Summary of a study on the TM01 radiation pattern of corrugated conical horn antennas with small flare angle

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Summary of a study on the $TM_{01}$ radiation pattern of corrugated conical horn antennas with small flare angle.

by

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Summary of a study on the TM_{01} radiation pattern of corrugated conical horn antennas with small flare angle

Th. Scharten

This summary is based on the technical reports Nr ETA-3-1969 and Nr ETA-30-1969 (Eindhoven University of Technology)

1. The configuration and its electromagnetic description
   1.1 Corrugated conical horn antenna

   ![](image1.png)

   Figure 1

   1.2 Electromagnetic model

   ![](image2.png)

   We assume a simple harmonic time dependence \( e^{-j\omega t} \). We suppose \( \ell_1 \ell_2 \ll \lambda_{guide} \) and \( R_o \approx a \gg \lambda_{guide} \). Furthermore we suppose the flare angle to be so small that if a TM_{0n} mode is excited in the horn, the aperture field can be approximated by the TM_{0n} mode field of a circular cylindrical, corrugated waveguide with inner radius \( a \), but now with a quadratic phase distribution in the radial aperture direction. For this case the longitudinal phase factor of the aperture field, \( e^{i\beta_n z} \), has to be replaced by the factor

   \[
e^{-j\beta_n (R_f - R_o)}
   \]

   where \( R_f = R_o \sqrt{1 + \frac{c^2}{R_o^2}} \approx R_o + \frac{c^2}{2R_o} \). So this factor reads

   \[
e^{i\beta_n \frac{c^2}{2R_o}}
   \]
2. Fields on the horn surfaces

2.1 Outer surface. On the outer surface we assume the wall currents to be zero; so we have

\[ \vec{n} \times \vec{E} = 0 \]
\[ \vec{n} \times \vec{H} = 0 \] on \( S_c \).

2.2 Inner surface. The surface impedance on the inner horn surface is determined by the relation

\[ Z_r = \frac{jX_r}{\epsilon_0} = \frac{t_1Z_{\text{groove}} + t_2Z_{\text{dam}}}{t_1 + t_2} \]

\[ = \frac{t_1}{t_1 + t_2} Z_{\text{groove}}, \quad \text{on } S_r \]

where

\[ Z_{\text{groove}} = \frac{jX_{\text{groove}}}{\epsilon_0} = j\frac{\mu_0}{\epsilon_0} \frac{J_0(ka) \Gamma_0(ka + kd) - J_0(ka + kd)}{J_1(ka) \Gamma_0(ka + kd) - J_0(ka + kd) \Gamma_1(ka)}, \]

being the input impedance of a shortened radial waveguide, \( a < \phi < a + \delta \), propagating a TEM wave.

2.3 Aperture. The aperture fields are found by considering a circular cylindrical waveguide (radius \( a \)) having the reactance wall condition, given above, and propagating a TM\( _{0n} \) mode (exp\( \{+i\beta_n z\} \)). Taking into account the quadratic phase distribution we find

\[ E_{\phi n} = -i\beta_n \lambda_n J_1(\lambda_n \rho) \exp \left( i\beta_n \rho^2 / 2\rho_0 \right) \]
\[ H_{\phi n} = -i\omega \epsilon_0 \lambda_n J_0(\lambda_n \rho) \exp \left( i\beta_n \rho^2 / 2\rho_0 \right), \quad \text{on } S_A \]

where \( \lambda_n \) is the \( n \)th root of the TM\( _{0n} \) characteristic equation

\[ \lambda J_0(\lambda a) - \omega \epsilon_0 \mu_0 \Gamma_0(\lambda a) = 0. \]

In our case \( ka \gg 1 \); so the surface reactance can be approximated by

\[ X_r = \sqrt{\frac{\mu_0}{\epsilon_0}} \frac{t_1}{t_1 + t_2} \tan kd. \]

It is shown that the characteristic equation has two imaginary solutions (surface wave solutions) if

\[ k \tan kd > \frac{2(t_1 + t_2)}{t_1 \delta}, \]

and real, single valued solutions if

\[ k \tan kd < \frac{2(t_1 + t_2)}{t_1 \delta}. \]
3. The radiation pattern

The energy-flow density can now be evaluated in the usual way, giving

\[ S_\theta(R,\theta) = (k \cos \theta + \beta_n)^2 \left| \int_0^\infty J_1(\lambda_n \rho) J_1(\lambda \rho \sin \theta) e^{i \beta_n \rho^2 \rho d\rho} \right|^2 \]

4. Results

Horn dimensions

- \( a = 0.132 \) (m)
- \( d = 0.009 \) (m)
- \( t_1 = 2.5 \) (mm)
- \( t_2 = 4.0 \) (mm)
- \( R = 0.493 \) (m)
- \( \theta_0 = 15^\circ \)

dimensions of the 'equivalent' waveguide

Figure 3 Dispersion curves for the circular cylindrical, corrugated waveguide

Figure 4-10 Theoretical and experimental TM_{01} radiation patterns in the frequency range 8.5 - 11.5 GHz

Figure 11 Half beamwidth characteristics
$\text{TM}_{01}$ radiation patterns

theoretical ---
experimental ----
frequency: 8.5 GHz
Figure 5

TM_{01} radiation patterns
theoretical ——
experimental ----
frequency: 9 GHz

relative power db

degrees
$TM_{01}$ radiation patterns
theoretical ———
experimental ———
frequency: 9.5 GHz

Figure 6
Figure 7

$TM_{01}$ radiation patterns
 theoretical ———
 experimental ———
 frequency: 10 GHz

[Graph showing theoretical and experimental radiation patterns over a range of degrees and frequency.]
Figure 8

TM\textsubscript{01} radiation patterns
theoretical
experimental
frequency: 10.5 GHz

degrees

relative power

db
TM$_{01}$ radiation patterns
theoretical ——
experimental ----
frequency: 11 GHz

Figure 9
$\text{TM}_{01}$ radiation patterns

theoretical ———

experimental ———

frequency: 11.5 GHz

Figure 10
Half beamwidth at 0, 10, 20, 30 db level respectively, as a function of frequency.