ON THE RADIATION EFFICIENCY OF COCO ANTENNAS

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1. Introduction

In the austral summer of 2000-2001 we installed a 4x4 Yagi array at the Artigas Uruguayan Base in King George Is, Antarctica. We originally planned for a simultaneous run with the Peruvian MST radar at Machu-Picchu, also at King George Is. However, due to logistical problems with the latter system the simultaneous observations were not performed. The Machu-Picchu antenna is of the COCO (coaxial-collinear) type with a ~10 dB larger physical antenna aperture than the Yagi array. To our surprise, the PMSE echoes at Artigas were stronger than the ones previously observed at Machu-Picchu (Balsley et al., 1995 and Woodman et al., 1999), for the same time of the year.

In order to determine if the differences can be attributed to antenna performance or to a large PMSE annual variability, we have proceeded to make an experimental calibration of the performance of both systems, mainly of their antennas. This experiment has been carried out at the Jicamarca Radio Observatory using Equatorial Electrojet echoes and a third common transmitter-receiver antenna for the comparison. We have determined that the COCO antenna gain has to be corrected by an efficiency factor of ~2 dB over whatever is the efficiency of the Yagi array. Part of the loss in efficiency is of ohmic nature and part is due to an uneven current distribution in the COCO line elements.

2. Calibration Experiments

The calibration experiments were performed using three 50 MHz antenna arrays: a 12x12 m Yagi array (see description in companion paper); a 9x100 m COCO array; and the JRO array (~300x300 m). The idea was to make *quasi* simultaneous observations of the scattering phenomena; i.e., the Equatorial Electrojet, using the three arrays. The two different configurations used for the comparisons are shown in Figure 1.

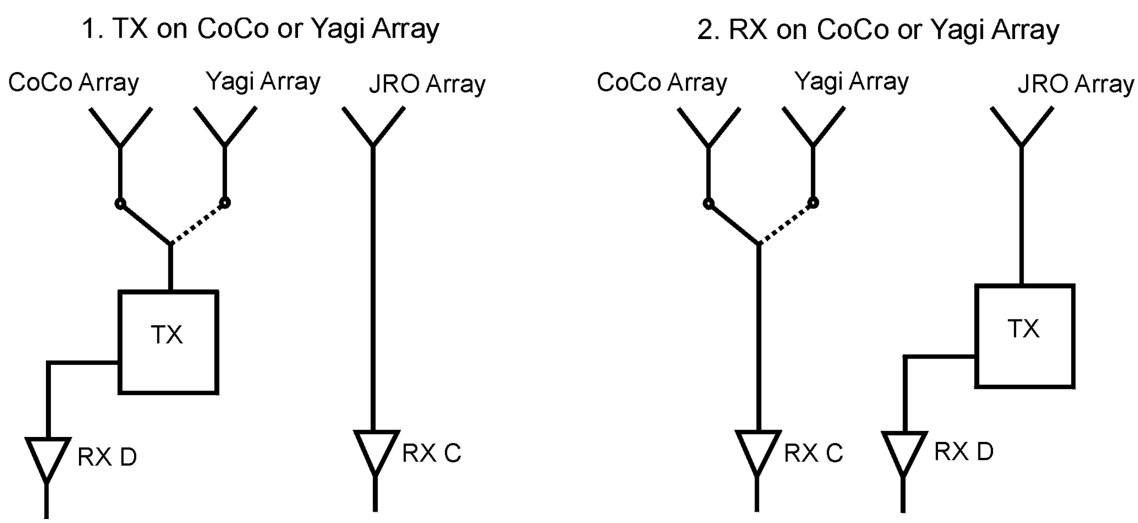

Figure 1: Configuration of the calibration experiments showing the experiment 1 on the left and experiment 2 on the right.

We have taken advantage of the narrow beam of the Jicamarca antenna. For experiment 1 it is essentially probing the field transmitted by the two antennas under calibration at the point of maximum gain. For experiment 2, it is effectively placing a point source at the center of the receiving antennas under calibration (the North-South dimension is reduced further because the aspect sensitivity.)

Experiment 1: Transmission on COCO and Yagi Arrays

In the first configuration/experiment the transmission is alternated between the COCO and Yagi arrays, while the JRO array is used for receiving (RXC). This configuration allows evaluating the transmission efficiency of the arrays under calibration. The signals at RXD correspond to the radar case that we will not analyze in this paper.

Experiment 2: Reception on COCO and Yagi Arrays

The second configuration/experiment allows evaluating the receiving efficiency of the two arrays. As shown in Figure 1, the JRO array is used for transmission and the COCO and Yagi arrays are alternated for reception (RXC).

An artist representation of the beam-widths and the corresponding pointing directions with respect to the perpendicular to B for the three antenna arrays are shown in Figure 2. The elements/lines of the Yagi/COCO arrays are oriented in the North-South magnetic direction (*Y*). The longest dimension of the COCO array (100m) also corresponds to the *Y* direction. The effective antenna dimensions, including the effective radius of the cross section of the array elements, for the COCO and Yagi arrays are shown in Table 1.

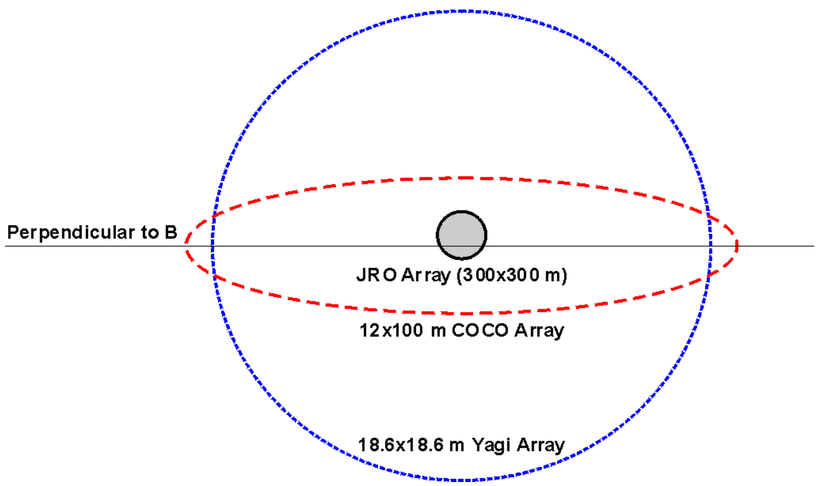

Figure 2: Artist representation of the antenna beam-widths and the corresponding pointing directions with respect to the perpendicular to B.

Table 1: COCO and Yagi antenna array dimensions (including the effective radius of the cross section of the array elements)

Antenna array	East-West dimension (*X*)	North-South dimension (*Y*)	Antenna Area [m^2]
COCO Array	$L_{C,X} = 12.0$m	$L_{C,Y} = 100$m	$A_C = 1200.00$
Yagi Array	$L_{Y,X} = 15.0$m	$L_{Y,Y} = 15.0$m	$A_Y = 225.00$

3. Experiment Results

Several calibration experiments have been performed after the 2000-2001 Antarctic campaign. The results presented and discussed here correspond to data gathered in December 1st, 2003.

The signal power ratios, S_C/S_Y, for the experiments 1 and 2 are shown in Tables 2 and 3 respectively.

Table 2: Experiment 1 results, Transmission on COCO and Yagi Arrays		
RX Antenna Array	**S_C/S_Y (SNR, dB)**	**S_C/S_Y (Total Power, dB)**
COCO / Yagi (RXD)	13.9237	11.1051
JRO (RXC)	5.4195	5.6255

Table 3: Experiment 2 results, Transmission on JRO Array		
RX Antenna Array	**S_C/S_Y (SNR, dB)**	**S_C/S_Y (Total Power, dB)**
COCO / Yagi (RXC)	5.9739	5.5257

Using the "one way" signal power ratios shown in tables 2 and 3 we can calculate the efficiency ratio between the COCO and Yagi Arrays. If we consider two antenna arrays, with areas A_C and A_Y and efficiencies ε_C and ε_Y, the ratio of signal power S_C/S_Y is given by:

$$\frac{S_C}{S_Y} = \frac{G'_C}{G'_Y} \tag{1}$$

where S is power, and G' is the effective gain. The antenna gain, G, for an ideal antenna is proportional to its area; i.e., $G = Ly \times Lx$. Ly and Lx are the dimensions of the antenna, including the effective radius of the cross section of the array elements (see Table 1). The effective gain G' is corrected by an efficiency factor (ε), that takes into account the illumination efficiency of the area (ε_B); and any Ohmic loss (ε_Ω).

$$G' = G\varepsilon = kA\varepsilon_B\varepsilon_\Omega = kA\varepsilon \tag{2}$$

Then, we can write,

$$\frac{S_C}{S_Y} = \left(\frac{\varepsilon_C G_C}{\varepsilon_Y G_Y}\right) = \left(\frac{\varepsilon_C A_C}{\varepsilon_Y A_Y}\right) \tag{3}$$

$$\frac{S_C}{S_Y} = \left(\frac{\varepsilon_C}{\varepsilon_Y}\right)\left(\frac{L_{C,X}L_{C,Y}}{L_{Y,X}L_{Y,Y}}\right) \tag{4}$$

and then,

$$\left[\left(\frac{\varepsilon_C}{\varepsilon_Y}\right)\right] = \left[\frac{S_C}{S_Y}\right] - \left[\left(\frac{L_{C,Y}L_{C,X}}{L_{Y,Y}L_{Y,X}}\right)\right] \tag{5}$$

where the [] operator denotes 10**Log*10 operation. The Total Power ratios for RXC in table 2 correspond to Transmission with the COCO and Yagi Arrays; i.e., one way case. The experimental total power ratio in the receiving antenna, $[S_C/S_Y]$, was 5.6255 dB, which we should correct for the insertion loss difference of the main feeding cables by -0.5 dB. The area ratio, $[A_C/A_Y]$, from table 1 is 7.27 dB. Therefore we have an efficiency ratio on transmission, $[\varepsilon_C/\varepsilon_Y]_T$, of -2.1445 dB.

We can also calculate the efficiency ratio on reception, $[\varepsilon_C/\varepsilon_Y]_R$, using expression (5) and the experimental values in table 3. We obtain an efficiency ratio on reception of -2.2443dB, which is reassuring since it differs by 0.0998 dB from the figure obtained in experiment 1.

4. Conclusions

- The special characteristics of the Jicamarca antenna array; i.e., its very narrow beam, has allowed probing the field transmitted by the COCO and Yagi antennas at the point of maximum gain. It has also been used to place a point source at the center of the antennas under calibration.
- The results for the Transmission and Reception experiments conform very well, as expected. The 0.0988 dB difference between experiments 1 and 2 can be attributed to experimental errors.
- We have found that the 100m COCO antenna gain has to be corrected by an efficiency factor of ~2.2 dB over whatever is the efficiency of the 3-element Yagi array. Therefore, assuming that the Yagi array is lossless, the gain of a 100m COCO antenna has to be corrected by an efficiency factor of ~2.2 dB.

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References

Balsley, B.B., R.F. Woodman, M. Sarango, R. Rodriguez, J. Urbina, E. Ragaini, J. Carey, M. Huaman, and A. Giraldez, On the lack of southern hemisphere polar mesosphere summer echoes, *J. Geophys. Res., 100(D6)*, 11685-11693, 1995

Woodman, R.F., B.B. Balsley, F. Aquino, L. Flores, E. Vasquez, M. Sarango, M. Huaman, and H. Soldi, First observations of polar mesosphere summer echoes in Antarctica, *J. Geophys. Res., 104(A10)*, 22577-22590, 1999