ST Radar @ 205 MHz , APAR Wind Profiler for Tropics

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Abstract: This paper describes a Stratosphere – Troposphere Radar realized as a fully Active Aperture Phased Array Radar (APAR), operating at an unconventional frequency of 205MHz, for the first time in the world, to meet the specific requirements of wind profiling over the Tropics. Traditionally, wind profilers are operating at 50MHz, 400MHz, 900MHz – 1340MHz, bands depending upon the height coverage requirements. 50MHz systems are essentially research radars covering the Middle & Upper Atmospheric region, consisting of Mesosphere, Stratosphere and Troposphere (MST) regions of the neutral middle atmosphere { 90kms to Atmospheric Boundary Layer (ABL) say 2Kms} , as well as the Ionosphere in the E & F regions through field aligned irregularities. They are derived from the Jicamarca Incoherent Scatter Radar (Woodman & Guillen ,1974), although the Neutral Atmospheric returns are essentially through Coherent Back Scatter mechanism. MST Radars are only a handful world wide and are at Jicamarca in Peru, MU Radar in Japan, MST Radar at Gadanki(India), Aberystwith in UK, EAR in Indonesia and Marsy in Svalbard , being the latest.

It is well known that the Wind Profilers depend on Bragg Scatter as the dominant scattering mechanism, unlike the Weather Radars which depend on Rayleigh & Mie Scattering mechanisms. The turbulent scale sizes which give rise to Bragg Scatter are height dependant with higher height coverage requiring larger wave lengths. That is the main reason for MST radars to be in the 50MHz (45-60 MHz) band, as the dominant scales at Mesospheric heights are expected to be around 3metres. The sensitivity of the wind profilers is a function of the Average Power Aperture Product, with MST Radars being in the region of 10^9 Watt $.m^2$. Thus MST radars employ large phased array antennas of the order of 100x100 m in size, thus making them extremely costly.

When it comes to Tropics, it is to be noted that the Tropopause is seen around 16 -18kms unlike the mid latitudes where it is around 10kms. This changes the picture drastically if one is interested in a wind profiler that covers marginally above the Tropical Tropopause, say 20kms to study the coupling and energy exchange mechanisms between Troposphere and Stratosphere. The reason lies in the frequency dependence of turbulent scale sizes , which need to be in the Inertial Sub Range , in order to produce meaningful back scattered signal returns to extract wind velocities. At this altitudes, every 1km increase in height coverage need significant increase in Power Aperture Product (PAP).

When the requirement for a Wind Profiler for Satish Dhawan Space Centre (SDSC) – SHAR, to support the Satellite Launch Vehicle Missions (like PSLV, GSLV, & GSLV MK-III) came up , specified height was 20Kms with a high resolution at lower heights and moderate resolution at 10kms & above was specified, ISRAD worked out a system design at 200MHz

band (hitherto not tried out any where), using a fully Active Aperture Phased Array Radar (APAR) design. the efforts by ISRAD-ISRO led to the Wireless Planning Commission of Government of India (WPC – GOI), allocating the 200MHz band for wind profiling in India.

However, ISRO management based on doubts expressed by some atmospheric scientists wanted to play it safe and adopted a proven carrier of 50MHz, but adopted the APAR based design for the Wind Profiler at SDSC- SHAR.

Subsequently, when Department of Science & Technology of Government of India (DST-GOI)) embarked on an ambitious plan to establish a few ST Radars to extract 3D wind data beyond the Tropical Tropopause (upto 20Kms), they adopted the 200MHz design concept, originally proposed for SDSC – SHAR., based on the unique allotment of this band for Wind Profiling in India.

One of the locations for establishing ST Radar identified by DST is Kochi at the Cochin University of Science & Technology (CUSAT). The atmospheric scientific community at CUSAT enthusiastically supported this and a contract was awarded to Data Patterns, Chennai for the design, development and commissioning of the ST Radar operating @ 205 MHz. This paper describes the world's first ST Radar system fully operational at this unique frequency. The system level design & configuration adopted is marginally different compared to the one proposed for SDSC- SHAR. ST Radar of CUSAT consists of 617 Yagi antenna elements arranged as a near circular aperture. Each antenna is driven by a Transmit Receive Module (TRM) with a Peak Power of 500 Watts @ a Duty Ratio extendable to 15%. To start with it consists of 4 Receive Chains consisting of LNA & Rf Amplifier forming part of TRM followed by a Direct Band width Sampling Digital Receiver. While one receiver is used in Doppler Beam Swinging (DBS) Mode, other three Receivers cater to Spaced Antenna (SA) mode of operation. In DBS Mode the 3^0 Beam can be positioned at any Azimuth with an accuracy of 1^0 with an Off Zenith Angle variable up to 30^0 without getting into grating lobes.

Initially a sub array of 49 active elements was tested to validate the concepts especially of the antenna , Transmit – Receive Modules (TRM) and the Digital Signal Processing (DSP) scheme based on FPGA's. The sub array testing was quite successful covering >6kms and results were described in a recent issue of Radio Science (Kottiyil et al.).

This paper shows the block schematic of the full ST Radar with 617 elements operating in DBS mode. Preliminary results of 3D components of wind u,v,w were obtained in the height region from 350m to 20kms, consistently and an inter comparison was carried out with GPS sonde launched from CUSAT to validate the measurements . Figures 1, shows the results of u&v showing complementary symmetry. Fig.2 shows the Inter comparison with GPS Sonde Thus the results vindicated the choice of 200MHz band for wind profiling over the Tropics .

Since te antenna array is oriented along the Magnetic Meridian, attempts were made to look at possible returns from field aligned irregularities in the E & F region of Ionosphere some encouraging results were obtained. However, these studies need to be continued further systematically . Some typical results are attached herewith as Figures 3, & 4..

Currently the ST Radar is operational in DBS mode, round the clock at the Advanced Centre for Atmospheric Radar Research (ACARR) at the Cochin University of Science & Technology (CUSAT) ,Kochi in the Indian state of Kerala. Efforts are on to adopt SA mode using 3 / 4 sub arrays to obtain high resolution data upto 5Kms.

ST Radar at CUSAT is certainly an interesting new addition to the Global network of Atmospheric Radars, operating at a unique frequency of 205 MHz.

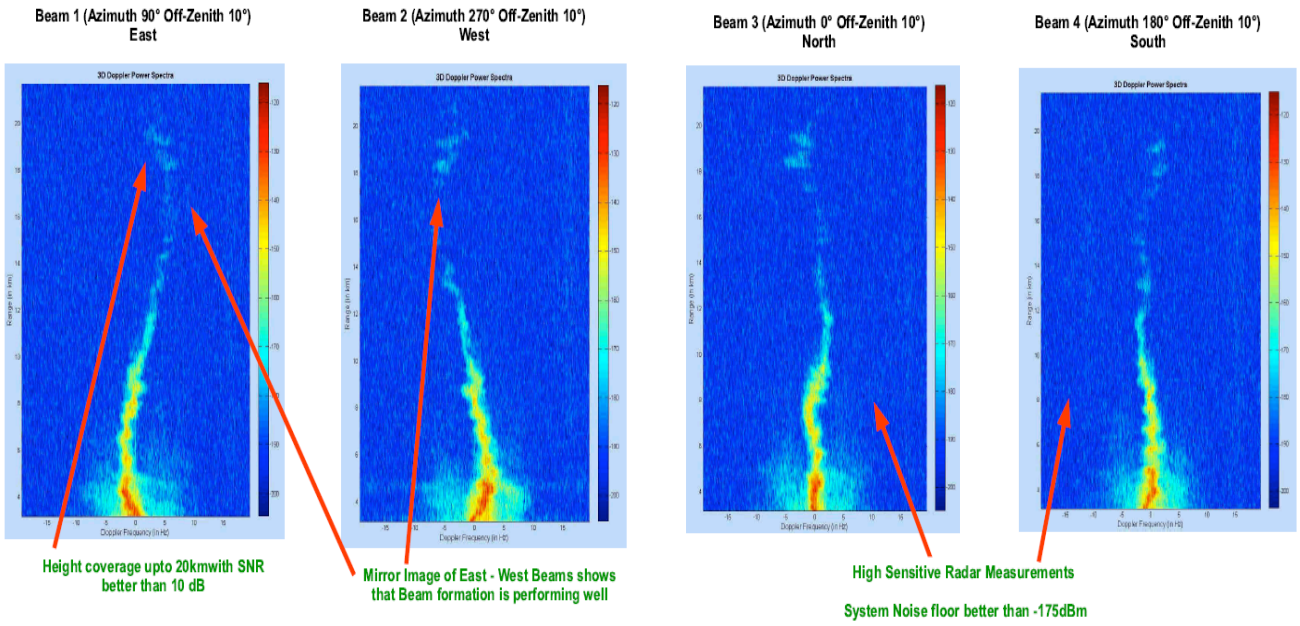


Fig 1.Zonal & Meridional Winds covering upto 20Km height & showing excellent symmetr

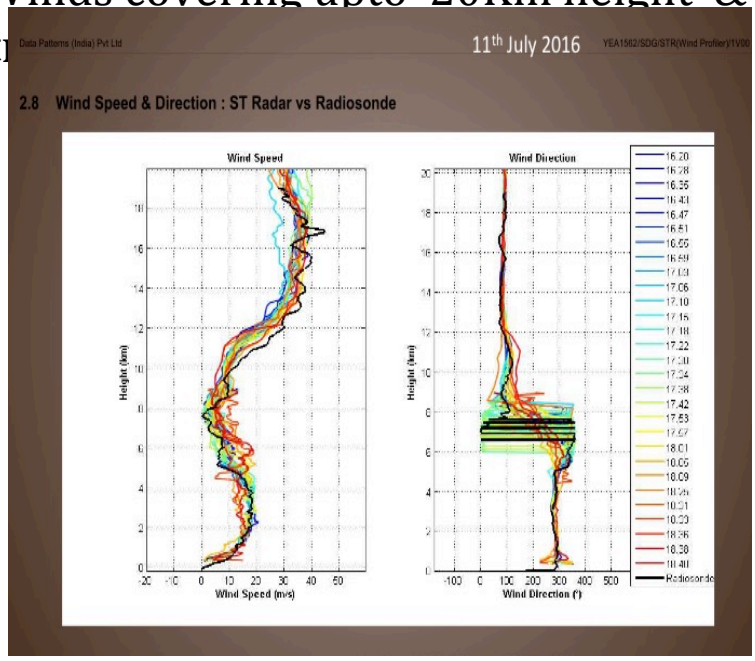
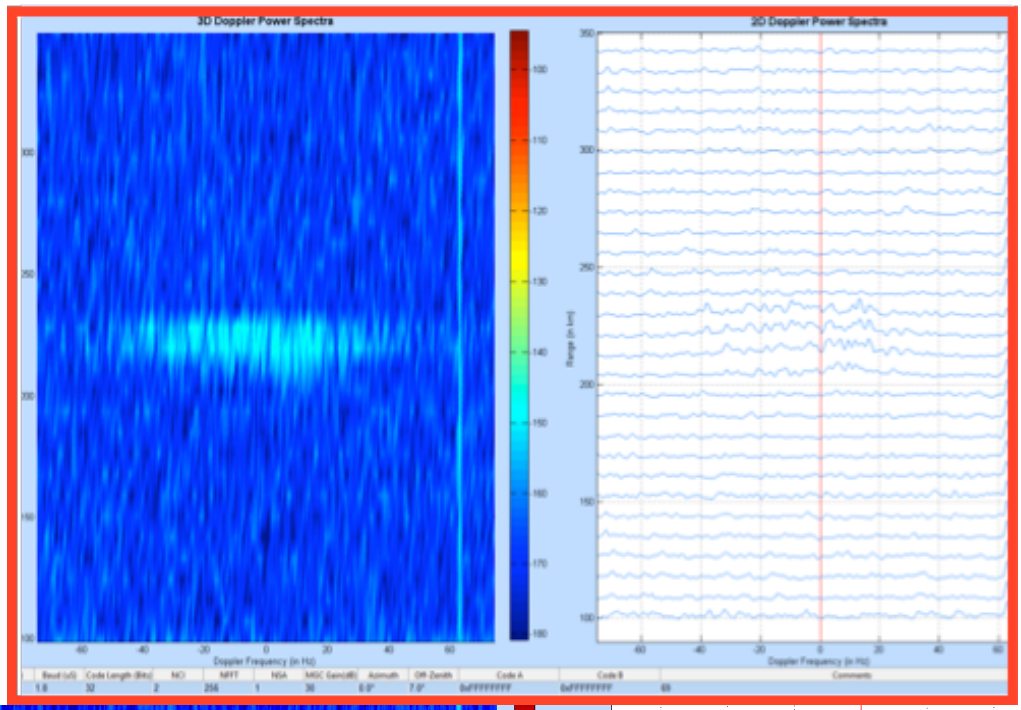


Fig 2. Wind Magnitude
&
Direction
Inter comparison with
GPS Sonde



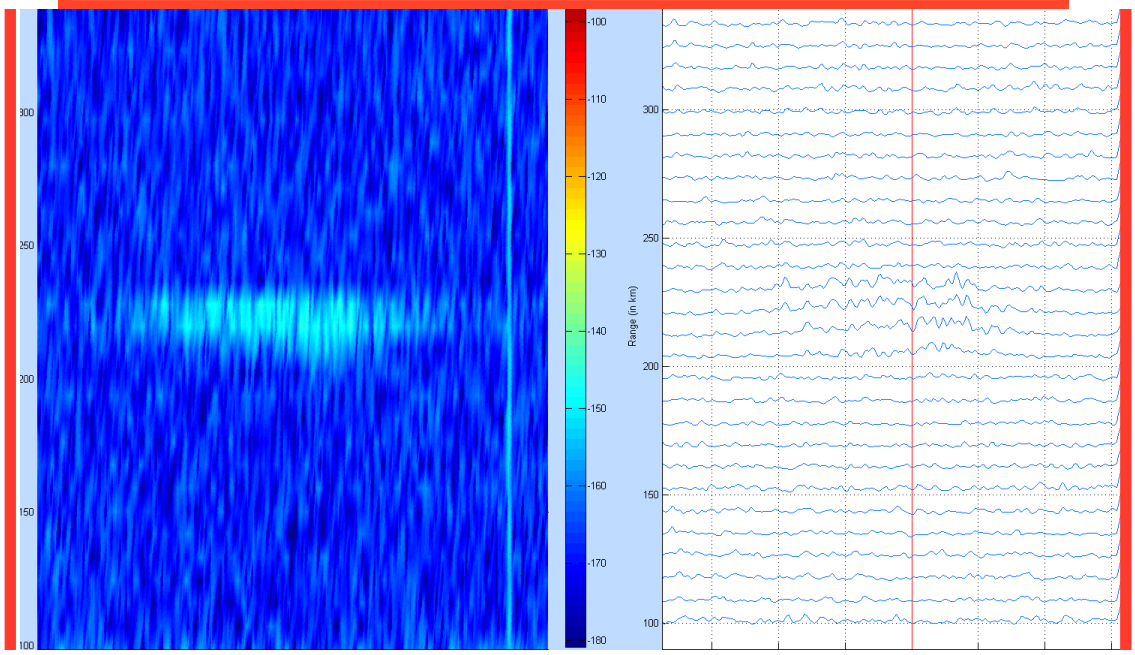


Fig 3. Echoes from D Region or Mesosphere?

Fig 4 Ionospheric Echoes from F Region