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"Number of Sources"

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1. Introduction

The number of sources that can be observed by an interferometer depends on many parameters, including correlated flux density of the source, antenna sensitivity (diameter and efficiency), system temperature, data rate, and integration time.

In this memo I will look at the number of sources that might be expected to be detected for a few examples of these parameters and provide information from which the number might be obtained by scaling. Because the parameter space is so large, not all cases will be covered. Also, the uncertainties in the values used should be kept in mind.

2. Antenna sensitivity

The system noise equivalent flux density is given by

$$SEFD = \frac{2kT_{sys}}{\eta \pi D^2 / 4} \tag{2.1}$$

where T_{sys} is the system temperature in Kelvins, k is Boltzman's constant (1.38e-23 J/K), η is antenna efficiency, D is diameter (m).

Receiver temperatures for MMIC low noise wide-band amplifiers are reported by Sandy Weinreb to be approximately 4K, 10K, and 50K at physical temperatures of 20K, 77K, and 300K. Additional contributions to the system temperature from cabling, atmosphere, etc may contribute another 10K – 20K, assuming that the feed transition is also cooled. For evaluation, use system temperatures of 20K, 50K, and 100K.

The SEFDs (rounded up by about 3%) for system temperatures of 20K, 50K, and 100K for a 12 m antenna with 50% efficiency are given in Table 1.

T_{sys} *(K)*	*SEFD (Jy)*
20	1000
50	2500
100	5000

3. Data rate and integration time

Assume a total bandwidth of 256 Mhz within a band (e.g., 16 channels of 16 MHz within the 8 – 9 GHz X-band). For 2-bit sampling at the Nyquist rate the data rate is 1.024 gigabits per second.

4. Minimum detectable correlated flux density

The 1-sigma noise level (in Jy) for an interferometer pair of identical antennas is

$$\sigma_S(\text{Jy}) = 1.285 * SEFD / \sqrt{2BT} \tag{4.1}$$

where the factor of 1.285 accounts for the two level sampling and sixteen delay channel correlation. B is bandwidth (Hz) and T is integration time (seconds).

The 1-sigma noise levels are given in Table 2 for integration times of 1 second and 30 seconds.

Thus, for a detection criterion of seven times the noise, the minimum detectable correlated flux density for a 30 second scan is approximately 0.2 Jy for a 50K system temperature and 0.4 Jy for 100K T_{sys}.

Table 2. 1-sigma noise level for 12 m antennas recording with 1 gigabit per second (0.5 megasamples/sec)

	1 sec integration		30 sec integration	
T_{sys} (K)	noise (Jy)	$S_{c,min}$ (Jy)	noise (Jy)	$S_{c,min}$ (Jy)
20	0.06	0.4	0.01	0.07
50	0.15	1.0	0.03	0.18
100	0.3	2.0	0.05	0.37

5. Source counts

The structure at S- and X-band of sources in the geodetic VLBI catalogue have been determined from the geodetic observations by Alan Fey et al at the USNO. From these structures the correlated flux densities have been tabulated as a function of baseline length in the file *flux.cat* (REF? URL?) which was initiated by D. B Shaffer. The cumulative numbers of sources at S-band and at X-band are shown for a range of baseline lengths in Figure 1 and Figure 2.

In a 30 second scan the number of sources available over the full sky on all baselines is, for S-band, at least 450 for a 50K system and approximately 300 for a 100K system, and for X-band the numbers are approximately 450 and 200. There appears to be a deficit in the number of weak sources for S-band.

Table 3. Number of detectable sources over sky

T_{sys} (K)	S-band	X-band
50	>450	450
100	300	200

Of course for geodetic work it is of no value for a source to be detectable at S-band and not at X-band. Furthermore, at frequencies higher than X-band the number of sources is likely to decrease even more, for two reasons: the system temperature is likely to be higher than at X-band and the correlated flux densities are probably lower as well.

6. Figures

Cumulative number of sources at X and S for baseline lengths from 450 km to 11600 km.