CROSS-POLARIZATION ANALYSIS OF DUAL FREQUENCY BAND CORRUGATED CONICAL HORNS

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1. INTRODUCTION

In order to meet the recent requirement for dual frequency band antennas, typically covering the 4/6 GHz and 11/14 GHz frequency bands simultaneously, it was necessary to develop a corrugated horn with excellent cross polarization performance characteristics. The two principal factors that contribute to cross polarization performance degradation are the cross polarization components of the dominant mode and the higher modes generated along the length of the horn.

The former cross polarization components, are basically determined by the the diameter and the slot dimensions of the hoen aperture and, can be satisfactorily reduced on larger horn. In contrast, the higher modes are determined by the sum of the higher modes generated along the whole length of the horn and are a particularly important consideration in the design of a dual frequency band horn.

This paper discusses and analyses the cross polarization performance characteristics of a dual frequency band corrugated horn, taking into consideration the higher mode contributions which are generated by discontinuous wall admittance, and compares theoretical values with actual experimental data.

2. ANALYSIS

2.1 General Remarks

Fig.1-1 shows a section of a typical corrugated conical horn. It is assumed that the field within the horn can be discribed in terms of a spherical hybrid mode approximation, with the co-ordinates used in the angaysis shown in Fig.1-2.

The equivalant wall admittance Y is given by (1), and (1)' gives a very good approximation.

$$Y = \frac{-jy_o}{(1-t/h)kR} \cdot \frac{\frac{\partial}{\partial\theta}\{P_n^m(\cos\theta)Q_n^m(\cos\theta_2) - P_n^m(\cos\theta_2)Q_n^m(\cos\theta)\}_{\theta=\theta_1}}{P_n^m(\cos\theta_1)Q_n^m(\cos\theta_2) - P_n^m(\cos\theta_2)Q_n^m(\cos\theta_1)} \quad \text{---(1)}$$

$$\simeq -jy_o\{\cot(kd) + 1/(kR\sin\theta_1)\}/(1-t/h) \quad \text{-----------------(1)'}$$

Where, k is the free space wave number and yo is the free space admittance.

Consequently, a corrugated horn can be considered as a horn with discontinueos wall admittance as shown in Fig.2, and the higher modes generated, are the result of mode conversion from dominant modes, due to discontinuous wall admittance.

2.2 Mode characteristics in the corrugated horn

For a normal sigle frequency band corrugated horn, the frequency region of $d = \lambda/4 \sim \lambda/2$ is applied. However, it is clear that similar wall admittance characteristics can be obtained in the frequency region of $d = 3\lambda/4 \sim \lambda$.

Therefore, a corrugated horn which can operate over the dual frequency band, such as C and Ku band, is realizable. In such a dual frequency band horn, the transmission mode differs depending on the operational frequency. A typical kb-ßb chart of a/b=1.6 is shown in Fig.3. In this case, HE11 mode is the dominant mode in the C band, however the EH12 modes become the diminant modes in the Ku band.

2.3 Generation of higher mode

In the corrugated horn shown in Fig.2, the mode conversion from the dominant mode to the higher mode occurs when the dominant made passes through the junction plane "S" between two sections of different wall admittance. The transmisson coefficient of the dominant and higher modes Tl and Tn are obtained as follows;

Let us consider the inner product

$$\langle \mathbf{E},\mathbf{H}' \rangle = \int_{R_0}^{R} d\phi \int_{0}^{\theta_1} \sin\theta d\theta (R\mathbf{E} \times R\mathbf{H}') \cdot \mathbf{i}_R \qquad \text{-----------------------(2)}$$

$$T_1 = [\langle \mathbf{e}_1,\mathbf{h}_1' \rangle + \langle \mathbf{e}_1',\mathbf{h}_1 \rangle]/2 \qquad \text{-----------------------(3)}$$

$$T_n = [\langle \mathbf{e}_1,\mathbf{h}_n \rangle + \langle \mathbf{e}_n',\mathbf{h}_1 \rangle]/2 - T_1 \cdot [\langle \mathbf{e}_1',\mathbf{h}_n' \rangle + \langle \mathbf{e}_n',\mathbf{h}_1' \rangle]/2 \qquad \text{----(4)}$$

where, $\mathbf{e}_1,\mathbf{h}_1$ are the transverse vector field of the forward dominant mode on the left-hand side, and $\mathbf{e}_1',\mathbf{h}_1',\mathbf{e}_n',\mathbf{h}_n'$ are those of the dominant and higher modes on the right-hand side. A normalization $\langle \mathbf{e}_1,\mathbf{h}_1 \rangle = 1$, $\langle \mathbf{e}_n,\mathbf{h}_n \rangle = 1$ has been assumed.

The complex amplitude of higher mode An(R) is obtained by the integration of conversions at each sections throughnt the whole length of the horn.

$$A_n(R) = \exp\{-j\int_{R_0}^{R} \beta_n dR\} \cdot \int_{R_0}^{R} \frac{dT_n}{dR'} \exp\{-j\int_{R_0}^{R} (\beta_1 - \beta_n) dR\} dR' \qquad \text{--------(5)}$$

where β_1, β_n are the propagation parameters of the dominant and higher modes.

3. CALCULATION AND EXPERIMENT

The cross-polarization radiation pattern is calculated from the dominant and higher mode distribution at the horn aperture by the method mentioned above. It is assumed that only the first higher modes, that is EH12 mode for C band and HE12 mode for Ku band, are converted, because the contribation and generation of those modes are the largest of all the higher modes.

Fig.4 shows the calculated and measured peak cross-polarization level. In this figure, the curve "a" shows the experimental measured value and "b" shows the calculated value. "c" and "d" shows the calculated values due to higher mode and cross component of dominant mode respectively, and "b" denotes the sum of "c" and "d" considering the phase difference.
Horn dimensions are aperture diameter = 274 mm,
half flare angle = 4.672 degrees and t/h = 0.25.

4. CONCLUSIONS

It was confirmed that the higher mode generated along the horn is one of the most impotant factors to degrade the cross-polarization performance of corrugated horn, and the contribution can be clarified by the aforementioned analysis method.

Studying the design to improve the cross-polarization performance based on these result, it can be predict that the following points are effective.

1. To make slow the change of discontinuous wall admittance especially in the transformation section from conical mode to hybrid mode.
2. To thin the edge thickness to decrease the wall admittance.
3. To select the most appropriate slot depth considering the balance between higher mode generation and cross-component of dominant mode frequency dependance.

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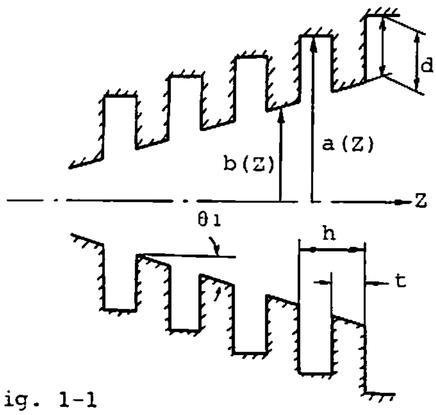

Fig. 1-1
Section of corrugated conical horn

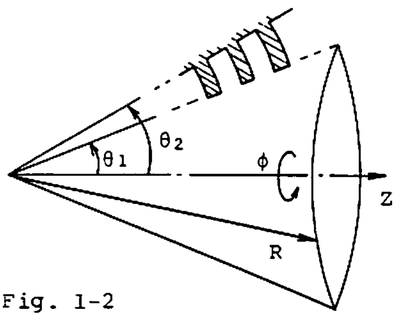

Fig. 1-2
Co-ordinate for analysis

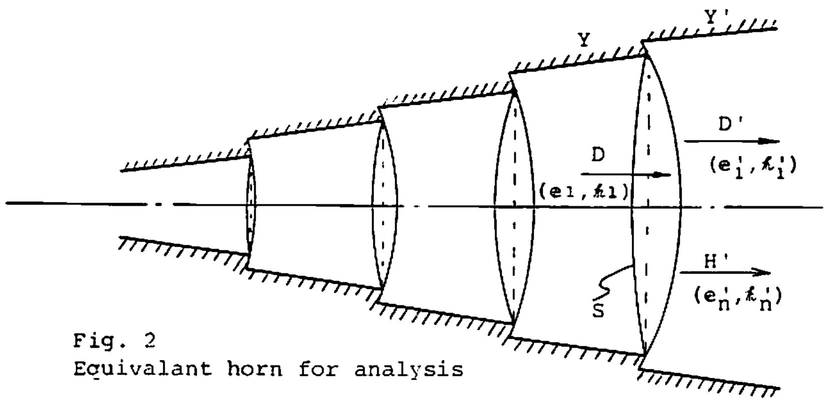

Fig. 2
Equivalant horn for analysis

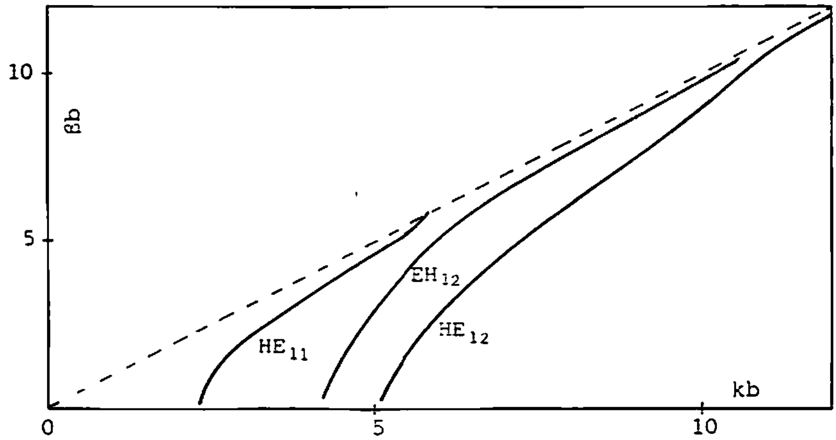

Fig. 3 Mode characteristics of corrugated horn(a/b) = 1.6
θ_1 = 4.672°

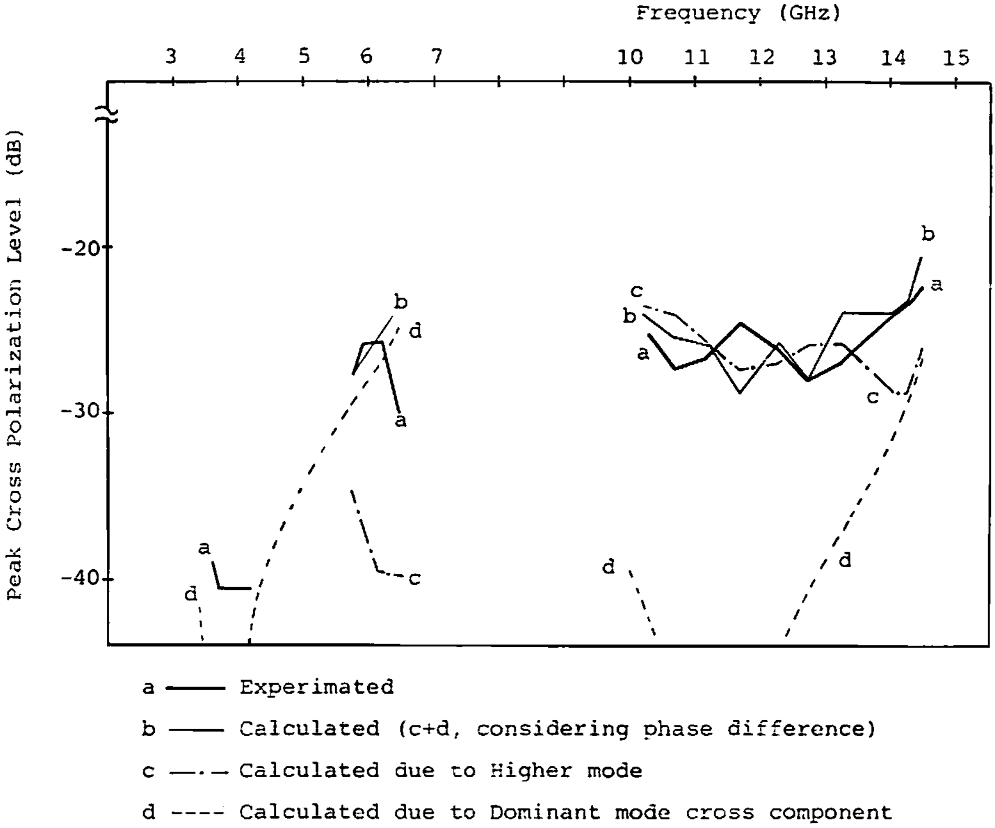

Fig. 4 Peak Cross-polarization level