CSIRO DIVISION OF RADIOPHYSICS

THE AUSTRALIA TELESCOPE

AT/20.1.1/023

Report to the 12th Meeting of the AT Advisory Committee

System Overview

G.J. Nelson

The system design for the compact array is now generally complete. Detailed specification is still however required in some areas. The Long Baseline Array is less well defined mainly because of uncertainties surrounding the clock and the tape recorders. These matters will be the subject of a report by Ray Norris.

In this report I propose only to comment on items that are new or have changed since my report to the 11th Advisory Committee Meeting (October 1985). Important changes to the system were in fact made between the time of that meeting and the time of publication of the minutes. I included those changes in the attachments to those minutes but I will also comment on them further here.

Antennas and Feeds

The problem of separating the wideband linearly polarized signals accepted by the AT feeds now seems to have a solution. There has been doubt up till now whether a small enough polarizer could be built (particularly at L/S band) to be cooled in the receiver dewar. It is hoped that the horse-shoe shaped design now proposed will meet these requirements thus allowing simultaneous observations in L and S bands with high sensitivity and with no cumbersome mechanical changes required when changing bands.

Questions remaining to be answered are the insertion loss of the polarizer and the time required to cool it to 20 K. 70 K operation is only an option in the unlikely event that the loss is very small.

Compact Array Receiving System

This system is summarized in figures 1-6.

Figure 1. The switching waveforms for the 0/180° and 0/90° phase switches and for the noise diodes have now been specified (AT/20.1.1/020). The added noise will be about 5% of T_{sys} and will be modulated on and off with a 500 Hz square wave. The transitions at different antennas will be timed to be in phase at the array tying point. The combined noise from the 6 antennas can then be used for tied array calibration. The 0/180°

switching waveforms will be square waves of frequencies 0, 250, 500, 1000, 2000, and 4000 Hz. These waveforms are all orthogonal, independent of lag. The 0/90° switching waveforms will also be square waves but with much longer periods. The switching frequencies will be 0, $1/\tau$, $2/\tau$, $4/\tau$, $8/\tau$ and $16/\tau$ where τ, the integration time is an integral multiple of 8 m sec. The time of a given switch transition can be controlled to within a microsecond but the periods will be precise to tens of nanosecond.

The 0/90° demodulation will probably be done at the 1.8-2.2 GHZ local oscillator in the conversion module rather than in the correlator as suggested previously. For good image rejection the 90° transitions at modulation and demodulation have to be very precise ($\simeq$ 0.5°) (AT/20.1.1/020) and therefore need to be set up digitally as in the fringe rotators. The choice of very show 0/90° switching rates is a direct consequence of this mode of operation because a significant dead time will result at each transition while a new phase is being established.

Local oscillator distribution to the antennas via optical fibre marginally failed to meet the required phase precision. The decision has therefore been made to use coaxial cable for that purpose. Optical fibres will still be used for returning the digitized IF signals.

The precision required of the level and gain monitors and the resolution of the fine and coarse level controllers have been specified in AT/20.1.1/016. These specifications are consistent with a dynamic range $>10^4$ in a 12 hour map or >500 in a single integration.

Figure 2

The main change on this figure is the addition of a second 16 MHz bandwidth in each IF for the tied array. This addition is only necessary if a 64 MHz bandwidth is required in a single polarization. It is shown in more detail in figure 4.

The precision of the gain control attenuator, used to equalize gains between polarizations and between antennas in the tied array has been specified in AT/20.1.1/016. The 0.25 dB step allows 1% polarization to be measured in a single integration time on each baseline of the LBA which involves the tied array.

Figure 3

The front end conversion scheme is considerably different to that presented at the last meeting. It is similar to that shown in Attachment 1(12) to the minutes. By providing a choice of IF bands after several of the mixers we have been able to limit the range of LO's that may otherwise have interfered with L/S and C/X observations. The frequency steps in the synthesizers have been reduced and the range of the phase rotator increased to allow for complete Doppler tracking for bandwidths below 32 MHz. For 32 MHz and above Doppler tracking in the correlator is provided.

Figure 4

Only minor changes have been made to the narrow band tuning scheme. (1) Some of the filter frequencies have been changed. (2) The line correlator sampler uses a fixed frequency clock and oversamples (the surplus samples will be discarded in the correlator). (3) A band inverter has been added to provide compatibility with other receiving systems. (4) A second 16 MHz band is filtered and tied so that a full 64 MHz band in a single polarization can be recorded for the LBA. (5) 0/180° phase modulation is applied to the tied array signals. The switching waveform is orthogonal to those used at other LBA antennas. (6) Sample statistics are monitored immediately after the tied array sampler and used to control the reference levels of the digitizer.

The most important change is to the 80 MHz local oscillator synthesizer. It now has a range of 1 MHz and frequency steps of 4 KHz. When combined with the frequency steps available in the front end local oscillators and the 5 KHz range of the fringe rotators this gives us complete Doppler tracking for bandwidths below 32 MHz.

Figure 5.

The main purpose of this figure is to illustrate how the sample statistics for controlling the reference levels of the digitizers are accumulated in the correlators. These statistics are monitored before the 0/180° phase switching is removed digitally. Also associated with each correlator is a switched correlator which measures the phase between related linearly polarized IF's.

Figure 6.

Four sets of array tying and polarization generation systems are provided. Two sets operate only on the additional 16 MHz bands shown in figure 4. The other two deal with bandwidths selectable from 0.5 to 16 MHz in factors of two. To provide circular polarization the phases between X-Y pairs of inputs are monitored with analogue switched correlators and precision so that the tied array beams in opposite polarizations maintained at 90°. The gains are also equalized to high are identical (but 90° out of phase) to a very high precision. These can be combined to give equal left and right circularly polarized signals or recorded directly as linearly polarized signals.

Long Baseline Array Receiving System

For Siding Spring, Parkes and possibly Hobart, it may be convenient to provide CA-like receiving systems complete with delay tracking, fine tuning, fringe rotation and digitally stabilized IF return from antenna focal cabin to control room. No additional design is then required and substantial parts of the CA system can then simply be copied for these sites. Figures 7-10 show a system of this type. The system is slightly simpler than for the CA because only 4 bit sampling of a 64 MHz bandwidth signal has to be provided at the antenna.

This system requires that digital rather than analogue IF inputs be supplied to the VLBA tape recorders. This modification is already a requirement for the tied array.

An option that might be used for Tidbinbilla and later additions to the LBA system is shown in figure 8. IF signals in the range 500-1000 MHz are input to complete VLBA recording systems via phase stabilized cables. For this option "add on" fringe rotation at the correlator is proposed with some loss of sensitivity.

Parkes and Siding Spring antennas must function as stand-alone systems as well as elements of the LBA. It is important however that these two functions be combined without a proliferation of different receivers but also without degradation of performance in either mode. Specifications for the Parkes receivers that meet these aims have been set out in AT/22.1.1/014. The first dewar will contain two channels each at L,S,C and X bands. The inputs will be separate circular waveguides accepting both polarizations for C and X bands and pairs of coaxial inputs at L and S bands. A variety of feeds can be attached to this dewar to give a selection of linear or circular polarizations single or dual beam or limited dual frequency operation in L/S, C/X or S/X bands. A second dewar with dual channels in L and S bands will be provided later to give better sensitivity for both LBA and stand-alone operation.

A similar approach will probably be adopted to provide dual beam stand-alone operation in bands above X band at Siding Spring. No beam switching is contemplated at either site. Rather beam differencing will be carried out in correlation receivers. These will also provide stand-alone polarization capabilities.

<u>Compact Array Correlator</u> (Figures 11-13).

16 MHz operation is now planned although chips to replace the earlier faulty ones have not yet arrived. It is expected that they also will be capable of operating at 16 MHz.

The correlator control computer will be a μVAX II and an associated Sky Warrior 15 M flop array processor which will share memory with the μVAX. This system will be capable of supporting:

1.	The largest line maps.	(AT/24.1.1/009
2.	Doppler tracking,	(AT/23.4/011)
3.	Bandwidth Synthesis.	(AT/20.1.1/019)
4.	2 m sec integration times, for wideband continuum.	(AT/20.1.1/013)
5.	Pulsar observations,	(AT/20.1.1/012) and
6.	Data output rates far in excess of the capabilities of current optical disk	(AT/24.1.1/009)

Computers

The nature of the on-line computers for the compact array is now fairly well defined. μVAX II's will be used for the synchronous, asynchronous and correlator control computers and possibly also for the antenna link controller. At the antennas the antenna control computers will be LSI 11/83 computers. The synchronous, asynchronous and correlator control computers will probably share access to disks and optical disks.

The choice of an off-line computing system will be made at an appropriate later date. One solution has always been to use a cluster of work stations using μVAX computers and some form of shared disk facilities for the smaller tasks and the cyber 205 for the large data cubes and wide field maps. It seems now that it may be unwise to rely too heavily on the Cyber 205 and a powerful computer such as the Convex C-1 with multiple work stations may be a better compromise.

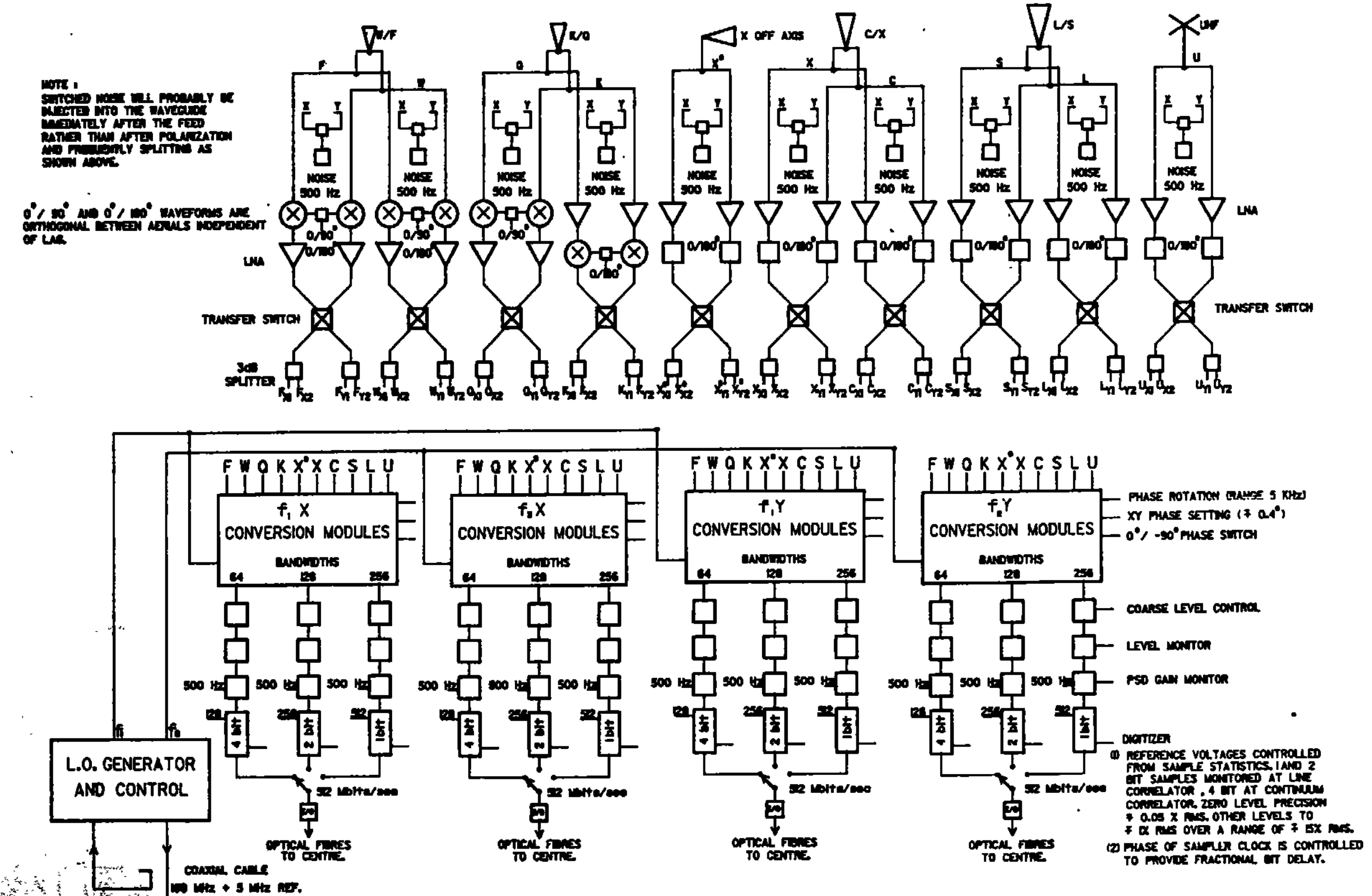
RF Interference Suppression

Minor modifications to the 22 m antennas will be carried out by the contractor so that adequate RF shielding of the vertex room can be achieved.

At a later date we will design and fit a rotating RFI contactor attached to the turret to seal the opening between vertex and feed cone rooms. Additional protection may involve absorbing material on the walls of the feed cone room and local shielding of computers in the pedestal room.

Consideration is also being given to means of shielding the Culgoora control building (the correlator will certainly be in a shielded room) and the Siding Spring Control room.

Graham Nelson,
23rd April, 1986.



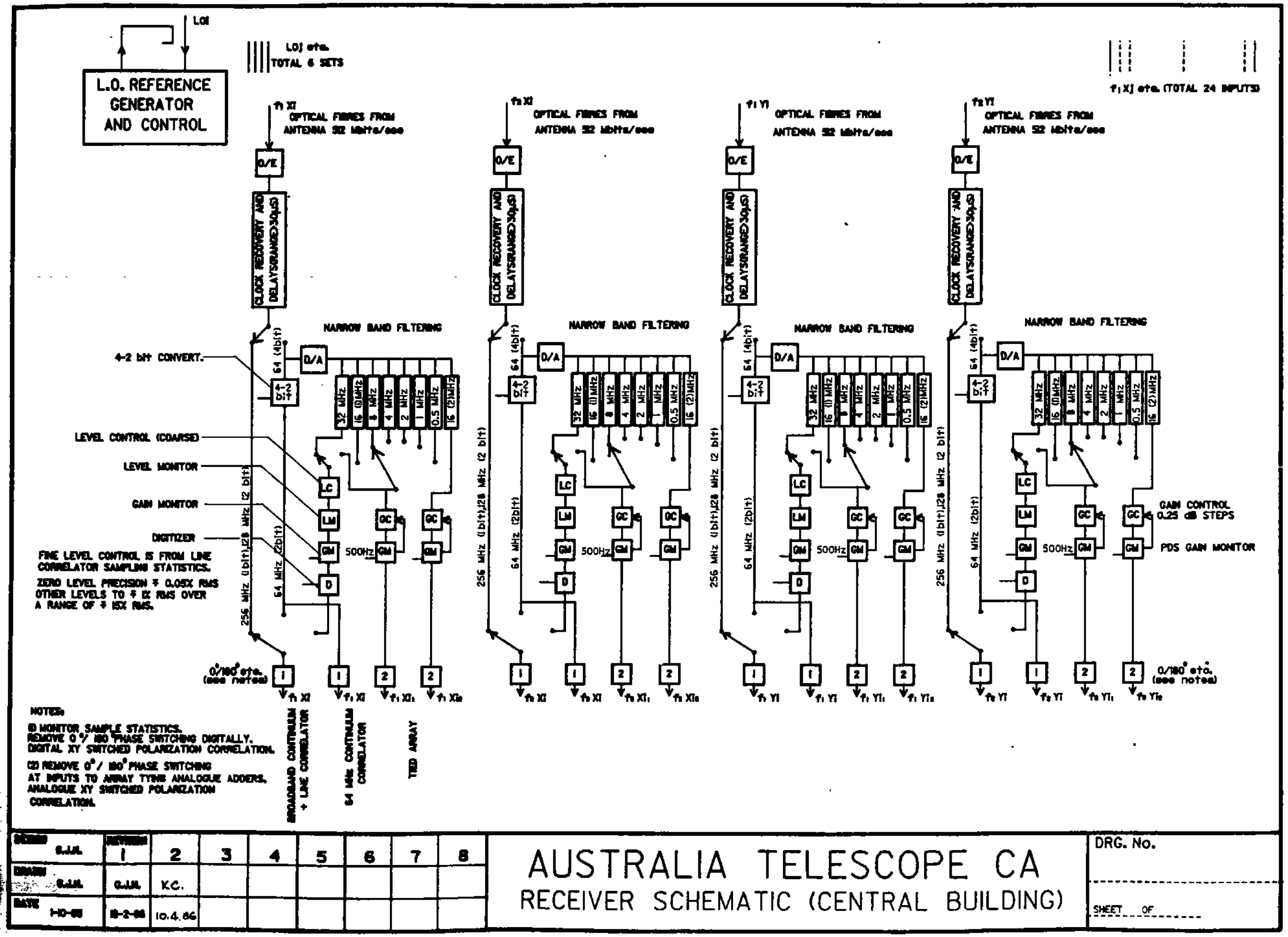
1	2		
	K.C.		
	10.4.86		

AUSTRALIA TELESCOPE CA
RECEIVER SCHEMATIC (AERIAL)

DRG. No.

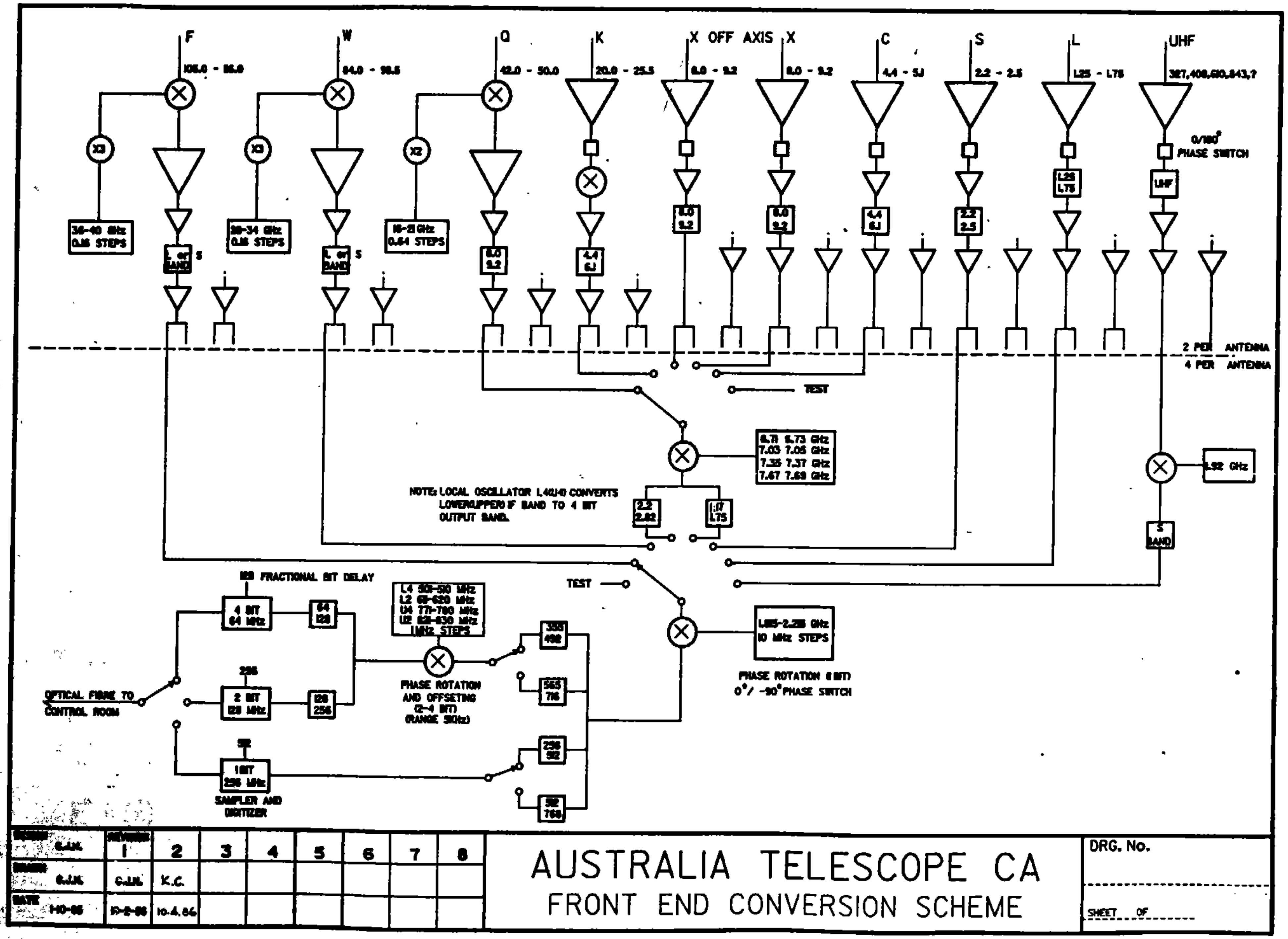
SHEET __ OF ____

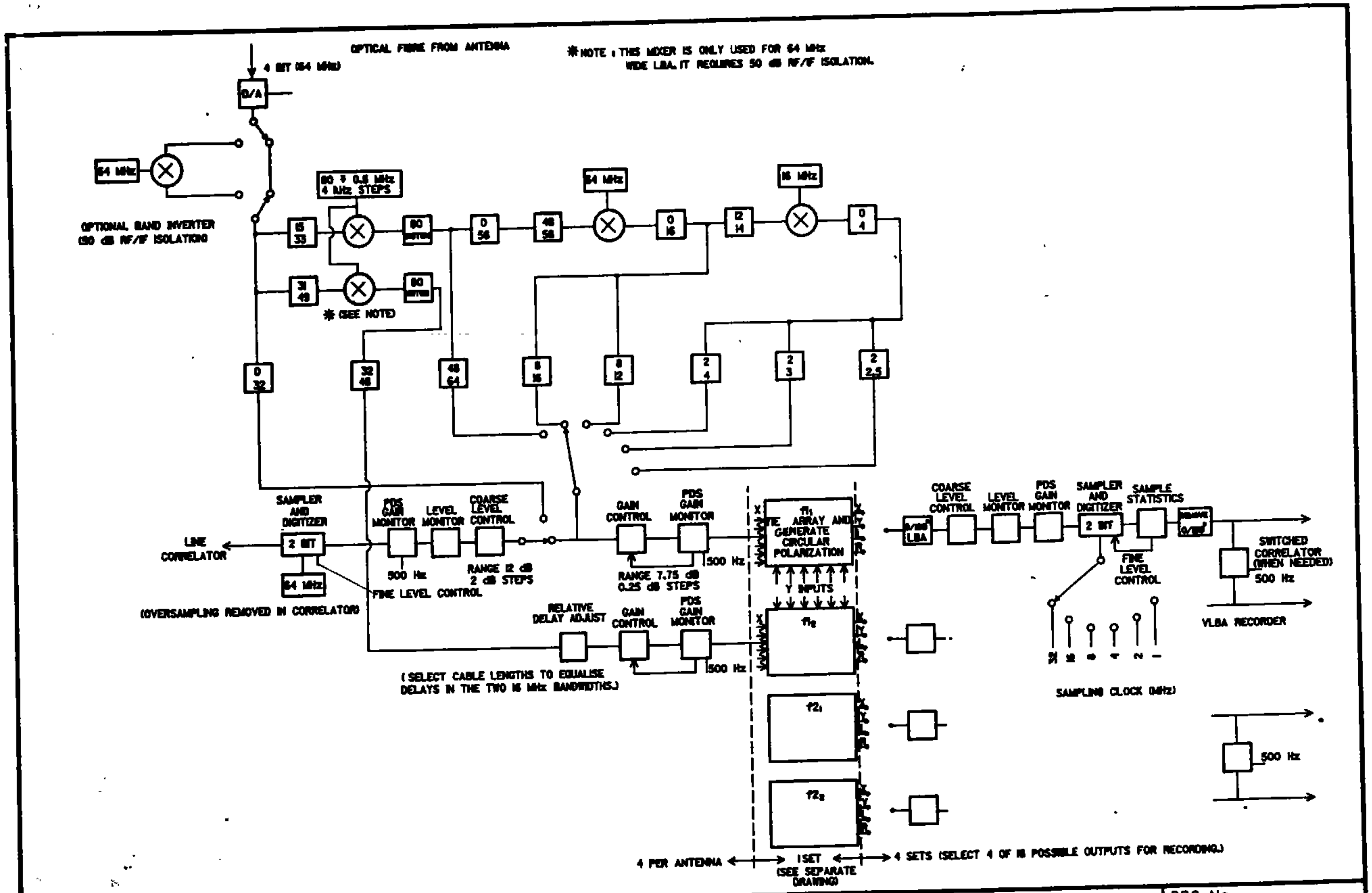
Figure 1



L.O. REFERENCE GENERATOR AND CONTROL
LOI
LOJ etc. TOTAL 6 SETS
OPTICAL FIBRES FROM ANTENNA 512 Mbits/sec
O/E
CLOCK RECOVERY AND DELAYS(RANGE>30μS)
NARROW BAND FILTERING
4-2 bit CONVERT.
D/A
64 (4bit)
32 MHz
16 (1)MHz
8 MHz
4 MHz
2 MHz
1 MHz
0.5 MHz
16 (2)MHz
LEVEL CONTROL (COARSE)
LEVEL MONITOR
GAIN MONITOR
DIGITIZER
FINE LEVEL CONTROL IS FROM LINE CORRELATOR SAMPLING STATISTICS.
ZERO LEVEL PRECISION ∓ 0.05% RMS OTHER LEVELS TO ∓ 1% RMS OVER A RANGE OF ∓ 15% RMS.
256 MHz (1bit),128 MHz (2 bit)
64 MHz (2bit)
500Hz
GAIN CONTROL 0.25 dB STEPS
PDS GAIN MONITOR
0/180° etc. (see notes)
f₁XJ etc. (TOTAL 24 INPUTS)
BROADBAND CONTINUUM + LINE CORRELATOR
64 MHz CONTINUUM CORRELATOR
TIED ARRAY
NOTES:
(1) MONITOR SAMPLE STATISTICS. REMOVE 0°/180° PHASE SWITCHING DIGITALLY. DIGITAL XY SWITCHED POLARIZATION CORRELATION.
(2) REMOVE 0°/180° PHASE SWITCHING AT INPUTS TO ARRAY TYING ANALOGUE ADDERS. ANALOGUE XY SWITCHED POLARIZATION CORRELATION.
DESIGN G.J.N.
DRAWN G.J.N.
DATE 1-10-85
REVISION 1 2 3 4 5 6 7 8
G.J.N. 18-2-86
K.C. 10.4.86
AUSTRALIA TELESCOPE CA
RECEIVER SCHEMATIC (CENTRAL BUILDING)
DRG. No.
SHEET OF

Figure 2


F
W
Q
K
X OFF AXIS
X
C
S
L
UHF
42.0 - 50.0
20.0 - 25.5
8.0 - 9.2
4.4 - 5.1
2.2 - 2.5
1.25 - 1.75
0/180° PHASE SWITCH
2 PER ANTENNA
4 PER ANTENNA
TEST
NOTE: LOCAL OSCILLATOR L4(U4) CONVERTS LOWER(UPPER) IF BAND TO 4 BIT OUTPUT BAND.
128 FRACTIONAL BIT DELAY
4 BIT 64 MHz
2 BIT 128 MHz
1 BIT 256 MHz SAMPLER AND DIGITIZER
OPTICAL FIBRE TO CONTROL ROOM
PHASE ROTATION AND OFFSETING (2-4 BIT) (RANGE 5KHz)
PHASE ROTATION (8 BIT) 0°/ -90° PHASE SWITCH
10 MHz STEPS
DRG. No.
SHEET OF
AUSTRALIA TELESCOPE CA
FRONT END CONVERSION SCHEME
Figure 3



DESIGN	G.J.N.	REVISION 1	2	3	4	5	6	7	8
DRAWN	G.J.N.	G.J.N.	K.C.						
DATE	1-10-85	18-2-86	10-4-86						

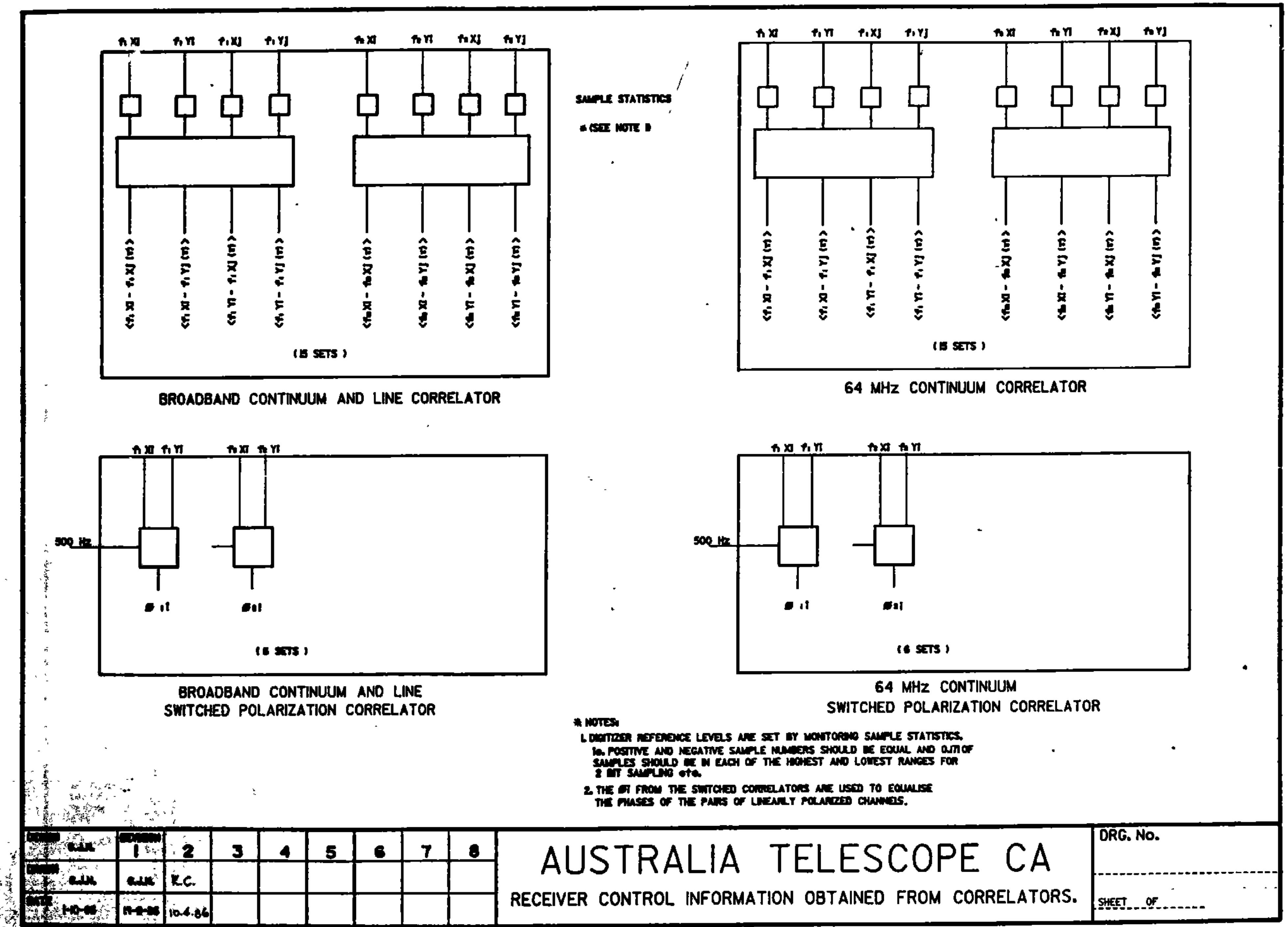
AUSTRALIA TELESCOPE CA

CONVERSION SCHEME NARROW BAND TUNING

DRG. No.

SHEET ___ OF ___

Figure 4



SAMPLE STATISTICS
(15 SETS)
BROADBAND CONTINUUM AND LINE CORRELATOR
(15 SETS)
64 MHz CONTINUUM CORRELATOR
500 Hz
(6 SETS)
BROADBAND CONTINUUM AND LINE
SWITCHED POLARIZATION CORRELATOR
500 Hz
(6 SETS)
64 MHz CONTINUUM
SWITCHED POLARIZATION CORRELATOR
NOTES:
1. DIGITIZER REFERENCE LEVELS ARE SET BY MONITORING SAMPLE STATISTICS.
2. THE ΔΦ FROM THE SWITCHED CORRELATORS ARE USED TO EQUALISE THE PHASES OF THE PAIRS OF LINEARLY POLARIZED CHANNELS.
1 2 3 4 5 6 7 8
K.C.
10.4.86
AUSTRALIA TELESCOPE CA
RECEIVER CONTROL INFORMATION OBTAINED FROM CORRELATORS.
DRG. No.
SHEET OF

Figure 5

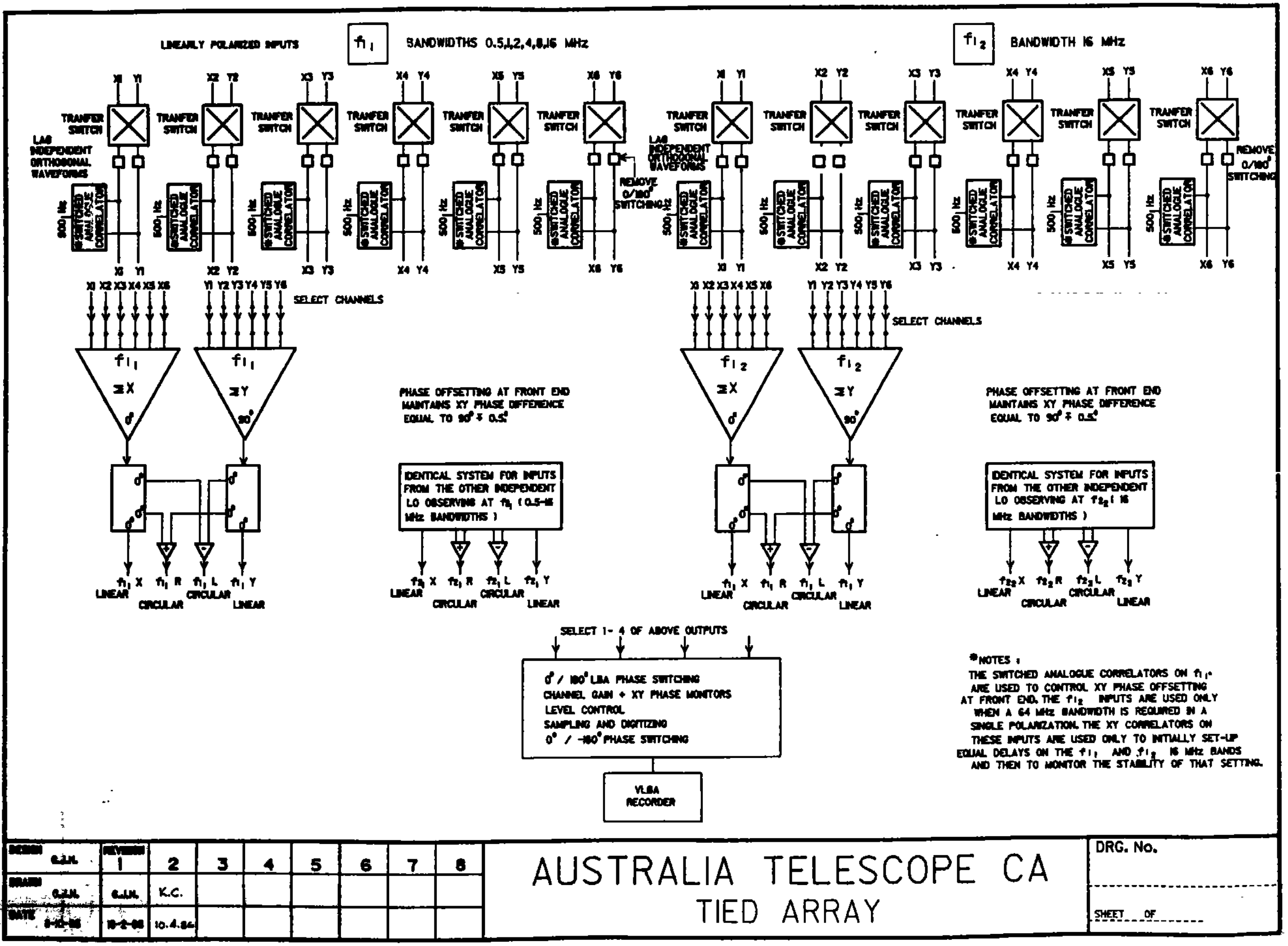

LINEARLY POLARIZED INPUTS
f_{l_1} BANDWIDTHS 0.5,1,2,4,8,16 MHz
f_{l_2} BANDWIDTH 16 MHz
TRANFER SWITCH
LAG INDEPENDENT ORTHOGONAL WAVEFORMS
500 Hz *SWITCHED ANALOGUE CORRELATOR
REMOVE 0/180° SWITCHING
SELECT CHANNELS
PHASE OFFSETTING AT FRONT END MAINTAINS XY PHASE DIFFERENCE EQUAL TO 90° ∓ 0.5°
IDENTICAL SYSTEM FOR INPUTS FROM THE OTHER INDEPENDENT LO OBSERVING AT f_{2_1} (0.5-16 MHz BANDWIDTHS)
IDENTICAL SYSTEM FOR INPUTS FROM THE OTHER INDEPENDENT LO OBSERVING AT f_{2_2} (16 MHz BANDWIDTHS)
LINEAR CIRCULAR CIRCULAR LINEAR
SELECT 1- 4 OF ABOVE OUTPUTS
0° / 180° LBA PHASE SWITCHING
CHANNEL GAIN + XY PHASE MONITORS
LEVEL CONTROL
SAMPLING AND DIGITIZING
0° / -180° PHASE SWITCHING
VLBA RECORDER
*NOTES :
THE SWITCHED ANALOGUE CORRELATORS ON f_{l_1}, ARE USED TO CONTROL XY PHASE OFFSETTING AT FRONT END. THE f_{l_2} INPUTS ARE USED ONLY WHEN A 64 MHz BANDWIDTH IS REQUIRED IN A SINGLE POLARIZATION. THE XY CORRELATORS ON THESE INPUTS ARE USED ONLY TO INITIALLY SET-UP EQUAL DELAYS ON THE f_{l_1} AND f_{l_2} 16 MHz BANDS AND THEN TO MONITOR THE STABILITY OF THAT SETTING.
DESIGN G.J.N.
DRAWN G.J.N.
REVISION 1 2 3 4 5 6 7 8
G.J.N. K.C.
10.4.84
AUSTRALIA TELESCOPE CA
TIED ARRAY
DRG. No.
SHEET OF

Figure 6

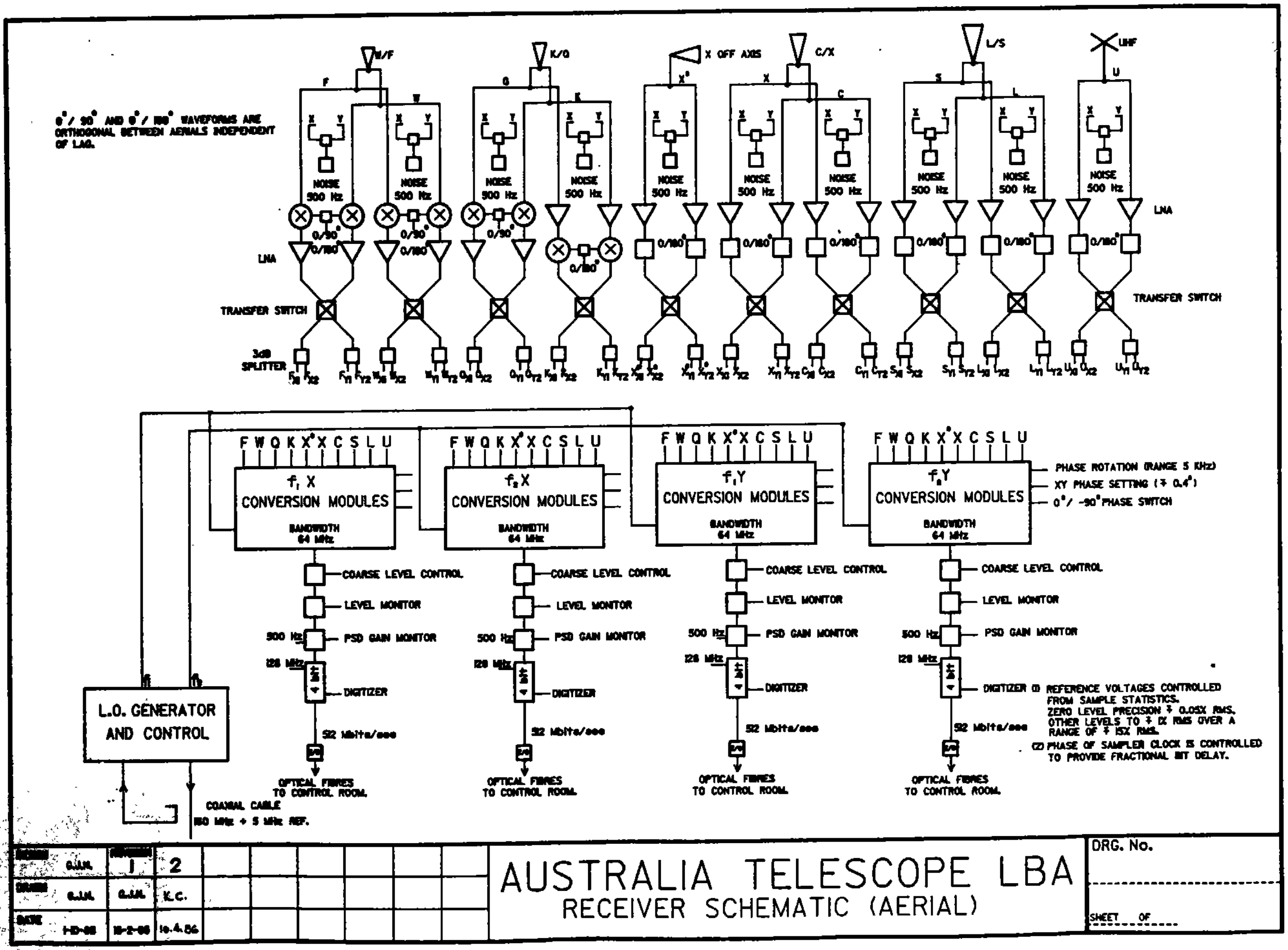

AUSTRALIA TELESCOPE LBA
RECEIVER SCHEMATIC (AERIAL)
DRG. No.
SHEET OF
0°/ 90° AND 0°/ 180° WAVEFORMS ARE ORTHOGONAL BETWEEN AERIALS INDEPENDENT OF LAG.
W/F
K/Q
X OFF AXIS
C/X
L/S
UHF
NOISE 500 Hz
LNA
TRANSFER SWITCH
3dB SPLITTER
f₁X CONVERSION MODULES
f₂X CONVERSION MODULES
f₁Y CONVERSION MODULES
f₂Y CONVERSION MODULES
BANDWIDTH 64 MHz
F W Q K X° X C S L U
PHASE ROTATION (RANGE 5 KHz)
XY PHASE SETTING (∓ 0.4°)
0°/ -90° PHASE SWITCH
COARSE LEVEL CONTROL
LEVEL MONITOR
PSD GAIN MONITOR
500 Hz
128 MHz
DIGITIZER
512 Mbits/sec
OPTICAL FIBRES TO CONTROL ROOM.
DIGITIZER (1) REFERENCE VOLTAGES CONTROLLED FROM SAMPLE STATISTICS. ZERO LEVEL PRECISION ∓ 0.05% RMS. OTHER LEVELS TO ∓ 1% RMS OVER A RANGE OF ∓ 15% RMS.
(2) PHASE OF SAMPLER CLOCK IS CONTROLLED TO PROVIDE FRACTIONAL BIT DELAY.
L.O. GENERATOR AND CONTROL
COAXIAL CABLE 160 MHz + 5 MHz REF.
2
K.C.
10.4.86

Figure 7

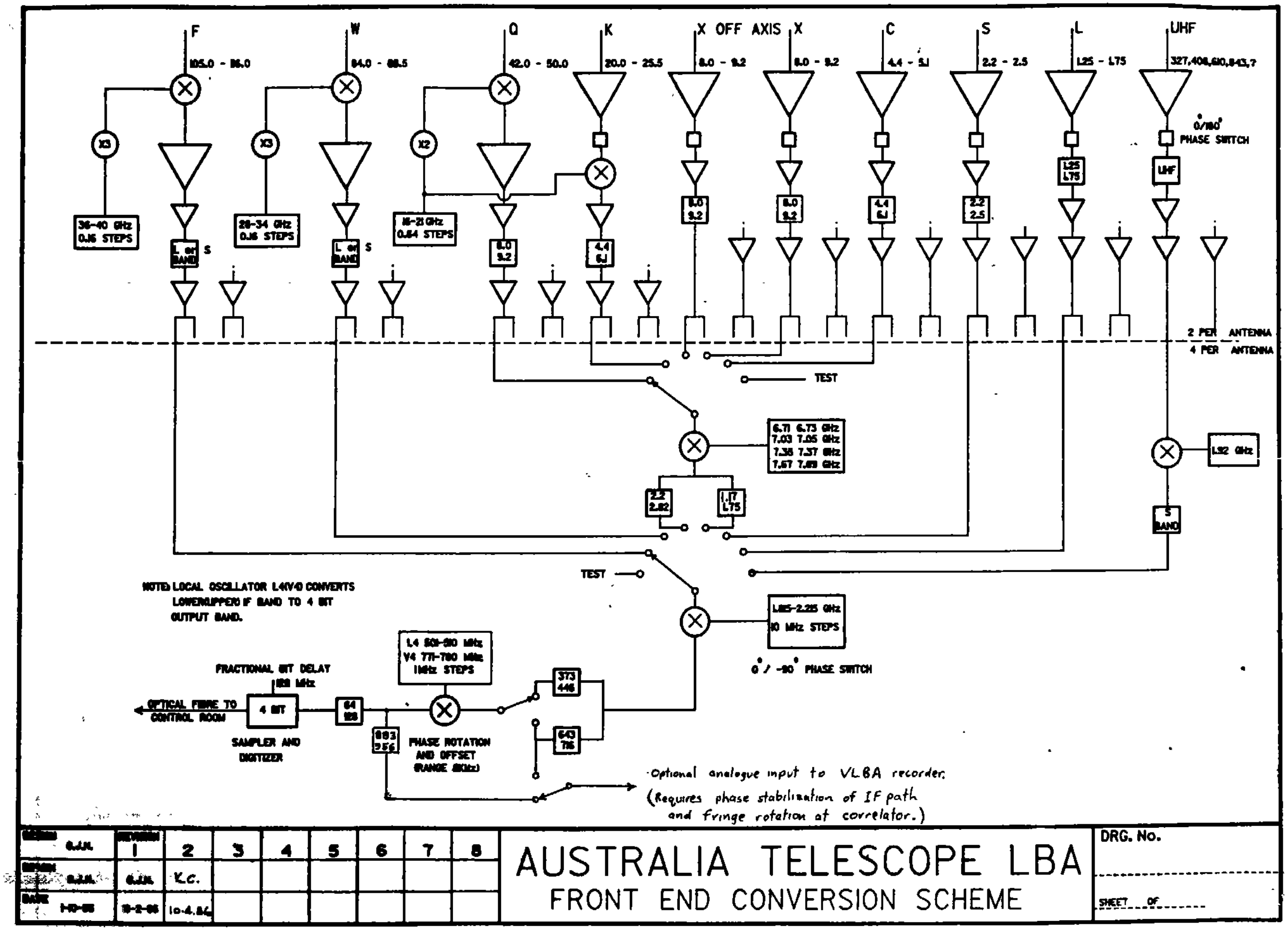

F
105.0 - 86.0
W
84.0 - 88.5
Q
42.0 - 50.0
K
20.0 - 25.5
X OFF AXIS
X
8.0 - 9.2
C
4.4 - 5.1
S
2.2 - 2.5
L
1.25 - 1.75
UHF
327,408,610,843.7
0/180° PHASE SWITCH
36-40 GHz 0.16 STEPS
28-34 GHz 0.16 STEPS
16-21 GHz 0.64 STEPS
X3
X2
L or S BAND
2 PER ANTENNA
4 PER ANTENNA
TEST
6.71 6.73 GHz 7.03 7.05 GHz 7.36 7.37 GHz 7.67 7.69 GHz
1.92 GHz
S BAND
1.005-2.235 GHz 10 MHz STEPS
0° / -90° PHASE SWITCH
NOTE: LOCAL OSCILLATOR L4(V4) CONVERTS LOWER(UPPER) IF BAND TO 4 BIT OUTPUT BAND.
L4 501-510 MHz V4 771-780 MHz 1MHz STEPS
FRACTIONAL BIT DELAY
128 MHz
OPTICAL FIBRE TO CONTROL ROOM
4 BIT
SAMPLER AND DIGITIZER
PHASE ROTATION AND OFFSET (RANGE 8KHz)
Optional analogue input to VLBA recorder. (Requires phase stabilization of IF path and fringe rotation at correlator.)
AUSTRALIA TELESCOPE LBA
FRONT END CONVERSION SCHEME
DRG. No.
SHEET OF

Figure 8

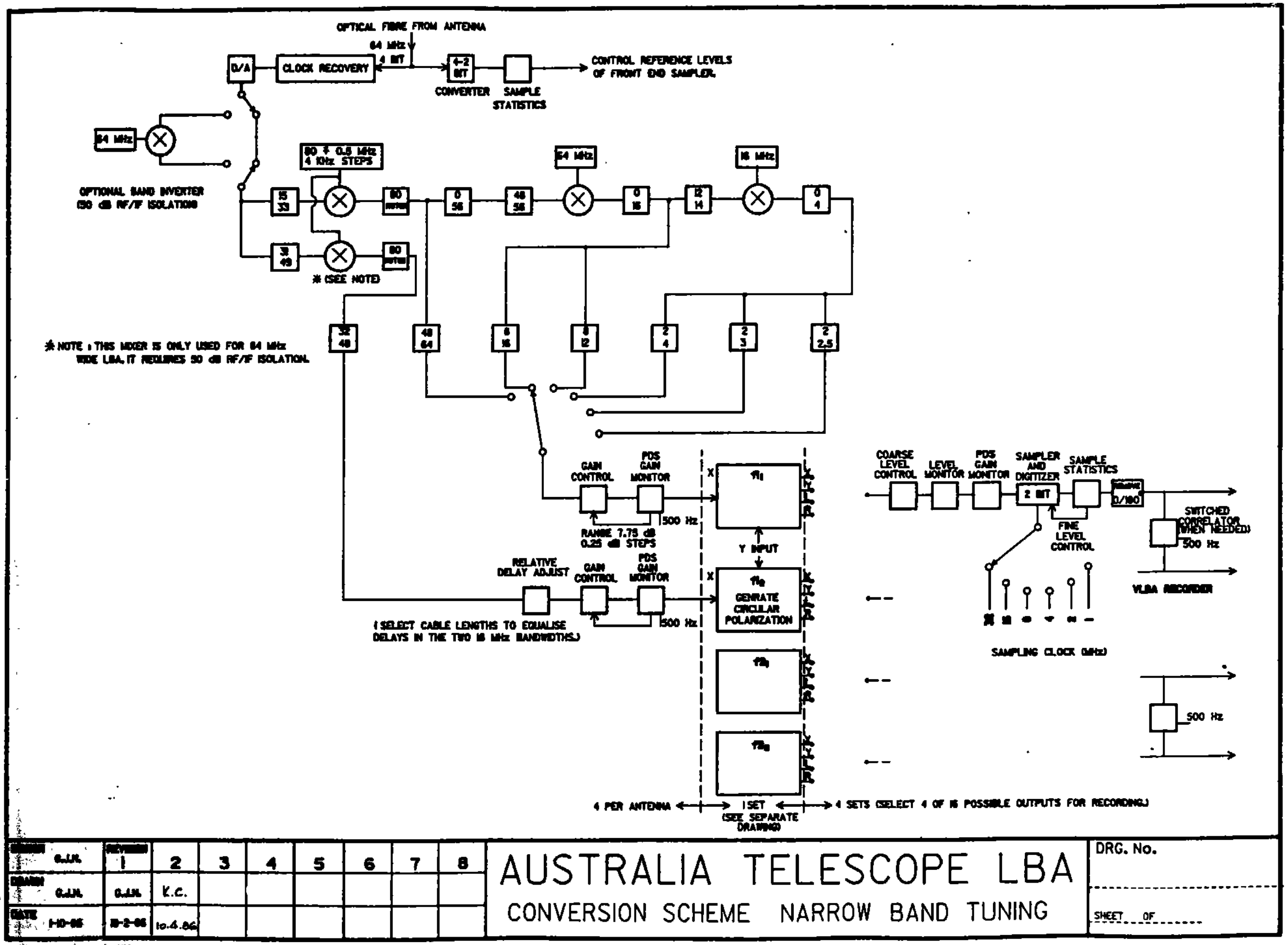
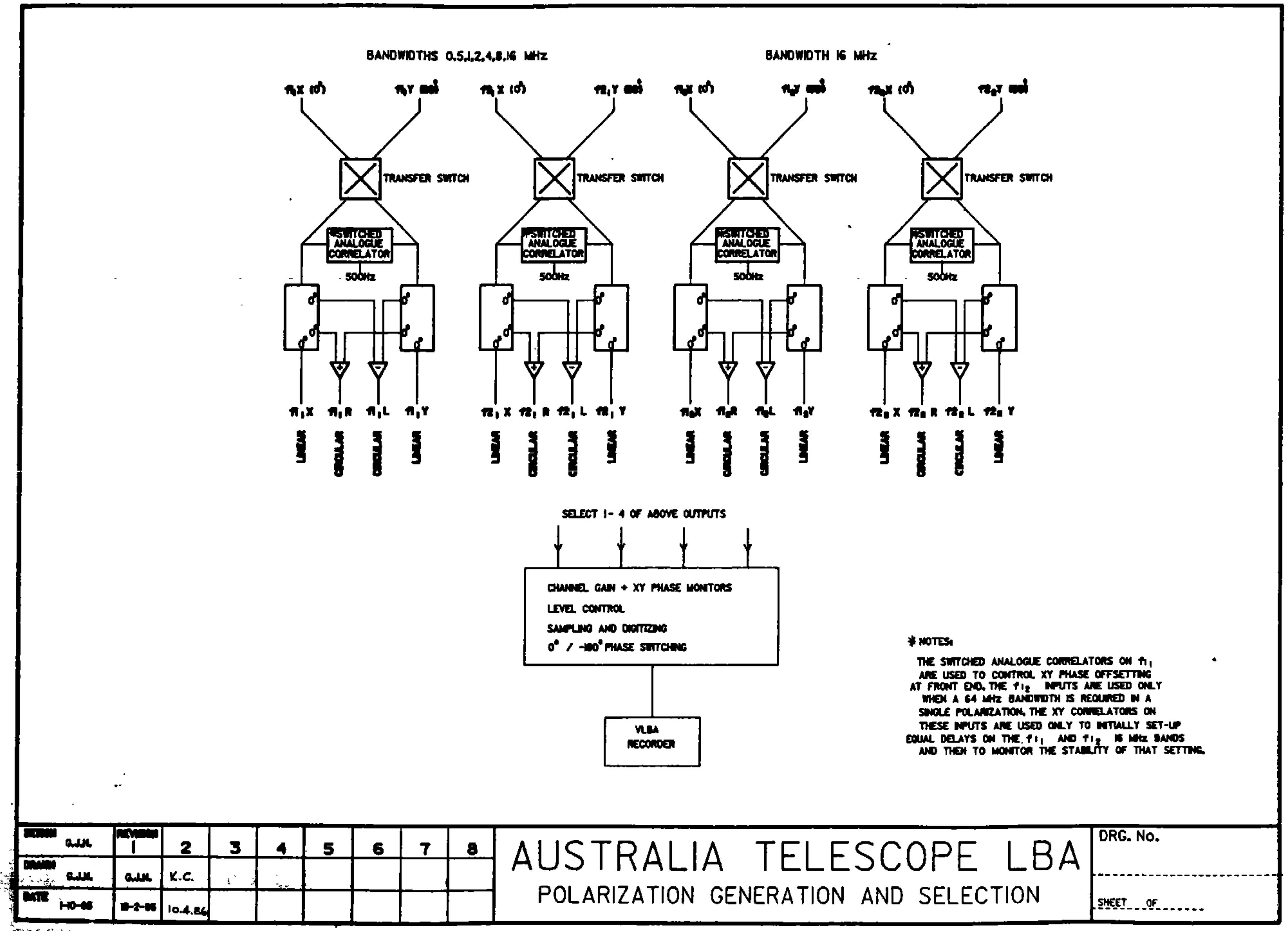
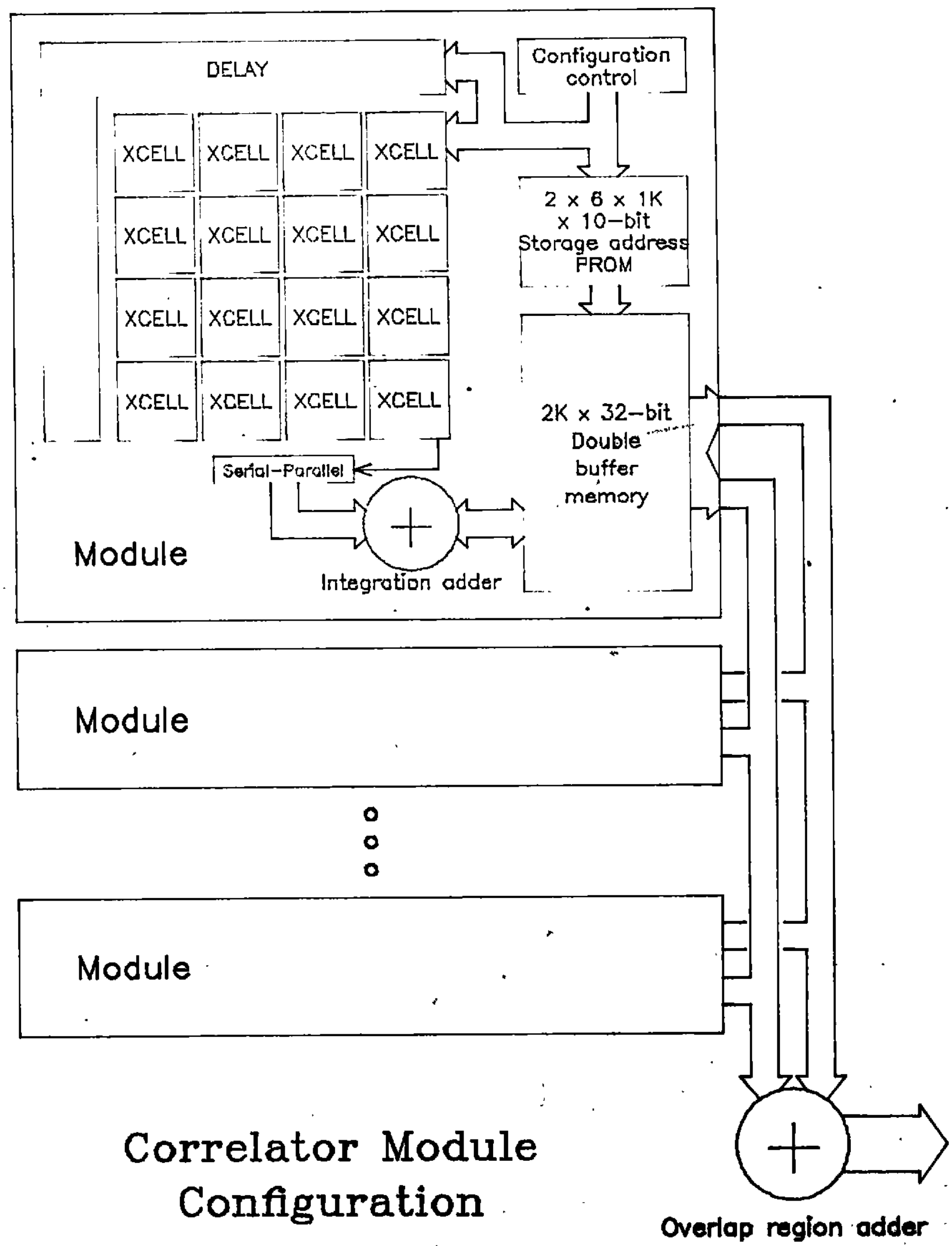

OPTICAL FIBRE FROM ANTENNA
64 MHz
4 BIT
D/A
CLOCK RECOVERY
4-2 BIT CONVERTER
SAMPLE STATISTICS
CONTROL REFERENCE LEVELS OF FRONT END SAMPLER.
64 MHz
OPTIONAL BAND INVERTER (50 dB RF/IF ISOLATION)
80 ± 0.5 MHz 4 KHz STEPS
64 MHz
16 MHz
* (SEE NOTE)
* NOTE : THIS MIXER IS ONLY USED FOR 64 MHz WIDE LBA. IT REQUIRES 50 dB RF/IF ISOLATION.
GAIN CONTROL
PDS GAIN MONITOR
500 Hz
RANGE 7.75 dB 0.25 dB STEPS
Y INPUT
RELATIVE DELAY ADJUST
GENRATE CIRCULAR POLARIZATION
(SELECT CABLE LENGTHS TO EQUALISE DELAYS IN THE TWO 16 MHz BANDWIDTHS.)
COARSE LEVEL CONTROL
LEVEL MONITOR
PDS GAIN MONITOR
SAMPLER AND DIGITIZER
2 BIT
SAMPLE STATISTICS
FINE LEVEL CONTROL
SWITCHED CORRELATOR (WHEN NEEDED)
500 Hz
VLBA RECORDER
SAMPLING CLOCK (MHz)
4 PER ANTENNA
1 SET (SEE SEPARATE DRAWING)
4 SETS (SELECT 4 OF 16 POSSIBLE OUTPUTS FOR RECORDING.)
AUSTRALIA TELESCOPE LBA
CONVERSION SCHEME NARROW BAND TUNING
DRG. No.
SHEET OF
1 2 3 4 5 6 7 8
K.C.
10.4.86

Figure 9



BANDWIDTHS 0.5,1,2,4,8,16 MHz
BANDWIDTH 16 MHz
TRANSFER SWITCH
SWITCHED ANALOGUE CORRELATOR
500Hz
LINEAR
CIRCULAR
SELECT 1-4 OF ABOVE OUTPUTS
CHANNEL GAIN + XY PHASE MONITORS
LEVEL CONTROL
SAMPLING AND DIGITIZING
0° / -180° PHASE SWITCHING
VLBA RECORDER
* NOTES:
THE SWITCHED ANALOGUE CORRELATORS ON f1 ARE USED TO CONTROL XY PHASE OFFSETTING AT FRONT END. THE f2 INPUTS ARE USED ONLY WHEN A 64 MHz BANDWIDTH IS REQUIRED IN A SINGLE POLARIZATION. THE XY CORRELATORS ON THESE INPUTS ARE USED ONLY TO INITIALLY SET-UP EQUAL DELAYS ON THE f1 AND f2 16 MHz BANDS AND THEN TO MONITOR THE STABILITY OF THAT SETTING.
AUSTRALIA TELESCOPE LBA
POLARIZATION GENERATION AND SELECTION
DRG. No.
SHEET OF
G.J.N.
K.C.
1-10-85
10.4.86

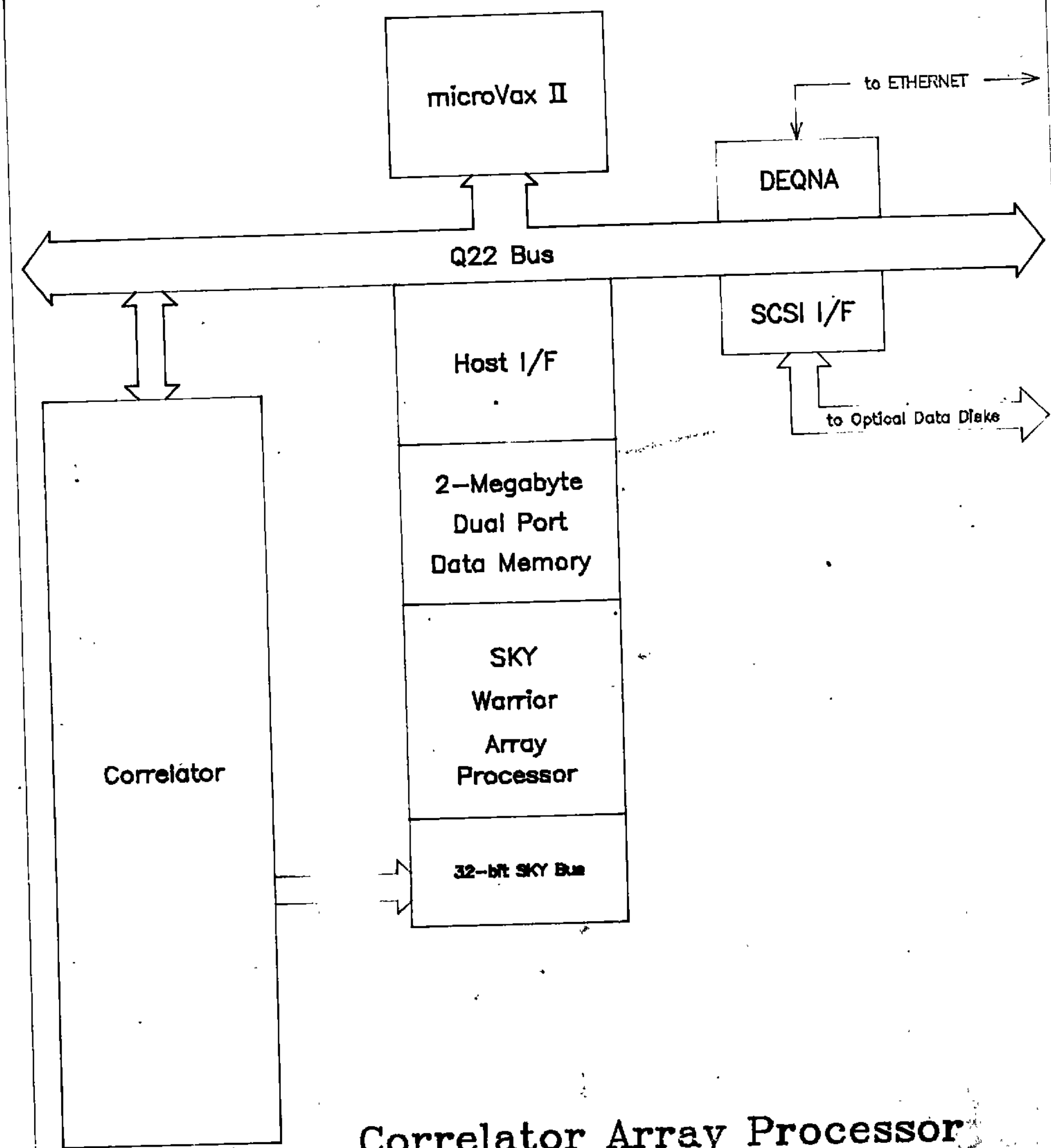
Figure 10



Correlator Module Configuration

CSIRO Radiophysics — A.J. Hunt, June 1985 CONFIG 1

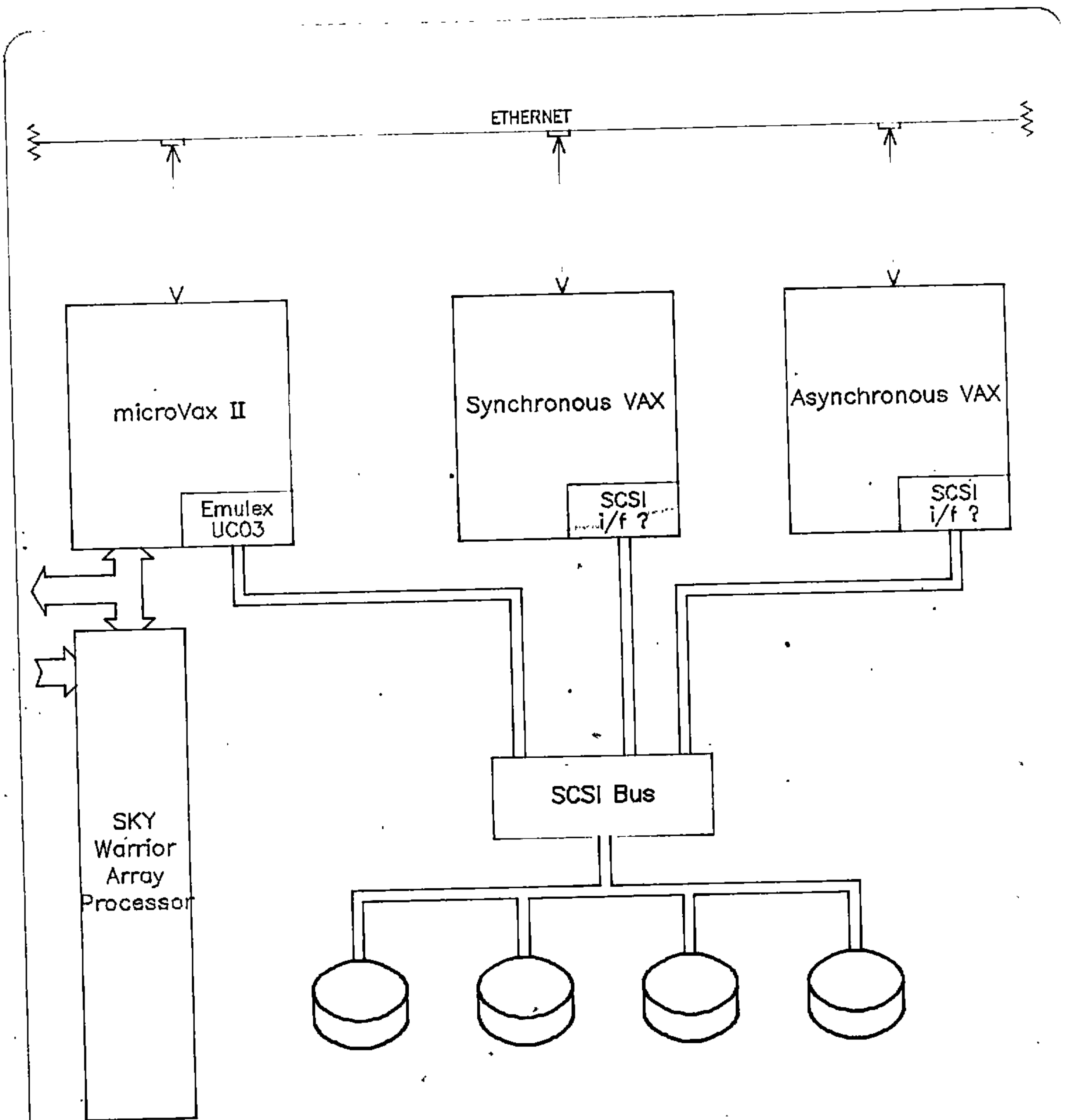
Figure 11



Correlator Array Processor
& Data Paths

Figure 12

CSIRO Radiophysics —— A.J. Hunt, April 1986 CONFIG 2



Correlator Data Paths to Disk

CSIRO Radiophysics — A.J. Hunt, April 1986 CONFIG 3

Figure 13