interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

12 METER MILLIMETER WAVE TELESCOPE

MEMO No. 33

May 13, 1981

To: 12 M File

From: J. M. Payne

Subject: PRELIMINARY DESIGN OF OPTICAL SYSTEM AND RECEIVER SYSTEM FOR THE 12 M ANTENNA

Introduction

Attached is a preliminary design for the 12 M receiver and optical system. The main features are as follows:

1) The optics is simple and straight forward. Although it would be nice to try new ideas, I have resisted the temptation where there is no clear advantage.

2) Different receivers may be selected by a simple mirror rotation.

3) Any receiver may be tuned to have a single sideband or double sideband response from the control room. In the single sideband case, the receiver input is terminated in a 15K load at the image frequency.

4) A calibration system, common to all receivers will permit the independent measure of
   a) Receiver temperature
   b) Sky temperature
   c) System temperature

5) The optical system does not preclude dichroic or even trichroic operation although this will not be featured immediately.

6) The LO injection system and sideband rejection system are able to operate at any IF frequency. Both these systems are dual polarization.

7) If the newly packaged receivers are not ready in time, an existing receiver may be mounted on the new surface with its existing feed system. The only extra cost is a subreflector (cost $700 and one month delivery.) This subreflector would fit our existing rotating mechanism.

8) The assumption is made that the minimum frequency of operation is 70 GHz.

I would appreciate any comments you may have.

THE OPTICAL SYSTEM

The geometry of the proposed optics is shown in figure 1 and the dimensions of the subreflector are given in Table 1. A 24 inch diameter subreflector will fit in the existing nutating mechanism. All dimensions are in inches as the numerically controlled lathe will not work in metric units. The main beam rotation for a given subreflector rotation is derived in figure 2 and a comparison between the existing geometry and the proposed geometry is shown in Table II. Note that our existing feed systems may be used, although we would prefer to incorporate the new BL Ulich design.

A typical receiver installation is shown in Figure 3. This is the 3 MM receiver and is the largest of the proposed receivers. The size of the optical parts of the receiver could be reduced either by making the receiver selection mirror an offset parabola or by incorporating a second lens at the input to the image terminator. At the moment we don't feel that this is necessary. The diameter of the beam at λ=3MM is 25 CM at the receiver selection mirror. To keep pointing errors to less than 1 arc sec requires a positioning accuracy of 50 arc secs for the mirror. A 15 bit encoder would be a suitable readout.

THE RECEIVING SYSTEMS

The main difference between the new receivers and our existing receivers lies in the dual polarization diplexer shown in Figure 4. The geometry has been changed from our existing design to accomodate any reasonable IF frequency. Also, with this geometry, identical devices may be used for L.O. diplexing or image terminating. The wire diameter has been chosen to be easy to work with as have the spacings. The polarization diplexer will be similar to our existing system.

It is important that we build and test the dual polarization diplexer as soon as possible. Lucky estimates three (3) weeks of shop time.

Other parts of the receivers will be the same components we now use.

A path length modulator will be incorporated into the mirror selection mechanism.

The calibration system will be similar to the system we are now constructing and will consist of two temperature controlled loads. This system will enable us to implement the cooled chopper principle of calibration suggested by Bobby Ulich.

PARABOLIC F/D = 0.42000

PARABOLIC HALF ANGLE= 61.52501

HYPERBOLIC DIAMETER = 24.00000

FOCUS TO FEED DISTANCE = 327.00000

HYPERBOLIC HALF ANGLE = 2.14430

MAGNIFICATION = 31.80590

ECCENTRICITY = 1.06492

FOCUS TO HYPERBOLIC VERTEX = 9.96771

HYPERBOLIC DEPTH AT EDGE = 3.45914

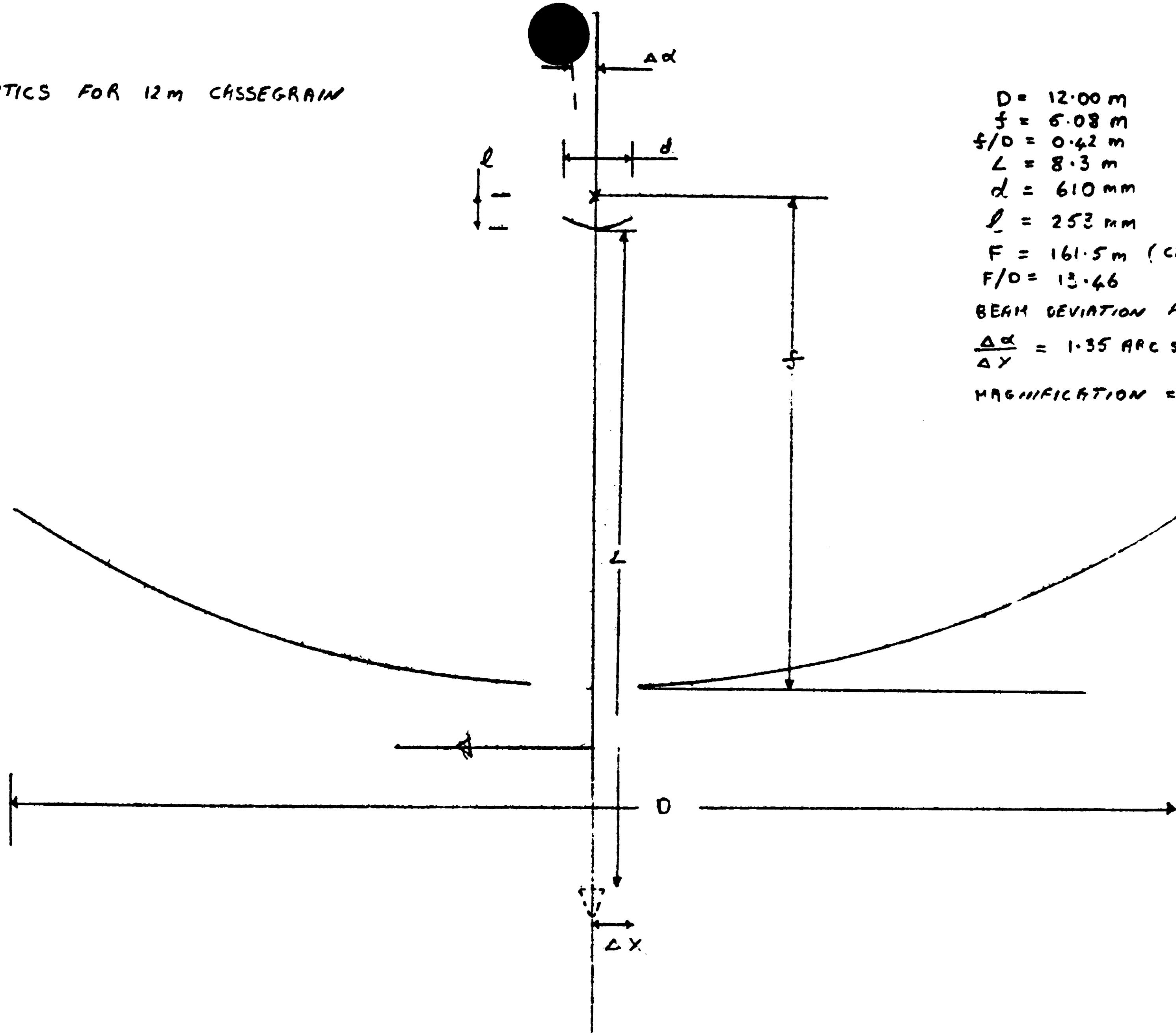
INCHES AND DEGREES

R	Z(R)	R	Z(R)	R	Z(R)
0.00	0.000	0.10	0.000	0.20	0.001
0.30	0.002	0.40	0.004	0.50	0.006
0.60	0.009	0.70	0.012	0.80	0.016
0.90	0.020	1.00	0.024	1.10	0.029
1.20	0.035	1.30	0.041	1.40	0.048
1.50	0.055	1.60	0.062	1.70	0.070
1.80	0.079	1.90	0.088	2.00	0.097
2.10	0.107	2.20	0.118	2.30	0.128
2.40	0.140	2.50	0.152	2.60	0.164
2.70	0.177	2.80	0.190	2.90	0.204
3.00	0.218	3.10	0.233	3.20	0.249
3.30	0.264	3.40	0.281	3.50	0.297
3.60	0.315	3.70	0.332	3.80	0.350
3.90	0.369	4.00	0.388	4.10	0.408
4.20	0.428	4.30	0.449	4.40	0.470
4.50	0.491	4.60	0.513	4.70	0.536
4.80	0.559	4.90	0.582	5.00	0.606
5.10	0.631	5.20	0.655	5.30	0.681
5.40	0.707	5.50	0.733	5.60	0.760
5.70	0.787	5.80	0.815	5.90	0.843
6.00	0.872	6.10	0.901	6.20	0.931
6.30	0.961	6.40	0.992	6.50	1.023
6.60	1.055	6.70	1.087	6.80	1.119
6.90	1.152	7.00	1.186	7.10	1.220
7.20	1.254	7.30	1.289	7.40	1.325
7.50	1.360	7.60	1.397	7.70	1.434
7.80	1.471	7.90	1.509	8.00	1.547
8.10	1.586	8.20	1.625	8.30	1.664
8.40	1.705	8.50	1.745	8.60	1.786
8.70	1.828	8.80	1.870	8.90	1.912
9.00	1.955	9.10	1.999	9.20	2.043
9.30	2.087	9.40	2.132	9.50	2.177
9.60	2.223	9.70	2.269	9.80	2.316
9.90	2.363	10.00	2.410	10.10	2.458
10.20	2.507	10.30	2.556	10.40	2.605
10.50	2.655	10.60	2.706	10.70	2.757
10.80	2.808	10.90	2.860	11.00	2.912
11.10	2.964	11.20	3.018	11.30	3.071
11.40	3.125	11.50	3.180	11.60	3.235
11.70	3.290	11.80	3.346	11.90	3.402
12.00	3.459				

TABLE II

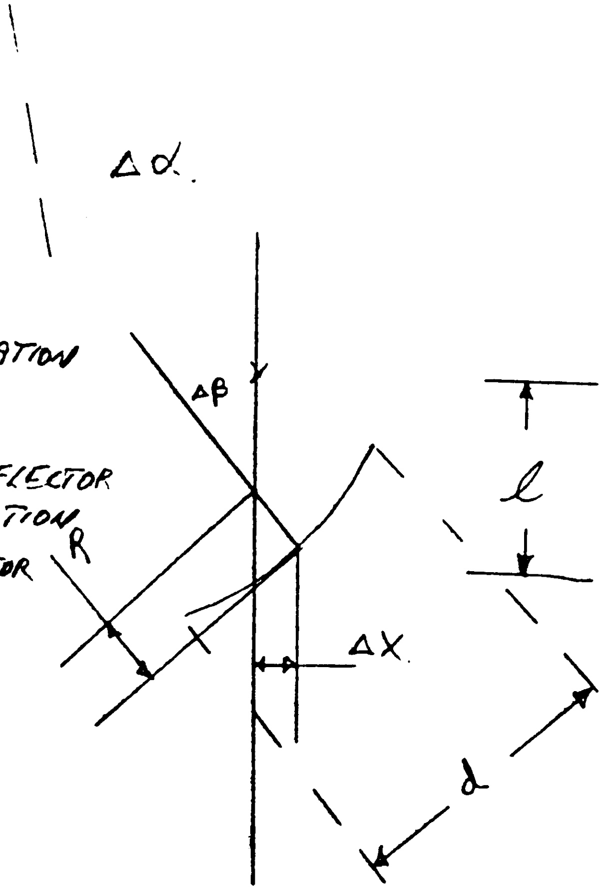
Displacement	11-m	12-m
Prime focus feed lateral displacement	22.3 arc sec/mm	34.3 arc sec/mm
C assegrain feed lateral displacement	1.36 arc sec/mm	1.27 arc sec/mm
Subreflector lateral displacement	21.0 arc sec/mm	39 arc sec/mm
Subreflector rotation	-0.0728 arc min/min	-0.0789 arc min/min
Magnification	17.2	31.8
Hyperbolic half angle	2.1 degrees	2.1 degrees
Eccentricity	1.229	1.065

PROPOSED OPTICS FOR 12m CASSEGRAIN TELESCOPE



D = 12·00 m
f = 5·08 m
f/D = 0·42 m
L = 8·3 m
d = 610 mm
ℓ = 253 mm
F = 161·5 m (CASS EQ FOCUS)
F/D = 13·46
BEAM DEVIATION FACTOR = 1·00
$\frac{\Delta\alpha}{\Delta X}$ = 1·35 ARC SEC / mm
MAGNIFICATION = 31·8

FIG 1



Δβ = SUBREFLECTOR ROTATION

Δα = BEAM ROTATION

R = DISTANCE FROM SUBREFLECTOR VERTEX TO AXIS OF ROTATION

BDf = PF BEAM DEV FACTOR

BDF = CASS " " "

ℓ = DIST. FROM FOCUS TO SUB VERTEX

R = 80 mm

$$\Delta X = R\,\Delta\beta \quad \text{(FOR SMALL DISPLACEMENTS)}$$

$$\angle\alpha = R\,\Delta\beta\left(\frac{BDf}{f} - \frac{BDF}{F}\right) - \frac{\Delta\beta\,\ell}{f}\left(BDf + BDF\right)$$

BDF = 1

BDf = 0.842 (BAARS FIG 12)

$$\Delta\alpha = 0.08\,\Delta\beta\left(\frac{0.842}{5.08} - \frac{1}{161.5}\right) - \frac{\Delta\beta \times 0.253}{5.08}\left(1.842\right)$$

$$\frac{\Delta\alpha}{\Delta\beta} = -0.0789$$

FIG 2 MAIN BEAM ROTATION / SUBREFLECTOR ROTATION

PROPOSED 12 m GEOMETRY

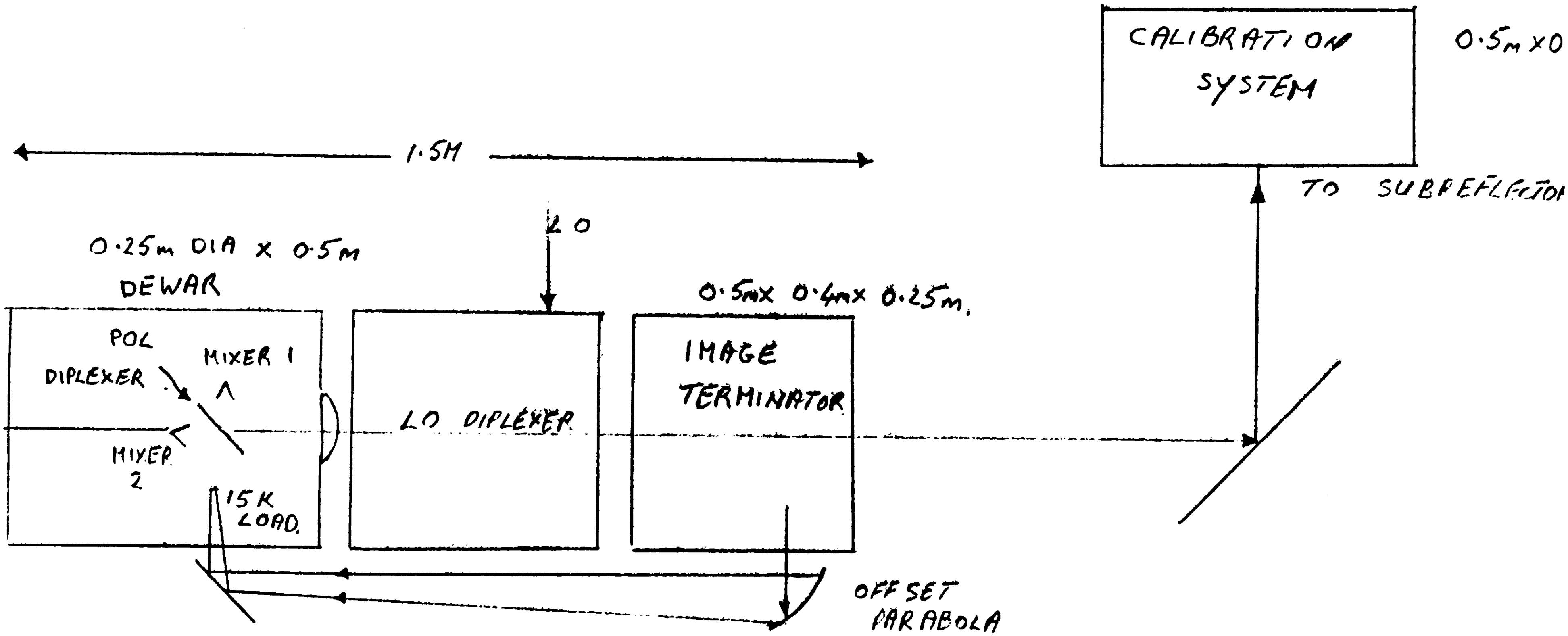
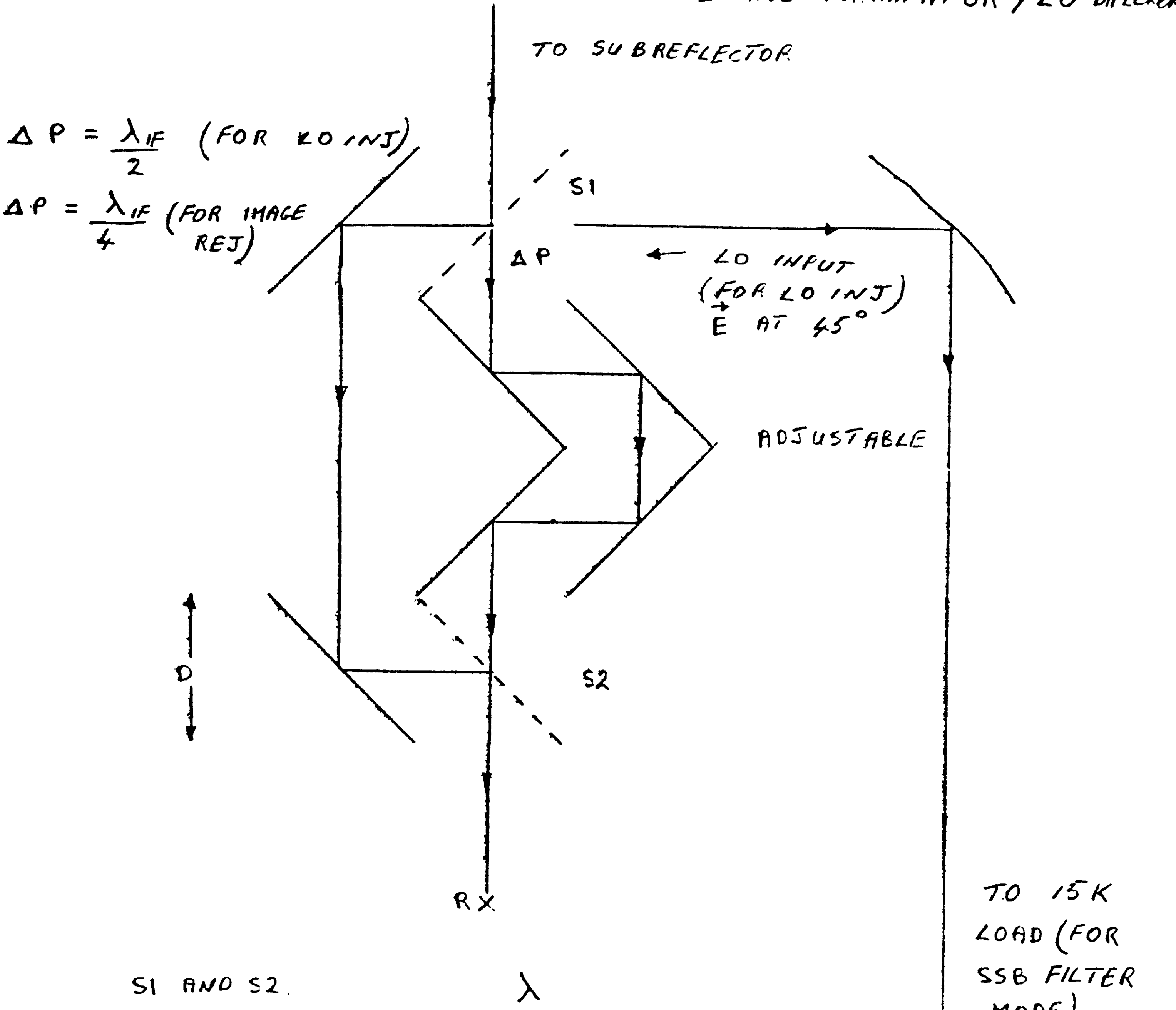
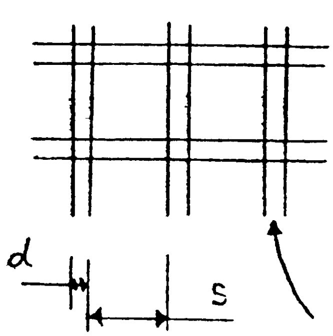


FIG 3 TYPICAL RECEIVER ARRANGEMENT

FIG 2
DUAL POLARIZATION
IMAGE TERMINATOR / LO DIPLEXER



S1 AND S2.



2 MIL WIRES

λ	3 mm	2 mm	1.2 mm	
d	2 MILS	2 MILS	2 MILS	
S	24 TPI	32 TPI	48 TPI	
D	16 cm	10.5 cm	6.3 cm	(APPROXIMATE)

FIG 4