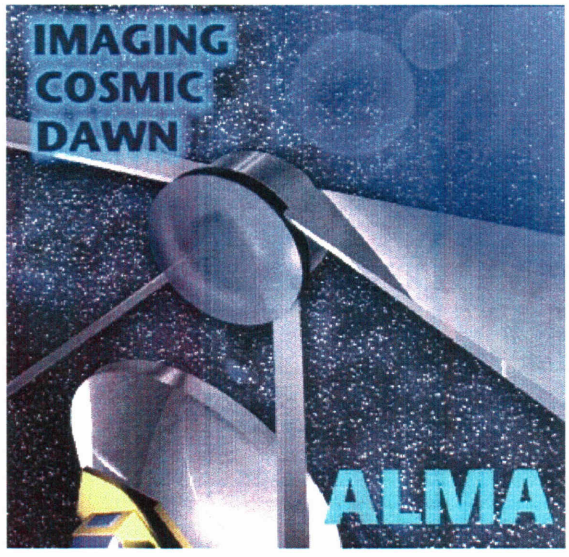
The Atacama Large Millimetre Array

Receiver Optics Design

Electromagnetic Analysis



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ABSTRACT:

This document reports the electromagnetic analysis of the receiver optics design for the Atacama Large Millimetre Array (ALMA) project. The optics design of the receivers covering the 10 frequency bands ranging from 31.3 GHz to 950 GHz is detailed in ALMA Memo 362, "ALMA Receiver Optics Design" [1]. Analysis was carried out using quasi-optics method and a physical optics software. The quasi-optics analysis results are Gaussian beam parameters, truncation loss at filter, mirrors and cryostat window and beam profiles at filter, mirrors and cryostat windows. Physical optics analysis results are the field distribution at the Cassegrain focus, field distribution at the secondary reflector giving the edge tapers, the radiation pattern in the far field, and main beam and cross-polar efficiencies. Both x- and y-polarised beams are given. The far field radiation patterns are also obtained as 3-D plots of the co- and cross-polar fields.

1 INTRODUCTION

The 10 frequency bands of the telescope array are shown in Table I below.

TABLE I
Receiver frequency bands.

Band	Lowest Frequency [GHz]	Mid-Band Frequency [GHz]	Highest Frequency [GHz]
1	31.3	38	45
2	67	78	90
3	89 (84†)	100	116
4	125	144	163
5	163	187	211
6	211	243	275
7	275	323	370
8	385	442	500
9	602	661	720
10	787	868	950

† Extension of band 3 down to 84 GHz is being considered.

Quasi-optics analysis [2] is carried out using thin lens approximation for the focusing elements.

Physical optics modelling is carried out on GRASP8 version 8.1.5 from TICRA Engineering Consultants of the Netherlands. The input is that of a source field with Gaussian distribution*. The analysis using a corrugated horn feed will be provided in a subsequent revision of this document.

For the physical optics modelling, the beam axis is targeted at the vertex of the hyperboloidal secondary reflector surface. Parameters and dimensions used for the simulations are given in [1]. Definitions for the symbols used are shown in Fig.1. The optical configuration for the antenna is shown in Fig. 2 while the data are given in Table II. The layout of the cryostat showing positions of the band cartridges is shown in Fig. 3.

* **Important note**: The PO results presented are obtained with ideal Gaussian feeds instead of corrugated horns. It is expected that there will be some different when results obtained using corrugated horn feeds are available later. However comparison of the field at the Cassagrain focus between the PO simulation using Gaussian feed and quasioptics computation using corrugated horn are given.

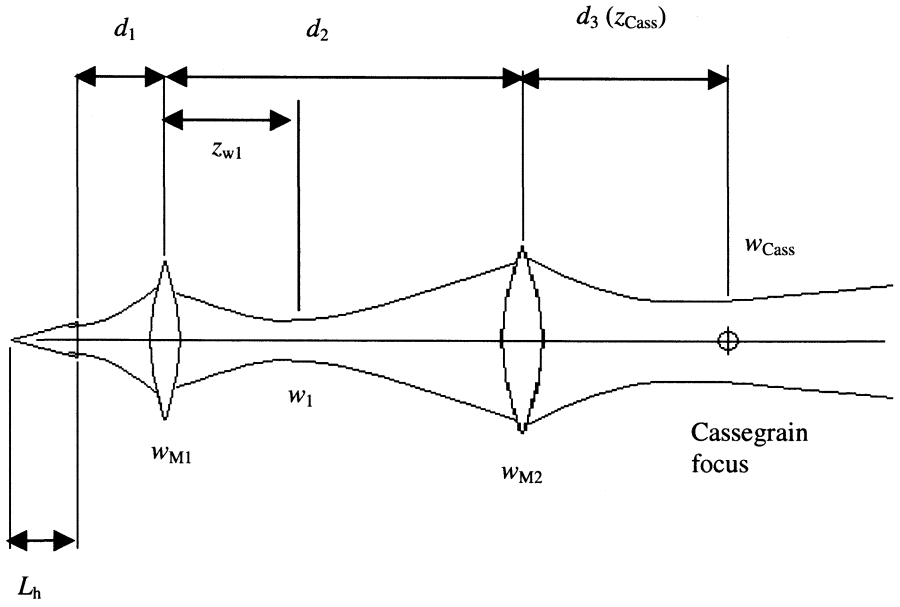


Figure 1. Definition of symbols used. Focusing elements are represented by lenses. Only one element is present in Bands 1 – 4.

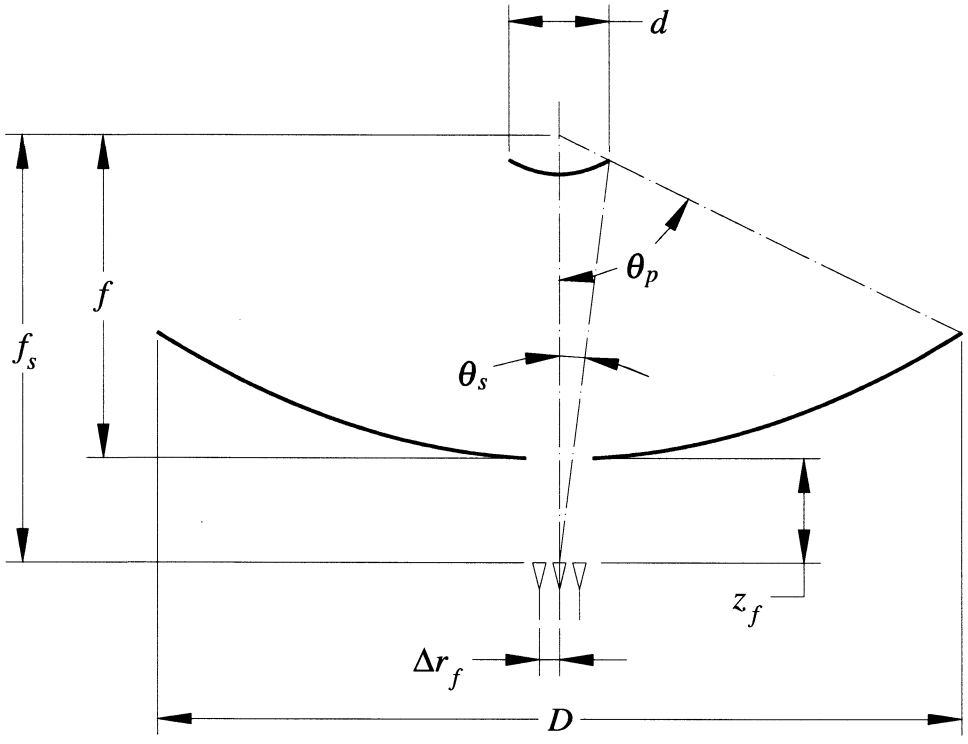


Figure 2. Optical Configuration of Antenna.

TABLE II
Antenna Optical Configuration Data.

Symbol	Description	Data
D	Primary Aperture	12.0 m
f	Focal Length of Primary	4.8 m
	f/D or Primary	0.40
d	Secondary Aperture	0.75 m
	Final f/D	8.00
e	Secondary Eccentricity	1.10526
θ_p	Primary Angle of Illumination	128.02°
θ_s	Secondary Angle of Illumination	7.16°
2c	Distance Between Primary and Secondary Foci	6.177 m
v	Primary Vertex Hole Clear Aperture	0.75 m

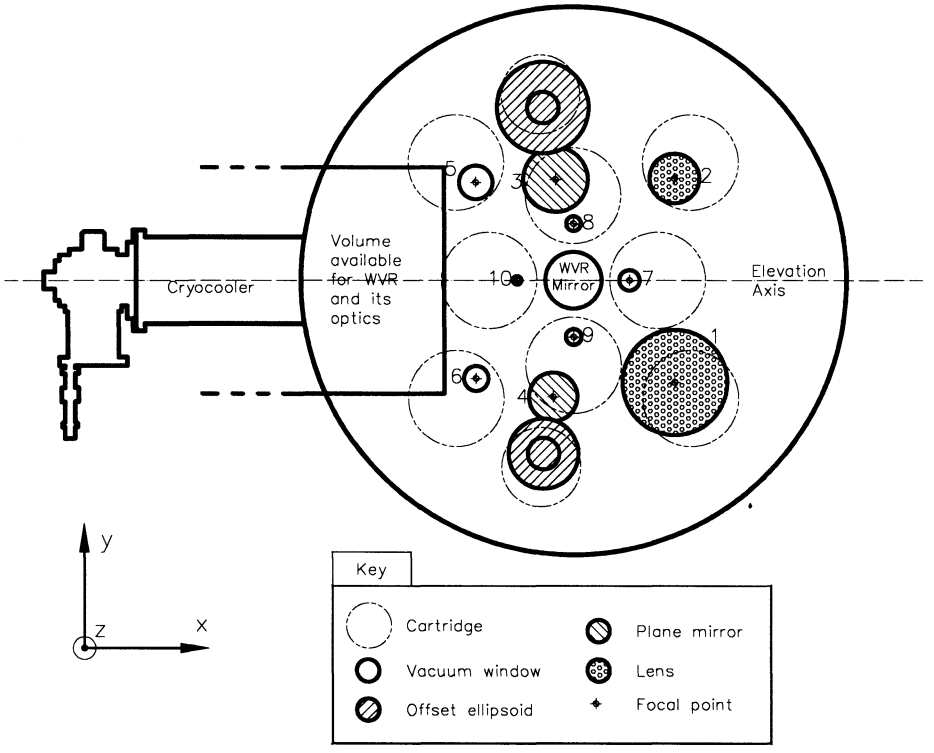


Fig. 3 Layout of band cartridges in cryostat.

2 BAND 1

2.1 Quasi-Optics Analysis

2.1.1 *Gaussian Beam Parameters*

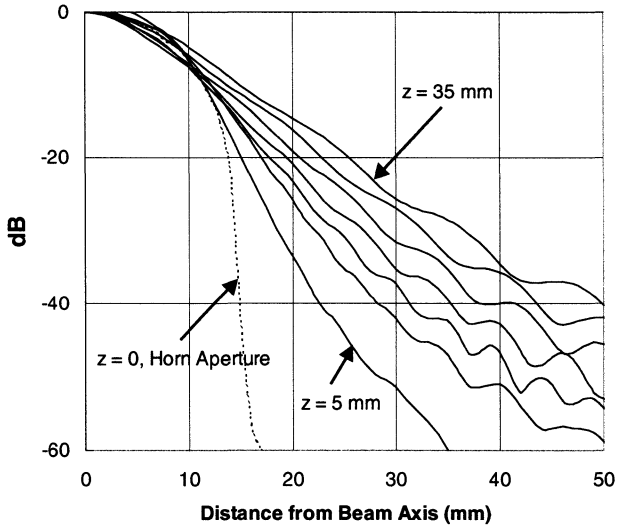
TABLE III(a)
Quasi-optics Gaussian beam parameters for Band 1.

Frequency [GHz]		**31.1**	**38**	**45**
λ [mm]		9.578034	7.889275	6.662055
Horn diameter	29.9			
Horn axial length	180.52			
Horn slant length	181.138			
Horn waist, w_0		9.488	9.427	9.353
Horn waist offset, $\Delta z(w_0)$		-4.94843	-7.20044	-9.93861
Waist at horn aperture, w_{ha}		9.620	9.620	9.620
d_1	193.0			
R_{s1}		202.353	206.456	211.323
f_1	188.0			
R_{i1}		2650.497	2103.010	1703.425
Waist at lens, w_{L1}	(dia. = 186)	64.311	54.157	46.955
$z_{w(Cass.)}$	170.0	550.181	495.728	462.331
$w_{Cass.}$		57.248	47.345	40.079
$d_{lens\text{-}subrefl}$		6359.86	6359.86	6359.86
$w_{subrefl}$	(dia. = 750)	314.650	314.621	314.603
$R_{subrefl}$	6000.00	6008.580	6000.005	5994.823
Edge Taper (dB)	12.00	12.34	12.34	12.34
$\Delta_{refocus}$		+8.88		+5.26
$w_{subrefl}$		314.185		314.879
$R_{subrefl}$		6000.005		5999.997
Edge Taper (dB)		12.37		12.32

Calculations based on thin lens approximation. All dimensions in mm.

2.1.2 *Truncation Loss at Filters*

The beam profiles at the filter are shown in Figures 4(a), (b) and (c). Truncation loss of the beam for a range of filter diameters are given in Tables III(b) – III(g).



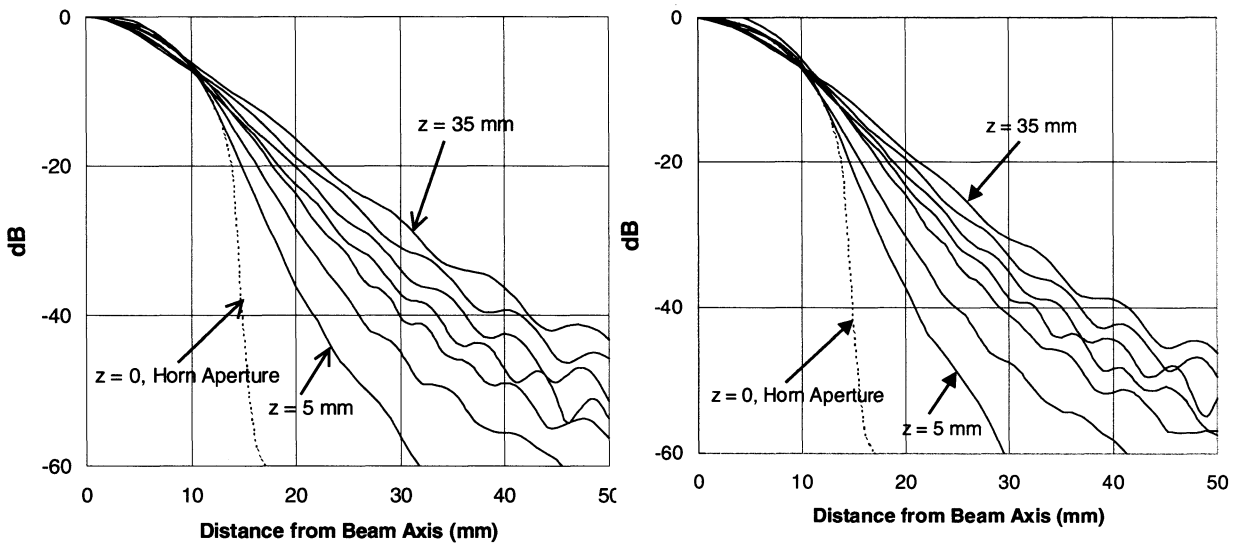


Figure 4. Beam profile at various distances from horn aperture; (a) 31.3 GHz, (b) 38 GHz and (c) 45 GHz.

TABLE III(b)
Truncated beam power at filter for Band 1 low limit frequency 31.3 GHz.

Truncation diameter (mm.)	**z from horn aperture (mm.)**						
	5	**10**	**15**	**20**	**25**	**30**	**35**
100	1.000	1.000	1.000	1.000	1.000	0.999	0.999
90	1.000	1.000	1.000	1.000	0.999	0.999	0.998
80	1.000	1.000	1.000	1.000	0.999	0.998	0.997
78	1.000	1.000	1.000	0.999	0.999	0.998	0.997
70	1.000	1.000	1.000	0.999	0.998	0.997	0.994
60	1.000	1.000	0.999	0.998	0.996	0.993	0.988
50	1.000	0.999	0.998	0.994	0.989	0.982	0.972
40	0.999	0.996	0.990	0.980	0.966	0.949	0.925

TABLE III(c)
Beam truncation loss in dB at filter for Band 1 low limit frequency 31.3 GHz.

Truncation diameter (mm.)	**z from horn aperture (mm.)**						
	5	**10**	**15**	**20**	**25**	**30**	**35**
100	-0.000	-0.000	-0.004	-0.001	-0.001	-0.003	-0.004
90	-0.000	-0.000	-0.004	-0.001	-0.002	-0.004	-0.007
80	-0.000	-0.000	-0.001	-0.002	-0.004	-0.007	-0.011
78	-0.000	-0.000	-0.001	-0.002	-0.005	-0.009	-0.013
70	-0.000	-0.000	-0.002	-0.004	-0.008	-0.014	-0.024
60	-0.000	-0.001	-0.004	-0.009	-0.018	-0.033	-0.051
50	-0.000	-0.003	-0.011	-0.026	-0.049	-0.080	-0.121
40	-0.003	-0.016	-0.044	-0.088	-0.148	-0.229	-0.339

TABLE III(d)
Truncated beam power at filter for Band 1 mid frequency 38 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 5	10	15	20	25	30	35
100	1.000	1.000	1.000	1.000	1.000	1.000	0.999
90	1.000	1.000	1.000	1.000	1.000	0.999	0.999
80	1.000	1.000	1.000	1.000	0.999	0.999	0.999
78	1.000	1.000	1.000	1.000	0.999	0.999	0.998
70	1.000	1.000	1.000	1.000	0.999	0.998	0.997
60	1.000	1.000	1.000	0.999	0.998	0.996	0.993
50	1.000	1.000	0.999	0.996	0.993	0.988	0.982
40	1.000	0.998	0.993	0.986	0.977	0.965	0.951

TABLE III(e)
Beam truncation loss in dB at filter for Band 1 mid frequency 38 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 5	10	15	20	25	30	35
100	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002
90	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001	-0.004
80	-0.000	-0.000	-0.000	-0.001	-0.002	-0.002	-0.007
78	-0.000	-0.000	-0.001	-0.001	-0.003	-0.003	-0.008
70	-0.000	-0.000	-0.001	-0.002	-0.004	-0.004	-0.014
60	-0.000	-0.001	-0.002	-0.005	-0.010	-0.010	-0.030
50	-0.000	-0.002	-0.006	-0.015	-0.030	-0.030	-0.080
40	-0.002	-0.010	-0.029	-0.060	-0.103	-0.103	-0.220

TABLE III(f)
Truncated beam power at filter for Band 1 high limit frequency 45 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 5	10	15	20	25	30	35
100	1.000	1.000	1.000	1.000	1.000	1.000	1.000
90	1.000	1.000	1.000	1.000	1.000	1.000	0.999
80	1.000	1.000	1.000	1.000	1.000	0.999	0.999
78	1.000	1.000	1.000	1.000	1.000	0.999	0.999
70	1.000	1.000	1.000	1.000	0.999	0.999	0.998
60	1.000	1.000	1.000	0.999	0.999	0.997	0.996
50	1.000	1.000	0.999	0.998	0.996	0.992	0.988
40	1.000	0.998	0.995	0.991	0.983	0.974	0.963

TABLE III(g)
Beam truncation loss in dB at filter for Band 1 high limit frequency 45 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 5	10	15	20	25	30	35
100	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001
90	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002
80	-0.000	-0.000	-0.000	-0.001	-0.001	-0.003	-0.004
78	-0.000	-0.000	-0.000	-0.001	-0.002	-0.003	-0.005
70	-0.000	-0.000	-0.001	-0.001	-0.003	-0.005	-0.008
60	-0.000	-0.000	-0.001	-0.003	-0.006	-0.011	-0.020
50	-0.000	-0.001	-0.004	-0.010	-0.019	-0.034	-0.051
40	-0.001	-0.007	-0.020	-0.041	-0.072	-0.014	-0.163

2.1.3 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 4(d), (e) and (f). Truncation loss of the beam for a range of window diameters is given in Table III(h) – III(m).

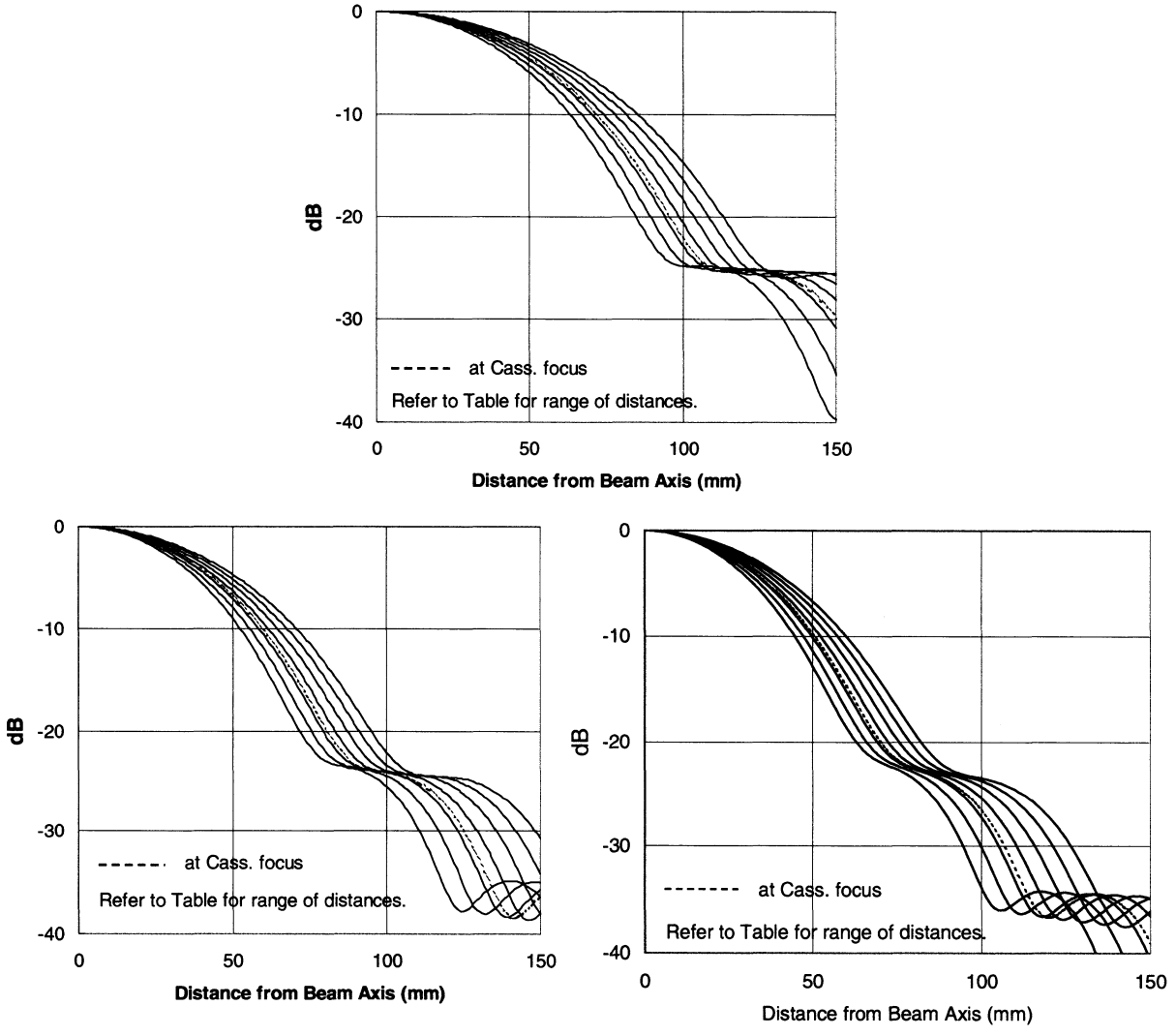


Figure 4. Beam profile at various distances from mirror 2; (d) 31.3 GHz, (e) 38 GHz and (f) 45 GHz.

TABLE III(h)
Truncated beam power at cryostat window for Band 1 low limit frequency 31.3 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 170	180	190	193	200	210	220	230
300	0.997	0.997	0.997	0.996	0.996	0.994	0.992	0.991
280	0.997	0.996	0.995	0.994	0.993	0.991	0.990	0.988
260	0.996	0.994	0.992	0.992	0.990	0.988	0.987	0.986
240	0.993	0.991	0.989	0.988	0.987	0.986	0.985	0.983
220	0.989	0.987	0.986	0.985	0.984	0.983	0.981	0.977
200	0.986	0.984	0.982	0.982	0.980	0.976	0.970	0.963
186	0.983	0.981	0.978	0.976	0.973	0.965	0.956	0.944
180	0.981	0.979	0.974	0.973	0.968	0.959	0.947	0.933
160	0.972	0.964	0.953	0.949	0.938	0.921	0.902	0.880
140	0.945	0.927	0.905	0.898	0.881	0.855	0.827	0.798
120	0.882	0.852	0.819	0.809	0.786	0.752	0.718	0.685

TABLE III(i)
Beam truncation loss in dB at cryostat window for Band 1 low limit frequency 31.3 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 170	180	190	193	200	210	220	230
300	-0.011	-0.012	-0.015	-0.016	-0.019	-0.026	-0.034	-0.041
280	-0.013	-0.016	-0.022	-0.024	-0.030	-0.038	-0.046	-0.052
260	-0.018	-0.025	-0.034	-0.037	-0.043	-0.051	-0.056	-0.061
240	-0.030	-0.040	-0.049	-0.051	-0.056	-0.062	-0.067	-0.073
220	-0.046	-0.055	-0.062	-0.064	-0.068	-0.075	-0.085	-0.100
200	-0.063	-0.070	-0.078	-0.081	-0.089	-0.106	-0.130	-0.164
186	-0.075	-0.084	-0.099	-0.104	-0.121	-0.153	-0.196	-0.250
180	-0.081	-0.094	-0.113	-0.121	-0.143	-0.184	-0.237	-0.302
160	-0.124	-0.160	-0.210	-0.228	-0.276	-0.356	-0.450	-0.556
140	-0.248	-0.331	-0.433	-0.467	-0.551	-0.683	-0.827	-0.980
120	-0.545	-0.698	-0.866	-0.919	-1.047	-1.238	-1.436	-1.640

TABLE III(j)
Truncated beam power at cryostat window for Band 1 mid frequency 38 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 170	180	190	193	200	210	220	230
300	0.999	0.998	0.998	0.998	0.997	0.997	0.997	0.996
280	0.998	0.997	0.997	0.997	0.997	0.997	0.996	0.995
260	0.997	0.997	0.997	0.997	0.996	0.995	0.994	0.992
240	0.997	0.997	0.996	0.995	0.994	0.992	0.990	0.988
220	0.996	0.994	0.992	0.992	0.990	0.988	0.986	0.984
200	0.993	0.990	0.988	0.987	0.985	0.984	0.982	0.980
186	0.989	0.986	0.984	0.984	0.982	0.980	0.978	0.975
180	0.987	0.985	0.983	0.982	0.981	0.978	0.976	0.972
160	0.981	0.979	0.976	0.975	0.972	0.967	0.959	0.950
140	0.972	0.967	0.959	0.956	0.949	0.935	0.920	0.902
120	0.947	0.932	0.913	0.907	0.892	0.868	0.843	0.816

TABLE III(k)
Beam truncation loss in dB at cryostat window for Band 1 mid frequency 38 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 170	180	190	193	200	210	220	230
300	-0.006	-0.008	-0.010	-0.011	-0.011	-0.012	-0.013	-0.015
280	-0.009	-0.011	-0.012	-0.012	-0.013	-0.014	-0.018	-0.023
260	-0.012	-0.012	-0.014	-0.014	-0.016	-0.021	-0.028	-0.036
240	-0.013	-0.015	-0.019	-0.021	-0.026	-0.035	-0.044	-0.052
220	-0.018	-0.024	-0.033	-0.036	-0.043	-0.053	-0.061	-0.068
200	-0.032	-0.043	-0.054	-0.057	-0.064	-0.072	-0.079	-0.087
186	-0.047	-0.059	-0.070	-0.072	-0.078	-0.086	-0.096	-0.110
180	-0.055	-0.067	-0.076	-0.079	-0.085	-0.095	-0.107	-0.125
160	-0.083	-0.093	-0.106	-0.111	-0.123	-0.148	-0.181	-0.224
140	-0.123	-0.147	-0.182	-0.195	-0.230	-0.290	-0.363	-0.448
120	-0.238	-0.307	-0.394	-0.423	-0.496	-0.613	-0.742	-0.881

TABLE III(l)
Truncated beam power at cryostat window for Band 1 high limit frequency 45 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 170	180	190	193	200	210	220	230
300	0.999	0.999	0.999	0.999	0.999	0.998	0.998	0.997
280	0.999	0.999	0.998	0.998	0.998	0.997	0.997	0.997
260	0.999	0.998	0.998	0.998	0.997	0.997	0.997	0.996
240	0.998	0.997	0.997	0.997	0.997	0.996	0.996	0.995
220	0.997	0.997	0.996	0.996	0.996	0.995	0.993	0.991
200	0.996	0.996	0.994	0.994	0.993	0.990	0.988	0.986
186	0.995	0.994	0.991	0.990	0.989	0.986	0.984	0.982
180	0.994	0.992	0.989	0.989	0.987	0.984	0.982	0.980
160	0.988	0.985	0.982	0.981	0.979	0.977	0.974	0.971
140	0.979	0.976	0.973	0.972	0.969	0.965	0.958	0.950
120	0.967	0.961	0.953	0.951	0.943	0.931	0.916	0.899

TABLE III(m)
Beam truncation loss in dB at cryostat window for Band 1 high limit frequency 45 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 170	180	190	193	200	210	220	230
300	-0.004	-0.004	-0.005	-0.005	-0.006	-0.008	-0.010	-0.011
280	-0.004	-0.005	-0.007	-0.007	-0.009	-0.011	-0.012	-0.013
260	-0.006	-0.008	-0.010	-0.011	-0.012	-0.013	-0.014	-0.016
240	-0.009	-0.012	-0.013	-0.013	-0.014	-0.016	-0.019	-0.024
220	-0.013	-0.014	-0.016	-0.016	-0.019	-0.024	-0.031	-0.040
200	-0.016	-0.019	-0.024	-0.027	-0.033	-0.043	-0.053	-0.063
186	-0.021	-0.028	-0.038	-0.042	-0.050	-0.061	-0.072	-0.081
180	-0.025	-0.034	-0.046	-0.050	-0.058	-0.070	-0.080	-0.089
160	-0.051	-0.065	-0.078	-0.082	-0.090	-0.101	-0.112	-0.127
140	-0.090	-0.105	-0.119	-0.123	-0.135	-0.156	-0.185	-0.221
120	-0.147	-0.173	-0.208	-0.220	-0.253	-0.311	-0.380	-0.461

3 BAND 2

3.1 Quasi-Optics Analysis

3.1.1 *Gaussian Beam Parameters*

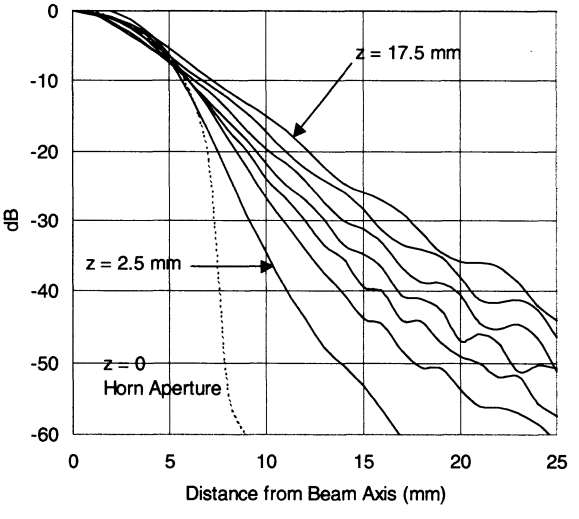
TABLE IV(a)
Quasi-optics Gaussian beam parameters for Band 2.

Frequency [GHz]		**67**	**78**	**90**
λ **[mm]**		4.474514	3.843493	3.331027
Horn diameter	15.0			
Horn axial length	90.26			
Horn slant length	90.571			
Horn waist, w_0		4.749	4.723	4.690
Horn waist offset, $\Delta z(w_0)$		-2.85972	-3.83282	-5.03230
Waist at horn aperture, w_{ha}		4.826	4.826	4.826
d_1	88.0			
R_{s1}		93.620	95.453	97.659
f_1	88.0			
R_{i1}		1465.849	1127.043	889.718
Waist at lens, w_{L1}	(dia. = 88.3)	27.658	24.252	21.548
$z_{w(Cass.)}$	70.0	173.502	173.502	173.502
$w_{Cass.}$		25.970	22.307	19.333
$d_{lens\text{-}subrefl}$		6145.80	6145.80	6145.80
$w_{subrefl}$	(dia. = 750)	328.571	328.302	328.113
$R_{subrefl}$	6000.00	6009.842	6000.000	5993.105
Edge Taper (dB)	12.00	11.31	11.33	11.35
$\Delta_{refocus}$		+9.90		+6.92
$w_{subrefl}$		328.030		328.492
$R_{subrefl}$		6000.005		6000.001
Edge Taper (dB)		11.35		11.35

Calculations based on thin lens approximation. All dimensions in mm.

3.1.2 *Truncation Loss at Filters*

The beam profiles at the filter are shown in Figures 5(a), (b) and (c). Truncation loss of the beam for a range of filter diameters are given in Tables IV(b) – IV(g).



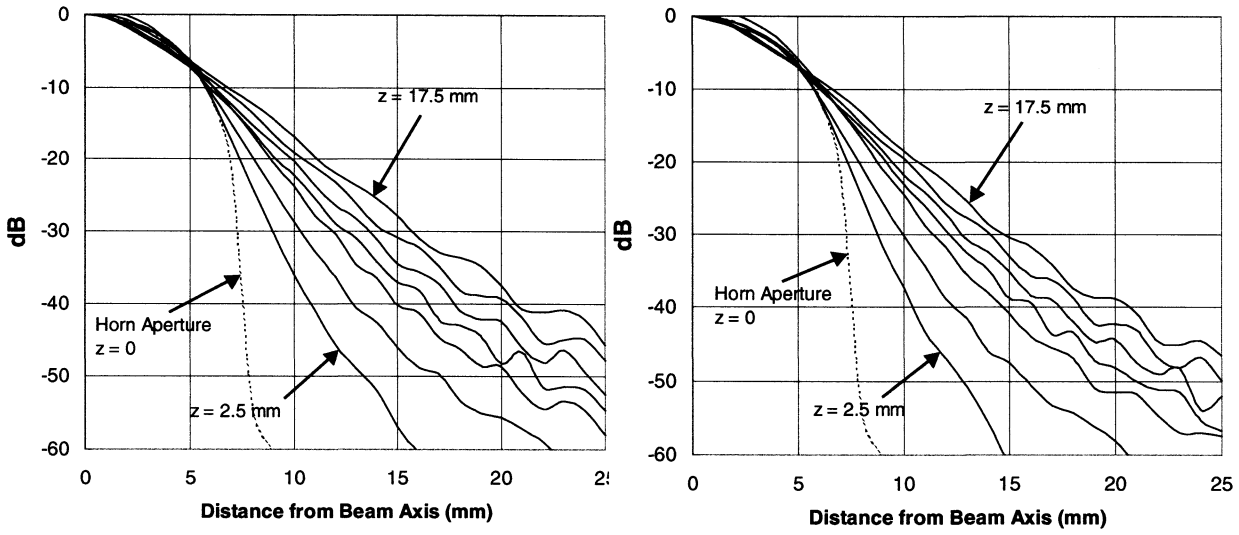


Figure 5. Beam profile at various distances from horn aperture; (a) 67 GHz, (b) 78 GHz and (c) 90 GHz.

TABLE IV(b)
Truncated beam power at filter for Band 2 low limit frequency 67 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5
50	1.000	1.000	1.000	1.000	1.000	1.000	0.999
45	1.000	1.000	1.000	1.000	1.000	0.999	0.999
43	1.000	1.000	1.000	1.000	0.999	0.999	0.998
40	1.000	1.000	1.000	1.000	0.999	0.999	0.998
35	1.000	1.000	1.000	0.999	0.999	0.997	0.996
30	1.000	1.000	0.999	0.998	0.996	0.994	0.990
25	1.000	0.999	0.998	0.995	0.991	0.984	0.977
20	1.000	0.997	0.991	0.983	0.970	0.956	0.934
15	0.992	0.977	0.955	0.929	0.900	0.864	0.834

TABLE IV(c)
Beam truncation loss in dB at filter for Band 2 low limit frequency 67 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5
50	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003
45	-0.000	-0.000	-0.000	-0.001	-0.002	-0.004	-0.005
43	-0.000	-0.000	-0.000	-0.002	-0.002	-0.004	-0.007
40	-0.000	-0.000	-0.001	-0.002	-0.003	-0.006	-0.010
35	-0.000	-0.000	-0.001	-0.003	-0.006	-0.012	-0.018
30	-0.000	-0.001	-0.003	-0.008	-0.015	-0.025	-0.045
25	-0.000	-0.003	-0.009	-0.021	-0.040	-0.071	-0.101
20	-0.002	-0.014	-0.038	-0.076	-0.134	-0.195	-0.294
15	-0.034	-0.103	-0.198	-0.320	-0.456	-0.634	-0.786

TABLE IV(d)
Truncated beam power at filter for Band 2 mid frequency 78 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5
50	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	1.000	1.000	1.000	1.000	1.000	1.000	0.999
43	1.000	1.000	1.000	1.000	1.000	0.999	0.999
40	1.000	1.000	1.000	1.000	1.000	0.999	0.999
35	1.000	1.000	1.000	1.000	0.999	0.998	0.997
30	1.000	1.000	1.000	0.999	0.998	0.996	0.994
25	1.000	1.000	0.999	0.997	0.993	0.989	0.983
20	1.000	0.998	0.994	0.987	0.978	0.966	0.953
15	0.994	0.981	0.963	0.942	0.918	0.890	0.858

TABLE IV(e)
Beam truncation loss in dB at filter for Band 2 mid frequency 78 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5
50	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002
45	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004
43	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004
40	-0.000	-0.000	-0.000	-0.001	-0.002	-0.004	-0.006
35	-0.000	-0.000	-0.001	-0.002	-0.004	-0.007	-0.013
30	-0.000	-0.001	-0.002	-0.005	-0.010	-0.018	-0.027
25	-0.000	-0.002	-0.006	-0.015	-0.029	-0.046	-0.076
20	-0.001	-0.009	-0.027	-0.057	-0.097	-0.150	-0.208
15	-0.027	-0.084	-0.163	-0.262	-0.371	-0.506	-0.666

TABLE IV(f)
Truncated beam power at filter for Band 2 high limit frequency 90 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5
50	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	1.000	1.000	1.000	1.000	1.000	1.000	0.999
43	1.000	1.000	1.000	1.000	1.000	1.000	0.999
40	1.000	1.000	1.000	1.000	1.000	0.999	0.999
35	1.000	1.000	1.000	1.000	0.999	0.999	0.998
30	1.000	1.000	1.000	0.999	0.999	0.997	0.995
25	1.000	1.000	0.999	0.998	0.996	0.992	0.988
20	1.000	0.998	0.995	0.991	0.983	0.974	0.963
15	0.995	0.984	0.969	0.951	0.930	0.909	0.882

TABLE IV(g)
Beam truncation loss in dB at filter for Band 2 high limit frequency 90 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5
50	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001
45	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002
43	-0.000	-0.000	-0.000	-0.000	-0.001	-0.002	-0.003
40	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004
35	-0.000	-0.000	-0.001	-0.001	-0.003	-0.005	-0.008
30	-0.000	-0.000	-0.001	-0.003	-0.006	-0.011	-0.020
25	-0.000	-0.001	-0.004	-0.010	-0.019	-0.034	-0.051
20	-0.001	-0.007	-0.020	-0.041	-0.073	-0.015	-0.164
15	-0.022	-0.070	-0.135	-0.216	-0.317	-0.415	-0.543

3.1.3 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 5(d), (e) and (f). Truncation loss of the beam for a range of window diameters is given in Table IV(h) – IV(m).

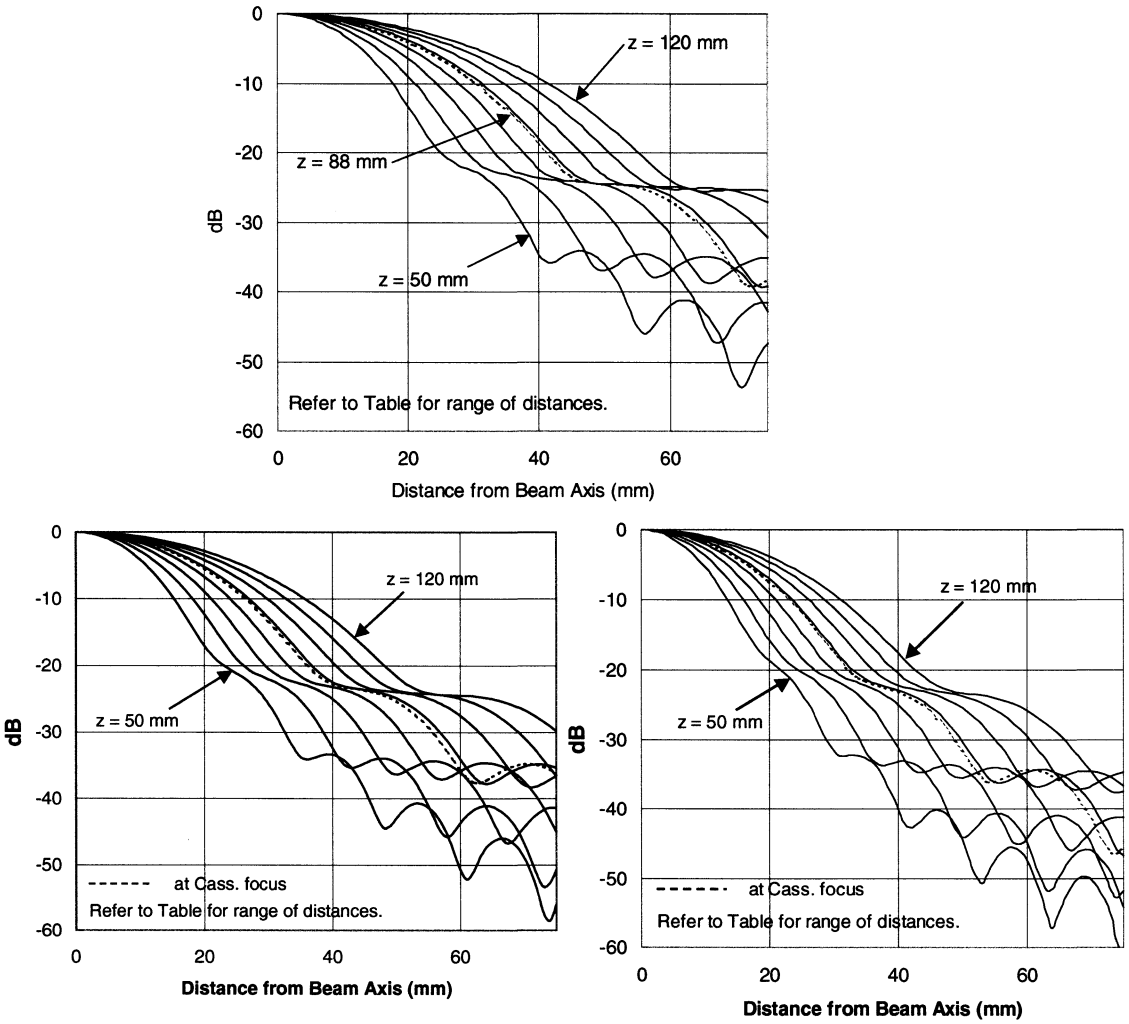


Figure 5. Beam profile at various distances from mirror 2; (d) 67 GHz, (e) 78 GHz and (f) 90 GHz.

TABLE IV(h)
Truncated beam power at cryostat window for Band 2 low limit frequency 67 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 50	60	70	80	88	90	100	110	120
150	1.000	0.999	0.999	0.998	0.997	0.997	0.997	0.995	0.991
140	1.000	0.999	0.999	0.998	0.997	0.997	0.995	0.992	0.989
130	0.999	0.999	0.998	0.997	0.997	0.996	0.993	0.989	0.986
120	0.999	0.999	0.997	0.997	0.994	0.994	0.989	0.986	0.984
110	0.999	0.998	0.997	0.995	0.991	0.990	0.986	0.983	0.979
100	0.999	0.997	0.995	0.990	0.986	0.986	0.982	0.977	0.967
90	0.997	0.996	0.991	0.985	0.982	0.981	0.975	0.962	0.941
88.3	0.997	0.996	0.990	0.984	0.981	0.980	0.973	0.958	0.935
80	0.996	0.992	0.985	0.980	0.974	0.972	0.956	0.929	0.893
70	0.994	0.985	0.978	0.968	0.952	0.947	0.912	0.867	0.815
60	0.985	0.975	0.962	0.933	0.897	0.887	0.830	0.768	0.705

TABLE IV(i)
Beam truncation loss in dB at cryostat window for Band 2 low limit frequency 67 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 50	60	70	80	88	90	100	110	120
150	-0.002	-0.003	-0.004	-0.008	-0.011	-0.011	-0.014	-0.023	-0.037
140	-0.002	-0.004	-0.006	-0.011	-0.012	-0.013	-0.020	-0.035	-0.049
130	-0.003	-0.004	-0.009	-0.012	-0.015	-0.017	-0.031	-0.048	-0.060
120	-0.004	-0.006	-0.012	-0.015	-0.024	-0.028	-0.047	-0.061	-0.072
110	-0.005	-0.010	-0.013	-0.024	-0.041	-0.045	-0.062	-0.074	-0.093
100	-0.006	-0.013	-0.020	-0.042	-0.060	-0.063	-0.078	-0.100	-0.146
90	-0.012	-0.017	-0.038	-0.064	-0.079	-0.082	-0.110	-0.167	-0.265
88.3	-0.012	-0.018	-0.042	-0.068	-0.083	-0.087	-0.119	-0.185	-0.294
80	-0.016	-0.033	-0.065	-0.088	-0.113	-0.122	-0.196	-0.320	-0.493
70	-0.027	-0.066	-0.096	-0.140	-0.213	-0.237	-0.400	-0.621	-0.888
60	-0.066	-0.108	-0.167	-0.301	-0.470	-0.520	-0.810	-1.148	-1.516

TABLE IV(j)
Truncated beam power at cryostat window for Band 2 mid frequency 78 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 50	60	70	80	88	90	100	110	120
150	1.000	1.000	0.999	0.999	0.999	0.998	0.997	0.997	0.996
140	1.000	1.000	0.999	0.999	0.998	0.998	0.997	0.996	0.994
130	1.000	0.999	0.999	0.998	0.997	0.997	0.997	0.995	0.991
120	1.000	0.999	0.999	0.997	0.997	0.997	0.995	0.991	0.987
110	0.999	0.999	0.998	0.997	0.996	0.995	0.991	0.987	0.984
100	0.999	0.998	0.997	0.996	0.992	0.991	0.986	0.983	0.979
90	0.999	0.997	0.996	0.992	0.987	0.986	0.981	0.977	0.969
88.3	0.999	0.997	0.995	0.991	0.986	0.985	0.980	0.975	0.967
80	0.997	0.996	0.992	0.985	0.981	0.980	0.974	0.963	0.945
70	0.996	0.992	0.984	0.977	0.971	0.969	0.954	0.929	0.895
60	0.992	0.982	0.973	0.961	0.945	0.939	0.904	0.858	0.807

TABLE IV(k)
Beam truncation loss in dB at cryostat window for Band 2 mid frequency 78 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 50	60	70	80	88	90	100	110	120
150	-0.001	-0.002	-0.003	-0.004	-0.006	-0.007	-0.011	-0.012	-0.016
140	-0.001	-0.002	-0.004	-0.005	-0.009	-0.010	-0.012	-0.015	-0.025
130	-0.002	-0.003	-0.005	-0.008	-0.012	-0.012	-0.015	-0.024	-0.039
120	-0.002	-0.004	-0.006	-0.012	-0.013	-0.014	-0.022	-0.039	-0.055
110	-0.003	-0.005	-0.010	-0.014	-0.018	-0.021	-0.038	-0.057	-0.071
100	-0.005	-0.008	-0.014	-0.019	-0.033	-0.037	-0.059	-0.076	-0.091
90	-0.006	-0.013	-0.018	-0.037	-0.057	-0.062	-0.082	-0.101	-0.135
88.3	-0.006	-0.014	-0.020	-0.041	-0.062	-0.067	-0.086	-0.108	-0.147
80	-0.011	-0.017	-0.036	-0.066	-0.085	-0.090	-0.115	-0.162	-0.243
70	-0.018	-0.034	-0.071	-0.101	-0.127	-0.136	-0.205	-0.319	-0.481
60	-0.033	-0.079	-0.119	-0.171	-0.248	-0.273	-0.440	-0.664	-0.931

TABLE IV(l)
Truncated beam power at cryostat window for Band 2 high limit frequency 90 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 50	60	70	80	88	90	100	110	120
150	1.000	1.000	1.000	0.999	0.999	0.999	0.999	0.998	0.997
140	1.000	1.000	0.999	0.999	0.999	0.999	0.998	0.997	0.997
130	1.000	1.000	0.999	0.999	0.998	0.998	0.997	0.997	0.996
120	1.000	0.999	0.999	0.999	0.998	0.997	0.997	0.996	0.993
110	1.000	0.999	0.999	0.998	0.997	0.997	0.996	0.993	0.989
100	0.999	0.999	0.998	0.997	0.996	0.996	0.993	0.988	0.984
90	0.999	0.998	0.997	0.996	0.993	0.992	0.987	0.982	0.978
88.3	0.999	0.998	0.997	0.995	0.992	0.991	0.986	0.981	0.977
80	0.999	0.997	0.996	0.992	0.987	0.985	0.980	0.974	0.967
70	0.997	0.995	0.991	0.993	0.977	0.976	0.969	0.959	0.941
60	0.995	0.990	0.980	0.971	0.963	0.961	0.944	0.917	0.882

TABLE IV(m)
Beam truncation loss in dB at cryostat window for Band 2 high limit frequency 90 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 50	60	70	80	88	90	100	110	120
150	-0.001	-0.001	-0.002	-0.003	-0.004	-0.004	-0.006	-0.010	-0.012
140	-0.001	-0.001	-0.002	-0.004	-0.005	-0.005	-0.009	-0.012	-0.014
130	-0.001	-0.002	-0.003	-0.005	-0.007	-0.008	-0.012	-0.014	-0.018
120	-0.001	-0.002	-0.004	-0.006	-0.010	-0.011	-0.014	-0.018	-0.030
110	-0.002	-0.004	-0.005	-0.010	-0.014	-0.014	-0.018	-0.031	-0.049
100	-0.002	-0.005	-0.009	-0.014	-0.017	-0.018	-0.032	-0.053	-0.072
90	-0.004	-0.007	-0.014	-0.019	-0.030	-0.034	-0.058	-0.080	-0.098
88.3	-0.005	-0.008	-0.015	-0.020	-0.034	-0.038	-0.063	-0.084	-0.103
80	-0.006	-0.014	-0.019	-0.036	-0.059	-0.065	-0.090	-0.112	-0.144
70	-0.012	-0.020	-0.039	-0.074	-0.099	-0.104	-0.135	-0.183	-0.263
60	-0.022	-0.044	-0.088	-0.127	-0.162	-0.173	-0.251	-0.376	-0.547

4 BAND 3

4.1 Quasi-Optics Analysis

4.1.1 *Gaussian Beam Parameters*

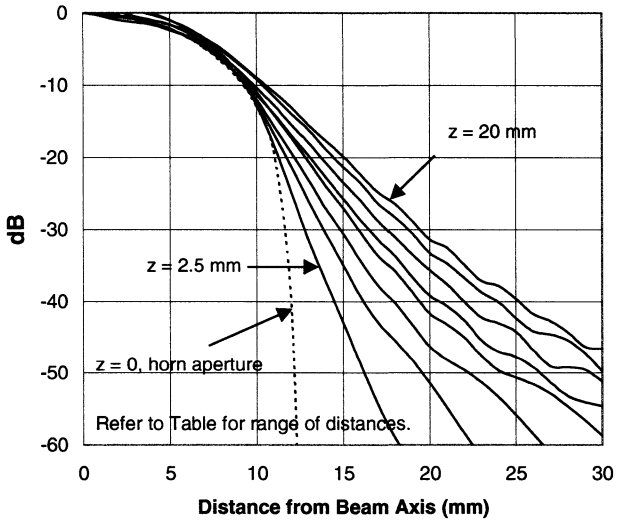
TABLE V(a)
Quasi-optics Gaussian beam parameters for Band 3.

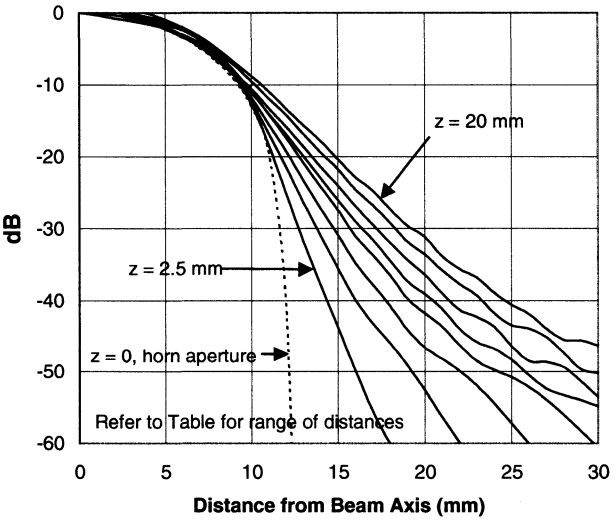
Frequency [GHz]		**84**	**89**	**100**	**116**
λ [mm]		3.568958	3.368455	2.997925	2.584418
Horn diameter	24.0				
Horn axial length	140.0				
Horn slant length	140.513				
Horn waist, w_0		7.234	7.180	7.056	6.863
Horn waist offset, $\Delta z(w_0)$		-17.2063	-19.0300	-23.2001	-29.5328
Waist at horn aperture, w_{ha}		7.722	7.722	7.722	7.722
d_1	152.70				
R_{s1}	190.745	182.394	185.192	191.373	200.218
f_1	149.08				
R_{i1}	682.553	816.220	764.522	674.578	583.682
Waist at mirror 1, w_{M1}	(dia. = 163)	27.646	26.631	24.814	22.897
d_2	170.00				
Waist at mirror 2, w_{M2}	(dia. = 115)	22.976	21.811	19.678	17.340
$z_{w(Cass.)}$	303.85	330.211	327.282	322.307	317.431
$w_{Cass.}$		21.333	20.140	17.932	15.465
$d_{mirror\text{-}subrefl}$		6303.32	6303.32	6303.32	6303.32
$w_{subrefl}$	(dia. = 750)	318.795	318.795	318.795	318.795
$R_{subrefl}$	6000.00	5999.977	5999.984	5999.997	6000.009
Edge Taper (dB)	12.00	12.02	12.02	12.02	12.02

All dimensions in mm.

4.1.2 *Truncation Loss at Filters*

The beam profiles at the filter are shown in Figures 6(a), (b), (c) and (d). Truncation loss of the beam for a range of filter diameters are given in Tables V(b) – V(i).





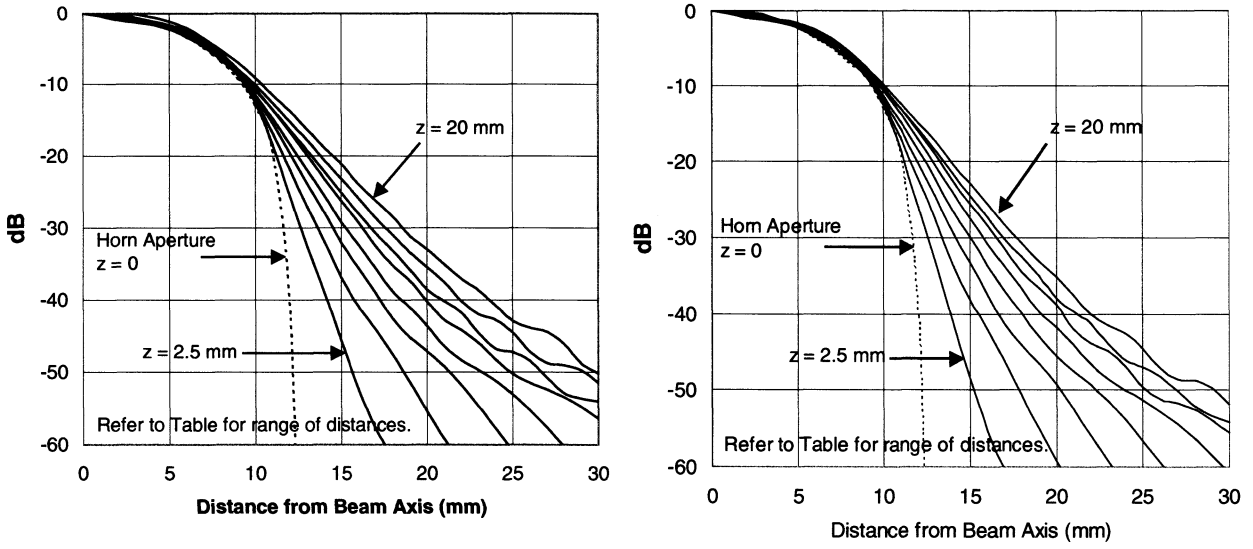


Figure 6. Beam profile at various distances from horn aperture; (a) 84 GHz, (b) 89 GHz, (c) 100 GHz and (d) 116 GHz.

TABLE V(b)
Truncated beam power at filter for Band 3 extended low limit frequency 84 GHz.

Truncation diameter (mm.)	**z from horn aperture (mm.)**							
	2.5	**5**	**7.5**	**10**	**12.5**	**15**	**17.5**	**20**
50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999
40	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.998
35	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.996
30	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.988
25	0.999	0.997	0.994	0.990	0.985	0.979	0.972	0.965

TABLE V(c)
Beam truncation loss in dB at filter for Band 3 extended low limit frequency 84 GHz.

Truncation diameter (mm.)	**z from horn aperture (mm.)**							
	2.5	**5**	**7.5**	**10**	**12.5**	**15**	**17.5**	**20**
50	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002
45	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003
40	-0.000	-0.000	-0.000	-0.001	-0.002	-0.003	-0.004	-0.007
35	-0.000	-0.000	-0.001	-0.002	-0.004	-0.007	-0.012	-0.018
30	-0.000	-0.001	-0.004	-0.009	-0.015	-0.025	-0.037	-0.050
25	-0.003	-0.012	-0.025	-0.043	-0.066	-0.093	-0.123	-0.155

TABLE V(d)
Truncated beam power at filter for Band 3 low limit frequency 89 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999
40	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.999
35	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.997
30	1.000	1.000	0.999	0.998	0.997	0.995	0.993	0.990
25	0.999	0.998	0.995	0.991	0.986	0.980	0.974	0.967

TABLE V(e)
Beam truncation loss in dB at filter for Band 3 low limit frequency 89 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
50	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001
45	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003
40	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.006
35	-0.000	-0.000	-0.001	-0.002	-0.004	-0.006	-0.010	-0.015
30	-0.000	-0.001	-0.003	-0.008	-0.014	-0.022	-0.032	-0.045
25	-0.003	-0.011	-0.023	-0.040	-0.061	-0.086	-0.113	-0.145

TABLE V(f)
Truncated beam power at filter for Band 3 mid frequency 100 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
40	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999
35	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.997
30	1.000	1.000	0.999	0.999	0.998	0.996	0.994	0.992
25	0.999	0.998	0.995	0.992	0.988	0.983	0.978	0.971

TABLE V(g)
Beam truncation loss in dB at filter for Band 3 mid frequency 100 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
50	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001
45	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002
40	-0.000	-0.000	-0.000	-0.000	-0.001	-0.002	-0.003	-0.004
35	-0.000	-0.000	-0.001	-0.001	-0.003	-0.005	-0.008	-0.012
30	-0.000	-0.001	-0.003	-0.006	-0.011	-0.017	-0.026	-0.037
25	-0.002	-0.009	-0.020	-0.034	-0.052	-0.074	-0.099	-0.126

TABLE V(h)
Truncated beam power at filter for Band 3 high limit frequency 116 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999
35	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.998
30	1.000	1.000	1.000	0.999	0.998	0.997	0.996	0.994
25	1.000	0.998	0.996	0.994	0.990	0.986	0.981	0.976

TABLE V(i)
Beam truncation loss in dB at filter for Band 3 high limit frequency 116 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
50	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001
45	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001
40	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003
35	-0.000	-0.000	-0.000	-0.001	-0.002	-0.003	-0.005	-0.008
30	-0.000	-0.001	-0.002	-0.004	-0.008	-0.013	-0.019	-0.028
25	-0.002	-0.007	-0.016	-0.028	-0.043	-0.061	-0.082	-0.106

4.1.3 *Truncation Loss at Mirrors*

The beam profiles at mirror 1 and mirror 2 are shown in Figures 6(e), (f), (g) and (h). Truncation loss of the beam for a range of mirror diameters is given in Table V(j) and V(k).

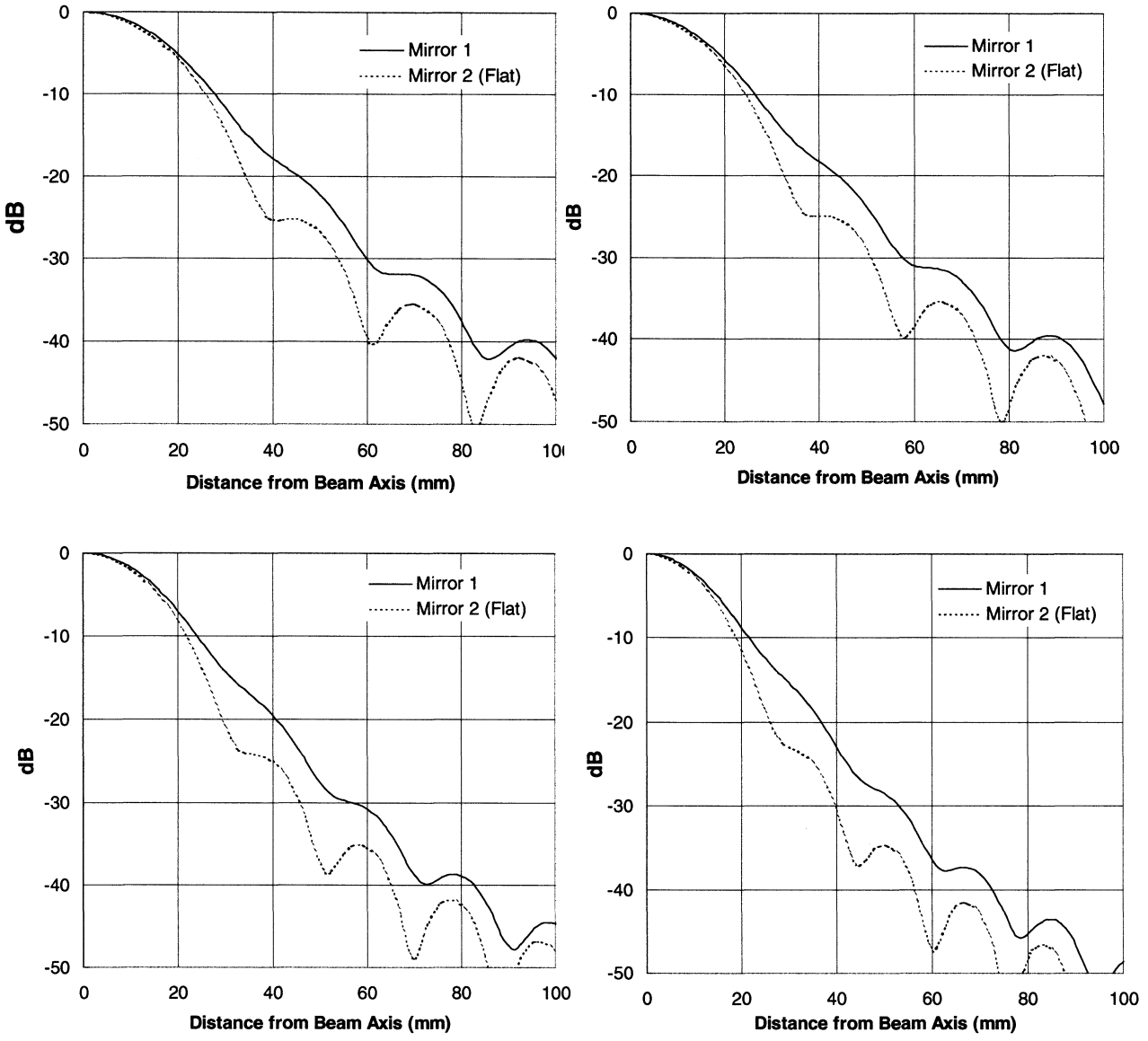


Figure 6. Beam profile at mirror 1 and mirror 2; (e) 84 GHz, (f) 89 GHz, (g) 100 GHz and (h) 116 GHz.

TABLE V(j)
Truncated beam power and loss at mirror 1 for Band 3.

Frequency	84 GHz		89 GHz		100 GHz		116 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
180	0.999	-0.005	0.999	-0.004	0.999	-0.003	1.000	-0.002
170	0.999	-0.006	0.999	-0.005	0.999	-0.003	0.999	-0.002
163	0.999	-0.006	0.999	-0.006	0.999	-0.004	0.999	-0.003
160	0.998	-0.007	0.999	-0.006	0.999	-0.005	0.999	-0.003
150	0.998	-0.010	0.998	-0.008	0.999	-0.006	0.999	-0.003
140	0.997	-0.015	0.997	-0.011	0.998	-0.007	0.999	-0.005
130	0.995	-0.020	0.996	-0.017	0.998	-0.010	0.998	-0.007

Diameter in mm., loss in dB.

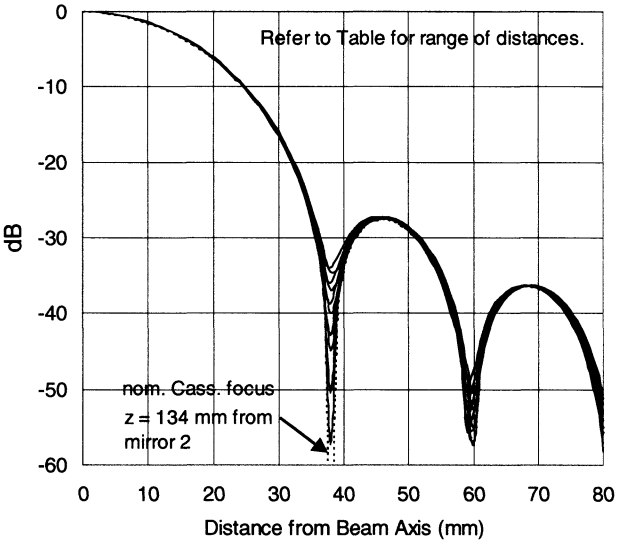
TABLE V(k)
Truncated beam power and loss at mirror 2 for Band 3.

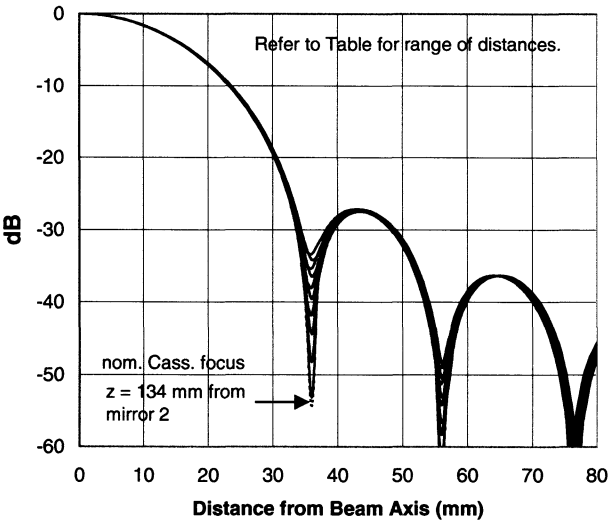
Frequency	84 GHz		89 GHz		100 GHz		116 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
150	0.999	-0.005	0.999	-0.004	0.999	-0.003	1.000	-0.002
140	0.998	-0.007	0.999	-0.005	0.999	-0.004	0.999	-0.002
130	0.998	-0.010	0.998	-0.008	0.999	-0.004	0.999	-0.004
120	0.997	-0.011	0.998	-0.011	0.998	-0.007	0.999	-0.004
115	0.997	-0.012	0.997	-0.011	0.998	-0.009	0.999	-0.004
110	0.997	-0.014	0.997	-0.012	0.998	-0.010	0.999	-0.005
100	0.994	-0.024	0.996	-0.017	0.997	-0.012	0.998	-0.009
90	0.990	-0.043	0.992	-0.033	0.996	-0.018	0.997	-0.013

Diameter in mm., loss in dB.

4.1.4 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 6(i), (j), (k) and (l). Truncation loss of the beam for a range of window diameters is given in Table V(l) – V(s).





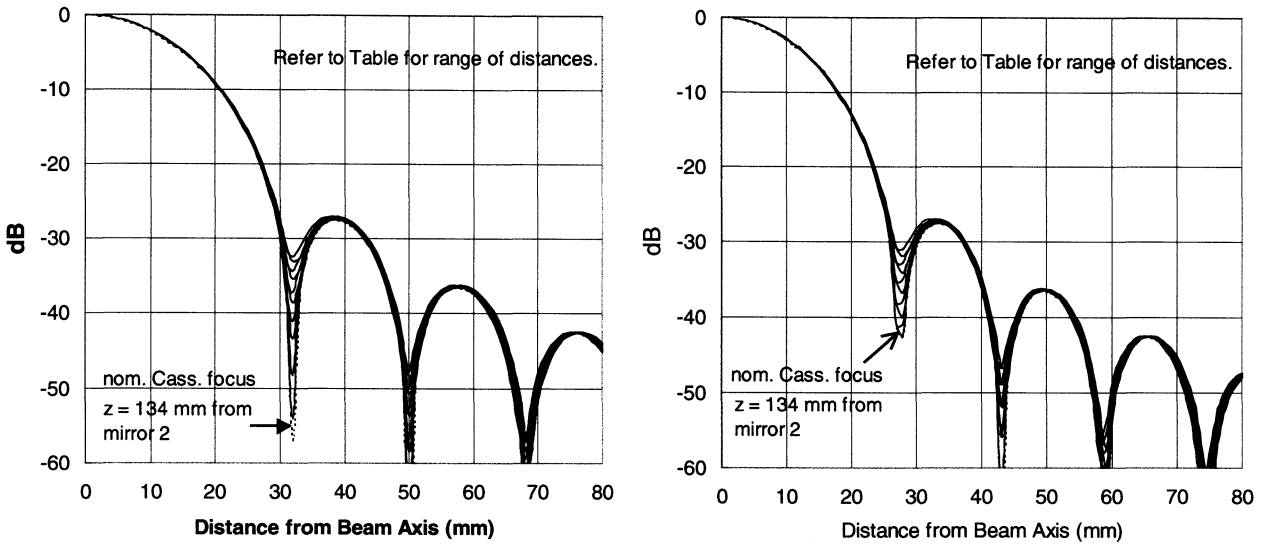


Figure 6. Beam profile at various distances from mirror 2; (i) 84 GHz, (j) 89 GHz, (k) 100 GHz and (l) 116 GHz.

TABLE V(l)
Truncated beam power at cryostat window for Band 3 extended low limit frequency 84 GHz.

Distance from mirror 2 (mm.)	**Window diameter (mm.)**								
	160	**140**	**120**	**100**	**80**	**60**	**56**	**40**	**30**
90	0.999	0.999	0.998	0.996	0.991	0.977	0.962	0.789	0.570
100	0.999	0.999	0.998	0.996	0.991	0.978	0.963	0.791	0.572
110	0.999	0.999	0.998	0.996	0.992	0.979	0.964	0.793	0.574
120	0.999	0.999	0.998	0.996	0.992	0.979	0.965	0.795	0.576
130	0.999	0.999	0.998	0.996	0.992	0.980	0.966	0.796	0.577
133.85[†]	0.999	0.999	0.998	0.996	0.992	0.980	0.966	0.797	0.578
140	0.999	0.999	0.998	0.996	0.992	0.980	0.966	0.797	0.578
150	0.999	0.999	0.998	0.996	0.992	0.980	0.966	0.798	0.579
160	0.999	0.999	0.998	0.996	0.992	0.980	0.966	0.799	0.580
170	0.999	0.999	0.998	0.996	0.991	0.980	0.966	0.799	0.581
180	0.999	0.999	0.998	0.996	0.991	0.979	0.966	0.800	0.581

[†] Cassegrain focus.

TABLE V(m)
Beam truncation loss in dB at cryostat window for Band 3 extended low limit frequency 84 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 160	140	120	100	80	60	56	40	30
90	-0.003	-0.006	-0.009	-0.017	-0.039	-0.101	-0.167	-1.027	-2.440
100	-0.003	-0.006	-0.009	-0.017	-0.038	-0.097	-0.162	-1.016	-2.425
110	-0.003	-0.006	-0.009	-0.016	-0.037	-0.093	-0.157	-1.006	-2.411
120	-0.003	-0.006	-0.009	-0.016	-0.036	-0.091	-0.154	-0.997	-2.399
130	-0.003	-0.006	-0.009	-0.016	-0.036	-0.089	-0.151	-0.989	-2.388
133.85†	-0.003	-0.006	-0.009	-0.016	-0.036	-0.088	-0.150	-0.987	-2.384
140	-0.003	-0.006	-0.009	-0.016	-0.036	-0.088	-0.149	-0.983	-2.379
150	-0.003	-0.006	-0.009	-0.016	-0.036	-0.088	-0.149	-0.978	-2.371
160	-0.003	-0.006	-0.009	-0.015	-0.037	-0.088	-0.149	-0.975	-2.364
170	-0.003	-0.006	-0.009	-0.015	-0.038	-0.089	-0.150	-0.972	-2.359
180	-0.003	-0.006	-0.009	-0.016	-0.039	-0.092	-0.152	-0.971	-2.356

† Cassegrain focus.

TABLE V(n)
Truncated beam power at cryostat window for Band 3 low limit frequency 89 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 160	140	120	100	80	60	56	40	30
90	0.999	0.999	0.998	0.997	0.992	0.984	0.975	0.829	0.614
100	0.999	0.999	0.998	0.997	0.992	0.985	0.976	0.831	0.616
110	0.999	0.999	0.998	0.997	0.992	0.986	0.977	0.833	0.618
120	0.999	0.999	0.998	0.997	0.992	0.986	0.978	0.834	0.620
130	0.999	0.999	0.998	0.997	0.992	0.987	0.978	0.836	0.622
133.85†	0.999	0.999	0.998	0.997	0.992	0.987	0.978	0.836	0.622
140	0.999	0.999	0.998	0.997	0.992	0.987	0.978	0.837	0.623
150	0.999	0.999	0.998	0.997	0.992	0.987	0.978	0.838	0.624
160	0.999	0.999	0.998	0.997	0.992	0.986	0.978	0.838	0.625
170	0.999	0.999	0.998	0.997	0.992	0.986	0.978	0.838	0.625
180	0.999	0.999	0.998	0.997	0.992	0.986	0.977	0.838	0.626

† Cassegrain focus.

TABLE V(o)
Beam truncation loss in dB at cryostat window for Band 3 low limit frequency 89 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 160	140	120	100	80	60	56	40	30
90	-0.003	-0.004	-0.009	-0.012	-0.036	-0.068	-0.110	-0.815	-2.116
100	-0.003	-0.004	-0.009	-0.012	-0.035	-0.064	-0.106	-0.804	-2.101
110	-0.003	-0.004	-0.008	-0.011	-0.034	-0.062	-0.102	-0.794	-2.087
120	-0.003	-0.004	-0.008	-0.011	-0.034	-0.060	-0.099	-0.786	-2.075
130	-0.003	-0.004	-0.008	-0.011	-0.034	-0.058	-0.097	-0.779	-2.065
133.85†	-0.003	-0.004	-0.008	-0.011	-0.034	-0.058	-0.096	-0.777	-2.061
140	-0.003	-0.004	-0.008	-0.011	-0.034	-0.058	-0.096	-0.774	-2.056
150	-0.003	-0.004	-0.008	-0.011	-0.034	-0.058	-0.096	-0.770	-2.049
160	-0.003	-0.004	-0.008	-0.011	-0.034	-0.059	-0.096	-0.767	-2.043
170	-0.003	-0.004	-0.008	-0.011	-0.034	-0.061	-0.098	-0.766	-2.040
180	-0.003	-0.004	-0.008	-0.011	-0.035	-0.063	-0.100	-0.766	-2.037

† Cassegrain focus.

TABLE V(p)
Truncated beam power at cryostat window for Band 3 mid frequency 100 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 160	140	120	100	80	60	56	40	30
90	1.000	0.999	0.999	0.998	0.995	0.990	0.988	0.897	0.704
100	1.000	0.999	0.999	0.998	0.995	0.991	0.998	0.900	0.707
110	1.000	0.999	0.999	0.998	0.995	0.991	0.989	0.901	0.709
120	1.000	0.999	0.999	0.998	0.995	0.991	0.990	0.903	0.711
130	1.000	0.999	0.999	0.998	0.995	0.991	0.990	0.904	0.712
133.85†	1.000	0.999	0.999	0.998	0.995	0.991	0.990	0.904	0.713
140	1.000	0.999	0.999	0.998	0.995	0.991	0.990	0.905	0.713
150	1.000	0.999	0.999	0.998	0.995	0.991	0.990	0.905	0.714
160	1.000	0.999	0.999	0.998	0.995	0.991	0.989	0.905	0.715
170	1.000	0.999	0.999	0.998	0.995	0.991	0.989	0.905	0.715
180	1.000	0.999	0.999	0.998	0.995	0.990	0.988	0.905	0.715

† Cassegrain focus.

TABLE V(q)
Beam truncation loss in dB at cryostat window for Band 3 mid frequency 100 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 160	140	120	100	80	60	56	40	30
90	-0.002	-0.003	-0.005	-0.009	-0.023	-0.044	-0.054	-0.470	-1.524
100	-0.002	-0.003	-0.005	-0.009	-0.023	-0.041	-0.050	-0.460	-1.509
110	-0.002	-0.003	-0.005	-0.009	-0.022	-0.039	-0.048	-0.451	-1.495
120	-0.002	-0.003	-0.005	-0.009	-0.022	-0.038	-0.046	-0.444	-1.484
130	-0.002	-0.003	-0.005	-0.009	-0.021	-0.037	-0.045	-0.439	-1.475
133.85†	-0.002	-0.003	-0.005	-0.009	-0.021	-0.037	-0.045	-0.437	-1.472
140	-0.002	-0.003	-0.005	-0.009	-0.021	-0.037	-0.045	-0.435	-1.467
150	-0.002	-0.003	-0.005	-0.009	-0.021	-0.038	-0.045	-0.433	-1.462
160	-0.002	-0.003	-0.005	-0.009	-0.021	-0.039	-0.047	-0.432	-1.458
170	-0.002	-0.003	-0.005	-0.009	-0.021	-0.041	-0.049	-0.433	-1.456
180	-0.002	-0.003	-0.005	-0.009	-0.022	-0.044	-0.052	-0.436	-1.457

† Cassegrain focus.

TABLE V(r)
Truncated beam power at cryostat window for Band 3 high limit frequency 116 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 160	140	120	100	80	60	56	40	30
90	1.000	1.000	0.999	0.998	0.998	0.991	0.990	0.957	0.812
100	1.000	1.000	0.999	0.999	0.998	0.991	0.991	0.959	0.815
110	1.000	1.000	0.999	0.999	0.998	0.992	0.991	0.960	0.817
120	1.000	1.000	0.999	0.999	0.998	0.992	0.992	0.961	0.819
130	1.000	1.000	0.999	0.999	0.998	0.992	0.992	0.962	0.821
133.85†	1.000	1.000	0.999	0.999	0.998	0.992	0.992	0.962	0.821
140	1.000	1.000	0.999	0.999	0.998	0.992	0.992	0.963	0.822
150	1.000	1.000	0.999	0.999	0.998	0.992	0.991	0.963	0.822
160	1.000	1.000	0.999	0.999	0.998	0.992	0.991	0.962	0.822
170	1.000	1.000	0.999	0.999	0.998	0.991	0.991	0.961	0.822
180	1.000	1.000	0.999	0.999	0.998	0.991	0.990	0.960	0.821

† Cassegrain focus.

TABLE V(s)
Beam truncation loss in dB at cryostat window for Band 3 high limit frequency 116 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 160	140	120	100	80	60	56	40	30
90	-0.002	-0.002	-0.003	-0.007	-0.010	-0.039	-0.042	-0.192	-0.905
100	-0.001	-0.002	-0.003	-0.006	-0.010	-0.037	-0.040	-0.183	-0.890
110	-0.001	-0.002	-0.003	-0.006	-0.010	-0.036	-0.038	-0.176	-0.877
120	-0.001	-0.002	-0.003	-0.006	-0.009	-0.035	-0.037	-0.171	-0.867
130	-0.001	-0.002	-0.003	-0.006	-0.009	-0.035	-0.036	-0.168	-0.859
133.85†	-0.001	-0.002	-0.003	-0.006	-0.009	-0.035	-0.036	-0.167	-0.856
140	-0.001	-0.002	-0.003	-0.006	-0.009	-0.035	-0.037	-0.166	-0.853
150	-0.001	-0.002	-0.003	-0.006	-0.009	-0.035	-0.037	-0.166	-0.850
160	-0.001	-0.002	-0.003	-0.006	-0.009	-0.036	-0.039	-0.168	-0.849
170	-0.001	-0.002	-0.003	-0.006	-0.010	-0.037	-0.040	-0.171	-0.851
180	-0.001	-0.002	-0.003	-0.006	-0.010	-0.039	-0.043	-0.176	-0.855

† Cassegrain focus.

4.2 Physical Optics Analysis

4.2.1 *Beam Profile at Cassegrain Focus*

Figures 6(m) – 4(p) show the beam profile at the Cassegrain focus with comparison of results obtained by both quasi-optics and physical optics.

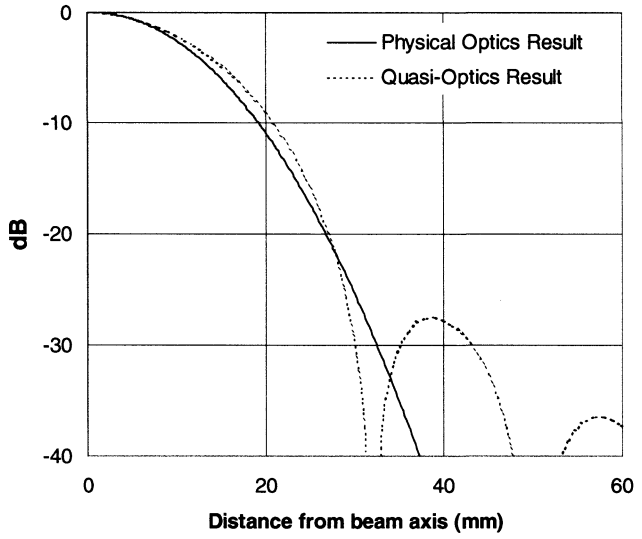


Figure 6(m). Beam profile at Cassegrain focus for Band 3 mid frequency 100 GHz.

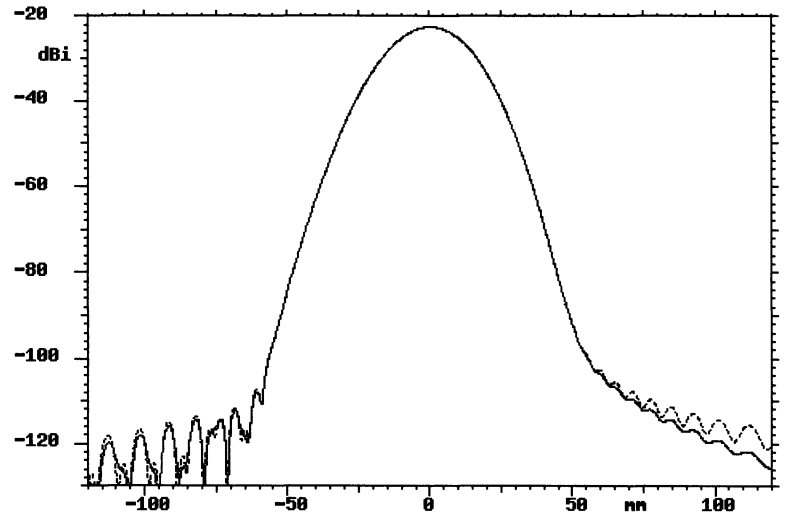


Figure 6(n). Beam profile of co-polar field at Cassegrain focus, Band 3 mid frequency 100 GHz; x-polarised source solid line, y-polarised source dotted line.

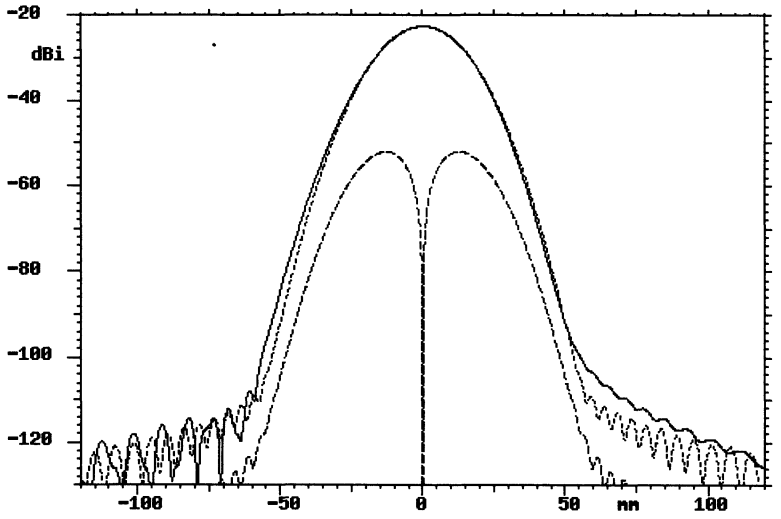


Figure 6(o). Beam profile at Cassegrain focus Band 3 mid frequency 100 GHz., x-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

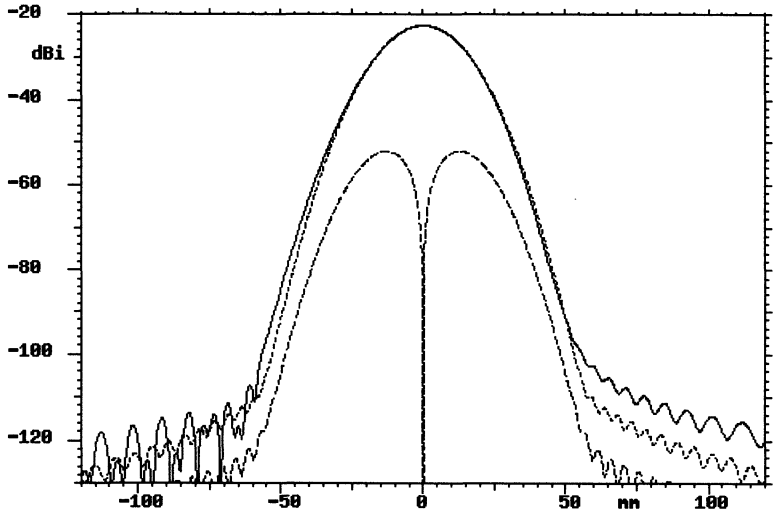


Figure 6(p). Beam profile at Cassegrain focus Band 3 mid frequency 100 GHz., y-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

4.2.2 *Beam Profile at Subreflector & Edge Taper*

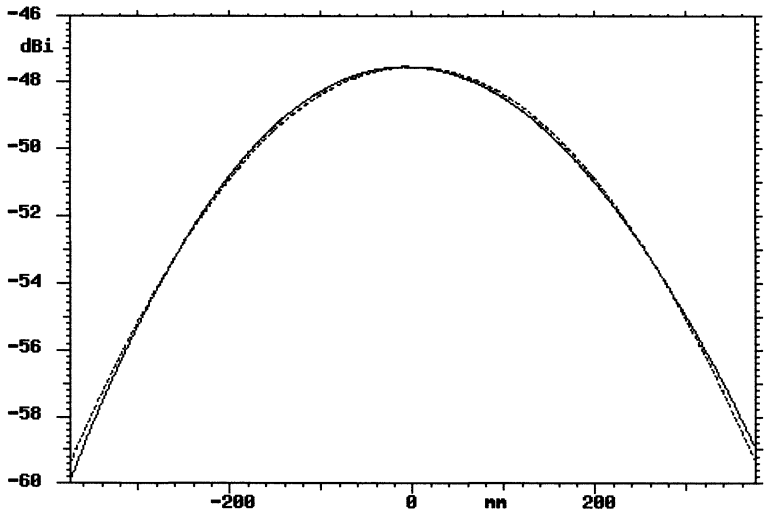


Figure 6(q). Beam profile at subreflector Band 3 mid frequency 100 GHz.; $\phi = 0^{o}$ solid line, $\phi = 90^{o}$ dash line.

The edge tapers at the subreflector corresponding to the four positions where $\phi = 0^{o}$ and 90^{o} are -11.9, -11, -11.5 and -11.4 respectively.

4.2.3 *Far Field Radiation Pattern*

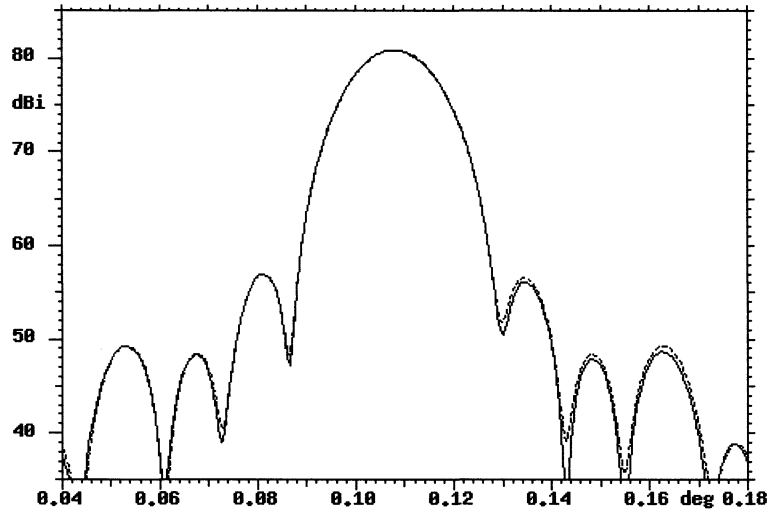


Figure 6(r). Antenna far field radiation pattern for Band 3 mid frequency 100 GHz.; x-polarised source solid line, y-polarised source dash line.

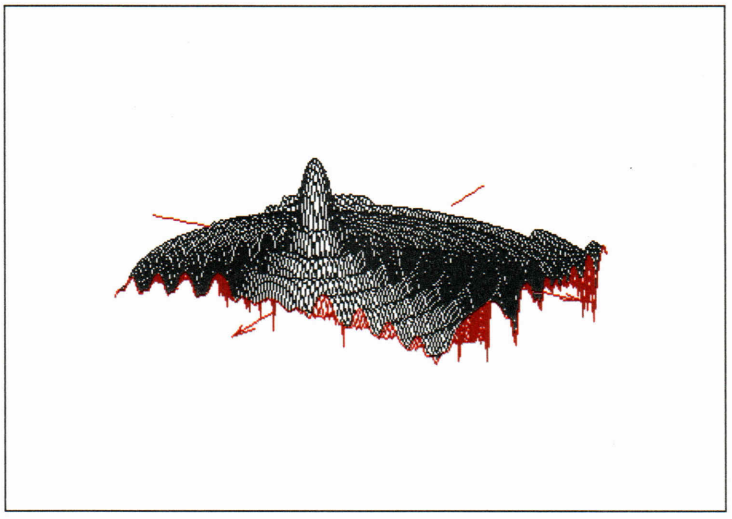


Figure 6(s). 3-D plot of antenna co-polar field radiation pattern.

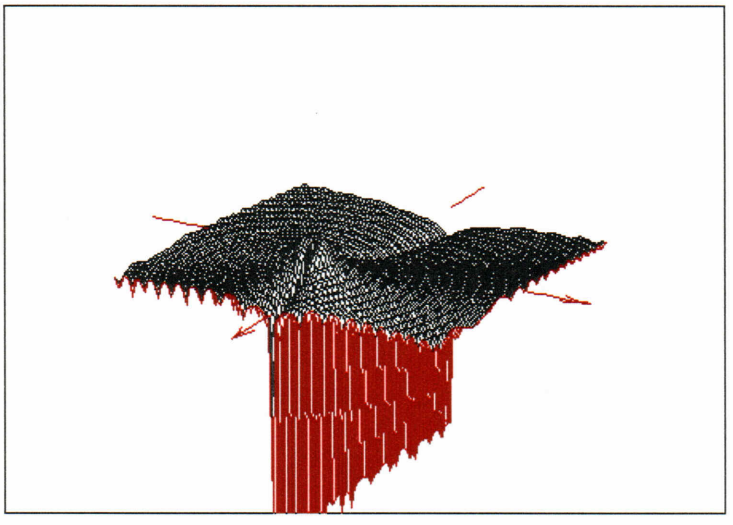


Figure 6(t). 3-D plot of antenna cross-polar field radiation pattern.

4.2.4 *Beam & Cross-Polar Efficiencies*

The beam efficiencies are shown in Table V(t) below.

TABLE V(t)
Beam efficiencies for Band 3 mid frequency 100 GHz defined by contours of the co-polarisation field.

Level below peak (dB)	**Co-polar (%)**	**Cross-polar (%)**
3.0	48.18	0.02
6.0	70.27	0.04
9.0	80.21	0.07
12.0	84.65	0.09
15.0	86.59	0.10
18.0	87.44	0.11
21.0	87.81	0.11
24.0	87.99	0.12
27.0	88.99	0.12
30.0	89.24	0.13
33.0	89.67	0.13
36.0	90.09	0.13
39.0	90.49	0.13
42.0	90.78	0.14
45.0	90.99	0.14
48.0	91.11	0.14
51.0	91.17	0.14
54.0	91.20	0.14
57.0	91.22	0.14
60.0	91.23	0.14

5 BAND 4

5.1 Quasi-Optics Analysis

5.1.1 *Gaussian Beam Parameters*

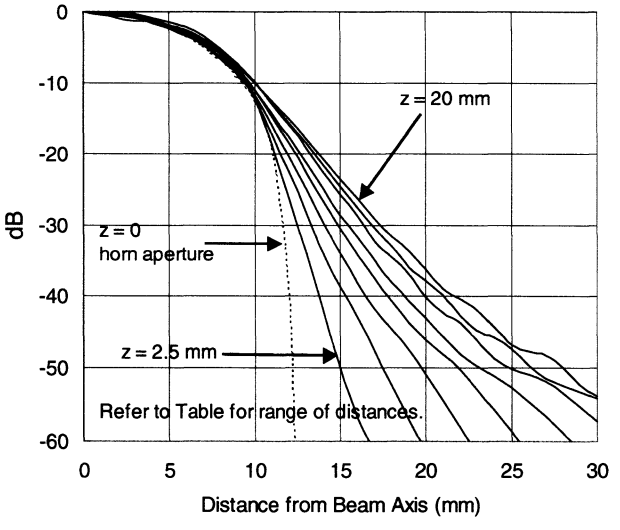
TABLE VI(a)
Quasi-optics Gaussian beam parameters for Band 4.

Frequency [GHz]		**125**	**144**	**163**
λ [mm]		2.398340	2.081892	1.839218
Horn diameter	24.0			
Horn axial length	140.0			
Horn slant length	140.513			
Horn waist, w_0		6.749	6.503	6.252
Horn waist offset, $\Delta z(w_0)$		-33.1695	-40.8641	-48.3996
Waist at horn aperture, w_{ha}		7.722	7.722	7.722
d_1	152.70			
R_{s1}	214.06	205.026	214.601	223.269
f_1	149.08			
R_{i1}	491.13	546.338	488.280	448.650
Waist at mirror 1, w_{M1}	(dia. = 124)	22.081	20.770	19.841
d_2	160.00			
Waist at mirror 2, w_{M2}	(dia. = 86)	16.565	14.868	13.610
$z_{w(Cass.)}$	303.85	315.470	312.469	310.453
$w_{Cass.}$		14.354	12.463	11.012
$d_{mirror\text{-}subrefl}$		6303.31	6303.30	6303.30
$w_{subrefl}$	(dia. = 750)	318.795	318.794	318.794
$R_{subrefl}$	6000.00	6000.003	6000.001	6000.006
Edge Taper (dB)	12.00	12.02	12.02	12.02

All dimensions in mm.

5.1.2 *Truncation Loss at Filters*

The beam profiles at the filter are shown in Figures 7(a), (b) and (c). Truncation loss of the beam for a range of filter diameters are given in Tables VI(b) – VI(g).



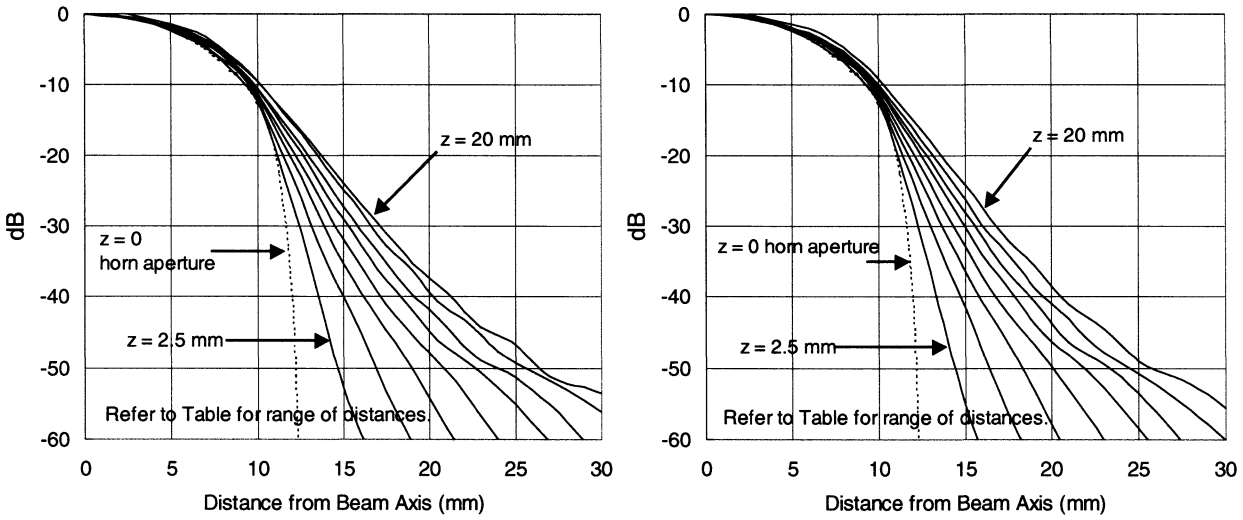


Figure 7. Beam profile at various distances from horn aperture; (a) 125 GHz, (b) 144 GHz and (c) 163 GHz.

TABLE VI(b)
Truncated beam power at filter for Band 4 low limit frequency 125 GHz.

Truncation diameter (mm.)	**z from horn aperture (mm.)**							
	2.5	**5**	**7.5**	**10**	**12.5**	**15**	**17.5**	**20**
60	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
55	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999
35	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.998
30	1.000	1.000	1.000	0.999	0.998	0.997	0.996	0.995
25	1.000	0.999	0.997	0.994	0.991	0.987	0.983	0.978

TABLE VI(c)
Beam truncation loss in dB at filter for Band 4 low limit frequency 125 GHz.

Truncation diameter (mm.)	**z from horn aperture (mm.)**							
	2.5	**5**	**7.5**	**10**	**12.5**	**15**	**17.5**	**20**
60	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
55	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
50	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001
45	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001
40	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.002
35	-0.000	-0.000	-0.000	-0.001	-0.002	-0.003	-0.004	-0.007
30	-0.000	-0.001	-0.002	-0.004	-0.007	-0.011	-0.017	-0.024
25	-0.002	-0.006	-0.014	-0.025	-0.039	-0.055	-0.075	-0.096

TABLE VI(d)
Truncated beam power at filter for Band 4 mid frequency 144 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
60	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
55	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
35	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999
30	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.996
25	1.000	0.999	0.997	0.995	0.993	0.989	0.986	0.981

TABLE VI(e)
Beam truncation loss in dB at filter for Band 4 mid frequency 144 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
60	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
55	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
50	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
45	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001
40	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002
35	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.005
30	-0.000	-0.000	-0.001	-0.003	-0.005	-0.008	-0.013	-0.018
25	-0.001	-0.005	-0.012	-0.021	-0.032	-0.046	-0.063	-0.082

TABLE VI(f)
Truncated beam power at filter for Band 4 high limit frequency 163 GHz.

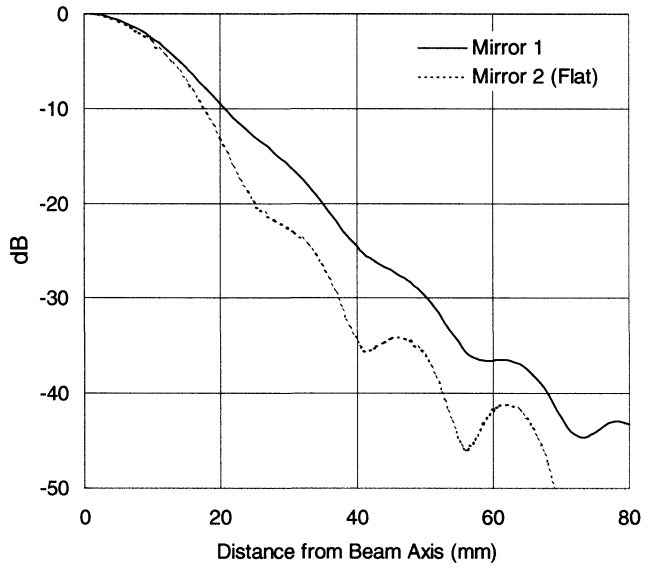
Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
60	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
55	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
35	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999
30	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.997
25	1.000	0.999	0.998	0.996	0.994	0.991	0.988	0.984

TABLE VI(g)
Beam truncation loss in dB at filter for Band 4 high limit frequency 163 GHz.

Truncation diameter (mm.)	z from horn aperture (mm.) 2.5	5	7.5	10	12.5	15	17.5	20
60	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
55	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
50	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
45	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
40	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.001	-0.001
35	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004
30	-0.000	-0.000	-0.001	-0.002	-0.004	-0.006	-0.010	-0.015
25	-0.001	-0.004	-0.010	-0.018	-0.028	-0.040	-0.054	-0.017

5.1.3 *Truncation Loss at Mirrors*

The beam profiles at mirror 1 and mirror 2 are shown in Figures 7(d), (e) and (f). Truncation loss of the beam for a range of mirror diameters is given in Table VI(h) and VI(i).



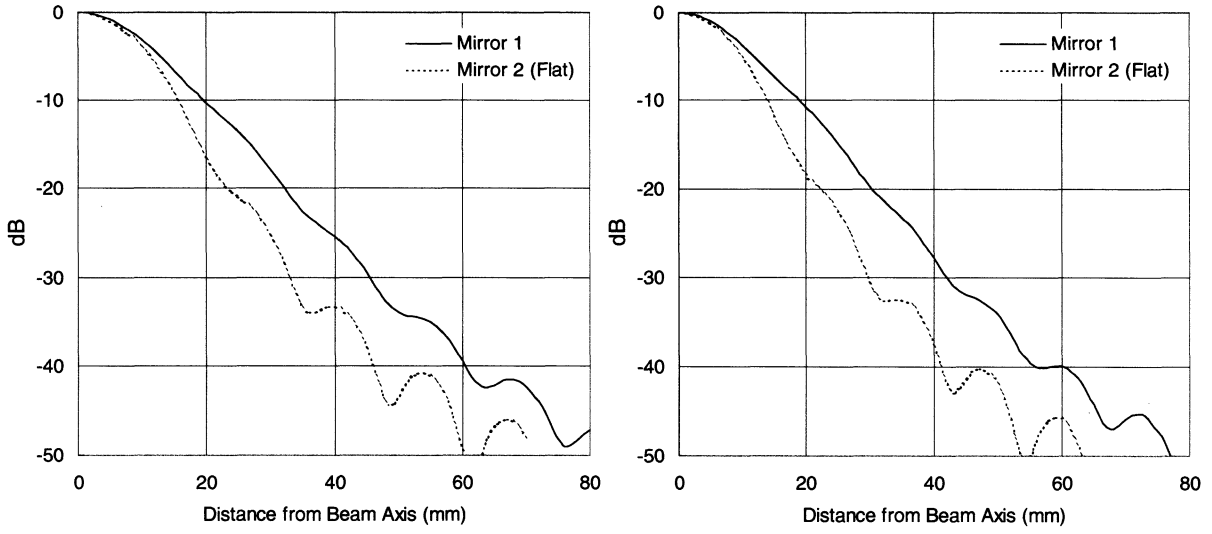


Figure 7. Beam profile at mirror 1 and mirror 2; (d) 125 GHz, (e) 144 GHz and (f) 163 GHz.

TABLE VI(h)
Truncated beam power and loss at mirror 1 for Band 4.

Frequency	**125 GHz**		**144 GHz**		**163 GHz**	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
160	0.999	-0.002	1.000	-0.002	1.000	-0.001
150	0.999	-0.003	1.000	-0.002	1.000	-0.001
140	0.999	-0.004	0.999	-0.003	1.000	-0.002
130	0.999	-0.005	0.999	-0.004	0.999	-0.002
124	0.998	-0.007	0.999	-0.004	0.999	-0.003
120	0.998	-0.008	0.999	-0.005	0.999	-0.004
110	0.997	-0.012	0.998	-0.008	0.999	-0.005
100	0.996	-0.019	0.997	-0.013	0.998	-0.009

Diameter in mm., loss in dB.

TABLE VI(i)
Truncated beam power and loss at mirror 2 for Band 4.

Frequency	**125 GHz**		**144 GHz**		**163 GHz**	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
140	1.000	-0.002	1.000	-0.001	1.000	-0.001
130	0.999	-0.002	1.000	-0.002	1.000	-0.001
120	0.999	-0.004	1.000	-0.002	1.000	-0.002
110	0.999	-0.005	0.999	-0.003	1.000	-0.002
100	0.999	-0.006	0.999	-0.005	0.999	-0.003
90	0.997	-0.012	0.999	-0.006	0.999	-0.005
86	0.997	-0.013	0.998	-0.008	0.999	-0.005
80	0.996	-0.016	0.997	-0.012	0.999	-0.006
70	0.994	-0.027	0.996	-0.018	0.997	-0.014

Diameter in mm., loss in dB.

5.1.4 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 7(g), (h) and (i). Truncation loss of the beam for a range of window diameters is given in Table VI(j) – VI(o).

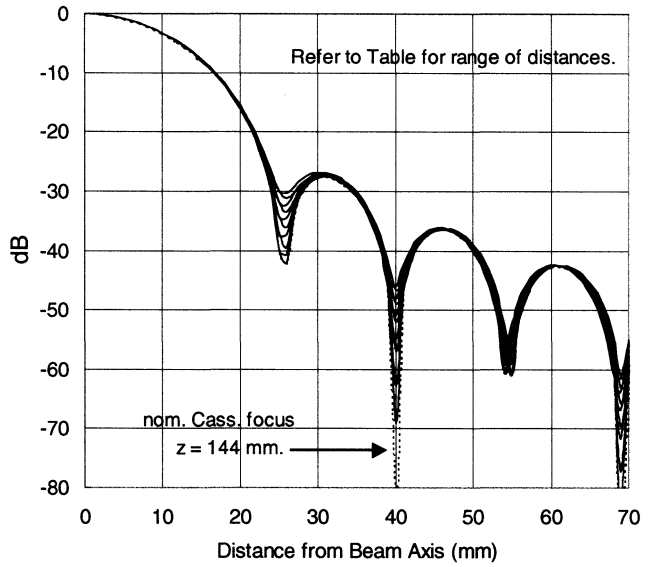
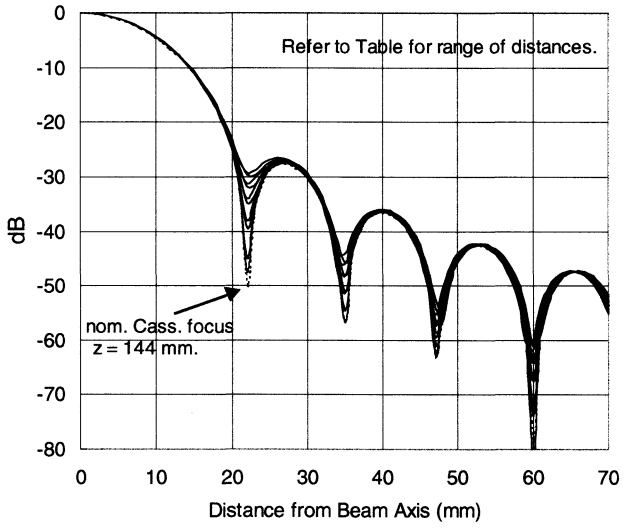


Figure 7. Beam profile at various distances from mirror 2; (g) 125 GHz, (h) 144 GHz and (i) 163 GHz.



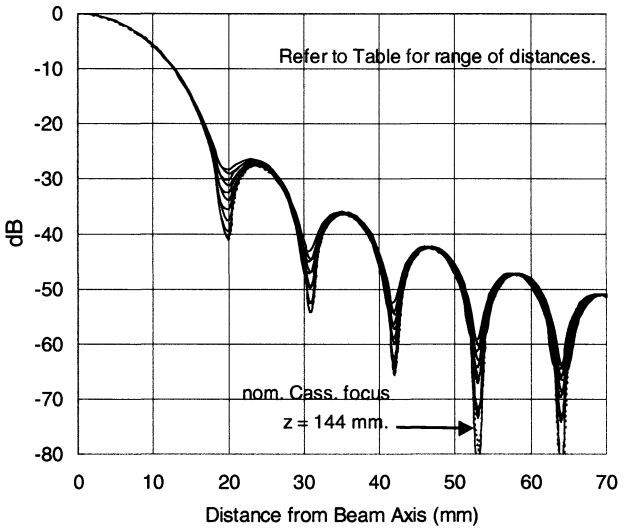


TABLE VI(j)
Truncated beam power at cryostat window for Band 4 low limit frequency 125 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 140	120	100	80	60	56	40	30
100	1.000	0.999	0.999	0.998	0.993	0.991	0.974	0.859
110	1.000	0.999	0.999	0.998	0.993	0.991	0.975	0.862
120	1.000	0.999	0.999	0.998	0.993	0.992	0.977	0.865
130	1.000	0.999	0.999	0.998	0.993	0.992	0.978	0.867
140	1.000	0.999	0.999	0.998	0.993	0.992	0.978	0.868
143.85†	1.000	0.999	0.999	0.998	0.993	0.992	0.979	0.869
150	1.000	0.999	0.999	0.998	0.993	0.992	0.979	0.869
160	1.000	0.999	0.999	0.998	0.993	0.992	0.979	0.870
170	1.000	0.999	0.999	0.998	0.993	0.992	0.978	0.869
180	1.000	0.999	0.999	0.998	0.993	0.991	0.977	0.869
190	1.000	0.999	0.999	0.998	0.993	0.991	0.976	0.867

† Cassegrain focus.

TABLE VI(k)
Beam truncation loss in dB at cryostat window for Band 4 low limit frequency 125 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 140	120	100	80	60	56	40	30
100	-0.002	-0.003	-0.004	-0.009	-0.032	-0.039	-0.116	-0.658
110	-0.002	-0.003	-0.004	-0.009	-0.031	-0.037	-0.108	-0.643
120	-0.002	-0.003	-0.004	-0.009	-0.030	-0.036	-0.102	-0.630
130	-0.002	-0.003	-0.004	-0.009	-0.029	-0.035	-0.097	-0.621
140	-0.002	-0.003	-0.004	-0.009	-0.029	-0.035	-0.094	-0.613
143.85†	-0.002	-0.003	-0.004	-0.009	-0.029	-0.035	-0.094	-0.611
150	-0.002	-0.003	-0.004	-0.009	-0.029	-0.035	-0.094	-0.609
160	-0.002	-0.003	-0.004	-0.009	-0.029	-0.035	-0.094	-0.607
170	-0.002	-0.003	-0.004	-0.009	-0.029	-0.036	-0.097	-0.608
180	-0.002	-0.003	-0.004	-0.009	-0.030	-0.037	-0.101	-0.611
190	-0.002	-0.003	-0.004	-0.009	-0.031	-0.039	-0.107	-0.618

† Cassegrain focus.

TABLE VI(l)
Truncated beam power at cryostat window for Band 4 mid frequency 144 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 140	120	100	80	60	56	40	30
100	1.000	1.000	0.999	0.998	0.997	0.995	0.987	0.930
110	1.000	1.000	0.999	0.998	0.997	0.995	0.989	0.933
120	1.000	1.000	0.999	0.998	0.997	0.995	0.990	0.935
130	1.000	1.000	0.999	0.999	0.997	0.995	0.990	0.937
140	1.000	1.000	0.999	0.999	0.997	0.995	0.991	0.938
143.85†	1.000	1.000	0.999	0.999	0.997	0.995	0.991	0.939
150	1.000	1.000	0.999	0.999	0.997	0.995	0.991	0.939
160	1.000	1.000	0.999	0.999	0.997	0.995	0.990	0.939
170	1.000	1.000	0.999	0.999	0.997	0.995	0.990	0.938
180	1.000	1.000	0.999	0.999	0.997	0.995	0.989	0.937
190	1.000	1.000	0.999	0.999	0.997	0.995	0.987	0.935

† Cassegrain focus.

TABLE VI(m)
Beam truncation loss in dB at cryostat window for Band 4 mid frequency 144 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 140	120	100	80	60	56	40	30
100	-0.001	-0.002	-0.003	-0.007	-0.015	-0.023	-0.056	-0.316
110	-0.001	-0.002	-0.003	-0.007	-0.014	-0.022	-0.050	-0.301
120	-0.001	-0.002	-0.003	-0.007	-0.014	-0.021	-0.045	-0.290
130	-0.001	-0.002	-0.003	-0.006	-0.013	-0.021	-0.042	-0.281
140	-0.001	-0.002	-0.003	-0.006	-0.013	-0.020	-0.040	-0.267
143.85†	-0.001	-0.002	-0.003	-0.006	-0.013	-0.020	-0.040	-0.275
150	-0.001	-0.002	-0.003	-0.006	-0.013	-0.020	-0.040	-0.273
160	-0.001	-0.002	-0.003	-0.006	-0.013	-0.020	-0.042	-0.274
170	-0.001	-0.002	-0.003	-0.006	-0.013	-0.021	-0.045	-0.278
180	-0.001	-0.002	-0.003	-0.006	-0.014	-0.021	-0.050	-0.284
190	-0.001	-0.002	-0.003	-0.006	-0.014	-0.022	-0.056	-0.294

† Cassegrain focus.

TABLE VI(n)
Truncated beam power at cryostat window for Band 4 high limit frequency 163 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 140	120	100	80	60	56	40	30
100	1.000	1.000	1.000	0.999	0.998	0.997	0.989	0.967
110	1.000	1.000	1.000	0.999	0.998	0.998	0.990	0.970
120	1.000	1.000	1.000	0.999	0.998	0.998	0.991	0.972
130	1.000	1.000	1.000	0.999	0.998	0.998	0.991	0.974
140	1.000	1.000	1.000	0.999	0.998	0.998	0.992	0.974
143.85†	1.000	1.000	1.000	0.999	0.998	0.998	0.992	0.975
150	1.000	1.000	1.000	0.999	0.998	0.998	0.992	0.975
160	1.000	1.000	1.000	0.999	0.998	0.998	0.991	0.974
170	1.000	1.000	1.000	0.999	0.998	0.998	0.991	0.973
180	1.000	1.000	1.000	0.999	0.998	0.998	0.990	0.971
190	1.000	1.000	1.000	0.999	0.998	0.997	0.989	0.968

† Cassegrain focus.

TABLE VI(o)
Beam truncation loss in dB at cryostat window for Band 4 high limit frequency 163 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 140	120	100	80	60	56	40	30
100	-0.001	-0.001	-0.002	-0.004	-0.010	-0.011	-0.048	-0.147
110	-0.001	-0.001	-0.002	-0.004	-0.009	-0.011	-0.043	-0.134
120	-0.001	-0.001	-0.002	-0.004	-0.009	-0.010	-0.040	-0.124
130	-0.001	-0.001	-0.002	-0.003	-0.009	-0.010	-0.037	-0.116
140	-0.001	-0.001	-0.002	-0.003	-0.009	-0.010	-0.036	-0.112
143.85†	-0.001	-0.001	-0.002	-0.003	-0.009	-0.010	-0.036	-0.112
150	-0.001	-0.001	-0.002	-0.003	-0.009	-0.010	-0.037	-0.111
160	-0.001	-0.001	-0.002	-0.003	-0.009	-0.010	-0.038	-0.114
170	-0.001	-0.001	-0.002	-0.004	-0.009	-0.010	-0.040	-0.119
180	-0.001	-0.001	-0.002	-0.004	-0.009	-0.011	-0.044	-0.128
190	-0.001	-0.001	-0.002	-0.004	-0.010	-0.011	-0.049	-0.139

† Cassegrain focus.

5.2 Physical Optics Analysis

5.2.1 *Beam Profile at Cassegrain Focus*

Figures 7(j) – (m) show the beam profile at the Cassegrain focus with comparison of results obtained by both quasi-optics and physical optics.

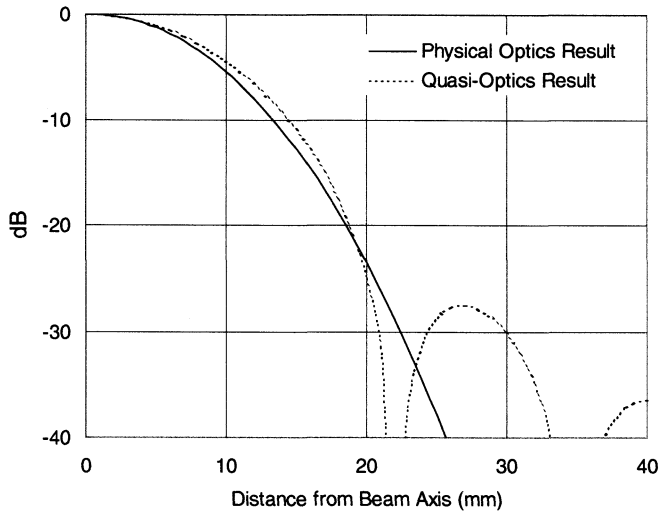


Figure 7(j). Beam profile at Cassegrain focus for Band 4 mid frequency 144 GHz.

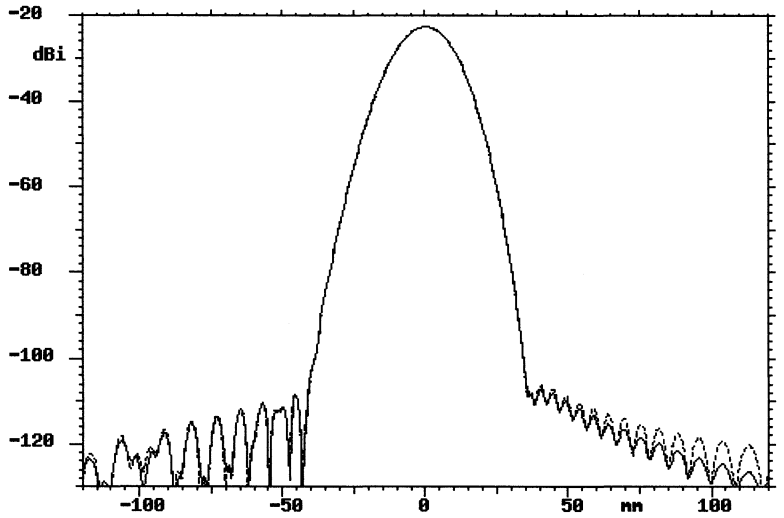


Figure 7(k). Beam profile of co-polar field at Cassegrain focus, Band 4 mid frequency 144 GHz; x-polarised source solid line, y-polarised source dotted line.

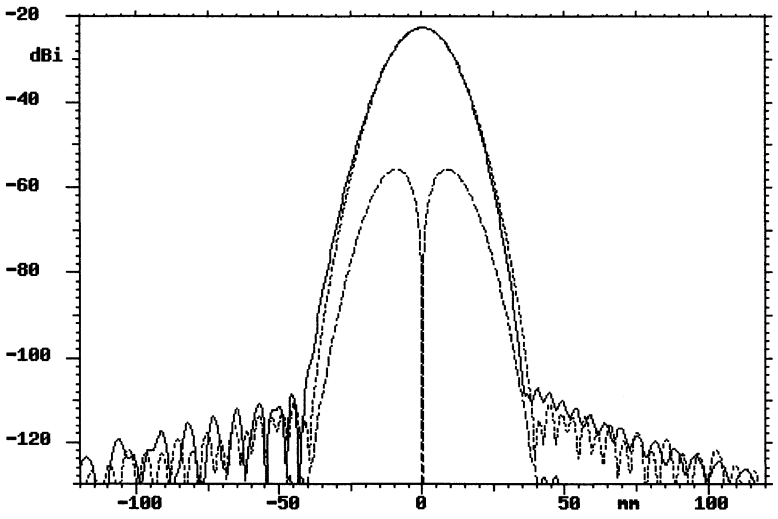


Figure 7(l). Beam profile at Cassegrain focus Band 4 mid frequency 144 GHz., x-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

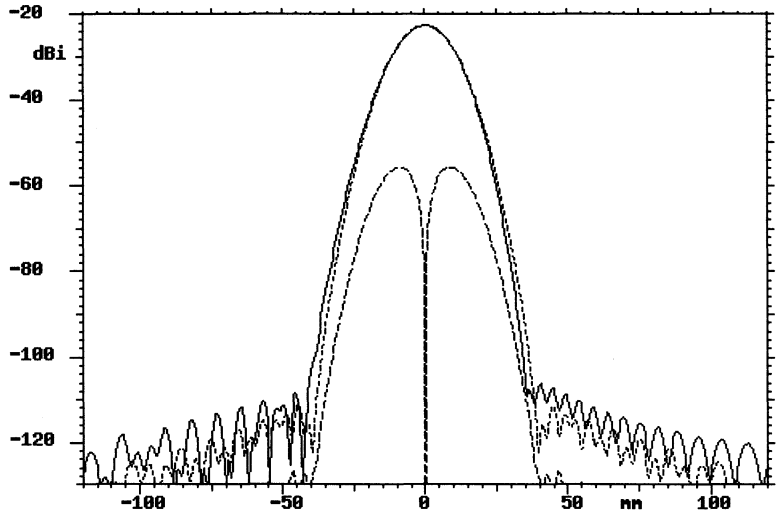


Figure 7(m). Beam profile at Cassegrain focus Band 4 mid frequency 144 GHz., y-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

5.2.2 *Beam Profile at Subreflector & Edge Taper*

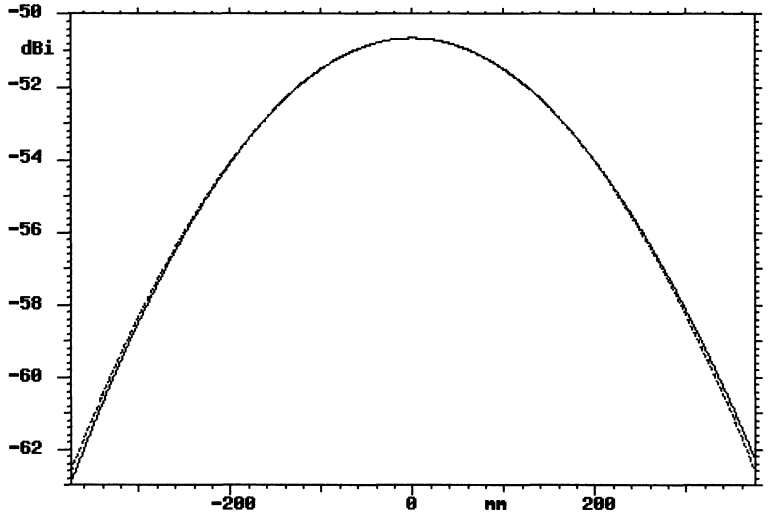


Figure 7(n). Beam profile at subreflector Band 4 mid frequency 144 GHz.; $\phi = 0^{o}$ solid line, $\phi = 90^{o}$ dash line.

The edge tapers at the subreflector corresponding to the four positions where $\phi = 0^{o}$ and 90^{o} are –11.8, -11.2, -11.5 and –11.5 respectively.

5.2.3 *Far Field Radiation Pattern*

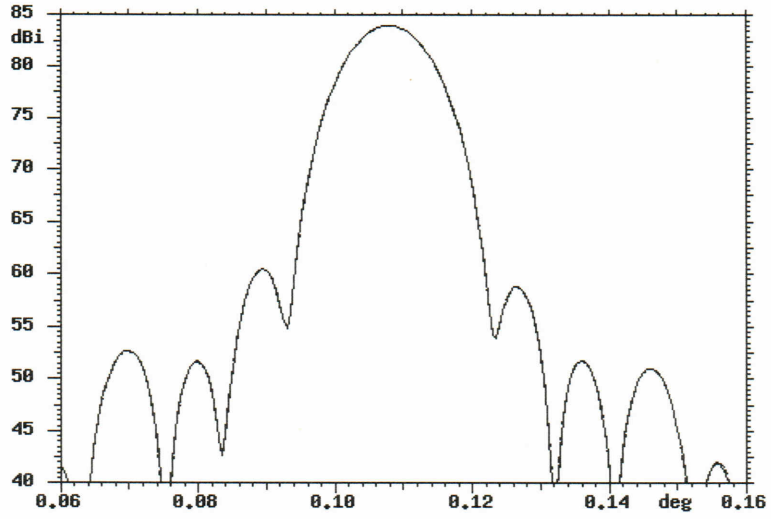


Figure 7(o). Antenna far field radiation pattern for Band 4 mid frequency 144 GHz.; x-polarised source solid line, y-polarised source dash line.

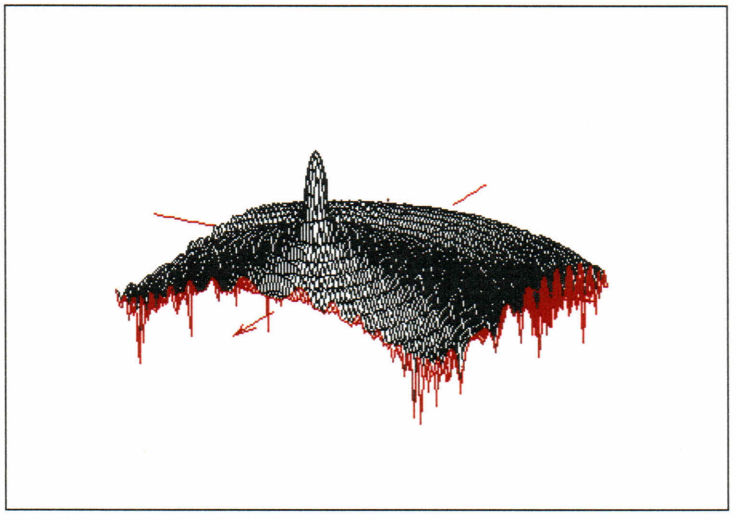


Figure 7(p). 3-D plot of antenna co-polar field radiation pattern.

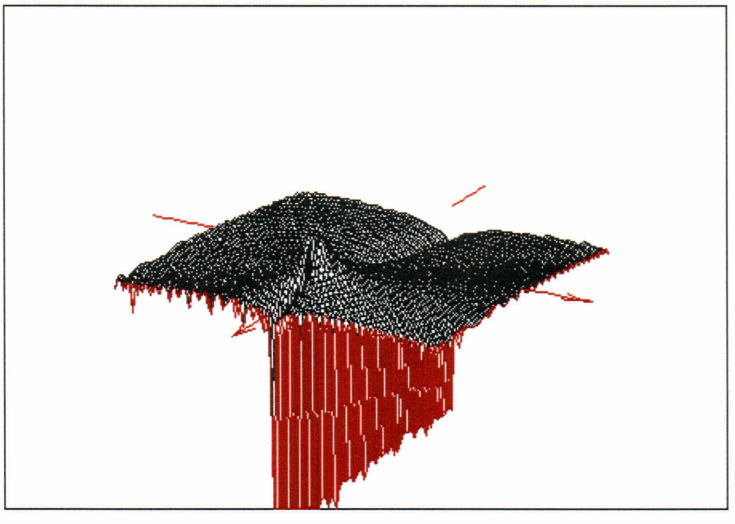


Figure 7(q). 3-D plot of antenna cross-polar field radiation pattern.

5.2.4 *Beam & Cross-Polar Efficiencies*

The beam efficiencies are shown in Table VI(p) below.

TABLE VI(p)
Beam efficiencies for Band 4 mid frequency 144 GHz
defined by contours of the co-polarisation field.

Level below peak (dB)	**Co-polar (%)**	**Cross-polar (%)**
3.0	47.98	0.01
6.0	70.15	0.02
9.0	80.21	0.03
12.0	84.68	0.04
15.0	86.68	0.05
18.0	87.56	0.06
21.0	87.94	0.06
24.0	88.21	0.06
27.0	89.22	0.06
30.0	89.51	0.07
33.0	89.89	0.07
36.0	90.29	0.07
39.0	90.69	0.07
42.0	91.03	0.07
45.0	91.27	0.07
48.0	91.42	0.07
51.0	91.51	0.07
54.0	91.57	0.07
57.0	91.61	0.07
60.0	91.64	0.07

6 BAND 5

6.1 Quasi-Optics Analysis

6.1.1 *Gaussian Beam Parameters*

TABLE VII(a)
Quasi-optics Gaussian beam parameters for Band 5.

Frequency [GHz]		**163**	**187**	**211**
λ **[mm]**		1.839218	1.603168	1.420817
Horn diameter	9.0			
Horn axial length	60.0			
Horn slant length	60.169			
Horn waist, w_0		2.817	2.793	2.767
Horn waist offset, $\Delta z(w_0)$		-3.22678	-4.17615	-5.21796
Waist at horn aperture, w_{ha}		2.896	2.896	2.896
d_1	60.05			
R_{s1}	67.778	66.181	67.867	69.661
f_1	32.756			
R_{i1}	63.394	64.857	63.315	61.829
Waist at mirror 1, w_{M1}	(dia. = 70)	13.449	12.061	11.020
z_{w1}		62.1191	60.3381	58.7160
w_1		2.763	2.615	2.473
d_2	140.00			
R_{s2}	81.821	80.065	81.917	83.533
f_2	67.192			
R_{i2}	375.817	417.921	373.803	343.476
Waist at mirror 2, w_{M2}	(dia. = 88)	16.731	15.763	15.070
$z_{w(Cass.)}$	229.84	236.924	235.187	234.007
$w_{Cass.}$		11.011	9.599	8.508
$d_{mirror\text{-}subrefl}$		6229.75	6229.75	6229.75
$w_{subrefl}$	(dia. = 750)	318.832	318.832	318.832
$R_{subrefl}$	6000.00	5999.981	6000.001	6000.015
Edge Taper (dB)	12.00	12.02	12.02	12.02

All dimensions in mm.

6.1.2 *Truncation Loss at Mirrors*

The beam profiles at mirror 1 and mirror 2 are shown in Figures 8(a), (b) and (c). Truncation loss of the beam for a range of mirror diameters is given in Table VII(b) and VII(c).

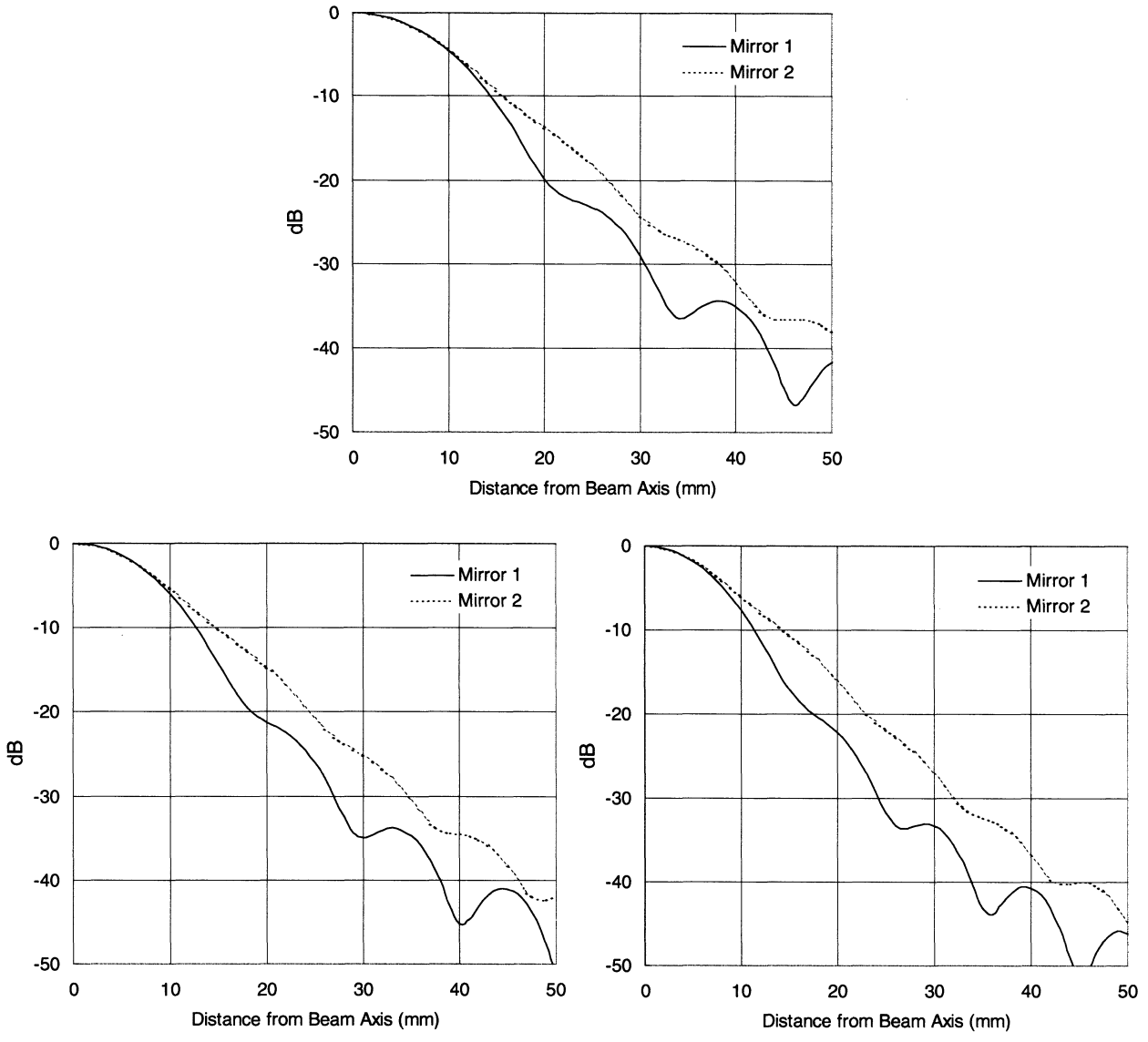


Figure 8. Beam profile at mirror 1 and mirror 2; (a) 163 GHz, (b) 187 GHz and (c) 211 GHz.

TABLE VII(b)
Truncated beam power and loss at mirror 1 for Band 5.

Frequency	**163 GHz**		**187 GHz**		**211 GHz**	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
100	0.999	-0.004	1.000	-0.002	1.000	-0.001
90	0.999	-0.004	0.999	-0.003	1.000	-0.002
88	0.999	-0.005			1.000	-0.002
80	0.998	-0.007	0.999	-0.005	0.999	-0.003
70	0.997	-0.013	0.998	-0.008	0.999	-0.005
60	0.995	-0.020	0.997	-0.015	0.998	-0.011
50	0.987	-0.058	0.993	-0.031	0.995	-0.020
40	0.971	-0.126	0.975	-0.098	0.985	-0.066
30	0.910	-0.410	0.941	-0.265	0.954	-0.206

Diameter in mm., loss in dB.

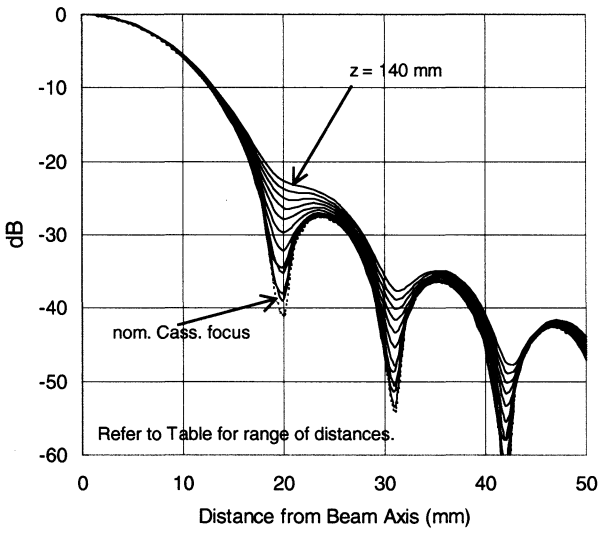
TABLE VII(c)
Truncated beam power and loss at mirror 2 for Band 5.

Frequency	163 GHz		187 GHz		211 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
100	0.999	-0.005	0.999	-0.004	0.999	-0.002
90	0.998	-0.009	0.999	-0.005	0.999	-0.004
88	0.998	-0.010	0.999	-0.006	0.999	-0.004
80	0.997	-0.014	0.998	-0.010	0.998	-0.007
70	0.993	-0.031	0.996	-0.019	0.997	-0.015
60	0.986	-0.063	0.989	-0.047	0.993	-0.031
50	0.966	-0.152	0.975	-0.109	0.980	-0.089
40	0.911	-0.403	0.931	-0.308	0.946	-0.240
30	0.801	-0.962	0.823	-0.847	0.842	-0.745

Diameter in mm., loss in dB.

6.1.3 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 8(d), (e) and (f). Truncation loss of the beam for a range of window diameters is given in Table VII(d) – VII(i).



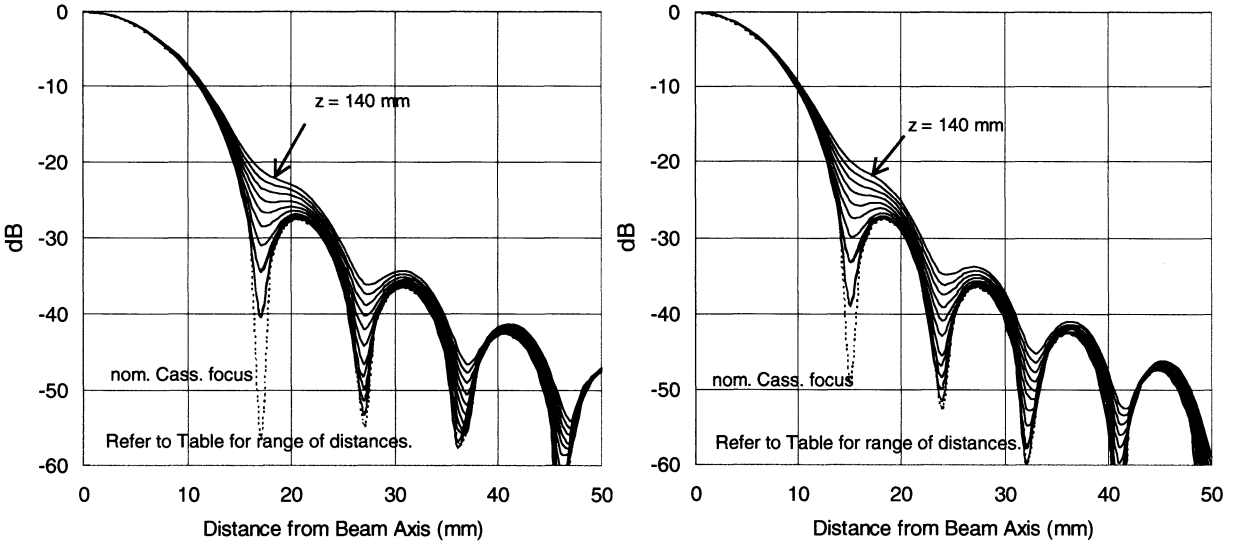


Figure 8. Beam profile at various distances from mirror 2; (d) 163 GHz, (e) 187 GHz and (f) 211 GHz.

TABLE VII(d)
Truncated beam power at cryostat window for Band 5 low limit frequency 163 GHz.

Distance from mirror 2 (mm.)	**Window diameter (mm.)**							
	100	**90**	**80**	**70**	**60**	**50**	**40**	**30**
250.00	1.000	0.999	0.999	0.998	0.998	0.996	0.991	0.974
240.00	1.000	0.999	0.999	0.998	0.998	0.996	0.992	0.975
229.84[†]	1.000	0.999	0.999	0.998	0.998	0.996	0.992	0.975
220.00	1.000	0.999	0.999	0.998	0.998	0.996	0.992	0.974
210.00	1.000	0.999	0.999	0.998	0.998	0.995	0.991	0.973
200.00	1.000	0.999	0.999	0.998	0.998	0.995	0.990	0.971
190.00	1.000	0.999	0.999	0.998	0.998	0.995	0.990	0.968
180.00	1.000	0.999	0.999	0.998	0.998	0.995	0.988	0.964
170.00	1.000	0.999	0.999	0.998	0.998	0.994	0.987	0.960
160.00	1.000	0.999	0.999	0.998	0.997	0.994	0.985	0.955
150.00	1.000	0.999	0.999	0.998	0.997	0.993	0.983	0.950
140.00	0.999	0.999	0.999	0.998	0.997	0.992	0.980	0.944

[†] Cassegrain focus.

TABLE VII(e)
Beam truncation loss in dB at cryostat window for Band 5 low limit frequency 163 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 100	90	80	70	60	50	40	30
250.00	-0.002	-0.003	-0.003	-0.007	-0.009	-0.019	-0.039	-0.115
240.00	-0.002	-0.003	-0.003	-0.007	-0.009	-0.019	-0.037	-0.112
229.84†	-0.002	-0.003	-0.003	-0.007	-0.009	-0.019	-0.036	-0.112
220.00	-0.002	-0.003	-0.003	-0.007	-0.009	-0.019	-0.037	-0.115
210.00	-0.002	-0.003	-0.004	-0.007	-0.009	-0.020	-0.039	-0.121
200.00	-0.002	-0.003	-0.004	-0.007	-0.009	-0.021	-0.024	-0.130
190.00	-0.002	-0.003	-0.004	-0.007	-0.010	-0.022	-0.046	-0.142
180.00	-0.002	-0.003	-0.004	-0.008	-0.010	-0.024	-0.051	-0.158
170.00	-0.002	-0.003	-0.004	-0.008	-0.011	-0.025	-0.058	-0.176
160.00	-0.002	-0.003	-0.004	-0.008	-0.011	-0.028	-0.066	-0.198
150.00	-0.002	-0.004	-0.004	-0.009	-0.012	-0.030	-0.075	-0.223
140.00	-0.002	-0.004	-0.005	-0.009	-0.014	-0.034	-0.086	-0.251

† Cassegrain focus.

TABLE VII(f)
Truncated beam power at cryostat window for Band 5 mid frequency 187 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 100	90	80	70	60	50	40	30
250.00	1.000	1.000	0.999	0.999	0.998	0.998	0.993	0.989
240.00	1.000	1.000	0.999	0.999	0.998	0.998	0.993	0.990
229.84†	1.000	1.000	0.999	0.999	0.998	0.998	0.993	0.990
220.00	1.000	1.000	0.999	0.999	0.998	0.998	0.993	0.989
210.00	1.000	1.000	0.999	0.999	0.998	0.998	0.993	0.989
200.00	1.000	1.000	0.999	0.999	0.998	0.998	0.993	0.987
190.00	1.000	1.000	0.999	0.999	0.998	0.998	0.992	0.984
180.00	1.000	1.000	0.999	0.999	0.998	0.997	0.991	0.981
170.00	1.000	1.000	0.999	0.999	0.998	0.997	0.990	0.978
160.00	1.000	1.000	0.999	0.999	0.998	0.997	0.989	0.973
150.00	1.000	1.000	0.999	0.999	0.998	0.996	0.988	0.968
140.00	1.000	1.000	0.999	0.999	0.998	0.996	0.986	0.963

† Cassegrain focus.

TABLE VII(g)
Beam truncation loss in dB at cryostat window for Band 5 mid frequency 187 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 100	90	80	70	60	50	40	30
250.00	-0.001	-0.002	-0.003	-0.003	-0.007	-0.009	-0.030	-0.049
240.00	-0.001	-0.002	-0.003	-0.003	-0.007	-0.009	-0.029	-0.045
229.84†	-0.001	-0.002	-0.003	-0.003	-0.007	-0.009	-0.029	-0.044
220.00	-0.001	-0.002	-0.003	-0.003	-0.007	-0.009	-0.030	-0.046
210.00	-0.001	-0.002	-0.003	-0.004	-0.007	-0.010	-0.031	-0.050
200.00	-0.001	-0.002	-0.003	-0.004	-0.008	-0.010	-0.033	-0.058
190.00	-0.001	-0.002	-0.003	-0.004	-0.008	-0.011	-0.035	-0.068
180.00	-0.002	-0.002	-0.003	-0.004	-0.008	-0.011	-0.039	-0.082
170.00	-0.002	-0.002	-0.003	-0.004	-0.009	-0.013	-0.043	-0.098
160.00	-0.002	-0.002	-0.003	-0.004	-0.009	-0.014	-0.048	-0.117
150.00	-0.002	-0.002	-0.004	-0.004	-0.010	-0.016	-0.054	-0.140
140.00	-0.002	-0.002	-0.004	-0.005	-0.011	-0.018	-0.061	-0.165

† Cassegrain focus.

TABLE VII(h)
Truncated beam power at cryostat window for Band 5 high limit frequency 211 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 100	90	80	70	60	50	40	30
250.00	1.000	1.000	1.000	0.999	0.999	0.998	0.996	0.991
240.00	1.000	1.000	1.000	0.999	0.999	0.998	0.996	0.991
229.84†	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.992
220.00	1.000	1.000	1.000	0.999	0.999	0.998	0.996	0.991
210.00	1.000	1.000	1.000	0.999	0.999	0.998	0.996	0.991
200.00	1.000	1.000	1.000	0.999	0.999	0.998	0.996	0.989
190.00	1.000	1.000	1.000	0.999	0.999	0.998	0.996	0.988
180.00	1.000	1.000	1.000	0.999	0.999	0.998	0.995	0.985
170.00	1.000	1.000	1.000	0.999	0.999	0.997	0.995	0.982
160.00	1.000	1.000	1.000	0.999	0.999	0.997	0.994	0.979
150.00	1.000	1.000	1.000	0.999	0.999	0.997	0.993	0.975
140.00	1.000	1.000	1.000	0.999	0.999	0.997	0.992	0.970

† Cassegrain focus.

TABLE VII(i)
Beam truncation loss in dB at cryostat window for Band 5 high limit frequency 211 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 100	90	80	70	60	50	40	30
250.00	-0.001	-0.001	-0.002	-0.003	-0.004	-0.009	-0.016	-0.041
240.00	-0.001	-0.001	-0.002	-0.003	-0.004	-0.009	-0.015	-0.038
229.84†	-0.001	-0.001	-0.002	-0.003	-0.004	-0.009	-0.015	-0.036
220.00	-0.001	-0.001	-0.002	-0.003	-0.004	-0.009	-0.016	-0.038
210.00	-0.001	-0.001	-0.002	-0.003	-0.004	-0.009	-0.016	-0.041
200.00	-0.001	-0.001	-0.002	-0.003	-0.004	-0.009	-0.017	-0.047
190.00	-0.001	-0.001	-0.002	-0.003	-0.004	-0.010	-0.019	-0.055
180.00	-0.001	-0.001	-0.002	-0.003	-0.004	-0.010	-0.021	-0.065
170.00	-0.001	-0.001	-0.002	-0.003	-0.005	-0.011	-0.023	-0.078
160.00	-0.001	-0.002	-0.002	-0.004	-0.005	-0.012	-0.027	-0.093
150.00	-0.001	-0.002	-0.002	-0.004	-0.005	-0.013	-0.030	-0.112
140.00	-0.001	-0.002	-0.002	-0.004	-0.006	-0.015	-0.035	-0.132

† Cassegrain focus.

6.2 Physical Optics Analysis

6.2.1 *Beam Profile at Cassegrain Focus*

Figures 8(g) – (j) show the beam profile at the Cassegrain with comparison of results obtained by both quasi-optics and physical optics.

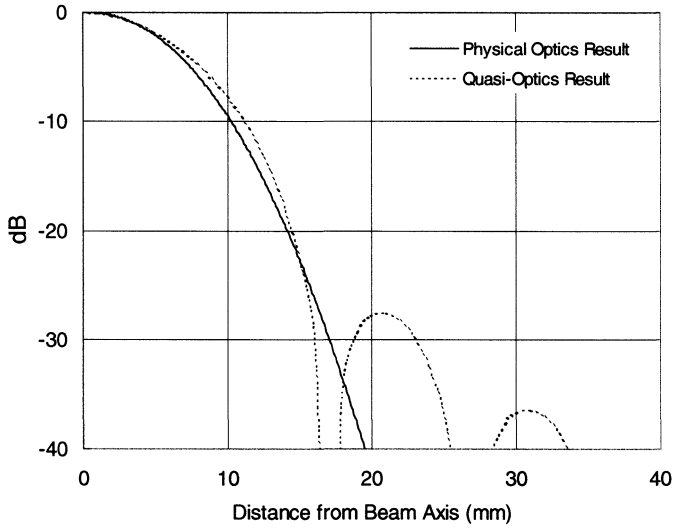


Figure 8(g). Beam profile at Cassegrain focus for Band 5 mid frequency 187 GHz.

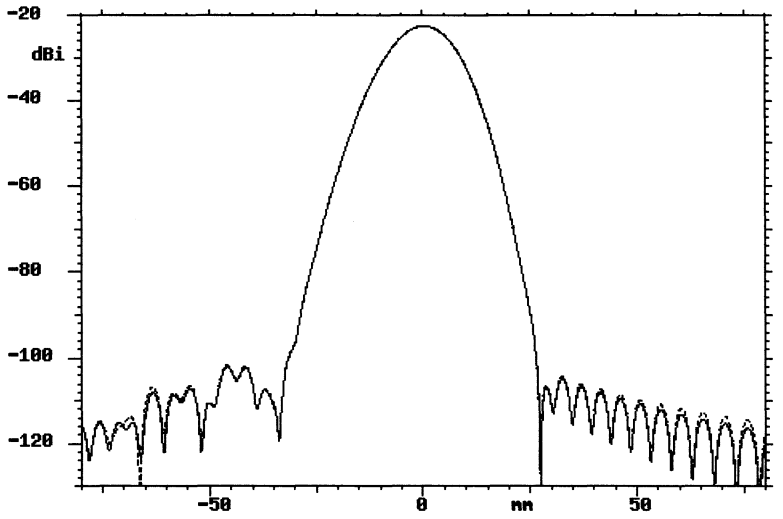


Figure 8(h). Beam profile of co-polar field at Cassegrain focus, Band 5 mid frequency 187 GHz; x-polarised source solid line, y-polarised source dotted line.

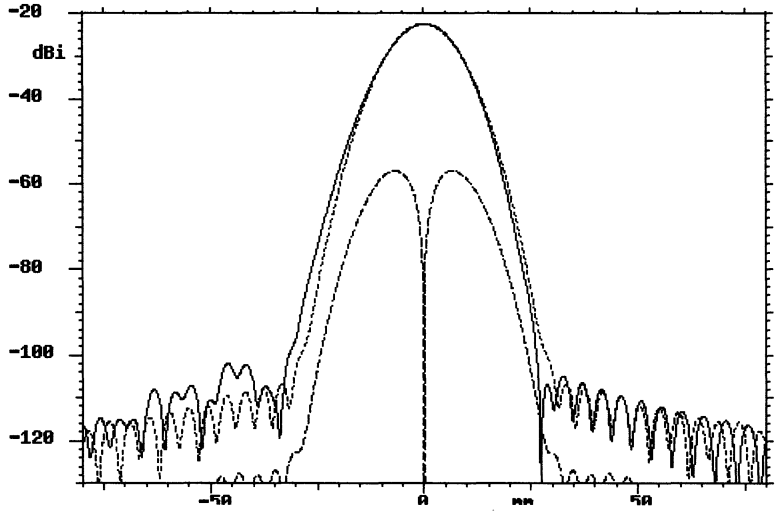


Figure 8(i). Beam profile at Cassegrain focus Band 5 mid frequency 187 GHz., x-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

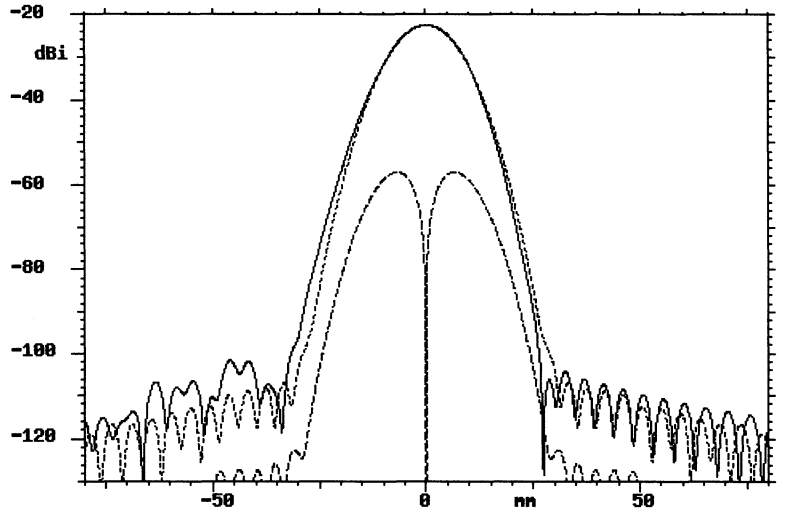


Figure 8(j). Beam profile at Cassegrain focus Band 5 mid frequency 187 GHz., y-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

6.2.2 *Beam Profile at Subreflector & Edge Taper*

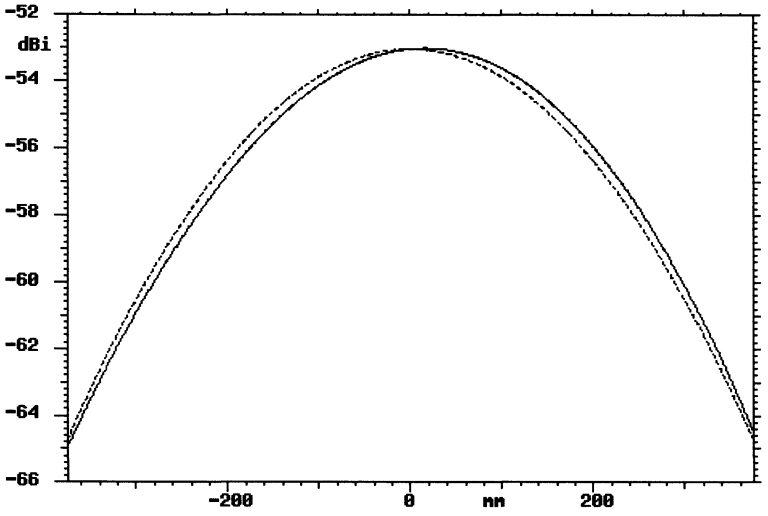


Figure 8(k). Beam profile at subreflector Band 5 mid frequency 187 GHz.; $\phi = 0^{\circ}$ solid line, $\phi = 90^{\circ}$ dash line.

The edge tapers at the subreflector corresponding to the four positions where $\phi = 0^{\circ}$ and 90° are –11.6, -11, -11.3 and –11.3 respectively.

6.2.3 *Far Field Radiation Pattern*

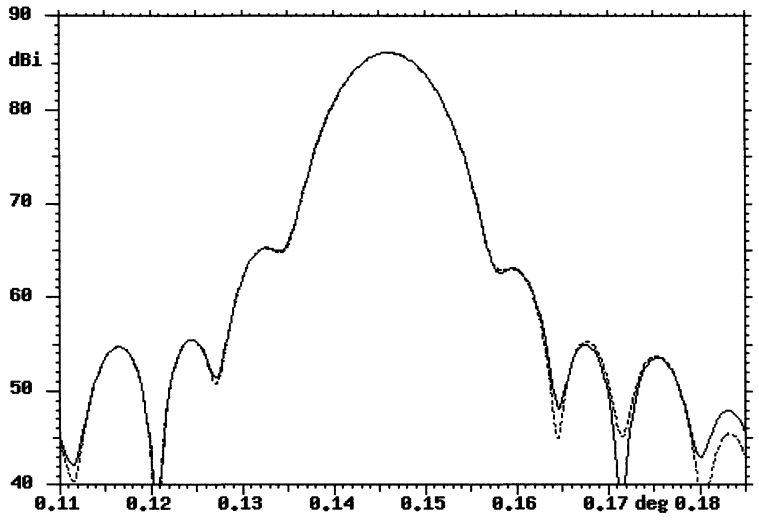


Figure 8(l). Antenna far field radiation pattern for Band 5 mid frequency 187 GHz.; x-polarised source solid line, y-polarised source dash line.

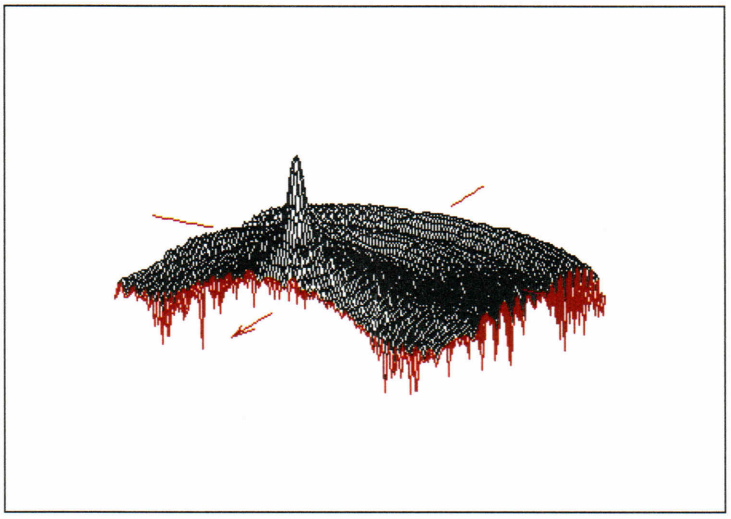


Figure 8(m). 3-D plot of antenna co-polar field radiation pattern.

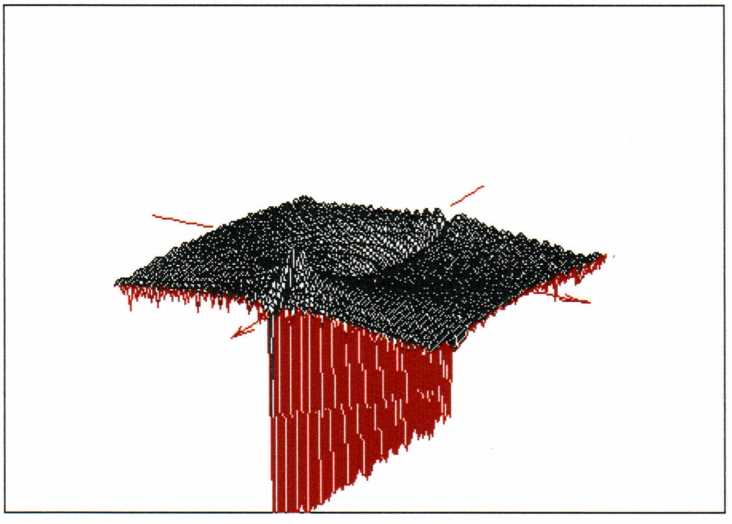


Figure 8(n). 3-D plot of antenna cross-polar field radiation pattern.

6.2.4 *Beam & Cross-Polar Efficiencies*

The beam efficiencies are shown in Table VII(j) below.

TABLE VII(j)
Beam efficiencies for Band 5 mid frequency 187 GHz
defined by contours of the co-polarisation field.

Level below peak (dB)	**Co-polar (%)**	**Cross-polar (%)**
3.0	46.24	0.00
6.0	67.98	0.01
9.0	78.01	0.02
12.0	82.60	0.03
15.0	84.74	0.03
18.0	85.80	0.03
21.0	86.51	0.04
24.0	88.45	0.04
27.0	88.80	0.04
30.0	88.92	0.04
33.0	89.48	0.04
36.0	89.83	0.04
39.0	90.18	0.04
42.0	90.51	0.04
45.0	90.76	0.04
48.0	90.90	0.04
51.0	90.97	0.04
54.0	91.03	0.04
57.0	91.09	0.04
60.0	91.12	0.04

7 BAND 6

7.1 Quasi-Optics Analysis

7.1.1 *Gaussian Beam Parameters*

TABLE VIII(a)
Quasi-optics Gaussian beam parameters for Band 6.

Frequency [GHz]		**211**	**243**	**275**
λ [mm]		1.420817	1.233714	1.090154
Horn diameter	7.0			
Horn axial length	50.0			
Horn slant length	50.122			
Horn waist, w_0		2.198	2.181	2.162
Horn waist offset, $\Delta z(w_0)$		-2.39022	-3.12161	-3.92921
Waist at horn aperture, w_{ha}		2.252	2.252	2.252
d_1	59.89			
R_{s1}	65.277	64.112	65.340	66.663
f_1	34.44			
R_{i1}	72.905	74.414	72.825	71.249
Waist at mirror 1, w_{M1}	(dia. = 64)	13.003	11.553	10.468
z_{w1}		71.5777	69.6292	67.7980
w_1		2.539	2.420	2.304
d_2	140.00			
R_{s2}	73.421	71.389	73.533	75.443
f_2	58.397			
R_{i2}	275.39	320.874	283.696	258.458
Waist at mirror 2, w_{M2}	(dia. = 70)	12.452	11.671	11.116
$z_{w(Cass.)}$	166.86	171.035	169.986	169.281
$w_{Cass.}$		8.509	7.389	6.530
$d_{mirror\text{-}subrefl}$		6166.76	6166.76	6166.76
$w_{subrefl}$	(dia. = 750)	318.796	318.796	318.796
$R_{subrefl}$	6000.00	5999.999	5999.997	5999.996
Edge Taper (dB)	12.00	12.02	12.02	12.02

All dimensions in mm.

7.1.2 *Truncation Loss at Mirrors*

The beam profiles at mirror 1 and mirror 2 are shown in Figures 9(a), (b) and (c). Truncation loss of the beam for a range of mirror diameters is given in Table VIII(b) and VIII(c).

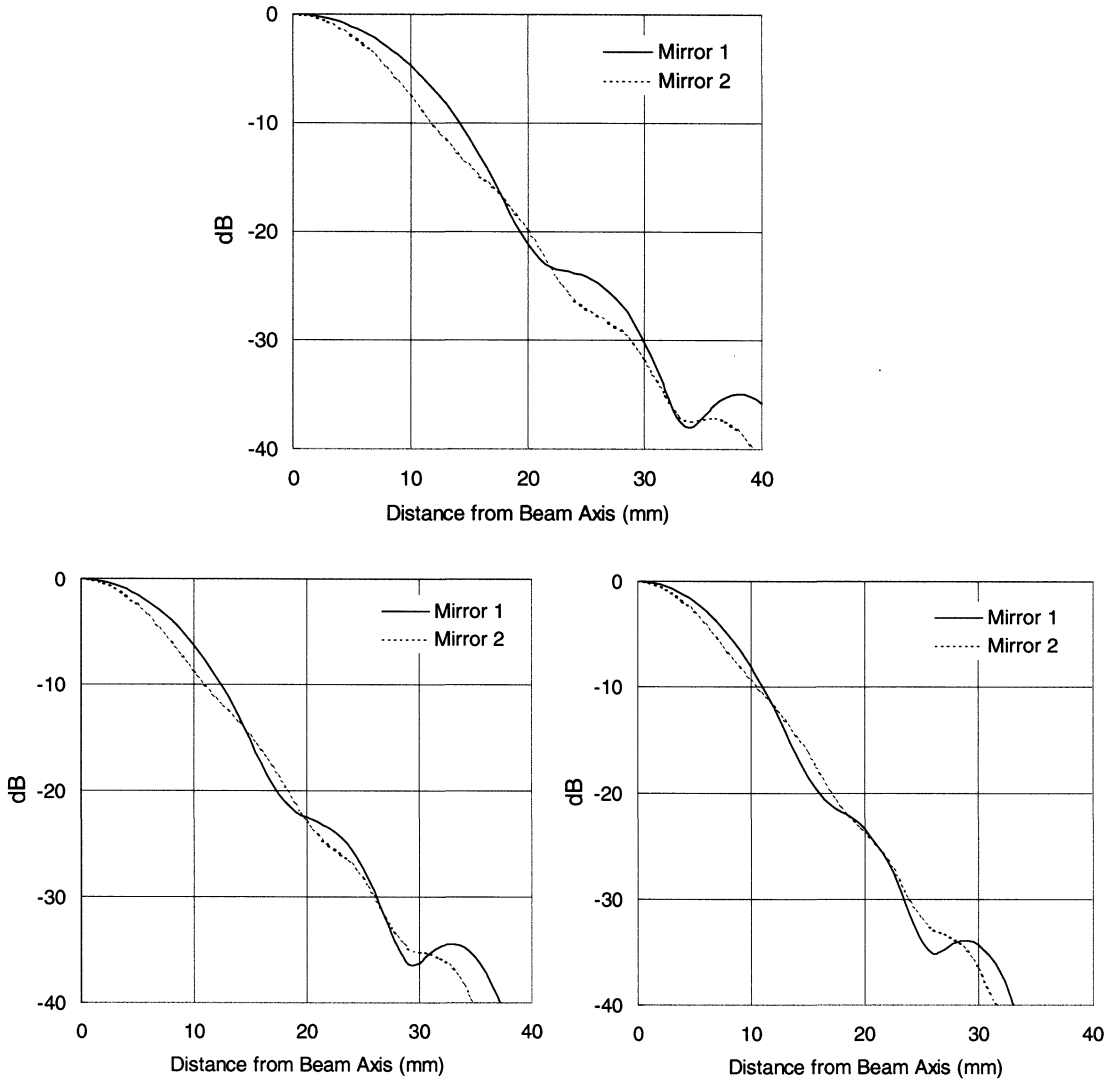


Figure 9. Beam profile at mirror 1 and mirror 2; (a) 211 GHz, (b) 243 GHz and (c) 275 GHz.

TABLE VIII(b)
Truncated beam power and loss at mirror 1 for Band 6.

Frequency	**211 GHz**		**243 GHz**		**275 GHz**	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
80	0.999	-0.006			0.999	-0.003
70	0.997	-0.012	0.998	-0.007	0.999	-0.005
64	0.997	-0.013	0.998	-0.011	0.999	-0.006
60	0.996	-0.017	0.997	-0.013	0.998	-0.009
50	0.989	-0.048	0.994	-0.024	0.996	-0.016
40	0.977	-0.101	0.982	-0.078	0.988	-0.050
30	0.923	-0.347	0.953	-0.207	0.965	-0.157
20	0.679	-1.680	0.771	-1.129	0.837	-0.773

Diameter in mm., loss in dB.

TABLE VIII(c)
Truncated beam power and loss at mirror 2 for Band 6.

Frequency	211 GHz		243 GHz		275 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
80	0.999	-0.004	0.999	-0.003	1.000	-0.002
70	0.998	-0.008	0.999	-0.004	0.999	-0.003
60	0.997	-0.014	0.998	-0.010	0.999	-0.006
50	0.991	-0.039	0.994	-0.024	0.996	-0.017
40	0.976	-0.107	0.982	-0.078	0.986	-0.060
30	0.914	-0.391	0.934	-0.297	0.949	-0.226
20	0.747	-1.270	0.775	-1.107	0.794	-1.003

Diameter in mm., loss in dB.

7.1.3 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 9(d), (e) and (f). Truncation loss of the beam for a range of window diameters is given in Table VIII(d) – VIII(i).

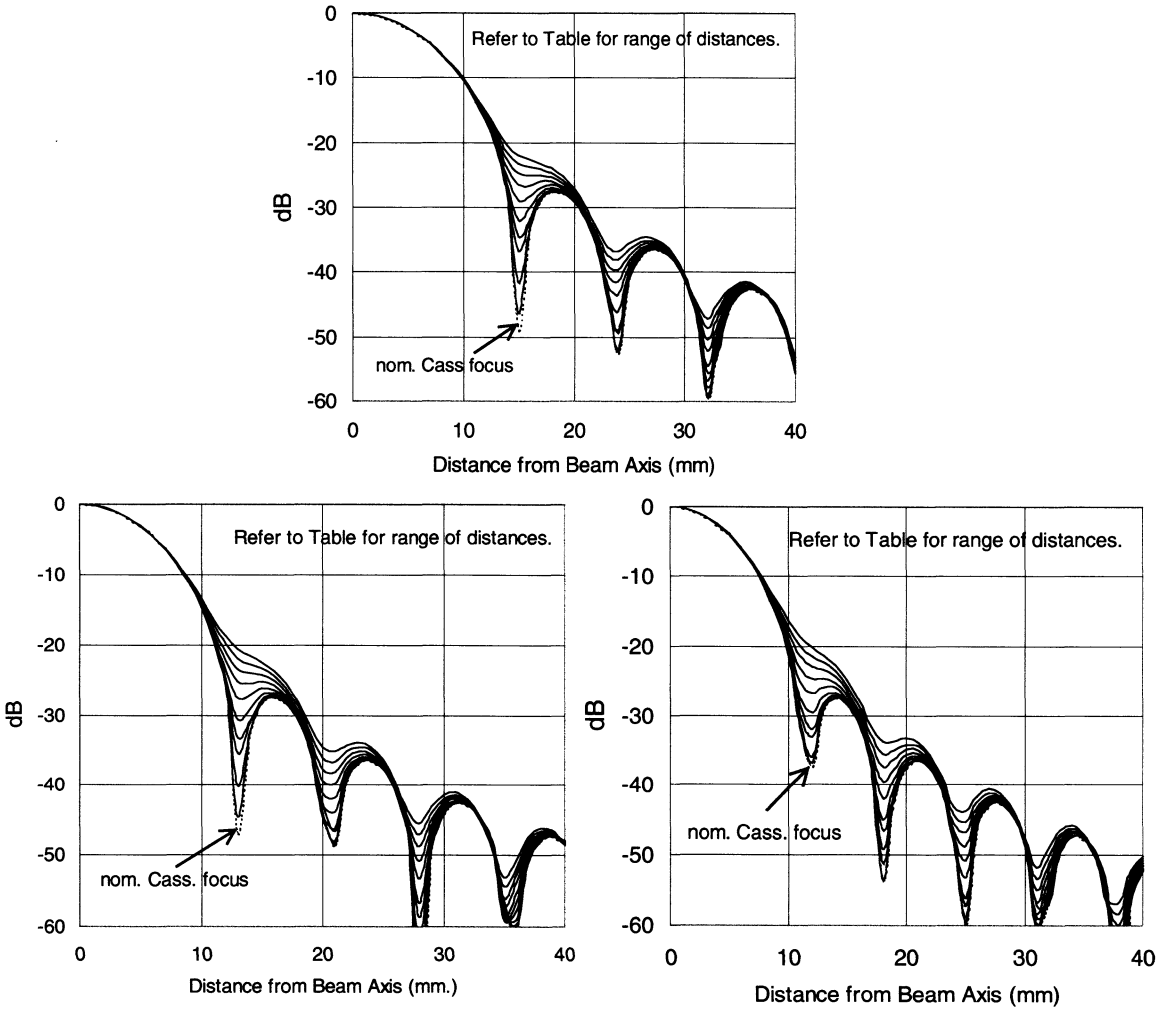


Figure 9. Beam profile at various distances from mirror2; (d) 211 GHz, (e) 243 GHz and (f) 275 GHz.

TABLE VIII(d)
Truncated beam power at cryostat window for Band 6 low limit frequency 211 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 80	70	60	50	40	30	20
150.00	1.000	0.999	0.999	0.998	0.996	0.991	0.926
160.00	1.000	0.999	0.999	0.998	0.996	0.992	0.928
166.86†	1.000	0.999	0.999	0.998	0.996	0.992	0.929
170.00	1.000	0.999	0.999	0.998	0.997	0.992	0.929
180.00	1.000	0.999	0.999	0.998	0.996	0.991	0.929
190.00	1.000	0.999	0.999	0.998	0.996	0.990	0.927
200.00	1.000	0.999	0.999	0.998	0.996	0.989	0.924
210.00	1.000	0.999	0.999	0.998	0.996	0.987	0.919
220.00	1.000	0.999	0.999	0.998	0.996	0.985	0.913
230.00	1.000	0.999	0.999	0.997	0.995	0.987	0.905
240.00	1.000	0.999	0.999	0.997	0.994	0.978	0.897

† Cassegrain focus.

TABLE VIII(e)
Beam truncation loss in dB at cryostat window for Band 6 low limit frequency 211 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 80	70	60	50	40	30	20
150.00	-0.002	-0.003	-0.004	-0.009	-0.016	-0.040	-0.334
160.00	-0.002	-0.003	-0.004	-0.009	-0.015	-0.037	-0.323
166.86†	-0.002	-0.003	-0.004	-0.009	-0.015	-0.036	-0.319
170.00	-0.002	-0.003	-0.004	-0.009	-0.015	-0.037	-0.318
180.00	-0.002	-0.003	-0.004	-0.009	-0.015	-0.038	-0.320
190.00	-0.002	-0.003	-0.004	-0.009	-0.016	-0.042	-0.329
200.00	-0.002	-0.003	-0.004	-0.009	-0.017	-0.049	-0.345
210.00	-0.002	-0.003	-0.004	-0.010	-0.018	-0.057	-0.367
220.00	-0.002	-0.003	-0.004	-0.010	-0.020	-0.068	-0.396
230.00	-0.002	-0.003	-0.004	-0.011	-0.022	-0.081	-0.432
240.00	-0.002	-0.003	-0.005	-0.012	-0.024	-0.096	-0.474

† Cassegrain focus.

TABLE VIII(f)
Truncated beam power at cryostat window for Band 6 mid frequency 243 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 80	70	60	50	40	30	20
150.00	1.000	1.000	0.999	0.999	0.998	0.992	0.971
160.00	1.000	1.000	0.999	0.999	0.998	0.993	0.973
166.86†	1.000	1.000	0.999	0.999	0.998	0.993	0.973
170.00	1.000	1.000	0.999	0.999	0.998	0.993	0.973
180.00	1.000	1.000	0.999	0.999	0.998	0.993	0.972
190.00	1.000	1.000	0.999	0.999	0.998	0.992	0.970
200.00	1.000	1.000	0.999	0.999	0.998	0.991	0.966
210.00	1.000	1.000	0.999	0.999	0.997	0.990	0.960
220.00	1.000	1.000	0.999	0.999	0.997	0.989	0.953
230.00	1.000	1.000	0.999	0.999	0.997	0.987	0.944
240.00	1.000	1.000	0.999	0.999	0.996	0.985	0.934

† Cassegrain focus.

TABLE VIII(g)
Beam truncation loss in dB at cryostat window for Band 6 mid frequency 243 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 80	70	60	50	40	30	20
150.00	-0.001	-0.002	-0.003	-0.005	-0.009	-0.034	-0.130
160.00	-0.001	-0.002	-0.003	-0.005	-0.009	-0.032	-0.120
166.86†	-0.001	-0.002	-0.003	-0.005	-0.009	-0.032	-0.117
170.00	-0.001	-0.002	-0.003	-0.005	-0.009	-0.032	-0.117
180.00	-0.001	-0.002	-0.003	-0.005	-0.009	-0.033	-0.127
190.00	-0.001	-0.002	-0.003	-0.005	-0.009	-0.035	-0.133
200.00	-0.001	-0.002	-0.003	-0.005	-0.010	-0.038	-0.151
210.00	-0.001	-0.002	-0.003	-0.005	-0.011	-0.043	-0.176
220.00	-0.001	-0.002	-0.003	-0.005	-0.012	-0.049	-0.209
230.00	-0.001	-0.002	-0.004	-0.006	-0.014	-0.057	-0.248
240.00	-0.001	-0.002	-0.004	-0.006	-0.016	-0.066	-0.294

† Cassegrain focus.

TABLE VIII(h)
Truncated beam power at cryostat window for Band 6 high limit frequency 275 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 80	70	60	50	40	30	20
150.00	1.000	1.000	1.000	0.999	0.998	0.996	0.987
160.00	1.000	1.000	1.000	0.999	0.998	0.996	0.988
166.86†	1.000	1.000	1.000	0.999	0.998	0.996	0.989
170.00	1.000	1.000	1.000	0.999	0.998	0.996	0.989
180.00	1.000	1.000	1.000	0.999	0.998	0.996	0.988
190.00	1.000	1.000	1.000	0.999	0.998	0.996	0.985
200.00	1.000	1.000	1.000	0.999	0.998	0.995	0.981
210.00	1.000	1.000	1.000	0.999	0.998	0.995	0.975
220.00	1.000	1.000	1.000	0.999	0.998	0.994	0.968
230.00	1.000	1.000	1.000	0.999	0.997	0.993	0.960
240.00	1.000	1.000	0.999	0.999	0.997	0.991	0.950

† Cassegrain focus.

TABLE VIII(i)
Beam truncation loss in dB at cryostat window for Band 6 high limit frequency 275 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 80	70	60	50	40	30	20
150.00	-0.001	-0.001	-0.002	-0.003	-0.008	-0.019	-0.059
160.00	-0.001	-0.001	-0.002	-0.003	-0.008	-0.018	-0.050
166.86†	-0.001	-0.001	-0.002	-0.003	-0.008	-0.018	-0.049
170.00	-0.001	-0.001	-0.002	-0.003	-0.008	-0.018	-0.049
180.00	-0.001	-0.001	-0.002	-0.003	-0.008	-0.018	-0.054
190.00	-0.001	-0.001	-0.002	-0.003	-0.008	-0.019	-0.065
200.00	-0.001	-0.001	-0.002	-0.004	-0.009	-0.021	-0.083
210.00	-0.001	-0.001	-0.002	-0.004	-0.009	-0.024	-0.108
220.00	-0.001	-0.001	-0.002	-0.004	-0.010	-0.027	-0.139
230.00	-0.001	-0.001	-0.002	-0.004	-0.011	-0.032	-0.177
240.00	-0.001	-0.001	-0.002	-0.005	-0.012	-0.038	-0.221

† Cassegrain focus.

7.2 Physical Optics Analysis

7.2.1 *Beam Profile at Cassegrain Focus*

Figures 9(g) – (j) show the beam profile at the Cassegrain with comparison of results obtained by both quasi-optics and physical optics.

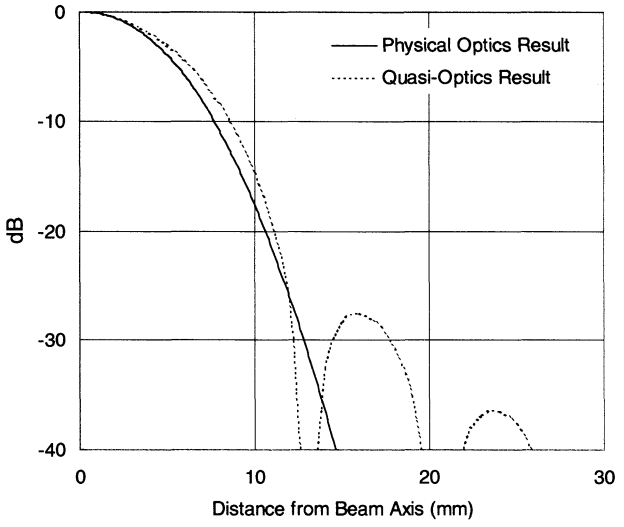


Figure 9(g). Beam profile at Cassegrain focus for Band 6 mid frequency 243 GHz.

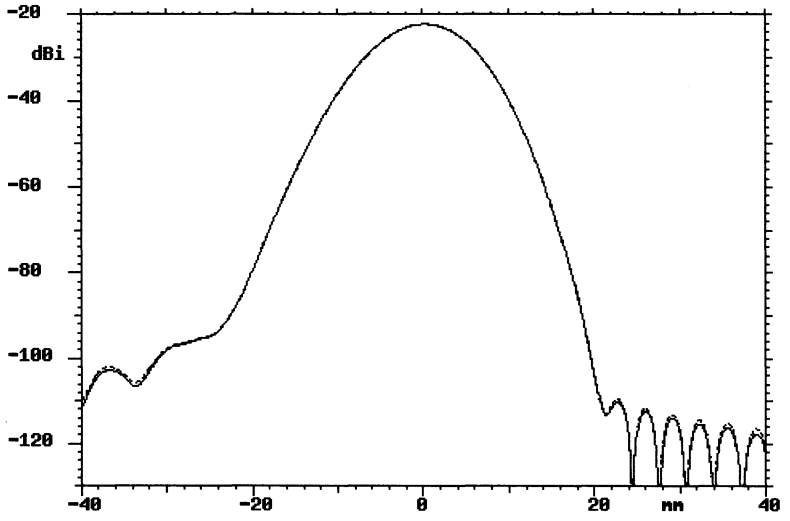


Figure 9(h). Beam profile of co-polar field at Cassegrain focus, Band 6 mid frequency 243 GHz; x-polarised source solid line, y-polarised source dotted line.

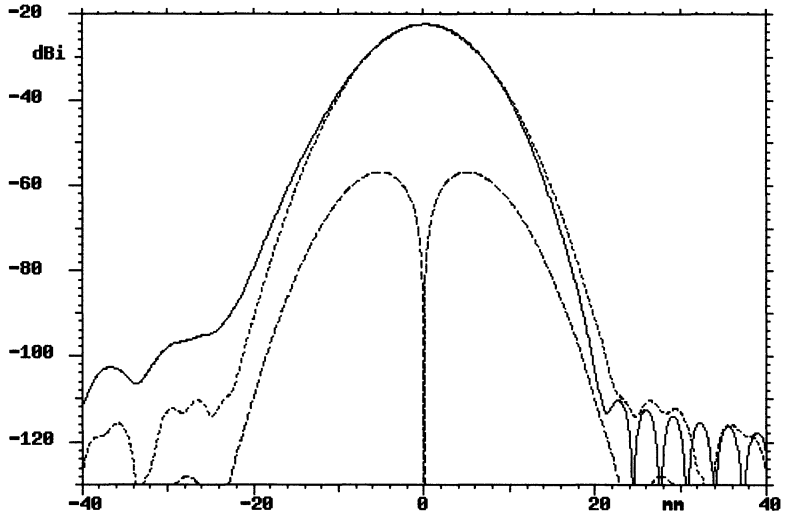


Figure 9(i). Beam profile at Cassegrain focus Band 6 mid frequency 243 GHz., x-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

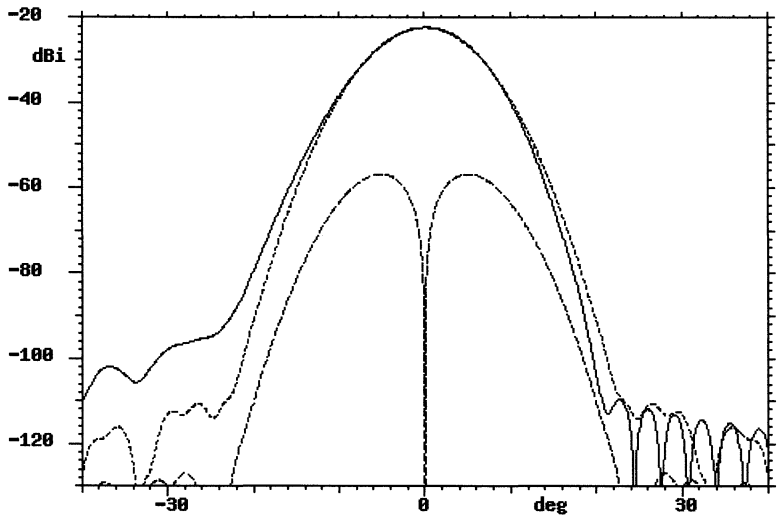


Figure 9(j). Beam profile at Cassegrain focus Band 6 mid frequency 243 GHz., y-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

7.2.2 *Beam Profile at Subreflector & Edge Taper*

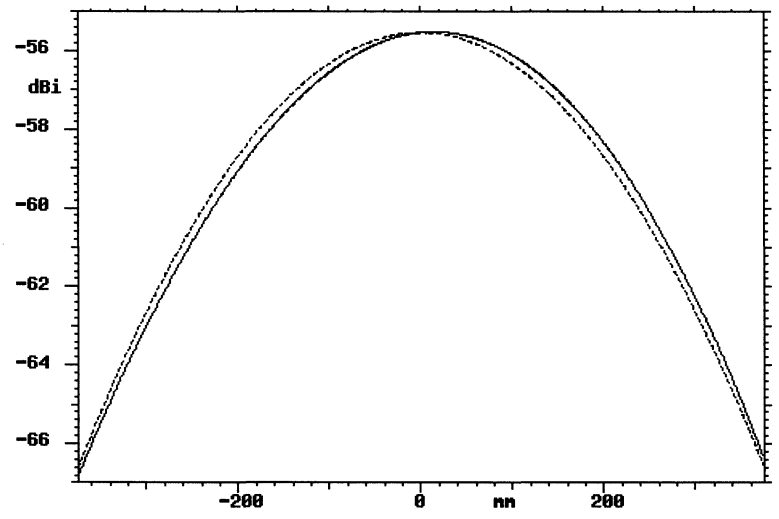


Figure 9(k). Beam profile at subreflector Band 6 mid frequency 243 GHz.; $\phi = 0^{o}$ solid line, $\phi = 90^{o}$ dash line.

The edge tapers at the subreflector corresponding to the four positions where $\phi = 0^{o}$ and 90^{o} are –10.9, -10.5, -10.7 and –10.7 respectively.

7.2.3 *Far Field Radiation Pattern*

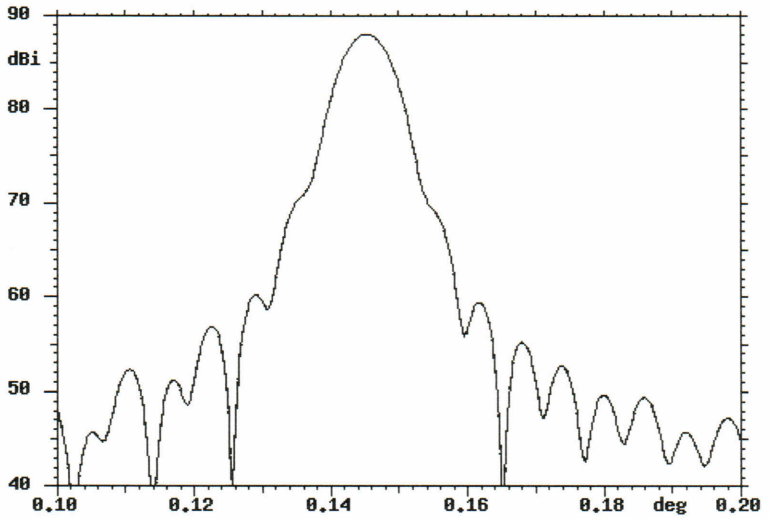


Figure 9(l). Antenna far field radiation pattern for Band 6 mid frequency 243 GHz.; x-polarised source solid line, y-polarised source dash line.

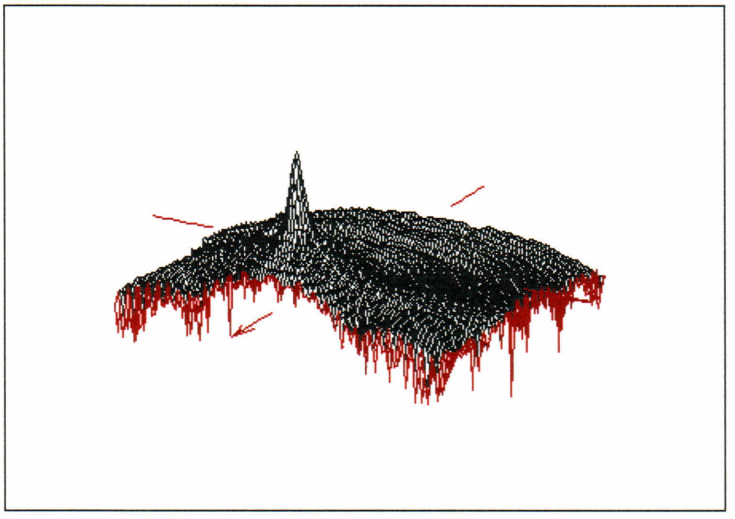


Figure 9(m). 3-D plot of antenna co-polar field radiation pattern.

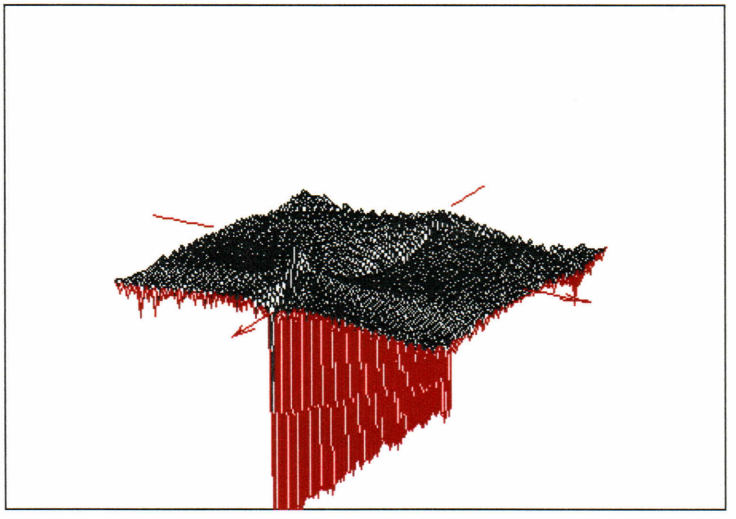


Figure 9(n). 3-D plot of antenna cross-polar field radiation pattern.

7.2.4 *Beam & Cross-Polar Efficiencies*

The beam efficiencies are shown in Table VIII(j) below.

TABLE VIII(j)
Beam efficiencies for Band 6 mid frequency 243 GHz defined by contours of the co-polarisation field.

Level below peak (dB)	**Co-polar (%)**	**Cross-polar (%)**
3.0	42.76	0.00
6.0	63.45	0.01
9.0	73.38	0.02
12.0	78.35	0.03
15.0	81.16	0.03
18.0	83.87	0.04
21.0	86.50	0.04
24.0	87.19	0.04
27.0	87.46	0.04
30.0	88.09	0.04
33.0	88.51	0.04
36.0	88.76	0.04
39.0	89.19	0.04
42.0	89.54	0.04
45.0	89.84	0.04
48.0	90.01	0.04
51.0	90.09	0.04
54.0	90.14	0.04
57.0	90.21	0.04
60.0	90.26	0.04

8 BAND 7

8.1 Quasi-Optics Analysis

8.1.1 *Gaussian Beam Parameters*

TABLE IX(a)
Quasi-optics Gaussian beam parameters for Band 7.

Frequency [GHz]		**275**	**323**	**370**
λ **[mm]**		1.090154	0.928150	0.810250
Horn diameter	6.0			
Horn axial length	43.0			
Horn slant length	43.105			
Horn waist, w_0		1.873	1.853	1.830
Horn waist offset, $\Delta z(w_0)$		-2.51955	-3.40042	-4.35476
Waist at horn aperture, w_{ha}		1.930	1.930	1.930
d_1	38.0			
R_{s1}	44.54	43.043	44.662	46.339
f_1	25.537			
R_{i1}	59.85	62.789	59.637	56.887
Waist at mirror 1, w_{M1}	(dia. = 35)	7.736	6.857	6.242
z_{w1}		55.4413	52.2922	49.8238
w_1		2.646	2.406	2.200
d_2	155.00			
R_{s2}	106.26	103.650	106.447	108.522
f_2	76.188			
R_{i2}	269.20	287.554	268.019	255.707
Waist at mirror 2, w_{M2}	(dia. = 70)	13.320	12.838	12.527
$z_{w(Cass.)}$	216.00	218.454	217.759	217.323
$w_{Cass.}$		6.529	5.559	4.853
$d_{mirror\text{-}subrefl}$		6215.94	6215.94	6215.94
$w_{subrefl}$	(dia. = 750)	318.801	318.801	318.801
$R_{subrefl}$	6000.00	6000.003	6000.005	6000.008
Edge Taper (dB)	12.00	12.02	12.02	12.02

All dimensions in mm.

8.1.2 *Truncation Loss at Mirrors*

The beam profiles at mirror 1 and mirror 2 are shown in Figures 10(a), (b) and (c). Truncation loss of the beam for a range of mirror diameters is given in Table IX(b) and IX(c).

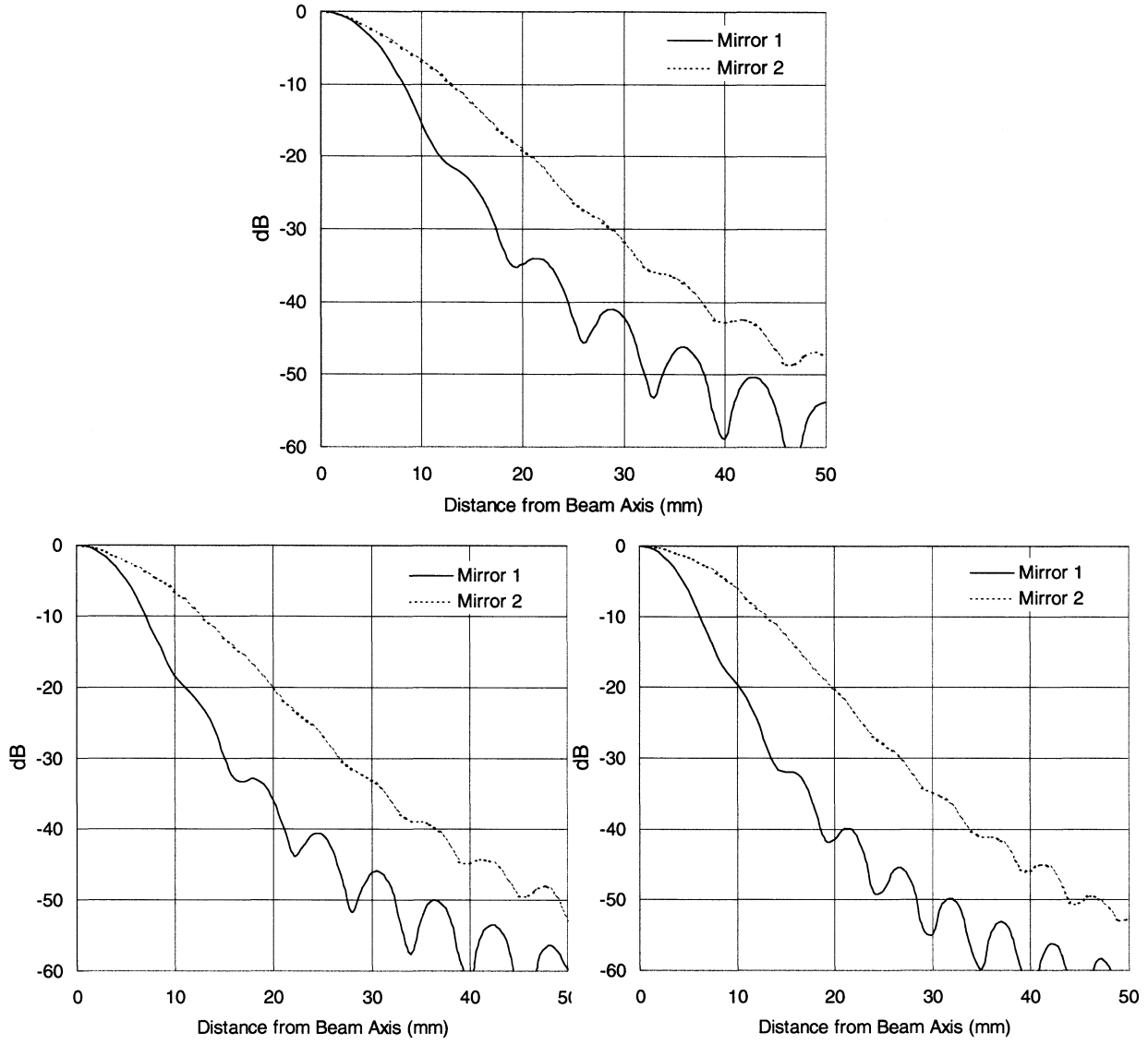


Figure 10. Beam profile at mirror 1 and mirror 2; (a) 275 GHz, (b) 323 GHz and (c) 370 GHz.

TABLE IX(b)
Truncated beam power and loss at mirror 1 for Band 7.

Frequency	**275 GHz**		**323 GHz**		**370 GHz**	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
60	0.999	-0.003	1.000	-0.002	1.000	-0.001
55	0.999	-0.004	1.000	-0.002	1.000	-0.001
50	0.999	-0.005	0.999	-0.003	0.999	-0.002
45	0.998	-0.008	0.999	-0.005	0.999	-0.003
40	0.997	-0.014	0.998	-0.007	0.999	-0.005
35	0.996	-0.019	0.997	-0.015	0.998	-0.008
30	0.989	-0.046	0.995	-0.023	0.996	-0.018
25	0.976	-0.106	0.985	-0.064	0.992	-0.036
20	0.950	-0.224	0.963	-0.165	0.972	-0.121

Diameter in mm., loss in dB.

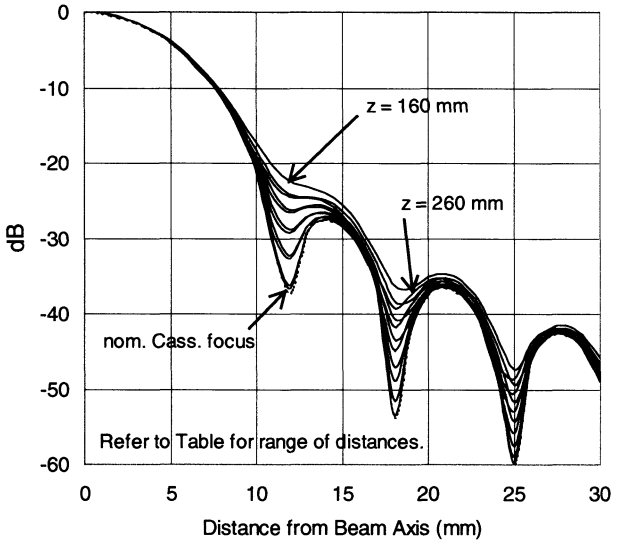
TABLE IX(c)
Truncated beam power and loss at mirror 2 for Band 7.

Frequency	275 GHz		323 GHz		370 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
90	1.000	-0.001	1.000	-0.001	1.000	-0.001
85	1.000	-0.002	1.000	-0.001	1.000	-0.001
80	0.999	-0.003	1.000	-0.002	1.000	-0.001
75	0.999	-0.004	0.999	-0.002	1.000	-0.002
70	0.999	-0.006	0.999	-0.004	0.999	-0.002
65	0.998	-0.008	0.999	-0.005	0.999	-0.003
60	0.997	-0.013	0.998	-0.008	0.999	-0.006
55	0.995	-0.022	0.997	-0.014	0.998	-0.010

Diameter in mm., loss in dB.

8.1.3 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 10(d), (e) and (f). Truncation loss of the beam for a range of window diameters is given in Table IX(d) –IX(i).



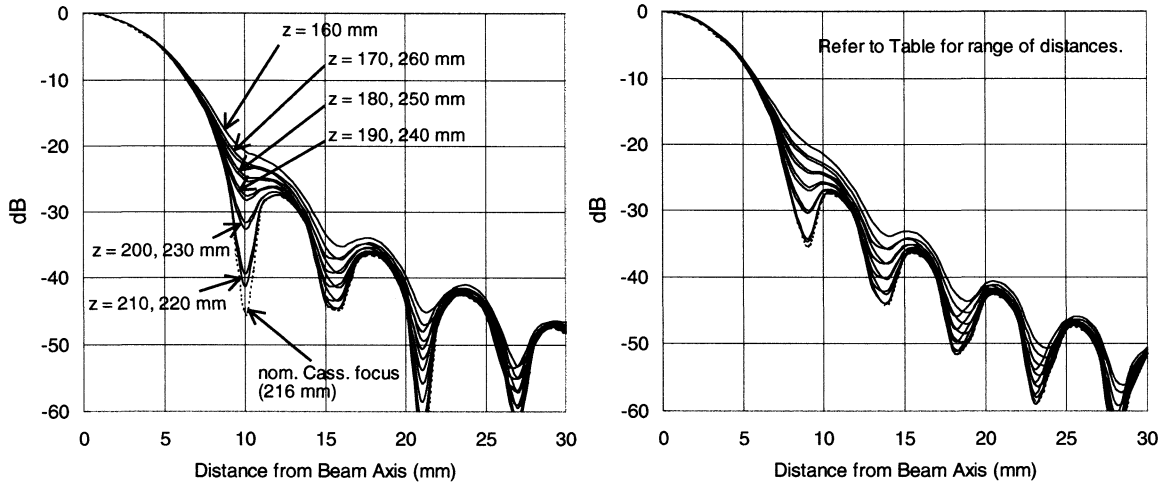


Figure 10. Beam profile at various distances from mirror 2; (d) 275 GHz, (e) 323 GHz and (f) 370 GHz.

TABLE IX(d)
Truncated beam power at cryostat window for Band 7 low limit frequency 275 GHz.

Distance from mirror 2 (mm.)	**Window diameter (mm.)**								
	60	**55**	**50**	**45**	**40**	**36**	**30**	**25**	**20**
160	1.000	0.999	0.999	0.999	0.998	0.997	0.995	0.987	0.975
170	1.000	0.999	0.999	0.999	0.998	0.998	0.995	0.989	0.981
180	1.000	0.999	0.999	0.999	0.998	0.998	0.996	0.990	0.985
190	1.000	0.999	0.999	0.999	0.998	0.998	0.996	0.991	0.988
200	1.000	0.999	0.999	0.999	0.998	0.998	0.996	0.992	0.989
210	1.000	0.999	0.999	0.999	0.998	0.998	0.996	0.992	0.989
216[†]	1.000	0.999	0.999	0.999	0.998	0.998	0.996	0.992	0.989
220	1.000	0.999	0.999	0.999	0.998	0.998	0.996	0.991	0.987
230	1.000	0.999	0.999	0.999	0.998	0.998	0.995	0.990	0.984
240	1.000	0.999	0.999	0.999	0.998	0.998	0.995	0.988	0.979
250	1.000	0.999	0.999	0.999	0.998	0.997	0.994	0.986	0.973
260	1.000	0.999	0.999	0.999	0.997	0.997	0.993	0.983	0.965

[†] Cassegrain focus.

TABLE IX(e)
Beam truncation loss in dB at cryostat window for Band 7 low limit frequency 275 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 60	55	50	45	40	36	30	25	20
160	-0.002	-0.003	-0.004	-0.005	-0.009	-0.012	-0.024	-0.059	-0.110
170	-0.002	-0.003	-0.004	-0.005	-0.009	-0.010	-0.021	-0.049	-0.085
180	-0.002	-0.003	-0.004	-0.004	-0.008	-0.009	-0.019	-0.042	-0.067
190	-0.002	-0.003	-0.003	-0.004	-0.008	-0.009	-0.018	-0.038	-0.055
200	-0.002	-0.003	-0.003	-0.004	-0.008	-0.009	-0.018	-0.036	-0.049
210	-0.002	-0.003	-0.003	-0.004	-0.008	-0.009	-0.018	-0.036	-0.050
216†	-0.002	-0.003	-0.003	-0.004	-0.008	-0.009	-0.018	-0.035	-0.049
220	-0.002	-0.003	-0.003	-0.004	-0.008	-0.009	-0.019	-0.039	-0.058
230	-0.002	-0.003	-0.004	-0.005	-0.008	-0.010	-0.021	-0.044	-0.072
240	-0.002	-0.003	-0.004	-0.005	-0.009	-0.011	-0.023	-0.052	-0.093
250	-0.002	-0.003	-0.004	-0.005	-0.010	-0.012	-0.027	-0.063	-0.121
260	-0.002	-0.003	-0.004	-0.006	-0.011	-0.014	-0.032	-0.077	-0.155

† Cassegrain focus.

TABLE IX(f)
Truncated beam power at cryostat window for Band 7 mid frequency 323 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 60	55	50	45	40	36	30	25	20
160	1.000	1.000	0.999	0.999	0.999	0.998	0.996	0.990	0.974
170	1.000	1.000	0.999	0.999	0.999	0.998	0.997	0.992	0.980
180	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.993	0.984
190	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.994	0.988
200	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.995	0.990
210	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.995	0.991
216†	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.995	0.992
220	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.995	0.992
230	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.995	0.991
240	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.995	0.989
250	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.994	0.985
260	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.993	0.981

† Cassegrain focus.

TABLE IX(g)
Beam truncation loss in dB at cryostat window for Band 7 mid frequency 323 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 60	55	50	45	40	36	30	25	20
160	-0.001	-0.002	-0.002	-0.004	-0.005	-0.009	-0.017	-0.042	-0.115
170	-0.001	-0.002	-0.002	-0.004	-0.005	-0.008	-0.014	-0.035	-0.089
180	-0.001	-0.002	-0.002	-0.004	-0.004	-0.007	-0.012	-0.029	-0.068
190	-0.001	-0.002	-0.002	-0.003	-0.004	-0.007	-0.010	-0.025	-0.053
200	-0.001	-0.002	-0.002	-0.003	-0.004	-0.006	-0.009	-0.022	-0.043
210	-0.001	-0.002	-0.002	-0.003	-0.004	-0.006	-0.009	-0.020	-0.037
216†	-0.001	-0.002	-0.002	-0.003	-0.004	-0.006	-0.009	-0.020	-0.036
220	-0.001	-0.002	-0.002	-0.003	-0.004	-0.006	-0.009	-0.020	-0.037
230	-0.001	-0.002	-0.002	-0.003	-0.004	-0.006	-0.009	-0.021	-0.041
240	-0.001	-0.002	-0.002	-0.003	-0.004	-0.006	-0.010	-0.023	-0.050
250	-0.001	-0.002	-0.002	-0.003	-0.004	-0.007	-0.011	-0.026	-0.064
260	-0.001	-0.002	-0.002	-0.004	-0.004	-0.007	-0.013	-0.031	-0.082

† Cassegrain focus.

TABLE IX(h)
Truncated beam power at cryostat window for Band 7 high limit frequency 370 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 60	55	50	45	40	36	30	25	20
160	1.000	1.000	1.000	0.999	0.999	0.999	0.997	0.995	0.982
170	1.000	1.000	1.000	1.000	0.999	0.999	0.997	0.996	0.986
180	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.989
190	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.991
200	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.992
210	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.993
216†	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.993
220	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.993
230	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.992
240	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.991
250	1.000	1.000	0.999	1.000	0.999	0.999	0.998	0.997	0.990
260	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.996	0.987

† Cassegrain focus.

TABLE IX(i)
Beam truncation loss in dB at cryostat window for Band 7 high limit frequency 370 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 60	55	50	45	40	36	30	25	20
160	-0.001	-0.001	-0.002	-0.002	-0.004	-0.005	-0.013	-0.023	-0.081
170	-0.001	-0.001	-0.002	-0.002	-0.004	-0.005	-0.011	-0.018	-0.063
180	-0.001	-0.001	-0.002	-0.002	-0.003	-0.004	-0.010	-0.014	-0.050
190	-0.001	-0.001	-0.002	-0.002	-0.003	-0.004	-0.009	-0.012	-0.040
200	-0.001	-0.001	-0.002	-0.002	-0.003	-0.004	-0.008	-0.010	-0.034
210	-0.001	-0.001	-0.001	-0.002	-0.003	-0.003	-0.008	-0.010	-0.031
216[†]	-0.001	-0.001	-0.001	-0.002	-0.003	-0.003	-0.008	-0.009	-0.030
220	-0.001	-0.001	-0.001	-0.002	-0.003	-0.003	-0.008	-0.009	-0.030
230	-0.001	-0.001	-0.001	-0.002	-0.003	-0.003	-0.008	-0.010	-0.033
240	-0.001	-0.001	-0.001	-0.002	-0.003	-0.004	-0.008	-0.011	-0.038
250	-0.001	-0.001	-0.002	-0.002	-0.003	-0.004	-0.009	-0.013	-0.046
260	-0.001	-0.001	-0.002	-0.002	-0.003	-0.004	-0.010	-0.017	-0.057

[†] Cassegrain focus.

8.2 Physical Optics Analysis [*This section pending design revision.]

8.2.1 *Beam Profile at Cassegrain Focus*

Figures 10(g) – (j) show the beam profile at the Cassegrain with comparison of results obtained by both quasi-optics and physical optics.

Figure 10(g). Beam profile at Cassegrain focus for Band 7 mid frequency 323 GHz.

8.2.2 *Beam Profile at Subreflector & Edge Taper*

8.2.3 *Far Field Radiation Pattern*

8.2.4 *Beam & Cross-Polar Efficiencies*

9 BAND 8

9.1 Quasi-Optics Analysis

9.1.1 *Gaussian Beam Parameters*

TABLE X(a)
Quasi-optics Gaussian beam parameters for Band 8.

Frequency [GHz]		**385**	**442**	**500**
λ **[mm]**		0.778682	0.678263	0.599585
Horn diameter	8.69			
Horn axial length	35.29			
Horn slant length	35.556			
Horn waist, w_0		2.092	1.959	1.833
Horn waist offset, $\Delta z(w_0)$		-15.6576	-18.1020	-20.2774
Waist at horn aperture, w_{ha}		2.796	2.796	2.796
d_1	90.0			
R_{s1}	110.88	108.606	111.025	113.087
f_1	41.79			
R_{i1}	67.07	67.927	67.014	66.285
Waist at mirror 1, w_{M1}	(dia. = 62)	12.694	12.074	11.628
z_{w1}		67.1937	66.3607	65.7097
w_1		1.319	1.192	1.083
d_2	125.00			
R_{s2}	59.32	58.659	59.379	59.928
f_2	46.65			
R_{i2}	218.5	227.866	217.615	210.550
Waist at mirror 2, w_{M2}	(dia. = 55)	10.941	10.684	10.503
$z_{w(Cass.)}$	186.00	186.378	186.084	185.883
$w_{Cass.}$		4.669	4.067	3.595
$d_{mirror\text{-}subrefl}$		6185.11	6185.11	6185.11
$w_{subrefl}$	(dia. = 750)	318.516	318.516	318.516
$R_{subrefl}$	6000.00	6000.021	6000.004	5999.992
Edge Taper (dB)	12.00	12.02	12.04	12.04

All dimensions in mm.

9.1.2 *Truncation Loss at Mirrors*

The beam profiles at mirror 1 and mirror 2 are shown in Figures 11(a), (b) and (c). Truncation loss of the beam for a range of mirror diameters is given in Table X(b) and X(c).

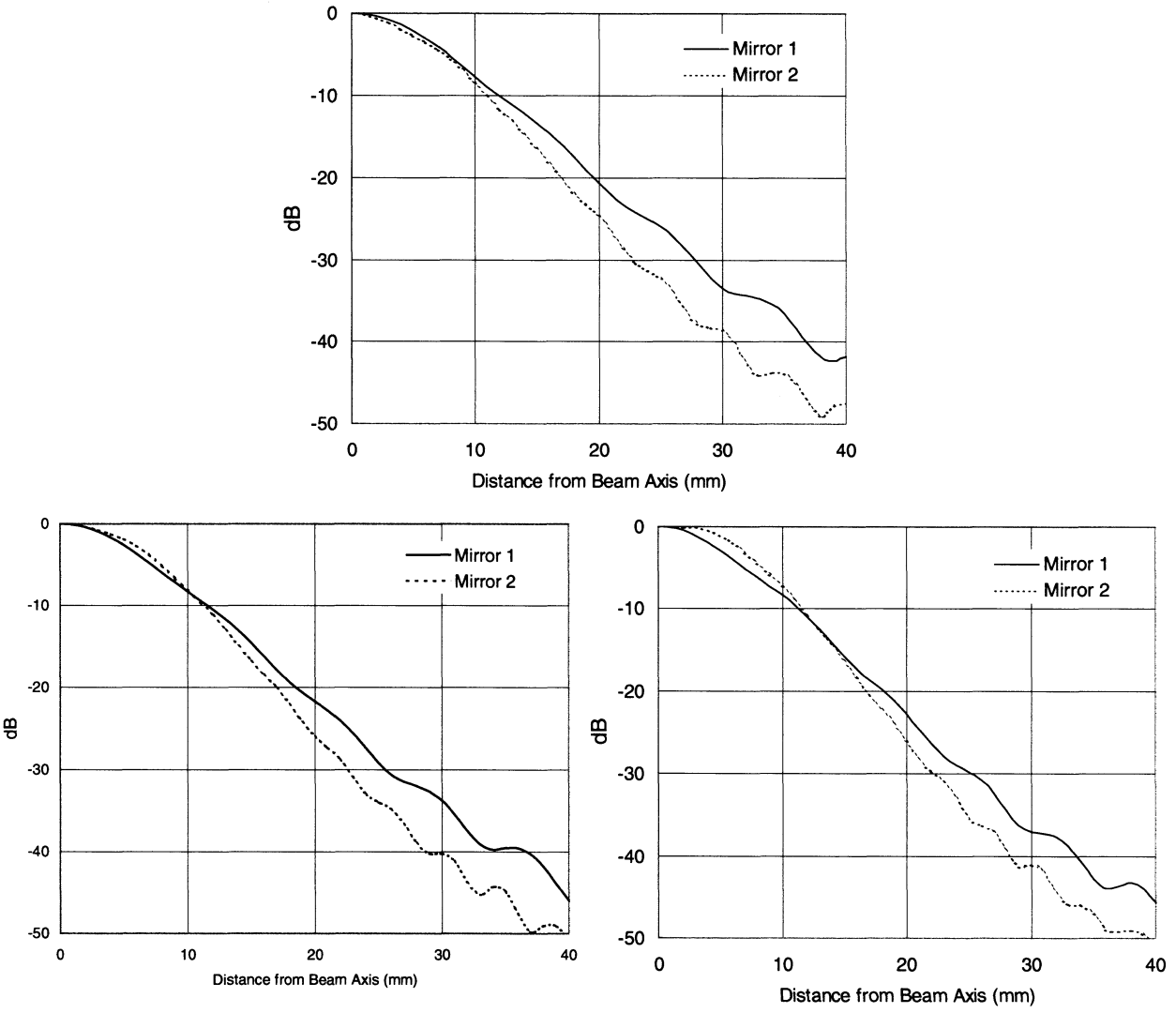


Figure 11. Beam profile at mirror 1 and mirror 2; (a) 385 GHz, (b) 442 GHz and (c) 500 GHz.

TABLE X(b)
Truncated beam power and loss at mirror 1 for Band 8.

Frequency	**385 GHz**		**442 GHz**		**500 GHz**	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
80	0.999	-0.004	0.999	-0.002	1.000	-0.001
75	0.999	-0.004	0.999	-0.003	0.999	-0.002
70	0.999	-0.006	0.999	-0.004	0.999	-0.003
65	0.998	-0.010	0.999	-0.006	0.999	-0.004
62	0.997	-0.012	0.998	-0.008	0.999	-0.006
60	0.997	-0.014	0.998	-0.009	0.998	-0.007
55	0.995	-0.021	0.996	-0.016	0.998	-0.010
50	0.991	-0.038	0.994	-0.025	0.996	-0.019
45	0.995	-0.067	0.990	-0.045	0.992	-0.033
40	0.974	-0.113	0.980	-0.088	0.986	-0.063

Diameter in mm., loss in dB.

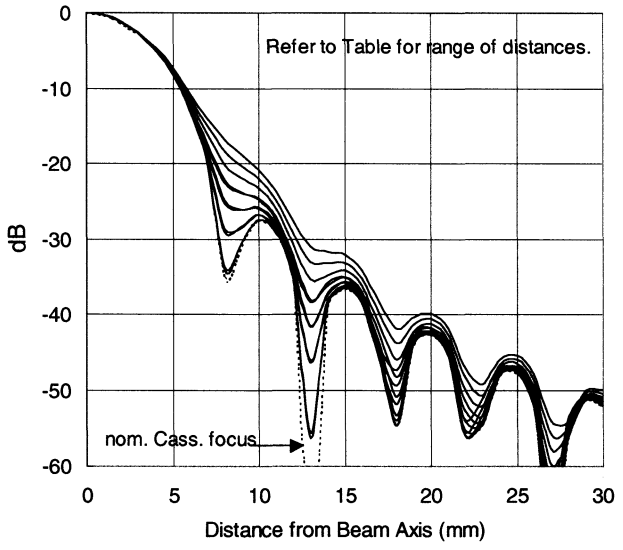
TABLE X(c)
Truncated beam power and loss at mirror 2 for Band 8.

Frequency	385 GHz		442 GHz		500 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
80	1.000	-0.001	1.000	-0.000	1.000	-0.000
75	1.000	-0.001	1.000	-0.001	1.000	-0.000
70	1.000	-0.001	1.000	-0.001	1.000	-0.001
65	1.000	-0.002	1.000	-0.001	1.000	-0.001
62	0.999	-0.003	1.000	-0.002	1.000	-0.001
60	0.999	-0.003	1.000	-0.002	1.000	-0.001
55	0.999	-0.005	0.999	-0.003	0.999	-0.002
50	0.998	-0.009	0.999	-0.006	0.999	-0.004
45	0.996	-0.017	0.997	-0.012	0.998	-0.009
40	0.992	-0.036	0.994	-0.026	0.996	-0.019

Diameter in mm., loss in dB.

9.1.3 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 11(d), (e) and (f). Truncation loss of the beam for a range of window diameters is given in Table X(d) – X(i).



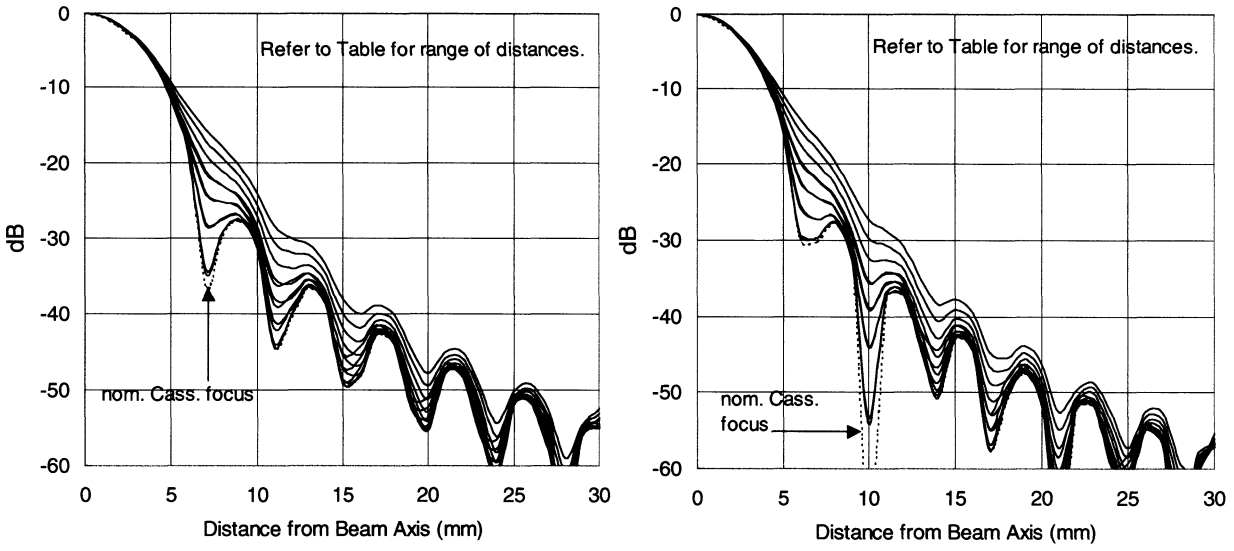


Figure 11. Beam profile at various distances from mirror 2; (d) 385 GHz, (e) 442 GHz and (f) 500 GHz.

TABLE X(d)
Truncated beam power at cryostat window for Band 8 low limit frequency 385 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	28	25	20	15
120	1.000	0.999	0.999	0.999	0.997	0.996	0.994	0.980	0.937
130	1.000	1.000	0.999	0.999	0.997	0.997	0.995	0.984	0.952
140	1.000	1.000	0.999	0.999	0.998	0.997	0.996	0.988	0.965
150	1.000	1.000	0.999	0.999	0.998	0.998	0.997	0.990	0.975
160	1.000	1.000	0.999	0.999	0.998	0.998	0.998	0.992	0.983
170	1.000	1.000	0.999	0.999	0.998	0.998	0.998	0.993	0.988
180	1.000	1.000	0.999	0.999	0.998	0.998	0.998	0.994	0.990
186[†]	1.000	1.000	0.999	0.999	0.998	0.998	0.998	0.994	0.991
190	1.000	1.000	0.999	0.999	0.998	0.998	0.998	0.994	0.991
200	1.000	1.000	0.999	0.999	0.998	0.998	0.998	0.994	0.988
210	1.000	1.000	0.999	0.999	0.998	0.998	0.998	0.993	0.983
220	1.000	1.000	0.999	0.999	0.998	0.998	0.997	0.991	0.976

[†] Cassegrain focus.

TABLE X(e)
Beam truncation loss in dB at cryostat window for Band 8 low limit frequency 385 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	28	25	20	15
120	-0.002	-0.002	-0.004	-0.006	-0.013	-0.019	-0.027	-0.088	-0.281
130	-0.002	-0.002	-0.003	-0.005	-0.011	-0.015	-0.021	-0.068	-0.212
140	-0.001	-0.002	-0.003	-0.005	-0.009	-0.013	-0.016	-0.053	-0.155
150	-0.001	-0.002	-0.003	-0.004	-0.008	-0.011	-0.013	-0.042	-0.109
160	-0.001	-0.002	-0.003	-0.004	-0.007	-0.009	-0.011	-0.034	-0.076
170	-0.001	-0.002	-0.003	-0.003	-0.007	-0.009	-0.010	-0.029	-0.053
180	-0.001	-0.002	-0.002	-0.003	-0.006	-0.008	-0.009	-0.026	-0.042
186[†]	-0.001	-0.002	-0.002	-0.003	-0.006	-0.008	-0.009	-0.026	-0.040
190	-0.001	-0.002	-0.002	-0.003	-0.006	-0.008	-0.009	-0.026	-0.041
200	-0.001	-0.002	-0.002	-0.003	-0.006	-0.009	-0.009	-0.028	-0.052
210	-0.001	-0.002	-0.003	-0.004	-0.007	-0.009	-0.011	-0.033	-0.073
220	-0.001	-0.002	-0.003	-0.004	-0.008	-0.010	-0.013	-0.039	-0.106

[†] Cassegrain focus.

TABLE X(f)
Truncated beam power at cryostat window for Band 8 mid frequency 442 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	28	25	20	15
120	1.000	1.000	0.999	0.999	0.998	0.998	0.995	0.988	0.951
130	1.000	1.000	0.999	0.999	0.999	0.998	0.996	0.991	0.963
140	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.994	0.973
150	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.995	0.980
160	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.996	0.986
170	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.997	0.990
180	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.997	0.991
186[†]	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.997	0.992
190	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.997	0.991
200	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.997	0.990
210	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.997	0.985
220	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.996	0.981

[†] Cassegrain focus.

TABLE X(g)
Beam truncation loss in dB at cryostat window for Band 8 mid frequency 442 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	28	25	20	15
120	-0.001	-0.001	-0.003	-0.004	-0.008	-0.011	-0.021	-0.052	-0.220
130	-0.001	-0.001	-0.002	-0.004	-0.006	-0.008	-0.016	-0.038	-0.165
140	-0.001	-0.001	-0.002	-0.003	-0.005	-0.007	-0.013	-0.028	-0.121
150	-0.001	-0.001	-0.002	-0.003	-0.004	-0.006	-0.011	-0.021	-0.086
160	-0.001	-0.001	-0.002	-0.003	-0.004	-0.005	-0.009	-0.016	-0.062
170	-0.001	-0.001	-0.002	-0.002	-0.004	-0.004	-0.008	-0.013	-0.045
180	-0.001	-0.001	-0.002	-0.002	-0.003	-0.004	-0.008	-0.012	-0.037
186[†]	-0.001	-0.001	-0.002	-0.002	-0.003	-0.004	-0.008	-0.012	-0.036
190	-0.001	-0.001	-0.002	-0.002	-0.003	-0.004	-0.008	-0.012	-0.037
200	-0.001	-0.001	-0.002	-0.002	-0.004	-0.004	-0.008	-0.013	-0.045
210	-0.001	-0.001	-0.002	-0.003	-0.004	-0.005	-0.009	-0.015	-0.060
220	-0.001	-0.001	-0.002	-0.003	-0.004	-0.005	-0.010	-0.019	-0.084

[†] Cassegrain focus.

TABLE X(h)
Truncated beam power at cryostat window for Band 8 high limit frequency 500 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	28	25	20	15
120	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.991	0.964
130	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.993	0.973
140	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.995	0.981
150	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.997	0.986
160	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.997	0.990
170	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.992
180	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.993
186[†]	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.993
190	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.993
200	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.998	0.992
210	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.997	0.990
220	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.997	0.987

[†] Cassegrain focus.

TABLE X(i)
Beam truncation loss in dB at cryostat window for Band 8 high limit frequency 500 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	28	25	20	15
120	-0.001	-0.001	-0.002	-0.003	-0.006	-0.008	-0.012	-0.040	-0.160
130	-0.001	-0.001	-0.001	-0.002	-0.005	-0.006	-0.009	-0.028	-0.117
140	-0.001	-0.001	-0.001	-0.002	-0.004	-0.005	-0.007	-0.020	-0.085
150	-0.001	-0.001	-0.001	-0.002	-0.004	-0.004	-0.006	-0.015	-0.061
160	-0.001	-0.001	-0.001	-0.002	-0.003	-0.004	-0.005	-0.012	-0.045
170	-0.001	-0.001	-0.001	-0.002	-0.003	-0.004	-0.004	-0.010	-0.035
180	-0.001	-0.001	-0.001	-0.002	-0.003	-0.003	-0.004	-0.009	-0.030
186[†]	-0.001	-0.001	-0.001	-0.002	-0.003	-0.003	-0.004	-0.009	-0.029
190	-0.001	-0.001	-0.001	-0.002	-0.003	-0.003	-0.004	-0.009	-0.029
200	-0.001	-0.001	-0.001	-0.002	-0.003	-0.004	-0.004	-0.010	-0.034
210	-0.001	-0.001	-0.001	-0.002	-0.003	-0.004	-0.005	-0.012	-0.043
220	-0.001	-0.001	-0.001	-0.002	-0.003	-0.004	-0.006	-0.015	-0.058

[†] Cassegrain focus.

9.2 **Physical Optics Analysis** [*This section pending design revision.]

9.2.1 *Beam Profile at Cassegrain Focus*

Figures 11(g) – (j) show the beam profile at the Cassegrain with comparison of results obtained by both quasi-optics and physical optics.

Figure 11(g). Beam profile at Cassegrain focus for Band 8 mid frequency 442 GHz.

9.2.2 *Beam Profile at Subreflector & Edge Taper*

9.2.3 *Far Field Radiation Pattern*

9.2.4 *Beam & Cross-Polar Efficiencies*

10 BAND 9

10.1 Quasi-Optics Analysis

10.1.1 *Gaussian Beam Parameters*

TABLE XI(a)
Quasi-optics Gaussian beam parameters for Band 9.

Frequency [GHz]		**602**	**661**	**720**
λ **[mm]**		0.497994	0.453544	0.416378
Horn diameter	4.22			
Horn axial length	12.87			
Horn slant length	13.042			
Horn waist, w_0		1.358	1.358	1.358
Horn waist offset, $\Delta z(w_0)$		-5.77716	-6.38361	-6.94053
Waist at horn aperture, w_{ha}		1.013	0.970	0.929
d_1	57.13			
R_{s1}	64.15	63.574	64.183	64.731
f_1	28.43			
R_{i1}	51.06	51.428	51.037	50.695
Waist at mirror 1, w_{M1}	(dia. = 48)	9.892	9.501	9.191
z_{w1}		51.0740	50.6993	50.3766
w_1		0.821	0.773	0.729
d_2	82.33			
R_{s2}	32.13	31.835	32.172	32.456
f_2	25.62			
R_{i2}	126.546	131.229	125.799	121.640
Waist at mirror 2, w_{M2}	(dia. = 35)	6.089	5.958	5.857
$z_{w(Cass.)}$	100.00	99.8028	99.7058	99.6317
$w_{Cass.}$		2.980	2.714	2.491
$d_{mirror\text{-}subrefl}$		6099.27	6099.27	6099.27
$w_{subrefl}$	(dia. = 750)	319.198	319.198	319.198
$R_{subrefl}$	6000.00	5999.990	5999.998	6000.004
Edge Taper (dB)	12.00	11.99	11.99	11.99

All dimensions in mm.

10.1.2 *Truncation Loss at Mirrors*

The beam profiles at mirror 1 and mirror 2 are shown in Figures 12(a), (b) and (c). Truncation loss of the beam for a range of mirror diameters is given in Table XI(b) and XI(c).

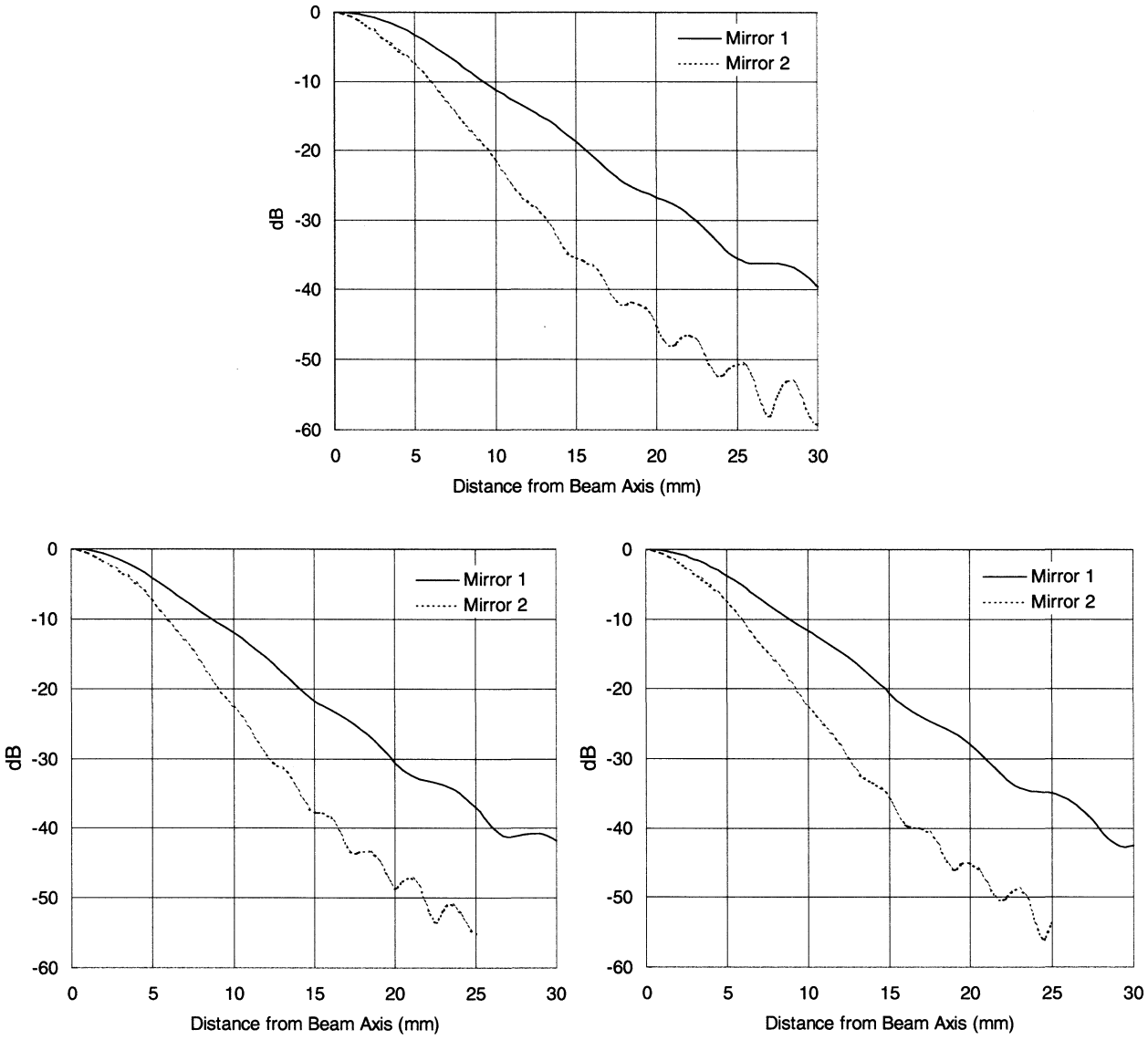


Figure 12. Beam profile at mirror 1 and mirror 2; (a) 602 GHz, (b) 661 GHz and (c) 720 GHz.

TABLE XI(b)
Truncated beam power and loss at mirror 1 for Band 9.

Frequency	602 GHz		661 GHz		720 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
60	0.999	-0.004	0.999	-0.004	0.999	-0.003
55	0.998	-0.007	0.999	-0.005	0.999	-0.004
50	0.997	-0.011	0.998	-0.009	0.999	-0.006
48	0.997	-0.013	0.998	-0.011	0.998	-0.008
45	0.996	-0.018	0.997	-0.014	0.997	-0.012
40	0.992	-0.037	0.994	-0.026	0.995	-0.020
35	0.985	-0.067	0.987	-0.056	0.990	-0.044
30	0.968	-0.139	0.975	-0.112	0.978	-0.096

Diameter in mm., loss in dB.

TABLE XI(c)
Truncated beam power and loss at mirror 2 for Band 9.

Frequency	602 GHz		661 GHz		720 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
50	1.000	-0.001	1.000	-0.000	1.000	-0.000
45	1.000	-0.001	1.000	-0.001	1.000	-0.001
40	1.000	-0.002	1.000	-0.001	1.000	-0.001
35	0.999	-0.003	0.999	-0.002	1.000	-0.002
30	0.998	-0.008	0.999	-0.006	0.999	-0.005
25	0.995	-0.022	0.996	-0.017	0.997	-0.014
20	0.983	-0.076	0.985	-0.064	0.988	-0.054

Diameter in mm., loss in dB.

10.1.3 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 12(d), (e) and (f). Truncation loss of the beam for a range of window diameters is given in Table XI(d) – XI(i).

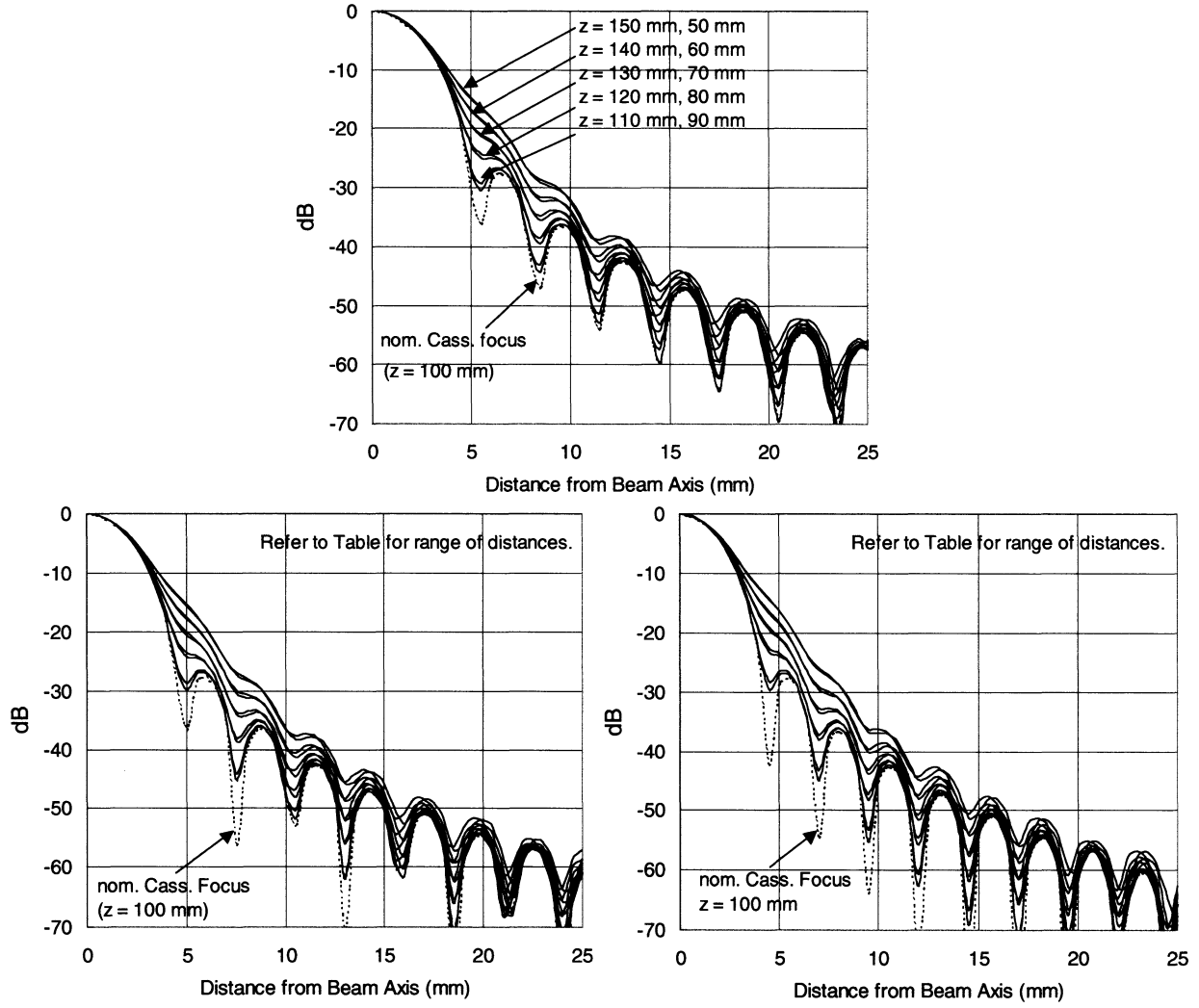


Figure 12. Beam profile at various distances from mirror 2; (d) 602 GHz, (e) 661 GHz and (f) 720 GHz.

TABLE XI(d)
Truncated beam power at cryostat window for Band 9 low limit frequency 602 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	26	20	15
50	1.000	1.000	1.000	1.000	0.999	0.999	0.987	0.989
60	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.993
70	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.995
80	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.997
90	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.997
100†	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.998
110	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.997
120	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.997
130	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.995
140	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.993
150	1.000	1.000	1.000	1.000	0.999	0.999	0.997	0.988

† Cassegrain focus.

TABLE XI(e)
Beam truncation loss in dB at cryostat window for Band 9 low limit frequency 602 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	26	20	15
50	-0.000	-0.001	-0.001	-0.001	-0.002	-0.004	-0.013	-0.049
60	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.009	-0.032
70	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.007	-0.021
80	-0.000	-0.000	-0.001	-0.001	-0.002	-0.002	-0.006	-0.014
90	-0.000	-0.000	-0.001	-0.001	-0.002	-0.002	-0.005	-0.011
100†	-0.000	-0.000	-0.001	-0.001	-0.002	-0.002	-0.005	-0.010
110	-0.000	-0.000	-0.001	-0.001	-0.002	-0.002	-0.005	-0.011
120	-0.000	-0.000	-0.001	-0.001	-0.002	-0.002	-0.006	-0.015
130	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.007	-0.021
140	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.009	-0.033
150	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.012	-0.050

† Cassegrain focus.

TABLE XI(f)
Truncated beam power at cryostat window for Band 9 mid frequency 661 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	26	20	15
50	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.991
60	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.994
70	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.996
80	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997
90	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
100†	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
110	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
120	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997
130	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.996
140	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.994
150	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.990

† Cassegrain focus.

TABLE XI(g)
Beam truncation loss in dB at cryostat window for Band 9 mid frequency 661 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	26	20	15
50	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.009	-0.041
60	-0.000	-0.000	-0.001	-0.001	-0.001	-0.002	-0.007	-0.026
70	-0.000	-0.000	-0.001	-0.001	-0.001	-0.002	-0.005	-0.017
80	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.012
90	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.009
100†	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.009
110	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.010
120	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.012
130	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.005	-0.018
140	-0.000	-0.000	-0.001	-0.001	-0.001	-0.002	-0.007	-0.027
150	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.010	-0.042

† Cassegrain focus.

TABLE XI(h)
Truncated beam power at cryostat window for Band 9 high limit frequency 720 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	26	20	15
50	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.992
60	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.995
70	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997
80	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
90	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
100†	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
110	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
120	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997
130	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997
140	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.995
150	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.992

† Cassegrain focus.

TABLE XI(i)
Beam truncation loss in dB at cryostat window for Band 9 high limit frequency 720 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 50	45	40	35	30	26	20	15
50	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.008	-0.034
60	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.006	-0.022
70	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.005	-0.015
80	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.011
90	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001	-0.003	-0.009
100†	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001	-0.003	-0.008
110	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001	-0.003	-0.009
120	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001	-0.004	-0.011
130	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.005	-0.015
140	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.006	-0.022
150	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.008	-0.034

† Cassegrain focus.

10.2 Physical Optics Analysis

10.2.1 *Beam Profile at Cassegrain Focus*

Figures 12(g) – (j) show the beam profile at the Cassegrain focus with comparison of results obtained by both quasi-optics and physical optics.

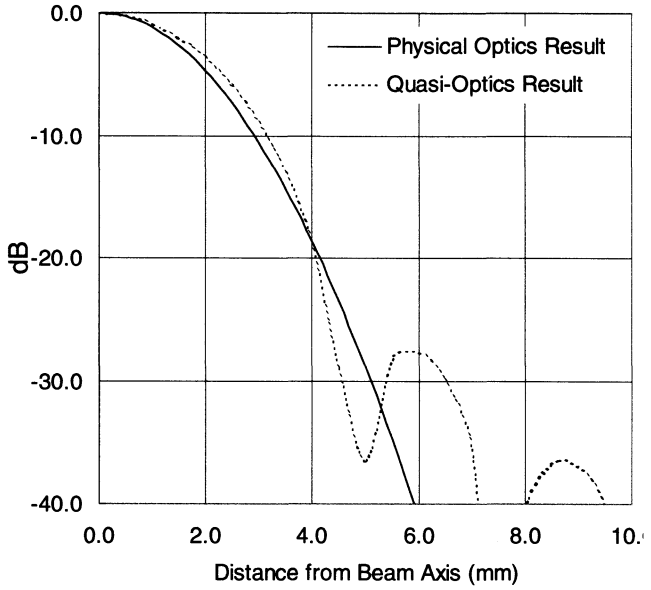


Figure 12(g). Beam profile at Cassegrain focus for Band 9 mid frequency 661 GHz.

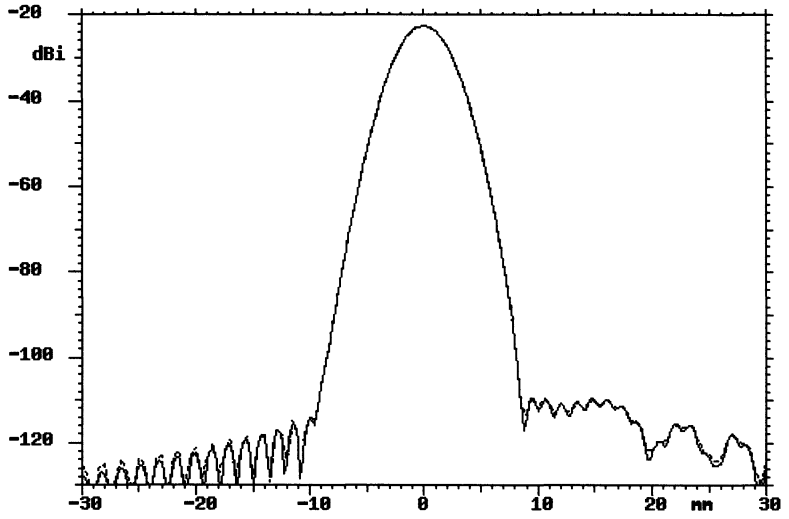


Figure 12(h). Beam profile of co-polar field at Cassegrain focus, Band 9 mid frequency 661 GHz; x-polarised source solid line, y-polarised source dotted line.

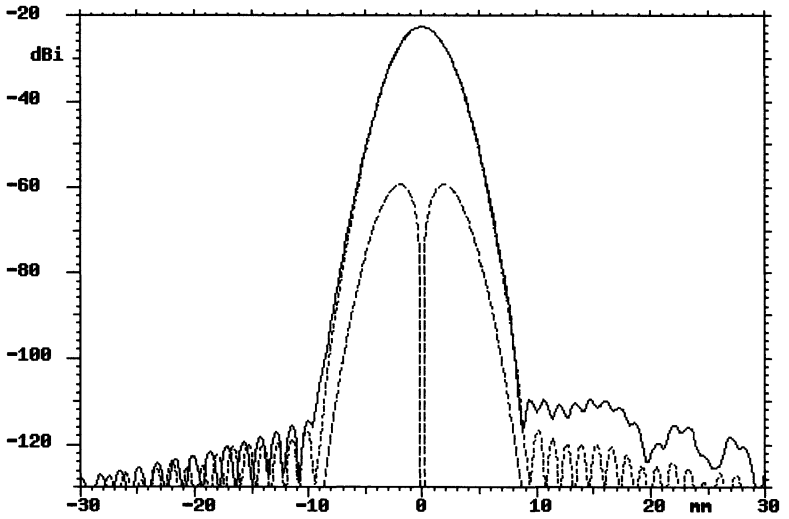


Figure 12(i). Beam profile at Cassegrain focus Band 9 mid frequency 661 GHz., x-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

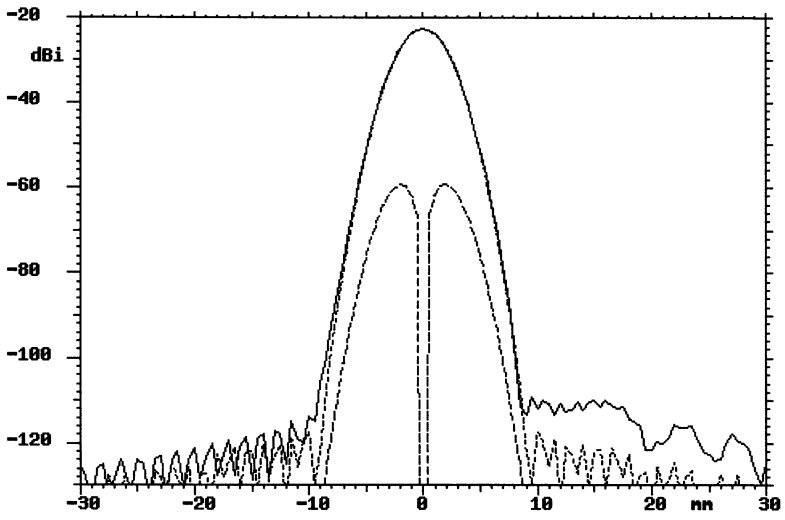


Figure 12(j). Beam profile at Cassegrain focus Band 9 mid frequency 661 GHz., y-polarised source; $\phi = 0^{o}$ co-polar field solid line, $\phi = 90^{o}$ co-polar field dotted line, $\phi = 90^{o}$ X-polar field dash line.

10.2.2 *Beam Profile at Subreflector & Edge Taper*

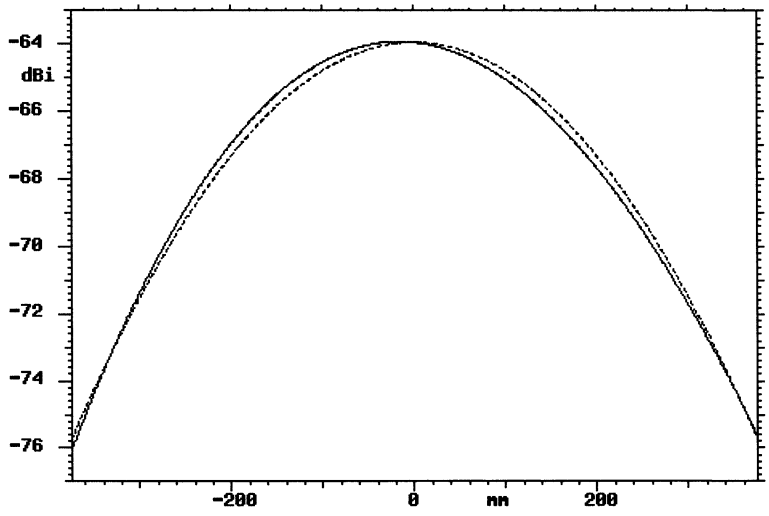


Figure 12(k). Beam profile at subreflector Band 9 mid frequency 661 GHz.; $\phi = 0^{o}$ solid line, $\phi = 90^{o}$ dash line.

The edge tapers at the subreflector corresponding to the four positions where $\phi = 0^{o}$ and 90^{o} are –11.7, -11.4, -11.4 and –11.4 respectively.

10.2.3 *Far Field Radiation Pattern*

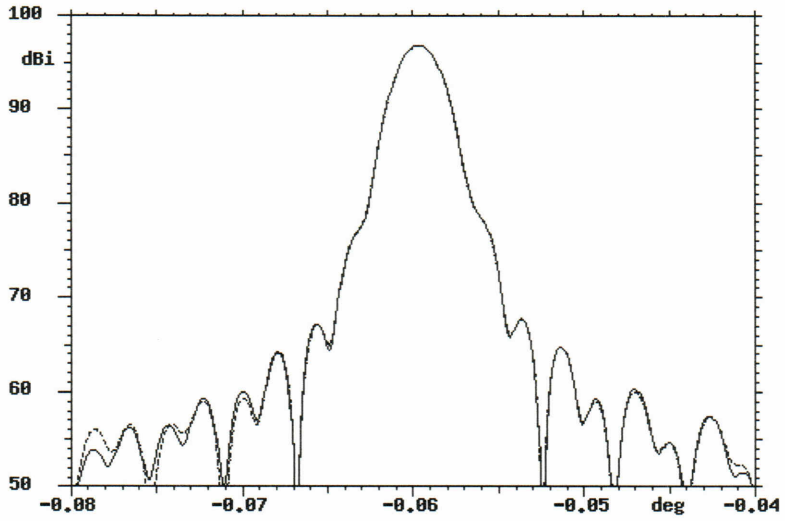


Figure 12(l). Antenna far field radiation pattern for Band 9 mid frequency 661 GHz.; x-polarised source solid line, y-polarised source dash line.

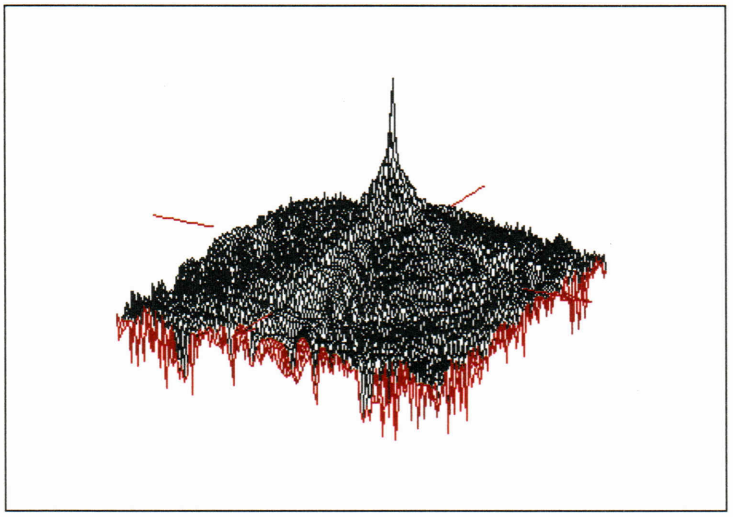


Figure 12(m). 3-D plot of antenna co-polar field radiation pattern.

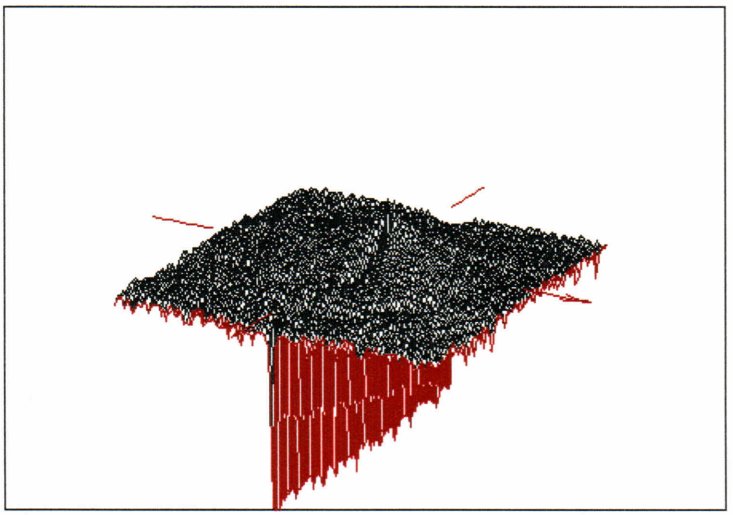


Figure 12(n). 3-D plot of antenna cross-polar field radiation pattern.

5.2.4 *Beam & Cross-Polar Efficiencies*

The beam efficiencies are shown in Table XI(j) below.

TABLE XI(j)
Beam efficiencies for Band 9 mid frequency 661 GHz
defined by contours of the co-polarisation field.

Level below peak (dB)	**Co-polar (%)**	**Cross-polar (%)**
3.0	40.82	0.00
6.0	63.90	0.01
9.0	75.11	0.01
12.0	80.70	0.02
15.0	83.91	0.02
18.0	85.86	0.02
21.0	87.98	0.02
24.0	88.89	0.02
27.0	89.26	0.02
30.0	89.57	0.02
33.0	89.98	0.02
36.0	90.34	0.02
39.0	90.72	0.02
42.0	91.06	0.02
45.0	91.39	0.02
48.0	91.61	0.02
51.0	91.72	0.02
54.0	91.77	0.02
57.0	91.85	0.02
60.0	91.93	0.02

11 BAND 10

11.1 Quasi-Optics Analysis

11.1.1 *Gaussian Beam Parameters*

TABLE XII(a)
Quasi-optics Gaussian beam parameters for Band 10.

Frequency [GHz]		**787**	**868**	**950**
λ **[mm]**		0.380931	0.345383	0.315571
Horn diameter	8.06			
Horn axial length	26.77			
Horn slant length	17.072			
Horn waist, w_0		1.138	1.049	0.972
Horn waist offset, $\Delta z(w_0)$		-21.8631	-22.6380	-23.2675
Waist at horn aperture, w_{ha}		2.593	2.593	2.593
d_1	82.0			
R_{s1}	105.379	104.959	105.597	106.108
f_1	35.31			
R_{i1}	53.31	53.211	53.049	52.921
Waist at mirror 1, w_{M1}	(dia. = 55)	11.130	11.012	10.921
z_{w1}		53.0670	52.9261	52.8156
w_1		0.579	0.529	0.486
d_2	100.0			
R_{s2}	47.151	47.096	47.212	47.302
f_2	37.77			
R_{i2}	189.847	190.741	188.866	187.434
Waist at mirror 2, w_{M2}	(dia. = 49)	9.847	9.797	9.759
$z_{w(Cass.)}$	181.00	180.473	180.422	180.383
$w_{Cass.}$		2.285	2.071	1.893
$d_{mirror\text{-}subrefl}$		6180.17	6180.17	6180.17
$w_{subrefl}$	(dia. = 750)	318.428	318.428	318.428
$R_{subrefl}$	6000.00	6000.006	6000.002	5999.999
Edge Taper (dB)	12.00	12.05	12.05	12.05

All dimensions in mm.

11.1.2 *Truncation Loss at Mirrors*

The beam profiles at mirror 1 and mirror 2 are shown in Figures 13(a), (b) and (c). Truncation loss of the beam for a range of mirror diameters is given in Table XII(b) and XII(c).

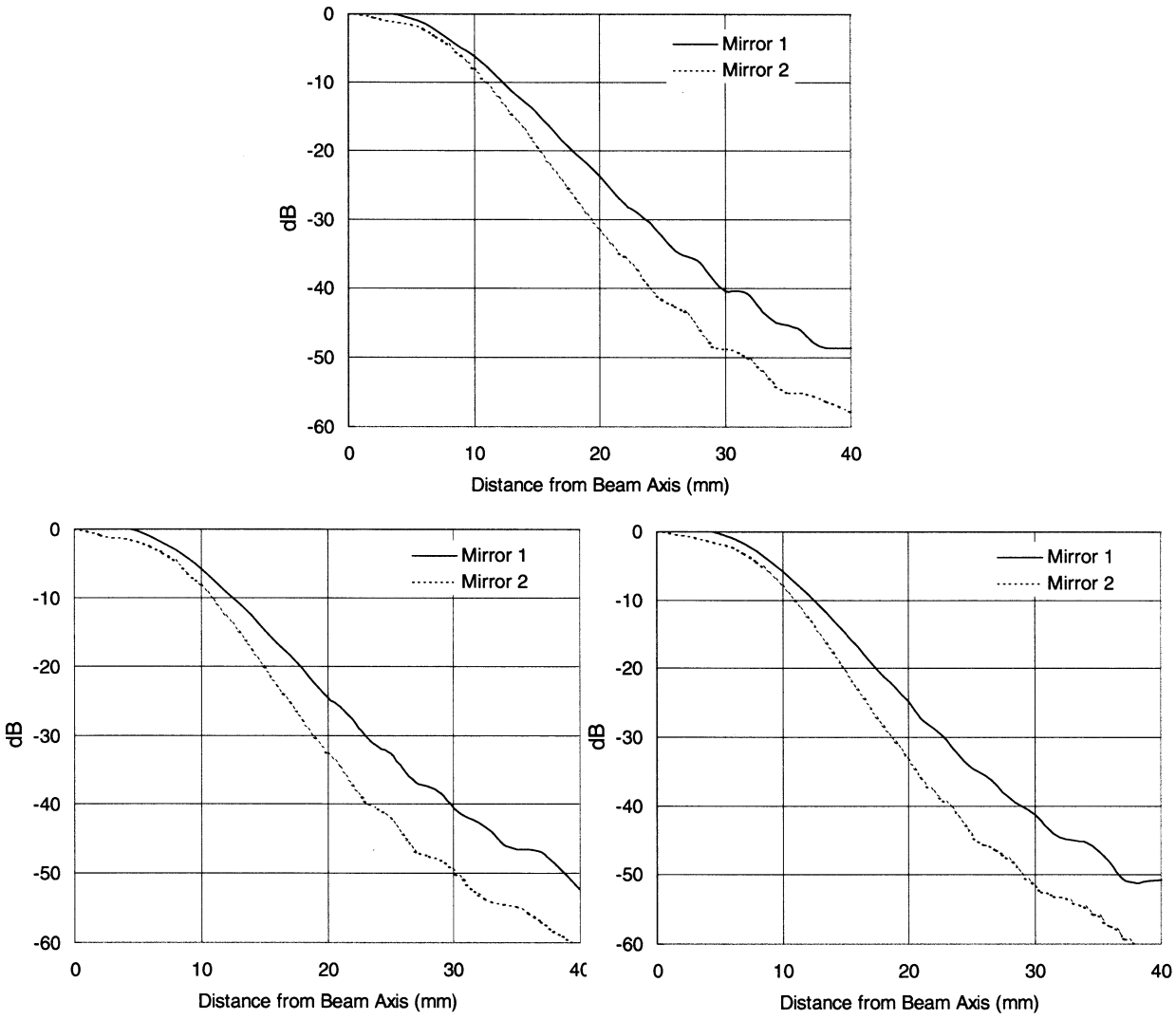


Figure 13. Beam profile at mirror 1 and mirror 2; (a) 787 GHz, (b) 868 GHz and (c) 950 GHz.

TABLE XII(b)
Truncated beam power and loss at mirror 1 for Band 10.

Frequency	787 GHz		868 GHz		950 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
70	1.000	-0.001	1.000	-0.001	1.000	-0.000
65	1.000	-0.001	1.000	-0.001	1.000	-0.001
60	1.000	-0.002	1.000	-0.001	1.000	-0.001
55	0.999	-0.003	0.999	-0.003	1.000	-0.002
50	0.999	-0.006	0.999	-0.005	0.999	-0.004
45	0.997	-0.013	0.998	-0.010	0.998	-0.008
40	0.994	-0.028	0.995	-0.022	0.996	-0.018
35	0.985	-0.066	0.987	-0.056	0.989	-0.047

Diameter in mm., loss in dB.

TABLE XII(c)
Truncated beam power and loss at mirror 2 for Band 10.

Frequency	787 GHz		868 GHz		950 GHz	
Diameter	**Power**	**Loss**	**Power**	**Loss**	**Power**	**Loss**
60	1.000	-0.000	1.000	-0.000	1.000	-0.000
55	1.000	-0.001	1.000	-0.000	1.000	-0.000
50	1.000	-0.001	1.000	-0.001	1.000	-0.001
49	1.000	-0.001	1.000	-0.001	1.000	-0.001
45	0.999	-0.002	1.000	-0.002	1.000	-0.001
40	0.999	-0.006	0.999	-0.004	0.999	-0.003
35	0.996	-0.016	0.997	-0.013	0.998	-0.011
30	0.988	-0.052	0.990	-0.045	0.991	-0.039

Diameter in mm., loss in dB.

11.1.3 *Truncation Loss at Cryostat Window*

The beam profiles at the cryostat window are shown in Figures 13(d), (e) and (f). Truncation loss of the beam for a range of window diameters is given in Table XII(d) – XII(i).

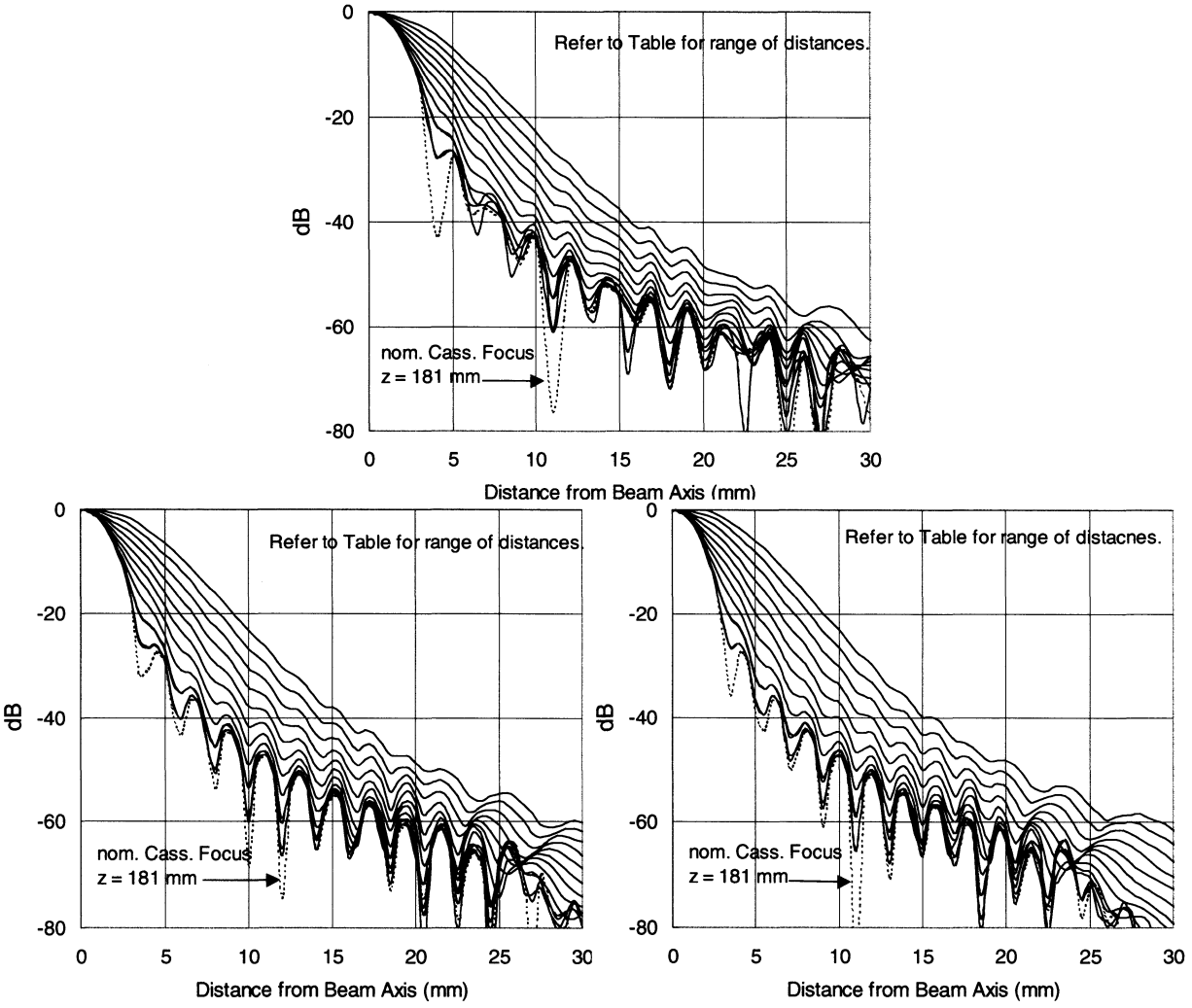


Figure 13. Beam profile at various distances from mirror 2; (d) 787 GHz, (e) 868 GHz and (f) 950 GHz.

TABLE XII(d)
Truncated beam power at cryostat window for Band 10 low limit frequency 787 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 45	40	35	30	25	20	15	10
80	1.000	1.000	1.000	0.999	0.998	0.990	0.950	0.772
90	1.000	1.000	1.000	0.999	0.998	0.993	0.965	0.823
100	1.000	1.000	1.000	1.000	0.999	0.996	0.977	0.868
110	1.000	1.000	1.000	1.000	0.999	0.997	0.985	0.905
120	1.000	1.000	1.000	1.000	0.999	0.998	0.991	0.935
130	1.000	1.000	1.000	1.000	1.000	0.999	0.994	0.958
140	1.000	1.000	1.000	1.000	1.000	0.999	0.996	0.974
150	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.984
160	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.990
170	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.994
181†	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.995
190	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.994
200	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.991

† Cassegrain focus.

TABLE XII(e)
Beam truncation loss in dB at cryostat window for Band 10 low limit frequency 787 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 45	40	35	30	25	20	15	10
80	-0.000	-0.001	-0.001	-0.003	-0.011	-0.045	-0.224	-1.124
90	-0.000	-0.001	-0.001	-0.003	-0.007	-0.029	-0.153	-0.847
100	-0.000	-0.001	-0.001	-0.002	-0.005	-0.019	-0.101	-0.617
110	-0.000	-0.000	-0.001	-0.002	-0.004	-0.013	-0.065	-0.433
120	-0.000	-0.000	-0.001	-0.001	-0.003	-0.009	-0.041	-0.292
130	-0.000	-0.000	-0.001	-0.001	-0.002	-0.006	-0.026	-0.188
140	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.016	-0.116
150	-0.000	-0.000	-0.001	-0.001	-0.001	-0.003	-0.011	-0.070
160	-0.000	-0.000	-0.001	-0.001	-0.001	-0.003	-0.008	-0.042
170	-0.000	-0.000	-0.001	-0.001	-0.001	-0.002	-0.006	-0.028
181†	-0.000	-0.000	-0.001	-0.001	-0.001	-0.002	-0.006	-0.023
190	-0.000	-0.000	-0.001	-0.001	-0.001	-0.002	-0.006	-0.027
200	-0.000	-0.000	-0.001	-0.001	-0.001	-0.002	-0.007	-0.040

† Cassegrain focus.

TABLE XII(f)
Truncated beam power at cryostat window for Band 10 mid frequency 868 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 45	40	35	30	25	20	15	10
80	1.000	1.000	1.000	0.999	0.998	0.992	0.955	0.779
90	1.000	1.000	1.000	1.000	0.999	0.995	0.970	0.831
100	1.000	1.000	1.000	1.000	0.999	0.996	0.981	0.877
110	1.000	1.000	1.000	1.000	0.999	0.998	0.988	0.915
120	1.000	1.000	1.000	1.000	0.999	0.999	0.993	0.944
130	1.000	1.000	1.000	1.000	1.000	0.999	0.996	0.966
140	1.000	1.000	1.000	1.000	1.000	0.999	0.997	0.980
150	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.989
160	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.994
170	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.996
181†	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997
190	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.996
200	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.994

† Cassegrain focus.

TABLE XII(g)
Beam truncation loss in dB at cryostat window for Band 10 mid frequency 868 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 45	40	35	30	25	20	15	10
80	-0.000	-0.001	-0.001	-0.003	-0.009	-0.037	-0.200	-1.087
90	-0.000	-0.000	-0.001	-0.002	-0.006	-0.024	-0.132	-0.803
100	-0.000	-0.000	-0.001	-0.002	-0.004	-0.015	-0.085	-0.570
110	-0.000	-0.000	-0.001	-0.001	-0.003	-0.010	-0.052	-0.386
120	-0.000	-0.000	-0.001	-0.001	-0.002	-0.007	-0.031	-0.248
130	-0.000	-0.000	-0.000	-0.001	-0.002	-0.004	-0.019	-0.150
140	-0.000	-0.000	-0.000	-0.001	-0.001	-0.003	-0.011	-0.086
150	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.007	-0.047
160	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.005	-0.026
170	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.016
181†	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.003	-0.013
190	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.004	-0.015
200	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.005	-0.024

† Cassegrain focus.

TABLE XII(h)
Truncated beam power at cryostat window for Band 10 high limit frequency 950 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 45	40	35	30	25	20	15	10
80	1.000	1.000	1.000	1.000	0.999	0.993	0.960	0.785
90	1.000	1.000	1.000	1.000	0.999	0.996	0.974	0.839
100	1.000	1.000	1.000	1.000	0.999	0.997	0.983	0.885
110	1.000	1.000	1.000	1.000	1.000	0.998	0.990	0.922
120	1.000	1.000	1.000	1.000	1.000	0.999	0.994	0.950
130	1.000	1.000	1.000	1.000	1.000	0.999	0.996	0.971
140	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.984
150	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.992
160	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.996
170	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997
181†	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
190	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
200	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.996

† Cassegrain focus.

TABLE XII(i)
Beam truncation loss in dB at cryostat window for Band 10 mid frequency 950 GHz.

Distance from mirror 2 (mm.)	Window diameter (mm.) 45	40	35	30	25	20	15	10
80	-0.000	-0.000	-0.001	-0.002	-0.006	-0.030	-0.179	-1.050
90	-0.000	-0.000	-0.001	-0.002	-0.004	-0.019	-0.116	-0.764
100	-0.000	-0.000	-0.001	-0.001	-0.003	-0.012	-0.072	-0.532
110	-0.000	-0.000	-0.000	-0.001	-0.002	-0.008	-0.044	-0.353
120	-0.000	-0.000	-0.000	-0.001	-0.002	-0.005	-0.026	-0.221
130	-0.000	-0.000	-0.000	-0.001	-0.001	-0.003	-0.016	-0.129
140	-0.000	-0.000	-0.000	-0.001	-0.001	-0.002	-0.010	-0.071
150	-0.000	-0.000	-0.000	-0.000	-0.001	-0.002	-0.006	-0.037
160	-0.000	-0.000	-0.000	-0.000	-0.001	-0.002	-0.004	-0.019
170	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.004	-0.011
181†	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.003	-0.009
190	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.004	-0.011
200	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001	-0.004	-0.018

† Cassegrain focus.

11.2 **Physical Optics Analysis** [*This section pending design revision.]

11.2.1 *Beam Profile at Cassegrain Focus*

Figures 13(g) – (j) show the beam profile at the Cassegrain with comparison of results obtained by both quasi-optics and physical optics.

Figure 13(g). Beam profile at Cassegrain focus for Band 10 mid frequency 868 GHz.

11.2.2 *Beam Profile at Subreflector & Edge Taper*

11.2.3 *Far Field Radiation Pattern*

11.2.4 *Beam & Cross-Polar Efficiencies*

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[2] Paul F Goldsmith, *Quasioptical Systems; Gaussian Beam, Quasioptical Propagation and Applications*, IEEE Press, New York, NY.