National Centre for Radio Astrophysics

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A Report on Accuracy between Feed Simulations and Measurements

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Objective:

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Ver. 1	16 March 2011	Initial Version

A Report on Accuracy between Feed Simulations and Measurements

WIPL-D is an extremely powerful program that allows fast and accurate analysis of metallic and/or dielectric/magnetic structures (antennas, scatterers, passive microwave circuits, etc.). The calculations are done in the frequency domain.

This user-friendly program enables us to define the geometry of any structure in an interactive way as combination of wires, plates and material objects. It continuously displays the 3-D structure as it evolves through its definition.

As an output, WIPL-D provides the current distribution on the structure, radiation pattern, near-field distribution, admittance, impedance, and s-parameters at the predefined feed points. WIPL-D also provides you with a variety of printer-based and/or graphic output capabilities, including 2-D and 3-D graphs of the parameters of interest.

A user does not need not to know the analysis method to use the program. WIPL-D efficiently executes most of the desired computations in reasonable time on any Windows based PC system, thereby making the software ideal for computer-aided design

Here is an attempt has made to simulate Our Existing GMRT Feeds and to study the characteristics of the feeds and to evaluate the software.

Fig a: Feeds on GMRT turret

1. **150 MHz Folded Dipole:**

This is one of the low frequency feed of GMRT antennas, covering the Astronomical band of 150 MHz. The unique feature of the boxing ring configuration is that it has more symmetricradiation characteristics (E and H plane patterns) than a single dipole like feed. Here onepair of dipole, combined as an adding type array provides sensitivity to one linearpolarization and another pair orthogonally oriented with respect to the first pair give sensitivity to the other polarization state.

A two-element array with a spacing of $\lambda/2$ gives an H plane pattern, which is very similar to the E-plane pattern. So it is appropriate to design the boxing ring with this dimension at the resonant frequency.

This feed employs four dipoles in a ``boxing ring'' configuration, placed above a plane reflector. The unique feature of the dipole is that it is wide-band i.e. has an octave bandwidth. It is a folded dipole with each arm being a ``*thick*'' dipole. A dipole is called '*thin*' when its diameter, $d > 0.05\ \lambda$. For such dipoles a sinusoidal current distribution can be assumed for the computation of input impedance and related radiation parameters. Thin dipoles have narrowband impedance characteristics. One method by which its acceptable operational bandwidth can be increased is to decrease the l/d ratio.

Fig b: 150MHz Folded Diple

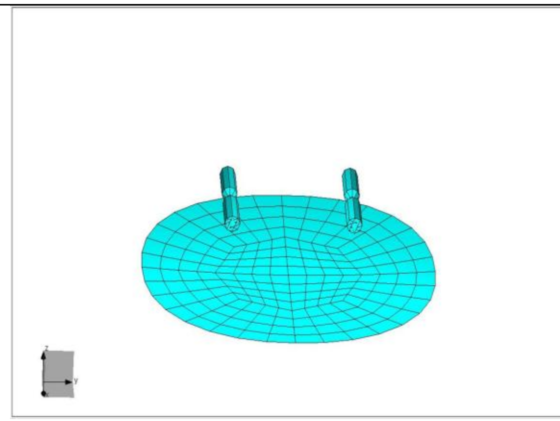

Fig c: 150MHz Folded Diple (simulation)

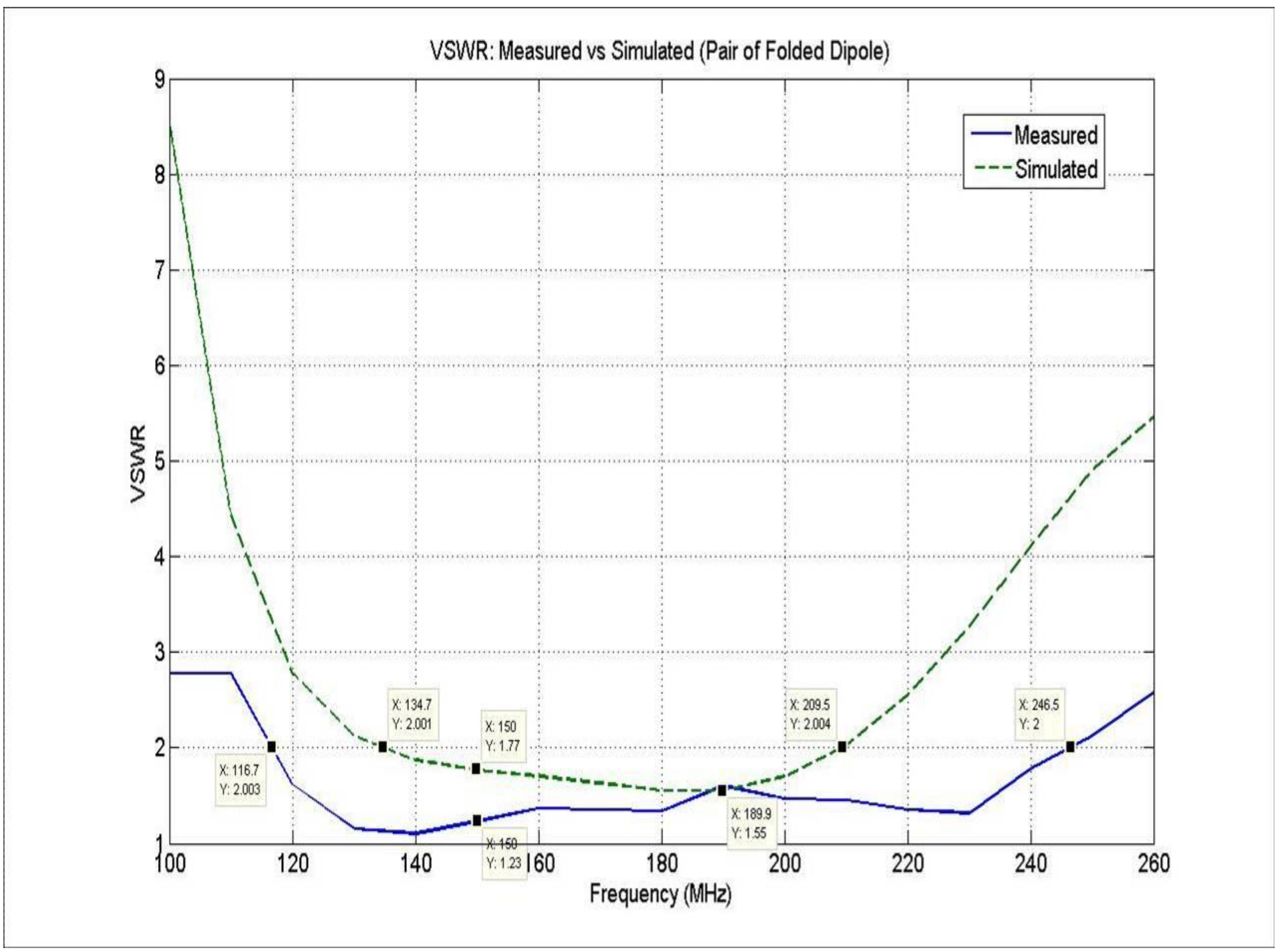

Fig d: VSWR Comparison of 150 MHz Folded Dipole

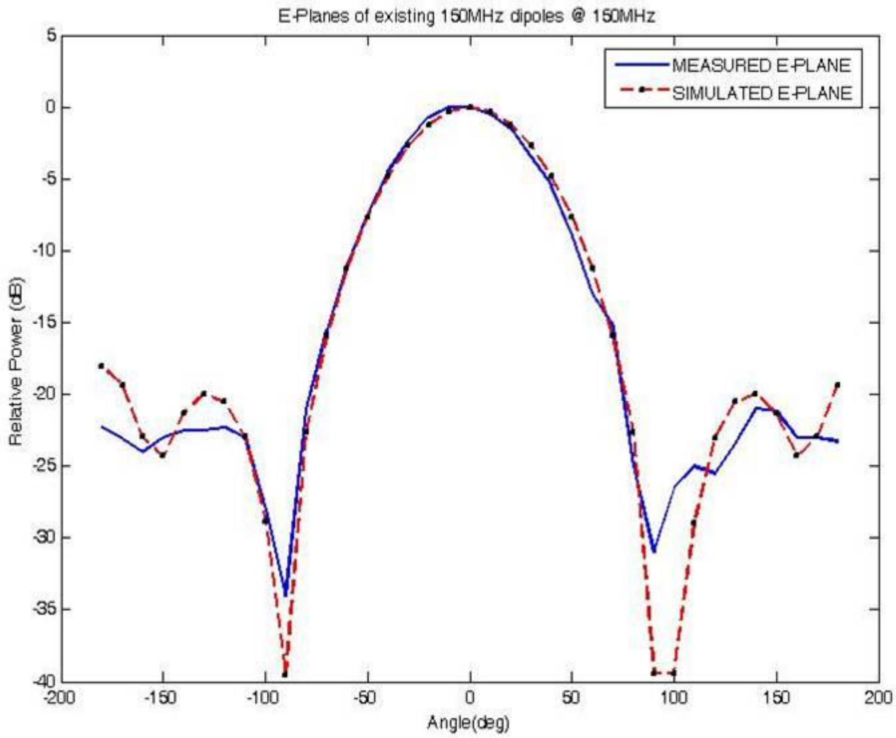

Fig e: E-Plane Match @ 150 MHz

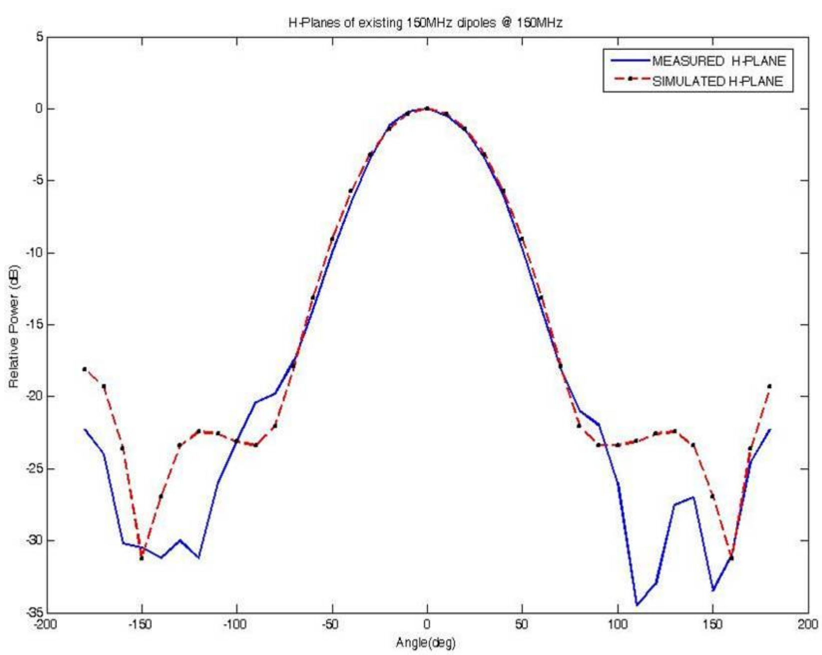

Fig f: H-Plane Match @ 150 MHz

2. **327 MHz Kildal Feed:**

This is one of the low frequency feed of GMRT antennas, covering the Astronomical band of 327 MHz.
Generally a dipole has a broader H pattern than its E pattern (the E pattern being in the plane containing the dipole). For good cross-polarization properties it was essential to have matched E and H plane patterns. An elegant method for achieving this pattern matching was given by P.S.Kildal, and involves placing a beam forming ring (BFR) above the dipole. The conducting ring is placed above the dipole in a plane parallel to the reflector and is supported by dielectric rods. The beam forming ring compresses the H-plane pattern while it has no significant effect on the E-plane.

Fig g: 327 MHz Kildal Feed

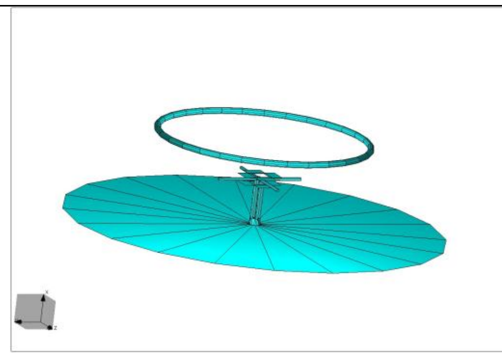

Fig h: 327 MHz Kildal Feed (simulation)

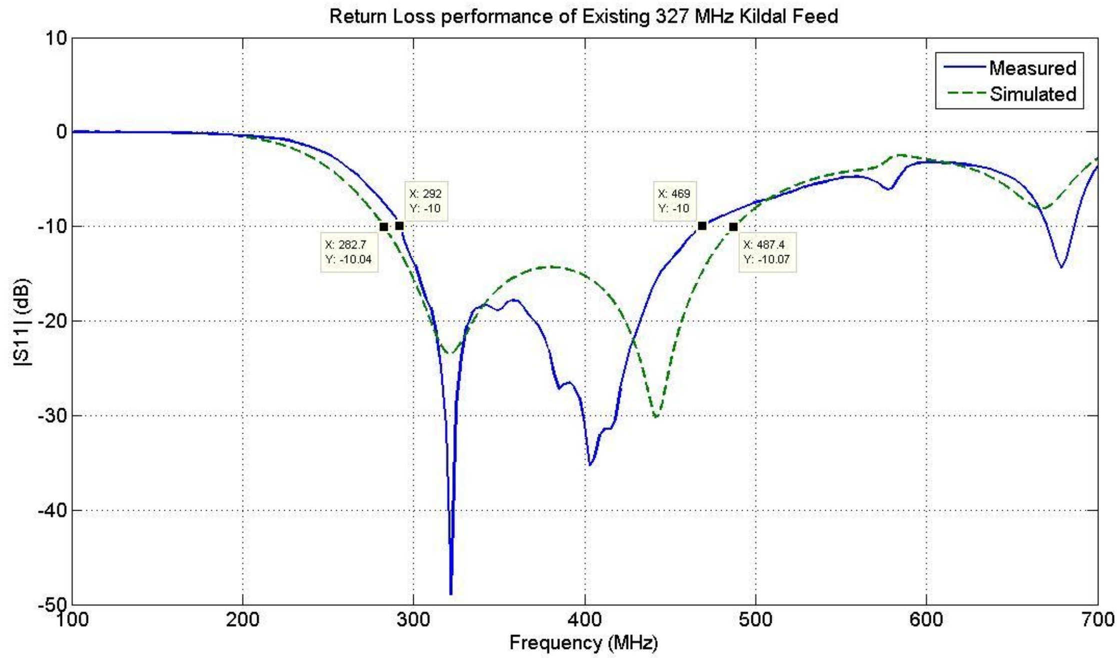

Fig i: Return Loss performance comparison of 327 MHz kildal Feed

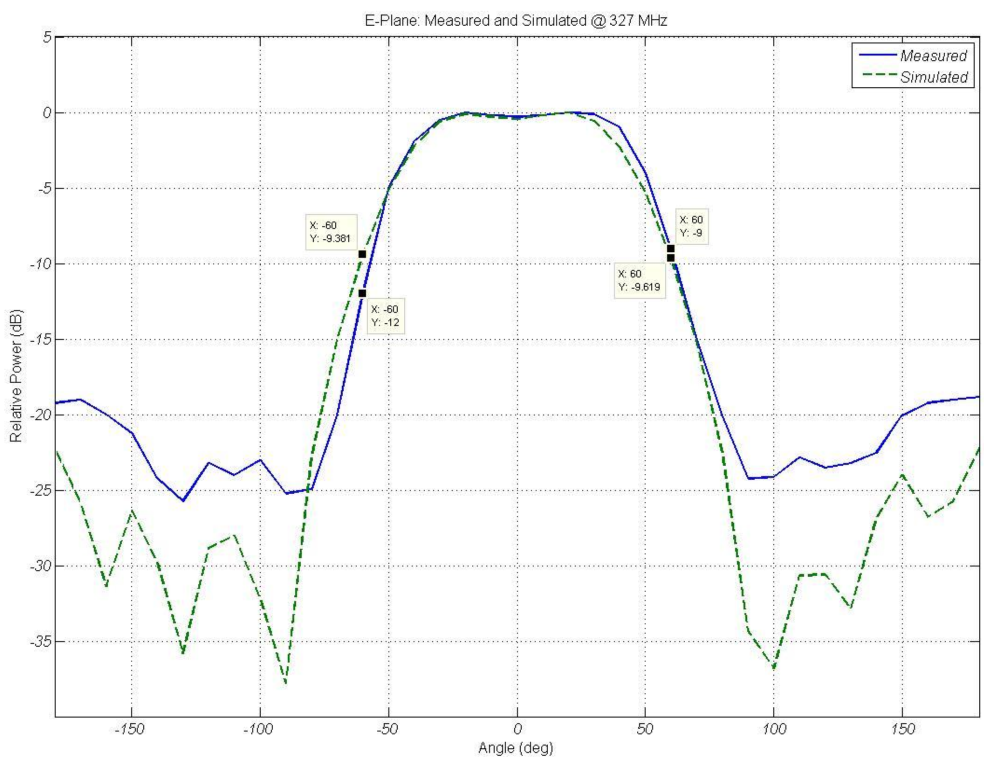

Fig j: E-Plane Match @ 327 MHz

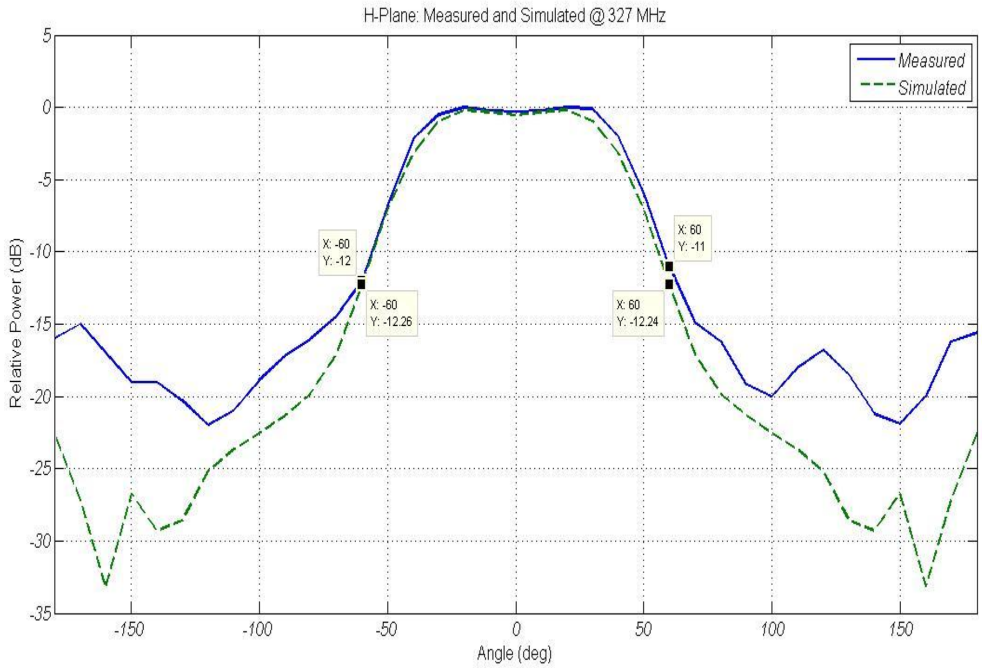

Fig k: H-Plane Match @ 327 MHz

3. 610 MHz Co-axial Feed:

The design of the GMRT 610 MHz/233 MHz waveguide feeds is based on an exhaustive theoretical analysis of the design of coaxial waveguide feeds. A constraint in such multi-frequency designs is that adjacent frequency bands should not overlap to within an octave. Thus at the GMRT either the 150 MHz or the 233 MHz could have been combined with 610 MHz. However the former choice was rejected since it resulted in unwieldy dimensions of the feed.

The fundamental mode of propagation in coaxial structures is TEM; hence the radiated field component along the axis is zero everywhere. Obviously for a feed this is the most undesirable characteristic. So propagation by an alternate mode (single or multiple) is essential. Coaxial waveguides must then be forced to radiate in TE_{11} mode. This can be achieved simply by exciting the probes in phase opposition.

In the dual frequency construction the outer conductor of the 610 MHz serves as the inner one for the 233 MHz. Quarter wavelength chokes are provided in both the frequency parts to cut down the surface currents on the outer conductor and thereby ensure pattern symmetry. The waveguide feeds have two pairs of probes. One pair supports a given plane polarization while the orthogonal pair supports the orthogonal polarization. Similar to the dipole feed, a quadrature hybrid at the back-end of the coaxial feed is used to convert the linear polarization to circular polarization. The rear-half of the 610 MHz feed, separated by a partition disc, is utilized to accommodate the baluns, quadrature hybrids and low-noise amplifiers of 610 MHz and the baluns of 233 MHz.

Fig l: 233/610 MHz co-axial feed

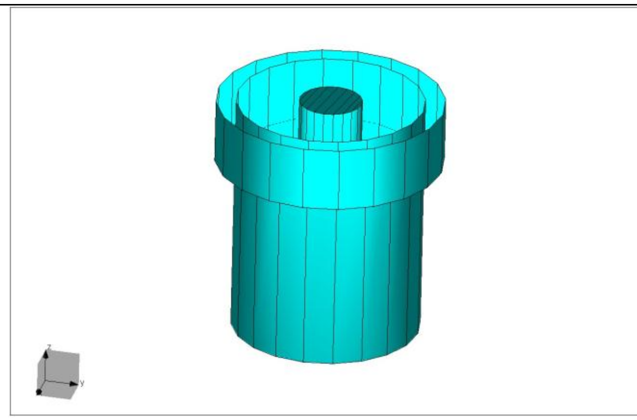

Fig m: 610 MHz co-axial feed (simulation)

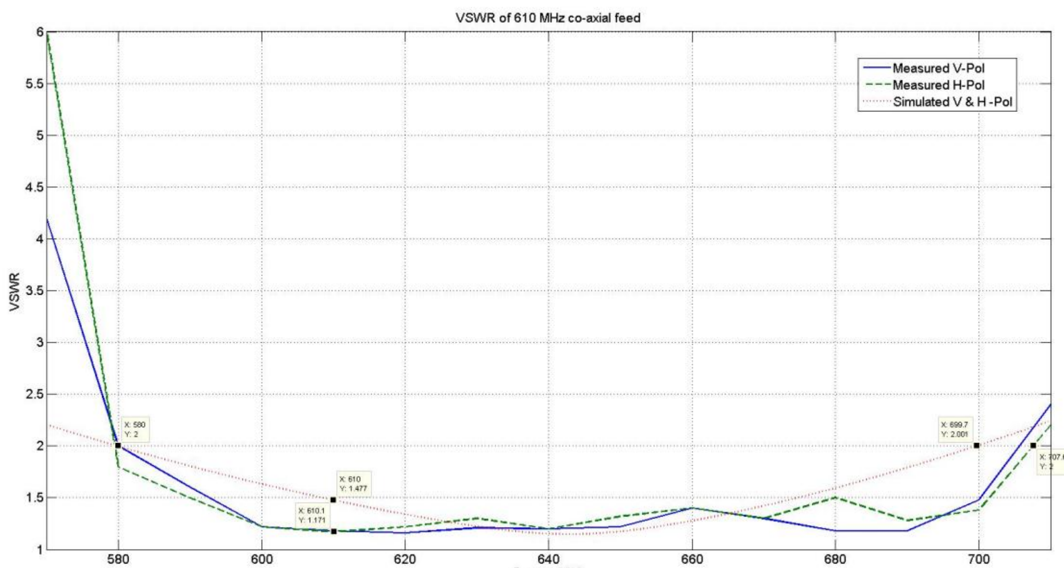

Fig n: VSWR comparison of 610 MHz co-axial feed

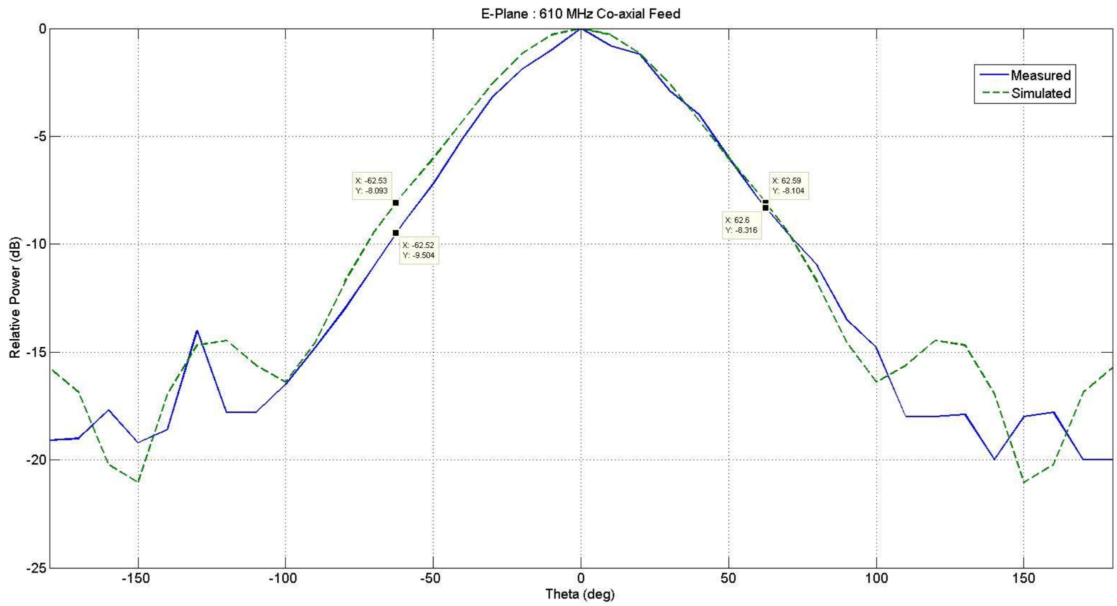

Fig o: E-Plane Match @ 610 MHz

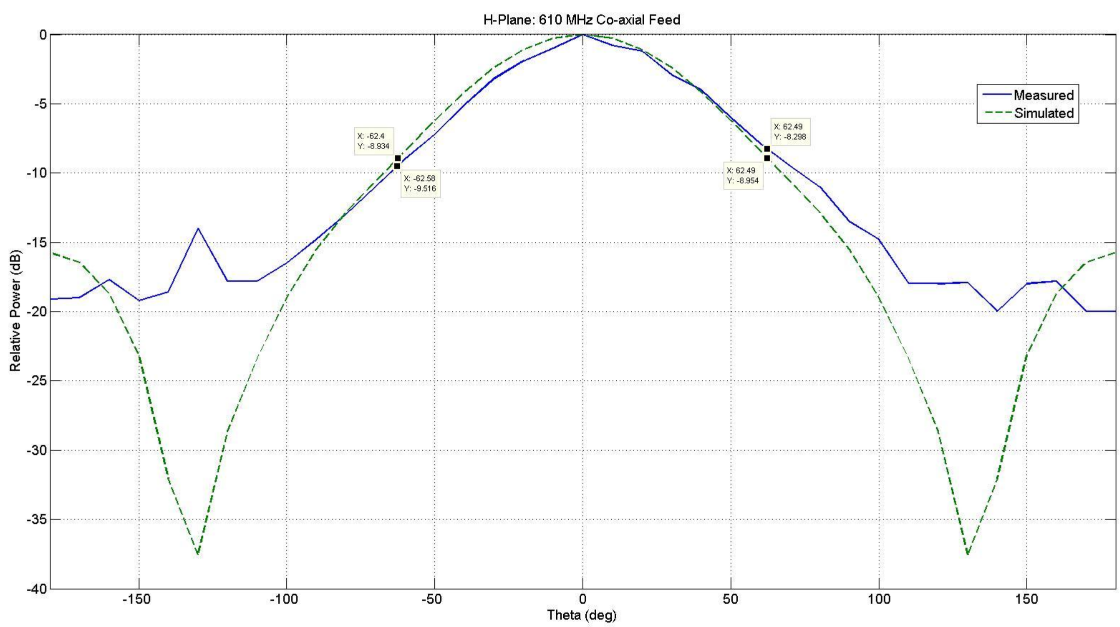

Fig p: H-Plane Match @ 610 MHz

Conclusion:

i) **Radiation Pattern**: The Software gives good match between simulations and measurements.

ii) **Return Loss**: The Bandwidth matches as the end points below -10dB matches well between simulations and measurements. But, the curve doesn't follow each other in the mid-band.

References:

1. G. Sankar, GMRT Antennas and Feeds (chapter-19), "Low Frequency Radio Astronomy ", 3rd Edition.

2. Guillou.L., Daniel.J-P., Terret.C., Madani.A., " Rayonnement d'un Doublet Replie Epais", Annales des Telecommunications, tome 30, nr 1-2. 1975.

3. Kildal, P-S., and Skyttemyr, S.A., " Dipole-Disk Antenna with Beam-Forming Ring ", IEEE Trans. on Ant. & Propg., Vol.AP-30, No.4, (1982).