Atmospheric Physics

Lecture 16

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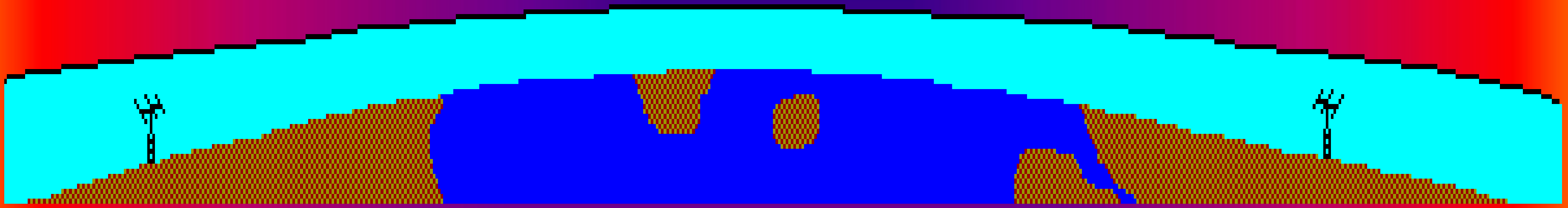
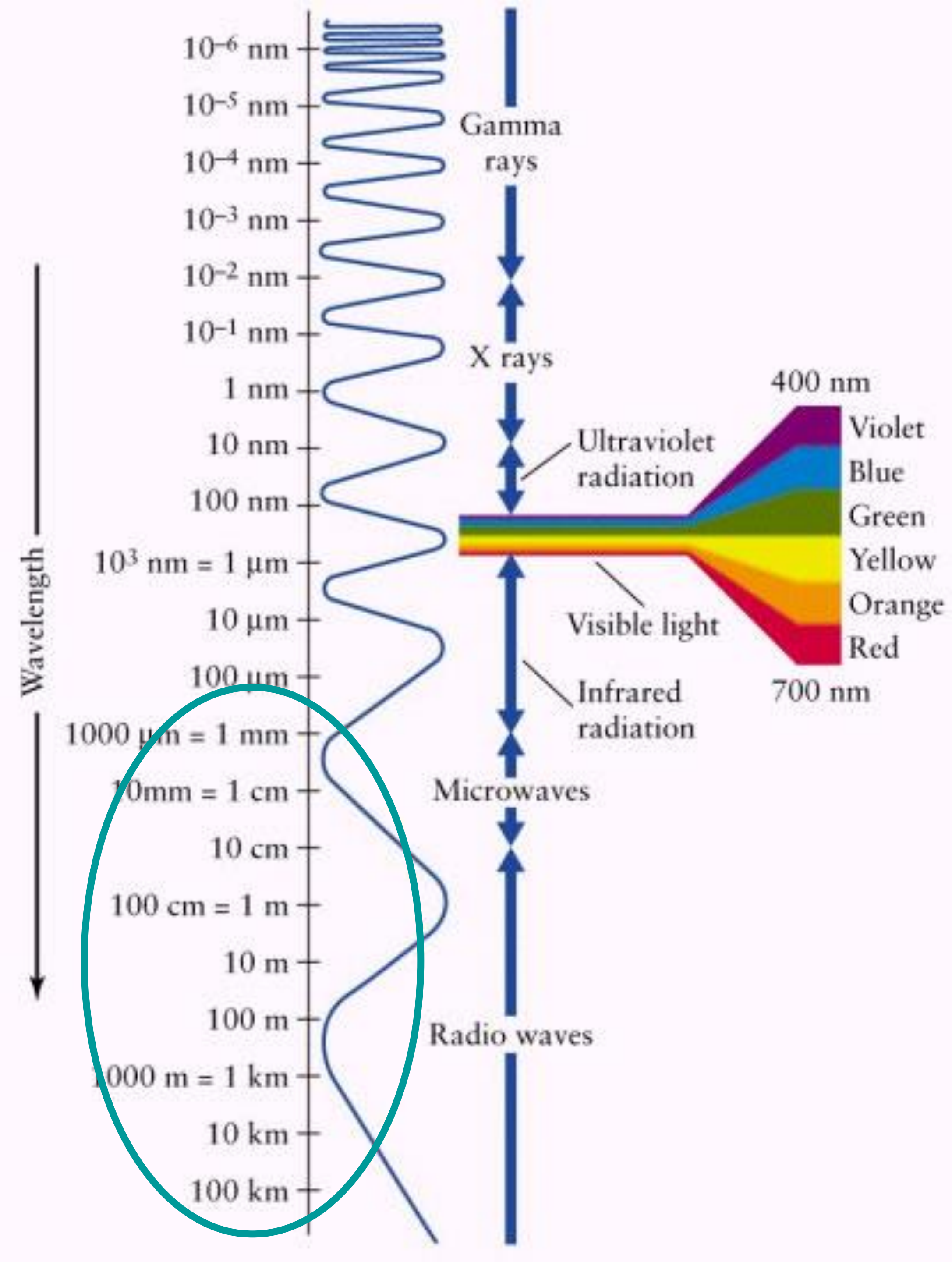
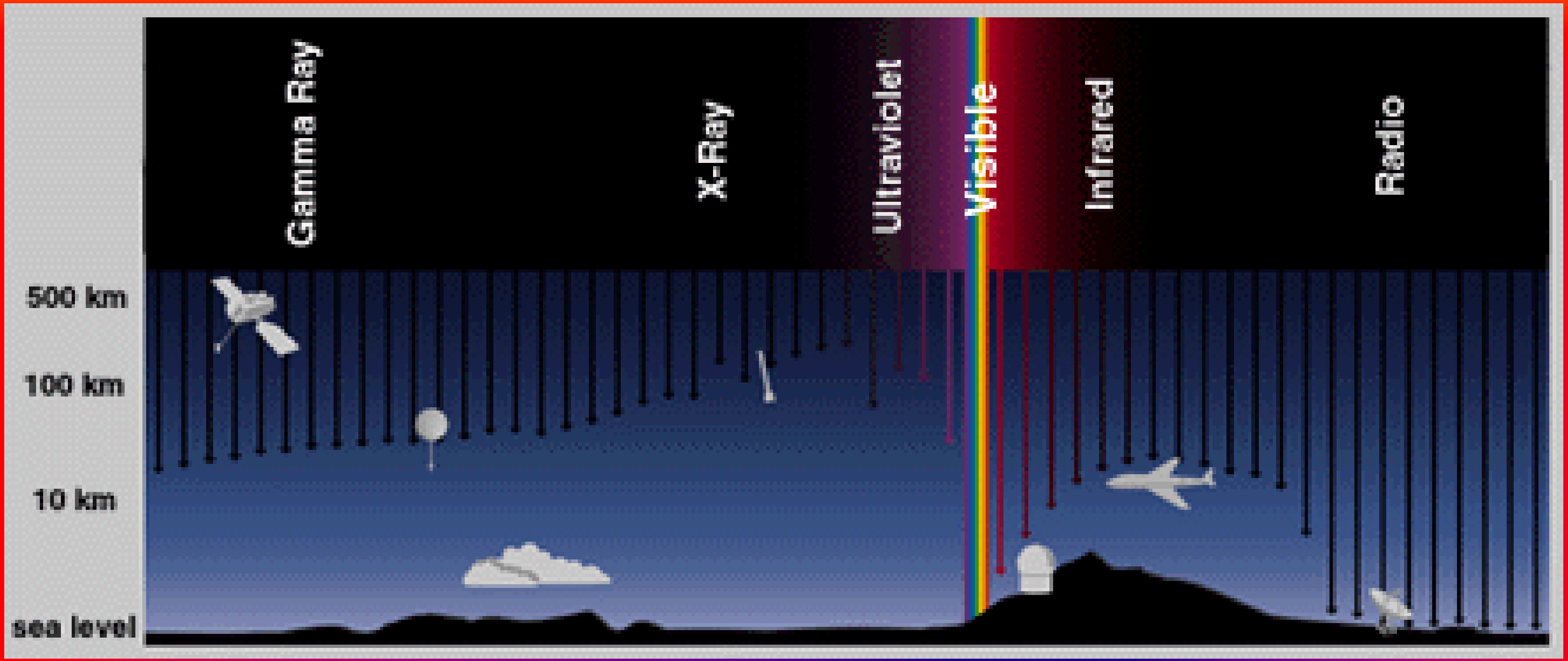
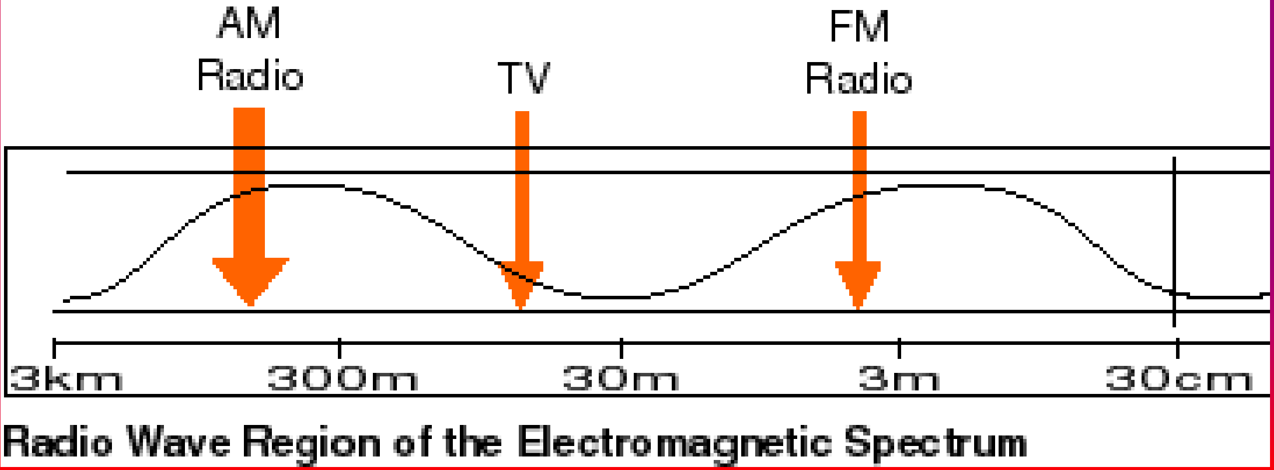


The FULL Electromagnetic Spectrum



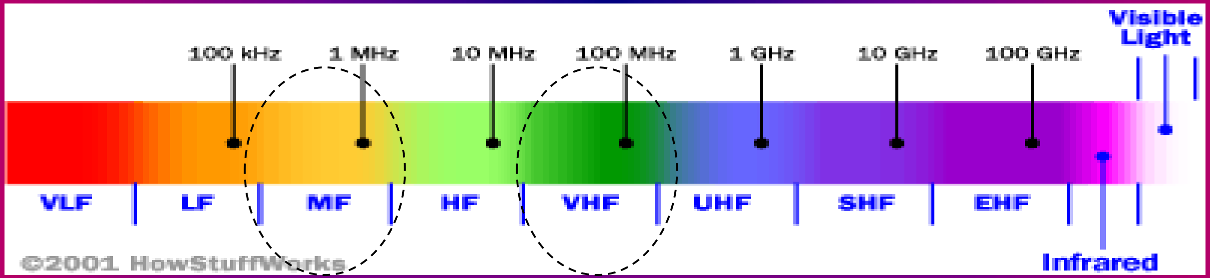

Gamma Ray
X-Ray
Ultraviolet
Visible
Infrared
Radio
500 km
100 km
10 km
sea level

Radio Waves


AM
Radio
TV
FM
Radio
3km
300m
30m
3m
30cm
Radio Wave Region of the Electromagnetic Spectrum

Radio waves of our interest

VLF	3 – 30	kHz
LF	30 – 300	kHz
MF	300 – 3000	kHz
HF	3 – 30	MHz
VHF	30 – 300	MHz
UHF	300 – 3000	MHz



AM radio FM radio/TV

For example, an AM radio system transmits electromagnetic waves with frequencies of 535 KHZ to 1.7 MHZ (MF band)
The FM radio system must operate with frequencies in the range of 88-108 MHz (VHF band)

Common frequency bands

AM radio - 535 KHZ to 1.7 MHZ

Short wave radio - bands from 5.9 to 26.1 MHZ

FM radio - 88 to 108 MHZ

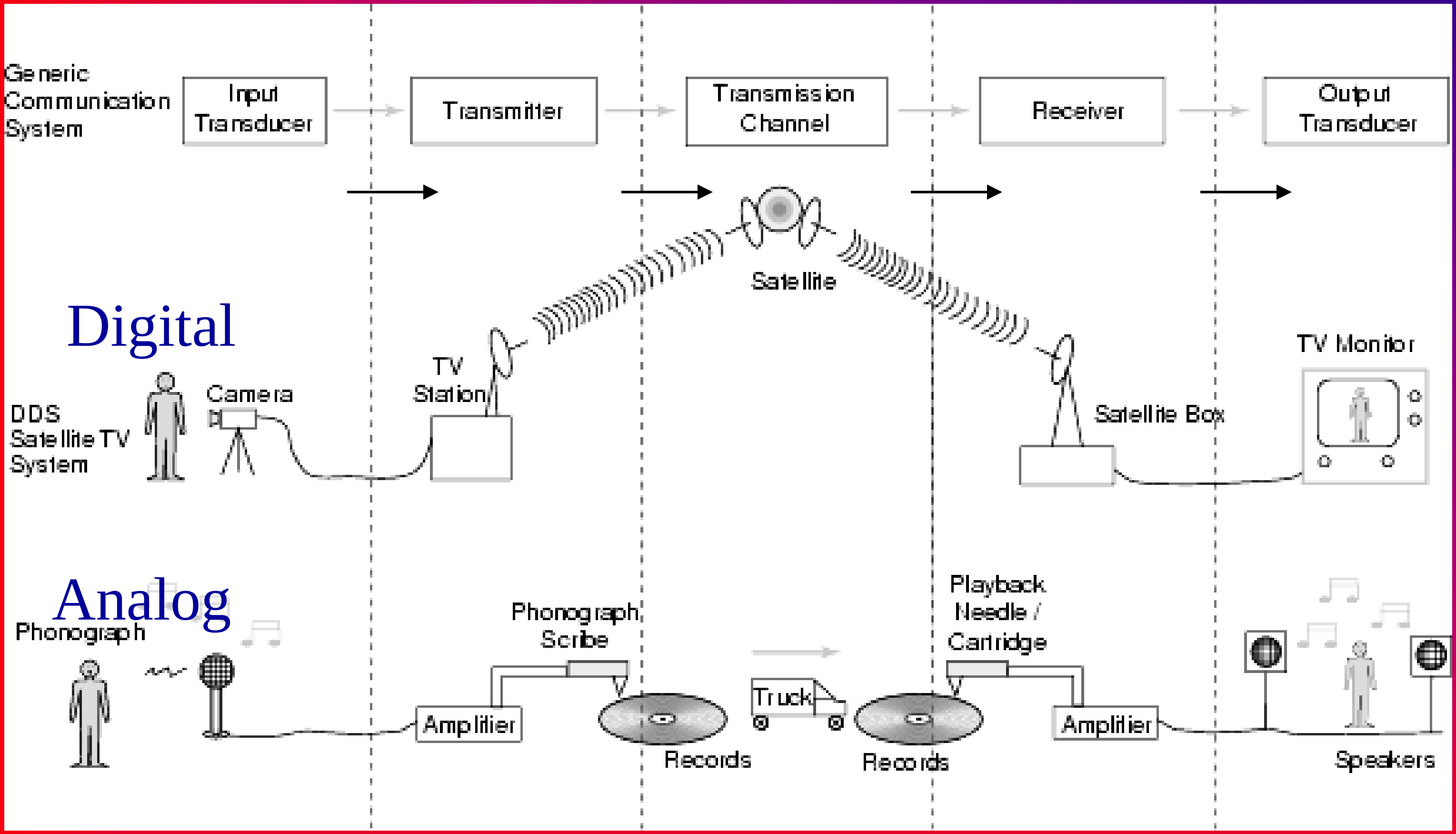
Television stations - 174 to 220 MHZ for

Radio waves have the longest wavelengths in the electromagnetic spectrum. These waves can be longer than a football field or as short as a football. Radio waves do more than just bring music to your radio.

They also carry signals for your television and cellular phones.

Cellular phones also use radio waves to transmit information. These waves are much smaller than TV and FM radio waves. Why are antennae on cell phones smaller than antennae on your radio?

Communication systems

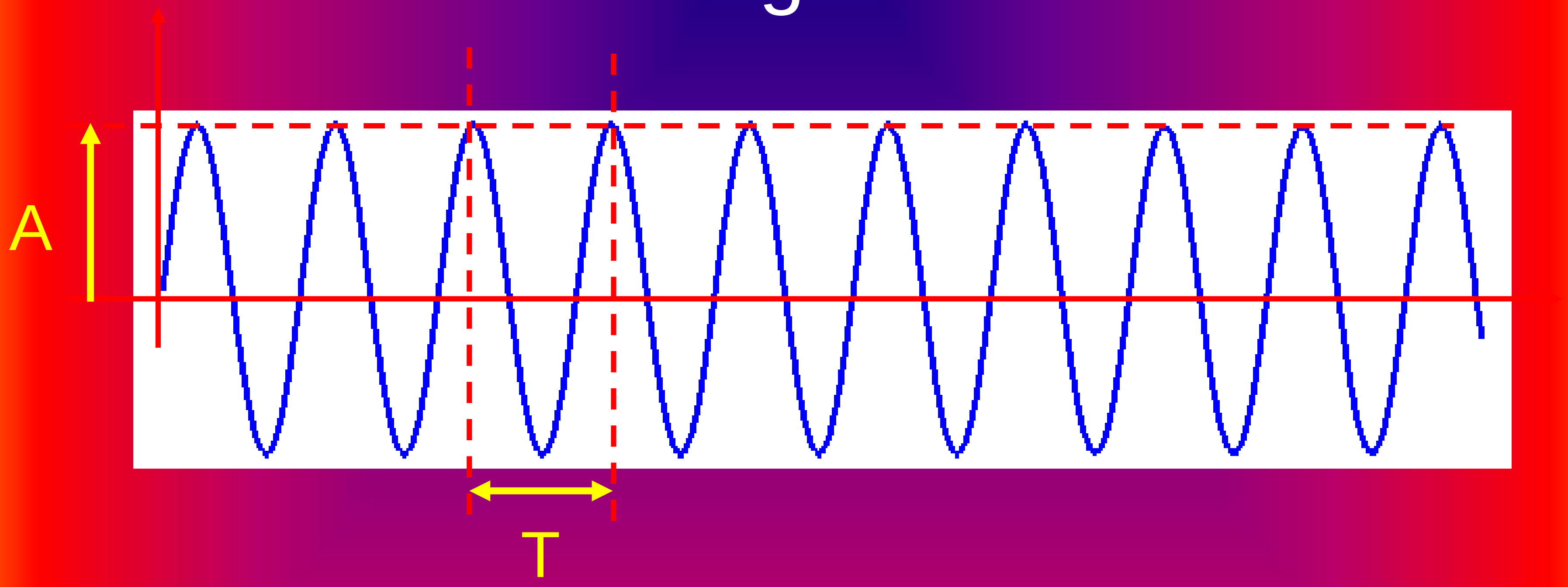


The block diagram on the top shows the blocks common to all communication systems

Remember the components of a communications system:

- *Input transducer:* The device that converts a physical signal from source to an electrical, mechanical or electromagnetic signal more suitable for communicating
- *Transmitter:* The device that sends the transduced signal
- *Transmission channel:* The physical medium on which the signal is carried
- *Receiver:* The device that recovers the transmitted signal from the channel
- *Output transducer:* The device that converts the received signal back into a useful quantity

Transmitting information

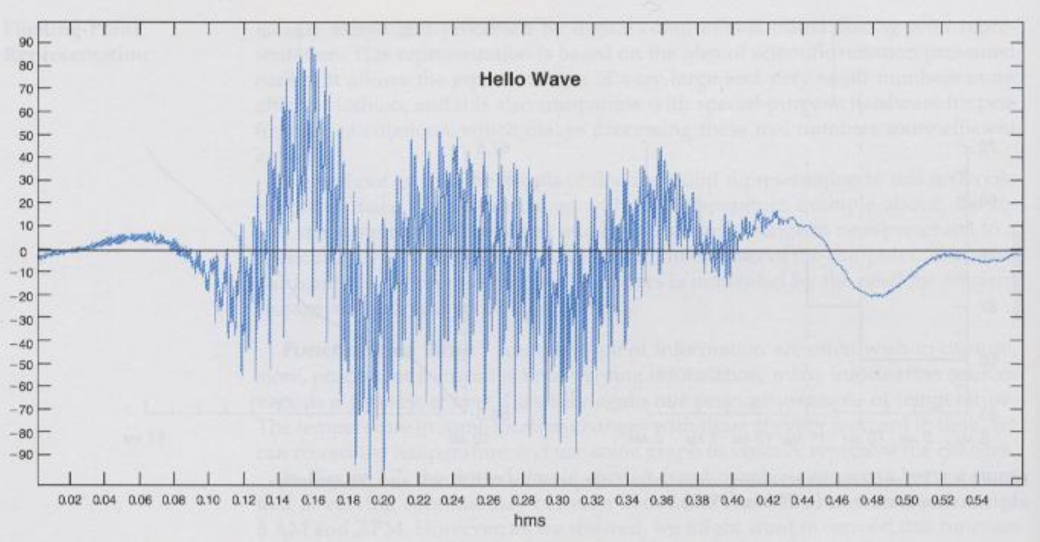


- a signal like the one above does not transmit any information – it just goes up and down, up and down
- both the amplitude (A) and the period (T) or frequency $f = 1 / T$ never change

Analog Modulation

- **The purpose of a communication system is to transmit information signals (baseband signals) through a communication channel**

- **The term *baseband* is used to designate the band of frequencies representing the original signal as delivered by the input transducer**
  - **For example, the voice signal from a microphone is a baseband signal, and contains frequencies in the range of 0-3000 Hz**
  - **The "hello" wave is a baseband signal:**

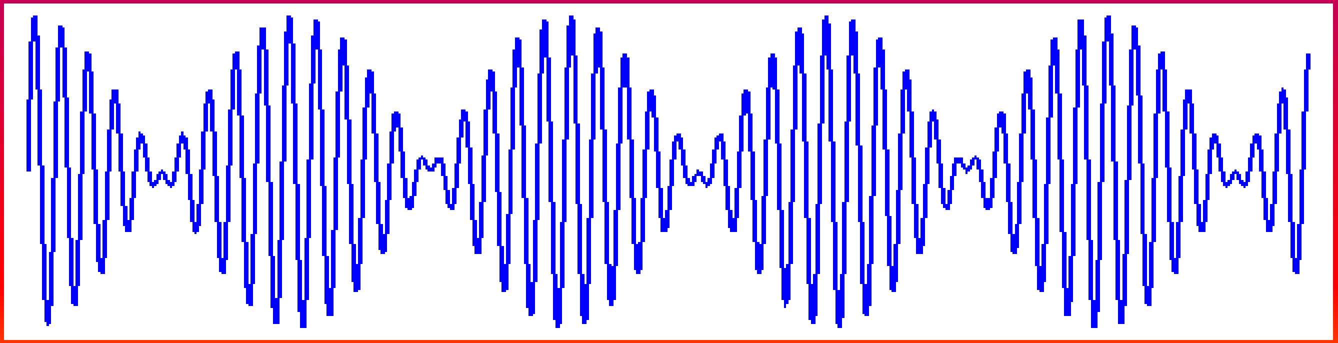


Amplitude Modulation (AM)

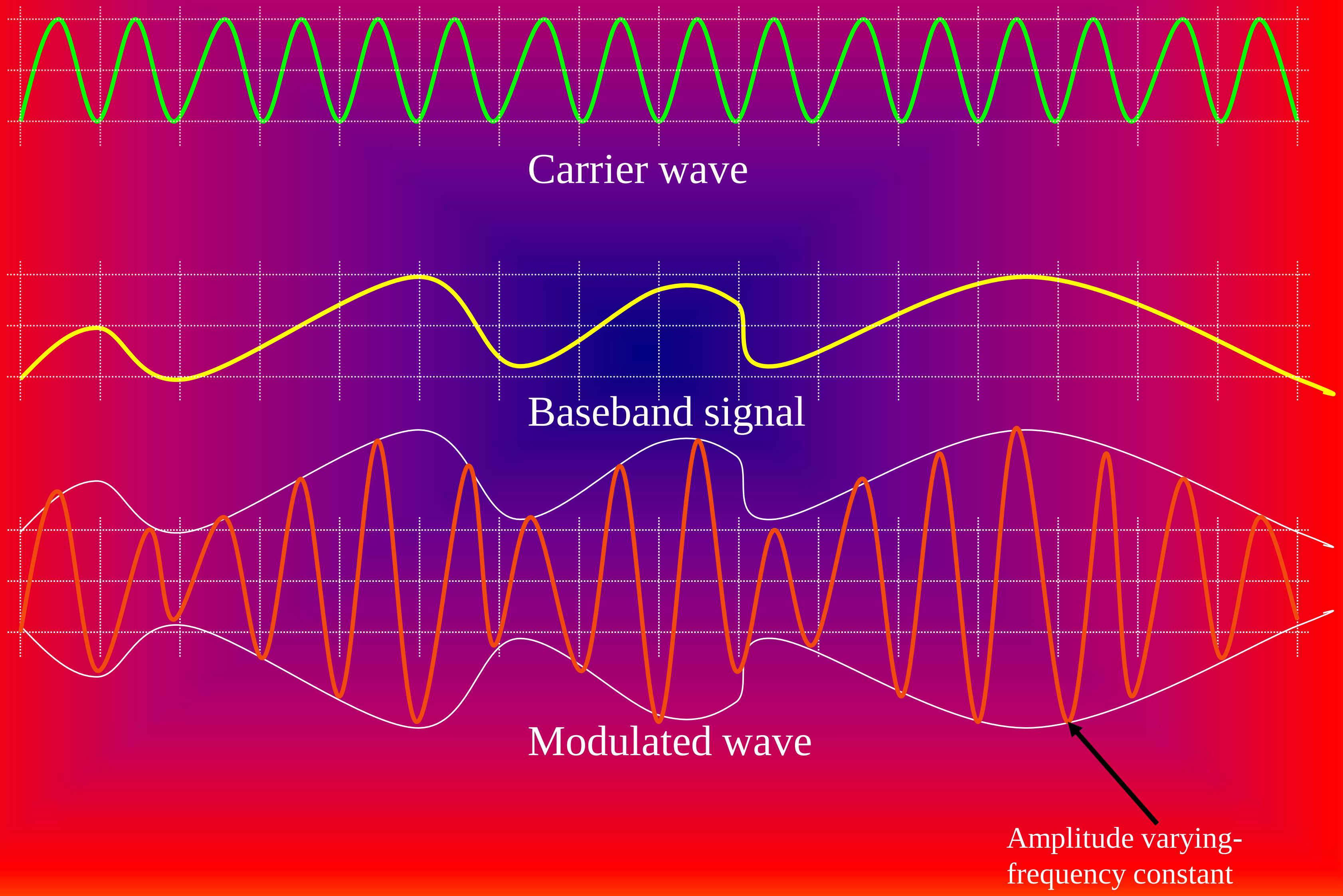
with AM the amplitude of the wave signal (carrier) is modulated (changed).

Amplitude modulation is the process of *varying the amplitude of a carrier wave in proportion to the amplitude of a baseband signal.*

the information is coded into the way that the amplitude is modulated



Amplitude Modulation

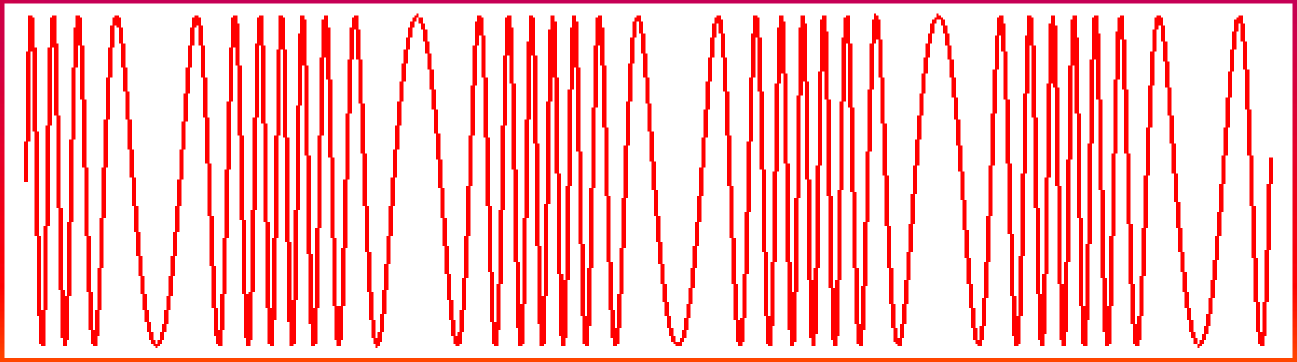


Frequency modulation (FM)

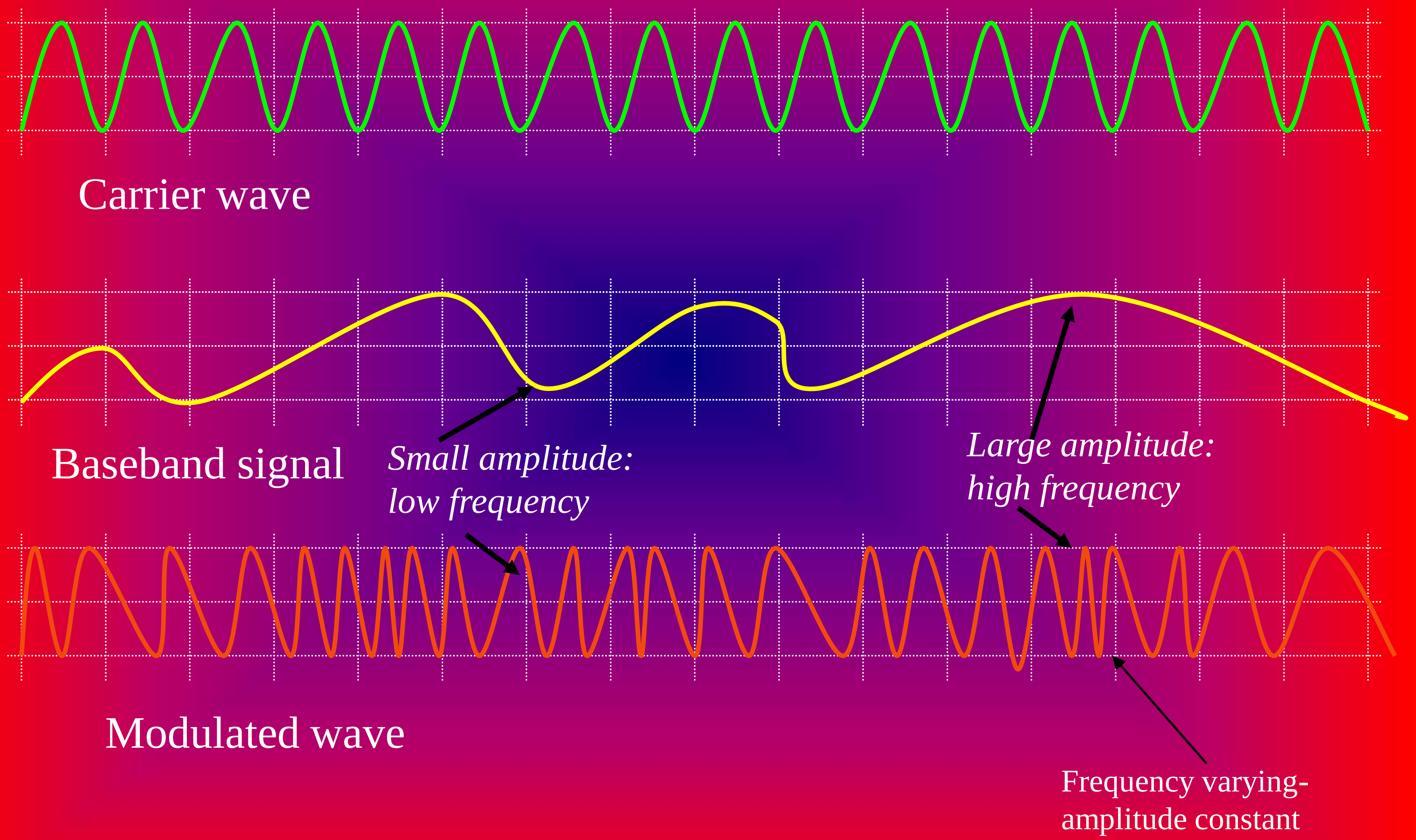
with FM signals the frequency of the signal is modulated

Frequency modulation is the process of *varying the frequency of a carrier wave in proportion to the amplitude of a baseband signal.*

information is coded into the way that the modulation frequency is varied



Frequency Modulation



The Ionosphere and Radio Wave Propagation

The ionosphere is important for radio wave (AM only) propagation.

Ionosphere is composed of the D, E, and F layers

The D layer is good at absorbing AM radio waves

D layer dissapears at night.... the E and F layers bounce the waves back to the earth

this explains why radio stations adjust their power output at sunset and sunrise

Refraction of Signals

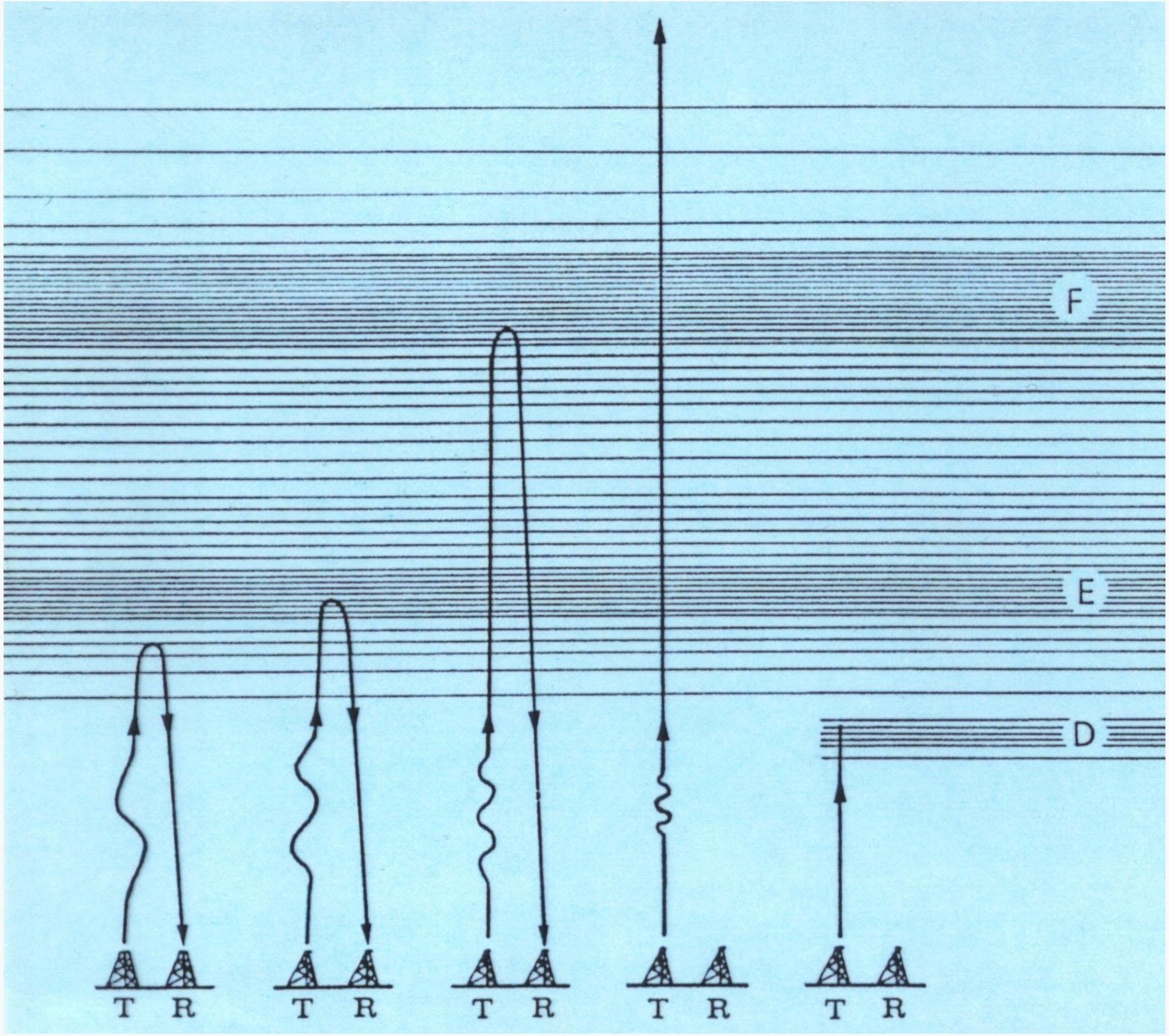
- Bending of signals by atmosphere decreases with increasing frequency
- Bending of signals by atmosphere increases with increasing ionization

Daytime Propagation

- D and E layers absorb lower frequencies, below about 8-10 MHz
- F layers return signals from about 10-30 MHz

Nighttime Propagation

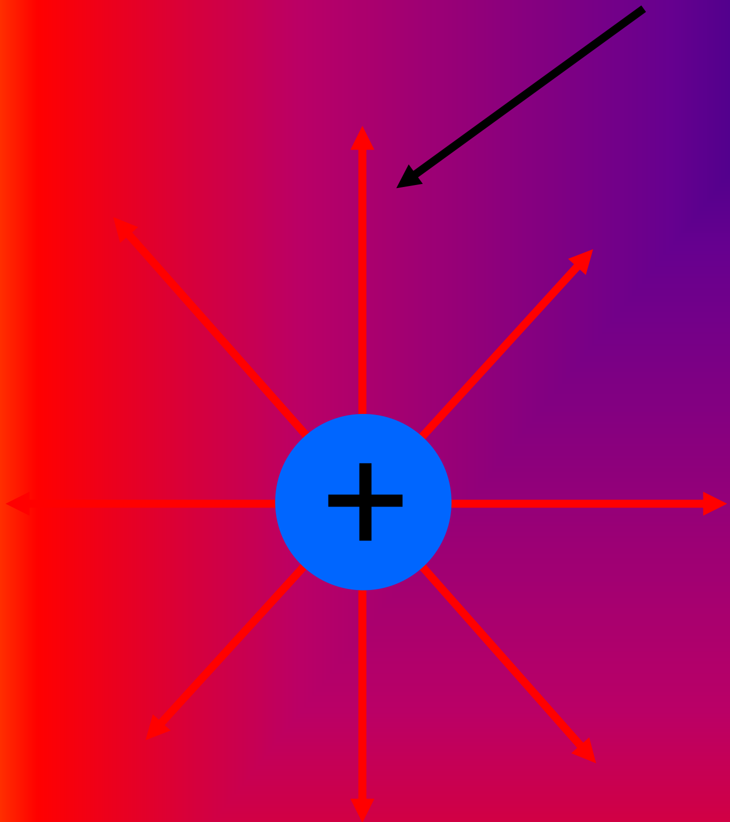
- D layer disappear
- F layer returns signals from about 2-10 MHz
- Higher frequencies pass through ionosphere into space


F
E
D
T R
T R
T R
T R
T R

Electric and Magnetic Fields

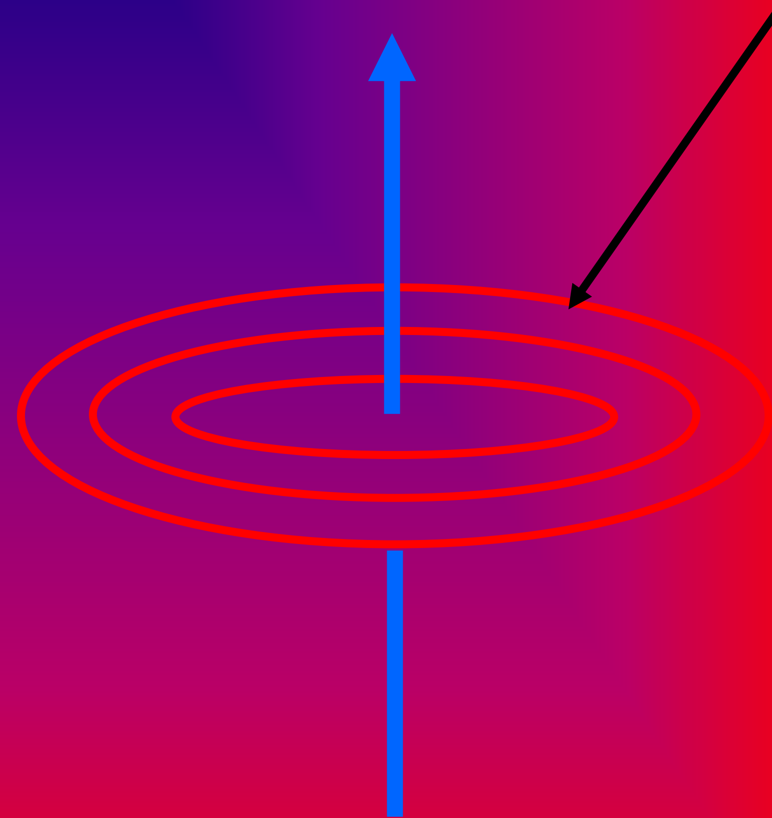
- electric charges produce electric fields
- electric currents (moving charges) produce magnetic fields
- an electromagnetic wave is a pattern of electric and magnetic fields that vibrate together in space and time in a synchronous fashion

Electric Field



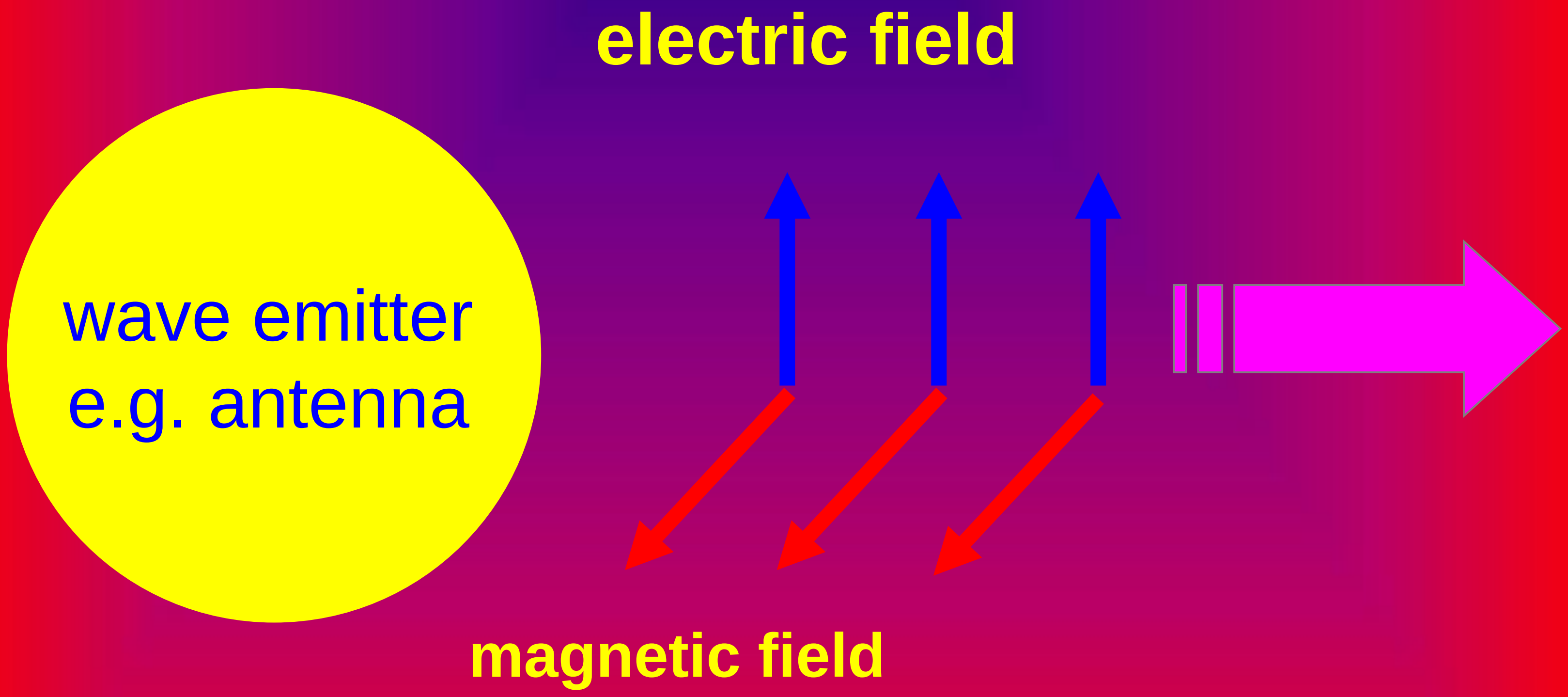
electric field of a
positive charge

Magnetic Field



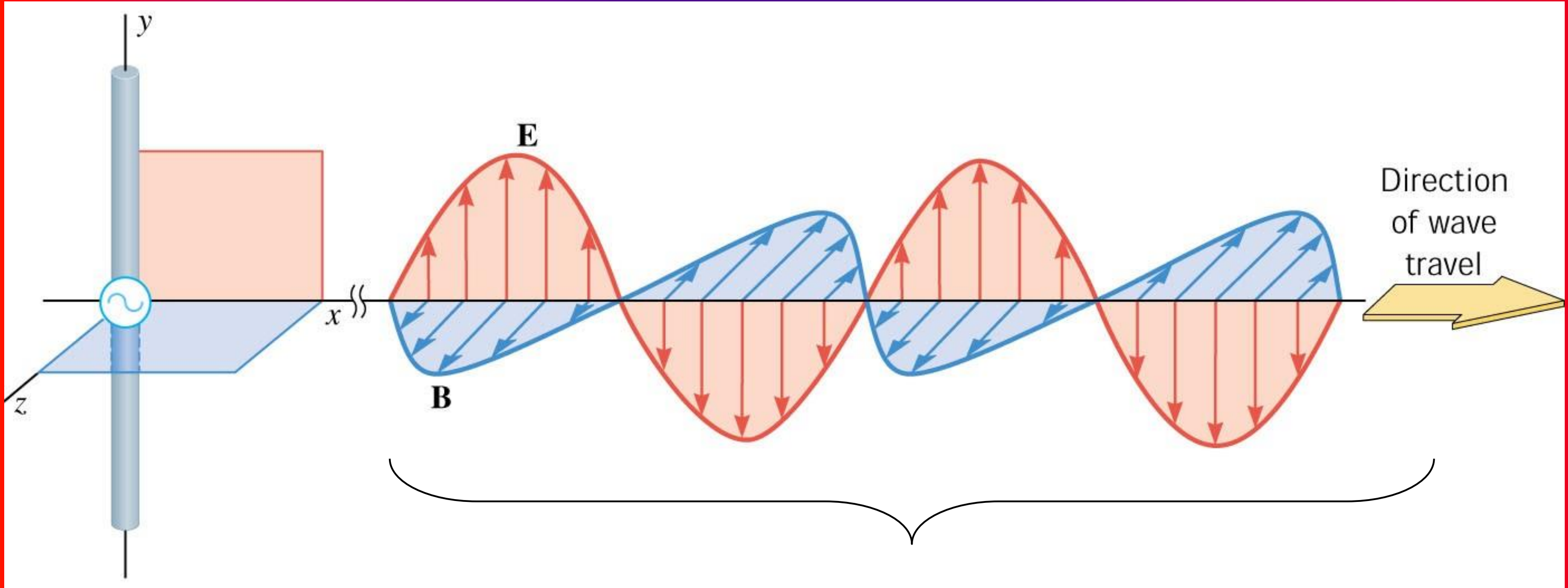
magnetic field of a
current in a wire

the generation of an electromagnetic wave



The time varying electric field generated the time varying magnetic field which generates the time varying electric field and so on and so on . . . .

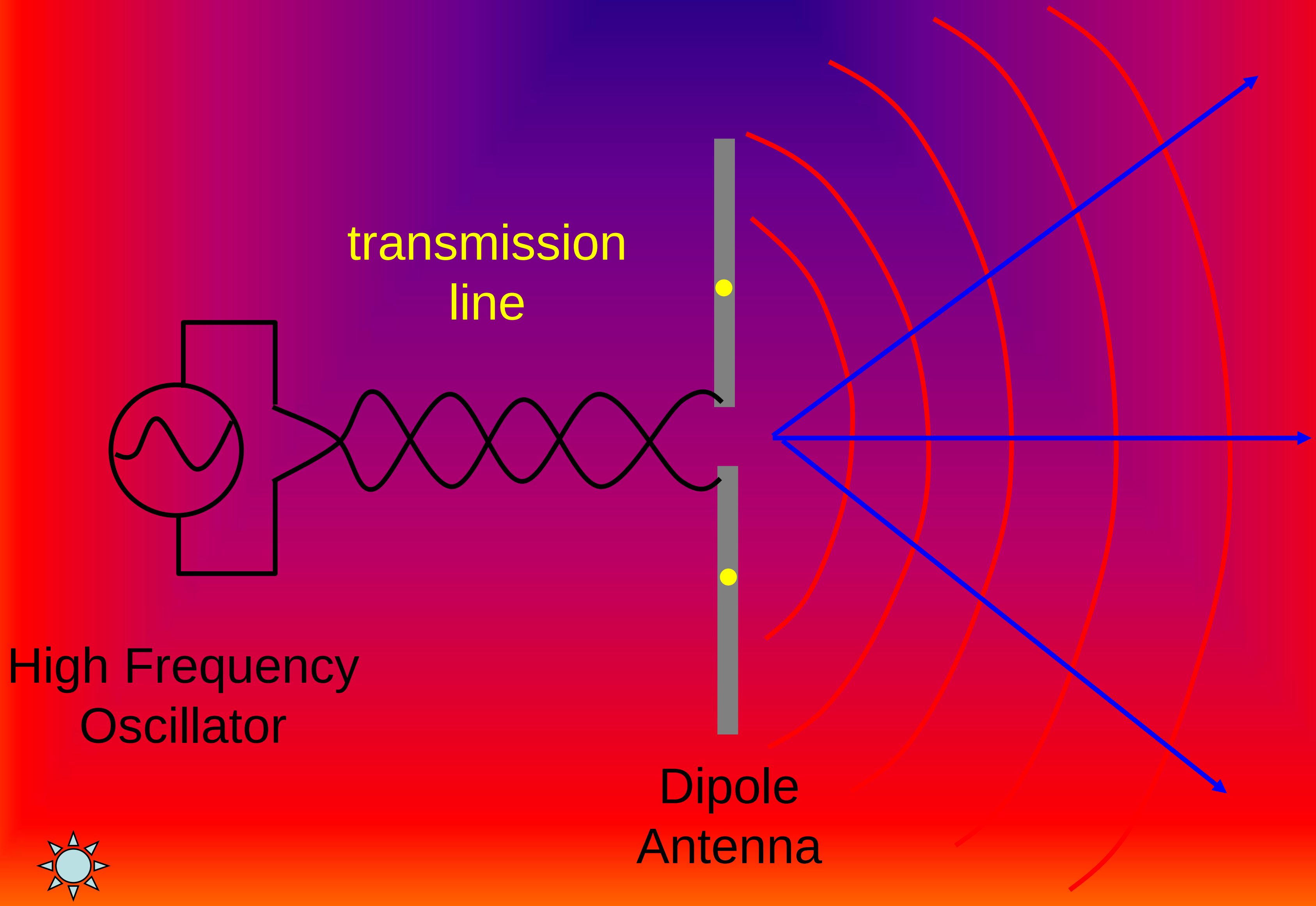
Electromagnetic Waves



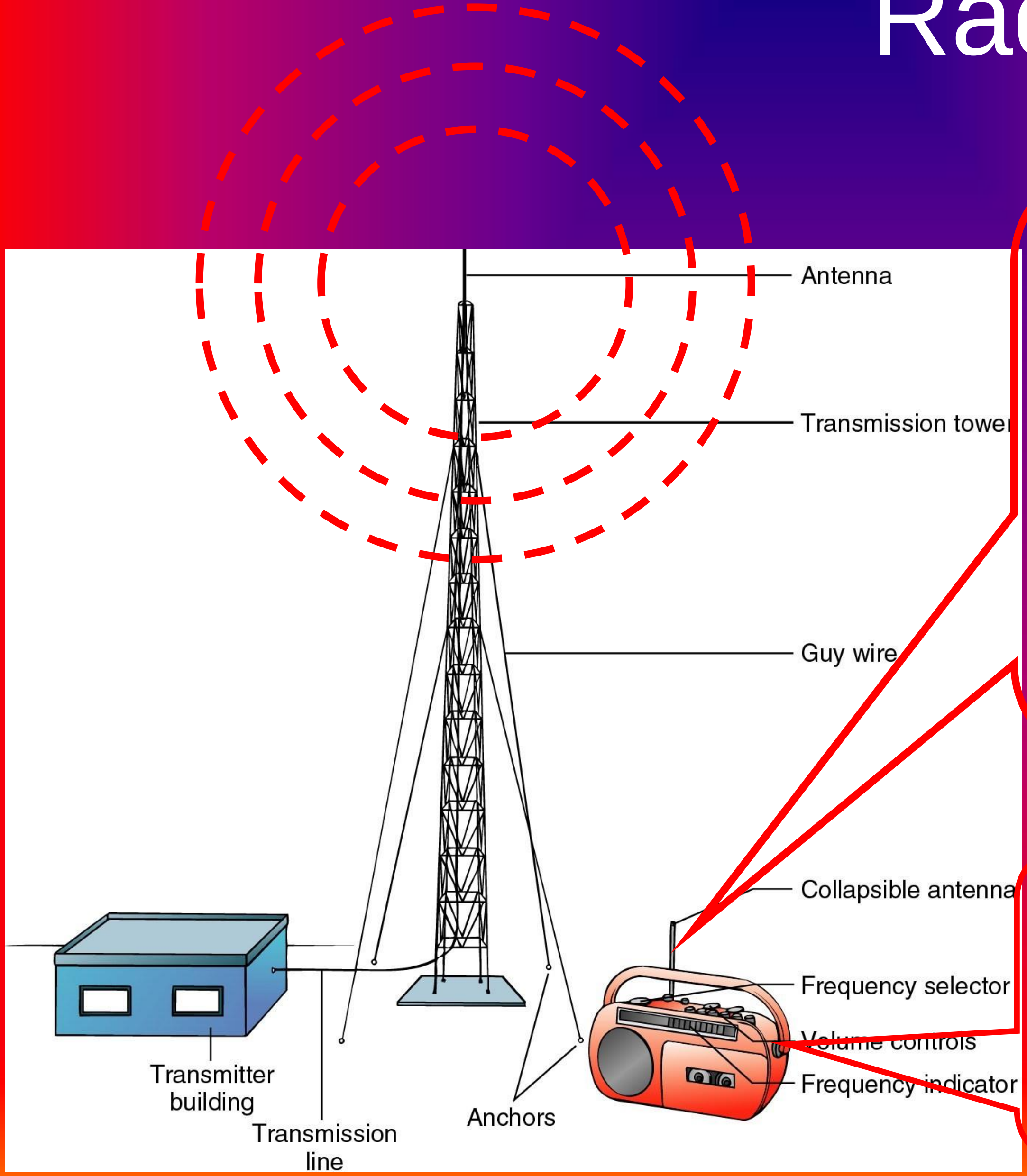
Antenna:
emits waves

EM WAVE: electric and magnetic fields moving through space at the speed of light 300,000 km/sec

How radio waves are produced



Radio antenna



the oscillating electric field of the EM wave causes the electrons in the receiving antenna to oscillate at the same frequency

the amplifier converts the electrical signal to sound waves

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$$\vec{F}_c = q\vec{E} \qquad F_L = q(\vec{v}\times\vec{B})$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t}$$

$$\vec{B} = \mu_0 \vec{H}, \quad \vec{\mathrm{D}} = \varepsilon_0 \vec{E}$$

$$\nabla \times \vec{H} = \vec{J} + \frac{1}{c^2 \mu_0 \varepsilon_0} \frac{\partial \vec{D}}{\partial t}$$

$$\vec{J} = ne\vec{v}$$

$$\vec{F} = e\vec{E}$$

$$m \frac{dv}{dt} = eE_0 \sin \omega t$$

$$v = -\frac{eE_0}{m\omega} \cos \omega t$$

$$\vec{J} = ne\vec{v} = -\frac{ne^2 E_0}{m\omega}\cos\omega t$$

$$D = \varepsilon_0 E = \varepsilon_0 E_0 \sin\omega t$$

$$\frac{\partial D}{\partial t} = \varepsilon_0 E_0 \omega \cos\omega t$$

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

$$\nabla \times \vec{H} = -\frac{ne^2 E_0}{m\omega}\cos\omega t + \varepsilon_0 \omega E_0 \cos\omega t$$

$$\nabla \times \vec{H} = \left[\varepsilon_0 \omega - \frac{ne^2}{m\omega} \right] E_0 \cos\omega t$$

$$\nabla \times \vec{H} = \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$

$$\omega_p = \left(\frac{ne^2}{\varepsilon_0 m} \right)^{1/2}$$

$$\omega_p = 2\pi f_p$$

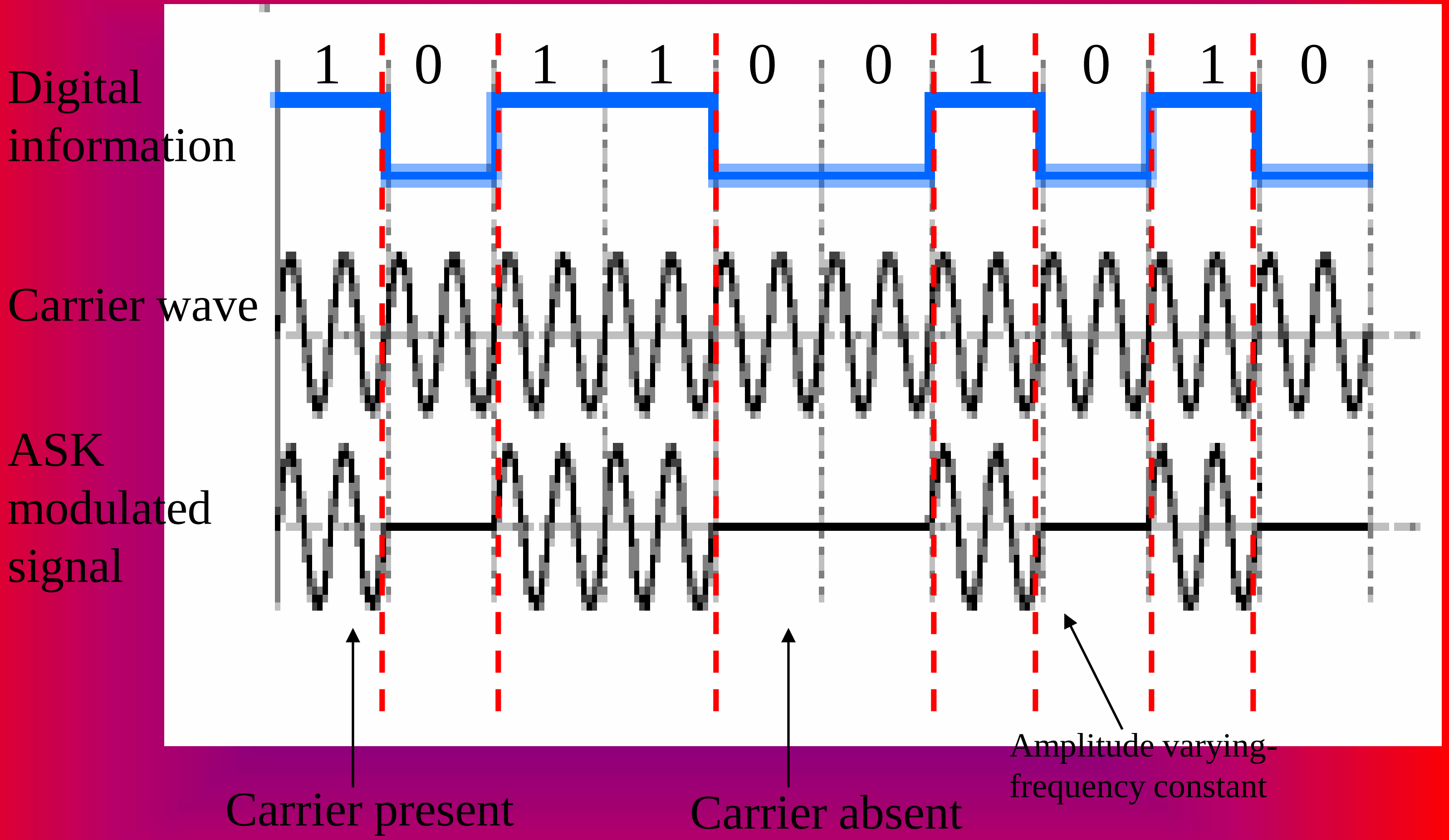
$$f_p^{\ 2} = \frac{ne^2}{4\pi^2 \varepsilon_0 m}$$


Thanks for your attention

Some Types of Digital Modulation

- Amplitude Shift Keying (ASK)
  - The most basic (binary) form of ASK involves the process of switching the carrier either on or off, in correspondence to a sequence of digital pulses that constitute the information signal. One binary digit is represented by the presence of a carrier, the other binary digit is represented by the absence of a carrier. Frequency remains fixed
- Frequency Shift Keying (FSK)
  - The most basic (binary) form of FSK involves the process of varying the frequency of a carrier wave by choosing one of two frequencies (binary FSK) in correspondence to a sequence of digital pulses that constitute the information signal. Two binary digits are represented by two frequencies around the carrier frequency. Amplitude remains fixed
- Phase Shift Keying (PSK)
  - Another form of digital modulation technique which we will not discuss

Amplitude Shift Keying



Frequency Shift Keying