Attenuation Measurement of Lossy Coatings of Carbon for Ka-Band Helix TWT Applications

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ABSTRACT

In a high efficiency traveling wave tube (TWT) amplifier, any reflections present in the device may cause oscillations and hence instability. A coating of lossy material on appropriate parts of the tubes (known as attenuators) is done to suppress these reflections. Carbon is a very commonly used material for this type of coating, and may be deposited by a number of techniques. In the present work, coatings of carbon were done on the dielectric substrate and evaluated for the attenuation performance at microwave frequencies. Three dielectric rods (APBN material) were coated with carbon by pyrolytic deposition method for different thickness. An experimental setup involving a rectangular wave-guide with a hole has been used for measuring the attenuation of the coated rods in the Ka-band frequency range. The same structure has been simulated using the Ansoft High Frequency Simulator (HFSS) and both the experimental and simulated results have been compared.

KEYWORDS

Attenuation Measurement, Carbon, Microwave Measurement, TWT

1. INTRODUCTION

Traveling wave tube (TWT) (Gilmour, 1994; Basu, 1996; Gittins, 1965; Minenna, 2019) as shown in Figure 1 is an ultra-high vacuum device, which is used as a high gain (gain > 50dB) and broad band (bandwidth up to 2 octaves) microwave amplifier. The applications include both commercial and military communication systems. Major components of a TWT are: Electron Gun, Slow Wave Structure, PPM focusing system, Input / Output couplers and the multi-stage depressed Collector for collecting the spent beam. In a TWT, RF wave amplification takes place when the electron beam velocity is nearly equal to the phase velocity of the traveling RF wave. A special type of RF structure is employed for slowing down the axial velocity of the RF wave for its interaction with the electron beam. This structure is known as the slow wave structure (SWS). Helix, made from the metallic tape or wire is a commonly used structure as SWS for wide-band and moderate output power (up to 1 KW). However, Coupled-cavity type slow-wave structure employing metallic cavities coupled to each other is used in the high-power tubes.

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Reflections (Wallander, 1972; Goebel et al., 1999) are common in the TWTs due to impedance mismatch problems and these reflections cause instability (Antonsen et al., 2002) in the device by producing oscillations (Alaria & Ghosh, 2019). Reflections occur, if there is an impedance mismatch either at input/output terminations or at any other interface because of loss or pitch variation along SWS. Some amount of power is reflected back from the output due to mismatch through the slow wave structure. If there is a mismatch at the input also, a portion of the signal will be reflected back towards the output and this may lead to oscillations caused by feedback signal when the following condition is satisfied:

\[
(G - L - R_\text{i} - R_\text{o}) > 0
\]

(1)

where:

- \(G\) = Gain of the device in dB
- \(L\) = Cold loss in dB
- \(R_\text{i}\) = Reflection coefficient at input end in dB
- \(R_\text{o}\) = Reflection coefficient at output end in dB

In order to avoid the problem of reflections, the slow wave structure uses severs and attenuators (Kumar et al., 2007). In TWT, helix is supported by three dielectric rods normally of APBN (Anisotropic Pyrolytically deposited Boron Nitride), which is a ceramic with high thermal conductivity (Wang et al., 2018). With the attenuator material coating, the helix support rods act as attenuators and are used to suppress the reflections. Such types of attenuators are highly beneficial to suppress the reflections and hence help in improving the stability of the device to large extent (Kumar et al., 2008, Kumar et al., 2007). Helix with support rods having attenuator coating is shown in Figure 2.

### 2. CARBON COATING

Three rectangular rods of APBN (60 \(\times\) 1.5 mm) were coated with carbon using the pyrolytic deposition method (Paik, 1964). This is the most widely used technique for making attenuators for high gain helix TWTs using hydrocarbons like heptane, benzene etc. In this method, the heptane gas is introduced in an evacuated chamber containing support rods surrounded by molybdenum heating coil. At elevated temperatures (around 850 °C) the hydrocarbon cracks as a result of thermal decomposition of the organic material and carbon gets deposited on the rods. Using this method, the rods were coated
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