BANNARI AMMAN INSTITUTE OF TECHNOLOGY

(An Autonomous Institution Affiliated to Anna University, Chennai)

SATHYAMANGALAM - 638 401

Discourse Questions

22EC503 - TRANSMISSION LINES AND ANTENNAS

1. Question

In TV communication, antenna is connected to receiver through Co-axial transmission line, where high frequency electrical signal is fed to radiate Electromagnetic signal. A transmission line is connected between receiver and antenna.

Figure: TV transmission system

Assume that the antenna is receiving the maximum signal without loss, then compute voltage standing wave ratio and reflection coefficient of a perfectly matched line with no reflection from the load side and also check whether the obtained result is within the minimum and maximum acceptable range of these values.

Answer

Voltage standing wave ratio and reflection coefficient of a perfectly matched line with no reflection from the load side is
Reflection coefficient (RC) =(ZL-Z0)/(ZL+Z0) = 0 (1 mark)
VSWR =(1+RC) / (1-RC) = 1 (1 mark)
the minimum and maximum acceptable range of these values
Reflection coefficient 0 to 1 and VSWR 1 to infinity It is within the acceptable range. (1 mark)

2. Question

In a distortion less line, the characteristic impedance Z0 is given by
a) Z0=sqrt(R/G)
b) Z0= sqrt(L/C)
c) Z0= sqrt((R+L)(G+C))
d) Z0=sqrt(LC/RG)

Answer

b) Z0= sqrt(L/C)

3. Question

Compute the SWR for the load impedance of 100 ohms connected to a 50-ohm transmission line

a) 2
b) 3
c)1
d) 0

Answer

a) 2

4. Question

If the RF transmission is terminated in its characteristic impedance Z0, which of the following statements is correct:

a) The input impedance of transmission line becomes Z0
b) The transmission line acts as an infinite long transmission line
c) The VSWR becomes one
d) The VSWR becomes infinite

Answer

c) The VSWR becomes one

5. Question

The characteristic impedance of a line having open and short impedances of 10 and 40 respectively is

a) 10
b) 400
c) 20
d) 4

Answer

c) 20

6. Question

In the BIT Conference room, two computers are interconnected by the coaxial cable of length 170mm long and terminal impedance of 100Ω and with a velocity of propagation $2*10^8$ m/s as shown the figure. Assume that the coaxial transmission line is a lossless line having distributed parameters L = 245nH/m and C =200pF/m.

Figure : Wired Communication System

a) Compute the characteristics impedance of the line, when there is no reflection from the personal computer to laptop and vice versa at a frequency of 1 GHz.
b) Illustrate the signal transmission between the source and load for load conditions of ZR= 0 and ZR= infinity
c) Determine the input impedance seen looking into the input terminals of the line at 1 GHz.

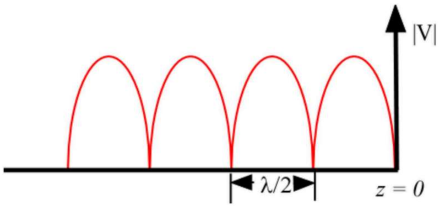
Answer

a) characteristics impedance (2 marks)

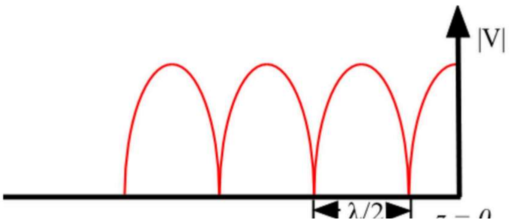
$$Z_0 = \sqrt{\frac{L}{C}} = 35\ \Omega$$

$$\beta = \text{Im}(\gamma) = \omega\sqrt{LC} = 44.0\ \text{rad/m}$$

b) ZR=0 (Short circuited) (1 mark)



ZR=infinity (open circuited) (1 mark)



Input Impedance (2 marks)

$$Z_L = 100\ \Omega \qquad Z_0 = 35\ \Omega \qquad l = 170\ \text{mm}$$

$$Z_i = Z_0 \frac{Z_L + jZ_0\tan(\beta l)}{Z_0 + jZ_0\tan(\beta l)} = (13.9 - j11.9)\ \Omega$$

7. Question

The main motive of any transmission line used has to transfer the maximum power of the signal to the load. This is only possible when the line and the load are coupled or matched. The incident wave is also called as forward wave and the reflected wave as backward wave as shown in the figure "Transmission System".

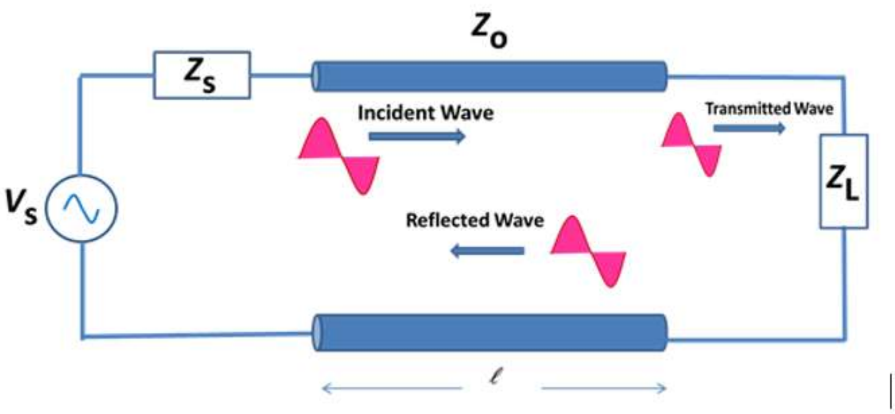
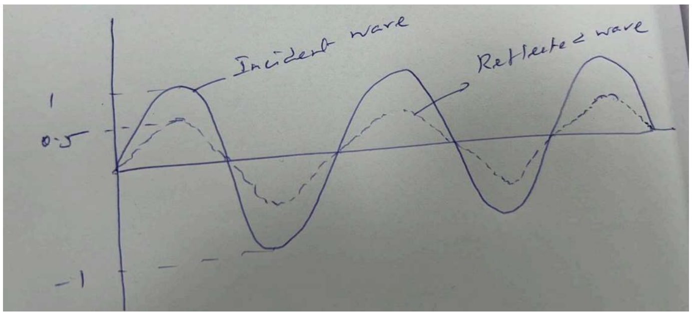


Figure : Transmission System

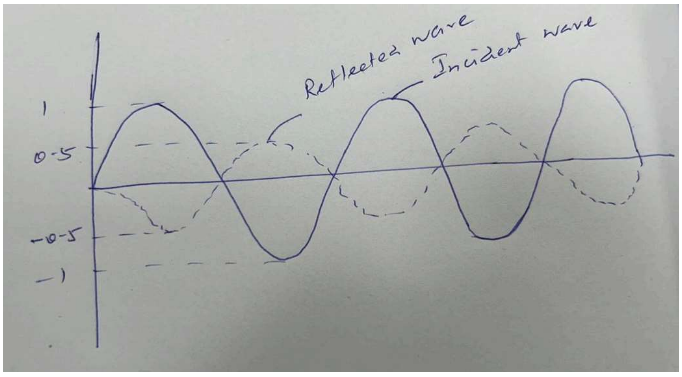
Illustrate the incident and reflected signal for the following values of impedance at terminal B :
Z_L = 3Zo and Z_L = Zo/3.
Also analyze at what condition the standing waves does not exist in the telephone system.

Answer

Reflection coefficient = (Z_L-Zo) / (Z_L+Zo)
When Z_L = 3Zo,
Reflection coefficient=(3Zo-Zo)/(3Zo+Zo) = 1/2 (1 mark)
50% of the signals reflected back. (1 mark)



When Z_L = Zo/3,
Reflection coefficient=(Zo/3-Zo)/(Zo/3+Zo) = -1/2 (1 mark)
50% of the signals reflected back with phase shift of 180 degree. (1 mark)



The standing waves does not exist in the telephone system for the condition Z_L = Zo (1 mark)

8. Question

Consider the below underwater communication scenario where transducers in the ships are used to detect the objects in their path way. If the object is detected, signals are transmitted to the surface station in the ship using submarine cables.

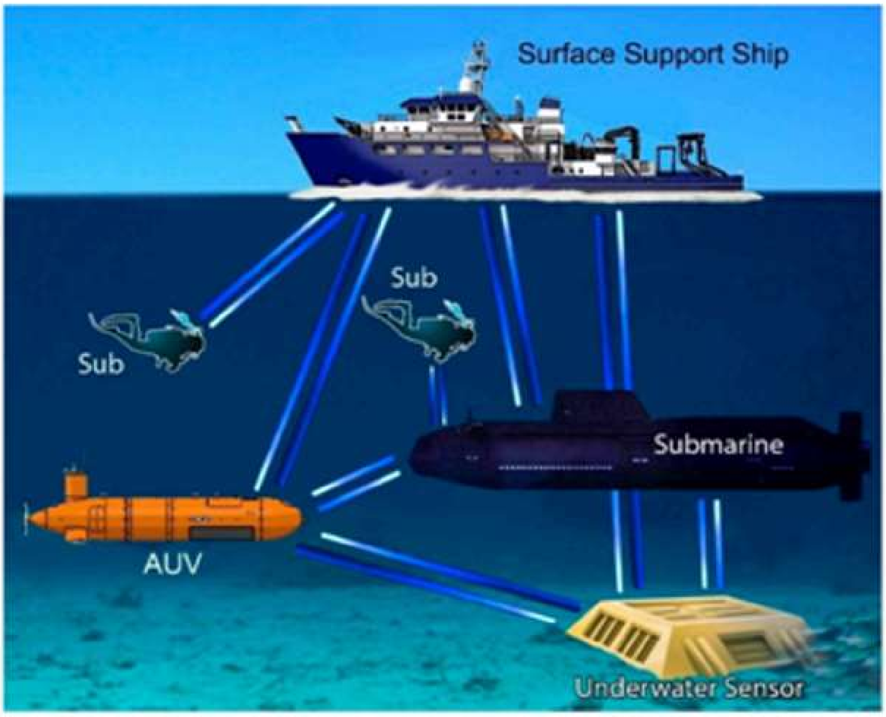


Figure: Underwater Communication System

The distortions in the submarine cables are interconnected by a twisted pair of cable having an impedance of 100 ohm and are connected to a load of 50 ohm. Due to mismatch in impedance, certain amount of power will be reflected back to the source side. This is quantified in terms of Voltage Standing Wave Ratio (VSWR or S). If VSWR is measured using a Network analyzer, then analyze the deviation in VSWR value from industry standard.

Answer

Reflection coefficient = (Z_L-Zo) / (Z_L+Zo) = (100-50)/(100+50)=50/150 = 1/3 (1 mark)
VSWR =1+G/1-G=2 (1 mark)
VSWR value from industry standard is 1 (1 mark)
VSWR value double from the industry standard (1 mark)

9. Question

A source of 50 Ω transmission line is connected to a load impedance yielding a VSWR of unity. For the stated condition, the value of load impedance is
a) Equal to source impedance
b) Greater than source impedance
c) Equal to load impedance
d) Greater than load impedance

Answer

a) Equal to source impedance

10. Question

A 100-Ω lossless air transmission line is connected to a complex load composed of a resistor in series with an inductor as shown in Figure "Load impedance". At 6 MHz, determine the reflection coefficient of the line.

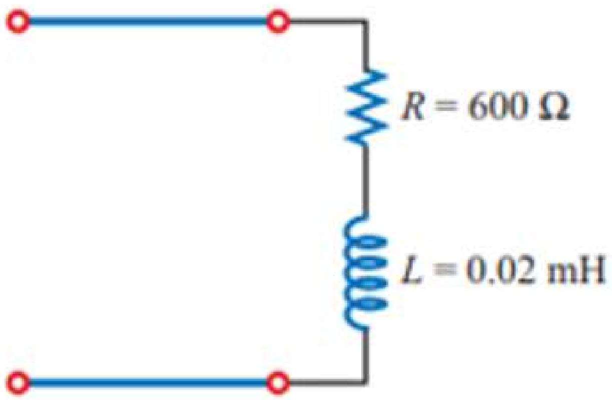


Figure: Load Impedance

Answer

ZL=R+jwL
ZL=600+j(2pi*6*e3*0.02e-3)
Reflection coefficient = ZL-Zo/ZL+Zo
ZL=600+j(2*pi*6e6*0.02e-3)
Answer: 0.9340

11. Question

If a transmission line is terminated with a resistance equal to its characteristic impedance, then
a) the reflection coefficient will be zero
b) the input impedance will be twice the terminating resistance
c) the standing wave ratio will be minimum
d) the line loss will be maximum

Answer

a) the reflection coefficient will be zero

12. Question

During practical implementation of RF applications it is required to match the different impedances of the interconnected blocks. The impedance matching is important for a maximum transfer of signal from a source and load.

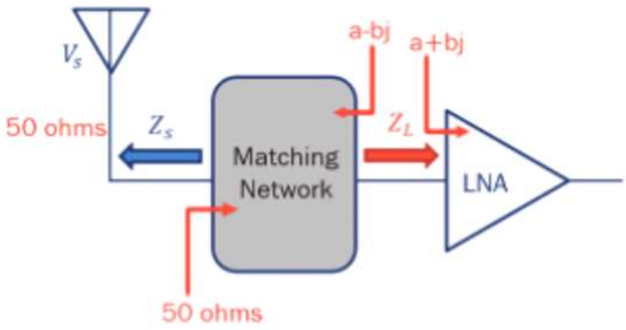


Figure: RF Network

The input impedance of the above transmission line is given by

$$Z_s = R_0\left[\frac{Z_R + jR_0 \tan(2\pi s/\lambda)}{R_0 + jZ_R \tan(2\pi s/\lambda)}\right]$$

The characteristics impedance of the antenna is 55 ohm and the receiver has a impedance of 155+j75 ohm. The sending end impedance is 155+j75 ohm at zero wavelength, and 55 ohm at 0.125 times the wavelength. Then, analyze the impact of the sending end impedance of the line when the line length is increased from zero wavelength to 1.183 times the wavelength.

Answer

$$\frac{2\pi}{\lambda} l = \frac{2\pi}{\lambda} \times 1.183\lambda = 7.43 \text{ radians}$$
$$= 7.43 \times \frac{180}{\pi} = 426^\circ$$
$$= 426^\circ - 360 = 66^\circ$$

(1 mark)

$$= 55\left[\frac{(155+j75) + j(55)\tan 66^\circ}{''}\right]$$
$$= 55(0.48 - 0.656j)$$
$$Z_s = 37.8 \angle -56.03^\circ$$

(2 marks)

Input impedance decreases to 37.8 ohms. when the length of the line increases, input impedance also changes in a phasal manner. (1 mark)

13. Question

If the total included angle of the 'V' is greater than $2\theta_m$ then the main lobe will be

a) a unique beam
b) split into two distinct beams
c) tilted downwards
d) tilted upwards

Answer

b) split into two distinct beams

14. Question

Traveling wave antenna can be designed by

a) minimizing reflections
b) maximizing reflections
c) proper termination
d) both proper termination and minimizing reflections

Answer

d) both proper termination and minimizing reflections

15. Question

The parameters that specify maximum power direction of Rhombic antenna is
a) Tilt angle
b) Height above ground
c) Angle of elevation
d) Wavelength

Answer

b) Height above ground

16. Question

Consider a scenario where a man standing with FM radio receives signal from V antenna of Base station, placed above the ground as shown in Figure.

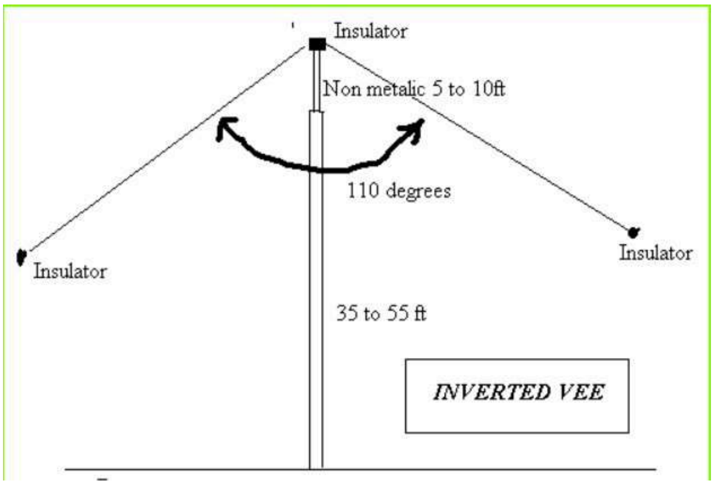


Figure : V Antenna

a) If the total included angle of the 'V' is greater than 2θm , then what will happen to the main lobe?

b) If the position of properly terminated antenna is reversed with three (A, B and C) different configurations as shown in the below figure, then analyze which configuration has to be used in order to have maximum signal strength in the direction of propagation? Justify your answer with proper reason.

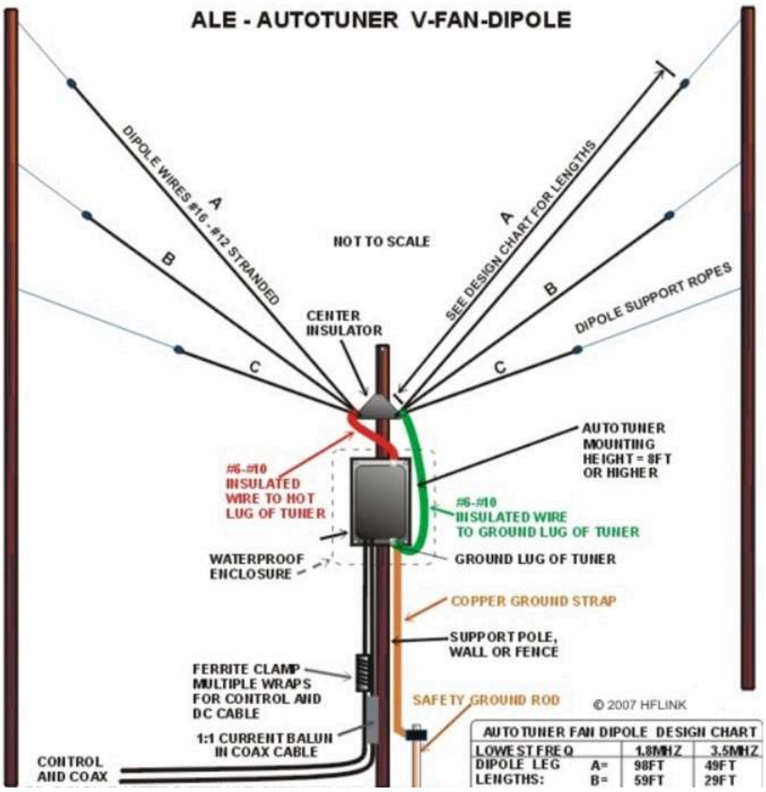


Figure: Inverted V Antenna

Answer

a) If the total included angle of the 'V' is greater than 2θm , then main lobe will be split into two distinct beams. (1 mark)

b) 'A' configuration has to be used in order to have a maximum signal strength in the direction of propagation. (1 mark).

The apex angle between the two arms of the V-antenna is inversely proportional to the signal strength. As the apex angle increases in configurations B and C compared to configuration A, the signal strength is highest in configuration A. (1 mark)

17. Question

The properties of the unidirectional travelling wave antenna is

a) Resonant, Periodic

b) Resonant, Aperiodic

c) Non- resonant, Periodic

d) Non- resonant, Aperiodic

Answer

d) Non- resonant, Aperiodic

18. Question

The actual radiating sources are electrically represented by current densities J1 and M1 and it radiates fields E1 and H1 everywhere. The closed surface 'S' is formed by enclosing the current densities J1 and M1 as shown in the figure. If the actual sources J1 and M1 are removed, then analyze whether the fields exist inside and outside of the boundary S of the equivalent source with its model. Also state the current densities induced due to E1 and H1 on the imaginary surface S.

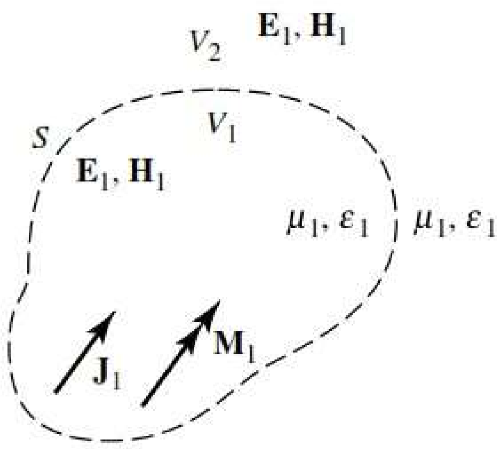
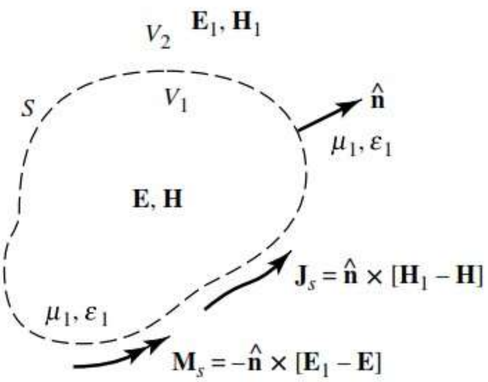


Figure: Actual Source Model

Answer

The original sources J1 and M1 are removed, and we assume that there exist fields E and H inside S and fields E1 and H1 outside of S. For these fields to exist within and outside S,
they must satisfy the boundary conditions on the tangential electric and magnetic field components. (2 marks)
An equivalent problem of the given problem is shown in the below Figure. (1 mark) .



Thus on the imaginary surface S there must exist the equivalent sources and the current densities induced due to E1 and H1 on the imaginary surface S is given by (1 mark)

$$\mathbf{J}_s = \hat{\mathbf{n}} \times [\mathbf{H}_1 - \mathbf{H}]$$
$$\mathbf{M}_s = -\hat{\mathbf{n}} \times [\mathbf{E}_1 - \mathbf{E}]$$

19. Question

Consider an aperture antenna as shown in figure. This antenna constitutes a large class of antennas, which emit EM waves through an opening (or aperture). At radio and microwave frequencies, horns, waveguide apertures, reflectors and microstrip patches are the models of aperture antennas.

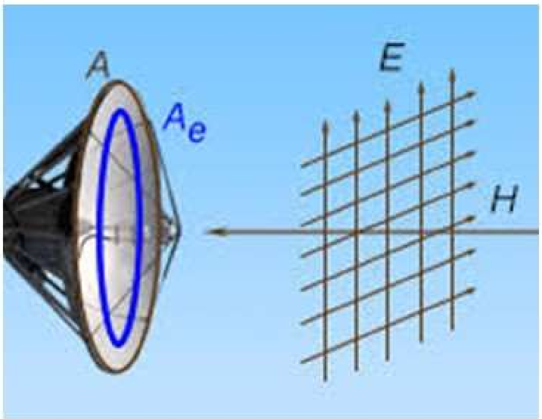


Figure: Aperture Antenna

The given aperture antenna with dimensions L*W of 10 cm by 15 cm, operates at a frequency of 2.4 GHz and has a directivity of 10.81 dBi for capturing signals from vehicles. If the antenna's dimensions are reduced by 50%, Then what will be the effect on directivity. Also compare the ability of the antenna to precisely detect or capture signals from specific direction.

Answer

Initial Directivity in Decimals: 10.81dBi
In Linear Scale: 12.08
Effect of Reducing Antenna Dimensions by 50%
New Dimensions: (1 mark)

$l' = 0.5 \times 10\ \text{cm} = 5\ \text{cm}$

$w' = 0.5 \times 15\ \text{cm} = 7.5\ \text{cm}$

New Directivity (1 mark)

$$D' = \frac{4\pi A'_{\text{eff}}}{\lambda^2} = \frac{4\pi \times 0.00375}{(0.125)^2} = \frac{0.015\pi}{0.015625} \approx 3.02\ (\text{linear scale})$$

In decibels:

$$D'_{\text{dBi}} = 10\log_{10}(3.02) \approx 4.81\,\text{dBi}$$

Directivity After Reduction:
Linear Scale: D'≈3.02
Decibels: D'≈4.81 dBi
Initial Directivity:
Linear: 12.08
dBi: 10.81 dBi
After Reducing Dimensions by 50% (Both Length and Width):
Linear: 3.02
dBi: 4.81 dBi
Directivity decreases by a factor of 4 (from approximately 12.08 to 3.02 in linear scale). In decibels, this is a decrease of approximately 6 dBi (from 10.81 dBi to 4.81 dBi). (1 mark)
This significant reduction in directivity implies that the antenna becomes less focused, leading to a broader beamwidth and reduced ability to precisely detect or capture signals from specific directions. (1 mark)

20. Question

You are designing a high-gain aperture antenna for a satellite communication system that operates at a frequency of 10 GHz. The uniform distribution of the rectangular aperture antenna on an infinite ground plane is shown in the figure

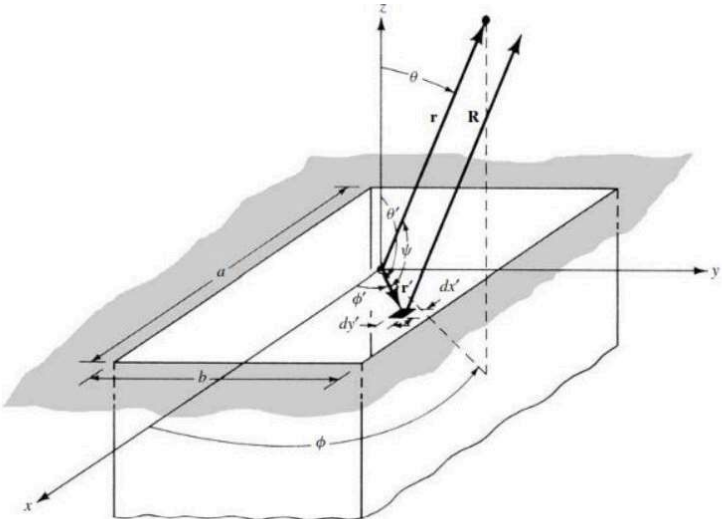


Figure: Aperture antenna for a satellite communication system

The electric field components radiated by the aperture antenna is given by

$$E_r = 0$$
$$E_\theta = j\frac{abkE_0e^{-jkr}}{2\pi r}\left[\sin\phi\left(\frac{\sin X}{X}\right)\left(\frac{\sin Y}{Y}\right)\right]$$
$$E_\phi = j\frac{abkE_0e^{-jkr}}{2\pi r}\left[\cos\theta\cos\phi\left(\frac{\sin X}{X}\right)\left(\frac{\sin Y}{Y}\right)\right]$$

where

$$X = \frac{ka}{2}\sin\theta\cos\phi$$
$$Y = \frac{kb}{2}\sin\theta\sin\phi$$

If the rectangular aperture antenna is placed on the E plane and H plane, then analyze the Electric field components radiated by the rectangular aperture antenna in the E and H planes.

Answer

E Plane pattern (3 marks)

E –Plane ($\phi = \pi/2$)

$$E_r = E_\phi = 0$$

$$E_\theta = j\frac{abkE_0e^{-jkr}}{2\pi r}\left[\frac{\sin\left(\frac{kb}{2}\sin\theta\right)}{\frac{kb}{2}\sin\theta}\right]$$

H Plane pattern (2 marks)

H –Plane ($\phi = 0$)

$$E_r = E_\theta = 0$$

$$E_\phi = j\frac{abkE_0e^{-jkr}}{2\pi r}\left\{\cos\theta\left[\frac{\sin\left(\frac{ka}{2}\sin\theta\right)}{\frac{ka}{2}\sin\theta}\right]\right\}$$

21. Question

Consider a scenario where you are receiving the signals from base station through the following long wire antenna, placed above the ground with h<< ƛ and it is shown in the below figure. Assume the length of the wire is 250 cm.

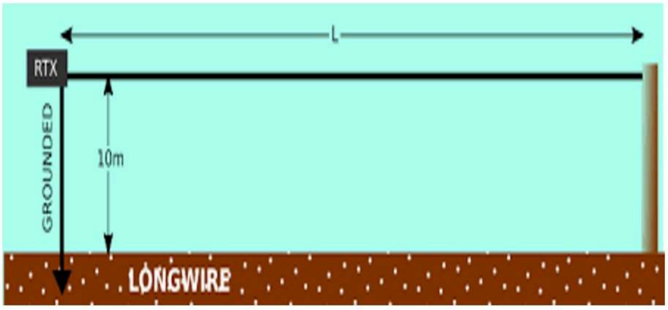


Figure 1: Long wire Antenna

a) To improve the signal directivity the long wire antenna is replaced by V antenna as shown in Figure. The soldier at remote places were able to receive the signal at particular direction. Identify the correct direction of transmission of the signal from the antenna to the soldier.

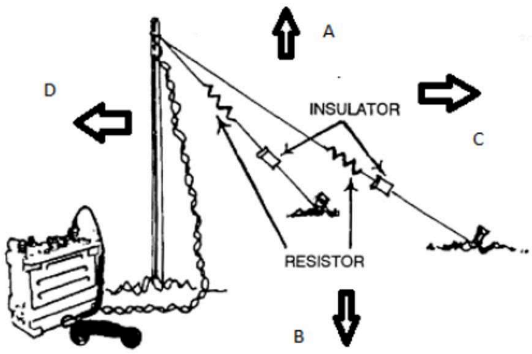


Figure: V Antenna

b) If the V antenna is replaced with rhombic antenna, then it produces the bidirectional pattern. Interpolate how you will change the bidirectional to unidirectional radiation pattern.

c) If the V antenna at base station is replaced with Rhombic antenna having proper termination as shown in the below figure, then find characteristics of the radiation pattern and direction of propagation.

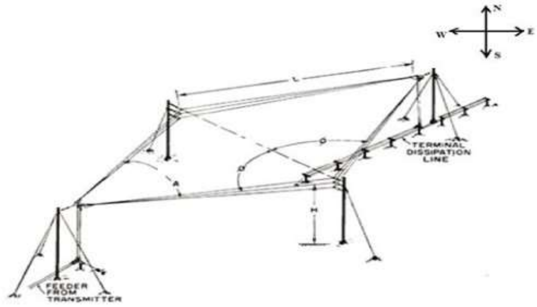


Figure: Rhombic antenna

Answer

a) V antenna radiates along 'B' direction. (2 marks)

b) The resultant pattern is the cumulative effect of the radiation at all four legs of the rhombic antenna. If the antenna is terminated with resistance, then it will change the pattern to unidirectional, (2 marks)

c) The characteristics of the radiation pattern is unidirectional and direction of propagation is in North-East direction (2 marks)

22. Question

Asymmetric spatial power divider using phase-amplitude metasurfaces driven by huygens principle as shown in the figure below are designed by proper phase and amplitude distribution over the surface to directly generate a desired number of beams with predetermined orientations and power budgets.

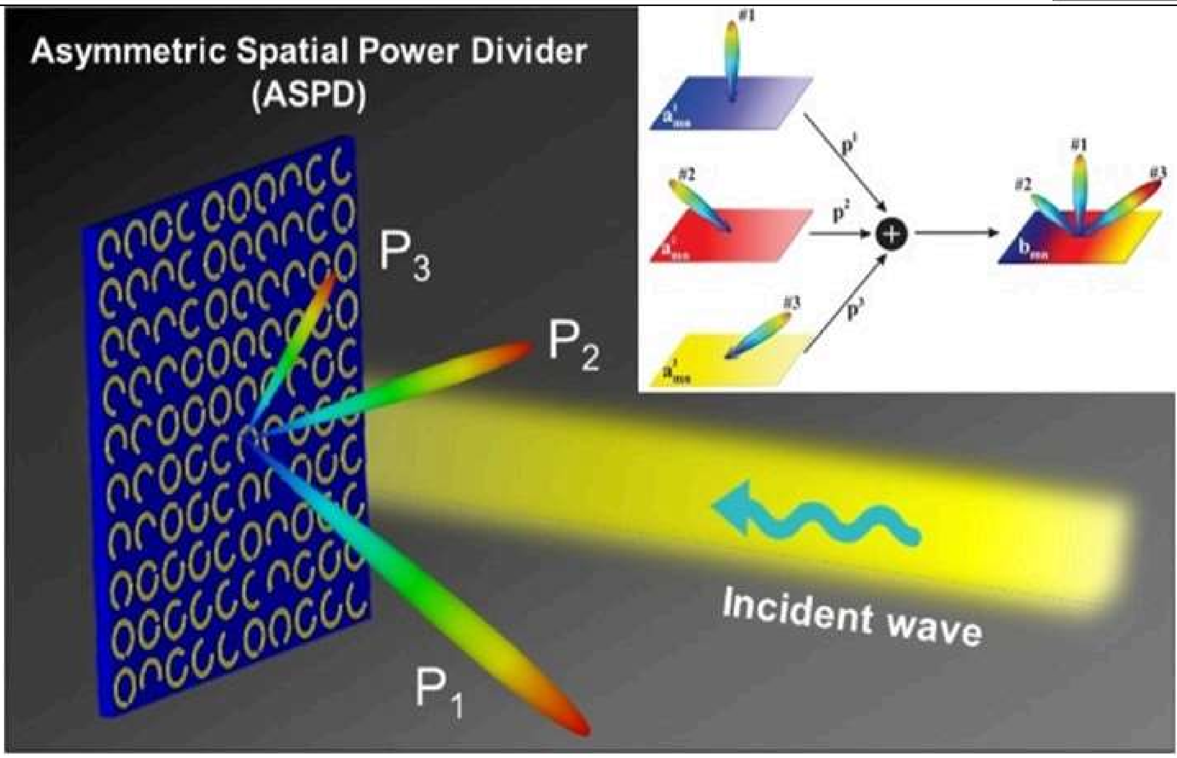


Figure: Asymmetric spatial power divider

Assertion (A): The field equivalence principle states that, actual sources are replaced by equivalent sources. The fictitious sources are said to be equivalent within a region because they produce the same fields within that region.

Reason (R): Field equivalence principle is based on the uniqueness theorem.

a) Both A and R are correct and R is correct explanation of A

b) Both A and R are correct and R is not correct explanation of A

c) Assertion is true but reason is false

d) Both assertion and reason are false.

Answer

a) Both A and R are correct and R is correct explanation of A

23. Question

The field radiated of a rhombus antenna can be found by ________ the fields radiated by its _____ legs.

a) adding, two
b) adding, four
c) subtracting, two
d) subtracting, four

Answer

b) adding, four

24. Question

Consider the maximum radiation of the inverted V- antenna is at its center which is similar to half-wave dipole. The angle between the legs of the antenna is 120 degree or 90 degree. The center of the antenna ought not be ________

a) Lower than $\lambda/2$
b) Higher than $\lambda/2$
c) Higher than $\lambda/4$
d) Lower than $\lambda/4$

Answer

c) Higher than $\lambda/4$

25. Question

Identify the antenna parameters which indicates the concentration of radiation in a particular direction?

a) Bandwidth
b) Gain
c) Polarization
d) VSWR

Answer

b) Gain

26. Question

The impedance of a folded dipole compares to a standard half-wave dipole is

a) One-fourth
b) Approximately half
c) Approximately four times higher
d) Identical.

Answer

c) Approximately four times higher

27. Question

Identify the primary reason for using folded dipole antennas in FM radio receivers.

a) Improved impedance matching
b) Higher power handling
c) Increased mechanical robustness
d) Enhanced signal polarization

Answer

a) Improved impedance matching

28. Question

A passive RADAR system is used to determine the velocity of moving vehicles by measuring the Doppler frequency of the target as shown in the figure below. The antenna used is assumed to be an infinitesimal dipole for reference calculations.

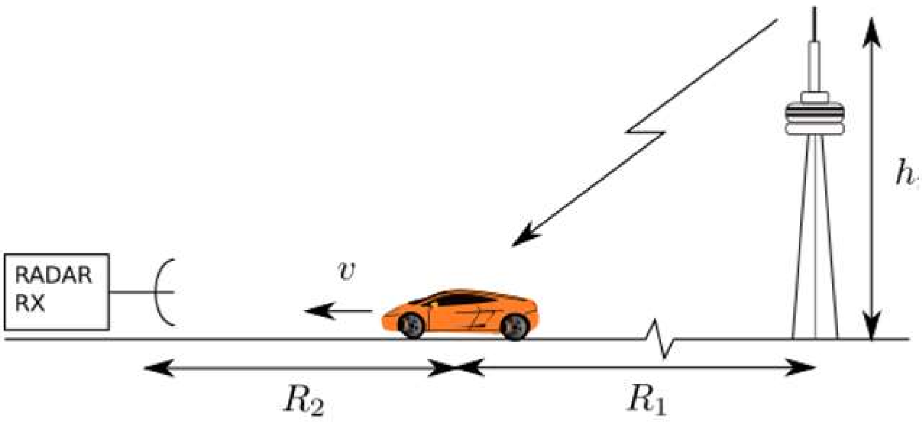


Figure : RADAR system

The electric field and magnetic field components radiated by the infinitesimal dipole antenna is given by

$$\boxed{E_r = \frac{2 I_m dl \cos\theta}{4\pi\varepsilon}\left[\frac{\cos\omega t_1}{c\, r^2} + \frac{\sin\omega t_1}{\omega\, r^3}\right]}$$

$$\boxed{E_\theta = \frac{I_m dl \sin\theta}{4\pi\,\varepsilon}\left[-\frac{\omega\sin\omega t_1}{c^2 r} + \frac{\cos\omega t_1}{c\, r^2} + \frac{\sin\omega t_1}{\omega\, r^3}\right]}$$

$$H_\phi = \frac{I\, dl \sin\theta}{4\pi}\left(\frac{-\omega\sin\omega t'}{rv} + \frac{\cos\omega t'}{r^2}\right)$$

a) Infer the name of the each components present in the given electric and magnetic fields as a function of distance. And also, analyze the nature of dominating field components in the near and far field regions.

b) If the antenna used in this RADAR system is replaced by the half wave dipole antenna with magnetic field radiation at a distance point is given by

$$H_\phi = \frac{jI_m\, e^{-j\beta r}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]$$

Then Analyze the total power radiated by the half wave dipole antenna in a spherical surface of radius 'r' involving only inverse distance term or radiation field.

Answer

Examination of the expressions for E theta and Er shows that both components have square of distance ($1/r^2$) term is called induction field.

In E theta first term varies inversely as distance ($1/r$) and is known as radiation field. In addition, both components of E have a term that varies as $1/r^3$. From their similarity with the components of the field of an electrostatic dipole, these $1/r^3$ terms are called the electrostatic field terms.

Consider the expression for H is seen to consist of two terms, one of which varies inversely as r (radiation field) and the other inversely as r^2.The second of these, called the induction field. (2 marks)

Induction field, will predominate at points close to the current element where r is small (near field) , whereas at great distances, where r is large (far field), the second term ($1/r^2$) becomes negligible compared with the first ($1/r$).

The only terms of E and H that contribute to this average power flow are the radiation or inverse-distance terms. At a large distance from the source these radiation terms are the only ones that have appreciable value, only l/r terms contribute to an average outward flow of power. (1 mark)

Half wave dipole antenna electric field is obtained from the given magnetic field given by (1 mark)

$$E_\theta = \eta H_\phi$$
$$= \frac{j60 I_m\, e^{-j\beta r}}{r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]$$

Power radiated is (2 marks)

Pav=1/2 (E×H*)

$$\frac{1}{2}\left\{\frac{j60 I_m\, e^{-j\beta r}}{r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right] \quad \frac{jI_m\, e^{+j\beta r}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]\right\}$$

E_θ and H_ϕ are in time phase so the maximum value in time of the Poynting vector is just the product of the peak values of E_θ and H_ϕ, and the average value in time of the Poynting vector will be one-half the peak value. Then

$$P_{av} = \frac{\eta I_m^2}{8\pi^2 r^2}\left[\frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\theta}\right]$$

In this expression I_m is peak current. In terms of effective current the radiated power would be

$$= \frac{1.218\eta\, I_{eff}^2\,(2)}{4\pi}$$

Radiated Power $\}$ $= 73.08\, I_{eff}^2$

29. Question

Underwater vehicles (Submarines) are mobile terminals that need to communicate between submarines to a ship, and submarines to shore as shown in figure. Due to increased need of higher data rates, printed dipole array antenna is used for signal transmission over longer distances.

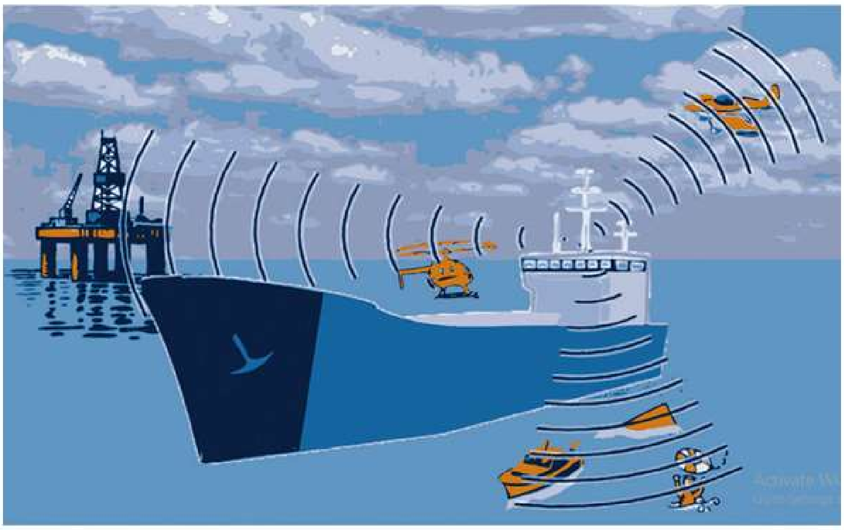


Figure : Communication between Ships and Submarines

Assume that if the single wire antenna is used in the system for the purpose of radiation, then identify in which of the following conditions, the antenna starts to radiate the signals.

Condition A: If a charge is not moving, current is not created in the single wire antenna

Condition B: If charge is moving with a uniform velocity if the wire is straight, and infinite in extent.

Condition C: If the wire is curved, bent, discontinuous, terminated, or truncated

Condition D: If charge is oscillating in a time-motion, it radiates even if the wire is straight.

If the single wire antenna is replaced by the two wire antenna, then plot the electric field pattern of the two wire line connected with an antenna.

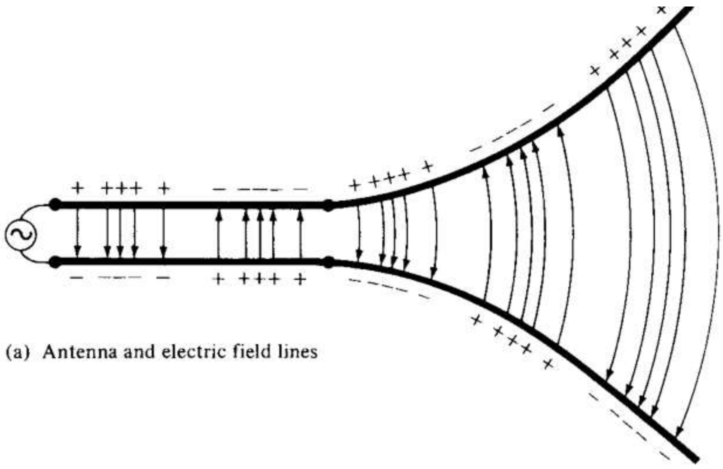
Answer

Single wire antenna radiates in the following conditions:

Condition C: If the wire is curved, bent, discontinuous, terminated, or truncated (1 mark)

Condition D: If charge is oscillating in a time-motion, it radiates even if the wire is straight. (1 mark)

Electric field pattern of the two wire antenna (1 mark)



(a) Antenna and electric field lines

30. Question

The effect of doubling the frequency have on the length of a half-wave dipole antenna is

a) Length is doubled

b) Length is halved

c) Length remains the same

d) Length is quadrupled

Answer

b) Length is halved

31. Question

You are part of a research team tasked with designing an innovative wire antenna system (as shown for a deep-space communication satellite. The antenna must be highly efficient, lightweight, and able to operate over a range of frequencies. To achieve this, you plan to use a heuristic approach to analyze the potentials associated with wire geometries and materials.

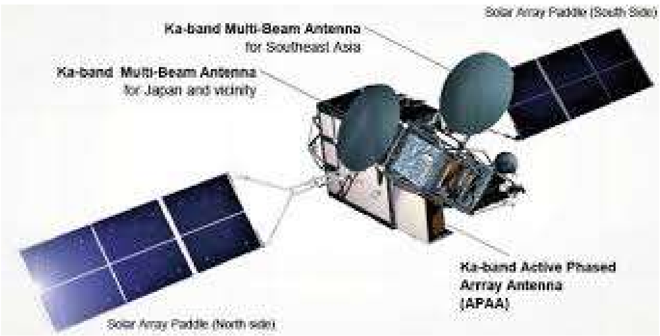


Figure: Deep Space Communication satellite

Assume that the vector potential was developed in the coil due to current density J which is placed along 'z' direction in a homogeneous medium and it is given by

$$\mathbf{A}(\mathbf{r}, t) = \frac{\mu}{4\pi} \int \frac{\mathbf{J}(\mathbf{r}', t)}{R} dV'$$

a) Analyze the potential at point 'P', as illustrated in the figure below, for a time-varying signal component by accounting for the travel time required for the signal to reach point 'P'

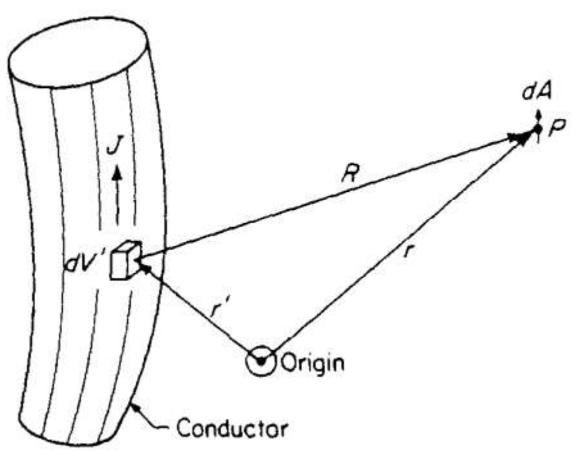


Figure: Current carrying coil

b) In the above analysis, if the current density J, integrated over the cross-sectional area of the wire, then remodify the potential at point 'P'. And also analyze the components of the potential in free space due to current carrying coil placed along 'Z' direction.

Answer

a) Travel time taken t=distance/ velocity
Distance between coil and point 'P' is R and v is velocity of the signal.
In the potential equation, a time delay of R/v seconds has been introduced, so that now the potentials have been delayed or retarded by this amount. For this reason they are often called retarded potentials. (1 mark)
And it is given by

$$\mathbf{A}(\mathbf{r}, t) = \frac{\mu}{4\pi} \int \frac{\mathbf{J}(\mathbf{r}', t - R/v)}{R} dV'$$

(1 mark)

b) The current density J, integrated over the cross-sectional area of the wire, is just the current I, and because this is assumed to be constant Radiation along the length, integration over the length gives Idl. (1 mark)

Therefore in this expression for vector potential becomes (1 mark)

$$A_z = \frac{\mu}{4\pi} \frac{I\,dl \cos \omega \left(t - \frac{r}{v}\right)}{r}$$

The components of potential in free space is analyzed using spherical coordinate system. It is defined using sine and cosine of the angle between coil and point 'P' in free space.

$$\boxed{A_r = A_z \cos\theta}$$

$$\boxed{A_\theta = -A_z \sin\theta}$$

$$A\phi = 0$$

(1 marks)

32. Question

The induction and radiation field are same at a distance of ___________ from the oscillating dipole

a) lamda/6
b) lamda /2
c) lamda
d) lamda/8

Answer

a) lamda/6

33. Question

The given figure shows the car loaded with rod antenna in the front side of the roof. Identify which among the following assertion and reason is appropriate regarding the signal transmission by these antennas.

Figure: Car loaded with rod antenna

Assertion (A): Length of the Rod Antenna must be equal to or slightly greater than quarter wavelength, connected directly to a large ground plane

Reason (B): Larger ground plane acts as a Perfect Electric Conductor, making the antenna's radiation pattern omni-directional
a) Both A and B are true, and B is the correct reason for A
b) Both A and B are true, and B is not the correct reason for A
c) A is true but B is false
d) A is false but B is true

Answer

b) Both A and B are true, and B is not the correct reason for A

34. Question

Unmanned aerial vehicles (UAVs) are mobile terminals that need to communicate with other UAVs, ground stations, and control centers. To meet the demand for higher data rates over extended distances, a small oscillating dipole antenna is used for signal transmission as shown in figure.

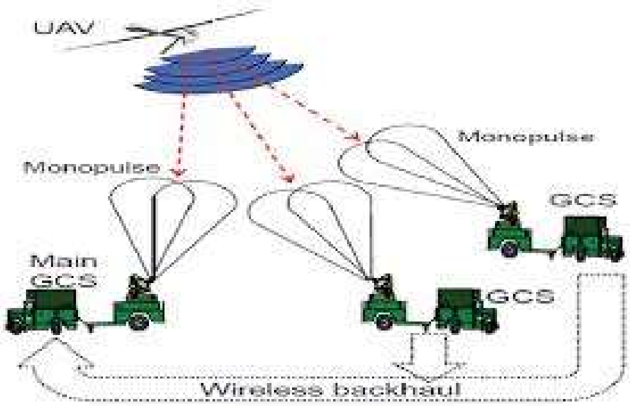


Figure : Unmanned aerial vehicles (UAVs) System

The total power radiated by the small oscillating dipole is given by

$$R_{\text{rad}} = 80\pi^2 \left(\frac{dl}{\lambda}\right)^2$$

Assume that if the small oscillating dipole is replaced by the practical center fed short dipole antenna and monopole antennas, then draw the current distributions of these antennas and compare the radiation resistance of these antennas for the antenna length of 2h.

Answer

For the same current I (at the terminals) the (short) practical dipole of length / will radiate only one-quarter as much power as the current element of the same length, which has the current I throughout its entire length. Therefore, the radiation resistance of a practical short dipole is one-quarter that of the current element of the same length. (1 mark)

$$R_{\text{rad}}\,(\text{short dipole}) = 20\pi^2 \left(\frac{l}{\lambda}\right)^2$$

$$\approx 200 \left(\frac{l}{\lambda}\right)^2$$

The monopole of height h or short vertical antenna mounted on a reflecting plane, produces the same field strengths above the plane as does the dipole of length l = 2h when both are fed with the same current. However, the short vertical antenna radiates only through the hemispherical surface above the plane, so its radiated power is only one-half that of the corresponding dipole. (1 mark)

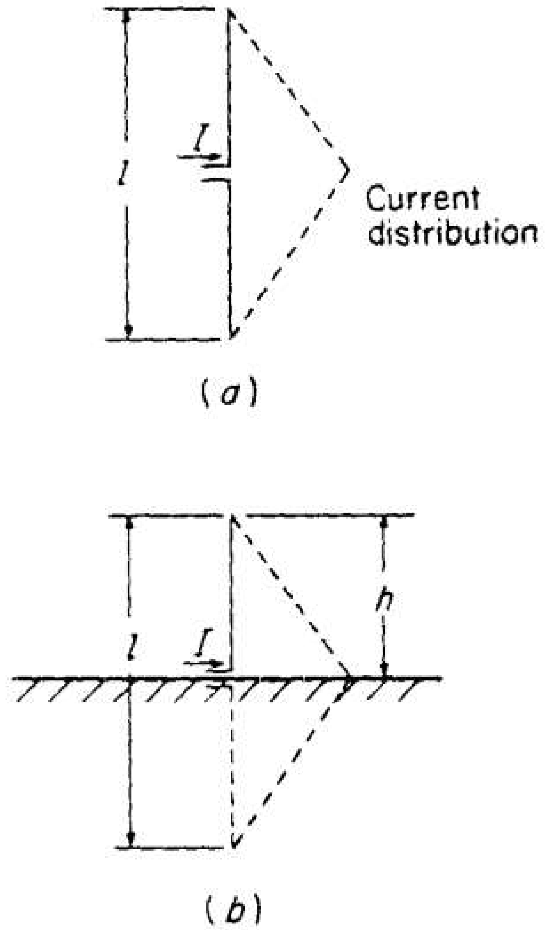
Therefore the radiation resistance of the monopole of height h = l/2 is (1 mark)

$$R_{\text{rad}}\,(\text{monopole}) = 10\pi^2 \left(\frac{l}{\lambda}\right)^2$$

$$= 40\pi^2 \left(\frac{h}{\lambda}\right)^2$$

$$\approx 400 \left(\frac{h}{\lambda}\right)^2$$

Current distribution of short dipole antenna (figure a) and monopole antenna (figure b) (1 mark)



35. Question

Compared to a broadside array with the same number of elements, how does the beamwidth of an end-fire array typically compare?

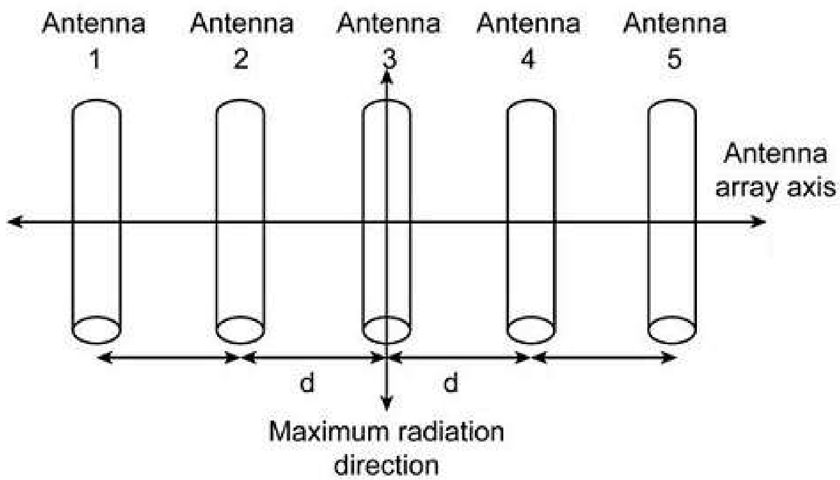
a) The beamwidth of the end-fire array is narrower than that of the broadside array.
b) The beamwidth of the end-fire array is wider than that of the broadside array.
c) The beamwidth of the end-fire array is the same as that of the broadside array.
d) The beamwidth of the end-fire array first narrows and then widens as more elements are added.

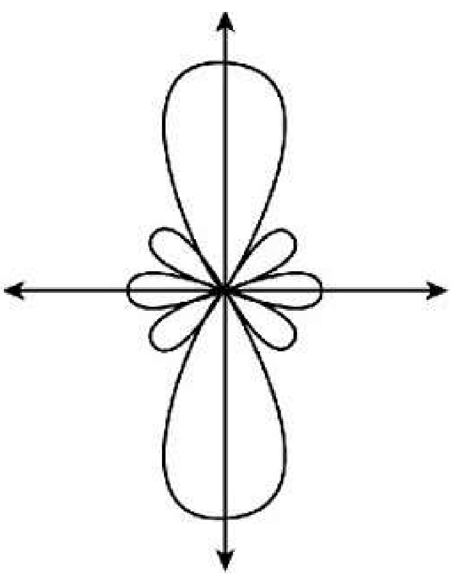
Answer

b) The beamwidth of the end-fire array is wider than that of the broadside array.

36. Question

Consider a 5-element binomial antenna array with excitation amplitudes given by the binomial coefficients 1,4,6,4,1.

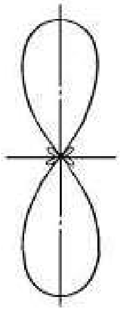




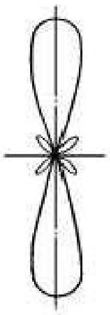
if you want to design new antenna arrays with 4 and 3 elements, respectively, using the binomial coefficient method.Compute the excitation amplitudes required for each element in the new 4-element and 3-element arrays also Illustrate the radiation pattern for the new elements.

Answer

- **For a 4-element array:** The excitation amplitudes are 1,3,3,1 ----- (1 Mark)
- **For a 3-element array:** The excitation amplitudes are 1,2,1 ------ (1 Mark)
- **Pattern with three elements** ------ (1 Mark)



Pattern with four elements ------ (1 Mark)



37. Question

When the length of a transmission line with characteristic impedance Z_0 is a multiple of λ/2, compute the input impedance Z_{in} if the line is open-circuited at the far end.

a)$Z_{in}=Z_0$
b)$Z_{in}=\infty$
c)$Z_{in}=0$
d)$Z_{in}=-jZ_0$

Answer

a)$Z_{in}=Z_0$

38. Question

Consider a transmission line for a high-frequency experimental setup as shown in below figure.

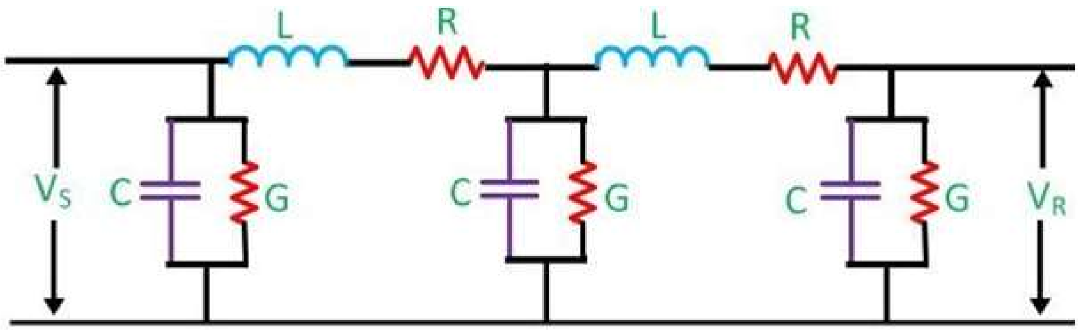


Figure :Transmission Line for high frequency setup

A university is setting up a 6 km transmission line for a high-frequency experimental setup operating at 500 MHz. The line parameters are L=0.5 μH/km, C=100 pF/km, R=2 Ω/km and G=0.6 μS/km. Given that the signal loss over the 6 km line is 1 dB, compute the signal loss when the line length is increased to 12 km.

Answer

$$\alpha = \frac{Loss}{Length} = \frac{1dB}{6km} = 0.1667\ dB/km$$ ------- (2 Mark)

Loss = 0.1667 x 12 =2dB ------- (2 Marks)

39. Question

Indicate,How does phase distortion impact digital signals in a communication system?
a) Causes constant amplitude across bits
b) Results in bit errors and timing issues
c) Enhances data transmission speed
d) Eliminates noise in the signal

Answer

b) Results in bit errors and timing issues

40. Question

A telephone line is equipped with loading coils placed every 5 km, each having an inductance of 10 mH. The line originally has a characteristic impedance of 100 ohms and was 30 km long. Indicate the primary effect of adding these loading coils.
a) increases the overall attenuation of the line.
b) reduces the line's characteristic impedance.
c) compensates for the capacitive effects of the line, reducing signal attenuation.
d)Decreases the line's overall inductance, improving signal quality.

Answer

c) compensates for the capacitive effects of the line, reducing signal attenuation.

41. Question

Consider a telecommunications company that is upgrading its infrastructure to support 5G technology.

Figure :5G Network

Interpret how would the requirement for a distortion less transmission line change with increasing frequency, and what design modifications would you recommend to maintain performance?

Answer

At high frequencies, the effects of skin effect (increasing RRR) and dielectric losses (increasing GGG) become significant (1 Mark)

To maintain distortion less transmission, it is crucial to use conductors with low resistivity and dielectrics with low loss tangent. (1 Mark)

Design modifications may include using coaxial cables or waveguides, employing materials with higher purity, and ensuring proper shielding to reduce external interference. Additionally, impedance matching becomes more critical to minimize reflections and ensure efficient power transfer (1 Mark)

42. Question

Assume an engineer is tasked with designing a scheme for placing loading coils on a 20 km telephone line, as shown in the figure, to achieve balanced transmission and minimize signal loss. The line has a capacitance of 80 pF/m.

What should be the required amount of inductance for each loading coil to achieve a lossless transmission line? Also, at what intervals should he place the coils along the 20 km line?

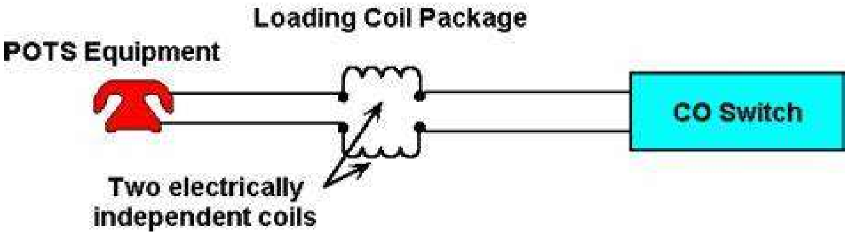


Figure: Loading coils on Telephone line

Answer

The characteristic impedance (Z_0) of a transmission line is

$$Z_0 = \sqrt{\frac{L}{C}} \quad \text{(1 Mark)}$$

$$L = Z0^2 \ X \ C \quad \text{(1 Mark)}$$

$$L = 600^2 \times 80 \times 10^{-12} = 0.028\text{mH/km} \quad \text{(1 Mark)}$$

Inductance per coil =28.8 x2=57.6 mH (1 Mark)

Placing loading coil at 2km (1 Mark)

43. Question

Indicate which parameter does not affect the propagation constant (γ) in a transmission line.

a) Resistance
b) Inductance
c) Capacitance
d) Load impedance

Answer

d) Load impedance

44. Question

Consider the telephone line connecting home telephone with central office, as shown in figure

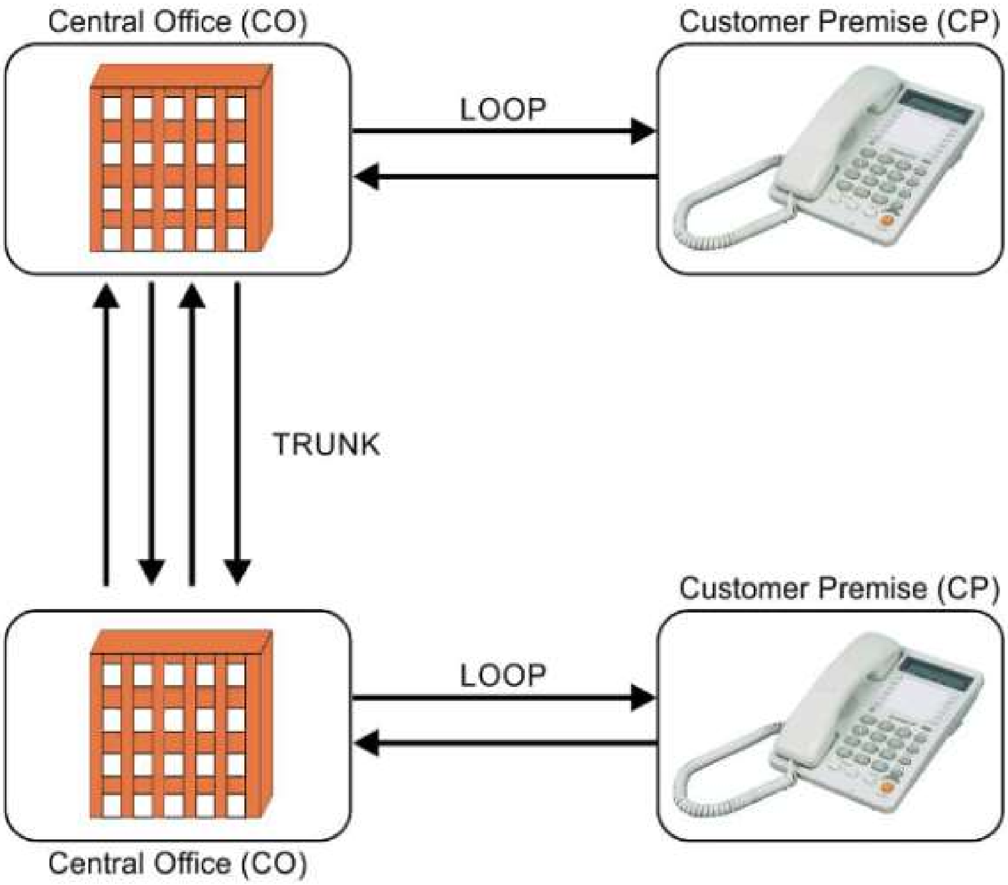


Figure:telephone line connecting home telephone with central office

A telecommunications company is using a 10 km telephone line to transmit signals at 500 MHz. The line parameters are: L=0.25 μH/km,C=200 pF/km,R=2 Ω/km, and G=1 μS/km.
Analyze whether the transmission loss is occur in the telephone line to ensure that 90% of the input power is delivered to the load.

Answer

$Z_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{0.25\mu H}{200pF}}$ = 35.36Ω (1 Mark)

$\alpha = \sqrt{RG} = \sqrt{2\Omega \times 1\mu S}$ =0.00141Np/km (1 Mark)

$e^{-\alpha d}$ = $e^{-0.0141}$ =0.986 (1 Mark)

$P_{load} = P_{in} \times e^{-2\alpha d} = P_{in} \times (0.986)^2 = 0.972 \times P_{in}$ (1 Mark)

$0.90 \times P_{in} = P_{load}$ (1 Mark)

This shows that the transmission loss is negligible, and nearly 97.2% of the power is delivered to the load (1 Mark)

45. Question

In transmission line theory, the equivalent model of a transmission line includes series inductance L and shunt capacitance C. If a beginner RF system designer mistakenly interchanges the roles of L and C While designing a transmission line to match two devices, how will this mistake affect the transmission line's characteristics?

a) There will not be any capacitive effect, but inductive effect will remain the same
b) Inductive effect is increased, but capacitive effect is decreased
c) The capacitative effect is increased, but inductive effect is decreased
d) Both the inductive effect and capacitive effect remain unchanged

Answer

c) The capacitative effect is increased, but inductive effect is decreased

46. Question

choose the potential issue which can arise from duct propagation in communication systems.

a) Signal attenuation
b) Multipath interference
c) Increased bandwidth
d) Improved signal clarity

Answer

b) Multipath interference

47. Question

Consider the below picture of the telephone line connecting home telephone with central office having the loading coils at particular distance in line.

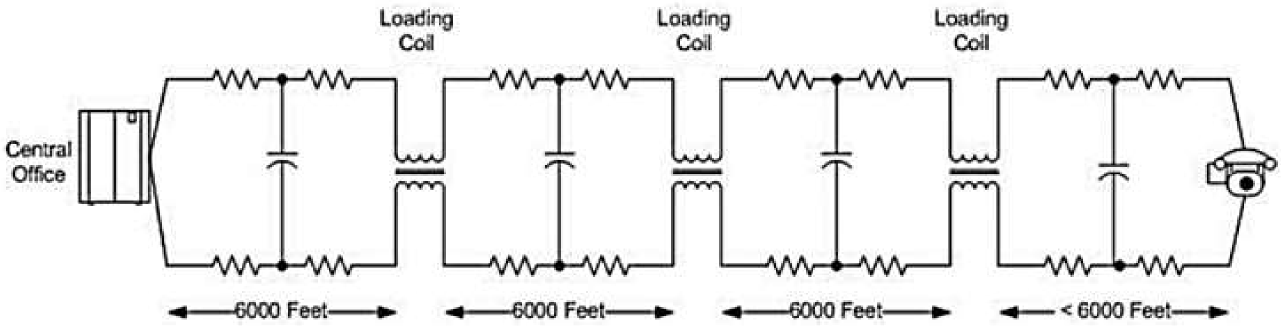


Figure: Telephone line

A transmission line has the following parameters: L=0.4 μH/km, C = 50 /pF/km, R=3 Ω/km, and G=0.4 μS/km.

Check whether the given transmission line satisfies the Heaviside condition to transmit the signal without any loss. If not, suggest one possible way to modify the line parameters to satisfy this condition.

Answer

$$\left.\begin{aligned} \frac{R}{L} &= \frac{3}{0.4\ X\ 10^{-6}} = 7.5\ X 10^{6} \\ \frac{G}{C} &= \frac{0.4\ X\ 10^{-6}}{50\ X\ 10^{-12}} = 8\ X 10^{6} \end{aligned}\right\} \quad \text{(1 Mark)}$$

$\frac{R}{L} \neq \frac{G}{C}$ Heaviside condition is not satisfied (1 Mark)

$\frac{R}{L} = \frac{Gnew}{C}$ (1 Mark)

G_{new} = 7.5 X10^{6} x50X10^{-12} =375 μS/km.

To satisfy the Heaviside condition for distortionless transmission, the conductance G of the transmission line should be adjusted from 0.4 μS/km to 375 μS/km. (1 Mark)

48. Question

An RF engineer adds series inductance to a transmission line to improve impedance matching at 1 GHz. However, the system starts experiencing unexpected signal distortion.

Analyze why the signal distortion occurs and propose a solution to maintain impedance matching without signal distortion

Answer

The signal distortion is likely due to the phase shift and increased inductive reactance at high frequencies. (1Mark)

A possible solution is to use a combination of series inductance and shunt capacitance to create a more stable matching network that minimizes phase distortion while achieving the desired impedance matching. (1Mark)

49. Question

The plasma frequency is the natural frequency at which charged particles in a plasma region oscillate. Plasma, being a completely ionized gas, contains positive charged nuclei and negative electrons, especially at high temperatures as shown in figure. This property plays a critical role in how electromagnetic waves interact with the plasma medium.

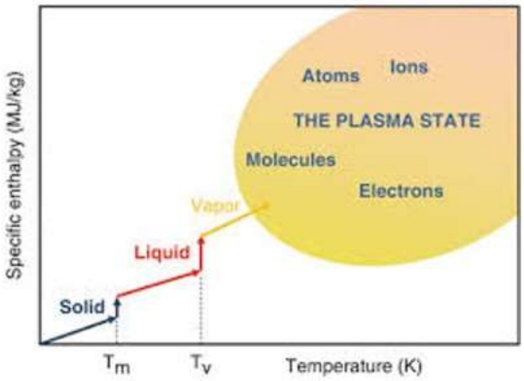


Figure: The Plasma State

Analyze the relative dielectric constant of the ionosphere and properties of the wave for the following conditions:

a) w(frequency) < wp(Plasma frequency)

b) w(frequency) = wp(Plasma frequency)

c) w(frequency) > wp(Plasma frequency)

Answer

The relative dielectric constant of the ionosphere (1 mark)

1. The relative dielectric constant of the ionosphere depends on the ratio of the plasma frequency ω_P and the wave frequency ω.

$$\varepsilon_r = 1 - \frac{\omega_P^2}{\omega^2} = 1 - \frac{81\ N}{f^2}$$

a) $\omega < \omega_p$ (2 marks)

For $\omega < \omega_P$, ε_r is negative. Propagation constant is purely imaginary. Under this condition, the plane wave becomes purely evanescent.

b) $\omega = \omega_p$

c) $\omega > \omega_p$ (2 marks)

when $\omega = \omega_P$, $\varepsilon_r = 0$

For $\omega > \omega_P$, $\varepsilon_r <$ unity

The region with high conductivity has high absorption at D – layer. So, F layer is suitable for long distance communication.

50. Question

A weather radar system operating at 9 GHz is monitoring storm clouds 5 km away. The radar uses an antenna with a gain of 200, and the radar cross-section of the clouds is 50m². The transmitted power of the radar is 200 kW and the received power is 2288μW

Using this information, compute the amount of power received by the radar after the signal reflects from the storm clouds. How would the received power change if the storm clouds moved 10 km away instead of 5 km?

Answer

$$P_r' = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 (10,000)^4}$$ --------(1 Mark)

$$P_r' = \frac{4.43556 \times 10^{12}}{1.937875 \times 10^{16}} = 2.288 \times 10^{-4}\ \mathrm{W}$$ --------(1 Mark)

$$P_r' = 2.288 \times 10^{-4}\ \mathrm{W} \times 10^6 = 228.8\ \mu\mathrm{W}$$ --------(1 Mark)

If the storm clouds move 10 km away, the received power would drop to 228.8 μW, which is 10 times less than the power at 5 km. -------- (1 Mark)

51. Question

Indicate,how does increasing the height of the transmitting antenna affect space wave propagation?

a) It decreases the coverage area.
b) It increases the line-of-sight range.
c) It has no effect on signal strength.
d) It reduces interference.

Answer

b) It increases the line-of-sight range.

52. Question

If a ground wave communication system operates at 5 MHz with a transmitting antenna height of 30 meters, the horizon distance is 22.6 km.

a)If the frequency of a ground wave transmission is increased to 10 MHz while keeping the antenna height constant, interpret the impact on the effective range? Justify the answer based on wave behavior

b) If the frequency is reduced from 5 MHz to 2 MHz, indicate the effect of decreased frequency.

Answer

Decreased Frequency and Ground Wave Behavior ------(2 Marks)

Ground waves are generally more effective at lower frequencies (below about 2-3 MHz). As frequency decreases, ground wave propagation can experience lower levels of attenuation .

Impact on Effective Range ------(1 Mark)

At 10 MHz, the ability of the wave to travel along the ground diminishes, leading to a shorter effective range. This is because higher frequencies tend to radiate energy more upwards rather than along the ground.

Justification ------(1 Mark)

Higher frequencies are associated with a shorter wavelength, which can make ground waves more susceptible to being absorbed by the ground and affected by physical obstacles (e.g., buildings, trees). This results in a reduction in the distance over which the signal can be effectively received.

53. Question

The main source of ionization in ionospheric layer is

a) Cosmic rays
b) X-rays
c) Particle reaction
d) Gamma rays

Answer

a) Cosmic rays

54. Question

Critical frequency of a layer is given by

a) fc=81 Nm
b) fc=81 Nm^2
c) fc=9 Nm
d) fc=9√Nm

Answer

d) fc=9√Nm

55. Question

The laptop 'M1' in space region 1 transmits the radio signal to mobile phone equipment 'M2' in another region through satellite communication. Identify the possible layers formed in the ionosphere including troposphere as shown in the figure due to the variations in the physical properties such as temperature, pressure, density, and composition.

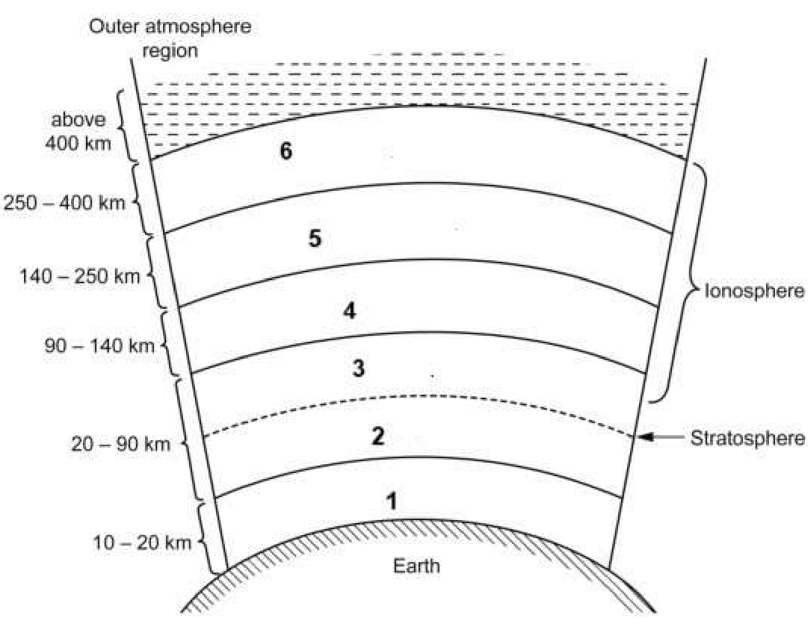


Figure: *Structure of the ionosphere including troposphere*

Answer

Each carries 0.5 marks

1- Troposphere layer
2- Tropopause layer
3 - D layer
4. E layer
5. F1 – layer
6. F2 – layer

56. Question

In a mixed environment (urban and rural), how should an engineer adapt the ground wave communication system to mitigate attenuation caused by urban obstacles?

a) Use lower frequencies exclusively.
b) Increase antenna height and use directional antennas.
c) Reduce transmission power.
d) Focus only on horizontal polarization.

Answer

b) Increase antenna height and use directional antennas.

57. Question

On the earth surface, a signal is transmitted with a frequency of 10 MHz by ionospheric propagation at different angles θ_1 and θ_2 ; $\theta_1 > \theta_2$ where θ represents the angle of incidence of the signal is shown in figure. Which signal will have larger skip distance in the given scenario?

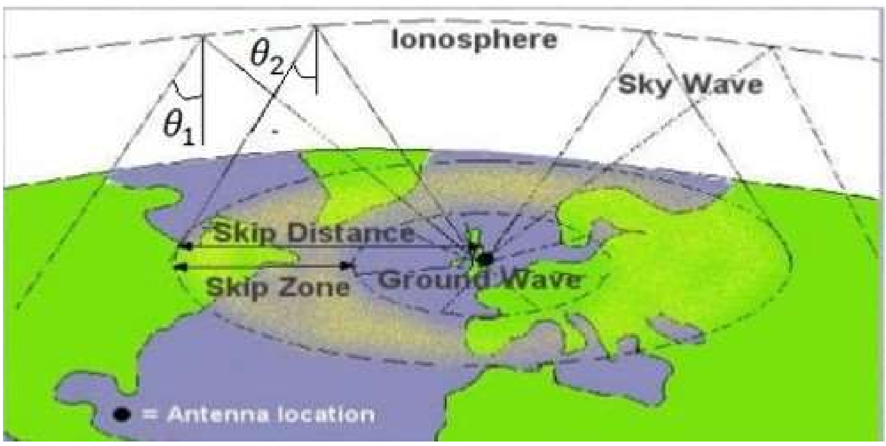


Figure: Ionospheric propagation

Answer

Skip Distance is defined as the shortest distance from the transmitter that can be covered by a fixed frequency.
Signal sent with angle of incidence θ_1 will have larger skip distance (2 mark)

58. Question

If suppose the moon is considered as a parasitic antenna to have communication between two points being separated far away from earth. Then the desired phenomenon that has to be taken into account is

a) Increasing distance
b) Nature of the scattering properties
c) Bandwidth
d) Permittivity

Answer

b) Nature of the scattering properties

59. Question

A flight radar system is designed to provide real-time aircraft information to a base station receiver. The base station needs to accurately track aircraft positions and communicate with satellites for navigation data. Additionally, the ADS-B system on the aircraft transmits its position data directly to the base station as shown in figure.

Figure: ADS-B system

Based on this scenario, answer the following questions:

a) Which mode of signal propagation would be most suitable for communication between the base station receiver and a GNS satellite? Explain your reasoning.
b) What type of signal propagation would the ADS-B receiver use to communicate effectively with the base station receiver on the ground?
c) In cases of terrain interference, how could the signal propagation mode affect the accuracy of the aircraft information received by the base station?

Answer

a) Line-of-Sight (LoS).(1 mark)
Reason: Satellites are located at high altitudes, either in geostationary or low Earth orbit, meaning they are far above the Earth's surface. The signals between the base station and the satellite must travel in a straight path with no significant obstruction, making line-of-sight propagation the best choice. (2 marks)
b) The line-of-sight (LoS) propagation is also the best mode for ADS-B receivers to communicate with the base station.(1 mark). since, ADS-B (Automatic Dependent Surveillance-Broadcast) relies on aircraft broadcasting its position, altitude, and velocity directly to ground stations. Since both aircraft and the base station need clear, unobstructed paths for efficient communication, LoS propagation is ideal, especially when the aircraft is flying at high altitudes.
c) In cases of terrain interference (e.g., mountains, tall buildings), line-of-sight (LoS) propagation can be disrupted, leading to signal blockage or degradation, which would affect the accuracy of the aircraft information received by the base station. If the aircraft or base station is blocked by such obstacles, the signal may not reach the base station clearly, resulting in intermittent or

inaccurate position data. In some cases, surface or ionospheric modes may allow signals to "bend" or reflect, but these methods are not typically reliable for high-frequency radar or ADS-B communications. (2 marks)

60. Question

The frequency at which the signal gets attenuated rather than reflected back to the earth

a) At Lowest Usable Frequency
b) Below Lowest Usable Frequency
c) Above Lowest Usable frequency
d) Critical Lowest Usable frequency

Answer

c) Above Lowest Usable frequency