CHANNELIZED RECEIVER COVERING 26 TO 60 GHZ
WITH PLANAR INTEGRATED-CIRCUIT COMPONENTS*

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ABSTRACT

A nine-channel downconverter covering 26 to 60 GHz is described. The system includes reproducible hybrid-coupled multiplexers, balanced integrated circuit (IC) mixers, built-in-test equipment, and LO's including a cavity-stabilized, lumped-element model. The system is the first of its kind to extensively utilize low-cost, high-Q, millimeter-wave IC's.

Introduction

Channelized receivers are preferred in surveillance applications where a high probability of intercept, low acquisition time, and high sensitivity are required. Since a large number of channels are required at millimeter wavelengths, it is important that the unit cost be small. This paper describes a nine-channel downconverter, covering the RF band of 26 to 60 GHz, which is the first of its kind to extensively utilize low-cost, high-Q, reproducible, E- and H-plane integrated circuits.

System Configuration

Based on a study of the performance goals, alternative block diagrams, and candidate IC components, a preferred system configuration was selected. Figure 1 is a block diagram of the preferred system. RF signals enter the system through standard waveguide ports, appropriate to the frequency band. (Band I covering 26 to 42 GHz has a WR-28 port; band II covering 42 to 60 GHz has a WR-19 port.) Each input is split by a bank of channel-dropping filters (CDF's). Each CDF contains dual, E-plane, band-pass filters (BPF's) embedded between hybrid, H-plane, 3-dB couplers (reference 1). After passing through the final CDF in the chain, the last channel is defined by a single BPF.

Each output of the multiplexer is fed to a balanced IC mixer and downconverted to the IF band of 4 to 8 GHz. In addition to waveguide RF/LO ports and an SMA IF port, each mixer contains a terminal for built-in-test equipment (BITE). By injecting a known dc voltage at each BITE terminal, potential problems such as failed mixer diodes or inadequate LO drive can be pinpointed.

The mixers are driven by a bank of Gunn oscillators. Each oscillator has an isolator at the output port and a voltage regulator at the dc input. All regulators are powered by a common 12-Vdc supply.

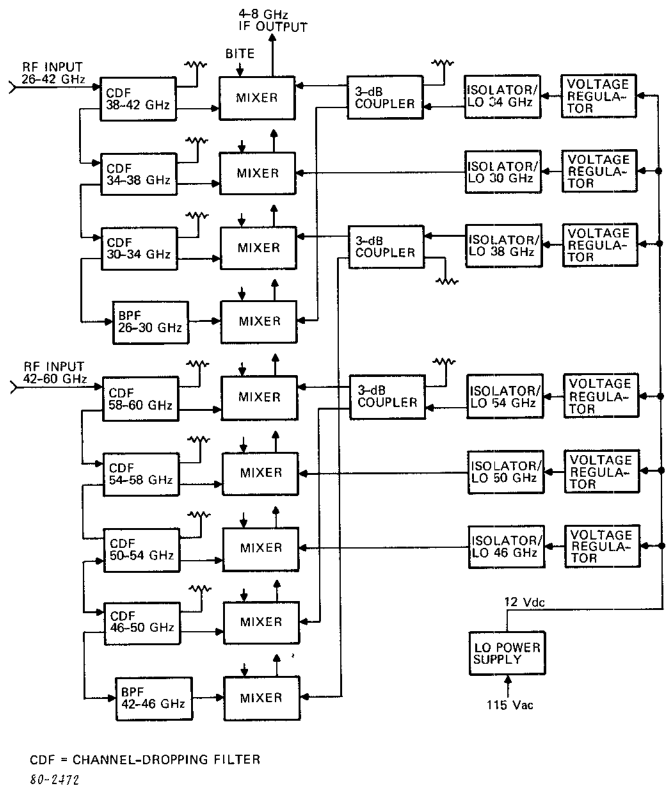

Figure 1. Channelized Receiver Block Diagram

H-plane 3-dB couplers allow the output of certain oscillators to be shared between two mixers, thereby reducing the required number of oscillators. The LO's include a lumped-element cavity-stabilized model, demonstrating precise frequency control without heater power or an active reference.

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Figure 2 shows the breadboard model of the channelized receiver. The downconverters are mounted on flat plates which can be hinged open, as shown, or folded into a rectangular system housing. When folded, all inputs, outputs, and BIT controls appear on one panel. Since the packaging density is low in the breadboard, a compact system is feasible with further work. Also indicated in Figure 2 are examples of the key components which are described in the following paragraphs.

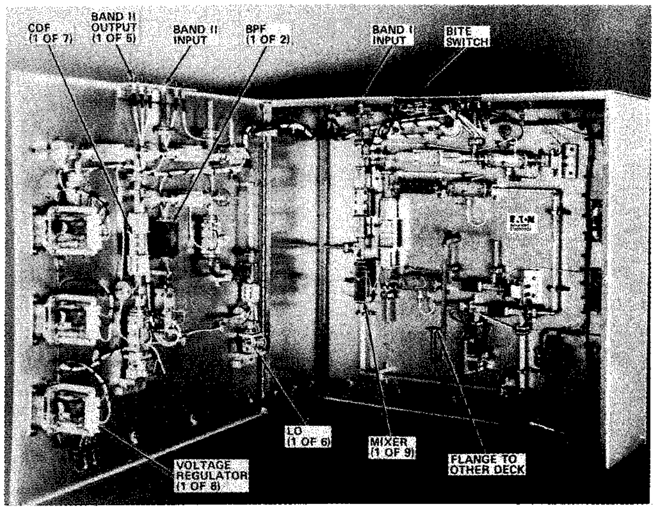

Figure 2. Breadboard System

Multiplexers

The multiplexers are based on a reproducible hybrid-coupled design, with low-loss photoetched circuits in all filters and couplers (reference 1). The filters are 7-pole, 0.1-dB Tchebycheff designs with an unloaded Q of greater than 1500 at 28 GHz. The band I multiplexer splits the RF range of 26 to 42 GHz into four contiguous channels. The insertion loss in each 4-GHz passband is 1.2 to 2.8 dB and the 45-dB rejection bandwidth is less than 8 GHz. In the five channels of band II, the passband loss is typically 2.5 to 4.5 dB. Experience has shown that little or no trimming will be required in future production runs.

Mixers

Balanced printed-circuit mixers have been developed to cover the RF band 26 to 60 GHz in nine channels. The mixers integrate fin-line, coplanar line, and microstrip on a single substrate and incorporate advanced beam-lead diodes (reference 2) in the RF bands above 42 GHz. Relative to an earlier design (reference 3), the mixers incorporate improvements which include better RF and LO transitions, higher cutoff diodes, bias junctions for BITE, and predictable matching elements based on computer-aided analyses.

Figure 3 shows typical mixers for bands I and II. Adjacent to each mixer assembly is a duplicate of the printed circuit which is mounted in the E-plane of the assembly. The circuits are printed on 5-mil Duroid 5880 and each includes cosine tapers at the RF and LO ports. Details on the computer-aided design of these circuits will be presented.

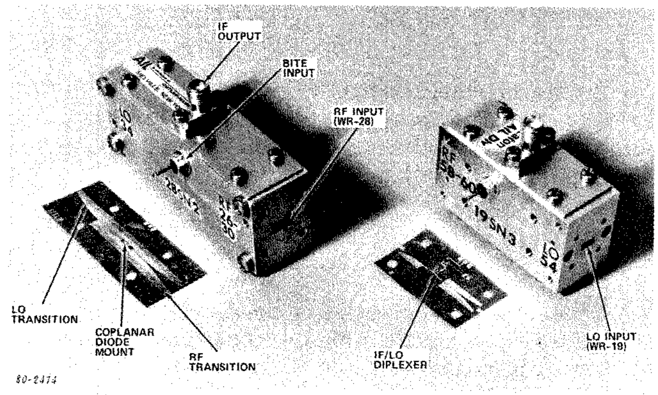

Figure 3. Printed-Circuit Balanced Mixer

Figure 4 shows how the conversion loss of typical mixers for bands I and II varies with LO power. A drive level of 10 to 13 dBm was found to be adequate, if not optimum, in all the mixers.

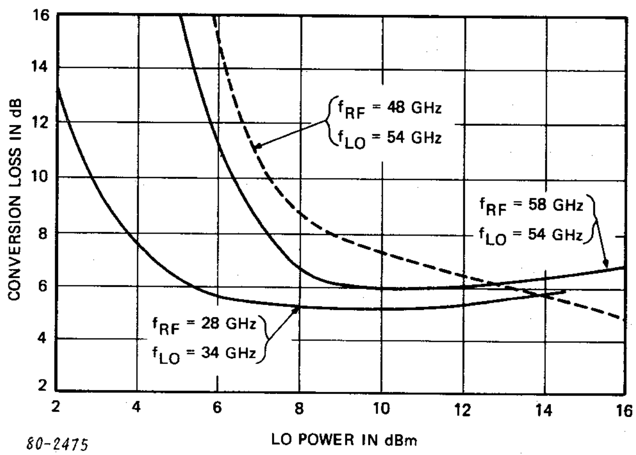

Figure 4. Mixer Conversion Loss Versus LO Power

Stabilized Local Oscillator

The system includes a cavity-stabilized, lumped-element, 34-GHz oscillator. This LO was developed to demonstrate that precise frequency control, and adequate output for two mixers, could be achieved without heater power or an active reference. The oscillator is in keeping with the low-cost objective of the system because very few discrete elements (that is, three) are required and the cavity is fabricated from commercial, copper-clad Invar-36 waveguide.

Figure 5 shows the 34-GHz oscillator which is stabilized by a reaction cavity. The equivalent circuit and the design procedures will be described.

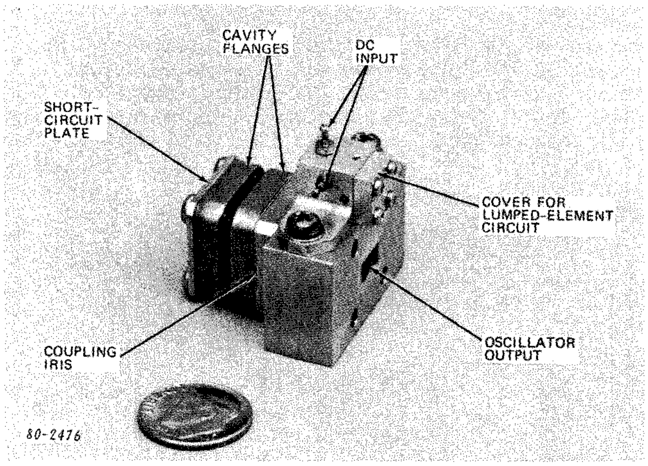

Figure 5. Cavity-Stabilized Lumped-Element Oscillator

With a composite cavity, fabricated from Invar waveguide and brass flanges, an average temperature stability of -290 kHz/^{o}C was measured from 10 to 60^{o}C. Moreover, calculations show that a stability of -110 kHz/^{o}C could be achieved if Invar flanges were substituted for brass in the cavity. This is better than three times the stability of commercial oscillators.

The measured power output of the stabilized oscillator was 15.2 to 14.7 dBm across the temperature range of 10 to 60^{o}C. This is more than adequate for two balanced self-biased mixers.

System Performance

Measurements of conversion loss, noise figure, and tangential sensitivity were performed on the breadboard system. Factory calibrated thermistors were used to measure the IF output power and the RF input power from 25 to 40 GHz. In the band of 40 to 60 GHz, the RF power was measured with a WR-19 thermistor (Hitachi F2512) calibrated against a dry calorimeter (PRD 666).

Figure 6 shows the measured conversion loss of the system. The passband conversion loss is typically 10 to 12 dB and the crossovers are in general agreement with the program objectives. Further improvement is feasible with refinements in the filter and mixer designs. Typical passband values for noise figure and tangential sensitivity are 14 dB and -100 dBm, respectively, measured with an IF contribution of 3.5 dB.

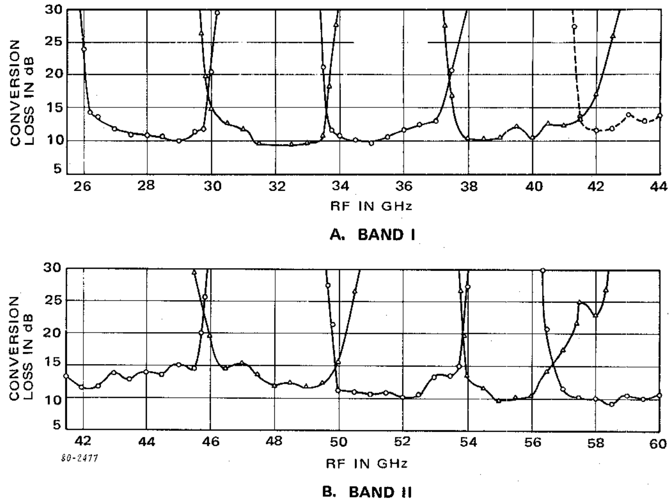

Figure 6. Conversion Loss of System

Conclusions

This paper has described a nine-channel down-converter, which is the first of its kind to extensively utilize low-cost, high-Q, millimeter-wave IC's. The breadboard system features predictable hybrid-coupled multiplexers, balanced IC mixers, BITE, and Gunn LO's including a cavity-stabilized, lumped-element model. A substantial reduction in size and weight is possible by repackaging the existing system or by modifying the block diagram. (Wider channels and alternative multiplexers are feasible.) Regardless of the block diagram chosen for future millimeter-wave surveillance receivers, the planar IC technology demonstrated in this program will be applicable to high-performance, reproducible, low-cost systems.

Acknowledgment

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References

1. K. D. Breuer and N. Worontzoff, "A Low Cost Multiplexer for Channelized Receiver Front Ends at Millimeter Waves," Digest of IEEE 1980 MTT-S Symposium, p 150-152, May 1980.

2. J. A. Calviello, et al, "High-Performance GaAs Beam-Lead Mixer Diodes for Millimeter and Sub-millimeter Applications," Electronics Letters, Vol 15, No. 17, p 509-510, August 1979.

3. P. J. Meier, "Printed-Circuit Balanced Mixer for the 4 and 5 mm Bands," Digest of IEEE 1979 MTT-S Symposium, p 84-86, April 1979.