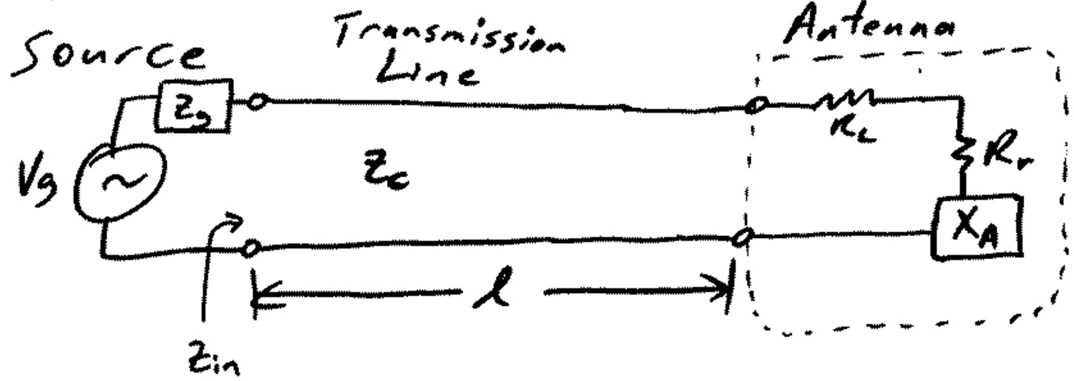
Chapter 1 Antennas

1.1 Introduction

Definition That part of a transmitting or receiving system that is designed to radiate or to receive electromagnetic waves. (IEEE Std 145-1993).

ex. Transmitting Antenna



$Z_c \equiv$ characteristic impedance of feeding transmission line

$Z_A \equiv$ load represented by antenna
$= (R_L + R_r) + jX_A$

$R_L \equiv$ conduction/dielectric losses in antenna (ohmic losses)

$R_r \equiv$ radiation resistance (power radiated by antenna that is "lost")

$X_A \equiv$ antenna reactance (stored energy in fields near antenna)

→ Ideally, want to radiate all power from source (all goes into R_r)

→ Practically, have ohmic losses R_L, mismatches, internal impedance of source, lossy t-lines. So, the maximum power is delivered when the antenna is <u>conjugate matched</u> (talk about in Chap. 2) $Z_{in} = Z_g^*$

1.2 Types of Antennas

Wire Antennas ex.
(cheap, reliable)

car (whip/monopole)

TV (loop (UHF) + "bunny ears"/dipole (VHF))

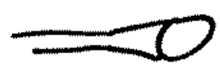
Helix (space communication)

Aperture
(rugged, high gains)

Dish Feeds →

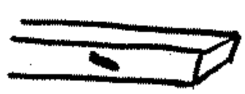
Pyramidal

Horns



Conical

Flush Mounted (Military) →

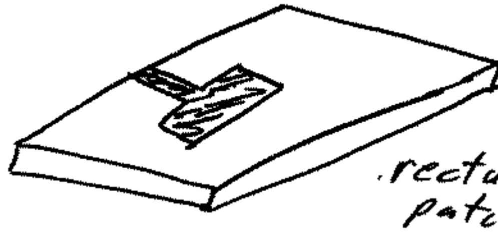


Slot in Waveguide

Chap 1 cont.

Microstrip

- cheap + easy to manufacture



rectangular patch

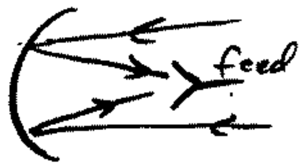
circular patch

Reflector Antennas

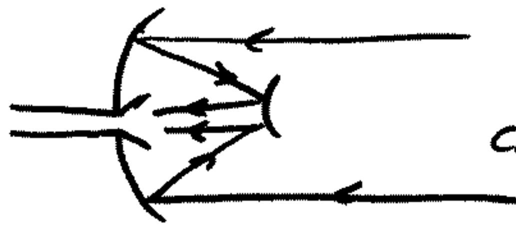
→ Very common for space applications

→ fed by other antenna

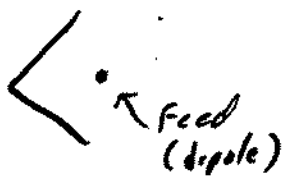
→ can achieve very large gains



parabolic dish



w/ Cassegrain feed



Corner reflector (side view)

Lens Antennas

→ not so common

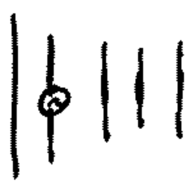
Convex-convex

Convex-plane

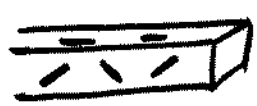
Arrays

→ use more than one antenna to achieve design goal

→ more flexibility to get desired radiation pattern, beam steering...



Yagi-Uda Array



slotted waveguide

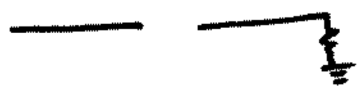
1.3 Radiation Mechanism

How is radiation accomplished? i.e. How do we take a confined wave/field in a t-line or waveguide and "detach" it to form a free-space wave?

For radiation to occur, must have a time-varying current or an acceleration (deceleration) of charge.

ex. Curved/bent wires 

discontinuity in wire 

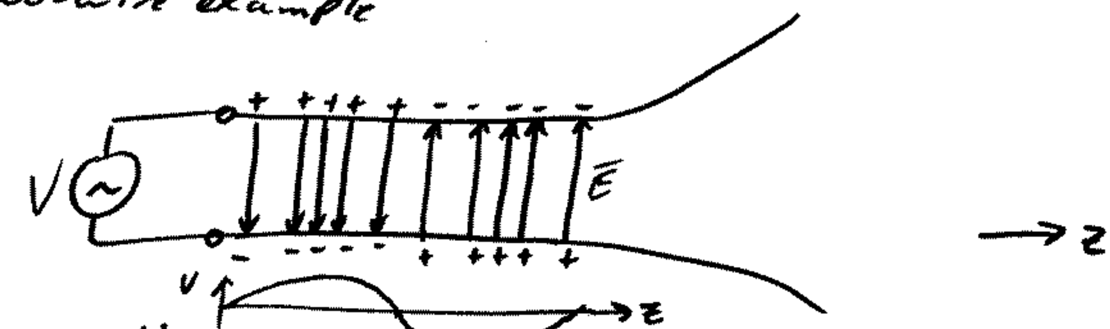
terminated/truncated wire 

Consequences

1. No charge movement → no current → No radiation
2. Uniform charge velocity (speed + direction)
   a) No radition if wire straight + ∞-ly long
   b) radiation if above ex. met
3. If charge is oscillating (e.g., sinusoidal excitement), it radiates even if wire is straight

1.3 cont.

Now let's consider how waves are radiated, using a two-wire example

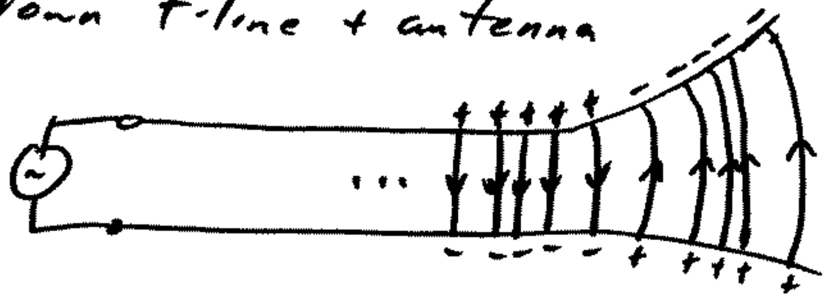


1) a voltage source creates an electric field between the conductors that propagates down the transmission line

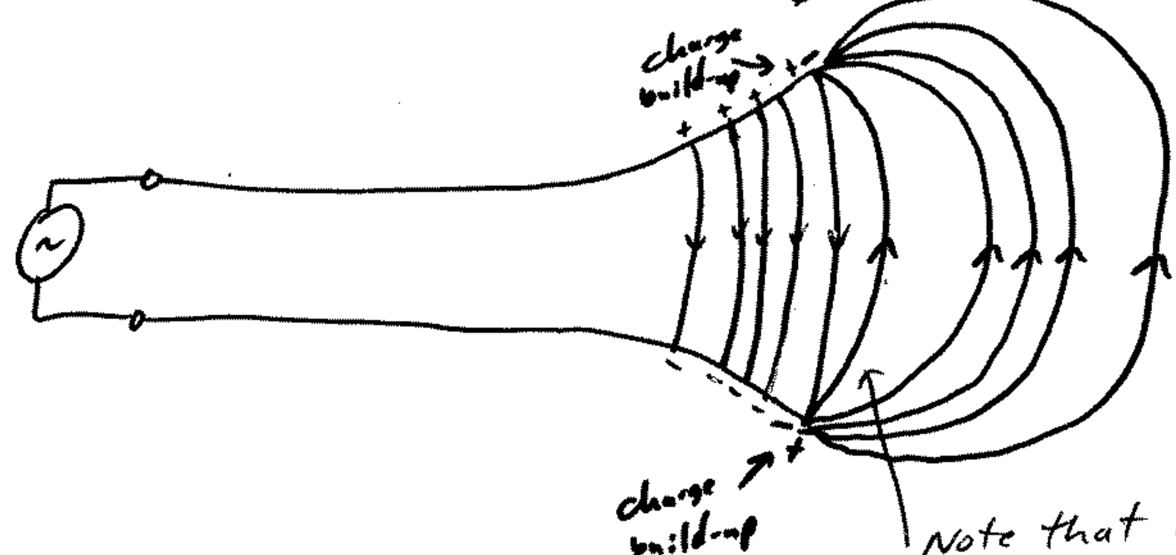
- Electric field lines act on free electrons so that they start on + charges + end on − charges
- the movement of charges induces a magnetic field
- remember electric field lines can:
  1) start on + charges and end on minus charges
  2) start on + charges and end at ∞
  3) start at ∞ and end on − charges
  4) form closed loops (no charges involved)
- magnetic field lines are always closed (no known physical magnetic charges)
  (* non-physical magnetic charges + current sometimes used for mathematical convenience)

2) Note, if the voltage source were to turn off, the E + H fields already created would continue to exist + be radiated (stone in pond analogy)

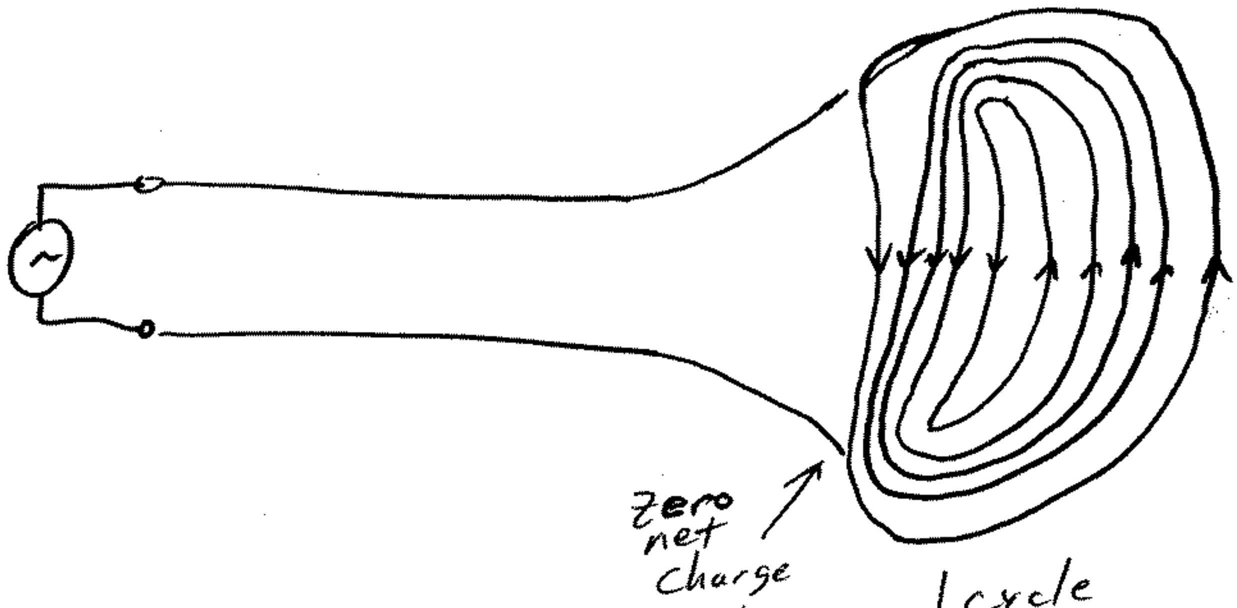
3) let electric field continue to progress down t-line + antenna



Only showing single cycle for clarity



Note that a closed loop is formed



zero net charge build-up after 1 cycle

1 cycle radiated (detached)

Chap. 1 cont.

Abbreviated History

Maxwell → Maxwell's Eqns 1873
→ radiated waves are electromagnetic

Hertz → 1886 demonstrated first wireless electromagnetic radiation (used spark gap generator and dipole + loop)

Marconi → 1901 achieved transatlantic wireless transmission

1900-1940's → most antenna work focused on wire antennas up to UHF (470-890 MHz) and related electronics

WW II years → MIT Radiation Lab (huge burst of theoretical as well as practical research)
→ aperture antennas (horns, waveguide slots, reflectors, ...)
→ high power RF/microwave sources such as Klystron + magnetron developed

late 19 0's –
1950's → frequency independent antennas (LPDA)
→ helical antennas

1960's – present → huge impact of computers making numerical methods practical (e.g. MoM, FDTD, ...)

1.5.2 Methods of Analysis

Integral Equation - takes integrals + breaks into pieces to form simultaneous linear eqns (matrices) and solves numerically

ex. Method of Moments (MoM) used by NEC program solves for currents (and charge distributions). Once these are known, $\bar{E}, \bar{H}, \ldots$ can be calculated.

→ best for wire antennas, small antennas (in terms of wavelengths)

Geometrical Theory of Diffraction (GTD)

→ better suited for larger problems (many λ) or high frequency problems

→ extension or application of optics

Finite-Difference Time-Domain (FDTD)

→ based on differential form of Maxwell's Eqns

→ extremely flexible for both geometry, materials, + signals

→ computationally expensive (memory + speed)

Finite Elements Method (FEM)

→ single frequency solution

→ works best on bounded problems

→ starts w/ differential eqn(s)