VLB ARRAY MEMO No. 81

FREQUENCY PROTECTION FOR THE TRANSCONTINENTAL RADIO TELESCOPE

A.R. THOMPSON, MARCH 1982

1.) Harmful Interference

Very long baseline interferometry is less sensitive to interference than any other observing technique used in radio astronomy. Three effects of the long antenna spacings help to suppress the response to interference.

(1) The sidereal motion of cosmic sources gives rise to very high fringe frequencies, and signals from transmitters that do not show this motion are highly attenuated in the data averaging.

(2) The time delay differences for signals that do not arrive from the direction of observation can substantially decorrelate unwanted signals.

(3) The spacings of the antennas are large enough that an unwanted signal is unlikely to be present at a harmful level at two antennas unless it originates in a satellite.

Thus it can generally be assumed that the interference to VLBI systems does not produce correlated components at the correlator input. The mechanism by which the performance of the radio telescope is degraded is the addition of uncorrelated power at the antennas which effectively increases the noise level. The harmful limit for such interference has not yet been studied in detail, but is estimated to be approximately 20 dB below the system noise power in a receiving channel. In estimating the flux density corresponding to this harmful limit the probability of interference from satellites should be included. It is therefore appropriate to consider a sidelobe gain of +10dB which typically occurs 7.6° from the main beam. The harmful flux density, S_I, is then given by

$$S_I = \frac{4\pi k T_s B f^2}{10^3 c^2} \ Wm^{-2}$$

Where $k = 1.38 \times 10^{-23}$ JK^{-1}, T_s = system noise temperature (K), B = receiving bandwidth (Hz) , f = observing frequency (Hz) and $c = 3 \times 10^8$ $m\ s^{-1}$.

2.) Observing Bands and Frequency Allocations

Table 1 lists the ten frequency ranges over which the TRT will be turnable. It also lists the U.S. allocations to radio astronomy within these tuning ranges, the sharing services and the allocations in adjacent bands in cases where air-to-ground or space-to-earth transmissions may occur. The final column of Table 1 gives the estimated harmful interference levels, S_I, calculated from the formula above. The bandwidth, B, is that of the radio astronomy band, or 100 MHz, whichever is the smaller. Note that the levels are 28 to 41 dB higher than the corresponding values for single-antenna systems given in CCIR Report 224-5 (CCIR 1982). All except two of the TRT tuning ranges contain bands that are allocated to radio astronomy within the U.S., and the primary mission of the instrument can be accomplished within these bands.

The two tuning ranges without a radio astronomy allocation are 2200-2300 MHz and 8400-8500 MHz. Both of these contain allocations to deep space communications, and VLBI observations have been made in these deep space bands for over a decade without serious interference. This practice arose because the large antennas and sensitive receivers that were developed for deep space projects were from time to time available for radio astronomy. The VLBI geodetic program that has been developed within NASA makes use of the deep space bands, and it would clearly be useful to include within the TRT the capability to compare the positions of the antennas with those of antennas in the geodetic network.

The TRT will have the capability of recording up to 100 MHz of input signal bandwidth for limited periods, and up to 50 MHz for general operation. There are numerous options in the way this can be used. For example, the system can record a full 100 MHz of continuous input bandwidth, or two 50 MHz bands at the same center frequency with opposite polarizations. There are also possibilities of observing in two different frequency bands simultaneously. The IF sections of the receiving system contain filters to select bandwidths that decrease by factors of two from 100 MHz down to 100 kHz. Each of the tuning bands of the TRT listed in Table 1, except for the two with deep space bands, contains from 3.9 MHz to 1000 MHz of spectrum with primary allocation to radio astronomy. The flexibility provided by the IF filters will therefore make it possible to observe entirely within the radio astronomy bands, or to extend outside of them to obtain enhanced sensitivity as the spectrum usage permits. The receiving bandwidths of 1.56 MHz down to 100 kHz will be used mainly for spectral line observations in the lines that radiate by maser action (Reid and Moran 1981). The most important of these are lines on those of the OH radicle at 1610, 1665, 1667, and 1720 MHz, H_2O at 22.235 GHz and silicon monoxide at 43 GHz. All of these are provided with some degree of frequency protection.

Some points specific to certain observing bands should be noted. The 320-410 MHz range will probably present the greatest difficulty with regard to interference. The 406.1-410 MHz band is heavily used in some areas by the fixed communications service. The 322-328.6 MHz band has an international allocation to radio astronomy that is not implemented within the U.S. Nevertheless, general experience indicates that parts of this band may be usable for radio astronomy, depending upon the antenna location. It has therefore been included within the tuning range to maximize the possibility of avoiding interference. The 320-410 MHz frequency range of the TRT is the least critical to the overall success of the project, and the investment in receiving components is relatively small because the input stages are operated at ambient temperature.

In the 4950-4990 MHz band protection to radio astronomy is provided in the vicinity of certain observatories, several of which are amongst sites considered for TRT telescopes.

In the 10.6-10.7 GHz band there is sufficient bandwidth allocated to radio astronomy on a primary-shared basis to allow use of the full 100 MHz recording bandwidth. As development occurs in the 10.6-10.68 GHz band the service sharing with radio astronomy is expected to be mainly the Digital Electronic Message Service (Moffett 1981). It is understood that under the proposed FCC rule making currently in progress radio astronomy will receive no protection in this band in the vicinity of the 100 most populous U.S. cities. The proposed limit on the e.i.r.p. in the 10.6-10.68 GHz band is +40 dBW, which requires an antenna gain of 43 dB (FCC 1981). In the unlikely event that a TRT antenna were situated within the main beam of such a transmission (which would probably be an internodal link) the separation required to avoid interference at the harmful level estimated in part 1 of this section is 70 km. The separation required for the lower transmitting gain likely to be used for node-to-user communication is estimated as 45 km.

In the 15.35-15.4 GHz and 23.4-24.0 GHz bands radio astronomy shares only with passive services so the full recording bandwidth can certainly be used. There should also be no problem in the 42.5-43.5 GHz band since none of the sharing services involve transmissions from aircraft or from space.

ART/bmg

REFERENCES

CCIR, Characteristics of the Radio Astronomy Service and Interference Protection Criteria, Report 224-5, Recommendations and Reports Vol. II, Geneva, 1982.

FCC, Third N.O.I., Implementation of the Final Acts of the World Administrative Radio Conference, FCC 81-323 29672, general Docket 80-739, 1981.

Moffett, A.T., Analysis of the Electromagnetic Compatibility of the Digital Electronic Message Service and the Radio Astronomy Service in the 10.6 to 10.68 GHz Band, Owens Valley Radio Observatory, Calif. Inst. of Technology, Pasadena, 1981.

Reid, M.J. and Moran, J.M., Masers, Ann. Rev. Astron. Astrophys., 19, 231-276, 1981.

Table 1. Radio astronomy Bands and Harmful limits within the TRT Tuning Ranges

TRT Tuning Range	U.S. Radio Ast. Allocation (2).	Sharing Services in R.A. Band	Adjacent Bands with Air-To Ground or Space-to-Earth Transmissions	Harmful Interference Levels. (3)
				(dB Wm^{-2})
320-410 MHz	322-328.6 MHz (F)	FIXED, MOBILE	225-328.6 MHz, Mobile 328.6-335.4 MHz, AERO. RADIONAV.	-161
	406.1-410 MHz (PS)	FIXED, MOBILE	403-406 MHz, MET. AIDS 410-420 MHz, MOBILE	-161
580-640 MHz	608-614 MHz (P)			-156
1350-1750 MHz	1300-1400 MHz (F) 1400-1427 MHZ (P)	RADIOLOC., AERO. RADIONAV.	1350-1400 MHz RADIOLOC. Mobile	-145
	1610.6-1613.8 MHz (S)	AERO, RADIONAV.		
	1660-1660.5 MHz (PS) 1660.5-1668.4 MHz (P) 1668.4-1670.0 MHz (PS)	AERO. MOB.-SAT. MET. AIDS	1670-1690 MHz MET.AIDS, MET.SAT.	
	1718.8-1722.2 MHz (F)	FIXED, MOBILE	1710-1850 MHz MOBILE	
2175-2425 MHz	(4)			
4900-6100 MHz	4950-4990 MHz (F) 4990-5000 MHz (P)	FIXED, MOBILE	4800-4990 MHz MOBILE 5000-5250 MHz AERO.RADIONAV.	-130 -137
8000-8800 MHz	(5)			
10.2-11.2 GHz	10.6-10.68 GHz (PS) 10.68-10.7 GHz (P)	FIXED	10.7-11.7 GHZ FIXED SAT.	-120 -127
14.9-15.9 GHz	15.35-15.4 GHz (P)		15.1365-15.35 GHz Mobile, Space Res. 15.4-15.7 GHz AERO.RADIONAV.	-118

21.3-25.3 GHz	22.01-22.21 GHz (F)	FIXED, MOBILE (6)		
	22.21-22.5 GHz (PS)	FIXED, MOBILE (6)	22.5-22.55 GHz MOB.,BROADCAST SAT.	
	22.81-22.86 GHz (F)	FIXED,MOB.,INTER-SAT., BROADCAST SAT.		
	23.07-23.12 GHz (F)	FIXED,MOB.,INTER-SAT.		
	23.6-24.0 GHz (P)		23.55-23.6 GHz MOBILE 24.0-24.05 GHz AMATEUR SAT.	-113
42.5-43.5 GHz	42.5-43.5 GHz (PS)	FIXED,FIXED SAT. MOBILE (6)	40.5-42.5 GHz BROADCAST SAT.	-106

(1) From FCC Second, Third, and Fourth N.O.I., Implementation of the Final Acts of the W.A.R.C., Geneva, 1979. General Docket No. 80-739

(2) Protection status: (F) = Footnote, (PS) Primary shared, (P) Primary exclusive or shared with passive services.

(3) From formula in text.

(4) Deep Space Band 2290-2300 MHz

(5) Deep Space Band 8400-8450 MHz

(6) Except aeronautical-mobile.