

# **Module 4**

## **Satellite Telemetry, Tracking And Telecommand**

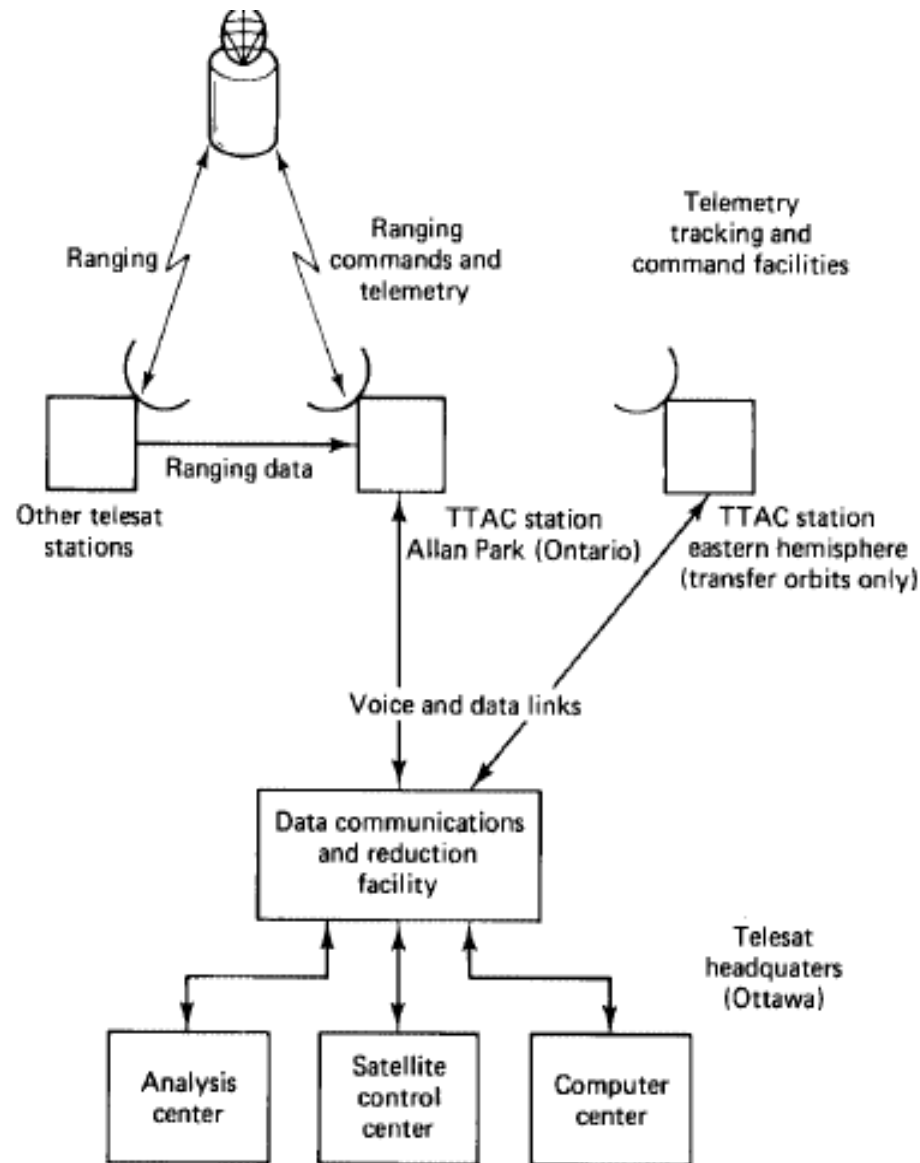
# Introduction

- Satellite communications system can be broadly divided into two segments, ground segment and a space segment.
- The space segment include the satellites, but also includes the ground facilities needed to keep the satellites operational, referred to as the *tracking, telemetry, and command* (TT&C).
- Telemetry, tracking, and command functions are complex operations which require special ground facilities in addition to the TT&C subsystems aboard the satellite.

# Three major tasks of TT&C

- Monitoring of the health and status of the satellite through the collection, processing, and transmission of data from the various spacecraft subsystem.
- Determination of the satellite's exact location through the reception, processing, and transmitting of ranging signals.
- Proper control of satellite through the reception, processing, and implementation of commands transmitted from the ground.

# Satellite Control System (TT&C)



**Figure 7.11** Satellite control system. (From *Telesat Canada*, 1983; courtesy of *Telesat Canada*.)

# Telemetry

- The telemetry, or telemetering, is *measurement at a distance*.
- Telemetry signals include attitude information, obtained from sun and earth sensors; environmental information such as the magnetic field intensity & direction and the frequency of meteorite impact.
- Spacecraft information such as temperatures, power supply, voltages, and stored-fuel pressure.
- Certain frequencies have been designated by international agreement for satellite telemetry transmissions.
- The telemetry subsystem transmits information about the satellite to the earth station.

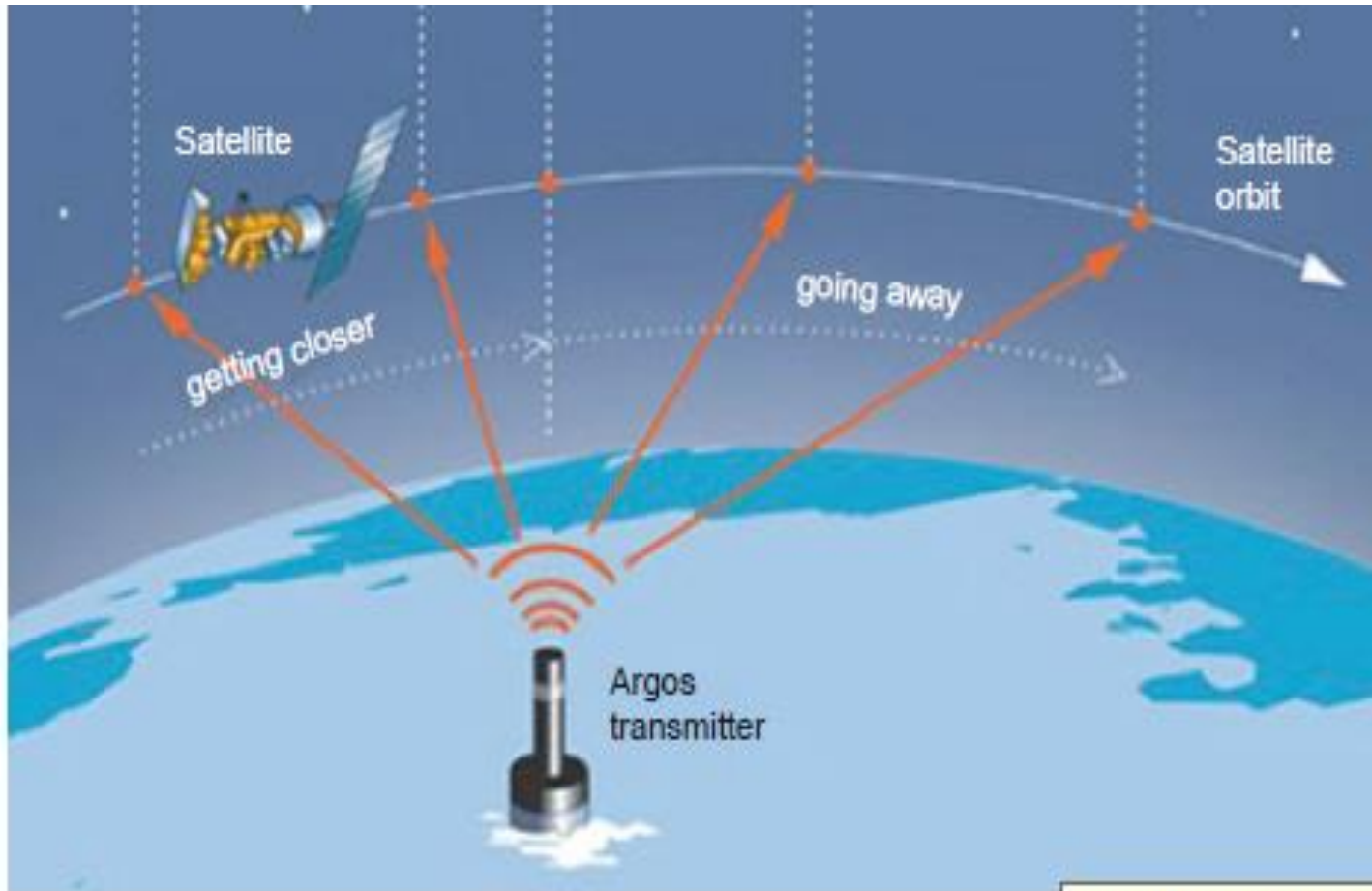
# Data Collection

- Measurements and status of health
- Power functions
- Telemetry functions
- Telecommand functions
- Attitude control functions
- Propulsion functions
- Structure functions
- Antenna functions
- Tracking functions
- Payload functions
- Miscellaneous functions
- Measurements:
  - Acceleration, velocity, displacement
  - Angular rate, angular position
  - Pressure
  - Temperature
  - Density
  - Resistance
  - Voltage, current
  - Intensity
  - Electric field, magnetic field

# Tracking

- Tracking of the satellite is accomplished by the satellite beacon signals which are received at the TT&C earth stations.
- Tracking is important during the transfer and drift orbital phases of the satellite launch.
- Once it is on station, the position of a satellite will tend to be shifted as a result of various disturbing forces.
- Therefore, it is necessary to track the satellite's movement and send correction signals as required.
- Tracking beacons are transmitted in the telemetry channel, or by pilot carriers at frequencies in one of the main communications channels, or by special tracking antennas.
- Satellite range from the ground station is required from time to time. This can be determined by measurement of the propagation delay of signals.

# Doppler Effect for tracking a Satellite

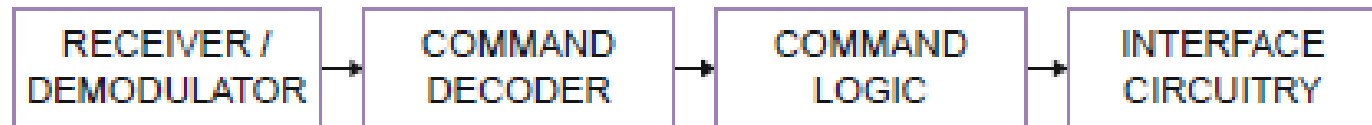


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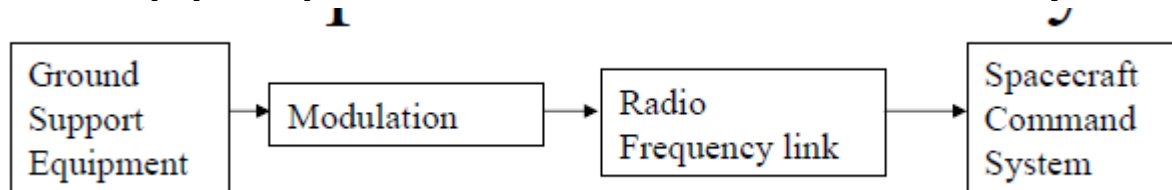


# Command

- The command subsystem receives command signals from the earth station, often in response to telemetered information.
- The command subsystem demodulates and decodes the command signals and routes these to the appropriate equipment needed to execute the necessary action.
- Attitude changes, communication transponders switched in and out of circuits, antennas redirected, and station keeping maneuvers carried out based on command signals.
- To prevent unauthorized commands from being received and decoded, the command signals are often encrypted.



- Decoders reproduce command messages and produce lock/enable and clock signals.
- Command logic validates the command
  - Default is to reject if any uncertainty of validity
  - Drives appropriate interface circuitry



- GSE operator selects command mnemonic
- Software creates command message in appropriate format and encodes it.
- Pulse code modulation (PCM)
- Phase shift keying (PSK)
- Frequency shift keying (FSK)

# Transducers

- Transducers convert energy from one form to another
- Outputs can be
  - –Resistance
  - –Capacitance
  - –Current
  - –Voltage

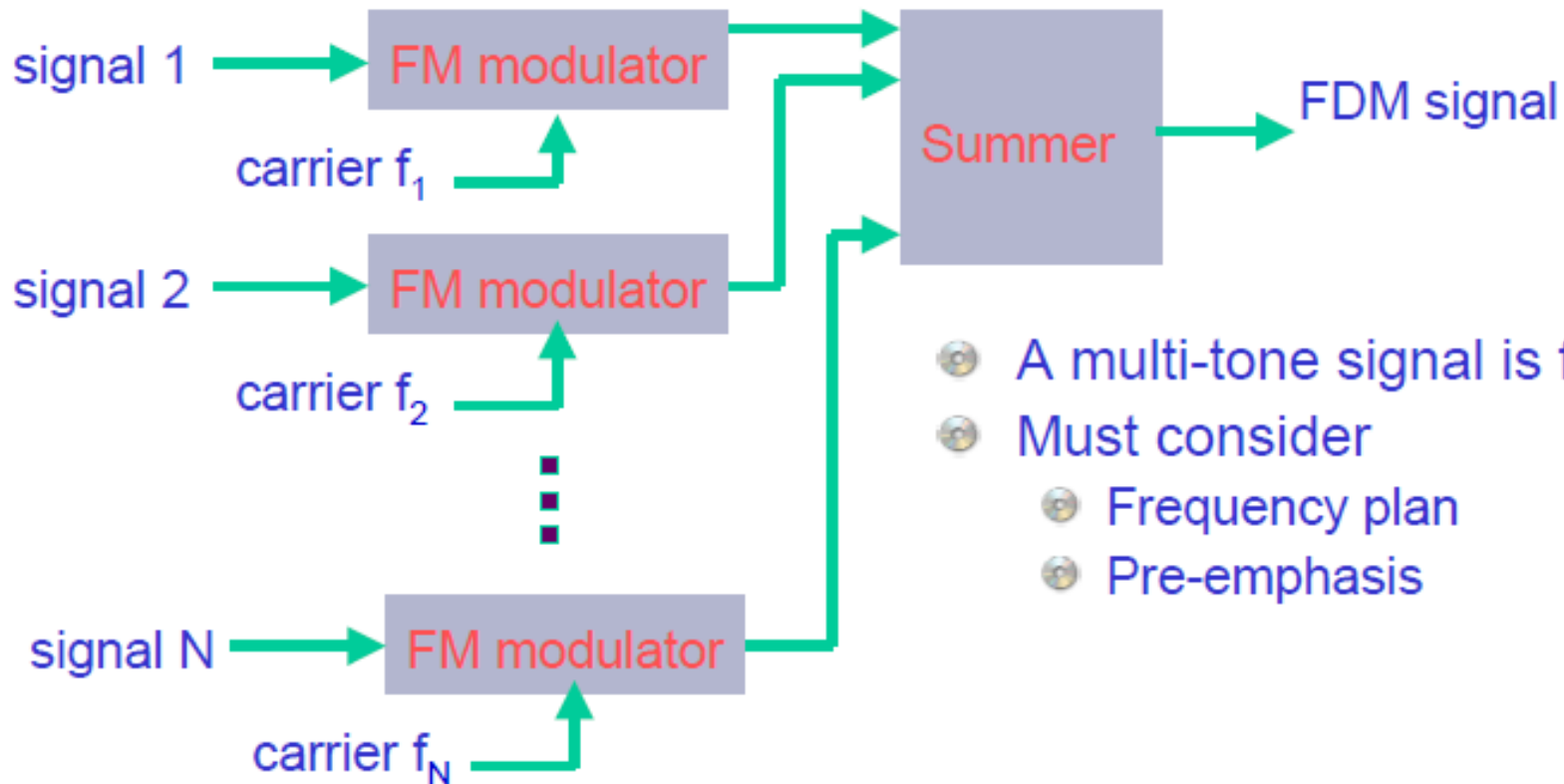
# Signal Conditioning and Selection

- Signal conditioner: may be passive or active
- Conditioning ensures Amplification, Noise filtering, proper level, dynamic range, frequency response, impedance, ground reference, common mode rejection and automatic gain control.
- Commutation selects the proper sensor at a given time
- Sampling frequency determined by the Nyquist criteria.

# Multiplexing

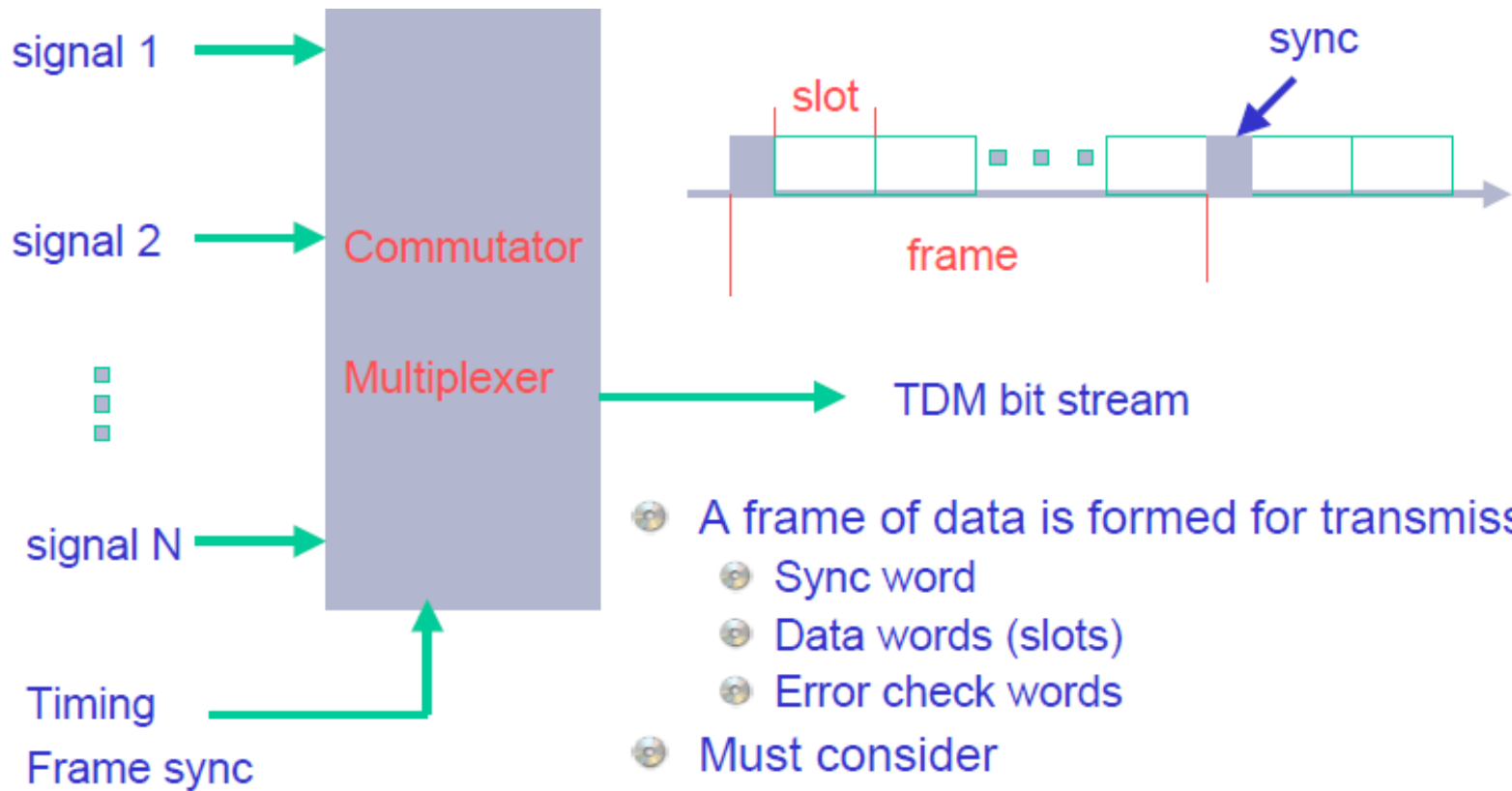
- When a series of input signals from different sources have to be transmitted along the same physical channel, multiplexing is used to allow several communication signals to be transmitted over a single medium.
- Frequency division multiplexing (FDM)
  - FDM places multiple incoming signals on different frequencies. Then are they are all transmitted at the same time.
  - The receiving FDM splits the frequencies into multiple signals again
- Time division multiplexing (TDM)
  - TDM slices multiple incoming signals into small time intervals.
  - Multiple incoming lines are merged into time slices that are transmitted via satellite
  - The receiving TDM splits the time slices back into separate signals

# FDM



- A multi-tone signal is formed
- Must consider
  - Frequency plan
  - Pre-emphasis

# TDM



- A frame of data is formed for transmission
  - Sync word
  - Data words (slots)
  - Error check words
- Must consider
  - Sampling rate
  - Slow and fast measurement data
  - Resolution and bit rate
  - Frame rate

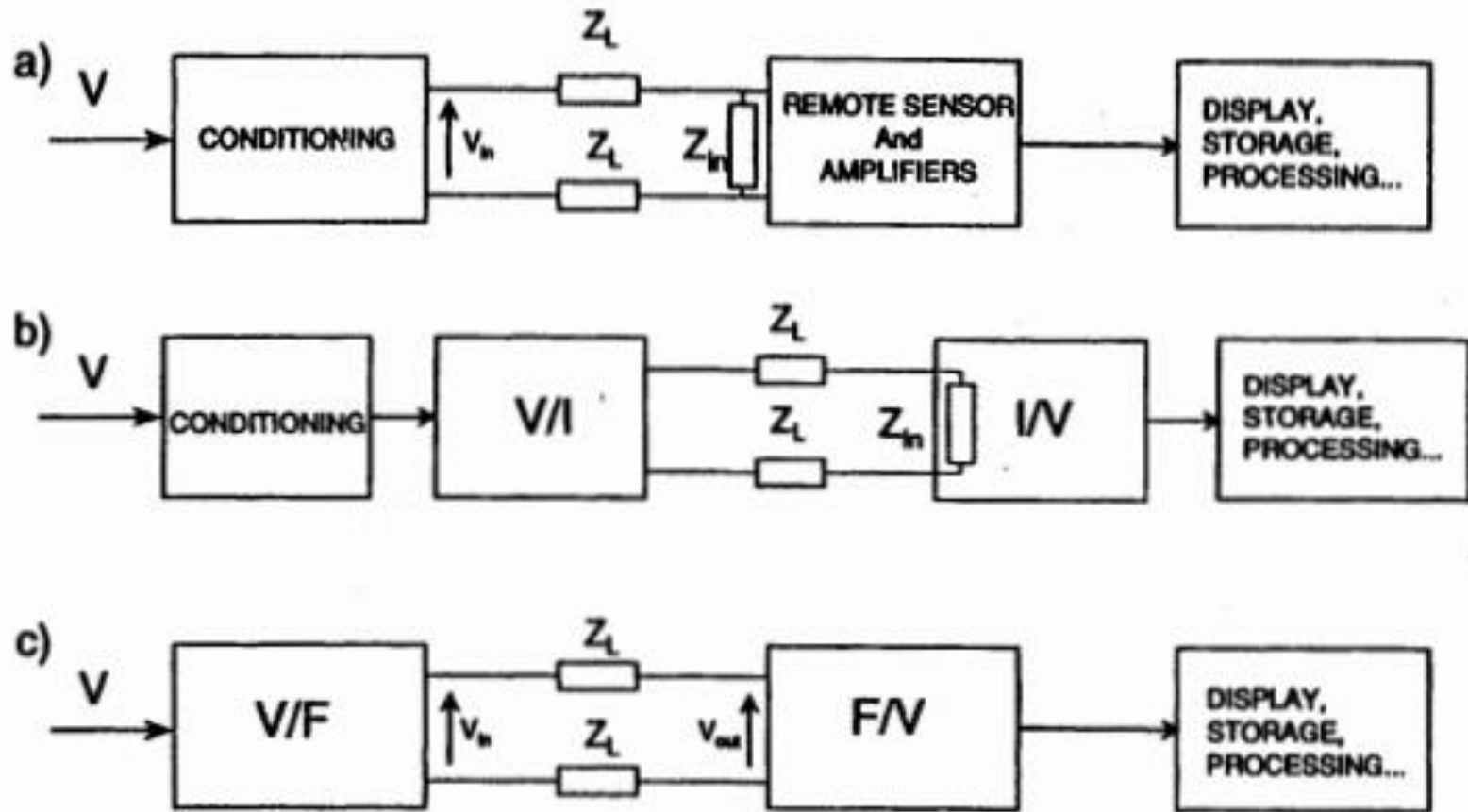
# Analog to Digital Conversion

- Converts voltages (0 – 5.1 v, or -2.56 to 2.54 v) to  $2^n-1$  discrete values
- Quantization error decreases as n increases

Type	Conversion Rate	Word Size	Power
High Speed ADC	$50 \times 10^6 / \text{sec}$	8 bit	2.5 W
High Resolution ADC	$1 \times 10^5 / \text{sec}$	16 bit	1.5 W
Low Power ADC	$2.5 \times 10^4 / \text{sec}$	8 bit	0.005 W

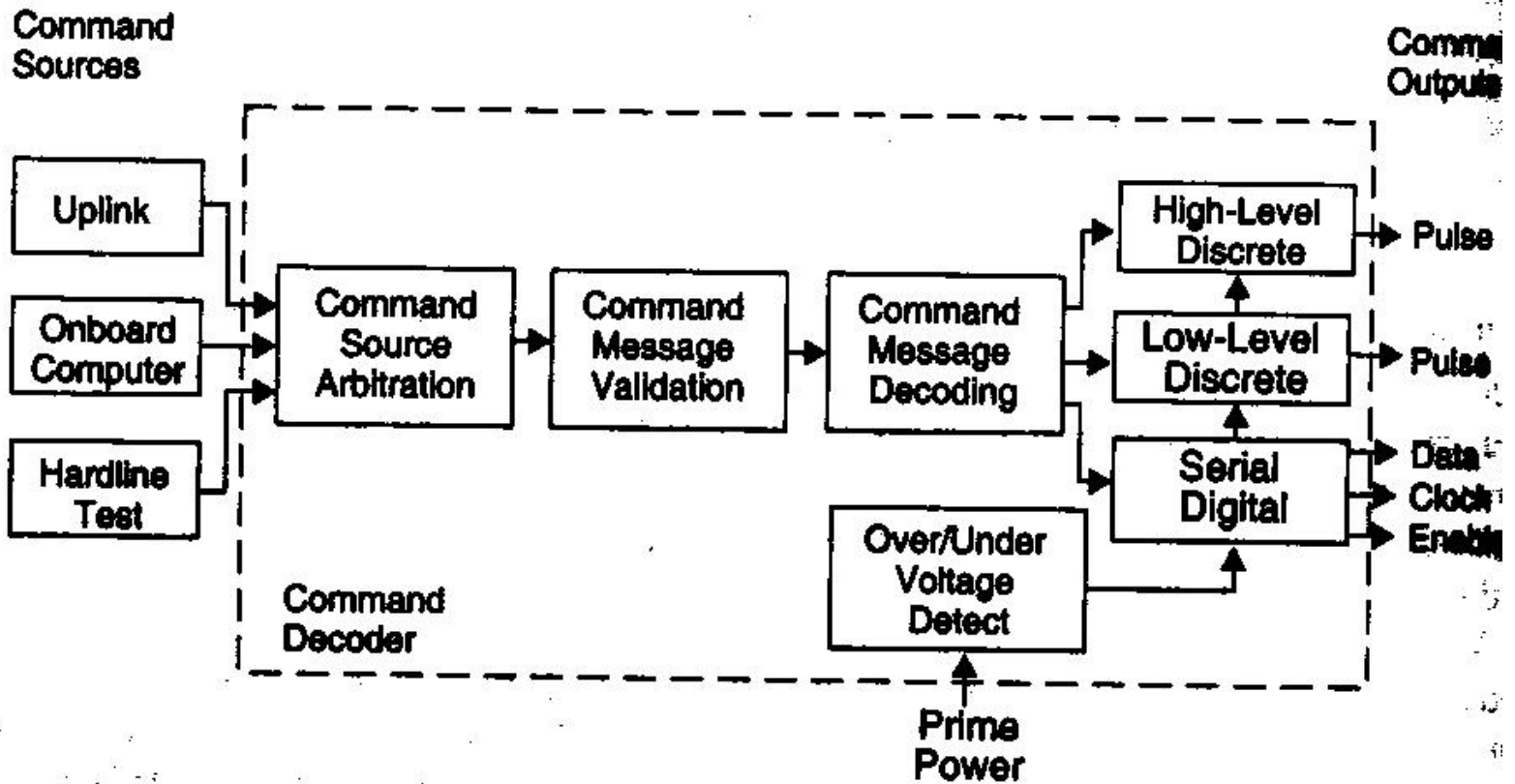


# Base Band Telemetry

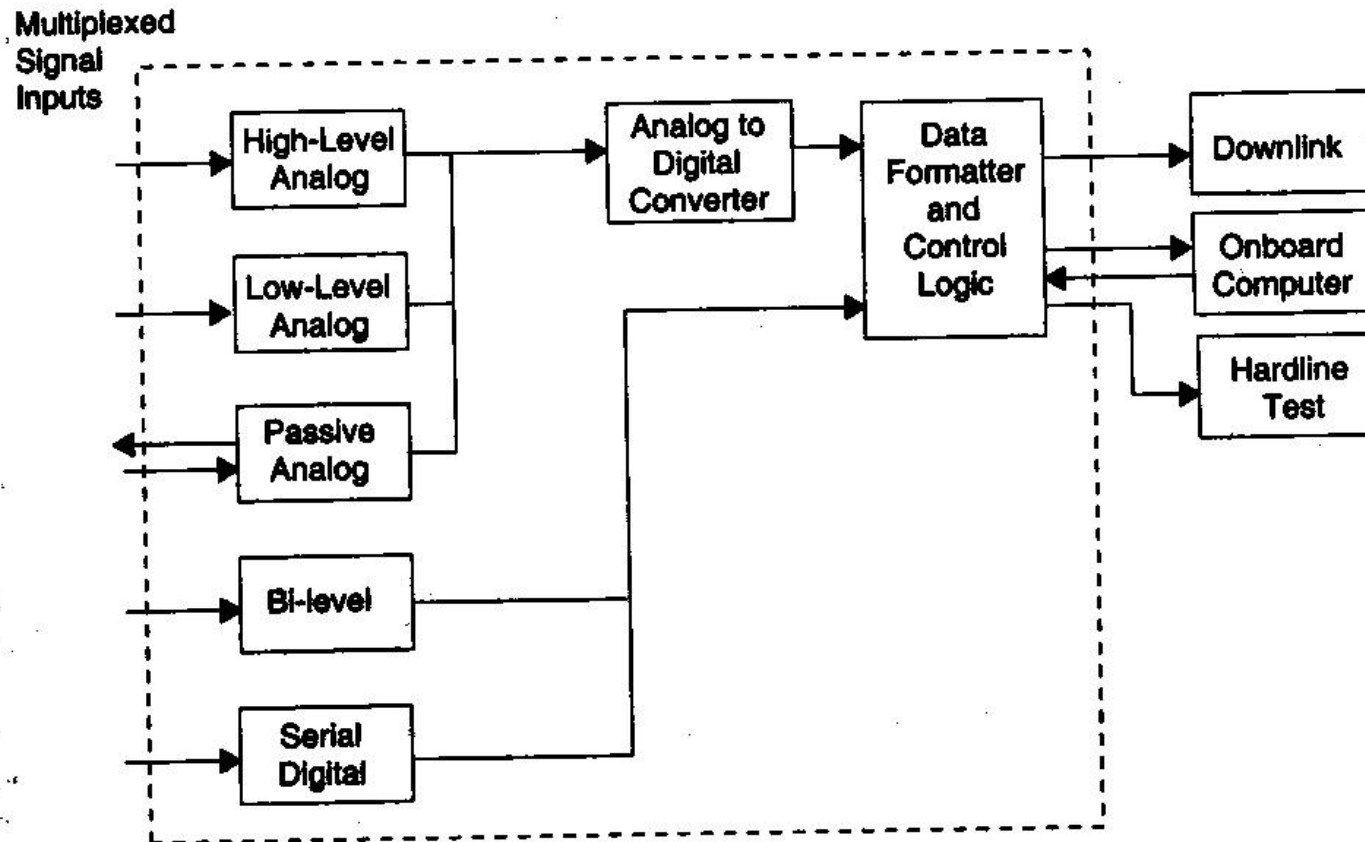


**FIGURE 87.3** Different configurations for base-band telemetry. In voltage-based-base band telemetry (a) the information is transmitted as variations of a voltage signal. Current-based-base band telemetry (b) is based on sending a current signal instead of a voltage signal to neutralize the signal degradation due to the voltage divider made up by the input impedance of the receiver ( $Z_{in}$ ) and the impedance of the lines ( $Z_L$ ). In frequency-based base-band telemetry (c), the information is transmitted as variations of frequency which makes this system immune to noise and interference that affect the amplitude of the transmitted signal.

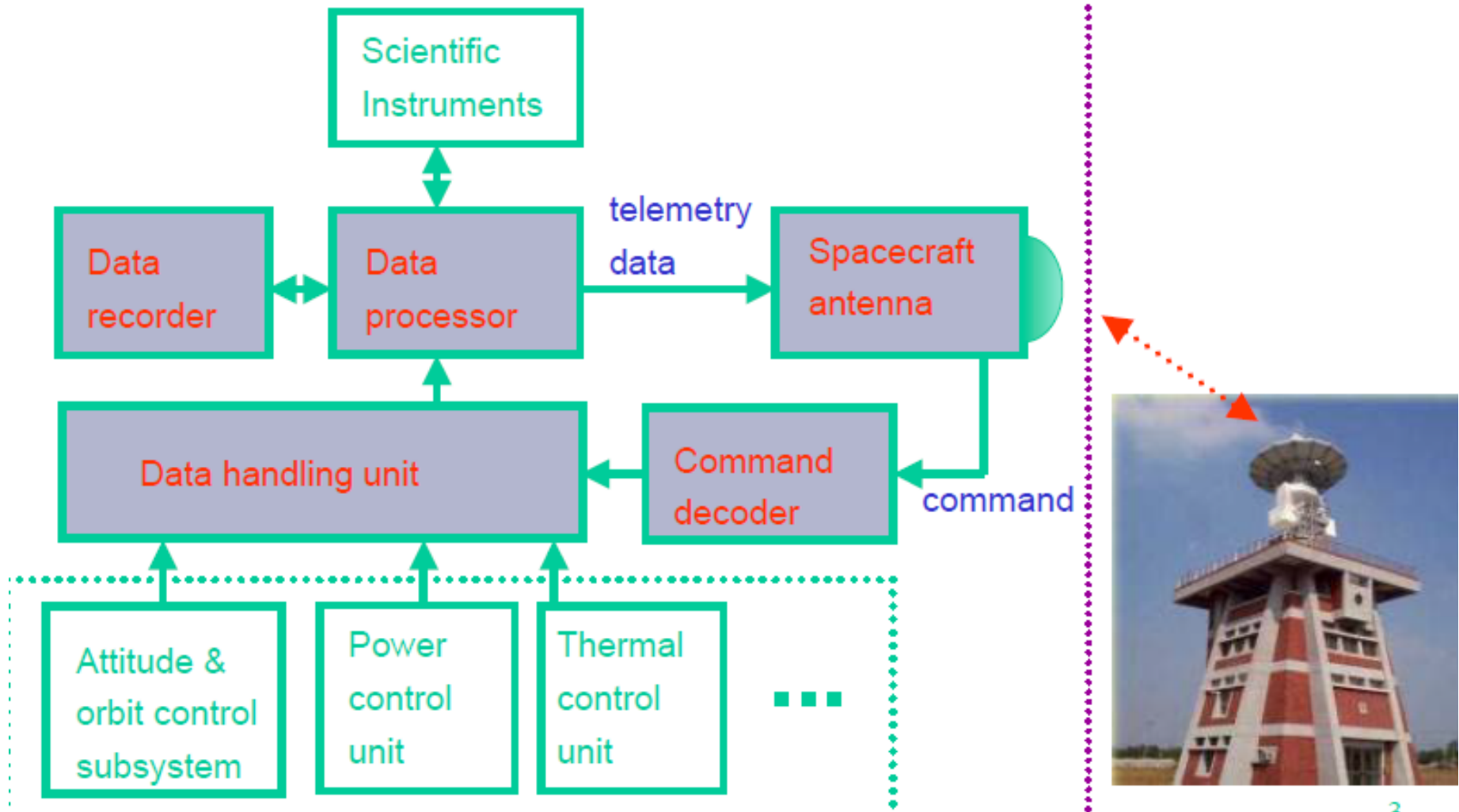
# Command handling



# Data Handling



# C&DH



# C&DH Issues

- No commands or transient signals may appear on command outputs during application or removal of prime power or during under/over voltage conditions.
- If a commands integrity is in doubt, reject it.
- Multiple commands are required for critical/dangerous operations.
- No single component failure can result in unintended operation.
- No commands shall interrupt the uplink source to the command decoder.