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Development and space qualification of GaN Solid State Power Amplifiers

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The development, test, and qualification of GaN Solid State Power Amplifiers (SSPAs) at The Johns Hopkins University Applied Physics Laboratory (JHU/APL) for both near-Earth and deep-space missions will be presented. JHU/APL has been developing GaAs SSPAs since the early 1990s, flying the first SSPA into deep space in 1996 on the NEAR mission [1], followed by the first phased array system deployed in deep-space [2] which was enabled by GaAs technology, and finally into the harsh radiation environment of Earth's radiation belts in 2011 on the Van Allen Probe mission [3]. The space community has been gradually adopting GaN SSPAs primarily due to the availability of proven space heritage high-power technologies such as GaAs SSPAs and Traveling Wave Tube Amplifiers (TWTAs). This presentation will highlight some of the historical work to the latest developments using GaN technology at JHU/APL for various challenging flight missions.

Work on GaN at JHU/APL began back in 2017 where prototypes of a 25 W X-Band GaN SSPA with an efficient Power Converter Unit (PCU) was developed for a Jovian lander application [4]. After these prototypes were developed, the designs were fitted into a space qualified package, meeting stringent thermal and hermetic requirements, in addition to having low insertion loss into and out of the package. Efficient power combiners using air-coaxial hybrid couplers were developed [5] to combine multiple amplifiers to generate higher power. SSPAs were configured to generate output power levels ranging from 5 W to 25 W, with power added efficiencies in the mid to upper thirty percent range.

The SSPAs were then taken through environmental tests and analyses specific to the space environment. First, a comprehensive three-axis vibration test, including both sine and random vibration was used to simulate the typical environment at launch. Next, a three-axis shock test was used to simulate separation of the spacecraft from the launch vehicle. The SSPAs were then subjected to numerous thermal cycles in a vacuum chamber to simulate the extreme thermal dynamics encountered during a space mission's lifetime. In addition to testing, the SSPA was analyzed for multipactor susceptibility using the conventional parallel-plate based method and a commercially available particle-in-cell simulator.

Relevant results from the development, testing, and analyses will be presented for an X-Band GaN SSPA design currently under development for NASA's Interstellar Mapping and Acceleration Probe (IMAP).

References

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