AN X-BAND LOW COST GaAs MONOLITHIC TRANSCEIVER

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ABSTRACT

A low cost X-band transceiver has been developed for multi-purpose applications. The transceiver, constructed using monolithic transceiver and power MMIC chips, is capable of delivering a transmitted power of greater than 23 dBm. Its bandwidth is voltage tunable to over 600 MHz. The control voltage of the VCO can be modulated and is applicable for FMCW or pulsed radar applications.

The entire transceiver, including its transmit/receive microstrip patch antennas and the dc circuitry, is packaged in a housing with dimensions of 3.5 x 2.0 x 2.0 inches. Due to the high yield and low fabrication cost of the monolithic transceiver chips, this unit is highly suitable for high volume production.

INTRODUCTION

CW radars are frequently employed in military systems as well as civilian applications, which include airborne navigation and civil marine radar. Advances in GaAs monolithic technology has made possible high volume production of affordable transceivers in many diverse commercial areas.

This paper describes a simple, low cost transceiver radar. The transceiver module includes the following key components: a GaAs monolithic transceiver chip, GaAs monolithic power amplifier chip, IF low noise amplifier, and transmit/receive microstrip patch antennas.

A simple monolithic transceiver chip provides frequency generation (VCO), mixing and amplitude amplification. This chip can be followed by a power amplifier to boost the transmitted power to improve far field detection and higher sensitivity. An IF low noise amplifier, located at the transceiver IF port, brings the RF to IF gain to approximately 34 dB.

The schematic diagram of the entire transceiver configuration is shown in Figure 1.

TRANSCEIVER CHIP

The transceiver consists of the following subcomponents: a voltage controlled oscillator, a two-stage gain/buffer amplifier, a 3 dB coupler, and a single balanced diode mixer.

The varactor tuned oscillator utilizes a 0.7 x 240 μm MESFET, and is voltage tunable to over 600 MHz bandwidth at X-band over a 4 volt dc tuning range, as shown in Figure 2.

The two-stage gain/buffer amplifier uses 0.7 x 240 μm devices to provide over 10 dB gain with approximately 13 dBm of output power. The amplifier also provides the following functions:

- reverse isolation to prevent oscillator frequency pulling due to external loading, and
- enough LO power to drive the mixer.

The power splitting from the VCO for the LO was performed by employing a 3 dB Lange coupler located between the two amplifiers and the mixer (Figure 1).

The single balanced diode mixer uses a 3 dB quadrature coupler at its LO and RF ports, achieved a conversion loss between 5.0 to 6.0 dB (the RF port connects directly to the receive antenna in this case).

The entire MMIC transceiver chip has a dimension of approximately 120 mil x 150 mil.

POWER AMPLIFIER

For demonstration, a power amplifier was included to improve detection sensitivity and increase range. The MMIC power amplifier provides about 14 dB of gain and boosts the total output power (point A of Figure 1) to about 23 dBm, across the entire operating frequency. The output power versus frequency is shown in Figure 3.

IF AMPLIFIERS

A commercial low noise amplifier was employed at the IF port of the transceiver. A two-stage LNA, each having a noise figure of less than 3.0 dB with gain of 20 dB provides a total gain of 40 dB. This brings the RF to IF gain in the order of 34 to 35 dB. A low noise amplifier was employed at the IF port to reduce second stage noise contribution due to the IF signal processor. One can place a low noise amplifier at the transceiver front end as the ultimate solution for improving transceiver noise performance, however, the cost associated with a X-band LNA far exceeds an IF LNA. Since it is the intention of this development to provide a high volume functional transceiver at a minimal cost, the former approach was adopted.

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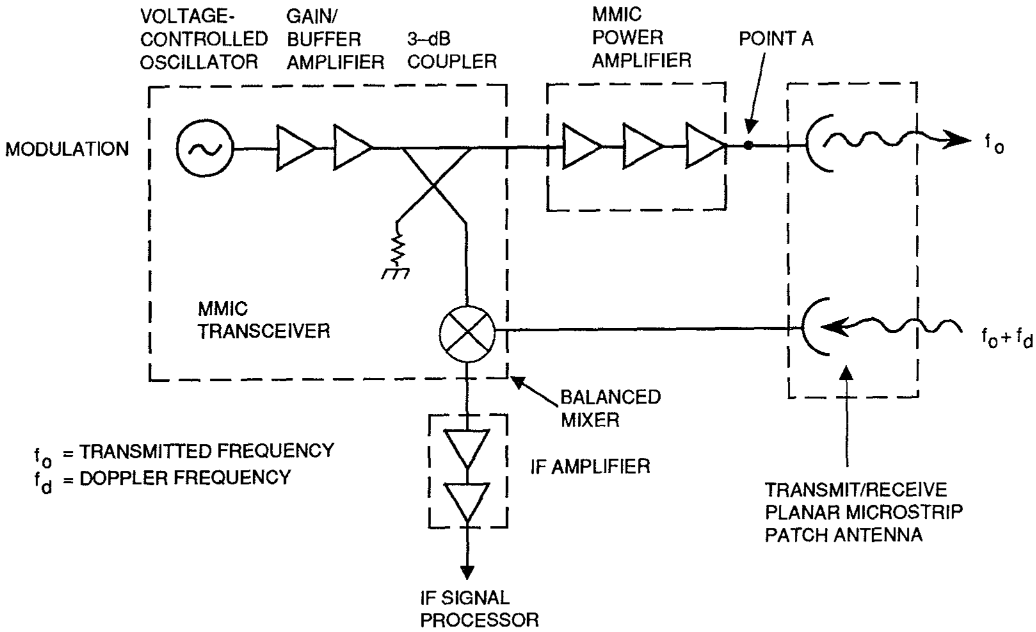

Figure 1 A low cost X-band transceiver.

MICROSTRIP PATCH ANTENNA

The microstrip patch antenna was fabricated on 30 mil thick Duroid 6002 substrate (ϵ_r = 2.98) for high radiation efficiency. Principle E and H plane patterns are shown in Figures 4 and 5. Using a rectangular patch array in the H-plane and a single patch in the E-plane, we achieved 3 dB beamwidths of 30 and 70 degrees, respectively. The H-plane sidelobe level is 15 dB down from the main lobe as can be observed in Figure 5 and the E-plane is relatively omni-directional. This experimental data is just one example of the flexibility of planar antenna design for custom pattern synthesis.

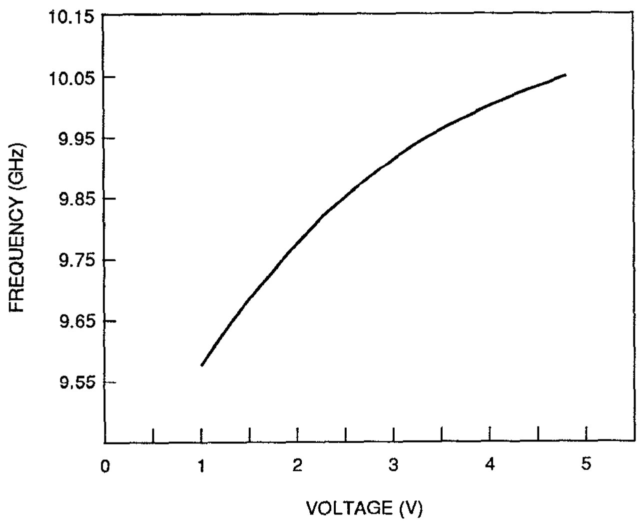

Figure 2 Frequency versus tuning voltage.

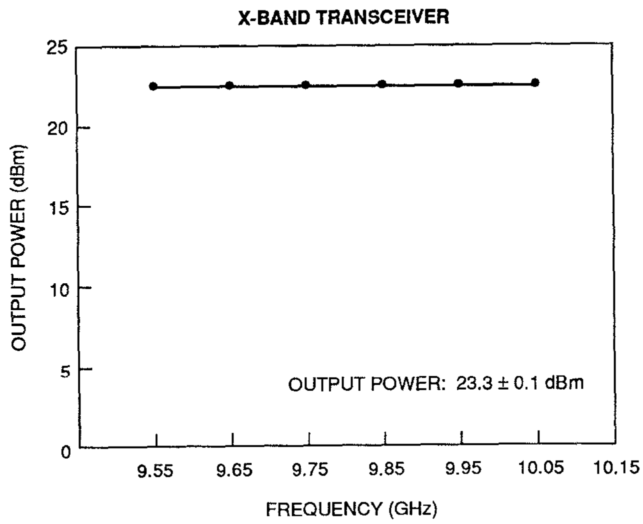

Figure 3 Output power versus frequency.

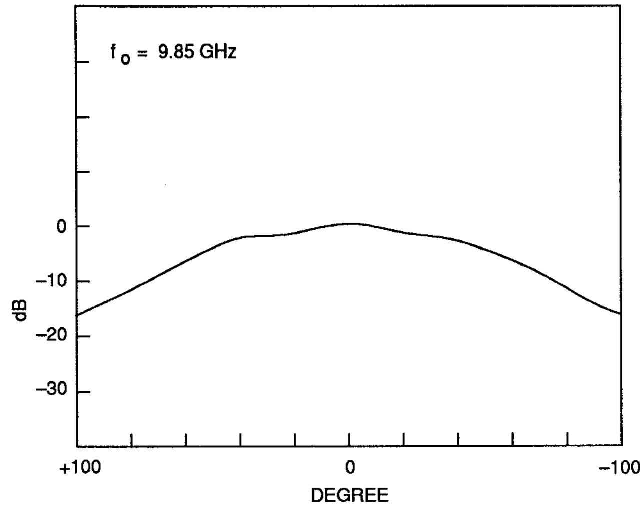

Figure 4 E-plane pattern.

INTEGRATION

The transceiver integration involves three subassemblies: RF components, dc bias circuitries, and transmit/receive antennas.

The RF components include the MMIC transceiver chip, a MMIC power amplifier, and the IF LNA. Both MMIC chips are mounted on a sub-carrier for ease of testing prior to integration. The two-stage LNA is mounted on the main carrier.

DC bias circuits, by-pass capacitors, and the RF subcarrier are mounted on the same planar surface of the main carrier.

The key feature of this transceiver is the ability of being compatible to planar microstrip antenna. The antenna, mounted on the backside of the main carrier, forms a microstrip antenna – main carrier – RF component sandwich. The transition from the antenna to RF subassembly is accomplished via a simple 50 ohm feedthrough which is soldered to the antenna array from the backside. Key reasons for mounting the RF subassemblies on the opposite side of the antenna are:

1. provides isolation between antennas and RF components,
2. allows transceiver testing prior to antenna integration,
3. allows antenna testing prior to transceiver integration,
4. permits compact transceiver integration.

The entire transceiver housing has a physical dimension of 3.5 x 2.0 x 2.0 inches. The RF assembly of this unit is shown in Figure 6.

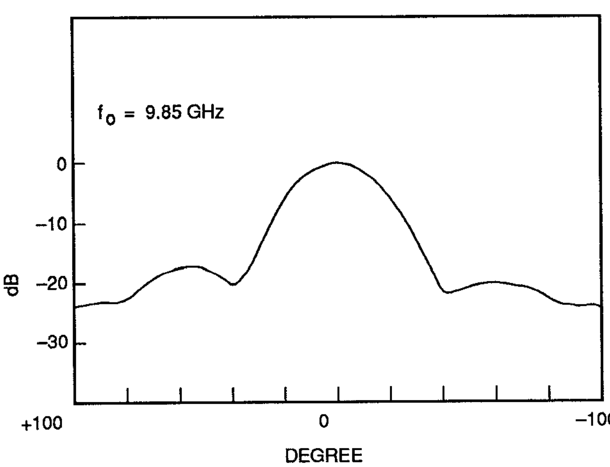

Figure 5 H-plane pattern.

TECHNICAL DISCUSSIONS

An optional MMIC power amplifier was included for higher power transmission and to improve detection sensitivity. In short range radar applications, a power amplifier is less likely needed. The amount of transmitted power depends on the design objectives. In general, the system requirement is governed by the signal to noise (SNR) ratio which can be derived from the radar equation (1):

$$S/N = \frac{P_t G A_e \sigma}{(4\pi)^2 k T_o B_N F_N R^4}$$

To maintain a constant SNR, higher transmitted power is needed for a smaller target and longer detection range. Similarly, higher antenna gain will reduce system noise performance. Of course, the IF signal processing technique also plays an important role in controlling SNR.

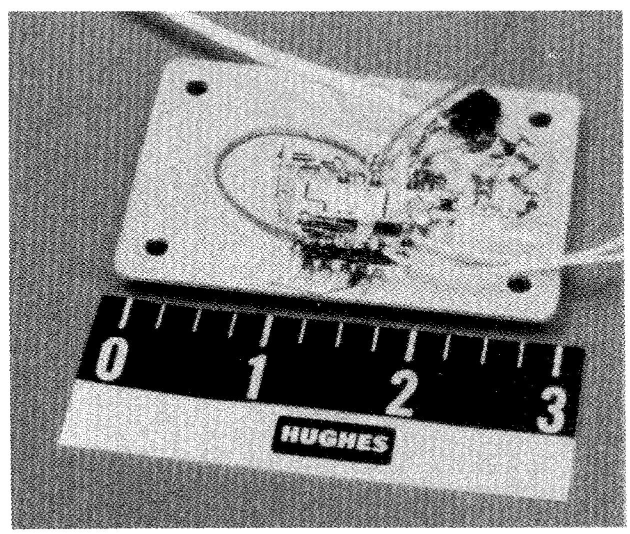

Figure 6 The transceiver's RF assembly.

SUMMARY

A low cost, X-band transceiver was developed utilizing a monolithic transceiver chip. The employment of all planar circuitries results in a compact, multi-functional transceiver that is highly suitable for high volume production.

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