PROPOSED SHF FM RECEIVER FOR SATELLITE BROADCASTING

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1. INTRODUCTION

The development of a low-noise converter of low cost and high sensitivity is needed for broadcasting satellites and ground station in the 12GHz band.

This paper presents the proposed receiving device which consists of the new microwave circuits such as planar circuits mounted in a waveguide and the new FM-AM converter network which is simplified compared with the usual method. As a result of our experiment using a 12GHz signal frequency and a 420MHz intermediate frequency, the converter we have developed on a trial basis has less than a 3.5dB conversion loss and a 4.5dB total noise figure (NF of the intermediate frequency amplifier is approximately 2.0dB).

The construction of our converter will be described below.

2. 12GHz LOW-NOISE CONVERTER WITH PLANAR CIRCUIT MOUNTED IN WAVEGUIDE

A high sensitivity and low cost converter needs to be constructed simply and to be mass-produced. We made efforts in lowering the cost especially with the application of the planar circuit. The construction of the circuit we suggest will be such that every necessary circuit element is arranged on a metal sheet merely by pressing or etcing, and the metal sheet is inserted in the waveguide. Therefore, the mass production of this converter is practicable because all the circuits are arranged on a plane metal sheet. The waveguide can be split, and the simple moulded plastic and the bending method are available.

Fig. 1 shows the planar circuit pattern — from left to right, a signal frequency bandpass filter, a Schottky barrier diode mount, a local oscillating frequency bandpass filter and a Gunn diode mount for local oscillation. A 0.3 - 0.5mm thick copper sheet is favorable for this pattern. When etching is used in forming the pattern, a 0.3mm copper sheet is available for dimensional precision. When pressing is used, the application of a 0.5mm thick metal sheet, for example, maintains the precision within 20μ.

2.1 Bandpass Filter

The proposed bandpass filter with planar circuit mounted in waveguide was used for the signal and the local oscillating .

The construction shown in Fig. 1 was used for the converter. A sheet of conductor with slots is placed in the middle of the waveguide. The resonance system of the slots allows the conductor sheet to function as a cut-off region in non-resonance frequency and provides it with pass characteristics in the vicinity of the resonance frequency. The diameter of the circle and the gap are adjusted for frequency adjustment.

Fig. 2 shows the characteristics of the signal frequency bandpass filter. This bandpass filter has a 12GHz central frequency, a 0.3dB inserting loss and 230MHz of 3dB bandwidth, providing attenuation of more than 30dB in the local oscillating frequency and the image frequency. No-load Q of approximately 1,500~2,000 is provided for both the bandpass filters.

2.2 Schottky Diode Mounte

A beam lead diode or a Schottky diode mount for microwave integrated circuits is employed on the assumption that the diode can be directly mounted on the planar circuit.

The important thing in selecting the construction of a diode mount is that we must find the circuit which matches the broad band of the diode impedance which varies from several tens to several hundred ohms in accordance with the local oscillating voltage. The round and the flat posts, the tip of which are shortened, and the open-tip probe antenna with radiant effect are taken into consideration. When the round and the flat posts are used alone, the height of the waveguide determines the length of the post, allowing extra reactance to be included. Therefore, correction is required, and matching will be more difficult. The bandwidth will inevitably be narrower. When the diode is mounted at the foot of the open-tip probe antenna with the radiating effect of the antenna, the following possibility is provided: The length of the antenna will vary the impedance from 50 to 200 ohms and the width of the antenna will widen the frequency bandwidth.

However, this converter was designed to be provided with a metal sheet. The open-tip probe antenna therefore needs backup from the diode and the antenna. Fig. 1 shows the construction that allows the diode to be mounted directly with the metal sheet alone. As shown in Fig. 1 , a distributed line transformer and a taper ridge are provided.

The IF terminal and DC lead are taken out from the foot of the diode.

2.3 Consideration of Image Impedance

It is necessary to consider the image impedance in reducing a conversion loss. In the TE mode in the image frequency, the signal frequency and the local oscillating frequency bandpass filter, which are arranged at both sides of the diode mount, cause a short at an inside point a little off the end surface of the filter. Accordingly, the distance between the two filters varies the impedance that is viewed from the diode in the image frequency. In a general idea, where the distance between the filters is selected equal to $n\lambda/2$ of the image frequency, the image impedance remains open. As the position of the signal frequency and the local oscillating frequency bandpass filter are adjusted to match the image impedance to the diode impedance in the signal frequency and the local oscillating frequency, however, it is impossible to adjust the distance between the filters independently for the image frequency. Where the signal frequency and the image frequency remain apart to a great extent, the open condition can not be maintained due to the change in frequency. In order to realize the open condition exactly, we must carry out a theoretical analysis on the diode and find out the distance between the filters and optimum mount form.

This report shows that the image impedance remains a little off the open condition and capacitive. This capacitive impedance is confirmed through the distance between the filters which have been matched with each other in the signal frequency and the local oscillating frequency.

2.4 Local Oscillating Circuits

The local oscillation source uses a Gunn diode, and the construction described in Section 2.2 is used as a mount. The problem on the Gunn diode is frequency fluctuation against temperature. However, we expect it to be settled with the aid of the correction method or the self-injection method which have been used. Now, simple correction suppresses the local oscillating frequency to fluctuate within approximately 2~3 MHz (-20° ~ +50°). If further suppression is required the self-injection method is available for the planar circuit. We will carry out studies on the self-injection method.

3. RESULTS OF OUR EXPERIMENT ON PROPOSED CONVERTER

We will describe the results of our experiment on the trial converter with the metal sheet on which every foregoing pattern is formed as shown in Fig. 1.

Fig. 3 shows the characteristics of the converter we have developed on a trial basis which has a 19mW (max) local oscillation output in the 12GHz signal frequency and the 420MHz intermediate frequency. We were successful in obtaining a minimum real conversion loss 3.2dB. An intermediate amplifier with approximately a 2.0dB noise figure was connected and measurement was carried out with liquid nitrogen as a noise source. As A result, the total noise figure 4.5dB was obtained. This value coincides with the result of the noise figure equation when an image impedance remains open and noise (diode current) produced by the Schottky barrier diode is generally used as shot noise.

4. FM-AM Converter

In the past, the video and sound signal were taken out from FM signal through discriminater and they modulated the VHF signal to get the conventional standard AM-VHF signal through a balance modulator.

By the new FM-AM converter proposed in this paper, the AM-VHF signal is directly get from the UHF-FM signal through the non-linear characteristics of a diode.

This system, therefore, does not require the discriminator, video and sound amplifier and demodulator, which results in the extremly simplified in a circuit and serving to make it in low cost.

The construction of this circuit is shown in Fig. 4. First, the FM-UHF signal is AM modulated through a slope of a filter, and it is applied to a diode.

When the VHF carrier signal is applied to terminal C of a balun, the VHF signal modulated corresponding to the FM, appeares at terminal D of a balun by the principle of the impedance variation for VHF at terminal E.

When the series resonant circuits of f_i $(= f_u - f_v)$ and f_m $(= 2f_u - f_v)$ are connected between the diode, the input admittance for VHF and UHF, g_v and g_u are given by eq.(1).

$$g_v = i_o \frac{2I_o(\alpha V_u)\, I_1(\alpha V_v)}{V_v} e^{-\alpha R_s i_o I_o(\alpha V_v) I_o(\alpha V_u)}$$
$$g_u = i_o \frac{2I_o(\alpha V_v)\, I_1(\alpha V_u)}{V_u} e^{-\alpha R_s i_o I_o(\alpha V_v) I_o(\alpha V_u)} \qquad (1)$$

where f_u and f_v are the frequencies of UHF and VHF carriers, $\alpha = \frac{e}{nKT}$, R_s: series resistance of the diode V_u and U_v are the amplitudes of UHF and VHF signals, I_o and I_1 are zeroth and 1st modified Bessel function.

On the other hand, V_u and V_v applied to the diode, should take the values of eq.(2).

$$V_v = \frac{2V_{mv}}{g_v(W+R_s)+1}, \quad V_u = \frac{2V_{mu}}{g_u(W+R_s)+1} \qquad (2)$$

, where V_{mu} and V_{mv} are the amplituded at the load impedance W which is replaced by a diode.

Since g_v and g_u are computed from eq.(1) and (2), the reflection coefficient Γ_v at terminal E is obtained from the eq.(3) and the values of g_v and g_u.

$$\Gamma v = \frac{1/g_v - R_o}{1/g_v + R_o} \qquad (3)$$

The theoritical relation between V_{mu} and Γ_v is shown in Fig. 4, which coincidents in less than 3% with experimental results.

Fig. 5 also shows the good performance in a linearity. The differential gain (DG) and differential phase (DP) of the trial FM-AM converter of this proposed system are less than 5% and 3° respectively so shown in Fig. 6.

Fig. 7 shows the blok diagram of trial SHF-FM receiver.

5. CONCLUSIONS

We have developed the foregoing receiver on a trial basis. We believe that the mass production of the receiver will be practicable because of its simple construction.

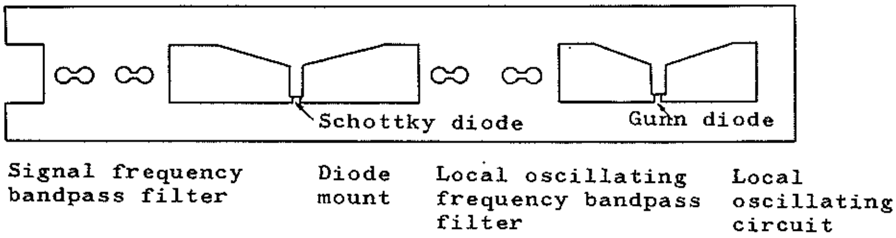

Fig. 1 Construction of 12GHz converter with mounted planar circuit in waveguide.

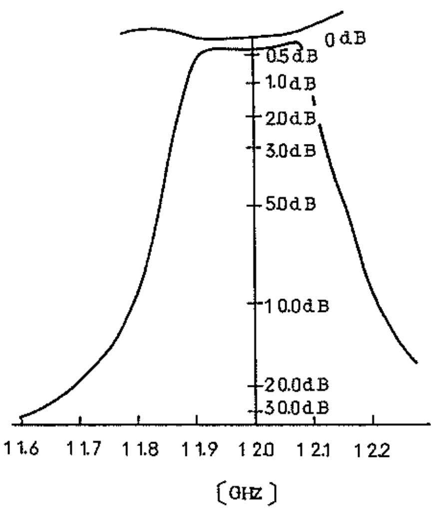

Fig. 2 Characteristics of signal frequency bandpass filter.

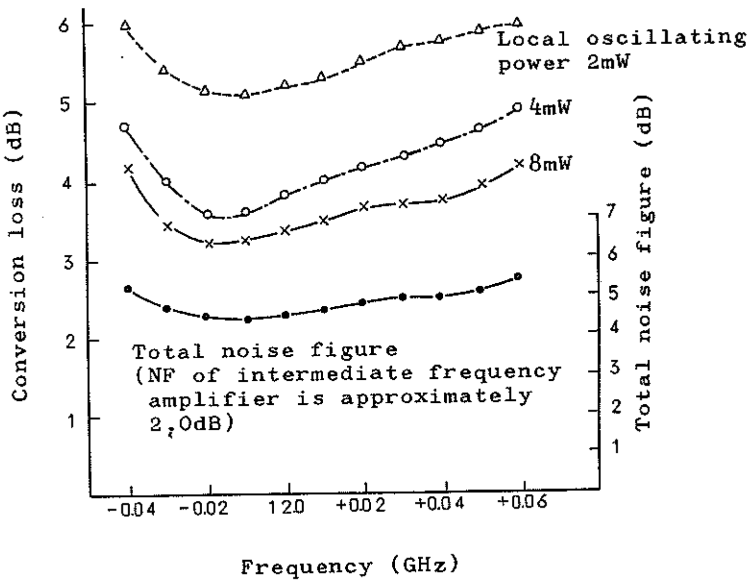

Fig. 3 Characteristics of 12GHz converter with mounted planar circuit in waveguide.

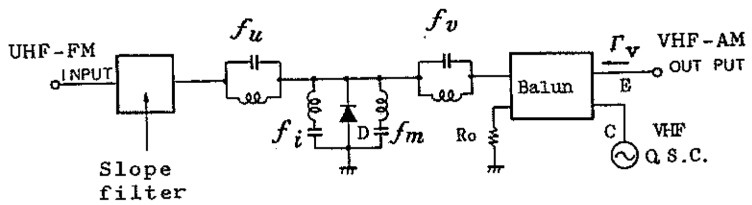

Fig. 4 Schematic diagram of New FM-AM converter

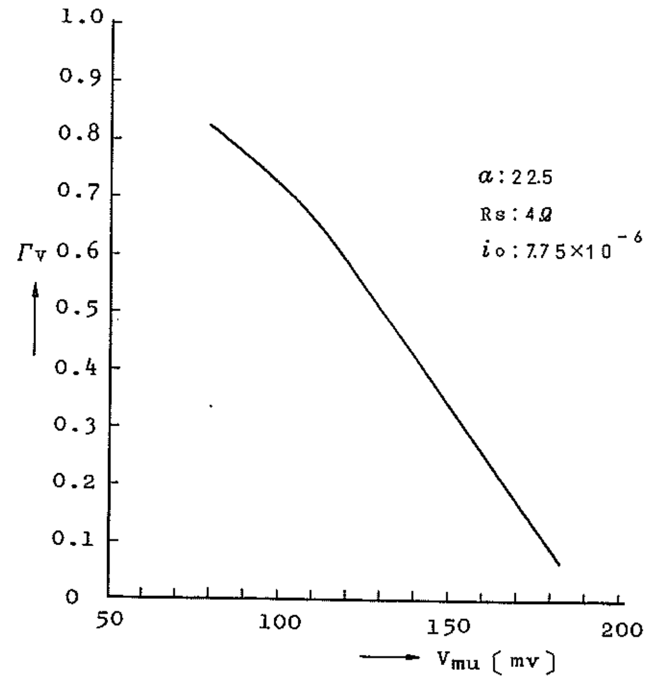

Fig. 5 Theoritical relation between Γv and Vmu

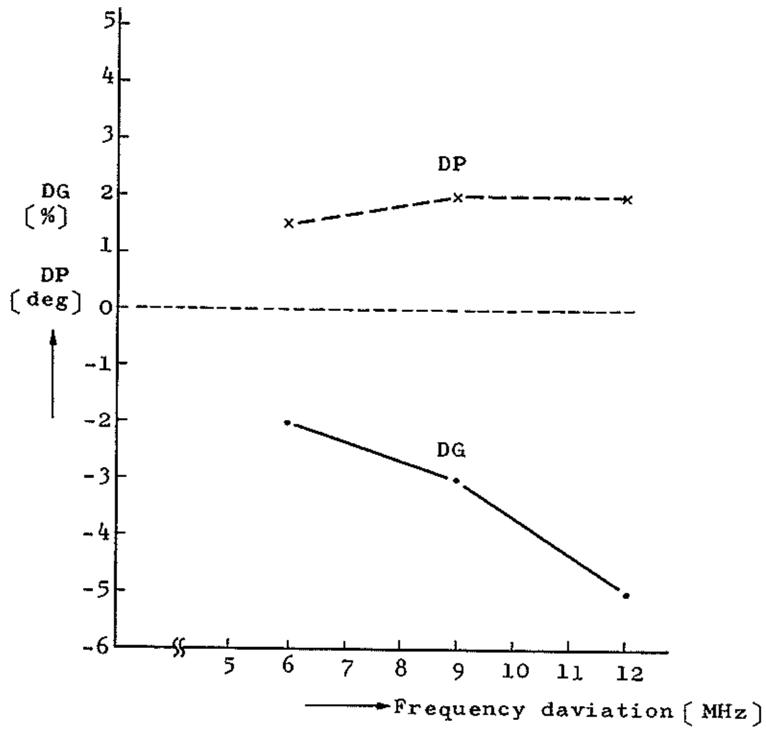

Fig. 6 DG and DP vs. Frequency daviation

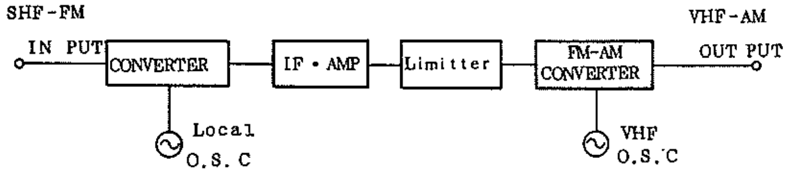

Fig. 7 Block diagram of trial SHF-FM Receiver