MEASUREMENT OF CROSS POLARIZATION COEFFICIENTS FOR GMRT ANTENNAS.

A Project Report

Divya Oberoi

The radiation reaching a telescope may be polarized because either the emission mechanism itself was such that the radiation was polarized to begin with or something caused the radiation to get polarised on it's way from the source to the telescope. Major emission processes which give rise to polarized radiation are synchrotron emission and cyclotron emission. Scattering by ISM may cause light to get polarised as it passes through it. Farday rotation changes the chracteristics of the polarised light as it passes through magnetoionic medium. The study of polarization of light from various sources thus has information to convey which is not available otherwise.

In order to study polarization of radiation incident on a telescope one needs to specify completely the E field vector of the incoming radiation. This may be done by using two dipoles placed perpendicular to each other in the focal plane of the telescope, which define two axes in the focal plane.

The E field pattern at the focal plane of a perfect parabolic dish due to a completely polarised source (polarized along the y axis) is shown schematically on page 2. From this figure it should be evident that even a perfect dish gives rise to some cross-polarisation because the dipoles which detect the light are extended objects. Cross polarization increases because of surface errors on the dish and by the very presence of dipoles themselves as it causes the field pattern in the focal plane to be modified. This contribution to cross polarization is refered to as 'Instrumental Polarization'. Apart from this, there is another component which adds to cross polarization which is due to the fact that impedence between the cables which carry the signal for the two polarizatons is not infinite so there is some leakage from one polarization to the other. This contribution to cross polarization is refered to as 'Cross talk'.

The equations presented on page 2 express the signal actually detected by the telescope in terms of the signal which was incident on it and cross polarization coeff. This brings out the fact that if correct measurements of polarizaton are to be made the contribution of cross coupled terms needs to be subtracted out.

EXPERIMENT : The philosophy behind the experiment was that if one looks at an unpolarized source then the correlation which one gets between the two polariztions may be attributed to the instrument. In order to choose the sources to be observed a literature survey was done and a list of sources which had significant polarization at 327 MHz was compiled and also some sources with polarization below detectable limits were identified. The list of polarized sources is appended.

Some details of the experimental setup like sampler configuration etc. are listed on page 3 and 4. We first tried to construct the quantity defined in equation 1 on page 4 as a measure of cross polarisation. There are some problems with this approach. One, the power plot on page 5 shows that the power in correlations from different polarization different antennas is around 10 dB lower than that in different polarization same antenna. This should not have been the case because both the antenna are looking at the same source and cross polarisation for the two correlations under consideration should have been comparable. The second problem is that the quantity as it is defined is not a very good measure of cross polarisation because while the numerator involves only the contribution from the source and the background the denominator involves the source, the background and the system temperature. It needs to be correctly normalised by source flux before it can serve as a proper measure of cross polarization. As a purely diagnostic move, the signal coming from the two antennas was decorrelated to see if the power in different polarizations same antenna and different polarization different antenna became comparable. The result is presented on page 6. The conclusion is that is the extra power being picked up by the correlations between the same antenna is being picked up before the delays are introduced as they get decorrelated on introduction of delays.

An alternative approach was tried in order to circumvent the problems discussed above. The idea behind it was to assume the antennas involved to be identical and then correlate the same and different polarizations from them. We constructed a quantity defined in equation 2 page 4, which involves correlation of different polarization different antennas in the numerator and same polarization different antennas in the denominator in a manner that the gains of the antennas cancel out from the numerator and the denominator. This quantity is a much sturdier estimate of cross polarizations because of the fact that correlation between same polarization different antenna gives you a fringe and the fringe amplitude is proportional to source strength. The cross polarisation must also be modulated by the same fringe frequency as it is nothing but self polar contribution leaking from one channel to the other. This allows one to pick out the amplitude corresponding to the fringe frequency from the correlation between different polarization different antennas. This relieves one of the problem of disentangling the noise floor from the actual signal, which is quite an advantage. Page 7 shows a typical plot of self polar and cross polar correlations.

The methodology of the experiment, the sources used and the data

analysed are listed on page 8. The results obtained were
D(USB) = 1.95 +/- 0.65 D(LSB) = 2.22 +/- 0.72 Page 9 presents a comparison of the cross correlation coefficients obtained by using the two different expressions mentioned on page 4.

In order to get a feel for how the cross correlation coeffs. vary as the source is sitting at different positions in the beam, the following experiment was done. A slew with known speed was performed while tracking a source. The results of the experiment are appended. The cross polarization coefficient (as defined in equation 2 page 4) is between 5 and 10 percent at the nulls of the main beam.

MEASUREMENT OF CROSS POLARIZATION COEFFICIENTS FOR GMRT ANTENNAS.

- WHY STUDY POLARIZATION ?
- HOW DOES ONE DO IT ?
- MEASUREMENT OF X POL COEFF.
- RESULTS

INFORMATION FROM POLARIZATION.

POL^{n} DUE TO 1.) EMISSION MECHANISM
2.) PROPAGATION EFFECT

EMISSION MECH.

SYNCHROTRON EMISSION $B_{\perp}$

CYCLOTRON EMISSION

PROPAGATION EFFECTS

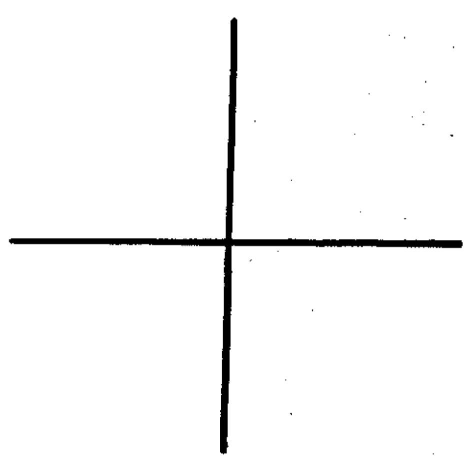
SCATTERING

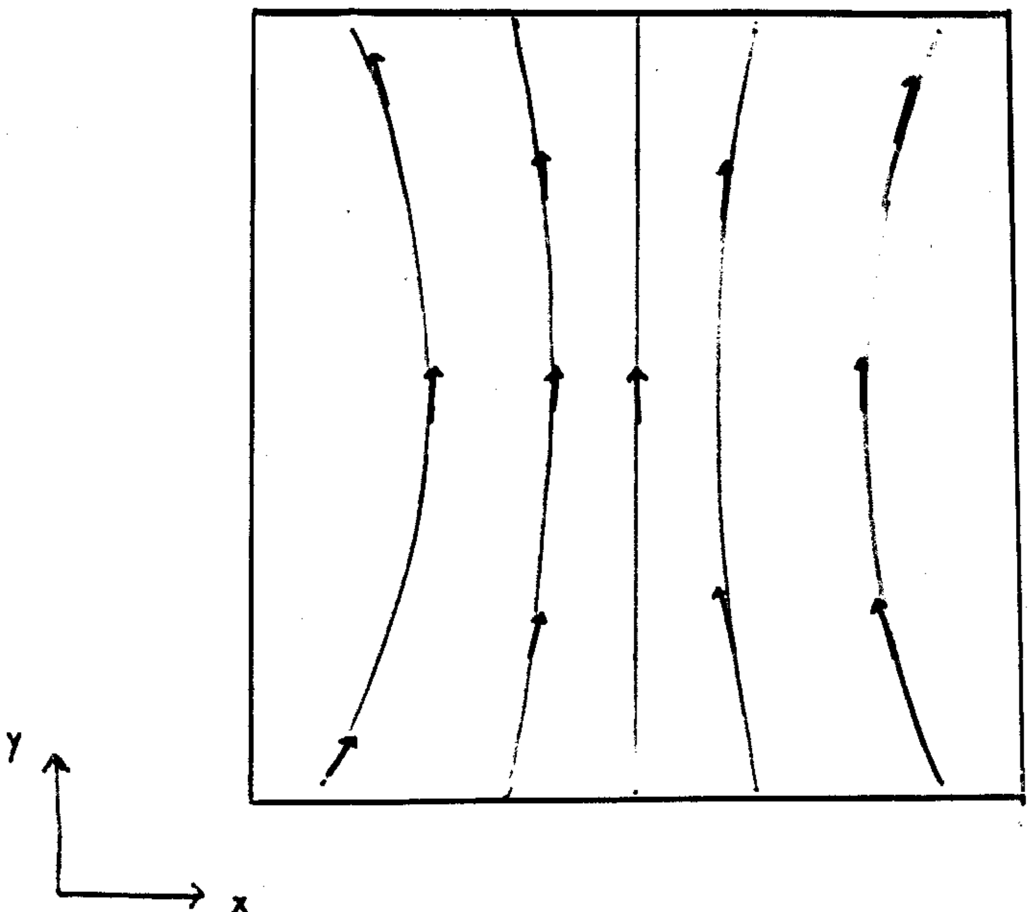
FARADAY ROTATION $B_{\parallel}$

EMISSION AT DIFFERENT DEPTHS IN THE OBJECT (FRONT BACK DEPOL^{n})

IN ORDER TO STUDY POLARIZATION....

PT. SOURCE AT INFINITY → PLANE WAVE





FIELD PATTERN AT THE FOCAL PLANE OF A (PERFECT) PARABOLIC DISH

INSTRUMENTAL POLARISATION.

CROSS TALK

CROSS COUPLING COEFF.

$$v_R = E_R \, e^{-i\chi} + \underline{D_R} \, E_L \, e^{i\chi}$$

$$v_L = E_L \, e^{i\chi} + \underline{D_L} \, E_R \, e^{-i\chi}$$

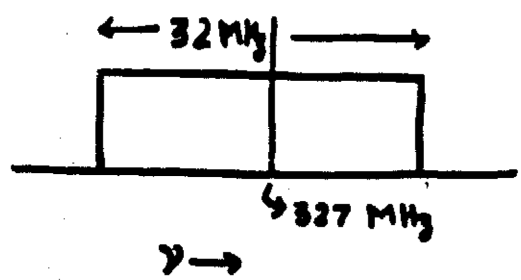
χ - parallactic angle
E_L + E_R - true ⊙ polarised signal incident
v_L + v_R - signal measured.
D_L + D_R - cross coupling coeff.

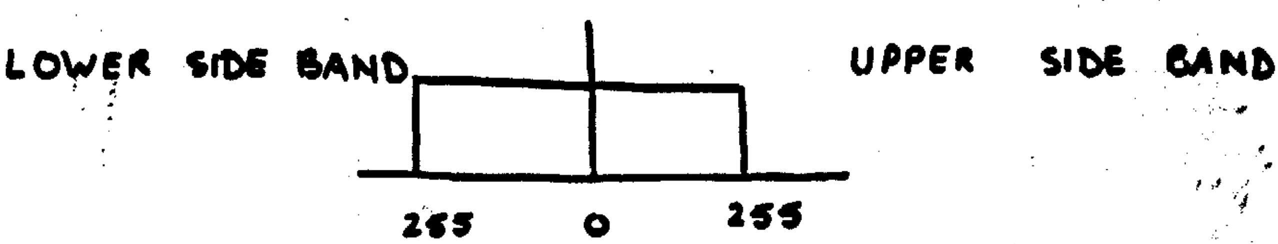
CORRECT MEASUREMENT OF POLARIZATION REQUIRE THAT THE CROSS COUPLED TERMS BE SUBTRACTED OUT.

EXPERIMENT

ANTENNAS USED	-	C_3, C_{12}
FREQ	-	327 MHz
BAND WIDTH	-	32 MHz
BEAM SIZE	-	$1^\circ.425 = 85'.50$
T_{sys}	-	120° K

FOR EACH POLARIZATION





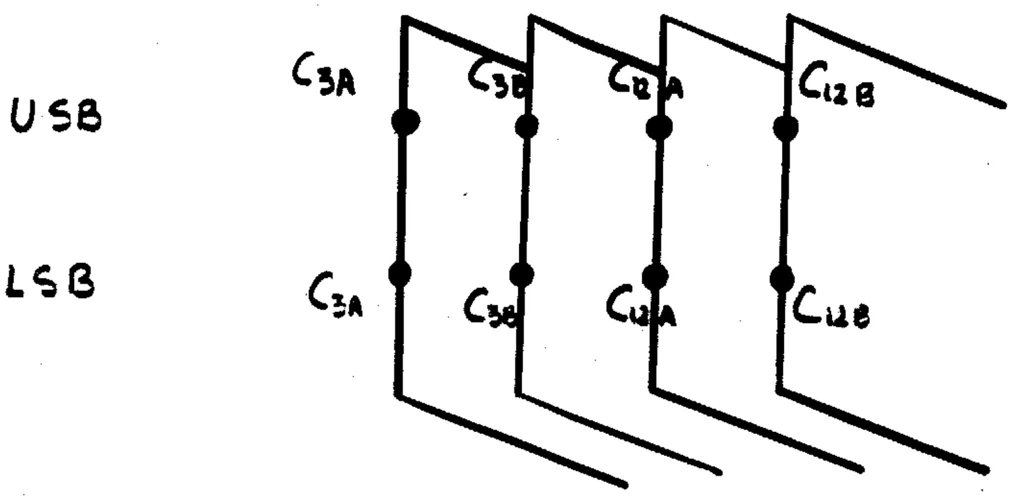
BASE BAND - 2 SIDE BANDS OF 16 MHz EACH FOR EACH POL^n.

IDEA - LOOK AT AN UNPOLARIZED SOURCE. ANY CORRELATION WHICH IS OBSERVED BETWEEN THE 2 POL^{n}S IS CONTRIBUTED BY THE INSTRUMENT.

LOOK AT (C_{3A}, C_{3B})

CORRELATION OF POL^n A FROM ANT. C_3 WITH POL^n B FROM ANT. C_3.

SAMPLER CONFIG.



CORRELATIONS AVAILABLE

ALL SELF CORR.

ALL CROSS CORR. IN EACH SIDE BAND.

$$D \equiv \frac{(C_{3A}, C_{3B})}{\left\{(C_{3A}, C_{3A})\ (C_{3B}, C_{3B})\right\}^{1/2}}$$

PROBLEM !!

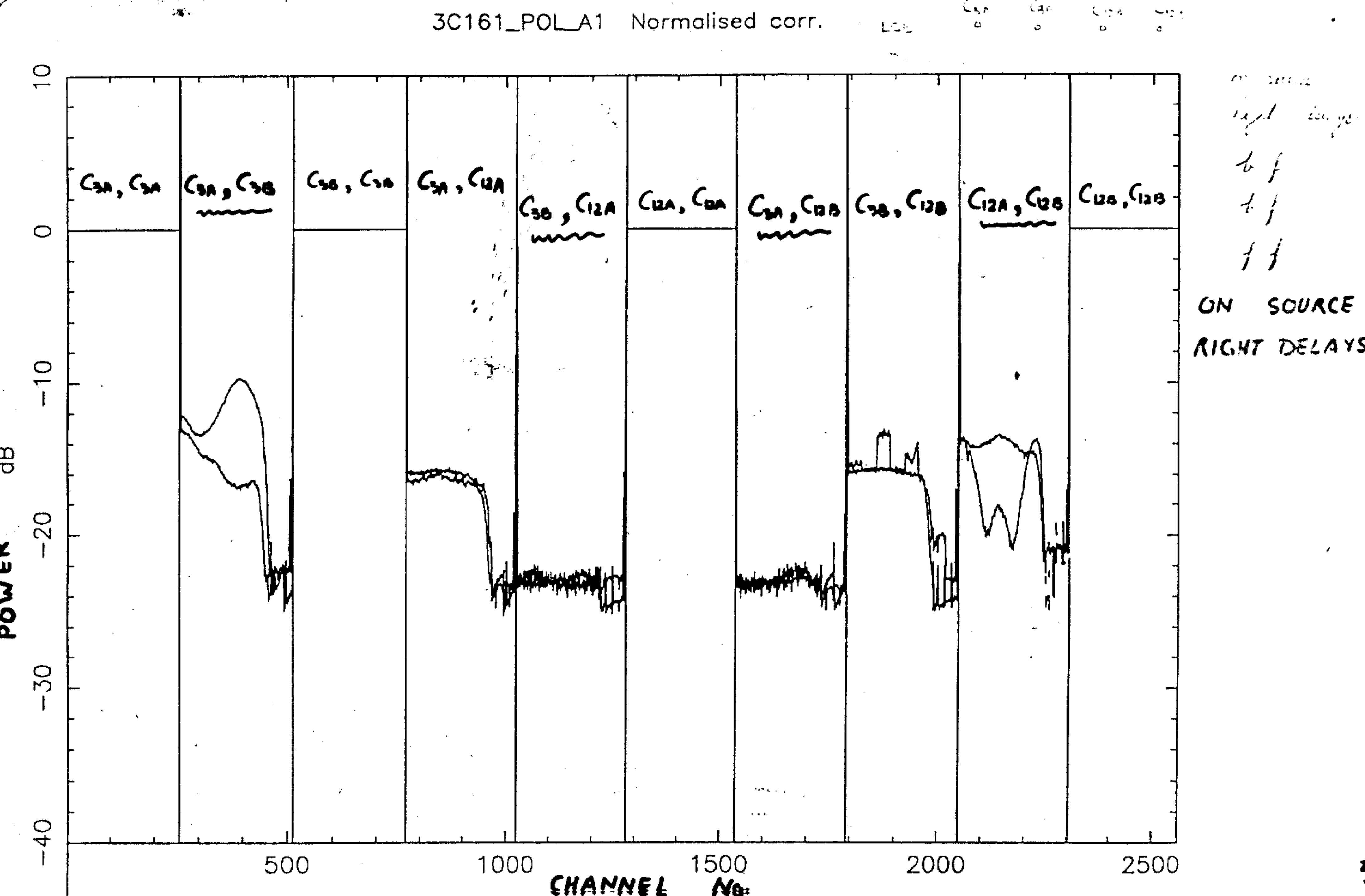
ALTERNATIVE APPROACH.

ASSUMPTION - IDENTICAL ANTENNAS (EXCEPT FOR THE GAINS)

$$D \equiv \left\{\frac{(C_{3A}, C_{12B})\ (C_{3B}, C_{12A})}{(C_{3A}, C_{12A})\ (C_{3B}, C_{12B})}\right\}^{1/2}$$

ADVANTAGE

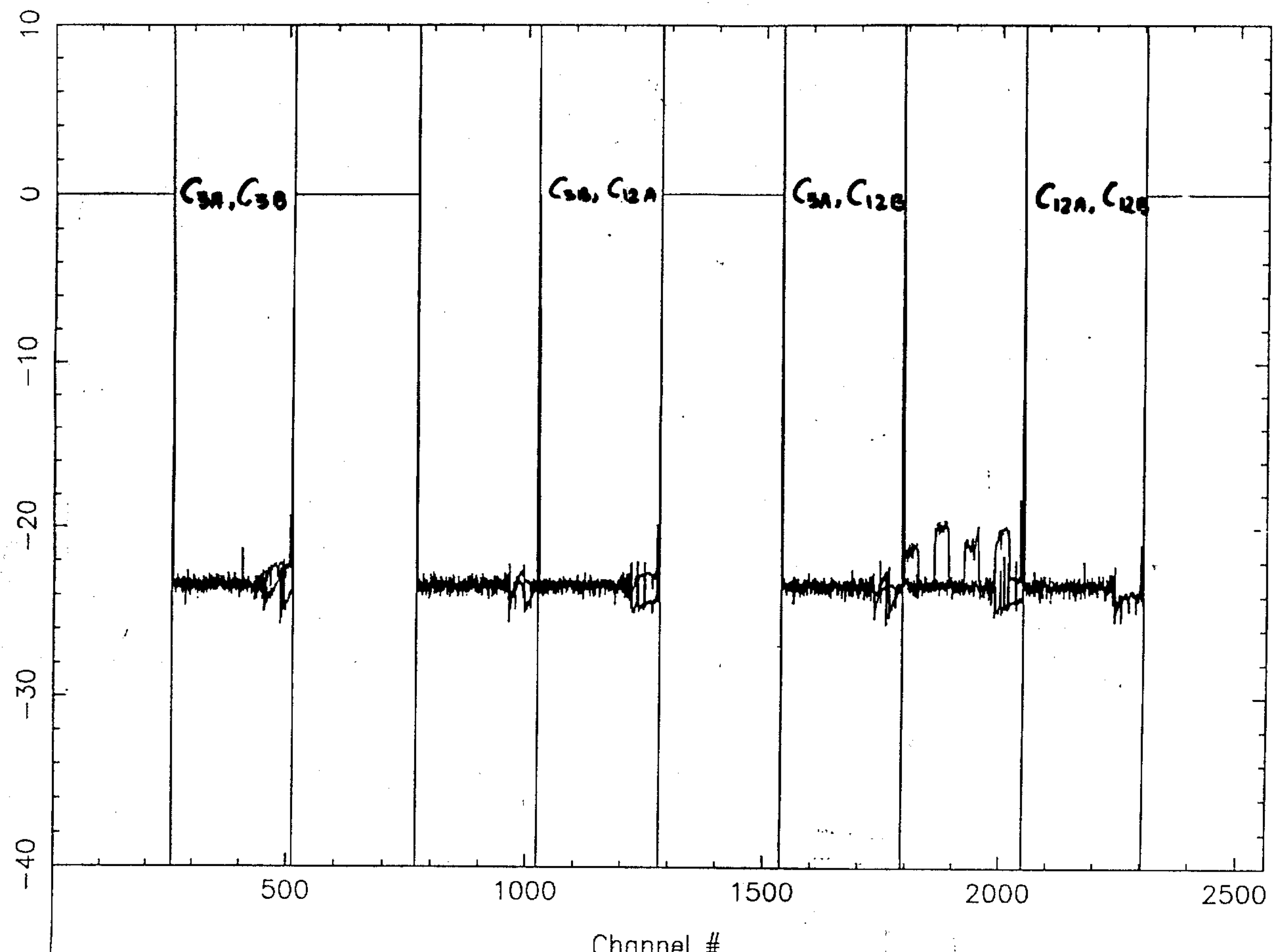
SELF CORR. BETWEEN DIFFERENT ANT. ⇒ FRING
X CORR. SHOULD ALSO HAVE THE SAME PERIOD. ALLOWS ONE TO PICK OUT AMPLITUDES CORRESPONDING TO THIS PERIOD IN SELF & Xs.



3C161_POL_A1 Normalised corr.
10
0
−10
−20
−30
−40
POWER dB
500
1000
1500
2000
2500
CHANNEL No:
C3A, C3A
C3A, C3B
C3B, C3B
C3A, C12A
C3B, C12A
C12A, C12A
C3A, C12B
C3B, C12B
C12A, C12B
C12B, C12B
ON SOURCE
RIGHT DELAYS

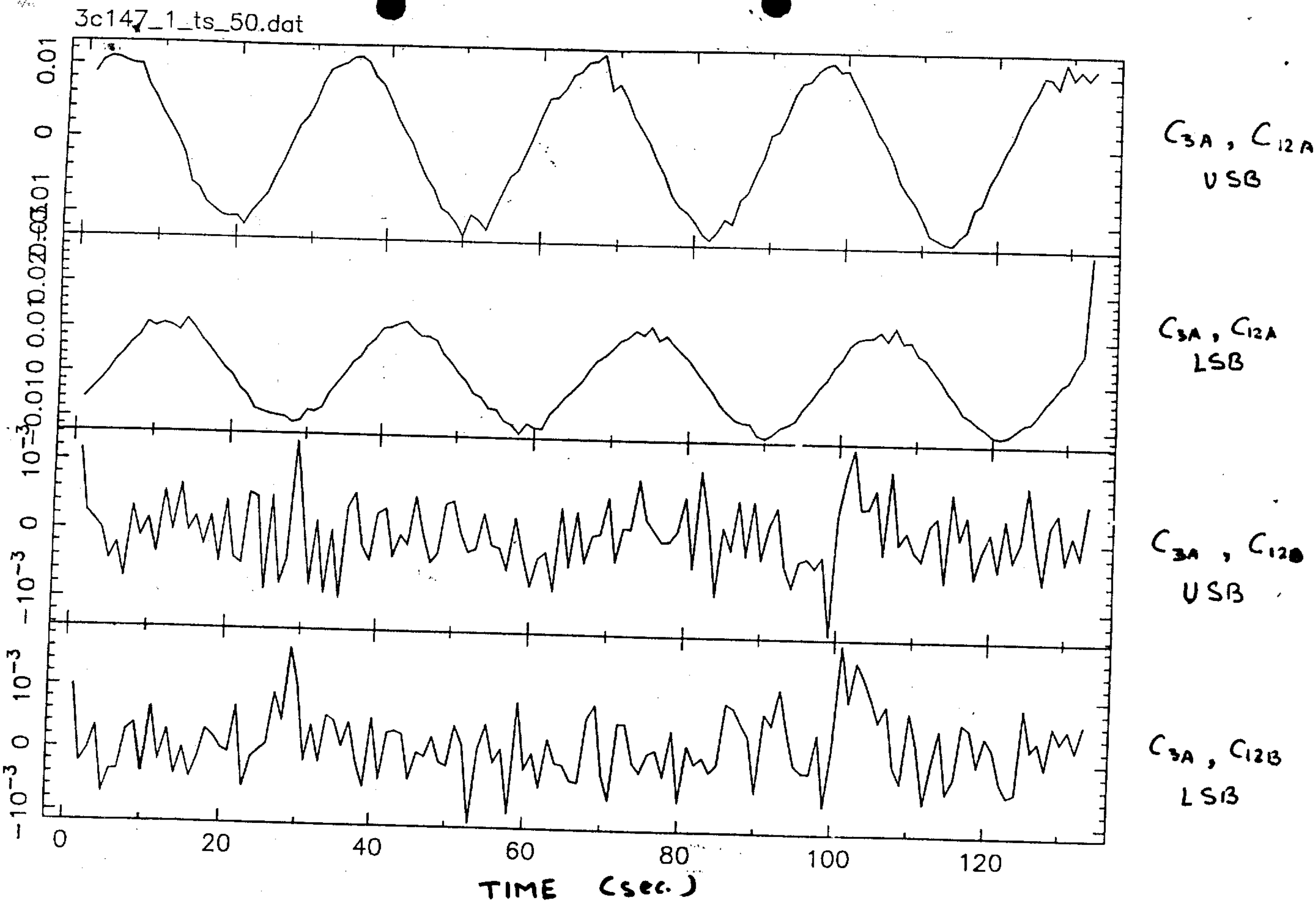
5.

3C161_POL_B1 Normalised corr.



on source
wrong delays
10
16
13

ON SOURCE
WRONG DELAYS



3c147_1_ts_50.dat
C3A , C12A USB
C3A , C12A LSB
C3A , C12B USB
C3A , C12B LSB
TIME (sec.)

7.

METHODOLOGY.

- FIT SINES TO FRINGES IN SELFS (QDP)
  - YIELDS PERIOD
- PICK OUT THE AMPLITUDES CORRESP. TO THIS PERIOD IN SELFS + CROSSES USING FT + PLUG THEM IN D.

SOURCES

3C 147	50 Jy	1"
3C 161	60 Jy	3"
CYG A	4700 Jy (408 MHz)	2'
HYDRA	67 Jy (960 MHz)	

DATA ANALYSED

CHANNEL # 25, 50 (150)

RIGHT DELAYS

ON SOURCE

RESULT

ON AXIS

$D_{USB} = 1.95 \pm 0.65$ %

$D_{LSB} = 2.22 \pm 0.72$ %

$D = \text{MEAN} \pm \text{RMS}/\sqrt{N}$

N – No OF DATA POINTS USED TO COMPUTE THE MEAN = 12

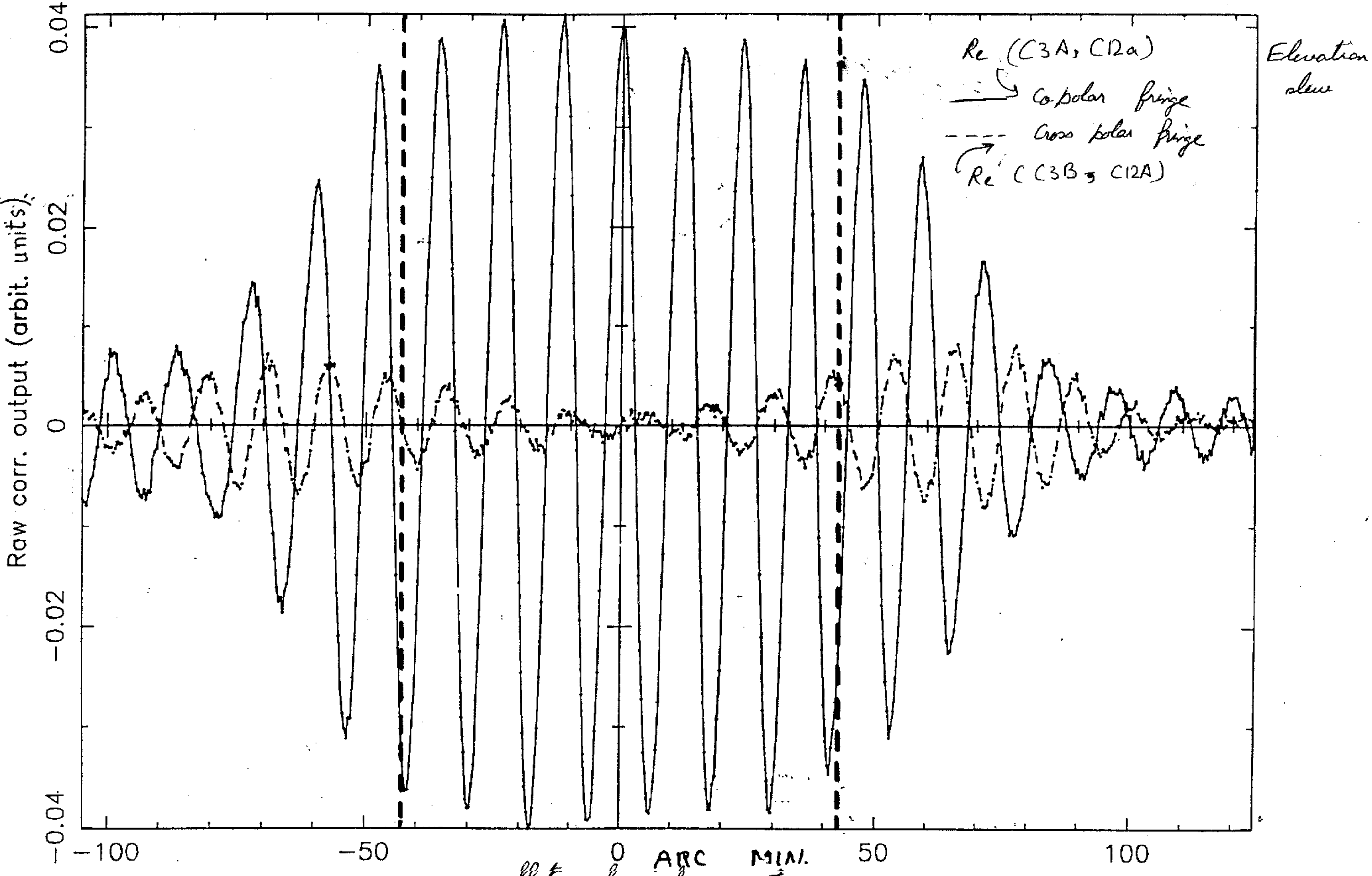
$$\frac{(C_{3A}, C_{3B})}{\sqrt{(C_{3A}, C_{3A})(C_{3B}, C_{3B})}}$$

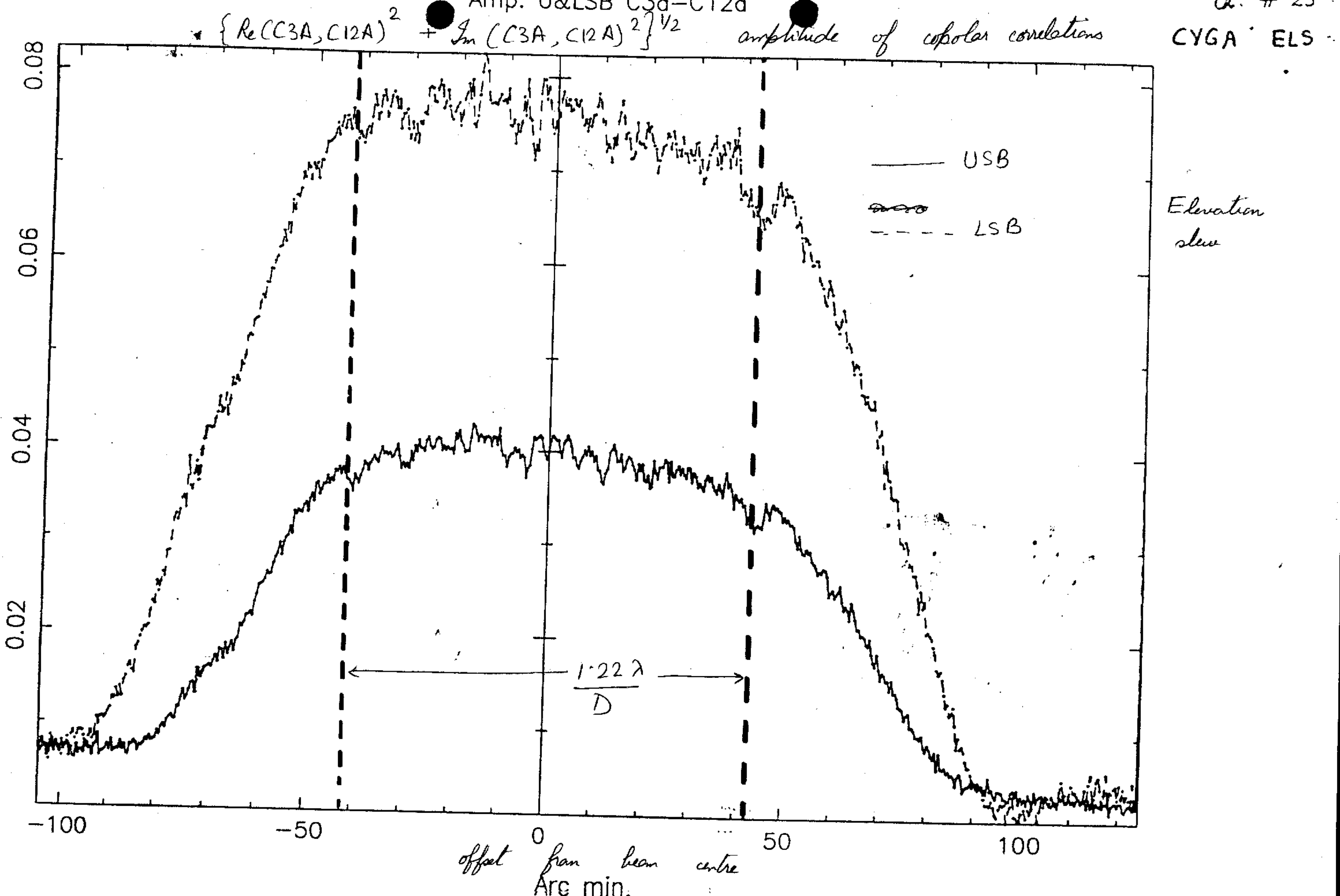
$$\left\{ \frac{(C_{3A}, C_{12B})(C_{3B}, C_{12A})}{((C_{3A}, C_{12A})(C_{3B}, C_{12B})} \right.$$

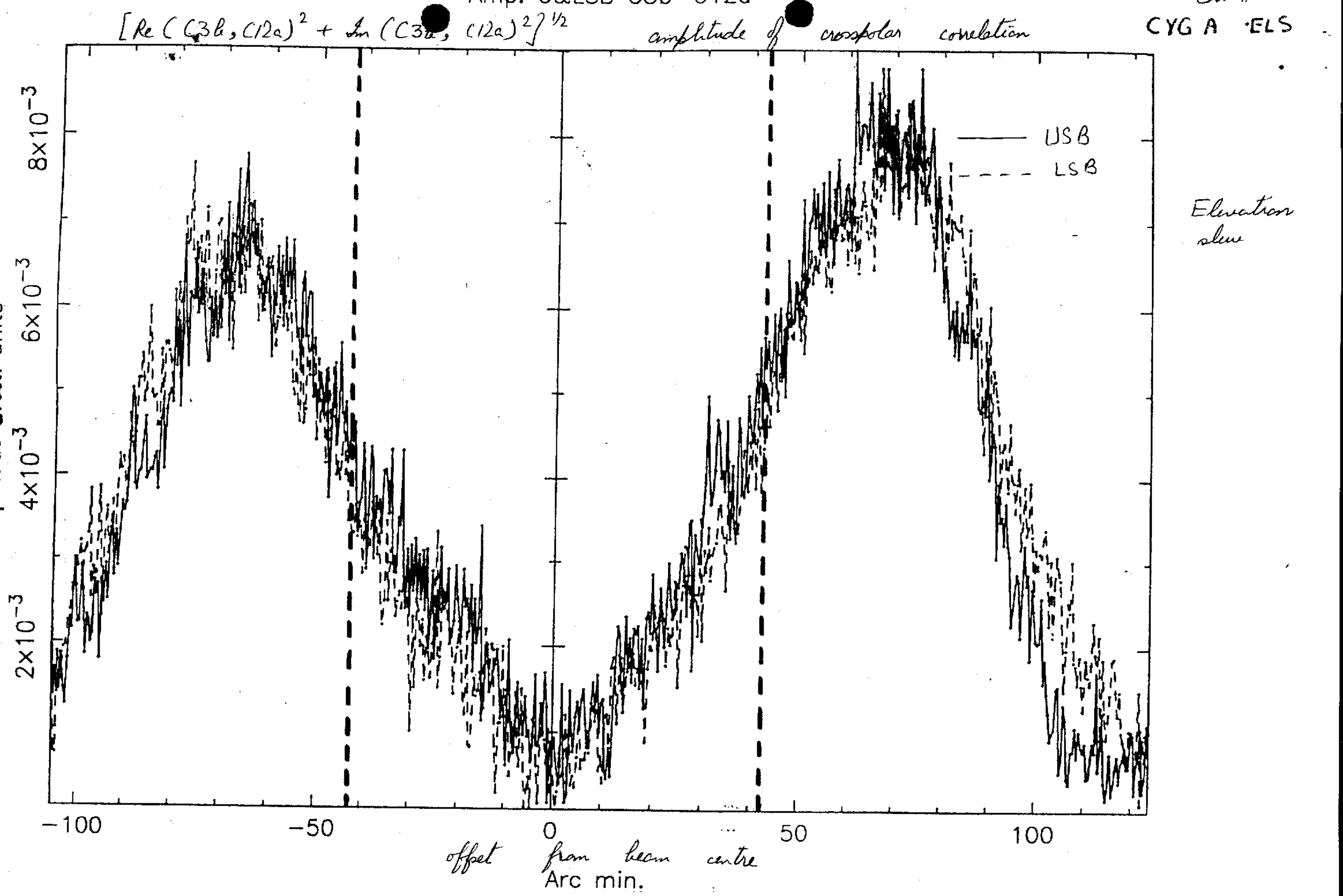
3C147	ON SOURCE		
# 25	$2{\cdot}667 \times 10^{-2}$	$1{\cdot}752 \times 10^{-2}$	USB
	$2{\cdot}999 \times 10^{-2}$	$2{\cdot}405 \times 10^{-2}$	LSB
# 50	$2{\cdot}876 \times 10^{-2}$	$2{\cdot}511 \times 10^{-2}$	
	$2{\cdot}461 \times 10^{-2}$	$2{\cdot}406 \times 10^{-2}$	
3C161	ON SOURCE		
# 25	$4{\cdot}418 \times 10^{-2}$	$3{\cdot}107 \times 10^{-2}$	
	$5{\cdot}166 \times 10^{-2}$	$4{\cdot}036 \times 10^{-2}$	
# 50	$3{\cdot}389 \times 10^{-2}$	$2{\cdot}746 \times 10^{-2}$	
	$4{\cdot}594 \times 10^{-2}$	$3{\cdot}379 \times 10^{-2}$	

CYG A ... Ch. # 25

USB Re C3a–C12a & C3b–C12b



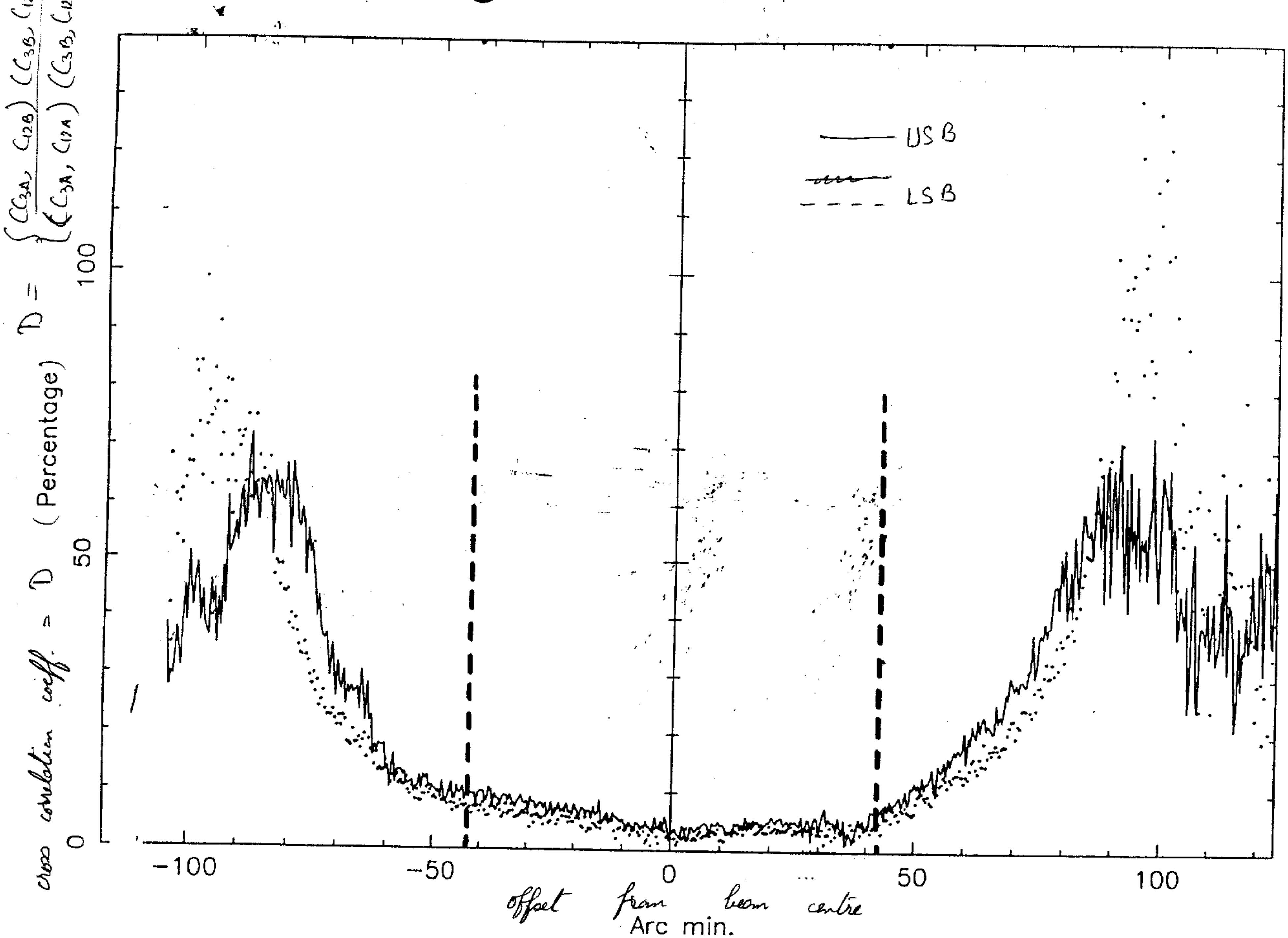

Amp. U&LSB C3a–C12a
{Re(C3A, C12A)^2 + Im(C3A, C12A)^2}^1/2
amplitude of copolar correlations
CYGA ELS
USB
LSB
Elevation slew
1·22 λ / D
0.08
0.06
0.04
0.02
−100
−50
0
50
100
offset from beam centre
Arc min.



[Re (C3b, C12a)^2 + Im (C3a, C12a)^2]^1/2
amplitude of crosspolar correlation
CYG A ELS
USB
LSB
Elevation slew
8×10^-3
6×10^-3
4×10^-3
2×10^-3
−100
−50
0
50
100
offset from beam centre
Arc min.

Normalised cross pol. coeff. USB & LSB

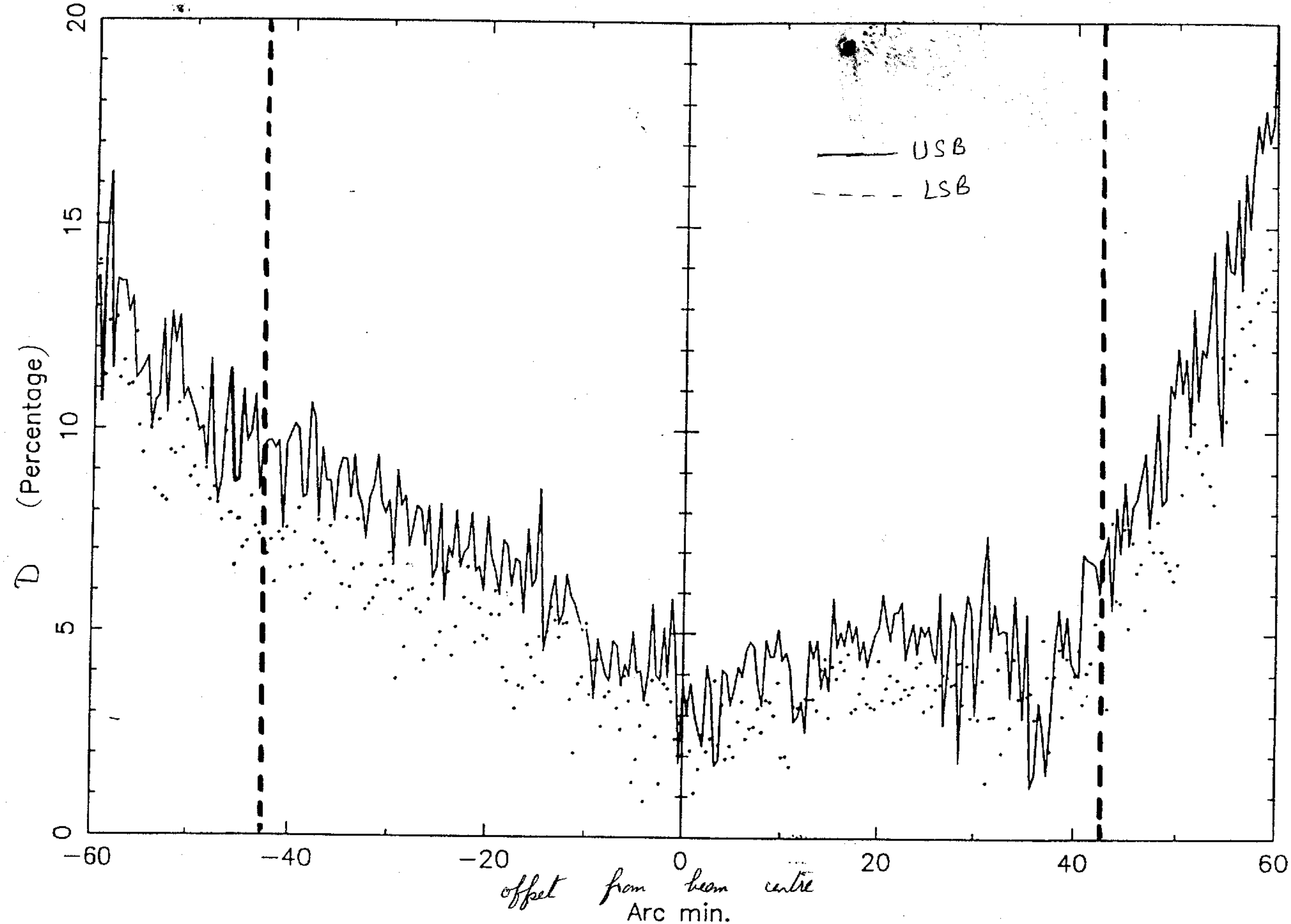
Cl. #25



Elevation slew

Normalised cross pol. coeff. USB & LSB

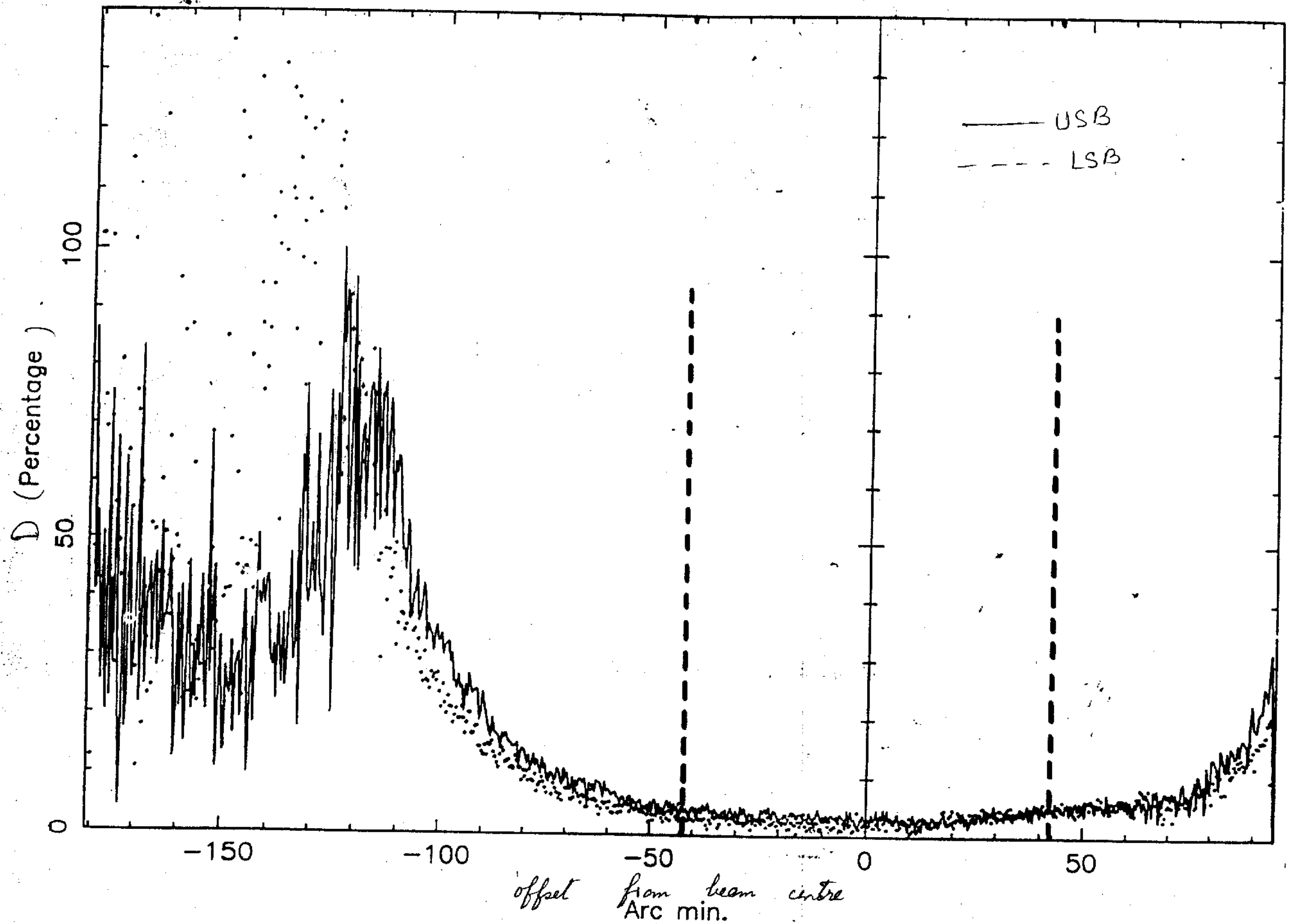
Ch. # 25



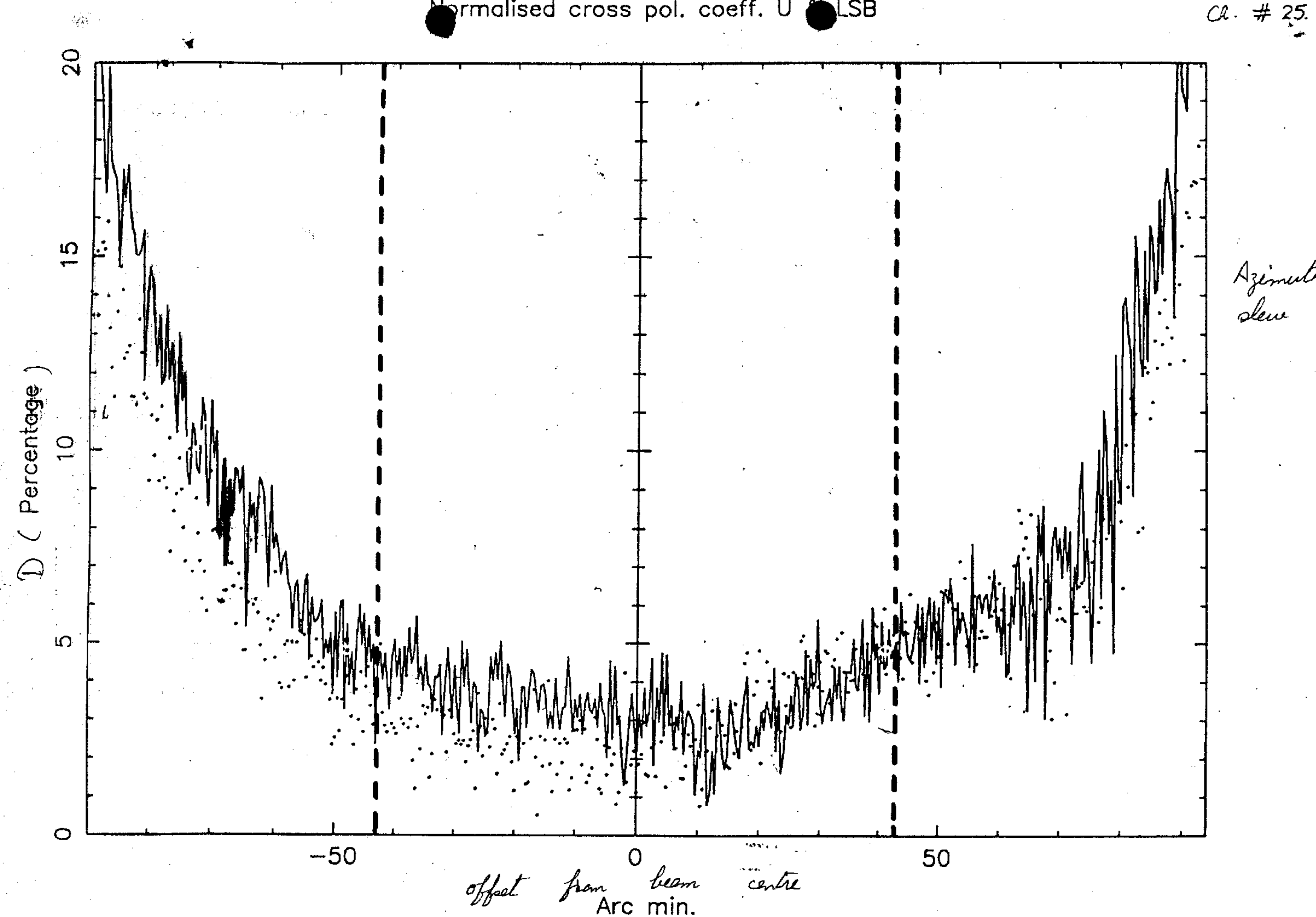
Elevation slew

rmalised cross pol. coeff. U & SB

a. #25



Azimuth slew



Normalised cross pol. coeff. U & LSB
Ch. # 25.
D (Percentage)
0
5
10
15
20
−50
0
50
offset from beam centre
Arc min.
Azimuth slew

CALIBRATORS

RA	DEC	SOURCE	FLUX (Jy)	m (%)	Pol flux (Jy)	ang size arc sec
34	+ 329	3C 48	(612 MHz) 20'60	5 →		
			(327'5) 42'7 ± '3		1	
33	+ 295	3C 123	(318) 135'45 ± 452			
			(612) 60'85	7	4'25	23'0
18	+165	3C 138	(327'5) 19'7 ± 0'3			
			(612) 10'5	12	1'26	
36	+36	3C 223	(408) 9'33 ± 0'7			290
			(612) 8'1	7'3	0'59	
2	+198	3C 264	(318) 18'06 ± 0'7			
			(612) 5'34	10	0'53	
6	+023	3C 273'0	(318) 64'0 ± 2'5			
			(612) 46'99	2'69	1'27	
2	+ 216	3C 274	(318) 11'34 ± 0'46			150
			(612) 3'80	17	0'65	
[illegible]	+307	3C 286	(327'5) 26'4 ± 0'2			
			(612) 17'1	12	2'05	
9	+ 24	3C 321	(318) 11'13 ± 0'45			290
			(612) 8'95	7'2	0'64	
6	+ 277	3C 341	(612) 2'45	22	0'54	82
3	+394	3C 452	(408) 31'6 ± 0'7			
			(612) 15'06	10	1'51	250
)	+158	3C 454'3	(318) 9'67 ± 0'4			
			(612) 12'89	8	1'3	