Radio Society of Great Britain

Advancing amateur radio since 1913

Radio Amateur Examination

Specification for Direct Entry to Full Licence

For Examinations held from 1 September 2024

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Contents

Document changes

Issue 0.1	*October 2020*	*Draft issue of direct entry syllabus for discussion and feedback*
Issue 1	*July 2022*	*First publication*
Issue 1a	*July 2022*	*Correct start date, publication date, up-rev document*
Issue 2.0	*June 2024*	*Revised syllabus – 2024 licence review*

Part 1

Introduction

This *Direct to Full* Radio Amateur Examination Specification sits alongside the structured suite of three examinations designed to give access to the amateur radio bands and provides a route for those with a technical background to obtain a Full licence in a single course of study and examination.

Ofcom requires that prospective radio amateurs must demonstrate a suitable level of competence and proficiency, by passing the appropriate examination, as a pre-requisite to holding a licence.

The *Direct to Full* examination may not be suitable for everybody and potential amateurs may wish to read the Specification for the three-tier suite before deciding this is the correct route for them.

The *Direct to Full* level examination gives access to the Amateur Radio (Full) Licence which offers all licence privileges and is recognised internationally.

The aim of this examination is to verify and assure the regulator that successful candidates have

- knowledge of the legal and ethical requirements of amateur radio
- an understanding of safe working practices and are mindful of the safety of others
- a secure foundation for further study of radio science and technology
- knowledge of good operating practices and procedures
- an understanding of basic electronic components and systems relevant to amateur radio

to the standard required to hold an Amateur Radio (Full) Licence.

Key Features

- A direct route of entry to Full licence privileges.
- Uses the same books as the three-tier suite of courses.
- The examination provides a complete backbone of theoretical knowledge.
- May be used within 6th form schools and colleges to enrich the Science and Technology curriculum.

The Assessment

The *Direct to Full* Level assessment consists of an examination comprising 75 questions lasting 2½ hours.

The examination must be carried out in accordance with RSGB approved procedures.

Examinations are only available to be taken on-line.

The candidate will receive their provisional result immediately at the end of the examination. Unless any exam irregularities are reported, this result will normally be officially confirmed after 6 working days after which time the results will be uploaded to the Ofcom licensing database. Candidates will use their candidate number and password to apply for their licence on-line on the Ofcom web site. A postal application option is available.

Prior Learning and Progression

There is no formal prior learning required but the assumption is made that the candidate is ready to learn or is proficient at STEM subjects broadly equivalent to a strong pass (top three grades) at GCSE or equivalent.

Some competence in mathematics will be required to sit the examination. Candidates may already be sufficiently proficient, or some aspects may need to be covered during the course. Details are given on page 7 under Prior Requirements.

Candidates could find it advantageous to attend a suitable course but there is no obligation to do so.

There is no formal route of progression beyond Full level, however there are many informal and academic opportunities for advancement and progression both in amateur radio and electronics generally. Possession of a Full Amateur Radio Licence is recognised as an advantage for entry into undergraduate training and many careers.

Candidates with disabilities

Arrangements can be made for candidates with disabilities to demonstrate knowledge by whatever means is judged appropriate.

Applications for special arrangements should be made **well in advance** of the examination to the Radio Society of Great Britain (RSGB) and will normally require a medical or other professional certificate advising the appropriate method of assessment or examination. Any waiver granted will be shown on the Register and Assessment Sheet (RAS) issued by the RSGB Examination Department.

Appeals after the examination citing disabilities or learning difficulties not previously declared cannot be considered.

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The Syllabus

The key words *Recall* and *Understand* are used to denote differing levels of comprehension.

Recall indicates the need to remember a fact and apply it fairly directly to a question or situation. A thorough understanding of why the fact is so and the full range of circumstances in which it is applicable is not required, but questions will expect a reasonable understanding of its meaning and implications.

Understand indicates the need for a more detailed knowledge of the subject, fully comprehending why the point is correct and the range of circumstances in which it is relevant and applicable. Typically, this will be where the candidates will find themselves having to make judgements or apply a practice to a wider range of circumstances.

Understand questions may use calculations (+-×÷) if the context permits.

Incorrect operation of a relatively powerful transmitter can cause quite widespread interference to other radio users which may have serious safety implications and infringe licence conditions.

Candidates will be expected to know in some detail how to operate correctly, what the effects of not doing so are and how to diagnose what might be wrong given such effects are occurring.

A statement of the mathematical abilities required to satisfactorily complete training is shown in the *Mathematics and Symbols* paragraphs below. If candidates do not possess that level of skill at the outset, then its early acquisition is essential. Training courses must recognise that need.

Examination Questions

The examination will assume background knowledge of the basic principles from all parts of this syllabus although questions themselves will be clearly aimed at the relevant syllabus items.

Questions assume that the candidate holds the licence level for which they are being examined and questions referring to 'you' should be interpreted accordingly.

It will be assumed that the candidate has some familiarity with operating practices and procedures, therefore some time spent as a listener or alongside an amateur operator will be advantageous in understanding the purpose and context of syllabus items and examination questions.

Some time spent on-air as a listener will be clearly advantageous in understanding the purpose and context of syllabus items and examination questions.

Allocation and Distribution of Questions

Each item in the Syllabus is uniquely identified in its Heading e.g. 1A1. Questions will be randomly selected from different syllabus items. The number of questions in each section is shown in the table:

Section 1	**Licensing conditions and station identification**	12	1 - 12
Section 2	**Operating practices and procedures**	6	13 - 18
Section 3	**Technical aspects**	10	19 - 28
Section 4	**Transmitters and receivers**	11	29 - 39
Section 5	**Feeders and antennas**	8	40 - 47
Section 6	**Propagation**	5	48 - 52
Section 7	**Electromagnetic compatibility (EMC)**	10	53 - 62
Section 8	**Safety**	8	63 - 70
Section 9	**Measurements and construction**	5	71 - 75
Total		75	

Pass Mark

The examination is marked in two parts.

Part 1 comprises Licensing and Operating, 18 questions with a pass mark of 14 or 77.7%.

Part 2 comprises the remaining sections, 57 questions with a pass mark of 36 questions or 63.2%.

Feedback

A feedback report will be produced for each candidate showing the question number, the selected syllabus item and the mark, correct or incorrect, for that question.

Formulae

All formulae will be provided. They will not be titled or explained, and candidates will be expected to recognise which formula is appropriate and may need to rearrange it, depending on the variable to be calculated.

Language

The language of assessment will be English.

Specimen Papers

Specimen Examination Question papers are available from the RSGB (www.rsgb.org).

Updates

Updates to this syllabus will be made from time to time and the latest version can be obtained from the RSGB website. Where the update involves a significant change to the syllabus content, the date from which the syllabus is valid for examinations will be amended to show the new period of validity of the syllabus. A minimum of three months' notice will be given. Minor syllabus changes, where the learning points have not been added are examinable immediately.

Tutors should note that all examinations will be in accordance with the syllabus which is current at the time of examination. Candidates must use only the information which will be provided in the examination, such as the licence schedule and band plan.

Any external changes, such as those affecting the licence will not be examinable until they have been formally announced as examinable. It should also be noted that the examination band plan is a specimen plan and not necessarily the live IARU/RSGB plan for on-air use.

Mathematics and Symbols

Some knowledge of mathematics will be required during any course and prior to the relevant examination. Tutors and candidates should address this requirement as necessary.

The following levels of knowledge and ability are needed by the time candidates are ready to take the examination.

Mathematical:

- Addition, subtraction, multiplication, and division.
- Simple fractions and their decimal equivalents.
- Multiple and sub-multiple units from pico to Giga.
- Conversion of numbers from $10^{!"\#}$ to $10^{"\#}$ to/from decimal.
- Understanding of simple formulae, e.g. $I = V/R$, and rearrange them to make any parameter the subject of the formula.
- Multiple and sub-multiple prefixes from Pico to Giga.
- Calculations with quantities from $10^{!"\#}$ to $10^{"\#}$ recognising that interim stages may go outside those limits.

- Use of simple formulae containing brackets, squared or square root operators
  e.g. $I = \sqrt{P/R}$ or $P = V^2/R$
- Use and transposition of more complex formulae
  e.g. $f = \frac{1}{\left(2\pi\sqrt{(LC)}\right)}$

Technical:

- A working knowledge of Ohm's law is assumed, as is a basic understanding of direct and alternating current.
- Some items explicitly in the CEPT HAREC syllabus are implicit in this document. For example, knowledge of Kirchhoff's Laws and the relationship between EMF and PD are contained within syllabus item 3A1 covering basic circuit theory.
- The units, symbols and abbreviations of relevant quantities will be used as required, for example Volt, Amp, Coulomb, Ohm, Hertz, Henry, Farad; along with terms such as resistance, reactance, impedance and resonance.

Part 2

Section 1 – Licensing conditions and station identification

1A Nature of amateur radio, types of licence and call signs

1A1 Recall that the amateur licence is for self-training in radio communications and is of a non-commercial nature. Business use and commercial advertising is not permitted.

Recall that the amateur licence permits operation in and over the United Kingdom, the Channel Islands and the Isle of Man in each case including their territorial seas.

Recall that the amateur licence also authorises operation aboard ships or aircraft registered in the United Kingdom, the Channel Islands or the Isle of Man in international water or airspace.

Recall that the licence does not permit use in other countries or their territorial waters or airspace.

Notes: In *practice a very low percentage of ships/aircraft are so registered and thus quite limited to the wider international arrangements for Full Licensees.*

Airborne *use has limited power and is primary allocations only.*

Note. Refer to 1F1 for CEPT / International arrangements.

1A2 Recall the various types of UK Amateur Licence.

Recall that Regional Secondary Locators (RSLs), although optional, are defined in the licence and frequently used by amateurs to identify the location of their transmitting station.

Recall the RSLs that may be used by individual amateurs: D, E, I, J, M, U, W

Recall that the use of an RSL is mandatory for all 2x series callsigns.

Recall that where an RSL is used, it must be used correctly.

Understand that suffixes may be used (but must not be offensive or obscure correct identification)

Recall that suffixes can optionally be used to indicate type of operation.

Recall the restrictions applicable to Licensees in operation from a ship or aircraft.

Note: The optional club secondary locators are not examined.

1A3 Recall that the Licensee must give immediate notice to Ofcom of any change to the Licensee's name and address quoted on the licence.

Recall that the Licensee must confirm that the details shown on the licence remain valid at least once every five years.

Recall that the licence can be revoked by Ofcom for breaches of licence conditions.

1A4 Recall the requirements for station identification.

Note: For the purposes of the examination this includes identifying when there is a change of:

- *frequency*
- *mode, including change of digital protocols.*
    - *FM (Frequency Modulation)*
    - *AM (Amplitude Modulation)*
    - *SSB (Single Sideband)*
    - *CW (Carrier Wave - Morse Code)*
    - *DATA (e.g. PSK, RTTY, WSPR, FT8)*
- *Supervisor*

Regional Secondary Locator, if used.

1B Operators and supervision

1B1 Understand the requirements for operating under supervision and when delegating supervisory responsibilities and the permitted uses and conditions.

Recall that only the licensee, or any other person operating under the licensee's direct supervision, may use the Radio Equipment.

Understand the meaning of direct supervision, duties of the supervisor and need for the operator to comply with the licence.

Understand the Licence meaning of the term Radio Equipment and the implications for identification of the station.

Recall that in certain circumstances the licensee may allow the equipment to be used by a member of a User Service.

Notes: : The term 'Radio Equipment' (in initial capitals) is a defined licence term meaning the equipment used and identified by the operator's call sign. If a visiting amateur uses the radio equipment with their own call sign, it is then deemed to be their Radio Equipment.

The nature of the circumstances and identity of the User Service are not examinable.

1C Messages

1C1 Understand the requirements relating to the content of messages and who messages may be sent to.

Recall that a 'Net' or 'Network' refers to a conversation with several amateurs with whom communication and identification has been established.

Understand the Licence requirements in respect of the receipt of messages from amateurs on non-UK frequencies.

Understand that people of all ages and backgrounds participate in amateur radio and that messages must not cause offence, particularly in the context of relevant legislation including the Wireless Telegraphy (Content of Transmission) Regulations (1988) and the Communications Act (2003).

1C2 Recall that the Licensee may pass messages on behalf of a User Service and may permit a member of the User Service to use the Radio Equipment to send messages.

Recall that, except under the direction of a member of a User Service who may obscure the message to retain confidentiality, all transmissions must be in plain language.

Understand the distinction between the use of codes and abbreviations and encryption.

Recall that in an international disaster, messages may be passed, internationally, on behalf of non-licensed persons.

Recall that non-amateur stations involved in disaster communications may also be heard on amateur frequencies.

1D Apparatus, inspection and closedown

1D1 Understand the requirements for clean and stable transmitters and the need to control transmitted bandwidth.

Understand the need to avoid Undue Interference to other wireless telegraphy.

Understand the need to conduct tests from time to time to ensure that the station is not causing Undue Interference to other radio users.

Understand the need to have equipment for the reception of messages on all frequencies and modes in use for transmissions.

Understand the role of Ofcom in cases of Undue Interference.

1D2 Recall the occasions for mandatory log keeping.

Understand the circumstances in which modification or cessation of operating of the station may be required.

Understand the circumstances in which modification of the transmitting equipment may be required.

1E Unattended and remote-control operation

1E1 Recall that the Licensee may use any communication link for the purposes of Remote Control of their station.

Recall that the Remote-control link must be adequately secure so as to ensure that no other person can operate the equipment.

Recall that if the Remote-Control link is in an amateur band that the licence requirements for the link are the same as the requirements for the main station.

Recall that a link in an amateur band must be above 30MHz.

Recall that a link in an amateur band must not be encrypted.

1F CEPT and international

1F1 Understand the requirements for operation by individual UK licensees abroad under the CEPT Recommendation T/R 61-01 and T/R 61-02.

Understand this facility does not extend to club or reciprocal licences.

Understand the purpose and function of the CEPT Harmonised Amateur Radio Examination Certificate (HAREC).

Recall that many countries will offer reciprocal licences to UK amateurs with a HAREC Full Licence, and that operation is in accordance with the host country's rules.

1F2 Identify the 3 ITU regions and recall that the frequencies are given in the ITU Radio Regulations.

1G Electromagnetic Fields

1G1 Understand relevant information in the licence.

- Origin and purpose of the EMF restrictions (ICNIRP),
- transmit power level at which the EMF restrictions apply,
- persons to which the EMF restrictions apply,
- Meaning of the term 'general public',
- Areas in which the general public need to be protected from EMF in breach of the limits,
- Records of EMF assessment and the need to re-assess,
- Procedure for carrying out an EMF assessment,
- Emergency situations.

1H Licence schedule

1H1 Identify relevant information in Schedule 1 and A2 Notice of coordination to the Full licence.

Recall the difference between Primary and Secondary status and that other services may also be present with such status in some allocations.

Section 2 – Operating practices and procedures

2A Good operating practices and procedures

2A1 Understand why one should listen on a frequency before calling and then ask if the frequency is in use.

Understand the reasons why some stations may use split Tx and Rx frequencies within a frequency band.

2A2 Recall how to make a CQ call in SSB and FM modes.

Understand the need to move off the calling channel when on VHF/UHF once contact is established.

Understand the meaning of Centre of Activity.

2A3 Recall common international call sign prefixes; EI (Republic of Ireland), F (France), I (Italy), JA (Japan), PA (The Netherlands), VE (Canada), VK (Australia), W (USA), ZL (New Zealand). Recall the phonetic alphabet.

2A5 Recall the meaning and the reason for use of the Q codes: QRM, QRN, QRP, QRT, QRZ, QSB, QSL, QSO, QSY, QTH.

Recall the meaning of the RST code, the number of divisions of each of the three items, eg 599, and their order of merit.

2A6 Understand the advisability and common practice of keeping a log.

Understand why UTC is used for logging time.

Recall that a log should typically detail the following information:

- date,
- time,
- mode,
- frequency,
- power (RF output)
- station.

Recall that when competing in a contest, additional information may be required according to the contest rules.

2A7 Understand that the transmission of music and the use of offensive or threatening language whilst on the air are unacceptable in amateur radio.

Understand how to respond to music or inappropriate language overheard or received from other stations.

2B Band plans

2B1 Recall that band plans are produced by the International Amateur Radio Union (IARU). Identify items on a typical band-plan (e.g. Centre of Activity, bandwidth and recommended modes).

Recall that narrow band modes are at the lower end of most bands.

Recall that lower sideband operation normally occurs below 10MHz and upper sideband above 10MHz.

Recall that transmissions on beacon frequencies must be avoided.

Recall that the band plans state that:

- no SSB operation should take place in the 10MHz (30m) band,
- no contests shall be organised in the 5MHz (60m), 10MHz (30m), 18MHz (17m) and 24MHz (12m), bands,
- transmissions on satellite frequencies should be avoided for terrestrial contacts.

Recall that band plans in other countries and IARU regions may not align with the UK band plan.

Recall that frequency bands are allocated for particular use, e.g. broadcasting, aeronautical, maritime and amateur.

Recall that some amateur bands are shared with or adjacent to other spectrum users.

Identify items on a provided chart of spectrum users.

Note: For the purposes of the examination narrow modes are CW and data.

The Band Plan supplied for examination purposes will be a typical plan and need not be one in current use. The Reference Booklet containing the examination band plan is available on the RSGB web site.

2C Repeaters

2C1 Recall that repeaters are mainly intended to extend the range of mobile stations.

Understand the reason for using a frequency offset between transmit and receive.

Understand why CTCSS tones are needed to access repeaters.

Recall that repeaters may have a 'reset' tone and a time-out facility.

Recall that simplex operation on repeater frequencies should not take place.

Note: Questions may ask why particular facilities exist (for example frequency offset or CTCSS), what operational issues they address or how they should be used to establish or maintain a contact.

2E Digital modes

2E1 Recall that there are digital voice (DV) and digital data (DD) modes available and that different systems may not be compatible.

Recall that appropriate radio equipment is needed for each of these digital systems.

Recall that DV radios may embed the callsign and this must be the same as the call sign of the operator.

Recall that when borrowing equipment, the borrower must amend the embedded callsign.

Recall that users of DV should check that the channel is not in use by other modes.

Recall that users of FM should check that the channel is not in use by other modes.

Recall that such checks are not 100% reliable.

2E2 Recall that several types of transmissions can be generated and received with the use of a personal computer and a suitable interface.

Recall minimal distortion can be obtained by careful adjustments between the DAC interface and the transmitter.

Recall other programs running on the PC that is handling the transmitter or receiver audio may cause interference e.g. warning beeps and alerts.

2F Satellites

2F1 Recall that satellites orbit the Earth at heights above 250km.

Understand that amateur satellites may be moving in relation to the Earth and will only be above the horizon at certain times.

Recall that amateur satellites operate in allocated frequencies within the band plans.

Recall that terrestrial operation on satellite frequencies should not take place.

2F2 Recall that satellite up-link and down-link frequencies are generally in different amateur bands and that details are published by amateur organisations.

Recall that the transmitting station must be able to receive both the up-link and down-link signals.

2F3 Understand that amateur satellites can only be used when they are above the horizon at both the sending and receiving stations, and that the movement of the satellite will cause frequency variation, known as Doppler shift, on the received signal, which must be allowed for when selecting operating frequencies.

2F4 Understand that satellites have a very limited power supply, derived from solar panels, and that excessive up-link power may result in wasteful and unfair use of the satellite's power.

Section 3 – Technical aspects

3A Circuits

3A1 Solve series/parallel resistor circuits to calculate currents, voltages, resistances and power given appropriate values.

3B Reactive components

3B1 Understand the basic construction of capacitors and the factors influencing their capacitance: area and separation of the plates, permittivity of dielectrics and formula C = kA/d. (where k = $\varepsilon_0\varepsilon_r$)

Recall that the Coulomb is the quantity of electricity, Q, given by current × time and that the charge on a capacitor is given by Q = V×C.

3B2 Recall that different dielectrics are used for different purposes, e.g. air, ceramic, mica and polyester; and that with some dielectrics, losses increase with increasing frequency.

Understand that capacitors have a breakdown voltage and that they need to be used within that voltage.

3B3 Calculate the effective capacitance of capacitors connected in series and parallel.

3B4 Understand the basic construction of inductors and the factors influencing their inductance: number and density of turns, the area enclosed and the permeability of the core.

Understand the term 'self-inductance' and recall that a 'back EMF' is produced as current flow changes in an inductor.

3B5 Calculate the effective inductance of inductors in series and in parallel.

3B6 Understand the rise and fall of current in an LR circuit and that the time constant $\tau = L / R$.

Understand the rise and fall of voltage in a CR circuit and that the time constant $\tau = C \times R$.

3C AC theory

3C1 Understand the sinusoidal curve as a graphical representation of the rise and fall of an alternating current or voltage over time and that both the frequency and the amplitude must be specified.

Recognise the graphical representation of a square wave.

Recall the meaning of frequency and periodic time.

Recall the concept of phase difference between two signals, and that it can be expressed in degrees.

Recall the range of frequencies for normal hearing: 20Hz to 15kHz.

Recall the range of frequencies for audio communication: 300Hz to 3kHz.

Recall the frequency bands for LF, MF, HF, VHF, UHF, SHF and EHF radio signals.

3C2 Understand that current lags potential difference by 90° in an inductor and that current leads potential difference by 90° in a capacitor.

Understand the use of capacitors for AC coupling (DC blocking) and decoupling AC signals (including RF bypass) to ground.

Understand the use of inductors for DC coupling (AC blocking) and decoupling of DC signals.

Calculate the reactance of capacitors and inductors.

3C3 Understand circuits containing resistance, reactance and impedance.

Calculate voltages, currents and powers.

3C4 Calculate frequency or wavelength given the other parameter.

Note: The velocity of radio waves will be given in the Reference Booklet.

3C5 Understand that where a conductor is several wavelengths long the magnitude and direction of the current and voltage at any instant in time will be different at different positions along the conductor.

3D Digital modes

3D1 Understand the difference between analogue and digital signals.

Recall that digital signals with more bits and/or increased sampling rate enables a more accurate representation of the analogue signal.

Recall that the error introduced by sampling the analogue signal to produce the digital signal is a form of distortion.

Understand that the sampling rate needs to be greater than twice the frequency of the analogue signal to adequately capture the detail of the analogue signal being sampled.

Recall that the minimum sampling rate is known as the Nyquist rate.

Understand that analogue to digital conversion can generate a false image of the signal if frequencies are present above the Nyquist rate.

Recall that these false images are known as aliases.

Understand that anti-aliasing filters are used to avoid this occurring.

3D2 Recall that digital signals in the time domain can be depicted in the frequency domain by using a mathematical operation known as a Fourier Transform (FT).

Recall that a Fourier Transform takes digital signals in the time domain and calculates the amplitudes and the frequencies which comprised the original signal.

3E Transformers

3E1 Understand the construction and operation of a transformer (power and RF) and the concept of mutual inductance.

Understand and apply the formulae relating transformer primary and secondary turns to primary and secondary potential differences, currents and impedances.

Understand that different magnetic materials used as cores for inductors and transformers perform best over different frequency ranges and that the frequency range affects their efficiency.

Recall that losses in the core material will cause heating which affects power handling and the required physical size of the core for the power concerned.

3F Tuned circuits and resonance

3F1 Recall that the energy stored in the capacitor and inductor in a tuned circuit can transfer from one to the other at a particular frequency, known as the resonant frequency.

Apply the formula for the resonant frequency of a tuned circuit to find values of f, L or C from given data.

Understand how the impedance of series and parallel tuned circuits changes with frequency and recognise their graphical representations.

3F2 Recall the equivalent circuit of a crystal and that it exhibits series and parallel resonance.

Recall that crystals are manufactured for either series or parallel operation and will only be stable and correct on the marked frequency when used in the intended manner.

3F3 Understand the concept of the magnification factor Q as applied to the voltages and currents in a resonant circuit.

Recall that voltages and circulating currents in tuned circuits can be very high and understand the implications for component rating.

Apply the formula for the Q factor given circuit component values.

Recall the definition of the half power point.

Apply the equation for Q given the resonant frequency and the half power points on the resonance curve.

Understand the meaning of dynamic resistance, R_D.

3G Semiconductor devices

3G1 Recall that a diode will only conduct in one direction and understand its V / I characteristic curve and forward voltage.

Recall that a Zener diode will conduct when the applied reverse bias potential is above its designed value and identify its V / I characteristic curve.

Recall that a variable capacitance diode behaves like a capacitor when reverse biased and that the capacitance of a reverse biased diode depends on the magnitude of the reverse bias.

3G2 Understand the basics of biasing NPN and PNP bipolar transistors and field effect transistors (FET) (including dual gate devices).

Understand that if the variation in the base current is large enough the collector current can be turned on and off and the transistor behaves as a switch.

Calculate values of base current required to act as a switch given appropriate circuit values.

Understand in simple terms how a (current) signal at the base causes a larger current signal at the collector and resulting change in instantaneous collector voltage.

Note: Circuits shown will use an NPN transistor connected in common emitter/common source mode.

3G3 Identify different types of small signal amplifiers (e.g. common emitter (source), emitter follower and common base) and explain their operation in terms of input and output impedances, current gain, voltage gain and phase change.

Recall the characteristics and typical circuit diagrams of different classes of amplifiers (i.e. A, B, A/B and C).

3G4 Recall that a transistor can be used to generate audio and radio frequencies by maintaining the oscillations in a tuned or frequency selective circuit.

Understand the feedback requirements to sustain oscillations in an oscillator.

Distinguish between a crystal oscillator and a variable frequency oscillator based on a tuned circuit.

Note: Diagrams will show the Colpitts oscillator.

3H Cells and power supplies

3H1 Recall that different technologies used in cells give different terminal voltages.

Recall that battery capacity (stored charge) is measured in Ampere-hours (Ah).

Understand that the energy stored in a battery is measured in Watt-hours (Wh).

Recall the characteristics and disposal methods of primary and secondary cells.

3H2 Understand the function of and identify different types of voltage regulating circuits (i.e. Zener diode/pass transistor and IC).

Note: questions on the characteristics of individual components are covered in other parts of this syllabus.

3H3 Understand the basic principles and operation of a switched mode power supply at block diagram level.

Section 4 – Transmitters and receivers

4A Transmitter concepts

4A1 Identify AM, FM, SSB, and data modulations from graphical representations in the time or frequency domain.

Understand the terms carrier, audio waveform and modulated waveform.

Recall the meaning of depth of modulation for amplitude modulation.

Recall the meanings of wide band and narrow band frequency modulation.

Recall the meaning of the term Peak Deviation.

Recall the meaning of Modulation Index and its effect on the number of FM sidebands.

4A2 Understand that SSB is more efficient than AM or FM because power is not used to transmit the carrier and the other sideband.

Understand that a second advantage is that the transmitted signal takes up only half the bandwidth, e.g. 3kHz not 6kHz.

4B Transmitter architecture

4B1 Understand the block diagrams of CW, AM, SSB and FM transmitters employing mixers to generate the final frequency.

Understand the block diagram of an FM transmitter employing frequency multipliers to generate the final frequency and the basis of frequency multiplication.

Calculate the frequencies employed given suitable data.

4C Oscillators

4C1 Recall the relative advantages and disadvantages of a crystal oscillator and a variable frequency oscillator (VFO).

Recall that the resonant frequency of the tuned circuit in a VFO determines the frequency of oscillation.

Recall that the frequency stability of an oscillator can be improved by rigid mechanical construction, screening the oscillator enclosure, a regulated DC supply and a buffer amplifier immediately after the oscillator circuit.

Recall that most modern oscillators are digital synthesisers, which are very stable and are based on a crystal reference.

Recall the effect and the importance of minimising drift.

4C2 Recall how sinusoidal waves may be produced by direct digital synthesis and the block diagram of a simple synthesiser.

Recall that increasing the number of bits in the synthesiser will increase the purity of the signal.

Recall the block diagram of a typical direct digital synthesis (DDS) system and that a DDS can generate audio and RF signals.

Recall the function of the clock, lookup table, digital to analogue converter (DAC) and low pass filter in a DDS block diagram.

4D Frequency multipliers

4D1 Understand that frequency multipliers use harmonics to generate frequencies above an oscillator's fundamental frequency (e.g. in a microwave transmitter).

4E Modulators

4E1 Understand the operation of AM, SSB and FM modulators.

Recall that a variable capacitance diode can be used in an oscillator to produce frequency modulation (FM).

Understand the need to limit the amplitude and frequency response of modulating signals.

Calculate the bandwidth of such transmissions.

4E2 Understand that an SSB filter is a Band Pass Filter that will only allow one sideband to pass to the Power Amplifier.

Recall that in an analogue transmitter, SSB filters are normally constructed from a number of quartz crystals or other resonators.

Identify typical sideband filter circuits and calculate relevant frequencies.

4F RF power amplifiers

4F1 Understand the concept of the efficiency of an amplifier stage and the relationship between the expected RF output power, DC input power, given the stage's efficiency.

4F2 Understand the need for linear amplification and identify which forms of modulation require a linear amplifier.

Identify simple RF transmitter Power Amplifier (PA) circuits.

Understand the meaning of linearity as applied to a circuit or amplifier.

Understand how distortion of a single frequency signal can produce harmonics of that frequency.

Understand how distortion of two (or more) frequencies can produce harmonics and intermodulation products of the input frequencies.

4F3 Recall the function of the main components of a PA circuit, i.e. collector/drain load, bias, input circuit, output filter and matching.

Understand the need for correct output load impedance.

4F4 Understand the implications for PA rating of different types of modulation and the effects of speech processing, with particular regard to peak to average power ratios.

Recall the function of automatic level control within the power amplifier circuit and when using an external power amplifier.

Recall the function and use of a manual RF power control.

4G Transmitter interference

4G1 Understand that over-modulation distorts the modulating signal resulting in harmonics of the audio which causes excessive transmitted bandwidth.

Understand that over-drive of the RF power amplifier can also result in excessive transmitted bandwidth.

Understand the need to drive external power amplifiers with the minimum power required for full output and how overdriving may cause harmonics and/or spurious intermodulation products and excessive transmitted bandwidth.

4G2 Recall that transmitters may radiate unwanted mixer products and identify suitable remedies. Understand the use of low pass, band pass and band stop (notch) filters in minimising the radiation of unwanted harmonics and mixer products.

4G3 Recall that unwanted emissions may be caused by parasitic oscillation and/or self-oscillation and identify suitable remedies.

Understand the cause, effects and avoidance of key clicks in a CW transmitter.

Recognise a diagrammatic representation of rise and fall time of the transmitted envelope.

Recall the cause and effect of chirp and identify suitable remedies.

4H Receiver concepts

4H1 Understand the block diagrams of the crystal diode receiver, and direct conversion receiver. Understand the functions of the RF amplifier, demodulator (detector), and audio amplifier as used in an analogue receiver.

4H2 Recall that a receiver's ability to detect weak signals is known as its sensitivity.

Recall that a receiver's ability to reject frequencies outside the wanted signal bandwidth is known as its selectivity.

Understand the limitations of tuned circuits in selecting wanted frequencies and the effect of the Q factor of tuned circuits.

Recall that Tone Squelch can be used to reject transmissions that do not carry the correct Tone Squelch frequency.

Note: Tone Squelch considerations also apply to transmitter architecture.

4H3 Understand that overloading a receiver causes intermodulation products and that those close to or within the wanted signal bandwidth limit the ability of the receiver to detect weak signals.

Recall that the dynamic range of a receiver is the difference between the minimum discernible signal and the maximum signal without overload.

Recall that dynamic range is expressed in decibels (dB).

4I Superheterodyne concepts

4I1 Understand the advantages and block diagram of superheterodyne (superhet) and double superhet receivers and the functions of each block.

4I2 Understand the function of a mixer, the generation of the Intermediate Frequency (IF) and other mixer products.

4I3 Understand the advantages and disadvantages of high and low intermediate frequencies and the rationale for the double and triple superhet.

Understand that for given RF and IF frequencies, there is a choice of two possible local oscillator (LO) frequencies.

Understand the reasons for the choice and calculate the frequencies.

Understand the origin of the image frequency and calculate the frequency from given parameters.

4I4 Understand the operation of an IF amplifier and the IF transformer.

Understand the concept of two LC tuned circuits utilising transformer coupling.

Identify under, critical, and over coupled response curves.

Understand how the gain of an IF amplifier can be varied, how this may cause distortion and how the effects of the distortion are avoided.

4I5 Recall the source and effects of phase noise.

Recall the unit of measurement is dBc/Hz.

4J RF amplifiers and external preamplifiers

4J1 Recall the operation of the RF amplifier.

Understand that external RF preamplifiers do not always improve overall performance and will reduce the dynamic range.

Understand why, at HF, this loss can be as much as the gain of the preamp but that at VHF and above a low noise preamplifier is beneficial.

Understand why most benefit is gained by locating any preamplifier near the antenna.

Understand that overloading will cause intermodulation products and spurious signals.

4K Demodulation

4K1 Understand the operation of basic analogue AM, CW, SSB and FM demodulator circuits and the function of the limiter for FM.

Identify relevant waveforms and calculate frequencies involved.

4L Automatic gain control (AGC)

4L1 Understand the source and use of an AGC voltage, including providing a signal voltage for the S meter.

Recall that the speed of the AGC response can be adjusted on both attack and decay.

4M SDR transmitters and receivers

4M1 Recall the different elements that make up the functions of an SDR block diagram.

Recall that the SDR receiver takes in all electrical signals from the antenna and digitises this input for processing in software.

Recall that SDR software uses a mathematical function called a Fourier transform which sifts the composite signal into its constituent independent frequencies for processing.

Recall that this can also be used to provide a spectrum or waterfall display.

Recall that the required signal is selected using a filter defined in software which can be much more selective than analogue filters.

Recall that demodulation is carried out in software.

4M2 Understand the meaning of the time domain and the frequency domain.

Understand how signals in the time domain may also be viewed in the frequency domain.

Identify for some simple harmonic waves, the spectrum obtained using the Fourier transform.
Recall that analogue and digital signals are transmitted by some form of amplitude and/or frequency/phase modulation.

Recall that amplitude and frequency/phase modulation can be portrayed on a phasor diagram.
Understand that to fully capture the information contained in the amplitude and phase of the signal that the position of the phasors must be resolved as the values on two axes at right angles.

4M3 Recall that mixing the RF or IF signal with two local oscillator signals 90 degrees different in phase will produce an in-phase (I) and quadrature (Q) component which can be digitised allowing all forms of modulation to be demodulated entirely by mathematical processes in a PC or using dedicated hardware.

Recall that this technique is the basis of SDR (software defined radio) receivers.

Recall that these techniques can also be used to create complex modulations for use in transmitters.

Recall that if sampling is carried out directly on the RF signal the extraction of I and Q components and subsequent demodulation may be carried out entirely by mathematical processes.

4N Transceivers

4N1 Understand that transceivers normally share oscillators between the transmitter and receiver circuits; and they may use common IF filters to limit both the transmitter and receiver bandwidths and that they also use common changeover circuits.

Recall the function and use of the RIT control.

4N2 Understand that using a transverter enables operation on frequency bands not covered by the primary transceiver equipment.

Calculate appropriate frequencies used in transverter operation.

Recall that transverters generally require a low power drive.

Understand the need for extra care to avoid transmitting out of band when using a transverter.
Recall that transverters require the correct interfacing with the primary equipment to control sequencing and prevent hot switching.

Understand the techniques of RF sensing and PTT (Push-To-Talk) transmit/receive switching.

Section 5 – Feeders and antennas

5A Feeders

5A1 Recall the correct cable types to use for RF signals and that coaxial cable is most widely used because of its screening properties.

Recall that in a correctly connected and terminated coaxial cable the RF field only exists within the cable and is not affected by objects outside the cable.

Understand the equal and opposite currents flowing in a balanced feeder cause equal and opposite fields around the two conductors and that these fields cancel out, but that nearby objects can cause an imbalance that makes the feeder radiate RF energy.

Recall that a rectangular waveguide must have its larger dimension greater than λ/2 for the signal to travel.

5A2 Recall that some RF energy is converted to heat in feeders, so they exhibit loss.

Recall that feeders cause loss of signal strength on both transmit and receive; the longer the cable, the greater the loss (in linear or dB units).

Recall that feeder loss increases with frequency and that low loss feeders (lowest dB per unit length) should be used at VHF and UHF.

Recall that twin feeder usually has lower loss than coaxial cable.

Understand the relationship between RF output power, feeder loss and power delivered to the antenna.

Calculate the unknown quantity given the other two.

5A3 Recall that feeders have a characteristic impedance which depends upon the diameter and spacing of the conductors and the dielectric material.

Recall that this impedance determines the ratio of the RF RMS potential difference to the RF, RMS current in a correctly terminated feeder.

Recall that for amateur use 50Ω coaxial feeder is normally used; that coaxial cable for TV and satellite receivers has a different impedance of 75Ω.

Recall that balanced feeder is commonly available from 75Ω to 600Ω.

Recall that correctly terminated means correctly connected with a resistive load equal to the characteristic impedance of the feeder.

5A4 Understand that the velocity factor of a feeder is the ratio of the velocity of radio waves in the feeder to that in free space and that the velocity factor is always less than unity.

Recall that the velocity factor for coaxial feeder with a solid polythene dielectric is approximately 0.67 or 2/3.

Perform calculations involving velocity factor, physical length, electrical length and frequency.

5B Baluns

5B1 Recall the difference between balanced and unbalanced signals in feeders and antennas and the purpose of a balun.

Understand the difference between a voltage balun and a current balun.

Recall the construction and use of transformer, sleeve and choke type baluns.

Identify the circuits of 1:1 and 4:1 transformer baluns.

5C Antenna concepts

5C1 Understand the concept of an antenna radiation pattern.

Understand the beam width and front-to-back ratio of an antenna.

Identify the polar diagrams for the half wave dipole and Yagi antennas.

Identify the directions of maximum and minimum radiation.

Understand that half-wave dipoles (mounted vertically), λ/4 (quarter wavelength) ground planes and 5/8 λ antennas are omni-directional.

Note – only dipole and Yagi antennas will be examined for radiation pattern.

5C2 Understand that antenna gain is the ability of the antenna to focus radiation in a particular direction.

Recall that a Yagi antenna typically has a higher gain because of its improved focussing ability.

Recall the gain of an antenna is normally expressed relative to a half-wave dipole and measured in dBd (a higher dBd value is a higher gain).

Recall that the directional power is expressed as Effective Radiated Power (ERP) and that this apparent power increase is known as gain.

Recall that ERP is calculated by multiplying the power applied to the antenna feed point by the gain of the antenna relative to a dipole (dBd).

Calculate ERP given antenna input power and antenna gain.

Recall that an isotropic radiator is a theoretical antenna that radiates equally in all directions.

Recall the Effective Isotropic Radiated Power (EIRP) is based on an isotropic antenna reference rather than a dipole and is expressed in dBi.

Recall that a half-wave dipole has a gain, in its optimum direction, of 2.15dBi.

5C3 Recall that the angle at which the radio wave leaves the antenna is known as the angle of radiation and that longer distance contact normally require a lower angle of radiation with respect to the surface of the earth.

Recall the effect of the ground on the angle of radiation.

Recall that VHF and UHF signals will normally be received most effectively when the transmitter and the receiver have the same antenna polarisation.

Recall that polarisation is less critical at HF because the polarisation may change during ionospheric reflection.

5C4 Recall that the current flowing into an antenna is related to the feed point impedance and the potential difference of the applied signal.

Recall that an antenna will only present the correct feed point impedance when fed with the frequency for which it is designed.

Recall that if the feed point impedance of the antenna does not match that of the feeder, energy will be reflected back down the feeder and that the proportion reflected depends upon the degree of mismatch.

Recall that a centre fed half-wave dipole has a feed point impedance of 73Ω in free space and that under practical conditions (e.g. due to ground proximity effects) this will be approximately 50Ω when used at its designed frequency.

5D Types of antenna

5D1 Identify the half-wave dipole, λ/4 (quarter wavelength) ground plane, Yagi, end-fed wire, 5/8 λ (five eighths wavelength) and parabolic (also known as 'aperture') antennas.

Recall that Yagi antennas have a half-wave driven element, a reflector that is slightly longer than the driven element and directors that are slightly shorter than the driven element.

Recall that an antenna trap is a parallel tuned circuit and understand how it enables a single antenna to be resonant and have an acceptable feed-point impedance on more than one frequency.

Recall that this technique may be extended to multi-element antennas such as Yagis.

5D2 Recall the current and voltage distribution on the centre fed dipole and λ/4 ground plane antennas.

Recall the feed point impedances of centre fed half-wave dipoles, quarter-wave and loaded 5/8 λ verticals, folded dipoles, full-wave loops and end fed λ/4 and λ/2 antennas.

Calculate suitable dimensions for dipole antennas allowing for end-factor correction.

Recall the effect of passive antenna elements on feed point impedance and the use of folded dipoles in Yagi antennas.

5E Standing waves

5E1 Understand the cause of standing waves and that the standing wave ratio (SWR) is a measure of the signal travelling back down the feeder expressed in terms of the standing waves caused by the reflected signal voltage (or current).

Recall that both forward and reflected signals are subjected to feeder loss.

Understand the effect of standing waves on the input impedance to the feeder.

5E2 Recall that return loss is the ratio of the forward signal power to the return signal power; normally expressed in dB.

Understand that a low SWR equates to a high return loss and a high SWR equates to a low return loss.

Understand that the loss in the feeder will reduce the SWR and increase the return loss as measured at the transmitter and that the SWR at the antenna is unaffected.

Recall that Return Loss at transmitter = Return Loss at antenna + 2 x (feeder loss).

5F Antenna matching units

5F1 Understand that Antenna Matching Units (AMUs) can cancel reactive components of the antenna system feed point impedance (before or after the feeder) and can transform impedances to an acceptable resistive value.

Understand that an AMU does not tune the feeder or the antenna to resonance.

Understand that if the AMU is located at the transmitter, it will have no effect on the actual SWR on the feeder between the AMU and antenna.

Identify typical AMU circuits i.e. T, Pi (p) and L circuits.

5F2 Understand that a quarter-wavelength of feeder can be used as an impedance transformer. Apply simple examples of the formula $Z_o^2 = Zin \times Zout$.

5G Plugs and Sockets

5G1 Recall that the plugs and sockets for RF should be of the correct type and that the braid of coaxial cable must be correctly connected to minimise RF signals getting into or out of the cable.

Identify BNC, N, SMA and PL259 plugs as shown in Table 2.

Note that correctly connected *means screen and inner conductor continuity through every plug and socket.*

Section 6 – Propagation

6A Radio propagation: key concepts

6A1 Recall that far away from a source, electromagnetic waves spread out according to an inverse square law of power flux density and that the electric field strength, measured in volts/metre, drops linearly with distance.

Note: Numerical calculations required at item 6E1 only.

6A2 Understand the meaning of ground wave, tropospheric (space) wave, sky wave, skip distance and skip zone (dead zone).

Recall that VHF and UHF signals normally pass through the ionosphere and at these frequencies propagation is within the troposphere situated below the ionosphere.

Recall that the ground wave has a limited range due to absorption of energy in the ground and that the loss increases with increasing frequency.

6A3 Recall that an electromagnetic wave comprises E and H fields in phase, at right-angles to each other and to the direction of travel.

Recall that the orientation of the E-field defines the polarisation of the electromagnetic wave.

Recall that the power flux density in Watts/m^2 is given by the product of E and H

Recall that in circular polarisation, the polarisation of the wave rotates as it propagates, with either a right-handed (clockwise from behind) or left-handed polarisation.

Recall that this is often used for satellite communication where the orientation of the satellite is indeterminate.

6B Ionosphere

6B1 Understand that the ionosphere comprises layers of ionised gases and that the ionisation is caused by solar emissions including ultra-violet radiation and charged solar particles.

Recall the ionospheric layers (D, E, F1 and F2) and approximate heights.

Recall that on HF most communication relies on the waves being refracted in the ionosphere and that the level of ionisation changes with the time of day, the time of year and according to the sunspot cycle (approximately 11 years).

Understand that it is the level of ionisation that determines the ability of the ionosphere to refract radio waves and that higher frequencies are harder to refract.

Understand that the sunspot number is an indicator of solar activity and that more sunspots give better HF propagation as a result of increased ionisation.

Understand the effects of Solar flares on propagation.

Note: The heights of the ionospheric layers vary on a daily, annual, and 11-year sunspot activity basis.

For the purposes of the examination the approximate heights are: D 70-80km; E 120km ; F1 200km; F2 300-400km.

6B2 Recall that the F2 layer provides the furthest refractions for HF signals (about 4000km) and that the F layers combine at night.

Recall that multiple hops permit worldwide propagation.

Understand how fading occurs and its effect on the received signal.

Recall that refraction within the ionosphere can change the polarisation of a radio wave.
Recall that Short Path ionospheric propagation of HF signals is the most direct route around the earth.

Recall that Long Path ionospheric propagation is where HF signals are received via the opposite route around the earth to the Short Path.

6B3 Recall that the D layer tends to absorb the lower radio frequencies during daylight hours and that it tends to disappear at night.

Recall that the lowest frequency that can pass through the D-layer without significant absorption is the lowest usable frequency (LUF)

Recall that the highest frequency that will be refracted over a given path is known as the maximum usable frequency (MUF).

Understand that if the D-layer absorption (LUF) occurs at frequencies higher than the MUF then no ionospheric propagation can occur.

Recall that the highest frequency that will be refracted back to the transmitter is known as the Critical Frequency of Vertical Incidence (critical frequency).

Recall that the MUF will be higher than the critical frequency.

Recall, in general terms how the MUF varies over the 24 hour cycle and the variation in MUF from summer to winter.

Recall that propagation where the signals are reflected vertically back from the ionosphere is known as Near Vertical Incidence Sky wave (NVIS).

Recall that NVIS is a technique employed on some low frequency bands (e.g. 5MHz) to make contacts over relatively short distances.

6B4 Recall that in addition to VHF and UHF, HF transmissions may be affected by Sporadic E propagation.

Recall that the height of the E layer will support a single hop of up to about 2000km and that multi-hop propagation can occur.

6C VHF and above

6C1 Recall that hills cause radio shadows and that signals become weaker as they penetrate buildings.

Recall that at VHF/UHF range decreases as frequency increases and that in general VHF/UHF waves have a range not much beyond line-of-sight.

Recall that certain atmospheric conditions can increase the range of VHF/UHF signals.

Recall that the range achieved at VHF/UHF is dependent on antenna height, antenna gain, having a clear path and transmitter power.

Understand that higher antennas are preferable to higher power as they improve both transmit and receive performance.

Recall that outdoor antennas will perform better than indoor antennas.

At VHF and above, multipath propagation can occur where signals are reflected off objects (such as a buildings or aircraft) and the reflected signal is received in addition to the direct signal.

6C2 Recall that falling snow, ice and heavy rain can attenuate signals at UHF and above.

6C3 Recall that contacts at VHF and above can be made by reflecting signals off the lunar surface and that this is known as Earth-Moon-Earth (EME) propagation.

Understand that as the Moon is a poor reflector of radio frequency signals and is a long way from the Earth, EME contacts generally need high power and high gain antennas accurately pointed at the Moon, and very sensitive, low noise receivers or the use of special low-signal strength modes to overcome the path loss.

Recall that it is possible to make contacts on the VHF bands by reflecting signals off the ionised gases created during an aurora and that this occurs at high northerly and southerly latitudes and that this is known as auroral propagation.

Recall that auroral ionised curtains form vertically in the ionosphere and that movement of these curtains cause rapid flutter on the signals.

6D Other features

6D1 Understand the factors affecting a link budget: transmitter power, feeder losses, antenna gains, path loss and receiver sensitivity.

Recall that path loss includes spreading loss and obstruction losses.

Section 7 – Electromagnetic compatibility (EMC)

7A EMC concepts

7A1 Understand that all electronic equipment is capable of radiating and absorbing radio frequency energy.

Recall that the basic principle of electromagnetic compatibility is that apparatus should be able to function satisfactorily in its electromagnetic environment without causing undue electromagnetic disturbance to other apparatus in that environment.

7A2 Understand that the immunity of a device is affected by the nature of its installation and that poor installation of an otherwise good item of equipment can compromise its safe and compliant operation.

Recall that the immunity of a device can often be improved by screening and filtering power, signal and control leads.

7A3 Understand that transmitters in domestic environments may give rise to RF fields stronger than the agreed immunity limits and special measures may have to be taken.

Understand that new electronic equipment should meet the British Standards Institute immunity requirements, but that existing equipment and poorly installed equipment may not.

7A4 Understand that screening with thin metal sheet is effective in reducing unwanted radiation from equipment and/or between stages within equipment.

7B Sources of interference and their effects

7B1 Recall that the more power a station runs, the more likely it is to cause interference.

Recall that speech transmissions, particularly AM and SSB may cause speech like sounds in analogue radio, audio systems and telephones.

Recall that FM transmission is less likely to cause problems but may mute or reduce the volume of the wanted signals (audio or RF).

7B2 Recall that some imported or home constructed electronic equipment may not meet relevant EMC standards.

Recall that radio amateurs are not required to demonstrate compliance with EMC standards for equipment they put into service but remain responsible for complying with Licence requirements regarding interference.

Recall that items containing radio communication facilities such as cordless and mobile telephones and information technology communication equipment may produce sufficiently strong signals to cause short range interference but are otherwise generally satisfactory.

Recall that imported devices and toys may not be compliant with the relevant standards.

7B3 Understand that blocking (or desensitisation) is an effect in a radio receiver where a strong, constant level interfering signal e.g. FM either swamps the wanted signal or drives the affected circuits out of their normal operating range such that the received audio or data is severely attenuated or muted.

Understand that cross-modulation is an effect in a radio receiver where the interfering signal is varying in strength e.g. AM or SSB such that the modulation on the interfering signal is added to the modulation on the wanted signal such that both may be heard with varying clarity.

7B4 Recall non-radio sources of interference and their effects:

- Arcing thermostats.
- Vehicle ignition systems.
- Electric Motors.
- Computers and peripherals.
- Switch mode power supplies.
- Plasma TVs.
- Very high bit rate digital subscriber line (VDSL) (broadband) equipment.
- LED lighting.
- Solar photovoltaic (PV) inverters.

Recall that this gives rise to various buzzing sounds on analogue radio receivers which can correlate with the nature and use of the interference source e.g. bursts of interference when a thermostat opens or closes.

Recall that interference to Digital Audio Broadcasting (DAB) may cause loss of signal (muted audio) and interference to digital televisions may cause the picture to freeze, pixelate (break up into larger squares), become jerky or disappear.

7C Routes of entry

7C1 Recall that interference occurs through local radio transmissions being conveyed to the affected equipment through pick-up in house wiring, TV antenna down-leads, telephone wiring etc and by direct pick-up.

Recall that direct pick up in affected devices tends to be independent of a specific frequency within a band although differences may be noticed between different bands. Direct pickup is especially an issue in the VHF/UHF bands.

Recall that amateur transmissions can enter audio stages via long speaker leads or other interconnections.

Understand that any semiconductor or diode junction within an electronic device can demodulate unwanted RF.

7C2 Understand that many TV mast-head and distribution amplifiers are wideband devices and can suffer from cross-modulation and overload causing intermodulation and blocking, and may also overload the TV.

7C3 Understand that amateur transmissions can be picked up by the intermediate frequency stages of TV and radio receivers.

Understand the potential for image frequency interference to analogue and digital radio.

Understand that television receivers and most broadcast radio receivers employ superhet circuits.

Recall the following typical frequencies used in radio and television receivers:

- Medium Wave radio broadcast 526 - 1606kHz
- VHF FM radio broadcast 87.5 - 108MHz
- VHF DAB radio broadcast 174 - 230MHz
- TV broadcast 470 - 694MHz
- Radio IFs typically 455 - 500kHz and 10.7MHz.

Note: Current design digital TV receivers use a variety of Intermediate frequencies between 4 and 39MHz

7C4 Recall that passive intermodulation products can be caused by corroded contacts in any metalwork, including transmitting and receiving antennas, supports and guttering.

7D Filtering and remedial measures

7D1 Understand that filters can be fitted in the leads from the power supply to the transmitter to help minimise RF energy entering the mains wiring.

Understand the use of mains filters to reduce RF, electric motor and thermostat interference to TV, radio and audio systems.

Understand the circuits of simple low pass, high pass, band pass and band stop (notch) filters and their response curves.

Understand the use of high, low, band pass and band stop (notch) filters of L, T and π configuration, including coaxial stubs as notch filters or traps, in improving the immunity of affected devices.

Recall the use of ferrite beads or rings in internal and external filtering.

Understand why a ferrite ring will attenuate common-mode currents without affecting the differential-mode wanted signal.

Recall that the filters should be fitted as close to the affected device as possible.

7D2 Understand the construction and use of a typical mains filter.

Identify a typical circuit of a braid breaking filter and a combined high pass/braid breaking filter and understand their use.

7D3 Recall how to use a suitable general coverage receiver to check for spurious and harmonic emissions from the station.

7D4 Understand the use of a dummy load in fault finding.

Recall that the resistor(s) used in a dummy load must be non-reactive, screened, and of a suitable power rating.

Recall how to use a dummy load to check if interference is being caused by a signal being radiated or leaking into the mains or other wiring.

7E Station design and antenna placement/general principles

7E1 Recall that EMC problems can be minimised by siting antennas as far away from houses as possible, as high as possible, and using balanced antennas at HF.

Recall that, at HF, horizontal dipoles are less likely to be a problem and that end-fed wires can present significant EMC problems.

Recall that balanced antenna systems tend to cause fewer EMC problems than unbalanced antennas.

Recall that both balanced and unbalanced feeders should leave the antenna at right-angles to minimise coupling.

Understand that siting a transmitting antenna close to mains wiring, TV or radio antennas and down-leads is a potential problem exacerbated by the use of a loft or indoor transmitting antenna.

Recall that information on the avoidance of interference by the correct choice and siting of antennas and suitable operating procedures is readily available from several sources.

Recall how to interconnect the transmitter, microphone, power supply, SWR meter and band or low pass filters, using appropriate cables, to minimise EMC problems.

Recall that reducing field strength to the minimum required for effective communication is good practice.

Apply the formula for the field strength surrounding an antenna given the ERP and distance from it.

Recall that information on avoiding interference can be obtained from the RSGB's EMC team and experienced local amateur radio club members.

7E2 Understand good RF grounding and bonding techniques.

Understand the effects of inadequate RF grounding and bonding.

7F Station design and antenna placement/mobile installations

7F1 Recall that the source document defining best practice for mobile installations is the Federation of Communication Services UK Code of Practice for the installation of mobile radio and related ancillary equipment in land based vehicles and that the vehicle manufacturer should be consulted for any vehicle specific requirements.

Recall that it is the vehicle owner’s responsibility to ensure that any radio installation is compatible with the vehicle's electrical and management systems and does not affect vehicle safety.

Recall that you may need to disclose to the company providing your motor insurance that you have installed the radio equipment in the vehicle.

Recall that professional advice should be sought for all vehicle installations.

7F2 Understand how to minimise the likelihood of stray RF currents entering the vehicle wiring and electronics.

Understand that mobile antenna location can affect the radiation field strength within the vehicle; e.g. wing or boot mounted antennas are likely to produce higher exposures than roof mounted antennas.

7G Social aspects and testing

7G1 Recall that EMC problems have the potential for causing neighbour disputes.

Recall the correct procedures for dealing with EMC complaints, whilst understanding that although new electronic equipment should meet the EMC standards, some existing equipment may not.

Recall that the RSGB provides information leaflets on EMC and interference.

Recall that advice is available from the RSGB EMC Committee.

7G2 Understand that a station log may help to deal with complaints of interference, and that this is a good reason to keep a log of all transmissions.

Understand the merits of both the amateur and the complainant keeping a log of the instances of interference.

Understand the merit of conducting tests in co-operation with the complainant in instances of interference.

Section 8 – Safety

8A Electricity

8A1 Understand that lethal voltages can exist in equipment and that live circuits may be exposed as soon as the equipment case is removed.

8A2 Recall that where a safety earth has been fitted that it must not be removed.

Recall that when considering safety earthing and RF earthing, professional advice must be obtained from a qualified electrician.

8A3 Recall the correct way to wire a 3-pin mains plug.

Recall that equipment fuses may be of a special type, such as quick blow or slow blow to allow for an initial surge of current and that the specified type must be fitted and different types are not interchangeable.

Understand that a fuse must be correctly rated for proper protection, or in accordance with the equipment manufacturers instructions.

8A4 Understand that an RCBO (Residual Current Circuit Breaker with Overcurrent protection) will give better protection against electric shock than relying solely on a conventional fuse which only protects against excessive current.

Note: The candidate must understand that an RCBO will detect currents to earth of about 30mA whereas a fuse will only blow at several amps and only when the fault is a short circuit (L-N or L-E). The candidate should also understand that adequate protection may not be provided in the event of contact with both live and neutral conductors.

The mechanics of RCBO operation (differential current sensing) is not examinable.

8A5 Understand that no work should be undertaken on live equipment unless it is not practicable to do otherwise.

Recall the appropriate precautions that must be taken to avoid electric shock.

E.g. Isolation transformer, insulated tool handles, one hand in pocket or behind back, rubber mats on work bench and floor or rubber soled shoes, master ‘off’ switch and availability of assistance.

8A6 Understand that all equipment should be controlled by a clearly marked master switch, the position of which should be known to others in the house or club.

Recall that, in the event of an accident or fire involving electricity, the first action is to switch off the power.

Recall that any casualties must not be touched unless the power has been switched off.

8A7 Understand that some batteries can supply very high currents which can be hazardous if subjected to short circuit.

Recall that battery charging must be in accordance with the manufacturer's instructions and that lithium batteries in particular can cause fire and explosion if not properly treated.

Understand that different battery technologies require different charging techniques and the correct type of charger must always be used.

Understand that vehicle batteries are a source of very high currents which can start a fire and that battery contents are corrosive.

Understand that hydrogen gas can be given off when charging batteries and that ample ventilation is required to prevent accumulation of explosive mixtures.

8B Using tools

8B1 Recall that eye protection must be worn when using tools to prevent eye damage from small particles, e.g. swarf.

8B2 Recall that all tools, including power tools, can be hazardous and should be handled with care and appropriate precautions taken.

Understand that one should be working behind the direction of operation of sharp tools.

8B3 Understand that any items being drilled, sawn or filed must be securely held in a vice or similar device to prevent them slipping or rotating.

8B4 Understand that the chuck key must be removed before using a power tool to prevent the key being ejected at high speed.

8B5 Understand that using a centre punch will help prevent a drill bit slipping.

8B6 Understand the reasons why a bench-mounted pillar drill is safer than a hand-held drill.

8B7 Understand that eye protection must be worn when soldering to prevent solder or flux from splashing into the eyes.

Understand that a soldering-iron stand must be used to avoid skin contact with the hot bit of the iron when not in use.

Understand that soldering workstations must be well ventilated to avoid inhalation of solder fumes, which can cause breathing problems particularly to people suffering from breathing disorders e.g. asthma.

8C Working at height

8C1 Recall that antenna erection is potentially hazardous and that it is advisable to have a responsible person to assist.

Recall that a ladder should be used at the correct angle (4:1 height-to-base ratio).

Understand that ladders must be adequately secured to prevent them slipping.

Understand why it is important not to overreach from a ladder, to prevent falling off.

8C2 Understand why, when working at height, a tool belt or similar device to carry tools should be used, and that it will help prevent falling objects.

Understand the need to wear hard hats when working at height or when others are working at height.

8D Working with RF

8D1 Understand what a waveguide is and why it is unwise to look down a waveguide or to stand close to or in front of high gain antennas as they may be in use.

8D2 Recall that antenna elements and other conductors carrying RF should not be touched whilst transmitting.

Recall that antennas should be mounted where people will not come into accidental contact with them.

Note: this does not apply to low powered devices such as hand-held equipment.

8E Lightning

8E1 Recall that thunderstorms carry significant static charges.

Understand that the static charge from thunderclouds can ionise the air to form a low resistance path to ground, enabling a very high current to flow as a lightning strike.

Understand the risks to human life, domestic property and electronic equipment associated with a direct strike and/or the build-up of static charges.

Understand that there is little that can be done to protect an amateur station from a direct lightning strike, but that good static discharge systems can prevent dangerous static charges building up on antenna systems during thunderstorms.

Understand that disconnecting antenna feeders from radio equipment also reduces the risks.

Recall that the local authority building department may be able to offer advice.

8F Working mobile and portable

8F1 Recall that elevated wires, masts and antennas must be suitably located and secured.

Recall that antennas and feeders must not be sited close to overhead power cables.

Recall that a lethal electric shock can result from antennas and ladders coming into contact with or attracting arcing from overhead lines.

8F2 Understand the reasons for not having wires trailing across the floor: trip hazards and the risk of frayed insulation.

8F3 Recall that excessive volume when wearing headphones can cause damage to hearing.

8F4 Recall that safety is everybody's responsibility and that one must be alert to any potentially unsafe circumstance, warn others and report the matter to the appropriate person.

Recall this equally applies in the 'shack' and when entertaining visitors.

Understand that operating in temporary premises and/or outdoors can introduce new hazards i.e. overhead power lines, inadequate electrical supplies, trailing cables, damp ground, and excessive field strengths.

Recall the additional safety precautions that should be taken whilst operating in temporary premises and/or outdoors i.e.

- site survey/risk assessment,
- cable routing/protection,
- correct fusing,
- use of Residual Current Devices (RCD's, RCBO's) • no adjustments or repairs to live equipment.

Recall that mains supplies in other countries may be of a different voltage or frequency, utilise different plugs and sockets and that UK specified equipment may not be suitable or hazardous if connected and used.

8F5 Understand that operating when mobile or maritime mobile can introduce new hazards e.g. insecure equipment, long/flexible antennas, accidental shorts to earth, lack of attention to driving.

Recall the additional safety precautions that should be taken whilst operating mobile and/or maritime mobile e.g. secure equipment, cable routing/protection, correct fusing, use of hands-free equipment, attention to good radio housekeeping.

8F6 Understand that a risk assessment should be performed when an activity could present a hazard to self or others.

Understand that risk assessment involves identification of hazards and the measures to mitigate the risk.

Recall a risk assessment needs to consider the likelihood of harm and the severity of that harm.

Recall that the significant findings of risk assessments need to be recorded.

Recall that risk assessment records are important in law and for insurance purposes.

Recall that risks should be expressed in understandable terms.

Recall that appropriate insurances should be obtained for all amateur radio activities but in particular where the public could be involved.

8F7 Recall the hazards associated with the use of electrical generators, electric shock, fuel storage, refilling, non-use indoors, carbon monoxide.

Section 9 – Measurements and construction

9A Measurements

9A1 Understand the use of series multiplier resistors in analogue voltmeters and parallel (shunts) in ammeters.

Understand the effect of the test meter on the circuit under test.

9A2 Understand the effect of measurement tolerance, calibration accuracy and time related drift on frequency measurements and the allowances to be made for transmission bandwidths.

9A3 Understand that signal generators and similar devices will have a source impedance and the effect on the signal level of attaching different load impedances.

Recall that not all measuring equipment will have a 50Ω input impedance.

Understand that the choice of measuring equipment may have an effect on the measurement result and on the object under test.

9A4 Understand that steady RF power may be determined by measuring the RF potential difference across a dummy load and that a steady audio signal, e.g. from an audio oscillator, will be required for AM and SSB measurements.

Understand the meaning of peak envelope power (PEP) of an SSB transmission and that it may be determined using a peak reading power meter or an oscilloscope and dummy load.

9A5 Recall the uses and limitations of crystal calibrators, digital frequency counters and standard frequency transmissions.

9A6 Identify the circuit of an SWR meter using either a sense-wire between the inner and outer conductors of a coaxial line or a current transformer and capacitive voltage tap.

Understand in simple terms how this leads to an SWR reading on devices using a single meter, twin meters or cross-needle twin meter.

9A7 Understand the purpose and basic operation of an oscilloscope.

Calculate the frequency and voltage of a waveform from given data.

Recall that the common lead on the oscilloscope is normally earthed and care must be taken when taking readings in high voltage circuits.

9A8 Understand the purpose and basic operation of a spectrum analyser.

Identify the fundamental and harmonics on a typical spectrum analyser display.

9B Decibels

9B1 Understand the meaning and use of decibels (dB)

Recall that dB represent a power ratio.

Recall that a power gain of 3dB equates to doubling the power and 10dB equates to a power tenfold increase.

Calculate the power gain or loss of various dB ratios. This includes examples such as 25W is equivalent to 14dBW.

Recall the meaning of:

- dBW (comparison with 1 W)
- dBi (comparison with an isotopic radiator) and • dBd (comparison with a half wave dipole).
- dBm (comparison with 1mW)
- dBV (comparison with 1V)

9C Components

9C1 Understand component tolerances and the effects they may have in circuit operation.

Recall that temperature has an effect on the value of components. Those with negative coefficients will decrease in value as temperature rises whereas those with positive coefficients will increase in value.

Understand the effect this will have on tuned circuits and remedial measures.

Note. Questions may include simple calculations.

9C2 Recall the resistor colour code, colours 0 to 9 with gold as multiplier.

Recall silver (10%) and gold (5%) as tolerance bands.

Identify the value of a resistor between 1Ω and 9MΩ from the E12 series.

Recall how to read both 4 band and 5 band resistors.

Note: Actual encoding or decoding of colours will be either 4 band or 5 band resistors. Candidates are not expected to know the values of the E12 series.

9D Soldering

9D1 Understand that soldering is a method of joining metal wires and components using solder and a hot soldering iron.

Recall that solder is a low melting point alloy and that many solders contain a flux to help the solder to flow and to prevent a layer of oxide forming on the surfaces to be joined.

Recall that some metals are easier to solder than others.

Understand that the tip of the soldering iron has to be cleaned to help remove any oxide and then tinned to prevent the oxide re-forming and to improve the conduction of heat to the joint.

Understand the reason for tinning wires prior to soldering.

Radio Society of Great Britain

Full Licence

Amateur Radio

Band Plans

For Examination use only

472 kHz (600m)	Necessary Bandwidth	UK Usage
472-479 kHz (Note-2)	**500**	**CW, QRSS and narrow-band digital modes (Note-1)**

Note-1: Usage recommendation: - 472-475 kHz CW-only 200Hz max BW, 475-479 kHz - CW & Digimodes

Note-2: It should be emphasised that this band is available on a non-interference basis to existing services.
UK amateurs should be aware that some overseas stations may be restricted in their use of transmit frequency in order avoid interference to nearby radionavigation service Non-Directional Beacons

LICENCE NOTES: Amateur Service **Secondary User.** Full Licensees only **- 5 Watts eirp maximum**
Note that specific conditions regarding this band are specified by the Licence Schedule notes

R.R. 5.80B The use of the frequency band 472-479 kHz in Algeria, Saudi Arabia, Azerbaijan, Bahrain, Belarus, China, Comoros, Djibouti, Egypt, United Arab Emirates, the Russian Federation, Iraq, Jordan, Kazakhstan, Kuwait, Lebanon, Libya, Mauritania, Oman, Uzbekistan, Qatar, Syrian Arab Republic, Kyrgyzstan, Somalia, Sudan, Tunisia and Yemen is limited to the maritime mobile and aeronautical radionavigation services. The amateur service shall not be used in the above-mentioned countries in this frequency band, and this should be taken into account by the countries authorizing such use. (WRC 12)

5 MHz (60m)	Available Width	UK Usage
5258.5 - 5264.0 kHz	5.5 kHz	**5262 kHz** - CW QRP Centre of Activity
5276.0 - 5284.0	8 kHz	**5278.5 kHz -** may be used for UK emergency comms traffic
5288.5 - 5292.0	3.5 kHz	**Beacons on 5290 kHz (Note-2)**
5298.0 - 5307.0	9 kHz	
5313.0 - 5323.0	10 kHz	**5317 kHz -** AM 6kHz max. bandwidth
5333.0 - 5338.0	5 kHz	
5354.0 - 5358.0	4 kHz	Within WRC-15 Band
5362.0 - 5374.5	12.5 kHz	Partly within WRC-15 band, WSPR
5378.0 - 5382.0	4 kHz	
5395.0 - 5401.5	6.5 kHz	
5403.5 - 5406.5	3 kHz	

Unless indicated, usage is all-modes (necessary bandwidth to be within channel limits)
Note 1: Upper Sideband is recommended for SSB activity.
Note 2: Activity should avoid interference to the experimental beacons on 5290 kHz
Note 3: Amplitude Modulation is permitted with a maximum bandwidth of 6kHz, on frequencies with at least 6kHz available width
Note 4: Contacts within the UK should avoid the WRC-15 band (5351.5 - 5366.5 kHz) if possible
For the latest current guidance refer to the RSGB website

LICENCE NOTES: Full Licensees only **Secondary User: 100W max**
Note that specific conditions regarding operating, transmission bandwidth, power and antennas are specified in the Licence

Notes to the Usage Plan

ITU-R Recommendation SM.328 (extract)
Necessary bandwidth: For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.

14MHz (20m)	Necessary Bandwidth	UK Usage
14,000-14,060 kHz	200 Hz	**Telegraphy - contest preferred** 14,055 kHz QRS (slow telegraphy Centre of Activity
14,060-14,070	200 Hz	**Telegraphy** 14,060 kHz QRP (low power) Centre of Activity
14,070-14,089	500 Hz	**Narrow band modes**
14,089-14,099	500 Hz	**Narrow band modes -** automatically controlled data stations (unattended)
14,099-14,101		**IBP - reserved exclusively for beacons**
14,101-14,112	2.7 kHz	**All modes -** automatically controlled data stations (unattended)
14,112-14,125	2.7 kHz	**All modes (excluding digimodes)**
14,125-14,300	2.7 kHz	**All modes -** SSB contest preferred segment 14,130kHz - digital voice centre of activity 14,195+- 5 kHz Priority for Dxpeditions 14,230 kHz - Image Centre of Activity. 14,285 kHz - QRP Centre of Activity
14,300-14,350	2.7 kHz	**All modes** 14,300 kHz Global Emergency Centre of Activity
LICENCE NOTES: Amateur Service **- Primary User.** 14,000-14,250 kHz Amateur Satellite Service - **Primary User.**		

Notes to the Band Plan

ITU-R Recommendation SM.328 (extract)
Necessary bandwidth: For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.

The use of Amplitude Modulation (AM) is acceptable in the all modes segments but users are asked to consider adjacent channel activity when selecting operating frequencies.

Foundation and Intermediate Licence holders are advised to check their licences for the permitted power limits and conditions applicable to their class of licence.

144 MHz (2m)	Necessary Bandwidth	UK Usage
144.000-144.025 MHz	2700Hz	**All modes** - including Satellite downlinks
144.025-144.100 MHz	500Hz	**Telegraphy** (including EME CW)
		144.050 MHz Telegraphy Centre of Activity
		144.100 MHz Random MS telegraphy calling (Note 1)
144.100-144.150	500Hz	**Telegraphy and MGM**
		EME MGM activity
144.150-144.400	2700Hz	**Telegraphy, MGM and SSB**
		144.250 MHz GB2RS news broadcast and slow Morse
		144.260 MHz See Note 10
		144.300 MHz SSB Centre of Activity
		144.370 MHz MGM MS calling
144.400-144.490		**Propagation Beacons only**
144.490-144.500		**Beacon guard band**
		144.491-144.493 MHz Personal Weak Signal MGM Beacons (BW: 500 Hz max)
144.500-144.794	20 kHz	**All Modes** (Note-8)
		144.500 MHz Image Modes (SSTV, Fax etc)
		144.600 MHz Data Centre of Activity (MGM, RTTY etc)
		144.6125 MHz UK Digital Voice (DV) calling (Note 9)
		144.625-144.675 MHz See Note 10
		144.750 MHz ATV Talk-back
		144.775-144.794 MHz See Note 10
144.794-144.990	12 kHz	**MGM / Digital Communications**
		144.800-144.9875 MHz Digital modes (including unattended)
		144.8000 MHz Unconnected nets - APRS, UiView etc (Note 14)
		144.8125 MHz DV Internet voice gateway (IARU common channel)
		144.8250 MHz DV Internet voice gateway (IARU common channel)
		144.8375 MHz DV Internet voice gateway (IARU common channel)
		144.8500 MHz DV Internet voice gateway (IARU common channel)
		144.8625 MHz DV Internet voice gateway (IARU common channel)
		144.8750 - 144.9125 MHz - Internet Gateways
		144.9250 MHz Digital usage
		144.9375 MHz Digital usage
		144.9500 MHz Digital usage
		144.9625 MHz FM Internet voice gateway
		144.9750, 144.9875 MHz tbd (Note 11)
144.990-145.1935	12 kHz	**FM/DV** RV48 - RV63 Repeater input exclusive (Note 2) (Note 5)
145.200	12 kHz	**FM/DV** Space communications (e.g. I.S.S.) - Earth-to-Space
		145.2000 MHz (Note 4) & (Note 10)
145.200-145.5935	12 kHz	**FM/DV** V16-V47 FM/DV simplex (Note 3) (Note 5) (Note-6)
		145.2250 MHz See Note 10
		145.2375 MHz FM Internet voice gateway (IARU common channel)
		145.2500 MHz Used for slow Morse transmissions
		145.2875 MHz FM Internet voice gateway (IARU common channel)
		145.3375 MHz FM Internet voice gateway (IARU common channel)
		145.5000 MHz FM calling (Note 12)
		145.5250 MHz Used for GB2RS news broadcast.
		145.5500 MHz Used for rally/exhibition talk-in
		145.5750, 145.5875 MHz (Note 11)
145.5935-145.7935	12 kHz	**FM/DV** RV48 - RV63 Repeater output (Note 2)
145.800	12 kHz	**FM/DV** Space communications (e.g. I.S.S.) - Space-Earth
145.806-146.000	12 kHz	**All Modes** - Satellite exclusive

Note 1: Meteor scatter operation can take place up to 26kHz higher than the reference frequency.
Note 2: 12.5kHz channels numbered RV48-RV63. RV48 input = 145.000 MHz, output=145.600 MHz.
Note 3: 12.5kHz simplex channels numbered V16-V47. V16=145.200 MHz.
Note 4: Emergency Communications Groups utilising this frequency should take steps to avoid interference to ISS operations in non-emergency situations.
Note 5: Embedded data traffic is allowed with digital voice (DV)
Note 6: Simplex use only - no DV gateways
Note 7: not used
Note 8: Amplitude Modulation (AM) is acceptable within the All Modes segment. AM usage is typically found on 144.550MHz. Users should consider adjacent channel activity when selecting operating frequencies
Note 9: In other countries IARU Region-1 recommend 145.375 MHz
Note 10: May be used for Emergency Communications and Community Events
Note 11: May be used for repeaters in other IARU Region-1 countries
Note 12: DV users are asked not to use this channel, and use 144.6125 MHz for calling.
Note 13: not used
Note 14: 144.800 use should be NBFM to avoid interference to 144.8125 DV Gateways

LICENCE NOTES: Amateur Service and Amateur Satellite Service - **Primary User.**
Beacons may be established for DF competitions except within 50 km of TA 012869 (Scarborough)

Formula sheet

$R_T = R_1 + R_2 + R_3$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	$V = IR$
$V_{out} = V_{in}\frac{R_2}{R_1 + R_2}$	$P = IV = \frac{V^2}{R} = I^2R$	$V_{rms} = \frac{V_{peak}}{\sqrt{2}}$
$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	$C_T = C_1 + C_2 + C_3$	$C = \frac{k_A}{d}$ where $k = \varepsilon_0\varepsilon_r$
$L_T = L_1 + L_2 + L_3$	$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$	$X_L = 2\pi fL$
$Z = \sqrt{R^2 + X^2}$	$V_T = \sqrt{{V_R}^2 + {V_C}^2}$ (or ${V_L}^2$)	$X_C = \frac{1}{2\pi fC}$
$f = \frac{1}{2\pi\sqrt{LC}}$	$t = \frac{1}{f}$	$t = CR$
$Q = \frac{2\pi fL}{R}$ or $\frac{1}{2\pi fCR}$	$Q = \frac{f_C}{f_U - f_L} = \frac{centre\ frequency}{bandwidth}$	$R_D = \frac{L}{CR}$
$Q = 2\pi fCR_D$	$bw = 2(AF_{max} + \Delta f)$	
$V_S = V_P\frac{N_S}{N_P}$	$I_P = I_S\frac{N_S}{N_P}$	$Z_P = Z_S\left(\frac{N_P}{N_S}\right)^2$
$I_C = \beta I_B$	$f_{step} = \frac{f_{crystal}}{A}$	$f_{out} = f_{crystal}\frac{N}{A}$
$v = 3 \times 10^8$ m/s	$E = \frac{7\sqrt{erp}}{d} = \frac{5.5\sqrt{eirp}}{d}$	$SWR = \frac{V_{max}}{V_{min}} = \frac{V_f + V_r}{V_f - V_r}$
$v = fl$	$erp = power \times gain$ (wrt dipole) $eirp = power \acute{} gain$ (isotropic)	${Z_0}^2 = Z_{in} \times Z_{out}$

$Gain(loss) = 20Log_{10}\frac{V_{out}}{V_{in}}$ dB	$Return\ loss = 10\ Log_{10}\frac{Incident\ power}{Reflected\ power}$ dB
$Gain\ (loss) = 10Log_{10}\frac{P_{out}}{P_{in}}$ dB	$Gain = 10Log_{10}\frac{Power\ from\ Yagi}{Power\ from\ dipole}$ dBd
$Gain\ (loss) = 10Log_{10}\frac{P_{out}}{P_{in}}$ dB	$Gain = 10Log_{10}\frac{Power\ from\ Yagi}{Power\ from\ isotropic}$ dBi