Upper Air Observations

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Upper Air Intercomparison 2021(TT-UAI)

Upper air Instruments Division

भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

The Upper Air Observations

- **Under the co-ordination of World Meteorological Organization (WMO), as part of the global meteorological network, upper air observations (radiosonde measurement) are generally carried out at around 1300 stations[1] across the globe.**
- **IMD has a network of 56 Radiosonde Radiowind (RS/RW) stations.**
- **62 stations in the upper air network of IMD having pilot balloon observations.**

[1]https://www.wmo.int/pages/prog/www/OSY/Gos-components.html

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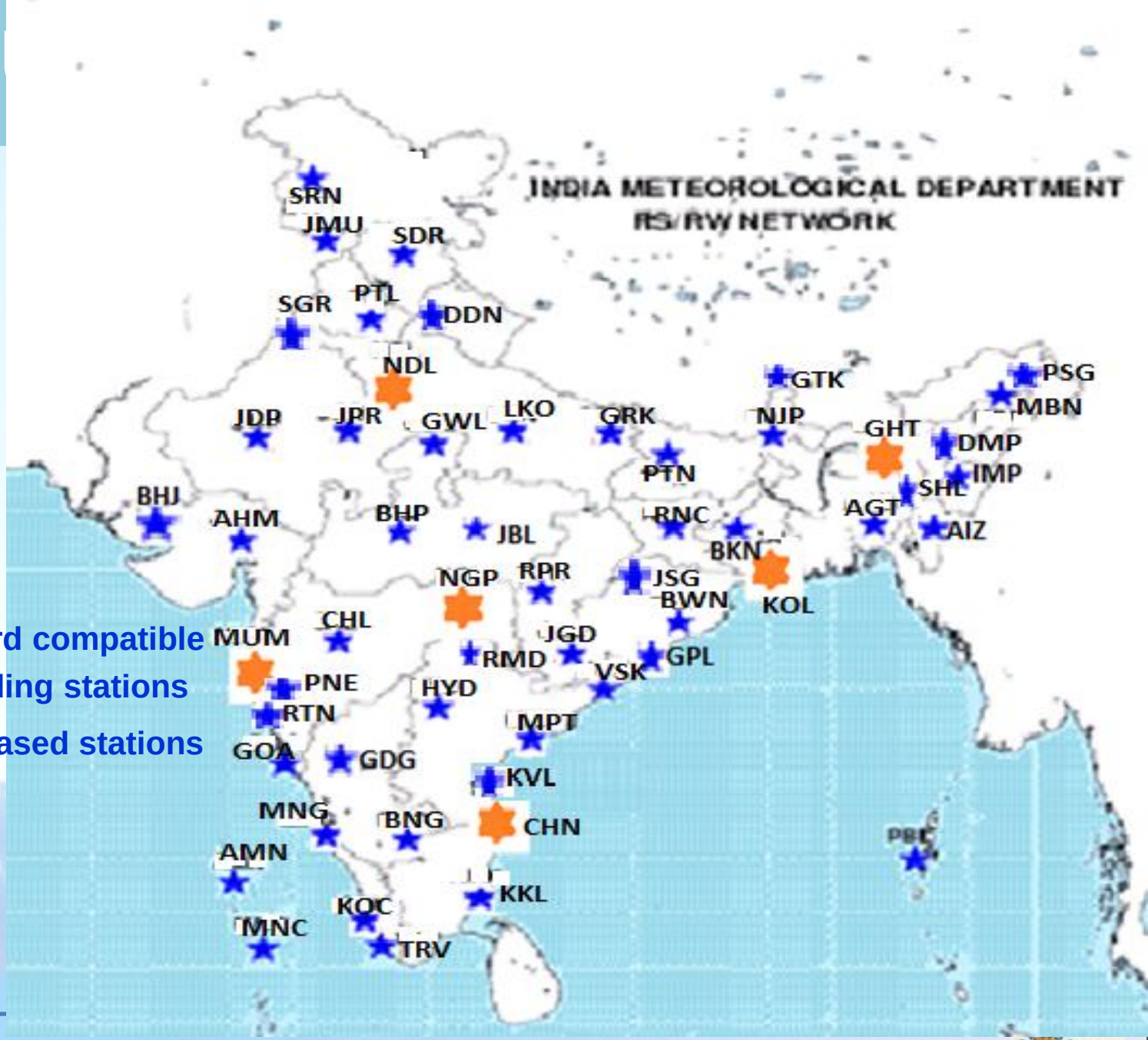
- **Upper air observations are taken at synoptic times (0000, 0600, 1200 and 1800 UTC) across the world.**
- **Radiosonde launches are carried out twice a day at more than 900 sites[2] (0000 & 1200 UTC).**
- **100-200 stations[2] having 1 ascent only.**
- **Four times a day at few sites.**
- **Besides these, around 540 stations taking pilot wind observations only.**

[2]https://www.wmo.int/pages/prog/www/OSY/Gos-components.html

The

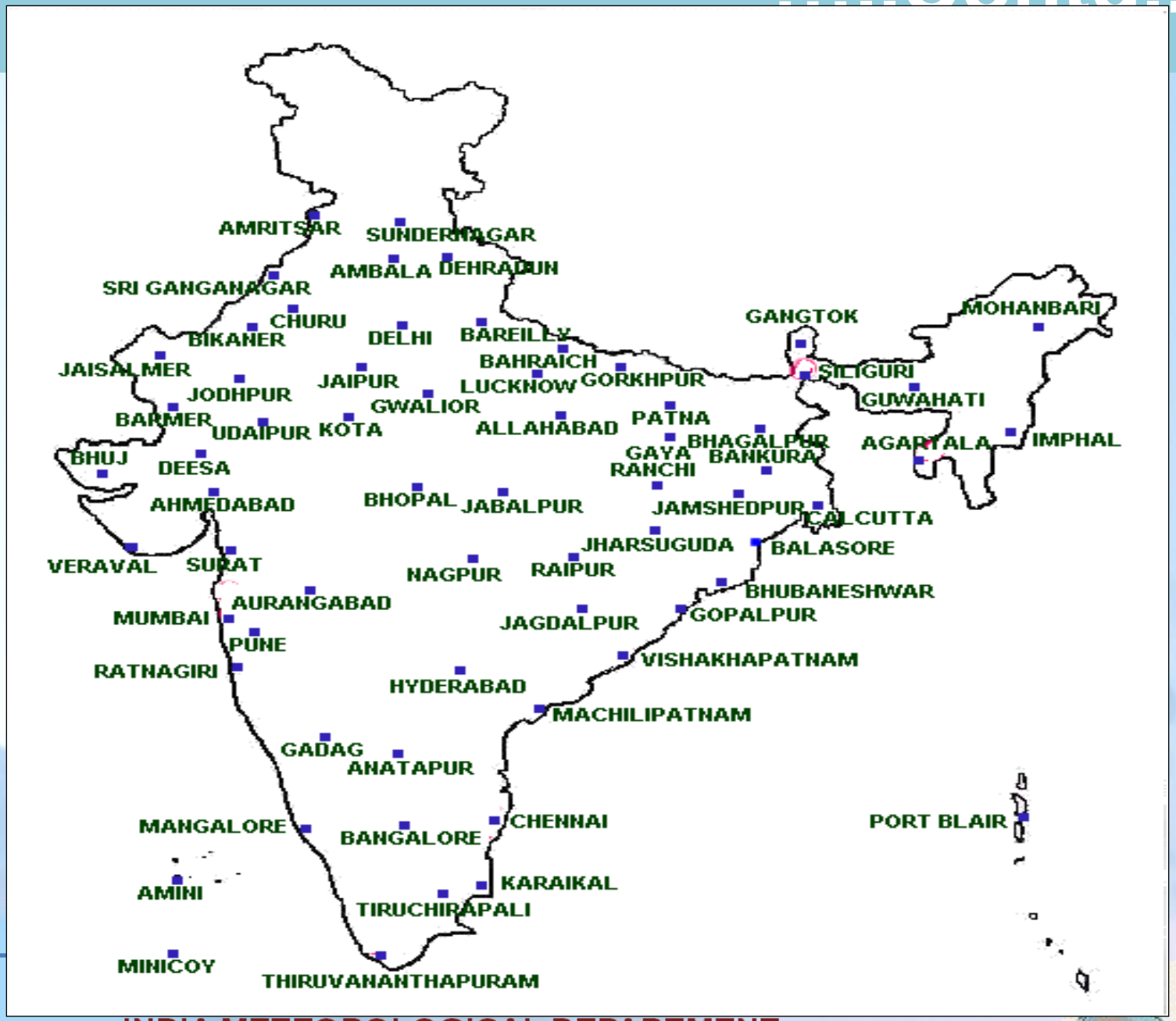
56 Radiosonde Radiowind (RS/RW) stations.



GUAN standard compatible Radiosounding stations

Other GPS based stations

- 62 stations having pilot balloon observations.



Elements of observations

- **In Radiosounding:-**

1. **Temperature**
2. **Humidity / Dew point temperature**
3. **Pressure / Height**
4. **Wind Direction**
5. **Wind Speed**

- **In Pilot Balloon Observations:-**

1. **Wind Direction**
2. **Wind Speed**

Measurement

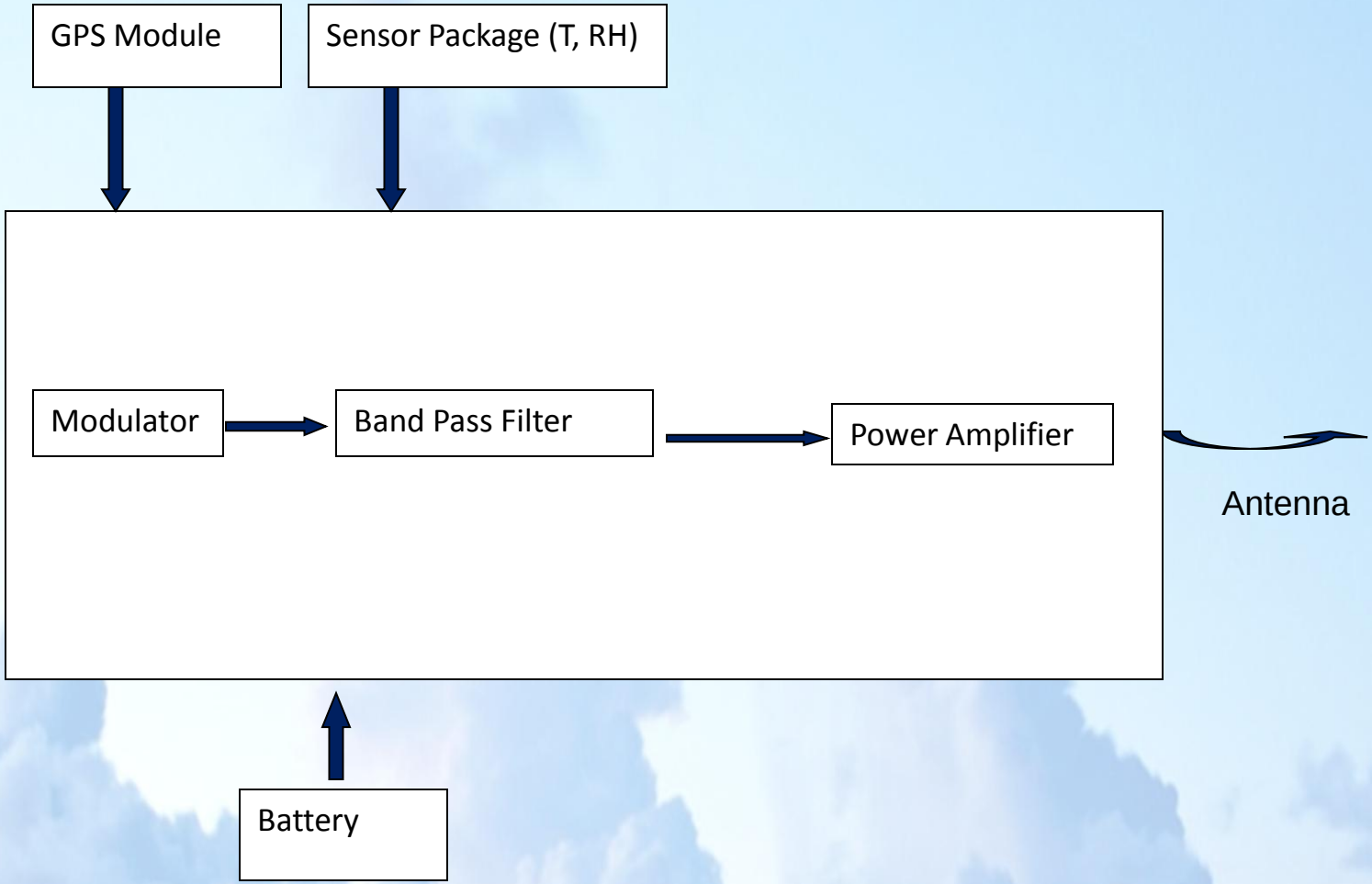
- **In Radiosounding:-**

1. Temperature--	Thermistors (Rod/Bead)
2. Humidity / Dew point temp	Hygristor (LiCl, C, Cap)
3. Pressure / Height	Press sensor, GPS height
4. Wind Direction	Tracking with GPS
5. Wind Speed	Tracking with GPS

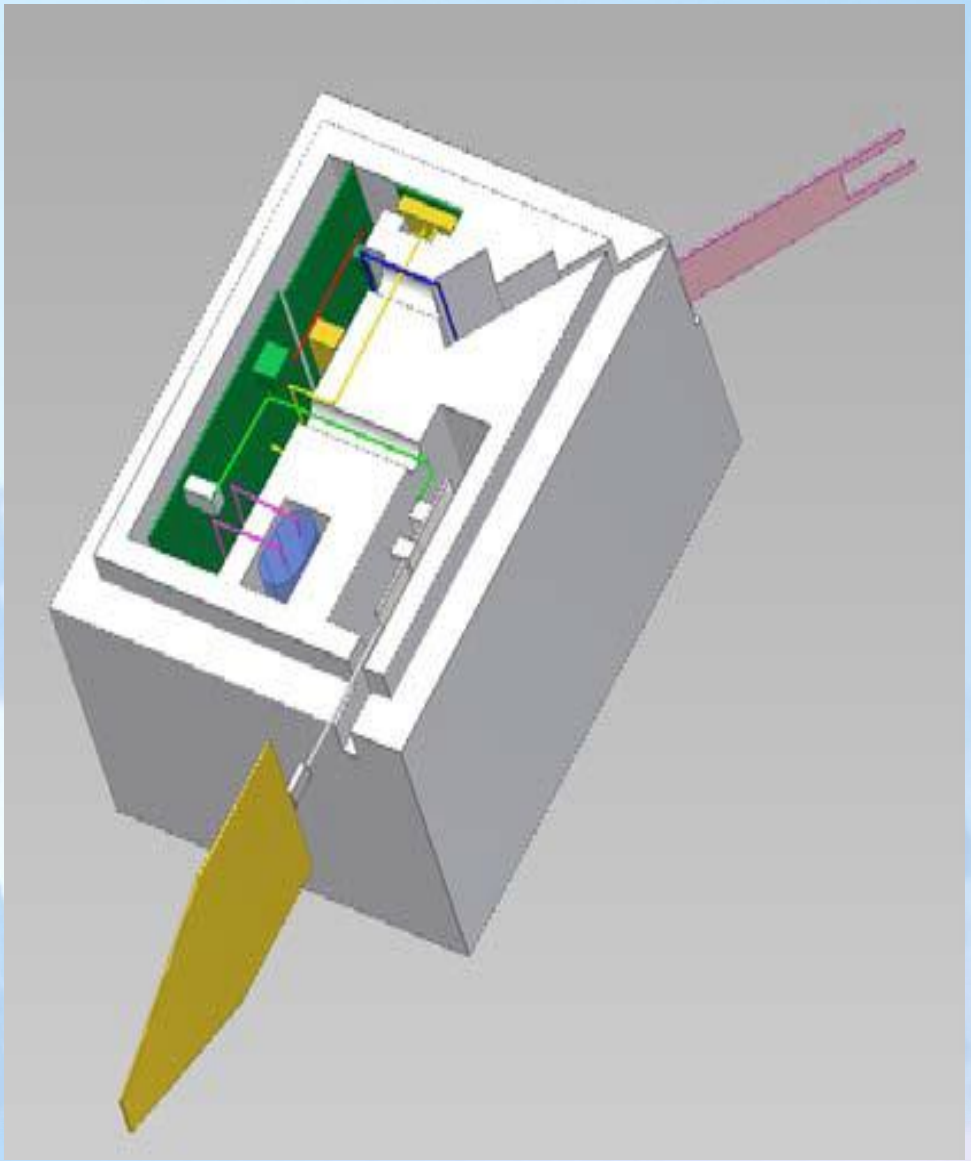
- **In Pilot Balloon Observations:-**

1. Wind Direction	Tracking of balloon
2. Wind Speed	Tracking of balloon

RADIOSONDE BLOCK DIAGRAM



Radiosonde launch



Radiosonde

GPSonde includes the following subsets:

- Temperature and humidity sensor boom
- 3D GPS Module
- Transmitter
- Microprocessor board
- Battery pack

GPS antenna for satellite reception and 400Mhz antenna for ground transmission.

Sounding Systems

- **Radiosounding:-**

1. **GPS based radiosounding systems**
2. **Radiotheodolite based sounding systems**
3. **Radiosonde Ground equipment using optical theodolite for wind observations.**
4. **Satellite derived profiles**

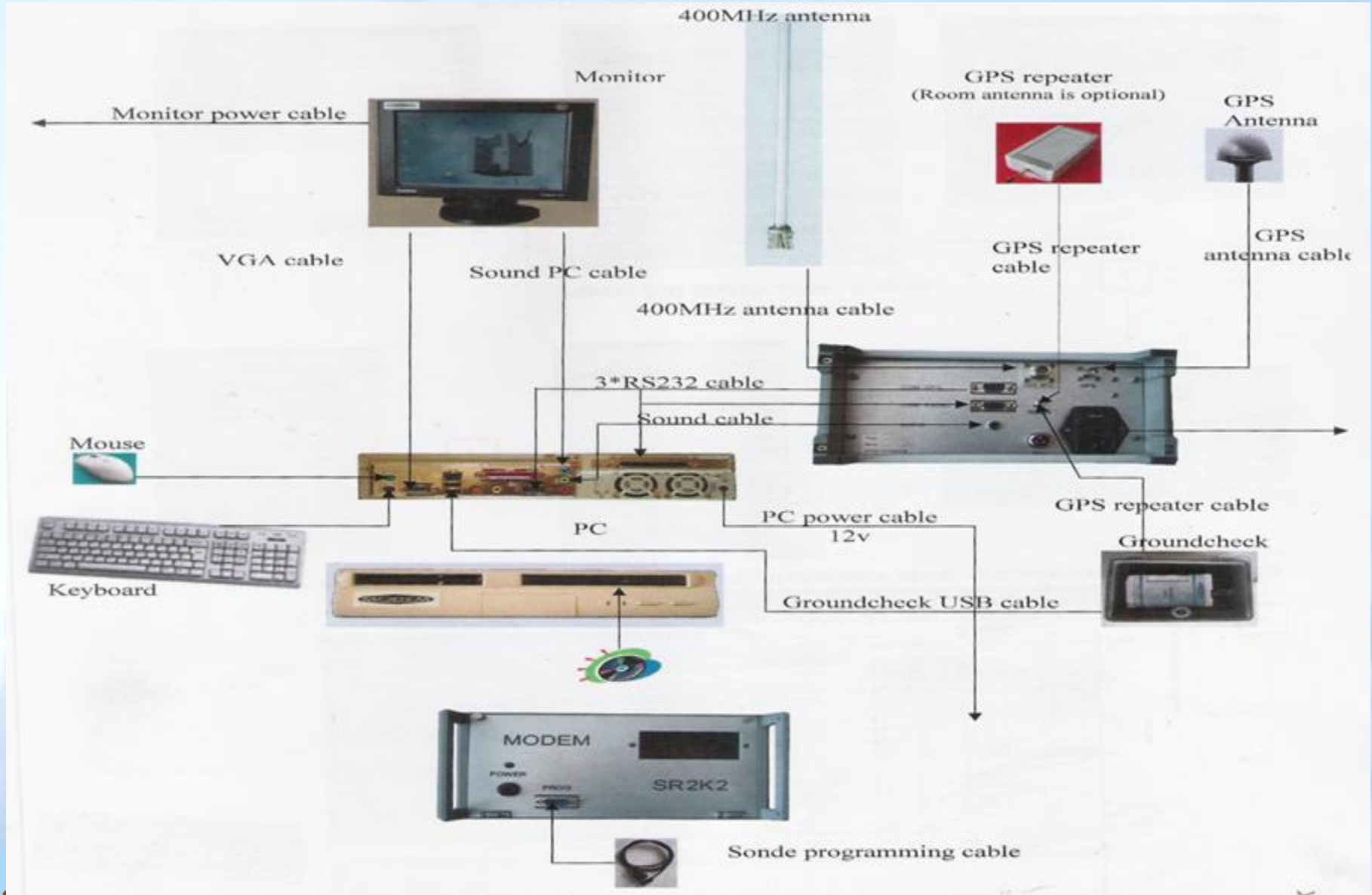
- **Wind only (Pilot Balloon) Observations:-**

1. **Optical Theodolites**
2. **Wind Profilers**
3. **SODAR**
4. **LIDAR**
5. **Pilot Sonde**

GPS based Sounding Systems

- GPS based radiosounding systems are latest in sounding.
- Fully Automatic.
- User Friendly.
- Auto tracking of balloon (transmitter)
- Auto detection.
- Minimum human interference.
- Very Light and portable type systems.
- Easy to maintain.

Radiosounding system (Ground equipment)

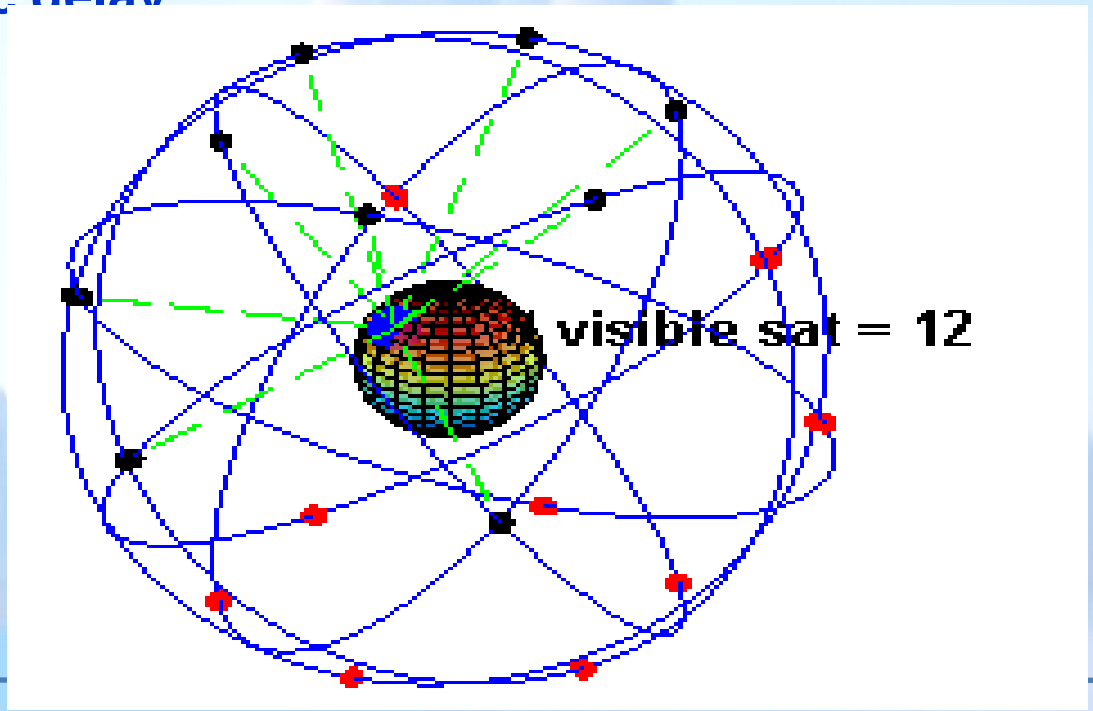


The GPS

- The Global Positioning System (GPS) is a space-based global navigation satellite system (GNSS) that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites.
- It is maintained by the United States government and is freely accessible by anyone with a GPS receiver with some technical limitations.
- Originally intended for military applications but in the 1980s the government made the system available for civilian use. It consist of 24 satellites placed into the orbit.
- Using messages received from a minimum of four visible satellites, a GPS receiver is able to determine the times sent and then the satellite positions corresponding to these times sent.
- While in upper air wind observations the latitude and longitude values obtained at each second is used for computing the drift of balloon by converting geographic co-ordinates to units electronic map (UTM) co-ordinates viz. North and East components (Northings and Eastings).
- Thus the wind components in zonal and meridional directions are then computed from these Northings and Eastings. The data is filtered to remove the noise before final winds are calculated.

The GPS

The GPS receiver compare the time a signal was transmitted by the GPS satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurement from a few more satellites, the receiver can determine the user's position by triangulation. Precise location of interest to geophysists required correction of position errors due to atmospheric delay



Radiosounding system

Receiver System is a ground instrument for reception of data from Sonde. It consists of following:

- **Decoder Board**
- **400 MHz Receiver Board**
- **GPS Board (14 channel)**
- **Power Supply Board 12V**
- **Barometer Board**

Antennae

There are three antennas for signal reception. They are:

GPS ANTENNA:

TRIMBLE BULLET GPS antenna is providing GPS signals from GPS Satellite to the SR2K2 which will be used as a reference GPS ground station for differential processing (DGPS).

Antennae

400 MHz ANTENNA(VERTICAL):

Omnidirectionnal active antenna with built-in low noise preamplifier. Its small size makes installation easy either on horizontal or vertical support. This antenna is used to receive the signal from 0° - 45° and 135° - 180°.

TURNSTILE ANTENNA:

It is a hemispherical antenna used to avoid silent zone, when the sonde attains elevation between 45° -135°. The tracking of sonde which is being a major difficulty in the existing systems has thus been overcome. The antenna is capable to receive signals from within the range of 500 kms. All the antennas may be disconnected when not in use to prevent damage from lightening.

Data Acquisition

TEMPERATURE:

Temperature sensor consists in a thermistor chip wrapped into a glass ball. Its tiny size (0.9 x 2 mm) allows response time around 1 to 1.3 second. Temperature sensor is led on a layer processed against humidity and solar radiations.

Boom end is painted with a special white coating to reduce solar radiation effects

HUMIDITY:

Humidity sensor consists in a capacitor of which value is directly proportional to relative humidity. It is composed of three components:

a) Basic layer as an electrode

b) A dielectric of which characteristics vary along with Relative Humidity.

c) A short response porous electrode as the second electrode of the capacitor.

A cap is provided for protecting the sensor from rain and mechanical damage.

PRESSURE:

Pressure is calculated from GPS altitude, temperature and humidity according to the barometric equation (Laplace Law).

GPS WIND FINDING:

3D GPS module provides the position of the sonde (latitude, longitude and altitude) as well as speed components (North-South, East-West and Z). These data are correlated to time. Position is calculated every second by triangulation method between 4 or more satellites. Velocity is not calculated from the difference between two positions but directly issued from Doppler. Differential GPS is used to compare the data in order to clear satellite disturbances and eventual interferences and thus most accurate data are obtained.

Raditheodolite based Systems

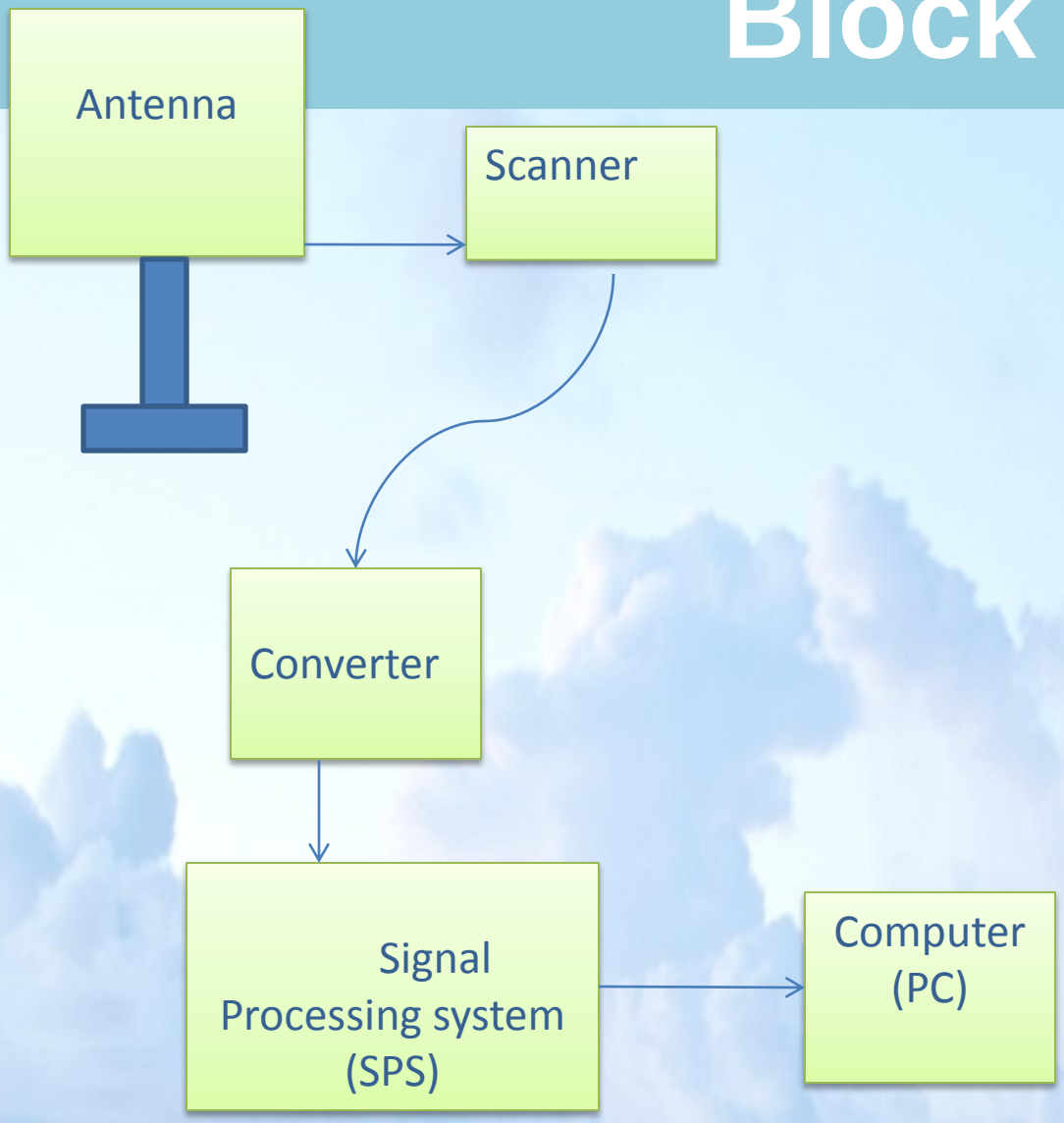
- Based on tracking of transmitter for sounding.
- New systems-- Auto tracking, but manual locking.
- Old systems-- manual tracking of balloon.
- Heavy systems because of large size of tracking antennae.
- More wear and tear--difficult maintenance.

Raditheodolite based Systems

IMD uses following type of radiotheodolite based systems-

1. **IMS-1500 radiotheodolite**
2. **SAMEER make raddiotheodolites**
3. **Radiosonde Ground Equipment (RSGE)**

Block Diagram-IMS



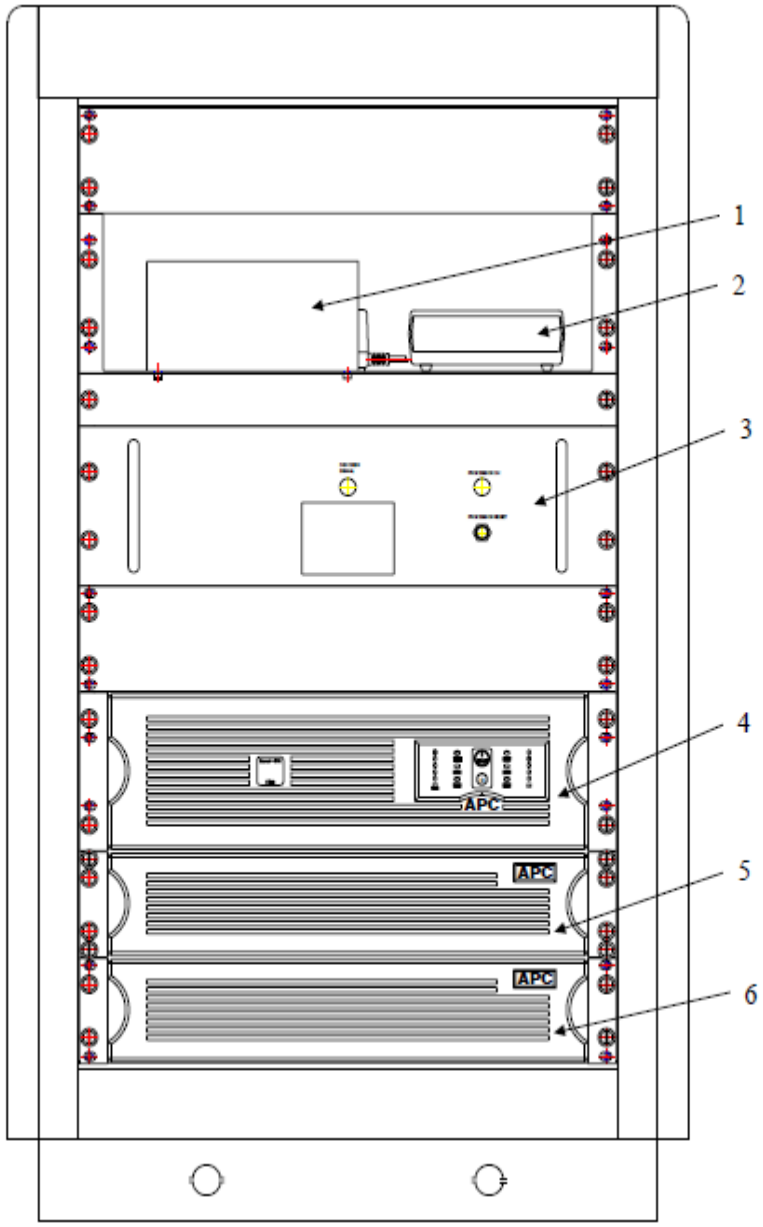
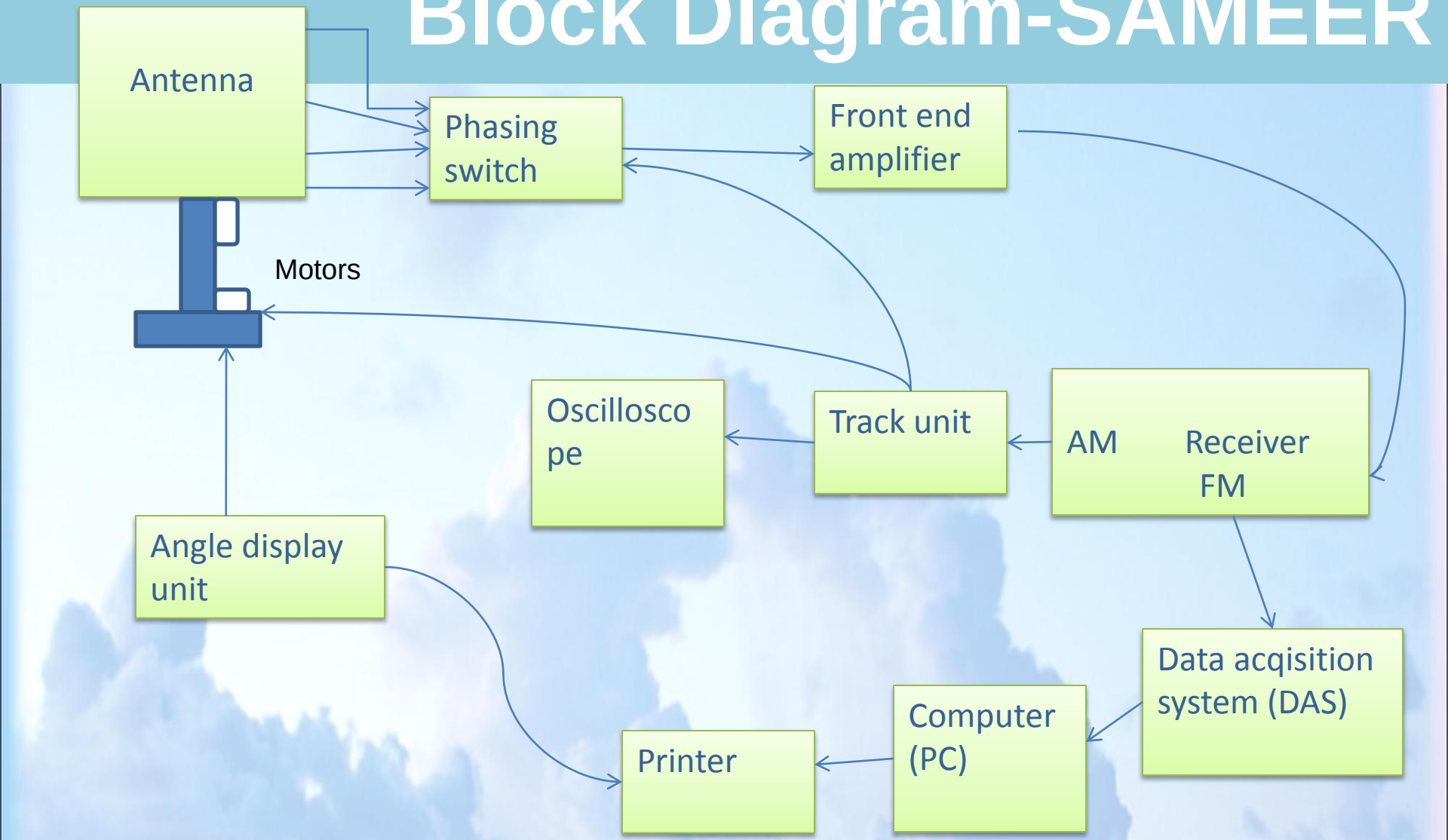


Figure 1-3: IMS-1500 Equipment Rack Assembly

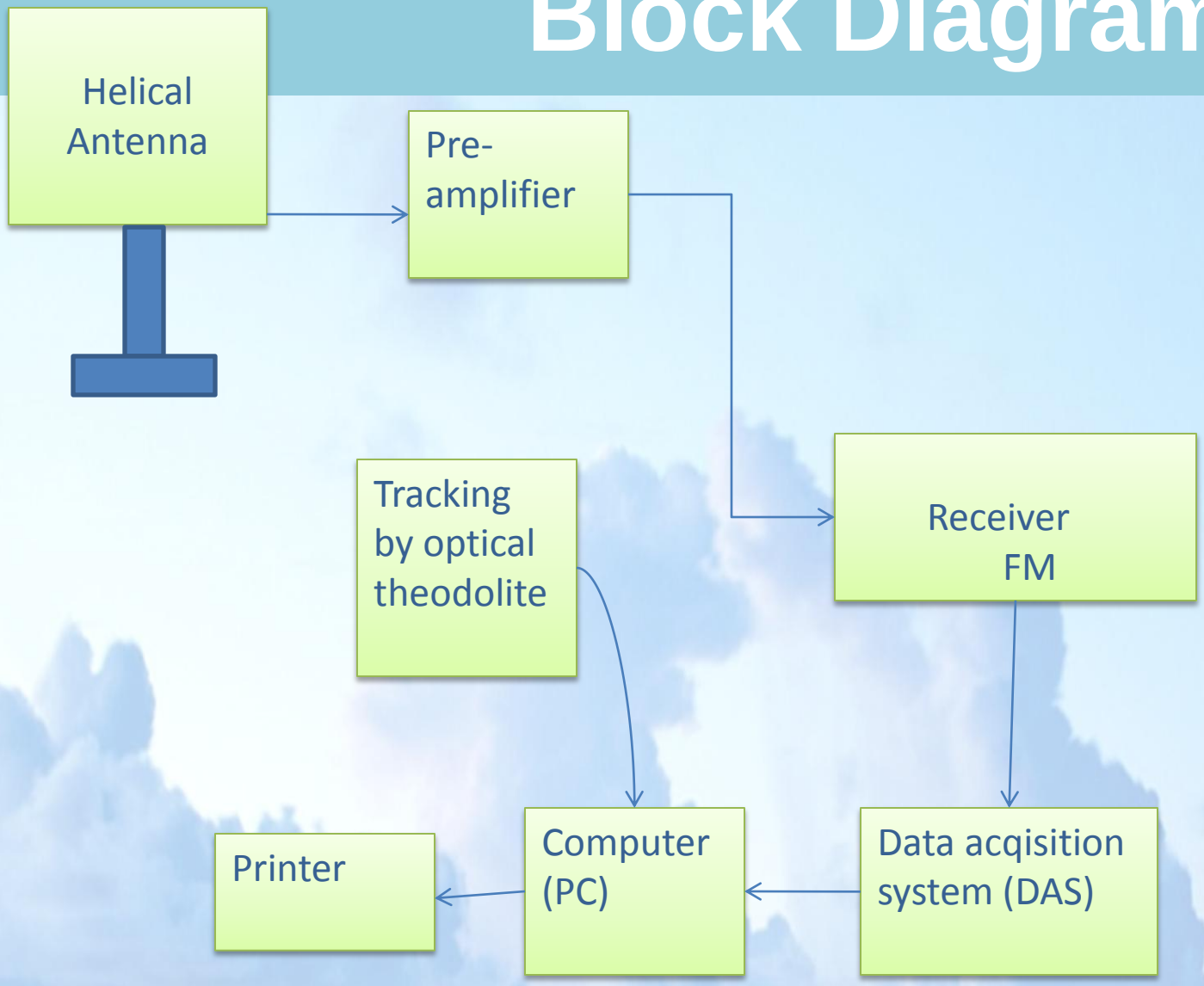
The Equipment Rack consists of:

- Power Supply (1)
- Data converter with its 17 VAC power supply (2)
- Signal Processing System (SPS) (3)
- Uninterruptible Power Supply (UPS) (4)
- Battery Pack (5)
- Battery Pack 6)

Block Diagram-SAMEER



Block Diagram-RSGE



Comparison between systems

S. N	Parameter	SAMEER	IMS	RSGE	GPS
1.	Carrier freq	401 (390-410)	1680 (1669.57-1700)	401 (395-406)	403 (400-406)
2.	IF	33	110	10.7	--
3	Tracking technique	Lobe switching	Conical scanning	helical	GPS
4	Balloon tracking	Manual	Automatic	Manual	Automatic

After sounding

- After sounding the system computes various parameters at different levels in the upper atmosphere up to 40 Km height.
- Final out put is a coded message as per WMO format used world wide.
- Data out put also available in pictorial form like trajectory of the balloon, t-phi gram, Stuve diagram, t-logP diagram, multi-curve display etc.
- The coded message is transmitted to the analysis and forecasting centres immediately after the observations.

Pilot Balloon(Only Wind) Obsns.

- These stations are taking wind observations (Direction and speed).
- Some stations take two ascents a day 0000 & 1200 UTC.
- Some stations take four ascents at synoptic hours.

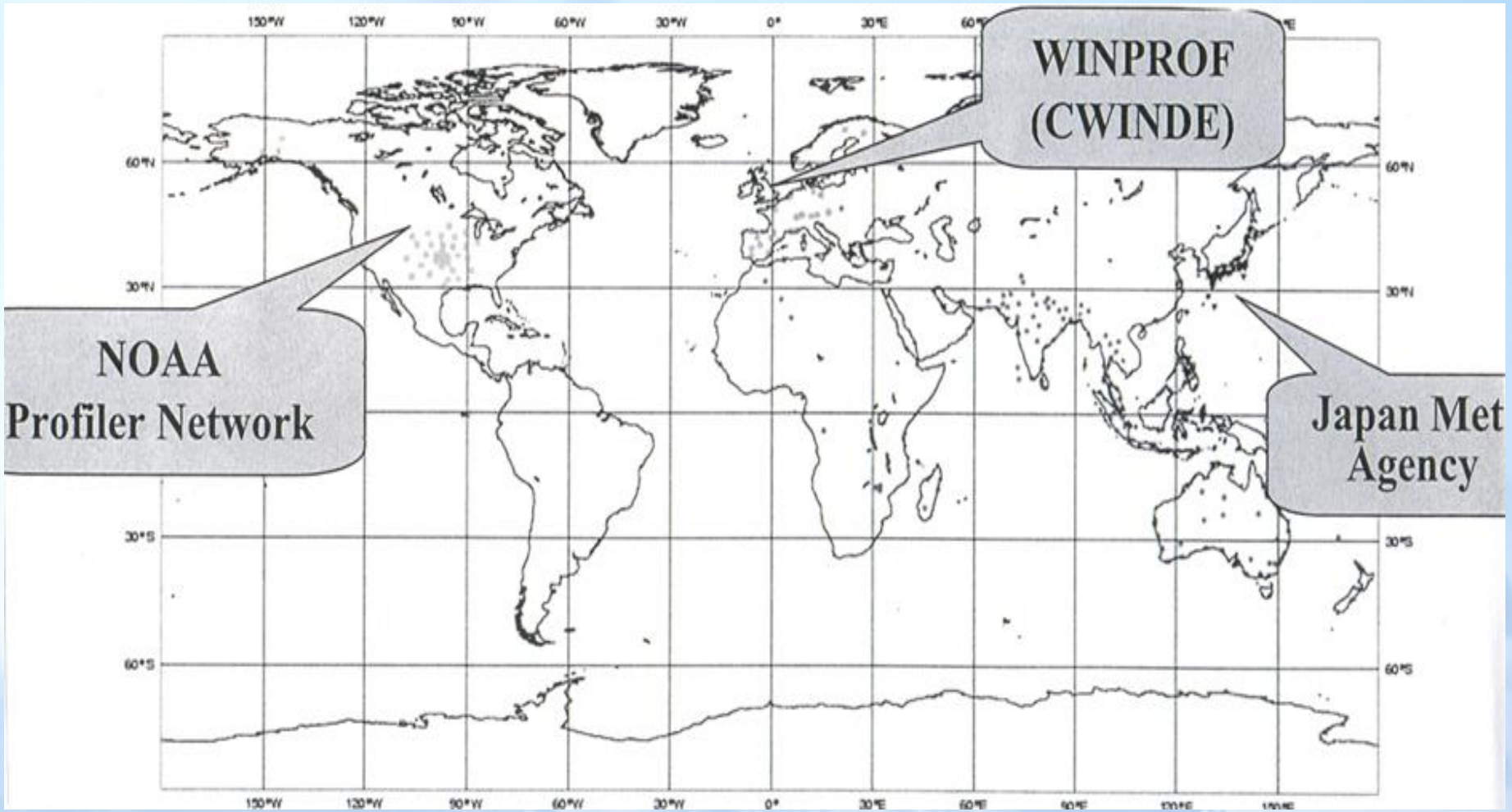
Various techniques for PB observations:-

1. Optical theodolite
2. Wind Profiler
3. SODAR
4. LIDAR
5. Pilot sonde

Wind Profiler

- In case of upper wind observations, Wind Profilers are capable to provide hourly or more frequent wind speed and direction values as a function of altitude.
- A wind profiler is a type of weather observing equipment that uses radar to detect the wind speed and direction at various elevations above the ground.
- Readings are made at different heights above sea level, up to the extent of the troposphere.
- Above this level there is inadequate water vapour present to produce a radar "bounce."

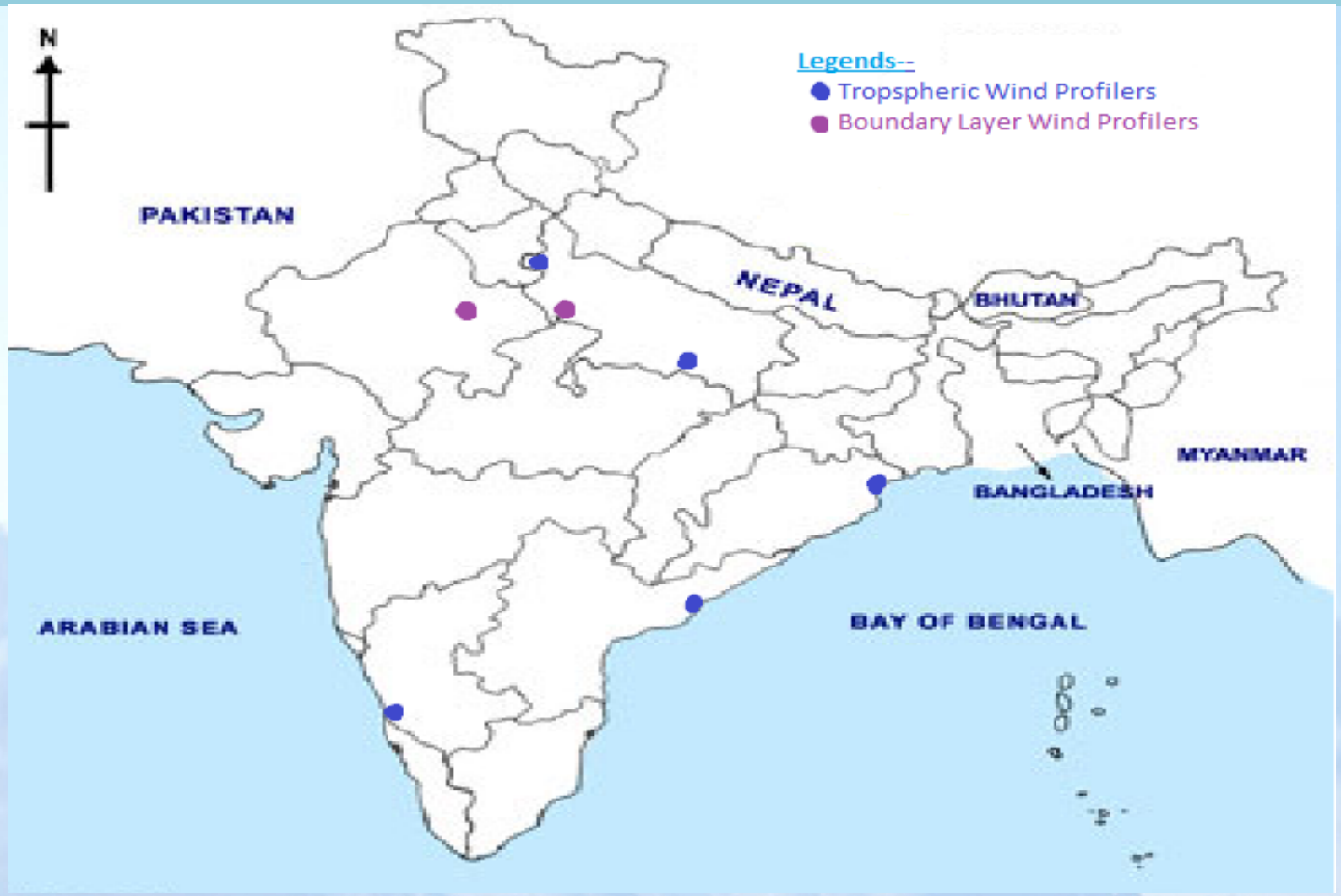
Major Wind Profiler Networks in the World



Major Wind Profiler Networks in the World

S.No	Network	Profiler
1	NOAA Profiler network, USA	35 UHF profiler (32 @ 404 MHz, 3 @449 MHz
2	JMA Wind Profiler network, Japan	31 profilers @ 1357 MHz
3	WINPROF, ECMWF network	21 WPR, 2 SODAR (19 LT WPs-14 Vaisala 3 Degreane make)

3. Proposed IMD network



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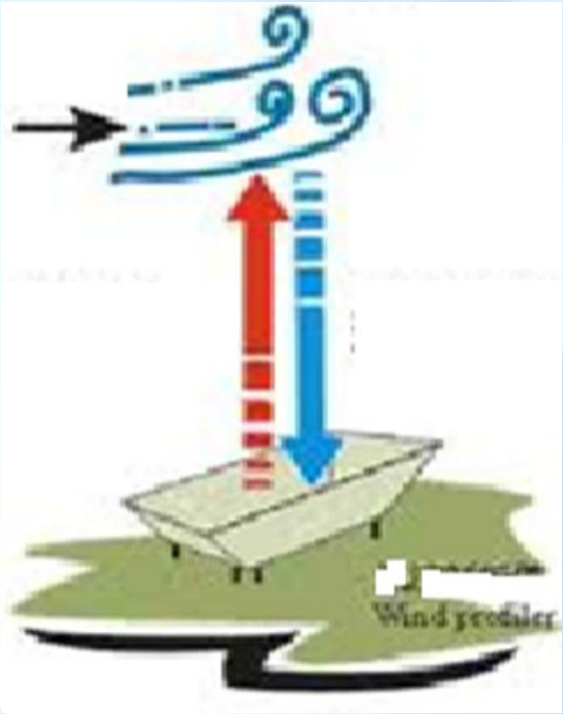
- **5 Nos. of Tropospheric type of Wind profilers at;**

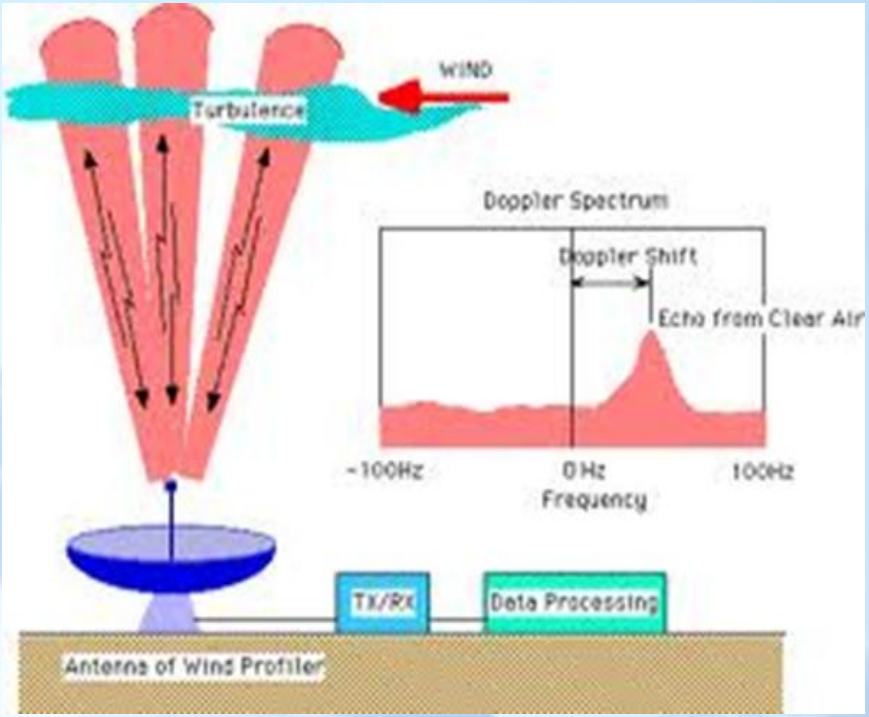
  ***New Delhi, Allahabad, Mangalore, Machhilipatnam and Balasore*.**

- **2 Nos. of Boundary layer type of wind profilers at;**

  ***Agra and Jaipur*.**

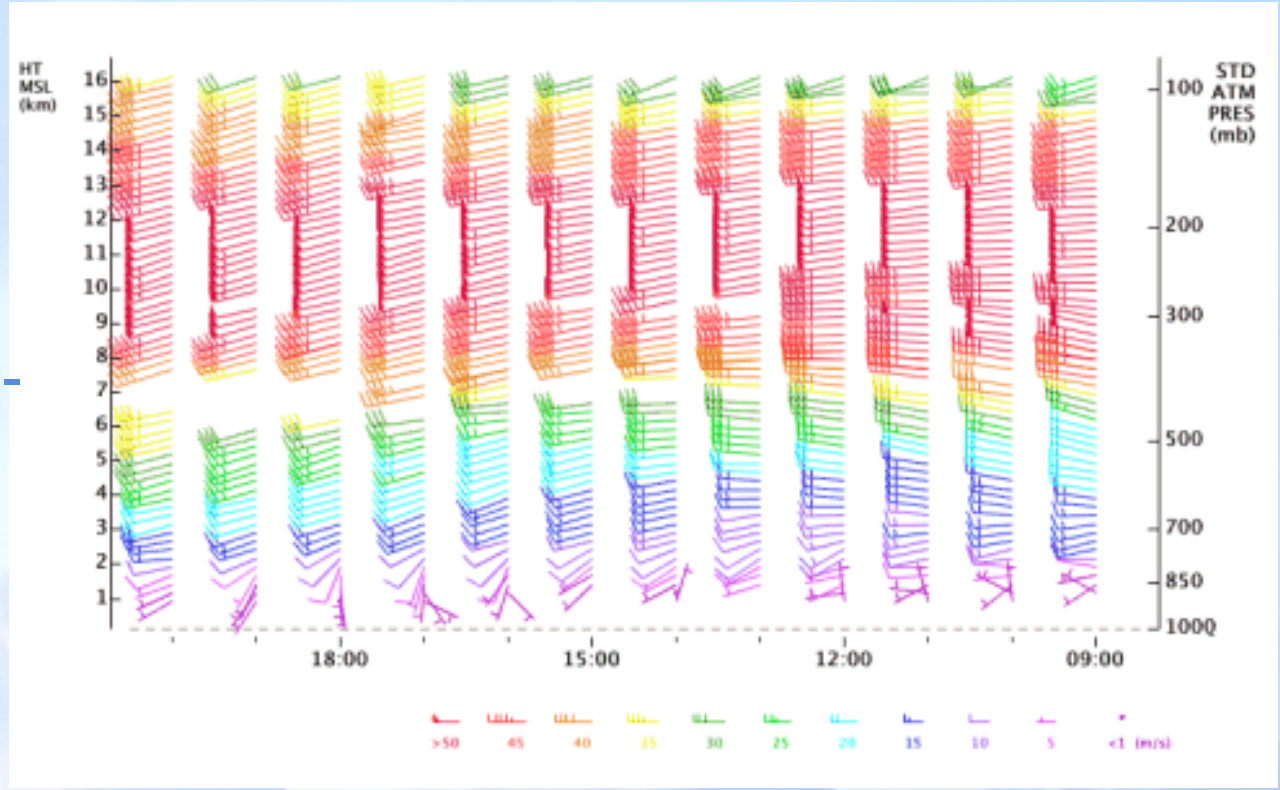
4. Concept


Wind profiler


WIND
Turbulence
Doppler Spectrum
Doppler Shift
Echo from Clear Air
-100Hz
0Hz
100Hz
Frequency
Tx/Rx
Data Processing
Antenna of Wind Profiler

6.Products

- The hourly averaged winds displayed at each height from every 6-minute data acquired.
- Wind speed
- Wind Direction



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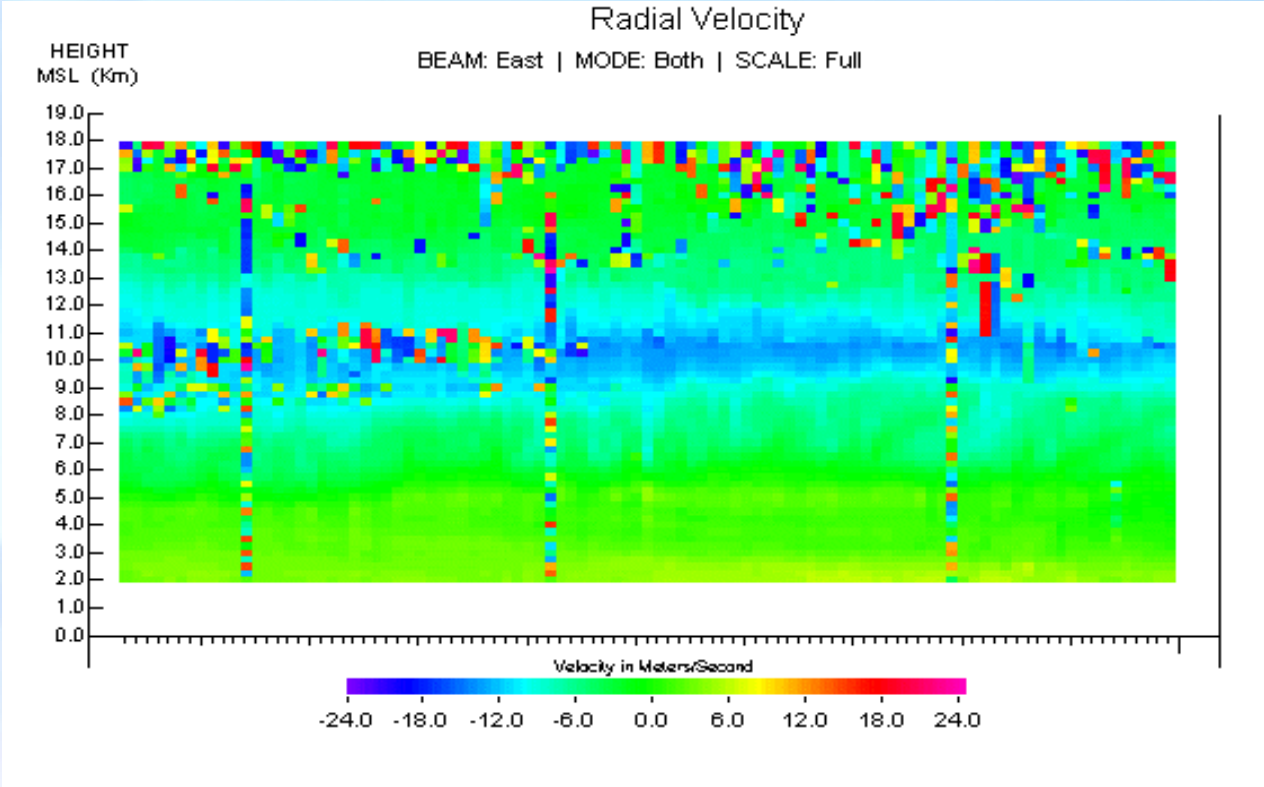
- The vertical velocity can be calculated by the 6-minute spectral moments data obtained from the vertical beam.

- Wind Shear

- Turbulence



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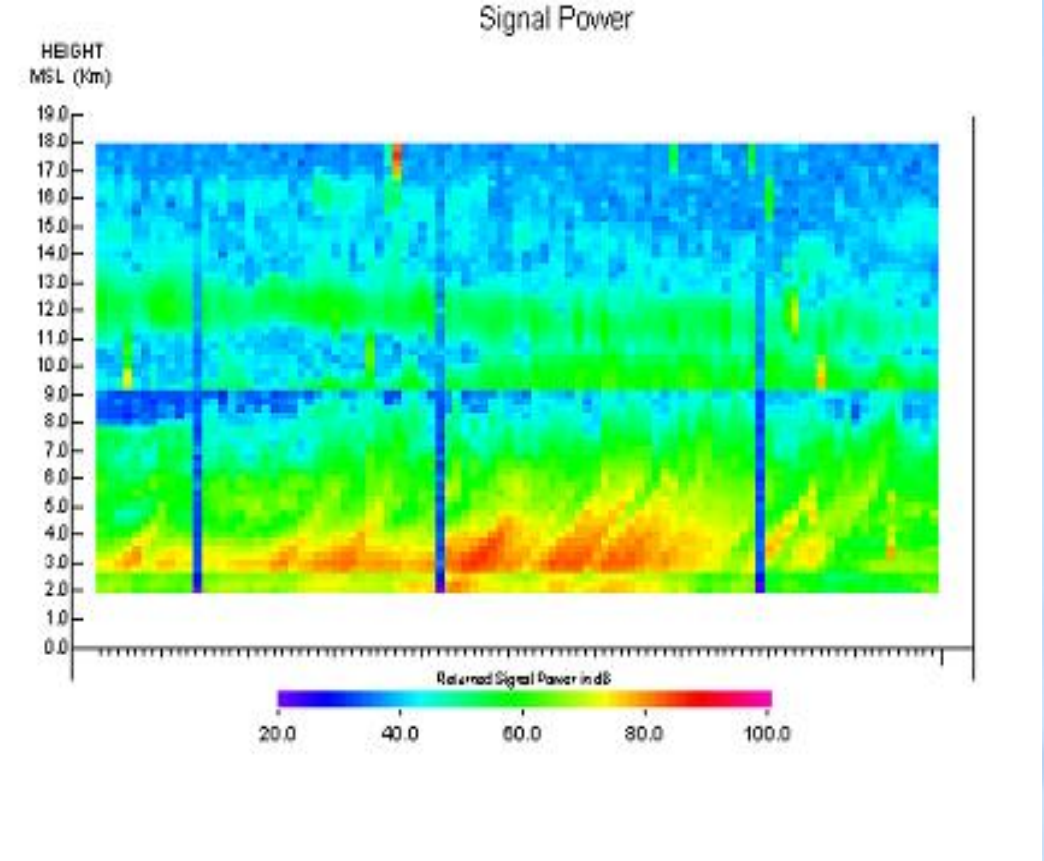
- High signal power values (greater than 60 dB) -*High moisture content or the presence of precipitation particles.*
- Low power values (less than 40 dB) - *Dry or stable atmosphere.*
- Moisture advection and cloud layers.
- Vertical extent of convection
- Bright bands (inferring the 0 degree C level) are all visible in signal power displays



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- High time resolution data: typical 30 minutes.
- Data almost instantaneous available (Nowcasting)
- Eulerian type of measurement (true vertical profile, all Heights measured at same time).
- Unambiguous profiles, independent of the assimilation system.
- Almost all weather.
- Existing and proven.

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- The biggest advantage of the wind profiler is that it continuously monitors the direction and speed of the wind without any break point or gap which makes it one of the accurate and efficient equipment in the field of environmental sciences and whether forecasting.
- It can prevent many fatal disastrous affect that can occur in the situation of storm and ocean imbalance.
- As it can measure the wind direction and speed above the sea level so it can easily detect from the speed of the wind about tidal waves and far storms that can hit the area in few hours.
- Very useful in reporting and alarming the flight situations which can prevent the major crashes. The flight reporting center can inform the pilot on cockpit in time about the upcoming air pockets that can pressurize the aircraft.
- This is done when the wind radar profilers measure the intensity turbulence and wind speed and inform the atmospheric stability to choose the appropriate action.
- Hence an important tool for NOWCASTING.

SODAR system

- SODAR (Sonic Detection And Ranging), is a meteorological instrument which measures the scattering of sound waves by atmospheric turbulence. SODAR systems are used to measure wind speed at various heights above the ground of the lower layer of the atmosphere.
- Sodar systems are like RADAR (radio detection and ranging) systems except that sound waves rather than radio waves are used for detection. Other names used for sodar systems include sounder, echosounder and acoustic radar.

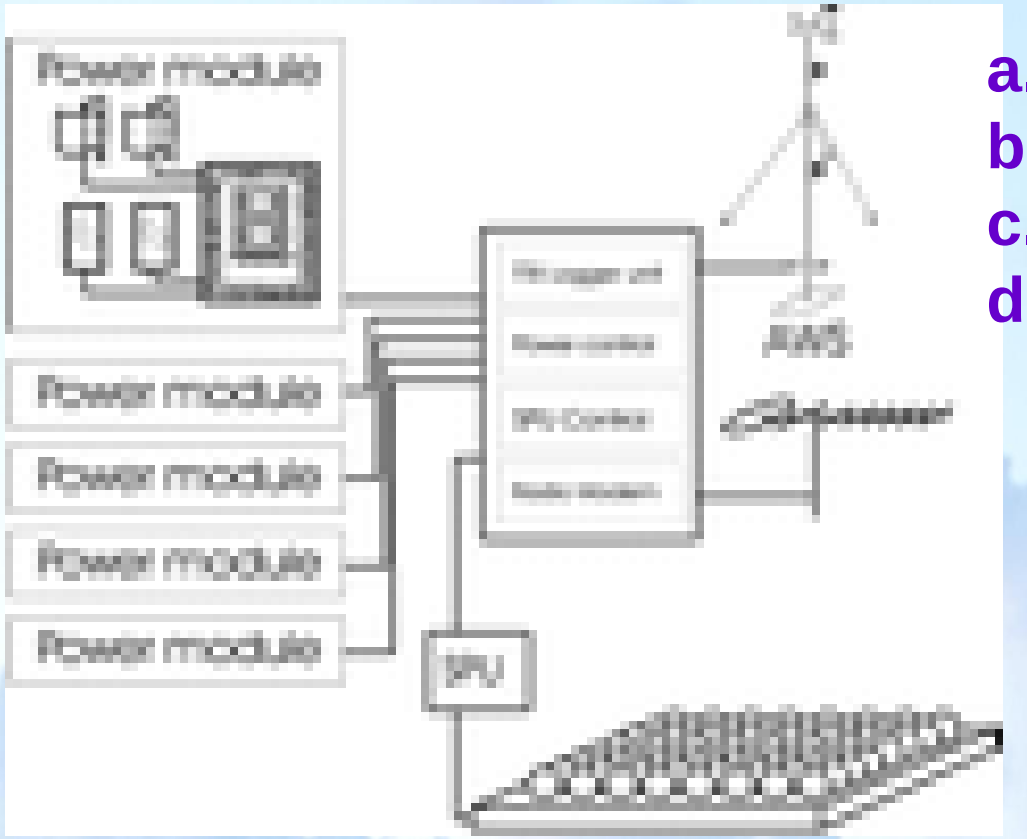
Contd.

- Obtaining atmospheric wind profiles at remote unmanned sites is a major technological challenge.
- Wind profilers that are based on Doppler radar techniques do not have the resolution that is required for boundary layer studies.
- Doppler sodar techniques offer the possibility of continuous wind profiling.
- Doppler sodar systems work by transmitting acoustic pulses upward into the atmosphere and detecting the Doppler shift in the backscatter signal. By using off-vertical acoustic paths, it is possible to calculate the velocity profile of the reflector, which is then assumed to be identical to the wind profile (Neff and Coulter 1986).
- Their disadvantage is that they are relatively power hungry compared to more passive systems, such as automatic weather stations.

Need….? (Winds in boundary layer)

- PB (No. of ascents / Min ht measurable)
- Wind profilers (Min ht measurable)
- RS/RW (No. of ascents)
- Lidar (High cost)

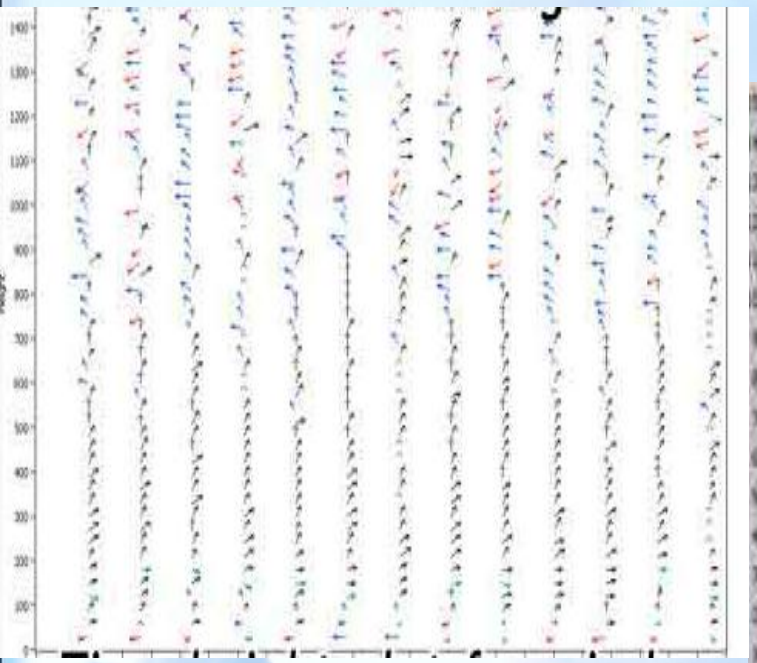
System Design



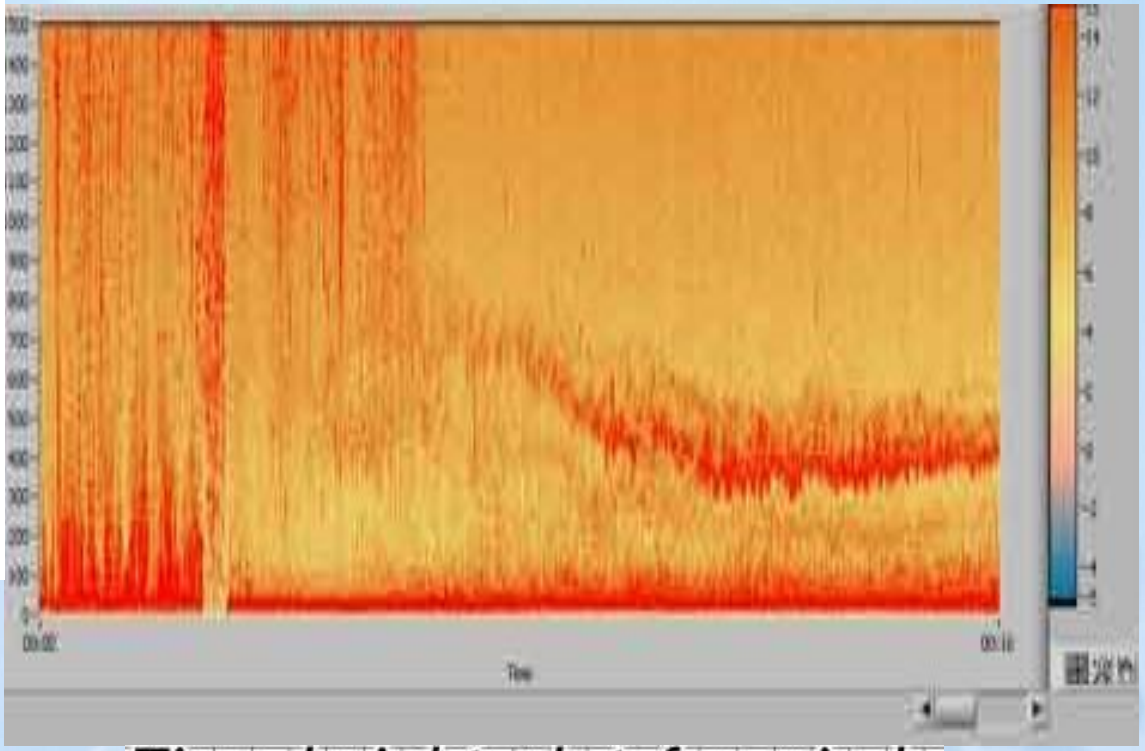
a. Doppler SODAR Antenna
b. Power System
c. Logging & Control unit
d. Calibration / System Health

a. SODAR Antenna

Products



SODAR Echogram



Time height plot for winds

Applications

- Meteorology
- Aviation Meteorology
- Environmental Impact studies
- Planetary boundary layer research
- Inversion detection
- Sea / land breeze studies
- Research in atmospheric dynamics
- Environmental monitoring
- Wind energy site evaluation

Some SODAR installations in India

- National Atmospheric Research Lab (NARL) Gadanki, Tirupati
- NPCIL, Kaiga, Uttar Karnataka
- SPL, V.S.S.C Trivendrum
- IITM, Pune

- *National Physical Laboratory (NPL), New Delhi*

Some Manufacturers

1. M/s SAMEER, Mumbai India
2. BIRAL (Bristol Industrial & Research Associates Ltd), UK
3. Atmospheric Systems Corporation, CA, USA
4. Kipp & Zonen USA Inc.
5. SciTek Krungthep Co., Ltd, Huay-Khwang,Bangkok
6. METEK GmbH, Germany
7. AQSystem Stockholm AB, Sweden

Pilot Sonde

- Even after modernization of the PB network.The data availability has not increased much because the observations by optical theodolites have constraints of getting less data in disturbed weather like fog, rain, cloudiness etc when it is eagerly needed.
- To overcome these weather constraints a weather proof system of PB observations is required.
- In radiosonde / radiowind (RS/RW) observations, most of the Meteorological agencies in the world have adopted the GPS based system of observations.
- On the same lines using the GPS technique the Pilot Balloon sonde may be developed and using that PB network may be further modernized.

Hardware Requirements

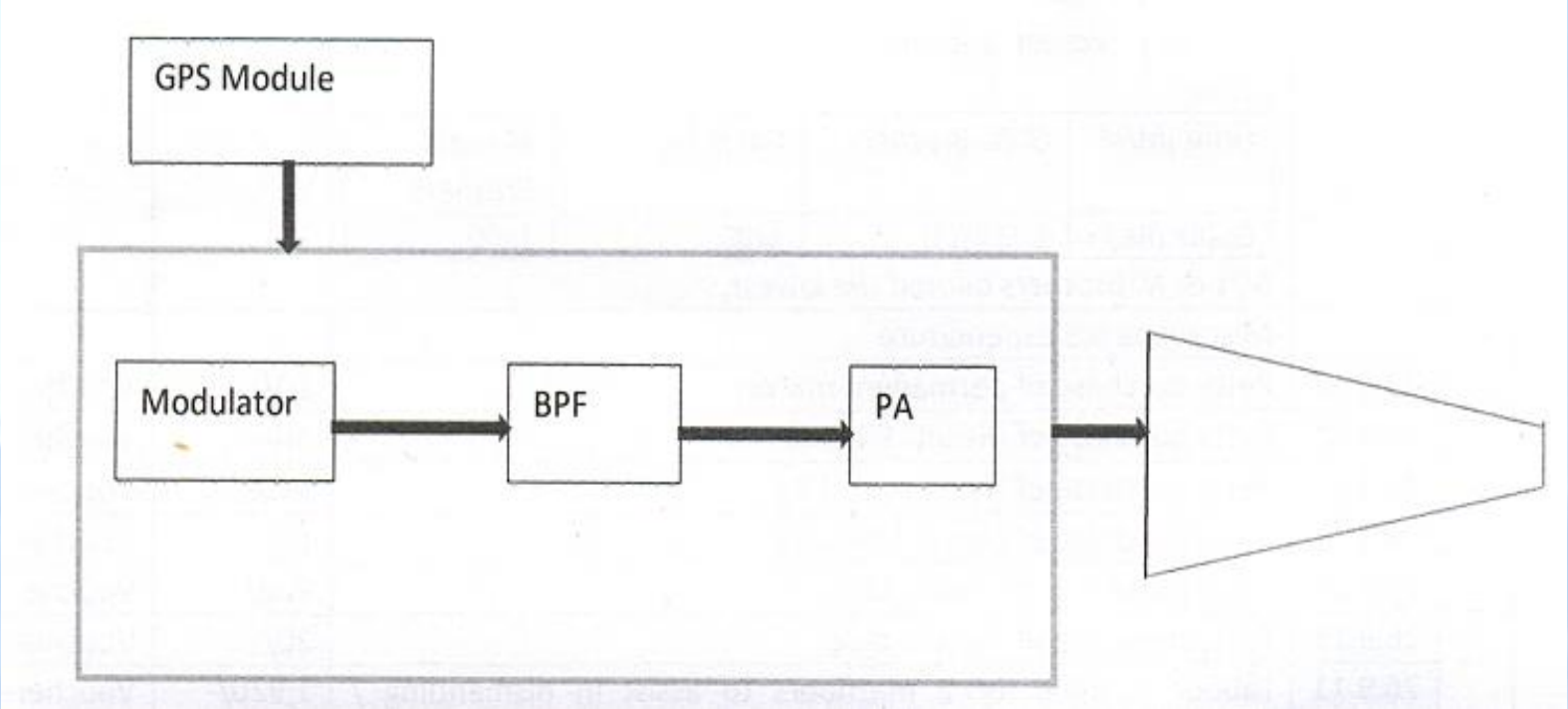
- The system requirement can be divided into two parts;
  A). The ground receiver system
  B). The Pilotsonde

A).The GPS based ground receiver systems being used with RS/RW system can be used for PB observations, hence no separate ground equipment are required.

- There are so many different type of brands are available in the world market which can be directly used.
- Even indigenous GPS based receiver system are also available.

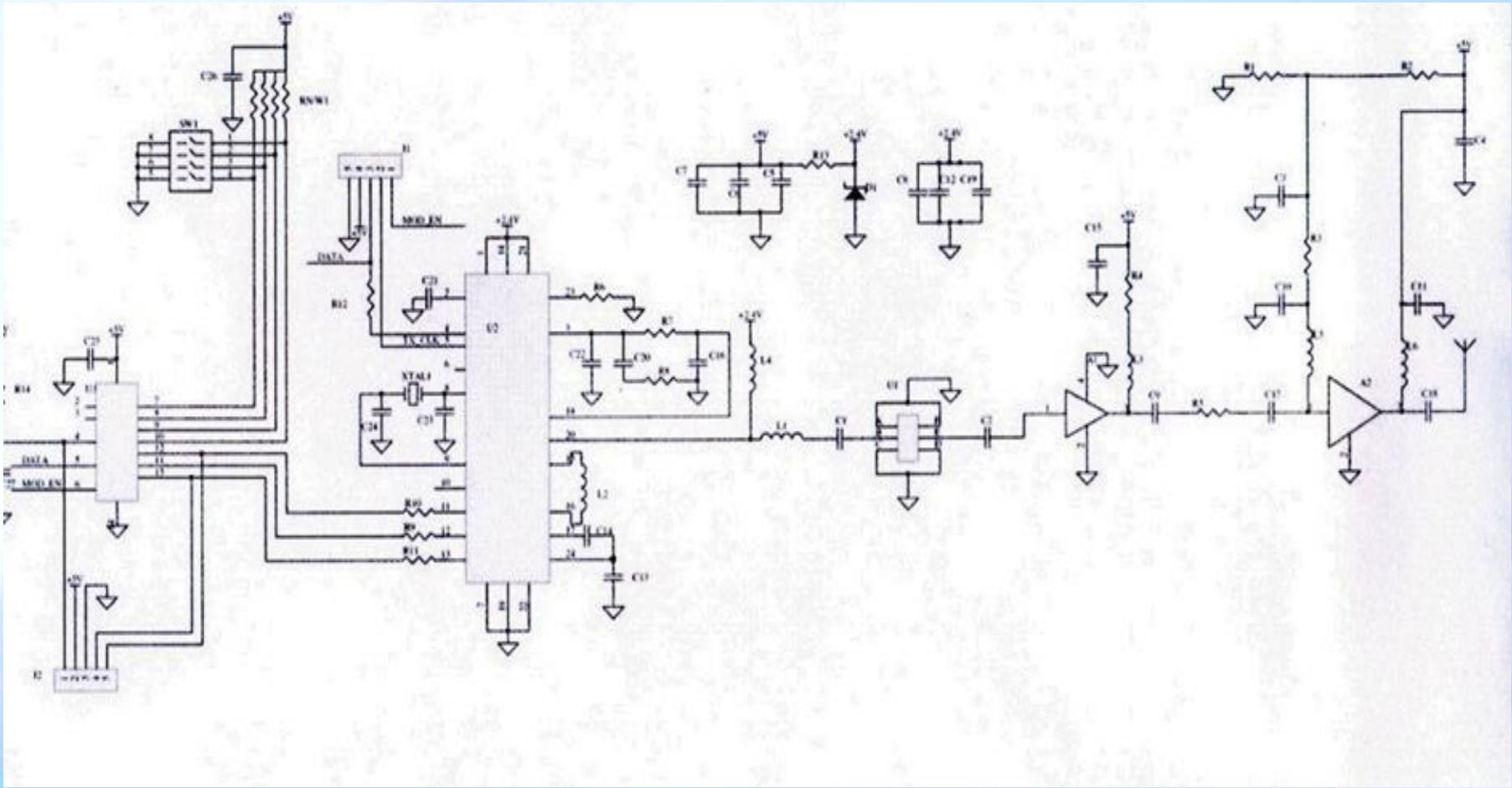
B). Pilot-sonde

The proposed pilot balloon sonde block diagram is given below;



Working

The schematic circuit diagram of Transmitter is given below;



Software requirements

- The wind computation part of the RS/RW software may be used in the pilotsonde observations, as it is capable of;

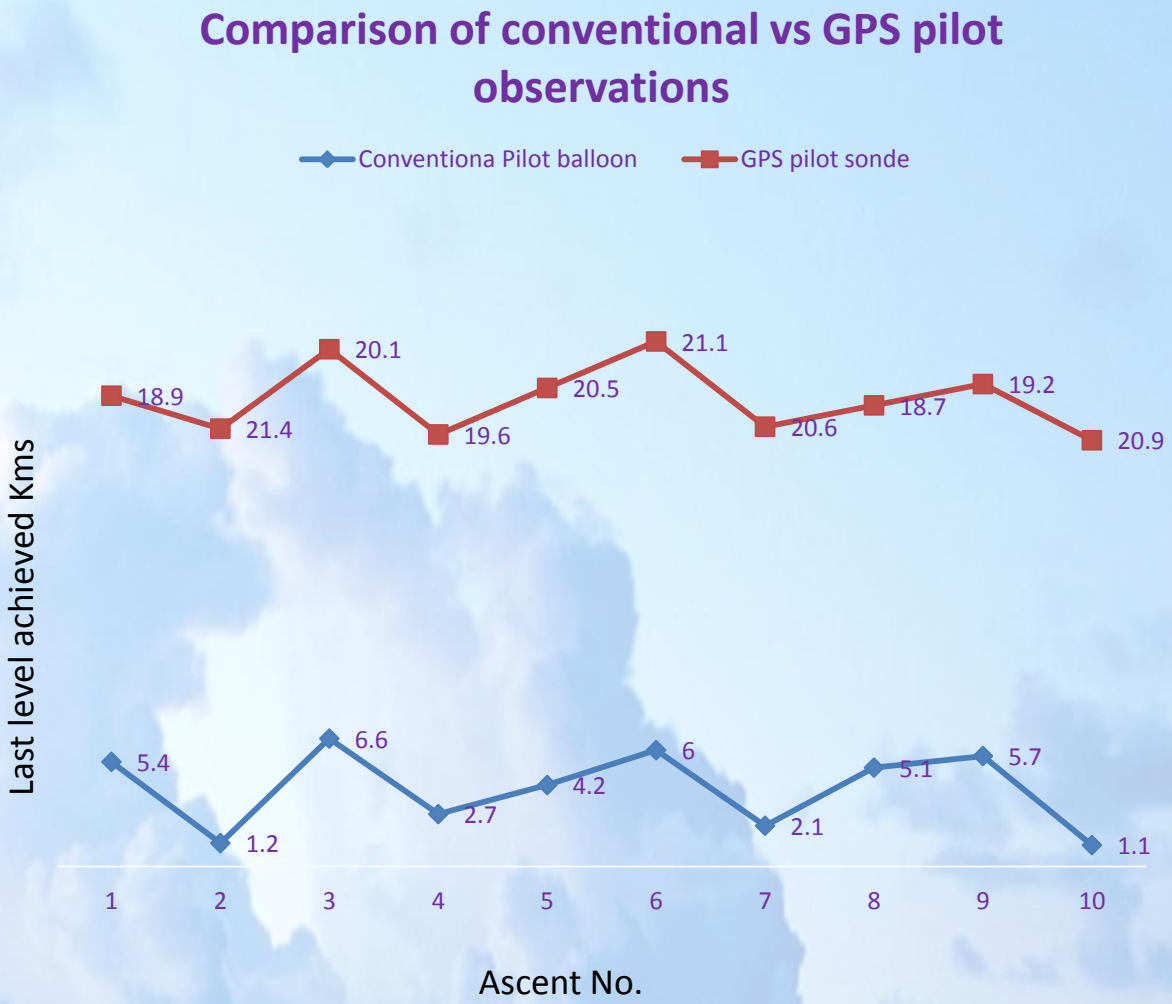
1. Displaying real time wind data with graphical user interface,
2. Display of complete processed results along with plots,
3. Generation of flight report
4. Generation of coded PB messages.

Advantage

- It is evident from GPs based RS/RW ascent that the flight termination in most of the cases is balloon burst.
- The GPS receiver does not lose the signal while ascending.
- The data availability depends mainly on the quality of balloon in all weather conditions.
- Whereas, the presently used PB observations using optical theodolites are heavily dependent on weather conditions.
- With optical theodolites, we get more data in clear weather and the data availability decreases with adverse weather.
- We get less data or no data when it is urgently required by the forecaster.
- The average height of PB balloon observations even after modernization of PB network, by providing each station a good quality optical theodolite system has an increase of just 0.5 to 1 km only and some stations have no change in their status of maximum height coverage.
- It is mainly because of weather constraints.
- The use of GPS based system in PB observations is expected to remove all these constraints.

Justifications

- For the data availability to a large extent, in most of the cases up to 20 Kms of height, especially in adverse weather conditions, when the data is eagerly awaited, the investment is justified.
- Hence it is feasible to implement the use of pilotsonde on operational basis in upper air network of IMD at PB stations.



Applications

- Meteorology
- Aviation Meteorology
- Environmental Impact studies
- Planetary boundary layer research
- Inversion detection
- Sea / land breeze studies
- Research in atmospheric dynamics
- Environmental monitoring
- Wind energy site evaluation

Future Plans

- **Sustenance of 6 Nos of high quality GPS based system-WMO-GUAN standard network.**
- **Expansion of GUAN standard network from 6 to 12 stations by up-gradation of 6 operational RS/RW stations to GUAN standard.**
- **Continuation of all 56 RS/RW stations with twice a day ascents.**
- ***Further expansion of operational RS/RW stations from 56 to 63 -procurement of GPS radiosondes from Indian sources to promote 'make in India' initiative.***
- **Up-gradation of PB network to GPS based.**

Thank You