

Conical versus gaussian profiled corrugated horn antennas

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Abstract: In this paper, a study of two equal size corrugated horn antennas; a conical and a gaussian profiled horn antenna (GPHA) has been developed.

It will be demonstrated that GPHA's provide lower sidelobes and wider bandwidths, while conical corrugated horn antennas offer higher directivities for the same aperture. Both type of antennas provide low crosspolar levels.

Introduction

According to reference [1], corrugated horn antennas are supposed to provide a nearly perfect HE_{11} hybrid mode at its aperture while the contribution of any other hybrid modes as HE_{1n} and EH_{1n} (with $n \geq 2$) should be reduced in order to obtain a low sidelobes and crosspolar levels.

It is known that the addition of EH_{1n} modes increases the crosspolar level of a corrugated horn antenna. Nevertheless, this paper shows that the idea of avoiding HE_{1n} modes to reduce sidelobes is not true. In fact, it will be proved that GPHA's provide a HE_{1n} mode mixture at the aperture as function of the relation between aperture radius (R) and beamwaist radius (ω_0) of the fundamental gaussian beam to be generated (fig. 1).

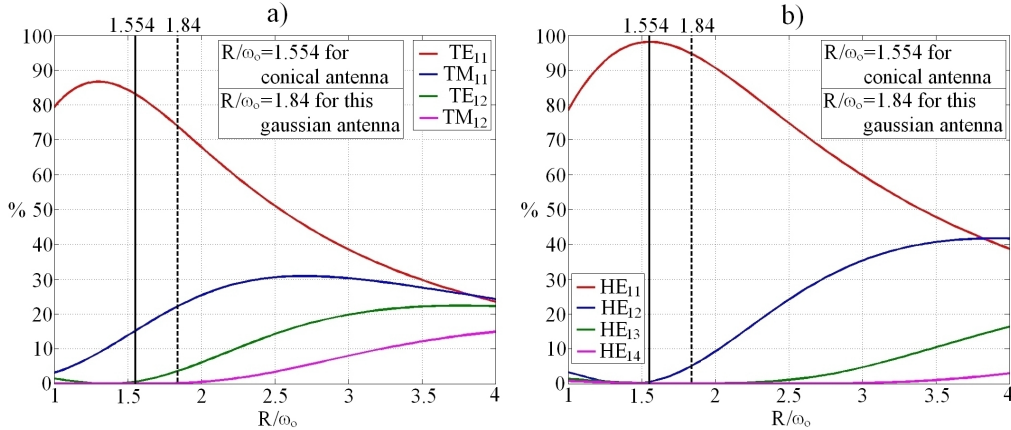


Fig. 1.- a) Fundamental gaussian mode decomposition in terms of TE and TM
 b) Fundamental gaussian mode decomposition in terms of HE and EH

Relation between gaussian modes and waveguide modes

The TE and TM basis define the modes inside of a smooth waveguide. On the other hand, the eigenmodes of a corrugated waveguide can be defined either as a mixture of TE and TM modes or by the HE and EH basis. This means that any HE or EH mode can be expanded as a combination of TE and TM modes (see table 1).

	TE ₁₁ (%)	TM ₁₁ (%)	TE ₁₂ (%)	TM ₁₂ (%)	TE ₁₃ (%)	TM ₁₃ (%)
HE ₁₁	84.496	14.606	0.082	0.613	0.0036	0.121

Table 1. HE₁₁ decomposition in TE_{1n} and TM_{1n} smooth waveguide modes

Using this property, up to now the mode mixture of 85% TE₁₁ and 15% TM₁₁ has been used to provide a HE₁₁ mode (see table 1). Furthermore, corrugated horn antennas have been always designed to provide at its output the aforementioned TE₁₁-TM₁₁ mixture.

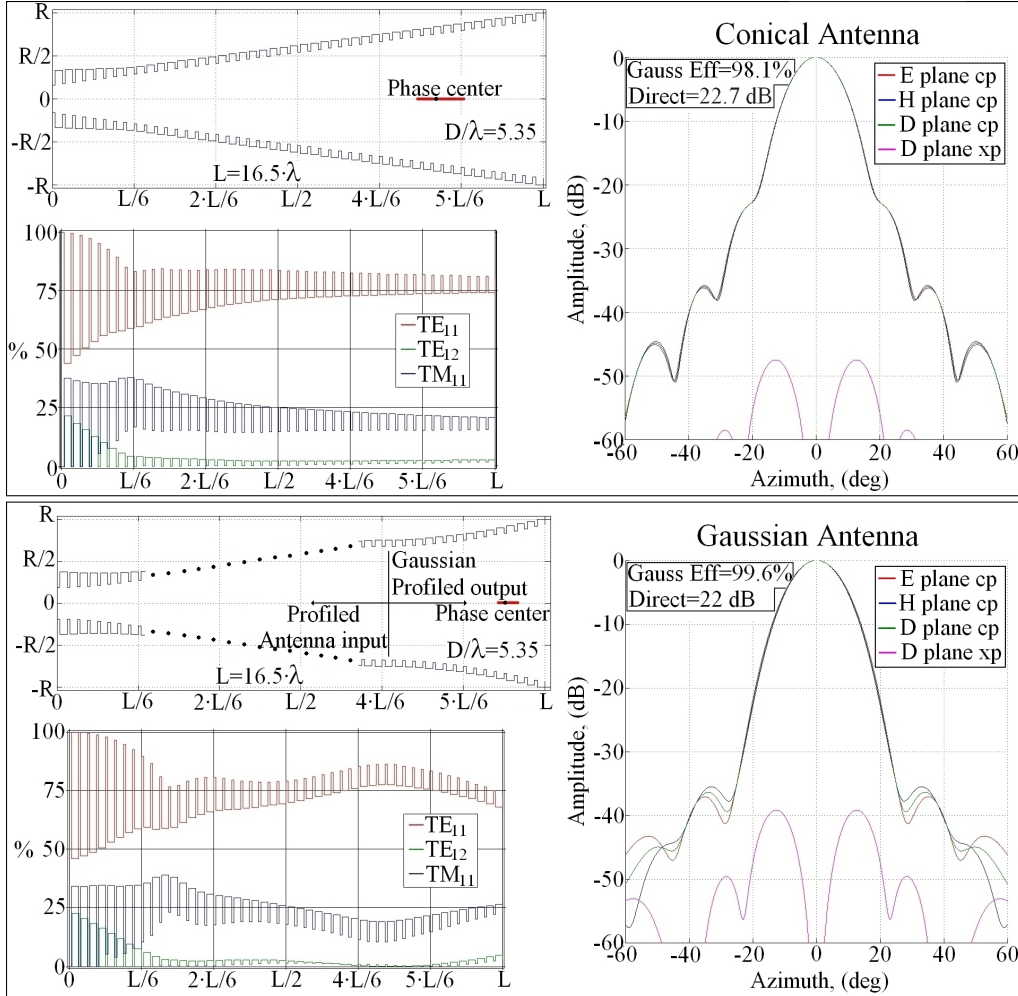


Fig. 2.- a) Conical and b) GPHA horn profiles together with the TE-TM mode evolution inside the antenna and the final radiation patterns at f_0

When we started the development of GPHA's 6 years ago, the main idea was to generate a pure fundamental gaussian beam mode (which is a solution of paraxial free space) instead of an HE₁₁ mode.

At this point, it should be noted that HE₁₁ mode has been always known as a gaussian-like mode because its field is nearly a pure gaussian, in fact it is up to 98.1% efficient with a fundamental gaussian beam of $R/\omega_0=1.554$ ($\omega_0/R=0.6435$) (fig. 1). Nevertheless, there are some important differences between both cases. These aspects will be commented in the following section.

Conical Corrugated Horns versus Gaussian Profiled Corrugated Horns

A conical corrugated horn antenna produces a field at its aperture that is nearly a pure HE_{11} mode with HE_{1n} modes lower than -20 dB with respect to the fundamental mode, (fig. 3b and fig. 1).

Looking at figure 3a, one can see that for a rather good performance antenna, the pure HE_{11} has a restriction: it is impossible to obtain an antenna pattern with sidelobes lower than -30 dB with directivities above 17 dB.

However, GPHA's in a natural way produce a mixture of HE_{1n} modes corresponding with the figure 1b, for a given R and ω_0 . In figure 3b significant reduction of sidelobe level is observed for GPHA's in relation with the equal-size conical counterpart.

It should be noted that both types of antennas present low amplitudes of crosspolarized EH_{1n} modes, but the GPHA is less frequency sensitive.

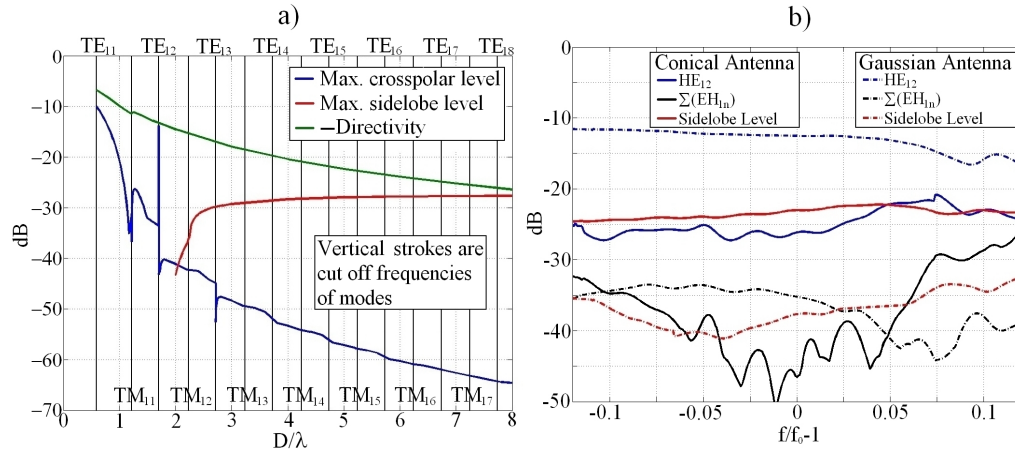


Fig. 3.- a) HE_{11} hybrid mode radiation properties against aperture diameter (D)
 b) Levels of higher order HE_{1n} - EH_{1n} modes at aperture and sidelobe level for the conical and the gaussian antennas against normalized frequency

The sidelobe level reduction for GPHA's can be evaluated looking at the aperture electric field of a conical corrugated antenna and a GPHA, (fig. 4a). The conical antenna provides a nearly perfect HE_{11} mode while the GPHA provides a narrower illumination. As sidelobe level is directly related to the electric field on the aperture edges, the HE_{11} mode will always present a higher sidelobe level.

Furthermore, the fact of increasing the GPHA length will reduce even more the sidelobe level, while in the conical one, the sidelobe level keeps constant, since the aperture field distribution remains the same (fig. 2a) [2].

Another advantage of GPHA's is related to the bandwidth, as it can be seen from the stability of the curves in figure 3b and 4b [3].

However, the horn aperture illumination efficiency is lower in a GPHA than in a conical horn (fig. 4a).

The efficiency to a fundamental gaussian beam larger than 99.1% versus 98.2% over a 25% bandwidth and phase center position with nearly flat position for 15% bandwidth are improvements added by the use of a GPHA (fig. 4b).

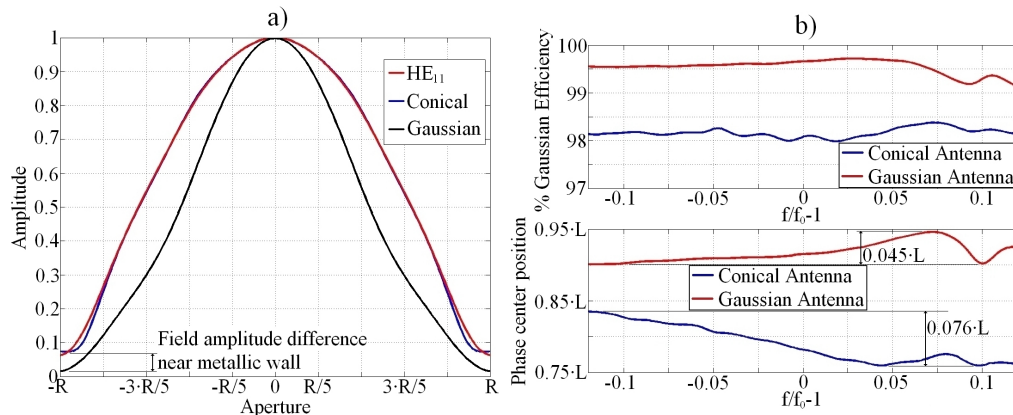


Fig. 4.- a) Aperture field of a conical corrugated horn antenna, a GPHA and a pure HE_{11} mode
 b) Efficiency to fundamental gaussian beam and phase center position for a GPHA and a conical corrugated horn antenna

It should be pointed out that the phase center stability is a great advantage for illumination of reflectors.

In general, for a given requirements, GPHA's offers a shorter solution than conical antennas.

Conclusions

Gaussian profiled corrugated horn antennas offer one of the best solutions for high performance horns where low sidelobes, wide bandwidth, low crosspolar levels, taper and phase center stability are important design parameters.

In spite of conical corrugated horn antennas illuminate more efficiently the antenna aperture than GPHA's, are unable to offer sidelobes lower than -30 dB. This lower aperture illumination efficiency for the GPHA's doesn't lead to longer profiles; on the contrary, very often a shorter profile can be designed due to the better radiation features.

Nearly all of the systems that use a conical corrugated horn profile could be improved by the use of a GPHA.

References

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