A Versatile Pulse Tester

By G8MNY   (BATC's CQTV No 195, Updated Oct 07)
(8 Bit ASCII Graphics use code page 437 or 850)

This tester based on ideas in magazine articles [1 & 2] & has been developed to have several useful functions.

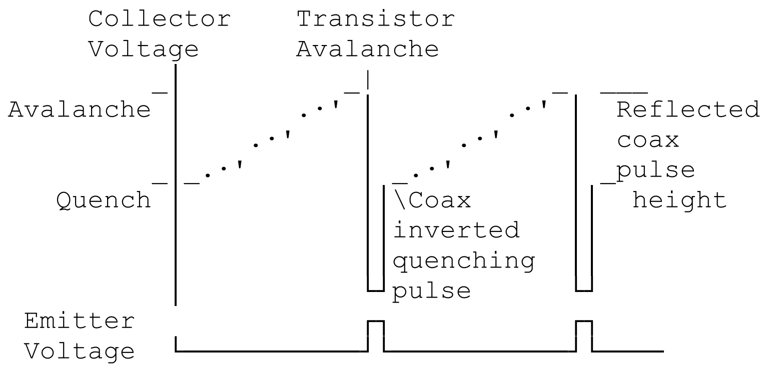
- Coax or Balanced Cable Fault Locator.
- Coax or Balanced Cable Impedance tester.
- Wideband Crystal Calibrator.
- Spectrum Analyser Calibrator.
- Filter Plotting (like a Tracking Generator).

THE CIRCUIT.

```
          ┌──────────────────────────────────────────────┐
+12V      │                                  HT 25-100V  │
─┤>├──────)──────┬───────┬470─┬────┬─────┬─────┐         │
    │     │      │)::    │    │    │C6   │     │         │    _
   +│     │  hi  │)::1mH │  _│_  ===    │     │         │   ( )
C1 ===  ┌─┤  PIV │)::    │  /_\'  │u1   │     │       100k │ │14cm of coax
100u│   │ ├─┤<├──┤       │    │10V │     │     │       ¼W   │_│sets pulse width
    │  ===│      │      10k   │────┘     │    + │16        │  (.)────────┐
    │ C2  │      │BFX84  │    │         10k   ┌──┴──┐    :   └───┐      │
    │ u1  │ 10k  │ \     │    │          ├────┤clk  │TRIM :       │Avalanche
    │     │      T1 ├───┤<├──┤    ┌─XTAL─┤ 10 │4040 │2-30p:     /transistor
    │     │ SET  │ e/ │    │    │    ├──1M──┤    │  Q2 ├──┤├──┬──┤  T4  │   Test
    │     │  HT<─┐│    │    │    │    │  ┌───┤    │     │7 250 : │  │\e─22─┬───┬@ Cable
    │     │ 100k │ │    │   ===   │    │ /  │    │ rst ├┐ KHz :100    │ 62 │ BNC
    │     │      │ _│_  │   C3    │    ├─T3 │    │Q5   ││ 11  : │   270  │  │
    │     │ 33k /_\  │    │   1n   C4   │ \e  │    └─────┘│     : └───────)──┴──┤
    │     │      │    │  /     │   1n   │   │   ===   5│8 │     : all short│     │ Monitor
    │     │  24V └─(──┤ T2     │  ===   │   │   C5   │ │  │     :  leads   ├─────@ Scope
    │     │      │    │ \e    │   │    │   │   15p  │ │  │     :         82    │ BNC
────┴─────┴──────┴────┴───────)──┴────┴───┴────┴───)──┴──┴────────────────┴─────┘
  DC-DC HT  CONVERTER         │    XTAL OSC       │ DIVIDER   NEEDLE PULSE GENERATOR
                              └───────────────────┘ 64KHz
```

NEEDLE PULSE GENERATOR.

The heart of the unit is NPN transistor T4 using its avalanche characteristics, which is actually just an ordinary high speed low voltage switching transistor run well over its voltage. A 100Û base resistor keeps the transistor off, but with high voltage applied to the collector the transistor will suddenly conduct in avalanche mode. But with a transmission line capacitance that gives a pulse quenching reflection from the length of unterminated coax onto the collector & a high value charging resistor, the transistor can be made to generate a stream of very narrow pulses on its own. This is because when it suddenly conducts as lower voltage is sent up the coax line gets reflected at the far end & produces an even lower voltage at the collector which stops (quenches) the conduction. After a while the voltage will have built up again & the whole cycle repeat.



These can be used as they are, for coax cable time domain reflection testing with just a suitable T4 emitter network & a good oscilloscope. With a 14cm length of 50 ohm coax as the capacitor & very short wiring to the output socket, I found the pulse width was around 3nS wide [1].

A very narrow pulse has wide bandwidth & if repeated with precise timebase can provide good RF markers up to the 1st null frequency determined by the pulse width. A 3nS wide pulse gives a 1st order null at 333MHz. For very fast pulse you need short coax line & a uWave transistor, & no leads just the surface mount components around a socket. Then pulse widths of less than 0.3nS are possible.

CRYSTAL CLOCK.

Using a 1MHz crystal oscillator & divide chain to obtain clocks of interest (other crystals & divide options can be used) to trigger the avalanche transistor T4, enables the output to be of more use than a free running circuit. As the transistor can be made to free run as a pulse generator with just high voltage, only low energy pulses are needed to start the avalanche effect so a low power CMOS 4040 divider IC can be used as a driver. Trigger sensitivity is a function of both the supply voltage & the size of the trigger pulse.

With 250kHz pulse repetition frequency, cable lengths of up to 500m can be pulse tested & with a wide 300kHz IF filter in a spectrum analyser a reasonable smooth graphs could be drawn of VHF filters etc.

HIGH VOLTAGE.

A stable voltage from a 30-100V is required for the avalanche effect this comes from a voltage controlled DC-DC converter driven by a medium speed clock. A 64kHz clock output feeds narrow edge pulses through a 1nF to a 10k pull up provide light bias. Then via a diode to stop problems with the negative going pulse, on to the base of a BFX84 T1 this has a small choke of around 1mH as the collector load. When T1 turns off high back emf from the choke goes through a high PIV diode to a 0.1uF to store the positive HT volts. A 100k pot samples some of this voltage, which is applied via a 24V zener to the base of T2 a NPN transistor that shorts out the base drive of T1. The result is that the drive pulse length is shortened giving simple but very efficient voltage control.

TESTING & ADJUSTMENT.

The project takes only 10mA when working correctly. So with a current limited supply, check the osc is running with a scope, then the divider IC. The BFX84 should have high voltage pulses on it to give an adjustable avalanche DC HT from 25-100V. With the trigger drive trimmer set to minimum connect the oscilloscope probe to the test coax port (not directly on the avalanche transistor's emitter).

Adjust the HT (40-80V) to make the narrow pulses start up, the scope should be set for 5V pulses & a fast or maximum timebase frequency. If there are no pulses, check the HT is present at the transistor & coax capacitor. If it is still not firing up then change the transistor for another fast switching NPN one. Adjusting the voltage higher should increase the free run repetition rate. Now turn down the HT until the pulses just stop (30-40V), turn up the clock drive trigger pulse trimmer, the pulses should reappear, but at 250kHz (4uS) period. Adjust the HT voltage & drive trimmer for best pulse reliability.

If the spectrum analyser/scanner shows any "in-between" frequencies [2] (narrow analyser filter needed) or a properly locked scope pulse display has other pulses faintly present then there is some false triggering, or the oscillator is being affected by the HT DC-DC converter etc.

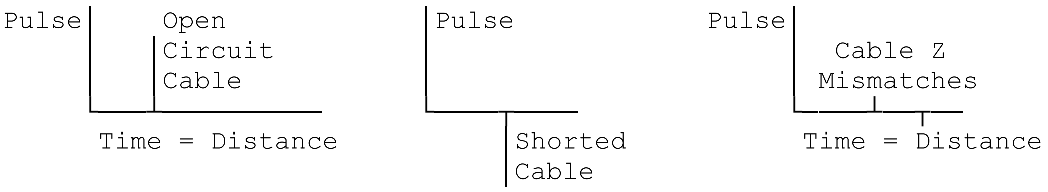
The C4 100pF can be made up of a trimmer & fixed C for accurately setting the marker frequency. Align the crystal trimmer so that the RF marker frequency zero beat with a know RF source or measure the pulse frequency on a good counter.

CABLE FAULT LOCATION.
Using the pulse source faults can be seen on the monitor scope as positive pulse reflection for high impedance fault (e.g. Breaks) & negative pulse reflection for a low impedance fault (e.g. Shorts). To minimise false echoes the scope should either have a good 1:10 probe connected to the monitor port or be connected with a terminated cable teed to the scope input.

How well the fault pulse echo can be seen & time measured will depend on your scope pulse performance, small height display can be more accurate, but generally a 20MHz scope can see down to about 2 metres, a 100MHz 20cms etc.

Wide curvy pulses often sharper if displayed smaller. The thinner pulses give greater time accuracy.

The location is the time difference between the initial pulse & the fault pulse, multiplied by the cable velocity, times 2 (there & back). Cables have velocity factors of between 0.66 of the speed of light (300M/uS) for solid coax, & 0.78 for semi air spaced types. Open balanced line velocity factor can be as high as 0.95.



If the fault is intermittent or not extreme (not O/C or S/C), or an identical cable length is available, then a calibration of the scope can be done with the far end open & shorted representing 100% cable length. Then the fault location can me measured off as a % of that length, this can be more accurate than unknown velocity factor & scope timebase accuracy.

Coiled up cable & odd drum lengths up to 3uS (500m) can be measured, but only if the cable loss is not too great as the reflection pulse weakens & spreads out.

```
           Pulse|       _
                |        Cable
                |       _ Loss          e.g.  50% Height = 6dB there & back loss
                |   |                             or 3dB over the length.
                |___|__________
                 Open Circuit Cable
```

VARIABLE COAX TERMINATION.
This is needed to measure coax impedance. The requirement is for a Zero to Open circuit variable load that is good to VHF, this is not that straight forward. I used a small 470Û carbon tracked pot, large ones & wire wounds are too inductive. I took it apart & modified the start of the track with Silver conductive paint to give a good Zero Ohms & about 75Û half way around, I also slashed across the far end track with a sharp knife several times to make the high resistance end more resistive (about 2k). The pot is mounted in a tin box, & wired up with short leads to a BNC socket, with the low resistance track end connected to the BNC centre & rotating wiper to ground. Then it is a simple matter to DC calibrate the knob with an Ohms scale.

```
       End of    o)───┐
        Test  BNC │   POT<┐
        Coax      └───┴───┘
```

With this variable load it is easy to check the impedance of any coax cable by either making the reflected pulse disappear on a scope trace for long cables.

```
On a SCOPE..
Pulse |                    Pulse |                  Pulse |
      |  Load                    | Load =                 | Load to
      | to low                   | cable Z                |   high
      └────┬──── Time            └───────── Time          └────┴──── Time

On a SPECTRUM ANALYSER...
dBs|   _ Load too low       dBs| Load = Cable Z      dBs|┐ Load to High
   | / \   /\   /\   /         |─────────               | \   /\   /\   /
   |/   \ /  \ /  \ /          |                        |  \ /  \ /  \ /
   |     V    V    V           |                        |   V    V    V
   └┬────┬────┬────┬─── Freq   └───────── Freq          └───┬────┬────┬─── Freq
```

For short cables where the close in pulses merge, then the uneven spectrum ripple due to end mismatch echo on an spectrum analyser/scanner is then the best way to see matching, as it flattening out the frequency ripple when the termination is correct.

Cable impedance is then the value of the termination, it is nearly always resistive unless you have a lapped screen audio cable! With a cable made of mixed impedance coaxes no null is possible. This will stop you using bits of non 75Û cables for video etc!

BALANCED LINE TESTING.
This needs a small pulse transformer in an add on box to isolate & match to a balanced line. A turns ratio of 1:2 will drive the line with about 200Û floating source. This is quite correct as most balanced lines are around 140Û at HF, even if used as 600Û at AF. For the transformer I used a small 2 hole ferrite core testing it with 1/2/3 turns to see which did not reduce the overall height of the DC pulse (not saturating) & did not cause too much negative pulse response (L too low), 3 turns was what I ended up with for the primary & therefore 6 turns for the secondary in slightly thinner enamelled copper wire. Avoid too many turns as this will reduce the magnetic coupling

increase winding capacitance & cause unwanted ringing etc. The same variable termination as above can be used to find the Z of any balanced line.

```
       _____  _______
 BNC     3  ):(        Balanced
       Turns):( 6 Turns
      ______):(_______ Line
          Small
        2 hole core
```

You may be surprised just how good ordinary twisted wire is, once it is properly matched.

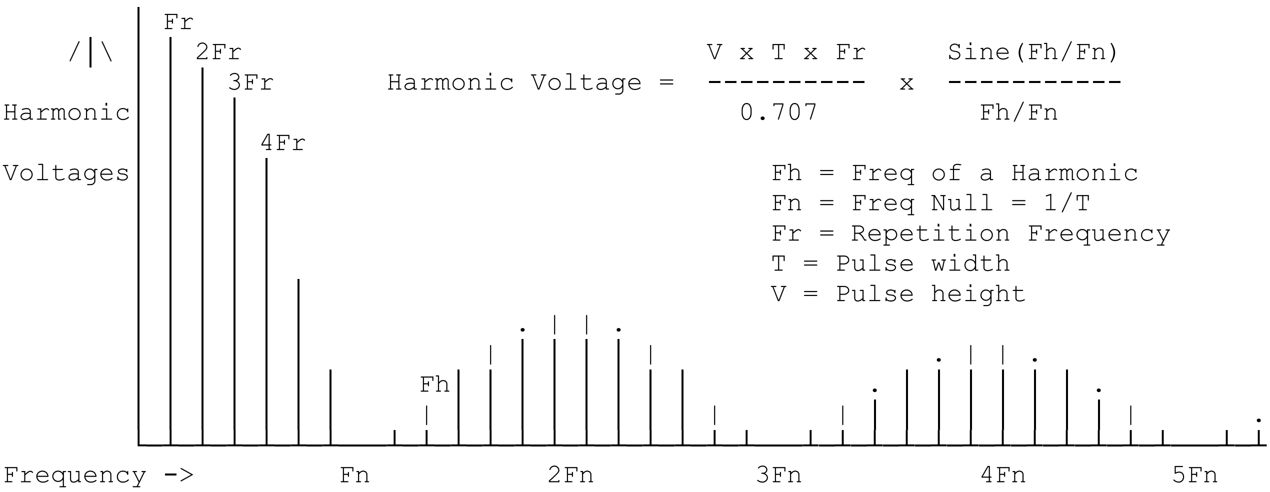
CRYSTAL CALIBRATOR.
As the narrow pulse has very high harmonic content strong signals can be heard into the GHz bands. The use of 250kHz as the pulse rate give 4 markers per MHz. Do not put the pulse output into a radiating aerial, as it will cause wideband QRM locally!

SPECTRUM ANALYSER CALIBRATION.
In theory the pulse spectrum is in the form of (sine x)/x [1] this gives an overall cosign shaped envelope of the markers to the 1st null frequency Fn, then much weaker repeating ½ sine wave shape envelopes to infinity.

```
                 _                        _
Pulse    ^     |~|                      |~|
Voltage        | |                      | |
         v ____| |______________________| |__
               | |
              >T<
                - Repetition Frequency -
```

Due to the vertical sides of the pulse, there must be a spectrum null in the Repetition pulse frequency harmonics at a frequency of 1/T as a sine wave ~ could not fit in the pulse.

If the terminated DC pulse height is measured with peak detector (fast diode & cap, mine was 8V which is 1.28 Watts of peak pulse power!) the true power level of any of the RF markers is then..



$$\text{Harmonic Voltage} = \frac{V \times T \times Fr}{0.707} \times \frac{\text{Sine}(Fh/Fn)}{Fh/Fn}$$

Fh = Freq of a Harmonic
Fn = Freq Null = 1/T
Fr = Repetition Frequency
T = Pulse width
V = Pulse height

A spreadsheet can be loaded with this formula & pulse data, then graphs can be plotted of the ideal spectrum for comparison. This assumes perfect terminations & ideal pulse shape etc. but a good starting point.

For UHF-SHF use, surface mount components "chip Rs & Transistor" are soldered directly across threaded BNC sockets with no wires or tags, this does give better results but with a lower pulse size of around 4V peak with a sub 0.3nS pulse length with 5cm of coax, with no visible spectrum Fn null up to 2GHz.

FILTER PLOTTING.
When this fairly broadband signal source is put via a VHF/UHF filter into a spectrum analyser with a 300kHz wide IF, the shape of the filter can be seen immediately & the filter performance easily adjusted. This is normally only possible with a tracking generator or a high power noise source.

```
dB Loss                                dB Loss
 0dB_|         _._ _._                  0dB_|        _
     |       /'¯  `-'¯  `\                  |      ,'`-'¯`-'`,
10dB_|      :             :            10dB_|      :         :
     |     |   Critically  |                |     |  Coupled  |
20dB_|    |     Coupled     |          20dB_|     :   3 pole  :
     |   |       2 Pole      |              |    |  VHF Filter |
30dB_|  ,'     VHF  Filter    `.       30dB_|    :             :
     |_./                       \._         | _./               \._
40dB |_____|________|________|______>F 40dB |____|________|________|____>F
          144      145      146   MHz          144      145      146  MHz
```

Although this noise source should not be put into a effective radiating aerial, handheld ¼ wave & helical whips do immediately give their frequency band away where they match the RF.

Be aware that this broadband pulse can easily overload wideband equipment (often only 2 tone calibrated), so a band limiting filter should be used before testing response of preamps etc.

References:- [1] Rx Calibrator & Tx Mon, by G4COL, Radcom June 1998.
             [2] Cable Fault Locator, D.Huddart, Electronics World March 2001.

Why don't U send an interesting bul?

73 de John G8MNY @ GB7CIP