US Radio/Millimeter/Submillimeter Science Features II
Baltimore, August 3-5, 2016

TELESCOPE OPTICS DESIGN

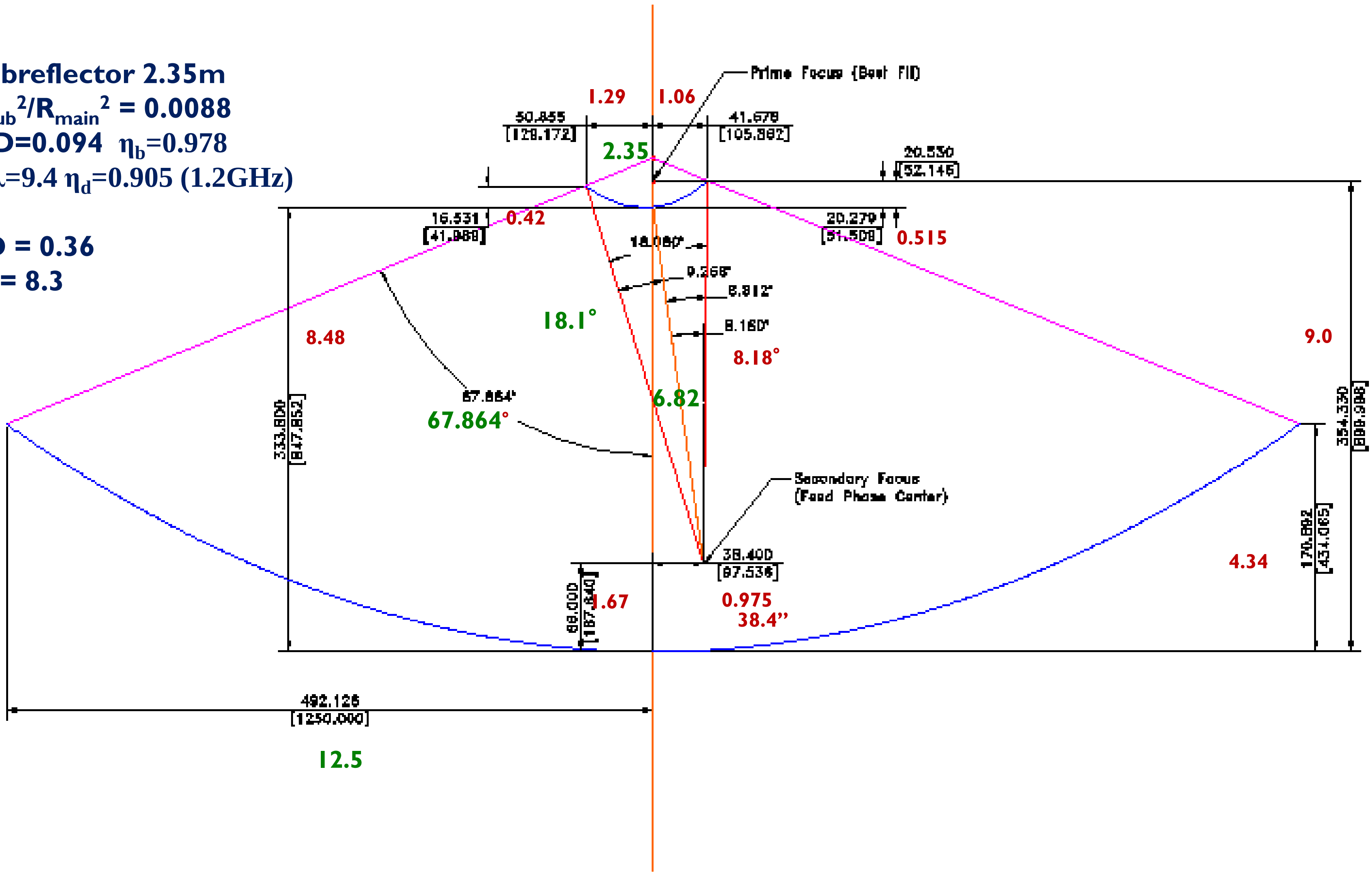
Parameters and Options

Sivasankaran Srikanth, CDL, NRAO Charlottesville

VLA ANTENNA GEOMETRY

Subreflector 2.35m
$R_{sub}^2/R_{main}^2 = 0.0088$
d/D=0.094 η_b=0.978
d/λ=9.4 η_d=0.905 (1.2GHz)

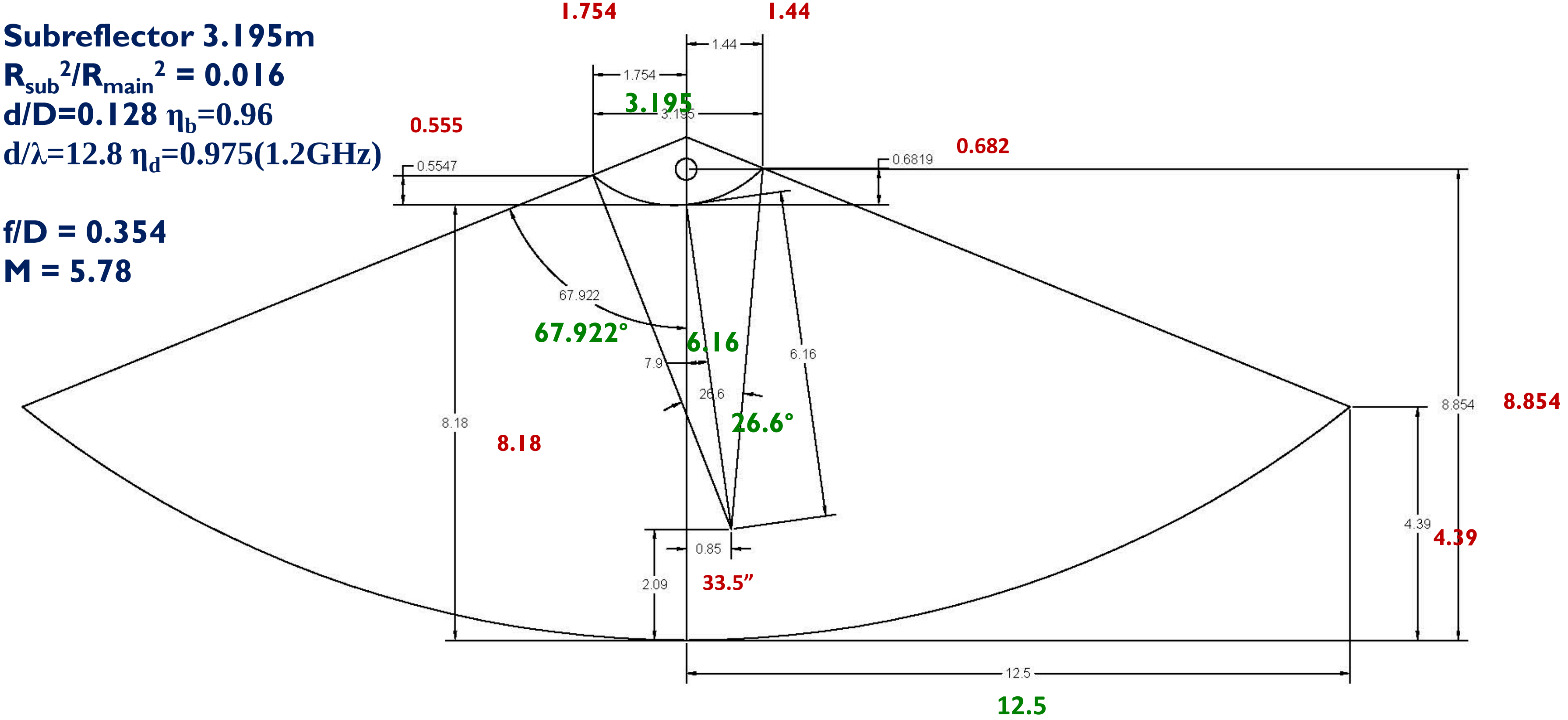
f/D = 0.36
M = 8.3



VLBA ANTENNA GEOMETRY

Subreflector 3.195m
R_{sub}^2/R_{main}^2 = 0.016
d/D=0.128 η_b=0.96
d/λ=12.8 η_d=0.975(1.2GHz)

f/D = 0.354
M = 5.78

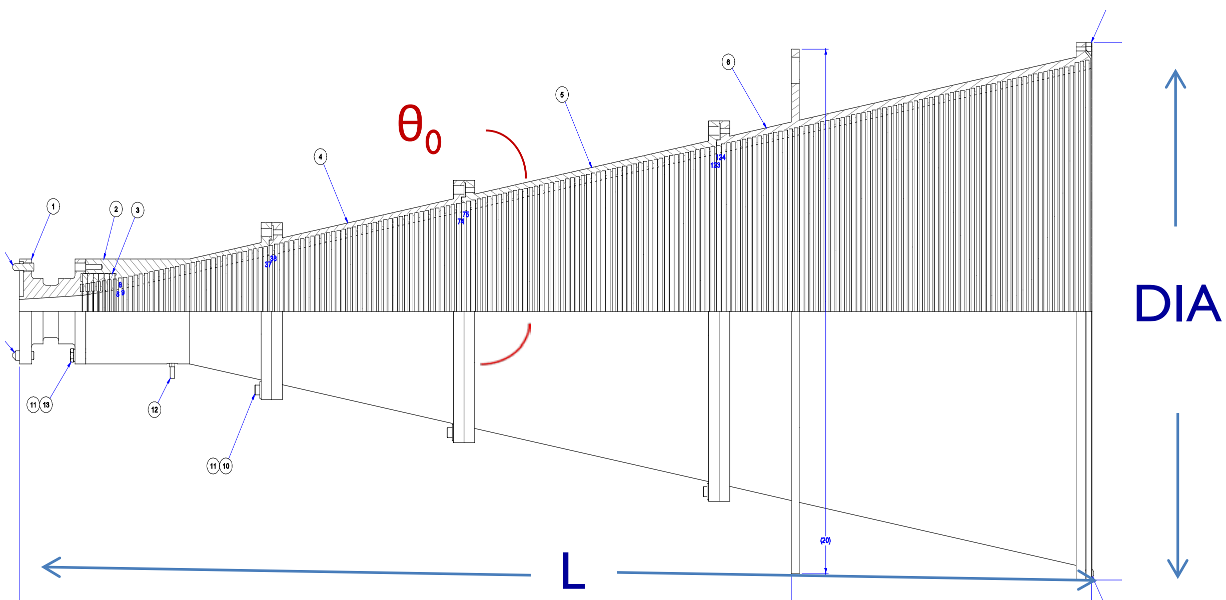


CASSEGRAIN TELESCOPE DESIGN PARAMETERS

	DIA Main	F $_{Main}$	Θ_{main} °	Ecc	F_{hyp}	MAG	Θ_{sub} °	DIA Sub	FI
VLAeq	25.0	9.2897	67.864	1.2734	7.691	8.3164	9.250	2.350	6.865
				1.2900	7.691	7.8966	9.7397	2.468	6.827
VLAeq	25.0	9.2897	67.864	1.2734	7.691	8.3164	9.250	2.350	6.865
				1.2734	7.500	8.3164	9.250	2.291	6.695
VLBAeq	25.0	9.2796	67.922	1.4179	7.416	5.7857	13.25	3.195	6.323

LINEAR TAPER CORRUGATED HORN

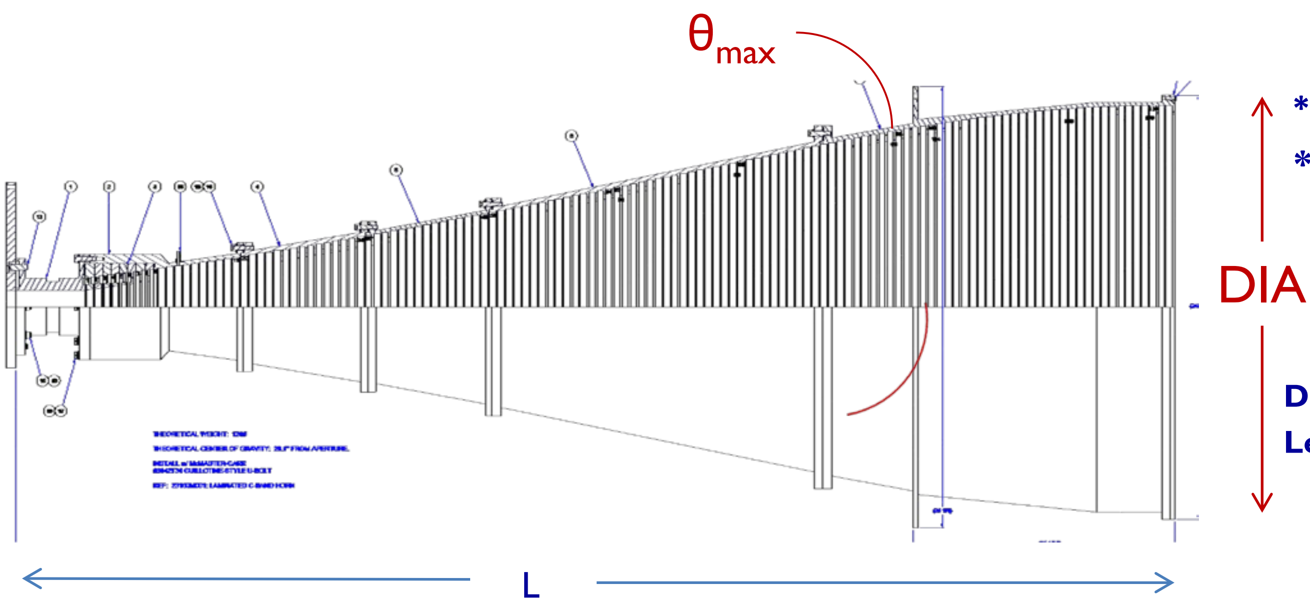
FEED	Freq (GHz)	Taper (dB) @θ_{sub}	θ_0	DIA	DIA/λ *	L/λ *	Taper **
EVLA-Ku	12-18	-14@9.25°	10.5°	12.3”	12.5	33.8	-14.0
VLBA	12-15.4	-14@13.25°	14°	8.0”	8.1	16.2	-14.5
SHAO-Ku	12-18	-15.5@13º	13º	8.5”	8.7	19.3	-15.6



* λ at low end
** Measured (dB)

PROFILE TAPER (COMPACT) CORRUGATED HORN

FEED	Freq (GHz)	Taper (dB) @ θ_{sub}	θ_{max}	DIA	DIA/ λ *	L/λ *	Taper (dB)**	Lin. D/λ
EVLA-C	4-8	-13@9.25°	12.0°	22.0"	7.5	22.3	-12.5	12.2
VLBA-C	4-8	-14@13.25°	15.0°	14.0"	4.7	10.6	-13.7	8.1



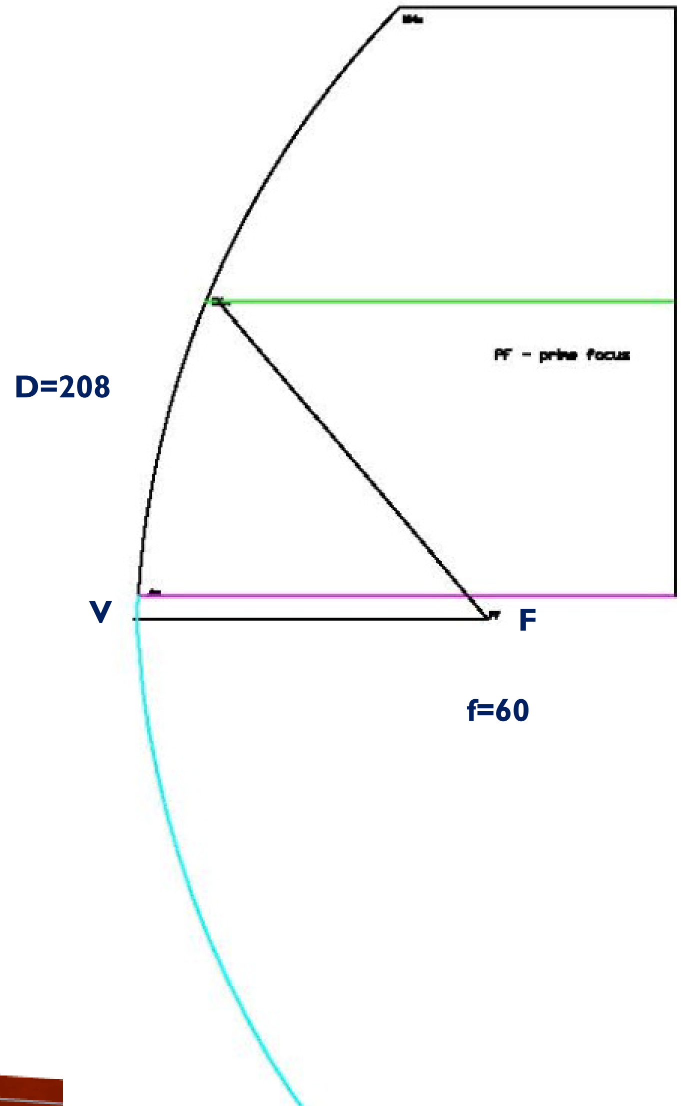
*λ at low end

** Measured (dB)

Diameter 35% smaller

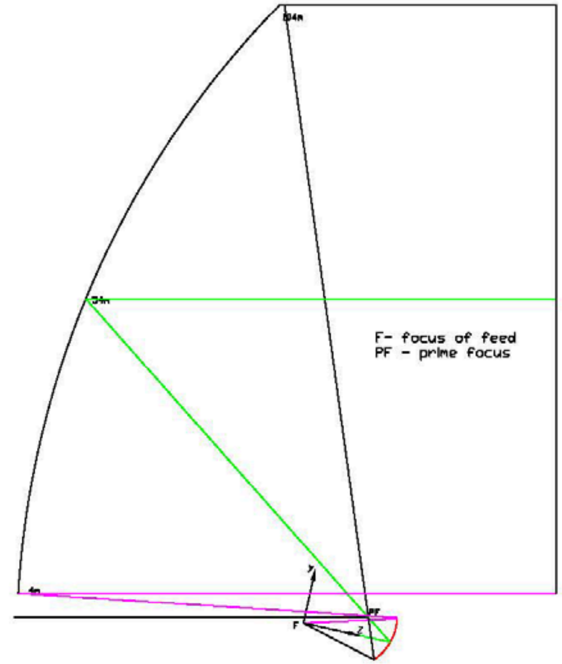
Length 25% less

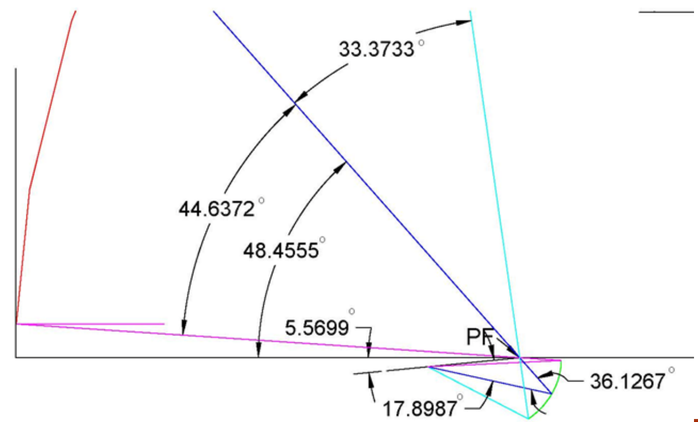
DUAL-OFFSET ANTENNA (GBT)



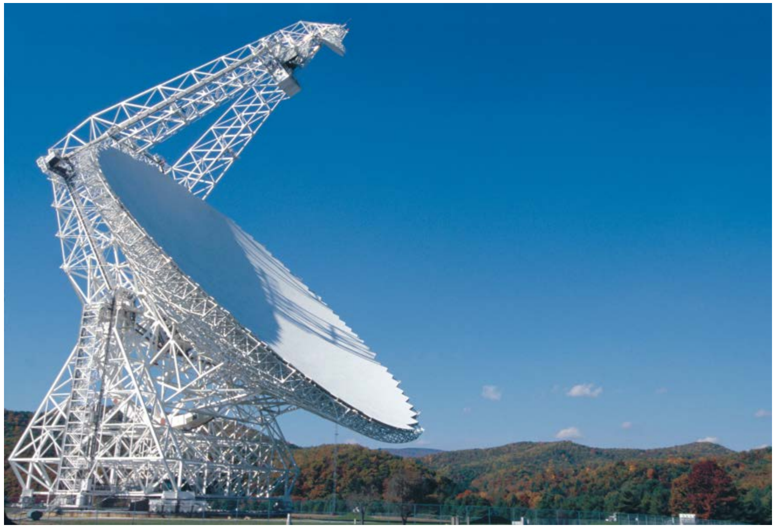
CYLINDER DIA 100
CENTER AT 54

ecc=0.528
Yc=54, f=60
fellip=11
M = 3.17
Sub=7.55x7.95
Fl=15.1





UNBLOCKED APETUTRE Vs SYMMETRIC



ADVANTAGES:

Higher aperture efficiency 5 to 8%

Lower side lobes ~15 dB

Lower $T_{antenna}$ ~3K

Minimized standing waves ~25 dB

Larger real estate

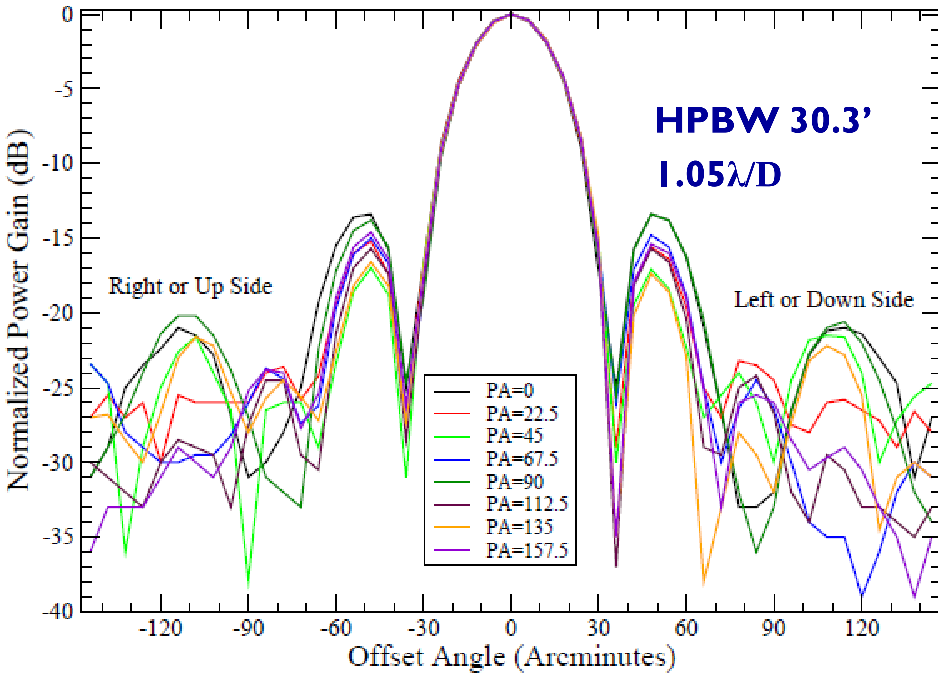
DISADVANTAGES:

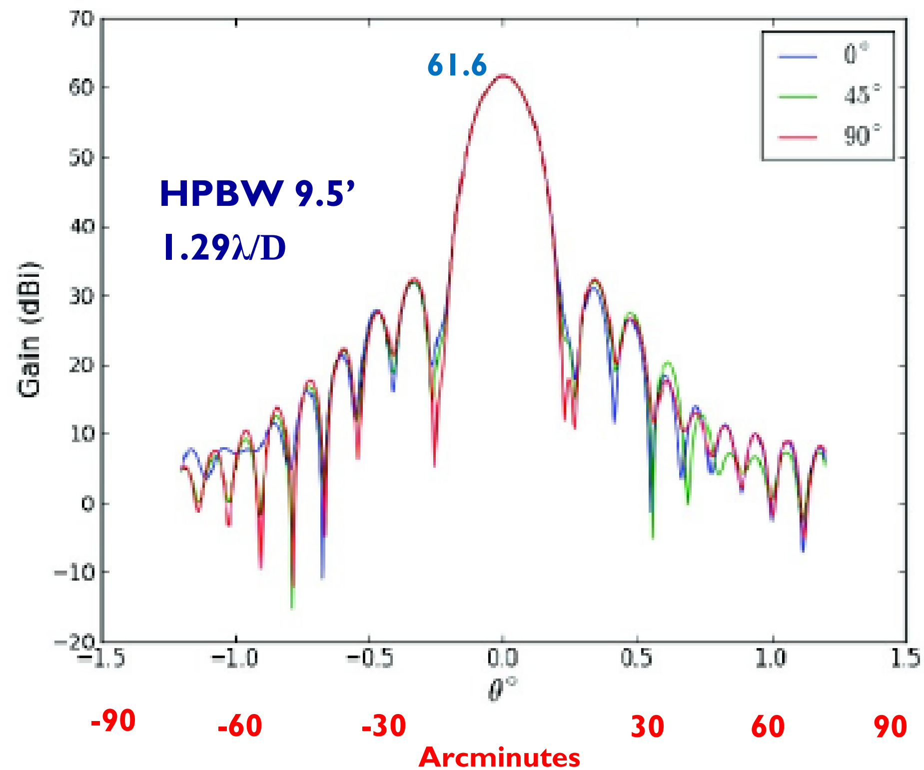
Complex structure

Poorer polarization performance – prime focus

Scanning performance

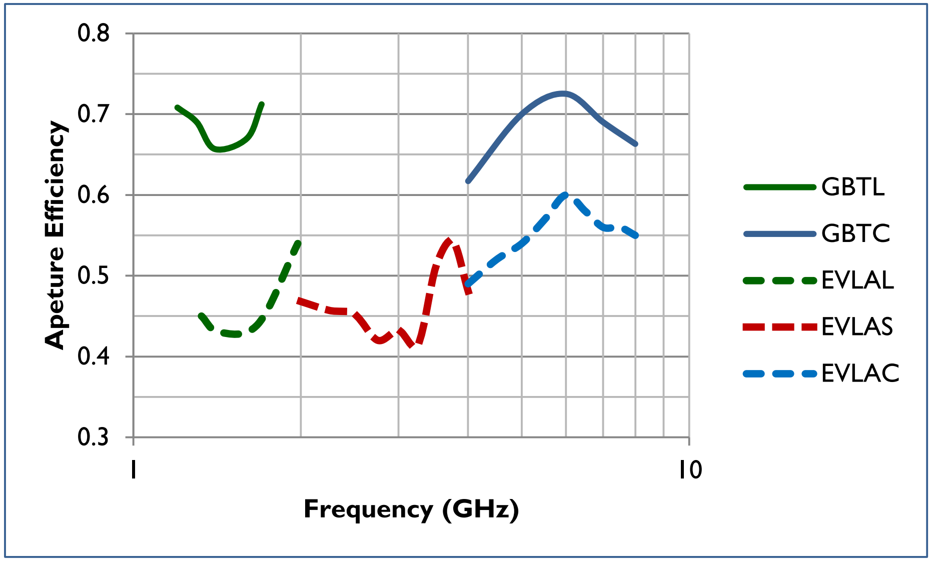
BEAM OF THE EVLA (1.425 GHz) & GBT (1.4 GHz)

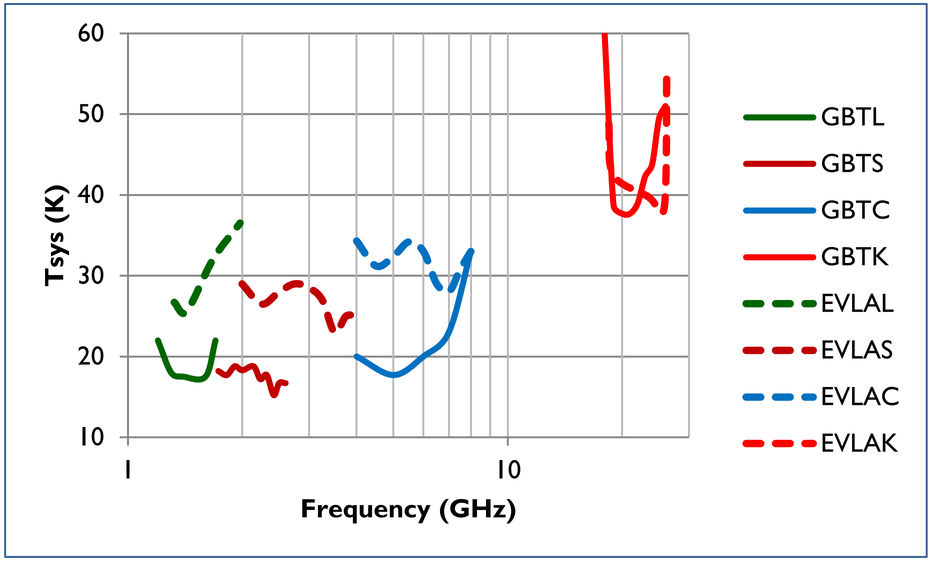




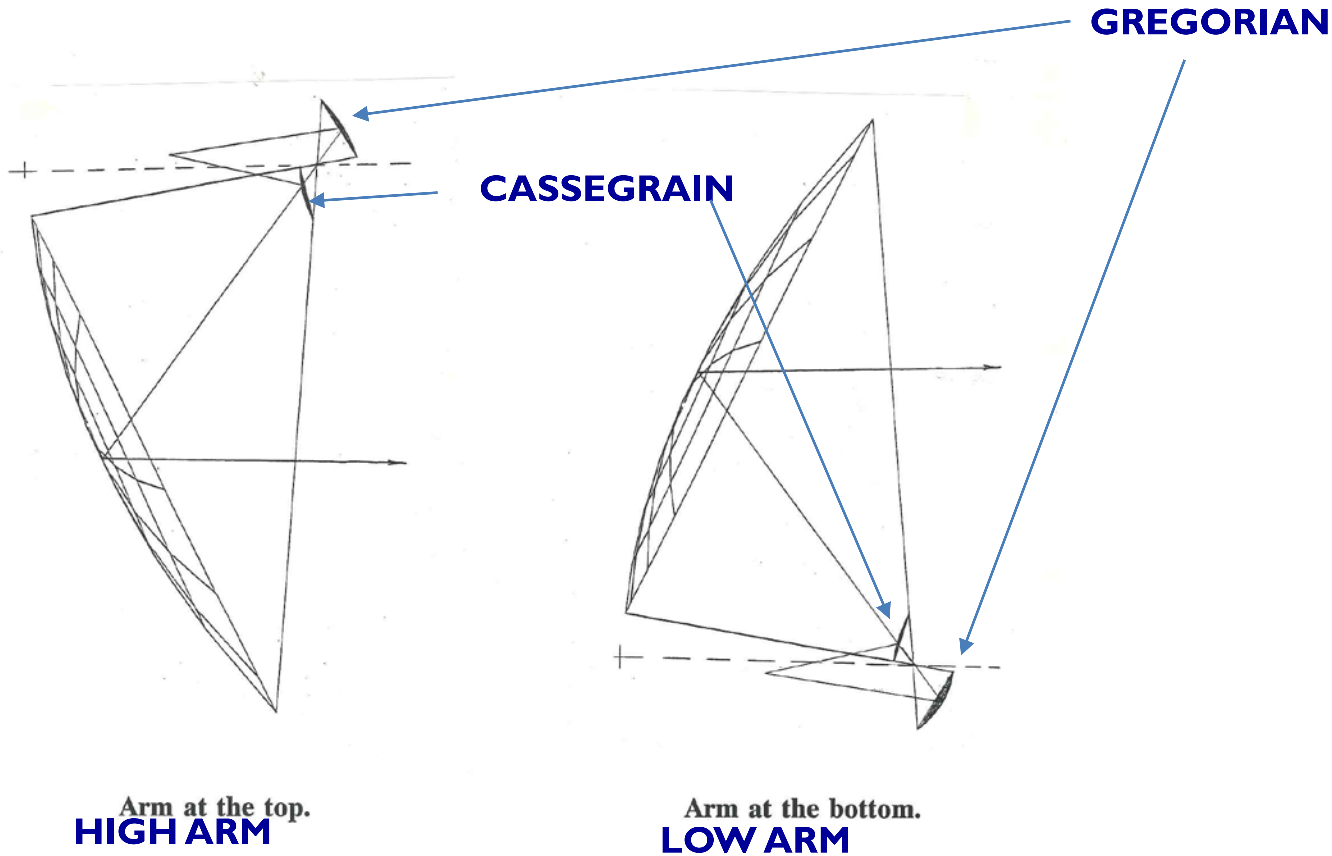
R. Perley et al., "Testing of theEVLA L-Band Feed", EVLA Memo 85

APERTURE η AND SYSTEM TEMPERATURE

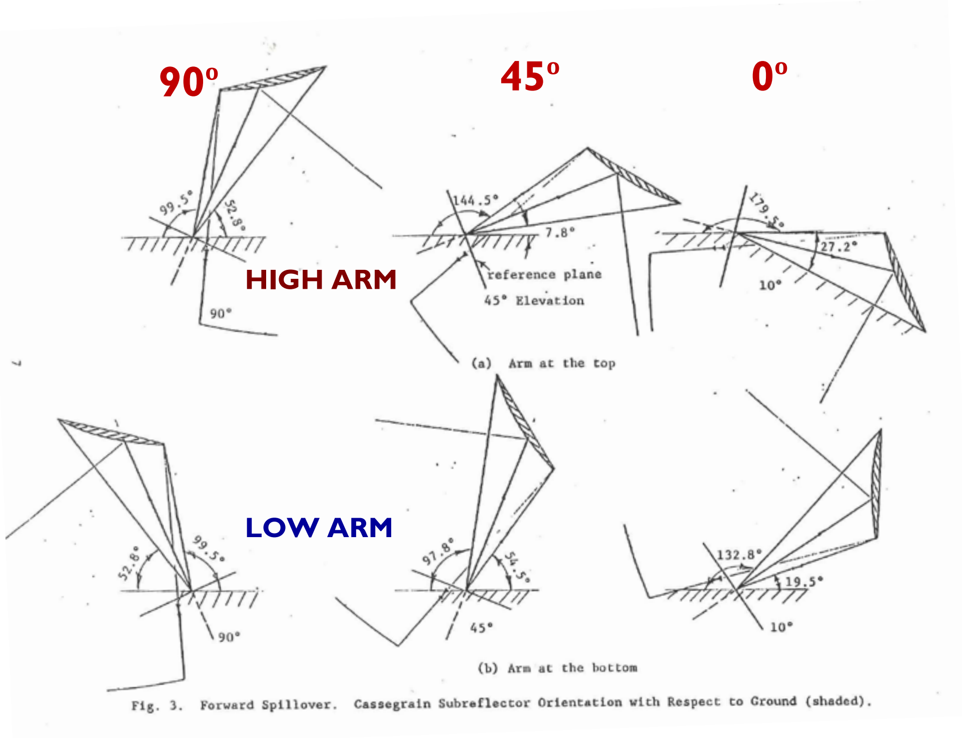


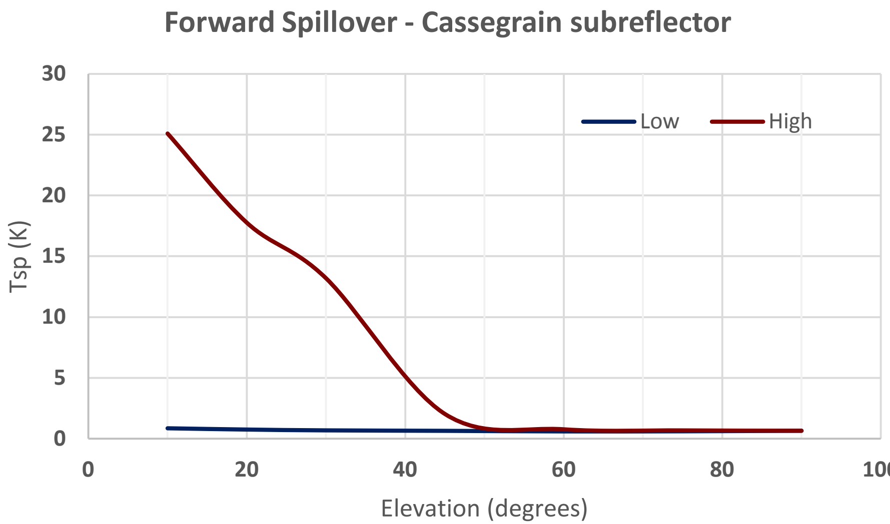


DUAL-OFFSET CASSEGRAIN, GREGORIAN ANTENNA



FORWARD SPILLOVER – CASSEGRAIN SUBRFLECTOR





S. Srikanth, "Spillover noise temperature calculations for the Green Bank clear aperture antenna," GBT Memo #16, October 4, 1989.

1.42 GHz

-12 dB taper

D_{sub}=35λ

Θ_{sub}=14°

FORWARD SPILLOVER – GREGORIAN SUBRFLECTOR

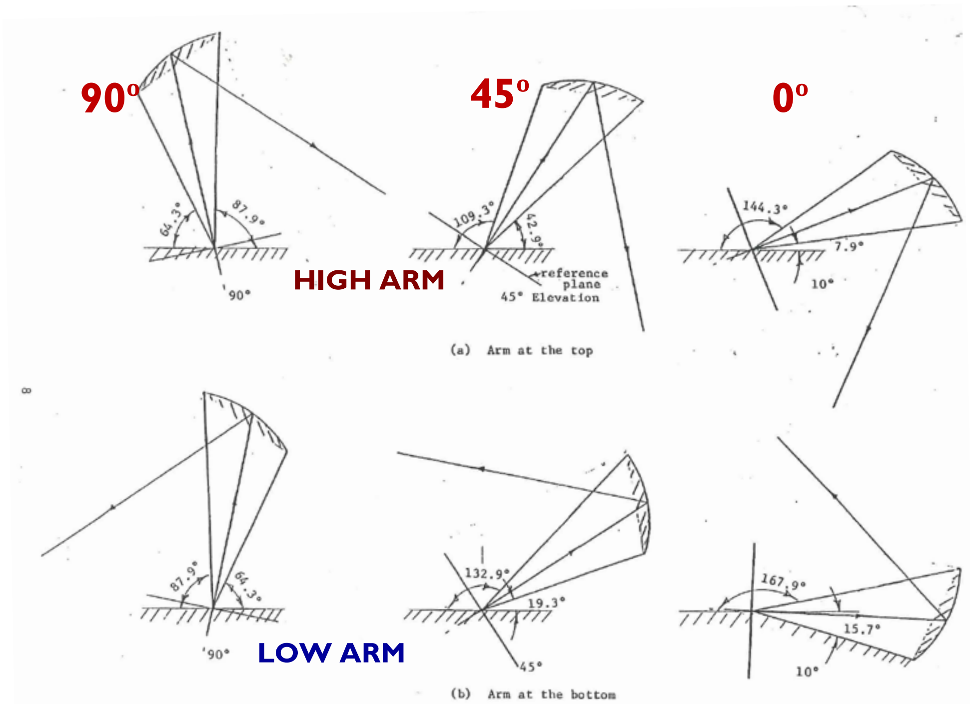
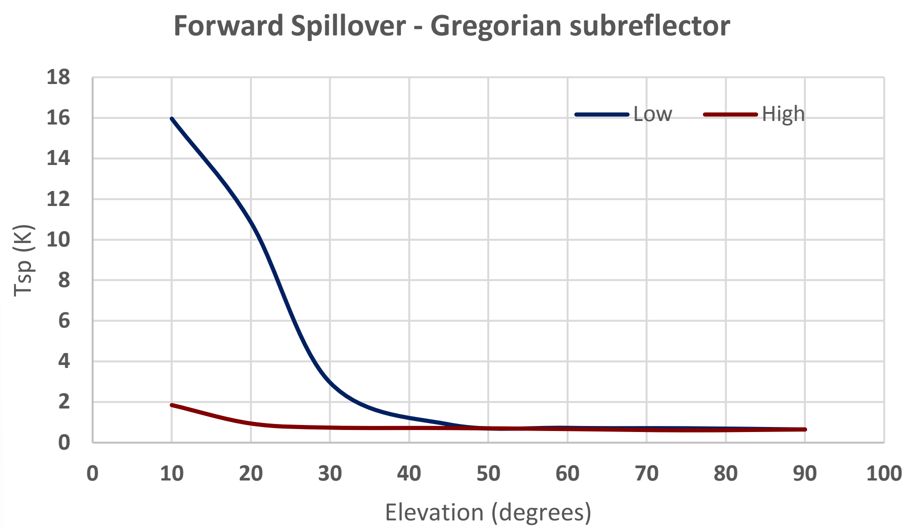


Fig. 4. Forward Spillover. Gregorian Subreflector Orientation with Respect to Ground (shaded).



1.42 GHz

-12 dB taper

D_{sub}=35λ

Θ_{sub}=14°

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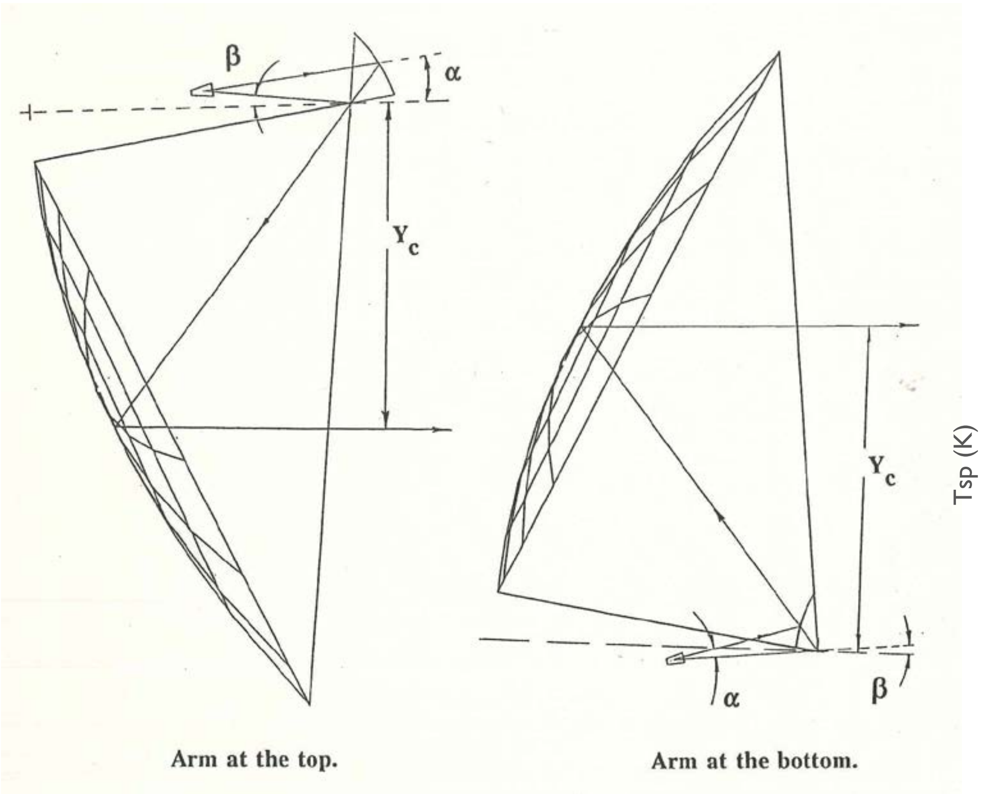
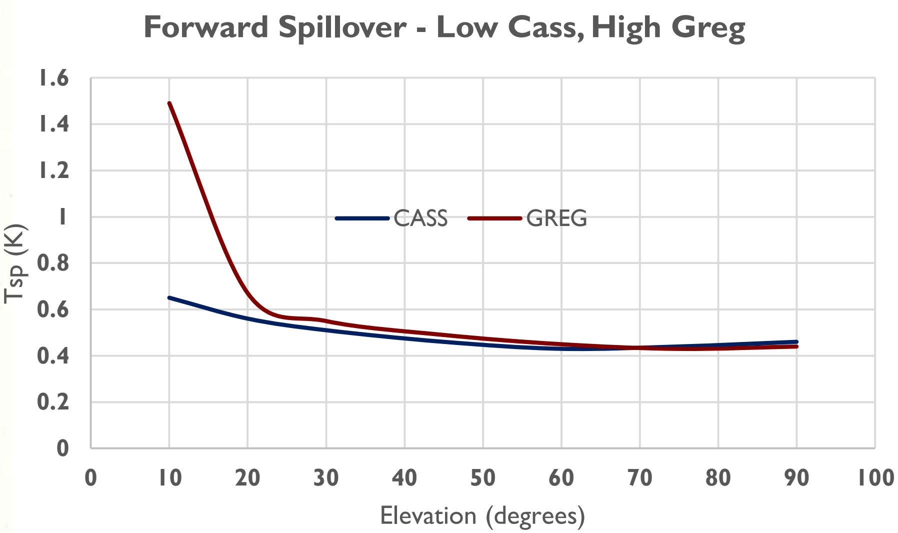
FORWARD SPILLOVER – LOW CASS., HIGH GREG.

	f (m)	Ecc	Yc (m)	α (º)	β (º)	sub (mxm)
GREG	11	0.528	54	17.9	5.57	7.6x7.9
CASS	14	1.894	54	17.9	5.57	6.8X8.7

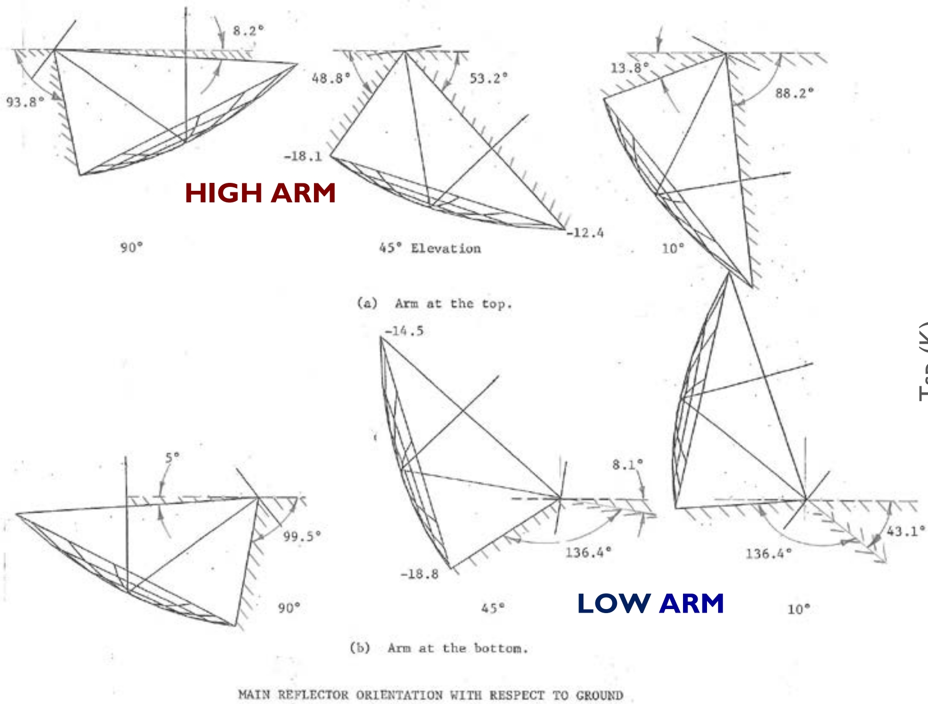


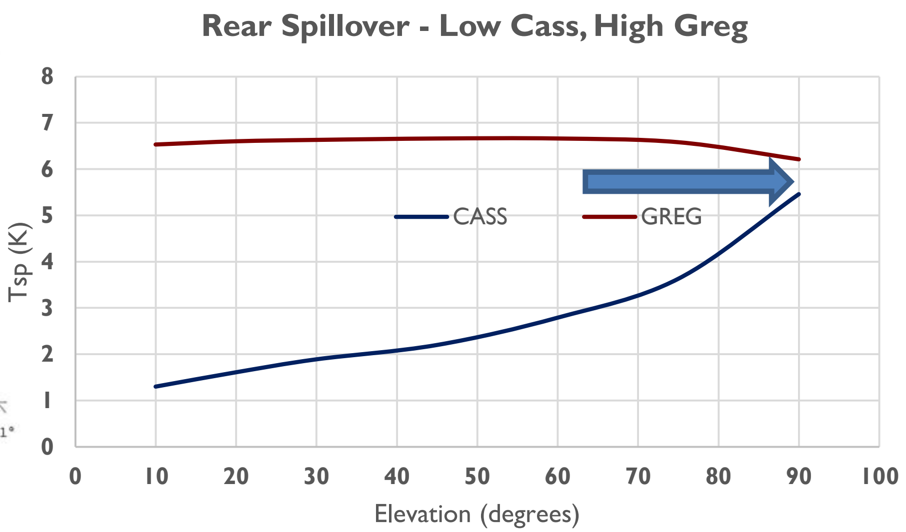
HIGH ARM

LOW ARM

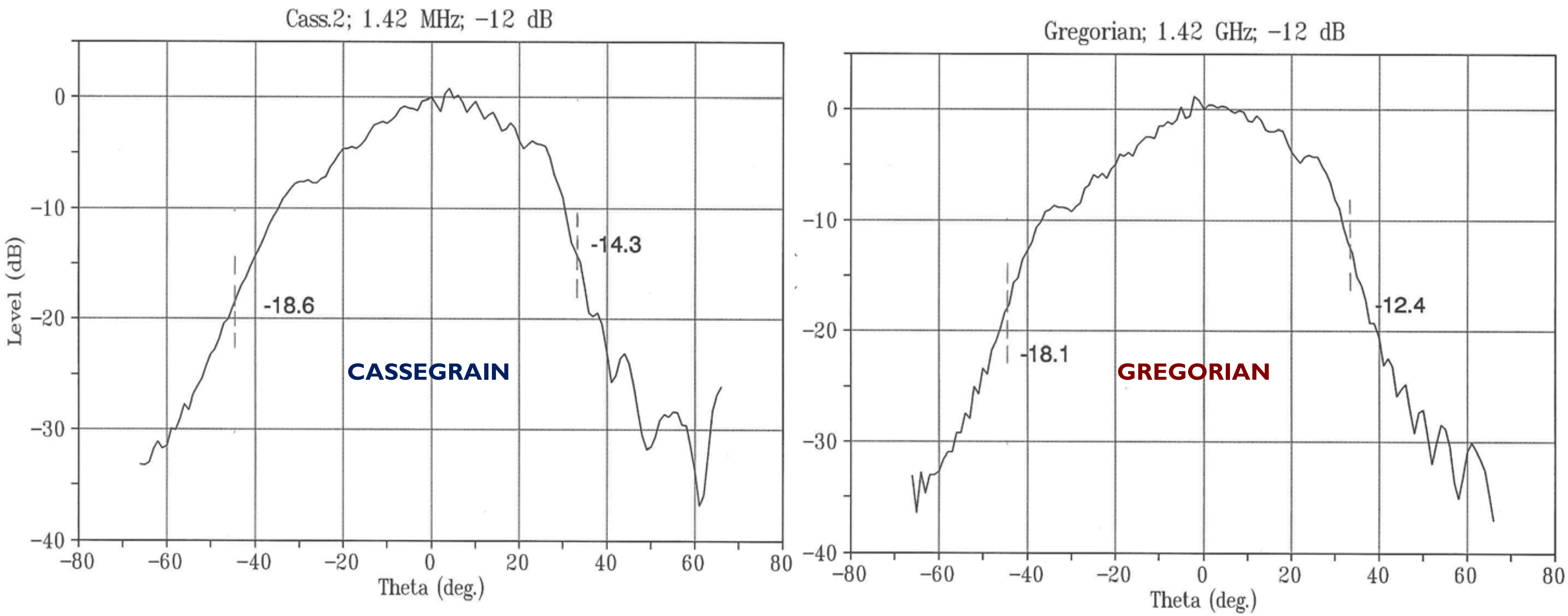


REAR SPILLOVER – LOW CASS., HIGH GREG.





SUBREFLECTOR SCATTERED PATTERN



DIFFRACTION LOSS

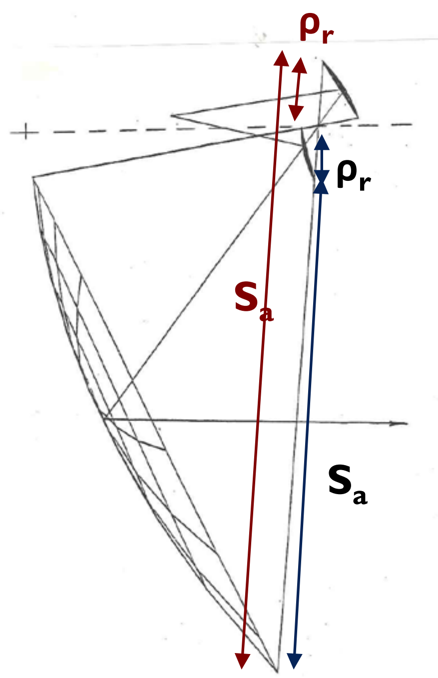
Transition region of edge diffracted field

$$\Delta\rho = \sqrt{\frac{\lambda}{\pi} S_a \left|1 \pm \frac{S_a}{|\rho_r|}\right|}$$

S_a – distance between edges of subreflector and main reflector

ρ_r – subreflector edge to prime focus distanc

$\Delta\rho_{gregorian} > \Delta\rho_{cassegrain}$



Spillover past mainreflector for -10 dB taper

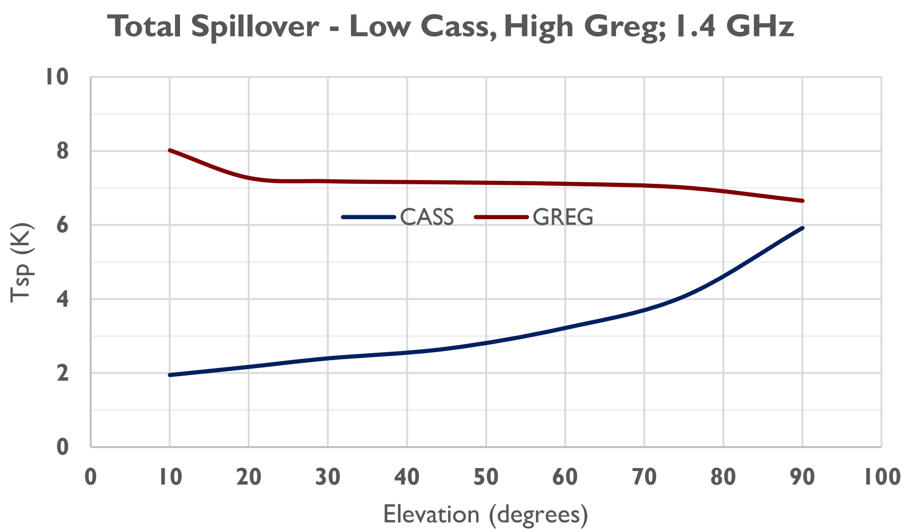
$$\Delta p = 0.09 \frac{\Delta\rho_a}{D}$$

$\Delta\rho_a$ – average of $\Delta\rho$ of the two edges

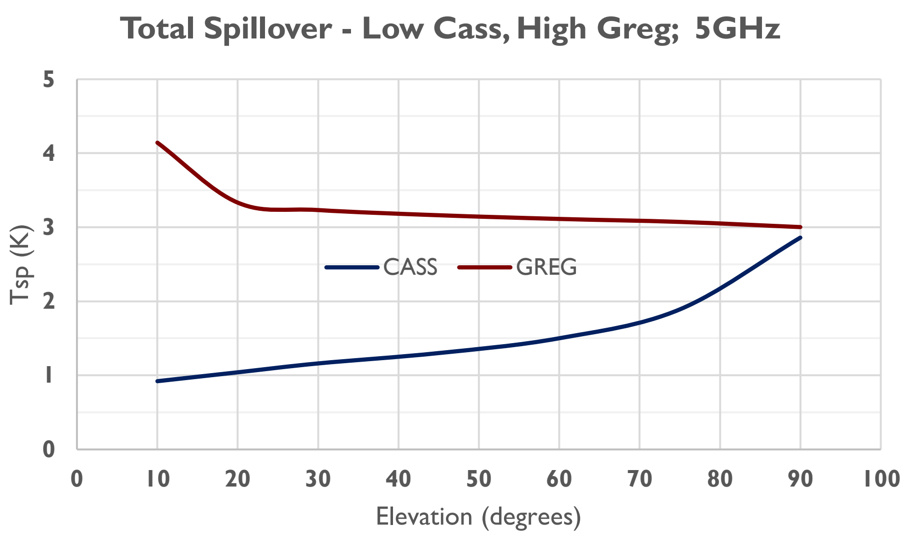
D – diameter of main reflector

1. P. Kildal and J. Stamnes "Asymptotic transition region theory for edge diffraction, Part I and Part II," IEEE Trans. Antennas and Propagation, Sept. 1990. AP-S Digest pp. 1350-1373
2. Private commn. P. Kildal Sept. 19, 1990.

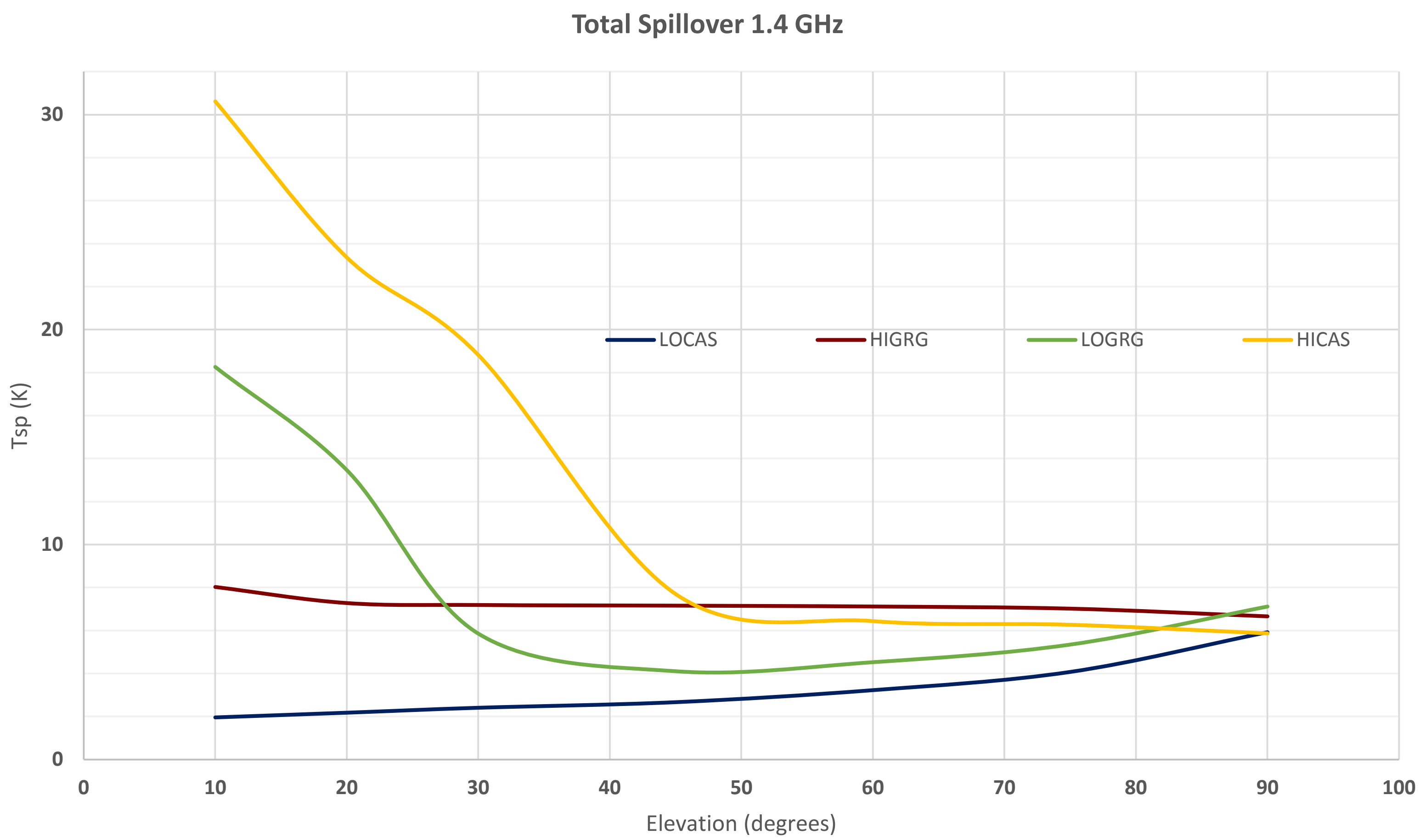
TOTAL SPILLOVER – LOW CASS., HIGH GREG.



S. Srikanth, "Comparison of Spillover loss of Offset Gregorian and Cassegrain Antennas," IEEE/AP-S Symposium , London, ON, 1991. AP-S Digest pp. 444-447



TOTAL SPILLOVER



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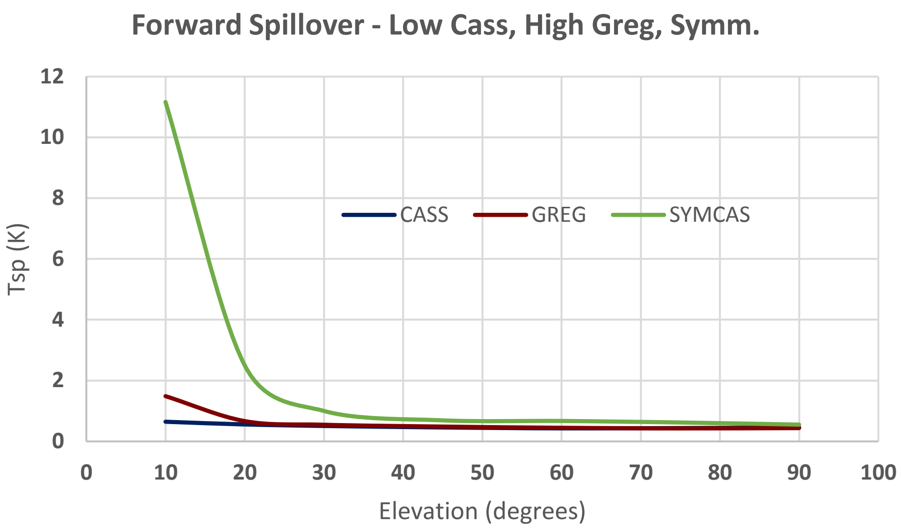
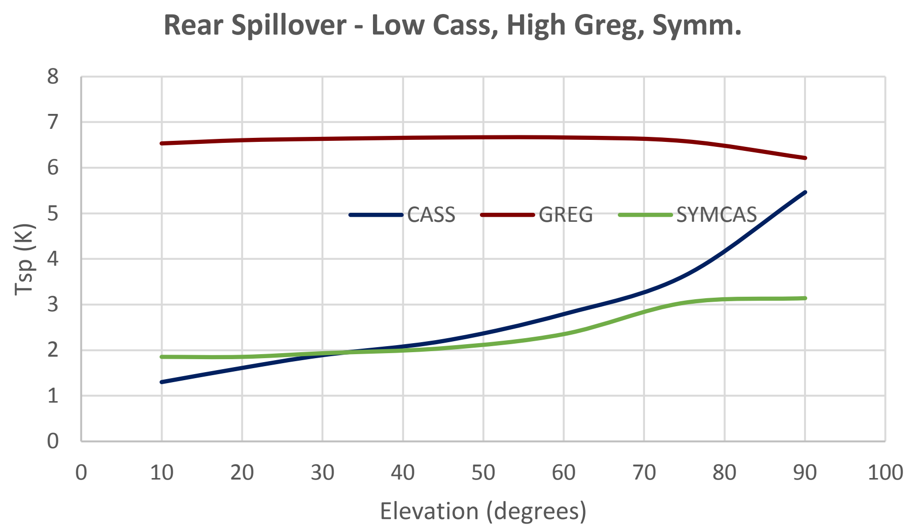
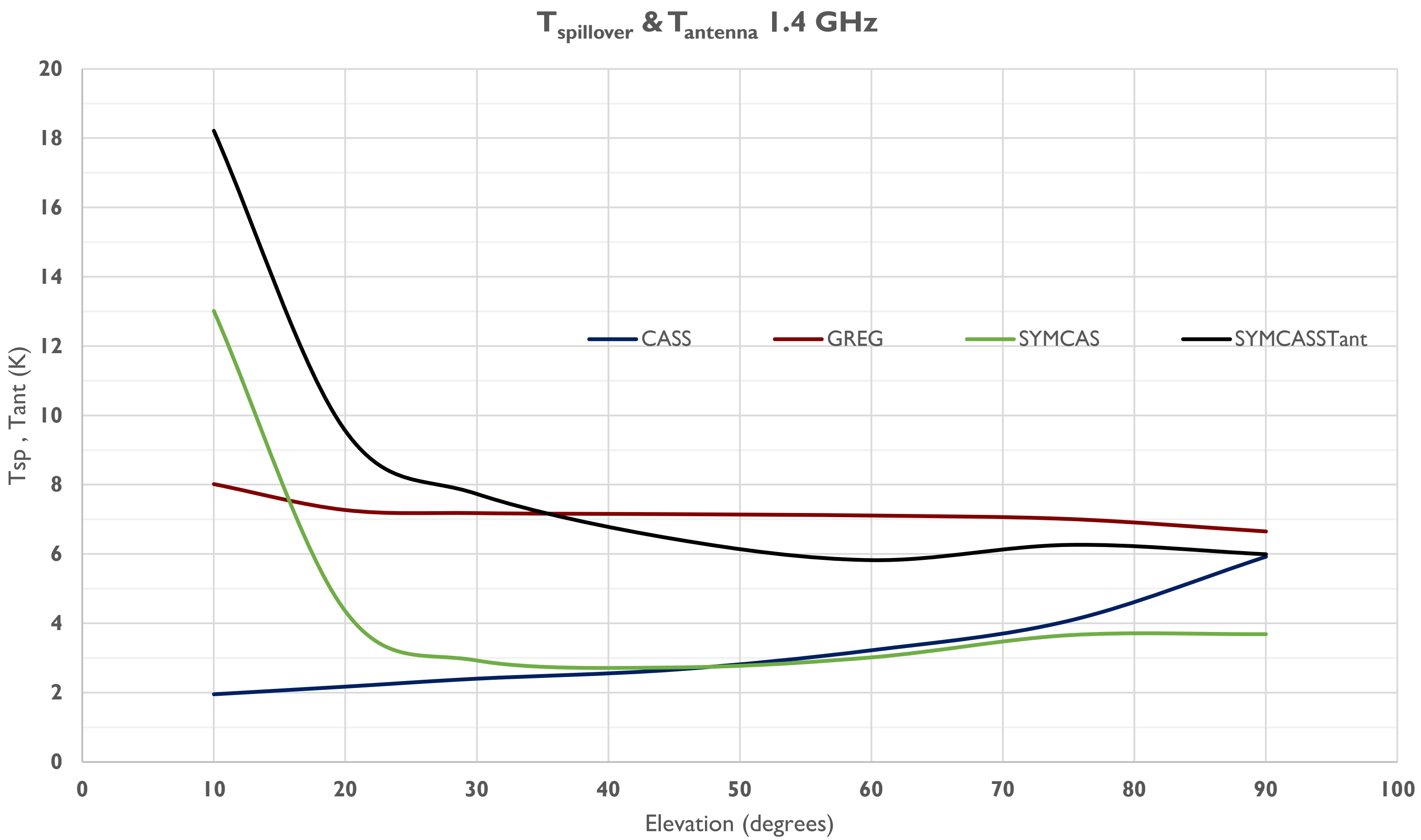
FORWARD, REAR SPILLOVER





TOTAL SPILLOVER, ANTENNA TEMPERATURE



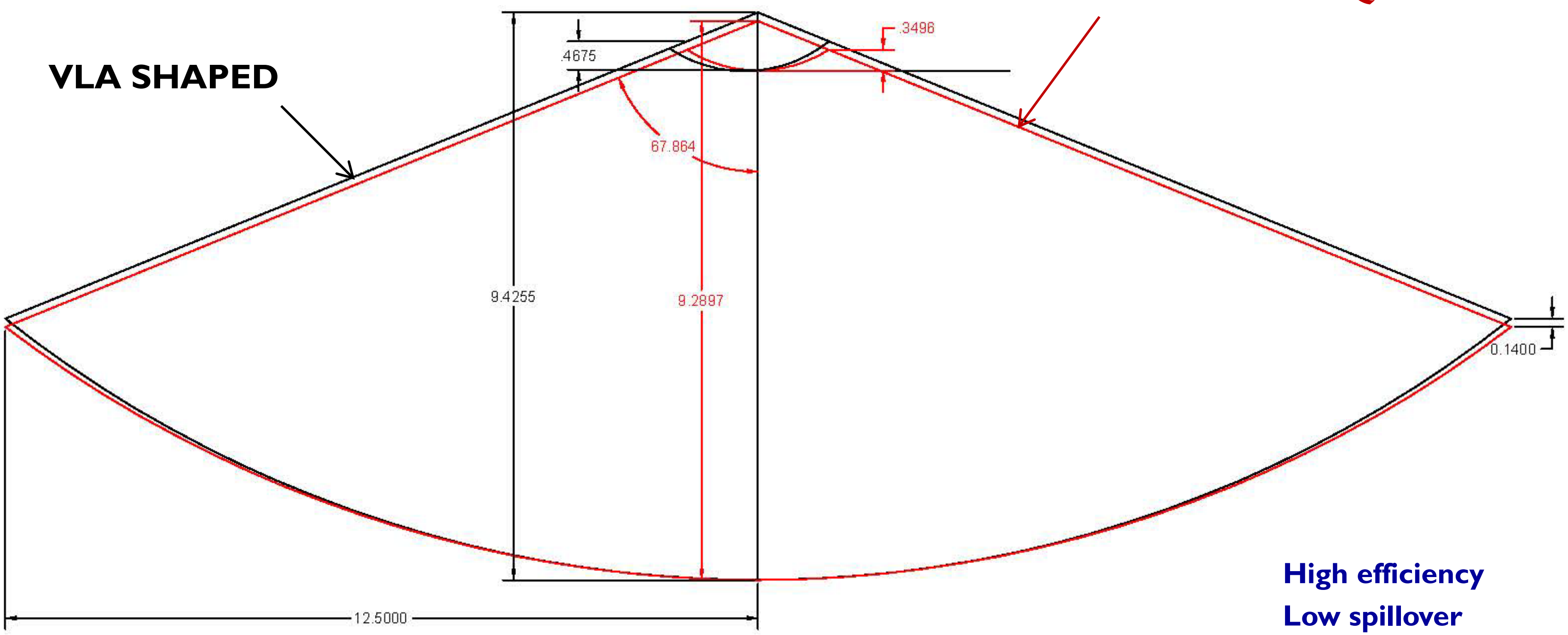
CASSEGRAIN EQUIVALENT & VLA SHAPED

CASSEGRAIN DEPTH 34.9 cms

SHAPED DEPTH 46.7 cms

CASSEGRAIN EQUIVALENT

VLA SHAPED



PARABOLA DEPTH 420 cms

SHAPED DEPTH 434 cms

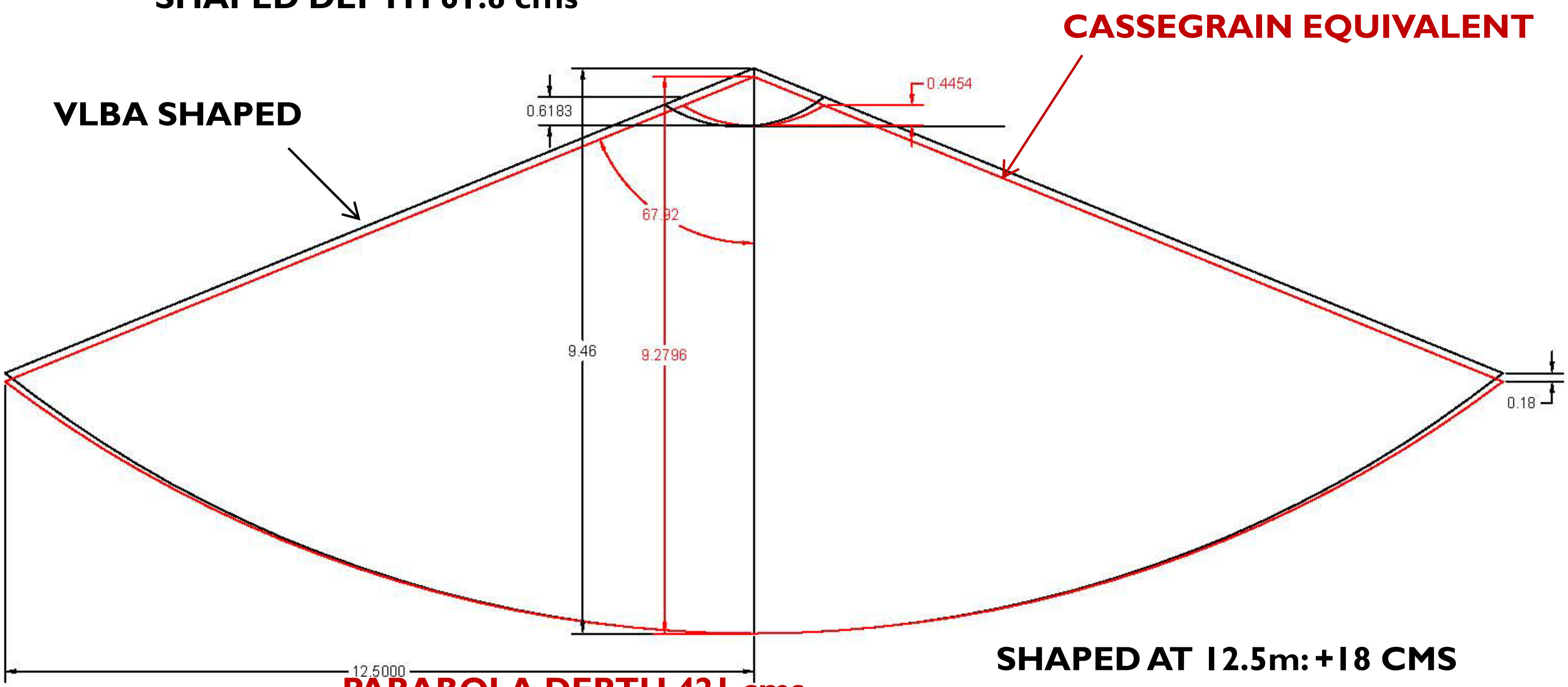
High efficiency

Low spillover

Uniform distribution

CASSEGRAIN EQUIVALENT & VLBA SHAPED

CASSEGRAIN DEPTH 44.5 cms
SHAPED DEPTH 61.8 cms

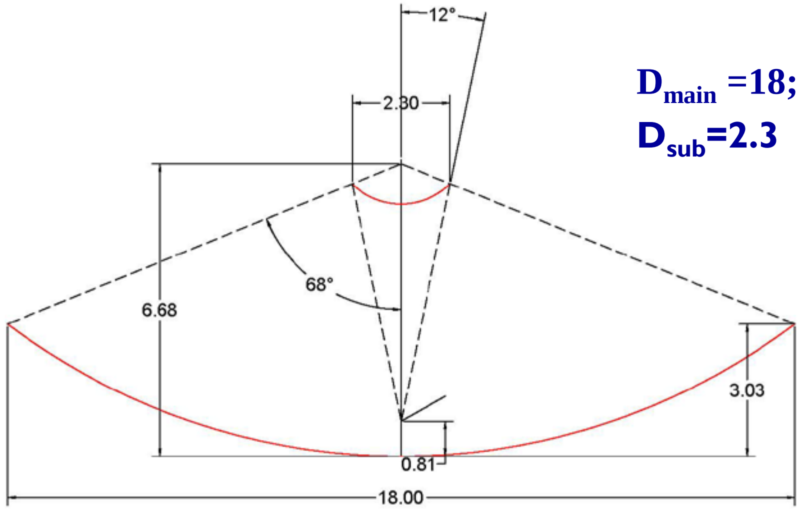


PARABOLA DEPTH 421 cms
SHAPED DEPTH 439 cms

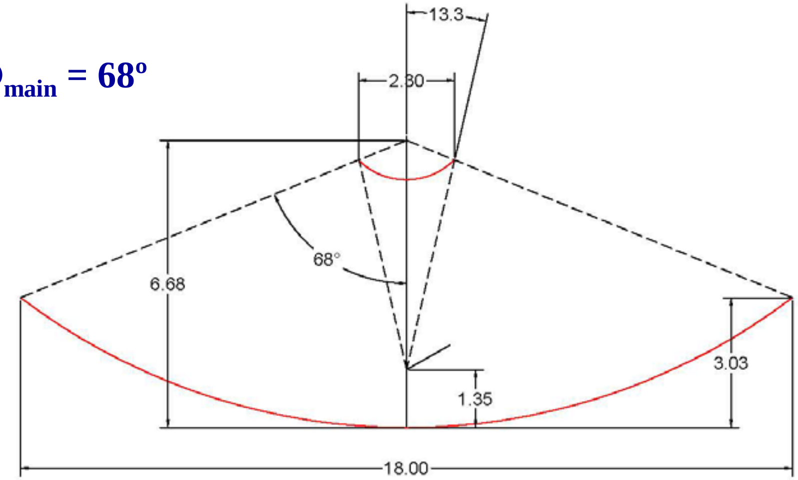
SHAPED AT 12.5m: +18 CMS
AT 9.1m: -17 CMS

ngVLA ANTENNA OPTICS OPTIONS

D_{main} =18; f=6.68 Θ_{main} = 68°
D_{sub}=2.3

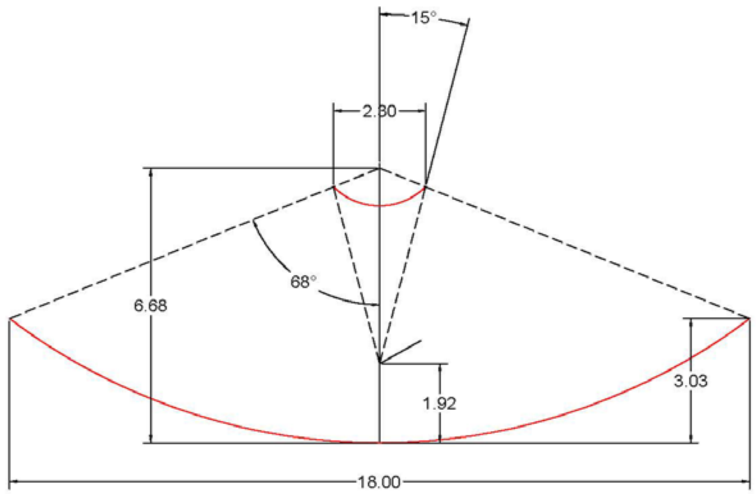


Θ_{sub} = 12°; Ecc=1.369
Hyb f = 5.876
Fl = 5.083



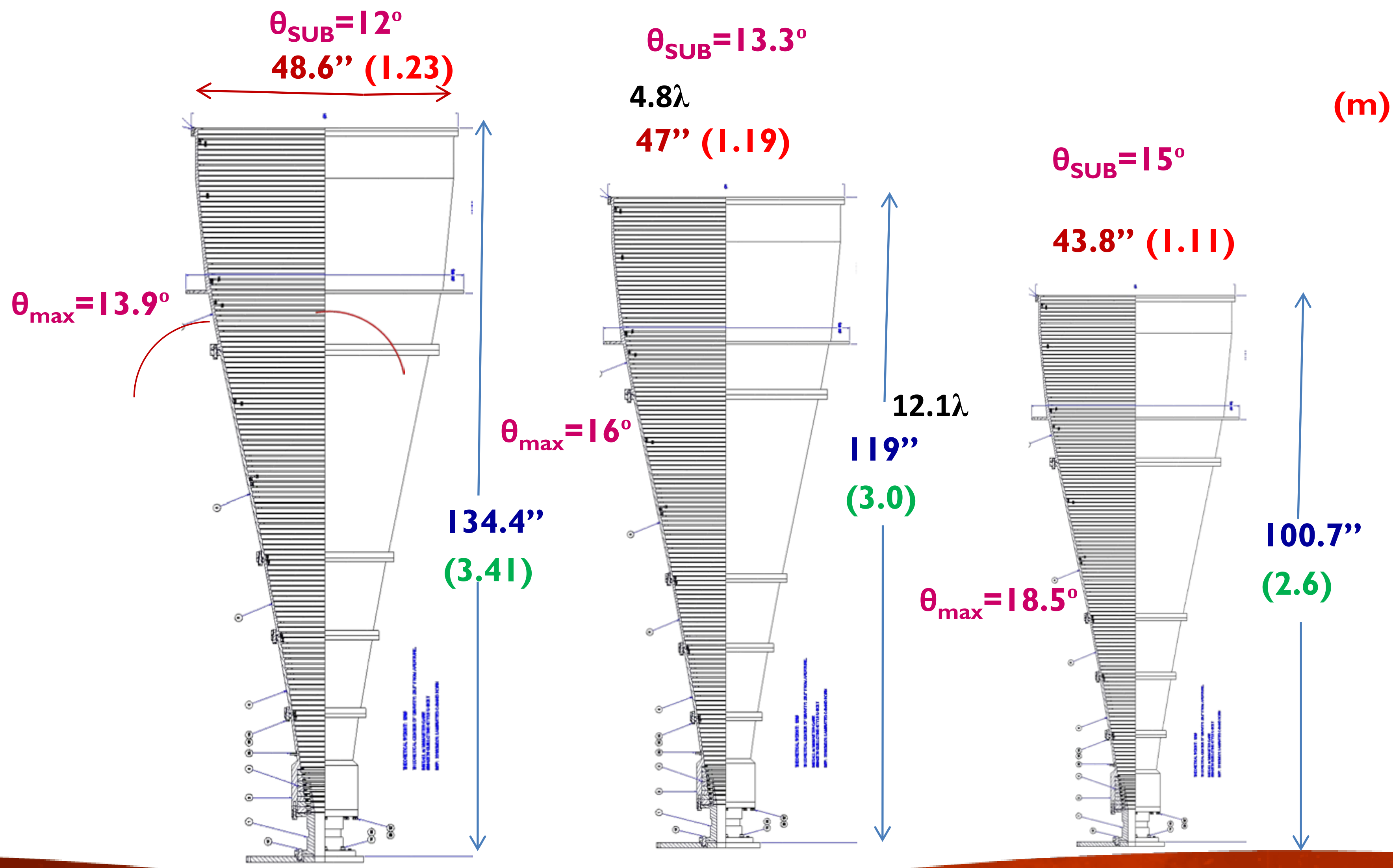
Θ_{sub}=13.3°; Ecc=1.418
Hyb f = 5.332
Fl = 4.545

$$\frac{{R_{sub}}^2}{{R_{main}}^2} = 0.016$$

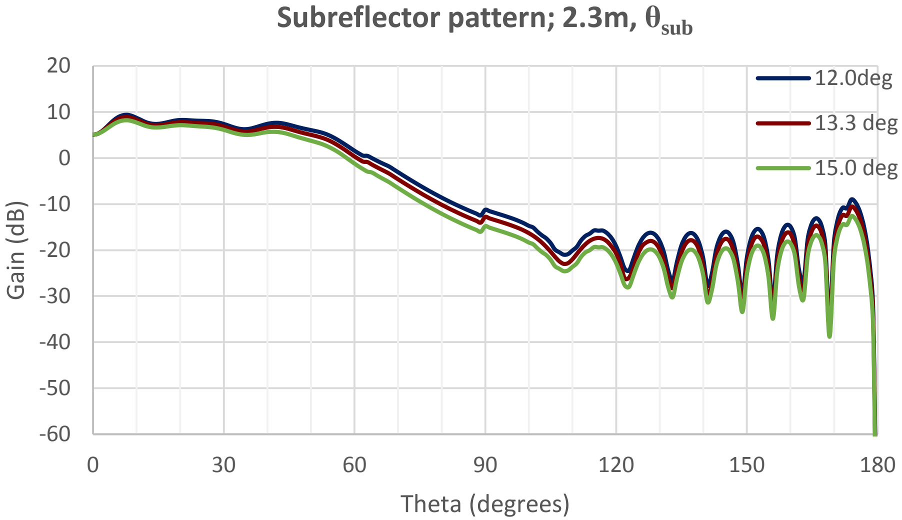


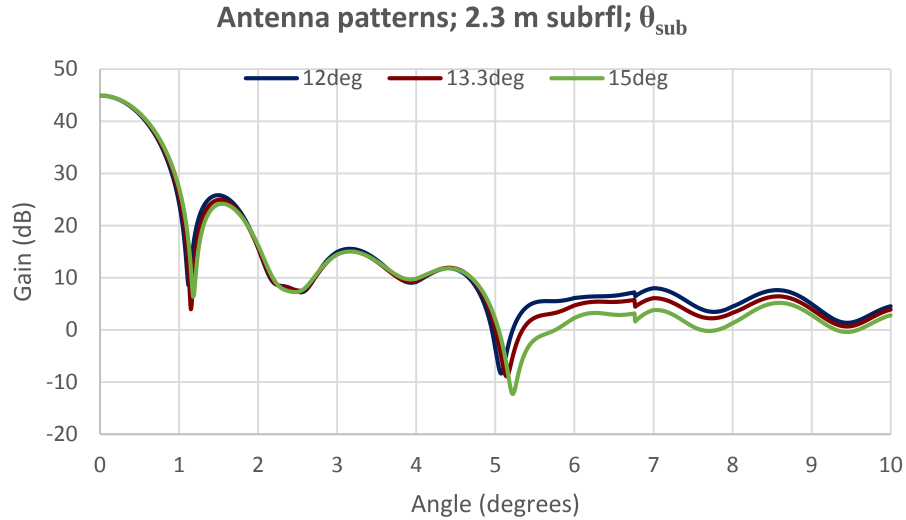
Θ_{sub} = 15°; Ecc=1.486
Hyb f = 4.758
Fl = 3.980

COMPACT FEED HORNS – 2.3m SUBREFLECTOR



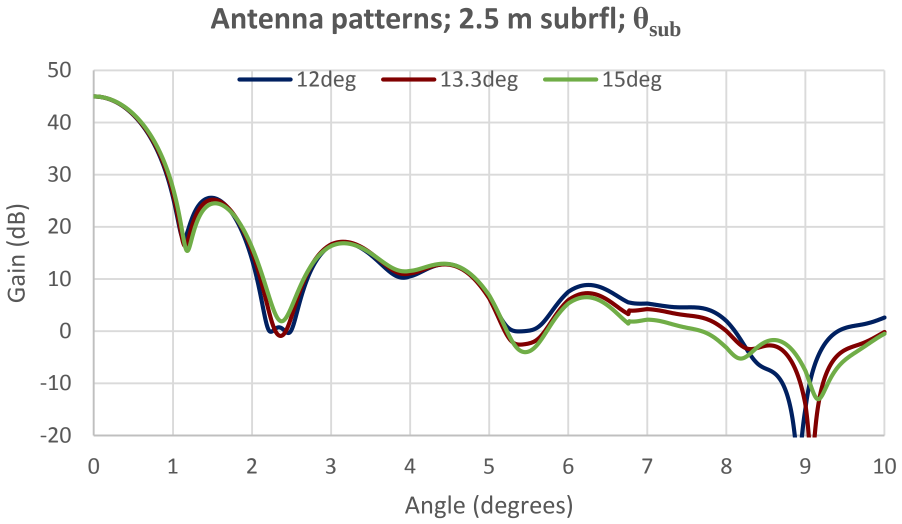
ANTENNA BEAM PATTERNS – 2.3m SUBREFLECTOR





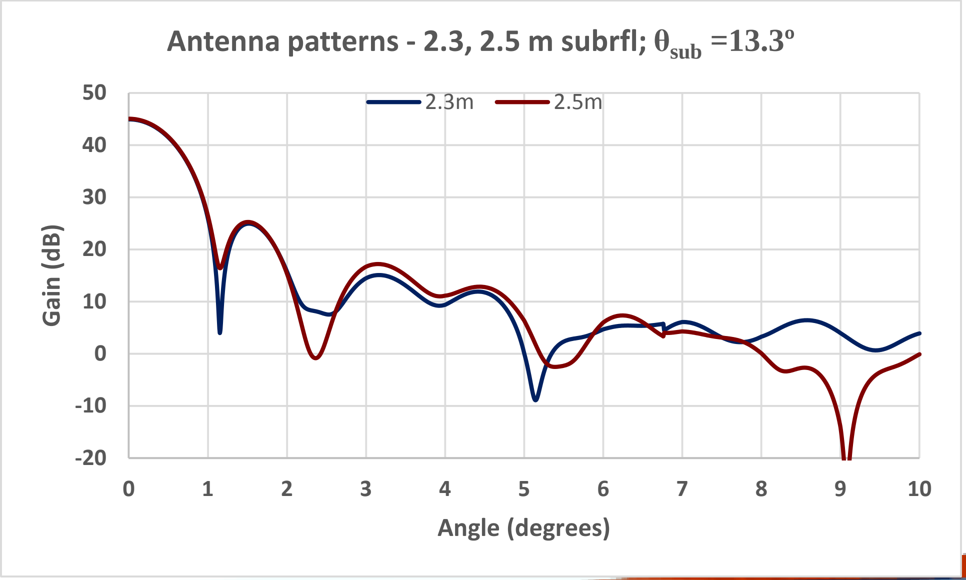
	12°	13.3°	15°
$\eta_{ill} * \eta_{sp}$	0.7435	0.7389	0.7253
η_{block}	0.9600	0.9600	0.9600
η_{diff}	0.9018	0.9018	0.9018
η_{ap}	0.6437	0.6389	0.6279

ANTENNA BEAM PATTERNS



	12°	13.3°	15°
$\eta_{ill} * \eta_{sp}$	0.7525	0.7452	0.7312
η_{block}	0.9553	0.9553	0.9553
η_{diff}	0.9093	0.9093	0.9093
η_{ap}	0.6537	0.6473	0.6352
η_{ap} 2.3m	0.6437	0.6389	0.6279

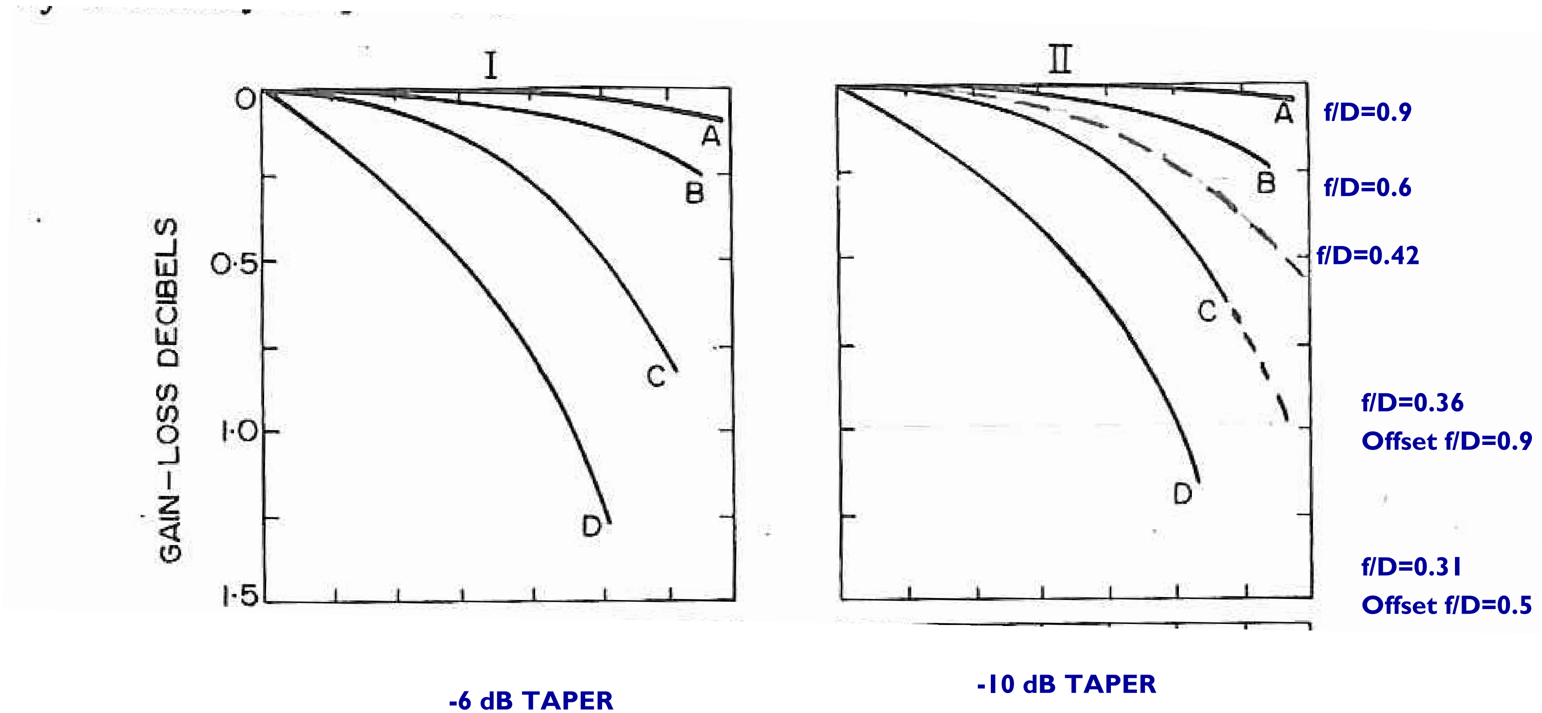
$$\frac{R_{sub}{}^2}{R_{main}{}^2} = 0.019$$



CASSEGRAIN TELESCOPE DESIGN PARAMETERS

	DIA Main	F Main	Θ_{main} °	Ecc	F_{hyp}	MAG	Θ_{sub} °	DIA Sub	FI
VLAeq	25.0	9.2897	67.864	1.2734	7.691	8.3164	9.250	2.350	6.865
				1.2600	7.691	8.6923	8.8518	2.253	6.897
				1.2900	7.691	7.8966	9.7397	2.468	6.827
VLAeq	25.0	9.2897	67.864	1.2734	7.691	8.3164	9.250	2.350	6.865
				1.2734	7.500	8.3164	9.250	2.291	6.695
				1.2734	7.900	8.3164	9.250	2.413	7.052

SCANNING LOSS, COMA LOBE VS. HPBW



DIFFRACTION LOSS

DIFFRACTION LOSSES

It has been stated that the losses and ground noise due to subreflector diffraction is larger in Gregorian than in Cassegrain antennas. This effect can be studied very easily in an approximate way by the method in [1].

The incident field on the main reflector can be considered as the sum of a GO field and an edge diffracted field. The edge diffracted field provides a transition region around the GO boundary, causing a finite slope of the total field. The lateral extent of the transition region is in the symmetry plane, according to [1, Part 1, Eq. (35)],

$$\Delta\rho = \sqrt{\frac{\lambda}{\pi} S_a \left| 1 \pm \frac{S_a}{|\rho_r|} \right|} \qquad (1)$$

where the upper sign is valid for the Gregorian and the lower for the Cassegrain, S_a is the spacing between corresponding reflector edges, and $|\rho_r|$ is the spacing between the subreflector edge and the primary focus (see figure). Normally, $|\rho_r|$ will have about the same size in both Cassegrain and Gregorian antennas with the same main and subreflector diameters, whereas S_a is slightly larger for the Gregorian case (see figure). Therefore,

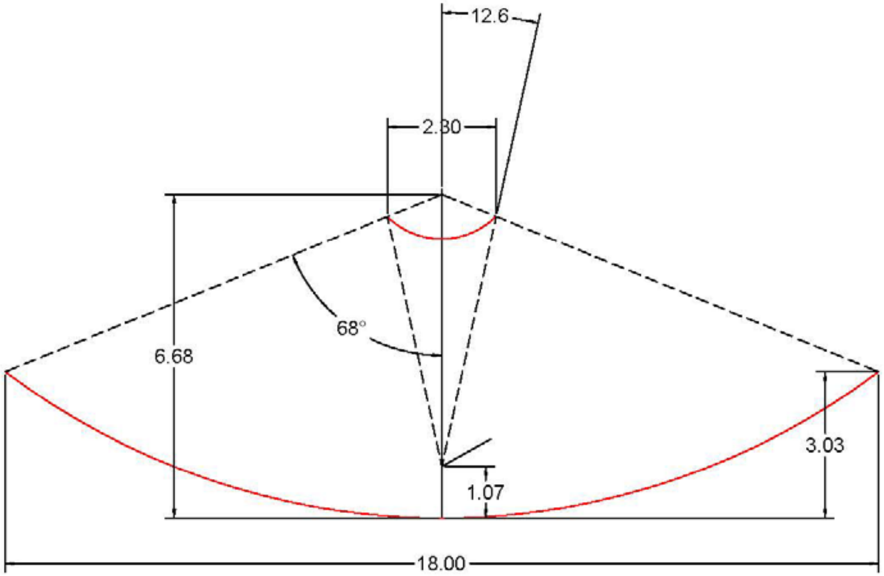
$$\Delta\rho_{Gregorian} > \Delta\rho_{Cassegrain} \qquad (2)$$

both for the upper and lower edge.

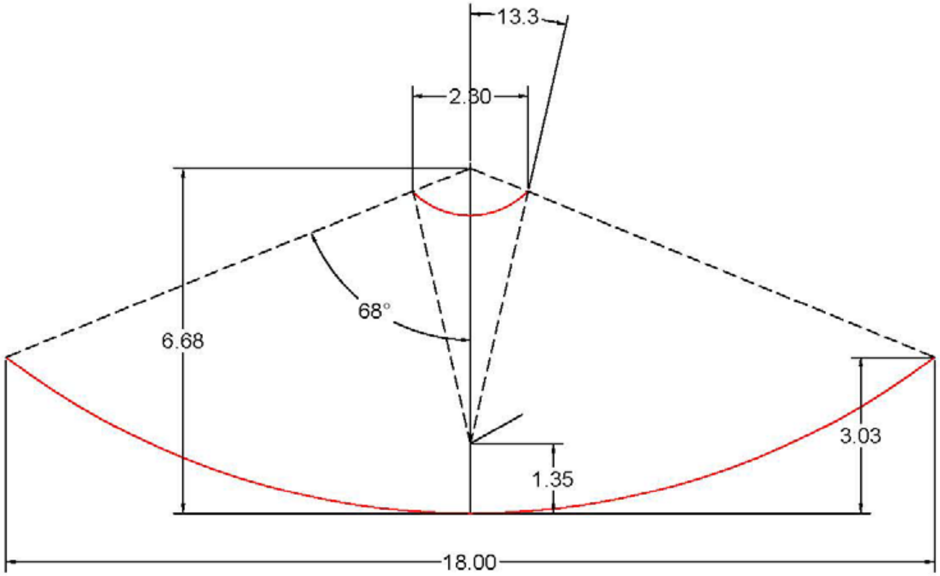
The spillover outside the main reflector due to subreflector diffraction is proportional to $\Delta\rho$ [1, Part II, Eq. (35)]. With an edge illumination of -10 dB the relative spillover is about

$$\Delta p = 0.1 \frac{1}{\sqrt{2\pi}} \left(\frac{\Delta\rho_a}{D/2} \right) = 0.09 \frac{\Delta\rho_a}{D} \qquad (3)$$

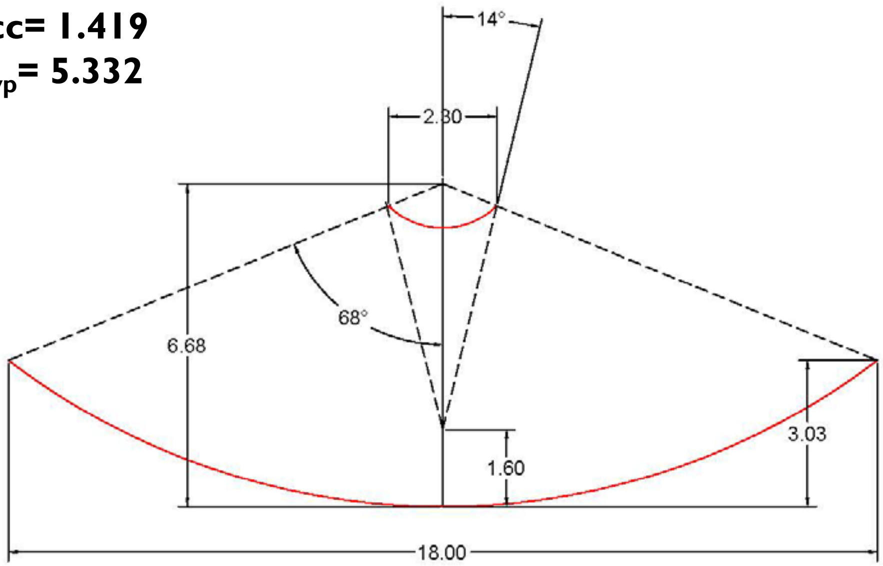
where D is the main reflector diameter and $\Delta\rho_a$ is the average of the $\Delta\rho$'s of the upper and lower edges.



ecc= 1.392
f_{hyp}= 5.610



ecc= 1.419
f_{hyp}= 5.332



ecc= 1.446
f_{hyp}= 5.078

SCANNING LOSS, COMA LOBE