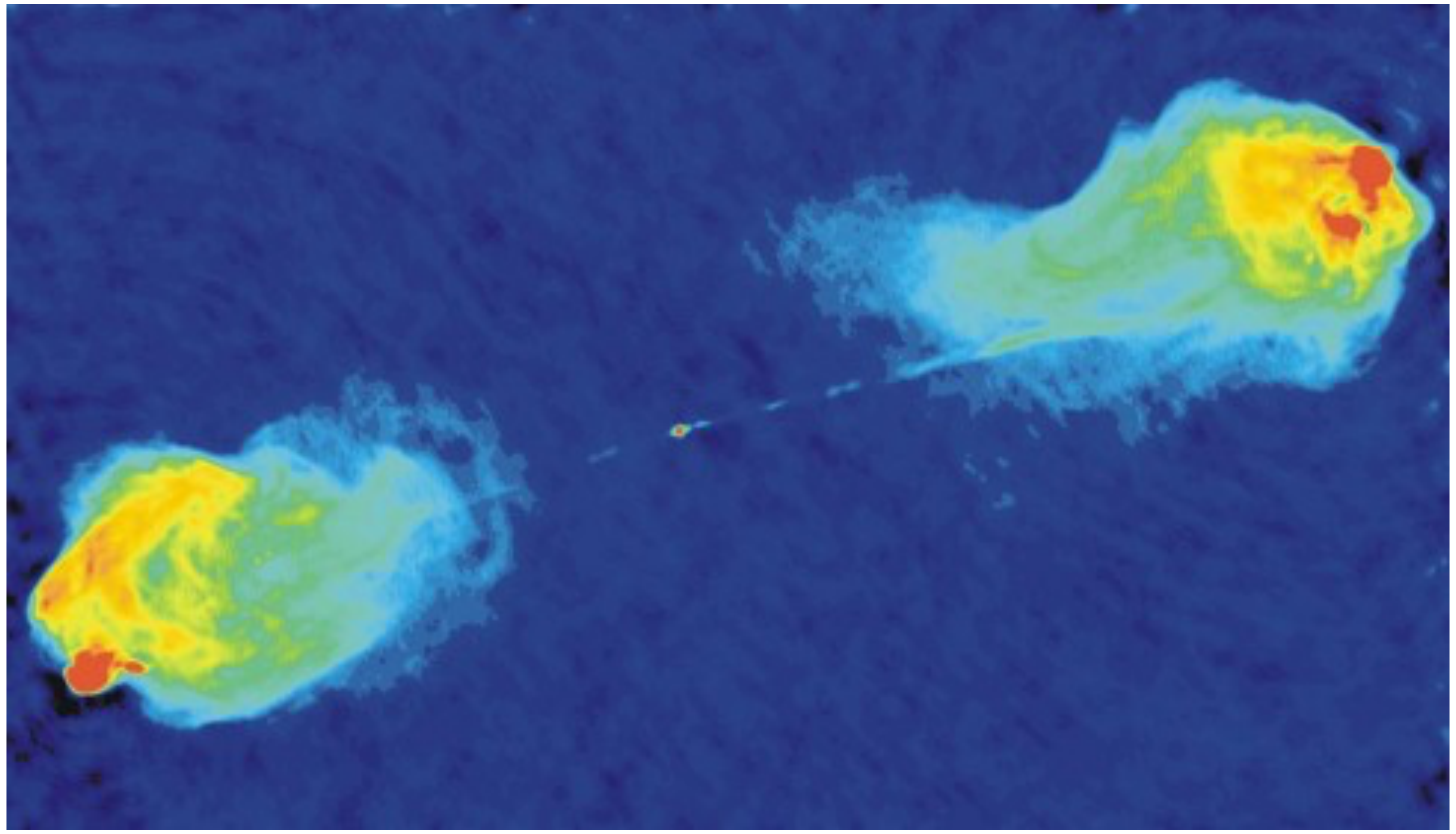
Hyperfréquence (Radiofrequency)

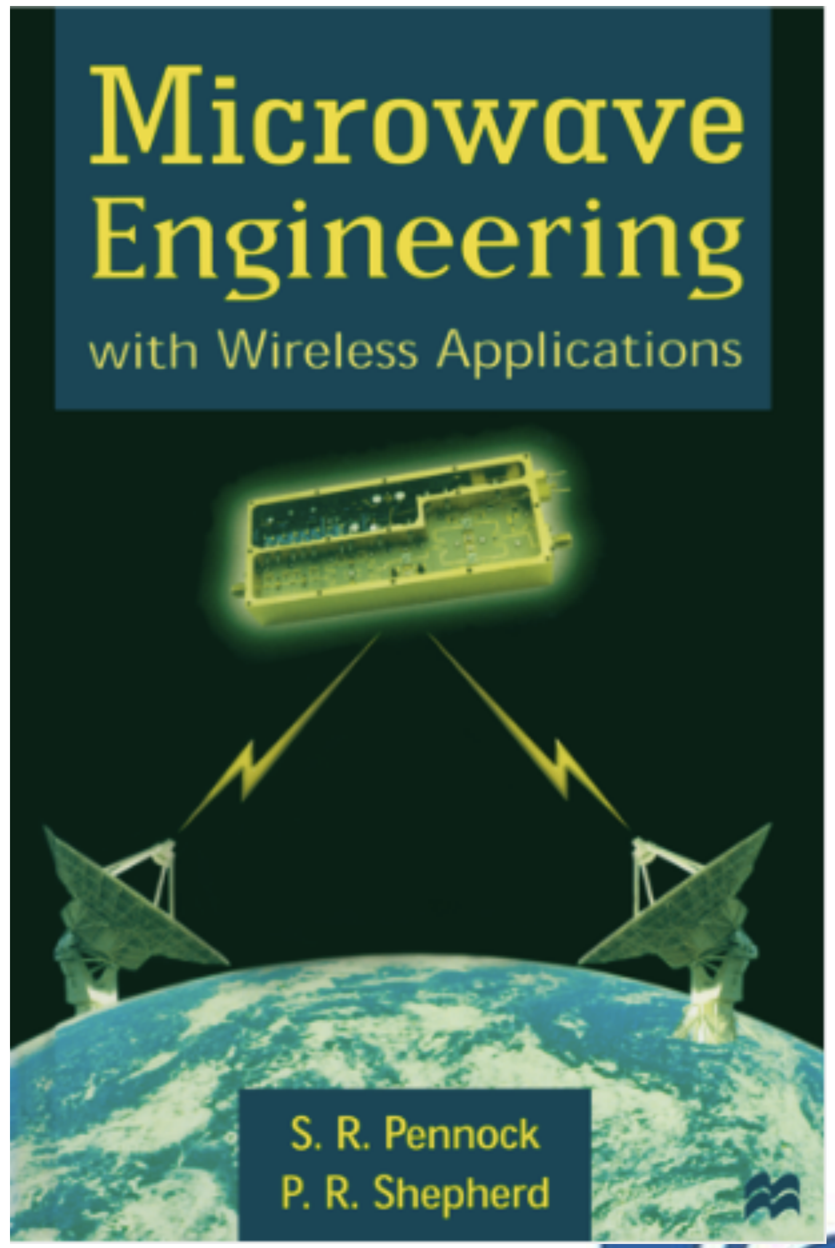


Radio Image. This image has been constructed of radio observations at the Very Large Array of a galaxy called Cygnus A.The radio image reveals jets of expelled material (more than 160,000 light-years long) on either side of the galaxy.ref.(National Radio Astronomy Observatory)

Dr. Lana Damaj

Radiofrequency

- **Description:**
  - In this course, students are introduced to radio frequency (RF) transmission in both wired and wireless media. High frequency signals and the properties of the propagation media will be introduced. Students will also learn about cable types and specifications; basic and practical antenna.
- **Reference books:**
  - Microwave Engineering with Wireless Applications,
    S. R. Pennock, P. R. Shepherd, Red Globe Press London
  - Microwave Engineering, David M. Pozar. Wiley, 4th Edition
- **Prerequisite:**
  - Electromagnetic fields,



Course outlines

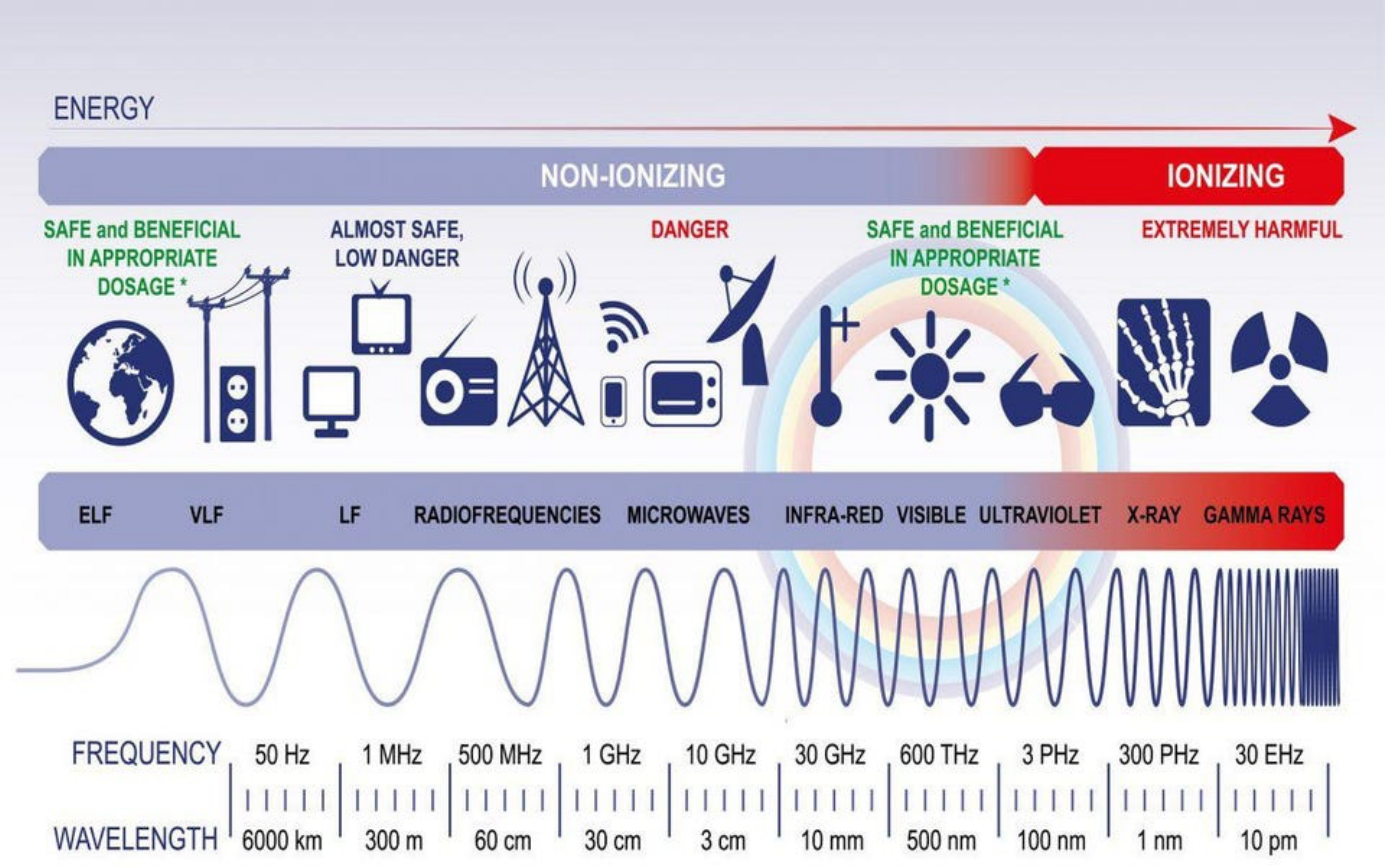
- **Part 1: Introduction and applications**
- **Part 2: Transmission lines**
  - **Types of transmission lines (coaxial cables, waveguides,…)**
- **Part 3: Radiofrequency parameters and components**
  - **Scattering parameters**
  - **Matching networks**
  - **RF components (Antenna, Coupler, Filters, …)**
  - **Wave propagation**

Part 1: outlines

- Introduction
- Brief history
- Generalized microwave transmitter/receiver
- Electromagnetic (EM) waves (review)
- EM waves propagation
- Guided propagation
- Unguided propagation

Introduction:

- Microwaves are playing a larger and more important role in everyday life. The region of microwaves are defined to be between 1 GHz and 100 GHz (30 cm to 3 mm free space wavelength).
- We are immersed in electromagnetic (EM) fields. They are everywhere, being generated naturally (e.g., solar radiation and lightning) and by us (e.g., radio stations, cell phones, and power lines).
- The wireless communications revolution has electromagnetics at its very core: Voice and data information is transmitted and received via antennas and high-frequency electronics, components requiring knowledge of electromagnetics to design and understand.
- Many of the new future developments in the communications field will occur at microwave frequencies as the majority of lower frequencies are already in use.



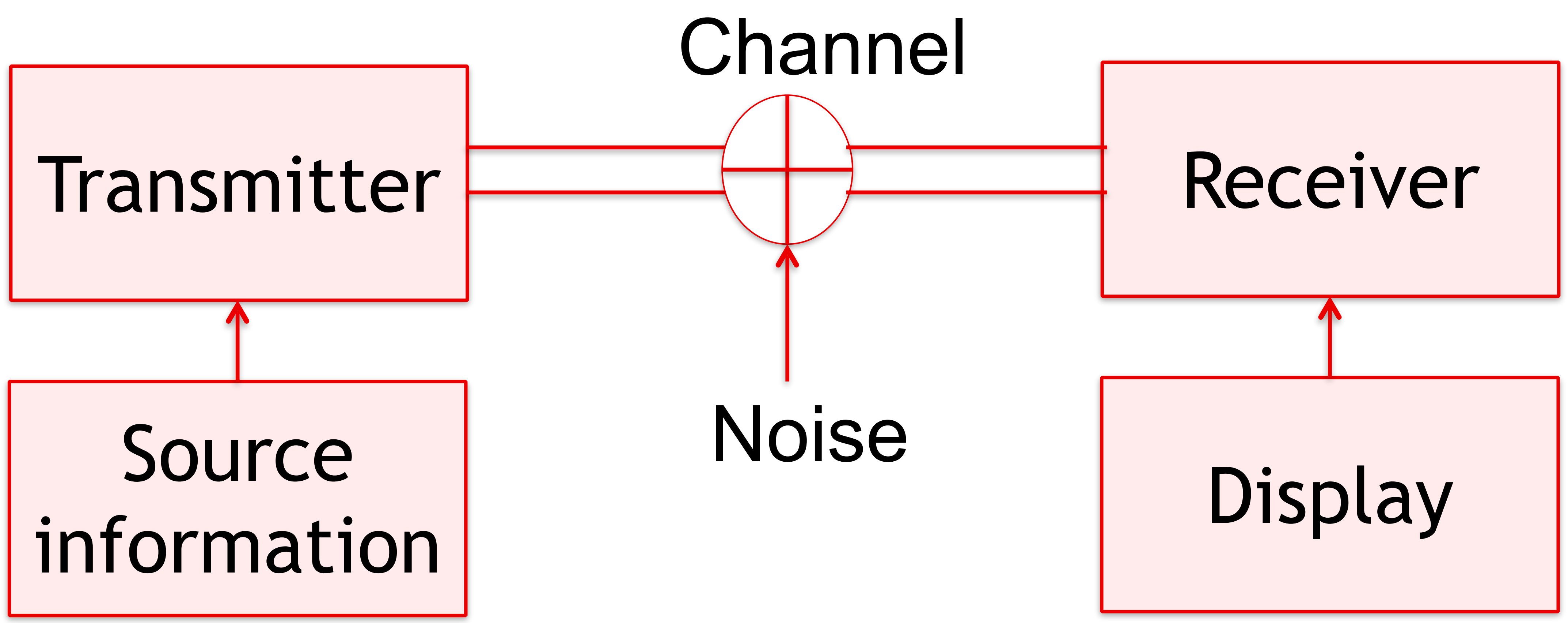
Brief history

- **The keys historical events in electromagnetic:**

  - ➡600 B.C: 1st record of electric and magnetic behavior by Thales of Miletus
  - ➡1600: William Gilbert postulates that earth is a giant magnet, does first recorded experimentation with electricity and magnetism
  - ➡1750: terms 'positive' and 'negative' charge coined by Ben Franklin
  - ➡1785: forces between charges measured by Charles Coulomb
  - ➡1800: Voltaic pile (battery) *invented* by Alessandro Volta
  - ➡1820: force between current carrying wires found by Andre Marie Ampere
  - ➡1826: Ohm' s Law published by Georg Simon Ohm
  - ➡1831: Michael Faraday finds that time-varying magnetic fields create electric fields
  - ➡1873: James Clerk Maxwell formulates Maxwell's equations, predicts presence of electromagnetic waves
  - ➡1887: Heinrich Hertz detects electromagnetic waves
  - ➡1901: Marconi transmits and receives radio waves across the Atlantic Ocean

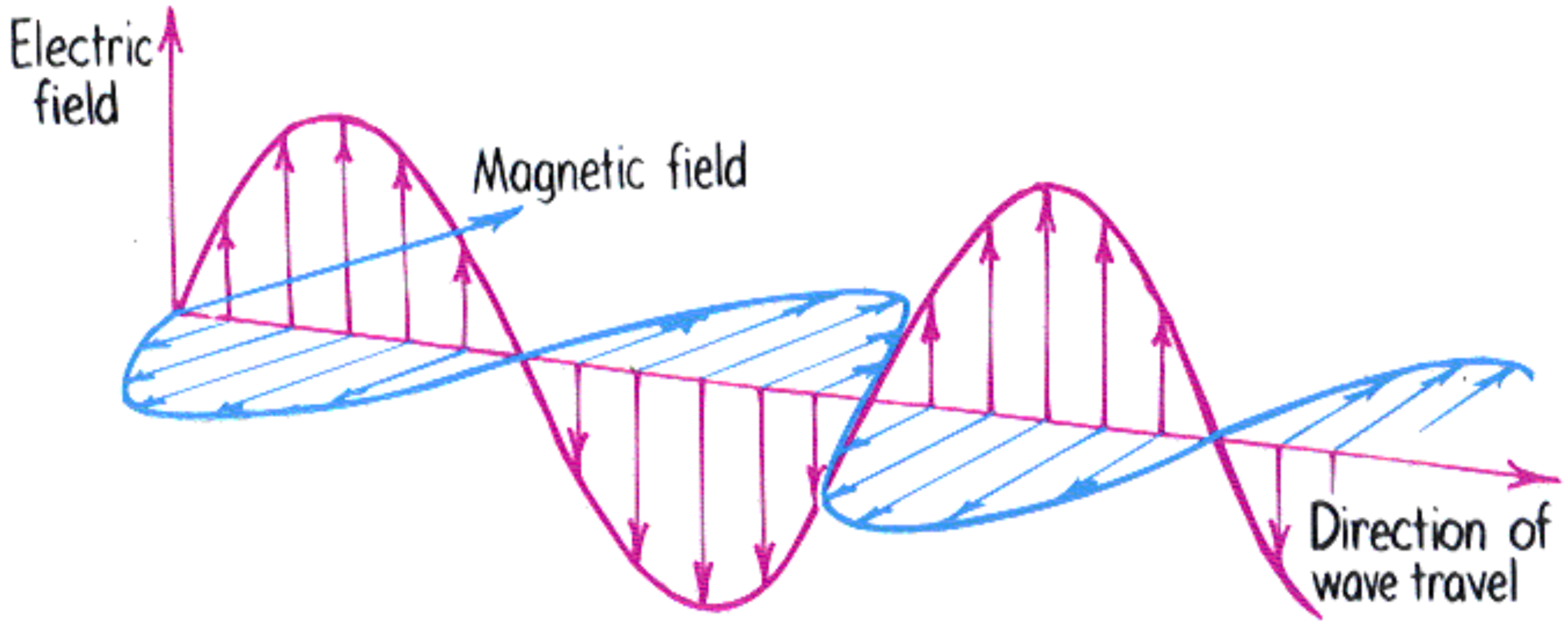
Generalized microwave transmitter/receiver

- **Transmitter: converts the electrical signal into a form that is suitable for transmission through the physical channel or transmission medium. In general, a transmitter performs the matching of the message signal to the channel by a process called modulation.**
- **Channel: the communication channel is the physical medium that connects the transmitter to the receiver. The physical channel may be:**
    - **a pair of wires that carry the electrical signals,**
    - **or an optical fiber that carries the information on a modulated light beam**
    - **or free space at which the signal are electromagnetic waves**
- **Receiver: the function of a receiver is to recover the message signal contained in the received signal. The main operations performed by a receiver are demodulation, filtering and decoding.**



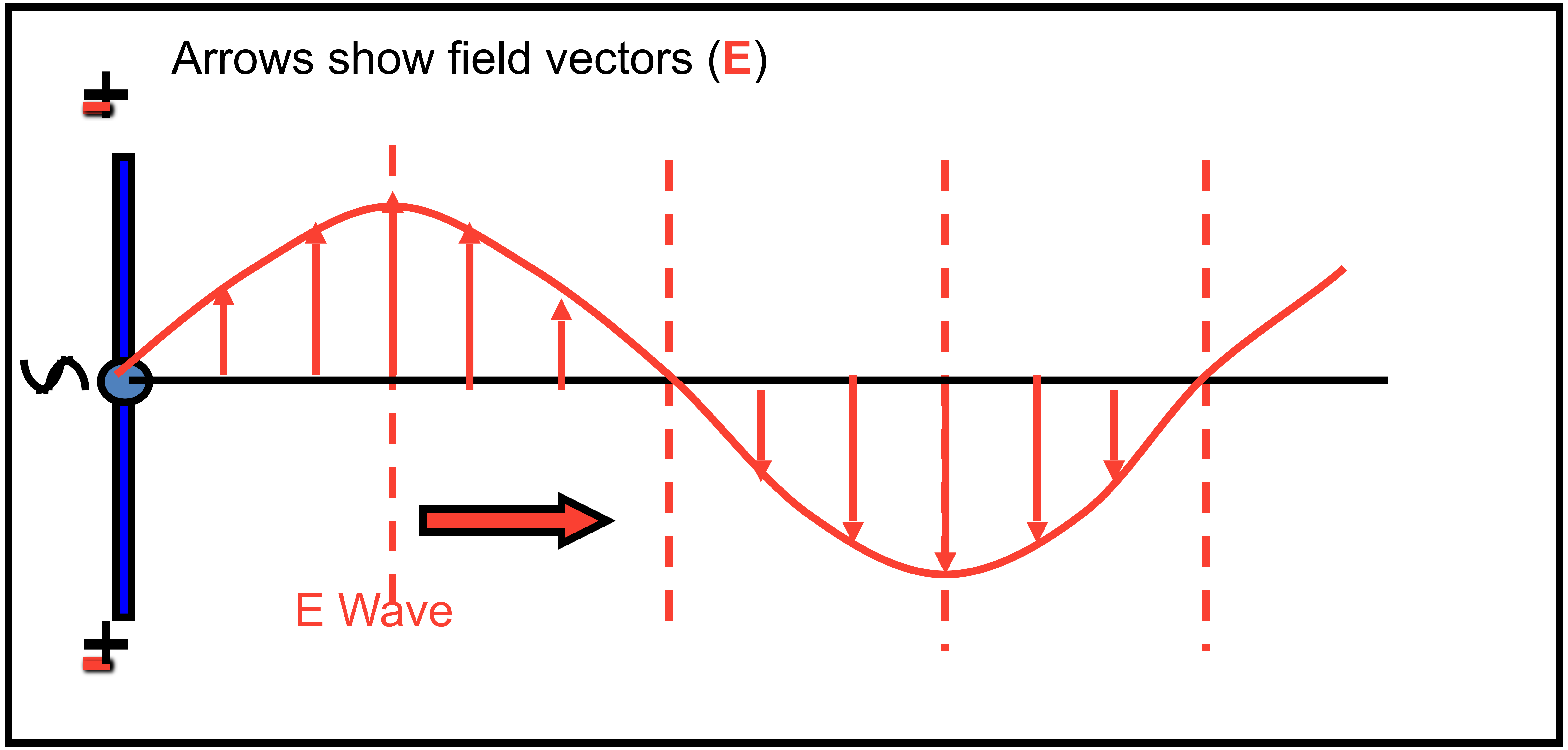
Electromagnetic (EM) waves (review)

- The Scottish physicist James Clerk Maxwell (1831-1879) who showed that electric and magnetic fields fluctuating together can form a propagating wave, appropriately called an electromagnetic wave.
- Sunlight is a mixture of electromagnetic waves having different wavelengths.
- For electromagnetic waves, propagation may occur in a vacuum as well as in a material medium.
- When an RF signal travels through a vacuum, it moves at the speed of light, which is approximately 300,000,000 meters per second.
- An electromagnetic wave in a vacuum consists of mutually perpendicular and oscillating electric and magnetic fields.



Electromagnetic (EM) waves (review)

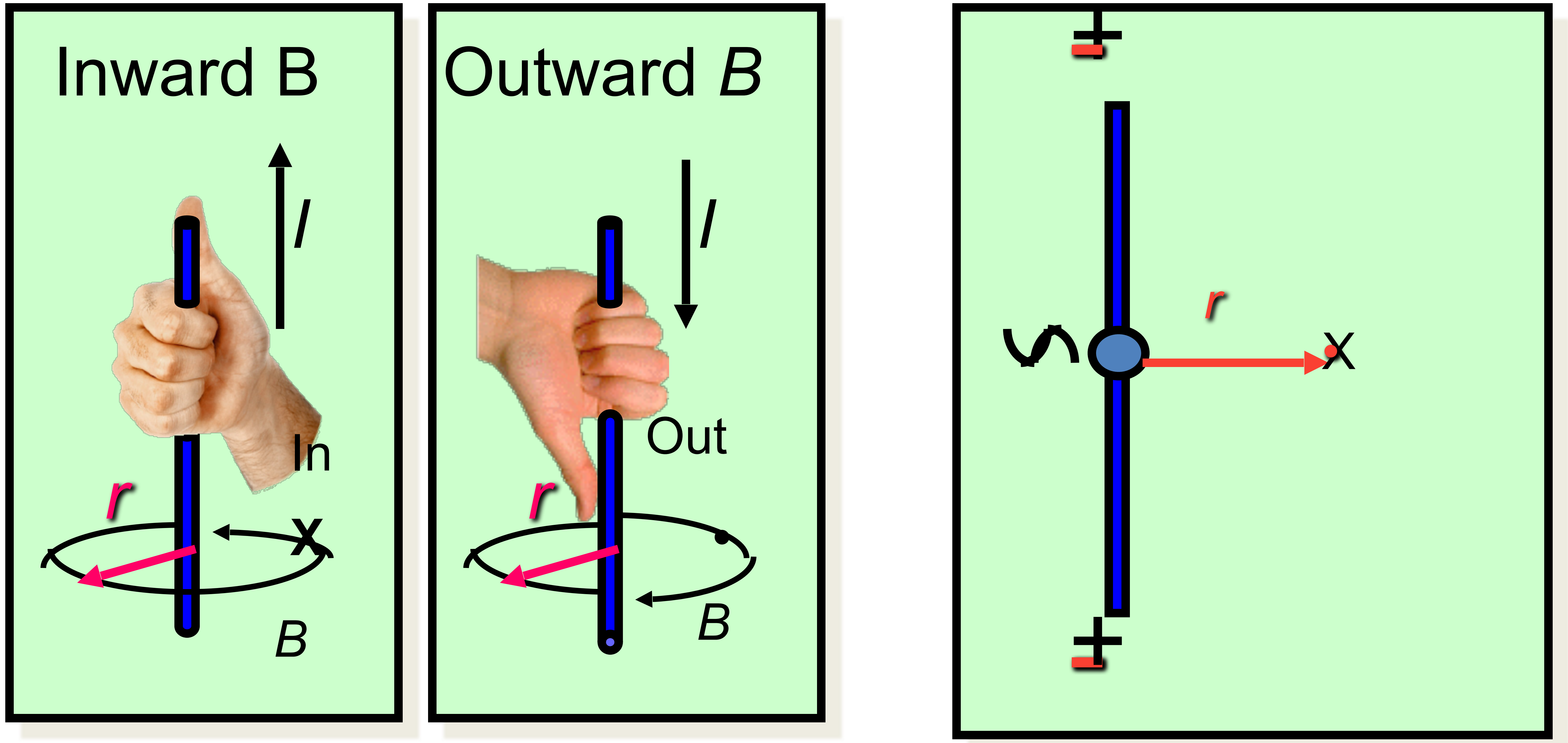
- **Production of an Electric Wave**
  - Consider two metal rods connected to an ac source with sinusoidal current and voltage.



Vertical transverse sinusoidal E-waves.

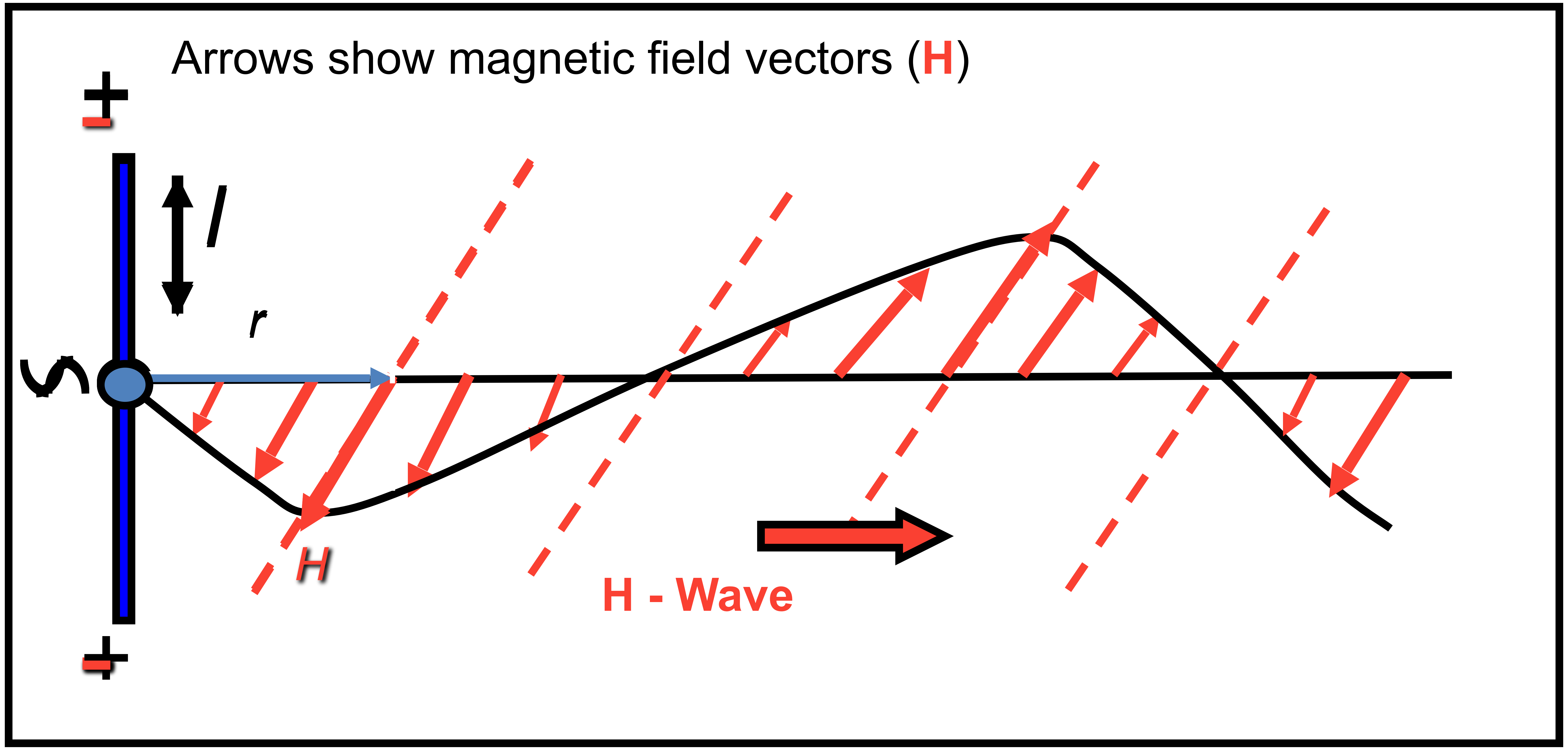
Electromagnetic (EM) waves (review)

- **An Alternating Magnetic Field**
  - The ac sinusoidal current also generates a magnetic wave alternating in and out of paper.



Electromagnetic (EM) waves (review)

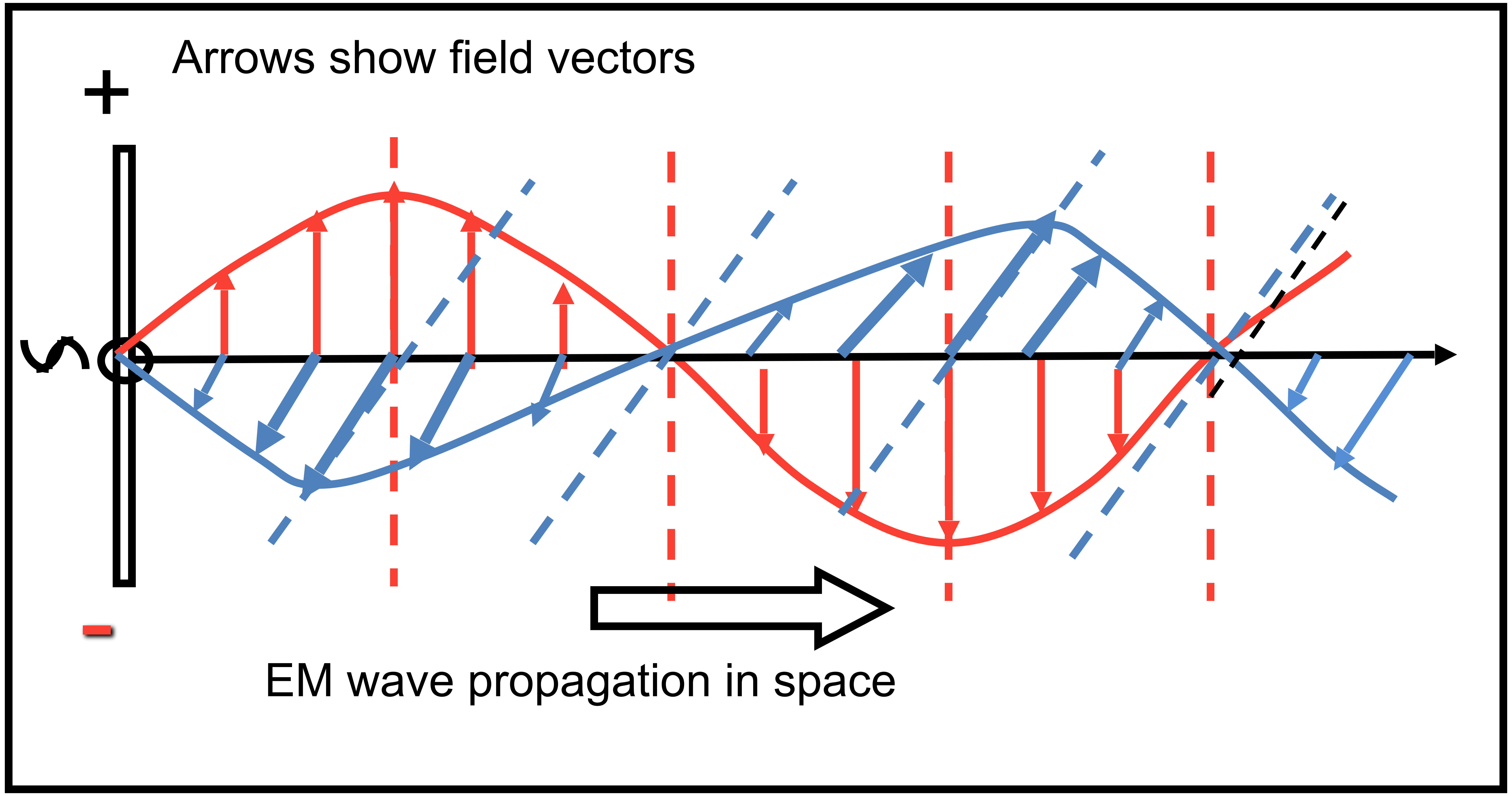
- **Magnetic Wave Generation**
  - The generation of a magnetic wave due to an oscillating ac current.



Horizontal transverse sinusoidal H-waves.

Electromagnetic (EM) waves (review)

- **An electromagnetic wave consists of combination of a transverse electric field and a transverse magnetic field perpendicular to each other.**



Electromagnetic (EM) waves (review)

- **EM wave properties:**
  - **The EM wave is a transverse wave, since the fields are perpendicular to the direction in which the wave travels.**
  - **All electromagnetic waves, regardless of their frequency, travel through a vacuum at the same speed, the speed of light c ($c = 3 \times 10^8$ m/s) (the speed is less in real medium).**
  - **Another important characteristic of electromagnetic waves is that they will travel in a straight line unless something changes their course.**

Electromagnetic (EM) waves (review)

- **EM Parameters characterizing Wave Propagation :**
  - **The propagation of an electromagnetic wave is described through different parameters: the electric and magnetic fields E and H , the electric flux density D and the magnetic induction B. Where:**

$$\vec{D} = \varepsilon * \vec{E}$$

$$\vec{B} = \mu * \vec{H}$$

  - **The ε (the permittivity) and μ (magnetic permeability) coefficients depend on the nature of the medium where the electromagnetic wave propagates. In the case of homogeneous, isotropic media, ε and μ are constants.**

Electromagnetic (EM) waves (review)

- **EM Parameters characterizing Wave Propagation :**
  - **The refractive index of a given medium can be characterized from its permittivity and permeability using the following equation:**

$$\boxed{n = \sqrt{\varepsilon\mu}}$$

  - **Maxwell's Equations:**

$$\vec{\nabla} \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t} \qquad \vec{\nabla} . \vec{D} = \rho$$

$$\vec{\nabla} \times \vec{H} = \varepsilon \frac{\partial \vec{E}}{\partial t} + \vec{j} \qquad \vec{\nabla} . \vec{B} = 0$$

  - **Where ρ is the density of the free charged particles.**

Electromagnetic (EM) waves (review)

- **EM Parameters characterizing Wave Propagation :**
  - **Propagation Velocity:**

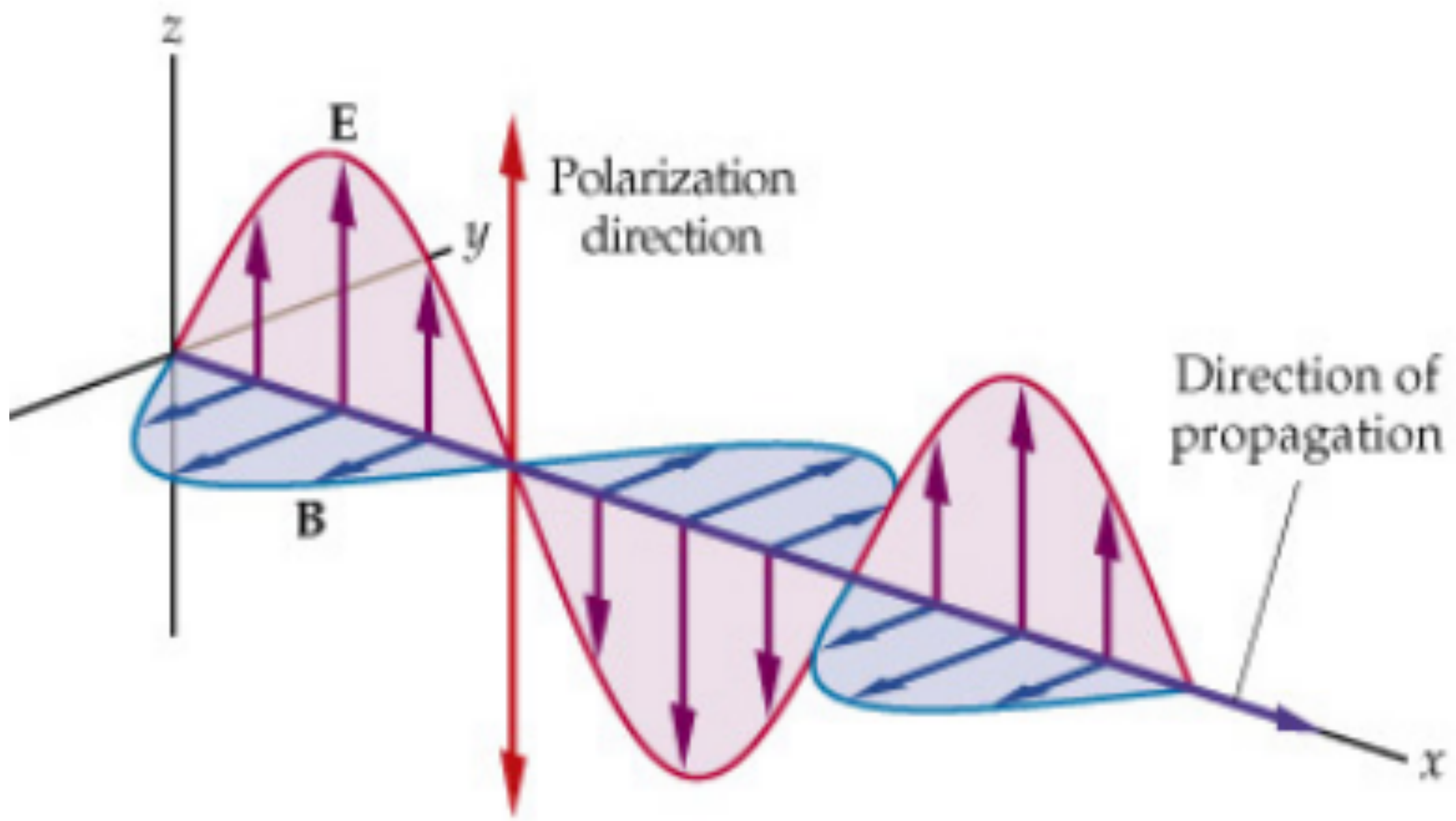
$$\boxed{v = \frac{1}{\sqrt{\varepsilon\mu}}}$$

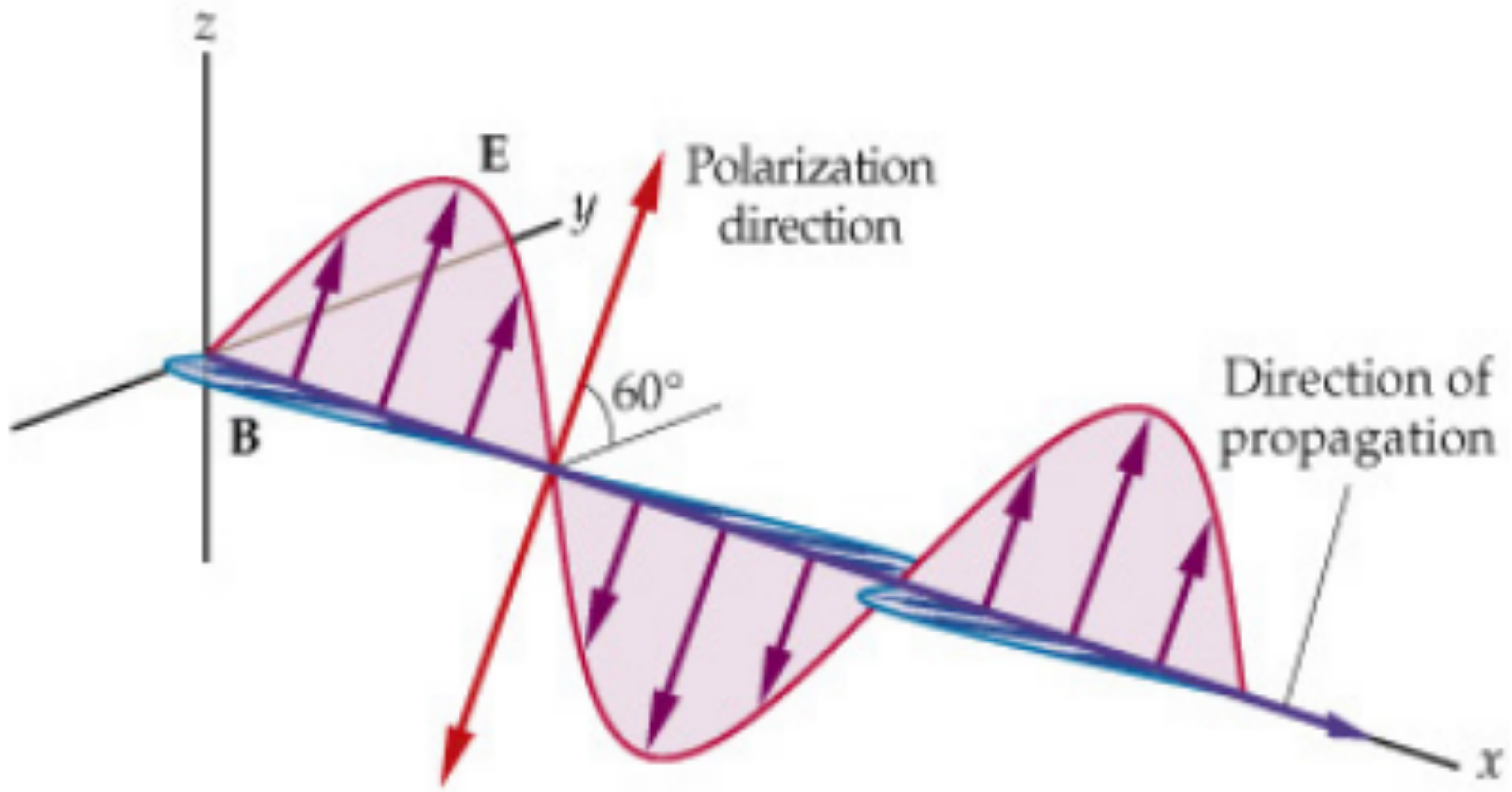
  - **Characteristic Impedance of the Propagation Medium:**

$$\boxed{E_x/H_y = (\mu/\varepsilon)^{1/2} = Zc}$$

Electromagnetic (EM) waves (review)

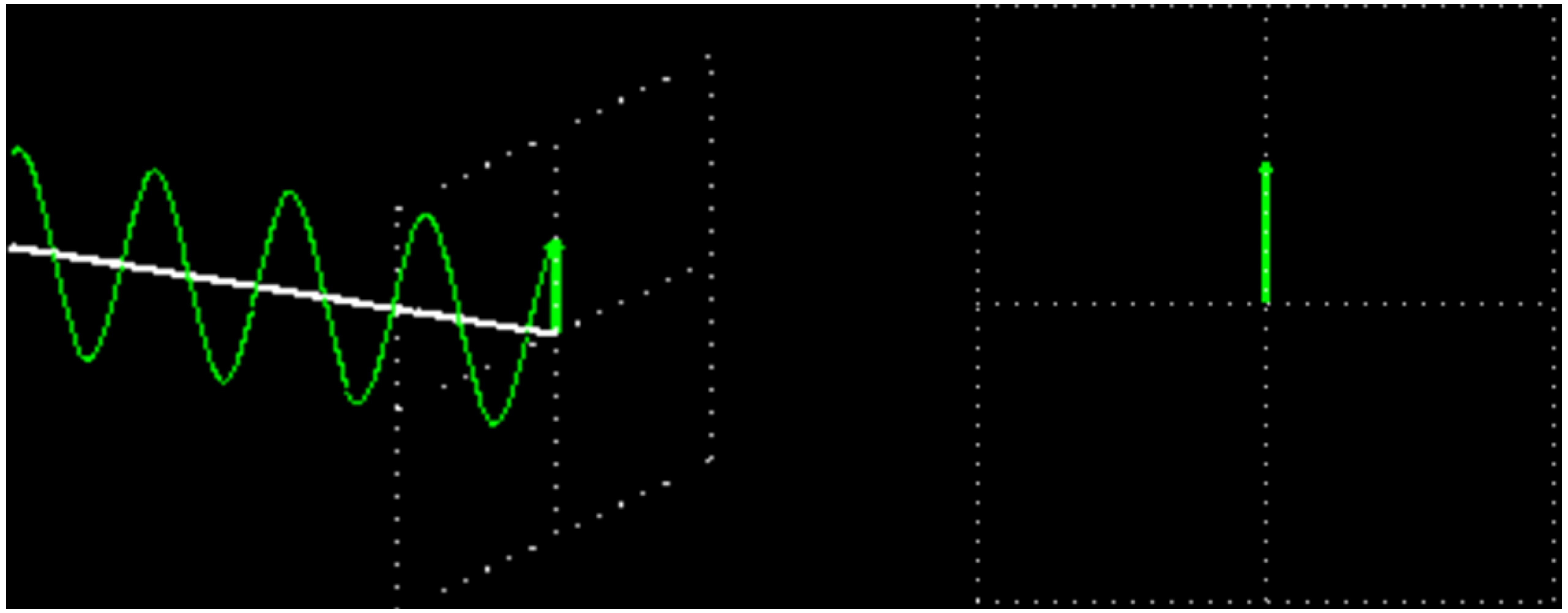
- **Polarization of electromagnetic waves:**
  - **The polarization of an electromagnetic wave is the direction along which its electric field vector, E, points.**
  - **The cases shown illustrate (a) polarization in the z direction and (b) polarization in the y-z plane, at an angle of 60° with respect to the y axis.**





Electromagnetic (EM) waves (review)

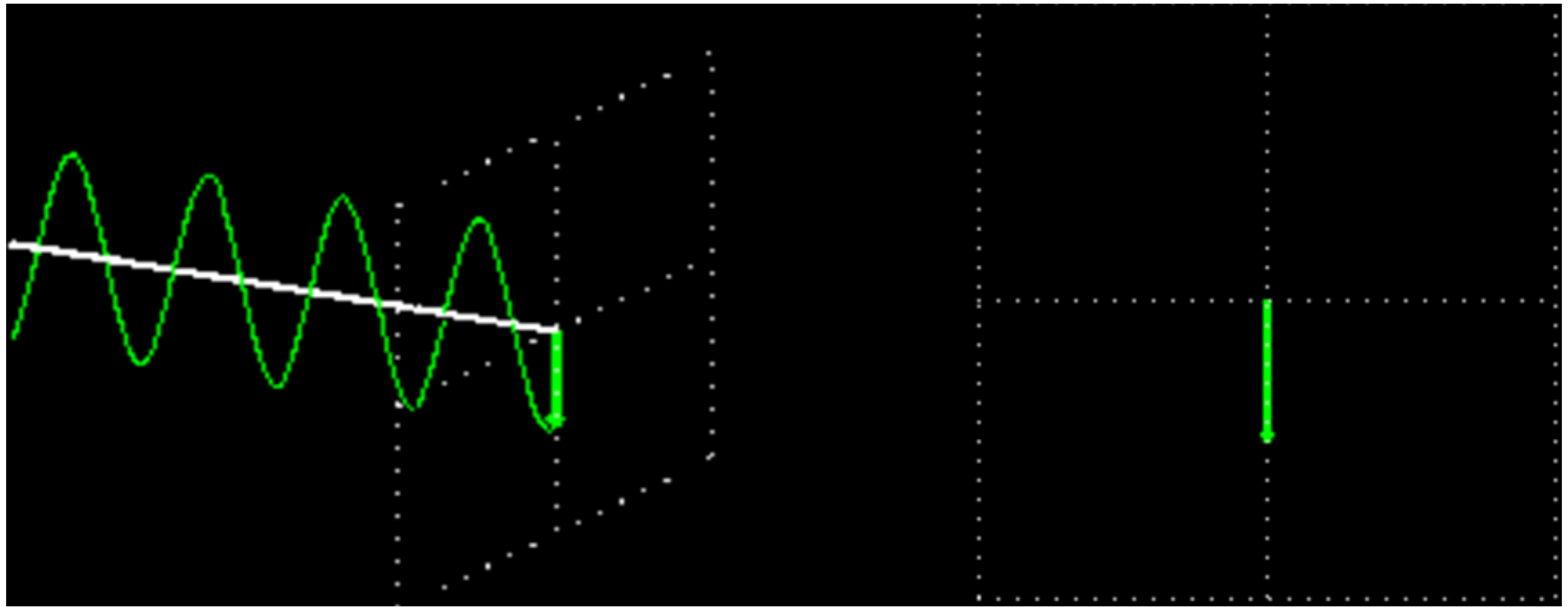
- Polarization of electromagnetic waves:
  - Linear polarisation



- The vector E oscillates along a straight line

Electromagnetic (EM) waves (review)

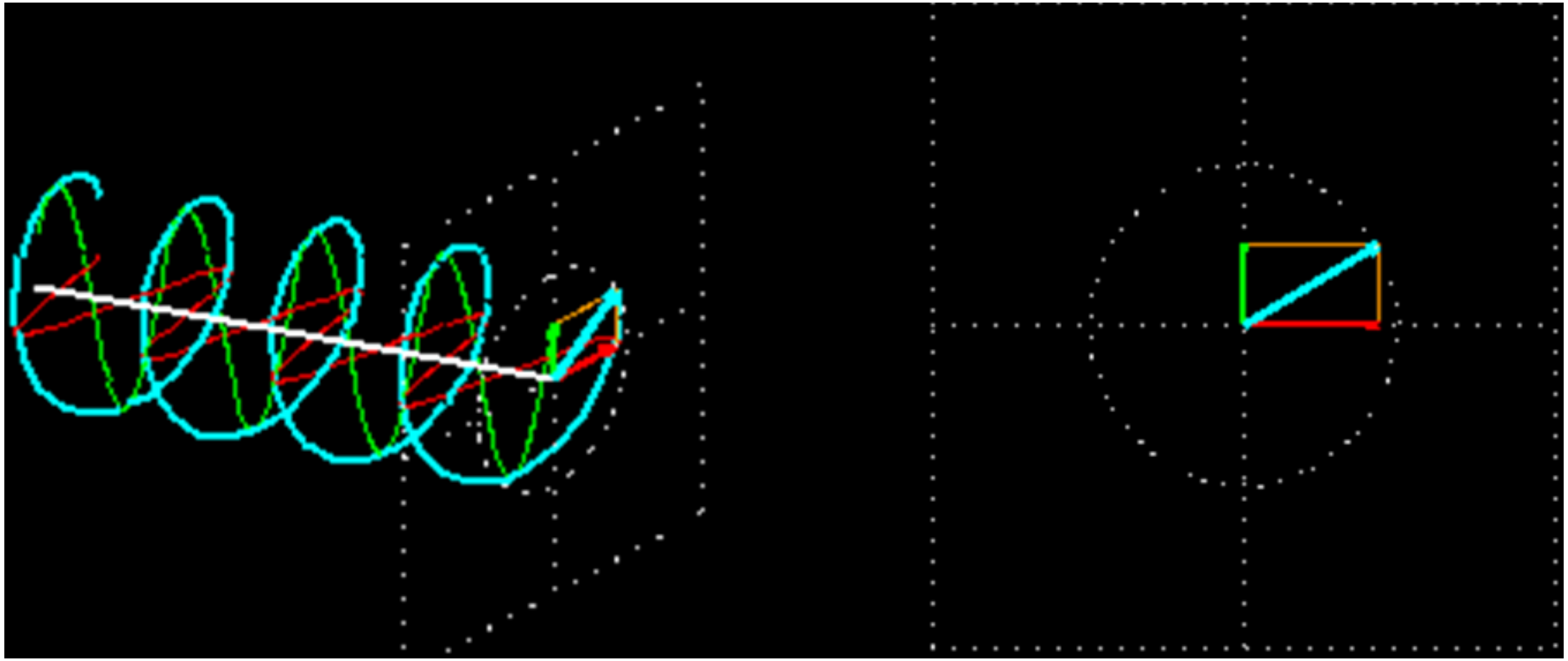
- Polarization of electromagnetic waves:
  - Linear polarisation



- The vector E oscillates along a straight line

Electromagnetic (EM) waves (review)

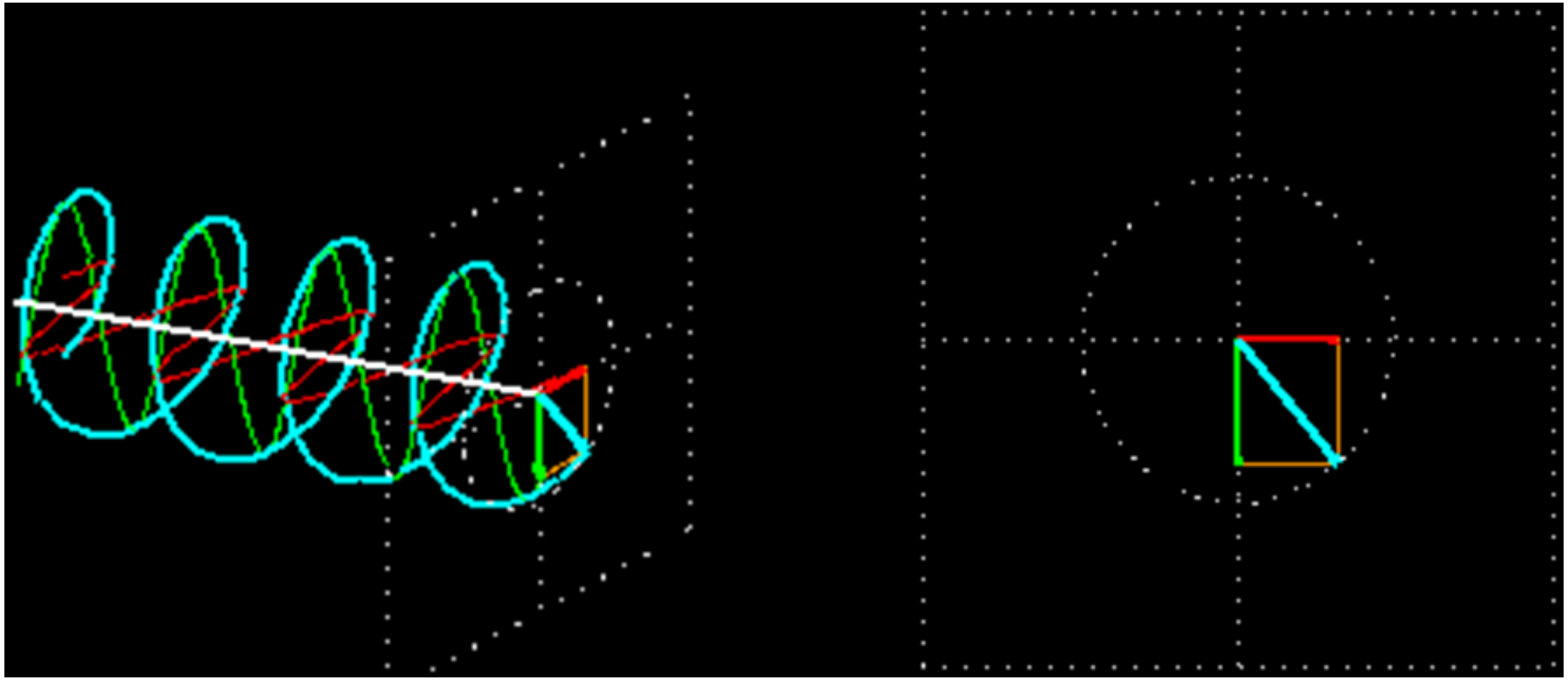
- **Polarization of electromagnetic waves:**
  - **Circular polarisation**



- **The vector E has two components $E_{x\ \text{and}}$ E_y et E_x=E_y in this case the vector E describes a circle**

Electromagnetic (EM) waves (review)

- **Polarization of electromagnetic waves:**
  - **Circular polarisation**



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Electromagnetic (EM) waves (review)

- **Polarization of electromagnetic waves:**
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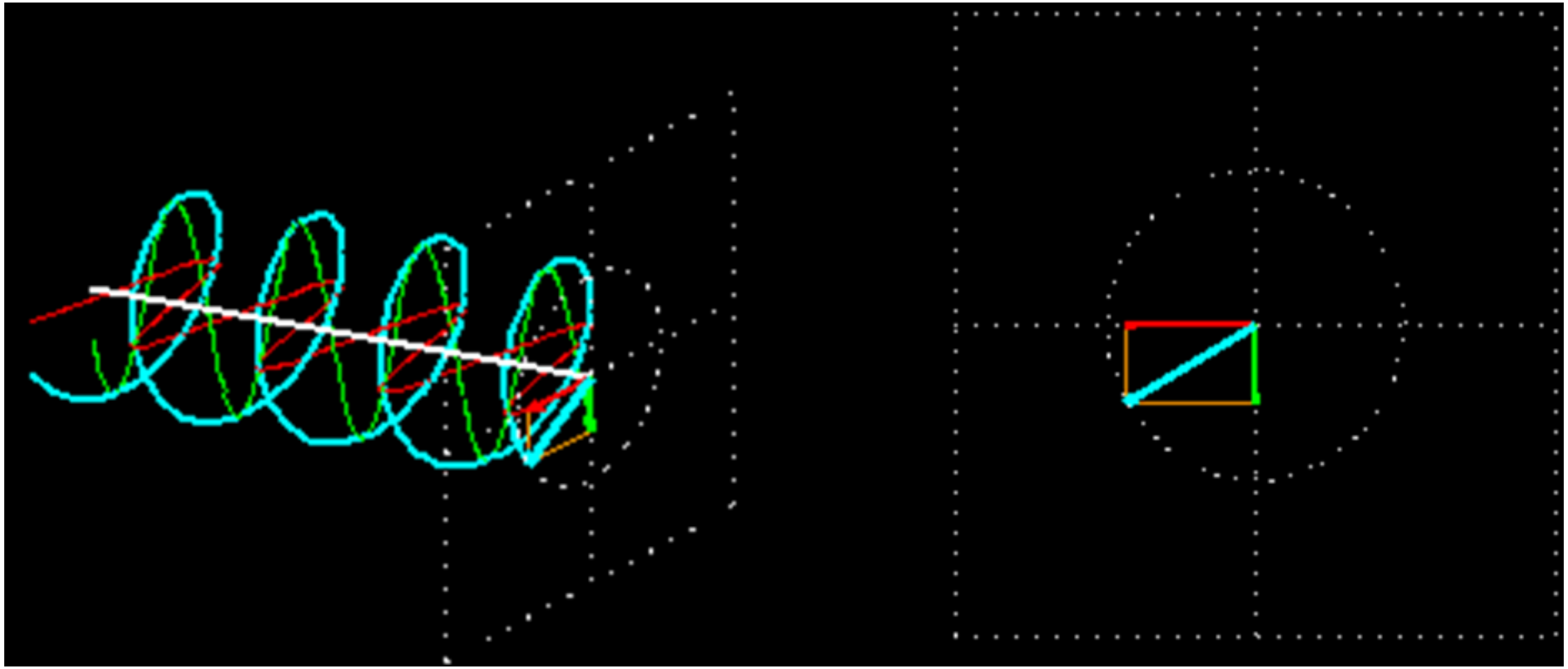
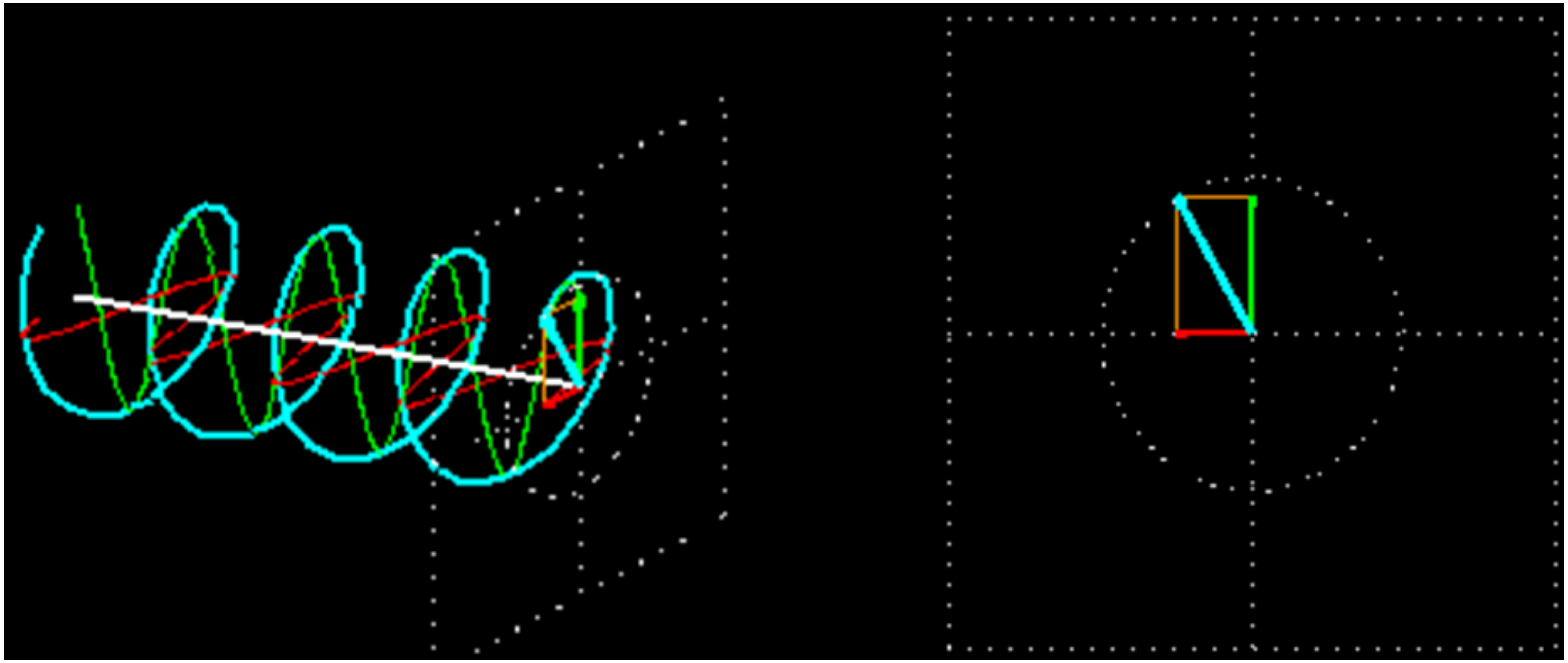


- **The vector E has two components E_x and E_y et E_x=E_y in this case the vector E describes a circle**

Electromagnetic (EM) waves (review)

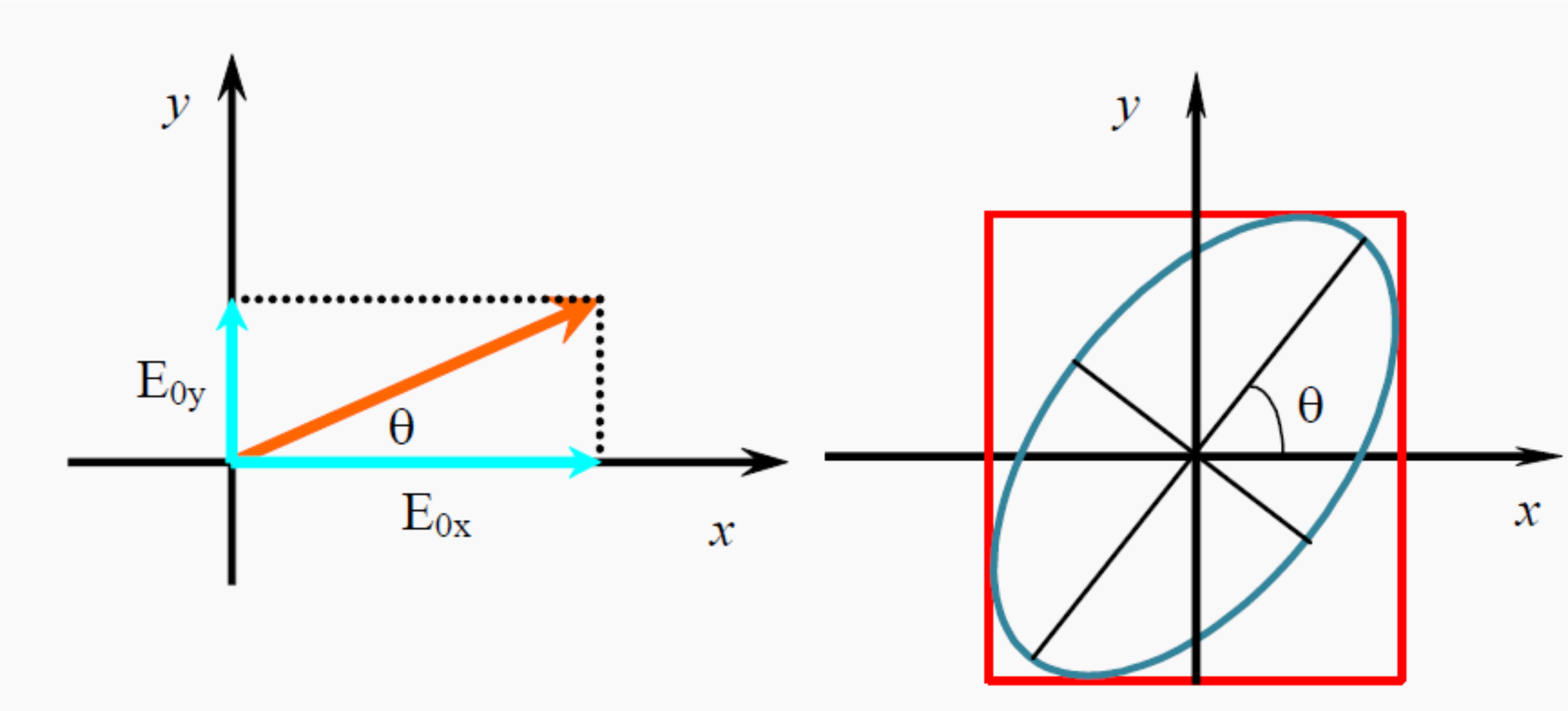
- **Polarization of electromagnetic waves:**
  - **Circular polarisation**



- **The vector E has two components E_x and E_y et $E_x=E_y$ in this case the vector E describes a circle**

Electromagnetic (EM) waves (review)

- **Polarization of electromagnetic waves:**
  - **Elliptical polarisation**



- **The vector E has two components E_x and E_y such that the vector E describes an ellipse**

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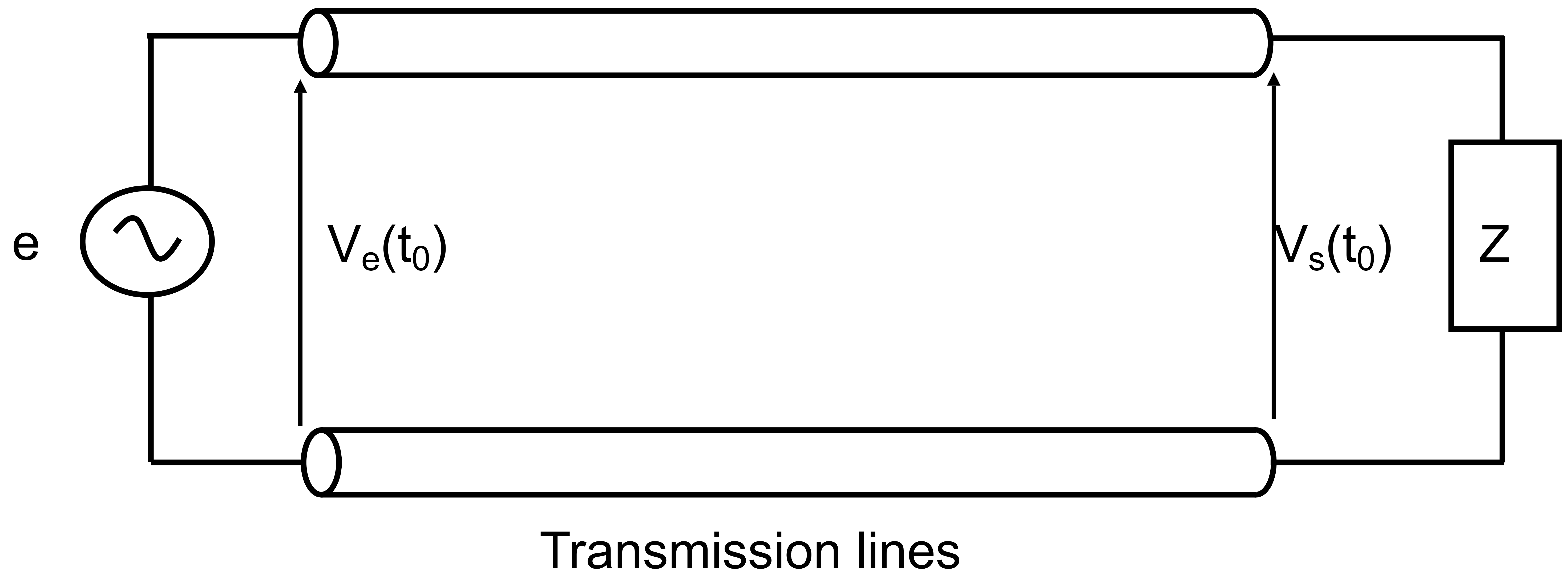
EM waves propagation

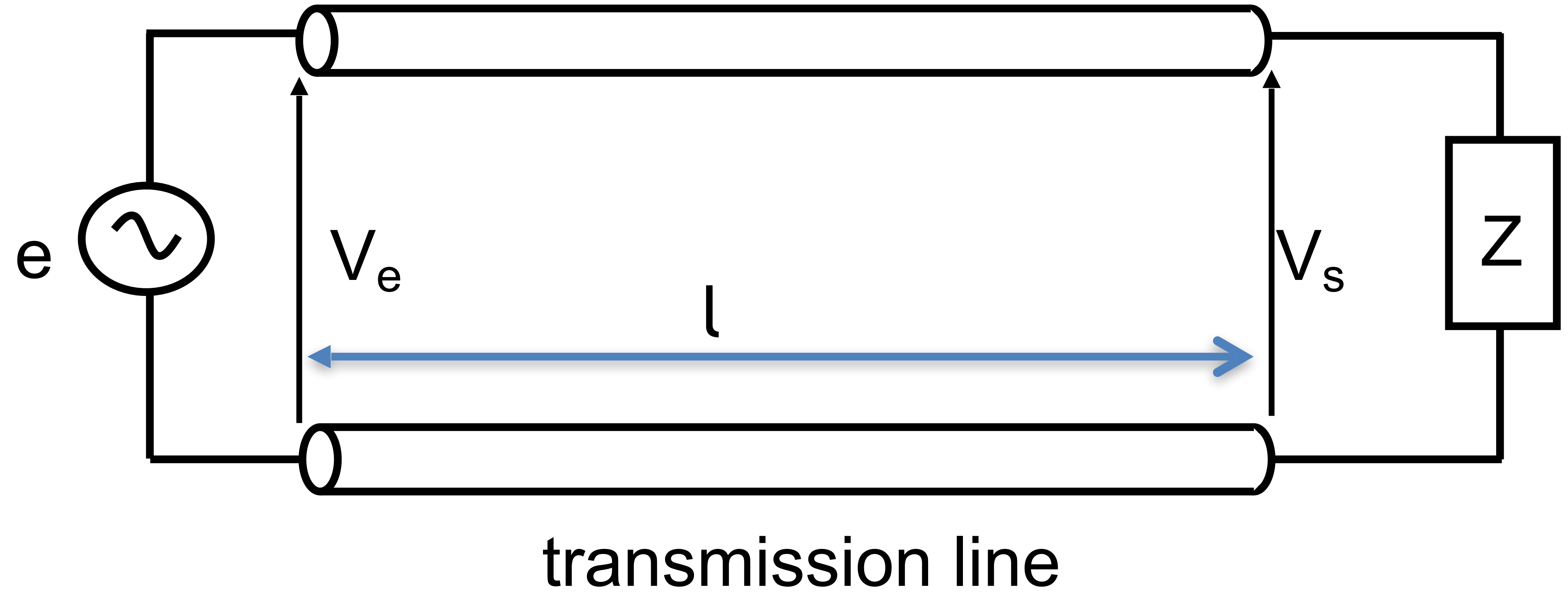
- **In a data transmission system, the transmission medium is the physical path between transmitter and receiver.**
- **Two types of propagation: Guided and unguided.**
- **For guided propagation, electromagnetic waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable, and optical fiber.**
- **For unguided media, wireless transmission occurs through the atmosphere, outer space, or water.**
- **The characteristics and quality of a data transmission are determined both by the characteristics of the medium and the characteristics of the signal.**
- **In the case of guided media, the medium itself is more important in determining the limitations of transmission.**
- **For unguided media, the bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics.**

Guided propagation

- At low frequencies, the circuit elements are lumped since voltage and current waves affect the entire circuit at the same time.
- At high frequencies, such treatment of circuit elements is not possible since voltage and current waves do not affect the entire circuit at the same time.
- Schematic of a transmission:

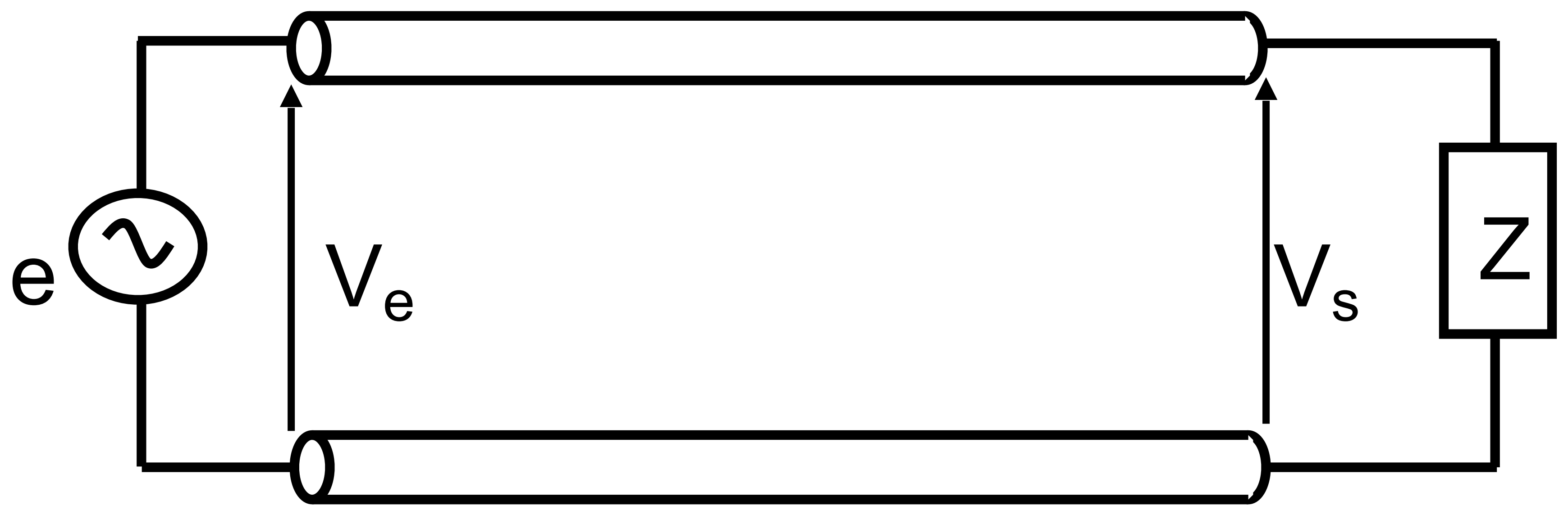


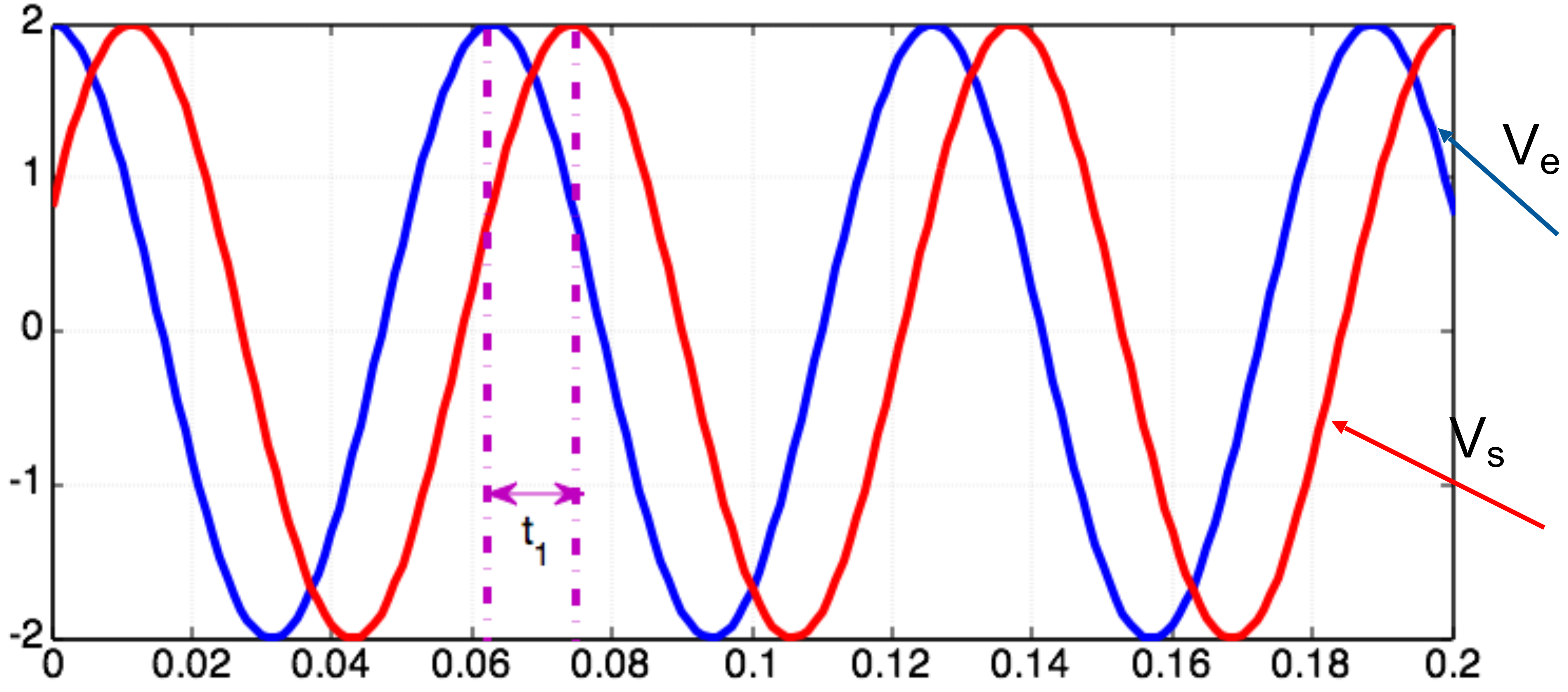
Guided propagation



- **Using circuit theory: $Ve(t_0)=Vs(t_0)$**
  - true under certain consideration (velocity of propagation, lines length)
- **$Ve(t)=A\cos(\omega t+\phi)$, avec ω: angular frequency et ϕ: the phase**
- **V_ϕ : the velocity of propagation, the signal need a time $t_1=l/V_\phi$ to travel the line.**
- **So: $V_s(t)=V_e(t-t_1)$ → $Vs(t)=A\cos(\omega(t-t_1)+\phi)= A\cos(\omega(t-l/V\phi)+\phi)$**

Guided propagation





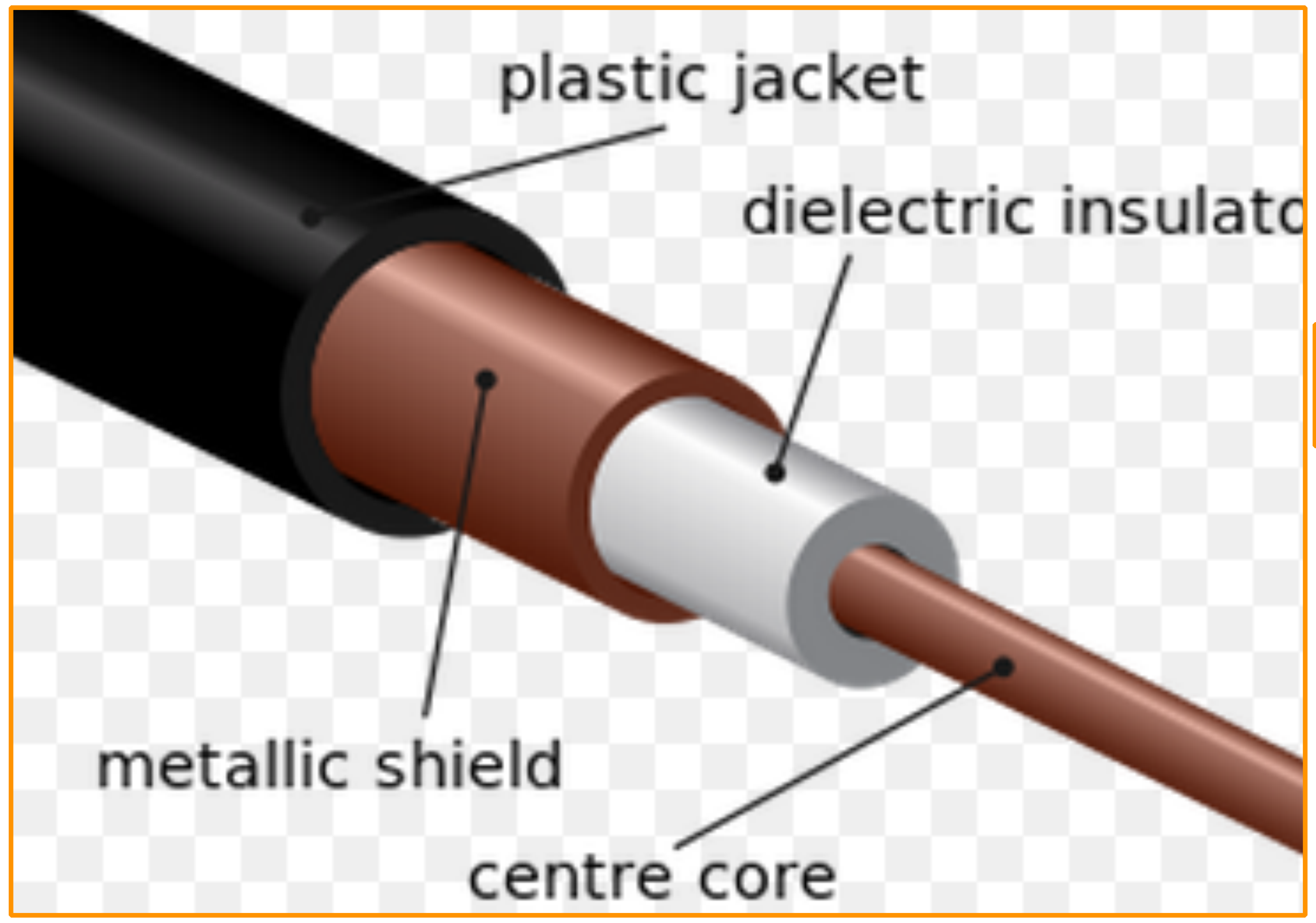
- $V_s(t)=V_e(t-t_1)$ → $V_s(t)=A\cos(\omega(t-t_1)+\phi)= A\cos(\omega(t-l/V_\phi)+\phi)$
- **Neglect the phenomena of propagation : $(t_1/T)<<1$, where T is the period of the signal.**
- **It depends on the frequency of the signal**

Guided propagation

- **For EDL (Electricité de Liban) lines:**
  - f=50 Hz, λ=c/f=6000 Km, so λ>> length of the lines used for transmission
  - t1<<T, there is no need to introduce the concept of propagation.
- **High frequency electronic circuits**
  - f=10 GHz, λ=c/f=3 cm
  - λ<< length of the transmission lines
  - It is therefore essential to take into account the propagation phenomena

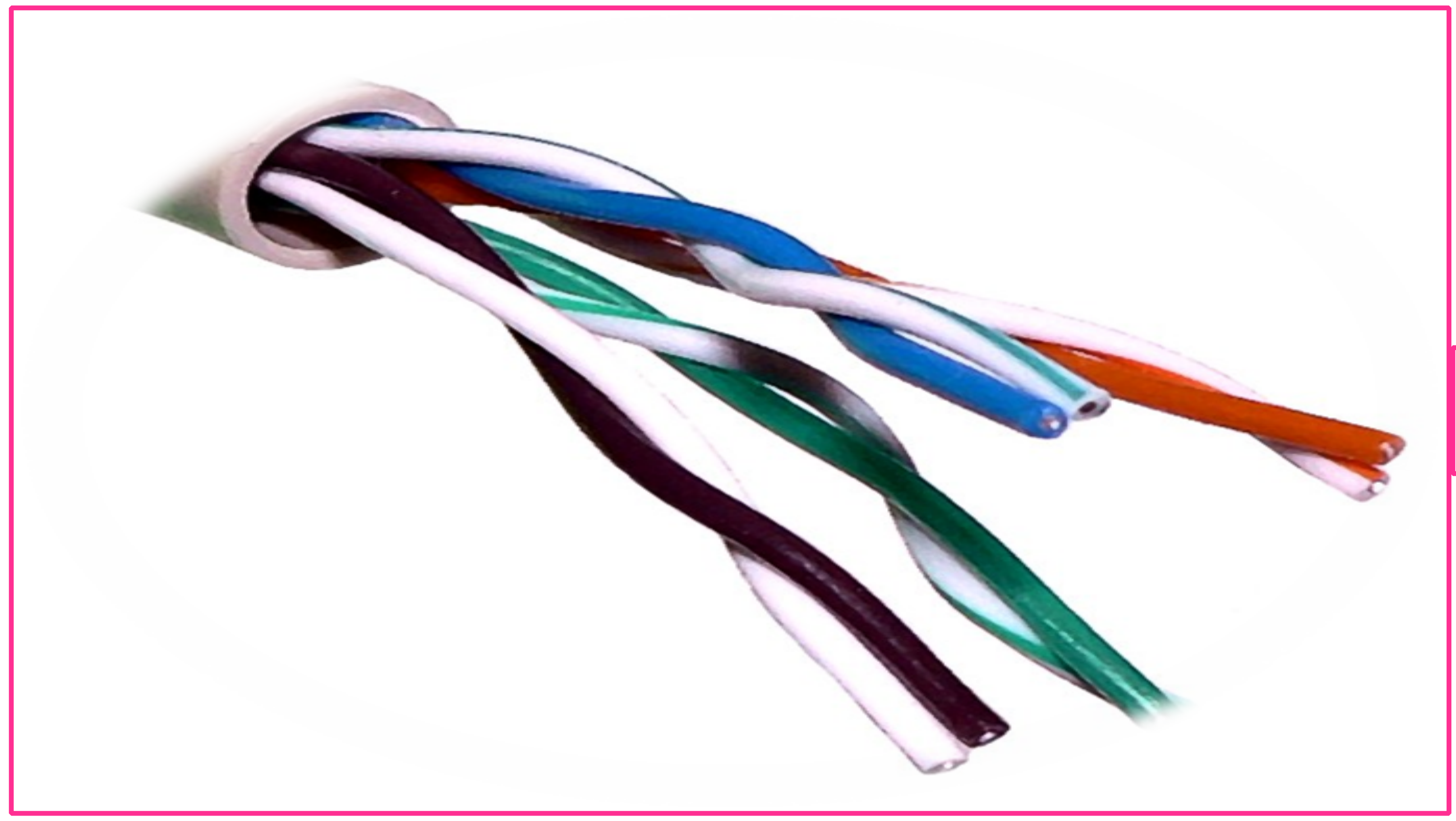
Examples of transmission lines

- **Coaxial Cable, waveguide…**

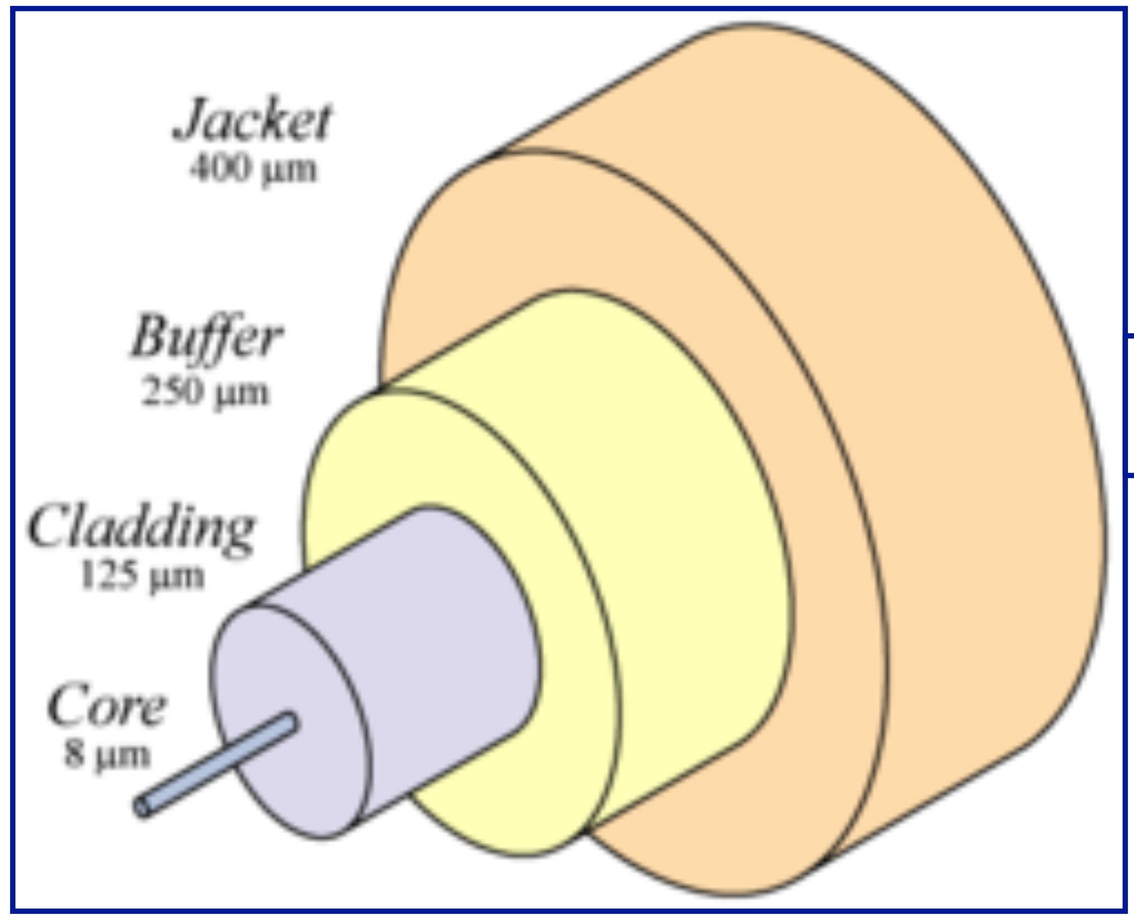


Coaxial Cable

Rectangular waveguide



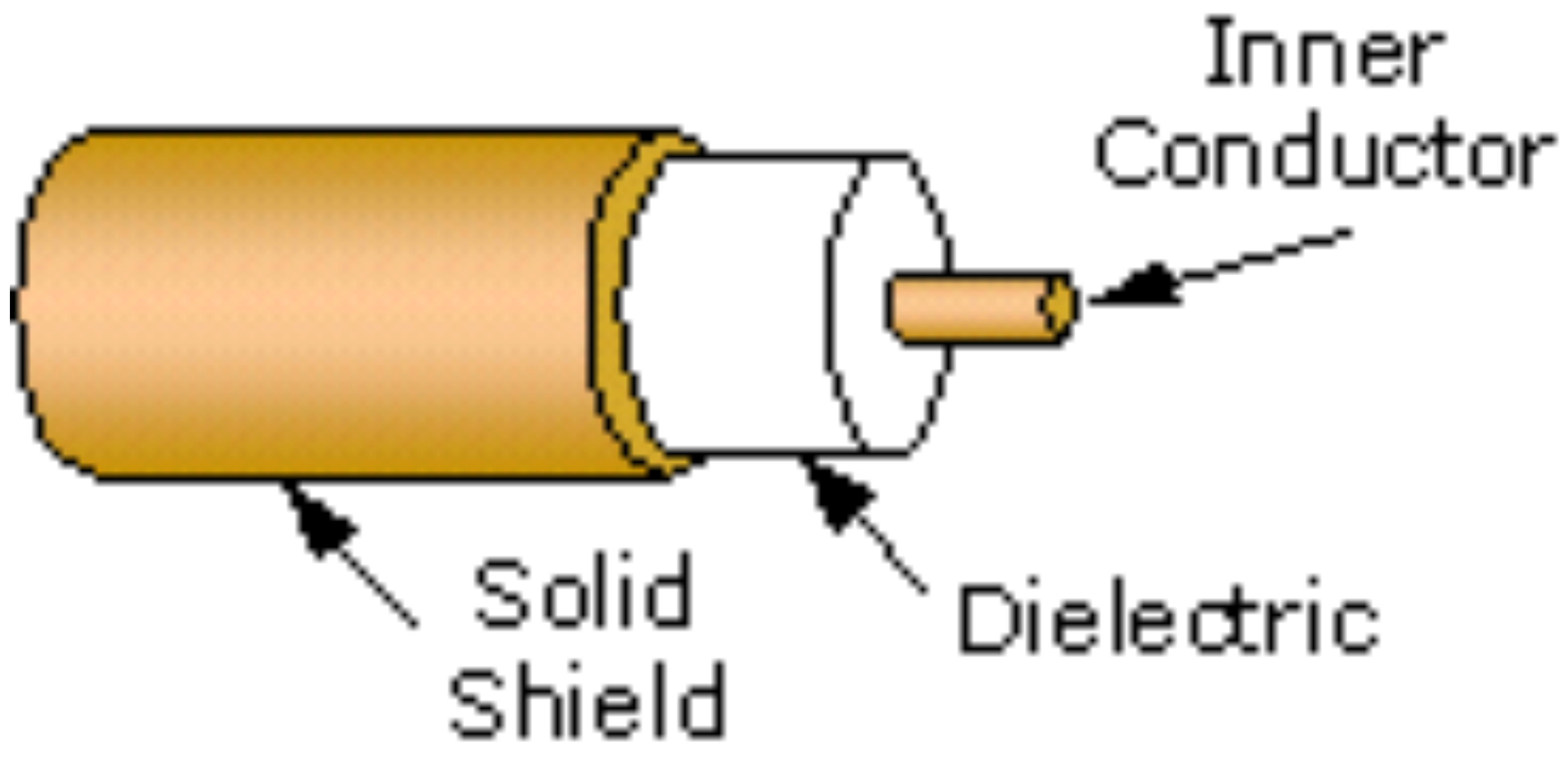
Fiber optics

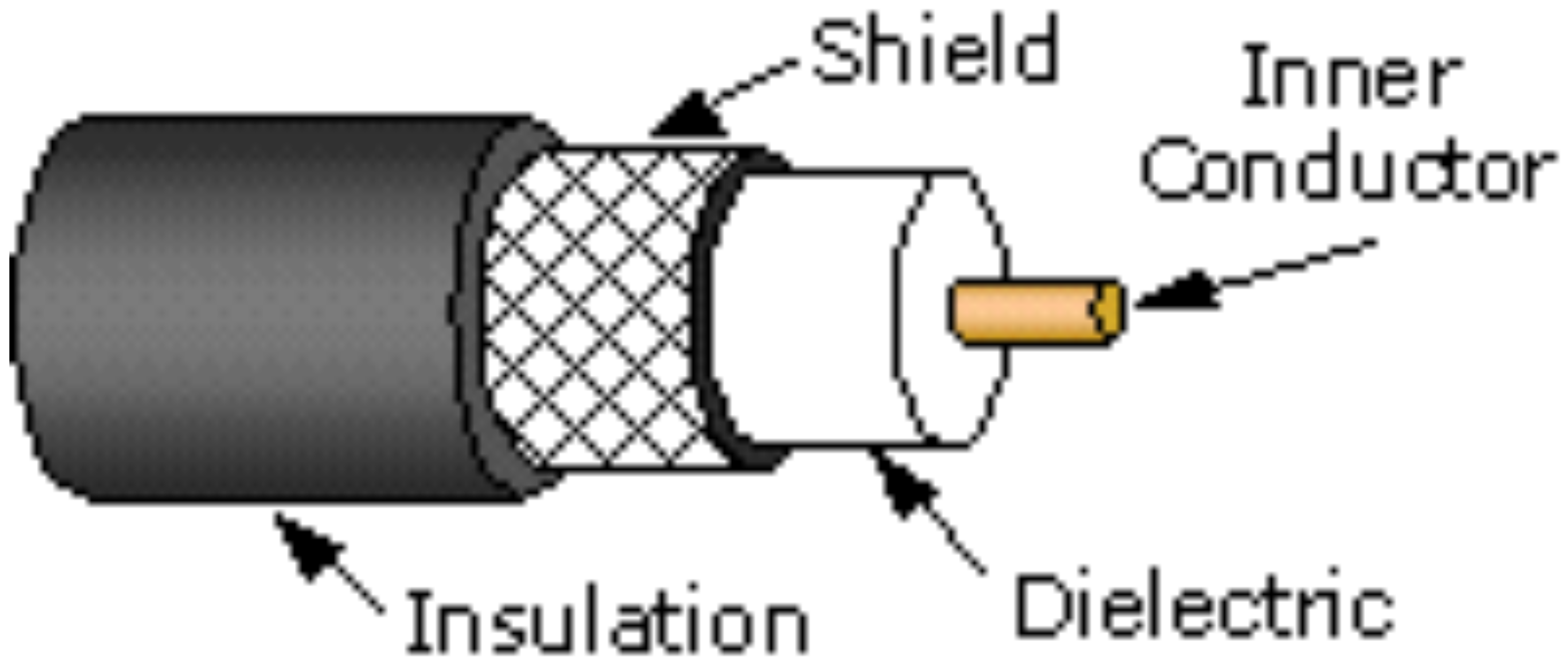


Fiber optics

General characteristics of coaxial cables

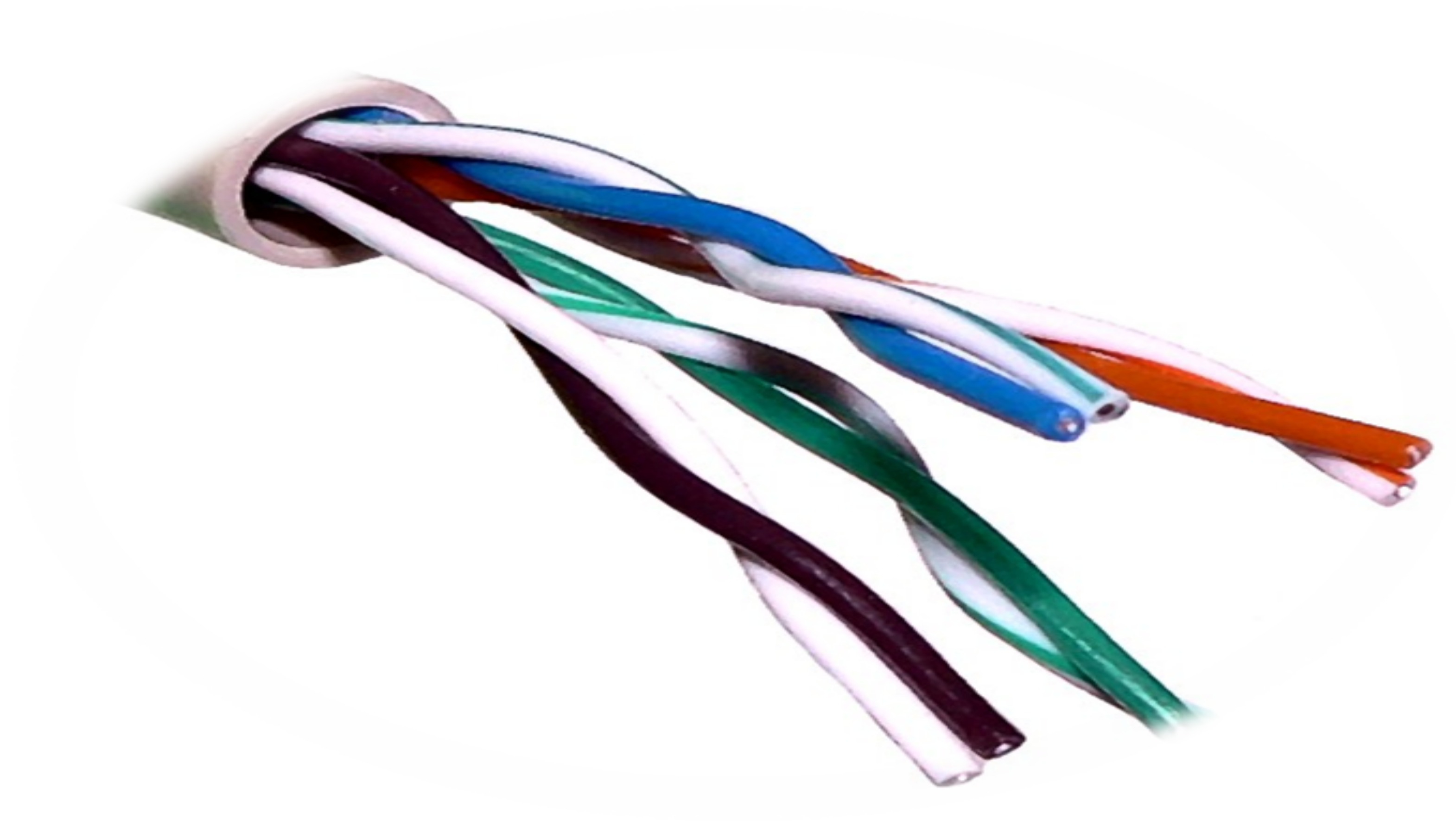
- Unbalanced line (center conductor and outer conductor are at different potentials vs. ground)
- Fields stay in the cable
- Coaxial cables has a proper impedance (50-ohm or 75-ohm)
- Good for moderate to high power handling
- High bandwidth





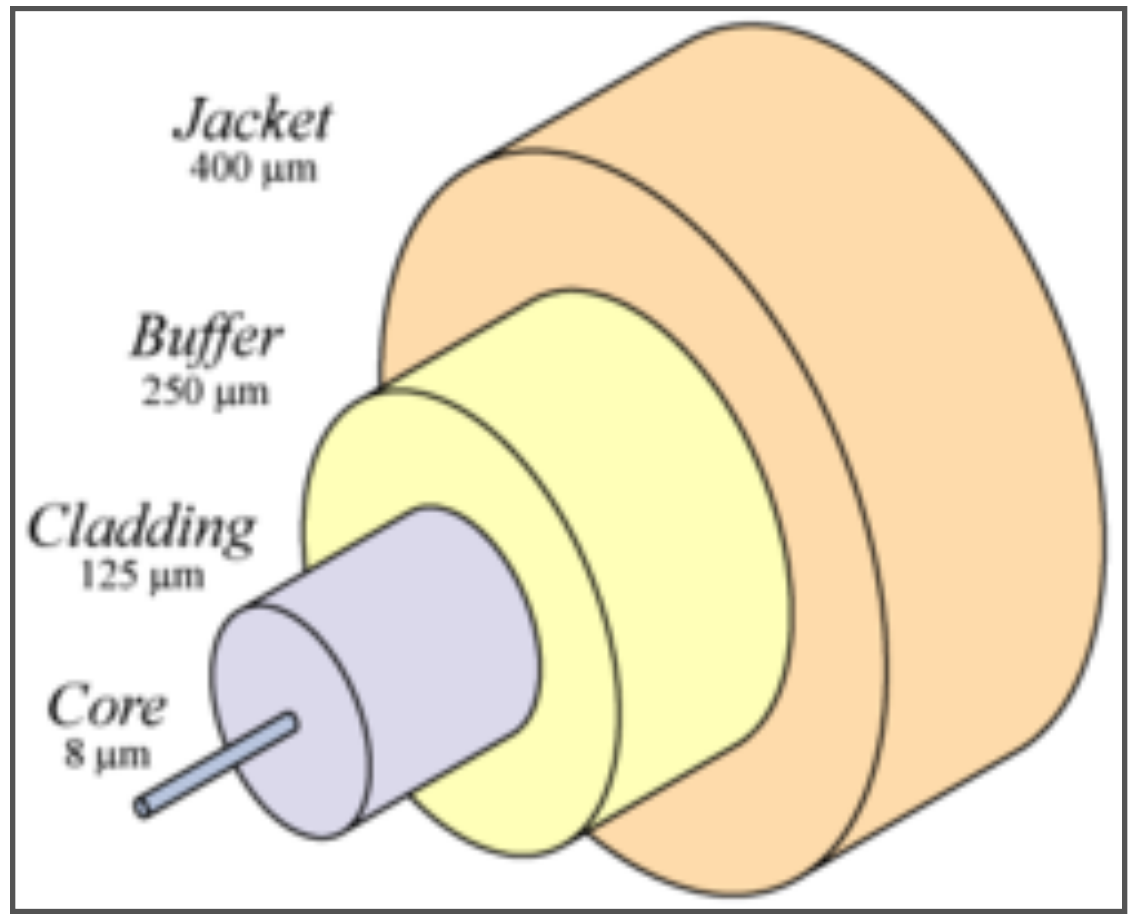
Twisted pair cables

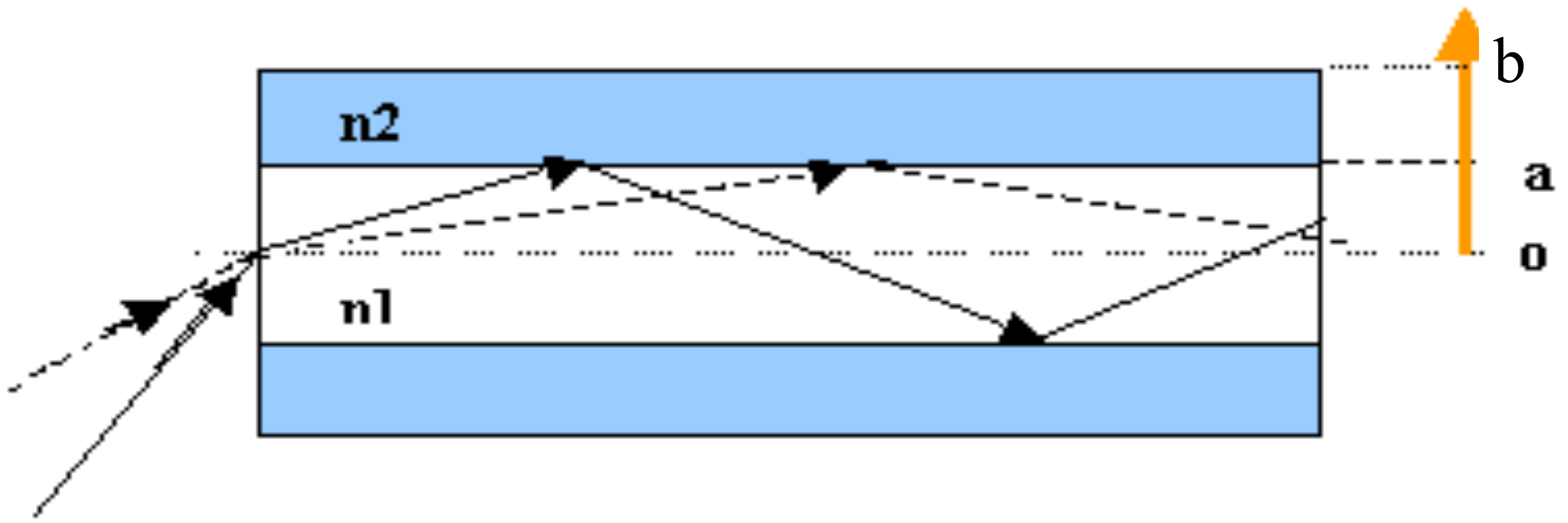
- **Twisted pair cabling is a type of wiring in which two conductors of a single circuit are twisted together for the purposes of canceling out electromagnetic interference (EMI) from external sources; for instance, electromagnetic radiation from unshielded twisted pair (UTP) cables, and crosstalk between neighboring pairs.**
- **Bandwidth: 0-2GHz**

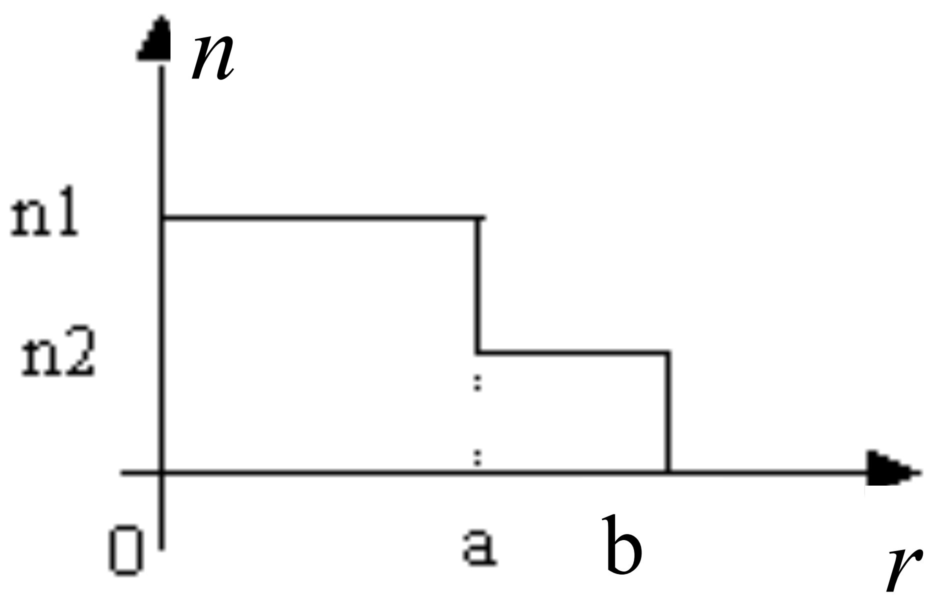


Fiber-Optic Guide

- Properties:
  - Can propagate a signal at any frequency (in theory)
  - Can be made very low loss
  - Has minimal signal distortion
  - Very immune to interference

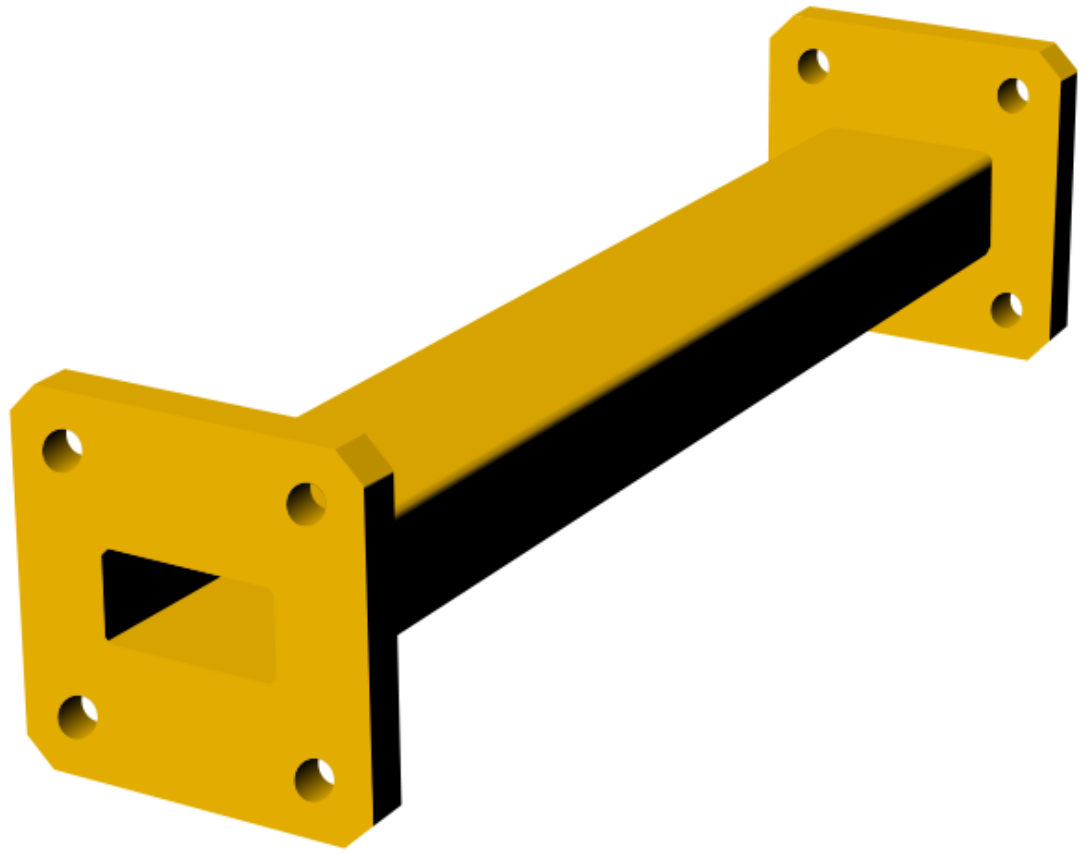






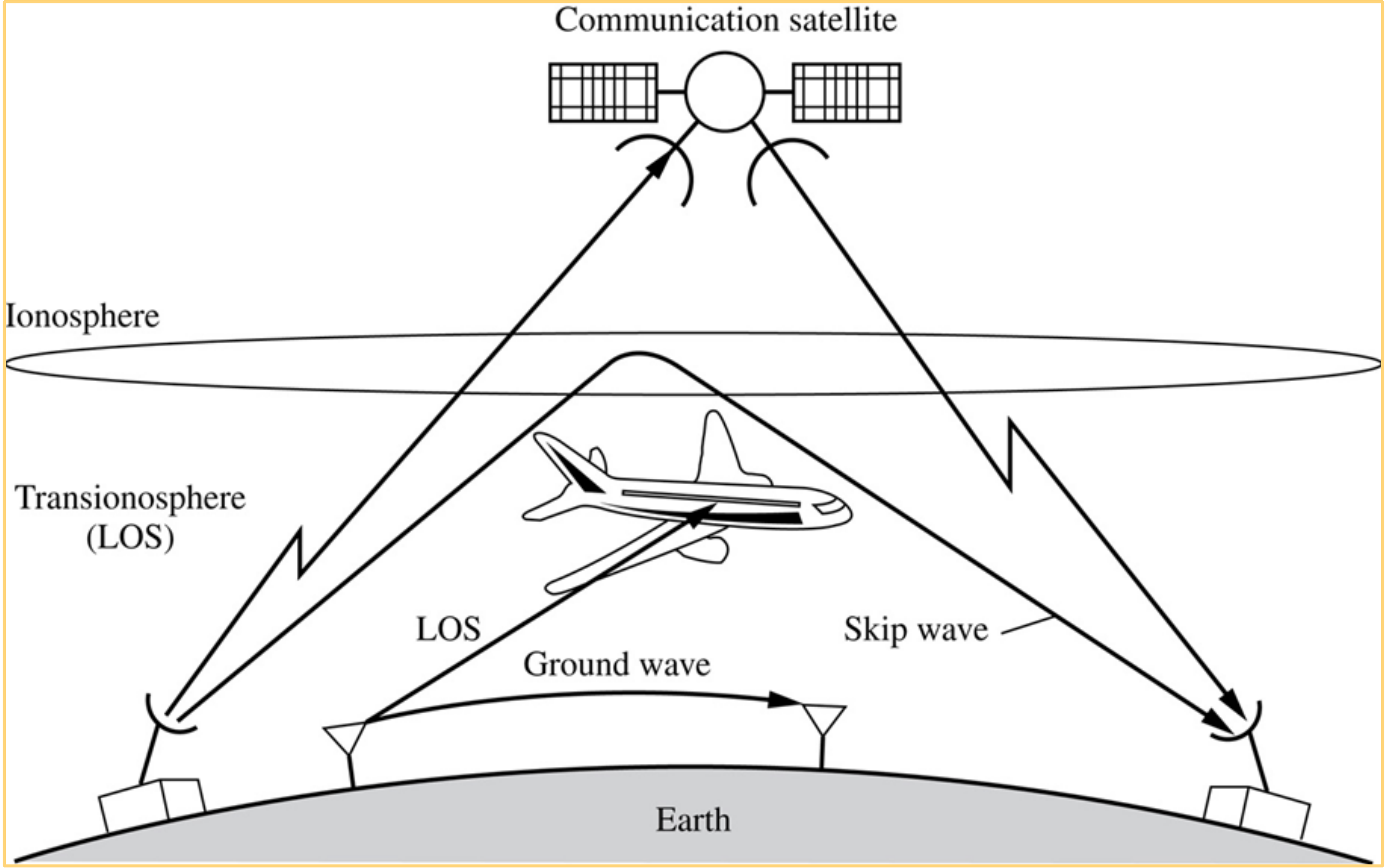
Waveguides

- Has a single hollow metal pipe
- Can propagate a signal only at high frequency: $\omega > \omega c$
- The width must be at least one-half of a wavelength
- Immune to interference
- Can handle large amounts of power
- Has low loss (compared with coaxial cable)



Wireless (Unguided) propagation

- The term wireless communication refers to the transfer of information using electromagnetic (EM) waves over the atmosphere rather than using any propagation medium that employs wires.
- Except for the case of propagation between two spacecraft in outer space, the intermediate medium between transmitter and receiver is never well approximated by free space.
- Depending on the distance involved and the frequency of the radiated waveform, a terrestrial communication link may depend on line-of-sight, ground-wave, or ionospheric skip-wave propagation.
- Antenna is an important component in wireless communication systems.



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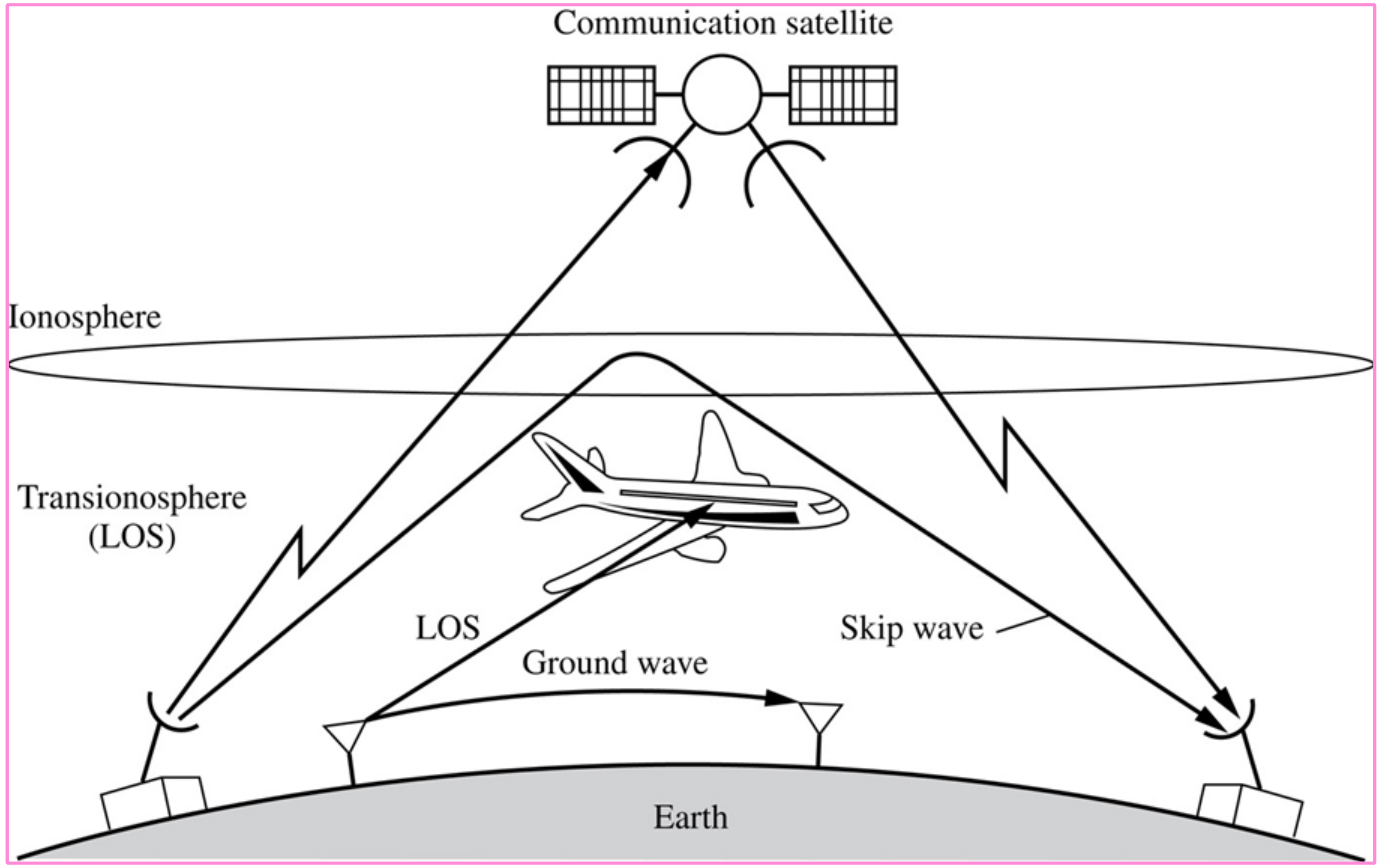
Wireless (Unguided) propagation

- At lower frequencies, or long wavelengths, propagating radio waves tend to follow the earth's surface.
- At higher frequencies, or short wavelengths, radio waves propagate in straight lines.
- Another phenomenon that occurs at lower frequencies is reflection (or refraction) of radio waves by the ionosphere
- Above about 300 MHz, propagation of radio waves is by line of sight, because the ionosphere will not bend radio waves in this frequency region sufficiently to reflect them back to the earth.
- Frequencies between 1GHz and 40 GHz are used for satellite communications



Wireless (Unguided) propagation

- At still higher frequencies, say above 1 or 2 GHz, atmospheric gases (mainly oxygen), water vapor, and precipitation absorb and scatter radio waves.
- This phenomenon manifests itself as attenuation of the received signal, with the attenuation generally being more severe the higher the frequency (there are resonance regions for absorption by gases that peak at certain frequencies).