A 100GHz-band Antenna Stacked Monolithic Receiver using Multilayered Configuration

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Abstract

This paper presents a 100 GHz band antenna stacked monolithic receiver. The receiver consists of four microstrip antennas made on a quartz substrate and four diode mixers fabricated on a GaAs substrate monolithically. The microstrip antennas and the four mixers are stacked to be back-to-back just like a multilayered configuration. The size of the four mixer chip is 6 mm x 6 mm. The conversion loss of the mixers is within 8.0 ± 0.5dB.

1.Introduction

For millimeter-wave receiving systems, the followings are required:
(1) reduction of feed line loss for low noise receiving;
(2) large aperture for high gain and sharp beam;
(3) reduction of spurious power radiation.

In recent years, many papers reported about integration of antenna and receiver or transmitter circuit [1]-[11]. Prof. Itoh's group reported the active antenna consisting of antenna array and FET's circuits on the same side of the substrate[3]-[4]. Prof. Rutledge's group proposed grid type circuits in which antennas and circuits are integrated: i.e. grid detector, grid phase shifter, grid amplifier, grid oscillator, grid doubler and grid mixer[5]-[7]. Qin et al. reported a control grid that can control antenna beam in millimeter wave band[8]. These grid type circuits are of quasi-optical configuration and suitable for very high frequency such as millimeter and sub-millimeter wave bands. Prof. Rebeiz's group reported planar monopulse receiver fabricated on GaAs substrate[9]. Mixer and amplifier circuits and four antennas are on the same side. By applying these monolithic or integrated antennas to the receiving systems, the above requirement (1) is satisfied and the requirement (2) may also be possible.

This paper describes an antenna stacked monolithic receiver. In addition to the requirements (1) and (2), the requirement (3) is satisfied by using multilayered configuration. Antenna elements are separated from receiver circuits by a ground plane. So, spurious radiation from the receiver circuits is suppressed. This configuration is also suitable for a future millimeter-wave antenna like a digital beam forming antenna or an adaptive antenna.

2.Circuit Configuration

2.1 Antenna stacked monolithic receiver

Figure 1 shows a block diagram of the antenna stacked monolithic receiver. Since the monolithic receiver converts received signal to intermediate frequency, the feed line loss is negligible, while the feed lines are long to a receiver IF and baseband circuits. Since the mixers are pumped by coherent local oscillator output signal(LO), this configuration can be easily applied to beam steering antenna like a digital beam forming.

Figure 2 shows a schematic configuration of the antenna stacked monolithic receiver. Four microstrip antennas are made on a quartz substrate and a receiver composed of four

mixers is fabricated on a GaAs substrate monolithically. They are stacked to be back-to-back together, and coupled through a slot[12]. The features of the configuration are:
(1) no interference between antenna and receiver;
(2) small size and area;
(3) independent optimization of antenna and receiver;
(4) small size of GaAs substrate;
(5) low coupling loss of antenna and receiver.

2.2 Mixer and other components

Local oscillator output signal(LO) is fed to mixers through Wilkinson power dividers. In order to make in phase operation of 4 mixers, LO feed circuits has symmetrical configuration and the diode polarization of mixer pairs is reversed each other.

In order to obtain matched characteristics of four mixers and low spurious radiation, each unit mixer is required to have characteristics as below:

(1) Low input VSWR ; (2)High isolation of LO to RF port .

So, unit mixer is designed in balanced mixer configuration using a Lange coupler. Junction capacitance of the mixer diode is optimized to get low conversion loss and broadband impedance matching.

3. Experimental Results

3.1 Mixer

Figure 3 shows a photograph of the mixer chip which was made for measurement and estimation of the unit mixer characteristics[13]. The thickness of GaAs substrate is 0.1mm. The junction capacitance of the mixer diode with 1 THz cutoff frequency was designed to be of 15fF. Figure 4 shows return loss of input port. Return loss is larger than 10dB from 75GHz to 100GHz. Figure 5 shows frequency characteristics of conversion loss of the mixer. Conversion loss of 8.5dB is obtained including microstrip line loss over wide frequency band from 75GHz to 105GHz.

3.2 Antenna stacked monolithic receiver

Four mixer IC and four microstrip antennas were fabricated on a GaAs and quartz respectively. Figure 6 shows a photograph of the four mixer IC. The four mixer IC chip is 6 mm x 6 mm. The thickness of GaAs substrate and that of quartz substrate for a microstrip antenna are 0.1mm and 0.2mm respectively. The diameter of the receiver front end including C-band IF amplifiers is less than 25mm. Figure 7 shows conversion loss of the mixers integrated in the four mixer IC. Conversion loss was obtained from antenna measurement. Antenna gain, span loss, feed line loss, and IF amplifier gain are excluded from the measured value. Conversion loss of 8.0 ± 0.5dB is achieved. The conversion loss characteristics of each mixers are in good coincidence. It seems that the four mixers do not interfere each other and operate independently.

4. Conclusion

A 100 GHz band antenna stacked monolithic receiver has been developed. It is suitable for a future millimeter-wave antenna like a digital beam forming antenna or an adaptive antenna.

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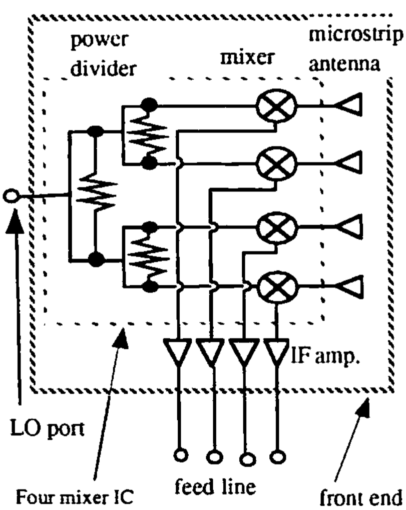

Fig.1 Block diagram of the receiver

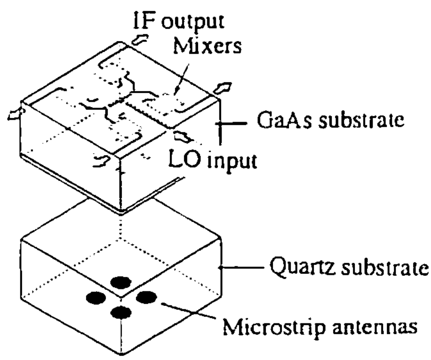

Fig.2 Schematic configuration

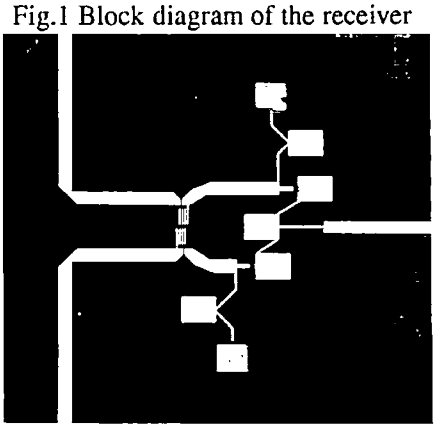

Fig. 3 Photograph of the unit mixer chip

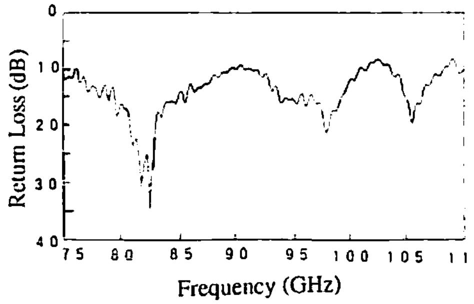

Fig. 4 Input port return loss

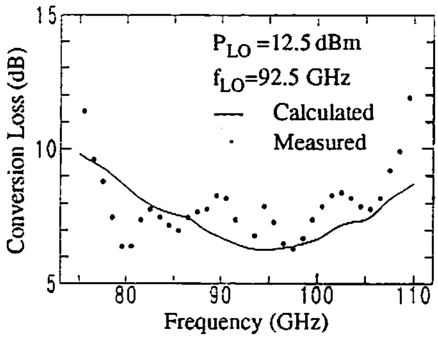

Fig. 5 Conversion loss of the unit mixer

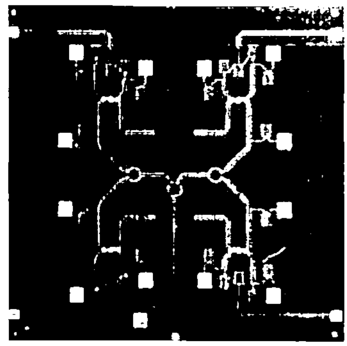

Fig. 6 Photograph of the four mixer IC

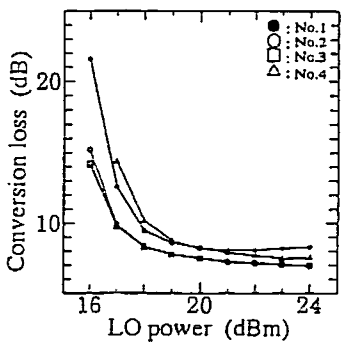

Fig. 7 Conversion loss of the mixers