The NCRA Test Range for Wide-band Feeds Development (under XI Plan)

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1 Introduction :

The old Test–Range (at NCRA,Pune) was constructed in 1989 and was used extensively during 1990 to 1992 for the prototype feeds characterization. The final designs for 327, 610 & 233 (dual frequency support) and 150 MHzs. feeds were frozen at this Range. The range too evolved from a primitive system (manual rotation; graduated disc to measure angles and received power measured by analog Vector Voltmeter) to an advanced one (stepper-motor driven; multi-turn potentiometer readout for angles and digitized power recorded on floppy disk), during those two–year period. Further improvements was limited by restricted space–availability and the Range was inadequate for 50 MHz prototype development. Keeping in mind the need for future developments in the GMRT feeds (wider bandwidth, enhanced polarization characteristics etc.),a new Range design is outlined here. The structures of the old range are dilapidated and beyond the stage of repair/ re-construction. So a new range is proposed to be built over the e-lab. terrace for the test antenna the source antenna could be placed either on CML terrace/Hostel terrace.The prime–source of reference for this design is the **IEEE Standard: 149-1979**.

2 Range Design Criteria :

The first and foremost criterion is to minimize the coupling between the Source and Test antennas' field. The reactive field of the Source antenna should be lower than 36 dB of its radiation field (at the Test antenna location). If it were higher than this level, the amount of mutual coupling between Source and Test can cause a measurable error in the level of the signal observed near the peak of the Test antenna's major– lobe, although similar effect on the side–lobes is negligible. In terms of the horizontal distance R_0 and the wavelength of interest, this criterion condenses to :

$$R_0 \geq 10 \cdot \lambda \tag{2.1}$$

The next criterion concerns about the Source antenna's radiation parameters. Broader beam-width source results in increased error due to reflections at the Test aperture. If a more directive source is used, the alignment of the Source antenna becomes more critical (i.e., one

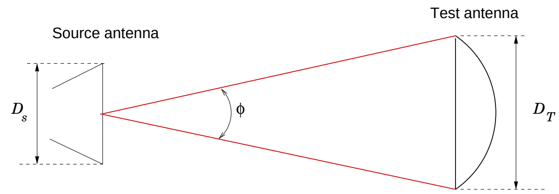


Fig. 1.

should orient the Source antenna so that its peak (of main–lobe) is centered on the Test antenna). So the parameter to be optimized here is the taper of the Source antenna's amplitude pattern. If the Source antenna taper is -0.5 dB then the apparent directivity reduction (of the Test antenna) is 0.15 dB as compared to a Source *without* any taper. Similarly if the taper is -0.25 dB the directivity reduction is 0.1 dB only.

Based on the geometry shown in Fig.1,if ϕ is the plane-angle subtended at the Source antenna, then

$$\phi = \frac{D_t}{2R_0} \tag{2.2}$$

The 0.25 dB amplitude taper condition can now be written as,

$$\frac{\phi}{\theta_{3dB}} \leq 0.3 \tag{2.3}$$

where,θ_{3dB} is the half-power beam-width of Source antenna's pattern.
If the above condition is satisfied then the re-radiated signal reaching the Test antenna will be $\leq$ 45 dB below the original received signal.

`Effect of Phase variation over the Test antenna aperture :`

The effect of phase variation is that the nulls of the Test antenna are partially filled and the amplitudes of the side-lobes are changed.The phase variation over aperture,$\Delta\phi$ is given by,

$$\Delta\phi \approx \frac{\pi {D_t}^2}{4\lambda R_0} \tag{2.4}$$

A common criterion is to restrict $\Delta\phi = \pi/8$ rad., and hence

$$R_0 \geq \frac{2{D_t}^2}{\lambda} \tag{2.5}$$

,the ubiquitous Eqn. of Test Range.

3 Elevated Ranges :

These Ranges are in which the Test and Source antennas are located on towers,or adjacent mountain peaks, or on the roofs of the adjacent buildings or on diagonally opposite sides of abandoned quarries. Generally it is designed over an approximately flat area. The effect of the surroundings are suppressed by:

1. careful choice of the Source antenna with regard to directivity and side-lobe level

2. clearance of the line-of-sight along the Range surface

3. redirecting or absorbing of energy reaching the Range surface or obstacles that cannot be removed

4. special signal processing techniques such as modulation tagging of the desired signal

5. use of short pulses in transmission

For Elevated Ranges, the 0.25 dB amplitude taper criterion modifies to a criterion for the diameter of the Source antenna d,such that

$$d \leq 0.37KD_t \tag{3.1}$$

where K is a constant ($K = 2$ for 2.5).
This presumes the main lobe of the Source antenna has a $\frac{\sin x}{x}$ amplitude characteristics. The basic design goal of Elevated Range should be – the Range surface in front of the Test antenna should not intercept any power contained in the main-lobe of the Source antenna. A better choice would be – the first null in the radiation pattern of the Source antenna be directed towards the base of the Test antenna tower. This leads to

$$d \geq \frac{1.5K \times D^2}{h_r} \tag{3.2}$$

where h_r is the height of the Test antenna. This is derived with the presumption that typical Source antennas have a main-lobe width $\sim$
$\frac{3\lambda}{d}$ rad.
Comparing 3.1 and 3.2,

$$\begin{aligned} h_r &\geq \frac{1.5D}{0.37} = 4.05D \quad (3.3) \\ &\geq 4D \\ & \quad (3.4) \end{aligned}$$

4 Ground reflections :

In Elevated Ranges the ground reflection is a serious design– constraint. The grazing angle of incidence,ψ should be kept small in order to avoid operating at the Brewster angle. As the Brewster angle is approached, the magnitude of the reflection coefficient of the flat range surface decreases to a low value for vertically–polarized waves, whereas the horizontal polarized waves are unaffected. Generally for dry soil surfaces, the Brewster angle is approximately 14°. In terms of the Range geometry,

$$\begin{aligned} \tan\psi &= \frac{2h_r}{R_0} \quad (4.1) \\ &\neq \tan 14^\circ = 0.249 \\ h_r &\neq 0.1247R_0 \\ & \quad (4.2) \end{aligned}$$

Eqns. (2.1),(2.3),(2.5),(3.4) and (4.2) are the complete set of design–equations for the Elevated Range.

5 New Test Range :

Since the Test antenna the Source antenna will be stationed on the terraces of e-lab CML/hostel, the h_r will be in the range 6.5 to 7.5 m. This does not satisfy the Eq.(3.4) for 50 150 MHz. feeds. To test a 120 MHz. feed, h_r should be $\geq$ 15.0 m., which implies keeping the antennas at water-tank's top(2nd floor terraces) at both ends. For the first-level design, if we choose a height of 7.5 m.it would cater to all feeds above 150 MHz. A re-deployed antennas at increased height of 15 m. at a later stage could serve the lower freq.band as well.

If R_0 is chosen as 100 m., then $\psi = 8.53°$, which is well below the Brewster limit of 14°. So the New Range's parameters are:
$h_r = 7.5$ m.; $R_0 = 100.0$ m.

The terrace of the e-lab will house the azimuth platform, which must rotate through full 360° . The Test antenna will be mounted on a metre-high mast, with adjustable height so as to be exactly at the beam centre of the Source antenna.Fig.2 illustrates the proposed test platform structure.

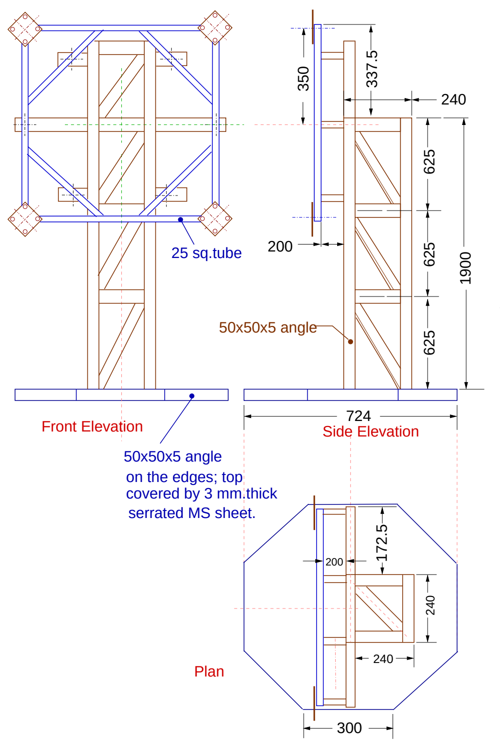
The azimuth rotation should be capable of the range : $\pm 200°$ and the rotational speed can be of $1 - -2°$ /sec. The RF cable to the Test antenna winding and un-winding can be taken care of by the drive circuit such that any two subsequent scanning (of the azimuth plane) will be done in mutually opposite rotating directions (i.e.,cw and c-cw). Angle read–out and data logging can be done by an incremental encoder fitted to the azimuth rotation.

The source antenna will be a log-periodic one covering the range of 100–2000 MHz.A small motorized assembly to position this antenna in horizontal, vertical,45° and 135° to the horizon will be needed. The latter two angular positions are for cross-polar co-polar radiation pattern measurements.

6 Powering the Source Antenna :

The proposed Range should be capable of testing antennas and feeds from 120 MHz to 2 GHz. Coaxial transmission lines can indeed support this full band yet the losses at high frequencies limit the sensitivity of the Range.

Presuming a total length of cable from Test tower to Source tower (with enough free–spooling at the Source tower, as pointed out in Sec.5) as 200 m., If one employs a low–loss cable (LMR500) the attenuation turn out to be : 14 dB at 450 MHz and 27 dB at 1.5 GHz. This LMR500 cable with a 40 dB amplifier will be able to support the full width of the frequency band but there are two limitations:



NCRA Test Range – Test Antenna Platform

Not to Scale ; All dimensions are in mm.	
Design & Drawn : G.Sankar.	
GMRT – TIFR	18.05.2010

- side–lobe as well as back–lobe power levels may not be discernible within the noise levels of amplifier

- Cable must be protected from rodents by encapsulating it in a PVC /G.I. pipe, buried at ∼;0.5 m. depth

If we choose LMR600, the attn.values are: 11 dB at 450 MHz. 22 dB at 1.5 GHz. and thicker cables like LMR1700 were used, then attn.goes down to 4 dB at 450 MHz. 8 dB at 1.5 GHz.

Another option is to install the currently developed CWDM Fibre- optic system to transmit and detect the RF in the analogue domain.Laser operates in the 1510 nm band.Fig.3 gives the basic block daigram of the CWDM fibre-system.

The output power of the receiver is limited to 0 dB and hence the 10 dB amplifier shown next to the receiver pumps enough power to the Source antenna. The optical receiver will be located at the Source tower. The optical fibre can be buried between the buildings, encapsulated by PVC /G.I. pipe.
For higher frequency measurements in the region of 2 – 5 GHz., the optical fibre system could be more cost-effective than the low-loss cable system.A prudent choice can be made depending on the demands of the test range usage.

7 Data logging :

The Test antenna's received power,as measured by a Spectrum Analyzer at every azimuth angle has to be logged into a LabVIEW interfaced PC along with the angle. Angle information can be directly acquired from the incremental encoder.
A RF power meter would be sufficient to measure the received power. A analyzer would augment the measurements by showing the local RFI scenario too; a 'quiet' time could be chosen to measure sensitive parameters of the feed under test (viz.during phase centre measurements).

The e-lab below the Test tower will house the following test equipments:

- Signal Generator (10 MHz to 5–6 GHz.)

- Optical Transmitter

- Drive–interface for Azimuth rotation and Angle–readout

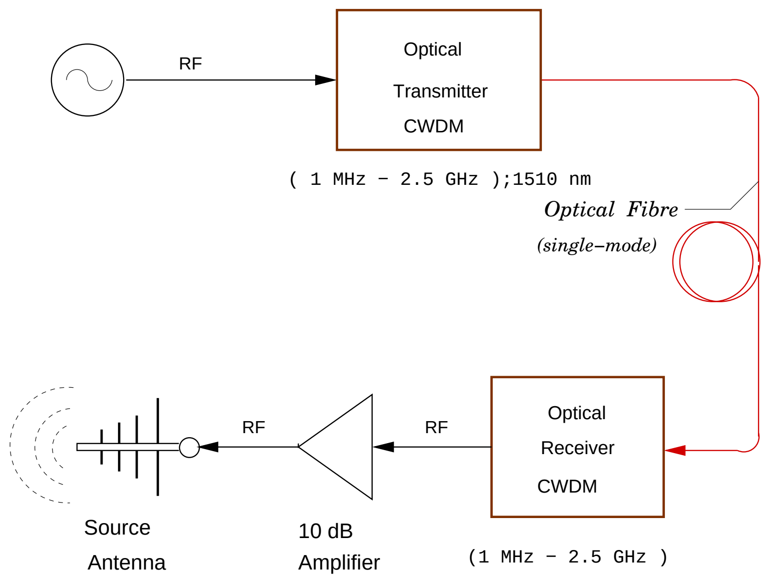


Fig. 3 Powering up the Source antenna – CWDM FO system.

- Spectrum Analyzer
- PC with LabVIEW, interfaced to the Spec.Analyzer
- Ink-jet printer/plotter(optional)

7.1 Note :

This is a revised report of a previous one titled 'The New Test Range at NCRA–TIFR Campus (Design & Technical Aspects)',Internal Tech.Report: AG-01/99,March 1999.

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