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TO: Acquisition Group

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SUBJECT: Preliminary Evaluation of Low Noise Voltage Tuned Oscillators

The VLBA video converters should cover 500 MHz to 1000 MHz and require a low noise oscillator or a more complex synthesizer design. The MK III converters use a tunnel diode oscillator which achieves close to the theoretical noise performance given by

$$S(\omega) = \log_{10}\left[\frac{KT}{Q^2P}\left(\frac{\omega_0}{\Delta}\right)^2\right] \quad dBc/Hz \qquad (1)$$

where

T=ambient temperature
Q=tank circuit Q
P=power in tank circuit
$\left(\frac{\Delta}{\omega_0}\right)$ =fractional frequency deviation from carrier

The tunnel diode oscillator performance, while good, would be improved by using a FET as the active dement to increase the power in the tank circuit. This is in fact suggested in the MK III manual but only recently have I found the time to look into the problem.

Noise Theory Continued

Equation 1 can be rewritten in terms of the voltage e across the tank circuit as follows:

$$S(\omega) = \log_{10}\left[\frac{KT\,Rs}{e^2}\left(\frac{\omega_0}{\Delta}\right)^2\right] \quad dBc/Hz \qquad (2)$$

where

Rs is the effective series resistance in the tank circuit.

An oscillator may also contain noise sources which couple into tuning action of the varactor and active element. These noise sources have the following spectrum:

$$S_T(\omega) = \log_{10}\left[KTR\left(\frac{\alpha}{\Delta}\right)^2\right] \quad dBc/Hz \qquad (3)$$

where

R=effective resistance of noise generator
T=effective temperature of noise generator
α=tuning sensitivity (radians/sec/volt)

Criteria for Lowest Noise Operation

1] Design the tank circuit for lowest possible Rs and make sure this is not significantly degraded by "loading effects" of the active element (i.e. loaded Q $\simeq$ tank Q).

2] Examine all sources of tuning noise (like large resistors in series with varactor tuning, FET gate) and shunt these sources with a low impedance at frequencies in the few Hz to few MHz range.

3] Maximize the oscillator voltage in the tank circuit within the contraints imposed by maximum allowable voltage range across the varactor.

Comments: a) The traditional microwave series resonant circuit discussed in the HP transistor catalog is not a good approach for criteria #1 as the circuit Q will almost certainly be limited by the active device rather than the tuning varactor.

b) The parallel resonant Colpitts' circuit is more appropriate, especially if tuning noise is minimized.

FET Tests

Tests have been made by taking the MK III 230-500 MHz oscillators and replacing the TD with a FET. The noise level at 10 KHz from the carrier at 420 MHz improved from -80 dBc/Hz to -100 dBc/Hz. The performance achieved is also better than the -90 dBc/Hz achieved by the best commercial VCOs in this frequency range. Figure 1 shows the circuit used and figure 2 the approximate equivalent. Even better performance should be possible by replacing the MV205 tuning diodes with GaAs diodes which have higher Q and lower series resistance. In addition the output tap should be moved towards ground to further raise the loaded Q.

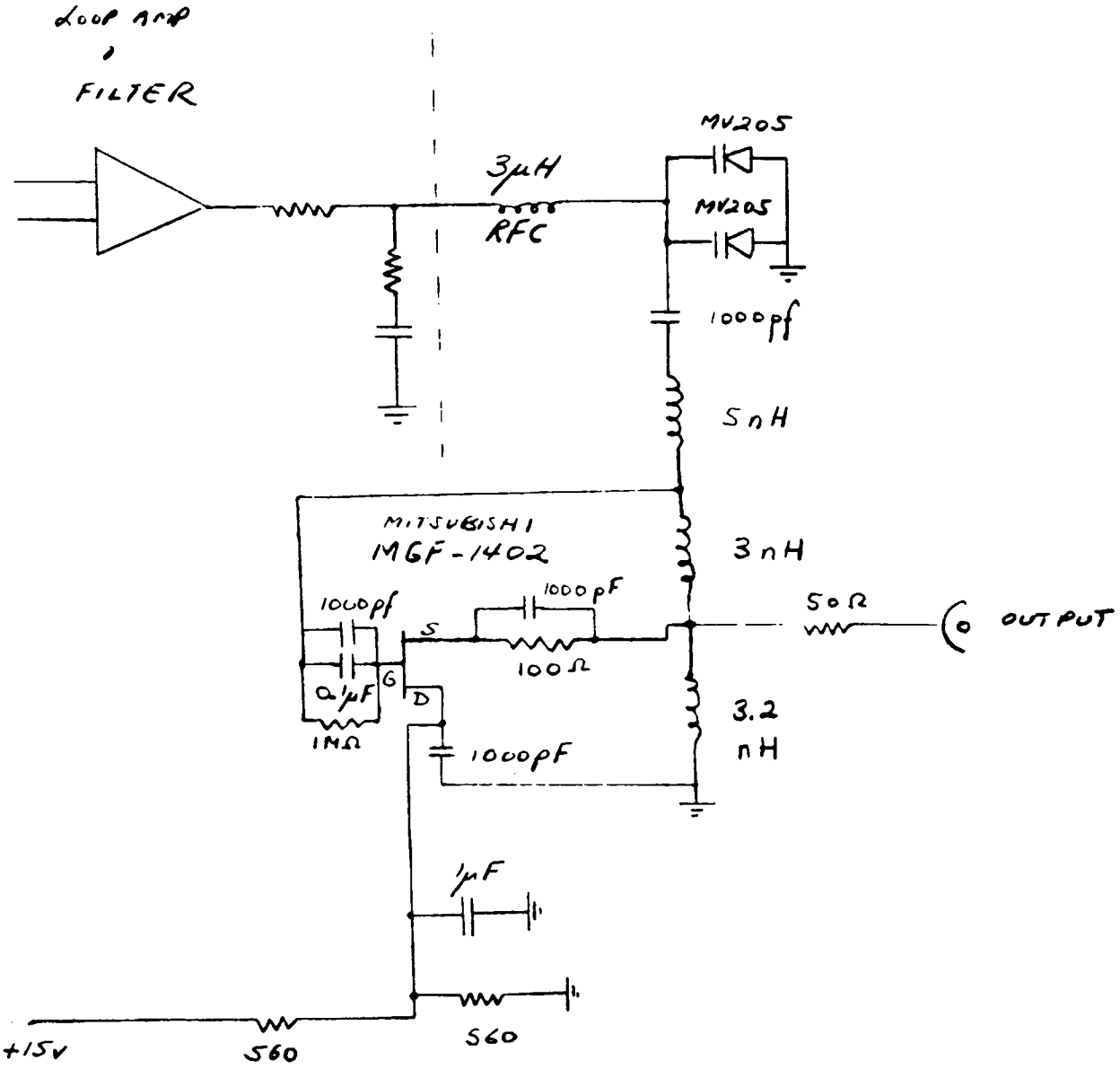
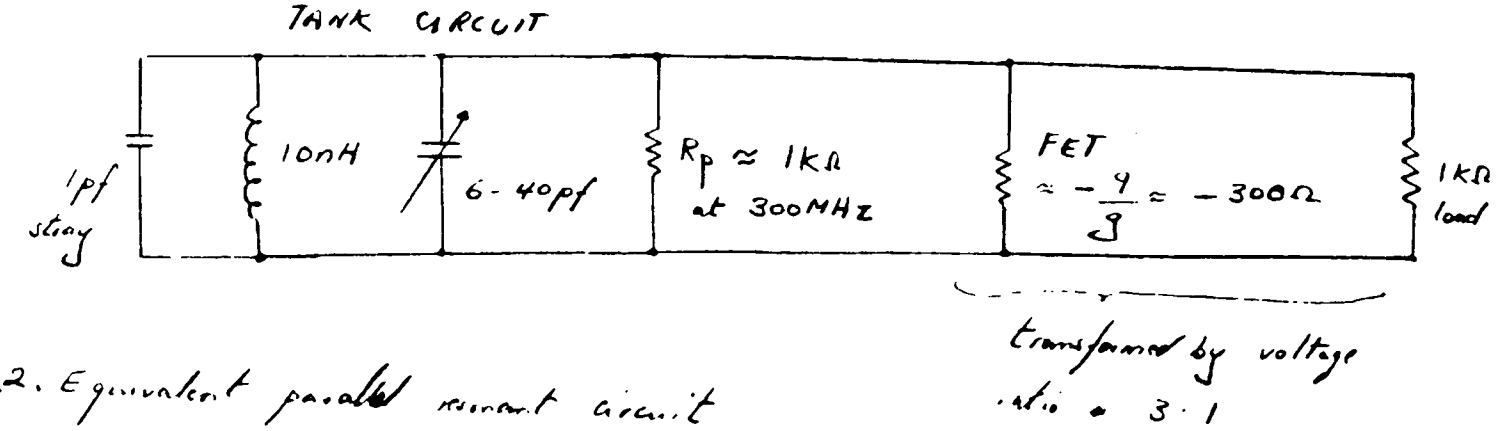


Figure 1. FET VCO 250 - 500 MHz



2. Equivalent parallel resonant circuit