# Advanced Digital Communication

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SEMSTER - II

## ADVANCED DIGITAL COMMUNICATIONS

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|---|---|---|---|---|
| Subject Code | : **12EC006** | IA Marks | : | 50 |
| No. of Lecture Hours /week | : 04 | Exam Hours | : | 03 |
| Total no. of Lecture Hours | : 52 | Exam Marks | : | 100 |

**Digital Modulation Techniques:** Digital Modulation Formats, Coherent Binary Modulation Techniques, Coherent Quadrature –Modulation Techniques, NonCoherent Binary Modulation Techniques, Comparison of Binary and Quaternary Modulation Techniques, M-ary Modulation Techniques, Power Spectra, Bandwidth Efficiency, M-ary Modulation formats viewed in the Light of the channel capacity Theorem, Effect of Intersymbol Interference, Bit Versus Symbol Error Probabilities, Synchronisation, Applications.(Ref.3 Chap.7)

**Coding Techniques:** Convolutional Encoding, Convolutional Encoder Representation, Formulation of the Convolutional Decoding Problem, Properties of Convolutional Codes: Distance property of convolutional codes, Systematic and Nonsystematic Convolutional Codes, Performance Bounds for Convolutional Codes, Coding Gain. Other Convolutional Decoding Algorithms: Sequential Decoding, Feedback Decoding,Turbo Codes.(Ref.2 Chap.7 & 8)

**Communication through band limited linear filter channels:** Optimum receiver for channels with ISI and AWGN, Linear equalization, Decision-feedback equalization, reduced complexity ML detectors, Iterative equalization and decoding-Turbo equalization. (Ref.1 Chap.10)

**Adaptive Equalization:** Adaptive linear equalizer, adaptive decision feedback equalizer, adaptive equalization of Trellis- coded signals, Recursive least squares algorithms for adaptive equalization, self recovering (blind) equalization. (Ref.1 Chap.11)

**Spread Spectrum Signals for Digital Communication:** Model of Spread Spectrum Digital Communication System, Direct Sequence Spread Spectrum Signals, Frequency-Hopped Spread Spectrum Signals, CDMA, time-hopping SS, Synchronization of SS systems. (Ref.1 Chap.13)

**Digital Communication Through Fading Multi-Path Channels:** Characterization of fading multi-path channels, the effect of signal characteristics on the choice of a channel model, frequency-Nonselective, slowly fading channel, diversity techniques for fading multi-path channels, Digital signal over a frequency-selective, slowly fading channel, coded wave forms for fading channels, multiple antenna systems. (Ref.1 Chap.14)

**REFERENCE BOOKS:**

1. John G. Proakis, **—Digital Communications**, 4th edition, McGraw Hill, 2001.

2. Bernard Sklar, **—"Digital Communications - Fundamentals and Applications"**, 2nd Edition Pearson Education (Asia) Ptv. Ltd, 2001.

3. Simon Haykin, **— Digital Communications**, John Wiley and Sons,

4. Andrew J. Viterbi, **—CDMA: Principles of Spread Spectrum Communications**, Prentice Hall, USA, 1995.

## Advanced Communication Lab

List of Experiments:-

1.Measurements of directivity and beamwidth of the following antennae from their

Radiation pattern: Pyramidal from ( Waveguide type). Parabola (dish type).

2.Determination of Modes, Transit time, Electronic timing range and sensitivity of Klystron source.

3.Determination of VI characteristic of GUNN Diode and measurement of guide wavelength, frequency and VSWR.

4.Determination of coupling coefficient and insertion loss of directional coupler and magic tree.

5.Antenna Resonance and Gain Bandwidth measurements..

6.Generation of bi-phase code from NRZ and vice-versa.

7.Digital modulation of speech signals and demodulation.

8.Generation of pseudo-random code using shift register, filtering.

9.Voice and data multiplexing (TDM) using optical fiber.

10.Performance of digital modulation and demodulation of known signals in presence of noise.

11.Study of WGN, computation of its auto-correlation and statistical parameter (MATLBA/SCILAB may used).

12.Discrete version of DPSK modulation & demodulation.

13.ASK, PSK and FSK using CD4051 IC.

***Any other experiments may be added to supplement the theory.***

# Introduction

# Modulation:

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- To prevent mutual interference between stations.
- To reduce the size of the antenna required.
- Transmitting and receiving antenna height must be $\lambda/4$.
- To send a 1 Hz ($\lambda = C/f = 3 * 10^8 m$) signal) its height must be 75,000 Km.
- If the same signal is modulated to some high frequency 88 MHZ ($\lambda = 3.4m$) , antenna height needed is 0.8522

Types of modulation:

Types of modulation:

1. Analog
2. Digital

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Types of Analog modulation:

1. Amplitude Modulation (AM)
2. Frequency Modulation (FM)
3. Phase Modulation (PM)

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Types of Digital modulation:

Types of modulation:

1. Analog
2. Digital

Types of Analog modulation:

1. Amplitude Modulation (AM)
2. Frequency Modulation (FM)
3. Phase Modulation (PM)

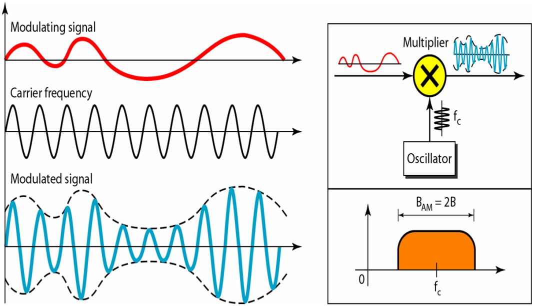
Types of Digital modulation:

1. Amplitude Shift Keying (ASK)
2. Frequency Shift Keying (FSK)
3. Phase Shift Keying (PSK)
4. Quadrature Amplitude Modulation(QAM)

# Amplitude Modulation:

## Amplitude Modulation:

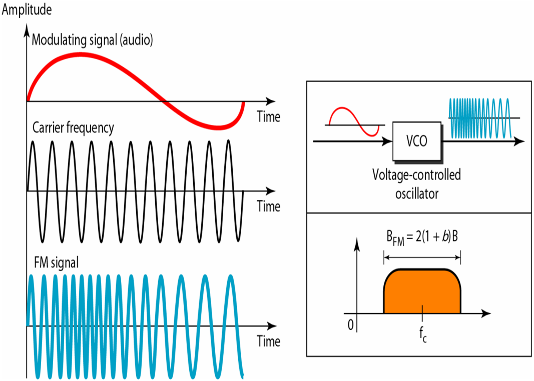
- The amplitude of the carrier signal is varied in accordance with message signal.
- The required bandwidth is 2B, where B is the bandwidth of the modulating signal
- Since on both sides of the carrier freq. fc, the spectrum is identical, we can discard one half, thus requiring a smaller bandwidth for transmission.



# Frequency Modulation:

## Frequency Modulation:

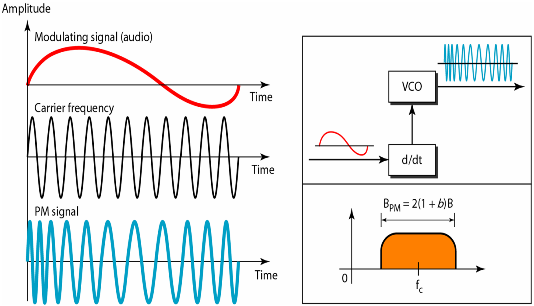
- The frequency of the carrier signal is varied in accordance with message signal.
- The bandwidth for FM is high, it is approximately 10 times of the signal frequency.



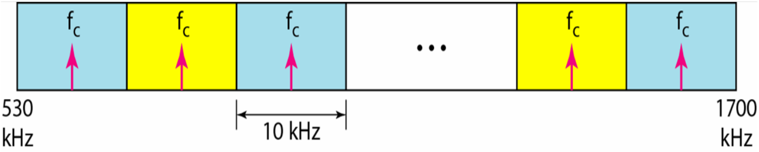
# Phase Modulation:

# Phase Modulation:

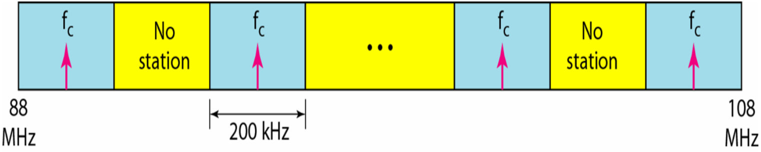
- The Phase of the carrier signal is varied in accordance with message signal.
- The phase change manifests itself as a frequency change but the instantaneous frequency change is proportional to the derivative of the amplitude.
- The bandwidth is higher than for AM.



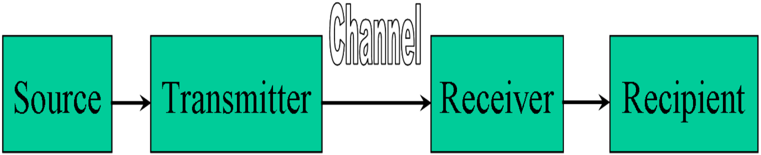
## AM band allocation




## FM band allocation

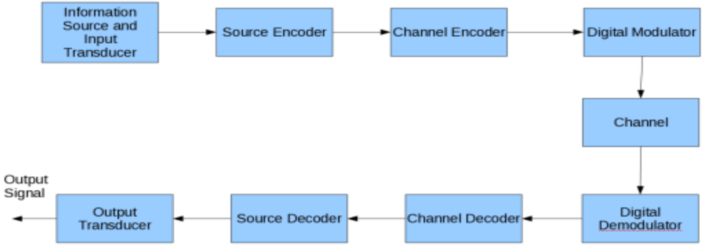


## Elements of a Communication System:




- Source: Analog or Digital
- Transmitter: transducer, amplifier, modulator, oscillator,power amp., antenna
- Channel: e.g. cable, optical fibre, free space
- Receiver: antenna, amplifier, demodulator, oscillator, power amplifier, transducer
- Recipient: e.g. person, speaker, computer

# Elements of a Communication System:




Basic elements of Digital Communication System

Types of information (Sources):

- Voice, data, video, music, email etc.

Types of communication systems :

- Public Switched Telephone Network (voice,fax,modem) Satellite systems Radio, TV broadcasting Cellular phones Computer networks (LANs, WANs, WLANs)

# Elements of a Communication System:

**Formatting**
- Character coding
- Sampling
- Quantization
- Pulse code modulation (PCM)

**Source Coding**
- Predictive coding
- Block coding
- Variable length coding
- Synthesis/analysis coding
- Lossless compression
- Lossy compression

**Baseband Signaling**
- PCM waveforms (line codes)
  - Nonreturn-to-zero (NRZ)
  - Return-to-zero (RZ)
  - Phase encoded
  - Multilevel binary
- *M*-ary pulse modulation
  - PAM, PPM, PDM

**Equalization**
- Maximum-likelihood sequence estimation (MLSE)
- Equalization with filters
  - Transversal or decision feedback
  - Preset or Adaptive
  - Symbol spaced or fractionally spaced

**Bandpass Signaling**

Coherent
- Phase shift keying (PSK)
- Frequency shift keying (FSK)
- Amplitude shift keying (ASK)
- Continuous phase modulation (CPM)
- Hybrids

Noncoherent
- Differential phase shift keying (DPSK)
- Frequency shift keying (FSK)
- Amplitude shift keying (ASK)
- Continuous phase modulation (CPM)
- Hybrids

**Channel Coding**

Waveform
- *M*-ary signaling
- Antipodal
- Orthogonal
- Trellis-coded modulation

Structured Sequences
- Block
- Convolutional
- Turbo

**Synchronization**
- Frequency synchronization
- Phase synchronization
- Symbol synchronization
- Frame synchronization
- Network synchronization

**Multiplexing/Multiple Access**
- Frequency division (FDM/FDMA)
- Time division (TDM/TDMA)
- Code division (CDM/CDMA)
- Space division (SDMA)
- Polarization division (PDMA)

**Spreading**
- Direct sequencing (DS)
- Frequency hopping (FH)
- Time hopping (TH)
- Hybrids

**Encryption**
- Block
- Data stream

**Figure 1.3** Basic digital communication transformations.

## Why Digital Communications ?:

- Digital techniques need to distinguish between discrete symbols allowing regeneration versus amplification
- Good processing techniques are available for digital signals:
  - Data compression (or source coding)
  - Error Correction (or channel coding) (A/D conversion)
  - Equalization
  - Security
- Easy to mix signals and data using digital techniques
- Easy to regenerate the distorted signal:
  - Regenerative repeaters along the transmission path can detect a digital signal and retransmit a new, clean (noise free) signal
  - These repeaters prevent accumulation of noise along the path
  - This is not possible with analog communication systems
  - Two-state signal representation

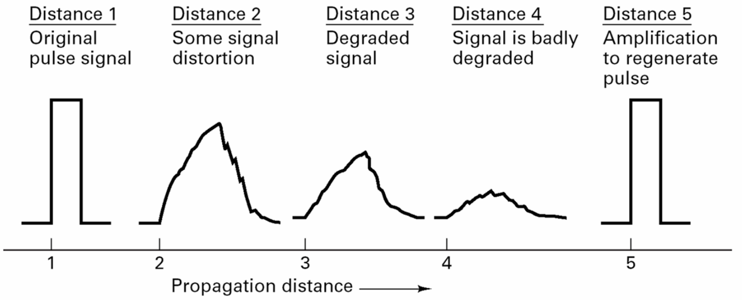



**Figure 1.1** Pulse degradation and regeneration.

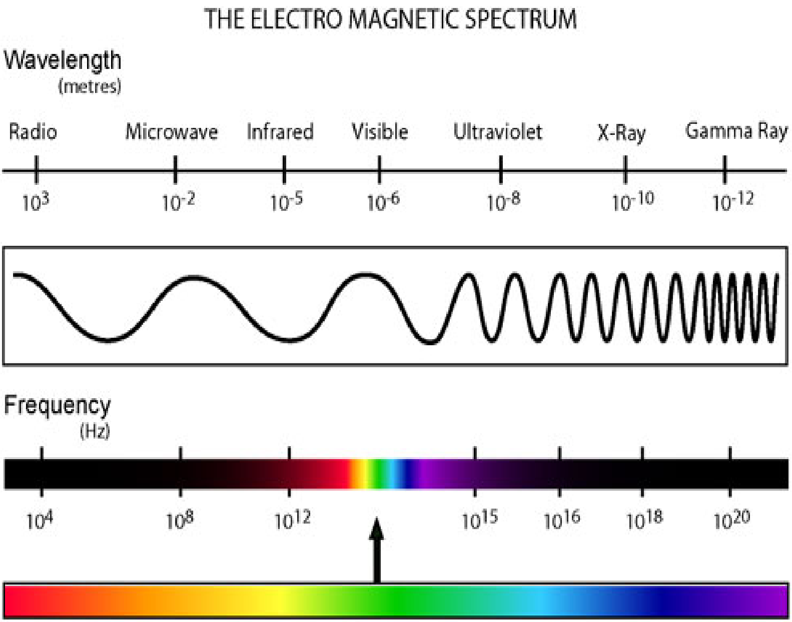
- The input to a digital system is in the form of a sequence of bits (binary or M-ary)
  - Immunity to distortion and interference
  - Digital communication is rugged in the sense that it is more immune to channel noise and distortion

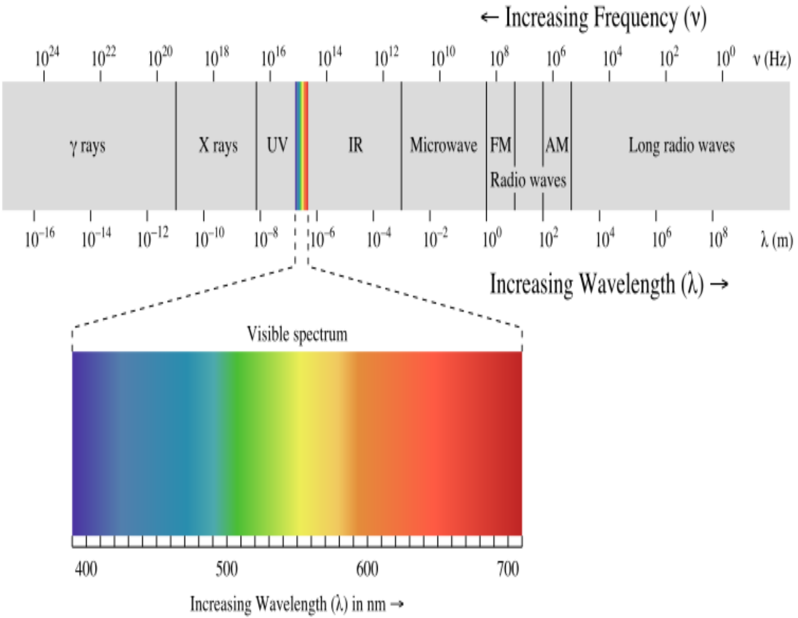
- Hardware is more flexible.
  - Digital hardware implementation is flexible and permits the use of microprocessors, mini-processors, digital switching and VLSI
- Shorter design and production cycle.
- The use of LSI and VLSI in the design of components and systems have resulted in lower cost.
  - Easier and more efficient to multiplex several digital signals
  - Digital multiplexing techniques: Time and Code Division Multiple Access - are easier to implement than analog techniques such as Frequency Division Multiple Access

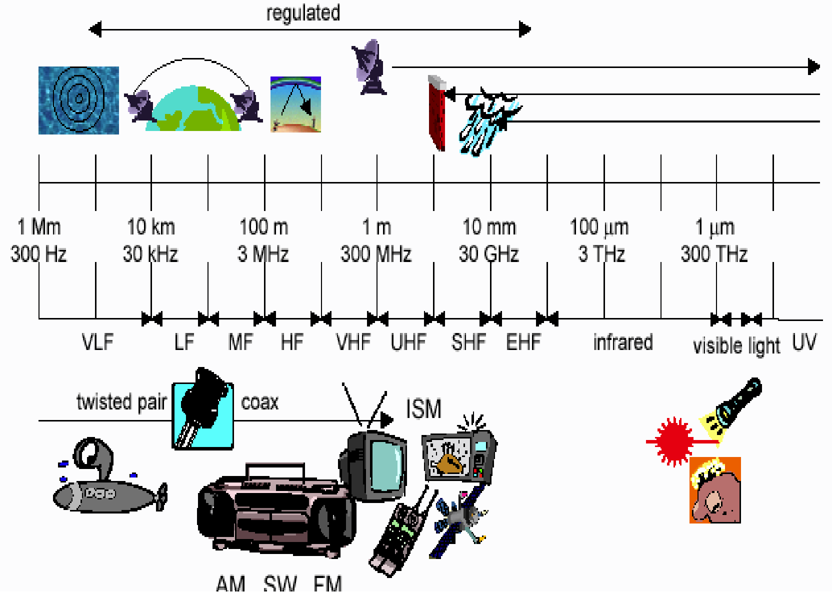
- Multiplexing:
  - Can combine different signal types  data, voice, text, etc
  - Data communication in computers is digital in nature whereas voice communication between people is analog in nature
  - The two types of communication are difficult to combine over the same medium in the analog domain.
  - Using digital techniques, it is possible to combine both format for transmission through a common medium
- Encryption and privacy techniques are easier to implement:
  - Better overall performance
  - Digital communication is inherently more efficient than analog in realizing the exchange of SNR for bandwidth
  - Digital signals can be coded to yield extremely low rates and high fidelity as well as privacy

## Electromagnetic Spectrum

| BAND | Frequency | Wavelength |
|---|---|---|
| ELF Extremely low frequency | 3Hz to 30Hz | 100,000km to 10,000 km |
| SLF Super low frequency | 30Hz to 300Hz | 10,000km to 1'000km |
| ULF Ultra low frequency | 300Hz to 3000Hz | 1,000km to 100km |
| VLF Very low frequency | 3kHz to 30kHz | 100km to 10km |
| LF Low frequency | 30kHz to 300kHz | 10km to 1km |
| MF Medium frequency | 300kHz to 3000kHz | 1km to 100m |
| HF High frequency | 3MHz to 30MHz | 100m to 10m |
| VHF Very high frequency | 3MHz to 30MHz | 100m to 10m |
| VHF Very high frequency | 30MHz to 300MHz | 10m to 1m |
| UHF Ultrahigh frequency | 300MHz to 3000MHz | 1m to 10cm |
| SHF Super high frequency | 3GHz to 30GHz | 10cm to 1cm |
| EHF Extremely high frequency | 30GHz to 300GHz | 1cm to 1mm |

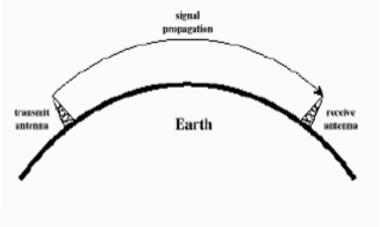

THE ELECTRO MAGNETIC SPECTRUM
Wavelength
(metres)
Radio
Microwave
Infrared
Visible
Ultraviolet
X-Ray
Gamma Ray
10^3
10^-2
10^-5
10^-6
10^-8
10^-10
10^-12
Frequency
(Hz)
10^4
10^8
10^12
10^15
10^16
10^18
10^20


← Increasing Frequency (ν)
$10^{24}$ $10^{22}$ $10^{20}$ $10^{18}$ $10^{16}$ $10^{14}$ $10^{12}$ $10^{10}$ $10^{8}$ $10^{6}$ $10^{4}$ $10^{2}$ $10^{0}$ ν (Hz)
γ rays
X rays
UV
IR
Microwave
FM
AM
Radio waves
Long radio waves
$10^{-16}$ $10^{-14}$ $10^{-12}$ $10^{-10}$ $10^{-8}$ $10^{-6}$ $10^{-4}$ $10^{-2}$ $10^{0}$ $10^{2}$ $10^{4}$ $10^{6}$ $10^{8}$ λ (m)
Increasing Wavelength (λ) →
Visible spectrum
400
500
600
700
Increasing Wavelength (λ) in nm →

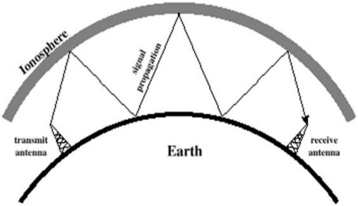

regulated
1 Mm
300 Hz
10 km
30 kHz
100 m
3 MHz
1 m
300 MHz
10 mm
30 GHz
100 μm
3 THz
1 μm
300 THz
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
infrared
visible light
UV
twisted pair
coax
ISM
AM SW FM

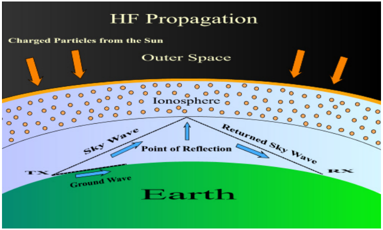
Radio Wave Propagation Modes:

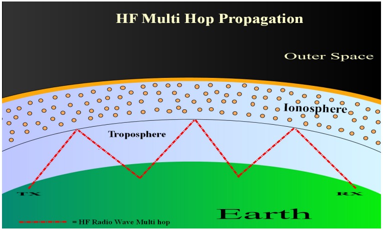
- Ground Wave Propagation: Follows contour of the earth.
- Can Propagate considerable distances
- Frequencies up to 2 MHz Example : AM radio

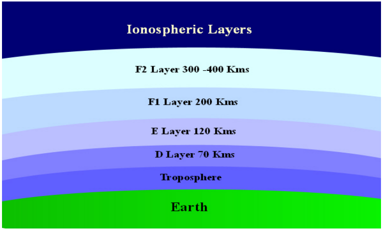


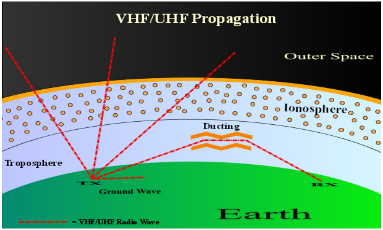
- Sky Wave Propagation: Signal reflected from ionized layer of atmosphere.
- Signal can travel a number of hops, back and forth between ionosphere and earths surface. Example: SW radio, Amateur radio




HF Propagation
Charged Particles from the Sun
Outer Space
Ionosphere
Sky Wave
Point of Reflection
Returned Sky Wave
TX
RX
Ground Wave
Earth


HF Multi Hop Propagation
Outer Space
Ionosphere
Troposphere
TX
RX
Earth
= HF Radio Wave Multi hop


Ionospheric Layers
F2 Layer 300 -400 Kms
F1 Layer 200 Kms
E Layer 120 Kms
D Layer 70 Kms
Troposphere
Earth


VHF/UHF Propagation
Outer Space
Ionosphere
Ducting
Troposphere
TX
Ground Wave
RX
Earth
= VHF/UHF Radio Wave

- Line-of-Sight Propagation: Transmitting and receiving antennas must be within line of sight. Example: Satellite communication, Ground communication