VLBA ACQUISITION MEMO #353

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To: VLBA Data Acquisition Group

From: Alan E.E. Rogers

Subject: Suggested use of NPN transistor in BBC oscillator for lower phase noise

The current design for the oscillator in BBC uses a MGF-1402 (2SK274) GaAs FET as the active element. Tests of the BBCs show the largest contributor to phase noise performance variations is the GaAs FET. The 1/f noise in the FET varies considerably from one batch to another. With some of the best FETs the total phase noise is close to 2°rms but others have phase noise of 5°and higher at the high end of the range (above 900 MHz).

For a given FET, some small improvements can be made by adjusting the loop gain, but, in general, the loop gain and bandwidth are close to optimum. I have checked loop performance with a spectrum analyzer and found it to conform fairly close to the circuit models shown in Figure 1.

At the suggestion of Larry Beno, I have tried an NPN transistor in place of the FET and have been able to obtain both lower noise performance and obtain oscillation over the full band (see VLBA Acquisition Memo #70 for previous tests of FETs and NPNs).

I was able to obtain good oscillator performance after I analyzed the NPN oscillator (using an equivalent circuit model with parameters from the data sheets) to match the base in order to obtain a negative resistance in the tank circuit over a range of collector current and frequency. Figure 2 shows the calculated admittance of the oscillator resonant ("tank") circuit between the transistor emitter and ground as shown in the circuit of Figure 3.

Changes needed to use NPN

1] Remove FET, ferrite cores, and PC land going to the gate.

2] Solder in NPN with collector going to positive bias supply (i.e., end of 20Ω resistor); emitter connected to negative bias (i.e, end of 100 pf chip capacitor).

3] Add 5.1 pF and 2000Ω resistor from oscillator inductor to transistor base as shown in the photograph of Figure 4b.

Figure 4a shows the typical difference in the oscillator spectrum for an NPN (AT 41435-3[1]) compared with one of the better MGF-1402 FETs.

[1]Further tests are needed to determine if this is the best choice - I plan to test samples of some newer devices.

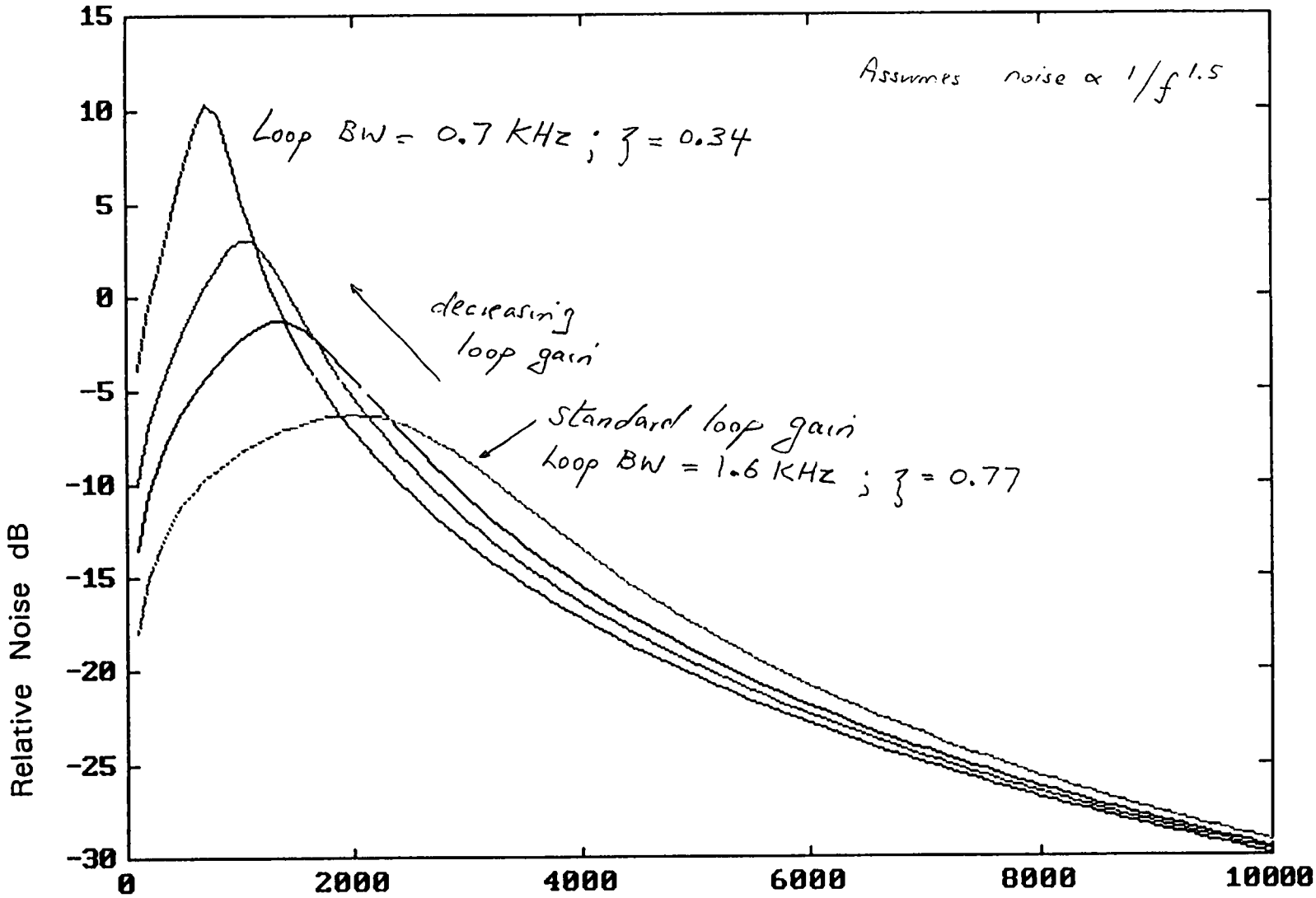

Assumes noise ∝ 1/f^1.5
Loop BW = 0.7 KHz ; ζ = 0.34
decreasing loop gain
Standard loop gain
Loop BW = 1.6 KHz ; ζ = 0.77
Relative Noise dB
15
10
5
0
-5
-10
-15
-20
-25
-30
0
2000
4000
6000
8000
10000
Frequency from carrier Hz

Figure 1

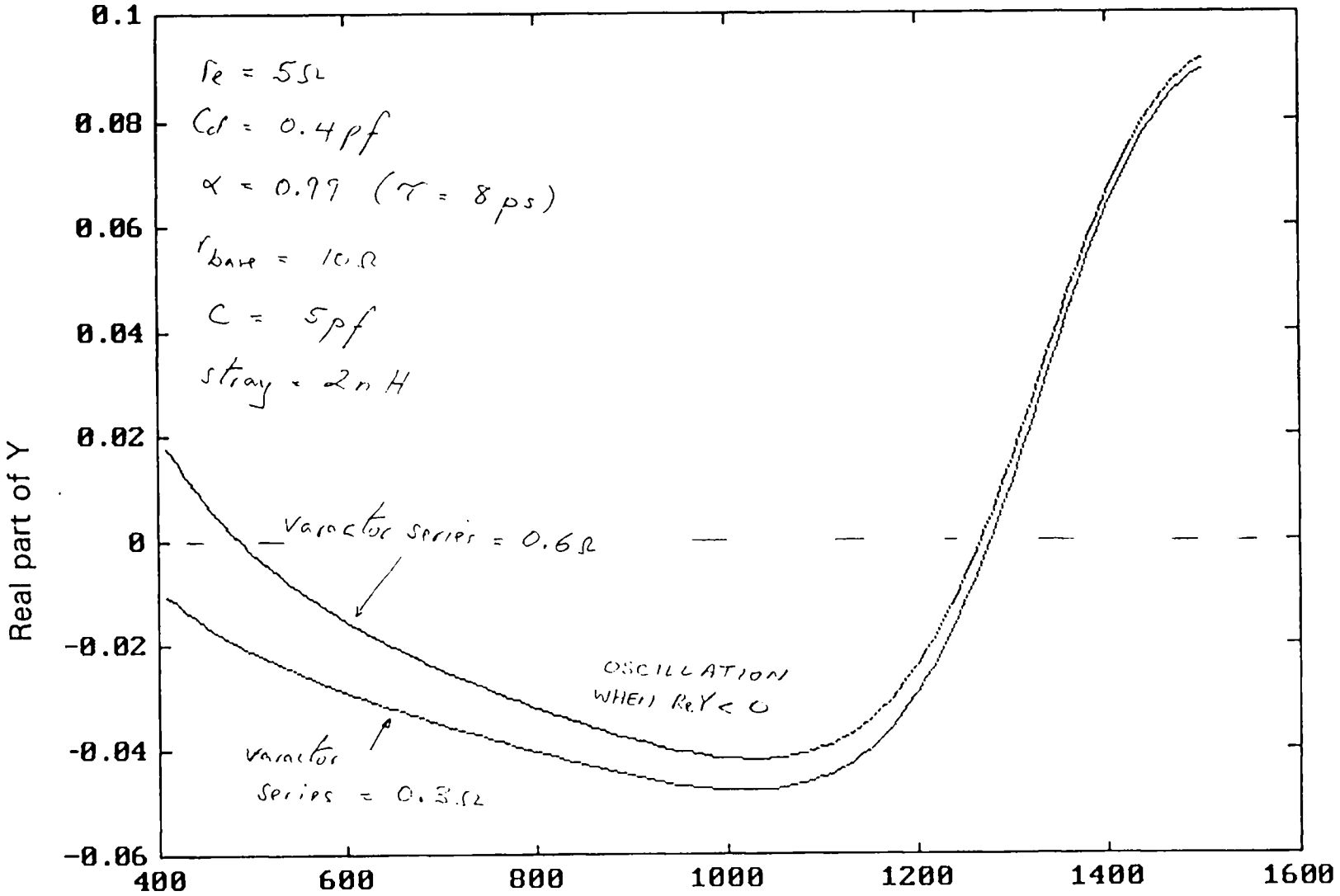
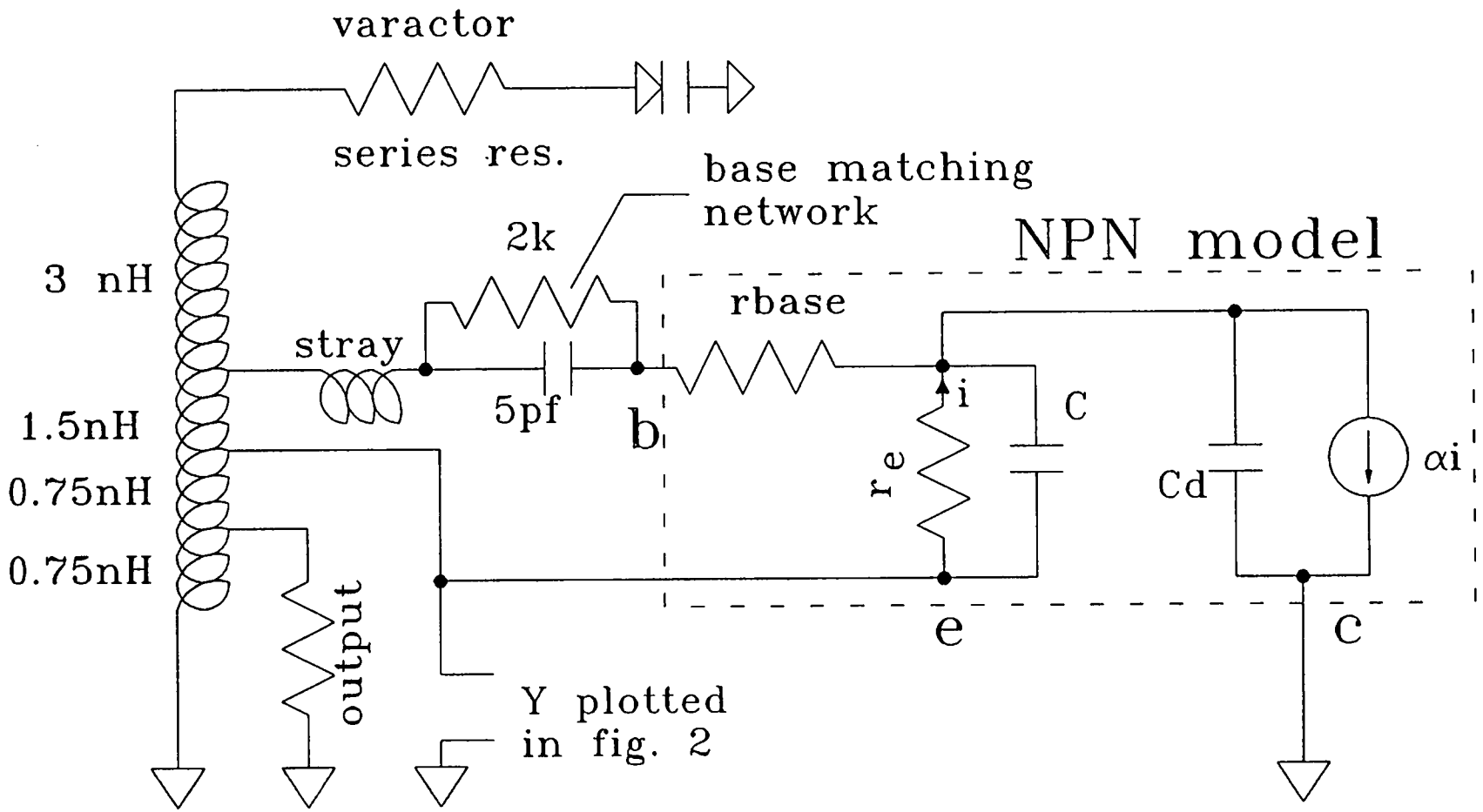


Figure 2 Freq. MHz



Notes: 1] Bias = 5 ma (same as used for FET)

2] NPN parameters from data book HP GaAs & Silicon products Designer's Catalog 1993

Fig. 3 Oscillator circuit model

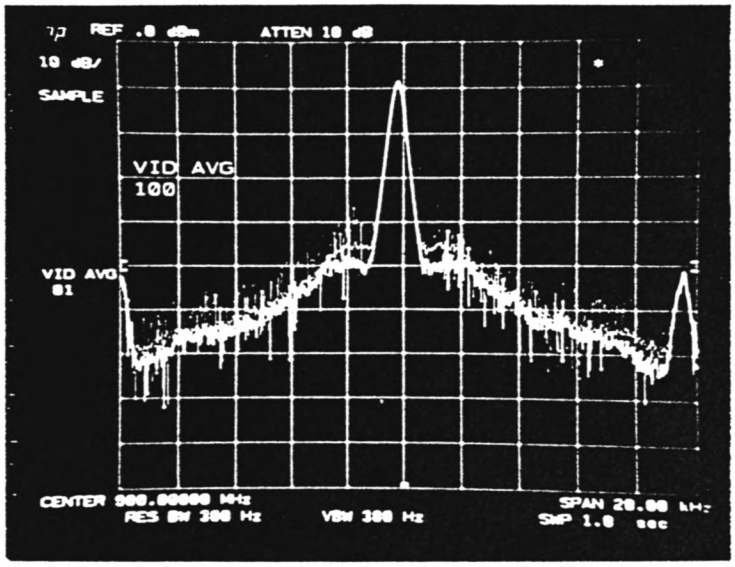


Figure 4a. "Bright" trace = NPN; "Dim" trace = FET

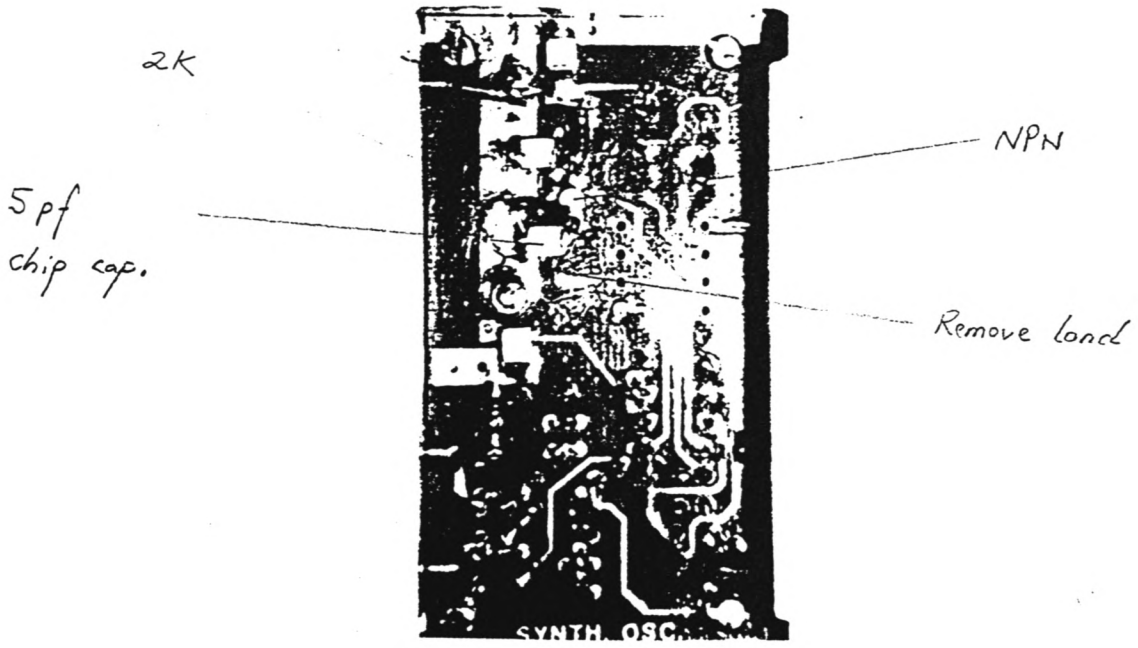


Figure 4b. Modified oscillator