ASTR240: Radio Astronomy

HW#5

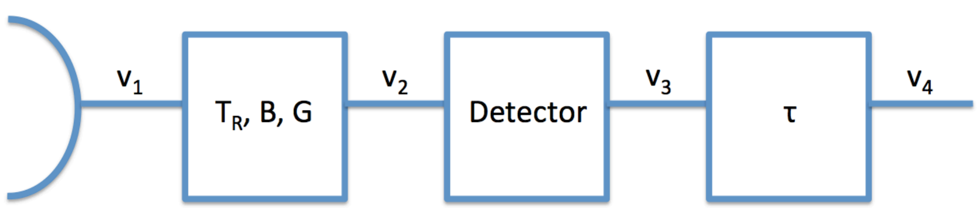
Due April 24, 2013

Problem 1

(Courtesy J. Moran)
Suppose you are given the option of searching for a point radio source (e.g., a Gamma Ray Burst, or GRB) of uncertain position with a big dish of diameter D that has only one receiver, or with an interferometric array of N elements of diameter d, with maximum baseline D. Assume that the source size is $< \lambda/D$ and its position uncertainty is $\pm\lambda/d$. Also, assume that the instruments have the same bandwidth and receiver temperatures. If you can have the same amount of total integration time on either instrument, which would you choose?

Problem 2

(Courtesy J. Moran)
Let's explore the performance of radiometers that have detectors that do not have a "square law" characteristic, i.e., $v_3 \neq v_2^2$. Consider a radiometer with a linear detector instead of a square law detector, as shown below:



Assume:
$v_3 = |v_2|$
$< v_2 >= 0$
$< v_2^2 >= kBG(T_R + T_A)$
Also assume that the signals are weak ($T_A \ll T_R$).

A) Show that

$$< v_4 >= \sqrt{\frac{2}{\pi} kBG(T_R + T_A)} \tag{1}$$

and hence that the term representing the signal is

$$\simeq T_A \sqrt{\frac{kBG}{2\pi T_R}} \tag{2}$$

B) Show that the rms noise, σ_4, is

$$\simeq \sqrt{\frac{(1 - \frac{2}{\pi})kBGT_R}{2B\tau}} \tag{3}$$

and that the radiometer sensitivity given by the equation

$$\Delta T = \sigma_4 / \left(\frac{\partial < v_4 >}{\partial T_A} \right) \tag{4}$$

is

$$\Delta T = \frac{1.07 T_R}{\sqrt{B\tau}} \tag{5}$$

Hence, this type of receiver is 7% worse than the square law detector receiver, and is linear in power only at low signal levels.

Problem 3

(Courtesy J. Moran)

I took the following calibration data on one of the antennas of the VLA in order to estimate the receiver temperature and the atmospheric opacity: The sources are weak enough that their contribution to the sys-

Time (UT)	Source	Elevation (°)	T_{Sys}/T_{Cal}
23:13	NGC3079	15	11.1
23:37	NGC3079	18	10.6
23:44	0917+624	27	9.6
00:30	4C39.25	23	10.0
00:50	0917+624	34	9.1
01:15	4C39.25	23	10.0
02:20	0917+624	45	8.9
04:50	0917+624	60	8.8
05:44	NRAO150	81	8.6
06:50	0917+624	61	8.9

tem temperature is negligible. Assume that the atmosphere is stable with time and can be modeled as a plane parallel absorbing medium. The calibration temperature (T_{Cal}) is 12.5 K ($T_{Sys} = T_{Rx} + T_{Atmosphere}$). Estimate the receiver temperature and the zenith opacity.