Maxwell's equat°

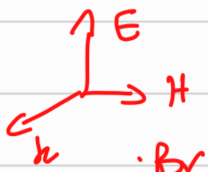
• No derivat° of Theo/equat Only the meaning

Need to know • Time ⟺ freq domain

Poyting theo (No derivat° Only meaning

+ how to use it to evaluate the power)

+ have to know • Plane waves



Spherical waves $\frac{e^{-j\beta r}}{r}$

Radiat°

→ ($B = \nabla \times A$ $\quad H = \frac{1}{\mu} \nabla \times A$)

only the meaning of the magnetic $\vec{}$ vect potent

Ideal dipole : No derivat° of E or H

• Memo the approximate solut° In far field

+ must know that $E = E_\theta \hat{\theta}$ • orientat°

$H = H_\varphi \hat{\varphi}$

" " everything % $\sin\theta$, % $\frac{e^{-j\beta r}}{r}$ spherical, % I

: Frequently asked in the past :

- Starting from E & H derive the total Real power Radiated by the Radiator

- Starting from the complet expression get the total power and show the diff between what we get using the complet expression / the aproximat

* Polarizat° often asked about

Must know everything (diff etc...)

- Linea Circular / RH, LH no eleptical (just that it's a general case)

- know how the field are Rotating in time

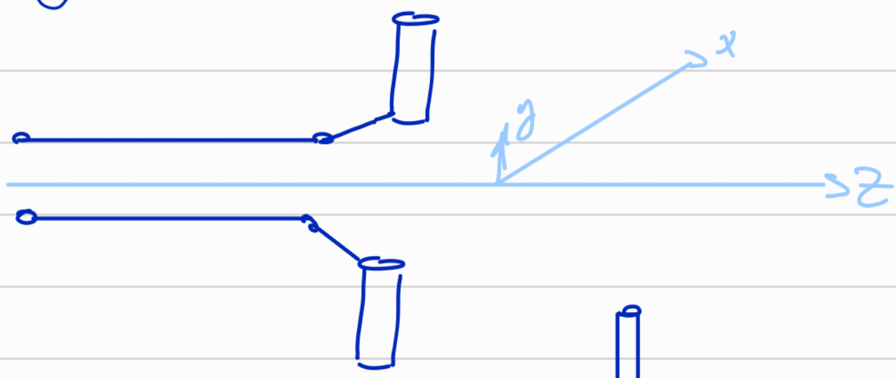
- Plot a CP field in time phasor domaine

- if E is CP prove that H is CP too

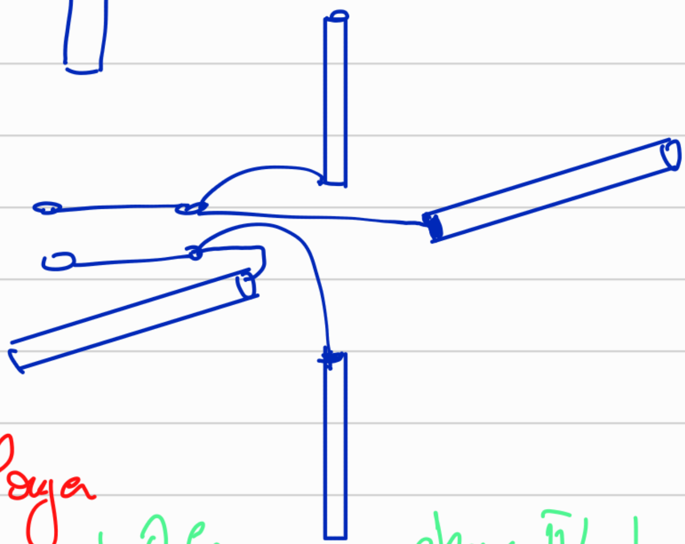
: freq asked

LP

exmp of Source of CP fields



(Show the phase delay) the one b has feeding TL longer



Pg 14

($\frac{\lambda}{4}$ longer → phase $\pi/2$)

Radiat' pattern everything (formulas D G e
Units
E plane
H "

: freq evaluat D of Ideal dipole

Beam solid Ang effective length / Array

evaluat the Radiated / dispated power

Obtain Friz formula & Radar equat'

(evaluate the power budget of a link using those formula

The meaning of the powers in those formulas

$$P_R = G_T G_R \left(\frac{\lambda}{4\pi R}\right)^2 P_T$$

P_R: Received

P_T: transmitt

Well understanding of this part

(Linear ⇒ Log)

Small dipoles & Loops

- What is a small dipole ?
- the diff between small dipol and Ideal dipol
  - Compare the power in both and evaluat the dis power Based on it

get the disipat Resistance Pg 7

- Skin depth formula
  - No ask of Imaginary part of Ime dance of short dipol

The short dipole has the same radiation pattern of the ideal dipole $|F(\theta,\varphi)| = |\sin\theta|$ and the directivity is $D = 1.5$

Same Radiat pattern & Directivity

The magnitude of the field radiated by the short dipole is one half of the magnitude radiated by the ideal dipole, the Poynting vector is one fourth, and so **the radiation resistance is one fourth that of the ideal dipole.**

short $E_s \alpha \frac{1}{2} E_i$

$S_s \propto \frac{1}{4} S_i$ ideal

$$P_R = \frac{1}{4}\frac{\pi}{3}\eta\frac{I^2\Delta z^2}{\lambda^2} \qquad R_R = \frac{2P_R}{I^2} = \frac{1}{2}\frac{\pi}{3}\eta\frac{\Delta z^2}{\lambda^2} \cong 20\pi^2\left(\frac{\Delta z}{\lambda}\right)^2$$

Losses

We want to estimate the dissipation resistance R_D, as well, and let's first consider again the uniform current distribution of an ideal dipole. The wire is a cylinder with radius a and length L and the current density must flow in the axial direction through the "skin" of the conductor having conductivity σ: **the dissipation resistance is proportional to the wire length and inversely proportional to the "skin" cross-section** that can be approximated by $2\pi a\delta$, where δ is the skin depth

Skin depth $\boxed{\delta = \frac{1}{\sqrt{\pi\mu f\sigma}}}$ $\qquad \boxed{R_D = \frac{L}{2\pi a\delta}\frac{1}{\sigma}} = \frac{L}{2\pi a}\sqrt{\frac{\pi\mu f}{\sigma}}$

Surface resistance $R_s = \sqrt{\frac{\pi\mu f}{\sigma}}$ $\qquad R_D = \frac{L}{2\pi a}R_s = \frac{L}{2\pi a}\sqrt{\frac{\pi\mu f}{\sigma}}$

The dissipation (or ohmic) resistance R_D of the short dipole is found by first determining the power dissipation from ohmic losses, which at any point along the antenna is proportional to the current squared. In fact, in general the total power is evaluated by integrating the current squared over the wire antenna.

Local Resistance

$\cancel{P_D = \frac{1}{2}R_D I^2}$

$$R_D = \frac{2P_D}{I^2} = \frac{1}{I^2}\frac{1}{2\pi a}\frac{1}{\delta\sigma}\int_{-\frac{\Delta z}{2}}^{+\frac{\Delta z}{2}} I(z')^2 dz' = \frac{1}{I^2}\frac{1}{2\pi a}\frac{1}{\delta\sigma}\frac{\Delta z}{3}I^2 = \frac{1}{3}\frac{\Delta z}{2\pi a}\frac{1}{\delta\sigma}$$

$$\int_{-\frac{\Delta z}{2}}^{+\frac{\Delta z}{2}} I(z')^2 dz' = \int_{-\frac{\Delta z}{2}}^{0} I^2\left[1 + 2\frac{z'}{\Delta z}\right]^2 dz' + \int_0^{+\frac{\Delta z}{2}} I^2\left[1 - 2\frac{z'}{\Delta z}\right]^2 dz' = \frac{\Delta z}{6}I^2 + \frac{\Delta z}{6}I^2 = \frac{\Delta z}{3}I^2$$

The dissipation resistance of the short dipole is one third that of an ideal dipole of the same length Δz and the radiation efficiency of the short dipole is given by

$P_D = \int_{-\frac{\Delta z}{2}}^{\frac{\Delta z}{2}} \frac{1}{2}\cdot\frac{1}{2\pi a\delta} I(z')\,dz'$

$$e_r = \frac{R_R}{R_R + R_D} = \frac{20\pi^2\left(\frac{\Delta z}{\lambda}\right)^2}{20\pi^2\left(\frac{\Delta z}{\lambda}\right)^2 + \frac{1}{3}\frac{\Delta z}{2\pi a}\frac{1}{\delta\sigma}}$$

Wire Antenna

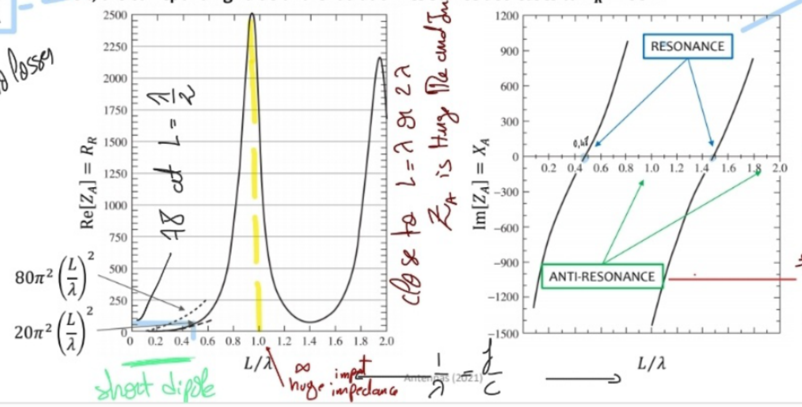
What is the Resonance and what kind of Current distribut= we get at Resonance

$D = 1,64$

As a funct° of freq

INPUT IMPEDANCE Z_A OF A CENTER-FED WIRE DIPOLE

In this example the radius of the wire is $a = 0.0005\,\lambda$. **The wire is at resonance when $\text{Im}[Z_A] = X_A = 0$ and it is at anti-resonance when $|X_A| = \infty$. In order to obtain $X_A = 0$ the dipole must be shortened to $L = 0.48\lambda$, the correponding value of the radiation resistance decreases to $R_R \cong 65\,\Omega$**

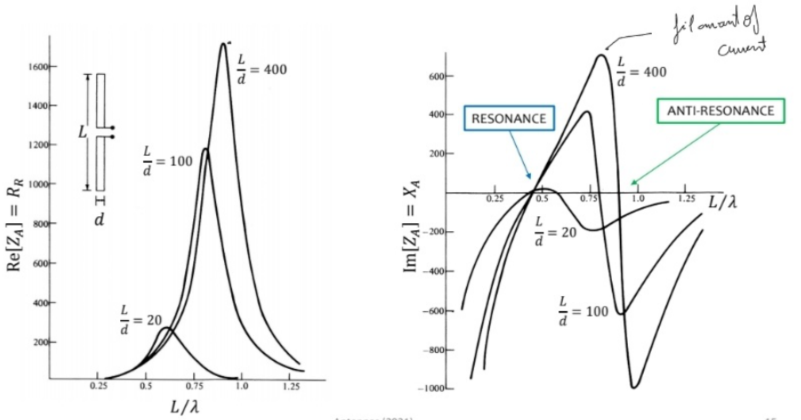


explain where is the resonance and Anti resonance

What will happen if we have thick wire?

plot qualitative $Z_A\left(\frac{L}{\lambda}\right)$ and explain

The input impedance depend on the length to diameter ratio of the wire (L/d). Starting from the values of Z_A it is possible to verify that the thicker the wire, the wider is the wire antenna working bandwidth.



to plot

General Solut° of an Array Antenna

The normalized array factor for an N element, uniformly excited ($a_n = A_0 e^{jn\alpha}$), equally spaced linear array reads as

$$\boxed{\frac{AF}{N} = \frac{\sin\left(N\frac{\psi}{2}\right)}{N\sin\left(\frac{\psi}{2}\right)}} \qquad \boxed{\psi = \beta d\cos\theta + \alpha} \qquad \boxed{|F(\theta,\varphi)| = \left|\frac{\sin\left(N\frac{\psi}{2}\right)}{N\sin\left(\frac{\psi}{2}\right)}\right|}$$

Normalized periodic sinc funct°

But the Radiat° pattern is as funct° of θ

The magnitude of the normalized array factor is the radiation pattern of the corresponding array of isotropic radiators.

important

$\psi = \beta d\cos\theta + \alpha$

- The array factor magnitude has a period of 2π in the variable ψ.
- The array factor is symmetric around $\psi = 0$ (it is an even function). | sin | is even // sin is odd
- The array factor maximum is N, and this value is achieved for $\psi_{MAX} = 0, \pm 2\pi, \pm 4\pi, \pm 6\pi, \cdots$
- The null directions are $\psi_{NULL} = \pm 2k\pi/N$ where k is an integer (with $k \neq N, k \neq 2N, k \neq 3N, \cdots$).
- The main lobes are of width $4\pi/N$ in the variable ψ, whereas for the minor lobes the width is $2\pi/N$.
- The number of lobes in one period equals $N-1$: one main lobe and $N-2$ side lobes.

is a max

$\psi \to 0$ $\Rightarrow$ $\frac{AF}{N} \to 1$ $\Rightarrow$ $AF = N$

But not $\frac{\psi}{2} = \pi$

What is a linear Array