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Beam Formation of 53 MHz Active Phased Array Pilot ST Radar at University of Calcutta using Radar Controller Software

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Abstract

A 53 MHz active phased array pilot ST Radar is designed and installed at University of Calcutta, Kolkata, India. Radar Controller (RC) software facilitates the users to set the experimental operational parameters as well as provides the ability to steer the antenna beam in different azimuth and elevation angles. The detailed functionality, features and beam formation using RC software will be discussed in this paper.

1. Introduction

Active phased array Radars are emerging in recent years in the atmospheric probing instruments with dedicated Transmit-Receive Modules (TRMs) for each radiating antenna. These radars have the ability to steer the beam in any desired direction and to perform multiple sheet experiments. The advantages of these radars are good spatial and temporal resolutions which help to observe finer features of the atmosphere [1].

One of the major subsystems of the Active Array radar system is the Radar Control (RC) software, which is usually termed as the brain of the entire system, the others being TRMs, RF subsystems such as exciter, analog receiver, distribution units etc. Each TRM is equipped with a FPGA based TCSG card, which generates the required controls for the proper operation of the TRM and monitoring the health status. Presently, a pilot version of ST radar, having 19 TRMs is operational with a beam width of 18° using the standard Doppler Beam Swinging (DBS) technique for deriving the velocity wind vectors. [2]. The proper pilot array operation requires the synchronization of the TRMs along with other subsystems such as Group Level Controller (GLC), Master Timing and Control Signal Generator (MTCSG). The Pilot Array Radar Controller software plays a major role in transferring the necessary experimental parameters and phase information for the required beam formation to each TCSG card [1].

2. Radar Controller Software Functionality and Features

2.1 ST Radar Pilot Array Network

The University of Calcutta Active phased Pilot Array ST Radar at Haringhata consists of a 19 three-element Yagi-Uda antenna array arranged in a hexagonal shape with a triangular grid. All the 19 antenna elements are connected to an individual 2 kW high power solid state Transmit-Receive Module (TRM) [2]. The individual TRMs are connected to a Group Level Controller (GLC) via a circular connector. The GLC is connected to the Master Timing and Control Signal Generator (MTCSG) through an optical fibre cable. The MTCSG unit is connected to the software-based Radar Controller (RC) PC through copper Ethernet switch. The functional and connectivity block diagram of the RC PC with GLC is shown in Figure 1.

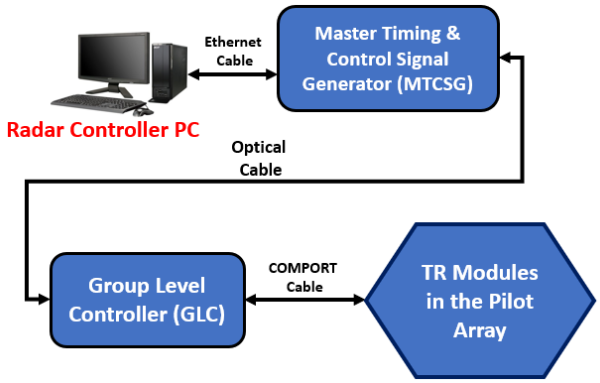

Figure 1. Connectivity Block Diagram of the Radar Controller Software with the Antenna Array.

2.2 Functionality of Radar Controller Software

One of the major functionalities of the Pilot Array is its ability to place the antenna array beam at any elevation and azimuthal angle with the help of inbuilt phase shifters placed in each TR module. With this electronic beam steering capability, the beam can be switched in micro intervals of time [1].

For the Pilot radar operation, the Radar Controller software will send the commands such as experimental specification data or parameters, i.e. Pulse Width, Inter Pulse Period, Number of Coherent Integrations (NCI), Number of Fast Fourier Transforms (NFFT), Number of Incoherent Integrations (NICI), number of beams, phase

file for the beam position information and other operation and control commands to the GLC. Then the GLC will distribute the parameters and commands to all the TRMs. The beam information, unlike the other commands, is different for each TRM because the phase shifter information is unique for each specific transmit and receive beam [1]. Figure 2 shows the screenshot of the RC user interface for an experimental sheet specification.

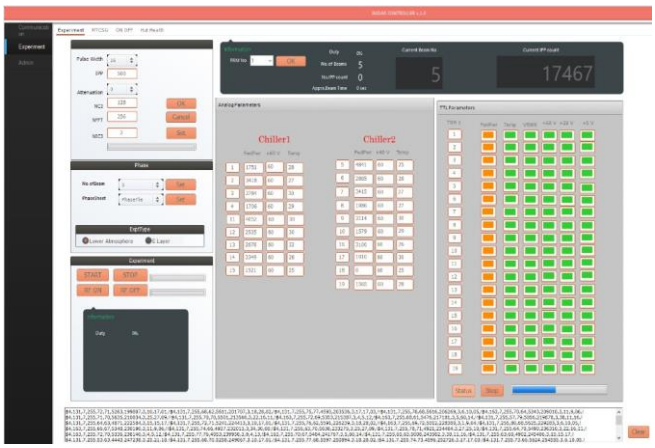

Figure 2. Experimental Parameters and TRMs status monitoring using RC software User-Interface.

2.3 Features of RC Software

The RC software for the Pilot array has been designed and developed to meet the major functionalities and features to operate the active phased array radar. Some of the major features of the Pilot Array Radar Controller software are as follows:

a. Flexibility in the selection of different operational parameters and beam directions.
b. Monitors the Hut/shelter health parameters such as inside temperatures, chillers working status, smoke detection, humidity etc.,
c. Able to send control commands such as interlock reset, individual TRM RF and power supply ON/OFF features
d. Clearly displays the experiment status in terms of the TRMs' forward powers, status of power supplies (+5V, +28V and +60V), Hut temperature and analog parameters such as TRMs forward power, +60V power supply and TRMs junction temperature.
e. Able to generate the different beams' phase files according the experiment
f. Flexibility in the selection of different operational parameters and beam directions.
g. Logs the health status of TRMs and Huts during the system operation.
h. Provides the semi-automated phase calibration in both transmit and receive paths

3. Electronic Beam Steering of Antenna Array with RC Software

The Pilot radar has the capability of beam steering from 0º – 30º along the off-zenith angle and 0º – 360º along the azimuth angle at a step of 1º. The resolution of 1º in both azimuth and off-zenith angles would enable a 3-D view of the atmosphere. Each TRM will have a 6-bit digital phase shifter in the common arm of the transmitter and receiver path. The minimum phase resolution of the digital phase shifter is 5.625º.

The RC software will create a phase file for the corresponding azimuth and elevation angles for a given experimental sheet specification. The phase values in the phase file are loaded to each TRM via ethernet and optical cables from RC PC to GLC. The GLC will distribute the phase value to the corresponding TRM through the Communication Port (COMPORT) cable. The antenna array geometry is shown in Figure 3.

The system is designed for the user to select the Elevation (ɵ) and Azimuth (ϕ) angles for an experimental sheet which will then be used by the RC software to determine the corresponding phase value for each TRM. The current design allows a beam tilt up to 30º in elevation. Figure 4 shows the antenna array radiation pattern in polar form/coordinates for the elevation angle 0º (ɵ=0º) in the right and 30º (ɵ=30º) in the left. Figure 5 shows the antenna array radiation pattern in polar form/coordinates for the azimuth angle ϕ =0º and the azimuth angle ϕ= 30º.

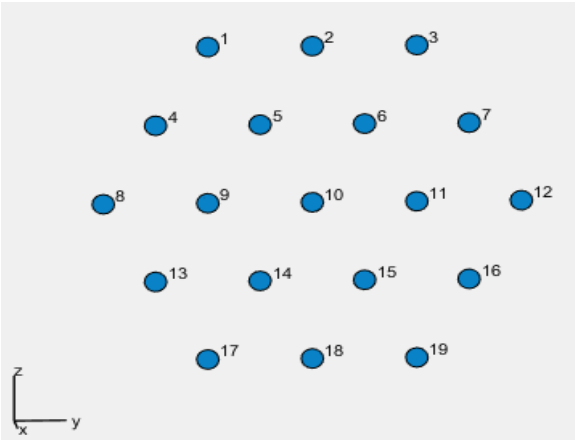

Figure 3. Pilot Array Antenna Geometry

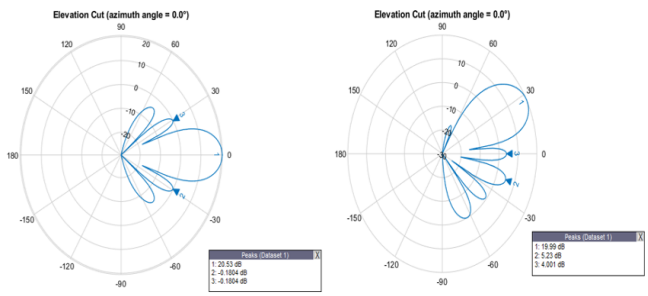

Figure 4. Antenna Radiation Pattern for elevation angle ɵ=0° (left) and for elevation angle ɵ=30° (right)

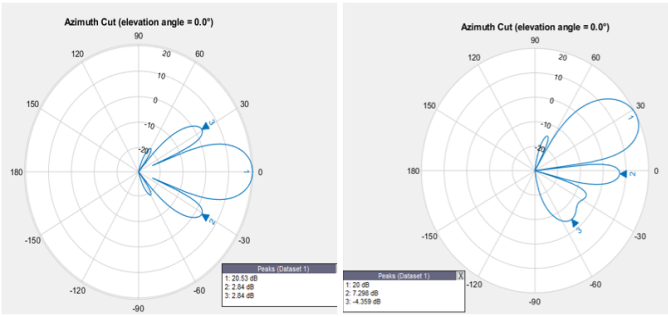

Figure 5. Antenna Radiation Pattern for azimuth angle ϕ =0° (left) and for azimuth angle ϕ =30° (right)

4. Conclusion

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An active phased array pilot ST Radar at 53 MHz is designed and installed at University of Calcutta, Kolkata, India. The system design includes Radar Controller (RC) software which provides flexibility of controlling the radar functionalities remotely. The design RC software also provides the ability to steer the antenna beam in different azimuth and elevation angles. A beam tilt of 30^0 in elevation and azimuth is tested and presented.

5. Acknowledgements

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6. References

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