NEW HETERODYNE RECEIVER HEAD

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ABSTRACT

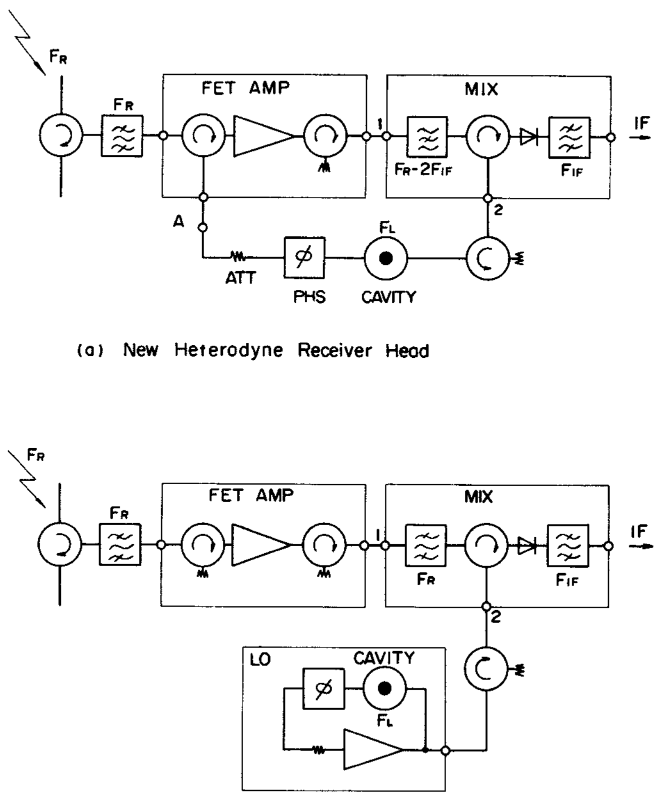
Low noise GaAs FET amplifiers are widely employed for heterodyne receiver heads in order to improve their noise figure. In the new heterodyne receiver head discussed here, the low noise GaAs FET amplifier used to improve the noise figure is also used for oscillation of the local signal without any degradation of the transmission characteristics, so that the local oscillator, used in a conventional heterodyne receiver head can be dispensed with. The configuration of the new heterodyne receiver head is a very effective low cost, low power consumption design for a MIC receiver head.

Introduction

A low noise GaAs FET amplifier (FET AMP) which is used to improve the noise figure (NF) of a heterodyne receiver head (RX HEAD), oscillates when positive feedback is applied to the FET AMP. As the FET AMP not only amplifies the transmission signal but also generates the local signal, the local oscillator can be removed, thereby reducing the cost and power consumption to achieve an effective MIC RX HEAD design. However, since the oscillation and amplification are combined in a single FET AMP, there is some degradation of the NF and the transmission characteristics, due to intermodulation (IM). In this RX HEAD, stable oscillation is achieved in the linear region of the FET AMP, by utilizing the saturation characteristics of the mixer (MIX) in a positive feedback loop which is necessary for oscillation of the local signal. Since the amplification of the transmission signal and the oscillation of the local signal operate in the linear region of the FET AMP, the degradation is negligible and the local oscillator can be removed. This paper describes the circuit configuration of the new RX HEAD employing a single FET AMP which not only amplifies the transmission signal but also generates the local signal at the same time. This paper also describes the experimental results in the 2 GHz band, showing the characteristics of the individual components, the over-all NF and the transmission characteristics.

Circuit Configuration

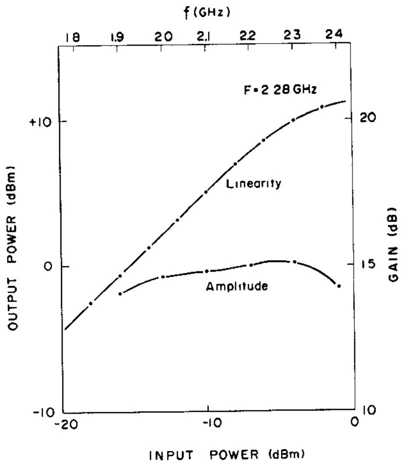
Fig. 1(a) shows the circuit configuration of the new RX HEAD. The FET AMP is positively fedback to oscillate through the MIX. The cavity (CAVITY) determines the frequency of the local signal and the phase shifter (PHS) adjusts the phase of the feedback signal to satisfy the oscillation phase condition at the frequency of the local signal. The attenuator (ATT) is also provided to adjust the feedback power of the local signal generated in the FET AMP. This local signal and the amplified transmission signal are applied to the MIX and converted to the IF signal. If the transfer function of the FET AMP is A and the positive feedback loop, which includes the MIX is β, then the oscillation condition is $A\beta = 1$, and the amplitude, $|A\beta| = 1$ in the steady state. In general, $|A\beta|$ will be one for the stable oscillation due to non-linearity of A which occurs at the saturation region of the FET AMP. Therefore, when the oscillation of the local signal operates in the saturation region of the FET AMP, the IM will be extremely poor and the transmission characteristics and the NF are degraded. To avoid such degradation, the new RX HEAD, as shown in Fig. 1(a), utilizes the saturation of the MIX between the input (Port 1) and the output terminal (Port 2) to obtain a stable condition, so that $|A\beta|$ will be one due to the non-linearity of $|\beta|$ which occurs before $|A|$. This MIX operates as a frequency converter and also a limitter, consequently the operating point of the local signal oscillation is set in the linear region of the FET AMP and interference can be neglected so that there is no degradation of either the transmission characteristics or the NF and a single FET AMP can be used as an oscillator and an amplifier, thereby eliminating the local oscillator in a conventional RX HEAD.



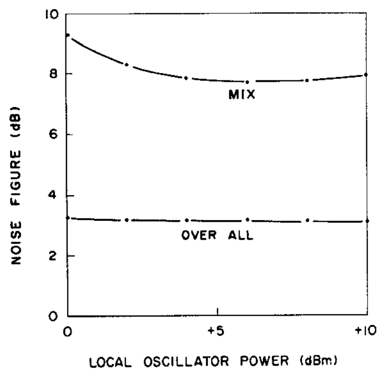
(a) New Heterodyne Receiver Head

(b) Conventional Heterodyne Receiver Head

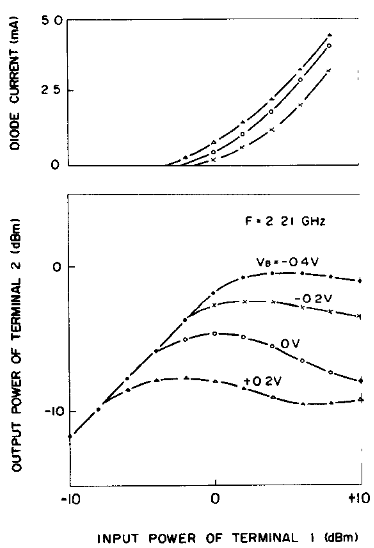
Heterodyne Receiver Head Block Diagram
Fig. 1



2 GHz GaAs FET Amplifier Characteristics
Fig 2



Noise Figure of Mixer and Conventional Heterodyne Receiver Head
Fig. 3



Limitter Characteristics of Mixer
Fig. 4

Results of Experiments at the 2 GHz Frequency Band

In the following experiments, the frequency relationship are f_R = 2.28 GHz, f_L = 2.21 GHz and f_{IF} = 70 MHz with a transmission capacity of 960 CH.

Individual Component Characteristics

(1) Low noise GaAs FET amplifier (FET AMP)
This amplifier consists of a single GaAs FET 2SK85 which provides 15 dB gain with +10 dBm output power at 1 dB gain compression and a NF of 1.8 dB as shown in Fig. 2.

(2) Mixer (MIX)
The MIX is a single-ended type using a GaAs schottky diode 1SS11 and the NF, which includes the NF of the pre-IF amplifier, is shown in Fig. 3. Fig. 3 also shows the NF of a conventional RX HEAD (Fig. 1(b)), which is about 3.2 dB. As mentioned before, this MIX operates as a limitter and its limitting performance is shown in Fig. 4. The limitting level depends on the DC bias voltage of the diode, V_B. As V_B is changed from -0.4V to +0.4V, the limitting level can be varied by about 10 dB.

(3) Other Components
The loaded Q of the CAVITY should be high as the resonant frequency of the CAVITY determines the oscillation frequency of the local signal. The PHS changes the line length by up to $\pm$100° at the 2 GHz band.

Oscillation Performance

When the resonant frequency of the CAVITY is adjusted to the frequency of the local signal and the phase of the closed loop is adjusted at $2n\pi$, point A (Fig. 1(a)) is disconnected to measure the open loop

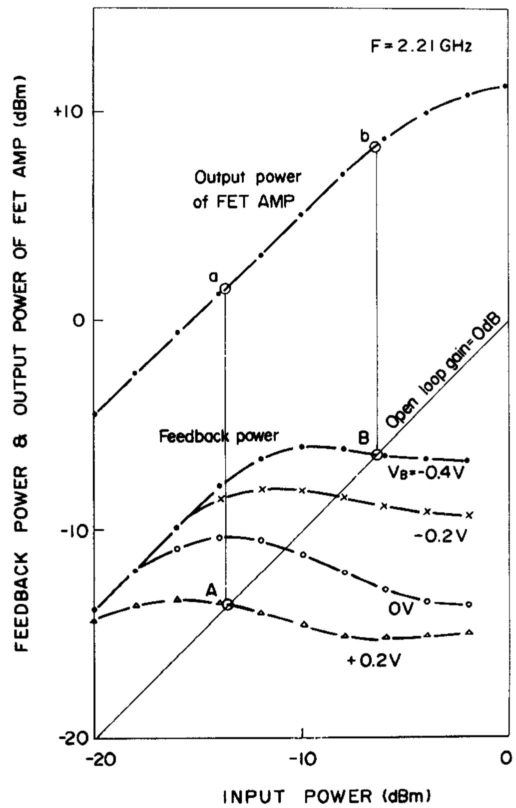


Fig. 5 Open Loop Characteristics

characteristics. The feedback power and the output power of the FET AMP vs. the input power at A is shown in Fig. 5. When V_B is greater than -0,4V, the limiting level of the feedback power depends on the MIX and not on the FET AMP. The operating point of the oscillation is indicated on the open loop gain = 0 dB line, for example in Fig. 5 when V_B is changed from +0.2V (the open loop gain is zero at A and the operating point of the FET AMP is at a) to -0.4V (the corresponding points are B and b respectively), the oscillation output power changes from +1.5 dBm to +8 dBm in the linear region of the FET AMP. When V_B is less than -0.4V, oscillation occurs in the saturation region of the FET AMP.

Over All Noise Figure and Transmission Characteristics

Fig. 6 shows the NF of the new RX HEAD, which is same as that of the conventional one (Fig. 3). Fig. 7 shows the DG, DP and amplitude characteristics of the new RX HEAD.

Conclusion

This new heterodyne receiver head has the following features.

(1) Transmission signal amplification and local signal generation are combined in a single GaAs FET AMP,

(2) low cost and low power consumption by eliminating the local oscillator RF device,

(3) configuration of this new RX HEAD is suitable for MIC design.

(4) This new heterodyne receiver head design can also be applied to the heterodyne transmitter head.

Acknowledgement

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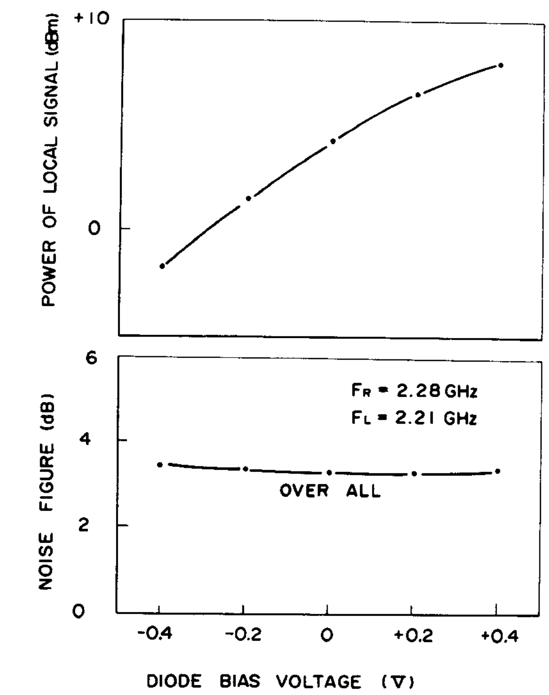
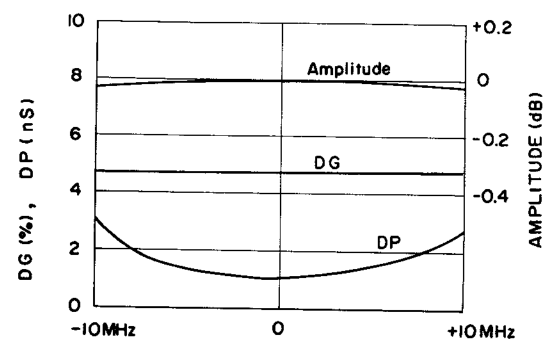


Noise Figure of New Heterodyne Receiver Head

Fig. 6



Transmission Characteristics of New Heterodyne Receiver Head

Fig. 7