Total Dose Test Report for GaN X-Band Amplifier

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I. Introduction

The purpose of this test was to determine the susceptibility to total ionizing radiation dose (TID) of a GaN-HEMT based X-band amplifier. GaN devices had previously been tested for TID damage, and the DC characteristics had been shown to be stable to very high doses. But the TID effect on the RF characteristics had not been reported.

II. AlGaN/GaN HEMT Devices Tested

The AlGaN/GaN HEMT-based hybrid test amplifiers were designed and developed at the Wright Site of Air Force Research Laboratory. The AFRL/SND-fabricated transistors were processed on commercial gallium nitride epitaxy grown on SiC substrates. The Metal Organic Chemical Vapor Deposition (MOCVD)-grown structure consisted of an AlGaN barrier layer on an unintentionally doped GaN buffer layer. The amplifier utilized a 0.3 micron gate-length, 150 micron gate-width, two-finger, T-gate, silicon nitride-passivated AlGaN/GaN HEMT, with total gate periphery of 300 microns. The device structure of the AFRL-fabricated 2 X 150 micron AlGaN/GaN HEMT was similar to that reported in [1]. Input and output impedance matching for the amplifiers was accomplished on alumina substrates. The transistors were die-attached onto copper tungsten carriers with a high thermal conductivity epoxy, and the alumina matching networks mounted with indium lead solder. For dc and microwave characterization purposes, the amplifier assembly was considered to be the Wiltron Universal Test Fixtured-hybrid amplifier assembly. The AFRL/SND-designed hybrid GaN power amplifiers were representative GaN technology test vehicles, with 3-4 W/mm 10 GHz power densities, simultaneously with >35% power-added efficiency and ~6.5 dB power gain, at a 20-volt drain bias.

III. Test Facility

Testing was at the Co-60 facility at GSFC, which is a room air source, where the pencils are raised up out of the floor, during exposures. Active dosimetry is performed, using air ionization probes. Testing is done in a step/stress manner, using a standard Pb/Al filter box. The maximum dose rate for the facility is slightly less than 30 rads/sec.

[1] R. Fitch, et. al., "Effect of Silicon Nitride PECVD Growth on AlGaN/GaN HEMT Dispersion and Breakdown Characteristics," 2004 Joint International Meeting of The Electrochemical Society, Honolulu, Hawaii, Oct. 3-8, 2004.

One part was also tested at IUCF (Indiana University Cyclotron Facility), with 200 MeV protons. The purpose of this test was simply to get a higher dose rate, so that the dose could be delivered in a shorter time. In principle, displacement damage effects were also possible with protons, but these were not expected to be significant.

IV. Test Procedure

Microwave power characterization at 10 GHz was performed at AFRL/SND on the GaN hybrid amplifiers prior to dc-biased total dose gamma radiation exposures at NASA-Goddard Space Flight Center (GSFC), as well as after the radiation exposures. Dose rate typically varies slightly from one exposure to the next, but is roughly 25 rads/s. Parts were under DC bias during exposures, but not actively exercised.

V. Results of Gamma and Proton Radiation

Microwave power characterization at 10 GHz was performed at AFRL/SND on the GaN hybrid amplifiers prior to dc-biased total dose gamma radiation exposures at NASA-Goddard Space Flight Center (GSFC), as well as after the radiation exposures. As shown below in Fig. 1, minimal changes in microwave power performance were observed before and after gamma radiation exposures. The change in characteristics that is observed is actually an improvement in power out and efficiency, after 2.2 Mrad, but it is not thought to be due to radiation. During the irradiation, the parts were under a 10-V bias, which was applied for about 20 hours. A similar improvement in power out and efficiency had been noted at AFRL from conditioning under bias, in the absence of radiation.

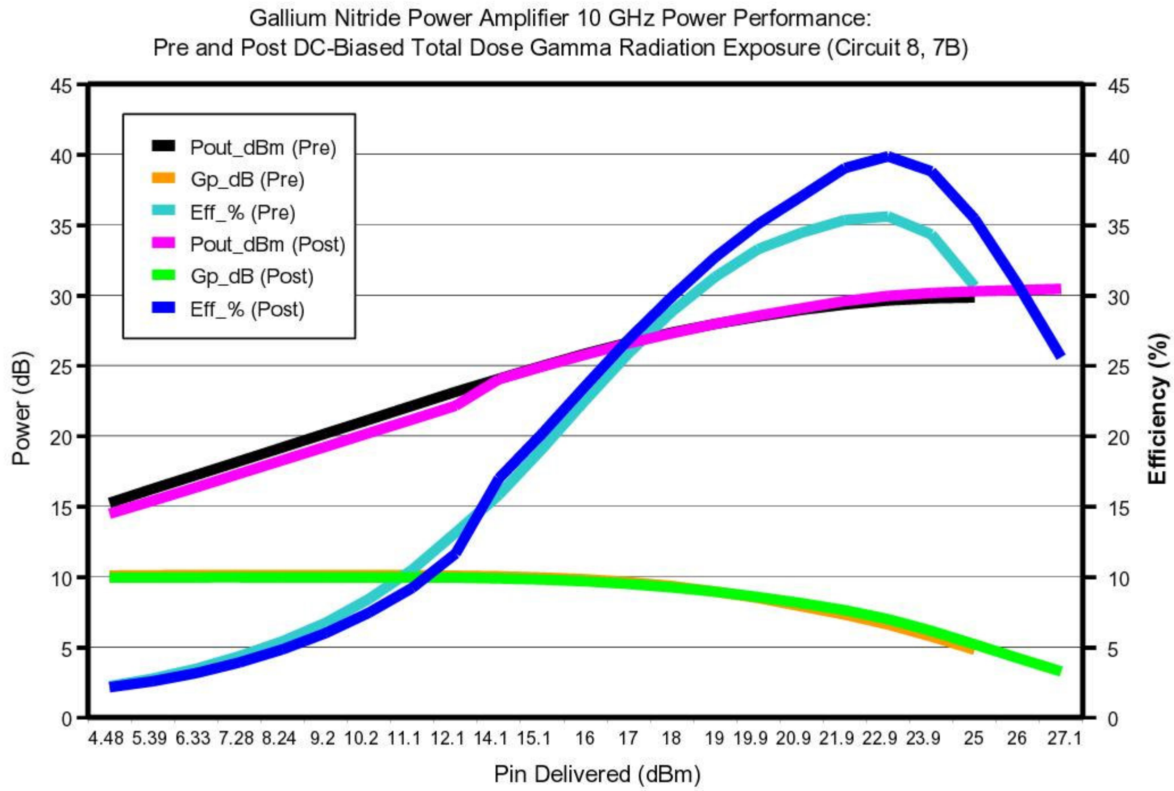

Fig. 1 Pre- and Post-Gamma Radiation Output Power, Gain, and Power-Added Efficiency for the X-Band AlGaN/GaN HEMT Hybrid Power Amplifier.

The part irradiated with protons received a total dose of 55 Mrad, with no measurable degradation. Figures 2 and 3 present the pre- and post-radiation DC I-V and I_d Vs V_g characteristics respectively, for the GaN Hybrid amplifier. Notice that there are minimal changes in these characteristics.

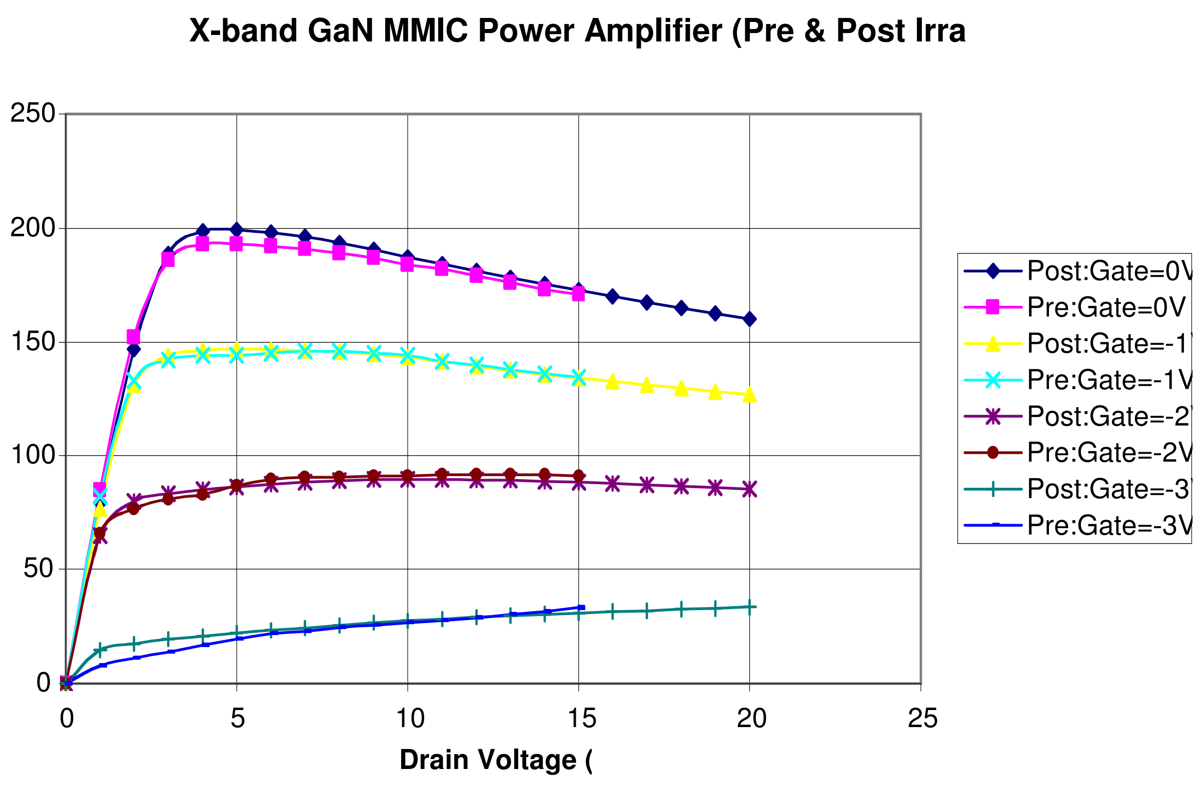

Fig. 2 Pre- and Post-Proton Radiation DC I-V Characteristics of the X-Band AlGaN/GaN HEMT Hybrid Power Amplifier.

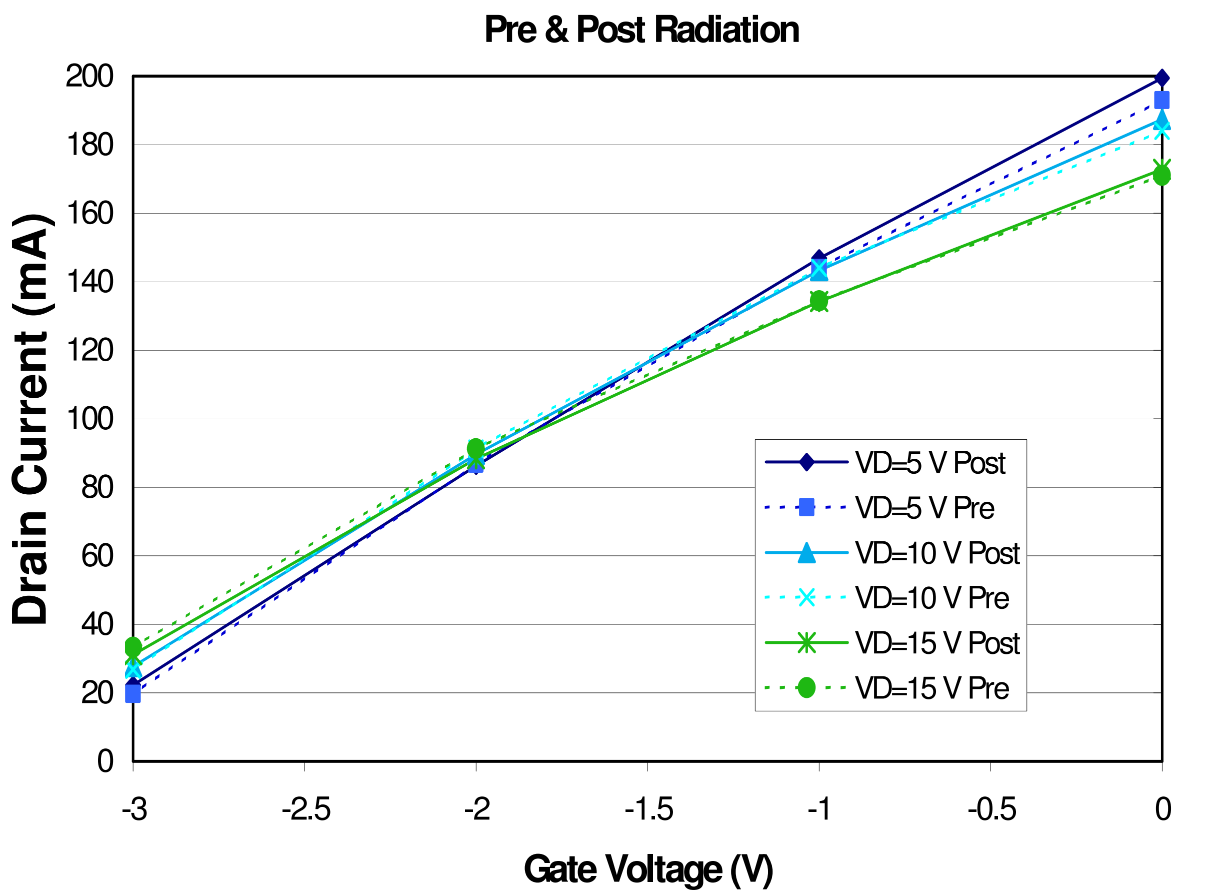

Fig. 3 Pre- and Post-Proton Radiation DC I_d versus V_g Characteristics of the X-Band AlGaN/GaN HEMT Hybrid Power Amplifier.