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THE EFFECT OF CW INTERFERENCE ON THE THREE ELEMENT INTERFEROMETER

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Introduction

Some concern has been expressed about the possibility of serious interference problems with the VLA, because of the numerous transmitters near the site, especially at the White Sands Missile range. Since there are no published quantitative results on the effect of interference on interferometers, and since speculation by the NRAO staff led to results which differed by several orders of magnitude, we attempted to measure the effect directly, using a typical CW interfering signal.

The experiment occupied three nights of filler time on the Green Bank interferometer. During the first night a variety of power levels was tested, for a number of regions having a large range of hour angle and declination. On the basis of these observations, we decided that the most useful experiment would be to map a single region of the sky, once with the transmitter on, and again with the transmitter off. The last two nights - Jan 17/18 and Jan 18/19, 1973 - were devoted to these observations.

Measurement of the Power Density of the Transmitted Radiation

We attempted to measure the power density of the radiation field at 85-1, with that antenna in the service position. The transmitting antenna was directed towards 85-1, in order to minimize the effects of stray radiation.

This path is shown by the dashed line in Figure 1. The power density was measured directly with a horn and radiometer; in addition, the power received by the 85-1 radiometer was measured, in order to estimate the effective area of 85-1 outside of the main beam.

a) Power density of the interfering signal

Power into transmitting horn	10^{-2} w at 8110 MHz
Gain of transmitting horn	22 db
Power received by test horn at 85-1	76 dbm (2.5×10^{-11} w)
Gain of test antenna	19 db
Effective area $\frac{G\lambda^2}{4\pi}$	8.6×10^{-3} m^{-2}
Power density	2.9×10^{-9} w m^{-2}
Measured path loss	-127 db
Predicted path loss	-111 db

b) Effective area of 85-1

Ratio, signal deflection to cal deflection	14.4
Equivalent temperature of cal	4.4°K
Power received in transmitted signal	5.2×10^{-14} w
Effective area of 85-1	1.8×10^{-5} or 7.8 db below isotropic

The Observations

To prepare for the mapping measurement, the transmitting antenna was directed toward the microwave link tower near the control building (the solid line of Figure 1). Note that the movable antennas were located at stations 18 and 27. With the three antennas near stow position, and with 10 mw transmitted from the lab, the received power was measured:

85-1 6×10^{-16} - 2×10^{-15} w
85-2 8×10^{-16} - 5×10^{-15} w
85-3 4×10^{-15} - 2×10^{-14} w

We experienced considerable fading of the signal, even though the power into the transmitting antenna was constant and the antennas were fixed. The range in signals given above is typical of the variation observed over a period of 5 minutes.

At these power levels the correlators were saturating a fair fraction of the time, showing correlated flux of typically 10 flux units, with peaks to 20 f.u. on correlators involving 85-3. We therefore reduced the radiated power by 15 db for the tracking experiment. Assuming that the effective areas of the telescopes were equal to that determined for 85-1, then the power densities near the three telescopes were 2×10^{-12}, 3×10^{-12} and 2×10^{-11} w m^{-2} at 1, 2, and 3, respectively. The CW signal at 8110 MHz was transmitted during the entire track.

The region selected was at 09^h20, +50°, a region of empty sky that is far enough to the north to permit synthesis of a reasonable beam. The point source 3C 236, at 10^h, +35° was chosen as the calibrator; its flux at 8085 MHz is 0.96 f.u. The selected region, called IN50 on the accompanying figures, was tracked from -4^h to $+4.5^h$, with interruptions of 10 min each hour for calibration.

On the night of Jan 17/18, 1973, the region IN50 was tracked with the transmitter on, at the power levels described above. On the following night, the observations were repeated, with the transmitter turned off. The data were processed through the standard interferometer programs, except that those points with a high rms which would normally be rejected were saved. Maps were then made of both IN50 and 3C 236 for each night.

Figure 2 shows a short record of the analog output for both the calibrator 3C 236 and the blank region IN50. A peak-to-peak deflection of 50 mm (i.e. full scale) corresponds to 4 flux units. In general the RR correlators are affected more than the LL correlators, and the 1-3 correlators more than the 1-2 correlators. For the source IN50, it is interesting to note that although the analog correlators show amplitudes of up to 4 flux units, the maximum amplitude observed by the computer after a 30 second integration is 0.15 flux units, not significantly greater than noise. The observations of 3C 236 are more seriously affected, because the interference signal is much stronger. Thus for IR3R the mean amplitude is 0.75 f.u., with a standard deviation for a single 30 second integration of 0.27 f.u., compared with 0.96 and 0.05 f.u. respectively during the control observation the next night. The phase is less sensitive to interference; for the observation shown, the mean phase is $-3\overset{\circ}{.}5 \pm 1\overset{\circ}{.}9$, compared with $0\overset{\circ}{.}0 \pm 1\overset{\circ}{.}6$ during the control observation.

Discussion

Figure 3 shows the predicted synthetic beam pattern for the observations of the field IN50. It shows spiral sidelobes of 10-20 percent, with two near sidelobes of -40 percent.

Figure 4 shows the map of IN50 in which the interference is present. A peak of 9 on the map corresponds to 0.018 f.u. The map is dominated by positive and negative ridges as indicated by the rough contours shown. For comparison, refer to Figure 5, in which the peak is only 0.005 f.u., with the interference absent.

The banding structure suggests that the interference is dominant at one hour angle only, and inspection of the data showed that there was a period of about one hour during which the correlators were near saturation, and the rms values were very high. If these data are deleted, as they surely would be during a normal observation, the effect of the interference is dramatically reduced, as is seen on Figure 6. Here the peak is only 0.006 f.u., not significantly greater than in Figure 5, and the band structure has nearly disappeared.

A similar set of maps for the calibrator 3C 236 is given in Figures 7-9. The beam pattern (Figure 7) is much poorer, since the source was sampled only 10 minutes of each hour. The effect of the interference (Figure 8) is clearly present, but it has created no serious distortion in the map; compared with the map made with no interfering signal (Figure 9), sidelobes have been increased by between 5 and 10 percent of the peak intensity.

Conclusion

This test has demonstrated that a CW signal of power density $\sim 2 \times 10^{-12}$ w m^{-2}, which is present during the entire observation produces a serious distortion ($\sim$ 0.02 f.u.) in a map of a blank region of sky made with the three element interferometer. To reduce the effect to a level comparable with the noise, the power density should be 5×10^{-13} w m^{-2}. Given the uncertainties in these measurements caused by the fading of the signal, a conservative value of the maximum acceptable power density would be 1×10^{-13} w m^{-2}. CW signals of higher level than this will produce a measurable effect on the data.

It will be possible in practice to work with data taken during periods of interference of higher level than 1×10^{-13} w m^{-2}, by careful editing of the data. Thus, by throwing away only 8 percent of the data in this trial, we reduced the integrated effect of the interference on the map by a factor of three. The most sensitive method of detecting weak interference seems to be by its effect on the rms of the individual 30 sec data points. The temperature equivalent of the interfering signals during the run ranged between 0.03°K for 85-1 to 0.4°K for 85-3, or roughly 10^{-3} of the system noise; this would be very hard to detect with an unswitched receiver. On the other hand, the rms of a 30 sec point shows the effects of the interference throughout the entire run. The typical rms value is 450 (in arbitrary units), and, in normal operation points with an rms greater than 1000 are automatically rejected. Approximately 16 percent of the data with interference has an rms greater than 600, and 10 percent (including all of the data during the hour when the interference was worst) has an rms greater than 1000. Therefore, had the data been edited in the usual way, about 10 percent would have been automatically rejected, and a map similar to that of Figure 6 would have been obtained.

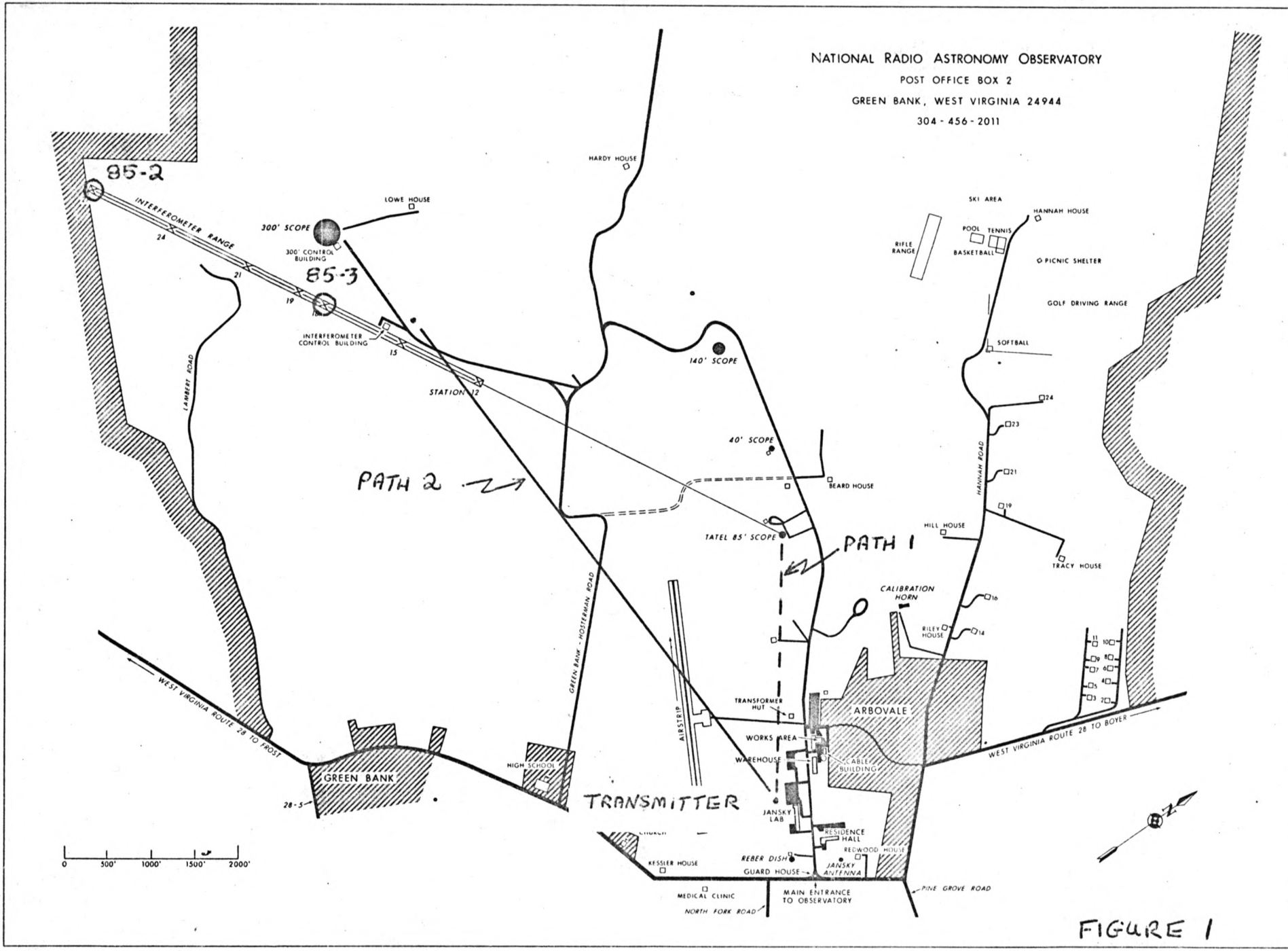
NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
GREEN BANK, WEST VIRGINIA 24944
304 - 456 - 2011
85-2
INTERFEROMETER RANGE
24
21
19
15
85-3
300' SCOPE
300' CONTROL BUILDING
LOWE HOUSE
HARDY HOUSE
INTERFEROMETER CONTROL BUILDING
STATION 12
LAMBERT ROAD
140' SCOPE
40' SCOPE
PATH 2
BEARD HOUSE
TATEL 85' SCOPE
PATH 1
SKI AREA
HANNAH HOUSE
RIFLE RANGE
POOL
TENNIS
BASKETBALL
PICNIC SHELTER
GOLF DRIVING RANGE
SOFTBALL
HANNAH ROAD
HILL HOUSE
TRACY HOUSE
CALIBRATION HORN
RILEY HOUSE
GREEN BANK - HOSTERMAN ROAD
AIRSTRIP
TRANSFORMER HUT
WORKS AREA
WAREHOUSE
CABLE BUILDING
ARBOVALE
WEST VIRGINIA ROUTE 28 TO FROST
WEST VIRGINIA ROUTE 28 TO BOYER
GREEN BANK
HIGH SCHOOL
28-5
TRANSMITTER
JANSKY LAB
RESIDENCE HALL
REDWOOD HOUSE
REBER DISH
JANSKY ANTENNA
KESSLER HOUSE
GUARD HOUSE
MEDICAL CLINIC
NORTH FORK ROAD
MAIN ENTRANCE TO OBSERVATORY
PINE GROVE ROAD
0
500'
1000'
1500'
2000'

FIGURE 1

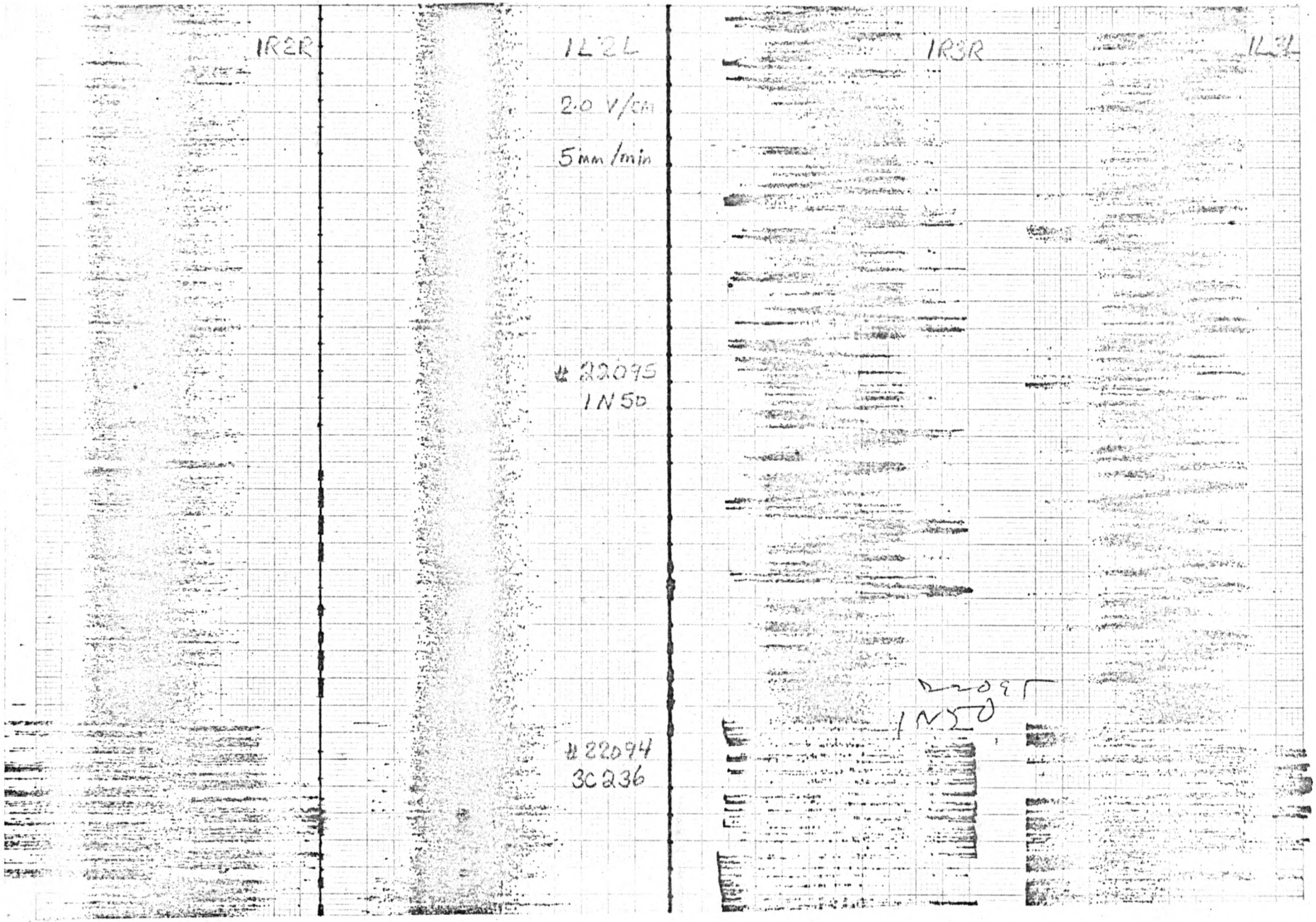
IR2R
IL2L
2.0 V/cm
5mm/min
22075
IN5D
22094
3C236
IR3R
IL3L
IN5D

FIGURE 2

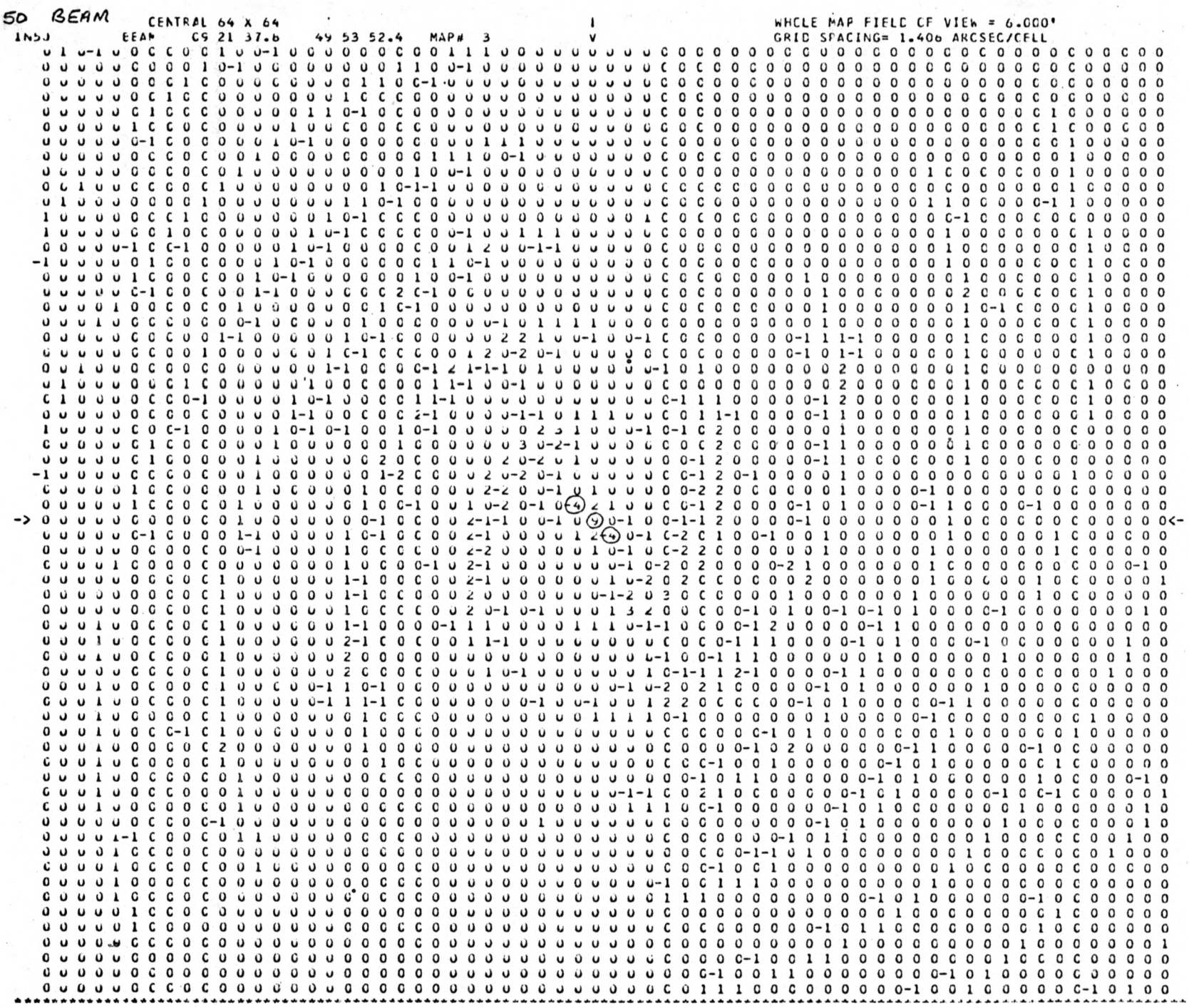
IN50 BEAM
CENTRAL 64 X 64
WHOLE MAP FIELD OF VIEW = 6.000'
GRID SPACING= 1.406 ARCSEC/CELL

FIGURE 3

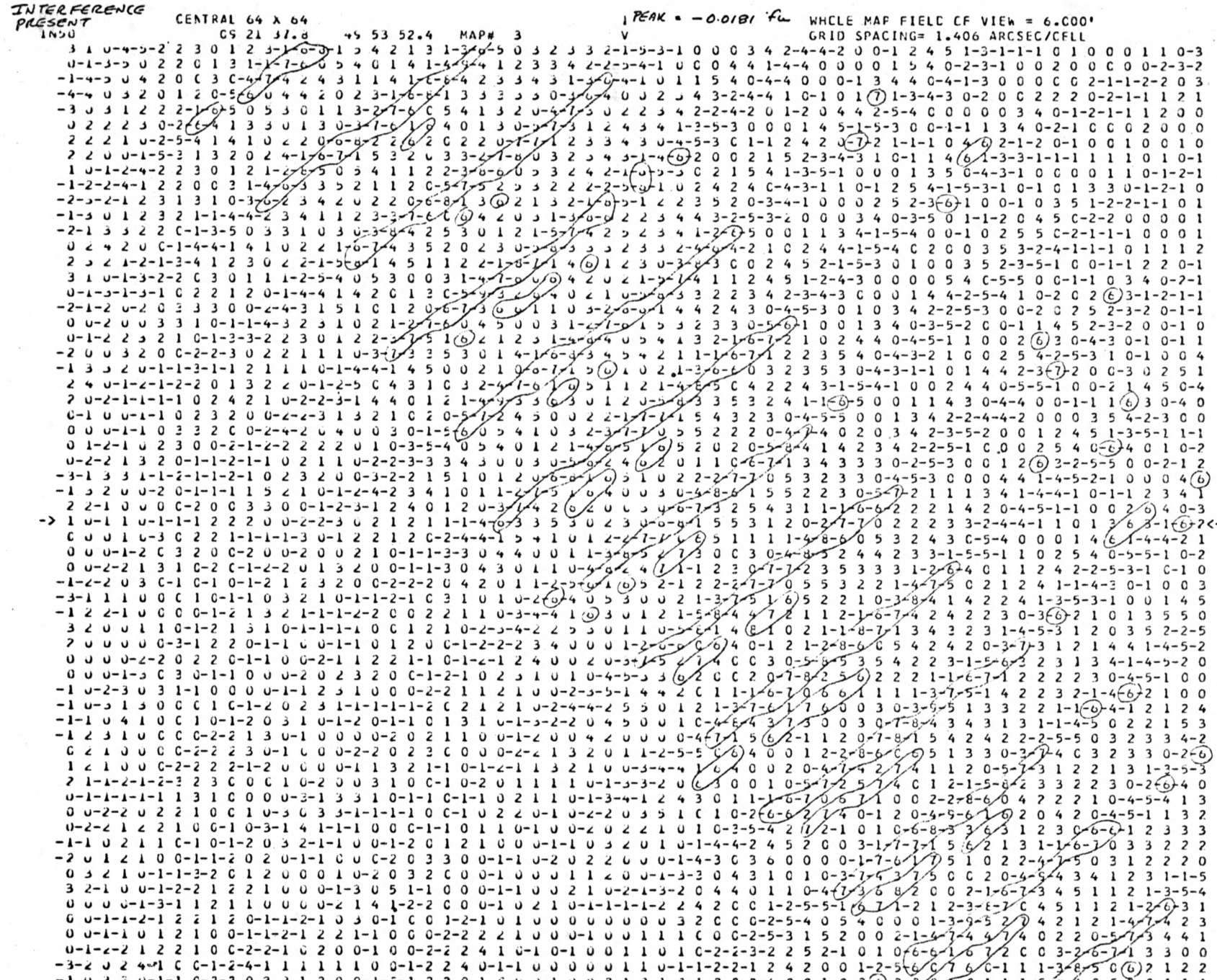
INTERFERENCE PRESENT
CENTRAL 64 X 64
CS 21 31.8 45 53 52.4 MAP# 3
PEAK = −0.0181 fu
WHOLE MAP FIELD OF VIEW = 6.000'
GRID SPACING= 1.406 ARCSEC/CELL

FIGURE 4

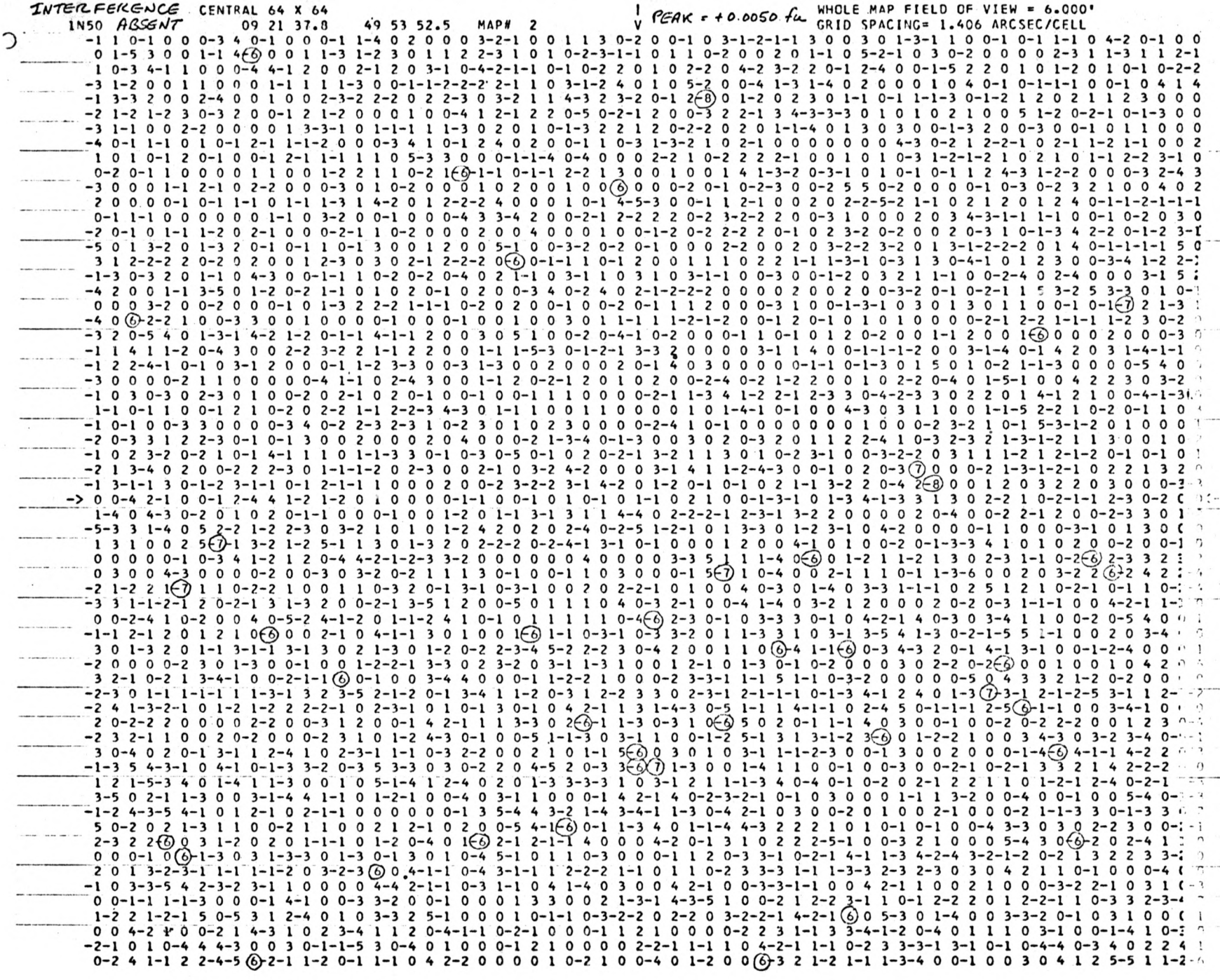
INTERFERENCE CENTRAL 64 X 64
1N50 ABSENT
09 21 37.8
49 53 52.5
MAP# 2
I V
PEAK = +0.0050 fu
WHOLE MAP FIELD OF VIEW = 6.000'
GRID SPACING= 1.406 ARCSEC/CELL

FIGURE 5


INTERFERENCE PRESENT
CENTRAL 64 X 64
SCAN 22.093 (48" when interference was maximum) has been omitted
PEAK = -0.0060 fu
WHOLE MAP FIELD OF VIEW = 6.000'
GRID SPACING= 1.406 ARCSEC/CELL
1N50
09 21 37.8
49 53 52.4
MAP# 4
V

FIGURE 6


3C236 BEAM
CENTRAL 64 X 64
WHOLE MAP FIELD OF VIEW = 6.000°
3C236 BEAM 10 04 29.4 35 01 49.5 MAP# 5
GRID SPACING= 1.40e ARCSEC/CELL

FIGURE 7


INTERFERENCE PRESENT
CENTRAL 64 X 64
PEAK = 0.963 fc
WHOLE MAP FIELD OF VIEW = 6.000'
GRID SPACING= 1.406 ARCSEC/CELL
MAP# 5

FIGURE 8

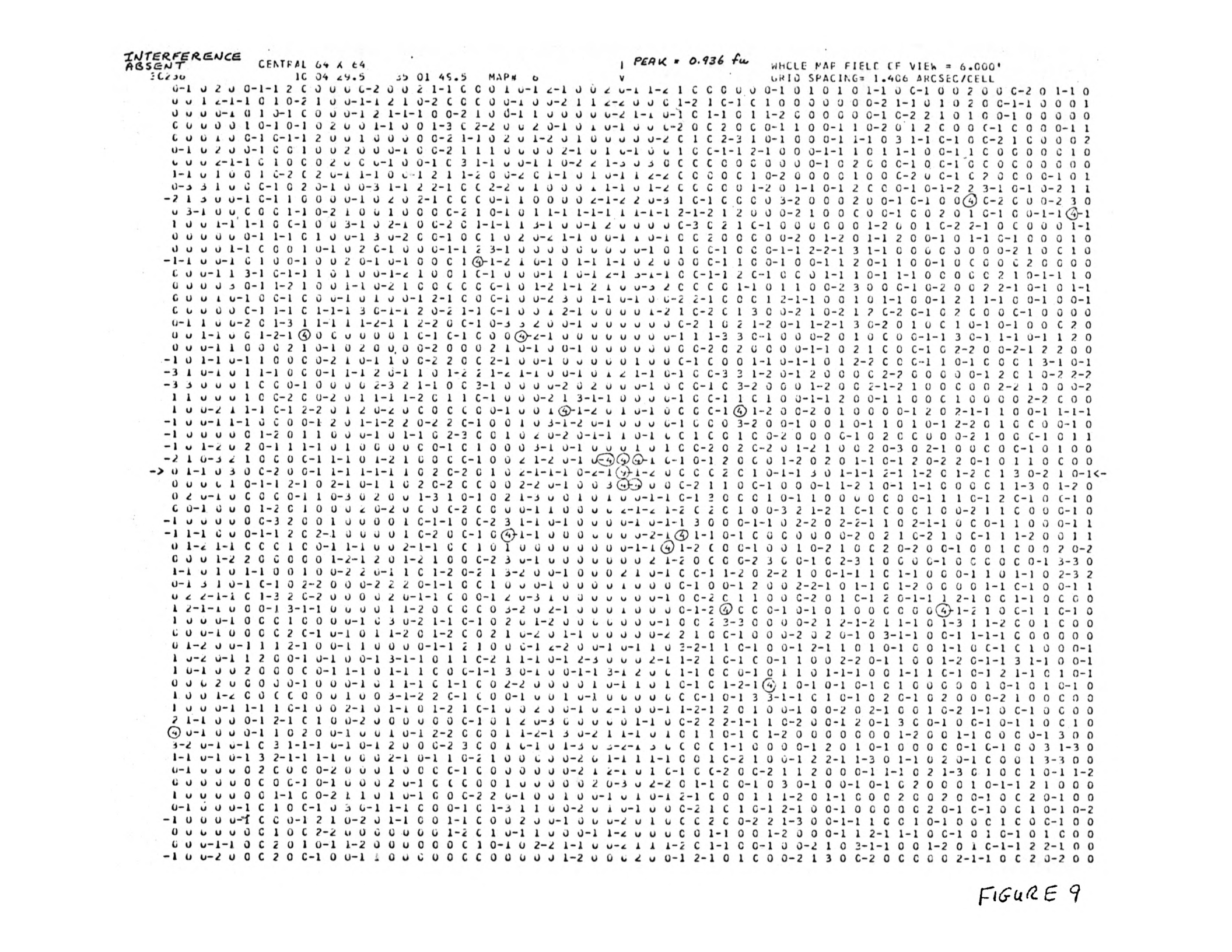
INTERFERENCE ABSENT
CENTRAL 64 X 64
PEAK = 0.936 fw
WHOLE MAP FIELD OF VIEW = 6.000'
GRID SPACING= 1.406 ARCSEC/CELL

FIGURE 9