Design aspects of wind profilers for tropical region

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Abstract: Determination of wind profiles over the launch station upto a height of 20 Km has become an essential requirement to support major launch vehicle missions of ISRO on a continuous basis . Satish Dhawan Space Centre at SHAR, the Space Port of India had projected the requirements of such a Wind profiler. Wind profilers provide 3Dimensional atmospheric wind data on a continuous basis with good spatial and temporal resolution. This continuous high resolution wind data is very useful for studying the development of wind shears, in near real time, especially over the rocket launch sites as wind shears affects the performance of the rockets. Wind profilers are found to be a cost effective solution in the long run, for generating seasonal climatology pertaining to high resolution wind profiles, when compared to Smoke trail technique and Balloon/Jimsphere technique.

Accuracies of 1 m/s for the wind speed and 5 $^{\circ}$ for the wind direction are required for horizontal component of the wind. A height resolution of 50 m is most desirable to predict the effects of wind shears and gusts on launch vehicles. However, height resolution and height coverage do not go together. Hence we prepare a system which gives better resolution (50 m) at lower heights and a resolution of 150 m to 300 m at heights above 4 Kms, upto 20 Kms which is just above the tropo - pause at tropical latitudes.

The principle involved in these radars is the same as that of the MST Radar. Wind profilers use naturally occurring smaller scale turbulent eddies as tracers of large scale atmospheric flow. The turbulent eddies with scale sizes corresponding to one half the radar wavelength cause fluctuations in radar refractive index, resulting in backscatter of the incident electromagnetic energy. The scattering phenomenon is not highly frequency dependent in the lower atmosphere as compared to the higher regions especially Mesosphere. Thus the constraint on the use of lower VHF frequencies for MST Radar is not applicable to the Stratosphere Troposphere Radar (ST radar) The upper limit of frequency for such radars is generally found to be around 1300 MHz beyond which meaningful reflections do not take place. The cause of the upper cutoff is vis-

cosity which helps in converting turbulent eddies into heat, thus reducing the back scattered signal. This happens at the inner scale of turbulence and if the half wavelength of the radar is smaller than the inner scale, the radar will experience viscous cutoff. Currently Clear Air Wind Profiling is done at three bands viz. 900 -1300 MHz to cover lower troposphere ($\sim$4Kms), 404 - 480MHz, to cover upto 12Kms(Beyond tropopause at Mid latitudes), and around 50MHz to cover upto 25Kms (ST) as well as Mesosphere upto 85Kms(MST Radars),with a gap between 25 to 60Kms in the Stratosphere where turbulence is minimal.

For tropics where the tropo pause is between 16 to 18 Kms,to design a wind profiler to cover upto 20Kms using 50MHz with required signal to ratios (post processing) to establish confidence levels for wind profile accuracies, becomes very expensive due to the excessive levels of sky noise in this band. 400 MHz band is too close to the viscous cut off at these altitudes and would therefore need a very high power aperture to obtain the required SNR, or unacceptably higher integration times to generate a profile, even though the sky noise is much lower.

Hence, the frequency band of 200MHz was revisited (while designing such a profiler for Kennedy Space Centre of NASA in the tropical region of Florida coast, a study conducted by pioneers in wind profiler technology like Dr Richard Strauch found 233MHz to be an ideal choice for a high resolution wind profiler for Space launch support, but could not obtain necessary frequency & siting clearances due to the crowded TV spectrum in USA) .It was found to be optimal both from the viscous cut off limit as well as sky noise points of view to arrive at a cost effective solution from the point of Power Aperture product needed. Fortunately, due to the remoteness of site and the unique nature of operation and benefiting from the less density of TV channels in India, frequency and siting clearances were obtained for this profiler, at an operating frequency of 204 with a band width of 4MHz.

This paper describes the design approach, the configuration and the performance specifications and features of this unique profiler, configured as an Active aperture phased array, with 576 T/R modules. Operation in conventional Doppler Beam Swinging (DBS) mode for height coverage of 20Kms and a novel Bistatic Spaced antenna mode for lower height coverage from 1 to 4Kms is described. The paper also presents details & results of an experiment conducted to show that dominant scales sizes do exist at the altitude around 20Kms giving rise to Bragg scatter at this wavelength.