Unexplored Areas of 432 MHz Feeds

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Contemporary advances in Electro Magnetic (EM) simulation software have made simulation of even large problems possible on desktop Personal Computers. A main-frame computer is no longer needed for analysis like this. Having access to EM-simulation software at work made me try to make some new evaluation of dish feeds for 432 MHz.

My experience of both computer simulation and professional antenna range measurements is that simulations for these kinds of antennas can be quite accurate, but that few antenna ranges in the world are large enough to make accurate measurements at a relatively long wavelength like 70 cm. One also has to remember that both simulations and measurements will characterize the properties of a dish feed antenna in a different environment from the one where it will be used, in the dish. Still, the accuracy of the simulation results is good enough to be used for judgement of the feed qualities and for optimizing its performance.

This paper addresses various properties of 432 MHz feeds that may not have been explored to a great extent before. It starts out with the basic radiating elements and their properties as a background for further in-depth discussions on the specific issues. Many more details can be found in the longer version of this paper on the Conference DVD.

Background

Looking into what feed to use for my 5.5 m 0.37 f/D dish on 432 MHz caught my interest for properties of the existing 432 MHz feeds. This need also opened my eyes to the possibility to make use of EM simulation software to get the info needed for making the right choice. It all resulted in the 432 MHz feed comparison report published on my web page in December 2010 [1].

This work also resulted in improved versions of two feeds that are already well known – a loop feed with a 1λ reflector and a patch feed with a small reflector – as well as the possibility to improve the performance of the Dual Dipole feed by using a baffle on the reflector.

From this work, discussions have led to other 432 MHz feed areas and issues that could be explored with the aid of EM-simulation software. This paper addresses some of these areas.

Wanted Feed Properties

Before we look into the details of feeds and the deeper questions and issues, we stop for a moment and think about what we want from a feed for an EME dish.

1. Optimum illumination of the dish
2. Minimal radiation outside the dish, either at the sides or backwards
3. Low losses
4. Minimal dimensions for less blocking as well as mechanical reasons
5. Clean polarization properties (low cross polar radiation)
6. Stable phase properties as function of illumination angle (Theta) in all Phi-cuts.

Some of these basic requirements may be contradictory to each other – even more so for some combinations of f/D and dish size. We need to find the best compromise, as usual.

Basic Radiating Elements

Now we know what we are looking for, let us see what basic radiating elements can be used in 432 MHz feeds:

- Dipole
- Loop
- Patch
- Annular Ring

Are there any fundamental differences between these basic radiating elements? Not really.

All exhibit a broader radiation pattern in the H-plane than in the E-plane. This fact need to be taken care of in order to fulfil the first and second criteria from above. One modern fable I heard was that a loop could be bent into an elliptic shape in order to equalize the E and H-plane beam widths. This is **not** true; the H-plane is still wider, regardless how you shape the loop. Same thing considering a circular patch or not; the H-plane is still wider than the E-plane.

All of the radiating elements need a reflector in order to make a dish feed. The reflector design gives you some degree of freedom to optimize the performance to your specific needs. In general terms, a larger reflector gives a more narrow beamwidth (BW) and smaller reflector a wider BW. This paper will focus more on this issue later.

So, the choice of radiating element is more or less up to your preferences. Some small differences in the implementation may guide your choice. Some of the radiating elements are inherently more suited for the implementation of switchable dual polarization in a single element, namely the patch and the annular ring.

How to Tame the Feed

Here is how to go from the basic radiating elements to a well functioning feed.

Main beam properties

As stated above, the BW in the E- and H-planes is not equal for any of the basic radiating elements. This is not acceptable as we want the illumination to be uniform in all Phi-cuts. If one of them is larger than the other you have to make a choice of f/D for either over illumination in one plane or under illumination in the other plane. You will never get the optimum illumination for both planes at the same time.

This was observed many years ago and the dual dipole feed was created. Here two dipoles are stacked in the H-plane, thereby reducing the H-plane BW to be very close the E-plane BW. The dual dipole feed works very well with dishes with an f/D from below 0.45 to 0.55. Below 0.45 the dish becomes under illuminated and the efficiency declines. Above 0.55 the dish is over illuminated and the antenna temperature starts to rise due to the spillover ground noise contribution.

Another way to reduce the H-plane BW to resemble the E-plane was suggested by Kildal in 1982 [2] in the form of the Beam Forming Ring (BFR). The BFR can be used on dipoles, loops and patches with similar success. The performance of a dipole or loop with a BFR is very close the Dual Dipole feed and is suitable to the same f/D range.

If your dish is on the deep side, you need to broaden the E-plane BW instead of narrowing the H-plane. A smaller reflector with a baffle on the reflector edge will increase the E-plane BW to be close to the H-plane BW. The use of a small reflector with a baffle is well known in the literature, and has been called different names like cavity feed etc. (Caution: just using a smaller reflector without the baffle will result in unequal BW in E- and H-planes as well as reduced Front to Back Ratio.)

We have not yet seen any 432 MHz feed design that will match the 1296 MHz Kumar type waveguide feeds when it comes to efficiency. Here is clearly an area for further research.

Cross-polar discrimination

Cross Polar Ratio (CPR) is a parameter that is often forgotten. In the main beam direction it does not do much harm, except for stealing power from the wanted polarization if the CPR is very poor. But in other directions the cross polarized radiation picks up as much noise as the wanted polarization, so noise pickup from both polarizations needs to be as low as possible.

One observation from the this work is that feeds with elaborate matching and loading circuits exhibit much worse CPR performance than a simpler design. These circuits also tend to affect the symmetry of the far field phase properties and the phase error may become excessive.

The use of a baffle on the reflector may help to clean up the CPR in some of these cases.

Back and side lobes

Excessive back lobes are mostly seen on feeds with small reflectors. If the Front to Back Ratio (FBR) of the feed is in the order of 10 dB and exhibits about the same BW, it steals about 0.4 dB of power that will not be reflected correctly from the dish. It will radiate in the same general forward direction as the dish, but not as part of the beam that has been formed by the dish, so that is doing no good for you.

Again, adding a baffle to the small reflector will improve the FBR dramatically. An FBR of 15 dB or better is a good figure to aim for and will give less than 0.15 dB of lost power.

Radiation at angles beyond the rim of the dish (including side lobes) will eventually see the ground and pick up noise in the receive case. Keep this radiation as low as possible. This is also a part of choosing the optimal feed for illuminating the dish in question as efficiently as possible.

Feed losses

In order to get as much power as possible to the dish in the Tx case and keep the antenna temperature down in the Rx case, we want to reduce the resistive losses as much as we can. Most of the feed designs today are designed with this in mind and do have minimal losses. I tried to make an estimation of the losses by simulation, but the losses were so small that they almost disappeared in the simulation accuracy of the feed. I think that most of the resistive losses come from the cabling close to the radiating element rather than from the radiating element itself. Keep all cables as short as possible and do not use excessive numbers of connectors and coaxial adapters. Use highly conductive material and high quality dielectrics in your feed designs to keep the losses to a minimum.

Putting the Feed in a Dish

Now we know a lot about how to get the most out of the feed by itself. But what may happen when we put the feed into our dish?

Dish reflection

When pointing a feed in the direction of the dish, a reflected wave from the dish will be present at the feed. The magnitude of the reflection from the dish depends on the wavelength, the focal length of the dish and the gain of the feed in the direction of the vertex of the dish.

The following expression can be used to calculate the reflection coefficient from the dish present at the feed [3]:

$$\Gamma = G \lambda / (4 \pi f)$$

where G is the gain (linear measure) of the feed in the direction of the vertex of the dish and f is the focal distance. This calculation is included in a small spreadsheet that can be found on my web page [4].

A few 432 MHz examples: My 5.5 m dish with f/D of 0.37 (2.04 m focal length) with the BFR Loop feed will give a return loss of 12.9 dB from the dish reflection alone. An 8 m dish with an f/D of 0.45 (3.6 m focal length) and a Dual Dipole feed will give a dish return loss of 16.1 dB. Values like this can clearly be seen on your SWR-meter and may deteriorate your station's performance. Tuning the feed in the dish is a delicate problem and need some work to find a practical solution. G3LTF presented a paper on this issue using stub matching [5]. K5GW reports that adjusting the feed to dish distance is a way to tune the match by getting the reflected wave out of phase with the inherent reflection of the feed. In that case, however, you need to pay attention to the focal distance and the phase centre of the feed while tuning. OK1DFC reports a more fortunate case, going from 30 dB return loss for the feed in free space to 50 dB when mounted at the focal point of the dish.

The situation for 1296 MHz is much better thanks to the shorter wavelength. For the same size dishes a VE4MA type feed in my 5.5 m dish will give about 28 dB dish return loss. For the 8 m, 0.45 f/D, a W2IMU dual mode feed will give about 26 dB dish return loss. This looks much better than on 432 MHz; but because the 1296 MHz feed will most probably be circular polarized, there will be a rotation reversal as the wave is reflected from the dish, which means that the reflected wave will not be seen on the Tx port but on the Rx port. So the change when the feed is mounted in the dish will be mostly in the Tx to Rx isolation, compared to any previous bench measurements.

Feed supports

It is always necessary to support the feed at the focal point of the dish. Have you ever wondered how this might interfere with the radiation properties of the feed? Will it destroy the good performance of the feed itself, and how may this affect the performance of the dish? Many different cases and configurations may exist; I just took an example to illustrate what can be expected.

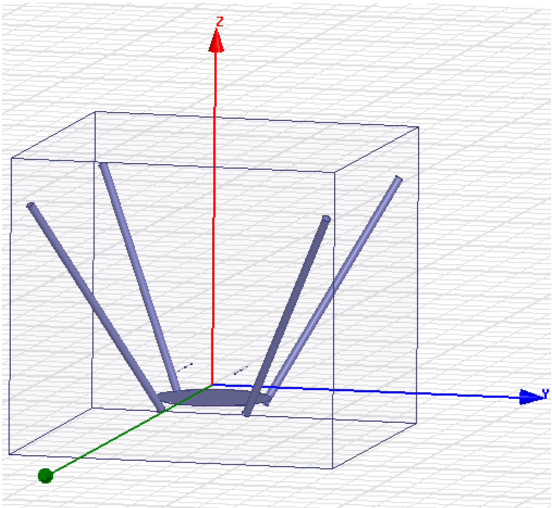
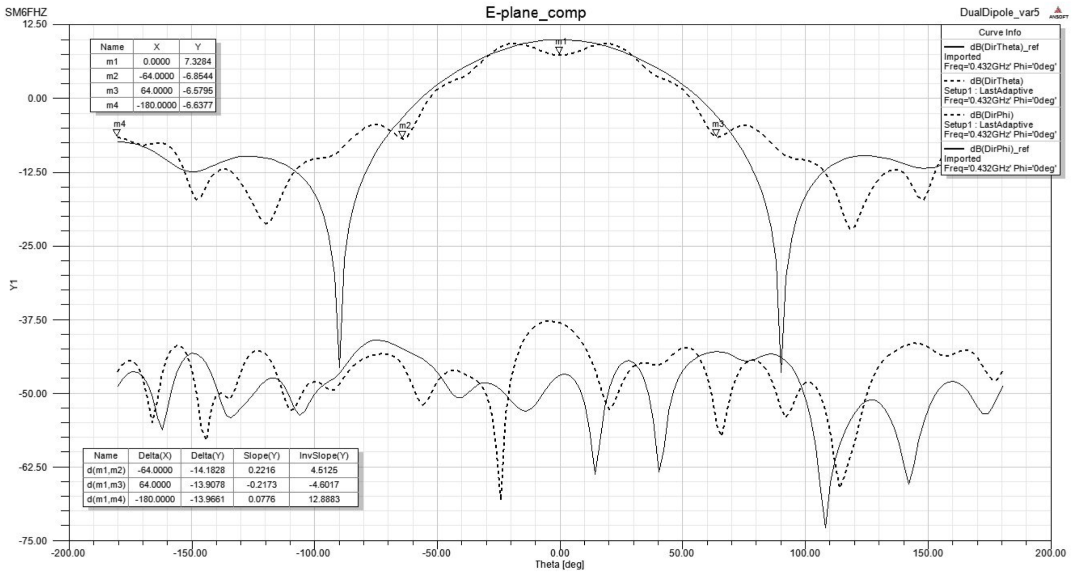


Figure1: Model for the simulated feed support structure, consisting of four 50mm dia metallic tubes with a length of 1600 mm. The feed is a dual dipole feed with 1λ circular reflector.

Figure 2: E-plane radiation plots for Co and Cross-polarization. Solid curves are the reference feed without the support structure; dashed curves are the pattern for the feed including the support.



As can be seen in Figure 2, the E-plane radiation plot, some interference from the feed support does arise. The nulls at 90° offset are filled out and the FBR is slightly reduced. The CPR is not affected to any large degree by the feed support. The H-plane radiation plots resemble the E-plane with similar degradation.

Figures 3 and 4 are Dish Efficiency graphs for the Dual Dipole feed, with and without the feed support (graphs generated by *Phasepat.exe* from W1GHZ [6]). As can be seen, the support does not destroy the performance of this particular feed. On the contrary, it improves the maximum efficiency by close to 5 % at an f/D of slightly below 0.5. The spill-over (antenna noise performance) is not negatively impacted either. Given this fortuitous improvement, the effect of the support legs can probably be optimized to improve the performance even further.

Figure 3: Dual dipole, no support

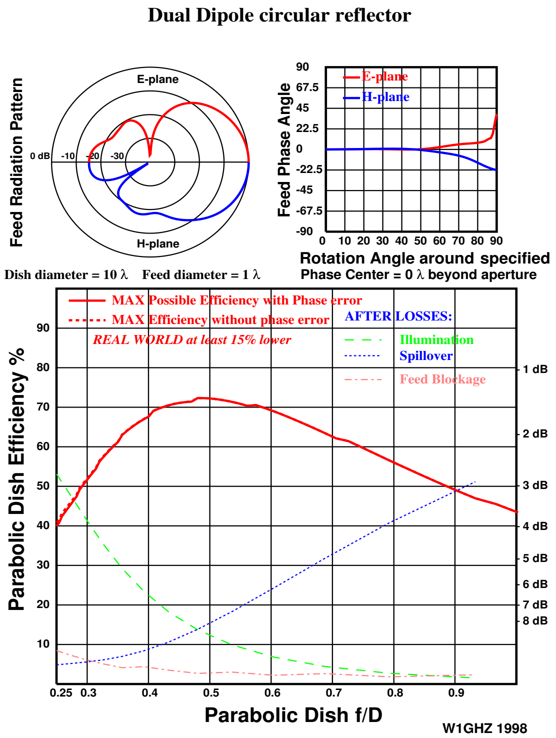
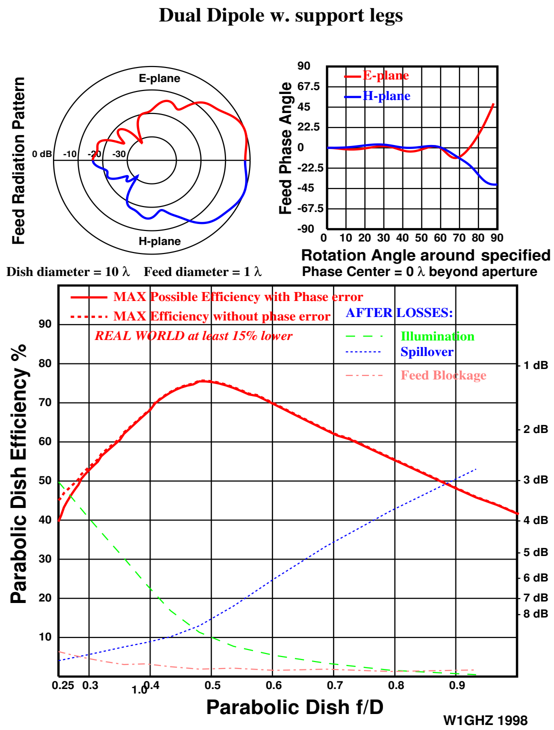


Figure 4: With support legs



Dual Band Configurations

One common Dual Band configuration is the Dual Dipole feed on 432 MHz and the W2IMU Dual Mode horn on 1296 MHz. Does the presence of the Dual Mode feed horn in the middle of the 432 MHz feed aperture makes any difference to the radiation properties of the Dual Dipole feed?

Figure 5 shows the simulation model consisting of two dipoles above a square reflector and the WG mouth part of the Dual Mode feed. The mouth of the 23 cm feed is 60 mm above the reflector surface (see note below).

Figure 5: Dual Dipole feed for 432 MHz and W2IMU horn for 1296 MHz

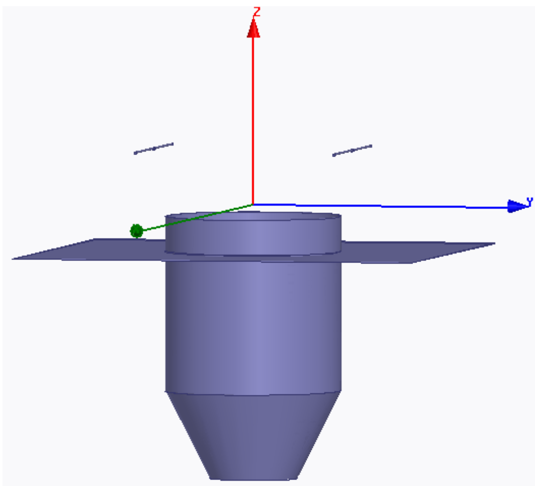
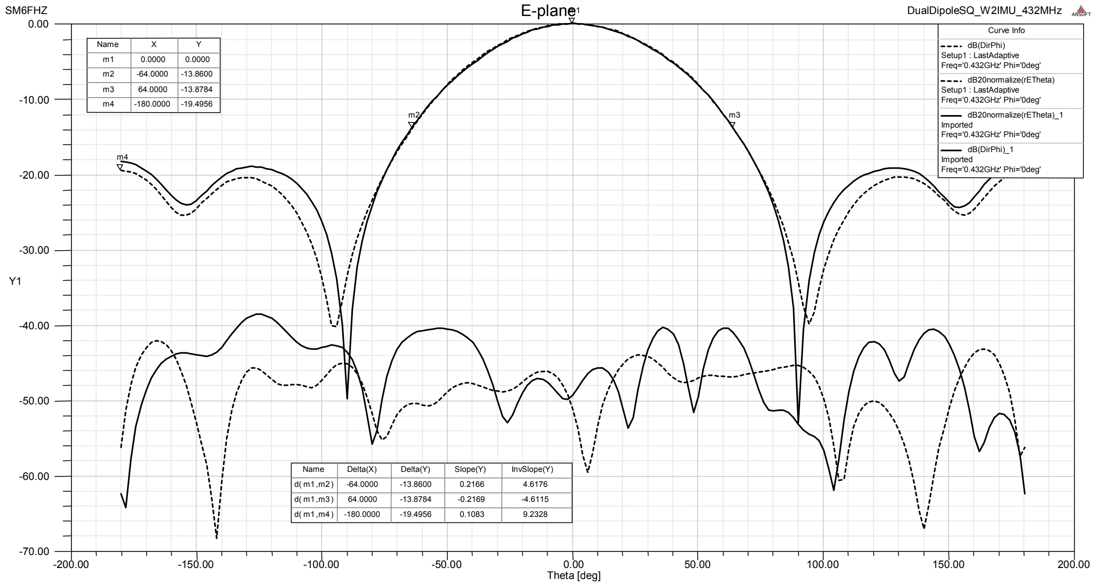


Figure 6: Dual Dipole feed for 432 MHz and W2IMU horn for 1296 MHz

Solid curves: reference Dual Dipole feed without the W2IMU horn.
Dashed curves: Dual Dipole feed with the W2IMU horn as shown above.



As can be seen in the graphs, the performance of the 432 MHz Dual Dipole feed is not degraded by the introduction of a the 1296 MHz feed in the centre of the reflector. On the contrary, it is slightly better with respect to spill-over and FBR. Not much impact from the 1296 MHz feed can be seen in the diagonal cuts either. The impact of the 432 MHz dipoles on the 1296 MHz feed performance will have to wait until a future report.

(Caution: the phase centres of the two antennas do not coincide in the model shown above. For a working Dual Band feed, the W2IMU horn needs to be moved another 20 mm forward. Radiation performance is still as good as before.)

Mechanical Tolerances

How sensitive is the RF performance of the feeds to mechanical tolerances? A few simulations reveal how careful you need to be in order to succeed in your feed project.

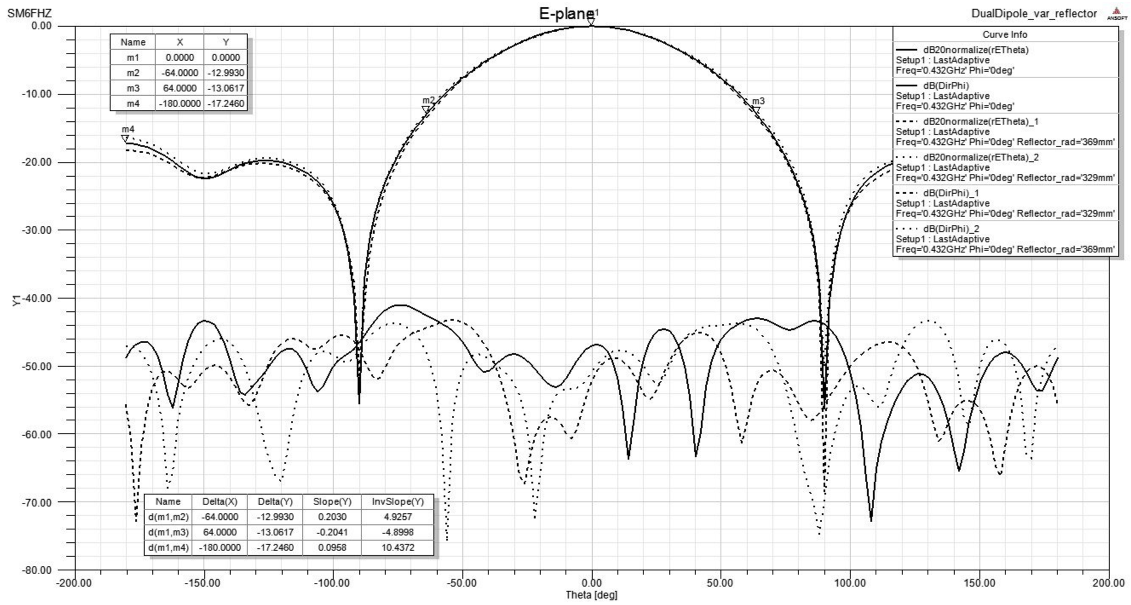
The feed that serves as an example is the Dual Dipole feed with 1λ circular reflector.

Reflector size: By varying the reflector radius in the simulation and studying the radiation properties, one can get a grasp of how sensitive the feed is to such variations.

As can be seen from the graphs this feed is quite insensitive to these variations. The H-plane variation performance resembles the E-plane performance shown in the graphs.

Figure 7: Variations in reflector radius

Solid curves: reference reflector radius
Dotted curves: 20mm larger radius
Dashed curves: 20mm smaller radius.



Dipole-reflector distance: Varying the dipole height over the reflector in the simulation and studying the variation in radiation properties show how sensitive the feed is for this variation. As shown in Figure 8, the feed performance is quite insensitive to variations of as much as 10 mm.

Dipole length: The dipole length determines the resonance frequency. A variation of the length of the dipole shifts the frequency for best impedance match. As shown in Figure 9, the feeds radiation properties are quite insensitive to the dipole length variations as well.

We can conclude that this Dual Dipole feed with 1λ circular reflector is quite insensitive to moderate variations in the major dimensions. The impact on the radiation pattern is very small for all three of the variations examined. The phase centre does not change to any extent that will alter the feed performance in the dish. The resonance frequency of the dipole changes as expected with the variation of the dipole length but this does not significantly affect performance in any other way.

Figure 8: Variations in dipole-reflector distance

Solid curves: reference distance
Dotted curves: 10 mm larger distance
Dashed curves: 10 mm smaller distance.

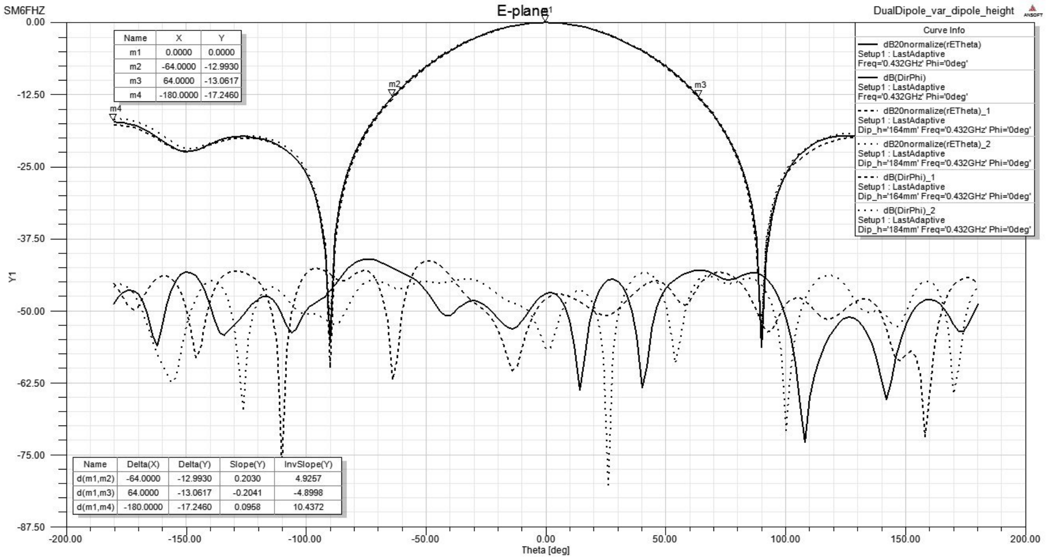
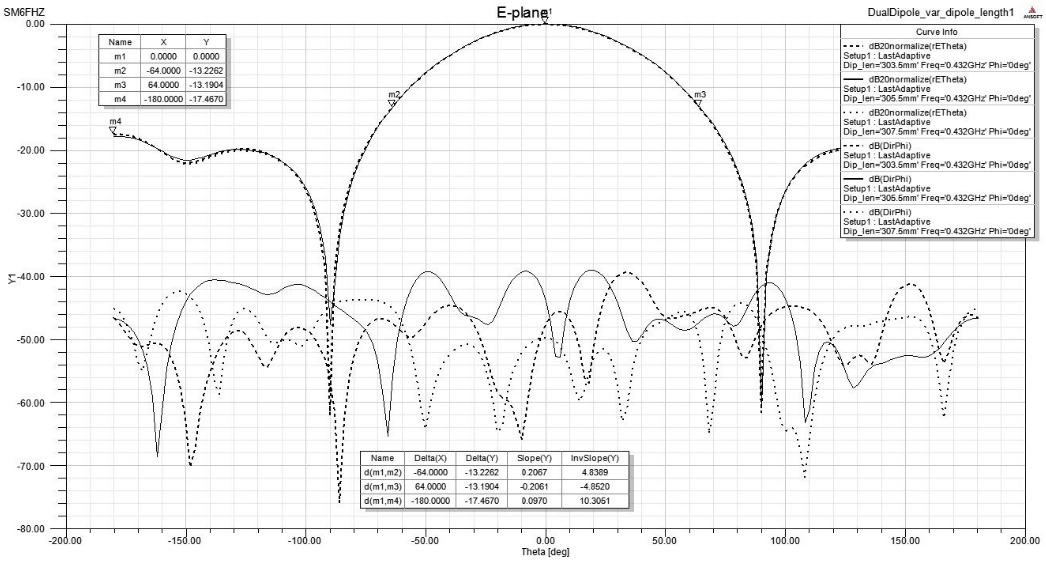


Figure 9: Variations in dipole length

Solid curves: reference length
Dotted curves: 2 mm longer
Dashed curves: 2 mm shorter.



Conclusion

In this paper I have given a few hints on the ideas behind how to plan and choose the feed for your dish. You can make a few choices when you plan your dish feed that will improve the end result if done in a sensible way.

It has been shown that a configuration of four metal feed support legs can have either the expected negative effect or, in at least some cases, an unexpected positive effect to improve the efficiency of a dish feed. This clearly offers opportunities for further investigation and even optimization.

By just scratching the surface of the myriad possible tolerance variations, one can see that they need not be catastrophic, but can indeed explain some loss experienced in a real world installation. In fact the Dual Dipole Feed shows only a small sensitivity to moderate variations of the dimensions, and it is sensible to expect that other similar feeds might exhibit the same behaviour.

I hope this paper will help and inspire some moonbouncers to take the next step and upgrade their dish with a feed for 432 MHz.

References

1. http://2ingandlin.se/Feed_comp_432_MHz.html
2. *Dipole-Disk Antenna with Beam-Forming Ring*, Per-Simon Kildal, Svein A. Skyttemyr, IEEE Transactions on Antennas and Propagation, Vol. AP-30, No. 4, July 1982, page 529 - 534
3. *Antenna Engineering Handbook*, H. Jasik et Al, McGraw-Hill Book Company, First Edition 1961
4. http://2ingandlin.se/Dish.xls
5. http://www.vk3um.com/G3LTF%20432%20eme%20feed%20v4.pdf
6. *Phasepat.exe*, W1GHZ Online Antenna Book, http://www.qsl.net/n1bwt/contents.htm