Design and Thermal simulation of the H-plane waveguide coupling for high power Ku Band Helix TWT

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Abstract

Due to broadband in nature and high power handling capability, helix TWT is the first choice for long distance communication purposes. This high output power was fed to the antenna through a waveguide coupling system. Therefore, design of the waveguide coupling system of the Helix TWT is very critical. In this paper, authors have presented the design of the H plane waveguide coupling for Ku band Helix TWT with capability to deliver output power of 300W. The design of the H plane waveguide coupling has been carried out in ANSYS HFSS. In addition, thermal simulation of the H plane waveguide coupling has been carried out for room and space environment temperatures using the ANSYS. The results of the HFSS simulation i.e. return loss characteristics and results of the thermal simulation i.e. temperature profile for the room & space environment temperature were presented in the paper.

1. Introduction

The long distance communication at high data rates demands use of high power high efficiency helix TWT. A schematic of TWT testing set up with the H plane waveguide coupling system is as shown in Fig. 1. A low

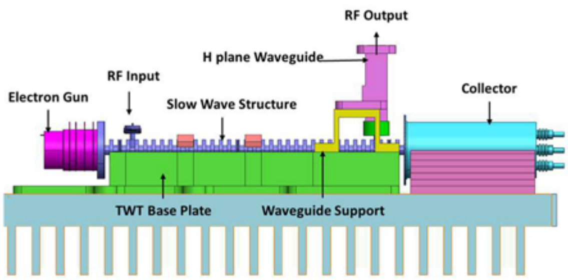

Figure 1. A TWT testing set up with H plane waveguide coupling

power RF signal is fed to the RF input section of the slow wave structure, the RF interaction happens between RF signal and DC beam. The amplified RF signal was extracted from last turn of the helix to waveguide coupling system. The waveguide coupling system is one of the most critical part of the helix TWT [1, 2, 7]. The function of the waveguide coupling system is to transfer amplified RF power from the helix end to the waveguide plumbing line [1-9]. To meet these requirements H plane waveguide coupling system has been designed for the Ku band frequency ranging from 10.5GHz to 12.5GHz with RF power handling capability of 300W. The cross section view of the H plane waveguide coupling system is as shown in Fig. 2. The H plane waveguide coupling system is divided in to two parts one is air region and another is vacuum region. H plane waveguide coupling has many advantages

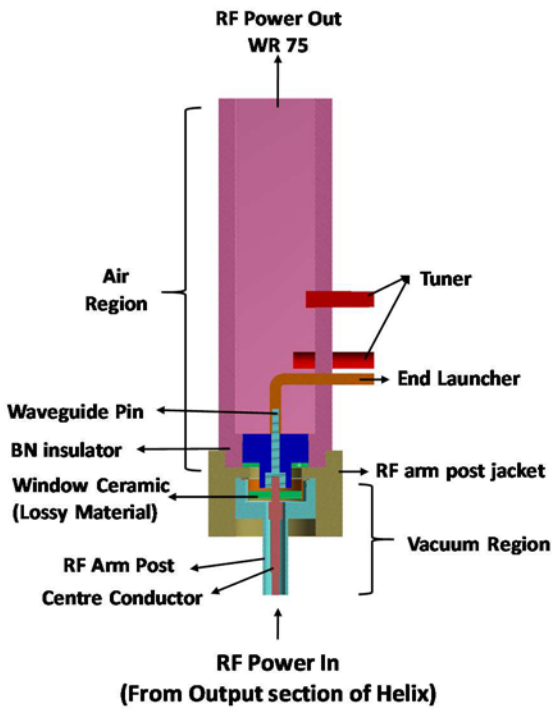

Figure 2. A cross section view of the H plane waveguide coupling

over E plane waveguide coupling like ease of fabrication, compact size, simplified design, lightweight, cost effective and simplified packaging design of the TWT. Hence, to overcome the limitations of the E plane waveguide coupling [2], in these paper authors have proposed the H plane waveguide coupling system. Moreover, the presented H plane waveguide coupling design has a tuning arrangement for tuning to desired operating frequency band.

2. HFSS Simulation and Result

The H plane waveguide coupling assembly has been modelled in ANSYS HFSS. The simulation set up of the H

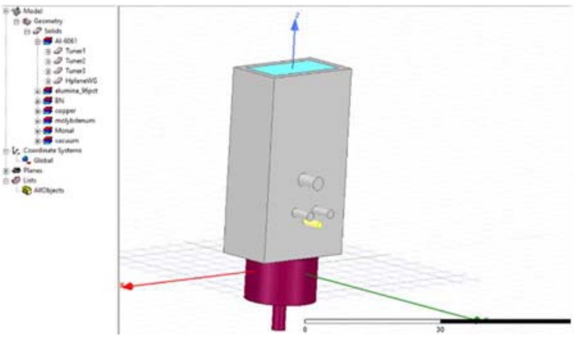

Figure 3. A simulation set up in the ANSYS HFSS

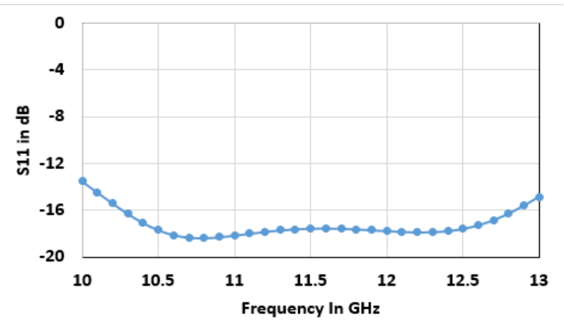

Figure 4. Plot for S11(dB) of H plane waveguide coupling assembly

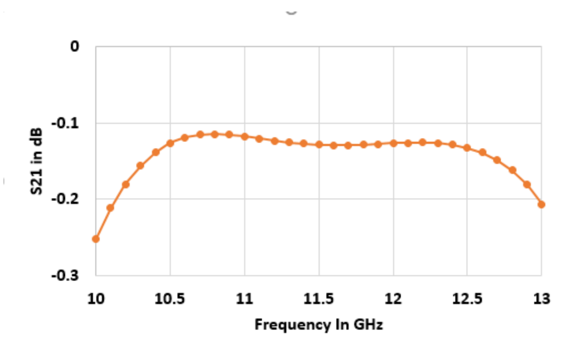

Figure 5. Plot for S21(dB) of H plane waveguide coupling assembly

plane waveguide coupling assembly is as shown in Fig. 3. Each component is made of different materials accordingly material property is applied. All the boundary conditions are applied in the HFSS to get the S11 and S21 characteristics of the H plane waveguide coupling assembly. The plot for the S11 is as shown in Fig. 4. The operating frequency band of TWT S11 is almost below -15dB. There are many design and simulation iterations carried out to improve S11. The plot for the S21 is as shown in the Fig 5.

3. Thermal Simulation and Result

A 3D design of the H plane waveguide coupling assembly

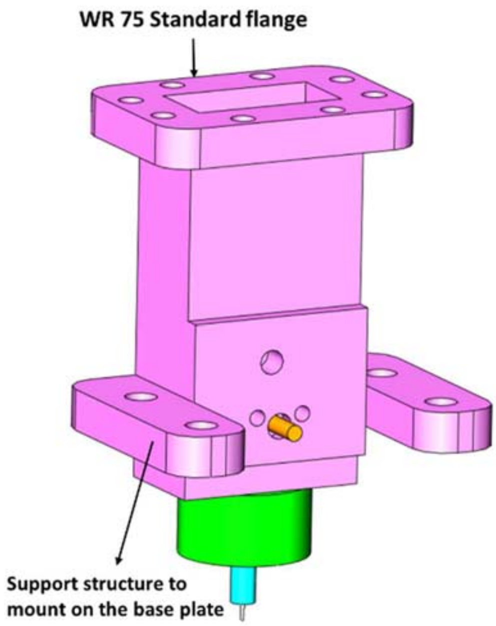

Figure 6. A 3D view of the H plane waveguide coupling assembly

with the support structure and WR 75 standard flange has been designed in the Solid Works as shown in Fig. 6. First, the H plane waveguide coupling assembly is simulated in

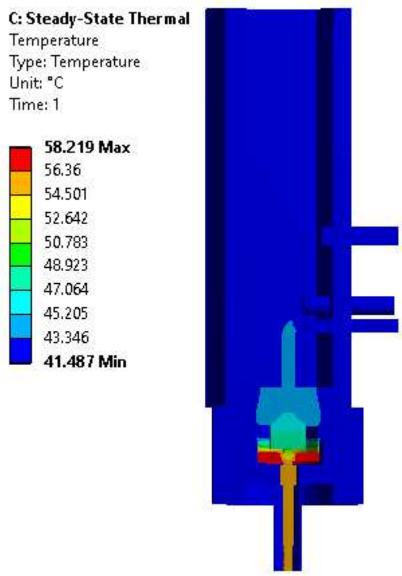

Figure 7. Temperature profile of the H plane waveguide coupling assembly under room temperature

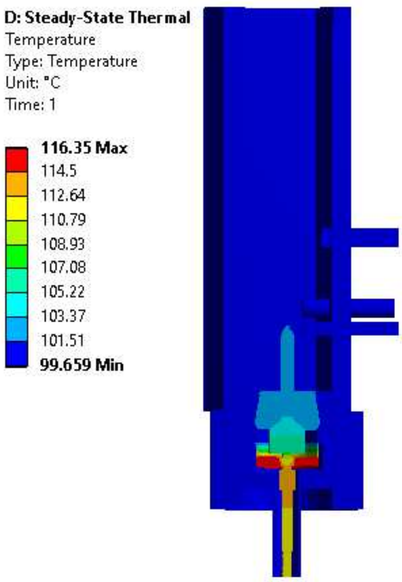

Figure 8. Temperature profile of the H plane waveguide coupling assembly under 85 ˚C environment temperature

the ANSYS HFSS for the return loss characteristics; later it was simulated in the ANSYS thermal module for the temperature profile. The heat loss in the window ceramic (lossy ceramic) due to 300 W RF power transition was estimated in the HFSS module and transferred to the thermal module of the ANSYS for thermal simulation. The temperature profile of the H plane waveguide coupling

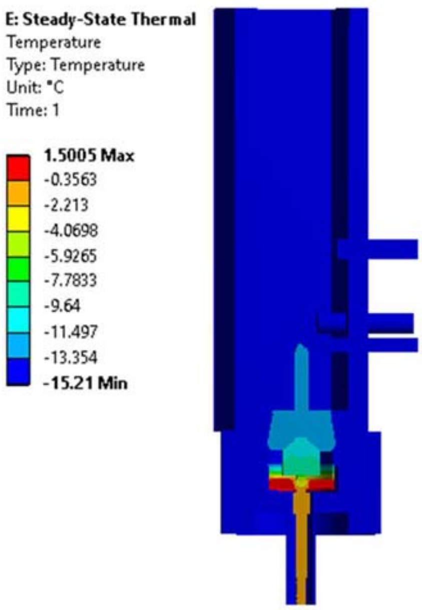

Figure 9. Temperature profile of the H plane waveguide coupling assembly under -40˚C environment temperature

assembly under room temperature is as shown in the figure 7. The maximum temperature of ~58.21 ˚C is at the lossy material and minimum at ~41.48 ˚C. However, Helix TWT has to face stringent requirements to operate in a space environment for its space application. Space TWT has to face extreme space temperatures of 85˚C and -40 ˚C. Hence, H plane waveguide coupling assembly is simulated for the space environmental temperatures. The temperature profile of the H plane waveguide coupling assembly under 85 ˚C environment temperature is as shown in the figure 8. In these conditions. Maximum temperature is ~116.35 ˚C and minimum temperature is ~99.65 ˚C. The temperature profile of the H plane waveguide coupling assembly under -40˚C environment temperature is as shown in the figure 9. In these conditions. Maximum temperature is ~1.5 ˚C and minimum temperature is ~-15.21 ˚C. However, in all environmental temperature cases maximum temperature is well below the limiting temperature of 200 ˚C. Therefore, the preset design of the H plane waveguide coupling assembly is capable of handling output power of 300W.

4. The fabricated H plane waveguide

Figure 10. The fabricated H plane waveguide with tuner

The fabricated H plane waveguide is as shown in the figure 10. It is made of AL-6061 material to make it lighter.

5. Conclusion

The proposed H plane waveguide coupling design has many advantages over conventional E plane waveguide coupling like ease of fabrication, compact size, simplified design, lightweight, cost effective and simplified packaging design of the TWT. The design and simulation of the H plane waveguide coupling assembly has been carried out successfully using the ANSYS HFSS. The thermal simulation results of the H plane waveguide coupling assembly suggest that the presented design is capable of handling output power of 300W. In addition, maximum temperatures under different environmental temperatures are well below the limiting temperature of the material. Therefore, the proposed design of the H plane waveguide coupling assembly will improve the overall performance of the helix TWT. The tuning arrangement makes it more convenient when TWT has to operate at particular sub bands of the operating frequency band.

6. Acknowledgements

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