AN X-BAND DUAL-GATE FET UP-CONVERTER

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An up-converter using dual-gate GaAs FET was operated at X-band output frequencies with an IF input at 700 MHz. The FET up-converter offers advantages of conversion gain (up to 15 dB), low noise figure (3.2 dB) and built-in port-to-port isolation. The power output saturated at +9 dBm, and the third-order IM product at the 1 dB compression point was -22 dBC.

INTRODUCTION

In frequency converters commonly used in today's heterodyne communication systems, the frequency conversion mechanism is the nonlinear mixing action of two-terminal devices. This type of passive frequency conversion scheme generally requires a high level of L.O. ($\sim$ +20 dBm), relatively complex circuit configuration and multiples of devices to achieve optimum conversion efficiency and high isolation between LO and signal ports. The output level of passive converters is also limited by the saturation characteristics of diodes. Active mixers using GaAs FETs have been demonstrated recently[1-5], which offer advantages of conversion gain, low noise and wide dynamic range. Previous studies of the frequency mixing mechanism of FETs, however, have been limited to its application in down-converters with IF frequency output. The subject of this paper is an up-converter (with an RF output frequency) using dual-gate FETs operating in the 7-8 GHz band. The FET up-converter requires low L.O. power (0$\sim$+10 dBm) and has a high (linear) conversion gain and low noise figure over a broad frequency range and built-in isolation between L.O. and signal output ports.

CIRCUIT DESIGN

The dual-gate FET used for the converter design was Raytheon's Model LND-832, whose gate dimensions are 1 μm x 500 μm. Typical characteristics of the device are: 10 dB gain and 3.5 dB noise figure in X-band, and over 30 dB of gain control by the second gate bias when it is used as a linear amplifier. The FET is characterized by two sets of 2X2 S-parameter matrices, each set representing the device S-parameters with one gate shorted. The impedance matching networks depicted in Figure 1 are designed with the aid of a computer for the lowest VSWR at respective RF and IF frequencies. Figure 2 shows the circuit configuration evolved by the computer and fabricated in an alumina substrate 0.025" thick. The FET is mounted on a carrier for easy handling.

EXPERIMENTAL RESULTS

The power transfer characteristics of the up-converter at three L.O. drive levels are shown in Figure 3. These results are obtained at the output frequency of 8.1 GHz. The input signal (IF) frequency for all experiments is 700 MHz. The conversion gain was measured as the power ratio of the output at 8.1 GHz to the input signal level at 700 MHz. The small signal gain decreased from 12 dB to 4 dB as the L.O. drive varied from +12 dBm to +3 dBm. The power output at the 1 dB gain compression point is +6 dBm and it saturated at +9 dBm with the L.O. level set at +12 dBm. The saturated power output at +6 dBm L.O. drive is about 2 dB lower. The output spectra measured on a spectral analyzer with 4 dispersion width are displayed in Figure 4. The spurious content of the output spectra is below -60 dBC in all cases.

With the L.O. frequency fixed at 7.2 GHz, the converter bandwidth was measured by varying the signal frequency over 700 ±250 MHz. Figure 5 shows the gain variation characteristics measured over the 500 MHz band. No attempt was made to improve the bandwidth, however. The associated noise figure of the up-converter was also measured and plotted in Figure 5. The noise figure was measured by terminating the signal port with a noise source with ENR of 16.0 dB. A conventional diode mixer was used to mix the output frequency down to 30 MHz IF. An AILTECH automatic noise figure indicator was used for the noise measurement. Circuit tuning in the signal input port did have an effect on the up-converter gain and noise figure performance. The best performance data measured was 3.2 dB noise figure and the associated conversion gain of 15 dB in a relatively narrow band ($\sim$ 100 MHz).

The intermodulation products measured with two equal amplitude input signals separated by 5 MHz are shown in Figure 6. The third-order intermodulation product level is -22 dBC at 1 dB gain compression point (P_{out} = +2 dBm), and the third-order intercept point is +18 dBm.

The L.O. feedthru and lower sideband output level depend on the passband characteristics (especially the lower cutoff) of the output matching network. In our experimental circuit, the L.O. level measured at the output port is +3 dBm (out of +10 dBm input), and it is relatively insensitive to the signal input level. The lower sideband output, which is linearly related to the signal input level, is generally 10 to 15 dB lower than the upper sideband output. The L.O. and the lower sideband rejection increases as the signal frequency increases and the frequency separation becomes wider. If the L.O. feedthru is suppressed, the output level of the up-converter is increased by as much as 3 dB. With the signal frequency increased to 1.7 GHz (and L.O. frequency of 6.5 GHz), the L.O. rejection was increased to 10 dB and the saturated power output increased to +12 dBm. A further improvement of both the output power and the sideband and LO rejection is expected in a balanced up-converter design.

The dual-gate FET provides "built-in" isolation between its signal, L.O. and output ports. The isolation from L.O. to signal ports was measured to be 32 dB and the isolation from the signal port to the L.O. port was measured to be 28 dB. The isolation from the output port to either of the input ports is greater than 20 dB.

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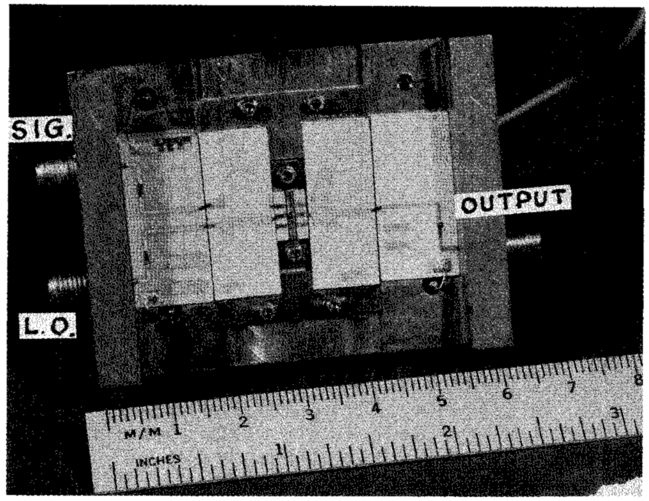


Figure 2 Photograph of the Converter

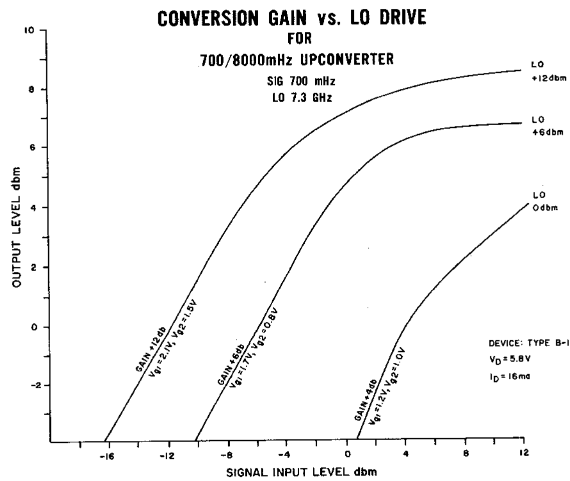


Figure 3 Conversion Gain Versus L.O. Drive Level

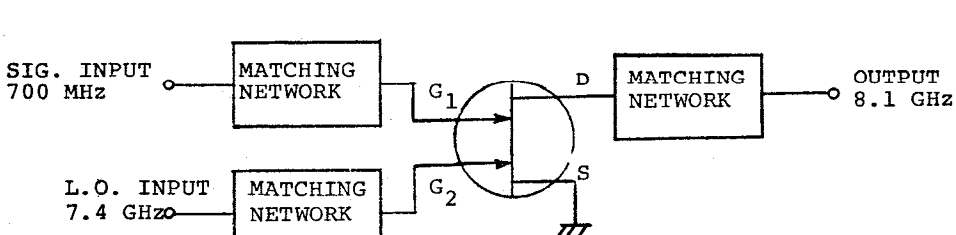
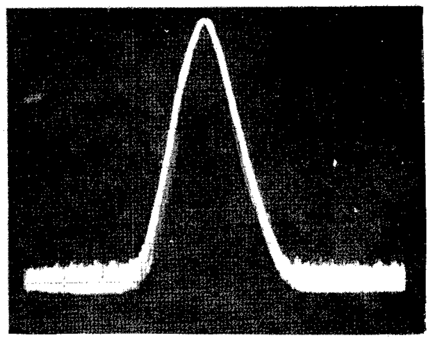
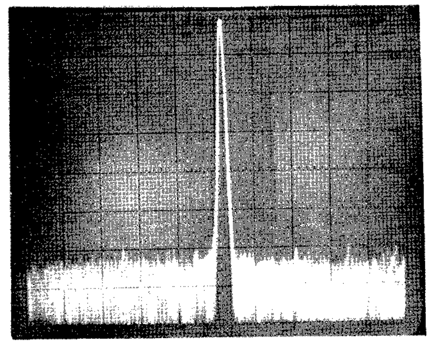


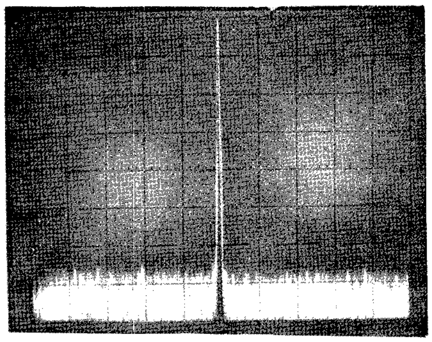
Figure 1 Dual-Gate FET Up-Converter Configuration



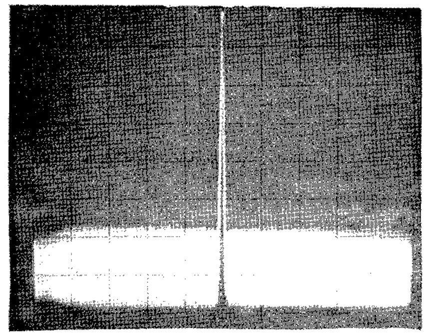
50 KH_z/cm



1 MH_z/cm



10 MH_z/cm



50 MH_z/cm

Figure 4 Output Spectra

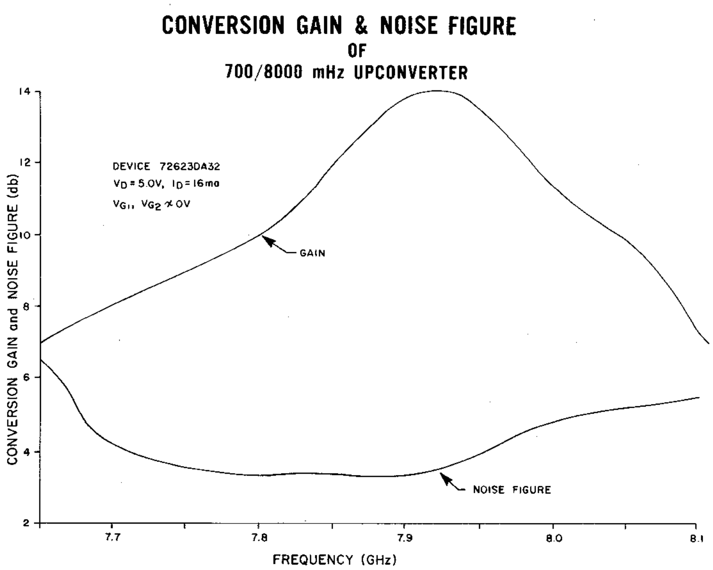


Figure 5 Conversion Gain and Noise Figure Versus Output Frequency

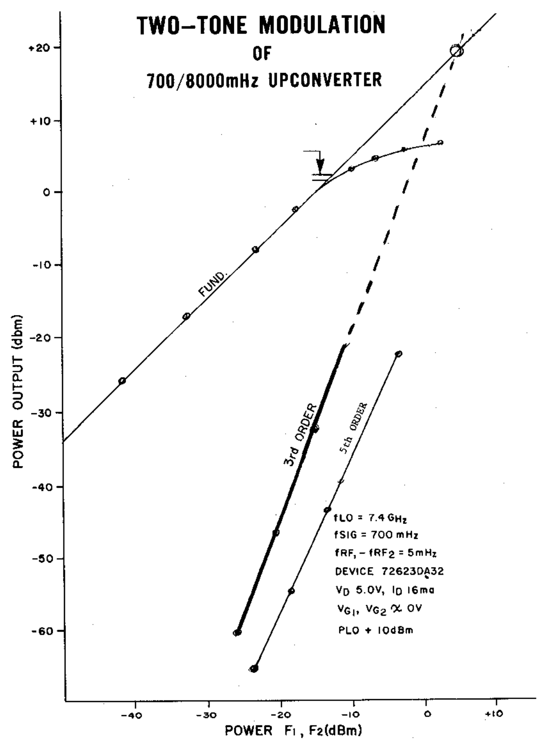


Figure 6 Intermodulation Products