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Low-Noise Mixer in Oversized Microstrip for 5-mm Band

PAUL J. MEIER

***Abstract*—This short paper summarizes the design and performance of a low-noise 5-mm mixer constructed in oversized microstrip—a new type of transmission line which is superior to microstrip at millimeter wavelengths. Including a 5-dB IF contribution, the measured noise figure was 9–10.5 dB over a wide range of LO frequencies and drive levels.**

Although standard microstrip techniques can be applied to millimeter components [1]–[3], several problems arise. These problems include critical tolerances, fragile substrates, thin conductor strips which are not completely compatible with hybrid devices, and difficulty in obtaining a simple transition to conventional waveguide. Mounting an integrated circuit between two waveguides [4], can alleviate these problems. This short paper discusses the design and performance of a low-noise wide-band millimeter mixer constructed in a new IC medium called oversized microstrip [5].

Normally, the thickness of a microstrip substrate is held to a small fraction of a guided quarter wavelength to restrict the radiation loss. If, however, we intentionally set the substrate thickness at a quarter wavelength, an efficient radiator may be printed on the ungrounded surface of the substrate. When mounted in a waveguide, as shown in Fig. 1, this radiator will couple to the TE_{10} waveguide mode and all the power may be delivered to an impedance-matched load (such as a mixer diode) provided that no energy is reradiated in some other mode such as the crossed TE_{01} mode. For this reason, the air-filled portion of the waveguide should not support the TE_{01} mode, which is automatically accomplished when a standard waveguide is operated within its normal frequency range. Moreover, the dielectric-filled portion of the waveguide should not support the TE_{01} mode, in order to prevent resonances within the substrate. This may be accomplished by reducing the waveguide size within the dielectric region, or by printing the radiator on a thin substrate which is suspended above the ground plane.

Fig. 1 illustrates the essential features of a mixer constructed in oversized microstrip. Both the local oscillator and the signal are coupled from the waveguide by a monopole, whose length and shape are selected to provide a wide-band impedance match to the diode. In the intended application, both the local oscillator and signal will be close in frequency, and fed to an array of mixers by quasi-optical techniques. (A small local-oscillator radiator illuminates the mixer array which is located in the focal region of a large spherical reflector.) Laboratory testing of each mixer is performed, external to the array, by injecting the local oscillator through a directional coupler. In each mixer, the diode is returned to ground at RF and dc by a direct connection to the waveguide housing. Bias is injected, and the IF signal is extracted through an RF-blocking network, which does not couple to the TE_{10} mode.

Fig. 2 shows an experimental model of a mixer constructed in oversized microstrip. The monopole, diode-mounting lands, and RF-blocking network are all printed on a Mylar gasket whose thickness is 0.005 in. The conductor patterns were formed by photoetching copper and nichrome layers vacuum deposited on the Mylar, followed by a protective gold flash. The gasket is then sandwiched between two UG-385/U flanges, one of which is the input to a short-circuit termination. The other flange has been modified to accept a pair of rectangular choke grooves and a radial channel for the bias port. Each choke groove is a quarter wave deep and spaced a quarter wave from the main WR-15 waveguide. The choke was evaluated separately, by measuring the insertion loss through the main waveguide with an unmetallized 0.005-in Mylar gasket in place. The loss measured less than 0.2 dB across the 55–63-GHz band. A radial channel was next milled in the special flange to accommodate the bias line and RF-blocking network. This channel has a negligible effect on the insertion loss of the system.

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The author is with the Applied Electronics Division, AIL, a division of Cutler–Hammer, Melville, N. Y. 11746.

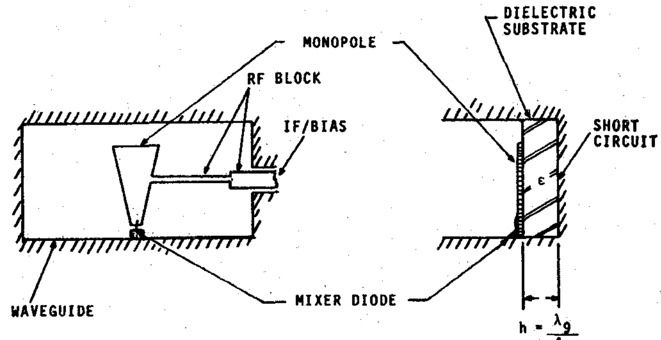

Fig. 1. Mixer in oversized microstrip.

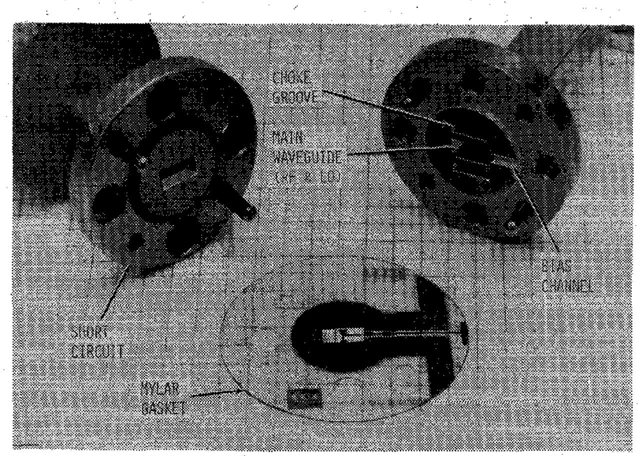

Fig. 2. Experimental mixer model.

The preliminary steps in the design of the oversized microstrip mixer included the selection of the optimum type of diode, and the impedance matching of the monopole to this diode. Optimum performance was obtained with preproduction samples of an advanced GaAs beam-lead Schottky-barrier diode. The diodes were developed by the British General Electric Company [3], and are expected to become commercially available in the near future.

Fig. 3 illustrates an advanced version of the oversized microstrip mixer, in which the monopole has been shortened and moved off axis to improve the impedance match. This mount also features a shielded miniature (SMA) output connector, which accommodates the high IF typically required in single-ended mixers. The Mylar was replaced by Kapton, as the latter can tolerate higher temperatures and, as such, is better suited to standard metallization and bonding techniques. With a forward bias of 0.6 V and 1.0 mW of drive, the VSWR of the final design was 2.0 or better across the band from 59 to 63 GHz. It is believed that further optimization of the shape and location of the monopole could result in still wider bandwidths. (Alternatively, enhanced performance across a narrow band, through suitable termination of the image frequency [4], is possible with a higher monopole Q.)

After a satisfactory impedance match had been obtained across a 4-GHz band, the noise figure of the mixer was measured. Measurements were performed by the standard Y-factor method with the aid of a noise tube calibrated against the AIL millimeter hot load [6]. An IF of 1.5 GHz was selected, as this frequency offers a good compromise between the degradation introduced by LO noise and

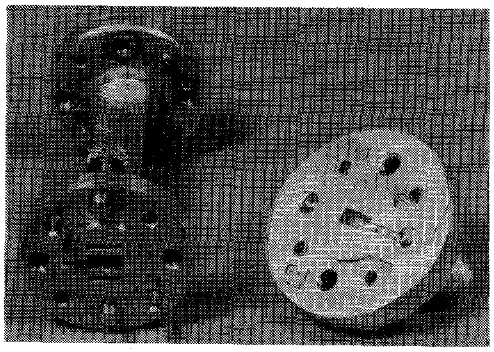

Fig. 3. Advanced mixer mount.

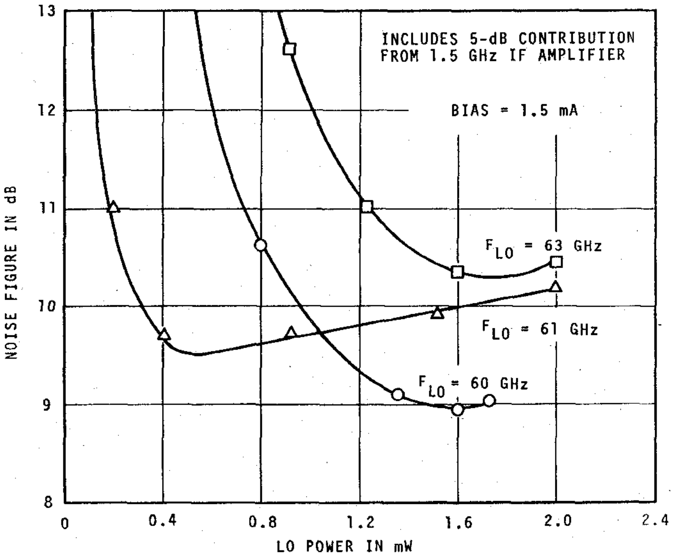

Fig. 4. Noise figure of mixer with GaAs diode.

the noise contributed by the IF amplifier. Fig. 4 shows how the measured noise figure varied with respect to LO power, with the LO frequency as a parameter. The 1.5-GHz IF contributed 5 dB to the measurement, and the dc bias voltage was varied to maintain a constant current of 1.5 mA through the diode. The measured noise figure was 9–10 dB for LO frequencies in the 60–61-GHz range for drive levels of 0.9–1.8 mW.

It is believed that an overall noise figure of 6 dB is feasible in future models with superior FET IF amplifiers. Owing to the low-loss characteristics of oversized microstrip, its freedom from tight tolerances and compatibility with hybrid devices, this new transmission line is well suited to a wide variety of integrated circuits throughout the millimeter spectrum.

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Simplified 12-GHz Low-Noise Converter with Mounted Planar Circuit in Waveguide

YOSHIHIRO KONISHI, SENIOR MEMBER, IEEE, KATSUAKI UENAKADA, NORIHIKO YAZAWA, NORIO HOSHINO, AND TADASHI TAKAHASHI

***Abstract*—A 12-GHz low-noise converter consisting of a planar circuit mounted in waveguide is described. This circuit consists of a metal sheet with proper patterns that is inserted in the middle of a waveguide parallel to the *E* plane. All circuit elements required for the converter are pressed or etched. This circuit is very useful for low-cost mass production and good performance. A measured noise figure of 4.5 dB was obtained with a 12-GHz signal frequency and a 420-MHz intermediate frequency.**

I. INTRODUCTION

A low-noise 100-GHz converter comprising a microwave integrated circuit mounted in a waveguide was reported by Konishi and Hoshino in 1971 [1]. A low-noise 12-GHz converter based on a similar principle is described in this short paper. It consists of a planar circuit mounted in a waveguide and is suitable for low-cost mass production.

Millimeter components using integrated circuits mounted in a waveguide were also developed by Meier in 1972 [2], where unloaded Q of this transmission line takes a value less than 900 at X band [3].

A new type of filter, that is, a planar circuit mounted in waveguide, that we have developed has an unloaded Q factor of 2000–2500 at X band. This new type of filter is used in our 12-GHz converter to achieve low-noise performance.

The 12-GHz converter described in this short paper has a mixer conversion loss of 3.5 dB and a total noise figure of 4.5 dB, including the contribution of an intermediate frequency amplifier with a noise figure of 2.0 dB at 420 MHz.

II. 12-GHz LOW-NOISE CONVERTER WITH MOUNTED PLANAR CIRCUIT IN WAVEGUIDE

A high-sensitivity and low-cost converter was required that could be constructed simply and be mass produced. The construction of the circuit we developed is such that every necessary circuit element is arranged on a metal sheet merely by pressing or etching, and the metal sheet is inserted into a waveguide.

We will describe the results of the experiment that was carried out on our converter with a mounted planar circuit.

Fig. 1 shows the planar circuit pattern from left to right, a signal frequency bandpass filter, a Schottky barrier diode mount, a local oscillator frequency bandpass filter, and a Gunn diode mount for the local oscillator. A 0.3–0.5-mm-thick copper sheet is favorable for this pattern. When etching is used in forming the pattern, a 0.3-mm copper sheet is utilized for dimensional precision. When pressing is used, with a 0.5-mm-thick metal sheet, dimensions are maintained within 20 μm.

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The authors are with the Technical Research Laboratories, Japan Broadcasting Corporation, Tokyo, Japan.