GIANT METREWAVE RADIO TELESCOPE
NATIONAL CENTRE FOR RADIO ASTROPHYSICS
TATA INSTITUTE OF FUNDAMENTAL RESEARCH

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'DIFFERENT ANTENNA EFFICIENCY COMPUTATION'

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I would also take the opportunity to thank Suresh Kumar sir and Anil Raut sir for their constant help provided to me during my stay here at GMRT.

I would also like to thank my Professor Dr.Somak Bhattacharyya sir for his support and helping me to get this opportunity.

Finally I would thank the entire GMRT staff for their cooperation provided to me without which it would have been difficult to get accustomed to the conditions here.

AIM AND BACKGROUND OF MY PROJECT

The project was intended to develop a GUI based software tool using MATLAB for calculating antenna efficiencies of GMRT antennas. The code written is used to calculate different types of antenna efficiency terms like Spill over efficiency, Taper efficiency, X-Polar efficiency, RMS efficiency, Mesh leakage efficiency and overall efficiency along with various noise temperature terms like Spill over temperature, Total scatter temperature Mesh leakage temperature and Ground temperature.

In fact GMRT has been using a software written in FORTRAN language for calculating the various efficiency terms and noise temperature terms for a long time.
But due to incompatibility of the newer operating systems with FORTRAN language, came the idea to recode the original software in some other programming language.

Though here at GMRT observatory, the antennas are Prime focus type, yet the code was developed for primary focus as well as cassegrain type of antennas.

Since, it is a GUI based software, it can be used comfortably by anyone. And this code has an extra updated features which would plot the secondary radiation pattern and also calculate the phase efficiency at a given del/lamda value.

And also, since this GUI is made in MATLAB, it generally works in a system which has a MATLAB software. But, since MATLAB is a costly software and thus not reachable to everyone, this GUI model has been made as an app i.e a .exe file which can be installed on any PC.

RADIO ASTRONOMY

We see the world around us, because our eyes detect visible light, a type of *electromagnetic radiation*. Objects on Earth and in space also emit other types of EM radiation that cannot be seen by the human eye, such as radio waves. The full range of all radiating EM waves is called the electromagnetic spectrum .Radio astronomy is the study of celestial objects that give off radio waves. With radio astronomy, we study astronomical phenomena that are often invisible or hidden in other portions of the electromagnetic spectrum. So, we take the help of Giant radio telescopes to observe these astronomical phenomenon.

RADIO TELESCOPE

Radio telescopes are used to study naturally occurring radio light from stars, galaxies, black holes, and other astronomical objects. We can also use them to transmit and reflect radio light off of planetary bodies in our solar system. These specially-designed telescopes observe the longest wavelengths of light, ranging from 1 millimetre to over 10 meters long. For comparison, visible light waves are only a few hundred nanometres long, and a nanometre is only 1/10,000th the thickness of a piece of paper. Naturally-occurring radio waves are extremely weak by the time they reach us from space. A cell phone signal is a billion times more powerful than the cosmic waves our telescopes detect.

Generally, we use parabolic reflectors as radio telescopes which act as receivers to study about the astronomical objects through the radiation pattern produced by them. And GMRT (Giant Metrewave Radio telescope) is one of the biggest radio telescopes which uses the principle of interferometry to observe the astronomical objects.

Parabolic reflector antenna

A parabolic reflector antenna has a parabolic shape reflective surface used to collect or project energy such as light, sound, or radio waves. Its shape is part of a circular paraboloid, that is, the surface generated by a parabola revolving around its axis. The parabolic reflector transforms an incoming plane wave traveling along the axis into a spherical wave converging toward the focus. Conversely, a spherical wave generated by a point source placed in the focus is reflected into a plane wave propagating as a collimated beam along the axis. So, a parabolic reflector follows the principles of geometrical optics.

There are mainly two types in which a parabolic antenna can be used.They are :

Cassegrain : Cassegrain antenna is a parabolic antenna in which the feed antenna is mounted at or behind the surface of the concave main parabolic reflector dish and is aimed at a smaller convex secondary reflector suspended in front of the primary reflector. The beam of radio waves from the feed illuminates the secondary reflector, which reflects it back to the main reflector dish, which reflects it forward again to form the desired beam

Prime Focus: It is the type of parabolic reflector antenna where the feed is kept at the focus.

The below shows the working of a parabolic reflector.

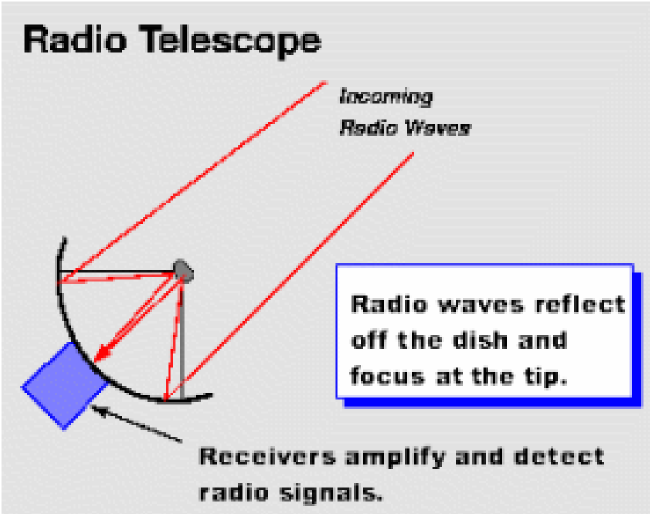


Fig 1 : working of a parabolic reflector

INTRODUCTION TO GMRT

NCRA has set up a unique facility for radio astronomical research using the metre wavelengths range of the radio spectrum, known as the Giant Metrewave Radio Telescope (GMRT), it is located at a site about 80 km north of Pune. GMRT consists of 30 fully steerable gigantic parabolic dishes of 45m diameter each spread over distances of upto 25 km. GMRT is one of the most challenging experimental programmes in basic sciences undertaken by Indian scientists and engineers.

The metre wavelength part of the radio spectrum has been particularly chosen for study with GMRT because man-made radio interference is considerably lower in this part of the spectrum in India. Although there are many outstanding astrophysics problems which are best studied at metre wavelengths, there has, so far, been no large facility anywhere in the world to exploit this part of the spectrum for astrophysical research.

Antenna Configuration: The number and configuration of the dishes was optimized to meet the principal astrophysical objectives which require sensitivity at high angular resolution as well as ability to image radio emission from diffuse extended regions. Fourteen of the thirty dishes are located more or less randomly in a compact Central Array in a region of about 1 sq km. The remaining sixteen dishes are spread out along the 3 arms of an approximately 'Y – Shaped 'configuration over a much larger region, with the longest interferometry baseline of about 25 km.

The multiplication or correlation of radio signals from all the 435 possible pairs of antennas or interferometers over several hours will thus enable radio images of celestial objects to be synthesized with a resolution equivalent to that obtainable with a single gigantic dish 25 kilometre in diameter! The array will operate in six frequency bands centred around 50, 153, 233, 325, 610 and 1420 MHz. All these feeds provide dual polarization outputs. In some configurations, dual-frequency observations are also possible.

The highest angular resolution achievable will range from about 60 arcsec at the lowest frequencies to about 2 arcsec at 1.4 GHz.

GMRT is an indigenous project. The construction of 30 large dishes at a relatively small cost has been possible due to an important technological breakthrough achieved by Indian Scientists and Engineers in the design of light-weight, low-cost dishes. The design is based on what is being called the **`SMART'** concept - for **S**tretch **M**esh **A**ttached to **R**ope **T**russes.

Introduction of Sensitivity Calculation

Astronomy is largely limited by two windows in the atmosphere's opacity- optical and radio. These windows provide complementary views of the objects in the universe . The radio-wave emission from these celestial objects is classified into two main groups- thermal and non-thermal. The information in these signals is their intensity and its distribution in space and variation in time. Being generated from a large number of random processes they almost all have the form of Gaussian noise. This is in common with passive imaging and in contrast to most communications signals, although wide band communications signals may have similar statistical behaviour. Thermal emissions are produced by the random motion of the particles in the object and can be represented by an equivalent temperature. The transparency of the object to radio-waves and its composition can affect emission intensity with respect to frequency. For instance ionized gas, neutral gas and solids all behave differently.

Non-thermal emission mechanisms can be more efficient and include plasma oscillations and synchrotron emission from relativistic electrons. These emissions are usually at least partially linearly or circularly polarized. Celestial radio emissions can vary smoothly with frequency referred to as continuum radiation or occur in narrow bands referred to as spectral lines. The sensitivity of continuum depends on the instantaneous bandwidth of the radio-telescope and so benefits from wide bandwidths. The spectral lines relevant to radio emission are due to resonances in molecules and atoms. Although these are narrow band at their origin, they can be Doppler shifted to very different frequencies and so wide bandwidths can be important for spectral-line observations as well.

The relevant figures of merit for a radio-telescope are the parameters that affect the quality of the data it produces. These data are most commonly maps of the celestial sphere, either bands of continuum radiation or spectral lines.

Sensitivity is defined by the smallest flux ΔS that a radio telescope can detect-

$$\Delta S \propto \frac{T_{sys}}{A_e\sqrt{B\tau}} \tag{1}$$

Where B is the considered bandwidth and τ is the integration time. Let’s consider the effective area A_e and the system temperature T_{sys}.

On the other-way we can say that sensitivity is closely related to the ratio G/T_{sys}. The impact of the each antenna's G/T in a synthesis array is addressed in some detail by Crane and Napier with the conclusion that the image sensitivity is proportional to the G/T.

The sensitivity equation of GMRT was proposed by Lal D et al, The equation is;-

$$\Delta S_{dB} = 10\log_{10}\left(\frac{T_{on,\nu}^{cal,Tot}}{T_{off,\nu}^{cal,Tot}}\right) \tag{2}$$

Where $T_{on,\nu}^{cal,Tot}$ is the total ON source system temperature in the direction of a calibrator at a ν frequency;

$$T_{on,\nu}^{cal,Tot} = T_{scr,\nu}^{cal} + T_{RX,\nu} + T_{Gnd,\nu} + T_{sky,\nu}^{cal} \tag{3}$$

Where $T_{off,\nu}^{cal,Tot}$ is the total Off source system temperature at a ν frequency;

$$T_{off,\nu}^{cal,Tot} = T_{RX,\nu} + T_{Gnd,\nu} + T_{sky,\nu}^{cal} \tag{4}$$

Whereas $T_{RX,\nu}$ is the receiver temperature, $T_{Gnd,\nu}$ is the ground temperature and $T_{sky,\nu}^{cal}$ sky temperature in a specific direction.

$$T_{scr,\nu}^{cal} = S_{\nu}^{cal} \times G \tag{5}$$

S_{ν}^{cal} is the calibrated source at different spot frequency and G is the antenna gain K Jy^{-1}. Where G antenna gain is;

$$G = \frac{SA_p\eta_{ov}}{2k} \tag{6}$$

Where S is the flux density in Jy and A_P is the physical area of the parabolic dish and η_{ov} is overall efficiency. [if we put source flux density is 1 Jy, and also Boltzmann's constant is include then]

$$G = \frac{A_p \times \eta_{ov}}{2760} \tag{7}$$

In this section we are give the fundamental equation of sensitivity. In the coming few section we explain the different parameters in sensitivity.

Antenna Efficiency Calculation

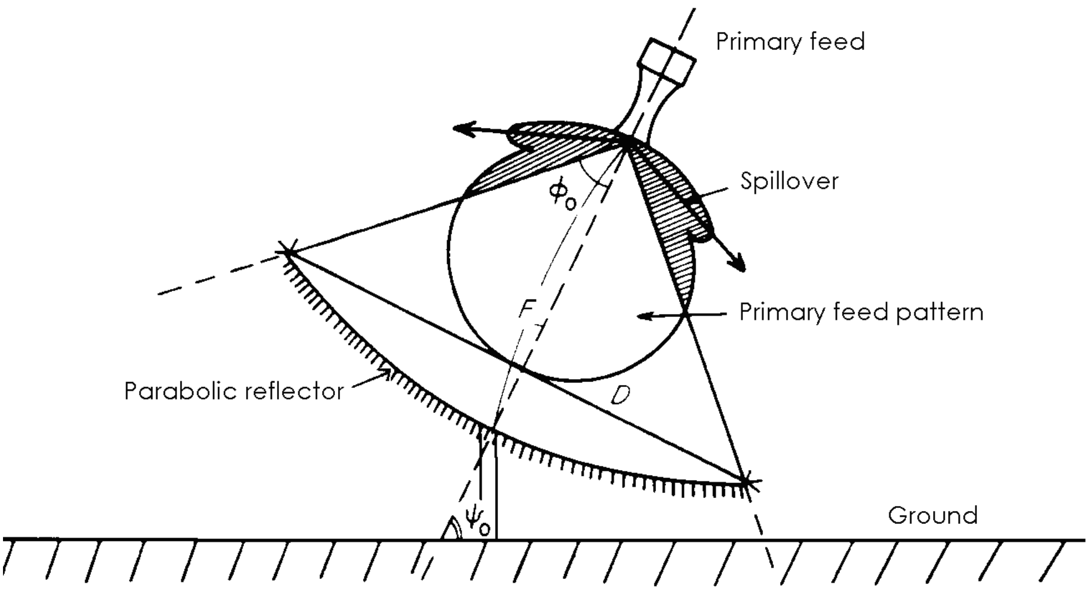


Fig.2 **Parabolic dish in prime focus antenna**

Let P_{in} be the input power to the feed. The power intercepted by the paraboloid *is* - $\eta_s\eta_f P_{in}$

Where η_s is the Spillover efficiency and η_f Feed efficiency [5].

The Aperture Efficiency of an antenna was defined the ratio of the effective radiating (or collecting) area of an antenna to the physical area of the antenna /The ration of on-axis radiation intensity (I_m) and the non-ideal illumination the on-axis radiation intensity (I).

The antenna overall efficiency (η_{ov}) is the product of three other sub efficiency that are, aperture efficiency (η_a), spillover efficiency (η_s), and feed efficiency (η_f) [5].

$$\eta_{ov} = \eta_a \eta_s \eta_f \tag{8}$$

Any dual polarized feed produces a radiation pattern as

$$E_f = \frac{e^{-jk_0 r}}{r}\left[a_\theta e_\theta(\theta)\sin\phi + a_\phi e_\phi(\theta)\sin\phi\right] \tag{9}$$

where θ,Φ are polar angles relative to the feed axis. Aperture field on the reflector aperture plane is of the form (from the ray of optics).

$$E_a = \frac{e^{-2jk_0 r}}{f}\cos^2\frac{\theta}{2}\left[a_x(e_\phi - e_\theta)\sin\phi\cos\phi + a_y(e_\phi\cos^2\phi + e_\theta\sin^2\phi)\right] \tag{10}$$

Where *f* is the focal length of the reflector. Fourier transform of the aperture field in (10), gives the far field zone radiated field of the reflector. The co- and cross-polarized fields of the feed are proportional to ($e_\theta \sin^2\Phi + e_\Phi \cos^2\Phi$) and ($e_\theta - e_\Phi$) $\sin\Phi \cos\Phi$, respectively, and these are translated into E_y and E_x on the aperture plane of the reflector as seen in Fig.3

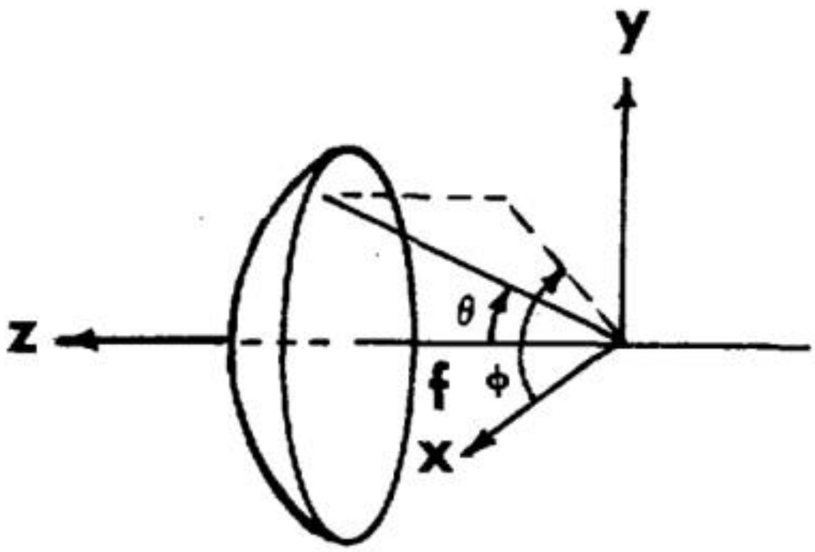


Fig.3. Prime focus antenna illuminated in θ and ϕ plane on the parabolic dish

From equation (10) Thomas [8] defines the Aperture efficiencies in the following form:-

$$\eta_a = \frac{8f^2}{a^2}\frac{[\int_0^{\theta_0}(|e_\theta|+|e_\phi|)\tan\frac{\theta}{2}d\theta]^2}{\int_0^{\theta_0}(|e_\theta|+|e_\phi|)\sin\theta d\theta}\times\frac{1}{2}\frac{[\int_0^{\theta_0}(|e_\theta|+|e_\phi|)^2\sin\theta d\theta]^2}{\int_0^{\theta_0}(|e_\theta|^2+|e_\phi|^2)\sin\theta d\theta}\times\frac{\left|\int_0^{\theta_0}(e_\theta+e_\phi)\tan\frac{\theta}{2}d\theta\right|^2}{\left[\int_0^{\theta_0}(|e_\theta|+|e_\phi|)\tan\frac{\theta}{2}d\theta\right]^2} \tag{11}$$

Aperture efficiency

Aperture efficiency (η_a):- The Aperture Efficiency of an antenna was defined the ratio of the effective radiating (or collecting) area of an antenna to the physical area of the antenna. The aperture efficiency (η_a) are the product of other three efficiency- illumination efficiency (η_i), cross polar efficiency (η_x) and phase efficiency (η_p).

$$\eta_a = \eta_i \eta_x \eta_p \tag{12}$$

Illumination efficiency (η_i):- The Illumination/Taper efficiency is a measure of the non-uniformity of the field across the aperture caused by the tapered radiation pattern, or other way we can say;

Loss due to non-uniform amplitude and phase illumination of the aperture plane.

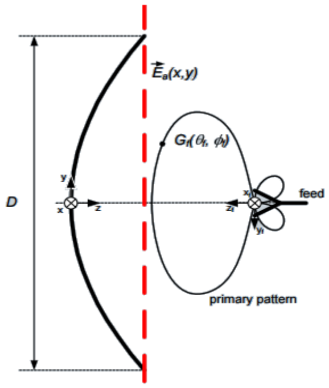


Fig.4. Illumination along the parabolic dish.

$$\eta_i = \frac{8f^2}{a^2}\frac{[\int_0^{\theta_0}(|e_\theta| + |e_\phi|)\tan\frac{\theta}{2}d\theta]^2}{\int_0^{\theta_0}(|e_\theta| + |e_\phi|)\sin\theta d\theta} \tag{13}$$

If $e_\phi = e_\theta$ the feed pattern and the aperture field have no cross-polarized field component [5].

Cross polar efficiency (η_x):- The cross polarization efficiency will be defined as the total co polarized radiated power divided by the total radiated power from the aperture.

$$\eta_x = \frac{1}{2}\frac{\int_0^{\theta_0}(|e_\theta| + |e_\phi|)^2\sin\theta d\theta}{\int_0^{\theta_0}(|e_\theta|^2 + |e_\phi|^2)\sin\theta d\theta} \tag{14}$$

For a rotationally symmetric reflector there is negligible additional cross polarization produced by the reflector itself;

$$\eta_x = \frac{\int_0^{\theta_0}(2|e_\theta + e_\phi|^2 + |e_\theta - e_\phi|^2)\sin\theta d\theta}{4\int_0^{\theta_0}(|e_\theta|^2 + |e_\phi|^2)\sin\theta d\theta} \tag{15}$$

Note that $\eta_x = 1$ whenever $e_\theta = e_\Phi$ but that $\eta_x < 1$ when $|e_\theta| = |e_\Phi|$ but the phase is not the same. If $e_\theta = je_\Phi$ then $\eta_x = 0.75$.

Phase efficiency (η_P):- The desired aperture field is Ey. This field produces maximum radiation on axis when E, is everywhere in phase. Hence the phase error efficiency could be defined as the ratio of the radiation intensity produced by E, on-axis to that produced by |Ey|.

$$\eta_p = \frac{\left|\int_0^{\theta_0} (e_\theta + e_\phi)\tan\frac{\theta}{2}d\theta\right|^2}{\left[\int_0^{\theta_0} (|e_\theta| + |e_\phi|)\tan\frac{\theta}{2}d\theta\right]^2} \tag{16}$$

Where f=focal length.

a = diameter of parabolic dish (45 miter dish).

e_θ and e_ϕ = electric field in θ direction and Φ direction.

θ_0 = Taper angle of Parabolic dish (62.624^0).

Spillover Efficiency

Spillover efficiency (η_S):- Spill-over is the ratio of the power intercepted by the reflecting elements to the total power. (Astron Definition now accepted by IEEE). Spillover is usually considered in transmit mode

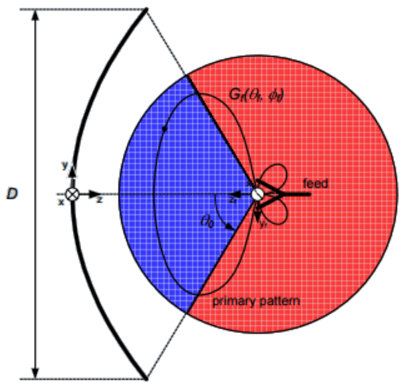


Fig.5. Prime focus along the parabolic dish.

In other ways when a feed illuminates the reflector, only a proportion of the power from the feed will intercept the reflector, the remainder being the spill-over power. This loss of power is quantified by the spill over efficiency.

$$\eta_s = \frac{\int_0^{\theta_0} (|e_\theta| + |e_\phi|)^2 \sin\theta d\theta}{\int_0^{\pi} (|e_\theta| + |e_\phi|)^2 \sin\theta d\theta} \tag{17}$$

The equation (17) can be rewrite in the other way;

$$\eta_s = \frac{\int_0^{\theta_0} (2|e_\theta + e_\phi|^2 + |e_\theta - e_\phi|^2)\sin\theta d\theta}{\int_0^{\pi} (2|e_\theta + e_\phi|^2 + |e_\theta - e_\phi|^2)\sin\theta d\theta} \tag{18}$$

It is observed that if the illumination efficiency increase then spillover efficiency decrease vis a vis is happen for reverse conditions.

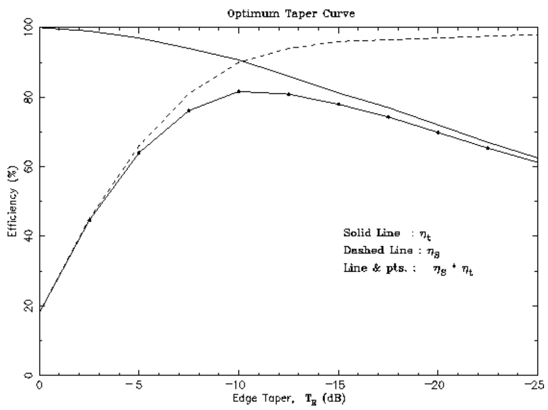


Fig.6. Illumination efficiency and Spillover efficiency and its product along with edge taper.

That is why for practical application we take its product. If the edge taper is 10 dB then its $\eta_i * \eta_s$ product reach upto 80%.

Where *f*=focal length.

a = diameter of parabolic dish (45 miter dish).

e_θ and e_ϕ =electric field in θ direction and Φ direction, θ_0 = Taper angle of Parabolic dish (62.624^0).

Feed Efficiency

Feed efficiency is the product of two sub efficiency- Mesh leakage efficiency (η_t) and Surface error efficiency (η_r).

$$\eta_f = \eta_t \eta_r \tag{19}$$

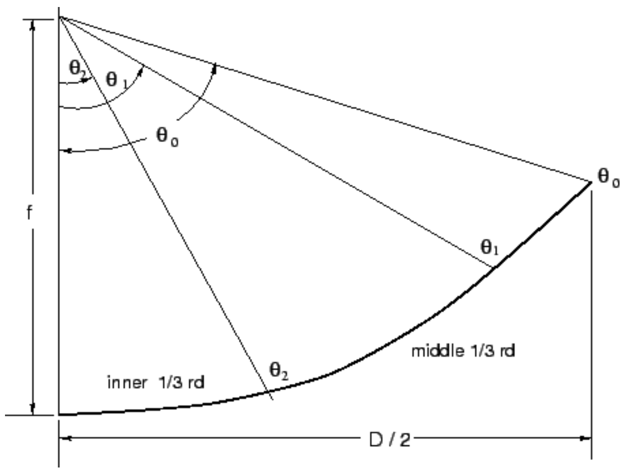


Fig.7. the sub division of the GMRT antenna surface into 3 zones. The mesh size as well as the rms surface error is different in the different zones.

Mesh leakage efficiency (η_t):- The respective transmission losses (at some given frequency) τ_1, τ_2 and τ_3 then Mesh leakage efficiency is;

$$\eta_t = \frac{B_1 + B_2 + B_3}{\int_0^{\theta_0} |e(\theta)|^2 \sin(\theta) d\theta} \tag{20}$$

Where

$$B_1 = (1-\tau_1)\int_0^{\theta_2} |e(\theta)|^2 \sin(\theta) d\theta$$

$$B_2 = (1-\tau_2)\int_{\theta_2}^{\theta_1} |e(\theta)|^2 \sin(\theta) d\theta$$

$$B_3 = (1-\tau_3)\int_{\theta_1}^{\theta_0} |e(\theta)|^2 \sin(\theta) d\theta \tag{21}$$

e_θ= Electric field in θ direction (assuming both E and H fields are symmetrical), and θ_0=62.624^0 θ_1=52.291^0 and θ_2=37.192^0

Surface error efficiency (η_s):- The respective surface error at some given frequency) σ_1, σ_2, and σ_3 then Mesh leakage efficiency is;

$$\eta_r = \frac{A_1 + A_2 + A_3}{\int_0^{\theta_0} |E(\theta)|^2 \sin(\theta) d\theta} \tag{22}$$

Where $$A_1 = \exp\left[-\left(\frac{4\pi\sigma_1}{\lambda}\right)^2\right]\int_{\theta_1}^{\theta_0} |e(\theta)|^2 \sin(\theta) d\theta$$

$$A_2 = \exp\left[-\left(\frac{4\pi\sigma_2}{\lambda}\right)^2\right]\int_{\theta_1}^{\theta_0} |e(\theta)|^2 \sin(\theta) d\theta \qquad (23)$$

$$A_3 = \exp\left[-\left(\frac{4\pi\sigma_3}{\lambda}\right)^2\right]\int_{\theta_1}^{\theta_0} |e(\theta)|^2 \sin(\theta) d\theta$$

Where e_θ = Electric field in θ direction (assuming both E and H fields are symmetrical), λ is wavelength.

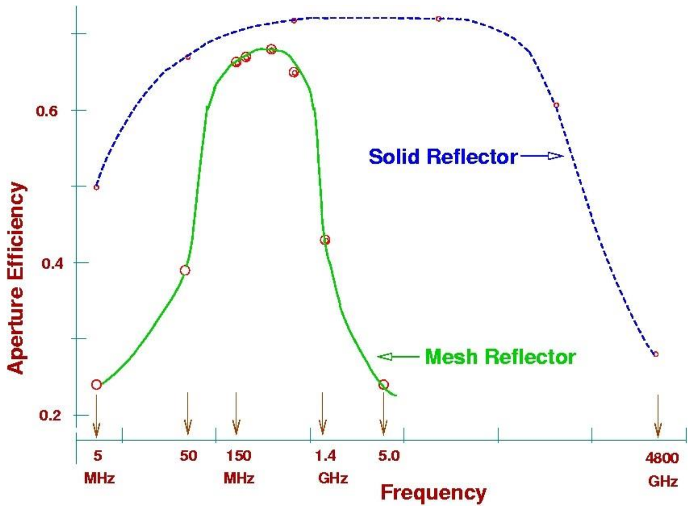


Fig 8: describes the solid and mesh reflector on efficiency at different frequencies

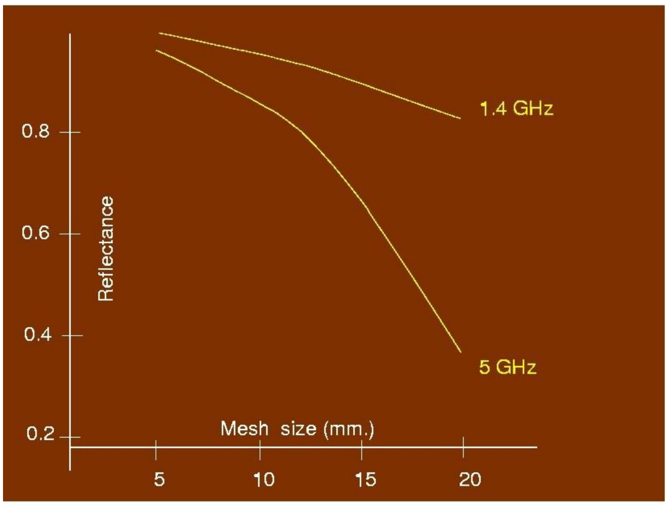


Fig 9: Describes the variation of reflectance property w.r.t mesh size at 1.4GHz and 5GHz

Parameter required for antenna efficiency calculation

The following parameter required for computing antenna efficiency they are fixed parameter and variable parameters are;-

Fixed parameters are:-

FOD- focal plane/ diameter
NL:-Number of Legs
D:-Diameter
FHA:-Feed House area
WLF:-Width of leg from Feed.
WLV:-Width of Leg Vert.
FLD:-Feed Leg Distance.
AL:-Leg Angle.

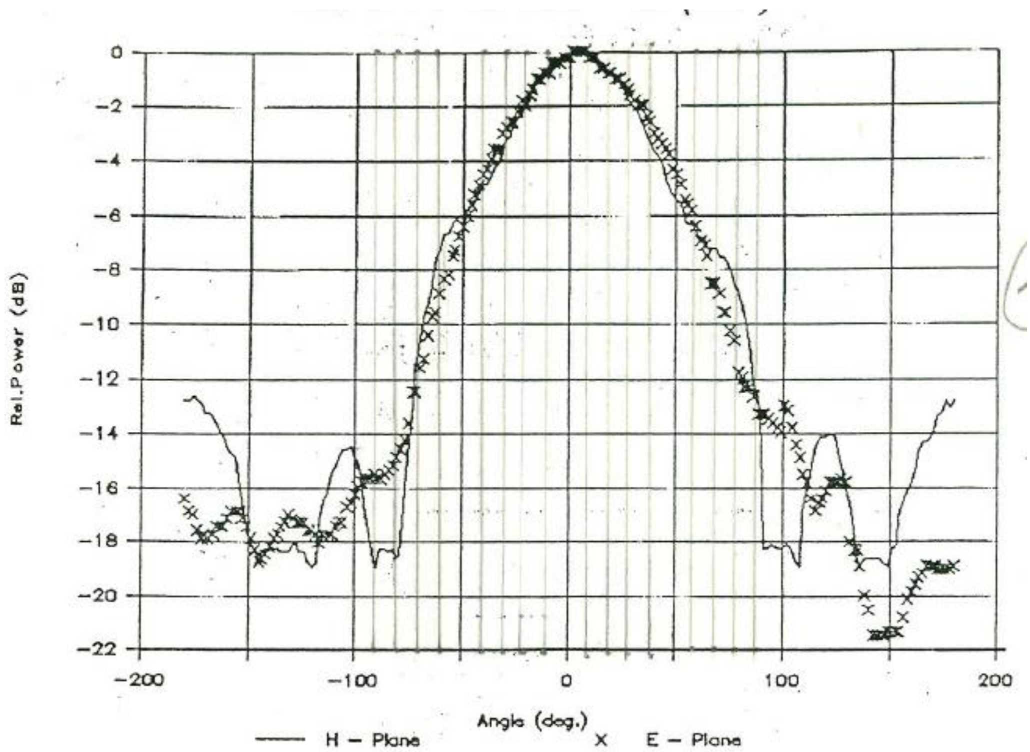
Variable parameters are:-

1. Frequency.
2. Radiation pattern
3. Mesh leakage efficiency, and Surface error efficiency.

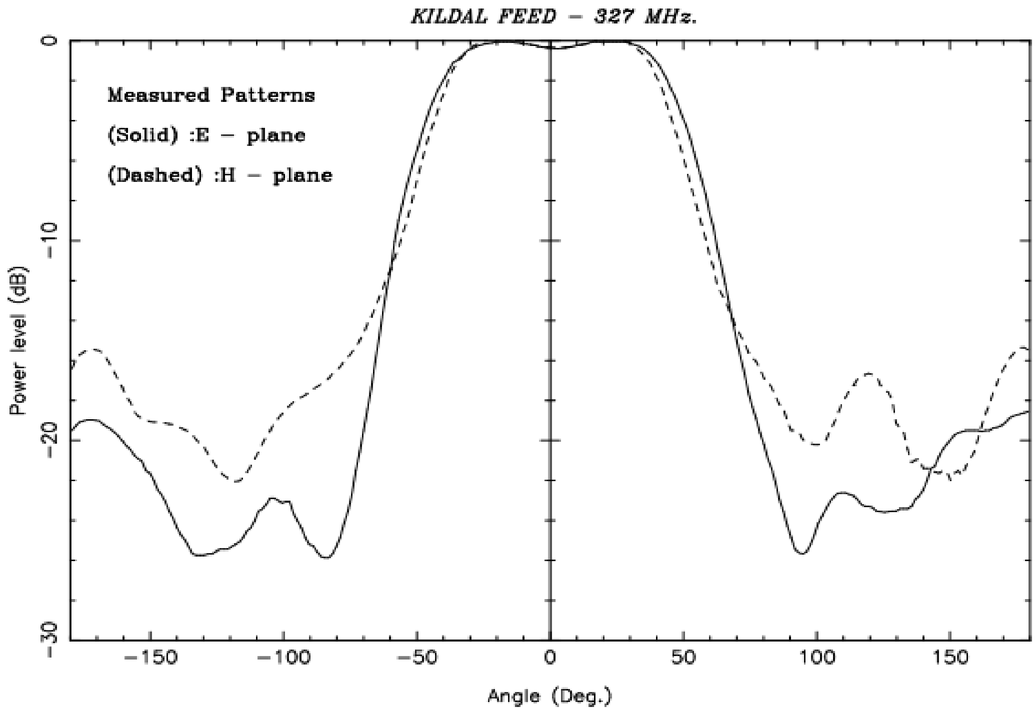
Antenna efficiency calculation of existing GMRT antennas

GMRT is operated in six frequency bands-50 MHz, 150 MHz, 235 MHz, 325 MHz, 610 MHz, and 1420 MHz. We are computed the efficiency calculation for all bands expect 50 MHz and 150 MHz.

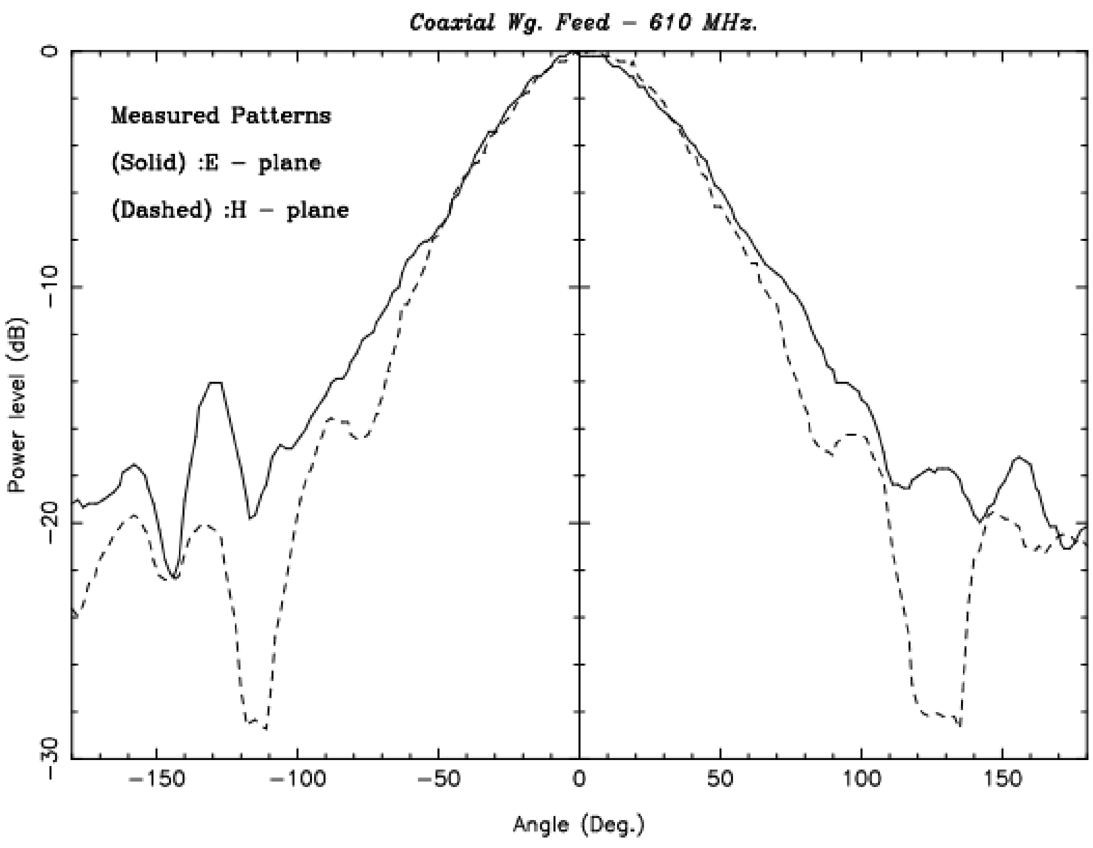
235 MHz band Radiation pattern



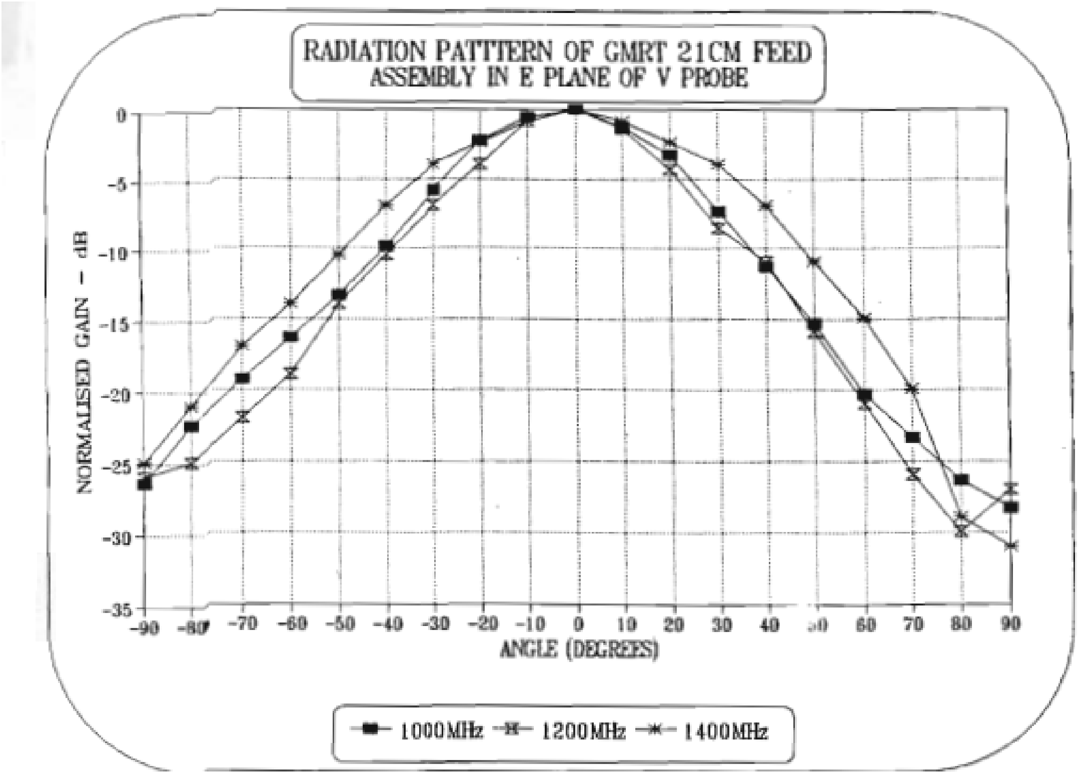
325 MHz Band Radiation pattern

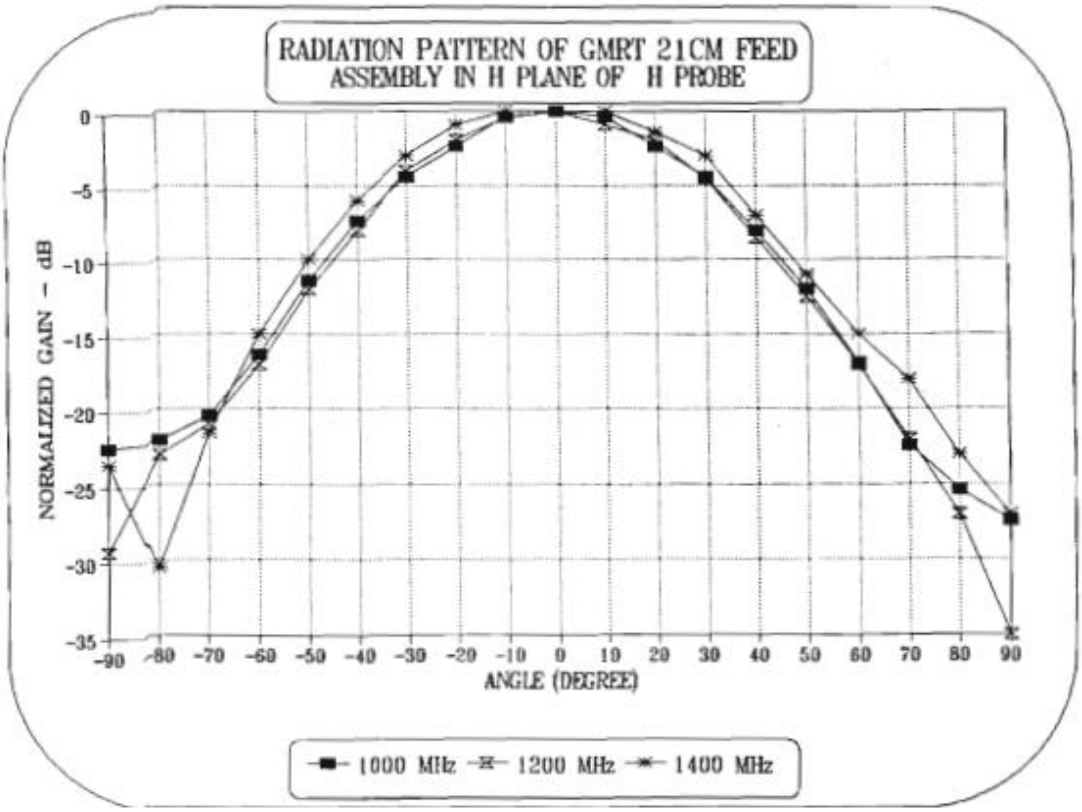


610 MHz Band Radiation pattern

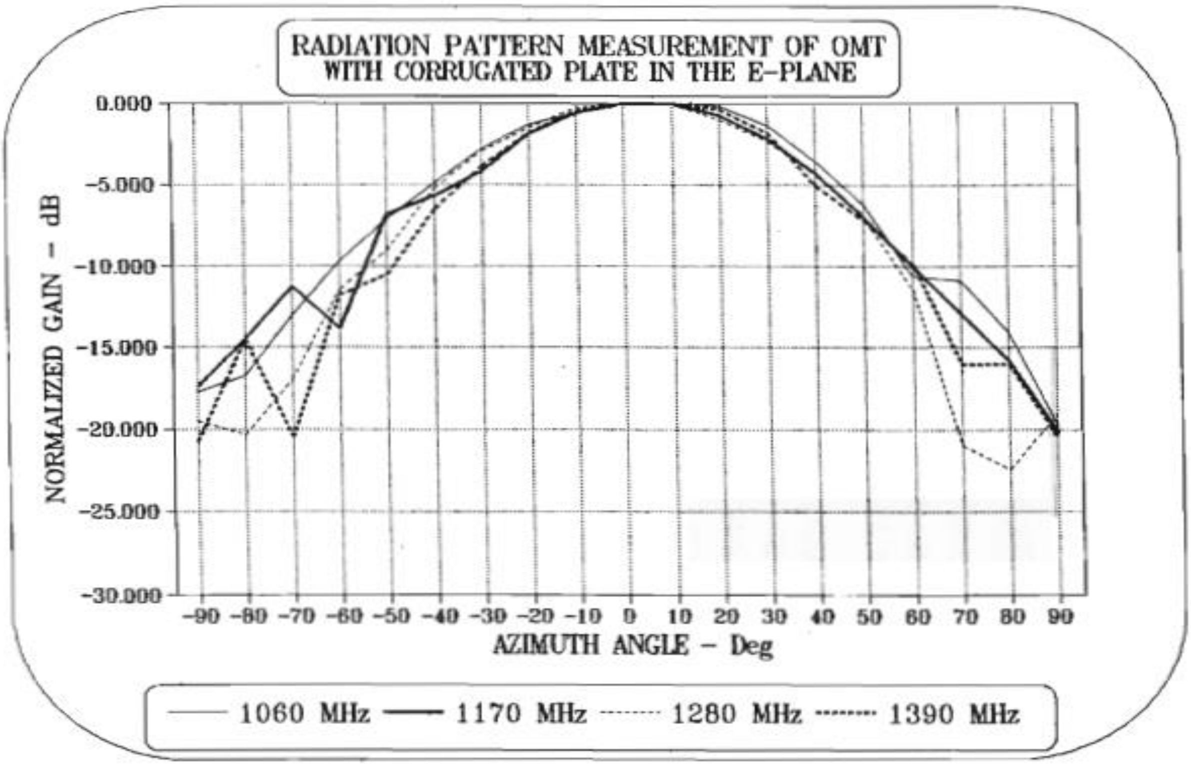


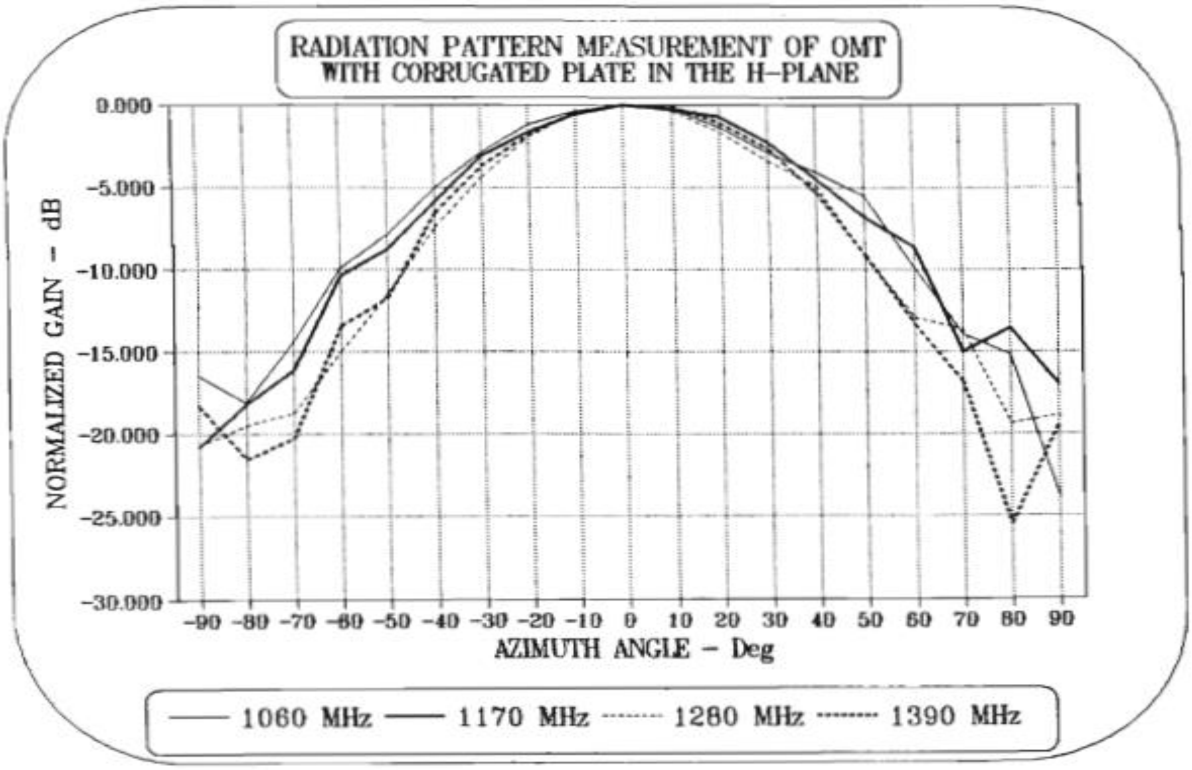
L Band Radiation pattern (1000 MHz, 1200 MHz, 1400 MHz)





L Band Radiation pattern (1060 MHz, 1170 MHz, 1280 MHz, and 1390 MHz)





Description of primary and secondary radiation pattern

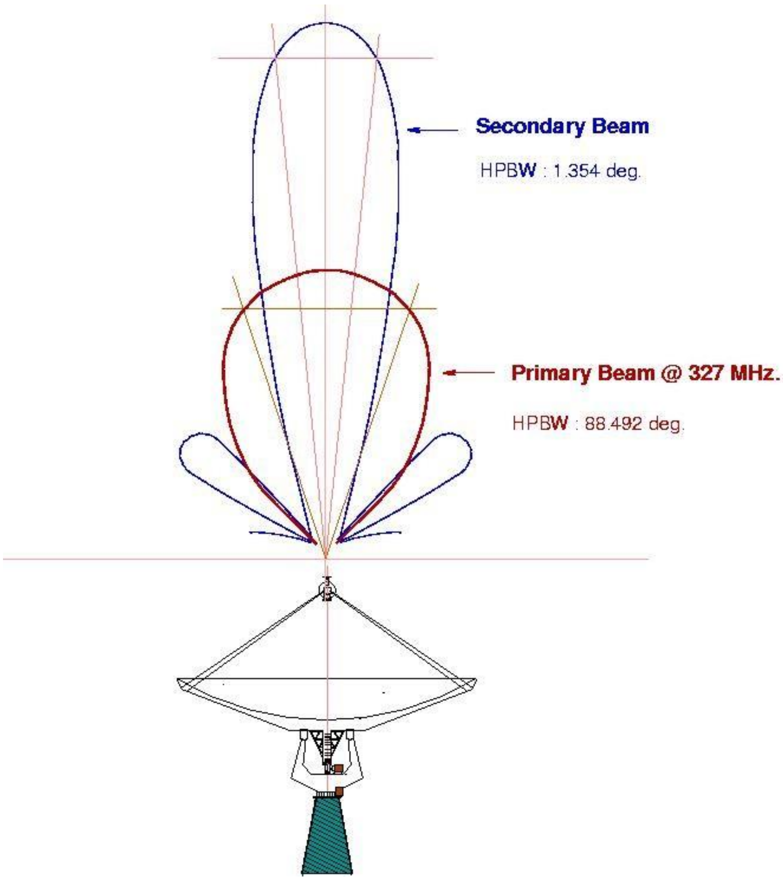


Fig 10: primary and secondary radiation pattern showing HPBW

System Temperature calculation

The power level of the radiation (W) can be traced from its reception by the feed, through the receiving system. The "signal" is generally noise-like (white noise, containing all frequencies in the band). For convenience, which will become clear, we often consider the equivalent noise temperature corresponding to the power level,

We can consider the power received by the antenna,

$$P_a = kT_a\Delta\nu, \quad (24)$$

Where T_a is the *antenna temperature,* and the output power of the receiver as

$$P_{tot} = P_a + P_{sys} => T_{tot} = T_a + T_{sys} \quad (25)$$

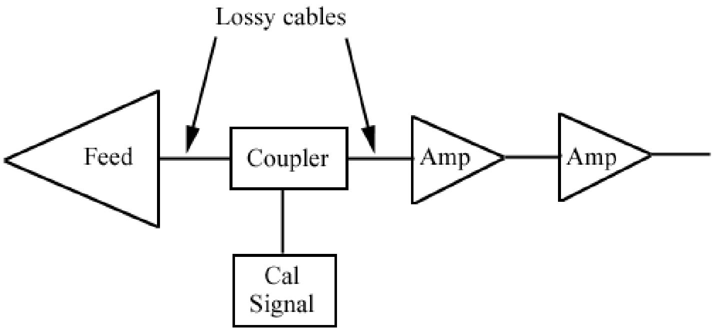


Fig.11. Sources of Noise in Receivers--the Front End

where Tsys is the system temperature, and represents the added noise of the system. It is a figure of merit, and should be kept as low as possible. We can break the system temperature into several contributions;

$$T_{sys} = T_{Rx} + T_{sky} + T_{Gnd} \tag{26}$$

T_{Rx} =Receiver Temperature;
T_{sky}= Sky background Temperature,
T_{Gnd}= Ground Temperature.

Ground Temperature (T_{Gnd})

Ground Temperature is addition of Spill-over temperature (T_{spill}), Mesh temperature (T_{mesh}) and Scatter temperature (T_{scat}).

$$T_{Gnd} = T_{spill} + T_{mesh} + T_{scat} \tag{28}$$

In the below we will describe the three temperature calculation are given below.

Spill Temperature (T_{spill})

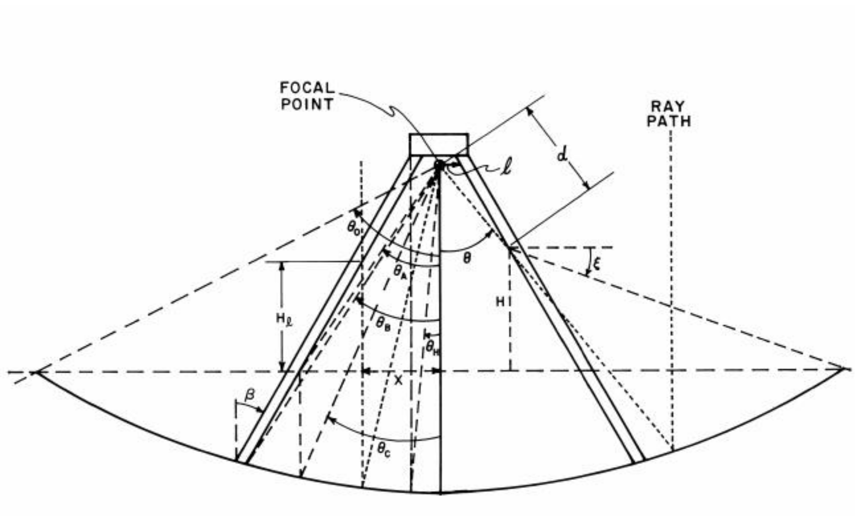


Fig.12. Feed Support legs

Spill-over temperature (Tspill) to account for radiation that the feed picks up in directions beyond the edge of the reflectors. The spill-over temperature is ;-

$$T_{spill} = T_g \frac{\int_{\theta_0}^{\frac{\pi}{2}} |E(\theta)|^2 \sin(\theta) d\theta}{\int_0^{\pi} |E(\theta)|^2 \sin(\theta) d\theta} \qquad (29)$$

where T_g=Effective ground Temperature (288 K)

Mesh leakage Temperature (T_{mesh})

Instead of solid if the parabolic reflector is mesh type. Then some part of ground energy will reflect back and that will increase the system temperature. That will called Mesh Leakage temperature (T_{mesh})

$$T_{mesh} = T_g(1-\eta_t), \qquad (30)$$

Where T_g=Effective ground Temperature (288 K)

η_t= Mesh leakage Efficiency

Effective Ground Temperature

NASA document says that the Black body temperature of Earth is 254.3 K, but due to Green house effect it vary from 283 K to 293 K, best take the average.

Scattered Temperature (T_{scat})

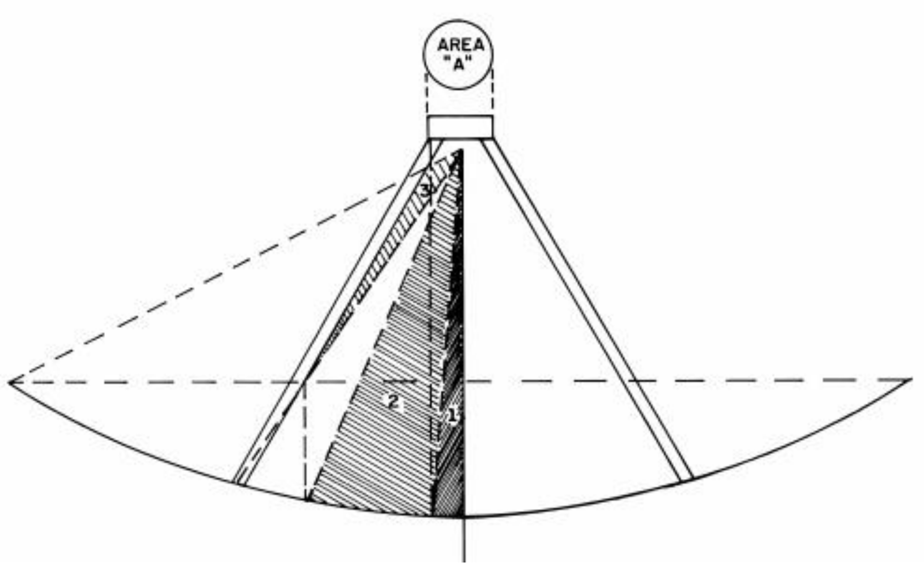


Fig.13. Ground Radiation scattering integrals

Due to feed support structures some of the ground radiation are scattered and contributed to increase the system temperature. Those scatter radiation are coming from feed house, dish to sky, and feed to dish scattered ground radiation temperatures, respectively (referred Fig 13). The total of the three is the increment to the system temperature due to feed support structure scattering. The scattering temperature equation is;

$$T_{scat} = T_g (S_H + S_L + S) \tag{31}$$

whereas T_g = Effective ground Temperature (288 K)

S_H = Integral of the fraction of energy scattered to the ground by the feed house.

S_L = The fraction of power scattered to the ground from all legs in region 2(refereed Fig.13).

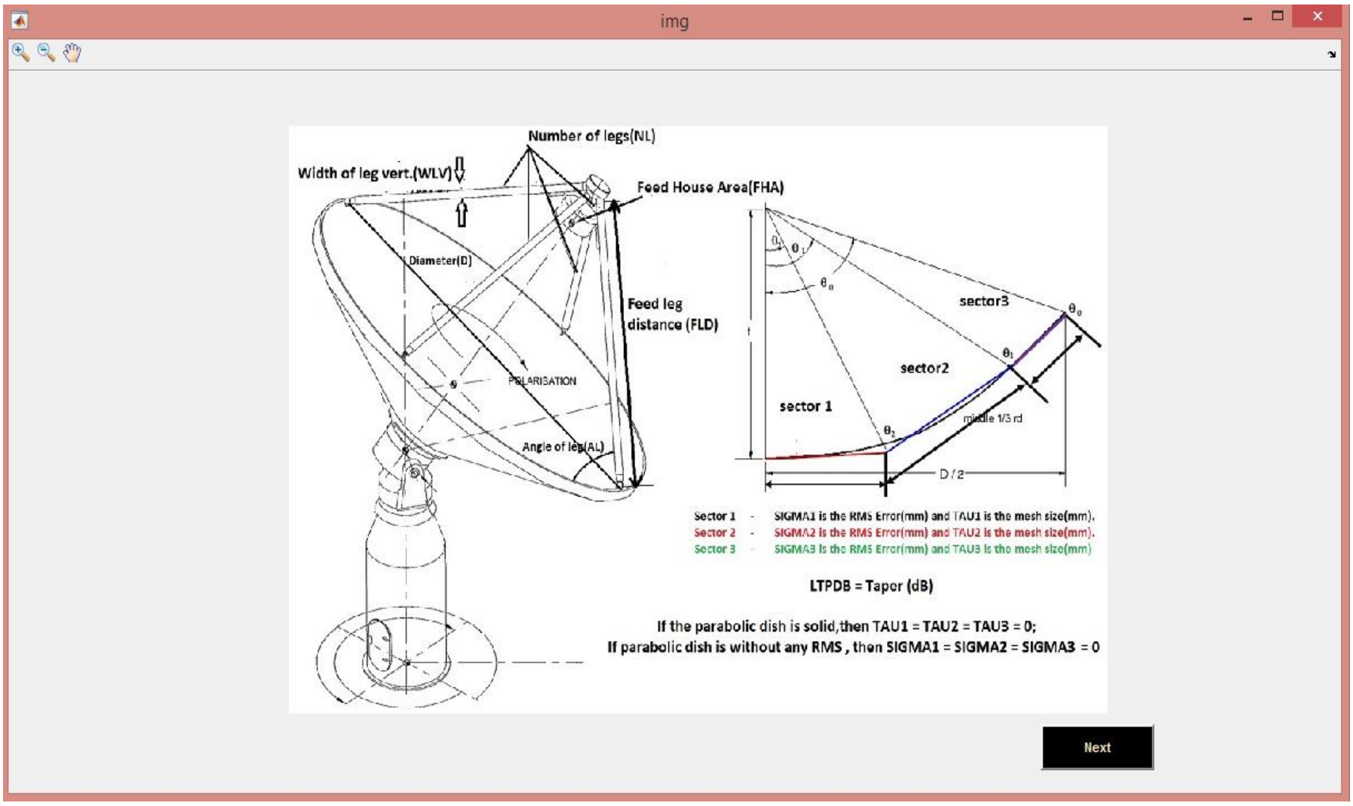
S = The fraction of radiation scattered to the ground between θ_A and θ_0 (refereed Fig.13).

GUI BASED ANTENNA EFFICIENCY CALCULATOR

It is a GUI interface which can be used to calculate the Antenna Efficiency and also the Temperature parameters based on the given input parameters.

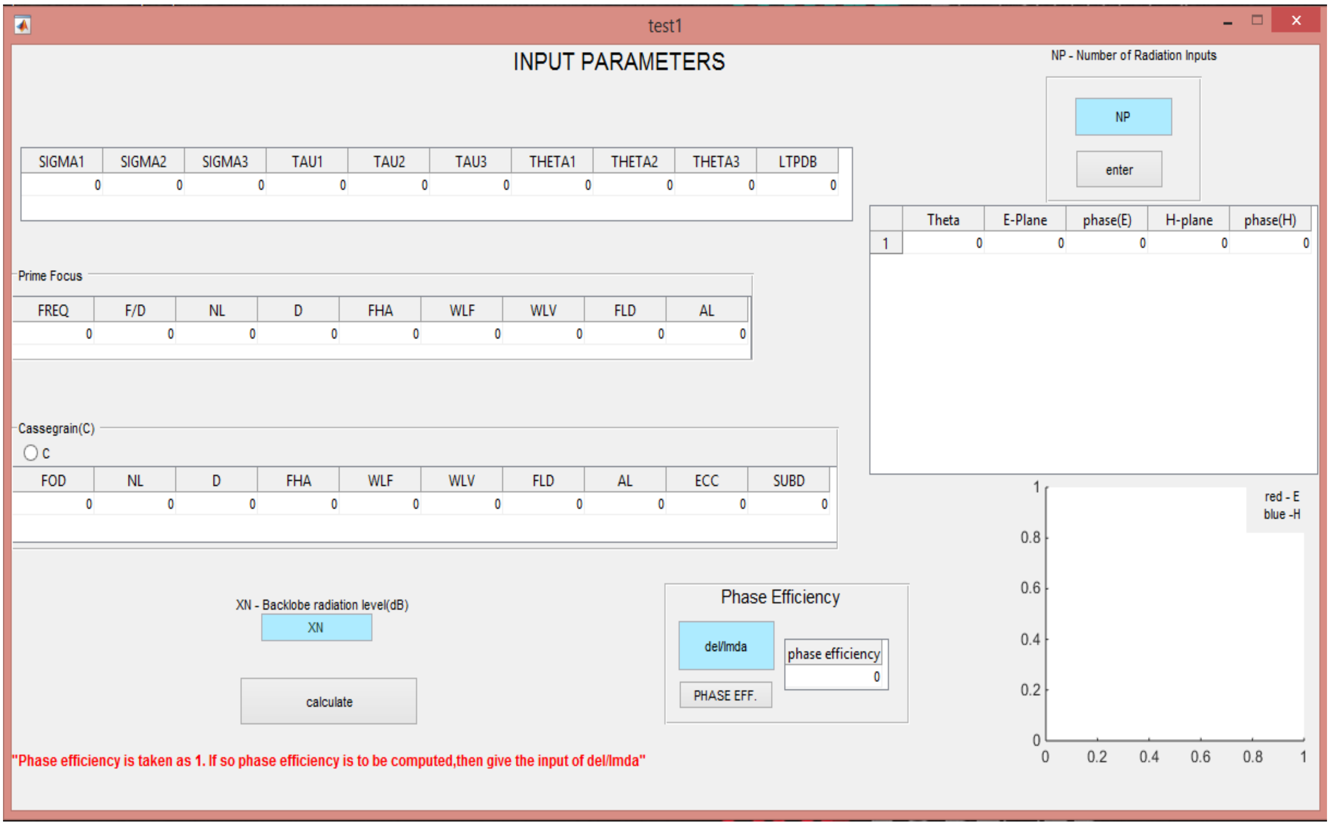
This GUI consists of 4 windows which are used to take input, give output and plot the secondary radiation pattern.

The first window shows the image which describes about the input parameters. And the GUI window is shown below:



In this window, On clicking the ‘Next’ button, we will get the GUI window which takes the input.

The GUI interface which takes input is shown below:



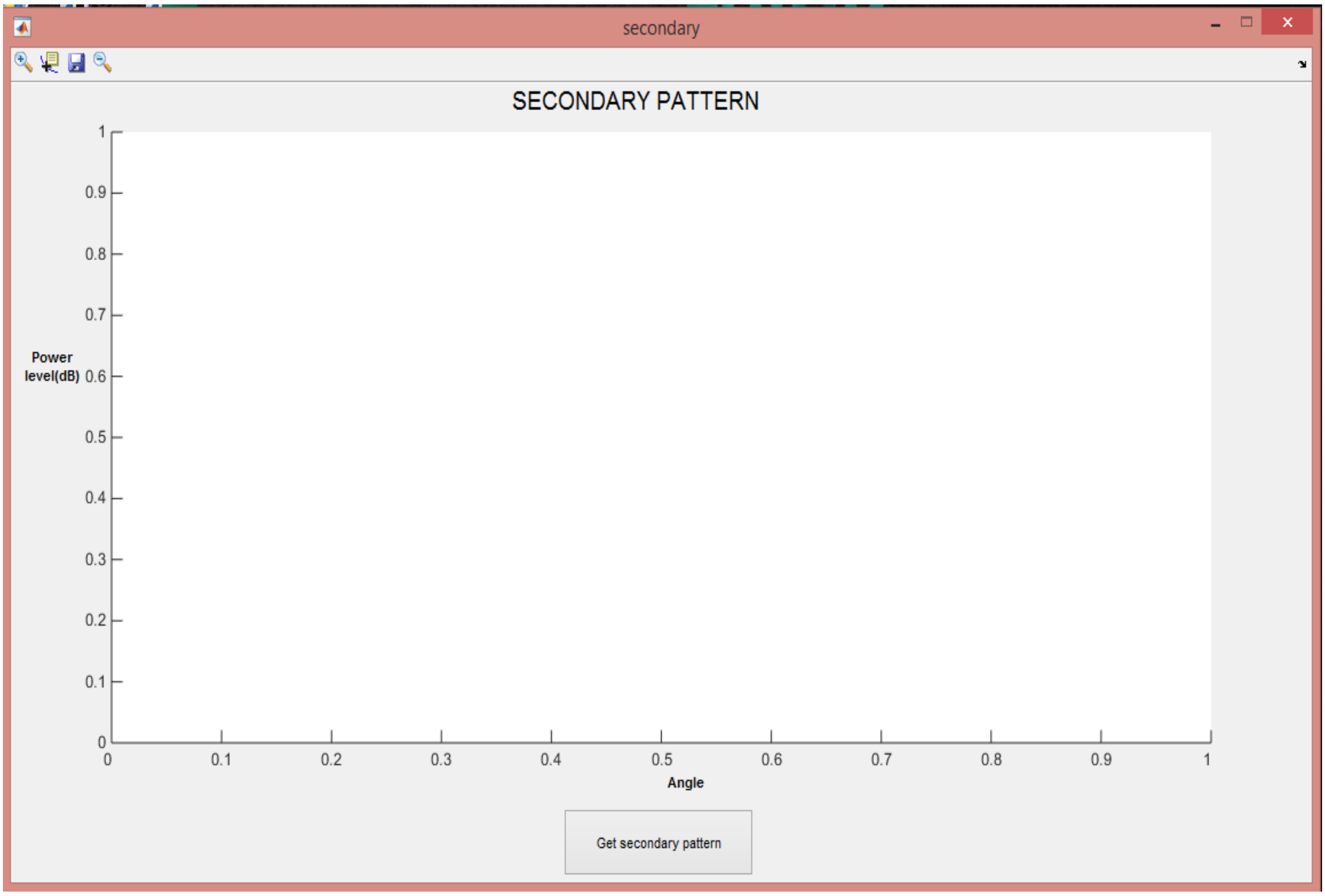
This is the window which is taking input parameters such as:

- SIGMA1 ,SIGMA2 and SIGMA3 – RMS errors (in mm)
- TAU1,TAU2,TAU3 – Mesh Sizes (in mm)
- THETA1, THETA2 and THETA3 (in degree)
- LTPDB – (Taper in dB)
- The C radio button is used to select for Cassegrain type of antenna and it also has a table which is used to give inputs for Cassegrain type antenna.
- Otherwise we have another table for giving inputs for Prime focus antenna.
- XN-back lobe (in dB).
- NP is used to enter the no. of parameters we want to give so that those many rows are given in the above table which has the parameters Theta , E- plane ,H – plane and phases.

Thus, these are the main input parameters we need to give to get the antenna efficiency and temperature parameters and also the secondary pattern. On clicking 'Calculate' button, it gives the secondary pattern and output and also we get a plot of radiation pattern that we have given as input in this window only at the bottom right corner.

Now, we also have another feature in this GUI which is helpful to find phase efficiency at a particular value of del/lmda which is given as input. Generally while calculating Overall efficiency, we take phase efficiency to be one.

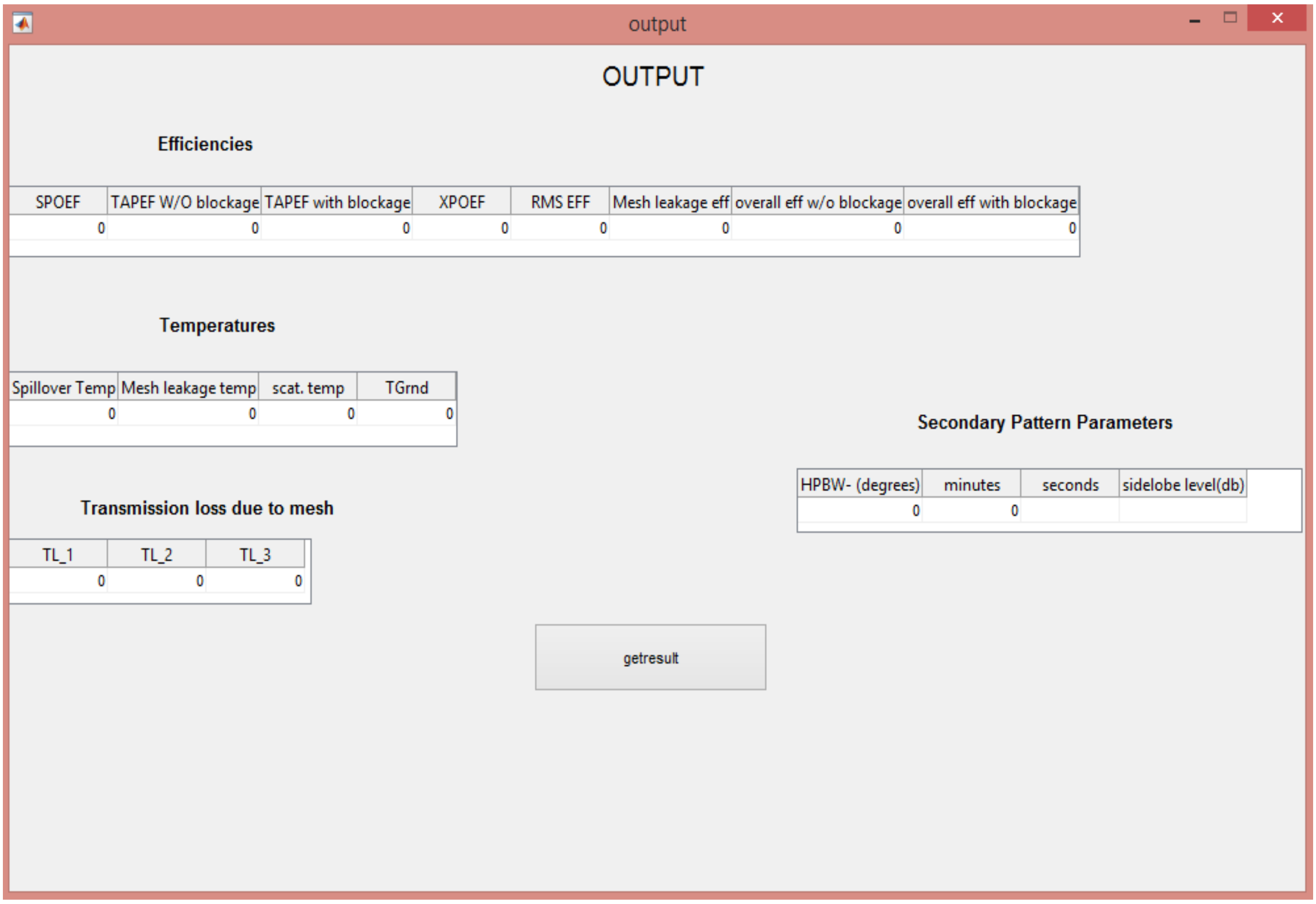
The GUI window which gives a plot of secondary pattern is shown below:



On clicking the 'Get Secondary Pattern button', we get the secondary pattern with Power level (dB) on Y-axis and Angle on X-axis.

This window has features like Zoom in, Zoom out, data pointer and also have an option for saving the plot.

And there is another GUI window which shows the output i.e. efficiencies and temperature parameters, etc., and the window is shown below:



This is the output window which gives many parameters like:

- Taper or Illumination efficiency with and without blockage
- Spill over Efficiency
- Cross polar efficiency
- RMS efficiency
- Mesh leakage Efficiency
- Overall Efficiency with and without blockage
- Spill over Temperature
- Mesh Leakage Temperature
- Scattering Temperature
- TGrnd (Mesh + Scatter + Spill over temperature)
- Transmission losses due to mesh and
- Half power bandwidth and side lobe level

Thus, these all parameters help us to understand the Efficiency and Ground temperature of an antenna, which is useful for computing the sensitivity analysis.

This GUI model is made using the MATLAB software. And thus it works only in a system which has a MATLAB. So, since MATLAB is a costlier software, this GUI model is made as a .exe using application compiler in MATLAB and thus the file which can be installed on any system which even don't have a MATLAB software in it.

Installation Steps:

- This application can be installed with or without internet.
- If you want to install with the help of Internet then make sure that your system is provided with the internet.
- Then in the given folder named with the application name for Efficiency_Computation_tool, go to the folder named as redistribution.
- And from there select the .exe file MyAppInstaller_web if you install through net or else run the .exe file named as MyAppInstaller_mcr and this will help you to install the application.
- And later you can open the installed application and use it to calculate the antenna efficiency parameters, etc.

RESULTS: -

Existing GMRT feed Efficiency calculation

Efficiency parameters	235 MHz	327MHz	610MHz	1000MHz	1200MHz	1400MHz
Taper eff. With blockage	0.8284	0.7144	0.8023	0.5706	0.5683	0.5983
Taper Eff. W/O blockage	0.8981	0.7797	0.873	0.6405	0.6379	0.6673
Spillover efficiency	0.7991	0.954	0.8359	0.7973	0.9235	0.7377
RMS efficiency	0.9856	0.9808	0.9502	0.8916	0.8453	0.7906
Crosspolar efficiency	0.9998	1.000	1	0.9976	0.9948	0.9984
Mesh leakage efficiency	0.9926	0.9911	0.9802	0.9643	0.9480	0.93
Overall efficiency with blockage	0.6475	0.6625	0.6291	0.3902	0.4184	0.3233
Overall efficiency w/o blockage	0.7020	0.723	0.6846	0.4380	0.4696	0.3605

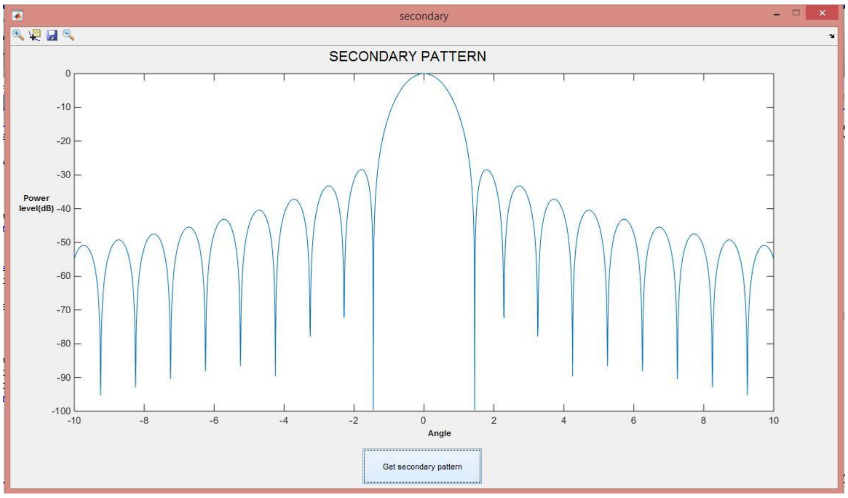
Ground Temperature calculation of existing GMRT bands (spot frequency)

Spot Frequency	Spill Over Temp (T_{spill})	Mesh leakage Tem (T_{mesh})	Scattered Temp (T_{scat})	Ground Temp (T_{Gnd})
235 MHz	48.9898K	2.1280K	2.2620K	48.9898K
327 MHz	9.4426K	2.5623K	2.6907K	14.6956K
610 MHz	32.9332K	5.7128K	2.6623K	41.3083K
1060 MHz	22.0630K	13.6941K	2.7999K	38.5569K
1170 MHz	19.2484K	16.3757K	2.7955K	38.42K
1280 MHz	10.997K	19.40K	3.1515K	33.55K

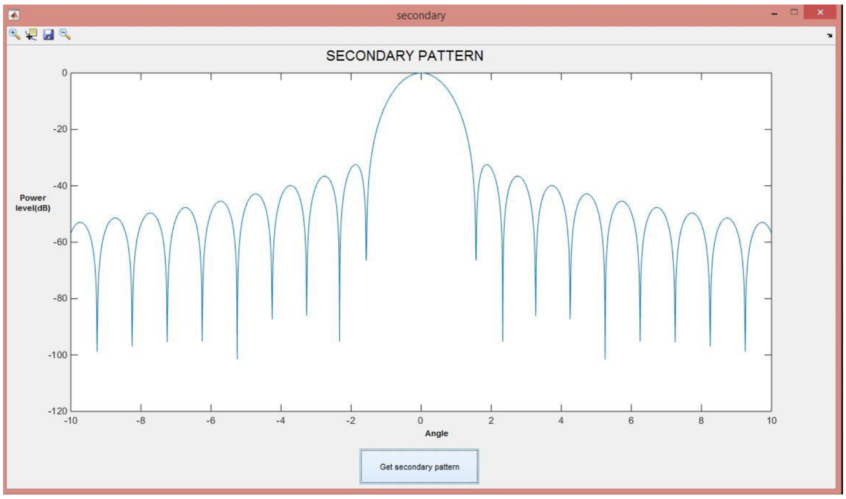
Taking effective ground temperature as 288K.

Computed secondary patterns of existing GMRT feed (spot frequency)

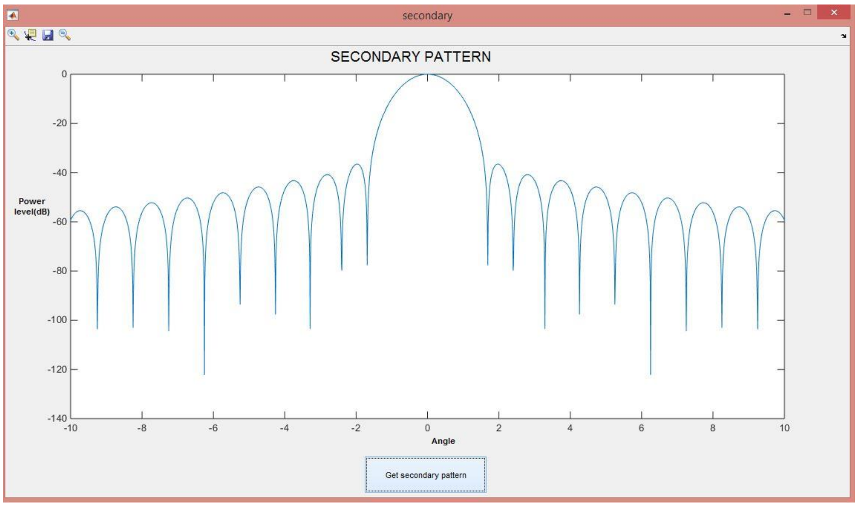
235MHz



327MHz



610MHz



Upgraded 250 – 500 MHz:-

Efficiency calculation

Frequency (Taper in dB)	Taper eff. (Blockage)	Cross-polar eff.	Spill over Eff.	RMS eff.	Mesh eff.	Overall eff.
250 MHz(12)	0.7404	0.9959	0.906	0.9869	0.9931	0.6548
300 MHz(13)	0.735	0.9985	0.9199	0.9852	0.9936	0.6606
327 MHz(12)	0.7429	0.9998	0.9391	0.9822	0.9926	0.68
360 MHz(11)	0.739	0.9996	0.9331	0.9791	0.992	0.669
400 MHz(15)	0.731	0.9964	0.946	0.9719	0.9896	0.663
450 MHz(11)	0.7685	0.9994	0.9545	0.9667	0.9875	0.6997
500 MHz(11)	0.748	0.9983	0.9449	0.9584	0.9851	0.667

Ground Temperature calculation

Frequency	Spill-over temp.	Mesh leakage temp.	Scattering temp.	Ground temp.
250 MHz	19.5439K	1.9991K	2.8304K	24.3734K
300 MHz	16.1184K	1.8423K	2.9609K	20.9216K
327 MHz	14.9336K	2.1251K	2.9921K	20.0509K
360 MHz	16.1342K	2.3604K	3.0341K	21.5287K
400 MHz	11.3613K	2.9917K	3.1886K	17.5416K
450 MHz	9.9105K	3.6027K	2.7070K	16.2202K
500 MHz	12.9759K	4.2859K	2.9271K	20.1888K

Secondary patterns HPBW and side lobes upgraded 250-500 MHz

Frequency	HPBW	Side lobes(dB)
250 MHz	1°50'0.4748"	-29.5
300 MHz	1°32'49.1498"	-30.6
327 MHz	1°25'9.3117"	-29.5
360 MHz	1°15'26.3666"	-28.25
400 MHz	1°11'19.9947"	-32.6
450 MHz	1°0'21.0933"	-28.25
500 MHz	54'18.9839"	-28.25

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