

# The MPI-SOUSY-VHF Radar at Jicamarca: High Altitude-Resolution Capabilities.

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The MPI-SOUSY radar has been moved from its original location at the Harz Mountains, Germany, to the Jicamarca Observatory. Two main modifications have been made to the system: 1) The antenna array now consists of 126 Yagis deployed in an square array of 16x16, 4 element Yagis, similar to the original ones, and 2) the control and data acquisition system has been modernized as described later on. The phase steering system has not been implemented yet, but is planned for the future.

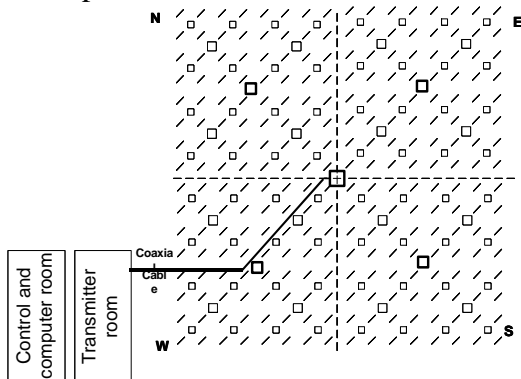


Figure 1 Distribution of the antenna array. The squares represent divide-by-four power dividers. Different sizes correspond to different power levels.

Figure 1 shows schematically the disposition of the Yagis and their interconnexion in the array. For the particular application described in this paper, they are all connected with the same phase, therefore the full array is practically pointing towards the zenith. Figure 2 shows a picture of the same in context with the Jicamarca main antenna.

One of the objectives of the move was to take advantage of the wider

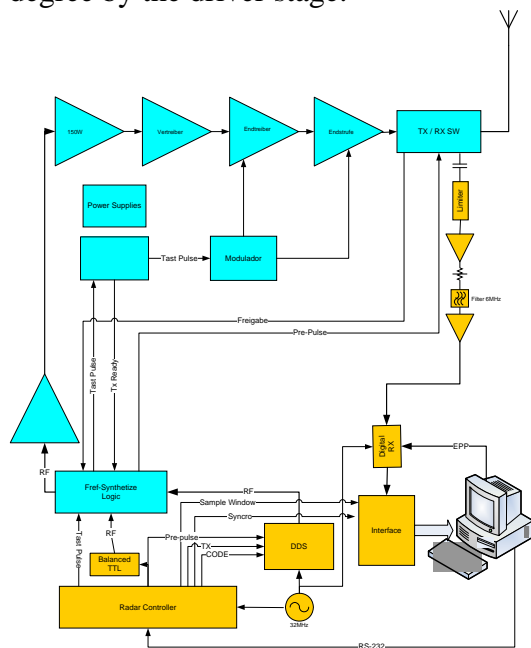
bandwidth of the SOUSY transmitter to obtain higher altitude-resolution radar measurements than it had been obtained at VHF frequencies in the past (50 MHz range in particular), at both atmospheric and ionospheric heights. Very stringent frequency allocation bandwidth at the Harz had limited its operation to 150 meter Gaussian shape pulses.



Figure 2-Partial view of the new antenna for the SOUSY radar (foreground). The large Jicamarca array is in the background.

Here we report the altitude resolution performance of the system driven to its maximum resolution capabilities. For this purpose, and also as a consequence of the old age of the original design, the control, receiver, data acquisition and processing system had to be redesigned. Figure 3 shows schematically the new system. It can be noticed that the entire transmitting system has not been modified. The main changes consist in the use of a dual channel (only one was used for this application) digital

receiving system to replace the original analog receiver, an off-the-shelf PC for processing, and a copy of the Jicamarca radar controller for pulse shape and sampling control. The radar controller was run with a 8 MHz clock, permitting a proper sampling rate at this frequency of a minimum transmitter Baud or pulse width of 250 nanosecond. It was found that the system resolution was limited by the transmitter bandwidth, namely that of the final power stage and in a lesser degree by the driver stage.



**Figure3- Block Diagram of the system. Light blue blocks are unmodified parts of the original system. Yellow blocks are current modifications**

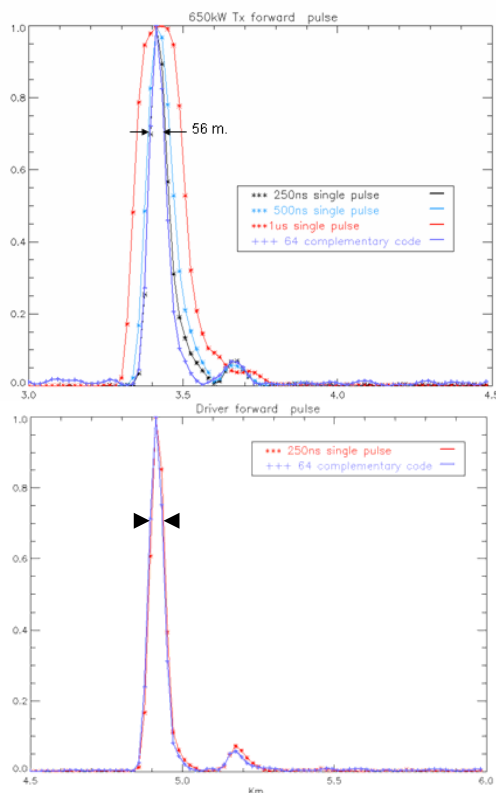
The system maximum resolution can be appreciated by inspection of Figure 4. There we show the shape of the amplitude of the transmitter pulse --- sampled at a directional coupler at the output of the final power amplifier--- for different widths of the square pulse excitation. Note there is not much difference in the width of the output pulse when the width of the excitation is reduced from 500 nsec to 250 nsec. This

is a consequence of the limited bandwidth of the final 600 kW amplifier. This came as a surprise since the this amplifier was suppose to be a modified Television transmitter (4 MHz BW). On the other hand the very stringent frequency allocation for the radar at its original location at the Harz must have required the designers to limit the bandwidth at the final power stage as well. Thus the minimum half power altitude resolution we can obtain with the system at this power level is 56 m. The same resolution is obtained when we transmit with a 250 nsec Baud 64-long complementary code, as shown by the green crosses curve in Figure 4, as we would expect.

We have also evaluated the performance of the radar if we use the previous 20 kW stage that is used as the driver to the final 600 kW stage. It is indeed possible to connect this stage to the antenna. We have evaluated the minimum system resolution in the same way by looking at the amplitude pulse shape of the transmitter output measured at the unidirectional coupler placed in the transmission line leading to the antenna. The results are displayed in Figure 4 for a single 250 nsec pulse, and for a 64 complementary code string with the same Baud width. In this case the resolution is not limited by the bandwidth of the final transmitter stage and we obtain a resolution of 37.5 meter.

The second minor peak at approximately 250 meters from the first is a reflection from a near by structure, very possibly from the metal structure of the main building. The reflection interpretation is evident from the much larger amplitude of this signal when we look at the reflected port of the directional coupler

We have used the 600 kW and the 20 kW transmitters to obtain echoes from the troposphere and stratosphere. In both cases we have used the 250 nsec 64 Baud pulse modulation schemes. Preliminary results with the 600 kW transmitter have been presented at this conference [Roettger, et. al., 2006, this issue]. Echoes were obtained to a maximum altitude of 21 km with this power level. Here we would like to show results obtain using the wider bandwidth, 20 kW transmitter.



**Figure 4. Shape of the transmitter pulse (amplitude) processed by the receiving system. The top panel shows the pulse using the 600 kW final stage for different excitations, the bottom panel shows the same but using the 20 kW driver stage and only 250 nsec modes. The secondary peak is due to a local strong reflection.**

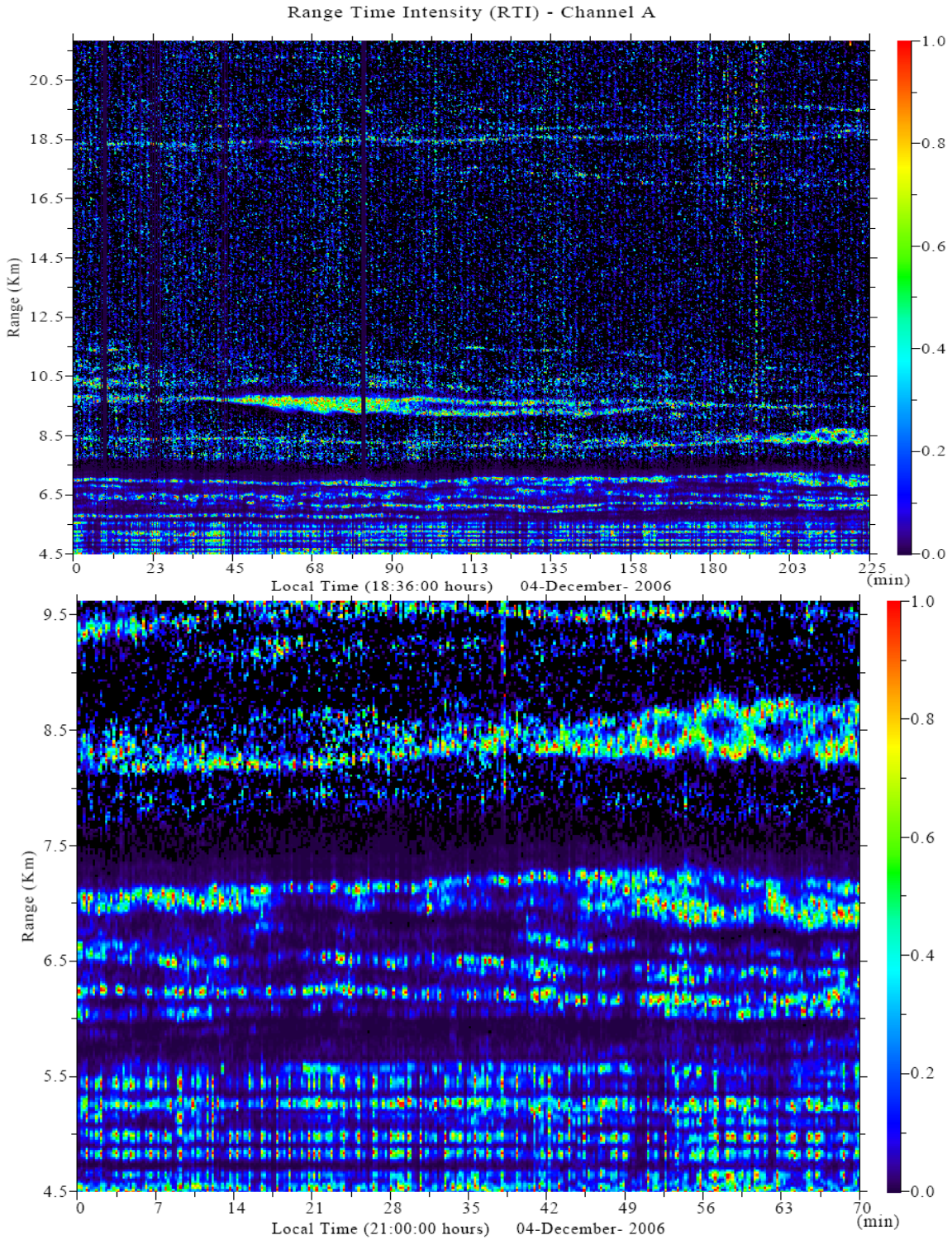
RTI plots using this latter system are shown in Figure 5 using a non-conventional scheme that requires some

explanation. It uses a linear power colour assignment to enhance the actual width of the layers. The large dynamic range of the power levels at different altitudes is taken care of by normalizing to the maximum power level in the local neighbourhood, defined by the region of 1 km altitude and 5 min duration centred on each point and weighted by a Gaussian of comparable dimensions (sigmas). The actual power level is recovered in a complementary plot (not shown here) showing the normalizing power level.

At the 20 kW level some sensitivity is lost, but we can still see the enhanced echoes normally observed at tropopause levels. In compensation, the system is capable of showing some persistent structures with widths comparable to its 37.5 m resolution. This makes the radar a unique tool to study the morphology of turbulent layers under statically stable stratified conditions, especially now that numerical models of the same already exist [Fritts et al., 2006, this issue].

We have been able to clearly resolve for the first time, at high tropospheric altitudes, billow structures as the ones seen at 8.5 km after the 195 min mark in Figure 5a ( zoomed in Figure 5b). Furthermore, we can see the development of a double layer (9 km altitude, 90 min mark), which can be interpreted as the narrow regions at the upper and lower edges of a wider turbulent layer, with a turbulent but invisible centre. Both features clearly agree with what is expected to see in the different stages of development of a Kelvin-Helmholtz instability, in accordance with Fritts et al. (2007) numerical simulations, presented at this conference.

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**Figure 5-** RTI obtained with the use of the 20 kW, 4 Mhz BW driver, of the SOUSY radar. Note that the power scale is linear and locally normalized (see text). The bottom panel is a zoomed view of the billows shown on the bottom and right hand corner of the top panel, starting at 21:00 hours LT