

Chapter 6. Parametric Investigation of SLH

6.1 Numerical Study of Stub Loaded Helix Parameters

Of the several parameters that define the geometry of the Stub Loaded Helix (SLH), the two that have the greatest impact on performance are the pitch angle, α , and stub depth, l_s . The pitch angle is most likely to affect the gain and axial ratio of the SLH, as the pitch establishes the spatial phasing between turns of the helix. The stub depth affects the bandwidth and axial ratio of the SLH, because they influence the electrical phasing of the currents around each turn.

In this chapter, we examine the effects of pitch angle and stub depth on the gain and axial ratio of an SLH. Using NEC a wire grid model of a five-turn SLH with a circumference of 1m was created. With a circumference of 1 m, the nominal midband frequency of the SLH is approximately 240 MHz. The design parameters and the variations examined are given in Table 6.1.

Table 6.1 Design Parameters and Variations Used in Parametric Studies

C, circumference	1 m
R, radius	0.1591 m
N, # of turns	5
α , pitch angle	6°, 7°, 8°, 9°, 10°, 11°
N_s , # of stubs-per-turn	4, 6, 8, 10
l_s , stub depth	0.5R, 0.66R, 0.75R, 0.8R, 0.9R

6.2 Simulation of Pitch Angle Variation

NEC was used to model the antenna gain and axial ratio over the bandwidth of 175 - 255 MHz. The pitch angle of the antenna was varied from 6° to 11° in increments of 1°. All other model parameters were held constant.

Figure 6.1 shows the predicted gain over frequency for each of the pitch angles modeled. From 175 to 255 MHz, the gain variations between pitch angles is relatively insignificant,

with the exception of the 11° pitch angle curve which shows a dip in its gain curve of approximately 2 dB less than the others. There is some deviation between the gain curves at the high and low ends of the frequency range, but this is not significant as will be explained later. Thus, it would appear from the modeling results that the pitch angle of the SLH has only a small impact on the gain of the antenna within the range of 6° to 10° . At $\alpha = 11^\circ$ there appears to be a somewhat greater effect.

The boresight axial ratios predicted by NEC are shown in Figure 6.2. Here, the effect of pitch angle is very pronounced. The curves have generally the same shape but the axial ratio level varies considerably. An axial ratio of 3 dB is generally regarded as the maximum acceptable level, thus a reference line has been included on the plot at the 3 dB level. The peak axial ratio and widest bandwidth occurs for the 8° curve. Within the range of 7° to 9° , acceptable axial ratio performance is obtained but at reduced bandwidth. Thus, we conclude that the optimum pitch angle for the SLH is 8° in the sense that this pitch angle minimizes the axial ratio over the widest bandwidth.

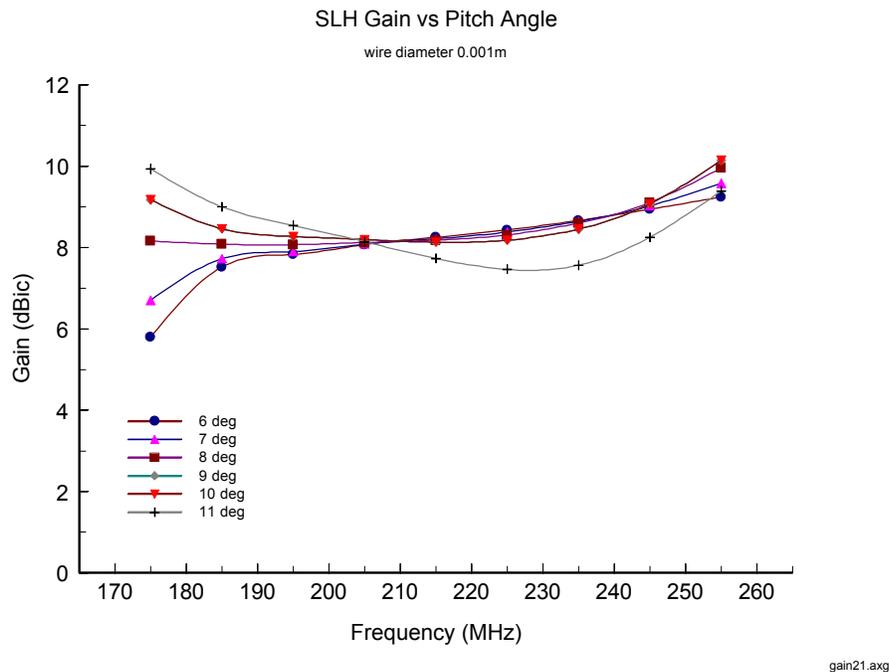


Figure 6.1. Gain versus pitch angle (α) for Stub Loaded Helix antenna simulated using NEC-4. Model parameters: $C_{SLH} = 1\text{m}$, $N = 5$, $N_s = 4$, $l_s = 0.6667$.

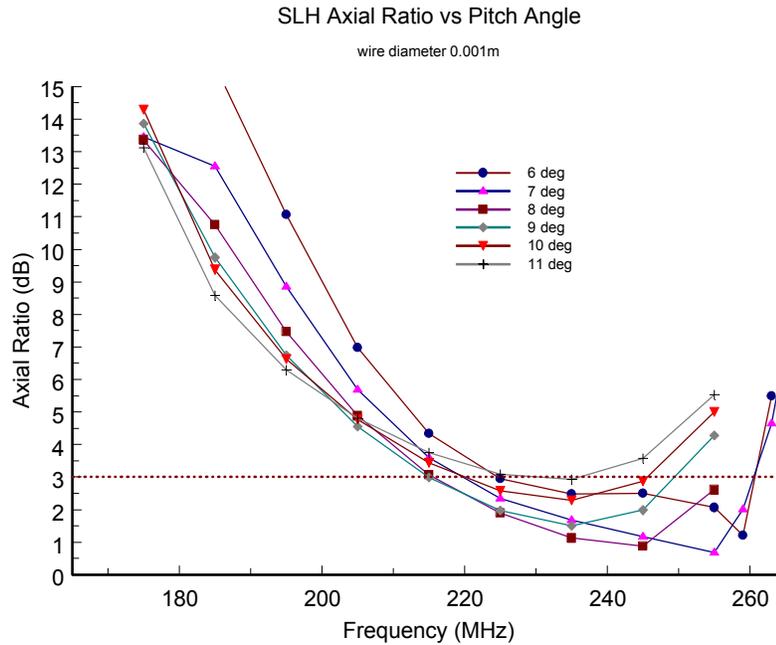


Figure 6.2. Axial ratio versus pitch angle (α) for Stub Loaded Helix antenna simulated using NEC-4. Model parameters: $C_{SLH} = 1\text{m}$, $N = 5$, $N_s = 4$, $l_s = 0.6667$

6.3 Simulations for Stub Depth Variations

The depth of the stubs, l_s , impacts the operational frequency of the Stub Loaded Helix as well as the axial ratio, and to a lesser extent, the gain performance. To examine these effects, we modeled a 1 m circumference, 5-turn SLH with 4-stubs/turn ($C=1\text{ m}$, $N=5$, $N_s=4$) with stubs whose depth was varied as $0.50 \cdot R$ (0.250m), $0.6667 \cdot R$ (0.333m), $0.750 \cdot R$ (0.375m), $0.80 \cdot R$ (0.40m) and $0.9 \cdot R$ (0.450m). For each stub depth the gain and axial ratio was calculated over the frequency range of 175 MHz to 285 MHz. The gain and axial ratio results are shown in Figures 6.3 and 6.4, respectively.

From Figure 6.3, there is little difference in the gain performance for the $l_s = 0.6667 \cdot R$ through $l_s = 0.90 \cdot R$ cases over most of the frequency range considered, except for the effects of frequency shifting of the curves. There is some decrease in gain at the lower end of the frequency range. The $l_s = 0.50 \cdot R$ case does exhibit approximately 1-1.5 dB more gain than the others at the lower end of the frequency range. The gain peaking and quick drop off with frequency that is characteristic of the SLH is evident in the $l_s = 0.6667 \cdot R$ through $l_s = 0.90 \cdot R$ curves. The $l_s = 0.50 \cdot R$ curve does not extend out far enough, the

gain peak is beyond the operational frequency range. Since the circumference of the helix was fixed while the stub depth was varied, there is some shifting in the frequency behavior of the antenna as expected. This accounts for the shifting of the gain peaks in Figure 6.3. From the results shown in Figure 6.3, we conclude that the stub depth does not have a major impact on the gain of the SLH. Other considerations, namely axial ratio performance, will dictate the optimum stub depth.

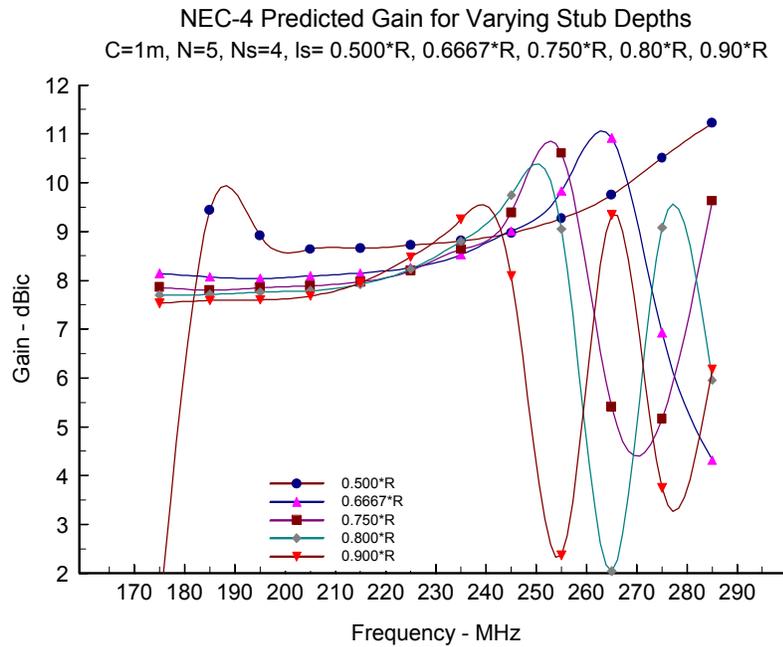


Figure 6.3 NEC predicted gain for a 5-turn SLH with stubs of varying depth with $C=1\text{m}$, $N=5$, $N_s=4$, $l_s = 0.500\cdot R, 0.6667\cdot R, 0.750\cdot R, 0.80\cdot R$, and $0.90\cdot R$.

While the gain is relatively insensitive to the stub depth, the axial ratio performance certainly is. Figure 6.4 shows the axial ratio (AR) performance predicted by NEC-4 for the different stub depths. A reference line is shown at the 3 dB point on the graph to indicate the usable bandwidth of the antenna. The maximum axial ratio for the $l_s = 0.500\cdot R$ case is only about 2 dB and the 3 dB AR bandwidth is relatively small at approximately 32 MHz.

The AR performance of the $l_s = 0.6667\cdot R$ and $l_s = 0.750\cdot R$ cases are very similar (if the frequency shift is ignored). The $l_s = 0.750\cdot R$ case has a slightly higher peak axial ratio. The 3 dB bandwidths for both cases are almost identical at approximately 41 MHz. The l_s

= $0.80 \cdot R$ and $0.9 \cdot R$ cases have higher axial ratio peaks but smaller AR bandwidths (40 MHz and 36.7 MHz, respectively) than the previous cases. Thus, it would appear that a stub depth between $0.6667 \cdot R$ and $0.75 \cdot R$ is optimal in the sense of maximizing the AR bandwidth. These values also coincide with values that produce good gain performance as illustrated in Figure 6.3. Longer stub depths can be used to obtain greater size reduction, but only at the expense of reduced axial ratio bandwidth and gain.

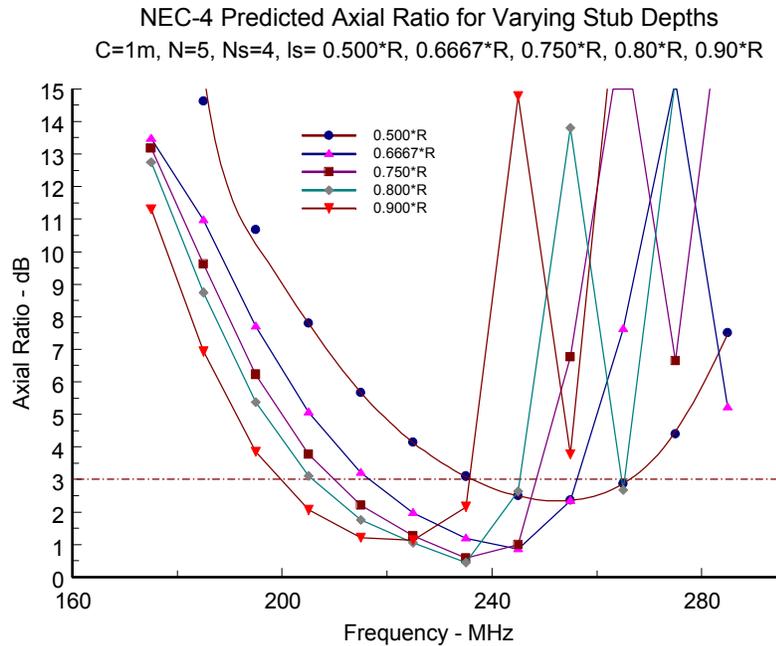


Figure 6.4 NEC predicted axial ratio for a 5-turn SLH with stubs of varying depth with $C=1\text{m}$, $N=5$, $N_s=4$, $l_s = 0.500 \cdot R, 0.6667 \cdot R, \text{ and } 0.750 \cdot R$.

6.4 Simulations for Various Numbers of Stubs Per Turn

The last SLH parameter examined was the number of stubs/turn. It was hypothesized that by increasing the number of stubs/turn might increase the axial ratio bandwidth of the antenna because of the more distributed discontinuities around the turn circumference. This turned out not to be the case.

In order to test this hypothesis, NEC models of a five turn SLH were constructed with 4, 6, 8, and 10 stubs/turn. The 4 stub/turn model was the reference model and the depths of

the stubs for all the other models were adjusted so that the total path length around a turn (helix winding plus stubs) remained the same as the reference model. This eliminated any additional size reduction effects that would have been present if a constant stub length had been used. Only an even number of stubs/turn were modeled but there is no reason to assume that using an uneven number of stubs/turn would produce results with any significant differences.

Figure 6.5 shows the NEC predicted gain versus frequency for each of the models. The high frequency gain peak moves down in frequency when going from 4 to 8 stubs/turn but the gain does not change significantly. Thus, we conclude that there is very little effect on gain by varying the number of stubs/turn. As we shall see, the bandwidth, and hence the range of usable gain, is limited by other factors.

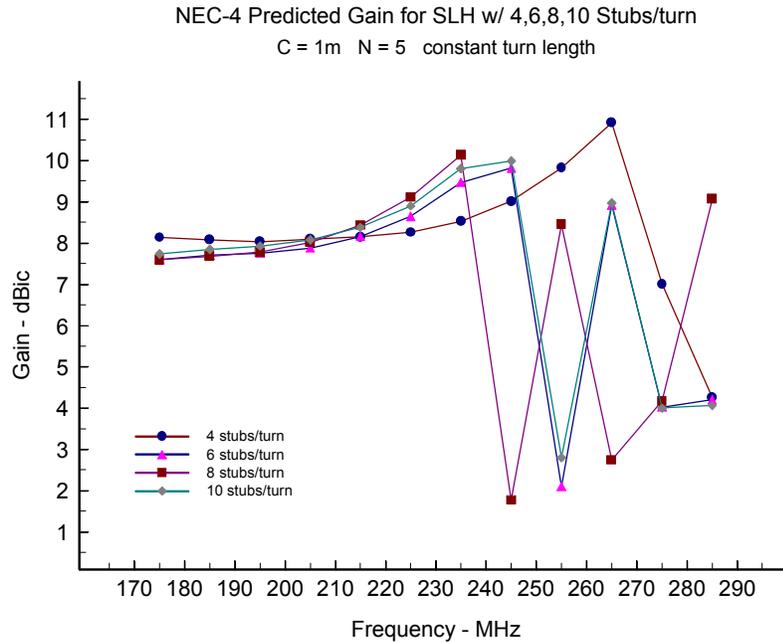


Figure 6.5 NEC predicted gain for 5 turn SLH with 4, 6, 8, and 10 stubs/turn. Total path length around turns, including stubs, was held constant at 1.84 m.

Figure 6.6 shows the NEC predicted axial ratio values for the 5-turn SLH models with different numbers of stubs/turn. Going from 4 stubs/turn to 6 or 8 stubs/turn does seem to shift the 3 dB axial ratio bandwidth lower in frequency. It does not, however, increase the axial ratio bandwidth. Table 3.3 shows the 3 dB axial ratio bandwidths from the plots in

Figure 6.6. The 4 stub/turn case has the widest AR bandwidth but also has the highest center frequency. The 6 stub/turn case has almost as wide an AR bandwidth but also has a lower center frequency. The 8 stub/turn case does not have as wide an AR bandwidth as either of the others but offers a small additional amount of size reduction by shifting the AR bandwidth lower in frequency. The 10 stub/turn case is almost identical to the 6 stub/turn case in both gain and axial ratio performance. However the additional complexity of using 10 stubs/turn is not justified if 6 stub/turn will give equal results.

It would appear from the models that 6 stubs/turn is the preferable configuration. It has an AR bandwidth almost as large as that for 4 stubs/turn but also offers a some additional size reduction over 4 stubs/turn. Using 6 stubs/turn requires additional mechanical complexity that may not be justified, depending on the application. Due to the additional complexity of creating a 6 stub/turn antenna, we have concluded that the 4 stub/turn design is preferable. Thus, our hypothesis that using additional stubs/turn would increase the AR bandwidth does not appear to be true.

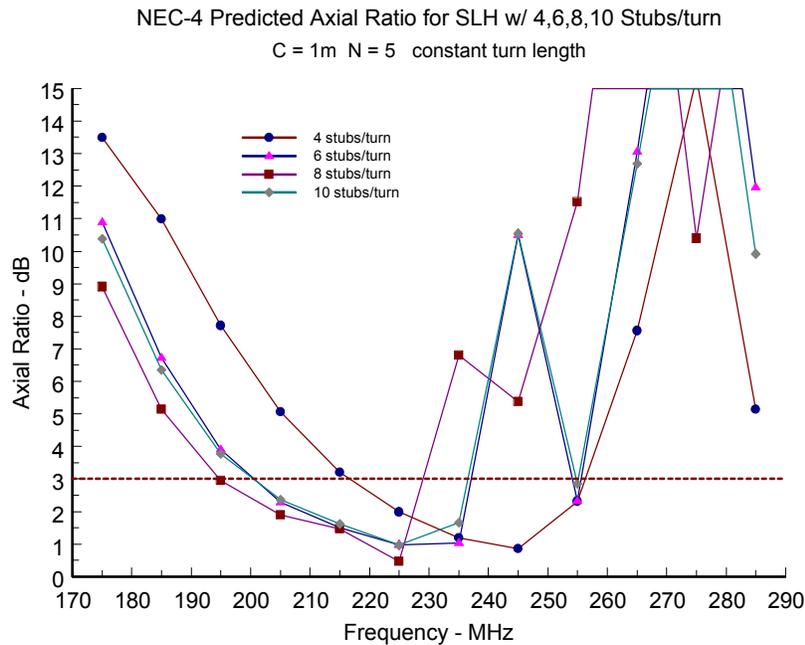


Figure 6.6 NEC predicted axial ratio for 5 turn SLH with 4, 6, 8, and 10 stubs/turn. Path length around turns was held constant at 1.84 m.

Table 6.2 3 dB Axial Ratio Bandwidths from Figure 6.6

# stubs/turn	3 dB AR Frequency Range	Center Frequency	3 dB AR BW	% BW
4	216.6 - 256.1 MHz	236.35 MHz	39.5 MHz	16.7%
6	200.5 - 236.4 MHz	218.45 MHz	36 MHz	16.5%
8	195.2 - 229 MHz	212.10 MHz	33.8 MHz	15.9%
10	200.5 - 236.4 MHz	218.45 MHz	36 MHz	16.5%

6.5 Parametric Studies Summary

Based on the parametric studies presented here we have developed a set of design rules for an 'optimum' Stub Loaded Helix design to maximize gain and axial ratio bandwidth. Although the impact of the variations in most design parameters are not extreme, the results of these parametric studies indicate that there are preferred design parameters that maximize gain and axial ratio performance of an SLH antenna. The relative insensitivity to design parameter variation is an attractive feature of the SLH in that construction accuracy is not critical to the performance of a functioning antenna.

In Section 6.2, we examined the effect of pitch angle. Gain was found to be relatively insensitive to pitch angle but axial ratio performance and bandwidth were. Pitch angles between 7° and 9° produced the largest (3 dB) axial ratio bandwidths with 8° appearing to be optimum.

In Section 6.3, the effects of stub depth were examined. Again, gain did not appear to be particularly sensitive to stub depth, but axial ratio performance was. It was found that stub depths between $0.6667 \cdot R$ and $0.75 \cdot R$ are optimal for maximizing the (3 dB) axial ratio bandwidth of a four stubs-per turn design .

In Section 6.4, the effect of the number of stubs-per-turn was examined, assuming a constant turn length, including stubs. Again, gain was not quite as sensitive to the number of stubs-per-turn used, but axial ratio was. The results of the simulations indicated that a

4 stubs-per-turn configuration offered the widest axial ratio bandwidth. However, it was observed that a 6 stub-per-turn configuration offered an axial ratio bandwidth almost as large but with an advantage of some additional size reduction, i.e. the operating band was moved down in frequency. Thus, there is a tradeoff to be made in the selection of this parameter. The 4 stubs-per-turn lends itself to a simpler construction technique and the largest axial ratio bandwidth. But the 6 stub-per-turn configuration offers slightly more size reduction.