MINIATURIZED NONDEGENERATE K_a-BAND PARAMP FOR EARTH TO SATELLITE COMMUNICATIONS

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Abstract

State-of-the-art millimeter wave paramp designs have been reduced to practice resulting in a miniaturized low-noise, all solid-state, K_a-band amplifier designed to meet stringent electrical and mechanical specifications. An amplifier gain of 18 dB and a noise figure of 3.8 dB were achieved. This amplifier has application to future generation communications systems, and because of its small size and weight, to upgrading existing systems.

Introduction

A miniaturized nondegenerate K_a-band paramp for earth to satellite communications has been developed. This paramp is based on techniques described by J. Whelehan and others[1] and is the practical realization of state-of-the-art electrical and mechanical design techniques, the low-noise parametric amplifier designed to operate in the frequency range of 36 to 38 GHz with an instantaneous bandwidth of 100 MHz. A gain of 18 dB with a noise figure of 3.8 dB were achieved using a solid-state pump at 101.4 GHz. The parametric amplifier and pump assembly are thermally stabilized and are designed to withstand rugged environments.

The most immediate application of the amplifier is in a variety of earth to satellite communications links. Because of its small size and weight, it also lends itself to retrofitting into existing systems for the purpose of upgrading established communications links.

This paper will discuss the design principles and performance of the parametric amplifier, of the pump, and of the electronics module.

Design Principles and Performance

A block diagram of the overall amplifier is shown in Figure 1. A key feature of the amplifier is a varactor which has a zero-volt bias cutoff in excess of 600 GHz, as measured at 70 GHz.[2] A noise temperature of 404 K (3.8 dB nF) was achieved with a pump frequency of 101.4 GHz at a level of approximately 20 mW. The pump power was derived by doubling the output of a 50.7 GHz fundamental Gunn diode oscillator.

A gain/noise temperature budget for the paramp and associated components is shown in Figure 2. As shown, in order to achieve a noise figure of 3.8 dB, it was necessary to attain a 2.6-dB noise figure for the parametric amplifier itself.

The parametric amplifier used in this system is a single-ended type and is shown in Figure 3. It consists of a varactor diode mounted across a reduced height ridge-waveguide. Ridge waveguide is employed so as to preserve mode purity at both the signal and idler frequencies, and by proper choice of dimensions to achieve a 2 to 1 relationship in guide wavelengths at the signal and idler frequencies. The diode is operated near series-resonance at the idler frequency; irises appropriately placed form the idler cavity and isolate the pump and signal circuits. Typical gain-bandwidth data is shown in Figure 4 and dynamic characteristics in Figure 5.

The pump source, as mentioned earlier, consists of a fundamental Gunn diode oscillator and a varactor doubler. An efficiency of 30 percent was achieved with a fundamental signal power of 100 mW. The doubler construction is similar to the parametric amplifier; it comprises a high cutoff unpackaged varactor diode across a reduced height waveguide and associated reactive tuning elements.

The final amplifier assembly is shown in Figure 6. Shown is the Gunn diode oscillator, its isolator, the doubler, the paramp, a four-port circulator, and a separate output isolator. The complete amplifier assembly occupies only 3.4 cubic inches and weighs 5 ounces. Also shown in the photograph is a band-pass band-stop filter assembly designed for receiver protection. The configuration shown satisfies a uniquely compact packaging constraint.

Conclusions

State-of-the-art millimeter wave paramp designs have been reduced to practice resulting in a miniaturized low-noise, all solid-state, K_a-band amplifier designed to meet stringent electrical and mechanical specifications. An amplifier gain of 18 dB and noise figure of 3.8 dB were achieved. This amplifier has application to future generation communications systems, and because of its small size and weight, to upgrading existing systems.

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References

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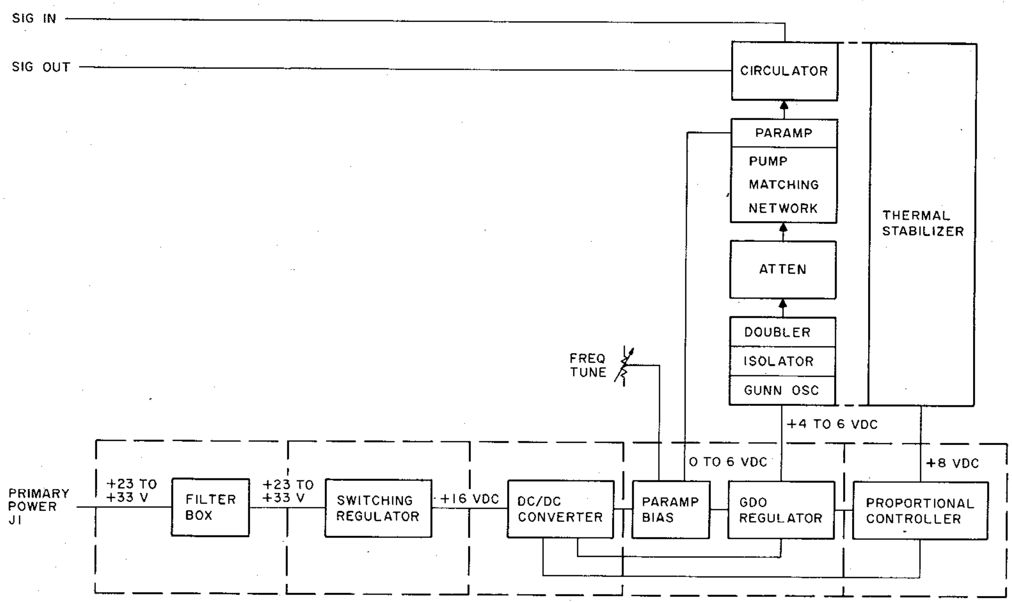
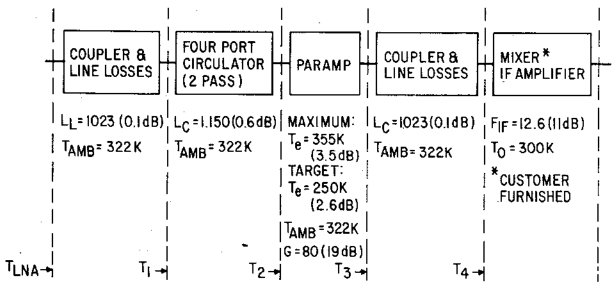


Fig. 1. Block diagram of paramp system



$T_4 = T_0(F_{IF}-1) = 3500K$

$T_3 = T_{AMB}(L_C-1) + L_C T_4 = 3587K$

$T_2 = T_e + \frac{T_3}{G} = 295K$ (TARGET); $400K$ (MAXIMUM)

$T_1 = T_{AMB}(L_C-1) + L_C T_2 = 387K$ (TARGET); $510K$ (MAXIMUM)

$T_{LNA} = T_{AMB}(L_L-1) + L_L T_1 = 404K$ (TARGET) $\rightarrow F_{LNA} = 3.8$ dB (TARGET)

$= 528K$ (MAXIMUM) $\rightarrow F_{LNA} = 4.5$ dB (MAXIMUM)

Fig. 2. Gain/noise temperature budget

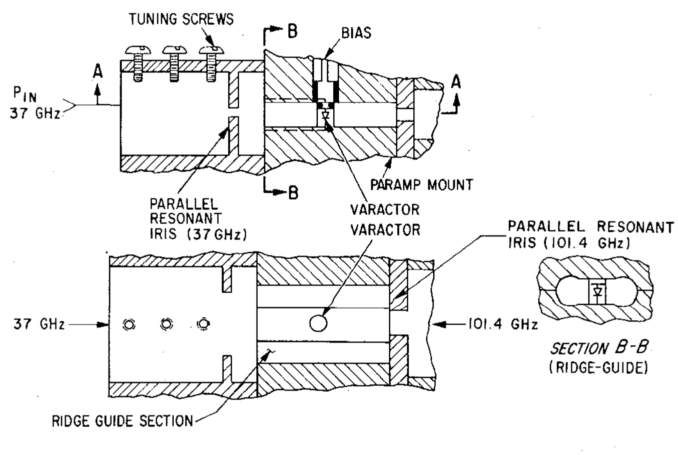


Fig. 3. Single-ended paramp configuration

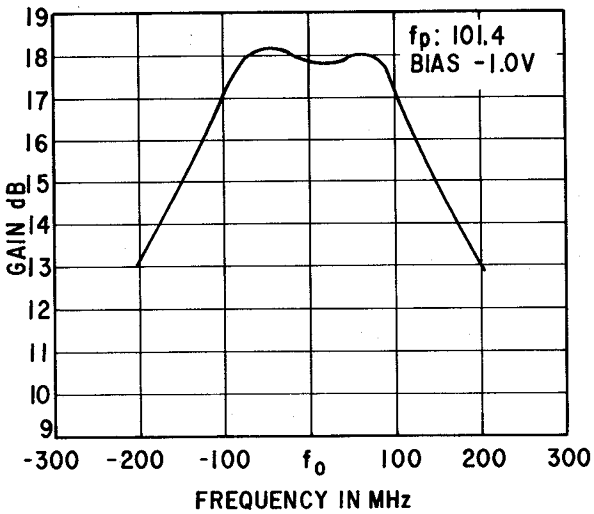


Fig. 4. Gain response

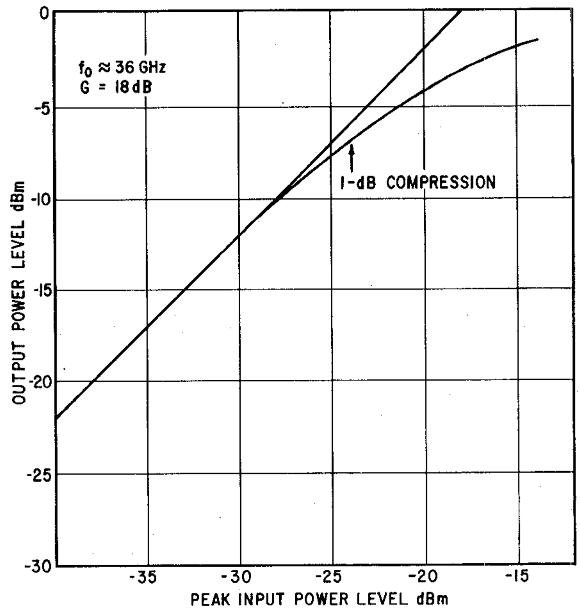


Fig. 5. Dynamic characteristics

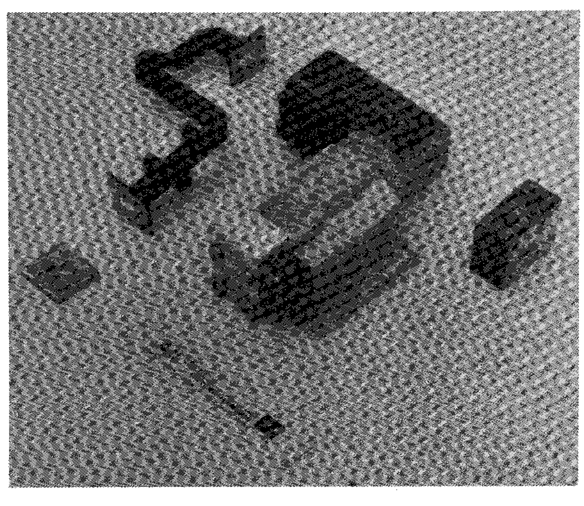


Fig. 6. Paramp assembly with filters