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A BALANCED 11 GHz HEMT UP-CONVERTER

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ABSTRACT

A 70 MHz to 11 GHz balanced up-converter circuit is described. HEMTs were found to be very suitable for this application due to their high gain at 11 GHz. The measured results show 7 dBm 1 dB gain compression point, 15 dBm third order intercept point, 3 dB conversion gain and 35 dB LO suppression.

INTRODUCTION

The main disadvantage of diode up-converter circuits are IF to RF conversion loss and poor linearity. Typically, conversion loss of 5 to 6 dB and third order intermodulation intercept point of 10 dBm are measured. A GaAs FET offers both conversion gain and a higher intercept point. However, unless FETs with gate length of 0.3 microns (or shorter) are used, any conversion gain at 11 GHz may be hard to obtain. As HEMT technology is maturing rapidly, the commercially available devices offer superior performance at a cost below that of a diode or FET up-converter. A balanced HEMT up-converter configuration offers excellent performance due to its high linearity when used in 64 QAM digital microwave radio.

THEORY OF OPERATION

There are two highly non-linear regions in HEMT operation:
1) gate pinch-off voltage and 2) drain current saturation (fig. 1). Gate pinch-off mode offers an inherent isolation between the up-converted signal output and the local oscillator (LO) input. It also requires less LO power to drive the HEMT current to the saturated value I_{dss}.

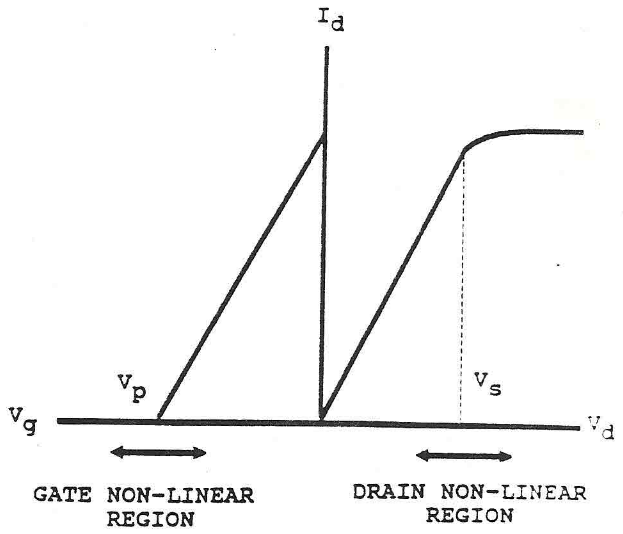


Figure 1: HEMT Non-Linear Regions

With HEMT biased at the gate pinch-off no drain current flows in the absence of LO drive. When a large LO drive is applied to the gate the drain current reaches I_{dss} value on positive LO half cycles. Thus the HEMT transconductance g_m is in effect pulsed at LO rate between zero and its maximum value.
The transconductance waveform approaches a square wave with the fundamental frequency component (ω_o) given by (fig. 2)

$$g_m(t) = 1/2\ g_m + 2/\pi\ g_m \sin \omega_o t + \ldots$$

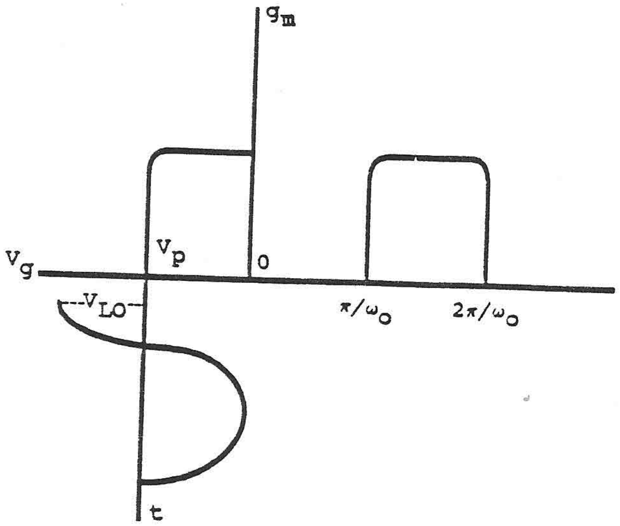
Substituting this in the simplified equivalent circuit (fig. 3), the following expression may be derived for the conversion gain:

$$G_c = 1/4\ (g_m / \pi\ \omega_1\ \bar{c}_g)^2\ R_d/R_g$$

Where ω_1 = input frequency
$\bar{c}_g$ = time average of gate capacitance

and the load resistance R_L is equal to the drain resistance R_D for maximum power transfer.

Compared with the expression for gain when used as an amplifier the conversion gain is lower by approximately, π^2 or 10 dB.



$$g_m(t) = 1/2\ g_m + 2/\pi \sin \omega_o t + \ldots$$

Figure 2: Transconductance Waveform

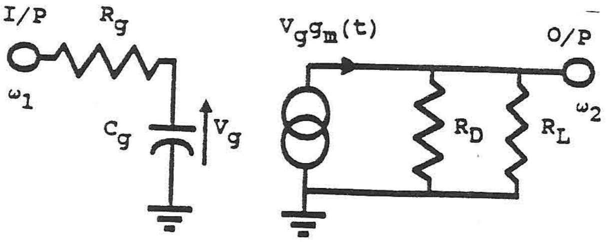


Figure 3: Up-Converter Equivalent Circuit

BALANCED CIRCUIT DESCRIPTION

The up-converter schematic and microstrip lay-out are shown in figures 4 and 5.

In order to cancel out a large LO signal in the up-converter output, a balanced circuit must be used. This consists of two HEMTs with the LO signal applied in antiphase to the two gates. This is achieved by means of an 180° splitter ("rat race" hybrid). When the outputs from the two drain circuits are now combined in-phase (Wilkinson combiner), a cancellation of the LO signal will take place in the up-converter output.

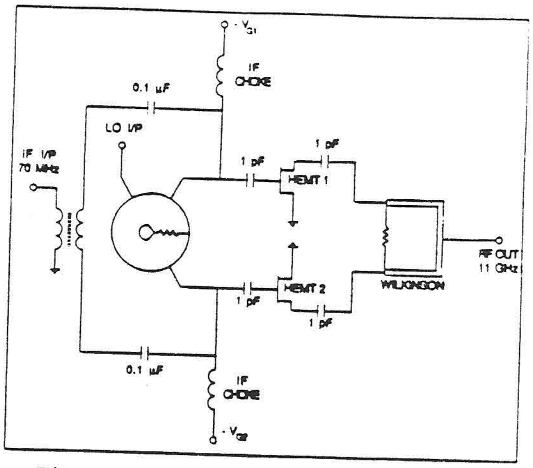


Figure 4: Up-Converter Circuit Schematic

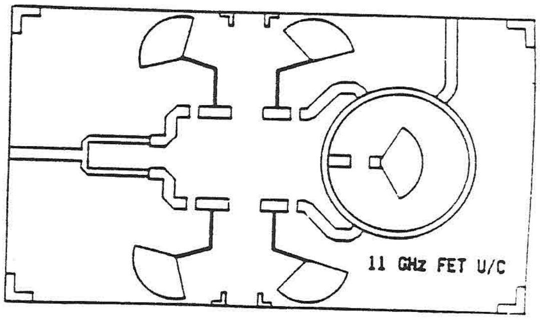


Figure 5: Up-Converter Lay-out on Microstrip

For the up-converted signals to add in phase in the Wilkinson combiner, the IF inputs to the gates of the two HEMTs must be in anti-phase. This is readily achieved by means of a balanced IF transformer.

IF chokes and 1 pF DC blocking capacitors prevent the IF signal from being shorted by the bias supply and the RF hybrid respectively. The HEMTs used were 2SK878. They were selected on the basis of their saturation output level and gain at 11 GHz. These were 13 dBm and 8 dB respectively, thus 5 dBm LO input to the gate was required to drive the HEMT to saturation level. The total LO drive of 10 dBm was required in order to account for hybrid and matching circuit losses and the fact that two HEMTs were used.