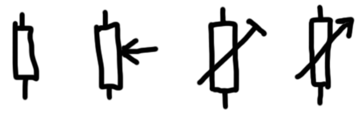
Intermediate Revision Notes - 2W0LGE

These notes are extracted from Rev6 of the Intermediate book, most of the waffle removed, and are mostly in bullet point form. They go hand in hand with the Foundation set of the same.

Symbols

Resistor (ohms)



fixed potentiometer preset variable

Capacitor (farad)

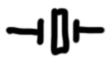
fixed electrolytic variable

Inductor (henry)

fixed with core

Transformer

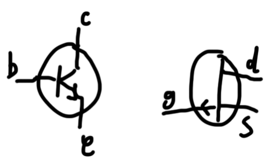
Quartz Crystal (hertz)



Diodes

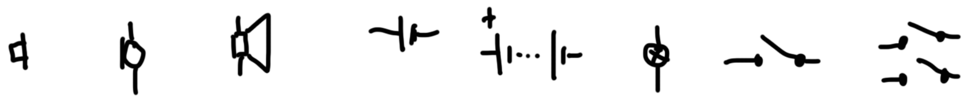
semi conductor variable led

Transistors



bipolar NPN with or without circle field effect FET

Others



earphone mic loudspeaker cell battery bulb SPST DPDT

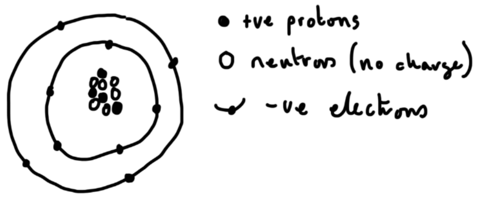
fuse antenna earth chassis ground

Soldering

- allows construction of all sorts of radio/electronic equipment
- method of joining metal
- beware of splashes
- solder bonds two metals to form a joint
- good electrical connection and good mechanical connection
- soldering irons in watts, 15w for RF components, 25w for larger jobs
- solder = lead + tin, or silver based
- flux helps solder to 'flow' and removes oxides
- flux built into solder is known as Rosen
- some metals solder well, such as copper, tin and brass
- aluminium or stainless steel need a different method
- clean the tip using wet sponge, then tin it, which prevents oxides and improves heat transfer
- bare wires also tinned
- quick process as to not damage components
- look for 'dry' joints, good is a bright hemisphere, bad is lumpy and dull
- use a stand and ventilation, Rosin is bad for asthma
- stand can prevent burns and accidents
- wear eye protection

Conductors, Insulators and Semiconductors

- some materials conduct readily, these are conductors
- some have high resistance and do not conduct, these are insulators



- shells, electrons orbit - valence shells
- nucleus is balanced by the -ve orbiting electrons

- outermost electrons not strongly attached, so in conductors they can be moved by applying a potential difference (PD)
- a battery in a DC circuit causes electrons in the wire/bulb to move along the conductor
- this movement is CURRENT

Conductors / Insulators

- conductors - low resistance, freely moveable electrons (copper, brass, steel, nickel)
- insulators - high resistance, electrons tightly bound and wont move easily (wood, rubber, plastic, ceramics, glass, dry air)

NOTE: electron flow can occur in insulators if the PD is large enough so the insulator 'breaks down'. The electrons are forced to move. Insulators may conduct when wet !

Semi Conductors

- half way house, not insulator, not a conductor, they behave like BOTH
- silicon - pure silicon is made impure by adding other substances - there are two forms

N + **P**

N has spare electrons **P** has few electrons or 'missing electrons'

Biasing

- semiconductors are either insulator or conductor depending upon the PD across and the current through
- current cant flow from P to N because it is short of electrons, it INSULATES
- move spare electrons from N to P to fill the ‘gaps in P’, and it becomes CONDUCTOR
- polarity is important for the PD as this influences which way the spare electrons move
- resistors set the PD and the current to make the device function…. this is called BIASING

Components and Symbols

Resistors

- ohms, kilo-ohm and mega-ohm
- the resist current flow
- carbon film - coat ceramic former with carbon, amount of carbon = resistance value
- metal film
- wire wound
- some variable resistors not linear (log pots)

Diodes

- flow in one direction only (what about a zener?)
- used in AC to DC conversion
- observe the correct polarity - the arrow / bar end of the device goes to 0v

Transistors

- active component
- on/off or oscillator as an amplifier
- bipolar and field effect

IC’s (Integrated circuits)

- hundreds and thousands of components
- black box solution, e.g. LM386
- often depicted as a triangle in circuits
- indent / spot next to pint 1

Note on Project Safety

- watch out for sharp edges etc
- use correct tools, and identify tool safety
- when drilling watch for swarf etc, use eye protection

13A mains plug + Electrical Safety

- high voltages on power lines, watch out when installing antennas
- fuse = safety device - metal strip or ceramic tube
- great for too much current but wont stop electric shock or death

RCD

- residual current device
- these sense mains AC and ‘trip’ if there is an imbalance between L + N, cause by leakage or contact with L
- approximately 30mA
- every shack should have one, can be on an extension cord, or in distribution panel in house

Multi-meters and Units of Measure

- must be able to make measurements
- analogue and digital MM's
- never touch probes when making measurements (dangerous and can change readings)
- 3 main reading types - voltage (V), current (amps), resistance (ohm)
- ac/dc selector, and range setting (might have auto)
- micro = 1 millionth (1 x 10^{-6}) u
- milli = 1 thousandth (1 x 10^{-3}) m
- mega = 1 million (1 x 10^{6}) M
- ensure range is correct or might damage MM
- ensure correct polarity

Readings

- voltage readings across two points V = across / parallel
- current readings through (in series) A = through / series
- switch off after use
- analogue vs digital - pro's con's for both

Potential Difference

- potential difference across conductor causes negative charged electrons to flow, this is current
- volts short for voltage
- lightbulb in circuit acts like a resistor glowing white hot
- resistor opposes current flow
- PD falls as current flows through resistor - due to linear relationship of V=IR
- voltmeter has HIGH internal resistance - parallel for volt reading
- PD across bulb + resistors add up to PD across battery (series)
- PD causes current to flow
- PD measure across
- PD supplied by the battery in series circuit is divided by the components in a circuit
- high internal resistance MM does not change the PD when in parallel
- **Kirchhoff Volt Law** (KVL) = sum of PD's in SERIES circuit EQUALS that of the BATTERY

Measure Current

- current - flow of electrons in AMPS (A)
- 1mA is 1 thousandth of an amp
- 1uA is 1 millionth of an amp
- meter is at risk when measuring current
- current measured in series
- very low internal resistance for the MM in current mode
- in a series circuit, the current is the same wherever measured
- current flows through complete circuit
- always start with MM in highest range
- never leave on CURRENT test

Licence Conditions 1

- foundation, intermediate, full (not advanced like every one talks about)
- **M6 2E0 M0**
- **G** - historic call signs
- **GB** - special event
- **MC** - club calls
- **D** - Isle of Man
- **E** - England
- **I** - Ireland
- **J** - Jersey
- **M** - Scotland
- **U** - Guernsey
- **W** - Wales

/P	- no address but a fixed station / temporary
/M	- mobile (vehicle or conveyance, pedestrian, or vessel on inbound water way)
/A	- alternative
/MM	- maratime mobile

- can operate under supervision using operators callsign and terms of his/her license
- intermediate may supervise another amateur under license conditions of the intermediate
- may use other amateur equipment unsupervised but under license conditions of own callsign
- intermediate NOT entitled to supervise unlicensed operators (only full call signs can do this)
- license under which the equipment is operated and hence the callsign is important, this defines who's the 'equipment is during operation', not the legal owner
- must NOT be used for business or advertising
- self training, leisure activity, but ok to say if you have a personal radio for sale

- Licensees may PASS messages on behalf of USER SERVICE, and permit members of the USER SERVICE to use the radio equipment to send messages. These are (for the purpose of the exam) :

POLICE
FIRE
AMBULANCE

Coastguard
British Red Cross
St Johns Ambulance
St Andrews Association
Woman's Royal Voluntary Service
Salvation Army

ANY government department

- Must transmit callsign at ~~least every 15 mins~~, and when establishing comms, or changing frequency, by the same mode that is being used — **this has now changed in 2015** to clearly identify the station at all times, and to use callsign as often as practical, doesn't specify when changing mode or frequency, but probably best to do it anyway, and when calling CQ
- NO airborne radio transmission
- NO seaward side of low water line as marked on charts
- /M on canal or inland water
- NOT all countries recognise intermediate
- **NOTE** it is **NOT** a requirement to use /P /M /A /MM, but it is class as good practice ! This can be a question, such as 'if you were going to a friends house for 10 days to set up a station, who was not a licensed amateur radio operator, what callsign would you use?' a) ring ofcom b) mw0tql c) use /P d) phone a friend…….. the answer is B

Input Power

- power is a measure of work done
- P=VI , power in WATTS, V in volts, I in AMPS
- James Watt
- mV to V, move decimal 3 to the left
- mA to A, move decimal 3 to the left
- output power from radio measure with RF power meter
- input power always greater than output power, many cases output < 50% of input
- input power is energy supplied to the circuit
- input power to bulb is rate at which energy is supplied to the bulb
- current through a resistor = electrical energy to heat energy

1000 mV = 1V
100 mA = 0.1A

Operating Practices

Q Codes

QRM - man made noise / other stations
QRN - natural noise / static
QRP - low power
QRT - closing down
QRZ - who is calling?
QSB - fading on signal

QSL - transmission success / ok received
QSO - contact / chat
QSY - change frequency
QTH - location

QRL - is this frequency in use?

Abbreviations

CQ - general call
DX - long distance
WX - weather

SIG - signals
UR - your
DE - from

K - go ahead
R - roger

RST

- morse - 3 digit report 599 for example - readability, signal, tone
- voice - 2 digit report normally, 59 for example - readability and signal

Prefixes

EI - Ireland (Irish republic)
F - France
I - Italy
JA - Japan

PA - Netherlands
VE - Canada
VK - Australia
W - America
ZL - New Zealand

QSL Cards

- post cards to validate a qso
- RSGB operate the UK QSL bureaux
- must either be an RSGB member or pay them to receive the cards
- only RSGB members can send through

Awards & Contests

- DX competitions
- contact as many as possible in short time
- serial numbers etc etc
- must log, submit, and follow rules

Other Info

- year book very handy for more info and call signs

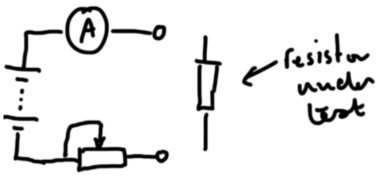
Measuring Resistance

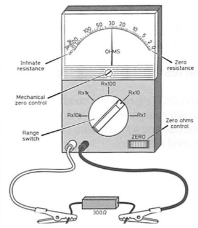
- coloured bands - the four colour system
- band 1 + 2 = value,   band 3 = zeros,   band 4 = tolerance

		tolerance
0 - black	**6 - blue**	**10% silver**
1 - brown	**7 - violet**	**5% gold**
2 - red	**8 - grey**	**2% red**
3 - orange	**9 - white**	**1% brown**
4 - yellow		
5 - green		

NOTE: **black as 3rd band** = no zeros, small value
gold as 3rd band = divide by 10
silver as 3rd band = divide by 100
eg, yellow violet gold gold = 47/10 = 4.7ohm
4 7 /10 5% +- 5%
or 4R7

Multimeter Internals





- The variable resistor/pot is there to zero the meter

NOTE: could have question to work out value of resistor based on the Multi Meter front face

Resistors in Series

- just add them when in series

Resistors in Parallel

- if the same value, take the value (single) and divide by total number of resistors, otherwise use :

$$R_{TOT} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N}}$$

- resistance in ohms
- rated using colour code
- measured using ohm-meter
- meter must be zeroed

AC

- current flow alternates in direction
- PD across resistor will rise and fall in accordance with OHMs law
- sine, square or saw
- sine wave - amplitude and frequency

$$V_{RMS} = 70.7\% \text{ of } V_{pk}$$

$$V_{pk} = \frac{V_{pp}}{2}$$

$$V_{RMS} = \frac{V_{pk}}{\sqrt{2}}$$

or

$$V_{RMS} = 0.707 \times V_{pk}$$

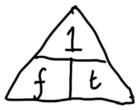
- amplitude is the height of peaks, or depths of troughs
- peak value (Vpk) = difference between 0 and positive or -ve peak (no sign)
- peak to peak (Vpp) = difference between -ve and +ve min and max (no sign), Vp
- RMS - root mean square (an average)

- RMS is equal to the current or PD of a DC supply that would result in same power dissipation
- need to calculate power in AC circuit? use OHMS law, but values must be in RMS, not Vpk or Vpp

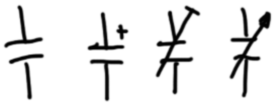
eg. how much power dissipated in 200Vpk AC psu with 1Apk? P=Vrms*Irms, P=(200*.707)*(1*.707) = 99.7W

Frequency of AC

- number of times per second it goes through a full cycle
- UK mains is 230V 50Hz
- if we know the cycle time, we can calculate frequency using



Capacitors



fixed   polarised preset   variable

- plates insulated by dielectric (normally) - some have more than 1 plate per side
- connect PD to cap, current will flow into the cap, this charges the plates - when full current stops flowing
- charge remains if PD removed
- store energy as electric field, this is capacitance
- **capacitance** measured in **farads**
- F, mF, uF, nF, pF

1F = 1000mF (milli , not used much)
1mF = 1000uF (micro)
1uF = 1000nF (nano)
1nF = 1000pF (pico)

- value of a capacitor defined by …. 1) size of plates   2) separation of plates 3) dielectric material
- they act as an insulator to DC, they can not pass DC
- AC passes as current changes, each side discharges, so AC is allowed to pass
- classified according to dielectric material - ceramic, polystyrene and polyester (common types)
- shapes and sizes vary, but normally two legs that can be soldered
- normally in the nF to pF ranges
- some are made by rolling the plates and dielectric into a spiral to make them smaller
- higher capacitance requires thinner dielectric - this is often formed chemically rather than using plastic
    - these become polarised and are known as electrolytic and have large values in the uF range
- variable capacitors generally use air as the insulator and two sets of metal plates that rotate to overlap

Dangers from Stored Charges

- circuits with high PD might have capacitors that store great charge and can be dangerous
- they should have a leak away circuit design to be safe

Inductors

- coil of wire - used in tuned circuits and filters
- magnetic field on the wire as current passes, additivity on each coil of wire
- when current ceases, the field collapses and releases energy into the wire
- **inductance** measured in **henrys**
- H - henry, mH - millihenry, uH - microhenry
- determined by length, number of turns and diameter
- core also influences the value
- various shapes and sizes, toroid, roller coaster, variable inductor (the ferrite core moves in and out)
- H, mH, uH

1H = 1000mH
1mH = 1000uH

Engineering Notation

- large or small numbers

giga	x 10^9	milli	x 10^{-3}
mega	x 10^6	micro	x 10^{-6}
kilo	x 10^3	nano	x 10^{-9}
		pico	x 10^{-12}

Reactance

In capacitors
- when caps charge/discharge they do not pass AC equally well, they provide some opposition to the current, this is referred to as reactance
- reactance (measured in ohms) due to capacitance is known as X_c
- using ohms law V=IR, becomes $V_{rms} = I_{rms} * X_c$

In inductors
- when AC current flows through an inductor the magnetic field repeatedly stores and releases energy over time as AC changes polarity
- the inductance provides some opposition to the current, this is referred to as reactance
- reactance (measured in ohms) due to inductance is known as X_L
- using ohms law V=IR, becomes $V_{rms} = I_{rms} * X_L$

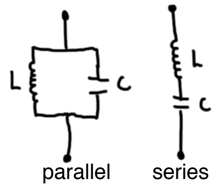
X_c = ratio of V_{rms} to I_{rms} as the cap stores energy in the form of an **ELECTRIC** field
X_L = ratio of V_{rms} to I_{rms} as the inductor stores energy in the form of a **MAGNETIC** field

Impedance

- resistance + reactance = impedance ($Z = R + X_c + X_L$)
- unit of measure of impedance is Z and is in ohms
- using ohms law V=IR, becomes $V_{rms} = I_{rms} * Z$

Z = ratio of overall V_{rms} to I_{rms} in a circuit that has both resistance and reactance

Tuned Circuits

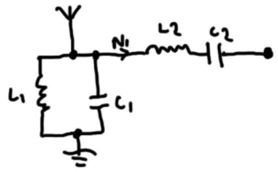


- may be resonant at a specific band of frequencies
- resonant frequency is the frequency that energy transfers from L to C - back and too
- **increase L or C to reduce frequency**
- **decrease L or C to increase frequency**

eg: (possible question) circuit is resonant @ 3.8mHz and you need it to be 3.5mHz…. you increase C or L !

Accepting or Rejecting Current Flow

- **Acceptor** — **LOW** impedance at resonant frequency allowing current to flow — **series tuned circuit**
- **Rejector** — **HIGH** impedance at resonant frequency preventing current flow — **parallel tuned circuit**
- trapped dipole has a number of parallel tuned circuits along the elements



- the parallel tuned circuit will allow current to flow to N1 on the tuned frequency, everything else is dumped to ground.
- the series tuned circuit will allow current to flow through

OHM's Law - Revisited

- current through a resistance is proportional to the PD across it, V = IR
- linear relationship

Parallel Circuits

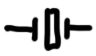
- resistors in parallel reduce the resistance (see formula above)
- total PD across series circuit is divided between components in the circuit - current is the same through each
- total PD across parallel circuit is equal across all components - current is divided by number of components

Kirchhoff current law (KCL) : sum of currents arriving at a junction in a parallel circuit is seen to equal sum of currents leaving that junction

RF Oscillators

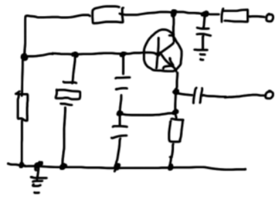
- RF oscillators
    - 3 mains types - **crystal**, **variable frequency (VFO)**, **frequency synthesised**
- audio frequency oscillator
- need to be stable

Crystals



- quartz crystal
- piezo electrical effect
- acts like tuned circuit
- frequency defined by size and thickness
- normally inside a metal can

Crystal Oscillator



do we need
to know this?

- use crystal with transistor to get stable oscillator
- transistor maintains the oscillations
- crystal set operating frequency
- disadvantage is that it operates on only **ONE** frequency
- popular in VHF + UHF transmitters

Variable Frequency Oscillator VFO

- resonant frequency of tuned circuit determine frequency for oscillations
- transistor maintains the oscillations in the tuned circuit
- need to recognise a CRYSTAL and an INDUCTOR/CAPACITOR base oscillator (look for the crystal symbol)
- range of VFO determined by min + max value of varicap
  - 10-100pF will be wider than 10-25pF
- may also need to vary the inductance by adjusting threaded core at the centre of the coil
- **MAY DRIFT** or **GET PULLED** from frequency , even outside the amateur band !!!! beware !!!!
- **A good VFO will have**
  - well regulated DC supply
  - rigid mechanical construction
  - screened enclosure (stray RF and constant temperature)
  - buffer amplifier will isolate the VFO, so changes such as TX/RX will not effect the VFO

Digital Frequency Synthesiser

- based on crystal oscillator
- enable wide range of frequencies
- very stable, but quite complex

Calibrating a VFO (practical)

- look for the zero beat
- inductor sets the mid point
- capacitor sets the range/width

Diode

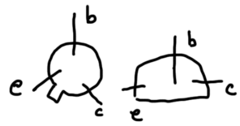
- current only in one direction
- rectification in AD to DC
- demodulator in an AM receiver
- has a single PN junction
- some made from material that emits light (led's)
- when a PD is applied with the correct polarity, spare electrons in N fill gaps in P, and current will flow
- the **forward BIAS** is the required volts to make this happen (~0.6v in silicon, ~0.3v in germanium)
  - low resistance when this happens
- if PD connected in reverse, no electrons will flow, this is **reverse BIAS**, and becomes an insulator
  - high resistance in this 'reverse' direction

Transistors

- they can be switches, amplifiers and oscillators
- 3 materials sandwiched, NPN or PNP
- electrodes connect to the layers of silicon
- emitter / collector / base

Transistor as a Switch

- when switched, a PD across the collector and the emitter
- electrons will not flow until a PD is applied to base/emitter of approx 0.6-0.7v @ base
- this small forward bias PD causes small current to flow from base to the emitter which causes larger current to flow from collector to emitter
- base to emitter current used to control collector to emitter current
- can be used as a switch, to change from RX to TX, or to key CW for example
- NPN's — BC108 & BC548
- human body = conductor, could be detected and used to close switch



Transistor as an Amplifier

- just enough PD across base for small current to flow collector to emitter
- apply additional small AC to base emitter
- emitter to collector will copy, and it will be a larger copy — amplified
- called amplification
- comparing collector to base current is on way to quantify 'gain'
- the ratio of collector current to base current is known as current gain β (beta)
- no units for β — we just say 'collector is X times base current'

$\beta = I_c / I_b$

Transistors used in Oscillator Circuits

- used to maintain oscillations in crystals and tuned circuits
- also to maintain oscillations in other frequency selective circuits to generate audio frequencies

Types of transistors

- NPN and PNP
- bipolar
- field effect (FET)
- see symbols on page 1

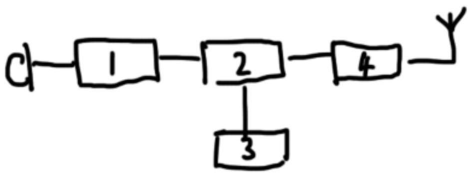
IC's

- P + N type material
- hundreds or thousands of transistors and diodes
- DIL - dual inline package (two rows of pins)
- PIC - programmable IC
- diodes and transistors do not have fixed resistances - they vary with current flowing through

Transmitters

- Simple TX recap

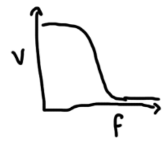
1) Audio amplifier
2) Modulator
3) Oscillator
4) RF Amplifier



RF Oscillators

- generates radio frequency signal
  - **crystal oscillator** - very stable, good quality
  - **variable frequency oscillator** - can drift
  - **digital frequency oscillator** - very stable, but complex

Low Pass Filter (LPF)



- every TX should have one as last block before antenna
- removes harmonics — removes multiples of the transmit frequency
- harmonics can be generated by active part of the TX and may cause interference to other amateur bands and radio users
- no such thing as 'first harmonic' — this is known as the fundamental or the design frequency
- second harmonic = fundamental * 2, third being = fundamental * 3
- third harmonics seem to generate more interference

Microphones

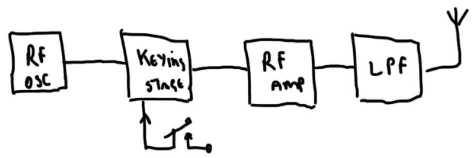
- convert air into mechanical movement, which in turn gets turned into electrical energy
- output AF (audio frequency)
- diaphragm connected to cone and a coil in a magnetic field
- produce low level AC (at AF) due to movement in magnetic field
- need amplifier
- normally includes filter to crop to 3kHz (minimum for voice)

Mixing

- when two frequencies are mixed, new frequencies are produced by adding and taking away
- they are the SUM and DIFFERENCE frequencies
- where there is AF mixed with RF we get side bands
- **sum + difference are upper and lower sidebands**
- this is known as modulation

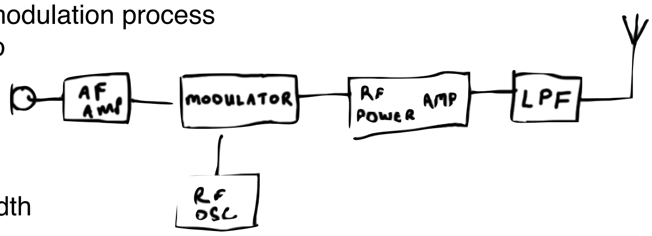
CW TX

- simplest type of amateur TX
- morse key used to modulate the carrier by switching signal path on/off using the eyeing stage
- why not key the oscillator or the PA? This causes problems
  - key the oscillator and you get chirp, or varying frequency
  - key the amplifier and you get interference/clicks due to high volts
- CW should have narrow bandwidth, no more than 1kHz, but typically 500Hz or less
- the keying might alter bandwidth



AM TX

- produces carrier and two sidebands
- carrier from RF oscillator
- sidebands from the sum and difference from the mixing/modulation process
- two sides are mirrors of each other and contain same info
- carrier and sidebands are amplified by the RF amplifier

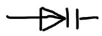


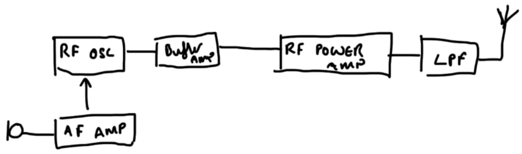
eg: transmit on 7.050mHz + 3kHz of audio

7047 7050 7053

lsb carrier usb = total of 6kHz bandwidth

FM TX

- modulates RF by changing the frequency of the RF oscillator by a small amount
- one way is to connect AF amp to RF oscillator - using a special diode - a variable capacitance diode 
- varicap diode
- when reversed biased the varicap diode acts like a capacitor (very small value)
- the AF from the AF amp, will vary the PD on varicap diode, and the capacitance will change
- this change will vary the tuned circuit that sets the frequency of the RF oscillator
- the amount of frequency change is called ‘deviation’
- ±3kHz on FM giving 6kHz bandwidth
- FM channels must be well separated to prevent channel interference

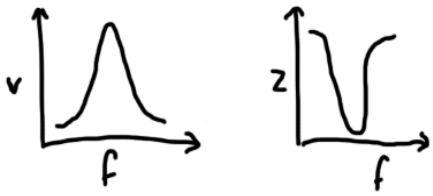


Buffer Amplifiers

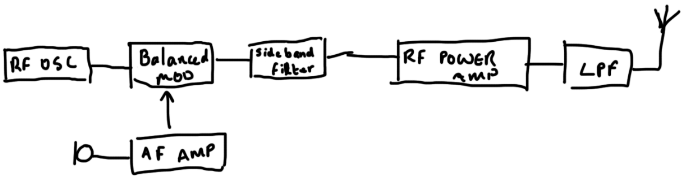
- isolates RF oscillator from rest of transmitter circuit
- prevents changes in transmitter from changing the oscillator frequency
- do we need to know circuit?

Band Pass Filters

- two cut off frequencies
- allows a BAND of frequencies to pass
- low impedance between the cut offs
- can be used to prevent harmonics
- used at the heart of an ssb tx



SSB TX (single side band)



- most complex for intermediate
- form of AM
- special modulator is used — a balanced modulator
- side band filter also used
- mixes AF with carrier but only allows side bands to pass
- removes or suppresses carrier
- side band filter - form of band pass the removes one sideband and lets the other through
- only one sideband is passed to the RF power amp and transmitted
- why remove the carrier and one sideband?
    - waste of power on the carrier and one sideband
    - ssb all info is on one side
    - reduction in bandwidth required — same as AF give or take

Data TX

- RTTY - radio teletype
- PSK31 - developed by amateurs
- SSTV - slow scan tv
- use one or more tones to modulate carrier
- SSB or FM

License Conditions 2

Beacons and unattended operation

- unattended operation of a beacon
  - for direction finding, competitions etc
  - remote control of main station — limit of 500mW on amateur bands only
  - or digital comms
- no other operators may use the remote operation
- tnc's? aprs?
- internet control NO, next room YES

Keep log

- person authorised from Ofcom can instruct you to keep a log of all TX over a specific time
- for investigation, compliance of terms, conditions and limitations of license
- used to trace source of interference
- times, frequency, power, mode, direction (for yagis)

Not cause undue interference

- must not cause undue interference to other radio users (wireless telegraphy)
- must reduce emissions to satisfaction of office authorised by ofcom if causing interference
- carry out tests from time to time to ensure station no causing interference
- *all about EMC

Inform ofcom of any changes

- inform ofcom of any changes to name, main station address or mailing address
- must confirm/validate at least every 5 years
- licence can be revoked by breaches of license conditions or for non-confirmation of license details

Apply the schedule

- take heed of the schedule and power frequency limitations

Power Supplies

- most modern TRX's require 12-14v DC

Batteries

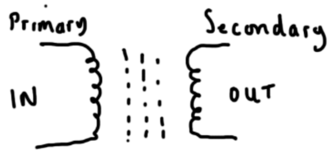
- stores energy in chemical form
- **chemical energy** changed to electrical when in circuit
- DC flows, until chemical energy is exhausted, said to be 'flat'
- flat cell must be disposed of in suitable manner
- **primary cells** — use once, convenient and portable, low power
  - expensive if replacements needed regularly
- **secondary cells** — rechargeable, such as ni-cad, ni-mh, and lithium ion
  - ni-cad's not permitted to be imported in the EU
- two or more cells become a battery
- 1.5v per cell
- generally chemical cell = low current, QRP station
- **lead acid** — more current, good for high power stations, very heavy
  - contain acid - attack all sorts from carpet to skin
  - use gell cell to avoid acid risks
  - remember - they produce high current, so lots of heat in a low resistance circuit

Mains PSU

- 230v AC 50Hz here in the UK
- need device to reduce this 230v PD and convert to AC — this is a mains PSU (transformer + rectifier)

Transformer

- use electromagnetic properties to pass AC from one circuit to another without direct connections
- isolating transformers
- normally two coils of wire wound on a single former
- normally insulated from each other
- **primary** & **secondary** windings
- PD on secondary depends on number of windings
- this is a direct ratio (turns ratio)



eg: primary has 10 windings, secondary has 5. 100V AC on primary becomes 50V AC on secondary

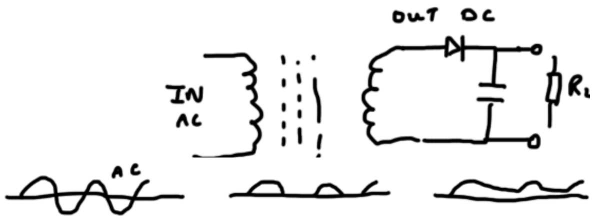
- an iron former concentrates magnetic field and stops it from affecting other components close by
- move a magnet through a coil and current will flow in the wire
- no current will flow if you hold the magnet still
- it is the changing magnetic field that causes the current to flow

As AC starts to flow in the primary, a magnetic field develops. As the AC changes polarity the magnetic field changes, and the current is induced in the secondary. The continues as long as the magnetic field changes.

- only works with ac
- passing DC through primary will have no effect on secondary because the magnetic field is not changing
- less turns on secondary = step down
- more turns on secondary = step up
- modern TRX's have step down
- some older sets have step up to produce the HV needed for valves etc. Very dangerous voltages

Diodes in transformers

- used to rectify the AC
- bridge rectifier used for the -ve parts of the AC
- use large value capacitor to 'smooth' the DC
- most supplies will take the smoothed DC and regulate the PD even more



Other Modulation Types

- packet, most packet work is short range on VHF and UHF
- RTTY, radio teletype used in HF
- PSK31, might replace RTTY? — phase shift keying
    - 31kHz wide bandwidth, many stations/signals can fit into the band
    - designed for keyboard/text comms
    - works well with weak signals
- sstv, slow scan tv
    - similar to fax
    - still images
    - slow, similar bandwidth to voice
    - used on HF for cross world image sharing
- fstv, fast scan tv
    - moving images
    - large bandwidth, greater than ssb + am
    - only suitable for UHF where bands are 'wider'
    - short range - but there are some repeaters

Radios and PC connectivity

- lots of software, HRD etc, require sound card, serial interface, or could be dedicate interface on radio

Advantages of the various Modes

- CW / morse considered most effective, greatest range for given power
- PSK31 perhaps considered the same now, but more complex equipment needed
- voice
- ssb, effective, best range with lowest bandwidth
- fm, shorter range, better quality
- in noisy conditions ssb and cw, which use lower bandwidth will produce higher readability, because bandwidth of receiver can be reduced to remove unwanted noise/interference
- they have different EMC characteristics !!! (note this could quite easily be a question, ssb is the worst)

Satellites

- orbiting transponders like repeaters, some 150km above the ground
- move in relation to earth and high only be above horizon at certain times
- both sending and receive station must be able to 'see' the satellite
- doppler shift occurs as satellite is move quite fast in relation to earth, must be allowed for when selecting frequency
- several up and down link frequencies, and modes
    - mode a = 145mHz up and 29mHz down
- must be able to receive on the uplink and downlink frequencies
- can be used with CW, SSB and FM
- band plan shows the frequencies
- limit the power used because the satellites have limited power supplies
- uplink power has an impact on downlink power
- downlink signal should be no stronger than the satellite beacon
- amsat.uk amongst others for information

Receivers

Basics

1) RF Amplifier + tuning, some sort of tuned circuit. Not all with have an RF amplifier at this stage
2) detector (demodulator) recovers transmitted signal from the modulated incoming signal
3) AF Amplifier, increases the volume of the recovered audio

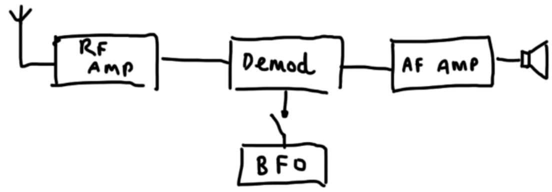
Loud speakers

- in many ways the direct opposite of a mic
- current flows through the coil in a magnetic field (permanent magnets)
    - causes the cone to move, which moves the air which enables us to hear
- AC signals

Crystal Diode Receiver

- one of the first deigns
- converts AM RF to AM
- need a crystal earphone but an AF amplifier could be used
- tuning stage is a large inductor and a variable capacitor
- detector/demodulator = single germanium diode, demodulates the AM signal by rectifying the signal (cuts off the -ve element)
- disadvantages - need strong signal, not very selective or sensitive (might tune a number of stations at once)

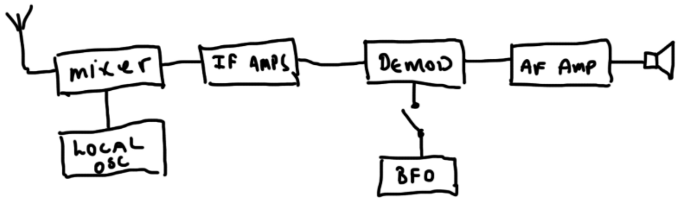
Tuned RF Receiver (TRF)



- includes RF amplifier over the crystal diode receiver
- also includes a beat frequency oscillator (BFO)
- RF amplifier increases the received signals before they are demodulated
- much more sensitive and can detect weaker signals
- normally the RF amp includes another tuned circuit
- far more selectivity than crystal diode receiver
- single diode demodulator just like the crystal diode receiver
- normally AM but can be modified

Super-Heterodyne Receiver

- basis of almost every modern RX today — from tv, broadcast radio etc
- local oscillator (LO) produces RF signal much in the same way as a TX
- mixer, mixes or heterodynes the selected RF signal from the antenna with the signal from the LO
- this produces a new signal, the intermediate frequency (IF)
- IF amps are used because there is a limit on how much sensitivity can be increased in the RF amps before they start to oscillate
- IF is similar, but it operates on a FIXED frequency
- it can therefore be made very selective and it will add more gain/sensitivity to the receiver
- number of IF amps all operate at the same frequency each adding more gain



IF - The intermediate Frequency

- why?
  - when we mix we get sum + difference
  - we can use filters to select either the sum or difference (as in ssb tx)
  - by selecting the sum or the difference from the RF+LO mixer, we make a very selective receiver with even more gain than the tuned RF receiver
  - by varying the LO - using a vfo - we can tune through the band, but the output from the mixer (IF) will always stay the same

eg: VFO tuned 5000-5300kHz, RF Amp tuned 80m 3500-3800kHz, IF tuned to the difference @ 1500kHz

so now if VFO is on 5000kHz and RF on 3500kHz, the difference will still be 1500kHz
also if VFO is on 5300kHz and RF on 3800kHz, the difference will still be 1500kHz

Tuned Circuits

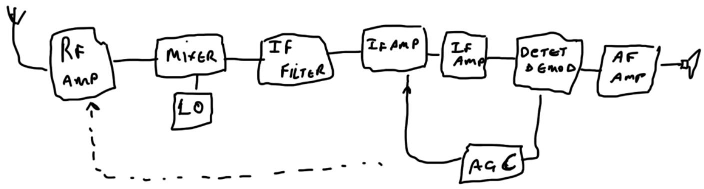
- can reject or accept specific frequencies
- both RF and IF amps will contain tuned circuits
  - RF will deal with a range and will need a form of variable capacitor
  - IF amp is fixed frequency so does not need variable tuned circuit
- when tuning a superhet receiver, you are actually shifting the LO and RF amp at the same time
  - known as tracking

Different Types of Modulation

- signal at the output of the IF depends on the transmission
- all the RX has done is amplify it (through RF amp, and IF amps) - this ignores signal type
- both crystal and tuned RF receiver use a diode to demodulate (superhet can but limits use to AM)
- both TRF and Superhet can be used on CW with a **Beat Frequency Oscillator**
    - tune it close by, say 1kHz from signal
    - mix the two, to produce sum and difference, one of which is at AF
    - if the BFO is at 1501kHz and mixed with IF signal in above example, the difference would be :
      1501 - 1500 = 1kHz (we can hear it, it is at AF) note: the sum would be 3+mHz not AF
    - BFO is tuneable over a small range to alter tone of the CW

- diode detection/demodulation + BFO can be used to resolve SSB
- superhet better to use product detector with fixed frequency oscillator = **CID - Carrier Insertion Oscillator**
    - runs lower in frequency than IF on USB
    - runs higher in frequency than IF on LSB
    - mixes with SSB to produce AF
    - replaces the carrier that was removed by the balanced modulator in the transmitter

AGC - Automatic Gain Control



- maintains steady level of AF output despite changes in input RF signal strength
- many ways to do this but most common is to sense signal strength at detector/demodulator and feed back changes to the IF amps (and sometimes the RF amps) to alter the gain
- helps keep wide range of signals constant volume for listener

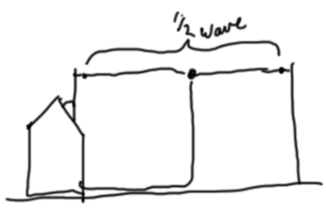
FM

- special type of demodulator is needed for FM
- frequency discriminator detects small frequency changes in the IF to produce AF

Summary

- **AM** - single diode
- **FM** - frequency discriminator
- **CW** - BFO + diode
- **SSB/CW** - product detector + Carrier Insertion Oscillator (CIO)

Antenna Matching



- antenna and feeder is vital in radio
- recap a 1/2 wave dipole, cut our length, then chop for swr

(note: watch out for questions that ask for element length - make sure you consider 1/2 wave for a dipole etc)

Need a Load !

- transmitter transfers power into a load
- antenna is normally the load (but can be a dummy load)
- no load and the power amp can be damaged
- most modern TRX expect 50ohm load impedance (resistance due to ac)
- some have auto power reduction to prevent damage
- can use 50ohm resistor (suitable wattage) as dummy load

note : properly tuned antenna system will only provide the correct load at a given frequency !

Feeder Impedance

- feeder carries RF from radio to the antenna
- antenna not in back of radio so we can get it up high and far away to reduce emc issues
- feeders have characteristic impedance, this is the AC characteristics
  - wire has some resistance
  - it is an elongated capacitor that introduces reactance
- spacing of conductors determines the impedance
- normally 50 ohm for amateur radio, 75 for TV, 90 for satellite
- if feeder is terminate by a resistive load (reactive load, i.e. the antenna) that matches the impedance, the length of coax will have no effect on impedance
  - load of 50 ohm at one end, with 50 ohm impedance cable, Z will be 50 ohm at the other end
- **the feeder impedance determines the ratio of RF rms PD to the RF rms current (Vrms = Irms * Z)**
- NOTE: antennas also have impedance

Feedpoint Impedance

- antennas made of rods, metal and wire
- conductors separated by air = capacitor which has some reactance
- some also have coils, which have reactance
- therefore ALL antennas have impedance at the feed point
- dipole is 50 ohm (this is in the book, it should be 72.3 ohm)
  - when dipole is balanced (dipole) and is tuned to wavelength of signal the impedance is 50 ohms
- therefore RF PD across feed point, current will flow
- RF current flowing in an antenna is related to the feed point impedance and feed point PD (another ohms law example)
- in general : max RF current -> max radiation (only when feed point has correct impedance)

Matching

- TX=50 ohm, feeder = 50 ohm, antenna = 50ohm …. all matched
- most effective transmission of power
- as if the feeder is not there

Mismatch at Antenna

- antenna is not correct length for frequency in use (wavelength)
- this will produce wave reflections
- come back down feeder and combine with power moving the other way
- this produces high and low voltage points, produces standing waves
- swr - great mismatch, greater swr
- 70ohm antenna, 50 feeder = good/ok match 1.5:1 swr
- 500ohm antenna, 50 feeder = bad match

Mistmatch at TX

- mismatched antenna will alter feed input impedance and will present incorrect load to TX
- will not operate at full effectiveness
- most TX will tolerate small mismatch which is why we can generally use antenna for entire band

AMU - Antenna Matching Unit

- large mismatch on band the antenna not designed for
- use an AMU or ATU
- they change the mismatch and present something more acceptable to the TX
- does not fix the issue, just hides it
- atu can provide additional protection against radiation of harmonics when the TX is matched

Safety Notes

- hazardous to use ladders and lifting long poles
- overhead power lines
- can jump the gap
- secure ladder to top, or person at bottom (better)
- 4:1 ratio

Antenna Feeders

Coax
- good connectors / plugs / sockets
- signal contained within braid
- outside doesn't get into central feeder
- can be on ground, around posts etc
- not just the gap between in/outer that determines impedance (dielectric thickness)
- most use outer jacket marking to show impedance

Balanced feeder
- current through conductor causes electromagnetic field
- one side cancels the other - so do not radiate, as long as balance is maintained
- can reduce EMC problems
- can connect direct to dipole
- need balun or twin feed ATU input
- characteristic impedance defined by gap of twin feeds, between 75 and 600ohm
- don't put close to objects
- don't bury or attach to walls

Feeder Losses

- all have some loss
- some energy is 'used up' and gets converted into heat
- happens in RX and TX, though we are most concerned about TX
- greater the length, greater the loss
- balanced cable, or twin feed, virtually no loss

Decibel Loss

- dB's can be added/subtracted
- dB loss

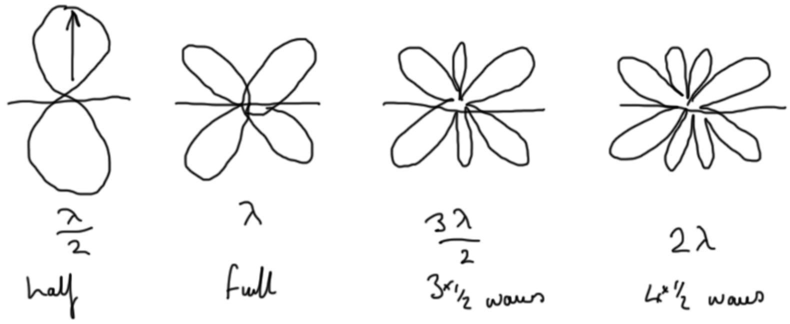
    3db = 1/2 the signal / remaining power
    6db = 1/4 the signal / remaining power
    9db = 1/8 the signal / remaining power
    10db = 1/10 the signal / remaining power

Decibel Gain

- antenna gain focuses RF
- ERP - estimated radiated power, can be directional
- check schedule for ERP on some frequencies (this is a catch question some times)
- dB gain

    3db = 2 x the signal / power
    6db = 4 x the signal / power
    9db = 8 x the signal / power
    10db = 10 x the signal / power

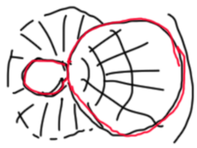
Polar Diagrams

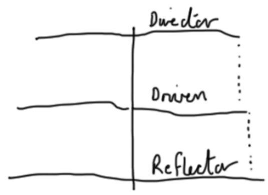


- most antennas do not radiate equally in all directions (main exception vertical ground antenna)
- same on RX, for example TV antennas, have lots of gain and need to be pointed in the correct direction
- dipole has max radiation 90° to the elements
- not much from ends

Yagi

- reflector, director, driven element (1/2 wave dipole normally, or folded dipole)
- reflector slightly longer than driven
- director slightly shorter than driven
- both parallel to driven
- direction of max gain is towards the director
- very little off the sides
- focused in one direction (erp is focused)





Polarisation

- vertical and horizontal (circular as well but not on intermediate)
- radio waves are one type of electro magnetic radiation
- made up from electric field **E**, and magnetic field **H**
- as RF current flows, two fields build up, to form radio waves
- two fields are independent and are at **right angles to each other**
- we know radiation pattern from dipole is at right angles, so therefore **E** is in the same plane as the antenna
- **E** (electric field) determines the polarisation

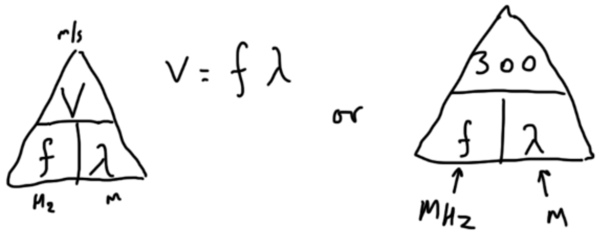
note: signals best received on the same polarisation. HF doesn't matter too much because of atmospheric scattering

Safety

- RF burns
- radio waves penetrate body, and may heat it up as it absorbs the energy
- don't get too close
- don't look down wave guides or stand infant of them (microwaves)
- dishes focus, and high gain antennas should not be stood in-front of or close to

if concerned contact : Health Protection Agency (HPA)
World Health Organisation
International Commission on Non Ionising Radiation Protection

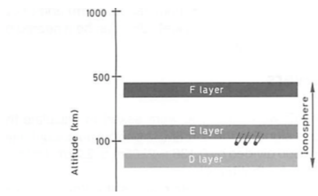
Propagation



- frequency of AC signal is in Hertz (Hz)
- 1 Hz = 1 cycle per second (remember kilo, mega and giga)
- frequency is related to wavelength
- lower the frequency, longer the wavelength
- higher the frequency, shorter the wavelength
- Velocity of the wave = Frequency x Wavelength
- wavelength is from 1 peak to the next peak

question: what is wavelength of signal at 10GHz
10GHz = 10 000 000 000 Hz = 10 000 MHz
therefore 300 / 10 000 = 3 / 100 = 0.03m which is 3cm wavelength

Ground Wave and Sky Wave



- skywave is reflected by the ionosphere
- ground wave direct, absorbed by ground, might curve slightly beyond horizon
- solar ultraviolet radiation ionises air molecules to create ionised particles
- ionosphere is from 70km to 400km
- **D E & F layers**
- F for HF comms (reflected HF signals on the F layer)
- big difference between day and night, also seasonal as lower radiation during the winter
- D layer molecules are tight, they absorb radio waves, so HF will not break through during the day
- LF waves are limited to ground wave during the day
- D vanishes quickly during darkness, and waves are now reflected by F
- F lasts for a while a night and the particles remain ionised providing reflections

- **E layer**, very little effect on HF
- but can get sporadic E on VHF
- might be linked to weather in summer, perhaps clouds of ionised gas in the E layer that move quickly
- very hard to predict
- lower VHF - around 150mHz, not as far reflections / distances covered by the signal

Sunspots

- solar cycle is 11 years, increase in sun spot activity
- increased solar activity = increased ionisation in upper atmosphere
- increased ionisation = increased HF propagation

Skip Distance and Skip Zone

- skip distance is where your signals ‘come out’ or land
- skip zone (or dead zone) is the gap between where your signals can not be heard
- HF used for nationwide and international communications (distances of over 4000km are common)
- as waves increase above 15mHz they are less likely to be reflected
- also, angle is a major factor (just like skipping a pebble on a pond)

VHF + UHF propagation

- high in frequency less likely to undergo ionospheric reflection
- roughly 30mHz and above signals pass right through and go into space
- sometimes however, VHF is reflected, and even 28mHz will not be reflected, all down to conditions
- the 30mHz split is a boundary between HF and VHF
- VHF-UHF - line of sight, with slight bending of ground wave, ranges approximately 100km
- on occasions this distance can increase dramatically
- the troposphere closest to the earth can bend signals sometimes, and is known as ‘temperature inversion’
- tropospheric ducting caused by warmer air trapped higher up and signals can go 100’s of kms
- weather can reduce propagation (rain / snow) as it absorbs shorter wavelengths (even local contacts)

Summary

- LF + MF - ground wave daytime, may reflect at night to extend range
- HF - ionospheric reflections gives fairly reliable international communications
- VHF + UHF - line of sight, can be enhanced with sporadic E and tropospheric ducting - hindered by snow and heavy rain

EMC - Electromagnetic Compatibility

- avoidance of interference between two items of electrical equipment
- radio TX can be a source
- EMC directive - legal requirement to ensure equipment does not radiate unwanted RF
- we produce RF as amateurs so there is a possibility of incompatibility
- professional radio is remote (such as Mendip), but most amateurs are in domestic settings
    - lots of sensitive equipment, such as TV, radio, cordless phones, baby monitors
- EMC rules do not really cover equipment where you TX very close to a baby monitor for example
    - need to provide extra immunity, or turn TX power down
    - new equipment is better at EMC than old
- could be a poor install or poor down feeds - minimal braid on TV down feed
- water ingress can degrade cables etc resulting in interference

Recognising Interference

- if tv/radio is closer than neighbours, ensure yours is ok
- taxis, delivery vans etc might be a source
- analogue TV reception , wavy lines, loss of colour, dotted lines, sound loss, audio breakthrough
- digital TV - not normally a problem, but might pixelate, or freeze, drop in quality
- interference can occur to music systems and telephones, but less common
    - audio breakthrough
- might be clear on AM or SSB if the system being interfered with is AM for example, but might just be noise otherwise

Direct Pickup

- picked up inside the device, can effect sound and pictures
- difficult to cure and requires modification inside the equipment
- do not modify neighbours equipment as problems will be on you
- more commonly picked up on the various cables, which act as antennas
- ferrite rings on leads, audio, power, may help

TV Amplifiers

- bad news as they tend to amplify everything
- strong signals from the TRX get amplified and swamp the weak TV signals
- try removing or using a HPF (high pass filter), before the amplifier (470mhz - 845mhz for example)

Down Lead Pickup

- if HF is the problem, might be being picked up on the braid, and conducted into the tv
- user ferrite ring and don't kink the cable
- might also need a HPF

Other Sources

- drill, thermostat, lawnmower, motors, sewing machines
- old devices might have developed a fault, but they should be correctly filtered - possible safety concerns
- other devices might have been ‘a bit noisy’ but the new sensitive TV is now having issues

What To Do? More Detective work !

- if tv problems vanish with a dummy load, must be signal strength
  - move antenna away
  - ferrite rings
  - point beam away
  - lower power

- if problem still there with dummy load
  - not the signal causing the issue
  - use battery, use short power leads
  - if battery solves problem, could be RF entering the mains wiring, try more filtering, ferrite, and screened mains cable

Dummy Load

- screen resistor
- in place of feeder and antenna
- test purposes , 50 ohms normally
- don’t use inductive resistors, only carbon
- outer metal case to act as an RF screen, and to get rid of heat
- very useful to check if RF escaping down power leads, or any other cable

Harmonics and Spurious Emissions

- check for unwanted emissions from time to time
- might be harmonics or spurious transmissions from faulty TX
- check not interfering with neighbour or any other users of wireless telegraphy
- low pass filter in the output should minimise the harmonics, but they shouldn't be there anyway
- there is a small chance the TX is producing spurious signals unrelated to the transmission, and perhaps only present when carrier is modulated

How To Check?

- wave meter, a crystal diode receiver that can be tuned over transmitted frequencies, plus 2nd and 3rd harmonic
  - not very sensitive, for todays use
- use a receiver instead, very sensitive
- dummy load on TX, mic gain at zero
- RX has no antenna, and set to CW mode
- on the TX output a CW tone and see if you can hear it on the RX, ensure RX is no over S9
- perhaps use a dummy load on the RX as well
- if RX is over S9 it might be getting swamped, and observed harmonics are not a TX issue
- if you do see a signal on a harmonic of the fundamental, then the TX has issue

Interference from Modulation

- set mic gain, inc, or pc audio output so that signal is kept free of distortion
- AM - too much amplitude - over modulation, bandwidth increases and creates splatter, interferes with other stations
  - same for SSB which is a form of AM
  - could end up wider than 3kHz
- FM - too much amplitude - wide deviation or over deviation
  - unintelligible signals
  - cause interference to adjacent stations/channels which is a breach of license conditions

NOTE: on AM, FM + SSB, too high mic gain can create AF amp harmonics, making audio bandwidth fed to modulator wider than it should be - this can cause over modulation and deviation - leads to excessive AM bandwidth and excessive FM deviation

Checking for Over-modulation

- try testing in other modes, ssb and am
- tune the RX off by 12mHz to see if you still get a signal - ensure sub s9 on tx frequency first
- move 3-4kHz either side, ideally you should not hearing anything
- adjust mic gain / tx power so that nothing is heard

Interference from CW

- can arise from poor CW keying
- need smooth transitions, and not a square wave
- such a square wave is likely to generate excessive bandwidth, similar to over-modulation on AM
- a filter will slow the rise and fall of the RF envelope to maintain narrow BW of a good CW transmission

Checking for Spurious Emissions

- it is like a game, could be anywhere, or anything
- direction finding
- see if they come and go with your TX
- strong broadcast ones can be picked up without antenna
- keep notes (ofcom might need them)
- make tests on each band
- friend or retailer may have test equipment
- this is seen as good practice

Good Radio Housekeeping

- keep cables tidy and organised, to prevent RF energy entering cables and other equipment
- keep RF,DC + Mic cables tidy and far away as possible
- good quality plugs and sockets
- screened cables and good coins
- DC power and mains lead should have ferrets close to the equipment as possible
- even a good TX may have spurious signals and/or harmonics
- add a low pass filter after the SWR meter, and before the AMU

Antennas

- keep as far away as possible
- avoid the attic as lots of other wires up there
- a temporary install in the shack is likely to cause issues
- balanced antennas less likely to cause interference
- vertical antennas - greater chance - need a very good RF earth

Earthing Requirements

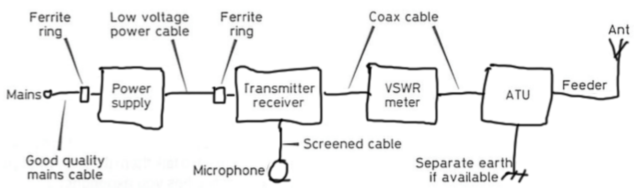
- two earths, mains and RF earth

Mains earth

- mains earth is for mains equipment, exception is double insulated (double box symbol)
- earth is for safety don't remove it

RF earth

- directs RF currents away from mains earth and down to ground - rods, damp soil etc
- 2m long copper rods (sometimes copper coated steel), hammered into the ground close to shack
- heavy duty cable to the ATU / TX
- if you wrap wires through a ferrite core, ensure gap is left to reduce capacitive coupling



Logs

- not a requirement, but good practice / house keeping
- log book hand incase interference occurs - can deny or look into cause
- if neighbour keeps a log of time of interference, can tally them up with the radio log
- ofcom will want you to keep a log if interference complaint is made formally
- handy to confirm QSL cards, entering contest and claiming rewards

Dealing with complaints

- honest, open, professional approach
- ask person to work with you to identify issue
- show you are serious about finding problem, but also serious about following your hobby
- don’t accept blame for any issue find, and don't agree to any permanent changes (such as TX after 9pm)
- if the equipment doesn't have enough immunity, could be his/her issue (your tv is ok for example)

Seeking Help

RSGB EMC committee
- leaflets aimed at amateurs, some for others making a complaint
- can download them, or can contact the EMC chairman

OFCOM
- publish advice leaflets
- can investigate
- last resort
- there is a charge, but might be refunded, if no fault of your own