

Efficiency Enhancement of a Semi-constrained Waveguide Monopulse Feeder for a Linear Phased Array Antenna

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1. Introduction

Linear phased array antenna such as end-fed traveling wave slotted waveguide array antenna has an input geometry of piling up slotted rectangular waveguides. In this feed geometry constrained feed or semi-constrained feed type can be used but not a space feeds. Most frequently used type of feeder for this type of antenna is a serial feeder using coupling slots in a waveguide. The required characteristics of a feeder are appropriate power distribution on the antenna aperture, low insertion loss and low return loss. Serial feeder has additional 0.5 dB insertion loss (about 10 % power consumption) at the terminated load because the serial feed usually adapts traveling-wave type slotted waveguide. In addition the serial feeder is not suitable for a monopulse feeder because it is impossible to achieve Hannan's optimum monopulse pattern [1].

The proposed feeder in [2] can be categorized as parallel semi-constrained feed. However it has the concept of a space feed because the aperture distribution comes from the E-plane sectoral corrugated horn. In addition to E-plane sectoral corrugated horn, it is suggested in this paper that the aperture modulated waveguide ports make enhancement of aperture efficiency of the antenna system.

2. Antenna Configuration

The geometry of the antenna system that the proposed feeder is applied to is basically a linear phased array antenna composed of N-row edge slotted waveguide array and ferrite phase shifters as depicted in Figure 1.

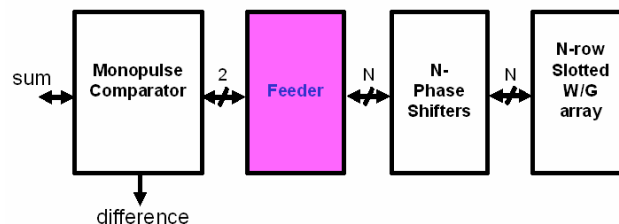


Figure 1: Conceptual diagram of the antenna system

The feeder combines two inputs from the monopulse comparator to one TE_{10} mode field which has uniform field distribution over the E-plane. The feeder makes the uniform field distribution to quasi-taylor distribution in order to lower the sidelobe level and then divides and feeds this distribution to N phase shifters. Phase shifters equalize phase differences between the ports and set the phase for beam steering. Finally N-row slotted W/G array radiates RF power to electromagnetic energy in free space. The power distribution requirement of the parallel feeder should satisfy the beamwidth of 3 deg.

and sidelobe level less than -20 dB of the antenna system. From the elevation pattern requirement one can easily show that cosine pedestal distribution with -15 dB edge tapering, which is a goal distribution of the corrugated horn, satisfy the elevation sidelobe level of -20 dB with some margin. 39 output ports are needed due to the $0.553 \lambda_0$ (λ_0 is a free space wavelength) spacing between slotted waveguides and the elevation beamwidth requirement. The edge tapering requirement and number of ports are basic requirements for the feeder so that the antenna system can achieve the elevation pattern requirements.

3. Design and Measurement

As mentioned previously, the feeder is basically composed of E-plane sectoral corrugated horn and N-port aperture-modulated pick-up aperture power divider.

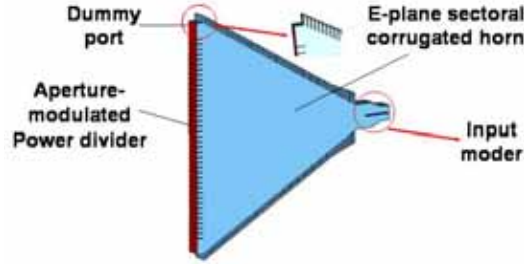


Figure 2: Proposed feeder geometry

The detail design procedures for input moder and E-plane sectoral corrugated horn are omitted here because they are well described in [2]. The well known hybrid mode analysis for rectangular corrugated waveguide is used to investigate the mode behavior in the E-plane sectoral corrugated horn [3, 4, 5]. The input moder has been designed to support just necessary modes in the E-plane sectoral corrugated horn. The optimized design values of the parallel feeder excluding power divider are shown in Table 1.

Table 1: Optimized design values of the parallel feeder

Parameters		Initial Values
Corrugated horn	Initial corrugation depth	$0.62\lambda_0$
	Final corrugation depth	$0.39\lambda_0$
	Profile	Sine profile
Input moder E-plane height		$1.11\lambda_0$

It was shown in [2] that all the requirements of the antenna system were satisfied when the uniform power divider was applied to the parallel feeder. However aperture efficiency of the antenna system to be applied is not an optimum value because the power distribution is cosine pedestal one in that case. The output E-field distribution over the E-plane from the corrugated horn has the form of cosine pedestal distribution. It is well known in the pattern synthesis that Taylor distribution has the lowest sidelobe level than any other distribution with the given same beamwidth. It can be easily converted from cosine distribution to quasi-taylor one by adjusting port height of the E-plane power divider. The converted port height can be calculated by the equation below. The port height h_m should proportional to the power ratio of the distributions in (1). The minimum port height is too small to machine if power ratio proportional equation is used. Therefore we choose the second best as the amplitude ratio proportional equation like (1) and that is why we call it as quasi-taylor distribution.

$$h_m = \sqrt{\frac{P_m^{tay}}{P_m^{\cos}}} N_p H_f, \quad N_p = \sum_{m=1}^M \sqrt{\frac{P_m^{tay}}{P_m^{\cos}}} \quad (1)$$

From (1) H_f is the E-plane height of the corrugated horn. In Figure 3, both of Taylor and Cosine distribution are shown in (a) and the necessary port height to convert the distribution is shown in (b).

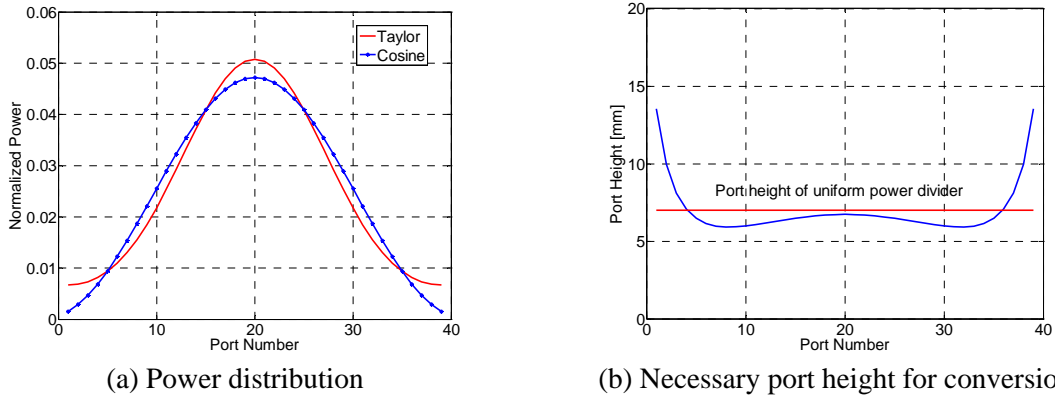


Figure 3: Power divider design results

The designed feeder has been machined and measured as depicted in Figure 4. The measured port power distribution at the center frequency is shown in Figure 5.

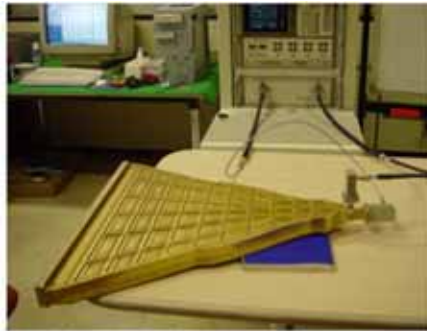


Figure 4: Measurement view of the feeder

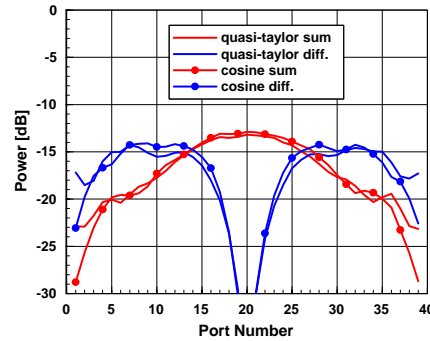


Figure 5: Measured port distribution at f_c

The calculated aperture efficiency from the measured feed port distribution is shown in Figure 6 (a) and their gain difference is shown in Figure 6 (b). From Figure 6 (b) one can observe that more than 0.6 dB gain is enhanced over the frequency range. The gain increase of 0.6 dB can directly enhance the performance of the surveillance radar in which this feeder would be applicable. The pattern in Figure 7 has been calculated from the measured distribution and array antenna geometry. The sidelobe level of the quasi-Taylor case is about 2 dB higher than the cosine distributed case. However, the sidelobe level is still lower than the requirement of -20 dB which was shown in Table 1.

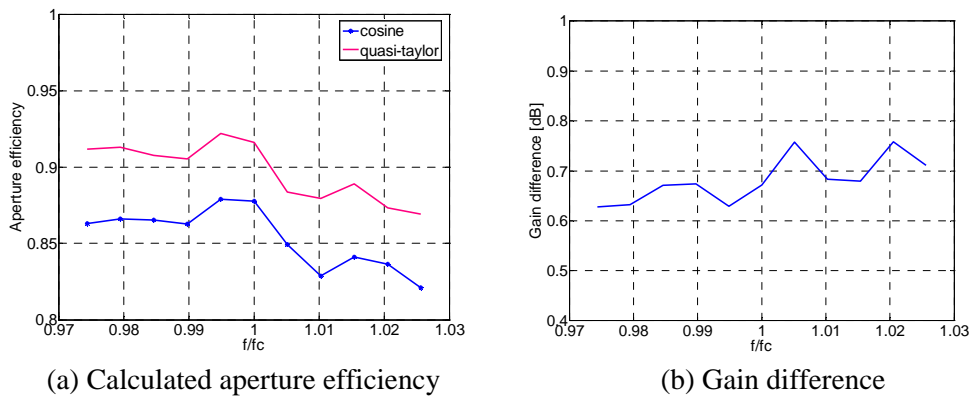


Figure 6: Calculated aperture efficiency and gain difference

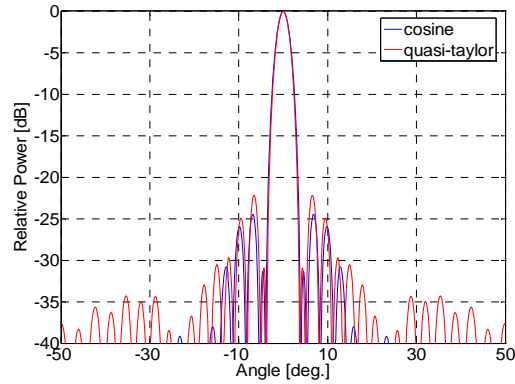


Figure 7: Calculated pattern from the measured power distribution of the feeder

4. Conclusions

In this paper, the method to enhance the aperture efficiency of the waveguide monopulse parallel feeder, which is an E-plane sectoral corrugated horn, is proposed. The pick-up apertures of the ports are modulated, from the uniform power divider which was proposed in [2], to have Taylor distribution as near as possible. It is shown that the estimated gain enhancement of the antenna, in which the proposed feeder is used, is more than 0.6 dB over the frequency range. If this antenna is applied to a radar system, detection performance would be upgraded as much as two-way gain of more than 1.2 dB.

Acknowledgments

This research was supported by KAIST BK 21 (Brain Korea 21), and ADD (Agency for Defense Development) through RDRC (Radiowave Detection Research Center) support program.

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