Thermal Analysis of The Slow Wave Structure (SWS) Assembly of The Travelling Wave Tube

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***Abstract*—Thermal management of helix slow-wave structure (SWS) in a traveling-wave tube (TWT) has great influence on its performance namely, average power handling capability, TWT efficiency, S-parameters, etc. The main source of thermal load of helix SWS is the intercepted power loss, which is assumed to be uniform over the TWT and as a measure of helix interception current during DC or RF testing. However, practically intercepted power loss would be different in different sections of TWT. Typically, it is higher in output section than input section due to growth of signal. In this paper, thermal analysis of helix SWS has been presented for three different cases namely, uniform heating, non-uniform heating and localized heating respectively and corresponding temperature distribution in different section of the SWS have been estimated using ANSYS.**

Keywords*—Thermal analysis, Slow-wave structure, Heat load, TWT

I. Introduction

High power, high efficiency, wideband helix TWTs are the most desirable power amplifiers used in satellite communication. Thermal management of space TWT always remain a constrain as it has direct relevance to the mass of the packaged TWT, reliability and performance. The slow wave structure of a TWT, comprises of input helix, output helix, dielectric supports and barrel envelope (with PPM). It is too sensitive to efficient thermal management with respect to performance, average power handling capability, S-parameters, efficiency, etc. [1]. This problem is aggravated when the structure transverse dimensions become comparable to wavelength at high frequencies. Thus, to efficiently handle these heat load, on board TWT base plate is connected to the heat pipe for active cooling and to maintain constant temperature [2].

During transportation of electron beam through the interaction structure, some of the electrons defocused and strike the helix and these phenomena is more pronounced at output helix where the RF signal grows to saturation or the beam lose their energy. Moreover, during optimization of the periodic permanent magnet (PPM) focusing structure, electron beam partially heats the helix forming hot spot. In this paper, these phenomena have been emphasized and presented for a TWT in which measured intercepted power is 11.8 W in saturation [3]. However, for simulation 12 W dissipated power has been taken for three different cases, uniform, non-uniform and localized heating, respectively and temperature at different structure regions have been estimated using ANSYS [4].

II. Thermal Simulation

The geometry of the SWS (Fig. 1) under study, modelled in the solid Works [5] and imported in the ANSYS for the thermal analysis, comprises of dissimilar materials having dissimilar thermal properties (Table-1). The structure has been analyzed for the three different cases: 1) uniform heat load of 12W on the helix, 2) non-uniform heat load of 2W at input helix and 10W at the output helix and 3) a local heating in the last 6 turns of the output helix with 4 W heat load, respectively.

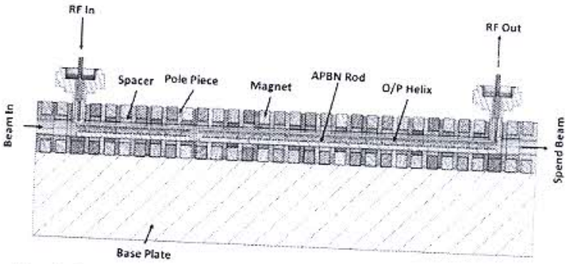

Fig. 1 A cross-section view of the SWS assembly with base plate

For analysis, heat load is applied on the inner surface of the helix. The heat transfer from, helix to dielectric support rod, dielectric support rod to barrel and barrel to magnets takes place through conduction. The heat loss to the environment takes place due to the forced convection and radiation. The base plate of the TWT is connected to the heat pipe for active cooling on the satellite panel to maintain constant temperature [2]. Thus, appropriate convective heat transfer coefficient is applied on the bottom surface of the base plate.

TABLE I. Thermal Properties Of Different Materials Used In Thermal Analysis

Sr. No.	*Part Name*	*Material*	*Thermal conductivity(W/mK)*
1	Pole piece	Soft Iron	80.4
2	Spacer	Monel	21
3	Magnet	Sm Co_5	10.5
4	Base plate	Al	167
5	Helix	W-Re	173
6	Support road	APBN	60
7	Coupler	Moly	138

III. Results and Summary

The temperature profile of the SWS assembly is as shown in the figure 2 for the uniform heat flux case. It can be seen that maximum helix temperature is ~40 °C and minimum temperature is ~34 °C. It is observed from the simulation that peak temperature value is same for both uniform heat load and non-uniform heat load, but output barrel has high thermal gradient compared to input barrel (figure 3). The maximum helix temperature of ~52 °C is observed in case of the local heating as shown in the figure 4.

Fig. 2 Temperature profile of SWS for the uniform heat load

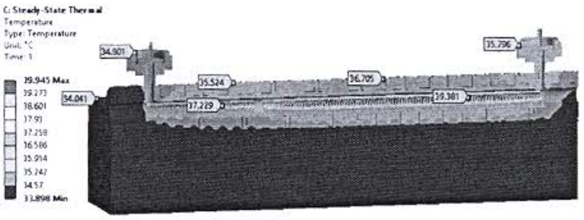

Fig. 3 Temperature profile of SWS for the non-uniform heat load

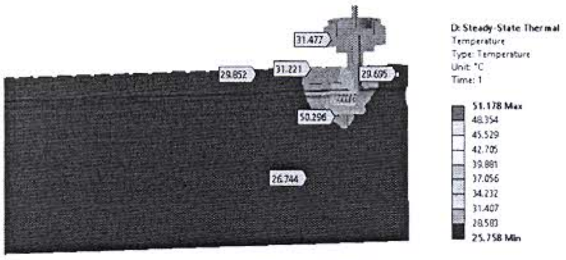

Fig. 4 Temperature profile of SWS for local heating

Practically, it has been observed that input barrel temperature remains < 40 ^{0}C and output barrel temperature remains < 50 ^{0}C in all cases and agreeing closely with the simulated results.

IV. Conclusion

The paper presents, a thermal analysis of the SWS under practical situations. It has been estimated that ~12W of power has to be dissipated in the SWS by both the energy balance principal and testing results. The maximum helix temperature of ~52 °C and barrel temperature of ~ 45 °C has estimated for the local heating case. However, during the testing of TWT it has been observed that barrel temperature is < 50 °C. Therefore, simulation results are complying with the TWT testing results for the worst load case scenario.

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