Simulation of 1420 MHz Loop Feed converted from the OM6AA's 1296 MHz version

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This report details a simulation study undertaken to convert the dimensions of OM6AA's 1296 MHz Loop Feed for use as a feed antenna for a 1420 MHz geodesic parabolic reflector. Key insights into the dimensional conversion process were gained through this simulation.

Introduction

Since the introduction of the geodesic parabolic antenna **[1]** in 2003, several construction reports have been received **[2]**. These construction examples fall into two categories: amateur radio and amateur radio astronomy. In amateur radio, antenna construction serves as a means for communication (QSO) and is also enjoyed as an end in itself. Conversely, in amateur radio astronomy, antenna construction is merely a means to the primary goal of observation, and simplicity in construction is often preferred. From this perspective, the ease of constructing geodesic parabolic antennas is understood to be a key factor in their acceptance within amateur radio astronomy. However, while the parabolic reflector itself can be constructed relatively easily, the selection and construction of a suitable feed antenna for it appear to pose some barriers in amateur radio astronomy.

Recently, an inquiry was received from an individual residing in Austria regarding the construction of a geodesic parabolic antenna for amateur radio astronomy, specifically asking about material selection. During a series of exchanges, the topic of feed antenna selection and construction arose, leading to the decision to evaluate OM6AA's Loop Feed **[3]**. Consequently, a simulation study was conducted using openEMS **[4]** with the FDTD method to examine the dimensional conversion prior to commencing construction.

This report summarizes the crucial aspects of the dimensional conversion. The dimensional conversion is fundamentally based on simple scaling by frequency ratio. By clarifying the characteristic changes in response to variations in dimensional parameters through simulation, the study aimed to address dimensional parameters that depend on readily available component materials during construction.

Figure-1 illustrates the external appearance of the Loop Feed (simulation model).

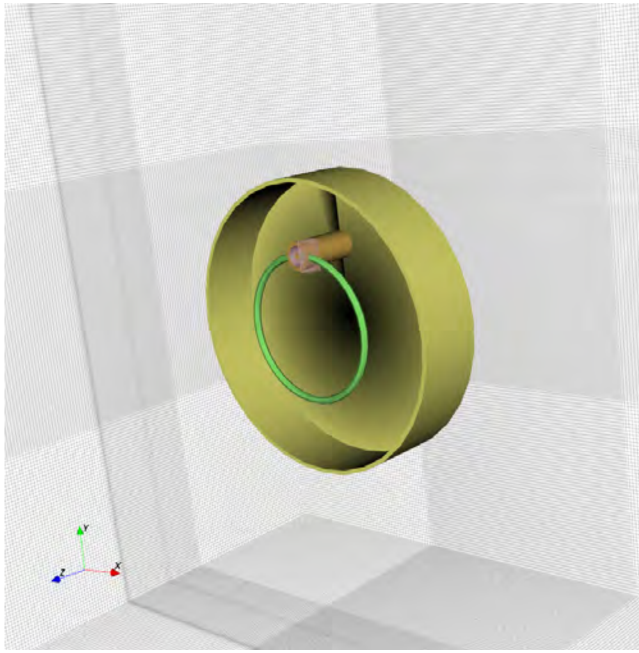

Figure – 1 : External appearance of the Loop Feed (simulation 3D model).

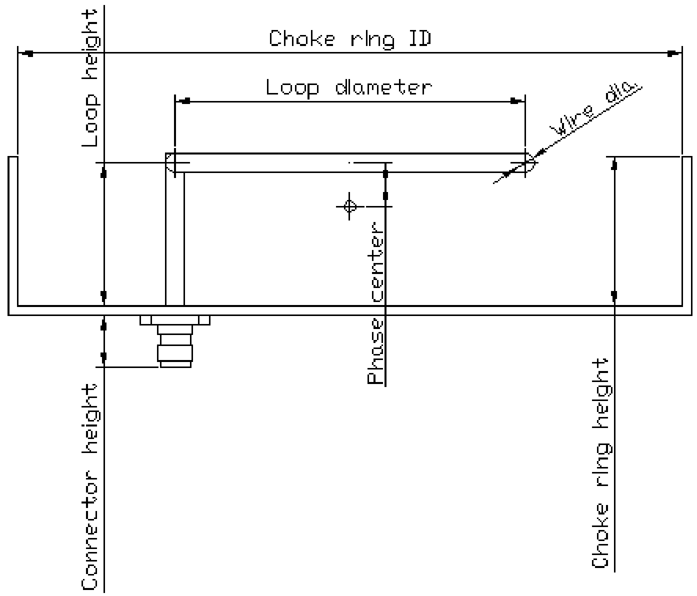

Figure – 2 : Definition of the dimensions (Cross section)

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OM6AA’s 1296 MHz Loop Feed

OM6AA discussed a Loop Feed suitable for a parabolic reflector with an f/D ratio of 0.4 in reference **[3]**, presenting both simulation and measurement results. This report investigates the conversion of the 1296 MHz practical example to 1420 MHz through simulation. To ensure the validity of the simulations presented herein, OM6AA's 1296 MHz Loop Feed is first replicated. The dimensions of this Loop Feed are provided in the 1296 MHz column of **Table – 2**, presented later.

Figure – 3 shows the s11 characteristics, and **Figure - 4** illustrates the radiation pattern. **Table – 1** compares the -10 dB illumination angle, an indicator of compatibility with the parabolic reflector in terms of radiation characteristics, with the values from reference **[3]**.

The good matching of the s11 characteristics in the 1296 MHz band shown in **Figure – 3**, and the good agreement with the original in the comparison of illumination angles in **Table – 1**, confirm the validity of the simulations in this report. It is interesting to note that the ripples observed in the radiation pattern closely resemble the measured values presented in reference **[3]**.

Model	OM6AA 1296 MHz	Simulation
E-plane angle (deg.) @ -10 dB	133.2	134
H-plane angle (deg.) @ -10 dB	143	149

Table – 1 : Comparison of illumination angle

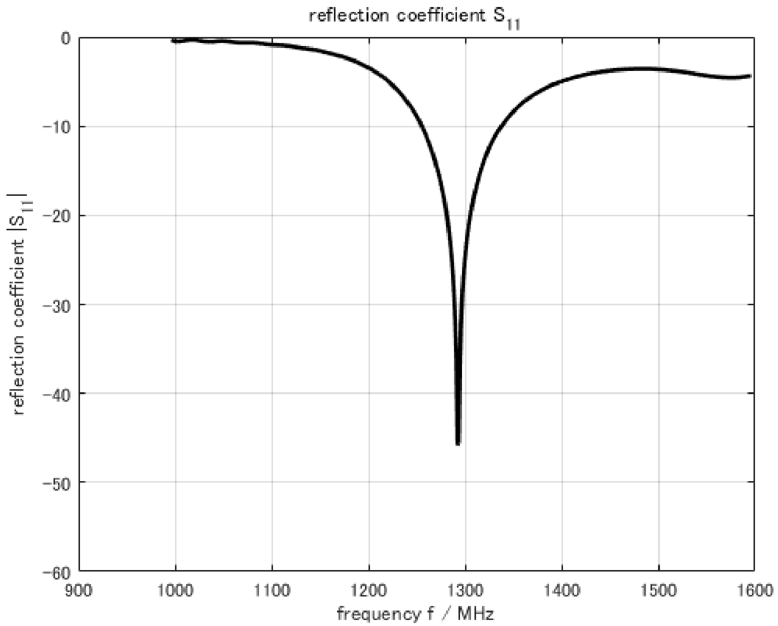

Figure – 3 ： s11 characteristics

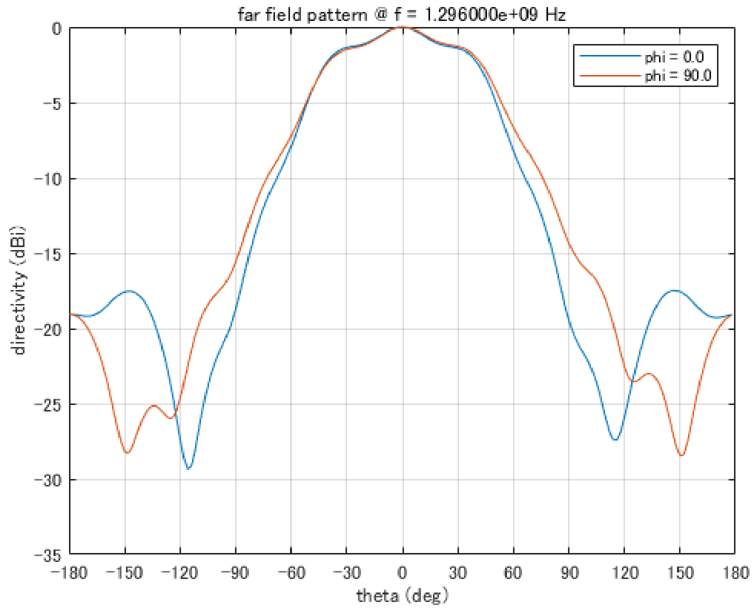

Figure – 4 ： Radiation pattern

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Conversion by Frequency Ratio

Antennas can generally be dimensionally converted by frequency ratio (the so-called Scaling Law). Therefore, the dimensions of the Loop Feed designed for 1296 MHz is converted to 1420 MHz, and its characteristics were verified through simulation. **Table – 2** shows the dimensions of the Loop Feed. The original dimensions were scaled down by a conversion ratio of 1296 / 1420 = 0.9127 (excluding the coaxial structure). **Figure – 2** defines the dimensions.

As shown in **Figure – 5**, the s11 resonance frequency of the Loop Feed with dimensions converted by frequency ratio is 1421 MHz. As shown in **Figure – 6**, the -10 dB illumination angles are E / H = 134 / 149 degrees. This confirms that the Scaling Law holds true for the original 1296 MHz version.

If the dimensions listed in **Table – 2** can be faithfully reproduced using readily available parts and material processing, the investigation would conclude here. However, in reality, readily available existing wires or materials that can be repurposed for choke rings (e.g., cake pans) are often used. Therefore, the characteristic changes due to dimensional variations are discussed next.

Center frequency (MHz)	1296	1420
Loop diameter (mm)	70.6	64.4
Loop height (mm)	28.7	26.2
Wire diameter (mm)	3.58	3.27
Choke ring ID (mm)	140.0	127.8
Choke ring depth (mm)	30.0	27.4
Choke ring thickness (mm)	2.0	1.8
Bottom plate thickness (mm)	5.0	4.6
Connector height (mm)	22.7	20.7

Table – 2 ： Dimensions of the Loop Feed

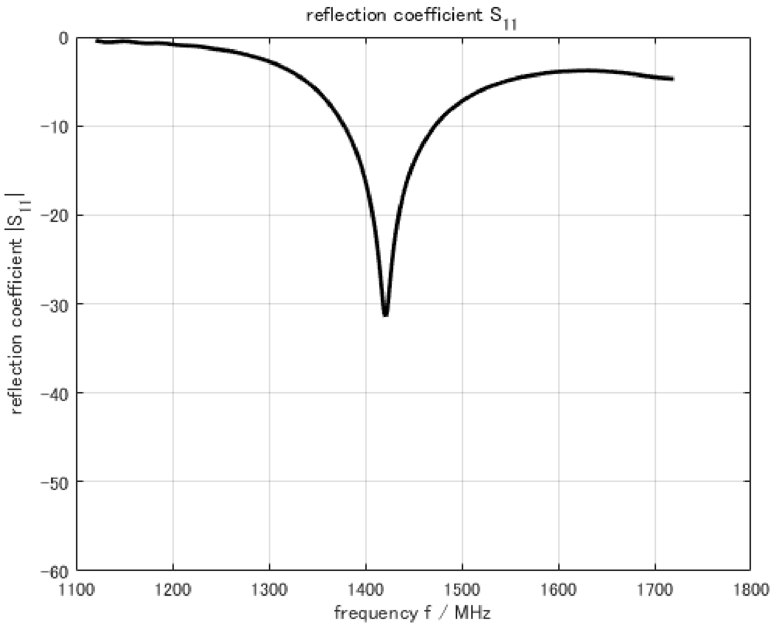

Figure – 5 ： s11 characteristics

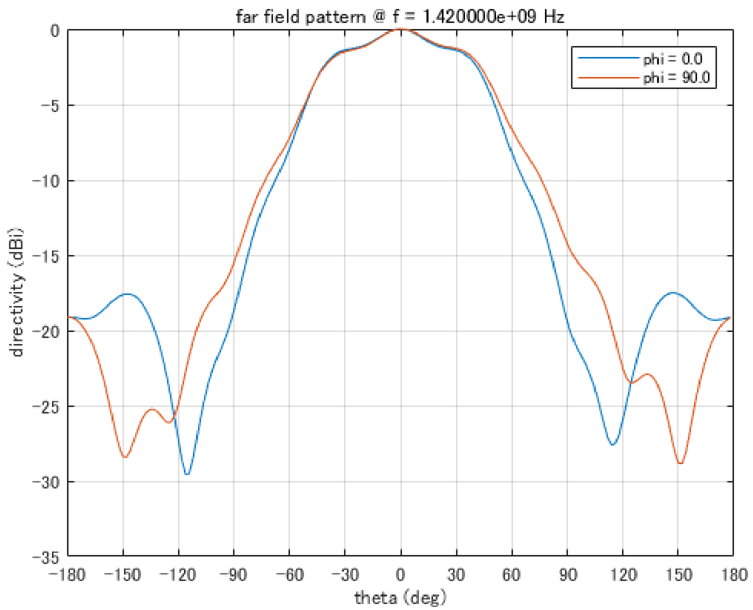

Figure – 6 ： Radiation pattern

Characteristic Changes Due to Dimensional Variation #1 - Wire Diameter

Simulations were performed to analyze the characteristics when the loop wire diameter was changed. All dimensions other than the wire diameter were kept the same as in **Table – 2**, and a list of dimensions is shown in **Table – 3**. The wire diameters were chosen as AWG (American Wire Gauge) #9 (2.906 mm), #10 (2.588 mm), and #11 (2.304 mm). The wire diameter scaled by the frequency ratio is 3.27 mm, which corresponds to AWG#8 at 3.264 mm.

Figure – 7 shows the change in s11 characteristics as the wire diameter changes, and **Figure – 8** shows the change in the -10 dB illumination angle. As the wire diameter becomes thinner, the resonance frequency slightly decreases, and no change is observed in the -10 dB illumination angle. Notably, in the case of the thinner AWG#11, the s11 at lower frequencies became oscillatory and positive, suggesting that the simulation may have failed in this region.

Center frequency (MHz)	1420
Loop diameter (mm)	64.4
Loop height (mm)	26.2
Wire diameter (mm)	**3.27, 2.906, 2.588, 2.304**
Choke ring ID (mm)	127.8
Choke ring depth (mm)	27.4
Choke ring thickness (mm)	1.8
Bottom plate thickness (mm)	4.6
Connector height (mm)	20.7

Table – 3 ： Dimensions of the Loop Feed - Wire diameter changed

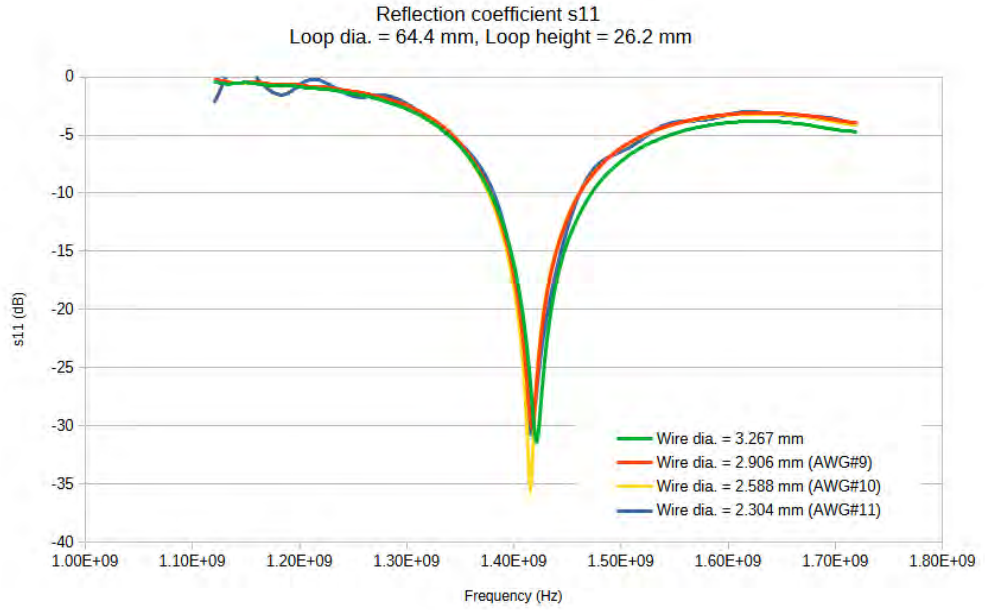

Figure – 7 ： Changes in s11 characteristics

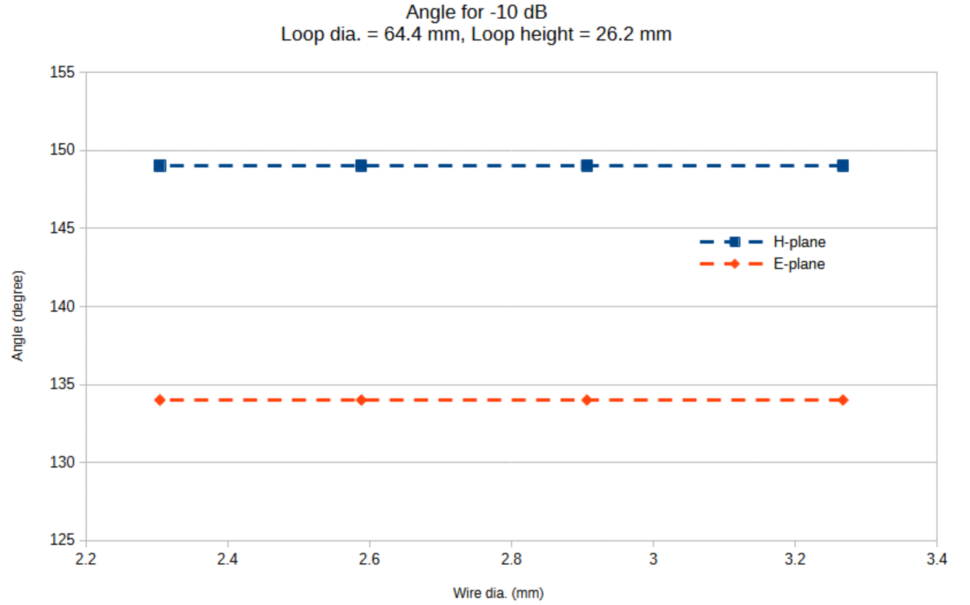

Figure – 8 ： Changes in –10 dB illumination angle

Characteristic Changes Due to Dimensional Variation #2 - Choke ring ID

In construction, when diverting existing parts, the inner diameter of the choke ring is likely to be a dimension with constraints. Cake pans are a conceivable existing item that can be diverting. Their diameters are typically 5 or 6 inches, and their depth can be adjusted by cutting to the desired size. These 5-inch or 6-inch diameters are nominal product values, and the actual diameter is expected to be slightly different due to tapers and rim folds for molding. Here, as shown in **Table – 4**, inner diameters of 125.0 mm and 152.0 mm were assumed.

As shown in **Figure – 9**, the best s11 point shifts slightly from 1428 MHz to 1420 MHz as the inner diameter of the choke ring decreases. As shown in **Figure – 10**, the -10 dB illumination angle broadens for both the E-plane and H-plane as the inner diameter of the choke ring decreases.

Center frequency (MHz)	1420
Loop diameter (mm)	64.4
Loop height (mm)	26.2
Wire diameter (mm)	3.27
Choke ring ID (mm)	**127.8, 125.0, 152.0**
Choke ring depth (mm)	27.4
Choke ring thickness (mm)	1.8
Bottom plate thickness (mm)	4.6
Connector height (mm)	20.7

Table – 4 ： Dimensions of the Loop Feed - Choke ring ID changed

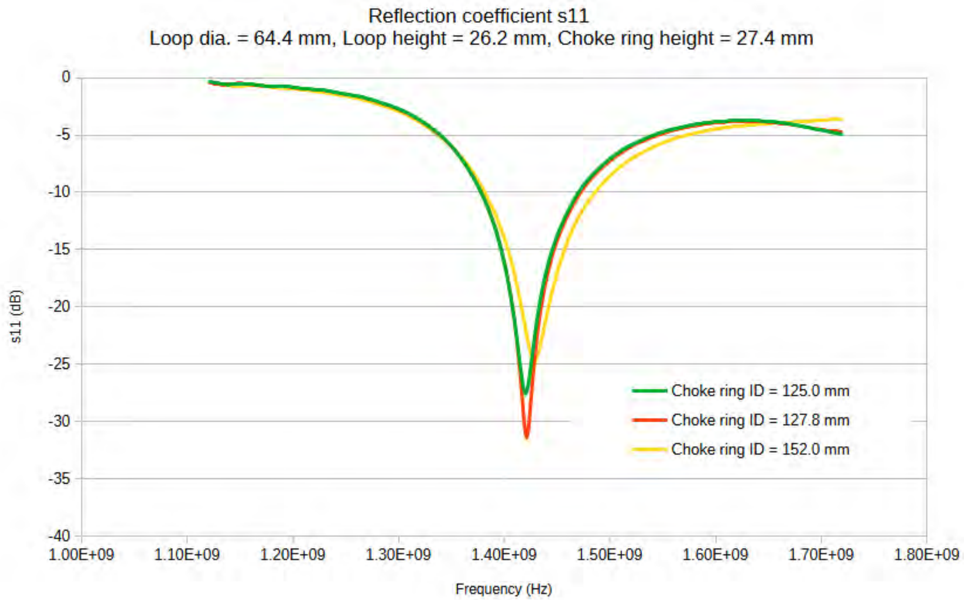

Figure – 9 ： Changes in s11 characteristics

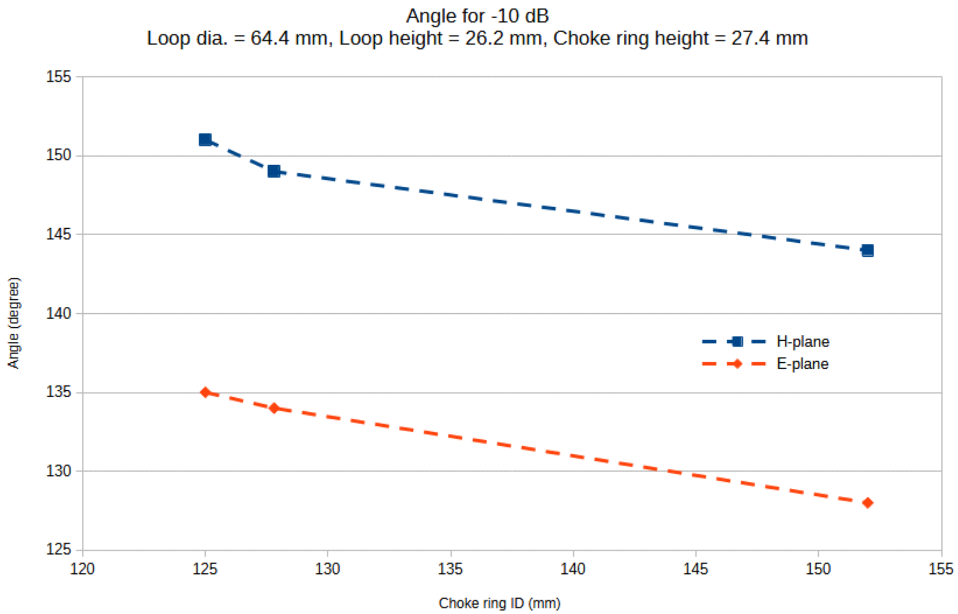

Figure – 10 ： Changes in –10 dB illumination angle

Characteristic Changes Due to Dimensional Variation #3 - Choke ring depth

While the choke ring inner diameter is determined by the diverted material, the choke ring depth serves as an adjustment parameter for the characteristics. Simulations were performed for depths of 25.4 mm and 29.4 mm, centered around the frequency-ratio converted value of 27.4 mm. A list of dimensions is shown in **Table – 5**.

As shown in **Figure – 11**, the best s11 point for both 25.4 mm and 29.4 mm choke ring depths is 1409 MHz, which is lower than the 1421 MHz observed at 27.4 mm. There is no simple proportional relationship with the choke ring depth. As shown in **Figure – 12**, the -10 dB illumination angle for the E-plane narrows as the choke ring depth decreases. The H-plane illumination angle also narrows slightly.

Center frequency (MHz)	1420
Loop diameter (mm)	64.4
Loop height (mm)	26.2
Wire diameter (mm)	3.27
Choke ring ID (mm)	127.8
Choke ring depth (mm)	**25.4, 27.4, 29.4**
Choke ring thickness (mm)	1.8
Bottom plate thickness (mm)	4.6
Connector height (mm)	20.7

Table – 5 ： Dimensions of the Loop Feed - Choke ring depth changed

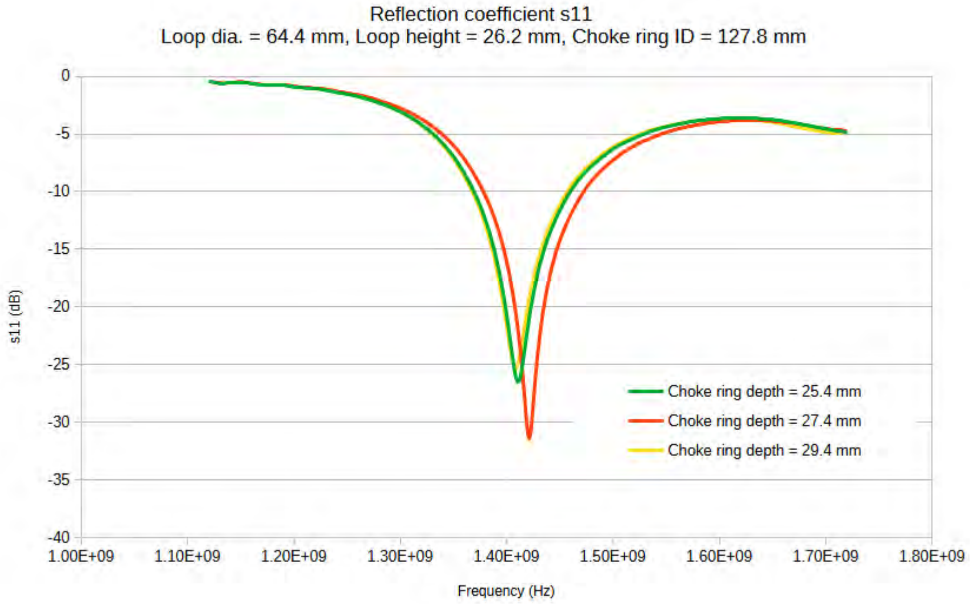

Figure – 11 ： Changes in s11 characteristics

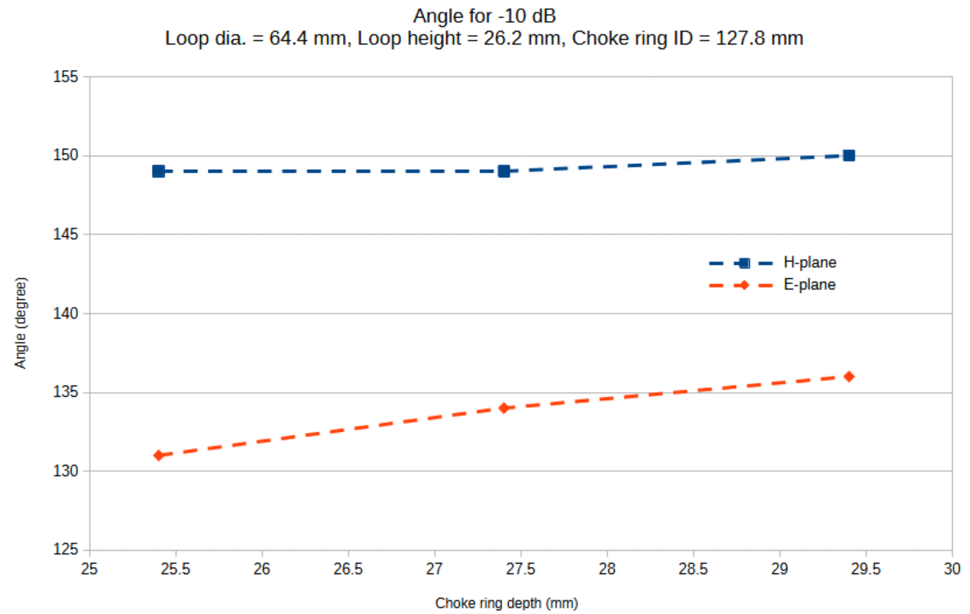

Figure – 12 ： Changes in –10 dB illumination angle

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Characteristic Changes Due to Dimensional Variation #4 - Loop height

The loop height was varied to 25.2 mm, 26.2 mm, 27.2 mm, and further to 29.2 mm. A list of dimensions is shown in **Table – 6**.

As shown in **Figure – 13**, the best s11 point does not have a simple proportional relationship with the loop height. It appears to have a relative relationship with the choke ring depth. This is likely due to the change in the loop's impedance as the spacing between the loop element and the choke ring changes, and also because the loop element's impedance is not 50 Ω, so the matching condition changes with variations in the length of the 50 Ω coaxial line, which is equal to the loop height.

As shown in **Figure – 14**, when the loop height is equal to or less than the choke ring depth, there is no change in the -10 dB illumination angle. However, when the loop extends beyond the choke ring, the illumination angle narrows.

Center frequency (MHz)	1420
Loop diameter (mm)	64.4
Loop height (mm)	**25.2, 26.2, 27.2, 29.2**
Wire diameter (mm)	3.27
Choke ring ID (mm)	127.8
Choke ring depth (mm)	27.4
Choke ring thickness (mm)	1.8
Bottom plate thickness (mm)	4.6
Connector height (mm)	20.7

Table – 6 ： Dimensions of the Loop Feed - Loop height changed

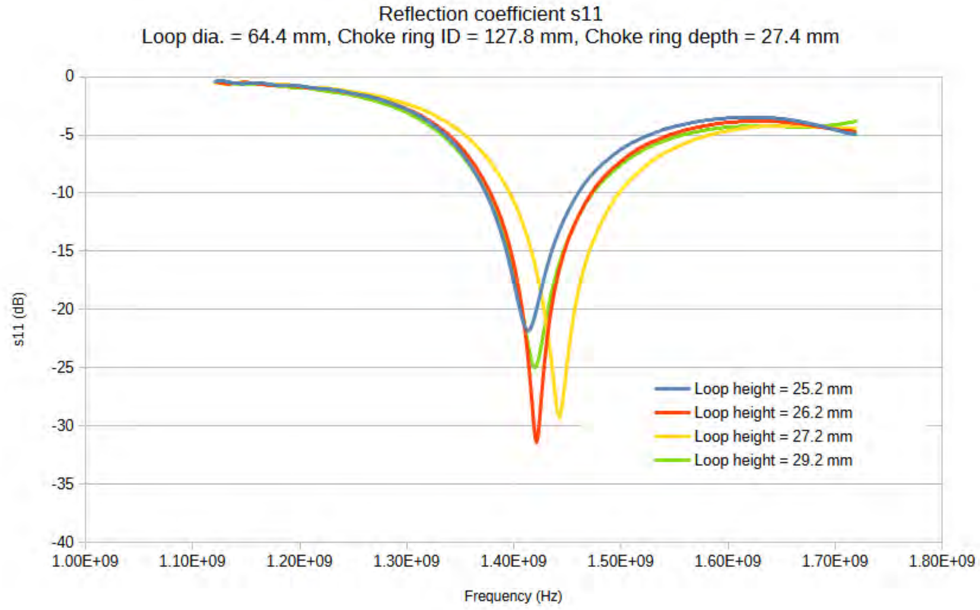

Figure – 13 ： Changes in s11 characteristics

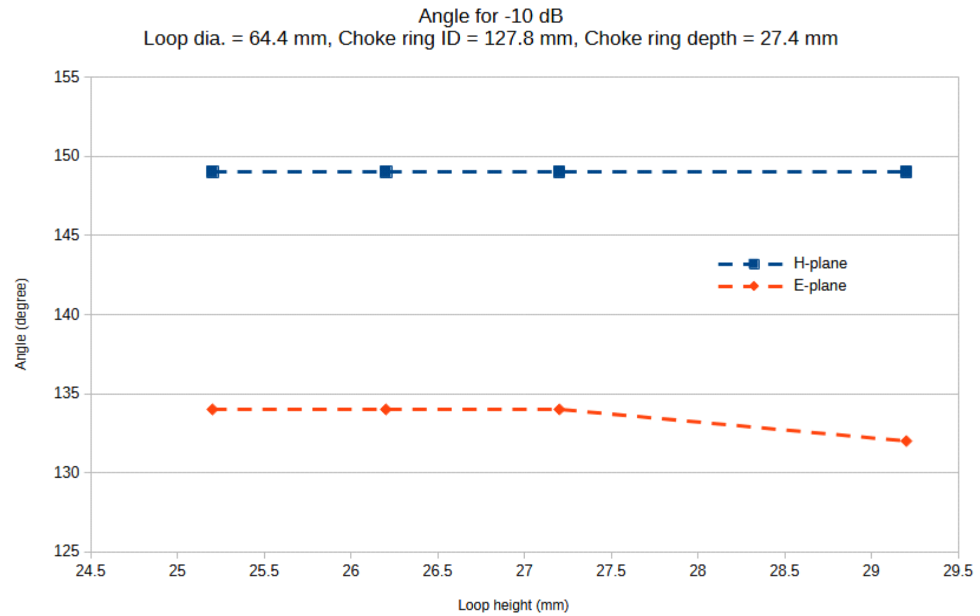

Figure – 14 ： Changes in –10 dB illumination angle

Characteristic Changes Due to Dimensional Variation #5 - Loop diameter

The loop length is fundamentally one wavelength, but it is not exactly one wavelength due to the influence of the loop wire diameter, loop height, and choke ring (diameter, depth). Simulations were conducted to examine the characteristic changes when the loop length varied. While it is more convenient to specify the wire length when cutting wire during fabrication, loop diameter is more convenient for parameterizing in simulations from a model generation perspective.

From the perspective of the "Scaling Law" mentioned in the "Conversion by Frequency Ratio" section, it is expected that the loop diameter and resonance frequency are proportionally related. Therefore, simulations were performed for 63.8 mm and 65.0 mm, representing ±1 % of 64.4 mm. A list of dimensions is shown in **Table – 7**.

As shown in **Figure – 15**, the best s11 points are 1408 MHz, 1421 MHz, and 1434 MHz, respectively, showing a ±1 % proportional relationship to 1421 MHz. **Figure – 16** shows the change in the -10 dB illumination angle when the loop diameter changes. The change in illumination angle due to loop diameter variation is small.

Center frequency (MHz)	1420
Loop diameter (mm)	**63.8, 64.4, 65.0**
Loop height (mm)	26.2
Wire diameter (mm)	3.27
Choke ring ID (mm)	127.8
Choke ring depth (mm)	27.4
Choke ring thickness (mm)	1.8
Bottom plate thickness (mm)	4.6
Connector height (mm)	20.7

Table – 7 ： Dimensions of the Loop Feed - Loop diameter changed

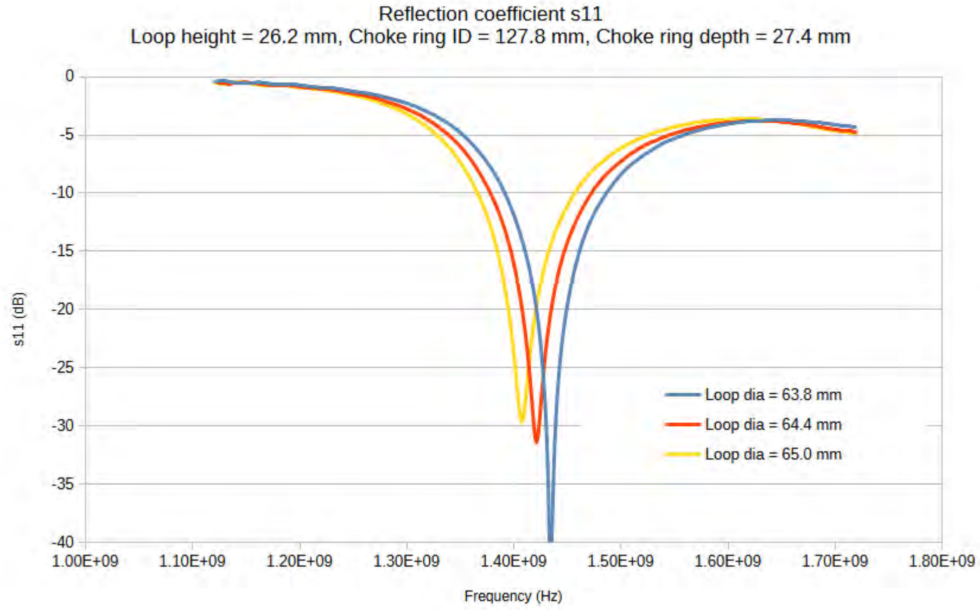

Figure – 15 ： Changes in s11 characteristics

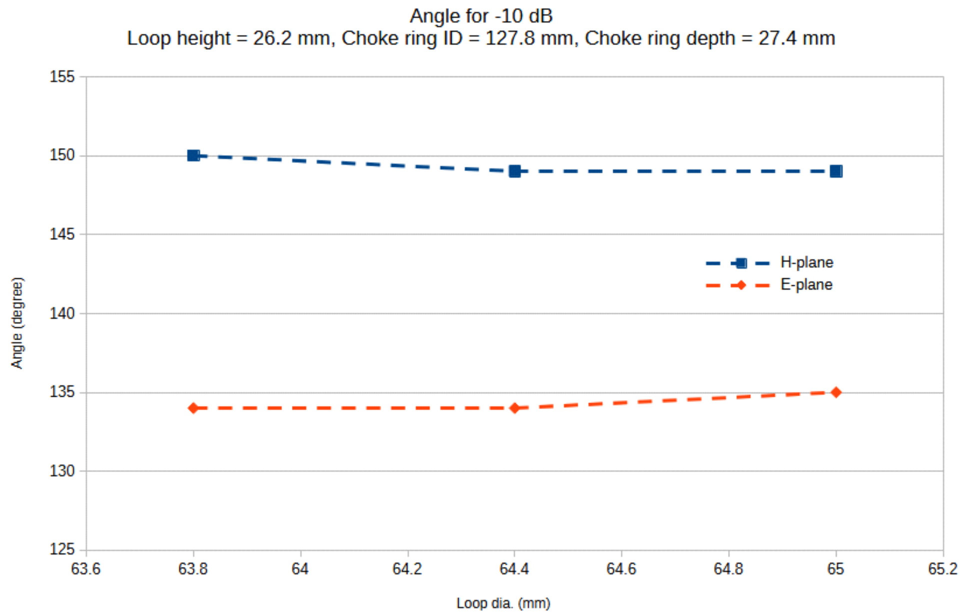

Figure – 16 ： Changes in –10 dB illumination angle

Summary of Characteristic Changes Due to Dimensional Variation

Table – 8 summarizes the simulation results of characteristic changes due to dimensional variations. The table shows the changes in the best s11 frequency and illumination angle when each dimensional parameter is **increased**. A "-" in the table indicates no change or no simple proportional relationship.

The best s11 values were better than -20 dB within the range of dimensional variations, suggesting that matching may not need to be the primary goal during fabrication and adjustment. On the other hand, the illumination angle is a primary characteristic goal for the feed and must be adjusted using available materials. The choke ring inner diameter is a given, while the choke ring depth and loop height offer degrees of freedom for adjustment. After adjusting these, the loop diameter should be adjusted so that the best s11 frequency is the target 1420 MHz. As shown in **Table – 8**, adjusting the loop diameter does not affect the illumination angle.

Design Example

As a design example for determining dimensional parameters, the case of diverting a 5-inch cake pan as a choke ring was simulated.

Based on the preceding simulations, it was found that when a 5-inch cake pan is diverted as a choke ring (i.e., the choke ring inner diameter is 125.0 mm), the illumination angle becomes slightly wider than the target E/H = 134/149 degrees. As a countermeasure, adjusting the choke ring depth was considered. From the simulation results summarized in **Table – 8**, it is evident that making the choke ring shallower narrows the illumination angle.

Figures – 17 and **– 18** show the results of a simulation with a choke ring depth of 26.0 mm, compared to the frequency-ratio converted 27.4 mm. As shown in **Table – 9**, the illumination angle approached the target value, but the best s11 frequency became 1441.6 MHz, higher than the target center frequency of 1420 MHz.

Dimensional parameter	s11 best frequency	angle @ -10 dB
Loop diameter	down	-
Loop height	-	narrow
Wire diameter	-	-
Choke ring ID	-	narrow
Choke ring depth	-	broaden

Table – 8 : Characteristic Changes Due to Dimensional Variation

Based on the preceding simulation results, an attempt was made to adjust the best s11 frequency without affecting the illumination angle by changing the loop diameter. Since loop diameter and frequency are inversely proportional, 65.4 mm (calculated as 64.4 × 1441.6 / 1420) was tried. The result was 1418.8 MHz. As a further correction, trying 65.3 mm (calculated as 65.4 × 1418.8 / 1420) yielded 1421.2 MHz, so this correction was finalized. These results are summarized as Case #2 and #3 in **Table – 9**. The difference of ±1.2 MHz from 1420 MHz in Case #2 and #3, where the loop diameter was corrected, represents the frequency resolution in the simulation. Considering this, the loop diameter that results in a center frequency of 1420 MHz is calculated to be 65.35 mm. However, considering manufacturing precision and simulation errors, a difference of 0.05 mm is negligible. Therefore, Case #3 in **Table – 9** is set as the final value for the design example. The finalized characteristics are shown in **Figure – 19** and **– 20**.

In this series of simulations, the dimensions determined by the frequency ratio, as shown in each table, were used for the bottom plate thickness and connector height. In actual construction, when diverting a cake pan, the bottom plate thickness would likely be 1.8 mm or less, similar to the choke ring thickness. Also, if an SMA connector is used, the connector height would be 9.4 mm. Both of these dimensions would differ from those used in the simulation. Simulations of dimensional changes for the bottom plate thickness and connector height revealed that these changes do

Case No.	#1	#2	#3
Loop diameter (mm)	**64.4**	**65.4**	**65.3**
Loop height (mm)	26.2	26.2	26.2
Wire diameter (mm)	3.26 (AWG#8)	3.26 (AWG#8)	3.26 (AWG#8)
Choke ring ID (mm)	125.0	125.0	125.0
Choke ring depth (mm)	26.0	26.0	26.0
Choke ring thickness (mm)	1.8	1.8	1.8
Bottom plate thickness (mm)	4.6	4.6	4.6
Connector height (mm)	20.7	20.7	20.7
Best s11 freq. (MHz)	**1441.6**	**1418.8**	**1421.2**
E / H angle (deg.) @ -10 dB	132 / 149	132 / 149	132 / 149

Table – 9 : Dimensions of the design example - Case #3 is the final value

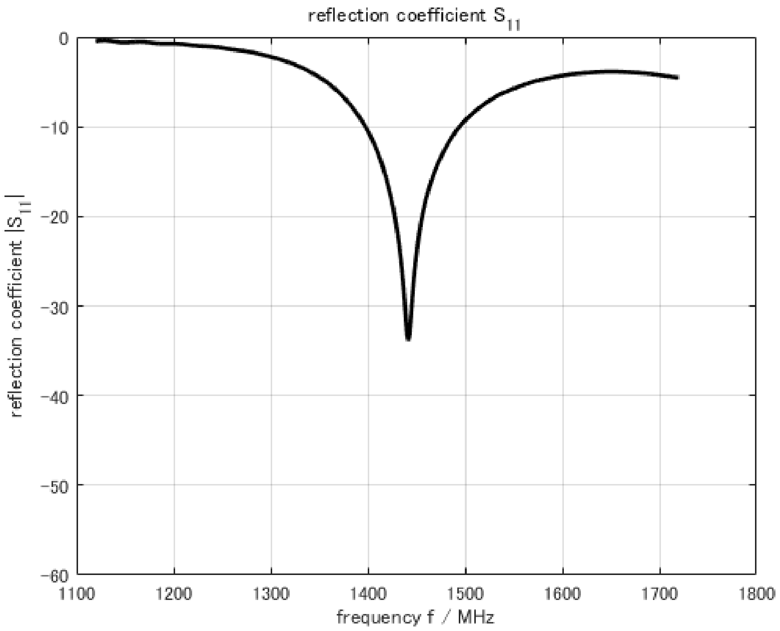

Figure – 17 ： s11 characteristics – Case #1

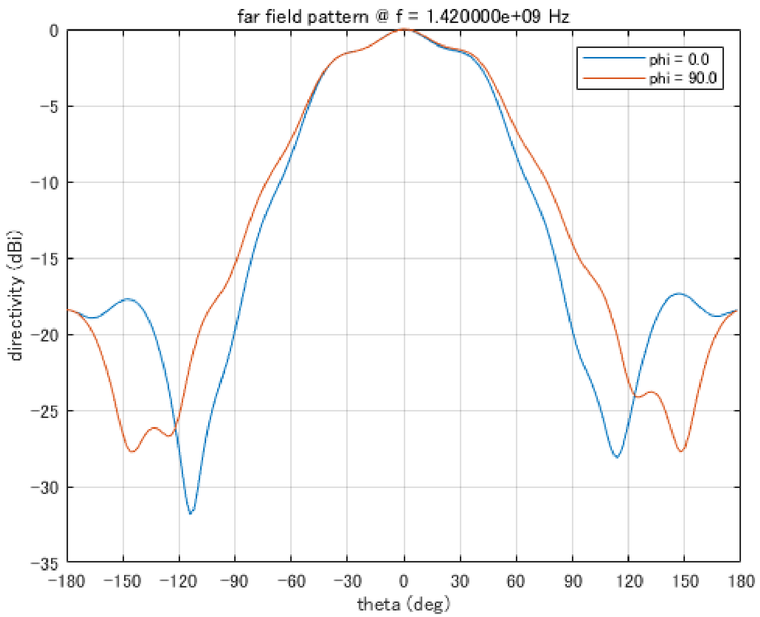

Figure – 18 ： Radiation pattern – Case #1

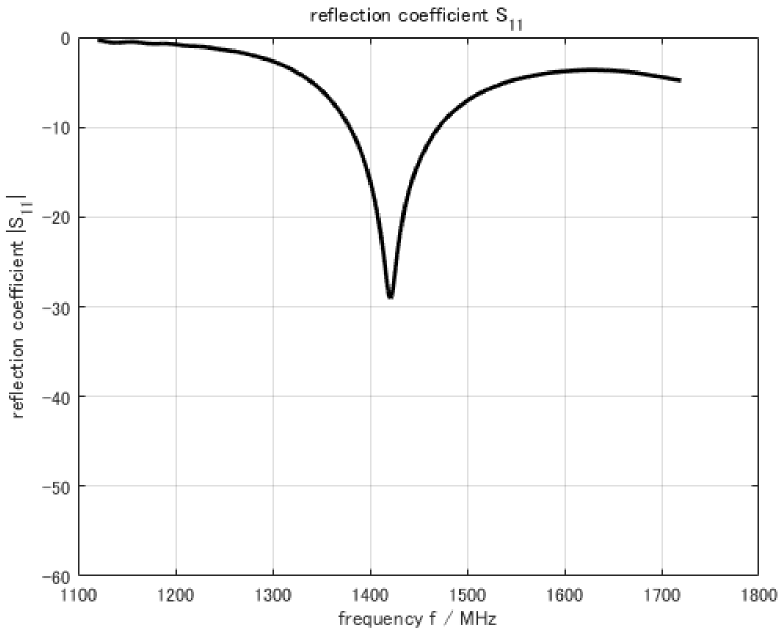

Figure – 19 ： s11 characteristics – Case #3

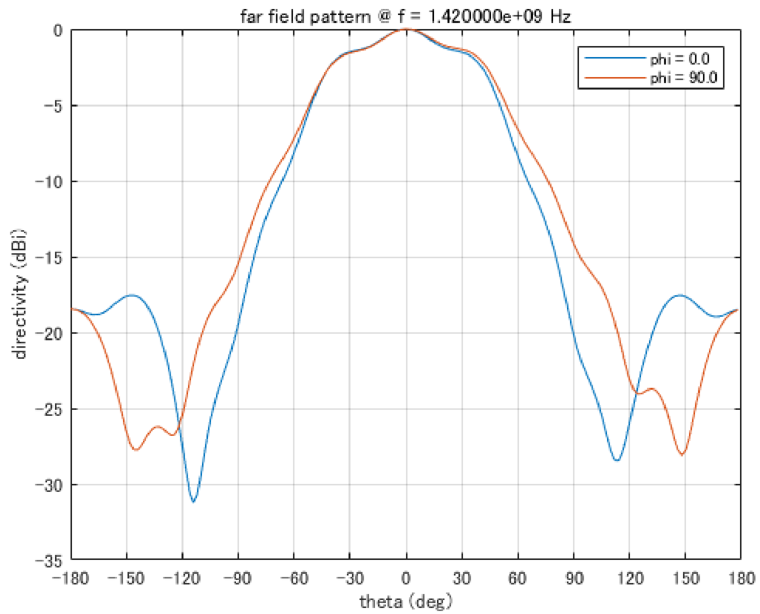

Figure – 20 ： Radiation pattern – Case #3

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not affect the s11 characteristics as long as the loop height, which is part of the coaxial line length, is maintained as designed.

Phase Center

The completed loop feed is positioned at the focal point of the parabolic reflector. It is essential to align the phase center of the loop feed with the focal point of the reflector. Since the phase center is not uniquely determined by the dimensions of the loop feed, measurement or simulation is required. Among the series of simulations mentioned previously, phase information was extracted from the radiation patterns of cases where the loop height and choke ring depth were varied, and the phase center was calculated. The calculated results are presented in Figure 21, with the difference in loop height and choke ring depth, Δ(Loop height – Choke ring depth), as a parameter. The position of the phase center is referenced to the loop's position; negative values indicate that it is behind the loop (closer to the bottom surface of the choke ring), and positive values indicate that it is in front of the loop.

In conclusion, for the aforementioned design example, Case #3, the phase center is -10 mm. Additionally, for frequency ratio conversion, the phase center is –8 mm.

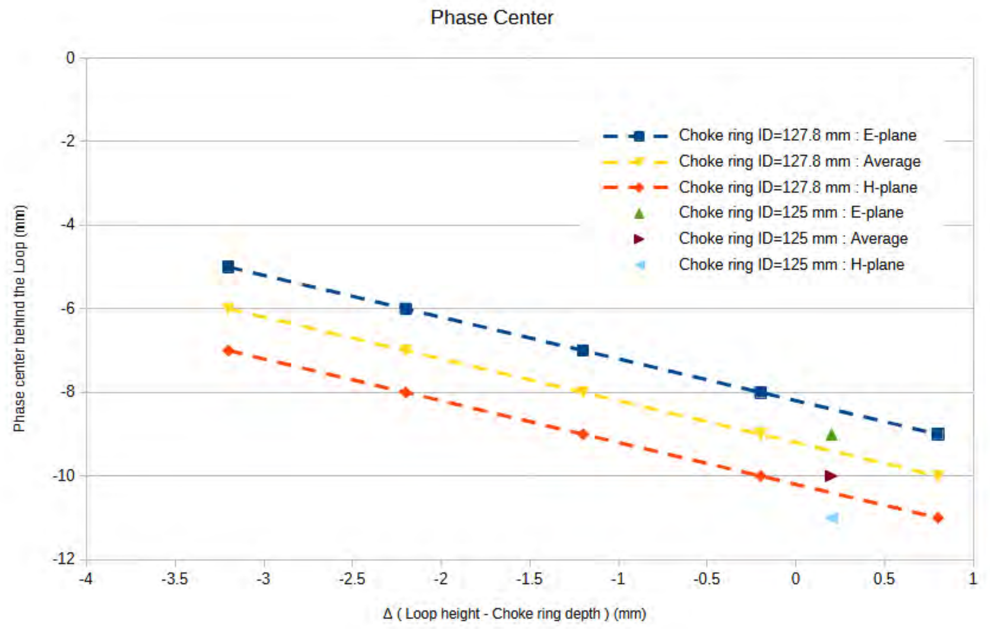

Figure – 21 ： Phase center

Conclusion

This simulation study successfully demonstrated the dimensional conversion of OM6AA's 1296 MHz Loop Feed to 1420 MHz for use with an f/D = 0.4 geodesic parabolic antenna in amateur radio astronomy. By simulating the characteristic changes due to variations in each element's dimensions using openEMS, practical dimensions for fabrication were determined.

Sincere gratitude is extended to Mr. Gary Dyck for his valuable discussions.

References

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