



A Novel 5 Step Septum Feed Suite

Swedish EME-meeting May 2013
SM6FHZ and SM6PGP

Updated Post Conference Issue

Outline



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- Features
- Design criteria / considerations
 - Wave Guides
 - Septum
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 - Probes
- Performance overview
- 23 cm 0.71 L W/G feed performance
 - Mechanical dimensions (for each feed)
 - Detailed information (for each feed)
- 23 cm 0.795 L W/G feed performance
- 9 cm 0.748 L W/G feed performance
- 6 cm 0.749 L W/G feed performance
- 3 cm 0.692 L W/G feed performance
- 3 cm 0.795 L W/G feed performance
- Realization
- On the air experience
- Lessons Learned
- Conclusions

Prerequisite

- I was in need for a new 23 cm feed to retrofit my 30 year old, ill built and corroded W2IMU feed. Then a need for feeds for the higher bands arose. What to do about that?
- Several existing 23 cm designs were available. I felt the performance had a potential to be improved with proper optimization using contemporary EM-simulation S/W
- Focus was put on f/D 0.32 to 0.42 (my 5.5 m dish is 0.37 f/D)
- N2UO adaptation of the W2IMU Dual Mode feed satisfies the need in the area of f/D's from ~ 0.42 to ~ 0.55
- The existing feeds for higher bands are mostly scaled versions of 23 cm feeds. I saw a opening for feeds specifically designed and optimized for the specific band to get the best possible performance
- I have learnt a lot about septums, chokes and wave guides along the way and have had a lot of fun and been frustrated as well at times

Features

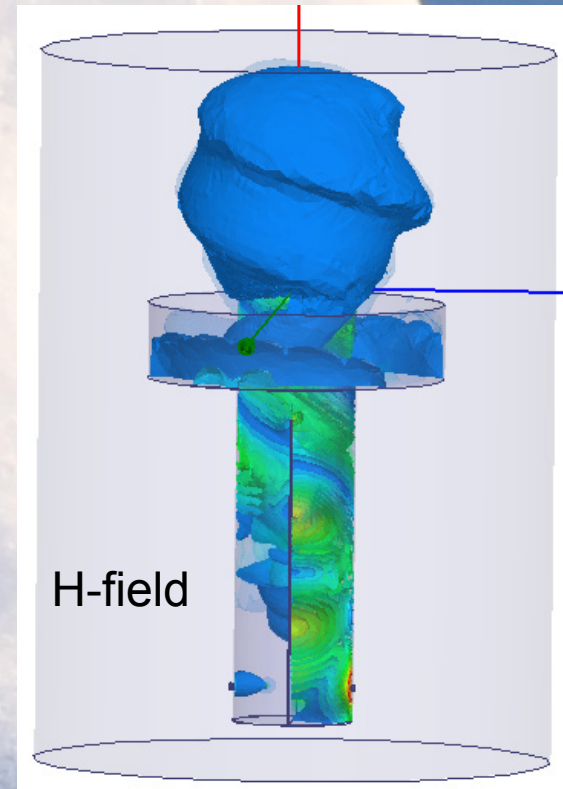
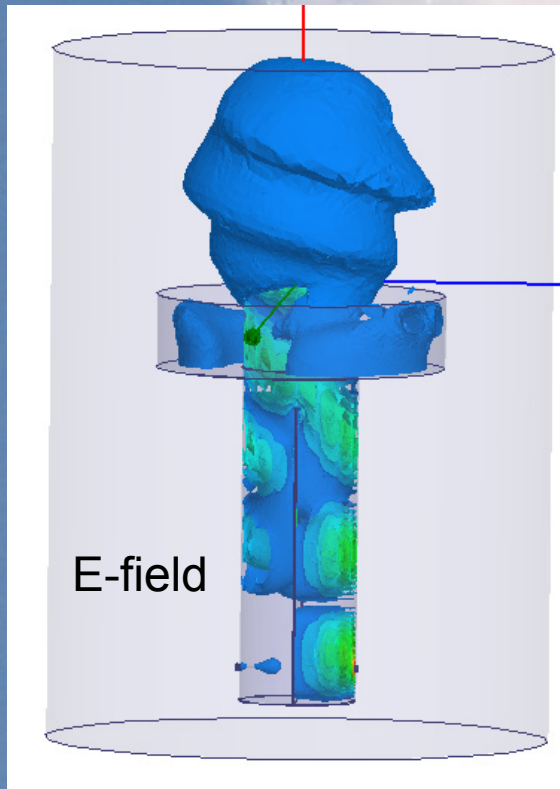
- Two 23 cm 5 step septum feeds for different f/D ranges
- 9, 6 and 3 cm feeds from standard metric plumbing copper or brass tubes
- Unprecedented top notch performance
- Focus on easy manufacturing and low tolerance sensitivity
- Suitable for f/D's ranging from 0.32 to 0.42
- The two 3 cm feeds cover both 10368 and 10450 MHz
- All comprising a Kumar choke structure

Design criteria

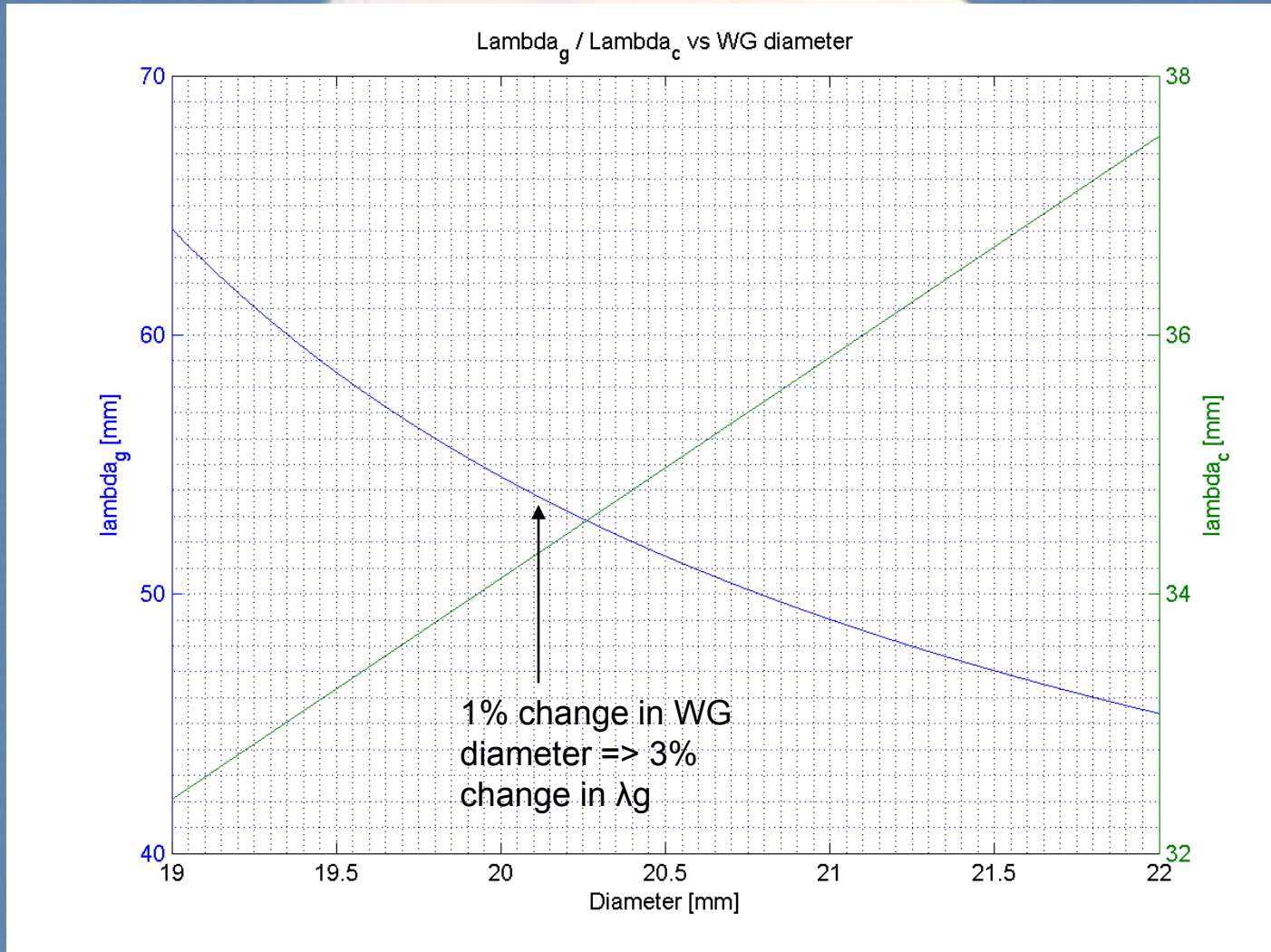
- We strive for
 - Optimum amplitude feed pattern
 - Flat phase response across the full dish surface (small phase errors)
 - Low axial ratio across the full dish surface (low cross polarization)
- We can not get all of this optimized at the same time, so we have to look for the best compromise.
- The W1GHZ feed efficiency evaluation S/W “Phase_CP” has been used for this evaluation.
 - This means that these results can be compared to the results of other feeds evaluated using the same S/W.
 - Phase_CP is the latest version of Pauls evaluation S/W and takes Cross Polar Radiation as well as radiation in the diagonal cuts into consideration for the performance calculation. The earlier version did not do that. This gives a more correct picture of the performance of each feed.
 - Phase_CP can be used for both circularly and linearly polarized feeds with great success

Wave Guide modes

- The lowest mode that propagate in a circular WG is called TE₁₁.

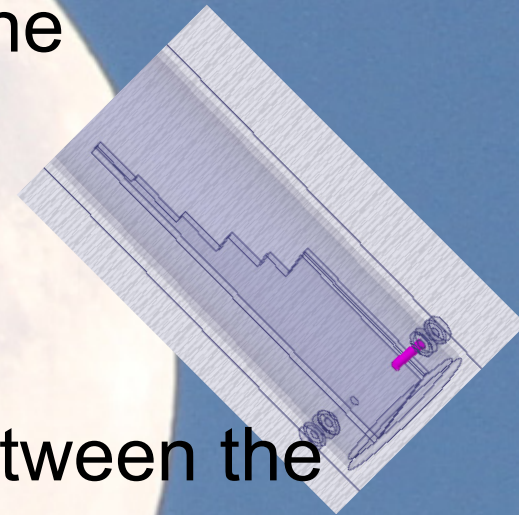


Wave Guide size and λ_g (10368 MHz)/ λ_c for TE11

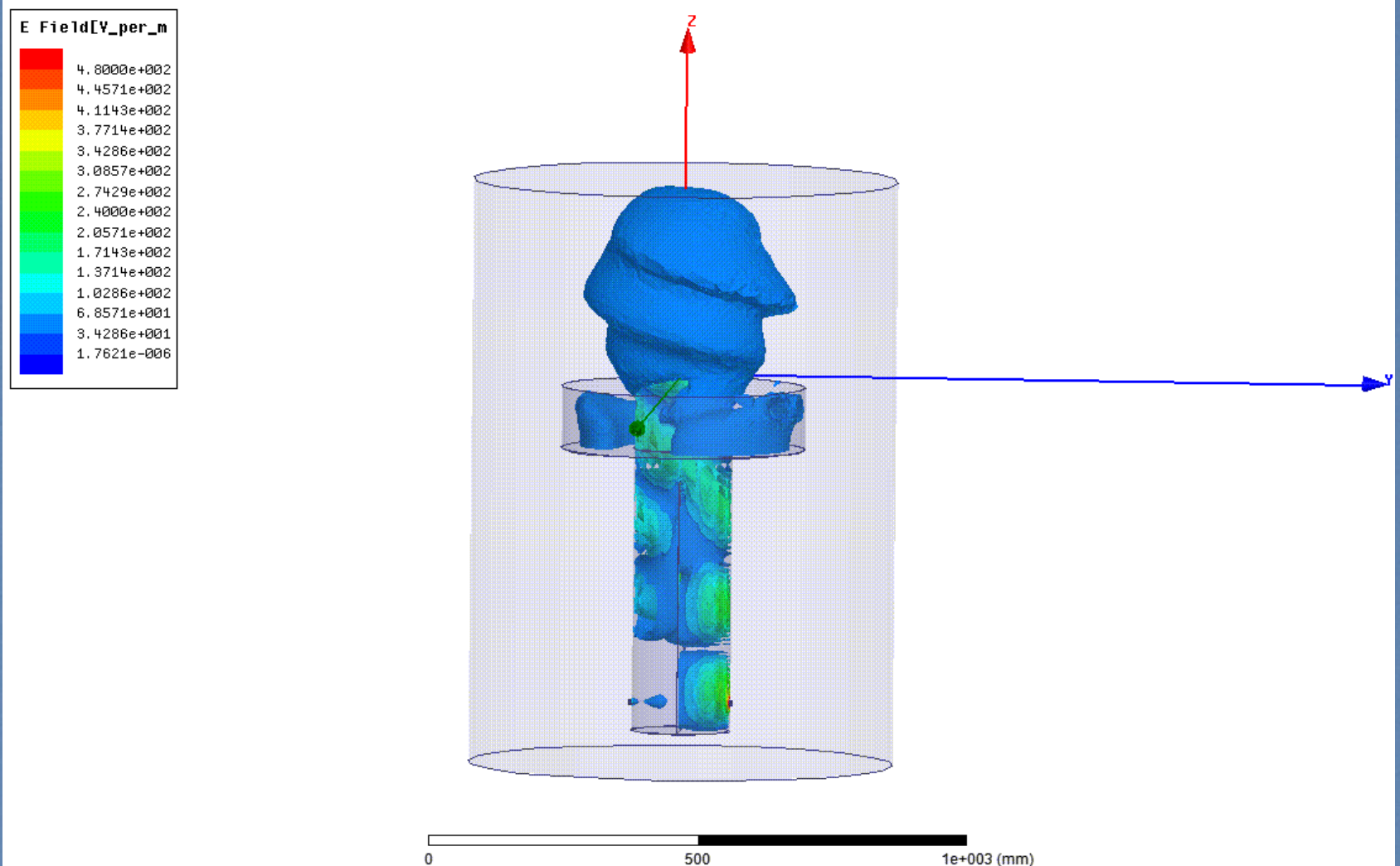


Septum considerations

- The septum shall generate a circularly polarized wave in a way that it contains only one polarization direction in each port. This ensures that we have
 - Good Axial Ratio
 - Low Cross Polar Radiation
- It shall also ensure good isolation between the two ports, Tx and Rx
- It shall do this over a reasonable band width
- In these designs this is accomplished by using a 5 step septum plate

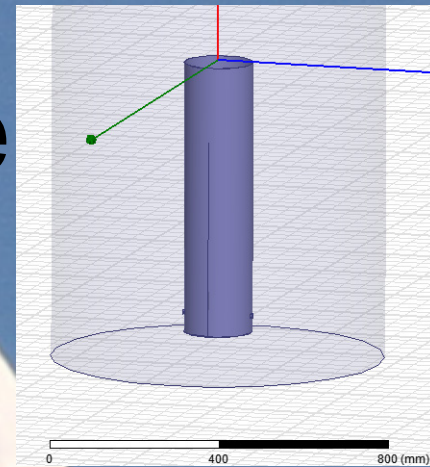


E-field variation over a full cycle

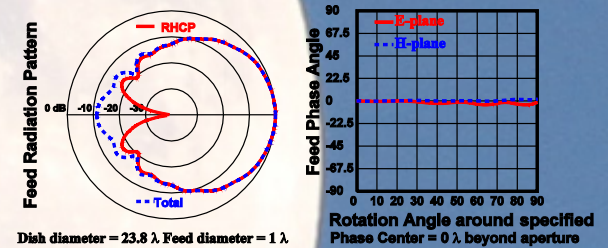
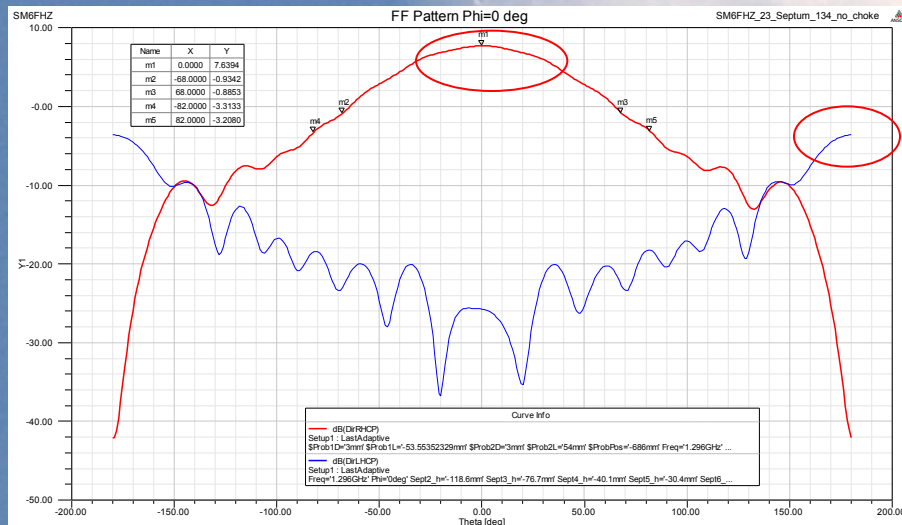


Feed without choke

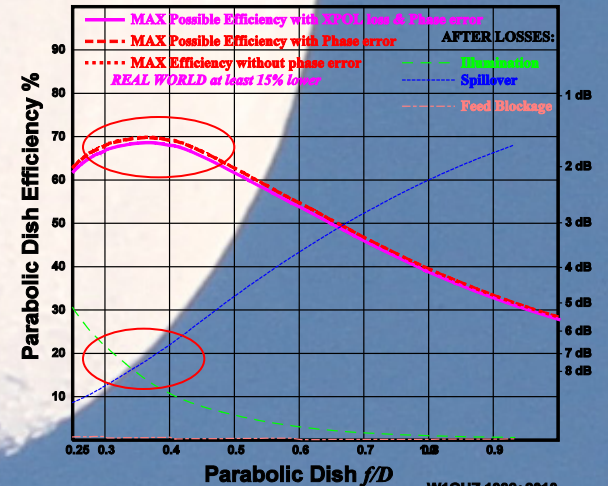
- No beam shaping in Co-pol
- High Cross-pol level in 180 deg
- Mediocre efficiency
- High noise temperature



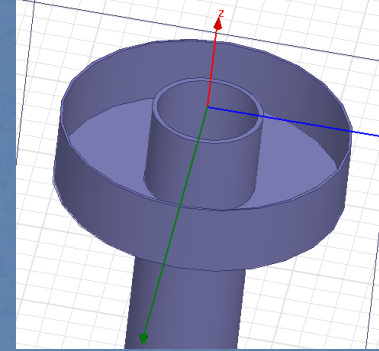
SM6FHZ 23 cm septum feed w/o choke



Dish diameter = 23.8 λ Feed diameter = 1 λ

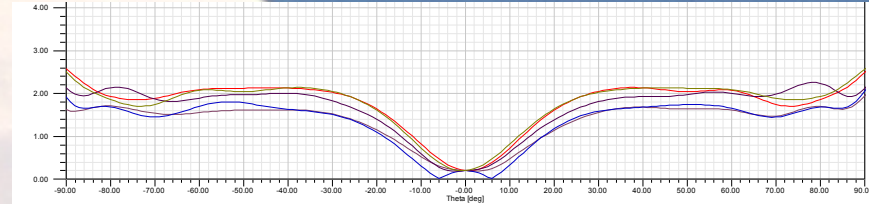


Why a Kumar choke?



- The Kumar choke is a efficient yet simple way of shaping the radiation pattern of the feed.
- It was first described by Dr. A. Kumar [Reduce Cross-Polarization In Reflector-Type Antennas, Microwaves, March 1978] and has been used by VE4MA in his feed designs.
- It has some limitations and interactions with the other parts of the feed.
 - The Axial Ratio at angular offsets from bore sight is controlled by the choke
 - The Return Loss and Isolation is not affected by the choke
 - The radiation pattern can be controlled by the position and the size of the choke
- Less elaborate than the Scalar choke but comparable or superior performance
- It can be optimized using EM-simulation SW.

Septum - choke interaction



- Axial ratio optimization
 - The septum sets the Axial Ratio at bore site and the choke governs the performance at angular off-sets from bore sight
 - The choke does not change the axial ratio at bore sight very much
- A well functioning septum is essential for getting a decent axial ratio also off bore sight

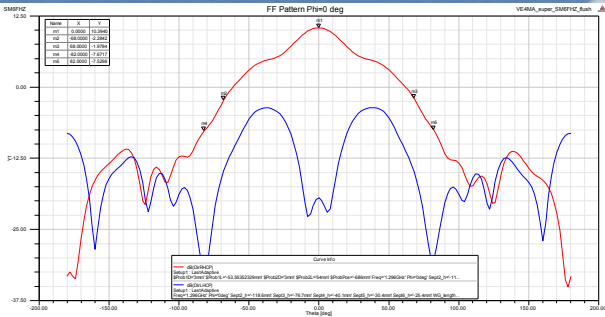
Choke impact on radiating pattern

- There is a contradiction between the wanted amplitude pattern and the phase error with respect to illumination angle
- By adjusting the choke position and dimensions you can find the best compromise
- Moving the choke with respect to the W/G mouth does not directly scale the feed pattern for other f/D 's. There is a price to pay.
- The best way to strive for optimal performance at other f/D 's is to change the dimension of the W/G mouth
- There are limitations on how much you can change the dimension of the W/G and maintaining the same W/G propagation mode
- W2IMU uses this in his “Dual Mode Feed” going to a higher mode as well as the first mode in the outer WG-section in an controlled way

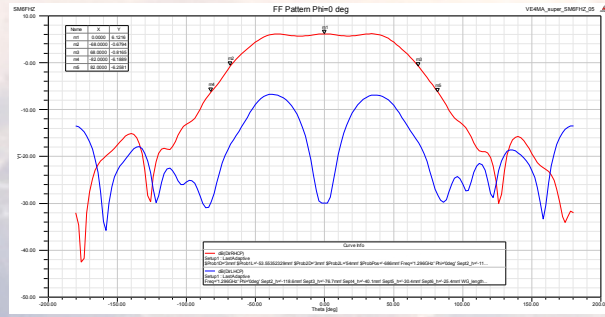
FF Pattern quick comparison

Choke position relative WG-mouth

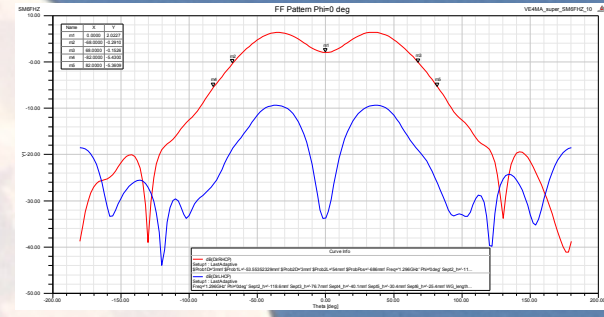
0L



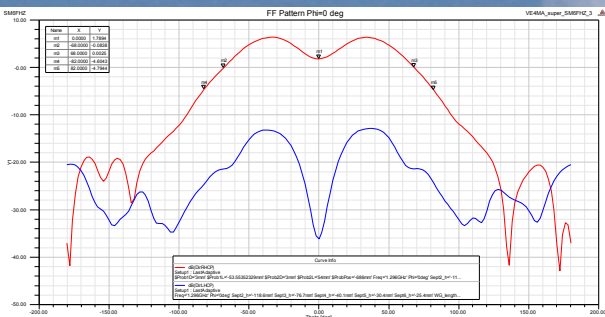
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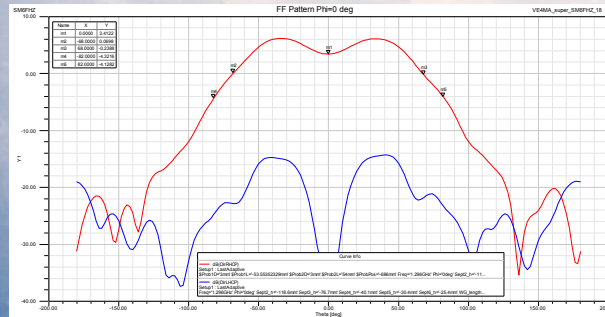
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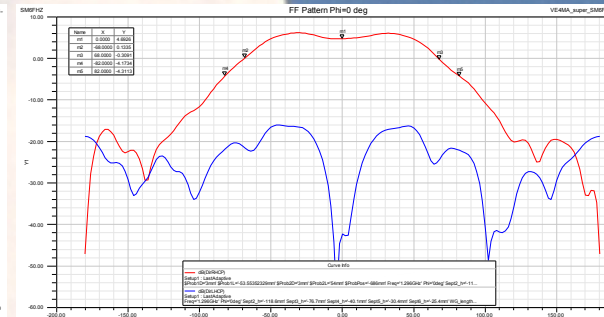
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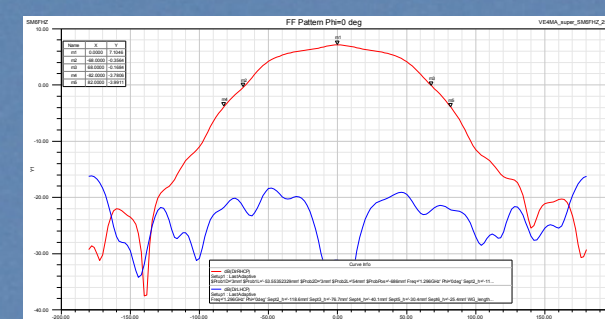
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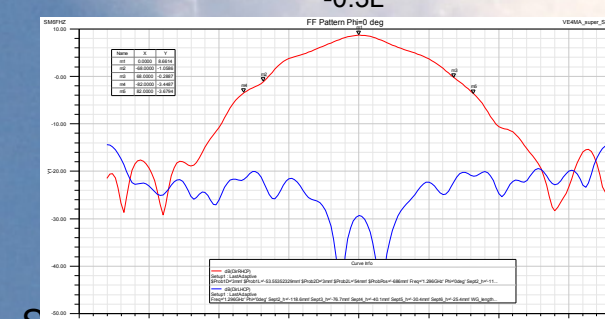
-0.2L



-0.25L



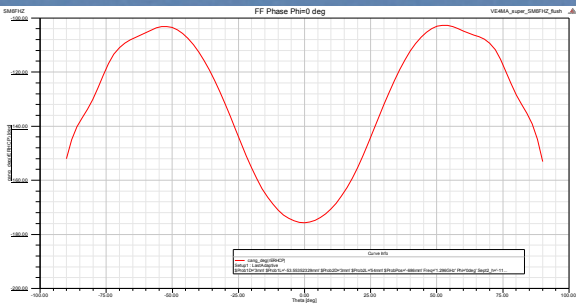
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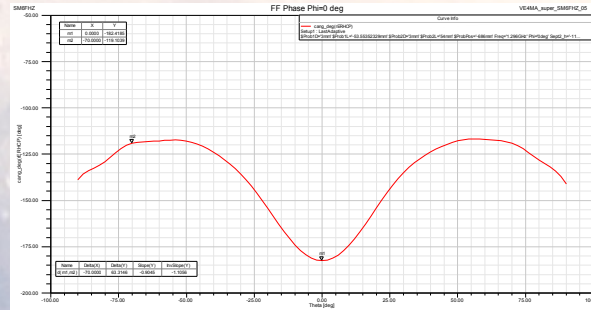
FF Phase error quick comparison

Choke position relative WG-mouth

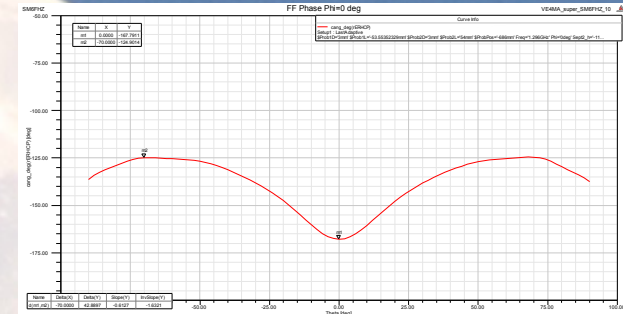
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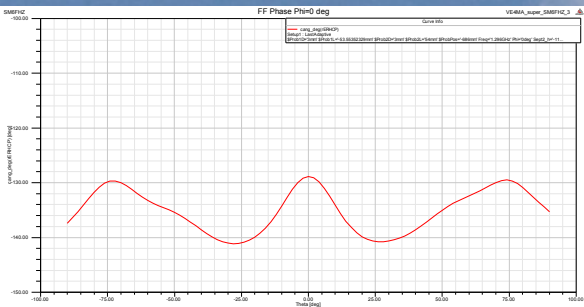
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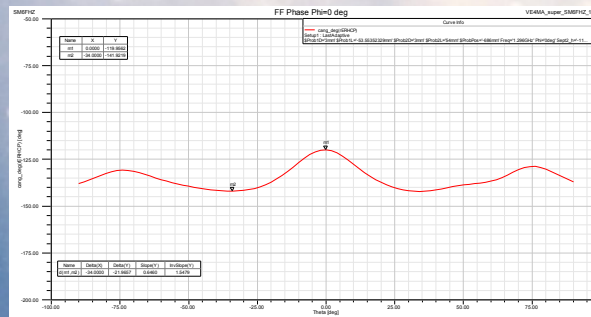
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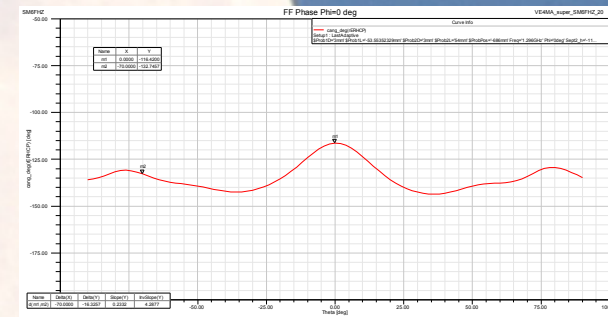
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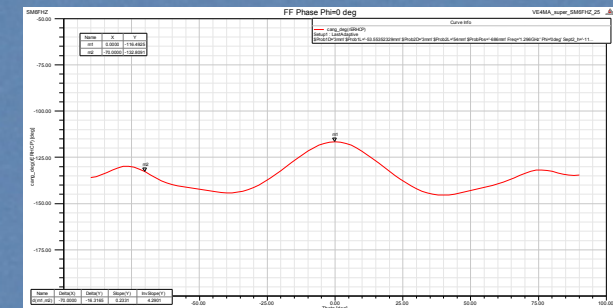
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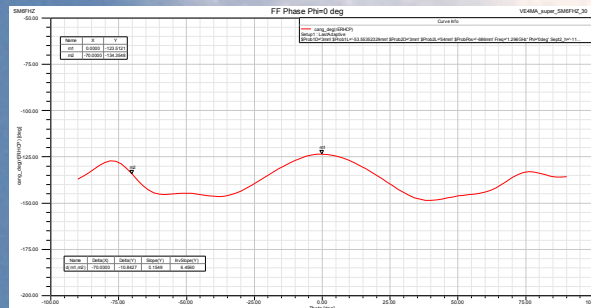
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-0.25L



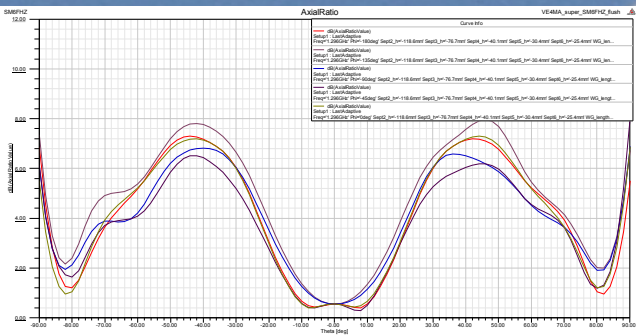
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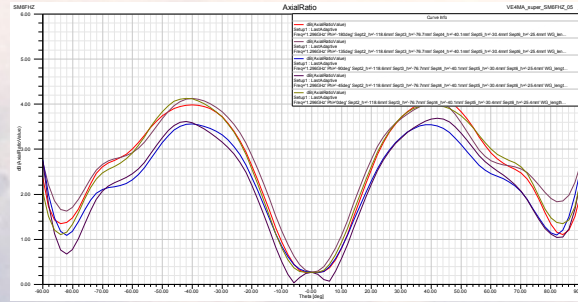
Axial Ratio quick comparison

Choke position relative WG-mouth

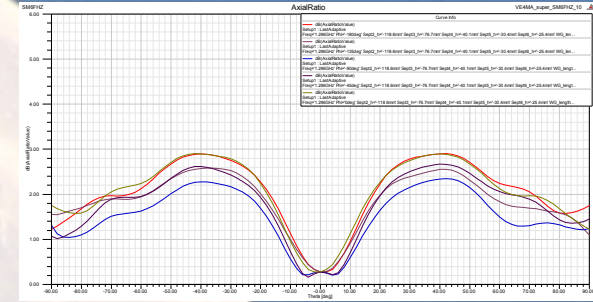
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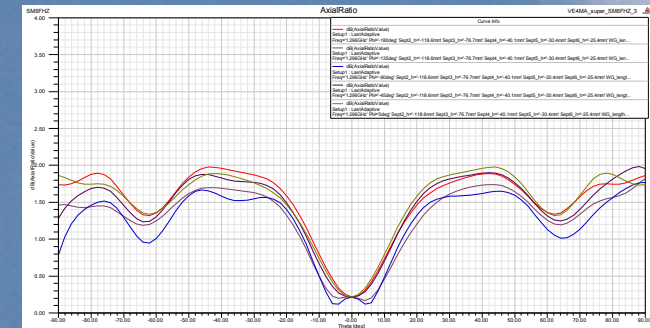
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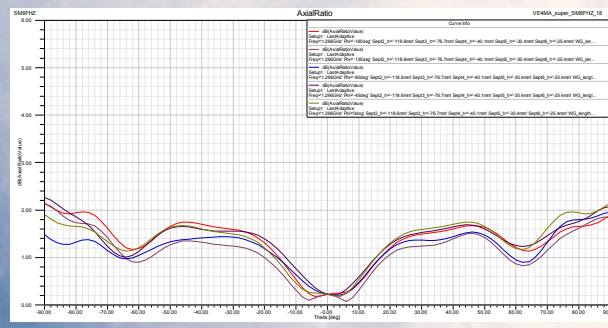
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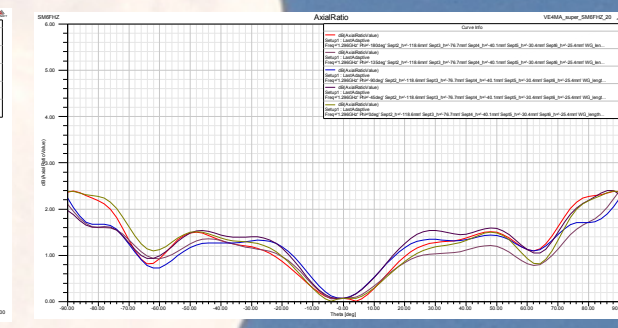
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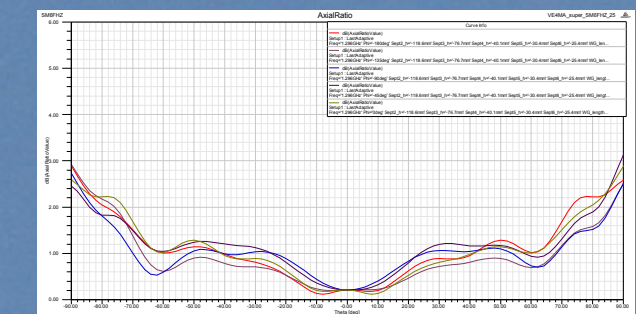
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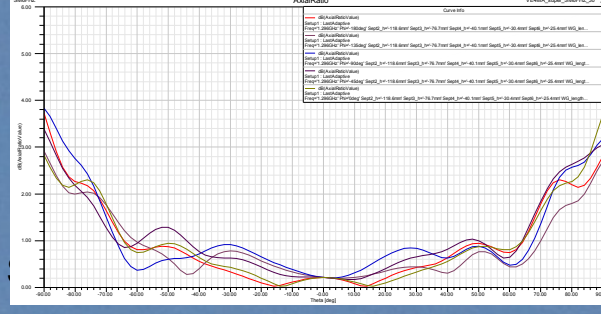
-0.2L



-0.25L



-0.3L



Putting the Feed in a Dish

Dish Reflexion

- Pointing your feed into the dish will result in a reflected wave from the dish entering the feed.
- The level of the reflexion coefficient (Γ) will be dependant on the gain of the feed (G), lambda (λ), and the focal length of the dish (f).

$$\Gamma = \frac{G\lambda}{4\pi f}$$

Putting the Feed in a Dish

Dish Reflexion

- How bad can it get?
 - With a linear feed you will see the reflected wave on the Tx port but with a circular polarized feed the reflected wave will show up in the Rx port due to the phase reversal upon the reflexion in the dish surface. This affects the isolation between Tx and Rx.
 - 1296 MHz, VE4MA type feed in a 5.5m, 0.37 f/D dish will result in 29 dB RL.
 - 1296 MHz, W2IMU type feed in a 8m, 0.45 f/D dish will result in 26 dB RL.
 - 5760 MHz, VE4MA type feed in a 5.5m, 0.37 f/D dish will result in >40 dB RL.
 - 5760 MHz, VE4MA type feed in a 2m, 0.37 f/D dish will result in 33 dB RL.
 - 10368 MHz, VE4MA type feed in a 5.5m, 0.37 f/D dish will result in 47 dB RL.
 - 10368 MHz, VE4MA type feed in a 2m, 0.37 f/D dish will result in 38 dB RL.
- A spread-sheet can be found on my web page for your own further testing.
- RA3AQ proposes using a small metal coin in the centre of the feed aperture in order to fine tune the isolation in situ. This need to be done specifically for each installation but can yield excellent isolation over a narrow frequency band
- Summary.
 - This reflexion is not a major problem on the higher bands on larger dishes.
 - If the reflexion is down below the 30 dB RL region you may consider to address it.

A large, bright, yellowish-white moon is the central focus of the image, set against a clear, deep blue sky. The moon's surface is detailed with numerous craters and darker, shadowed regions. The text is overlaid on the moon's surface.

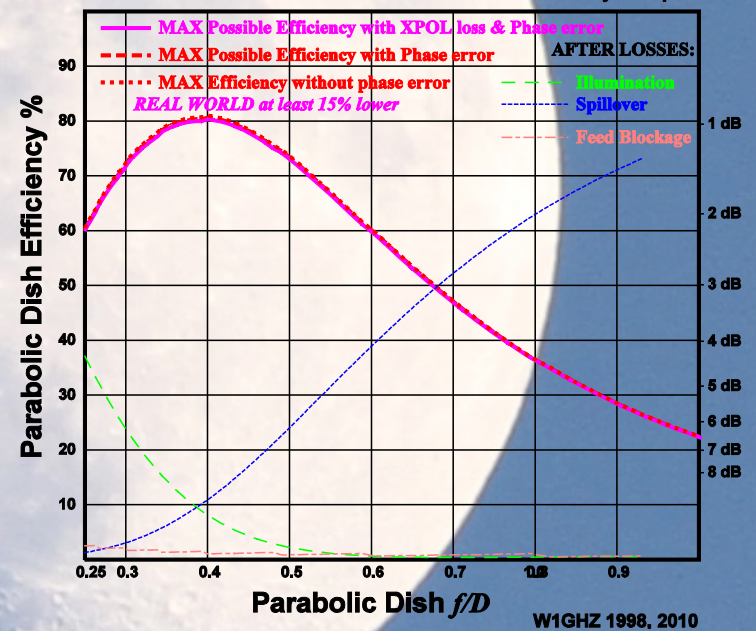
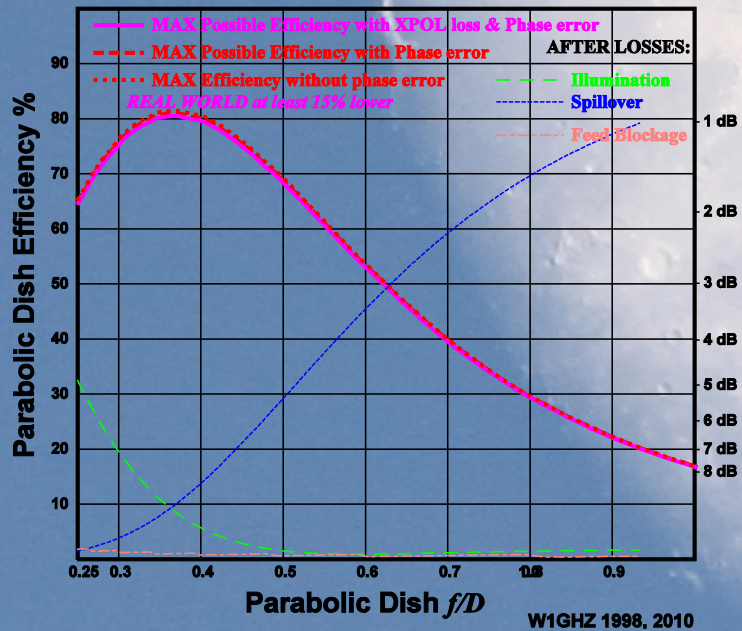
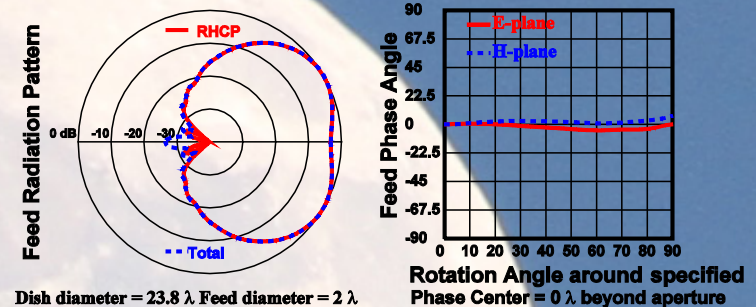
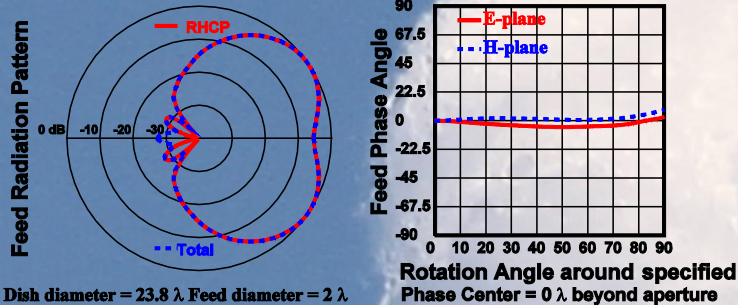
InDish Performance

A quick look at all 5 feeds

InDish Performance 23 cm (5.5 m dish)

SM6FHZ 23 cm Septum feed 0.71L WG

SM6FHZ 23 cm septum feed 0.795L WG



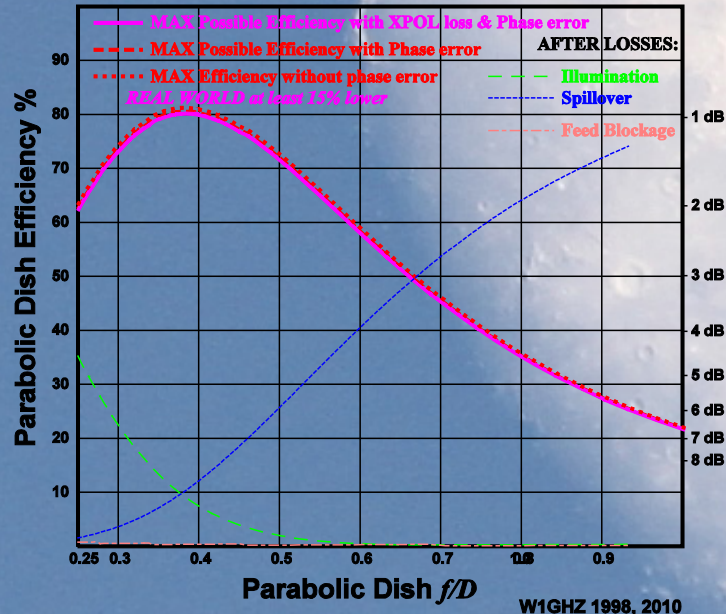
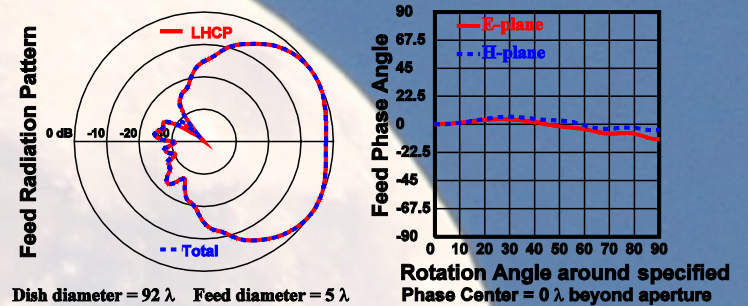
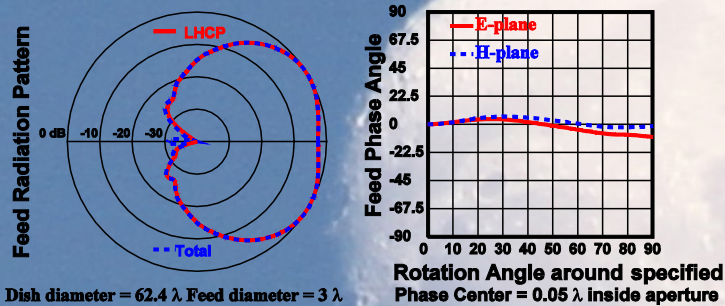
23 cm 0.71 L W/G feed performance

23 cm 0.795 L W/G feed performance

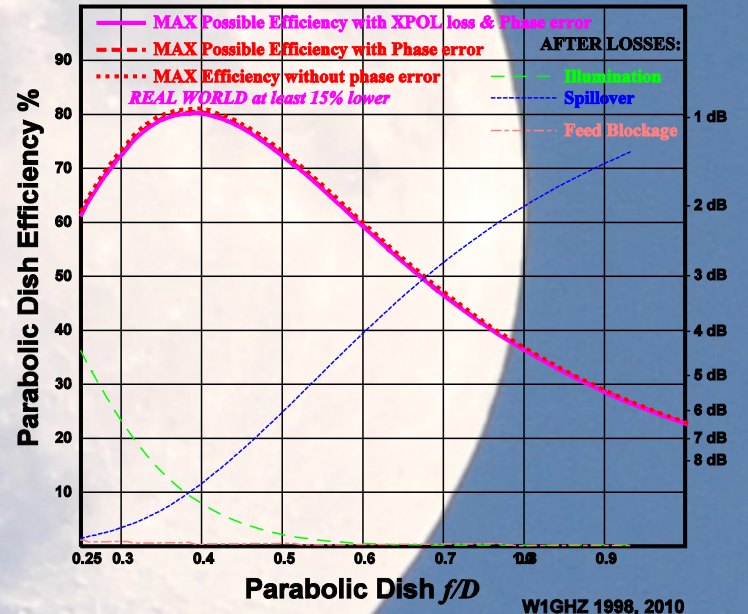
InDish Performance 9/6 cm

SM6FHZ 9 cm Kumar feed

SM6FHZ Kumar 6 cm 0.125 wl



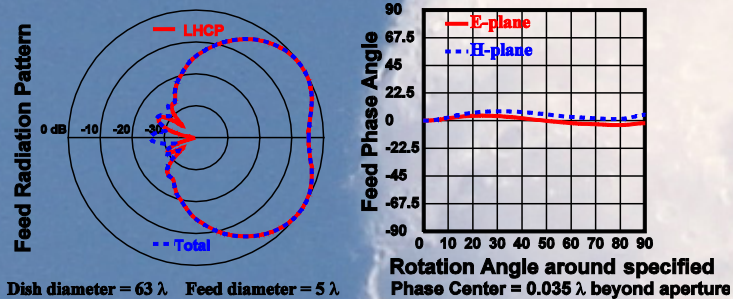
9 cm feed performance
(5.5m dish)



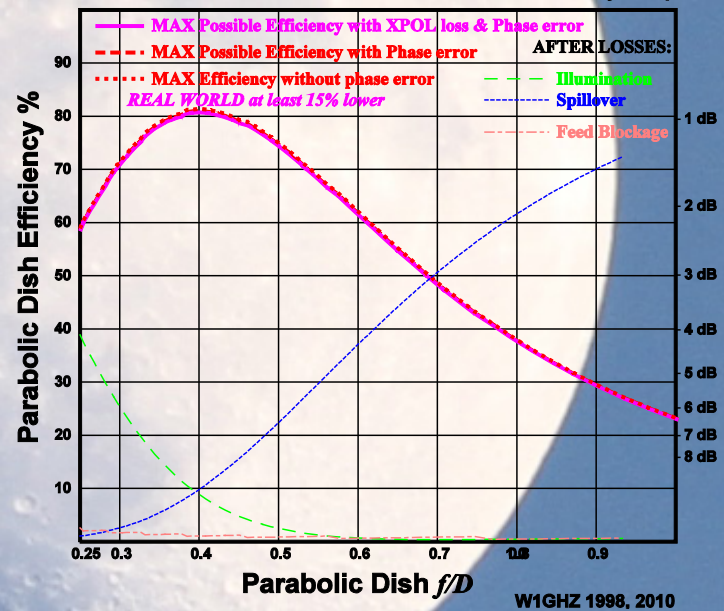
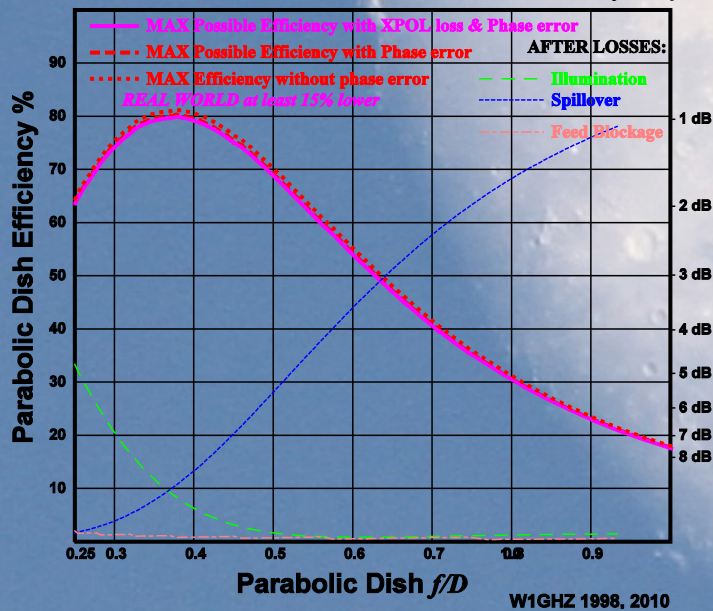
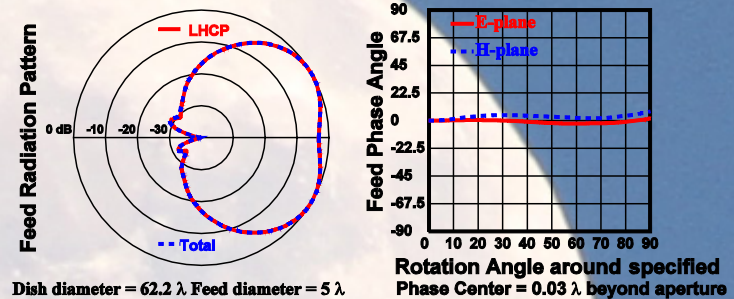
6 cm feed performance
(5.5 m dish)

InDish Performance 3 cm (1.8 m dish)

SM6FHZ 3 cm septum feed 0.692L WG




SM6FHZ 3 cm septum feed 0.795L WG



3 cm 0.692 L W/G feed performance

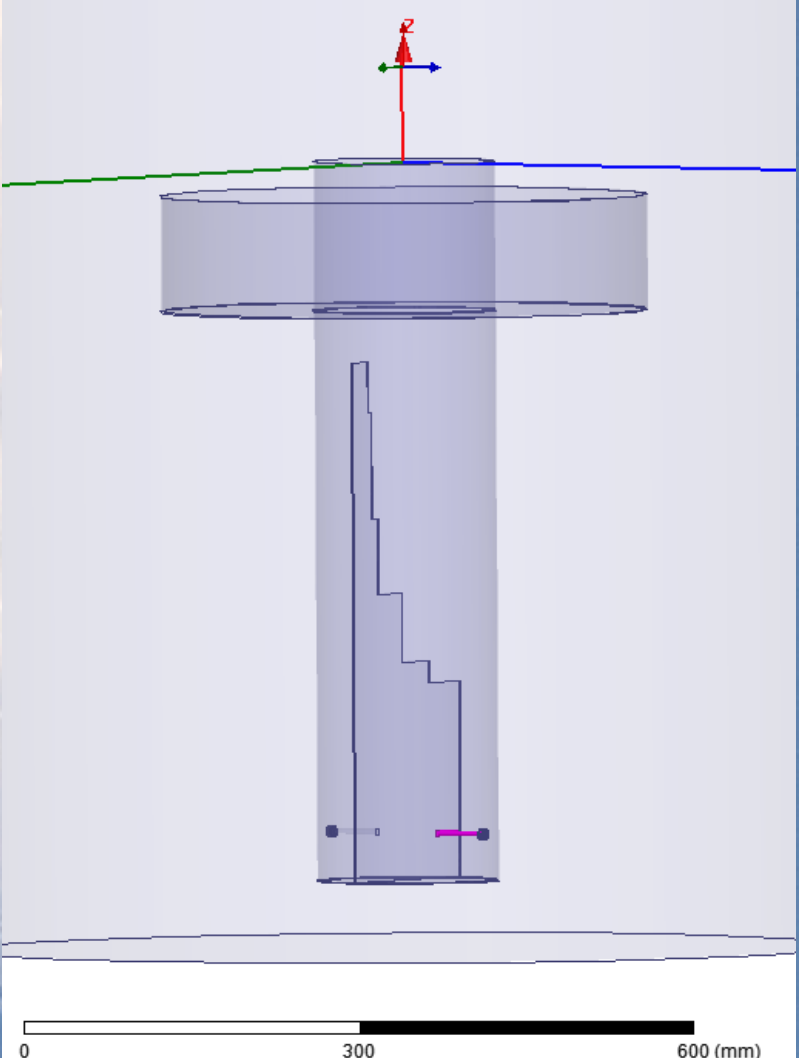
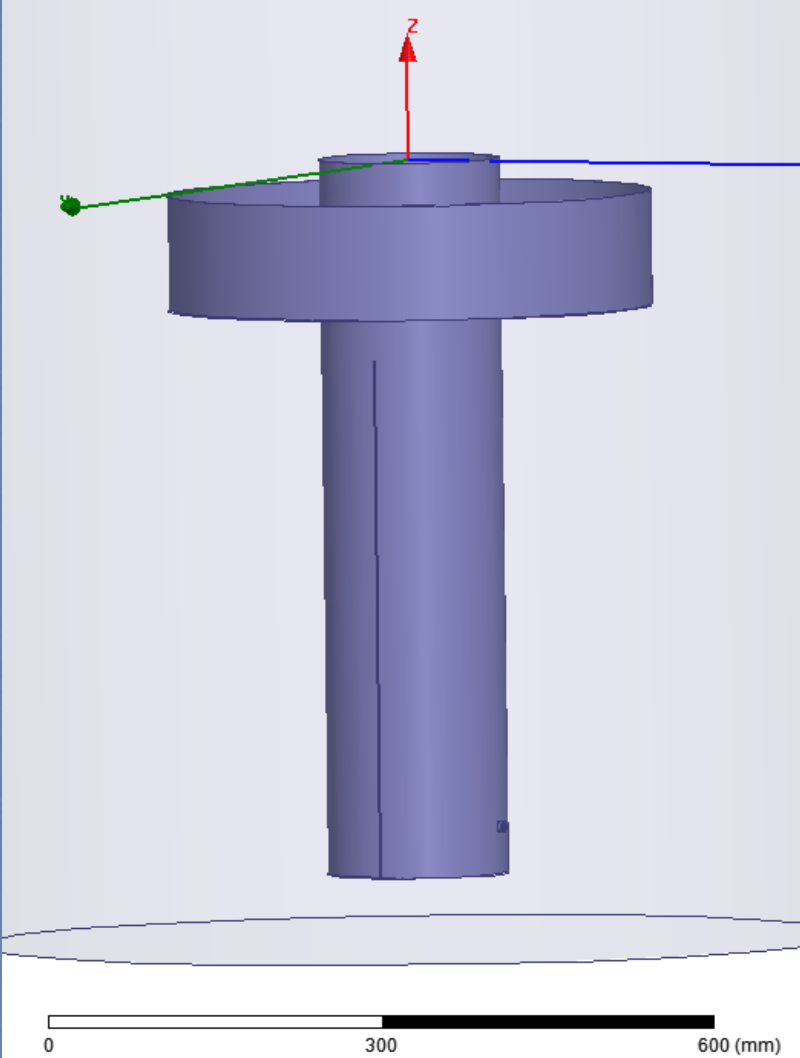
3 cm 0.795 L W/G feed performance



SM6FHZ 23 cm 5 step septum
feed

0.71 lambda W/G

Solid and transparent models from the simulation



WG and choke dimensions

Phase center -5.0

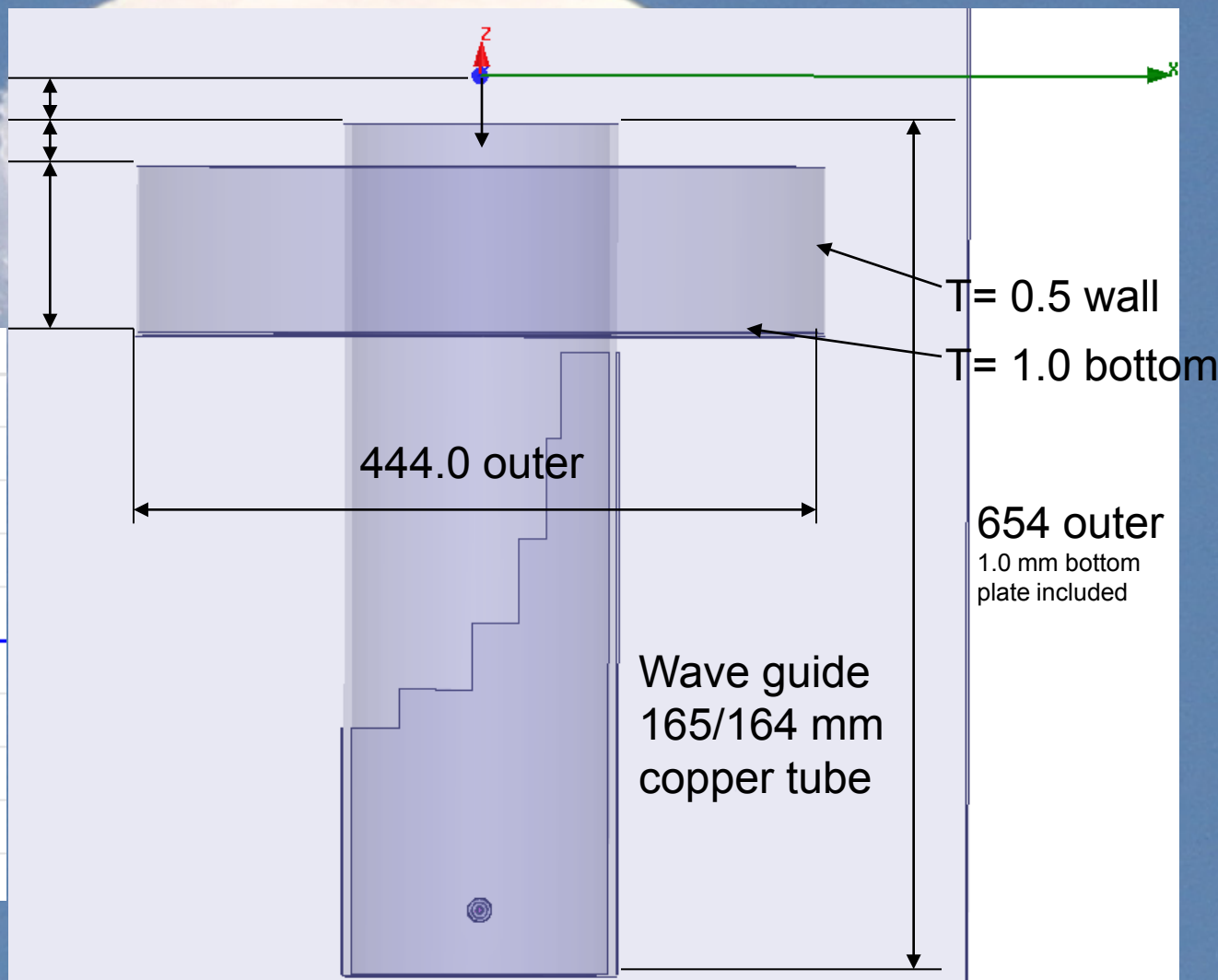
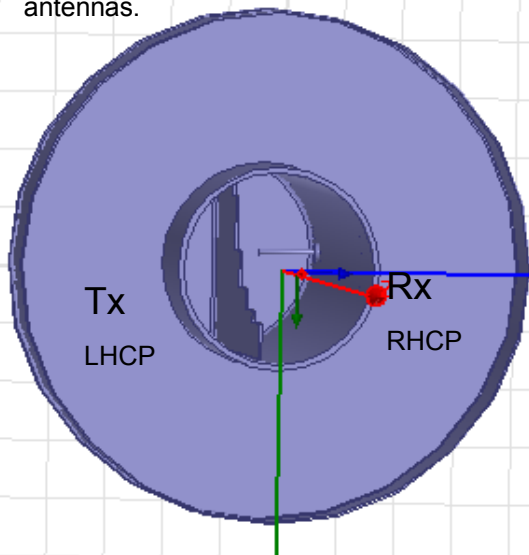
31

Circular polarization convention for EME according to Crawford Hill Bulletin No 1:

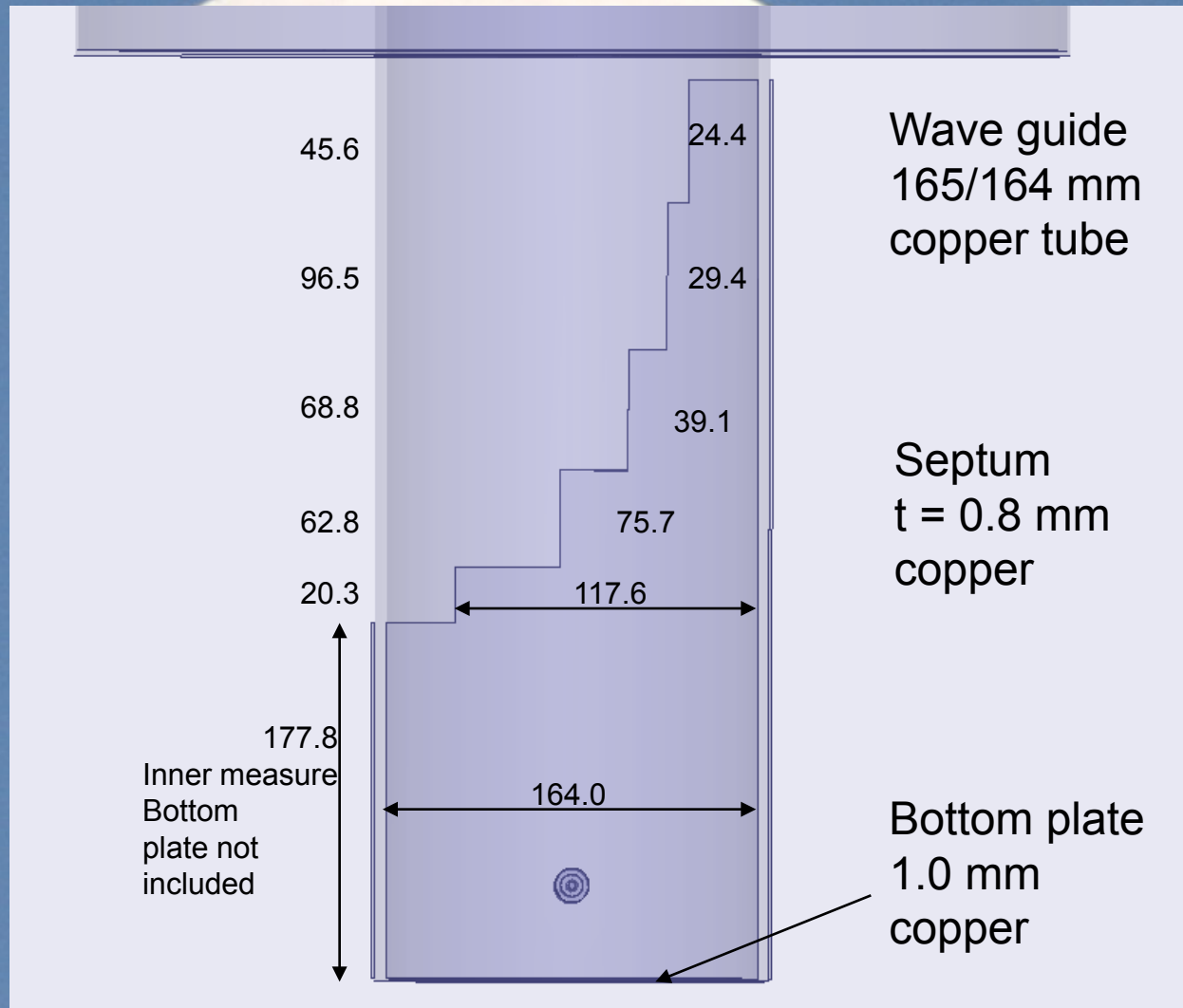
Tx RHCP in space
Rx LHCP in space

Take polarization reversal into account when using reflector antennas.

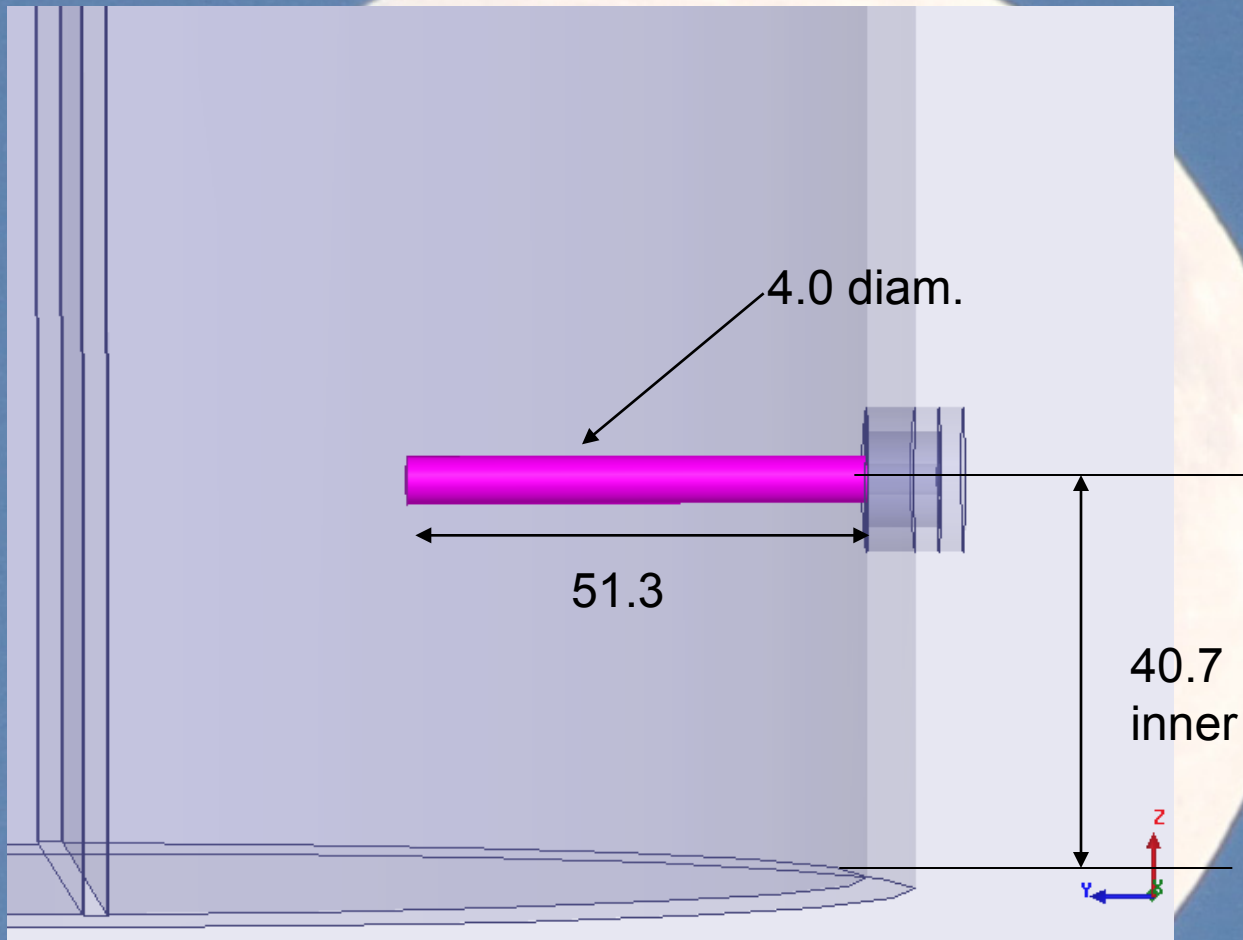
105.0
outer



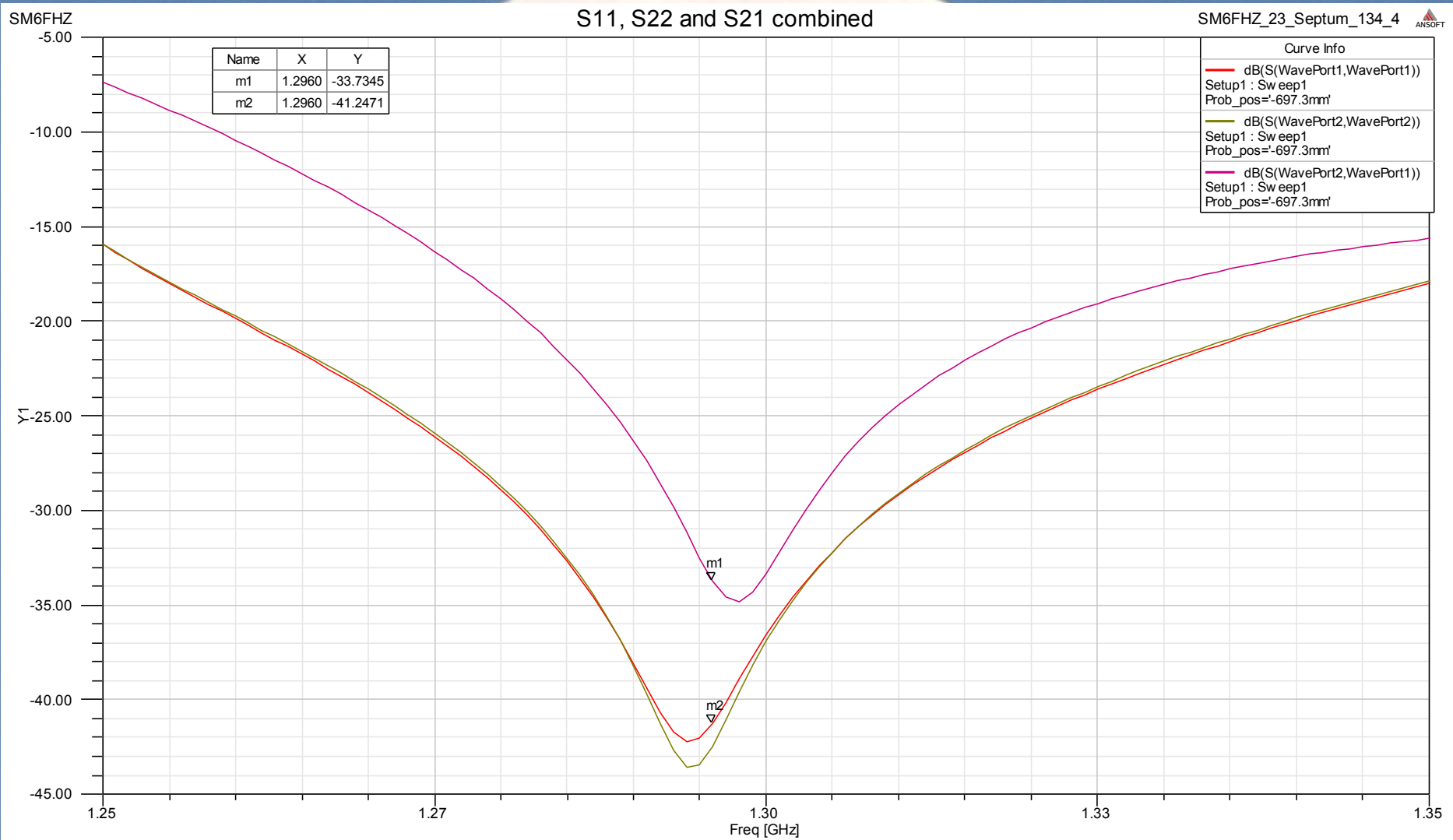
Septum dimensions



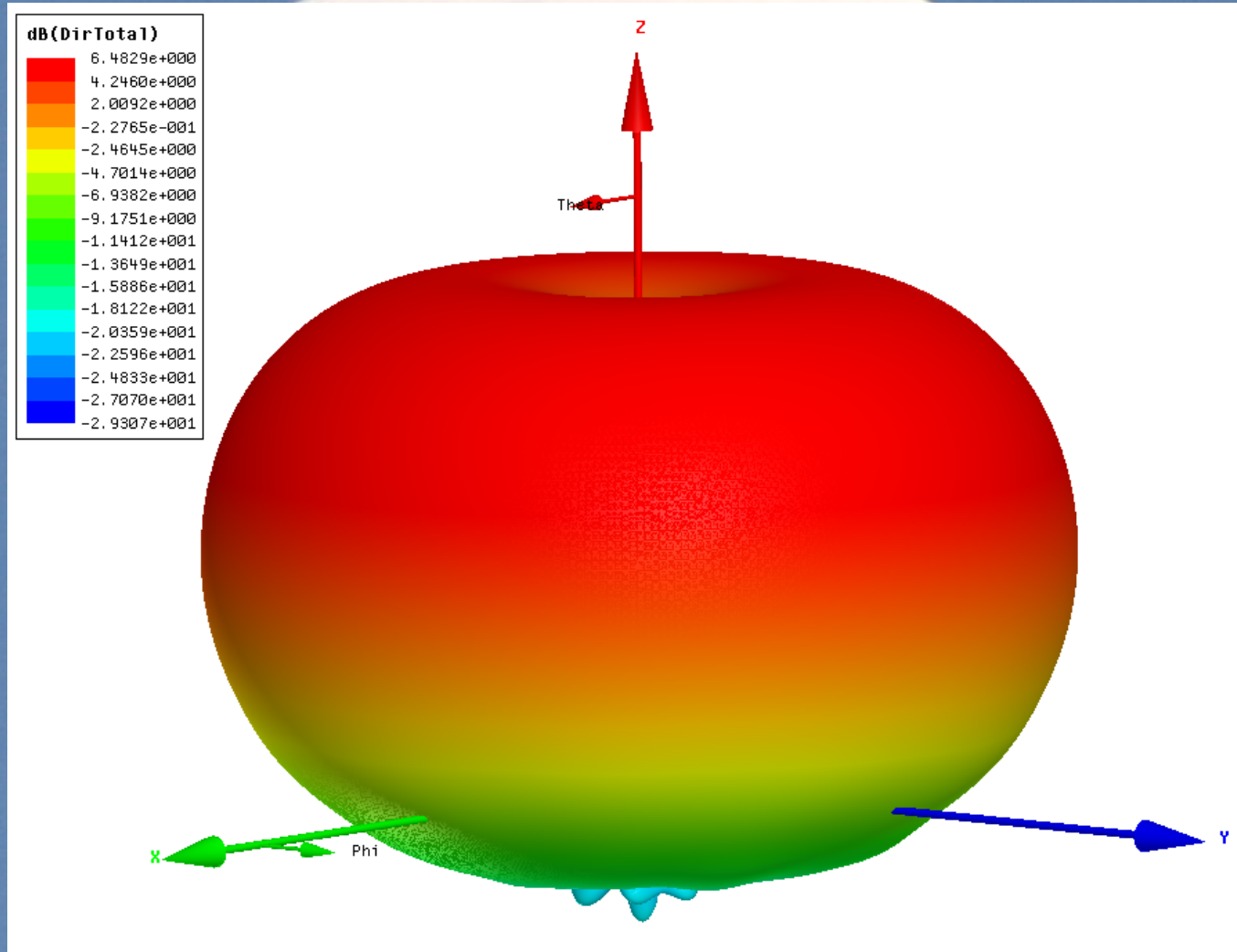
Probe dimensions



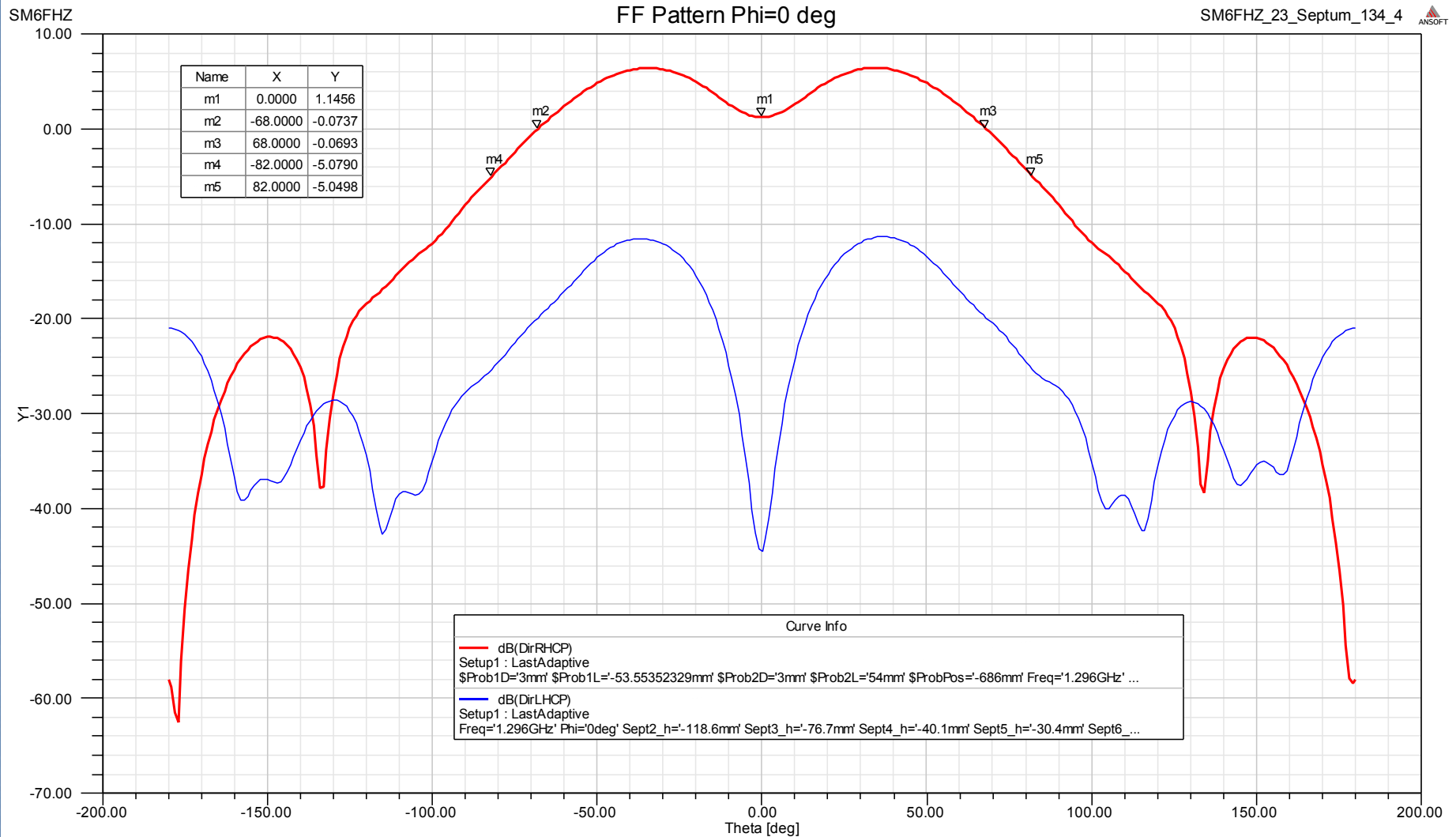
S11, S22, S21 combined



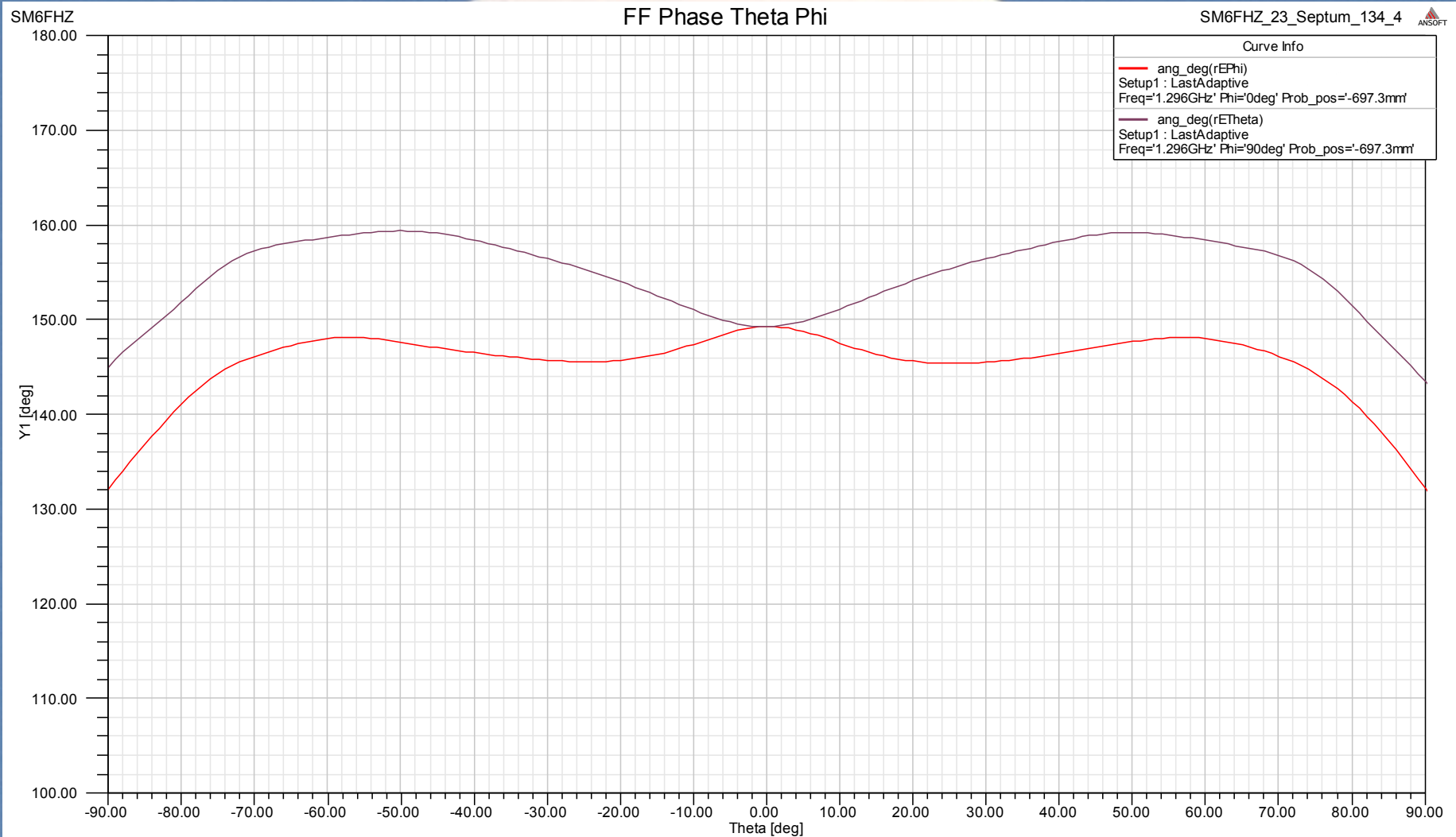
3D Total Power Far Field pattern



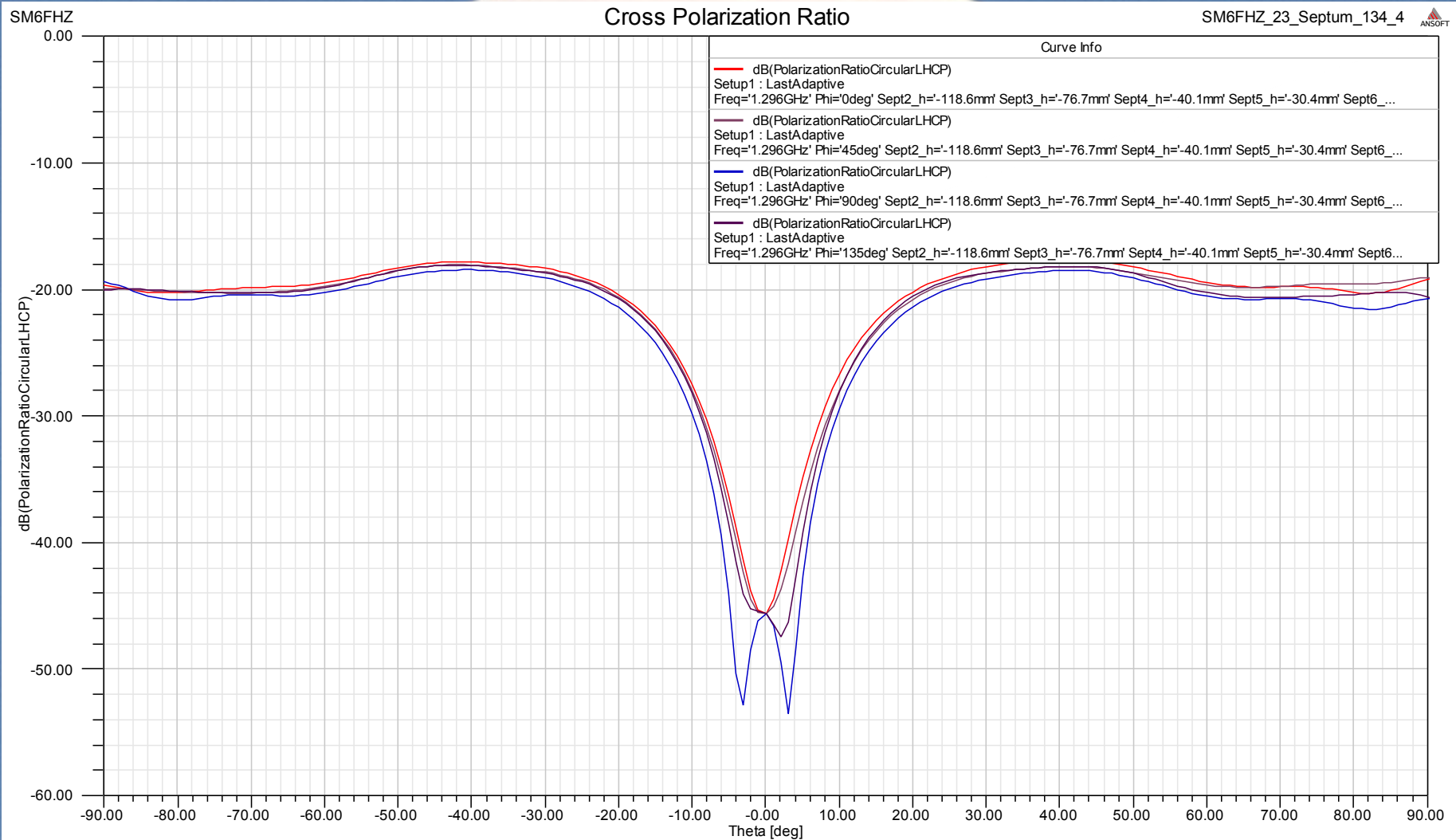
Far Field Pattern 0 deg



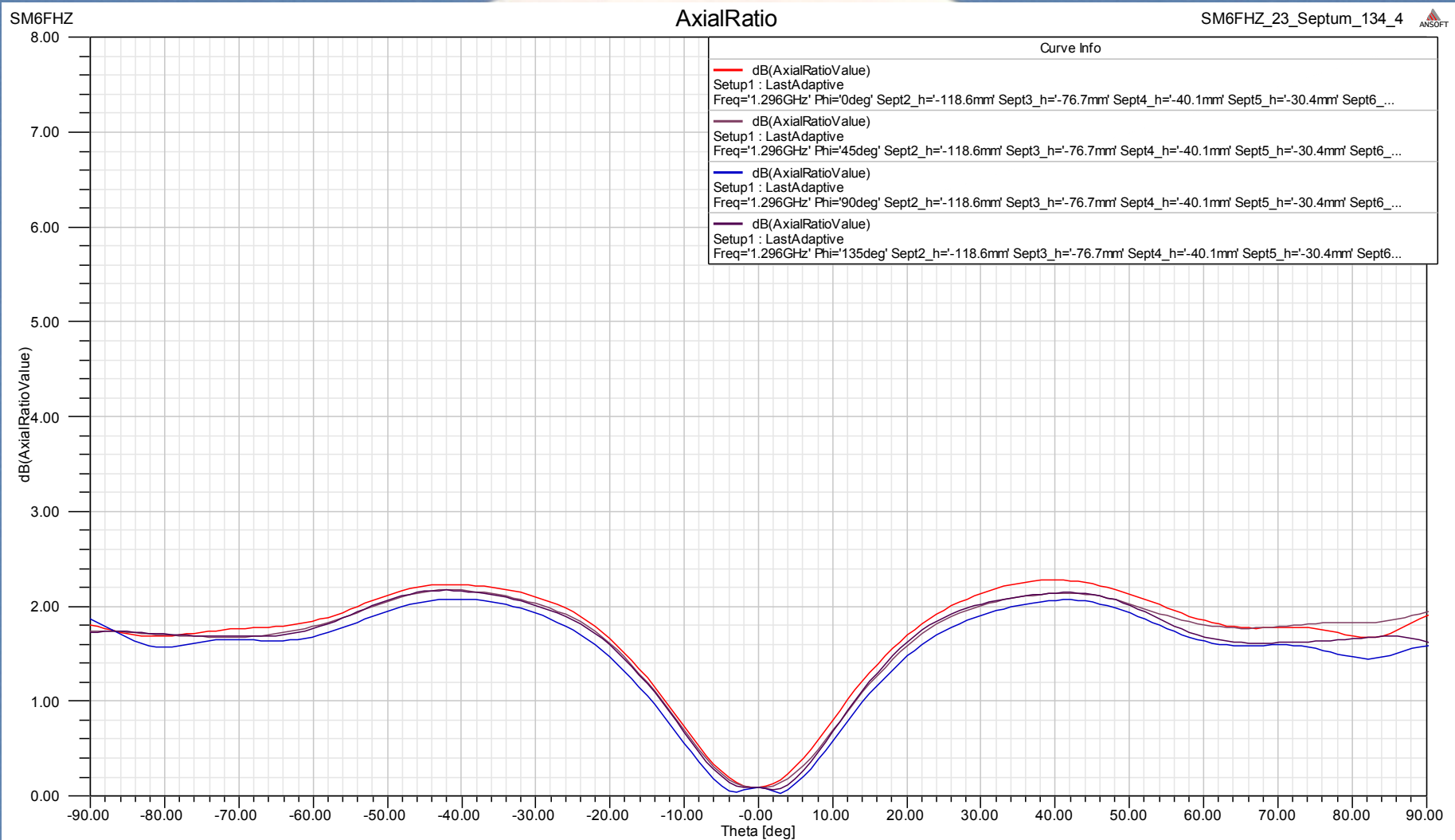
Far Field Phase error




Cross Polar Ratio



Axial Ratio

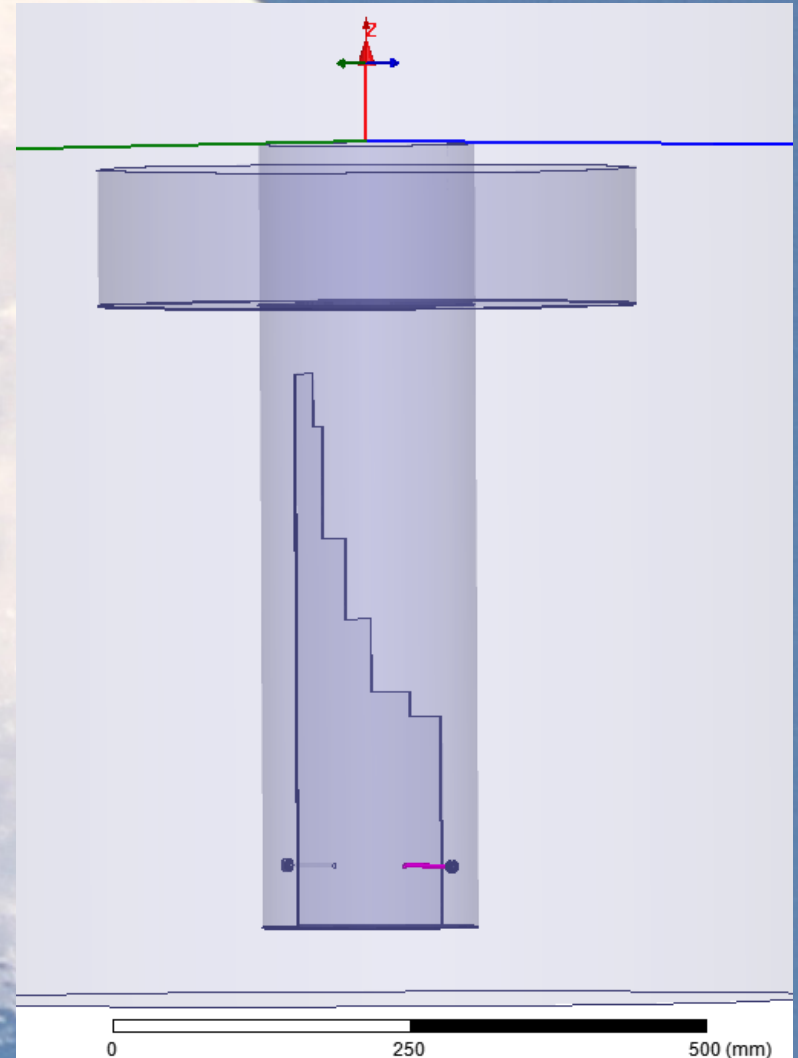
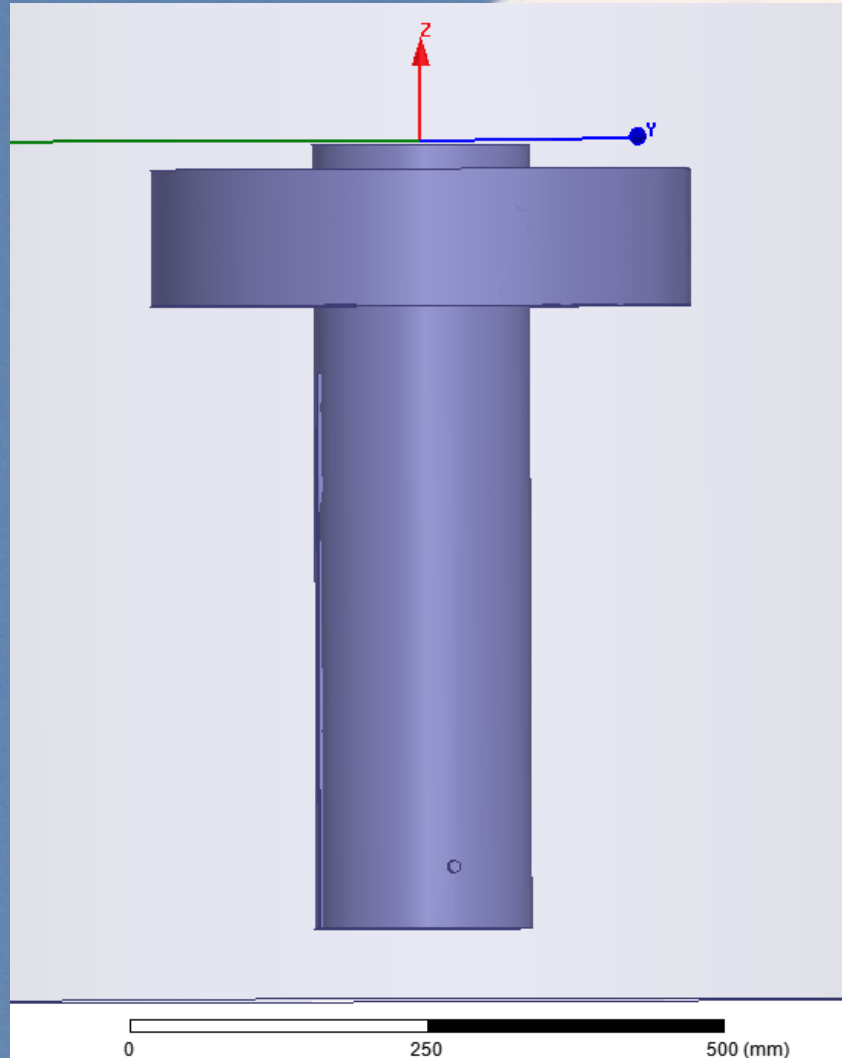




SM6FHZ 23 cm 5 step septum
feed

0.795 lambda W/G

Solid and transparent models from the simulation



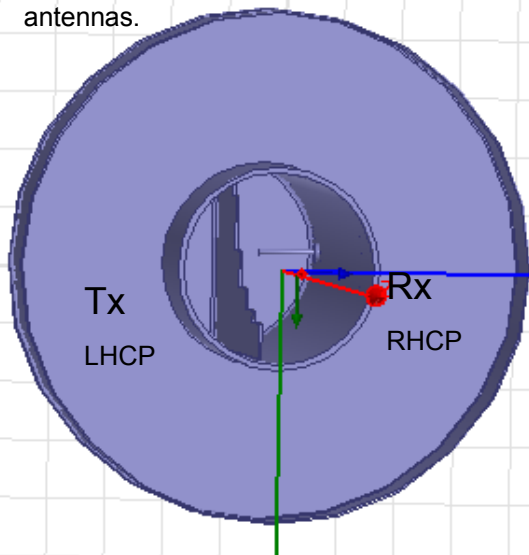
WG and choke dimensions

Phase center 4.0
21

Circular polarization convention
for EME according to Crawford
Hill Bulletin No 1:

Tx RHCP in space
Rx LHCP in space

Take polarization reversal into
account when using reflector
antennas.



117 outer

460 outer

T = 0.5 wall

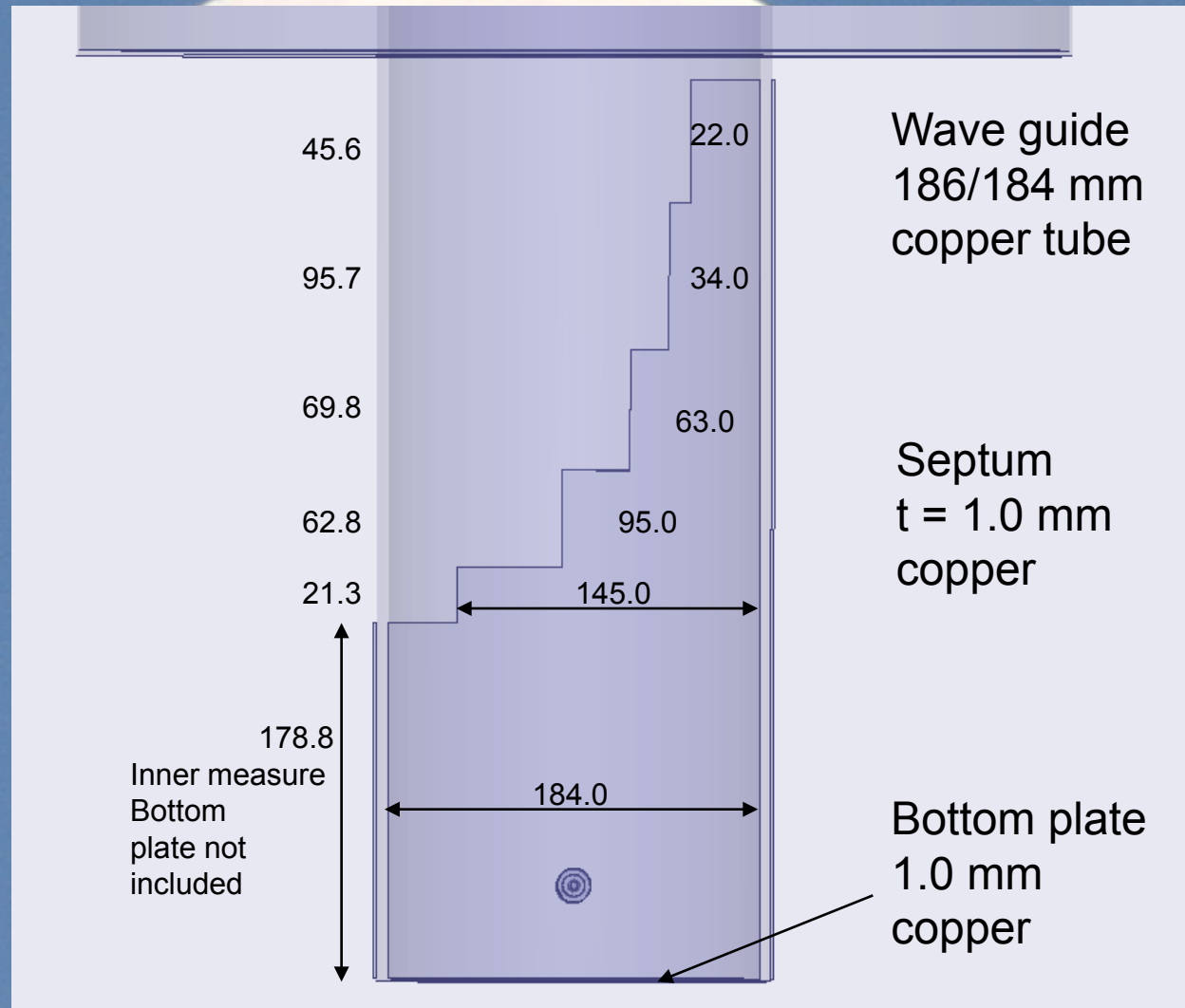
T = 1.0 bottom

670 outer

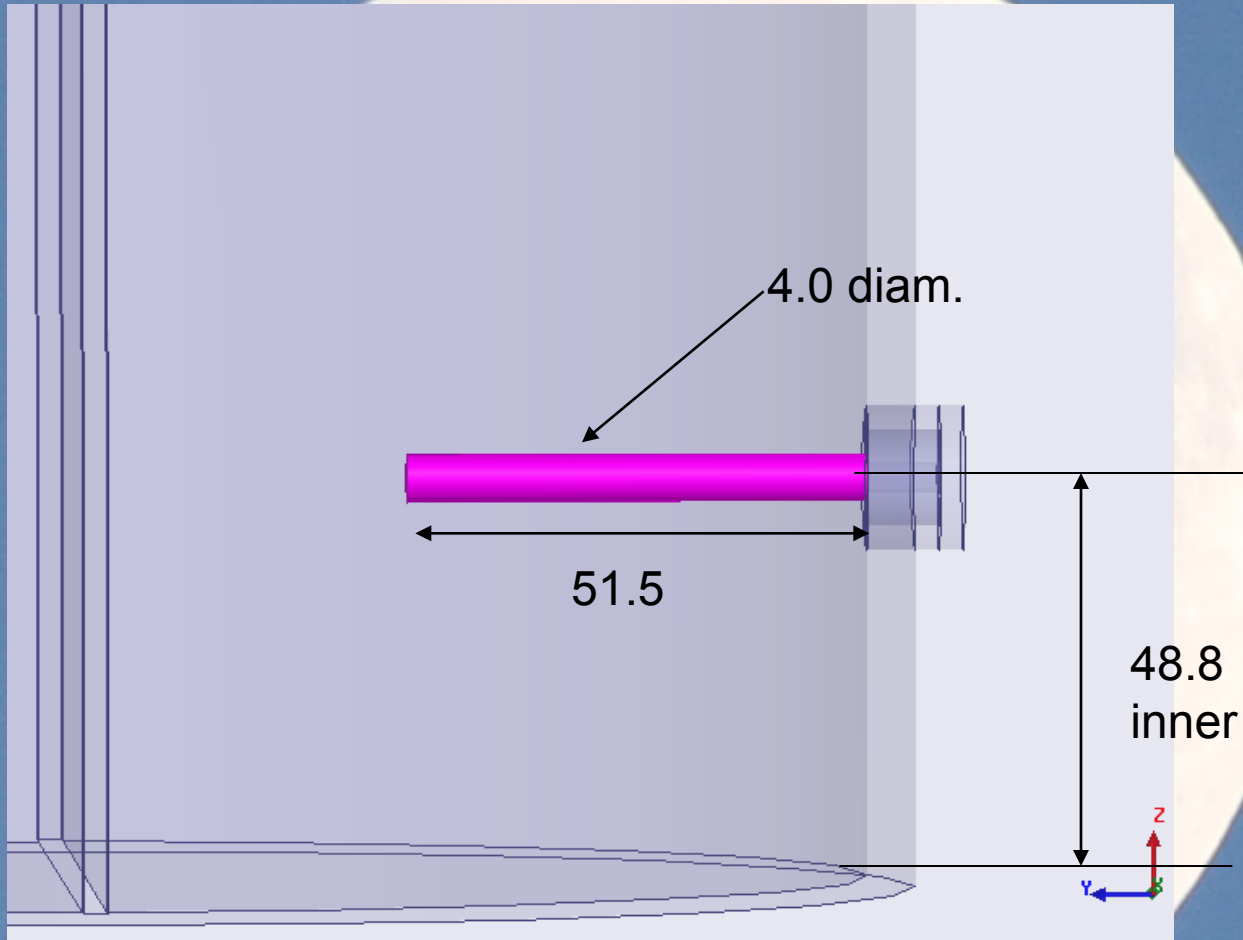
1.0 mm bottom
plate included

Wave guide
186/184 mm
copper tube

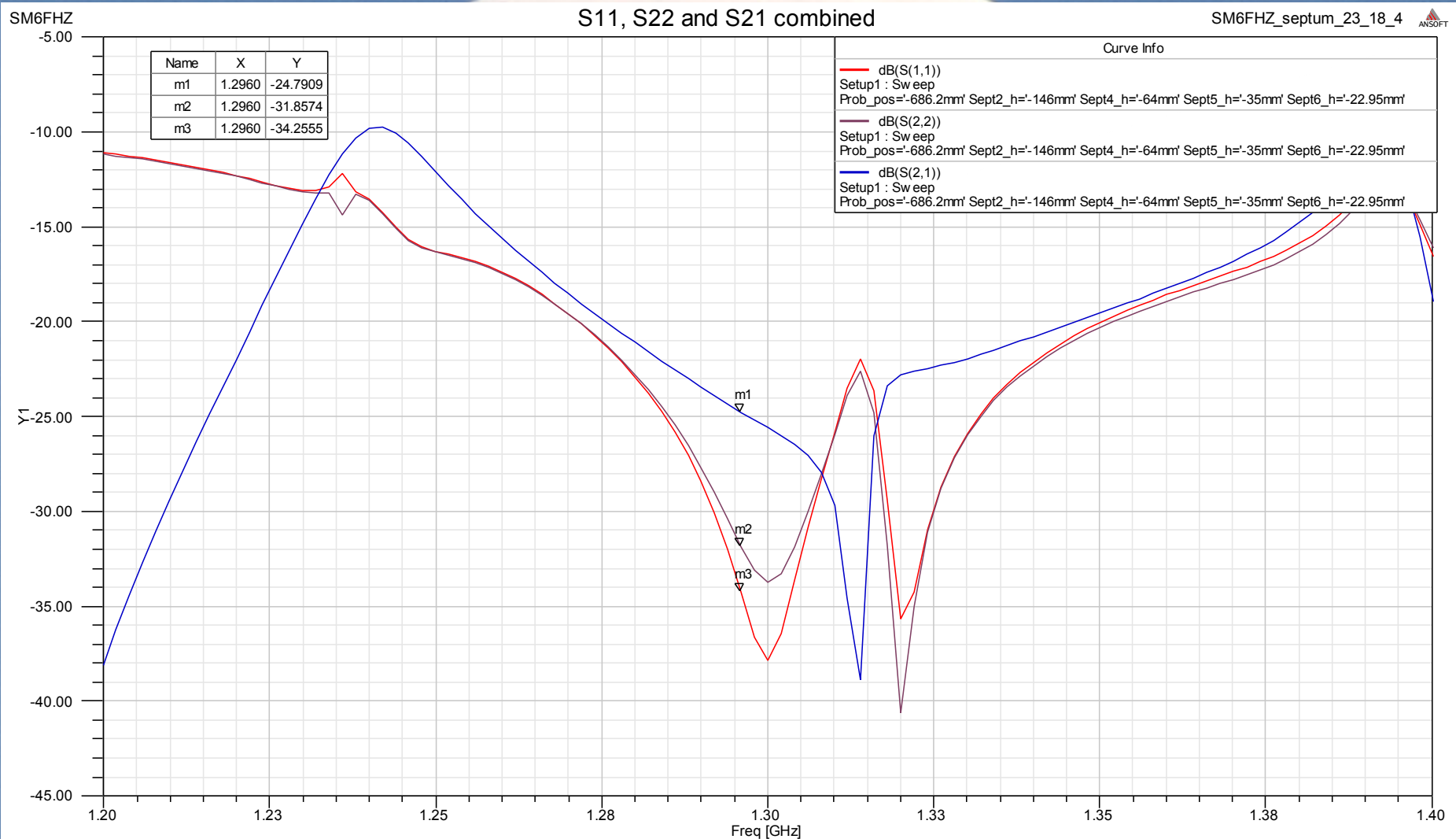
Septum dimensions



Probe dimensions




S11, S22, S21 combined



Complex impedance Rx-port

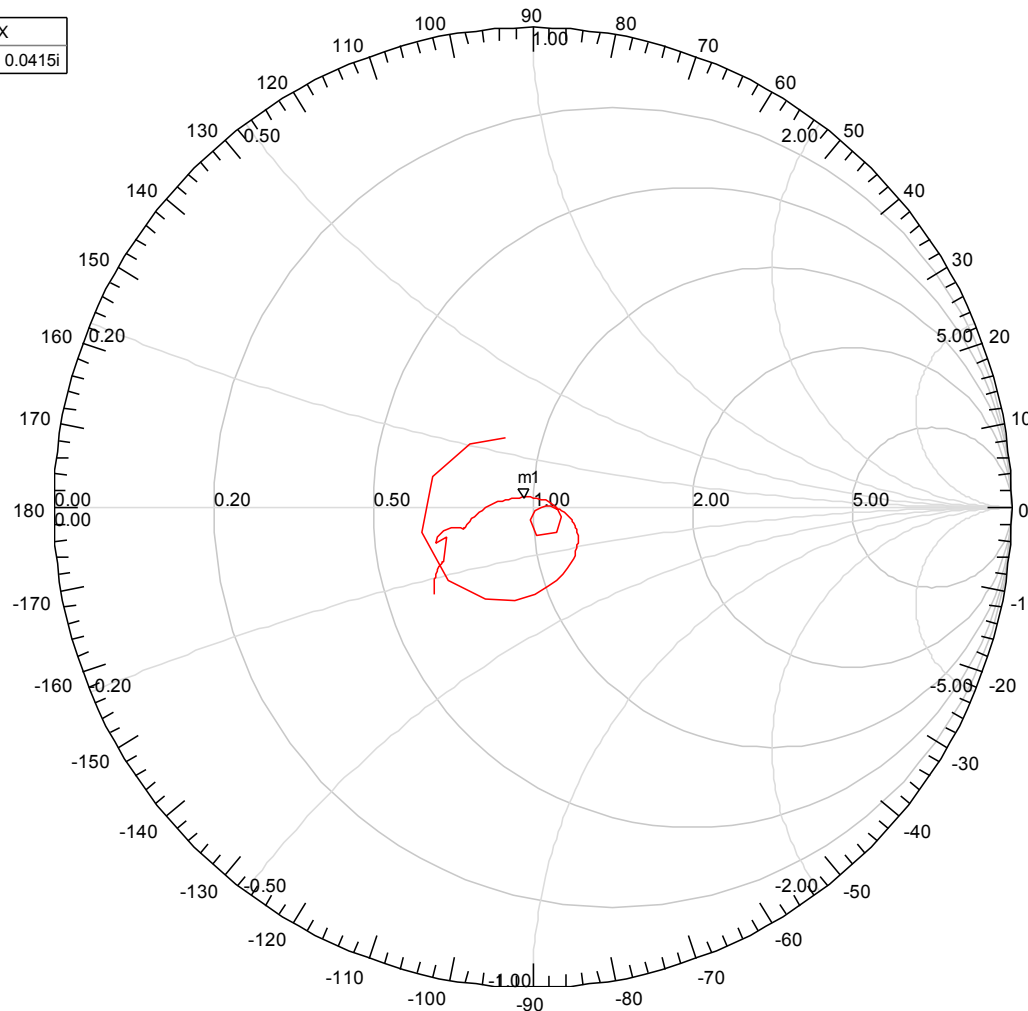
SM6FHZ

Smith Chart Rx-port

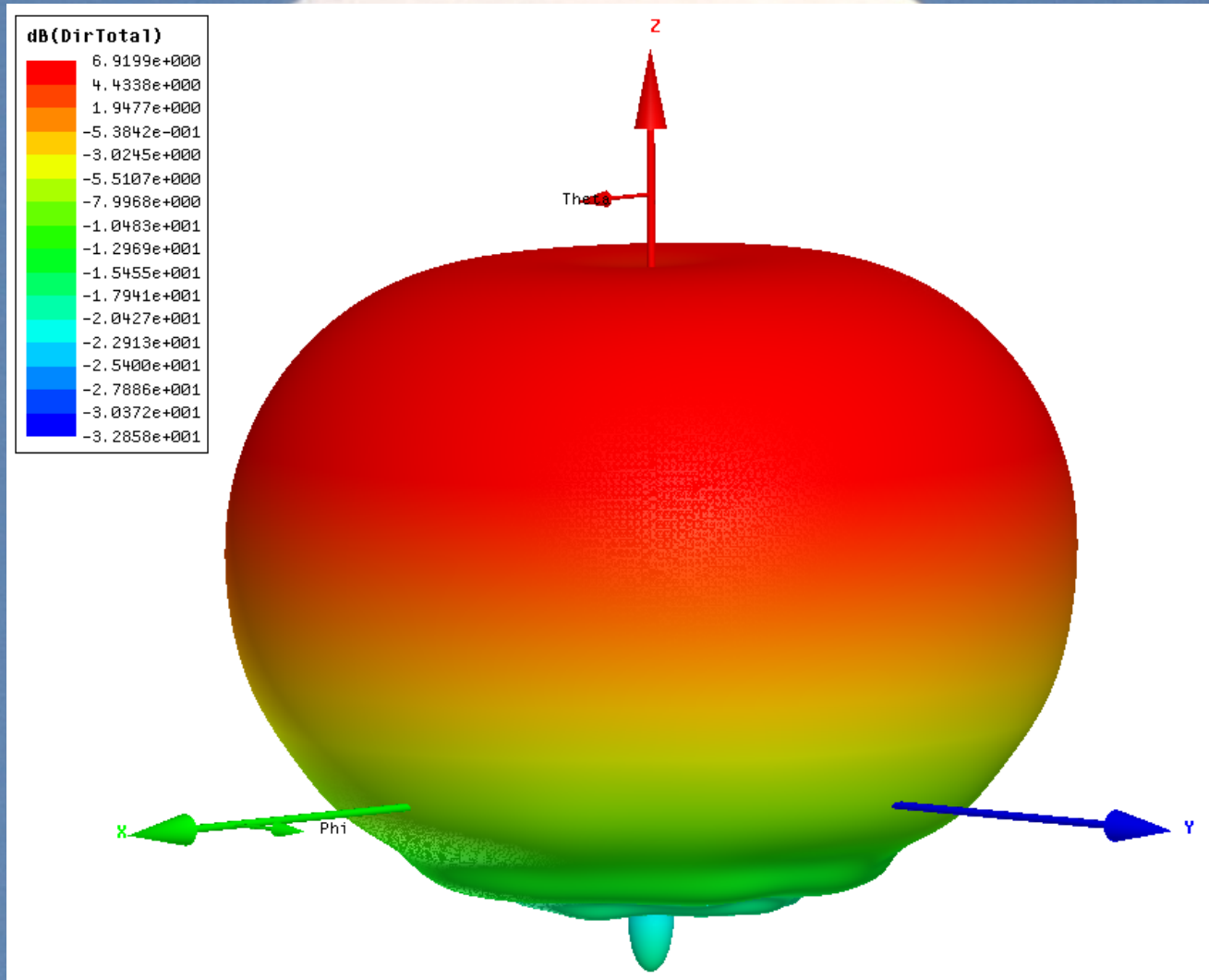
SM6FHZ_septum_23_18_4 

Name	Freq	Ang	Mag	RX
m1	1.2970	123.2444	0.0255	0.9715 + 0.0415i

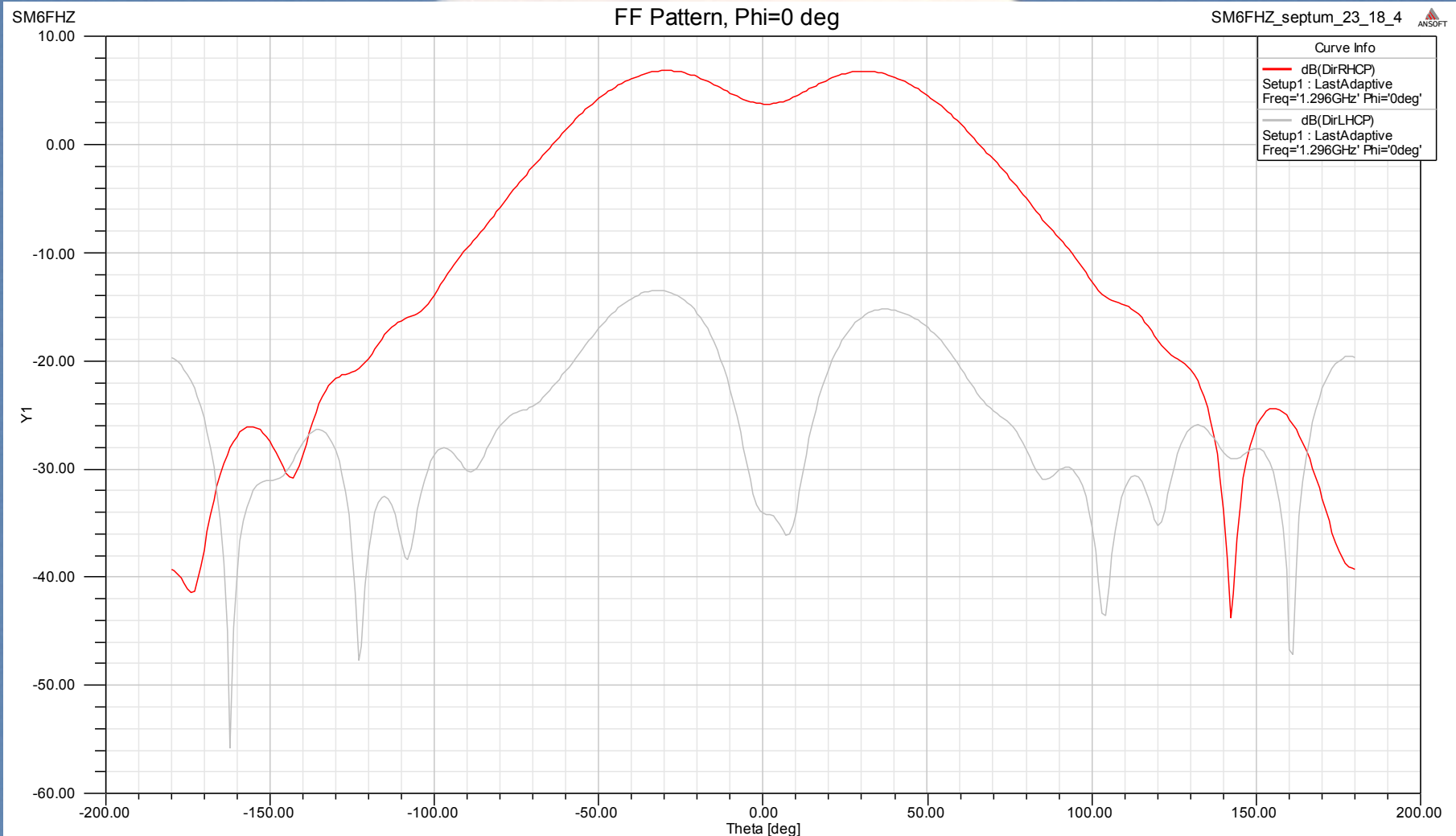
Curve Info
— S(2,2)
Setup1 : Sweep



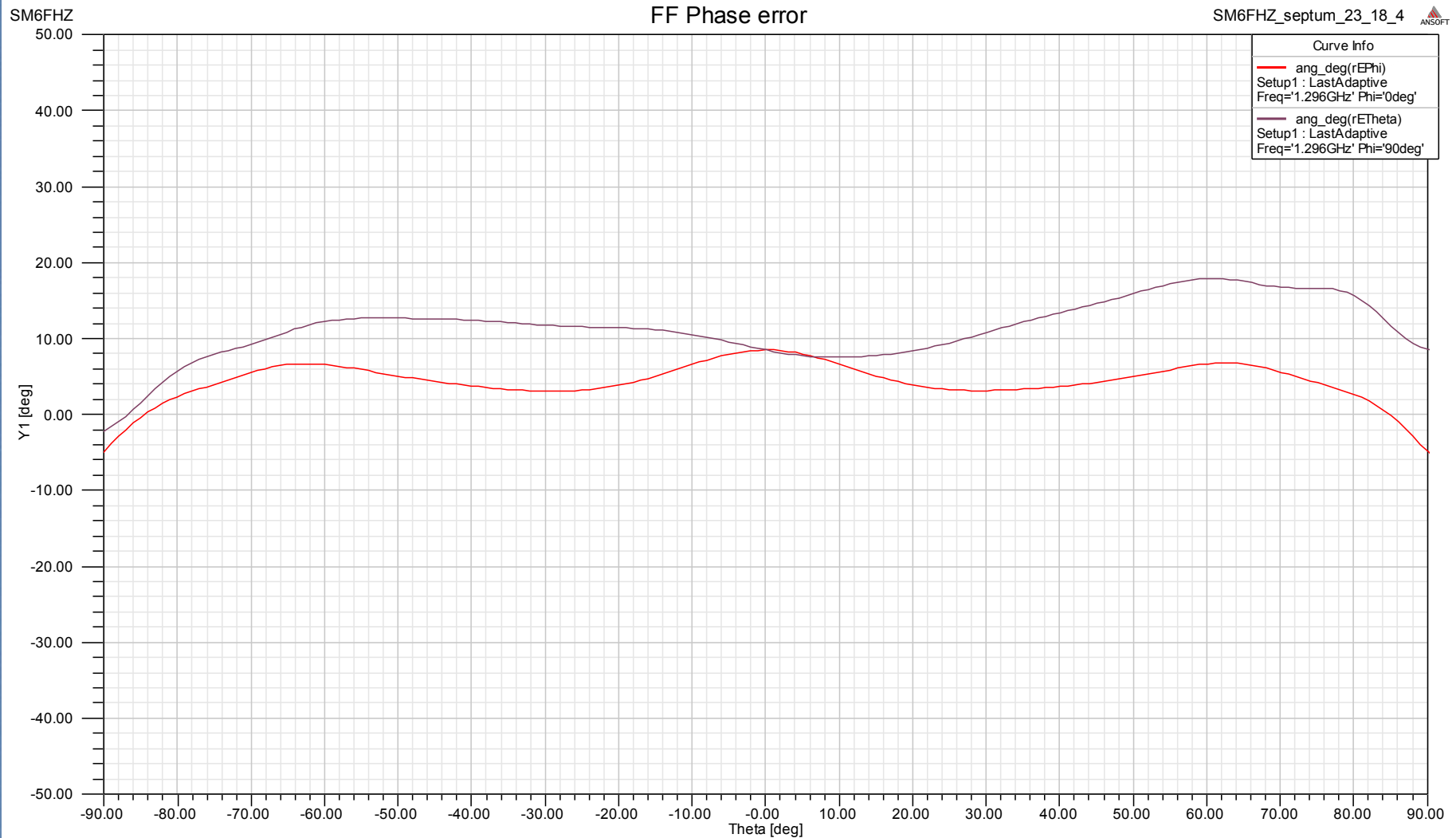
3D Total Power Far Field pattern



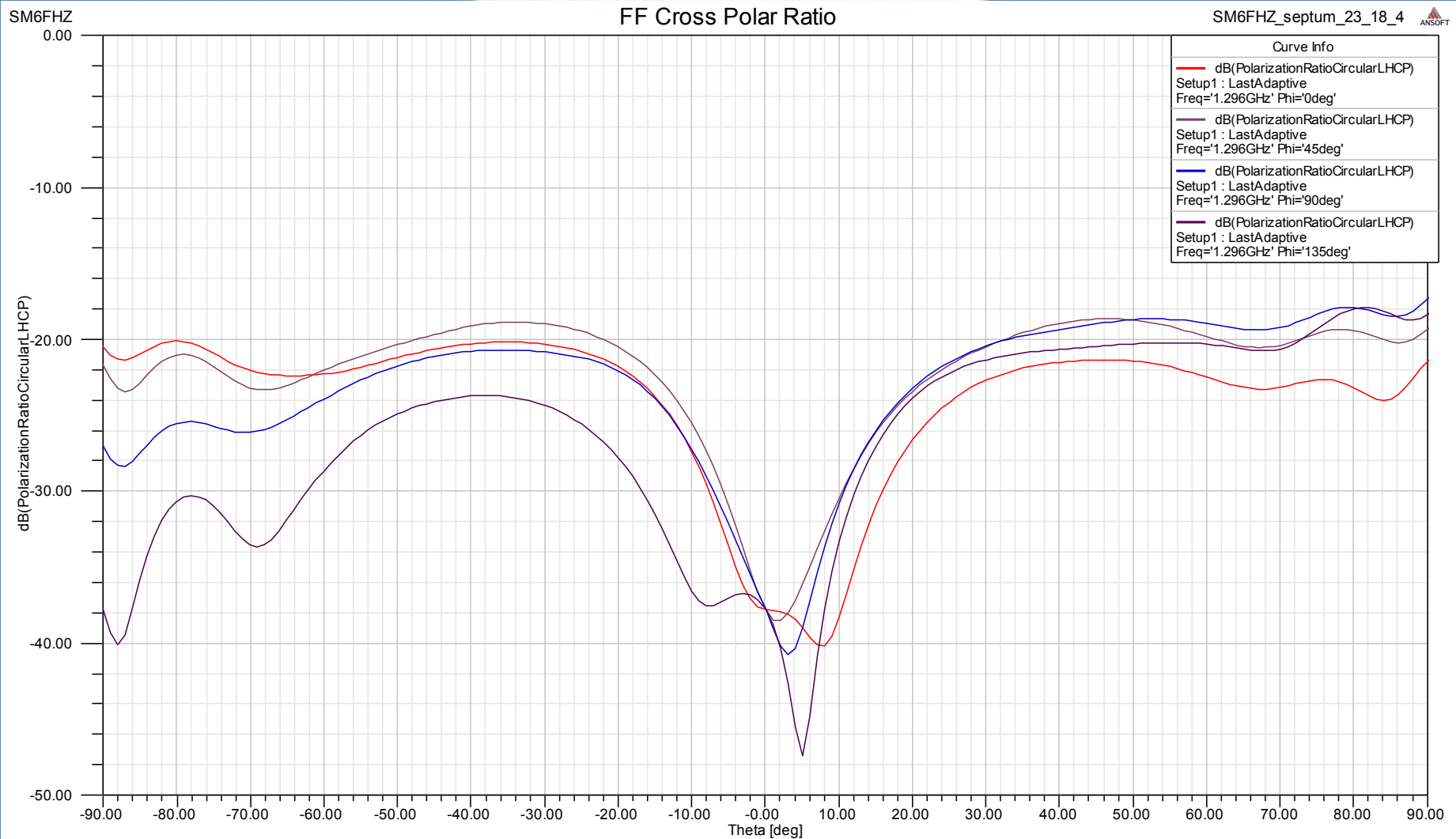
Far Field Pattern 0 deg



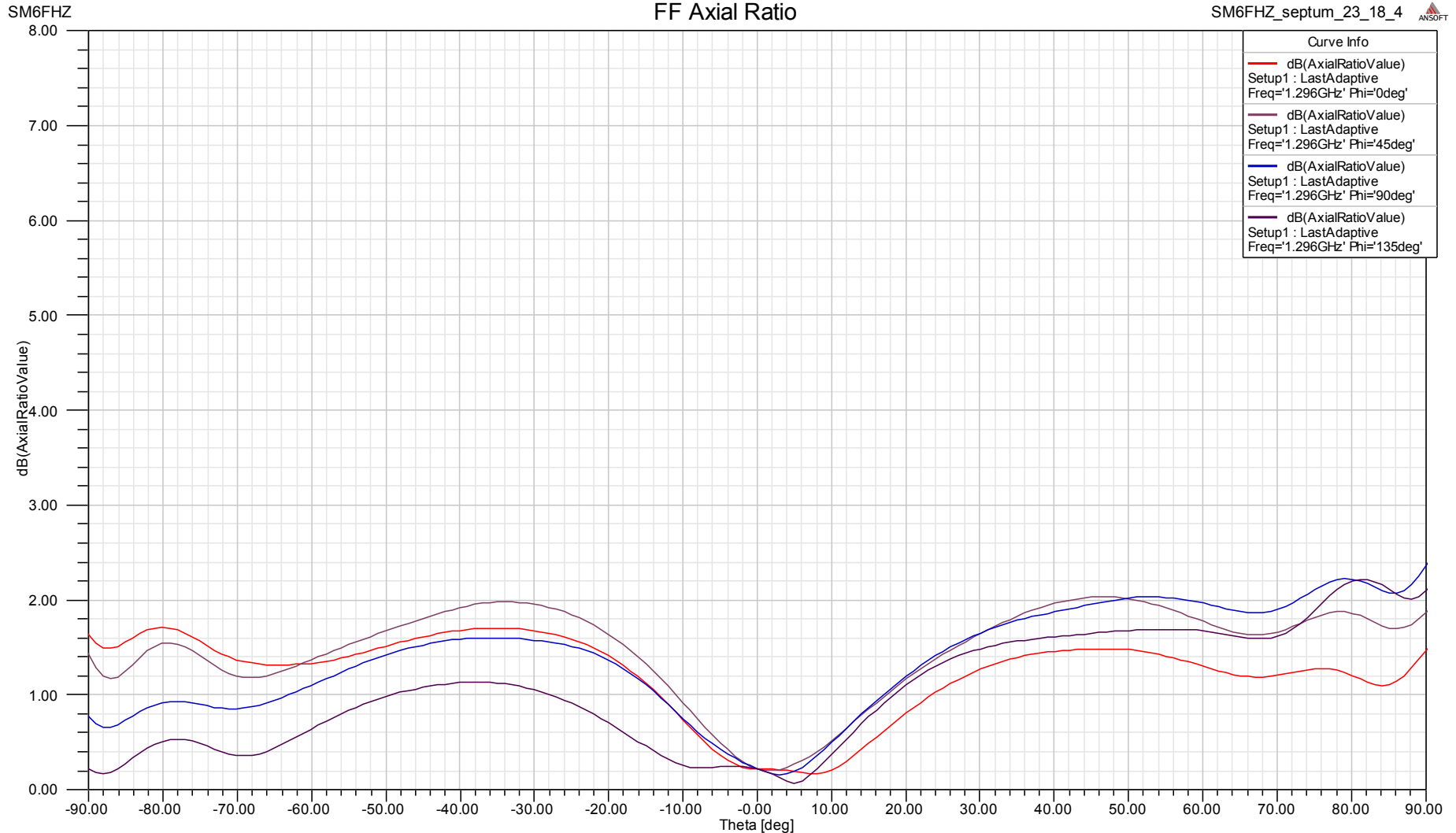
Far Field Phase error




Cross Polar Ratio



Axial Ratio

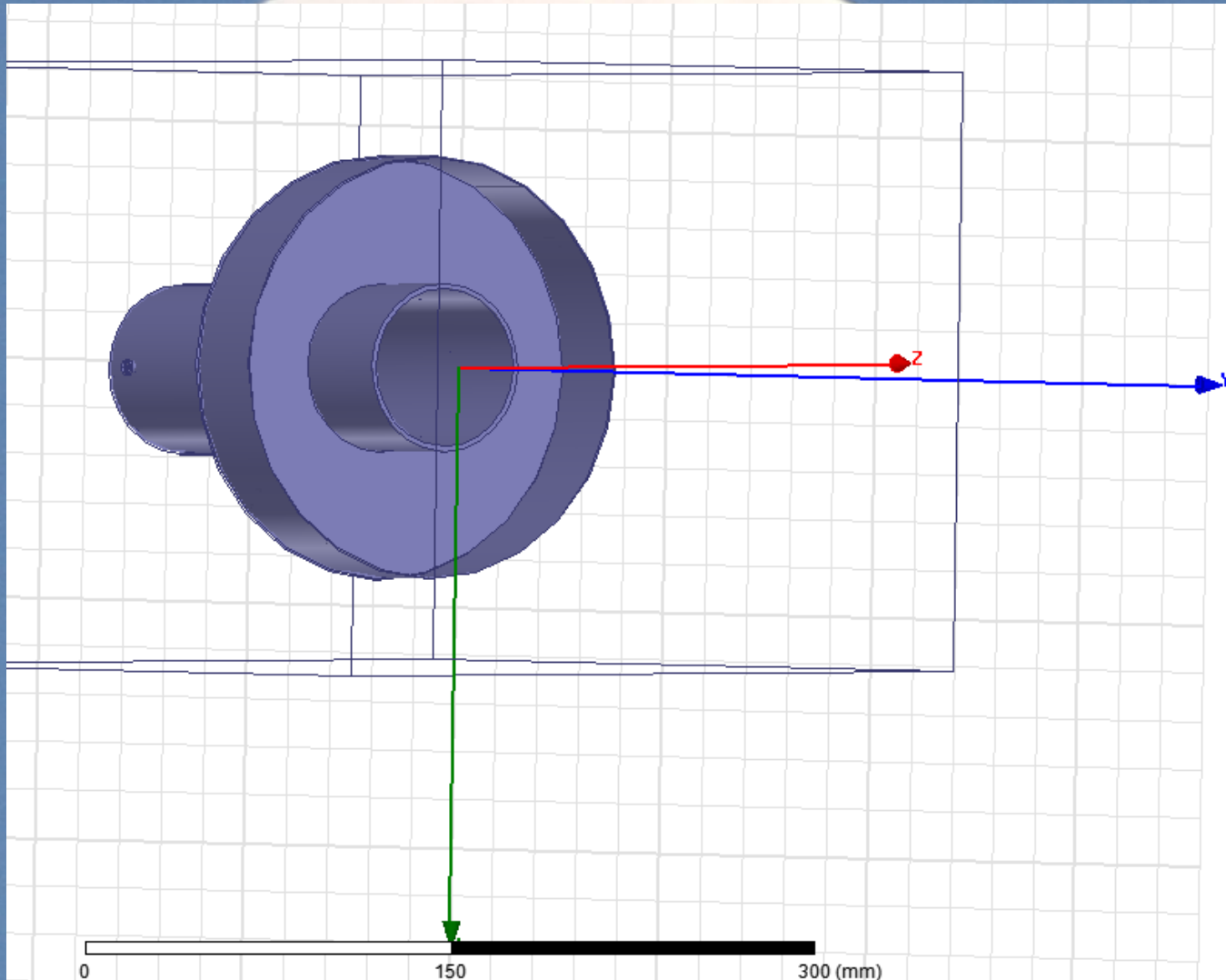


A large, bright, yellowish-white moon is centered in the frame against a clear, deep blue sky. The moon's surface is covered in numerous small, dark spots representing craters. The lighting is bright, suggesting a clear day.

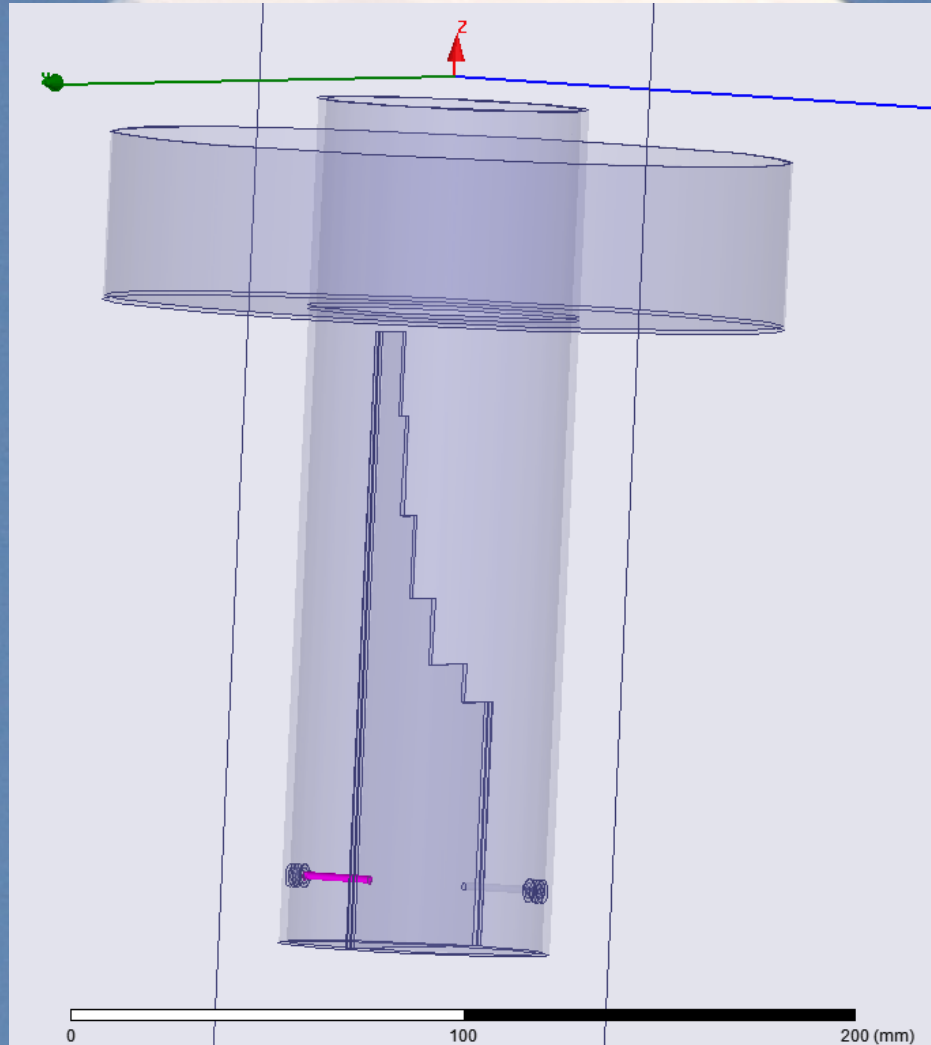
SM6FHZ 9 cm 5 step septum
feed

0.748 lambda W/G

Model



Transparent model



WG and choke dimensions

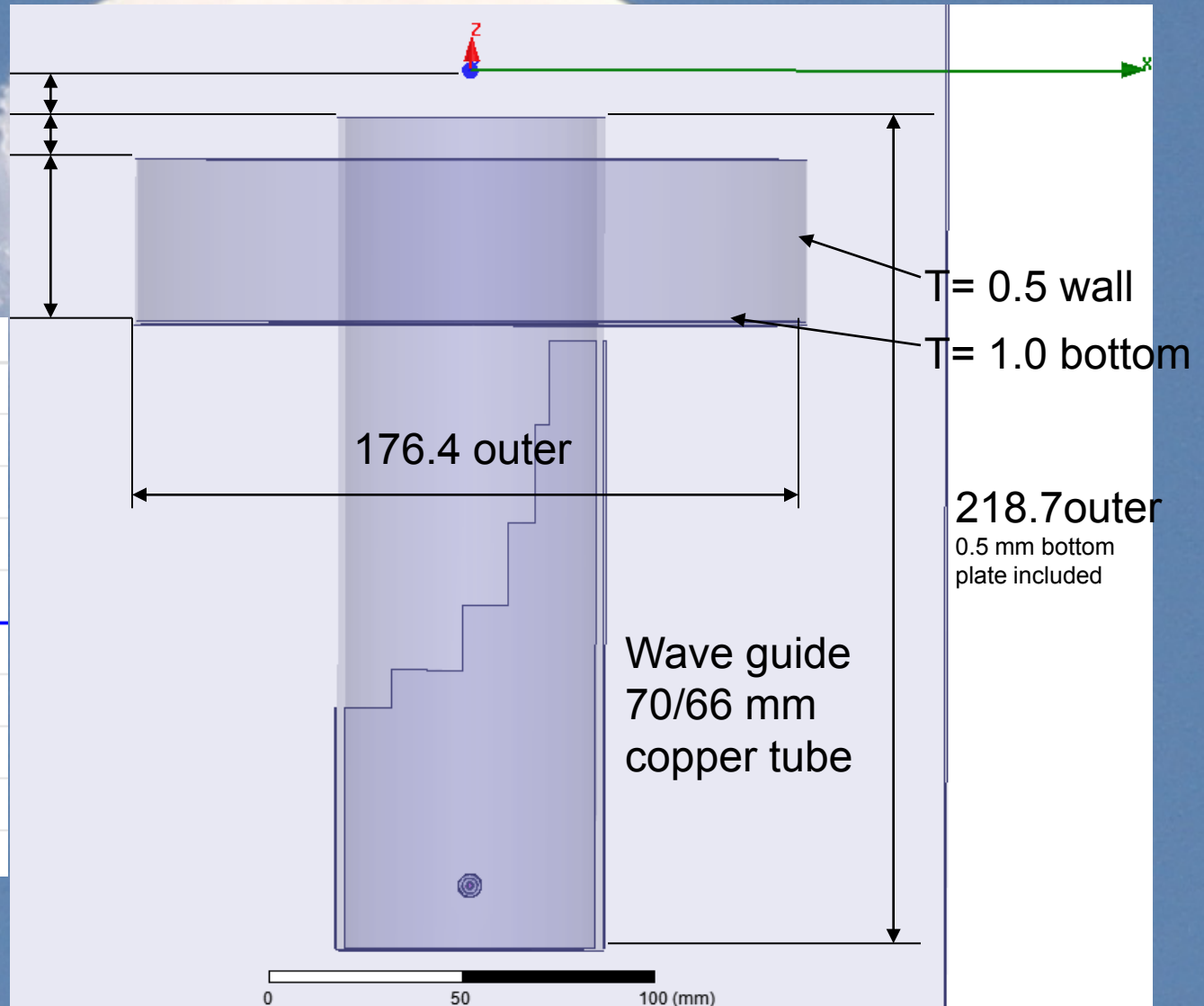
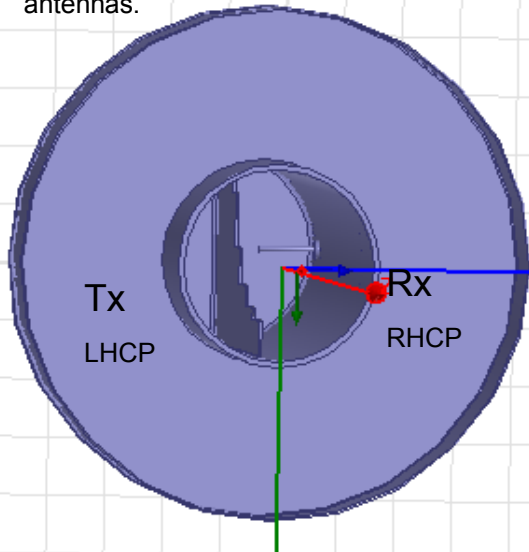
Phase center 2.0
11

Circular polarization convention
for EME according to Crawford
Hill Bulletin No 1:

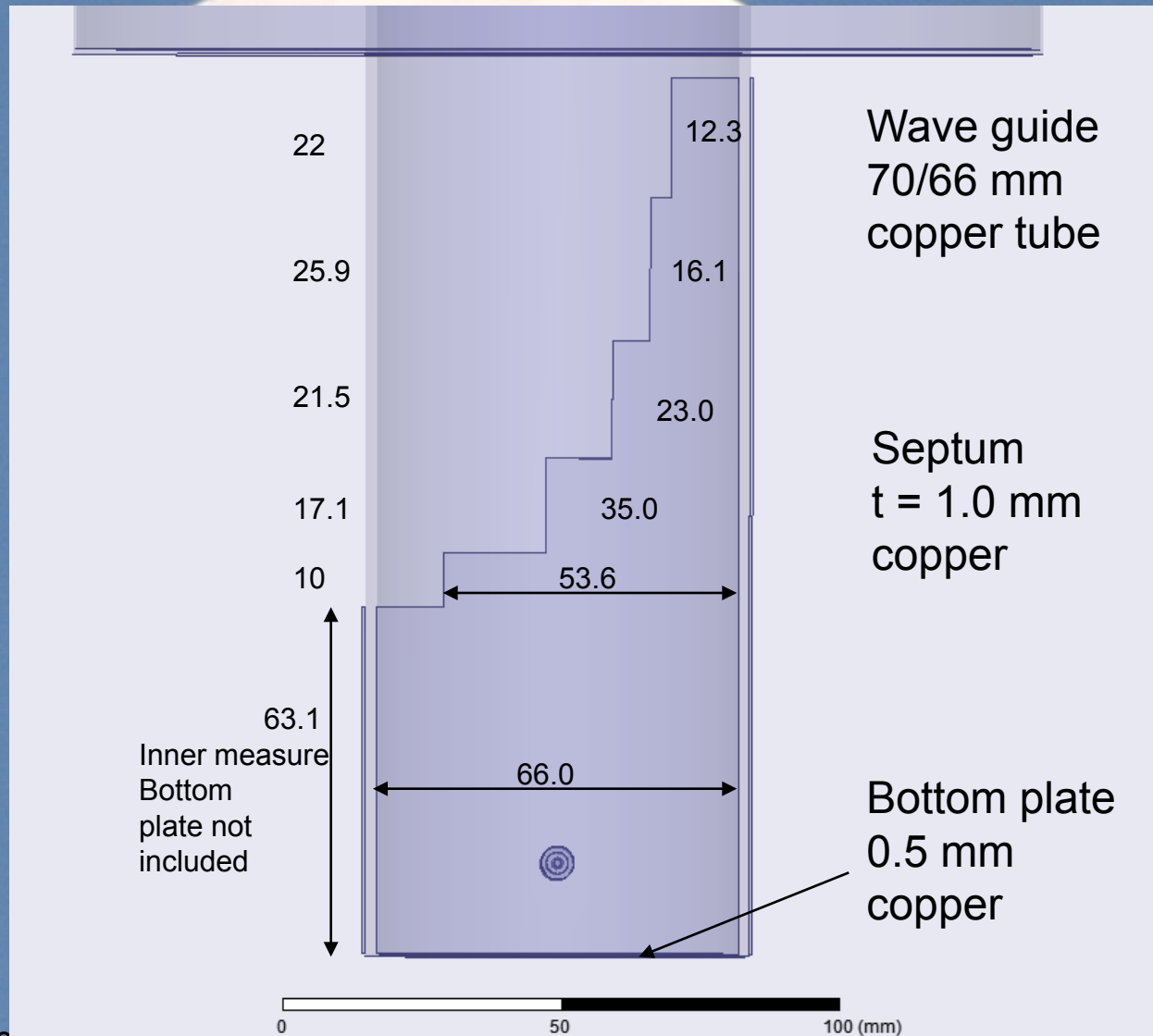
Tx RHCP in space
Rx LHCP in space

Take polarization reversal into
account when using reflector
antennas.

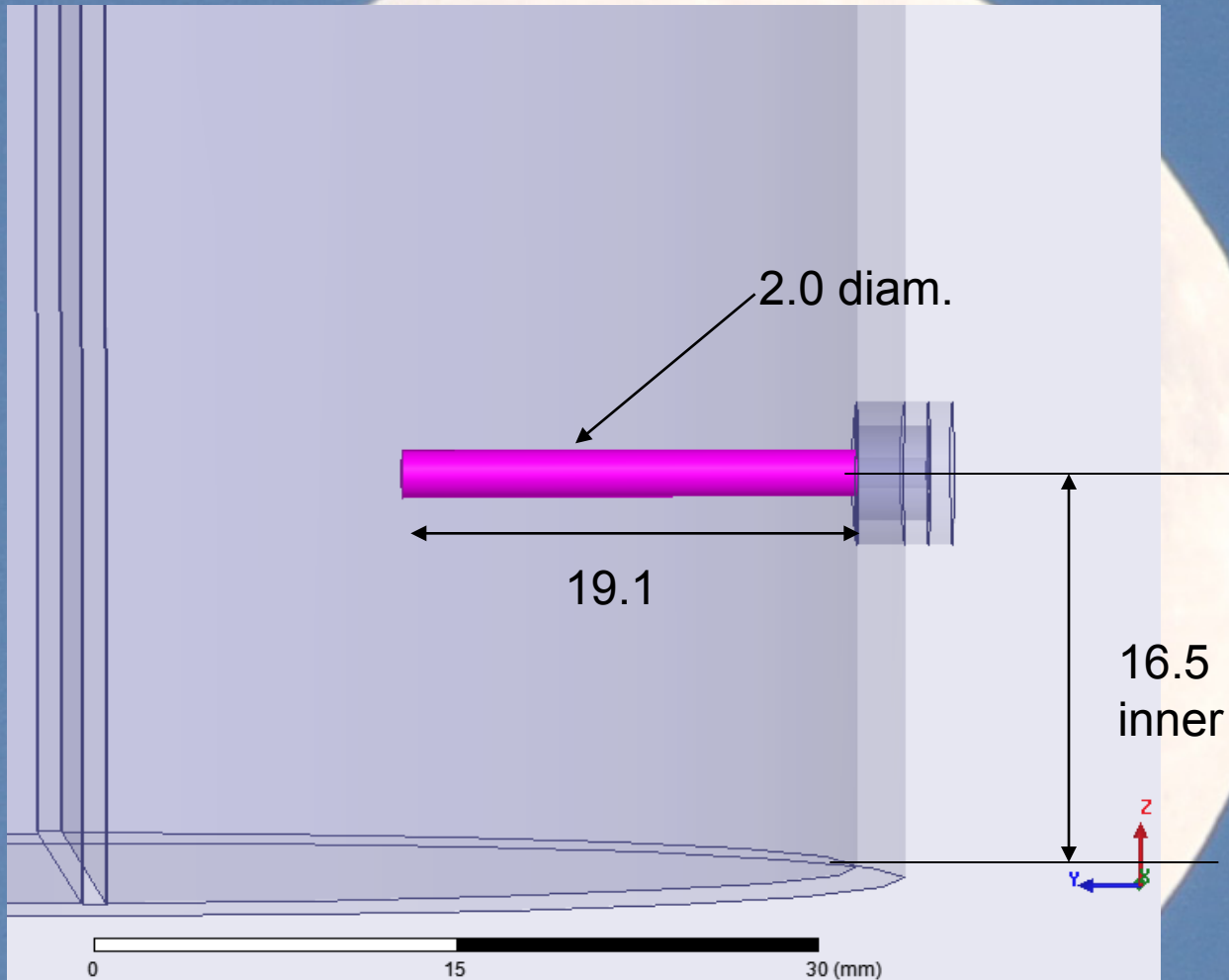
43.5
outer



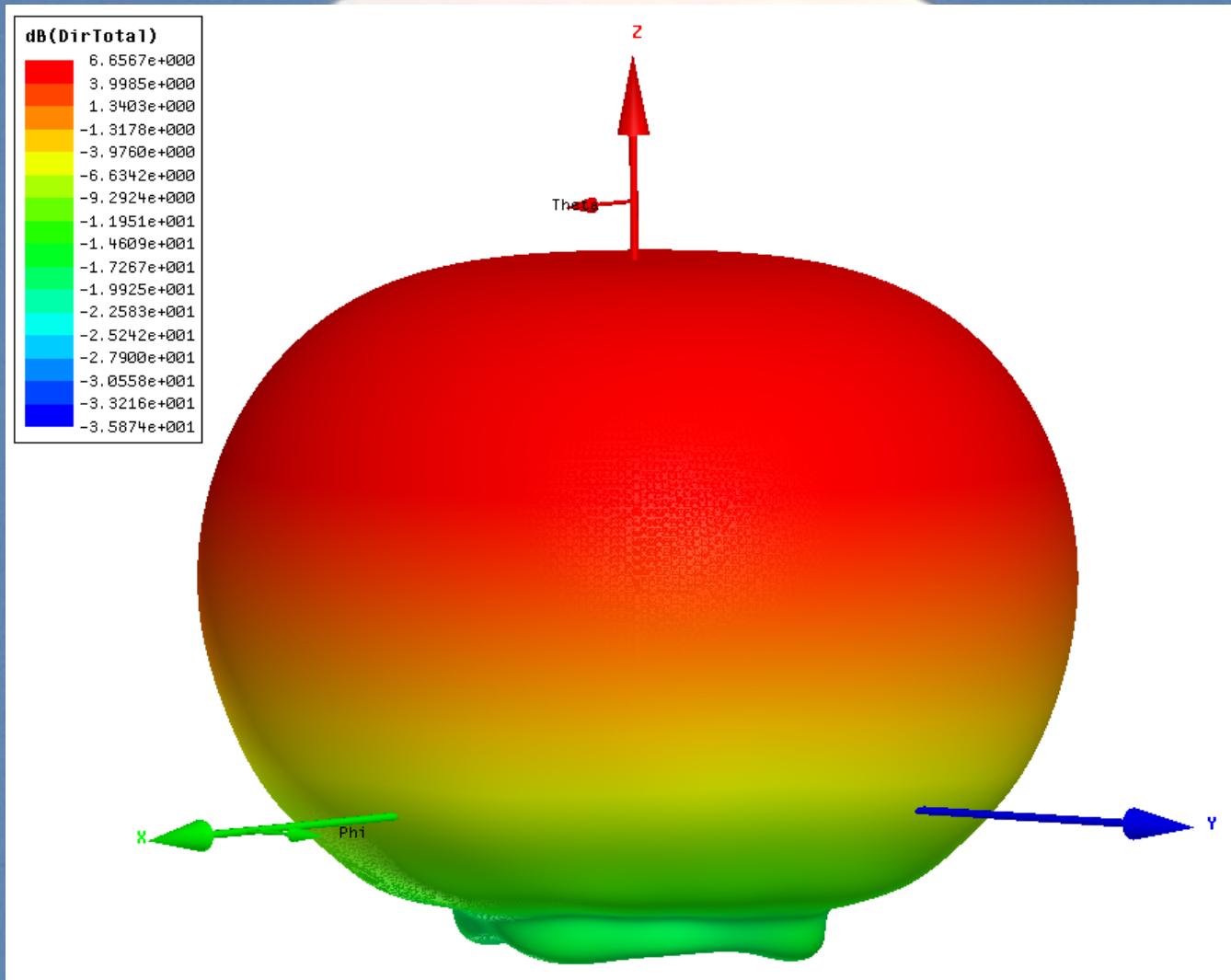
Septum dimensions



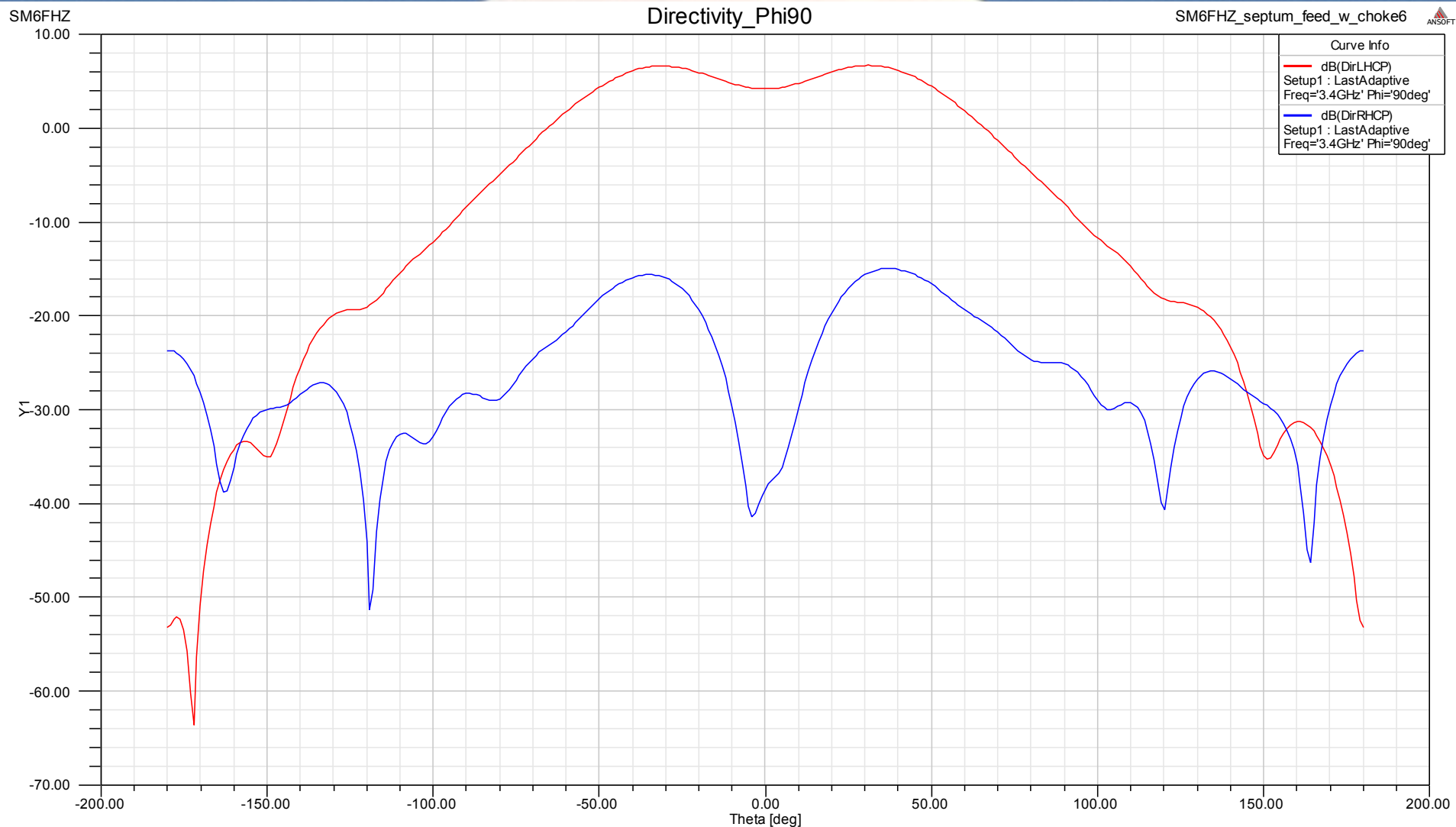
Probe dimensions



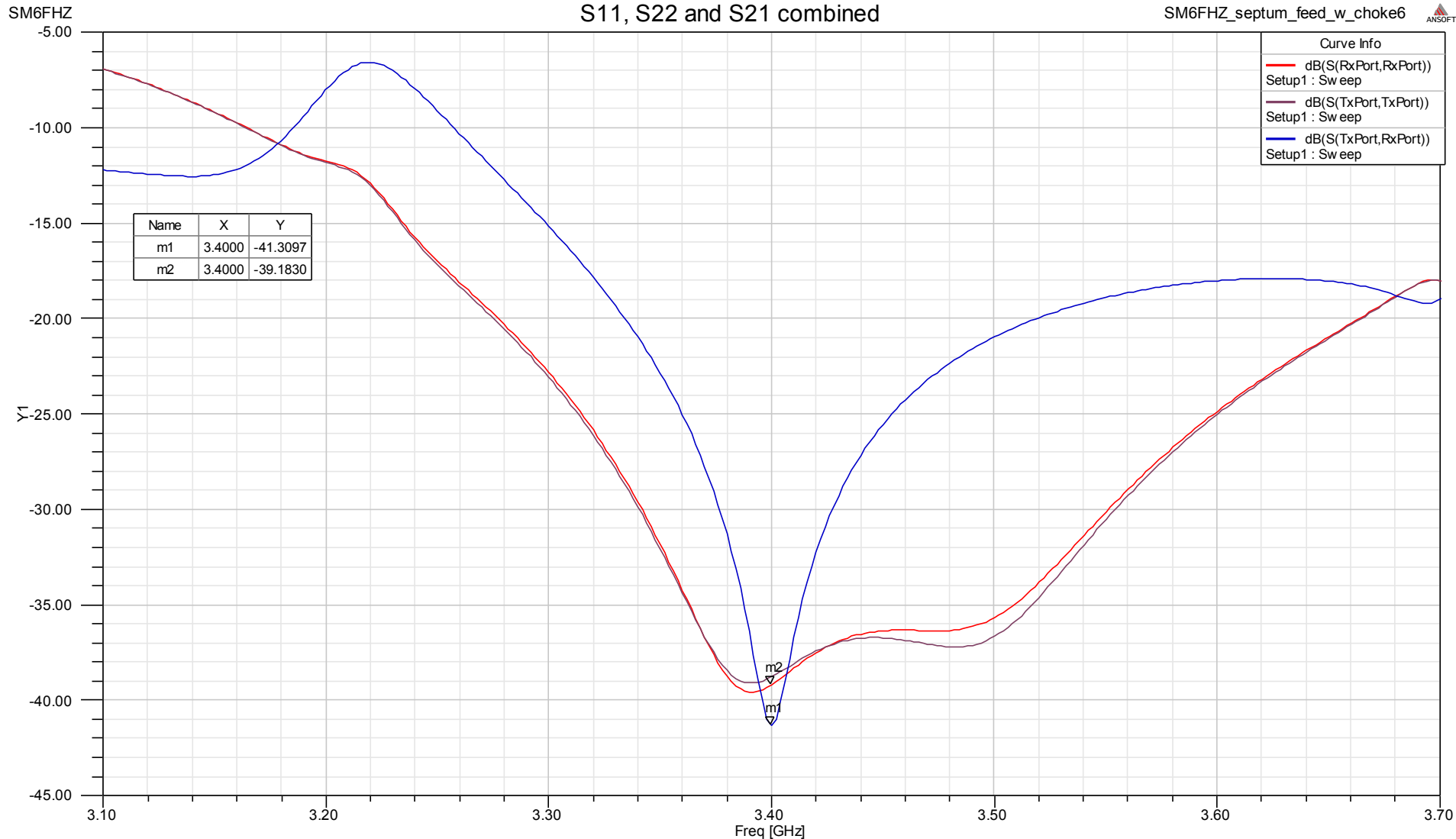
FF 3D Total Power pattern



FF Directivity pattern

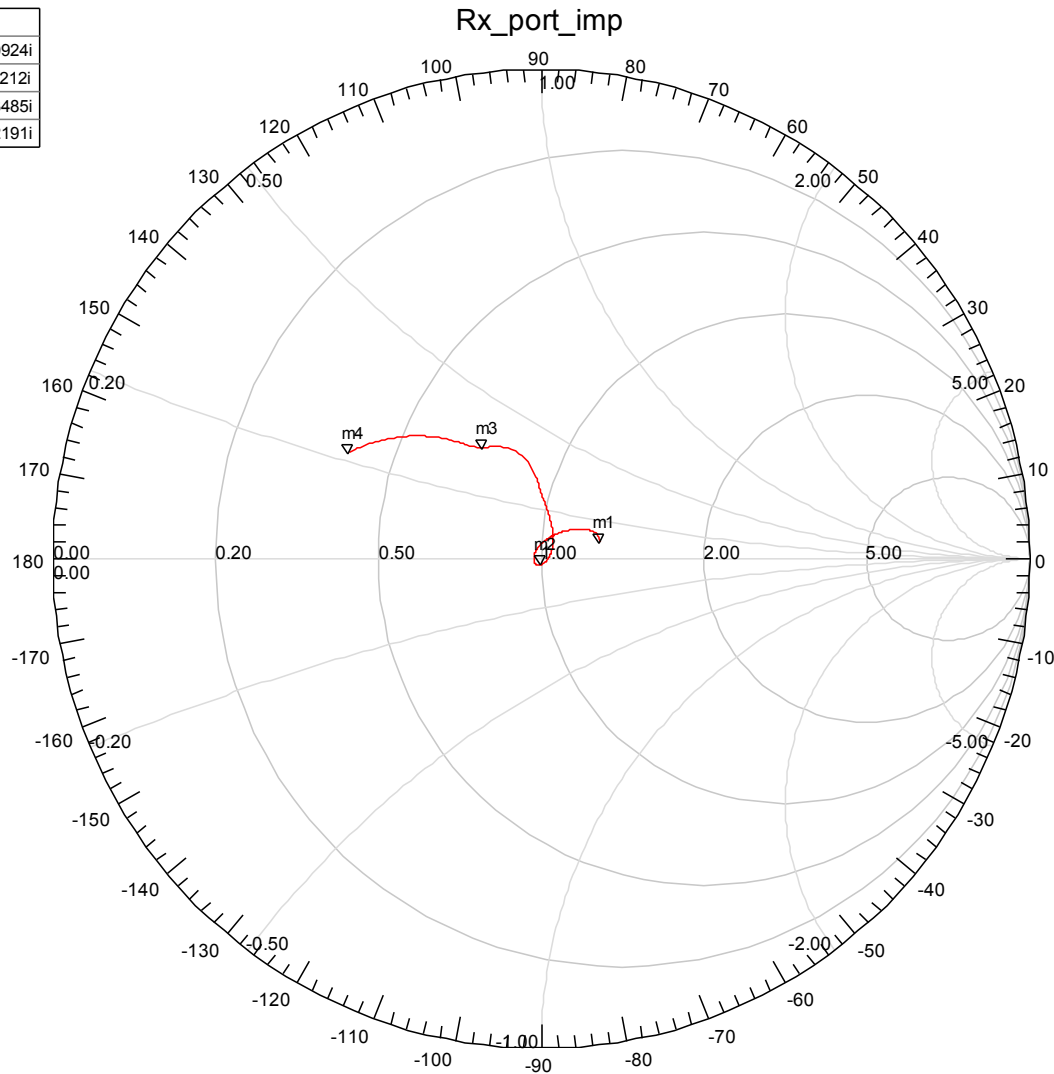


S11, S22 and S21 combined



Complex impedance Rx-port

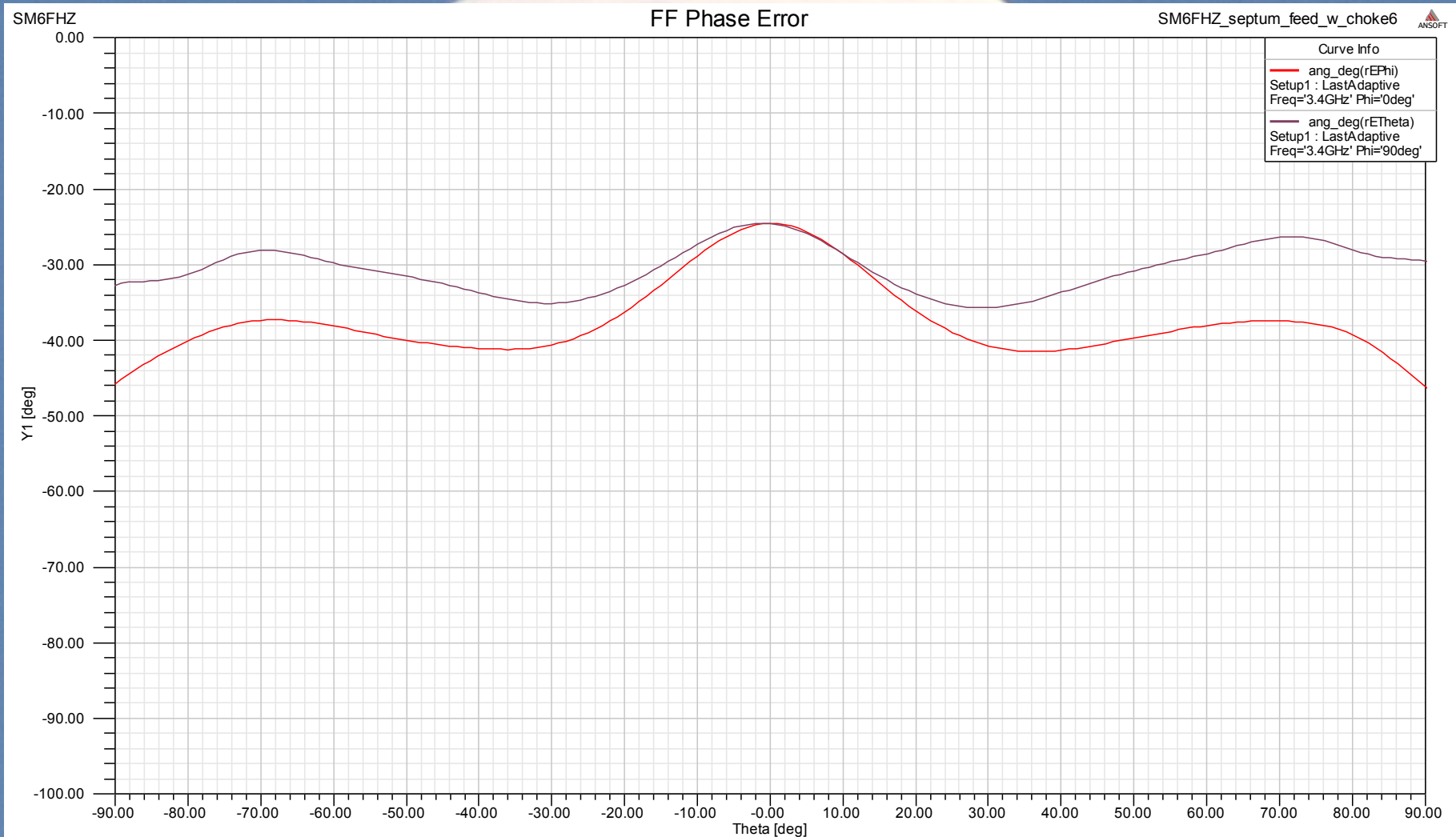
Name	Freq	Ang	Mag	RX
m1	3.7000	16.6154	0.1253	1.2692 + 0.0924i
m2	3.4000	-73.3845	0.0110	1.0061 - 0.0212i
m3	3.2000	117.7322	0.2570	0.7156 + 0.3485i
m4	3.1000	151.0225	0.4496	0.4012 + 0.2191i



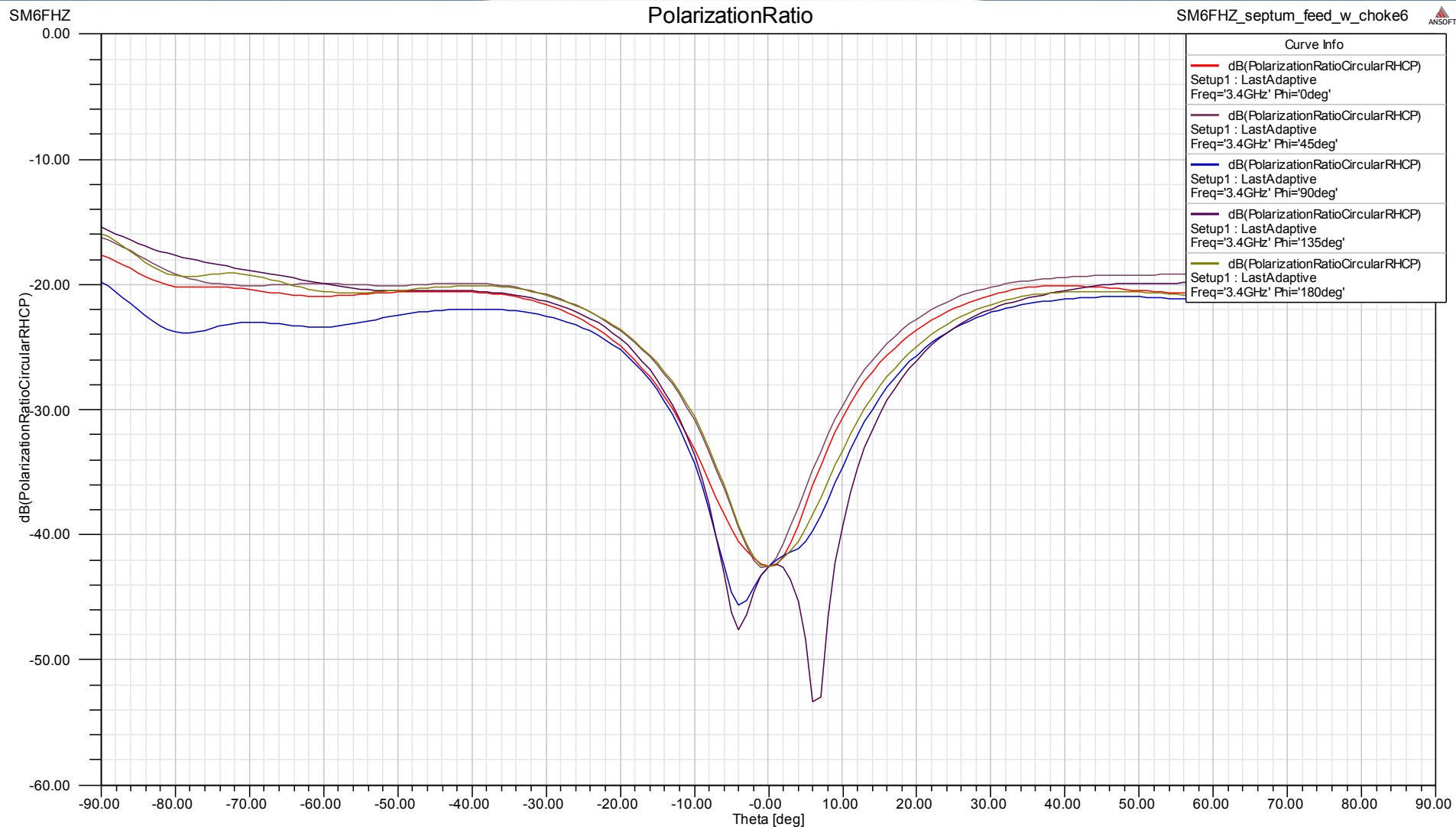
SM6FHZ_septum_feed_w_choke6 ANSOFT

Curve Info
 — S(RxPort,RxPort)
 Setup1 : Sw eep

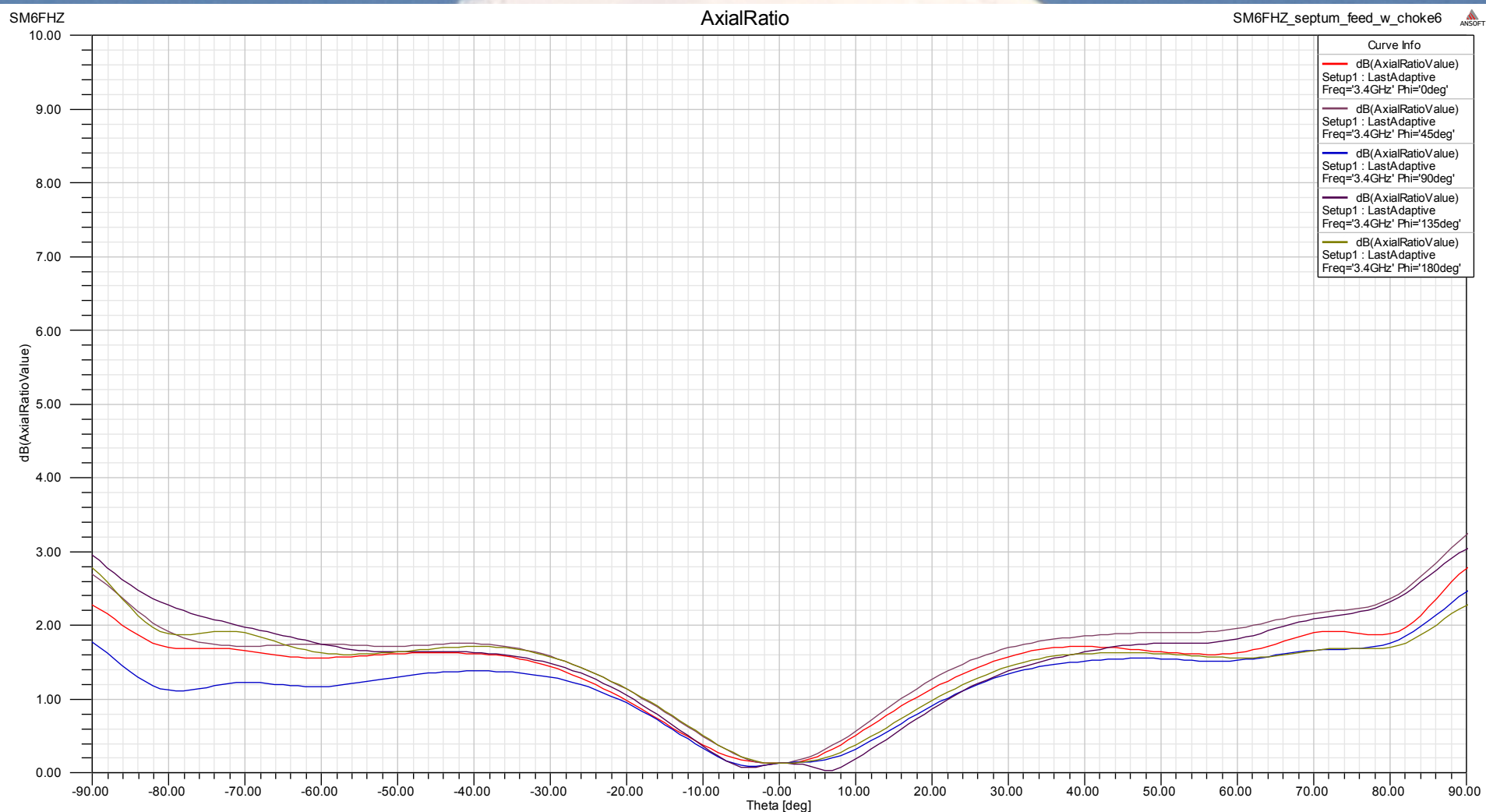
FF Phase error



Cross Polarization Ratio

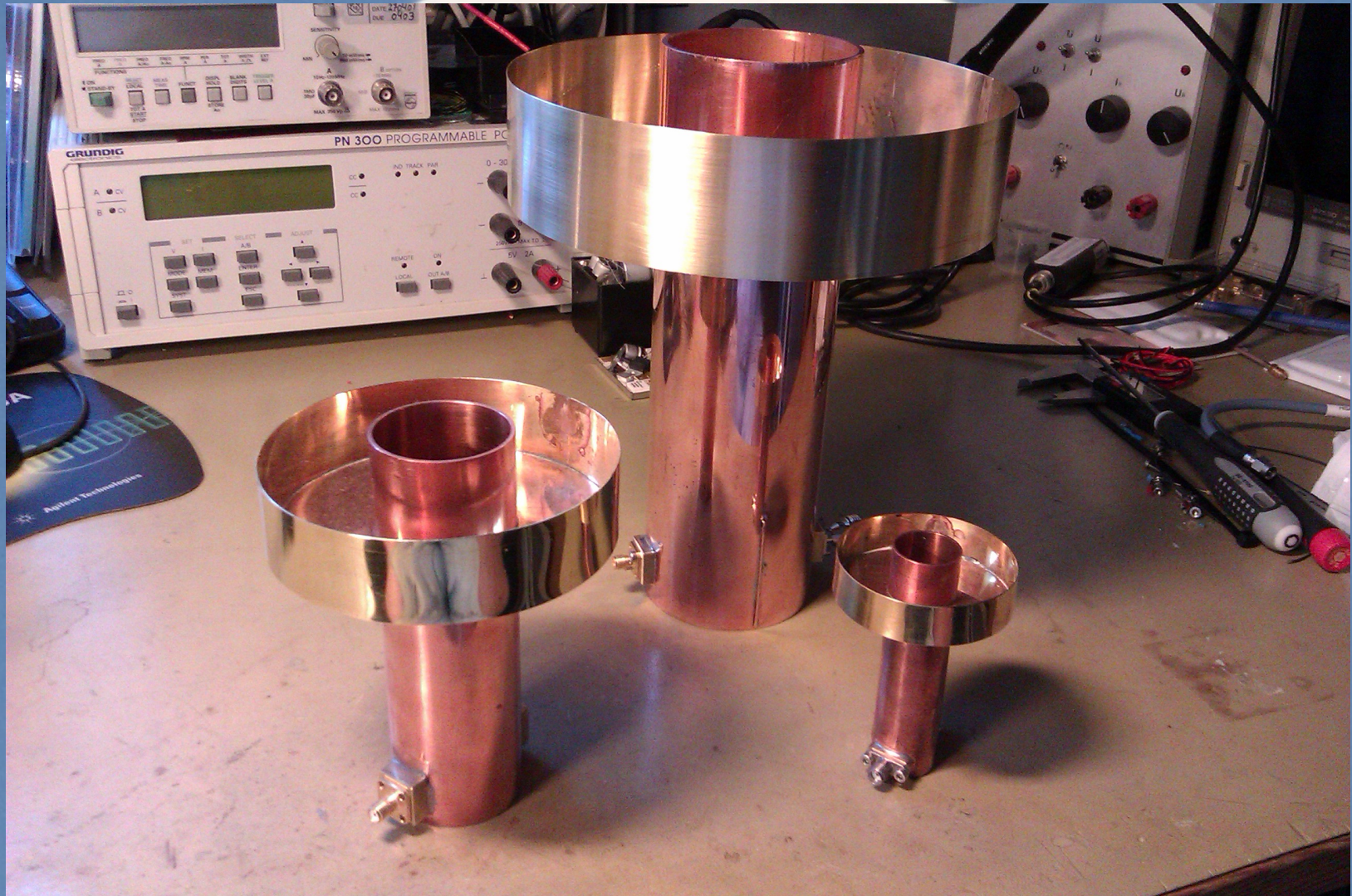


Axial Ratio

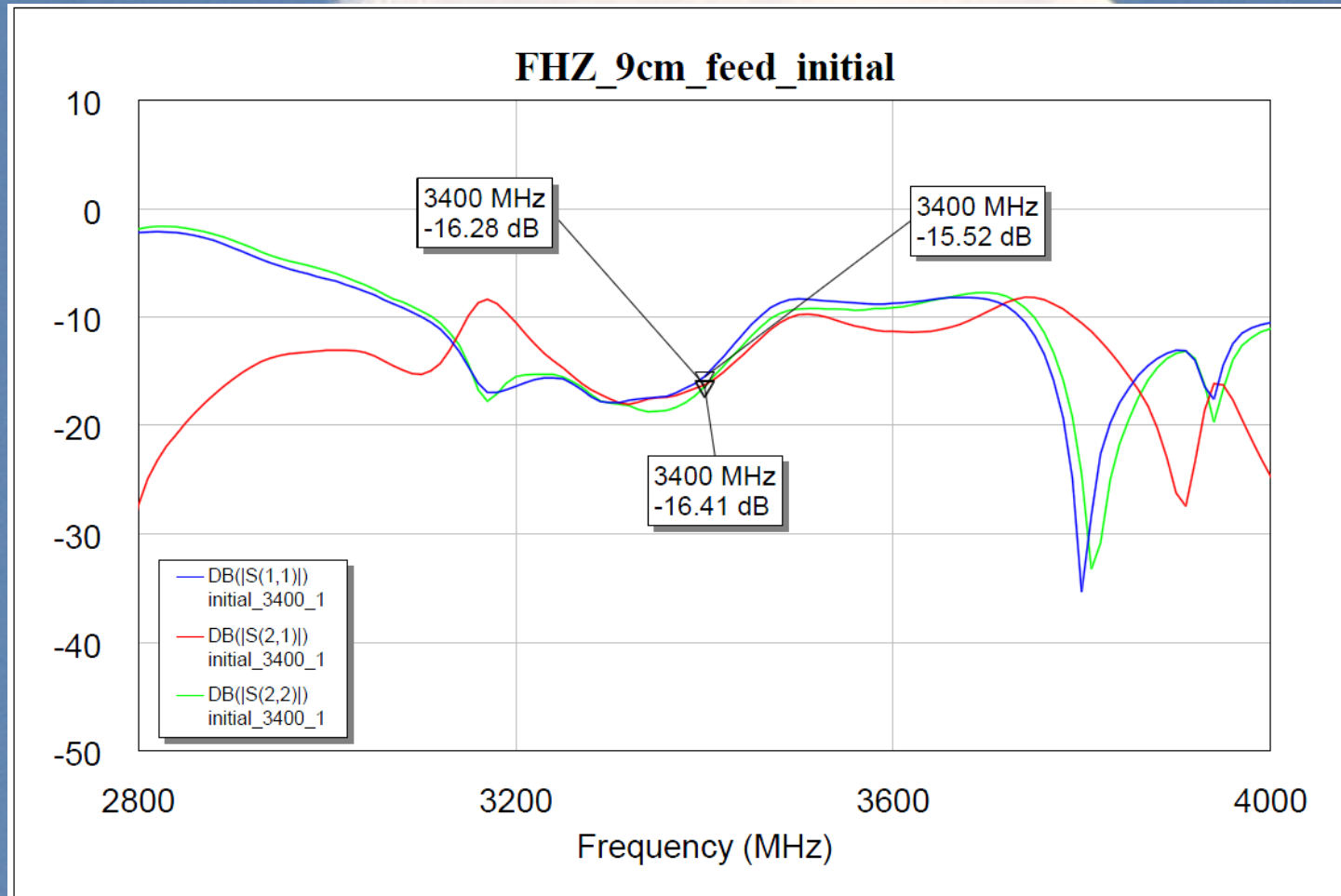


Realization

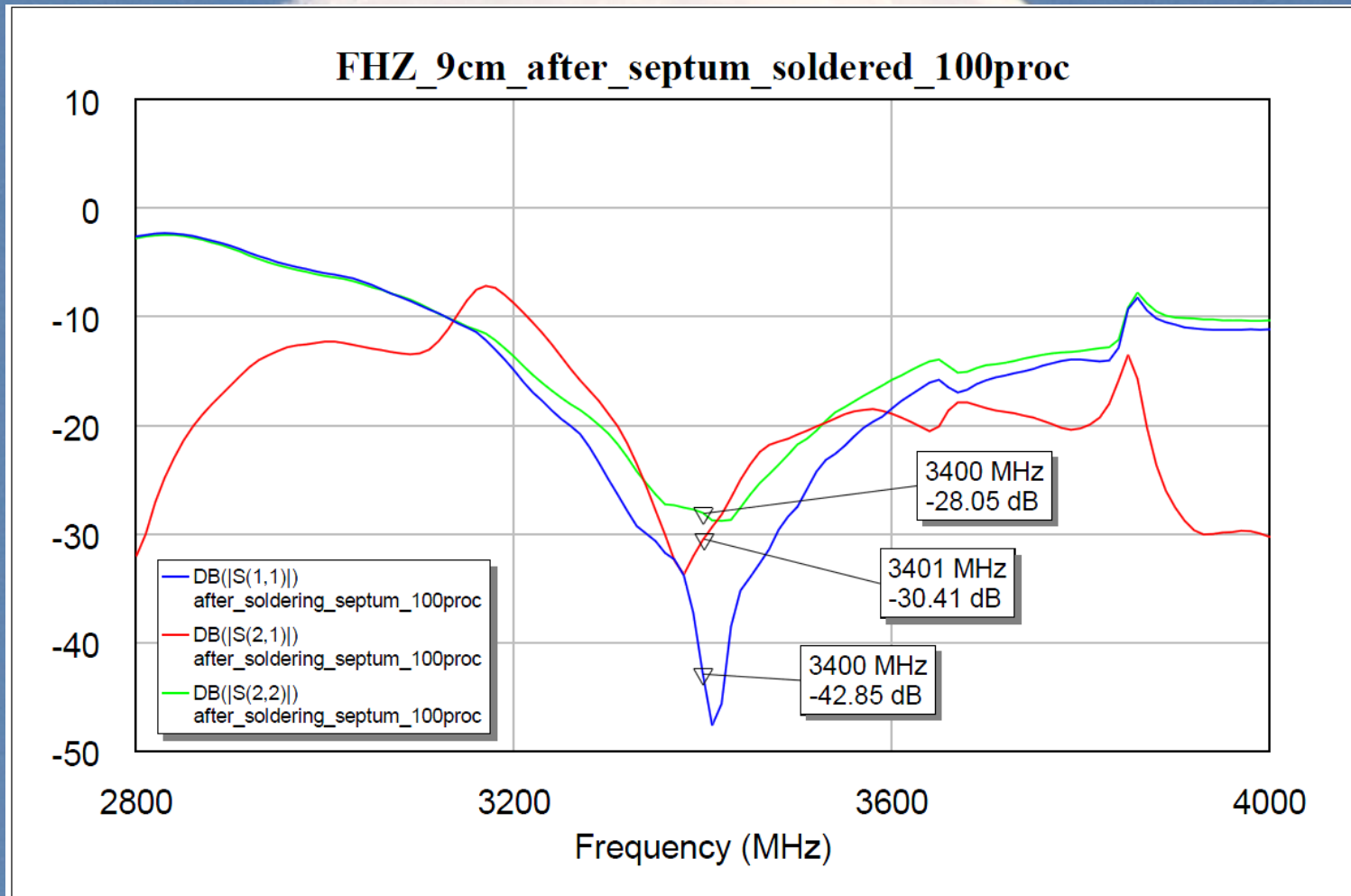
9, 6 and 3 cm feeds comparison



Measured performance with partial septum soldering



Measured performance



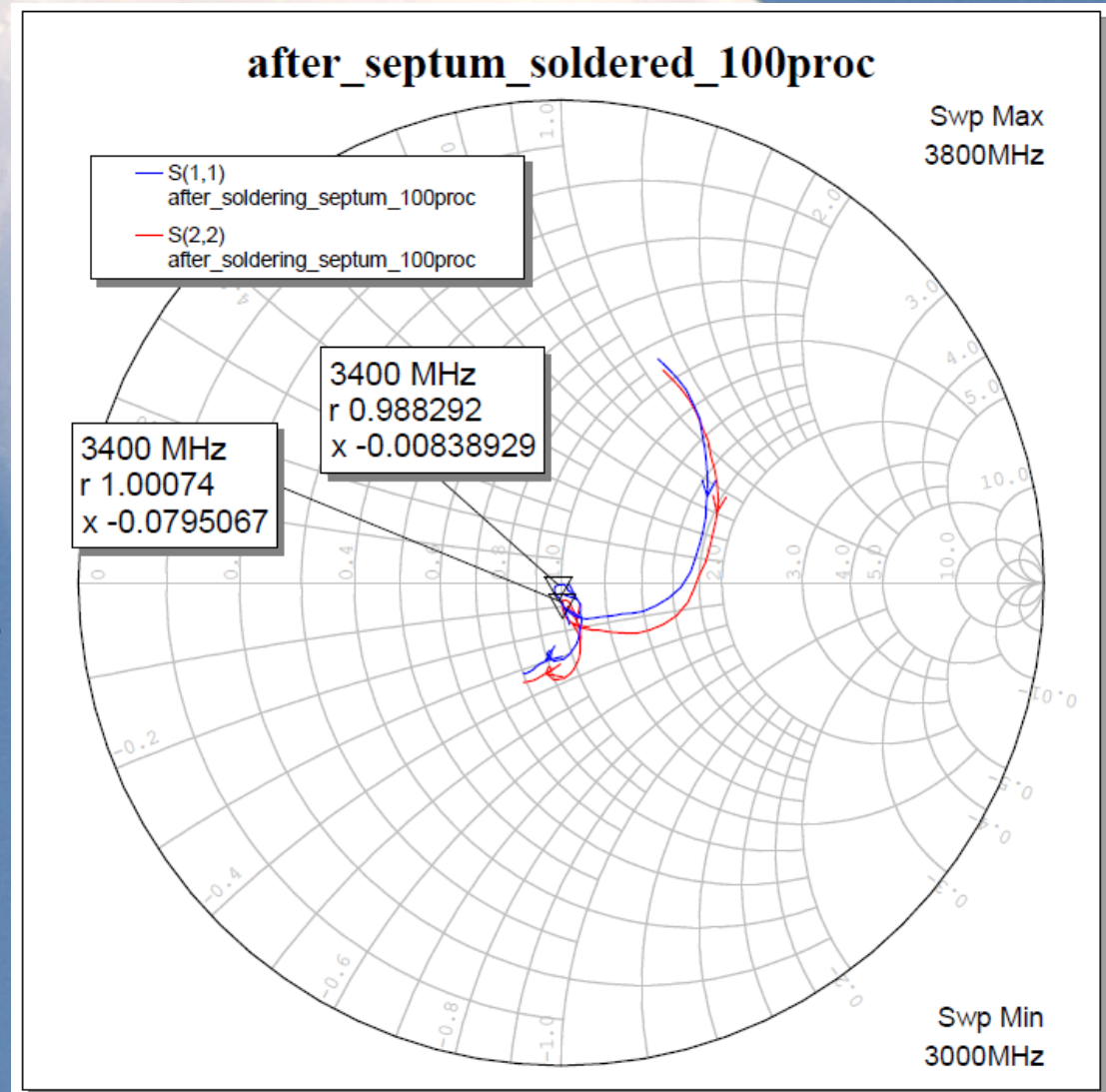
Measured complex impedance

Reference plane about 15 mm (~0.25 WL in teflon) out from the simulated case.

SMA connector on feed included in measurement.

Measurement sweep 200 MHz wider than simulation sweep

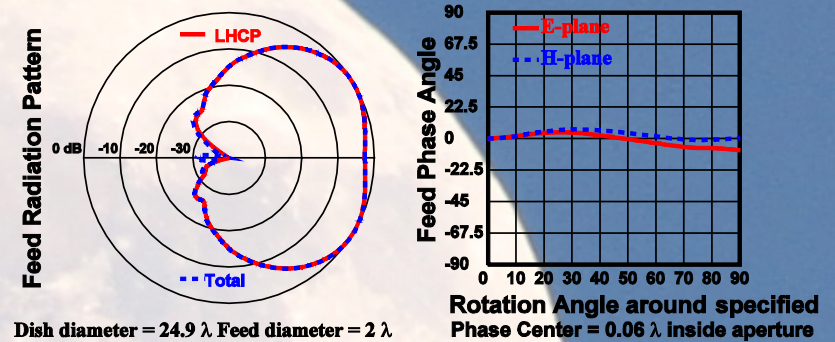
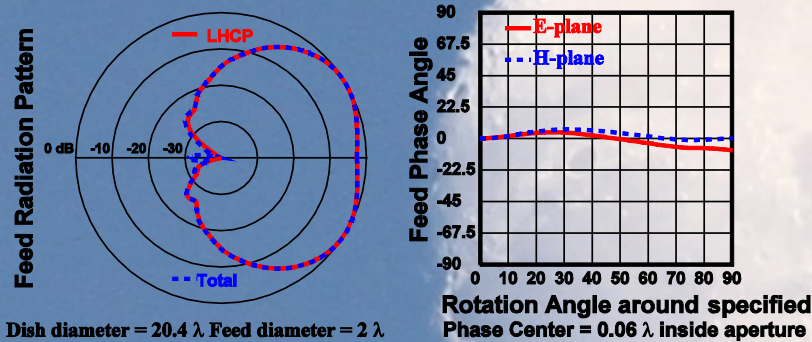
Very good agreement between simulated and measured performance.



InDish Performance, 1.8 and 2.2 m dish

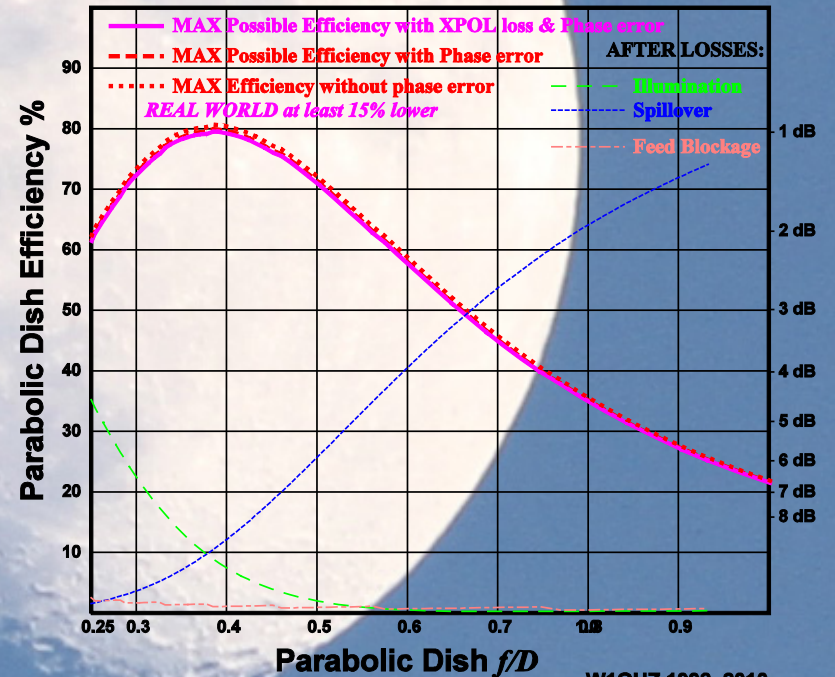
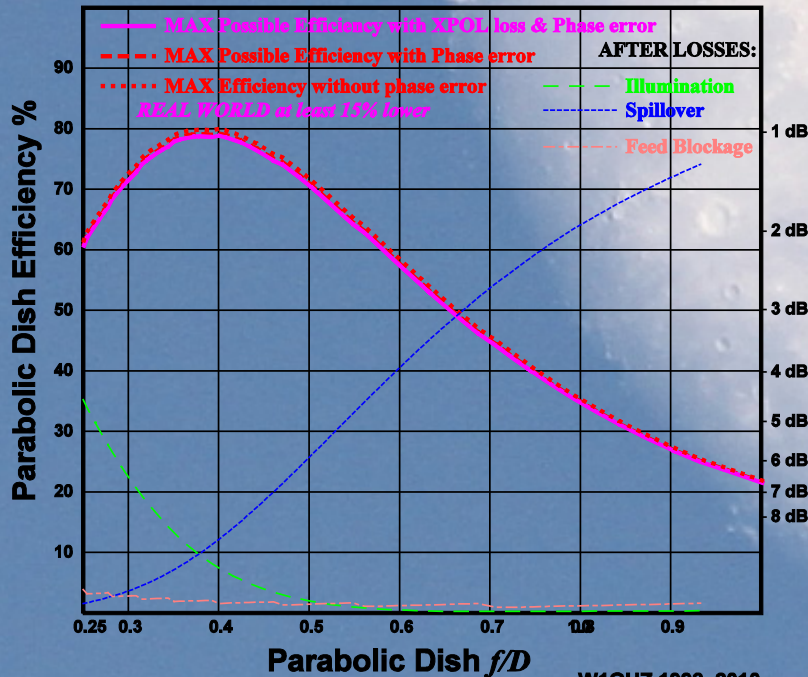
SM6FHZ 9 cm septum feed in 1.8 m dish

SM6FHZ 9 cm septum feed in 2.2 m dish




Dish diameter = 20.4λ Feed diameter = 2λ

Dish diameter = 24.9λ Feed diameter = 2λ



W1GHZ 1998, 2010

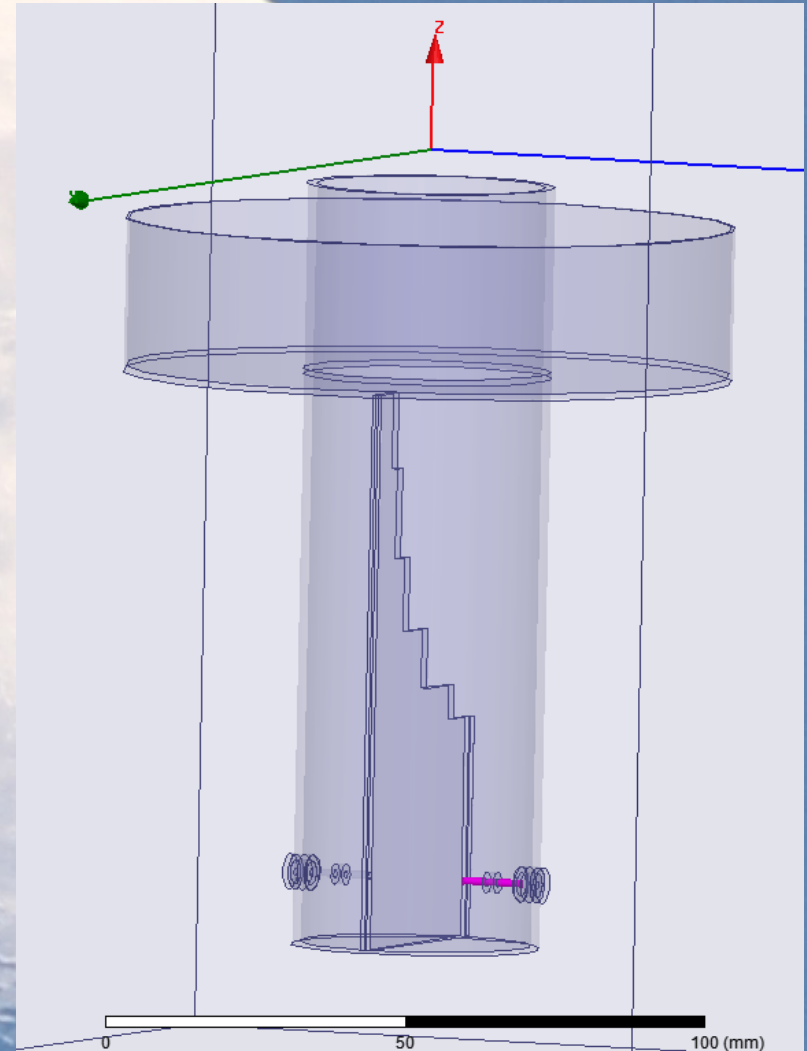
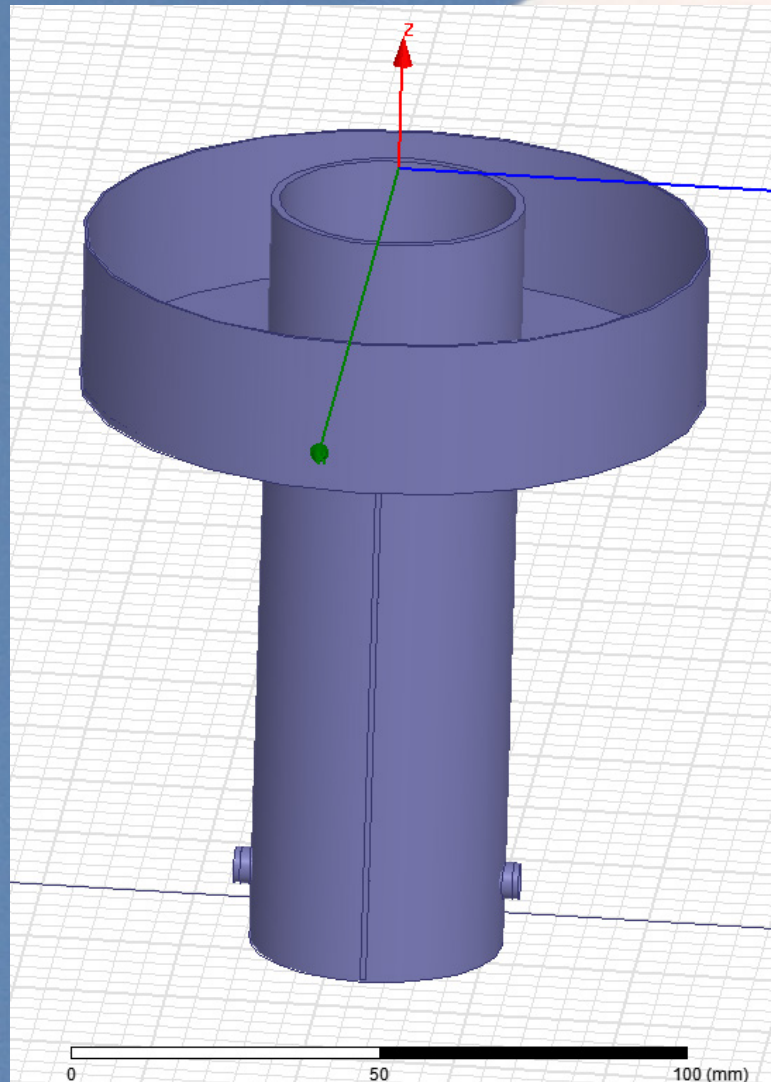
W1GHZ 1998, 2010



SM6FHZ 6 cm 5 step septum
feed

0.749 lambda W/G

Solid and transparent models from the simulation

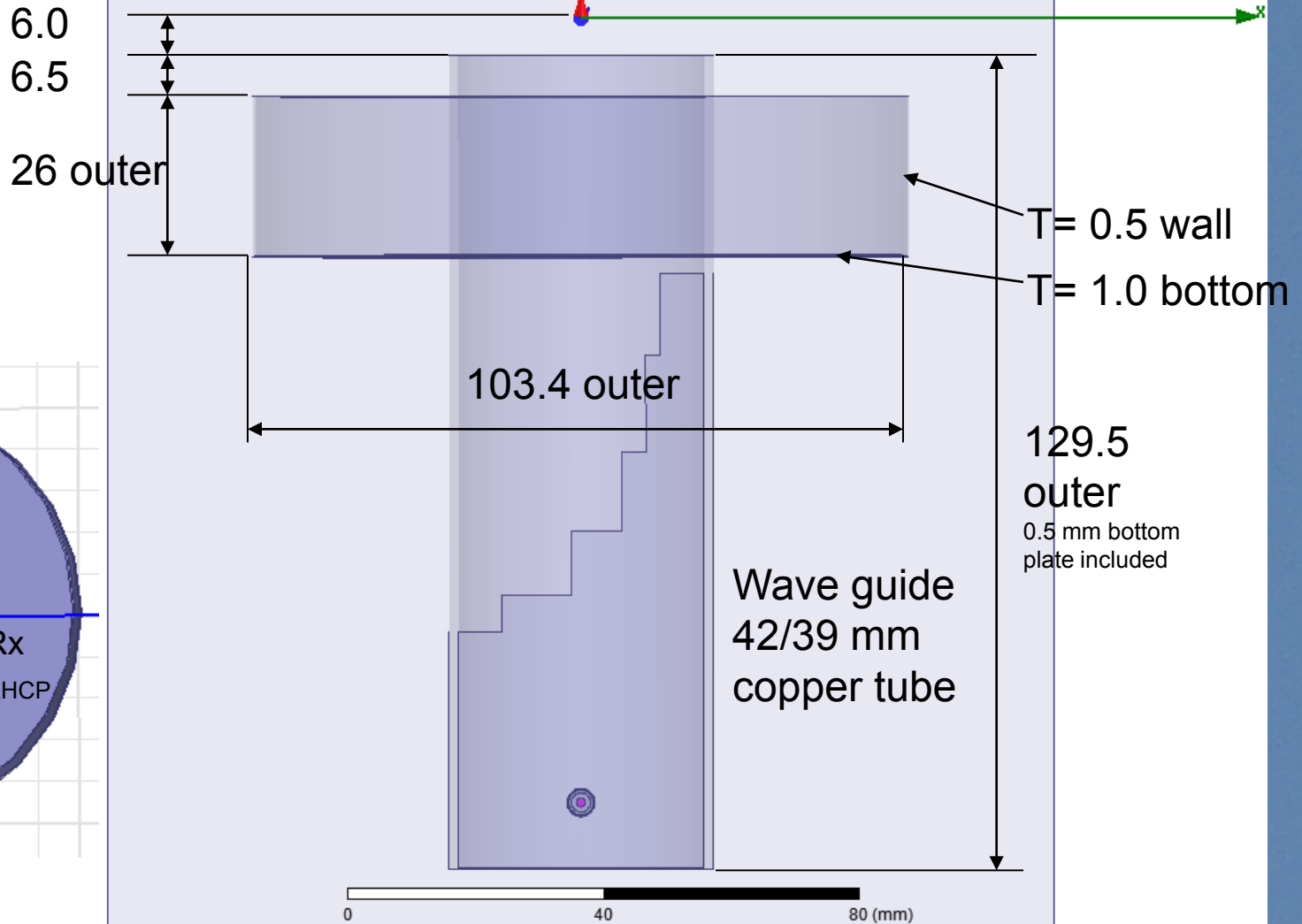
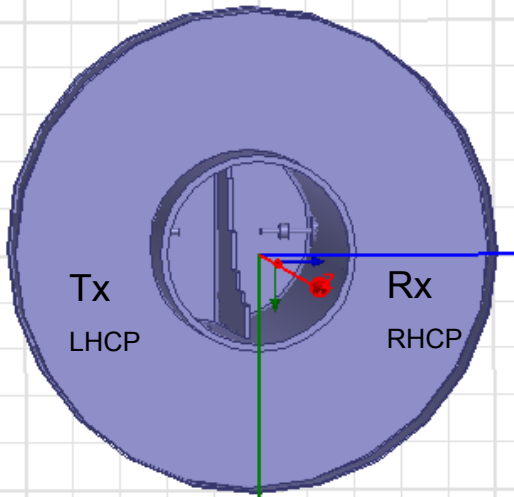


WG and choke dimensions

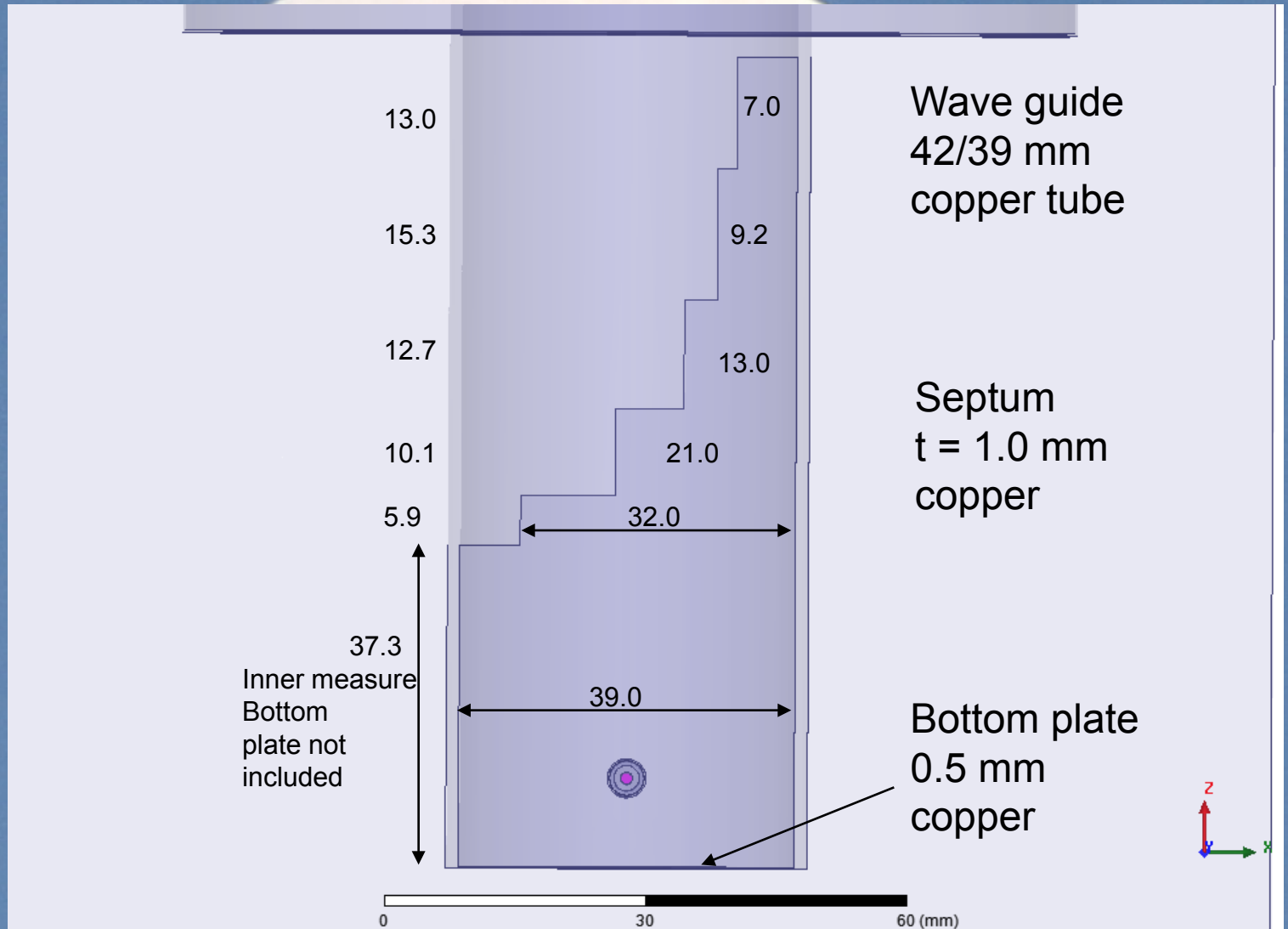
Circular polarization convention for EME according to Crawford Hill Bulletin No 1:

Tx RHCP in space
Rx LHCP in space

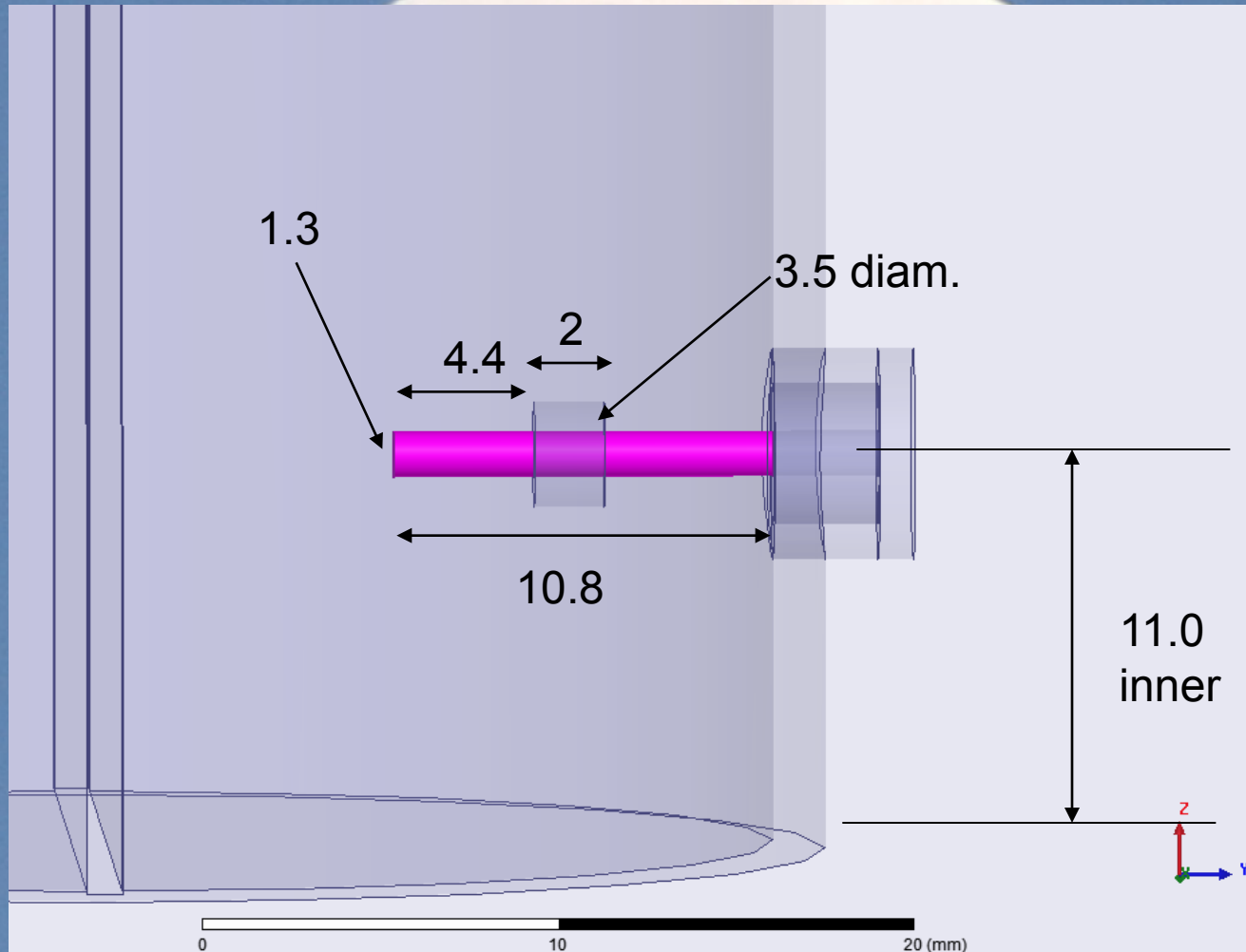
Take polarization reversal into account when using reflector antennas.



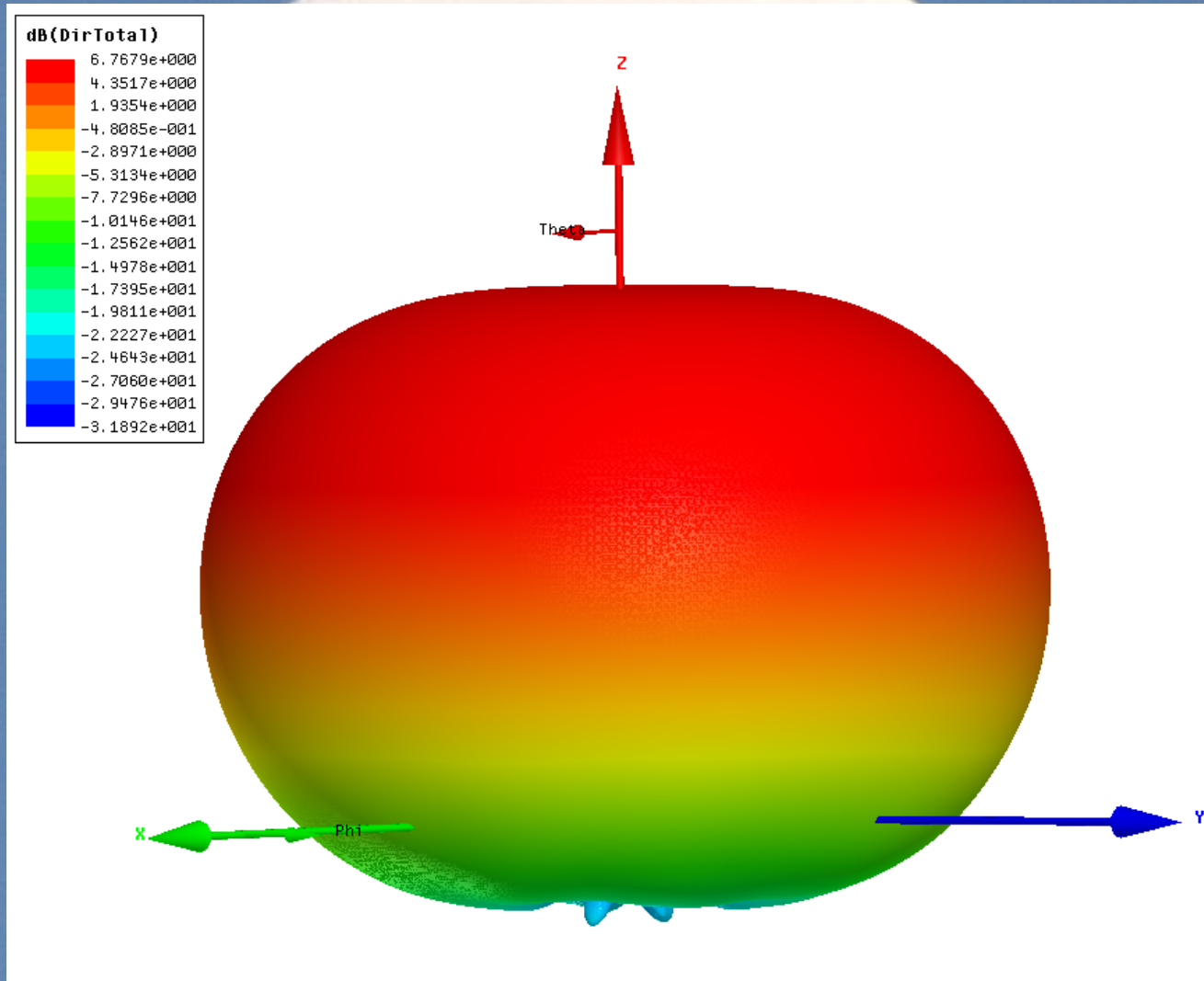
Septum dimensions



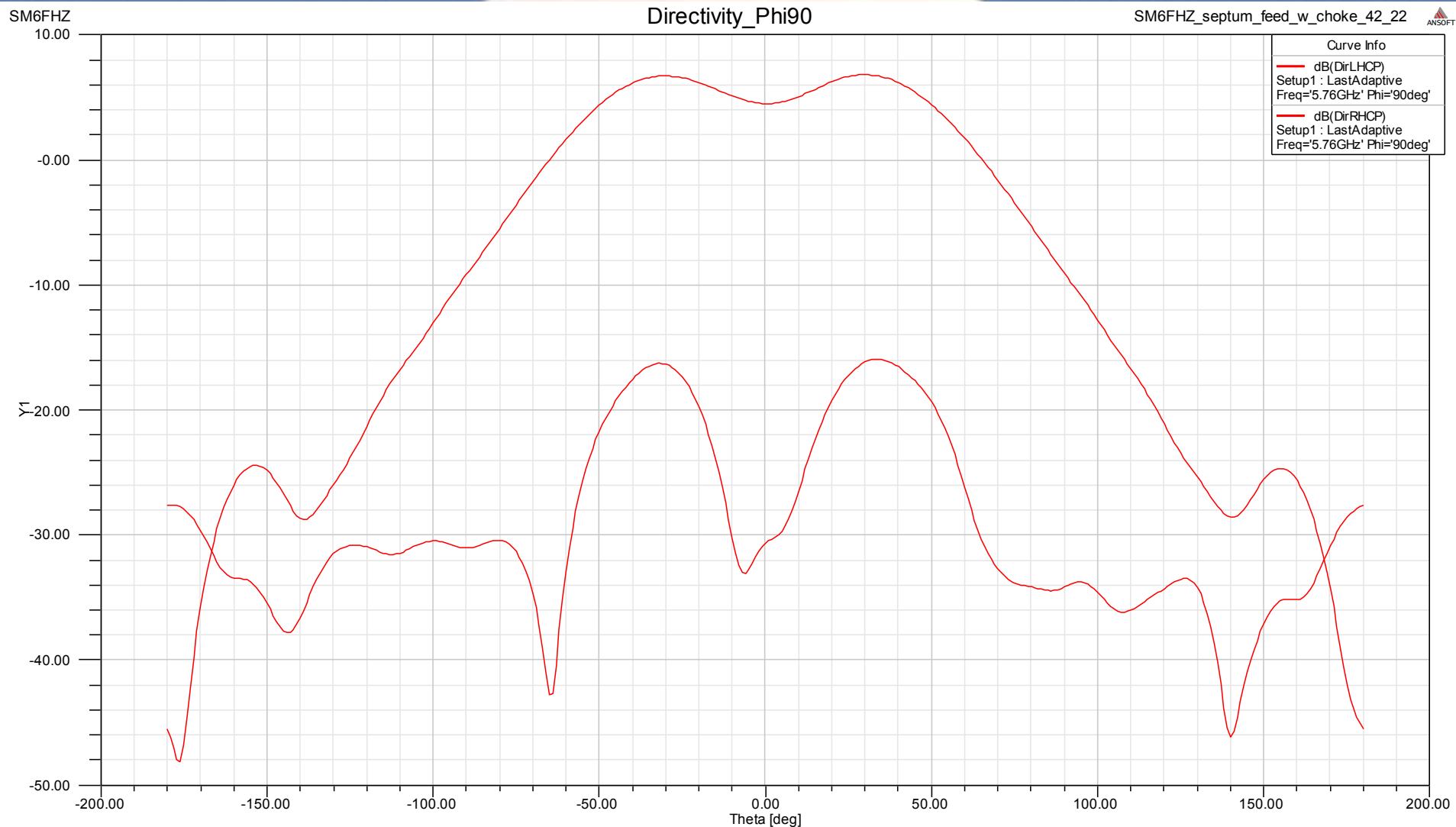
Probe dimensions



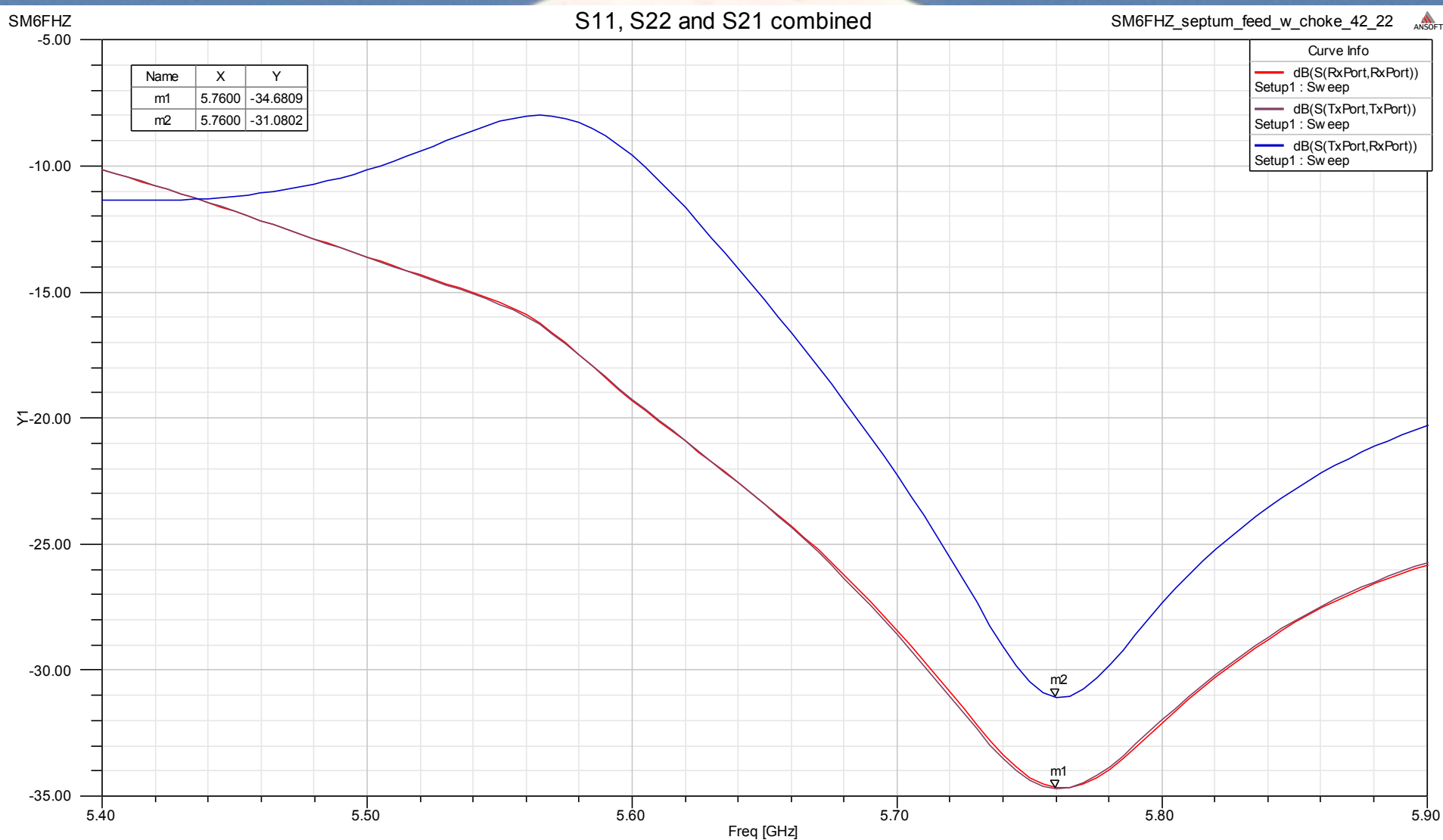
FF 3D Total Power pattern



FF Directivity pattern

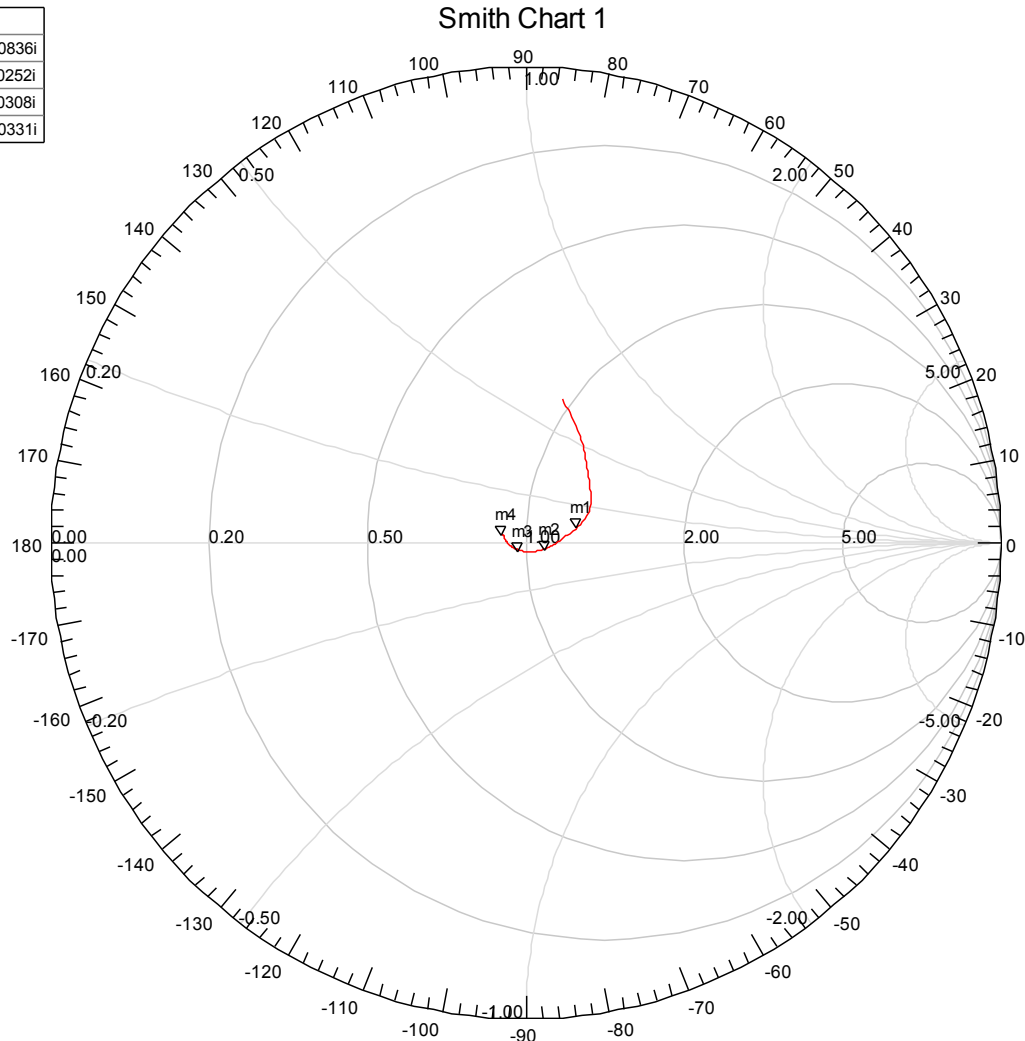


S11, S22 and S21 combined

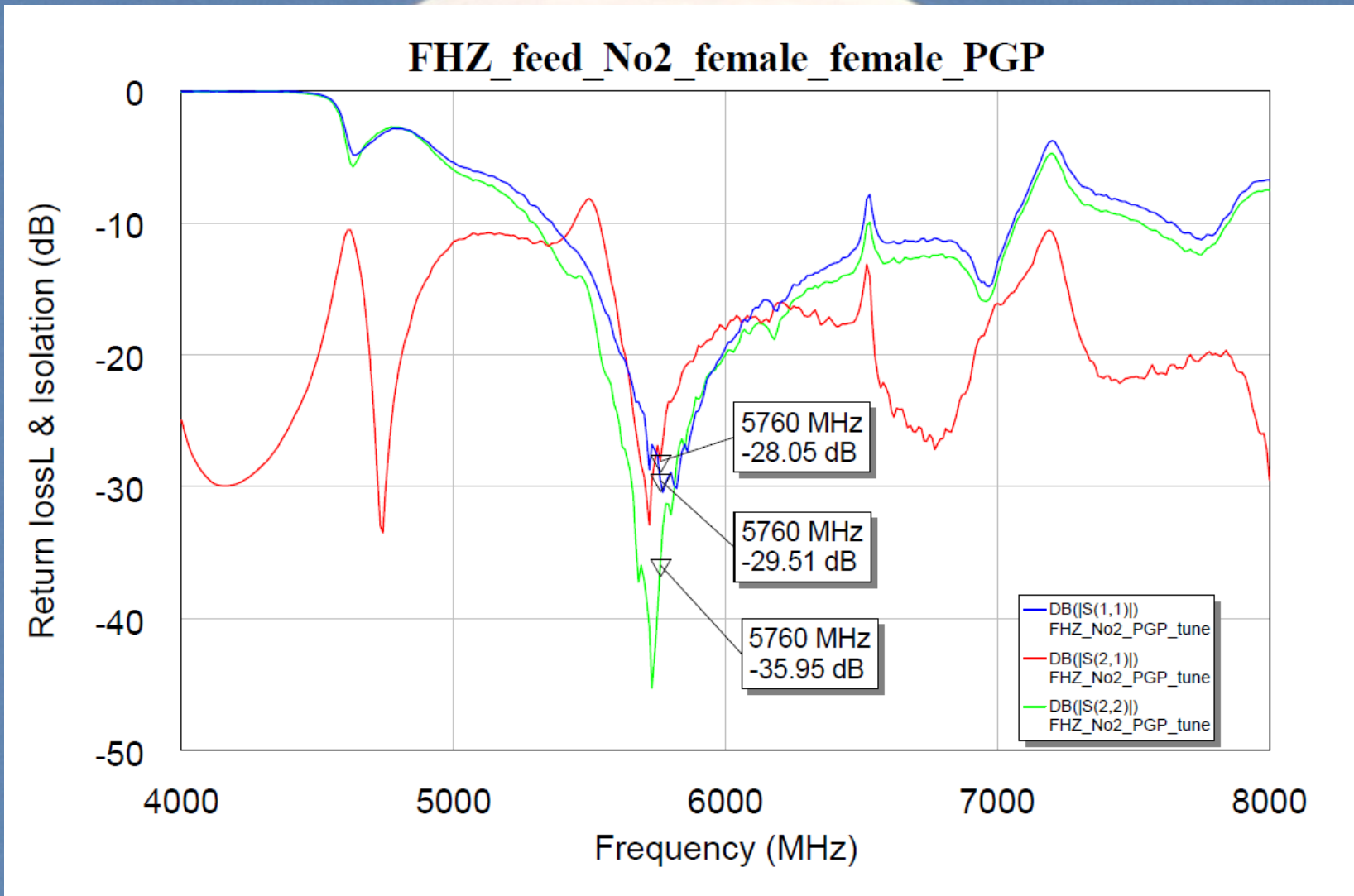


Complex impedance Rx-port

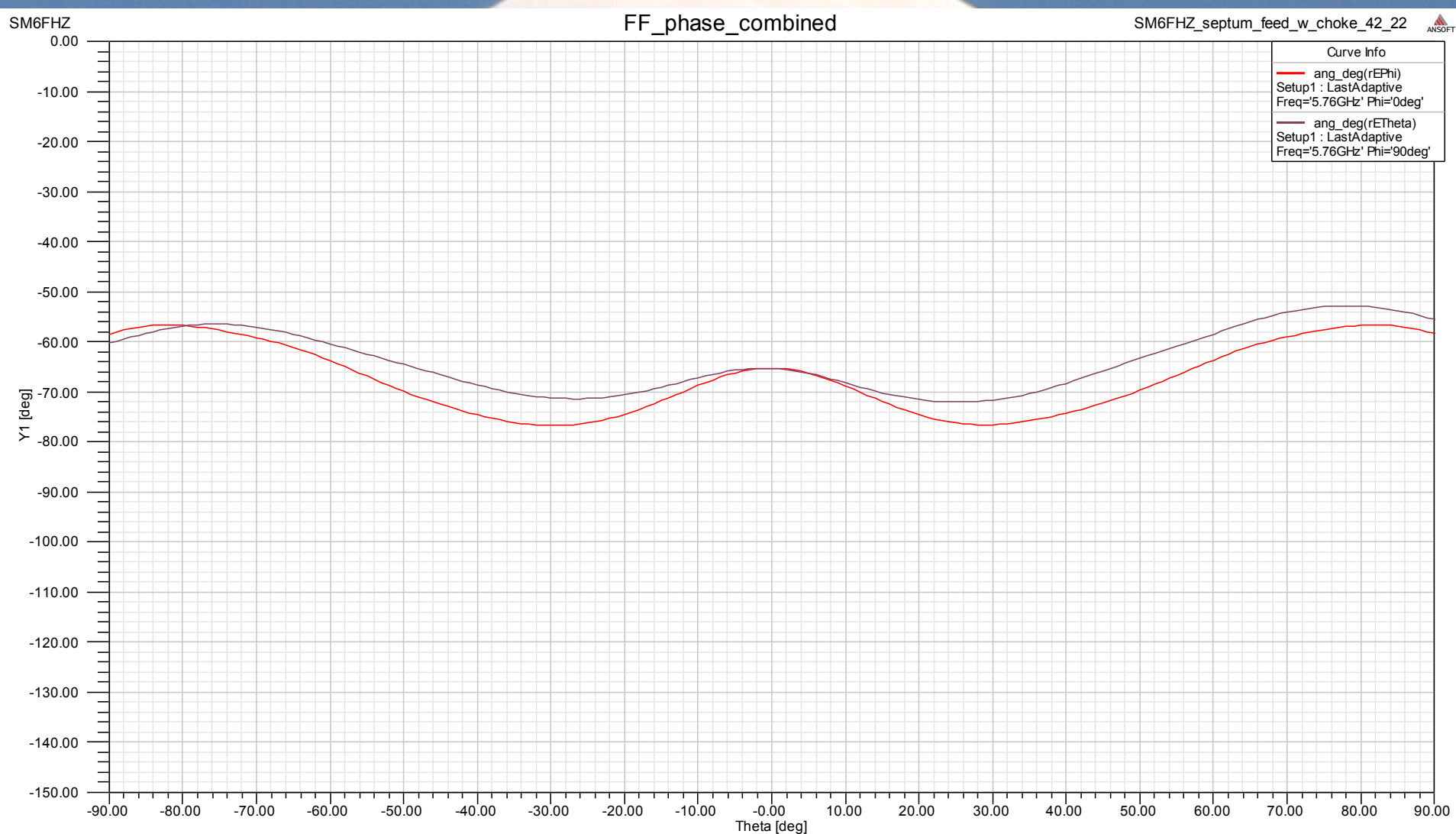
Name	Freq	Ang	Mag	RX
m1	5.5950	16.9581	0.1139	1.2414 + 0.0836i
m2	5.6900	-15.5465	0.0432	1.0866 - 0.0252i
m3	5.7850	-131.4701	0.0212	0.9719 - 0.0308i
m4	5.9000	159.2115	0.0512	0.9081 + 0.0331i



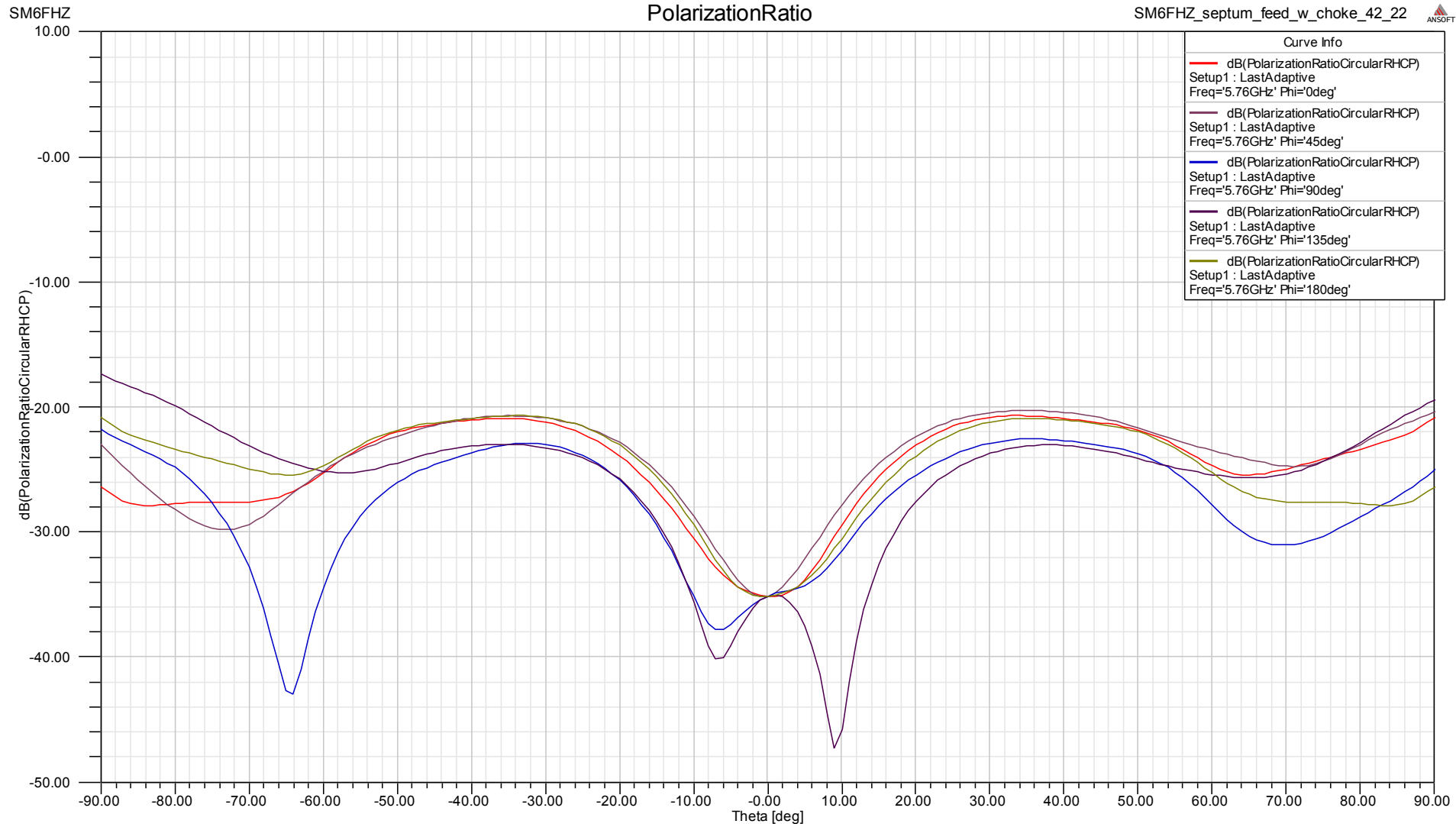
Measurements



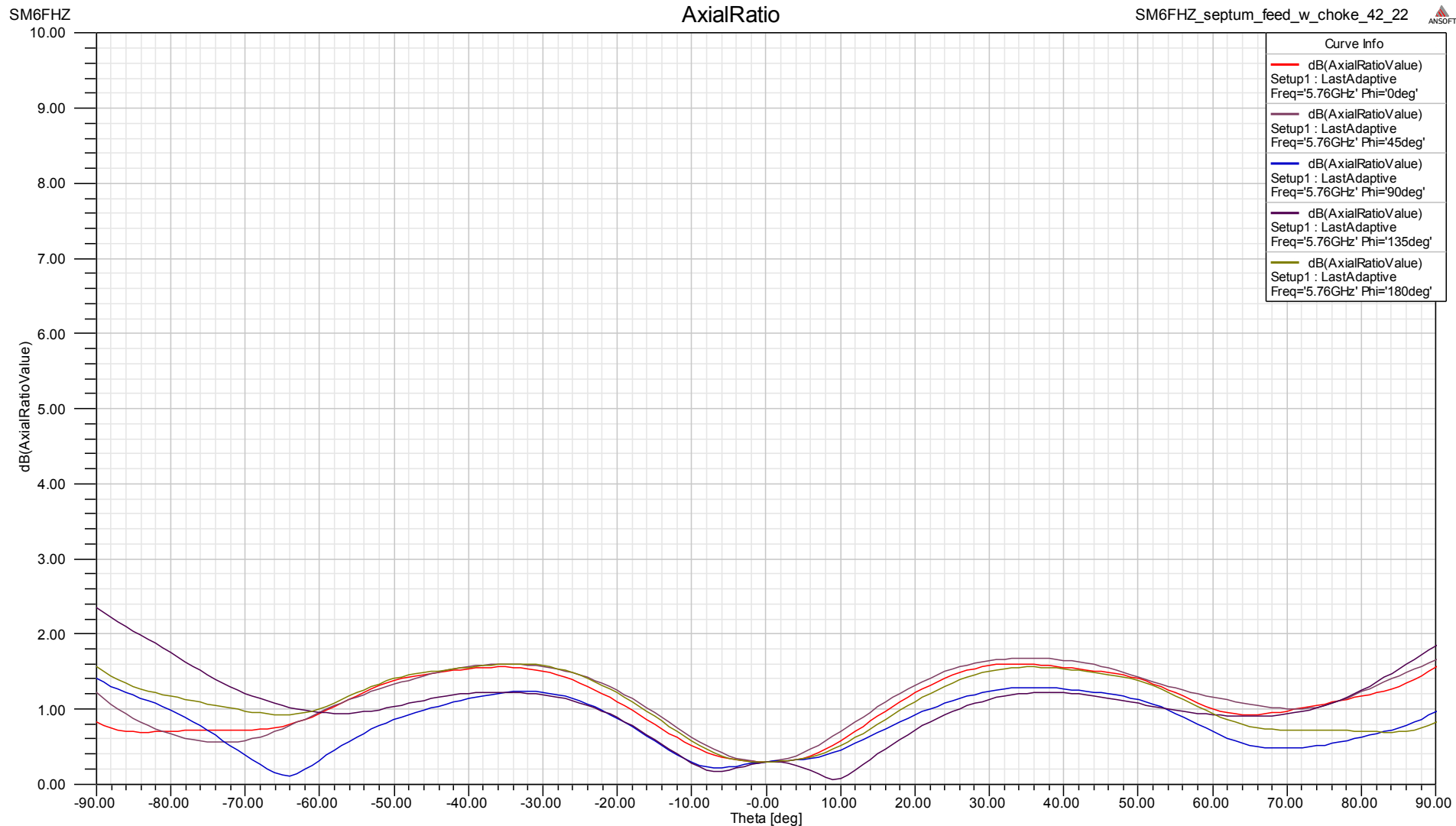
FF Phase error



Cross Polarization Ratio



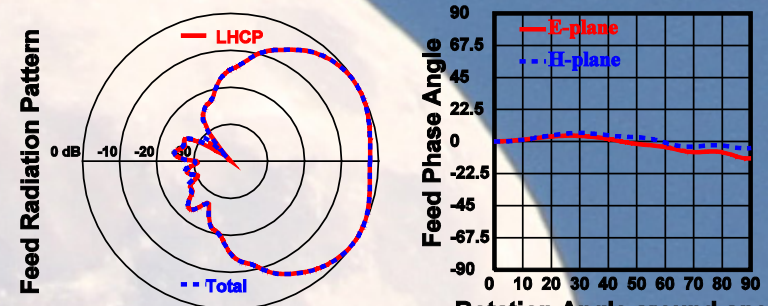
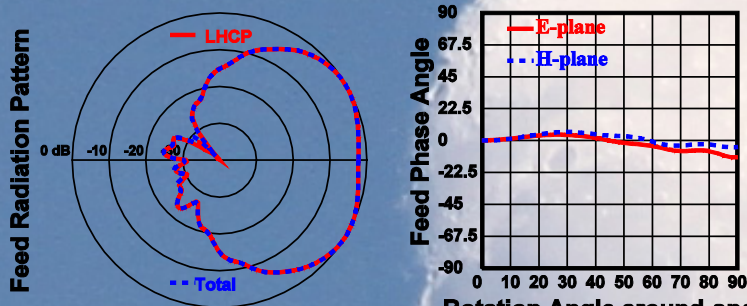
Axial Ratio



InDish Performance

PGP 1.8 m dish w. FHZ 6 cm Kumar feed

PGP 2.2 m dish w. FHZ Kumar 6 cm feed

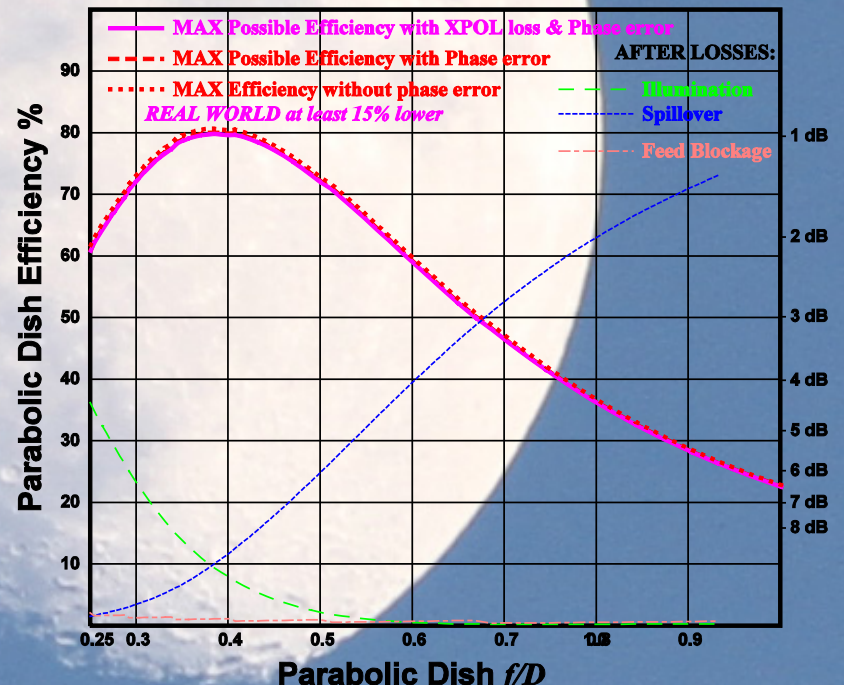
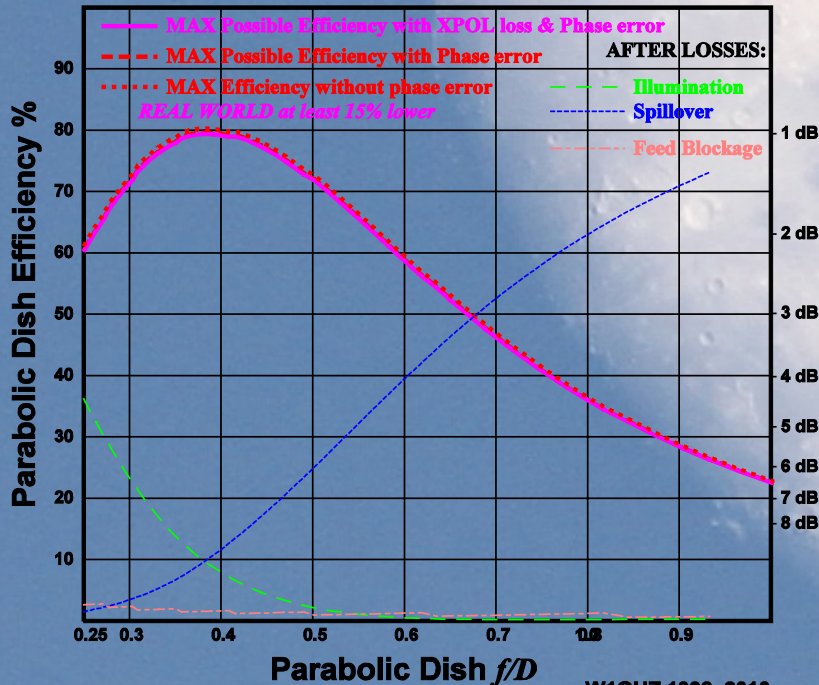


Dish diameter = 34.6λ Feed diameter = 3λ

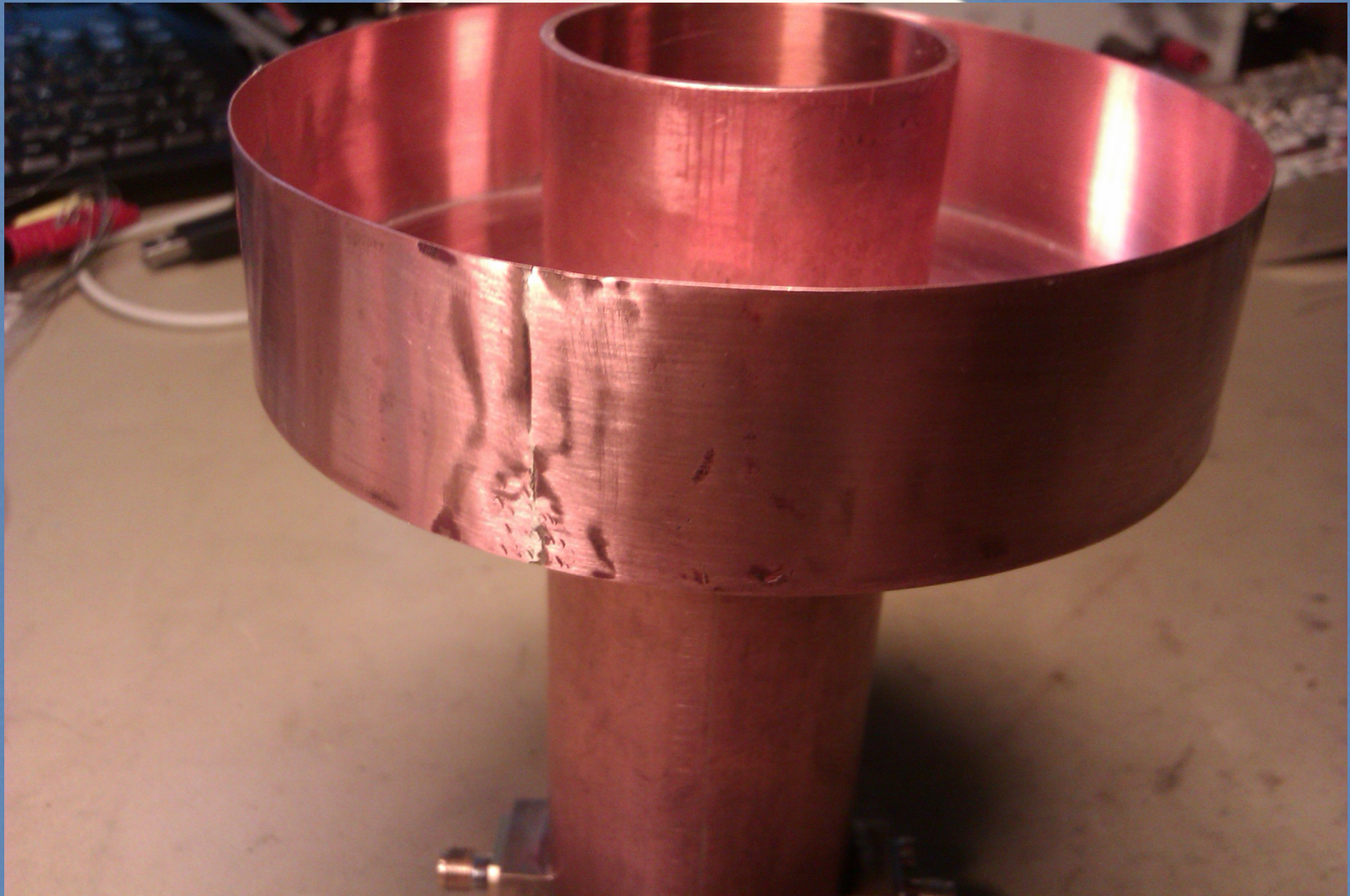
Dish diameter = 42.2λ Feed diameter = 3λ


Rotation Angle around specified Phase Center = 0λ beyond aperture

Rotation Angle around specified Phase Center = 0λ beyond aperture



Realization

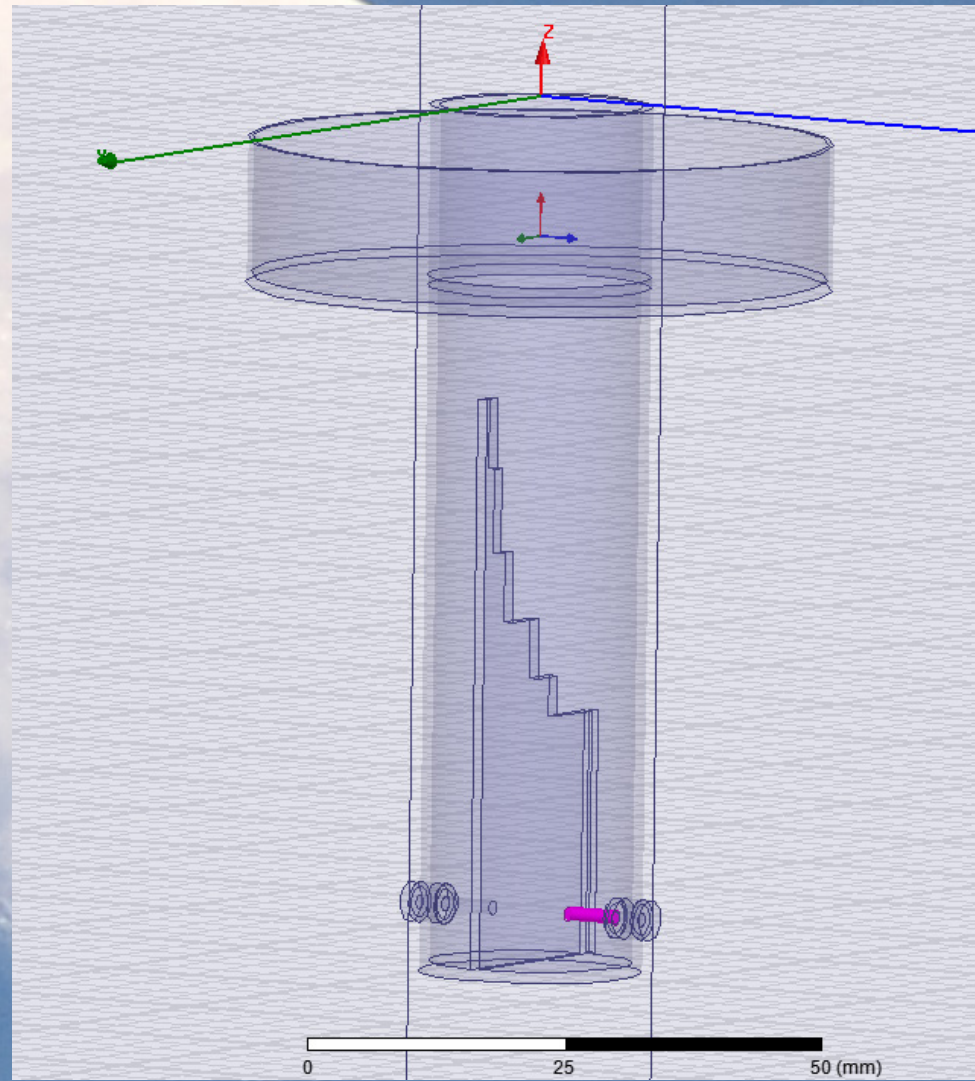
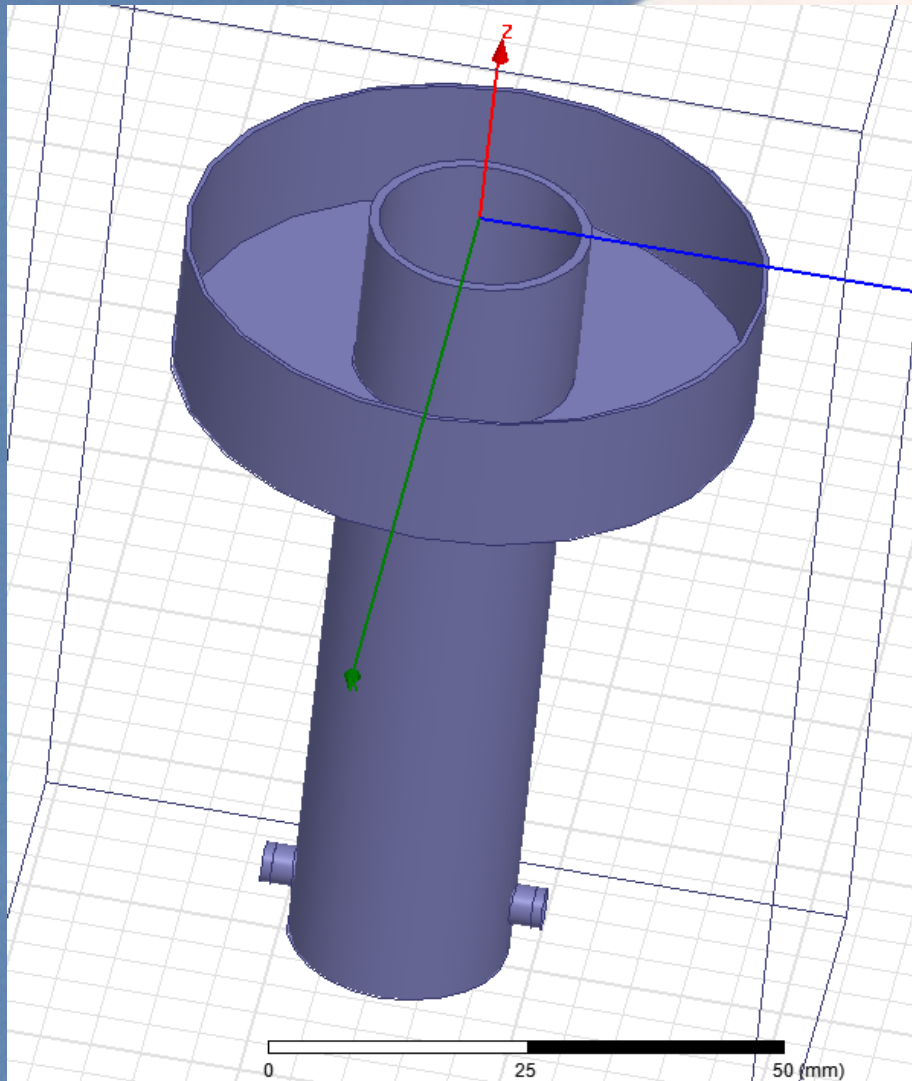


A large, bright, yellowish-white moon is centered in the upper half of the frame against a clear, deep blue sky. The moon's surface is covered in numerous small, dark spots representing craters. The text is overlaid on the moon's surface.

SM6FHZ 3 cm 5 step septum
feed

0.692 lambda W/G

Solid and transparent models from the simulation

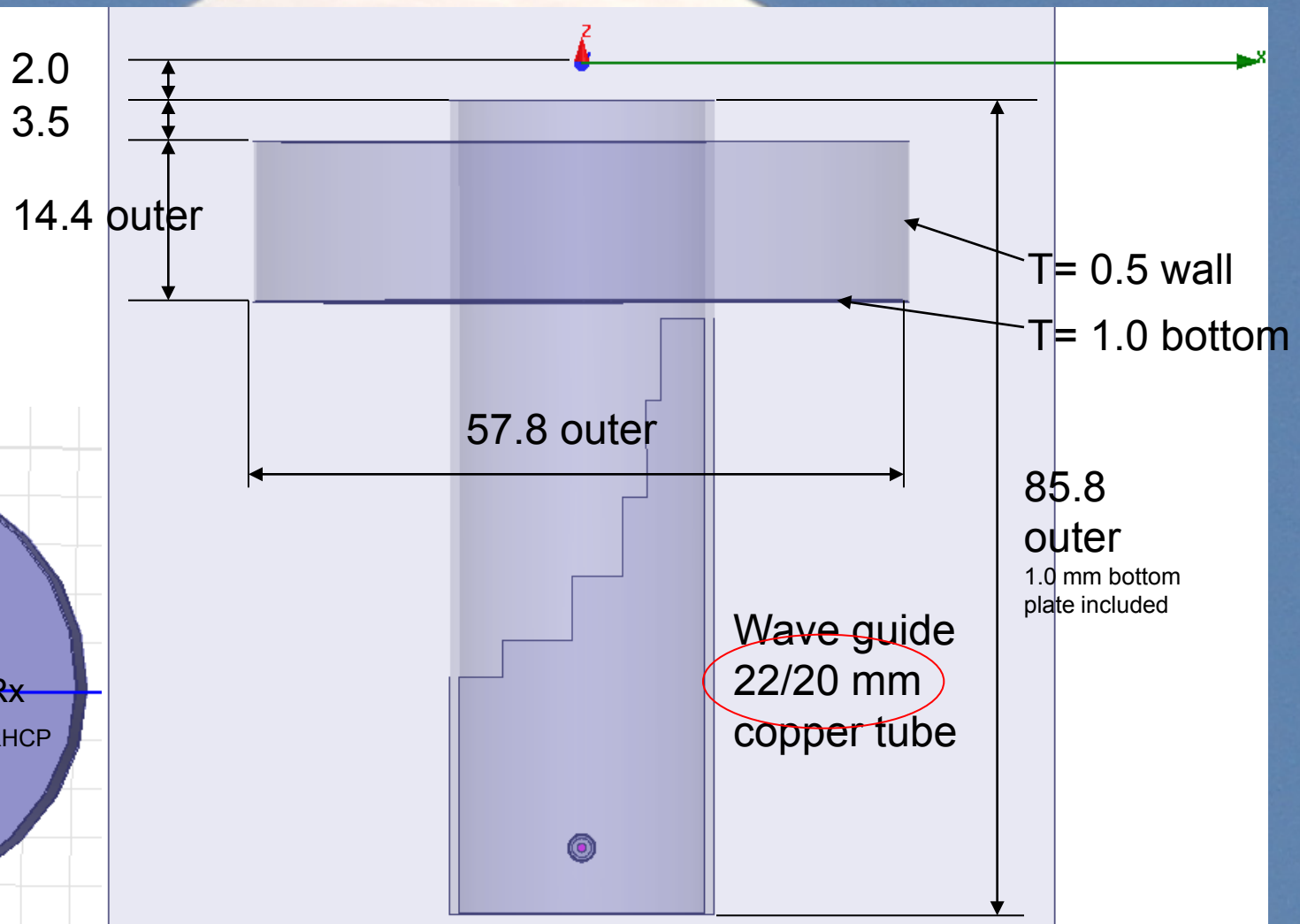
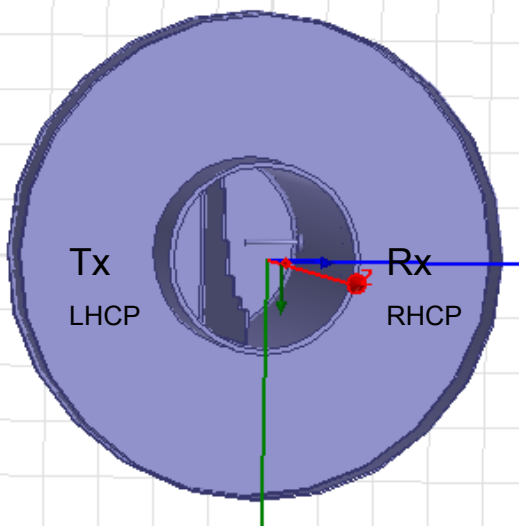


WG and choke dimensions

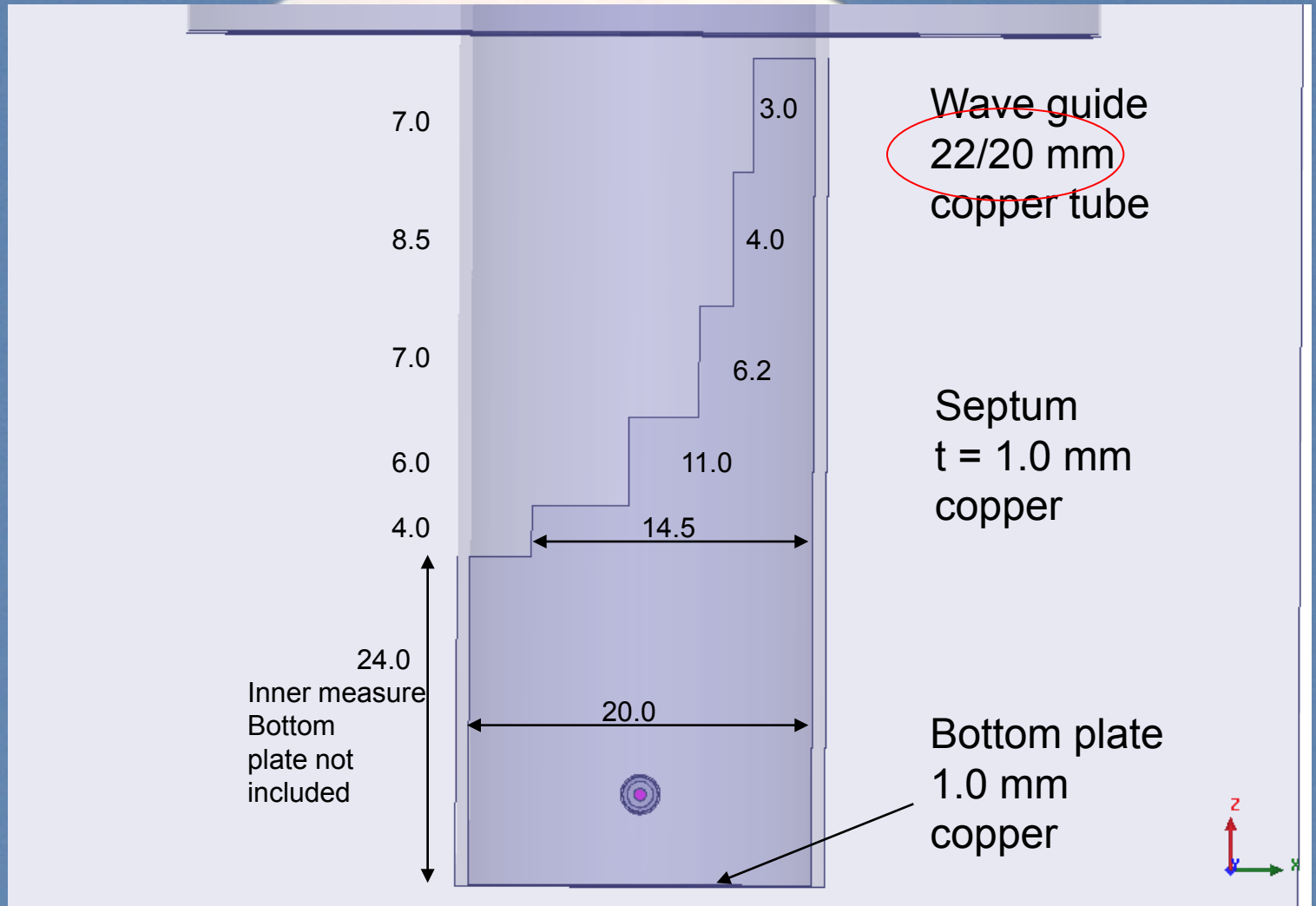
Circular polarization convention for EME according to Crawford Hill Bulletin No 1:

Tx RHCP in space
Rx LHCP in space

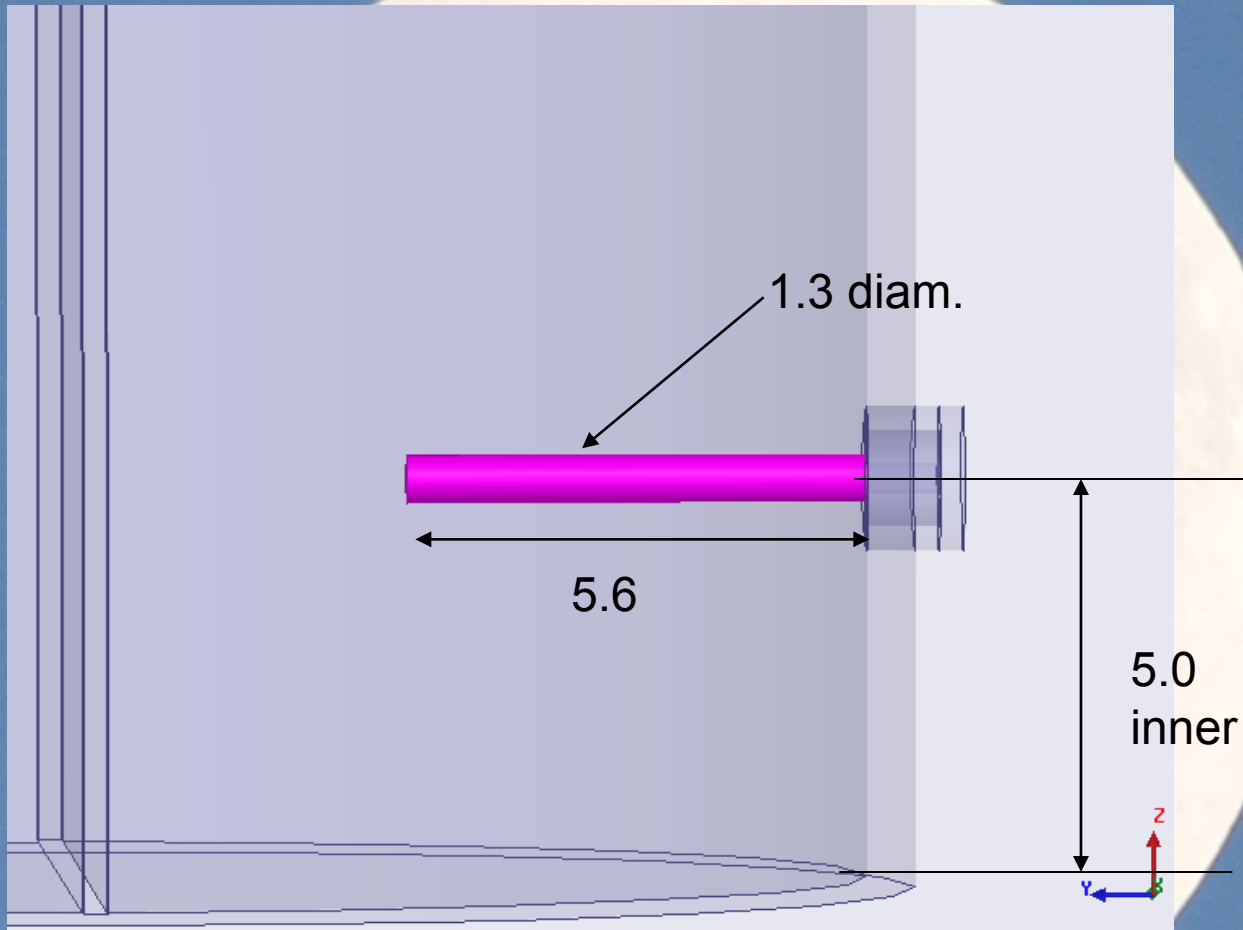
Take polarization reversal into account when using reflector antennas.



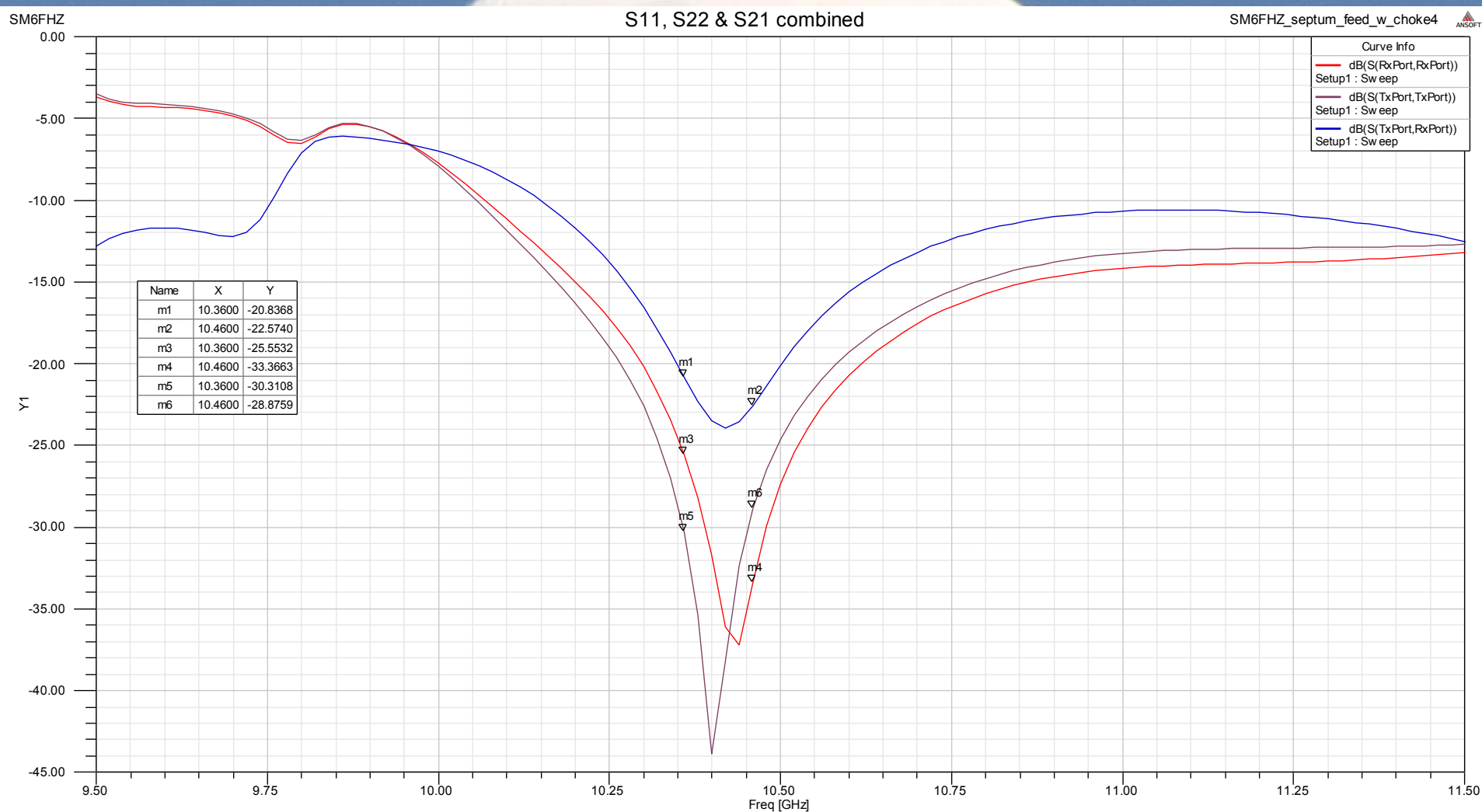
Septum dimensions



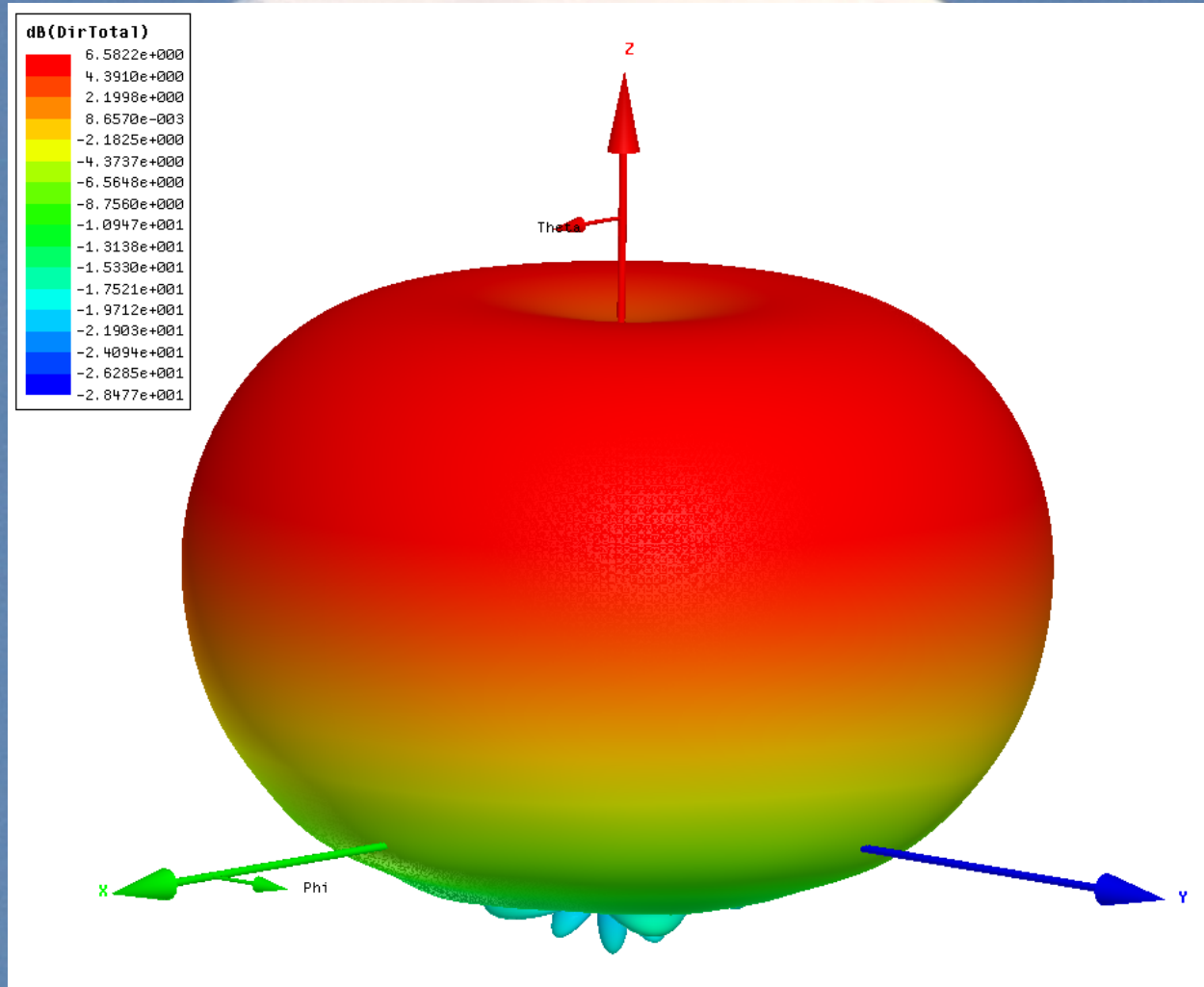
Probe dimensions



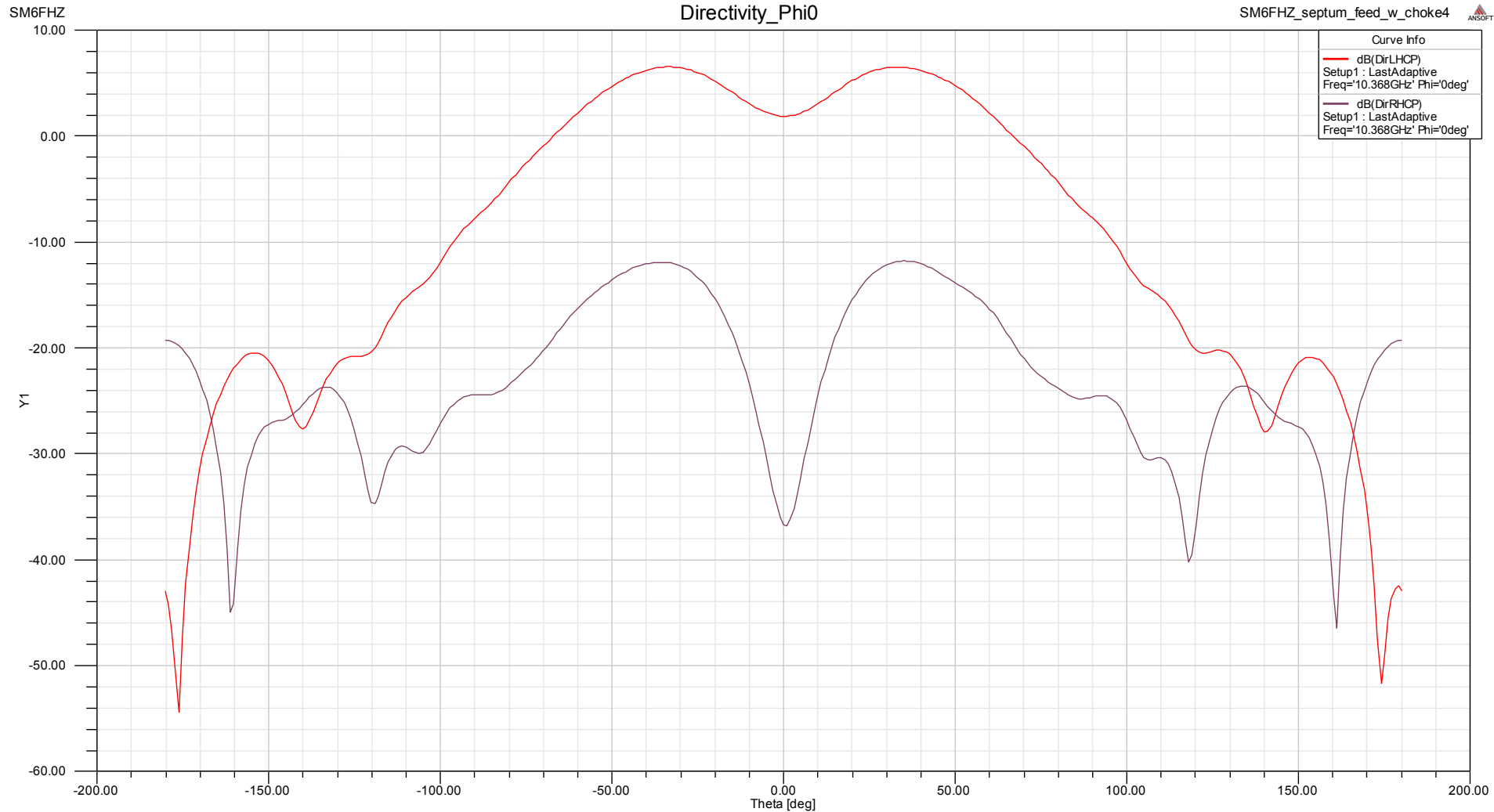
S11, S22, S21 combined



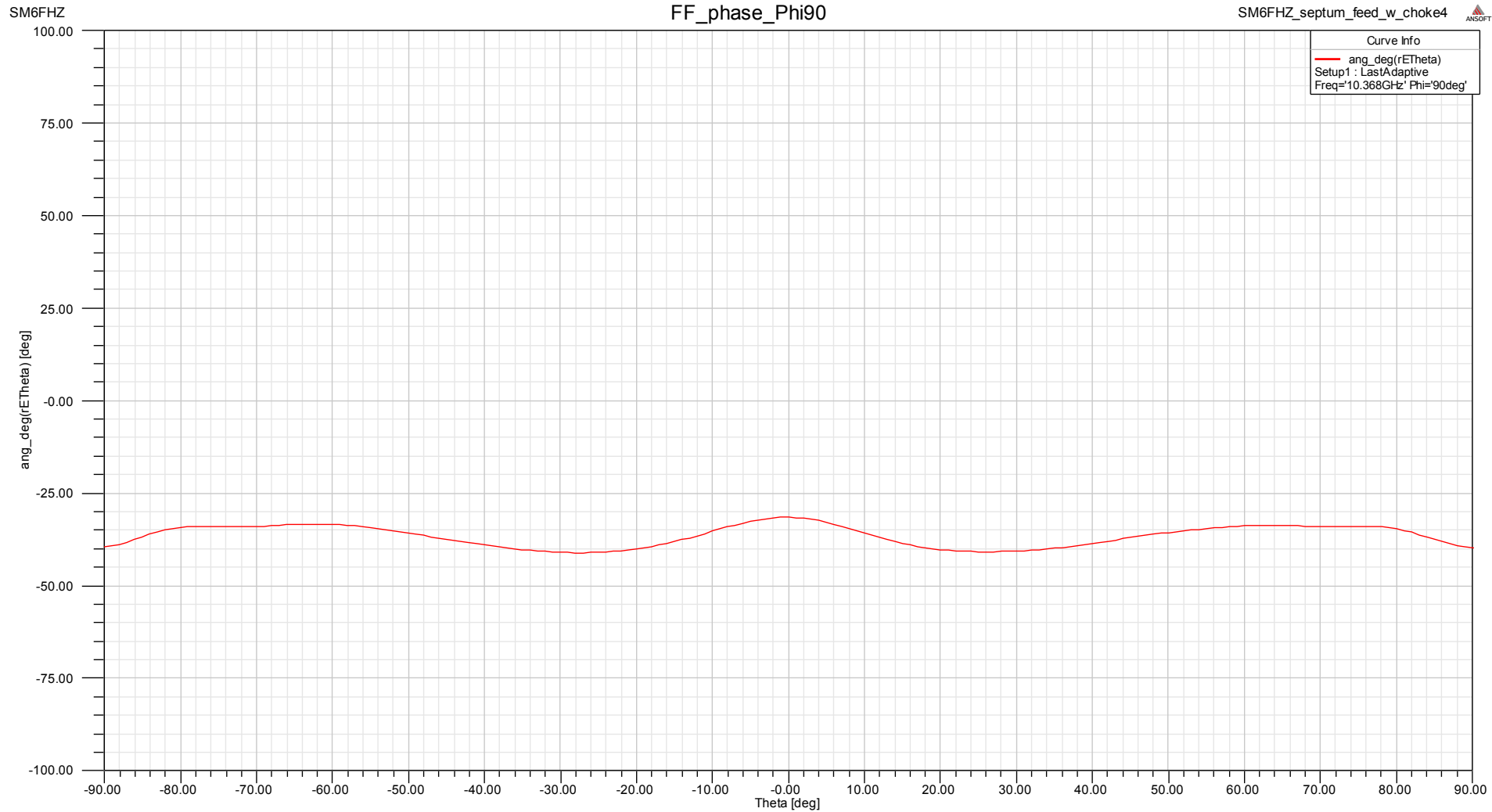
3D Total Power Far Field pattern



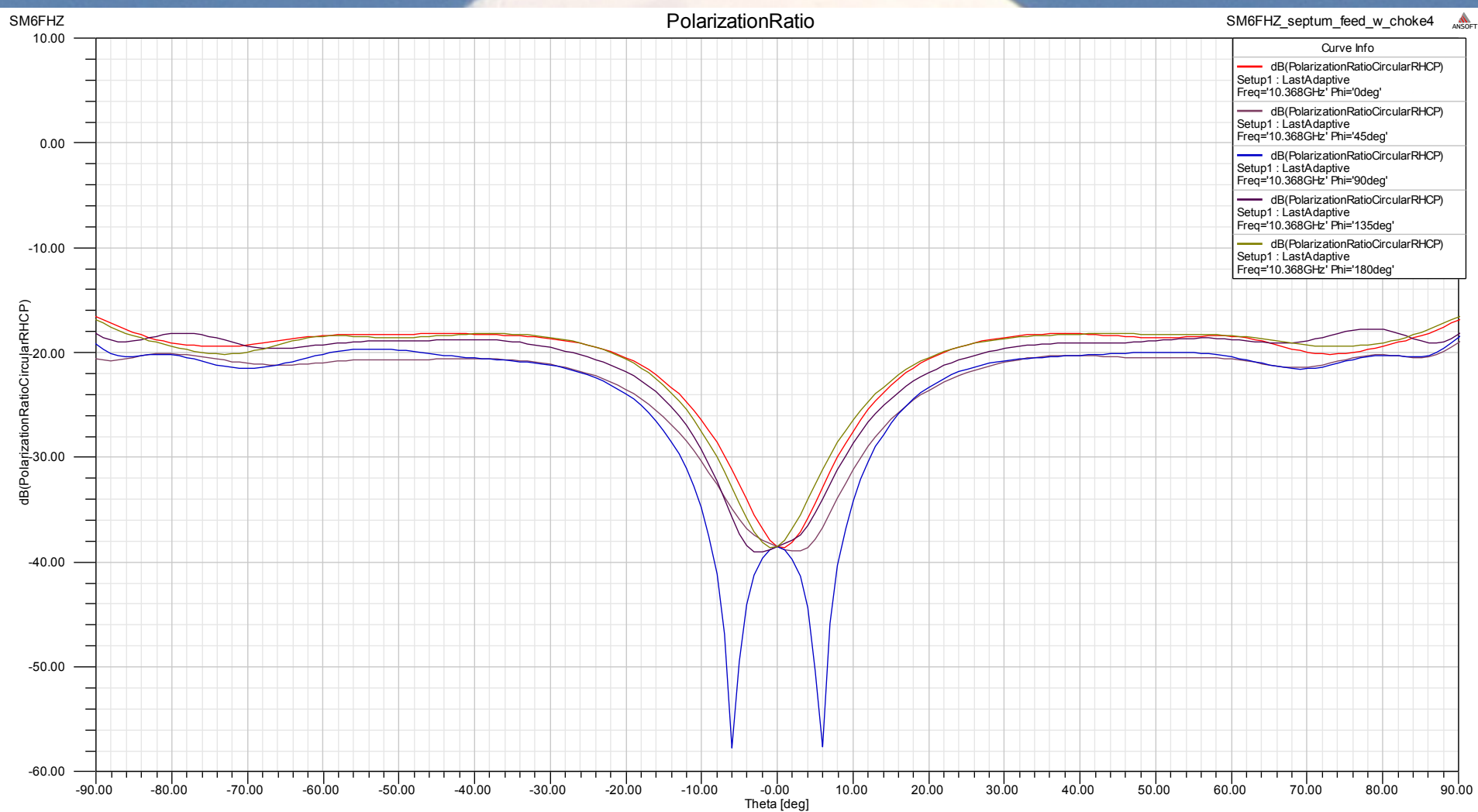
Far Field Pattern 0 deg



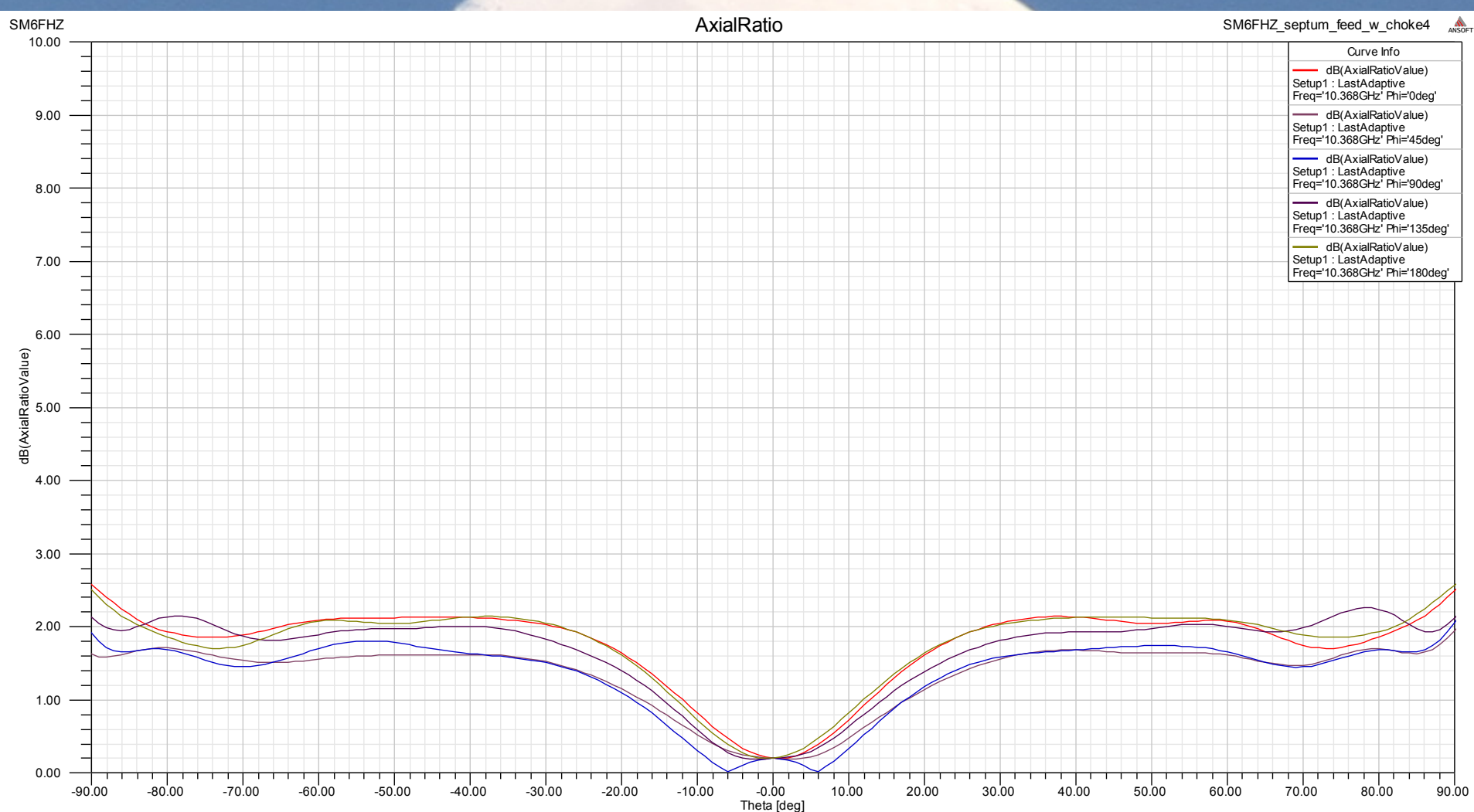
Far Field Phase



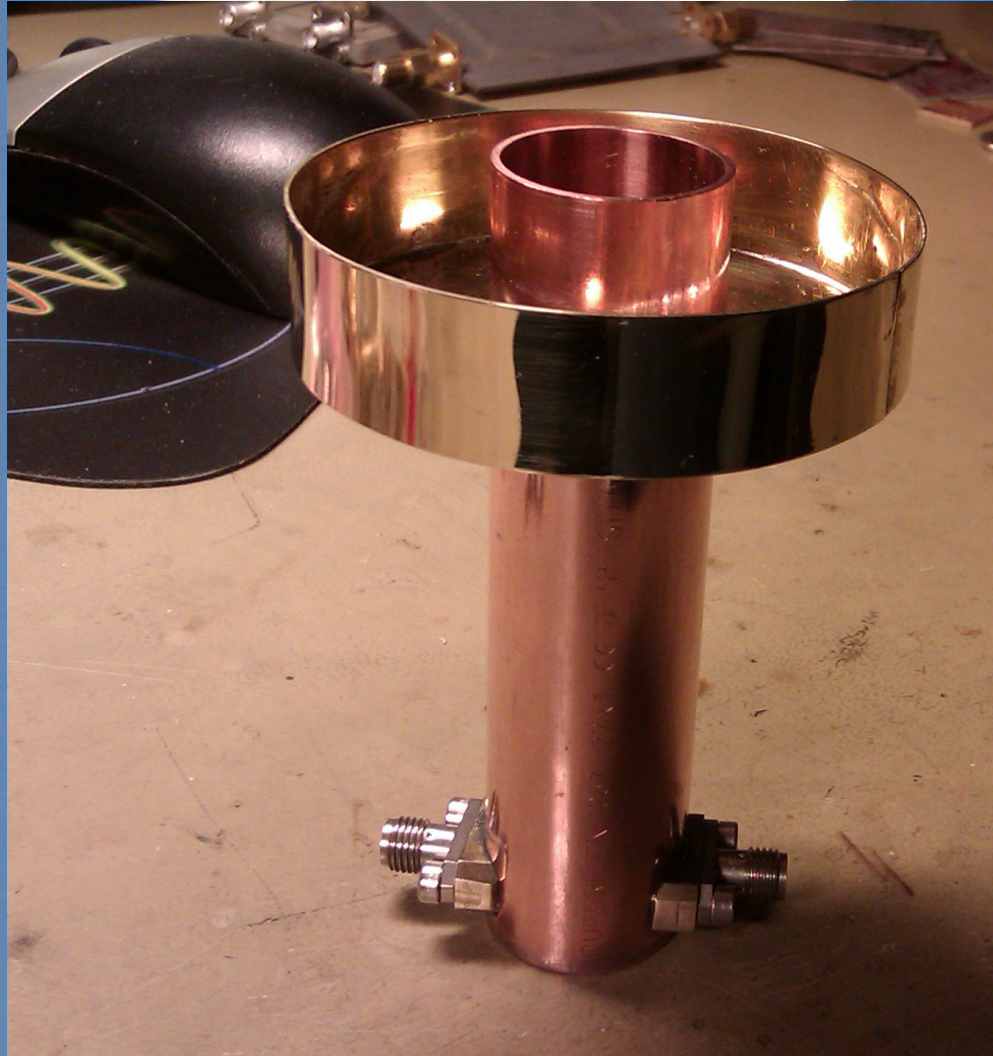
Cross Polar Ratio



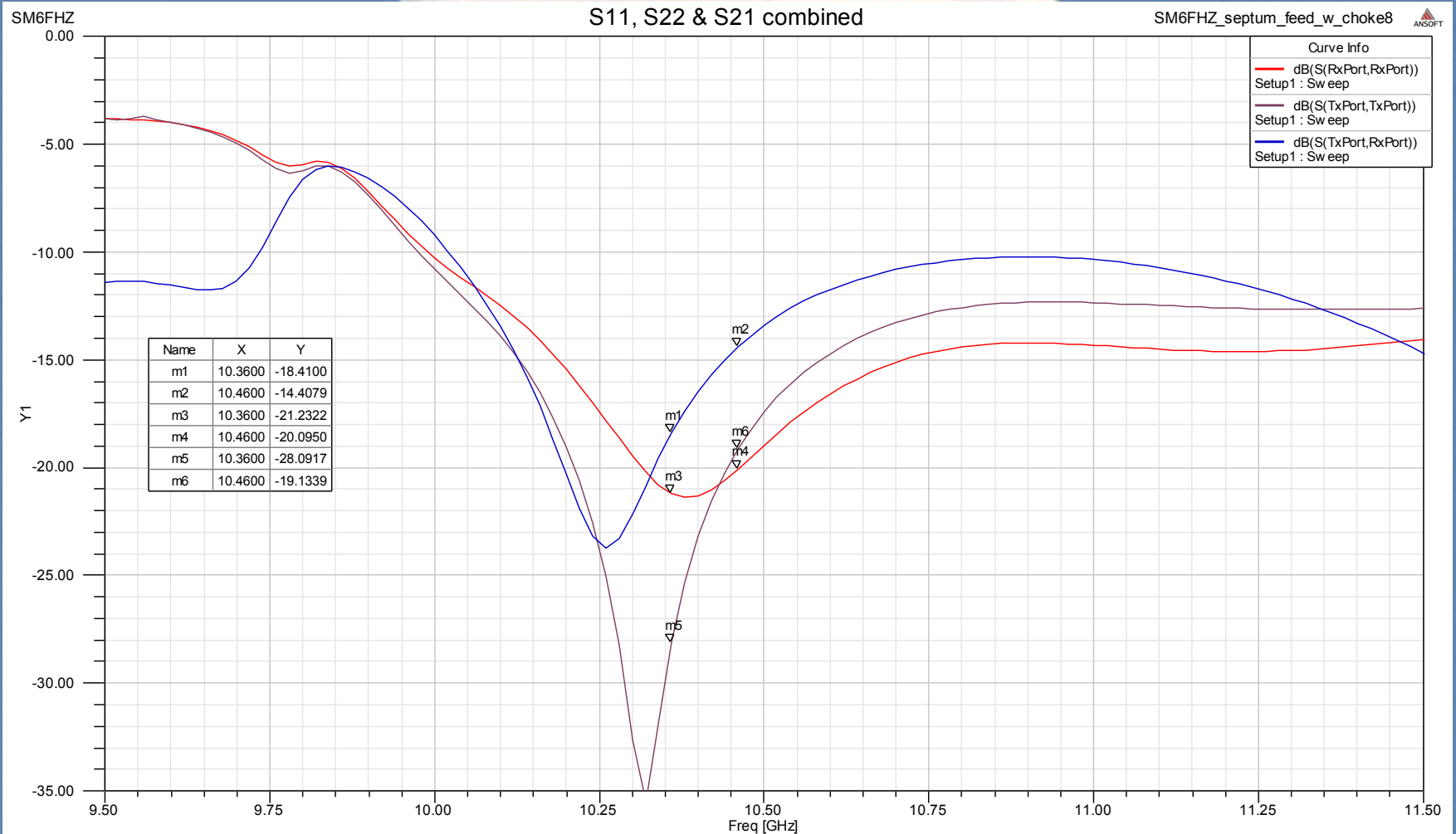
Axial Ratio



Realization



+0.2 mm WG-diam, +1 mm septum, +1 mm WG-length

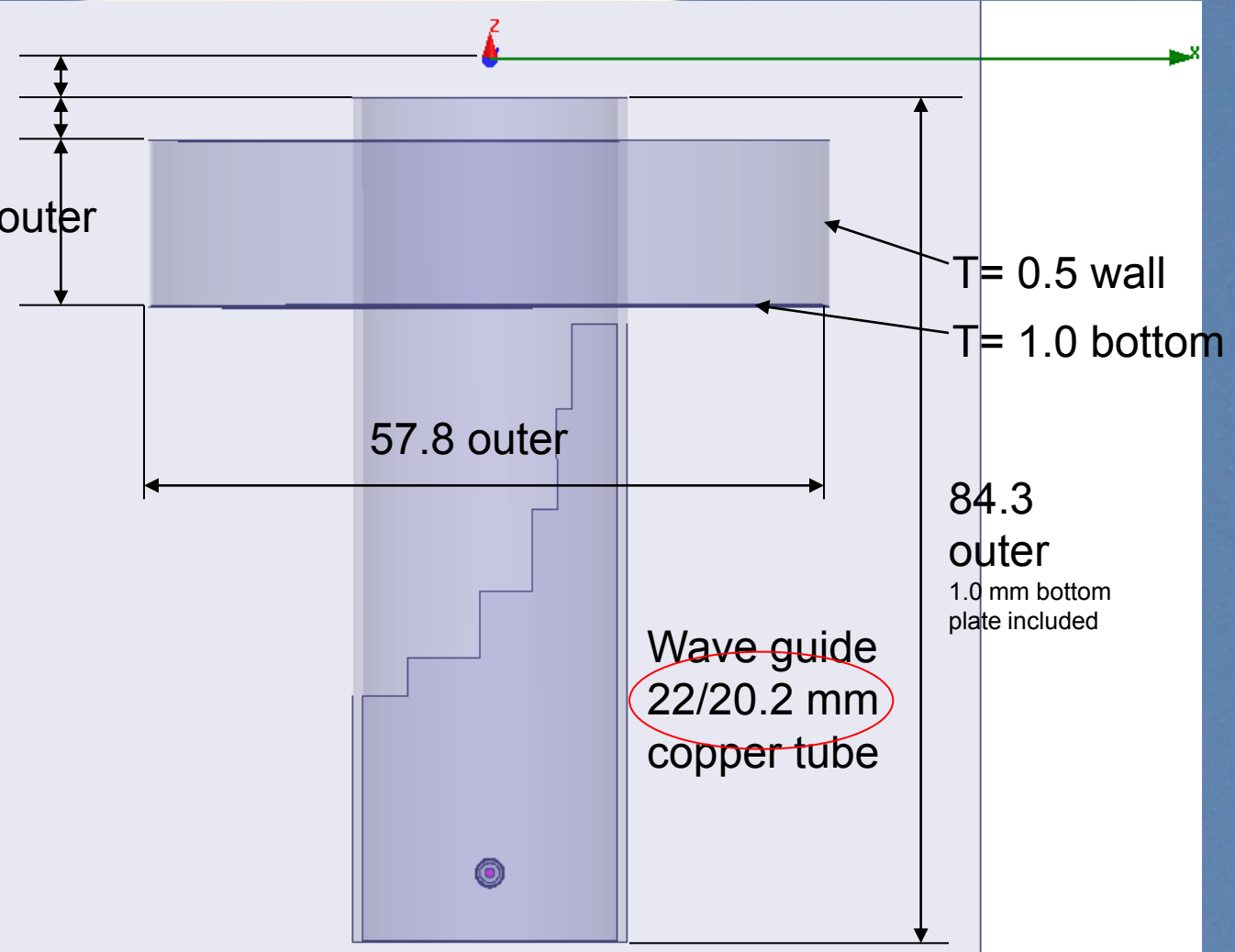
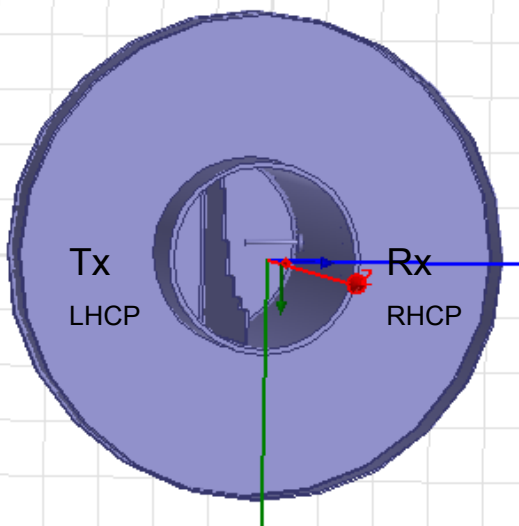


WG and choke dimensions

Circular polarization convention for EME according to Crawford Hill Bulletin No 1:

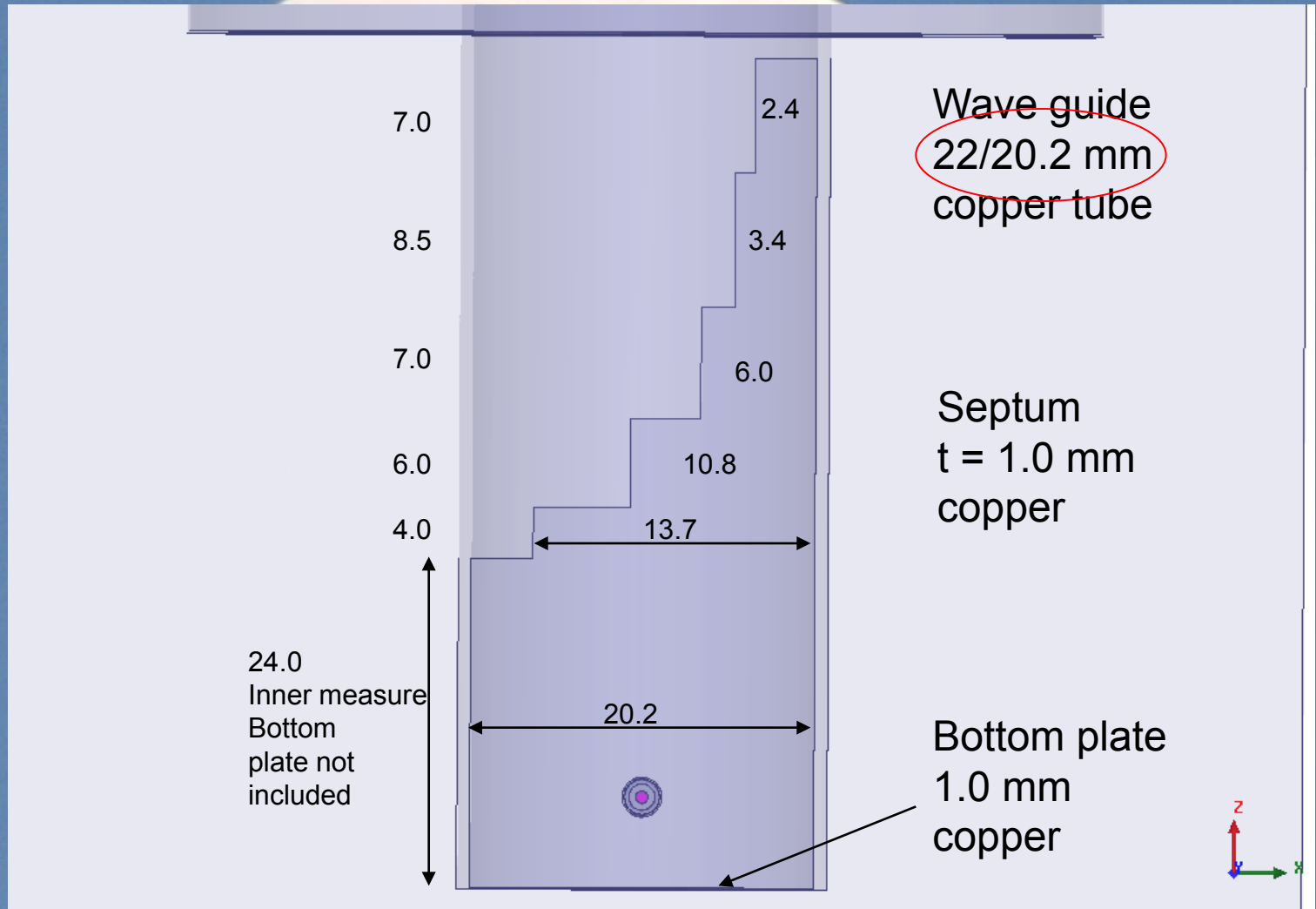
Tx RHCP in space
Rx LHCP in space

Take polarization reversal into account when using reflector antennas.

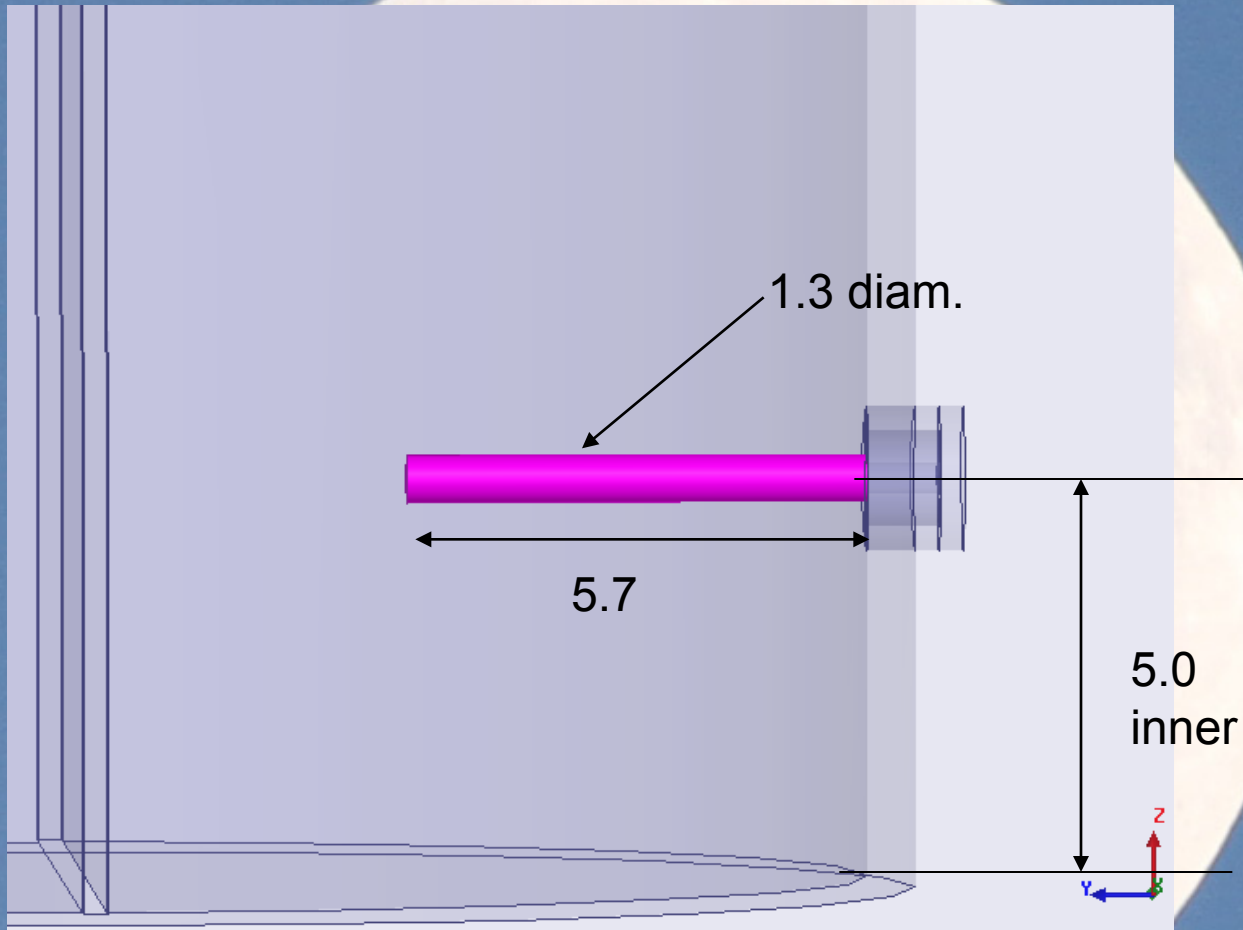


Wave guide
22/20.2 mm
copper tube

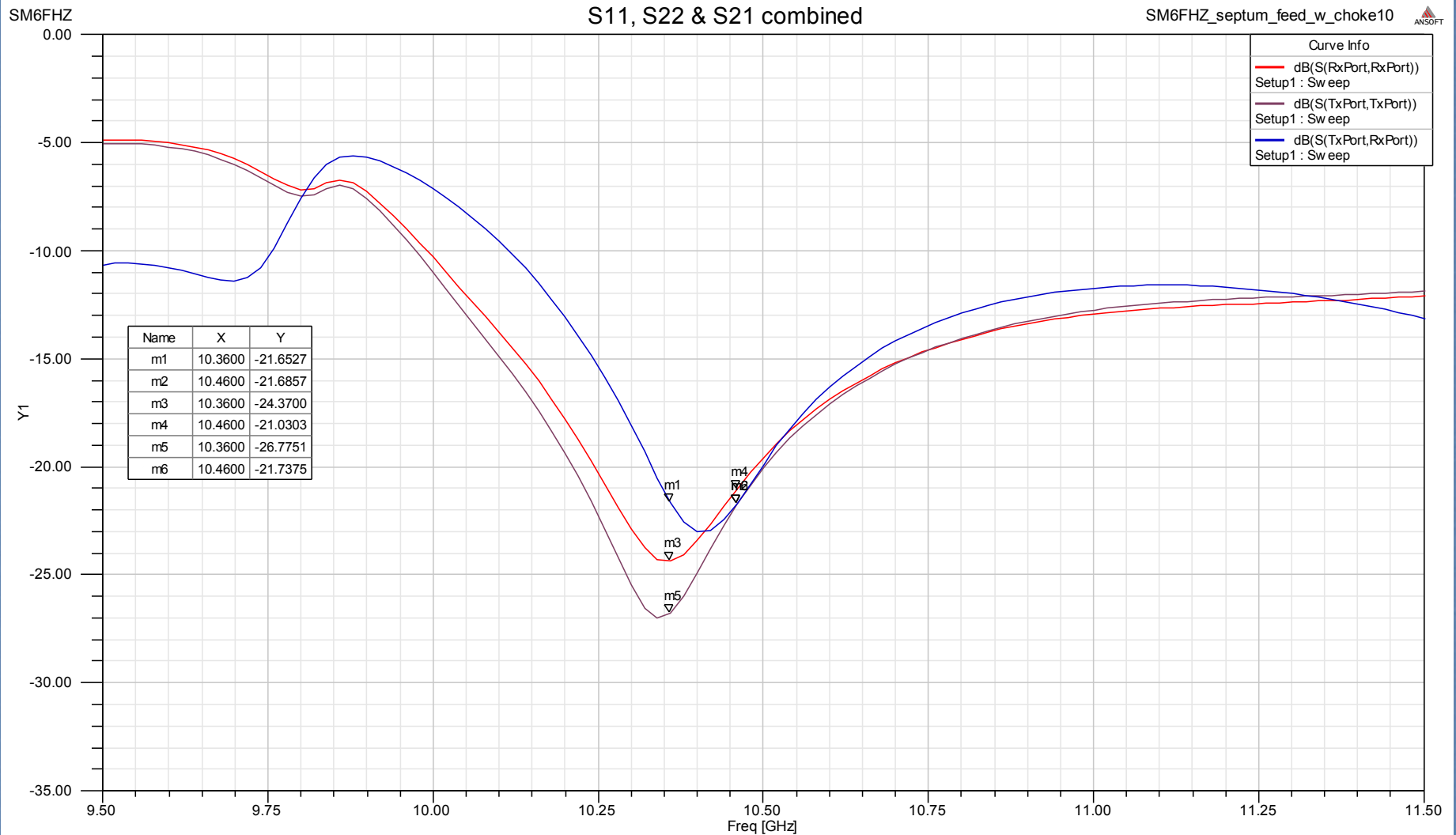
Septum dimensions



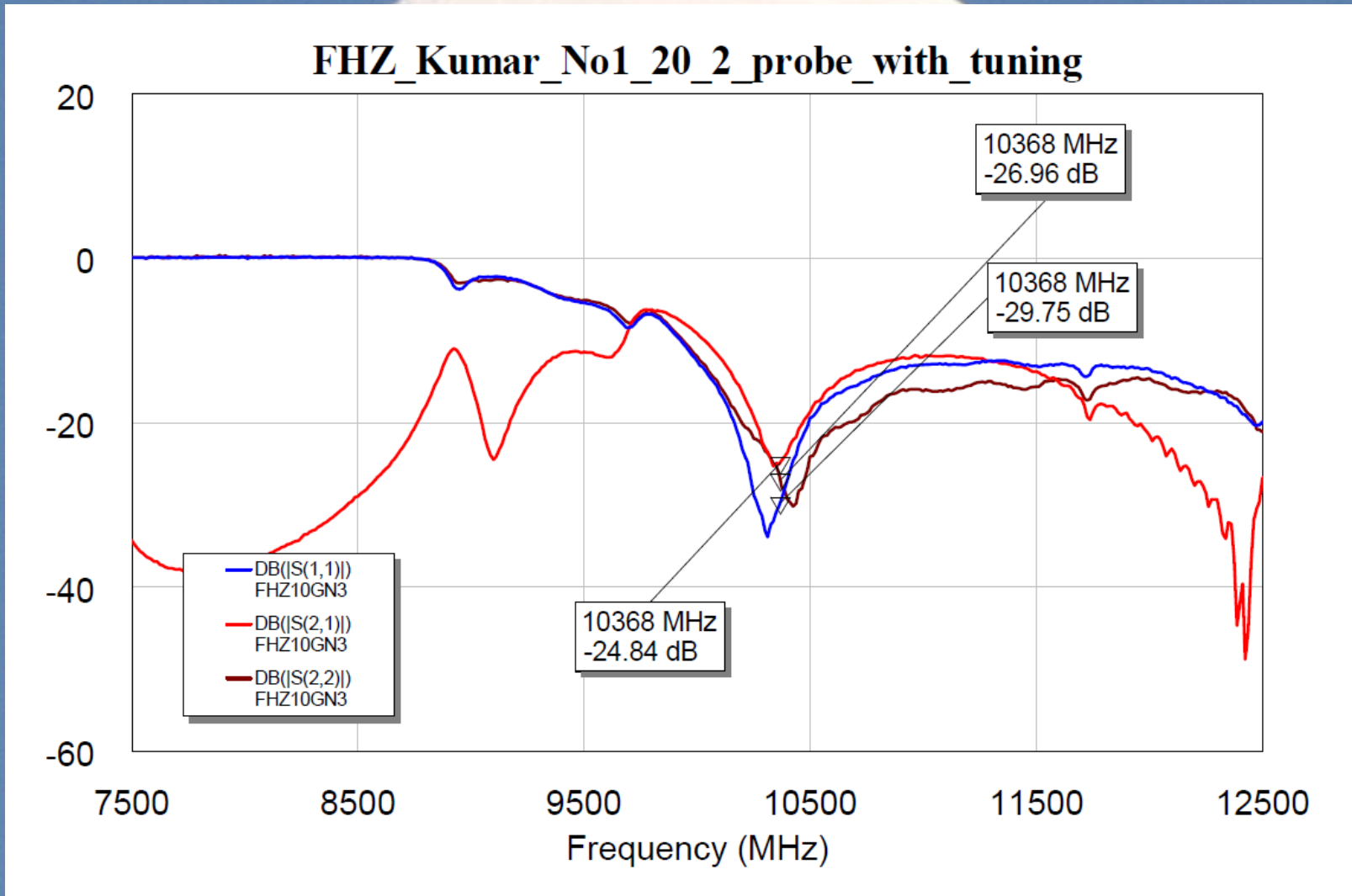
Probe dimensions



20,2 mm WG-inner diam optimized



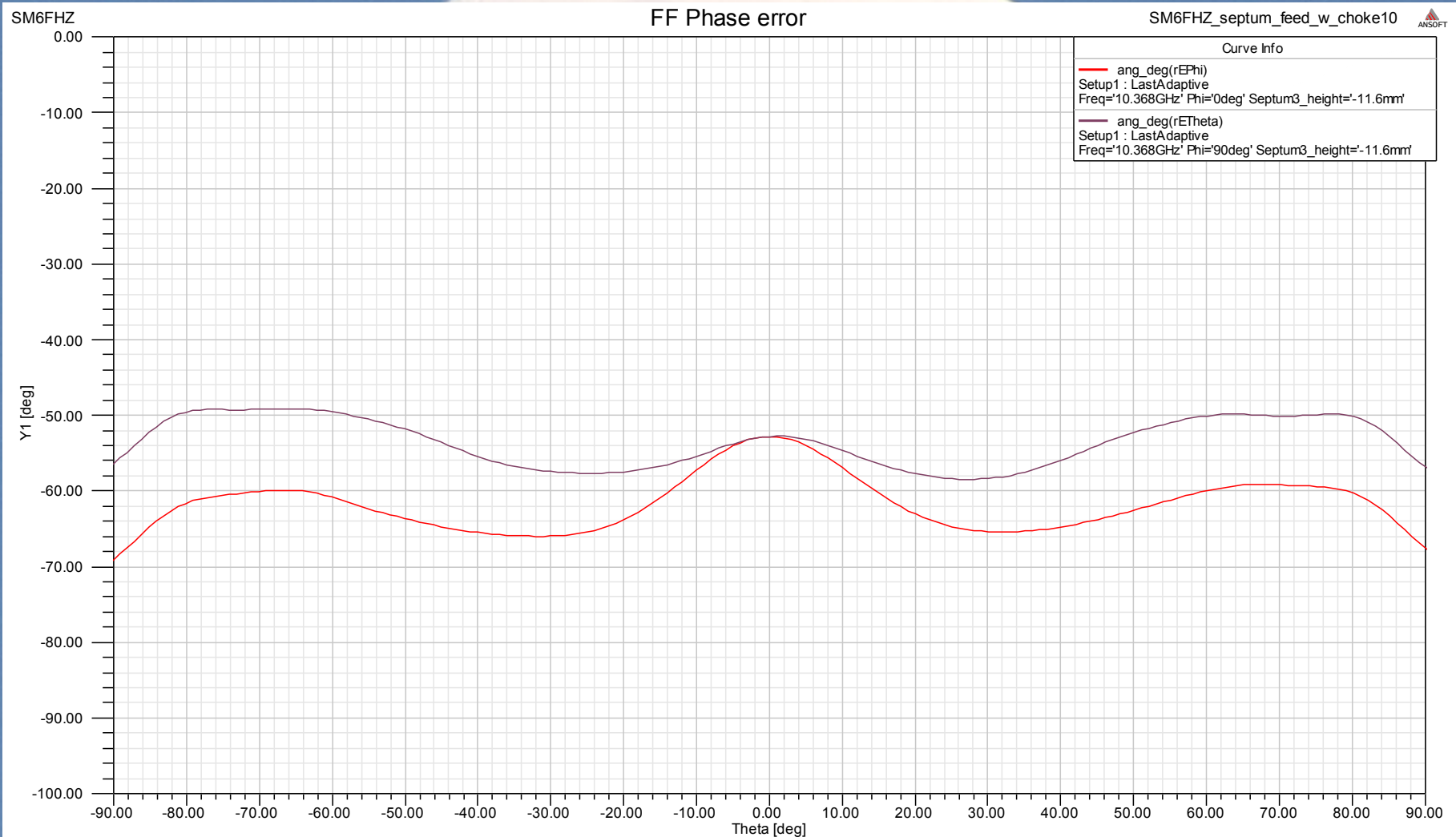
Measurements



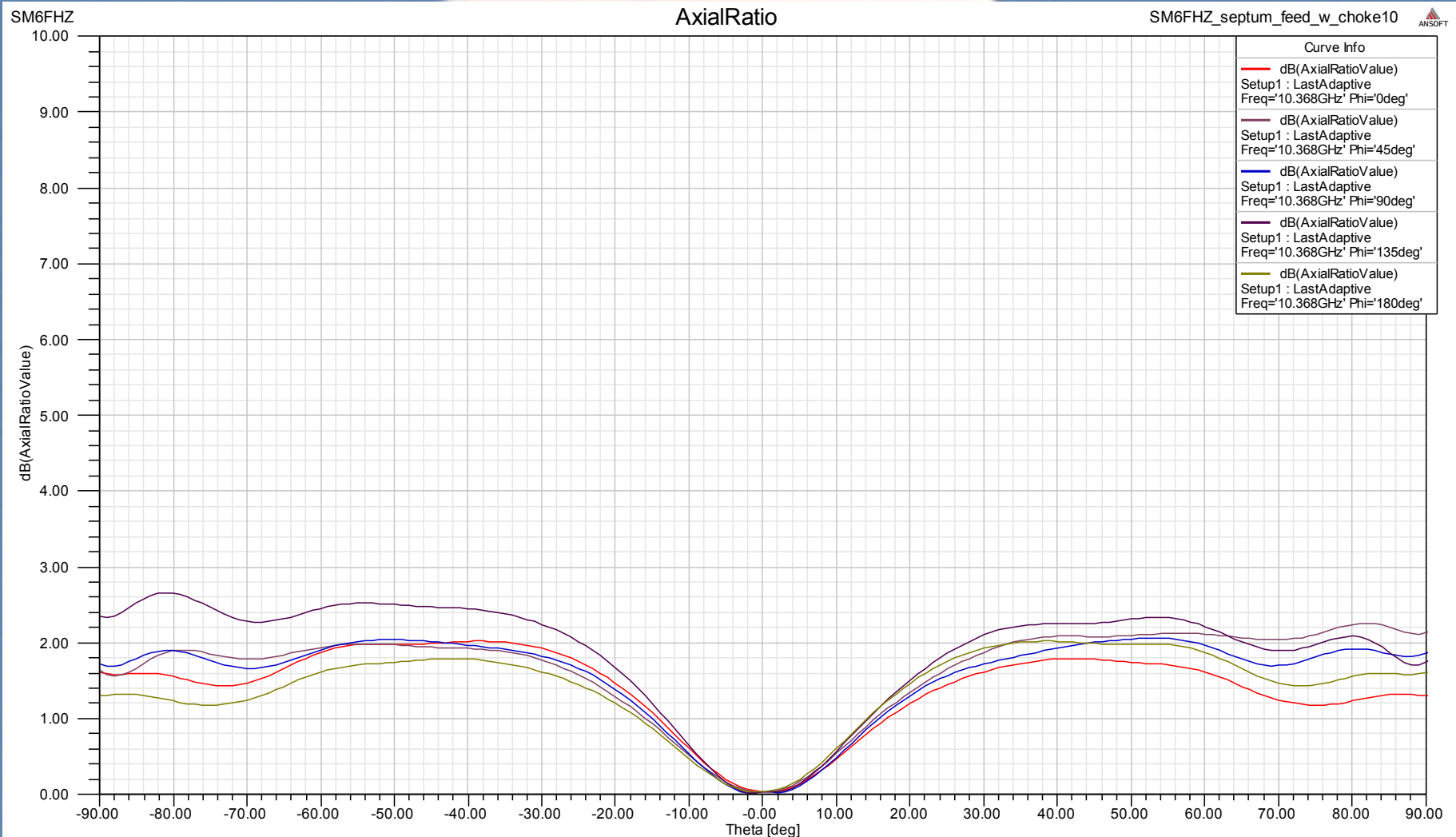
Far Field Pattern 0 deg




FF Phase error



Axial Ratio

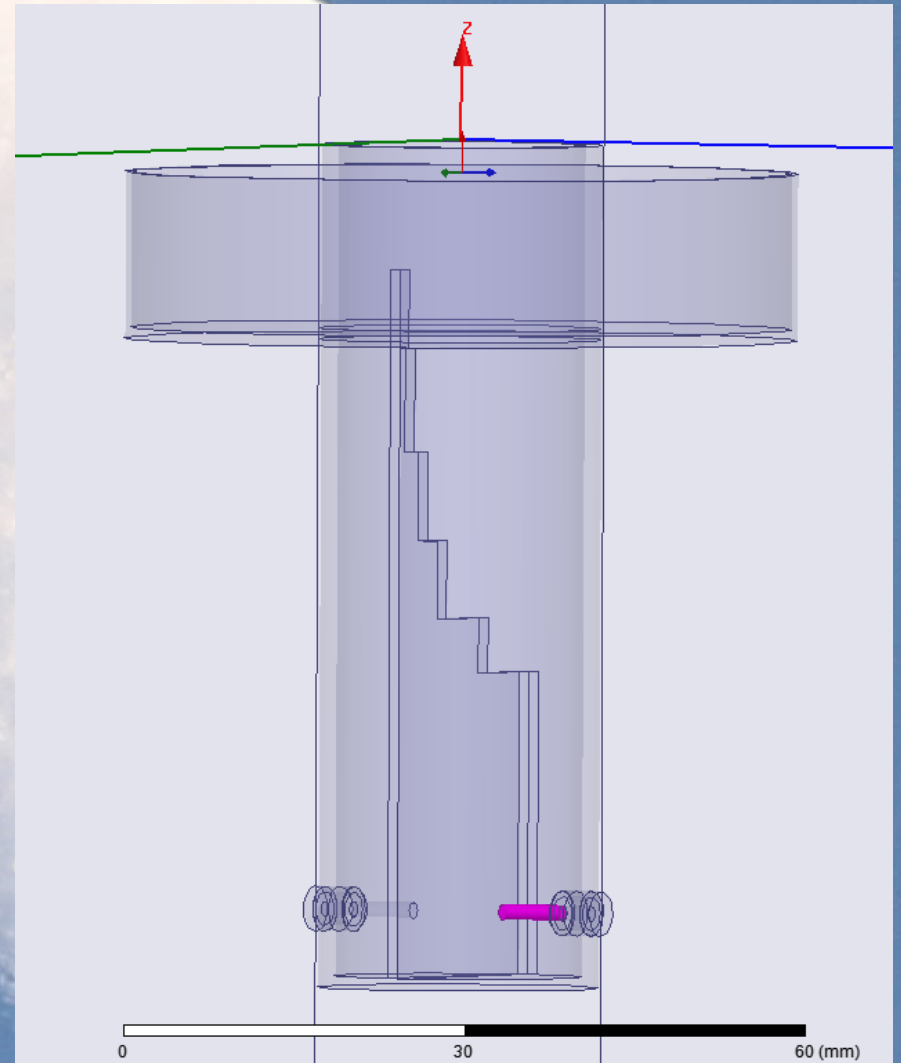
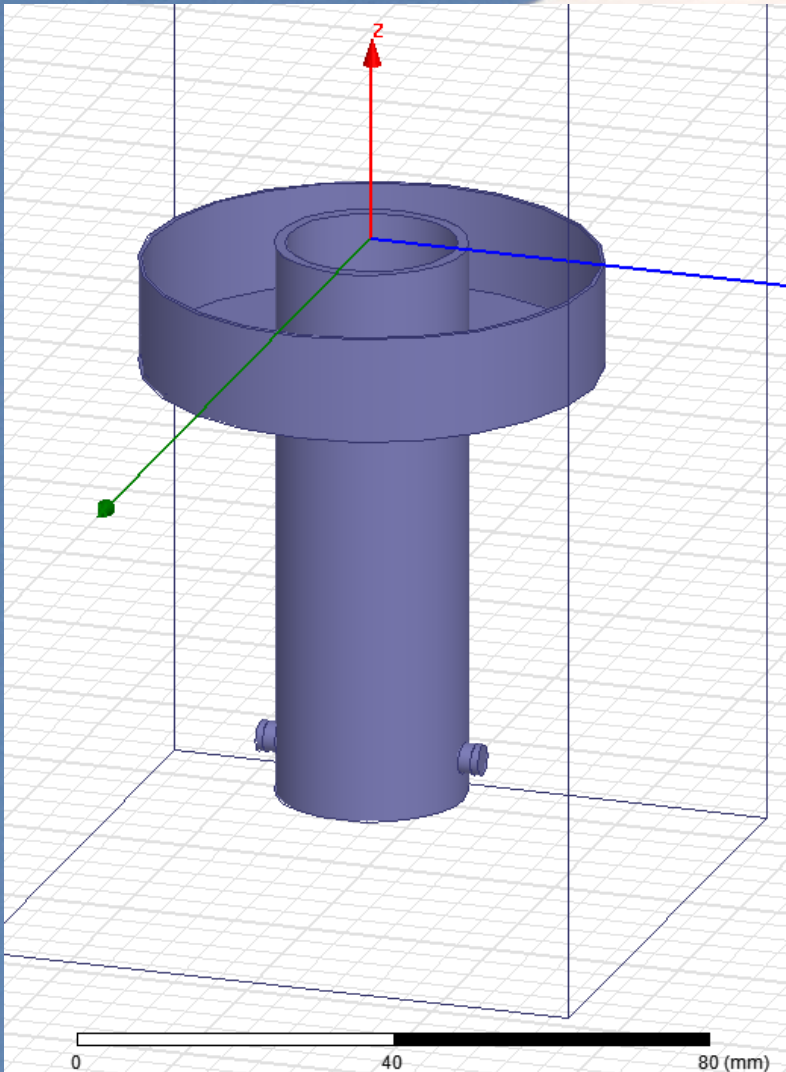




SM6FHZ 3 cm 5 step septum
feed

0.795 lambda W/G

Solid and transparent models from the simulation

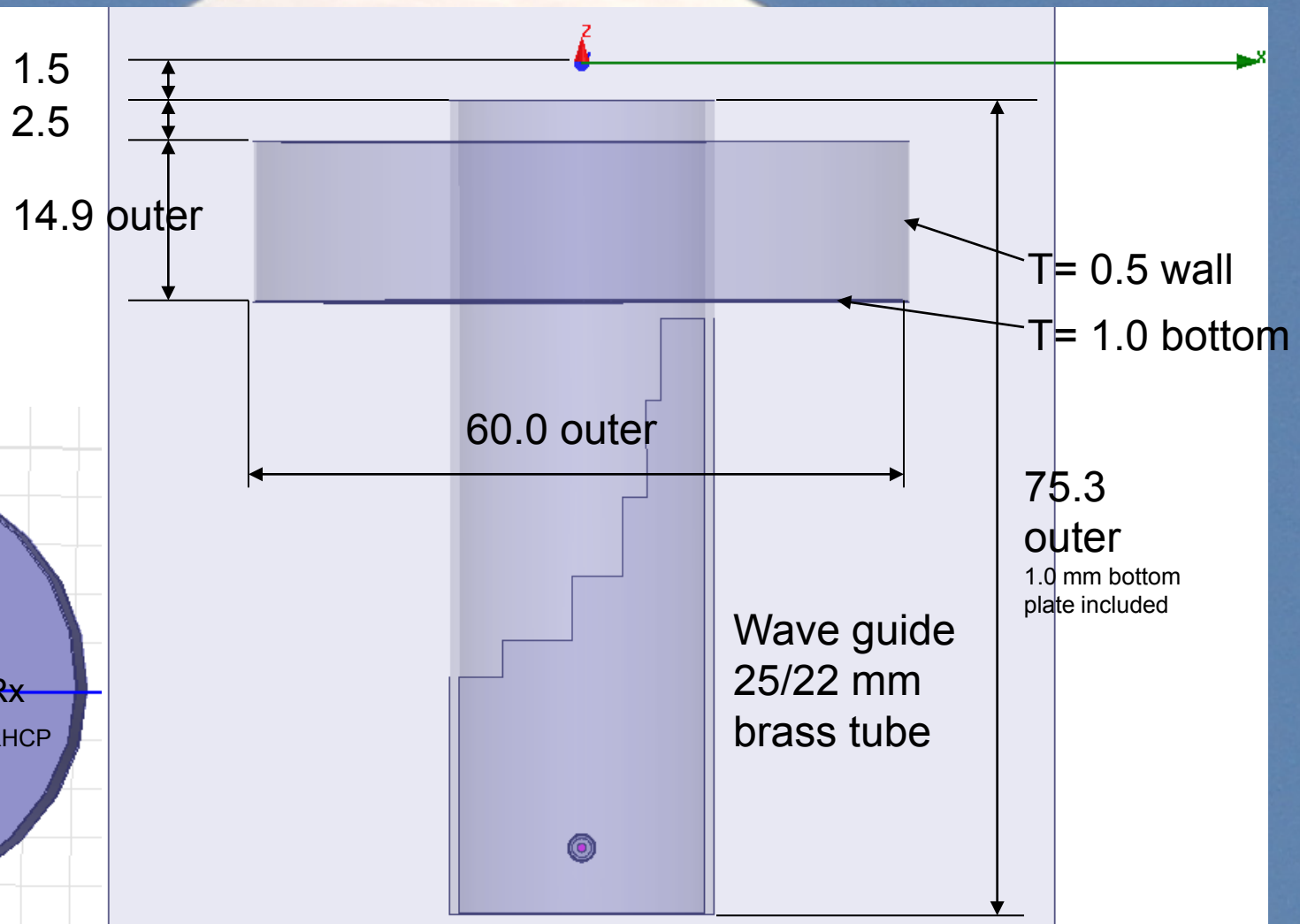
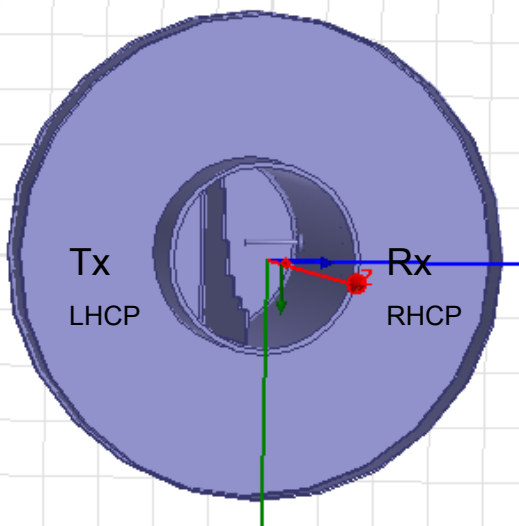


WG and choke dimensions

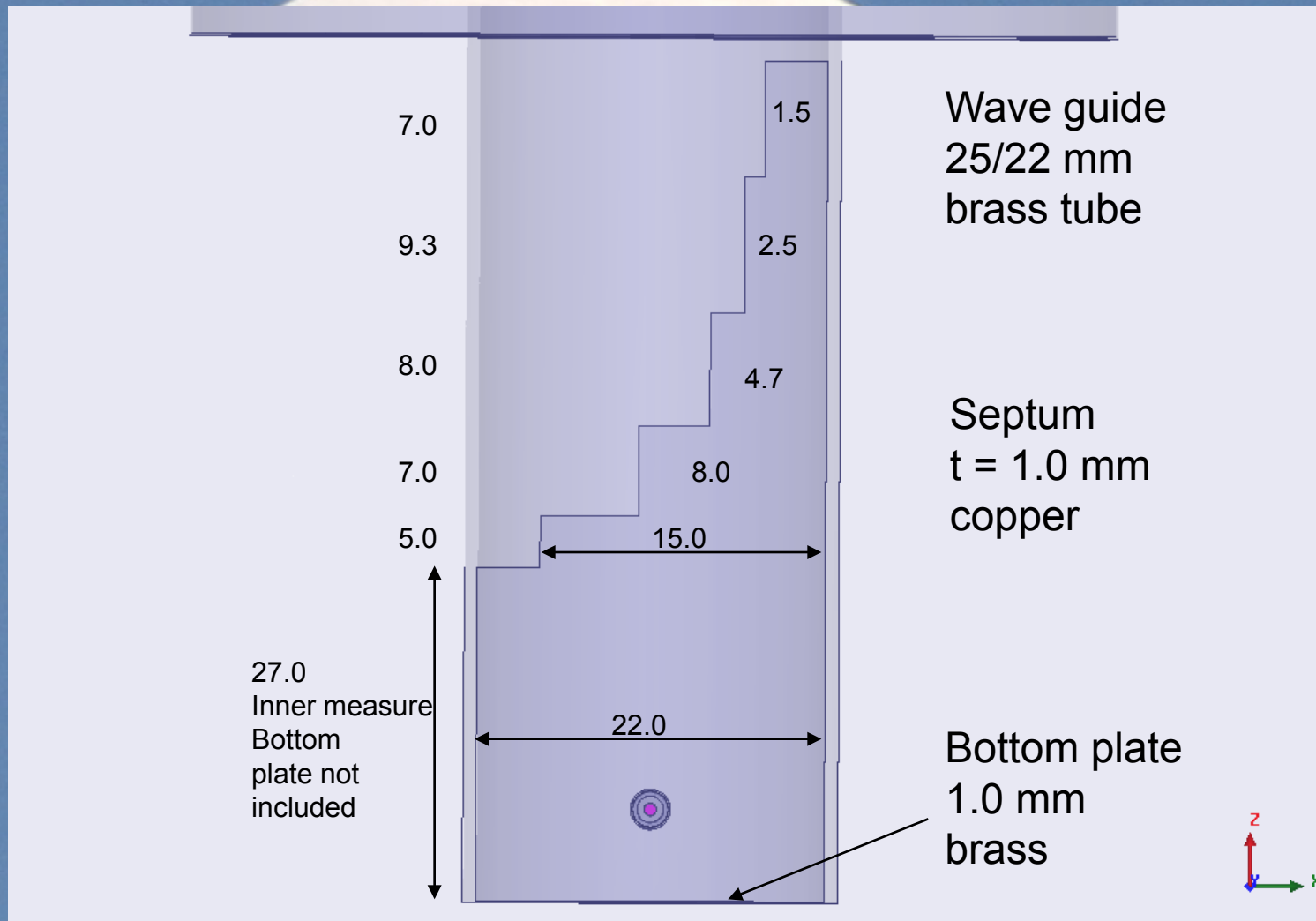
Circular polarization convention for EME according to Crawford Hill Bulletin No 1:

Tx RHCP in space
Rx LHCP in space

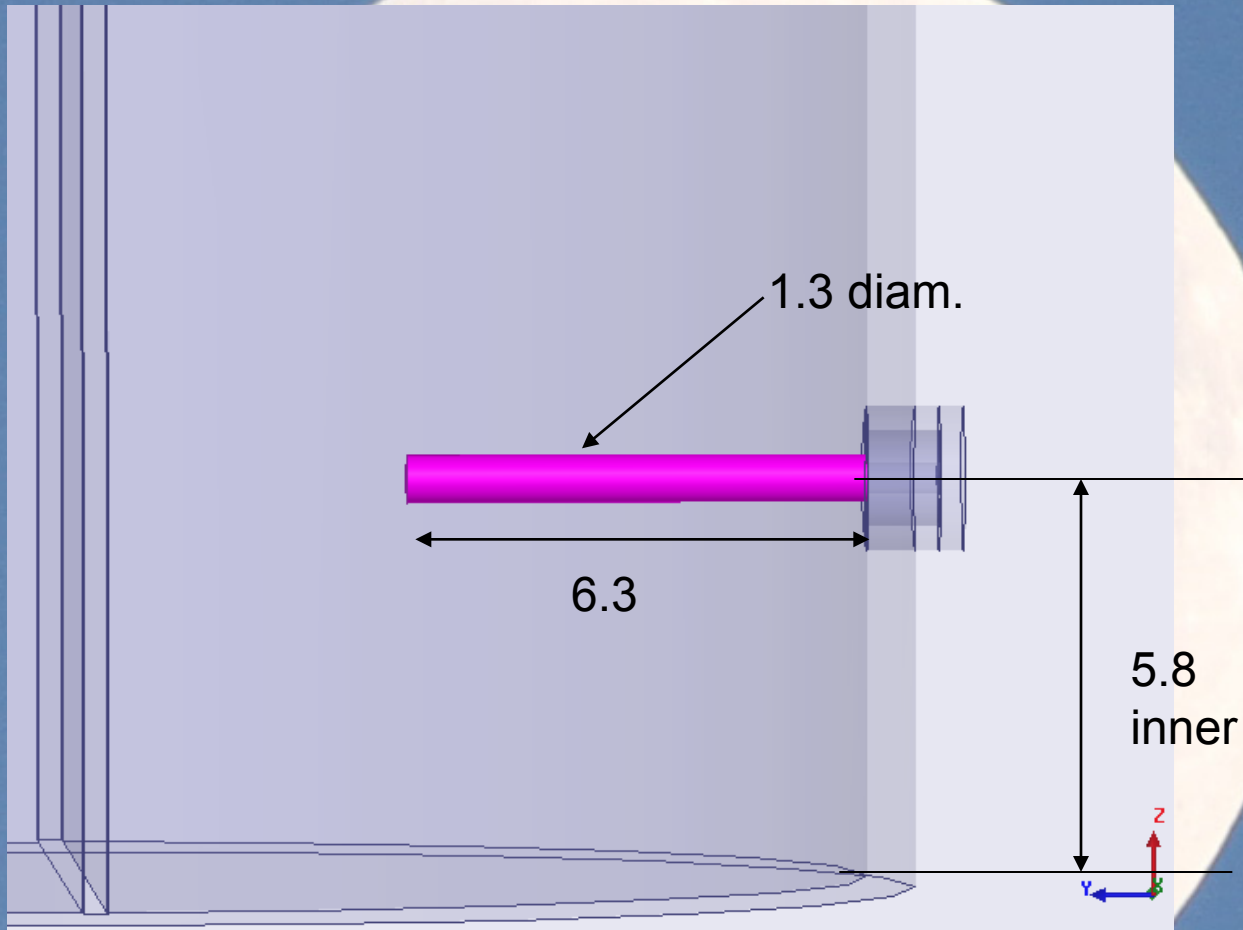
Take polarization reversal into account when using reflector antennas.



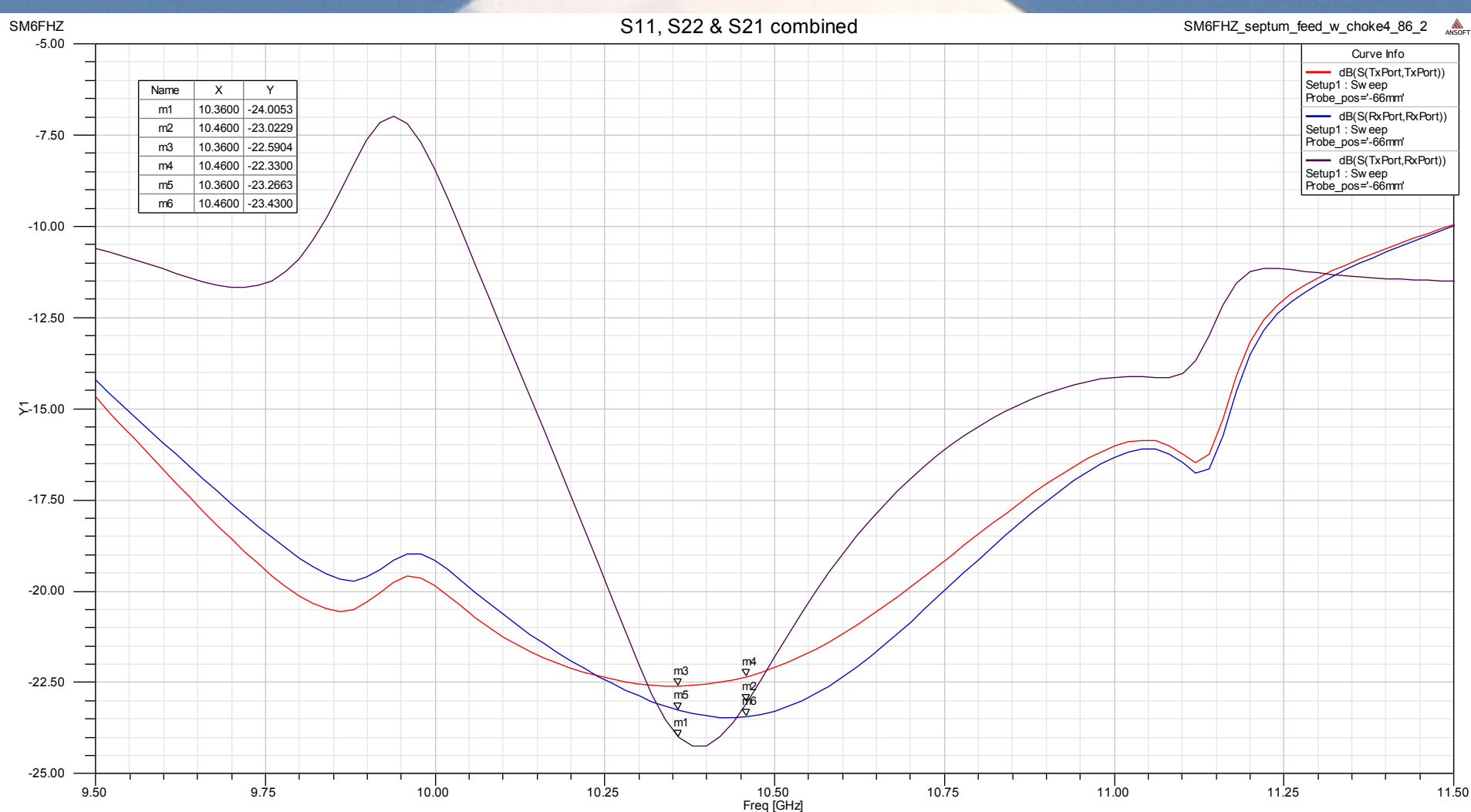
Septum dimensions



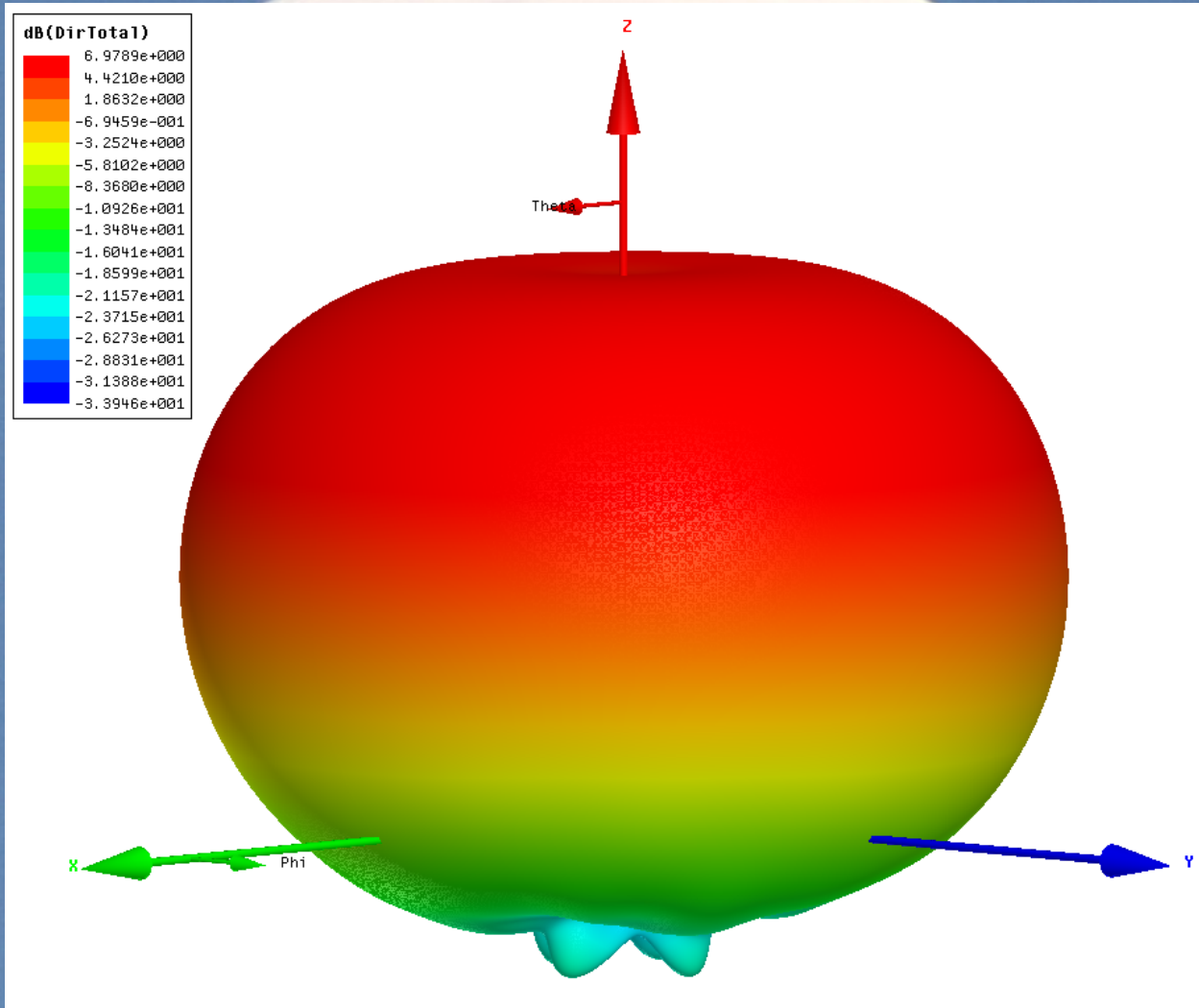
Probe dimensions



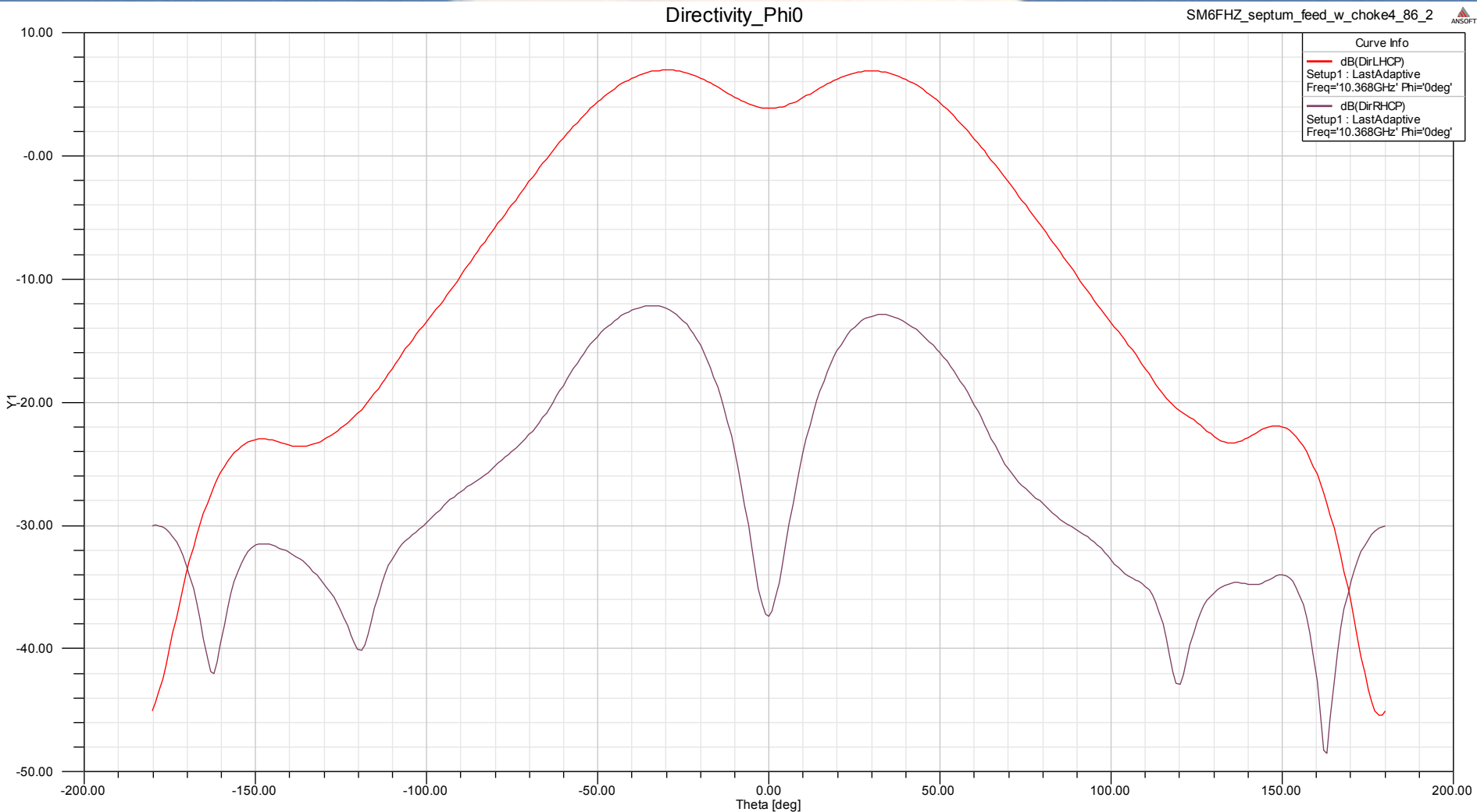
S11, S22, S21 combined



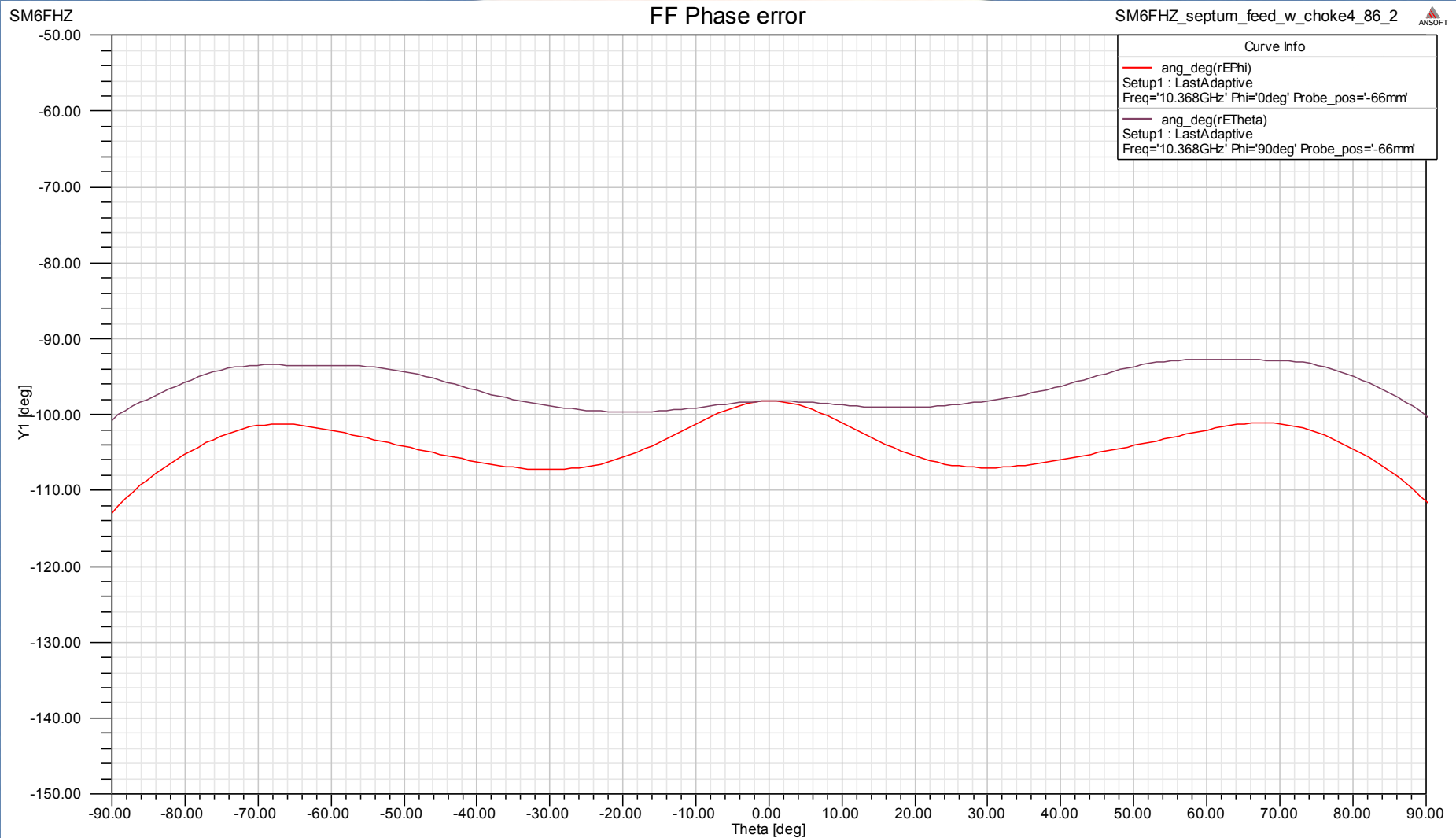
3D Total Power Far Field pattern



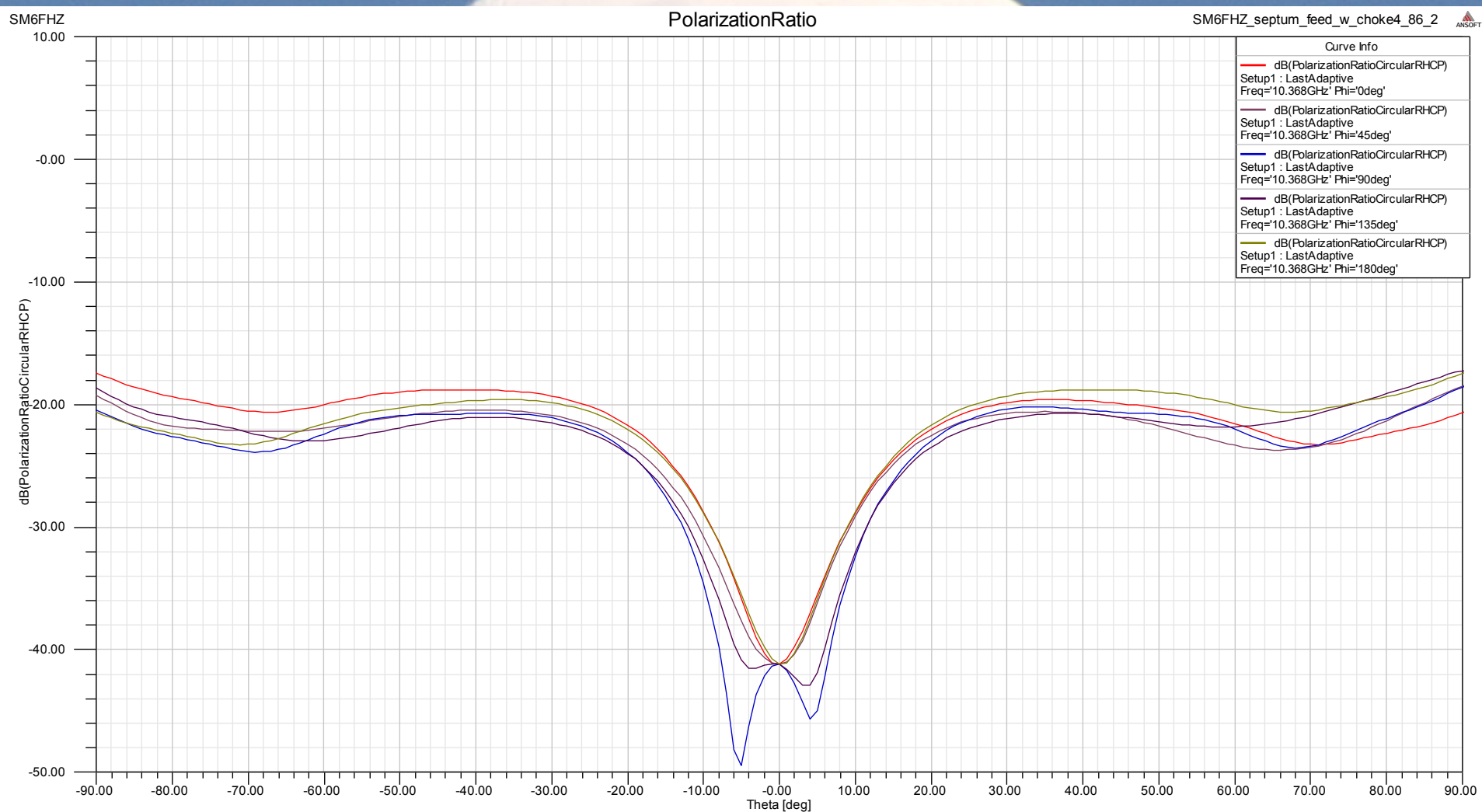
Far Field Pattern 0 deg



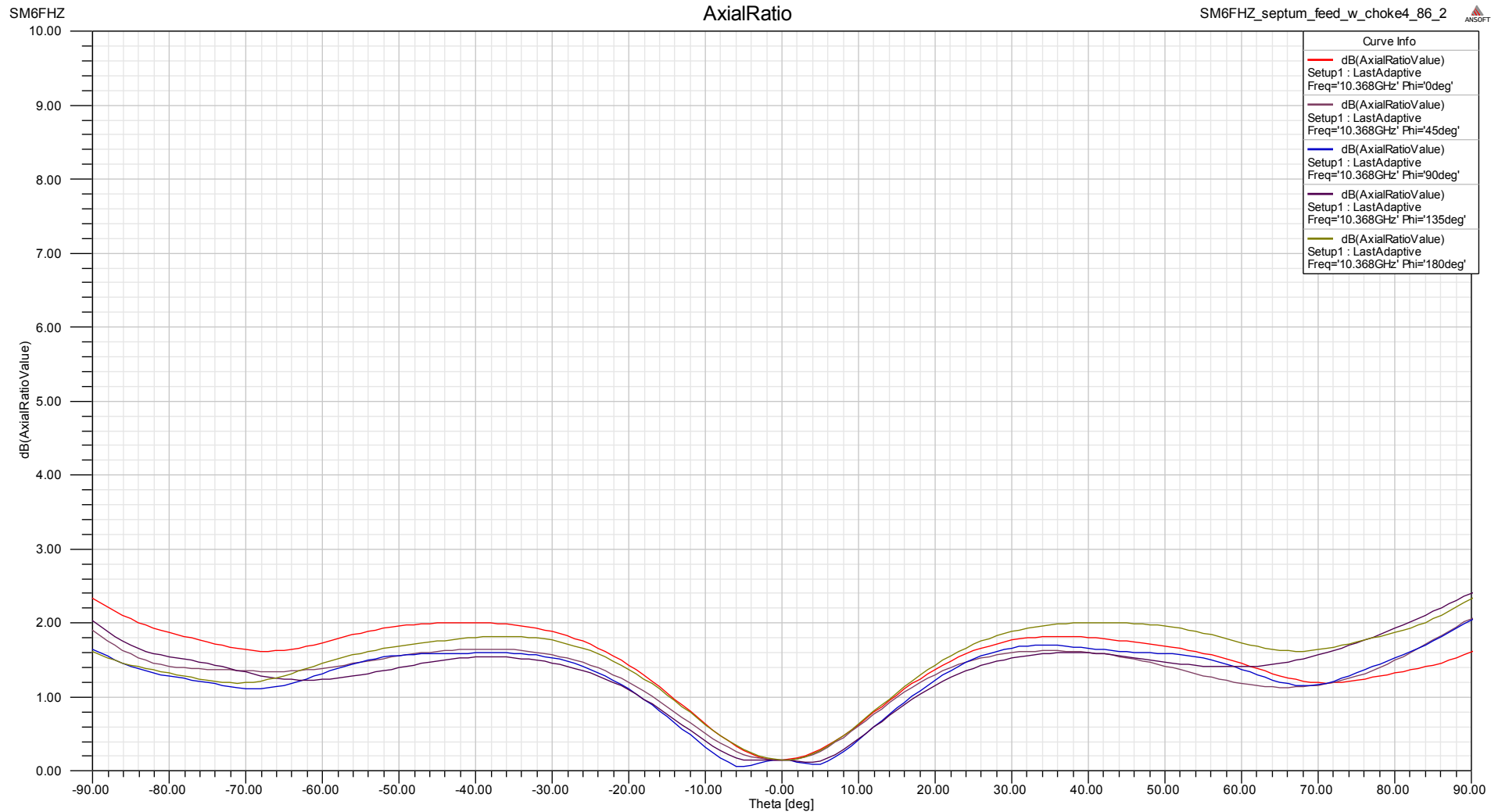
Far Field Phase error



Cross Polar Ratio



Axial Ratio



On the air experience 6 cm



- SM6FHZ 6 cm
 - 17 dB sun noise and 1.1 dB moon noise.
 - 13 initials
 - Nice returns from the moon with 17 W at the feed of the 5.5 m solid dish
- SM6PGP 6 cm
 - 12 dB sun noise and 0.3 dB moon noise
 - 9 initials
 - Moon returns readable with 90 W at the feed in an 1.8 m solid dish

On the air experience 3 cm

- SM6PGP 3 cm
 - 10 dB sun noise and 0.3 dB moon noise
 - 4 stations heard (positively identified on CW) via the moon
 - Antenna 1.8 m solid dish

Lessons Learned

- Scaling feed dimensions from a one band design to another band is at your own risk
 - The material used (thickness etc) plays a important role. It is not obvious how to scale material thickness. I argue that you will not know what radiation pattern you will get if scaled.
- Soldering of the septum to 100% is crucial
 - This is true for all soldering joints in the feed
- The inner WG diameter is sensitive to tolerances
 - 0.2 mm larger diameter on 10 GHz moved the optimum isolation >100 MHz down

Conclusion



- 5 new septum feeds from 23 cm to 3 cm have been presented
- All of them show very good performance
- The feeds for 3 cm are circularly polarized as well
- The 9 cm, 6 cm and 3 cm feeds are based on standard metric Cu or brass tubes for easy manufacturing
- So far three of the feeds have been built, measured and used. All of them show very good correlation between simulated and measured performance.

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Thank you for your attention



See you all via the moon on the higher bands