UEC747: ANTENNA AND WAVE PROPAGATION

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Lecture 4: Need of EMT in Antenna

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Module Objective:

On the completion of this module students should understand the need of Electromagnetics in Antenna

Module Objective:

On the completion of this module students should
Gain thorough understanding of

- Vector Algebra
- Coordinate System
- Time Varying Fields, Maxwell's Equations
- Time Harmonic Fields, and Plane Electromagnetic Waves

Why EMFT?

To properly understand all phenomenon driving antennas behavior, as well as their integration in a complete system, pre-requisites are:

- basics of electromagnetism (Maxwell's equations, EM wave propagation…);

- basic knowledge of transmission lines theory and particularly impedance matching principles (progressive or stationary waves..);

- take a step back: antennas represent a practical and "visual" application of Maxwell's theory, building the bridge between purely theoretical equations and real physical phenomenon.

Use of Electromagnetics in Antenna

- Advances in electrical engineering have enabled engineers to predict the performance of any complex electrical circuit or network.
- The theory used to simplify any complex circuit or network is circuit theory that simplifies any complex network to a simple network with the help of various circuit theorems.
- The electrical circuit operates at low frequencies so the current (I) or voltage (V) in circuit theory is a function of only one variable i.e time (t). For example the current at the output of any complex network can be of the form
- $$I(t) = I_0 \sin(\omega t)$$

Use of Electromagnetics in Antenna

This topic is about electromagnetics (EM),the electrical foundation of electrical and Computer Engineering, or, how electricity *really* works.

-- Look into the black boxes.

- Linear Circuit is a simple part of EM, so it was taught first. Circuit theory is nothing but a low-frequency approximation ($l << \lambda$, $h << \lambda$ for lumped circuits or $h << \lambda$ for distributed circuits) to electromagnetic theory. As frequency increases, the circuit theory falls apart and the electromagnetic theory must be used
- However there are an increasing number of cases in ECE where circuit theory fails (e.g. faster computers, higher communications frequencies, power electronics, power system transients,), and therefore EM must supplement circuit theory. *But, don't worry*…
- Also EM is the basis for many devices (machinery, antennas, etc.), and one of the physical foundations of any active electronic device.

Electrical Engineering is Applied Electromagnetics

- As devices get smaller and smaller, and frequencies get higher and higher, circuit theory is less able to adequately describe the performance or to predict the operation of circuits.
- At very high frequencies, transmission line and guided wave theory must be used in applications such as high speed electronics, micro/nano electronics, integrated circuits.
- However at radio frequency (r.f) or microwave frequency (μw) the circuit analysis becomes difficult as at high frequencies the circuit elements do not remain lumped and are considered as distributed elements.
- In the analysis of circuit with distributed elements, as in the case of transmission line, one more parameter distance is added.
- The output of such high frequency network is found in terms of Electric field vector (E) or Magnetic field vector (H). The theory dealing with E and H vectors is known as field theory. The voltage and currents are integrated effects of E and H field. Field theory is more difficult to deal than circuit theory as more than one variable is involved. In case of transmission line distance along the line is an added variable.
- Other applications include: Fiber Optics, Microwave Communication Systems, Antennas and Wave Propagation, Optical Computing, Electromagnetic Interference, Electromagnetic Compatibility, Biology and Medicine/Biomedical Imaging.

- As use of the electromagnetic frequency spectrum increases, the demand for engineers who have practical working knowledge in the area of electromagnetics continues to grow.
- Electromagnetic engineers design: high frequency or optoelectronic circuits, antennas and waveguides; electrical circuits that function properly in the presence of external interference while not interfering with other equipment.
- The electromagnetics technical specialty prepares future engineers for employment in industry in the areas of radar, antennas, fiber optics, high frequency circuits, electromagnetic compatibility and microwave communication.

Electromagnetics is Everywhere

Electromagnetics is fundamental to the advancement of electrical and computer technology!

- An engineer can design transmitter and receiver of any radio communication system using circuit theory. But for designing the circuit between output of transmitter and antenna at the transmitting side and between antenna and input of receiver at the receiving side the circuit theory fails. The engineer, thus turns to field theory to find solve the circuit between out put of transmitter up to the input of receiver.

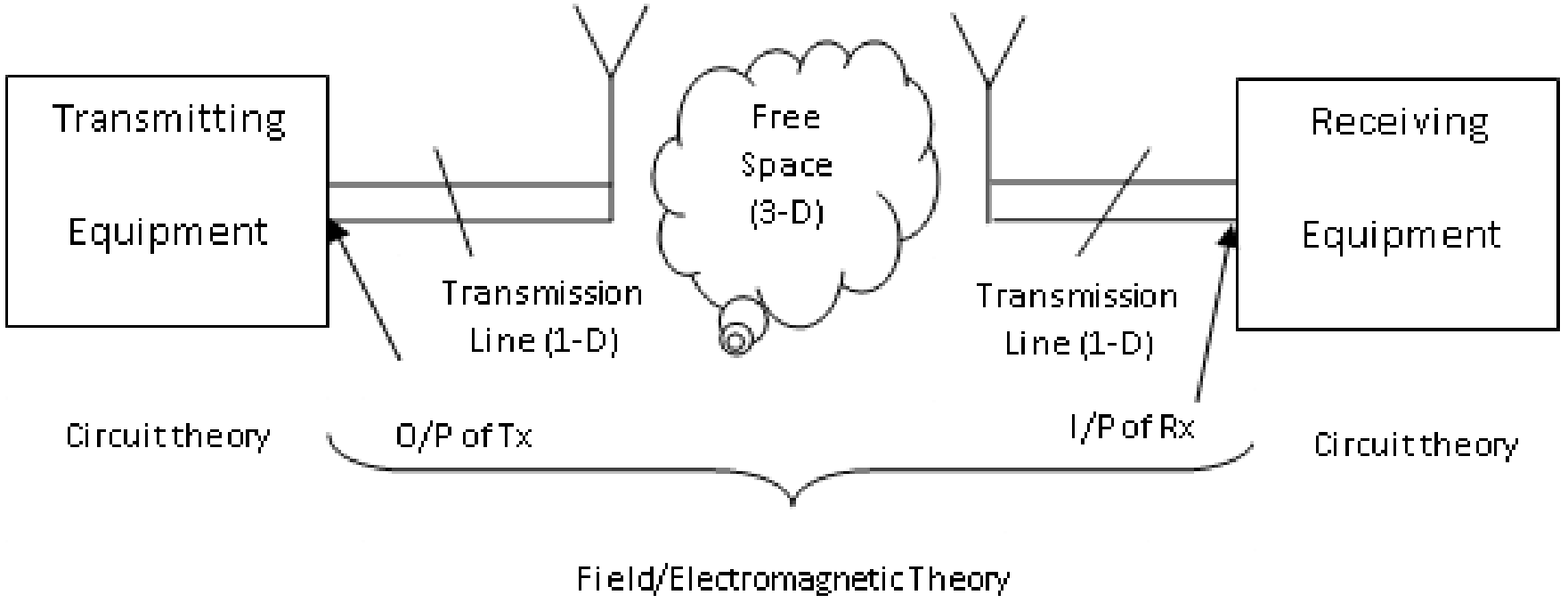

Fig.1.1 Transformation of signal from circuit theory to field theory

- The transformation of signal from circuit theory to field theory or electromagnetic theory is shown in figure 1.1.
- The current and voltage in transmitting and receiving equipment can be found using circuit theory, being function of one variable time only. However, as the signal comes out of transmitter and enters transmission line it becomes function of distance also, one space variable.
- The E and H fields in transmission line can be found using field theory. When signal radiates from antenna it is function of 3-space variables as well as function of time also.
- The solution of E and H fields in free space can be found using electromagnetic theory tends to be complex, as fields are now function of 3 space variables.
- The additional complexity can be reduced with knowledge of Electromagnetics and vector analysis. The solution of electromagnetic theory problems using vector analysis result in real economy of time.
- The antenna is considered as point source radiating in free space. In order to analyze any antenna it becomes necessary to understand the 3 dimensional (3-D) vector mathematical operations.
- The analysis can be extended to n dimensions easily. Next electromagnetics and mathematics of vector analysis needed for analysis and synthesis of antenna is briefly discussed.

What is Electromagnetics?

- Electromagnetics is the study of Charges:
  (i) at rest (ii) in motion

- The subject of electromagnetics may be divided into 3 branches:
  - Electrostatics: charges are at rest (no time-variation)
  - Magnetostatics: charges are in steady-motion (no time-variation)
  - Electrodynamics: charges are in time-varying motion
    (give rise to waves that propagate and carry energy and information)

Steps in Studying Electromagnetics for Antenna

- Define basic quantities (e.g., E-field, H-field)
- Define the rules of operation (mathematics) of these quantities (e.g., Vector Algebra)

Why is Electromagnetics Difficult?

Electric and Magnetic Field:

- are 3-dimensional !
- are vectors !
- vary in space and as well as in time !
- are governed by PDEs (partial differential equations)

Therefore →

- Solution of electromagnetic problems requires a high level of abstract thinking !
- Students must develop a deep physical understanding !

Math is just a powerful tool !

Review of Vector Algebra is necessary

THANKS