RADAR

RADAR is an acronym for Radio Detection and Ranging. It is a device capable of detecting objects at far off distances, measuring the distance or range of the object by using electromagnetic waves.

Radar frequencies

The spectrum of the electromagnetic waves shows frequencies up to 10^{24} Hz. This very large range is subdivided in to different bands of frequencies having specific properties of propagation and absorption in atmosphere, as given below.

Radar bands and the corresponding frequency bands and wavelength

Band Designation	Frequency	Wavelength
HF	3 – 30 MHz	100 – 10m
VHF	30-300MHz	10-1 m
UHF	300 - 1000MHz	1 - 0.3 m
L	1-2 GHz	30-15 cm
S	**2-4 GHz**	**15-8 cm**
C	**4-8 GHz**	**8-4 cm**
X	**8-12 GHz**	**4-2.5 cm**
Ku	12-18 GHz	2.5-1.7 cm
K	18-27 GHz	1.7-1.2 cm
Ka	27-40 GHz	1.2-0.75 cm
mm or W	40-300 GHz	7.5 – 1mm

It is easier to build high-power transmitters in lower frequencies. The RF attenuation is lower in lower frequencies than in higher frequencies. On the other hand the measurement accuracy is reduced, because the low frequency antennas are very large insize,whichreduces the angle accuracy and resolution. Use of these frequency-bands in other communications and broadcasting services causes interferences with Radar Operation.

High frequency (HF) radars (3 – 30 MHz) systems measure the speed and direction of ocean surface currents in near real time. Currents in the ocean are equivalent to winds in the atmosphere because they move things from one location to another. These currents carry nutrients as well as pollutants, so it is important to know the currents for ecological and economic reasons. The currents carry any floating object, which is why Coast Guard search and rescue operators use HF radar data to make critical decisions when rescuing disabled vessels and people stranded in the water. These radars can measure currents over a large region of the coastal ocean, from a few kilometres offshore up to 200 km, and can operate under any weather conditions.

VHF Radars (30-300MHz) are used for observing mesosphere, stratosphere and troposphere. The Indian MST Radar is a highly sensitive VHF phased array radar operating at 53 MHz with total transmitting power of 2.5 MW (peak) and the phased array consists of 1024 crossed three-element Yagi antennas occupying an area of 130m x 130m. .The MST Radar provides estimates of atmospheric parameters with very high resolution on a continuous basis for the study of different dynamical processes in the atmosphere. It is an important research tool in the investigation of prevailing winds, waves (including gravity waves) turbulence, and atmospheric stability.

UHF- Radars(300 MHz to1 GHz) are used in specialized Radar for the operation of radars for the detection and tracking of satellites and ballistic missiles over a long range. These radars operate for early warning and target acquisition like the surveillance radar for the Medium Extended Air Defense System (MEADS). Wind profilers work with these frequencies for monitoring the wind and temperature patterns in the atmosphere.

L-Band Frequency (1 to 2 GHz) is used in long-range air-surveillance radars up toto 250 NM (≈400 km).Earth curvature limits the maximum range for targets flying with low altitude. In Air Traffic Management (ATM) long-range surveillance radars like the Air Route Surveillance Radar (ARSR) works in this frequency band. Coupled with a Mono-pulse Secondary Surveillance Radar (MSSR) they use a relatively large, but slower rotating antenna.

Operational weather radars (X band, C band & S band)function at 3cm, 5cm and 10 cm wave lengths for storm detection and cyclone tracking.For clouds detection millimeter wave radars are used. Other factors being equal, the echo returns from clouds or precipitation increases with shorter wavelengths. In addition, for the same antenna size, the beam width is narrower in shorter wavelength, which results in greater resolution. But the attenuation of the radar energy increases sharply as the wavelength decreases. Hence, the choice of the operational wavelength of the radar depends on its intended use. Short wavelengths of the order of 1 cm or less are suited for cloud detection. For detection of light to moderate rainfall and thunderstorms, a wavelength of 3 cm is found to be suitable. At this wavelength it is possible to obtain, a pencil beam of 1° width with an antenna of 2.5 m diameter. However, in regions of widespread thunderstorm activity or cyclones, the use of higher wavelengths especially 10 cm is preferred because of the severe attenuation ofradiation 3 cm wave length in heavy rain. To obtain a beam width of 1°, an antenna with diameter of about 9 m is required for 10 cm wavelength radiation. To strike a useful compromise between attenuation and beam width for a light weight fixed small antenna size, wavelength of 5.7 cm in the C-band, is used. This wavelength is particularly suitable for airborne radars and in temperate latitudes.

In IMD different types of radar network operating in S band X band frequency for the purpose of cyclone and storm detection & tracking were installed. Recently C band radars also have been installed.

Doppler Weather Radars

The existing old radars of IMD’s radar network are being upgraded with modern radars in a phased manner. Accordingly 4 S-band DWRs imported from Germany were installed at Chennai, Kolkata, Machilipatnam and Visakhapatnam. A DWR developedby Indian Space Research Organisation (ISRO) under a collaborative programme with IMD was installed at Sriharikota. Doppler weather radars provide information of wind (radial velocity) and its variance (spectrum width) in addition to the reflectivity. It helps to observe the distribution of rainfall rates, accumulated rain over a period of time, vertical profile of horizontal wind, signatures of cyclones and tornadoes, maximum wind in cyclones, wind shear and turbulence, probability of severe weather and hail and the likely size of hailstones are important among the products. Digital radar data are being assimilated into Numerical Weather Prediction (NWP) models. This opens up numerous possibilities for weather analysis and forecast and now-cast of various weather phenomena.

Out of 12 S band DWRs procured from M/s Beijing Metstar, China. Eight numbers are installed at Delhi, Hyderabad, Nagpur, Agartala, Patna, Lucknow, Patiala, and Mohanbari; and one is nearing installation at Bhopal.

Two DWRs, from M/s BEL, Bangalore based on ISRO technology, are being installed at Mumbai and Bhuj. These are S-band DWRs and will be used for detection& trackingof cyclones from Arabian Seaand other weather events.

Two C-band Polarimetric DWRs procured from M/s Vaisala Oyj, Finland are installed at Delhi and Jaipur. Polarimetric radars are capable of providing realistic estimates of Rainfall measurements, automatic classification of hydrometeors in addition to the capabilities of DWRs.

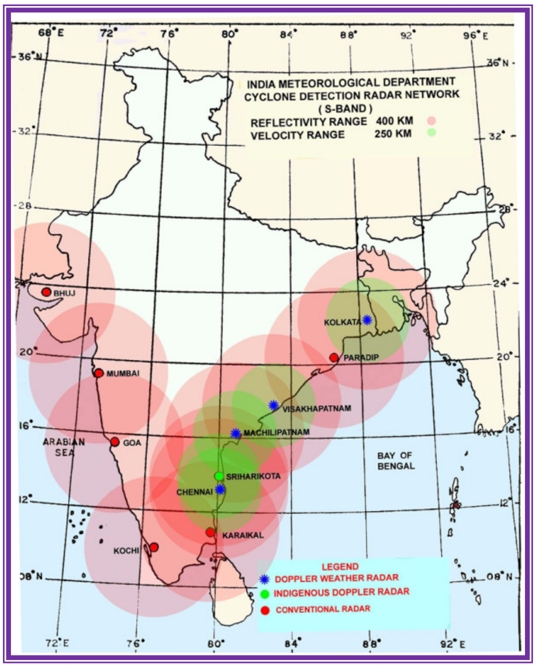


Fig. 1.1 Radar network of Cyclone Detection Radars.(Radars at Chennai, Kolkata, Machilipatnam and Visakhapatnam have Doppler Capability)

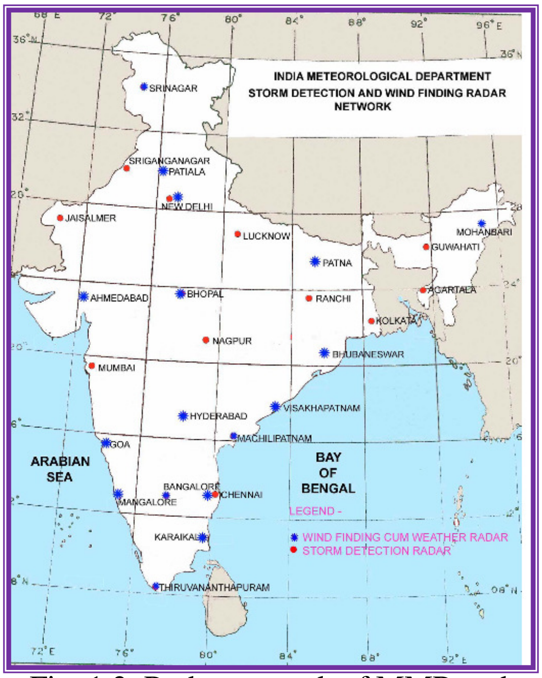


Fig. 1.2 Radar network of MMR and windfinding radars

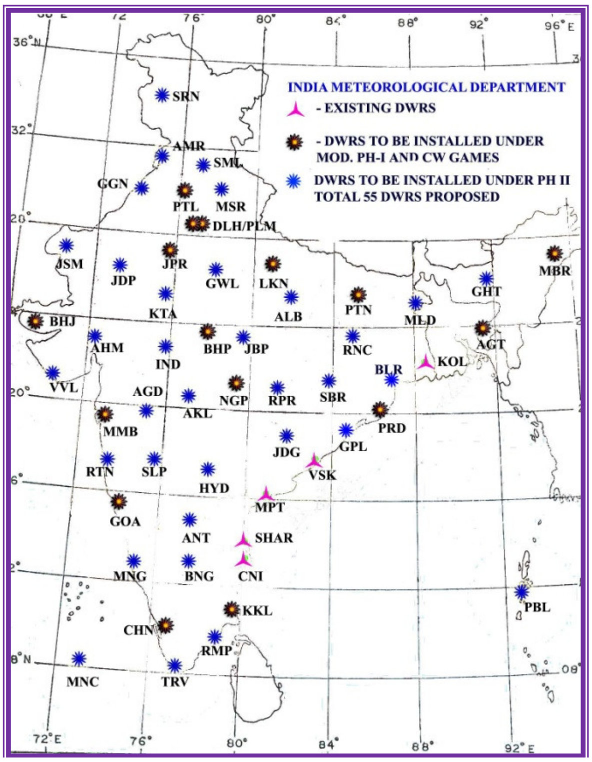


Fig. 1.3 Radar network of 55 DWRs after completion of modernization programme of India Meteorological Department.

Chapter 2

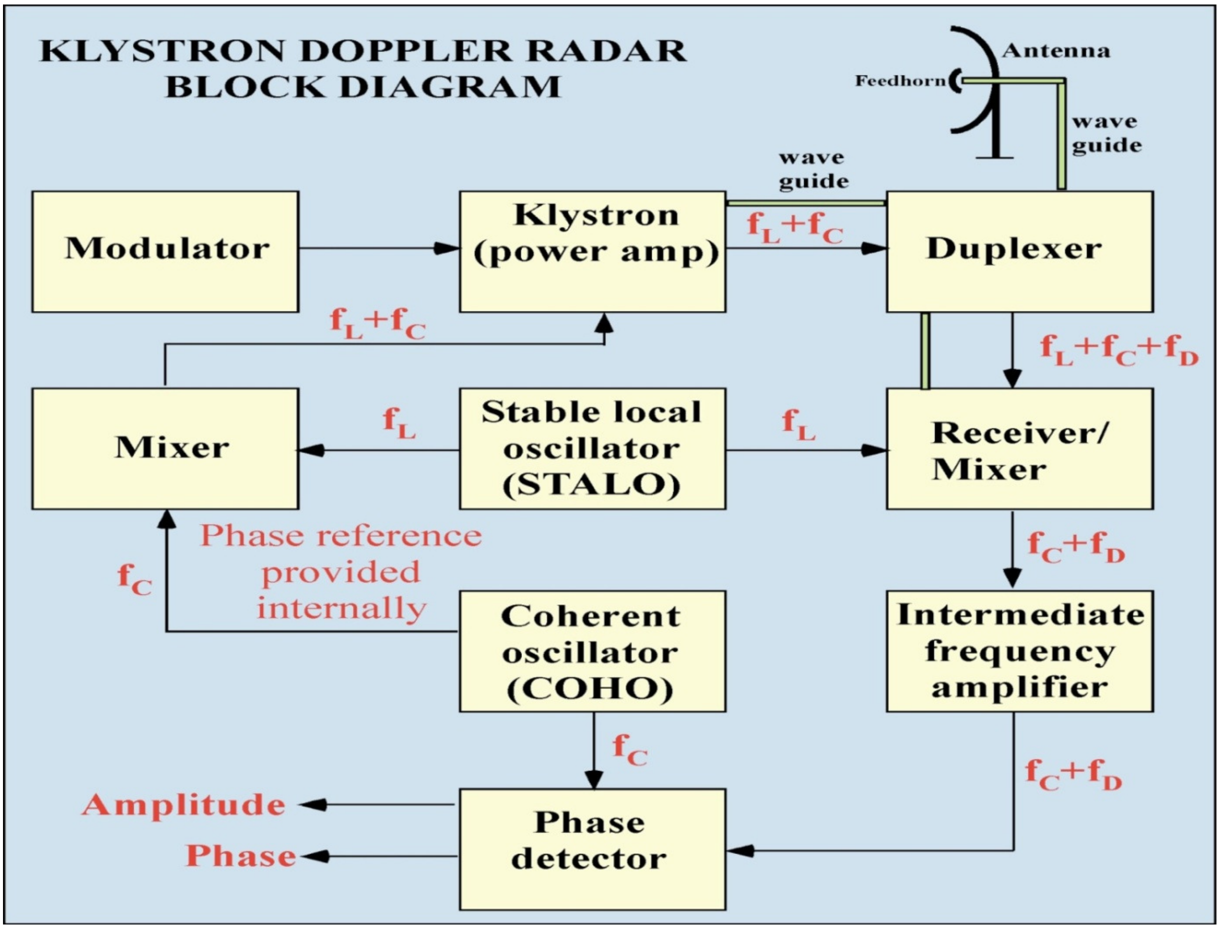
Doppler Weather Radar Principles

1. Doppler Principles

"Doppler" radar makes use of the Doppler Effect to measure velocity of moving targets it detects. It works by detecting the change in the frequency of the transmitted and returned signal arising due to the movement of the target. The velocity component of a target relative to the radar beam is known as the "radial velocity".

2. Working of a Pulsed Doppler Weather Radar

A Doppler Weather Radar (DWR) consists of a RF transmitter that generate high power microwave radiation in pulses, an antenna to send the signal out to space and to receive scattered energy (echoes) from targets around, a servo system to move the antenna in a planned schedule scan, a receiver to detect and process the received echo signals and a display unit to graphically present the signal in user understandable form. Magnetrons, klystrons and travelling wave tubes still continue to be the main RF oscillators of most radar



transmitters.

Transmitter: The transmitter generates the RF energy either in oscillator mode, or in Amplifier mode from a stable RF Source (STALO). Klystrons are used for this purpose most of the time in DWRs for the purpose of coherence to detect the phase differences in the transmitted and received frequencies. RF Power transmitters of the order of 500 KW are common, where as transmitter with 1000 KW power is also used in a IMD radar. Though general working voltages are of the order of 1KV, some transmitters use high voltages of the order of 70KV.

RF Oscillator Tubes: Magnetrons, Klystron, Thyratron are the popularly used tubes in weather radars. Magnetrons are mostly used in conventional non Doppler radars. After improved technology Magnetrons are also being used in DWRs .Klystrons are used in DWRs particularly to achieve high coherence between the transmitted and received pulses. These Klystrons are used as Amplifiers where the output power& pulse repetition frequency is controlled by modulator circuits.

Wave guides: RF power is transmitted to the antenna using wave guides which are also known as travelling wave tubes. Wave guides are hollow metal tubes with rectangular cross section, made from aluminum or gun metal. In the waveguide chain where ever bends are required L-bends and U-bends are used. Flexible wave guides are also used where-ever links are to be negotiated slightly, during installation.

Antenna and duplexers: A Radar antenna is generally a parabolic dish antenna that is very sensitive with high gain. It is generally designed to generate beam of about 1 degree beam-width for generating high resolution data sets. The same antenna is used for transmitting and receiving the RF Signals. The switching is done by duplexers. Duplexers allow the receiver to be cut-off from antenna during transmission to safe guard the receiver. Circulators are one type of duplexers and when ferrite materials are used as core of these circulators, they are known as ferrite circulators.

Receivers: Receivers are divided into two types basically. RF Front end amplifiers are RF booster amplifiers that increase the signal strength of received energy. Mixer-amplifier actually mixes the Received energy with STALO frequencies and the generated Intermediate Frequency IF is used for further processing. In general 10 MHz or 30 MHz are the IF frequencies. Some radars use two-stage IF mixing.

Signal Processors: Signal processing is the most complicated of all radar hardware. It involves deriving the echo properties/radar base parameters from the received signals. Algorithms like Pulse pair and Fast Fourier Transformation (FFT) techniques are used for this. The basic output of the Receiver consists of information on Amplitude and Phase of the received signal. From amplitude information we deduce the intensity of the back-scattered signal and from Phase information we deduce the radial velocity of the moving targets.

Servo System: The Servo system is the hard ware part of remote control of antenna. It consists of antenna gear assembly, motor systems, position encoders, servo controllers and a control console. Modern servo systems are operated based on computer programs/scan schedule stored in workstation of radar controller.

Radar Controllers: A modern DWR needs coordinated operation between transmitter, receiver, servo, antenna, data collection, signal processing and display systems. This needs a central monitoring and control of all the operations flawlessly. A Radar controller is a programme that takes care of all these operations, based on the inputs from the operator either in manual (immediate) mode or in automatic (pre-programmed) mode. Most of the modern radars are generally operated in fully automatic mode that takes care of the operation, calibration, data acquisition, product generation and data dissemination.