Research on Vacuum Test of Sealed TWT

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Abstract: *Vacuum is an important parameter which is related to TWTs' long term operation and reliability. Vacuum deteriorate rate in tuning, vibration, thermal and vacuum thermal tests can be used to evaluate a TWT's functional quality in a short-term way. By using TWT electrodes and cathode, an ion current test system is applied to scale vacuum status. After calibration, ion current and vacuum are matched in pairs. We tested a TWT's vacuum over a long term of tuning and environmental tests.*

Keywords: vacuum; TWT; reliability

Introduction

As a typical vacuum electronic device, Traveling wave tubes (TWTs) amplify microwave by electron-wave energy transfer, where electrons experience acceleration, bunching, energy transferring and recovering. During the whole life span of electrons, electrons colliding with electrodes or residual gases may stop beam-wave interaction process and influence microwave output signals in amplitude or phase. Research[1] shows that electron-gas collision may cause ion noise increasing, microwave phase shift and electrodes arc discharge. Maintaining high vacuum is crucial to TWTs for high reliability and long-life operation.

The vacuum is easily to be achieved and measured during manufacturing by using vacuum meter installed in pumping systems. TWTs are of 10^{-7}Pa vacuum when separated from pumping system, which has been proved enough for TWTs space application. But the deterioration rates of vacuum in TWTs tuning, vibration tests and thermal tests periods are hard to test. The change rate is a parameter for direct and fast reliability assessment. It is helpful for eliminating functional reduction TWTs caused by long term vacuum deteriorate.

In this paper, we introduced a test system for vacuum test after TWTs separated from pumping system. Ion current is applied to represent vacuum after calibration. The vacuum are tested when TWT experienced tuning, vibration, thermal and vacuum thermal tests.

Test system

The test system is consist of three DC power suppliers, mA-level ampere meter and pA-level ampere meter. The electrodes used in vacuum test are cathode and two anodes in TWT gun region.

Cathode is used as electron source and provides certain number of electrons for electrons and gases collides. A DC voltage U_f is applied to filament and cathode which heated cathode to work temperature. It is the same as the TWT normal operation parameters.

The 1st anode is also electron accelerating electrode, and employed as electron collection electrode as well. The voltage U_{A1} is determined by total number of electrons captured by the first anode, generally set electron current I_{A1} to be 1mA, for the sake of enough electrons take part in colliding and less deteriorate of local vacuum in cathode area.

The 2nd anode is set to be positive ion collector. The electric field between two anodes should make sure that electrons are reflected to the first anode. The ion current I_{A2}

is proportional to vacuum as below:

$$I_{A2} = kI_{A1}P$$

where P is the local vacuum in Pascal and k is a pressure coefficient.

The electric field of electron gun is plotted in Figure 1. The DC power suppliers applied on 1st anode is positive and 2nd anode negative. The trajectories of electrons are displayed in Figure 2. Electrons are filled up in decelerate region to ensure adequate electron-gas collision.

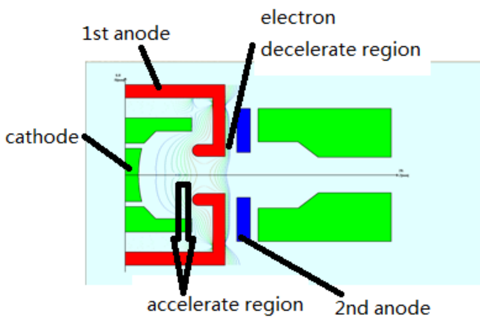

Figure 1. Distribute of electric field in electron gun region

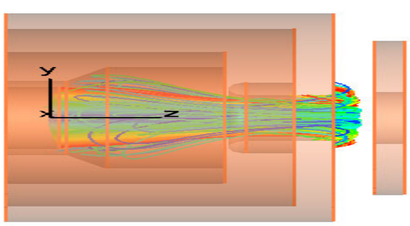

Figure 2. Electron trajectory in vacuum test

Considering ion current is of nA level, the current test is sensitive to electric-magnetic field filled in environmental and inter-modulate of three power suppliers. The vacuum test system is installed in a shielded room of -60dBc shielding ratio over wide frequency range. The power suppliers are isolated to each other of -50dBc. Test results show that ion current stability is of 0.01nA level.

Test results

A Ku band TWT is tested under parameters as listed in table 1. Electrons emitted from cathode are 1.037mA. As filament heated to work temperature, the number of ions increases with electrons tills a steady level of 0.58nA. The electrons and ions variation process are plotted in Figure 3. In some other TWTs, there exist a peak ion-current when electrons emitted from cathode, for the reason of low local vacuum in the gun region. After a short term operation, gases are reabsorbed by internal material surface and the vacuum maintains a steady state.

Table 1. TWT operation parameters in vacuum test

Uf(V)	UA1(V)	IA1(V)	UA2(V)
4.38	201.1	1.037	-201.3

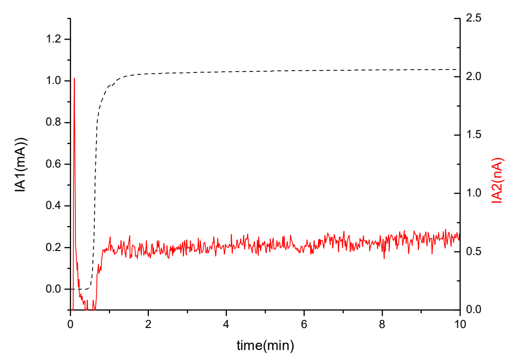

Figure 3. Typical variation process of ions and electrons current over operating time

Conclusion

The vacuum of TWTs sealed from pumping system is tested by using an ion-current test system, on the condition of calibration of relations between ion-current and vacuum. By tracing TWT vacuum over whole operation phases, we can find a proper way to evaluate reliability and long-lifespan requirement of a TWT.

References

1. Wallace M. Manheimer, "On the Theory of Ion Noise in Microwave Tubes", IEEE Transactions on Plasma Science, Vol. 27, No. 4, August 1999, pp 1146-1163.