BROADBANDING AN ELECTRONICALLY SWITCHED TWO-CHANNEL Ka-BAND PARAMETRIC AMPLIFIER

S. Nussbaum and E. Sard

Abstract

A technique using realizable waveguide networks to broadband an electronically switched, dual-channel, Ka-band parametric amplifier has been developed. A waveguide network producing a controlled resonant susceptance slope at two frequency bands, separated by 1.14 GHz, has been built to accomplish broadbanding of each channel independently. An amplifier gain of 18 dB over a bandwidth greater than 100 MHz, and a noise figure of 3.6 dB were achieved at each channel.

Introduction

Tunable paramps at Ka-band have relatively narrow single-tuned instantaneous bandwidths. Therefore, a two channel system at Ka-band, recently built at AIL, which utilized two broadbanded units was used with consequent reduced cost-effectiveness and reliability. The problem at hand was how to achieve such a relatively broadband gain response at two channels with a single paramp stage. Thus, an electronically switched, dual-channel, Ka-band parametric amplifier has been developed for satellite communication purposes. The channels are 1.14 GHz apart and are independently broadbanded to obtain a 1-dB bandwidth greater than 100 MHz at a minimum gain of 18 dB.

Design Principles

The paramp gain response is broadbanded by a double-tuning technique. At a common reference plane, the amplifier negative impedance appears series resonant in both channels. Double tuning is achieved by connecting parallel resonances, of the proper susceptance slope and resonant frequency as well as the proper impedance transformation, across the amplifier terminals, as shown in Figure 1.

Equation 1 gives the parallel resonance susceptance slope necessary to double tune the amplifier for a maximally flat instantaneous response.

$$\left(\frac{dB}{df}\right)_o = \frac{G_g}{R}\left(\frac{dX}{df}\right)_o \frac{G_o^{1/4} - 1}{G_o^{1/4} + 1} \qquad (1)$$

where the transformed circulator conductance is:

$$G_g = \frac{1}{R}\,\frac{G_o^{1/2} - 1}{G_o^{1/2} + 1}$$

Also, G_o is the midband reflection power gain, and the series resonant paramp impedance is approximately:

$$-R + j\left(\frac{dX}{df}\right)_o \Delta f$$

In order to broadband the paramp at two separate frequencies, a network to provide two parallel resonant susceptance slopes was designed. A Ka-band amplifier similar to the one described in reference 1 was tuned to produce a gain envelope response which covers the required center frequencies at the proper gain levels.

The amplifier negative impedance locus at each center frequency was rotated to a common series resonant reference plane at which double tuning was applied by a parallel resonant network. Figure 2 plots the measured impedance of this network. Two individual high-impedance parallel-resonances at 36.9 and 38 GHz are shown at the same reference plane. Two series resonant slopes are also plotted in Figure 2 at the same reference plane. These are typical measured paramp negative resistances at two bias levels corresponding to the desired center frequencies of each channel. Theoretical broadbanding of the series resonances using equation 1, is plotted at the center of the chart.

Description of Amplifier

The design of the broadbanding network is based on the model shown in Figure 3A. The network represents two parallel resonant circuits in series with each other, and shunted across the main guide. The resonator cavities are located one-half wavelength from the series junction for minimum interaction. The resonant susceptance slope is transformed to the main line with the appropriate impedance transformation to minimize loss. An assembled waveguide network is shown in Figure 3B. The unit basically consists of E and H plane Tee's joined through a transformer section. The various sections are fabricated from standard WR-28 waveguide and flanges. Each cavity is coupled through an iris and its resonant frequency is adjusted by a tuning screw.

Figure 4 shows the final amplifier assembly with the major components identified. These include: the gunn diode oscillator (GDO), its isolator, a doubler to 101.4 GHz, the paramp, the broadbanding network, and the input 5-port circulator. The paramp and doubler have been discussed to a certain extent in a previous paper (reference 1). The amplifier operation is instantaneously switched between a 36.87 GHz and a 38.01 GHz center frequency. Figure 5 shows the operation and the electronic switching between channels.

Two controls utilized to switch the amplifier are paramp bias and pump power. The bias is switched from -1.5 V to -0.5 V as the pump power is attenuated by 4 to 5 dB.

The doubler to 101.4 GHz is operated in a combination of fixed or self-bias modes. Generally, a doubler produces a self bias depending on its input power and operating efficiency. Forcing the doubler to operate at a different bias reduces its efficiency and hence its output power is attenuated. This technique permits a remote attenuation of the paramp pump power. At the paramp high bias, the doubler is operated at self bias for maximum efficiency. When the paramp bias is lowered, the doubler is fixed biased to operate at a higher or lower negative voltage for a lower efficiency. This technique provides an attenuation of about 1 dB per volt of fixed bias voltage.

Figure 6 presents measured gain bandwidth data. A double tuned Tchebycheff response of a 1-dB bandwidth greater than 100 MHz at each channel was realized. The degree of double tuning was controlled independently at each channel. This was done by changing the coupling iris diameter and retuning the cavity to the desired center frequency. A gain of 18 dB with a noise figure of 3.6 dB was measured for each channel.

Conclusion

The design criteria and performance of a switchable dual-channel parametric amplifier have been described.

Two broadbanded responses of a single paramp stage separated by more than 1 GHz have been demonstrated to have an independent double tuning control. This amplifier can readily be utilized to upgrade existing communication systems to provide broadbanded dual-channel operation with a single amplifier stage.

Acknowledgements

This work was supported by the Air Force Avionics Laboratory at Wright-Patterson Air Force Base, under the project direction of Mr. Roger Swanson. The basic amplifier development was done at AIL under the direction of Mr. James J. Whelehan. The advice and direction of E. Kraemer and J. J. Taub are gratefully acknowledged. Technical assistance was provided by L. Sadinsky.

Reference

1. M. A. Balfour, A. Larsen, S. Nussbaum, and J. Whelehan, "Miniaturized Non-Degenerate Ka-Band Parametric Amplifier for Earth-to-Satellite Communication Systems," IEE S-MTT, 1974.

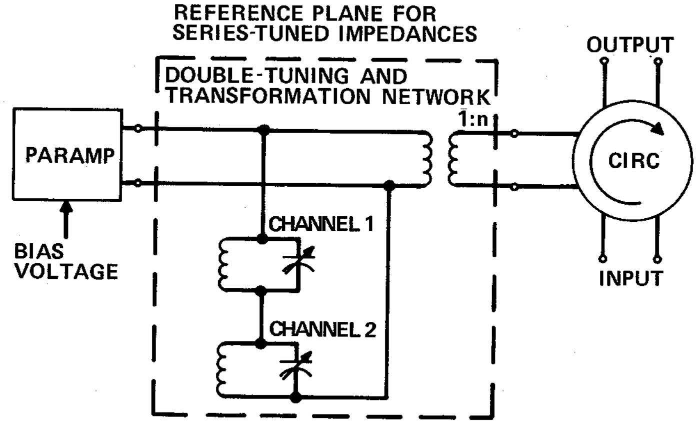

Fig. 1-Equivalent Broadbanding Circuit

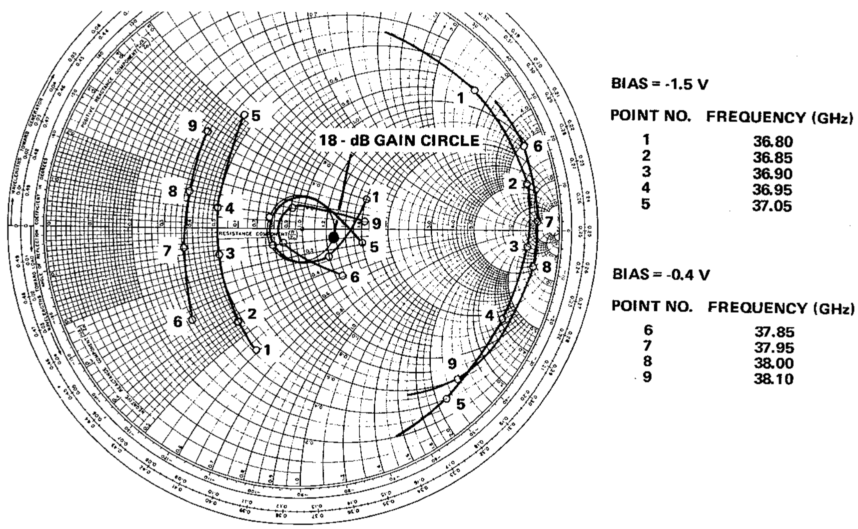

Fig. 2-Measured Amplifier and Network Impedance Double Tuned at a Common Reference

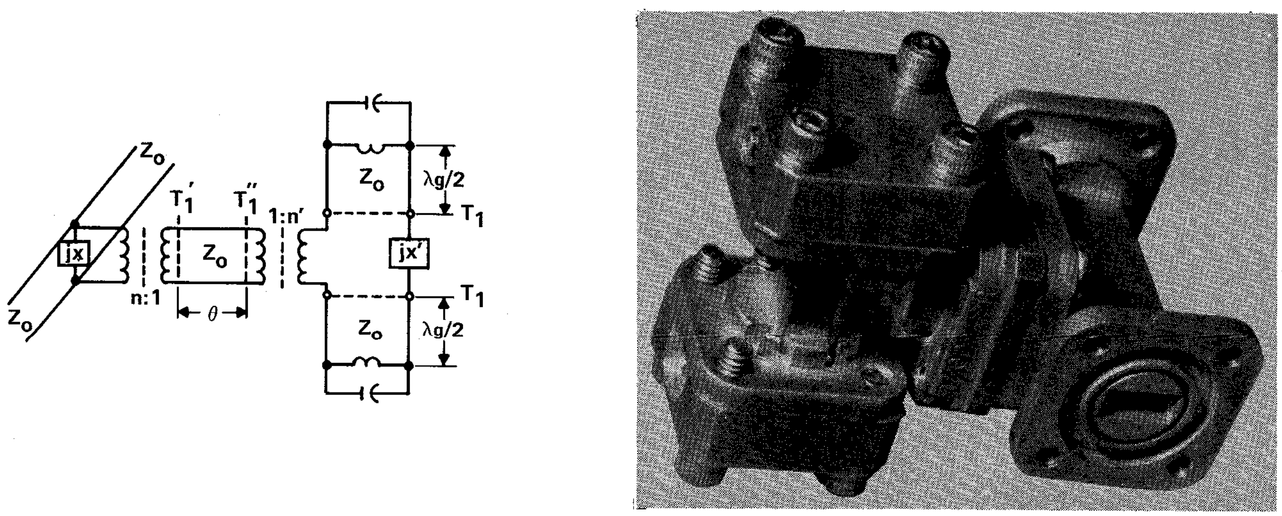

Fig. 3-Broadbanding Network

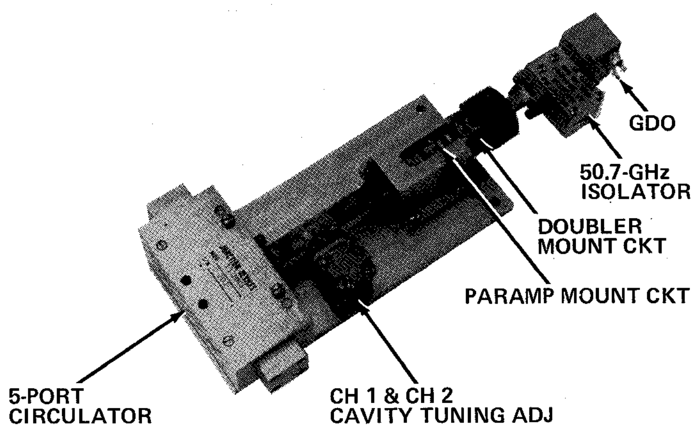

Fig. 4-Assembled Parametric Amplifier Stage

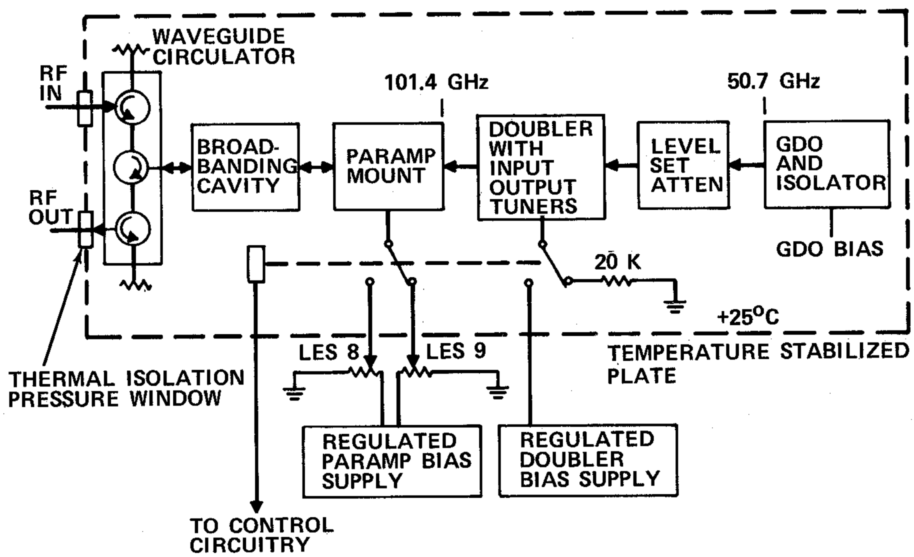

Fig. 5-Block Diagram of Ka-Band Amplifier

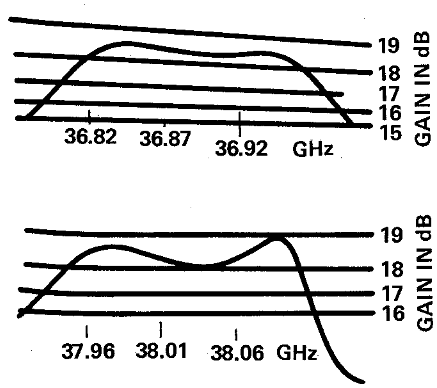

Fig. 6-Measured Gain Response of Channel 1
and Channel 2