400 Mb/s QPSK MIC REGENERATOR AT CARRIER FREQUENCY USING GaAs MESFET

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ABSTRACT

A novel MIC (microwave integrated circuit) GaAs MESFET (metal-semiconductor field effect transistor) direct phase regenerator without detection is described. An experimental 400 Mb/s QPSK (quadri-phase shift keying) regenerator at 1.7 GHz carrier frequency, shows as good performance as conventional baseband regenerator.

INTRODUCTION

A direct phase regenerator (DPR) can directly regenerate and reshape PSK signals at carrier frequency without a detector and a modulator. The cost and size of the repeater using the DPR can significantly be reduced, as compared with a conventional repeater which uses the detector, baseband regenerator and modulator.

The direct phase regenerators reported so far use tunnel diode parametric amplifiers.[1] In such a regenerator, since circulators are inevitable in order to separate the input and the output signals, the assembled circuit would be very complicated when the MIC technique is to be applied.

This paper proposes a new type of DPR using GaAs MESFET and MIC technique.[2] Since an FET is a two-port device, the new type of regenerator needs no circulator. Moreover, this DPR promises sufficiently good performance to take the place of a conventional baseband regenerator, because circuits using FETs are precisely designable.

DPR FOR BPSK SIGNAL

Principle

The BPSK-DPR (bi-phase PSK-DPR) consists of an FET parametric mixer, as shown in Fig.1. In Fig.1, both the input signal A cos ($\omega_0 t + \phi$) and the local oscillator signal B cos $2\omega_0 t$ are applied to the MES gate junction and mixed there. Here, ϕ is the phase of the incoming signal, which is the sum of the wanted signal phase Φ and the unwanted signal phase $\Delta\Phi$ caused by noise and bandwidth limitation. The local signal is obtained by doubling the frequency of the carrier signal recovered from the input signal by a conventional method, for example, using carrier recovery circuit with phase lock loop. The phase of the converted signal C cos ($\omega_0 t - \phi$) is just a phase inversion of the input signal A cos ($\omega_0 t + \phi$).

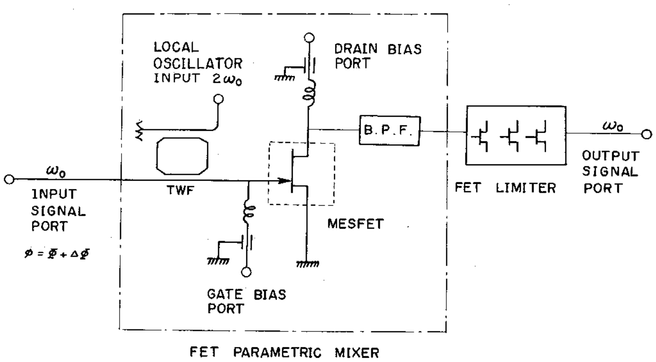

Fig.1 BPSK MESFET DPR circuit diagram.

Both A cos ($\omega_0 t + \phi$) and C cos ($\omega_0 t - \phi$) are amplified by the same FET and appear at the drain port.

If A and C are equal, the output signal becomes 2 A $|\cos\Phi|$ cos ($\omega_0 t + \Phi$), in which the phase of this signal is always fixed, either at 0 ($|\phi| \leq \pi/2$, i.e., $\Phi = 0$) or π ($\pi/2 \leq |\phi| \leq \pi$, i.e., $\Phi = \pi$), although the amplitude varies with ϕ . This phase fixation can be utilized in the direct phase regeneration.

Parametric mixer

The parametric mixer is achieved by designing the FET mixer[3] to maintain A=C at the local signal frequency $2\omega_0$.[2] Figure 2 shows calculated values of required local oscillator power, conversion gain and gate current for the FET used. From this figure, it is seen that the condition of the minimum local signal input with high conversion gain can be obtained by setting the gate bias at V≃1.3 [V].

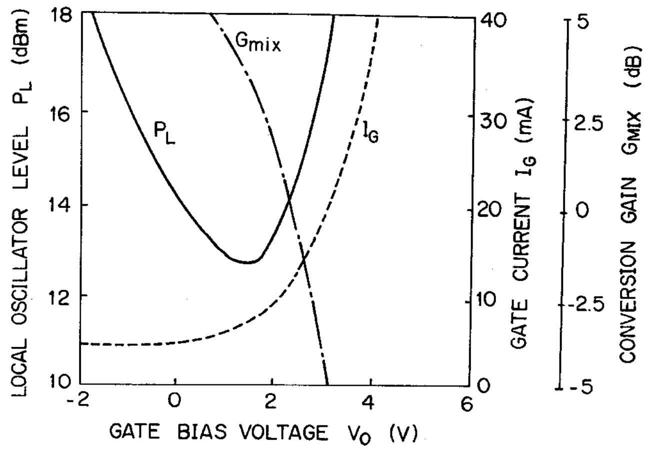

Fig.2 MESFET DPR characteristics (series resistance R is 50 ohm).

Limiter

A limiter is necessary to remove the output amplitude variation with input phase, i.e., 2 A $|\cos\phi|$. An essential problem of the limiter is to reduce AM-PM conversion.

The AM-PM conversion is analysed using a MESFET equivalent circuit, as illustrated in Fig.3.

In this figure, R_L and L represents the source resistance and the inductance to reduce the AM-PM conversion, respectively. MES gate junction nonlinear conductance g depends on a source voltage V_S and causes AM-PM conversion.

If the FET gate junction has no series resistance ($R=R_G+R_i+R_S=0$), the AM-PM conversion can be easily removed by tuning out junction capacitance C at the

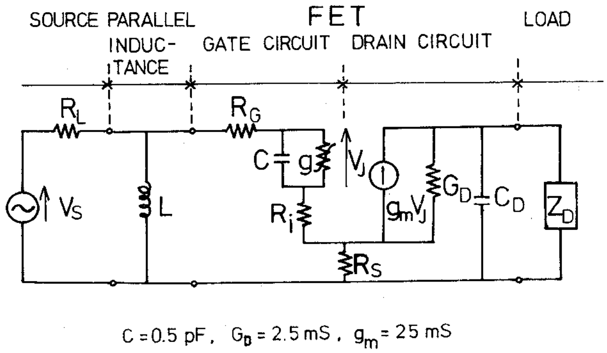

Fig.3 Equivalent MESFET limiter circuit.

center frequency ω_0, i.e., putting $\omega_0 L$ to be $1/\omega_0 C$. Under this condition, the V_J phase is kept constant, regardless of g variation with V_S change.

Even if the series resistance cannot be neglected, conditions are obtained under which V_J phase is independent of g.[4]

This condition can be expressed by the following equation.

$$\omega_0 L = \frac{R_L^2 k \pm \sqrt{R_L^4 k^2 - 4\omega_0^2 C^2 R^2 R_S^2 (R + R_L)^2}}{2\omega_0 C (R + R_L)^2} \quad \text{--- (1)}$$

where $k = 1 + g_m R_S / 2$.

Figure 4 shows numerical calculation results. When R=0, $\omega_0 L$ is constant and equals $1/\omega_0 C$, regardless of R_L. If R is not zero and R_L is not so large, $\omega_0 L$ depends on R_L and is smaller than $1/\omega_0 C$. For large R_L, $\omega_0 L$ is approximated by $k/\omega_0 C \simeq 1/\omega_0 C$, as can be seen from Eq.(1).

Source resistance R_L is determined from another circuit consideration of the AM-PM conversion frequency dependence and the small signal gain of the limiter. For example, a suitable R_L value is about 100 ohms for R = 50 ohm. Hence, the proper value of $\omega_0 L$ is 80 ohms, from Fig.4.

An experimental AM-PM conversion value is within 1 degree/dB between 1.4 and 2.0 GHz.

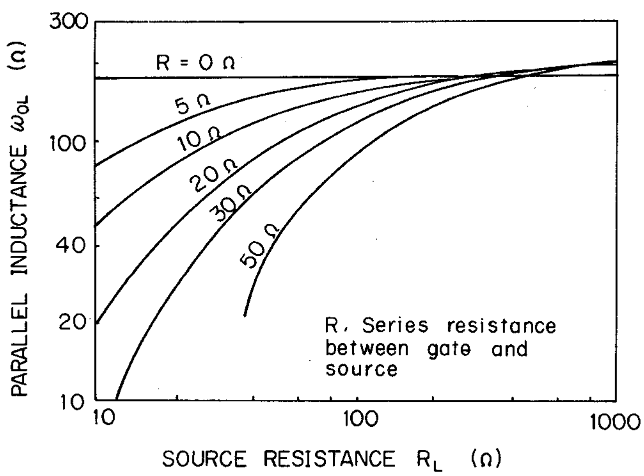

Fig.4 Relation between R_S and $_0L$, when AM-PM conversion is zero.

DPR FOR QPSK SIGNAL

Principle

A QSK-DPR is feasible by using a couple of BPSK regenerators with carrier recovery circuit, as shown in Fig.5. In Fig.5, the input signal is divided into signals ② and ③ , using a 90° hybrid. Since signal ② lags signal ③ by a phase angle of $\pi/2$, the discriminating thresholds of two BPSK-DPR are orthogonal. Obtained BPSK signals ④ and ⑤ are orthogonally combined and QPSK signal ⑥ appears at the output port.

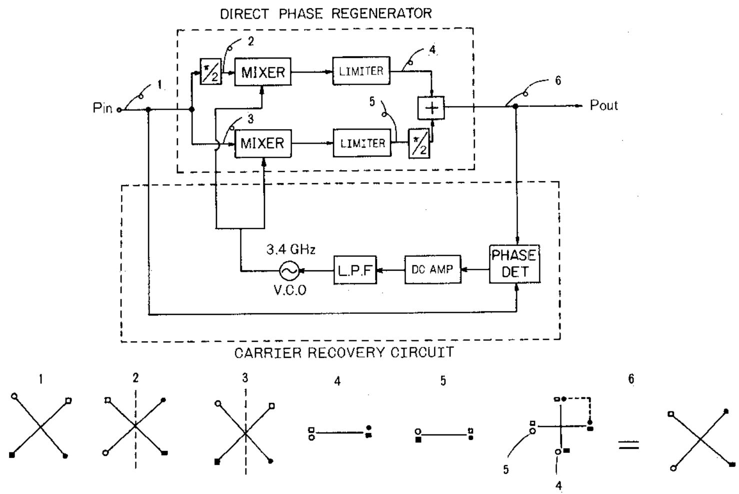

Fig.5 DPR Structure for QPSK.

Experimental QPSK-DPR

The experimental QPSK-DPR is fabricated on an alumina ceramic substrate at 1.7 GHz carrier frequency, as shown in Fig.6. In order to separate the local oscillator from the input signal, a traveling wave filter is used between a 3-dB hybrid and a mixer FET. The FETs used here are n-channel GaAs MESFETs developed for X-band low-noise amplifiers or oscillators. The parametric mixer output filter is a fifth-order Chebyshev-type, low-pass filter with 1.8 GHz cutoff frequency and eliminates the local signal. The size of this DPR is about 1/2 that of the conventional baseband regenerator.

The major performance parameters of this DPR are tabulated in Table 1 and typical regenerator static characteristics are shown in Fig.7. The output phase

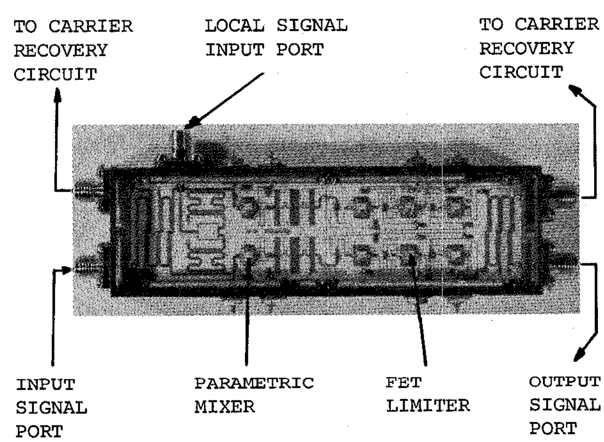

Fig.6 Experimental QPSK DPR.

TABLE I

EXPERIMENTAL REGENERATOR PERFORMANCE

MODULATION SPEED	400 Mb/s
INPUT SIGNAL FREQUENCY	1.7 GHz
INPUT SIGNAL POWER	0 dBm
OUTPUT SIGNAL POWER	8 dBm
REFERENCE CARRIER FREQ.	3.4 GHz
CARRIER LOCK RANGE	10 MHz
CARRIER C/N	30 dB
OUTPUT SIGNAL PHASE ERROR	3°
C/N DEGRADATION (ONE HOP)	1 dB (BW=+100MHz)
SIZE	110x100x35 mm^3
WEIGHT	0.8 kg
SOURCE POWER	6.7 W

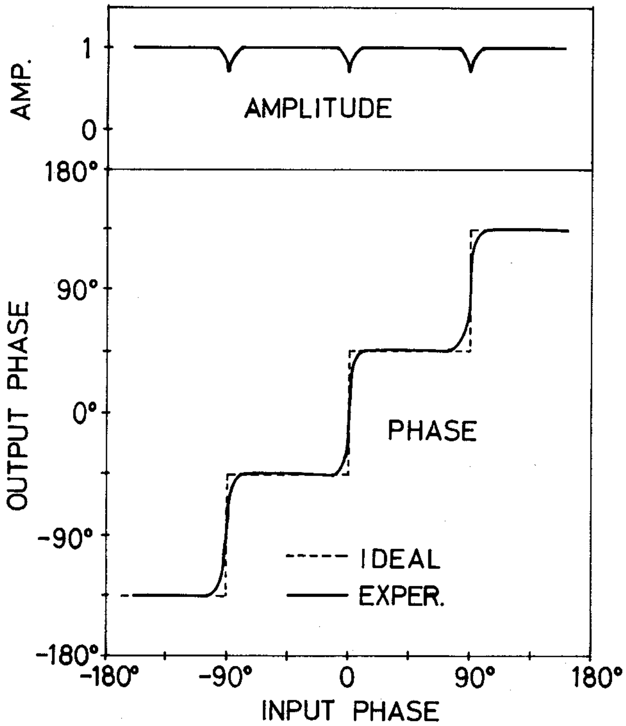

Fig.7 Measured input-output phase and amplitude characteristic versus input phase.

locus due to input signal phase is step-like and the amplitude characteristics is almost flat. These results show that very fine regeneration is obtained using this DPR. Moreover, it has been found, by dynamic performance measurements, that this DPR has the following features,

(1) DPR operates at very high speed of 400 Mb/s, as seen from Fig.8 which shows typical eye-diagrams.
(2) Equivalent C/N degradation is about 1 dB at a 10^{-6} bit error rate.
(3) Degradation due to from 10 °C to +45 °C temperature variation is less than 1 dB.

Since these values are the same as the reported baseband regenerator values, the developed DPR can take the place of the baseband regenerator.

CONCLUSION

The GaAs MESFET direct phase regenerator has been newly developed using MIC technique. The circuit construction is simple and the fabrication is easy, because this type of regenerator does not require any

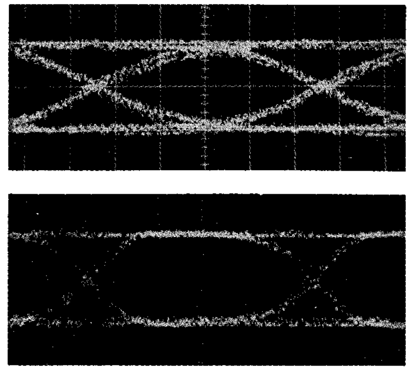

Fig.8 Eye-diagrams for 400 Mb/s QPSK signals.

indispensable circulator for a regenerator using a tunnel diode. The experimental results satisfy all the required characteristics for practical use.

ACKNOWLEDGMENT

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