PHASE CALIBRATION OF THE VERY LONG BASELINE ARRAY (VLBA)

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Abstract

The delay through a microwave receiver can be calibrated by injecting short duration pulses (< 25 picosecond risetime) with constant repetition rate (typically 1 MHz) through a coupler into the input of the receiver. The phases of the tones generated by the pulse train are measured to determine the receiver phase and group delay.

Short duration microwave pulses with risetime less than 25 picoseconds have a spectrum extending up to about 50 GHz. When pulses with a repetition rate f are injected into a microwave receiver they generate a tone every f *Hz*. The phase of these tones is measured by quadrature digital mixing and then used to calibrate the phase and group delay of a VLBI receiver such as those of the VLBA. The pulse generator utilizes a tunnel diode to generate pulses whose stability relative to the frequency reference is better than 2 *ps/°C*. The generator is very compact and simple so that it is easily located close to the low noise front end of the receiver.

The pulses have an average power small enough to increase the system temperature by less than 1% so that they allow continuous delay calibration simultaneous with the reception of radio astronomical signals.

Actual output level of the pulse generator at 8 GHz is about -90 *dBm* per tone for 1 MHz rail spacing. The tunnel diode pulses are gated with a microwave switch prior to injection into the receiver. The gate is driven by a digital divider and is used to pass every *Nth.* positive pulse. Thus the repetition rate can be changed by selecting the division ratio.

In the VLBA the tones are measured by quadrature digital mixing of the digitized signals prior to recording. If necessary, the tones can also be extracted at the central VLBA processor during correlation. The digital mixer uses ROM generated sine and cosine functions, table look-up multiplication, and 32-bit counter accumulators. The phase can be determined to a 1-sigma noise of

$$(\pi/2)^{\frac{1}{2}}(Ts/Tcal)^{\frac{1}{2}}(2BT)^{-\frac{1}{2}} \text{ radians}$$

for 1-bit radio astronomical data, where

$2B$ = sample rate *(Hz)*

T = coherent integration time (secs)

Ts = system temperature *(°K)*

$Tcal$ = average pulse power over baseband bandwidth *B(°K)*.

For a calibration tone of -100 *dBm* injected through a 40 *dB* coupler the pulse cal temperature is *0.7°K* averaged over 1 *MHz*. This tone can be measured to within 0.3 degrees in 1 second when extracted from a 1 *MHz* bandwidth for a receiver with 30*°K* system temperature. The group delay is determined from the phases of several tones over the observing band.

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