60 GHz INTEGRATED CIRCUIT QUADRIPHASE EXCITER AND MODULATOR

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ABSTRACT

An integrated circuit quadriphase shift keying (QPSK) exciter and modulator have demonstrated excellent performance directly modulating a carrier frequency of 60 GHz with an output phase error of less than 3 degrees and maximum amplitude error of 0.5 dB. The unit was packaged into a volume of 1.8x2.5x0.35 in. Multigigabit data streams are possible.

INTRODUCTION

Future intersatellite communication systems will require direct modulation at 60 GHz to enhance the signal processing capability. For most systems, particularly space applications, small and lightweight components are essential to alleviate severe system design constraints. Thus, to achieve wideband, high-data rate and small size, direct modulation techniques at millimeter waves using solid-state integrated circuit technology are an important part of technology development.

Integrated circuit and waveguide phase-shift-keying modulators have been fabricated for use in digital communicatons at microwave frequencies[1-4]. Because of dimension limitations, innovative design modifications have to be devised to apply these techniques at 60 GHz.

This paper presents an integrated circuit QPSK exciter/modulator directly modulating a 60 GHz carrier frequency with state-of-the-art performance. An output phase error of ±3° and amplitude error of ±0.5 dB have been achieved. The modulator was designed for multigigabit data rates.

SYSTEM DESCRIPTION

Figure 1 is a functional block diagram of the exciter/modulator. The system consists of three major parts: a 60 GHz stable source, a QPSK modulator and a data driver. The 60 GHz source contains a microstrip Gunn VCO phase-locked to a low frequency reference source to achieve high stability and low FM noise. The output power is coupled into the QPSK modulator with modulated outputs controlled by the data driver. The modulated quadriphase output is fed to a waveguide through a microstrip-to-waveguide transition.

COMPONENTS DEVELOPMENT

Two major components of the subsystem are the Gunn VCO and QPSK modulator. The Gunn VCO was built on 5-mil Duroid substrate in microstrip. Figure 2 shows the circuit layout. A two-section microstrip transformer was designed to match the Gunn impedance to the 50-ohm line impedance. A varactor chip was mounted next to the Gunn diode to achieve electronic tuning. The performance of this Gunn diode is shown in Figure 3. A varactor tuning range of over 500 MHz has been achieved with greater than +11 dBm output power at 60 GHz. The tuning is quite linear and the output power is reasonably flat over the tuning range which is sufficient for phaselock applications.

The Gunn VCO is phaselocked to a stable 14.4828 GHz reference signal through a 4th subharmonic mixer[5] to generate a 2.06896 GHz IF signal. The 14.4828 GHz reference signal is generated from the 2.06896 GHz stable source through an X7 frequency multiplier. The IF signal from the subharmonic mixer is then fed into the phase detector which, in turn, controls the Gunn VCO.

The circuit layout of the QPSK modulator is given in Figure 4, where both sides of the substrate are shown. The circuit was fabricated on sapphire substrate for small size (sapphire has a dielectric constant of 10 compared to 2.2 of Duroid). The use of sapphire substrate also gives the advantage of directly translating the design to GaAs monolithic circuit, which has a dielectric constant close to that of sapphire. The circuit operates as follows: The unmodulated RF carrier enters the circuit on microstrip and goes to the in-phase power divider. The signal is divided into two equal amplitude in-phase signals. One arm of the power divider drives the biphase switch #1 directly. A 90° phase shifter is introduced at the input of biphase switch #2. The biphase switches introduce an additional 0° or 180° phase shift to each signal as the data inputs switch the Schottky-barrier diodes. The two biphase modulated signals are then summed in an in-phase power combiner, producing a quadriphase modulated signal. The detailed design of these components is quite lengthy and will not be given here. This modulator chip has dimensions of 0.1x0.275 in.

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SYSTEM PERFORMANCE

The QPSK modulator chip was integrated with the Gunn VCO, subharmonic mixer, directional coupler, and a microstrip-to-waveguide transition to form the RF exciter/modulator module. Figure 5 shows the circuit board in the RF exciter/modulator module. The unit has a volume of 1.8x2.5x0.35 in.

A 60 GHz network analyzer was modified to measure S_{21} for phase and amplitude balance testing. The QPSK data inputs are digitally stepped through the four states with a bias source. Figure 6 shows the results of these measurements. A phase imbalance of less than ±3° and an amplitude imbalance of 0.5 dB were achieved. Figure 7 shows the spectrum of modulated signal.

The output power of the unit is -2 dBm, which can be used to injeciton-lock an IMPATT amplifier before transmitting. The modulator, tested up to 650 MBPS because of the limitations of the available testing equipment, has the potential of operating at multigigabit data rates.

CONCLUSIONS

A microstrip 60 GHz QPSK exciter/modulator was developed with state-of-the-art performance. The unit is very small and capable of handling wideband, high data rates. The results have firmly established direct modulation techniques using integrated circuits at millimeter-wave frequencies.

ACKNOWLEDGMENTS

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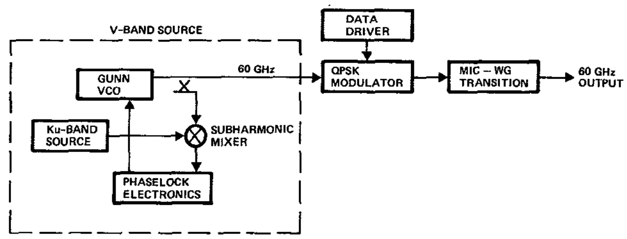
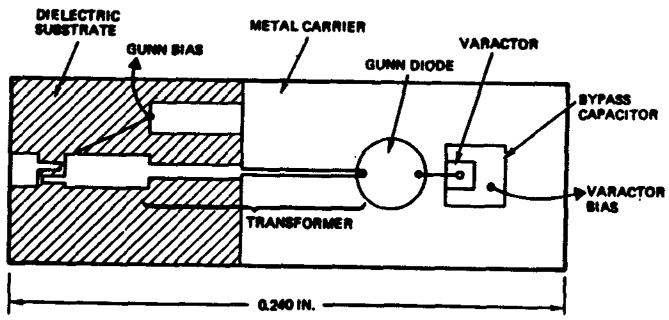
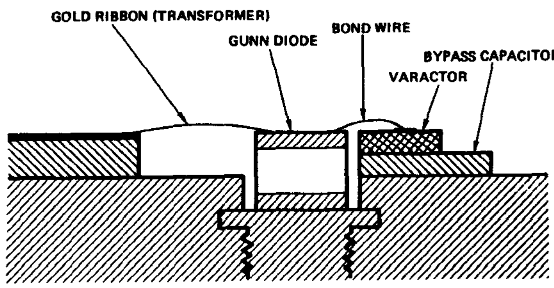


Figure 1. Block Diagram of QPSK Exciter/Modulator



(Front View)



(Side View)

Figure 2. Gunn VCO Circuit Layout (Size: 0.080 x 0.240 in.).

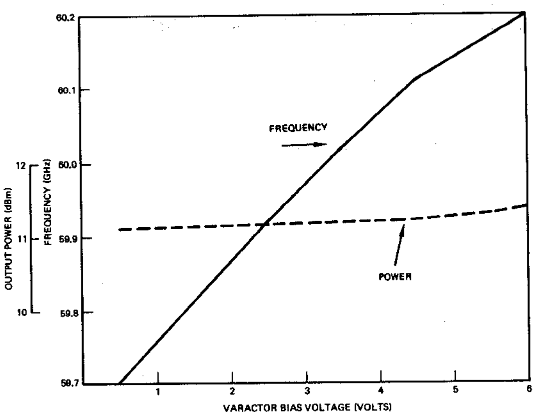


Figure 3. 60 GHz Gunn VCO Performance

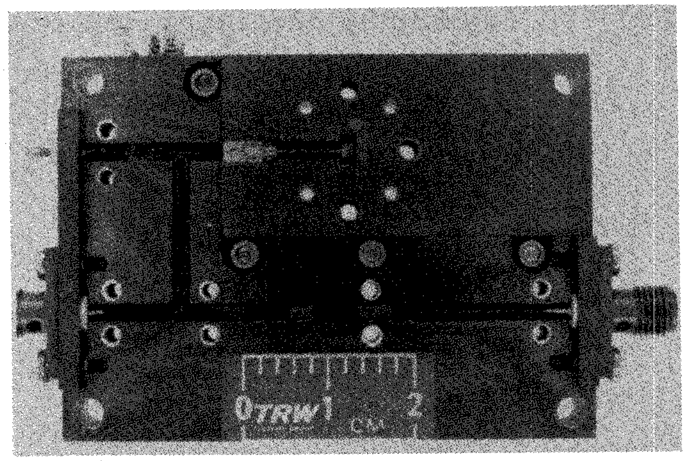


Figure 5. RF Exciter/Modulator Module

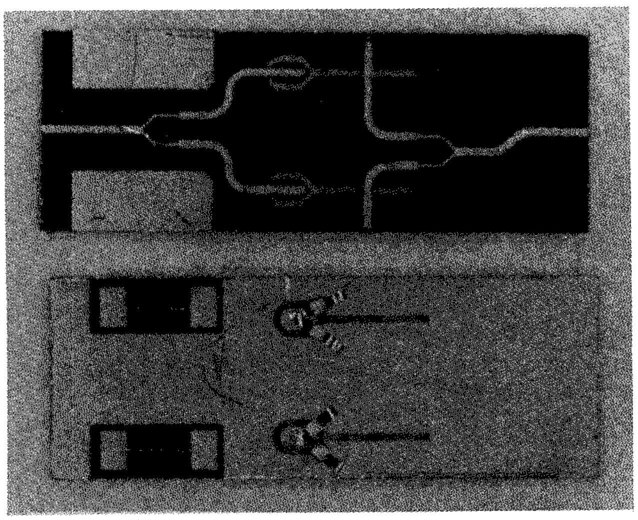


Figure 4. Both Sides of QPSK Modulator Chip

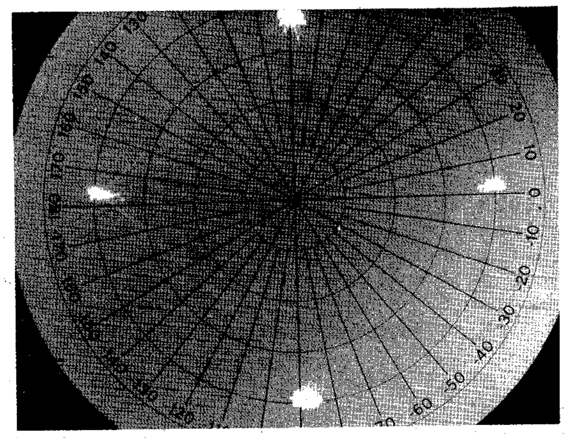


Figure 6. Phase and Amplitude Measurements for QPSK Modulator

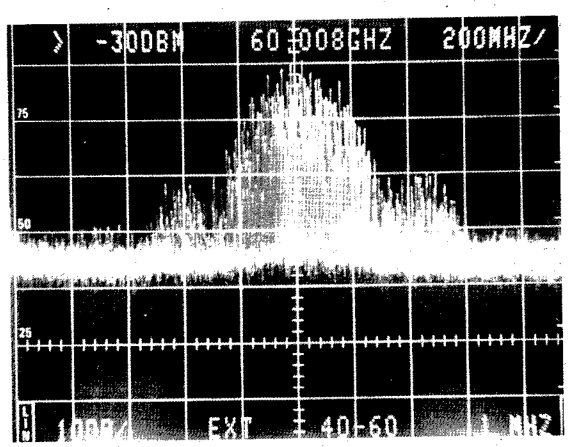


Figure 7. Spectrum of Modulated Signal