VLBA Electronics Memo No. 36

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To: VLBA Electronics Group

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Subject: Phase Calibration Injection

Various phase calibration schemes have been used in VLBI. Most of these use a pulse generator which is injected into the front-end through a coupler in much the same fashion as a noise diode. The pulse generator produces uniformly spaced "rails or tones" in the frequency domain. An individual tone can be extracted in the processor and used to determine the phase through the interferometer at the frequency of the tone. If the equivalent noise temperature of an individual tone average over the baseband bandwidth is Tcal then the phase of this tone can be measured with one sigma error of

$$\left(\frac{\pi}{2}\right)^{1/2}\left(\frac{T_{cal}}{T_{sys}}\right)^{-1/2}(2BT)^{-1/2} \quad \text{radians} \qquad (1)$$

for 2-level processing where for

$$\frac{Tcal}{Tsys} = 0.01 \text{ (1\% of system noise)}$$

B = 2 MHz
T = 1 sec (coherent integration)

the error is approximately 0.5 degrees of phase. Since the individual tones are coherent and add up to a narrow pulse the delay through the receiver can be determined (relative to the pulse epoch) from the phase difference between tones.

For a step function generator the equivalent noise power output is

$$\approx \left[\frac{V^2}{2R(2\pi f)^2\, TK}\right]^{o}K \qquad (2)$$

where

V = voltage step ≈ 0.4 volt for tunnel diode
R = load resistance = 50Ω
f = frequency in Hz
T = pulse repetition period (1 μsec in S/X systems)
K = Boltzmann's constant

If the generator is near the upper limit of its' frequency range then

τ = pulse width ≈ $1/(2\pi f)$

and equation 2 is approximately

$$\left[\frac{V^2\tau^2}{2R\,TK}\right] \quad {}^{o}K \qquad (3)$$

Calibrators built for the NASA S/X receivers use tunnel diode pulse generators (with ≈ 30 psec rise time) run at a 1 MHz rate (1 pulse per microsecond), and produce about 30,000°K at 8 GHz or about 1000°K at 40 GHz. If used without amplification+ these calibrators will be too weak if the injection coupling is much greater than 30 dB.

+Amplification could be used - but will increase the cost. With amplification 40 dB coupling would be acceptable.