Real time communication in ocean observation platform

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Ocean Observations

Ocean observing systems collect ocean and weather data and provide data in real time to a variety of users such as forecasters, emergency and coastal managers researchers and educators and many more.

Observing systems consist of sensors that collect data, the platforms that host these sensors(satellite sand Ocean Buoys), and technology that sends the data to a data collection center, in real time.

Ocean Parameters

Temperature, Currents, Salinity, Sea Ice, Sea Level, Wind, Bio geo Chemistry

(1) Satellite Based Observations: Satellites are being used to observe the ocean since 1970s. There are several satellites that carry specialized sensors for measuring ocean conditions over large areas of the ocean. Common products from satellites include sea surface temperature and chlorophyll.

(2) In-situ Observations: Oceanographers have used in-situ platforms to observe the oceans for ages. It is to day important as complement to satellite based observations. When assimilated in models, in situ observations calibrate the models and serve as a reference point.

Real Time Communication

- In real time communication there is a direct path between the sender and the receiver although there are many several nodes in between but it goes from sender to receiver without any storage and delay. It belongs to peer to peer communication.
- Generally Real time communication (RTC) is called "LIVE COMMUNICATION".
- In the context of Global Observation System, there are two modes ,
- Real time: Early Tsunami warning
- Near Real Time: Weather data

Ocean Parameters ,satellites and platforms

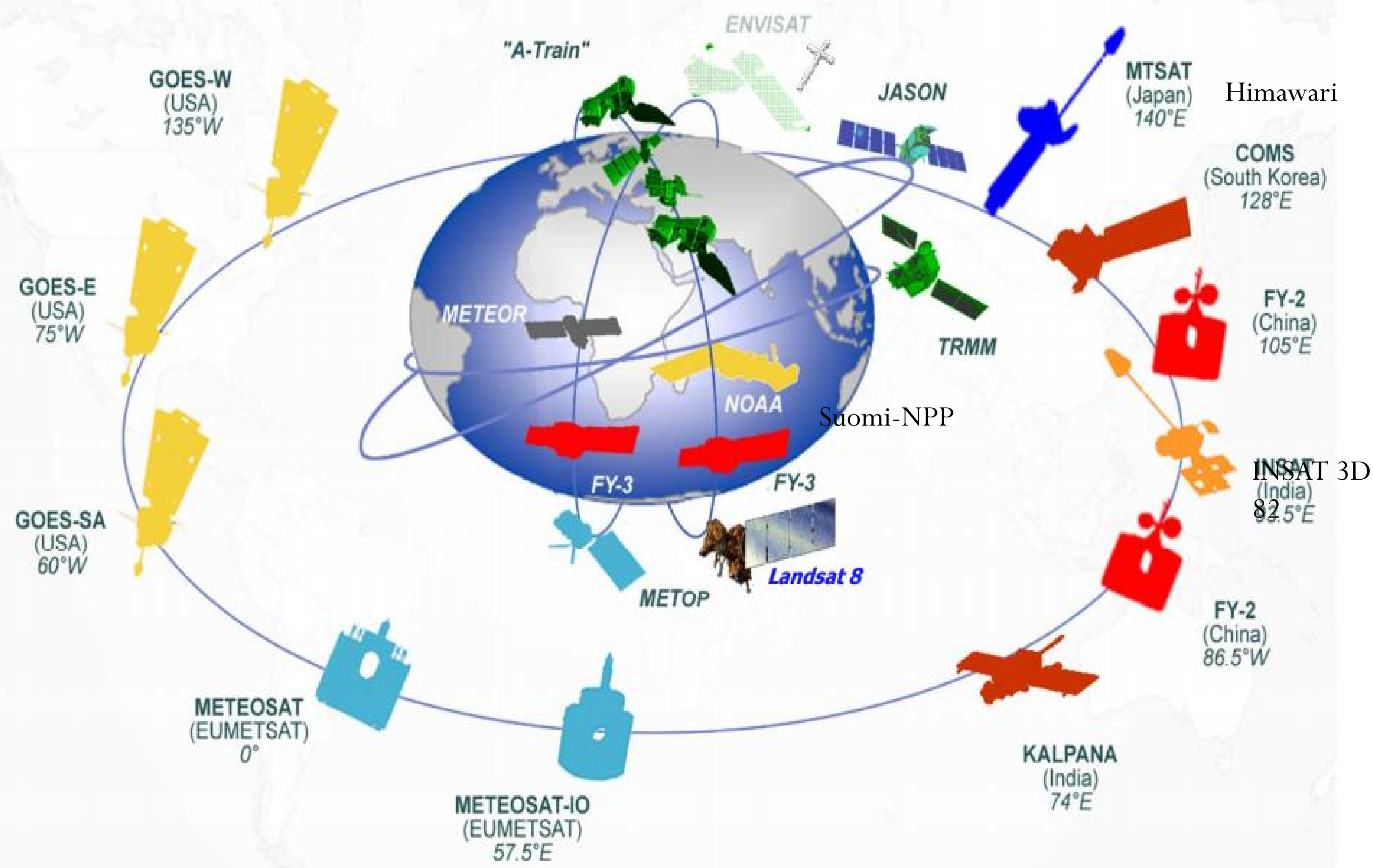
Parameter	Satellite Based	In-Situ
Temperature	Infrared Radiometer, Microwave radiometer (SST)	Ships of Opportunity, Drifting Buoys, Argo Profiling Floats, Moored Buoys, Research vessels, Ship AWS,XBT
Currents	Altimeter Altimeter+ Scatterometers(Sea Surface currents and winds)	Argo(Deep Ocean Currents), Drifting Buoys, Gliders(surface to 1000m)
Salinity	Microwave Radiometer	Profiling Floats, Moored Buoys
Sea Ice	Microwave Radiometers(Concentration, Drift), Microwave Scatterometers(extent, edge, type) Infrared Sensors(extent)	Ice Buoys(Temperature, mass, drift)
Sea Level	Altimeters	Tide Gauges
Wind	Microwave Radiometers, Microwave Scatterometers, SAR, Altimeters	Moored Buoy, Ship AWS
Bio Geo Chemistry	Spectrometers	Research vessels, Gliders

Satellite Based Observation

Instrument Type	Ocean Parameter measured	Satelltes
Spectrometer	Chlorophyll, Organic and mineral content, SST, Sea Ice Cover	Aqua(USA) Envisat(Europe)
Infrared Radiometer	SST	NOAA,Metop ,Envisat, Aqua, TERRA, Suami-NPP, Meteosat, DMSP,INSAT,
Microwave Radiometer	Atmospheric water vapor content, Atmospheric water liquid content(Cloud), Rain Rates, Sea Ice concentration type, extent, SST, Salinity	DMSP, TRMM, Aqua + JAXA developed by Japan, Envisat, Jason-1,2,3
Altimeter	Sea Surface Height, Ocean Surface wind speed, Wave Height, Sea Ice	Jason-1,2,3 Envisat,
Scattero meter	Wind speed and Heading(10m above ocean surface), Rain, Sea Ice Concentration	Metop
Synthetic Aperture Radar(SAR)	Wind, Surface Wave Field, Sea Ice Monitoring	Radasat-1,2, Envisat

GROUP ON EARTH OBSERVATIONS

Space-based Assets



IN-SITU Platforms

Drifting buoy(SST, Pressure)

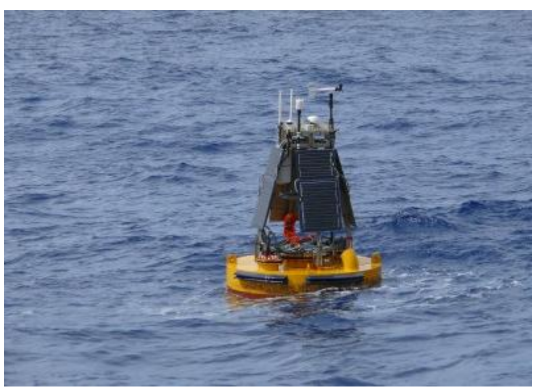
ARGO(CTD)

Wave raider buoy(Wave Height, direction)

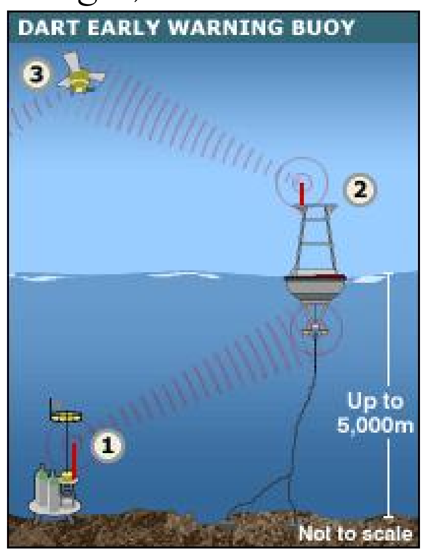
Communication : Argos, INSAT and other regional

Communication : INSAT

Moored buoy(Met sensors, SST, Wave



Tsunami Buoy (Wave height)



Tide Gauge(Tide Heiht)

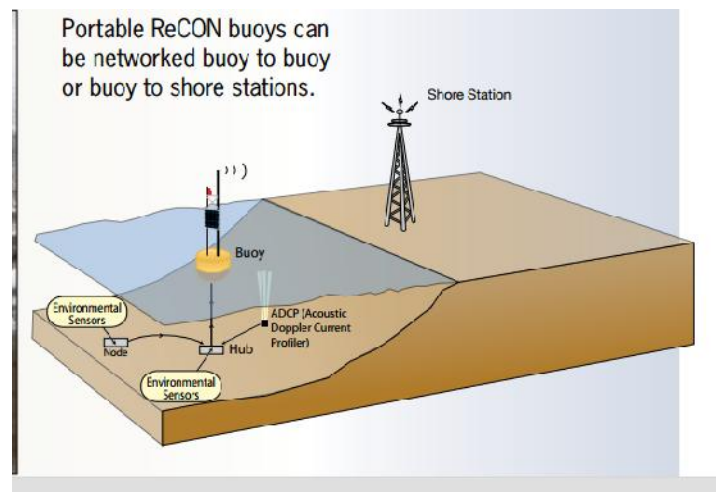
Ship AWS

Communication : INMARSAT

Met sensors, Long/Short wave radiation, SST, Turbidity

Glider(CTD,..

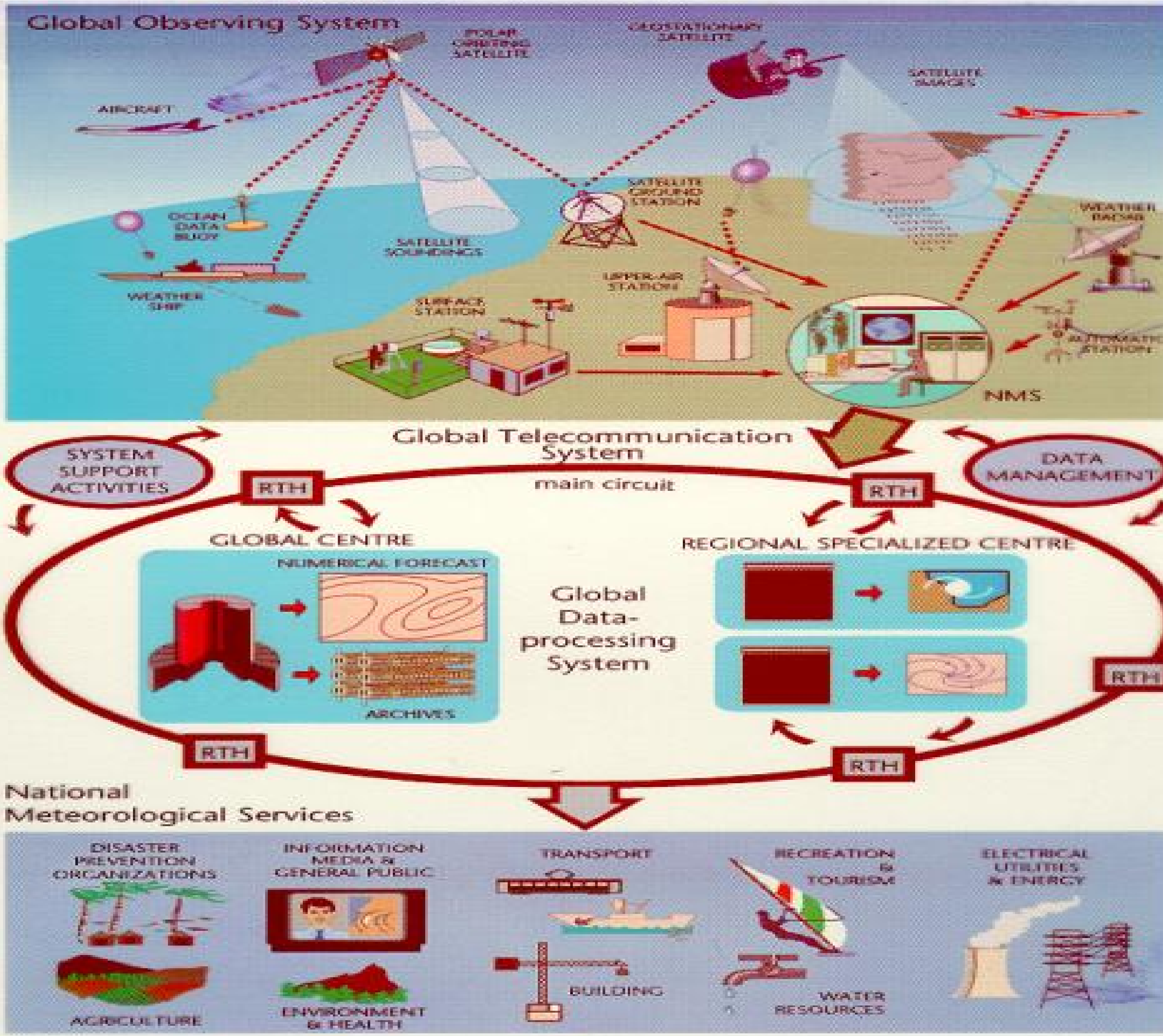
Coastal Radar(Wave height, Direction)



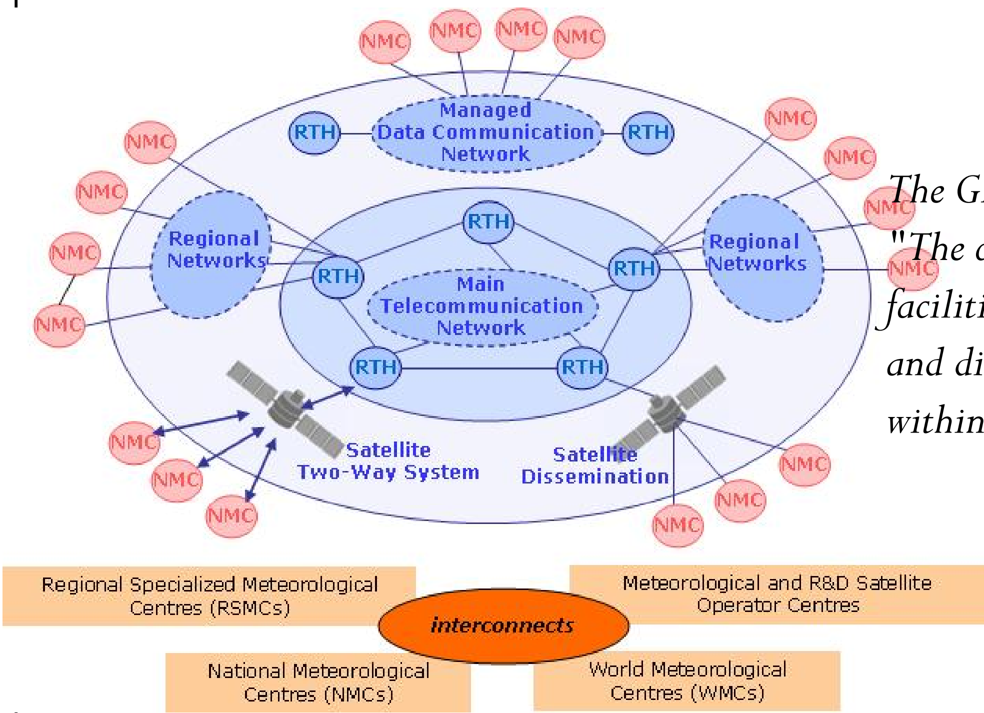
Communication Network

- **Established in 2005, GEO (Global Earth Observation)** is a voluntary partnership of governments and organizations that co ordinate take decision for comprehensive and sustained Earth observations and information." GEO Member governments include 102 nations and the European Commission, and 95 Participating Organizations comprised of international bodies with a mandate in Earth observations.
- Together, the GEO community is creating a **Global Earth Observation System of Systems (GEOSS)** that will link Earth observation resources world-wide across for different users.
- GEOSS information exchange has been principally based on the Internet, the **Global Telecommunications Network (GTS)** component of the WMO Information System (WIS) and satellite based distribution systems such as **GEONET Cast**. A key counterpart will be the ITU.

  GOOS(under GEOSS) is the Global Ocean Observing System. **GOOS** is designed and being implemented to embrace the oceans as a single entity, to provide a global view of the ocean system. It is a permanent global system for observations, modeling and analysis of marine and ocean variables to support operational ocean services worldwide. GOOS provides accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible, and the basis for forecasts of climate change.


Global Observing System
POLAR ORBITING SATELLITE
GEOSTATIONARY SATELLITE
SATELLITE IMAGES
AIRCRAFT
OCEAN DATA BUOY
SATELLITE SOUNDINGS
SATELLITE GROUND STATION
WEATHER RADAR
WEATHER SHIP
UPPER-AIR STATION
SURFACE STATION
AUTOMATIC STATION
NMS
Global Telecommunication System
SYSTEM SUPPORT ACTIVITIES
DATA MANAGEMENT
RTH
main circuit
RTH
GLOBAL CENTRE
REGIONAL SPECIALIZED CENTRE
NUMERICAL FORECAST
Global Data-processing System
ARCHIVES
RTH
RTH
RTH
National Meteorological Services
DISASTER PREVENTION ORGANIZATIONS
INFORMATION MEDIA & GENERAL PUBLIC
TRANSPORT
RECREATION & TOURISM
ELECTRICAL UTILITIES & ENERGY
BUILDING
AGRICULTURE
ENVIRONMENT & HEALTH
WATER RESOURCES

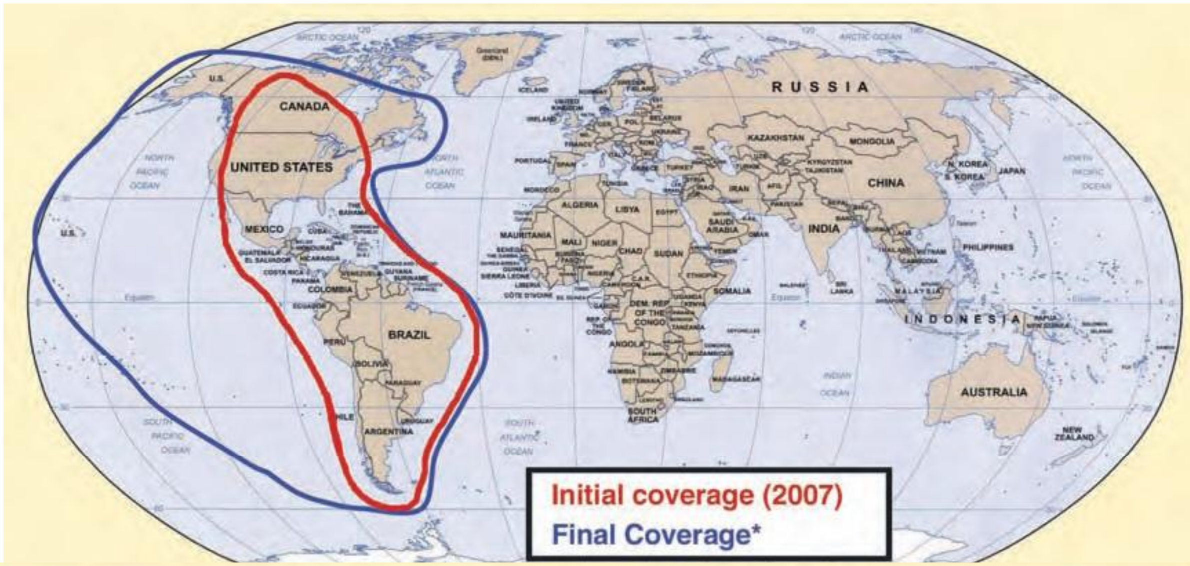
Global Telecommunication System (GTS)

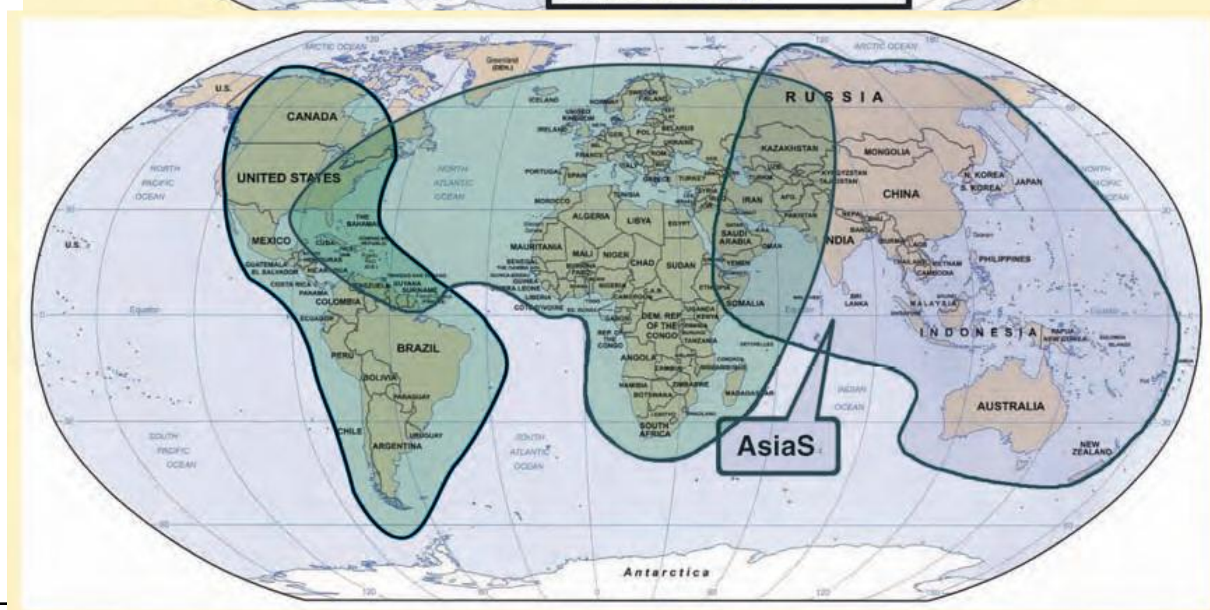


The Global Telecommunication System (GTS) is defined as: "The co-ordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange and distribution of observations and processed information within the framework of the World Weather Watch."

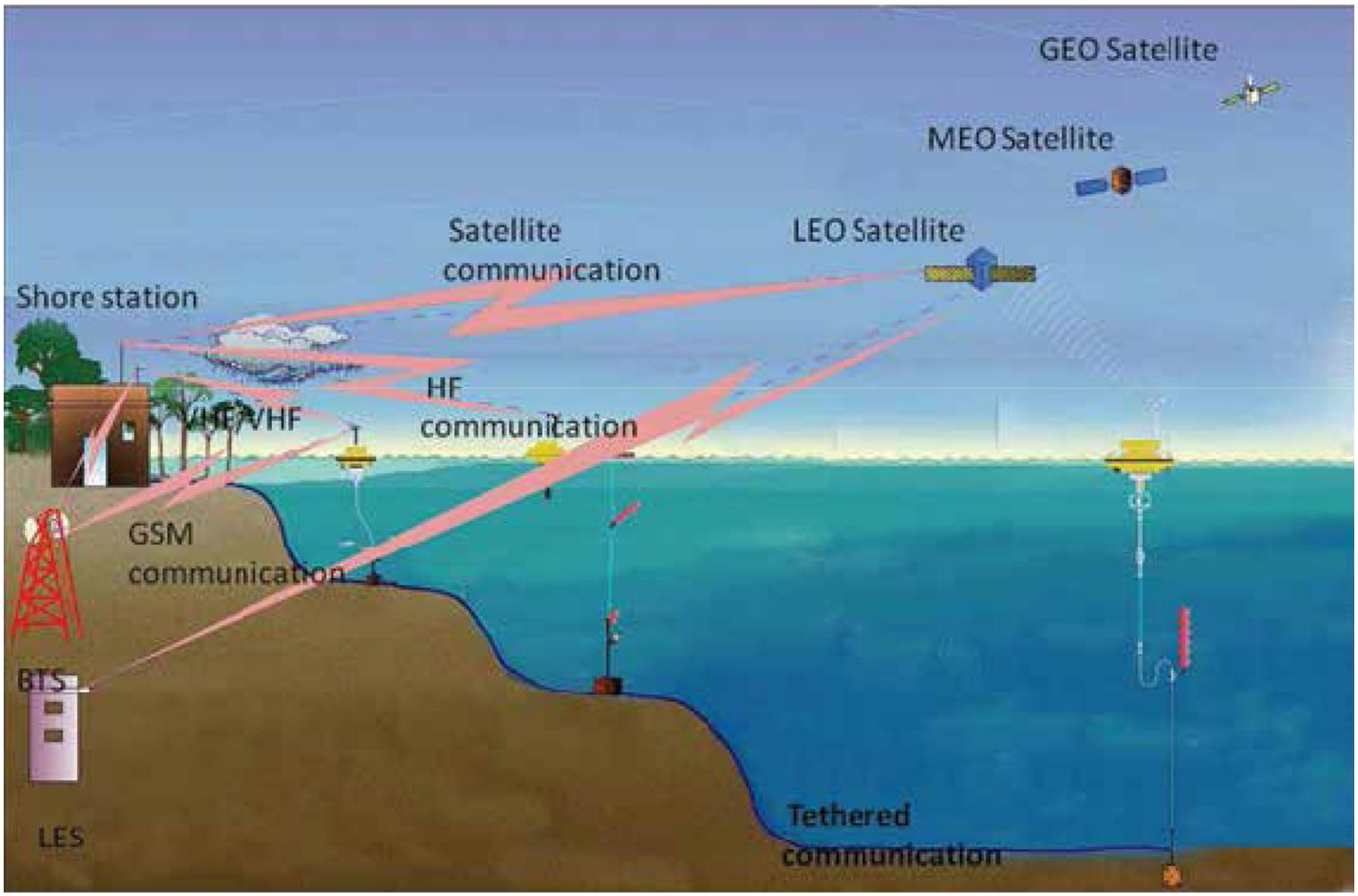
The GTS is an integrated network of surface-based and satellite-based telecommunication links of point-to-point circuits, and multi-point circuits, interconnecting meteorological telecommunication centers operated by countries for round-the-clock reliable and near-real-time collection and distribution of all meteorological and related data, forecasts and alerts. This secured communication network enables real-time exchange of information, critical for forecasting and warning of hydro meteorological hazards.

GeonetCast





Different mode of Communication



Satellite based Data Collection System

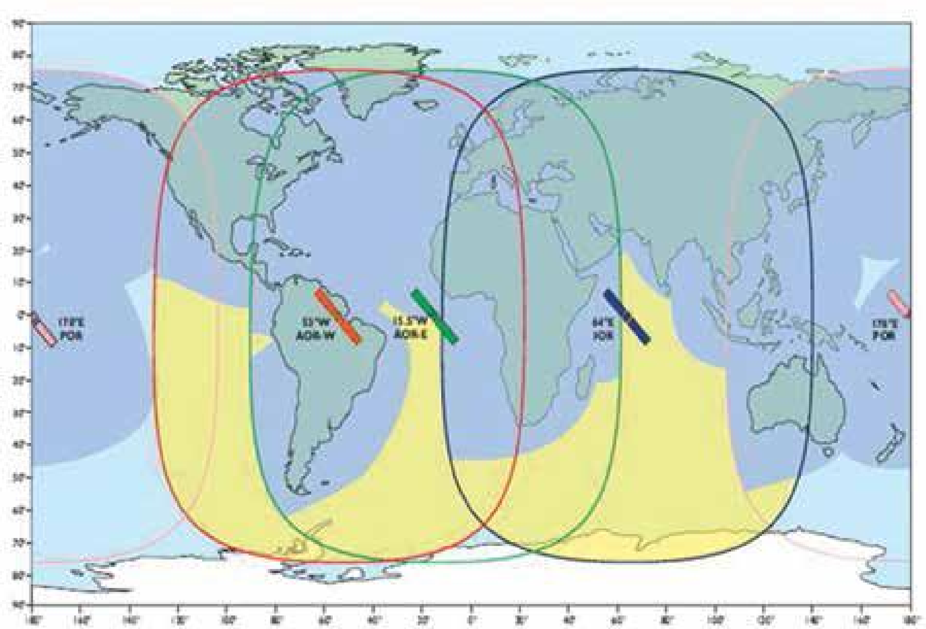
One Way : (1)ARGOS data collection and Location System-Polar satellite system

- (2) Data Collection System- Geo Synchronous Satellite System(GOES(USA), Meteosat (Europe), INSAT(India), Himawari (Japan) COMS(Korea),FY(China),..

Two Way: ARGOS data Collection and Location System (ARGOS 3),

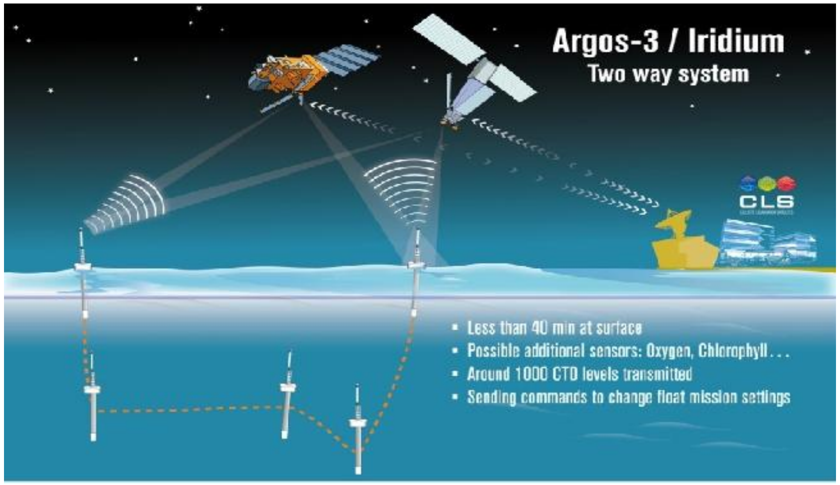
Communication Satellites: LEO(IRIDIUM), Geo Stationary (INMARSAT, INSAT MSS,….)

INMARSAT Coverage

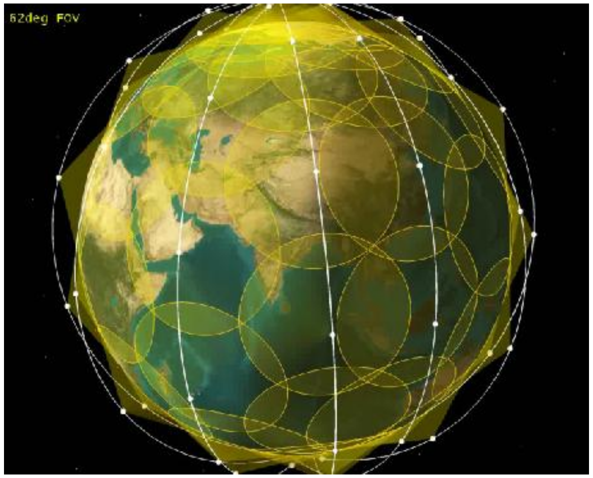


INSAT Coverage

ARGOS-3

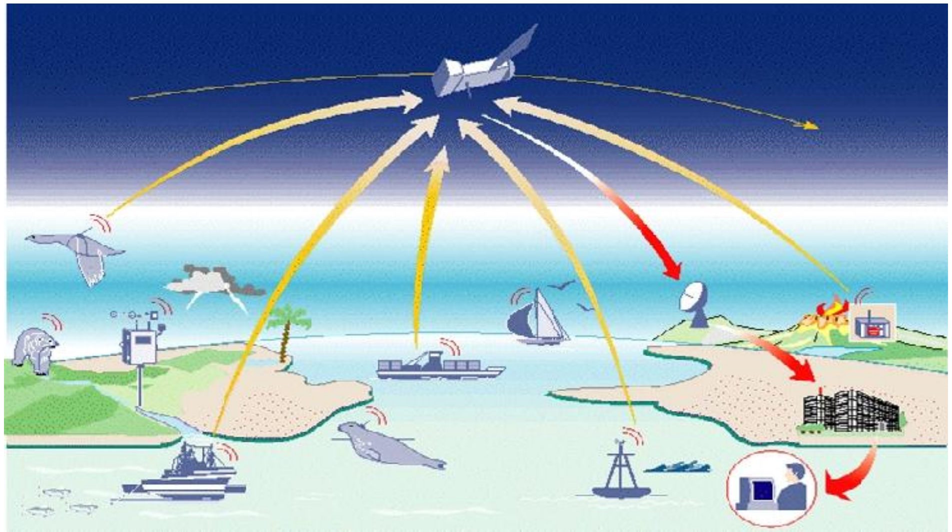


IRIDIUM Coverage



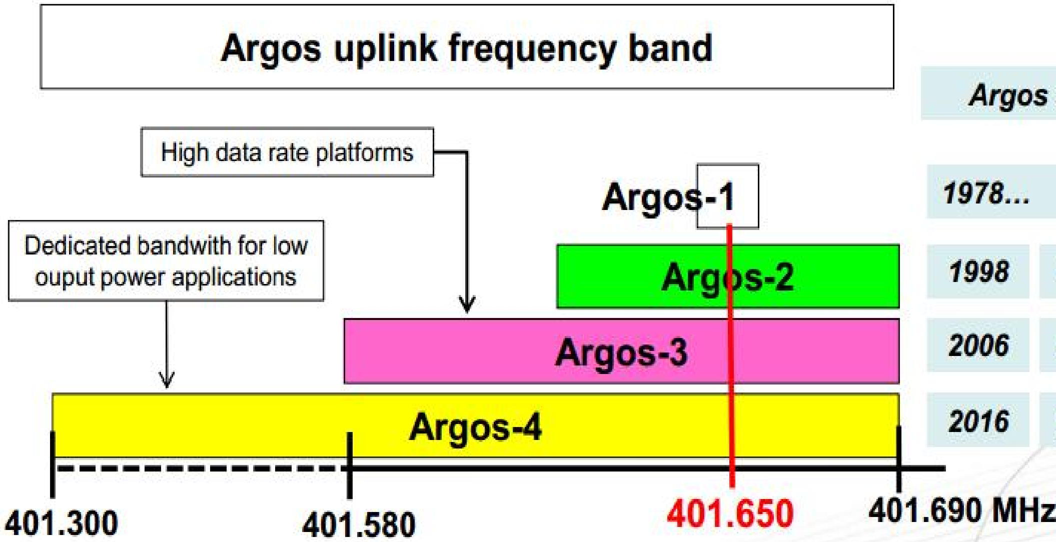
ARGOS

The Argos satellite-based location and data collection system enables scientists to gather information on any "object" equipped with an appropriate transmitter, anywhere in the world.
ARGOS in not an Acronym, rather, it is chosen name for the system



Argos transmitters' messages are recorded by a constellation of satellites carrying Argos instruments, and then relayed to dedicated processing canters. This system, has been operational since 1978, and was initiated jointly by France and the United States. The system is operated worldwide by CLS, a subsidiary of CNES, and the French institute of marine research and exploration

ARGOS System



Argos satellites launch years

1978…			
1998	*2000*	*2002*	*2005*
2006	*2009*	*2012*	*2013*
2016	*2018*	*2020*	*…*

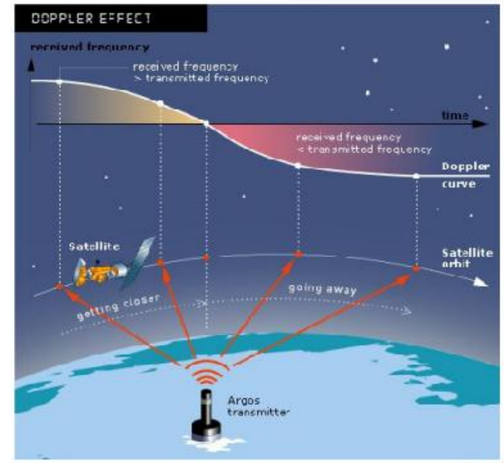
Initial Argos frequency band and uplink modulation are preserved

- **Sustainability of the Argos satellite system is compatible with long lifetime program (like Argo with floats lifetime ~10 years)**

ARGOS

- ARGOS(NOAA, Metop , SARAL, ADEOS)
- There are 8 ARGOS Operational
- 4XARGOS 2
- 4X ARGOS 3 (Downlink is 'ON' only in Two)

  (Metop B, SARAL, Downlink at 401.65MHz)



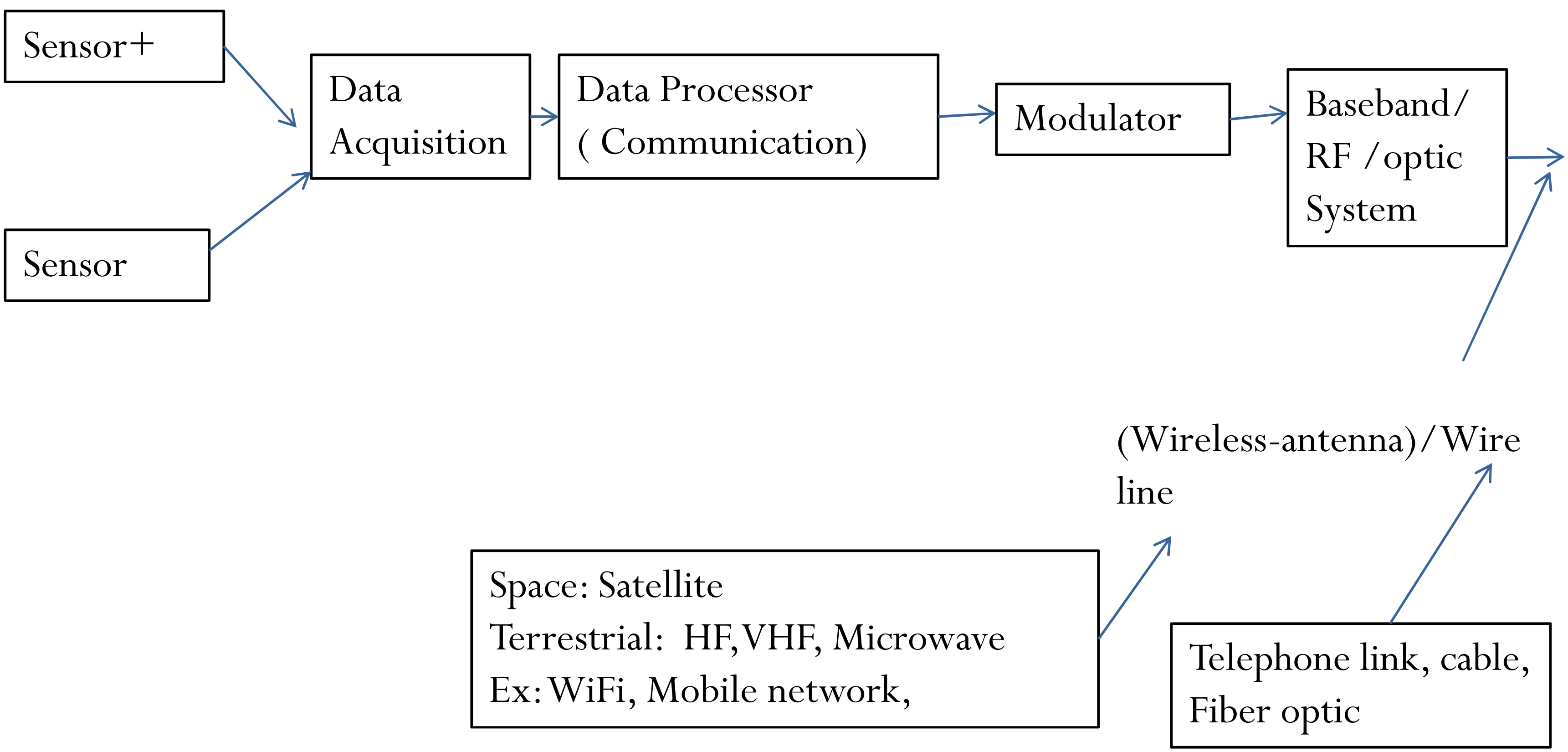
GPS free positioning system
Position accuracy up to 250 m

•For a volume of data per profile < 0.5 KB: Argos-2

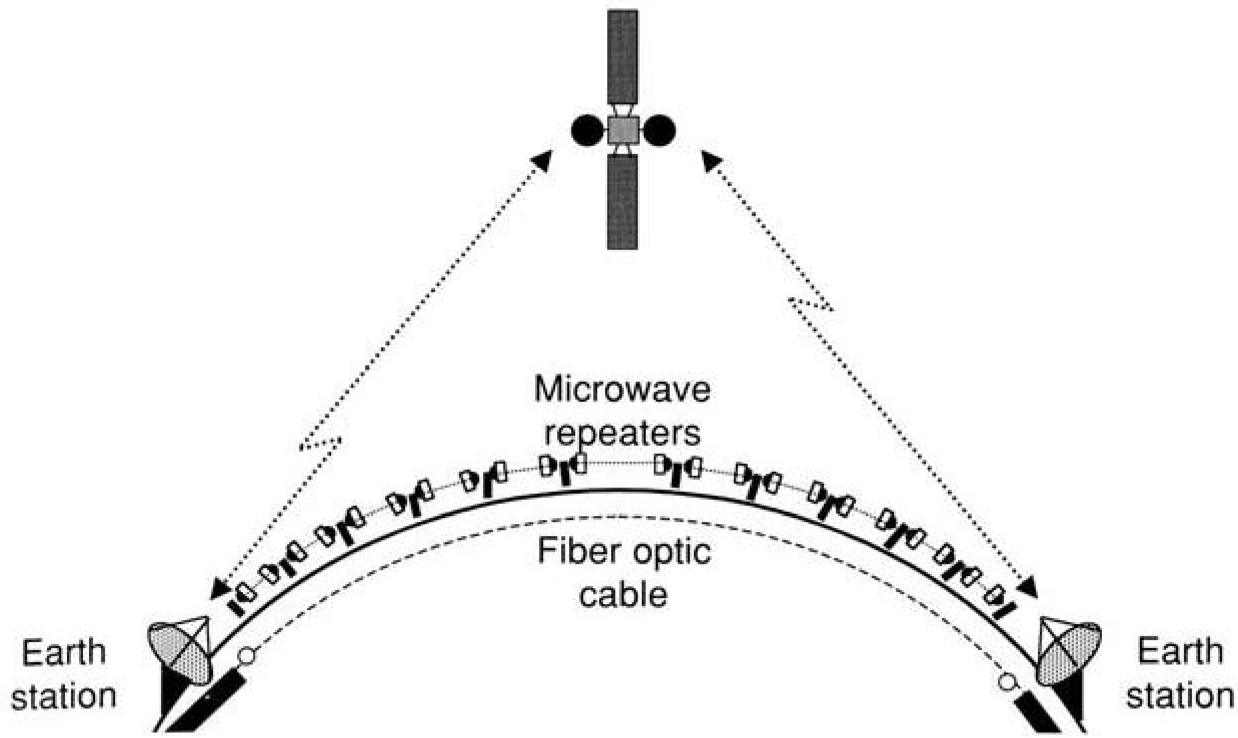
•For a volume of data per profile from 0.5 KB to 2.5KB
  Argos-3 low data rate mode

• For a volume of data per profile > 2.5 Kbytes , Argos-3 high data rate mode.

Communication Link



Satellite


Microwave
repeaters
Fiber optic
cable
Earth
station
Earth
station

Satellite orbits

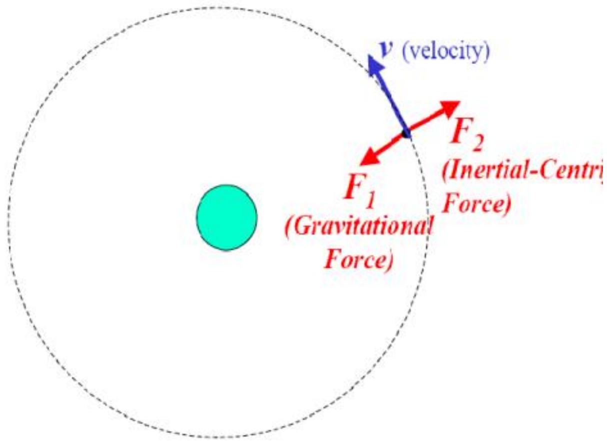
$$F_{net} = \frac{m_{sat} v^2}{R}$$

$$F_g = \frac{G m_{sat} M_e}{R^2}$$

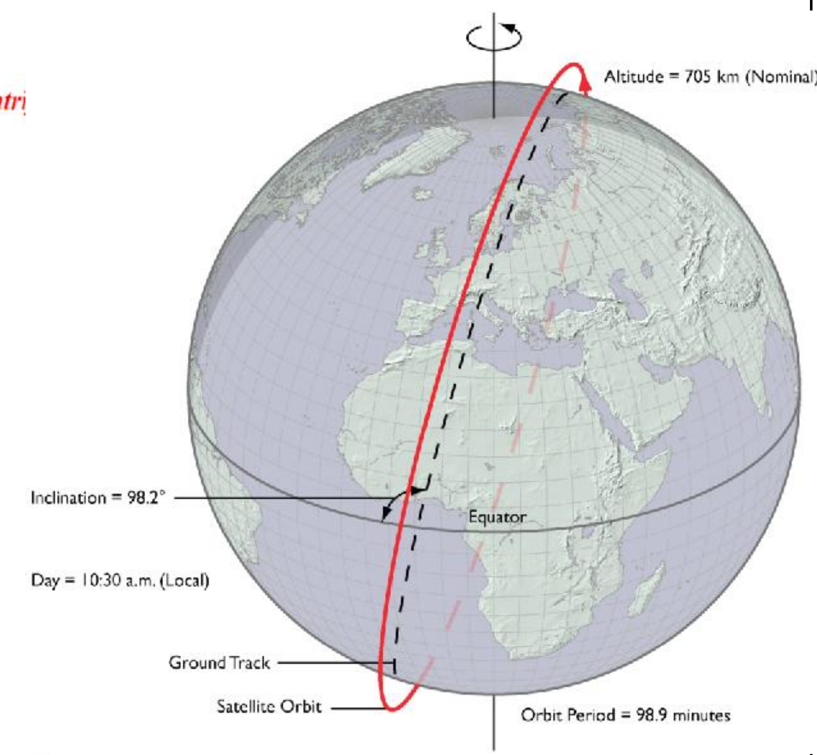
$$v^2 = \frac{G M_e}{R}, v = \frac{2\pi R}{T}$$

$$T^2 = \frac{4\pi^2 R^3}{G M_e}$$

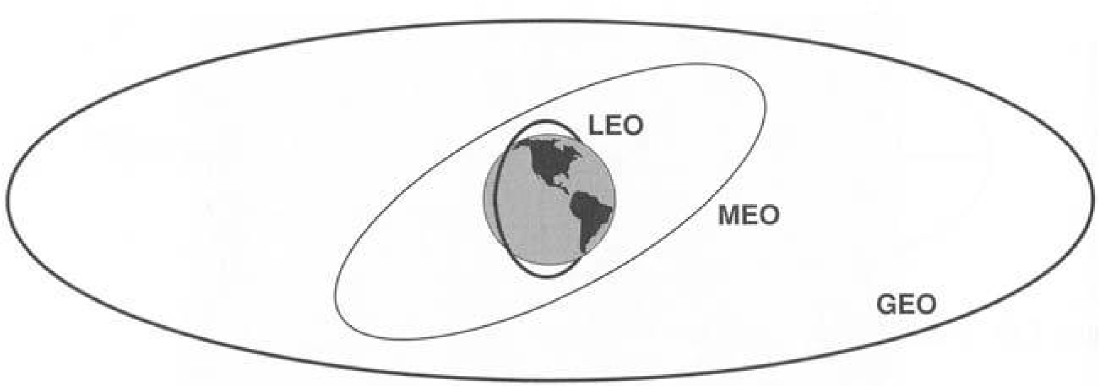
$$T^2 \propto R^3$$



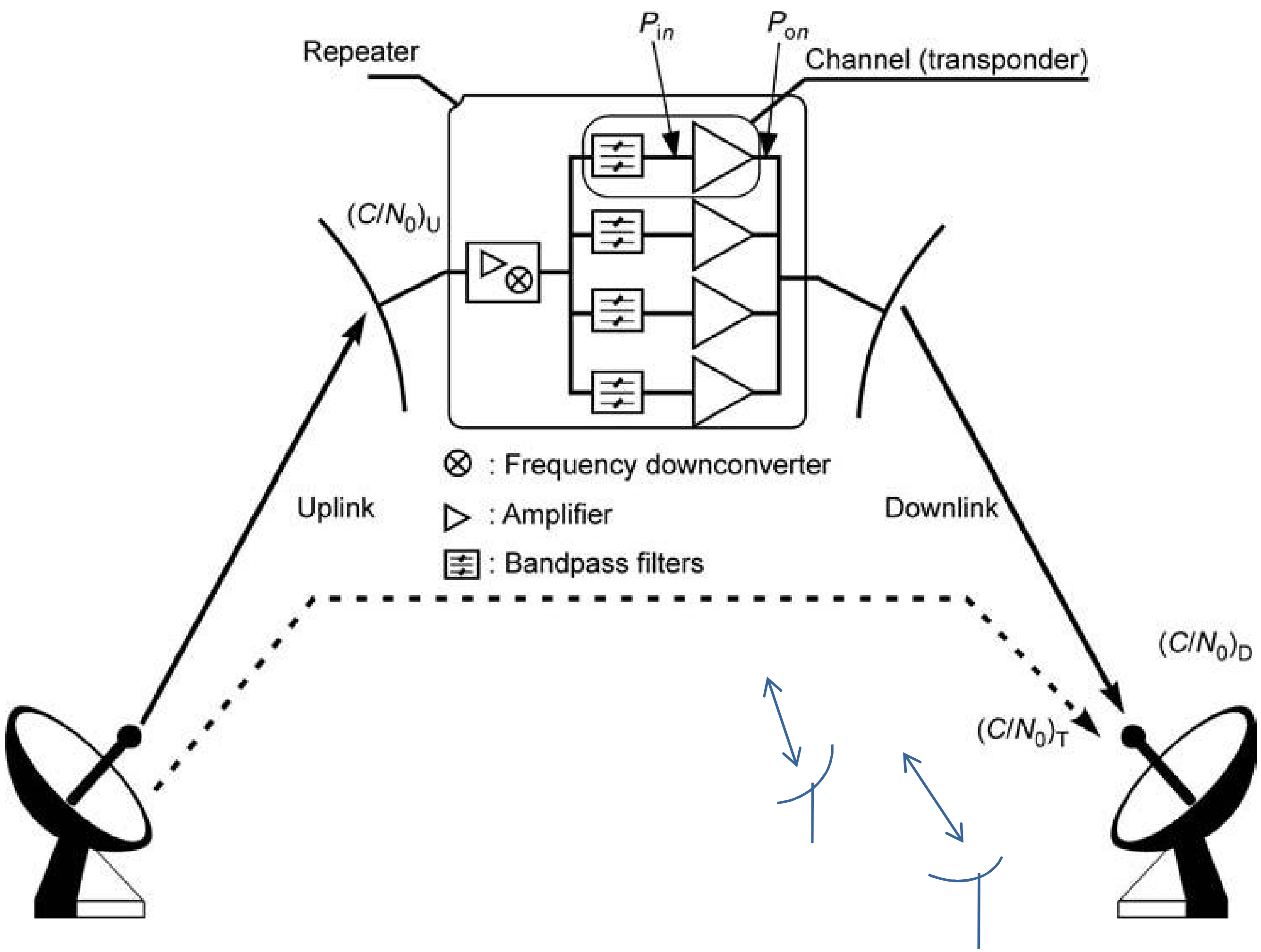
Sun-Synchronous Orbit



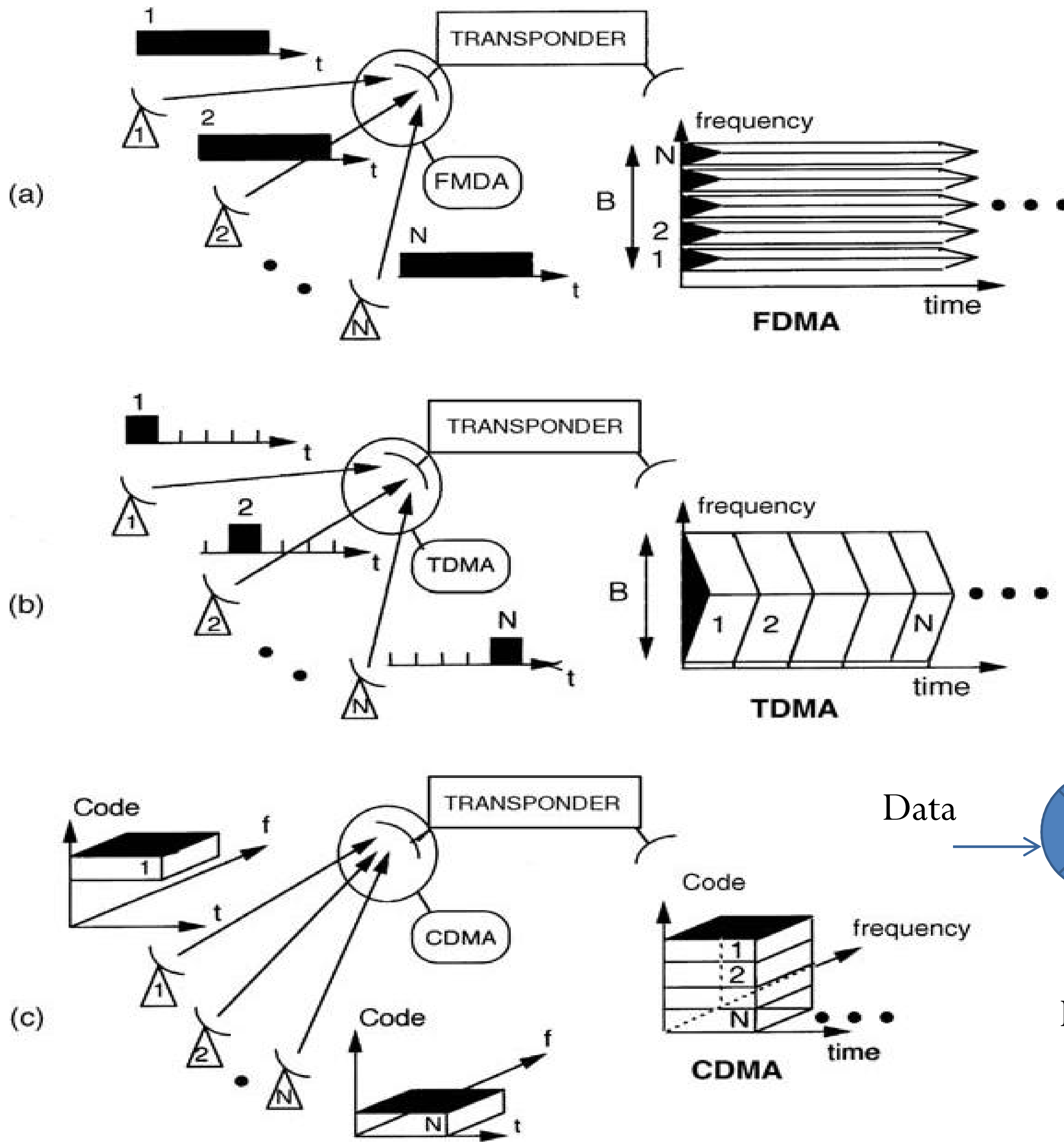
Satellite Orbits

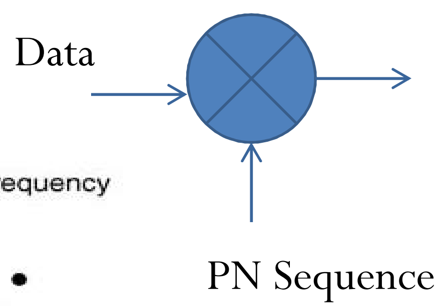


Satellite Transponder



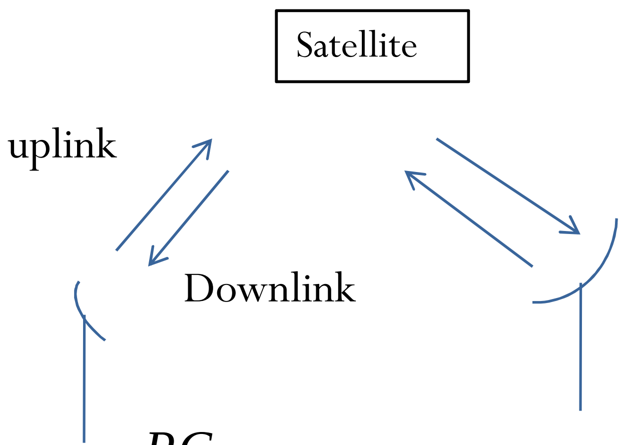
Satellite- Multiple Access





ITU Designation			Military Radar band Designation	
ITU Band	Designation	Frequency	Designation	Frequency
3	ULF	300Hz-3KHz	HF	3-30MHz
4	VLF	3-30KHz	VHF	30-300MHz
5	LF	30-300KHz	L	1-2GHz
6	MF	300-3000KHz	S	2-4GHz
7	HF	3-30MHz	C	4-8GHz
8	VHF	30-300MHz	X	8-12GHZ
9	UHF	300-3000MHz	Ku	12-18GHz
10	SHF	3-30GHz	K	18-27GHz
11	EHF	30-300GHz	Ka	27-40GHz
12		300-3000GHz	mm	40-300GHz
13		3-30THz	V	40-75THz
14		30-300THz	W	75-110THz
15		300-3000THz	mm	110-300THz

Communication satellites Link Parameters



P_t= Transmit power
G_t= Gain of transmit Antenna
A_e= Effective Area of the Receiving Antenna
R= Range Between Earth Station/Terminal to Satellite
P_tG_t= Effective Isotropic Radiative Power (EIRP)
P_r= S=Receive signal Power at the receiving system
N=kTB Noise Power at the receiving system, T =N/kB
k= Boltzmann Constant, B=Bandwidth of Rx system

$$P_r = \frac{P_t G_t}{4\pi R^2} A_e,$$

$$G_r = \frac{4\pi A_e}{\lambda^2} \Rightarrow A_e = \frac{G_r \lambda^2}{4\pi}$$

$$P_r = \frac{P_t G_t}{4\pi R^2}\left(\frac{G_r \lambda^2}{4\pi}\right)$$

$$P_r = \frac{P_t G_t G_r}{}\left(\frac{\lambda}{4\pi R}\right)^2 \quad \Rightarrow \frac{P_r}{N} \Rightarrow \frac{S}{kTB} = \frac{P_t G_t G_r}{kTB}\left(\frac{\lambda}{4\pi R}\right)^2 \Rightarrow \frac{(P_t G_t)}{kB}\left(\frac{G_r}{T}\right)\left(\frac{\lambda}{4\pi R}\right)^2$$

Taking log on both sides,
S/N= EIRP+G/T-Path loss, where path loss= $20\log\left(\frac{4\pi R}{\lambda}\right)$

Channel capacity Theorem

$$\left(\frac{S}{N}\right) = EIRP + \frac{G}{T} - Pathloss$$

$$Channel \quad Capacity, C = B\log_2\left(1 + \frac{S}{N}\right)$$

$$\left(\frac{E_b}{kT}\right)\left(\frac{R}{B}\right) = EIRP + \frac{G}{T} - Pathloss$$

$$\left(\frac{E_b}{N_0}\right) = EIRP + \frac{G}{T} - pathloss - \frac{R}{B}$$

Modulation

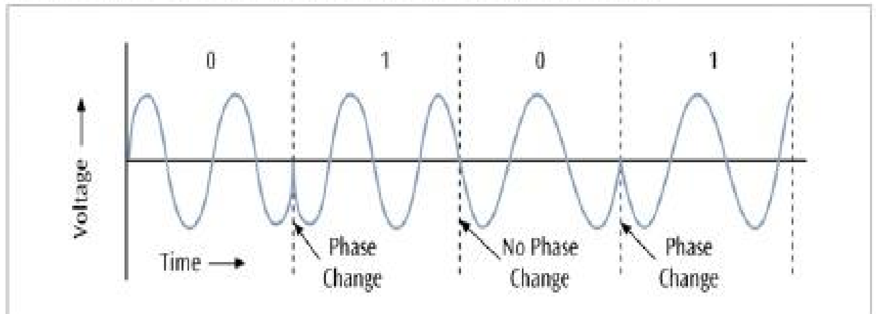
Modulation: In a Radio communication, the digital data is transmitted on a sinusoidal carrier by varying one or more parameters of the carrier signal such as, amplitude, frequency or phase,

$$v(t) = V_0 Sin\left(2\text{®}ft + \text{¤}\right)$$

amplitude frequency Phase

Phase Shift Keying

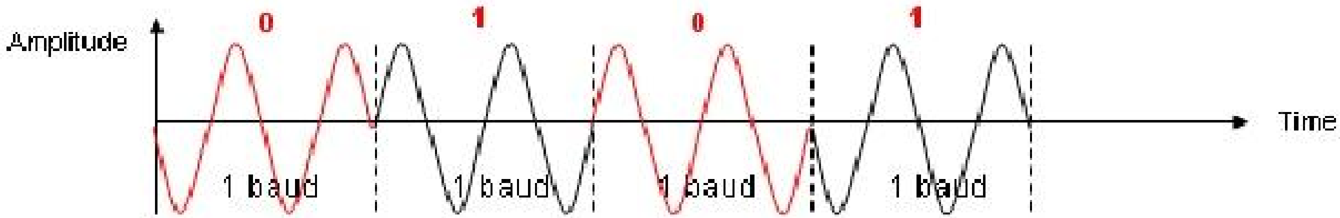
- One phase change encodes a 0 while another phase change encodes a 1 (a form of phase modulation)



$$s(t) = \begin{cases} A\cos(2\pi f_c t) & \text{binary } 1 \\ A\cos(2\pi f_c t + \pi) & \text{binary } 0 \end{cases}$$

DBPSK, QPSK

- Differential BPSK
  - 0 = same phase as last signal element
  - 1 = 180º shift from last signal element



- Four Level: QPSK

$$s(t) = \begin{cases} A\cos\left(2\pi f_c t + \frac{\pi}{4}\right) & 11 \\ A\cos\left(2\pi f_c t + \frac{3\pi}{4}\right) & 01 \\ A\cos\left(2\pi f_c t - \frac{3\pi}{4}\right) & 00 \\ A\cos\left(2\pi f_c t - \frac{\pi}{4}\right) & 10 \end{cases}$$

Metrics for Digital Modulation

- **Power Efficiency**
  - Ability of a modulation technique to preserve the fidelity of the digital message at low power levels
  - Designer can increase noise immunity by increasing signal power
  - Power efficiency is a measure of how much signal power should be increased to achieve a particular BER for a given modulation scheme
  - Signal energy per bit / noise power spectral density: E_b / N_0
- **Bandwidth Efficiency**
  - Ability to accomodate data within a limited bandwidth
  - Tradeoff between data rate and pulse width
  - Thruput data rate per hertz: R/B bps per Hz
- **Shannon Limit: Channel capacity / bandwidth**
  - $C/B = \log_2(1 + S/N)$

Channel Coding

Error control coding aims at developing methods for coding to check the correctness of the bit stream transmitted. The bit stream representation of a symbol is called the codeword of that symbol:

Linear Code

Convolution Code

Linear Block Code

K(Message bits)	n-k(Check bits)

Code Rate=k/n

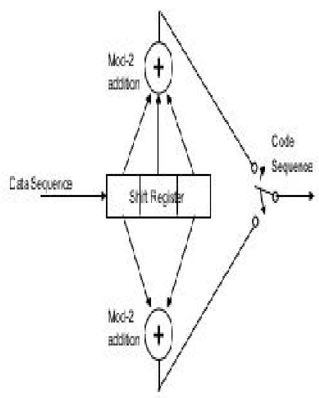
No of errors that could be corrected, $t \leq \frac{1}{2}(d_{min}-1)$

d_{min}= Hamming distance, Ex Hamming distance between the code word 101101, and 001100: is 2; No of positions the code word differ

Forward Error Correcting Code(FEC): Convolution Code

Convolutional Codes

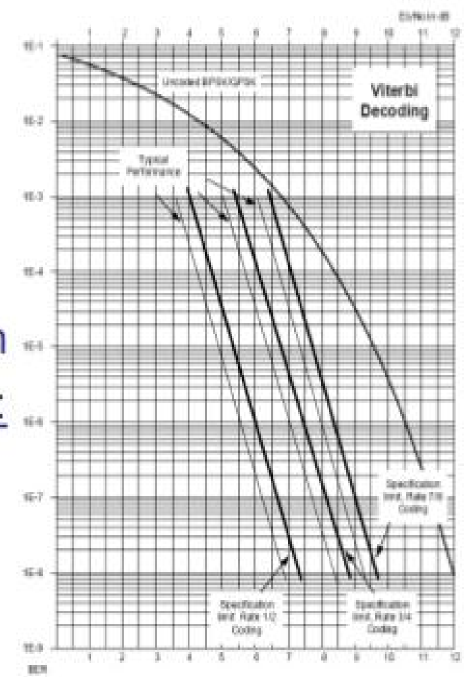
- Operates bit-by-bit on incoming data; similar to a stream cipher



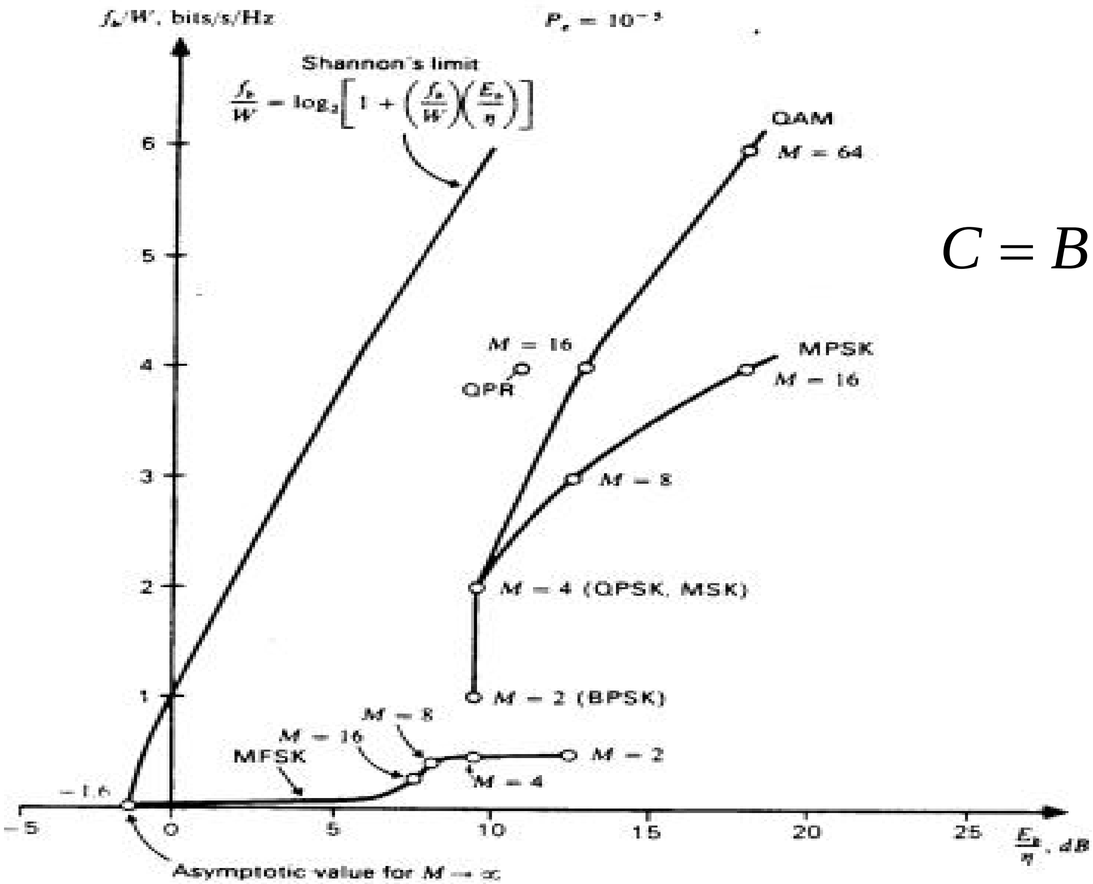
R=1/2 K=3 Convolutional Encoder

Convolutional encoding w/ Viterbi Decoding

Rate	Coding Gain @ 10^{-5} BER:
1/2	**4.8 dB**
3/4	**3.3 dB**
7/8	**2.3 dB**



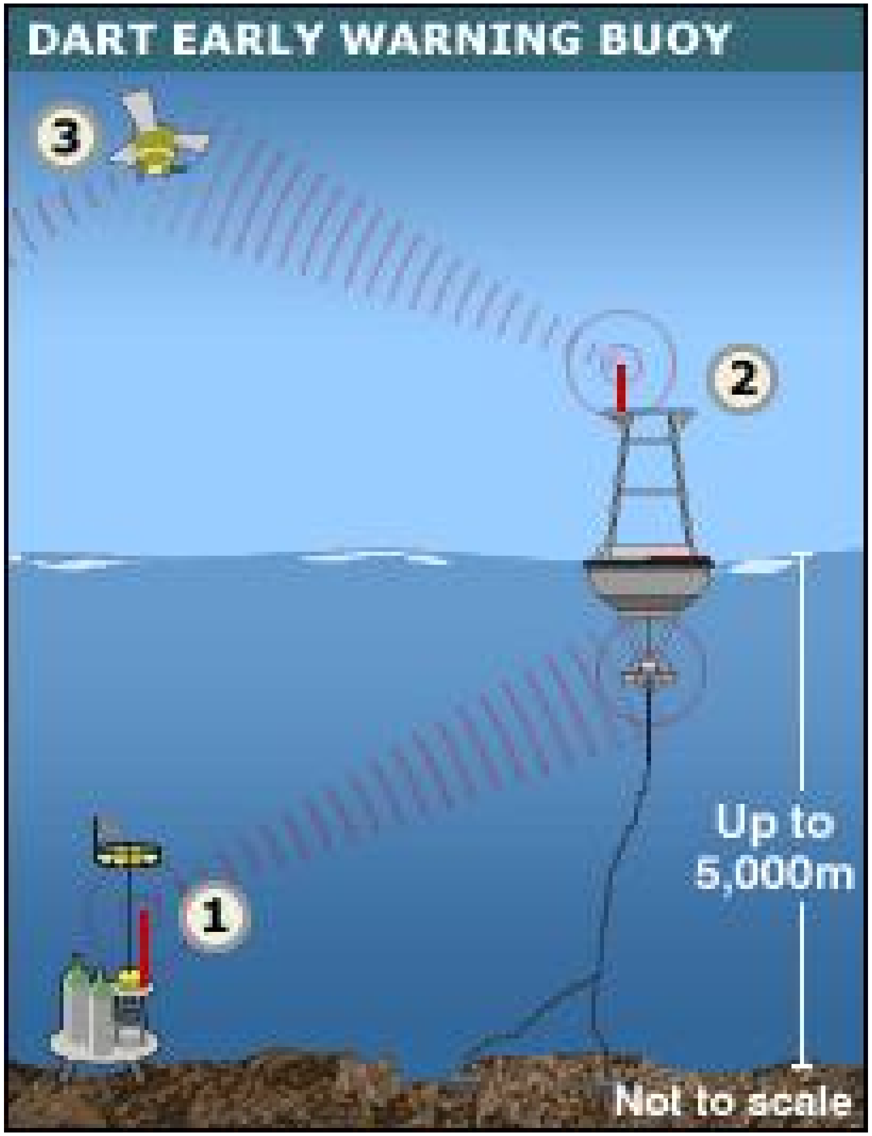
Comparison of Modulation Scheme



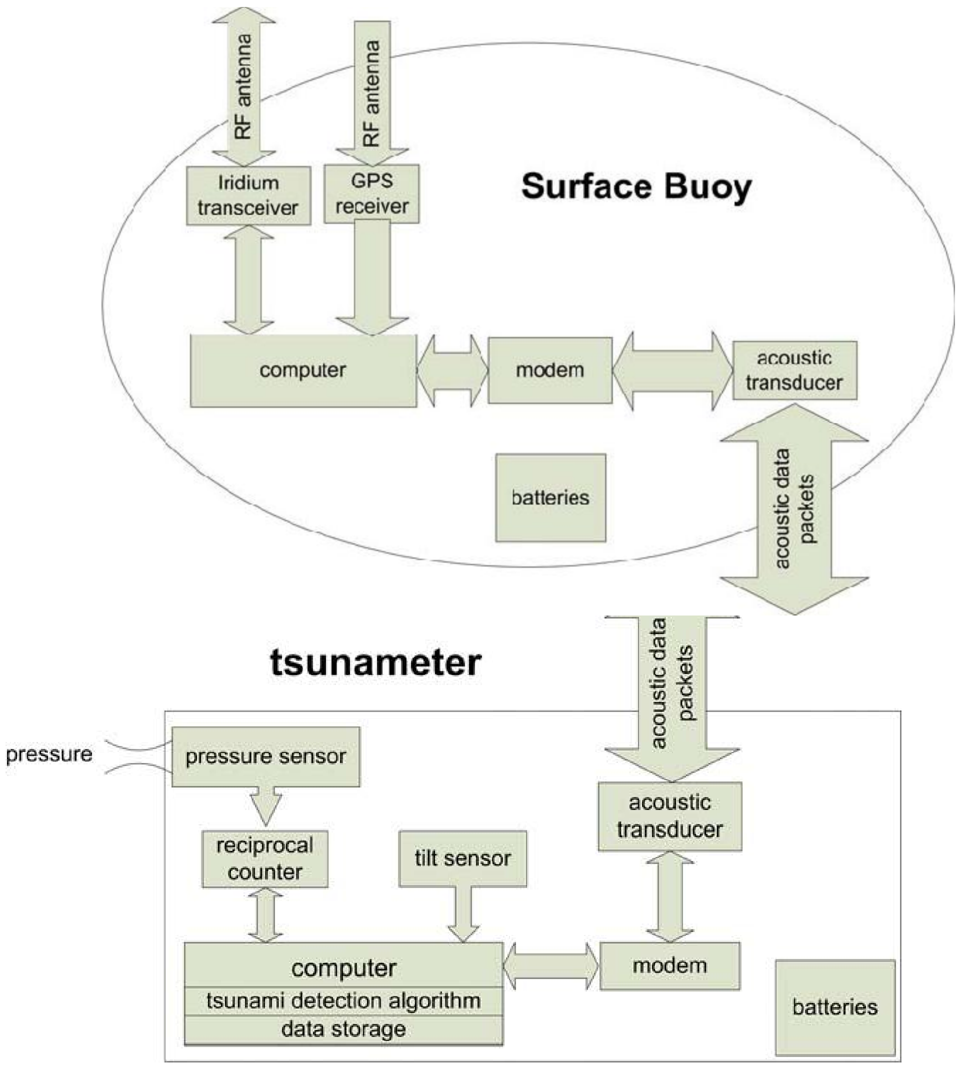
bits/s/Hz vs. E_b/η for Probability of Error = 10^{-5}

$$C = B\log_2\left(1+\frac{S}{N}\right)$$

Tsunami Detection System



Tsunami Detection System



- Bottom Pressure Recorder (BPR) measures small changes in pressure at the seafloor.
- Data sent acoustically to surface buoy, then via satellite to the Warning Centers.
- Normal transmissions: Hourly reporting of 15 minute data to confirm system readiness.
- Two Event Modes:
  - *Automatic*: Triggered by seismic or tsunami wave
  - *Request*: Warning Center triggers data stream

Acoustic Modem- Tsunami Buoy

- Acoustic Modem is relatively slow 1500m/s
- There are other conditions such as signal absorption(which increases with frequency)
  geometric spreading loss, shadow zone, multipath, ambient noise
- Most commonly MFSK is used, PSK also is used but prone to error
  Packetized, convolution coded and error check bit are introduced,
- Modem available in different ranges, Low frequency: 9-14, Mid frequency 16-21, and
  high frequency 25-30KHz. Half duplex, ARQ,
- Used for AUV,ROV, under water sensor network for sea floor observation

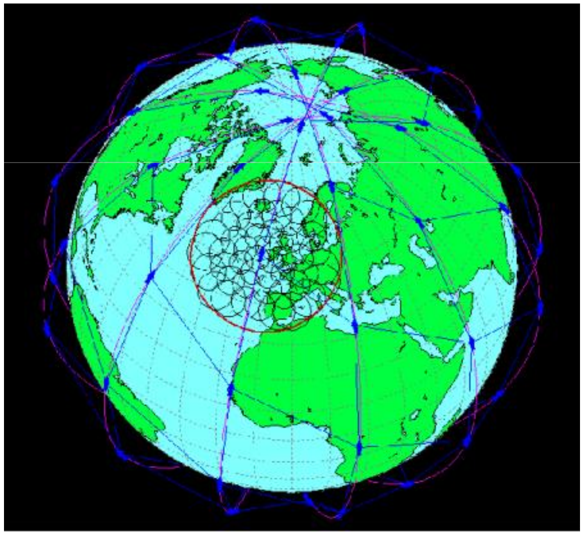
- Typical Specifications:: Tsunami
- Mid frequency: 16-21 KHz
- Modulation: MFSK
- Data Rate: Transmit mode Power: 15W
- Listen mode : 15-230mW
- Depth: 6000m
- Material : titanium

Tsunami Buoy Specifications

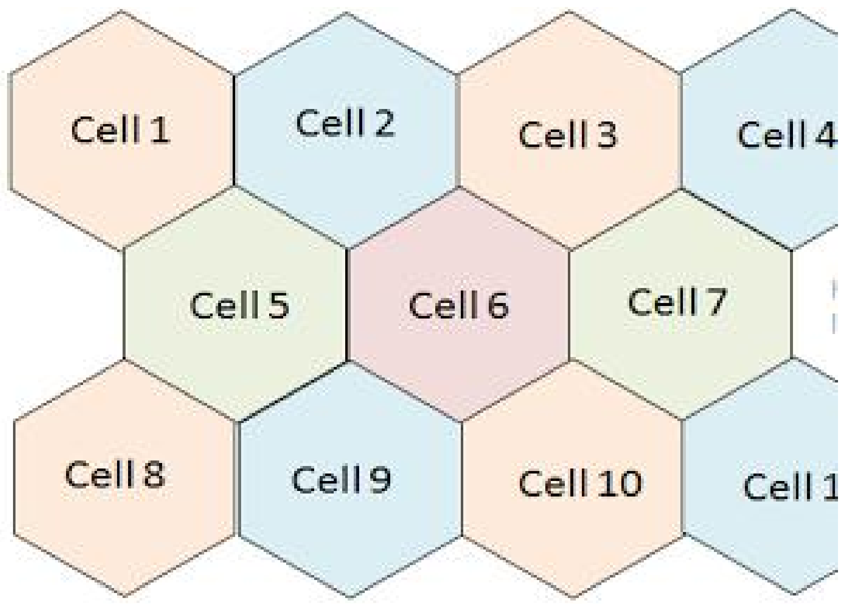
Mandatory Characteristic	Specification
Measurement sensitivity	Less than 1 millimeter in 6,000 meters
Sampling interval, internal record	15 seconds
Sampling interval, event reports	15 and 60 seconds
Sampling interval, tidal reports	15 minutes
Two-way end-to-end communications (two channels)	On demand, tsunami warning center trigger
Tsunami data report trigger	Automatically by tsunami detection algorithm
Data flow, BPR to TWC	Less than three minutes after triggered event
Desired Characteristic	**Specification**
Reliability and data return ratio	Greater than 80 percent (STB 98 percent)
Maximum/minimum deployment depth	6,000 meters/1,500 meters
Maximum deployment conditions	Sea State 4
Theoretical battery life, buoy	Greater than two years
Theoretical battery life, tsunameter	Greater than four years
Maximum status report interval	Less than 6 hours

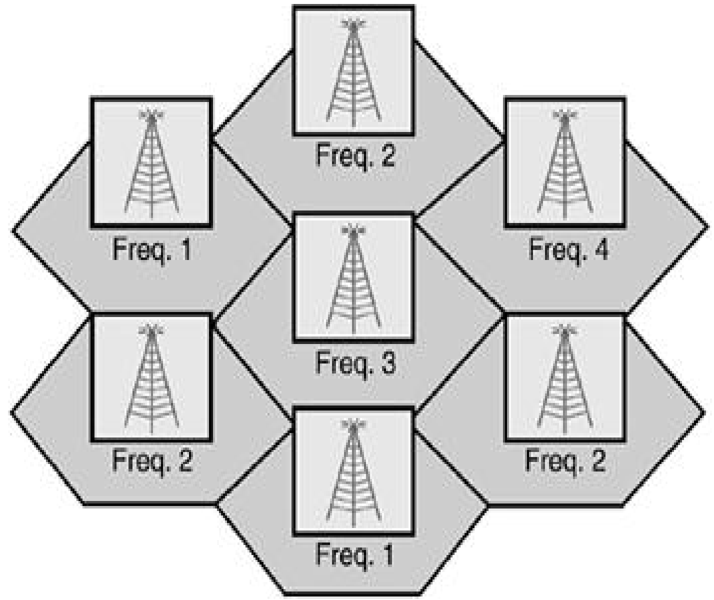
Iridium

- Constellation of 66 satellites in a Near Polar Low Earth (780 km) Orbit (LEO), in 11 satellite in 6 orbital plane
- Each satellite has 48 spot beams – Beam overlap,
- Each foot print approximately 4800Kmin diameter.
- On-orbit spares.
- Requires only one gateway.
- Use L band for Tx/Rx for the subscriber unit, K band for inter satellite link and gate way
- Satellite Access Scheme FDMA/TDMA
- Voice at 4.8Kbps and data at 2400kbps , duplex
- Minimal set-up time, low latency, no echo



GSM Cell

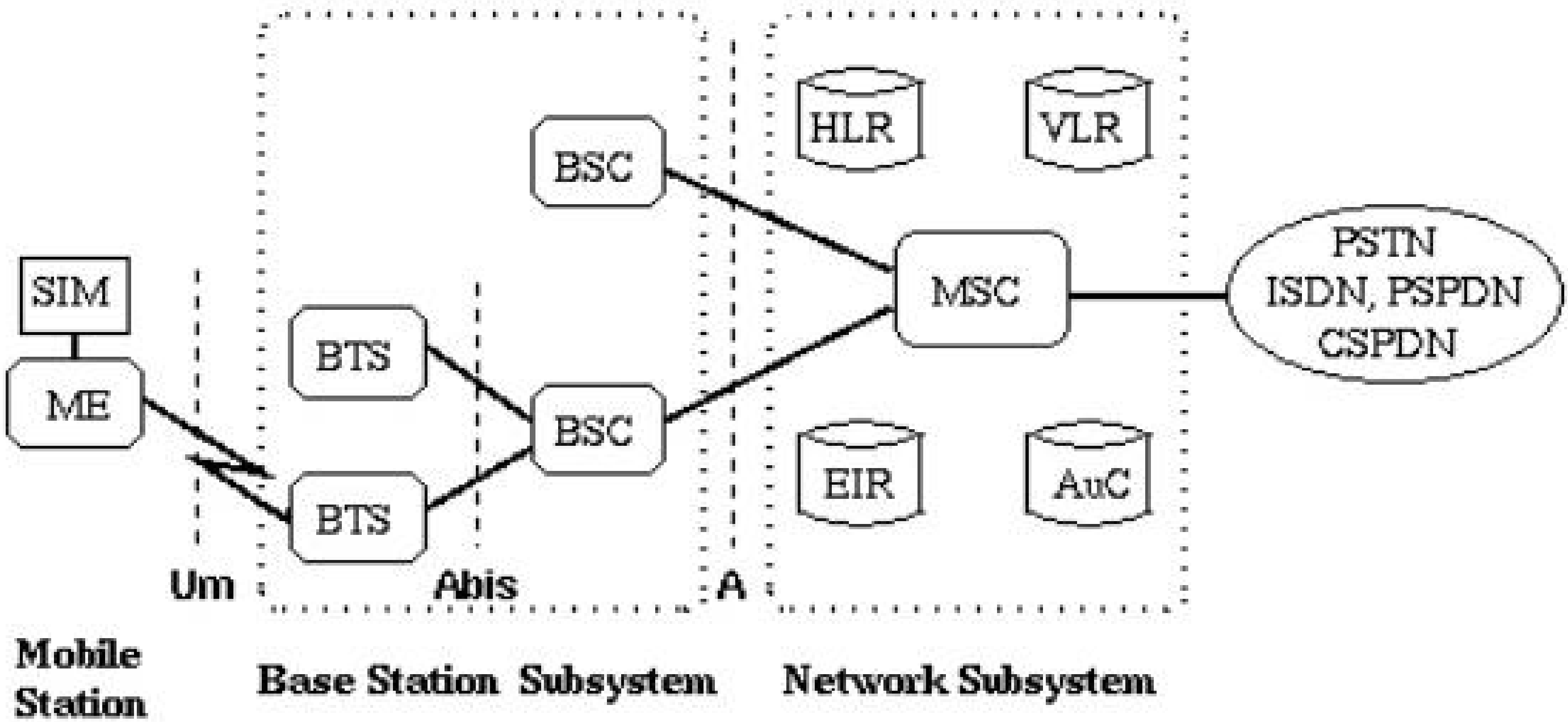




The area which a base station covers is called a cell and the place where the base station and antennas are located is called a cell site.

A cell is an area which is covered by each base station. This area is divided into regular shaped cells, which can be hexagonal, square, circular or some other regular shapes. Though the most commonly used are the hexagonal cells. It looks like a cell in a honeycomb as shown in the diagram below. Cell sizes can range from 1Km to 50 km in radius.

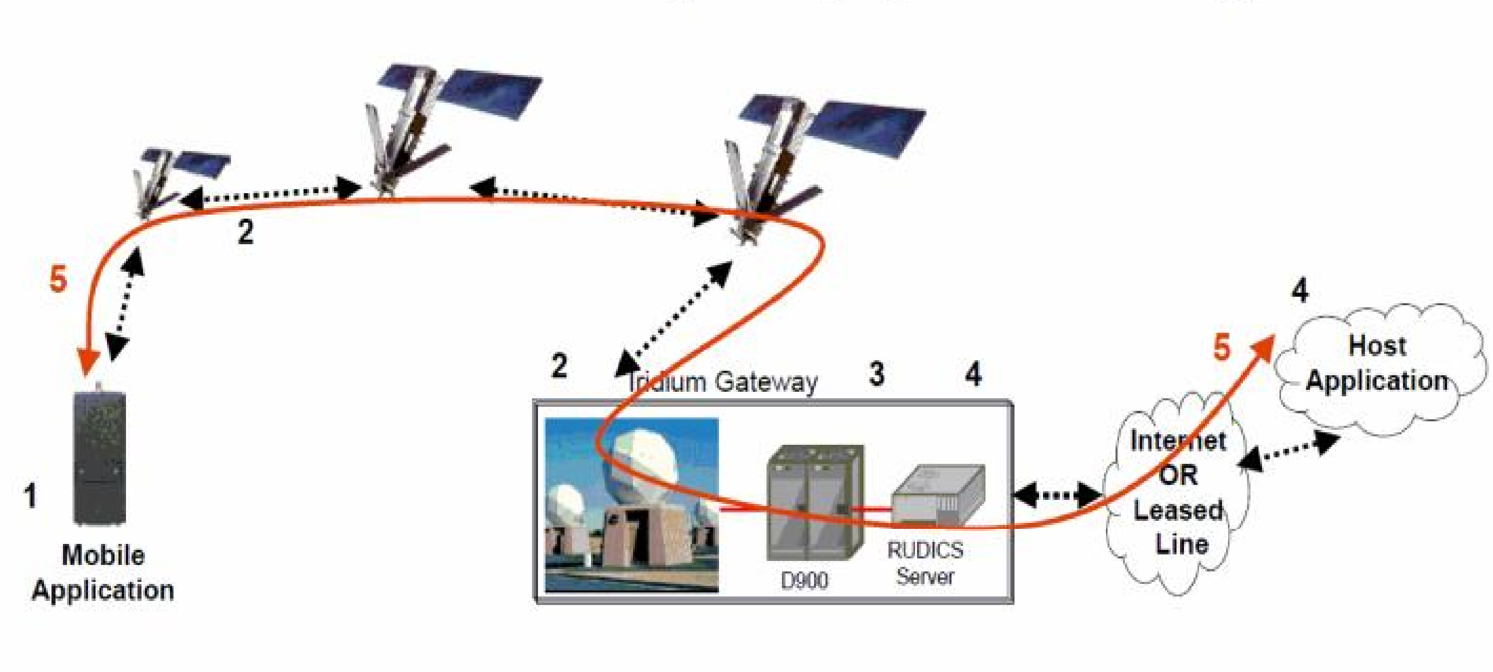
GSM System Architecture



SIM Subscriber Identity Module
ME Mobile Equipment
BTS Base Transceiver Station
BSC Base Station Controller
HLR Home Location Register
VLR Visitor Location Register
MSC Mobile services Switching Center
EIR Equipment Identity Register
AuC Authentication Center

Iridium

A RUDICS Data Call from a remote application (ISU) to the central Host Application



Sequence of Events:

1. Mobile application places call to a custom RUDICS Server Number
2. Call request is routed over the constellation for user authentication and call set-up.
3. Switch connects to RUDICS Server, secondary authentication conducted
4. RUDICS Server terminates call to pre-configured IP Address
5. End-to-End IP connection established, over the constellation, between the Host Application and Mobile Application

Router-based unrestricted digital internetworking connectivity solution (RUDICS) is an enhanced gateway termination and origination capability for circuit switched data calls across the Iridium satellite network

INMARSAT-Tsunami Buoy

- INMARSAT terminal operates at a low data rate of 600 bps with high power consumption of 2W in standby mode and 23W in transmit mode. Due to the inherent disadvantages of high power consumption (i) the battery on the buoys need frequent replacements (ii) high data latency and data gaps while operating in tsunami event mode.(iii) low data rate

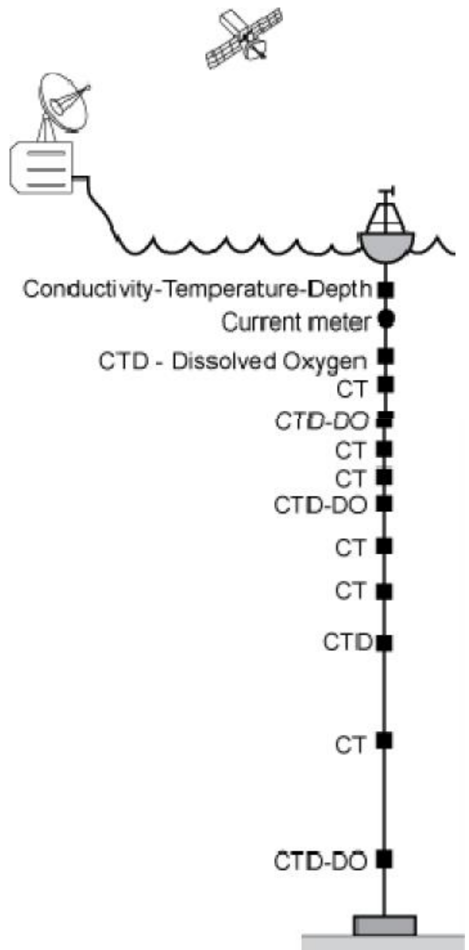
- INMARSAT communication is approved by Indian Government. Important factors that decide the most appropriate satellite communication link to be used for buoy systems are: (a) power consumption of the transceiver electronics, (b) high data rate and (c) low latency.

- IRIDIUM communication is used in more than 90 % of the tsunami buoys operating globally. IRIDIUM satellite terminal supports 2400bps with very low power consumption of 250mW in standby mode and around 2.5W in transmit mode.

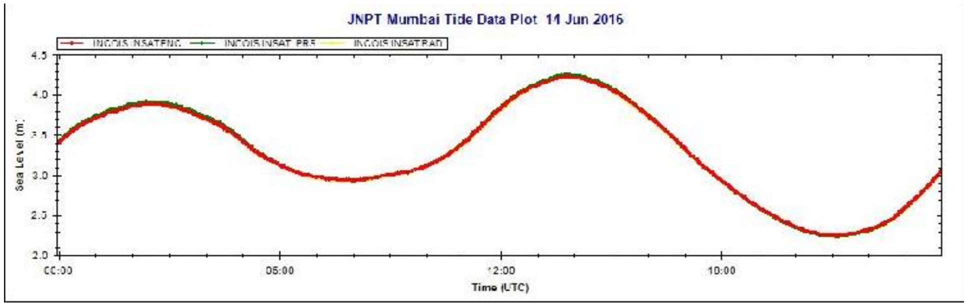
Moored Buoy

- Moored buoys gather weather and ocean data from sensors mounted on the buoy and attached to its mooring system. he observations from buoys transmitted through satellite to the user through INMARSAT/INSAT Geo system or similar system

Inductive mooring



Tide Gauge

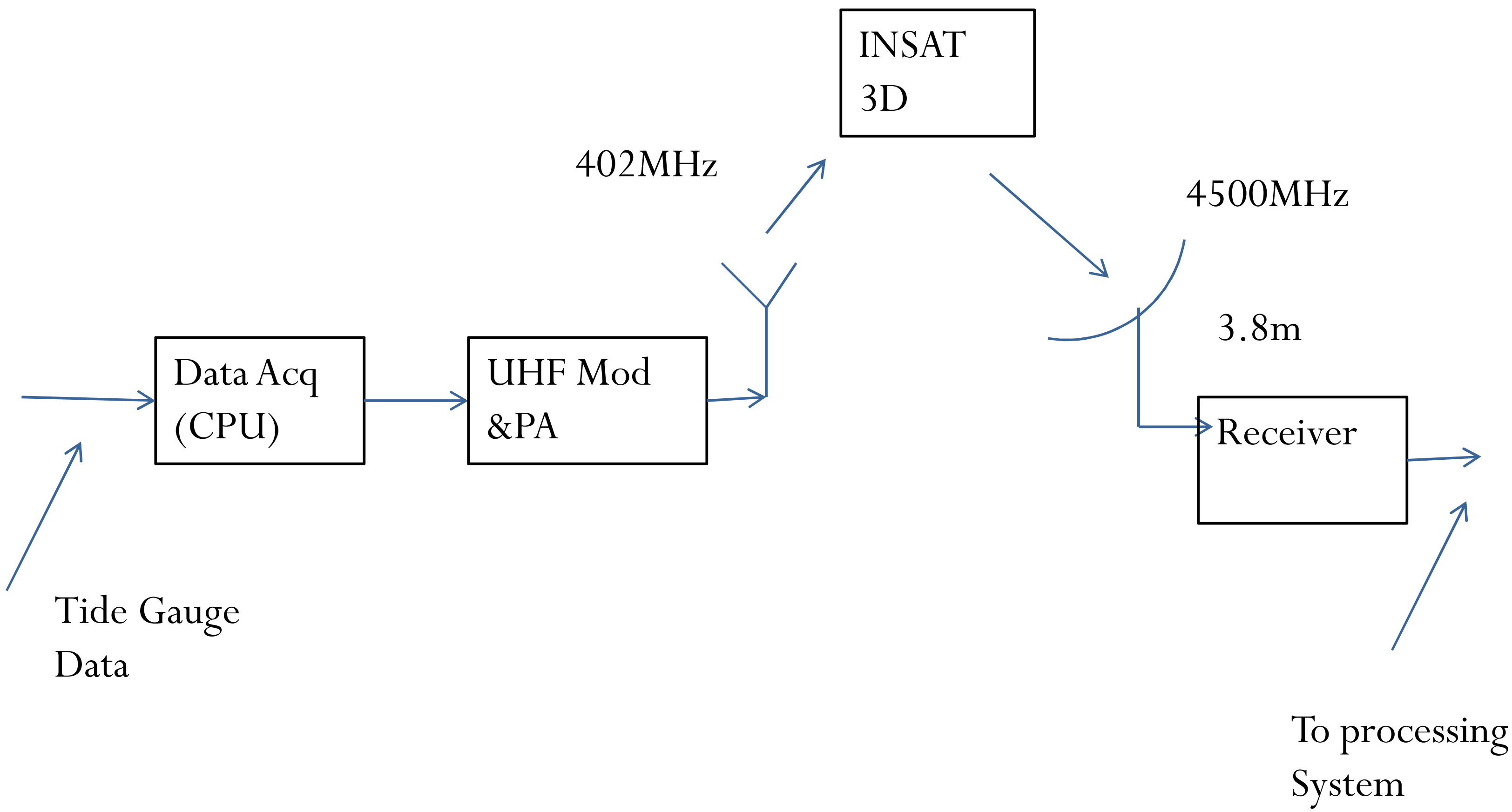

JNPT Mumbai Tide Data Plot 14 Jun 2016
Sea Level (m)
4.5
4.0
3.0
2.0
00:00
05:00
12:00
10:00
Time (UTC)

INSAT System for data collection

- Data Collection Through INSAT
- INSAT 3D: DRT transponder of INSAT 3D
- Transponder: Receive: 402.75+/-100KHz
- EIRP: 18dBW

- MSS Transponder of INSAT 3C: Supports one way & Two Way
- Receive: 2670-2690MHz
- Transmit: 2500-2520MHz
- EIRP: 37dBW

Tide gauge data collection through DRT transponder



Tide Gauge Transmission Through INSAT

INSAT Transmitter

Transmit Power : 10W

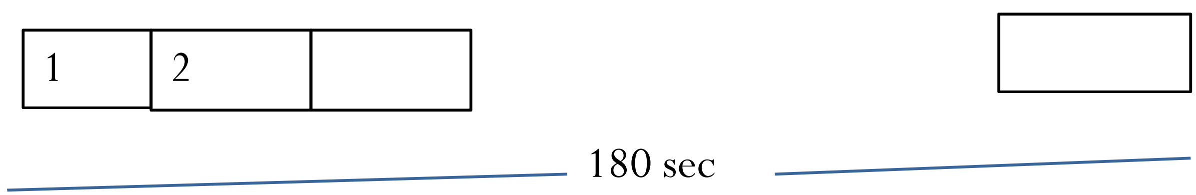
Antenna: single Patch antenna

Transmission Scheme : TDMA

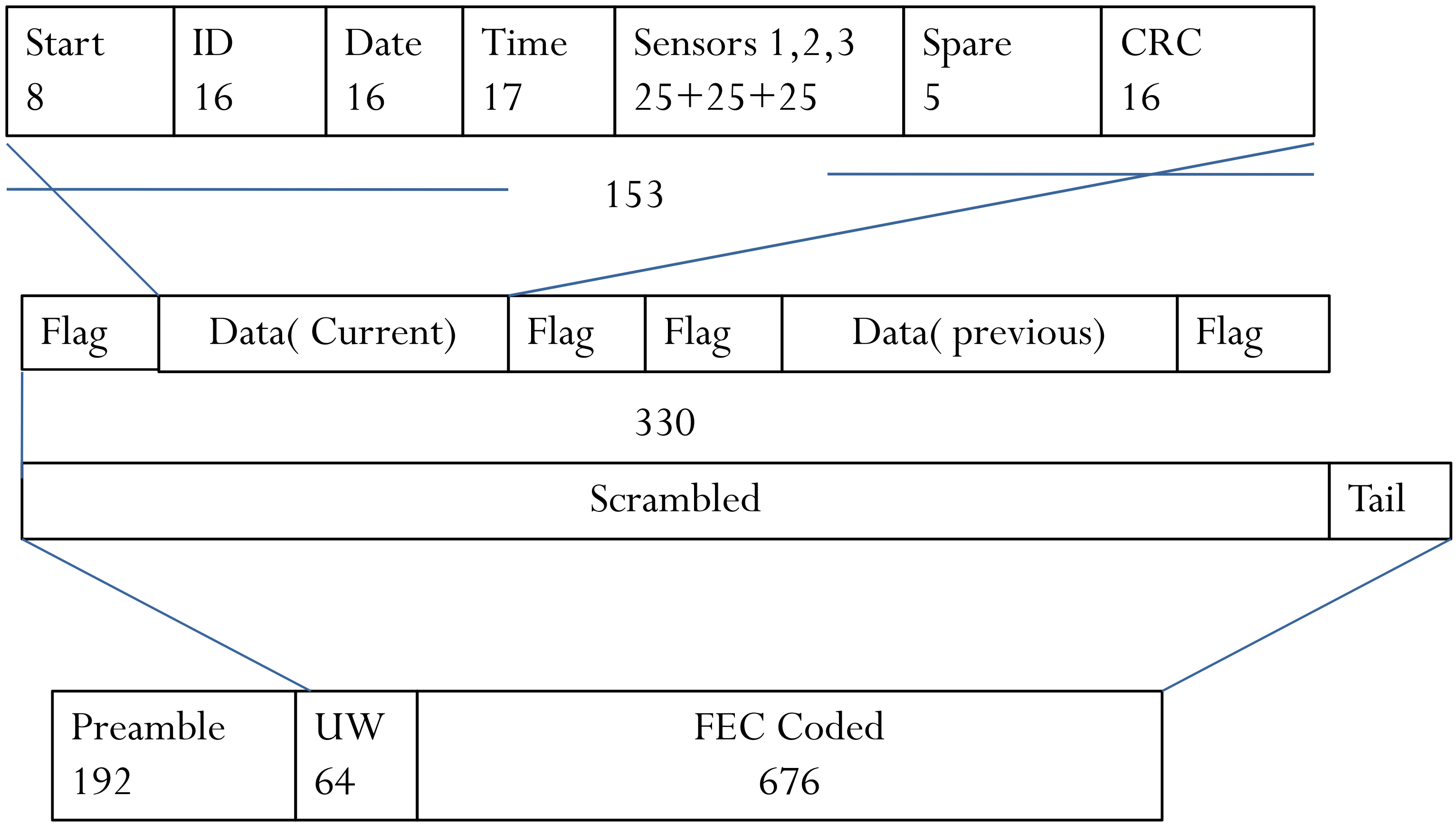
Timing : Derived Through GPS

Frame : 3 Minutes

Slot size: 1.5 second



Tide Gauge Data transmission through INSAT



932 bits (1.55sec)

Message Bytes: 53,
compressed to 13 Bytes
Ex; Date: 4 bits

Communication through INSAT DRT Transponder

Parameter	Uplink
Up link frequency	402.75 Mhz
Max. Slant range	41130 K
Uplink path loss	177 dB
Tx Power (5W)	10 DBw
Net antenna gain (including cable loss)	-3 dBi
Tx EIR	7 dBw
Satellite G/T	-19.0 dB/K
Uplink C/No.	36.6dBHz

Parameter	**Downlink**
Down link freq	4505 Mhz
Down link path loss	197.0 db
Satellite EIRP	-1 DBW
Link Margin	2.5 dB
G/T of earth station (3m)	17 dB/K
Down link C/No	47.6 dBHz
Total C / No	39.5 dBHz
Required C/No	33dBHz

Suomi NPP Down link

Transmit EIRP	12.79dBW
Frequency	7812MHz
Information Rate	15.0Mbps
Modulation	QPSK
Channel Coding	Convolution Coding, K=7,1/2 rate
Down link Path loss	179.5dB
G/T	22.2dB/K
Downlink C/No	83.9
C/N	12.14dB
C/N required Clear Sky	6.90dB
Margin	5.2dB

Thank You