Radio Communications Foundation

# Advanced Level Certificate in Radio Communications Specification

For Examinations held after 1 July 2007

**Publication date: 22 February 2007**

# Contents



Document changes

| | | |
|---|---|---|
| Issue 3 | January 2007 | Issued in response to licence conditions update in November 2006 |
| Issue 3a | February 2007 | Changes to licence cross-references in syllabus item 2 resulting from lettering changes in licence clause 17(1). |

Section 1

# Syllabus

## Introduction

The Advanced Radio Amateur Examination is the final part of a structured suite of three examinations designed to give access to the amateur radio bands. This examination gives access to the Amateur Radio (Full) Licence. All prospective radio amateurs must demonstrate a suitable level of competence and proficiency as a pre-requisite to holding a licence.

This syllabus sets out the requirements for the final tier in the 3 tier suite. It assumes that candidates have completed the requirements of the Foundation and Intermediate examinations syllabuses and passed the associated examinations.

## Key Features

- Part of a progressive system of learning designed to promote an understanding of radio communications science, technology and practice sufficient to allow the licensed operator to work safely on the amateur radio bands.
- Clear presentation of content for easy reference.
- The examination suite as a whole provides a backbone of theoretical knowledge whilst at the same time requiring 'on-air' experience and practical skills.
- A Syllabus Guide amplifies syllabus points and assessment procedures.
- A students' workbook is available covering the syllabus and giving a scheme of work for a training course whilst being suitable for self-study if desired.
- Can be used within schools to enrich the Science and Technology curriculum.

## The Assessment

Assessment is by a written examination paper of 62 multiple choice questions each with 4 possible responses. The examination lasts 2 hours and is available every 2 months. Papers will continue to be marked centrally and results issued by post within 28 days of the scripts being returned from all participating examination centres. The results will also be entered centrally onto the Ofcom licensing database and candidates will use their candidate number and password to make on-line application for their licence. A postal application option will be available.

## Prior Learning and Progression

A pass in the Intermediate examination is an entry requirement for the Advanced examination. Training may commence at any time and students progress to the Advanced examination at their own pace. Candidates are encouraged to attend a suitable course but there is no obligation to do so.

As this is the final tier of this three tier suite of examinations, there is no formal route within this suite for further progression. 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 sit the examination by whatever means is judged appropriate after consultation with their health professional. This syllabus does not require practical demonstrations and should not therefore represent any disincentive or barrier to students capable of meeting the academic standard required. 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 certificate. Appeals after the examination citing disabilities not previously declared cannot be considered.

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## The Advanced Syllabus

The overarching aim of the Advanced examination is to test the depth of understanding of the candidate. Since they have already successfully completed the first two tiers of the examination suite, it is judged appropriate at this level to encourage candidates to **understand** principles rather than simply recall facts. Where used in the syllabus the term "Recall" indicates a need to memorise a basic fact and apply it fairly directly to a situation or question. Extensive background knowledge and understanding is not expected, although some degree of interpretation may be required in an Advanced examination question.

The term " Understanding" indicates a need to more fully appreciate the origin and implications of a given subject area.

## Examination Questions

Questions on the Advanced syllabus will assume the candidate is familiar with basic principles studied at Foundation and Intermediate levels.
For example, in attempting a question on the subject of interference, the candidate may need to be aware of how unwanted frequencies are produced, their potential to cause interference and how they may enter a victim device. This may require an understanding of the principle of mixing, the production of harmonics, and the recall of susceptible frequencies of the victim device.

It will be assumed that the candidate has some familiarity with amateur operating practices and procedures as outlined in all 3 syllabuses. This will include, for example, a broad understanding of such issues as amateur band plans although examination of specific knowledge will be in line with the syllabus.

Some time spent on-air either as a listener or as an amateur operator at Foundation or Intermediate level will be clearly advantageous in understanding the purpose and context of syllabus items and examination questions.

## Formulae

A formula sheet will be provided during the examination. The formulae will not be titled or explained and candidates will be expected to recognise which formula is appropriate and may need to transpose it depending on the parameter to be calculated.

| *Syllabus* | | *Assessment Objectives* | |
|---|---|---|---|
| | **1. Amateur radio** | | |
| 1a | Nature of Amateur Radio | 1a.1 | Nothing examinable at this level. |
| | **2. Licensing Conditions** | | **Note: that a complete copy of the Licence document and schedules will be provided in the exam.**<br>*Licence clause numbers given below are for ease of reference and do not necessarily indicate that clauses not quoted are outside the scope of the syllabus.* |
| | Licence document | | Understand the licence clauses set out below:<br>This includes the Notes to the licence and schedules. |
| 2a | Types of licence, format of call signs including Regional Secondary Locators | 2a.1 | Identify the types of UK licence and the format of all call signs in use including regional secondary locators, but NOT including club, special event and contest call signs.<br>17(1)(l) 17(2) Licence documents<br>2(1) (a), (b), (c) and (d) 17(1) (b), (x) and (tt) Location<br>13(1), 2(2), 2(3) Notes (d) (e) Identity of Location<br>9(3) Non-use in aircraft, airborne vehicles including clause 17(1)(c) |
| 2b | User Services and international disasters | 2b.1 | 1(2) 17(1)(qq) User Services<br>1(3) International disaster communications.<br>Messages may be passed, internationally, on behalf of non-licensed persons;<br>Recall that non-amateur stations involved in international disaster communications may also be heard on amateur frequencies.<br>*Note: Candidates need only know that the category 1 and 2 responders (in the Civil Contingencies Act) are typically 'blue light' services, central government and local authority emergency planning staff; a full list is not required.* |

| Syllabus | | Assessment Objectives | | |
|---|---|---|---|---|
| 2c | Supervision of licensed and non-licensed persons | 2c.1 | 3(3) | Meaning of 'direct supervision', duties of the supervisor and need for the operator to comply with the licence. |
| | | | 3(3)(a) | Meaning of a recognised training course as defined in clause 17(1)(dd) |
| | | | 3(3)(b) | Use by non-UK licensed persons |
| | | | 3(3)(c) | II. Identification of a Disqualified Person as defined in clause 17(1)(j) and meaning of 'reasonable grounds to believe is not a Disqualified Person'. |
| | | | | III. Meaning of 'Radio Amateurs' Examination Pass Certificate as defined in 17(1)(bb) |
| | | | 3(4) | Procedure for sending Messages by non-licensed persons (greetings messages) |
| | | | 3(5) | Delegation of supervisory responsibility and permitted uses and conditions. |
| 2d | Maritime Mobile operation | 2d.1 | 2(1)(e) | Use whilst Maritime Mobile and meaning of Maritime Mobile as shown in clauses 17(1)(v), (ss). |
| | | | 9(4) | Installation use and changes. |
| | | | 9(5) | Radio silence |
| | | | 9(6) | Know the 3 ITU regions and that the frequencies are given in the ITU Radio Regulations. |
| | | | 5(3) | Close down. |
| | | | 12(2) | Log keeping |
| | | | Note (d) IV | Optional Suffix '/MM' to call sign. |
| 2e | CEPT and reciprocal licensing | 2e.1 | Operation abroad under the CEPT Recommendation and under reciprocal licences. | |
| | | | Nature of CEPT and reciprocal licences | |
| | | | 16(1) | Operation in CEPT countries by UK licensed amateurs. |
| | | | 16(2) | Rules for operation in CEPT countries. |
| | | | Recall that many countries will offer reciprocal licences to UK amateurs with a Full licence and that operation is in accordance with the host country's rules. | |

| Syllabus | | Assessment Objectives | |
|---|---|---|---|
| 2f | Messages | 2f.1 | 11(1) 11(2) 11(3) 11(4) messages.<br>9(7) receipt of messages from amateurs on non-UK frequencies.<br>14(1) 14(2) recorded and re-transmitted messages.<br>Note (i) inappropriate messages. |
| 2g | Unattended operation | 2g.1 | 10(1) 17(1)(ll) Unattended use<br>10(2) 17(1)(ff) Unattended remote control<br>10(3) Remotely controlled equipment not for general use<br>10(4) 10(5) 10(6) 10(7) 11(2) Remote control links |
| 2h | Logging and Identification | 2h.1 | 12(1), Occasions for mandatory log keeping.<br>13(1) Identification |
| 2i | Apparatus, Inspection Closedown and renewal. | 2i.1 | 7(1) 7(3) 7(4) 7(5) 7(6) Equipment.<br>8(1) 5(1) Inspection.<br>5(1) 5(2) Closedown<br>4(1) 4(2) 4(3) 4(4) 4(5) 6(2) 6(3) Note (j) Renewal and revocation. |
| 2j | Schedule | 2j.1 | Clause 9(2) and apply Schedule 1, Table C and the notes to the schedule. |

| *Syllabus* | | *Assessment Objectives* | |
|---|---|---|---|
| **3. Technical Aspects** | | | |
| | | | *Note that any unit prefix from pico to Giga may be used (in multiples of $10^3$) in any question or calculation.* |
| 3a | Potential Difference and Electromotive Force | 3a.1 | Understand the difference between potential difference (p.d.) and electromotive force (e.m.f.). |
| | | | Understand the concept of source resistance (impedance) and voltage drop due to current flow. |
| 3b | Resistance | 3b.1 | Understand and apply the formulae for calculating the combined values of resistors in series and/or in parallel. |
| | | | *Resistors of different values may be used in series, parallel or combined series and parallel circuits.* |
| 3c | Power in DC circuits | 3c.1 | Understand and apply the formulae relating power to potential difference, current and resistance. |
| 3d | Potential dividers | 3d.1 | Understand that two or more resistors can be arranged to act as a potential divider and apply the formula. |
| 3e | Capacitance | 3e.1 | Understand the factors influencing the capacitance of a capacitor; area and separation of the plates, permittivity of dielectrics and formula C=KA/d. |
| | | 3e.2 | Understand that capacitors have a breakdown voltage and that they need to be used within that voltage. |
| | | 3e.3 | 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. |

| Syllabus | | Assessment Objectives | |
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| | | 3e.4 | Understand the charging and discharging of a capacitor in a CR circuit and the meaning of the time constant T=CR.<br>Recall the dangers of stored charges on large or high voltage capacitors.<br>Recall that large value resistors can be used to provide leakage paths for these stored charges. |
| | | 3e.5 | Understand and apply the formulae for calculating the combined values of capacitors in series and in parallel. |
| 3f | Inductance | 3f.1 | Understand the term 'self inductance' and recall that a 'back EMF.' is produced as current flow changes in an inductor. |
| | | 3f.2 | Recall that the inductance of a coil increases with increasing number of turns, increasing coil diameter and decreasing spacing between turns.<br>Understand the use of high permeability cores and slug tuning. |
| | | 3f.3 | Understand the rise and fall of current in an LR circuit. |
| | | 3f.4 | Understand and apply the formulae for calculating the combined values of inductors in series and in parallel. |
| 3g | AC circuits | 3g.1 | Understand that the root mean square (RMS) value of a sinusoidal current has the same heating effect as a direct current of the same value and is 0·707 of its peak value. |
| | | 3g.2 | Recall that the period of a sine wave is equal to 1/f and that the frequency of a sine wave is equal to 1/T (where f = frequency in Hertz and T = time interval in seconds). |
| | | 3g.3 | Understand the concept of phase difference, and that it can be expressed in degrees and that one full cycle is equal to 360 degrees. |

| Syllabus | | Assessment Objectives | |
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| | | 3h.1 | Recall that for a resistor, the potential difference and current are in phase.<br>Recall that current lags potential difference by 90°in an inductor and that current leads by 90° in a capacitor.<br>Recall that the term ‘reactance’ describes the opposition to current flow in a purely inductive or capacitive circuit where the phase difference between V and I is 90°.<br>Understand and apply the equations for inductive and capacitive reactance. |
| | | 3h.2 | Understand that impedance is a combination of resistance and reactance and apply the formulae for impedance and current in a series CR or LR circuit. |
| | | 3h.3 | Understand the use of capacitors for AC coupling (DC blocking) and decoupling AC signals (including RF bypass) to ground. |
| 3i | Tuned Circuits | 3i.1 | Understand that at resonance $X_C = X_L$ and the formula for resonant frequency.<br>Apply the formula to find values of f, L or C from given data. |
| | | 3i.2 | Identify resonance curves for series and parallel tuned circuits. |
| | | 3i.3 | Understand the concept of the magnification factor Q as applied to the voltages and currents in a resonant circuit.<br>Understand and apply the formula for Q factor given circuit component values.<br>Recall the definitions of the half power point and the shape factor of resonance curves.<br>Apply the equation for Q given the resonant frequency and the half power points on the resonance curve. |
| | | 3i.4 | Understand the meaning of dynamic resistance.<br>Understand and apply the formula for $R_D$ given component values.<br>Understand the effect of damping resistors in a tuned circuit. |
| | | 3i.5 | Recall the equivalent circuit of a crystal and that it exhibits series and parallel resonance. |

| Syllabus | | Assessment Objectives | |
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| | | 3i.6 | Recall that voltages and circulating currents in tuned circuits can be very high and understand the implications for component rating. |
| 3j | Transformers | 3j.1 | Understand the concept of mutual inductance.<br>Understand and apply the formulae relating transformer primary and secondary turns to primary and secondary potential differences and currents. |
| | | 3j.2 | Understand and apply the formula relating transformer primary and secondary turns to primary and secondary impedances. |
| | | 3j.3 | Understand the cause and effects of eddy currents and the need for laminations (or ferrites) in transformers. |
| 3k | Filters | 3k.1 | Identify the circuits of low pass, high pass, band pass and band stop (notch) filters and their response curves. Understand the concept of the cut-off frequency.<br>Recall that crystals can be used in filter circuits. |
| 3l | Screening | 3l.1 | Recall that screening with thin metal sheet is effective in reducing unwanted radiation from equipment and/or between stages within equipment. |
| 3m | Temperature effects | 3m.1 | Recall that temperature has an effect on the value of components. Those with negative coefficients will reduce 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. |
| 3n | Solid state devices | 3n.1 | Understand that doping of semiconductor material (silicon and germanium) produces p-type (electron deficient) and n-type (electron rich) semiconductors. Understand current flow in terms of electron and hole movement.<br>Understand how the p-n junction forms a semiconductor diode.<br>Understand the formation and effect of the depletion layer.<br>Understand that an applied potential difference can cause electrons to flow across the p-n junction (forward bias) or prevent electron flow (reverse bias) depending on polarity. |

| Syllabus | | Assessment Objectives | |
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| | | 3n.2 | Recall that a Zener diode will conduct when the reverse bias potential is above its designed value and identify its V/I characteristic curve. |
| | | 3n.3 | Understand that the depletion layer in a reverse biased diode forms the dielectric of a capacitor and that the magnitude of the reverse bias affects the width of the layer and the capacitance. |
| | | 3n.4 | Understand the 3 layer model of the transistor (npn and pnp) and the channel model of the FET. |
| | | 3n.5 | Understand the basics of biasing bipolar and FET transistors (including dual gate devices). |
| | | 3n.6 | 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. |
| | | 3n.7 | Recall the characteristics and typical circuit diagrams of different classes of amplifiers (i.e. A, B, A/B and C). |
| | | 3n.8 | Understand the concept of the efficiency of an amplifier stage and be able to estimate expected RF output power for a given DC input power, given the stage's efficiency. |
| 3o | Decibels | 3o.1 | Recall the equations for decibel power and voltage ratios.<br>Recall (or determine) the power gain or loss of various dB ratios based on ± 3, 6, 9, 12, 15 and 10, 20, 30dB. (This includes examples such as 25W ≡ 20-6=14dBW.) |
| 3p | Mains Power Supplies | 3p.1 | Recall the circuit diagrams and characteristics of different types of rectifier and smoothing circuits (i.e. half wave, full wave and bridge). |
| | | 3p.2 | Understand the need for rectifier diodes to have a sufficient peak inverse voltage (PIV) rating and calculate the PIV in diode/capacitor circuits. |

| Syllabus | | Assessment Objectives | |
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| | | 3p.3 | Understand the function of stabilising circuits and identify different types of stabilising circuits (i.e. Zener diode/pass transistor and IC)<br>*Note: questions on the characteristics of individual components are covered earlier in this syllabus, e.g. 3n.2. This sub-section is on complete circuits.* |
| **4. Transmitters and Receivers** | | | |
| 4a | Transmitter architecture | 4a.1 | Understand the block diagram of an SSB transmitter employing mixers to generate the final frequency.<br>Understand the block diagram of an FM transmitter employing either frequency multipliers or mixers to generate the final frequency. |
| 4b | Oscillators | 4b.1 | Understand the function of the components in typical VFO and crystal oscillators. |
| 4c | Frequency synthesis | 4c.1 | Recall the block diagram of a frequency synthesiser and the functions of the stages (i.e. oscillator, fixed divider, phase detector, LPF, voltage controlled oscillator and programmable divider).<br>Recall how sine 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. |
| 4d | Frequency multipliers | 4d.1 | Understand that frequency multipliers use harmonics to generate frequencies above an oscillator's fundamental frequency (e.g. in a microwave transmitter) |
| 4e | Mixers | 4e.1 | Understand that the desired frequency is often produced by mixing together the output from two or more frequency sources, e.g. VFO, crystal oscillator or synthesiser.<br>Understand how unwanted frequencies may also be produced. |

| Syllabus | | Assessment Objectives | |
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| 4f | Modulation | 4f.1 | Recall the meaning of the term peak deviation.<br>Recall the meanings of wide band and narrow band frequency modulation.<br>Recall the meaning of depth of modulation for amplitude modulation. |
| | | 4f.2 | Understand the operation of AM, SSB and FM modulators.<br>Recall the bandwidth of such transmissions. |
| | | 4f.3 | Understand, in functional terms, the operation of data modulators for F1B (direct frequency shift), F2B (frequency shift keyed audio tone on an f.m. transmitter) and J2B (frequency shift keyed audio tone on an s.s.b. transmitter). |
| 4g | Power Amplifiers | 4g.1 | Understand the need for linear amplification and identify which forms of modulation require a linear amplifier. |
| | | 4g.2 | Recall the function of the main components; anode/collector load, bias, input circuit, output filter and matching in a PA circuit. |
| | | 4g.3 | Recall the operation of a valve in a power amplifier. Recall the function for the heater, cathode, control grid and anode.<br>Recall the advantages and disadvantages of valve PA circuits. |
| | | 4g.4 | 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. |
| | | 4g.5 | Recall the function of automatic level control within the power amplifier and when using an external power amplifier. Recall the function and use of a manual RF power control. |
| 4h | Transmitter Interference | 4h.1 | Recall the effect and the importance of minimising drift. |
| | | 4h.2 | Recall the cause and effect of ‘chirp’ and identify suitable remedies.<br>Recall the cause and effect of ‘key clicks’ and the shaping of Morse keying waveforms. |

| Syllabus | | Assessment Objectives | |
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| | | 4h.3 | Understand ways to avoid generating harmonics (e.g. use of push-pull amplifiers, use of inductive coupling between stages, avoiding high drive levels).<br>Recall that transmitters may radiate unwanted mixer products and identify suitable remedies.<br>Understand the use of low and band pass filters in minimising the radiation of unwanted harmonics and mixer products. |
| | | 4h.4 | Recall that unwanted emissions may be caused by parasitic oscillation and/or self oscillation and identify suitable remedies. |
| | | 4h.5 | Understand that over modulation causes harmonics (of the modulating signal), which may result in excessive bandwidth. |
| | | 4h.6 | Understand how frequency synthesisers may not produce the intended frequency. Identify remedial measures (out of lock inhibit). |
| 4i | External Power Amplifiers | 4i.1 | 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. |
| 4j | Receiver parameters and terminology | 4j.1 | Understand the terms selectivity and 60 dB bandwidth. |
| | | 4j.2 | 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. |
| | | 4j.3 | Recall, in simple terms, the meaning of “signal to noise ratio” as applied to a receiver specification. Recall that the noise generated in the receiver will influence the minimum discernible signal. |
| 4k | Receiver architecture | 4k.1 | Understand the block diagram of superhet and double superhet receivers and the functions of each block. |

| Syllabus | | Assessment Objectives | |
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| 4l | R.F. amplifier and pre-amplifier | 4l.1 | Recall the operation of the RF amplifier.<br>Understand that external RF preamplifiers do not always improve overall performance and will reduce the dynamic range by an amount approximately equal to the gain of the pre-amp. Understand that overloading will cause intermodulation and spurious signals. |
| 4m | Mixer and Local Oscillator | 4m.1 | Understand the function of a mixer, the generation of the intermediate frequency (IF) and other mixer products.<br>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. |
| | | 4m.2 | Understand the origin of the second channel or image frequency and calculate the frequency from given parameters. |
| 4n | IF amplifier | 4n.1 | Understand the advantages and disadvantages of high and low intermediate frequencies and the rationale for the double superhet. |
| | | 4n.2 | Understand the operation of an IF amplifier and the IF transformer.<br>Understand the concept of two LC tuned circuits utilising transformer coupling. Identify critical and over-coupled response curves.<br>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. *Note: the reason to vary the gain (AGC) is covered at item 4p.* |
| 4o | Demodulation | 4o.1 | Understand the operation of AM, CW, SSB and FM demodulators. |
| 4p | Automatic Gain Control | 4p.1 | Understand the derivation and use of an AGC voltage.<br>Recall that automatic gain control circuits can also be used to drive S meters. |
| 4q | Down-converters and transverters | 4q.1 | Understand that VHF and UHF operation can be carried out by using down converters and transverters ahead of HF equipment. |

| Syllabus | | Assessment Objectives | |
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| 4r | Transceivers | 4r.1 | Understand that transceivers normally share oscillators between the transmitter and receiver circuits; and they may use common i.f. filters to limit both the transmitter and receiver bandwidths and that they also use common change-over circuits.<br>Recall the function and use of the RIT control. |
| | **5. Feeder and Antenna** | | |
| 5a | Feeder basics. | 5a.1 | 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. Calculate physical feeder lengths given the frequency and velocity factor. Recall that the velocity factor for coaxial feeder with a polythene dielectric is approximately 0·67 or 2/3. Recall that feeder loss increases with increasing frequency and that lower loss feeders may be desirable at VHF, UHF and above. |
| | | 5a.2 | Understand that a quarter-wave length of feeder can be used as an impedance transformer. Apply simple examples of the formula $Z_0^2=Z_{in}\times Z_{out}$. |
| | | 5a.3 | Recall the basic construction and use of waveguides. |
| 5b | Baluns | 5b.1 | Recall the construction and use of transformer, sleeve and choke type baluns.<br>Identify the circuits of 1:1 and 4:1 transformer baluns. |
| 5c | Antennas | 5c.1 | Recall the equation for calculating half-wavelengths and be able to apply ‘end factor correction’ in calculating the approximate physical lengths of dipole elements. |
| | | 5c.2 | Recall that the angle at which the propagated radio wave leaves the antenna is known as the (vertical) angle of radiation and that longer distances require a lower angle of radiation.<br>Recall the effect of the ground on the angle of radiation. |

| Syllabus | | Assessment Objectives | |
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| | | 5c.3 | Recall the current and voltage distribution on the dipole and λ/4 ground plane antennas.<br><br>Recall the feed-point impedances of half-wave dipoles, quarter-wave and loaded 5λ/8 verticals, folded dipoles, full-wave loops and end fed λ/4 and λ/2 antennas.<br><br>Recall the effect of passive antenna elements on feed point impedance and the use of folded dipoles in Yagi antennas. |
| | | 5c.4 | Identify folded and trap dipoles and quad antennas in addition to those in earlier syllabuses. |
| | | 5c.5 | 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. |
| 5d | Return Loss and SWR | 5d.1 | Understand 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). |
| | | 5d.2 | Recall that return loss is the ratio of the forward signal power to the return signal power; normally expressed in dB.<br><br>Understand that a low SWR equates to a high return loss and a high SWR equates to a low return loss. |
| | | 5d.3 | 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.<br><br>Recall that Return Loss at transmitter = Return Loss at antenna + 2×(feeder loss) |

| Syllabus | | Assessment Objectives | |
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| 5e | Antenna Matching Units | 5e.1 | Understand that AMUs (ATUs) can “tune-out” reactive components of the antenna system feed-point impedance (before or after the feeder) and can transform impedances to an acceptable resistive value.<br>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.<br>Identify typical AMU circuits (i.e. T, Pi and L circuits). |
| **6. Propagation** | | | |
| 6a | Electromagnetic Radiation | 6a.1 | Recall that an e-m wave comprises E and H fields in phase, at right angles and at right-angles to the direction of travel.<br>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.<br>Recall that this is often used for satellite communication where the orientation of the satellite is indeterminate.<br>Recall that the transmit and receive antennas should have the same polarisation. |
| | | 6a.2 | Recall that under free space conditions e-m waves travel in straight lines and spread out according to an inverse square law of power flux density and that that the field strength, measured in volts/metre, drops linearly with distance.<br>*Numerical calculations required at item 7c1 only.* |
| 6b | Ionosphere | 6b.1 | 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.<br>Recall the ionospheric layers (D, E, F1 and F2) and approximate heights. |
| | | 6b.2 | Recall that the E layer can refract radio waves and that sporadic-E is caused by areas of highly ionised gas that can refract waves in the VHF band. Recall that the E layer supports single hops up to about 2000km. |

| Syllabus | | Assessment Objectives | |
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| | | 6b.3 | Recall that the F2 layer provides the furthest refractions for HF signals (about 4000km) and that the F layers combine at night.<br>Recall that multiple hops permit world-wide propagation. |
| | | 6b.4 | Understand how fading occurs and its effect on the received signal. |
| | | 6b.5 | Recall that the highest frequency that will be refracted back to the transmitter is known as the Critical Frequency of Vertical Incidence (critical frequency).<br>Recall that the highest frequency that will be refracted over a given path is known as the 'maximum usable frequency' (MUF) and that this will be higher than the critical frequency.<br>Recall, in general terms how the MUF varies over the 24 hour cycle and the variation in MUF from summer to winter. |
| | | 6b.6 | Recall that the D layer tends to absorb the lower radio frequencies during daylight hours and that it tends to disappear at night.<br>Understand that if the D-layer absorption occurs at frequencies higher than the MUF, then no ionospheric propagation can occur. |
| | | 6b.7 | Recall which amateur bands will be "open" to support ionospheric propagation at different times of the day and year.<br>*Questions will be asked on 3·5 and 21MHz propagation over the 24 hour cycle.* |
| 6c | Ground wave | 6c.1 | 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. |

| *Syllabus* | | *Assessment Objectives* | |
|---|---|---|---|
| **7. EMC** | | | |
| 7a | Routes of entry into TV and Radio | 7a.1 | Understand that amateur transmissions can be picked up by the intermediate frequency stages of TV and radio receivers and identify related amateur transmissions.<br>Understand that television receivers and most broadcast radio receivers employ superheterodyne circuits and recall some typical frequencies used in radio and television receivers; i.e. 470-854MHz TV RF 33-40MHz TV IF, video baseband 0-5MHz Radio IFs typically 455-500kHz and 10·7MHz.<br>Understand the potential for second channel (image frequency) interference. |
| | | 7a.2 | Recall that amateur transmissions can enter the RF stages and cause cross modulation and/or blocking.<br>Recall that cross modulation occurs when strong varying transmissions (e.g. AM, SSB or CW signals) impresses its own modulation on the wanted signal.<br>Recall that blocking (also known as desensitisation) occurs when strong constant transmissions (e.g. f.m. signals) cause the radio or television to be overloaded. |
| | | 7a.3 | Understand that mast-head amplifiers are frequently wide band devices and can suffer from cross-modulation and overload (causing intermodulation and blocking), and may also overload the TV. |
| | | 7a.4 | Recall that amateur transmissions can enter audio stages via long speaker leads or other interconnections.<br>Understand that any p-n junction within an electronic device can rectify unwanted RF. |
| | | 7a.5 | Recall that passive intermodulation products can be caused by corroded contacts in any metalwork, including transmitting and receiving antennas, supports and guttering. |
| | | 7a.6 | Understand that ghosting is caused by external reflections and does not normally indicate a fault in the TV receiver. |
| 7b | Filters | 7b.1 | Understand the construction and use of a typical mains filter. |

| Syllabus | | Assessment Objectives | |
|---|---|---|---|
| | | 7b.2 | Identify a typical circuit of a braid-breaking filter and a combined high-pass/braid-breaking filter. Understand their use.<br>Understand why a ferrite ring will attenuate common-mode currents without affecting the differential-mode wanted signal. |
| | | 7b.3 | Recall the use of ferrite beads or rings in internal and external filtering. |
| | | 7b.4 | Understand the use of notch filters including coaxial stubs as notch filters or traps in minimising an unwanted signal. |
| | | 7b.5 | Understand the use of high, low and band pass filters in improving the immunity of affected devices. |
| 7c | Field Strength | 7c.1 | Recall that reducing field strength to the minimum required for effective communication is good radio housekeeping. Recall and apply the formula for the field strength surrounding an antenna given the ERP and distance from it. |
| 7d | Feeders and Antennas | 7d.1 | Recall that balanced antenna systems tend to cause fewer EMC problems than unbalanced antennas.<br>Recall that the feeder (balanced or unbalanced) should leave the antenna at right-angles to minimise coupling. |
| 7e | Mobile Installations | 7e.1 | Understand that EMC problems in motor vehicles can have serious safety implications and identify suitable precautions. |
| 7f | Social issues | 7f.1 | 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. |

| *Syllabus* | | *Assessment Objectives* | |
|---|---|---|---|
| | **8. Operating Practices and Procedures.** | | |
| 8a | Packet Radio | 8a.1 | Recall that Packet radio transmits messages in data format that can be received directly, stored in a mailbox for reception at a later date or forwarded through a network of mailboxes.<br>Understand the difference between store and forward mailboxes and digipeating. |
| 8b | Repeaters | 8b.1 | Recall the purpose and operation of repeaters and the correct procedures in using them.<br>E.g. offsets on 144 and 433MHz; time-out and reset tone; voice procedures. |
| 8c | Intermodulation | 8c.1 | Understand how to identify whether the distant transmitter or the local receiver is producing intermodulation products. |
| 8d | Special events | 8d.1 | Recall the purpose of special event stations and the format of their call signs. |
| 8e | Band Plans | 8e.1 | Recall that band plans are produced by the IARU.<br>Recall that the band plans state that:<br>no SSB operation should take place in the 10MHz (30m) band<br>no contests should be organised in the 10MHz (30m), 18MHz (17m) and 24MHz (12m), bands<br>narrow band modes are at the lower end of most bands<br>lower sideband operation normally occurs below 10MHz and upper sideband above 10MHz<br>transmission on beacon frequencies must be avoided<br>transmissions on satellite frequencies should be avoided for terrestrial contacts.<br>*Questions on beacon and satellite frequencies will be limited to the 14MHz (20m) and 144MHz (2m) bands and a copy of the relevant Band Plans will be provided.* |

| *Syllabus* | | *Assessment Objectives* | |
|---|---|---|---|
| **9. Safety** | | | |
| 9a | High Voltage Equipment | 9a.1 | Understand that all equipment should be controlled by a master switch, the position of which should be known to others in the house or club. |
| | | 9a.2 | Understand that all exposed metal surfaces should be properly earthed. |
| | | 9a.3 | Understand that no work should be undertaken on live equipment unless it is not practicable to do so.<br>Understand that suitable precautions must be taken to avoid electric shock. |
| | | 9a.4 | Recall that thermionic valve equipment generally uses power supplies with potentials higher than the domestic mains supply. |
| 9b | Portable operation | 9b.1 | 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, excessive field strengths).<br>Recall the additional safety precautions that should be taken whilst operating in temporary premises and/or outdoors (i.e. site survey, cable routing/protection, correct fusing, use of RCDs, no adjustments or repairs to live equipment). |
| 9c | Mobile operation | 9c.1 | Understand that operating in vehicles and vessels can introduce new hazards (i.e. insecure equipment, long/flexible antennas, accidental shorts to earth, lack of attention to driving, RF induction into vehicle control circuits).<br>Recall the additional safety precautions that should be taken whilst operating mobile and/or maritime mobile (i.e. secure equipment, cable routing/protection, correct fusing, use of hands-free equipment, attention to good radio housekeeping). |

| Syllabus | | Assessment Objectives | |
|---|---|---|---|
| 9d | R.F. | 9d.1 | Recall that the Health Protection Agency (HPA) has published Investigation levels for exposure to RF radiation for UK amateur radio.<br><br>Recall that compliance with HPA investigation levels will ensure that exposures are below the recommended limits and that the lowest investigation level for electric field strength is 28V/m (at 10-146MHz).<br><br>Understand that if the investigation level is exceeded the cause must be investigated and steps taken to reduce the exposure to below the investigation levels. |
| 9e | Lightning Protection | 9e.1 | Recall that thunderstorms carry heavy static charges.<br><br>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.<br><br>Understand the risks to human life, domestic property and electronic equipment associated with a direct strike and/or the build up of static charges.<br><br>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. |
| 9f | Protective multiple earthing | 9f.1 | Recall that in PME systems the main earth terminal is connected to the neutral of the electricity service at the consumers' premises and that all metal pipes and fittings within the premises are also connected to the PME bonding point.<br><br>Recall that under severe fault conditions PME systems have the potential to cause fatal electric shocks and/or fires in amateur radio stations.<br><br>Recall that the RF earth in an amateur station should be connected to the PME bonding point in accordance with IEE Wiring Regulations to maintain safety under fault conditions. |

| *Syllabus* | | *Assessment Objectives* | |
|---|---|---|---|
| | **10. Measurements** | | |
| 10a | Meters | 10a.1 | Understand the use of multiplier resistors in analogue voltmeters, shunts in ammeters and the effect of the test meter on the circuit under test. |
| 10b | Frequency Checking | 10b.1 | Recall the uses and limitations of absorption wavemeters, heterodyne wavemeters, crystal calibrators, digital frequency counters and standard frequency transmissions. |
| | | 10b.2 | Understand the effect of measurement tolerance, calibration accuracy and time related drift on frequency measurements and the allowances to be made for transmission bandwidths. |
| 10c | Oscilloscopes | 10c.1 | Understand the purpose and basic operation of an oscilloscope. Calculate the frequency and voltage of a waveform from given data. |
| 10d | R.F. Power measurements | 10d.1 | Understand that steady RF power may be determined by measuring the RF potential difference across a dummy load.<br>Understand the meaning of PEP (peak envelope power) of an SSB transmission and that it may be determined using a peak reading power meter or an oscilloscope and dummy load. |
| 10e | SWR measurements | 10e.1 | Identify the circuit of an SWR meter and understand its operation. |

Section 2

# Formula sheet

This formula sheet will be provided to candidates in the examination and may be used to answer any question.

$R_T = R_1 + R_2 + R_3$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$V = IR$

$V_{out} = V_{in} \frac{R_2}{R_1 + R_2}$

$P = VI = \frac{V^2}{R} = I^2R$

$V_{rms} = \frac{V_{peak}}{\sqrt{2}}$

$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$C_T = C_1 + C_2 + C_3$

$C = \frac{kA}{d}$ where $k = \varepsilon_0 \varepsilon_r$

$L_T = L_1 + L_2 + L_3$

$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2}$

$X_L = 2\pi fL$

$Z = \sqrt{R^2 + X^2}$

$V_T = \sqrt{V_R{}^2 + V_C{}^2}$ (or $V_L{}^2$)

$X_C = \frac{1}{2\pi fC}$

$f = \frac{1}{2\pi\sqrt{LC}}$

$T = \frac{1}{f}$

$\tau = CR$

$Q = \frac{2\pi fL}{R}$ or $\frac{1}{2\pi fCR}$

$Q = \frac{f_C}{f_U - F_L} = \frac{\text{centre frequency}}{\text{bandwidth}}$

$R_D = \frac{L}{CR}$

$Q = 2\pi fCR_D$

$V_S = V_P \frac{N_s}{N_p}$

$I_P = I_S \frac{N_s}{N_p}$

$Z_P = Z_S \left( \frac{N_p}{N_s} \right)^2$

$I_C = \beta I_B$

$f_{step} = \frac{f_{crystal}}{A}$

$F_{out} = f_{crystal} \frac{N}{A}$

$c = 3 \times 10^8$ m/s

$\text{Gain (loss)} = 10\text{Log}_{10} \frac{\text{power out}}{\text{power in}}$ dB

$SWR = \frac{V_{max}}{V_{min}} = \frac{V_f + V_r}{V_f - V_r}$

$v = f\lambda$

$\text{Gain (loss)} = 20\text{Log}_{10} \frac{\text{voltage out}}{\text{voltage in}}$ dB

$Z_0{}^2 = Z_{in} \times Z_{out}$

$E = \frac{7\sqrt{erp}}{d}$

$\text{Return Loss} = 10\text{Log}_{10} \frac{\text{Reflected power}}{\text{Incident power}}$

$bw = 2(AF_{max} + \Delta f)$

erp= power × gain (linear)

$\text{Gain} = 10\text{Log}_{10} \frac{\text{power from Yagi}}{\text{power from dipole}}$ dBd

Section 3

# Examination Schedule

## Advanced Radio Communication Examination
## Assessment Schedule

Questions in the examination paper will be selected from the syllabus according to the table below. They may not necessarily be in the same order as shown here.

| Question number | Syllabus Section Number | Number of Questions |
|---|---|---|
| 1 | 2a.1 | 1 |
| 2 | 2b.1 | 1 |
| 3 | 2c.1 | 1 |
| 4 | 2d.1 | 1 |
| 5 | 2e.1 2e.2 | 1 |
| 6 | 2f.1 | 1 |
| 7 | 2g.1 | 1 |
| 8 | 2h.1 | 1 |
| 9 | 2i.1 | 1 |
| 10 | 2j.1 | 1 |
| | **Total Licensing Conditions** | **10** |
| 11 | 3a.1, 3b.1, 3c.1, 3d.1 | 1 |
| 12 | 3e.1, 3e.2, 3e.3, 3e.4, 3e.5 | 1 |
| 13 | 3f.1, 3f.2, 3f.3, 3f.4 | 1 |
| 14 | 3g.1, 3g.2, 3g.3 | 1 |
| 15 | 3h.1, 3h.2, 3h.3 | 1 |
| 16 | 3i.1, 3i.2, 3i.3, 3i.4, 3i.5, 3i.6 | 1 |
| 17 | 3j.1, 3j.2, 3j.3 | 1 |
| 18 | 3k.1 | 1 |
| 19 | 3l.1, 3m.1, 3o! | 1 |
| 20 | 3n.1, 3n.2, 3n.3, 3n.4 | 1 |
| 21 | 3n.5, 3n.6, 3n.7, 3n.8 | 1 |
| 22 | 3p.1, 3p.2, 3p.3 | 1 |
| | **Total Basic Electronics** | **12** |

| Question number | Syllabus Section Number | Number of Questions |
|---|---|---|
| 23 | 4a.1, 4b.1, 4c.1 | 1 |
| 24 | 4d.1, 4e.1 | 1 |
| 25 | 4f.1, 4f.2, 4f.3 | 1 |
| 26 | 4g.1, 4g.2, 4g.3, 4g.4, 4g.5 | 1 |
| 27 | 4h.1, 4h.2 | 1 |
| 28 | 4h.3, 4h.4, 4h.5 | 1 |
| 29 | 4h.6, 4i.1 | 1 |
| 30 | 4j.1, 4j.2, 4j.3 | 1 |
| 31 | 4k.1 | 1 |
| 32 | 4l.1, 4n.2 | 1 |
| 33 | 4m.1, 4m.2, 4n.1 | 1 |
| 34 | 4o.1, 4p.1 | 1 |
| 35 | 4q.1, 4r.1 | 1 |
| | **Total Transmitters and receivers** | **13** |
| 36 | 5a.1, 5a.2, 5a.3, 5b.1 | 1 |
| 37 | 5c.1, 5c.2, 5c.3 | 1 |
| 38 | 5c.4, 5c.5 | 1 |
| 39 | 5d.1, 5d.2, 5d.3 | 1 |
| 40 | 5e.1 | 1 |
| | **Total Feeders and Antennas** | **5** |
| 41 | 6a.1, 6a.2 | 1 |
| 42 | 6b.1, 6b.2, 6b.3, 6b.4 | 1 |
| 43 | 6b.5, 6b.6, 6b.7, 6c.1 | 1 |
| | **Total Propagation** | **3** |

| Question number | Syllabus Section Number | Number of Questions |
|---|---|---|
| 44 | 7a.1 | 1 |
| 45 | 7a.2, 7a.3 | 1 |
| 46 | 7a.4, 7a.5, 7a.6 | 1 |
| 47 | 7b.1, 7b.2 | 1 |
| 48 | 7b.3, 7b.4, 7b.5 | 1 |
| 49 | 7c.1 | 1 |
| 50 | 7d.1, 7e.1 | 1 |
| 51 | 7f.1 | 1 |
| | **Total EMC** | **8** |
| 52 | 8a.1 | 1 |
| 53 | 8b.1 | 1 |
| 54 | 8c.1, 8d.1 | 1 |
| 55 | 8e.1 | 1 |
| | **Total Operating Practices and procedures** | **4** |
| 56 | 9a.1, 9a.2, 9a.3, 9a.4 | 1 |
| 57 | 9b.1, 9c.1, 9d.1 | 1 |
| 58 | 9e.1, 9f.1 | 1 |
| | **Total Safety** | **3** |
| 59 | 10a.1 | 1 |
| 60 | 10b.1, 10b.2 | 1 |
| 61 | 10c.1 | 1 |
| 62 | 10d.1, 10e.1 | 1 |
| | **Total Measurements** | **4** |
| | **Total Number of Questions** | **62** |