

Realization of Wide Band Waveguide Terminations at Ku-Band

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Abstract. The present paper describes the design and development of wide band matched waveguide terminations for high power (< 100 Watt) and low power (< 10 watts) applications at Ku-band. The WR-62 rectangular waveguide, lossy Eccosorb dielectric material and metallic short has been used to realize the termination. Two configurations of waveguide terminations i.e. conical tapered and wedge tapered have been developed using lossy dielectric. The waveguide termination has been simulated on full wave ANSYS's High-Frequency Structure Simulator. The developed waveguide terminations have voltage standing wave ratio less than 1.25 over the 12.5 to 15.5 GHz frequency band of the antenna.

Keywords: Microwave, reflection coefficient, waveguide termination.

1. Introduction

In microwave network, the unused ports should not be left open/short as it would introduce mismatch between ports and hence the VSWR of the circuit would be affected. The reflected signal from the open/short-circuited port interfere with the incident signal and standing wave is formed inside the microwave components. Standing wave causes the losses of RF signal in the circuit and hence it affects the overall efficiency of the microwave components. A waveguide termination is used to avoid the standing wave condition by absorbing the reflected wave completely.

Matched waveguide termination is a single port device, mostly used in Radio Frequency (RF) measurement systems and can be integrated with other waveguide components (such as a circulator, directional coupler, magic-tee etc.) in microwave communication system. Also in the multipoint antenna system, the inactive port should be terminated with match load to avoid its effect on the active port of antenna. The main function of waveguide termination is to completely absorb the RF power at end of the waveguide and minimize the reflection from the shorting end of the waveguide.

The development work of waveguide termination started in the mid-twentieth century. Presently several methods have been used for the design of matched termination such as inductive and capacitive iris, lossy dielectric load, tuning, and dissipative elements etc. [1–4]. Various type of microwave absorber, such as dielectric absorbers, magnetic absorbers, ferrites, and ferroelectrics have been used in the development of waveguide terminations. Selection of particular configuration and absorbing material depends on the amount of attenuation, power handling, and frequency of operation [5–8].

All of the above-said configurations have limitations in terms of a band of operation and power handling capability. Waveguide terminations or loads are preferred for high power applications. In waveguide termination the absorbing material absorbs the electromagnetic energy completely and dissipate in the surrounding. Generally, high power Termination is

used as a dummy load in high power system while low power termination is used for measurement purpose.

The present paper describes the design, simulation, optimization and development of a wideband high power and low power waveguide termination at Ku-Band frequency.

2. Design Approach

Waveguide termination consists of a standard rectangular waveguide, lossy resistive material, and a shorting metallic plate. Waveguides are selected based on the frequency of operation. For Ku-band frequency band, WR-62 standard rectangular waveguide (7.9 mm x 15.8 mm) has been selected. Selection of RF absorbing materials depends on the bandwidth requirement, amount of attenuation and power handling requirement.

A highly lossy material with a high dielectric constant is generally preferred for termination. ECCOSORB® MF-117 (magnetically loaded epoxy material with dielectric constant (ϵ_r) of 20.6, the complex permeability of $1+2j$ and dielectric loss tangent ($\tan \delta$) of 0.02 has been selected as RF absorbing material for both high power and low power waveguide termination[9]. The value of ϵ_r and loss tangent of this material vary slightly over the frequency band. It decreases with increase in frequency. The value of ϵ_r of the selected material is 21.0 at 10.GHz and 20.6 at 18 GHz. To reflect the remaining un-attenuated signal back into the dielectric material a shorting plate (having the ideally zero impedance) is used. Thus reflection of RF signal for dominant mode is minimized.

2.1. High power waveguide termination

For high power waveguide termination, the dielectric material should withstand high temperature. To minimize the reflection coefficient (S_{11}) caused by the mismatch (due to load in the waveguide) a wedge tapered lossy dielectric load is used in the waveguide. Wedges are placed inside a waveguide in such a way that its plane is perpendicular to the magnetic field of dominant mode. When the magnetic field line, intercepted by wedges, current is induced, it causes the

power loss of the RF signal. The lossy material does not act on the electric field of microwave signal since the electric field on the surface of the shorting plate is zero. However, it acts on the magnetic field to absorb the signal. Here, the maximum surface area of the lossy Ecosorb dielectric material remains in contact with the metallic wall of the waveguide.

Due to absorption of RF signal, heat is produced and is conducted into the metallic wall of the waveguide. Proper temperature management should be adapted to get the desired performance. The cooling mechanism such as cooling fan, forced air, and water cooling should be used to maintain the temperature of the waveguide according to wattage rating of waveguide termination. To minimize the breakdown of material at high power due to arcing, tapering of dielectric materials is done in the narrow wall of the waveguide where the electric field strength is almost negligible. Also, Wedges in waveguide creates reactance effects and produces higher order modes which need to be taken care.

2.2. Low power waveguide termination

ECCOSORB® MF-117 is also used to design a low power termination but the design changes. In this case, to absorb the RF power completely and minimizing the reflection coefficient a tapered conical shaped configuration of the dielectric material is used. Highly lossy dielectric conical rod is placed at the center of the E-field in the waveguide. The current induced in the conical rod is converted to heat energy by the high resistance of the dielectric material.

Horizontal tapering of rod towards the center is done to create a smooth impedance matching to the incoming RF wave. Reflection of the RF signal is further minimized by considering the tapered length more than two guided wavelength at the lowest frequency of operation. Detailed sketch of both terminations is shown in Figure 1. Here L1 is straight section length and L2 is the tapered length of the dielectric load. The total length of the lossy dielectric load is L1 + L2.

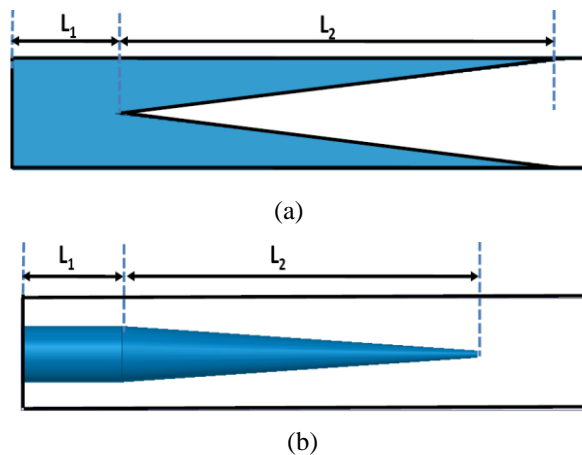


Fig. 1. Sketch of waveguide termination (a) High power (b) Low power

When taper length L2 is greater than a two guided wavelength at the lowest operating frequency, reflections are very small. The length L2 is selected in such a way that the

total loss through L1 and L2 is greater than 20 dB. Therefore 20 dB attenuation of the signal is achieved in the forward direction and back reflection of the signal from metallic wall further introduce 20 dB attenuation resulting in total attenuation of 40 dB. For analysis of both type of terminations, finite element method based on ANSYS's HFSS EM simulation tool has been used. 3D CAD model of high power & low power terminations are shown in Figure 2.

After modeling the terminations, simulation and optimization have been carried out for minimum reflection coefficient over the desired frequency band. The total length of Ecosorb material L1+ L2 has been taken as 100 mm. Effect of tapered length (L2) on the VSWR has been shown in Figure 3 and 4. From the figure, it is found that by decreasing the tapered length value of VSWR increases which corresponds to less absorption of the EM wave.

3. Fabrication & Results

In the case of high power termination, development of V-shaped load in a single piece is difficult due to tool radius. Hence for sharp V shape, the load is fabricated into two identical pieces of ECCOSORB material using a milling machine and fitted into the waveguide.

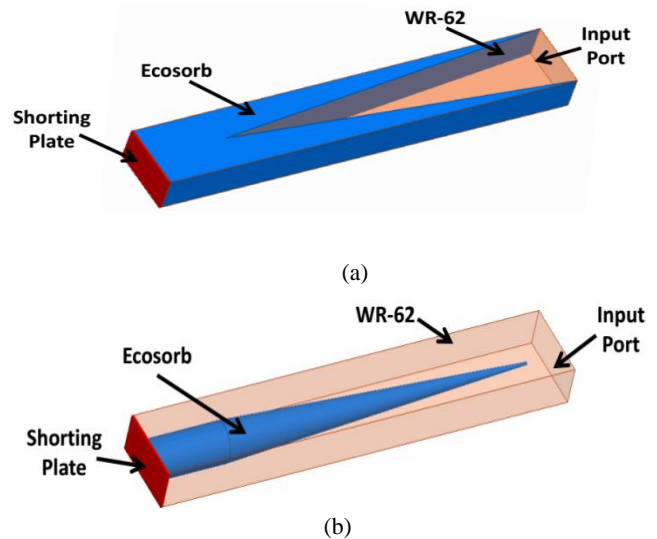


Fig. 2. 3-D CAD model of waveguide termination (a) High power (b) Low power

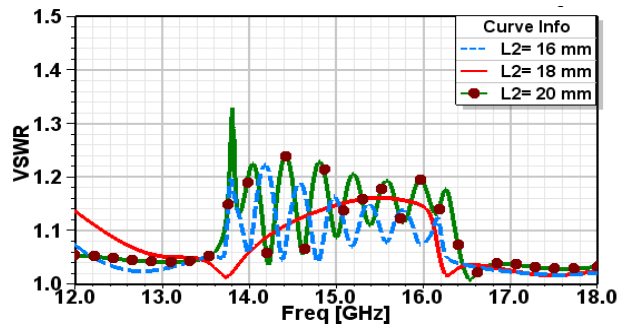


Fig. 3. Effect of taper length (L2) of the wedge on VSWR

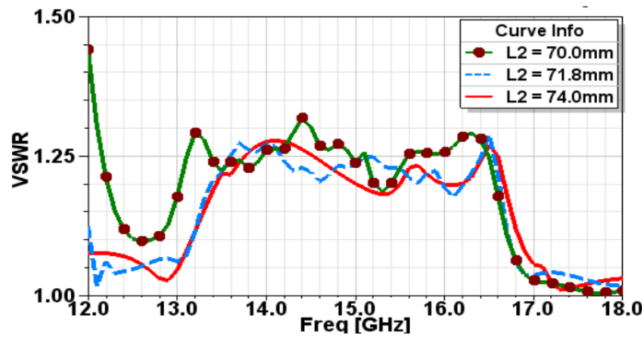


Fig. 4. Effect of conical taper length (L2) on VSWR

For low power application, a conically tapered load of same material has been fabricated on a lathe machine. The ECCOSORB material being hard and brittle in nature, hence carbide cutter is used for machining it. The photograph of fabricated Loads for both types of termination is shown in Figure 5.

A metallic short of aluminum has been developed for both types of termination which has been placed at the end of termination. The developed termination has UG 1655/U flange. The Developed waveguide termination is shown in Figure 6.

The evaluation of waveguide termination has been carried out using Agilent vector network analyzer. The measured VSWR of both terminations are shown in figure 7 & 8. The measured results are very close to simulated value. Some deviations in the measured results may be accorded to fabrication tolerance & measurement inaccuracy.



(a)



(b)

Fig. 5. Developed loads (a) High power (b) Low power



Fig. 6. Developed waveguide termination

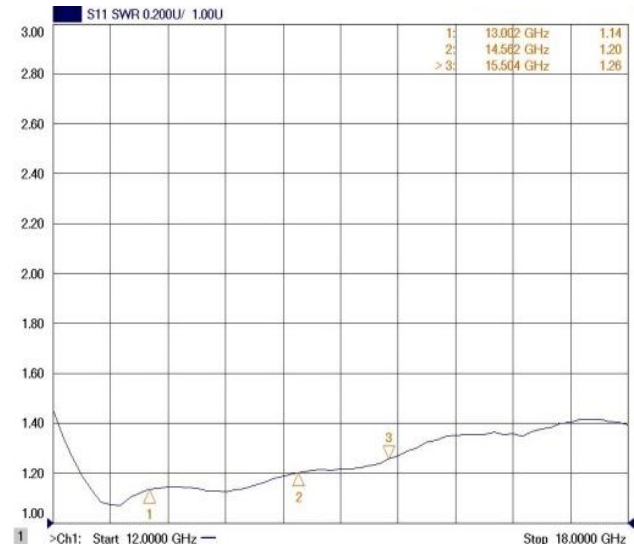


Fig. 7. Measured VSWR of high power W/G termination

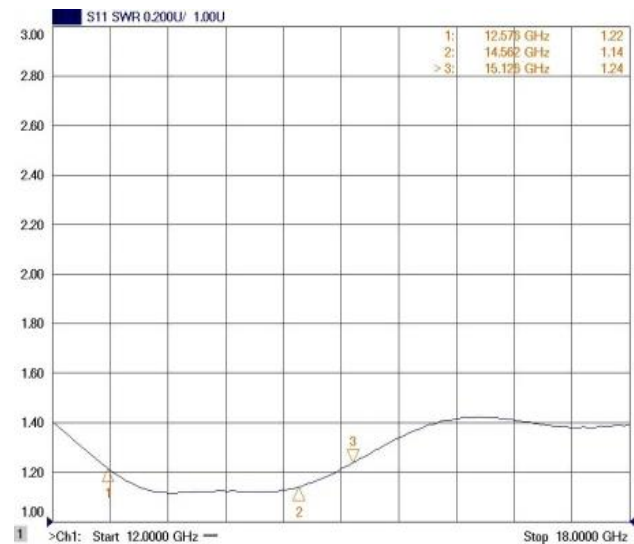


Fig. 8. Measured VSWR of low power W/G termination

4. Conclusion

A high power and low power waveguide termination have been designed, simulated, optimized and developed at Ku-Band frequency (12.0-18.0 GHz). The measured VSWR of both terminations are less than 1.25 over the frequency band 12.5 to 15.5 GHz. The developed waveguide termination may be used for terminating the inactive ports of waveguide components during measurement of the multiport antenna system. It may also be used while making a isolation from a circulator. The designed terminations can also be used with high power waveguide components.

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Biography of the authors

Pramendra Kumar Verma received his B. Tech. degree in Electronics Engineering from V.B.S.P.U., Jaunpur and M.E. degree in Microwave Engineering from J.E.C., Jabalpur. He has published more than twenty paper in International journals and IEEE conferences. His area of research includes design and development of microwave and mmwave antennas, slotted waveguide omni-directional antenna, conformal phased array antenna, reflector antenna, waveguide components etc. He is a member of ATMS society and a life member of IETE. He is also reveiwer of EuMA IJMWT, USA and IJAMT, India.



Raj Kumar obtained his M. E. degree in Microwave & Radar from the University of Roorkee (presently IIT Roorkee). He has published more than thirty papers in International journals and IEEE conferences. His areas of interest include the microwave and mm-wave antennas design including omni directional antenna, fan beam antenna, slotted array antenna, antenna for radiometry, microstrip antennas, design of waveguide filters, reflector antennas, horn antennas, conformal antennas, phased array antenna etc. He is fellow of ATMS Society.

