SARL STUDY GUIDE
FOR ENTRY LEVEL AMATEUR RADIO LICENCE (ZU)

Revised March2013

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- Syllabus
- Study guide

NOTES:

This guide has been compiled from material published in the RAE Manual produced for the SARL by Andrew Roos ZS6AAA.

Serious study of the material in this guide will enable the candidate to write the entry level license examination (ZU)

Candidates should note that they require having a full copy of the regulations available for reference. Candidates will however only be examined on the regulations contained in the guide. However failure to comply with the provisions as contained in the full regulations is an offence.

The entry level license examination is not a HAREC examination and will not allow operation in other countries.

Syllabus for Radio Amateur Entry Level Course and Examination (ZU Licence)

The examination will be by multiple choice. There will be 20 questions covering regulations and operating procedure and 10 questions on Part 2 (Technical). Candidates must achieve 50% in each section and an overall 65% to pass.

Candidates must also pass a hands-on HF operation test as for the ZS licence.

Part 1 Practical Operating Aspects
In addition to the multiple choice examination, the candidate will also have to do a hands-on test

Familiarisation with the controls of a receiver, transmitter or transceiver

a. Power On/Off, band switch, frequency tuning and display, volume, power level and display, microphone gain etc.

b. HF operation
   i. Tuning in USB and LSB,
   ii. Making initial calls, calling CQ,
   iii. Ability to make a contact(s) in the accepted format, signal reports, name and station information etc. thus demonstrating how the equipment is used.

c. VHF operation
   i. Ability to make a contact(s) as above for HF
   ii. FM operation
   iii. Operation through a repeater

d. Need for a log book and the information to be recorded.

e. Demonstrate understanding of antennas matching and the use of SWR meter.
   i. Understand the importance of correct matching
   ii. Ability to use the Standing Wave Meter and an Antenna Tuner to match an antenna to a transmitter.
   iii. Fitting a coaxial connector

f. Use the phonetic alphabet and common amateur vocabulary as necessary in b) and c).

g. National Amateur band plans

Part 2 Technical Content

The candidate is expected to have a very basic knowledge and must be able to add, subtract, multiply and handle fractions

1. Basics Units and symbols
    b. Electrical circuits
    c. Power and resistance
    d. Ohms Law
    e. Alternating currents and voltages
2. Frequency and wavelength
3. Transmitters
    a. Block diagram of a simple transmitter
    b. Modulation types
4. Receivers
    a. Block diagram of a simple receiver and detector
5. Feeders and Antennas
    a. Feeders, coaxial and suitable plugs
    b. Antenna types, dipole, ground plane, end fed wire
    c. Antenna matching
    d. Antenna Tuning Unit
    e. Standing waves and SWR meters, radiated power and e.i.r.p.
    f. Dummy loads
6. Propagation
    a. Wave propagation
    b. Range
    c. Ionosphere
    d. Daily changes in propagation
7. Electromagnetic Compatibility
    a. Causes of interference
    b. Minimising the problems
    c. Earthing, antenna types
    d. Power and emission types
    e. Immunity
    f. Social aspects
    g. Sources of assistance
8. Safety Considerations
    a. High voltages and currents
    b. Mains plugs and earthing
    c. Accidents
    d. Antenna location
    e. Batteries
    f. General shock hazards

Part 3 Amateur Radio Regulations

The candidate must have a knowledge and understanding of the Radio Regulations as pertaining to Amateur Radio and will be tested on the sections for a class B licence (ZU) and the general provisions of the regulations (Section G)

Chapter 1 - Introduction to Amateur Radio

This chapter has been designed to give you an introduction to the various facets of Amateur Radio. Although you are not being examined on this chapter, it forms a useful introductory basis for the chapters that follow.

Amateur radio is a hobby that involves experimenting with radio (and related technologies like television and electronics) for fun and education. It is also known as "Ham Radio" and radio amateurs are sometimes referred to as "hams." Like most hobbies, there are many different activities that fall under its umbrella.

Communicating With Other Amateurs

Using radio to communicate with other amateurs is one of the foundations of the hobby. Most amateurs have a radio station of their own, which can range from a simple single-band handheld transceiver (a combination of a *transmitter* and a *receiver* is known as a *transceiver*) for talking to others in the same town, to a sophisticated station that is capable of worldwide communication. Many clubs also have club stations that are available for use by club members.

Radio amateurs communicate in many different *modes*. The most common are by voice (known as *phone* although it does not use the telephone system), Morse code (also referred to a *CW*) and various digital modes including *slow-scan television*.

The content of an amateur communication (known as a *QSO*) ranges from the briefest exchange of name and location up to long conversations (known as *rag-chews*) that may last an hour or more. Amateur radio is not like the phone system since you generally cannot dial a particular station. If you want to speak to a particular person, then you must agree a time and a frequency where you will meet – this is known as a schedule, or "sked" for short. Otherwise, you can just speak to whoever happens to be listening and is interested in a chat, which is a great way to make new friends. There are also some regularly scheduled networks (or "nets") where operators who share a common interest get together at a particular time and frequency to exchange ideas.

Collecting QSL Cards

After communicating with another amateur (especially one in a foreign country), it is customary to send a QSL card, which is a postcard-sized card with information about yourself and your station, and details of the QSO such as the date, time, frequency, mode and the call sign of the station worked. Many amateurs take a great deal of pride in their QSL cards, which are works of art. As well as being something to display and a nice reminder of the contact, QSL cards are often required if you wish to claim a contact for an award (see below).

Building Radio and Electronics Equipment

Many amateurs build at least some of their equipment. Some build equipment from purchased kits or from plans found in amateur radio magazines. Others build their equipment from scratch, doing all the necessary design and sourcing the components themselves. The complexity ranges from simple projects, such as a computer soundcard interface that can be built in an evening to complete radio transmitters and receivers that may take months or years of work. Today microprocessors and digital signal processing (DSP) is an increasingly important part of the hobby, so building equipment may also involve writing the necessary micro-controller or DSP programs. Of course, if you do not enjoy electronics, then everything you need to participate in the hobby can be purchased off the shelf.

Building Antennas

Most amateurs build at least some of their own antennas. Antennas may range from a simple wire antenna suspended from a tree, to a complex multi-element beam sitting on top of a large tower. Antenna projects can be very rewarding as good results may be obtained from fairly simple designs. There are a number of software packages available that allow you to design an antenna and model its performance before you invest in the construction of the antenna.

Public Service and Emergency Communications

Radio amateurs have a proud history of making their skills and equipment available for public service and emergency communications. On the public service side, amateurs provide communications for many sporting events such as rallies, marathons and cycle tours where their ability to communicate effectively from remote places is of great assistance to the organizers.

Many amateurs also ensure that their radio stations have some alternative power source (which could be batteries, a generator or solar power) so that they can continue to provide communications in the event that a natural disaster disrupts the telephone and power distribution systems. In South Africa, Hamnet, a special interest group of the South African Radio League, coordinates amateur emergency communications.

DXing

"DXing" means communicating with as many different places as possible, often-in order to qualify for certificates and awards. (The term comes from the use of "DX" as an abbreviation for "long distance.") There are many different awards, including The DXCC (DX Century Club) certificate, which you qualify for by communicating with 100 or more different countries. The Worked All ZS award, for contacting 100 stations in the various regions of South Africa (the award's name comes from the fact that "ZS" is one of the call sign prefixes assigned to South African radio stations).

DXpeditions

Because DXers are always on the lookout for countries, islands, mountains or provinces that they have not worked before, there is often a flurry of interest and activity when a rare country or island is "activated" by some intrepid radio amateur setting up a station. Expeditions to unusual places for the purpose of setting up and operating a radio station there are called "DXpeditions," and participating in DXpeditions is itself a very rewarding and challenging activity.

Contests

Contests bring out the competitive nature of some radio amateurs, who enjoy the challenge to contact as many different stations as possible over a predetermined period of anything from an hour or two up to 48 hours. Contests may be run on a local, national, regional or international basis and may attract anything from 10 to 5,000 contestants. Many contests have several entry categories to allow similarly equipped stations to compete amongst each other.

Satellite Communications

The amateur community has successfully launched a number of small communications satellites for the use of radio amateurs around the world. Communicating with other amateurs via satellite (or via the earth's natural satellite, the moon) gives radio amateurs an unparalleled opportunity to learn about the technology that underlies much of the modern era of communications. Because amateurs themselves develop these satellites as a cooperative, non-profit venture, those who are interested in the design and construction of satellites also have the opportunity to study the designs and may eventually be able to contribute to new amateur satellite projects.

Chapter 2 - Basic Electrical Concepts

You will be examined on this chapter. The paper will have 10 questions.

Basic Units and Symbols

Electrical Circuits

If you measure or calculate the amount of something, you usually need to specify the unit of measurement. For example, if you weigh something and then say that it weighs "10," this does not mean very much unless you specify the unit of measurement – 10 grams, or 10 kilograms

The units of measure used in this course are the standard S.I. units that are used throughout most of the Western world. Each unit has a name, like "volt" or "ampere," and a corresponding abbreviation, like "V" for volt and "A" for ampere. This saves time when writing quantities – for example a current of "10 A" rather than "10 amperes."

V is volt
A is Amp (it measures current which is denoted by the symbol "I"
W is Watts

It is important to note that the way abbreviations are written have different meanings. When written in a capital letter (uppercase) the abbreviation indicates a large unit and when written in small letters (lowercase) a smaller unit. You need to know the following units:

m is milli for example mA which is one thousands of an Amp
M is mega for example MW is mega Watt or one million Watts
k is kilo for example kV which is 1000 Volt

Ohms Law

Ohm's law states that the electric potential (V) across a conductor is proportional to the current (I) flowing through the conductor. It can be written as $V = I R$, where R is the *resistance* of the conductor. Resistance may be thought of as the opposition to the flow of electric current through a conductor or electric circuit. Resistance is measured in *ohms*, with the abbreviation Ω. Ohm's law can be used to find the electric potential across a conductor, or current flowing through the conductor, or the resistance of the conductor provided that the other two quantities are known.

Ohm's Law: $V = I R$

Note that the multiplication sign between "I" and "R" is omitted. In mathematics when two symbols are written next to each other, it is assumed that they are to be multiplied together.

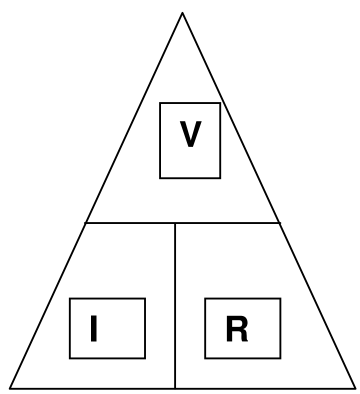
This form of Ohm's law is convenient if you know the current flowing through a conductor and the resistance of the conductor, and want to calculate the electrical potential (voltage) across the conductor. It shows that you can calculate the voltage by multiplying the current by the resistance.

For example, if a current of 5A is flowing through a conductor with a resistance of 2 ohm then the electric potential (voltage) across the conductor can be calculated by replacing the "I" with 5 and the "R" with 2 in the equation for Ohm's law, giving
V = 5 x 2 = 10 V

Note the somewhat confusing use of "V" both as the symbol for electric potential (voltage) and also as the abbreviation for the unit "volt." In this equation, the V on the left hand side (before the equals sign) is the symbol for electric potential. The V after the number 10 is the abbreviation for the unit, volts. The two meanings are not the same and you should take care not to confuse them. You should be able to work out the correct meaning from the context in which the "V" appears. The symbol E is also used for electric potential. So you may see Ohm's law written as $E = I R$ instead of $V = I R$.

Rearranging Ohm's Law
This is all well and good if you know the current and the resistance and want to calculate the voltage. However, Ohm's law can also be used to find either the current or the resistance if both the other quantities are known. This is done by using simple algebra to rearrange Ohm's law as follows:
There is a simple way of remembering Ohm's law. Remember the diagram below and always write it down on your exam paper. It makes it easier to do any calculation.

To find the voltage, put your finger on the V and it shows that V= I x R. To find the current in the circuit close the I with your finger and the formula is I = V/R



Examples

(1) A resistor is connected across a 12 volt battery. The current flowing in the circuit is 2 amp. Calculate the value of the resistor

We want to calculate R so from the ohms law triangle the formula is V/I
V = 12 volt, I = 2 Amp R= 12/2 = 6 Ohm

(2) In a circuit the current flowing is 2 Amp through a 100 Ohm resister. What is the battery voltage? V= I x R = 2 x 100 = 200 Volt.

The Resistor and Potentiometer

Electronic circuits are usually constructed from components that can be purchased at electronics outlets. One such component is the *resistor*, which is simply a conductor that has a known resistance. Resistors are available in values ranging from a fraction of an ohm to several hundred mega-ohms.

Different Types of Resistors

Resistors come in several different types, which are suited to specific applications: Carbon Film resistors are the most common, inexpensive, general-purpose resistors.

The Potentiometer

A related component is the potentiometer, which has a variable resistance. This is typically constructed as a circular carbon track with a known resistance and a wiper that can be moved over the track by turning a control knob. The resistance from one side of the track to the other remains constant, but the resistance between either side of the wiper depends on the position of the control knob.

Alternating Current

In direct current (D.C.) circuits, the current always flows in one direction. This is because the two terminals of the voltage sources used to power these circuits always have the same polarity – one terminal (the positive one) is always positive with respect to the other terminal. This causes the current to flow in only one direction in the circuit. However, in other circuits, the direction in which the current flows is constantly changing. The current flows first in one direction, then in the reverse direction, then in the original direction again and so on, with the direction changing at regular intervals, usually many times each second. The circuits are called *alternating current* (A.C.) circuits. Power for these circuits may be supplied by alternating current (A.C.) power supplies, such as the mains supply. With A.C. power supplies, there is no "positive" or "negative" terminal. Instead, one terminal will be positive with respect to the other for a brief period, and then the roles will reverse and the other terminal will become more positive for a brief period, and so on. Although the abbreviation A.C. stands for "alternating current," it is also used to refer to voltages, in phrases such as "An A.C. Voltage" and "15V A.C."

Capacitance and the Capacitor

The capacitor is a component that consists of two electrically conductive *plates* separated by a thin layer of some insulating material known as the *dielectric*.

Inductance and the Inductor

A typical inductor consists of a coil of wire, which may be wound around a former or may be self-supporting. When a current flows through the wire, it generates a magnetic field, just like an electromagnet would. Whenever the current flowing through the inductor changes, the corresponding changes to the magnetic field induce a voltage into the inductor that opposes the change in the flow of current. This is known as "self inductance" since the voltage is induced in the same coil that generates the magnetic field.

Inductor Values

The value of an inductor indicates how much energy it can store in its magnetic field, and hence how effectively it can oppose attempts to change the current flowing through it. The value of an inductor is measured in henrys; with the abbreviation H. Typical values are measured in micro-henrys (µH) or milli-henrys (mH).

The value of an inductor depends on the number of turns and spacing between the turns of wire – the more turns, the higher the value. It also depends on the *permeability* of the material inside the coil, which may be air (for an *air-wound* inductor) or a metallic core (typically made of iron ferrite). The permeability of the core affects the strength of the magnetic field that will be caused by a current flowing through the inductor. Since iron ferrite has much higher permeability than air, a ferrite-cored inductor will have a greater inductance than an air-cored inductor with the same number of turns. Although iron ferrite cored inductors have higher inductance than air-cored inductors, they also have higher losses, especially at radio frequencies. Air core inductors may be wound with stiff wire, in which case they can be self-supporting, or they may be wound on a plastic former. Inductance is usually abbreviated "L," since "I" is already taken for current!

Expressing Power Levels in dBW and dBM

In the Radio Regulations, the power levels that apply to amateur transmissions are not expressed in watts, but rather in dBW. The unit dBW means "decibels referenced to 1 watt." It is a way to express actual powers in decibel notation. Note that one cannot express an actual power – say 100 W – in decibels since decibels are used to express the *ratio* of two powers. However if you make one of the two powers a standard reference level, then by expressing the ratio of the other power to this standard reference level you can compute an actual power level. One of the common reference levels is 1 watt, and the resulting unit is given the abbreviation "dBW." For example, the maximum power level specified for a Class A1 (ZS) license is 26 dBW. This means "26 dB over 1 watt." Since 26 dB is a ratio of 400, 26 dBW means 400 W.

The maximum power level for a class B (ZU) license is 13 dBW which is 20 Watt

dBM is an abbreviation for the power ratio in decibel (dB) of the measured power referenced to one millwatt (mW). It is used in radio, microwave and fiber optic networks as a convenient measure of absolute power because of its capability to express both very large and very small values in a short form.

Receivers

There are many different types of receivers designed to receive a particular signal such as

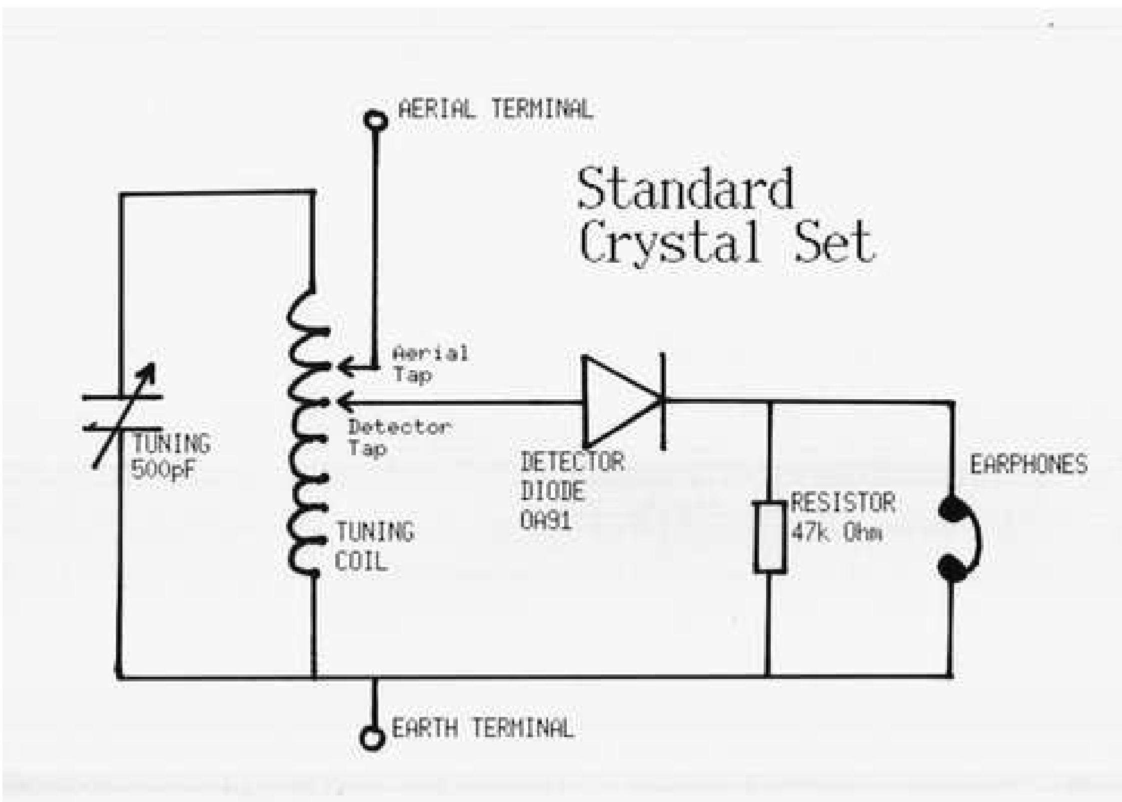
- AM Amplitude Modulation – like a ordinary medium wave broadcast receiver or in its simplest form a crystal set receiver
- FM Frequency Modulation. This type of receiver is used to receive FM broadcast stations like radio 5, SAFM, RSG etc. Radio amateurs also use FM receivers on VHF and UHF frequencies.
- SSB Single Side band Receivers. These receivers are used on the short-

wave bands. A SSB signals can be likened to an AM signal. An AM signal consists of a carrier and two sidebands. In generating an SSB signal the one side band and the carrier are removed and only one sideband is transmitted. The receiver thus has to have the ability to re-insert the carrier to enable the signals to be converted back to AM. In Amateur Radio Lower sideband (LSB) is used on 40 and 80 metres and upper sideband (USB) on the bands below 40 metres

For the purpose of this course we will only discuss a basic crystal radio and a direct conversion receiver.

The Crystal Radio

In years gone by every young person interested in radio would build a crystal set. The name comes from the fact that a small crystal with a catswisker was used as a detector. Now a day it is still fun to build a crystal set but replacing the crystal arrangement with a simple diode. Try the circuit below and you will have fun.



Because of the simplicity of crystal sets, it is often difficult to separate stations. When tuned into one station it is often possible to hear another close by station in the background, this is due to lack of *selectivity*. This can be reduced somewhat by adjusting the positions of the Aerial Tap and Detector Tap. Moving them closer to the bottom of the coil, the earthy end reduces the load on the tuned circuit and this improves selectivity, however it does also reduce *sensitivity* which can make the station quieter. Headphones will often swamp a tuned circuit and reduce its selectivity (Q factor), so moving the tapping point lower down improves this situation. Every circumstance is bound to be different though so the best balance has to be found by experimentation.

The modern 'standard crystal set' shown above uses a Crystal Earphone, since suitable high impedance magnetic headphones (of 2000 to 4000 ohms) are no longer available. The resistor allows the current to flow through the circuit more efficiently when using a crystal earphone.

In a modern crystal set the detector used is a *Diode.* The most suitable diodes are OA81, OA91 or IN94 which are widely available.

The coil is 70 turns of 30 gauge enamelled copper wire wound around the centre of a toilet roll and tapped every 10 turns, by scraping off the enamel insulation and making a small twist.

The medium wave signal is fed from the antenna to the tuned circuit. The combination of the variable capacitor and the Inductance (coil) tune in the station for example 702 kHz, in other words the circuit is resonant at 702 kHz. The RF signal is rectified by the diode and the resultant weak audio signal to feed to the crystal earphone.

A lot of fun can be had with this simple device.

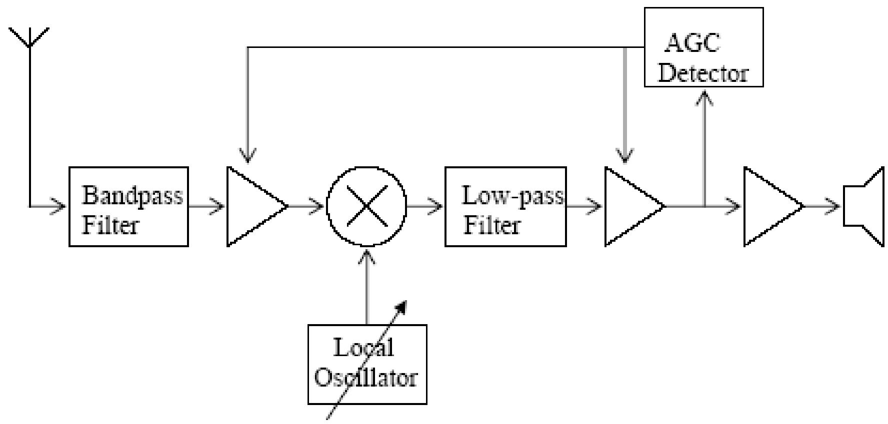
The Direct-Conversion Receiver

A design that is used in quite a few homebuilt receivers is the Direct Conversion receiver. In a Direct Conversion receiver, the radio-frequency signal from the antenna is mixed with a locally generated oscillator signal, producing the usual sum and difference mixing products.

The frequency of the oscillator that generates this local mixing signal – it is known as the *local oscillator* (LO) or *beat frequency oscillator* (BFO) – is set so the difference mixing product is at audio frequency. In this way the Direct Conversion receiver “directly converts,” the desired radio frequency signals to audio, where it can be filtered and amplified. Let us look at the circuit in a little more detail.

The signal from the antenna first passes through a band pass filter. Its role is to reject interference from strong local commercial broadcast stations and the like.

The signal is then amplified by an RF amplifier and fed into the product detector, in the diagram represented by the symbol for a mixer – the circle with a cross in it. (“Mixer,” “Modulator” and “Product Detector” are different names for essentially the same circuit, depending on the exact role it plays.) The product detector mixes the amplified RF signal with a signal generated by the tuneable local oscillator, generating the usual sum and difference-mixing product.



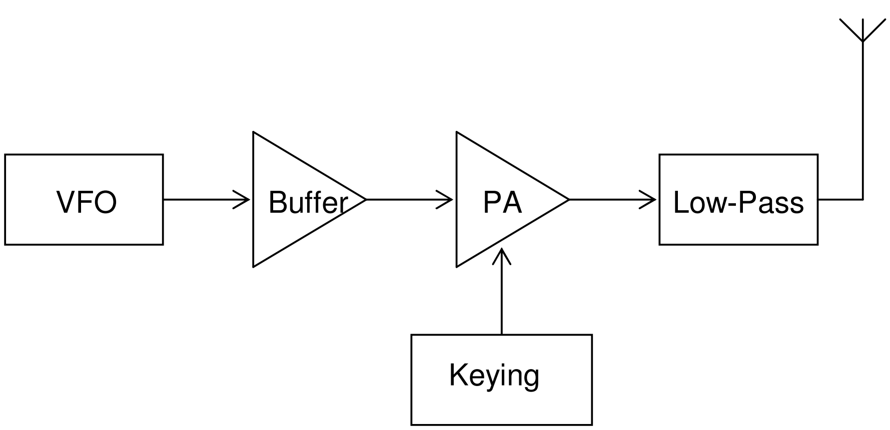
A Direct-Conversion Receiver

Suppose we want to receive an upper-sideband signal on 14.200 MHz. By convention, we refer to the frequency of a single-sideband signal as the frequency where the carrier would have been if it had not been suppressed. So the upper sideband of this USB signal (i.e. all that is left of it after the carrier and lower sideband were removed) will range in frequency from 14.2003 MHz to 14.2030 MHz, 300 Hz to 3 KHz above the (suppressed) carrier. If the local oscillator is set to exactly 14.200 MHz, – the frequency where the carrier would have been – then the difference mixing products will range in frequency between 300 Hz and 3 KHz. What we have done is to translate the USB signal from its frequency of 14.200 MHz back to the audio frequency range.

TRANSMITTERS

A Single-Band CW Transmitter

One of the simplest transmitters is a VFO-controlled single-band CW transmitter. All you need is the variable frequency oscillator, a buffer amplifier (to prevent the variable loading of the power amplifier from affecting the oscillator frequency causing chirp), a keyed power amplifier and a low-pass filter to attenuate harmonics.



A Simple Single-Band CW Transmitter

In this design the PA could run Class C for maximum efficiency since linearity is not required when amplifying a CW signal. This would generate additional harmonics at twice the desired output frequency and higher frequencies, but these could be easily eliminated by the output low-pass filter. The block labeled "keying" should include a keying waveform shaper, to prevent the key-clicks that would be caused by turning the carrier on or off too rapidly.

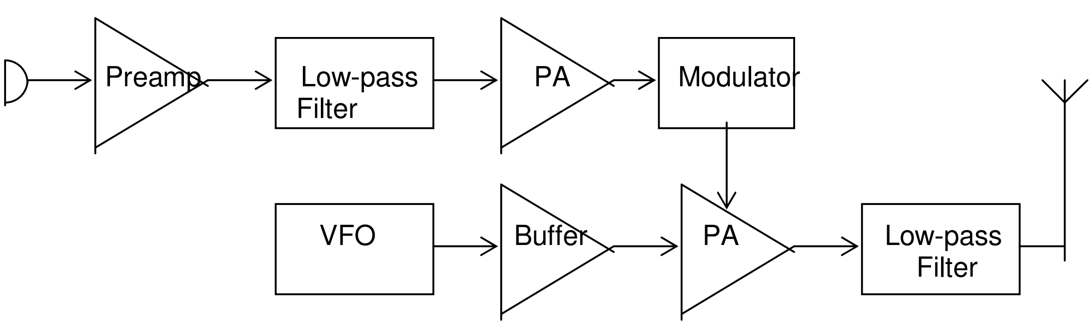
A design like this would be most suitable for the 80 m (3,5 MHz) or 40 m (7 MHz) bands, to keep the VFO frequency fairly low in order to allow reasonable frequency stability (VFOs are usually best kept below 10 MHz for good stability).

An Amplitude-Modulated (AM) Transmitter

There are two different ways to build AM transmitters. One way is to generate a low-level amplitude-modulated signal, and then amplify this to obtain the desired output power. This has the disadvantage that linear amplification is required because the AM signal contains many frequency components and non-linear amplification would cause inter-modulation distortion. However it is the most common method in modern *multimode* transceivers that can generate AM, SSB and CW signals (and often also FM). This is because low-level modulation is the simplest way to generate an SSB signal, and the same circuitry can also be used to generate an AM signal.

However for specialized AM transmitters there is an alternative, which is to generate the carrier signal and amplify it up to the desired output power, and then use a high-level modulator to modulate it at the full output power. This allows more efficient Class C amplifiers to be used to amplify the carrier signal, since before it is modulated it contains only a single frequency component (the carrier frequency) and so does not suffer from inter-modulation distortion.

The following circuit shows a VFO-controlled AM transmitter using high-level modulation.



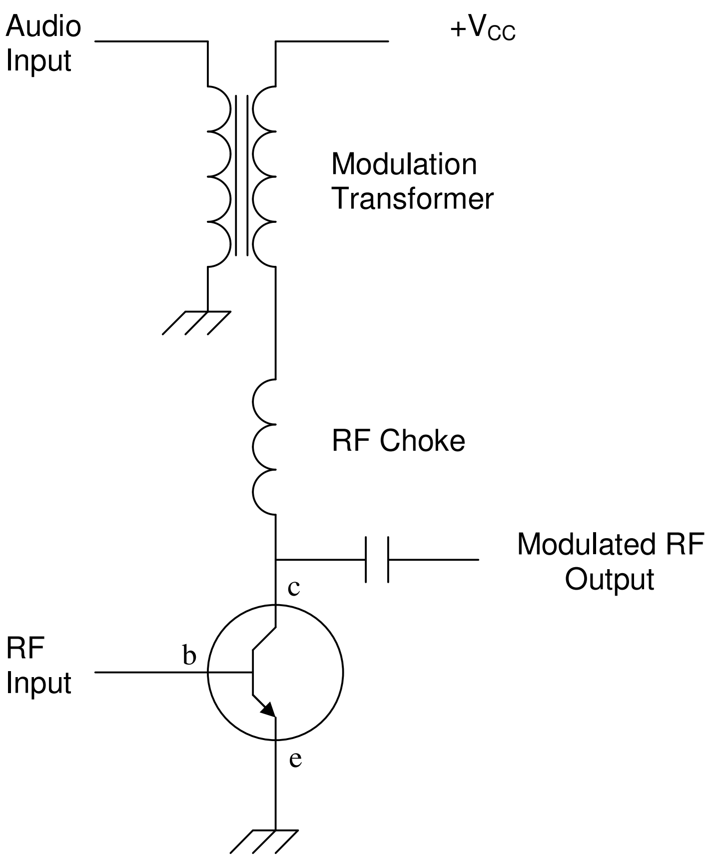
A VFO-controlled AM transmitter using high-level modulation

The audio input from the microphone is pre-amplified and then filtered to remove audio components above the voice range of 300 Hz – 3 kHz. The audio signal is further amplified by a power amplifier and fed to a high-level modulator that controls the

Class C RF power amplifier. The input to this amplifier comes from a VFO operating on the intended output signal.

Two-thirds of the energy in an amplitude-modulated signal is contained in the carrier and the remaining one-third in the modulation sidebands. In this circuit, the energy for the modulation sidebands is provided by the audio power amplifier. So if the carrier power were 100 W, then the audio power amplifier would have to supply 50 W to fully modulate the signal.

A high-level modulator typically consists of a *modulation transformer* that modulates the supply voltage to the final output stage depending on the audio modulation. An illustrative circuit diagram is shown below.

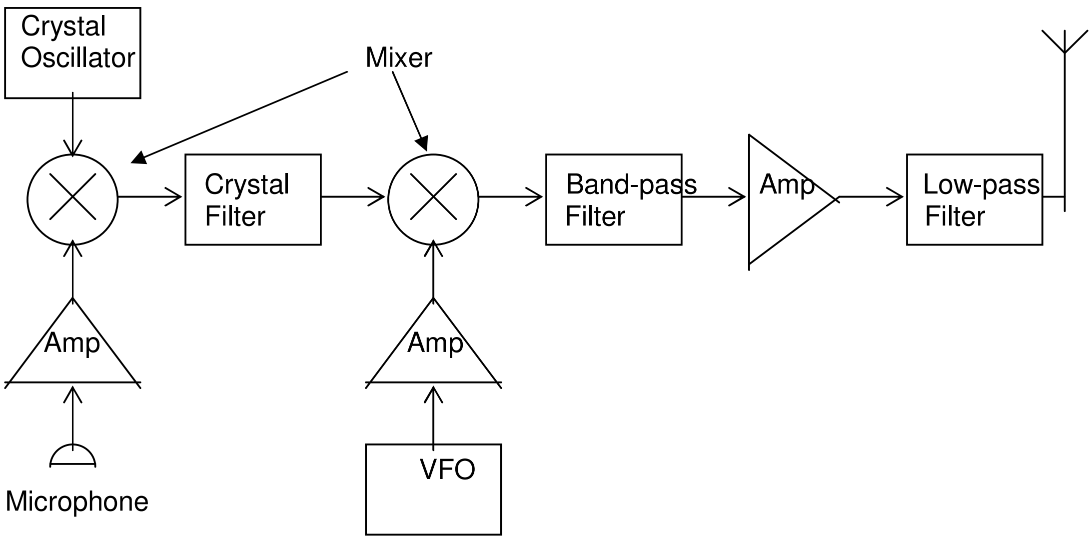


High-level modulation using a modulation transformer

For an example of an AM transmitter using low-level modulation, see the simple SSB transmitter described below. If the balanced modulator is replaced with an unbalanced modulator, and a crystal filter is used that is wide enough to permit both the upper and the lower sidebands to pass, then the result is a low-level modulated AM transmitter.

A Simple SSB Transmitter

The following block diagram shows a simple single-band VFO controlled SSB transmitter for the phone segment of the 20 m band, from 14,100 to 14,350 MHz.



A Simple Single-Sideband Transmitter

In this simple single-sideband transmitter, the carrier is generated by a crystal oscillator at a fixed frequency, perhaps 9,000 0 MHz. This is modulated by the amplified audio input in a balanced modulator (represented here by a circle with a cross inside it, the symbol for a mixer). Because the modulator is balanced, the output signal contains the upper and lower sidebands, but no carrier (so it is a double-sideband suppressed-carrier signal). A very narrow band-pass crystal filter is used to select the upper sideband only, i.e. frequencies from 9,000 3 to 9,003 0 MHz, eliminating the lower sideband. This is called the “filter method” of SSB generation.

Note that all the filters that are sufficiently selective to pass one sideband while rejecting the other are fixed-tuned, so the resonant frequency cannot be altered. This means that the SSB signal must be generated at a fixed frequency and then mixed up or down to the desired output frequency.

In this case the 9 MHz upper-sideband signal is mixed with the output of a variable-frequency oscillator that ranges from 5,100 to 5,350 MHz, resulting in two signals. The sum will be a USB signal in the range 14,100-14,350 MHz, while the difference will be an USB signal ranging from 3,900-3,650 MHz. The band-pass filter following the mixer is an ordinary inductor-capacitor filter, which is designed to pass the frequency range 14,100–14,350 MHz (the phone segment of the 20 m amateur band) while rejecting frequencies in the range 5,100–5,350 MHz, the unwanted mixing product.

This is followed by a linear RF power amplifier (probably running in class AB) and a final low-pass filter that will pass the desired output frequencies in the range 14,100–14,350 MHz while rejecting harmonics at 28,200 MHz and above.

Antennas

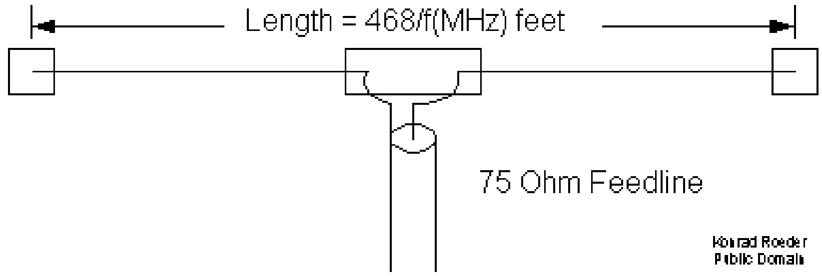
There are many different types of antennas, some are vertical, others slope and others again are horizontal. They all do the same work. Either receive radio signals or transmit radio signals.

Antennas convert electrical energy – which requires conductors to carry it – into electromagnetic energy, which is able to radiate through space. An electrical current flowing in a conductor generates a magnetic field in the space around the conductor. This is the principle behind electromagnets. If the current flowing in the conductor varies with time, then the magnetic field around the conductor will also vary with time. However according to the principle of induction a varying magnetic field will give rise to an electric field; and conversely, a varying electric field will give rise to a magnetic field. So by varying the current in a conductor, we can create a varying magnetic field, which will in turn create a varying electric field, which will create a varying magnetic field, and so on. The resulting interrelated varying electric and magnetic fields are called electromagnetic waves, and can travel long distances. At the frequencies that we are interested in, these electromagnetic waves are radio waves, although heat, light, and x-rays are also examples of electromagnetic waves of higher frequencies.

In electromagnetic waves, the electric and magnetic fields are perpendicular (at right angles) to each other, and both are perpendicular to the direction of motion of the wave. So if the electric field is horizontal with respect to the surface of the earth, the magnetic field will be vertical; while if the electric field is vertical, then the magnetic field will be horizontal. We refer to the *polarization* of electromagnetic waves according to the orientation of the electric field. So if the electric field is horizontally oriented, then the wave is horizontally polarized; while if the electric field is vertically oriented, it is vertically polarized

Polarization is important because a vertically polarized antenna will not respond to horizontally polarized radio waves, and vice-versa. So for line of sight communications it is important that the polarization of the transmitting antenna should be the same as that of the receiving antenna.

A simple dipole antenna



Propagation
Propagation means the process by which radio waves get from the antenna of the transmitter to the antenna of a distant receiver. This chapter introduces the different propagation modes used by amateurs.

Direct Wave (line of Sight) Propagation
Electromagnetic radiation generally travels in straight lines, so if radio waves can travel straight from the transmitting antenna to the receiving antenna without passing through anything that blocks it, then communication is possible. This simplest form of propagation is known as "direct wave" propagation. It is also called "line of sight" propagation although this term is a bit misleading since some things that block light, such as a wooden structure, are transparent to radio waves.

Direct wave propagation affects all frequencies. The range possible depends on the terrain and the height of the antennas. In flat terrain, with both antennas 10m high, the range of direct wave propagation is about 20 km. However, hilly terrain can be used to good effect by placing one of the antennas on top of a hill where it can be "seen" from much further away. This is why VHF repeaters are usually located on high sites, since they rely on direct wave propagation.

Ground Wave Propagation
Low and medium frequencies *refract* around the surface of the earth. Refraction is caused by the nearby ground slowing the radio wave down slightly, causing it to bend towards the ground. However because the ground itself is bending with the curvature of the earth, the effect is that the ground wave "hugs" the earth. Refraction is most pronounced at lower frequencies, so this effect is most significant in the low and medium frequency bands. It is present but less effective in the high frequency (HF) bands and absent at VHF and above. This is why you can still listen to medium wave AM commercial broadcast stations up to 100 km or so away from the transmitter – the medium wave broadcast frequencies (530 KHz – 1.6 MHz) are low enough for good ground wave propagation to occur. However commercial FM transmitters use VHF frequencies (88-108 MHz), which are only propagated by direct wave.

The Atmosphere
The atmosphere consists of three layers: troposphere, stratosphere and ionosphere. The ionosphere is that part of the upper atmosphere where free electrons occur in sufficient density to have an appreciable influence on the propagation of radio frequency electromagnetic waves. It extends from approximately 50 km to 800 km above the earth's surface.

The ionosphere is divided into four layers. The D layer, which extends from 50-90 km above the surface, is only present during daylight hours. As soon as the sun's ionising radiation is no longer present, electrons and ions rapidly recombine to form neutral (un-ionised) gas and the D layer disappears. The principle effect of the D layer is to absorb radio waves. It affects low frequencies much more than high frequencies.

The upper three layers have a different effect. Instead of simply absorbing radio waves, they bend them by refraction. If a wave is bent sufficiently then it may return to earth a considerable distance from the transmitter, almost as though it had been reflected off the ionosphere. The amount of refraction (bending) depends on frequency is more pronounced at lower frequencies. The upper layers are the E layer, which extends from 90 to 150 m above the surface; the F1 layer, which extends from 150 to 180 km; and the F2 layer, which extends from 180 km to 300 km or higher. At night, the E layer dissipates while the F1 and F2 layers combine to form a single F layer that is less strongly ionised than during the daytime.

Sky Wave (Ionospheric) Propagation

The effect of this is that during the daytime, the D layer will absorb low frequencies, but higher frequencies will make it through the D layer and can be refracted back to earth by the E, F1 or F2 layers. Higher frequencies still will not be refracted sufficiently by the E, F1 and F2 layers and will continue out into space instead of being returned to earth. Refraction by the F2 layer (or at night by the single F layer) is responsible for most long-distance HF communication.

At night, the D layer dissipates almost immediately and the E layer more gradually, while the F1 and F2 layers combine to form a single less strongly ionized layer. Now that there is no D layer to absorb low frequencies, they can be reflected from the F layer and travel long distances. However high frequencies are not be refracted sufficiently by the more weakly ionized night time F layer, so they will be lost into space.

This process of being refracted from the ionosphere is also known as "skip." The maximum skip distance for the E layer is around 2 500 km, and about 5 000 km for the F layer. Longer paths may be achieved by multi-hop propagation, where the refracted signal bounces of the surface of the earth back to the ionosphere and is refracted back to earth again.

Electromagnetic Compatibility

Electromagnetic compatibility (EMC) is the process of ensuring that equipment that radiates electromagnetic radiation, such as an amateur transmitter, does not interfere with equipment that may be sensitive to electromagnetic radiation, such as television and radio receivers.

EMC problems can be classified according to whether the device that is radiating the signal causing interference is an *intentional radiator* (that is, a device that is intended by virtue of its function to radiate, such as an amateur transmitter or a garage opening remote control) or an *unintentional radiator* (that is, a device that does not need to radiate in order to perform its intended function, such as a motor vehicle ignition system or an electric fence) and whether the device being interfered with is a *receiver* (that is, equipment designed to receive radio signals at some frequency) or is not a receiver (such as a CD player that is picking up breakthrough from nearby transmissions).

Unintentional Radiators

There are strict limits to the maximum permitted radiation from any system that does not have to radiate in order to operate correctly. If a system that does not include a radio transmitter of some kind is causing interference, then that is generally because the system is radiating more than permitted, and it should be repaired or replaced at the owner's expense. For example, if you receive interference from a neighbour's electric fence, then that probably indicates that the electric fence is radiating more than is permitted, and the neighbour is responsible for having the defect rectified, and must turn the electric fence off until it complies with requirements. Of course convincing your neighbour of this may be difficult!

Interference to non-receiving equipment

The converse applies when the equipment being interfered with is not intended to receive radio signals. For example, suppose your neighbour reports that your radio transmissions are "breaking through" on their stereo system when they are listening to CDs. Because the stereo system when listening to CDs is not supposed to receive radio signals, the problem lies with the stereo, not with the radio transmitter. Often the root cause is that the affected equipment was not designed for, and has not been tested in, environments with strong RF signals present. Unfortunately, it is quite legal for such equipment to be sold, and it will work fine for 99% of the time, since in most locations it will encounter only weak electromagnetic radiation from distant transmitters. Then an amateur moves in next door, sets up equipment that is operating within the limits of their license, and all of a sudden, the neighbour's CD player receives interference. It is quite natural for the neighbour to think that this is the amateur's fault, and that they must fix the problem or stop transmitting. However, in actual fact, the fault lies with the manufacturer of the equipment for not designing it to withstand the levels of electromagnetic radiation that may result form a nearby amateur installation.

In this case, even though it is the neighbour's responsibility to solve the problem, it would be diplomatic for the amateur concerned to make his or her technical skills available to the neighbour to help diagnose the problem and suggest solutions. Apart from good neighbourliness, the same neighbour may have the opportunity to comment on your application to erect a tower, and is more likely to be kindly disposed to such a request if you South African Radio League Radio have helped them to solve any problems that appear to have been caused by your transmissions in the past!

Intentional Radiators interfering with Receivers

The situation is slightly more complex if an intentional radiator (such as your amateur transmitter) interferes with a device that is intended to receive radio signals (such s your neighbour's television). In this case, the key question is the nature of the interfering signal. If the interfering signal is in all respects a legal licensed transmission – that is, it is within an amateur band, does not exceed the power permitted for the band and license holder, and is a clean signal – then the problem is being caused by the receiving equipment being affected by an out of band signal, and it is the receiving equipment that is defective and must be repaired. On the other hand, if the transmitted signal in any way does not conform with the requirements of your license, then you should first correct the problem with the transmitted signal before suggesting to your neighbour that they have their TV fixed! This is particularly important because if interference is reported to ICASA then their first course of action will probably be to inspect your transmitting equipment. If it is found to be out of order in any way then you may be held responsible for the interference and, even if you are not, the transmitting equipment can be confiscated if it does not conform with your license requirements. Once again, as a matter of diplomacy, it is a good idea to assist your neighbour if possible to solve the interference problem, even if you have determined that your transmitter is operating quite legally. As well as maintaining peace in the neighbourhood, this will help to maintain the good reputation of amateur radio. However if this is not possible – for example, if your neighbour refuses your assistance and insists that you just stop operating – then as long as you are certain that your equipment is operating legally, then you are entitled to continue to operate despite the interference to your neighbour's television or other equipment.

Electrical Safety

In South Africa electrical mains power ranges between 220 and 240 Volt 50 Hertz, with 230 V the most common.

Safety around the Home

Electricity surrounds us Thus, to know more about it and to understand it further is important. The first and most critical aspect to learn about electricity is safety. Playing around with electricity can be dangerous. Make sure that you and your family know how to work with electricity safely.

Conducting important Routine Safety Inspections

Equipment needing repairs or replacement should be attended to immediately. Not doing so could result in an accident. Breakages and excessive wear and tear on electrical equipment can occur frequently so you need to make regular inspections and take precautions to ensure your safety.

- Here are some general points to look for when making an inspection:
- Breakages
- Wear/deterioration
- Signs of overheating
- Missing parts (screws, covers, switches)
- Faulty appliance controls
- Doors and covers not closely smoothly or adequately.
- Correct labelling when needed (eg. Electricity requirements)
- Loose Fixtures or fittings

It is also important to test your equipment regularly - switch it on and off and look for possible problems or faulty connections. Taking time to make sure you are using your equipment safely could save your life later on.

Plugs and Electric Sockets

1. Look for the SABS sign and only use SABS approved plugs.
2. Do not overload plugs - rather use an adaptor.
3. Do not pull a plug by the cord.
4. Switch the switch off at the wall socket, before pulling the plug out.
5. Do not connect electrical appliances to light sockets.
6. Ensure that all wall sockets have their switches in the "off" mode, when not in use.
7. Never put bare wires into sockets.

How to fit a plug?

1. Bare the ends of the three wires inside the electrical cord for about half a centimetre, by cutting away the plastic insulation.
2. Gently twist the strands of copper wire with your fingers until each strand is tight.
3. Fold over the twisted strands.
4. Remove the plug cover by either "snapping" or unscrewing it.
5. Unscrew the little screws on each of the plug's pins.
6. Insert the twisted copper wires into the holes in the pins.
7. The green and yellow wire must always be inserted into the top pin.
8. The blue wire is inserted into the left pin (the pin is marked with a blue spot or the letter N).
9. The brown wire is inserted into the right pin (the pin is marked with a brown spot or the letter L)
10. Tighten the little screw on each of the plug's pins.
11. Make sure the electrical cord is firmly gripped by the arrestor clips.
12. Replace the cover of the plug.

The next section deals with operating procedure which you will be examined on. There will be 10 questions.

Operating Procedure

HF Phone Procedures

The Phonetic Alphabet

The phonetic alphabet is used whenever information must be spelt out. It should be used for call signs when initiating a contact. Once it is clear that the other station has your call sign correct then you can revert to normal pronunciation (“ZU1XYX” instead of the phonetic “*Zulu Uniform One X-ray Yankee Zulu* .”

The standard phonetic alphabet is:

Alpha	*Juliet*	*Sierra*
Bravo	*Kilo*	*Tango*
Charlie	*Lima*	*Uniform*
Delta	*Mike*	*Victor*
Echo	*November*	*Whisky* (or *Water* in Muslim countries)
Foxtrot	*Oscar*	*X-Ray*
Golf	*Papa*	*Yankee*
Hotel	*Quebec*	*Zulu*
India	*Romeo*	

Q CODES

The following are the official Q-codes. The last column indicate general usage

QRM	Are you being interfered with? *or* Is my transmission being interfered with?	I am being interfered with *or* Your transmission is being interfered with ...	Interference
QRN	Are you troubled by static?	I am troubled by static	Static interference
QRP	Shall I decrease transmitter power?	Decrease transmitter power.	Low power transmission normally 5 watt or less
QRS	Shall I send more slowly?	Send more slowly	Please send slower
QRT	Shall I stop sending?	Stop sending.	I am closing down
QRV	Are you ready?	I am ready.	I am ready to recieve, write down etc
QRX	When will you call me again?	I will call you again at ... hours (on ... kHz (*or* MHz)).	Please stand by a moment
QRZ	Who is calling me?	You are being called by ... (on ... kHz (*or* MHz)).	Who is calling me
QSL	Can you acknowledge receipt?	I am acknowledging receipt.	Please send a QSL card
QTH	What is your position in latitude and longitude (*or according to any other indication*)?	My position is ... latitude, ... longitude (*or according to any other indication*).	My location (Town, city etc)

These words have been chosen so they are easily distinguishable from one another. This, plus knowing the words that are included in the phonetic alphabet, aids intelligibility in poor conditions. For example, if you hear only "elta" then you know the word must have been "Delta." These advantages are lost if non-standard phonetics are used, so you should always use the standard phonetic alphabet.

Initiating Contacts

Before calling, you should listen for at least 30 seconds to see whether the frequency is clear. If you do not hear anyone else on or near the frequency, then you can ask whether the frequency is clear:
Is this frequency in use? Zulu Uniform One X-ray Yankee Zulu (ZU1XYZ)

Wait another thirty seconds and if you have not heard anything then you can proceed to call "CQ" to ask for a contact.

CQ CQ CQ this is Zulu Uniform One X-ray Yankee Zulu standing by.

Wait for 5 seconds. If you do not receive a response, then call again. If after you have tried many times you still have not received a response, then this may indicate that propagation conditions are poor on the band you have chosen.

If you want, you can make a *directional* call, which means asking for only certain stations to reply. If you call *CQ DX,* this means you are asking for only "long distance" (DX) contacts, which usually means stations on another continent. If you call "CQ Europe" or "CQ Germany" then you are asking only for stations from a particular continent or country to reply.

Replying to a CQ

If you hear a station calling CQ and you would like to make contact, then before you call, check the following:

1. Is it a directional call, and if so are you in the right area to respond? For example, a South African station should not respond to "CQ Japan" but may respond to "CQ Africa" or to "CQ DX" from a non-African station.

2. Make sure you know where the station is listening for a response. Usually this will be on the same frequency as their call. However rare DX stations may work "split" which means they are listening on a different frequency, generally higher than the one they are calling on. For example, if you hear a DX station call "Sierra Tango Zero Romeo Yankee up five" it means the operator will be listening 5 KHz higher than the frequency they called on. You will need to know how to activate the "split" function on your transceiver to work this station.

3. Ensure that a suitable antenna is connected and (if necessary) that your antenna tuning unit (ATU) is correctly set for the frequency and antenna. If the ATU is not set then *do not* tune up on the frequency where you hear the CQ call, as this most inconsiderate and will call interference to the station calling. Rather change frequency by at least 3 KHz to an unoccupied frequency, and after checking that the frequency is not in use, tune up there and then return to the frequency where you heard the call.

Of course it is wise to check these things *before* you search for stations calling CQ, so when you hear one you can respond immediately. Suppose you hear W1XX calling and having checked everything you are ready to call. Then you would say:
Whisky One X-ray X-ray this is Zulu Uniform One X-ray Yankee Zulu, Zulu Uniform One X-ray Yankee Zulu (ZU1XYZ) standing by.

Note that the call sign of the station being called is always given *first*, and the call sign of the station calling comes *second*. This is important and getting it wrong will mark you as a poor operator.

It is unnecessary to repeat the call sign of the station you are calling several times – after all, she or he presumably knows his/her call sign, and unless conditions are bad, once is normally sufficient for them to see that you have got it right. Under poor conditions, however, you might want to repeat it a couple of times.

Exchanging Reports

After making contacts, the first things stations do is usually to exchange signal reports and basic information such as the name and location of the operator. Signal reports are exchanged according to the standard Readability-Strength (Tone) code, usually abbreviated RST. The Tone part is only used for CW communication, so for Phone it is RS – Readability and Strength only. The meaning of the RST values are as shown below:

READABILTY
1 -- Unreadable
2 -- Barely readable, occasional words distinguishable
3 -- Readable with considerable difficulty
4 -- Readable with practically no difficulty
5 -- Perfectly readable

SIGNAL STRENGTH
1 -- Faint signals, barely perceptible
2 -- Very weak signals
3 -- Weak signals
4 -- Fair signals
5 -- Fairly good signals
6 -- Good signals
7 -- Moderately strong signals
8 -- Strong signals
9 -- Extremely strong signals

TONE

1 -- Sixty cycle a.c. or less, very rough and broad
2 -- Very rough a.c. , very harsh and broad
3 -- Rough a.c. tone, rectified but not filtered
4 -- Rough note, some trace of filtering
5 -- Filtered rectified a.c. but strongly ripple-modulated
6 -- Filtered tone, definite trace of ripple modulation
7 -- Near pure tone, trace of ripple modulation
8 -- Near perfect tone, slight trace of modulation
9 -- Perfect tone, no trace of ripple or modulation of any kind

The Q-code "QTH" is often used to mean the location of the operator, although this is actually incorrect usage as the Q code should only be used in Morse code, and normal plain language should be used in Phone. So you might hear the following reply from W1XX: *Zulu Uniform One X-ray Yankee Zulu this is Whisky One X-ray X-ray. Thanks for the call, you are five and six, fifty-six. My name is Bob, Bravo Oscar November, and my QTH is Boston, Massachusetts. ZU1XYZ from W1XX.*

The signal report indicates that our signal is perfectly readable, with good signal strength. You would reply with a signal report, and also your name and location.
W1XX from ZU1XYZ Good morning Bob, thanks for the report. Your RST is five nine,
five nine here in Cape Town. My name is Andrew, Alpha November Delta Romeo Echo Whiskey, Andrew. I'm testing a new rig here, a Kenwood TS850S, running 100 watts into a triband Yagi at 15 metres. Back to you Bob. W1XX this is ZU1XYZ.

And so the conversation continues. You must by law identify your station on each separate transmission (each "over"). However once you are sure that the other station has your **callsign correct you can use plain language instead of the phonetic alphabet.**

After the QSO

If you have not already filled in your log during the QSO, then you should do so immediately after the QSO. Remember that you are required by law to keep a log of all HF transmissions (including unanswered CQs, but no-one actually logs these).
If you have offered to send a QSL card, then it is a good idea to write it out immediately, as it can become a chore if you wait for hundreds of QSOs to accumulate before writing out the cards.

Radio Regulations

The regulations that you will be examined on must be downloaded from http://www.sarl.org.za/public/licences/rae.asp . You should have a copy of the full regulations in your possession. Download a copy from www.sarl.org.za