AT/15.5/020

CSIRO DIVISION OF RADIOPHYSICS

AT INTERFERENCE SURVEY NO. 2

CONTENTS

1. INTRODUCTION

This reoort presents in some detail, results obtained from a second interference survey conducted at two sites. Siding Spring Mountain was tested from 3/8/83 to 5/8/83 to complement the survey done in May/June 1983. The second site was Culgoora corresponding to the proposed compact array location.

The emphasis, of this second survey, particulary at Siding Spring was on spectral analysis rather than the more sensitive Total Power/Peak Detector (Chart recorder) system.

2. DESRIPTION OF TECHNIQUES AND EQUIPMENT

Apart from minor technical variations equipment was as in the first interference survey (ref. AT/15.7/012). However an upgraded spectrum analyser was used (HP 85698) in conjunction with a HP 85 control computer to permit more efficient and reliable spectral analysis. Most of the spectra recorded where taken by monitoring after the LNA of the front end of the system. However greater sensitivity was achieved by observing the IF response but only at the expense of a greatly reduced bandwidth (ie from a maximun of 500MHz with the LNA to about 10MHz with the down converted system, centred at 30MHz).

Spectral analysis consisted of computer data logging of the digital output of the spectrum analyser. Two types of output were taken from the azimuthal scans.

(i) Digital Average : takes the average of the last 64 scans with uniform weighting.

(ii) Max Hold : retains the highest peak level at each frequency over a period of 3 minutes.

The first type of output gives an accurate measurement of the average power (spectral density). The second is useful for catching transitory signals.

Also used at Culgoora was the Chart recorder system consisting of two channels.

(i) Gated Total Power : utilising a noise adding radiometer mode.

(ii) Peak Detection : captures highly impulsive interference.

Frequencies investigated at Culgoora were:

(i) 327 MHz
(ii) 408 MHz
(iii) 1420 MHz
(iv) 2295 MHz

whilst Siding Spring excluded 1420 MHz due to time constraints.

3. RESULTS OBTAINED

(i) SUMMARY

(a) SIDING SPRING MOUNTAIN SURVEY (1)

FREQUENCY	POLARISATION	BANDWIDTH (MHz)
327	45 degree	50
408	45 degree	10
408	horizontal	200
408	vertical	200
2100 (2)	horizontal	500
2100	vertical	500

(b) CULGOORA SURVEY

FREQUENCY	POLARISATION	BANDWIDTH (MHz)
327	45 degree	10
327	45 degree	200
408	horizontal	10
408	vertical	10
408	45 degree	200
1420 (3)	45 degree	10
2295 (4)	45 degree	200

Notes

(1) Each survey consisted of azimuthal scans at increments of 30 degrees from the north. 'Digital average' and 'Max Hold' spectra data were recorded on data cassettes.

(2) The 'Telecom Survey' which includes the 2295 MHz A.T. astronomical frequency.

(3) In addition a 'Total Power/Peak Detector' survey was done.

(4) The 2295 MHz survey was corrupted by the sweeping LO of the Culgoora spectrograph.

RESULTS OBTAINED

(i) DETAILS

(a) SIDING SPRING MOUNTAIN SURVEY

***327 MHz**

The observation band was 302 MHz to 352 MHz. Below is a summary of the transmitters present, their directions and intensities. Note that due to possible temporal variations in the strength of the transmitters the direction indicated may only be considered as an estimate of the true bearing.

GRAPH 3.1 TYPICAL SIDING SPRING 327MHz SPECTRUM @ 90 deg E
(Uncalibrated vertical scale)

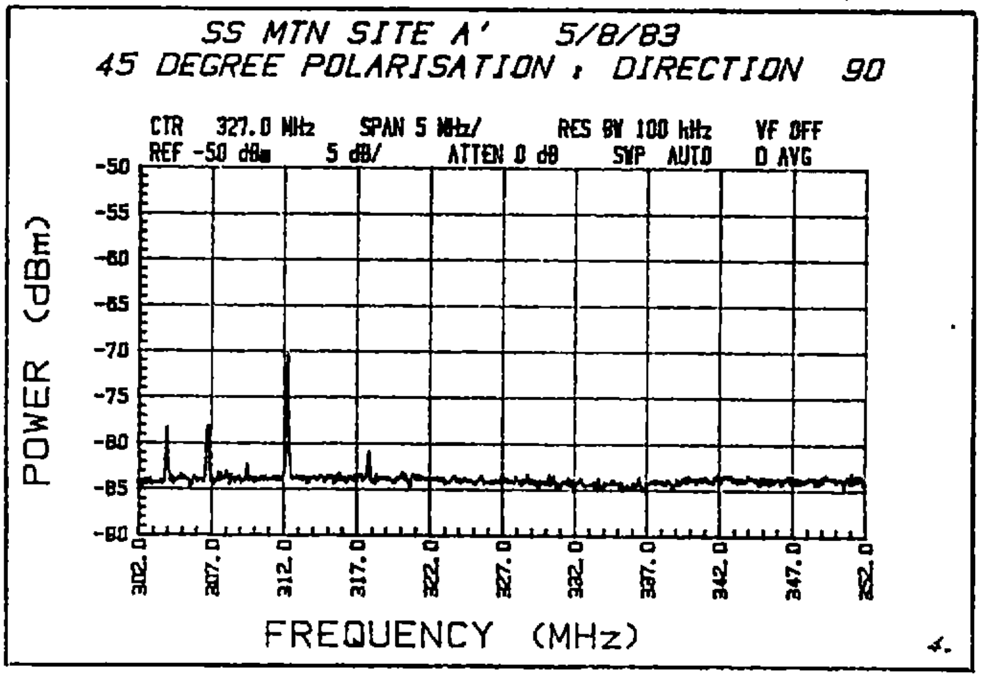


TABLE 3.1 TRANSMITTERS IN 302-352 MHz BAND

FREQUENCY MHz	DIRECTION North=0	POLARIZATION (1)	SYST TEMP deg K (2)(3)
304.0	30	-	200
306.2	300	-	50
306.8	330	-	140
309.5	30	-	40
312.3	150	-	1000
317.8	90	-	50
318.9	60	-	40
320.1	180	-	30
323.8	60	-	50

Notes
(1) Polarization of test equipment antenna was 45 degrees.
(2) Interference equipment antenna temperature increase due to transmitter.
(3) Assumes transmitter is within passband ie before filtering

Comments and Summary @ 327 MHz

In the first interference survey it was noted that interference was present outside the band. This survey confirmed it as interference from the diesel generator which supplies the AC power to the equipment in remote locations. In as much as variations in the total average power (of the interference) were previously observed, it will be necessary to shield the generator before we can assertain the true source (and composition) of this variation.

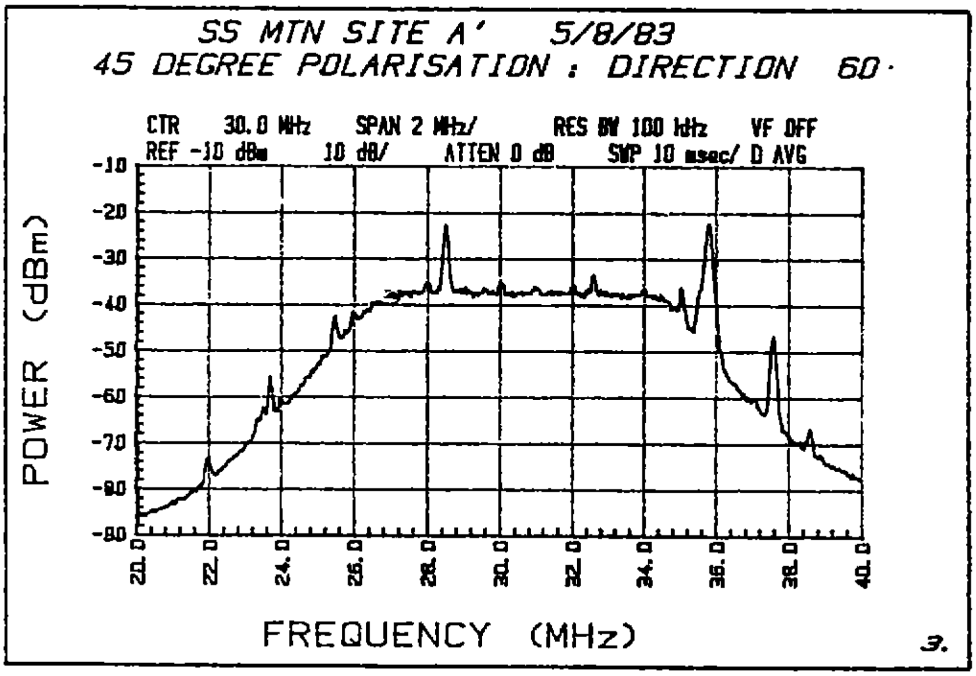
The diesel generator also produced interference manifesting itself as impulses on the 'max hold' spectrum hence this may cast doubt on the validity of some of the transmitters listed from the digital average record. Questionable transmitters are listed as such.

There seems to be no significant (strong) transmitters in the radio astronomy band.

*408 MHz

Both narrow band and broadband observations were undertaken. Numerous transmitters were detected inside and adjacent to the radio astronomy band. Below is table 3.2 with the relevant details.

GRAPH 3.2 TYPICAL SIDING SPRING 408MHz SPECTRUM @ 60 deg NEE
(LO @ 378MHz, uncalibrated vertical scale)



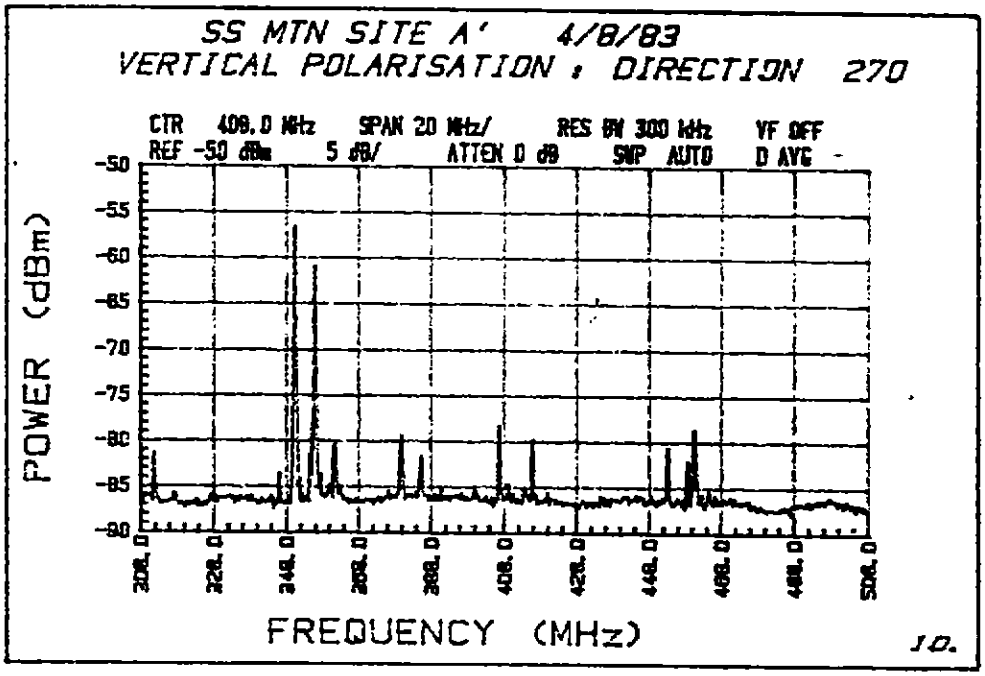
Comments and Summary @ 408 MHz

The first interference survey classified three types of interferring signal as seen on the spectrum analyser. Class (iii) strong, swept frequency signal was found to be due to poorly shielded equipment (specifically a frequency meter) rather than an airborne radar or other external source of interference. This highlights the precautions necessary when operating with sensitive equipment. Class (i) and class (ii) type transmissions (see AT/15.7/012) were again observed and are real.

With the increased sensitivity of the spectrum analyser over the one used in the first interference survey, it was possible to unambiguously evaluate the diesel generators merits in terms of interference. It was found that, particulary apparent on the max hold mode of operation, interference was produced in the form of impulses over a broad frequency range. The digital average mode of operation did not suffer adversely due to its filtering nature. However this provides incentive for adequate shielding in the future interference surveys.

The quantity and intensity of the interference present will make sensitive astronomical observations rather dubious at this location without extensive filtering.

GRAPH 3.3 TYPICAL SIDING SPRING 408MHz SPECTRUM @ 270 deg NEE
(Uncalibrated vertical scale)



GRAPH 3.4 TYPICAL SIDING SPRING 408MHz SPECTRUM @ 270 deg NEE
(Uncalibrated vertical scale)

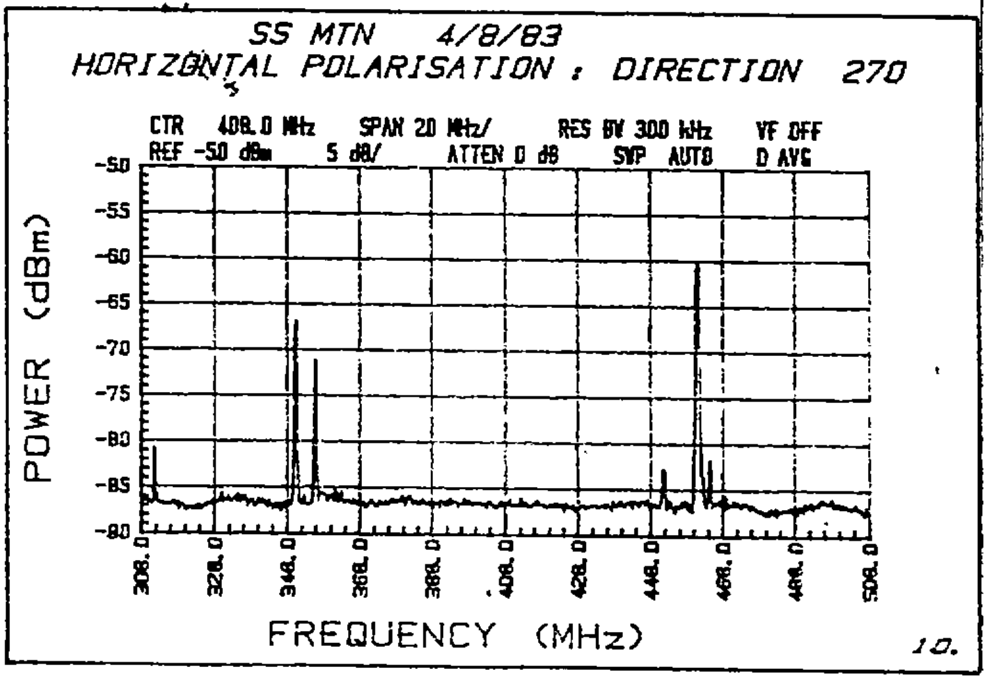


TABLE 3.2 TRANSMITTERS IN 350-470 MHz BAND

FREQUENCY MHz	DIRECTION North=0	POLARIZATION	SYST TEMP deg K
350.5	0	vertical	30000
352.6q	300	horizontal	20
355.9	0	vertical	6000
357.6	330	vertical	25
360.1q	0	vertical	10
361.3	120	horizontal	75
361.8	300	vertical	30
363.0q	60	horizontal	12
371.3q	60	horizontal	10
371.8q	330	vertical	10
379.7q	120	horizontal	10
380.1	270	vertical	30
385.1q	120	horizontal	8
385.5	270	vertical	15
400.2	210	horizontal	15
401.6	30	-	10
401.9	150	-	30
403.6	60	vertical	5
405.6	330	horizontal	5
406.6	0	vertical	200
409.1	210	vertical	10
410.7	60	-	5
413.2	300	-	15
413.6	60	horizontal	75
413.9v	60	horizontal	950
415.1	30	-	5
415.6	30	vertical	190
416.6	30	-	10
419.7	30	horizontal	60
420.1	30	vertical	40
431.3q	210	horizontal	10
440.9q	120	vertical	10
450.9q	30	horizontal	12
451.8	210	horizontal	20
452.2	30	vertical	30
453.0	30	horizontal	30
453.4	330	vertical	30
454.7q	60	vertical	10
455.1q	60	horizontal	10
456.8q	60	vertical	15
458.8	270	vertical	20
460.9	300	horizontal	6000
461.3	30	vertical	2400
462.6	210	horizontal	100
464.7	210	horizontal	150
465.5	30	vertical	10
467.6q	60	vertical	10

Key

- \- unknown polarisation
- q questionable transmitters
- v variable, non constant, class (ii) transmitter, this transmitter peaked at ~10000 during visual observation

*S BAND (1850-2350 MHz)

Principally this survey was done to verify frequencies and intensities of transmitters for Telecom. In as much as it covers the AT astronomical band around 2295 MHz it is useful as an interference survey though at reduced sensitivity. The table below gives the results of the measurements.

TABLE 3.3 TRANSMITTERS IN THE 1900-2300 MHz BAND

FREQUENCY MHz	(1)(2) DIRECTION North=0	POLARIZATION	(3)(4) SYST TEMP deg K
1906	210	vertical	25
1921	210	horizontal	6300
2023	210	vertical	160
2038	210	horizontal	6300
2121	210	vertical	140
2135	210	horizontal	1300
2239	210	vertical	25
2252	210	horizontal	200

Notes

(1) Only the dominant direction for a given frequency is shown.
(2) Cenn Cruaich direction corresponds to 210 (SSW).
(3) Interference equipment antenna temperature increase due to transmitter.
(4) Assumes transmitter is within passband ie before filtering.

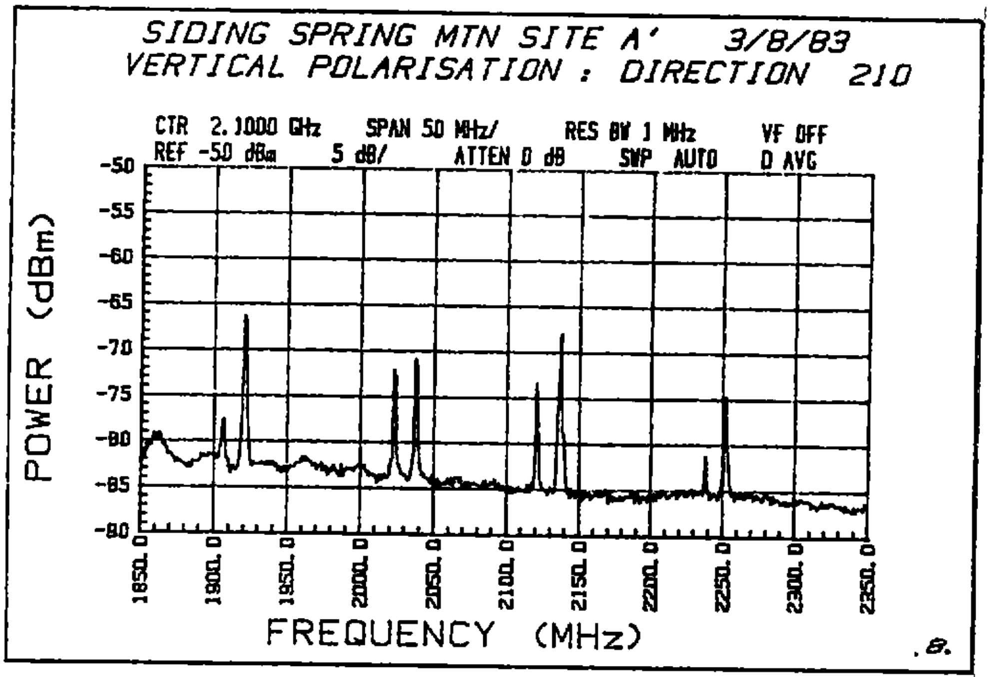
Comments and Summary a S Band

Results obtained are compatible with the first interference survey namely no adverse of harmful sources of interference in and around the astronomical band. The nearest significant transmitter in frquency was at 2251 MHz which as shown in the first interference survey had negligible effect on the sensitive total power system (lying outside the system passband).

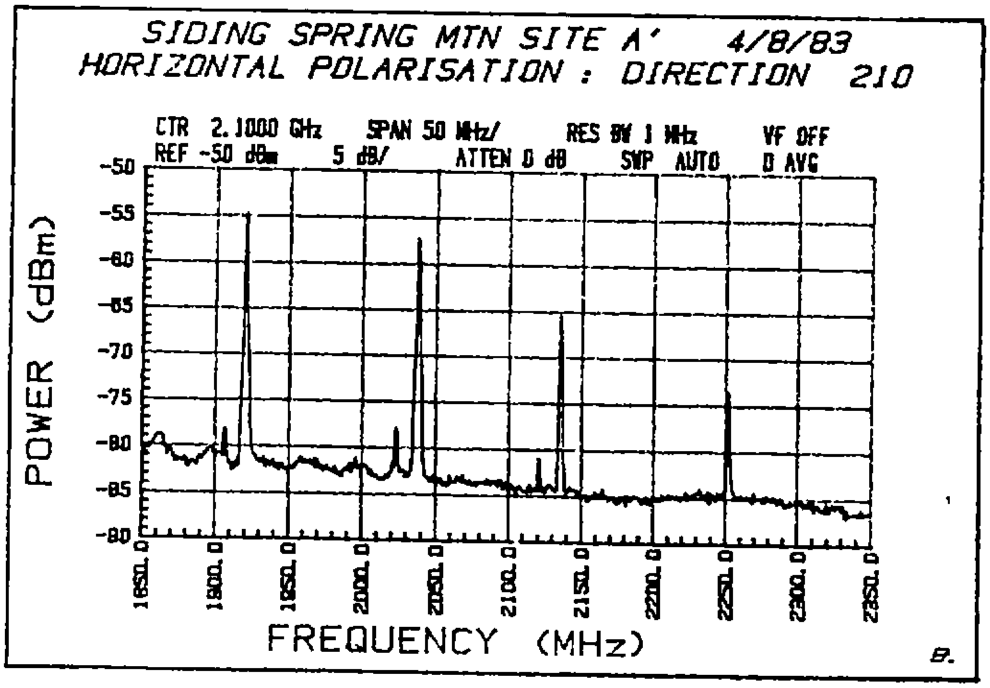
The microwave link for the A.T. will of course be lying in this part of the radio spectrum hence the above data provides an indication of possible frequency windows for its location.

S band, as well as L band (not observed this survey due to time constraints) would seem to be suitable for astronomical observations, there being no significant, discernible, harmful interference at Siding Spring Mountain within the astronomical band.

GRAPH 3.5 TYPICAL SIDING SPRING S BAND SPECTRUM @ 210 DEG SSW
(Uncalibrated vertical scale)



GRAPH 3.6 TYPICAL SIDING SPRING S BAND SPECTRUM @ 210 deg SSW
(Uncalibrated vertical scale)



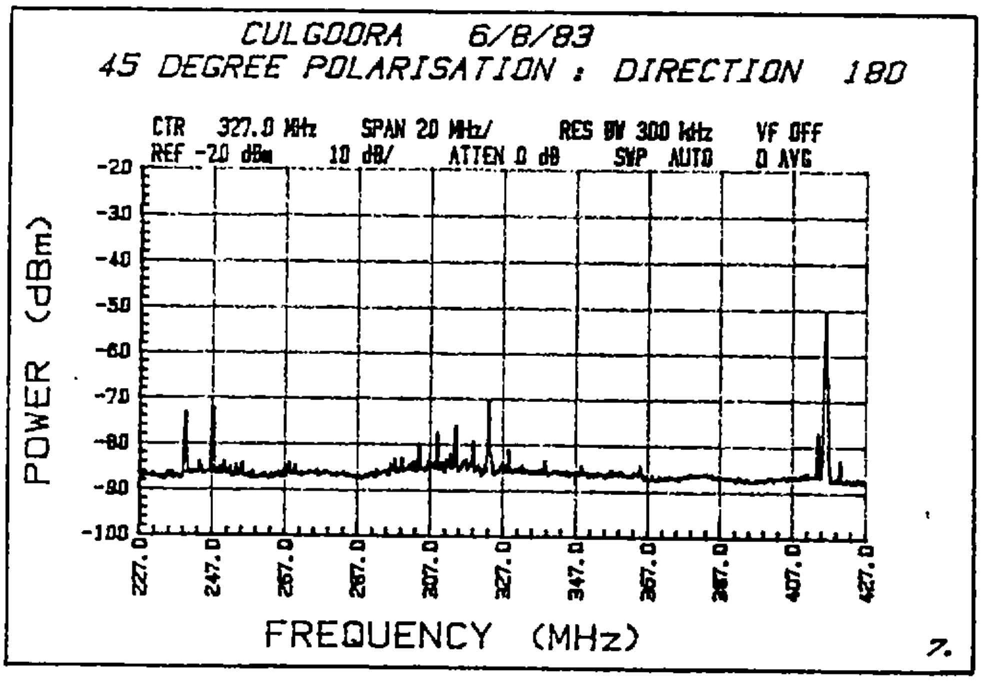
(b) CULGOORA SURVEY

Reservations about all results at Culgoora must be expressed before the results are presented in full. The radio environment around the test site, on top of the main building, can be expected (and was) quite active, to the point where some ambiguity necessarily results. Specifically shielding from the heliograph and spectrograph were perhaps inadequate and thus some of the observed sources of interference may have been very local. The results though still remain useful given that the philosophy that the actual source of the interference is irrelevant only its effect (frequency and intensity) is important. The A.T. can expect to have many internal sources of interference and thus the Culgoora spectrograph perhaps may be considered a preliminary model for this type of self-induced interference. The Culgoora spectrograph was in some cases unambigously identified as the source of interference, hence tests done during dormant periods would seem to be desirable in the future.

*327 MHz

A table summarizing the results is presented below. The most intense signal @ 323.5 MHz is strongly suspected of being locally produced. Supportive of this conclusion is its relative directional independence and maximun in the direction of the bulk of the building on which the tests were done (between 150-180 degreees azimuth). Indeed virtually all the transmitters detected showed maxima in this general direction.

GRAPH 3.7 TYPICAL CULGOORA 327 MHz SPECTRUM @ 180 deg S
(Uncalibrated vertical scale)



GRAPH 3.8 TYPICAL CULGOORA 327MHz SPECTRUM @ 180 deg S
(LO @ 297MHz, uncalibrated vertical scale)

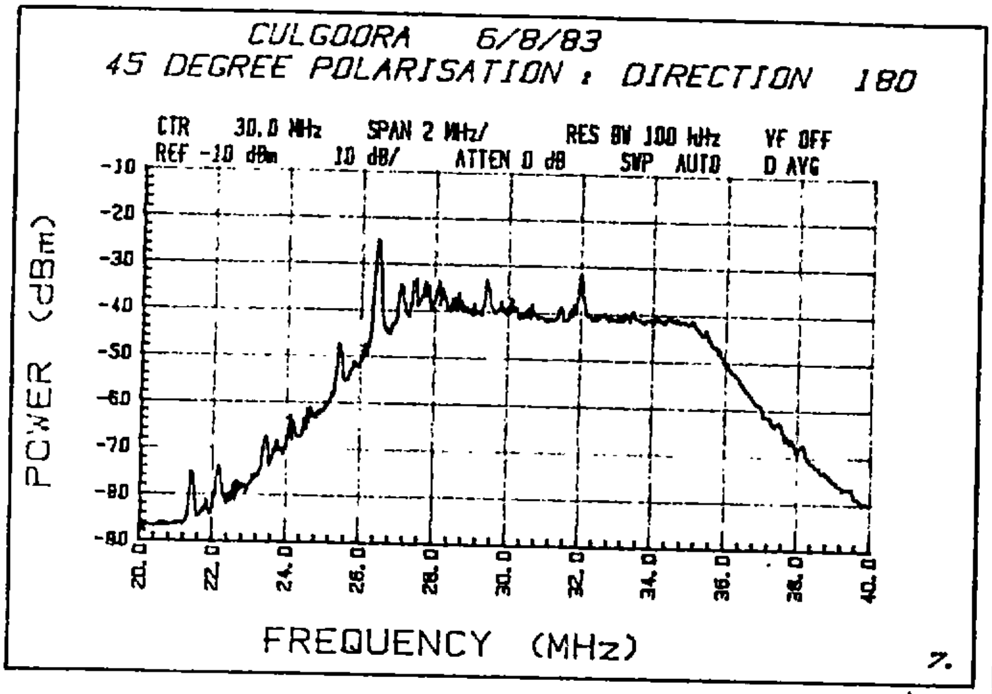


TABLE 3.4 TRANSMITTERS IN 300-380 MHz BAND

FREQUENCY MHz	DIRECTION North=0	POLARIZATION	SYST TEMP deg K
299.1	180	-	15
304.1	180	-	30
309.1	180	-	70
314.1	180	-	100
318.4q	180	-	10
319.2q	180	-	10
320.5q	180	-	5
322.4q	180	-	10
323.5	150	-	600
324.1q	180	-	10
324.5q	180	-	5
326.5q	180	-	5
329.0q	180	-	10
332.3	90	-	600
328.7q	180	-	20
338.7q	180	-	10
364.9	90	-	220
370.3	60	-	380
375.8	60	-	10
379.1	60	-	300

Key

- unknown transmitter polarisation
q questionable transmitter

Comments and Summary @ 327 MHz

The 327 MHz spectrum seemed to be corrupted by a number of transmissions. The nature and characteristics of these suggest in fact they are generated locally in the CSIRO buildings at the site and not distant, powerful transmitters. However it would be foolish to discount this latter possibility. Clearly further tests done during a dormant period of operation of the Culgoora spectrograph would resolve the confusion as to the source of the interference.

*408 MHz

Various bandwidths around 408 MHz were observed. The table below summarises the relevant details, merging the different surveys.

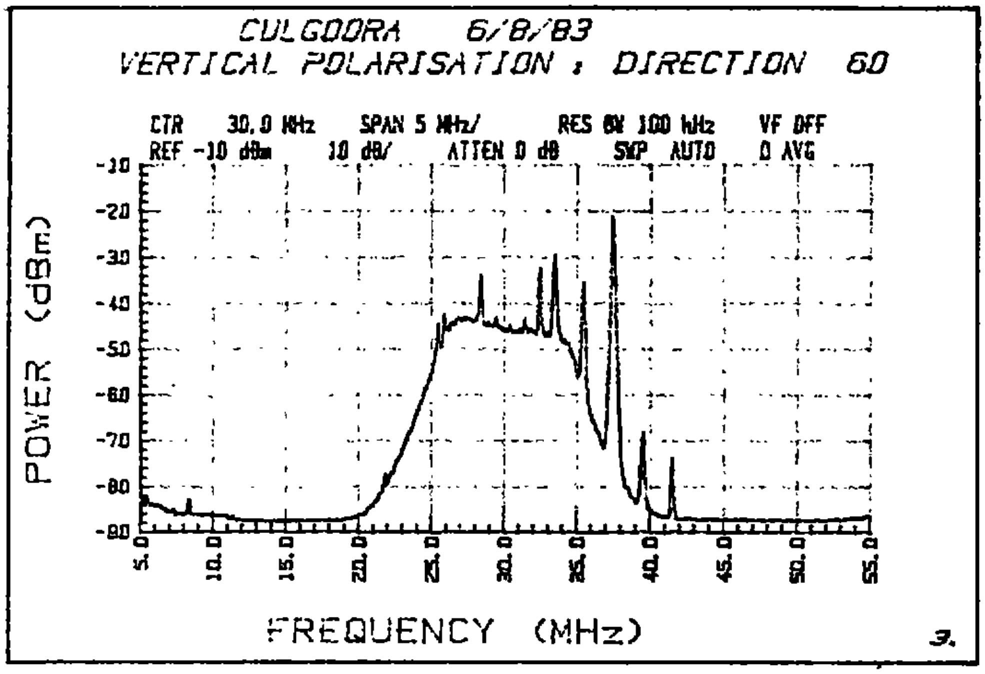
TABLE 3.5 TRANSMITTERS IN BAND 350-450 MHz

FREQUENCY MHz	DIRECTION North=0	POLARIZATION	SYST TEMP deg K
353.9	330	-	30
364.8	90	-	50
372.3	180	-	40
386.4	150	-	40
399.9	270	horizontal	30
400.4	30	horizontal	95
403.5	120	vertical	25
403.9	60	horizontal	75
406.4	60	horizontal	30
406.9	60	-	95
407.5	90	horizontal	30
409.5	90	horizontal	20
410.5	60	horizontal	755
411.5	60	vertical	120
413.5	300	vertical	60000
415.5	90	vertical	1000000
416.5	30	horizontal	10
417.6	300	vertical	300
419.6	90	horizontal	3800
420.2	90	-	4750
421.9	120	-	60
451.0	90	-	300
453.1	90	-	600
455.2	270	-	240
460.6	270	-	75000
462.7	270	-	240000
464.8	270	-	380000
466.9	30	-	30

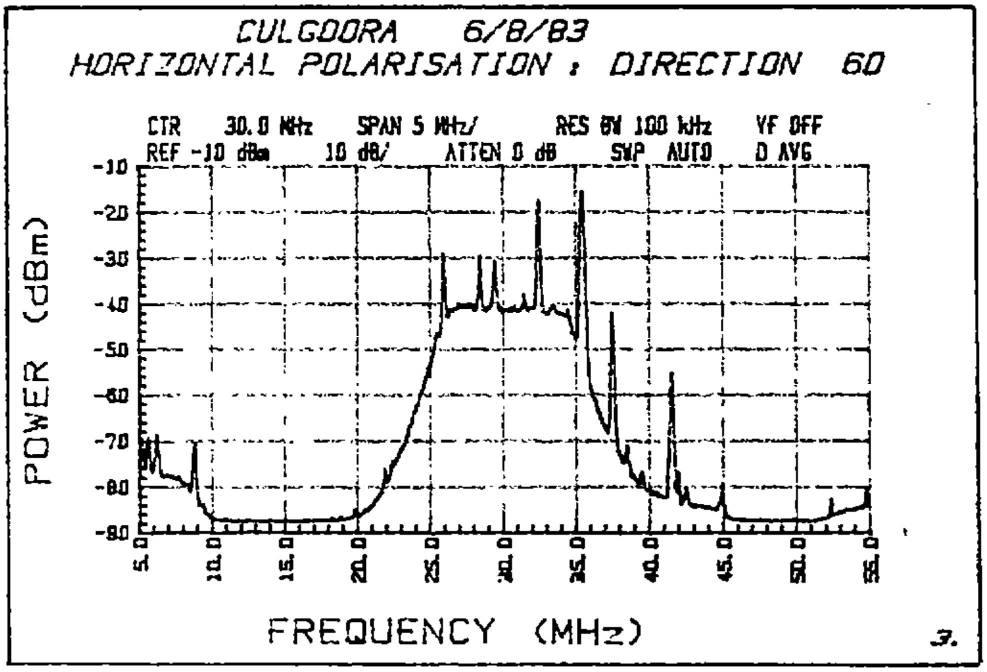
Key

- unknown transmitter polarisation (observation done at 45 deg antenna polarisation)

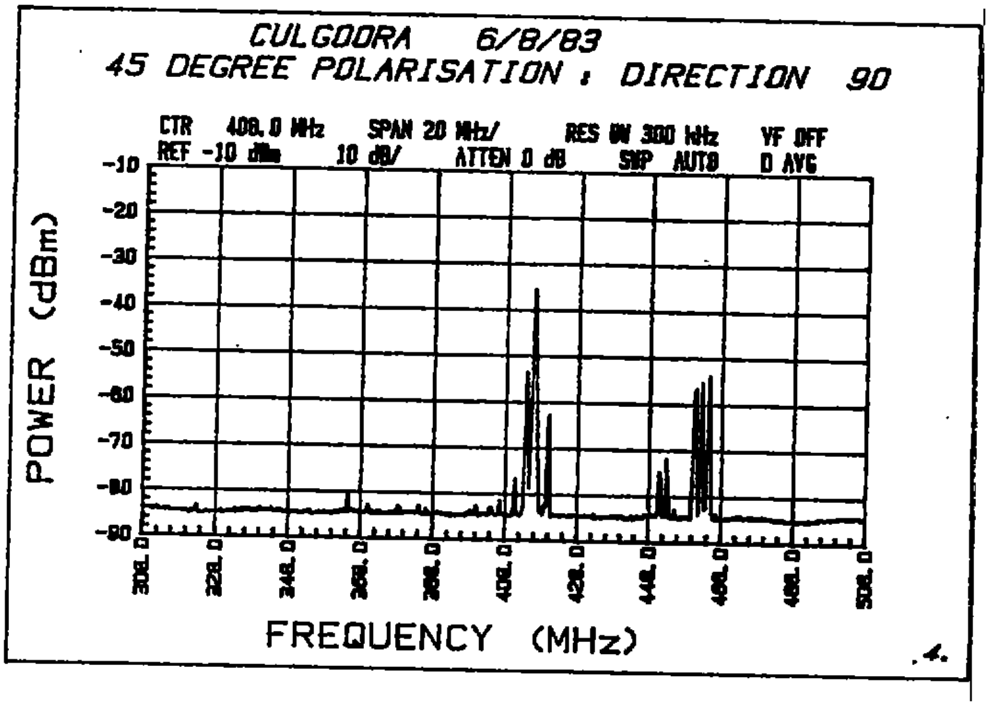
GRAPH 3.9 TYPICAL CULGOORA 408MHz SPECTRUM @ 60 deg NEE
(LO @ 378MHz, uncalibrated vertical scale)



GRAPH 3.10 TYPICAL CULGOORA 408MHz SPECTRUM @ 60 DEG NEE
(LO @ 378MHz, uncalibrated vertical scale)



GRAPH 3.11 TYPICAL CULGOORA 408MHz SPECTRUM @ 90 deg E
(Uncalibrated vertical scale)



Comments and Summary @ 408 MHz

Like Siding Spring Mountain there seems to be a number of transmitters in the astronomical band. These seem to be all of the constant, fixed frequency type of transmitter (class (i)). More disturbing than the quantity is the intensity of the transmitters, particularly at the frequencies 413.5 and 415.5 MHz. In the latter case it can be seen from the spectrum given in graph 3.9 that the transmitter lies approximately 55dB above the system noise level although just outside the 10MHz bandwidth of the interference receiver.

As expressed before some of these signals may not be distant sources but locally produced. If this is not the case then the interference levels indicated here are potentially more harmful than at Siding Spring.

*L BAND (1420 MHz)

As well as the spectrum observations, the chart recorder system was used with the more sensitive back-end system. This permitted actual power measurements to be done directly as well as a peak detector survey. The spectrum analyser showed no transmitters in or around the L band astronomical radio spectrum. Hence no data on this aspect of the survey is tabulated. However for the total average power/peak detector survey results will be tabulated in a manner analogous to the first interference survey. The measurements were done for 4 minutes per 30 degree azimuthal increment.

TABLE 3.6 1420 MHz TOTAL AVERAGE POWER/PEAK DETECTOR SURVEY

DIRECTION	ANTENNA TEMP(K)		FLUX x10 Jy (1)		PEAK DETECTOR
north = 0	rms	p-p	rms	p-p	# observations
0	1.8	2.8	14	22	quiet
30	1.8	2.0	14	16	quiet
60	1.8	3.1	14	24	quiet
90	1.2	1.8	9	14	1 impulse
120	1.2	1.8	9	14	quiet
150	1.8	3.5	14	27	quiet
180	2.4	3.7	19	29	1 impulse
210	2.4	4.0	19	31	many impulses
240	1.8	3.5	14	27	few impulses
270	1.8	3.1	14	24	1 impulses
300	1.8	3.1	14	24	1 impulses
330	1.8	2.8	14	22	few impulses

Comments and Summary @ L Band

The rms variation is due to system instability rather than any real interferring signal. The flux may be considered an upper limit to any real interferring flux which may be present. There was a 40 deg K antenna temperature variation of the mean background level for different directions presumably due to the amount of ground radiation in the beam. There seems to be some correlation between total average power and the peak detector results indicating the presence of impulsive interference at a fairly weak level. The direction 210 (SSW) corresponded with the location of the local workshop, however this may not necessarily be the location of the source of the impulses. Certainly no transmitters were observed in this direction on the spectrum analyser.

Apart from this unknown signal, the site seems free from any serious form of interference. At least as a preliminary judgement, astronomical observations are feasible at Culgoora.

Notes

(1) Flux levels correspond to system temperature fluctuations of approximately 1% .

*S BAND (2295 MHz)

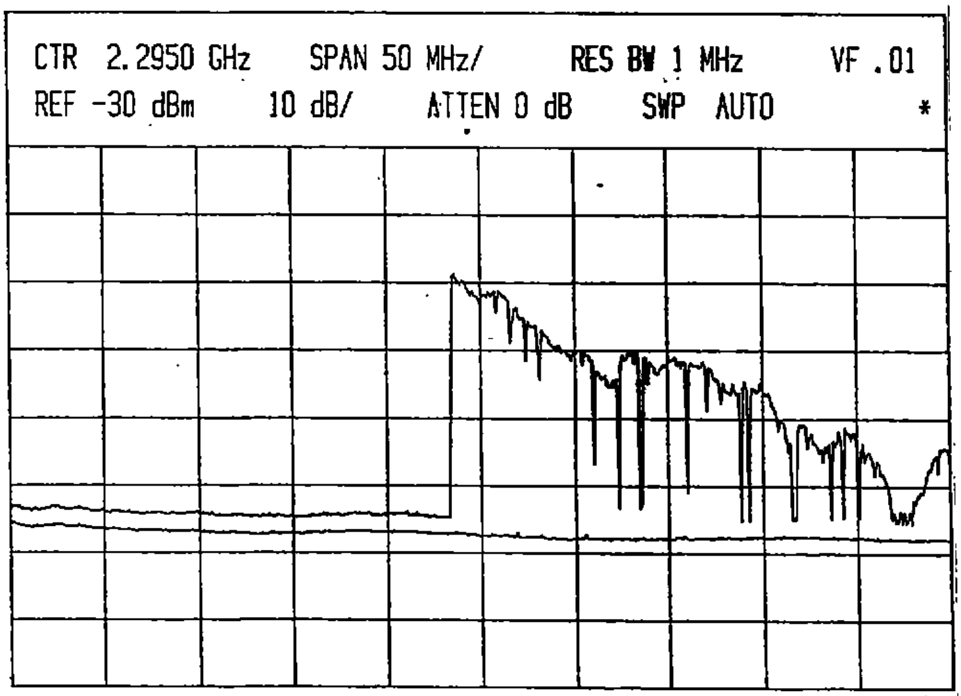
Comments and Summary @ S Band

At this frequency the observations were corrupted presumably by the Culgoora spectrograph, the spectrum analyser displaying the effects on broadband with a sweeping frequency signal (the LO). Hence over a period of time the peak hold mode of operation displayed the envelope of this signal (graph 3.12). Thus the presence of interference over this frequnecy range could not reliably be determined.

However over the narrow band 2295+/-5 MHz on digital average mode the spectrum analyser showed a total lack of fixed frequency transmitters in all directions. The beneficial effects of the digital average mode were to supress the 'random' samples of this signal ie the power in a given frequency band was not statistically significant.

The sweeping LO started at appox 2280 MHz and extended beyond 2550 MHz.- Clearly further tests at Culgoora should be done in a locally radio-quiet environment.

GRAPH 3.12 CORRUPTING SWEEPING FREQUENCY LO ENVELOPE
(Uncalibrated vertical scale)



4. SITE CHARACTERISTICS

(a) Siding Spring Mountain

As in the first interference survey see AT/15.7/012.

(b) Culgoora

Equipment was set up on the flat roof of the main building. Due to availability of power, the generator was not needed or used. The horizon was restricted in the direction 150-180 degrees (SSE-S) due to the building structure. This was not considered important. Indeed time constraints did not permit relocation of the equipment to make allowance for this. In certain directions the beam of our test antenna seemed to be directed towards the mesh of the large mesh parabolic antennas. Thus this may have caused some sheilding (NW). The potential problems due to locally produced interference indicate that perhaps the main building site chosen is not ideal even though it gave a height advantage.

5. WEATHER CONDITIONS DURING OBSERVATION

Both sites experienced fine sunny weather.

6. OBJECTIVES NOT ACHIEVED

The survey in its original preception was intended as a preliminary one, to test the merits of a more automated type of interference measurement. Data was collected via computer rather than scrolls of chart recorder paper. The fact that total average average power measurements were done in addition to the intended spectrum analysis indicates objectives were exceeded. The enormity and reliability of the data collected more than justifies the use of a computer based system. Few objectives were not achieved due to a more realistic estimation of what was attainable given the time constraints.

7. EQUIPMENT RECOMMENDATIONS AND COMMENTS .

(a) Diesel Generator

It was clear from this survey that with increased spectrum analyser sensitivity there was interference produced by this generator at a fairly low level, particularly significant on the max hold mode of operation. Hence a cage may be necessary for this generator in the future (for remote locations).

(b) Automation

An automated system under computer control with a (non-human) antenna rotator would be desirable, allowing unattended data gathering sections etc. However the development may require some man-hours (at a technical level).

(c) Calibration

More emphasis on this aspect is required particulary with the front end/spectrum analyser combination measurements.

8. GENERAL CONCLUSIONS

Positive aspects of the survey were clarification of observations made in the first interference survey. Specifically some of the 'unknown' sources of interference were identified to be the diesel generator and a poorly shielded frequency meter.

A fairly complete list of transmitters at both sites is given with information on their characteristics particularly their signal strengths. It should be noted that a significant portion of the transmitters listed would in fact lie outside the astronomical bands and thus can fairly safely be disregarded. As for transmitters in and immediately adjacent to these bands the strengths given indicate the level of rejection required to prevent adverse effects such as amplifier saturation.

In terms of the interference present it would seem that 408 then 327 MHz are problem frequencies, particulary at Culgoora. It is clear that tests done at Culgoora in the future will be required to be done in a locally quiet radio environment to yield unambiguous results. The two higher frequencies don't seem to suffer adversely from interference hence it seems minimal precautions will be necessary to undertake astronomical observations.

The appendices provide information on relating the tabulated data in the report to effects on the A.T. both in engineering and astronomical terms, complete with justification and assumptions.

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G. F. GERARD

APPENDIX A

EFFECTIVE BANDWIDTHS OF TRANSMITTERS

Problem Definition

Given a typical spectrum of a transmitter from a spectrum analyser, what is the effective bandwidth of the signal? Here we model the transmitter spectrum as being flat over the effective bandwidth (ie rectangular). The reference level is taken as the peak level of the spectrum (measured).

An implicit assumption is that the spectrum analyser resolution bandwidth is less than the approximate effective bandwidth of the signal ie the spectrum shows some structure.

Survey

Since we have taken the data digitally it is a relatively simple matter to determine the effective bandwidth as defined above. It amounts to taking inverse dB's then summing and dividing (averaging or integrating).

The results are given graphically on the following pages.

Since the spectrum analyser noise floor or the system noise may contribute significantly to the transmitter total measured power using this procedure (if say the maximun signal strength above this level is only 10dB or so), it was made possible to define the frequency limits over which the integration would be performed. This amounts to chosing the limits such that the furthest significant (or visible) sidelobes are included in the integration. The effective model signal is shown as a rectangle centred on the frequency of the peak level along with the selected integration limits.

Results

Typical effective bandwidths are ~10kHz.

Self Check

The last two diagrams shown are in fact the same transmitter which switched its modulation regularly each second or so. Given that the total power transmitted would probably remain constant in time for this signal we can verify:

- the consistency of this conjecture
- the correctness of the procedure above and of the equations used

(note the integration limits were chosen to be the same)

The differences in peak levels taken from the digital data (not the graphs shown) was 8.5dB = 7.08

Hence

'pseudo power' in frame 5 101.8

'pseudo power' in frame 6 13.9 x 7.08 = 98.4

a difference of 3.5% .

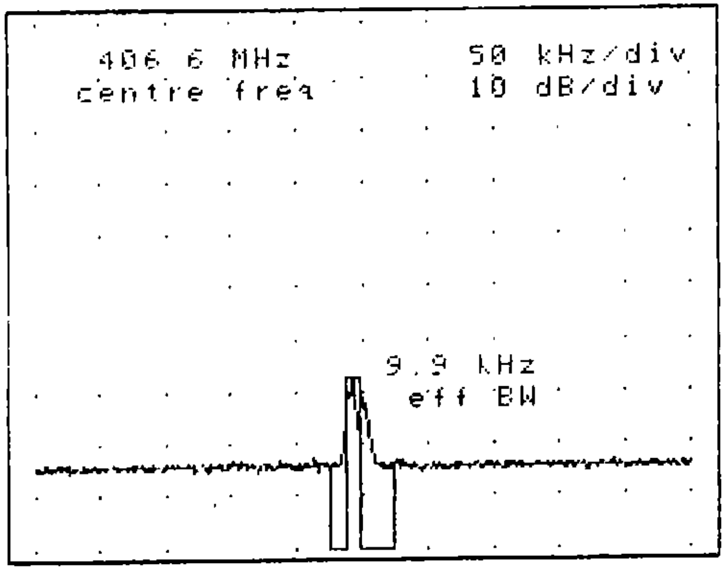
Given the noise present, plus the mode of spectrum analyser measurement (not true power levels ie not 'digital average' or 'sample' mode see HP 8569B manual), this indicates that the same total power level exists in both modulations within statistical uncertainity. This certainly is not obvious comparing the two spectra and indeed it would be impossible to humanly estimate that this was the case.

Note that frame 5 represents the greatest effective bandwidth (greatest spread) of a signal measured due principally to a lack of a dominating carrier (peak level usually).

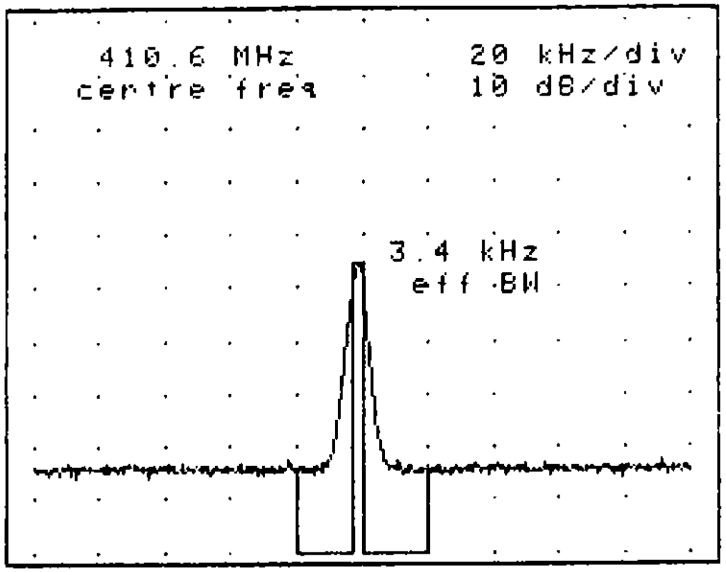
Conclusions

The effective bandwidth is usually irrelevant if the Resolution Bandwidth of the spectrum analyser measurements is greater than it.

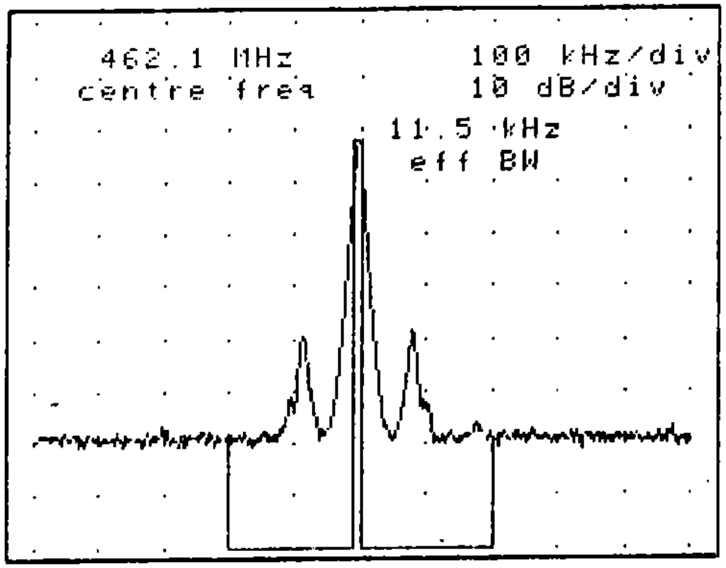
This appendix shows that the assumptions made elsewhere in the report are valid, namely we can assume the Resoution Bandwidth of the measurements is greater than the typical effective signal bandwidth.



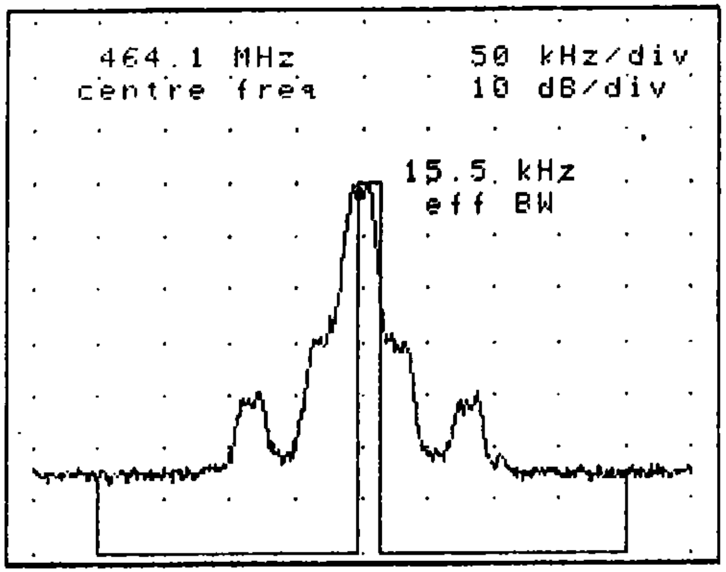
Frame 1



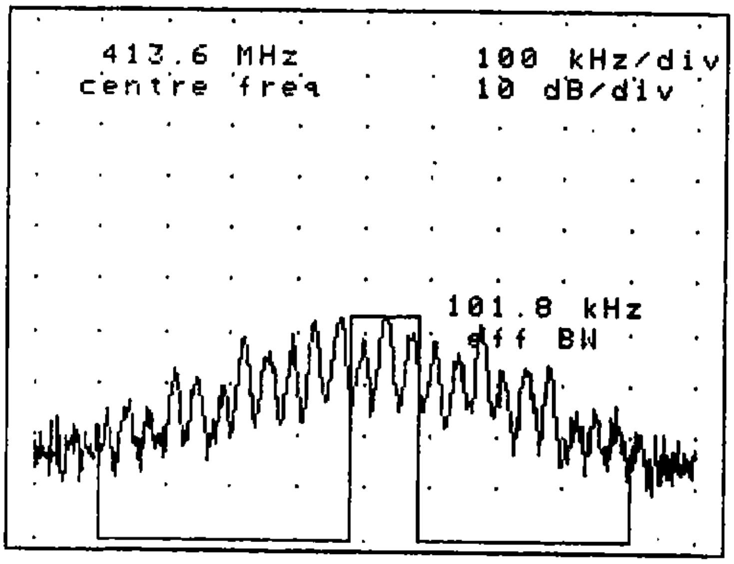
Frame 2



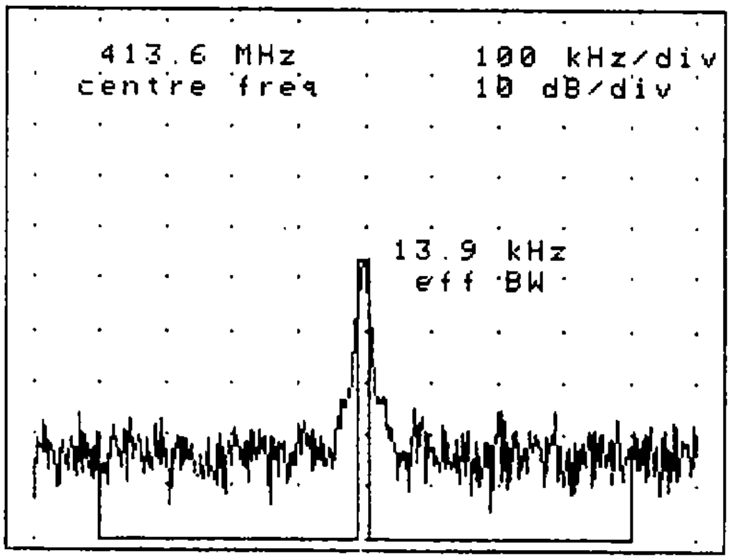
Frame 3



Frame 4



Frame 5



Frame 6

APPENDIX B

ESTIMATING THE HARMFUL EFFECT OF INTERFERENCE ON THE A.T.

(IN TERMS OF SYSTEM TEMPERATURE INCREASE)

Problem Definition

Given that interference from either a single or a number of transmitters (transmissions) results in an antenna temperature increase in the interference measuring equipment. What is the corresponding expected A.T. antenna temperature increase in the absence of rejecting filters etc? (We exclude broadband interference from this analysis.)

Symbol Definitions

Description	symbol	status
gain of interference test antenna	G^{i}_{o}	known
gain of A.T. antenna though side lobes	G^{AT}_{sl}	estimate
BW of interference equipment	B^{i}	known
BW of A.T. astronomical observation	B^{AT}	known
interference system temp increase	T^{i}_{ant}	known
A.T. system temp increase	T^{AT}_{ant}	desired

Equation

$$T^{AT}_{ant} = \frac{B^{i}}{B^{AT}} \times \frac{G^{AT}_{sl}}{G^{i}_{o}} \times T^{i}_{ant} \qquad \text{.........} \; (i)$$

ie just scale appropiately through bandwidth and gain ratios.

APPENDIX C

ESTIMATING THE EFFECTIVE SYSTEM TEMPERATURE INCREASE FROM SPECTRUM ANALYSER MEASUREMENTS

Problem Definition

Given an interferring signal from a relatively narrow band transmitter, what is the temperature increase induced in the system?

Symbol Definitions

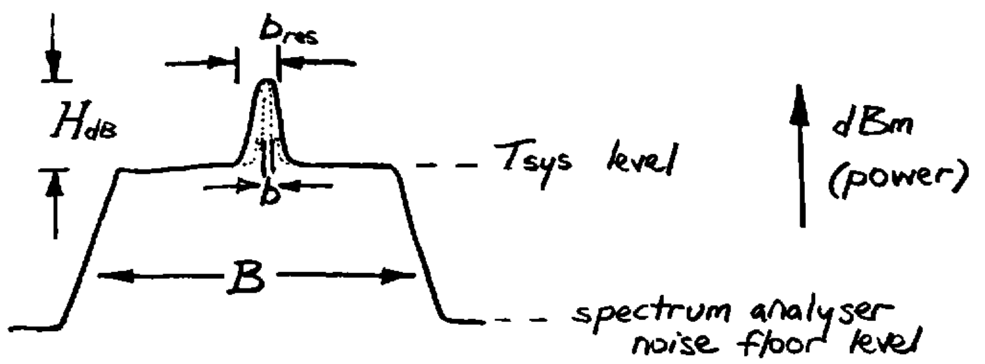
Description	symbol	status
noise bandwidth of system (receiver)	B	known
resolution bandwidth setting	b res	known
transmitter effective bandwidth	b	unknown
system temperature	T 'sys	known
transmitter power level above T sys	H dB	measured
system temperature increase due to transmitter	T eff	desired

Equation

The assumption here is that the effective bandwidth of the transmitter is less than the resolution bandwidth of the spectrum analyser (see Appendix A for justification).

ie $b_{res} > b$

Have spectrum analyser picture



Now let

$$H = 10^{(H\ dB/10)}$$

Then we have

$$H \cdot T_{sys} \cdot \frac{b_{res}}{B} = (H-1) \cdot T_{sys} \cdot \frac{b_{res}}{B} + T_{sys} \cdot \frac{b_{res}}{B}$$

total power (deg K) in b res bandwidth interval	transmitter contribution	system contribution

Thus the effective system temperature increase due to the transmitter is

$$T_{eff} = (H-1) \cdot T_{sys} \cdot b_{res}$$

provided the transmitter effective bandwidth is less than the resolution bandwidth setting on the spectrum analyser.

APPENDIX D

HARMFUL INTERFERENCE LEVELS TO A.T. ASTRONOMICAL OBSERVATIONS

Problem Definition

This appendix attempts to merge the various expressions of harmful levels of interference to astronomical observations which have appeared in the literature and elsewhere. In particular this appendix relates the following.

(i) Interference equipment sensitivity
(ii) CCIR Report 224-5 defined harmful interference levels
(iii) VLBA Memo #81
(iv) A.T. system temperature increase
(v) Measured levels

It is also necessary to consider a number of parameters which basically appear as assumptions or reasonable estimates in the analysis. Breifly these include;

(a) Length of typical A.T. astronomical observation
(b) Bandwidth of observation
(c) Line or Continuous spectral observation
(d) Spacial diversity of antenna array elements
(e) Interferring signal spectrum
(f) Estimated harmful A.T. system temperature increase

The qualitative effects of these factors is fairly straightforward but nonetheless important. Increasing (a) implies an increased level of instrument sensitivity. While for (b) it is basically the opposite. However in this case there is greater possibility of overload or amplifier saturation. Factors (c) and (e) are interrelated and any quantitative measure is meaningless without their relationship. Factor (d) effectively provides a buffer given that extremely widely spaced elements (eg 100km or so) reduce the possibity of interferring signal correlation from fixed terrestial transmitters. Factor (f) can be estimated from experience and bears a simple indirect relationship to (a).

Comparison

The basis of VLBA Memo #81 is an estimated harmful interference level would lie approximately 20dB below system noise power under the following conditions. Long antenna spacings (in arrays) improve interference rejection over single dish observations due to decorrelation. Considering the possibility of satellite interference the unwanted signal is assumed to come in through the astronomical telescopes sidelobes where the gain is ~10dB corresponding to less than 10 degrees from the boresight. Hence the quoted harmful interferring flux density is,

$$S_i = \underbrace{k\,B\,.\,\underbrace{T_s / 100}_{\text{est harmful syst temp increase}}}_{\text{power in B bandwidth interval}}\,.\;1 / A_e \qquad W\,m^{-2}$$

where A_e the effective area & sidelobe gain G is given by

$$A_e = G\,.\,\lambda^2 / 4\pi \quad m^2 \quad , \quad G = 10$$

In VLBA Memo #81 it is shown by explicit calculation that these levels of intereference are 30-40 dB higher (stronger) than the estimated harmful levels given in CCIR Report 224-5 (1982) for different frequencies. The CCIR values are however for single dish astronomical observations involving an integration time of 30 minutes.

A.T. example calculations

1420 MHz calculation

From the total power survey done with the more sensitive chart recorder/peak detector equipment, a maximun temperature variation of 4.0 degrees was recorded, as reference to table 3.7 will indicate. However this temperature rise or variation relates to the measuring equipment not the astronomical instrument (the A.T.). Appendix B shows the simple relationship between these two rises. Applying this, assuming the bandwidths of the two are the same, yields the equivalent induced A.T. temperature rise due to the same source of 'interference' to be 0.8 degrees. (A.T. sidelobe gain 10dB, 1420 MHz interference equipment horn gain 17dB, bandwidth (both) 10MHz).

Thus we find that this 'interference' is 17 dB below a system temperature estimate of 40°K @ 1420 MHz. Hence this level is of marginal concern, given the 20 dB factor of the VLBA Memo.

408 MHz calculation

Given that the A.T. system temperature @ 408MHz is about 100 degrees K and the measuring equipment upper bound sensitivity (stability) is approximately 4°K, we find the equivalent A.T. temperature rise to be 1.5°K (since the measuring equipment yagi gain is only 14 dB, an excess of only 4 dB over the A.T. sidelobes). Then this minimun detectable interference level is 18 dB below the A.T. system temperature. This figure closely corresponds to the 20 dB estimate given in the VLBA memo. Equivalently what this means is; the limit of detectability of the test equipment corresponds to the estimated harmful levels to the A.T. Hence any detectable interference on this total power mode is potentially harmful to astronomical observations.

We now present an explicit calculation to further show the inter-relationships. The resulting values are given in the astronomical unit Jansky's Jy which is just the spectral flux density scaled by 10 power 26. It is useful to model the interferring signal spectrum as being flat over the observation bandwidth.

We desire the minimun harmful level in Jansky's corresponding to interference 20 dB below the 100°K system temperature @ 408 MHz.

$$W_i = k \cdot T_s / 100 \cdot 1 / A_e \quad W\,Hz^{-1}\,m^{-2} \quad (10^{-26}\ Jy)$$

where

$$A_e = G \cdot \lambda^2 / 4\pi \quad m^2 \quad , \quad G = 10$$

$$= 0.43 \quad m^2$$

$$T_s = 100°\,K \quad , \quad k = 1.38 \times 10^{-23}$$

Hence $$W_i = 3200 \quad Jy$$

The CCIR report gives the value 3.2 Jy as the level harmful to single dish observations of 30 minutes appox duration. So this confirms the 30 dB factor found in the VLBA memo.

It should be pointed out that this buffer factor between the single dish and array values depends heavily on a number of other parameters particularly the spacing of the elements in the array. So the 30 dB value should only be associated with the A.T. configuration involving the inclusion of the Siding Spring and Parkes Antennas (and even better, Tidbinbilla) not just the compact array at Culgoora. This ensures element spacings of 100's km giving greater decorrelation of terrestial sources of interference. This buffer factor should be appended to a smaller value given less diverse array configurations.

It is clear from the measured data collected that at 408 MHz there exist a number of sources of harmful interference. Note however data is also given for transmitters outside the astronomical band in these tables.

The parameters for 327 MHz are very similiar to those at 408 MHz thus the same general comments apply. However interference is less extreme though still significant at this frequency.

Table D1 below summarises the results of this appendix.

TABLE D1 SUMMARY OF HARMFUL LEVELS (Bandwidth 10 MHz)

FREQUENCY	A.T. PARAMETERS		I.M.E. PARAMETERS		
	(1) syst temp	(2) harm. temp	ant. gain	(3) harm. temp	(4) min. temp
MHz	deg K	deg K	dB	deg K	deg K
327	100	1.0 0.8	14	2.5 2.0	4.0
408	100	1.0 1.0	14	2.5 2.5	4.0
1420	40	0.4 0.1	17	2.0 0.5	1.2
2295	40	0.4 0.2	17	2.0 1.0	5.0

Notes

(1) Based on presently realisable systems.

(2) The first column relates to a 20 dB scaling of the system temperatures as outlined in VLBA Memo #81. The second column is a figure based on CCIR Report 224. The single dish figures (in Jy's) are scaled by 30 dB to account for decorrelation then converted to temperature via the effective area and Boltsmann's constant.
The single dish CCIR Report 224-5 figures are:

327 MHz	1.6 Jy
408 MHz	3.2 Jy
1420 MHz	3.2 Jy
2295 MHz	20.0 Jy

for a continuum, 2000 second integration time, astronomical observation.

(3) Same as note (2). Also this column is a scaled version of the corresponding A.T. column via the I.M.E. antenna gain excess over the A.T. sidelobe gain estimate 10 dB.

(4) Minimun (rms) temperature variation due to intrinsic I.M.E. instability as seen on Total average power. All except 1420 MHz are based on interference survey I and preliminary calibration tests. We can see immediately that harmful interference levels are of the same order as the minimun detectable signal levels of the I.M.E.(as claimed in the text).

I.M.E. - Interference Measuring Equipment