ANALYSIS OF PYRAMIDAL HORN ANTENNA WITH TRAPEZOID WAVEGUIDE IN MULTIPLE-BAND PART 1 : THEORITIAL DESIGN

Taesik Choi*, Boyoung Kim, Hyodal Park
Department of Electronics, School of Engineering, Inha University
253, Younghyun-dong, Namgu, Incheon, 402-751, Korea
E-mail: spmari@naver.com

1. Introduction

We proposed the design method for fabrication of miniaturized pyramidal horn antenna in multiple-band. In general, pyramidal horn antenna with standard rectangular waveguide operates in single band, but it's not suitable for using this waveguide if multiple-band. To overcome this problem, we designed new type waveguide, which is applicable small-size horn antenna instead of rectangular waveguide as describing design procedure in order.

2. Trapezoid waveguide

For wideband performance, stepped-impedance transformers are used to obtain reflection-less transition. To design waveguide, a stepwise wall profile provides for a large number of degrees of freedom and also includes large evanescent field content. A multi-resolution optimization strategy allows good convergence during synthesis [1]. But, it's not easy to apply this method due to limited antenna length. We proposed trapezoid waveguide (TW) that defined as configuration, which is analogous to H-sectional horn. The TW derived from dimension collation of standard waveguide. Suppose that higher and lower frequency is in different band and not adjacent band, respectively. Physical dimension consists of standard waveguide of higher band, except wide width determined from width of waveguide including a half of higher band. This structure, however, doesn't have good efficiency due to mode transformation and the null increase as increasing operating frequency. Because of this, we applied discontinuous structure inside waveguide.

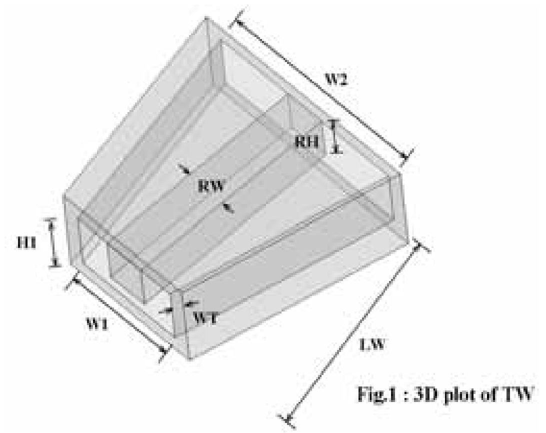
Conducting posts in rectangular waveguide play a role in many waveguide bandpass filters such as waveguide filters, evanescent mode waveguide filters [2]. Also, by introduction of ridge configuration to the waveguide, the cut-off frequency of the dominant mode is reduced to a larger extent than the cut-off of the first higher-order mode frequency [3]. Especially, evanescent-mode ridge waveguide lowpass and bandpass filters are presented, where various ridge configurations are used and wide spurious-free out of band response [4]. Serrations are introduced in the ridge waveguide to reduce the resonator length and suppress the spurious response. But, we didn't employ this structure since it's hard to fabricate miniature size. To obtain specified frequency in multiple-band, we employed simple

ISBN: 89-86522-78-0 94460

single ridge structure and posts inside TW.

3. Design Procedure

In this paper, for operating from X to Ka band (8~40GHz), waveguide is designed 7.11mm and 12.95mm width, 3.56mm height, and 1.0mm thickness. Design restricted condition (DRC) is just reference. Also, length of waveguide is 14.22mm(a cut-off wavelength of higher band). When inserting single-ridge inside waveguide, its width and height is 2.6mm and 3.16, respectively. The TW what we designed and used dimension is shown in Fig.1 and Table.1, respectively.



Model Dimension	Originate from
W1 = 7.11	WR-28
W2 = 12.95	WR-51
H1 = 3.56	WR-28
LW = A cut-off wavelength	WR-28
WT = 1.00	-
RW = 2.60	-
RH = 3.16	-

Table 1. Dimension of 3D TW plot

$$DRC : W1 \leq 2 \cdot H1,\ \ 2 \cdot H1 \leq W2 \leq 3 \cdot H1$$

Fig.1: Trapezoid waveguide 3D plot

Table.1: TW Dimension in mm

Unlike the existing rectangular waveguide, there are some properties of TW. First, horn size is determined by changing waveguide dimension when connecting waveguide and horn. That is, aperture width and flare angle of horn antenna is dependent on waveguide. Common line generates if two imaginary planes including height of wide width and E-plane (propagating direction +z direction, y-z plane) cross. When imaginary arbitrary point v_1 moves on its line, E-flare angle can be changed. If v_1 laid on center of line, E-plane angle is constant; otherwise, E-flare angle is different, respectively. Asymmetric upside (θ_{E1}) and downside (θ_{E2}) of E-flare angle can be changed as varying H-plane altitude due to v_1 position. In that case, horn antenna may have beam tilting effect toward front aperture because upside and downside of E-flare angle has different value. Second, the length of horn

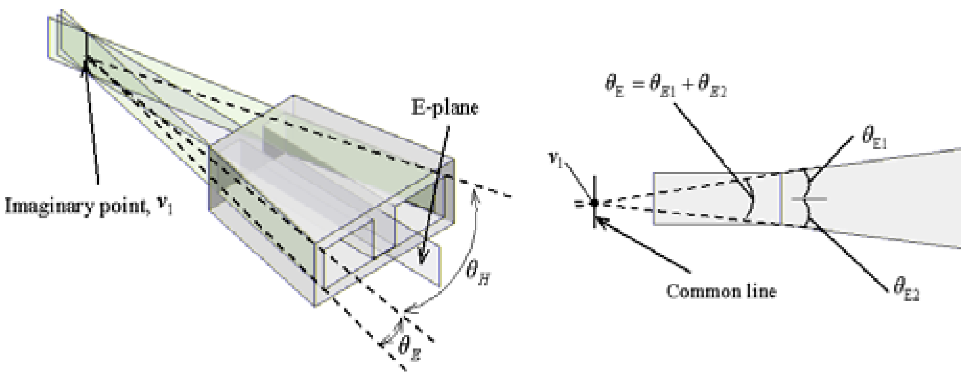
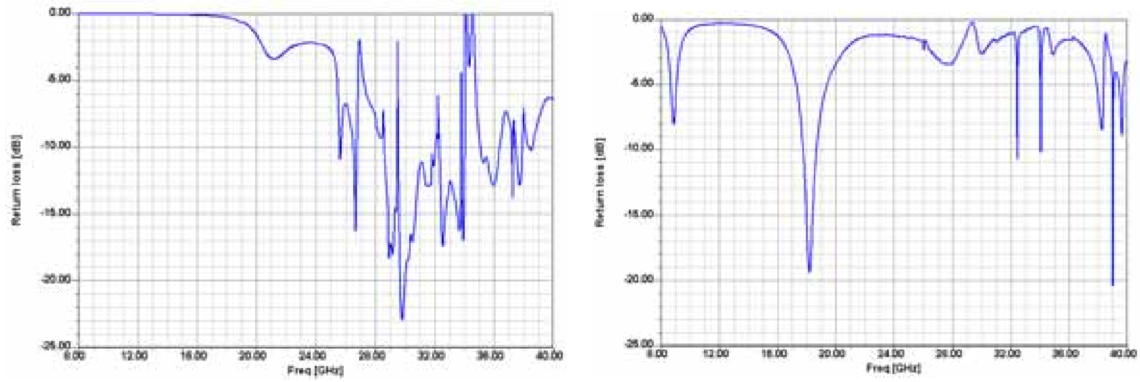


Fig.2: Determination of E-and H-flare angle according to E-plane common line and imaginary point

antenna with TW can be shorter than horn with rectangular, since TW plays role of waveguide and horn as part of H-sectional horn, respectively. Fig.2 shows 3D plot of flare angle determination and E-plane cross-section, respectively. Based on description before, we implemented pyramidal horn.

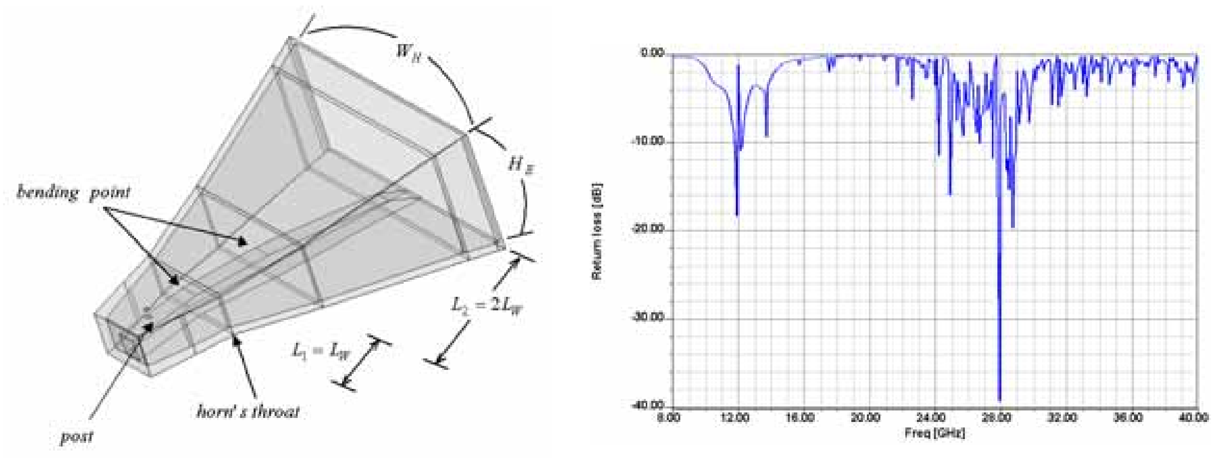
Fig.3 shows the results of TW with ridge and without ridge for operating from X- to Ka-band. In case of TW with ridge [see fig. 2(b)], the magnitude of reflection coefficients, $|\Gamma|$, stays close to -19dB, -20dB at 18GHz, 39GHz, respectively, over wide-band. But fig.2 (a) did not have resonance frequency over X and Ka-band (8~24GHz).



(a) (b)

Fig.3: Results of return loss Trapezoid waveguide (a) Without single-ridge (b) With single-ridge

Next, design pyramidal horn antenna with single-ridge waveguide. Fig.4 (a) shows 3D plot E-and H-plane of horn antenna with TW. Conducting post with gap (same material with horn) is added on waveguide roof for bandpass filter. Single-ridge with 2.6 width is bent at two point, where multiple cut-off waveguide of center frequency (24GHz) and extended to aperture end. As shown fig.4 (a), horn's throat is placed at 1st bending point if it's hard to distinguish in case that waveguide and horn is parallel. If horn H-plane flare angle is parallel to its waveguide and horn length ($L_1 + L_2$) is three times of L_W , aperture width is 42.89mm, or H-flare angle 23.2°(W_H). Also, upside and downside of E-flare is asymmetrical on z-axis, 11.6° and 7.4°, respectively. Post is placed 0.25 λ in back of horn's throat (height 1.5mm and 0.3mm radius).



(a) (b)

Fig.4: (a) 3D plot of pyramidal horn antenna with single-ridge TW (b) Result of return loss

Fig.4 (b) shows result of return loss against frequency. $|\Gamma|$ of fig.4 (b) is less than –10dB through multiple-band and antenna have resonance at 12GHz(X-band), 24~25GHz(K-band), 28~29GHz(Ka-band), respectively. In comparison with fig.3 (b), resonance point is shifted to lower band. In this paper, we considered result of return loss only.

4. Conclusion

In this work, we proposed design method of irregular waveguide (TW) and pyramidal horn applying its waveguide. Using waveguide filter such as conducting post and single-ridge, we experimented small-size pyramidal horn antenna with TW for operating multiple-band. Through the reference model, we presented design procedure in order and obtained resonance values over multiple-band. Next part Ⅱ, we will demonstrate application using this model

5. Reference

[1] Ming-Chuan Yang, Jia-Han Li, and Kevin J. Webb “Functional waveguide mode transformer”, *IEEE Trans. Microwave Theory Tech.*, vol.52, pp.161-169

[2] Hui-Wen Yao, Chi Wang, and Kwathar A. Zaki “Modeling conducting posts in rectangular waveguides for filter applications” in *Proc. IEEE AP-S Int. Symp.*, vol.1, 1995, pp.1566-1571.

[3] J.Uher, J.Bornemann, and Uwe Rosenberg “Waveguide components for antenna feed systems: Theory and CAD” Boston·London: Artech House, 1993.

[4] Tao Shen and Kawthar A. Zaki “Length reduction of Evanescent-mode ridge waveguide bandpass filters” in *IEEE MTT-S Int. Microwave Symp. Dig.*, vol.3, 2001, pp.1491-14945.