DC Analysis of Space Traveling Wave Tube

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Abstract

The electron trajectory, from electron gun to collector through helix, of traveling wave tube (TWT) with magnetic field in DC condition is analyzed. The electron beam from cathode in the electron gun is confined by the PPM focusing structure and traversed helix in the RF section and collected in the collector. This paper presents complete DC simulation of a TWT and minimization of helix interception current by optimizing magnetic field as well as with secondary emission in collector using OPERA simulation software.

1. Introduction

TWT amplifier used in satellite communication, demands for very high efficiency. Helix interception current is one of the critical element affecting TWT efficiency and performance. To ensure laminar and confined flow of electron beam through RF section, DC characteristics of tube is essential to optimize focusing structure to ensure very good beam transmission before RF signal is applied. This helps in optimizing focusing structure and which can easily be re-optimized, if necessary, with a little effort when amplification occurs. As beam traverse helix in RF section, some of electrons gets de-focused due to space-charge effect and intercept helix thereby giving helix interception current. Moreover, due to periodicity of the focusing structure and also due to space charge forces, the beam scallop about mean position [1]. In conventional TWT design, electron gun, focusing structure and collector are designed and simulated independently in different softwares. In collector as beam strikes, could be a multi staged depressed collector, secondary electron are emitted and causing back-steaming of electrons, which in turn enhances helix interception current. With these individual design of subsections, it become cumbersome to analyse the effect of space charge forces, magnetic focusing and back streaming on interception current. So, it becomes noteworthy to simulate and analyse complete TWT in DC condition, to get clear-cut picture of interception. Helix interception current has direct relevance with the efficiency, performance of the TWT. In this paper, complete DC analysis, using OPERA [2], of a TWT is carried out [3] and presented to minimize helix interception current without simulation of individual subassemblies, as done conventionally in designing a TWT using other commercial software packages.

2. DC Analysis

Electron gun is modeled in Opera software for required beam optics with a set of electrodes and potentials. The electron beam emitted from the cathode follows the universal beam spread curve, and starts to diverge due to space charge forces.To traverse the electron beam in RF interaction structure and collect in the collector, PPM focusing is applied. To maintainminimum scalloping and to get required beam diameter/filling factor, PPM focusing is optimized. The model of electron gunwith PPM focusing and electron trajectory are shown in Fig. 1 and Fig. 2, respectively.

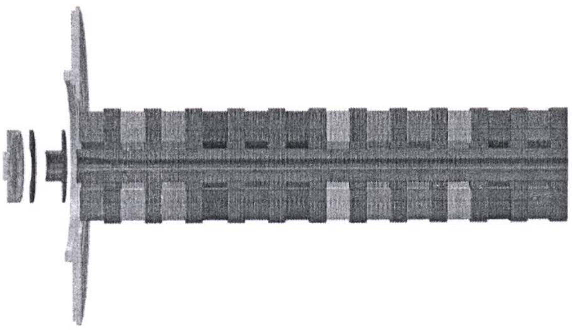

Figure 1. Electron gun with PPM focusing structure.

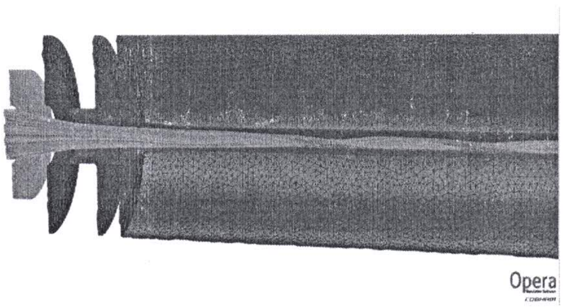

Figure 2. Electron beam trajectory in presence of magnetic field.

For DC analysis, combined simulation of electron gun, RF section and collector have been carried out. As electron beam traverses RF section, electrons may intercept the helix to give rise of interception current. To reduce interception and to achieve required beam diameter magnetic field has been optimized, but large magnetic field will reduce the output power [4]. The DC model of TWT, including RF section and collector is shown in Figure 3.

As the electron beam hits the collector electrodes, secondary emission electrons would be generated and these travel back in the RF section and contribute to body current. So, leakage magnetic field profile in collector and its electrode potentials have been optimized such that to get minimum back streaming electrons and hence helix interception. Beam trajectory in helix and secondary emission in collector is shown in Figure 4 and Figure 5 respectively as part of full tube DC simulation.

Figure 3. DC model of TWT

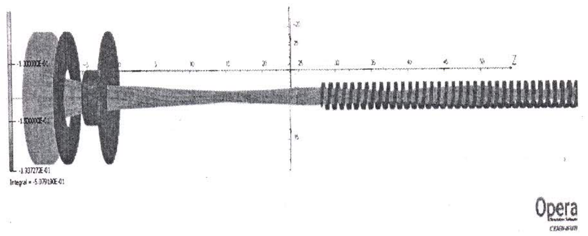

Figure 4. Electron beam trajectory in helix.

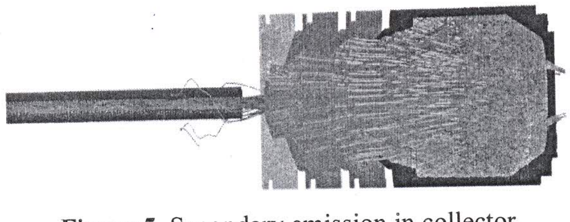

Figure 5. Secondary emission in collector.

In this optimized DC analysis, the total interception current from all effects is 1.6 mA for the beam current of 141.09 mA.

3. Conclusion

In this paper complete DC analysis of helix TWT has been studied to get minimum helix interception current by optimizing magnetic field profile and suppressing secondary electron by adjusting leakage magnetic flux in collector and presented. Minimum body current, beam radius and less scalloping with reduced secondary emission is obtained.

4. Acknowledgements

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5. References

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