TRANSFER PROPERTIES OF THE UPPER-SIDEBAND VARACTOR UPCONVERTER

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ABSTRACT

The large signal upper-sideband varactor upconverter is theoretically investigated. Using measurable quantities as parameters, gain linearity and phase conversion are computed and optimized at specific input mismatches. Furthermore, noise conversion from bias and inputs is studied under large signal conditions. The bias termination proves to be critical to all noise transfer coefficients.

INTRODUCTION

The upper-sideband varactor upconverter may be used as power stage in SSB-AM applications with moderate power-bandwidth products. The upconverter can meet the stringent linearity requirements, if one of the known linearization schemes /1/,/2/ is applied. However, the non-overdriven abrupt junction varactor upconverter treated here, is nonlinear solely due to two effects. The first effect is secondary mixing of a multi-tone signal with LO intermodulation sidebands. The second is gain compression, occurring with any number of input tones. With a single frequency IF, the gain compression is caused by power level dependent mismatch of the input ports.

The first part of this work theoretically investigates the nonlinear effects and possible linearization by various mismatch conditions at the interfaces between the signal sources and the upconverter, thus completing other investigations /3/, /4/, which are too specialized.

In the second part, the noise conversion from input and bias ports is calculated. Under certain conditions, such noise may deteriorate the transmission quality.

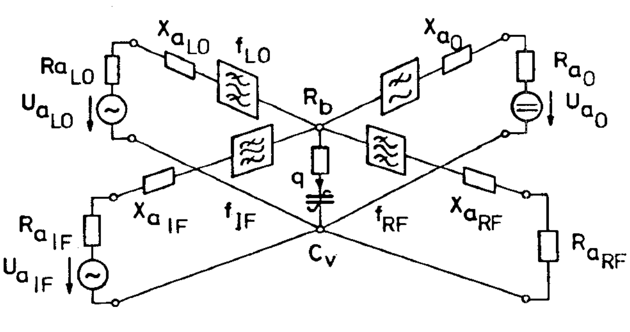

Fig. 1: Upconverter equivalent circuit

EFFECTS OF INPUT PORT MISMATCH

The results of the steady-state, three-frequency analysis given here are intended for comparison with measurements. Available source powers and reflection coefficients are used as parameters. The analysis is based upon the equivalent circuit Fig. 1. Besides ideal bandpass filters, tuning inductances are inserted into each branch to enable varactor capacitance compensation.

The computational procedure can be outlined as follows: At full drive, the charge amplitudes are evaluated for maximum output power /5/, and all varactor and external quantities are determined. Arbitrarily chosen input reflection coefficients are taken into account. Then, the available IF power is lowered stepwise, while all other external circuit elements including bias voltage are kept constant. The numerical problem can be reduced to two nonlinear equations. The procedure is repeated for various mismatches, or varying IF frequency. A ratio of varactor cutoff to output frequency of 200 is used. Normalization of results is based on varactor data, frequencies and available LO power /4//5/. In the following, any input mismatch will be specified at full drive and is adjusted by varying the source resistance or tuning inductance. Circuit elements not mentioned are tuned for complex matching.

The basic case is the fully matched upconverter. At full drive, it touches the border of instability /4/. Gain and phase conversion plots are shown in Figs. 2 and 3. The graphs are computed for varying IF frequency within a band of 20 %. The high gain nonlinearity is caused by the superposition of increasing reflection at both inputs, with decreasing IF power. The task is now to select mat ching conditions for improved linearity by cancellation of mismatch effects.

In the next four cases, either the real or the imaginary part of the port impedance is mismatched.

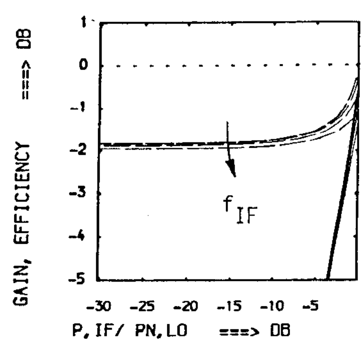

Fig. 2:
Gain (- -) and RF efficiency vs. available IF power.

Normalization factors for
gain : f_{RF}/f_{IF},
effic. : f_{RF}/f_{LO},
IF power: PN,LO = $= P_{LO,avail} * f_{IF}/f_{LO}$.

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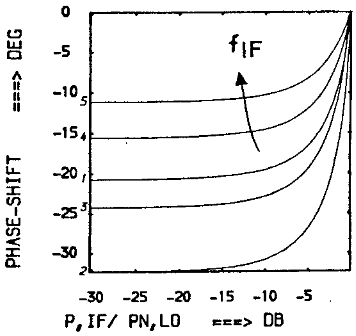

Fig. 3:
IF to RF phase conversion vs. available IF power.

For Normalizations, see Fig. 2.

The mismatches will be called real resp. reactive.

Results for IF port real mismatch are shown in Fig. 4. Choosing the source resistance too high, graphs 1 to 3, increases the small signal gain to its theoretical value. Linearization and saturation are more or less pronounced. Too small source resistances are causing instability near full drive, graph 5. The phase conversions are almost unaffected by these mismatches.

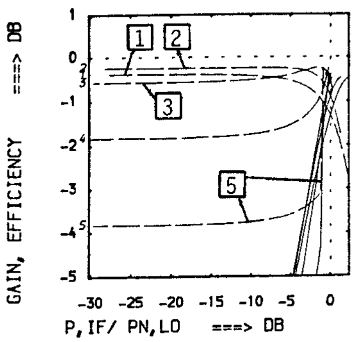

Fig. 4:
IF real mismatch.

Gain (- -) and RF efficiency vs. available IF power.

For Normalizations, see Fig. 2.

Reactive mismatch of the IF port improves linearity at the expense of reduced small signal gain, Fig. 5. The phase conversion can be decreased, if the port is inductively overcompensated, see graphs 4 and 5 in Fig. 6.

Mismatching the LO requires higher available oscillator power. Similar to the IF real mismatch, too high LO source resistances lead to linearization, seeming to be perfect: Fig. 7, graphs 1, 2. If the resistance is too small, instability occurs, graph 5. The phase shift may also be minimized. Any reactive mismatch of the LO port improves the linearity of the gain and the amount of phase shift in the same way as above but without instabilities.

Considering intermodulation characteristics, a strong mismatch at the LO port will prevent those LO sideband currents to flow, which are the origin of intermodulation by secondary mixing. For multicarrier signals, mismatching the LO is preferable, if there are no LO power constraints.

To conclude, all matching conditions have been optimized by computer for best linearity of the gain curve, up to 5 dB below full drive, at IF midband frequency. Results are shown in Figs. 8 and 9, the graphs are plotted for different IF frequencies, as in Figs. 2, 3. A wide range linearization has been obtained at almost no loss in RF efficiency. Off midband, the linearity is slightly

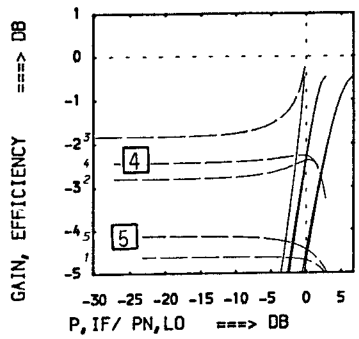

Fig. 5:
IF reactive mismatch.

Gain (- -) and RF efficiency vs. available IF power.

For Normalizations, see Fig. 2.

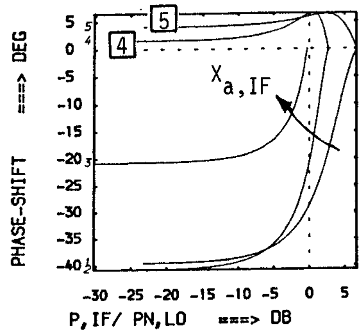

Fig. 6:
IF reactive mismatch.

IF to RF phase conversion vs. available IF power.

For Normalizations, see Fig. 2.

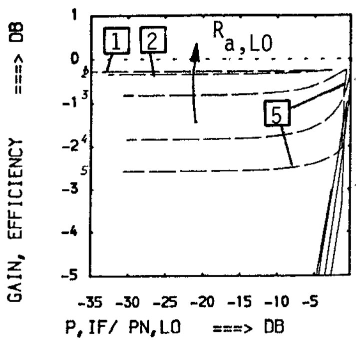

Fig. 7:
LO real mismatch.

Gain (- -) and RF efficiency vs. available IF power.

For Normalizations, see Fig. 2.

deteriorated. A mutual cancellation of mismatch can be detected from the input reflection coefficients plotted in Fig. 9, with labels '1' at full drive.

The matching conditions of practical upconverters can be compared with the values plotted here, if the impedance transformations of the passive networks surrounding the upconverter are known. The preferable kind of mismatch depends upon the desired gain and phase characteristic.

NOISE CONVERSION

The noise conversion for the upconverter fully matched at full drive has been computed using parametric matrix equations /5/ and the equivalent circuit Fig. 1. All sources may now include additional noise sources, the source impedance being the same as for the large signals. The split-up into AM and PM components follows /6/. Only upconversion to the output is of interest. The conversion coefficients are normalized to the ratio of output to input noise frequency.

The choice of the bias source impedance is

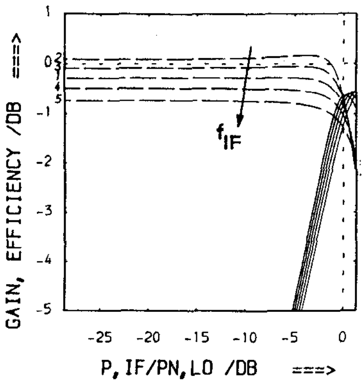

Fig. 8:
Computer optimized mismatch.

Gain (- -) and RF efficiency vs. available IF power.

For Normalizations, see Fig. 2.

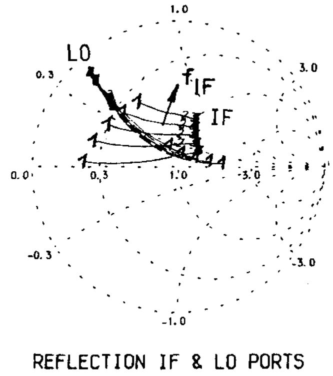

Fig. 9:
Computer optimized mismatch.

Loci of reflection coefficients for IF (——) and LO (- -) input ports.

free. The input capacitance of the varactor at bias noise frequency is nearly independent of IF power. The capacitance was compensated for by a series inductance. The following plots show graphs for various bias source resistances.

Fig. 10 displays the bias noise return loss. Off full drive, it shows parametric amplification, becoming very high when the source resistance equals the varactor series resistance, normalized to the ratio of noise to cutoff frequency, graph 2. This condition will be called noise matching.

Parametric amplification acts on most noise conversions into the RF band, see Figs. 11, 12 for noise from bias resp. LO-PM noise. Depending on the IF level, all normalized noise conversions attain a smooth maximum, except for noise matching. With a high normalization factor for low frequency noise, and noise match, the output signal of the upconverter may be disturbed. A strong bias mismatch at all noise frequencies is therefore recommended.

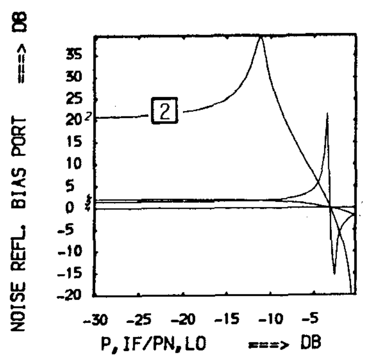

Fig. 10:
Reflection coefficient for noise injected at the bias port vs. available IF power.

For Normalizations, Fig. 2.

CONCLUSIONS

The influence of input mismatches on the large signal nonlinear behaviour of the upconverter has been investigated. Several types of input port mismatches are qualified for stable gain linearization.

Noise from the bias source may have high conversion gain into the output band, especially for low noise frequencies. If such noise cannot be eliminated, there must be a high reflection at the bias interface, across the bias filter passband.

ACKNOWLEDGEMENT

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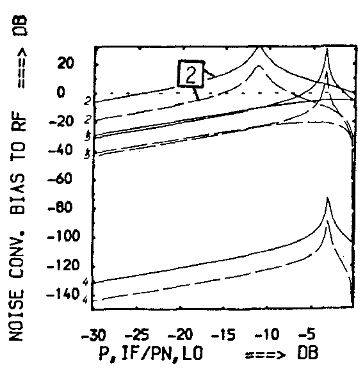

Fig. 11:
Noise Conversion from bias to RF,AM (——) and PM (- -) vs. available IF power.

For Normalizations, see text and Fig. 2.

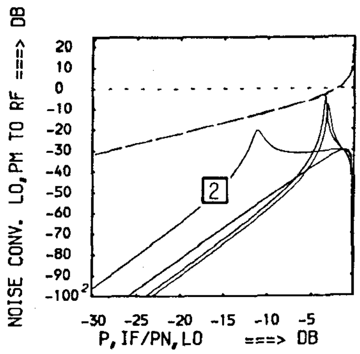

Fig. 12:
PM noise conversion from LO to RF,AM (——) and PM (- -) vs. available IF power.

For Normalizations, see text and Fig. 2.