VLB ARRAY MEMO No. 53

January 7, 1982

Suggested Numbers of Spare Modules for the VLB Array

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This memorandum describes an investigation of the failure rates of VLA modules, and the use of these data to estimate the numbers of spare modules required for the VLB array. It is assumed that the electronics for the VLB array will be subdivided into modules of similar complexity and reliability to those used in the VLA.

1. VLA Reliability Data

The VLA data have been taken from the maintenance records that are on file in a computer data base and can be accessed through a program (MAINT) which sorts records and produces various statistical data. Jon Spargo has been largely responsible for the organization of this facility. The data of interest here are the mean times between failures (MTBF) for different types of modules. In this study 'failure' refers to any condition that results in the generation of a maintenance request, and includes hardware failures, cases where some adjustment was necessary, and cases where the fault could not be found when maintenance was performed. Table 1 lists the numbers of failures and the MTBF per module for 33 types of modules for the 15-month period October 1, 1980 through December 30, 1981. Data for the last six months of this period were also examined separately and did not show any significant changes. Table 1 also contains figures for ten non-modular units that are not included in the following statistics.

The distribution of MTBF values is shown in Table 2. Two main conclusions can be drawn. First, roughly equal numbers of modules fall within the four MTBF categories <1000 days, 1000-2000 days, 2000-4000 days, >4000 days. Second, there does not appear to be much correlation between the MTBF and the subsystem of the module (front-end, local oscillator, etc.). The modules with poorest reliability include the F3 (17-20 GHz L.O.) which contains a frequency-agile, phase-lock loop; the D1 (Sampler) for which adjustment is known to rather critical; the F5 (Front-End Control); and the T5 (Baseband Driver) which contains a problem that we expect to eliminate.

2. Application to the VLB Array

Those electronics modules at a VLB antenna for which a failure would put the whole antenna out of operation are in a special category and will be referred to as critical modules. For such modules a spare will have to be carried at each site. For the non-critical modules we assume the following scheme will apply. The spares will be kept at a central maintenance location, and when a module fails at an antenna the operator at that site will request shipment of a spare. The failed module will be immediately shipped back to the central location where it will be repaired and become a spare unit. It will be assumed that the time interval from shipment of the spare to the antenna to the completion of repair of the returned unit does not exceed five days. As a criterion for the number of spares to be carried, let us state that for each type of module the probability that all spares are out in the return-and-repair process must not exceed 1%.

Suppose that there are N_m of a particular type of module in each of the 10 antennas in the array. The mean failure rate for that particular type of module is 10 N_m/MTBF failures per day, where MTBF is in days. the probability, P, that one module of a particular type will be in the return-and-repair process is 50 N_m/MTBF. Thus we require

$$P^n = (50\ N_m/\mathrm{MTBF})^n < 0.01$$

where n is the number of spares of the particular module type to be carried at the central location. Table 3 gives values of n for modules with MTBF values of 500, 1500, 2500 and >4000 days, which are representative of the four categories within which the VLA modules are roughly equally distributed. For each MTBF category values of N_m = 1, 2 and 4 are considered. For 75% of the cases in Table 3, n = 2, and the mean of n for all cases is 2.4. However, since the types of modules for which there are four units at an antenna are likely to less than 1/3 of all types, the mean value of n that is finally required may be less than 2.4. As a round figure for costing purposes 2½ spares per module type is suggested for the non-critical types. This is a fairly conservative figure, and one could argue in favor of a larger number to offset lower initial reliability, loss of modules in transit, etc.

When one of the critical modules fails it will be replaced by the on-site spare and the failed unit will be returned for repair. Two courses of action are then possible. Another spare can be sent out immediately from the central location, or else the failed unit can be repaired and returned. In the first case the mean number of spares required per critical module type is $10 + 2\frac{1}{2} = 12\frac{1}{2}$, and in the second case just 10.

Table 1 Maintenance Statistics for VLA Electronics, 80/09/01 to 81/12/30

Type of Unit	No. of Failures	MTBF (days)	Type of Unit	No. of Failures	MTBF (days)
Front End (Uncooled)			IF Receiver		
F1, Bias Control	2	12,000	T3, Baseband Conv.	2	4,500
F4, Freq. Converter	6	4,000	T4, Baseband Filters	7	2,600
F5, F.E. Control	24	500	T5, Baseband Driver	65	280
F6, RF Splitter	4	2,200	T6, Baseband Cont.	4	2,200
F7, Ant. IF Filters	0				
F8, IF Offset	0		Sampler		
			D1, Sampler	43	560
LO (Antenna)					
F2, Upconv. Pump	16	750	Monitor & Control		
F3, 17-20 GHz LO	69	170	M1, Data Set	22	2,800
L1, 5-50 MHz VCXO	6	2,000	M2, Data Tap	0	
L2, Harmonic Gen	1	12,000	M3, Central Buffer	9	1,400
L3, LO Tx	11	1,100	M4, Antenna Buffer	7	1,800
L4, LO Rx	6	2,000	M7, F/R Control	7	1,700
L5, LO Control	6	2,000	M8, F/R Power	6	2,000
L6, 2-4 GHz Synth.	37	650			
L7, Fringe Gen.	6	4,000	Non-Modular Units		
L8, Timing Gen.	14	860	Refrigerator	56	214
			Compressor	25	480
LO (Central)			Vac. Pump	1	12,000
L9, Ant. LO Rx	6	2,000	Dewar	1	12,000
L10, Ant. LO Tx	0		Upconverter	3	8,100
L11, Ant. LO Control	6	6,000	Paramp	17	1,700
L14, Ant. LO Filter	12	1,000	KU-Mixer	4	6,000
			K-Mixer	17	1,400
Transmission			Coax Switch	5	4,800
T1, Modem	17	1,400	Paramp Pump	16	1,500
T2, IF Combiner	12	2,000			

Table 2 MTBF Categories

MTBF (days)	No. of Module Types
<1000	7
1000-2000	9
2000-4000	8
>4000	9

Table 3 Calculation of Required Numbers of Spares, n.

MTBF Category (days)	Mean MTBF (days)	N_m = 1 per Ant.		N_m=2 per Ant.		N_m=4 per Ant.	
		P (%)	n	P (%)	n	P (%)	n
<1000	500	10	2	20	3	40	5
1000-2000	1500	3.3	2	6.7	2	13	3
2000-4000	3000	1.6	2	3.3	2	6.7	2
>4000	>4000	<1.3	2	<2.5	2	<5	2

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