Inverted Amos Antenna as Linear Feed for Cylindrical Parabolic Reflector

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Introduction

In this paper I will try to examine the parameters which are leading to the optimum efficiency of a cylindrical parabolic antenna illuminated by collinear dipole array in front of plane reflector.

In the article [1] there are explanations about different types of parabolic reflectors which are produced by different slicing of surface created by rotation of parabolic curve around its axis.

Another type of parabolic surface reflector can be created by extruding (drawing) parabolic curve along the line which is perpendicular to the plane in which parabolic curve lies in. Because the focus point is also drawing along the line, focus line is created instead of focus point.

As a result we have cylindrical parabolic surface with focus line.

This type of reflector surface needs specific linear feed for good illumination efficiency.

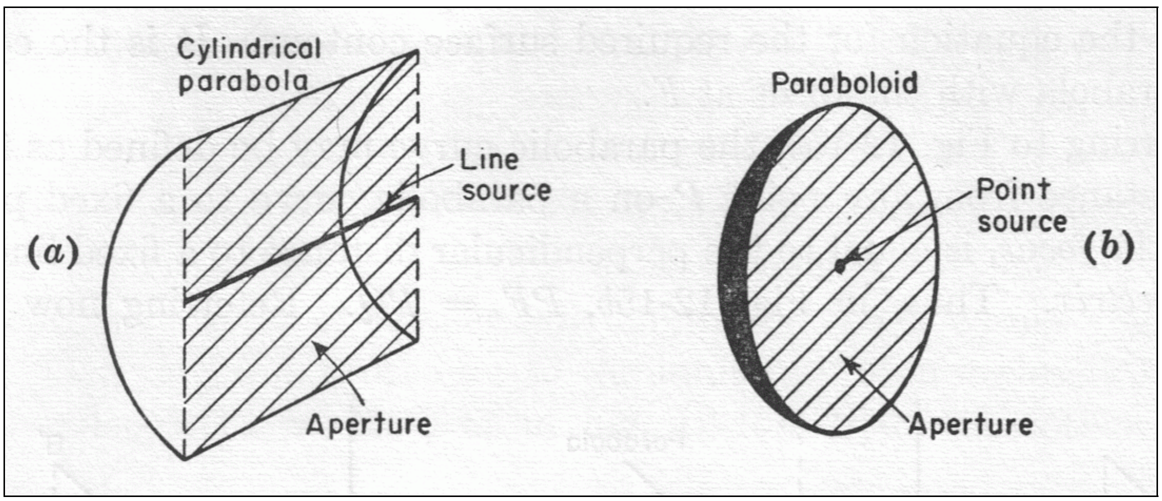

Fig. 1: Line source and cylindrical parabolic reflector (a) and point source and rotational parabolic reflector (b).

Inverted Amos antenna as a feed

I decided to use the Inverted Amos antenna [2] as a feed for the cylindrical parabolic antenna because of its specific collinear construction which very well corresponds to demands on optimal linear feed characteristics. Possibility of using Inverted Amos antenna with different number of dipoles, and thus different length, gives me some extra flexibility in cylindrical parabolic antenna illumination analysis.

Usual parabolic reflectors created by rotation of parabolic curve around its axis achieve their optimum illumination efficiency when illumination taper, which is the ratio of power density at its rim to power density at its center, is about -10 dB.

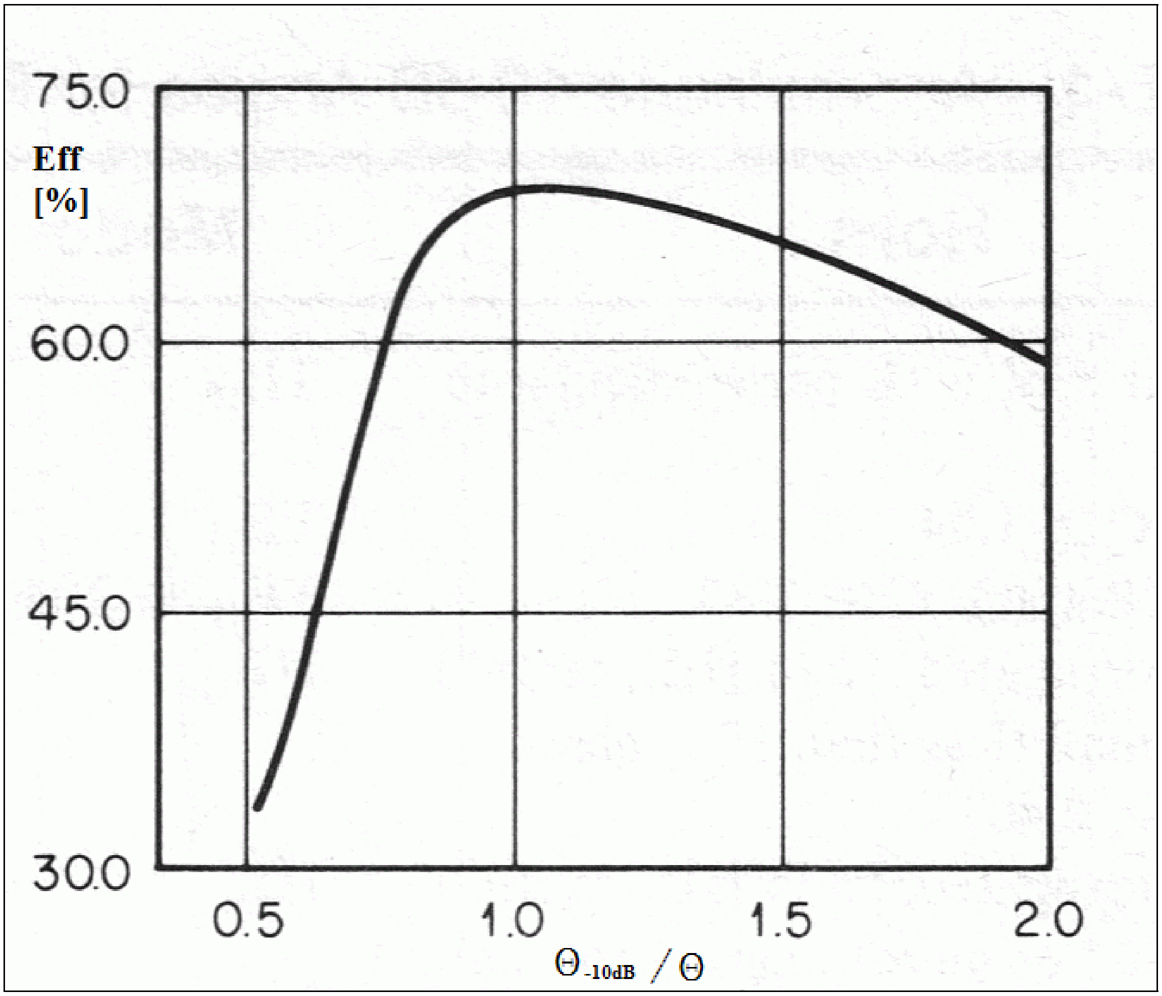

Fig. 2: Aperture efficiency of parabolic reflector with various illumination tapers given as ratio of angle for -10 dB illumination taper θ_{-10dB} and subtended angle θ.

Illumination taper which is lower than about -10dB increases spillover and back lobes of antenna. High back lobes lower antenna efficiency.
On the other hand, illumination taper higher than about -10db gives lower efficiency due to under-illumination of parabolic surface. For receiving purposes where low side lobe level is important, for instance in radio astronomy, it is advisable to use feed with higher illumination taper in order to trade off the antenna efficiency for antenna low noise temperature.
Equivalent illumination taper is the sum of two attenuations: feed's directivity and space attenuation. First of them differently illuminates parabolic reflector surface due to its radiation diagram which have maximum gain at bore sight of the main beam and lower gain by the side. Second one differently illuminates parabolic reflector due to higher distance, and thus higher space loss, of the parabolic reflector rim than the reflector center to the focus point or the focus line.
The illumination problems of a linear feed used with cylindrical parabolic reflector are very similar to the point source feed problems used with rotational parabolic reflector. The difference is only in space attenuation and side lobes size.

For cylindrical parabolic reflector and linear feed, value of the space attenuation as a function of angle for parabolic plane is the same as for rotational parabolic reflectors and can be seen on Fig. 3.
But for the other, linear plane values must be halved because the space attenuation factor for the line source is given by the square root of the values for point source [3, 4].

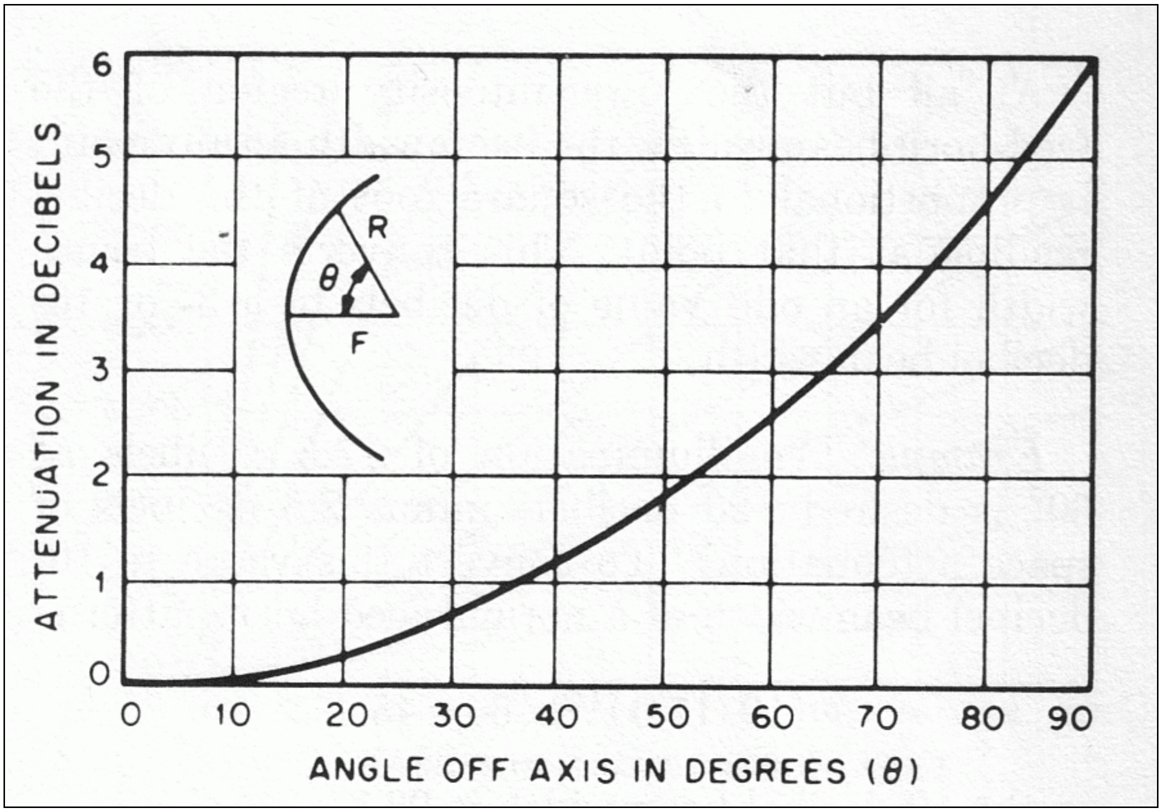

Fig. 3: Space attenuation as a function of half of subtended angle θ.

Cylindrical Parabolic surface and linear feed matching
The Inverted Amos antenna has very different E and H diagrams because of its collinear design. See Fig. 4 and 5.
According to that, it is necessary to create cylindrical parabolic surface which will best fit these diagrams and would produce the best illumination efficiency.
If we take the Inverted Amos antenna so that its E plane is horizontal and H plane is vertical, than cylindrical parabolic surface have to be quite narrow and tall to fit narrow horizontal and wide vertical diagram.
The question arises: how wide and how tall it should be?
Height of reflector surface can be determined by choosing appropriate illumination taper similarly as for usual rotational type of parabolas, about -10 dB.
But problem is with the width of surface because we have to deal with linear feed which is quite different than usual point one.

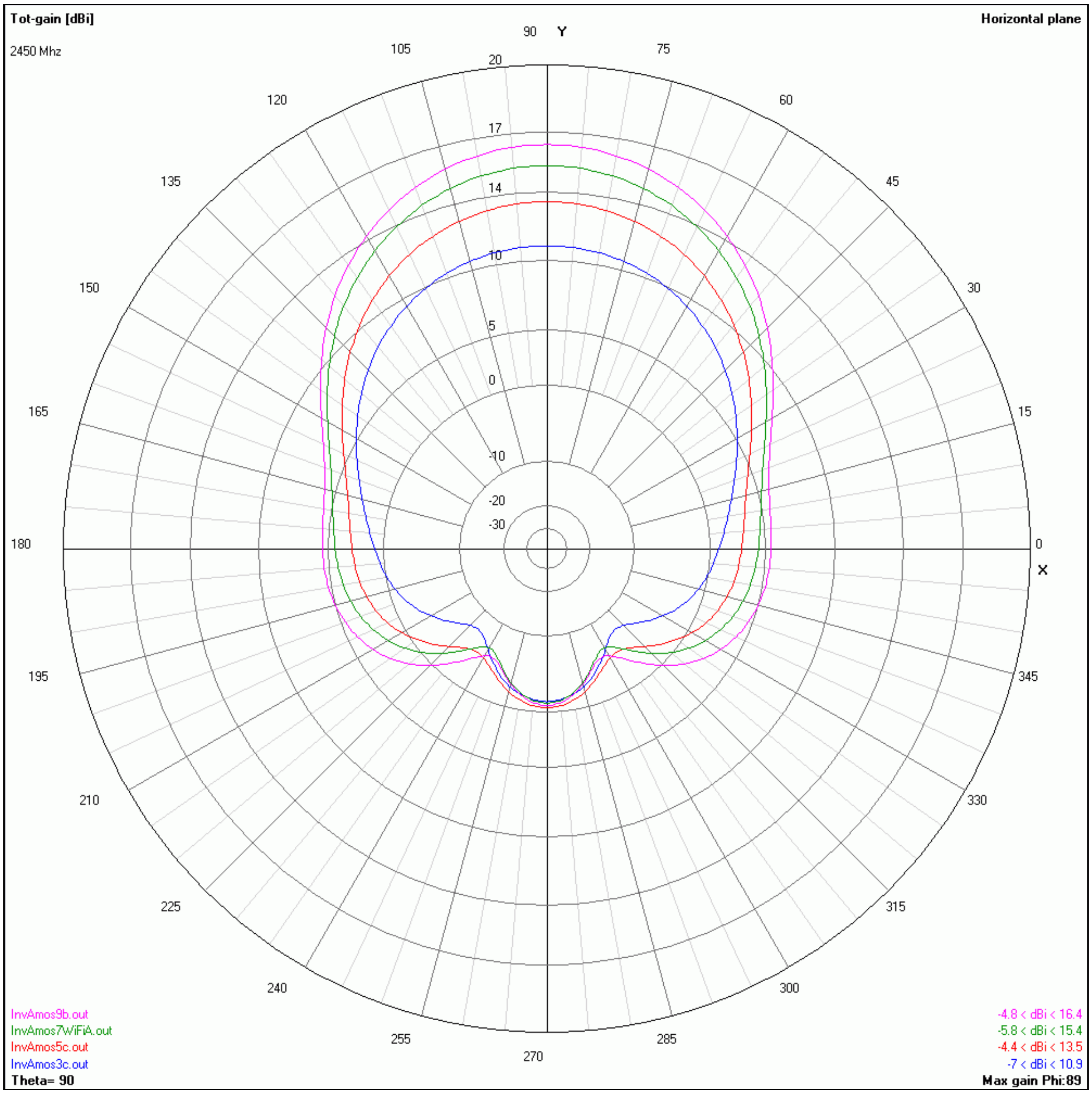

Fig. 4: H plane radiation diagram of Inverted Amos antenna with different number of 3, 5, 7, and 9 dipoles.

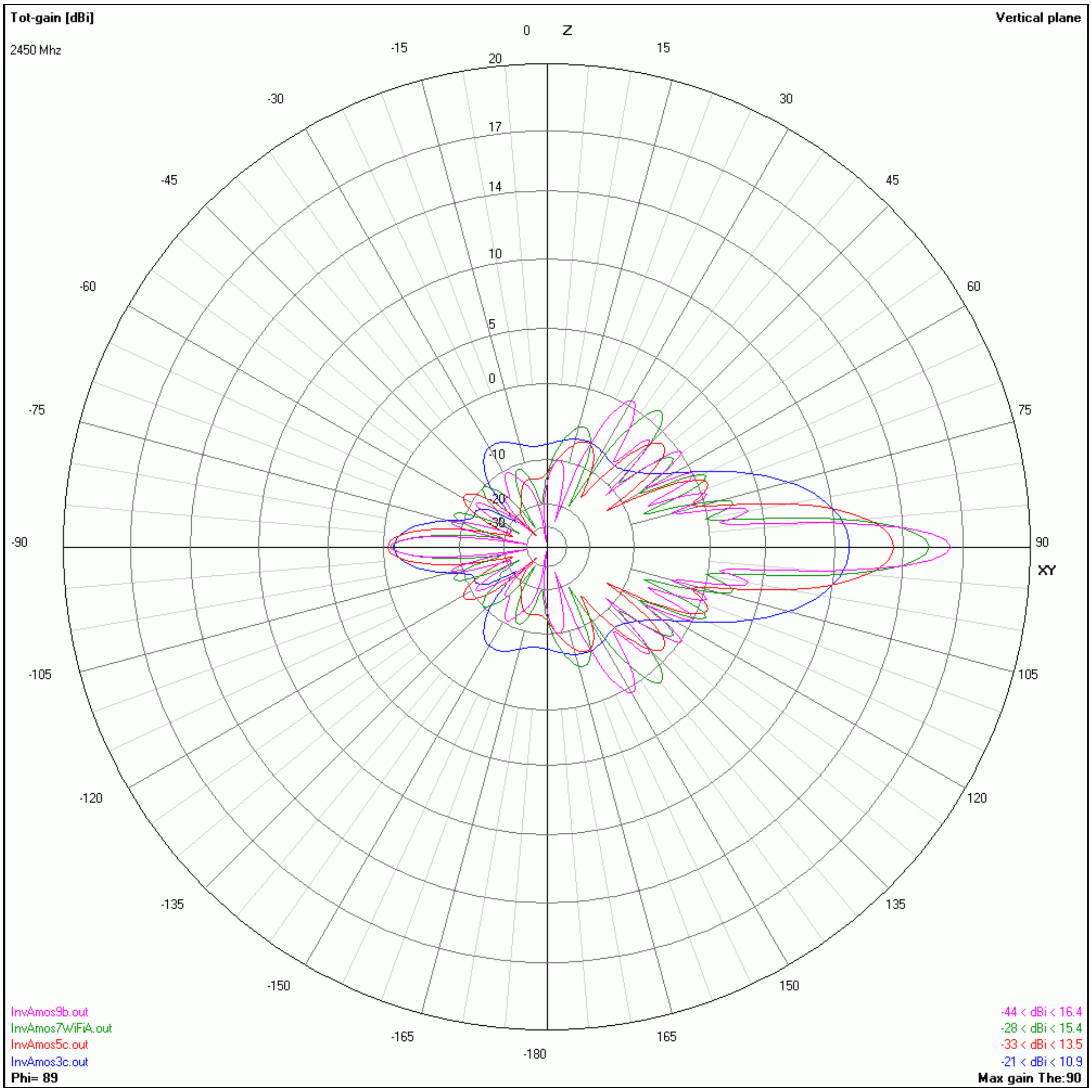

Fig. 5: E plane radiation diagram of Inverted Amos antenna with different number of 3, 5, 7, and 9 dipoles.

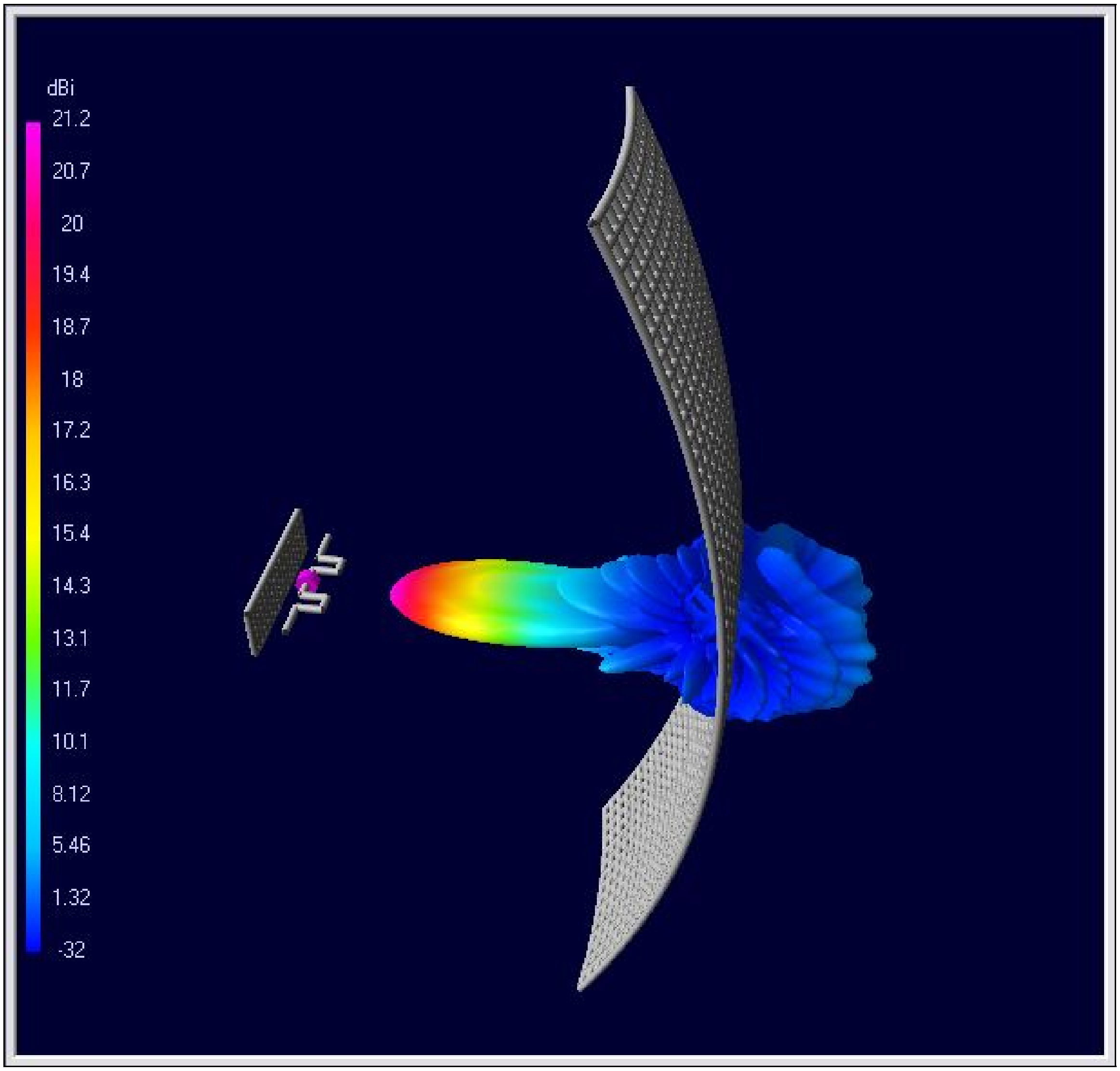

Fig. 6: Short linear feed (Inv. Amos 3 antenna) illuminate classical parabolic reflector

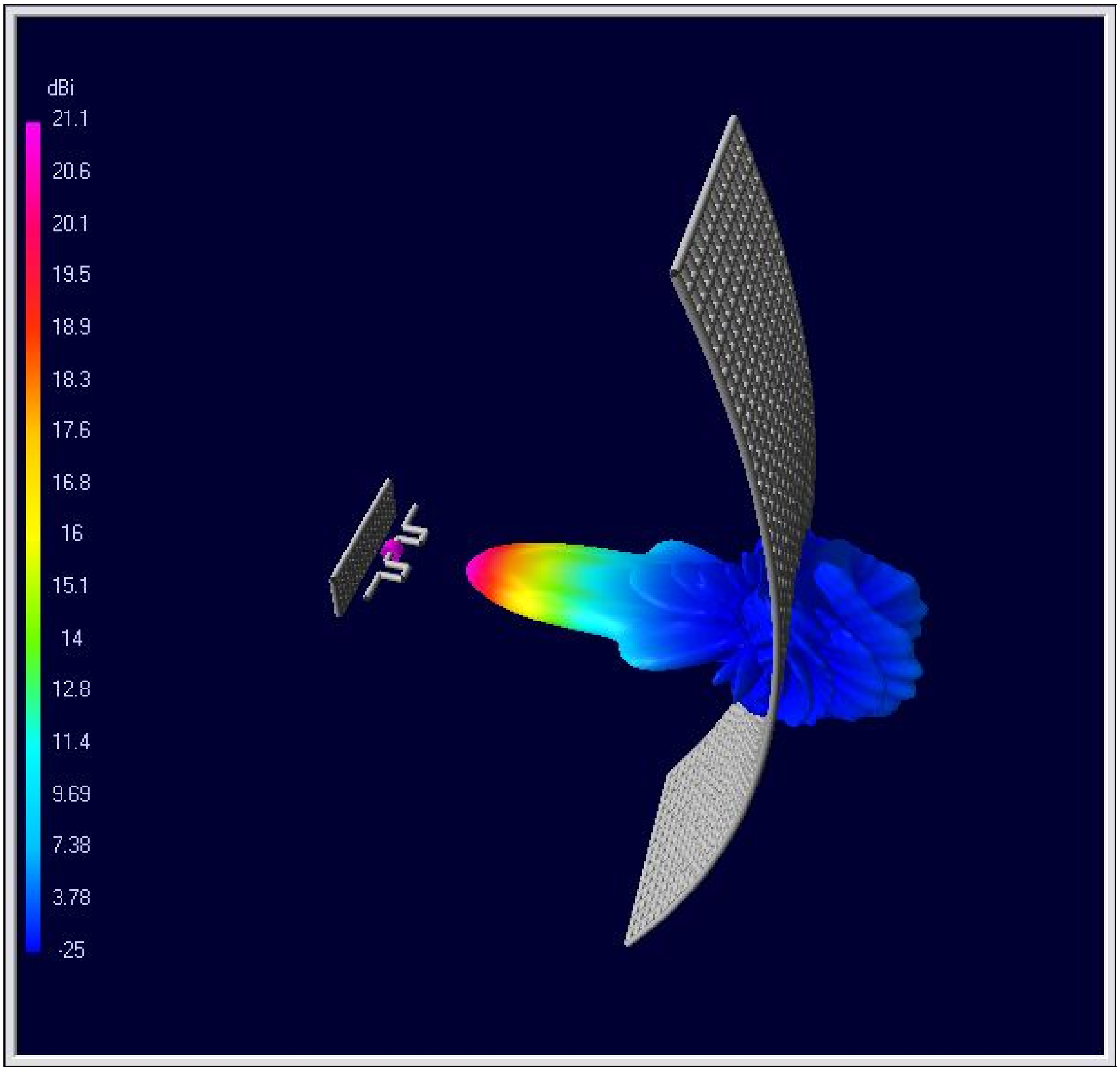

Fig. 7: Short linear feed (Inv. Amos 3 antenna) illuminate cylindrical parabolic reflector

How long should linear feed be?
If we take same rule of thumb for surface width as for its height following -10 dB illumination taper we can get narrower parabolic surface than the feed itself, especially for longer feeds with more dipoles and thus narrower diagram.
On the other hand, if we take shorter feed, for instance Inverted Amos antenna with 3 dipoles instead of 5, we have feed which becomes akin to point source feed and parabolic surface must be concave along another reflector dimension in order to compensate phase errors of such not true linear feed.

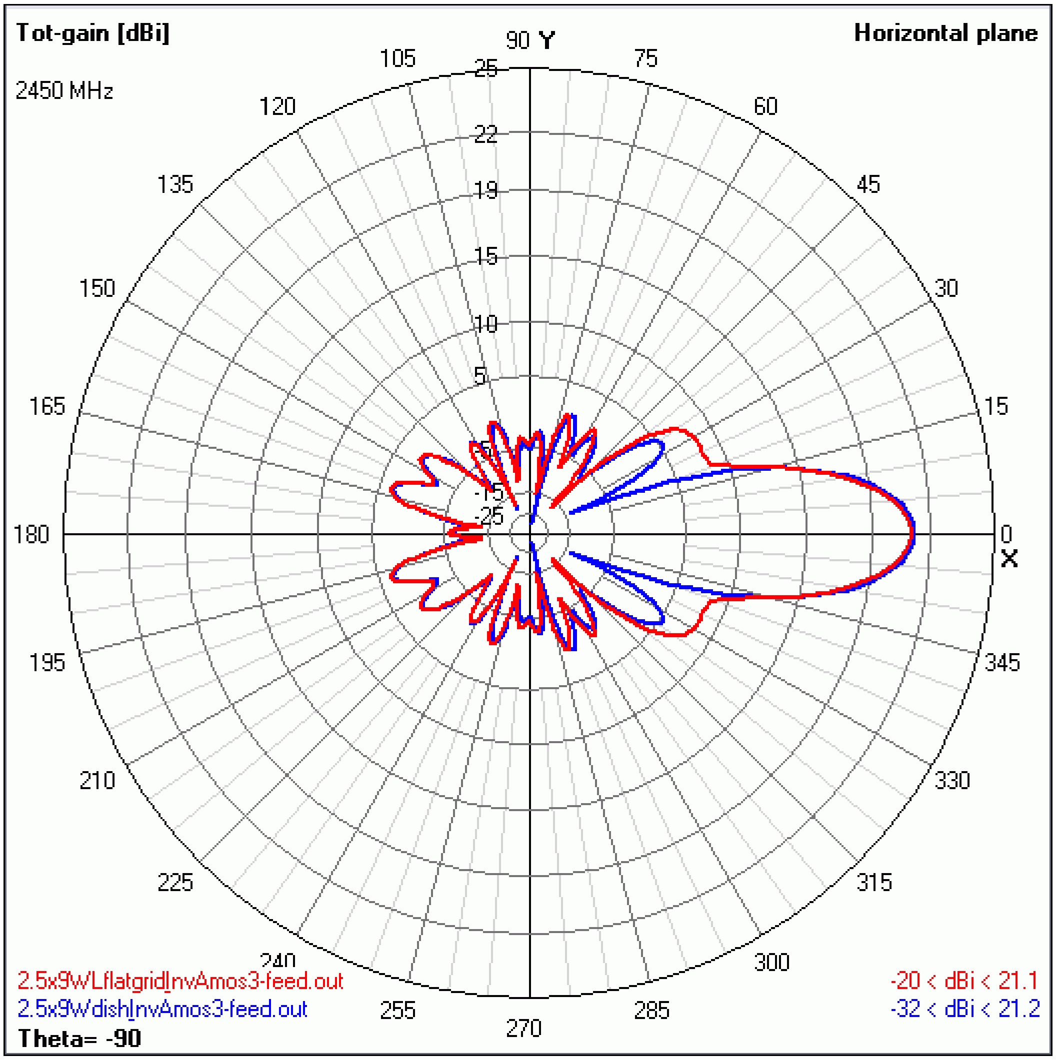

Fig. 8: Short linear feed (Inv. Amos 3 antenna) illuminate classical and cylindrical 2.5 x 9 wavelength parabolic reflector - horizontal diagrams

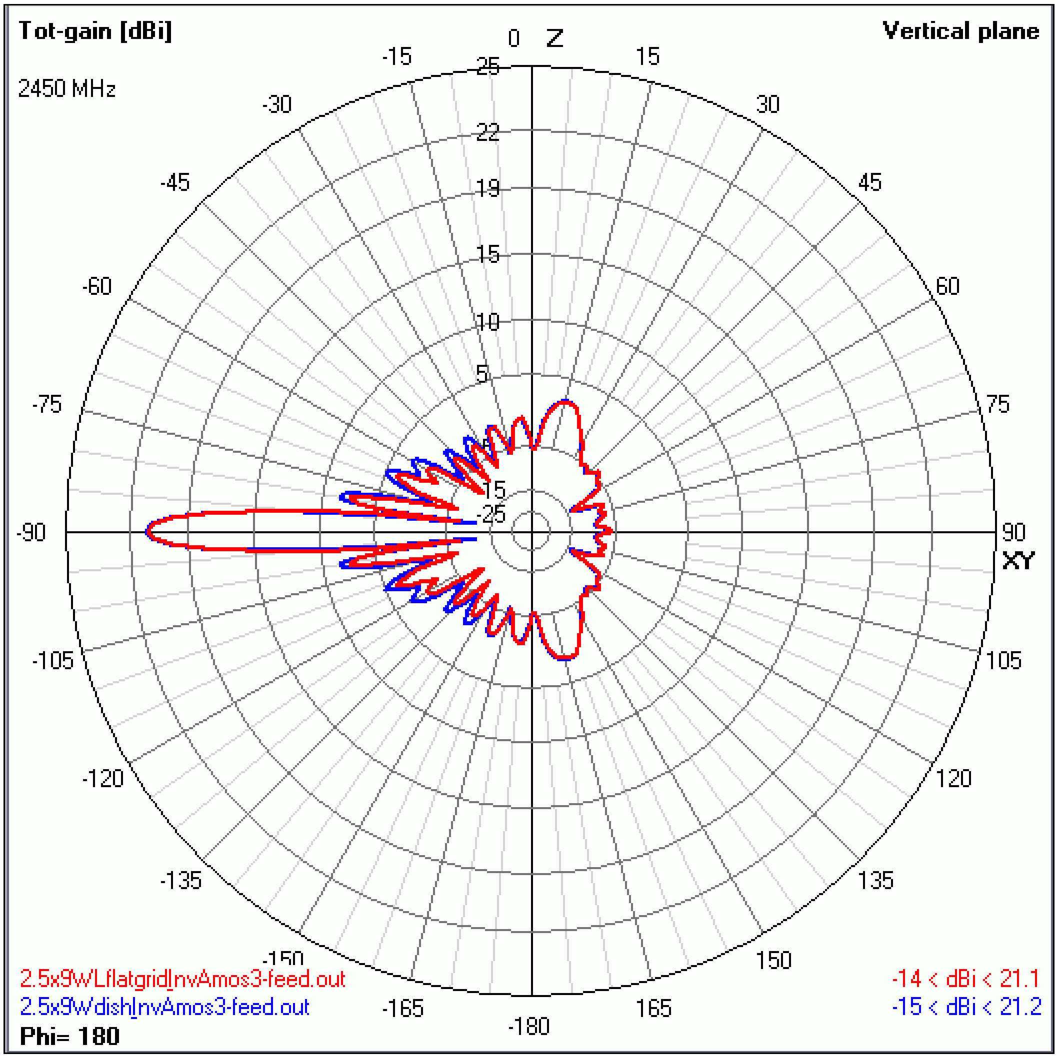

Fig. 9: Short linear feed (Inv. Amos 3 antenna) illuminate classical and cylindrical 2.5 x 9 wavelength parabolic reflector – vertical diagrams

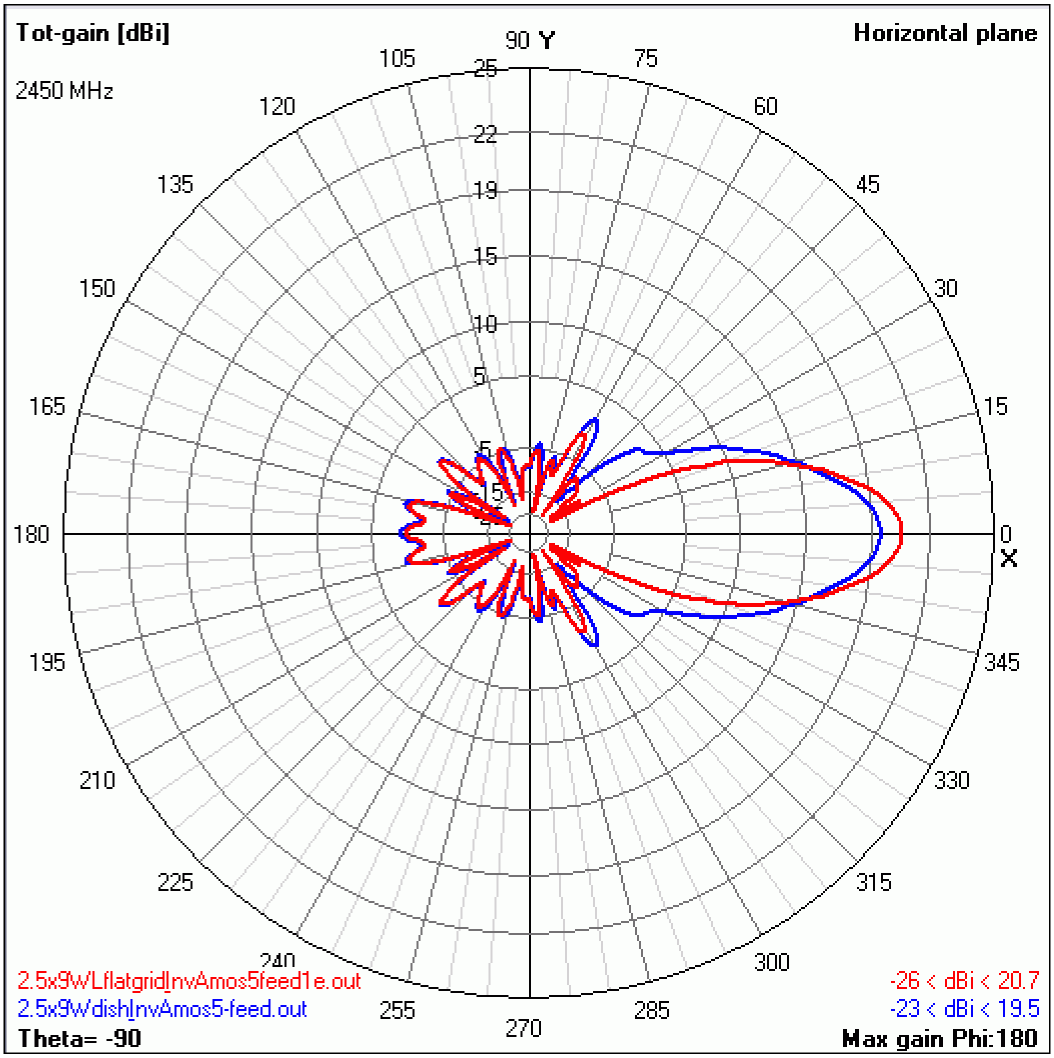

Fig. 10: Long linear feed (Inv. Amos 5 antenna) illuminate classical and cylindrical 2.5 x 9 wavelength parabolic reflector – horizontal diagrams

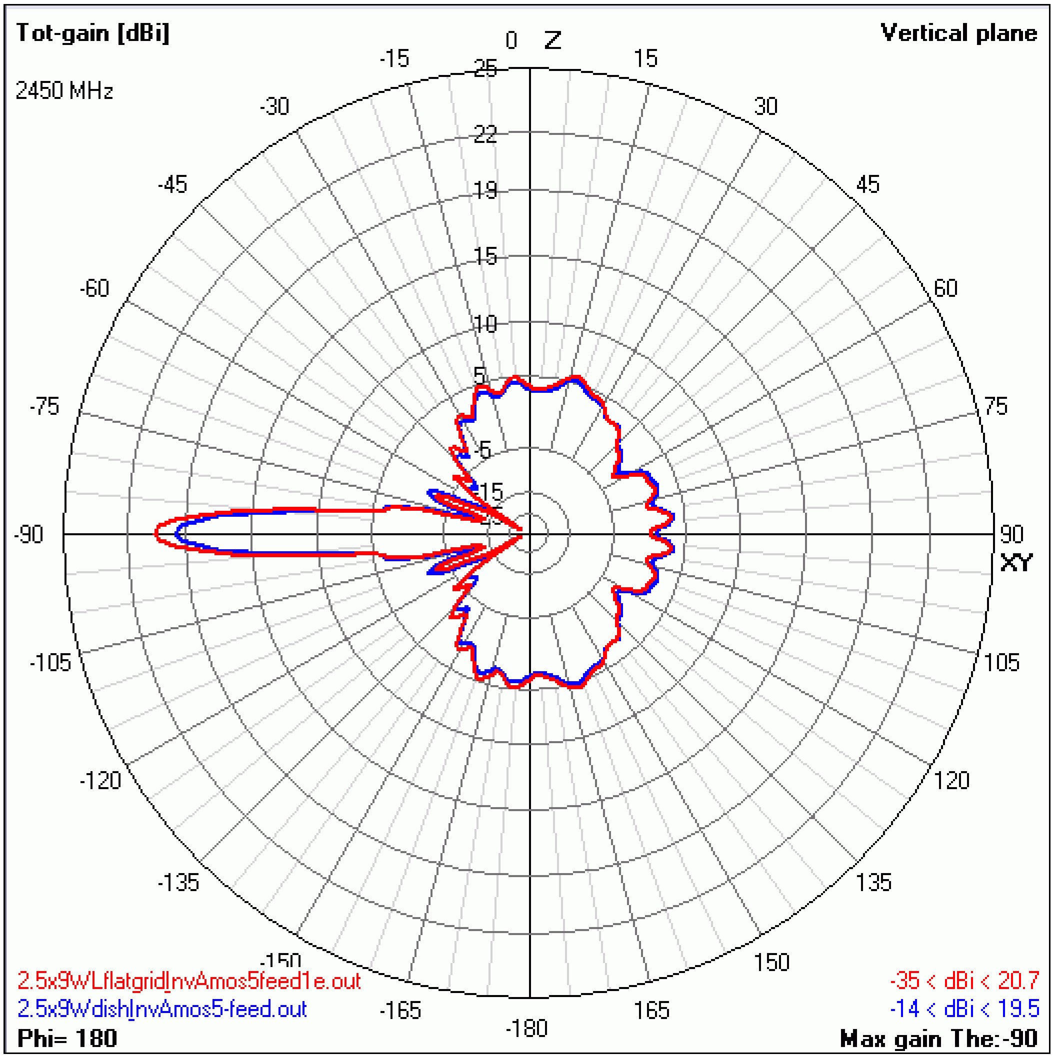

Fig. 11: Long linear feed (Inv. Amos 5 antenna) illuminate classical and cylindrical 2.5 x 9 wavelength parabolic reflector – vertical diagrams

It can be clearly demonstrated on Fig. 8 and 9 where same Inverted Amos 3 feed is used with two different reflector types. First one is the classical parabolic dish and second is the cylindrical parabolic dish both of the same size and focus distance.
From the diagrams it is obvious that the classic dish, with its curvature, compensated some phase errors in horizontal plane which are introduced by not ideal (too short) linear feed.
Using longer linear feed with 5 dipoles shows that such phase errors don't occur, see Fig 10 and 11. But the longer feed produces higher side and back lobes due to higher spillover. In spite of that, the cylindrical parabolic dish produces over 1 dB higher gain than the classic parabolic dish with same, long feed.
The Inverted Amos antenna feed with more dipoles, for instance 7 or 9 dipoles, gives better approximation to true linear feed but its horizontal diagram becomes very narrow and needs very narrow strip of parabolic surface for high efficiency.

It becomes obvious that the Inverted Amos antennas with 3 and 5 dipoles are the best compromise between:
1. as short as possible feed in order to preserve wide enough feed diagram, and
2. as long as possible feed to better approximate linear feed.

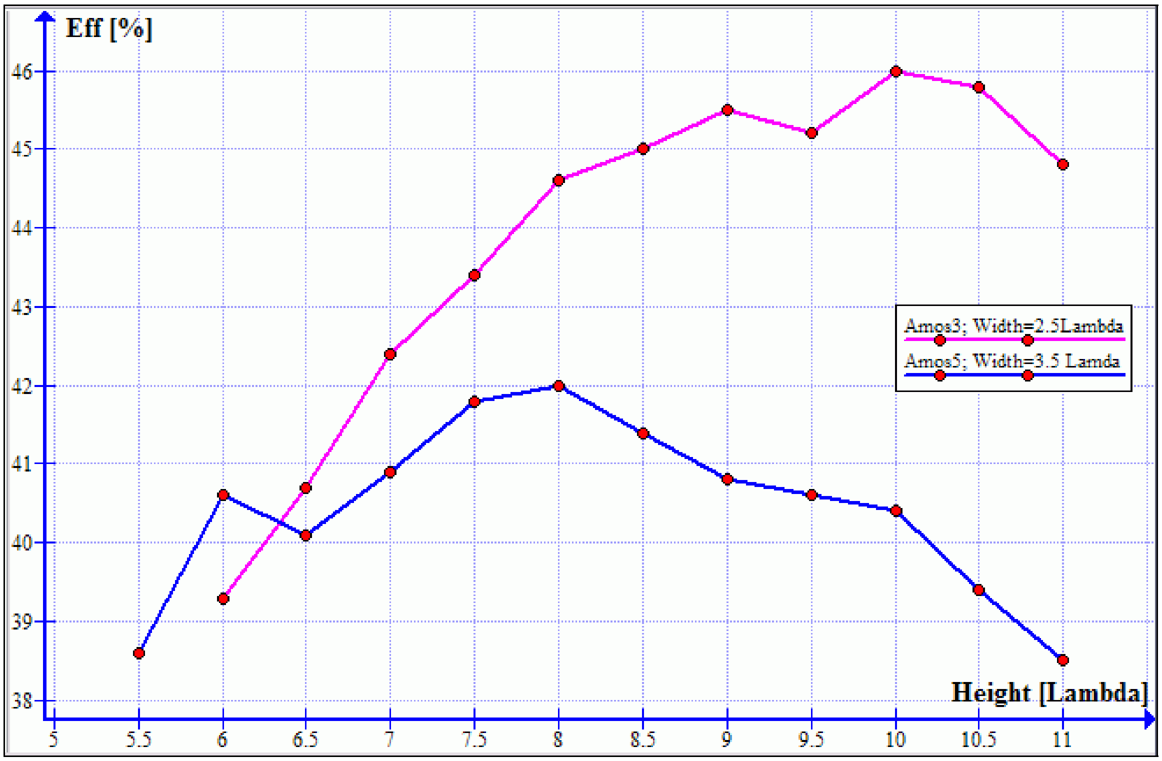

Fig. 12: Cylindrical parabolic reflector efficiency for various reflector's heights, two constant widths and different linear feeds

How high should cylindrical surface be?
First, I wanted to examine how high should cylindrical surface be for the optimum illumination efficiency. For this test I decided to use reflector surface which is the same or little wider of Inverted Amos 5 feed's reflector width, which is 3.3 λ wide.
Second test was with Amos 3 feed whose reflector is 1.55 λ wide.
With the fixed focus distance of 4.32 λ and surface width of 3.5 and 2.5 λ, I changed surface height from 5.5 to 11 λ monitoring antenna gain **G**. Results are compared to gain **Go** of the same, 100% efficiently illuminated, surface area: **Go=4*PI*A**, where **A** is the cross section (aperture) of the parabolic surface area given in square wavelengths.
Then we get illumination efficiency as antenna gain ratio: **Eff= G/Go**, where **G** is gain of antenna in numbers, not in dB.
Results are given on diagram on Fig. 12.
Analysis of results shows that we got expected behavior of illumination efficiency with changing illumination taper by changing surface height which is similar to normal rotational parabolic reflectors.
The only exception from that is small increase in efficiency with very small reflector height which corresponds to very low illumination taper.

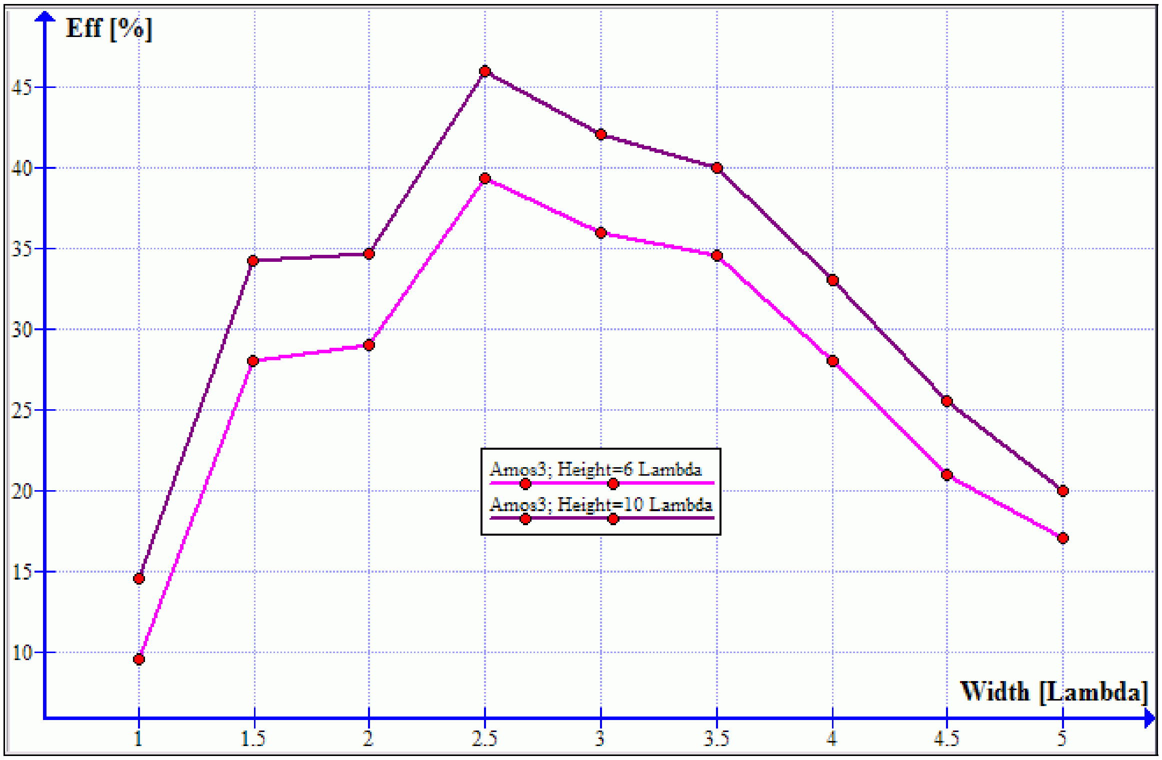

Fig. 13: Cylindrical parabolic reflector efficiency for various reflector's widths, two constant heights and short linear feed Inv. Amos 3 antenna

How wide should cylindrical surface be?
Similar examination has been done for surface width. With the fixed focus distance of 4.32 λ and choosing surface heights which in previous test gave some of the peaks of illumination efficiency I changed the width of the reflector surface from 1 to 5 λ monitoring the antenna gain.
Results are given in diagrams on Fig. 13 and 14.
As can be seen on diagrams there is again some unusual small efficiency increase at very low illumination taper.

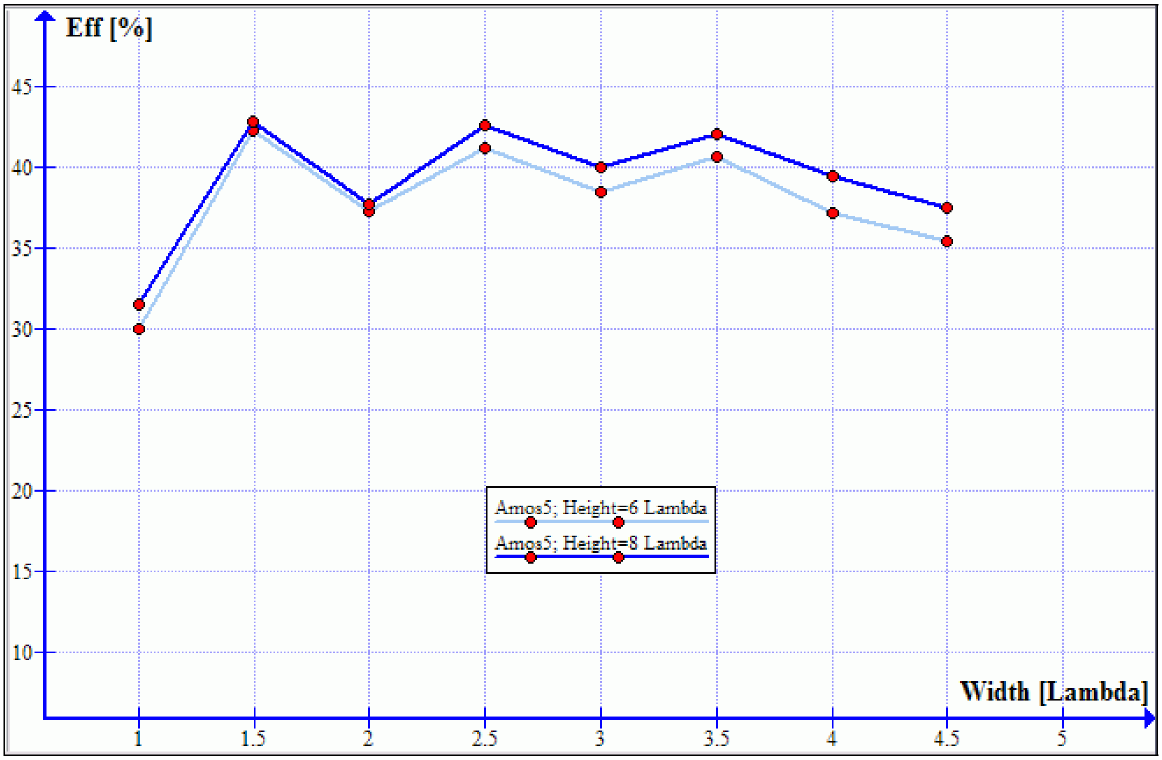

Fig. 14: Cylindrical parabolic reflector efficiency for various reflector's widths, two constant heights and long linear feed Inv. Amos 5 antenna

Analysis of results

It is interesting to compare results of illumination taper efficiency of the cylindrical parabolic reflector with results for the usual rotational parabolic reflector.

Height of cylindrical surface behaves in very similar manner as diameter for rotational surfaces. Antenna efficiency have broad peak at optimum illumination taper which is a compromise between spillover increase and illumination efficiency decrease due to under-illuminated surface at reflector periphery.

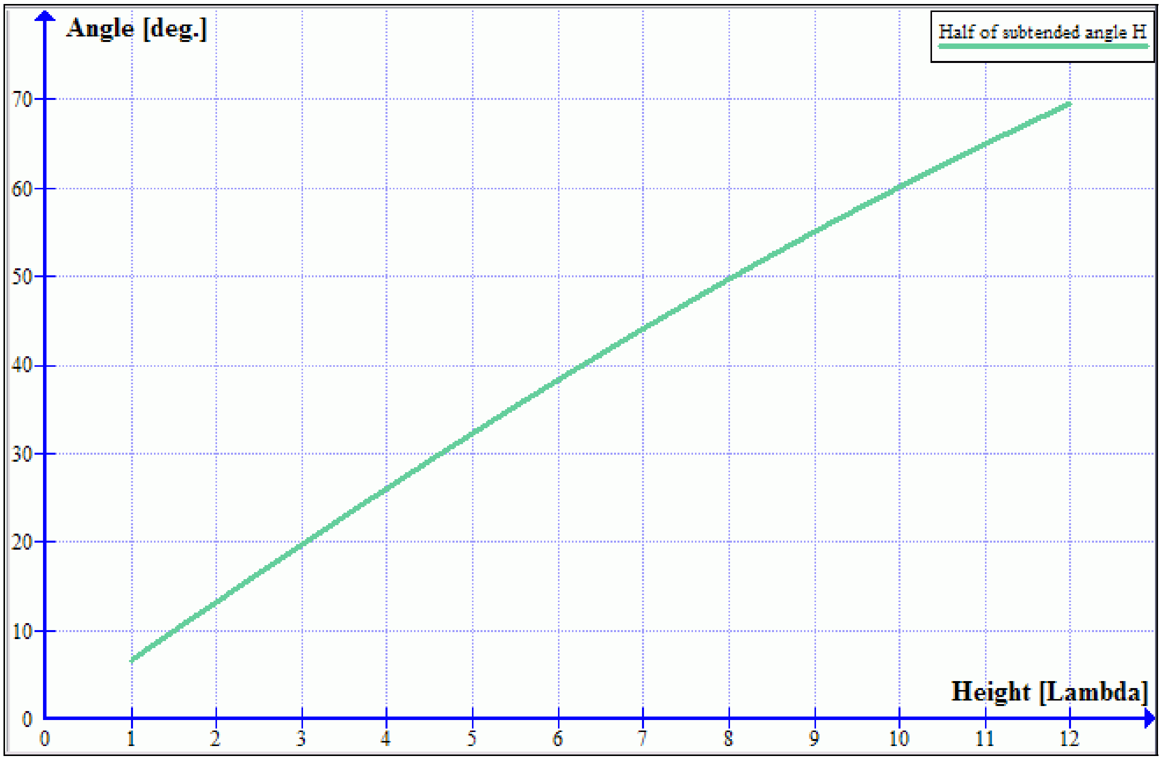

Fig. 15: Half of subtended angle of the cylindrical parabolic reflector for various reflector heights

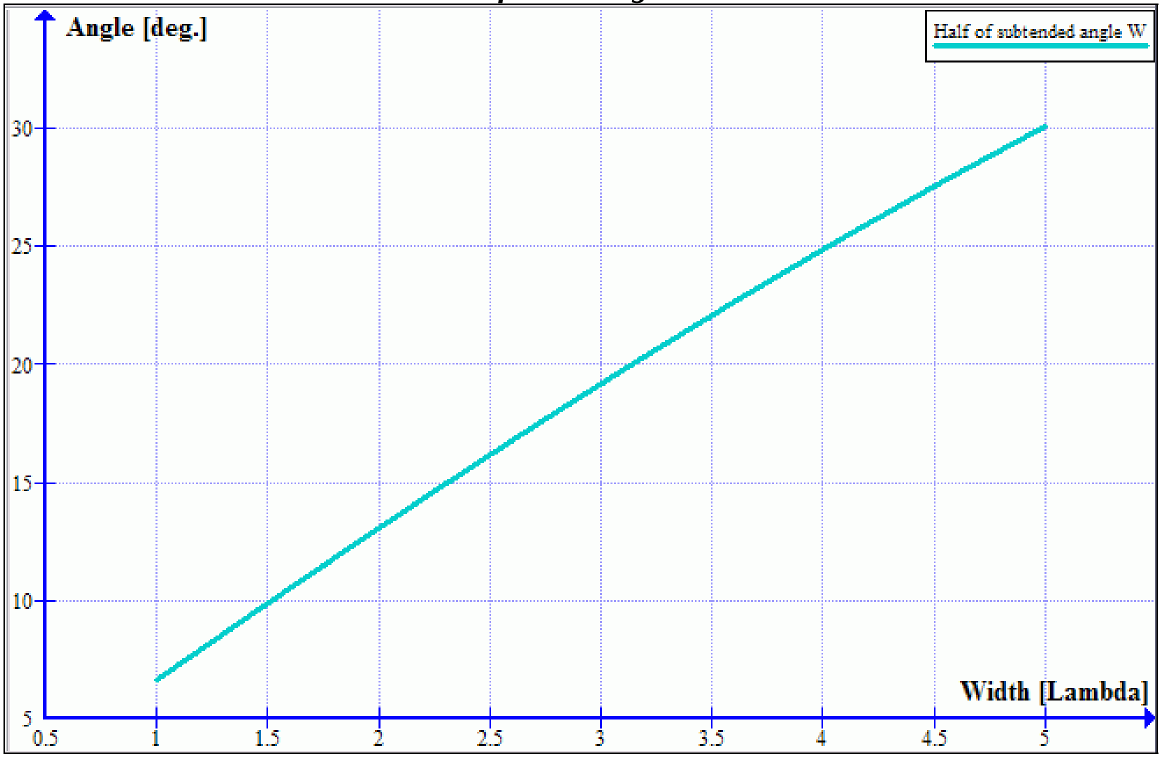

Fig. 16: Half of subtended angle of the cylindrical parabolic reflector for various reflector widths

Efficiency peak happens with feed illumination taper of about -5 to -9 dB with added space attenuation.
The best antenna efficiency for feed with 5 dipoles was achieved with 1.5 wavelength wide reflector which is 8 wavelengths high, for the cylindrical parabolic surface with focus distance of 4.32 wavelengths. This corresponds to illumination taper of -6 to -7 dB. Similar results are got for shorter feed with 3 dipoles. The best illumination efficiency is for reflector surface height of 10 λ and width of 2.5 λ which corresponds to illumination taper of -5 dB to -9 dB.
It is very similar as what we have with usual rotational parabolic reflectors which achieve their best efficiency with broad band of illumination taper values between -6 dB and -12dB.
Rotational structures, due to their radial symmetry, don't have any exception of this rule. But cylindrical structures behave little differently and show some deviation of that rule in low illumination taper range.

Table 1.
Illumination taper for various cylindrical parabolic reflector heights and feeds

Height	Half Sub. Angle	Space Attenuation	Inv. Amos 3 Illumination Taper	Inv. Amos 5 Illumination Taper
[λ]	[degrees]	[dB]	[dB]	[dB]
6	38	-1.1	-3.5	-4
8	49	-1.9	-6.5	-7
10	60	-2.7	-9	-10

Table 2.
Illumination taper for various cylindrical parabolic reflector widths and feeds

Width	Half Sub. Angle	Space Attenuation	Inv. Amos 3 Illumination Taper	Inv. Amos 5 Illumination Taper
[λ]	[degrees]	[dB]	[dB]	[dB]
1.5	10	-0.1	-2	-6
2.5	16	-0.15	-5	-12
3.5	22	-0.2	-10	-10

This departure from rule can be exploiting to construct antenna with similar illumination efficiency which has different (very often more suitable) dimensions.
This led me to conclusion that it would be possible to achieve similar antenna efficiency with pretty smaller height of reflector surface, i.e. with lower illumination taper.
I decided to try 2.5 x 6 wavelength reflector with longer feed, according to results I already got for various dimensions of cylindrical parabolic surface.

As I expected, I got very similar illumination efficiency for such little wider but considerably lower surface as for narrower and taller one. The difference in illumination efficiency is below 1%. See diagram on fig. 14.
It demonstrated that it is possible to arbitrary choose any of the diagram "peaks" on Fig. 12, 13 and 14, for antenna height, width and feed type, and construct antenna with still good efficiency. This opportunity gives some flexibility in construction of appropriate cylindrical parabolic reflector for purposes where dimensions and aspect ratio are of any consideration. This can justify using cylindrical parabolic reflector even though it can give little lower overall antenna efficiency then usual rotational type of parabolic reflector with point source feed.

Conclusion

According to presented analysis we can conclude that the collinear antennas Inverted Amos with 3 and 5 dipoles can be successfully used as linear feeds for cylindrical parabolic reflectors.
Some deviation in efficiency under various illumination taper compared with efficiency of usual rotational parabolic reflectors can be used for the construction of cylindrical parabolic reflectors with different width to height ratio but without high loss in antenna efficiency. It shows flexibility to surface aspect ratio maintaining good efficiency.
These structures show pretty high tolerances to different illumination taper keeping relatively good antenna efficiency.
Construction of cylindrical parabolic surface is much easier than usual rotational parabolic surface. That gives some interesting opportunity for use at UHF/SHF bands.

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Reference

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BRIEF BIOGRAPHY OF THE AUTHOR

Dragoslav Dobričić, YU1AW, is a retired electronic engineer and worked for 40 years in Radio Television Belgrade on installing, maintaining and servicing radio and television transmitters, microwave links, TV and FM repeaters and antennas. At the end of his career, he mostly worked on various projects for power amplifiers, RF filters and multiplexers, communications systems and VHF and UHF antennas.

For over 40 years, Dragan has published articles with different original constructions of power amplifiers, low noise preamplifiers, antennas for HF, VHF, UHF and SHF bands. He has been a licensed Ham radio since 1964. Married and has two grown up children, a son and a daughter.