UNIT-2

1. What is retarded potential? Explain different approaches to solve radiation problems?

Ans:

Retarded Potential

The potential functions are defined as,

$$A(r,t) = \frac{\mu}{4\Pi} \int \frac{J(r^1, t - R/v)}{R} dv^1$$

$$V(r,t) = \frac{1}{4\Pi\epsilon} \int \frac{\rho(r^1, t - R/v)}{R} dv^1$$

The above potential functions-are called as Retarded potentials. Since a time delay of 'R/v' has been introduced. So that now the potentials have been delayed or retarded by '*R/v*'

Approaches to Solve Radiation Problems

A difficulty in the subject of electromagnetic is, it is hard to visualize electromagnetic wave propagation and interaction. With today's advanced numerical and computational methods, and computational and visualization software and hardware, this dilemma can, to a large extent, be minimized. To address this problem, computer program have been developed to animate and visualize three radiation problems. Each problem is solved using the Finite-Difference Time-Domain (FD-TD) method, a method which solves maxwell's equations as a function of time in discrete time steps at discrete points in space. A picture of the fields can then be taken at each time step to create a movie which can be viewed as a function of time.

The three radiation problems that are animated and can be visualized using the computer program are,

(a) Infinite length line source (two dimensional) excited by a single Gaussian Pulse and radiating in an unbounded medium.

(b) Infinite length line source excited by a single Gaussian Pulse and radiating inside a Perfectly Electric Conducting (PEC) square cylinder

(c) E-plane sectoral horn excited by a continuous co-sinusoidal voltage source and radiating in an unbounded medium.

In order to animate and then visualize each of the three radiation problems, the user needs the professional edition of MATLAB[11] and the MATLAB-File, to produce the corresponding FD-TD solution of each radiation problem. For each radiation problem, the M-File executed in MATLAB produces a movie by taking a picture of the computational domain every third time step. The movie is viewed as a function of time as the wave travels in the computational space.

(i) Infinite Line Source in as Unbounded Medium:

The first FD-TD solution is that of an infinite length line source excited by a single time derivative Gaussian pulse, with a duration of approximately 0.4 nano seconds, in a two dimensional *TMz* - computational domain. The unbounded medium is simulated using a six layer Beranger Perfectly Matched Layer (PML) Absorbing Boundary Condition (ABC) to truncate the computational space at finite distance without, in principle creating any reflections. Thus the pulse travels radically outward creating a traveling type of a wave front. The outward moving wave fronts are easily for the sily identified using the coloring scheme for the intensity when viewing the movie. The movie is created by the MATLAB M-File which produces the FD-TD solution by taking a picture of the computational domain every third time step. The movie is 37 frames long covering 185 picoseconds of elapsed time. The entire computational space is 15.3 cm by 15.3 cm and is modeled by 2500 square FD-TD cells (50x50), including 6 cells to implement the PML ABC.

(ii) Infinite Line Source in a PEC Square Cylinder

This problem is simulated similarly as that of the line source in an unbounded medium, including the characteristics of the pulse. The major difference is that the computational domain of this problem is truncated by PEC walls, therefore there is no need for PML ABC. For this problem pulse travels in an outward direction and is reflected when it reaches the walls of the cylinder. The reflected pulses along with the radially outward traveling pulse interface constructively and destructively with each other and create a standing type wavefront. The peaks and valleys of the modified wavefront can be easily identified when viewing the movie, using colored or gray scale intensity schemes. Sufficient time is allowed in the movie to permit the pulse to travel-form the source to the walls of the cylinder. Each time step is 5 picoseconds and each FD-TD cell is 3 mm on, a side. The movie is 70 frames long covering 350 picoseconds of elapsed time. The square cylinder and thus the computational space, has a cross section of 15.3 cm by 15.3 cm and is modeled using an area 50 by FD-TD cells.

(iii) E-plane Sectoral Horn in an Unfounded Medium

The E-plane sectoral horn is excited by a co sinusoidal voltage (CW) of 9.84 GHz in a *TE*2 computational domain, instead of Gaussian pulse excitation of the previous two problems. The unbounded medium is implemented using an eight-layer Beranger *PMLABC.* The computational space is 25.4 cm by 25.4 cm and is modeled using 100 by 100 FD-TD cells (each square cell being 2.54 mm on a side). The movie is 70 frames long covering 296 picoseconds of elapsed time and is created by taking a picture every third frame. Each time step is 4.23 picoseconds in duration. The horn has total fare angle of 52° and its fared section is 2.62 cm long, is fed by a parallel plate 1cm wide and 4.06 cm long, and has a aperture of 3.56 cm.

2.What is polarization? How many types of polarizations are used in antenna? Explain?

Ans: Electromagnetic Polarization

Electromagnetic polarization refers to the orientation of the electric field vector with respect to earth's surface. In this concept, the electric field whose orientation is varied in regular intervals to retain its strength along all directions. A polarization vector is a vector whose direction is along the path of the polarization (i.e., electric field orientation direction).

There are three kinds of polarization namely,

1. Linear-polarization
2. Circular polarization
3. Elliptical polarization.

1. Linear Polarization

It is also known as plane polarization. In this electric field is confined to only one particular direction.

There are two forms of linear polarization. They are,.

(i) Horizontal polarization

(ii) Vertical polarization.

In horizontal polarization, the electric field propagates parallel to the earth's surface, whereas in vertical polarization, the electric field propagates perpendicular to the earth's surface.

2. Circular Polarization

The polarization in which polarization vector rotates 360° over one period of the wave is referred as circular polarization. In the circular polarization, the strength of the field vector has a constant Value in all directions of polarization.

3. Elliptical Polarization

The elliptical polarization in which also, the polarization vector rotates 360° over one period of the wave. In elliptical polarization, the strength of the field varies with the changes in polarization.

This polarization is further classified into left handed and right handed elliptical polarization based on the rotating direction of the wave. If the vector rotates in clockwise direction, it is referred to as right handed and if the vector rotates in anticlockwise direction, it is referred to as left handed.

3. State reciprocity theorem for antennas. Prove that he self –impedance of an antenna in transmitting and receiving antenna are same?

Ans:

Reciprocity Theorem

Statement

Reciprocity theorem states that when current I is applied at the terminals of antenna 1, an e.m.f E_{21} induces at terminals of antenna 2 and when current I applied at the terminals of antenna 2, an e.m.f E_{12} induces at terminals of antenna 1, then $E_{12} = E_{21}$ provided $I_1 = I_2$.

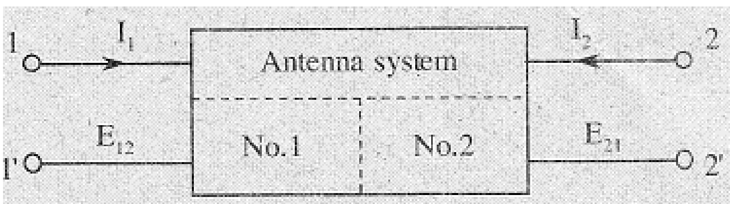


Fig 3.1 General Antenna System

Equality of Antenna Impedance

Consider, the two antennas separated with wide separation as shown below figure 3.2.

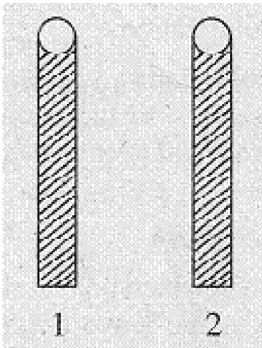


Fig 3.2 Two antennas 1 and 2 with a wide separation

The current distribution is same in case of transmitting and receiving antenna. Let antenna no. 1 is the transmitting antenna and antenna no.2 is the receiving antenna. The self impedance (Z_{11}) of transmitting antenna is given by,

$$E_1 = Z_{11}I_1 + Z_{12}I_2$$

Here,

Z_{11} = Self impedance of antenna1

Z_{12} = Mutual impedance between the two antennas.

Since the separation is more, mutual impedance (Z_{12}) is neglected,

$$Z_{12} = 0$$

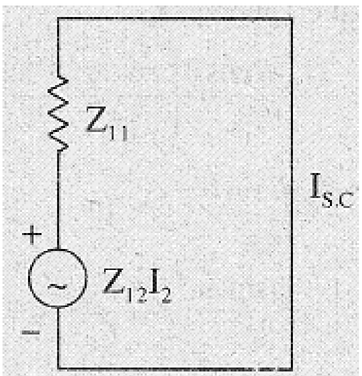
$$E_1 = Z_{11}I_1 + Z_{12}I_2$$

$$E_1 = Z_{11}I_1 + 0(I_2)$$

$$\boxed{Z_{11} = E_1/I_1}$$

The receiving antenna under open circuit and short circuit conditions are shown below.

(a) Receiving Antenna under Open Circuit Condition



Here,

Fig 3.3 Reciving antenna under open circuit condition

$$E_1 = Z_{11}I_1 + Z_{12}I_2$$

When the receiving antenna is open circuited, current I_1 is zero

$$E_1 = Z_{11}(0) + Z_{12}I_2$$

$$\boxed{E_{OC} = Z_{12}I_2}$$

(b) Receiving Antenna under Short Circuit Condition

When the receiving antenna is short circuited, the voltage (E) will be zero.

$$E_1 = Z_{11}I_1 + Z_{12}I_2$$

$$0 = Z_{11}I_{SC} + Z_{12}I_2$$

$$\boxed{I_{SC} = - Z_{12} I_2/ Z_{11}}$$

From above, the term $Z_{12}I_2$ acts as a voltage source and Z_{11} as the self impedance. Hence, impedance of the antenna is same whether it is used for transmission or reception

4. State the Maximum power transfer theorem and bring out their importance in antenna measurements?

Ans:

Maximum Power Transfer Theorem

Statement

Maximum power transfer theorem states that, an antenna can radiated maximum power, when the terminal resistance, R_L of the antenna is same as that of finite source resistance, R_S.

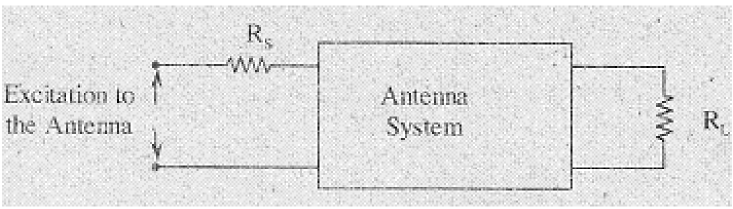


Fig 2.4.1 Maximum Power Transfer Theorem

This theorem applies to the maximum power, but not for maximum efficiency. If the antenna terminal resistance is made large than the resistance of the source, then the efficiency is more, since most of the power is generated at the terminals, but the overall power is lowered. If the internal source resistance is made larger than the terminal resistance then most of the power ends up being dissipated in the source.

Thus, the main use of maximum power transfer theorem for antennas is impedance matching i.e., maximum power transfer to and from an antenna occurs when the source or receiver impedance is same as that of antenna. But, when an antenna is not correctly matched internal reflections will occur.

5. Find the effective length of a half-wave dipole?

Ans:

Effective Length of a Half-wave Dipole

The effective length of an antenna is defined as the ratio of induced voltage at the terminal of the receiving antenna under open circuited condition to the incident electric field intensity i.e.,

Effective length, l_e = open circuited voltage/ Incident field strength

$$l_e = V / E$$

However, the included voltage 'V' also depends on the effective aperture as,

$$A_e = (V^2 R_L) / \{[(R_A + R_L)^2 + (X_A + X_L)^2]\, P\}$$

Where,

R_L = Load resistance
R_A = Antenna resistance
X_L = Load reactance
X_A = Antenna reactance
P = Poynting vector.

$$V^2 = \{A_e [(R_A + R_L)^2 + (X_A + X_L)^2]\, P\} / R_L$$

Since,

$P = E^2/Z$, Where Z – Intrinsic impedance
$= 120\pi$

$$V^2 = \{A_e [(R_A + R_L)^2 + (X_A + X_L)^2]\, E^2\} / Z\, R_L$$

$$V = \sqrt{\{Ae\ [(RA\ + RL)^2\ +\ (XA\ +\ XL)^2]E^2\}/\ Z\ RL}$$

Then,

Effective length, $l_e = V / E = \sqrt{\{Ae\ [(RA\ + RL)^2\ +\ (XA\ +\ XL)^2]\}/\ Z\ RL}$

For obtaining maximum effective aperture,

$X_A = -X_L$
$R_A = R_L = R_r$ =Radiation resistance

Thus,

$$l_e = \sqrt{Ae(2Rr)^2/ZRr}\ =\ 2\sqrt{AeRr/Z}$$

But, the effective aperture of a half wave dipole is given by, $A_e = 0.13\lambda^2$ and the radiation resistance of a half wave dipole is, $R_r = 73\Omega$.

$$(l_e)_{\lambda/2\ \text{dipole}} = 2\sqrt{(0.13\lambda^2 X\ 73)/\ 120\pi} = 0.318\lambda.$$

6. Write short note on small loops.
Ans:

The field pattern of a small circular loop of radius *a* may be determined very simple by considering a square loop of the same area, that is.

$$d^2 = \pi a^2 \qquad \ldots(1)$$

where d = side length of square loop

It is assumed that the loop dimensions are small compared to the wavelength. It will be shown that the far-field patterns of circular and square loops of the same area are the same when the loops are small but different when they are large in terms of the wavelength.

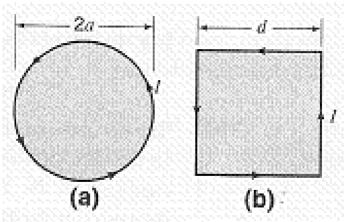


Fig 2.6.1 (a) Circular loop (b) square loop

If loop is oriented as in fig.2.6.2, its far electric field has only an E_Φ component. To find the far-field pattern in the yz plane, it is only necessary to consider two of the four small linear dipoles (2 and 4). A cross section through the loop in the yz plane is presented in Fig.2.6.3. Since the individual small dipoles 2 and 4 are nondirectional in the yz plane, fee field pattern of the loop in this plane is the same as that for two isotropic point sources. Thus,

$$E_\Phi = -E_{\Phi 0}\, e^{j\psi/2} + E_{\Phi 0}\, e^{-j\psi/2} \qquad \ldots(2)$$

Where $E_{\Phi 0}$ = electric field from individual dipole and

$$\psi = (2\pi d/\lambda)\sin\theta = d_r \sin\theta \qquad \ldots(3)$$

It follows that

$$E_\Phi = -2j\, E_{\Phi 0} \sin(d_r \sin\theta/2) \qquad \ldots(4)$$

The factor j in (4) indicates that the total field E_Φ is in phase quadrature with the field $E_{\Phi 0}$ be individual dipole.

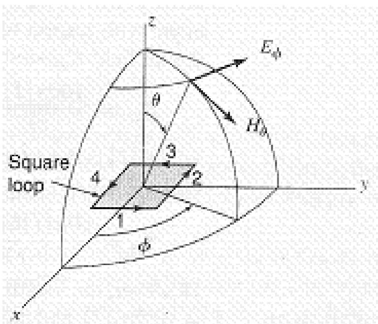


Fig 2.6.2 Relation of square loop to coordinates

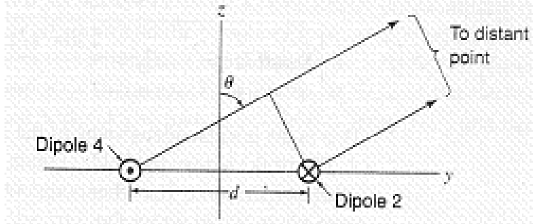


Fig 2.6.3 Construction for finding for field of dipoles 2 and dipole 4 of square loop.

However, the length L of the short dipole is the same as *d*, that is, L = *d*.

$$\text{Small loop } E_\Phi = (120\pi^2 I \sin\theta A)/r\lambda^2$$

This is the instantaneous value of the E_Φ, component of the far field of a small loop of area *A*. The peak value of the field is obtained by replacing [I] by I_0, where I_0 is the peak current in time on the loop.

7. Compare far fields of small loop and short dipole?

Ans:

Comparison of far fields of Small Loop and Short Dipole

It is of interest to compare the far-field expressions for a small loop with those for a short electric dipole. The comparison is made in table. The presence of the operator j in the dipole expressions and its absence in the loop equations indicate that the fields of the electric dipole and of the loop are in time-phase quadrature, the current I being in the same phase in both the dipole and loop. This quadrature relationship is a fundamental difference between fields of loops and dipoles.

Field	Electric Dipole	Loop
Electric	$E_\theta = (j\,60\,\pi[\,I\,]\sin\theta\,L)/(r\,\lambda)$	$E_\Phi = (120\,\pi^2[\,I\,]\sin\theta\,A)/(r\,\lambda^2)$
Magnetic	$H_\Phi = (j\,[\,I\,]\sin\theta\,L)/(2r\,\lambda)$	$H_\theta = (\pi\,[\,I\,]\sin\theta\,A)/(r\,\lambda^2)$

8.What are the different advantages and disadvantages of loop antennas?

Ans:

Advantages

1. A small loop is generally used as magnetic dipole.
2. A loop antenna has directional properties whereas a simple vertical antenna not has the same.
3. The induced e.m.f around the loop must be equal to the difference between the two vertical sides only.
4. No e.m.f is produced in case of horizontal arms of a loop antenna.
5. The radiation pattern of the loop antenna does not depend upon the shape of the loop (for small loops).
6. The currents are at same magnitude and phase, throughout the loop.

Disadvantages

1. Transmission efficiency of the loop is very poor.
2. It is suitable for low and medium frequencies and not for high frequencies.
3. In loop antenna, the two nulls of the pattern result in 180° ambiguity.
4. Loop antennas used as direction finders are unable to distinguish between bearing of a distant transmitter and its reciprocal bearing.

9. Sketch the far field patterns of loops of 0.1λ, λ and 3λ/2 diameter. What is the effect of the shape of the small loop on its far field pattern?

Ans:

The far field of loop antenna is,

$E_{\Phi} = (\mu\omega[I]a\ I_1(\beta\ a \sin\theta))/2r$

$H_{\theta} = (\beta\ a[I]\ J_1(\beta\ a \sin\theta))/2r$

The above expression shows the far field pattern for loop of any size. The far field expressions E_{Φ} and H_{θ} as a function of θ is given by $J_1\ (C_{\lambda} \sin\theta)$

Here,

C_{λ} = Circumference of the loop

$C_{\lambda} = a\beta$

$\beta = (2\pi/\lambda)$

$C_{\lambda} = (2\pi/\lambda)\ a$

$$\boxed{C_{\lambda} = (2\pi a/\lambda)}$$

Far Field Patterns of Loops of 0.1λ, λ and 3λ/4 diameters

(i) Field patterns of 0.1λ

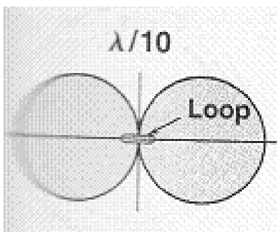


fig 9.1 Field pattern of 0.1λ

(ii) **Field pattern of λ**

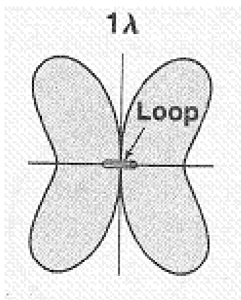


fig 9.2 Field Pattern of λ

(iii) Field pattern of 3λ/2 Diameter

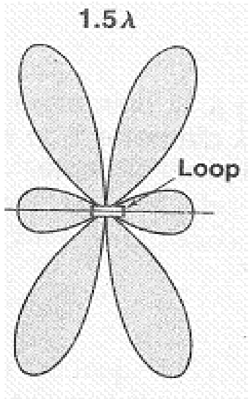


fig 9.3 Field pattern of 3λ/2

10. Define and explain directivity and power gain for an antenna. What is the relation between the two?

Ans:

Directivity

It is defined as the ratio of maximum radiation intensity of subject or test antenna to the radiation intensity of an isotropic antenna.

(or)

Directivity is defined as the ratio of maximum radiation intensity to the average radiation intensity.

$$\boxed{\text{Directivity, } D = U_{max}/U_{avg} = \frac{\textit{Maximum radiation intensity}}{\textit{Average radiation intensity}}}$$

Directivity (D) in terms of total power radiated is,

$D = 4\pi$ x Maximum radiation intensity/ Total power radiated

$$\boxed{D = (4\pi \times U_{max}) / W_T}$$

Therefore

$$\boxed{U_{av} = W_T/4\pi}$$

Power Gain (G_P)

It is defined as the ratio of radiation intensity in given direction to the total input power.

G_P = Radiation intensity in given direction / Total input power

$G_P = U(\theta,\Phi)/[W_T / 4\pi]$

Therefore,

Total input power, $P_i = W_T / 4\pi$

$$\boxed{G_P = (4\pi\, U(\theta,\Phi) / W_T)}$$

Therefore, thus the power gain (G_P) depends upon volume of the radiation pattern.

Relation between Directivity and Power Gain

The expression for power gain of an antenna is given by,

$$G_P = (4\pi\, U(\theta,\Phi)) / P_{in} \qquad \ldots(1)$$

However, the relation between total radiated power, P_{rad} and the total input power, P_{in} is given by,

$$P_{rad} = C\, P_{in} \qquad \ldots.\ (2)$$

Where,

η_{rad} = Antenna radiation efficiency

Then, equation (1) can be written as,

$$G_P = (4\pi\, U(\theta,\Phi)) / (P_{rad} / \eta_{rad})$$

$$G_P = \eta_{rad}\, (4\pi\, U(\theta,\Phi)) / (P_{rad})$$

$$G_P = \eta_{rad}\, D \qquad [D = (4\pi\, U(\theta,\Phi)) / (P_{rad})]$$

$$\boxed{\text{Therefore, } G_P = \eta_{rad}\, D}$$