BALANCED FET UP-CONVERTER FOR 6 GHz, 64-QAM RADIO

P. BURA D. GELERMAN

NORTHERN TELECOM, MONTREAL, CANADA

ABSTRACT

70 MHz to 6 GHz balanced FET up-converter is described. Third order intercept point of 26 dBm, conversion gain of 3 dB and 33 dB LO suppression were measured. Its highly linear performance makes it suitable for 64-QAM radio. Bit error rates lower than 10^{-27} were measured at 2.7 dBm RMS (64-QAM) output level.

1.0 Introduction

A single ended (un-balanced) FET up-converter (U/C) circuit was first designed and tested in June 1980 (1). In this circuit both Local Oscillator (LO) and IF signals are applied to the gate of the FET and the up-converted output is taken from the FET drain circuit. The circuit had approximately 4 dB IF to U/C output conversion gain and 8 dBm, 1 dB compressed output level.
The major disadvantage was a large LO leakage level: 18 dBm, i.e. the same level as applied to the gate.
In order to reduce the side-band filter requirements, more than 20 dB LO rejection is needed. This can be accomplished by means of a balanced FET up-converter circuit.

2.0 Circuit description

A balanced U/C circuit is shown in Figure 1.
For LO suppression at the output, there must be 180° phase shift for the LO signal passing through the two FET's (F1 and F2). This is achieved by means of an in-phase (Wilkinson) splitter at the input and a 180° combiner ("rat race") at the output. The two splitters/combiners can be interchanged. An alternative version used quadrature hybrids at the input and the output.
The IF signal is fed to the two gates in anti-phase. This is equivalent to the polarity reversal in a diode up-converter. The phase reversal is achieved by means of an IF transformer with a centre-tapped secondary. IF chokes and 4pF capacitors prevent the IF signal from being shorted by the bias supply and RF hybrid respectively.
FETs used are NE695. They were selected on the basis of the saturation level and gain at 6 GHz. The saturation level determines the LO level required while gain will determine IF to U/C conversion. NE695 has 22 dBm 1 dB compression point and 9 dB linear gain at 6 GHz.
The FETs are biased at the pinch-off, i.e. approximately zero drain current in absence of the LO drive. With a full drive, the drain current reaches 40mA at 9v drain bias.

3.0 Results

3.1 Conversion Gain & 1 dB compression point

Pout versus Pin curve is shown in Figure 2. The linear conversion gain is 1.7 dB. Taking into account the side-band filter loss and loss of the combiner in the U/C output the conversion gain becomes 3.0 dB. This is in good agreement with the previous results for a single ended U/C.
The 1 dB compression point is 13.5 dBm (14.5 dBm before the filter).

3.2 Intermodulation Ratio (IMR) and the Intercept Point

This was measured using two equal input tones at 68 and 72 MHz. The results are tabulated below:

Pout (single tone level) dBm	6	7	8
IMR dBc	40	38	36

The third order intercept point is thus 26 dBm.
A typical diode U/C IMR is specified at 36 dBc at -5 dBm (single tone output level). Thus, the results for the FET U/C show a 13 dB increase in the operating output power level.

3.3 LO Suppression

With the FET U/C driven with 18 dBm LO level, the LO leakage measured before the side-band filter was -15 dBm, or 33 dB below the input level. With the U/C operating at 3 dBm rms output, the LO leakage will be 19 dB below the output. This is appreciably better than a diode U/C performance. This means that the filtering requirement, compared with the diode U/C, can be slightly relaxed.

3.4 Bit error rate (BER) measurement

To evaluate the suitability of the up-converter for a 64-QAM digital radio, the BER was measured in a test set-up shown in Figure 3.
An external 70 MHz IF amplifier is used to raise the 64-QAM modulated up-converter input to the required level. A common LO was used to power both the up-converter and the down-converter with 17 dBm and 7 dBm respectively. The LO frequency was 6305 MHz. A waveguide cavity band-pass filter (6375 MHz) with 1 dB insertion loss was used to reject the lower side-band and the LO leakage.
The signal was then attenuated to -30 dBm level and fed to the down-converter and then to the demodulator.

The measured BER, as a function of the output power, is shown in Figure 4. It increases from 10^{-31} at 1 dBm output to 10^{-20} at 3.7 dBm.

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For a diode up-converter similar BER performance is achieved at -10 dBm output level. Thus, the FET up-converter again shows a 13 dB increase in the operating output level for the same LO drive.

4.0 Conclusions

The balanced FET up-converter shows two advantages compared with a balanced diode up-converter:

1) 2 dB IF to 6 GHz gain compared with 6 dB loss.

2) higher output level for the same linearity requirement.

The FET up-converter was found suitable for the highly linear 64-QAM digital radio application: BER of 10^{-26} was measured at 3 dBm rms, or 8 dBm peak state level. This was a 13 dB increase over a diode up-converter, with the same LO drive. The increased up-converter output reduces the gain requirement in the transmitter power amplifier.

Reference:

1) P. Bura "70 MHz to 6 GHz FET up-converter" 1981 European Microwave Conference Proceedings pp. 215-219.

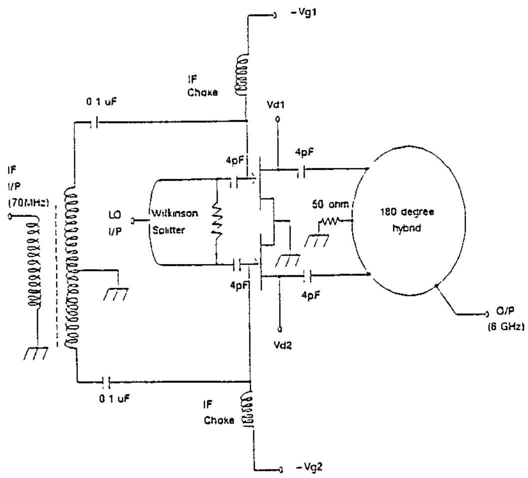

Fig. 1 70MHz to 6 GHz Balanced FET U/C

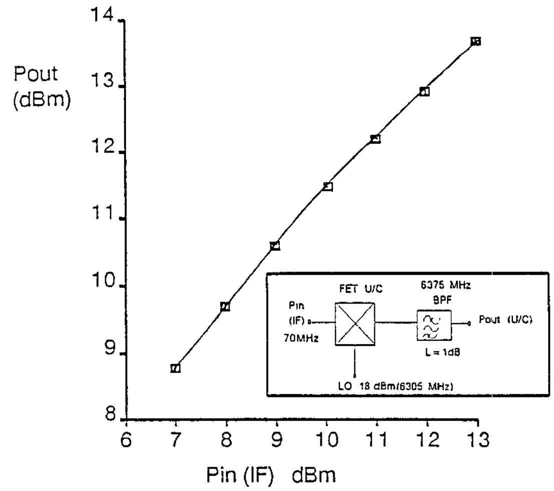

Fig. 2 Pout vs. Pin

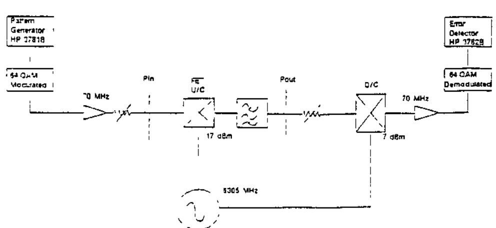

Fig 3 Bit Error Rate Measurement Set-Up

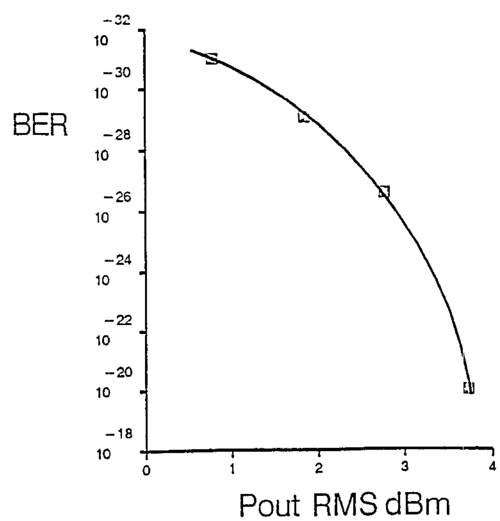

Fig. 4 BER vs. Pout