Benha University
Faculty of Engineering
Shoubra

Antennas &Wave Propagation
ECE 411

Electrical Eng. Dept.
4th year communication
2015-2016

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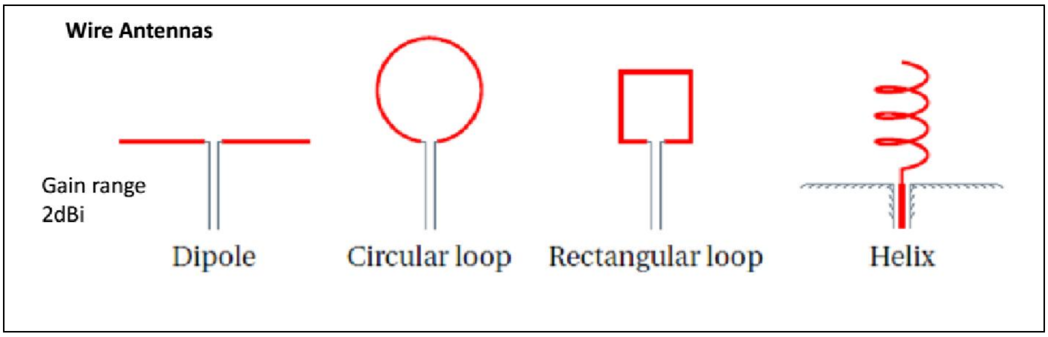
# Sheet (1)... Solution

1. **Define** antenna and State different types of antenna.

**Antenna is defined as**
A transducer designed to transmit and receive electromagnetic waves, it converts signals on electric circuits (V&I) to EM waves (E&H) radiate in space and vise versa.

Antenna can be categorized by:
- ❑ Narrow band versus broadband
- ❑ Size in comparison to the wavelength (e.g., electrically small antennas)
- ❑ Omni-directional versus directional antennas
- ❑ Polarization (linear, circular, or elliptic)
- ❑ **Antenna Types by Physical Structure**
  - Wire antennas
  - Aperture antennas
  - Microstrip antennas
  - Antenna arrays
  - Reflector antennas

2. **Draw** some familiar types of antenna.

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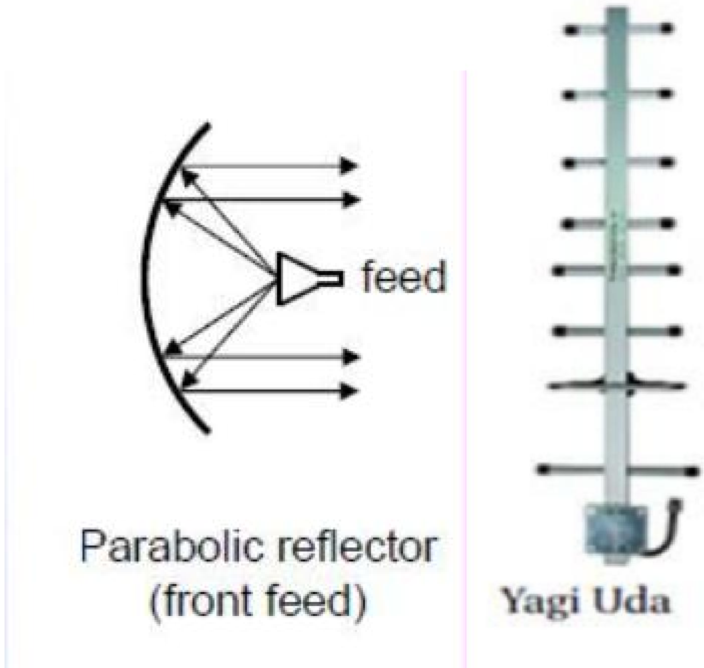


3. **Which** antenna may be used for

i. UHF/VHF TV.

| |
|---|
| Yagi |

ii. WLAN protocols.

| |
|---|
| Monopole – Dipole - Patch |

iii. Satellite communications.

| |
|---|
| Dish – Micro strip - Helical |

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**4. Describe** radiation mechanism for single wire antenna.

**•Radiation Mechanism**

**○ For single wire**

Current in a thin wire with a linear charge density $q_l$ (C/m):

$$I_z = q_l v_z \quad \text{(A)}.$$

**Thin Wire**

If the current is time varying

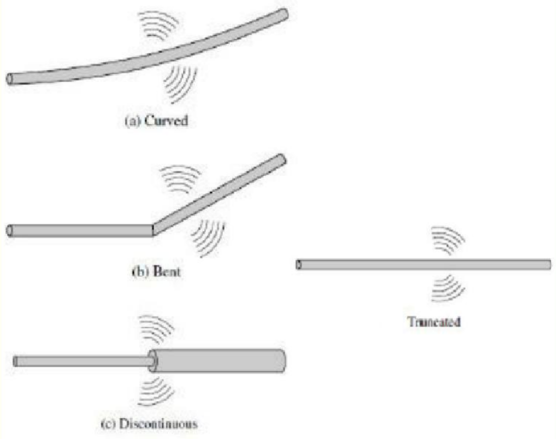
$$\frac{dIz}{dt} = q_l \frac{dv_z}{dt} = q_l a_z$$

where $a_z$ (m/s$^2$) is the acceleration. If the wire is of length $l$, then

$$l\frac{dIz}{dt} = lq_l \frac{dv_z}{dt} = lq_l a_z$$

**this equation**

is the basic relation between current and charge, and it also serves as the fundamental relation of electromagnetic radiation.




A disturbance introduced on the wire creates charges acceleration:

To create radiation, there must be a time-varying current or an acceleration (or deceleration) of charge.

- To create charge acceleration (or deceleration) the wire must be curved, bent, discontinuous, or terminated.
- Periodic charge acceleration (or deceleration) or time-varying current is also created when charge is oscillating in a time-harmonic motion.

1. If charge is moving with a uniform velocity:
   (a) There is no radiation if the wire is straight, and infinite in extent.
   (b) There is radiation if the wire is curved, bent, discontinuous, terminated, or truncated.
2. If charge is oscillating in a time-motion, it radiates even if the wire is straight.

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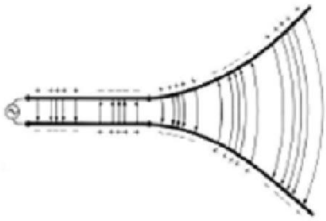
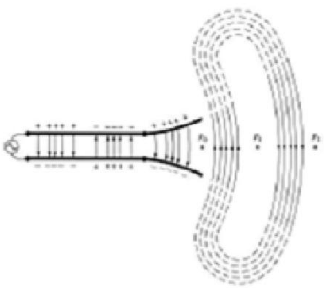
## 5. **Describe** radiation mechanism for two wires antenna.

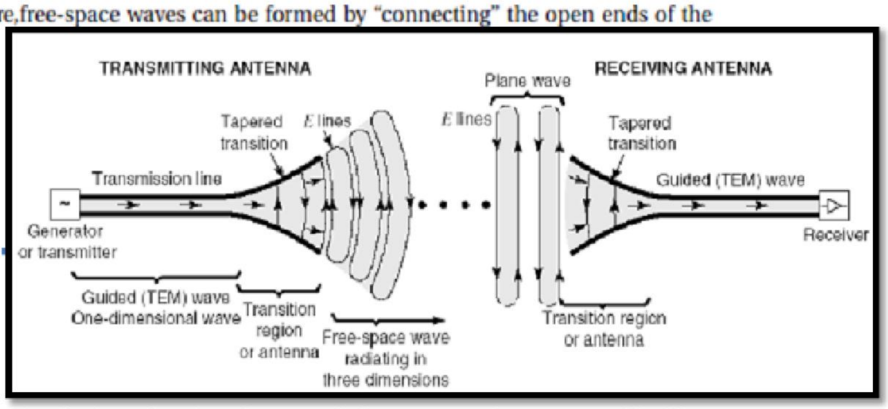
### ○ For two wires

- Applying a voltage across the two-conductor transmission line creates an electric field between the conductors.
- The movement of the charges creates a current that in turn creates a magnetic field intensity.
- The creation of time-varying electric and magnetic fields between the conductors forms electromagnetic waves which travel along the transmission line.



- If we remove part of the antenna structure, free-space waves can be formed by "connecting" the open ends of the electric lines.






- If the initial electric disturbance by the source is of a short duration, the created electromagnetic waves travel inside the transmission line, then into the antenna, and finally are radiated as free-space waves, even if the electric source has ceased to exist.
- If the electric disturbance is of a continuous nature, electromagnetic waves exist continuously and follow in their travel behind the others.
- However, when the waves are radiated, they form closed loops and there are no charges to sustain their existence.
- Electric charges are required to excite the fields but are not needed to sustain them.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**6. Derive** the wave equation described by magnetic vector potential. (***Report***)

**Vector potential $\vec{A}$ for electric current source $\vec{J}$**

$$\nabla \cdot \vec{B} = 0$$

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

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

$$\nabla \times \vec{H} = j\omega\varepsilon\vec{E} + \vec{J}$$

$$\nabla \times \vec{E} = -j\omega\mu\vec{H}$$

$$\nabla \cdot \vec{B} = \mu \nabla \cdot \vec{H} = 0$$

$\text{div curl} = 0$ or $\nabla \cdot (\nabla \times \vec{V}) = 0$

$\text{curl grad} = 0$ or $\nabla \times (\nabla \phi) = 0$

$\nabla \cdot \vec{V} = 0 \Rightarrow$ there exists $\vec{U}$ so that $\vec{V} = \nabla \times \vec{U}$

$\nabla \times \vec{V} = 0 \Rightarrow$ there exists $\phi$ so that $\vec{V} = \nabla \phi$

Since $\nabla \cdot \vec{B} = 0$

$\vec{B}_A = \nabla \times \vec{A}$ $\quad \left(\nabla \cdot \vec{B} = \nabla \cdot (\nabla \times \vec{A}) = 0 \quad \text{according to } (*)\right)$

$\boxed{\vec{H}_A = \frac{1}{\mu} \nabla \times \vec{A}}$ $\quad \left(\vec{B}_A = \mu \vec{H}_A\right)$

The vector $\vec{A}$ is called ***magnetic vector potential***.

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$$\nabla \times \vec{E}_A = -j\omega\mu \vec{H}_A = -j\omega \nabla \times \vec{A} \quad \Rightarrow \quad \nabla \times \left(\vec{E}_A + j\omega \vec{A}\right) = 0$$

Since $\nabla \times \left(\vec{E}_A + j\omega \vec{A}\right) = 0$, there exists a scalar function $\phi_e$ so that

$$\vec{E}_A + j\omega \vec{A} = -\nabla \phi_e \quad \Rightarrow \quad \boxed{\vec{E}_A = -\nabla \phi_e - j\omega \vec{A}}$$

$$\left(\nabla \times (-\nabla \phi_e) = 0\right)$$

$$\nabla \times \vec{H}_A = j\omega\varepsilon \vec{E}_A + \vec{J}$$

$$\frac{1}{\mu} \nabla \times \nabla \times \vec{A} = j\omega\varepsilon(-\nabla \phi_e - j\omega \vec{A}) + \vec{J}$$

$$\Downarrow \quad \leftarrow \quad \nabla \times \nabla \times \vec{A} = \nabla\left(\nabla \cdot \vec{A}\right) - \nabla^2 \vec{A}$$

$$\nabla\left(\nabla \cdot \vec{A}\right) - \nabla^2 \vec{A} = -j\omega\varepsilon\mu \nabla \phi_e + \omega^2 \varepsilon\mu \vec{A} + \mu \vec{J}$$

$$\boxed{\nabla \cdot \vec{A} = -j\omega\varepsilon\mu\phi_e} \quad \Rightarrow \quad \boxed{\nabla^2 \vec{A} + \omega^2 \varepsilon\mu \vec{A} = -\mu \vec{J}}$$

Inhomogeneous wave equation for $\vec{A}$

A solution for this inhomogeneous wave equation

$$\vec{A} = \frac{\mu}{4\pi} \iiint_V \vec{J} \frac{e^{-jkR}}{R} dv'$$

$$\boxed{\begin{aligned} \vec{H}_A &= \frac{1}{\mu} \nabla \times \vec{A} \\ \vec{E}_A &= -\nabla \phi_e - j\omega \vec{A} = -j\omega \vec{A} - j \frac{1}{\omega\mu\varepsilon} \nabla(\nabla \cdot \vec{A}) \end{aligned}}$$

$$\uparrow$$

$$\boxed{\nabla \cdot \vec{A} = -j\omega\varepsilon\mu\phi_e}$$

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Similarly Vector potential $\vec{F}$ for magnetic current source $\vec{M}$

$$\vec{F} = \frac{\varepsilon}{4\pi} \iiint_V \vec{M} \frac{e^{-jkR}}{R} dv'$$

$$\vec{E}_F = -\frac{1}{\varepsilon} \nabla \times \vec{F}$$

$$\vec{H}_F = -\nabla \phi_m - j\omega \vec{F} = -j\omega \vec{F} - j\frac{1}{\omega\mu\varepsilon} \nabla(\nabla \cdot \vec{F})$$

$$\nabla \cdot \vec{F} = -j\omega\varepsilon\mu\phi_m$$

## The total fields

$$\vec{E} = \vec{E}_A + \vec{E}_F$$

$$\vec{H} = \vec{H}_A + \vec{H}_F$$

### Summary of the analysis procedure

1) Specify the sources $\vec{J}$ and $\vec{M}$
2) Find the vector potential $\vec{A}$ and $\vec{F}$
3) Find the field contributions $\vec{E}$ and $\vec{H}$

Good Luck

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