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Transmitter microdischarges in communications and broadcast Satellites

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ABSTRACT

Most commercial communications and broadcast satellites operating at microwave radio frequencies use traveling wave tube amplifiers (TWTAs) as high power transmitters. Since TWTAs work at high voltages, it is not uncommon to experience micro-discharges, especially early in life. This observation led to the introduction of an autonomous restart function in the companion high voltage power supply (the electronic power conditioner or EPC) of the TWTA as a safety feature. A microdischarge with enough energy above a threshold would lead to a momentary removal of high voltages, followed by an automatic restart, which is usually sufficient to allow the microdischarge event to clear with minimal loss of RF transmission. In most cases the energy involved in the microdischarge is low enough that the removal of high voltages is not required and the event may go undetected.

However, an unusual signature was first noted in early 1997 on a Ku-band satellite transmitter, where the characteristics of the microdischarge event were such that the control anode voltage dropped below nominal and typically recovered over a 20 min period. Such microdischarge events became known as the "20 min Effect" which has since been observed over subsequent years on other Ku-band TWTAs, as well as on Ka-band and S-band satellite TWTA transmitters in numerous satellites.

This paper summarizes the in-orbit data on such microdischarges as well as the believed cause. In addition, the paper includes results from three S-band TWTAs which have operated on life test for many years. Due to ease of their monitoring instrumentation as contrast to monitoring microdischarges on orbiting operational satellites via telemetry, new data have been accumulated on this effect. The data substantiate the previous findings that microdischarges do not significantly affect satellite operation or their transmissions nor diminish the TWTAs performance, including long lifetime.

Contents

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1. Introduction

1.1. Communications/broadcast satellites

There have been many hundreds of commercial communications and broadcast satellites placed in orbit over the last two decades to provide a wide range of services. Characteristically the satellites need to radiate high EIRP (Effective Isotropic Radiated Power) over their service area(s) to provide the needed transmission capacity with the required signal quality and availability. The frequency bands typically used are the L-, S-, C-, Ku- and Ka-, although herein only the S-, Ku- and Ka-bands will be discussed.

To generate the high EIRP, transmitters are employed with output power in the range of 45 to 260 W per transmitter. Higher powers can be obtained by combining multiple transmitters. The high power amplifier most commonly used is the Traveling Wave Tube Amplifier (TWTA), with many thousands operating with high reliability (Ref. [4]). The TWTA is composed of a TWT (Traveling Wave Tube) and its associated EPC (Electronic Power Conditioner), as described in Ref. [1], Pages 6–8. Figs. 1–3 (taken from Figs. 2–4 from that Reference) show a TWTA, a block diagram of the TWT and a block diagram of the EPC.

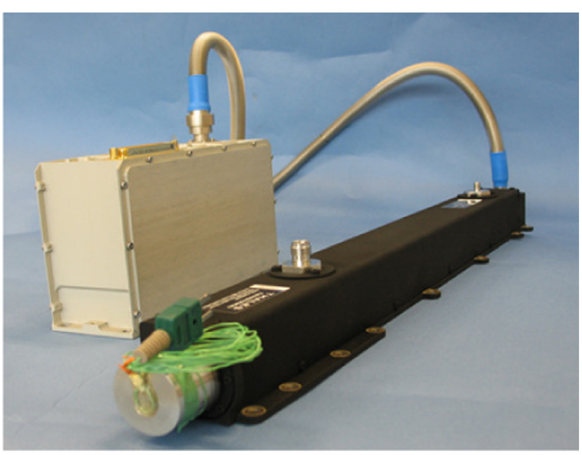

Fig. 1. S-band TWTA.

1.2. High voltage microdischarges

The TWTAs under consideration are similar at the various frequency bands with the main difference being sizing and spacing of the components to accommodate the different wavelengths. They have been the workhorse for transmitters in almost all communications and broadcast satellites over the last two decades due to their ability to generate high radio frequency power with good efficiency over long lifetimes, typically 15–20 years. To accomplish this efficient operation, the TWT requires high DC voltages. This raises the possibility for infrequent high voltage discharges which led to the introduction into the EPC of an autonomous restart function. Essentially a discharge with enough energy above a threshold would lead to a momentary loss of the high voltages followed by the automatic restart sufficient to allow the event to clear with minimal loss of radio frequency transmission. In the most extreme cases the energy is high enough to lead to a complete switch off (known as a "Spurious Switch Off," or SSO). However, for most microdischarges, the energy is low enough that removal of the high voltages is not required. The normal telemetry in most commercial communications and broadcast satellites may not record such events since they are short and the TWTA telemetry is not generally sufficient for thorough analysis of such effects.

2. Microdischarge determination

2.1. Effect occurrence

The first reported microdischarge of this nature was in January

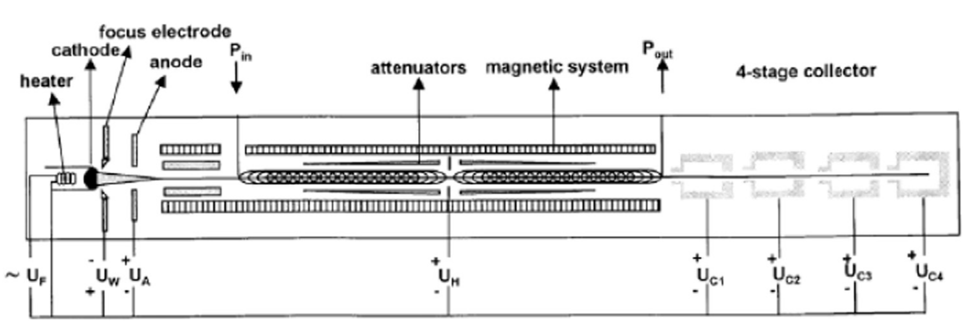

Fig. 2. TWT Block Diagram.