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To: VLBA Data Acquisition Group

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Subject: The Effect of Bias Current Fluctuations on the Phase Noise of a FET Oscillator

Further tests of the FET oscillator phase noise indicate that the under constant voltage bias the major process for conversion of the low frequency (1/f) noise in the FET to phase noise is up-conversion from nonlinearities in the FET rather than parametric up-conversion via the tuning or "pulling" of the oscillator by the FET. The main reason for coming to this conclusion is that stabilization of the bias voltages dramatically increases the phase noise while stabilization of the bias current (which increases the voltage fluctuations on the gate) decreases the phase noise. The parametric up-conversion process requires voltage fluctuations while the mixing process requires current fluctuations. By controlling the bias current the mixing process is suppressed as observed. The up-conversion by mixing and the up-conversion by tuning of the FET low frequency noise will have the same spectral exponent of -2 (-6 dB/octave) added to the exponent of the low frequency noise. Up-conversion by mixing is Q dependent (owing to the filtering of the mixed products by the tank circuit) which up-conversion by tuning is not Q dependent.

The following table shows the dependence of the various phase noise processes of loaded Q, oscillation power and frequency deviation from the carrier.

	EXPONENT OF DEPENDENCE		
Origin of Phase Noise	Loaded Q	Oscillation Power	Deviation from Carrier
FET noise	-2	-1	-2
(1/F) FET noise upconverted by mixing	-2	0 (see Note 2)	-3
(1/F) FET noise upconverted by tuning	0	0	-3

Notes: 1. (1/F) noise exponent assumed to be -1 (-3dB/octave)
2. FET non-linearity assumed to be square law the presence of higher order terms will make the phase noise increase with oscillation power.

The test results given in Acquisition Memo #70 were made with the simple bias arrangement of a 200 ohm resistor from the FET source to ground (grounded gate and positive supply voltage on the drain). This arrangement provides neither a constant current (since 200 ohm is not a very large resistor) nor a constant voltage bias (since the 200 ohm is only bypassed with a small R.F. capacitor of 200 pF). At the time, I did not know whether a constant voltage or constant current bias would give the lowest phase noise until Sandy Weinreb made a comment which motivated me to look at the problem.

The figure below shows the phase noise measured with both a constant current bias (provided by a 3.6K ohm resistor from minus 15 volts to the source) and with a constant voltage (provided by a low frequency bypassing of the source with a 3 uF capacitor). Similar results were obtained using an additional transistor to provide a low noise constant current. In addition it didn't make any appreciable difference whether the constant current source was on the source or the drain of the FET (although the bias circuit was very different in these two cases). With a constant current bias there is still some reduction in phase noise when the voltage between drain and source is reduced but considerably less than is shown in Figure 1 of Acquisition Memo #70. The current bias value effects the oscillator power (at low bias the oscillation will cease) but has little effect on the phase noise. Under conditions of constant current it is assumed that the remaining phase noise (whch is still higher than the theoretical noise floor) is due to up-conversion via tuning - but more tests are needed to establish this assumption. The more constant current provided by a large resistor to the negative supply does improve the phase noise (compared with the 200 ohm to ground) over the original circuit at frequencies above 800 MHz. A more complete understanding could lead to even further improvements in the oscillator performance although the effort may not be justified at this time.

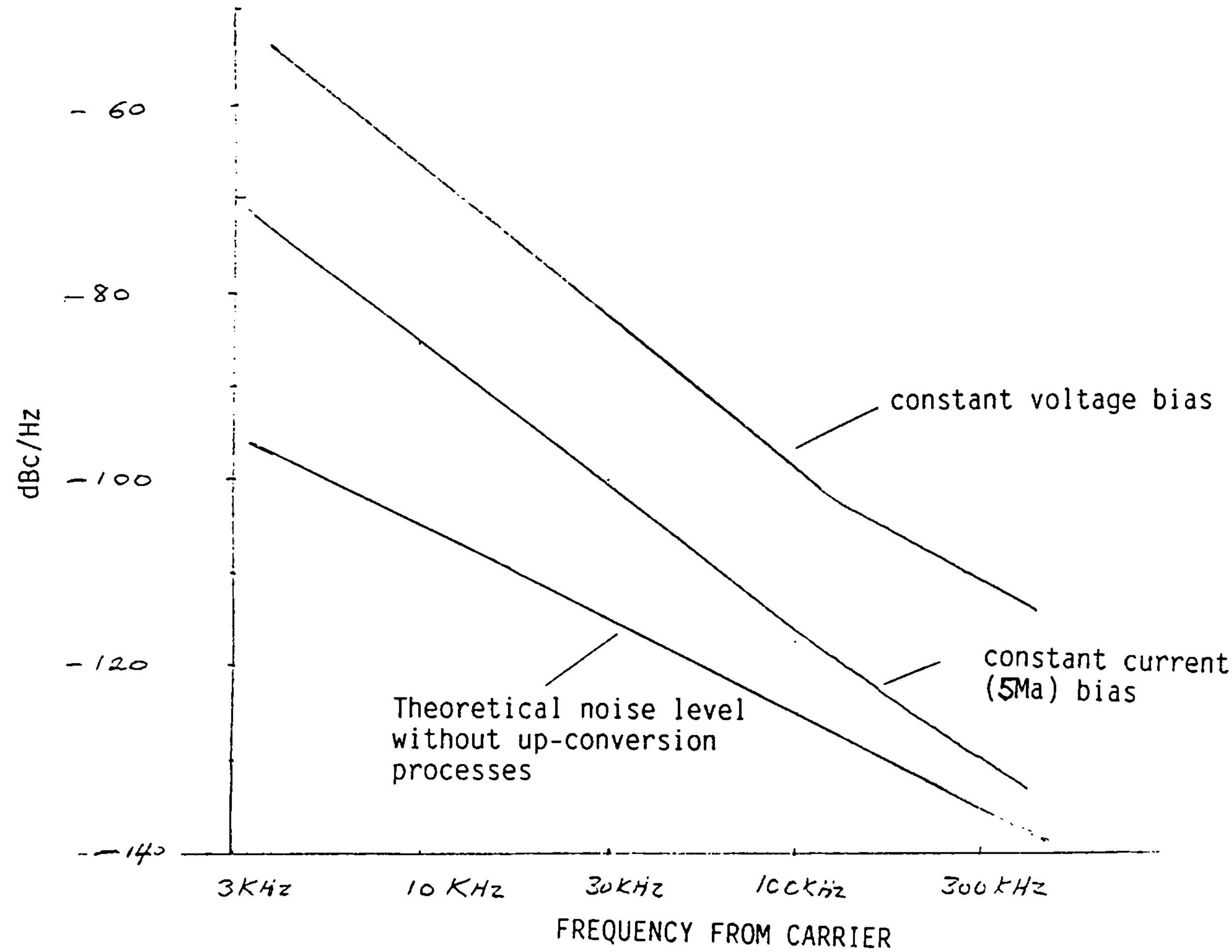

Figure. Oscillator phase noise at 900 MHz