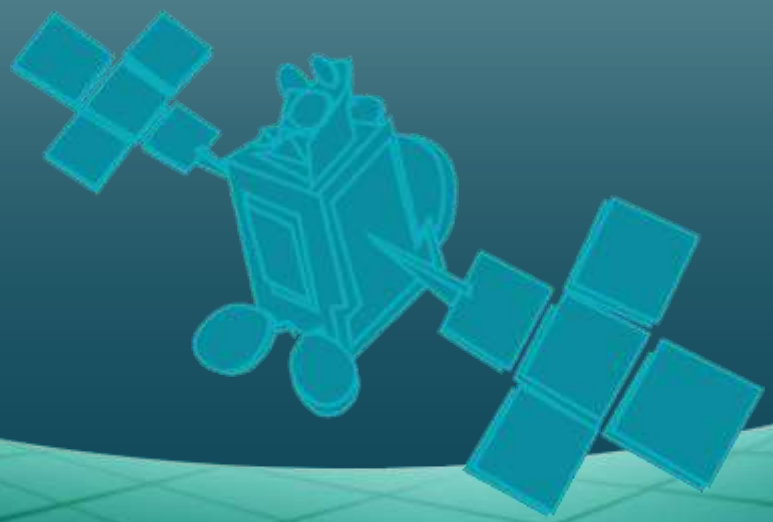
Satellite Communication

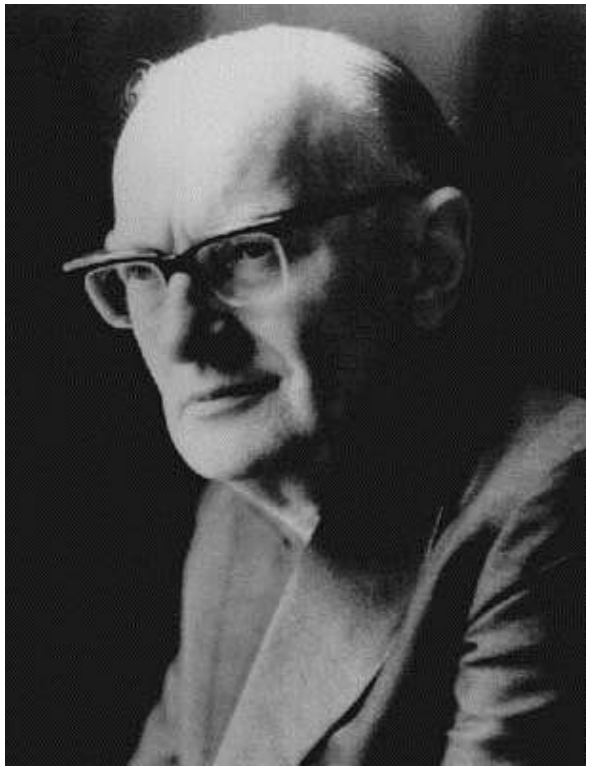
Satcom ABC series (1)



WU Boyang
APMT

Godfather of Satcom

- A landmark scientific paper
  - Extra-terrestrial Relays
    -- Can Rocket Stations Give Worldwide Radio Coverage?
    ⇨ by Arthur C. Clarke
    ⇨ published at Wireless World, 1945
    ⇨ http://lakdiva.org/clarke/1945ww/1945ww_oct_305-308.html
  - the concept about intercontinental radio relay communication by GEO satellites
- The Clarke Orbit
  - GSO (geosynchronous orbit)
  - GEO (geostationary earth orbit)
- Satellite communication
  - successfully demonstrated in the 1960's
  - more applications in the late 70's and early 80's



Godfather of Satcom (cont.)

- Sir Arthur C. Clarke
  - Dec. 1917 (England) - March 2008 (Sri Lanka)
  - As a radar specialist in RAF of UK during World War II
  - As a scientist
    - ⇨ the Assistant Editor for Science Abstracts, UK
    - ⇨ the Professorship of the Physical Research Laboratory, India,
    - ⇨ the Fellowship of King's College, London,
    - ⇨ the Chancellor of the University of Moratuwa, Sri Lanka
  - As a science fiction writer
    - ⇨ dozens of published Essays, short stories and novels (1937 to 2006)
    - ⇨ an Oscar nomination in 1969 for his screenplay of 2001: A Space Odyssey
    - ⇨ http://www.arthurcclarke.net/?scifi=1&type=0
    - ⇨ Knight of the British Empire
    - ⇨ an asteroid was named in Clarke's honour, (4923 Clarke)
  - Epitaph: He never grew up, but he never stopped growing
  - Homepage: http://www.arthurcclarke.net

Introduction

- Decibel
- History of Satellites
- GEO Satellite Communication

Antenna

Space Segment

- Communication Satellite
- Frequency and Polarization Plan
- Transponder and Transmission Loss

Earth Segment

- Carrier and Network
- Earth Station and VSAT Terminal

Decibel

CHINA APMT

- Notation
  - Normalized notation
    - absolute value: 300000000, 0.00000003
  - Exponential notation or scientific notation
    - Index number: 3×10^{8}, 3×10^{-8}
  - Logarithmic notation
    - logarithm, decibel: 84.8dB, -75.2dB
- Decibel
  - dB
    - a logarithmic unit of measurement
    - 10 times the common logarithm (to base 10)
  - To represent a very large range (ratio or exact value) as a convenient number
  - To simplify addition and subtraction operation to multiplication and division

Decibel (cont.)

CHINA APMT

❖ Frequently-used data

absolute value	logarithm		logarithm	absolute value
2	3dB		2dB	1.6
3	4.8dB		1dB	1.3
5	7dB		0.5dB	1.1
7	8.5dB		0.2dB	1.05
20	13dB		-0.2dB	0.95
300	24.8dB		-0.5dB	0.9
5000	37dB		-1dB	0.8
70000	48.5dB		-2dB	0.6

Decibel (cont.)

CHINA APMT

- Simplified operation
  - Example

    300000000 / 0.00000003 = 1000000000000000 = 1 x 10^{16}

    84.8dB - -75.2dB = 160dB => 1 x 10^{16} = 1000000000000000

    0.00000003 / 300000000 = 0.000000000000001 = 1 x 10^{-16}

    -75.2dB - 84.8dB = -160dB => 1 x 10^{-16} = 0.000000000000001
  - Cascaded gain

    $G_{Total} = G_1 * G_2 * G_3 = G_{dB1} + G_{dB2} + G_{dB3}$
  - Power density

    $P_0 = P / BW$ (W/Hz) = $P_{dBW} – BW_{dBHz}$ (dBW/Hz)
  - Count by Frequently-used data

    36MHz = 2x2x3x3x1000000 (Hz) = 3+3+5+5+60 (dBHz)

Decibel (cont.)

CHINA APMT

- dB in satellite communication
  - Unit for gain or loss: $G = P_2 / P_1$, $G_{dB} = 10 \log_{10} (P_2 / P_1)$
  - Unit for power
    - dBW: power relative to 1 watt, 1W = 0dBW
    - dBm: power relative to 1 milliwatt, 1mW = 0dBm, 0dBW = 30dBm
  - Unit for bandwidth: 10Hz = 10dBHz, 1MHz = 60dBHz
  - Unit for temperature: 50 Kelvin = 17dBk, 300 Kelvin = 24.8dBk
  - Unit for antenna gain
    - dBi: the forward gain of an antenna compared with the hypothetical isotropic antenna, which uniformly distributes energy in all directions
  - Unit for density: 50Watt /10MHz = 17dBW - 70dBHz = -53dBW/Hz
  - Unit for reference value
    - dBc: decibels relative to carrier, the power ratio of a carrier to another, or the desired signal to unwanted spurious outputs

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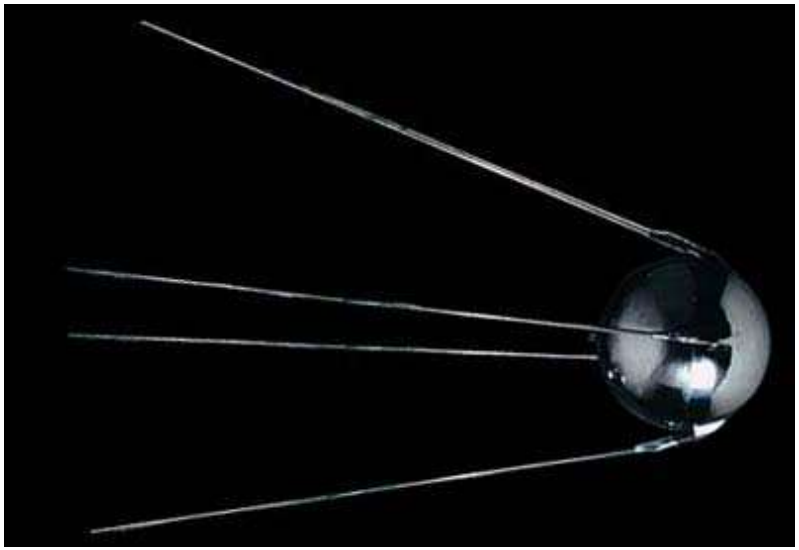
Artificial Satellites

- The first artificial satellite
  - Sputnik 01 (also called PS1)
    - The Soviet Union
    - Launch date: 4 Oct 1957
    - Mission duration: 21 days
  - Orbital parameters
    - Perigee/Apogee: 227/945 km
    - Inclination: 65 deg
    - Period: 96.1 min
  - Specifications
    - Dimension: 58 cm (diameter)
    - Mass at launch: 83.6 kg
    - Frequencies: 20.005 & 40.002 MHz



Artificial Satellites (cont.)

CHINA APMT

- The first artificial satellite of USA
  - Explorer-I (also called Satellite 1958 Alpha)
    - Launch date: 31 Jan 1958
    - Mission duration: 111 days
  - Orbital parameters
    - Perigee/Apogee: 360/2535 km
    - Inclination: 33 deg
    - Period: 114.9 min
  - Specifications
    - Mass at launch: 13.9 kg
    - Frequency: 108 MHz
    - Transmitter power: 60mW（30 days）& 10mW（105 days）
  - Onboard instruments: cosmic ray detector, temperature sensors, etc.
  - Discovery: Van Allen radiation belt (the belts consists of energetic charged particles around the Earth)

The History of Comsat

CHINA APMT

- The first satellite communication test
  - SCORE, USA
    - Launch date: 18 Dec 1958
    - Mission duration: 34 days (the batteries lasted 12 days)
  - Orbital parameters
    - Perigee/Apogee: 183/1481 km
    - Inclination: 32 deg
    - Period: 110.5 min
  - Specifications
    - Mass of payload: 68 kg (at the top of the Atlas missile)
    - Frequency: 108 MHz
    - Transmitter power: 60mW（30 days）& 10mW（105 days）
  - Real-time and store-and-forward (by 2 tape recorders) repeater for orbiting relay communications

The History of Comsat (cont.)

- Passive balloon satellite
  - Echo 1, USA
    - Launch date: 12 Aug 1960
  - Orbital parameters
    - Perigee/Apogee: 1524/1864 km
    - Inclination: 47.2 deg
    - Period: 118.3 min
  - Specifications
    - Diameter: 30.5 m
    - Mass: 180 kg
    - Beacon frequency: 107.9 MHz
  - Aluminum surface acting as a passive reflector, to bounce off the microwave signals (telephone, radio and TV signals modulated at 960 and 2390 MHz)

The History of Comsat (cont.)

- The first active microwave communication satellite
  - Telstar 1, NASA, USA
    - Launch date: 10 July 1962
  - Orbital parameters
    - Perigee/Apogee: 952/5933 km
    - Inclination: 44.8 deg
    - Period: 157.8 min
  - Specifications
    - Diameter: 0.88 m
    - Mass: 77 kg
    - Up- and down-link frequency: 6 and 4 GHz
    - Antenna: Omni
    - One television channel or multi-telephone circuits
  - Moving across the sky at up to 1.5 deg/sec, and the communication period is about 20 minutes in each 2.5 hour

The History of Comsat (cont.)

- The first GSO communication satellite
  - Syncom 2, NASA, USA
    - Launch date: 26 July 1963
  - Orbit slot: 55W/26W/28.5E
  - Bus
    - Spin stabilized
    - Dimension: 0.71m (diameter), 0.39m (height)
    - Mass: 68 kg
    - DC power: 29 W
  - Two transponders
    - Up- and down-link frequency: 7360 and 1815 MHz
    - BW: 13MHz (low quality TV) and 5MHz (110ch telephone/fax)
    - TWTA: 2 W
    - Slotted dipole antenna: 2dBi (gain), 25deg (beam width)
  - 32.7deg inclined rather than geostationary, the sub-satellite track looks like “8”, and tracking antenna is needed in ES

The History of Comsat (cont.)

- The first GEO communication satellite
  - Syncom 3, NASA, USA
    - ⇨ Launch date: 19 Aug 1964
  - Orbit slot: 64W/180E/25W/165E/6W
  - Bus and Payload: same as Syncom 2
  - TV transmission for Tokyo Olympic Games

The History of Comsat (cont.)

- the first commercial communications satellite
  - Intelsat 1 (nicknamed Early Bird)
    - Launch date: 6 March 1965
    - Mission duration: 3.5 Years
  - Orbit slot: 28W/38W
  - Bus
    - HS 301, Spin stabilized
    - Dimension: 0.76m (diameter), 0.59m (height)
    - Mass: 149 kg
    - DC power: 40 W
  - Two transponders
    - BW: 50MHz
    - TWTA: 6 W
    - 240 voice circuits or one TV channel, the capacity of cross-Atlantic communication was increased for about 50%
  - The first transoceanic live TV broadcast

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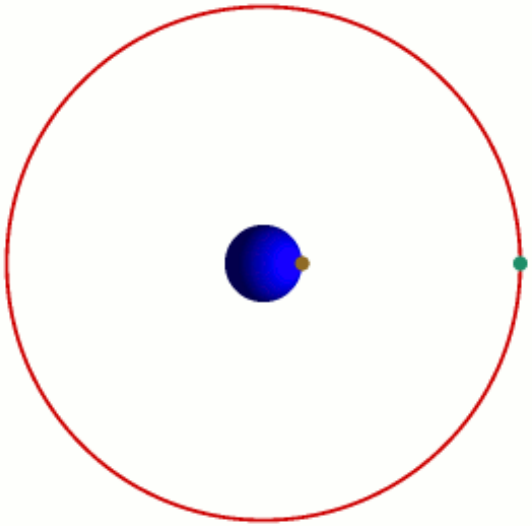
Geostationary Earth Orbit

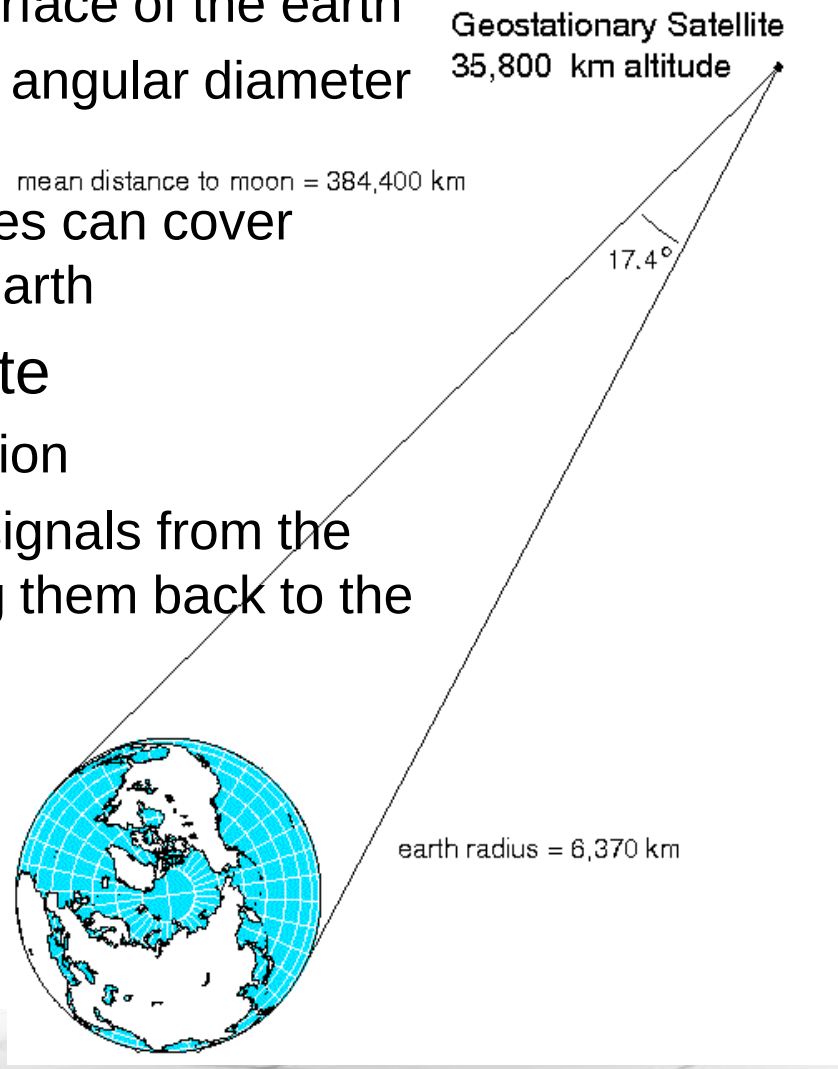
- Geosynchronous orbit
  - GSO
  - Orbital period: one sidereal day, matching the earth's rotation period
- Geostationary earth orbit
  - GEO
  - A circular geosynchronous orbit at zero inclination
- Orbital velocity and attitude
  - Balance: between centripetal force and centrifugal force
  - Mean earth radius: 6378km
  - Velocity: 11040km/h or 3.07km/s
  - Attitude of GEO orbit: 35786km



GEO Satellite

CHINA APMT

- GEO satellite
  - Appearing fixed above the surface of the earth
  - Seeing the earth at GEO, the angular diameter is about 17.4 degrees
  - Proper orbited 3 GEO satellites can cover almost whole surface of the earth
- GEO communication satellite
  - Microwave relay communication
  - As a repeater: receiving the signals from the earth, and then retransmitting them back to the earth



Coverage

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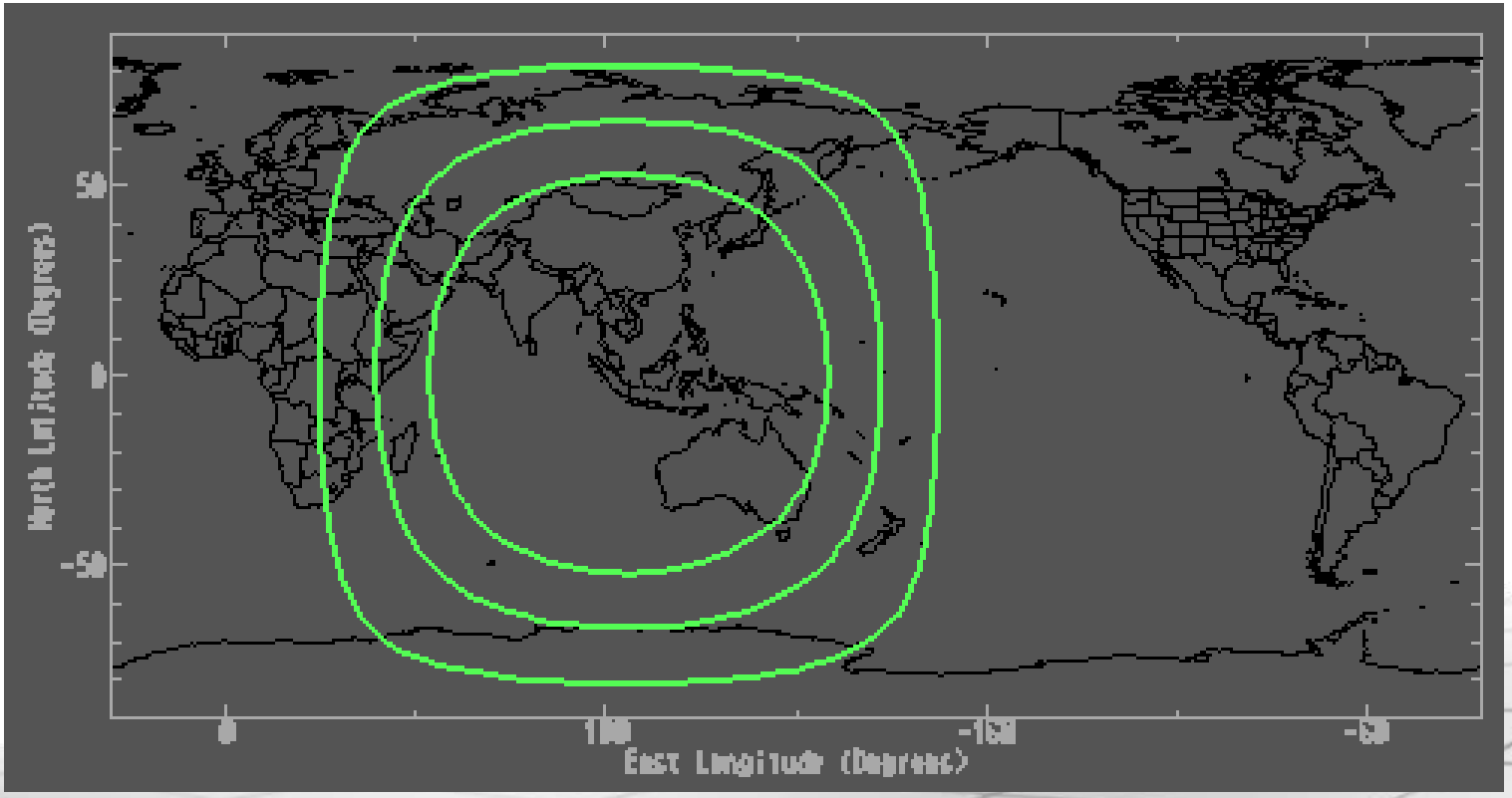
- The service area of the GEO satellite at 105.5E
  - Green lines are relative to the coverage with 0, 15 and 30 degrees elevation
  - 0 elevation coverage is up to 80 degrees latitude
  - Projection method of the figure is EquiRectangular



GEO Satellite Communication

CHINA APMT

- Wide coverage
  - Suitable for broadcasting
  - Same cost for long or short communication distance
  - Easy for network expansion and emergency terminal setting
  - Difficult to find interference resource
- Long distance
  - One-way transmitting (up- or down-link)
    - about 37000 to 41000 km
  - Long time-delay
    - one-hoop needs about 1/4 sec
  - Huge transmission loss
    - 200/196 dB loss for C-band up/down-link
    - 207/206 dB loss for Ku-band up/down-link

GEO Satellite Communication (cont.)

- High frequency
  - Wider frequency band and more capacity
  - Rain attenuation existed in Ku- and Ka-band
- High costs in configuration and operation
  - Transponder (bandwidth resource and power resource)
  - Antennas and earth station equipments
  - (Network management system)
  - Installation costs for the network and earth stations

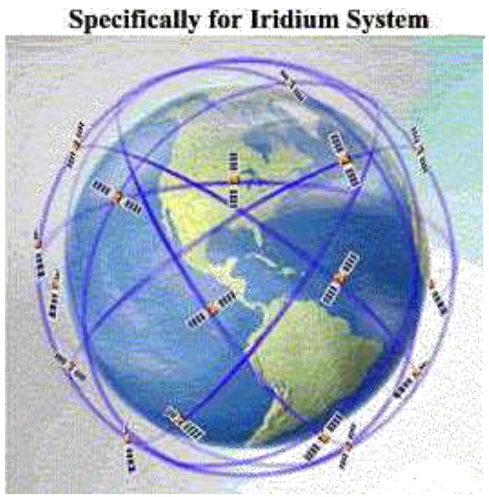
Classifications

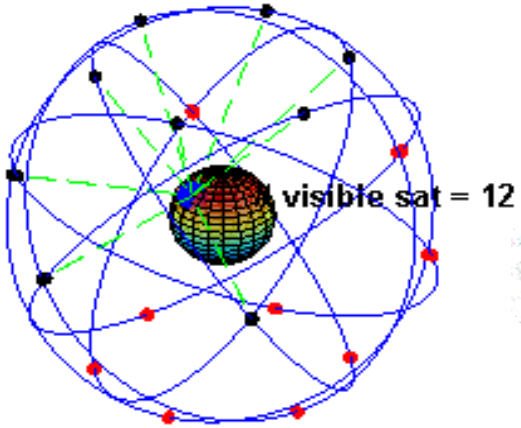
- By service
  - FSS, Fixed Satellite Service
  - BSS, Broadcasting Satellite Service
  - MSS, Mobile Satellite Service
- By frequency band
  - L-band, 1-2 (or 0.39-1.55) GHz, mobile communication and radio broadcast
  - S-band, 2-3 (or 1.55-5.2) GHz, mobile communication and TV broadcast
  - C-band, 4-6 (or 3.7-6.2) GHz, fixed communication and radio broadcast
  - X-band, 7-8 (or 5.2-10.9) GHz, fixed communication
  - Ku-band, 10-14 (or 10.7-18) GHz, fixed communication and direct-to-home TV broadcast
  - Ka-band, 17-31 (or 18-40) GHz , fixed and mobile communication

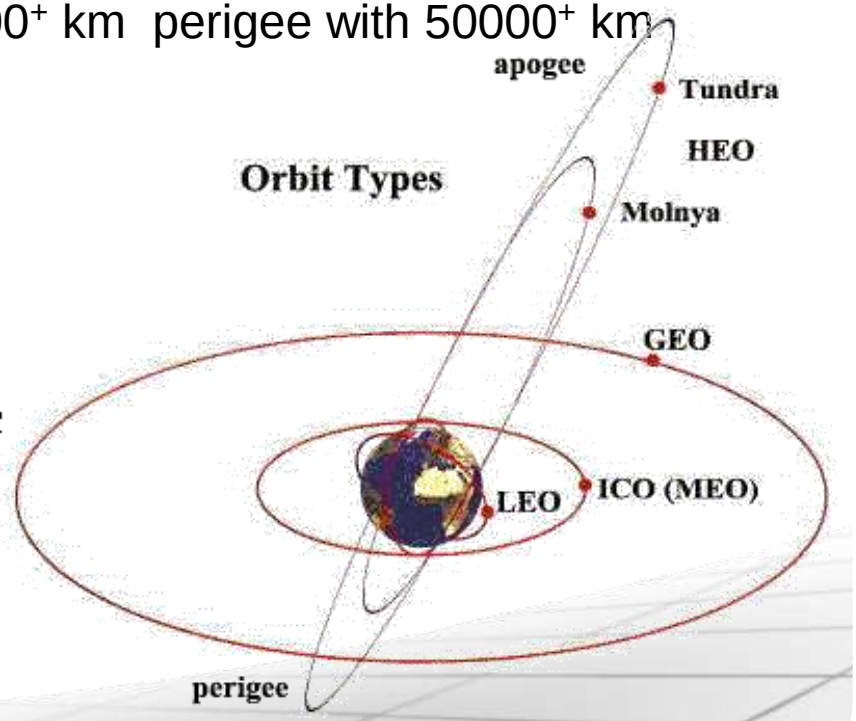
Classifications (cont.)

CHINA APMT

- By orbit
  - Height
    - ⇨ LEO, low earth orbit, 700 to 1400 km attitude, 40+ satellites for global coverage
    - ⇨ MEO, medium earth orbit, 10000 to 15000 km, 10 to 15 satellites for global coverage
    - ⇨ HEO, highly elliptical orbit, 500+ km perigee with 50000+ km apogee



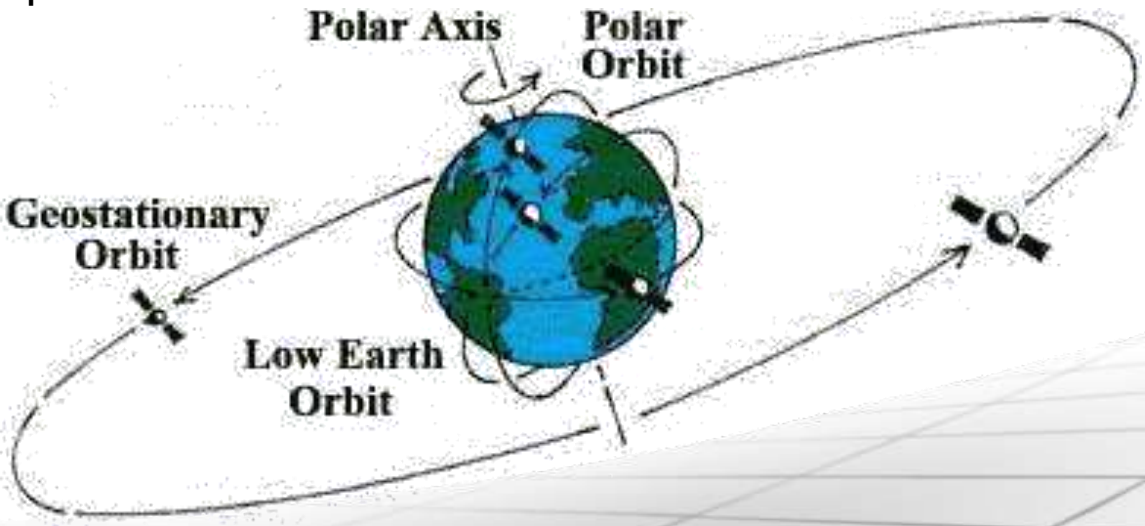




Classifications (cont.)

CHINA APMT

- By orbit (cont.)
  - Shape
    - eccentricity: circular orbit and elliptical orbit
    - orbit: equatorial orbit, inclined orbit, polar orbit (also called sun-synchronous orbit)
  - GEO
    - geostationary earth orbit
    - circular pro-grade orbit in the equatorial plane
    - orbital period equal to that of the earth



Classifications (cont.)

CHINA APMT

- By Payload
  - Transparent channel
    - also called bent pipe payload
    - receiving and transmission
  - On-board processing
    - also called regenerative payload
    - receiving, regeneration (demodulation, rearrangement and re-modulation) and then re-transmission
  - Store-and-forward
    - receiving, store, and then re-transmission
    - normally used for LEO and MEO

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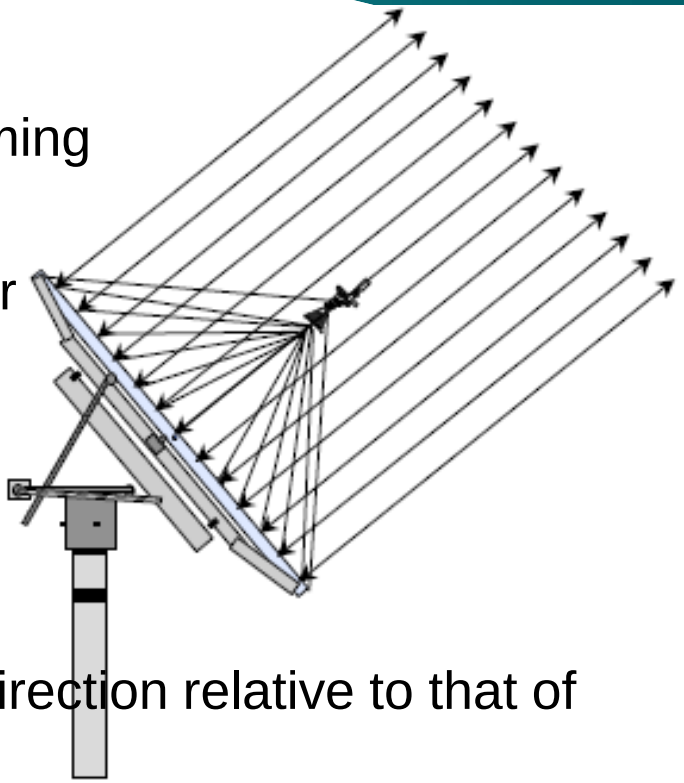
Reflector Antenna

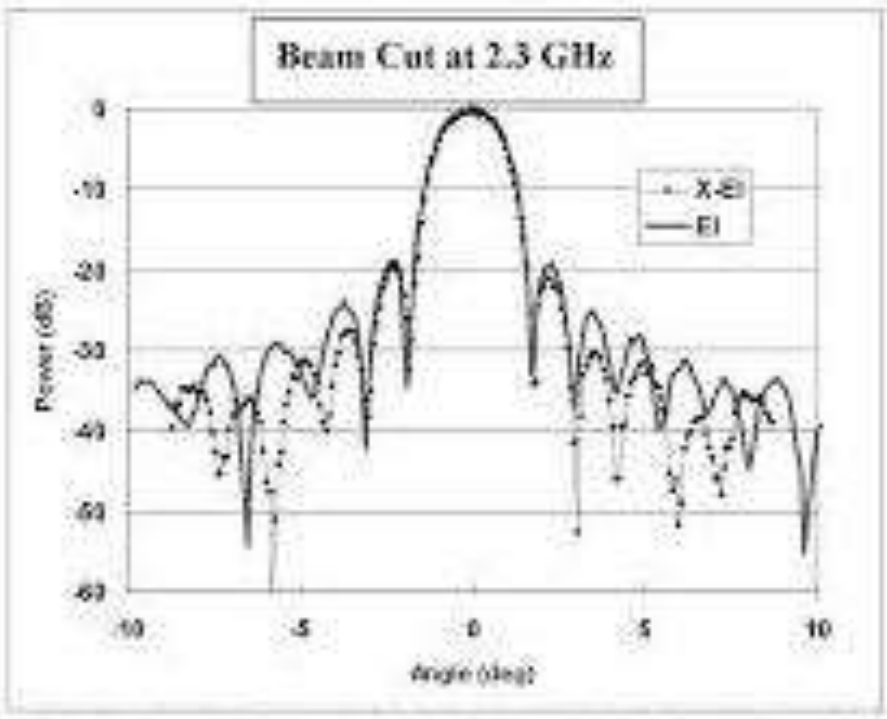


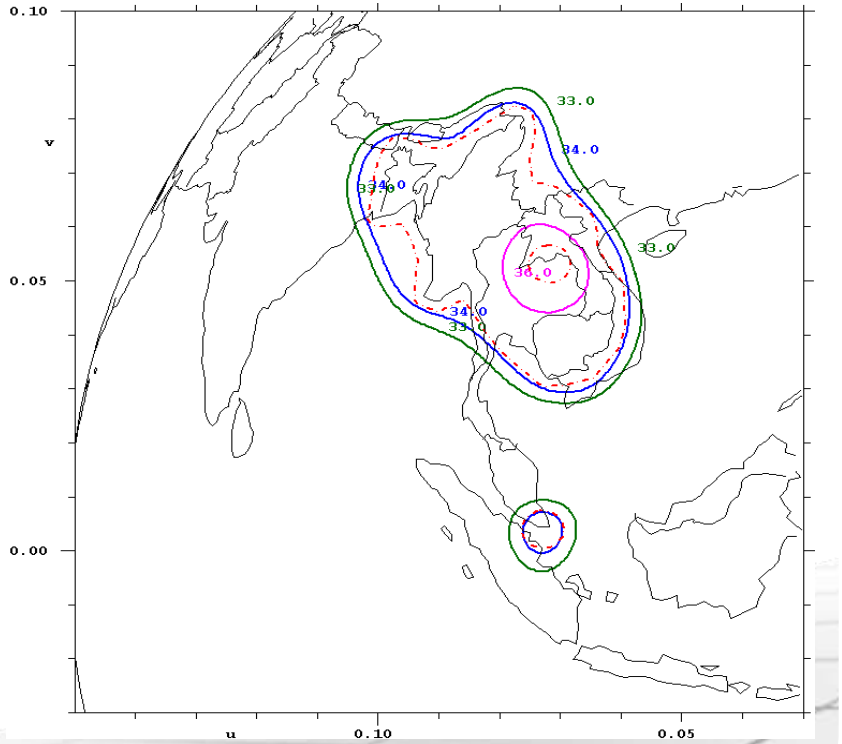
- Directional antenna
  - Focus the signal energy for overcoming transmission loss
  - Parabolic reflector antenna: used for earth stations
  - Beam forming antenna: used for communication satellites
- Antenna gain
  - Ratio of radiated power in a given direction relative to that of an isotropic antenna
  - The unit of antenna gain is dBi, where i means isotropic
  - Antenna gain is proportional to the square of signal frequency
  - Antenna gain of a parabolic reflector antenna is proportional to the square of the diameter of the reflector

Reflector Antenna (cont.)

CHINA APMT

- Antenna radiation pattern
  - The distribution of antenna gain at an angular coordinate
  - Parabolic reflector antenna: by the coordinates of azimuth angle and elevation angle
  - Beam forming antenna: by contour map





Parabolic Reflector Antenna

CHINA APMT

- Antenna gain

  $G = 10\lg(\eta(\pi fD/c)^2)$ (dBi)

  where, f is frequency, D is diameter, η is efficiency, and c is light speed

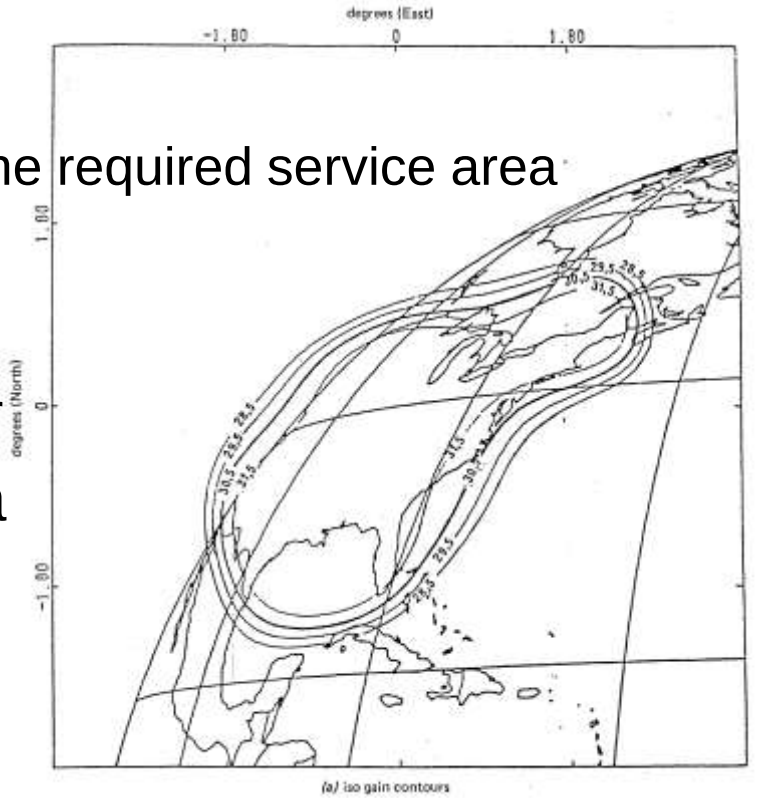
  - It is proportional to the square of signal frequency
  - It is proportional to the square of diameter of the reflector
  - Frequently used data

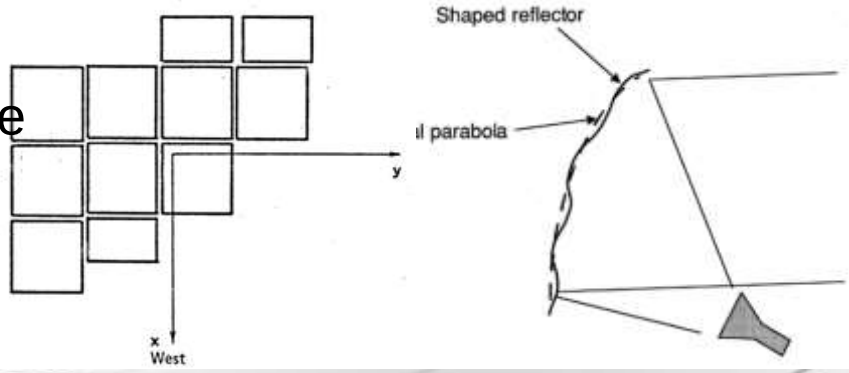
C-band	6175MHz	3950MHz		Ku-band	14.25GHz	12.5GHz
Diameter (m)	U/L (dBi)	D/L (dBi)		Diameter (m)	U/L (dBi)	D/L (dBi)
1.8	40	36		1.2	43	42
2.4	42	39		1.8	47	45
3	44	41		2.4	49	48
4.5	48	44		3	51	50
6.2	51	47		4.5	55	54

Beam Forming Antenna

CHINA APMT

- Why beam forming
  - To form the antenna pattern as the required service area
- How beam forming
  - Single reflector with multi-feeds
  - Single feed with shaped reflector
- Relationship between antenna pattern and transponder parameters
  - The receive pattern is relative to G/T and SFD
  - The transmit pattern is relative to EIRP





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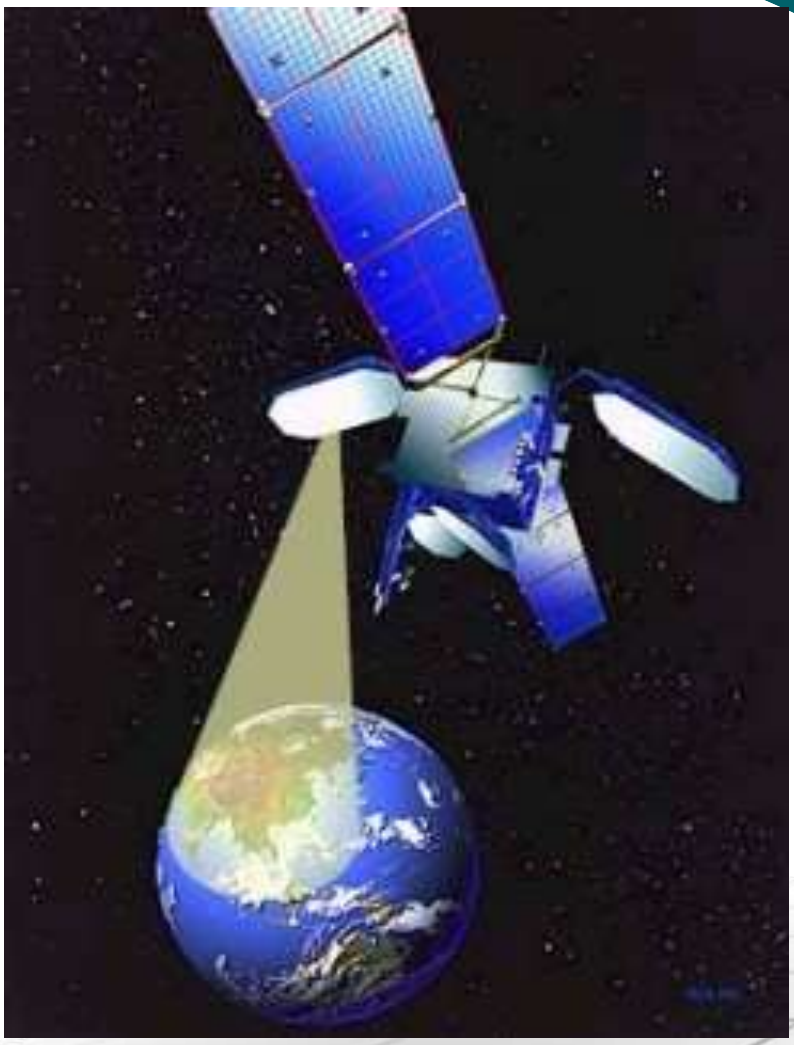
Communication Satellite

- Two main parts
  - Payload: communication subsystem
  - Bus: platform
- Payload
  - Antennas
  - Transponders
    - ⇨ transponder = trans(mitter) + (res)ponder
    - ⇨ repeater: to receive, amplify and retransmit the incoming signals
- Bus
  - Telemetry and command subsystem
  - Electrical power subsystem
  - Attitude control subsystem
  - Thermal control subsystem
  - Propulsion subsystem

Communication Satellite (cont.)

- Orbital slot
  - Longitude
  - 128.5E for LaoSat-1
- Frequency band
  - C-band, 500+300+300 MHz
  - Ku-band, 500+250+500 MHz
  - Ka-band, 500+2000 MHz
- Footprint
  - Service coverage for given frequency band
  - Determined by antenna beam forming



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Frequency Band

- Up-link and down-link
  - Up-link
    - ⇨U/L, the carrier from earth station to satellite
  - Down-link
    - ⇨D/L, the carrier from satellite to E/S
  - U/L and D/L using different frequencies
    - ⇨to avoid interference with each other
  - U/L frequency is normally higher than that of D/L
    - ⇨higher gain for receiving antennas
    - ⇨smaller size for traveling wave tube and TWTA in E/S

Frequency Band (cont.)

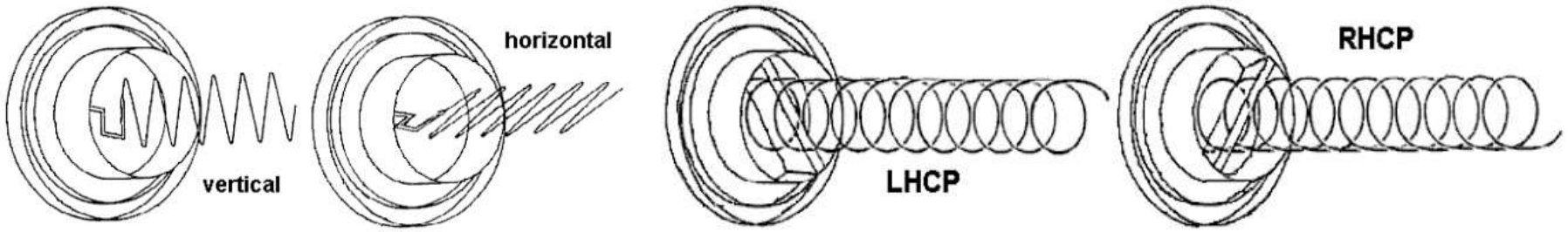
CHINA APMT

- Common frequency bands for FSS
  - C-band: 5850-6425MHz (U/L) and 3725-4200MHz (D/L)
  - Expand C-band: 6425-6725MHz/3400-3700MHz
  - Ku-band: 14.0-14.5GHz/12.25-12.75GHz (for ITU region 3)
  - Ka-band: 27.5-31.0GHz/17.7-21.2GHz
- Common frequency bands for BSS
  - Ku-band: 14.5-14.8GHz/11.7-12.2GHz (for ITU region 3)
  - Ka-band: 17.3-17.8GHz (U/L, for ITU region 3)

Polarization

CHINA APMT

- Polarization
  - The orientation of electromagnetic fields radiating
    - ⇨linear polarization and circular polarization
  - Linear polarization
    - ⇨cross-pol or mutual orthogonal: horizontal and vertical
  - Circular polarization
    - ⇨cross-pol or mutual orthogonal: LHCP (left hand circular polarization) and RHCP (right hand circular polarization)
  - Orthogonal polarization frequency reuse
    - ⇨spectrum resource could be double used by cross polarization



Polarization (cont.)

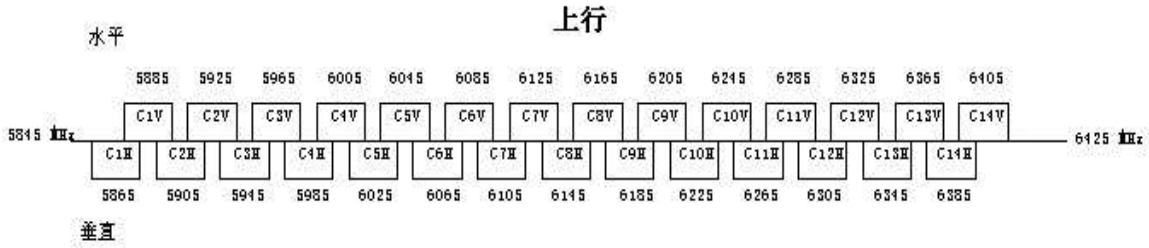
CHINA APMT

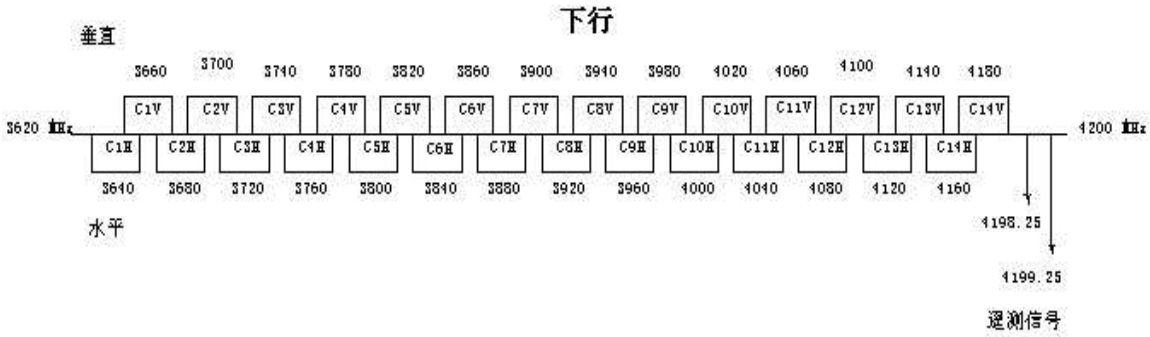
- Common polarization for FSS
  - Linear polarization
    - ⇨ often used by regional and domestic communication satellites
  - Circular polarization
    - ⇨ often used by INTELSAT satellites in C-band
- Common polarization for BSS
  - Circular polarization
    - ⇨ assigned for BSS bands by ITU
  - Linear polarization
    - ⇨ could also reassigned for BSS bands

Frequency and Polarization Plan

CHINA APMT

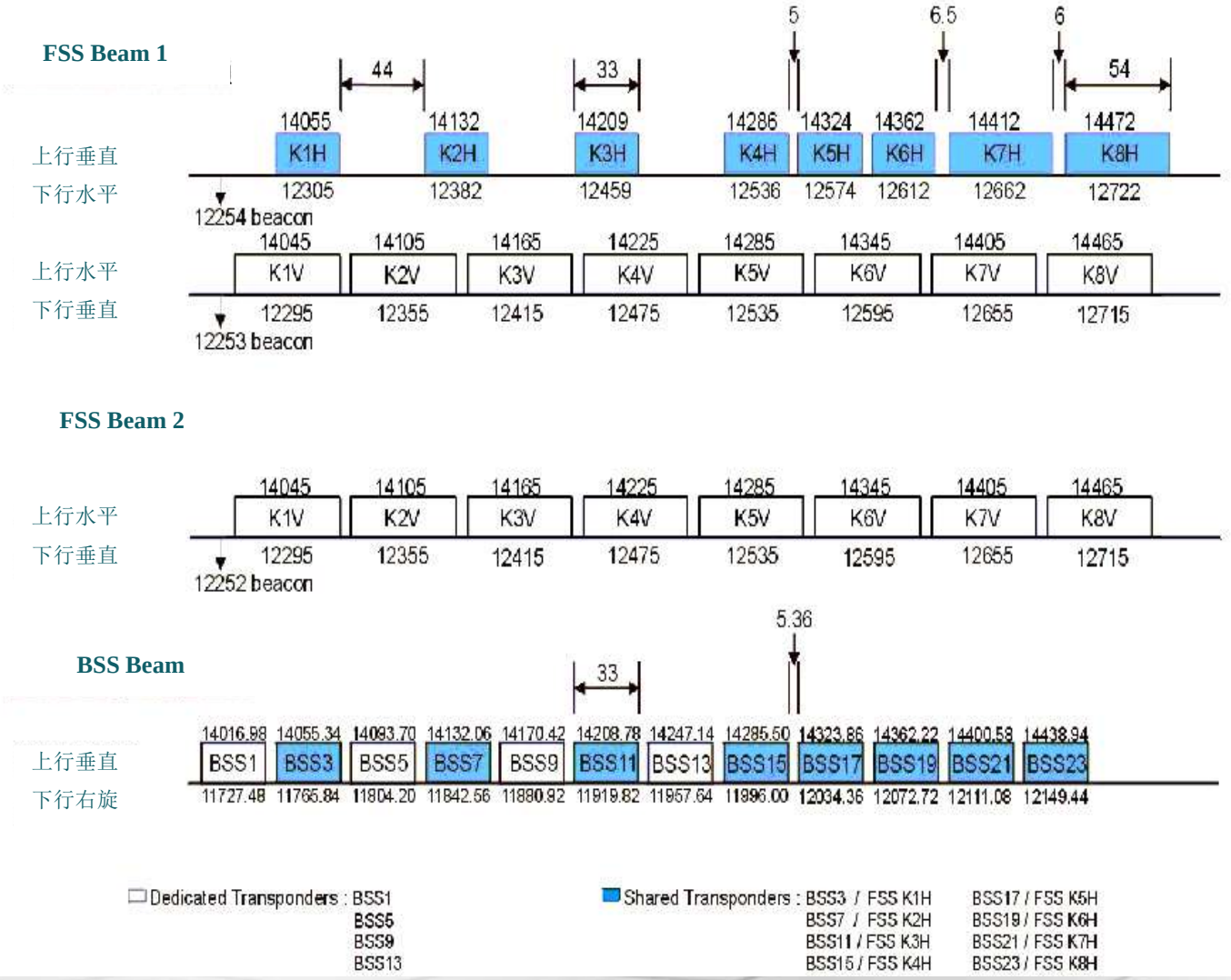
- Whole frequency band of a communication satellite is normally divided into several sub-bands or channels
  - Each channel (also called transponder) is consisted by one set of amplifiers and filters as an independent path
  - Two cross-pol channels could share same frequency band
  - The bandwidth of C-band transponder is about 36 or 72MHz





Frequency and Polarization Plan (cont.)

- The bandwidth of Ku-band transponder is about 54 or 36MHz

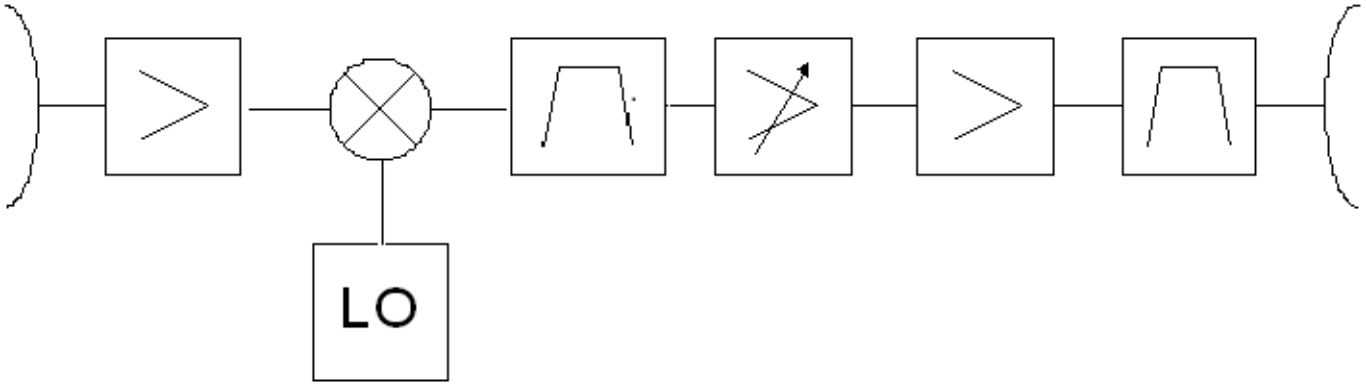


- Introduction
  - Decibel
  - History of Satellites
  - GEO Satellite Communication
- Antenna
- **Space Segment**
  - Communication Satellite
  - Frequency and Polarization Plan
  - **Transponder and Transmission Loss**
- Earth Segment
  - Carrier and Network
  - Earth Station and VSAT Terminal

Transponder

CHINA APMT

- Bent pipe transponder
  - Signal is only filtered, frequency converted and amplified in it
    - ⇨ (up-link signals in the service area is received by Rx-antenna)
    - ⇨ signals are pre-amplified by LNA
    - ⇨ U/L frequency is converted to D/L frequency by down-converter
    - ⇨ relevant frequency component is selected by input BPF
    - ⇨ signal level is properly amplified by channel amplifier with the adjusted gain
    - ⇨ output signal is amplified by power amplifier
    - ⇨ out-of-band interference is filtered by output BPF to protect the adjacent channels
    - ⇨ (down-link signals is directionally transmitted by Tx-antenna)

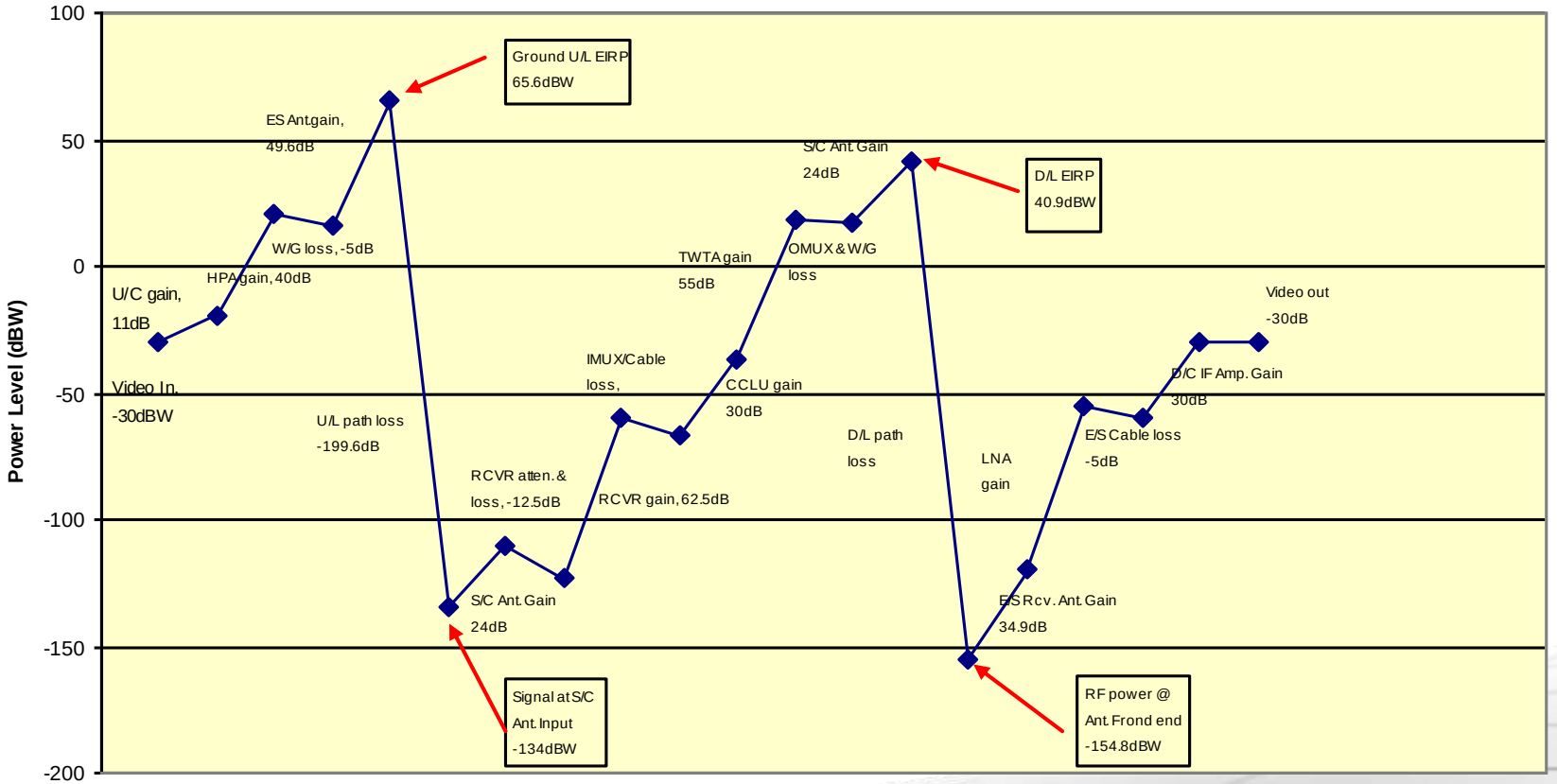


Transponder (cont.)

CHINA APMT

- Bent pipe transponder (cont.)
  - Nearly 200dB gain to counteract the huge free space loss

The Signal Level change through the S/C C-band communication link



Transmission Loss

CHINA APMT

- Transmission loss in free space

  $L_f = (4\pi d / \lambda)^2$

  $L_{f\text{-}dB} = 10\lg(4\pi d/\lambda)^2 = 20\lg(4\pi d/\lambda)$ (dB)

  where, d is distance (meter), and l is wavelength (the ratio of light speed to signal frequency)

  $\lambda = c/f = 3 \times 10^8 / f$ (m)

  - It is proportional to the square of signal frequency
  - It is proportional to the square of transmission distance
  - Free space loss at the distance of 36000km
    - ⇨195.6dB at 4GHz
    - ⇨199.1dB at 6GHz
    - ⇨205.2dB at 12GHz
    - ⇨206.5dB at 14GHz

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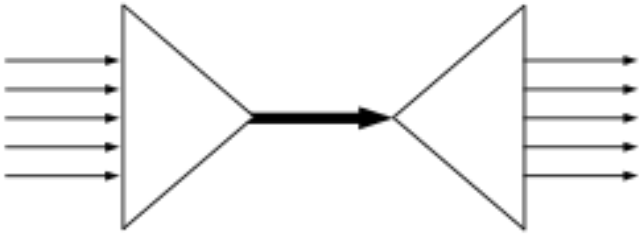
Multiplexing

- Multiplex
  - Physical layer, layer 1 of OSI (Open Systems Interconnection) model
  - Multiplexing low data rate signals over a single high data rate link
  - Multiplexing narrow band carriers over a wide band common channel

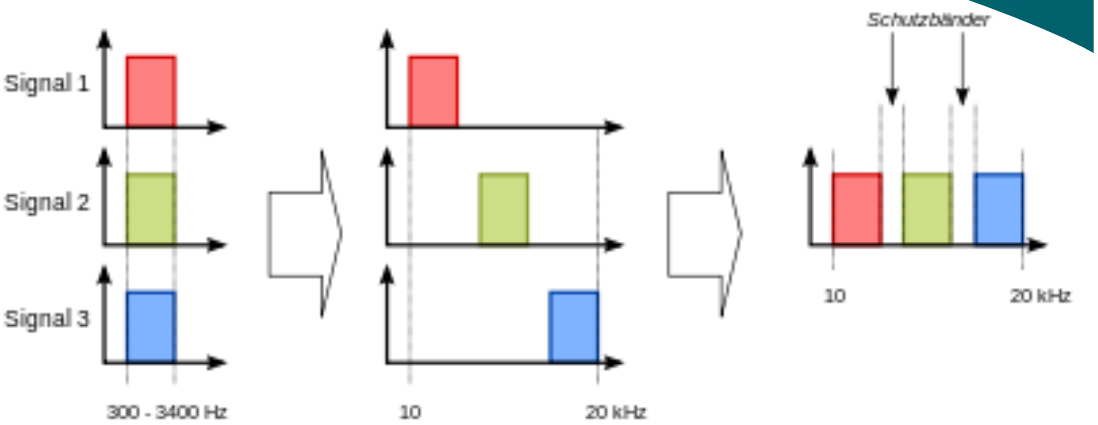


- TDM
  - Time-division multiplexing
  - Sequencing groups of input digital data into one multiplexed stream

Multiplex (cont.)

CHINA APMT

- FDM
  - Frequency-division multiplexing
  - combining several signals (analog or digital) into one medium by sending signals in several distinct frequency ranges



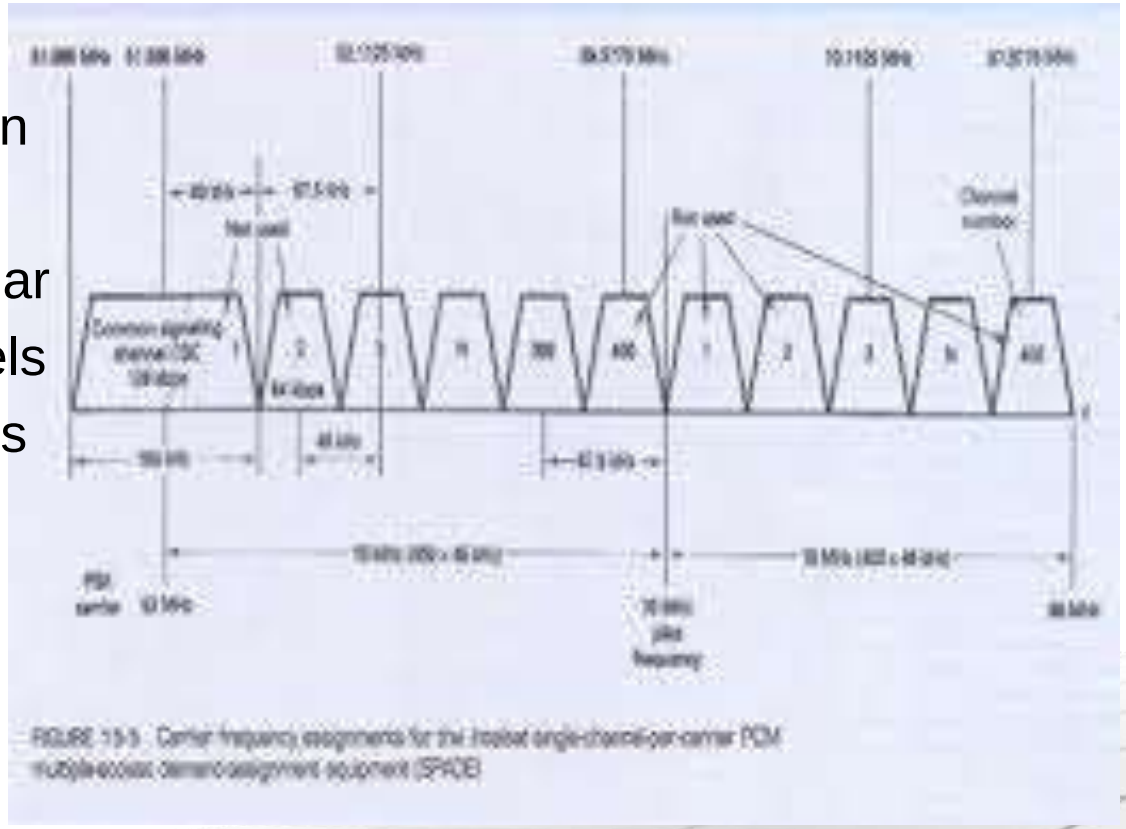
OFDM: Sub-carriers are closely spaced until overlap.

- OFDM
  - Orthogonal frequency division multiplexing
  - Sub-carriers are orthogonal each other
  - Inter-carrier guard bands are not required

Multiple Access

CHINA APMT

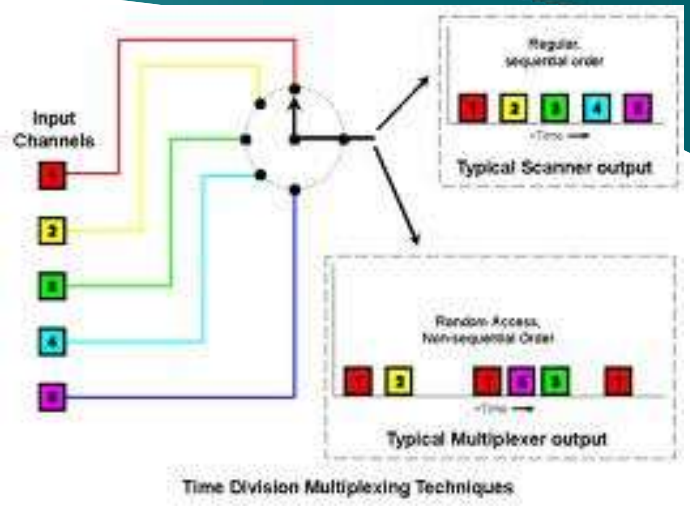
- Multiple Access
  - Data link layer, layer 2 of OSI model
  - One channel shared by several signals and offering multi-point transmission
- FDMA
  - Frequency division multiple access
  - Assigning particular frequency channels to different carriers

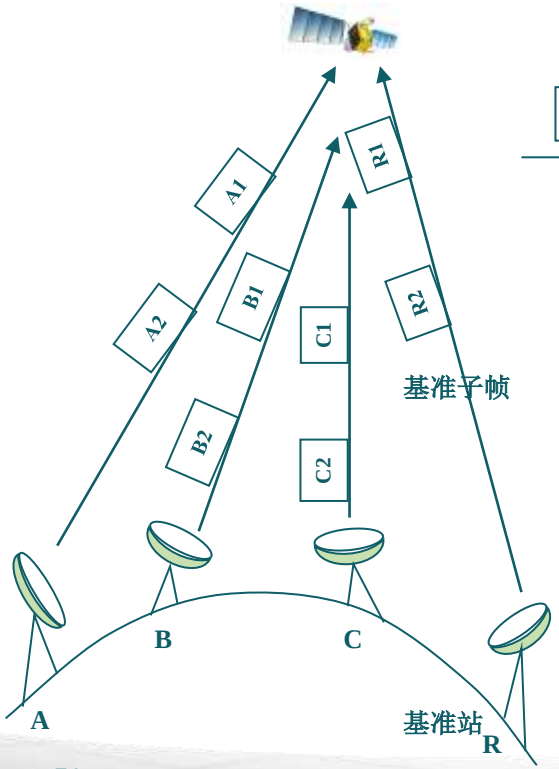


Multiple Access (cont.)

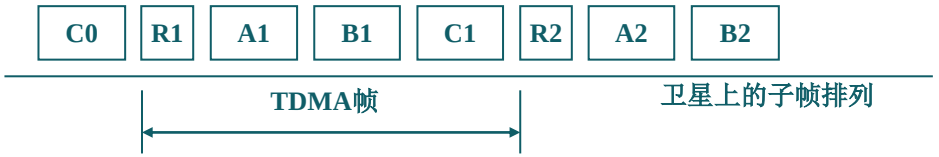
CHINA APMT

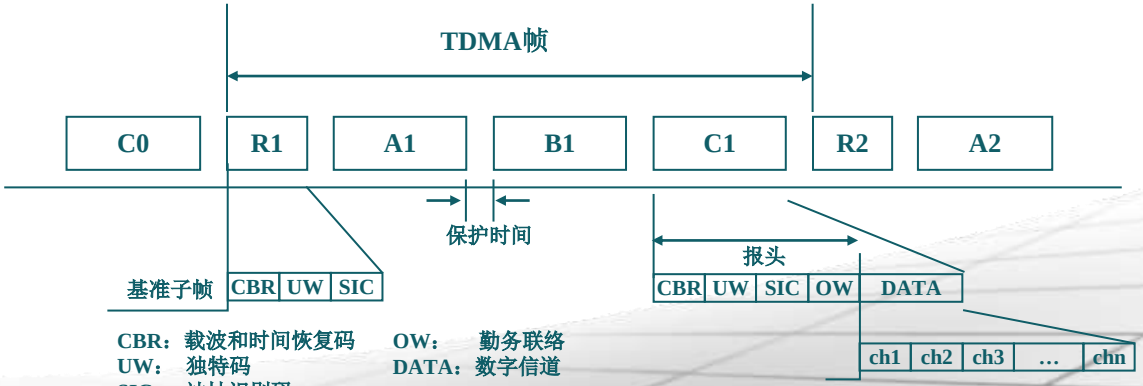
- TDMA
  - Time division multiple access
  - To provide different time-slots to different data-streams in a cyclically repetitive frame structure





TDMA多址方式的工作原理图



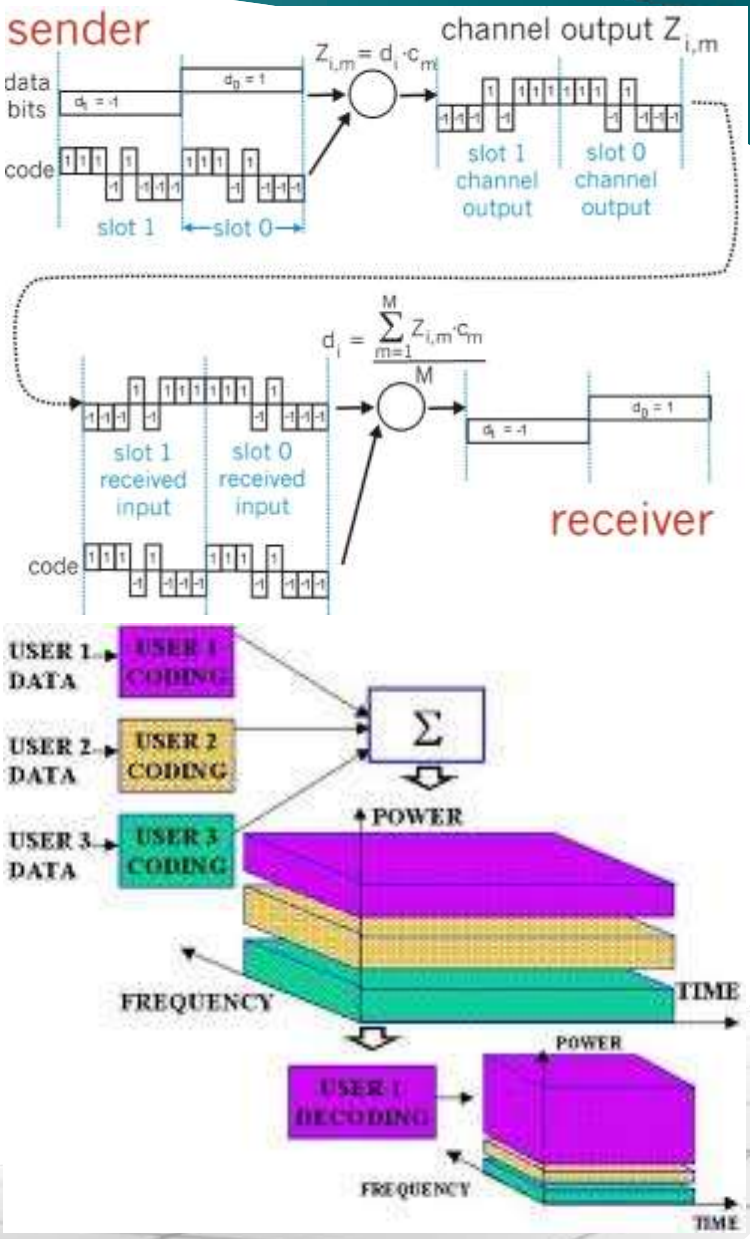


CBR：载波和时间恢复码　　OW：　勤务联络
UW：　独特码　　DATA：数字信道
SIC：　站址识别码

Multiple Access (cont.)

CHINA APMT

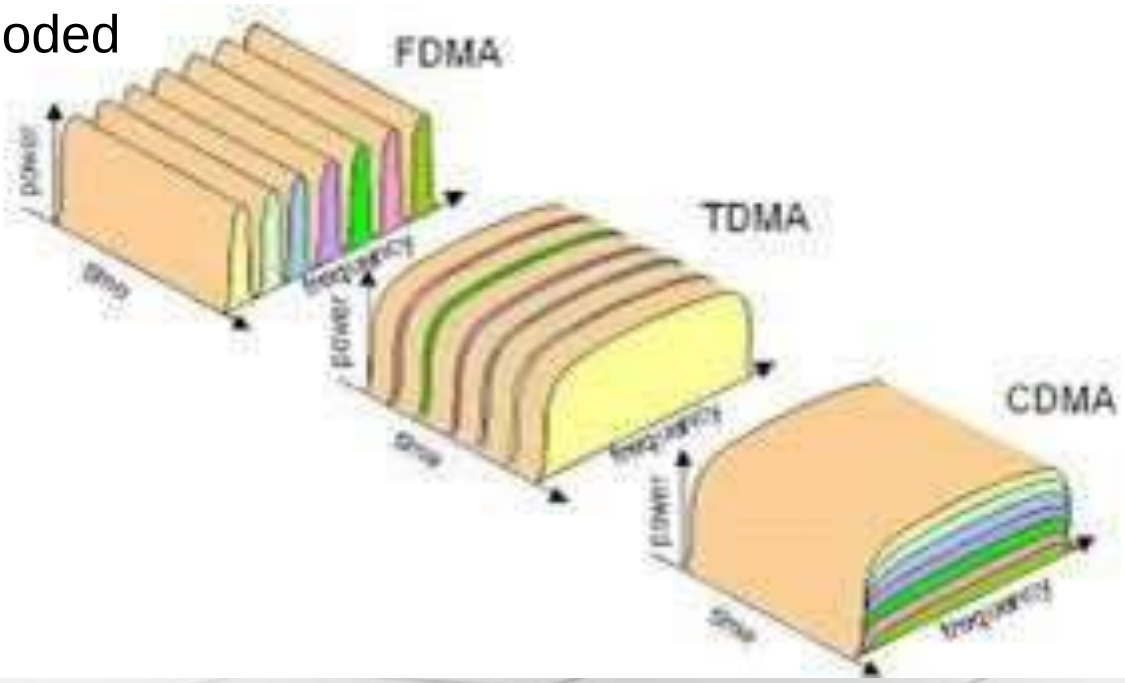
- CDMA
  - Code division multiple access: a kind of spread-spectrum multiple access
  - Signals encoded by unique spreading codes (orthogonal to others)
  - Spread-spectrum signals sharing a frequency band simultaneously
  - Each signal behaving like noise to others
  - The paired transmitters and receivers recognize their assigned and correlated code sequences, which look to all others as pseudorandom noise



Multiple Access (cont.)

CHINA APMT

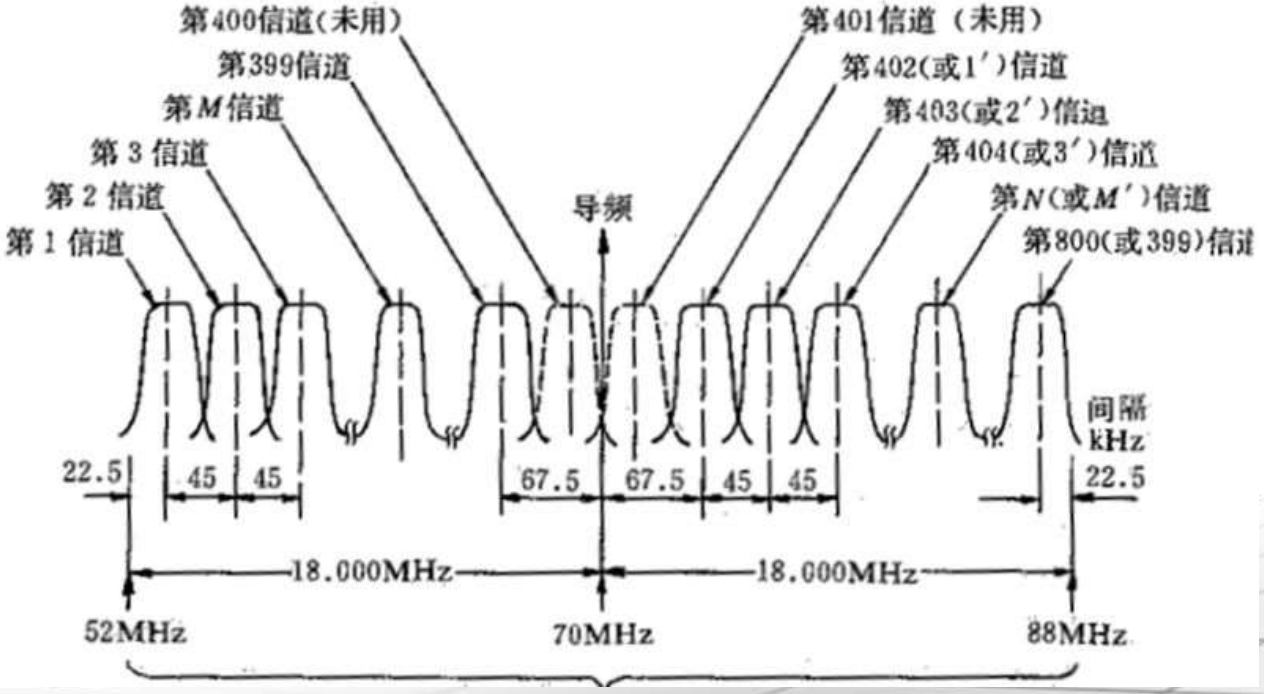
- Brief summary
  - FDMA: each carrier assigned fixed frequency band continually, desired channel filtered out by BPF
  - TDMA: each station utilizing allocated time slot in data frame cyclically, relative data stream picked up by synchronous technique
  - CDMA: all users share same frequency band simultaneously, required data encoded by unique code



Carrier

CHINA APMT

- FDM/FM/FDMA
  - Analog voice signals combined onto a group carrier by FDM, modulated as a FM carrier, then transmitted by FDMA
- SCPC/FDMA
  - SCPC (single channel per carrier, a signal at a given frequency band) carriers transmitted by FDMA

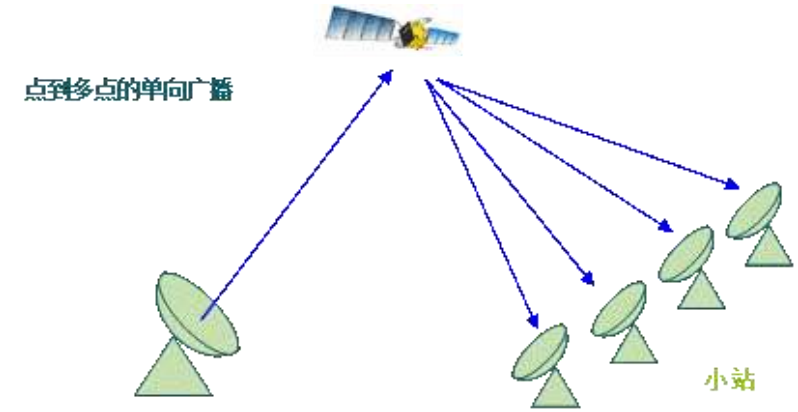


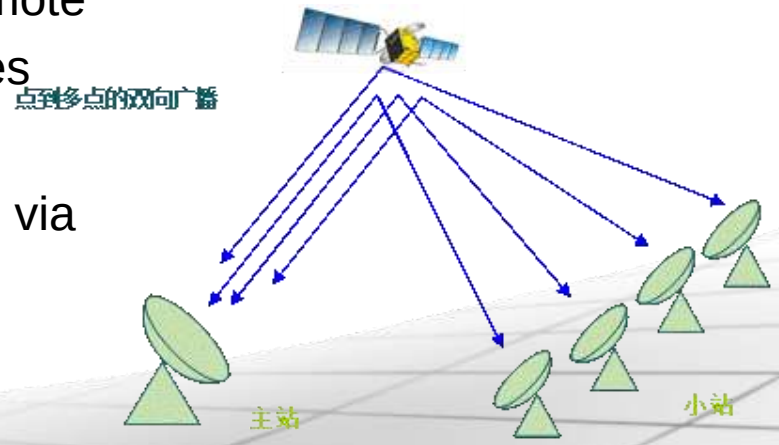
Carrier (cont.)

- TDM/PSK/FDMA
  - Digital voice signals or data combined by TDM, modulated as a PSK carrier, then transmitted by FDMA
  - IDR: intermediate data rate
  - IBS: Intelsat business service
- TDM/PSK/TDMA
  - Digital voice signals or data combined by TDM, modulated as a PSK carrier, then transmitted by TDMA
  - DVB: digital video broadcasting
    - ⇨ MCPC (multi channel per carrier)
    - ⇨ broadcast, multicast, unicast

Network

- Point to point
  - Communication carrier from one earth station to another
  - Carriers between two earth stations
  - FDM/FM/FDMA, SCPC/FDMA, TDM/PSK/FDMA
- Star network
  - Broadcasting
    - TV or data, one way
  - Intercommunication
    - single hop between hub and remote
    - double hop between two remotes
  - TDM/PSK/TDMA
    - DVB, DVB-RCS (return channel via satellite), Hughes-PES

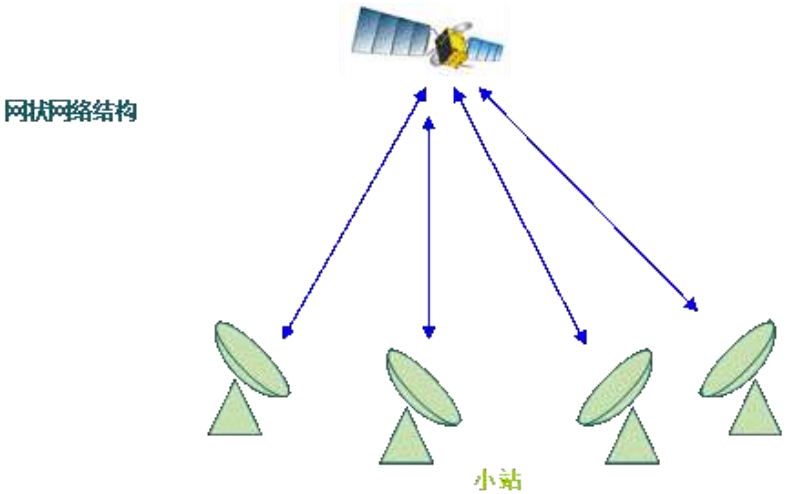




Network (cont.)

CHINA APMT

- Mesh network
  - With or without hub station
  - Single hop, short delay
  - Higher efficiency in bandwidth
  - More complicated and expensive for network management system
  - TDM/PSK/FDMA
    - ⇨ Hughes-TES



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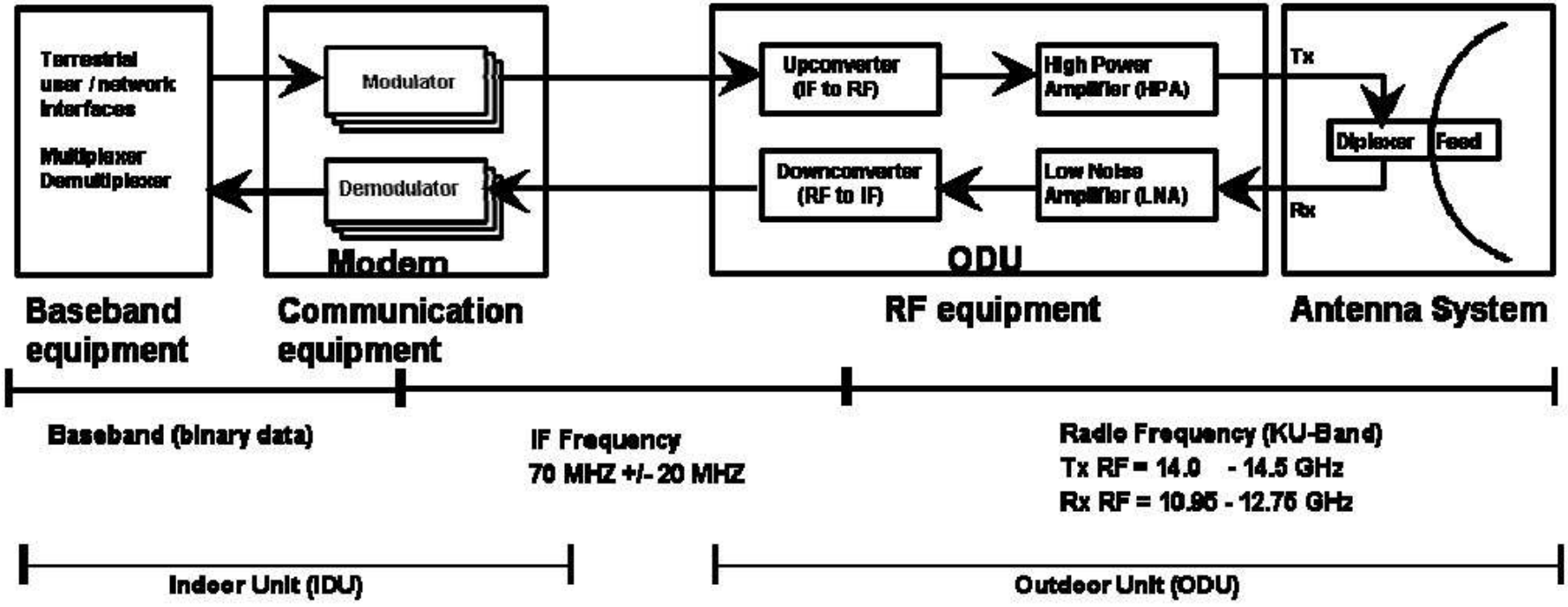
Earth Station

CHINA APMT

- Uplink
  - (BB) - MOD (IF) - U/C (RF) - HPA - antenna - satellite
- Downlink
  - Satellite - antenna - LNA (RF) - D/C (IF) - DEMOD (BB)



Schematic diagram typical VSAT system with IF radio input

Earth Station (cont.)

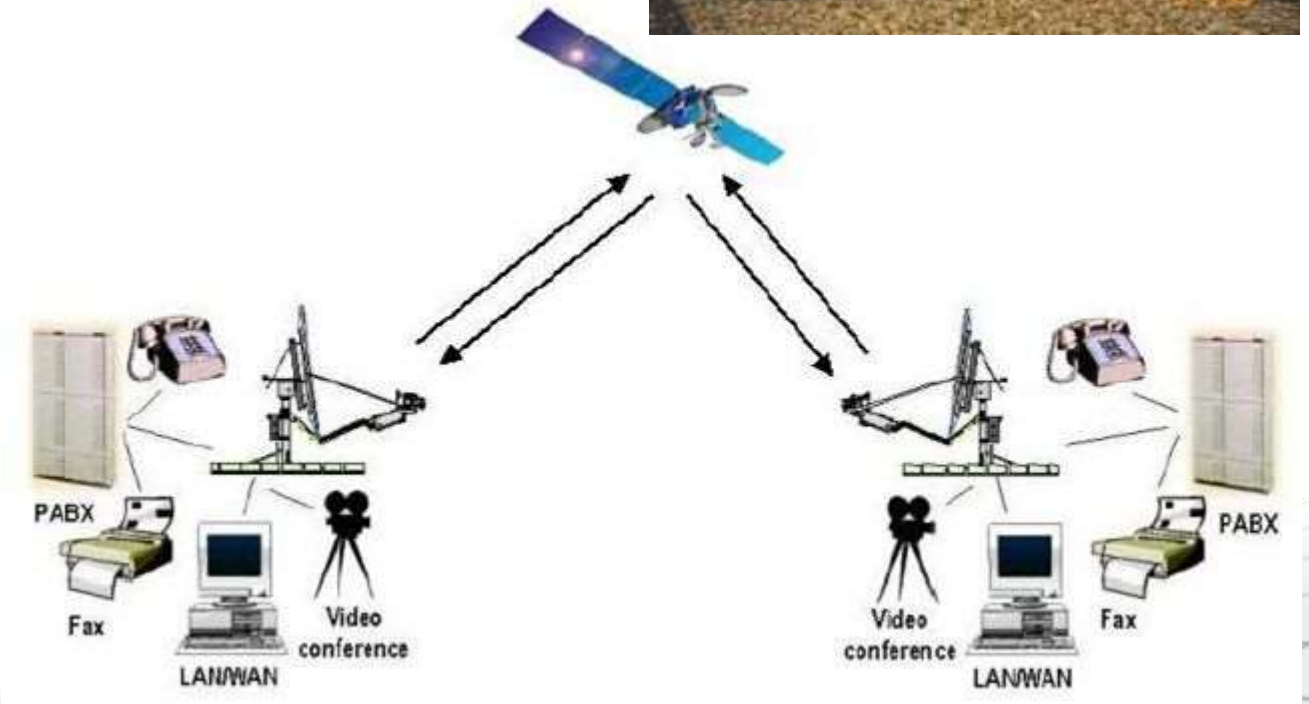
- Satellite control station
  - Telemetry processing
  - Manual and automatic commanding
  - On-board software management
  - Mission archive and web-based data distribution
- Teleport
  - Broadband hub or gateway station
  - Connecting satellite circuits with terrestrial fiber
  - Providing TV, Internet and enterprise network connections

SES-Astra earth station in Luxemburg

Earth Station (cont.)

CHINA APMT

- VSAT
  - Very small aperture terminal
  - 3.8m or less antenna
  - Out-door transceiver
  - In-door modem and interface
  - Home and business services



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