DDPP 2163 Propagation Systems

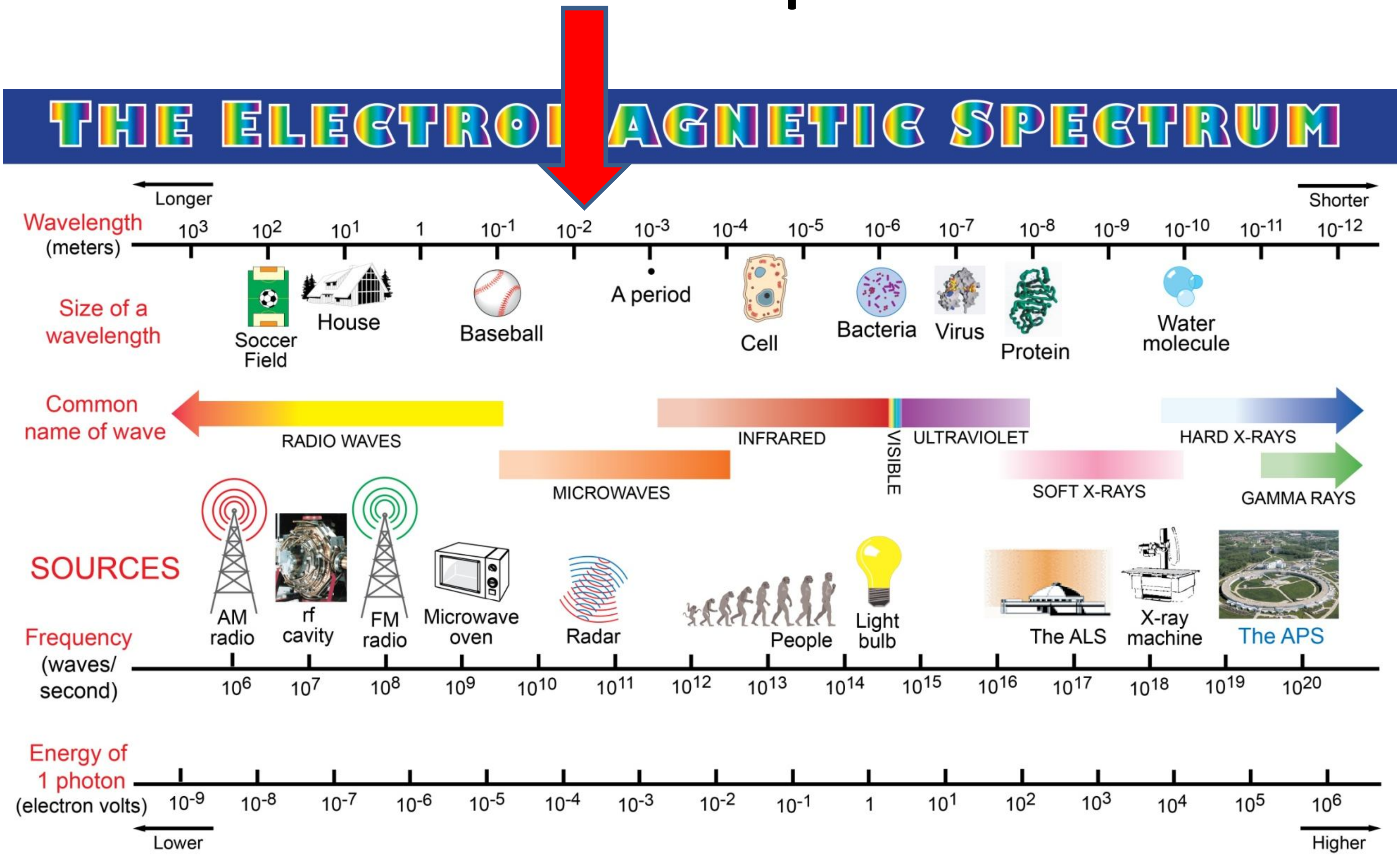
Microwave Devices and Antenna

Introduction

Introduction

- The lower boundary for microwave signals is conventionally set at 1 GHz.
- Microwave frequencies are **1 GHz** and above – UHF and SHF.
- **Waveguides** are used for high microwave frequencies and provide an alternative to conventional transmission lines.

Microwave Spectrum



Waveguides

- A waveguide is essentially a pipe through which electromagnetic waves travel.
- It is possible to build a waveguide for any frequency, but waveguides operate essentially as high-pass filters.
- Waveguides have no radiation loss.

Waveguides Examples

Rectangular Waveguides

Other types of waveguides

Circular waveguide

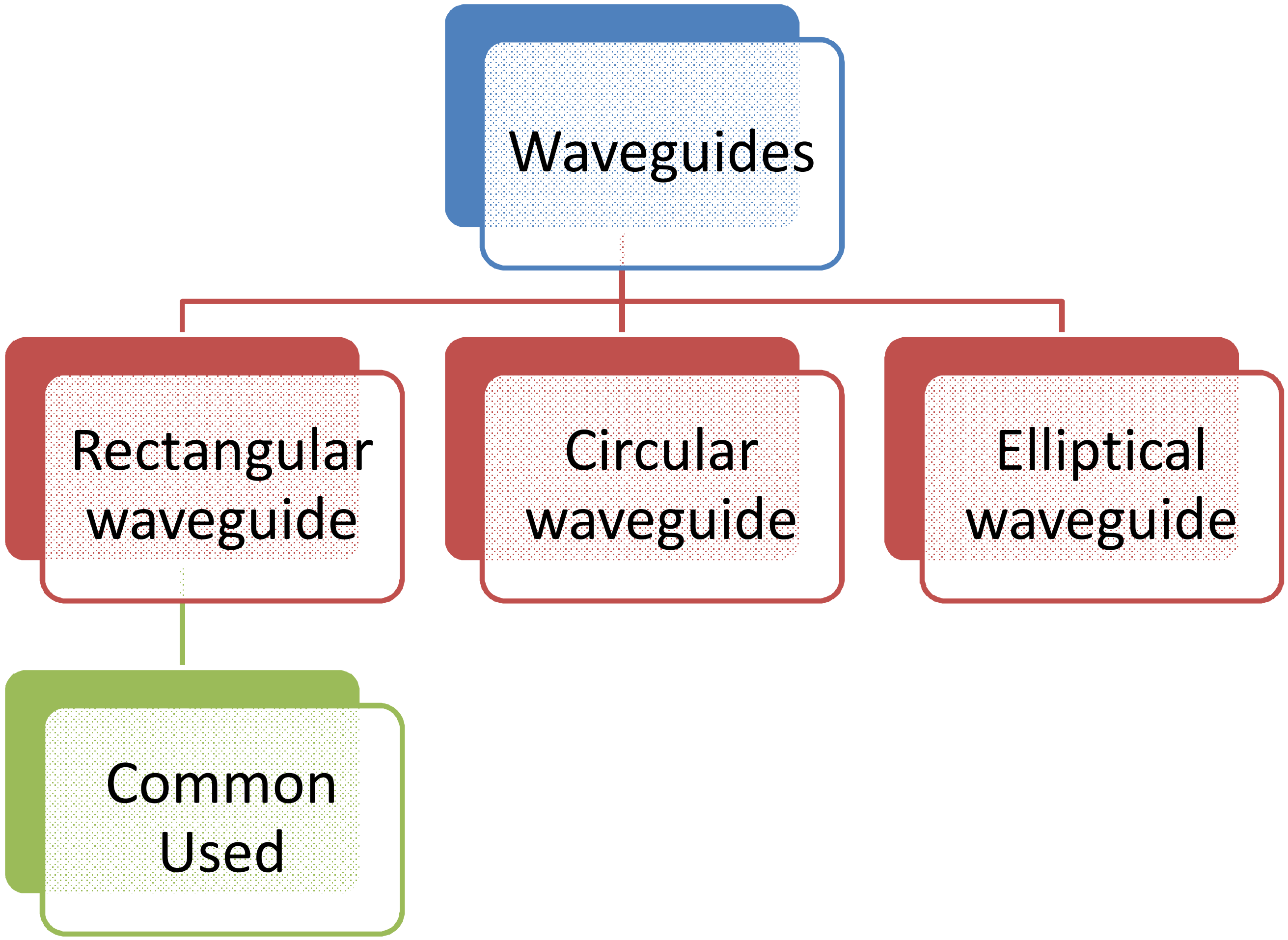
Ridged waveguides

Other types of waveguides

Circular-to-rectangular taper

Flexible waveguide

Types of waveguides



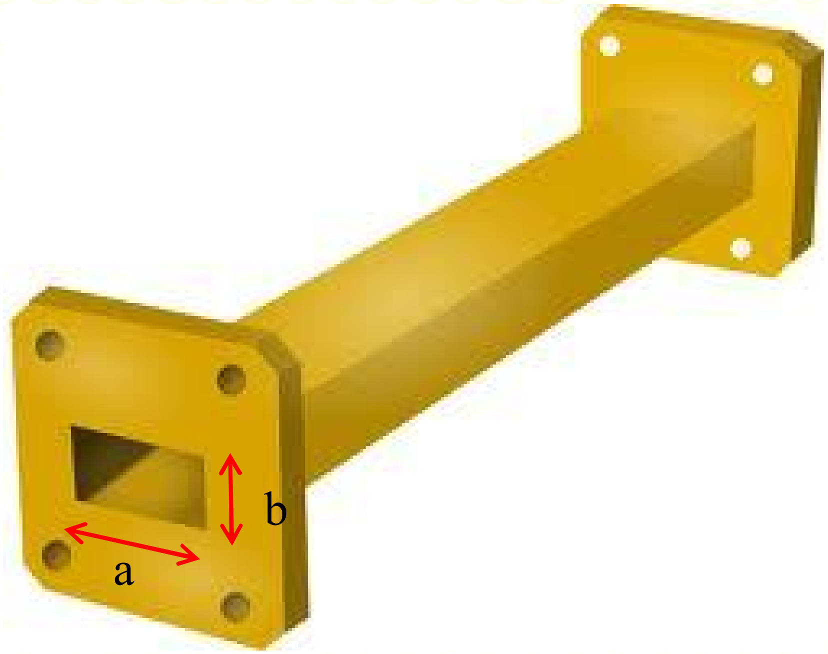
Waveguides

- EM waves travel along the guide, by reflection to and from the walls.
- EM energy propagates down a waveguide by reflecting back and forth in a **zig-zag pattern**, with E-field *maximum* at the *center* of the guide and *zero* at the *surface* of the walls.

Waveguide does not conduct current

Rectangular Waveguide

- Figure below show the cross-sectional view of a rectangular waveguide.



- a = longer dimension of the waveguide cross section
- b = shorter dimension of the waveguide cross section
- Typically ; **a = 2b**

Modes

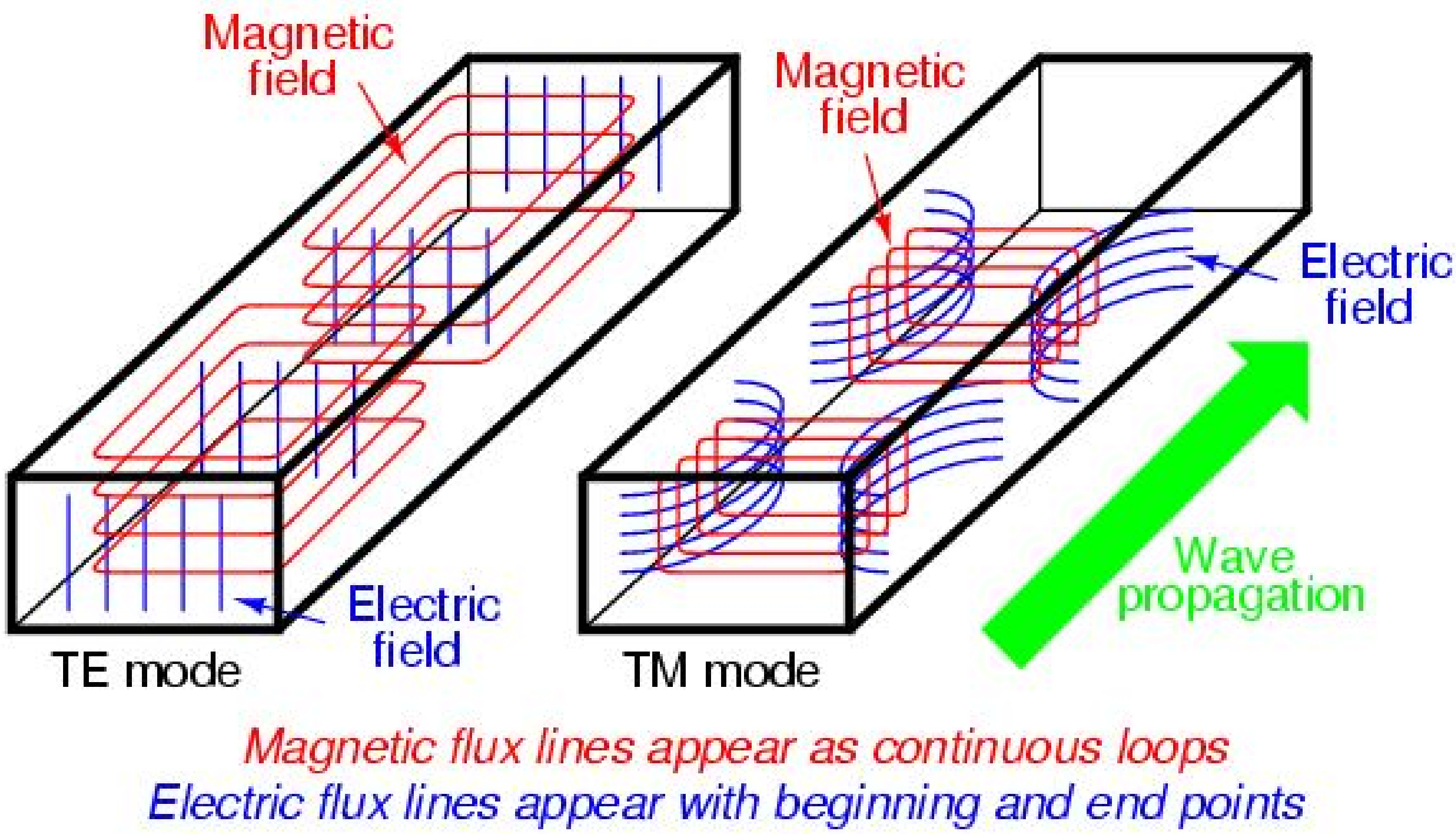
- There are a number of modes that electrical energy can propagate along a waveguide.
- All modes must satisfy certain boundary conditions.
- Types of modes, which depends on the signal frequency
  - Low-order mode – faster propagation
  - High-order mode – slower propagation
- It is desirable to have only one mode propagating in a waveguide – *Single mode propagation*.
- *Multimode propagation* causes a pulse to arrive at the far end at several different times

Dispersion limits the usefulness of waveguides with pulsed signals and other forms of modulation.

Mode Types

- Modes are designated as either transverse electric (TE) or transverse magnetic (TM).
- The term TE means that there is *no component of the electric field* along the length of the guide.
- Electric field line are everywhere transverse (i.e. perpendicular to the guide walls).

TE and TM Modes



Standard designation of TE & TM

- The standard designated the modes for rectangular waveguide as $\mathbf{TE_{m,n}}$ and $\mathbf{TM_{m,n}}$.
- **m** and **n** are integers designating the number of *half-cycles of the wave* (electric or magnetic) that exists between each pair of walls.
- **m** is measured along the x-axis of the waveguide (**a** dimension).
- **n** is measured along the y-axis of the waveguide (**b** dimension).

Dominant Modes

- Dominant mode depends upon the shape of the waveguide.
- For a circular waveguide, the dominant mode is TE_{11}, but the TM_{01} mode is also used because it has circular symmetry.
- In a rectangular waveguide, the **dominant mode** is **$TE_{1,0}$**.
- Dominant mode – because it is the most 'natural' mode and have the lowest cutoff frequency.

Cutoff frequency and Cutoff wavelength

- Each mode has a cutoff frequency.
- The cutoff frequency
  - the minimum frequency of operation in a waveguide
  - an absolute limiting frequency
  - **frequency below** the cutoff frequency will **not** propagate through the waveguide
- The cutoff wavelength
  - minimum wavelength that a wave can propagate
  - the smallest free space wavelength that will not propagate in the waveguide

Cutoff frequency and Cutoff wavelength

- The cutoff wavelength and frequency are determined by the cross-sectional dimensions of the waveguide.

$$\lambda_c = \frac{2}{\sqrt{(\frac{m}{a})^2 + (\frac{n}{b})^2}} \qquad f_C = \frac{c}{\lambda_C}$$

- The cutoff wavelength for $\mathbf{TE_{1,0}}$; $\lambda_C = 2a$

- So, the cutoff frequency for $\mathbf{TE_{1,0}}$; $f_C = \frac{c}{2a}$

where f_C = cutoff frequency (Hertz)

λ_C = cutoff wavelength (meters per cycle)

a = longer dimension of the waveguide cross section (meter)

Group and Phase Velocity

- Phase velocity is the rate at which the wave *appears* to move along the wall of the guide.
- The phase velocity is always greater than the speed of light.
- A phase velocity faster than the speed of light is possible because it is not really the velocity of anything.
- Phase velocity is used when calculating the wavelength in a guide, but the group velocity is used to determine the length of time it takes for a signal to move from one end to the other.

$$v_p = \frac{c}{\sqrt{1-\left(\frac{\lambda}{\lambda_c}\right)^2}} = \frac{c}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

Group Velocity

- The actual speed at which a signal travels down a waveguide is called the **group velocity**, and is less than the speed of light.
- For a rectangular guide, group velocity is given by the formula:

$$v_g = c\sqrt{1-\left(\frac{\lambda}{\lambda_c}\right)^2} = c\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

- In the dominant mode: $$v_g = c\sqrt{1-\left(\frac{\lambda}{2a}\right)^2}$$

- The relationship between the phase velocity & group velocity;

$$v_p v_g = c^2$$

END