Chapter 1

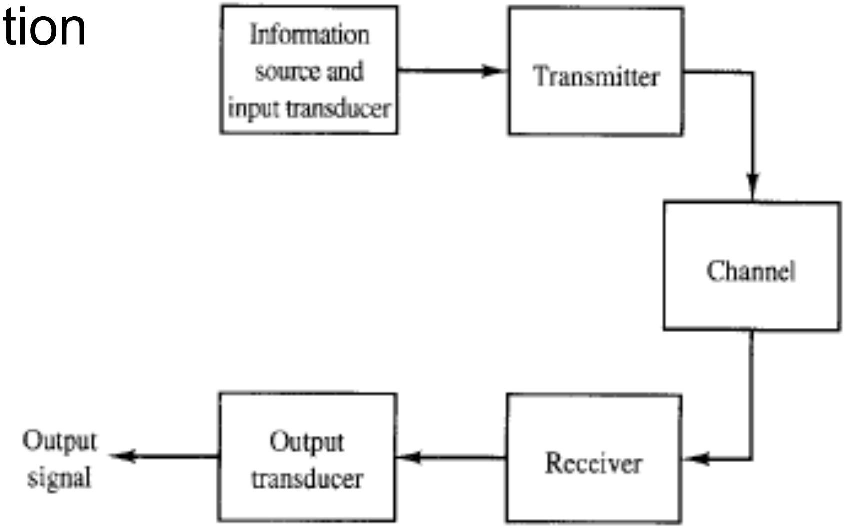
Introduction to Analog & Digital Communications

Outline

- Signals and Communication Systems
- Digital & Analog Sources & Systems
- Block Diagram of a Communication System
- Deterministic and Random Signals
- Frequency Allocations Frequency Allocations
- Review
  - Logarithmic Power Calculations

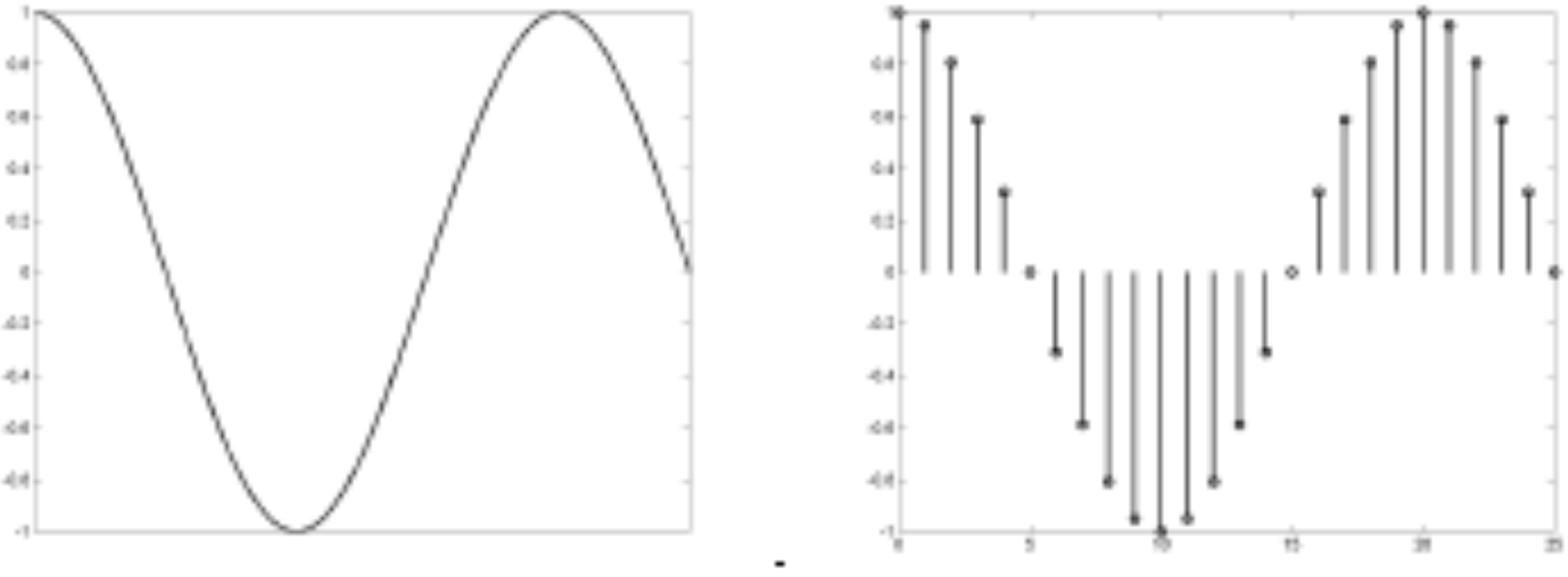
Communication Systems

- What is a signal?
  - a single-valued function of time that conveys information
- What is a communication system?
  - Enabling the process of transmitting meaningful signals from one location to another (e.g., Sender to Receiver over a communication channel)
- Key design issues of a communication system
  - Selection of the information-bearing waveform or signal
  - Bandwidth
  - Signal power and energy consumption
  - Probability of error
  - System noise and its impact
  - Data rate
  - As well as….
    - Cost of the system



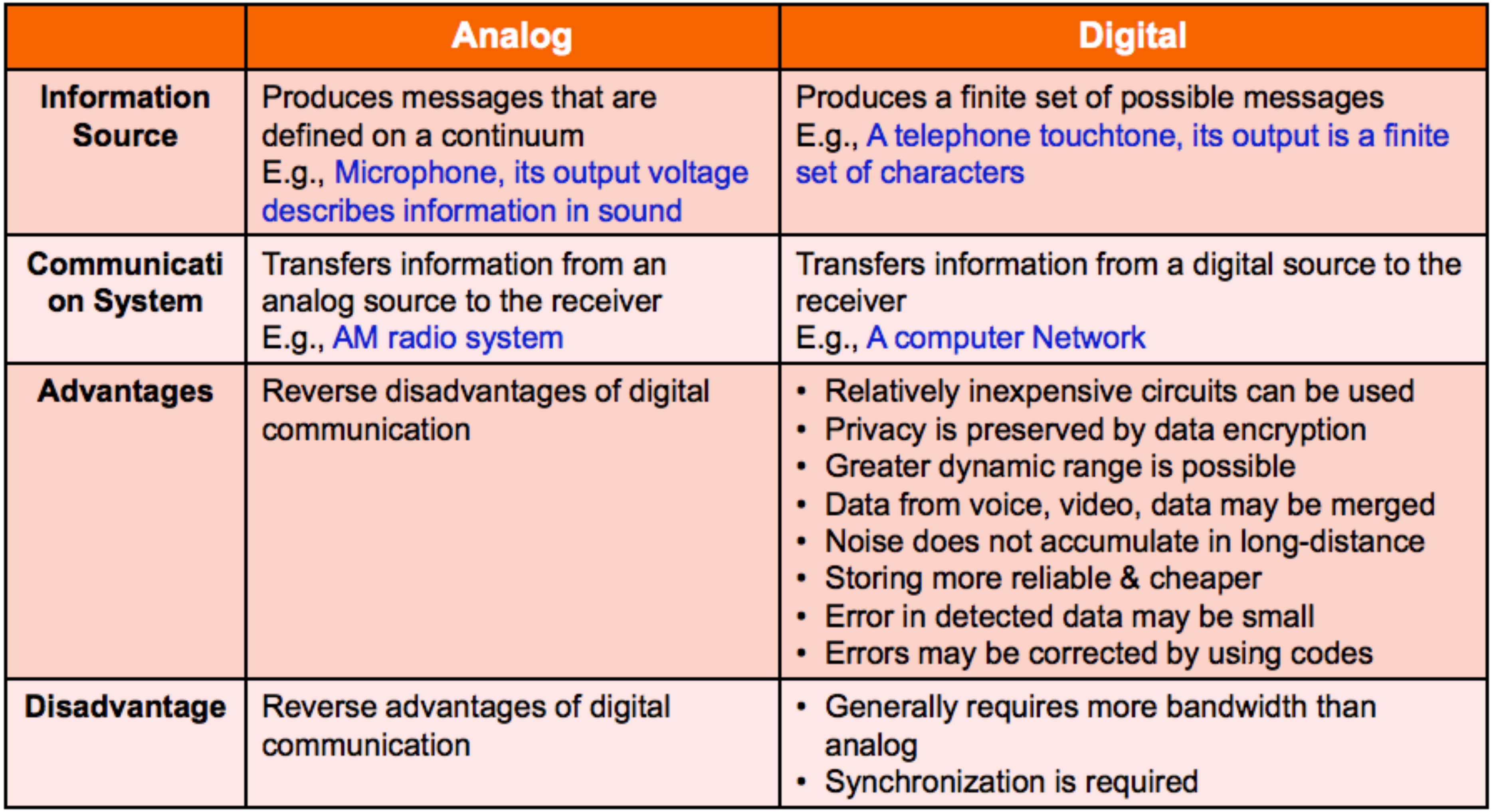
Digital Vs. Analog Signal

- **Analog** signal: continuous function of time with continuous amplitude
- **Discrete-time** signal: only defined at discrete points in time, amplitude continuous
- **Digital** signal: discrete in both time and amplitude (e.g., PCM signals,



Analog Vs. Digital Systems

- A quick comparison



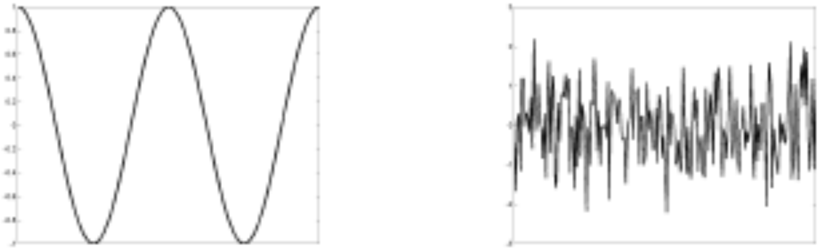
	Analog	Digital
Information Source	Produces messages that are defined on a continuum E.g., Microphone, its output voltage describes information in sound	Produces a finite set of possible messages E.g., A telephone touchtone, its output is a finite set of characters
Communication System	Transfers information from an analog source to the receiver E.g., AM radio system	Transfers information from a digital source to the receiver E.g., A computer Network
Advantages	Reverse disadvantages of digital communication	• Relatively inexpensive circuits can be used • Privacy is preserved by data encryption • Greater dynamic range is possible • Data from voice, video, data may be merged • Noise does not accumulate in long-distance • Storing more reliable & cheaper • Error in detected data may be small • Errors may be corrected by using codes
Disadvantage	Reverse advantages of digital communication	• Generally requires more bandwidth than analog • Synchronization is required

Deterministic Vs. Random Waveforms

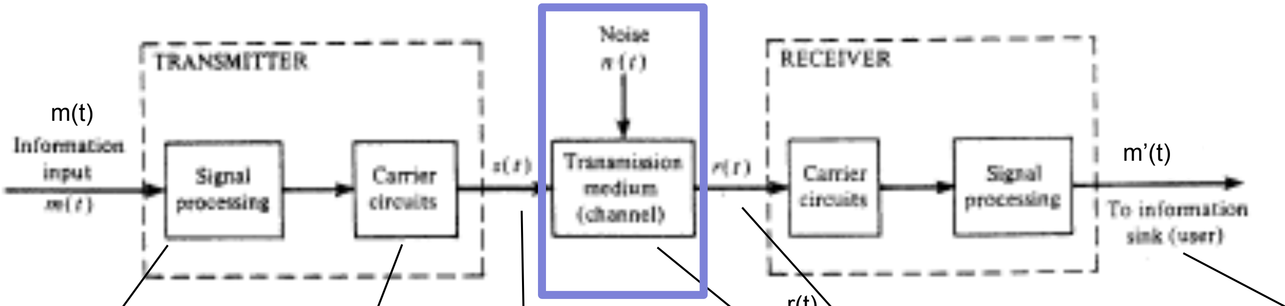
- Deterministic waveform can be modeled as a completely specified function of time, e.g., if

  $\omega(t) = A \cos(\omega_o t + \varphi)$, *where* A, ω_o, & φ, *are known constant,*

  describes a waveform, this waveform is deterministic because
  - for any t, the value of $\omega(t)$ can be evaluated.
- Random (or stochastic) waveform cannot be completely specified as a function of time & must be modeled probabilistically, e.g., noise is described by a random waveform.
- In this course we use a deterministic approach in analyzing communication systems without going to statistical analysis.



Communication System Block Diagram



Baseband Signals (fc=0)

- LPF
- ADC
- Baseband Processor
- Coding (parity for error detection)

- Baseband signal
- Adds carrier signal
- Also referred to as modulation

- Freq. band or Bandpass Signals (fc>>0) e.g., AM has fc=850 KHz

$$s(t) = R(t)\cos[\omega_c t + \theta(t)]$$

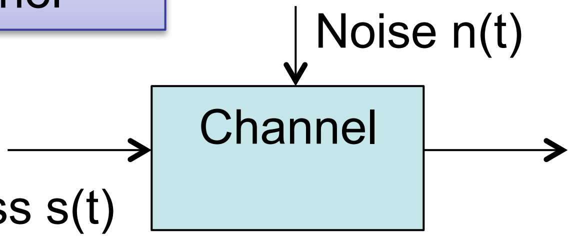
Guided or unguided

Corrupted signal due to noise!

Baseband Signals (fc=0)

Note that if phase =0 → pure sinusoid, with zero BW

Model for effect of noise can be additive Gaussian noise channel



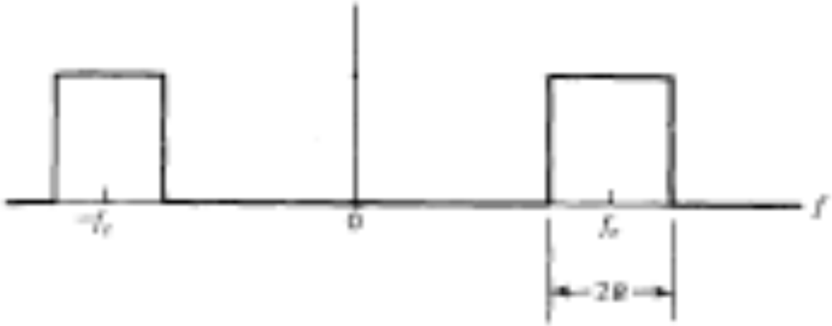
Bandpass s(t)

$r(t) = s(t) + n(t)$

Bandwidth

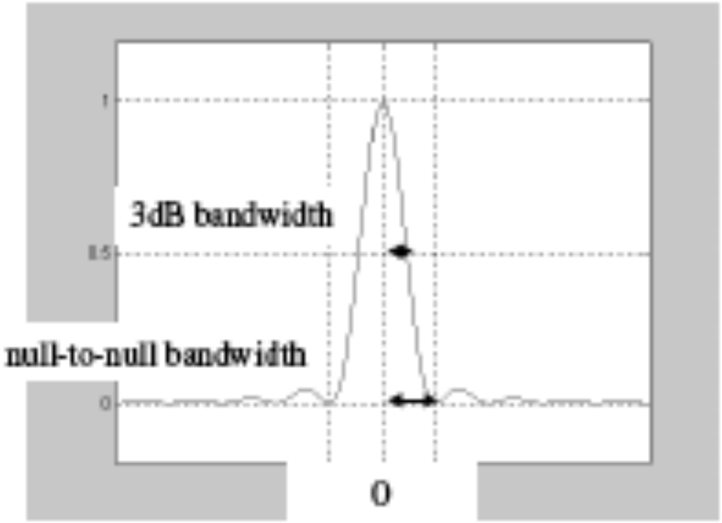
- Extent of the significant spectral content of a signal for positive frequencies

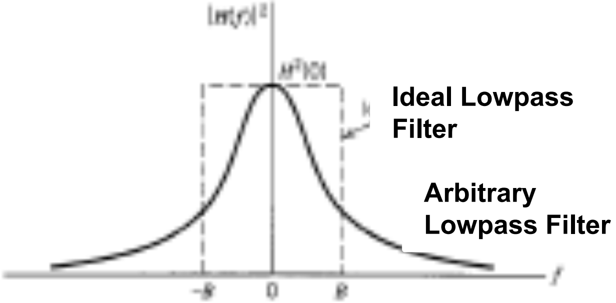
Baseband signal, B/W = B



Bandpass signal, B/W = $2B$

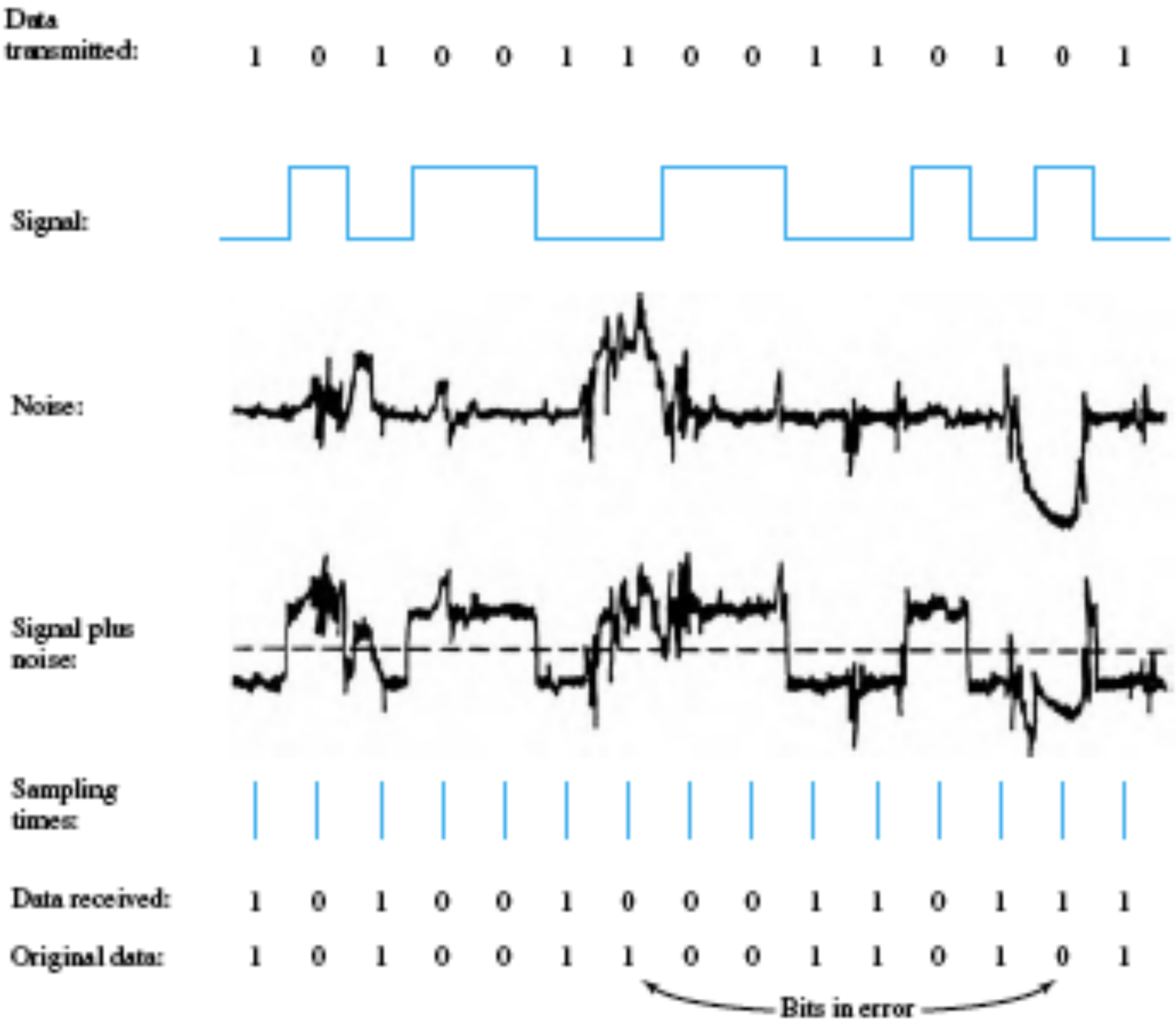
Magnitude-square spectrum





Noise Equivalent BW

Signal & Noise



Frequency Allocations

- Wireless communication uses the atmosphere for transmission channel.
- The interference & propagation conditions strongly depend on frequency.
- To provide some order & minimize the interference, ITU, an international standardization organization, has set frequency assignment & technical standards.
- The spectrum of EM frequencies are defined in terms of frequency bands for various communication applications, e.g., radio, TV, remote controls, cell phone, radar.

Frequency	Classification	Typical Uses
3 – 30 kHz	Very Low Frequencies (VLF)	Navigation & Submarine communication
30 – 300 kHz	Low Frequencies (LF)	Marine & long range navigation
300 – 3000 kHz	Medium Frequencies (MF)	AM broadcast & Maritime radio
3 – 30 MHz	High Frequencies (HF)	Amateur radio, SW radio, telephone, telegraph
30 – 300 MHz	Very High Frequencies (VHF)	VHF TV, FM & 2-way radio, aircraft comm.
0.3 – 3 GHz	Ultra High Frequencies (UHF)	UHF TV, cellular phone, GPS, radar, PCS
3 – 30 GHz	Super High Frequencies (SHF)	Satellite communication & microwave links
30 – 300 GHz	Extra High Frequencies (EHF)	Satellite, radar & remote sensing
10^3 – 10^7 GHz	Infrared, visible light, & UV	Optical communications

FCC = Federal Communications Commission, ITU = International Telecommunications Union, RF = Radio Frequency, EM = Electromagnetic

In US, FCC administers & regulates RF as

Frequency Allocations - Example

Example 1: What is the antenna length for an AM transmitter at 1 MHz?

Solution: At 1 MHz, $\lambda = \frac{c}{f_c} = \frac{3x10^8 m/s}{1x10^6} = 300m$

Note that for efficient radiation, the length of the antenna must be longer than 1/10 the wavelength → Antenna length = 30 m

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Review

Power in Telecommunication Systems – Power change can have large dynamic range

- Remember:

$$10^{x} = y \xrightarrow{then} \log(10^{x}) = \log y \xrightarrow{Hence} x = \log y$$

- Example 1: if P2=2mW and P1 = 1mW →

  $10\log_{10}(P2/P1)=3.01$ dB
- Example 2: if P2=1KW and P1=10W →20dB
- What if dB is given and you must find P2/P1?
  - P2/P1 = Antilog(dB/10) = $10^{dB/10}$.
- Example 3: if dB is +10 what is P2/P1?
  - P2/P1 = Antilog(+10/10) = $10^{+10/10}$ = 10

We tend to express power in dBW or dBm

Decibel values refer to relative magnitudes or changes in magnitude, not to an absolute level. It is convenient to be able to refer to an absolute level of power or voltage in decibels so that gains and losses with reference to an initial signal level may be calculated easily. The **dBW (decibel-Watt)** is used extensively in microwave applications. The value of 1 W is selected as a reference and defined to be 0 dBW. The absolute decibel level of power in dBW is defined as

$$\text{Power}_{\text{dBW}} = 10 \log \frac{\text{Power}_{\text{W}}}{1\ \text{W}}$$

EXAMPLE 3.9 A power of 1000 W is 30 dBW, and a power of 1 mW is −30 dBW.

Another common unit is the **dBm (decibel-milliWatt)**, which uses 1 mW as the reference. Thus 0 dBm = 1 mW. The formula is

$$\text{Power}_{\text{dBm}} = 10 \log \frac{\text{Power}_{\text{mW}}}{1\ \text{mW}}$$

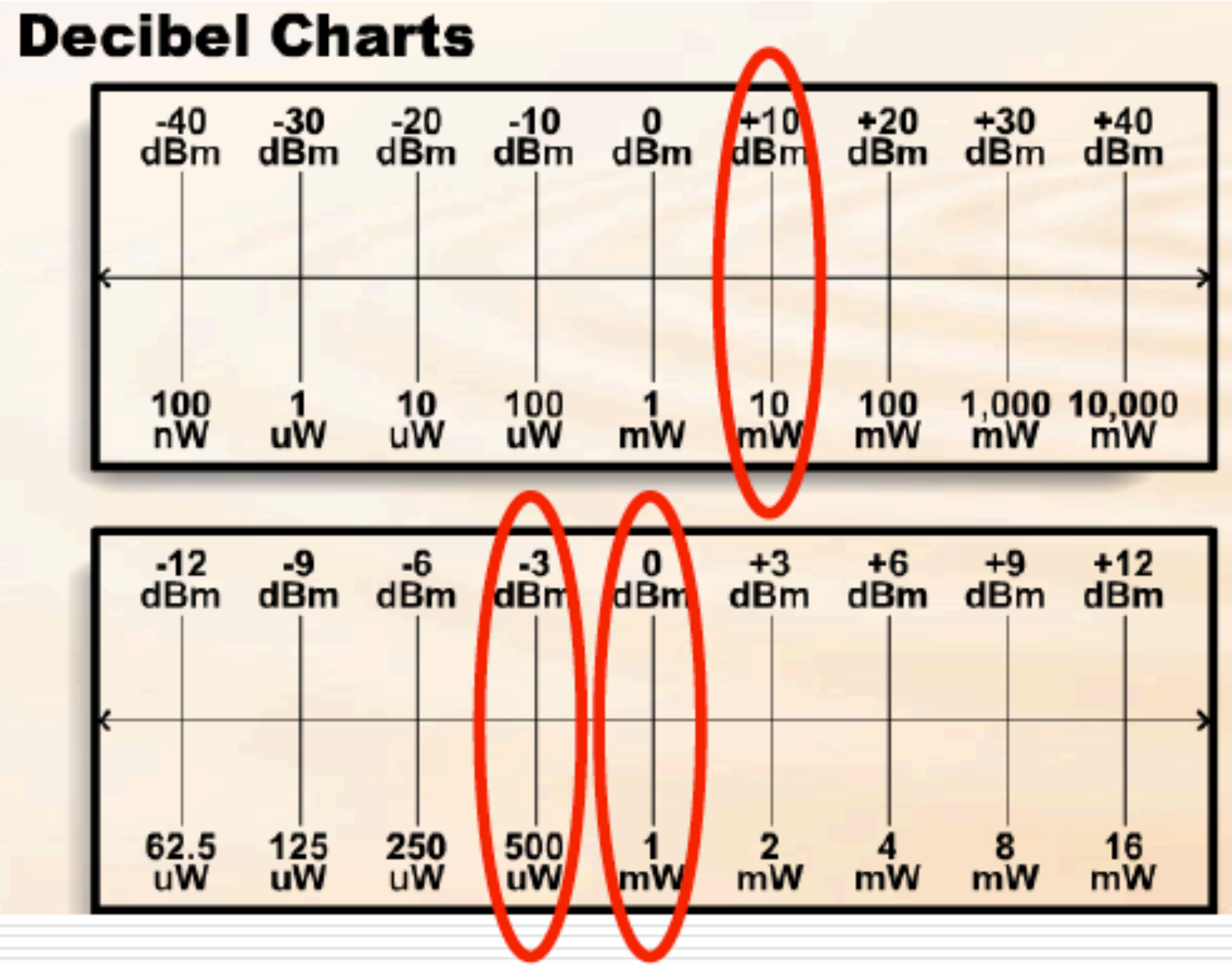
Note the following relationships:

$$+30\ \text{dBm} = 0\ \text{dBW}$$
$$0\ \text{dBm} = -30\ \text{dBW}$$

A unit in common use in cable television and broadband LAN applications is the **dBmV (decibel-millivolt)**. This is an absolute unit with 0 dBmV equivalent to 1 mV. Thus

$$\text{Voltage}_{\text{dBmV}} = 20 \log \frac{\text{Voltage}_{\text{mV}}}{1\ \text{mV}}$$

dBm


Decibel Charts
-40 dBm
-30 dBm
-20 dBm
-10 dBm
0 dBm
+10 dBm
+20 dBm
+30 dBm
+40 dBm
100 nW
1 uW
10 uW
100 uW
1 mW
10 mW
100 mW
1,000 mW
10,000 mW
-12 dBm
-9 dBm
-6 dBm
-3 dBm
0 dBm
+3 dBm
+6 dBm
+9 dBm
+12 dBm
62.5 uW
125 uW
250 uW
500 uW
1 mW
2 mW
4 mW
8 mW
16 mW

References

- Leon W. Couch II, Digital and Analog Communication Systems, 8th edition, Pearson / Prentice, Chapter 1
- Stallings, William. *Data and Computer Communications, 10/e*. Pearson Education, Chapter 3