PHY 359 2.0 / ASP 487 2.0 Telecommunication

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Course Content

1. Introduction to Telecommunication Systems.

- Historical developments and current trends.
- Radio frequency spectrum and their application.

2. Signals and signal space.

- Continuous and discrete-time sinusoidal signal,
- Discrete-time unit step and unit impulse sequence, delayed unit impulses, Unit impulse function.
- Definition of a system, Interconnection of two systems in cascade and parallel, Feedback interconnection of two systems.
- convolution integral, Linear time-invariant system.
- Signal flow chart.

3. Elementary concepts in Telecommunications

- Types of communication channels.
- Analog filter design, Oscillator circuits.
- Bandwidth and filtering, Types of noise.
- Signal-to-noise ratio (SNR equation),
- Analog Modulation theory(AM, FM),
- Phase modulation.

Course Content

4. Transmission.

- Guided and unguided transmission.
- Multiplexing, Transmission networks, and Multiplexing hierarchies for high-speed communication networks.

5. Telecommunication Devices.

- Simple transmitter and Receiver circuits.
- The radio receiver and transmitter.
- The TV receiver, Modems, and Cellular phones.

6. Antenna theory and Signal propagation.

- Types of antenna, Antenna design, Gain, and radiation pattern.

7. Transmission line.

- Types of transmission line(coaxial cables, twisted pair).
- Lumped Parameters and Model of Transmission line theoretical and software base, Smith chart.

Course Content

8. Broadcasting Systems.

- Basic concepts of broadcasting, television, and radio broadcasting networks.

9. Satellite communication and terrestrial microwave communication.

- Free space and troposphere wave propagation, satellite services, and applications of terrestrial microwave communication.

10. Digital Communication

- ASK modulation
- FSK modulation
- PSK modulation, etc…

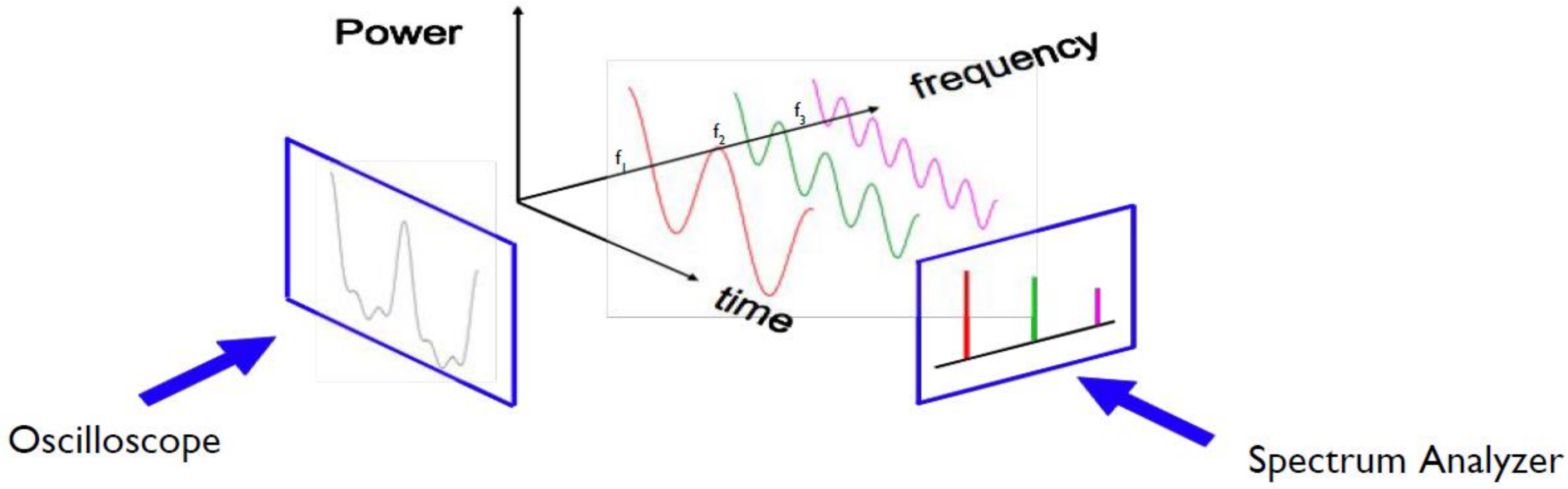
Introduction to Telecommunication Systems.

Radio Electronics
RF Technology

Prerequisites Basics Concepts

- Fourier Series – Approximating a periodic function using a trigonometric series
- Fourier Transform – Converting a time domain function to frequency domain

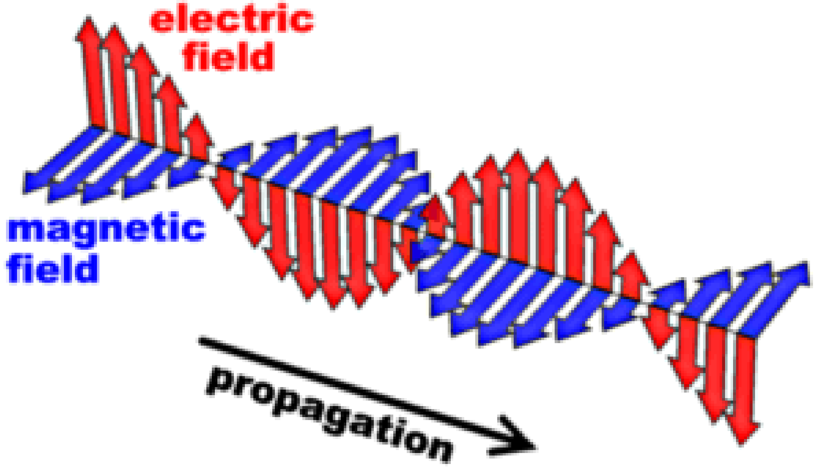
$$X(f) = \int_{-\infty}^{+\infty} x(t)e^{-j2\pi ft}\,dt$$



Introduction

What is Radio Frequency (RF) Technology?

- Using electro-magnetic waves between 1MHz – 300GHz mainly for information exchange *(Common convention - 1MHz-1GHz: RF, 1-30GHz: Microwave region & 30-300GHz: Millimeter-wave region)*
- Electro-magnetic waves propagate at the speed of light 3 x10^8 m/s
- The electric & magnetic fields of a plane wave oscillate in phase & are perpendicular to each other and also to the direction of propagation



Why use RF Technology?

- Relationship between frequency & wavelength

  $f = C / \lambda$

- Antennas radiate efficiently when their size is comparable to the signal's wavelength
- If we use low frequency signals large antennas would be needed

  Example:

  f=100kHz & since $C=3 \times 10^8$m/s

  $\lambda = 3000$m = 3km

  An antenna as large as a fraction of 3km would be needed!

- Also electromagnetic waves can be considered as oscillating particles of insignificant mass, giving the energy of these photons as

  $W = hf$ ($h = 6.6256 \times 10^{-34}$Js, is the Planck constant)

- Therefore higher the frequency higher the energy

Where do we use RF Technology?

Television

Radio

Microwave Oven

Satellite

Radio Astronomy

GPS

Remote Keys

MRI Scanner

Cordless Phone

Mobile Phone

History of RF Technology

- James Clerk Maxwell predicted the existence of electromagnetic waves and came up with “Maxwell’s Equations”
- Heinrich Hertz experimentally proved the existence of radio waves and verified Maxwell’s equations
- Guglielmo Marconi was the first to use radio waves for communication purposes. Marconi’s wireless telegraph sent the letter “S” in Morse code across the Atlantic ocean (distance over 3000km)
- Alexander Popov also did experiments around the same time as Marconi
- John Ambrose Fleming invented the rectifying vacuum tube, the diode, to which a third electrode was later added, by Lee De Forest to form the triode. The grid controlled the current and made amplification possible.

History of RF Technology.

- De Forest and Edwin Armstrong independently discovered regenerative feedback, the phenomenon used to produce a continuous carrier wave, which could be modulated by a voice signal
- Armstrong also invented the super-hetrodyne receiver making broadcasting possible
- AM stations stared in 1919 & regular TV transmission in 1935
- Armstrong next invented the FM radio which was not accepted till World War II

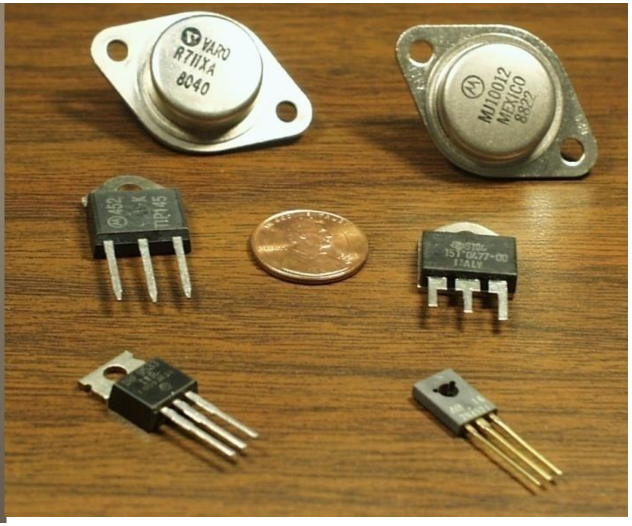
History of RF Technology..

- Karl Jansky, studying radio noise, detetcted a steady hiss from our own galaxy, which was the beginning of radio astronomy
- The principle of radar was introduced by Christian Hu¨lsmeyer, long before but was only developed during world war II
- The Radiation Laboratory, established at Massachusetts Institute of Technology during World War II, developed radar, radio-navigation, microwave components, microwave theory, electronics & education in the field

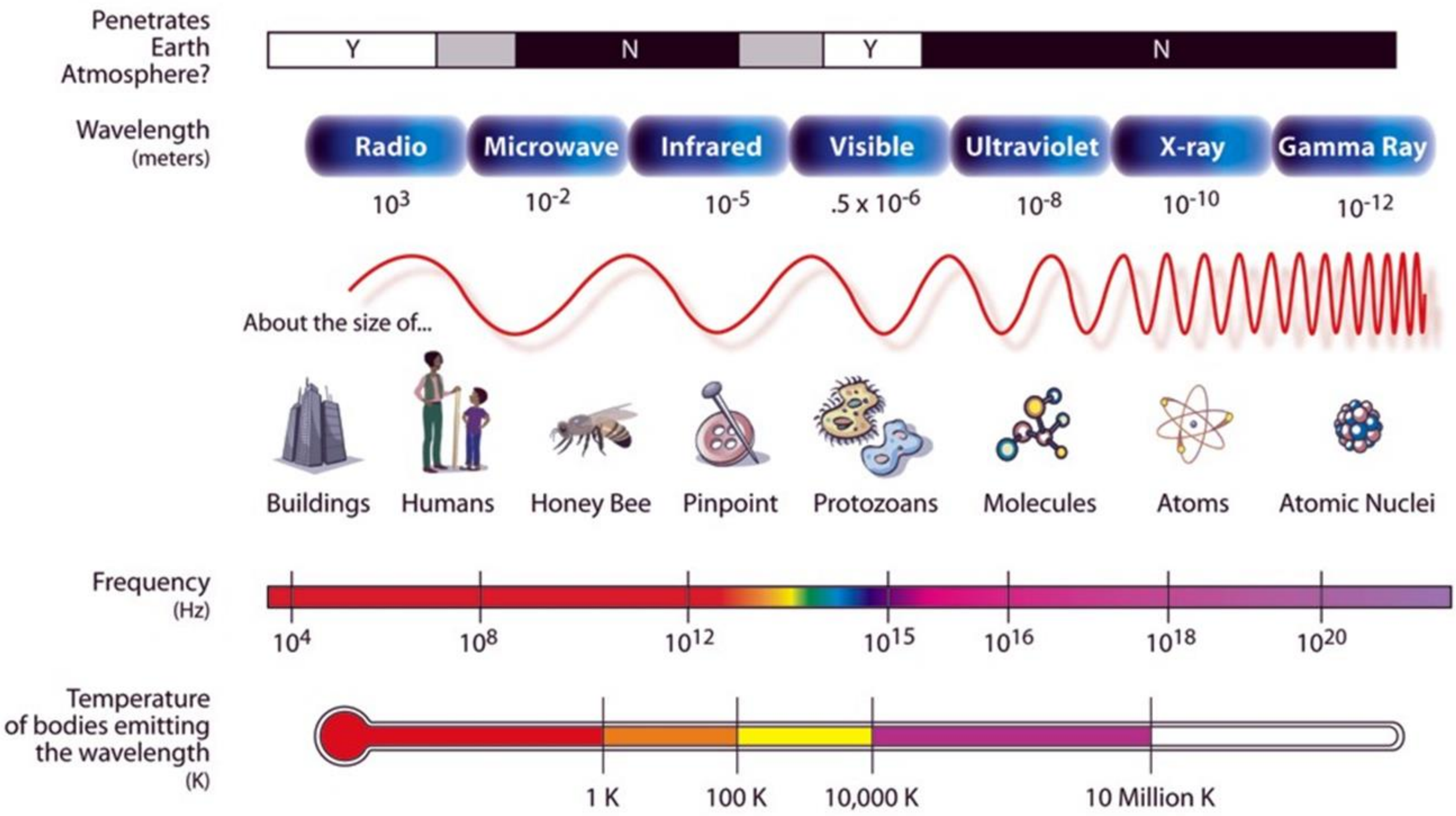
History of RF Technology..

- Bardeen, Brattain, and Shockley invented the transistor, leading to a new era in radio frequency electronics

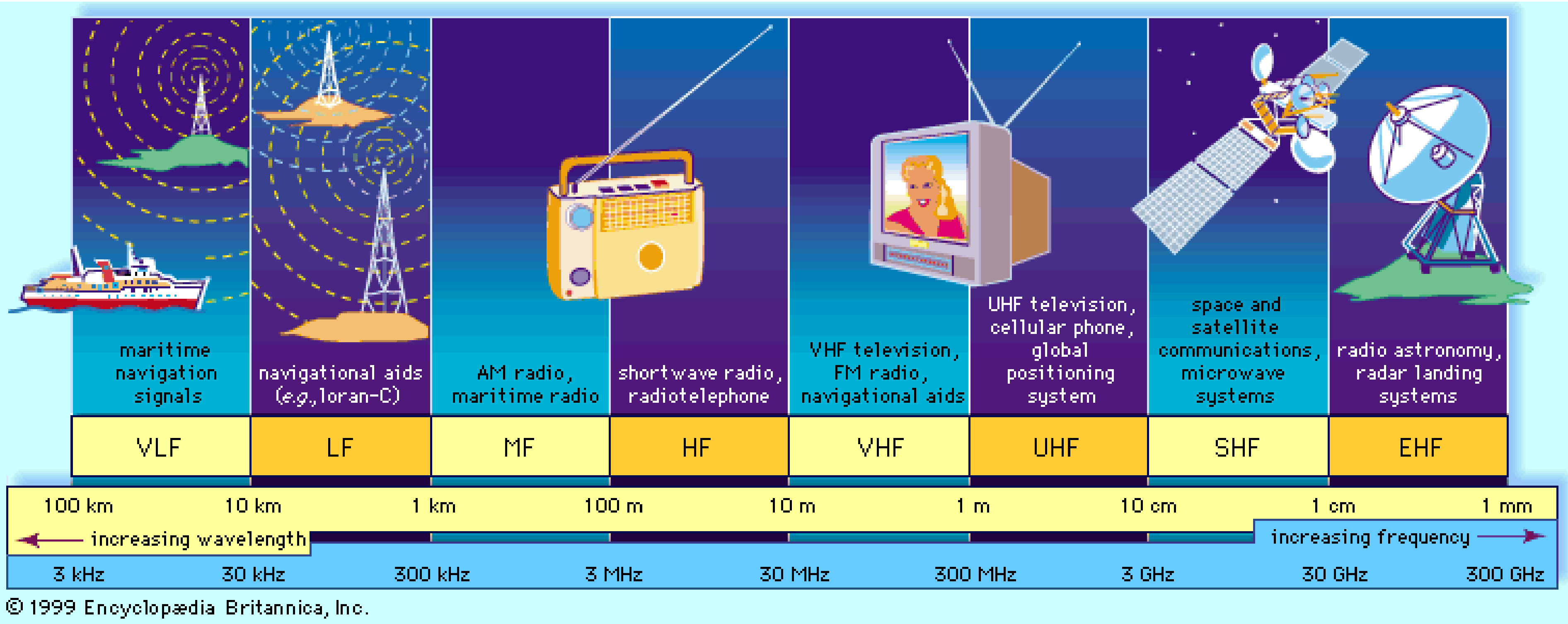
- Transistors replaced the bulky vacuum tubes to produce much smaller appliances



Electro Magnetic Spectrum



Frequency Spectrum…



Frequency Bands

Band	Frequency	Wavelength
Extremely Low Frequency (ELF)	< 3 kHz	> 100 km
Very Low Frequency (VLF)	3 – 30 kHz	10 – 100 km
Low Frequency (LF)	30 – 300 kHz	1 -10 km
Medium Frequency (MF)	300 kHz – 3 MHz	100 m -1 km
High Frequency (HF)	3 – 30 MHz	10 -100 m
Very High Frequency (VHF)	30 – 300 MHz	1 – 10 m
Ultra-High Frequency (UHF)	300 MHz – 3 GHz	10 cm – 1 m
Super-High Frequency (SHF)	3 – 30 GHz	1 – 10 cm
Extra-High Frequency (EHF)	30 – 300 GHz	0.1 – 1cm

Microwave Frequencies

Band	Frequency	Band	Frequency
L	1 – 2 GHz	Ku	12.4 – 18 GHz
S	2 – 4 GHz	K	18 – 26.5 GHz
C	4 – 8 GHz	Ka	26.5 – 40 GHz
X	8 –12.4 GHz		

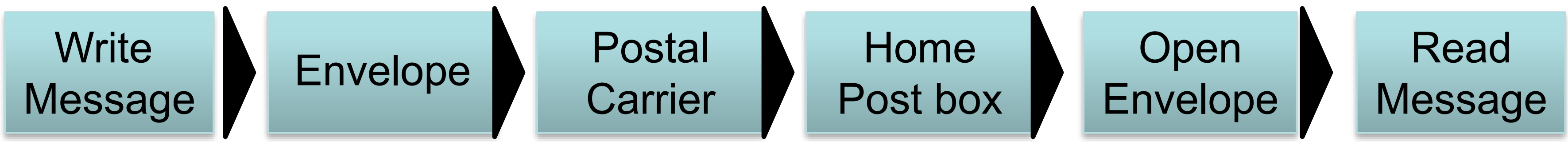
Allocation of Radio Frequencies

- Radio waves have many applications and many users, and harmful interference will occur if signals can be transmitted at free will!
- Internationally, the radio spectrum is regulated by the **I**nternational **T**elecommunications **U**nion (**ITU**)
- Locally the allocation of frequencies is controlled by the **T**elecommunications **R**egulatory **C**ommission (**TRC**)
- Additionally all radio and other electrical equipment must comply with the electromagnetic compatibility (EMC) requirements and standards to assure interference-free operation

RF Communication

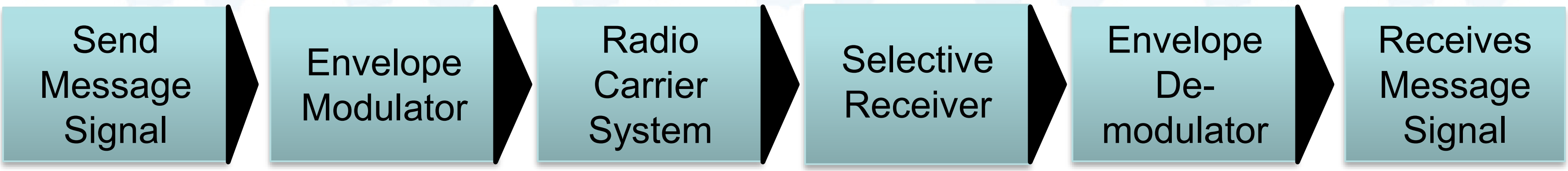
Overview of a RF Communication System

- Using the simple postal system to send a message:



- Compare with a radio system:

Overview of a RF Communication System..



- Message signal can be voice, video, data etc.
- Modulator circuits envelope the message signal for transmission purposes
- RF carrier with an enveloped message, known as a modulated wave, is used to transmit over long distances
- Demodulators recover the enveloped carrier wave when it arrives at its destination
- Selective or tuned circuits select the correct messages for a particular receiver

Overview of a RF Communication System..

Send Message Signal → Envelope Modulator → Radio Carrier System → Selective Receiver → Envelope De-modulator → Receives Message Signal

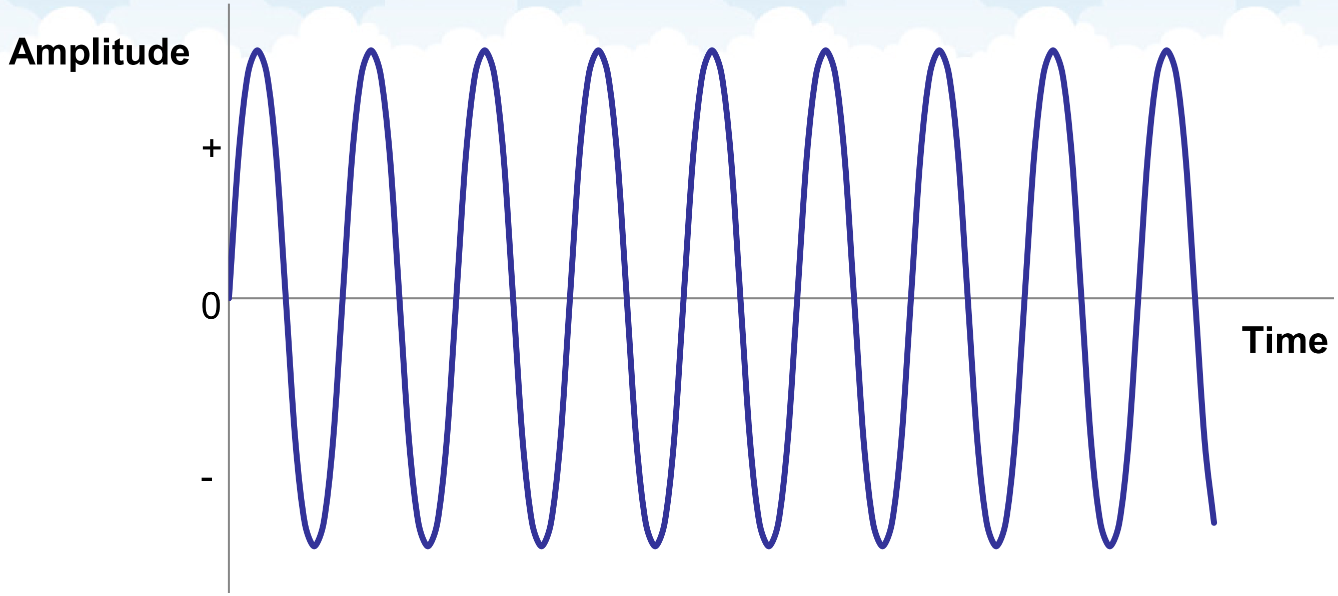
- Amplifiers ensure that signals sent and received have sufficient amplitudes to operate message reading devices such as a loudspeaker and/or a video screen
- Transmitting antenna ensures the signal is transmitted
- Receiving antenna collects only the desired signals selectively

Transmission and Reception

Modulation and Demodulation

- Modulation is the process of converting a message signal to a transmittable form, by varying some characteristic of a carrier signal
- Demodulation information system at the receiving end must be compatible with the modulation information system at the transmitter
- Modulation and demodulation techniques should be compatible

RF Carrier Signal



$$c(t) = A_c \cos(\omega_c t + \Phi_c)$$

$c(t)$ = instantaneous carrier amplitude (volts)
A_c = carrier amplitude (peak volts)
ω_c = angular frequency in radians and $\omega_c = 2\pi f_c$
f_c = carrier frequency (hertz)
Φ_c = carrier phase delay (radians)

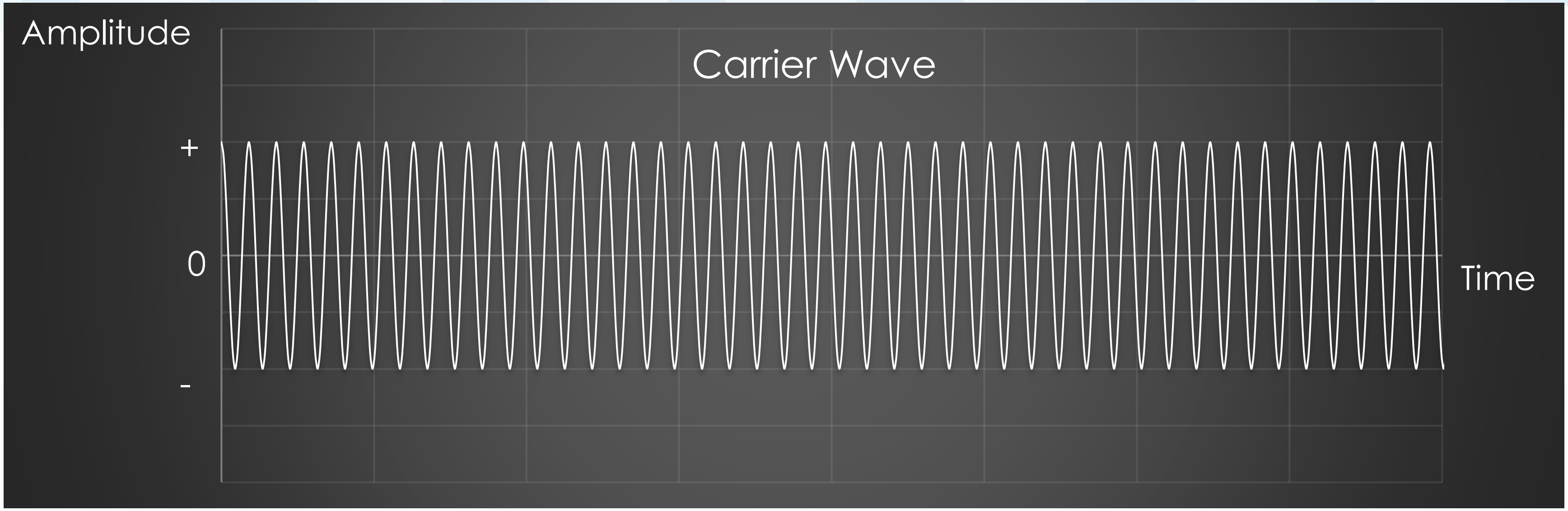
Modulation Techniques

- Sinusoidal wave serves as radio carrier wave
- Message signal must be modulated on the sinusoidal wave

Amplitude Modulation	• Changing carrier wave amplitude
Frequency Modulation	• Changing carrier wave frequency
Phase Modulation	• Changing carrier wave phase

- Combination of above techniques can be used, which is preferred by digital modulation

Carrier Wave



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f_c = carrier frequency (hertz)
Φ_c = carrier phase delay (radians)

Amplitude Modulation

- Amplitude Modulation (AM) is used in short and medium wave radio transmission
- AM is varying the amplitude of a carrier wave, c(t), about a mean value, linearly with the baseband (message) signal, m(t)
- Carrier wave is given by:

$$c(t) = A_c \cos(\omega_c t + \Phi_c)$$

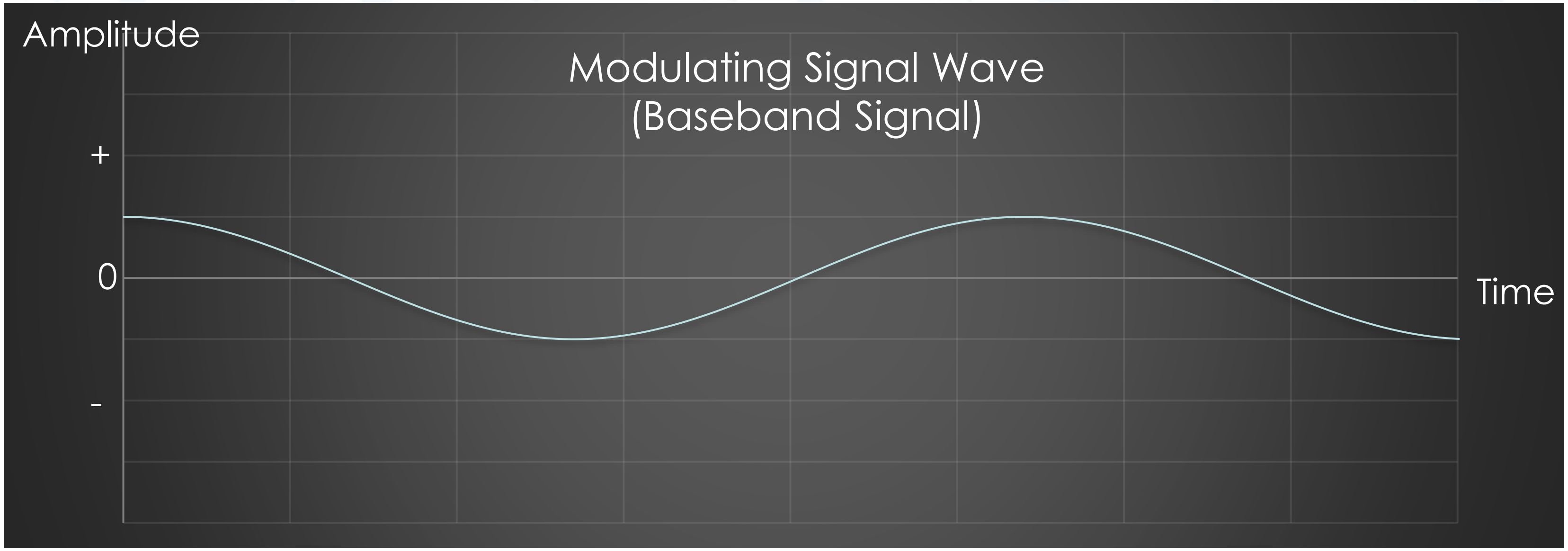
- AM modulated wave is given by:

$$s(t) = A_c[1+k_a m(t)] \cos(\omega_c t + \Phi_c)$$

- k_a is the amplitude sensitivity of the modulator
- For simplicity:

$$s(t) = A_c[1+m(t)] \cos(\omega_c t)$$

A Simple Baseband Signal



$$m(t) = A_m \cos(\omega_m t)$$

$m(t)$ = instantaneous modulating amplitude (volts)
A_m = modulating amplitude (peak volts)
ω_m = angular frequency in radians and $\omega_m = 2\pi f_m$
f_m = modulating frequency (hertz)

Amplitude Modulation..

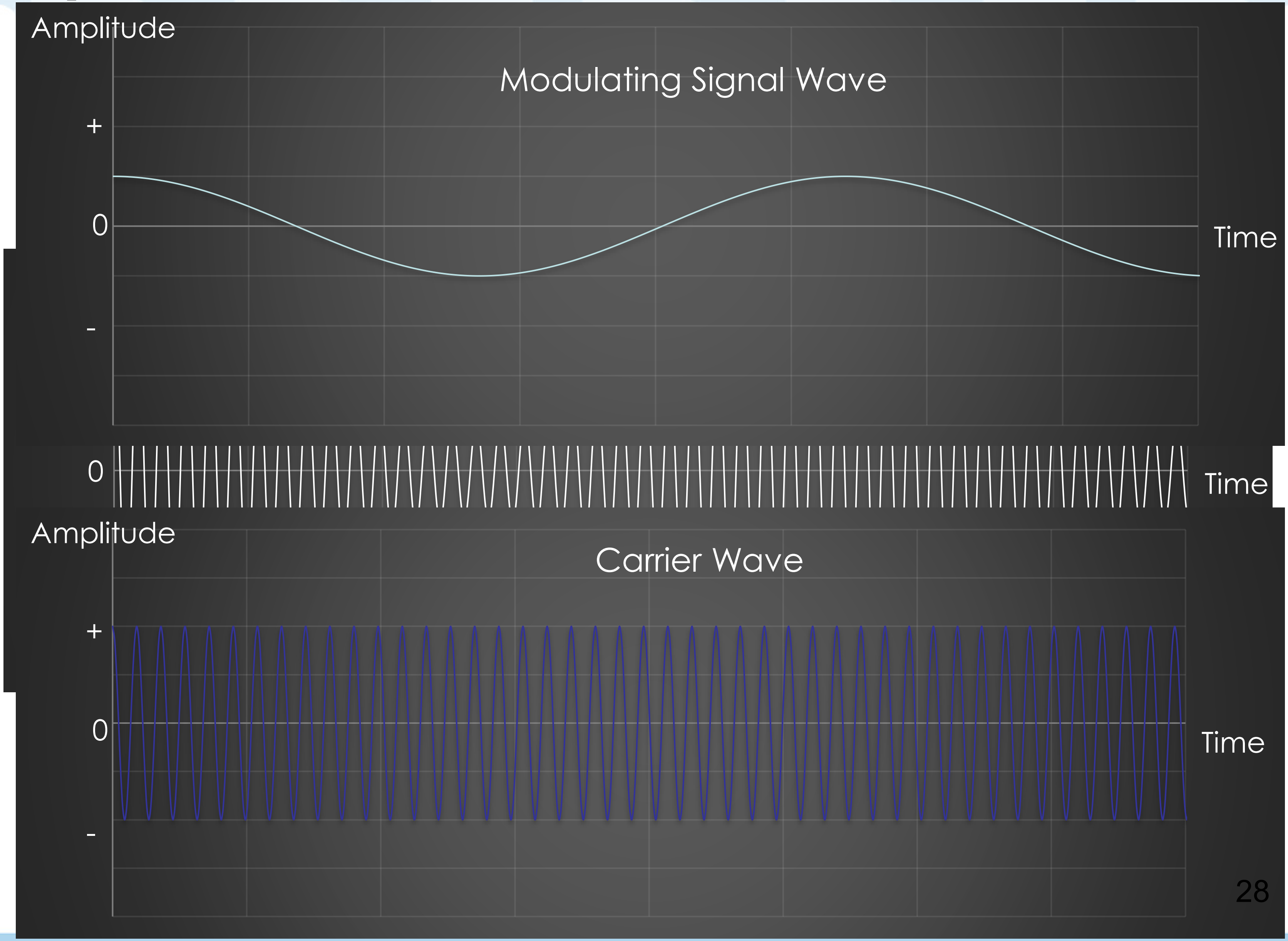
- Amplitude of carrier is made to vary about A_c by the message signal m(t)

$$m(t) = A_m \cos(\omega_m t)$$

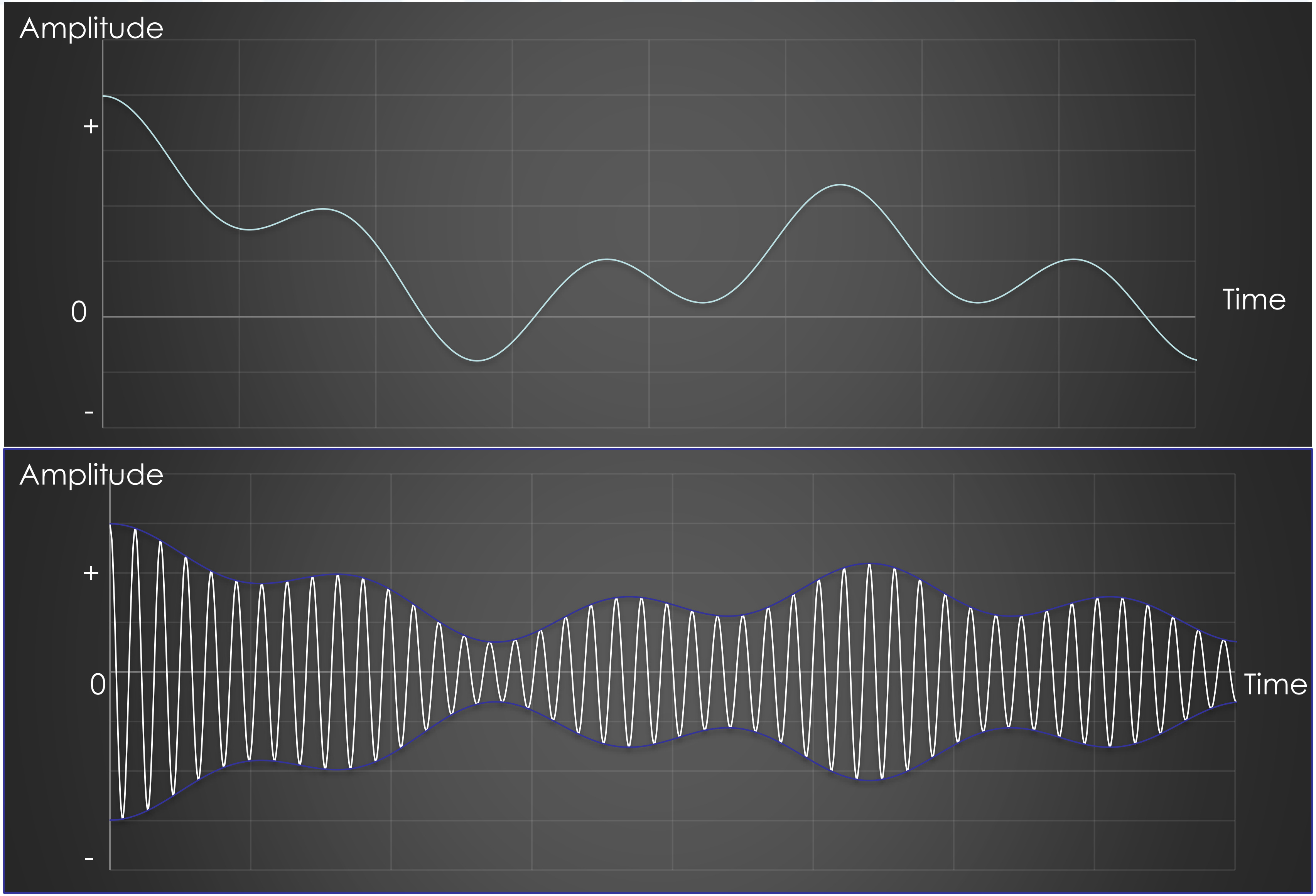
- Modulated signal becomes:

$$s(t) = A_c[1+m(t)] \cos(\omega_c t)$$
$$s(t) = A_c[1+A_m \cos(\omega_m t)] \cos(\omega_c t)$$

Amplitude Modulation..

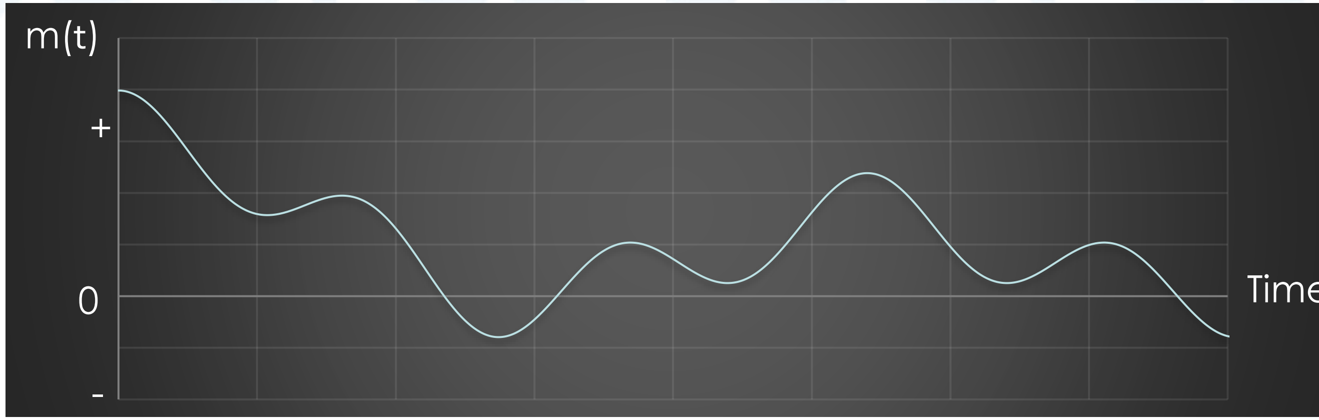


A Realistic Baseband Signal



Frequency Domain Representation

Time Domain



Fourier Transform

Frequency Domain