VLA ELECTRONICS MEMO #110

THE EFFECT OF RADIO INTERFERENCE ON THE VLA

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It is convenient to separate the effects of interference on the VLA into two classes: Those problems that exist for the individual antenna elements and their electronic systems and those problems that are peculiar to the VLA as an aperture synthesis correlation array.

1 The Single Dish Problem

The effect of interference on the electronic system of the VLA is dependent on whether or not the interference frequency is within the pass band of the receiving system and is dependent on the power level of the interference. The interference power entering the receiver will depend on the position of the interference source in the radiation pattern of the antenna. Typically, the gain of large antennas at angles far from the main beam is slightly below istropic gain (Hansen, 1964). Table 1 shows estimates of the gain and wide-angle sidelobe levels for the VLA 25 m. antennas.

Wavelength (cm)		Gain On Main Beam	Approx. Level Of Wide-Angle Side Lobes Relative to Main Beam	Angle At Which Gain Is Istropic
22	L	48 dB	-52 dB	13°
6	C	59	-63	8°
2	Ku	68	-73	6°
1.35	K	72	-77	5°

Table 1. Gain and Sidelobe Estimates for VLA Antennas

Also shown in Table 1 is an estimate of the angle at which the gain of the antenna has fallen to istropic.

Provided that the antennas are tracking a source near the zenith and that the interfering source is on the ground Table 1 shows that the antenna pattern reduces the interference level by at least 50 dB. However, if the antennas are at their lowest elevation (5°), or if the interfering source is airborn, the isolation against interference provided by the antenna pattern may be much lower. Table 2 lists the interference power flux densities at the antennas needed to cause malfunction in the VLA electronics system under the assumption that the interference is within the frequency passband of the receivers. It is also assumed that the polarization of the interference signal is the same as the polarization of the radiation pattern in the direction of the interfering source. Table 2 gives flux densities for the two cases of an interfering source in the main beam and in the wide angle sidelobes (-50 dB) of the antennas.

Type of Malfunction	Power Level At Paramp Input (dBm)	Interference Flux Density Needed at Antennas (watts/m^2)	
		Interfering Source On Main Beam	Interfering Source In Wide Angle Sidelobes
Paramp diode burnout	20	10^{-4}	10^{1}
Overload in paramp resulting in approx 0.1 dB change in gain	-55	10^{-11}	10^{-6}
Interference power equals system noise power (100 MHz bandwidth, 40°K system temp.)	-100	10^{-16}	10^{-11}
Interference signal triggers ALC Loop	-120	10^{-18}	10^{-13}

Table 2. Effect of Interference on VLA Electronics

The main effect of interference at frequencies outside the receiver passband will be to change the receiver gain at frequencies within the passband. This results from overloading causing a change in the bias currents of the paramp diodes. The sensitivity of the paramps to interference outside their passbands is shown in Fig. 1.

2 The Correlation Array Problem

In this section we consider those effects of radio interference that are peculiar to the VLA as an aperture synthesis correlation array. We will discuss the effects of interference in the three areas of correlation, fringe fitting and data inversion.

Most radio interference has narrow bandwidth compared to the operating bandwidth of the VLA (100 MHz) so that even though the interference signals received by two antennas arrive at the correlator with a time delay between them, they will remain correlated. The delay between the two interference signals entering the correlator results from the physical separation between the two antennas and from the delays inserted into the transmission paths of the two signals. The cross correlation of two signals having a uniform power spectrum over a bandwidth Δf and with a relative delay between them of τ is proportional to sinc $(\Delta f.\tau)$ where

$$\text{sinc}\ (\Delta f.\tau) = \frac{\sin\ (\pi\Delta f.\tau)}{\pi\ \Delta f\ \tau} \qquad (2.1)$$

Assuming that the IF delays are set for a radio source at the zenith and that the interfering source is at ground level and in line with the two antennas, Table 3 shows the bandwidths needed to reduce sinc $(\Delta f.\tau)$ to -3 dB and -10 dB for the longest and shortest baselines of the VLA configurations with highest and lowest resolution.

Array Configuration	Baseline	τ (μsec)	Δf	
			sinc (Δf.τ)=3 dB	sinc (Δf.τ)=10 dB
Lowest Resolution	30 m 1347 m	.1 4.5	6 MHz 130 kHz	9 MHz 200 kHz
Highest Resolution	500 m 36 Km	1.6 120	400 kHz 5 kHz	540 kHz 8 kHz

Table 3. Interference decorrelation due to delay

Table 3 shows that only the very narrowest bandwidth interference signals such as unmodulated carriers, single channel communication links and CW radar will remain completely correlated for all baselines. Broader bandwidth interference such as multichannel communication links (100 kHz-10 MHz) or pulsed radar (1-10 MHz) will be important for only the compact array configurations.

The fringe fitting step is important from the point of view of separating interference signals from desired signals. The output of the correlator is a sine wave of a predetermined frequency whose modulus and phase will be determined by fringe fitting over a 10 second record. This means that the bandwidth of the fringe filter will be approximately 0.1 Hz. Typically, fringes with frequencies more than 0.1 Hz away from the frequency used for the fringe fitting will be attenuated by more than 15 dB. The RC integrator on the output of the correlation will further reduce the effect of fringes at frequencies higher than the correct one by 6 dB per octave of fringe frequency. It seems likely that most interfering sources will be motionless with respect to the array and will therefore have a natural fringe rate of zero. Sources of interference, such as airborne sources, that are moving with respect to the array will produce fringes but the probability of the frequency being close to the correct one is very low. Pulsed interference could produce a periodic correlator output but pulse repetition rates of most radars is about 50 times higher than the natural fringe frequencies for the VLA at L Band. Assuming zero natural fringe frequency for the interference then, the fringe frequency separation between interference and desired signals is simply the observed source natural fringe rate. This frequency difference is not effected by any fringe rotation. The natural fringe rate for a celestial source observed with a baseline D is given by

$$7.3\text{x}10^{-5}\ \frac{D}{\lambda}\cos d \cos \delta \sin (H-h) \quad \text{fringes/sec} \qquad (2.2)$$

where (d,h) and (δ,H) are the (declination, hour-angle) of the baseline pole and source at δ=0 on the meridian (cos d cos δ sin (H-h)=1), a 37 Km baseline at λ=21 cm has a natural fringe rate of 12 fringes/sec and a 100 m baseline gives .03 fringes/sec. When the hour angle of the source is equal to the hour angle of the baseline (crossover) the fringe frequency drops to zero. Assuming typical values of cos d = cos δ = 0.7, (2.2) shows that baselines longer than 4 Km will have fringe frequencies less than 0.1 fringes/sec for less than 5% of a 12 hour observing run, whilst baselines less than 600 m will have fringe frequencies less than 0.1 fringes/sec for more than 50% of the time. It should be noted that when the source fringe rate is >0.1 fringe/sec, the presence of interference will produce a large RMS error between the correlator output and the sinusoidal fringe fitted to it, but if the source fringe rate is low, the presence of a constant interference signal will not effect the RMS error.

The last problem to be discussed is the effect that interference may be expected to have in the final map after Fourier inversion of the data has been carried out. The linear phase shift in the uv plane resulting from the variation of the IF delays as a source is tracked and the fringe frequency is the same for a motionless interference source as it is for a radio source located at the Celestial

Pole. Such a source, if its visibility function is present in the uv plane, would be aliased into the synthesized map at an accurately calculable position. However, this concept does not seem to be of any practical value because of the complexity of the equivalent source at the north pole. In most practical situations it is reasonable to consider both the modulus and phase of the visibility function of an interference source to be randomly varying over the uv plane. The phase is randomized by (a) the different delays between the 350 antenna pairs due to the interference source - array geometry, (b) variations in the phase at each antenna due to changes in the propagation paths and (c) the scanning of the antenna sidelobe pattern through the interference source. (b) and (c) above also tend to randomize the modulus of the visibility function as do the effects of delay-bandwidth decorrelation, fringe frequency filtering and time variability of the interference. It is probably, therefore, that interference, rather than inserting a compact source into the synthesized map, will contribute random noise with an RMS level that is constant over the whole map. This conclusion is born out by the measurement made by Hogg and Dolan 1973). It is necessary to estimate how small the interference power density at the antenna must be to keep the interference noise in the synthesized map within a tolerable level. One estimate may be obtained by imposing the constraint that in the uv plane, the visibility function due to interference must be no greater than the uncertainty in source visibility due to system noise. The uncertainty Δv in the correlator output due to system noise is given by (Christiansen and Högbom, 1969)

$$\Delta v = \frac{\sqrt{2 \; K \; T \; \Delta f}}{\sqrt{\Delta f . t}} \quad \text{watts} \tag{2.3}$$

where K is Boltzmans constant, T is the system temperature, Δf is the bandwidth and t is the integration time. If the visibility function due to interference is to be less than Δ, we require that

$$P < \frac{\Delta \nu}{A_e} \quad \text{watt/m}^2 \qquad (2.4)$$

where P is the interference power density at the antenna and A_e is the effective area of the antenna in the direction of the interference. It is assumed that the interference is not decorrelated by delays and that fringe frequency filtering does not reduce its level in the uv plane (reasonable assumptions for the lower resolution array configurations at L Band). Assuming $A_e = 10^{-5} \times 0.5 \times \frac{\pi D^2}{4}$ for antenna diameter D (see section 1), with T = 40°K, Δf = 100 MHz, t = 10 sec we require

$$P < 10^{-15} \text{ watts/m}^2 \qquad (2.4)$$

Thus, interference signals less than 10^{-15} watts/m^2 will no increase the error level in maps synthesized by the VLA.

References

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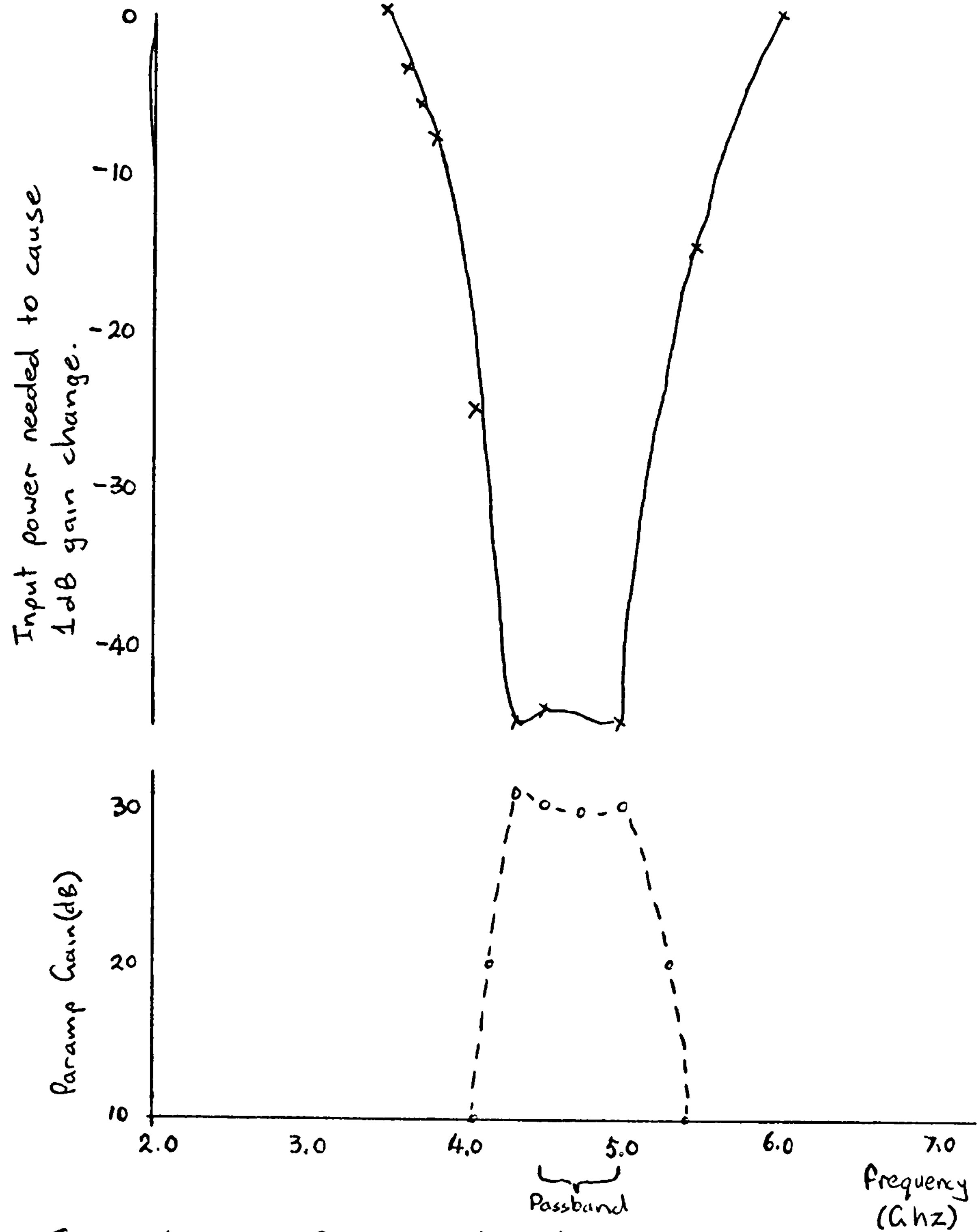

Figure 1: VLA Paramp Characteristics