A FOUR STAGE, 30 dB GAIN, 100 mW GUNN EFFECT AMPLIFIER IN Ka-BAND

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Abstract

Design and performance of a four-stage, 30 dB gain Gunn effect amplifier are described. The frequency response at different input power levels in given, as well as gain variation versus temperature. Saturated output power is 250 mW.

Introduction

This paper describes the design and performance of a four stage, 30 dB gain GaAs Gunn effect amplifier with 100 mW output power at 35.7 to 37.2 GHz. The amplifier is used as a driver for the output TWT in a satellite communications ground station.

Medium power amplification for this frequency range has been traditionally provided by traveling wave tubes. Solid state millimeter wave amplifiers utilizing Si-IMPATT devices having up to 0.5 W power output with moderate gain (10 dB) have been reported.[1] IMPATT amplifiers have substantially higher noise figure than Gunn effect amplifiers (i.e. Transferred Electron Amplifiers or TEAs). Gunn effect Ka-band amplifiers with single stage noise figures of 18 dB for GaAs and 7dB for InP have been demonstrated, but these amplifiers exhibited narrow bandwidths (0.2 GHz) and output powers of less than 10 mW.[2,3] Recent progress reported here, includes the development of a high gain millimeter wave amplifier with 30 dB gain at 100 mW output power over 2 GHz bandwidth and moderately low overall noise figure of 21 dB. This amplifier, based on GaAs Gunn devices, provides a high reliability, solid state building block for new communications systems in Ka-band.

Amplifier Design

Each amplifier stage is of the negative resistance reflection type, comprising the Gunn diode, a matching network and a ferrite circulator. The Gunn diodes used have an active length of 2.5 um and a doping density of 6×10^{15} cm^{-3}.[4] The diode is hermetically sealed in a package with a ceramic ring of 0.030 inch dia., 0.012 inch high, mounted on a copper heat sink. This package provides a low shunt capacity and a low series inductance, both of which are necessary for good amplifier designs. Stable gain is provided by the matching network, which consists of a coaxial line section, approximately half wavelength long at centerband, and a coax to waveguide transformer. The inverse of the diode impedance, estimated from the impedance characteristics of an X-band device is shown on a Smith Chart, normalized to 50 ohms (Figure 1.). The inverse of the packaged diode impedance, including the package parasitics, is represented by "$-Z_d$ locus" in the figure. By optimizing the various circuit parameters, the impedance "seen" by the packaged diode is designed to yield a single stage gain of 10 to 12 dB over 36 to 40 GHz (see Z_c locus). Care must be taken to suppress oscillations above 40 GHz, as can be seen from the proximity of the $-Z_d$ and Z_c loci in the neighborhood of 45 GHz. Bias is applied via a multisection low pass filter.

Ferrite circulators and isolators make the stage unidirectional. Gain flatness is severely limited by the VSWR of the circulator. Referring to Figure 2, it can be seen that the maximum ripple due to 1.1:1 VSWR can be as high as ± 1.5 dB at 10 dB nominal gain.

Gunn Effect Amplifier Performance

Two stage[5] and four stage amplifiers have been developed. The two stage amplifier exhibited 12 dB gain at 100 mW output over 36.7 to 38.7 GHz, with ± 0.5 dB gain variation. Small signal gain was 20 dB with 3 dB variation. The amplifier had less than ± 1° phase deviation from linear over 200 MHz and 5°/dB AM-PM conversion at rated output. The frequency response of the four stage amplifier at different input power levels is shown in Figure 3. The figure indicates 33 dB gain at -10 dBm input power, with ± 1 dB large signal variation and 6-10 dB compression. Exceptionally smooth saturation behaviour is indicated, with no detuning or gain expansion. Saturated output power is approximately 250 mW. Output power variation versus temperature at rated input is given in Figure 4. The output power is seen to drop only 1.0 dB at the high frequency end as the base plate temperature is increased from 25°C to 60°C. Third order intermodulation distortion has been measured at two frequencies in the band and the 3-IM intercept was calculated to be 2 dB above the saturated power output at both frequencies. At the 1 dB compression point, the 3-IM products were down 18 dB and at rated power, 15 dB. Power consumption, including regulators, was 10 V and 3 A.

Conclusion

The feasibility of obtaining a stable medium-power millimeter wave amplifier with 30 dB gain has been demonstrated by cascading four reflection type Gunn amplifier stages. Stability is ensured by a properly designed matching network and interstage and input/output isolation. Gunn amplifiers with their inherent long lifetime and low supply voltages can offer attractive alternatives to tube amplifiers in low power driver applications.

Acknowledgment

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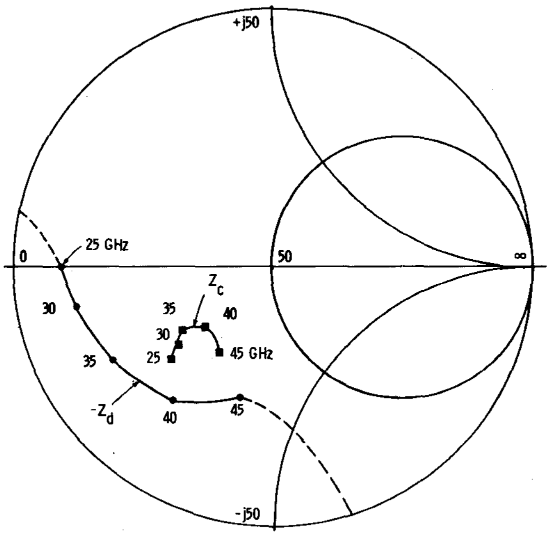

Fig. 1. Smith chart representation or diode and circuit impedances in Ka-band

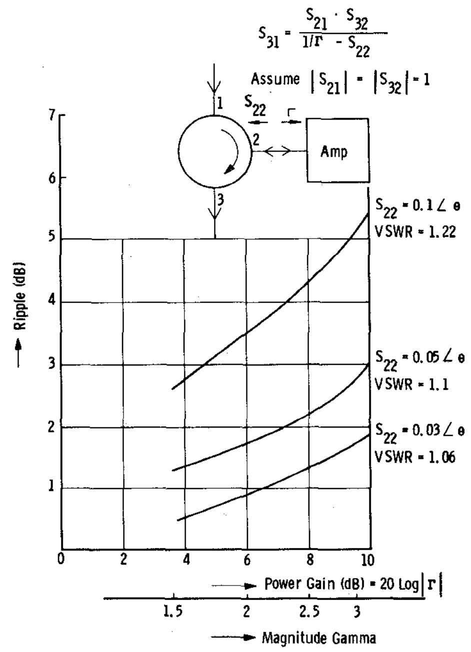

Fig. 2. Amplifier ripple as related to circulator mismatch

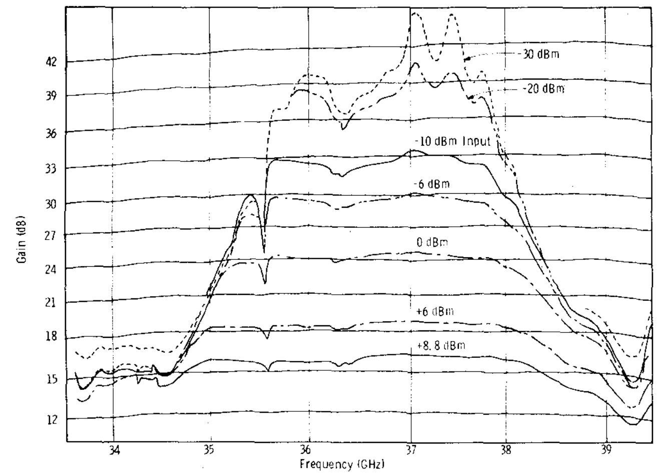

Fig. 3. Frequency response as a function of input power level

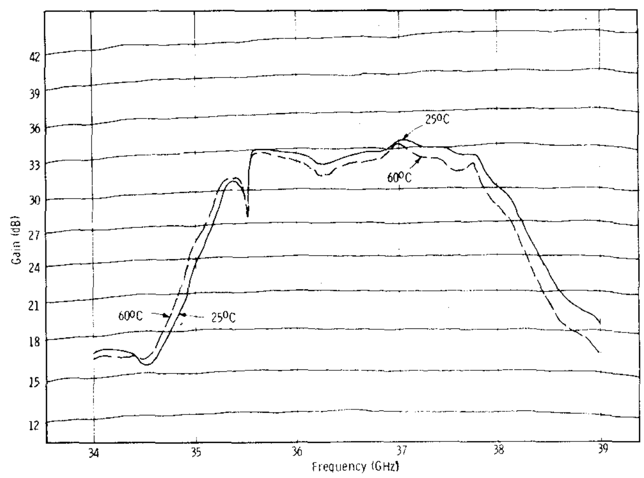

Fig. 4. Gain variation as a function of temperature