FET MIXERS FOR COMMUNICATION SATELLITE TRANSPONDERS

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Abstract

Two different types of FET mixer circuits have been developed for 6/4 GHz frequency translation for communications satellite transponder.

Gate mixer uses non-linear $I_d - V_g$ characteristic, with LO being injected into the gate circuit, while in the drain mixer the LO is injected into the drain circuit and non-linear $I_d - V_d$ characteristic is utilized.

Both circuits yielded conversion gains up to 3 dB over 500 MHz bandwidth. However, the noise figure of the drain mixer as low as 4 dB was measured compared with 5.7 dB for the gate mixer.

When a sufficiently strong LO signal is applied to the gate of an FET biased close to pinch-off, the drain current will be modulated between zero and the saturation value I_{dss}. Simultaneously FET transconductance, gm, will also vary be between zero and its peak value. Since gm remains fairly constant down to small values of the drain current, the gm waveform can be regarded as approximating a square-wave. For this limiting condition, the intrinsic mixer conversion gain is given by:

$$G_c = \frac{1}{4} \left(\frac{gm}{\pi \omega \overline{C_g}} \right)^2 \frac{R_D}{R_g}$$

where, $\overline{C_g}$ - is the time average of the gate-to-source capacitance,

R_D, R_g - drain and gate resistances.

For a typical 1 μ gate FET this yields a conversion gain of 7 dB at 6 GHz.

In the case of the drain mixer, the LO is injected into the drain circuit with resultant modulation of the drain resistance between a low and high value corresponding to the saturated electron flow in the channel. An accurate estimate of the intrinsic conversion gain is more difficult in this case as both the resistance and the transconduction are modulated.

Both types of the MIC mixer circuit are developed for communications satellite transponder application. The input frequency range is from 5.925 to 6.425 GHz and the output frequency is 3.7 to 4.2 GHz with LO frequency being 2.225 GHz.

The gate mixer circuit is shown in Figure 1. A diplexer circuit, consisting of a bandpass filter for the signal and a lowpass filter for the LO is used in the common input to the gate. A broadband signal matching circuit then follows while the LO matching is done before the lowpass filter. The broadband output circuit matches the drain impedance to 50 ohm output. In the actual transponder receiver, additional filtering is used to further suppress the LO and its second harmonic in the output.

The drain mixer is shown in Figure 2. It consists of the input and output matching circuits with a lowpass filter for the LO injection to the drain. LO rejection in the output is parpartially accomplished by means of a quarter-wave open-circuited stub.

The conversion gain of the two circuits is shown in Figure 3. Although conversion gain of 6 dB was measured when optimized for narrow-band performance, in good agreement with the calculated intrinsic value, a reduction in the gain had to be accepted when the circuits were broad-banded over the required frequency range. The filter insertion losses are not included in the curves shown. Typically, the conversion gain will be reduced by 1 dB due to the insertion loss of the input and output filter.

The noise figure of the two mixers is shown in Figure 4. The minimum noise figure for the drain mixer of 4 dB is only 1.3 dB higher than the noise figure of the FET in a 6 GHz amplifier circuit.

It is interesting to note that the drain mixer has an appreciably lower noise figure than the gate mixer. This is probably due to the parametric upconversion of the low frequency noise in the FET to the output frequency, in the case of the gate mixer. With the gate Schottky-barrier remaining in the reverse bias condition over the whole of LO cycle, the variation of the depletion layer width results in the corresponding capacitance modulation which leads to noise upconversion. In the drain mixer, very little gate capacitance modulation takes place.

The third-order intermodulation distortion intercept point of 16 dBm was measured. The group delay ripple, including the contribution from the filters, was $\pm$ 0.5 nsec. The inband spurious product ($2 f_s - 4 f_{LO}$) was 70 dB below carrier at the output.

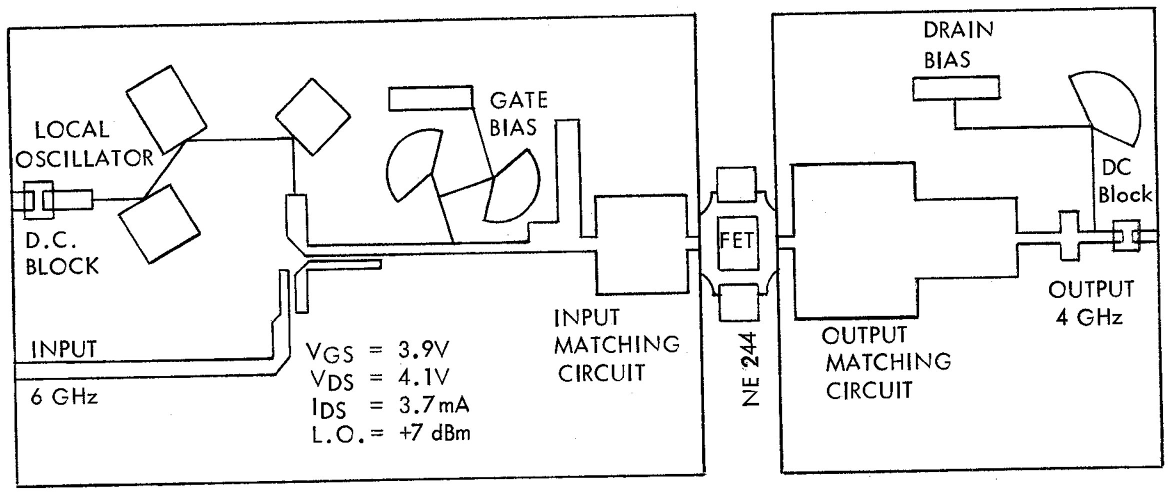

FIGURE 1. GATE MIXER.

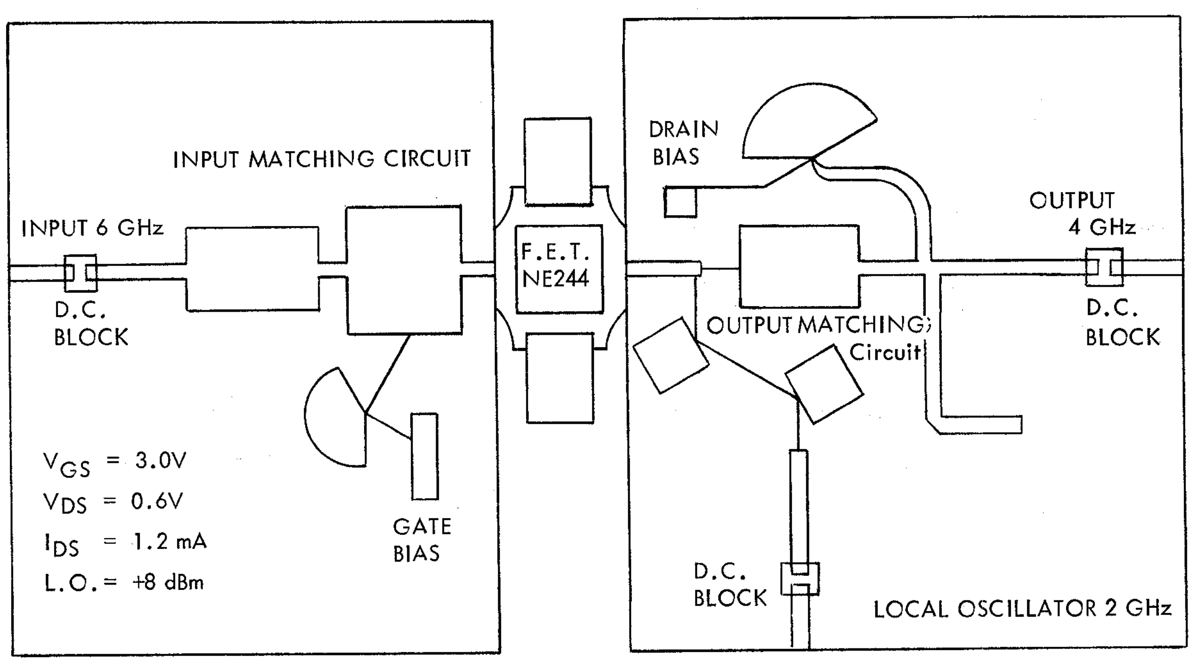

FIGURE 2. DRAIN MIXER.

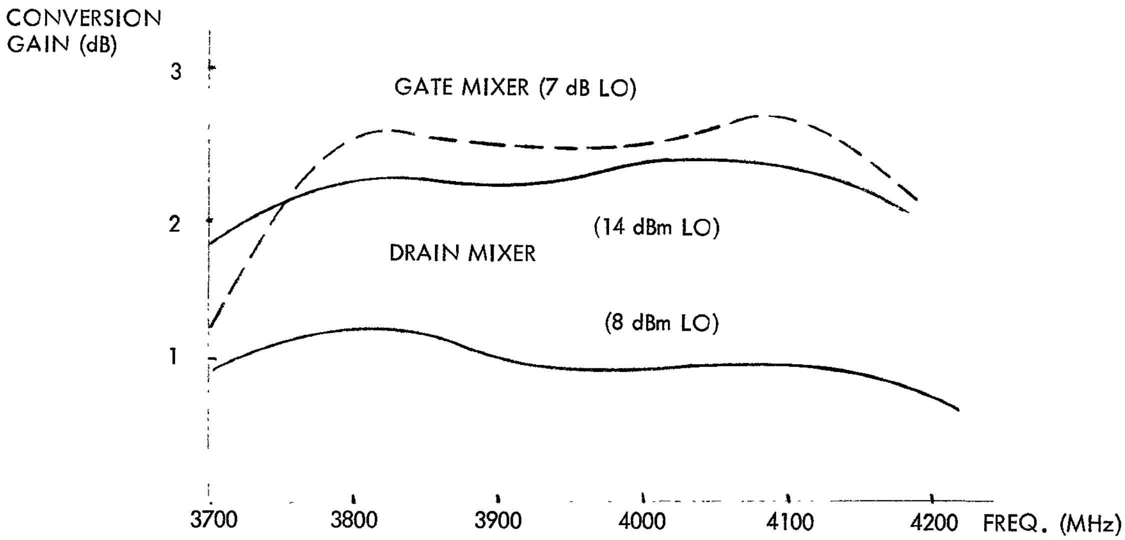

FIGURE 3. MIXER CONVERSION GAIN.

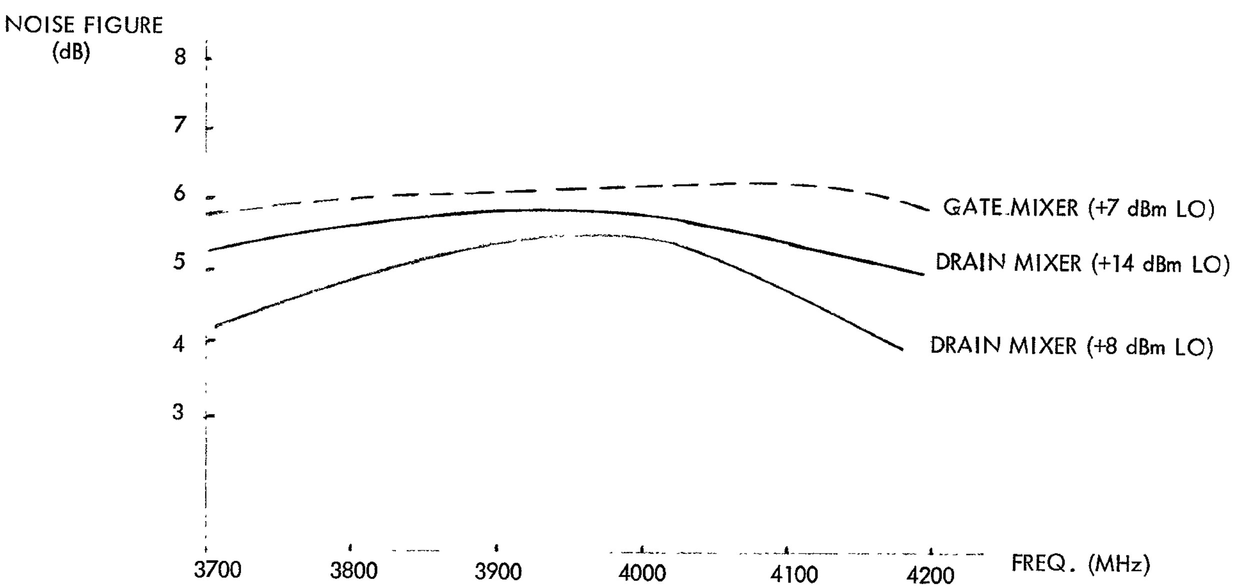

FIGURE 4. NOISE FIGURE.