of the design is shown. This improvement has been possible due to the optimisation of the profile by means of the use of a mode matching code (μ wave Wizard) instead of a time consuming finite element code.

Introduction

Corrugated Gaussian Profiled Horn Antennas (GPHA's) are one of the best output profiles any corrugated horn antenna can use. However, to make use of these type of profiles, we must feed them at an appropriate input diameter that will define the copolar pattern decay (directivity of the antenna) with a quite pure HE_{11} hybrid mode [3,4,5,6]. To obtain such an hybrid mode at the input diameter of a corrugated GPHA we can make use of a normal corrugated profile but this solution is quite long; we can use another shorter profiled possibilities [4,6]; but usually the best obtainable corrugated input profile that generates a quite pure HE_{11} mode is an empirical profile that we can obtain by means of optimisation codes [1,7].

During the development of the empirical profiles to be connected to a corrugated GPHA output we discovered that any other horn that obtains an HE_{11} mode at its output has the possibility to be connected to a corrugated GPHA output profile. In this category some horn antenna examples that can fit are Potter type horns [8], and choked waveguide horns [9].

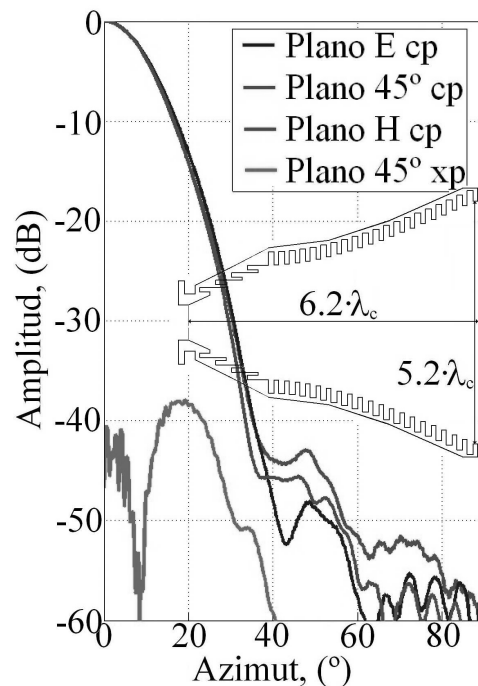


Fig. 1. Measured radiation pattern at f_c of the first choked-gaussian TT&C horn antenna

The Potter type horns have a narrow bandwidth although they can be very short, their mass is small because they are made by means of smooth waveguide and are simple to manufacture; so they sometimes offer a good possibility. The choked waveguide horns have wider bandwidths in a very short length and they are also quite simple to manufacture; so these were a nice candidate to employ the connection.

We can say that at present probably the choked-gaussian horns are for many applications the best and most compact profiles available. The research has just been initiated [1] and some radiation parameters such as crosspolar levels and bandwidth have been improved from the first solution given in [1]. This paper is going to show the advances in these type of profiles although the research to better improve bandwidth is being made at present.

State of the art Global Earth Coverage Horn Antennas

Global earth coverage horn antennas mean an approximate gain around 20.8 dBi or an edge taper at -3 dB of 8.7 degrees, the angle subtended by the earth from a geostationary satellite. Some very nice examples of global earth coverage horn antennas can be found on [1,10,11,12].

On the sidelobe level and the spillover radiation

The discussion initiated in [1] stated that the choked-gaussian horn had a radiation pattern with a sidelobe level measured at the central frequency of -43 dB, see figure 1. In fact, as a corrugated GPHA, the choked-gaussian horn antenna presents a radiation pattern decay that is very similar to a fundamental gaussian beam decay. But as Telemetry, Tracking and Control horn antennas (TT&C horn antennas) are designed to present at exactly 8.7 degrees a -3 dB radiation pattern decay it is much better to define the radiation pattern of each TT&C horn antenna by means of the illumination and spillover efficiencies. These efficiencies can be calculated by means of the integral equations given in [9]. The illumination efficiency integral equation will give us the needed information about how well illuminated the earth will be by such a radiation pattern. The spillover efficiency integral equation will give us the necessary information about the energy radiated towards unwanted direction (radiation outside the 8.7 degrees angle subtended by the earth in this case).

The results of illumination and spillover efficiencies for the first choked-gaussian horn antenna of [1] can be found in table 1. Simulation and measurement results have been included because the measurement was made at discrete frequencies and the exact radiation pattern decay at -3 dB exactly passing at 8.7 degrees was not measured. Also a comparison with the pure fundamental gaussian beam is given in table 1 as well as the total efficiency of the antenna result of the product of illumination and spillover efficiencies.

Note that for the simulation of the first design of a choked-gaussian horn in [1], Ansoft-HFSS finite element code was used. Once we have upgraded to mode matching codes (μ Wave Wizard software) to simulate the antennas, better and quicker results can be obtained; that's the reason why we have made an actualization of the bandwidth for the first design of a choked-gaussian horn and its maximum crosspolar level at f_c with respect to [1].

On the manufacture precision

To calculate the manufacture precision of a corrugated horn antenna is quite simple. It consists in including a random number generator to add to the whole theoretical profile values up to a certain ceiling number affecting then to the length and radius values at each part of the horn. Several simulations of this randomized profiles with different ceilings in the random deviation give values on manufacture precision quickly and efficiently.

The measured radiation pattern for the choked-gaussian horn presented in figure 1 validates the manufacture precision calculation. In fact, the manufacture precision for such a horn antenna ($\pm 0.0017 \cdot \lambda_c$) was made coincident with the ceiling of the random number generator. Copolar patterns remained nearly unchanged between simulation and measurement however crosspolar pattern raised several dB's between simulation and measurement, probably another manufacture errors related to concentric corrugations manufacture are the reason for this deviation. An error in manufacture precision was accidentally included in [1] where it was claimed to be double of the value aforementioned.

Another advantage of the choked-gaussian horns manufacture is that they avoid the complicated throat region of the rest of corrugated horns. This region is common to the rest of corrugated horn antennas where many times the $\lambda/2$ corrugation depths at this part to match the mode traveling in the smooth waveguide to the corrugated waveguide presents manufacture problems to be machined by conventional milling techniques.

New choked-gaussian horn design for global earth coverage

An effort has been made since the discover of the nice properties of choked-gaussian horns reflected in [1] towards improving size, crosspolar levels and bandwidth. Size can be slightly improved but the weight of the antenna has been greatly improved with the simplicity of reducing the width of the corrugations in the new profiles. This makes this antenna more suitable for space applications. Crosspolar levels have been improved reaching in simulation values below -60 dB easily. Return loss of the choked-gaussian horns is not a problem, in fact it is easy to keep it within 30%

bandwidth with values below -30 dB. But, in spite of improving the crosspolar level of the choked-gaussian horns we can say that its radiation properties (regarding both copolar and crosspolar pattern) degradate themselves quicker than in a normal corrugated horn antenna, and the maximum achievable bandwidth at present is never above 20%. This new choked-gaussian horn antenna profile can be found in figure 2. To make a mass comparison with the first choked-gaussian horn of [1], the mass of both horns has been calculated by means of an exterior wall thickness of $\lambda_c/20$ and aluminum as manufacture material, (the aluminum used has a density of 2.702 gr/cm^3). This wall thickness can also be seen depicted in figure 2.

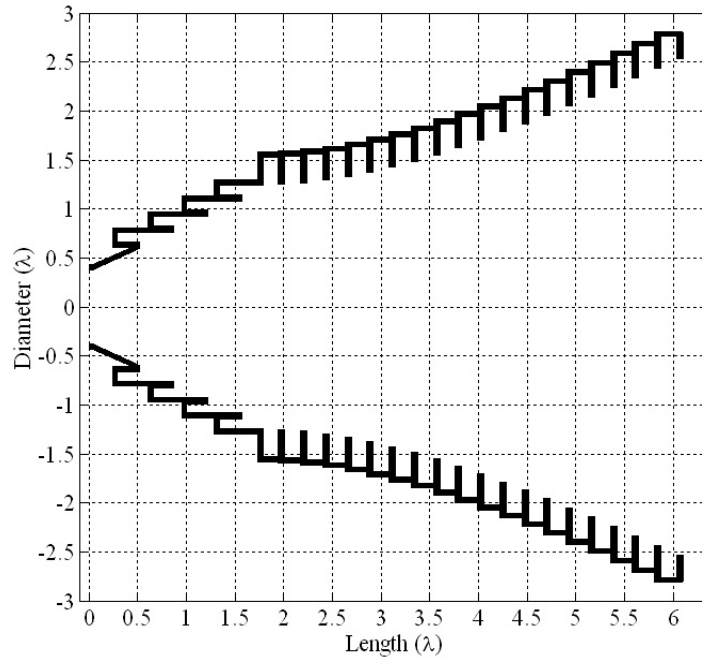


Fig. 2. New profile for the TT&C choked gaussian horn with a $\lambda_c/20$ wall thickness.

The new profile for the choked-gaussian horn presents a length of $6.1 \cdot \lambda_c$ and a diameter of $5.07 \cdot \lambda_c$. An effective reduction of one corrugation period, a better spillover efficiency and a wider bandwidth response with respect to the first choked-gaussian horn of [1] has been obtained, see figures 3 and 4.

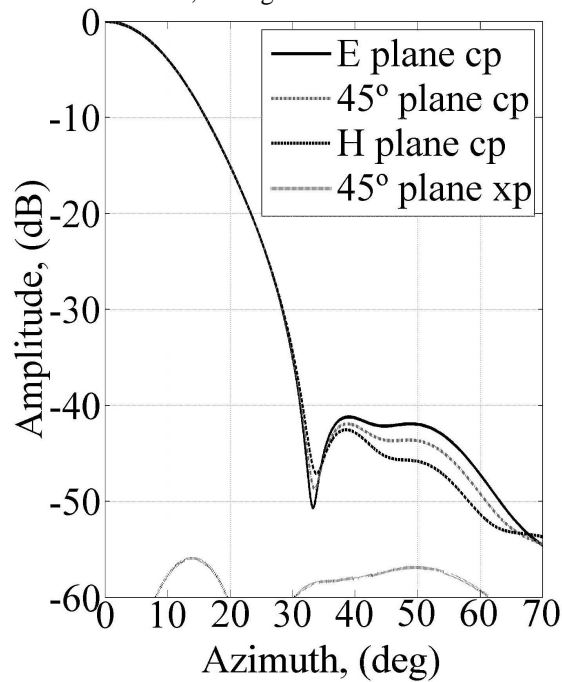


Fig. 3. Simulated far field radiation pattern of the new profile choked-gaussian horn

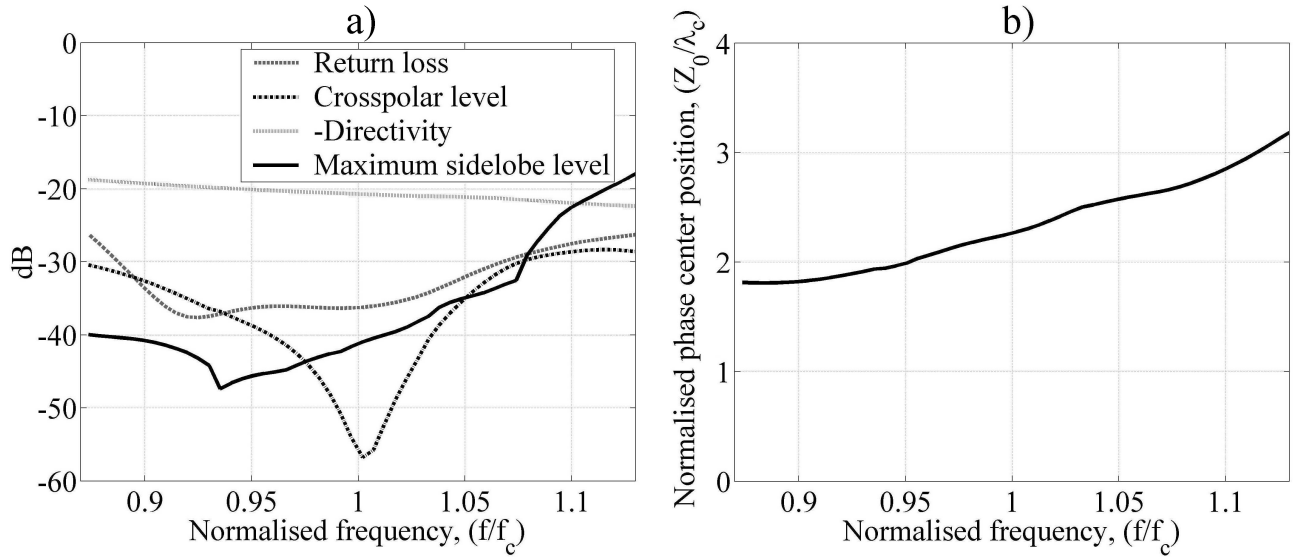


Fig. 4. Simulated radiation pattern characteristics of the new choked gaussian horn antenna design along the band
a) Return loss, crosspolar level, sidelobe level and directivity against normalised frequency
b) Normalised phase centre position with respect to the antenna aperture

This antenna presents approximately a simulated bandwidth of 18 % for -30 dB sidelobe level, crosspolar level and return loss and a simulated 7 % bandwidth for -30 dB return loss, -40 dB crosspolar level and -36 dB sidelobe level. Also the spillover efficiency, the mass and the size have been improved compared to the previous [1] choked-gaussian horn, in fact, this new design presents thinner corrugation tooth width ($2/7$ of the period of corrugation) and 1 corrugation period less than the first choked-gaussian horn in [1]. This parameters and others can be checked in table 1.

Table 1. Comparison of simulated performance of the new choked-gaussian global earth coverage horn

Horn	1 st design choked-gaussian (measurement at $0.99 \cdot f_c$)	1 st design choked-gaussian (simulation at f_c)	Current design choked-gaussian (simulation at f_c)	Pure fundamental gaussian beam
Gain (dBi)	20.5 dBi	20.67 dBi	20.72 dBi	20.81 dBi
Horn weight	-----	$29.86 \cdot \lambda_c^*$	$21.91 \cdot \lambda_c^*$	Not applicable
Sidelobe level (f_c)	-43 dB	-43 dB	-41 dB	No sidelobe
X-polar level (f_c)	-38 dB	-45 dB	-56 dB	No crosspol.
Illumination efficiency, η_i	0.990	0.990	0.990	0.990
Spillover efficiency, η_s	0.472	0.484	0.490	0.500
Total efficiency, $\eta_i \cdot \eta_s$	0.467	0.479	0.485	0.495
Length (λ_c)	$6.2 \cdot \lambda_c$	$6.2 \cdot \lambda_c$	$6.1 \cdot \lambda_c$	Not applicable
Diameter (λ_c)	$5.2 \cdot \lambda_c$	$5.2 \cdot \lambda_c$	$5.07 \cdot \lambda_c$	Not applicable
Return loss at f_c	-42 dB	-36.6 dB	-36.3 dB	Not applicable
Bandwidth (%)	16%	13 %	18 %	Not applicable

*Notice for the mass comparison: if λ_c is expressed in meters, the mass will be given in kilograms and if λ_c is expressed in millimeters, the mass will be given in grams.

Conclusions

Choked-gaussian horns are a good solution now-a-days for around 15-20% bandwidth requirements, being probably at present the most compact and light profile a corrugated horn designer can use for such bandwidth.

Manufacture of choked-gaussian horns is easier due to the lack of the $\lambda/2$ to $\lambda/4$ impedance adapter at the throat. Needed tolerance values are among the standard for normal corrugated horn antennas.

Bandwidth requirement of choked-gaussian horns is still restricted to 15-20% due to the choked waveguide input part, a deep research is being carried out at present to improve this parameter.

Return loss bandwidth of choked-gaussian horns is really good keeping values below -30 dB within a 30% bandwidth.

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