NATIONAL EXAMS, December 2013

07-ElecA7, Electromagnetics

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. Candidates may use one of two calculators, the Casio or Sharp approved models. This is a closed book exam.

3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

4. All questions are of equal value.

5. Aids: $\varepsilon_0 = 8.85 \times 10^{-12}\, F/m, \quad \mu_0 = 4\pi \times 10^{-7}\, H/m$

1. The pulse repetition frequency of a pulse generator is 20 KHz. The internal impedance of the generator is 100 ohms, the pulse width and amplitude of the EMF are 1 microsecond and 15 volts. The generator drives a load resistance of 25 ohms through a section of transmission line of 50 ohm characteristic impedance and 2×10^8 m/s propagation velocity.

   What is the shortest length of the line such that the steady state load voltage is a sequence of pulses of 1 microsecond width and 20 KHz PRF (i.e. identical in shape with FMF), and what is their amplitude?

2. The characteristic impedance and propagation velocity of a transmission line are 50 ohms and 3×10^8 m/s respectively. A section of the line is terminated in a parallel connection of open-circuited and short-circuited sections of 50 cm length of the same line and of a 50 ohm resistor.

   What is the lowest frequency at which the SWR on the line will be one and what will be the SWR at 50 MHz?

3. The power density of a 1 GHz (10^9 Hz) plane wave propagating due north-west and 45° up is 10^{-3} W/m^2. The wave is horizontally polarized (electric field). Magnetic field of the wave is monitored by a circular loop of 2 cm^2 area located in a vertical plane rotating at 60 RPM about vertical axis of the loop.

   (i) What is the RMS voltage induced in the loop, and

   (ii) for what orientation of the rotating plane of the loop is the induced voltage maximum?

4. Inside dimensions of a rectangular waveguide are 10 mm × 4 mm. The waveguide is completely filled with dielectric material of relative permittivity 9.

   In what frequency range only one mode will propagate in the waveguide?

5. Two 1 m long current elements located at the same point radiate 10 MHz signals into free space. One of the elements is aligned horizontally in north-south direction, the other vertically. The current in the vertical element is double that in the horizontal one. The relative phase of the two currents is 90°.

Specify at least one direction of propagation in which the combined signals of the two elements can produce a circularly polarized signal.

Aid : $E = Z_0 \, l \, I \, k \sin\theta \; e^{-jtr}/(4\pi r)$

6. The RMS of spatial average value of tangential component of magnetic field intensity vector $\vec{H}$ evaluated along the circumference of a horizontal 1 m × 1 m square located in a 1 MHz electromagnetic field is 10^{-4} A/m in vacuum.

What is the RMS value of spatial average value of time derivative of vertical component of electric field intensity vector $\vec{E}$ evaluated over the 1 m × 1 m horizontal square area?

Aid : curl $\vec{H} = \varepsilon_0 \frac{\delta \vec{E}}{\delta t}$

7. A 1 GHz (10^9 Hz) plane wave propagates in seawater. The relative permittivity and conductivity of seawater are 81 and 7 $(\text{ohmmeters})^{-1}$ respectively.

Determine the attenuation of the wave expressing it in units of decibel per meter.

8. A 20 KHz electromagnetic plane wave propagating in a body of freshwater impinges on the water-air surface at 30° angle of incidence (angle between the direction of propagation and normal of the reflecting surface).

At what height above the surface (i.e. in air) will the signal amplitude be reduced to 10% of the amplitude of the incident signal?

Relative permittivity of freshwater is 81, conductivity is zero.