Communications and Sensors

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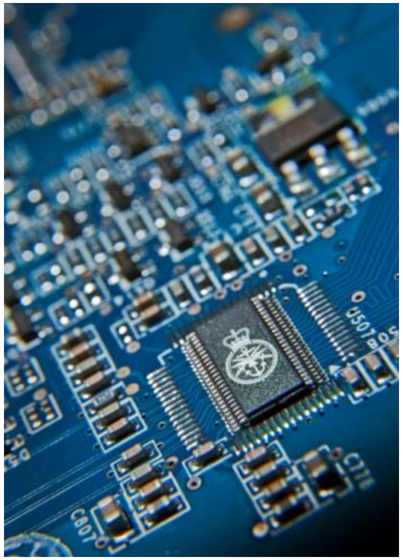
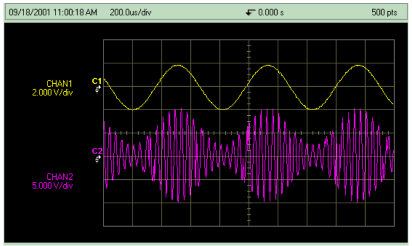
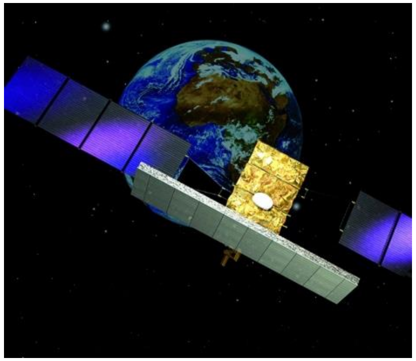
Communications and Sensors

This module provides a foundation to electronics, sensors and communications technologies, to allow students to understand the capabilities and limitations. These will be illustrated with case studies of practical systems, developed with the practitioner. Specific topics covered are:

- Voltage, current, power, decibels
- Electromagnetic waves, acoustic waves, antennas and propagation, directivity, gain, polarization, atmospheric loss, resolution
- Analogue electronics, amplifiers, filters
- Digital electronics and processing
- Electronic circuits, miniaturization, battery technology
- Communications: the RF spectrum, noise, bandwidth, modulation, one-way transmission, cellphones, WiFi, radiolocation
- Sensors: IR and optical frequencies, radar, the radar equation, countermeasures
- Satellites and orbits, imaging radar, GPS;
- Acoustic sensors, propagation, speech







Module description

This module develops an understanding of the principles of electronics technology, in the context of communications and sensing. The approach is deliberately not deeply mathematical, but rather concentrates on physical principles and pictorial representation of concepts, so that students have an understanding of what is and what is not feasible and can ask intelligent questions.

The module covers the basic principles of electromagnetic and acoustic waves and propagation, the configurations and properties of different kinds of antennas, the principles and properties of common communications systems, such as cellular phones and WiFi, the configurations and properties of common sensing systems, such as optical and IR imaging, radar, and imaging radar, the use of satellites for communications, sensing and navigation (GNSS), including jamming and spoofing, and the fundamentals of acoustic sensing, both above-water and underwater.

Warning – may contain equations !

Yes – there will be some equations. After all, this subject is quantitative, and we need to be able to understand and justify why something will or will not work.

Equations are the shorthand that we use to express the interrelationships between the parameters that show how a system behaves. In most cases, sticking numbers into an equation on a calculator will show you what's reasonable and what isn't, and hence to be able to ask the right questions. Don't be scared of them !

Assessment

Method (eg, exam, practical, course work)	Weighting	Length
Two Multiple Choice Question tests, one on fundamentals (topics 1 – 4) and one on applications (topics 5 – 9)	25% each	40 questions each
Individual Research Topic: Report	25%	3000 words
Individual Research Topic: Poster	25%	one A4 page (powerpoint) template provided

Lecture 1: Introduction and fundamentals

This topic covers the fundamental concepts of electronics and of waves (electromagnetic and acoustic):

Electricity – voltage, current power; units, dc and ac; Ohm's law

Waves – frequency, period, amplitude, phase, angular frequency, concept of bandwidth

Time domain and frequency domain representation

Electromagnetic waves – propagation, polarisation, the EM spectrum

Acoustic waves – propagation in air and underwater

Noise, decibels, signal-to-noise ratio

Lecture 2: Antennas and propagation

This topic covers the physical principles of antennas and wave propagation: transmission lines – coaxial, waveguide, stripline, matching

Radiation – radiation patterns, sidelobes, directivity, gain, relationship to wavelength and physical dimensions, bandwidth

Simple antennas – dipole, horn, parabolic dish, yagis, printed antennas, slots, arrays

Miniature antennas, wearable antennas

Propagation – inverse square law, tropospheric propagation, propagation in urban environments and through walls, multipath, ionospheric propagation
Shielding, Faraday cage

Lecture 3: Analogue electronics

This topic covers the fundamentals of electronic components and circuits: diodes, transistors, FETs, amplifiers, oscillators, filters, integrated circuits

Printed circuit board (PCB) technology, miniaturisation

Battery technology, harvesting, solar power

Lecture 4: Digital electronics

Advantages of digital processing: programmability, reproducibility, miniaturization. Moore's law

ADCs and DACs, the Sampling Theorem

Digital logic

Memory technology, capacity and speed

Digital signal processing (DSP), Field programmable gate arrays (FPGAs).
Simple digital processing operations such as Fast Fourier Transform (FFT)
Dynamic range, software defined radios (SDRs)

Lecture 5: Case studies

In this session the practitioner will present a number (5 or so) case studies which illustrate how the concepts covered in the course are employed in real systems, in each case demonstrating the capabilities and limitations.

At this point the group exercise topics will be introduced and allocated (5 students per group)

Lecture 6: Communications

This topic covers the fundamentals of communications, so that students understand the principles of common communications systems.

The RF spectrum, Noise, modulation, bandwidth

Digital and analogue modulation/demodulation, AM, FM, digital modulation (OFDM)

One-way transmission, Shannon's formula

Broadcasting (AM, FM, analogue TV, DAB, DVB-T, …)

Cellphones (GSM, 3G, 4G, …), WiFi

Radiolocation

Lecture 7: Sensing

This topic covers the fundamentals of sensing using electromagnetic waves.

RF, visible, IR, mmW and THz radiation

Active and passive sensors

Imaging, resolution

Optical and IR imaging

Radar – pulsed operation, the radar equation, detection, clutter, Doppler effect, examples of radar systems and their capabilities

Countermeasures – jamming and deception

Target tracking

Lecture 8: Satellites

This topic covers the use of satellite technology for communications, sensing and navigation.

Satellite orbits (LEO, MEO, GEO) and satellite launching

The space environment; space qualification of hardware, space debris

Spaceborne Synthetic Aperture Radar (SAR), interferometric SAR, change detection

Satellite navigation (GNSS), including jamming and spoofing

Microsatellites

Lecture 9: Acoustic sensing

This topic covers the basics of acoustic sensing, including:

(i) the detection and analysis of speech in indoor and outdoor environments, typical sensor configurations and achievable performance and ranges.

(ii) the use of acoustic sensing underwater: sonar; passive sonar, active sonar, SAS; sonobuoys; anti-submarine warfare (ASW)

10: Group exercise presentations

Each group presents their solution to the group exercise problems, and answers questions.

Reading list

Each lecture will have its own list of references for further reading, but good sources of information about the topic as a whole are:

Horowitz & Hill, *The Art of Electronics* (3rd ed.), Cambridge University Press, 2015.

Griffiths, H.D., Baker, C.J. and Adamy, D., *Stimson's Introduction to Airborne Radar* (3rd ed.), Scitech Publishing Inc., Raleigh NC, May 2014.

Kraus, J., *Antennas* (second edition), McGraw-Hill, 1988
https://archive.org/details/Antennas2ndbyjohnD.Kraus1988/page/n7

Daniels, D.J., *EM Detection of Concealed Targets*, IEEE-Wiley, 2010

Key points

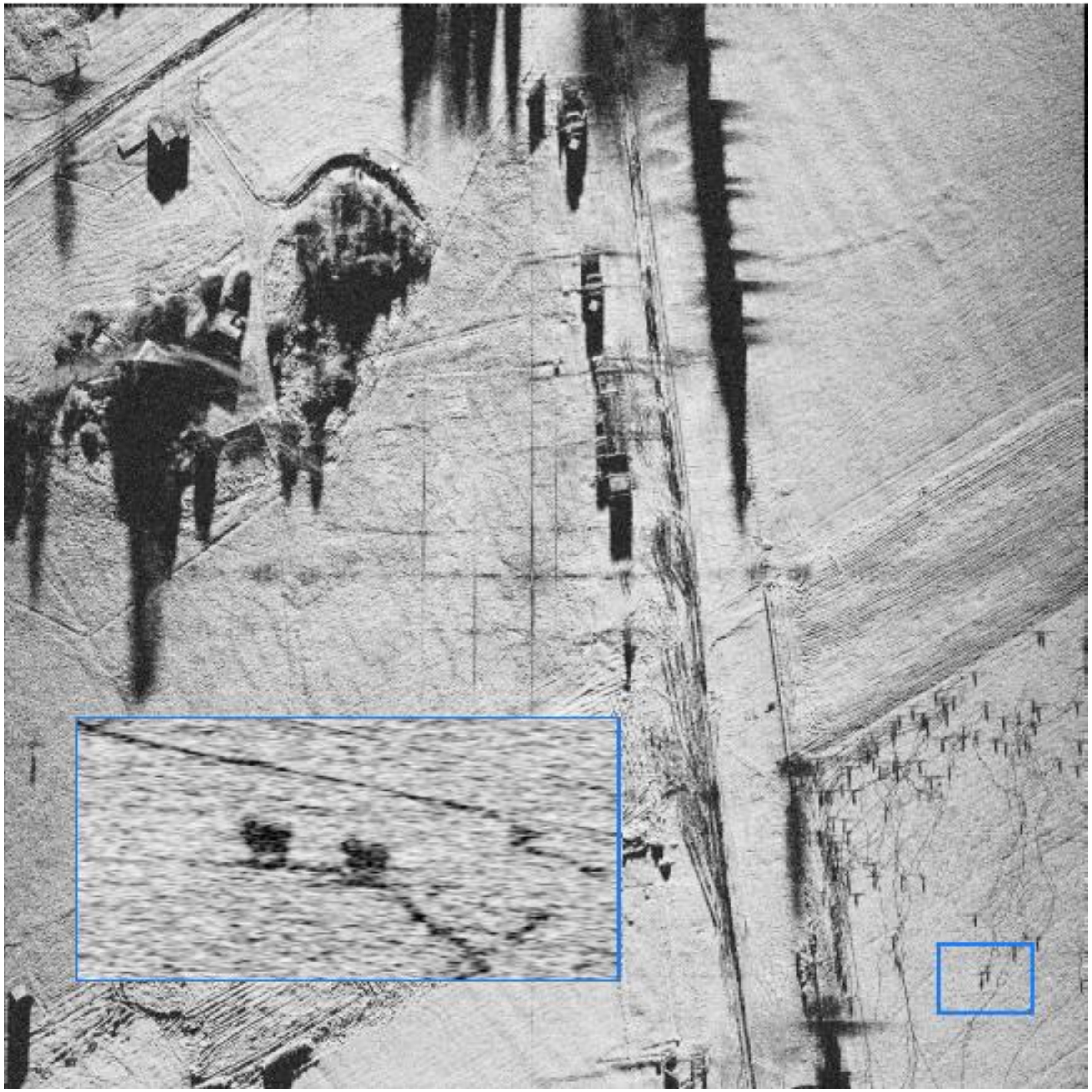
Each lecture will also have a slide or two that attempt to summarise the key points.

And also a glossary to define abbreviations and acronyms

Bright Spark

Bright Spark is a Dstl Experimental SAR system designed and built by THALES.

It is a Ka-band Synthetic Aperture Radar sensor providing unprecedented resolution and was used as a technical demonstration of the "art of the possible"



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