UEC747: ANTENNA AND WAVE PROPAGATION

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Lecture 3: Definition of Antenna

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and

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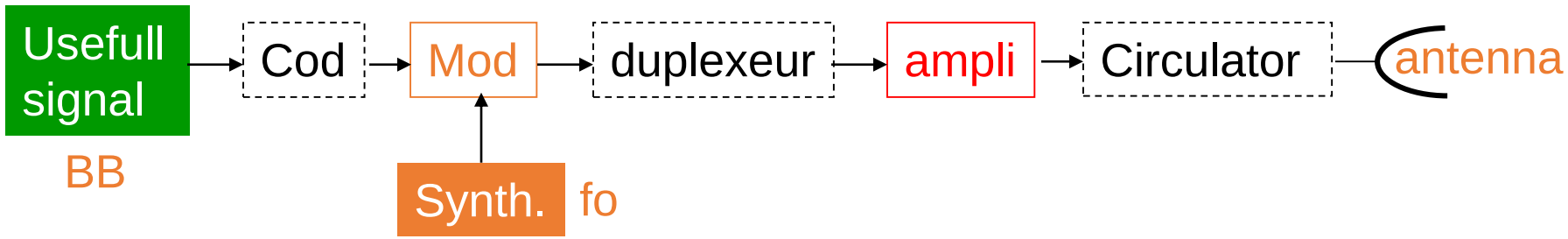
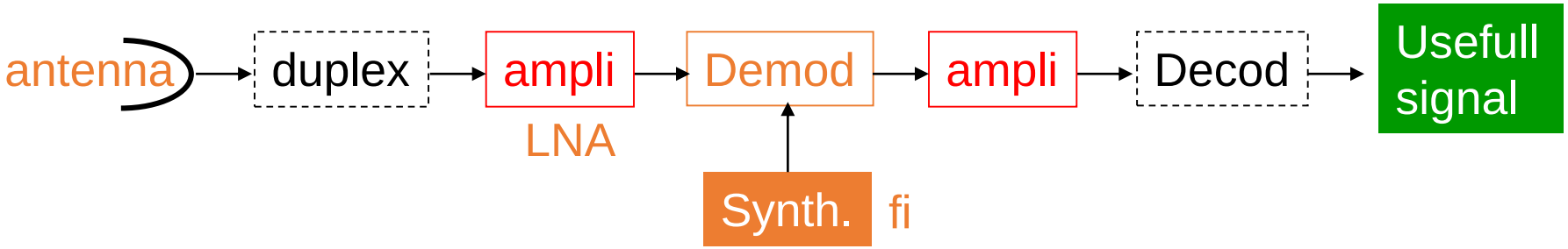
Radio transmission chain

Transmitter part:

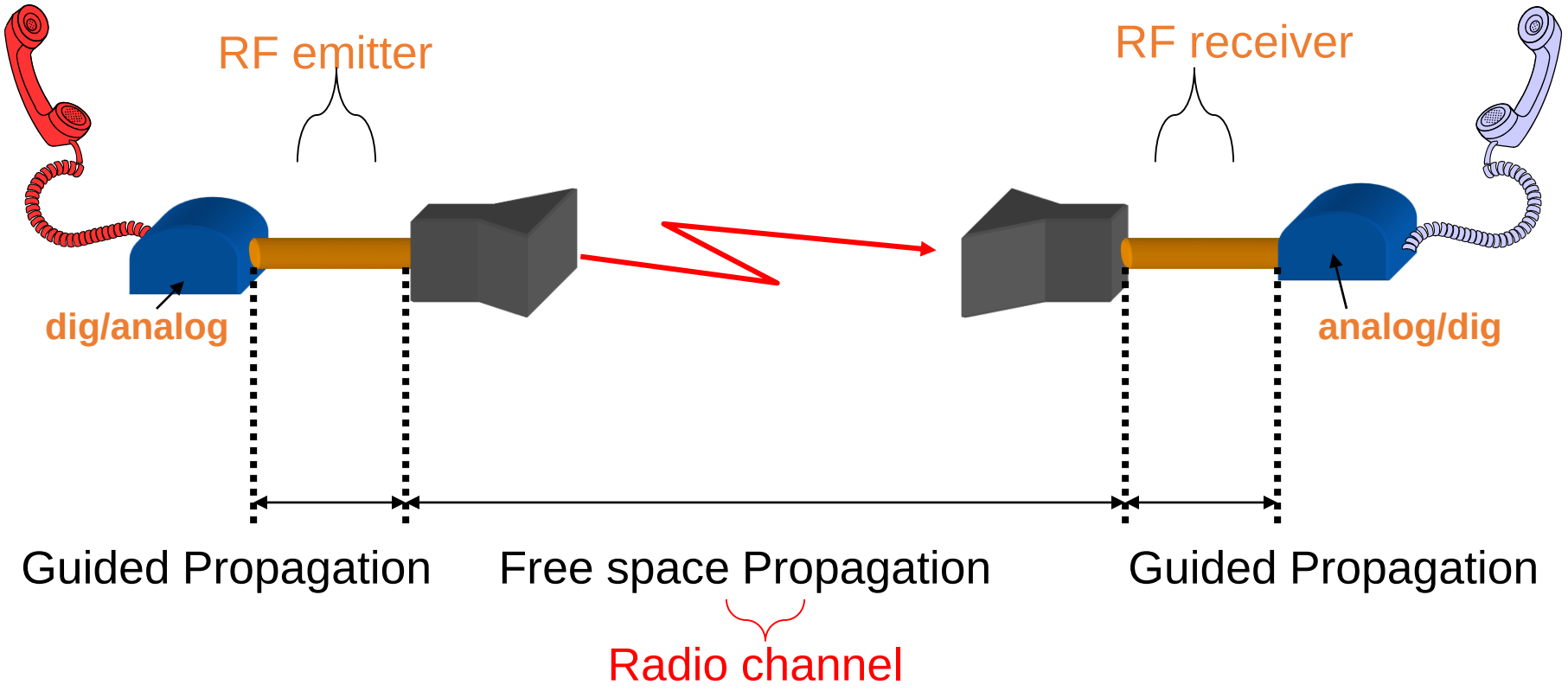


Receiver part:



Guided /Free Space Propagation

Global radio transmission chain:

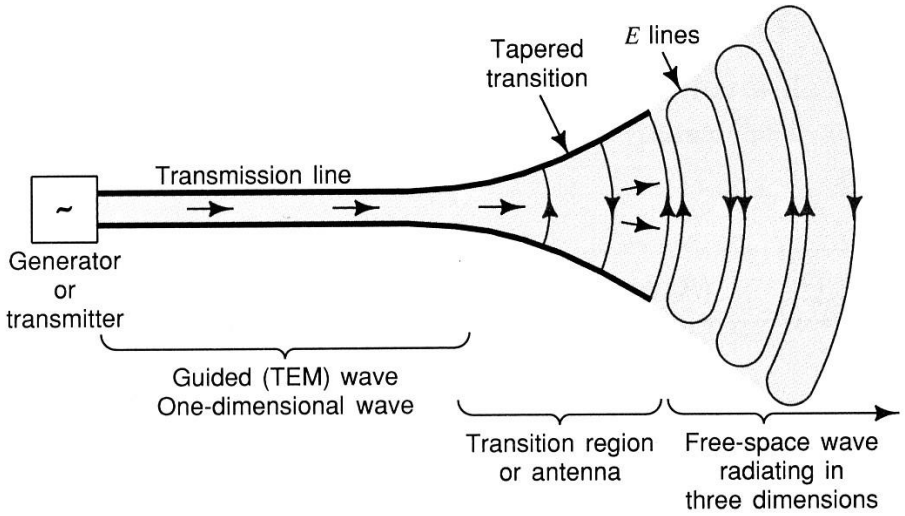


"Boxes" containing the electronics are connected to the antennas via lines or cables (feeders). From a signal processing perspective, the set of deformations of the wave generated by the wireless + wired transmission form the radio channel.

What is Guided electromagnetic wave ?

- Cables
  - Used at frequencies below 35 GHz
- Waveguides
  - Used between 0.4 GHz to 350 GHz
- Quasi-optical system
  - Used above 30 GHz
- TEM wave in cables and quasi-optical systems (same as free space)
- TM,TE and combinations in waveguides
  - E or H field component in the direction of propagation
  - Wave bounces on the inner walls of the guide
  - Lower and upper frequency limits
  - Cross section dimensions proportional to wavelength

Transition from guided wave to free space wave



Launching of EM wave

Open up the cable and separate wires

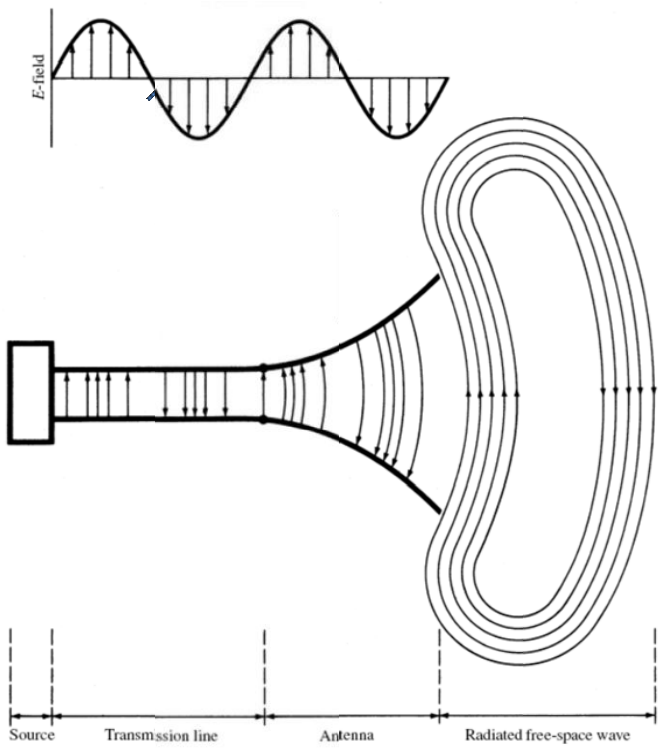
Dipole antenna

Open and flare up wave guide

Horn antenna

What is an antenna?

- An antenna is defined by Webster's Dictionary as "a usually metallic device (as a rod or wire) for radiating or receiving radio waves."
- Antenna is a linear and passive device of metal and/or dielectric structure used to radiate electromagnetic energy in free space.
- The definition of antenna is not limited electromagnetic waves but it is also applicable to acoustic waves used in under water communications.



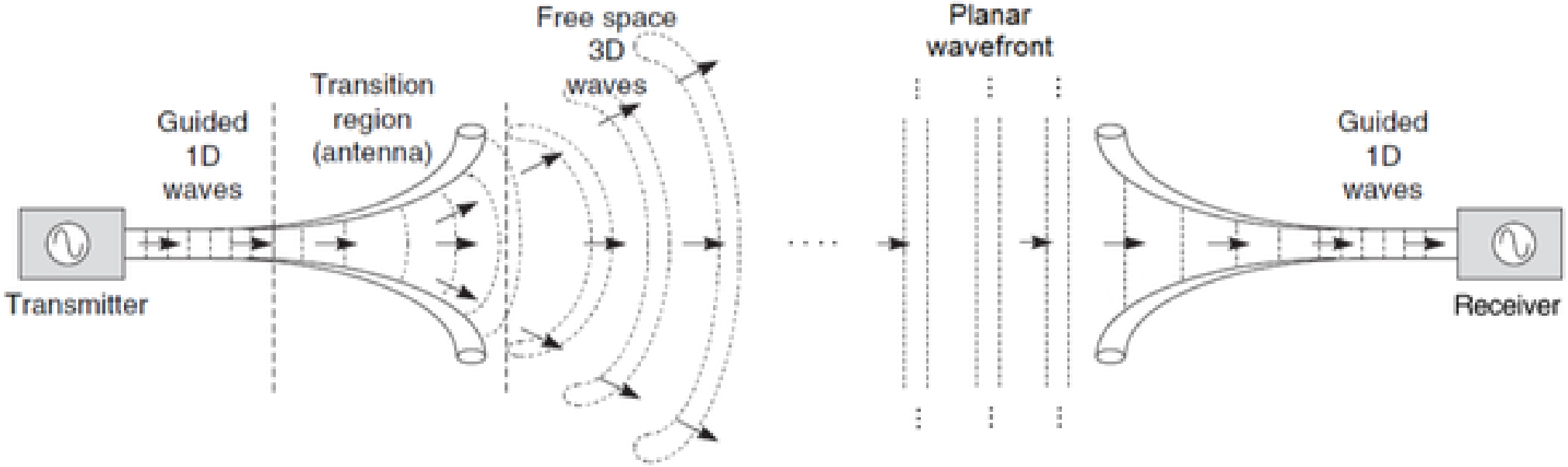
Antenna definition (IEEE)

- The IEEE Standard Definitions of Terms for Antennas defines the antenna or aerial as "a means for radiating or receiving radio waves."

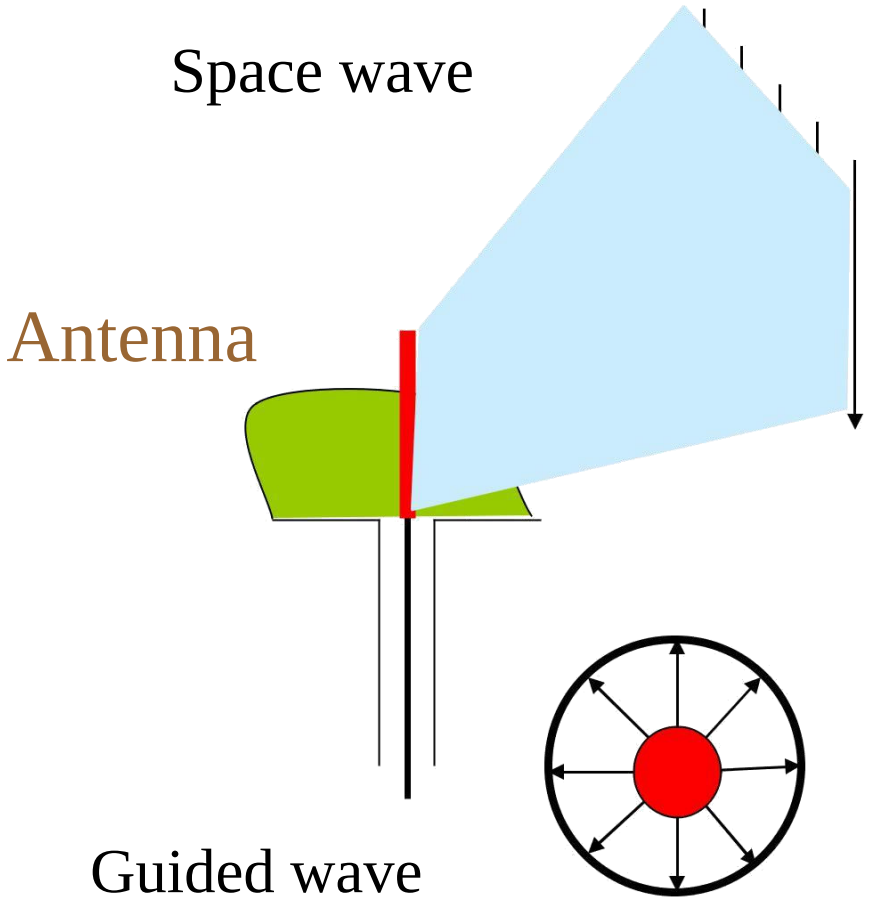
Reciprocity

The antennas are reciprocal devices which can be used as both transmitting and receiving elements.
It can also be used to receive electromagnetic energy in free space.

- Transmission and reception antennas can be used interchangeably
- Medium must be linear, passive and isotropic
- Caveat: Antennas are usually optimised for reception or transmission not both !



Definition: What is an antenna?



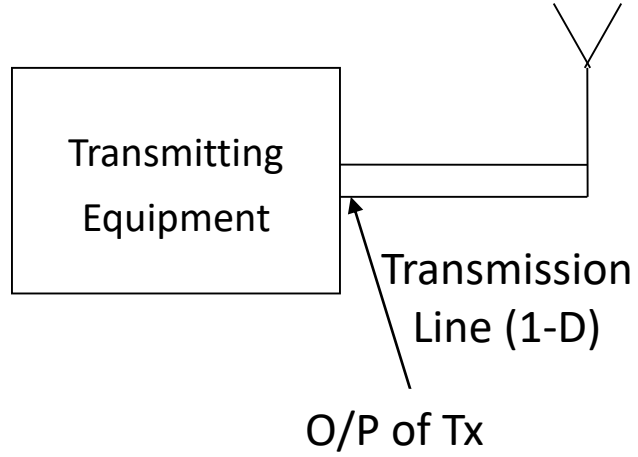
- Transformation of a guided EM wave in transmission line (waveguide) into a freely propagating EM wave in space (or vice versa) with specified directional characteristics
  - The specific form of the radiated wave is defined by the antenna structure and the environment

- The output of antenna is spherical waves.
- Antenna can be considered as a transducer that converts electrical energy to spherical waves.

See also http://en.wiktionary.org/wiki/antenna and http://en.wikipedia.org/wiki/Antenna_(radio)

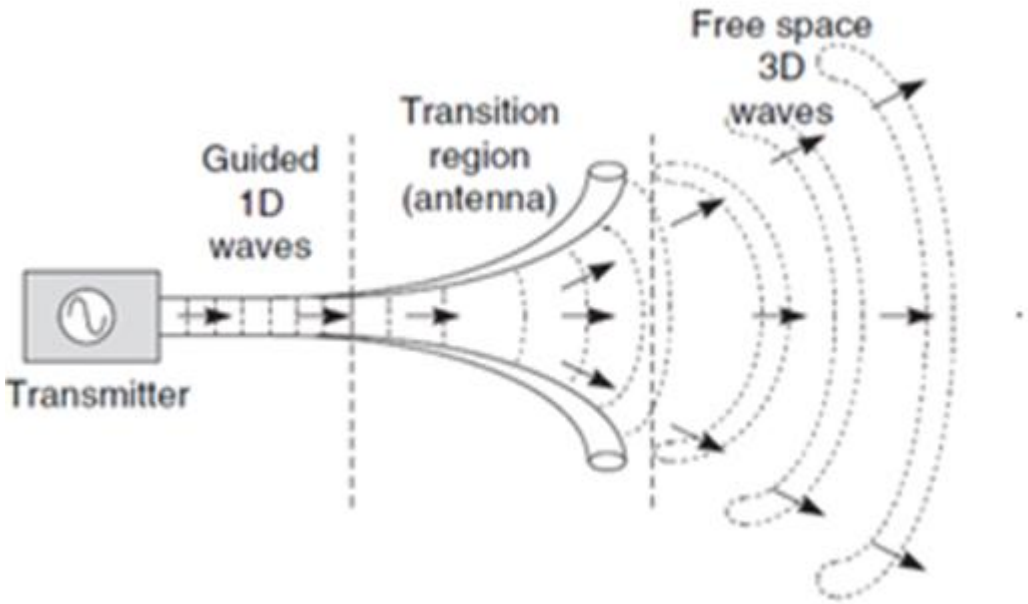
Definition: What is an antenna?

- Electrical Power from transmitter is guided to antenna through feeder line or transmission line or wave guide as shown in figure. The energy flowing in transmission line is guided energy.
- Antenna can be considered as device converts guided energy into E.M. energy.
- Hence antenna is a device used for ttransformation of a guided EM wave in transmission line (waveguide) into a freely propagating EM wave in space (or vice versa) with specified directional characteristics.



Definition: What is an antenna?

- Antenna can be considered as structure used for ttransformation from time-function in one-dimensional space (transmission line or wave guide) into time-function in three dimensional space (e.m wave).
- Antenna can also be called a device which transforms a bounded wave into unbounded wave.

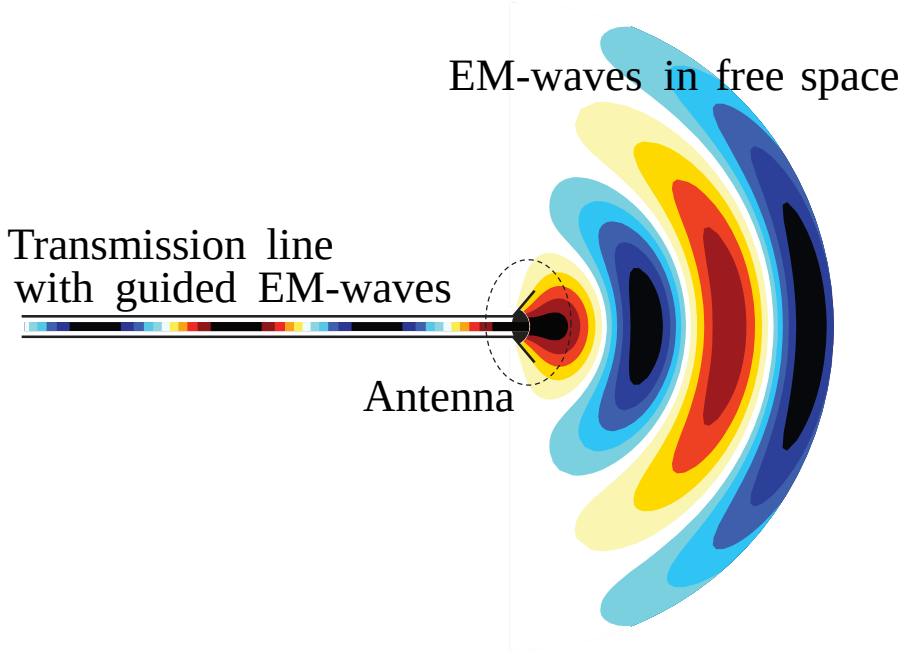


- **Region of transition between guided and free space propagation**

Definition: What is an antenna?

- **Transition from guided waves on transmission lines to free space waves.**

The antenna is the transitional structure between free-space and a guiding device. The guiding device or transmission line may take the form of a coaxial line or a hollow pipe, and it is used to transport electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver.



Definition: What is an antenna?

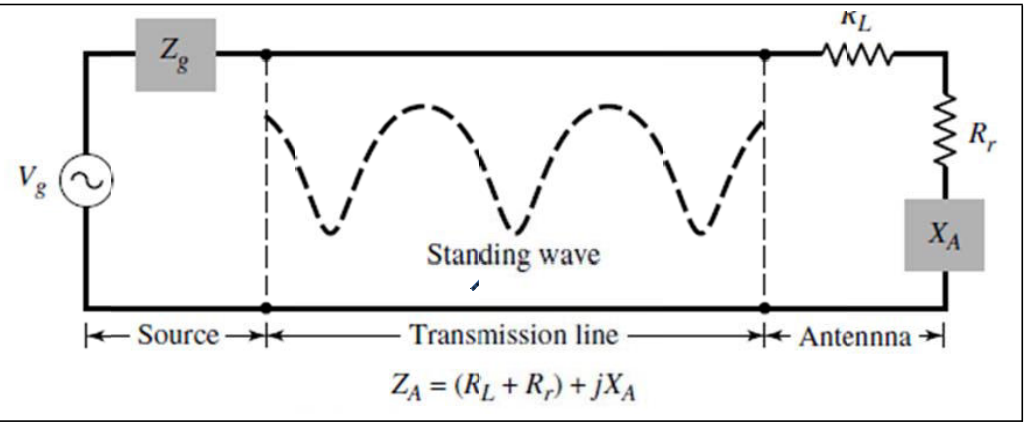
The free space impedance is 377 ohms while transmission line or wave guide impedance is not 377 ohms so antenna can be considered as transitional structure between free space and guiding device, which matches free space impedance with transmission line impedance. It can be considered as region of transition between guided and free space propagation.

Definition: What is an antenna?

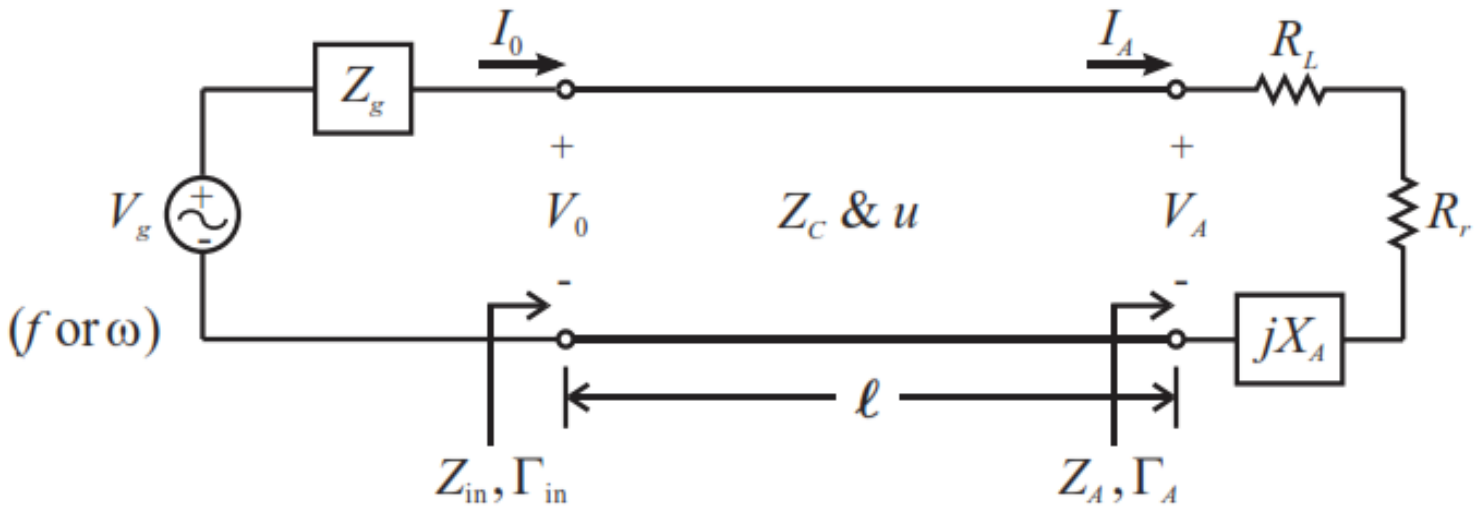
- Concentrates incoming wave onto a sensor (receiving case)
- Launches waves from a guiding structure into space or air (transmitting case)
- Often part of a signal transmitting system over some distance
- Not limited to electromagnetic waves (e.g. acoustic waves)
- Transformation from time-function in one-dimensional space into time-function in three dimensional space
- Device for transmitting or receiving electromagnetic waves
- Transducer between free space and transmission line
- Directional spatial filter
- Some other old words for antenna
  - Aerial
  - Radiator

Transmitting antenna equivalent circuit

A transmission-line Thevenin equivalent of the antenna system of Figure 1.1 in the transmitting mode is shown in Figure 1.2.



- The source is represented by an ideal generator
- The transmission line is represented by a line with characteristic impedance Zc
- The antenna is represented by a load $Z_A = (R_L + R_r) + j X_A$ connected to the transmission line.
- R_L: represent the conduction and dielectric losses associated with the antenna structure
- R_r :referred to as the radiation resistance, is used to represent radiation by the antenna
- X_A represent the imaginary part of the impedance associated with radiation by the antenna



Loss

Under ideal conditions, energy generated by the source should be totally transferred to the radiation resistance Rr. Practically, we have conduction-dielectric losses due to the lossy nature of the transmission line and the antenna R_L , *i*mpedance mismatches leading to reflections(mismatch) losses at the interface between the line and the antenna, internal impedance of source.

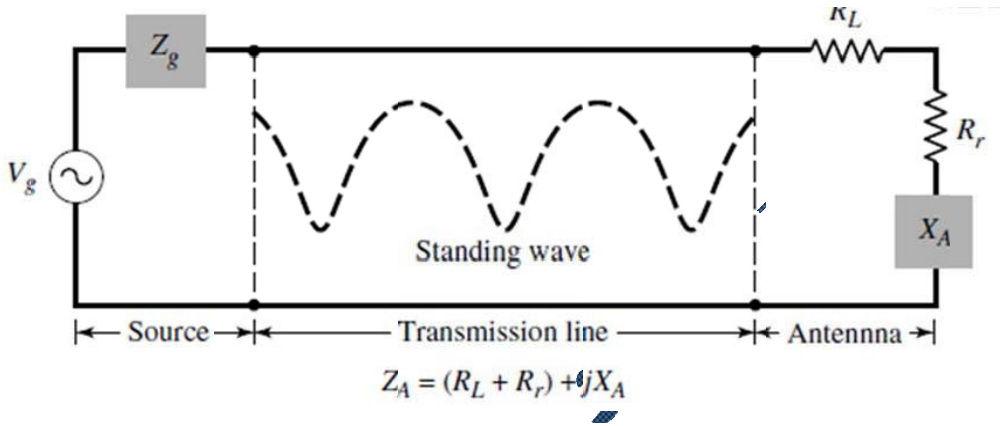
Matching

Taking into account the internal impedance of the source and neglecting line and reflection losses, maximum power is delivered to the antenna under conjugate matching.

The reflected waves from the interface create, along with the traveling waves from the source toward the antenna, standing waves, inside the transmission.

A typical standing wave pattern is shown dashed in Figure 1.2.If the antenna system is not properly designed, the transmission line could act to a large degree as an energy storage element instead of as a wave guiding and energy transporting device.

The losses due to the line, antenna, and the standing waves are undesirable.



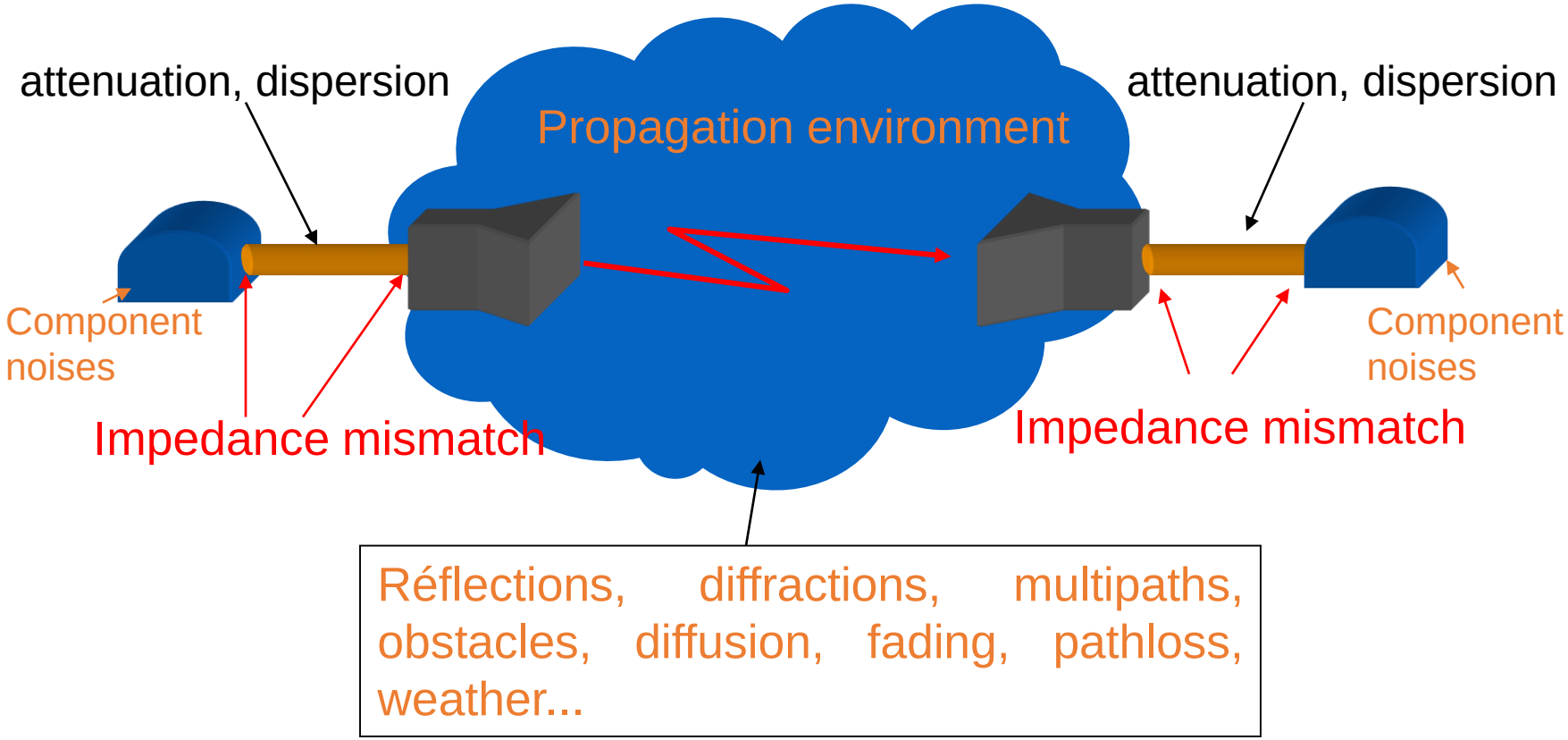
- The losses due to the line can be minimized by selecting low-loss lines.
- The standing waves can be reduced by matching the impedance of the antenna to the characteristic impedance of the line.

An equivalent similar to that of Figure 1.2 is used to represent the antenna system in the receiving mode where the source is replaced by a receiver. All other parts of the transmission-line equivalent remain the same. The radiation resistance Rr is used to represent energy from the free space wave to the antenna.

Difference between transmission line, resonator and antenna(Radiator)

- Transmission line
  - Power transport medium - must avoid power reflections, otherwise use matching devices
- Radiator
  - Must radiate efficiently – must be of a size comparable with the half-wavelength
- Resonator
  - Unavoidable - for broadband applications resonances must be attenuated

Where do we loose energy?



And all these parameters are varying in time, frequency, space and wave polarization…

Quiz

We use a transmitting antenna to radiate radio wave and a receiving antenna to capture the RF energy carried by the wave.

Somebody told that the receiving antenna also radiates radio waves during the reception.

Is it a true fact or a slip of the tongue?

THANKS