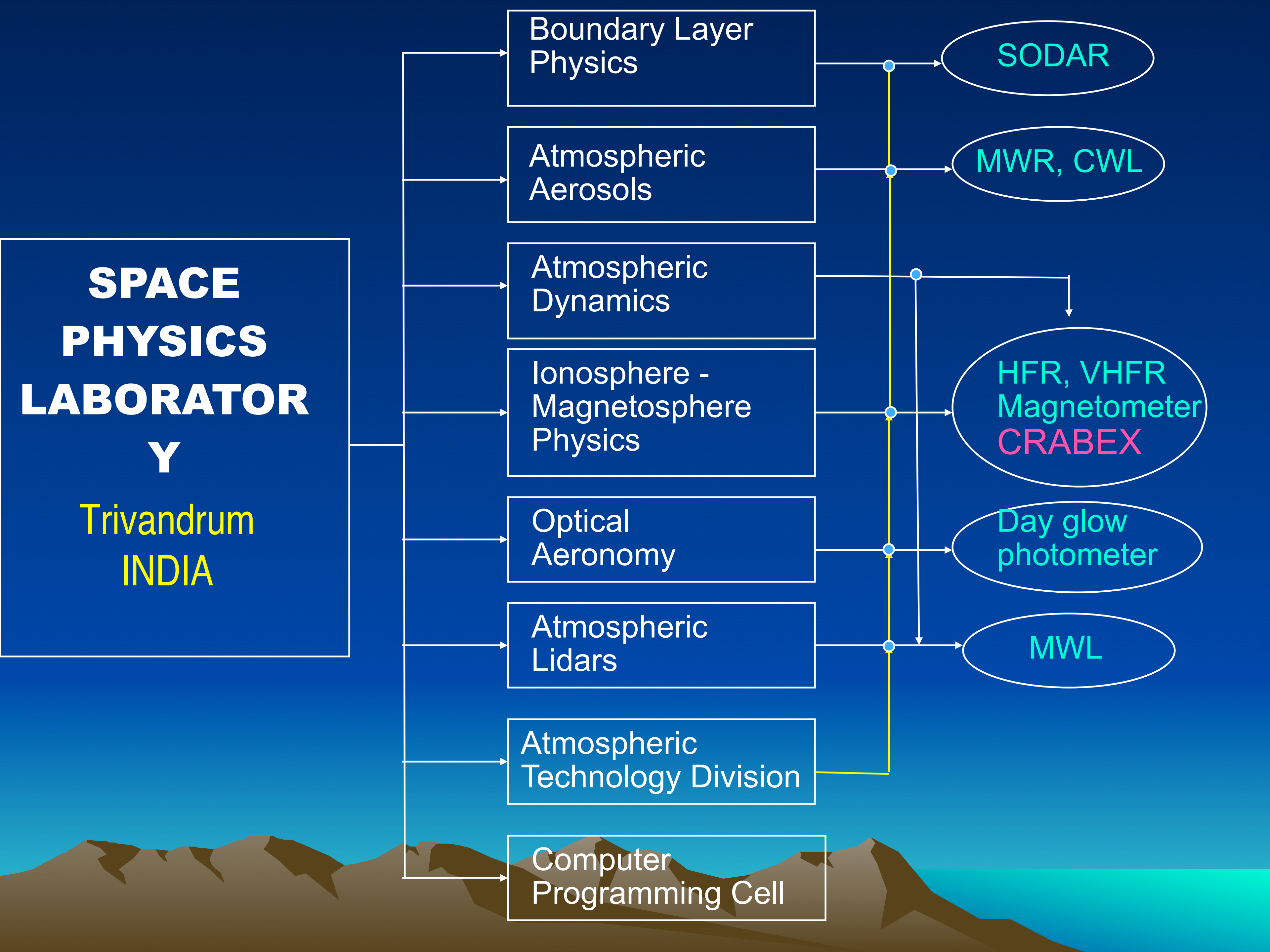
Various aspects in the design and realization of coherent beacon receiver system station and networks for the study of ionospheric tomography

Sreelatha.P.
Space Physics Laboratory
Vikram Sarabhai Space Centre INDIA

INDIA
The external boundaries of India on this map have not been authenticated and may not be correct.
Great Himalaya Range
Srinagar
Leh
CHINA
PAKISTAN
Shimla
Chandigarh
Delhi
NEPAL
Gangtok
Itanagar
Jaisalmer
Darjeeling
Agra
Jaipur
Shillong
Varanasi
BANGLA-DESH
Udaipur
Khajuraho
Bhopal
Gandhinagar
Kolkata (Calcutta)
Kanha National Park
Bhubaneswar
Mumbai (Bombay)
INDIA
MYANMAR
Bay of Bengal
Hyderabad
Goa
Vijayawada
Arabian Sea
Panaji
Bangalore
Chennai (Madras)
Andaman Islands
Kochi (Cochin)
Mysore
Kerala
SRI LANKA
Nicobar Islands
0 400 km
0 250 mi
INDIAN OCEAN
© Lonely Planet

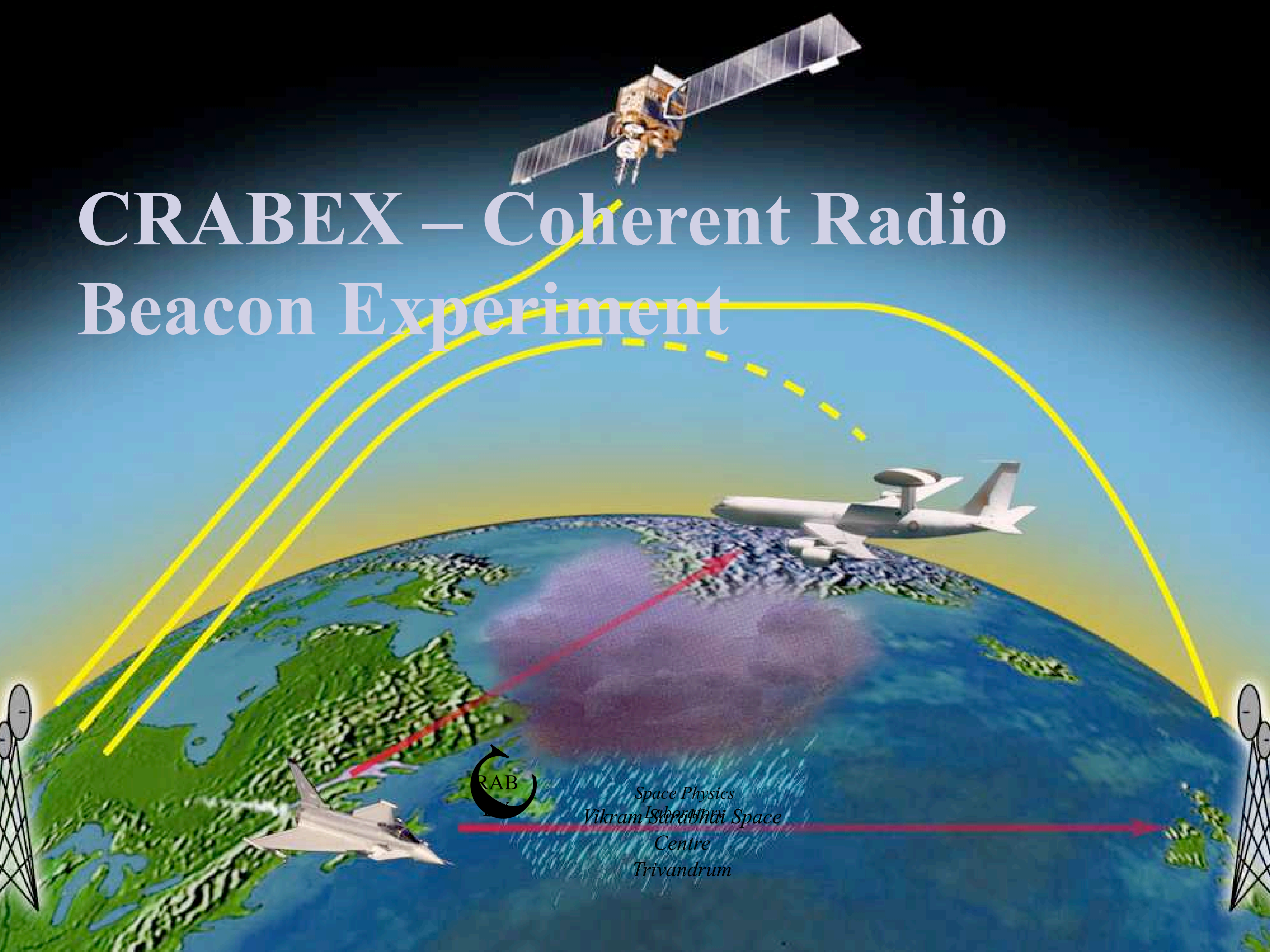

MAP OF
KERALA
SOUTH CANARA
KASARAGOD
KARNATAKA
COORG
KANNUR
MYSORE
WAYANAD
KOZHIKODE
NILGIRIS
MALAPPURAM
PALAKKAD
COIMBATORE
THRISSUR
TAMILNADU
LAKSHADWEEP SEA
ERNAKULAM
IDUKKI
MADURAI
KOTTAYAM
ALAPPUZHA
PATHANAMTHITTA
KOLLAM
TIRUNELVELI
THIRUVANANTHAPURAM
KANNIYAKUMARI
REFERENCE
STATE BOUNDARY
DISTRICT BOUNDARY
TALUK BOUNDARY
IMPORTANT ROADS
RAILWAY
LAKES & RIVERS
DISTRICT HEADQUARTERS
TALUK HEADQUARTERS
IMPORTANT PLACES


Thiruvananthapuram
(Kerala)
KOLLAM
To Kollam
N
47
Kilimanur
Kappil
Varkkallai
Ponmudi
Agattumuri
Vettur
Attingal
Attingal
Pallod
Kadakkavur
Chirayinkeezhu
Kallar
TAMILNADU
Anchuthengu
Mangalapuram
Murukkumpuzha
Neyyar Dam & Wild Life Sanctuary
Kaniyapuram
Parattipalli
Aruvikkara
Attipara
Map not to Scale
THIRUVANANTHAPURAM
Perumkulam
Nemom
Kovillur
Balarampuram
Neyyattinkara
Kovalam
Vilinjam
Parassala
Puvar
To Kuzhitturra
National Highway
District Boundary
River
State Highway
Road
Railway Track
District Headquarter
Taluk Headquarter
Town
Tourist Place
Airport
Copyright (c) Compare Infobase Pvt. Ltd. 2001-02



SPACE PHYSICS LABORATORY
Trivandrum INDIA
Boundary Layer Physics
Atmospheric Aerosols
Atmospheric Dynamics
Ionosphere - Magnetosphere Physics
Optical Aeronomy
Atmospheric Lidars
Atmospheric Technology Division
Computer Programming Cell
SODAR
MWR, CWL
HFR, VHFR
Magnetometer
CRABEX
Day glow photometer
MWL

CRABEX – Coherent Radio Beacon Experiment



Space Physics Laboratory
Vikram Sarabhai Space Centre
Trivandrum

The Coherent Radio Beacon Experiment (CRABEX) is a national project proposed by Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum, India, involving various National Laboratories and Universities, all over the country.

The main scientific objective is for carrying out detailed studies on electron density distribution of various scale sizes in the low latitude ionosphere.

The experiment makes use of coherent beacon signals being transmitted by the orbiting satellites, which will be received simultaneously by a number of ground receiving stations.

Satellite radio beacons have been used for measuring the Total Electron Content (TEC) of the ionosphere, which is the line integral of the electron density along the ray path of the radio waves from the satellite to the ground receiver.

If these measurements are made for a large number of intersecting paths between a satellite in a low orbit and several ground receivers, then the electron density distribution in a section of ionosphere could in principle be reconstructed.

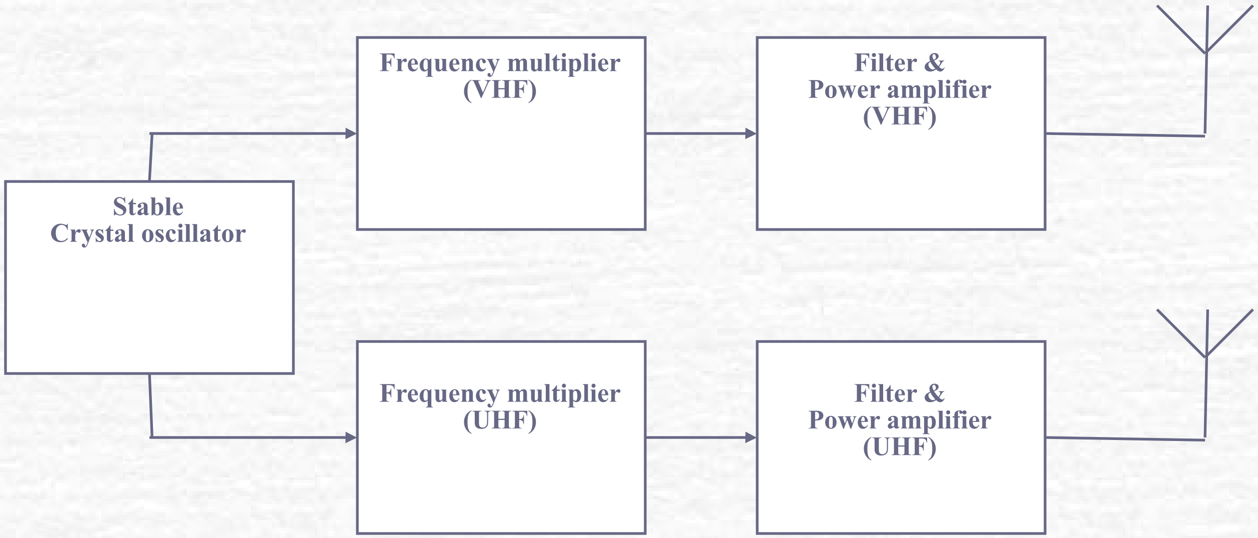
The integrated electron content simultaneously measured from the locations in the orbit plane of the satellite will be used for ray tomography, in which the two dimensional (latitude and altitude) distribution of the electron density can be computed.

Satellite beacons are particularly suited for monitoring the location of large scale ionospheric features such as midlatitude trough, the equatorial anomaly, enhanced contents during solar flares etc.

The scintillation of VHF and UHF radio waves traversing the ionosphere are related to plasma irregularities in the ionosphere and have direct bearing on communications.

Phase I

Deployment of very sensitive, high gain ground receivers at identified locations over the country and using them for the reception of 150 and 400 MHz from the orbiting satellites



GENERAL BLOCK SCHEMATIC OF A COHERENT RADIO BEACON TRANSMITTER ONBOARD LOW EARTH ORBITING SATELLITES (LEOS)

Link Budget for LEOS

Frequency(MHz)	150	400
Tx Power O/P (mw)	1000 (+30 dBm)	1000 (+30 dBm)
Tx Antenna Gain (dBc)	+3	+3
EIRP (dBm)	+33	+33
Free Space Loss(dB)	-142	-150.5
Rx Antenna Gain (dB)	+4	+4
Polarisation Loss (dB)	-3	-3
Link Margin (dB)	-2	-2
Signal Power at Rx I/p (dBm)	-110	-118.5
Rx Noise Temp (°K)	1000	1000
Antenna Noise Temp (°K)	3000	1000
System Noise Temp (dB)	36.02	33.01
Boltzmann Constant (dBm/Hz/°K)	-198.6	-198.6
Rx Noise (dBm/Hz)	-162.6	-165.6
Rx Bandwidth (dBHz)	30 (1 KHz)	30 (1 KHz)
Rx Noise Power (dBm)	-132.6	-135.6
S/N Ratio (dB)	22.6	17.1

Requirements of the receiver

1. The receiver should be able to give the differential phase difference between the coherent signals.

2. The signal strengths of both the coherent frequencies should be available.

3. All the above data should be sampled simultaneously for storage onto PC, to ensure minimal phase drift.

Major aspects in the design of the receiver system

1. Should be coherent, so that any strong extraneous noise in the bands of interest also will not make the system unlock, when the system is tracking the satellite.

2. The exact time of satellite pass should be available, with its frequencies of transmission.

3. The location of the antennae should be such that both the antennae view the satellite at the same time.

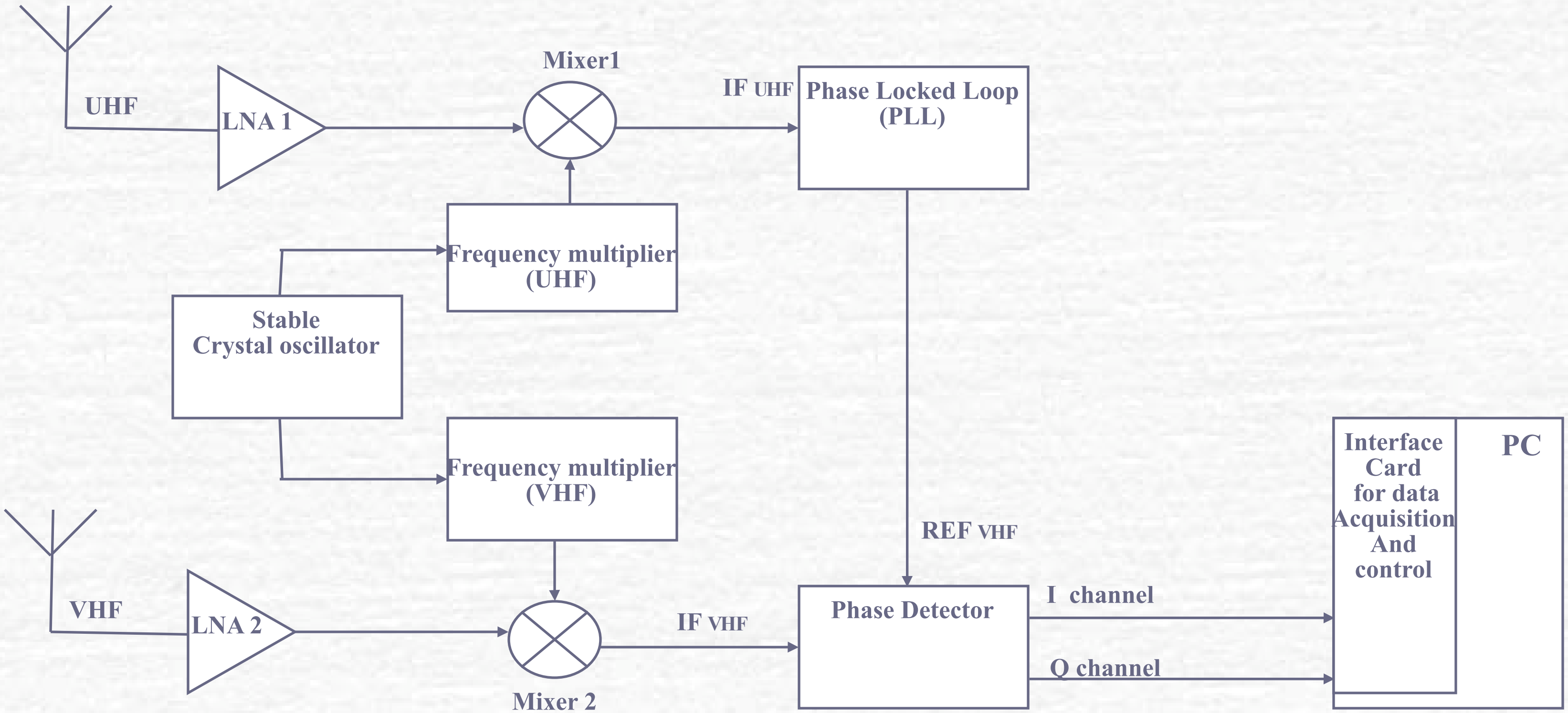
4. The antennae should be located in a preferably noise free environment.

5. The cable lengths from the antenna to the front end should be phase matched at both the frequencies.

6. The receiver should take care of the Doppler shift in frequency of the moving satellite.

7. All the outputs are sampled using a simultaneous sampling card and later converted to digital form using a PC addon card.

8. The data acquisition software should start acquisition as soon as the system locks to both the frequencies, with preferably an online display of the signals being acquired.



GENERAL BLOCK SCHEMATIC OF A COHERENT RADIO BEACON RECEIVER FOR LEOS RECEPTION

Present CRABEX Receiver system design

The receiver consists of antennae, an outdoor unit, an indoor unit and PC based data acquisition card and software.

The receiver makes use of two crossed dipole antennae – one for 150 MHz and one for 400 MHz for satellite signal reception.

For ensuring phase coherence between the two received signals, phase matched cables of electrical length 6 metres is used.

The down-conversion to Intermediate frequency (IF) is done in the outdoor unit itself, to minimize signal loss due to long cables

Both the incoming signals are tracked using two separate Phase locked Loops (PLLs) to improve the Signal-to-Noise Ratio (SNR) of the system

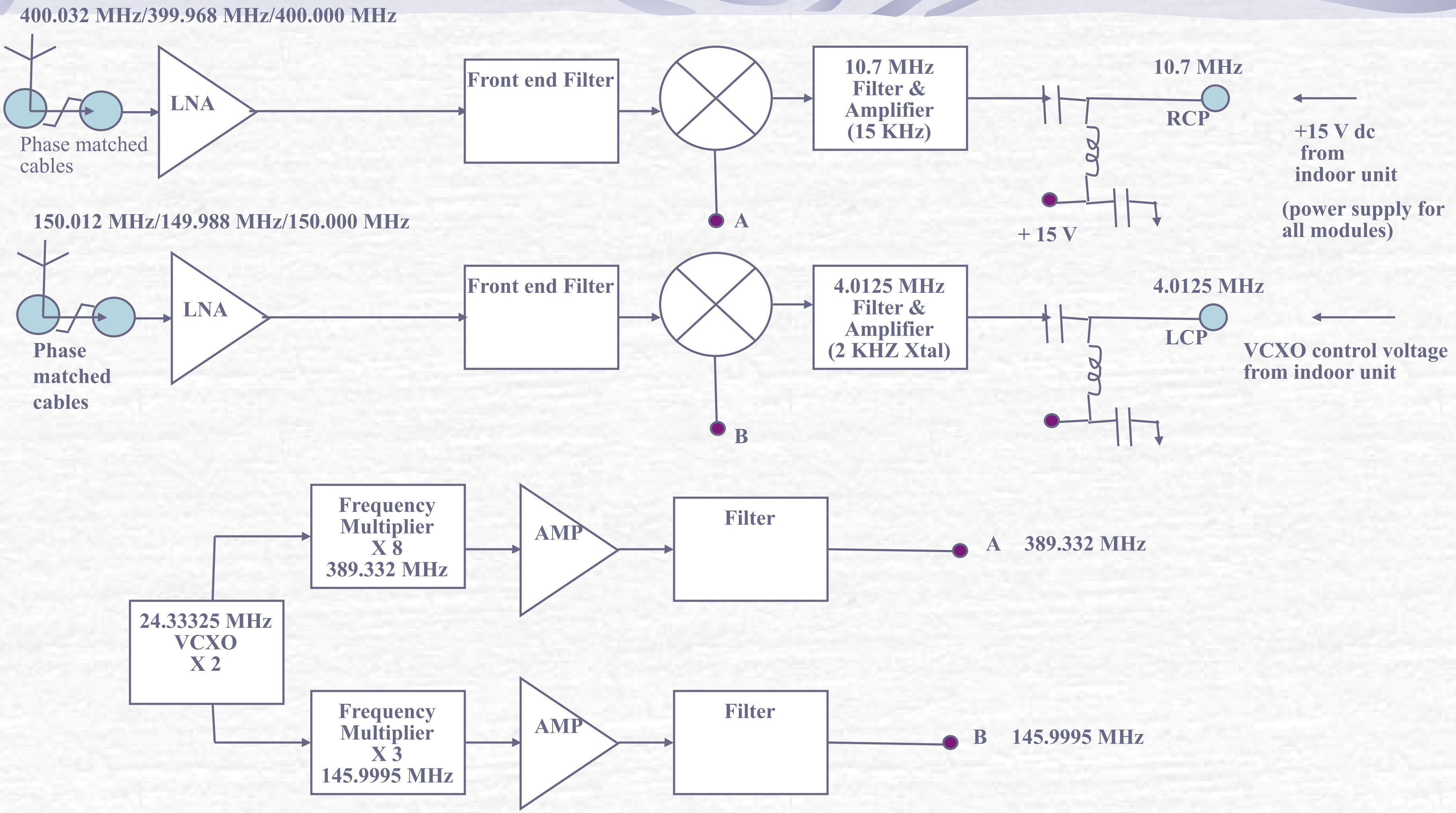
The differential phase between the carriers is measured as quadrature outputs, i.e, I and Q channels, so that the phase is obtained as

$\Phi = \tan^{-1}(Q/I)$

The amplitude channels are taken at the output of the respective filter - amplifiers

All the four data channels are fed to an 8 channel simultaneous sampling card, which is then digitized for storage to PC using an addon card

In order to track the satellite, a Voltage Controlled Crystal Oscillator (VCXO) is being used as the Local Oscillator (LO) of the front end mixer. The voltage control for the same is done by monitoring the IF in the indoor unit. This monitoring is provided in the front panel



SIMPLIFIED BLOCK SCHEMATIC OF OUTDOOR UNIT OF CRABEX RECEIVER FOR LEOS

To take care of the satellite Doppler effect

The maximum doppler from a Low Earth Orbiting Satellite (LEOS) is ± 8 KHz

There are basically four sets of satellites that transmit signals in the frequencies of our interest

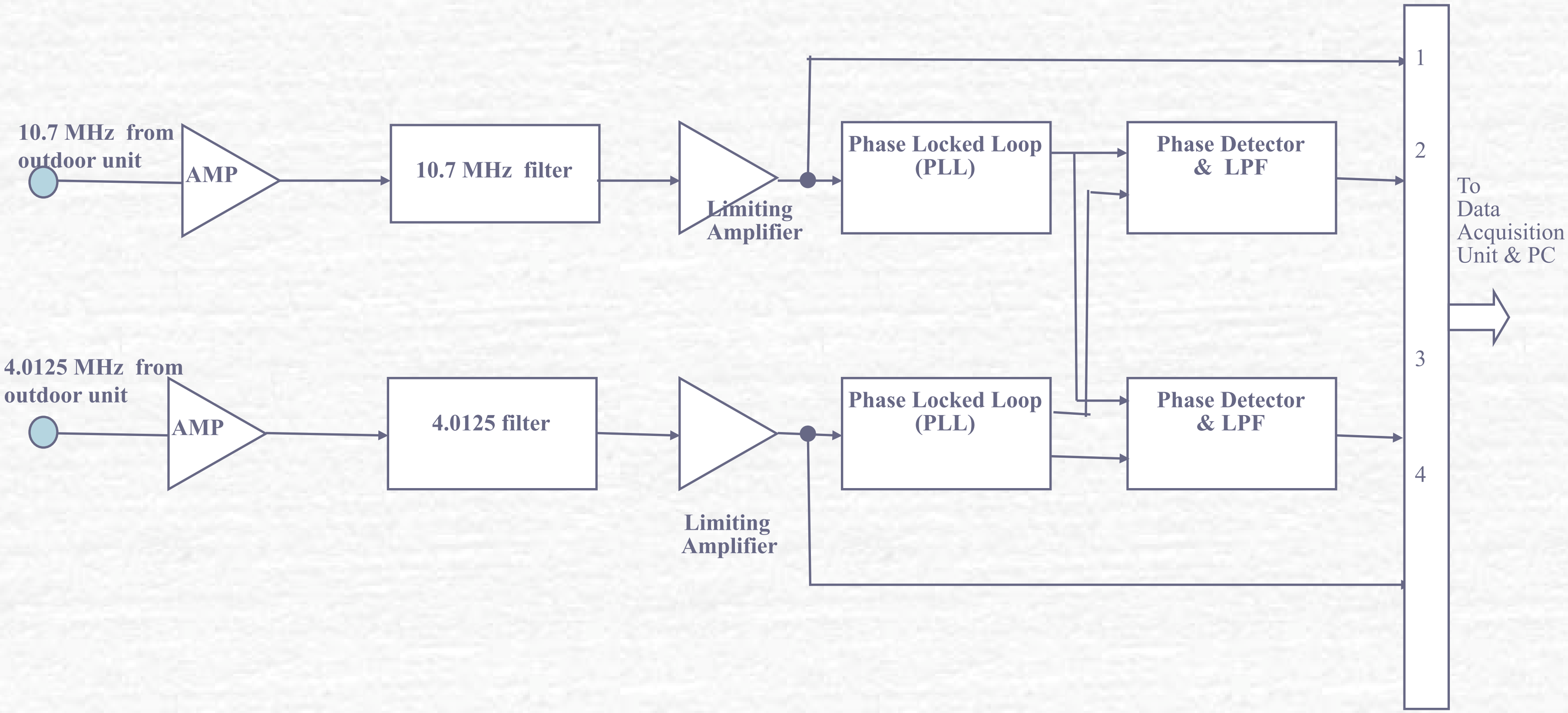
1. Russian Tsikada series : 150, 400 MHz
   0 ppm offset
2. US NNSS operational series : -80 ppm offset
3. NNSS maintenance offset series : -145 ppm offset
4. Others : + 80 ppm offset

The CRABEX receiver tracks automatically each of these satellites in 20 channels, with each channel having a bandwidth of 500 Hz and an overlapping bandwidth of tens of Hz.

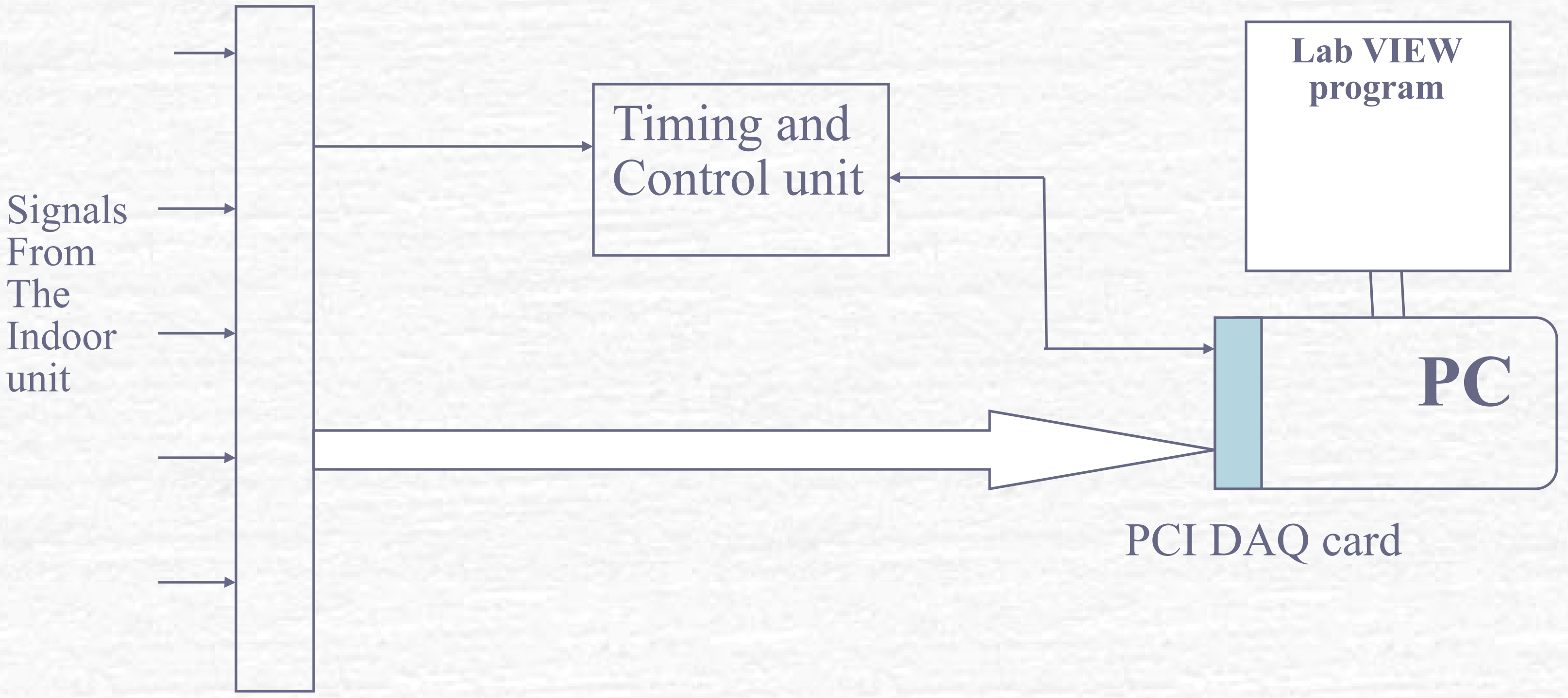
Indicators are provided in the front panel to indicate the PLL lock of the 150 and 400 MHz signals.

Provision for manual tracking also exists.

As soon as the lock indicators become stable in the first channel, the data acquisition software starts, acquires and saves the data on PC.



SIMPLIFIED BLOCK SCHEMATIC OF INDOOR UNIT FOR LEOS



BLOCK SCHEMATIC OF THE DATA ACQUISITION SYSTEM

Specifications of the CRABEX receiver system for LEOS

Type	: Coherent Detection
Operation	: Auto acquisition of data
Receiver frequencies	: One of the three sets at a time
	(i) 150 MHz, 400 MHz
	(ii) 149.988 MHz, 399.968 MHz
	(iii)150.012 MHz, 400.032 MHz

Antenna

Type of antenna	: Crossed dipole
Antenna gain	: ^{3} 4 dB for all the frequencies
Antenna Beamwidth	: ~ 110°

Receiver System

Input signal dynamic range	: 30dB for all channels (-100 to –127 dBm)
Maximum input handling capability	: -95 dBm
Input signal level expected	: -100 to -120 dBm (150 MHz)
	-117 to -127 dBm (400 MHz)
Video BW	: ~ 1 KHz
SNR	: 35 dB (after coherent averaging) for 150 MHz
No. of outputs available	: Four
	(i) I channel of 150 MHz
	(ii) Q channel of 150 MHz
	(iii) Amplitude channel of 150 MHz
	(iv) Amplitude channel of 400 MHz

Data acquisition system

Sampling rate	: 100 samples per sec, typ.
No. of bits	: 16 bit

Requirements for CRABEX receiver chain of stations

The stations should be in almost the same longitude so as to observe the same satellite passes, and also for development of ionospheric tomography.

For this, the most important is the time synchronisation between the stations.

Good data for reconstruction of ionospheric tomogram requires that all receivers perform identically for high elevation passes.

As the time information from the satellite are not extracted by this receiver, GPS modules are made use of for the synchronization.

The time, date and station code are extracted from the GPS, and these get entered as part of the data.

The output sequence required from each of the GPS modules are first programmed to the requirement.

Each code sequence is for a duration of 100msec

The data acquisition software senses the rising edge of the GPS signals and records the time code. This ensures that the time synchronization between stations is better than 100 msec.

The data acquisition software acquires the GPS Codes first, and this starts the data acquisition


INDIA
The external boundaries of India on this map have not been authenticated and may not be correct.
Great Himalaya Range
Srinagar
Leh
CHINA
PAKISTAN
Shimla
Chandigarh
Delhi
NEPAL
Gangtok
Itanagar
Jaisalmer
Darjeeling
Agra
Jaipur
Shillong
Varanasi
BANGLA-DESH
Udaipur
Khajuraho
Bhopal
Kolkata (Calcutta)
Gandhinagar
Kanha National Park
Bhubaneswar
Mumbai (Bombay)
INDIA
MYANMAR
Hyderabad
Bay of Bengal
Goa
Vijayawada
Arabian Sea
Panaji
Tirupati
Bangalore
Chennai (Madras)
Andaman Islands
Kochi (Cochin)
Mysore
Kerala
SRI LANKA
Nicobar Islands
0 400 km
0 250 mi
INDIAN OCEAN
© Lonely Planet

CRABEX Receiver Locations for LEOS

1. Ahmedabad Physical Research laboratory (PRL)
2. ***Bangalore/ Hoskote Indian Institute of Astrophysics (IIA)***
3. ***Bhopal Barkathulla University***
4. Calcutta University of Calcutta
5. ***Delhi National Physical laboratory (NPL)***
6. Dibrugarh University of Dibrugarh
7. ***Hyderabad Osmania University***

3. Mumbai Indian Institute of Geomagnetism (IIG)

9. Leh Indian Institute of Astrophysics (IIA)
10. Tirupati National MST Radar Facility (NMRF)
11. ***Trivandrum SPACE PHYSICS LABORATORY (SPL)***
12. Waltair Andhra University

Status

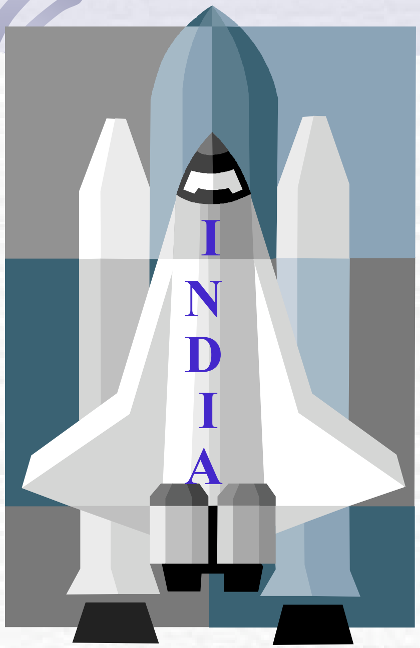
The initial proposed meridional chain of five receivers are set up at Trivandrum, Hoskote, Hyderabad, Bhopal and New Delhi.

The data from the stations are daily sent to the focal centre at Trivandrum by email now.

The quality of data at these stations are being analysed for optimising their locations.

Future

The present stations would all be linked by Internet for sending the data to the nodal centre. Wherein the labs are located at further distances from the main buildings (like in Trivandrum, Bhopal and Delhi at present) which only have the internet access, wireless networking is going to be proposed as the next immediate phase.



Thank You