A COMPACT LOW COST 60 GHZ COMMUNICATOR

M-4

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ABSTRACT

A 60 GHz communicator is described. A low cost suspended substrate circuit performs as a modulator, duplexer and down-converter. A single unstabilized Gunn oscillator acts as both transmitter and receiver local oscillator. The communicator has eight selectable subcarrier channels.

Introduction

A low cost helmet mounted transceiver has been built for short range communications at 60 GHz. The use of suspended substrate techniques has resulted in a compact light weight millimeter wave circuit occupying a volume of .2 cubic inches. The head mounted portion of the communicator including antenna and low frequency circuits occupies a cylinder of four inch diameter and 1½ inch height. Total weight of the head mounted portion of the communicator is 9.5 ounces. Communication range is 300 feet with 360 degree azimuth and 20 degree elevation coverage.

Circuit Operation

To keep cost to a minimum, a 50 milliwatt Gunn oscillator serves as both transmitter and receiver local oscillator. To eliminate the requirement for Gunn oscillator frequency control circuits, information is carried on a frequency modulated subcarrier. A block diagram of the communicator is shown in figure 1.

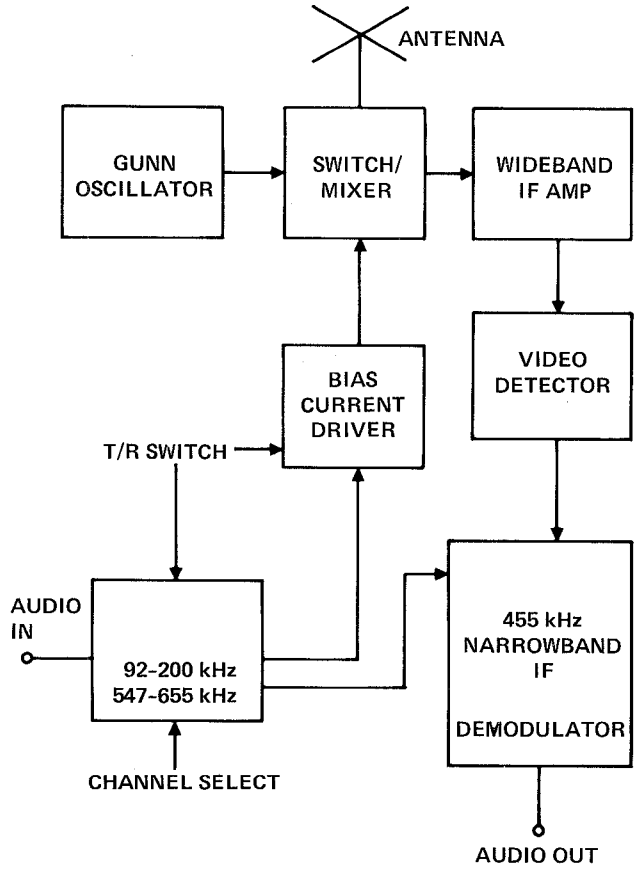

Figure 1.

In the transmit mode, power from the Gunn oscillator is switched on and off at the subcarrier frequency by the switch/mixer. The resulting 60 GHz signal with subcarrier is transmitted through the antenna. The subcarrier frequency is generated by a small frequency synthesizer and is frequency modulated by the input audio signal. The synthesizer can produce eight selectable subcarrier frequencies between 92 and 200 kHz.

In the receive mode the switch/mixer downconverts the received signal to a wideband (1-400 MHz) intermediate frequency (IF). A wideband IF is required to allow for the thermal drift of the unstabilized Gunn oscillators of both the transmitting and receiving units. After amplification the IF is video detected to recover the subcarrier frequency. The recovered subcarrier is up-converted to a 455 kHz second IF, amplified, and demodulated by a commercially available integrated circuit. The frequency synthesizer provides the appropriate low frequency local oscillator signal for the second mixer.

Switch/Mixer

The key component in the millimeter wave portion of the communicator is the suspended substrate switch/mixer which performs as a modulator, duplexer and downconverter. The substrate material is .005 inch Duroid, and is suspended in channels .080 inch wide by .040 inch deep. The substrate configuration is shown in figure 2. Line widths and probe dimensions are scaled from those given in reference 1. The circuit consists of a 90 degree hybrid balanced mixer with provisions for biasing the diodes. Quarter wave transformers match the impedance of the diodes to the higher impedance of the hybrid. The circuit is coupled to the antenna and Gunn oscillator through probe transitions. The IF signal from the two diodes (Alpha DMK 6606AM) is summed in the hybrid and removed through a spur-line filter. The opposite ends of the diodes are grounded at the IF frequency. In the receive mode the diodes are biased for minimum conversion loss. Conversion loss of the mixer is about 6 dB.

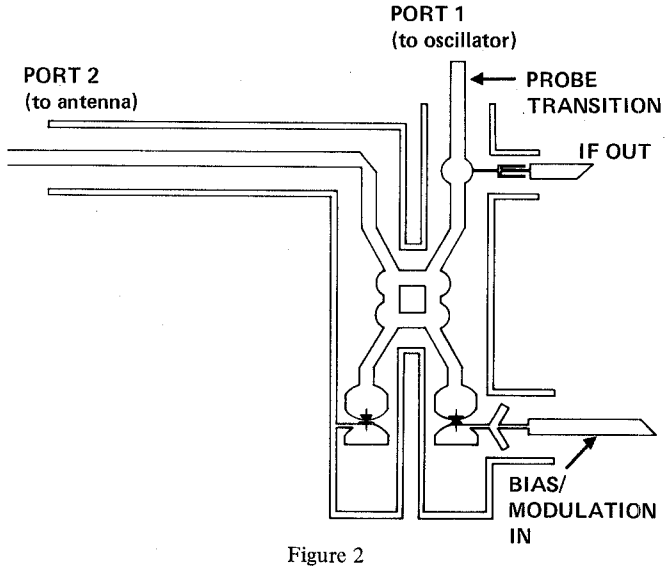

Figure 2

In the transmit mode the diode bias is used to modulate the impedance of the diodes. The isolation between ports 1 and 2 of the circuit is a function of the impedance match of the diodes to the circuit. With heavy forward bias (about 30 mA), power from port 1

is reflected to port 2 with about 2.4 dB loss. When biased for good impedance match, the isolation between ports 1 and 2 is 12 to 15 dB. In this manner the mixer can be used as a modulator with an on-off ratio of 10 dB or greater, and a minimum insertion loss of 2.4 dB. Connection of the Gunn oscillator to port 1 and the antenna to port 2 allows the circuit to act as the input mixer during the receive mode as well as the modulator during the transmit mode. Since the transmitter and receiver share all of the millimeter wave components, no other duplexing mechanism is required.

Antenna

The antenna is a vertically polarized bicone with 20 degree 3 dB elevation beamwidth. A sectional view of the antenna and suspended substrate circuit is shown in figure 3. The antenna diameter is 4 inches and the vertical aperture is .5 inch. A Rexolite ring serves as a separator and support for the upper cone, and is 1.5 wavelengths thick at 60 GHz.

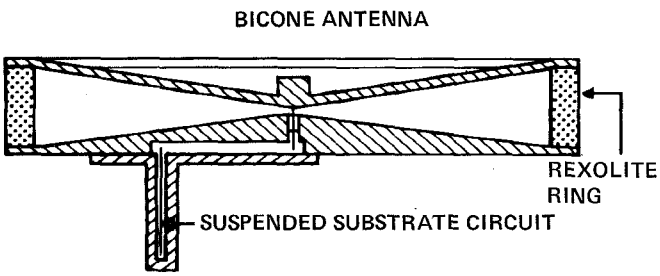

Figure 3

The 15 ohm antenna impedance is transformed by a short coaxial section which is probe coupled to a waveguide milled into the bottom surface of the lower cone. The waveguide serves as a high-pass filter, and also allows the suspended substrate circuit to be probe coupled to the antenna circuit at a point away from the center of the antenna. Measured antenna gain is between 6 and 7 dBi. A photograph of a partially disassembled communicator is shown in figure 4.

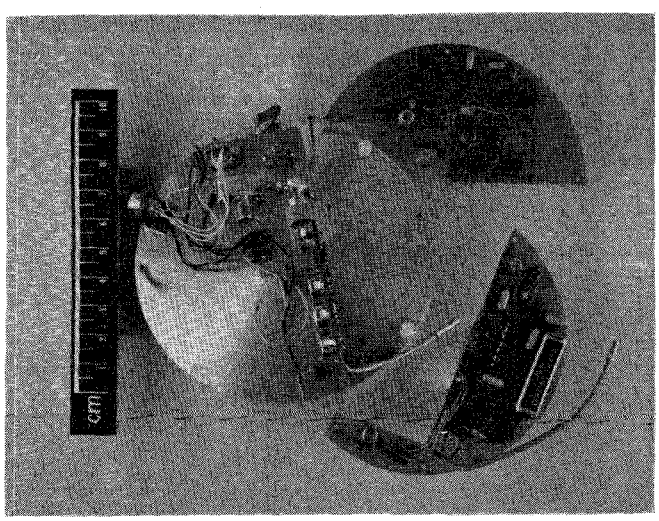

Figure 4

IF Amplifier, Video Detector

The wideband if amplifier has 57 dB gain from 1 to 400 MHz. Since all communicators of this type would be tuned arbitrarily close to the nominal 60 GHz frequency, it is important that the IF amplifier work at frequencies as low as possible without overlapping the subcarrier frequency range. This reduces the possibility of communication failure due to communicators being tuned to almost identical frequencies. To avoid increasing detector noise levels at the subcarrier frequencies, the IF amplifier should have no gain in the subcarrier frequency range. The output of the IF amplifier is coupled through a wideband transformer to a General Electric BD-4 back diode. The tangential sensitivity of this detector is better than -45 dBm.

Conclusion

A simple millimeter wave circuit built using suspended substrate techniques and an unstabilized Gunn oscillator has allowed the production of a lightweight, compact low cost communicator. The design is also appropriate for longer range communications at other frequencies using appropriate directional antennas. Use of temperature compensated Gunn oscillators with lower thermal frequency drift would allow a reduction of IF bandwidth and a resultant increase in system sensitivity and range.

References

1. Hislop, A. and D. Rubin
"Suspended Substrate Ka Band Multiplexer," Microwave Journal, Vol. 24, June 1981, pp 73-77.