Antenna Tuning by Stealth

How to match your HF antenna system to your transceiver without switching on the transmitter!

by Kelvin Barnsdale, ZL3KB *

IMAGINE the scenario: you change from the 20m band to 80m looking for DX. On 3660kHz you hear ZS3DXC just finishing a QSO! What do you have to do? (Please do not say you tune up on his frequency!) Store the frequency, tune away and find a clear frequency, select a transmission mode that will give some RF, turn the power down, adjust the antenna tuning unit (ATU), change the mode back, recall the frequency. By this time, he has probably gone away. Never mind, he would not have heard you anyway because you forgot to turn the power back up!

Quiet as a mouse: the prototype form of the tuning indicator.

Now try this scenario – you hear the ZS3DXC station, turn on your Silent Tuning Indicator, adjust the ATU using the receiver (on his frequency, with no transmission from you), turn the indicator off and call him. You have tuned your ATU with no transmission at all!

At the heart of this clever unit is the noise bridge [1], about which a few words need to be said.

THE NOISE BRIDGE

TO UNDERSTAND how the noise bridge functions, we need to refresh our memories about bridges and noise.

THE BASIC BRIDGE CIRCUIT

The Noise Bridge is like the Wheatstone Bridge shown in **Fig 1**, but fed from an AC source. In the left arms of the bridge, two resistors, RA and RB, are shown; they have equal values. In the opposite arms of the bridge are impedances Z and X. X is an unknown impedance, and Z is variable. A meter (or generalised detector) is connected across the centre points of the arms.

For the meter to read zero (a condition in which we say the bridge is 'balanced'), the voltages on its two leads must be the same. Because RA and RB are equal, the bridge can be balanced only if Z = X. Therefore, if we know the particular value of the variable impedance Z, that value must be equal to the 'unknown' value, X. In simple bridges, all the components are resistors, enabling unknown resistance values to be measured.

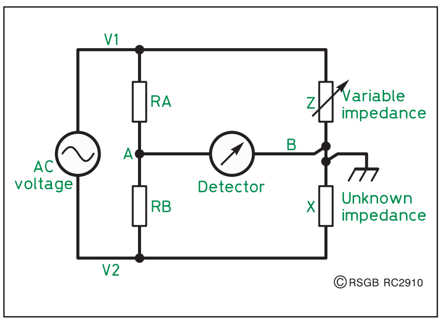

Fig 1: A basic bridge circuit, where resistors RA and RB are 'balanced' against Z and X.

In more general terms, if the known component is an impedance made up of a combination of resistance and capacitance, the bridge can measure complex impedances made up of capacitance or inductance.

WHY NOISE?

If the unknown impedance is not a pure resistance, ie it possesses reactance as well as resistance, the bridge balance will depend on the frequency of the voltage source, which could be a signal generator, for example. We are aiming to use a radio receiver as our detector (to replace the meter in Fig 1), so our signal generator would have to cover all the amateur bands on which we want to work. The device is getting more complex by the minute *unless* we can generate all these frequencies at the same time! Fortunately, we can, by using a source of near-white noise. With the receiver as your detector, you can measure resistances or impedances by adjusting the bridge for minimum (ideally zero) received noise.

PRINCIPLES

THE SILENT TUNING Indicator consists of a 50Ω fixed impedance noise bridge that is permanently connected in the antenna line, ready to be switched in at any time. For convenience, it uses the Galbraith Noise Bridge PCB [2], with a 50Ω resistor in place of the variable resistor. This ensures that, at

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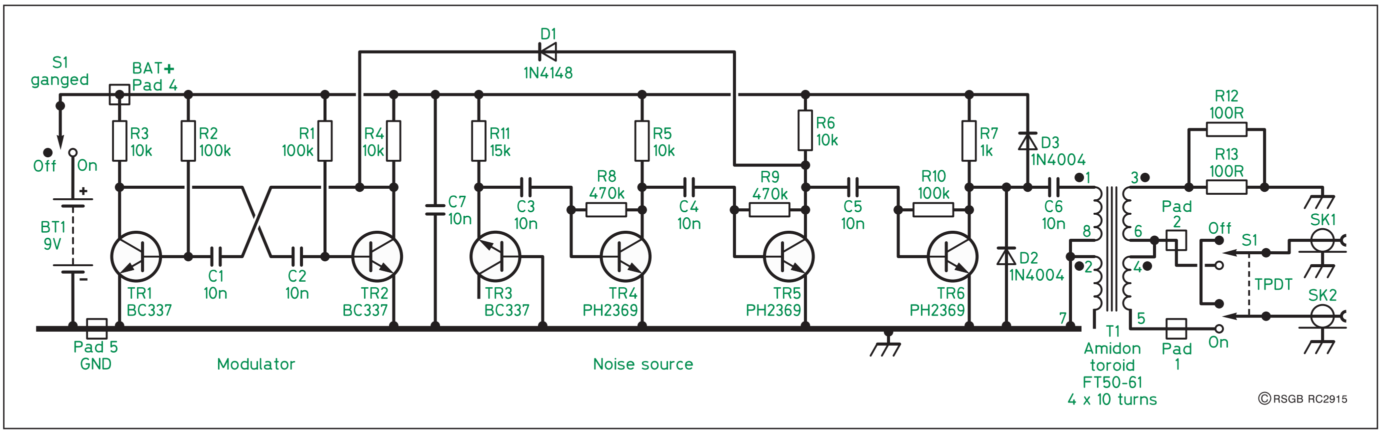


Fig 2: The complete circuit of the Silent Tuning Indicator

balance, the bridge is measuring a 50Ω impedance.

The noise bridge operates like this. When switched into circuit, the antenna and ATU are connected to one side of the bridge, and the accurate 50Ω resistor is internally connected to the other side. In the middle of the bridge is your receiver, acting as a detector. When the ATU is not tuned, the bridge is unbalanced and the receiver hears lots of noise from the noise bridge. Once the ATU is adjusted correctly, it presents 50Ω as the 'unknown' impedance, the bridge is balanced and the noise heard in the receiver drops to a minimum or zero. The transmitter is never activated for this operation!

THE COMPLETE CIRCUIT

THERE ARE three main constituents of the Noise Bridge circuit - the noise generator, the modulator, and the balun.

THE NOISE GENERATOR

This is shown in **Fig 2**. A diode is often used as a noise source, but in this design, the reverse-biased base-emitter junction of a transistor, TR3, is used. This generates a low-noise signal which is, in turn, amplified by TR4, TR5 and TR6. Because the noise source is rich in low-frequency components, the higher frequencies are (to an extent) recovered by over-driving the later stages.

THE MODULATOR

The design also incorporates a modulator, which consists of a two-transistor audio oscillator comprising TR1 and TR2, and a diode switch to modulate the signal on the collector of TR5.

Why modulate the noise? When measuring the impedance of large antennas, the noise generated in the noise bridge has to compete with the noise coming from the antenna, and sometimes the latter is overwhelming. This design modulates the bridge-generated noise, and gives the ability to discern which is bridge noise, to be tuned to a minimum, and which is antenna noise. This also gives the bridge a second use, as a modulated wide band signal generator for fault finding on receivers! This section of the bridge, namely TR1,TR2, R1, R2, R3, R4, C1, C2 and D1, can be omitted if no modulation is required.

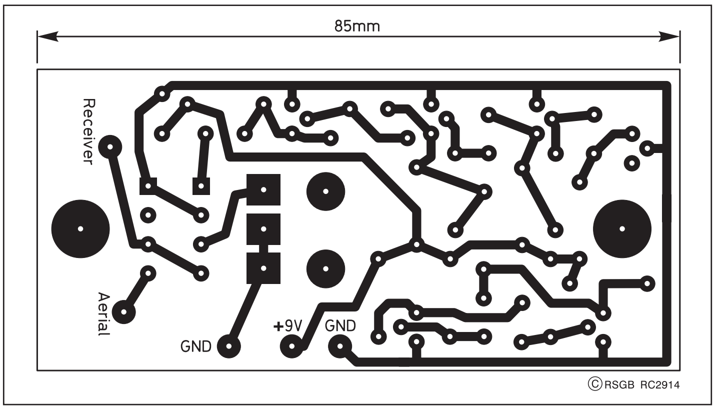


Fig 3: The PCB design, shown actual size f*rom the track side*. See the text for an explanation of the two circular pads in the centre.

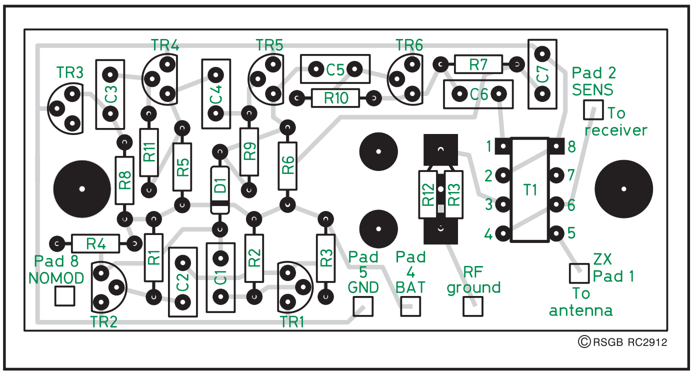


Fig 4: The component layout on the PCB.

COMPONENTS

THE DESIGN has concentrated on using parts readily available or rattling around in the trusty old junk box.

TRANSISTORS

Transistors TR4, TR5 and TR6 can be those listed or any high-speed switching transistor having good gain at VHF. TR1, TR2 and TR3 are ordinary audio types

TRANSFORMER BALUN

The balanced AC drive to the circuit is provided by the incorporation of a balun, the toroidal transformer, T1, to the right on Fig 2. The voltage divider RA and RB shown in Fig 1 is replaced by the centre-tapped secondary of T1, the receiver being connected from the centre to ground. The accurate 50Ω resistor, made up of two non-inductive resistors, R12 and R13, is connected between the opposite end of the same winding and ground.

Thorough tests were carried out to determine the best type of ferrite to use. The type finally selected provided a good noise level up to 145MHz.

CONSTRUCTION

SOME GENERAL information on the construction of the prototype is now given.

THE BOX

I built the unit into a 64 x 115mm diecast box (including battery) with the antenna switch and power switch combined into a 3-pole double throw toggle switch mounted close to the antenna BNC connectors, as can be seen in the photograph. Note that the RF connectors are close to the switch to pre-

COMPONENTS LIST

Resistors, all 0.25W, unless stated otherwise

R1, 2, 10	100kΩ
R3 - 6	10kΩ
R7	1kΩ
R8, 9	470kΩ
R11	15kΩ
R12,13	100Ω, non-inductive

Capacitors

C1 - 6	10nF ceramic
C7	10nF ceramic

Semiconductors

D1	1N4148
D2	1N4004
D3	1N4004
TR1 - 3	BC337 or any audio npn type
TR4 - 6	PH2369 or 2N2222A etc

(D2 & D3 mounted under PCB)

Other items

T1	Ferrite toroid Amidon FT50-61 with 0.3mm enamelled copper wire (see text)
S1	3-pole 2-way rotary switch
BT1	9V battery & connector clip

BNC/SO239 sockets as required

The Noise Bridge PCB is available from: Branch 05 Projects group, PO Box 1733, Christchurch, New Zealand. Email: kb.ew@xtra.co.nz

serve the high-frequency performance. Another construction idea would be to build the unit inside the ATU. Wherever it goes, it takes the place of a SWR bridge, and it is a lot cheaper.

The ferrite balun is rather deceiving – it looks harder to make than it really is and, if 0.3mm wire is used, it is not fiddly.

THE PCB

The Noise Bridge PCB layout is shown in **Fig 3** and **Fig 4**, and was originally designed as a piece of test equipment with a variable balance resistor instead of our fixed value of 50Ω. This is made up of two resistors, R12 and R13, as mentioned previously.

Two 1N4004 D2 and D3 diodes are fitted around the transistor, TR6, to protect against inadvertent transmitter power destroying the circuit. These are fitted under the PCB directly onto the tracks.

Eagle-eyed readers may have noticed the appearance of a resistor in the second photograph, below and slightly to the left of TR6, which is not shown in the PCB layout of Figs 3 and 4. I decided, after the project was complete, to fit a small LED to indicate the 'power on' condition. The LED can be seen in the first photograph. The mysterious resistor is simply the current-limiting resistor for the LED, and is soldered to the two empty circular pads shown in Fig 3. Mystery solved!

Printed circuit boards are available from the NZART Branch05 projects group (see the Components list). Parts can be scavenged from junk but, if bought new, the total parts cost would probably come to less than £10.

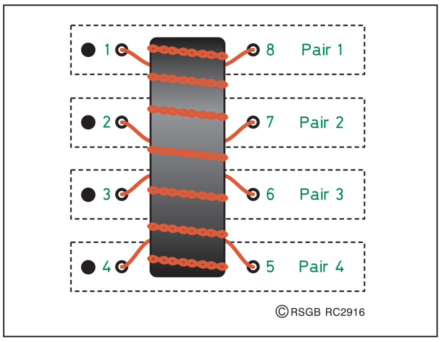


Fig 5: The connections for T1, which correspond with those shown on Fig 3. The winding on the toroid is four twisted strands of 0.3mm enamelled copper wire.

MAKING THE TRANSFORMER BALUN

The transformer T1, should really be called a balun, as it converts the unbalanced output of the noise generator to a perfectly balanced noise source across the bridge. It will be noted that this design has an unused winding between pins 2 and 7. This completely balances the capacitive coupling between primary and secondary.

A little care should be taken in winding this component.

- Twist together four 180mm strands of 0.3mm enamel copper wire. Aim to have a twist of about 40 rotations over this length.
- Wind 10 turns of the twisted bundle through the centre hole. Note: one turn is equivalent to one pass through the centre hole. Wind the turns evenly around the toroid so that the start is very close to the finish.
- Separate the ends and remove the insulating enamel. This can be done with a soldering iron on most wire types now.
- Use a buzzer or ohmmeter to identify the four pairs of windings. Arrange them as in the diagram **Fig 5**. This is the lead out pattern needed for the PCB.

I used masking tape to keep the strand ends together throughout the twisting and winding process, and a marking on the tape shows the pair orientation for placing into the PCB.

The PCB tracks connect the windings in the correct phase as long as the pair groups are maintained as in Fig 5.

PCB ASSEMBLY AND TESTING

THERE SHOULD BE no special problems with this, as long as care is taken in soldering the component leads and avoiding

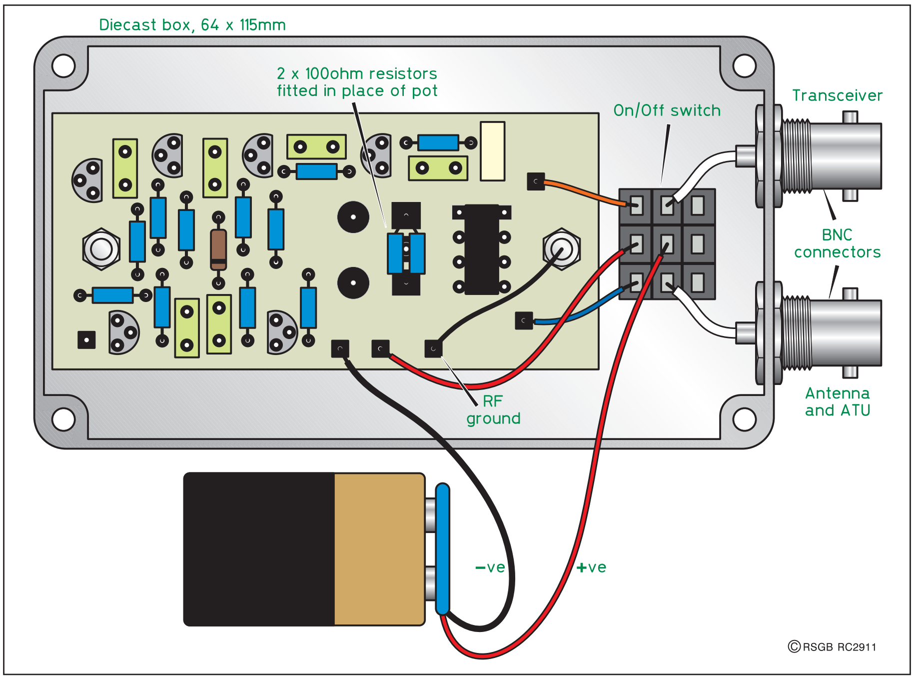
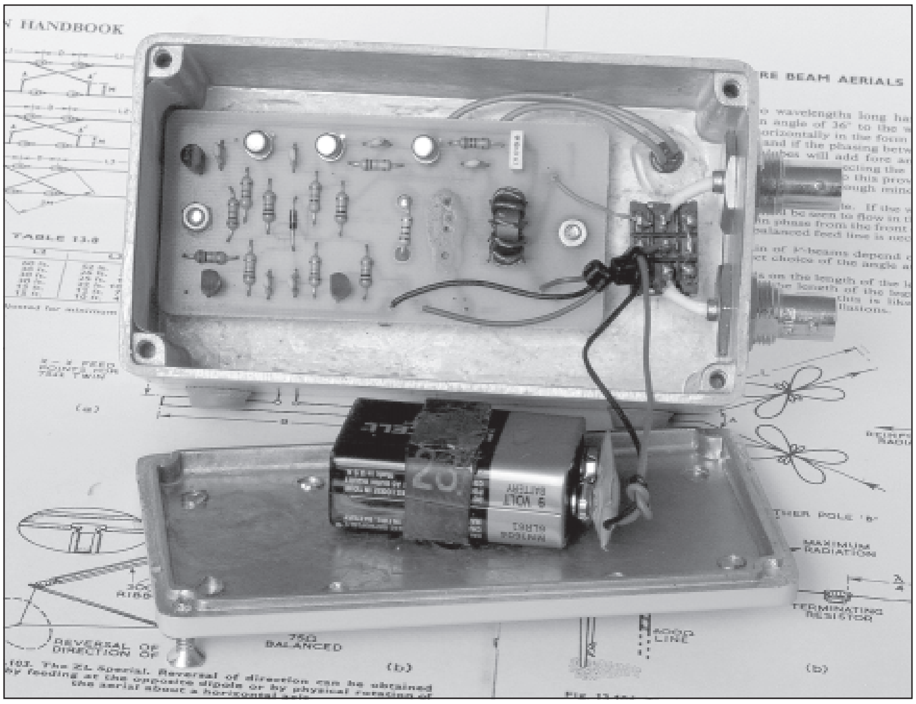


Fig 6:The mounting of the PCB inside the diecast aluminium box.



Not a complex design: the internal layout of the tuning indicator.

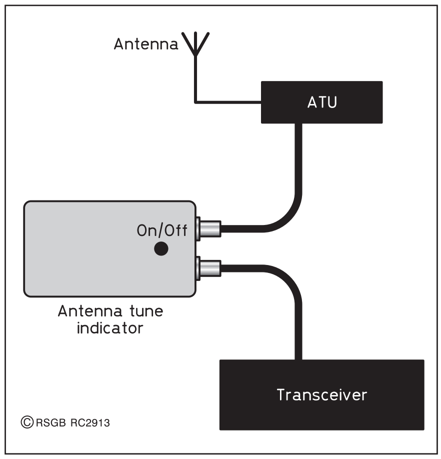


Fig 7: Connection of the Silent Tuning Indicator between transceiver and ATU.

shorting between tracks with solder 'whiskers' or 'spurs'. The track density on the PCB is fairly low, so problems of this sort should be rare.

When the components have been soldered in, hold up the board to a strong light and check for any unwanted inter-track short-circuits.

Although the circuit can be tested out of the case, it is a sufficiently robust circuit that mounting it carefully in the case together with all off-board connections is not a recipe for disaster!

Connect your receiver to SK1 and antenna to SK2. Switch on the receiver and set the frequency to your favourite segment of the 20m band, for example. With the Silent Tuning Indicator (STI) in the 'off' position, you should be able to operate as you did before.

When the STI is switched on, there should be an immediate loud hiss from the receiver loudspeaker. Now try operating the balance controls on your ATU; changes in each should change the volume of the hiss, and it should be possible to find, by using the controls sequentially, a minimum (or even a null) in the hiss signal. Your STI is working!

OPERATING

WITH THE UNIT permanently in the transmitter feeder, as shown in **Fig 7**, it can be turned on whenever the ATU needs adjustment. When turned on, the S-meter on the receiver should show a level of noise of S9 or more. Adjust the ATU controls until the noise level dips to S3 or less, although I find the match is good enough if dipped below S8. Searching for a null is much like tuning for a minimum on a standard VSWR meter. Remember to turn the STI off before transmitting, or that rare DX will definitely get away! ♦

REFERENCES

[1] 'Noise Bridge', ZL3KB, *Break-In*, NZART, September 1998

[2] The Galbraith Noise Bridge first appeared in *Break-In* in the 1980s. 'Galbraith' is a generic name given to projects originated by the author's club.

RadCom Helplines FOR MEMBERS

● John, GW3EJR, is looking for user handbooks for early computing equipment, the **Amstrad PC1512/1640**, and the **Micro PMP135 dot-matrix printer**. GW3EJR, QTHR. Tel: 01239 682 629.

● Harry, G3NGX, has recently acquired an old and non-functioning **Hallicrafters SX-28 Skyrider**. He would appreciate copies of the circuit diagram or handbook, plus information on locating reviews and modifications. He will reimburse all expenses, but would appreciate a call first. He can offer, in return, copies of the BC221 and CR100 handbooks. G3NGX, QTHR. Tel: 01491 872 919.

● Michael, MI1MTC, is looking for information on a small elegant multimeter, about 25 years old, marked **Milano ICE Italy, Supertester 680R**, 20,000 ohms per volt, with 22 sockets, scales for volts, amps, resistance, capacitance, frequency and decibels. It has a 3V internal battery, mains input, rectangular plastic case, hinged lids top and bottom, and measures 135 x 105 x 55mm. MI1MTC, QTHR. Tel: 028 6862 1436 or e-mail michael.clarke@swiftsoft.net

● John, G3GTJ, is looking for any technical information and historic data relating to **Marconi aircraft radio receiver type 118M** ref: 5821-99-970-8401. It is an HF receiver of the post-war period. All costs will be reimbursed. G3GTJ, QTHR. Tel: 01963 240 319.

● Ken, G3DJK, seeks a **listing of all XZ2 callsigns** that existed in 1947. Please contact him if you are able to assist. G3DJK, QTHR. Tel: 020 8679 2717.

● Christchurch ARS is searching for an operating/instruction/maintenance manual for a **Lafayette HA-600A HF receiver** as part of a refurbishment project. All expenses will be reimbursed. G7WSN, QTHR. Tel: 01202 484 892 (eves).

● Stephen, G0HMN, wishes to thank all those who answered his query in the 'Helplines' column, and via the amateur radio newsgroup on the Internet. He appreciates your kindness and generosity. As he says: "If you're stuck for something, ask for help. I know it works". G0HMN, QTHR.

● Don, G3WDY, would very much appreciate the loan (for photocopying) of the manual and circuit diagram for the **AVO Transistor Analyser**. Guaranteed speedy return. G3WDY, QTHR. Tel: 020 8653 4738.

● G0KYE requires the colour code for rewiring a **Yaesu FT-One** mode switch. He has the technical manual, but this does not give the colour code. Tel: 01752 705 759.

More Helplines on p40...

'Helplines' is a free service to members. Requests for help are published in the order they are received. We regret it is not possible to provide an undertaking of when any submitted request will be published.