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Description of the Design:

The SWAN-Antenna Design Challenge required a design of an antenna with the following specifications:

1. Dual orthogonal linear polarization reception, using two separate sub-units with relative orientation of 90 degrees.

2. Efficient radiative coupling over the band from 50 MHz to 500 MHz, with return loss of more than 8 dB over at least 80-320 MHz (i.e. S11 < -8 dB).

3. Total projected span of the structure (Width*Breadth) to be within 1 square meter, and an extended conducting reflector below, defining the "ground plane" (for the entire array), is to be an integral part of the design.

Thought process :

We are complete novices at designing an antenna. Initially, we came up with three antenna designs (modifications of a standard bow-tie) :

1. **Wired Bow-tie** : this standard design, being wired couldn't cover a spectrum as large as 450 MHz at a centre frequency of 300MHz.

2. **Fractal bow-tie :** This design, even after having the current distribution property to give a broadband range, couldn't be altered to suit the frequency ranges, and gave low return losses.

3. **Log periodic toothed bow-tie:**
This design, though could fit in the S(1,1) below the required conditions, had problems with its structural arrangement with the central cylindrical hub (CCH), as LP toothed bowties require them to solid having substrates, hence couldn't accommodate the central cylindrical hub in between the two separate polarizations.

Shifting our focus to achieving staggering bandwidth, we then started working on the classic log periodic dipole antenna.

As the challenge requires an antenna capable of resonating at low frequencies we decided to use a log periodic dipole antenna(**LPDA**). After studying the basics of the LPDA, we decided to use trial and error analysis to estimate the boom dimensions and spacing instead of rigorously applying the transmission line theory.

Consequently, modifying the basic antenna, we tried artificially applying inductance caps and impedance resistances to the elements, but again, had to rely on trial and error as we couldn't get our hands on any formulae related to the frequency dependence of the inductance hat and its dimensions or the resistance magnitudes, leading to the failure of proper execution of these features, and ultimately deciding to eliminate them.

Referring to different research publications, we tried varying the parameters so as to suit our needs and moreover, getting an idea on the effect of variation of different parameters on the reflection coefficient. All of our previous efforts are also included in the submission file.

Antenna specifications :

The LPDA consists of a number of half-wave dipole driven elements of gradually increasing length, each consisting of a pair of metal rods. The dipoles are mounted together in a line, connected in parallel to the feedline with alternating phase. Electrically, it simulates a series of two or three-element Yagi antennas connected together, each tuned to a different frequency.

In order to achieve balanced feed and desirable interference, we used a double boom structure with each boom having alternately placed half dipoles. Each polarization utilizes two such antennas for symmetric reception of radio waves. This is done as any offset produced is comparable to the wavelength of incoming waves.

We have created a 16-element log-periodic dipole array based on this [1] paper. And after going through many iterations of log periodic antennas (which are all included in the given zip file), we finally decided on the structure described below.

Element Number	Length of Element (cm)	Distance from center (excluding central hub radius of 5cm) (cm)	Radius of Element (mm)
1	7.8	-	4
2	9.12	1.13	4
3	10.54	2.48	4
4	12.34	4.03	4
5	14.22	5.89	4.25
6	16.6	8.03	4.25
7	19.18	10.6	6.4
8	22.5	13.57	6.4

9	26.14	17.02	6.4
10	30.3	21	6.4
11	35.26	25.66	6.4
12	41.0	31.13	6.4
13	47.64	37.41	6.4
14	61.175	44.79	6.4
15	80.67	53.21	6.4
16	93.675	63.03	6.4

Note that the lengths of elements 14, 15, and 16 are not the same as in [1]; on experimentation we found that the value of S11 improved after multiplying the original by 1.25.

The boom is 64 cm long, and 2x2 cm in width and height. The connector stub at the end of the double-boom structure is 2x2x4 cm, 4 cm being the separation of the booms.

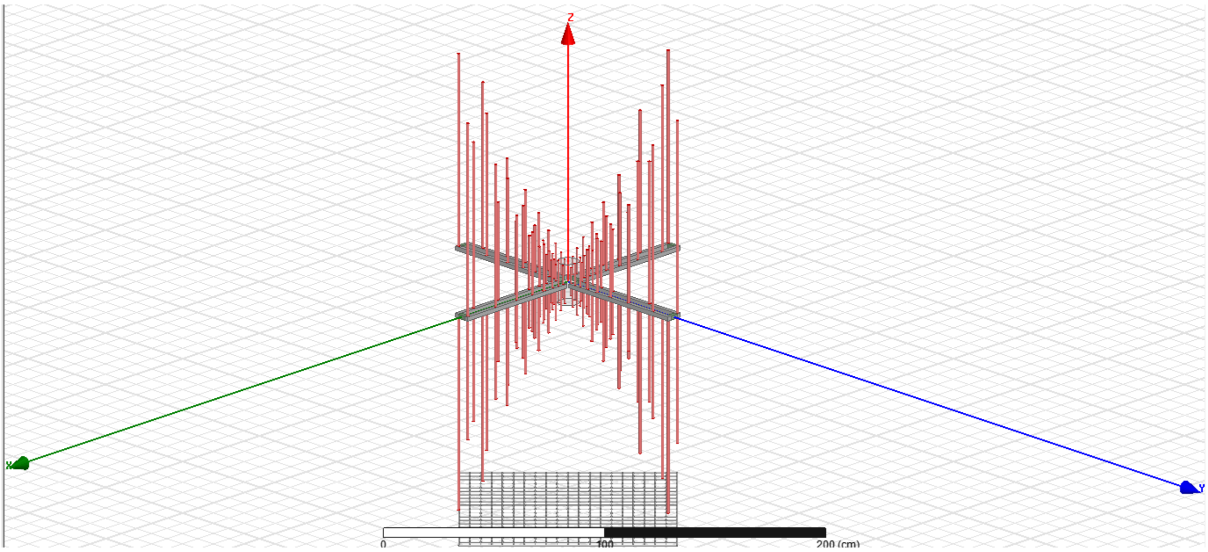
Both the booms and the teeth are made of *aluminum*. The booms are solid. The central cylindrical hub is 5cm in radius, made of PVC, for housing the LNA. The ground mesh is made of 3.155mm radius *stainless steel* wires 5cm apart.

Structural details:

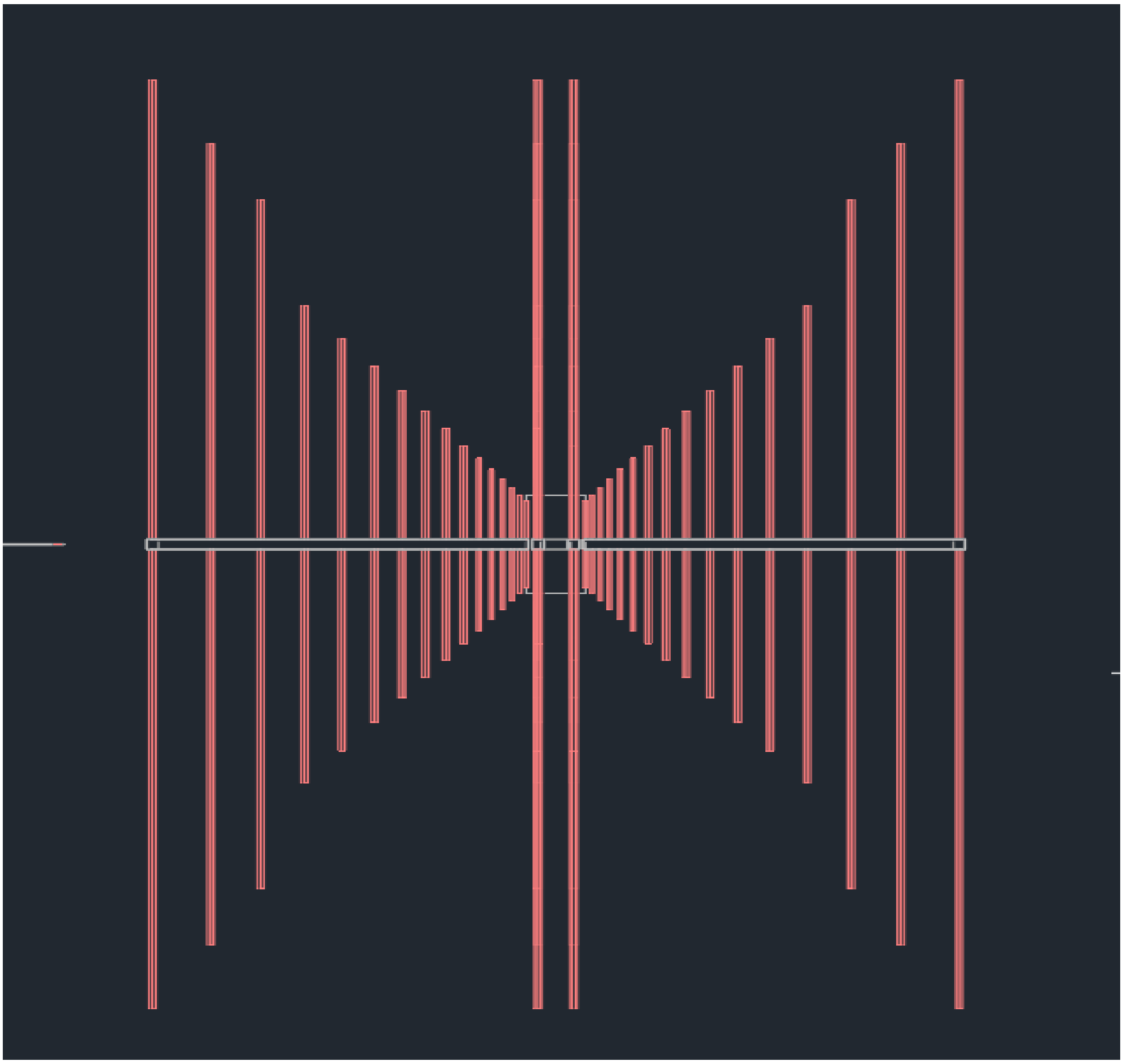
A clear (scaled) drawing of the mechanical structure, including conducting and non-conducting parts clearly identified, with mention of dimensions for each of the parts/components, in appropriate units.

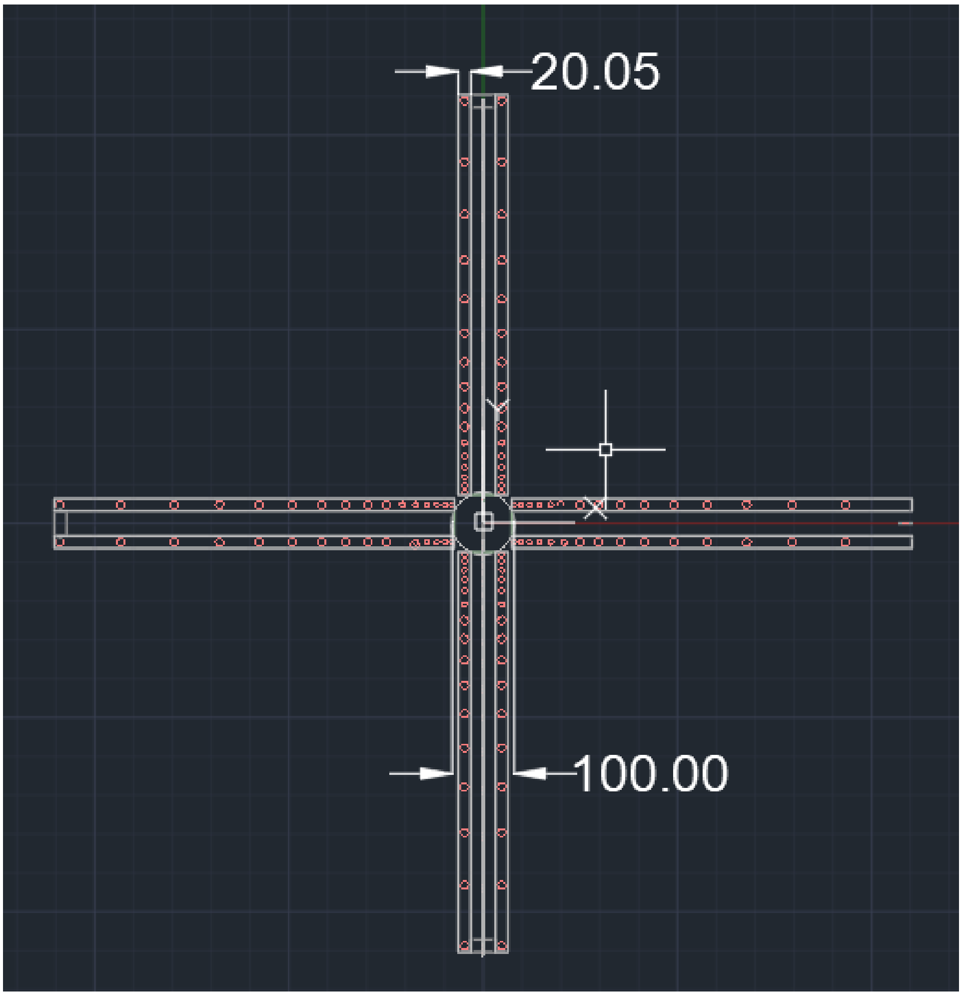
Pictures of the design in X-Y, Y-Z and X-Z plane, Z being the vertical direction.

View of the Antenna in HFSS:



CAD (w/applicable dimensions):



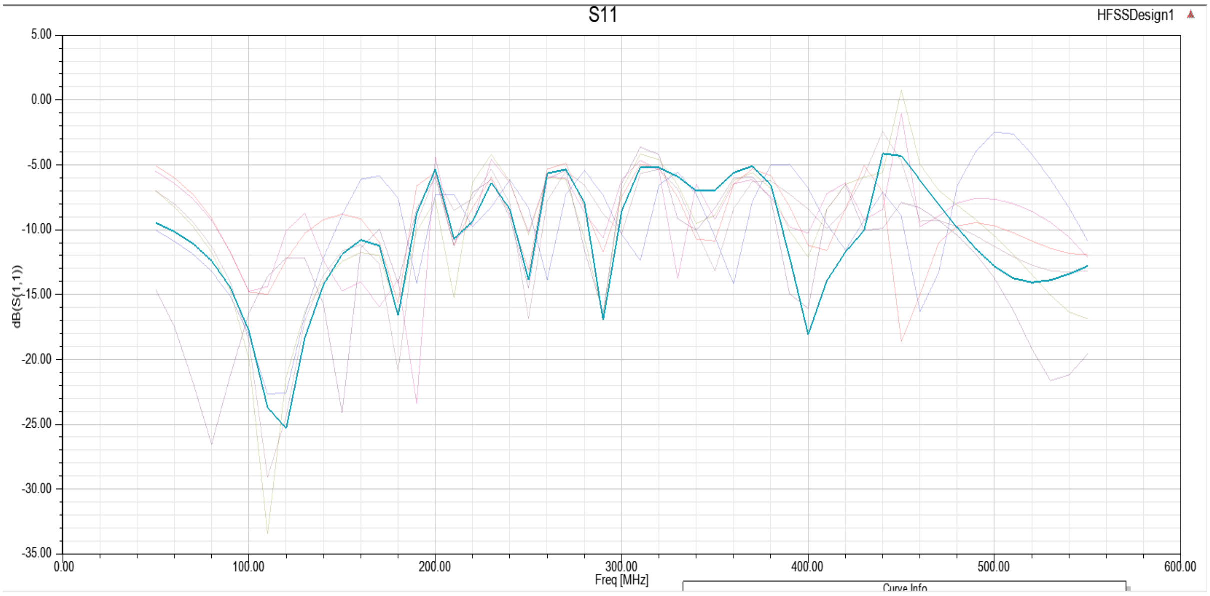


Performance description:

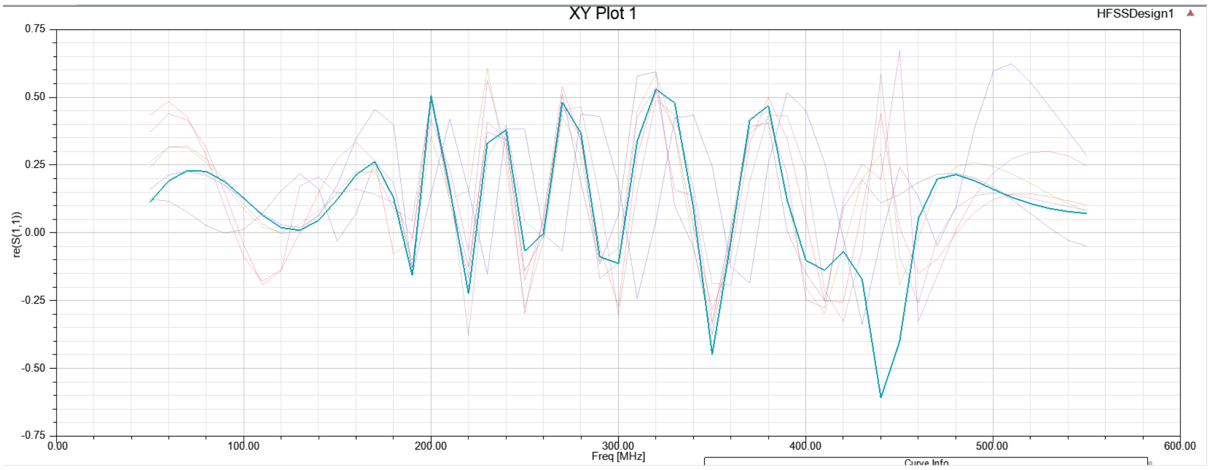
Plots showing a) Return loss/S11 (both real and imaginary parts)
b) Impedance (both real and imaginary parts),
c) VSWR
d) Radiation efficiency
all as functions of frequency (50-500 MHz)

Per Element Graphs:

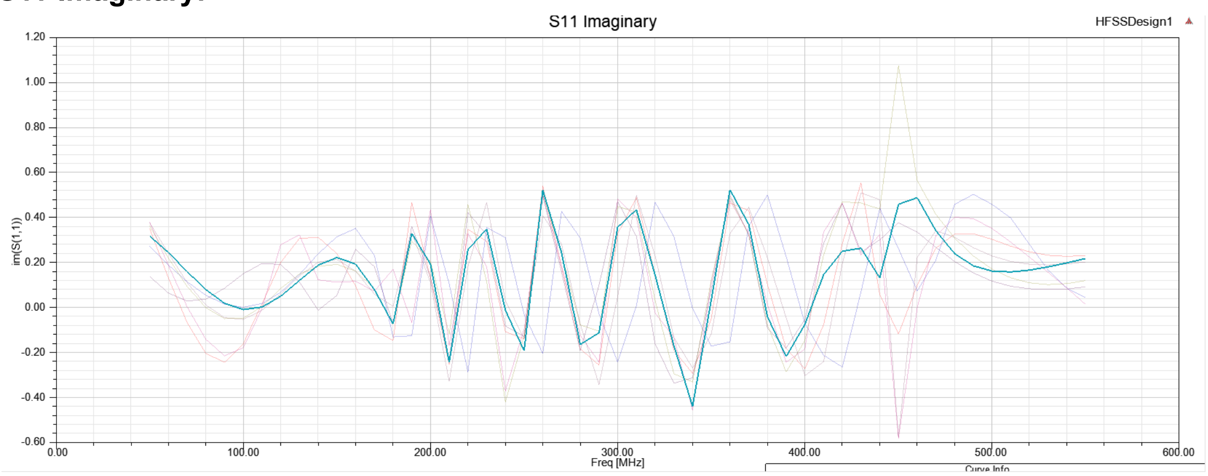
1. **S11**:



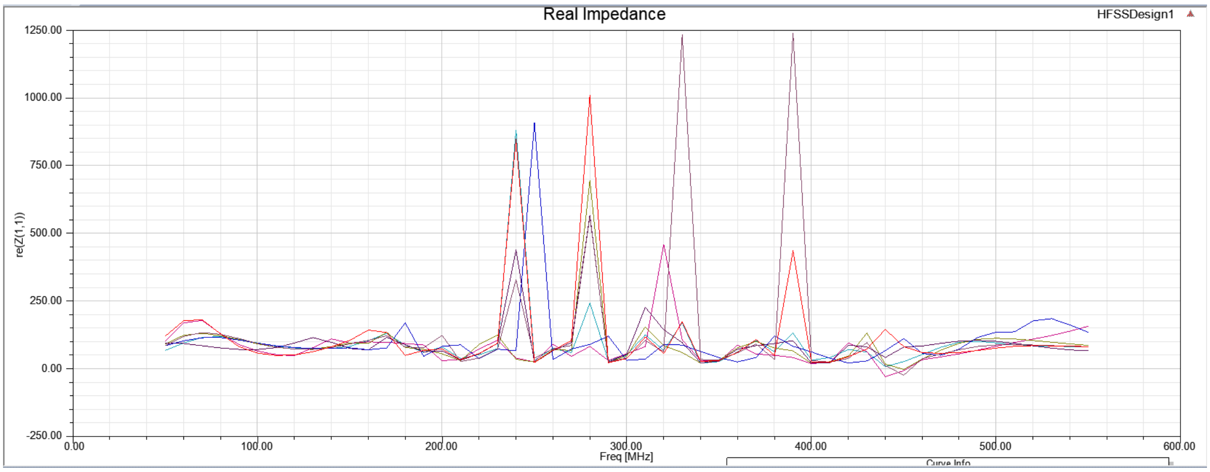
2. **S11-Real:**



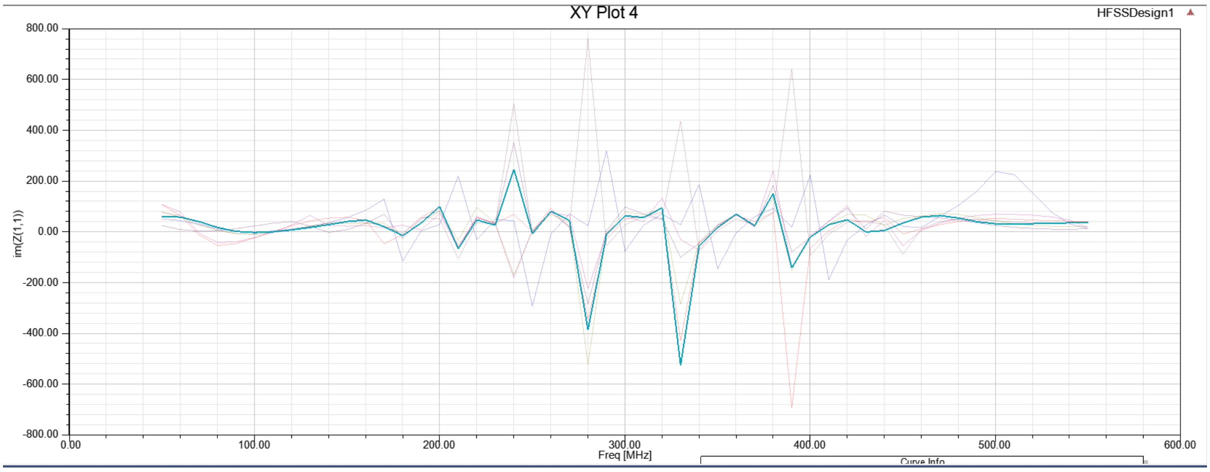
3. **S11-Imaginary:**



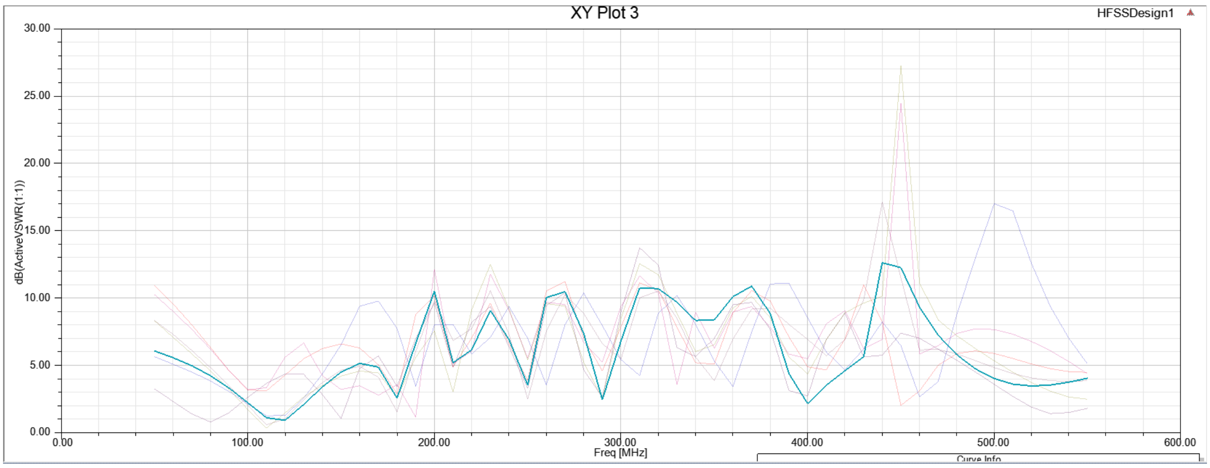
4. Impedance-Real:



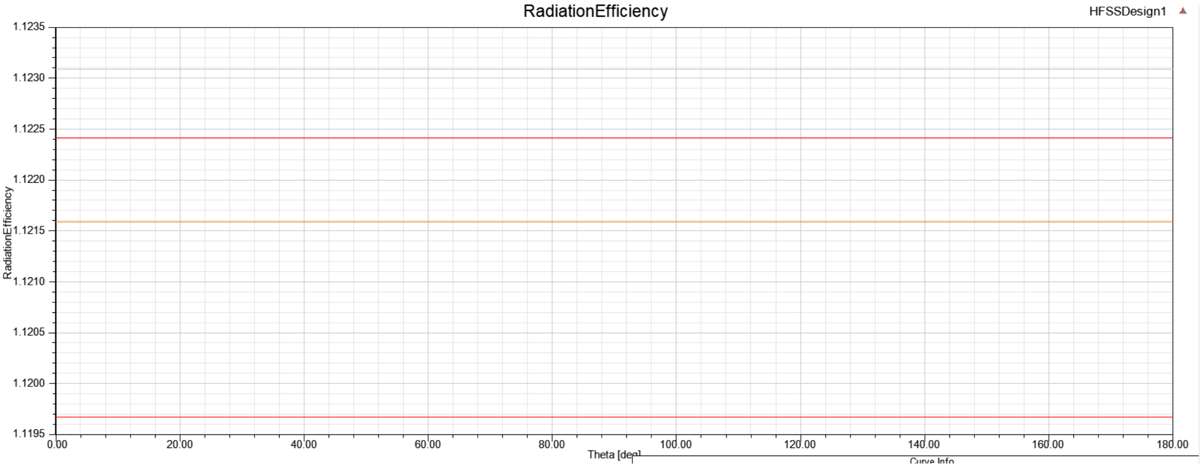
5. Impedance-Imaginary:



6. VSWR:

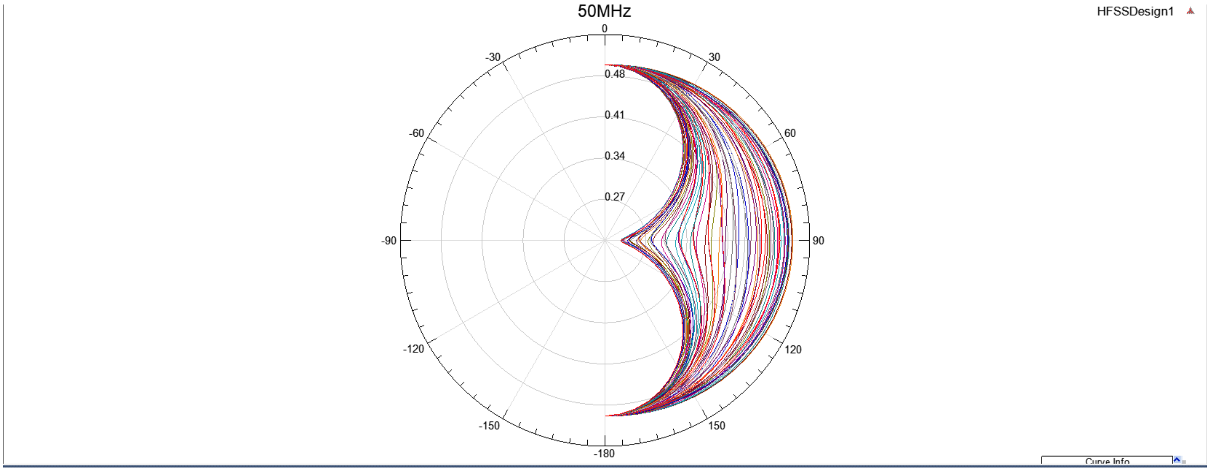


7. Radiation Efficiency

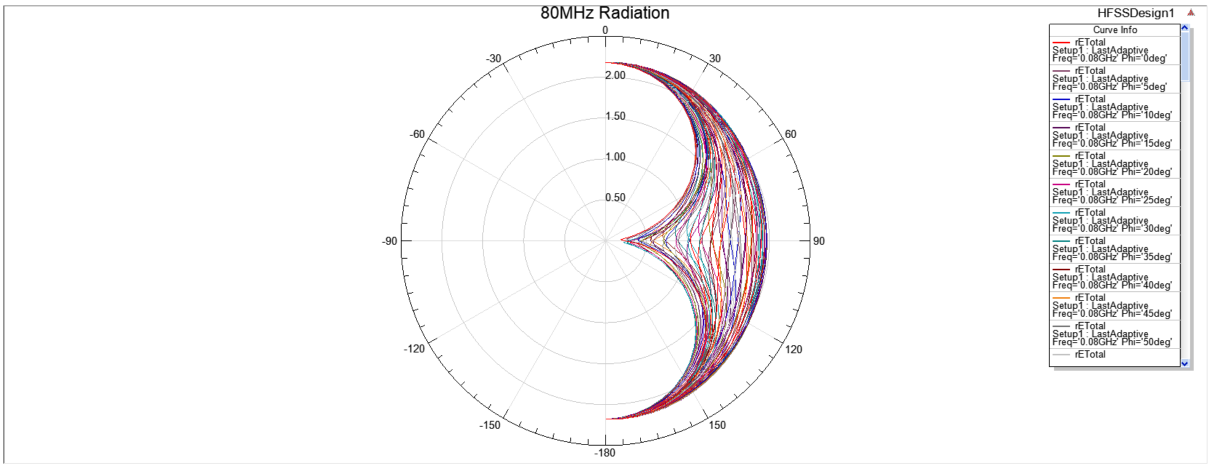


Far-field Radiation Pattern:

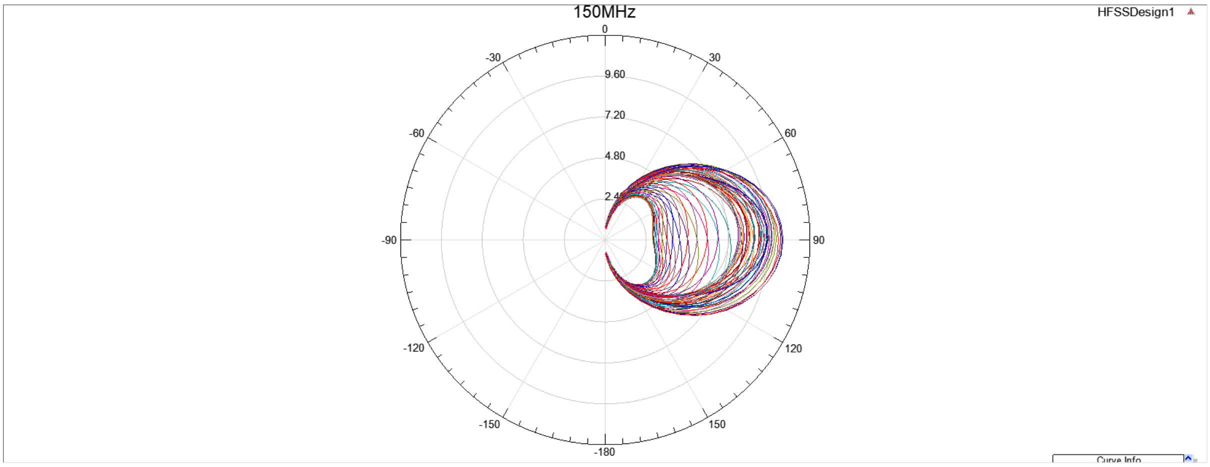
1. 50MHz:



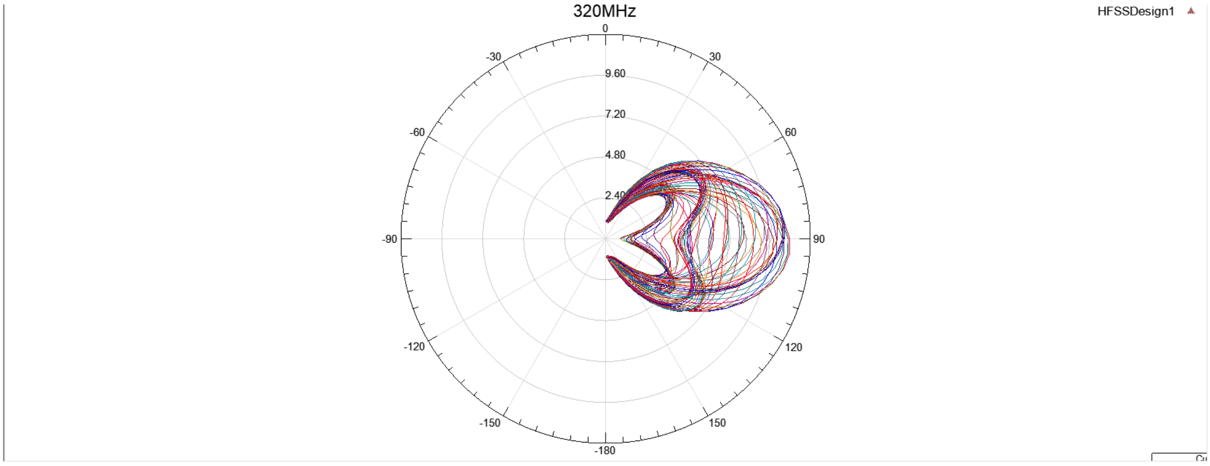
2. 80MHz:



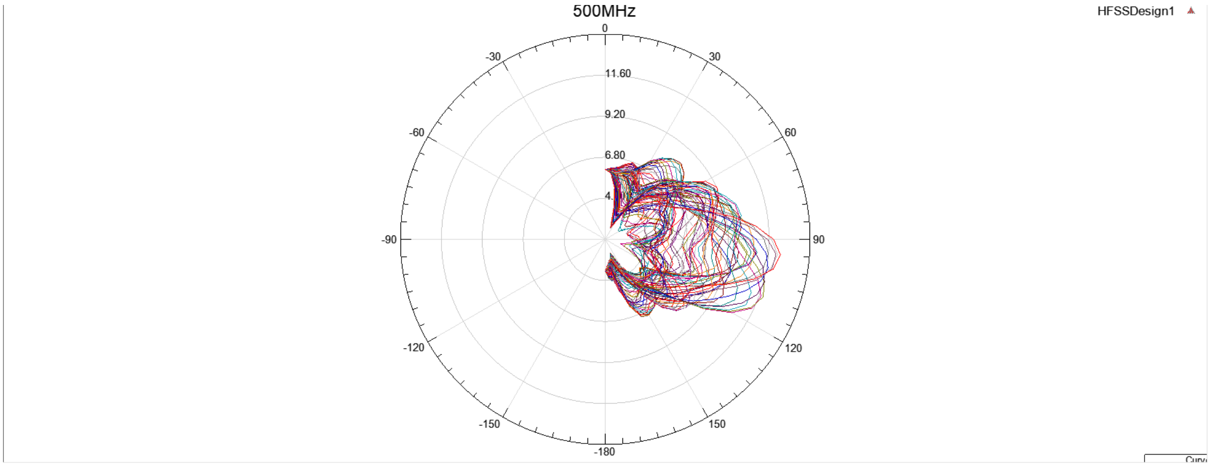
3. 150MHz:



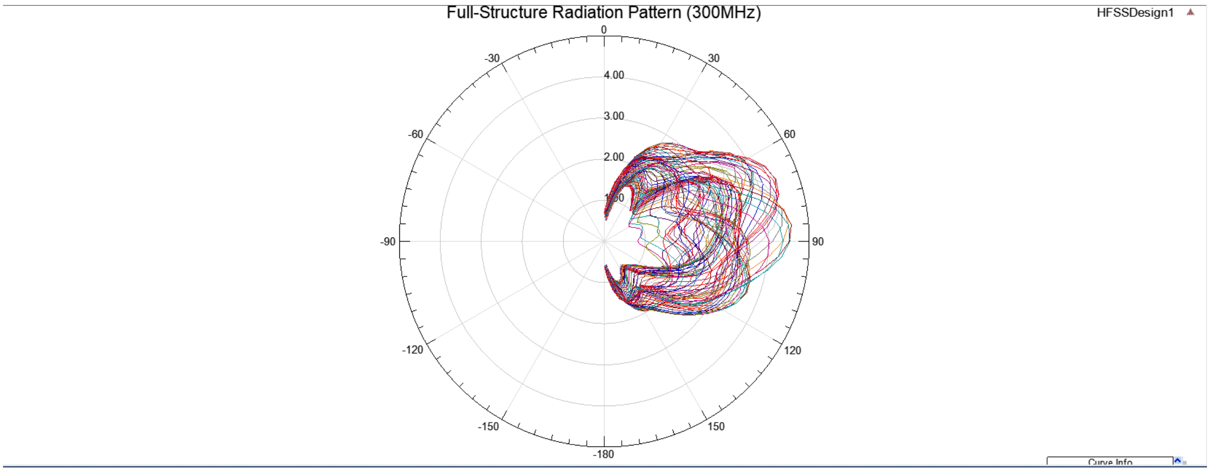
4. 320MHz:



5.500MHz



6. Full Structure Radiation Pattern (300MHz)



Assessment of the sensitivity of the above performance:

We found out that three parameters affect S11 the most - the distance between the booms, the position of the middle tooth on the boom, and the separation between the 8th, 9th, 10th teeth on each boom. Special care will have to be taken, as these vary to the 5th decimal. We believe this is a non-issue as this can be achieved on modern CNC lathes, which have an accuracy of 2-20 microns.

Clear statement(s) highlighting assumptions made, including the type of conducting/non-conducting material to be used and their assumed properties, etc., in your design/simulation.

General assumptions:

For the **S1,1** graphs, we simulated each arm one by one to give an answer for each unit individually. We assumed that as the inputs are orthogonal, both elements of polarizations will not interfere with each other. The return loss characteristics are not as good for the entire structure; however we assume that this is due to HFSS' internal characteristics, and the hardware limitations of our personal computers, which do not have HPC facilities.

The input impedance was set at 75 Ohm (no reactive impedance) and the results were obtained. It was seen that the performance was marginally worse at 50 Ohm. The assumption is that practically, the input impedance will account for the impedance of the solid booms themselves, so we anticipate 80 Ohm.

Assumed material Parameters:

We have used aluminium as the main conducting material. The following table enumerates material properties as used in the simulation.

Parameters for Aluminium	Value

Relative Permeability	1.000021
Relative Permittivity	1
Bulk Conductivity	38E6 1/ohm-meter
Mass Density	2689 kg/m^3

PVC is used as the non conducting material in the dummy cylindrical hub. The assumed parameters are given in this table.

Parameters for PVC	**Value**
Relative Permeability	1
Relative Permittivity	2.7
Bulk Conductivity	0 Siemens/meter
Mass Density	1467 kg/m^3 but 0 in HFSS

Stainless steel is used for the reflective, conducting ground plane, its parameters are as follows.

Parameters for Stainless steel	**Value**
Relative Permeability	1
Relative Permittivity	3.1
Bulk Conductivity	11E5 Siemens/meter
Mass Density	8055 kg/m^3

Software used:

Ansys Electromagnetic Desktop (HFSS) 17.0.1

References:

1. “Broadband Logarithmically periodic Antenna Structures” by R. H. DuHammel and D. E. Isabelle
2. “Logarithmically Periodic Antenna Arrays” by R. H. DuHammel and D. G. Berry
3. “Circularly Polarized Log-Periodic Dipole Antenna for EMI Measurements” by Ryoji Wakabayashi, Kazuo Shimada, et.al
4. “A Novel Log-Periodic Dipole Antenna with Distributed Inductive Load” by BingGong, Ling Hua Su, et al.
5. C Balanis, Antenna Theory