ST Radar system for wind profiling over Himalayas

VISWANATHAN G[1], Samaresh Bhattacharjee[1], Narendra Singh[1], Ramarao V[2], Sudhir C[2], VENKATESHRAO I[2], Swamy N[3], Balakrishnan S[3], Harender P[4]

[1] Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital,

[2]Spanwave Technology Solutions Pvt Ltd, [3]Vikas Communications, [4]Electronics Corporation of India Ltd.

Abstract

Increasing interest in the Himalayan Environment has resulted in view of the Global warning scenario including Transboundary flow of aerosols and pollutants and the need for characterizing winds, waves turbulence and Aerosol optical depth, etc. of the neutral atmosphere over the Himalayan region. Aryabhatta Research Institute of Observational Sciences (ARIES) located at Nainital(29.24^{o}N,79.28^{o}E) at an altitude of 6250m is making Aerosol optical depth measurements using LIDARS and other atmospheric measurements routinely. In order to .augment the facilities for measurement of atmospheric dynamics, ST radar with height coverage of 20Kms take care of exchanges between Troposphere & Stratosphere is being established.

Wind Profiling over the Tropical region with a height coverage beyond the tropopause poses challenges in the choice of frequency and optimization of performance parameters at system level like for example the Power Aperture Product (PAP) , which is generally considered as the figure of merit for such radars. The main reason is the occurrence of tropical tropopause around 16to 18kms as against the mid latitude values of around 10kms. Commercial wind profilers operating around 440MHz make use of the reduced sky noise temperature to cover the height region of marginally >10kms with reasonable power aperture values to make the systems cost effective. However , in order to study tropo – stratospheric exchanges beyond the Tropopause over the tropics one is forced to use much lower frequencies with attendant increase in Sky Noise temperature resulting in much higher PAP to meet Signal to Noise Ratio (SNR) needed for estimation accuracies, mainly because of the scale size of irregularities giving rise to Bragg Scatter is a direct function of height. In order to achieve a height coverage of 20kms , slightly beyond the tropical tropopause the 440MHz band will have a limitation from the scale size point of view, due to viscous damping. Traditionally the 50MHz band used for Mesosphere Statosphere & Troposphere radars were therefore used for the ST Radar application also over tropics resulting in physically much larger antenna sizes and enhanced PAP values, thus increasing the cost of ST radars almost close to that of MST Radars. Figure 1 shows the height coverage vs scale size for clear air radars dependant upon Bragg scatter . (ref: MAP handbook vol 9).

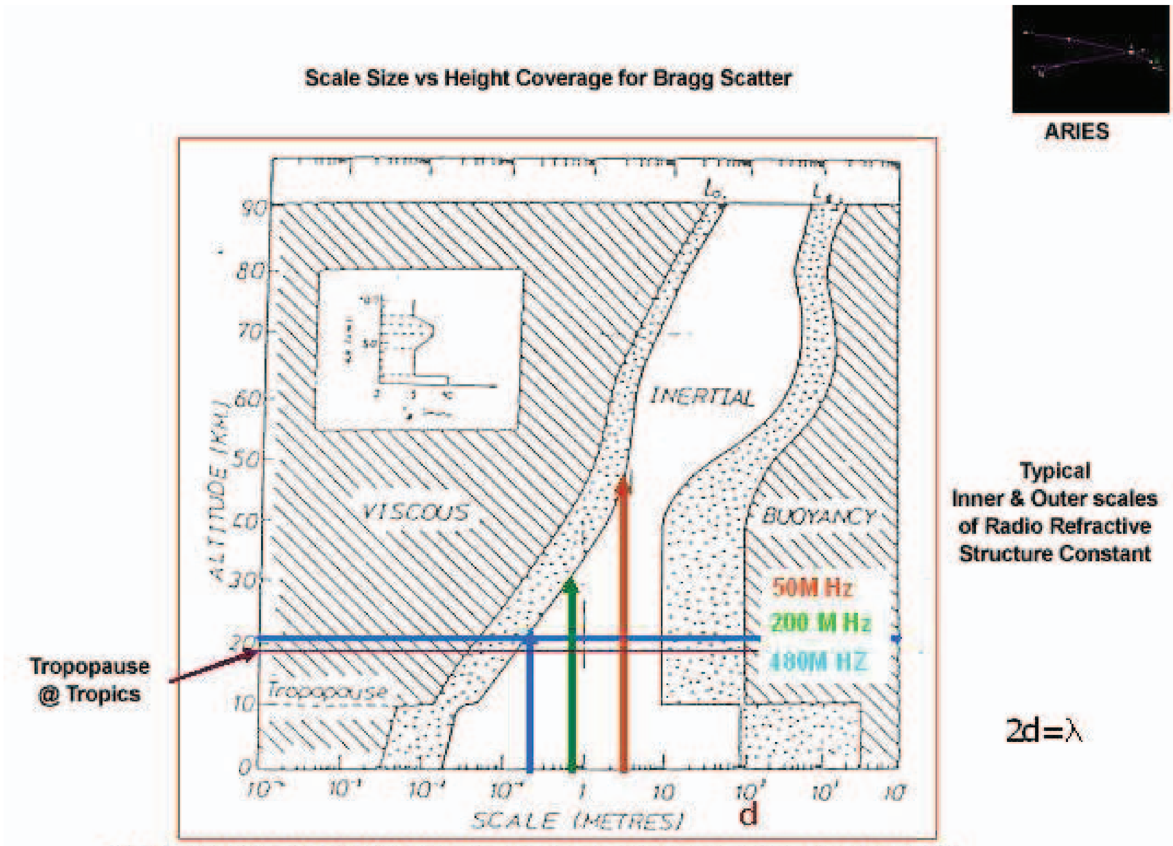

Fig 1. CHOICE OF FREQUENCY –GUIDELINE DATA (from MAP Vol. 9)

Stratosphere – Troposphere Radar (ST Radar) for ARIES is designed for operation in the 200MHz Band of VHF, to derive the advantages of reduced Sky Noise as compared to 50MHz band at the same time ensuring that the Bragg scatter will result based on the scale size being in the Inertial subrange. However, we were required to take special clearance from the Wireless Planning Commission (WPC) of the Govt of India as the 200MHz band is also used for Television Broadcast. A carrier frequency of 206.5 MHz was allotted by WPC after a detailed coordination among the different users of frequency spectrum in India. Thus the ST Radar for ARIES represents a cost effective solution for probing the neutral atmosphere well beyond the tropopause over the tropical region. Based on this initiative the Department of Science and Technology of the Government of India is planning for a network of ST radars, over the subcontinent.

This paper describes the design aspects of the active aperture phased array radar to be operated at 206.5 MHz for measuring three dimensional wind vector over the troposphere and lower stratosphere regions of the tropical atmosphere. The system is designed for installation at Manora peak, Nainital in the campus of Aryabhatta Research Institute for observational sciences, an autonomous laboratory of the Department of Science and Technology, Govt. of India.

Power aperture product, pulse compression schemes and digital signal processing and data visualisation schemes are described for the conventional Doppler Beam Swinging (DBS) mode, as well as a bistatic Spaced Antenna

Drift (SAD) mode to cover lower height region overcoming the limitations usually imposed by the TR recovery time and the near field limitations of a large phased array antenna. Operation in these modes provides height coverage from 0.5 km to 20 Km with variable height resolutions from 75 metres to 300 meters as a function of height.

Power aperture product of ~10*8 Watt.m^2 is planned to be realized using individual TR Modules with peak power of 400 W feeding three element Yagi Uda Antenna elements, 588 in number arranged in a circular aperture providing a 3^o beamwidth and ~ -15 dB SLL, in the full aperture DBS mode operation to probe up to 20kms. The SAD mode is realised to cover a height region from 0.5 to ~ 4Km using combinations of three sub arrays with reduced PAP.

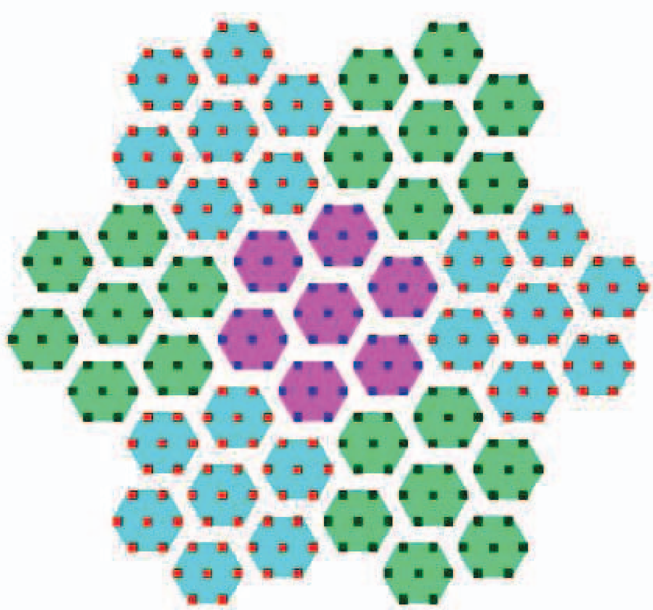

Fig - 2: Spaced Antenna Drift (SAD) mode options

Other subsystems like the RF coherent signal generator with Biphase coder with variable code sequence, pulse lengths, a versatile four channel digital receiver, FPGA based decoder, CAN based Beam Steering Unit and Radar Controller which is the man machine interface are also described.

The data visualisation in the form of power spectra vs height, 3D spectra and UVW vs Height are also described. A BITE system to alert the operator on the status of different subsystems as well as to provide an insight into the power aperture product for a given observation is also described. Another important aspect of the system is the provision to record raw IQ data for an extended period for one hour to validate the data system and for system checks. This feature also helps in calibrating the radar when used with built in simulator as well as external calibration.

BIO DATA OF AUTHOR

Shri. G.Viswanathan, Director (Rtd.) - ISRAD / ISRO. G.Viswanathan, born in 1945 at Chittoor in Andhra Pradesh, graduated in Physics from Madras University & after Obtaining his DMIT in Electronics and Telecommunications Engg from Madras Institute of Technology in 1967, worked on design & development of Avionic packages for IAF, at Aeronautical Development Establishment of DRDO, for two& half years, before joining ISRO in 1970 at Thumba Equatorial Rocket Launching Station (TERLS, now a part of Vikram Sarabhai Space Centre), as a Radar Engineer. He was responsible for the Design & Development of Tracking Radar Systems for Satellite Launch Vehicle Missions from India's Space Port viz Sri Harikota (SHAR). He later on initiated the development of PCMC radar system as a joint development project between ISRO & BEL to support PSLV Mission. Thereafter, he was the Project Director for the Establishment of the MST radar at Gadanki near Tirupati as a major Scientific Facility for Atmospheric Research in India. Indian MST radar system happens to be the Second largest such facilities in the world. He was also Co Investigator for the Ground validation of the Tropical Rain fall Measuring Mission (TRMM), especially for the Space borne Precipitation Radar (PR), along with the Japanese Aerospace Agency. Later he was responsible for the design development and commissioning of the state of art Doppler Weather Radar system for IMD as an inter agency project between DOS & DST. Based on Technology transfer from ISRO to BEL the DWR system is now in production to meet national requirements. As the Director of ISRO Radar Development Unit (ISRAD), headed a team of Radar system professionals in realizing Tracking & Weather radar systems for national development, including the next generation tracking radars for GSLV Mk-III through technology support to L&T. He is a Fellow of IETE & a Member of a number of professional societies in India & abroad including IEEE. He has published more than 25 Technical & Scientific papers in National & International journals. After super superannuation from ISRO in 2007, he is currently the Adjunct Professor at Aryabhatta Research Institute for Observational Sciences, Nainital, where ST Radar is being established by DST. He is also a Member of the Committee on Technology Vision for Ministry of Earth Sciences and Chairman of the Sub committee on Atmospheric Technology. He was awarded the IETE – IRSI award for excellence in Radar systems in 1992. With his leader ship, ISRAD received the first team award instituted by Astronautical Society of India, for the development of Doppler Weather Radar System. He was felicitated by IAF & Met Society in Feb 2008 for his outstanding contributions in Space & Aviation Meteorology. He has recently (on Aug25, 2009) received the ISRO Merit award from the Hon. Prime Minister of India Dr Man Mohan Singh for his contributions towards Atmospheric and Weather Radars.