WAVY-WALLED MULTIMODE HORN WITH WIDE BANDWIDTH

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Abstract: This paper has developed a 30 %-bandwidth multimode horn which has no corrugation. This horn which is designed by using the optimization technique has a high efficiency and a low cross-polarization component. We discuss the performance of the designed horn in X-band numerically and experimentally.

INTRODUCTION
To realize low cross-polarization horns with simple structure, we have developed multimode horns with no corrugation, which are designed by using the optimization technique combined with the mode-matching approach. However, the frequency bandwidths of the conventional compact horns are usually limited up to about 5-15 % [1]. So we have proposed a new objective function in the optimization procedure to realize the wide bandwidth. As a result, this paper presents a multimode horn with a low cross-polarization component less than -30 dB over 30 %-bandwidth. The wide band characteristics have been successfully achieved by using an optimized wavy wall instead of the corrugation.

DESIGN METHOD
Figure 1 shows the basic geometry of the proposed horn. The design parameters are defined by inner diameters $D_n$ ($n = 1, 2, \ldots, N$) and the total axial length $L$. The continuous configuration of the taper is obtained by cubic spline function interpolating through these points. In the analytical procedure, we use the cylindrical mode-matching approach [2, 3] in order to analyze effectively such an arbitrary taper. Also, in the optimization procedure, the objective functions are defined by return loss, the cross-polarization component, spill-over loss and rotational symmetry in the co-polar pattern. These objective functions are minimized by using the non-linear programming such as the revised Marquardt method. Then, an optimum taper configuration is determined by varying the axial length as well as the inner diameters.

DESIGN EXAMPLE
We now design a horn with frequency bandwidth of 30 %. The design goal in our optimization is to achieve VSWR < 1.065 and the cross polarization component < -30dB at the frequency band 8.45–11.45 GHz. Figure 2 shows the designed horn. In the optimization procedure, we take the number of design parameters $N = 27$. The number of division for the stepwise approximation is chosen to be 300 and then the number of cylindrical modes for the mode-matching analysis is 80 in each waveguide. The peak cross-polarization level and VSWR of the designed horn which satisfy the design goals within the specified frequency are indicated in Fig. 3. Figure 4 shows mode coefficients at the aperture and also Fig. 5 shows the frequency characteristics of the 3dB and 10dB beam-widths and the aperture efficiency. Thus, the proposed horn works well to realize the wide-band characteristics. Besides, the behavior of the mode conversions due to the designed taper configuration is shown along the horn axis in Fig. 6, where the amount of amplitude and phase are normalized by that of the TE$_{11}$ mode. Figure 7 shows the aperture amplitude and the phase distributions. It is clear from Fig. 6 that these tapered amplitude distributions similar to corrugated horns are obtained by mainly controlling the triple-mode, and also the low cross-polarization component is achieved by generating further higher-order modes.

Fig. 1. Basic geometry of wavy-walled horn.                Fig. 2. Designed horn antenna.
Fig. 3. Optimized results.

Fig. 4. Frequency characteristics of mode coefficients.

Fig. 5. Frequency characteristics of (a) beam-widths and (b) aperture efficiency.

Fig. 6. Behavior of mode conversions.
(a) Amplitude and (b) phase.

Fig. 7. Aperture distribution at center frequency.
EXPERIMENTS
We performed a set of measurements on the designed horn in the X band. The external view of the fabricated horn is shown in Fig. 8. Figure 9 compares frequency characteristics between the measured and the predicted VSWR. The measured result agrees well with the predicted one. This result verifies that the proposed horn has excellent VSWR characteristics over 30%-bandwidth. Figure 10 also shows the far-field radiation patterns at the center frequency 10GHz. The rotationally symmetrical radiation pattern is achieved and also the measured results are good agreement with the predicted ones in both the co-polar and the cross-polar patterns. Furthermore, Fig. 11 shows the frequency characteristics of peak cross-polarization levels. It is obvious from these results that our horn has the low cross-polarization component over wide frequency band.

Fig. 8. External view of fabricated horn in X band.

Fig. 9. Measured and predicted VSWR.

Fig. 10. Measured and predicted radiation patterns at 10 GHz.

Fig. 11. Measured and predicted peak cross-polarization levels.

CONCLUDING REMARKS
The wide-band multimode horn with the wavy-walled taper has been developed by the optimization-design procedure. The numerical and experimental discussions have verified that the designed wavy wall works well to realize the horn with high performance.

REFERENCES