Ultra-Thin Broadband OMT with Turnstile Junction

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***Abstract* — This paper presents an ultra-thin broadband waveguide orthomode transducer (OMT) for low profile reflector antenna feed systems. The presented OMT is composed of a turnstile junction with a metallic pyramid, a circular-to-square waveguide step, and thin combiners/ dividers. A broadband design of the OMT is performed by applying a circular-to-square waveguide step to obtain good match. An ultra-thin Ku-band OMT fabricated with the aid of the design techniques has realized wideband excellent performance with very low height, that is, VSWR less than 1.18 over 30% bandwidth and reducing the height to 20.2mm.**

I. INTRODUCTION

Because of increasing the communication capacity and versatility of the antenna system, orthomode dual-polarization operation is often required. OMTs, key components of orthogonal dual-polarized antenna feed systems, are used to separate the orthogonal signals excited at the common port. In spite of a need to develop a broadband OMT, there are few types of broadband OMTs [1,2]. Typical examples of broadband OMTs are distinct dual junction type OMT [3] and equal dual junction type OMT [4]. The former has ports of side wall dual-junction, ports of longitudinal dual junction, and a septum within branching region. The latter has four longitudinal dual junction ports and pyramidal insert within the common waveguide. However, those OMTs need complex structure and large size with respect to the common waveguide axis.

In this paper, we present a broadband thin OMT which is composed of a waveguide turnstile junction with metallic pyramid, a circular-to-square waveguide step and thin combiners/dividers. The waveguide turnstile junction with the metallic pyramid is suitable for realizing thin and simple structure and a good match over the wide bandwidths. In particular, the circular-to-square waveguide step is effectively used to obtain good reflection characteristics in the lower frequency band. We present design techniques to improve reflection characteristics by applying a circular-to-square waveguide step at the common port. In addition, the structure contributes to low-profile of the antenna systems, because the interface port, that is circular waveguide, can be designed as the radius is large relatively. Combiners/ dividers have unique structures which are composed of E-plane stepped impedance transformer with H-plane bends and E-plane T-junctions, and the structures also contribute to low height of the OMT. Furthermore, the presented OMT can be manufactured by just assembling three parts. In practice, a Ku-band ultra-thin broadband OMT is fabricated with the aid of the above design techniques.

II. CONFIGURATION

Fig.1 shows a structure of thin broadband waveguide OMT. This OMT is composed of a turnstile junction with a metallic pyramid within branching region, a circular-to-square waveguide step and thin combiners/ dividers. Facing ports of the junction are interconnected by waveguide combiner/divider. The combiners/dividers are composed of E-plane stepped impedance transformer with H-plane bends and waveguide E-plane T-junction. According to the above structure, two combiners/dividers can be located between the bottom and the top of the turnstile junction. Fig.2 shows the manufacturing method of the thin OMT. The OMT is fabricated with ease by assembling three metal plates which are excavated by numerical control machining respectively.

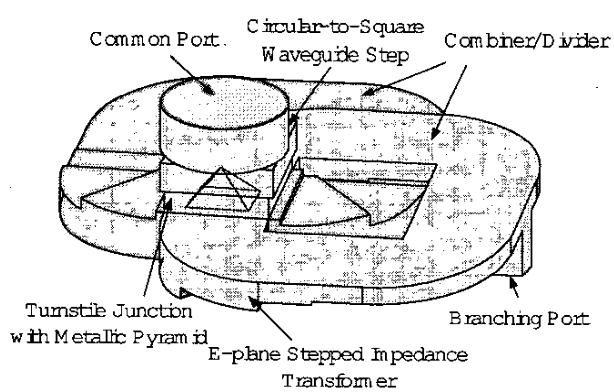

Fig. 1. Thin Turnstile Junction OMT with thin waveguide combiners/dividers

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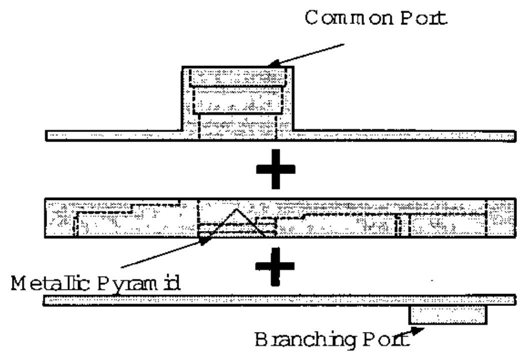


Fig. 2. Concept of Manufacturing Thin Turnstile Junction OMT

III. DESIGN

A . Turnstile Junction with Metallic Pyramid

Fig.3 shows a structure of a turnstile junction with a metallic pyramid within branching region. The common square waveguide port is handling the orthogonal dual-polarized wave.(Vertically (V) polarized wave and Horizontally (H) polarized wave). V-polarized wave is divided between Port1 and Port3, and isolated from Port2 and Port4. On the other hand, H-polarized wave is divided between Port2 and Port4, and isolated from Port1 and Port3. Fig.4 shows electric field of turnstile junction cross section. For each polarized wave, the turnstile junction can be represented as approximately two symmetrical E-plane waveguide mitered bends. A good match is achieved by determining optimum height and base of the pyramid, which is derived by modifying optimum dimensions of the mitered bend. Fig.4 shows calculated reflection characteristics of designed Ku-band turnstile junction with metallic pyramid. The data are computed by Ansoft HFSS. In this turnstile junction, dimension of common waveguide is 16 ~ 16mm, dimension is 16 ~8mm, height of the pyramid is 7mm and

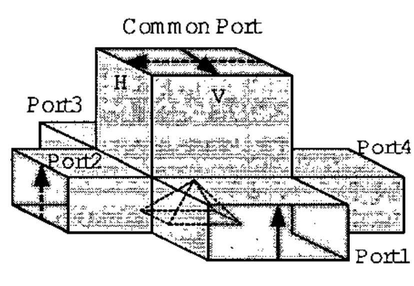


Fig. 3. Turnstile Junction with Metallic Pyramid

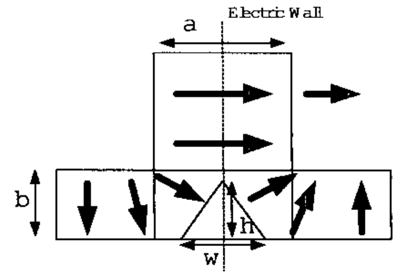


Fig. 4. Electric Field of Turnstile Junction Cross Section

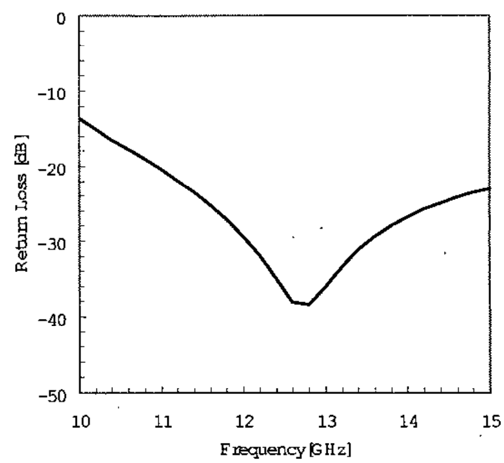


Fig. 5. Computed Performance of Ku-band Turnstile Junction with Metallic Pyramid.

base of the pyramid is 10 ~10mm. As shown in Fig.4, turnstile junction with metallic pyramid has a good reflection characteristic in the frequency range between 11.5GHz and 14.5GHz. However, in the frequency range less than 11.5GHz, the reflection characteristics get worse.

B. Circular-to-Square Waveguide Step

The turnstile junction with metallic pyramid doesn't have good performance in the frequency range less than 11.5GHz, as stated above. On the other hand, a circular-to-square waveguide step is required, because a circular waveguide is mainly required as interface of common port. In this paper, we proposed a broadband design of the OMT, which is performed by combining the turnstile junction and the circular-to-square waveguide step. According to the technique, the dimensions of the circular-to-square waveguide step are designed as the reflected wave at waveguide step compensates the reflected wave at the turnstile junction. Reflection characteristics in the frequency range less than 11.5GHz are improved. Fig.5 shows calculated reflection characteristics of a turnstile junction, a circular-to-square waveguide, and a turnstile junction with a circular-to-square waveguide step. The waveguide step is designed in the Ku-band, and the radius of circular waveguide is 24mm, the dimensions of the first and second square waveguide are 19 ~19mm and 1616mm, respectively. As shown in Fig.5, turnstile junction without circular-to-square waveguide steps has a good performance in higher frequency, but in lower frequency not. On the other hand, the turnstile junction with the designed circular-to-square waveguide step also has a good reflection characteristic in lower frequency. Here the designed waveguide step is needed to perform as matching element in the frequency range less than 11.5GHz, and as just transformer in higher frequency. Furthermore, in the case that a horn antenna is connected at common port, it is possible to shorten a horn antenna, because radius of circular waveguide can be large relatively.

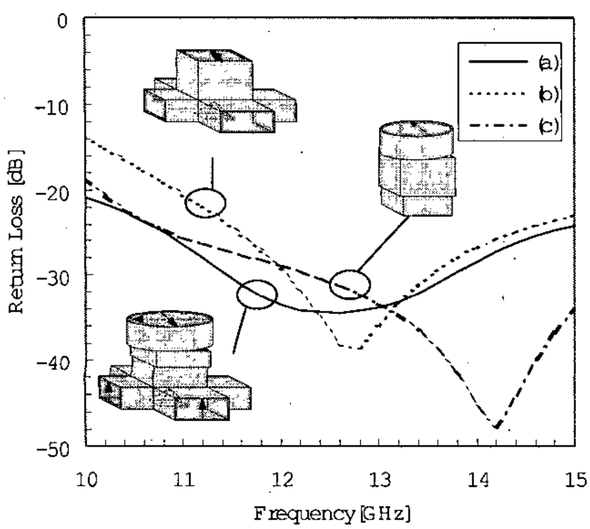
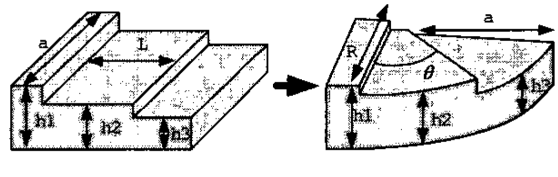


Fig. 5. Computed Performance of (a) Turnstile Junction with Circular-to-Square Waveguide Step, (b) Turnstile Junction without Circular-to-Square Waveguide Step and (c) Circular-to-Square Waveguide Step.

C.Thin Combiner/Divider

Facing two branching waveguides are interconnected by symmetric waveguide combiners/dividers. Each combiners/dividers are composed of E-plane stepped impedance transformer with H-plane waveguide bends and E-plane waveguide T-junction. The combiners/dividers cross each other without increasing the height of the OMT by applying the thin combiner/divider structure. As shown in Fig.6, the dimension of E-plane transformer with H-plane bends is derived by designed straight stepped impedance waveguide transformer [5]. Thus, ˘ is given by

$$\theta = \frac{L}{R - a/2}$$



(a) Stepped Impedance transformer (b) Stepped Impedance transformer with H-plane bend

Fig. 6. Design Concept of E-plane Transformer with Bend

IV. Experimental Results

Fig.7 shows the calculated and measured reflection characteristics of the above designed Ku-band turnstile junction with metallic pyramid and rectangular waveguide step. The dimension of common square waveguide is 16 ~16 mm, the dimension of branching rectangular waveguide is 16 ~8 mm, the height of metallic pyramid is 7mm and the base of is 10 ~10mm. The fabricated turnstile junction with metallic pyramid has a excellent performance, that is, the VSWRs less than 1.15 over the frequency range between 10.7GHz and 15GHz. Furthermore, good agreement is obtained between calculated data and measured data. The above results have verified the efficiency of the proposed broadband design technique.

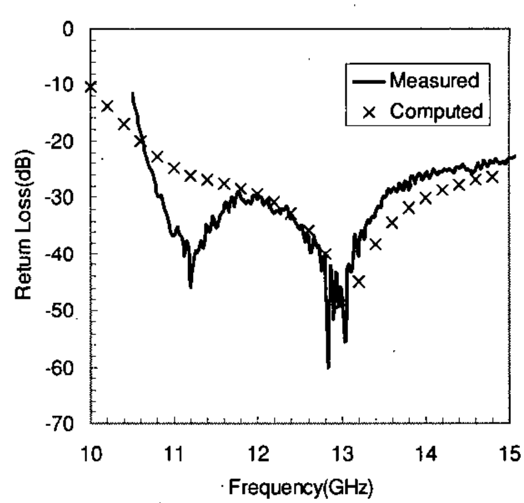


Fig. 7. Measured and Calculated Frequency Responses of Fabricated Turnstile Junction with Metallic Pyramid

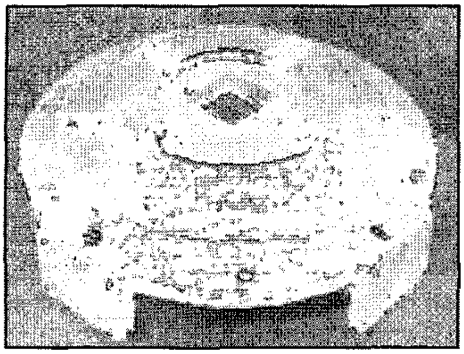
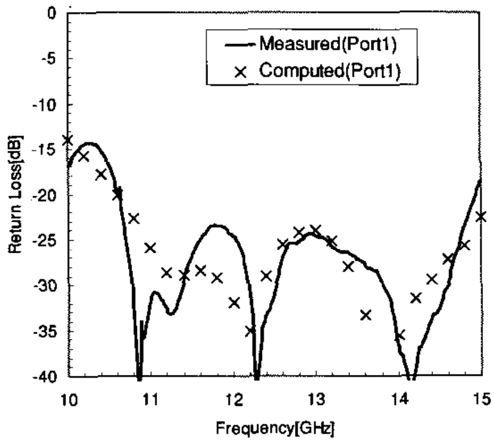
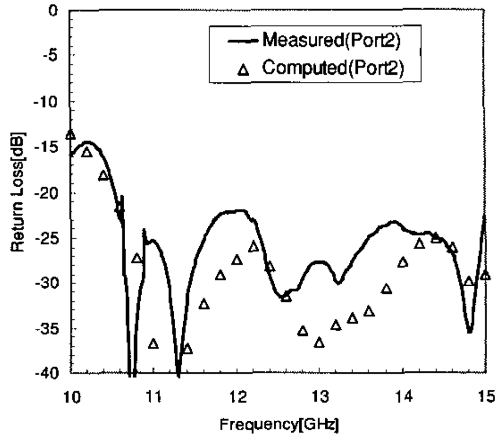


Fig. 8. Photograph of Fabricated Ku-band Ultra-Thin OMT

The designed Ku-band thin turnstile junction OMT with thin combiner/divider has been fabricated. Fig.8 shows a photograph of the fabricated OMT. In this OMT, a circular common waveguide with a diameter of 24mm, two rectangular branching waveguides with dimensions of 16 ~6 mm and aperture and stepped-impedance transformer are formed by assembling three machined parts. Fig.9 shows Measured and Calculated Reflection Characteristics of the Fabricated OMT. The fabricated OMT has an excellent performance, that is, the VSWRs less than 1.18, the isolations more than 40dB and insertion loss less than 0.1dB over the frequency range between 11GHz and 14.9GHz. Moreover, good agreement is obtained between calculated result and measured result. Besides, the height between the bottom of combiner/ divider and circular-to-square waveguide step is 20.2 mm, that is to say, ultra-thin OMT has been obtained.



(a) Port1



(b)Port2

Fig. 9. Measured and Calculated Reflection Characteristics of the Fabricated Ku-band Thin OMT

V. CONCLUSION

The thin OMT, which has good performance over large bandwidth, has been introduced. Thin structure of the presented OMT is achieved by using the turnstile junction and the stepped combiners/dividers. Broadband performance has been achieved by connecting circular-to-square waveguide with common port. A Ku-band OMT fabricated with aim of the analysis and design has realized excellent performances. The presented OMT is useful for low-profile reflector antenna feed systems.

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