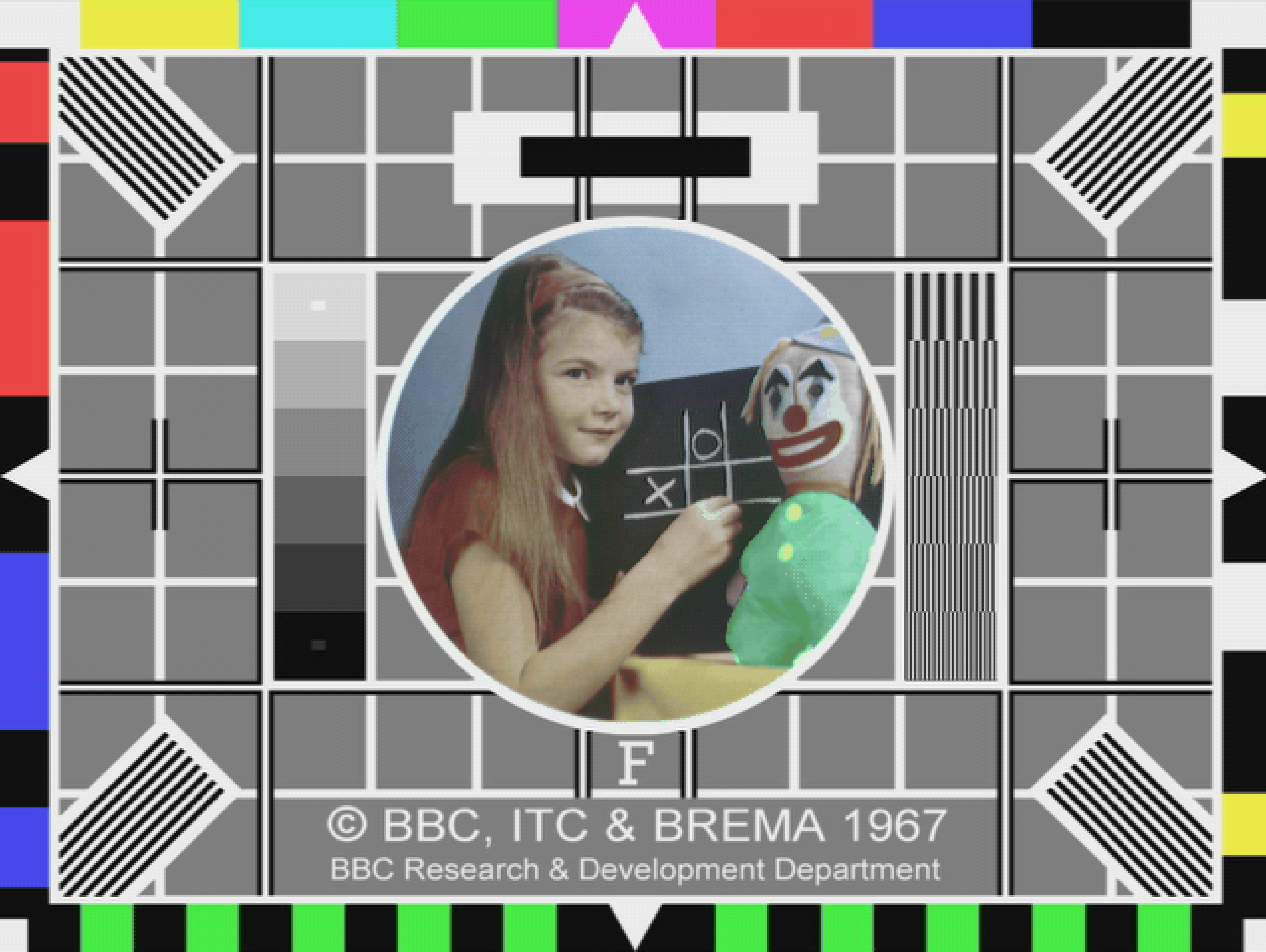

F
© BBC, ITC & BREMA 1967
BBC Research & Development Department

Are you like this man?

When your radio gear goes wrong do you take it back to the dealer?

If you do, then the next hour may not be of interest to you ...so you can go home if you like!

OR

you can stay and enter the world of ...

TEST GEAR and HOW TO USE IT

OR ~ AN ALTERNATIVE TO OPERATING!

Peter Day, G3PHO

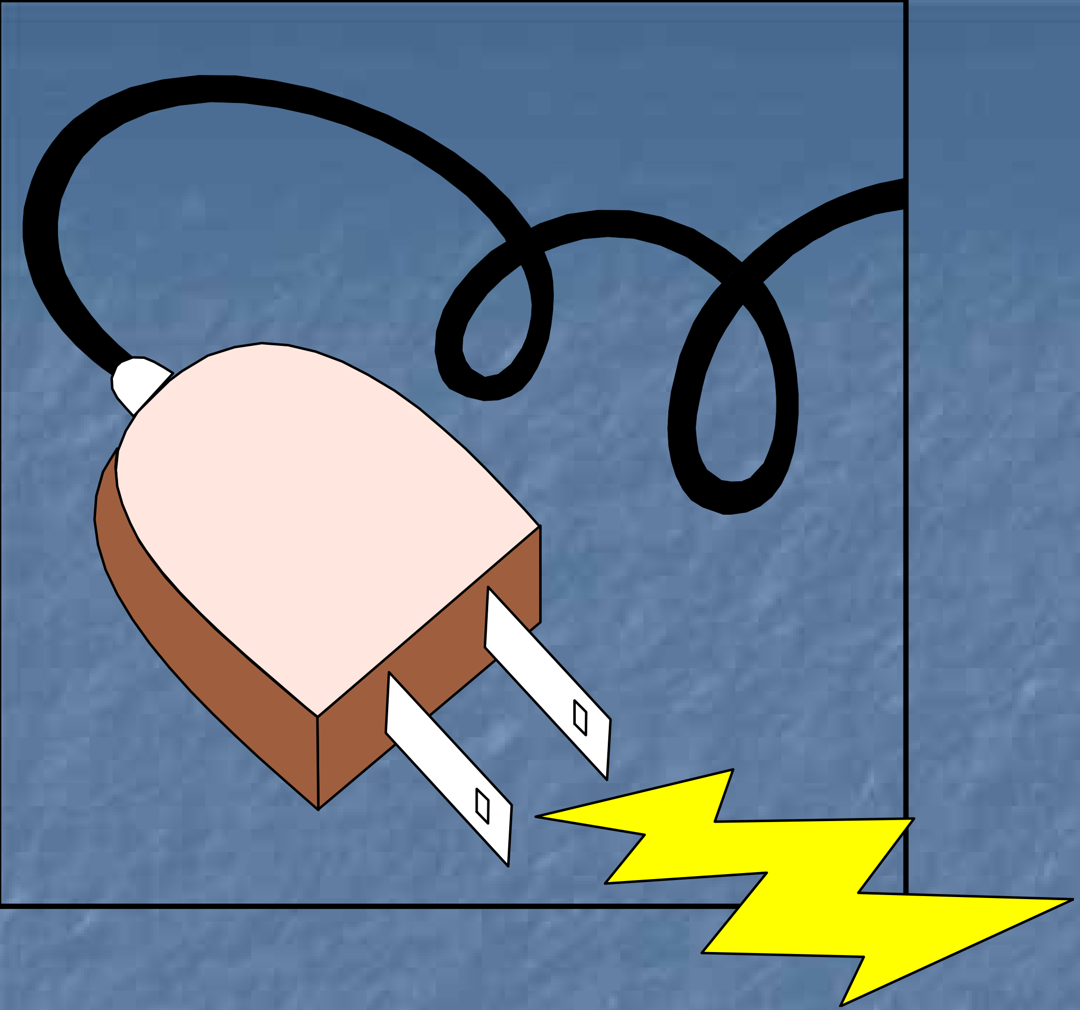
warning!

- Test gear and testing can become addictive ....
- You have been warned!

TEST GEAR and HOW TO USE IT

Contents

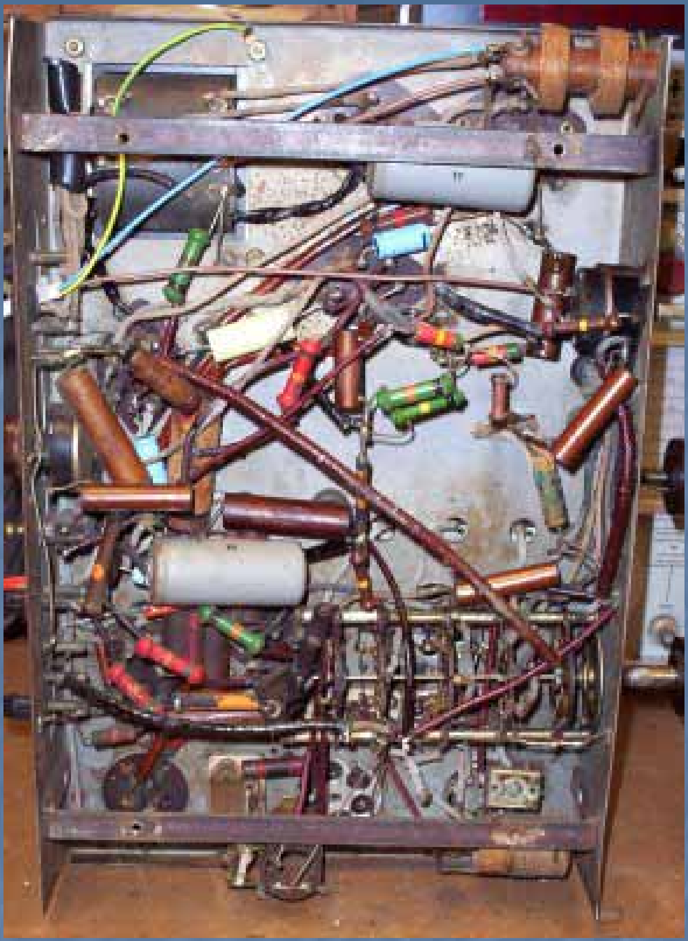
- Why test?
- Test what?
- With what do I test?
- Basic test gear required in an amateur shack
- Advanced test equipment
- Simple home made test equipment
- Software alternatives to “real” test equipment
- The Oscilloscope - demonstration
- The Spectrum Analyser - demonstration



Why test ?

Why test ?

- To find faults



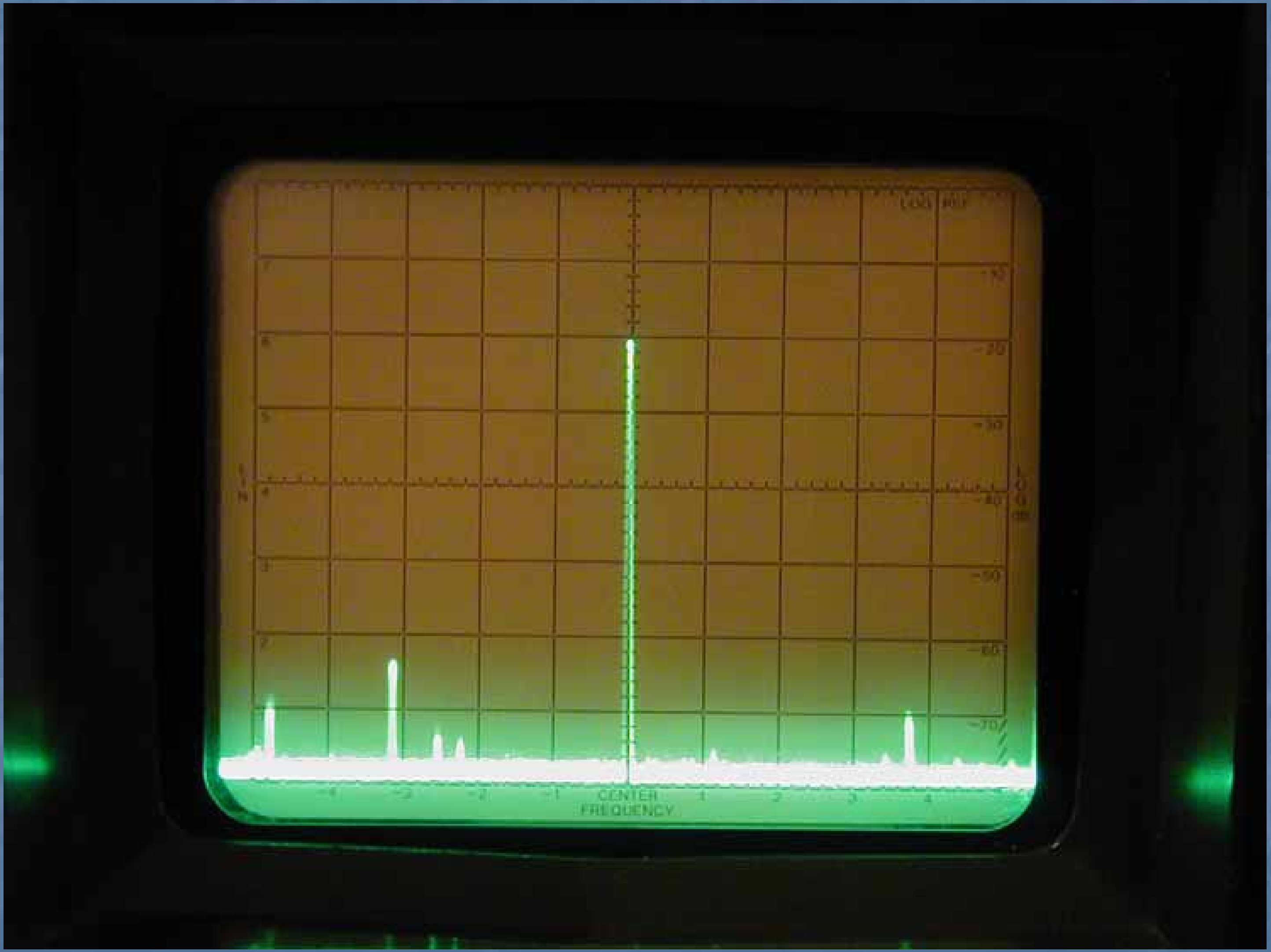
When I were a lad!

Today…Icom 736

Why test ?

- Checking performance of our equipment

Why test ?



- Re-aligning equipment

Why test?

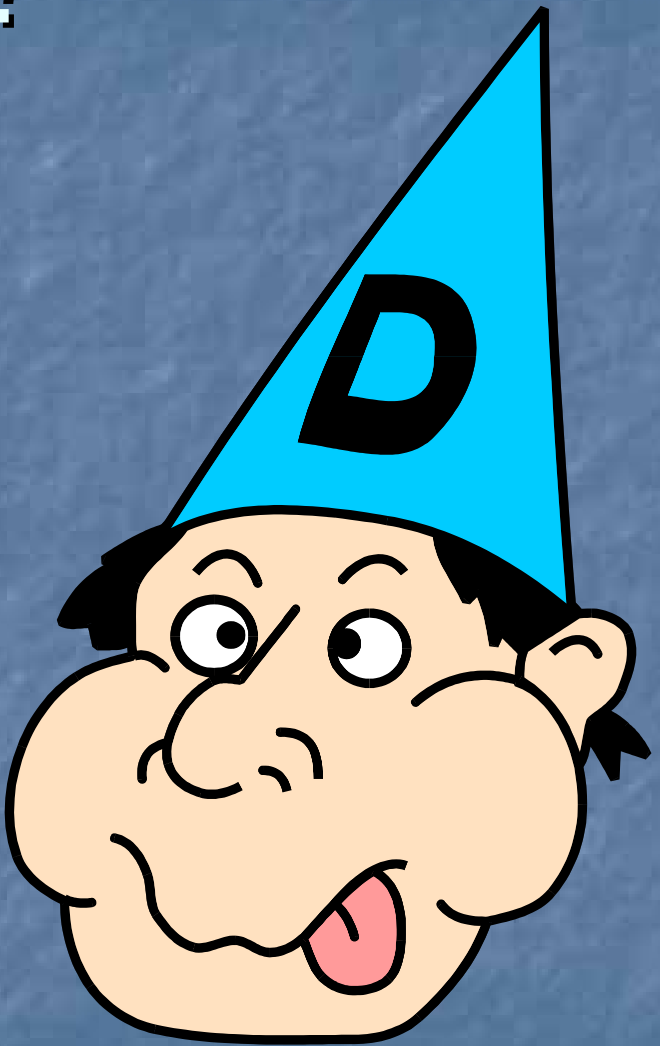
- Setting up homemade equipment

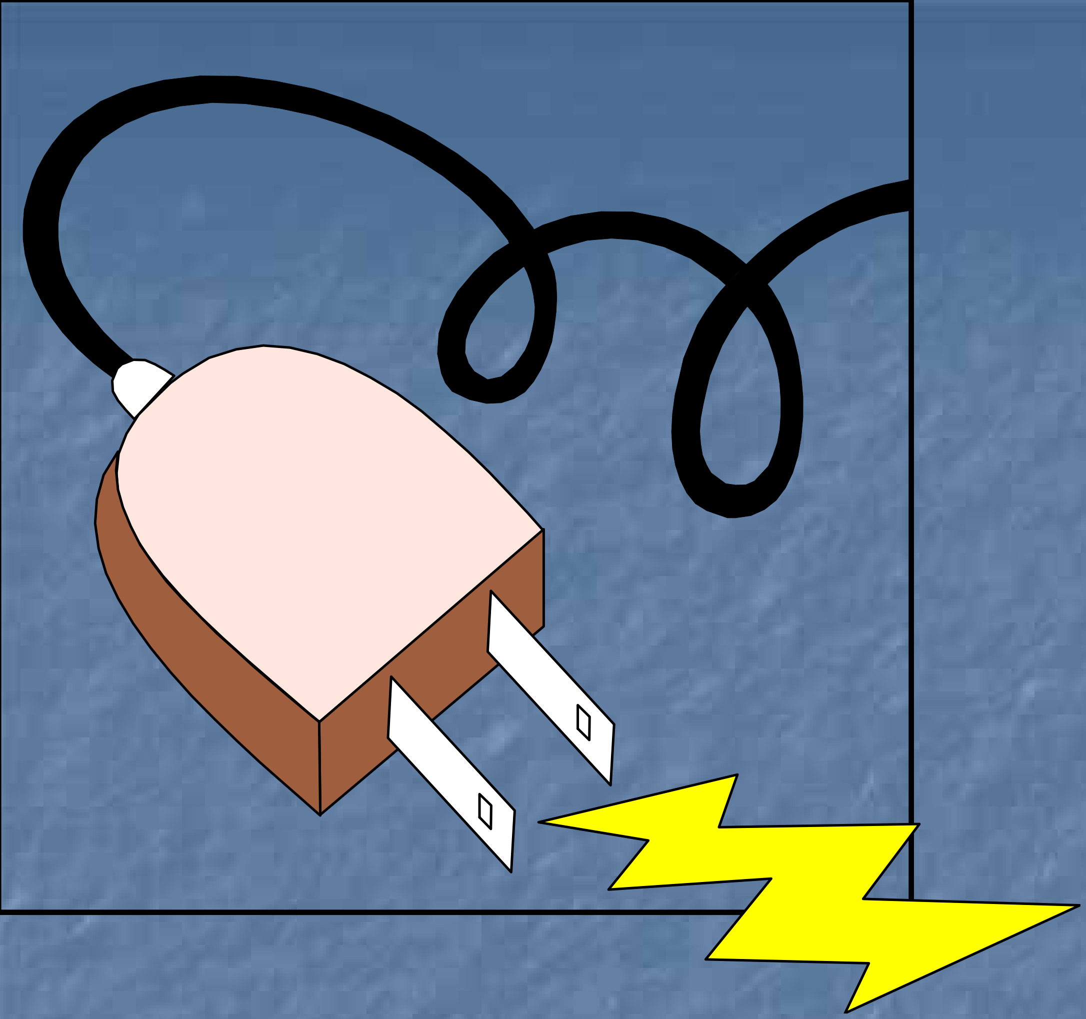
Why test?

- **Input voltages and current**
  - Is the equipment getting the correct power supply ?

Why test?

- To learn something!
- To live up to the aim of the Amateur Radio licence regarding “self training” (see your BR68 !)





Test what ?

Test what ?

- Power output … is it working?

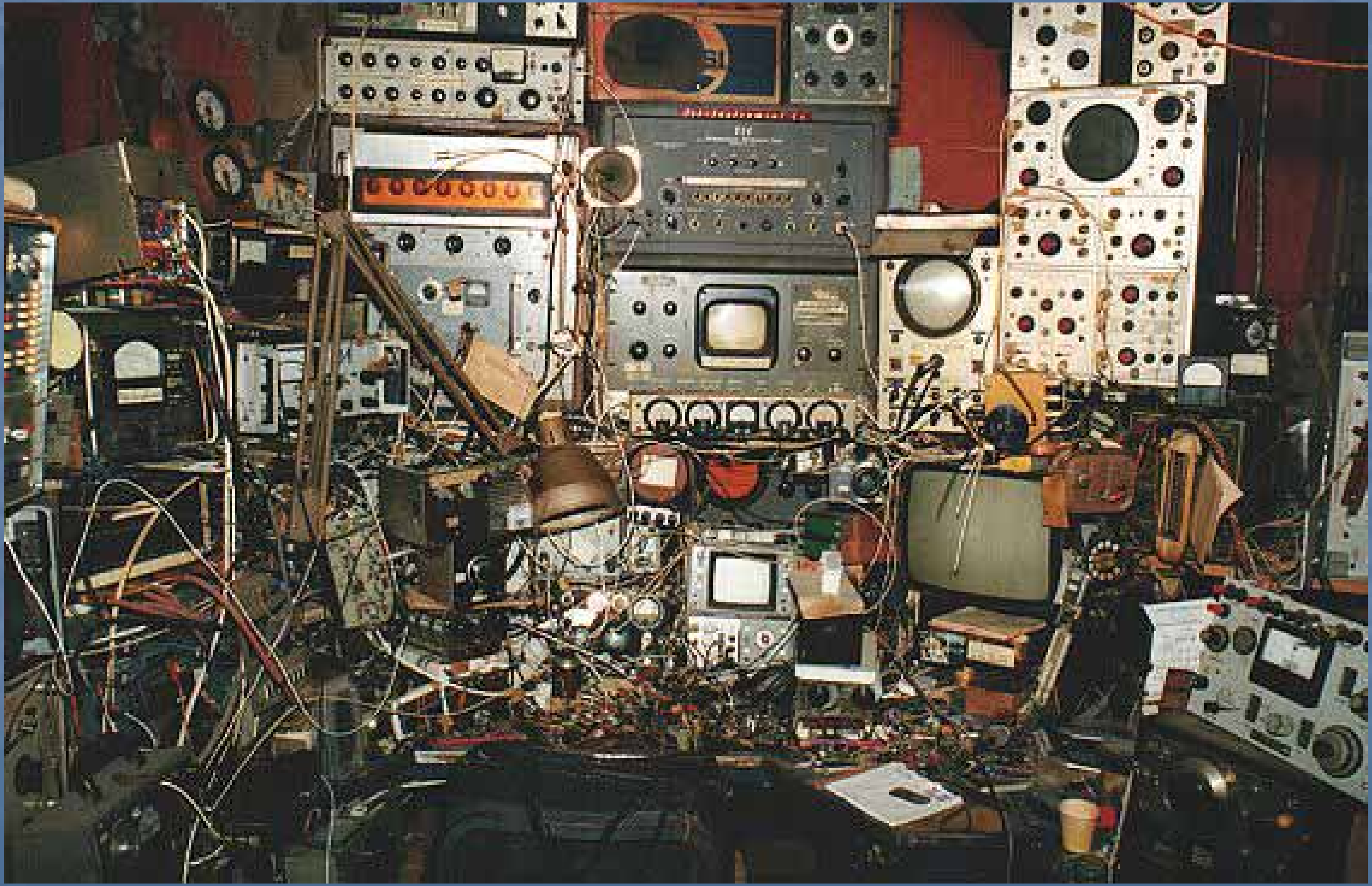
Test what ?

- **Transmit signal quality … what does it sound like?**

  - This applies to both ‘phone’ (ssb, FM, etc) and datamodes (including CW)

  - Don’t assume a completely shop-bought station will sound good all the time!

Even this station might sound better than the previous one!



Test what ?

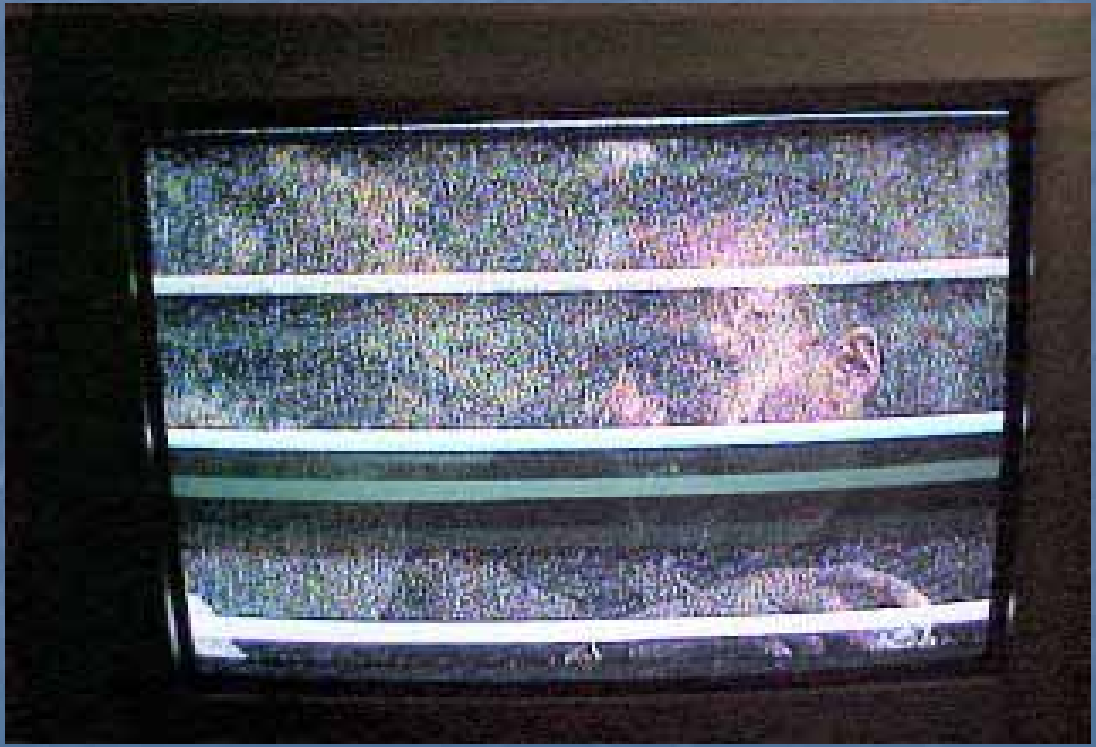
- **Frequency – accuracy, stability, resettability**

- Modern “blackboxes” are not frequency counters” !
- Modern gear <u>can</u> (and does) drift !

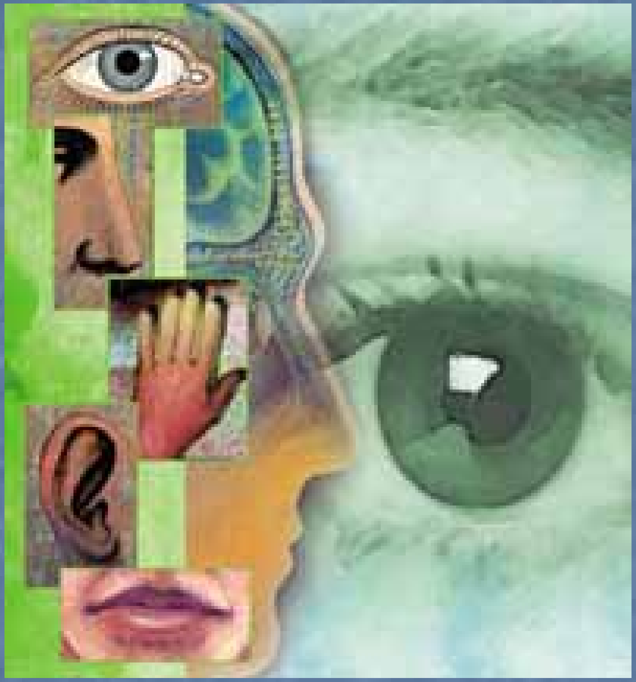
Test what ?

Interference to domestic radios, TVs and audio systems.

- HiFi Interference
- TVI
- Interference **<u>to</u>** your amateur radio equipment



With what do I test?



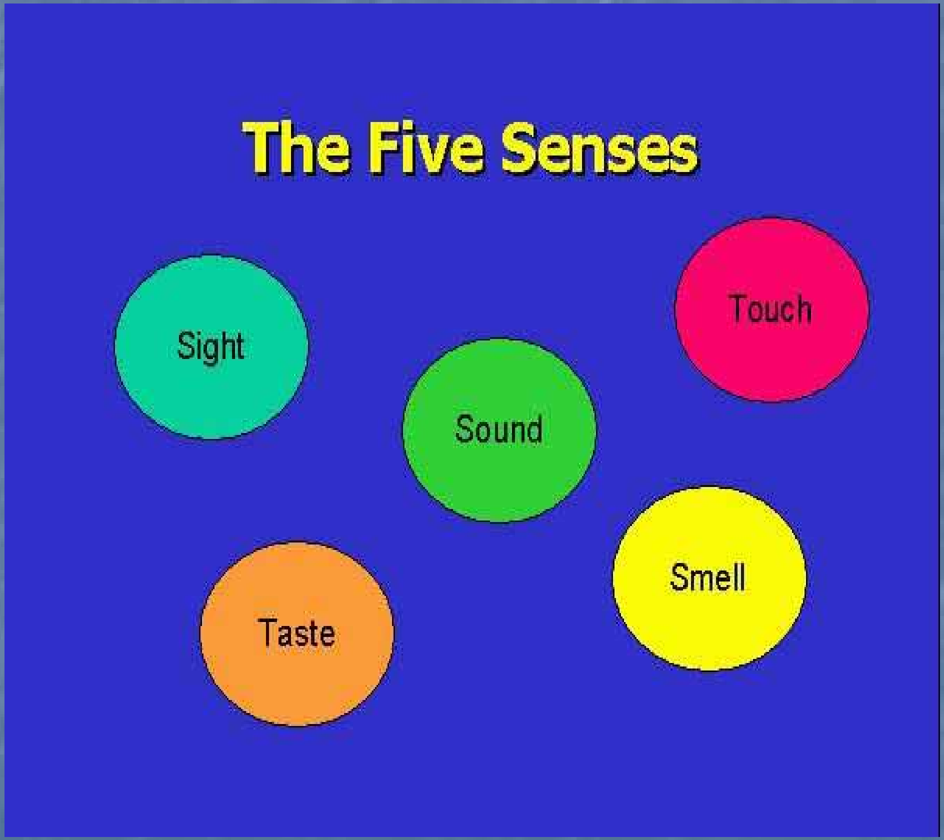
- Your <u>six</u> senses

+

- Test equipment

Without either you are working in the dark!

FIRST TESTS USE YOUR SIX SENSES



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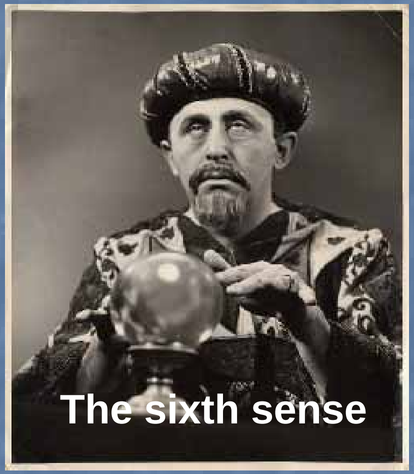
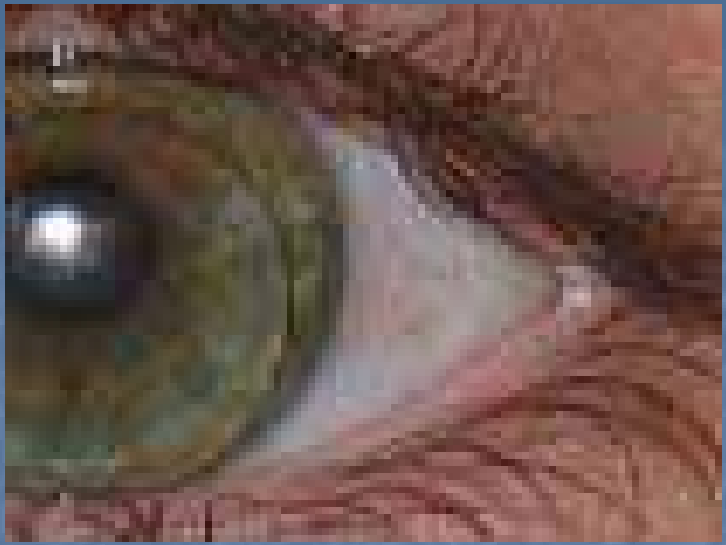




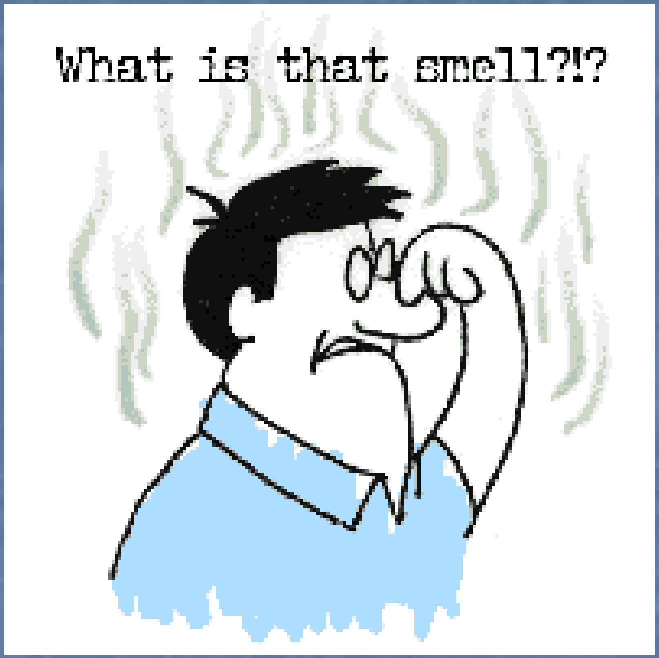
LOOK !

- For signs of broken wires
- For bad connections, especially soldered joints
- For signs of overheating … burnt or charred components
- For dirt and corrosion, especially around switches and connectors

LISTEN !

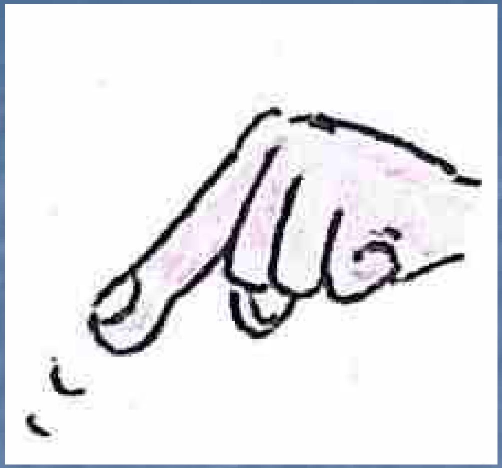
- For distorted audio
- Arching and sizzling sounds
- Microphonic noise when component is tapped
- Feedback … especially RF feed back and “FM-ing”

Smell !



- You can't mistake the smell of burning components!
- Take care as some are toxic

Touch !



- CAREFUL ! Switch off equipment before inserting digit!
- But .. if feeling for overheating components you may need to have the gear switched on, so take great care with high voltages

Taste !

The Sixth Sense !

- Build up experience and use what you have acquired
- After a while you'll develop a "sixth sense" and know where to look for the fault

TEST GEAR - the bare minimum

- What basic items of test equipment should I have in my radio shack?

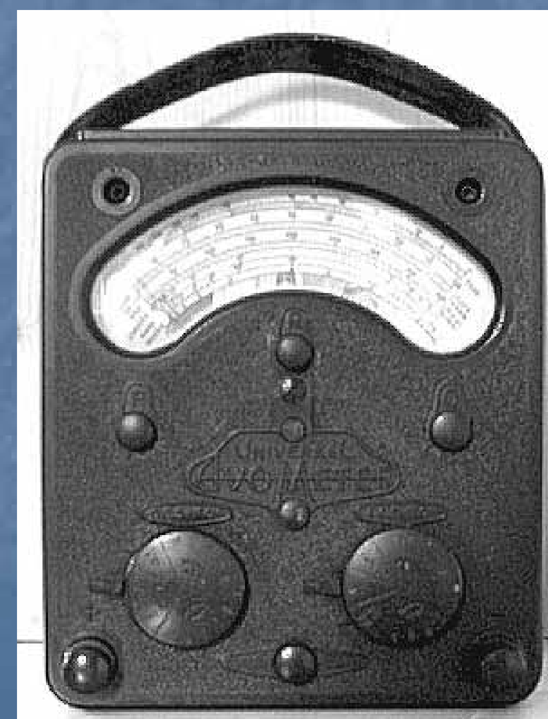
TEST GEAR - the bare minimum

Multimeter ("Test Meter")
Both types needed

digital

analogue

analogue



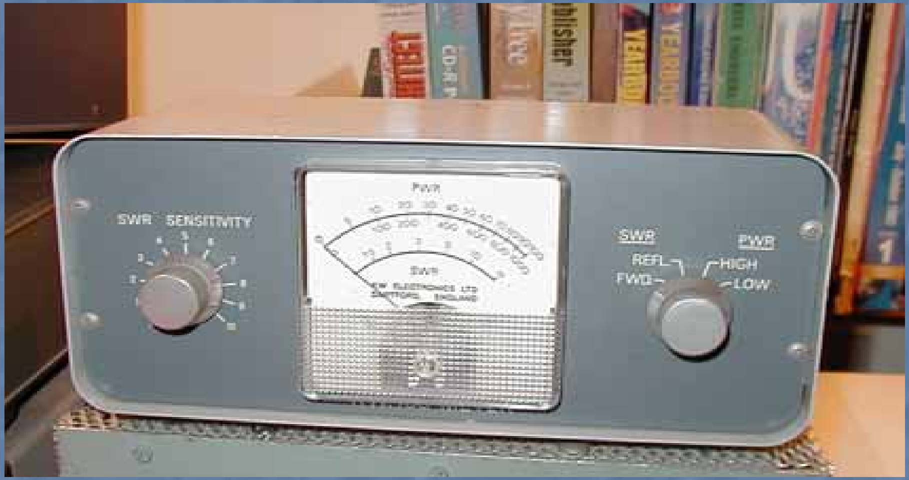
USES OF THE MULTIMETER

- Testing antenna and power connections with continuity tester function.
- Verifying transceivers are being fed with the correct voltage.
- Checking polarity of power connections.
- Measuring the current drawn by station equipment.
- Making voltage and current checks when developing or troubleshooting circuits.
- Checking values of components (esp. resistors)

TEST GEAR - the bare minimum

Power meter/SWR indicators

Bird Thru Line



KW Electronics

Watson VHF/UHF

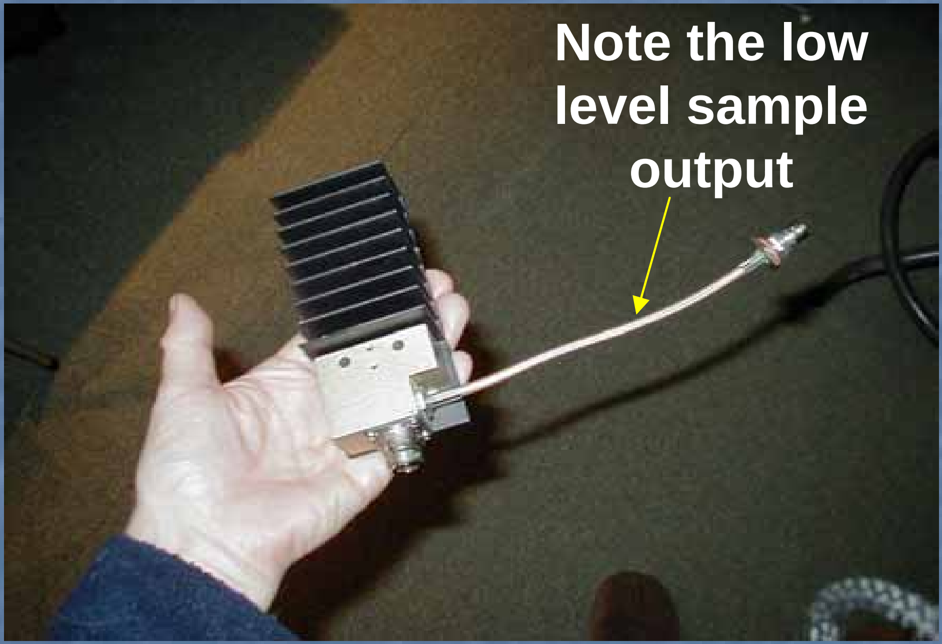
TEST GEAR - the bare minimum

RF PROBE - for checking RF levels in circuits

This detects RF and presents it as a voltage suitable for display on a low range voltmeter or on an oscilloscope

TEST GEAR - the bare minimum

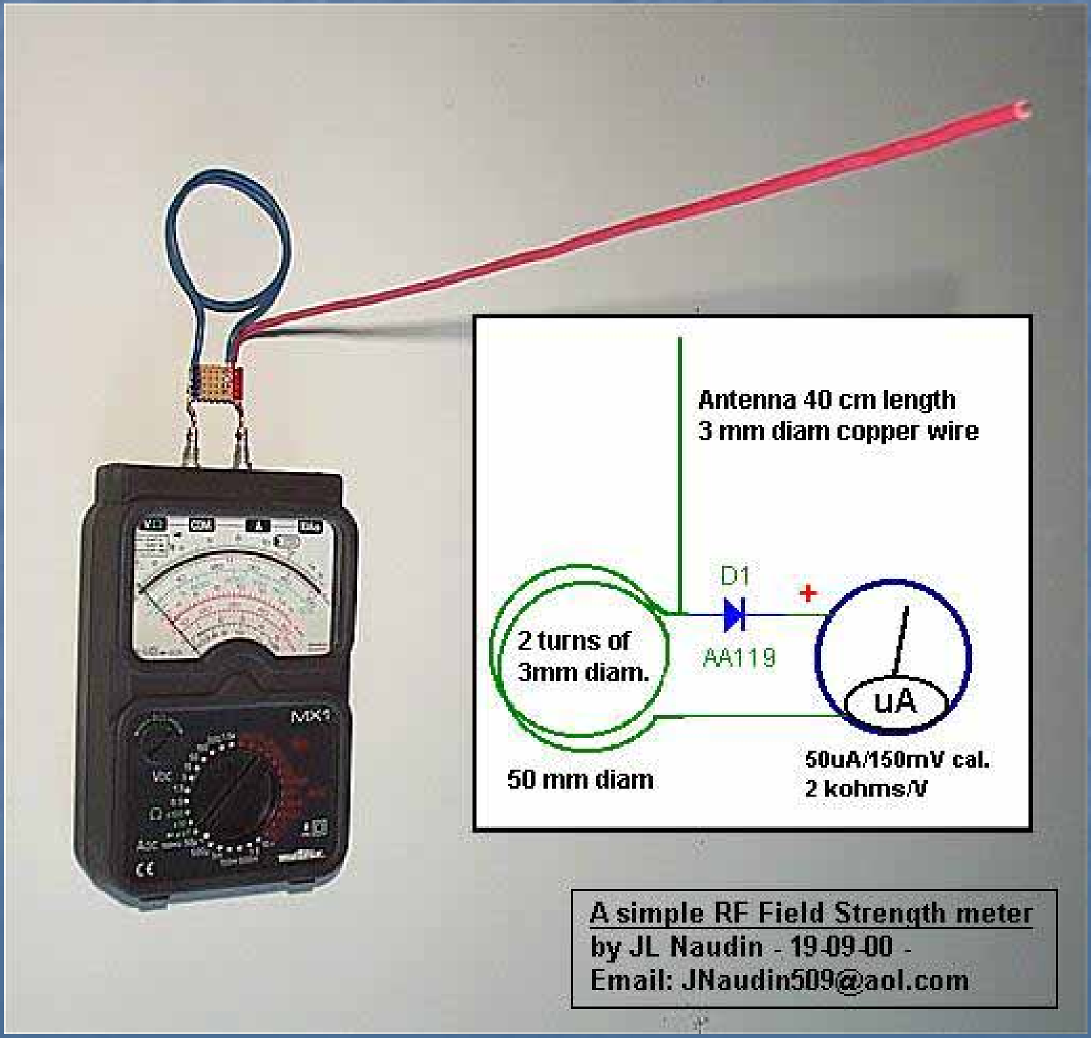
Dummy Load



Should be rated for more than your maximum RF output!

TEST GEAR - the bare minimum

RF “sniffer” or Field Strength Meter



TEST GEAR - the bare minimum

RF “sniffer” or Field Strength Meter

Sheffield A.R.Club Project

TEST GEAR - the bare minimum

Frequency standard and/or counter

This counter cost only £2 at a rally in 2004 !

TEST GEAR - the bare minimum

Frequency standard– 100kHz,1MHz, 5MHz and 10MHz
Needed to calibrate counter and other frequency measuring gear

Below:

The “Poor Man’s Caesium Clock

Above: MSF locked frequency source

Cheap-to-build home made standards

TEST GEAR - the bare minimum

Passable alternative to a frequency standard and/or counter

- A good low power general coverage transceiver
- Must be multimode RX across the whole range

TEST GEAR - the bare minimum

Absorption Wavemeter

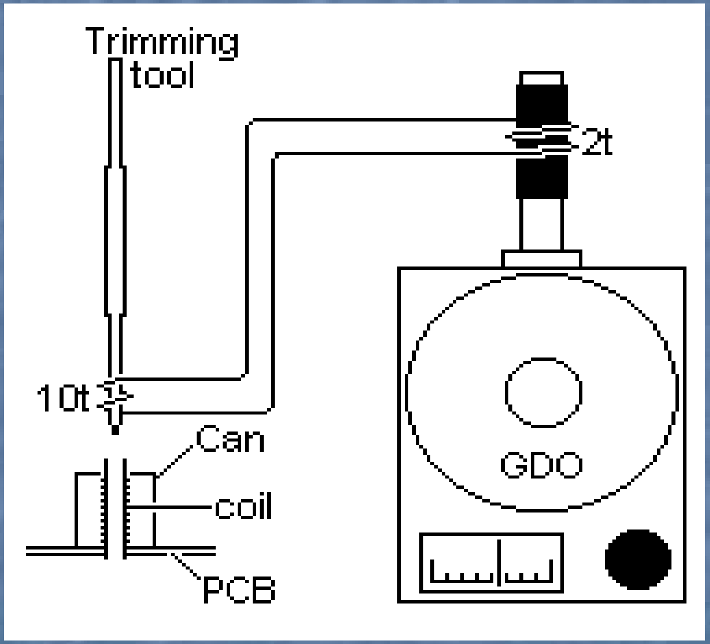
TEST GEAR - the bare minimum

Absorption Wavemeter – microwave types

TEST GEAR - the bare minimum

Grid dip oscillator = GDO or Dip oscillator

Main instrument



Tuning a coil

TEST GEAR - the bare minimum

Modulated Signal Source - Signal Generator

TEST GEAR - the bare minimum

Modulated Audio oscillator

Kit, less box, knobs, LED and BNC connector is only £4.99 at Maplin

TEST GEAR - the bare minimum

Oscilloscope

Buy the widest bandwidth you can afford

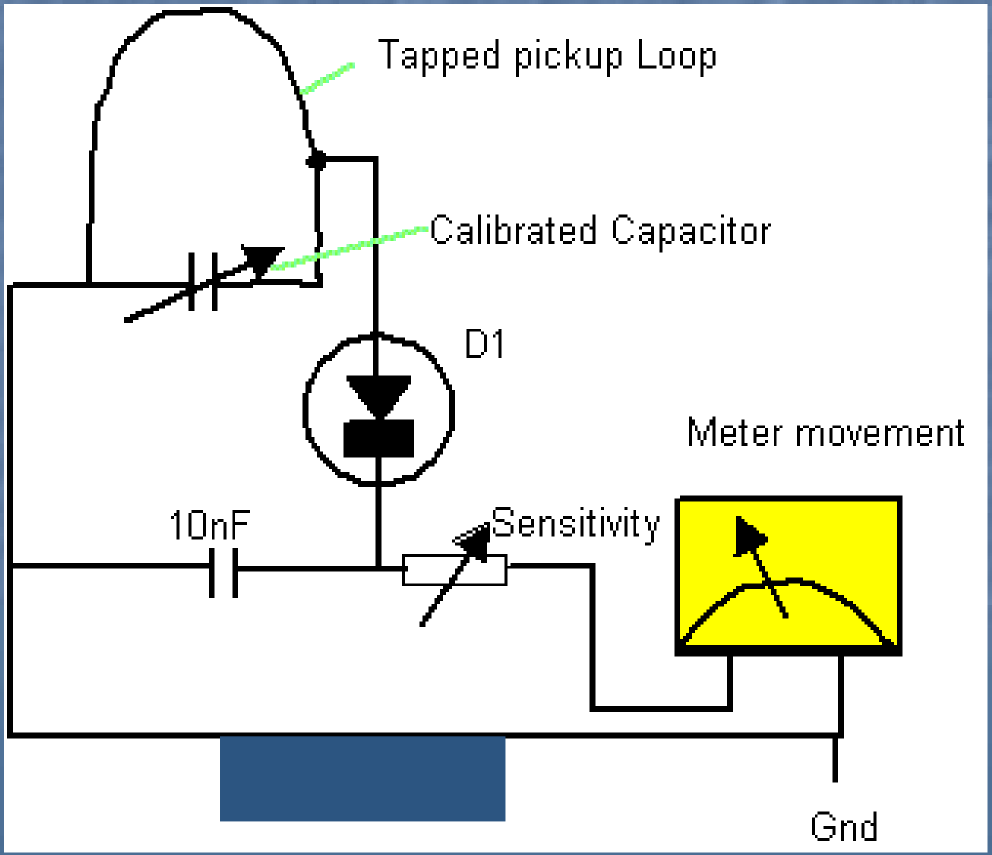
SIMPLE HOME MADE TEST GEAR

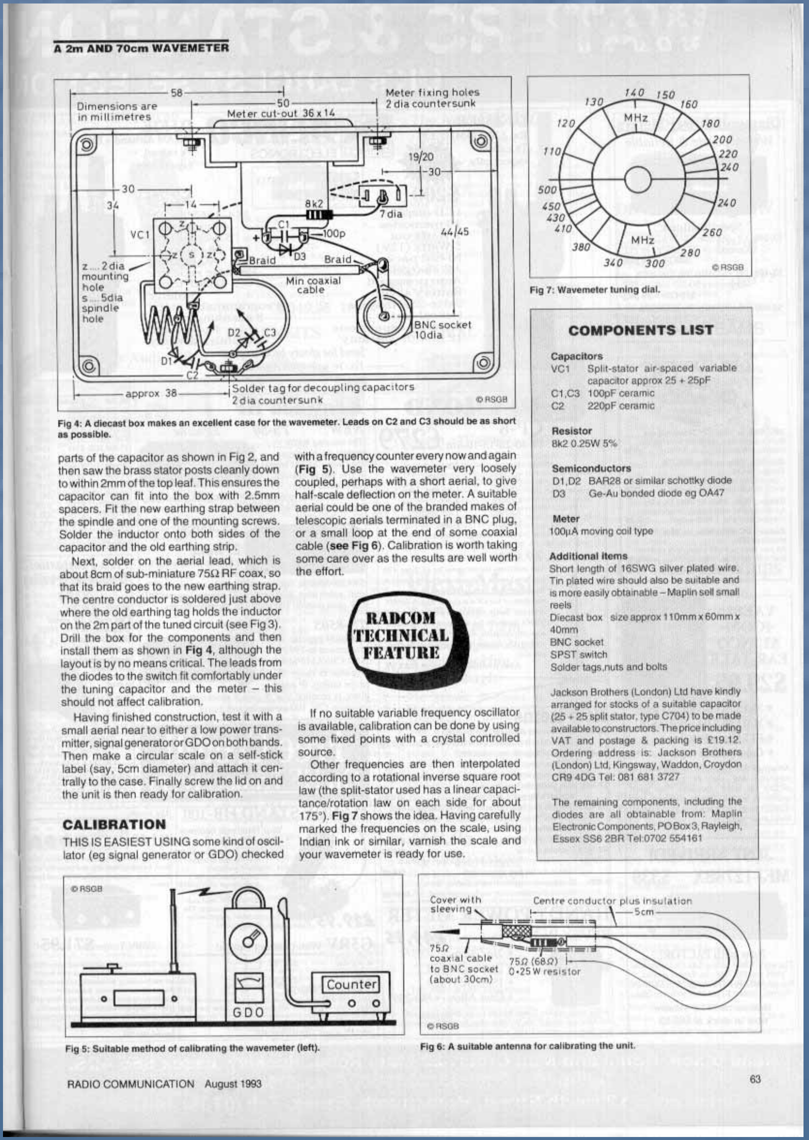
- These could be your first of many home construction projects
- Go on....have a go!

SIMPLE HOME MADE TEST GEAR

Absorption Wavemeter

Easily home made





A 2m AND 70cm WAVEMETER

Fig 4: A diecast box makes an excellent case for the wavemeter. Leads on C2 and C3 should be as short as possible.

parts of the capacitor as shown in Fig 2, and then saw the brass stator posts cleanly down to within 2mm of the top leaf. This ensures the capacitor can fit into the box with 2.5mm spacers. Fit the new earthing strap between the spindle and one of the mounting screws. Solder the inductor onto both sides of the capacitor and the old earthing strip.

Next, solder on the aerial lead, which is about 8cm of sub-miniature 75Ω RF coax, so that its braid goes to the new earthing strap. The centre conductor is soldered just above where the old earthing tag holds the inductor on the 2m part of the tuned circuit (see Fig 3). Drill the box for the components and then install them as shown in **Fig 4**, although the layout is by no means critical. The leads from the diodes to the switch fit comfortably under the tuning capacitor and the meter – this should not affect calibration.

Having finished construction, test it with a small aerial near to either a low power transmitter, signal generator or GDO on both bands. Then make a circular scale on a self-stick label (say, 5cm diameter) and attach it centrally to the case. Finally screw the lid on and the unit is then ready for calibration.

CALIBRATION

THIS IS EASIEST USING some kind of oscillator (eg signal generator or GDO) checked with a frequency counter every now and again (**Fig 5**). Use the wavemeter very loosely coupled, perhaps with a short aerial, to give half-scale deflection on the meter. A suitable aerial could be one of the branded makes of telescopic aerials terminated in a BNC plug, or a small loop at the end of some coaxial cable (**see Fig 6**). Calibration is worth taking some care over as the results are well worth the effort.

RADCOM TECHNICAL FEATURE

If no suitable variable frequency oscillator is available, calibration can be done by using some fixed points with a crystal controlled source.

Other frequencies are then interpolated according to a rotational inverse square root law (the split-stator used has a linear capacitance/rotation law on each side for about 175°). **Fig 7** shows the idea. Having carefully marked the frequencies on the scale, using Indian ink or similar, varnish the scale and your wavemeter is ready for use.

Fig 7: Wavemeter tuning dial.

COMPONENTS LIST

Capacitors
VC1 Split-stator air-spaced variable capacitor approx 25 + 25pF
C1,C3 100pF ceramic
C2 220pF ceramic

Resistor
8k2 0.25W 5%

Semiconductors
D1,D2 BAR28 or similar schottky diode
D3 Ge-Au bonded diode eg OA47

Meter
100μA moving coil type

Additional items
Short length of 16SWG silver plated wire. Tin plated wire should also be suitable and is more easily obtainable – Maplin sell small reels
Diecast box size approx 110mm x 60mm x 40mm
BNC socket
SPST switch
Solder tags,nuts and bolts

Jackson Brothers (London) Ltd have kindly arranged for stocks of a suitable capacitor (25 + 25 split stator, type C704) to be made available to constructors. The price including VAT and postage & packing is £19.12. Ordering address is: Jackson Brothers (London) Ltd, Kingsway, Waddon, Croydon CR9 4DG Tel: 081 681 3727

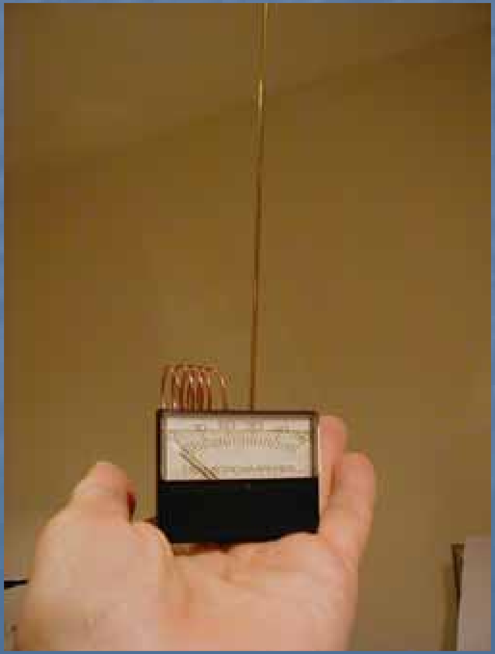
The remaining components, including the diodes are all obtainable from: Maplin Electronic Components, PO Box 3, Rayleigh, Essex SS6 2BR Tel:0702 554161

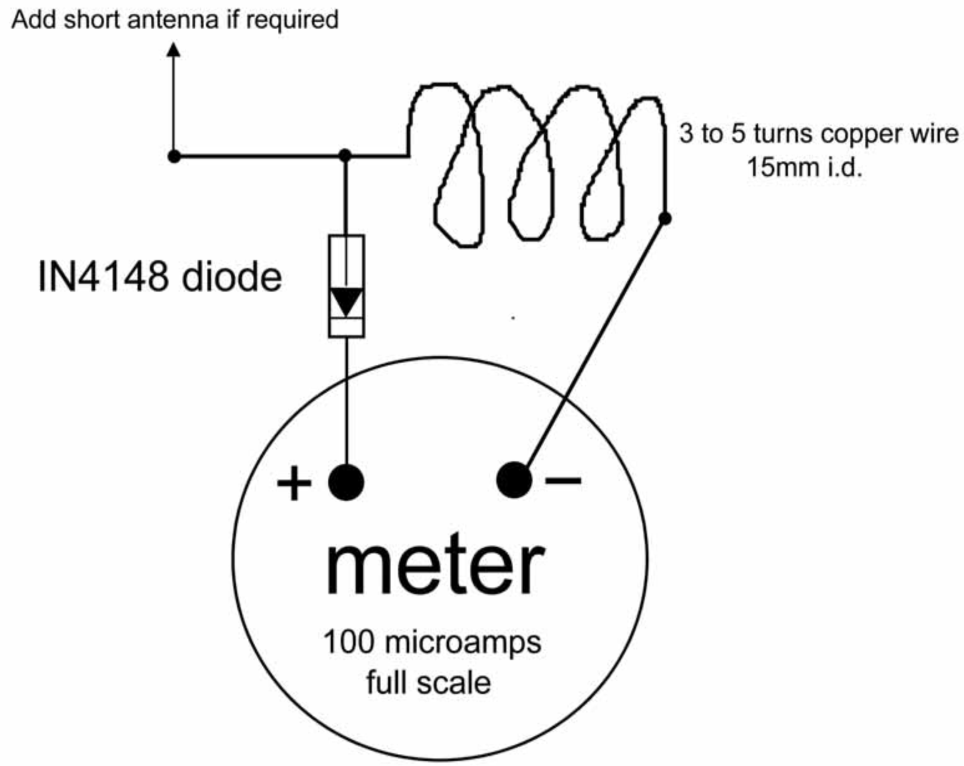
Fig 5: Suitable method of calibrating the wavemeter (left).

Fig 6: A suitable antenna for calibrating the unit.

SIMPLE HOME MADE TEST GEAR

RF “sniffer” or
Field Strength
Meter

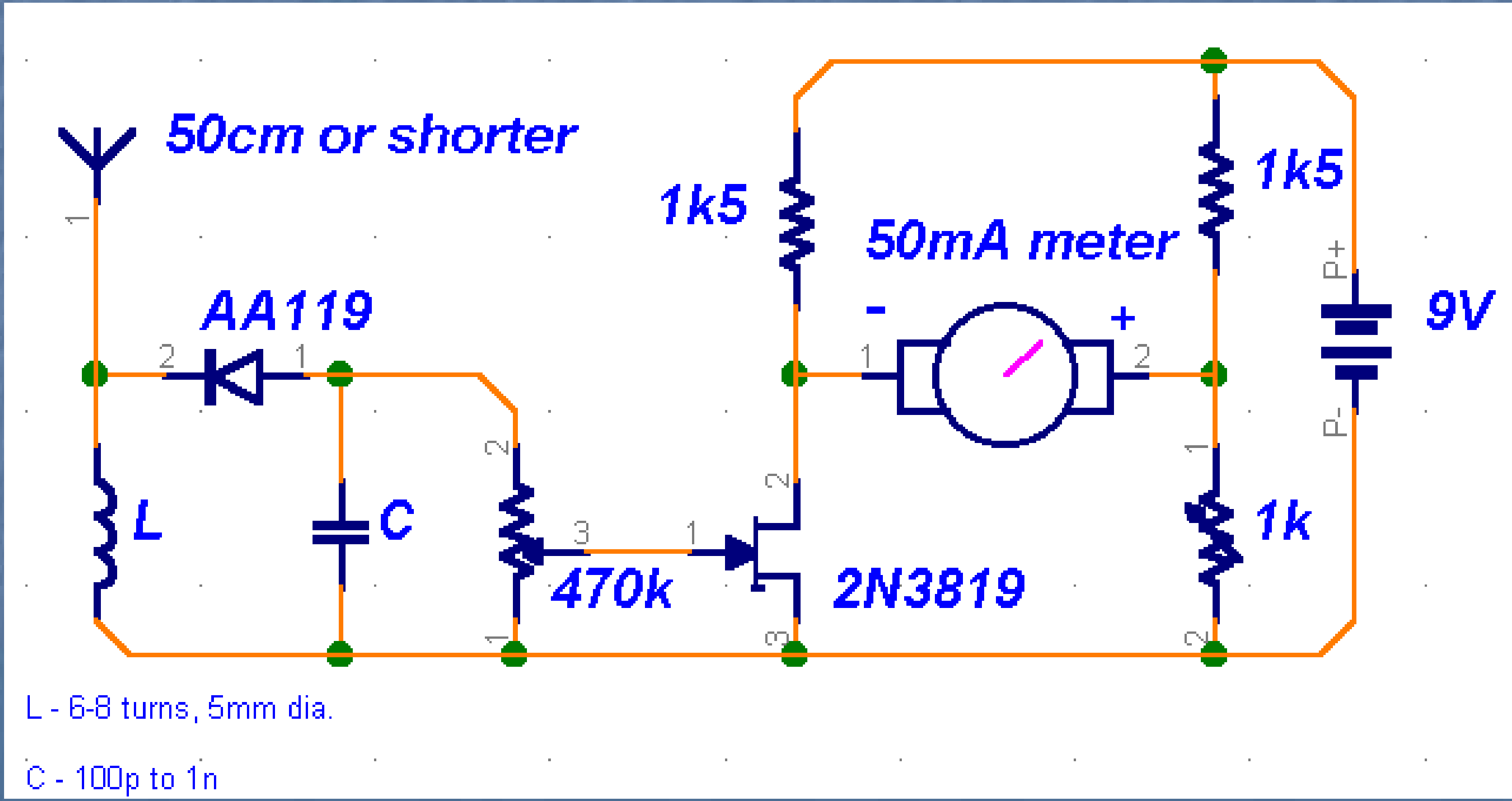




A Simple RF Sniffer
or Field Strength Meter

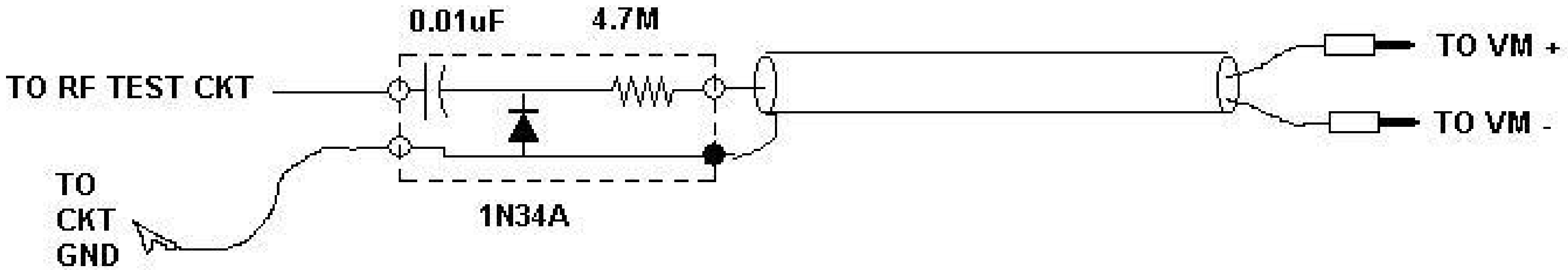
SIMPLE HOME MADE TEST GEAR

RF “sniffer” or Field Strength Meter



SIMPLE HOME MADE TEST GEAR

RF PROBE



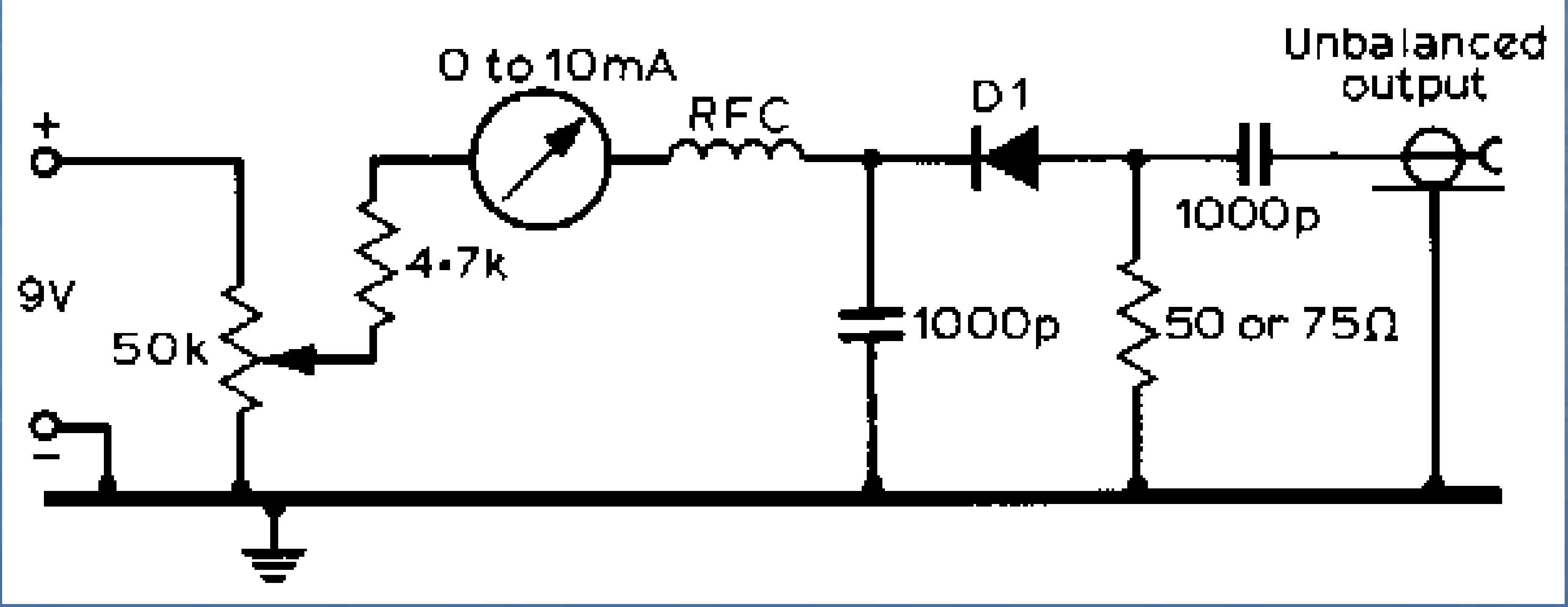
CLASSIC RF PROBE

Reads RMS Equivalent Voltage in test circuit, if Voltmeter is 10 -11 Meg Input Impedance;
Reads 4X RMS Equiv Voltage if VM is 1Meg Input Impedance (Set VM to measure DCV)

SIMPLE HOME MADE TEST GEAR

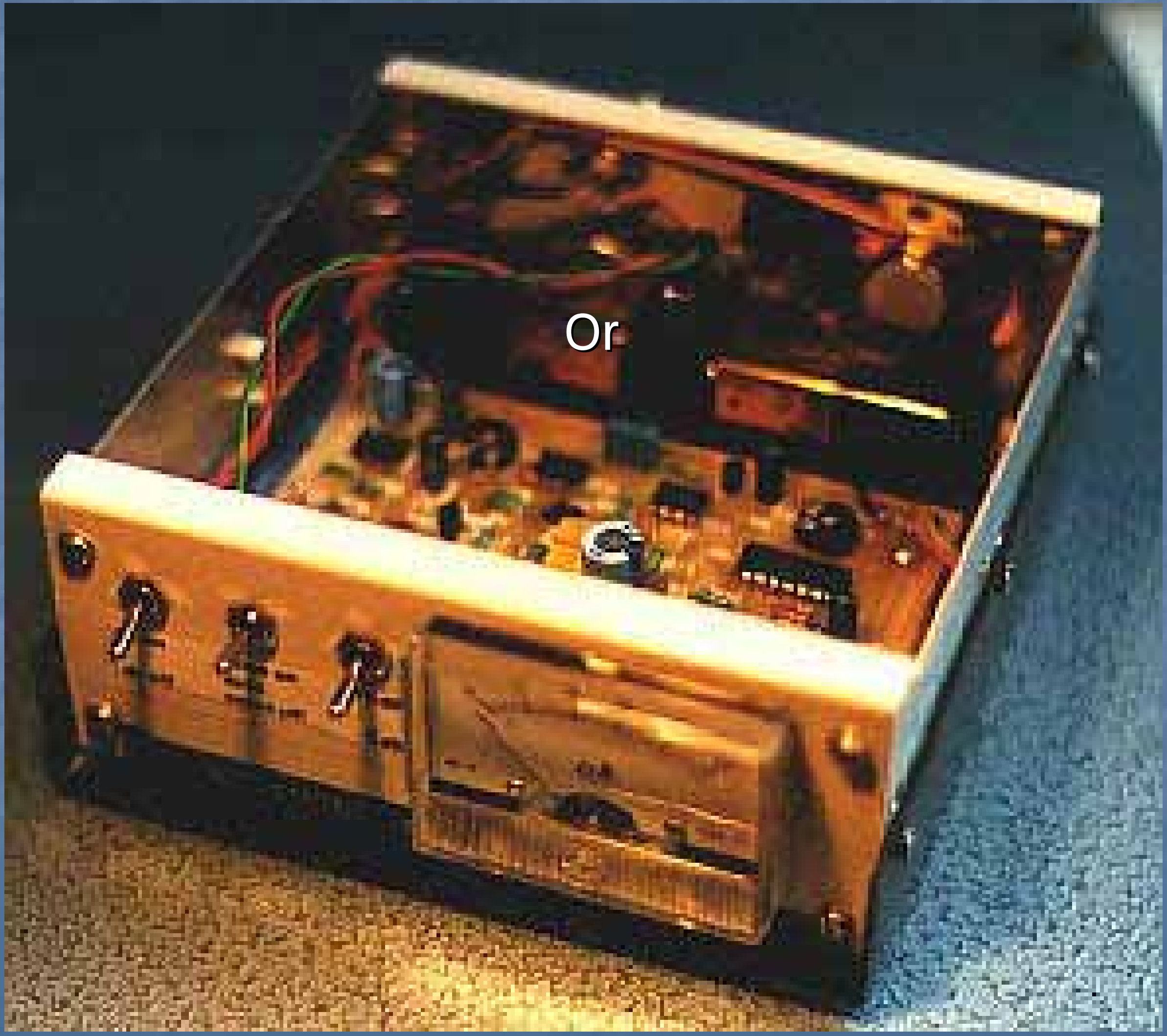
Noise source ..

useful for aligning receiver front ends and preamplifiers



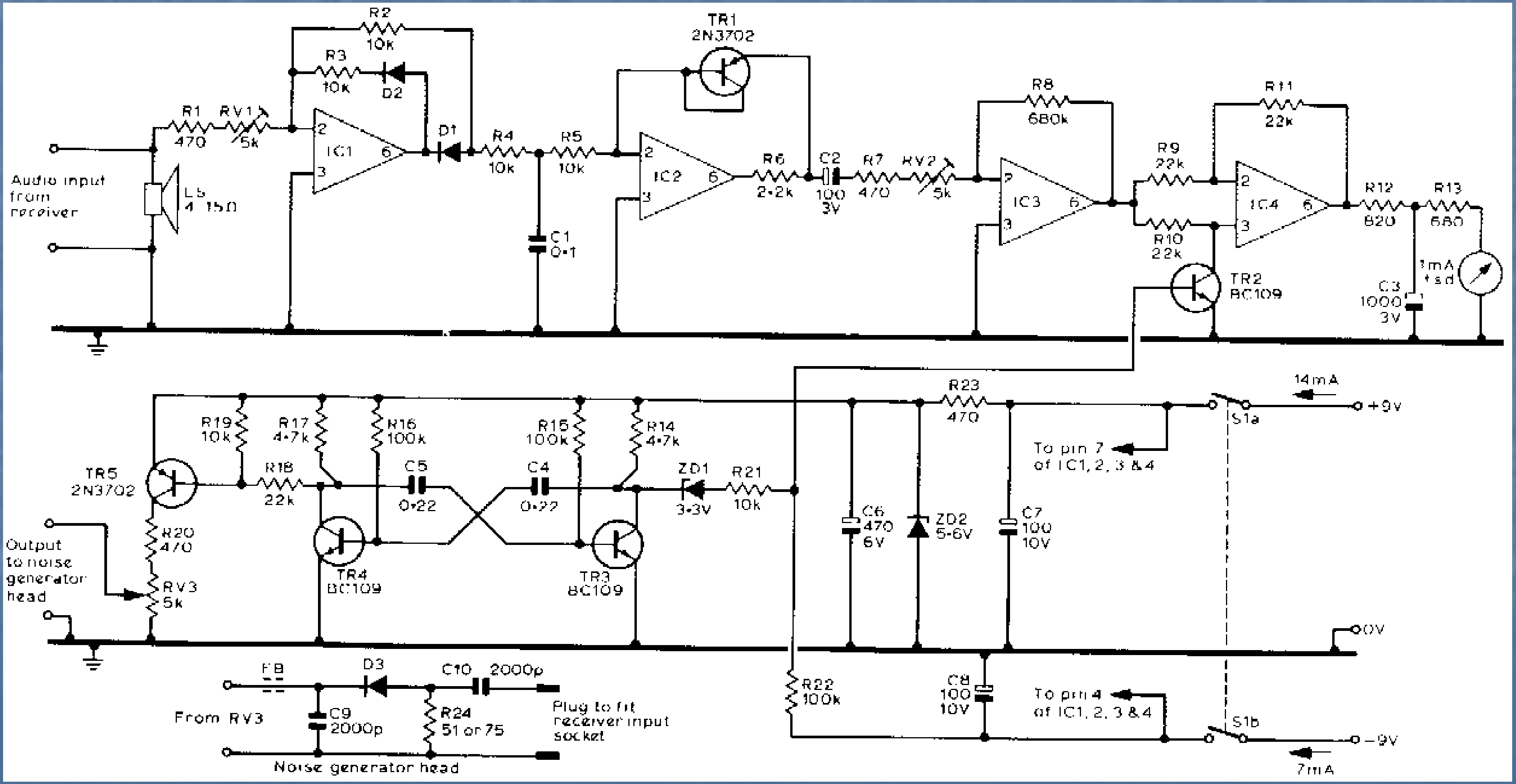
SIMPLE HOME MADE TEST GEAR

G4COM Noise Figure Indicator



SIMPLE HOME MADE TEST GEAR

G4COM Noise Figure Indicator



ADVANCED TEST GEAR

These items are not essential at first but soon become so once you’ve caught the testing bug!

ADVANCED TEST GEAR

Laboratory Power Meter

Bird Thru-line Wattmeter

ADVANCED TEST GEAR

Laboratory Power Meter

HP436

Marconi tft power meter

ADVANCED TEST GEAR

Laboratory Power Meter

HP436A with power meter head on calibration output

ADVANCED TEST GEAR

Function Generator – an advanced audio oscillator

ADVANCED TEST GEAR

Frequency standard– 100kHz, 1MHz, 5MHz and 10MHz
Needed to calibrate counter and other frequency measuring gear

Expensive commercial standard

ADVANCED TEST GEAR

DIGITAL MULTIMETER - BENCH TYPE

These cost £5 for the two at the 2005 Wakefield Rally!

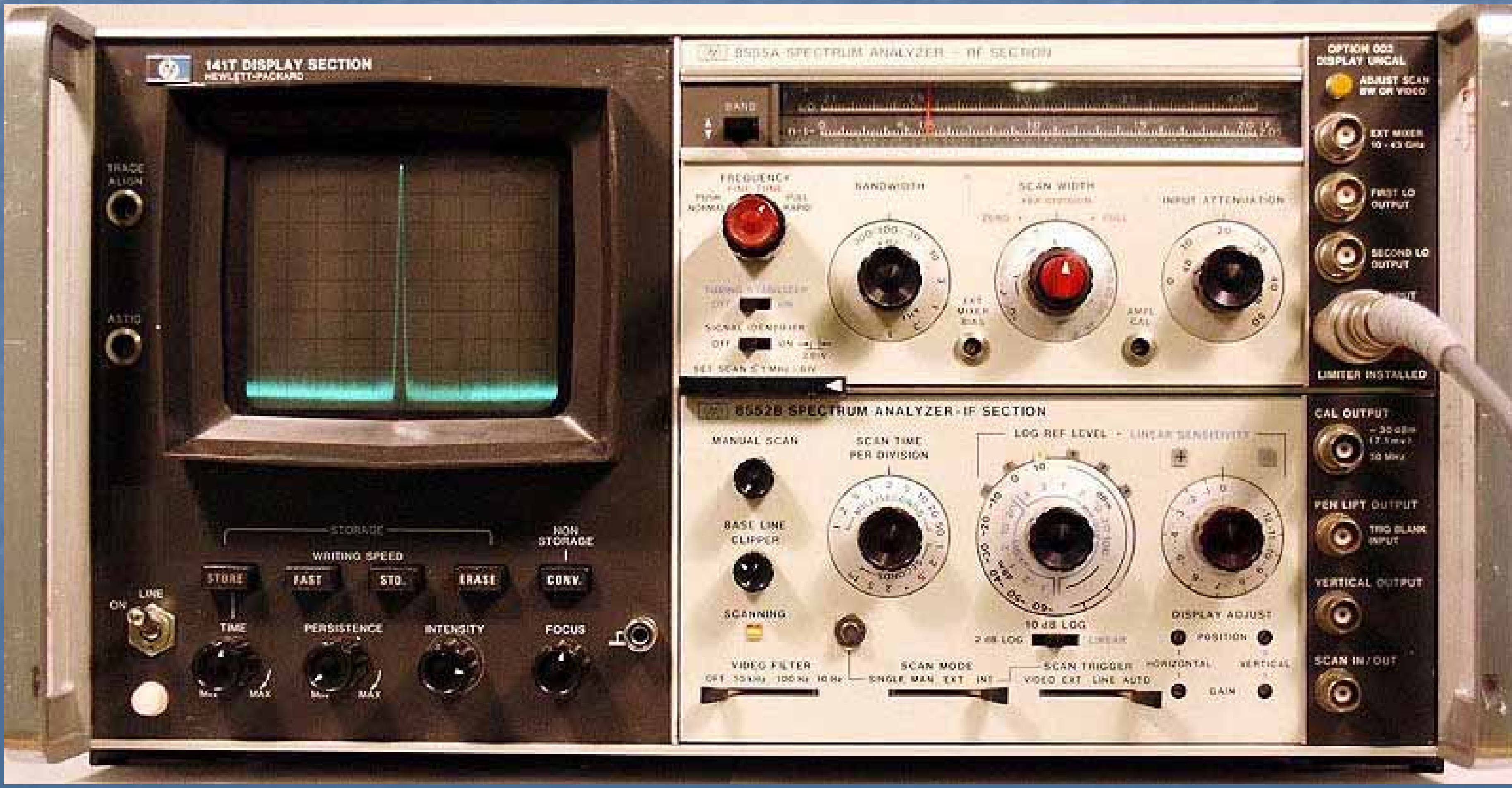
ADVANCED TEST GEAR

RF Millivoltmeter

ADVANCED TEST GEAR

Spectrum Analyser – HP141T main frame with HP8555A RF plug-in and HP8552 IF plug-in

Reaches 18GHz (to 40GHz with external mixer)



ADVANCED TEST GEAR

Analysers often have a mainframe into which plug in modules for different frequency ranges can be fitted

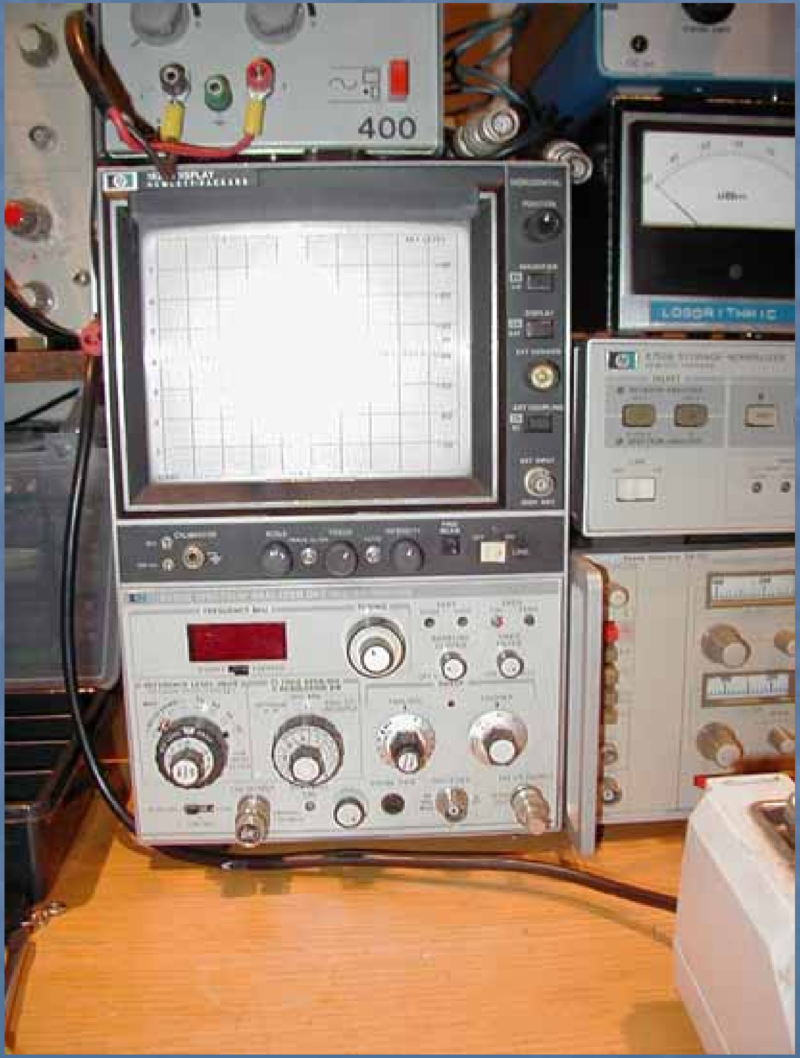
ADVANCED TEST GEAR

Spectrum Analyser

HP182 mainframe

With HP8558B RF plug-in

100kHz to 1.5GHz



ADVANCED TEST GEAR

Spectrum Analyser

HP8558B RF plug-in for the HP182T mainframe

100kHz to 1.5GHz

ADVANCED TEST GEAR

Spectrum Analyser Adapter

for an oscilloscope

Thandar TSA1000 (0-1GHz)

ADVANCED TEST GEAR

Home made Spectrum Analyser Adapter

for an oscilloscope:

Poor Man’s Spectrum Analyser by G4PMK

ADVANCED TEST GEAR

Ailtech 7514 Precision Noise Figure Indicator (PANFI)

Wiltron 610D 0-18GHz sweeper

HP141T Spectrum Analyser

ADVANCED TEST GEAR

Network Analyser

ADVANCED TEST GEAR

Network Analyser

ADVANCED TEST GEAR

Precision Noise Figure Indicator (PANFI)

ADVANCED TEST GEAR

Precision Noise Figure Indicator (PANFI)

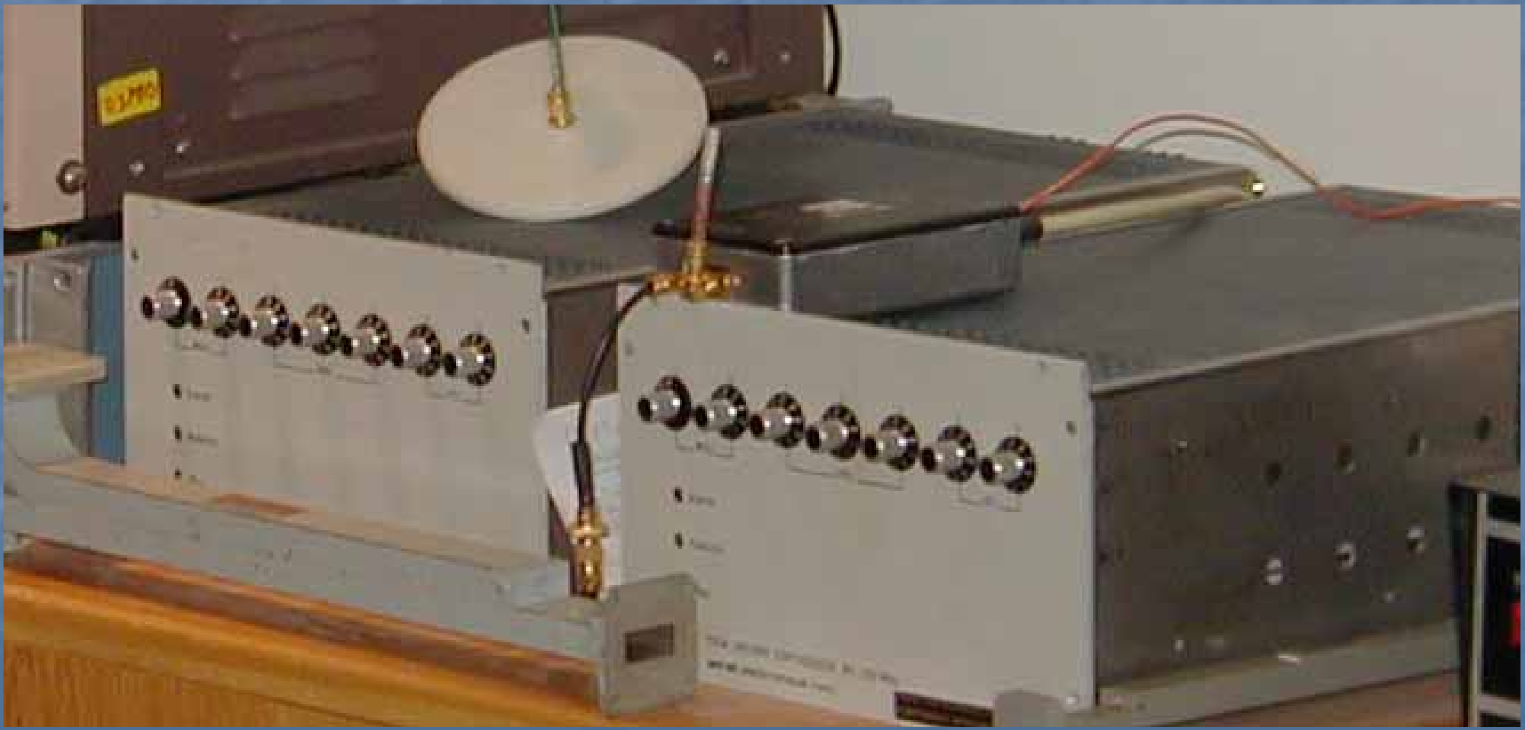
AILTECH 7514 (around £125 second hand)

ADVANCED TEST GEAR

Professional Noise Sources

ADVANCED TEST GEAR

Adret 5104 Synthesised Signal sources



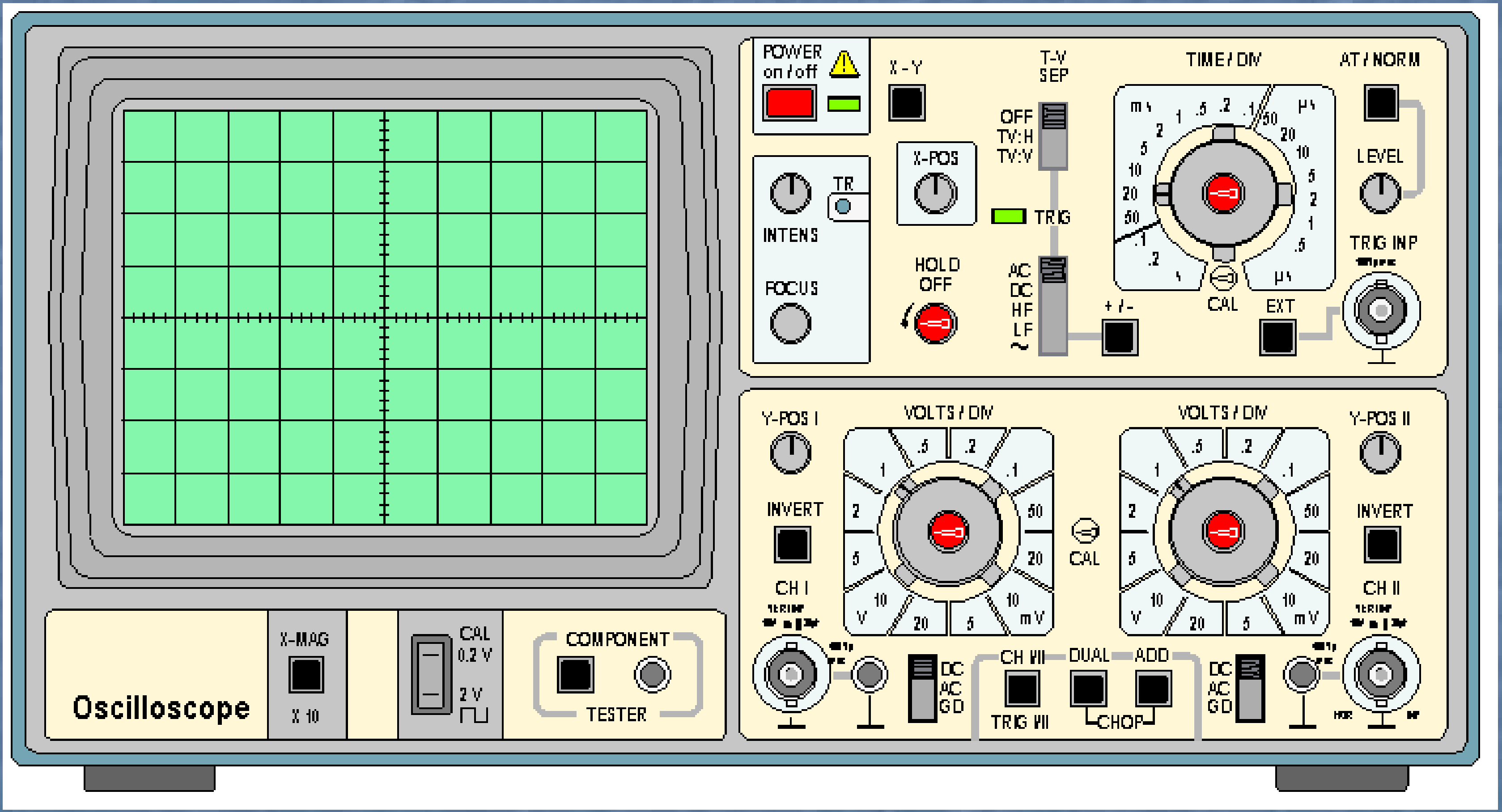
SOFTWARE DERIVED TEST GEAR

- A wide range of free test software is available on the “web”
- Audio generator, spectrum analyser, circuit simulation software is easily run via a sound card or serial input
- Popular software includes the versatile Spectrum Lab

THE OSCILLOSCOPE

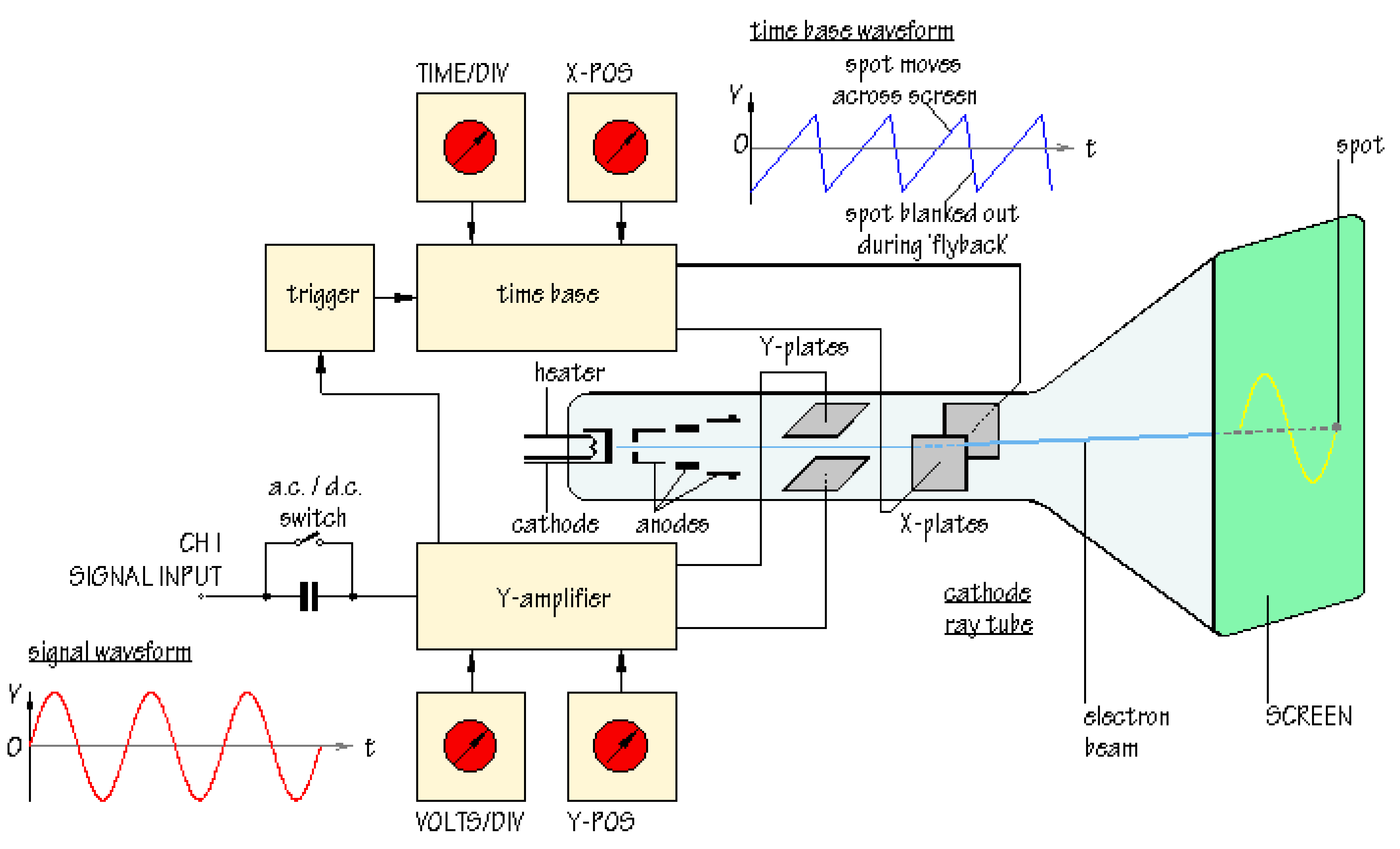
- One of the most versatile and useful items in any radio shack
- An oscilloscope measures voltage changes over a defined time period
- DC voltages remain at a constant level against time
- AC voltages change (alternate) with time
- An oscilloscope therefore measures changes in the time domain

THE OSCILLOSCOPE

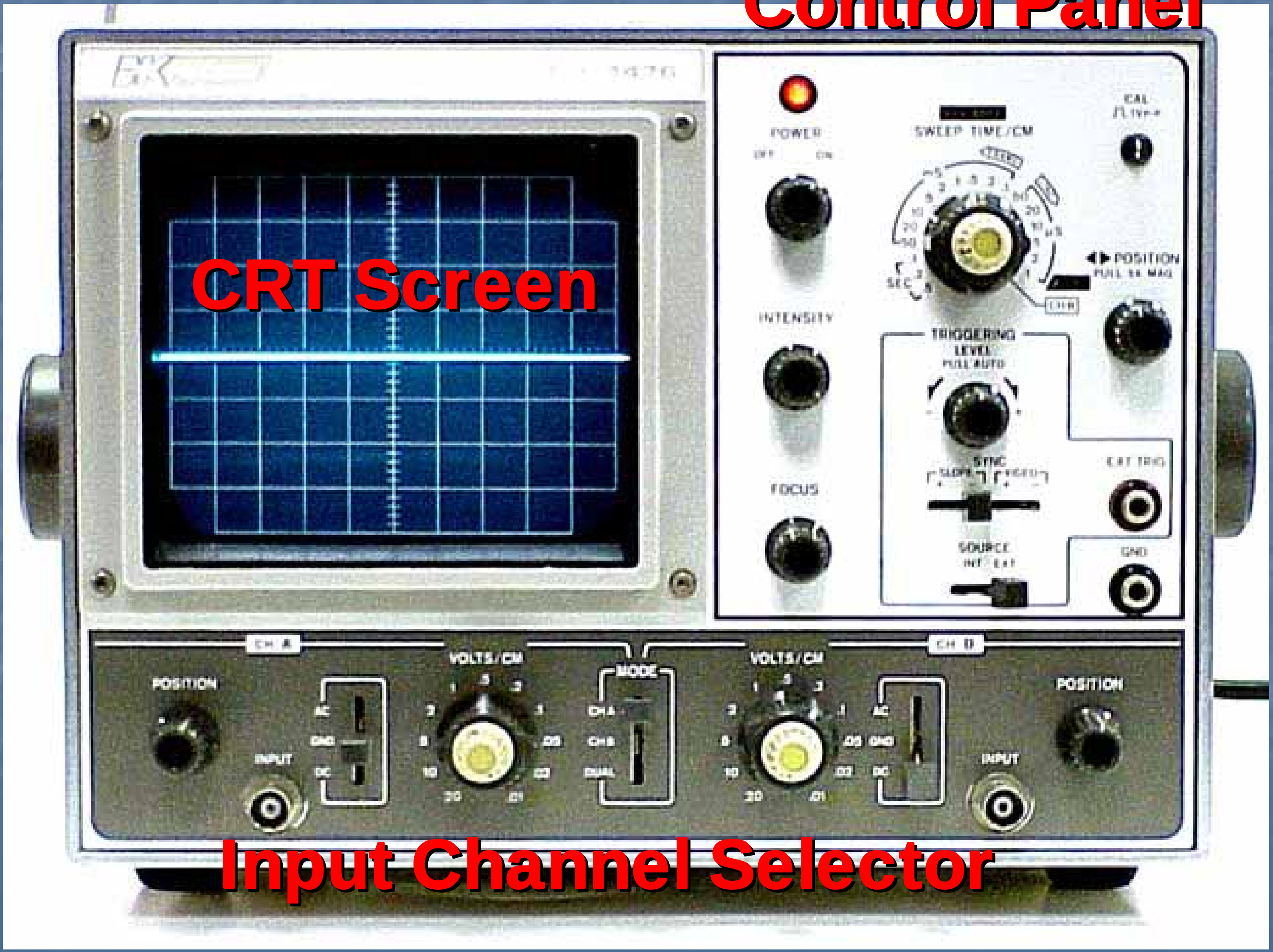


CONTROLS

THE OSCILLOSCOPE



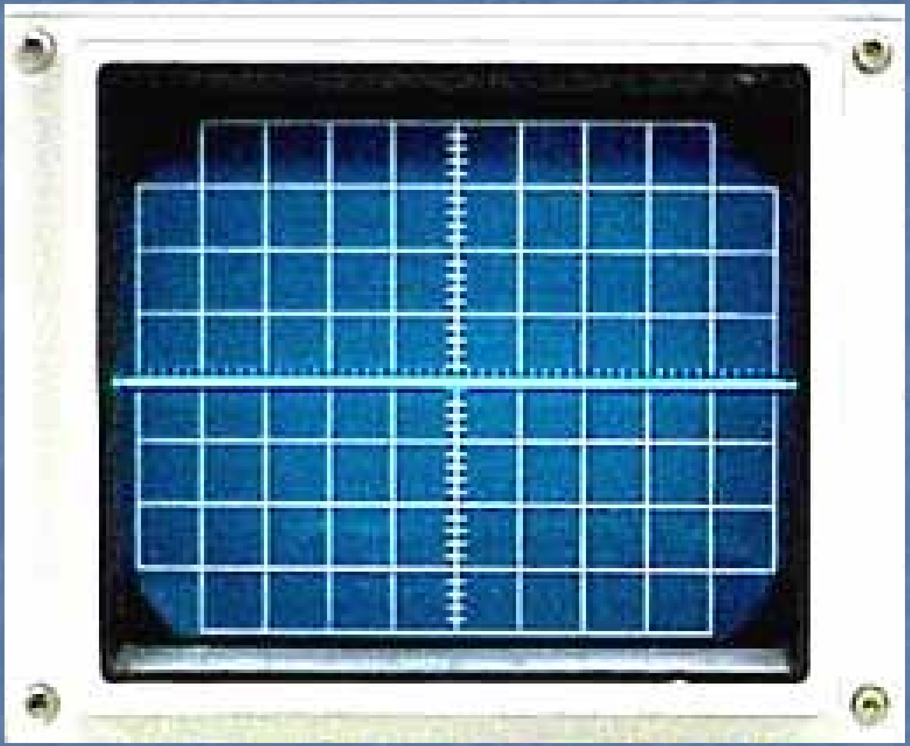
THE OSCILLOSCOPE



THE OSCILLOSCOPE

- The screen has ruled divisions both horizontally and vertically.
- The major divisions are marked off in centimeters; the middle lines also have minor divisions every 0.2 of a centimeter.

The Display



THE OSCILLOSCOPE

Input Channel Selector

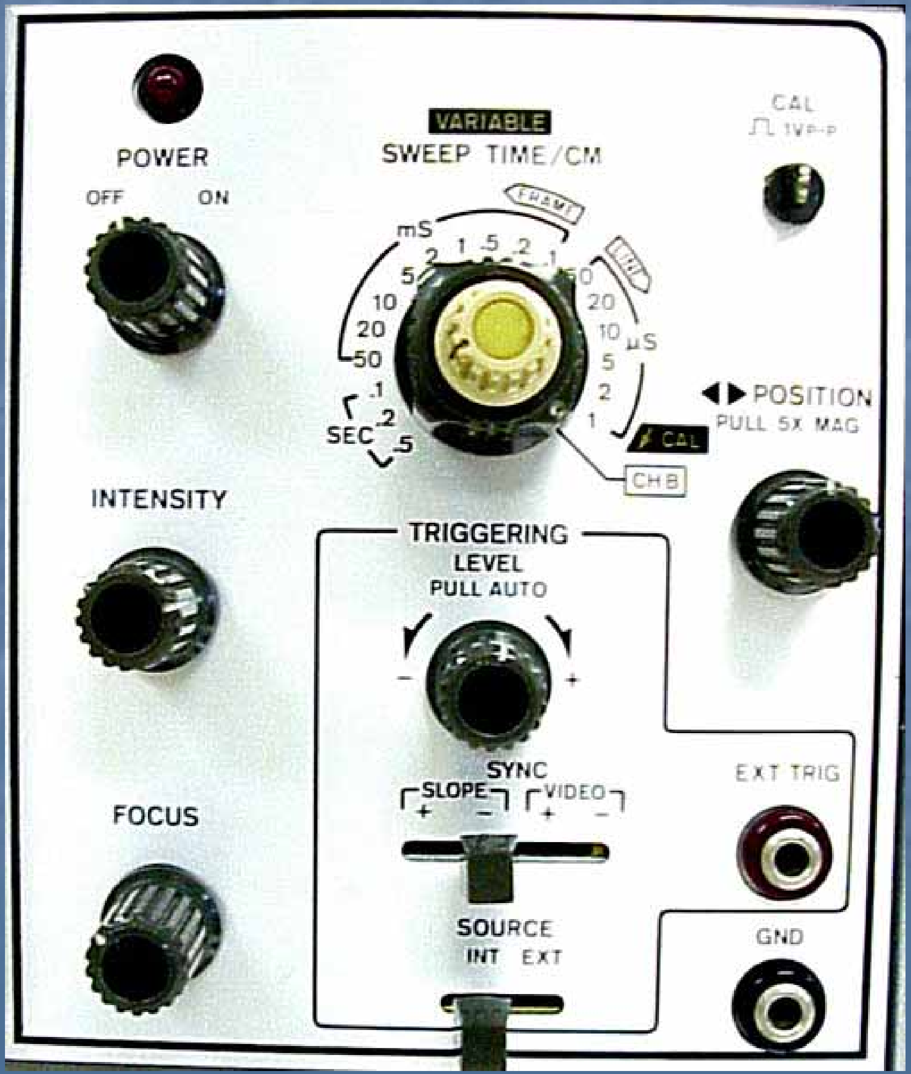
- This area is broken into two parts: the left half for channel A and the right half for channel B.
- In the center of this section lies the mode switch that determines which channel will serve as an input to the scope:A, B or Dual.

Channel A **Channel B**

THE OSCILLOSCOPE

Control Panel

- The section to the right of the screen contains the controls necessary to adjust the triggering and sweep time of the waveform.
- Controls for display brightness and focus are normally in this section



THE OSCILLOSCOPE

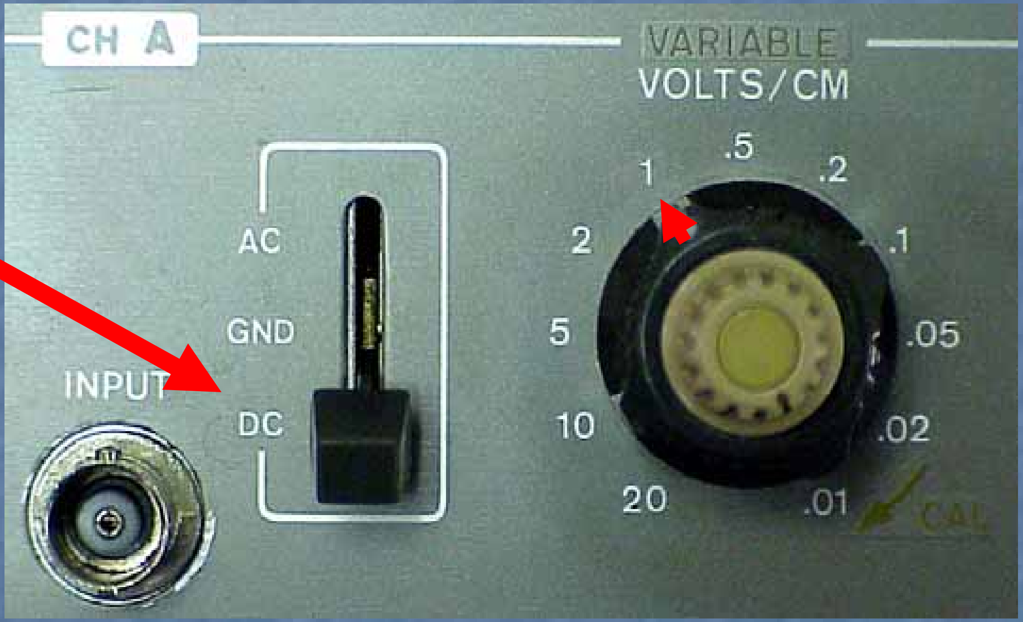
Volts/cm Dial

- The volts/cm dial tells you the number of volts to be represented by each centimeter vertically on the screen.
- Here the outer dial is set to one, so each centimeter equals one volt.

THE OSCILLOSCOPE

Measuring a Direct Current Voltage

- **Switch the A.C.-GND-D.C. switch to the D.C. position.**
- **Setting the volts/cm dial to 1 gives a full vertical scale of 10 Volts**
- **Turn the beige dial clockwise all the way to put the volts/cm dial in the "calibrated" position.**



THE OSCILLOSCOPE

Sweep time/cm Dial

- The sweep time/cm switch sets up the time it takes for the dot to scan across the screen. Here it's set to 2 milliseconds per centimetre

- Since there are 10 cm across the screen it would take the dot 20ms to cross from left to right

- The concentric control in the middle is set to 'calibrate' for normal operation

THE OSCILLOSCOPE

Measuring DC Voltage

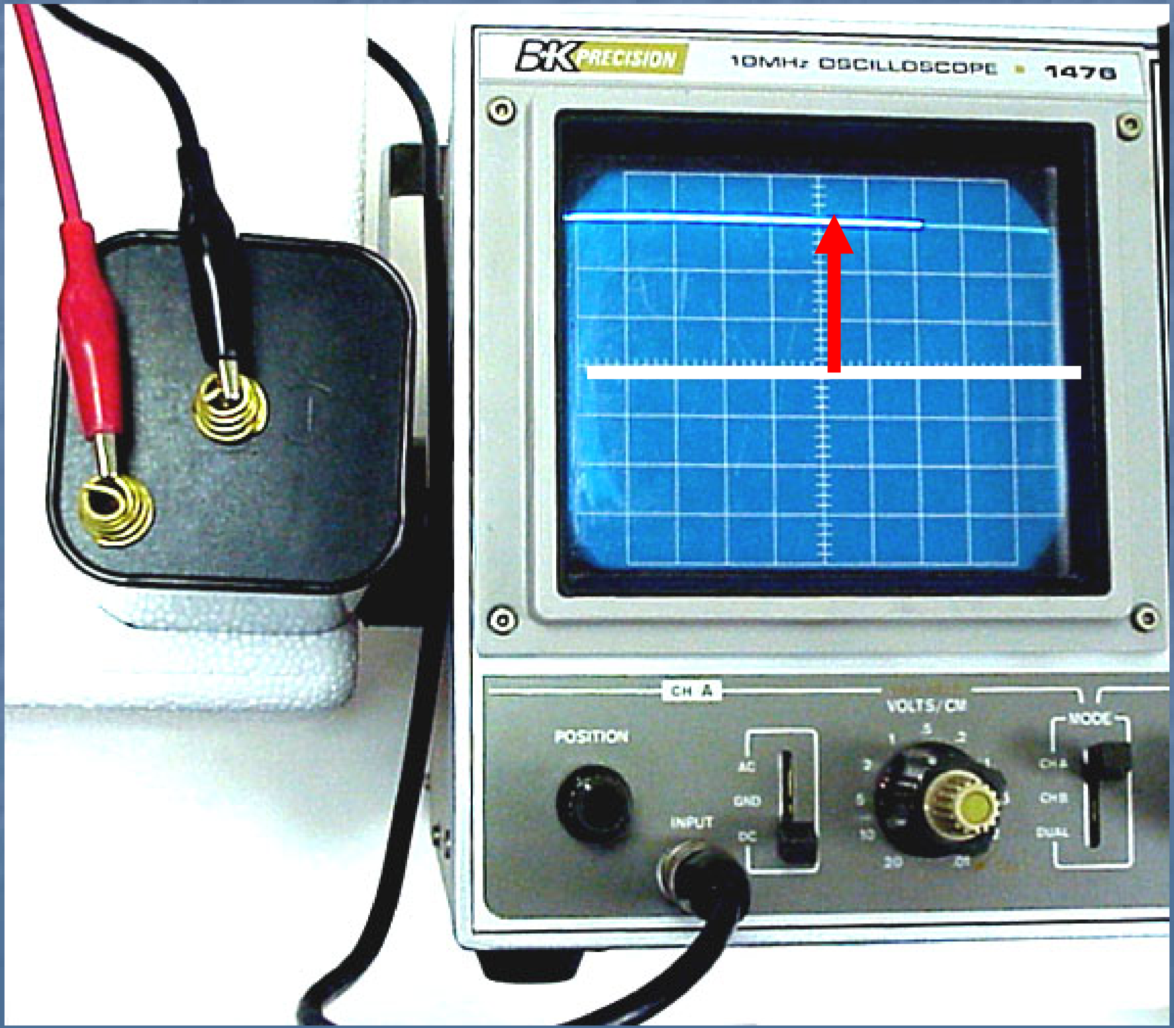
To get started you should follow these steps:

- Set mode to channel A.
- Connect cable to input A. Leads should be free.
- Turn power ON and wait for dot or line to appear.
- Set triggering level knob to auto setting.
- Adjust intensity and focus as needed.
- Set sweep time /sec knob till the line on the screen is seen clear and steady.
- Adjust horizontal and vertical position knob to make sure that the line is fully visible.

THE OSCILLOSCOPE

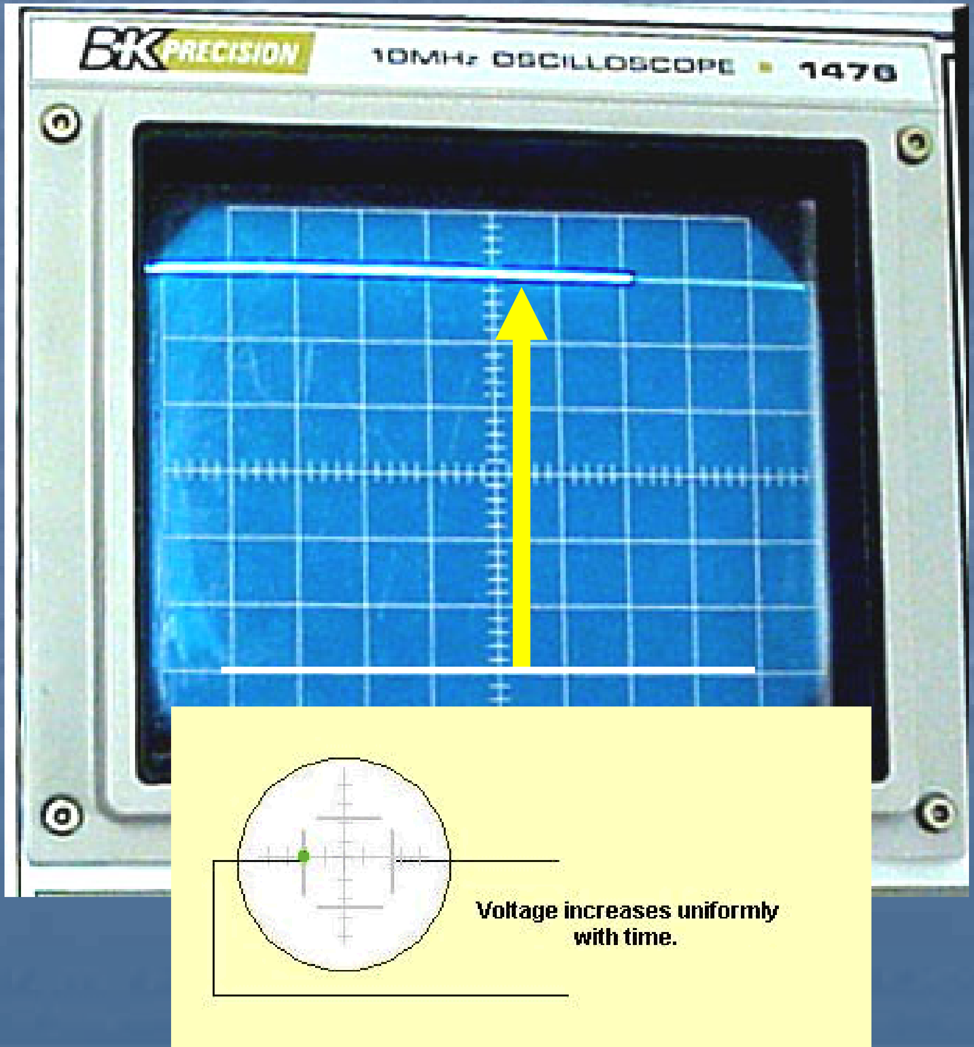
Measuring DC Voltage

- In this example a battery is being measured
- With the vertical scale set at 2 volts per cm, the horizontal trace deflects 3 divisions up the screen if the leads are connected across a 6V DC battery



THE OSCILLOSCOPE

Measuring DC Voltage



A DC voltage will give a straight line across the screen

The original zero volts input trace will be deflected by the applied voltage

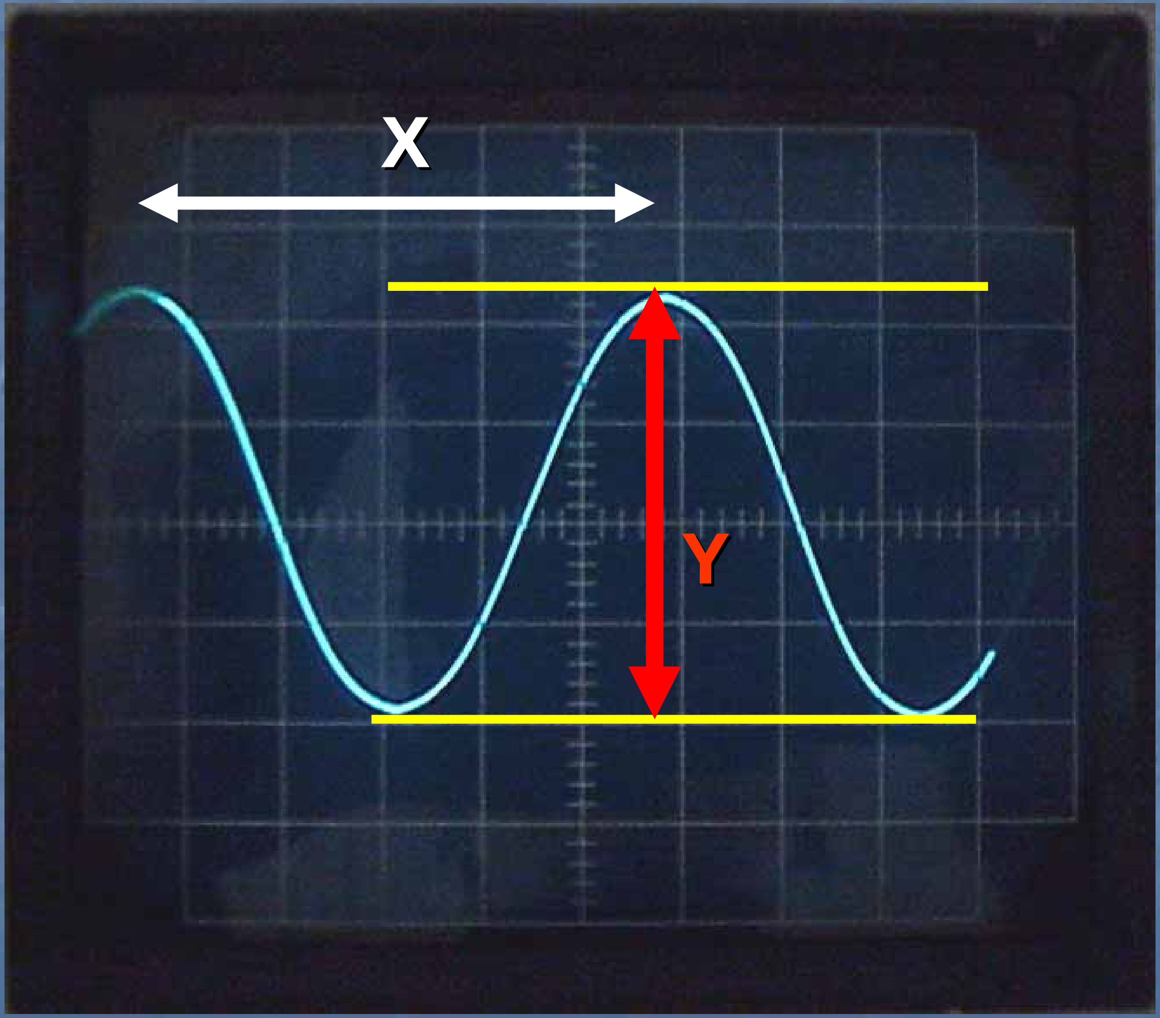
THE OSCILLOSCOPE

Measuring AC Voltage

- Flip the AC-GND-DC switch to AC on the oscilloscope.
- Set the VOLTS/cm dial to a suitable sensitivity; remember to twist the inner dial clockwise to the 'calibrate' position.
- Set the sweep TIME/cm dial to required sensitivity. Twist the inner dial clockwise to the 'calibrate' position.
- Make sure the line trace is centered on the screen using the vertical and horizontal position dials.
- Flip the source switch to internal.
- If necessary, adjust the triggering level knob until you get a steady picture. The triggering level knob should be set initially to 'auto'.
- Adjust the intensity and focus to get a good sharp image.
- Apply input to Channel A connector

THE OSCILLOSCOPE

An AC waveform



AC wave forms produce a rising and falling pattern on the 'scope screen

The shape of the waveform can vary from a sine wave, shown here to a square wave, for example

THE OSCILLOSCOPE

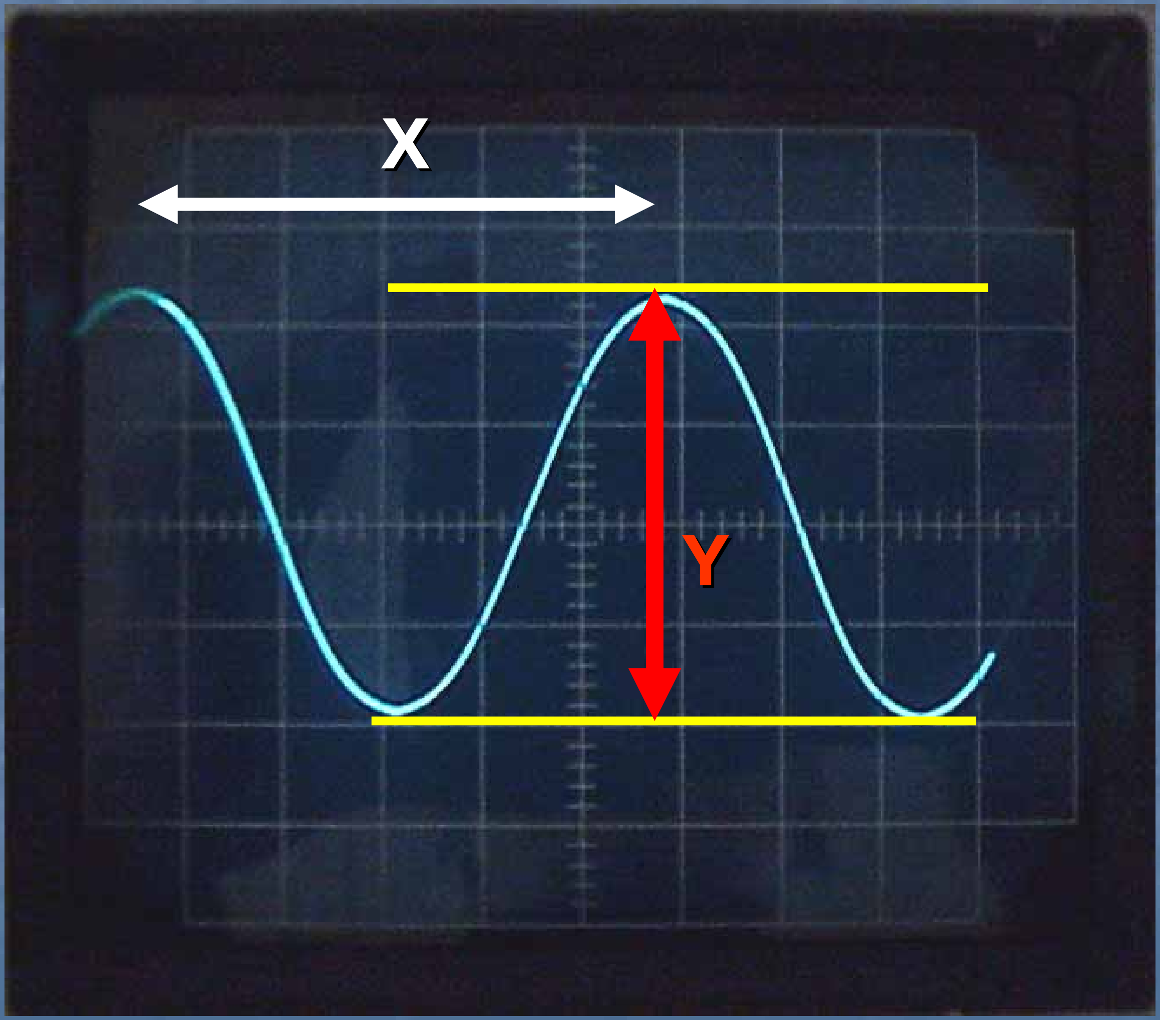
An AC waveform

Distance X = wavelength

(which can be translated into frequency)

Distance Y = amplitude

(voltage)

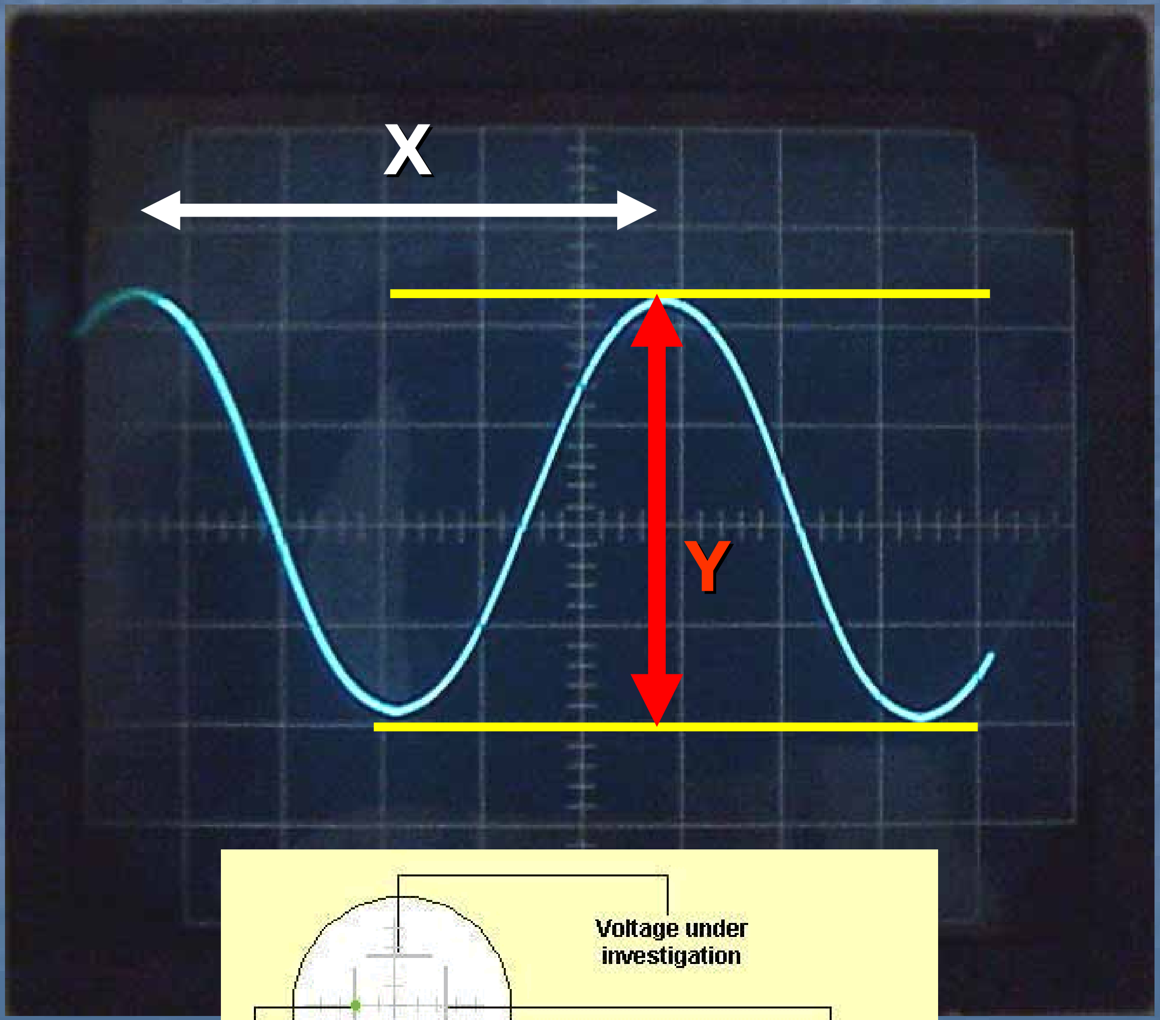


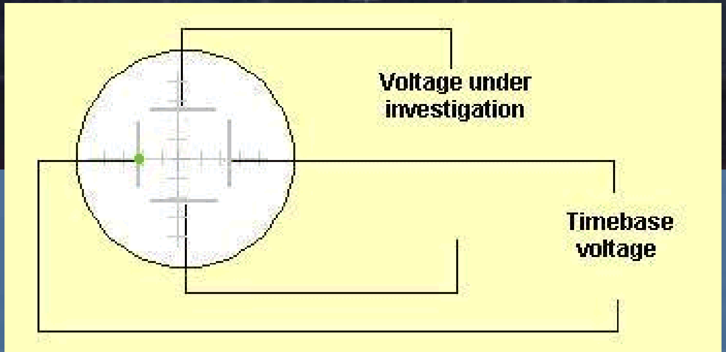
THE OSCILLOSCOPE

Example of measuring Frequency

X = one cycle of the input. Since this is 5cm of the horizontal scale and the sweep time is set to 2 milliseconds per cm, the time for 1 cycle is therefore 10milliseconds.

This translates to 100 cycles per second (=100c/s or 100Hz)





THE OSCILLOSCOPE

Example of measuring Frequency

Since the oscilloscope measures the applied voltage and frequency, no amount of varying the settings on the scope will change the applied voltage and frequency.

The measurement stays constant as the relative X and Y scales are varied.

Therefore one can choose a scale to enable an easy calculation of voltage and frequency

THE OSCILLOSCOPE

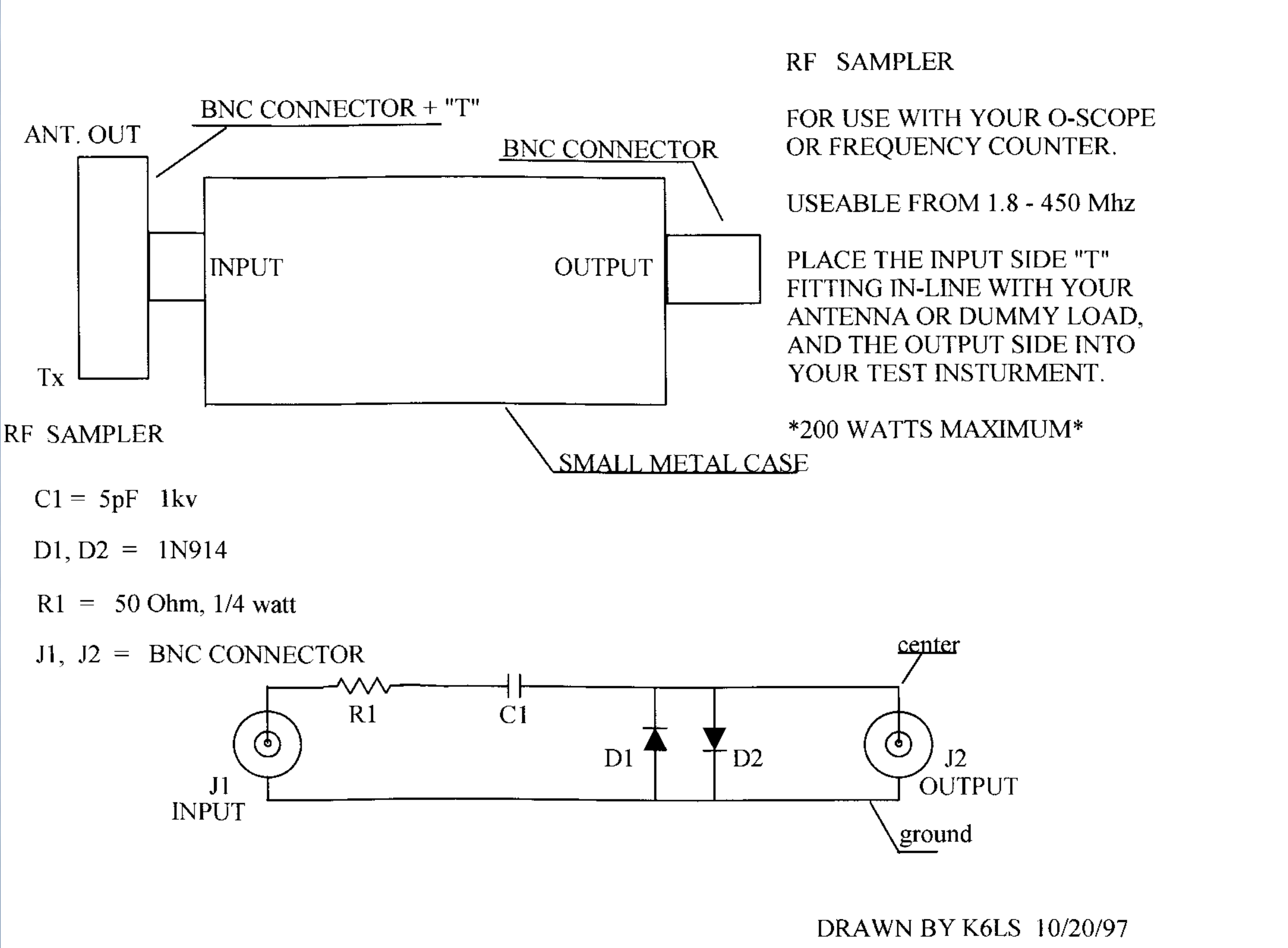
USING A ‘SCOPE TO MONITOR
RF TRANSMISSIONS

To successfully do this, the scope must have bandwidth greater than the maximum frequency of the transmission.

e.g. you’d need at least a 35MHz bandwidth scope to ”see” 28MHz RF on the screen

THE OSCILLOSCOPE

A sample of RF from the transmit output should be made available. A dummy load can be modified to produce a “whiff” of RF at low level, or make the RF sampler shown here

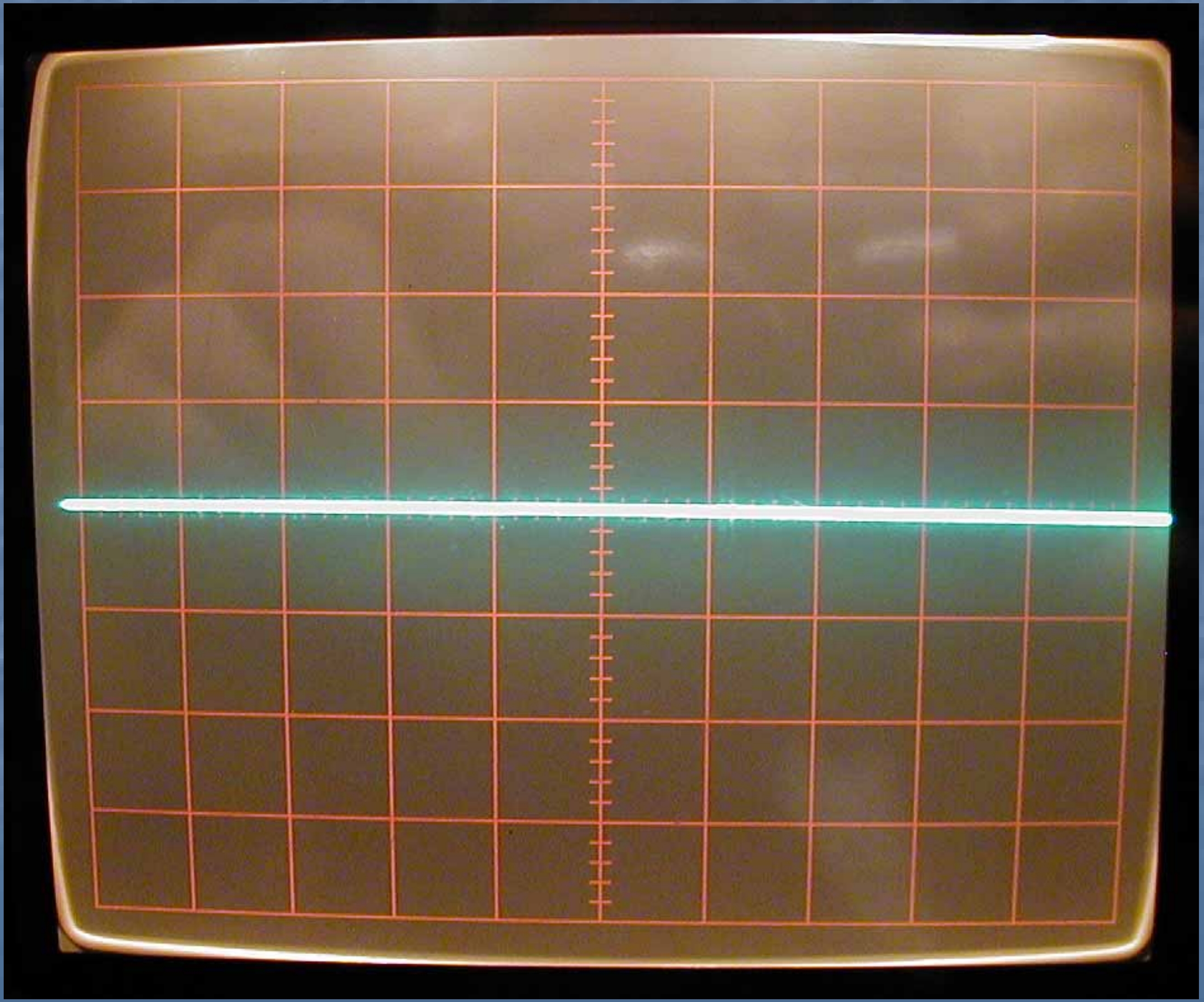


THE OSCILLOSCOPE

RF MEASUREMENT (1)

Set the zero-signal horizontal trace to occupy the centre line

Illuminate the screen's calibration grid



THE OSCILLOSCOPE

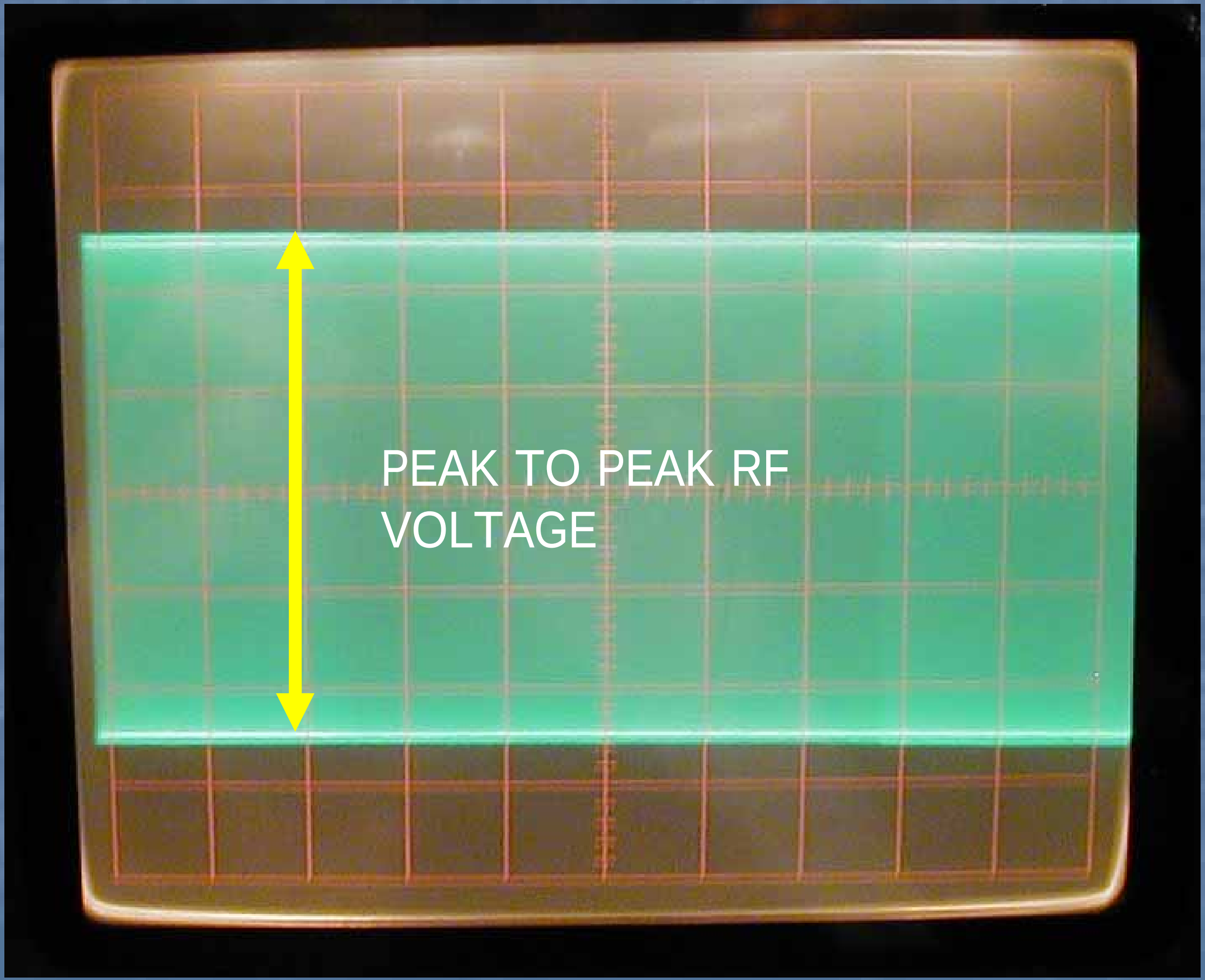
RF MEASUREMENT: SSB

Either whistle hard into the TX/RX microphone

OR

Put the key down to produce a steady signal on the screen

Adjust the Y axis calibration control to give a trace as shown left.



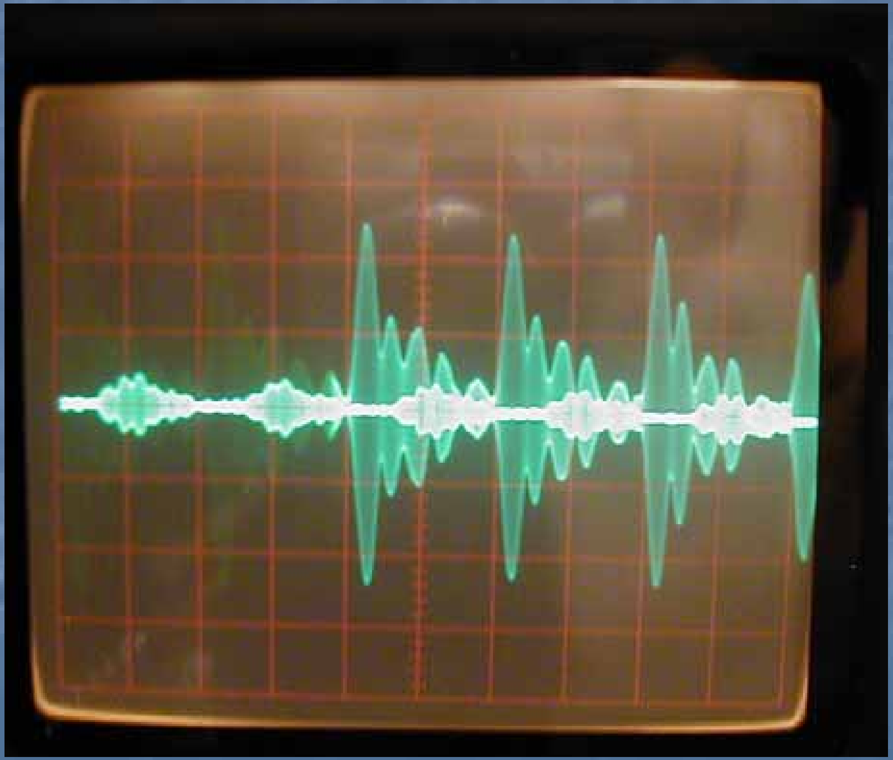
The trace will expand either side of the centre horizontal line

THE OSCILLOSCOPE

RF MEASUREMENT: SSB

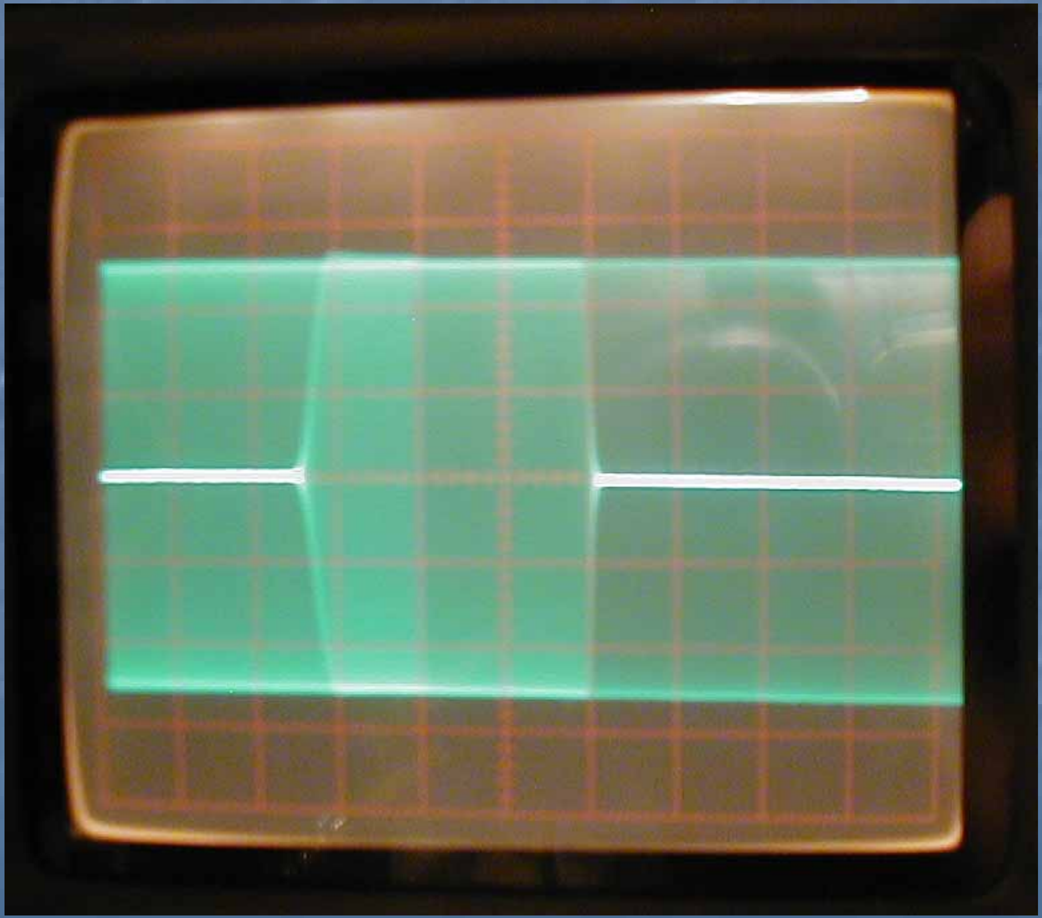
Adjust the sweep time to produce a trace similar to the one shown right.

Without altering the scope's vertical gain control, adjust your TX microphone gain and any other TX control (processor, etc) so that only the peaks of your voice modulation reach the same height as the previous loud whistle or key-down trace.



THE OSCILLOSCOPE

Monitoring CW keying wave forms



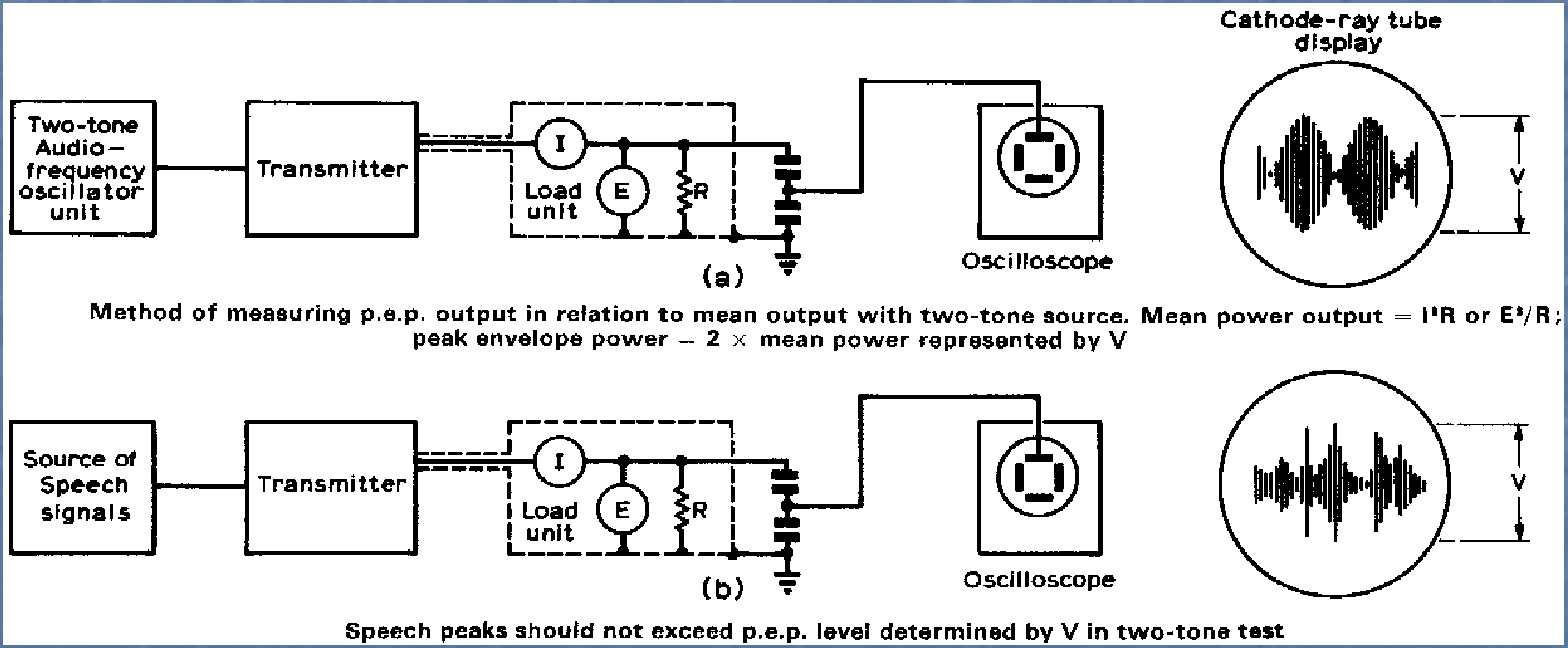
Send a series of dots and observe the shape each dot wave form as it appears on the screen.

The example shown left illustrates a very sharp response and could potentially cause key clicks

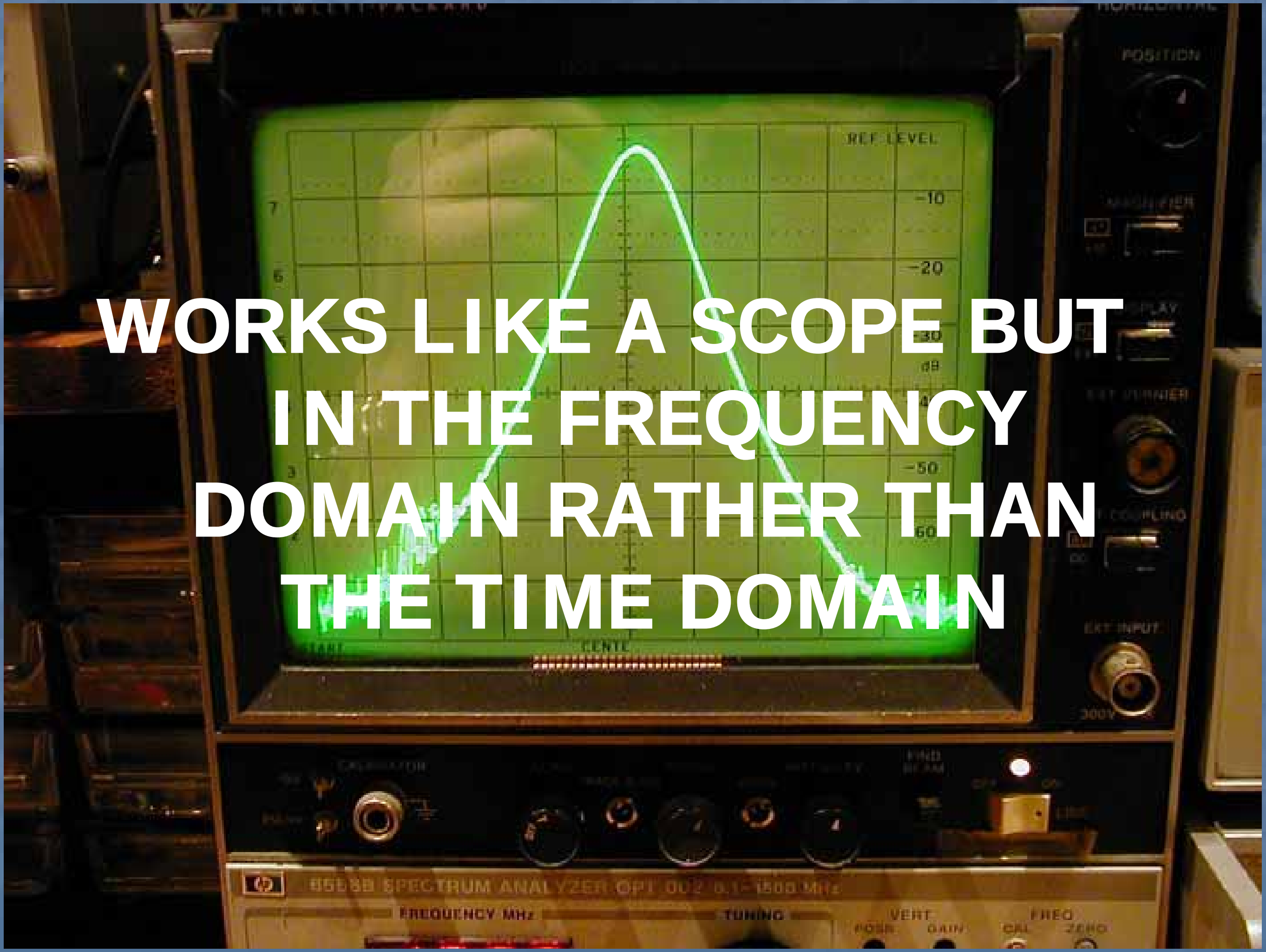
Adjust keying circuit for a gentler rise and a smoother corner at the top and bottom of the leading edge.

THE OSCILLOSCOPE

Two tone test for SSB transmitters



THE SPECTRUM ANALYSER



WORKS LIKE A SCOPE BUT IN THE FREQUENCY DOMAIN RATHER THAN THE TIME DOMAIN

THE SPECTRUM ANALYSER

A spectrum analyser is basically a superhet receiver whose local oscillator is rapidly swept across a section of the spectrum and any RF received converted into a visual display of amplitude on the screen.

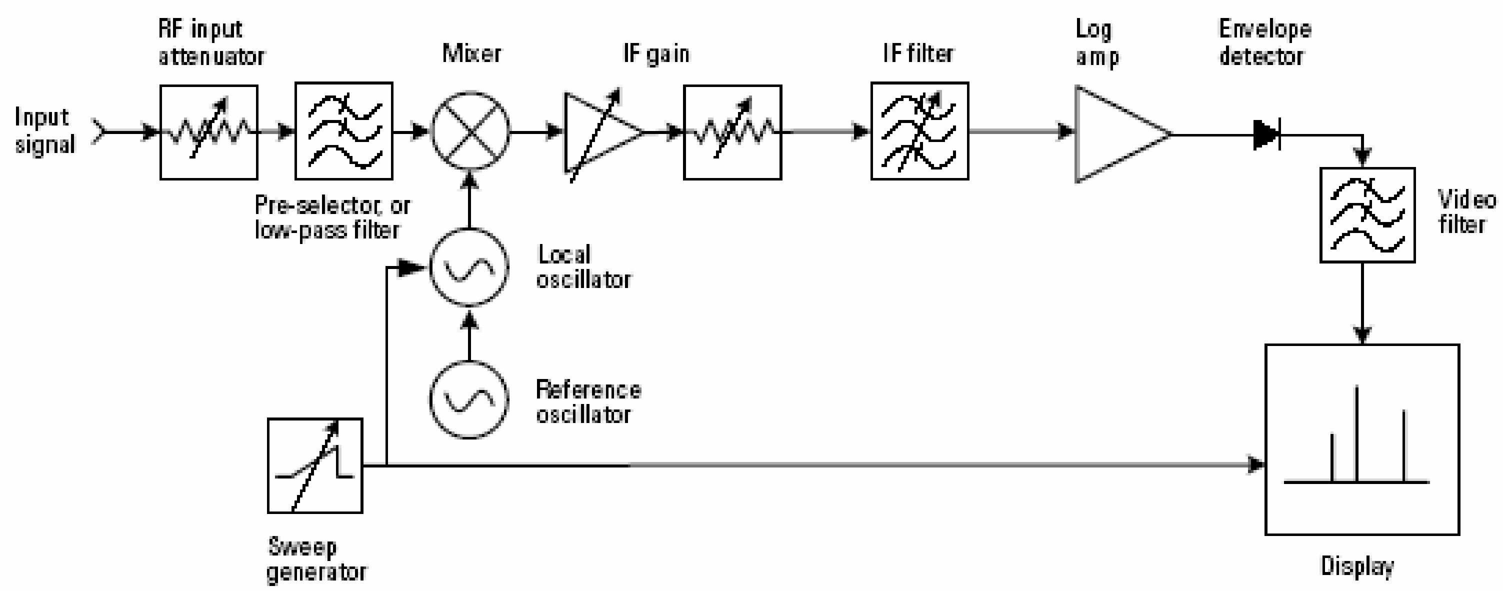


Figure 2-1. Block diagram of a classic superheterodyne spectrum analyzer

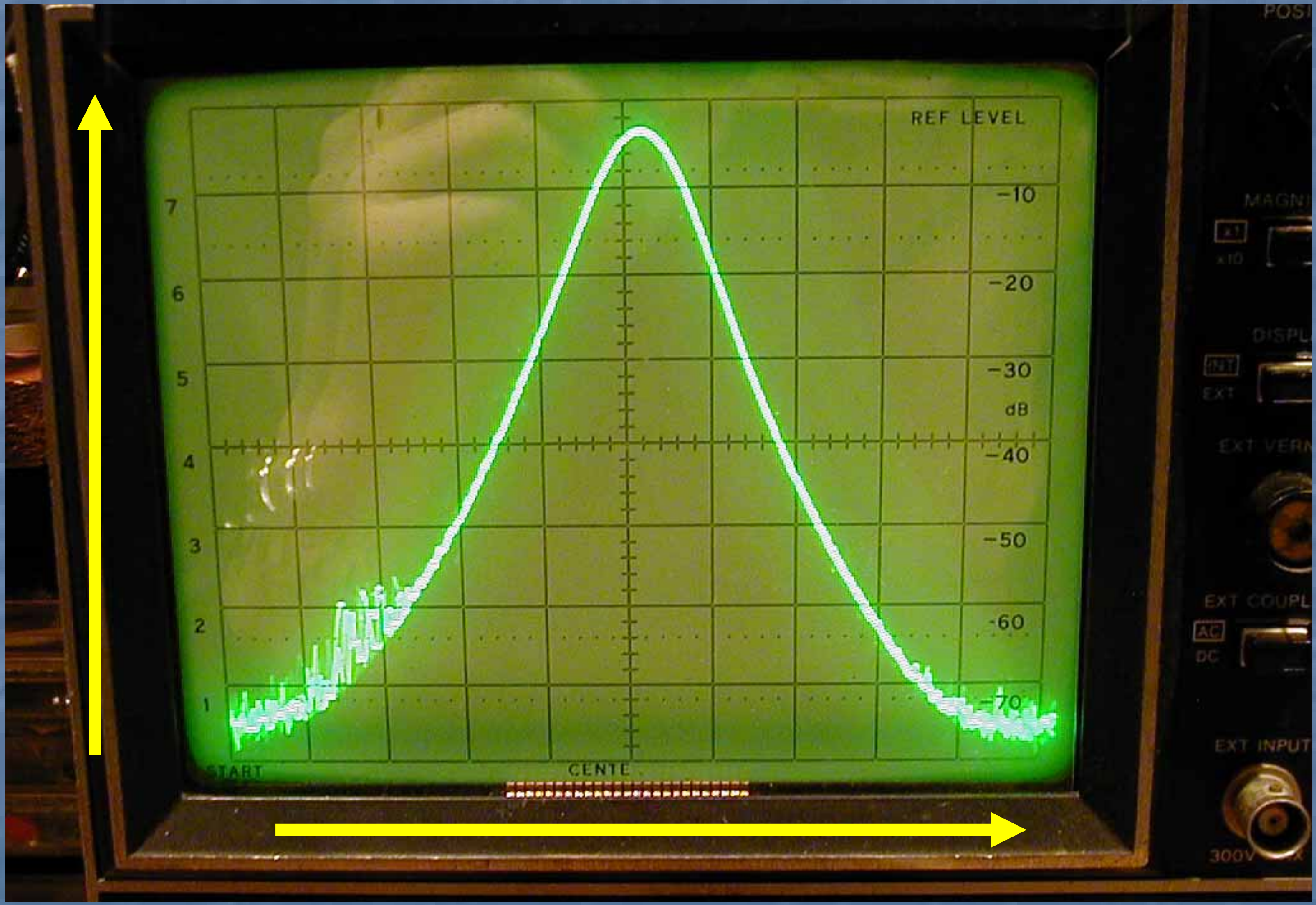
THE SPECTRUM ANALYSER

A FEW OF ITS USES:

- Checking and adjustment of oscillators, mixers, multipliers
- Checking harmonics
- Checking RF output and signal purity
- Noise figure measurement
- Alignment of filters

THE SPECTRUM ANALYSER

Y AXIS IS CALIBRATED IN AMPLITUDE (e.g in dB)



X AXIS IS CALIBRATED IN FREQUENCY

THE SPECTRUM ANALYSER

DANGER!

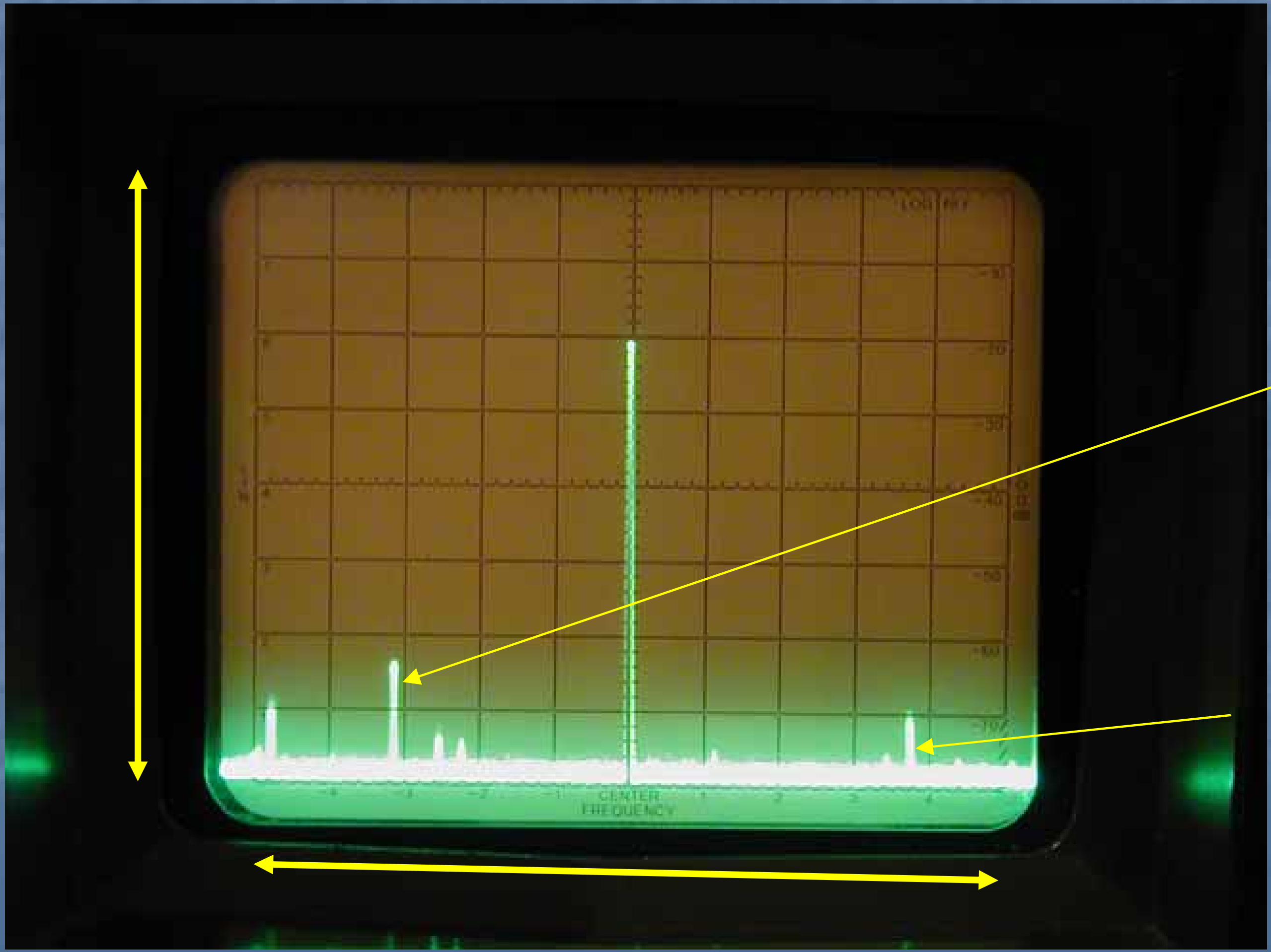
Spectrum analysers have very limited power handling capabilities. Therefore only a few milliwatts of RF must be applied to the input connector. Suitable attenuation outside the analyser is ESSENTIAL to prevent damage to the equipment and to prevent undesirable spurious responses on the display!

THE SPECTRUM ANALYSER

Example of an oscillator / multiplier showing a 500MHz wanted output plus harmonics and other unwanted products

Vertical axis

= 80dB in 10dB divisions



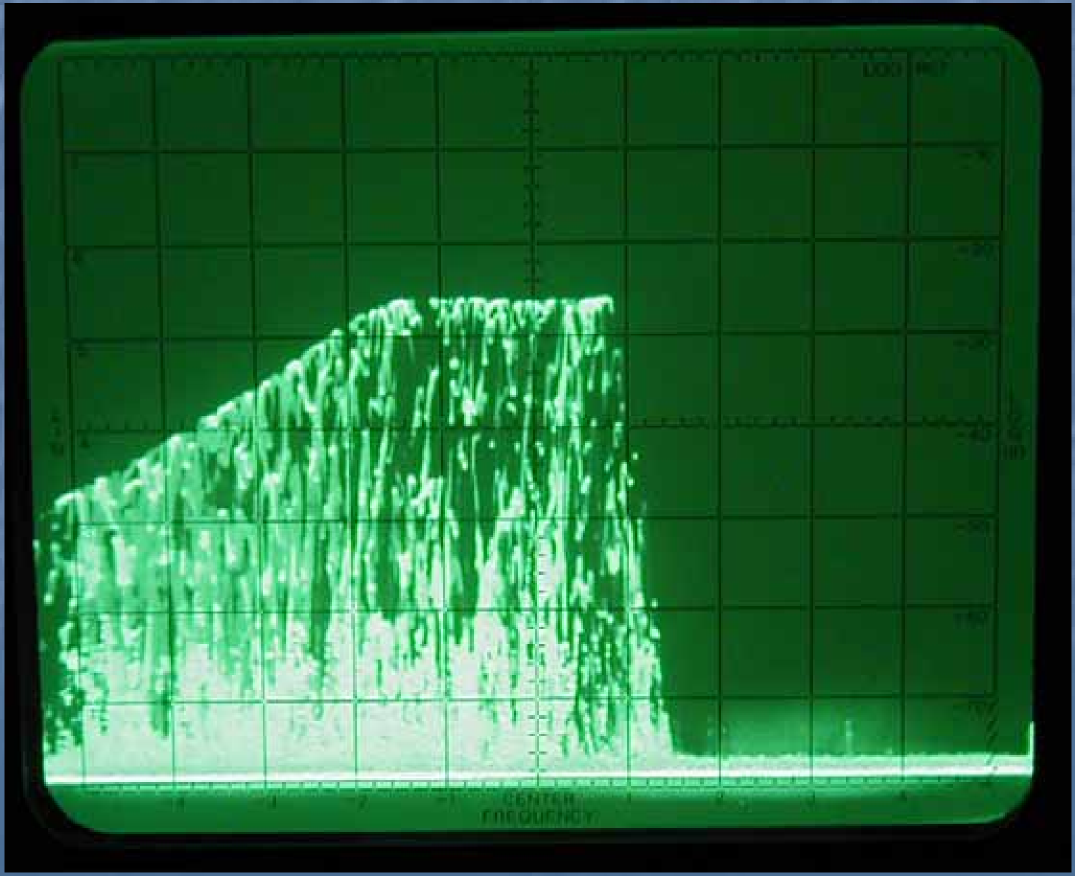
There is an unwanted product on approx 190MHz at 43dB down on the 500MHz signal.

At approx 870MHz is a product 50dB down

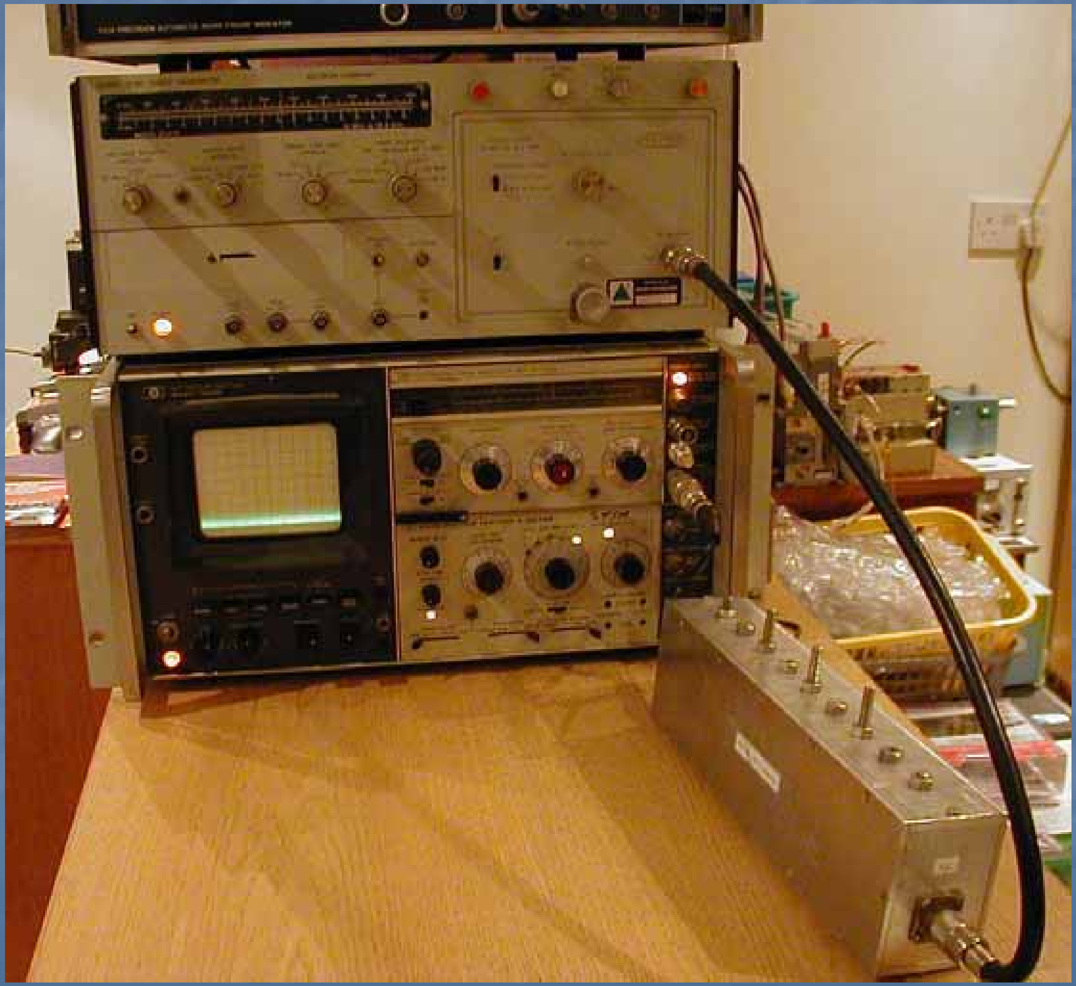
X axis = 0 to 1GHz (1000MHz) in 100MHz divisions

THE SPECTRUM ANALYSER

Filter alignment … achieved by rapidly sweeping an oscillator across an appropriate frequency range and displaying the amplitude on the spectrum analyser



THE SPECTRUM ANALYSER

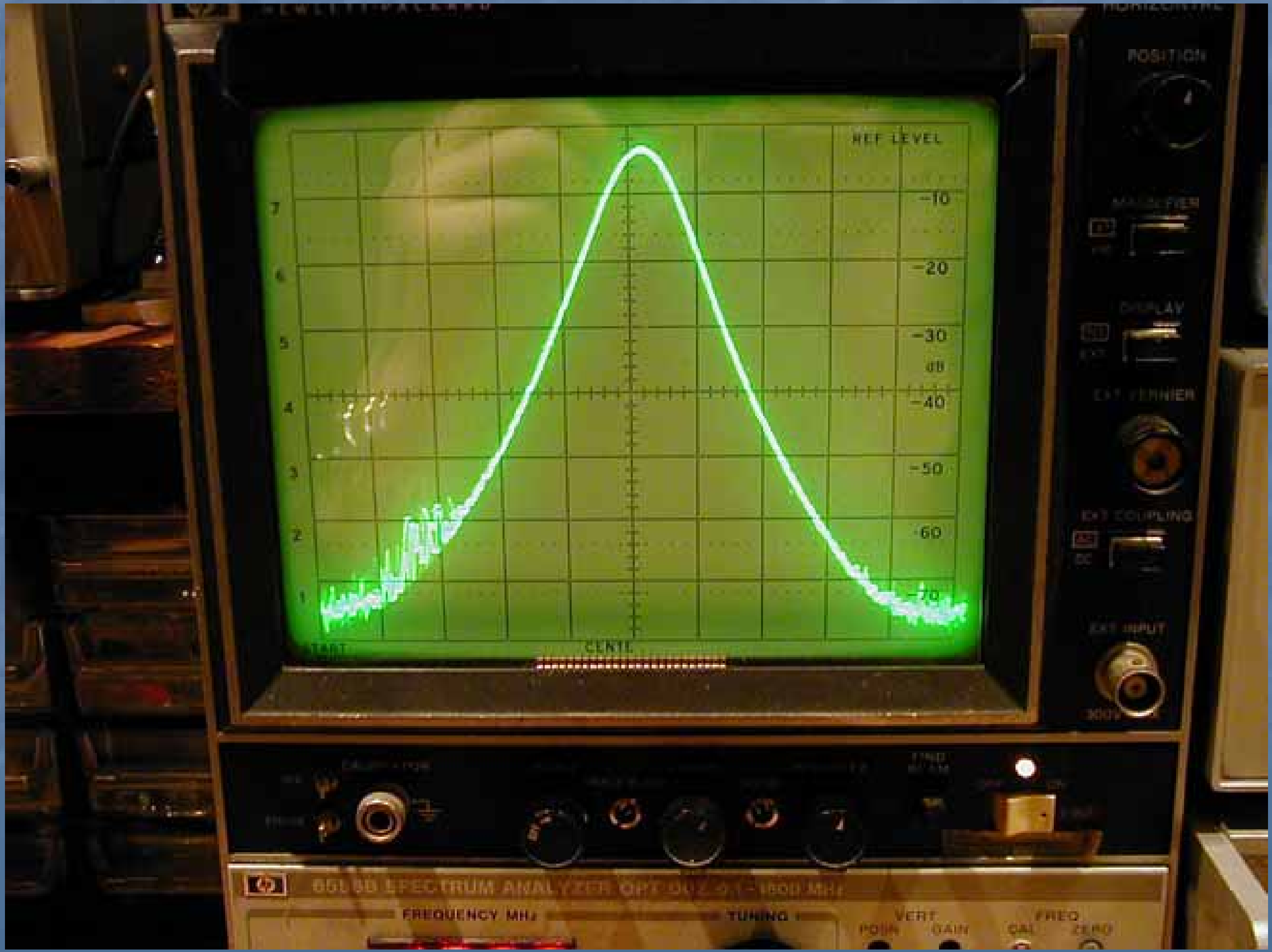


Setting up sweeper oscillator and spectrum analyser to tune up a 144MHz bandpass filter

The sweeper output must be constant across the whole frequency range swept

THE SPECTRUM ANALYSER

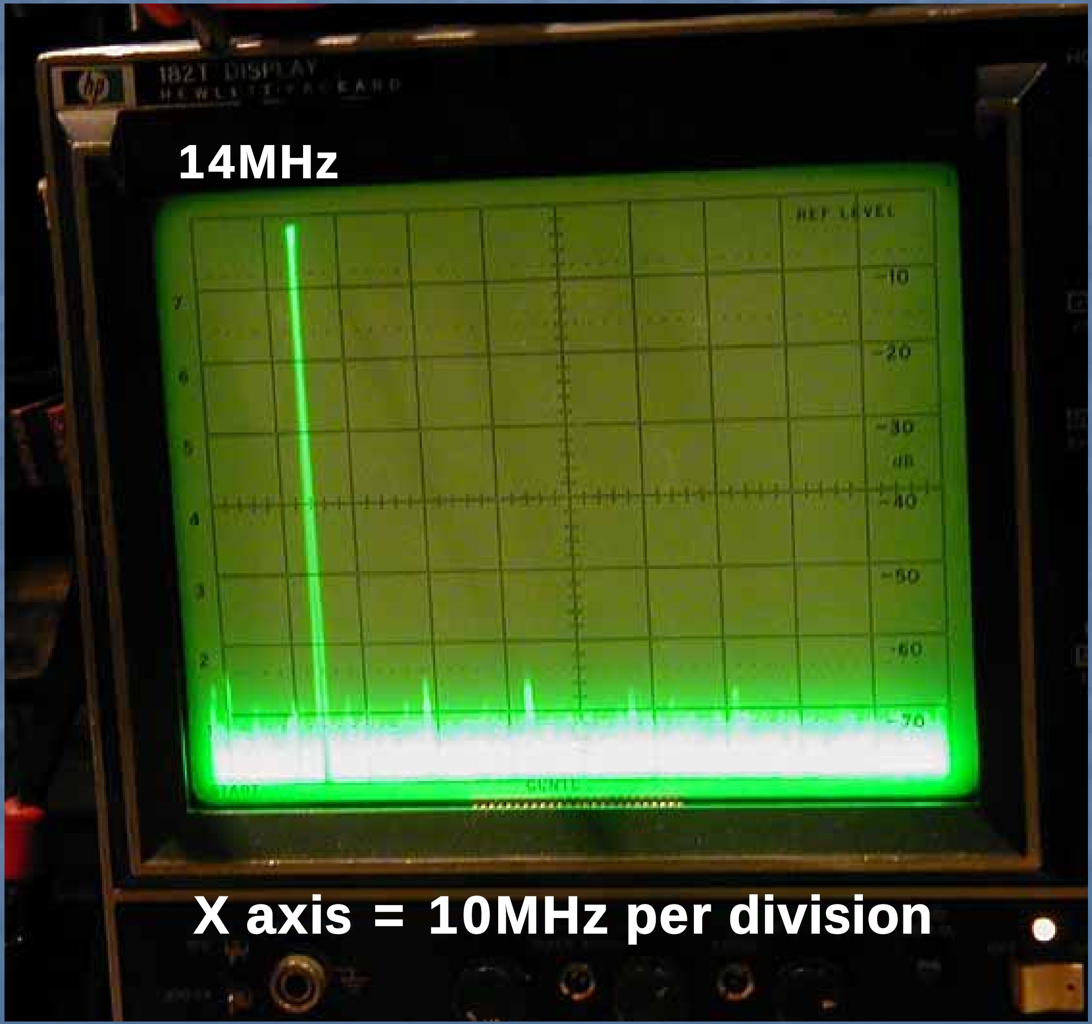
Spectral purity checks … oscillator phase noise



THE SPECTRUM ANALYSER

Checking an FT847 transceiver for harmonic radiation

The wanted signal is on 14MHz. The second (28MHz), third (42MHz) and fourth (56MHz) harmonics can be seen to the right of the 14MHz one but at over 65dB down on the 100 watts of 14MHz. This is well within the spec of the equipment.

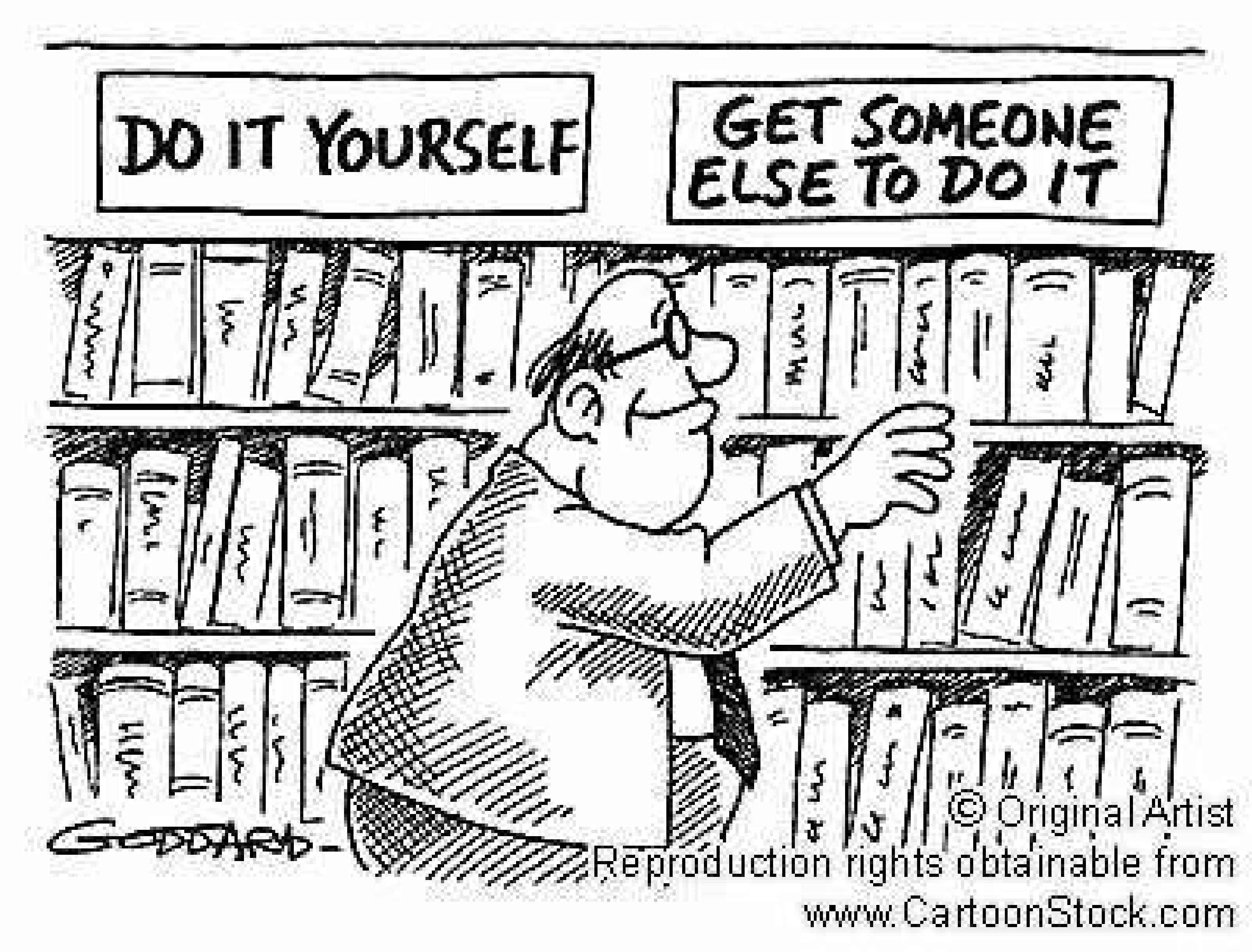


100 watts – 65dB = approx 30 microwatts!

WHERE TO NEXT ?

THE CHOICE IS YOURS ….

ARE YOU LIKE THIS MAN?



OR LIKE THIS ?

TESTING

TESTING

TESTING

TESTING

THE END

Join the RSGB
to defend your hobby

Amateur Radio needs you!