National Exams May 2011

07-Elec-B9

Electromagnetic Field, Transmission Lines, Antennas & Radiation

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

1. A 50 Ohm, 3×10^8 m/s transmission line is terminated in a load consisting of a 50 Ohm resistor in parallel with a 10.6 pF capacitor. Two short-circuited stubs of identical line across the load terminals should,
   (i) match the load to the line at 300 MHz and,
   (ii) isolate the load from a 400 MHz signal.

   What are the shortest lengths of the two stubs?

2. Two 50 MHz horizontally polarized plane waves propagate horizontally in free space, one due north-west, the other due north-east. The power densities of the two waves are 10^{-8} W/m^2. At a point X in space the combined electric field of the two waves possesses only the north-south component. Determine:
   (i) the RMS amplitude of the combined electric field at point X and,
   (ii) the location of point Y closest to X at which the combined electric field possesses only the east-west component.

3. An X-band waveguide (internal dimensions 2.25 cm × 1 cm) is filled with dielectric of relative permittivity 2.25. A 6 GHz signal propagates in the waveguide from which a 1 mm long transverse slice of dielectric has been removed. If the portion of the waveguide following the gap is terminated in a matched load, what is the reflection coefficient for the 6 GHz signal?
   Aid: Characteristic impedance in a waveguide, $Z_\varepsilon = \left(Z_0/\sqrt{\varepsilon_r}\right)\left(\lambda_g/\lambda_\varepsilon\right)$.

4. A 30 GHz plane wave propagating in free space is normally incident on an infinite dielectric slab of relative permittivity 2.25, backed by free space.

   (i) What is the smallest, non zero thickness of the slab such that no reflection occurs?
   (ii) What is the closest frequency different from 30 GHz for which no reflection would occur?

5. A 1 m long vertical current element located on a perfectly conducting ground plane radiates a 10 MHz and a 5MHz signals into free space. The maximum 10 MHz electric field 10 km away from the source is 10^{-4} v/m RMS. 5 MHz current in the current element is quadruple of the 10 MHz current.

   Determine:

   (i) the vertical RMS component of the 5 MHz signal 2.9 km above a 5 km radius circle centered on the radiating element and,
   (ii) the power density of the 10 MHz signal at the same location.

6. The width between nulls of the main beam of a uniformly illuminated circular paraboloidal antenna is 1.2 λ/(antenna radius) in meters. At what range can a 30

GHz, 1 m diameter paraboloidal antenna resolve two targets 100 m apart laterally?

7. Antenna currents in a broadside linear phased array are of the same amplitude, with vertical antennas uniformly spaced. The width between nulls of the main beam is 5.7°, the sweep of the beam is ± 30°. The beam is steered by shifting the phases of adjacent currents by a constant amount not exceeding ± 45° range.
For signal frequency of 1 GHz determine:
(i) the separation between antennas and,
(ii) the number thereof.

8. A 10 GHz plane wave propagates in salt water. The relative permittivity and conductivity of salt water are 80 and 4.5 $(\text{Ohm m})^{-1}$ respectively.

What is the attenuation of the wave expressed in dB/m?

Aid: the attenuation is very large, so do not be surprised by the result.