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DSES Antenna Study

For the Artemis-II Mission



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EXECUTIVE SUMMARY (REVISED WITH PROPOSED FLARE ANALYSIS)

The Deep Space Exploration Society (DSES) has been selected by NASA to participate in a volunteer tracking initiative supporting the Artemis II mission. As part of this effort, the 60-foot radio telescope at the Plishner Radio Telescope site will be used to receive S-band signals from the Orion spacecraft. A key technical question is whether the RF Hamdesign CIR-2320 septum feed, tuned to 2216.5 MHz, requires modification—specifically the addition of a flare—to achieve optimal performance with the DSES dish.

A first-order analysis shows that the unmodified feed, with a -10 dB beamwidth of approximately 115° , closely matches the angular extent of the reflector ($\approx 61.5^\circ$ half-angle for $f/D = 0.42$), producing an edge taper near -12 dB. This corresponds to near-optimal illumination for a prime-focus reflector and results in system performance close to the theoretical optimum. This establishes a baseline against which any proposed modification must demonstrate measurable improvement.

To evaluate potential improvements, two flare configurations were analyzed: a literature-based “optimal” flare consistent with published septum feed designs, and a proposed conical flare with a length of 320 mm and a half-angle of 17.4° . The optimal flare produces a modest improvement in beam symmetry and a small increase in G/T , indicating that the baseline feed is already operating near optimal performance.

In contrast, a first-order geometric analysis of the proposed conical flare shows that it produces an effective aperture of approximately 2.1 wavelengths, resulting in a significantly narrower beam ($\approx 45^\circ$ at -10 dB). This beamwidth is substantially smaller than required to fully illuminate the reflector, leading to under-illumination, increased taper loss, and reduced aperture efficiency.

Detailed modeling incorporating E- and H-plane effects, system temperature, and G/T confirms that while properly designed flares can provide incremental benefits, the proposed conical flare degrades overall system performance relative to both the unmodified feed and an optimized flare design.

Based on these results, the unmodified CIR-2320 septum feed is well matched to the DSES dish and provides near-optimal performance. While modest flare designs may offer small improvements, the proposed conical flare geometry is not well suited to this reflector and is predicted to reduce system performance.



SYSTEM MODEL AND ASSUMPTIONS

Dish/feed model with blockage, elevation, sun-noise, and detailed flare comparison

Frequency:	2217.0 MHz	ground temperature:	290.00 K	estimated G/T:	31.59 dB/K
Wavelength:	0.1352 m	evaluation elevation:	30.0 deg	<u>Proposed conical flare estimate</u>	
Dish diameter:	60.0 ft	<u>CIR-2320 nominal case</u>		throat diameter:	90.0 mm
(18.288 m)		-10 dB beamwidth:	115.0 deg	flare length:	320.0 mm
Dish f/D:	0.420	pattern exponent n:	3.7067	flare half-angle:	17.4 deg
Dish edge half-angle:	61.53 deg	rim taper:	-11.92 dB	exit diameter:	290.6 mm
<u>Receiver model</u>		spillover efficiency:	0.9694	approx 3 dB beamwidth:	31.2 deg
LNA gain:	20.0 dB	taper efficiency:	0.8195	approx 10 dB beamwidth:	46.5 deg
LNA noise figure:	0.40 dB	feed efficiency:	0.7944	estimated G/T:	26.23 dB/K
LNA noise temperature:	27.98 K	aperture efficiency estimate:	0.4896	<u>Sun-noise estimate</u>	
Extra rx temperature:	5.00 K	estimated beam FWHM:	0.642 deg	solar flux:	120.0 SFU
Total rx temperature:	32.98 K	estimated Tsys:	61.25 K	sun coupling factor:	0.3210
<u>Efficiency model</u>		estimated gain:	49.46 dBi	antenna temp on Sun:	17938.03 K
eta_misc:	0.620	estimated G/T:	31.59 dB/K	Y-factor on Sun:	293.8772
blocked diameter:	1.000 m	<u>Optimal flare estimate</u>		Sun noise increase:	24.68 dB
blockage efficiency:	0.9940	flare aperture:	140.0 mm	<u>Best beamwidth in sweep at this elevation</u>	
<u>Atmosphere / sky model</u>		flare length:	120.0 mm	best -10 dB beamwidth:	107.8 deg
cold sky temperature:	8.00 K	E-plane beamwidth:	112.0 deg	best G/T:	31.66 dB/K
zenith atmospheric temp:	6.00 K	H-plane beamwidth:	118.0 deg		
		avg beamwidth:	115.0 deg		

The “optimal flare” configuration evaluated in this study is based on published septum feed designs intended for prime-focus reflectors with $f/D \approx 0.4$. These designs employ a short, square or near-square flare section that expands the feed aperture to approximately 1.0–1.1 wavelengths (≈ 140 mm at 2217 MHz) with a flare length on the order of 0.8–1.0 wavelengths (≈ 100 – 130 mm). The purpose of this flare is not to significantly narrow the beam, but to improve symmetry between the E-plane and H-plane patterns and to reduce diffraction effects at the feed aperture. As a result, the overall illumination beamwidth remains close to that of the unflared feed, while achieving modest improvements in edge illumination uniformity and taper efficiency.¹ The dimensions used in this study are consistent with these published approaches and represent a physically reasonable implementation of an optimized flare for the DSES dish geometry.

¹ Representative septum feed flare geometries are described in:

- W1GHZ, “A Septum Feed for Circular Polarization”, which shows square flare transitions with aperture dimensions on the order of 1.1–1.4 λ and emphasizes matching the flare to reflector geometry.
- OK1DFC, “Septum Feed Flare for 2320 MHz”, which provides dimensioned flare designs and notes that modest flare sizes are appropriate for reflectors near $f/D \approx 0.4$, while larger flares are intended for different geometries.

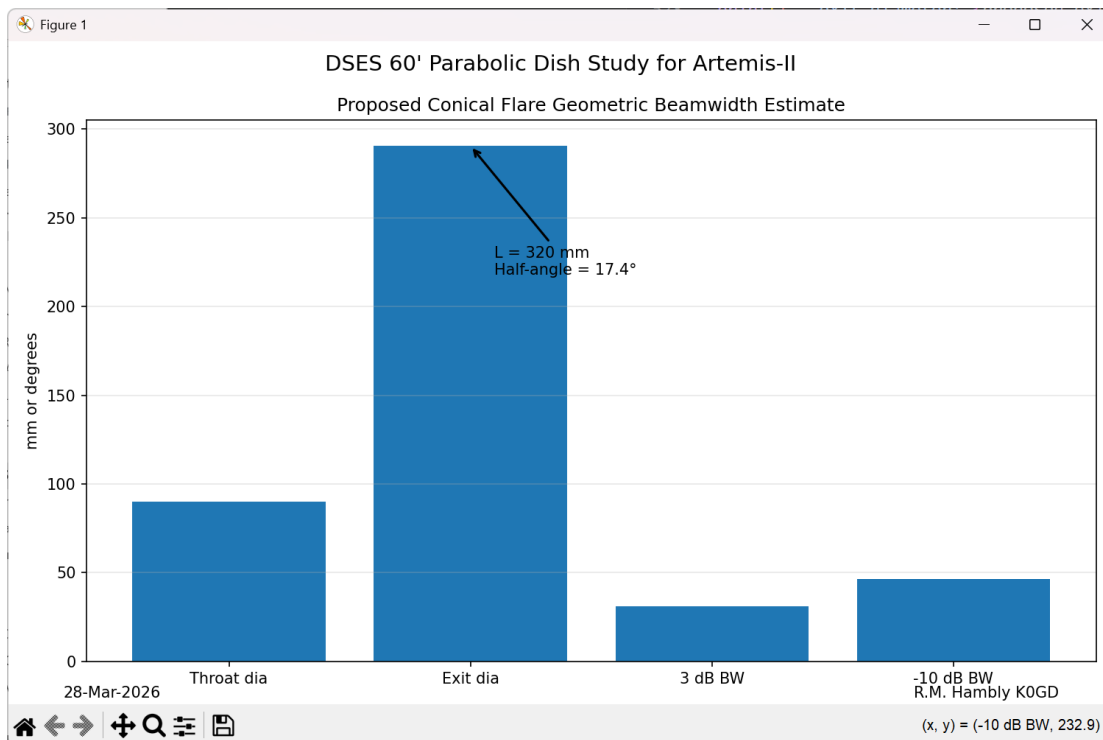


PROPOSED CONICAL FLARE GEOMETRIC BEAMWIDTH ESTIMATE

This plot presents a first-order geometric estimate of the radiation beamwidth produced by the proposed conical flare attached to the septum feed. The flare is modeled as a circular conical transition with a length of 320 mm and a half-angle of 17.4°, attached to an assumed feed mouth diameter of 90 mm. These dimensions yield an effective aperture diameter of approximately 290 mm ($\approx 2.1\lambda$ at 2217 MHz). Using standard aperture-beamwidth relationships, this corresponds to an estimated 3 dB beamwidth of approximately 31° and a -10 dB beamwidth of approximately 47°. These estimates are based on standard aperture-beamwidth relationships and provide a first-order indication of beamwidth scaling with effective aperture size, sufficient to assess illumination compatibility with the reflector.

For comparison, the unmodified septum feed exhibits an illumination beamwidth of approximately 115° at the -10 dB level, which is well matched to the angular extent of the DSES reflector ($\approx 61.5^\circ$ half-angle for $f/D = 0.42$). The proposed conical flare therefore produces a beam that is substantially narrower than required for effective illumination of the dish. This indicates under-illumination of the outer portions of the reflector, reducing effective aperture utilization.

This estimate is based on a simplified geometric model and does not include higher-order electromagnetic effects such as phase error, diffraction, or detailed E- and H-plane variations. However, it provides a clear first-order indication that the proposed flare geometry leads to a beamwidth that is not well matched to the DSES dish and is therefore likely to degrade overall system performance relative to the unmodified feed or a properly optimized flare.

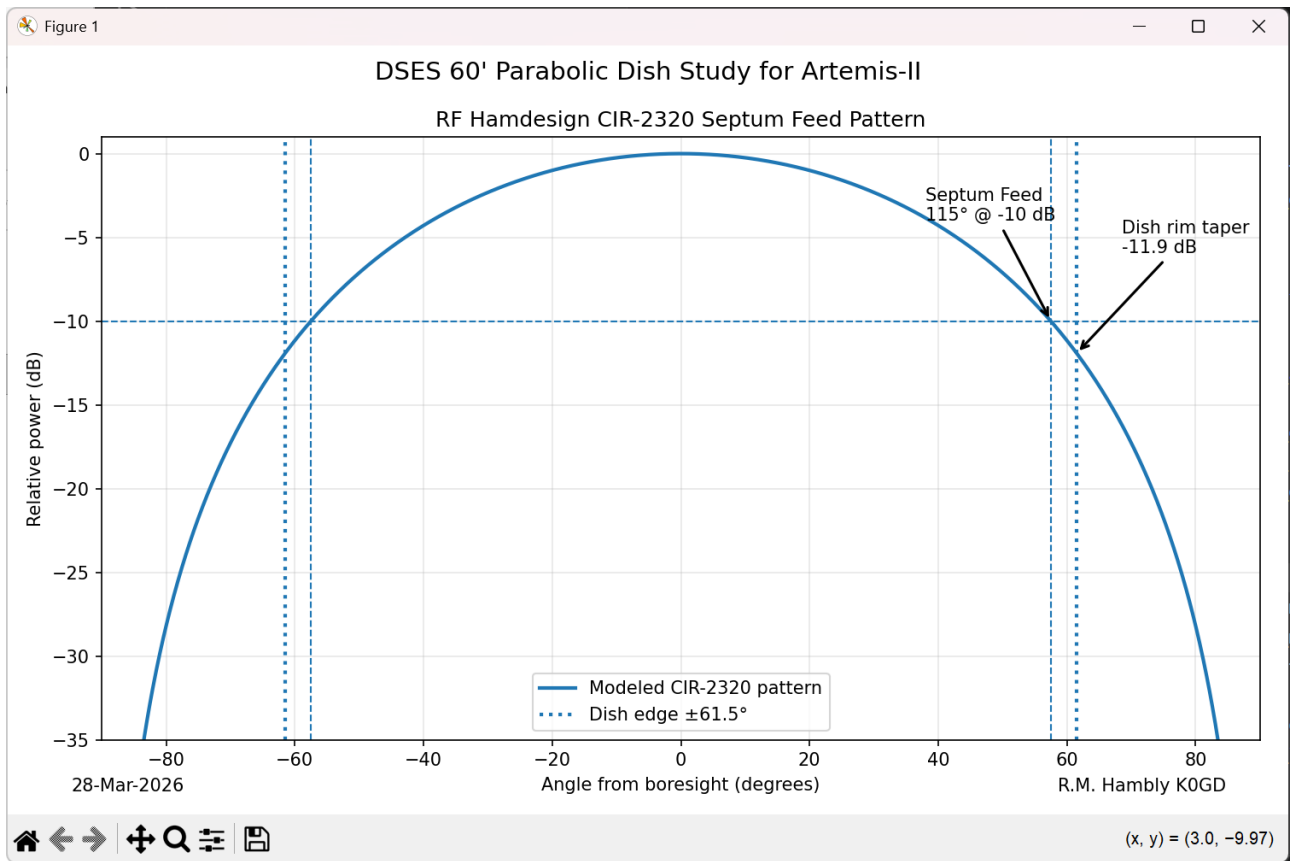




BASELINE FEED BEHAVIOR

FEED PATTERN (CIR-2320 SYNTHETIC PATTERN)

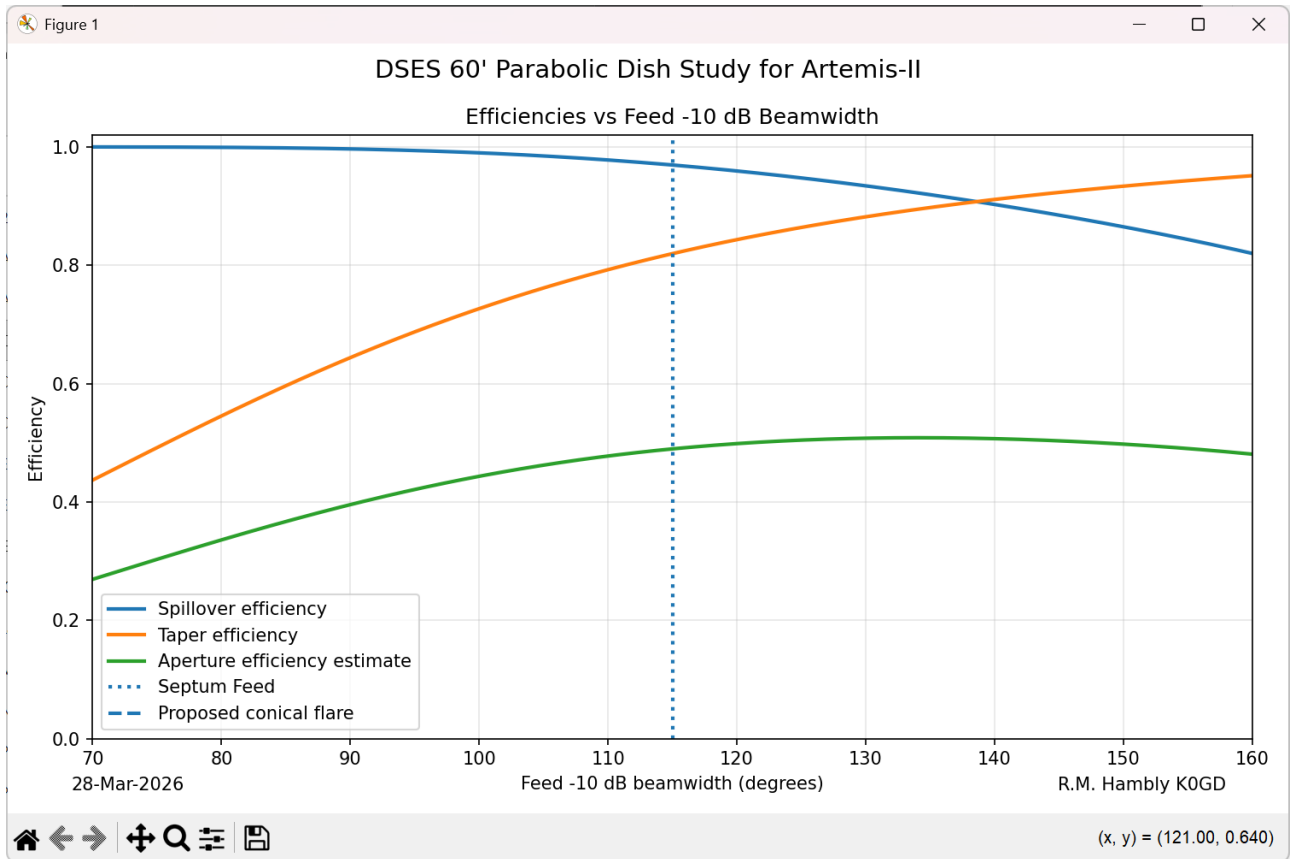
This plot shows the modeled radiation pattern of the RF Hamdesign CIR-2320 feed, derived from its specified 115° beamwidth at the -10 dB level. The pattern is approximated using a cosine-to-the-n formulation to represent a smooth, rotationally symmetric horn response. The vertical dashed lines indicate the -10 dB beamwidth limits, while the dotted lines mark the angular extent of the dish as seen from the feed for an $f/D = 0.42$ reflector. The resulting edge illumination of approximately -12 dB demonstrates that the feed provides a near-optimal taper for minimizing spillover while maintaining good aperture efficiency.





EFFICIENCY TERMS VS BEAMWIDTH

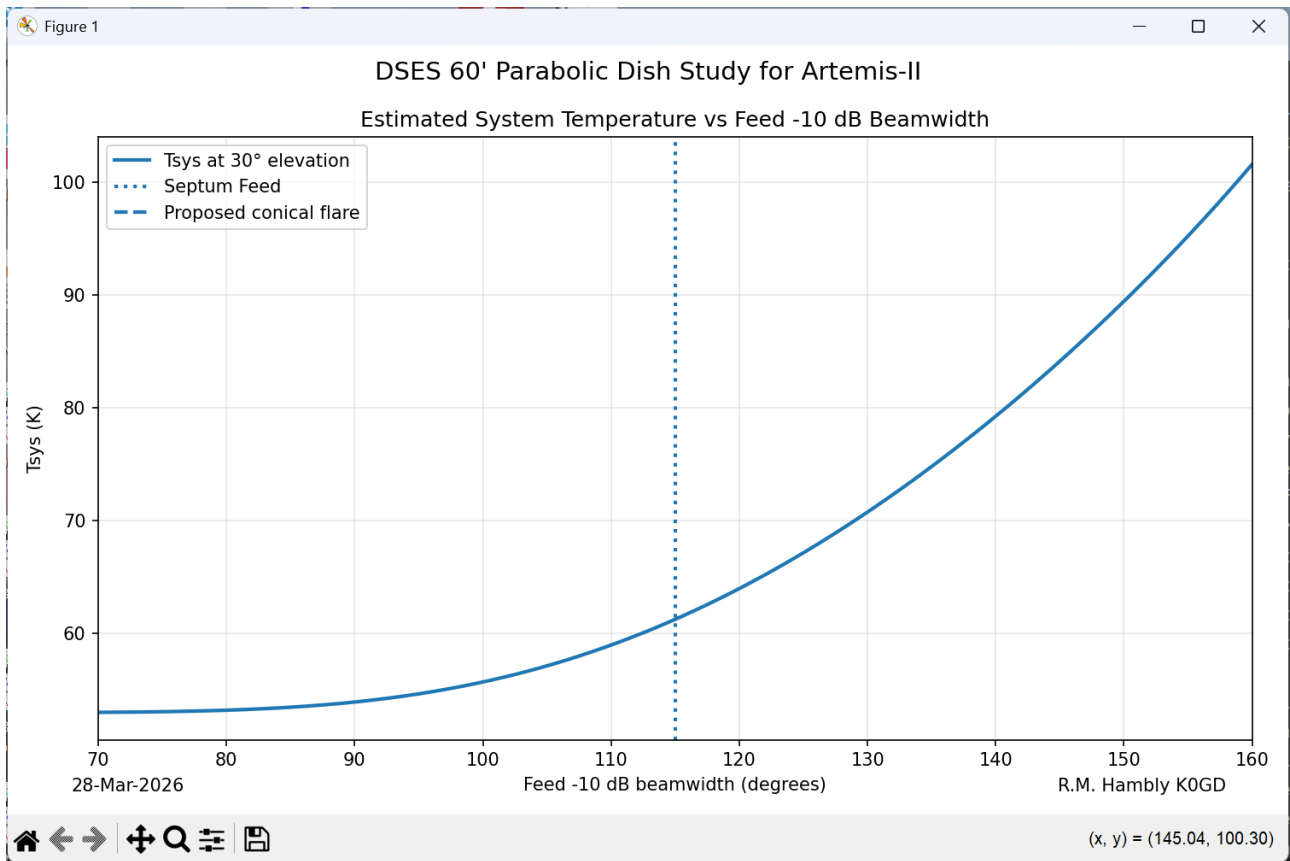
This chart illustrates the trade-off between spillover efficiency, taper efficiency, and their product (effective aperture efficiency) as a function of feed beamwidth. Narrower beams improve spillover efficiency by reducing power radiated beyond the dish, but at the cost of increased taper loss due to under-illumination of the reflector. Conversely, wider beams improve taper efficiency but increase spillover noise. The intersection of these competing effects produces a broad optimum region. The CIR-2320's 115° beamwidth lies within this region, indicating that its design is well matched to dishes with f/D near 0.4.





SYSTEM TEMPERATURE VS BEAMWIDTH

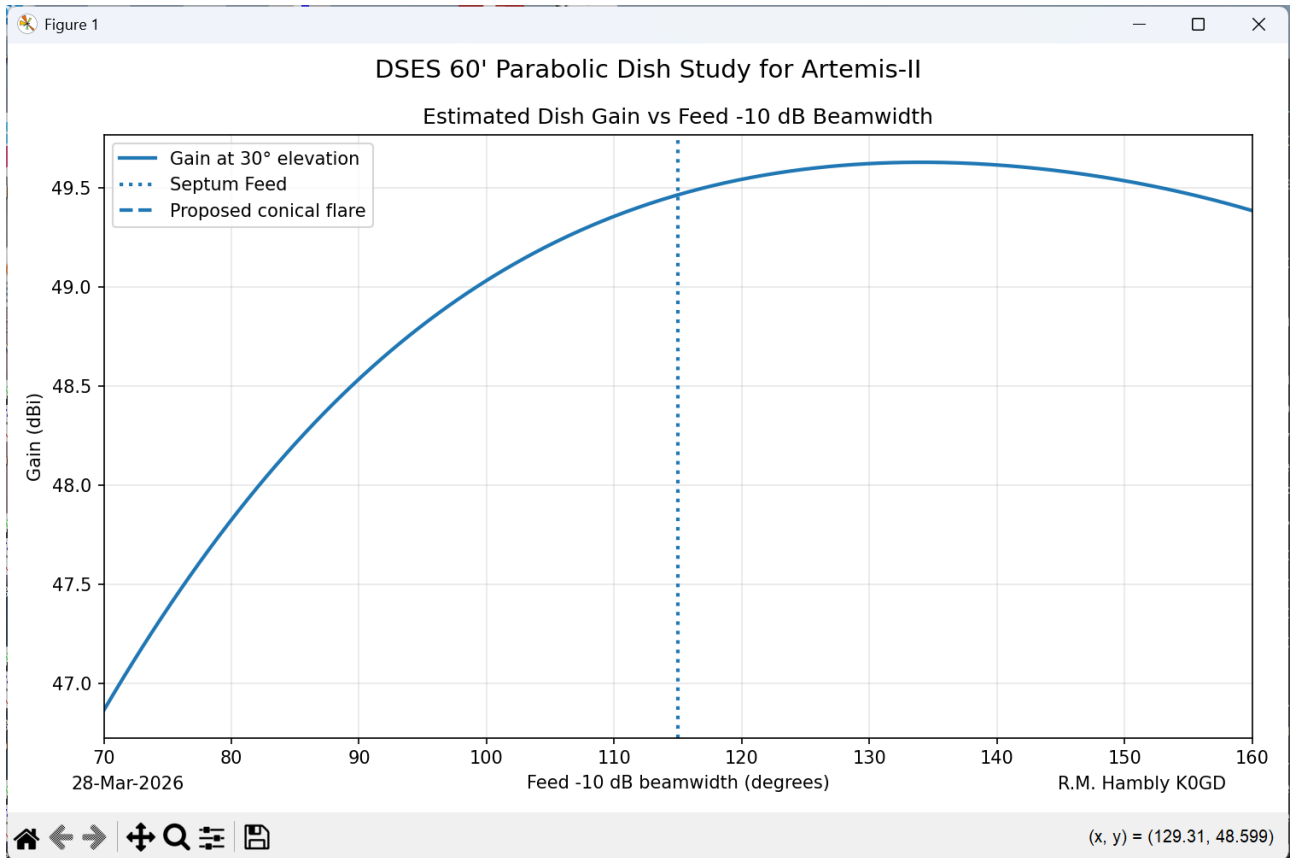
This plot shows the estimated system temperature as a function of feed beamwidth at a fixed elevation angle. The system temperature includes receiver noise, sky noise, and ground noise introduced via spillover. As beamwidth increases, spillover rises and more of the feed pattern intercepts the warm ground, causing a rapid increase in system temperature. Narrower beams reduce spillover and thus lower system temperature, but only up to the point where taper losses begin to degrade overall performance. The CIR-2320 provides a balanced compromise between these effects.





DISH GAIN VS BEAMWIDTH

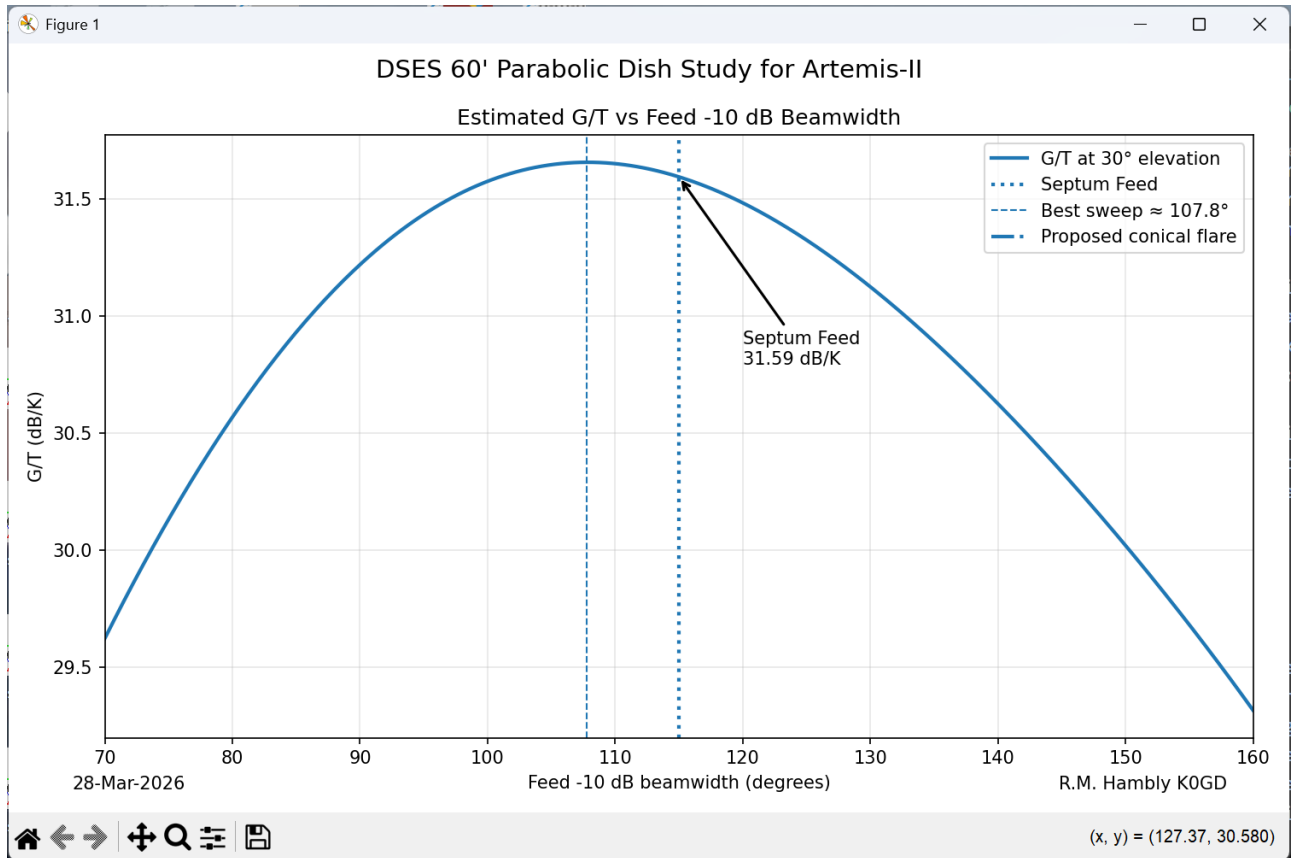
This chart presents the estimated antenna gain as a function of feed beamwidth, incorporating taper, spillover, and fixed efficiency factors. Gain increases as illumination becomes more uniform across the dish, but excessive beamwidth leads to spillover losses that reduce effective aperture utilization. The resulting curve shows a broad maximum, with the CIR-2320 operating near this peak. This confirms that its illumination pattern efficiently excites the reflector aperture for maximum forward gain.





G/T VS BEAMWIDTH

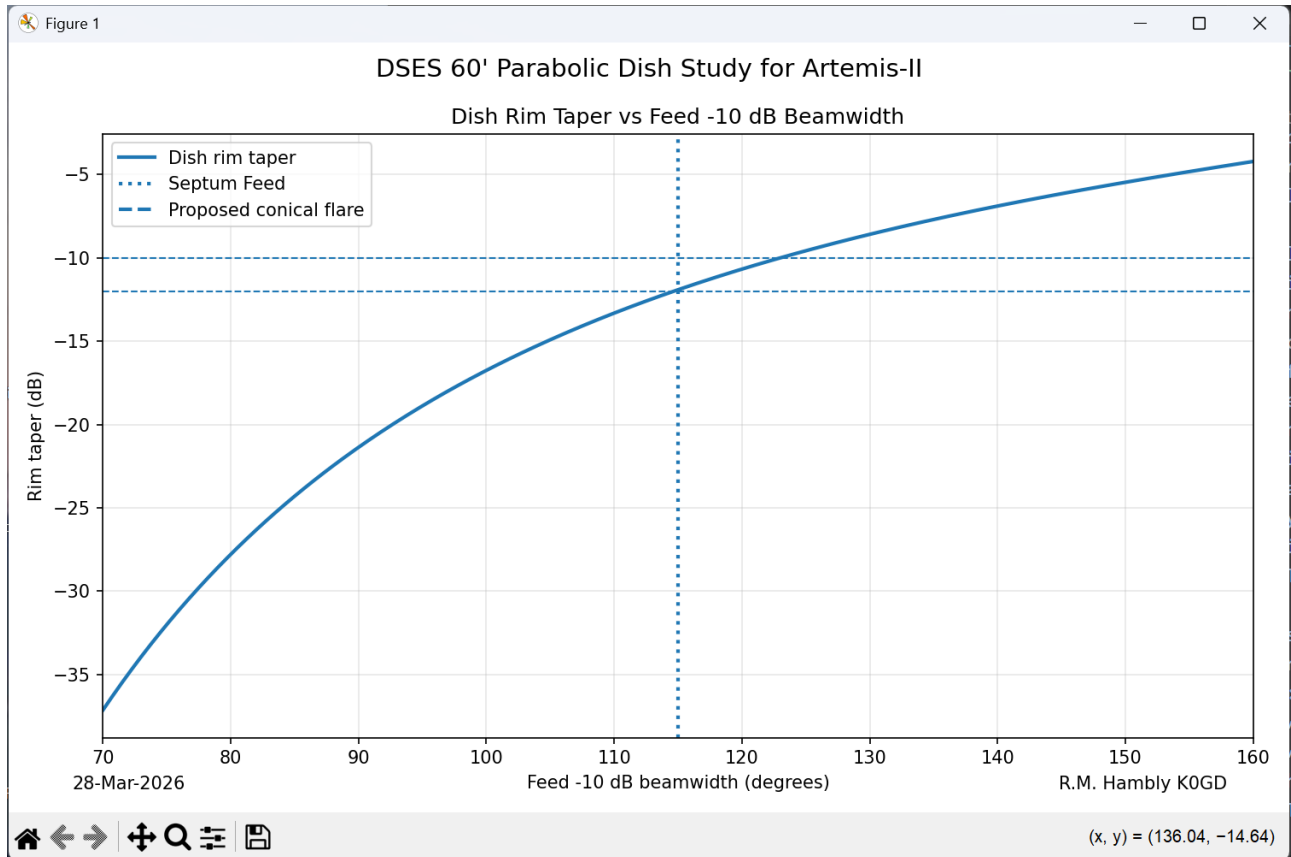
This is the most important performance plot, showing the estimated ratio of antenna gain to system temperature (G/T) as a function of feed beamwidth. The curve captures the combined effects of illumination efficiency and noise pickup. The optimum beamwidth corresponds to the maximum G/T, where the trade-off between gain and noise is balanced. The CIR-2320 lies close to this optimum, demonstrating that its beamwidth is well suited for maximizing receive sensitivity in this system configuration.





RIM TAPER VS BEAMWIDTH

This plot shows the feed illumination level at the dish edge (rim taper) as a function of beamwidth. Typical design targets for prime-focus dishes are in the range of -10 to -15 dB. The chart confirms that the CIR-2320 produces a rim taper of approximately -12 dB for an $f/D = 0.42$ reflector, which is widely regarded as a good compromise between aperture efficiency and spillover noise. This further supports its suitability for the given dish geometry.

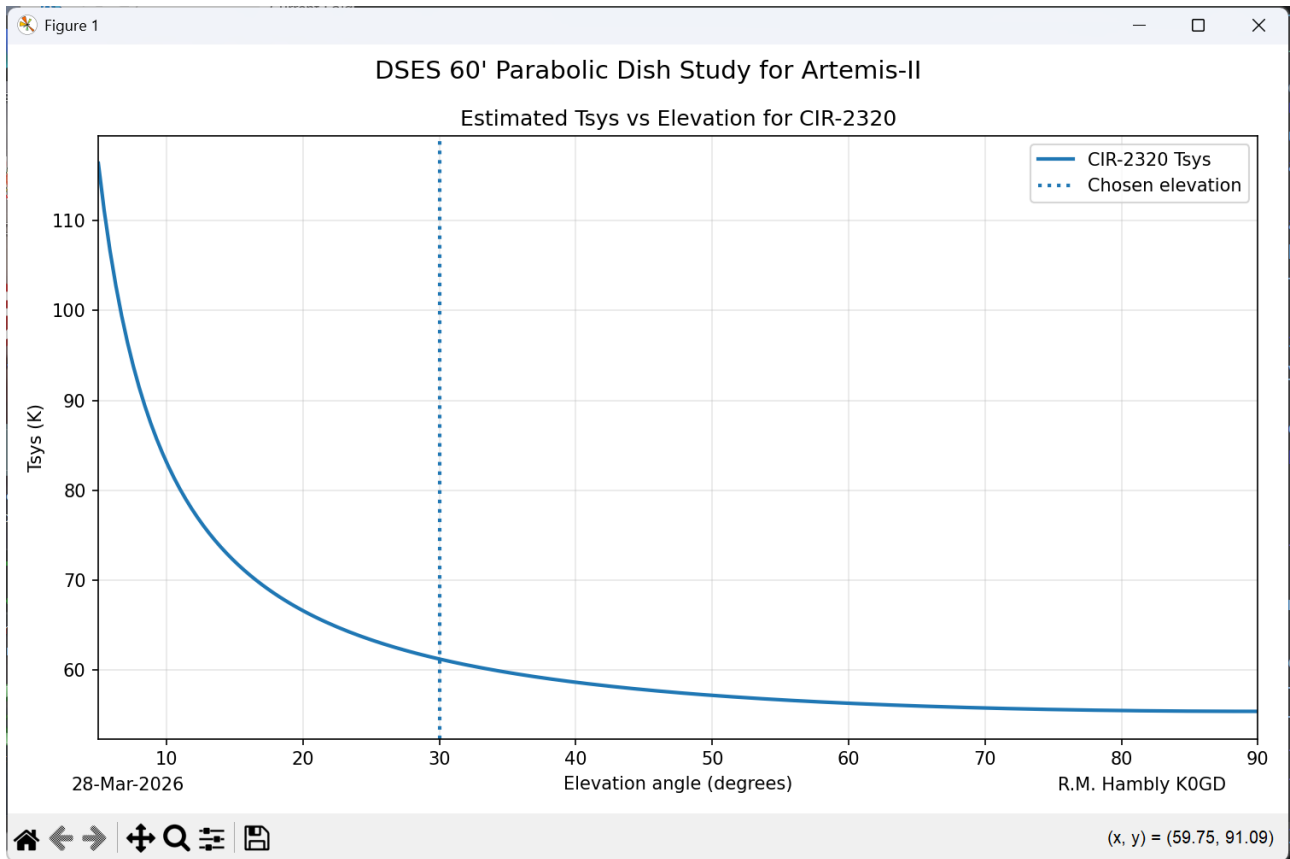




SYSTEM-LEVEL BEHAVIOR

SYSTEM TEMPERATURE VS ELEVATION

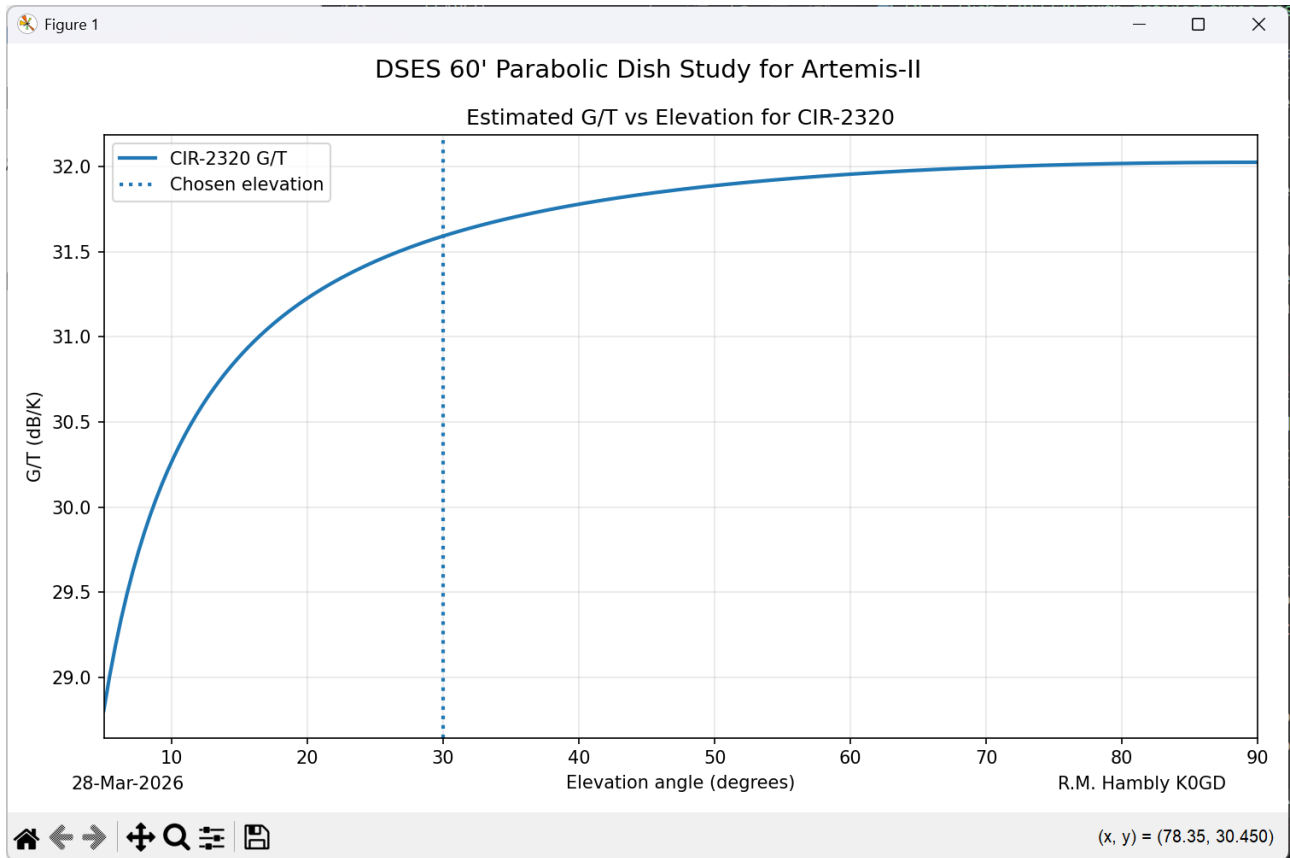
This plot shows how system temperature varies with elevation angle for the CIR-2320 feed. As elevation decreases, atmospheric path length increases, raising sky noise temperature. Additionally, spillover may increasingly intercept warm ground at low elevations. The result is a significant rise in system temperature toward the horizon. This behavior emphasizes the importance of high-elevation operation for low-noise observations, particularly in weak-signal applications.





G/T VS ELEVATION

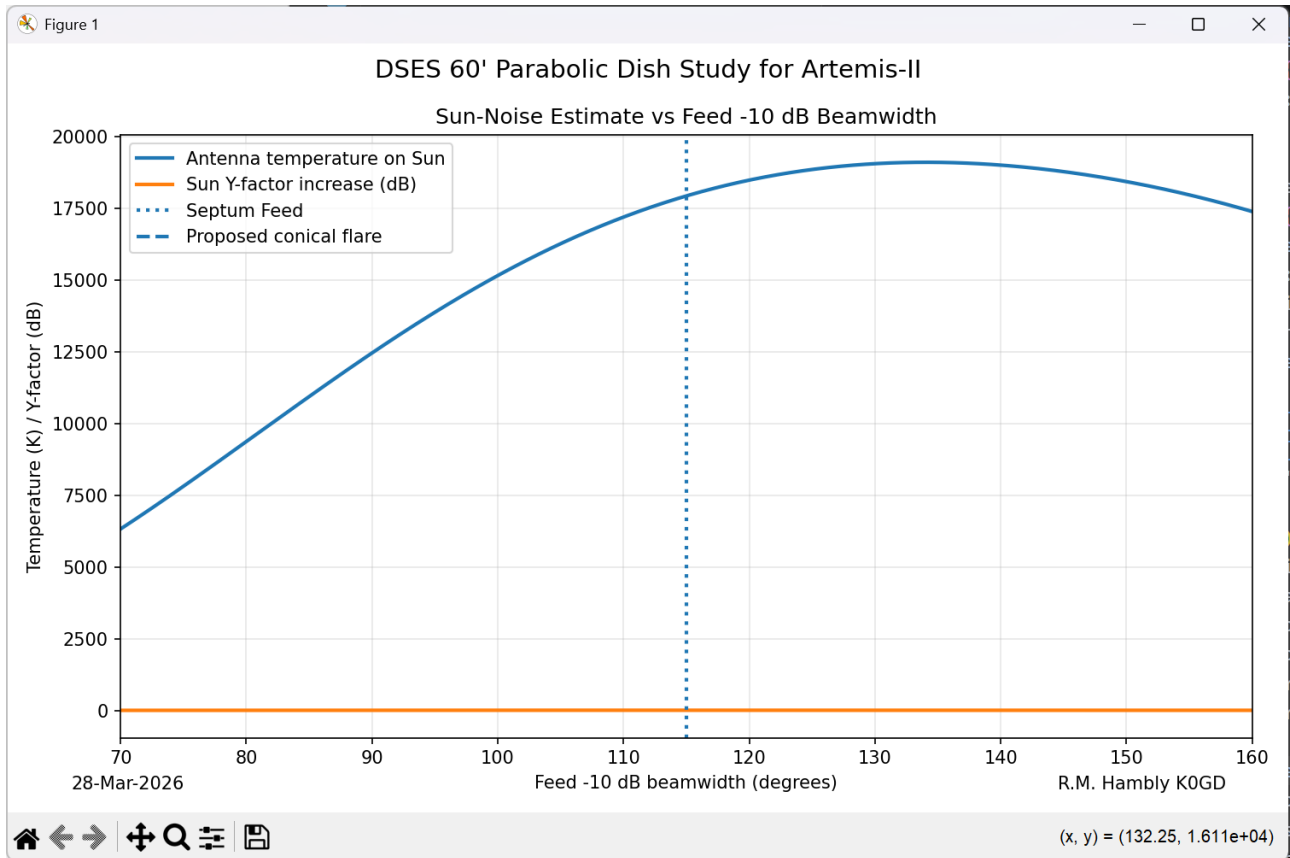
This chart shows the corresponding variation in G/T with elevation angle. Because antenna gain remains essentially constant, changes in G/T are dominated by system temperature. As elevation increases, reduced atmospheric absorption and lower effective sky temperature improve G/T. The curve demonstrates that system sensitivity is strongly elevation-dependent, reinforcing the advantage of scheduling observations at higher elevation angles whenever possible.





SUN-NOISE ESTIMATE VS BEAMWIDTH

This plot estimates the antenna temperature contribution from the Sun and the resulting Y-factor as a function of feed beamwidth. It accounts for beam dilution due to the finite angular size of the solar disk and the antenna beamwidth. Narrower beams concentrate more energy on the Sun, increasing antenna temperature, while wider beams dilute the signal. The CIR-2320 provides a moderate sun-noise response consistent with its beamwidth, making it suitable for calibration purposes while maintaining good overall system performance.





DETAILED FEED COMPARISONS

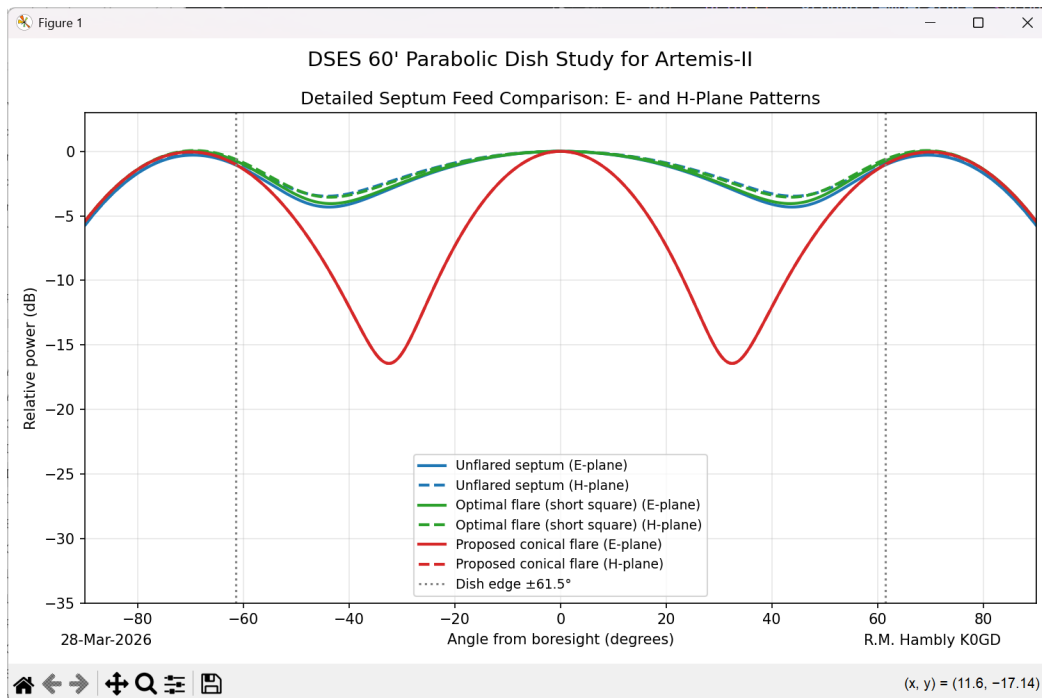
DETAILED SEPTUM FEED COMPARISON: E- AND H-PLANE PATTERNS

This plot compares the modeled E-plane and H-plane radiation patterns for three septum feed configurations: the unflared feed, a literature-based optimal flare, and the proposed conical flare. The unflared septum feed exhibits a modest asymmetry between the E-plane and H-plane beamwidths, reflecting the rectangular geometry of the waveguide aperture. This asymmetry results in slight azimuthal variation in dish illumination but remains within acceptable limits for system performance.

The optimal flare configuration, based on published septum feed designs for reflectors with $f/D \approx 0.4$, produces a more balanced radiation pattern with reduced E/H-plane disparity. This results in a smoother and more uniform illumination of the reflector, with only minor changes to overall beamwidth. The improvement is primarily in beam symmetry rather than beam narrowing.

In contrast, the proposed conical flare produces a significantly narrower beam in both planes due to its large effective aperture. While this configuration reduces asymmetry, it does so by substantially tightening the radiation pattern rather than by optimizing the transition from the feed to free space. The resulting beam is considerably narrower than required to fully illuminate the reflector aperture, indicating that the primary effect of the proposed flare is a reduction in beamwidth rather than an improvement in illumination symmetry.

Overall, this comparison demonstrates that while a properly designed flare can improve beam symmetry with minimal impact on beamwidth, the proposed conical flare alters the radiation pattern in a fundamentally different way, leading to a beam that is not well matched to the dish geometry.





DETAILED SEPTUM FEED COMPARISON: UNFLARED VS FLARED

This chart compares the overall system performance of three septum feed configurations: the unflared feed, a literature-based optimal flare, and the proposed conical flare, using G/T as the primary performance metric. The unflared configuration provides a baseline that is already well matched to the DSES reflector ($f/D = 0.42$), producing near-optimal illumination with acceptable edge taper and minimal spillover.

The optimal flare configuration, based on published designs scaled for this frequency and reflector geometry, produces a modest improvement in performance. This improvement results primarily from increased beam symmetry and slightly improved edge illumination, leading to a small increase in taper efficiency and a corresponding incremental gain in G/T. The magnitude of this improvement is limited, indicating that the unflared feed is already operating close to the optimum for this system.

In contrast, the proposed conical flare results in a noticeable reduction in system performance. The large effective aperture of the flare produces a significantly narrower beamwidth, leading to under-illumination of the reflector and increased taper loss. Although the flare reduces asymmetry between planes, this benefit is outweighed by the reduction in effective aperture utilization. The resulting decrease in G/T demonstrates that the proposed flare is not well matched to the reflector geometry.

This comparison shows that properly designed flares can provide incremental performance improvements, but only when matched to the reflector geometry.

