

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: $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$, $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$.

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,
- match the load to the line at 300 MHz and,
 - 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/m². At a point X in space the combined electric field of the two waves possesses only the north-south component. Determine:
- the RMS amplitude of the combined electric field at point X and,
 - 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 \times 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, $Z_E = (Z_0 / \sqrt{\epsilon_r}) (\lambda_g / \lambda_E)$.

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.
- What is the smallest, non zero thickness of the slab such that no reflection occurs?
 - 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:

- the vertical RMS component of the 5 MHz signal 2.9 km above a 5 km radius circle centered on the radiating element and,
 - 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 $1.2 \lambda / (\text{antenna radius})$ 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 $\pm 30^\circ$. The beam is steered by shifting the phases of adjacent currents by a constant amount not exceeding $\pm 45^\circ$ 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.