Design and Simulation of a Multi-element Broadband Feed for Parabolic Dishes

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October 2013

By

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ABSTRACT:

In this report, we describe the design and electromagnetic simulations of a multi-element dipole array. In the proposed design, it is planned to place several co-located Folded Dipole arrays operating at different frequencies above a reflector with each array connected to separate set of LNAs in order to ensure good matching for each array with return loss of < -10 dB (SWR < 2). Each array consists of a ‘Boxing Ring’ pattern with 4 dipoles in a square pattern above a plain reflector. This design was tentatively nicknamed as ‘Russian Doll’ array by one of us (Swarup 2006). For the work done so far, we have considered only two independent boxing ring arrays, one at 150 +/- 30 MHz and second at 210 MHz +/- 30 MHz, the latter is placed inside the former. The design has been optimized using the EM wave solver software, ‘IE3D’. All the dipoles were excited simultaneously. For elements of the boxing rings, we have considered the dimensions of the Fat Folded Dipole feed at 150 MHz of the GMRT. Firstly, we optimized the spacing and heights above an infinite reflector of a pair of Fat Dipoles at 150 MHz, in order to obtain nearly the same E and H patterns at 150 MHz in order to achieve better polarization capability. We then determined E and H patterns at 130 MHz and 170 MHz and found that these were different but not by a large value. For the 210 MHz feed all the dimensions of the dipoles and their spacings were scaled by the ratio 150/210. Our final results for the 2 independent boxing rings, placed one inside other,

show return loss was < -10db (SWR < 2) from about 145MHz -260 MHz. Further optimization may give low return loss from about 130 MHz to 245 MHz, preferred range for observations with the GMRT.

(It is proposed to carry out further optimization by another batch of three 4th year B.E. students of MIT, Pune, by scaling all the dimensions of the above dual feed in order to simulate, design and fabricate a feed for the frequency range of ~ 550-850MHz, and also co-locating a third boxing ring operating in the frequency range of ~ 200- 250 MHz, including their connection to separate low noise amplifiers).

1. INTRODUCTION

Primary antenna feeds for parabolic dishes require: (a) appropriate illumination to maximize the gain (efficiency) of the antenna; (b) E and H pattern nearly same for being able to make accurate polarization observations; (c) low return loss (Standing wave ratio < ~ 2) to ensure good matching with the Low Noise Amplifier (LNA) and (d) to obtain the above parameters over a large bandwidth. At microwaves, waveguide feeds have been developed to provide a large bandwidth but there are only a few designs available at m and dcm wavelengths. Particularly, the "Eleven Feed" by Kildal and colleagues [2-6] (that provides a large bandwidth but the return loss for that feed is poor over a large frequency range. Recently the GMRT group has developed two separate designs, (a) one covering ~ 130 MHz to 250MHz using 2 rings rather one ring in the Kildal's design (1985) (the original Kildal's design with one ring was used in the earlier 327 MHz feed at the GMRT) and (b) another from 260 MHz to ~ 500 MHz using a conical Feed but its polarization performance is not optimum (ITR by Hanumanth Rao and colleagues, in preparation).

This Report is based on a B.E. Project Report by Kaneskar et al. of MIT, Pune [Reference 8].

In Section 2 of the present report, a brief description is given of the GMRT and of the existing feeds placed near the focus of the 45m parabolic dishes of the GMRT. We then describe the design of the existing 150 MHz feed of the GMRT that consists of 4 Fat Folded Dipoles arranged in a Boxing Ring pattern placed above a reflector of about one wavelength in size.

In Section 3, we describe simulations for different geometric configurations of the 150 MHz fat-Folded Dipole feed of the GMRT using the 'IE3D' software. We have determined E and H patterns of the 150 MHz pair of folded dipoles over a large frequency range, particularly for different values of the spacing of the dipole pair (D) and their height (H) above a plane reflector. The optimum values were then selected for the design of two co-located Boxing Rings, operating in the frequency range of 130-170 MHz and 180-240 MHz, as described in Section 4. Results and discussions are given in Section 5, Conclusions in Section 6, References in Section 7, and Acknowledgement in Section 8.

2. GMRT and the 150 MHz Feed

2.1GMRT:

The Giant Metrewave Radio Telescope (GMRT) consists of an array of 30 antennas. Each of the 30 antennas has a diameter of 45m, and operate in different frequency bands from 130 MHz to 1450 MHz. The antennas have been constructed using a novel technique also known as SMART (stretched mesh attached to rope trusses). The reflecting surface consists of panels of wire mesh which is attached to rope trusses, and by appropriate tensioning of the wires used for attachment the desired parabolic shape is achieved. This design reduces the wind load as well as the total weight of the antenna. It also makes the entire array very economical [1]. It may be noted that the GMRT is the largest radio telescope in the world operating at dcm and metre wavelengths. Since such a facility does not exist elsewhere, GMRT is being used for astronomical observations by hundreds of astronomers and students from 30 countries, including those from India.

Near the focus of each of the 30 nos. of parabolic dishes of 45m diameter of the GMRT, are placed primary antenna feeds operating in four different frequency bands on a rotating turret [6], The antenna feed for operation in the frequency band of (1) 1000-1450 MHz is a waveguide feed, (2) the feed for the bands of 610 MHz and 233 MHz is a dual coaxial feed, (3) the feed for the 327 MHz feed is "Kildal feed [5] and the feed for the 130 MHz band uses a 'Boxing Ring' consisting of 4 fat dipoles as described in more detail in this report. The presently installed feeds operate over a relatively narrow frequency band. For enhancing the performance of the GMRT for astronomical investigations, NCRA scientists and engineers has now been decided to achieve operational capability over almost all of the frequency band from ~ 130 MHz to 1450 MHz.

The purpose of the present work is to design an antenna feed for operation from about 130 MHz to 250 MHz with SWR < 2 and optimum polarization capability.

2.2 The 150 MHz feed of the GMRT

The 150 MHz feed of the GMRT consists of four 'fat' dipoles arranged in a 'boxing ring' configuration that is placed above a hexagonal plane metallic reflector of about 1.2 λ on each side [6, 7]. It is known that an array of two dipoles with a spacing of λ/2 gives an H plane pattern, which is similar to the E-plane pattern. Further, this pair placed above a reflector gives the required illumination pattern for illuminating a parabolic dish, minimizing spill over of the radiation pattern of the primary feed yet ensuring an optimum efficiency of the parabolic dish [6]. A single pair is sensitive to only one linear polarization, in the same direction as that of the dipoles. For obtaining sensitivity to both of the orthogonal polarizations, another pair of two more dipoles are placed in a perpendicular direction, in a boxing ring pattern. It may be noted that a simpler configuration of two cross dipoles is also sensitive to two orthogonal polarizations but such a configuration does not give appropriate illumination pattern, as required for optimum illumination for a parabolic dish, unless a ring is placed above the pair as done by Kildal and Skyttemyr (5); that design has been used for the 327 MHz feed of the GMRT but has a relatively narrow bandwidth.

A thin dipole of diameter < about 0.0001 λ is resonant over a narrow bandwidth; the imaginary component of its impedance is close to zero only over a relatively narrow frequency range. In order to obtain good matching of the Feed to the LNA, it is generally desired to achieve return loss of < -10 dB (Standing Wave Ratio, SWR < 2). A 'fat dipole' with a diameter d of > 0.005 λ minimizes variation of the imaginary component. .As is known that an antenna with an **l/d ~ 5000** has an acceptable bandwidth of about **3%**, while an antenna of the same length but with an **l/d ~ 260** has a bandwidth of about **30%**. Further, the 'fat dipoles' used for the GMRT were of 'folded' type that increases the input resistance by about 4 times. A 'Balun' is used for matching to 50 ohm input impedance of the low noise amplifiers (6, 7).

To summarize, in order to obtain optimum illumination pattern over a relatively wider bandwidth, it was decided to use Fat Dipoles for the 150 MHz feed of the GMRT. These four Fat Diploes were placed in a square 'boxing ring' configuration placed ~ λ/4 above a metallic reflector. Each pair of the boxing ring is separated by ~ λ/2 spacing. The present GMRT feed operating near 150 MHz has poor cross-polarization capability, as compared to that at other frequencies. The cross-polar peak for 150 MHz is only -17 dB and the on-axis cross polarization is also at about the same level [7].

The overall dimensions of the feed are:

- Length of Folded Dipole : = 780 mm
- Height above the reflector : = 600 mm
- Reflector Length (diagonal of octagon) : = 2400 mm
- l/d = 6.48

One-pair of outputs from the dipoles which are parallel to each other are connected to a power-combiner, whose output goes to one port of the quadrature hybrid (which adds two linear polarized signals to yield one circular polarized signal). Similarly the orthogonal pair of dipole is connected to the other port of the hybrid to yield orthogonal polarized signal. Both the power combiners and the quadrature hybrids are mounted inside one of the front-end chassis, placed behind the feed.

The Fat Folded dipole in the feed installed at GMRT has the following dimensions:

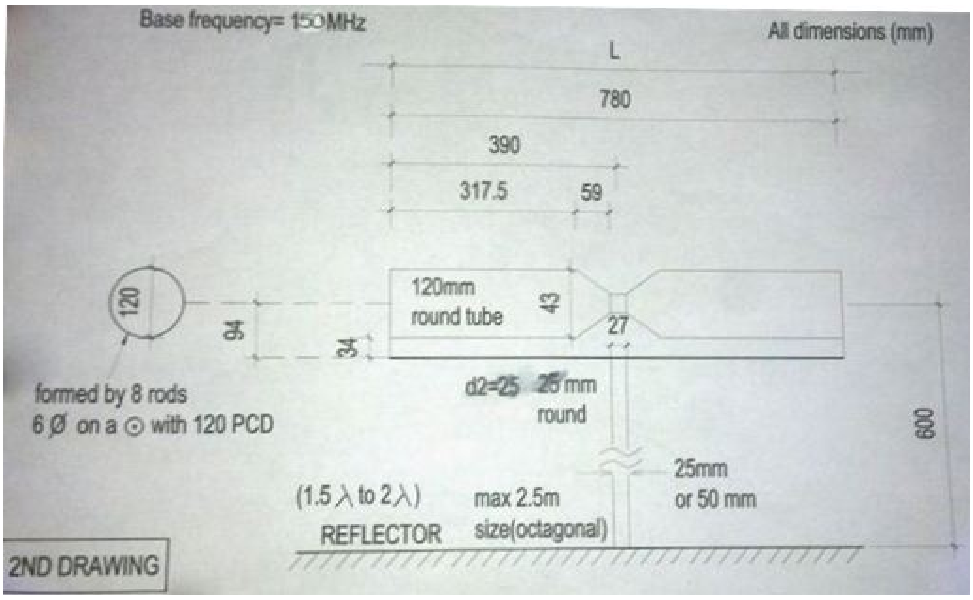

FIG 3.1: Schematic dimensions of the Fat Folded Dipole

A Fat Folded dipole antenna of the above dimensions resonates at 150MHz.

The present design is based on the same dimensions of the Fat Folded dipole antenna.

3. Simulations of Different Geometric Configurations of the 150 MHz Fat-Folded Dipole Feed of the GMRT.

The aim of our project is to design a novel primary antenna feed configuration to be placed near the focus of the 45 m dishes of the GMRT, that will give symmetric polarization characteristics and low Standing wave ratio of < 2:1 (low return loss of <-10dB) over a wide bandwidth. For this purpose, we have made number of simulations, in a step by step by step basis, as described in this section. In this Report we present only a summary (for details see the B. Tech thesis [Reference 8]..

a. Fat Dipole Configurations

In this section we present different geometric configurations of the Fat-Folded Dipole for comparison purpose. All the following configurations were made at a height of 600 mm (0.3λ) and with a space of 1000 mm (0.5λ).

Several different types of Fat dipoles were considered in iteration and their characteristics determined using EM wave solver software, 'IE3D'

1. Single Fat Dipole
2. Pair of Fat Dipole
3. Fat folded Dipole
4. Pair of Fat folded Dipole
5. Fat folded Dipole with support
6. Pair of Fat folded Dipole with support
7. Inverted Fat folded Dipole
8. Pair of inverted Fat folded Dipole

b. Comparison of all iterations

1. Single Fat Dipole and Fat Folded Dipole

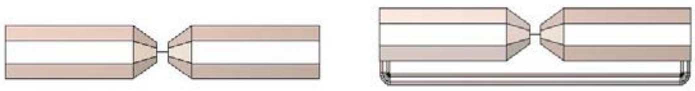

FIG 3.1: Single fat dipole and fat folded dipole

The main difference occurs in the impedance characteristics and S parameter S (1,1). The Characteristic Impedance of Fat Folded Dipole is greater than that of the Single fat dipole. Fat Dipole gives better S parameter Characteristics than Fat Folded Dipole.

We find that the impedance of the Fat dipole has a higher value than that of the Fat Folded dipole. Also, the S parameter curve is sharper in the case of Fat Dipole; it is wider for the Fat Folded Dipole.

2. Compare Fat Folded Dipole and Pair of fat folded Dipole

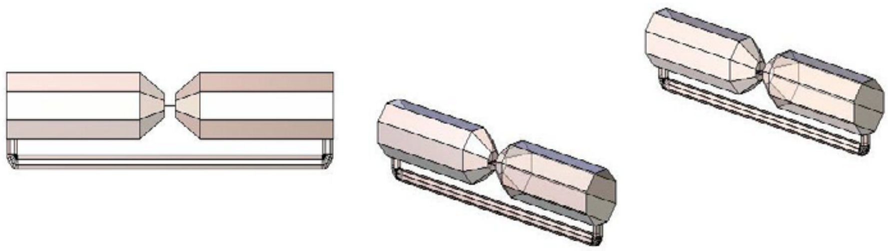

FIG 3.2: Fat Folded Dipole and Pair of fat folded Dipole

The Pair of Fat Folded Dipole gives better Radiation pattern than a single dipole. The E and H patterns are precisely same in the lower frequencies of 110MHz to 140MHz for a Pair of Fat Folded Dipole.

Summary:

By implementing a pair of Fat Folded Dipoles, we get better radiation patterns. Though the E- Plane (Phi=0 deg) does not change substantially, the H-Plane (Phi=90deg) becomes sharper and hence the two planes have a very similar radiation characteristics. (i.e. Same radiation in the E and H planes.)

3. **Compare Pair of Fat Dipole and Pair of Fat Folded Dipole**

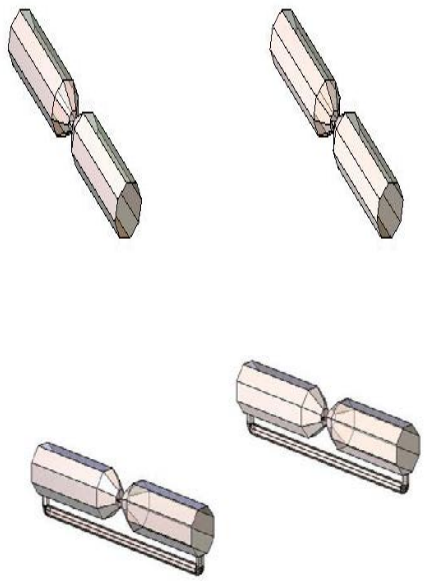

FIG 3.3: Fat Dipole and Pair of Fat Folded Dipole

We find that the Fat Folded Dipole has higher impedance than that that of the Fat Dipole; we also find better E and H plane matching for the Fat Folded Dipole compared to the Fat Dipole. Higher values of the Impedance of the Fat Folded Dipole is not significant as we can use appropriate impedance matching techniques.

4. **Compare Fat folded Dipole and Fat Folded Dipole with support**

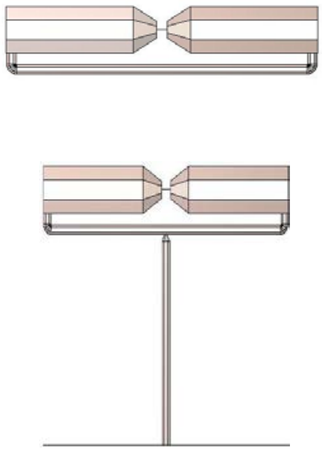

FIG 3.4: Fat folded Dipole and Fat Folded Dipole with support

Since the support is Perpendicular to the plane of polarization, it is not found to have any effect on the Radiation pattern of the Dipole. Also, there is no change in the impedance characteristic plots.

5. **Inverted Pair of Fat Folded Dipole**

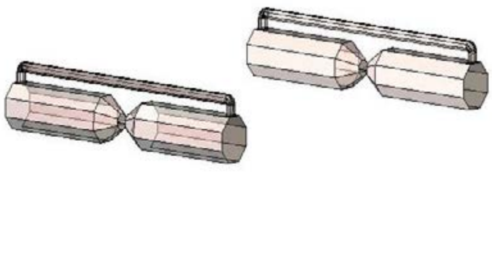

FIG 3.5: Inverted Pair of Fat Folded Dipole

The results are comparatively same as that of Fat folded dipole pair. Since it is easy to connect the Coaxial cable to the feed in Inverted form, this geometry has been considered.

6. **Compare Fat Folded Dipole Pair with and without Support**

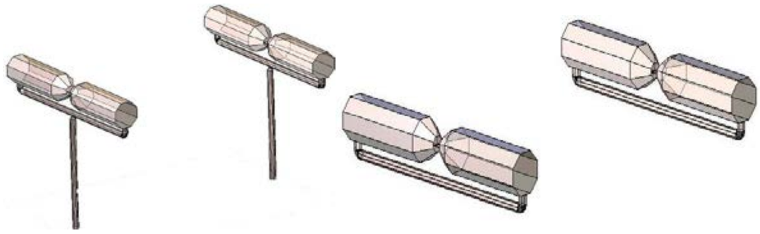

FIG 3.6: Fat Folded Dipole Pair with and without Support

Since the support does not make any difference in the results, the pairs give same results for Impedance and Radiation Patterns. Reason as stated above, the support being perpendicular to the plane of polarization, does not affect the Impedance and the Radiation characteristics.

c. <u>Optimization of Pair of Fat-Folded Dipole</u>

Initial aim of our project was to design an array of Fat Folded Dipole working in the frequency range of 130 MHz- 170MHz. Work was started with the FFD at 145MHz using IE3D Software from Zealand. Geometric modeling of the FFD was done on paper and the same was designed using the software. Initial design comprised of FFD with a support above an infinite reflector (Ground). The resonator was designed to resonate at 145MHz. Similarly a pair of FFD was designed. Basically the variable parameters for the design were S or D and H. **S or D** :- Spacing between the FFD pair . **H** :- Height of FFD pair above ground.

Length ‘L’ of the dipole was adjusted to ‘**L res**’ so that input impedance Zin is purely real at resonant frequency i.e. the imaginary part of impedance at 145MHz is zero. This was done by using the Optimization tool in IE3D. In order to obtain close matching of the E- and H. Radiation Patterns at the desired frequency, different combinations of heights and spacing were considered in the simulations (see Table 4.1 in the next sub-section).

The Dipole feed being optimized is to be used to gather information about the parameters of incoming radiation from distant celestial radio sources located far away in the Universe. It is desirable to obtain close matching of the E and H patterns for being measure values of the polarization of incoming waves that has rather small values at metre wavelengths, and hence a combination of the spacing H between a pair of dipoles and their height D above the reflector and was selected which had a close matching of the E-plane and H-plane patterns.

An internal report of GMRT by Dr. Hanumantha Rao was referred and the results were compared. So the Fat Folded Dipole at 150MHz was simulated for different combinations of height and spacing as discussed below.

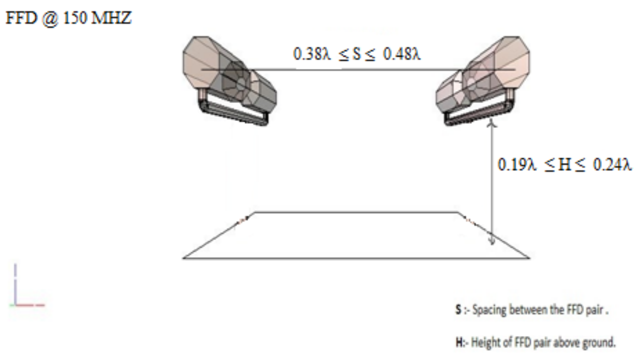

FIG 3.7: Variations in the Height and Spacing of FFD @ 150MHz

In the above configuration, S was varied from 0.38λ to 0.48λ while H was varied from 0.19λ to 0.24λ, i.e.

$0.38\lambda \leq S \leq 0.48\lambda$ (total of 10 values) and
$0.19\lambda \leq H \leq 0.24\lambda$ (total of 6 values).

4. Optimization of the Fat Folded Dipole Configuration (Spacing D & Height H Above the Reflector) and Colocation of Two Boxing Rings at 150 MHz and 210 MHz: ("Russian Doll" Configuration")

Amongst all the geometries discussed above we decided to optimize 'Fat-Folded Dipole'. The combinations used initially were 0.50λ D and 0.30λ H. This combination was expected to provide good Radiation Pattern characteristics along the required bandwidth of 130MHz to 170MHz. Good Radiation Pattern is the one in which the 'Directivity (dBi) vs Elevation angle (degrees)' graph shows less difference for E-plane (phi=0˚) and H-plane (phi=90˚) patterns. But the above values of D and H showed wide variation between the two patterns. We then varied the above values.

NOTE: The following results are to be read as follows:

i. The GREEN colored trace represents PHI=0degrees.
ii. The RED colored trace represents PHI=90degrees.

iii. In the radiation pattern curves, the X axis represents Elevation angle and Y axis represents Directivity(dBi).

iv. In the Return Loss curve, X axis represents Frequency(GHz) and Y axis represents S11(Return Loss)

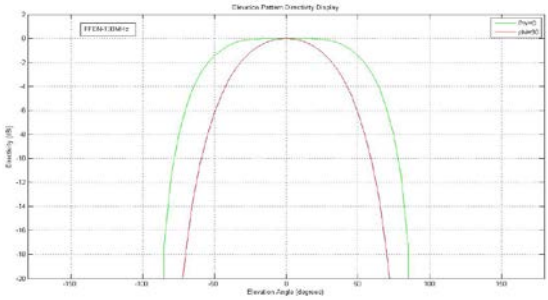

FIG 4.1: Radiation pattern @ 130 MHz for FFDN pair at 0.50λ D and 0.30λ H

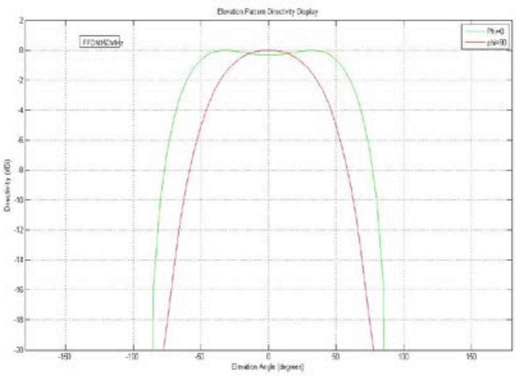

FIG 4.2: Radiation pattern @ 150 MHz for FFDN pair at 0.50λ D and 0.30λ

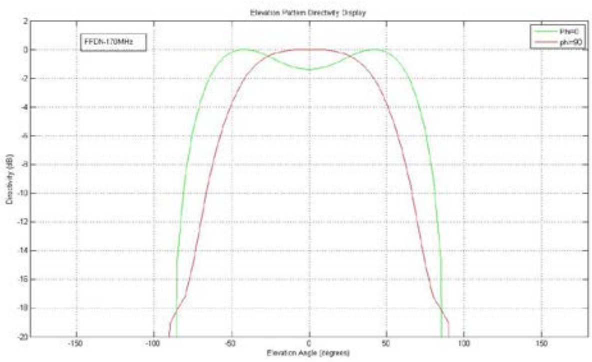

FIG 4.3: Radiation pattern @ 170 MHz for FFDN pair at 0.50λ D and 0.30λ H

To solve to obtain close matching of the E and H patterns, we tried different combinations of heights and distance in order to get acceptable Radiation Patterns. Therefore, we varied the distance between the pairs from 0.43λ to 0.48λ and height was varied from 0.20λ to 0.23λ. Thus the Radiation Patterns improved significantly.

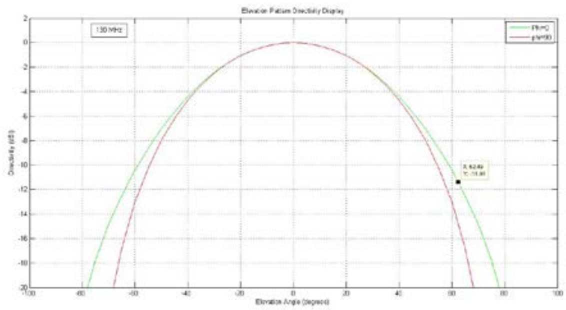

FIG 4.4: Radiation pattern @ 130 MHz for FFDN pair at 0.43λ D and 0.20λ H

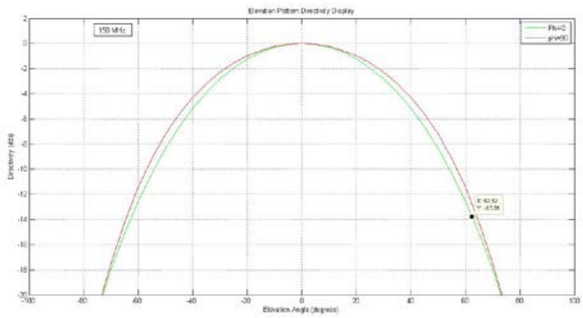

FIG 4.5: Radiation pattern @ 150 MHz for FFDN pair at 0.43λ D and 0.20λ H

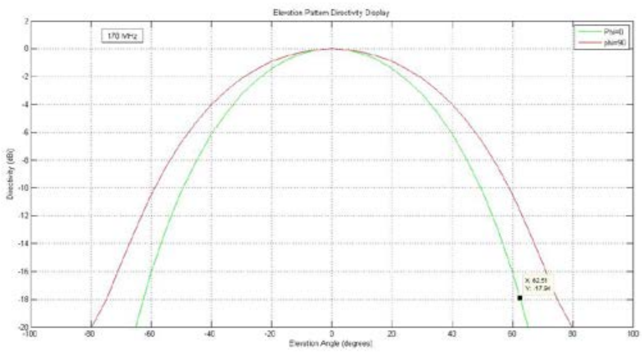

FIG 4.6: Radiation pattern @ 170 MHz for FFDN pair at 0.43λ D and 0.20λ H

From all the combinations we found out that as we decreased the distance between the dipole pairs the results started getting better. Hence, further simulations were done by reducing the spacing between the dipole pair. Spacing between the dipole pair was reduced to 0.38λ.

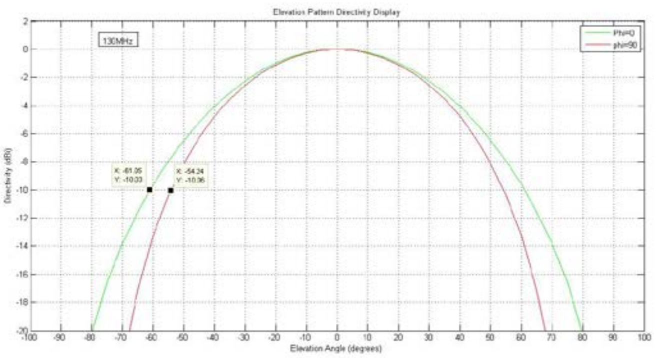

FIG 4.7: Radiation pattern @ 130 MHz for FFDN pair at 0.40λ D and 0.19λ H

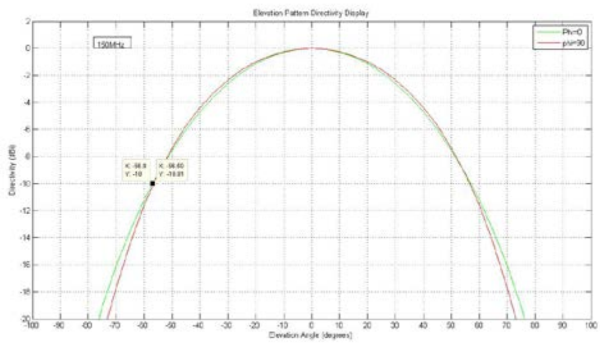

FIG 4.8: Radiation pattern @ 150 MHz for FFDN pair at 0.40λ D and 0.19λ H

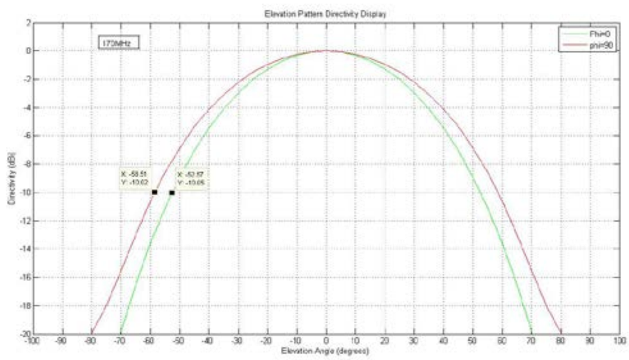

FIG 4.9: Radiation pattern @ 170 MHz for FFDN pair at 0.40λ D and 0.19λ H

All the different heights and spacing used for deriving radiation patterns are compiled in the Table 4.

Table 4.1: **Elevation angle values for E and H plane**

D	H	130 MHz			150 MHz			170 MHz		
		ϕ= 0˚	ϕ=90˚	Δ	ϕ= 0˚	ϕ=90˚	Δ	ϕ= 0˚	ϕ=90˚	Δ
0.38	0.19	62.49	54.15	8.34	59.05	56.64	2.41	54.97	58.58	3.61
	0.2	62.93	54.65	8.28	59.39	57.54	1.85	55.54	59	3.46
	0.21	62.48	54.22	8.26	59.52	57.1	2.42	56.82	60.11	3.29
	0.22	63.77	55.48	8.29	60.6	57.9	2.7	56.75	60	3.25
	0.23	64.14	55.89	8.25	61.17	58.37	2.8	57.45	60.49	3.04
	0.24	64.67	56.28	8.39	61.77	58.83	2.94	58.22	61.05	2.83
0.39	0.19	61.73	54.2	7.53	58	56.65	1.35	53.7	58.52	4.82
	0.2	62.17	54.74	7.43	58.45	57.05	1.4	54.3	59	4.7
	0.21	62.47	55.08	7.39	58.97	57.41	1.56	54.9	59.42	4.52
	0.22	62.86	55.4	7.46	59.56	57.71	1.85	55.42	59.93	4.51
	0.23	63.43	55.89	7.54	60.25	58.48	1.77	56.17	60.48	4.31
	0.24	63.93	56.17	7.76	60.64	58.79	1.85	56.91	60.98	4.07
0.4	0.19	61.05	54.24	6.81	56.9	56.59	0.31	52.57	58.51	5.94
	0.2	61.37	54.57	6.8	57.34	57	0.34	53.03	58.92	5.89
	0.21	61.7	55.05	6.65	57.85	57.4	0.45	53.6	59.46	5.86
	0.22	62.17	55.45	6.72	58.35	57.83	0.52	54.22	59.88	5.66
	0.23	62.48	55.84	6.64	59.06	58.38	0.68	54.8	60.45	5.65
	0.24	62.89	56.18	6.71	59.59	58.76	0.83	55.52	60.98	5.46
0.41	0.19	60	54.15	5.85	56.55	55.9	0.65	51.33	58.46	7.13
	0.2	60.64	54.79	5.85	56.96	56.37	0.59	51.76	58.88	7.12
	0.21	60.8	55	5.8	56	57	1	52.3	59	6.7
	0.22	61.37	55.41	5.96	57.91	57.4	0.51	52.95	60	7.05
	0.23	61.75	55.81	5.94	58.27	57.82	0.45	53.48	60.4	6.92
	0.24	62	56.5	5.5	58.72	58.33	0.39	54.14	60.92	6.78
0.42	0.19	59.5	54.02	5.48	56.73	54.91	1.82	50.2	58.42	8.22
	0.2	59.8	54.5	5.3	55.23	57	1.77	50.71	59	8.29
	0.21	60.17	55.01	5.16	57.35	55.79	1.56	51.08	59.37	8.29
	0.22	60	55	5	56.15	57.77	1.62	51.64	60	8.36
	0.23	60.96	55.82	5.14	56.7	58.24	1.54	52.19	60.37	8.18
	0.24	61.35	56.17	5.18	57.3	58.7	1.4	52.15	60.37	8.22
	0.25	61.83	56.62	5.21	57.85	59.2	1.35	53.47	61.64	8.17
	0.26	62.28	57.14	5.14	58.47	59.74	1.27	54.21	62.07	7.86
	0.27	62.77	57.41	5.36	59.36	60.33	0.97	54.97	62.68	7.71
	0.28	63.3	57.89	5.41	60.07	60.72	0.65	55.86	63.36	7.5
	0.29	63.93	58.27	5.66	60.69	61.22	0.53	56.56	64.12	7.56

	0.3	64.58	61.19	3.39	61.75	61.43	0.32	57.51	65	7.49
D	**H**	**130 MHz**			**150 MHz**			**170 MHz**		
		ϕ= 0˚	ϕ=90˚	**Δ**	ϕ= 0˚	ϕ=90˚	**Δ**	ϕ= 0˚	ϕ=90˚	**Δ**
0.43										
	0.2	58.5	53	5.5	54.1	57.2	3.1	49.75	59.5	9.75
	0.21	59	53.5	5.5	54	57	3	49	59	10
	0.22	59.3	55	4.3	55.2	58	2.8	51	60	9
	0.23	60	55	5	55.8	58.37	2.57	50.8	60.4	9.6
	0.24	60.52	56.18	4.34	56.18	58.72	2.54	51.49	60.9	9.41
	0.25	60.92	56.5	4.42	56.66	59.19	2.53	52.15	61.42	9.27
	0.26	61.43	56.99	4.44	57.27	59.73	2.46	52.78	61.96	9.18
	0.27	61.85	57.35	4.5	57.91	60.19	2.28	53.61	62.65	9.04
	0.28	62.44	57.8	4.64	58.67	60.74	2.07	54.29	63.37	9.08
	0.29	62.98	58.25	4.73	59.37	61.26	1.89	55.15	64.11	8.96
	0.3	63.63	58.75	4.88	60.26	61.77	1.51	55.99	65	9.01
0.44										
	0.2	60.3	53.9	6.4	52	56	4	47	58	11
	0.21	60	54	6	54.9	56.7	1.8	50	58.6	8.6
	0.22	58	54.3	3.7	53	57	4	48	60	12
	0.23	58.4	54.9	3.5	52.5	56.2	3.7	48.7	60.5	11.8
0.45										
	0.2	56.1	53.6	2.5	51	56	5	46.9	58	11.1
	0.21	56.6	54	2.6	51.1	56.5	5.4	48.1	58.8	10.7
	0.22	57	54.2	2.8	52	57	5	48.9	59	10.1
	0.23	57.4	55	2.4	52.2	57.2	5	49.1	60.1	11
0.46										
	0.2	57.2	55.3	1.9	52	58	6	46.9	59.1	12.2
	0.21	56.79	55	1.79	52.9	57.46	4.56	47.1	59	11.9
	0.22	57	55.2	1.8	51.8	57.91	6.11	47.5	60	12.5
	0.23	57.3	55.81	1.49	58.27	53.1	5.17	48	60.4	12.4

From the graphs and the table we found that results were best for the 0.40λ D and 0.19λ H. But at this spacing we faced the problem of overlapping between 2 adjacent dipoles in the Boxing Ring configuration. We also noticed that there is no significant change in Radiation Pattern results as we change the height of the combinations.

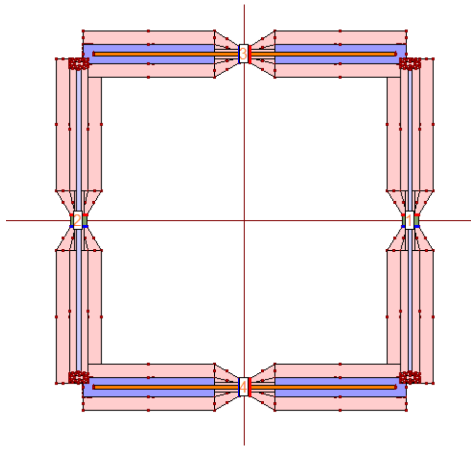

FIG 4.10: Overlapping of Dipoles

Using this result, a conclusion was made to place the dipoles at unequal heights above the reflector. This facilitated us to use the best spacing between the dipoles for the boxing ring configuration.

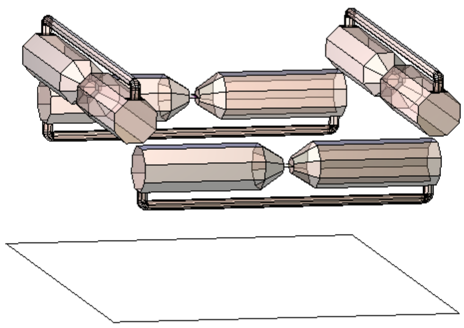

FIG 4.11: Pair of Fat-Folded Dipole with Boxing Ring Configuration arranged at different heights

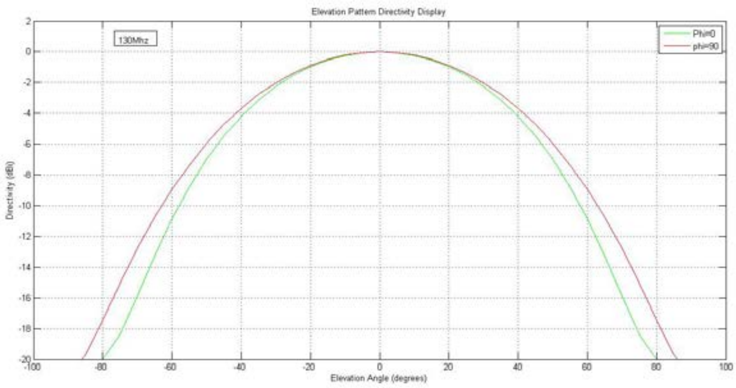

FIG 4.12: Radiation pattern @130 MHz for boxing ring configuration: 0.40λ D and 0.19λ H

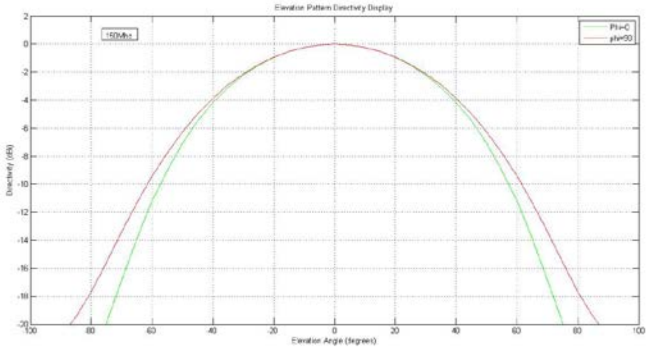

FIG 4.13: Radiation pattern @ 150 MHz for boxing ring configuration: 0.40λ D and 0.19λ H

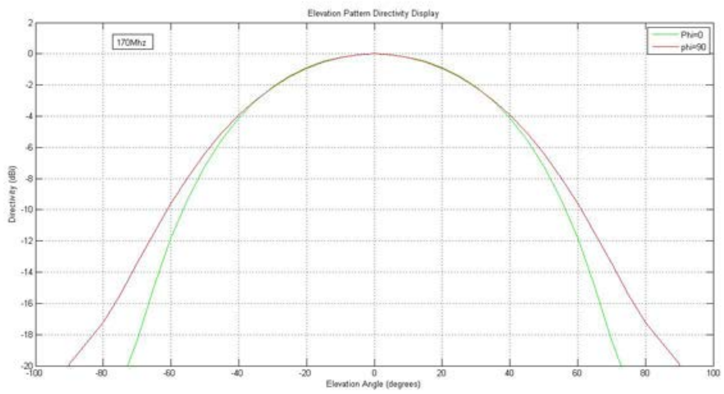

FIG 4.14: Radiation pattern @ 170 MHz for boxing ring configuration: 0.40λ D and 0.19λ H.

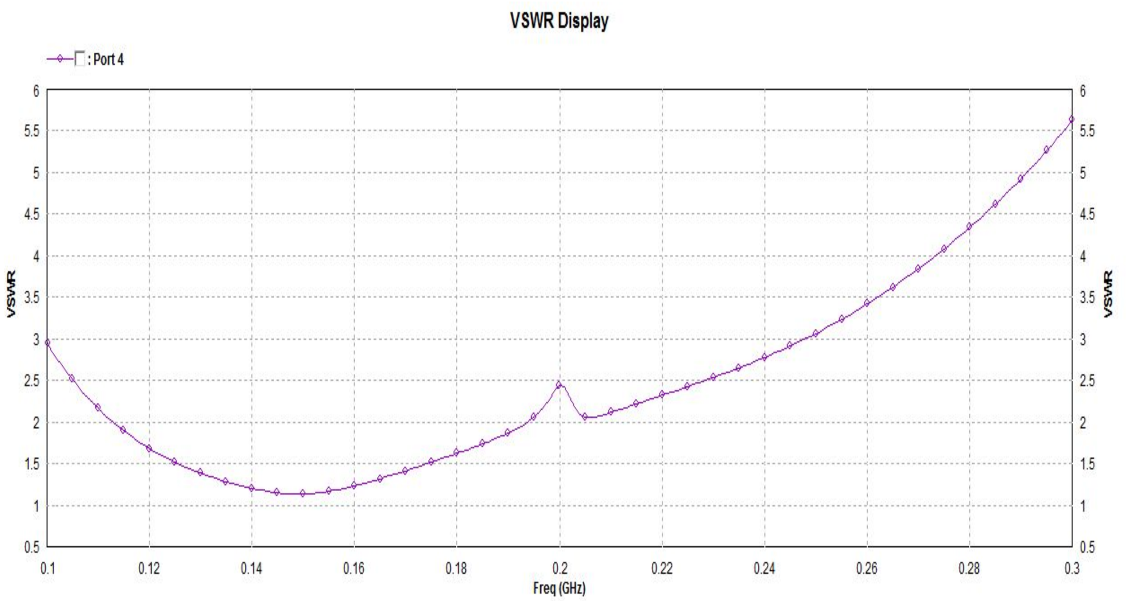

FIG 4.15: VSWR for boxing ring configuration at 0.40λ D and 0.19 H.

After optimizing 150 MHz Fat Folded Dipole, another pair that would resonate at 210MHz was made. Hence, for the second pair, all the dimensions of the optimized 150MHz Dipole pair were scaled down by a factor of 150/210 i.e, 0.714.

This resulted in a second pair of Fat Folded Dipole with smaller dimension and lesser spacing and height as shown in Fig 6.16 and its respective results in Figs. 6.17 to 6.20.

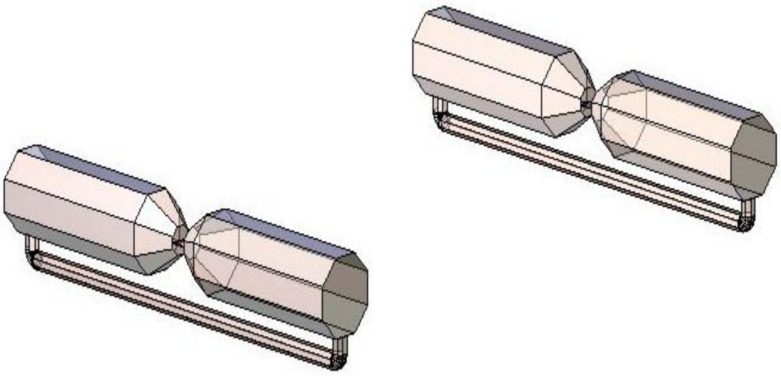

FIG 4.16: Pair of Fat Folded Dipole at 210MHz

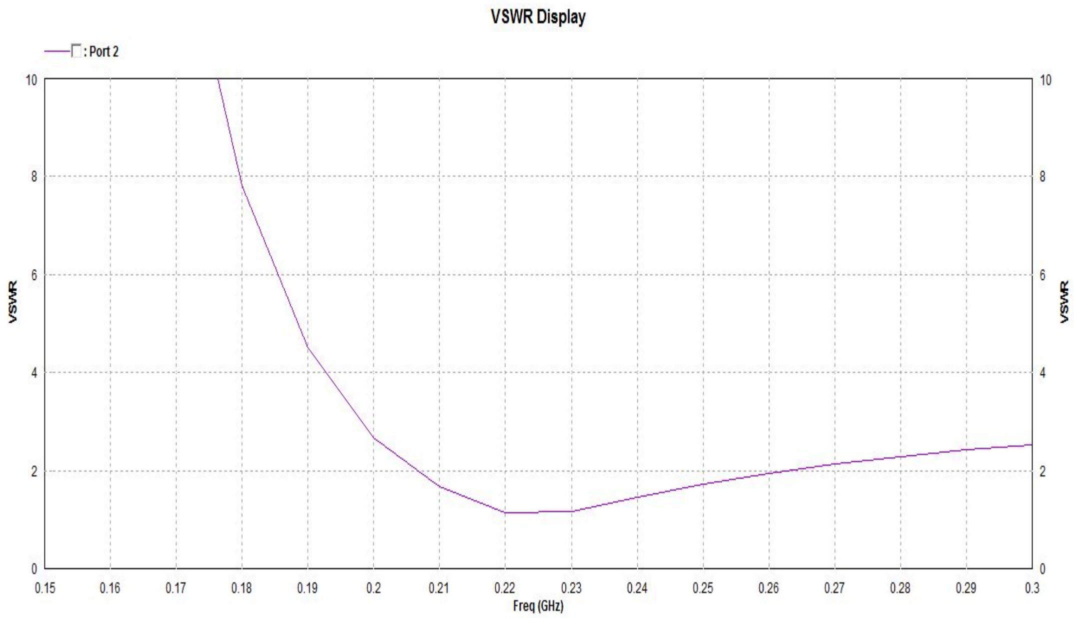

FIG 4.17: VSWR of Fat Folded Dipole Pair resonating at 210MHz

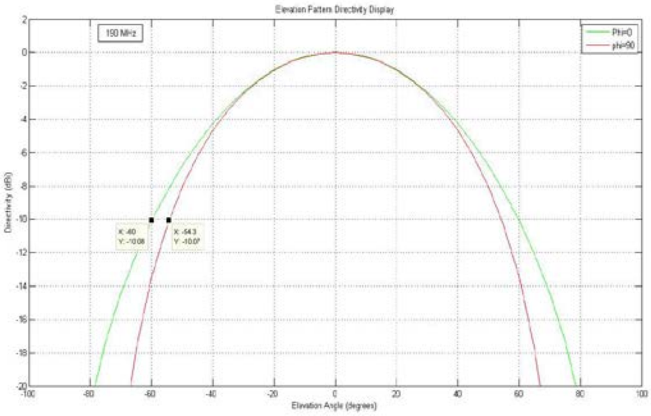

FIG 4.18: Radiation Pattern at 190MHz for FFD pair resonating at 210MHz

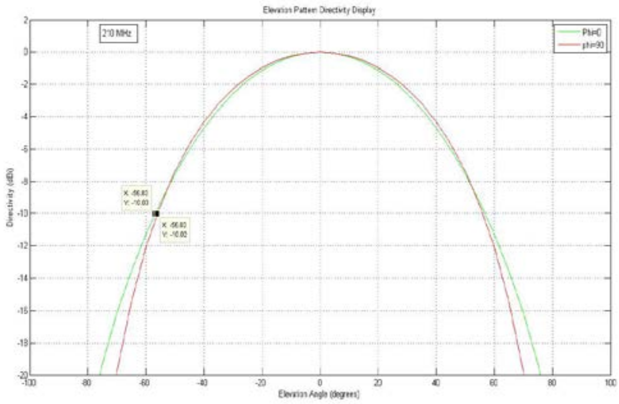

FIG 4.19: Radiation Pattern at 210 MHz for FFD pair resonating at 210MHz

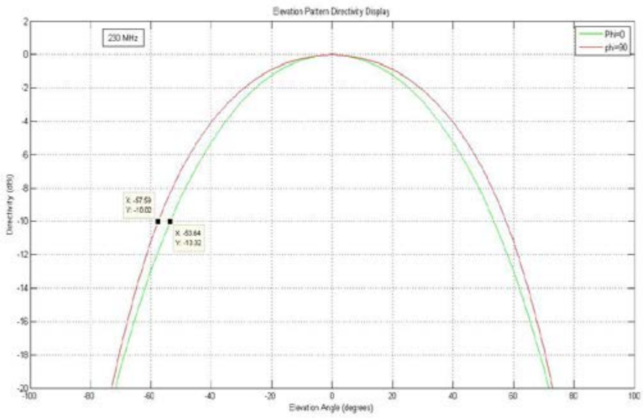

FIG 4.20: Radiation Pattern at 230 MHz for FFD pair resonating at 210MHz

After the simulation of the smaller dipole the two dipole pair were implemented in a Russian Doll pattern where the larger dipole (@150Mhz) was kept at outside and the smaller dipole(@170Mhz) in the following manner

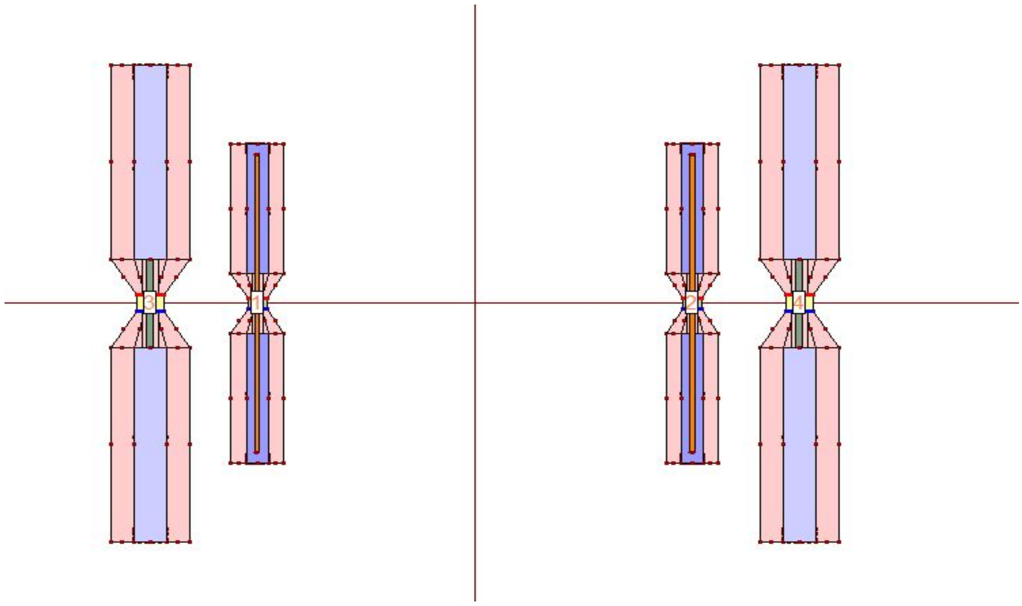

FIG 4.21: Russian Doll pattern implementation of the dipoles

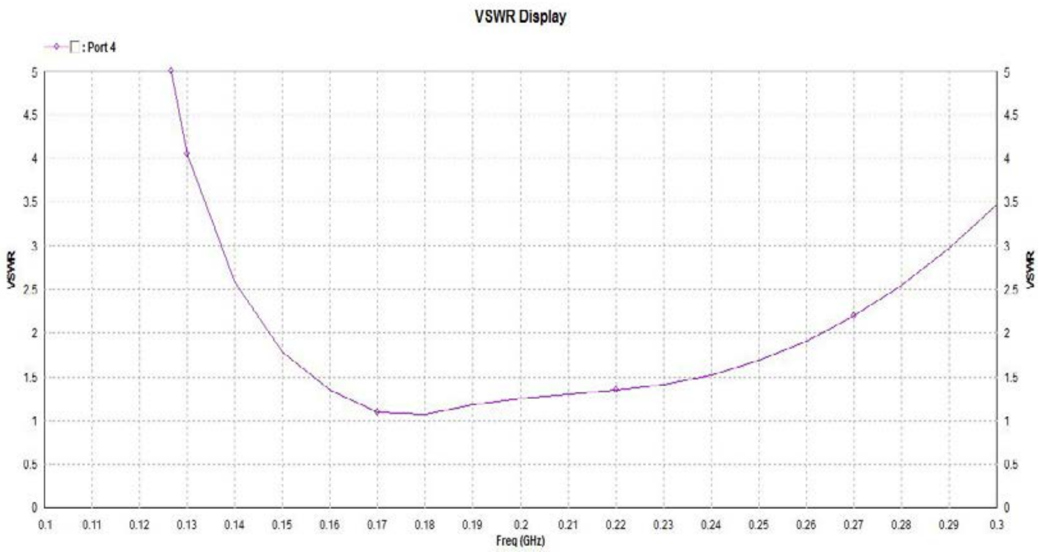

FIG 4.22: VSWR of the Russian Doll implementation

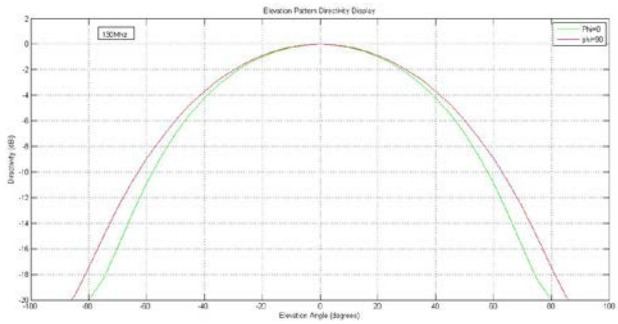

FIG 4.23: Radiation Pattern at 130 MHz for Russian Doll pattern

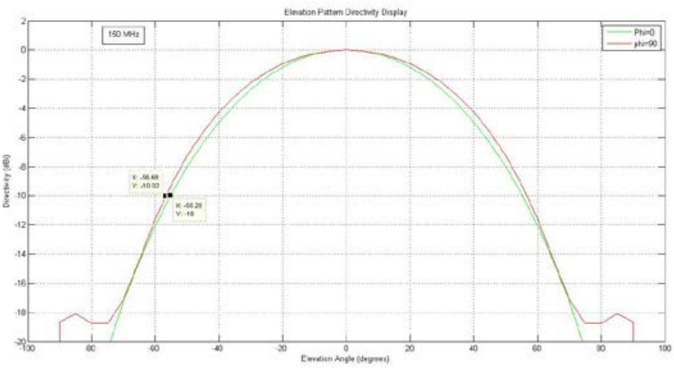

FIG 4.24: Radiation Pattern at 150 MHz for Russian Doll pattern

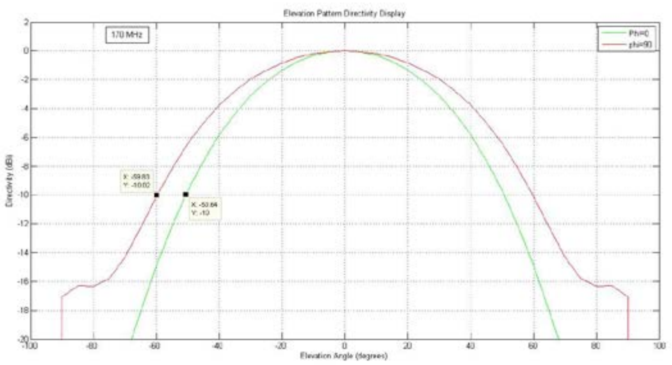

FIG 4.25: Radiation Pattern at 170 MHz for Russian Doll pattern

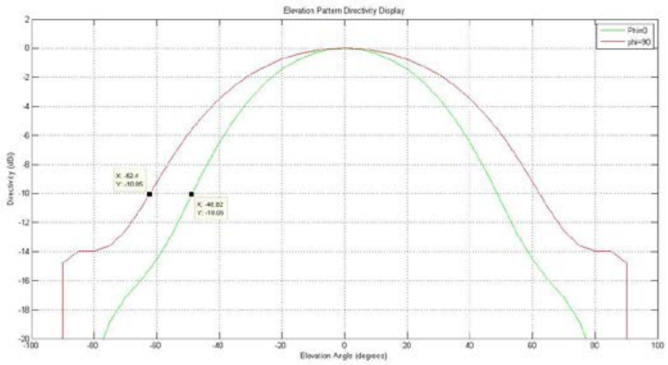

FIG 4.26: Radiation Pattern at 190 MHz for Russian Doll pattern

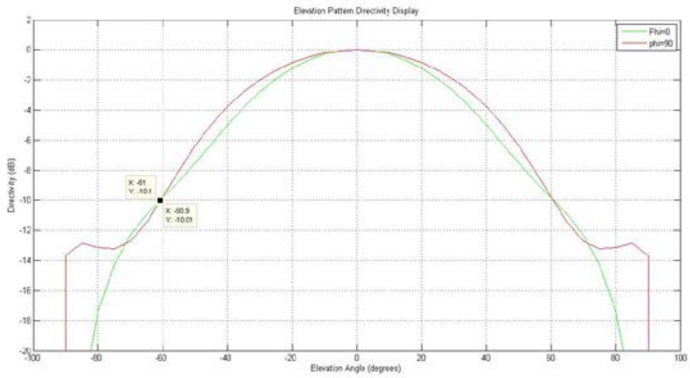

FIG 4.27: Radiation Pattern at 210 MHz for Russian Doll pattern

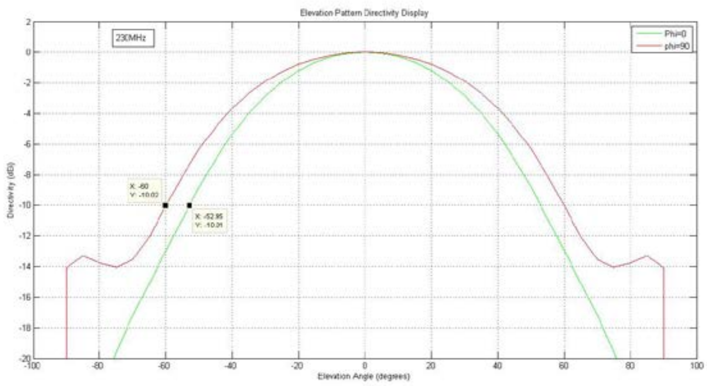

FIG 4.28: Radiation Pattern at 230 MHz for Russian Doll pattern

Summary:

After considering various combinations of Height and Spacing, the following combinations were found to show the best results:

1. Pair of FFD at 150MHz: 0.40λ D and 0.19 λ H

2. Boxing Ring at 150MHz:
    a. Pair 1: FFD at 150MHz: 0.40 λ D and 0.19 λ H, where λ = 2m.

    b. Pair 2: Inverted FFD at 150MHz: D = 0.40 λ D and H = 0.25 λ

3. Russian Doll (Two Boxing Rings, one outer and another inner) at 150MHz and 210Mhz:
    a. Pair 1: FFD at 150MHz: D = 0.40 λ and H = 0.19 λ, where λ = 2m.

    b. Pair 2: FFD at 210MHz: D = 0.286 and H = 0.136 λ H, where λ = 2m.

4. Our results for the 2 independent boxing rings, placed one inside other, show return loss was < -10db (SWR < 2) from about 145MHz -260 MHz. Further optimization may give return loss< -10db (SWR < 2) from about 130 MHz to 245 MHz, preferred range for observations with the GMRT.

5. Conclusion

Our objective is to co-locate 2 pairs of Feeds optimized at 150 MHz and 210 MHz, connected independently to separate sets of LNAs, in order to obtain nearly same E and H patterns over the frequency range of ~ 130 MHz to 250 MHz and SWR < 2 (return loss < -10dB).

For the 150 MHz Fat Folded Dipoles, we considered the same dimensions as those of the 150 MHz Fat Folded Dipoles of the 150 MHz feed of the GMRT. We then calculated E and H pattern variations using the EM wave solver software, 'IE3D'. All the dipoles were excited simultaneously. We varied spacing, D, between the outer Fat Folded Dipole Pairs and their height H above an infinite conducting reflector. Our aim was to minimize E and H variations in the frequency range of 130 MHz to 170 MHz. Thus we selected D = 0.40 λ and H = 0.19 λ.

It is shown that the "Russian Doll" concept (multi-element array) gives a broad bandwidth, good polarization performance and SWR < 2: 1 (return loss < -10 dB), over the frequency range of ~ 130MHz -250 MHz, by designing dual Boxing rings, one inside another. It is proposed to carry out further optimization by another batch of 4^{th} year B.Tech students by scaling all dimensions of the above dual feed in order to simulate, design and fabricate a feed for the frequency range of ~ 550-850MHz, including connection to low noise amplifiers and then testing the performance in the NCRA test range.

6. References

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7. Acknowledgement (by the 3 students):

We have great pleasure in presenting our project titled

“DESIGN, SIMULATION AND IMPLEMENTATION OF FAT-FOLDED DIPOLE ANTENNA ARRAY**”**

This task of obtaining excellent result is to harmonize the group of unique personalities to face various interests and to initiate abilities all towards directions. Just as skilled hands are necessary to carve a dainty status from raw stone, it is our fortune that we got Prof. (Dr.) G.N. Mulay as our project guide. Under the knowledgeable guidance of Prof.(Dr.) Govind Swarup, Former director, GMRT for orienting us in the right direction towards our goal. We are highly thankful to them as it would have been impossible to acquire our target without their constant guidance. Eventually we are thankful to all teaching and non-teaching staff members who helped us directly and indirectly in completion of this project.

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