MIC ASSEMBLY FOR 12-GHz DIRECT BROADCAST SATELLITE RECEIVER

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ABSTRACT

This paper describes the MIC assembly for 12-GHz direct broadcast satellite(DBS) earth-station receivers. It is a compact assembly consisting of a GaAsFET amplifier, an image rejection filter, a diode mixer, a dielectric resonator oscillator and an IF amplifier. A DBS receiver incorporating this unit achieves an overall noise figure <3.0dB for frequencies from 11.7 to 12.2GHz.

Introduction

The use of direct broadcast satellite (DBS) systems has become a matter of increasing interest in various countries during the past few years. The outdoor unit is one of the important constituents of the system. This paper describes an outdoor unit for 12-GHz DBS earth-station receiver developed by NRIET. It consists of a 12-GHz low noise amplifier (LNA), a 10-GHz image rejection filter (BRF) which is included in the LNA circuit, a 12-GHz single diode mixer (SMD), an 11-GHz dielectric resonator oscillator (DRO) and an 1-GHz IF amplifier (IFA). All these RF components use packaged active devices (which were made in P.R. China) and are realized in hybrid MIC technology. All the RF components are integrated into a compact hermetically sealed assembly with an input BJ-120 waveguide and an output type N coaxial connector. A DC-DC converter is also included to supply stabilized voltages to the abovementioned components. The block diagram of the outdoor unit is shown in Fig.1. The main design consideration is to obtain high performances and reliability at a low cost.

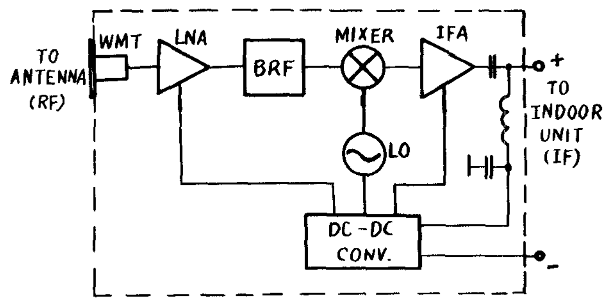

Fig.1 Block diagram of the outdoor Unit for DBS receiver

Low-Noise Amplifier (LNA)

The LNA plays an important role in DBS for achieving high C/N of the receiver. It is a two-stage GaAsFET amplifier using low noise GaAsFET type WC-60 with 0.5 μm gate length(The noise figure of the FET is 1.8 dB).The single stage LNA is developed first. The source and load reflection coefficients for minimum noise figure and maximum gain of the FET may be obtained through measurements of its noise parameters(1) and s-parameters. The circuit of the LNA is designed for minimum noise figure at the same time obtaining relatively high gain. $\lambda/4$ impedance transformers together with short sections of series microstrip lines are used to form the input and output matching networks. Correc-

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tions for dispersions, discontinuity effects[2] and parasitic impedances arising from the mount of the FET must be considered in the precise design on alumina substrate at Ku-band. Careful design of microstrip DC blocks and elements for microstrip biases are also needed.

After evaluations of the single-stage LNA the two-stage LNA was designed. Its circuit diagram is shown in Fig.2. The alumina substrates containing the input, output and interstage matching circuits are fixed onto a ground plane and separated by ridges that held the FETs and ground their sources and packages. Use of this mounting structure allows some adjustments to be performed to optimize the performances of the amplifier. This structure also insures good contacts between the sources of FETs and metal ground, so high gain and stability may be achieved.

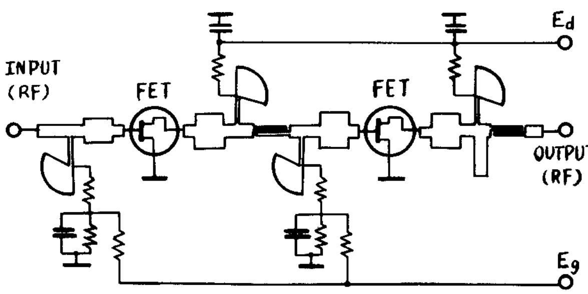


Fig. 2 Circuit diagram of 2-stage low-noise FET amplifier

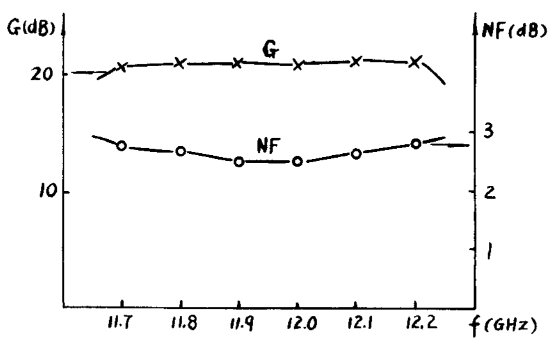


Fig. 3 Measured noise figure and gain vs. frequency of the LNA

A low loss waveguide-microstrip transition (WMT)joins directly the input of the LNA to the antenna feeder. The area of the LNA is 20x 45 mm.

The typical performances of the LNA (shown in Fig.3) are: noise figure $\lessdot$ 2.8dB, gain $\geqslant$ 20dB and gain ripple $\lessdot$ 1dB for frequencies from 11.7 to 12.2 GHz.

A simple BRF is included in the output circuit of the LNA. Connecting with this BRF the image rejection of the LNA is better than 15dB (while f_{LO}= 10.73GHz) within the cooresponding 500 GHz image frequency band.

Single Diode Mixer (SDM)

The mixer uses GaAs schottky barrier diode type WH513 (conversion loss of the diode is 3.5 dB at 12 GHz). The circuit diagram of the mixer is shown in Fig. 4.[3]

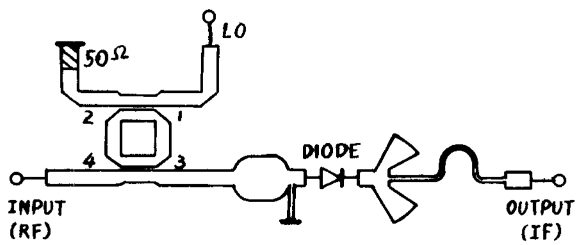


Fig. 4 Circuit diagram of the single diode mixer

A travelling wave ring-directional filter with circumference equals to λ_{LO} is used for LO and signal injections. The insertion loss of the LO path is about 4 dB, while the loss of the signal path is less than 0.5 dB within 500-MHz frequency band. The isolation between port 1 and port 4 in Fig. 4 is not less than 20 dB. The cut-off frequency of the low-pass impedance transformer on the output side of the mixer diode is around 1.6-GHz. It matches the IF impedance to 50-Ω, at the same time terminates the LO, signal, image and sum frequencies. A grounded $\lambda_s/4$ microstrip stub is used to provide a dc return for the diode current and presents a suitable IF inductance to the diode. The SDM is fabricated on a 20x 25mm alumina substrate. It achieves good noise performances within the operating frequency band as a post-stage of the LNA.

Dielectric Resonator Oscillator(DRO)

The local oscillator is of the negative resistance type. [4] Its circuit diagram is shown in Fig.5. It uses GaAsFET type WC-59 as an active device. The FET is a common-drain configuration. Its gate is connected to a micristrip line terminated by a 50-Ω microstrip resistor. Single power supply is needed. A high Q dielectric resonator (with unloaded Q higher than 5,000 at 10-GHz and relative dielectric constant 38) is used to stabilize the oscillation frequency. In oder to let the whole circuit satisfy oscillation condition at the resonant frequency of the dielectric resonator, the reflection coefficients(including the magnitudes and the phases) seen from each of the two sides of the FET should be calculated after the measurement of the s-parameters of the FET. Then the output matching network may be designed. The coupling of the dielectric resonator to the 50-ohm microstrip line and its distance from the FET may be estimated and determined by experiments. The DRO is fabricated on a 25x 30 mm alumina substrate.

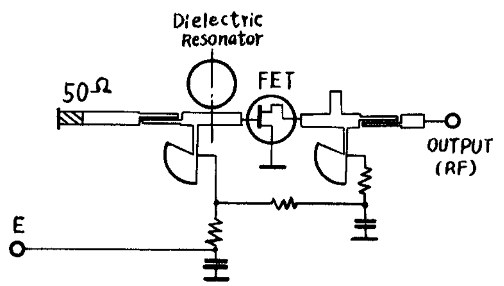


Fig. 5 Circuit diagram of the dielectric resonator oscillator

The RF performances of the DRO are: output power $>$ 5mW and frequency stability $\pm$ 0.18-MHz for oscillation frequency 10.73 GHz over temperature range of -20° — +50°C.

IF Amplifier (IFA)

The IFA is a four-stage bipolar transistor amplifier fabricated on teflon/ fiberglass substrate. The circuit diagram is shown in Fig.6. It uses transistors type GG-41(noise figure of the device is 1.6dB). The input network matches the output impedance of the mixer to the bipolar transistor for achieving low noise figure. There are lossy matching networks between interstages for compensating the negative sloped gain frequency characteristic of the transistors and achieving flattened response over wide frequency band. They also contribute to the stable operation of the IFA. A $\lambda_u/4$ stub terminated by a RF bypass capacitor in series with a microstrip resistor is included in each of the interstage networks. There is a dissipative pi- network at the output of the IFA for reducing

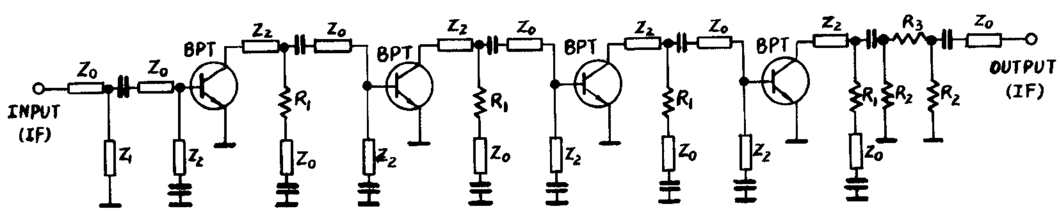
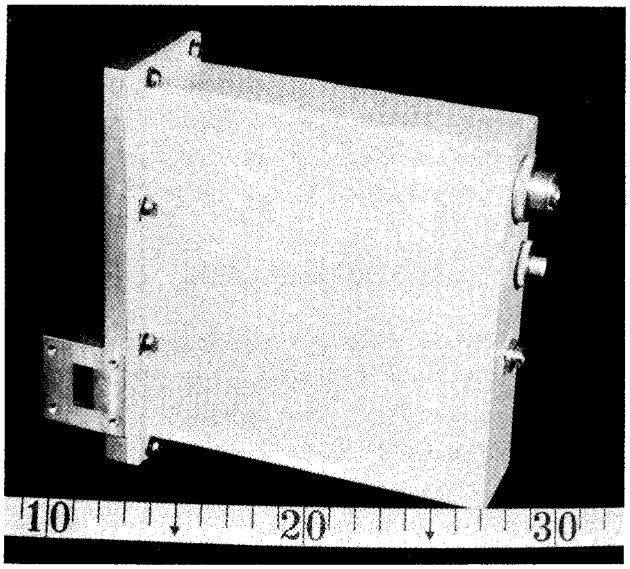


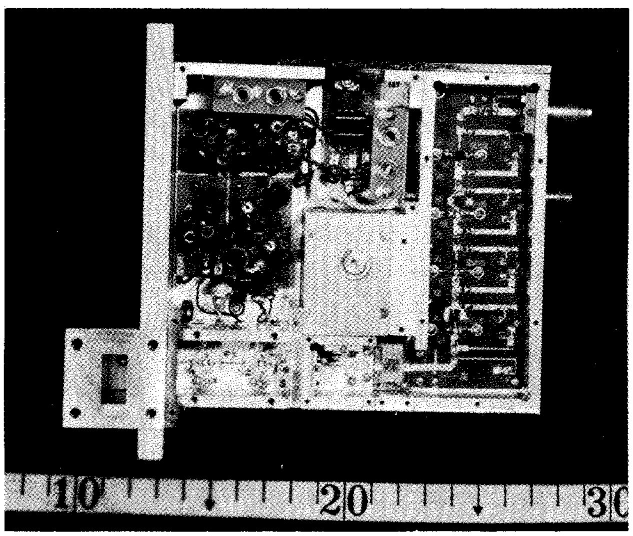
Fig. 6 Circuit diagram of the IF amplifier

the output VSWR of the IFA and making it easier to connect with the indoor unit via a long cable. The performances of the IFA are: noise figure ⩽2dB, gain ⩾36dB, gain ripple < 2dB and output VSWR <1.5 for frequencies from 0.98 to 1.48 GHz.

RF Performances of the Outdoor Unit



(a)



(b)

Fig. 7 General view (a) and inner view (b) of the outdoor unit

The general view and inner view of the outdoor unit are shown separately in Fig.7 (a) and (b). Its dimensions are 17x 18x 5 cm. All the RF components are firmly connected by short sections of 50-ohm lines. No RF connectors are used within this unit, so that high reliability may be achieved.

The measured performances of the RF assembly are: noise figure 2.6—3.0dB, gain 52 ±1.5dB for frequencies from 11.7 to 12.2 GHz (shown in Fig.8).

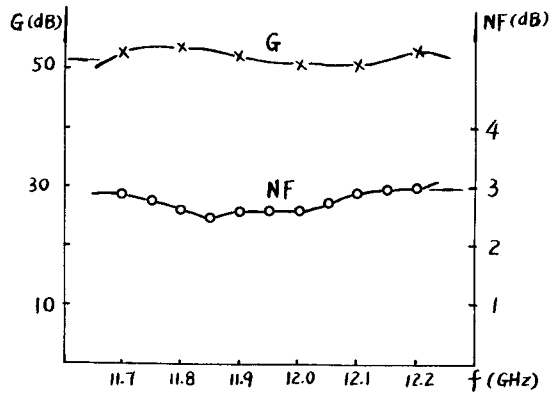


Fig. 8 Measured overall noise figure and gain vs. frequency of the outdoor unit

The outdoor unit works very well in the 12-GHz DBS receiving system. All the electrical performances presented in this paper are based on a production batch.

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