A NONDEGENERATE MILLIMETER WAVE PARAMETRIC AMPLIFIER WITH A SOLID-STATE PUMP SOURCE

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Abstract

A state-of-the-art nondegenerate millimeter wave parametric amplifier that utilized a reliable solid-state pump source at 105 GHz has been successfully developed and tested in the 55 to 65 GHz frequency band. A gain of 14 dB with a 1-dB bandwidth of 670 MHz has been obtained. The measured single-sideband noise factor of the paramp averaged 5.9 dB across the operating passband.

A nondegenerate (single-sideband) millimeter wave parametric amplifier that utilized a solid-state pump source has been successfully developed and tested for operation in the 55 to 65 GHz frequency band. To our knowledge, this is the highest frequency nondegenerate parametric amplifier reported to date. Previous authors have reported development of a degenerate parametric amplifier at 33.6 GHz (reference 1) as well as a degenerate amplifier at 24 GHz (reference 2) for operation in the millimeter wave region. A single-stage double-tuned parametric amplifier with a midband gain of 14 dB and a 1-dB bandwidth of 670 MHz has been obtained in the 55 to 65 GHz frequency band. The measured average single-sideband noise factor was 5.9 dB across the operating passband when measured with an argon noise tube that had been calibrated against a 1000 Kelvin hot load (reference 3) whose equivalent noise power was known to be better than ±1.3 percent. The parametric amplifier was pumped by a solid-state pump source at a frequency of 105 GHz that was generated by a 35-GHz Gunn effect oscillator and a varactor tripler. A block diagram of the millimeter wave parametric amplifier is shown in Figure 1, while a photograph of the developed hardware is shown in Figure 2. The techniques utilized for this paramp development lend itself for successful development of nondegenerate paramps up to 100 GHz, and possibly beyond depending on the availability of stable pump sources for operation with parametric amplifiers.

The achievement of the millimeter wave paramp was largely due to the successful development of a reliable gallium arsenide varactor whose cutoff frequency, as measured at 70 GHz at zero volt bias, was greater than 600 GHz (reference 4). This high quality varactor coupled with minimum stray capacitance that was required for successful operation in the millimeter wave region was used in the parametric amplifier as well as the achievement of a very efficient varactor tripler.

The parametric amplifier developed was a single-ended (one varactor) design in which the idler frequency was below the signal frequency. This design approach was utilized to enable successful operation of the paramp with a solid-state pump source that was within the present state of the art. The varactor was mounted in the center of a reduced height waveguide mount in which the series resonance of the varactor was used for the signal circuit in the 55 to 65 GHz range. A homogeneous quarter-wave transformer was utilized to transform the nominal waveguide impedance to that required for proper operation of the parametric amplifier. The reduced height waveguide was cut off at the idler circuit and the equivalent inductance due to the cut off characteristics of the waveguide, presented in series to the varactor, formed the idler resonance. Pump power (≈ 15 milliwatts) was coupled through a waveguide that propagated the pump frequency and was cut off to both the signal and idler frequency. A resonant iris at the pump input to the reduced height mount efficiently coupled the pump power in the paramp. The parametric amplifier was then double-tuned by an iris coupled filter whose susceptance slope was chosen to obtain a maximally flat double-tuned response. A five-port circulator that consisted of three 3-port circulators joined together was used for the circulator that was a compact turnstile approach (reference 5) in which a minimum isolation from the paramp (port 2) to the antenna input (port 1) was 40 dB over a 2-GHz bandwidth. The insertion loss of the two passes of the circulator was measured to be 0.75 dB (maximum). A photograph of the paramp itself is shown in Figure 3.

Pump power of 15 milliwatts was obtained with a Gunn effect oscillator that produced 120 milliwatts of pump power at 35 GHz. An isolator was used at the output of the oscillator to make it insensitive to load changes. A very efficient varactor tripler was used to multiply the 35-GHz input to the required 105 GHz required for operation of the paramp itself.

The varactor tripler utilized the same varactor as the paramp itself in which an efficiency of better than 20 percent was obtained (output to input including circuit and tuning losses).

With the above development, a plot of the system insertion gain versus frequency of the double-tuned amplifier is shown in Figure 4. A plot of the measured paramp noise factor versus frequency is shown in Figure 5. An argon noise source that had been calibrated against a 1000 Kelvin hot load was used for the measurement. The calculated accuracy of the noise figure measurement was determined to be less than five percent. A plot of the measured dynamic range of the paramp is shown in Figure 6.

In conclusion, a new millimeter wave (55 to 65 GHz) nondegenerate parametric amplifier has been developed in which a system gain of 14 dB and a 1 -dB bandwidth of 670 MHz was measured. The measured average noise factor was 5.9 dB across the operating passband when operated with a solid-state source at 105 GHz. The development of a high quality varactor with low parasitics enabled these successfully advised developments.

References

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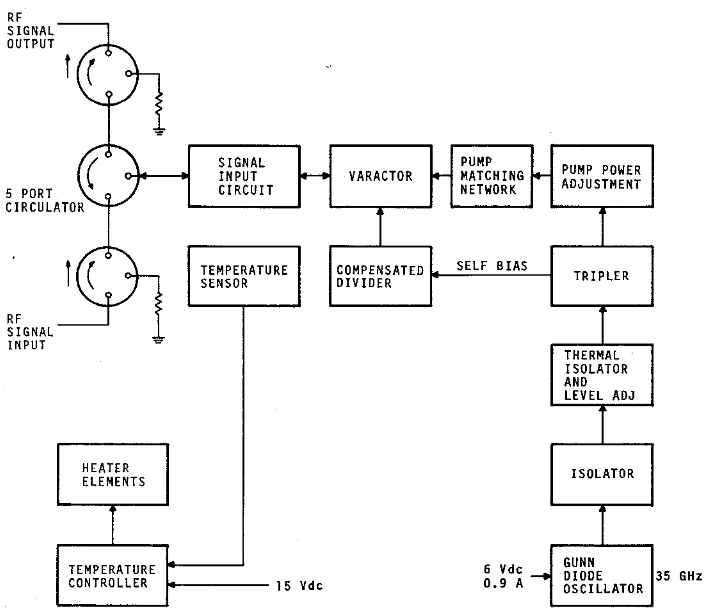

FIGURE 1. BLOCK DIAGRAM OF PARAMETRIC AMPLIFIER SYSTEM

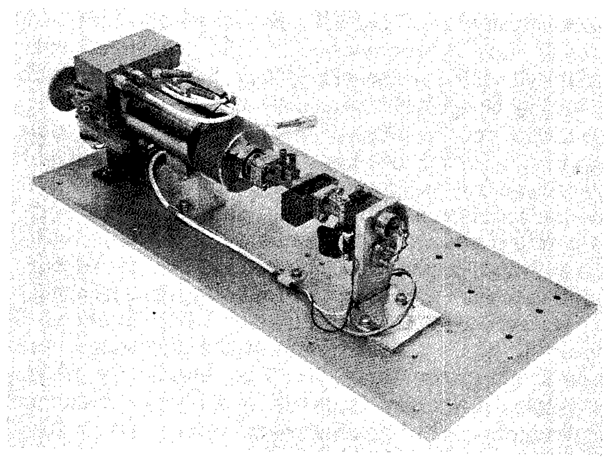

FIGURE 2. PARAMETRIC AMPLIFIER SYSTEM

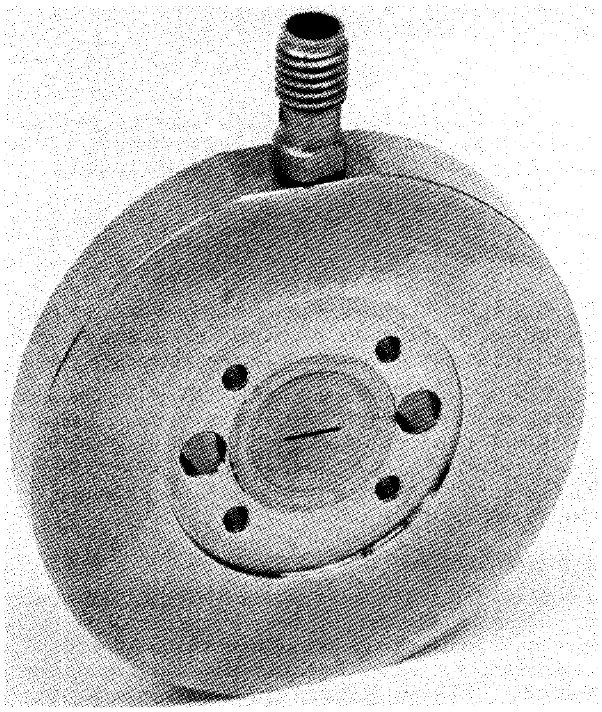

FIGURE 3. PARAMETRIC AMPLIFIER MOUNT

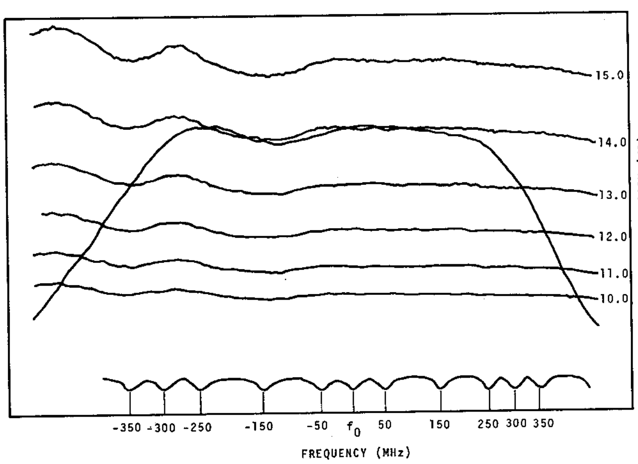

FIGURE 4. RECORDED PLOT OF SYSTEM RESPONSE

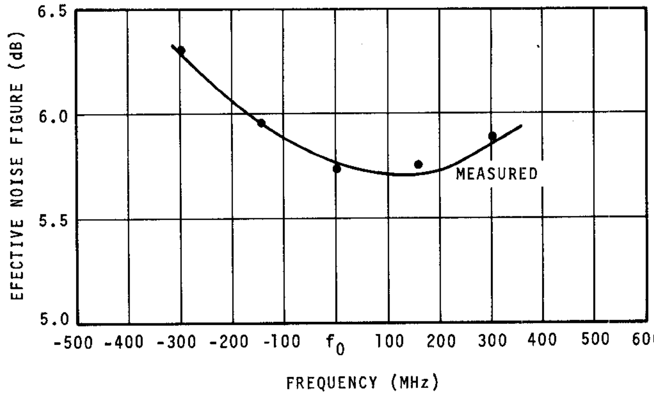

FIGURE 5. NOISE FIGURE OF THE SYSTEM

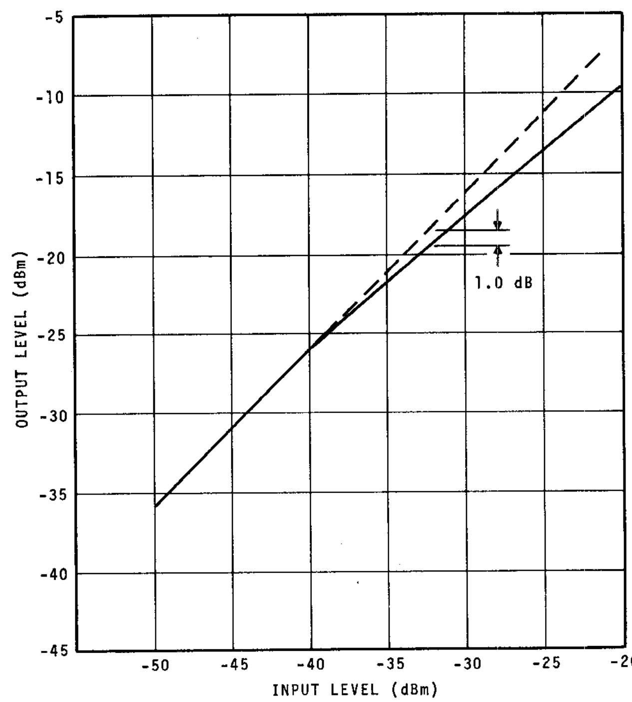

FIGURE 6. INPUT-OUTPUT CHARACTERISTICS AT MIDBAND