Loughborough University

ANTENNAS, RADAR AND METAMATERIALS

22WSD523

Semester 1 2022 In-Person Exam paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

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ANTENNAS, RADAR AND METAMATERIALS

(22WSD523)

January 2023 2 Hours

Answer ALL THREE questions.

Questions carry the marks shown.

State any assumptions you make.

ALL working out for calculated questions must be shown to gain FULL marks.

Any University approved calculator is permitted.

A range of formulae and tables likely to be of benefit in the solution of these questions are provided at the rear of the paper.

1.

a) What is the typical fractional bandwidth and gain of a resonant dipole antenna? [2 marks]

b) What happens to the frequency and fractional bandwidth as we increase the length of a dipole antenna? [2 marks]

c) Sketch the radiation patterns of a vertical dipole antenna in the Azimuth and Elevation planes. [2 marks]

d) What is the relationship between directivity and gain? Explain why this is important in practice. [2 marks]

e) Describe the radiation patterns of a monopole with a small ground plane and also a large ground plane. [2 marks]

f) List the main advantages and disadvantages of patch antennas. [2 marks]

g) What is the impedance at the edge and the centre of a patch antenna? How do we find the 50 Ω point? [2 marks]

h) Describe or sketch two methods of achieving circular polarisation for patch antennas. [2 marks]

i) Explain why a dipole antenna positioned close to and parallel to a piece of metal will not be an effective antenna. Explain how this could be improved using metamaterials. Describe the challenges of using these types of metamaterials in practice. [4 marks]

2. A 2D array of 8 vertical dipoles operates at 60 GHz. The spacing between elements is 0.2λ.

a) Describe two benefits for using antenna arrays and give two commercial applications. [3 marks]

b) With reference to the array factor, sketch the graph of sin(x)/x. Identify the x values which give the maximum, halfpower, first null and first sidelobe. [3 marks]

c) If we want the maximum directivity at broadside, derive the expression for the required phase difference between elements in terms of the element separation. State any assumptions you make. [2 marks]

d) Derive expressions for the angle for the half power criteria, the first null and the first sidelobe. [6 marks]

e) Calculate angles for the halfpower beamwidth, the first null and first sidelobe. Calculate the Directivity at the first sidelobe. Sketch the pattern. [6 marks]

3.

a) Discuss the factors that dictate whether a radar system should be designed to operate at a high or low frequency. [3 marks]

b) By starting from a radiating isotropic source, derive the radar equation which relates the power received to the power transmitted. State any assumptions you make. [7 marks]

c) The signal from the transmitter takes 1 microsecond to return to the receiver after reflecting off the target. Calculate the distance from the radar to the target. [1 mark]

d) A monostatic 10 GHz radar transmits 100 W using a patch array antenna with a gain of 15 dBi. The radar is 100 m from the target. The received power is 0.01 mW. Calculate the radar cross section of the target. [5 marks]

e) A 10 GHz radar signal is incident on two cars; one is moving at 50 km/hour towards the radar, the other car is travelling at 180 km/hour away from the radar. Calculate the Doppler frequency shift of the received signal in each case. [4 marks]

W. G. Whittow