NCRA Test Range - An Estimate of Ground reflections

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Internal Technical Note : **AG–03/11**

1 Introduction :

This note addresses the problem of ground reflections on the proposed NCRA Test Range[1]. Computations are done on two aspects:

- Path loss calculation for the direct radiation from the Source Antenna
- The reflected path from the ground - how detrimental is it to the Test Antenna

2 Path Loss :

Standard radar equation, which gives the intercepted power P_r of the receiving antenna at a distance d, when the transmitting antenna transmits at frequency f is:

$$P_r = P_t + G_t + G_r - (32.44 + 20\log d + 20\log f) \tag{1}$$

where,
P_t is the transmitted power in dBm
G_t and G_r are the respective antenna gains of transmitting and receiving
and d is given in kms. and f is in MHz.
The quantities within the bracket is the Path loss term, L_{fs} for free-space, given in dBs. For our Test Range geometry, $d = 0.1$ (km.)and for frequencies ranging from 120 to 2000 MHzs., the table below gives the computed values:

f (MHz.)	L_{fs} (dB)
120	54.02
150	55.96
233	59.79
327	62.73
450	65.50
610	68.15
1000	72.44
1500	75.96

The frequencies given are the operating ones of GMRT antennas. From this table it could be inferred that if the Transmitting antenna is powered by a Signal Generator at +10 dBm, different cable choices would yield:
`(The two values given are for 450 and 1500 MHz.and for a cable length of 200 m.in total ; the` P_r `value is the sum of` P_t `and` $-L_{fs}$`.)`

Cable type	Cable loss (dB)	P_t dBm	P_r dBm
LMR500	14, 27	-4, -17	-69.5, -92.9
LMR600	11, 22	-1, -12	-66.5, -87.9
LMR1700	4, 8	+6, +2	-59.5, -73.9

The wide-band amplifier required to be connected between the Test Antenna and the power-measuring device (Spectrum Analyzer) must have a gain of $\sim$ 60 dB for LMR500 cable and $\sim$ 40 dB for LMR1700.

Higher gain of amplifiers can lead to oscillations and hence 40 dB gain would be an optimum choice, yet the LMR1700 cable is a bulky and costly one; the CWDM FO system mentioned in [1], could be an easier and practical choice for all the frequencies of interest.

3 Ground Reflections :

As outlined in [1], the Antenna height,h_r is 7.5 m. and the range distance,R_0 is 100 m. Exactly half-way the transmitted beam would intercept the ground at angle $\psi = 8.53°$. Assuming a 9-dB gain for the transmitting antenna, the power radiated at this small angle would be in the range of 0.3 dB. Hence it is safer to assume a power level of 0 dBm itself at angle ψ.Considering a ray traveling at this angle (whose angle of incidence will be $90-\psi$), would suffer a path loss for a distance of $\sqrt{50^2+7.5^2}$ first,then the reflected ray would be attenuated by the ground-reflectance and finally undergo one more path loss along the same diagonal path.
Let us estimate one-by-one:

1. `Incident ray path loss:`

The diagonal length is 50.56 m. and using Eqn.(1),L_i is 66.59 dB.

2. `Reflectance values:`

Ref.[2] illustrates that the reflectance for a non-magnetic, lossless dielectric medium having permittivity,ϵ_2 is different for the polarization plane. Considering our Range terminology, these can be denoted as ρ_E and ρ_H, which are referred as $\rho_\parallel$ and $\rho_\perp$ respectively by Kraus.Parallel means the electric vector of linear-polarized source is parallel to the medium interface(here, the ground)plane and vice-versa. As per our Range geometry and convention, the above renaming is clearly valid.
If ϵ_1 is the other medium through which the EM wave propagates and meets the boundary of ϵ_2's surface, the reflectance values are given by:

$$\rho_E = \frac{-\epsilon_r \cos\theta_i + \beta}{\epsilon_r \cos\theta_i + \beta}$$

and

$$\rho_H = \frac{\cos\theta_i - \beta}{\cos\theta_i + \beta}$$

where

$$\epsilon_r = \frac{\epsilon_2}{\epsilon_1},$$
$$\beta = \sqrt{\epsilon_r - \sin^2\theta_i}.$$

θ_i is the angle of incidence of the EM wave w.r.to the normal at the boundary of ϵ_1 and ϵ_2. Here for the Range, $\epsilon_1 = 1.0$ as the medium is air. ϵ_2 is taken as 3.4 (vide, Sec.A-12 of [2]; pg.741).

Plugging-in these values and taking $\theta_i = 90 - \psi$, we get
$\rho_E = 0.5105$ and
$|\rho_H| = 0.826$.

3.`Reflected ray path loss:`

Incident ray as given in part-1, suffers reflectance attenuation; since those terms are power ratio in dBs, one must convert them to voltage ratios, multiply the reflectance

values and reconvert to power ratio again: Thus the ρ_E component value goes down from -66.6 dB to -72.44 dB, while the ρ_H component changes to -68.26 dB.
The reflected ray path loss is identical to the first: - 66.6 dB.
Thus the final reflected ray reaching the test antenna by ground reflection, is at a power level of $-72.44 + (-66.6) = -139.04$ dB for the E-component and -134.86 dB for the H-component.

4 Conclusion:

The above values indicate clearly that the ground-reflected em-wave reaching the test antenna will be in the range of -135 dBm, which is barely detectable. So ground reflections in the case of the NCRA Test Range can easily be neglected.

5 Reference :

1. G.Sankar,The NCRA Test Range for Wide-band Feeds Development (under XI Plan),Internal Tech. Report: AG-01/10, 21 Sep.,2010

2. J.D.Kraus,Electromagnetics,Mc-Graw Hill Book Co.,3rd Edn.,1988.

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