Hermetically Sealed Aperture Coupled Ka-Band Waveguide-to-Micro Strip Transition for Space Applications

Raval Vidhi. P
PG student
L.J.I.E.T , Ahmedabad

Mr. Nimesh Prabhakar
Assistant Professor
L.J.I.E.T , Ahmedabad

Abstract

This paper presents design of millimeter-wave transition from waveguide to Microstrip. Transition designed is an aperture coupled transition where energy coupling from Microstrip line is done through slot in its ground plane to metal patch element placed on other side of substrate. Critical parameters of design are optimized by using a 3-D solver ANSOFT HFFS software tool and return loss better than 15 dB and its minimum insertion loss is 0.37dB over 34.5GHz–36GHz frequency range for back-back structure. The small aperture design offers low radiation loss, miniaturized design and is reasonably insensitive to mechanical misalignment between waveguide and Microstrip circuit.
Keywords: Microstrip transitions, aperture coupled, hermetically sealed, ka-band, waveguide transition

---

I. INTRODUCTION

In Millimeter wave circuits transition is required to provide connection between two different transmission structure and also for impedance transform between transmission with different characteristics impedance. Aperture coupling has been widely utilized in microwave circuits within multi-layered media as vertical transition as well as directional coupler also used in Duplexers, high power combining devices; low loss antenna feed structure, high Q microwave filters. An EM transition between rectangular waveguide and planar transmission line involves two major aspects i.e. Field matching and Impedance matching.
Transition fall into the following 3 groups [1]:

1) Transition that are along the propagation direction of the waveguide [2].
2) Transition which couple energy via apertures that are cut in the broad wall or end wall of the waveguide [3].
3) Transition that utilizes probes transverse to the propagation direction of the waveguide [4].

There are various types of Millimeter wave transitions from waveguide to Microstrip line. The ridge waveguide type [5], Quasi–Yagi type [6] and planar waveguide type [7] have been studied as longitudinal connection of waveguide with Microstrip line. With regard to vertical transition, a conventional type of probe feeding has wideband characteristics, but it needs a metal back short with a quarter wavelengths on substrate [8]. The replacement of metal short block is a patch element in the waveguide to achieve sufficient coupling between waveguide and Microstrip line [9]. The slot coupling achieve coupling between Microstrip lines and patch element in waveguide by means of a slot, it is composed of two dielectric substrates without a metal short block [10].

Aperture coupled transition offers several advantages like no waveguide back-sort required, compact and most important advantage for space applications is that it is inherently hermetically sealed which simplifies design and size of circuits .A wideband characteristic improves the assembly tolerances, considering shifts in the resonant frequency that are mainly caused by assembly errors, but sideband deign for a transition having a patch element in the waveguide is a drawback of aperture coupled transition and it can be found in literature [11].

In this paper, a millimeter wave waveguide transition to Microstrip line on waveguide narrow wall using rectangular patch element is proposed. The transition is composed on a single dielectric substrate attached to waveguide. The design of transition is presented. The design methodology includes two important aspects. These are maximum bandwidth and low insertion losses.

II. DESIGN APPROACH

In designing the transition, a field matching and impedance matching is major concern in order to ensure an efficient field transition. Generally, fields are matched by shaping the structure. Therefore, mechanical design (by optimizing location, depth and width of probe) provides the field match and keeps reactance due to transition discontinuity small, whereas electrical design (impedance matching solution) provides impedance match.

Field matching is achieved through mechanical design (depends on location, depth and width of probe) and matching elements like inductive line and transformer provides impedance match.
Critical parameters affecting the performance of transition are as below

A. Location of Probe with Respect to Short:
The probe (Microstrip patch) is inserted in waveguide where reflected EM energy combines in phase with the incident wave.

B. Depth of Probe:
The probe depth is adjusted to have minimum reactance. Depth is so adjusted that reactance just changes from inductive to capacitive.

C. Width of Probe:
The change in strip width has little effect on input reactance. A probe of narrow width is chosen to have lesser effect on filed distribution inside the waveguide, but not narrow enough to cause excessive conductor loss. The width of patch is kept less than patch length. The substrate fits the full height to facilitate precise misalignment during assembly.

1) Selection of Waveguide [12]

WR-28 waveguide
Frequency range: 34.5 GHz to 36GHz
Dimension: 7.1mm × 3.56mm
Length of waveguide: 25 mm

III. TRANSITION REALIZATION

This paper proposes a transition from waveguide to Microstrip line which employs the method of proximity coupling. The waveguide to Microstrip line transition connects a perpendicular rectangular waveguide and Microstrip line. A probe at one end of Microstrip line is inserted into the waveguide whose one end is short circuited. RT-Duroid (relative dielectric constant 2.2, thickness 0.254mm) with conductor pattern on its both sides is placed on open ended waveguide (WR-28). The rectangular patch element and ground are etched on the backside. Via holes are placed along the circumference of waveguide short to connect electrically to ground. The aperture of dielectric substrate is covered with an upper waveguide. The electric current on the probe couples to magnetic field 〚TE〛_10 dominant mode of waveguide. Via holes surround the waveguide in the substrate in order to reduce leakage of parallel plate mode transmitting into the substrate.

The waveguide used here is WR-28 that as dimensions of 7.56 mm × 3.56mm. Port numbers are defined as #1 for waveguide and #2 and #3for Microstrip lines. The parameters of transition from waveguide to Microstrip lines are shown in TABLE 1.

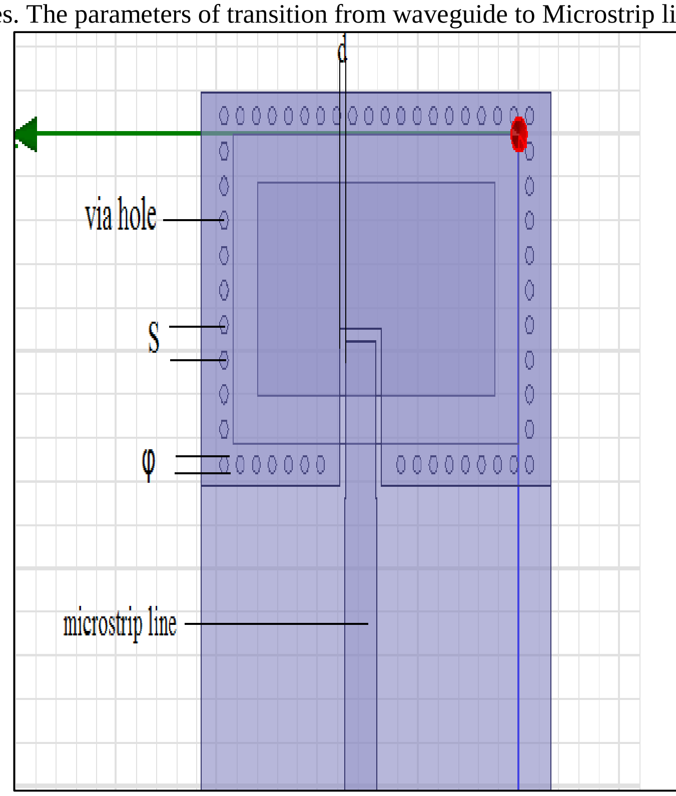

Fig. 1: Upper pattern of waveguide to Microstrip transition

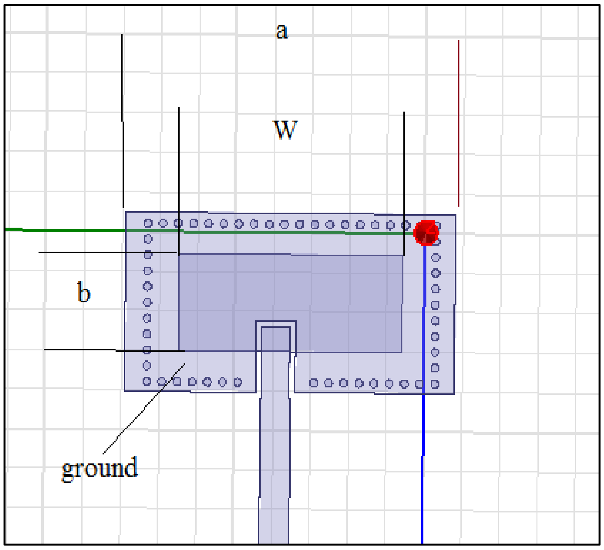

Fig. 2: Lower pattern of waveguide to Microstrip transition

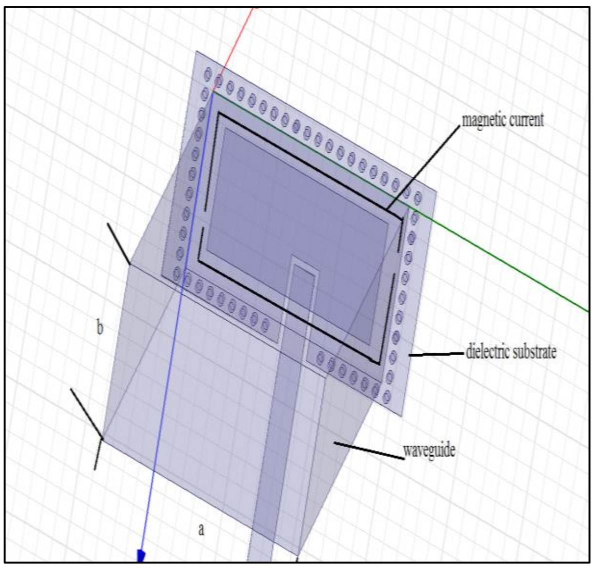

Fig. 3: Side view of waveguide to Microstrip transition

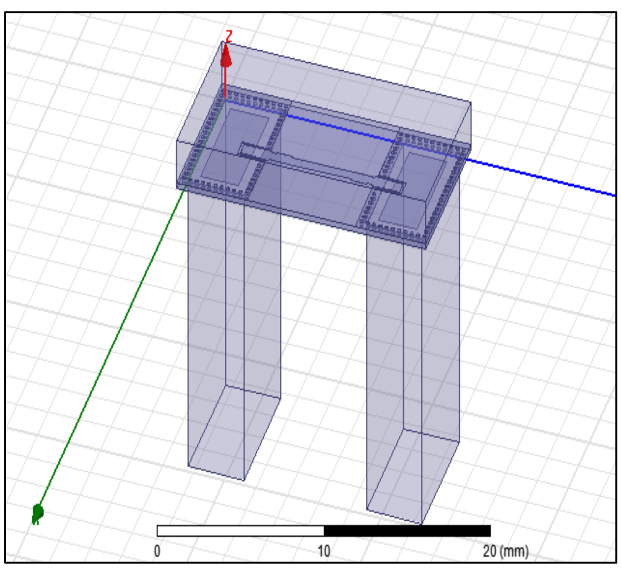

Fig. 4: Back-back Configuration of waveguide to Microstrip transition

The design frequency ranges from 34.5 GHz to 36 GHz.

Table - 1
Parameters of transition

Parameters	*Values*
Width W of patch element	*5.889 mm*
Length L of patch element	*2.45 mm*
Length ρ of inserted Microstrip lines	*1.8mm*
Width g of gaps	*0.1 mm*
Loss tangent of substrate	*0.0009*
Thickness of substrate h	*0.254 mm*
Relative permittivity ε	*2.2*
Broad wall length a of waveguide	*7.1 mm*
Narrow wall length b of waveguide	*3.56 mm*
Diameter φ of via holes	*0.2 mm*
Space S between via holes	*0.4 mm*

The mode conversion from waveguide to Microstrip line is achieved using the resonance of patch element. The dominant 〖TE〗_10 mode of waveguide is converted to Quasi-TEM mode of Microstrip lines, using dominant 〖TM〗_10 mode of patch element. The bandwidth of transition is limited by the resonance. Thus, the wideband design is led by analysis of resonance of patch element in the waveguide.

IV. SIMULATED RESULTS

The entire structure is designed using FEM based HFSS simulator. Transition structure was analyzed over the wide frequency band 34.5 to 36GHz. Simulated results for transition which are shown in figure.

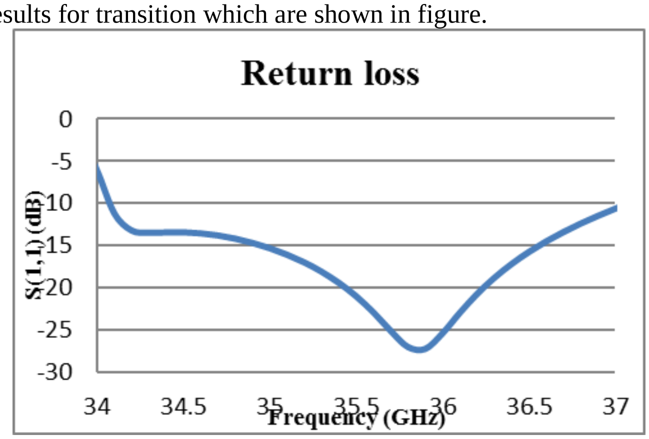

Fig. 6: Reflection characteristics |S11| for single waveguide to Microstrip transition

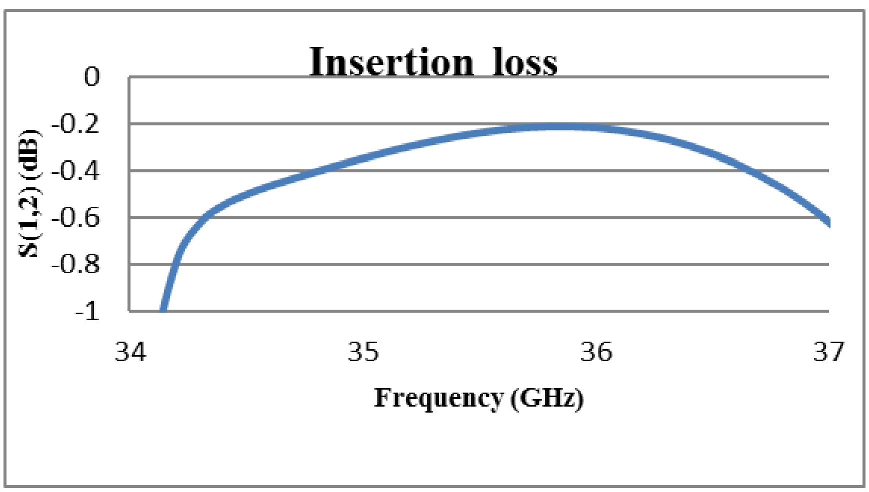

Fig. 7: Insertion loss |S21| for single waveguide to Microstrip transition

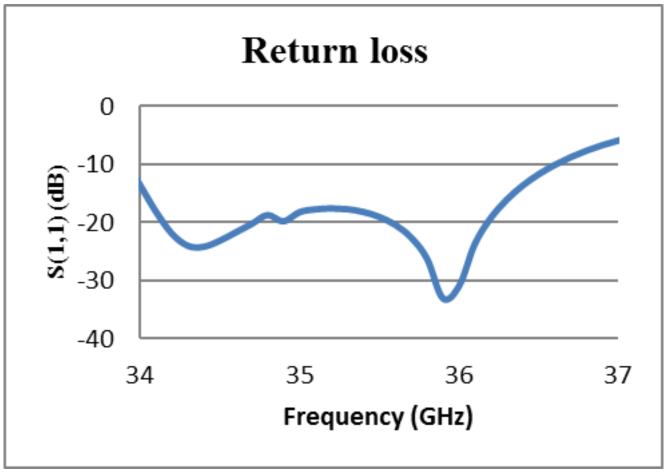

Fig. 8: Reflection characteristics |S11| for back-back configuration

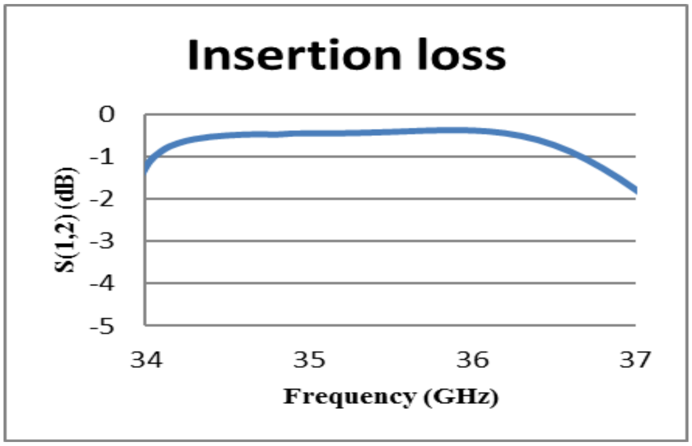

Fig. 9: Insertion loss |S21| for back-back configuration

V. CONCLUSION

In this paper, an aperture coupled waveguide to Microstrip transition is presented which is hermetically sealed which is basic advantage of using aperture coupled transition for space applications. Simulated results show that designed transition has minimum insertion loss of 0.37dB and return loss better than 15dB for back-back configuration over a frequency range of 34.5GHz to 36GHz.

REFERENCES

[1] Leong, Yoke-Choy, and Sander Weinreb. "Full band waveguide-to-microstrip probe transitions." In Microwave Symposium Digest, 1999 IEEE MTT-S International, vol. 4, pp. 1435-1438. IEEE, 1999.
[2] Kwon, Hyuk-Ja. "Waveguide to microstrip probe transition for Ka-band transceiver applications." In 2008 Asia-Pacific Microwave Conference. 2008.
[3] Li, Guo Mei, and Li Qing. "The design of Ka band waveguide-to-microstrip transition." In Computational Problem-Solving (ICCP), 2011 International Conference on, pp. 136-138. IEEE, 2011.
[4] Wu, Peng, Yong Zhang, Zhi Gang Wang, Shi Chun Sun, and Rui Min Xu. "Waveguide to microstrip probe transition for millimetre wave applications using LTCC technology." In Electromagnetic Compatibility (APEMC), 2010 Asia-Pacific Symposium on, pp. 1387-1389. IEEE, 2010.
[5] Ding, Yan, and Ke Wu. "Substrate integrated waveguide-to-microstrip transition in multilayer substrate." Microwave Theory and Techniques, IEEE Transactions on 55, no. 12 (2007): 2839-2844.Letters, IEEE 13, no. 7 (2003): 262-264.
[6] Kaneda, Noriaki, Yongxi Qian, and Tatsuo Itoh. "A broad-band microstrip-to-waveguide transition using quasi-Yagi antenna." Microwave Theory and Techniques, IEEE Transactions on 47, no. 12 (1999): 2562-2567.
[7] Deslandes, Dominic, and Ke Wu. "Integrated microstrip and rectangular waveguide in planar form." Microwave and Wireless Components Letters, IEEE 11, no. 2 (2001): 68-70.
[8] Svedin, Jan, Tony Pellikka, and Lars-Gunnar Huss. "A direct transition from microstrip to waveguide for millimeter-wave MMICs using LTCC." In Microwave Conference Proceedings (APMC), 2011 Asia-Pacific, pp. 102-105. IEEE, 2011.
[9] Lee, H. Y., D. S. Jun, S. E. Moon, E. K. Kim, J. H. Park, and K. H. Park. "Wideband aperture coupled stacked patch type microstrip to waveguide transition for V-band." In Microwave Conference, 2006. APMC 2006. Asia-Pacific, pp. 360-362. IEEE, 2006
[10] H. Iizuka, T. Watanabe, K. Sato, and K. Nishikawa, "Millimeter-wave
[11] microstrip line to waveguide transition fabricated on a single layer. dielectric substrate," IEICE Trans. Commun., vol. E85-B, no. 6, pp.1169–1177, Jun. 2002.
[12] Microwave Journel, June 2008, "Millimeter wave applications: From Satellite Communications to Security System."
[13] Seo, Kazuyuki, Kunio Sakakibara, and Nobuyoshi Kikuma. "Microstrip-to-waveguide transition using waveguide with large broad-wall in millimeter-wave band." In Ultra-Wideband (ICUWB), 2010 IEEE International Conference on, vol. 1, pp. 1-4. IEEE, 2010.