Wide-beam forming using binary phase coding

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In imaging work, it is desirable to have the transmitting beam width matched to the receiving one. One possibility to do this at Jicamarca, when single receiving modules are employed, is using one antenna module as the transmitting array (the whole Jicamarca array consists of 8 by 8 modules). However, with this solution one cannot transmit the high peak power available at Jicamarca (~2 MW). A second solution, where high transmission power is possible, consist on transmitting with all the antenna modules, but using 4 different sets of binary codes (0 or 180 phase delays), i.e., a two-dimensional complementary phase code. After the decoding process, the information obtained is equivalent to what one would obtain if the high power were transmitted on a single antenna module. The wide beam information is synthesized by adding the second-order statistics obtained with each set of codes. We have tested this idea at Jicamarca to get three-dimensional images of the tropopause and lower stratosphere. For transmission we have used four sets of codes, where each code consists of 4 by 4 elements.

Topic 6: Achievements and Highlights.

Wide-beam Forming using Binary Phase Coding

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Introduction

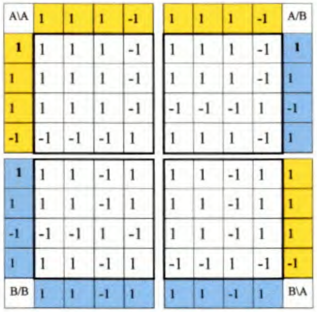
In imaging work, it is desirable to have the transmitting beam width matched to the receiving one. One possibility to do this at Jicamarca, when single receiving modules are employed, is using one antenna module as the transmitting array (the whole Jicamarca array consists of 8 by 8 modules). However, with this solution one cannot transmit the high peak power available at Jicamarca (~2 MW). A second solution, where high transmission power is possible, consists on transmitting with all the antenna modules, but using 4 different sets of binary codes (0 or 180 phase delays), i.e., a two-dimensional complementary phase code. After the decoding process, the information obtained is equivalent to what one would obtain if the high power were transmitted on a single antenna module. The wide beam information is synthesized by adding the second-order statistics obtained with each set of codes. Below we describe the how the binary codes are obtained, and also how the idea was implemented at Jicamarca. Finally, we present 2D images of the equatorial electrojet (EEJ), tropopause and lower stratosphere.

Experimental Description

The idea is similar to complementary pulse coding, but instead of sending a long pulse (coded) to synthesize a smaller one, we transmit with a large antenna (coded) to synthesize a smaller one. Therefore a 2D approach is needed. In Figure 1 we show an example of 4 complementary codes of 4x4 elements. The codes have been obtained by combining the two sequences of a 1D complementary code, i.e., A=[1,1,1,-1] (in yellow) and B=[1,1,-1,1] (in light blue), so that we formed the codes AA, AB, BB, BA.

Each of the 4 x 4 codes were implemented on different quarters of the Jicamarca antenna. Each quarter consist of 4x4 modules and the coding was implemented through phase changes (i.e., with cables). For examples "1" was replaced with 0° and "-1" with 180°. In Figure 2 we show the antenna pattern for each of the coded quarters, and in Figure 3 we show the synthesized pattern after adding the four coded patterns of Figure 2. Note that this pattern is identical to what one would obtained if a single module were used.

In practice, we implemented the 2D codes of Figure 1 by transmitting with only two quarters with two polarizations (i.e., four antennas). The receiving system consisted of 4 cross-polarized modules (Figure 4), where each polarization set was connected to a different JULIA acquisition system. Only one radar controller was used for the two JULIA systems. Each of the quarters were excited as shown in Figure 5, i.e., first, codes AA and AB were transmitted, and ½ IPP later, codes BB and BA were transmitted.



A\A	1	1	1	-1	1	1	1	-1	A/B
1	1	1	1	-1	1	1	1	-1	1
1	1	1	1	-1	1	1	1	-1	1
1	1	1	1	-1	-1	-1	-1	1	-1
-1	-1	-1	-1	1	1	1	1	-1	1
1	1	1	-1	1	1	1	-1	1	1
1	1	1	-1	1	1	1	-1	1	1
-1	-1	-1	1	-1	1	1	-1	1	1
1	1	1	-1	1	-1	-1	1	-1	-1
B/B	1	1	-1	1	1	1	-1	1	B\A

Figure 1. An example of 2D complementary binary codes of 4x4 elements. These codes have been obtained by combining the 1D complementary codes of 4 elements (i.e., A=[1,1,1,-1] in yellow, and B=[1,1,-1,1] in light blue). The label of each 2D code is located at the outer corners.

Experimental Results

Observations were made in the EEJ, the tropopause and lower stratosphere. In Figure 6 we show a 2D image of the EEJ after decoding, using a long integration time of 1 min. The decoding process have been done by adding the second order statistics of each of the code sequences. In Figure 7 we show the 2D images, processing each of the antenna codes separately.

In Figure 8 we show a time sequence of EEJ images obtained every 1 s at 100.4 km altitude. Note the evolution of the scattering centers. 2D images of tropopause and stratospheric heights are shown in Figure 9. These images were obtained with 3 min integration. The characteristic ellipse (half-power points of an assumed one anisotropic Gaussian blob) is shown with a black line and has been obtained using antennas A, C and D. Note that not much gain in information is attained by adding a four antenna.

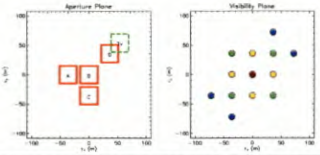


Figure 4. Receiving antenna configuration and visibility domain (top). There are two independent receiving antennas for location (using orthogonal polarizations). The visibility domain indicates the number of independent samples and their

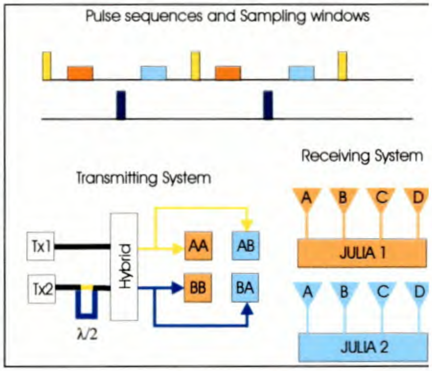


Figure 5. Pulse sequence (top right) and transmitting, receiving, and acquisition system configuration (bottom right). The yellow pulses correspond to transmitting with antenna codes AA and AB, while the blue pulses to antenna codes BB and BA. Antennas in orange use the down polarization, and their outputs go to the acquisition system JULIA 1, while antennas in light blue corresponds to the up polarization and their outputs go to JULIA 2.

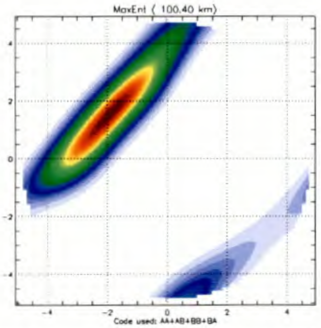


Figure 6. 2D EEJ image attained after "decoding", i.e., after adding the second order statistics obtained with the different codes. This image have been obtained after a "long" integration time (~ 1min).

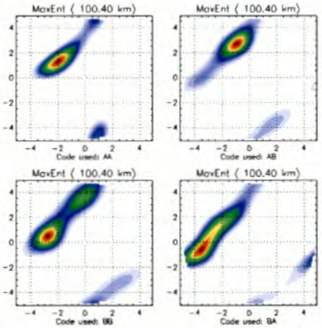


Figure 7. 2D EEJ images (after ~ 1 min integration) obtained for each of the binary codes of Figure 1. These patterns are in good agreement with what we expect to get, considering an EEJ brightness like Figure 8 and the antenna patterns of Figure 2.

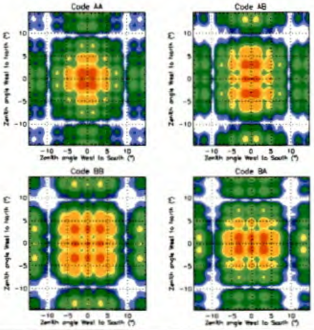


Figure 2. Antenna patterns for each quarter of the Jicamarca antenna (i.e., 4 x 4 modules). The quarters were phased with the 2D binary codes of Figure 1 (AA, AB, BB, BA). In practice, "1" represents 0° phasing, and "-1" 180°.

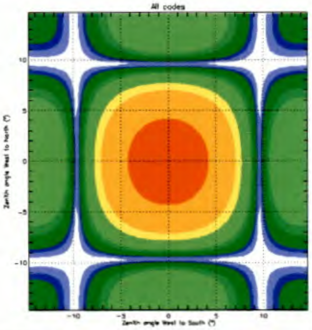


Figure 3. Antenna pattern after adding the all four patterns of Figure 2. This pattern is equal to the pattern of one of the Jicamarca modules (i.e., 1/64th of the whole antenna)

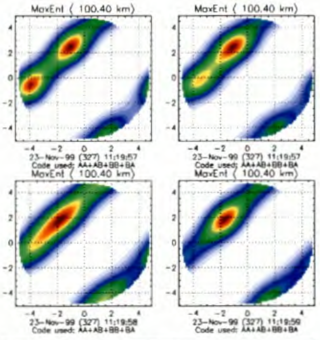


Figure 8. Decoded 2D images of the EEJ taken every ~1 s. Note the evolution of the scattering centers from frame to frame. Images at the bottom right are due to spatial aliasing resulting from the antenna configuration used.

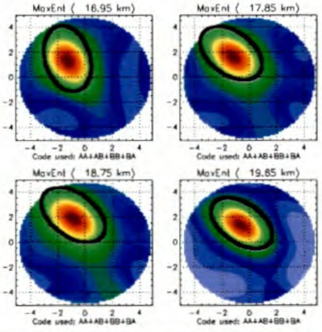


Figure 9. Decoded 2D images of the tropopause and lower stratosphere, using an integration time of ~ 3 min. The black ellipses represent the characteristic ellipses (half-power points of an assumed one anisotropic Gaussian