Antennas

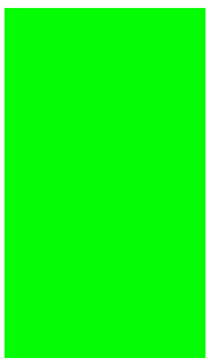
~~Electronic Theory~~

Electromagnetic Waves

An electromagnetic wave has three components.

1. Magnetic field.
2. Electric field
3. A direction of travel.

The magnetic and electric components are at 90 degrees to each other and both are at 90 degrees to direction of travel.



Radiating a Signal

In order to create an electromagnetic wave in the atmosphere capable of travelling a fair distance it is necessarry to feed the signal from the transmitter to an aerial or antenna.
The basic antenna is usually taken to be a piece of wire or rod half a wavelength long electrically.

$$= \frac{150}{f(\text{MHz})} \quad \text{metres}$$

In reality the actual length is less than this due to.

a). The velocity of propagation in the wire is less than in free space - velocity factor.

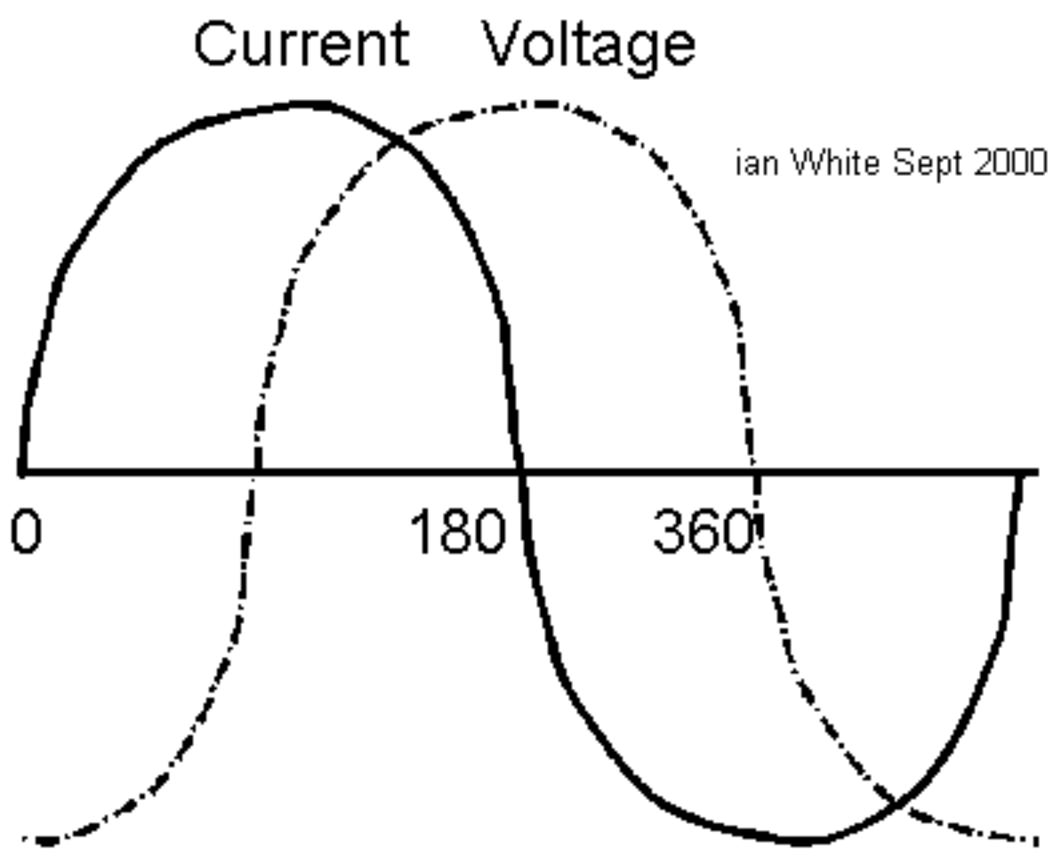
b). Presence of objects near to the wire.

c). The diameter of the wire.

Normally 5% is allowed for these factors.

The antenna has to be connected to the transmitter via some sort of cable or

feeder. The point of connection is known as the feedpoint which is usually the centre in a conventinal dipole.
The connection point is important as the impedance (voltage to current ratio) changes with the feedpoint as shown below. Note that the diagram shows the relationship accross a full wavelength of wire. A dipole antenna is a half wavelength.



At certain points in the antenna large currents flow whereas at others there is a build up of voltage with little current flow. We say that the impedance of the antenna varies along its length being high at some points where high voltages exist and low where high currents flow.

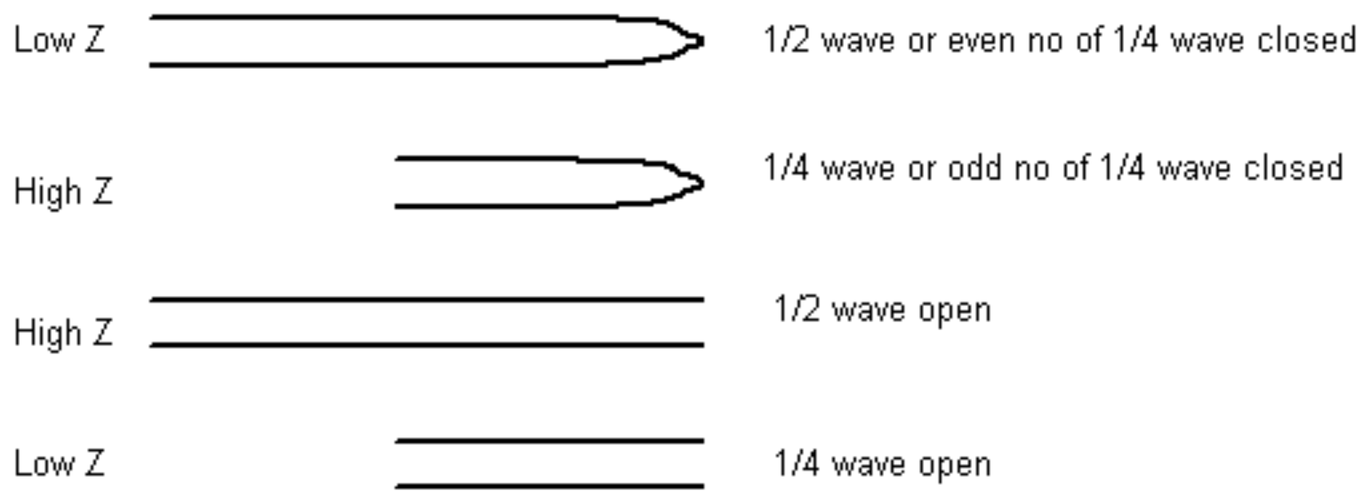
Transmission Lines ~ Feeders

These are used to feed the signal from the transmitter to the antenna. and vice versa when receiving.

Two main types are used
balanced - usually two wires separated by insulaters.
unbalanced - such as coaxial cables.

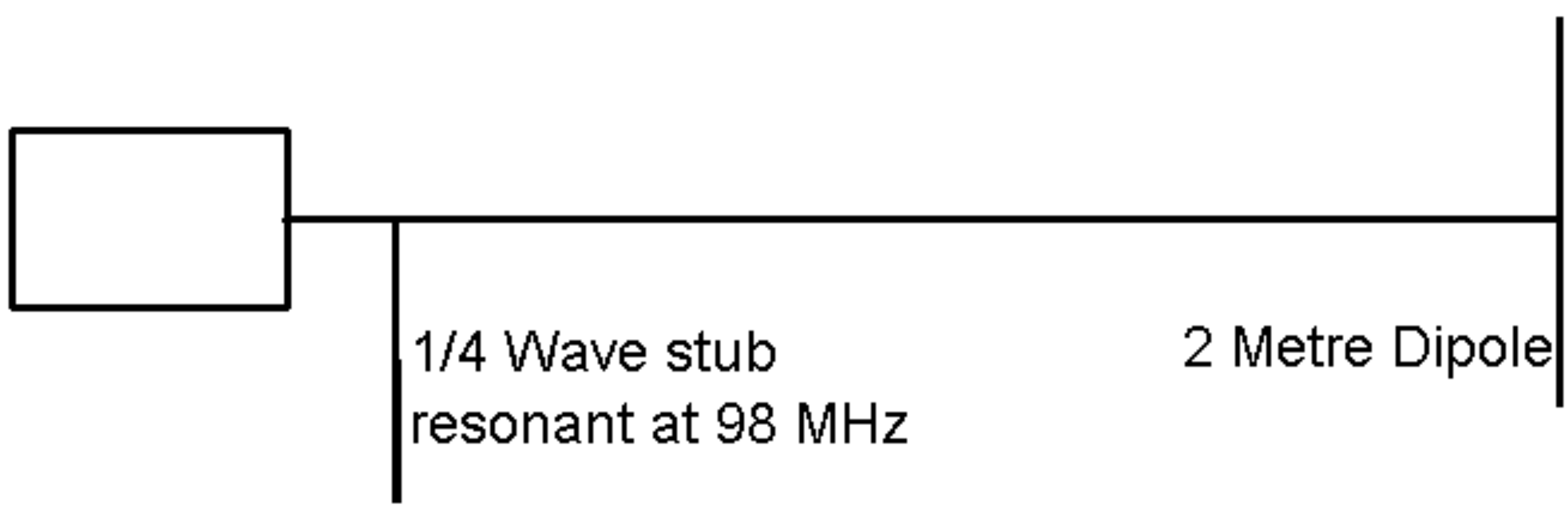
In a balanced system neither side is earthed - in an unbalanced system one side is in effect earthed.
Feeders of either type are said to have a characteristic impedance.
This is the impedance which exists at any point along the cable if it is terminated with the same impedance. Calculation of the impedance of a feeder is not required for the RAE and will not be dealt with here.

However if a line is terminated with an impedance other than its characteristic impedance standing waves ~ resonance may be set up in the feeder similar to an aerial wire. The impedance then varies along the feeder.
The impedance of open and closed length as shown below should be learnt for the RAE.



It can be seen from the above that a piece of coax feeder which is a 1/4 wavelength long at the operating frequency presents a short circuit at the other end at the operating frequency only.

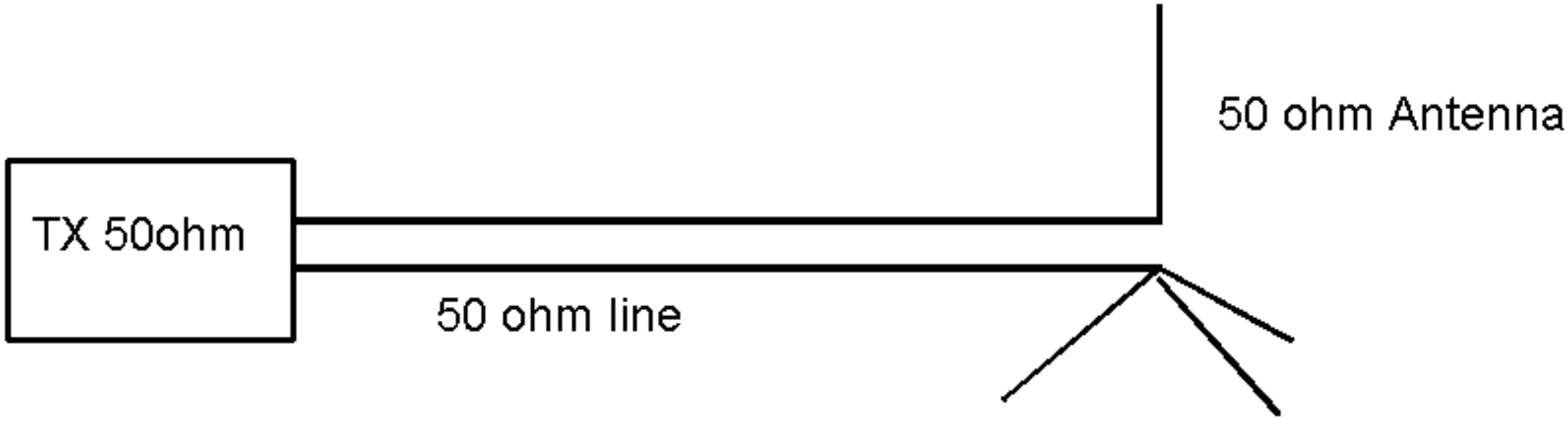
If a tranmitter had a spurious emission at low level and was radiating interference at 98 MHz a stub a 1/4 wave long can be coonnected to the transmit feeder and will attenuate this frequency whilst having little effect on the main signal at say 145MHz.



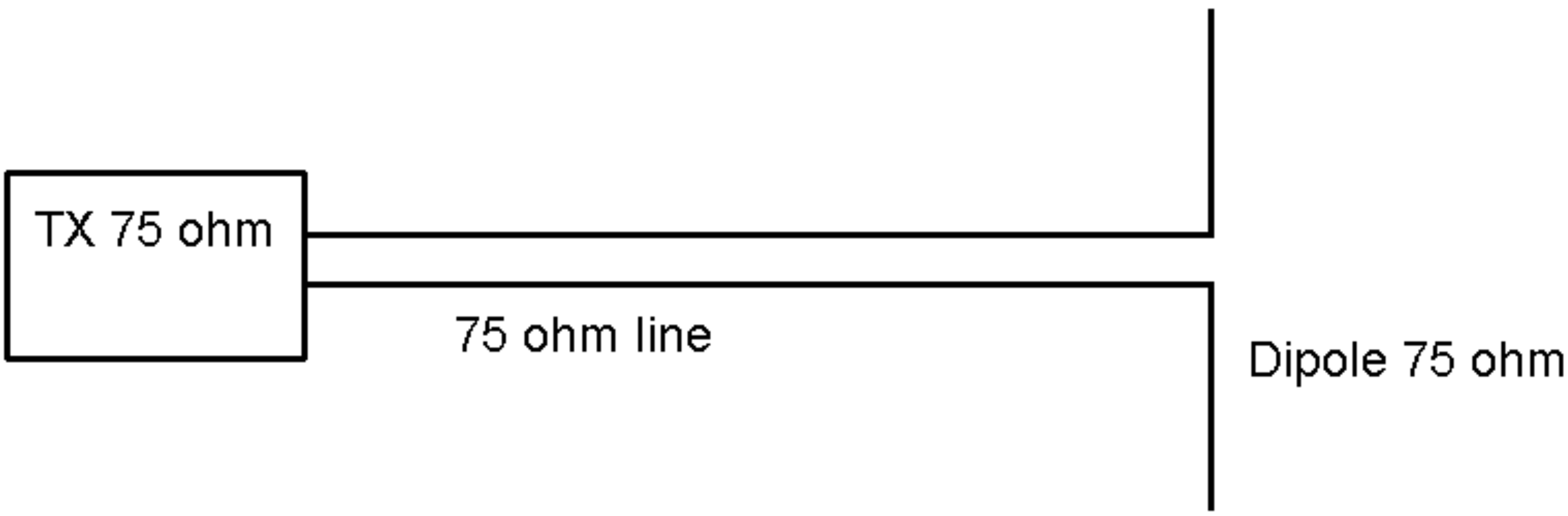
Matching the Antenna to the transmitter

It can be seen from the foregoing that power is only carried along a transmission line if it is matched correctly i.e.

The characteristic impedance of the line is similar to that of the transmitter and the aerial.



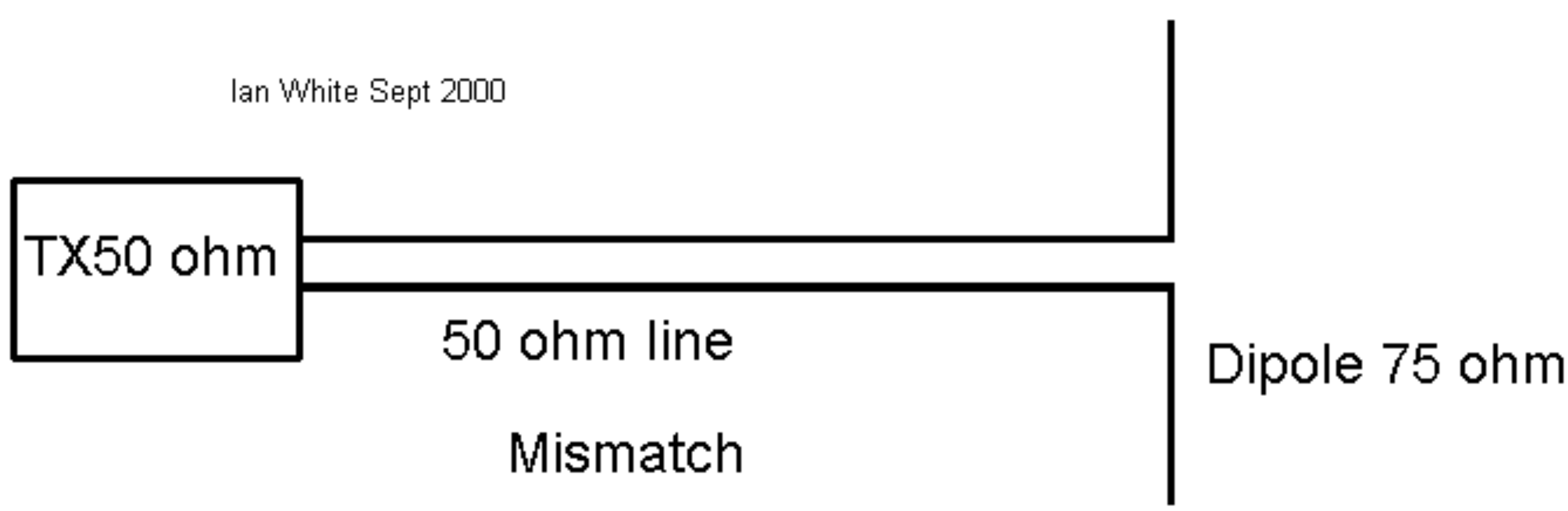
A transmitter can be designed to work into a 75 ohm impedance aerial



We have already said that the impedance of an aerial varies along its length, this fact is used in aerial matching, the best feedpoint being chosen to give the correct impedance.

Standing Wave Ratio

If power from the transmitter is fed along a transmission line to the antenna and this is not matched to the transmission line and transmitter the power is not transferred effeciently in to the aerial.

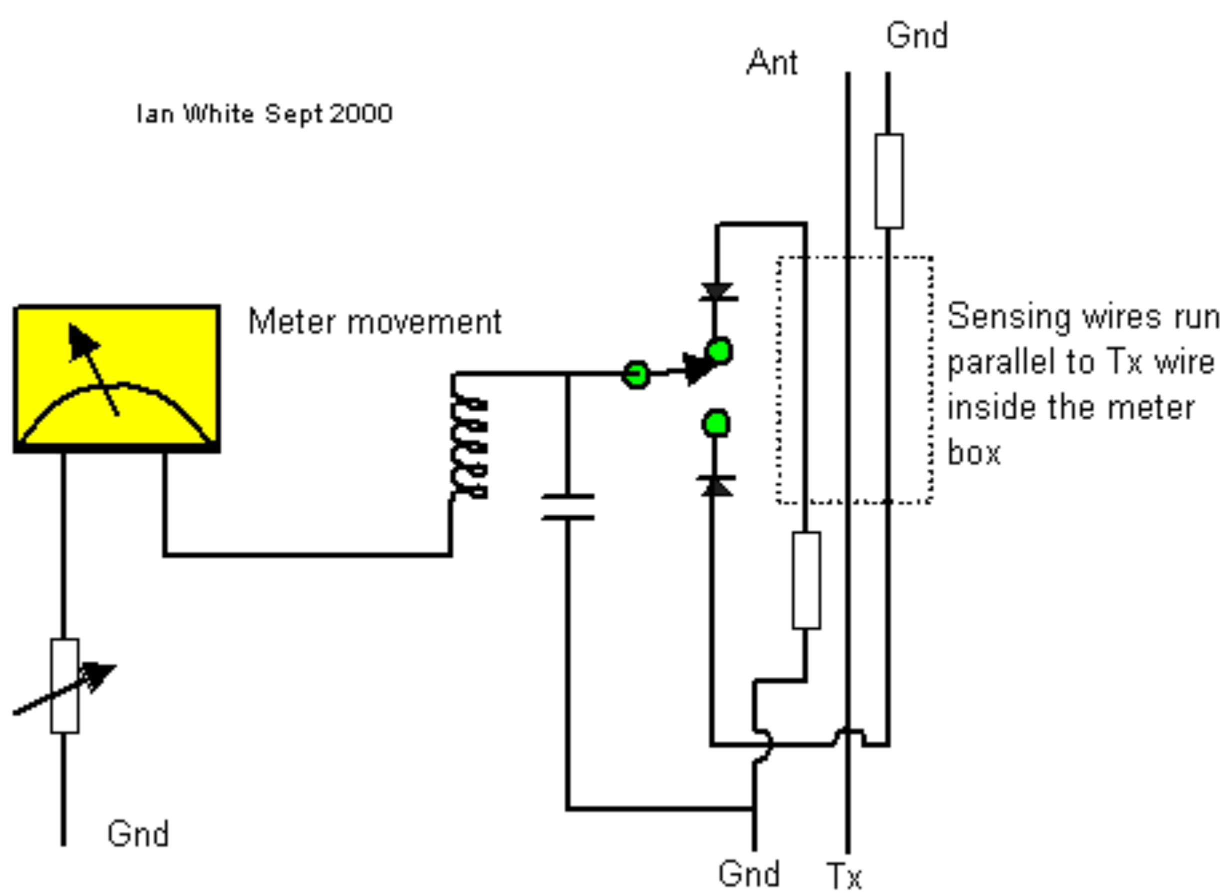


As a result of the power not being transferred to the antenna some power is reflected back along the transmission line, a standing wave is set up and the relationship between V and I ie the impedance of the line at the frequency of the signal varies along its length.

$$S.W.R. = \frac{V_{MAX}}{V_{MIN}} = \frac{I_{MAX}}{I_{MIN}} = \frac{Z_O}{R} \text{ or } \frac{R}{Z_O}$$

The theoretical S.W.R. in the fig above would be 1.5:1 Note that V.S.W.R. is always expressed as a ratio and there are no units.

The S.W.R. can be measured by the use of a meter. This measures the RF current flowing along the line in both directions and makes a comparison between the two. The circuit is as shown below.



SWR Meter Circuit

I

In the above diagram the two components L1 and C1 are used to filter out R.F. so that D.C. is applied to the meter.
The area surrounded by the dotted line consists of three wires of spacing and diameter to give a match similar to a section of 50 ohm feeder. This couples to two RF connectors near either end of the meter housing.

Any piece of wire which is carrying R.F. currents and which is suspended in free space will tend to radiate electromagnetic (radio) waves which have two components an electrical one and a magnetic one.

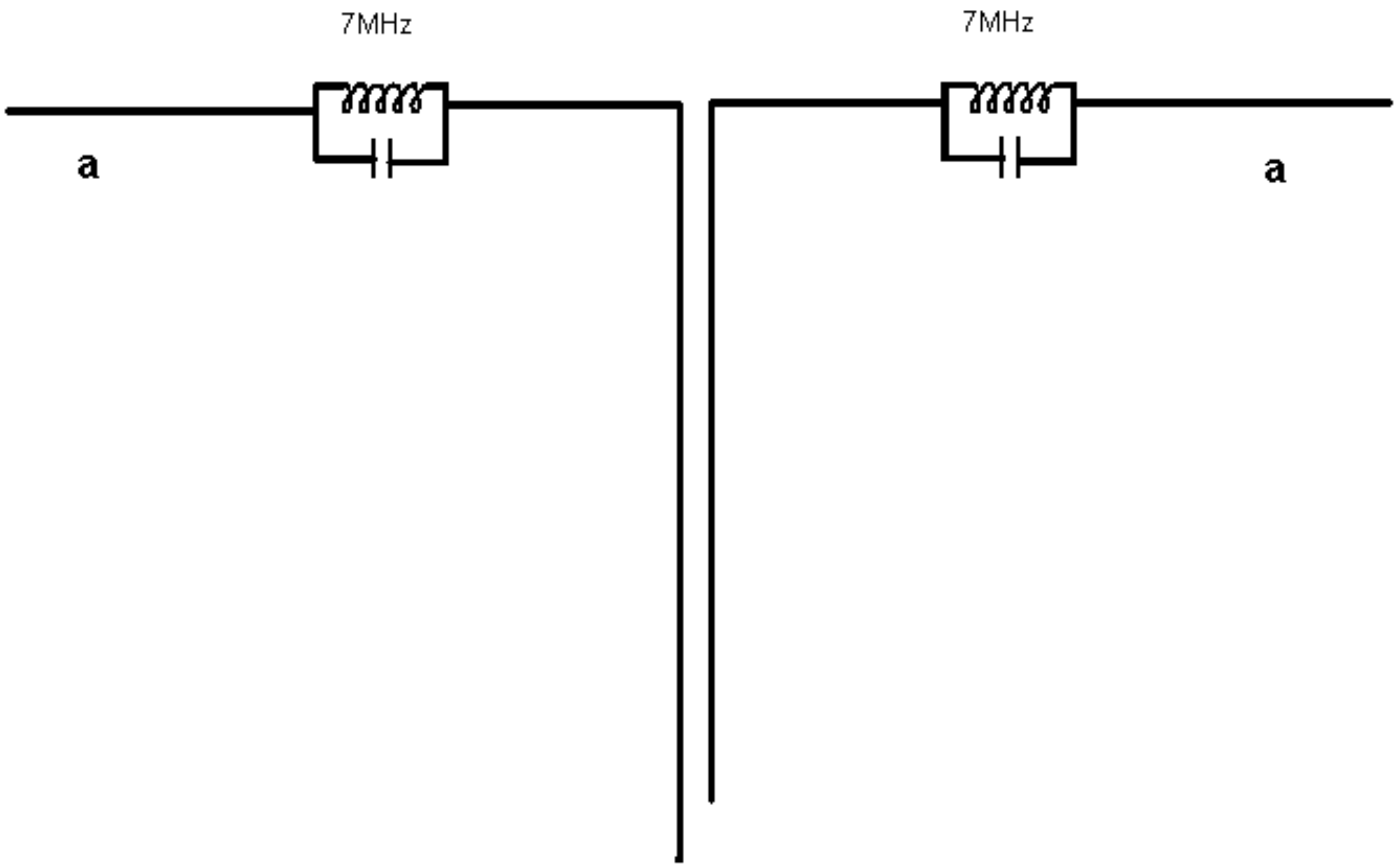
In order to maximise this property aerials are made in a form where resonance occurs ~ this means that higher currents will flow and give increased radiation. The aerial will radiate less signal at unwanted frequencies.
Resonance occurs when the aerial is a multiple of 1/4 wavelength in length.

eg 1/4 wave   1/2 wave.

One of the reasons why most of the amateur bands are arranged in multiples of each other is illustrated by the fact that a dipole cut for 7 Mhz (40 metres) will radiate at the third harmonic on 21 Mhz (15 metres) whenn it is 1 and a half wavelengths long.

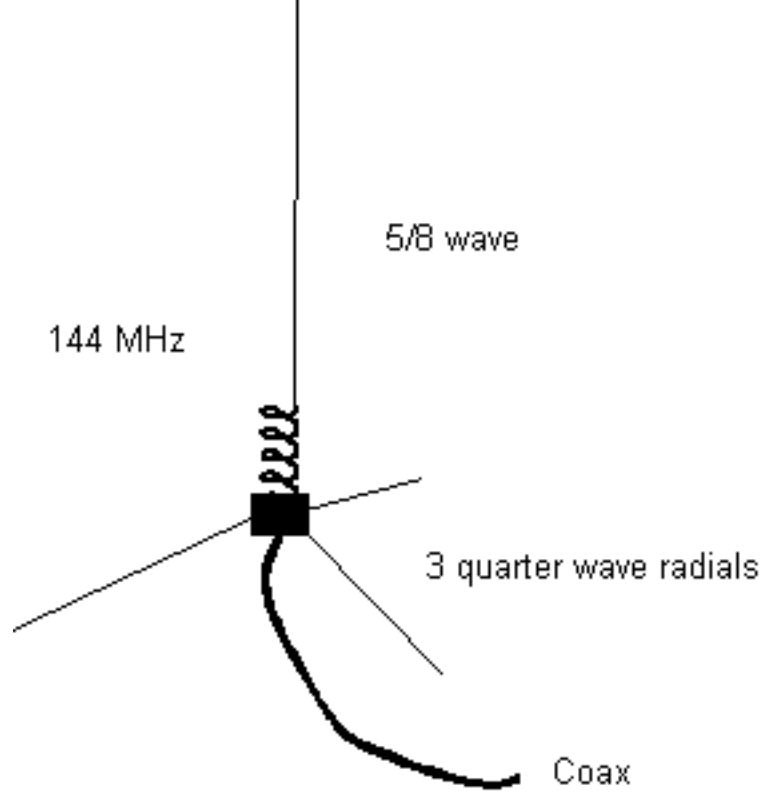
Trap Dipole

If it is intended to use a dipole on several bands traps may be incorporated



Here the LC tuned circuit of the traps shortens the aerial when working at the resonant frequency of the trap.
At a lower frequency the trap does not shorten it but brings in the outer sections and increases the length.
These sections shown as A and B in the diagram are shorter than one might expect because the traps increase the electronic length of the aerial.

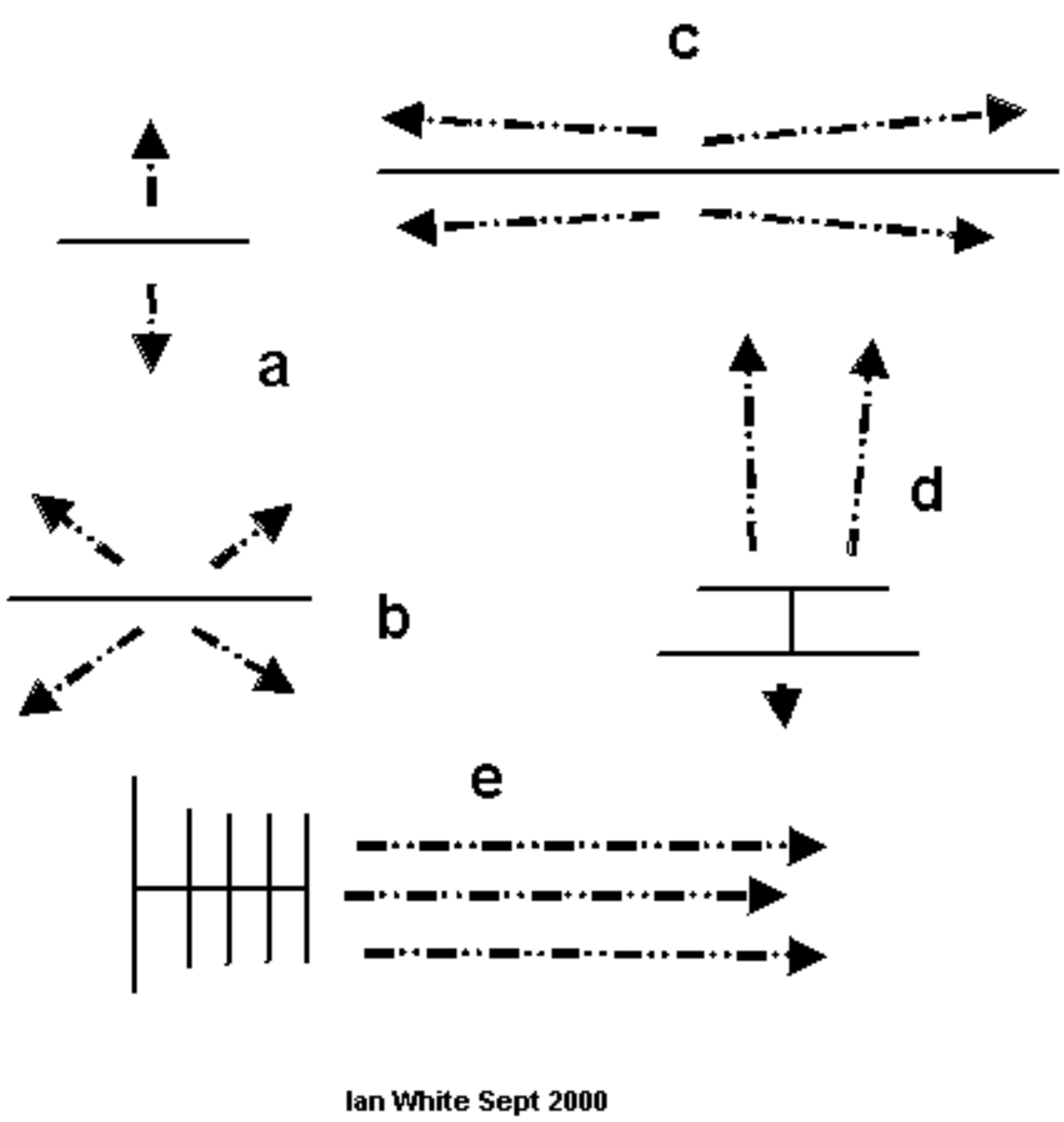
Another example where a the length is electronically increased is the 5/8 ths wave which is often used on two metres. Here the base loading coil adds an 1/8 l to the aerial which effectively makes it resonant as 3/4 l.



The coil helps to give it a better matching impedance of around 50W.

Directional Properties of antennas.

1. Vertical antennas.
All the vertiacal antennas are omnidirectional but the angle of radiation varies. Usually the lower this is the better in amateur radio.
see below different directional properties.



Above dotted lines show the principal radiation direction from

a) 1/2 wave dipole
b) 3/2 waves
c) large multiple of half waves.
d) 1/2 wave with reflector
e) 1/2 wave with reflector and directors (Yagi).

The effect of adding directors is to create a narrower angle of radiation with power concentrated into a more narrow beam. The power at the center of the beam is found to have increased so we say that the antenna has a gain or increased E.R.P. (effective radiated power).

The effective radiated power is measured in watts.

The gain is measured in decibels.
Decibels are a logarithmic scale and are always measured relative to some starting point or unit.

A small i Dbi compares the increase to an isoptropic source.

A small w as in Dbw compares power to one watt.
thus 26dbw = 400 watts

Power increases by 10 times for each 10 decibels of gain.
2 times for each 3 decibels.

+1Db	**1.3 times power**
+3Db	**2 times power**
+6Db	**4X**
+10Db	**10 X**
+13Db	**20 X**
+20Db	**100 X**
+26Db	**400 X**

The decibel notation is used because it compares the power with an original level. Consider

"Power has increased by 1 watt."

This could mean an increase from 100 to 101 watts or 0.25 to 1.25 watts using the decibel notation :-

Number of decibels = $10 \log_{10} \frac{W2}{W1}$

Example:
What would the decibel increase be if the power is increased from 0.25 watts to 1.25 watts

Decibel increase = $10 \log_{10} \frac{W2}{W1} = 10 \log_{10} 5 = 7\text{dB}$.

Next consider the increase from 100 watts to 101 watts

Decibel increase = $10 \log_{10} \frac{W2}{W1} = 10 \log_{10} \frac{101}{100} = 0.04 \text{ dB}$

The power of a radio transmitter is usually expressed in dbw The small w means that the power is expressed as an increase in power compared with 1 watt.

ie

400 watts = $10 \log_{10} \frac{400}{1} = 26\text{dBw}$

Why not check this yourself with the windows calculator. Choose view | scientific to give access to logs?

Power Supplies

In this section we look at how to obtain DC voltages from AC mains.

Amateur radio equipment draws its power from a variety of supply voltages which tend to be governed by the types of devices used.

For instance a 2 metre PA running in Class C may use a transistor which gives 25 watts out for 2 watts in at 24 volts. Reducing the voltage reduces the power gain drastically so that at 12 volts the same device may only give 10 watts out. Increasing the supply voltage will increase the gain but the device will break down if too much voltage is applied.

In the power supply the voltage is determined largely by the mains transformer.

The secondary voltage V_S is given by:-

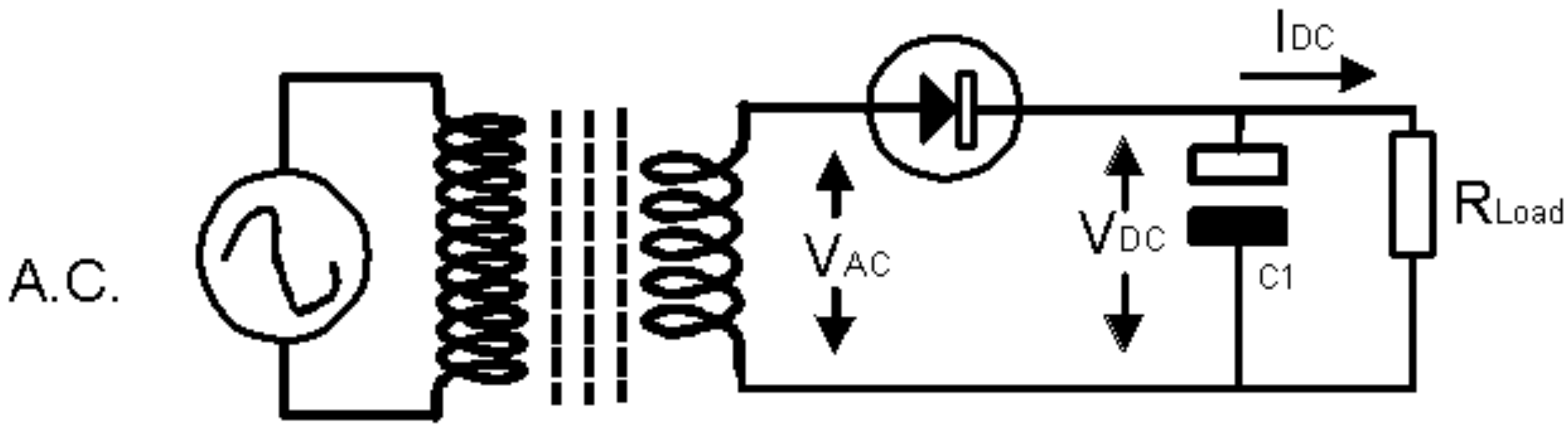
V_S = No. of turns on secondary X V_P
No. of turns on primary

$$V_S = \frac{\text{No. of turns on secondary}}{\text{No. of turns on primary}} \times V_P$$

V_P = primary voltage

Rectifying circuits

1) Half Wave - produces 50 Hz ripple



C_1 is known as the reservoir capacitor. It's purpose is to store energy during the positive half cycle and supply the load during the negative half cycle.

C_1 is usually very large typically 10,000 mF per amp drawn from the supply.

The diode only conducts for that part of the half cycle when the positive voltage is above the of the charge in the capacitor. A high current of short duration flows through the diode. - this is often limited by a series resistor to prevent an excessive surge at switch on when the capacitor is fully discharged.

Capacitors for this application must not only be of the correct working voltage and capacitance but also be able to withstand a high ripple current without overheating.

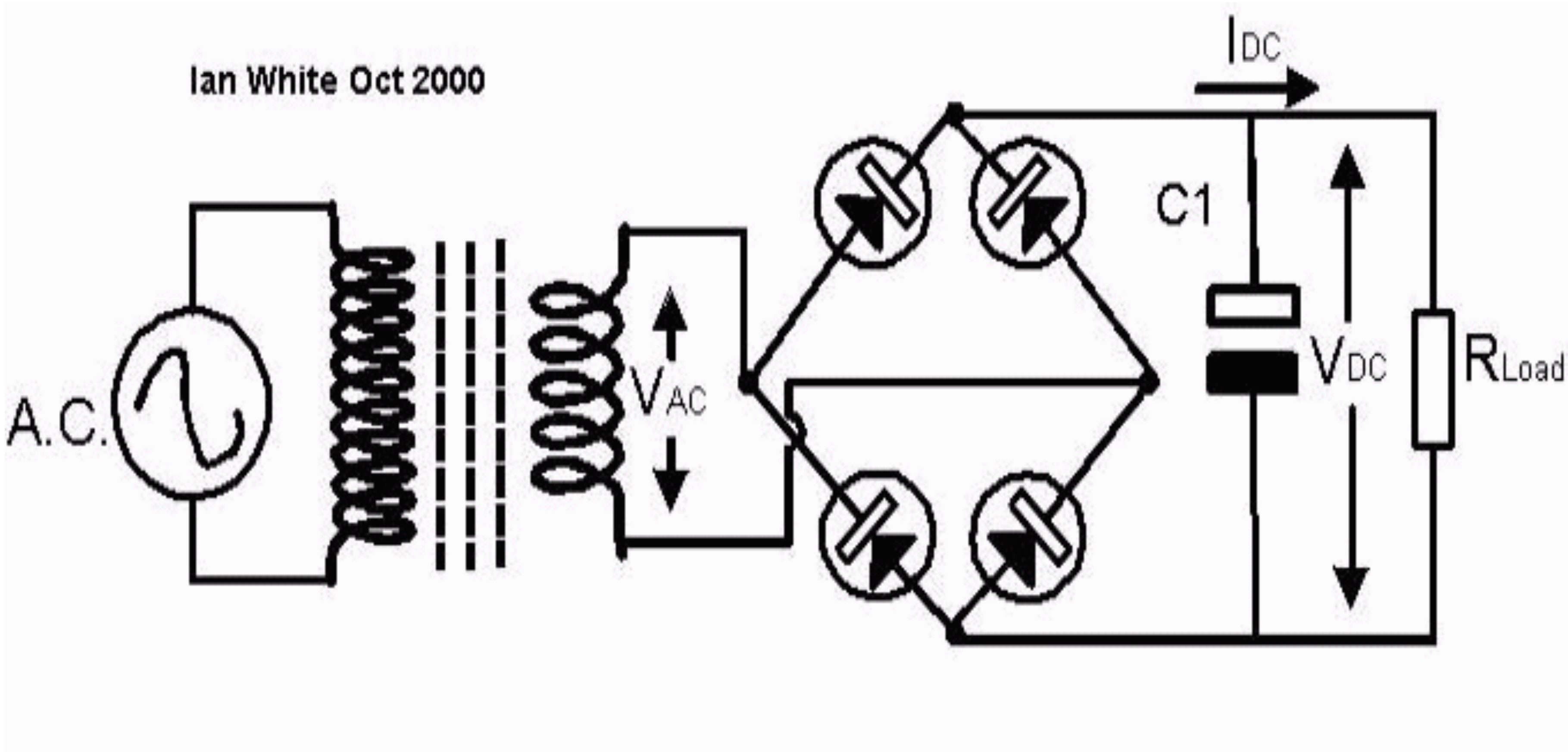
Peak inverse voltage across rectifier.

This is usually the pk-pk voltage of the AC supply.

Bridge Rectification

Here an arrangement of four diodes gives full wave rectification. This means that both negative and positive half cycles are conducted through the diodes and charge the reservoir capacitor twice as often.

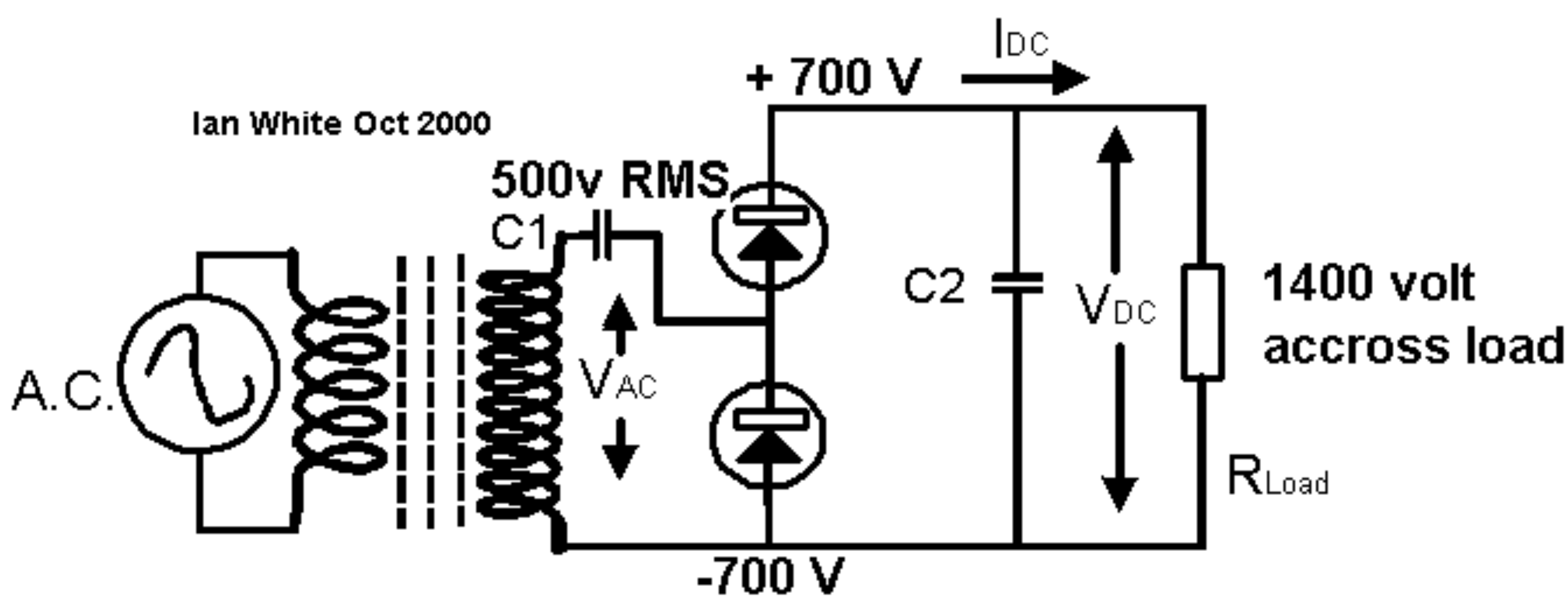
- the frequency of the ripple is therefore twice that of half wave rectification i.e. 100 Hz.



Voltage Multipliers.

Used for high voltages at low currents often to drive CRT's in oscilloscopes.

Advantage is that the transformer can be made smaller because less turns are required on the secondary and less insulation. High voltages can cause breakdown in transformer windings.

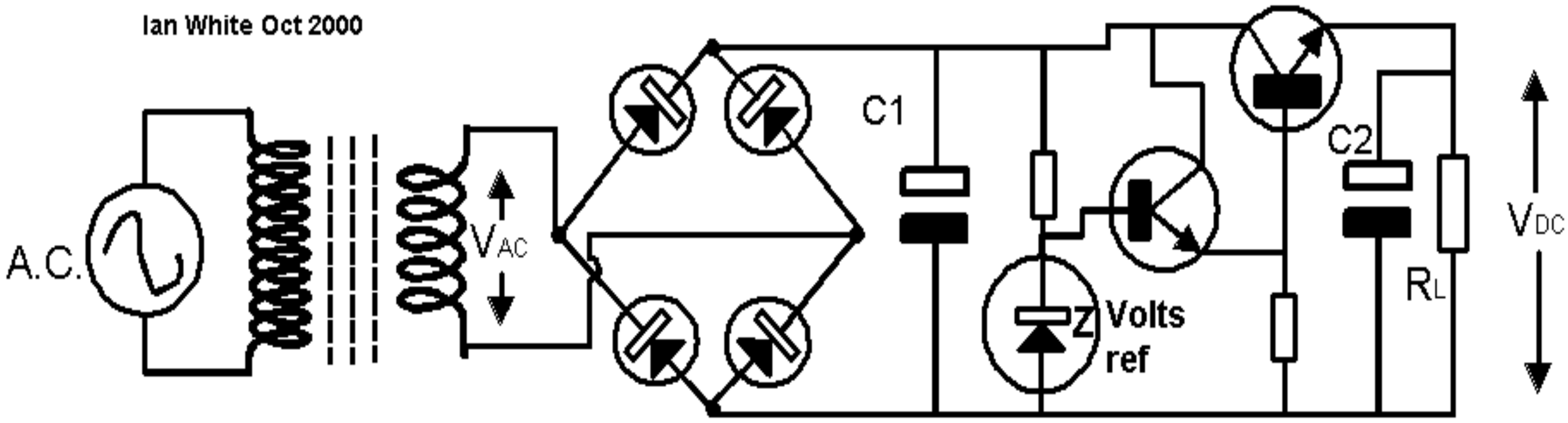


Metallic (Faraday) Screen

Sometimes an earthed metal screen is placed between the windings of a transformer. Its function is to remove interference from the mains and in the case of a transmitter it helps prevent signal being radiated by the mains. The screen is made of thin copper and does not form a continuous layer right round the transformer as this would act as a shorted turn and cause the transformer to overheat.

Regulated power supplies

In the circuit below a transformer reduces the AC mains voltage to about 12 volts AC. This is converted to DC by a rectifier bridge . A single half wave rectifier may be used but a bridge is more efficient. The resultant voltage is about 18 DC. This is reduced and stabilised by the regulator circuit to give a stable 12-14 volt DC at the output. Often an IC with as few as three connections forms the regulator circuit.



Notes on Safety

Low voltage power supplies are often capable of delivering high currents.

Although DC voltages less than 50 volts are unlikely to cause serious electric shock the high currents involved can cause metallic objects to get very hot if a short circuit occurs. Always switch off the power before using metal tools in equipment and take care not to wear rings when working on equipment where there is a risk from exposed terminals.

All equipment in the radio shack should be connected to a common switch. Other members of the household should be aware of its position so that it can be turned off quickly if a problem occurs.

The earthing of the mains outlets should be checked to ensure that it conforms to IEE regulations.

All wiring should be properly insulated and high voltage connections must not be exposed.

Capacitors in power packs should have a suitable bleeder resistor across there terminals so that they do not become a shock hazard when the equipment is serviced. The RSGB recommends that this applies to high voltage capacitors over 0.01mF. The size of the bleeder resistor should be 1/C megohms.

Indicator lamps showing when mains is on should be installed and maintained on equipment.

Double pole mains switches should always be used with the correct type of fuses. Switches should be off when fuses are changed.

If metal cased equipment has inspection covers which can be easily opened the use of micro switches which turn off the power when opening is recommended.

Test prods and lamps should be insulated.

Attention to floor coverings is important. Rubber or suitable insulating materials help prevent serious shocks. Damp increases the likelihood of electric shock.

It is always best to switch off before making adjusments. If live adjustments to equipment cannot be avoided always use one hand and keep the other in your pocket. Always use tools with insulated handles.

Do not wear headphones when making internal adjustments to live equipment.

Ensure metal cases of microphones; Morse keys; are properly connected to the chassis of equipment.

Do not use meters with metal adjusting screws or control knobs with metal grub screws and shafts on high voltage equipment.

Mains and other high voltages should be avoided on antennas. An Rf choke will provide a suitable DC path to earth.

RF voltages can be a hazard if a person comes in contact with a high voltages node on an antenna. Transmitting antennas should be suitable sited and all cables insulated.

Measurement of RF power ~ Dummy Loads and Modulation Monitors.

In order to extract power from a transmitting device it is necessary to provide a good impedance match to the device.

Failure to do so causes excessive power to be dissapated in the same way as a battery which is overloaded.

Also because of the nature of RF standing waves can be produced in the transmission lines at points of mismatch and energy is reflected back to the transmitter increasing heat dissipation still further.

Aerials and feeders have to be carefully designed to match to the transmitter.

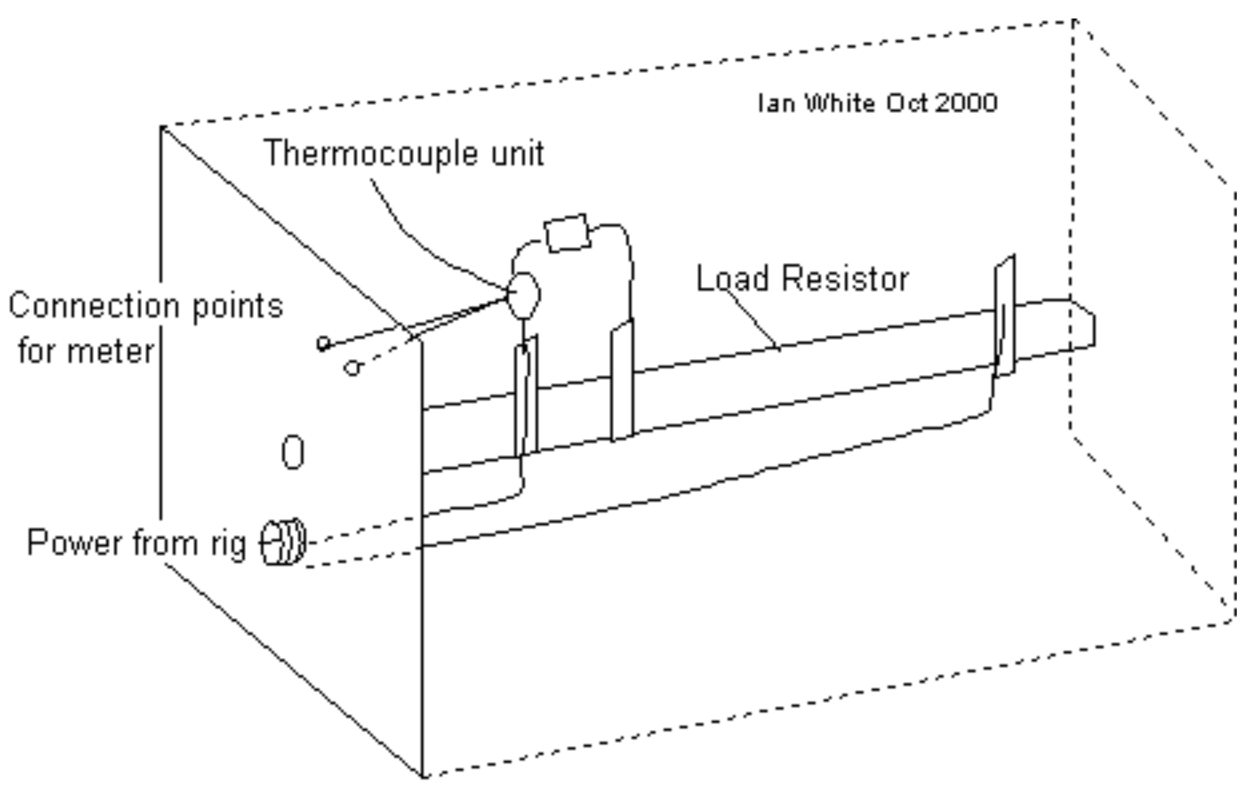
If tests are to be carried out on a transmitter it is necessary to provide a dummy load of the correct impedance otherwise maximum output power will not be obtained and the equipment could suffer damage.

Dummy loads are made from non inductive resistors which must be capable of dissipating the required power. At H.F. they are often enclosed in an oil filled container. The oil helps dissipate the heat. Another requirement is that the load should be screened as unwanted radiation (transmission) may occur during tests. Non inductive loads are used to avoid resonances which would occur with stray capacitances and produce impedances which varied with frequency. V.H.F. loads are carefully designed to avoid this.

Power Measurement

A thermocouple meter (RF ammeter) is the best way of measuring R.F. power and is often used in conjunction with a dummy load. The thermocouple device consists of a glass envelope containing a filament or heater which is close to a thermocouple. This develops an E.M.F proportional to the heat generated which is read on the meter.

The thermocouple unit may be enclosed in the meter or may be part of a combined dummy load, this latter arrangement is helpful at V.H.F. where leads to a meter could cause problems because of there inductance and ability to radiate.



Above is the type of setup that might be used where a load resistor with 10% tap is placed in a screened box indicated by dotted lines.
Power from the rig is applied accros the resistor and a small amount is tapped off to the thermocouple unit. In this case the leads from the thermocouple are brought to connectors at the front which can be connected to an external meter. Alternatively the meter could be mounted on the front.

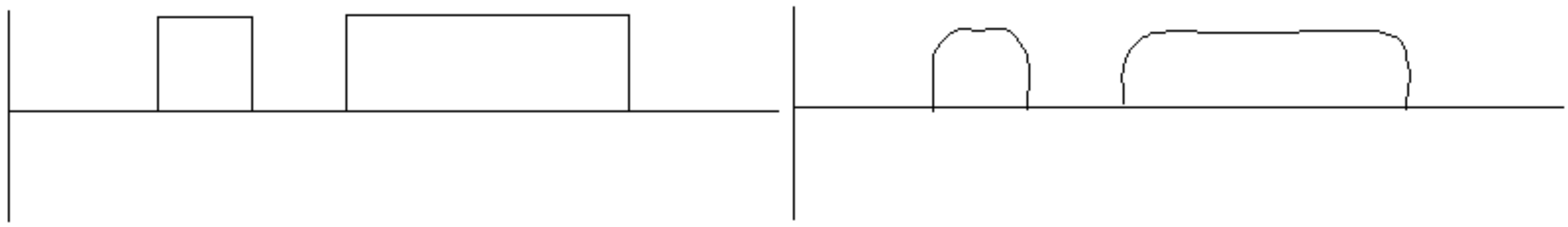
For further information see the book "Test Equipment for Radio amateurs"

Transmitter Interference

Causes of interference to other users either amateur or other services due to incorrectly aligned or set up transmitters are as follows.

1. Key clicks on C.W. - keying the wrong stage
2. Overdriving of the P.A. or other stages.
3. Incorrect bias level applied to linea stages e.g. amplifiers which should be linea running in Class C.
4. Spurious emissions due to poor choice of mixing frequencies.
5. or oscillation of P.A. or other stages due to instability.

1. Key Clicks on C.W.



(a) (b)

Two fast a rise and fall time as in a causes harmonics to be produced which are heard as key clicks over a wide range of frequencies as in (a).
- minimised by key click filter to give a less abrupt change as shown in (b)

Also it is good practice to key the lowest power stage possible but not the oscillator which should run continuously at a stable frequency.
Keying the oscillator produces an effect known as "chirp" which is caused by the oscillator taking time to stabilise each time the key is pressed.

Overdriving of the modulating or P.A. stage in telephony produces.

a) Flat topping (squaring)
of envelope on a.m. or s.s.b.
This is rich in harmonics and produces sidebandsoutside wanted bandwidth -- a wide signal.

b) Over modulation of F.M. or P.M. - excessive deviation produces unwanted extra sidebands.
-- a wide signal.

c) Incorrectly set up P.A. Stages producing non linearity. ie due to faulty or incorrect setting up a linea runs in Class C.

Unwanted harmonics are produced
-- wide signal with distortion

d) Spurious emissions due to insufficient rejection of frequencies involved in mixing.

Self oscillation of P.A. stages -- feedback due to poor design inadequate decoupling etc.

Production of harmonics often by overdriving the P.A.
This can be detected and then avoided by the use of an absorbtion wavemeter to check for harmonics and other spurii.

Holders of an amateur license should undertake such checks *from time to time*.

Using Decibels

Decibels are used in amateur radio and electronics for relative measurements. The scale is logarithmic and is uses base 10 logarithm.

Although we can show the relationship as

power decibels = 10 * $\log_{10}$ power in watts.

The value given should be shown as Db_w which means power is relative to one watt.

There is an easy approach to decibel problems which depends on remembering a few simple relationships.

For every 3dB the power doubles.

For every 10 dB the power increases 10 times

? What power in watts is 23 dbw 20/10 = 2 add 2 zeros

=100 watts

for 3 db the power doubles so 200 watts

If calculation is about voltage gain for instance in a receiver then this is given by

voltage gain decibels = 20 * $\log_{10}$

The same rules apply then double it.