Initial External Experiment Plan for IIP Radiometer

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March 15th, 2002

1 Introduction

External tests are required for the IIP radiometer to demonstrate successful ground-based observations of natural media. It is suggested that observations of a large water tank be considered, as one of the principle applications of L-band radiometry is sea salinity sensing. The following issues are important in design of these experiments:

- Radiometer frequencies of 1413 ± 200 MHz should be considered; maximum and minimum electromagnetic wavelengths are then approximately 25 and 18 cm, respectively.
- Observation angles (from nadir) in the range 30 to 60 degrees are desirable because satellite observations typically occur in this range. 53 degrees is often considered an ideal sea observing angle. An ability to vary the antenna angle is desirable, including upward observations of the sky.
- Antenna sizes should be minimized within other constraints for simplicity and to reduce the distance to the far field. However, highly directional antennas are desirable to simplify data interpretation.
- Spot sizes on the ground should be minimized within other constraints to avoid the need for large external targets (i.e. a large water pool).
- Locating the antenna on the ESL roof is desirable for simplicity. The ESL roof has levels at 7 m and 10 m above the ground. Potential issues with architect regarding loading/mounting here.
- Maintaining polarization purity of antenna is important, since vertical and horizontal brightnesses can be significantly different for a water surface at oblique observation.
- Issues related to observation in the far field of the spot on the ground may be important. However since this is not intended to be a phase-accurate system this can likely be neglected.

2 Basic geometry

Figure 1 illustrates the basic geometry under consideration: a radiometer antenna located at height H and with 2-sided beamwidth 2ψ observes the ground at polar angle θ. Trigonometry for this geometry shows that

$$X = H \tan\theta \tag{1}$$

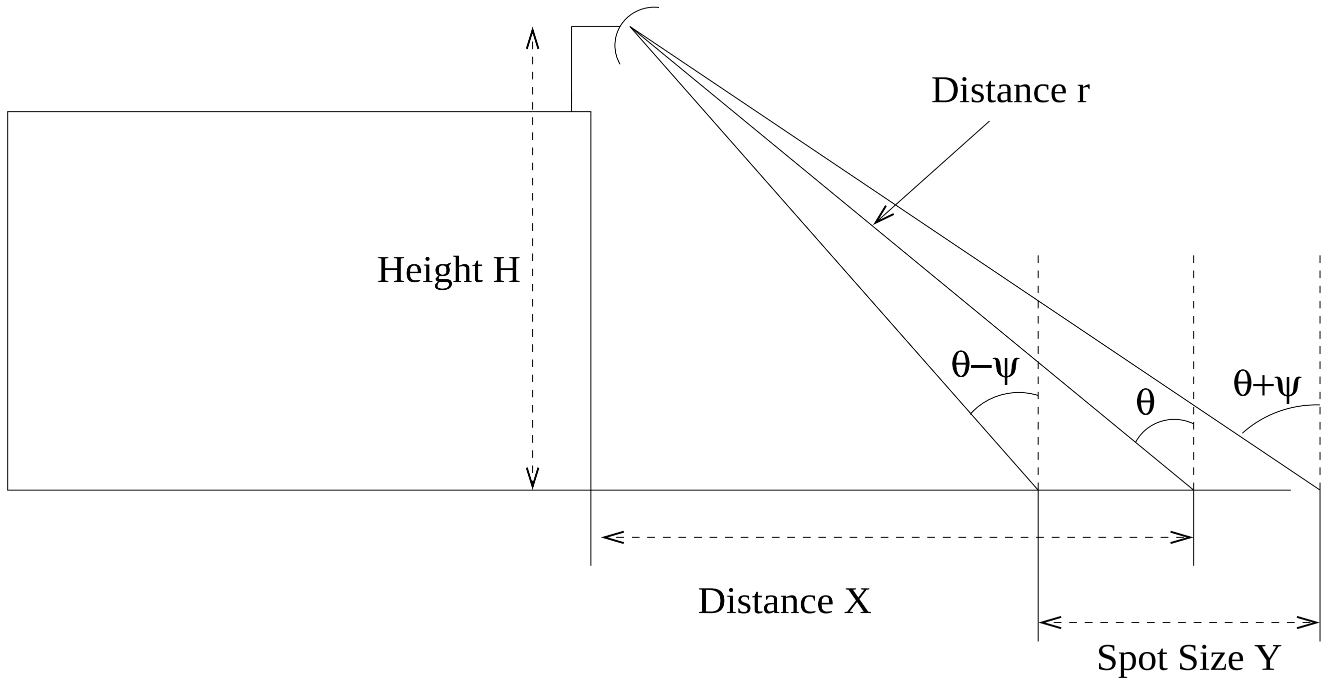

Figure 1: Basic geometry of experiment

$$
\begin{aligned}
r &= H/\cos\theta && (2)\\
Y &= H\left[\tan\left(\theta+\psi\right)-\tan\left(\theta-\psi\right)\right] && (3)\\
&\approx H\left(2\psi\right)\sec^2\theta && (4)
\end{aligned}
$$

3 Far field issues

The far field distance for an antenna of aperture diameter D is given by

$$
r_{\mathrm{far}} = \frac{2D^2}{\lambda} \qquad (5)
$$

Using $\lambda_{\mathrm{min}} = 0.18$ m here to maximize this distance, the distance to the far field is then approximately 16 m for a 1.2 m diameter antenna, 25 m for a 1.5 m diameter antenna, and 44.44 m for a 2 m diameter antenna.

Since $r = H\sec\theta$, we can plot the distance between the antenna and ground for varying observation angles assuming antenna heights of either 7 or 10 m. Figure 2 plots these results, and demonstrates that antennas located on the roof of the ESL will not easily achieve far-field observation in the desired observation angle range unless the antenna diameter is chosen as 1.2 m or smaller and the 10 m height used. With a 1.2 m diameter antenna at height 10 m, far-field operation is achieved for angles larger than 50 degrees. Figure 3 plots the distance along the ground from the antenna to the spot center versus observation angle.

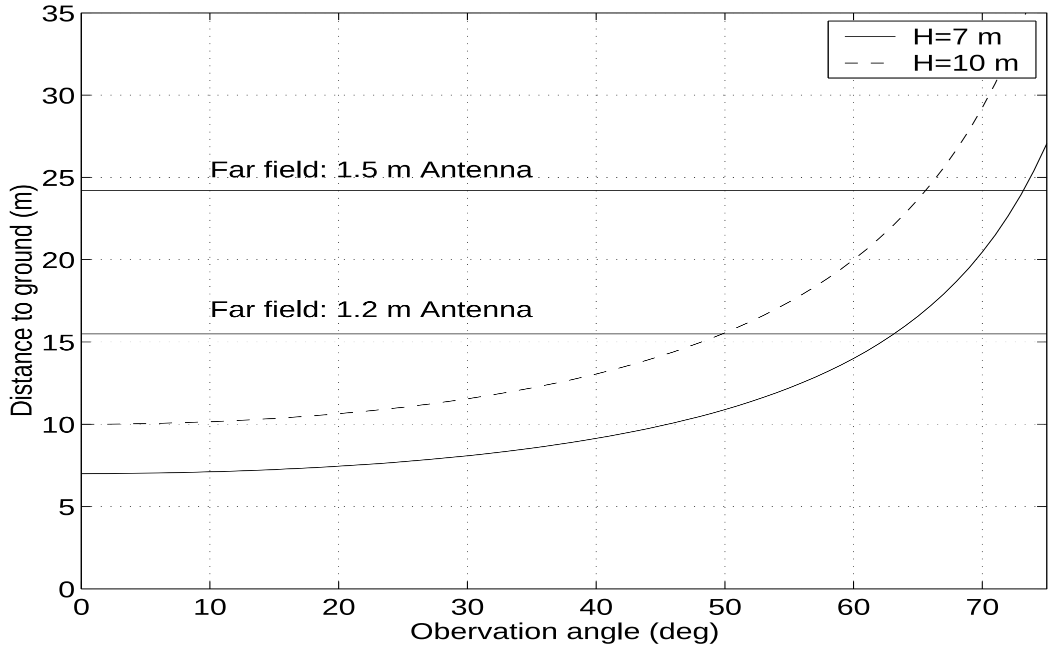

Figure 2: Distance between antenna and ground for two antenna heights as function of observation angle. Distances to far-field for 1.2 m and 1.5 m antenna sizes marked as lines.

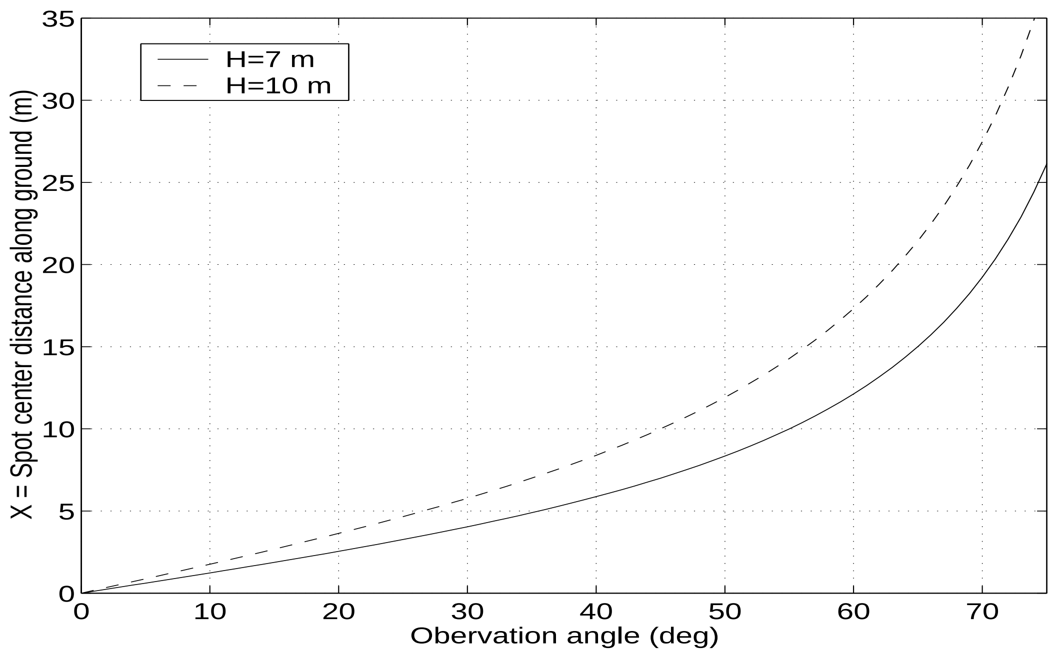

Figure 3: Distance on ground to spot center for two antenna heights as function of observation angle

4 Spot-size issues

Because the far-field distance fixes the size of the antenna, the spot-size also becomes fixed. For a typical aperture antenna, the beamwidth can be approximated by

$$2\psi \approx \frac{\lambda}{D}\left(\frac{1}{Q}\right) \tag{6}$$

where $Q < 1$ is an aperture efficiency factor, here assumed to be 0.8. As an example, using $\lambda_{\max} = 0.25$ m and $D = 1.2$ m gives a two-sided beamwidth of 0.2604 radians or approximately 15 degrees. The along-range spot diameter on the ground is

$$\begin{aligned} Y &\approx H\,(2\psi)\sec^2\theta && (7)\\ &= r\,(2\psi)\sec\theta && (8)\\ &\geq \left(\frac{2D^2}{\lambda}\right)\left(\frac{\lambda}{D}\right)1.25\sec\theta && (9)\\ &\geq 2.5D\sec\theta && (10)\end{aligned}$$

The final equality combines far-field (equation (5)), beamwidth (equation (6)), and geometry (equation (7)) factors to demonstrate that minimum spot sizes in the far field are directly proportional to the antenna size and independent of the antenna height. Spot diameter in cross range is $2r\sin\theta\sin\psi = 2H\tan\theta\sin\psi$.

Figure 4 plots the along-range and cross-range spot sizes versus observation angle for a 1.2 m antenna at height 10 m. Results show that at observation angles greater than 50 degrees, the 3 dB spot size on the ground will be at least 6 m in along range diameter, and 3 m in cross range diameter. To achieve a majority of the antenna pattern on the target, a factor of at least 2 would likely be needed, leading to a 12 x 6 m target (approximately 40 by 20 feet) on the ground. Such a size water pool is possible, but would be unwieldy, particularly if multiple observation angles (and target ranges X) are desired.

5 Discussion

Given the results of this study, it is clear that operation from the 10 m level of the ESL roof would be possible, but required target sizes would be large. Spot sizes could be reduced by using an antenna smaller than 1.2 m diameter, but the resulting antenna pattern would be too broad to make data interpretation reasonable. Other possible ways of avoiding the large target are:

- Surround a smaller water pool with highly reflecting material. Experiments could then be performed to quantify the fraction of the antenna pattern observing the water pool. However, this would undoubtedly increase the error of the measurement. Because high accuracy is an all-important issue for sea salinity sensing, this is not recommended.

- Use "compact range" type antenna designs to reduce the far-field requirement. Careful antenna design and testing would be required here that has not been directly planned as part of the project.

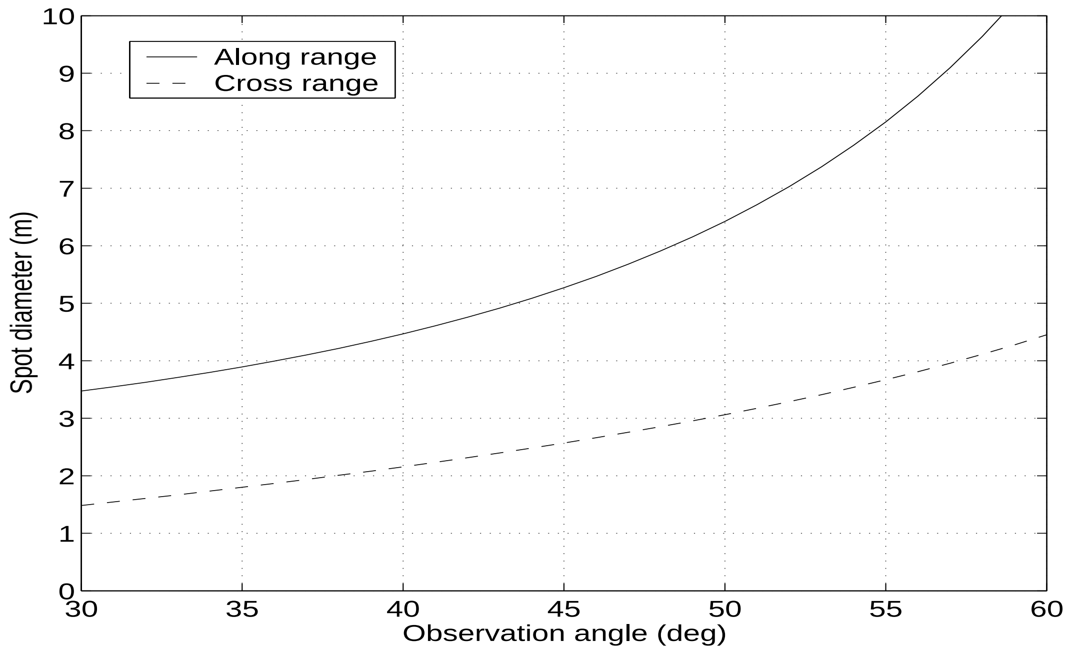

Figure 4: Along- and cross-range spot diameters for antenna size 1.2 m and antenna height 10 m.

- Operation near a natural body of water. Not convenient for repeated testing unless an OSU controlled facility is available.