B.L. ULICH APRIL 23, 1979

BLANKING NOISE

Consider the total power output voltage of a continuum microwave radiometer to be described statistically as a stationary gaussian random variable. The variance of the voltage $v(t)$ is defined as

$$V[v(t)] \equiv C^2[\Delta T_{RMS}]^2 \qquad (1)$$

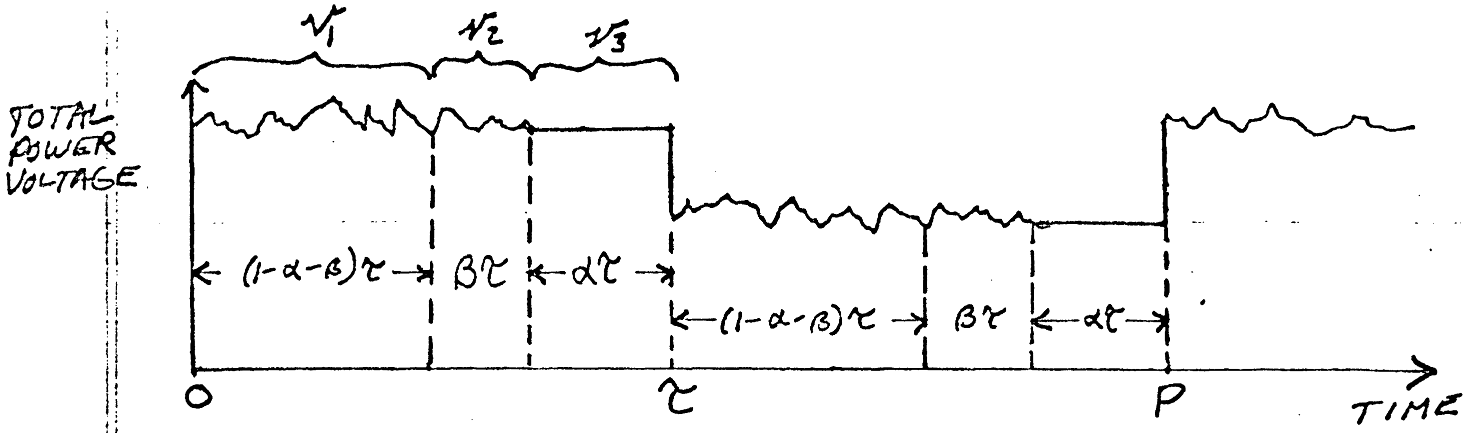
for one second of integration time per sample. Neglecting gain variations, one can calculate the theoretical noise referred to the input power spectral density as

$$\Delta T_{RMS} = \frac{K T_{SYSTEM}}{\sqrt{\text{Bandwidth}}} \qquad (2)$$

where $K = 1$ for a total power radiometer.

Suppose we blank the total power signal for a relative fraction α of the time in one half-cycle of a Dicke switch period and then synchronously detect the signal. How much will the output noise change?

Let $P \equiv$ Dicke switch period
$\tau \equiv P/2$ = Time during one half-cycle
$\alpha\tau \equiv$ Time the signal is held constant by the blanking circuit
$\beta\tau \equiv$ Time the signal is integrated to determine the holding voltage



The parameters v_i represent the mean value of $v(t)$ during the sections of the half-cycle as indicated in the drawing. Formally,

$$v_1 \equiv \frac{1}{(1-\alpha-\beta)\tau} \int_0^{(1-\alpha-\beta)\tau} v(t)\,dt \qquad (3)$$

$$v_2 \equiv \frac{1}{\beta\tau} \int_{(1-\alpha-\beta)\tau}^{(1-\alpha)\tau} v(t)\,dt \qquad (4)$$

$$v_3 \equiv \frac{1}{\alpha\tau} \int_{(1-\alpha)\tau}^{\tau} v(t)\,dt \qquad (5)$$

The mean value of $v(t)$ averaged over the entire half-cycle is defined as v_0 and is given by

$$v_0 \equiv \frac{1}{\tau} \int_0^{\tau} v(t)\,dt\,, \qquad (6)$$

and $\therefore v_0 = (1-\alpha-\beta)v_1 + \beta v_2 + \alpha v_3\,.$ (7)

Recall that the holding voltage v_3 is simply the mean of $v(t)$ during the period of length $\beta\tau$ immediately preceding the holding time. That is, $v_3 = v_2$.

Therefore,

$$\nu_0 = (1-\alpha-\beta)\nu_1 + (\alpha+\beta)\nu_2 . \tag{8}$$

The variance of ν_0 is

$$V[\nu_0] = (1-\alpha-\beta)^2 V[\nu_1] + (\alpha+\beta)^2 V[\nu_2] \tag{9}$$

where ν_1 and ν_2 are clearly independent variables and their correlation coefficient is zero. The variances are simply given by

$$V[\nu_1] = \left[\frac{C \cdot \Delta T_{RMS}}{\sqrt{(1-\alpha-\beta)\,\tau}}\right]^2 \tag{10}$$

$$\text{and} \quad V[\nu_2] = \left[\frac{C \cdot \Delta T_{RMS}}{\sqrt{\beta\,\tau}}\right]^2 \tag{11}$$

$$\therefore V[\nu_0] = \frac{(1-\alpha-\beta)^{\cancel{2}} C^2 \Delta T_{RMS}^2}{\cancel{(1-\alpha-\beta)}\,\tau} + \frac{(\alpha+\beta)^2 C^2 \Delta T_{RMS}^2}{\beta\,\tau} \tag{12}$$

$$\therefore V[\nu_0] = \left[\frac{C\,\Delta T_{RMS}}{\sqrt{\tau}}\right]^2 \left[1-\alpha-\beta + \frac{\alpha^2+2\alpha\beta+\beta^2}{\beta}\right] \tag{13}$$

$$\text{Define } \Delta_0 \equiv \sqrt{V[\nu_0]} = \frac{C\,\Delta T_{RMS}}{\sqrt{\tau}} \sqrt{1+\alpha+\alpha^2/\beta} \tag{14}$$

In the absence of blanking, the standard deviation of the mean voltage during a half-cycle is

$$\Delta_{NB} \equiv \frac{C\,\Delta T_{RMS}}{\sqrt{\tau}} \tag{15}$$

and the factor by which blanking increases the RMS noise out of the synchronous detector is

$$\boxed{F \equiv \frac{\Delta_0}{\Delta_{NB}} = \sqrt{1+\alpha+\alpha^2/\beta}} . \tag{16}$$

It is immediately obvious that blanking can only increase the noise level. This is strictly true only if $\beta \leq 1-\alpha$, for which the preceding analysis is valid. Values of $\beta > 1-\alpha$ are not allowed since information will be lost. That is, $v(t)$ will be integrated over both signal and reference halves of the full period, and the difference output of the synchronous detector will be reduced. Smoothing of alternate half-cycles is known as "reference averaging" and is useful for load switching, but not for beam switching. Only in this case can F be less than one.

"Optimum" blanking occurs when $\beta = 1-\alpha$,

$$F_{OPT} \equiv F\big|_{\beta=1-\alpha} = \sqrt{1+\alpha+\frac{\alpha^2}{1-\alpha}} \qquad (17)$$

$$\boxed{F_{OPT} = \frac{1}{\sqrt{1-\alpha}}} \qquad (18)$$

That is, in the optimum case, the noise is just what one would get with no blanking and a half-cycle of length $(1-\alpha)\tau$. Clearly the only effect is reduced integration time.

CASE I: NRAO SBE: $\alpha = 0.32$, Optimum case

$$F_{OPT} = \frac{1}{\sqrt{1-.32}} = 1.21$$

Measured $F = 1.22 \pm 0.05$

S/R Freq. = 1.25 Hz
τ = 400 ms
60 ms Blanking
RC = 66 ms on input to sample/hold

CASE II : $\alpha = 0.15$, $\beta = 0.33$

$$F = \sqrt{1 + 0.15 + 0.15^2/0.33} = 1.10$$

$$F\,(\text{Measured}) = 1.12 \pm 0.08$$

CASE III : $\alpha = 0.3$, $\beta = 0.04$

$$F = \sqrt{1 + 0.3 + 0.3^2/.04} = 1.9$$

$$F\,(\text{Measured}) = 1.7 \pm 0.2$$

NOTE:
When calculating α and β, remember that the equivalent integration time of an RC filter is 2RC.

c: Balister
Davis
Freund
Gordon
Hollis
Howard
Payne
Ross
Weinreb
Dent
Owen
Rudnick