PicATUne

- an intelligent antenna tuning unit

Part one, by Peter Rhodes, BSc, G3XJP

Issue 3.4, June 27

AN AUTOMATIC ATU is not for the merely lazy - though it does indeed offer delightful convenience. Its great virtue is that it allows the ATU to be placed where it will do the most good. And that is often not in the shack. Equally, given a remote ATU capability, many choices of antenna and feed point become much more realistic in the average domestic setting.

THE TARGET ENVIRONMENT

MOST OF US are limited in our ability to exploit a nine band HF Tx/Rx by the lack of a nine band antenna. Equally, few of us have the ability or desire to erect nine monoband antennas. Some, perhaps - but not nine. So a reasonable length of wire represents a realistic and effective approach for at least casual use - if it can be effectively fed and matched. **Fig 1** is pretty representative.

I would argue that the most common domestic garden in the UK is most naturally amenable to end-fed antennas. That is, with the house typically at the front of the plot (not in the middle) and any other support, natural or otherwise more often available at the far end than in the middle.

If like me, the centre of your antenna coincides with the centre of the back lawn, then feeding in the centre is simply not a viable option. Not least because the weight of even the lightest feeder drags down the wire at just the point where you want the most height. Secondly, one way or another the feeder run ends up parallel to the antenna with the consequent likelihood of imbalance. And most of all, because it is domestically unacceptable to both ourselves and our neighbours.

Having said that, there is nothing the matter with a good multi-band doublet.

THE END FED OPTION

END FEEDING BRINGS a different set of issues, but at least the wire is light, tight, as high as the supports permit - and as invisible as any single wire can ever be.

There is now a choice. Do you bring the end of the antenna to the shack - or move the shack near to the end of the antenna?

The former inevitably runs a critical part of the antenna past masonry, piping and mains wiring with all the attendant risks of noise pick-up and TVI. The latter implies a bedroom or loft shack which may or may not suit you - and presents the additional problem of finding a good multi-band RF earth. Most critically, both result in high antenna voltages in the shack with all the usual problems of RF feedback. Faced with these two choices in the past, I have tried both. Today, with the benefit of that experience I would reject both. It is very difficult to make either work well.

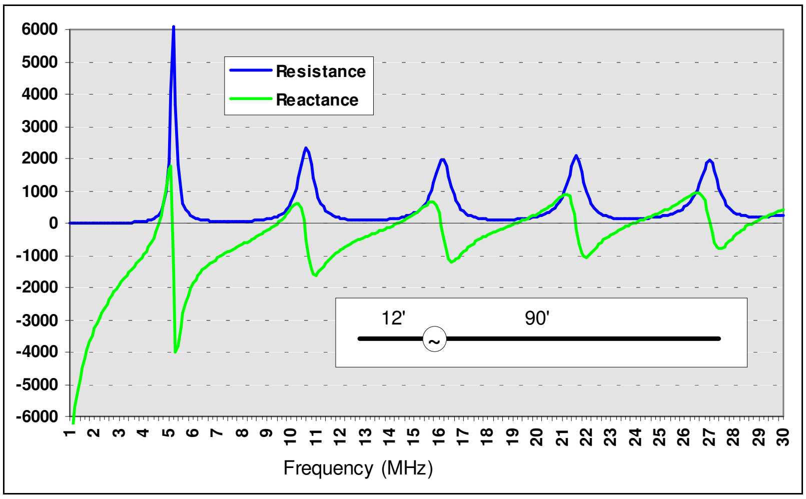

Fig 1: Typical end-fed wire with 'short' counterpoise. In this case:- 90' long with a 12' counterpoise - using 1mm wire - 30' high over average ground. Plot of feedpoint resistance and reactance (□) - versus frequency (MHz).

BUT THE REMOTE ATU .....

..... gives you a third option. Namely you can leave the shack where it is. Instead of bringing the antenna to a shack-bound ATU, you can take the ATU to the end of the antenna - and feed coax from the shack to it.

Given a choice, why would you put an ATU in your shack anyway? Only to be able to get at the knobs. Its logical place is up near the antenna where the matching process should be carried out - and this is only a realistic strategy if the ATU is automatic. Nobody wants to be scrambling around in the loft every time you change bands.

WHY BUILD ONE?

WELL, WHY NOT? There are a number of commercial auto-ATUs on the market but all the ones I have seen are necessarily over specified for amateur needs - and attract a proportionate price.

Firstly, you don't need general HF coverage - only the HF amateur bands. Secondly, you don't need to match every possible antenna length at every possible frequency. You only need to match your antenna at the time - and it greatly reduces the cost and stress on the ATU if you are prepared to prune your antenna lightly to avoid truly diabolical lengths.

THE LESSONS OF HISTORY

THIS CONSTRUCTION project was originally chosen for development on the grounds that the hardware side would be easy and all the serious effort could go into the PIC software.

After all, an L-match only has two significant components. Well, 18 months later and it wasn't quite that simple!

I share with you some of the development fun since it applies to the design of any ATU.

The first prototype was built in a PCB enclosure with the 'hot' capacitor plates etched on the inside of the casing. The coil was a rather feeble offering on PVC tube. It appeared to work brilliantly. That is, it would find a match close to unity SWR for most lengths of wire on most frequencies. But there was a small problem. All the bands seemed pretty dead and signal reports were well down - compared to the same antenna through a commercial 3kW manual T-match.

I woke up one morning realising that I was missing the whole point; that the design objective of merely matching antennas was flawed and that the real problem was to match antennas *efficiently*. What annoyed me most was that I had allowed basic RF engineering practice to be masked by the advertising claims of most ATU manufacturers - who differentiate their products on the basis of power handling and the range of antennas that they can match. And I was blindly following.

To cut to the end of the story with the benefit of hindsight it is time to declare XJP's Axiom for ATUs (so called only because Peter got there with his Principle before I did).

XJP's Axiom states that "An ATU constructed of poor quality components is more likely to provide a *better* match to your Tx/Rx than one constructed of good quality components." Now the dictionary will tell you that an Axiom is self-evidently true. This one is self-evident only when you have examined the evidence.

Crudely, it arises because poorer quality components accept, absorb and dissipate 'forward' power as heat - leaving less to go back as 'reflected' power.

Try the following test. Take about 100m of the worst quality 50Ω coax you can find. Make it even worse by puncturing the sheath at frequent intervals and leave it out in the rain until the braid has seriously corroded. Wind it up, put it in a box with some connectors and label it "Automatic ATU". Advertise it as a 100W instantly tuning auto-ATU which will match any antenna at any frequency - and you should make a quick albeit brief fortune. I assure you it will present a pretty good match to your Tx on all bands - no matter what antenna (if any) you put on the output.

You could achieve much the same effect with a 20dB attenuator. What objective test would you apply to differentiate such a device from the real thing - since both will meet the advertising claims?

You simply have to consider not the match itself but also the efficiency of the match - and this is down to the quality (literally Q) of the components used. Low Q components absorb the power you feed to them, dissipating it as heat; and in extreme cases they can absorb so much power that there is none remaining to reflect; and your measured SWR will be immaculate.

Although that is an extreme, all ATUs exhibit this feature; it is only a matter of degree. When you purchase one, automatic or otherwise, you are relying on the RF Engineers winning the battle with their Marketing colleagues by specifying high Q (typically high cost) components. If they don't then the ATU can achieve a significant percentage of its advertised matching range by simply tuning into itself and getting hot. And if you really stress it, it will literally melt. Remember you only need a 1dB insertion loss to dissipate 20% of your power.

The light dawned for me when I looked at a program called TL.exe by R. Dean Straw, N6BV distributed with the 1997 ARRL Handbook. This has a utility which models the performance of various ATU configurations, modelling real world components of specifiable Q. It allows you to explore the limits, producing virtual smoke instead of the real thing. Note that it does not use the standard formulae for T, L and Pi networks found in many reference books - which usually assume lossless components and purely resistive loads.

As an example, try tuning up a 5Ω resistive load on 1.8MHz using a T-match with a 200pf output capacitor. Even if you specify good quality components (big fat coils, wide-spaced variables etc), nearly half your power (43%) will be dissipated in the ATU. If you arbitrarily halve the Q of the inductor and capacitors then the loss rises to 62%. At 400W input, the coil alone would be dissipating about 200W at over 8A circulating current with nearly 3.5kV across it. Something's got to give!

After development was complete, Tony Preedy, G3LNP published his eye-opening article [1] on how to fix a £250 ATU for a mere two pence - by converting it to have an L-match option. This is compulsive and compulsory reading.

Indeed in the previous example, if you used an L-match instead of a T-match - using components of identical Q - then the loss would be less than 2%, rising to 3.5% for the half-Q example.

XJP's Axiom was applying with a vengeance on my first prototype. The PCB capacitors (fibreglass dielectric) have a hopeless Q and the coil was not much better. But despite having a limited number of discrete L and C combinations, it would match most anything! Finally and fortuitously, it melted.

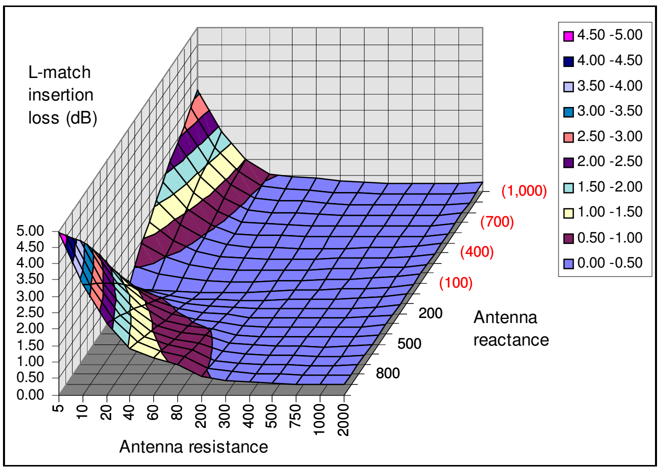

Fig 3: Projected L-match insertion loss as a function of antenna feedpoint impedance

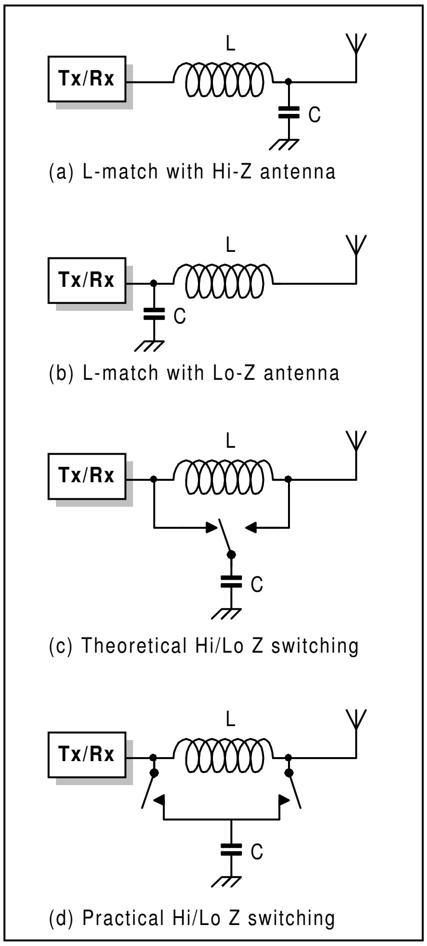

Fig 2: Basic L-match configurations. Both the L and C values are variable or switchable

SOME RF ENGINEERING

CHASTENED by this experience, and already well over budget I fixed on the L-match configuration with switched elements as per **Fig 2(d)**. Of the serious alternatives, the Pi never gives a more efficient match but sometimes uses more convenient values; and the T will match a wider impedance range for a given L and C range - but often at the expense of appalling internal losses.

Switching the C values removes the greatest objection to the L configuration, namely that you need a very wide capacitance range. In practice a 20-2000pf variable with several kV rating is hopelessly impracticable. For this reason, driving variable elements with stepper motors was ruled out - also on the grounds of cost and the time to drive to a pre-stored solution.

Two relays are used to switch impedance since this reduces the voltage breakdown risk in practice. It also allows two 'straight through' modes, one with optional series L; and one with optional shunt C. These are invaluable in matching antennas already near resonance.

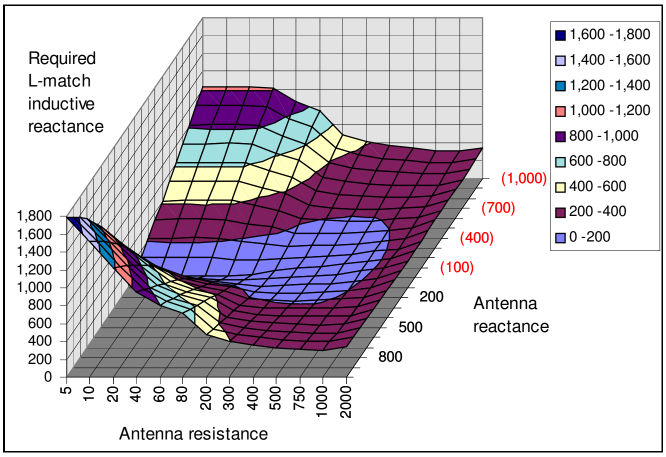

Fig 4: Required series inductive reactance to match antenna impedance.

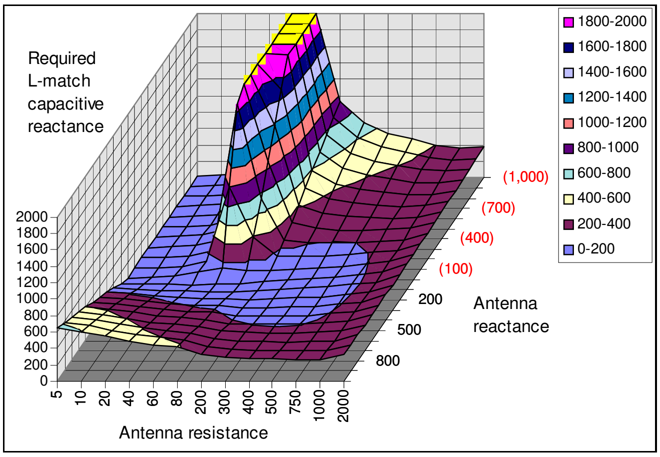

Fig 5: Required shunt capacitive reactance to match antenna impedance.

For scoping purposes, I built a spreadsheet model of an L-match. The task is not trivial since solving the equations for real components with loss must be iterative. This model allowed me to visualise behaviour by plotting some graphs - which produce some strange shapes that you might not instinctively expect from two passive components. This is called ' getting your mind round the problem' .

The design process as ever is circular. What L and C range do I need? What breakdown voltage do I need? What is available ... and what can I afford?

And anyway, just what is the feedpoint impedance of an end-fed wire? I could find nothing useful in any of my reference books - so EZNEC was used to plot **Fig 1** showing a typical scenario. It is typical in the sense that you can scale it to different sizes and still produce the same general results. Namely, the most difficult region is at and below half-wave resonance - where the feedpoint resistance falls to a low value and the reactive component becomes increasingly negative - ie capacitive. Ultimately, if you want to use a very short antenna on a low frequency, even if you can match it, losses are likely to be high - and no amount of matching will improve an intrinsically poor antenna.

Now the search was on for relays which would have low C across the contacts, low C from contacts to the coil and most of all, the ability to stand some serious kV across the open contacts. And handle several amps. If cost is a consideration, then I do not think such relays exist. Not to say you may not pick something up in a junk sale, but for a reproducible design, I could find nothing. So I went the other way and purchased the cheapest relays I could reliably source and modified them to suit the application. Removing the normally closed contacts opens the gap; and wiring the two contact sets in series results in about a net 1.5kV rating.

Originally my relays were of the type where the rocker arm is an integral part of the contact. Since this form of relay has about 8pf between the contact set and the coil, you can see that it doesn' t take many such relays - even with no capacitors - before you have more C than is required on the HF bands. So avoid these.

Now for the capacitors. High voltage, high Q capacitors are rightly an extraordinary price - so given a need for obscure values it was an easy early call to build them. Fortunately, polyethylene is a good dielectric and cheaply available. The issue here is that most polyethylene film is repeatedly recycled nowadays so there are risks of contamination. My first attempt was with 12 thou packaging film sandwiched between two PCB plates. It worked well, but when it did fail (I had included some copper swarf between the plates) the monolithic nature of the construction meant I had to rebuild the whole capacitor bank to effect a repair. With this film, inclusions were easily visible to the naked eye. Worse, the physical size of the capacitor bank meant the smallest residual value was about 50pf which is somewhat excessive.

I then tried rolling layers of aluminium foil and polyethylene into cigar shapes. The capacitor values were unstable. The issue here is that the rolling process requires the layers to travel a different distance (differing diameters) so that varying amounts of air were trapped in the sandwich.

Next came multiple parallel flat plates with a polyethylene dielectric. Firstly I used aluminium foil plates but the inevitable transition joint to copper gave problems. Being unable to source copper foil (which might be better if you can find some), I finally settled on brass shim which is cheaply and widely available.

The dielectric is made from multiple

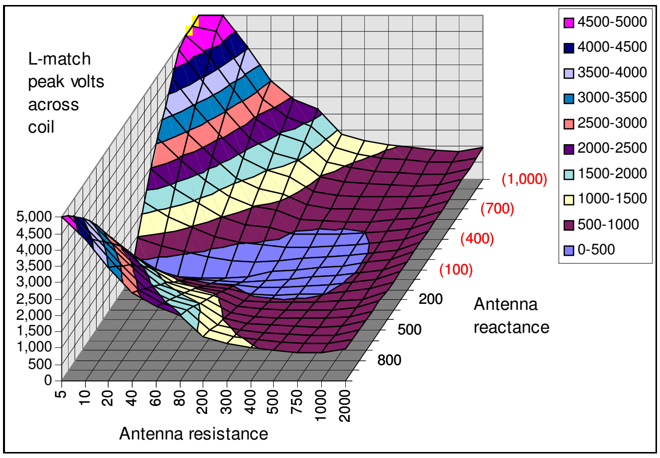

Fig 6: Peak voltage across coil - and its associated relay contacts when open - for 200W input. Low resistance loads are difficult unless resonant (ie low reactance also). Anything over 1.5kV is unrealistic.

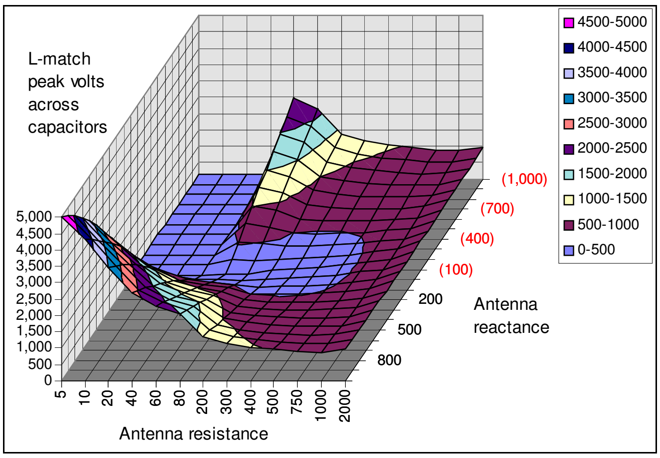

Fig 7: Peak volts across capacitors and their associated relay contacts when open - for 200W input. Note the risk zone when feeding a 50Ω antenna when near resonance.

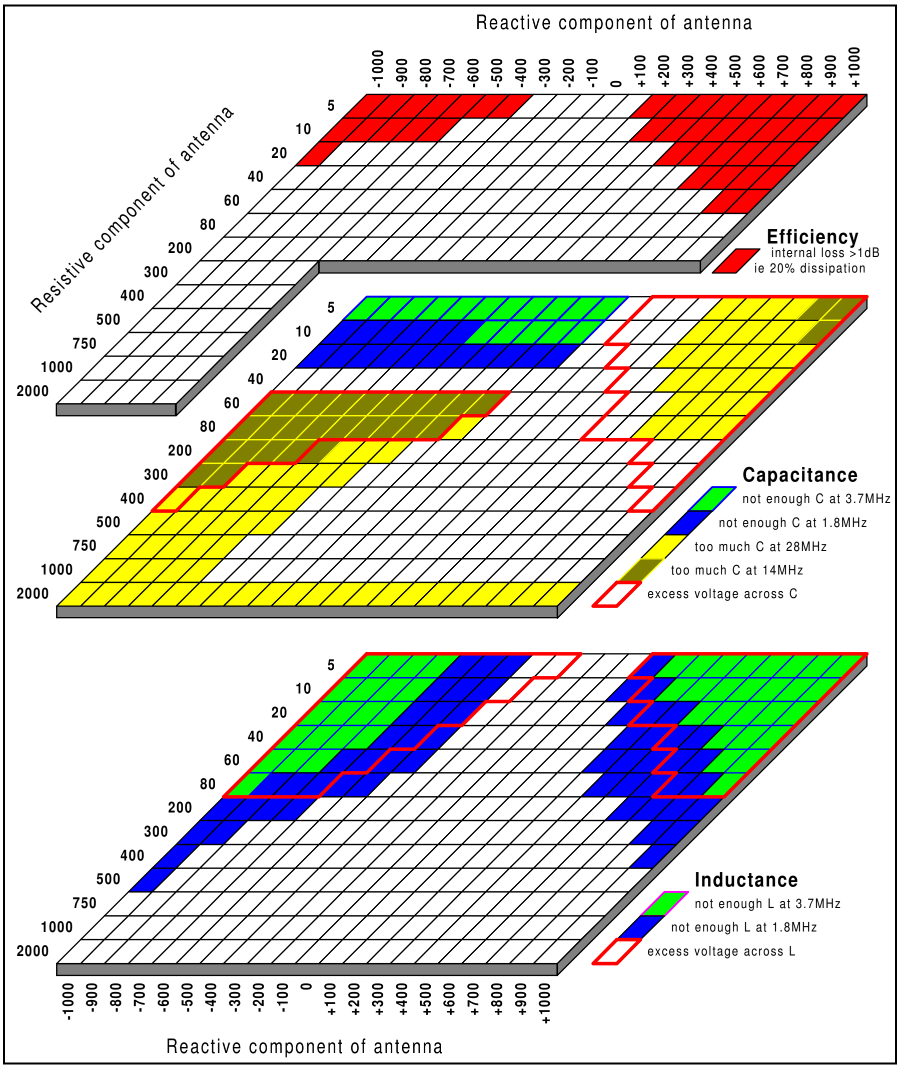

Fig 8: Summary of L-match tuning limits for low-pass configuration (ie series L, shunt C and with the C switched from one end of the L to the other for best match). Note the resistive component axis is simply a collection of useful values and the scale is strictly non-linear. Parameters used are:- Capacitance range 20-1500pf. Inductance range 0.1-30µH. The Q of the coil and the capacitors are both assumed to be 200. Voltage limits used are 1kV across the capacitors and 1.5kV across the coil (and their respective switching relays) for 200W input power.

layers of thin film on the grounds that if there are any inclusions they are less likely to coincide. I found that freezer bags from a well know supermarket have just the right properties - with no visible inclusions. The capacitors are given a 400% safety margin (6kV rating), wetted with DC4 grease to exclude air and have performed extremely reliably. But if there should ever be a failure each of the eleven capacitors can be individually rebuilt.

Polyethylene is a high Q dielectric at HF. Not quite as good as PTFE but better than mica, most ceramics and not least, about 100 times better than epoxy resin glass fibre [2]. My thanks to David, G4FQR who did a lot of the materials science research.

APPLYING REALITY

ARMED WITH A SET of parameters that could be achieved in practice at a reasonable cost, these were plugged into the L-match model to explore the limits. All ATUs, auto and otherwise have limits. It's just that they are not always quoted.

All the graphs assume Q_L and Q_C of 200. This is close to the values I measured at 10MHz. The Q falls with increasing frequency, but there again, at higher frequencies you tend to need less of both L and C. In all cases, the L-match impedance switching configuration is that which produces minimum loss. All the graphs can be viewed for a specific frequency by converting the reactance values to their L and C equivalents using the usual formulae.

Fig 3 predicts the insertion loss, showing that the difficult zone is at low resistances, especially when combined with high reactances of either sign. And that inductive reactance is marginally more difficult to handle than capacitive. If you mentally plot the risky zones onto Fig 1, you will see that bigger losses can be expected at lower frequencies - especially below resonance. But there again, the real Q will be higher there also.

Figs 4 & 5 are basically used to see just how much L and C range is needed. The corner of the plot both below 50Ω antenna resistance and with negative reactance uses the low-Z configuration. It demonstrates the need for wild capacitor swings when feeding a near 50Ω load and is probably why ATUs with no straight-through capability do not fit coax output sockets.

Figs 6 & 7 explore the flashover risks. In practice the relays themselves are the limiting device, not the coil and capacitor banks. As an insurance against any damage under fault conditions or if straying into the flashover zones, a spark-gap is fitted. Conversely, there are many antenna impedances which would allow full legal limit with no issues.

All of these graphs are summarised in **Fig 8**. To reiterate, this graph is not peculiar to PicATUne. It applies to any L-match with the L/C range and Q values quoted.

The general approach is to produce a 'balanced design'. That is, one which covers most of the situations most of the time - and if it is unsuitable for some antenna impedance on the basis of exceeding any one parameter then it might as well fail on as many parameters as possible. In other words, there is no point in adding extra C to widen the matching range on 160m if the power dissipation would be excessive anyway. To take that very example, as a result of this graph and practical experience I increased the maximum C to about 2,400pf.

We leave this section with the haunting question. What is the power rating of your present ATU? Well ..... it depends! Absolutely on the load you are matching and somewhat on the internal losses you (or it) are prepared to tolerate. But there can never be a simple answer.

PicATUne FEATURES

THE BASIC ATU configuration is an L-match with more than a quarter of a million relay switched L, C and Z combinations. In addition it has 64 series L or 2048 shunt C possibilities in 'straight through' mode. It is rated at 200w for most antennas and substantially more for some.

It will match end fed, coax fed and (with a balun) balanced antennas - at any frequency in the nine amateur HF bands only - to 50Ω.

Optional outputs also allow you to automatically switch antennas as a function of which band you are on.

'RESTORE FROM BEFORE'

In normal operational use, all you do is transmit the first letter of your callsign on SSB - or a morse dot - and PicATUne will apply your pre-stored matching solution. It's that simple.

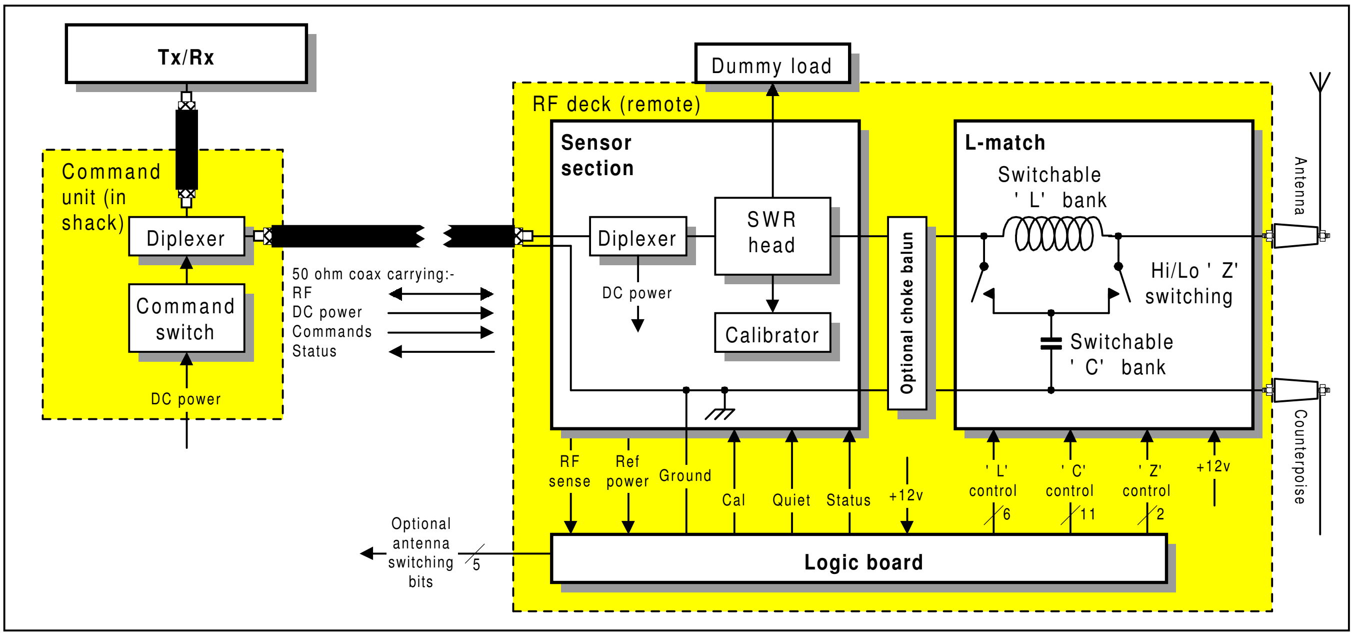

Fig 9: PicATUne block diagram. The optional choke balun may be omitted if only unbalanced antennas are contemplated.

'MATCH FROM SCRATCH'

Obviously the matching solutions have to be discovered and remembered in the first place. This training process requires about 15 seconds of steady carrier at about the 5-10W level on any given frequency.

PicATUne remembers up to 1,000 potentially different solutions - which works out at one every 5kHz over the whole HF amateur spectrum.

Actually 'Restore from Before' is even simpler than described above, since PicATUne will search out the solution for the *nearest* frequency within the band. So, this removes the necessity for training on every possible spot frequency. But equally you can train at more frequent intervals if your antenna tuning is 'sharp'.

As a matter of policy, PicATUne will never start looking for a new solution unless explicitly told to. When so commanded, PicATUne will always look for the best possible match. Specifically it will not settle for an 'acceptable' solution if a better one exists even though this may take longer.

QUIET MATCHING

An auto-ATU is particularly prone by its nature to generate tuning carriers. On social grounds, it was considered irresponsible not to design to minimise these.

When 'Matching from Scratch', PicATUne uses a 'quiet tune' approach to attenuate the radiated signal by some 25dB, thus saving stress on your Tx, ATU and fellow amateurs.

PHYSICAL CONSTRUCTION

PicATUne comprises two enclosures (see **Fig 9**):-

- The Command Unit - which goes in the shack. It contains few components, the critical one being a simple push-button switch - the Command Switch - for controlling the ATU.
- The ATU itself - mounted remotely - which contains the RF deck (L-match and the relays to switch it), the control logic, an SWR head and a dummy load.

These two enclosures are connected only by the 50Ω coax feeder. All commands to the ATU and status information back - as well as DC power and RF - are multiplexed on the coax thus minimising installation complexity.

The remote ATU is housed in a polystyrene case which in my case - if you pardon the pun - is sealed against the UK climate. The issue here is to make it air tight. Waterproof is not enough since if it breathes moist British air, condensation will occur. Mine is also painted white (externally) since it faces south. This helps to keep temperatures down and prevent UV degradation. It is your decision how much effort and money you want to spend on environmental protection.

The use of polystyrene (absolutely not metal) is critical to the RF performance.

OPERATOR INTERFACE

You communicate with PicATUne using a single push on the Command Switch - while your transceiver is on receive.

PicATUne replies with a menu of choices - sent to your receiver in CW. Each choice consists of one character. A choice is picked from the menu by pressing the Command Switch during or immediately after the sending of the desired character.

PicATUne also communicates status information using CW - on request.

YOUR CONTRIBUTION

Besides building PicATUne, you will need to supply an HF Tx/Rx, an SWR bridge, 13-14v DC at about 1.5 amps, the antenna itself and a suitable length of 50Ω coax feeder from the shack to the remote ATU. Your Tx should be capable of delivering 5-10w of steady carrier for extended periods. (NB this project is not suitable for SWLs since you need to transmit and radiate to use PicATUne.)

WHAT'S IN A NAME?

BEFORE WE FILL the columns of 'The Last Word' with the semantics of "ATU" versus "ASTU" versus "AMU" - let me declare that PicATUne no more tunes your antenna than any other ATU. It only matches it. So, my apologies, but you have to agree that PicASTUne is not a very catchy name!

BETA TESTING

THIS PROJECT WAS BUILT by Alan G3TIE, David G4FQR and Keith G3OHN before publication - in order to verify the drawings and to demonstrate reproduceability. You can proceed with confidence!

REFERENCES

[1] 'Save Your Tuner for Two Pence', Tony Preedy, G3LNP *RadCom*, May 2000.

[2] 'Radio Data Reference Book', GR Jessop, G6JP and RS Hewes, G3TDR published by RSGB

PicATUne

- an intelligent antenna tuning unit

Part two, by Peter Rhodes, BSc, G3XJP

Issue 5.4 July 23rd

THIS MONTH concentrates on circuit diagrams - with the complete project components list. An assembly drawing is provided for context. Full construction detail is covered in later parts.

L-MATCH

THE HEART of the system is shown in **Fig 10**. The main coil of 63 turns is tapped so that using every combination of its switching relays, the coil can be switched from 0 to 63 turns in one turn increments. The location of the taps is such that those on the smallest number of turns are not adjacent. This reduces their mutual inductance and means the total inductance of the coil builds up rather more slowly from low values - effectively increasing the resolution at low inductances. Hence the 'strange' tap sequence on L1.

I still have a general unease about the effect on Q of shorting turns. Suffice it to say that it works well - and high power linear amplifier Pi networks have been doing it for years.

Even when the whole coil is shorted out, the inductance is not zero. Not only do the leads contribute, but the relay contacts themselves look remarkably like a small one turn coil when closed. Each relay contact is in fact two normally open contacts in series - arranged so that the two little coils they form are mutually opposing.

The same switching process is applied to the capacitors, giving a theoretical range of capacitance from 0 to 2047pf in 1pf increments. These values are definitely theoretical because there are also strays to consider; and the capacitors are home made so their values will not be (and need not be) exactly as shown.

I have found it completely impossible to source high voltage capacitors of a suitable Q at anything like an acceptable price. If you are contemplating genuine QRP operation only, you could try 500v silvered mica units connected in series-parallel combinations to give a 1kV rating.

Mine use a polyethylene dielectric with a nominal 6kV rating which will handle 200W into almost every real-world antenna - and 400W into many.

So that you don't find out the hard way, a spark gap is fitted. The gap is set as small as you can for your power and your antenna - but ultimately at absolutely no more than the breakdown voltage of your relays. Physically it is simply two stiff pieces of wire with the gap between them adjusted with a set of feeler gauges - reckoning the dielectric strength of air at 20v per thou ie 50 thou per kV.

For impedance switching purposes, either RL1 is closed for a low-Z antenna or RL2 is closed for a high-Z antenna. Both are left open for an antenna requiring only series L and both are closed for one requiring no matching (straight through) or only shunt C.

My output terminals TP1 and TP2 are low voltage 30A terminals. Given the polystyrene case, there is no requirement for anything more exotic. SK2 is fitted if you want to use a coax fed antenna, which by its nature will be already reasonably matched. It should have a good insulator such as PTFE to avoid the risk of voltage breakdown.

Although the L-match circuit looks simple enough, it occupies the vast majority of the RF deck board area.

RF DECK SENSOR SECTION

THIS PART of the board (**Fig 11**) has several purposes. The most significant surrounds the SWR head which comprises T1 and T2 with the coupled port terminated at 50Ω by R1 and R2/R3 in parallel. D24 detects any reflected voltage. The circuit was lifted directly from an article in Sprat [3] by Tony Lymer, GM0DHD - which in turn is based on the "Stockton Bridge" by Dave Stockton, GM4ZNX - and the original Quiet Tune work by Underhill and Lewis [4], referred to in 'Technical Topics' on several occasions [5].

It has two great virtues in this application.

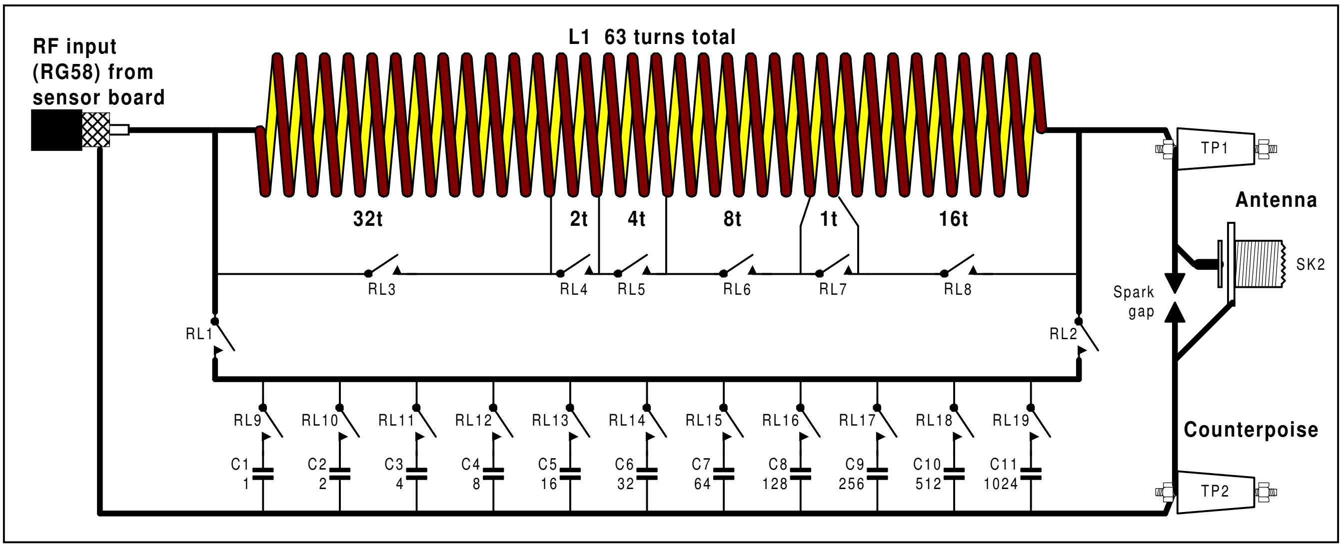

Fig 10: L-match section of RF deck circuit diagram. Note the explicit nature of the 'ground' return via the coax feed only. Details of the relays and their coil connections are provided later, but note that each contact shown is in fact two normally open contacts in series both to increase the breakdown voltage and to reduce capacitance across the contacts. Capacitor values C1-C11 are nominal.

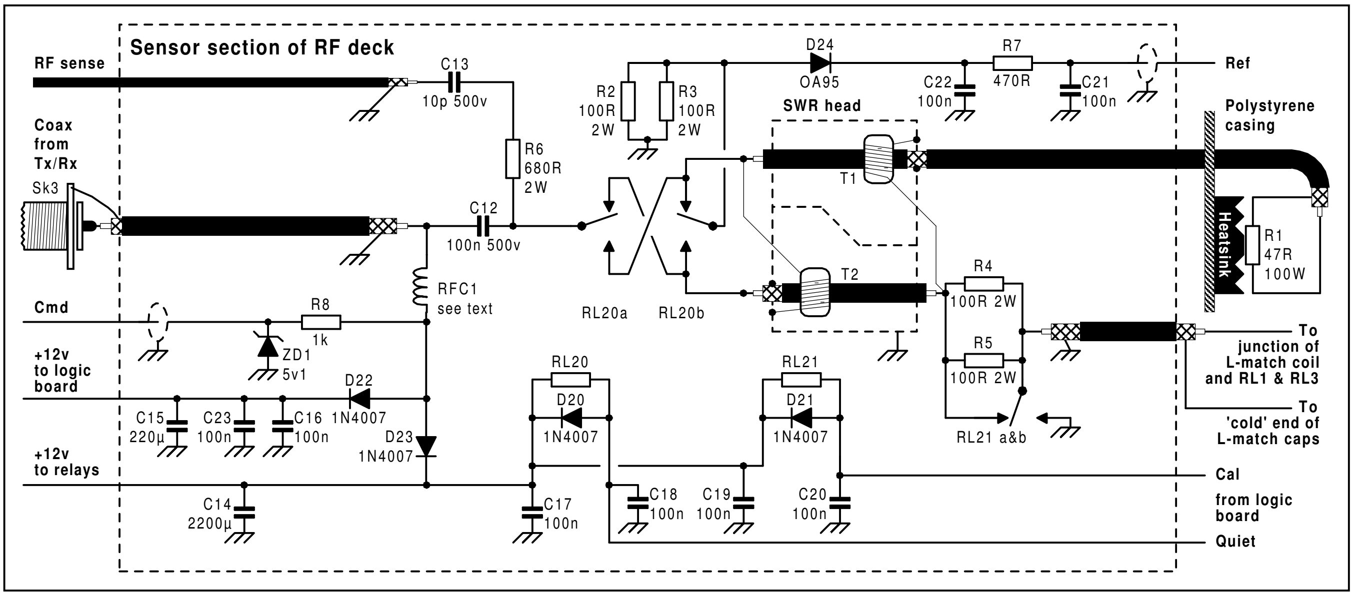

Fig 11: RF deck sensor section circuit diagram. The dummy load R1 is fitted outside the case to reduce internal heat dissipation and to minimise the case ' breathing' under thermal cycling.

Firstly, while searching for a match the Tx power delivered to the antenna is attenuated by 1/256 - so not much escapes! The balance is dissipated in R1.

Secondly - during matching - your Tx sees something very close to 50Ω irrespective of the state of the L-match and antenna combination.

This is a much healthier state of affairs than asking your Tx to look at a varying load during matching. It also means that there are no issues arising from your Tx throttling back under SWR protection - which in turn means that there is no requirement to measure forward power in order to find a matching solution. (If you were to measure forward power it would be substantially constant during matching - despite wild swings in the L and C values.)

This requires only that you don' t gratuitously alter the Tx output power during the matching process - which is not an unreasonable request. So, the usual diode to detect forward power is omitted - and so ' SWR head' is technically a misnomer.

R1 (non-inductive thick film technology) - and its heatsink - needs to dissipate the full Tx power while searching for a match. This is typically 10W but you also need a safety margin. It can also be used as a conventional dummy load. I fitted 200W dissipation capability to stress the system, but 100W would be more than adequate for most purposes. Your decision.

Next is the RF sense lead. This simply taps off a sniff of RF to allow the PIC to determine when the Tx is on. The values of R6 and C13 are somewhat critical in allowing the PIC to discriminate between no transmission and extreme QRP operation across the whole HF spectrum - while not saturating at higher power levels.

This is one of those annoying situations where although you know perfectly well whether you are transmitting or not, the PIC doesn' t! RF sense is also used to measure Tx frequency - and status messages are also fed back to your Rx via this line.

The command (Cmd) line is DC coupled all the way back to your Command Unit and is used by the PIC to sense Command Switch operation. ZD1 makes sure the line to the PIC does not exceed specification. D22 and D23 allow DC power to reach the PIC and relays - which survive on the energy stored in C15 and C14 respectively during Command Switch transients.

The Cal relay, associated with R4/R5 allows a 50Ω load to be substituted for the L-match and antenna, giving the PIC the opportunity to calibrate zero reflected power on the actual frequency and at the actual power level being used on every occasion. It also lets the PIC ground the L-match/antenna to seriously attenuate any incoming signals so that they do not swamp any status messages being sent to your Rx at the time. And equally, this prevents status messages from being broadcast.

The less than obvious configuration of the changeover contacts was adopted to make sure that there is always a reasonable load presented to your Tx even during the switching time of the relay. The two sets of changeover contacts are wired in parallel only because they are there.

LOGIC BOARD

THE HARDWARE of the logic board (see **Fig 12**) is truly unremarkable in the sense that the same board is suitable for my central heating controller, vox unit, burglar alarm etc - with IC3-IC6 variously removed as required by the scale of the application.

The operation of the various I/O lines is discussed because in the event of any problems, their behaviour is observable on a ' scope.

The Cmd line is routed to the interrupt pin so that operator commands get priority.

The RF Sense line goes to both RB4 - where any change causes an interrupt - and to the real time clock register for frequency counting purposes.

By a strange quirk of fate, on the one day in the 18 month development when I had just finished a 50MHz prescaler, Ed, EI9GQ pointed out to me that the PIC already contains that capability.

The small issue is that you cannot read the internal prescaler from the software. Its somewhat like trying to measure the amount of water in a bucket when you are not allowed to simply pour that water into a measuring jug. The workaround is to pour some other water into the jug, then pour that into the bucket and wait for the bucket to overflow. Given you know the capacity of the bucket, you can then compute how much water was in it in the first place - by simple subtraction.

To count RF cycles, both RB4 and RA4/RTCC are set as input pins for the counting gate time - in this case 400µS - at the end of which RB4 is changed to an output pin to freeze the count. RB4 is then toggled high/low until the main counter register changes. This happens because the prescaler finally overflows. Knowing how many times RB4 was toggled, the value of the 8 most significant bits in the main counter as well as the 8 least significant bits in its prescaler are determined, giving a count with 16 bits resolution and an error of ± 1 count. One expensive prescaler chip saved!

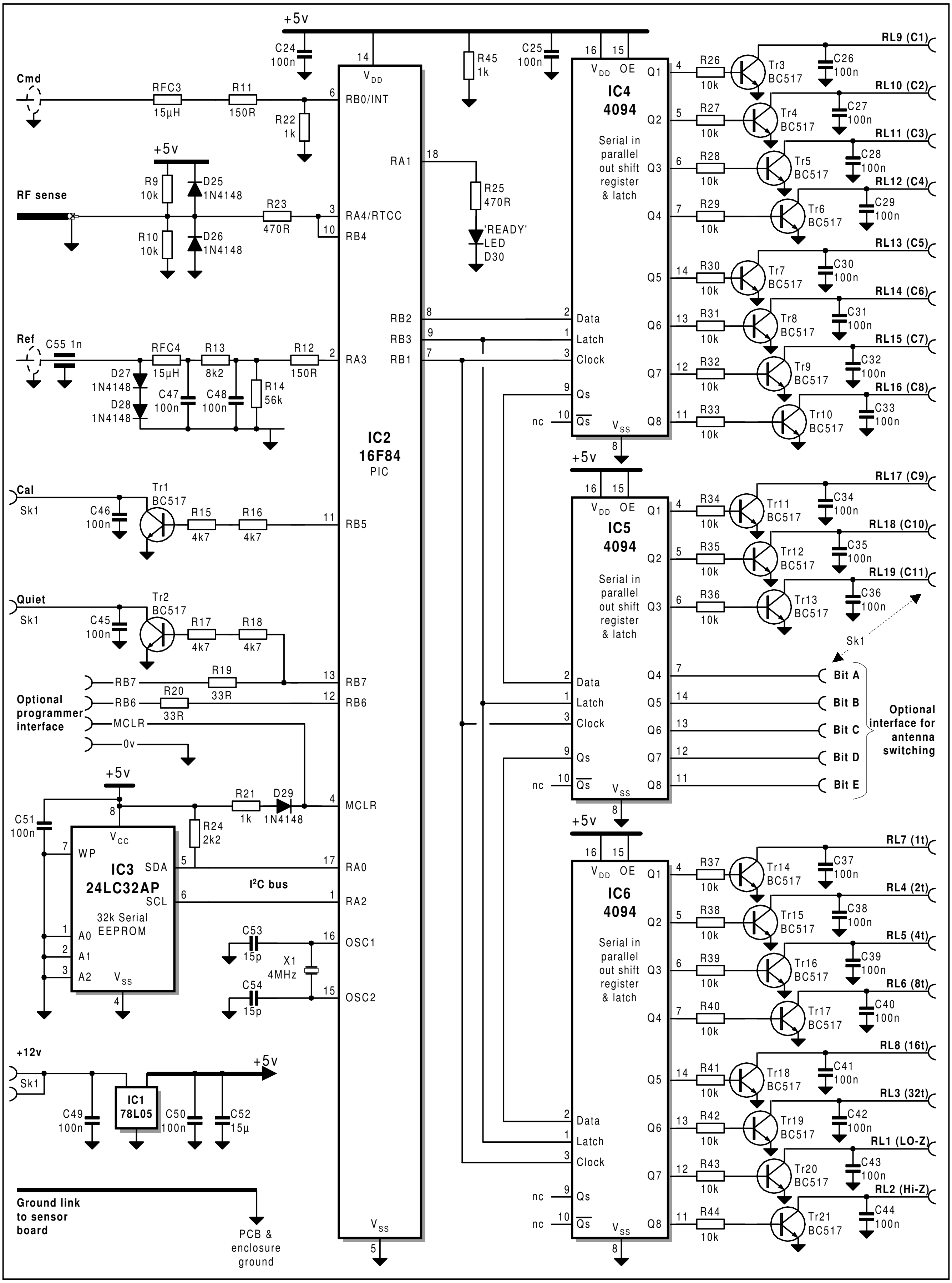

Fig 12: Logic board circuit diagram **The PCB is assembled into an enclosure with a ground link to the sensor section of the main RF deck. If *in-situ* programming of the PIC is not required, R19 and R20 may be omitted. Both the PIC and the serial EEPROM require programming before use. The optional antenna switching interface is discussed in the text.**

The Ref input is a DC level representing reflected power. It is filtered and integrated by the various CR combinations. To be of any use, it needs to be digitised - and the traditional solution is an A/D converter, either a separate chip or a totally different PIC with built-in A/D.

However in this case, adapting an idea from Peter Grigson, G0TLE [6], the RA3 pin is normally set as an input. When a reflected power measurement is required, RA3 is changed to an output pin, pulsed high and then instantly reconfigured as an input pin. The time taken for RA3 to fall below the ' 1' threshold is then determined, giving a measure of the voltage across C48. The width of the high pulse on RA3 is adjusted with the Cal relay energised - and therefore no reflected power - to calibrate the zero point.

The process is crude but effective, given the requirement is only to determine the direction of change as the L and C values are altered. One A/D converter saved!

The Cal and Quiet outputs are driven directly from the PIC in order to get at them quickly. All other switching outputs go via IC4-6 and are subject to the delay of serially clocking 24 bits into these registers - before they are actioned by pulsing the latch line. Discrete transistor drivers were used because I could not get the same packing density using IC drivers.

The five output bits A-E are included to allow external switching. Bit A may be set or cleared by you from the Command Unit at any time. Bits B-E are set automatically by which band you are on. You can configure which bands set which bits. More about this later, but it is a feature envisaged for applications such as feeding stacked monoband antennas from one coax feed to a PicATUne mounted at the mast head. If you require this feature, the outputs would typically go to transistor relay drivers just like the other outputs. Provision is made on the PCB for their inclusion.

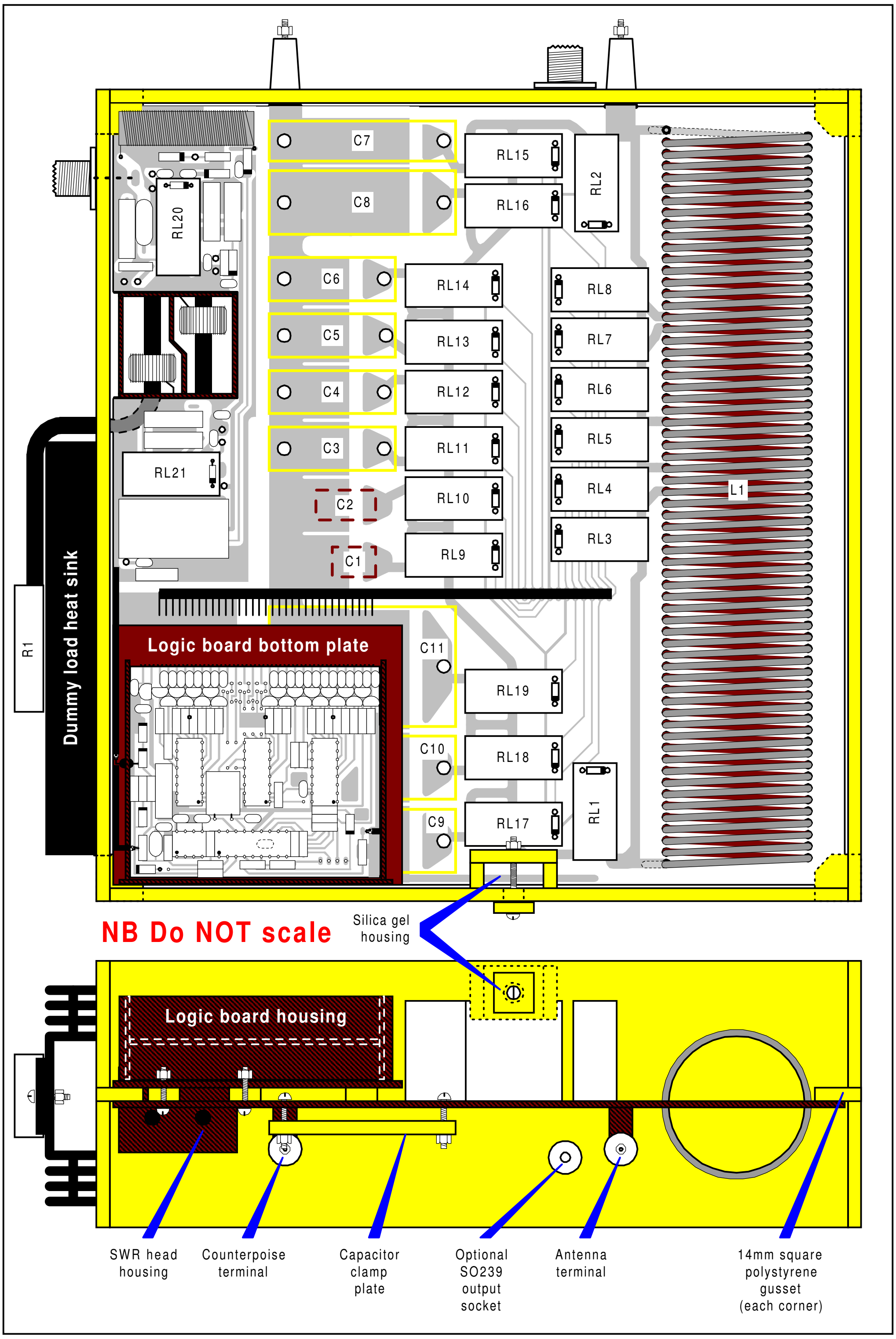

Fig 13: Half scale assembly drawing of RF deck in its polystyrene enclosure, viewed from the component side. Also shown are the component locations and references for the L-match section. Not illustrated is the top screening plate on the logic board or those on the top and bottom of the SWR head. Note that in all cases the diodes are wired directly across the relay coil terminals. Diode references are the same as the corresponding relay eg D17 is across RL17 coil etc. The antenna and counterpoise terminals are connected to the PCB by short stubs of PCB material soldered at right angles to the main board.

The ' Ready' LED is useful during commissioning and can be seen with an average pair of binoculars from 100m at night. It is there for confidence that all is well, and lights when PicATUne is waiting patiently for you to do something different. Such as press the Command Switch or change from Tx to Rx or vice versa. During speech or CW it flashes off and on once per ' Restore from Before' software cycle ie about 10 times per second.

Finally, IC3 the 32k serial EEPROM. This stores all the matching solutions indexed by frequency, your configuration options, band edge markers and CW messages. A standard serial bus protocol passes all the address and data bytes across the SDA line, clocked by SCL.

OVERALL ASSEMBLY

IN ORDER TO give you an early feel for the appearance of PicATUne, **Fig 13** illustrates the RF deck in its polystyrene enclosure. The top and bottom enclosure plates are not shown. These are simply further sheets of 4mm polystyrene some 5cm larger than the case all round - and are clamped up externally to the enclosure with some brass nuts and studding - having first run a fillet of bathroom sealant around each lip. They also have mounting points, reinforced as necessary to your requirements.

The orientation of the assembly in service is not critical, but is envisaged with the coil at the top and the input connector and dummy load at the bottom; mounted either on a vertical face or mast.

COMPONENTS LIST

Capacitors

C1-C11, home made comprising:-
M3 x 12mm nylon screws .... 25 approx
M3 nylon nuts .... 25 approx
Tesco large freezer bags .... 1 box
DC4 grease .... 1 tube
Brass shim .... 3 sheets 10"x 4"x 5 thou
(also used to make covers for SWR head and logic board assy)
C12, C56 .... 100n 500v
C13 .... 10p 500v silvered mica
C14 .... 2200µF 16v axial electrolytic
C15 .... 220µF 16v axial electrolytic
C16-C51, C57, C58 (38 off) .... 100n 20v disc ceramic or monolithic
C52 .... 15µF 10v axial electrolytic
C53,C54 .... 15p ceramic plate
C55 .... 1n feedthrough

Diodes

D1-D23, D31 .... 1N4007 or similar
D24 .... OA95
D25-29 .... 1N4148 or similar
D30 .... 'READY' LED
D32 .... 'MATCH COMPLETE' LED
ZD1 .... 5v1 250mW

Inductors

L1 .... 250g 2mm enam copper (see text)
RFC1, RFC2 .... 3/8" (10mm) dia ferrite rod x approx 1.5in long. Fully wind with 1 layer of 28SWG enam copper.
RFC3, RFC4 .... 15µH axial choke
T1, T2 .... each 16t of 24SWG enam on Fair-Rite 61001101 ring

Resistors 1/8-1/4W, 5-10% unless specified

R1 .... 47R 100W non-inductive. See text
R2-R5 .... 100R 2W carbon
R6 .... 680R 2W carbon
R7, R23, R25, R46 .... 470R
R8, R21, R22, R45 .... 1k
R11,12 .... 150R
R13 .... 8k2
R14 .... 56k
R15-18 .... 4k7
R19,20 .... 33R
R24, R48 .... 2k2
R26-44, R9, R10 (21 off) 10k
R47 .... 100k

Relays - all purchased identical

See text. All have 12v coil, approx 250Ω
RL1-RL19 .... DPCO modified to SPNO
RL20, RL21 .... DPCO unmodified

Semiconductors

IC1 .... 78L05
IC2 .... 16F84-04/P PIC
IC3 .... 24LC32AP 32k Serial EEPROM
both IC2 and IC3 need to be programmed.
IC4-IC6 4094
Tr1-Tr21 .... BC517
Tr22 .... BC516

Misc

Choke balun .... 23 turns of RG58 round 4 x 10mm ferrite rods, 145mm long. See text
Sk1 .... 28-way SIL wire-wrap socket strip
Pl1 .... 28-way SIL mating plug strip
Sk2 ...... optional coax output SO239 round with PTFE insulation
Sk3 .... coax input SO239 round
Sw1 .... SPCO break before make, 1.5A non-latching, click action, push button
TP1, TP2 .... 30A terminal posts
X1 .... 4MHz wire lead crystal
RG58 coax .... approx 0.5m
Min coax .... approx 0.5m
Min screened audio lead .... approx 0.5m
Screened box and connector
.... for Command Unit
Heatsink for R1 .... 0.7°C/W. See text
8 pin DIL turned pin socket .... 1 off
16 pin DIL turned pin socket .... 3 off
18 pin DIL turned pin socket .... 1 off
Single-sided fibreglass PCB
.... 233.4 x 220mm (double Eurocard)
Some double sided PCB for logic board and some screen partitions. Preferably not fibreglass.
Polystyrene 4mm sheet for casing and capacitor clamps. See text.
Polystyrene cement .... 1 tube
Heat transfer compound for R1
Silicone bath sealant, silica gel and brass studding, nuts, washers for sealed casing

SUPPLIERS

The relays (60-4610) and the double Eurocard PCB (34-0815) were purchased from Rapid Electronics Ltd, Heckworth Close, Colchester, Essex CO4 4TB, Tel 01206 751166.

2mm wire for L1 is available in 500g reels from Scientific Wire Co Ltd, 18 Raven Rd., London E18 1HW. Tel 0181 5050002.

4mm polystyrene sheet is available from most DIY stores. Brass shim is available in model shops. DC4 grease, M3 nylon screws & nuts and R1 are available from Farnell as are the PIC and EEPROM. If you want them programmed with my software, then I would be happy to supply them for £15 with an SAE.

If you were to purchase all the components from new at full retail price, you should budget about £100.

TEST EQUIPMENT

THE ONLY EXCEPTIONAL requirement is for a capacitance meter with 1pf discrimination in the range 10-3000pf. This is needed to build capacitors C1-C11. The capacitance range on a digital multimeter is ideal. Absolute accuracy is not important, but repeatability is. If you don't have such an instrument, one suggestion from David, G4FQR is to use the capacitors as the frequency determining element of a simple audio oscillator (eg NE555) and measure the resultant frequency.

REFERENCES

[3] 'Sprat', Issue No. 97, Winter 1998/9
[4] 'Electronics Letters', Underhill & Lewis, 4/1/79
[5] 'Technical Topics', Pat Hawker, G3VA *RadCom*, Oct 1987 and Feb 1988
[6] The 'Backpacker QRP Transceiver' by Peter Grigson, G0TLE, *RadCom* Nov 1998

PicATUne

- an intelligent antenna tuning unit

Part three, by Peter Rhodes, BSc, G3XJP

Issue 6.4 Aug 18

THIS MONTH the overall approach to constructing PicATUne is outlined along with specific details and techniques for building the RF deck.

COMMAND UNIT

THIS IS the shack end of PicATUne and as you can see from **Fig 14**, it is not very elaborate. Its purpose is to route DC power up the coax to the remote ATU. The operation of Sw1, the Command Switch, may look obtuse, since it evidently does the same job in both switch positions. The secret lies in the brief break in supply during the changeover period. This break is detected by the PIC in the ATU and interpreted as a command.

Constructional detail is left to you. It should be built into a screened box. You may also want to take the opportunity of fitting a power on/off switch.

It is however very important that this unit be fitted last in the coax line up to the ATU since many SWR bridges, power meters and coax switches could be damaged if you apply DC power to them via the coax inner. To prevent you from ever fitting the unit the 'wrong way round' I suggest you wire the coax to the Tx/Rx as a flying lead and fit a connector for the lead to the ATU - as illustrated.

CONSTRUCTION STRATEGY

THE CORRECT construction sequence for building the RF deck is important - and not intuitive. Specific details for each step follow as required.

The first task is to wind the main L-match coil, L1. This then allows you to correctly locate and drill its mounting holes on the main PCB.

Make a start on modifying the relays. This is a somewhat boring task, so depending on your attitude to such things you may want to set a target of doing, say, 5 a day at about 5 minutes each; there are 19 to do - so you get an early finish on the last day.

Then manufacture the RF deck PCB, fit L1 to the board and complete the population of the board - with the specific exception of capacitors C1-C11.

You can also build the Command Unit; and start to slowly build the 4-sided polystyrene housing. Slowly, so that you don't get impatient waiting for glue to set.

Also build the logic board and fully populate it. The functionality of the PIC on this board can be independently tested.

Fit the main PCB to the polystyrene housing. Fit also the input and output connectors and the dummy load.

Now build and trim the L-match capacitors. You should allow about 2 days for this.

Then mount the logic board on the main PCB, complete all the interstage wiring, and you are ready for commissioning.

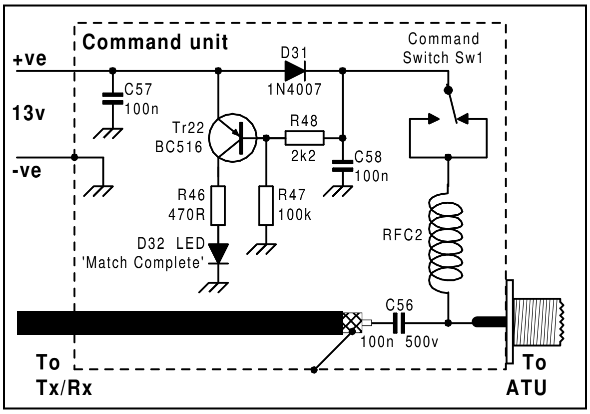

Fig 14: Command Unit circuit diagram. This unit goes in the shack 'in series' with the coax feed to the remote ATU.

WINDING L1

THE SPECIFIED 250g reel gives little margin for waste, so don't be generous with the ends.

Clamp the free end of the reel in a bench vice or similar, pass a screwdriver blade through the reel centre hole and walk away, unreeling (absolutely not unwinding) the entire length (about 8.75m) in a straight line.

Take a tubular mandrel at least 35cm long by 40-43mm outside diameter (eg waste pipe, scaffold pole etc). 43mm is ideal. Drill a 2.5mm hole about 20mm from one end. Pass the wire through the hole and bend back about 3cm.

Keeping the wire under tension using your body weight, wind on about 5 turns, close spaced. The winding sense (left/right hand thread) does not matter. Then apply as much pull as you and the far support will stand. This will help to take any slight kinks out of the wire and tighten up the existing turns. You may care to sit down first to do this since the risk of injury from enforced sitting is considerable.

Wind on the remaining length. You may find it easier to maintain tension by facing away from the far mounting point with the wire passing under your arm - leaning forwards and walking backwards.

If you are using a 43mm OD mandrel you will have to work hard to get 63 turns out of 250g. Keep giving it a good pull after every few turns and if you are not out of breath at the end, you are pretty fit.

Release the far end and let the coil spring out. Check that the achieved ID is between 42-46mm. Gently stretch the length to about 22cm by pulling the ends apart. Now count the complete turns and trim both ends to give exactly 63 full turns plus an extra 1cm (or so) for making off the ends. File back the diameter of the ends since the act of cutting will inevitably have crushed them. Finally, remove the enamel for about 5mm both ends.

You can now lay off the achieved L1 diameter onto the main PCB by adjusting the location of the 63 holes nearest the board edge. Note that this row of holes is displaced from the inner row (of 64 holes) by half the distance between adjacent holes - to give the required helix.

PCB TECHNOLOGY

THE RF DECK AND logic board are quite different in nature and are probably amenable to different approaches.

One of the rewarding features of my two previous articles was the amount of feedback I got from people who had tackled a major project for the first time - with the satisfaction of not using a commercial board. So I make no apologies for elaborating a further approach to one-off board manufacture which is suitable for the style of board used in this project - and many others. The devil is in the detail.

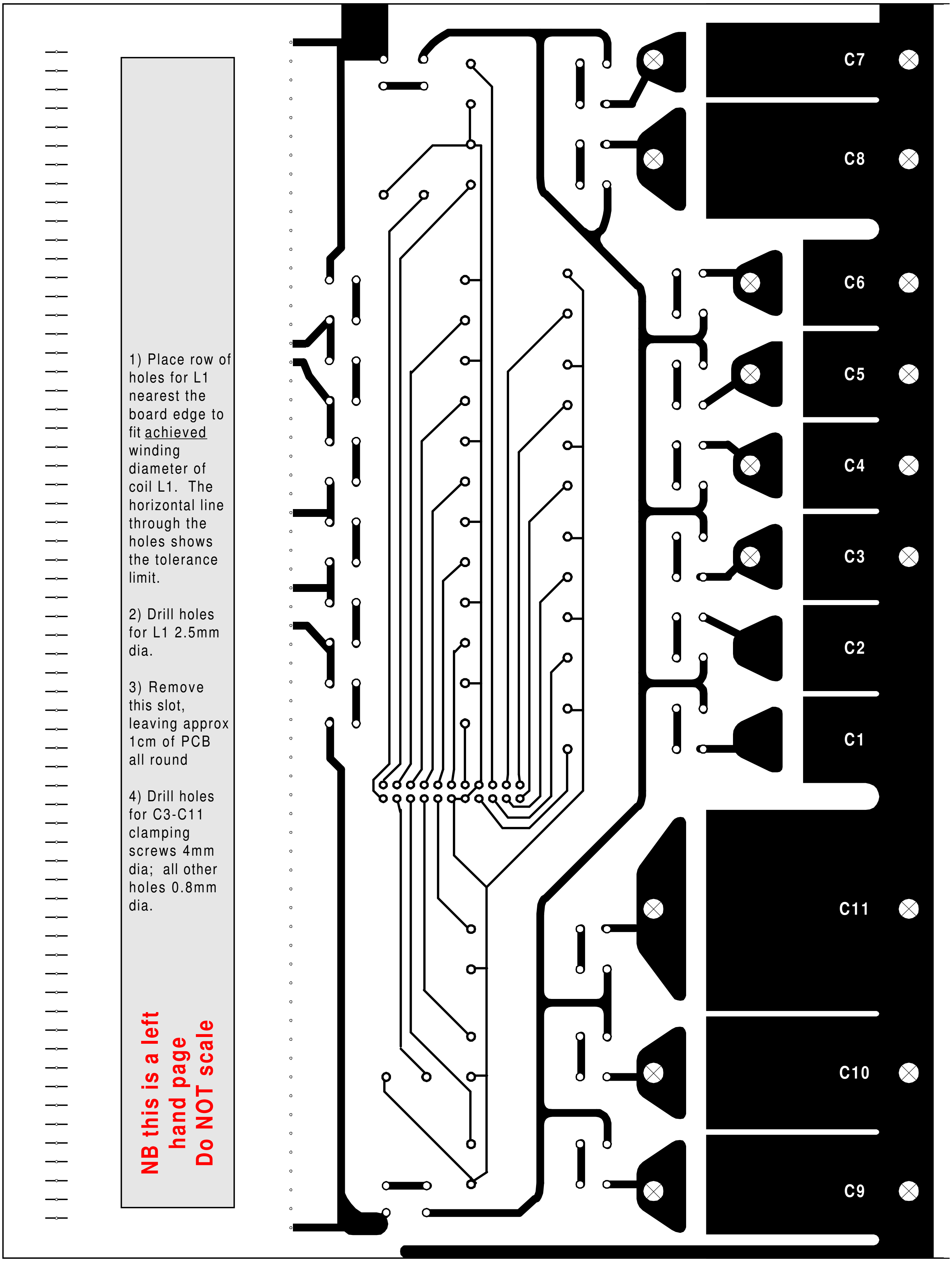

Fig 15: L-match section of RF deck PCB. The illustration edge is also the PCB edge except on the right hand side. The PCB artwork continues on the page opposite with a fully etched gap between the two sections. See text for discussion of etching issues.

MAKING THE RF DECK PCB

THIS IS A LARGE BOARD (see **Figs 15** and **16**). So the first issue is that it may not fit your UV exposure box (but you don' t need one) or your usual etching tray. If necessary, the board can be cut (there are several obvious places) and rejoined with epoxy resin later. But you are still left with the longest dimension intact.

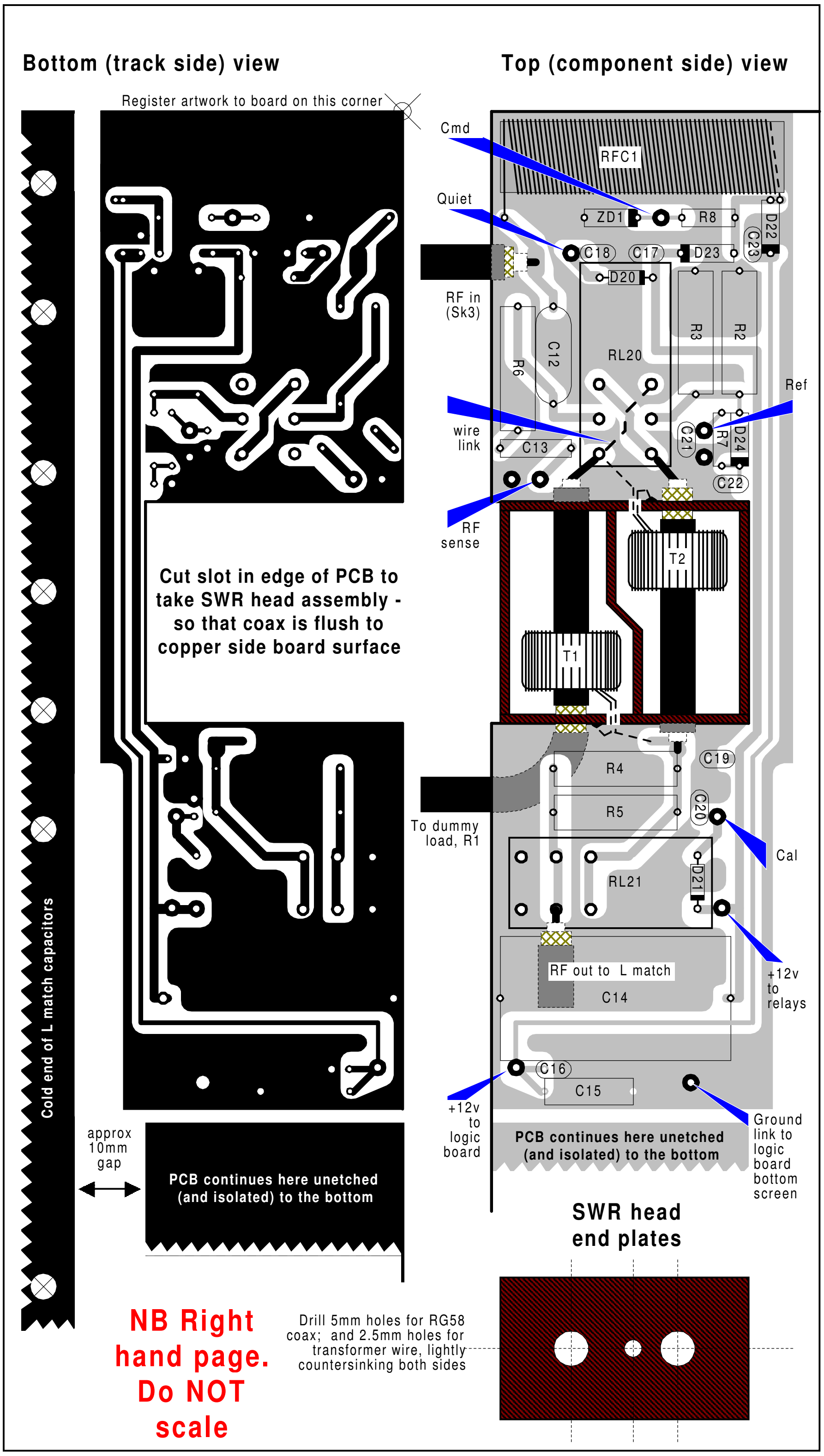

Fig 16: Sensor section of RF deck PCB. Note that all the coax cables are fitted on the underside (track side) of the board. Bond RFC1 to board after fitting board to casing.

Garden centres have trays which are large enough for etching. Photographic developing trays, old oven trays, cat litter boxes also spring to mind. If you get really stuck you could use the final casing (4 sides and a base) thereby testing its environmental integrity.

The second issue is that there is a lot of copper contrast from large fully etched areas through quite fine lines to large unetched areas. These arise from RF design practice and a desire to achieve minimal residual capacitance. You would be very brave to attempt to etch all this in one pass through the etch tray.

Let me describe how I did it as a three stage process without cutting the board - but with no claim that this is the only possible approach.

Firstly, centre punch all the holes through from the artwork and drill them with a 0.8mm bit. This is the finished hole size for most holes and a pilot hole for others.

At this point I took the opportunity to make a start on the polystyrene capacitor clamp plates. Clamp a strip of polystyrene sheet (226x55mm) to the board with some scrap wood backing. Register it centrally to the board edges and the holes for C11. Then drill the holes for all the capacitors at 0.8mm through the polystyrene using the board as a template - and then again using a 4mm HSS bit. This gives final size holes in both the board and polystyrene.

A note on drilling polystyrene. Always use a soft wood backing. Use a sharp bit, slow speed and light pressure - otherwise you will melt the hole rather than drill it. Clear the swarf from the flutes frequently or it will fuse to the drill leaving you with a polystyrene rod.

Now cut the slots in the board for the SWR head and under L1. The latter, by the way, is because no effort should be spared in the quest to keep the Q of L1 as high as possible.

At this point I lowered the L1 edge of the board into some old room temperature etching solution - not quite up to the inner row of holes - and went to bed. In the morning, the vast majority of the copper was gone and the solution was totally exhausted. Use this doubtful practice only when there is no possibility of overetching. Keith, G3OHN recommends scoring the board into 1cm strips and then pulling off the copper with some thin nosed pliers while applying heat with a large soldering iron. That completes stage 1, a crude etch to chunk off the big area of copper around L1. Stage 2 is slightly less crude - to remove other large areas of copper.

Lightly rub over the board with some fine wet and dry (used wet with a drop of washing up liquid) until the board has a lightly scratched - but absolutely not polished - finish. Rinse thoroughly under the hot tap and air dry.

Using matt black spray paint, give the board two light even coats of paint, letting it dry in between coats. At this point there should be no copper sheen showing through the paint.

Register and tape a copy of the artwork to the PCB. Using a craft knife, cut out areas on the artwork where you are confident no copper is to remain - playing it safe. Any area with one dimension greater than about 3mm is a fair target. Can I emphasise, this is not a precision process so do not waste time by overelaborating it. Cut right through to mark the paint and reinforce the marking with a pencil if necessary. Remove the destroyed art work.

Using a sharp chisel shaped blade about 2-3mm across, crudely remove the paint from the defined areas. You don' t need to get absolutely all the paint off, just enough so that the etchant will get a good first look at the larger areas.

Now etch the board. Slight underetching is acceptable, because it is going to get another dip later.

Clean off all the paint using cellulose thinners. Make sure you get it all off or it will resist the final etch. Give the board a light rub over with wet and dry again just to be sure.

Now 'back to the drawing board'. Draw in all the wanted track/areas using an indelible waterproof pen. Most stationery shops stock the Staedtler Lumocolor Permanent Black, 317 (Medium) and 318 (Fine). Some other colours do not work - and I have consistently had worse results using an 'etch resist pen'. As long as you join up the right dots roughly following the layout, you won't go wrong; but keep the DC leads to the L-match relays as far from the wider RF tracking as you can. Making it look beautiful is another dimension which is down to your personal taste. By the way, I also used cellulose paint with a brush to rapidly cover the larger areas.

Using the indelible pen, there is a definite technique you need to use. That is, you do not 'float' the ink onto the board - which is particularly easy with a new pen. You have to continuously press quite hard and rub the ink on with the nib - in order to get etchant-proof adhesion to the board. It should feel like trying to write with an empty biro on greaseproof paper.

Now give the board its final etch. Do not raise the etchant temperature to the point where there is visible steam or it can leach under the ink. And if there was ever a moment to use new etching solution, this is it.

RELAY MODIFICATION

IF YOU USE the relays I have specified, then 19 of them will need modifying. **Fig 17** shows the general picture. See also the assembly drawing in Part 2, Fig 13. Note that the protective diodes are not all physically the same way round, but the cathode is always connected to the common +12v rail.

REMOVING THE RELAY CASE

The first task is to remove the relay case. It is glued to the base with a weak adhesive.

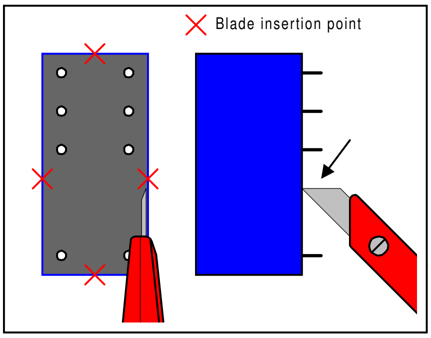

Fig 18: Relay modification, removing the case.

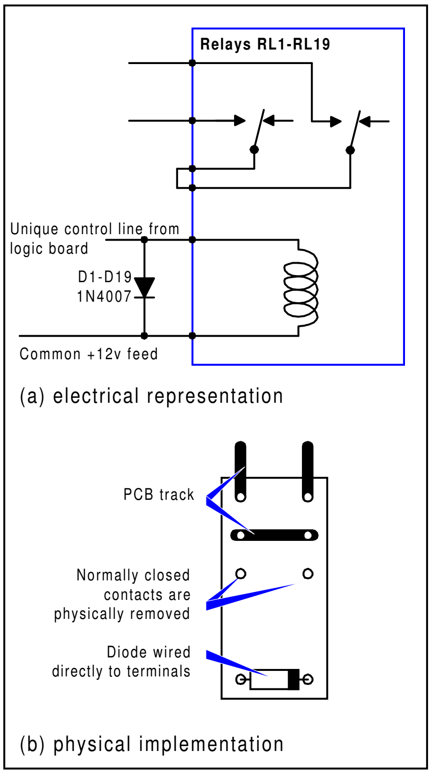

Fig 17: L-match relay detail. Starting with 2-pole changeover the relay is modified and wired to give a logical single-pole normally open contact.

Start on a long edge. Holding the relay firmly on a flat surface with the base vertical, insert the point of a craft knife into the meniscus formed by the adhesive around the base. Press firmly in and down and the adhesive will split. See **Fig 18**. Run the blade all the way down to the corner, turn the relay the other way up and again run the blade to the corner. Repeat for the other long edge and then the two shorter ones. After that, the base should lever out using the point of the blade with no effort. If it does not, the predictable cause is that you have not split the adhesive all the way to the corners - in both directions.

Splitting the case can easily happen and it doesn't matter - so long as you keep the cases and bases paired together. Note that the case goes back on with the small vent hole over the contacts. Some come apart more easily than others but I succeeded with little persistence on my first and only batch of 19 attempts.

REMOVING THE CONTACTS

Grip the relay base in a vice. Using a soldering iron (very hot, if you have the choice) apply heat to the pin of the normally closed (largest) contact - using some solder to ensure thermal transfer. Count to about 10 (you will determine your own figure) and then quickly grab the contact arm near the contact with a pair of thin nosed pliers - and firmly pull it out sideways from the relay.

If there is any substantial resistance, it is not hot enough. The contact arm will melt its way through the base material which, being thermoplastic, will largely self-heal. Turn the relay over and repeat for the normally closed contact on the other side. Check the alignment of the remaining contacts. Apply 12v to the coil and verify operation, because it is never easy to remove relays from PCBs if you get problems subsequently. Replace the case (with a little click). I did not reglue them since the case is not sealed anyway.

When you get numb with boredom doing all this, remember that you have probably saved yourself between £200-£500 on real relays.

FITTING L1 TO THE PCB

BEFORE ATTEMPTING to fit L1, the coil must be finished in every other respect - ie 63 full turns (plus a few mm for the end connections). The holes in the PCB must also have been drilled to suit your achieved coil diameter. If there is a significant error on the latter the coil will bind as you try to screw it into the holes - and in the worst case you could end up with insufficient turns. The PCB itself should be fully etched but unpopulated.

Clamp the board securely in a vice and determine which end feels most comfortable to screw the coil in from - this probably varies between left and right handed people.

Offer the coil to the board, passing the leading end of the wire through the end hole in the inner row. The direction through the hole will be determined by the sense in which you wound the coil in the first place - and is unimportant.

Start screwing the coil into the holes, supporting its weight with one hand and with the other, hold the coil with your fingers inside, thumb outside. The first few turns are awkward and two pairs of hands are useful.

Thereafter, feed no more than a couple of centimetres at a time into the starting hole - and work it along the length of the coil. If it binds, it will be because the PCB is forming a chord to the coil circle instead of the diameter. Or because you are feeding a different length out of the free end than you are inserting into the coil at the other. Either way, sighting along the axis of the coil can be useful and a little pulling and pushing will clear it. If the board starts to buckle, this is an extreme symptom with the same causes. Do not be tempted to use any form of lubrication. There is a definite knack to it and, as ever, you will have acquired it by the time you have finished!

Screw the coil in until all turns are in and the ends are at the ends, so to speak. Now you know that these two end points on the coil are in the correct place - and why it was so important to start off with the correct size of coil in the first place.

One end will arrive at the copper side through a hole, the other end from above; the hole at this latter end is not used. For each end, bend it through a right angle - and while holding the plane of the end turn at right angles to the board, solder it to the board, using a large soldering iron.

Now adjust all the other turns for an even appearance - as viewed from any and every direction.

Then solder the taps on the coil to the PCB track, starting near the middle of the coil and working out towards the ends. Pull the wire through the hole somewhat to improve access and remove the enamel on the outer diameter with a craft knife. Tin the wire, readjust its position relative to the hole, adjust the angle of the turn and solder to the track.

When all the taps have been soldered, make any final adjustments to the remaining turns and then apply some epoxy resin to all the coil holes - on one side of the board only. Probably the best way is to mix the resin with a nail, and then use the nail to draw out a thread of resin which you let drop across the wire where it enters the holes.

Once the resin has been applied, place the board so that gravity acts to flow the resin into the holes. Fit some temporary spacers between any deviant turns and leave to cure overnight. You will then find that the coil and that end of the board has acquired substantial mechanically stiffness - having effectively applied 63 triangulating struts to the PCB.

The result will be a truly fine nearly air-spaced coil of great beauty. Can you imagine the mass production costs of making something so wonderful?

BUILDING THE SWR HEAD

FIT THE SWR HEAD only after all other components have been fitted to the sensor section of the board.

Symmetry is the keynote throughout. Start by making the two end-plates of the SWR head enclosure from double-sided PCB as per the template in **Fig 16**.

Cut out also two side plates and, making sure it fits the slot cut-out in the main PCB, assemble into a four-sided box - seam soldering the internal corners. Note that although the two end-plates are identical, they are fitted mirrored so that the offset hole near the centre of each end-plate is not opposite its partner.

Fit the box to the board, checking that it is the correct way up as per the drawing and so that the edges of the holes for the coax are flush with the copper side track.

NB Because of the inherent symmetry, it is very easy in this and subsequent steps to 'get things the wrong way round'. Always look at the board from the component side and compare with the component side view in Fig 16.

When you are satisfied, seam solder the enclosure into position.

Start with the shorter length of RG58, the one passing through T2. Prepare the ungrounded end leaving as little braid showing as possible. Pass the coax through both holes and cut off to the required length, making an allowance for the slight bending of the inner at each end. Score the sheath at the grounded end just inside the enclosure. Withdraw the coax and fully prepare the grounded end, leaving enough braid exposed to solder to both the inside and outside of the enclosure.

Note that whatever else happens, each piece of coax is grounded at one end only.

Repeat a similar (but pretty well opposite order) process for the longer piece of coax through T1. Make sure you leave plenty of surplus length to reach your dummy load. In this case, prepare the grounded end first. Cut off a ring of sheath about 5mm long some 5cm from one end. Pass the coax through its holes and cut to length. Score the sheath 2mm outside the box, remove the coax and prepare the ungrounded end.

Wind the two transformers, T1 and T2, spacing the turns evenly around the torroid. Put two twists in the leads to stabilise the winding.

Offer T2 up to the enclosure, passing both wires through their hole. Using a length of scrap RG58 to centre the torroid, locate it about 5mm from the end-plate inner wall. Trim one of its leads to ground to the outer wall, the other to the track - as per the drawing. Note that the sense of these windings is important, but wire them at random at this stage. Simply leave enough length on the leads so that they can be swapped over later if needed.

Withdraw the coax, then the torroid and bare and tin its leads. Refit as above - but this time, use the prepared piece of coax. Solder into position both torroid leads and both coax inners - and the braid of the coax to the inner and outer screen walls.

Now cut and bend a piece of brass shim to form the internal divider (full height of the box) and solder it in position.

After first ensuring the cross-connecting wire link on RL20 is in position, repeat the above process to fit T1 and its associated coax.

Cut and bend a further piece of brass shim to form either a top or bottom cover - with external lips - and seam solder it in position to the outer of all four enclosure walls. The other cover may be left until after initial testing - to maintain interim access - and then finally soldered at four points only to maintain emergency access thereafter.

NEXT MONTH

CONCLUDES the build phase and covers early testing.

PicATUne

- an intelligent antenna tuning unit

Part four, by Peter Rhodes, BSc, G3XJP

Issue 4.4 Aug 18

THIS MONTH concludes the construction phase with the building of the case, the logic board, the system wiring and the capacitors.

BUILDING THE CASE

THE POLYSTYRENE CASE comprises four sides, each 8cm high - and a top and bottom cover. The sides are glued together with polystyrene cement. The top and bottom covers are not built until after final test. They have a 5cm external lip all round and are clamped together by bolts passing outside the enclosure.

Allow at least a 1mm tolerance gap all round to the RF deck and cut the four side panels accordingly. I used 244 x 80mm and 222 x 80mm, both twice.

I butt jointed the corners and also cut in a 14mm square fillet half way up each side at each corner. With hindsight, this latter was probably not too good an idea since it adds another environmental leak risk, but at the time I was unsure of the bonding strength and wanted to add more rigidity. I suggest you simply glue in a 10mm square fillet to each internal corner. The component side of the RF deck rests on these, secured with M3 nylon nuts and screws as required.

Using emery, remove the polished finish from the polystyrene where it is to be glued; ensure you allow for the joints to be butted the right way round. Glue together the sides firstly into two pairs of Ls, including the gusset - and when set, into a square. Do not attempt it in one go! A polyethylene bag over a finger tip helps to draw out a clean fillet and ensures there are no gaps either internally or externally.

Radius the corners of the RF deck and fit to the case, with the component side resting on the gussets. At this stage RFC1 can be bonded to the board, clearing the gusset.

Make up some means of housing some silica gel. **Fig 19** shows a suggested approach. It is mounted above RL17 on the casing wall. The nylon gauze referred to in the caption is the engineering term for lady's tights.

Take two pieces of PCB about 3 x 1cm and solder them at right angles to the board to pick up the track to the antenna and counterpoise terminals. Drill a pilot hole right through the case and the PCB for each terminal - about 2cm from the board face. Drill also pilot holes for the input and output sockets, for the coax lead to the dummy load and for the silica gel chamber.

Remove the board and fully drill the holes. For the SO239 sockets I first used a 19mm flat wood bit - from the outside - to a depth of about 1mm. Although SO239s nominally fit a 4mm thick panel, you only get the backing nut on about half a turn - and in any event, you also need to allow some depth for waterproofing compound later.

Refit the board and fit all the external connectors, dry at this stage. Wire up the output SO239 socket to the output terminals using some 2mm wire. Wire up the input socket using 2mm wire to link the washer to the board ground - and a trivial length of RG58 for the inner.

Cut a piece of single sided PCB (87 x 78mm) for the base of the logic board. It also clamps up on the gusset in the logic board corner. Place it hard into the corner on the component side, copper side facing out. Mark positions for four holes which will foul neither the logic board assembly nor the earthy plates of C9-C11. Cut six pieces of polystyrene about 1cm square to use as spacers and drill four of them and the holes in the board at 4mm dia. Glue the spacers to the board using the two undrilled ones to provide even spacing over C9-C11. Secure the base to the RF board using M3 nylon screws and nuts - and clamping up on the corner gusset. Run a short heavy ground link from the base plate to the hole provided on the RF sense section.

Fit the dummy load to its heatsink with some thermal transfer compound. Then mount the heatsink to some polystyrene sheet with nuts and bolts. Then glue the polystyrene to the casing and when set, make off the coax lead on the dummy load.

Fit a length of RG58 from RL21 to the input end of the L-match. The braid should be grounded at both ends. To this end, I soldered a short stub of PCB at right angles to the main board to pick up the connection to the 'earthy' end of the L-match capacitors - and made off the braid of the coax to this stub.

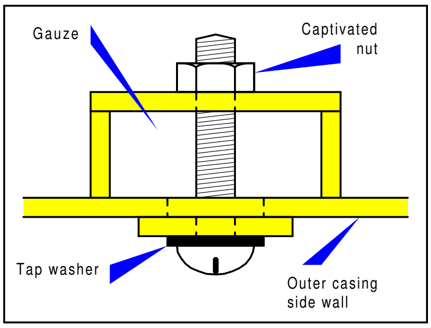

Fig 19: Suggested silica gel chamber construction - approx 25 x 12mm - made from polystyrene with nylon gauze bonded over the two open sides. The nut is bonded with epoxy resin to captivate it (liberally grease thread with DC4 first). The access hole in the casing is about 5mm and is sealed with an external polystyrene 'washer' and some bathroom sealant. The screw is sealed with a tap washer.

BUILDING THE LOGIC BOARD

ANY PCB TECHNOLOGY can be used for this board. A technique for using an iron-on etch resistant mask produced directly from the artwork, described by Ed, EI9GQ [7] is particularly appropriate.

Referring to **Fig 20**, the holes for transistors Tr1-Tr21 should be drilled 0.6mm; the remainder at 0.7mm. Lightly countersink the holes on the ground plane side. Having drilled the board, I masked the ground plane side with spray paint and then used indelible pen for the tracking.

The only critical element is the 0.1" pitch lines to take Sk1. These all line up on one or more of the holes so using a piece of strip-board as a guide, you should have no trouble.

For the finer tracking around the BC517 transistors, I penned in additional horizontal lines at right angles to the wanted tracks and then used a scalpel blade to remove the ink and restore the gap between the holes.

It is also worth while casually filling in any larger unused areas. This helps to achieve an even etch and reduce etchant consumption.

Having etched the board and cleaned it, make up the three vertical side panels from some double sided PCB - about 25mm high. Note the T junctions where they meet, ensuring that both faces of the sides are grounded. Seam solder the internal and external corners and mount the logic board about half way up the partition, soldering the edges of the ground plane.

Populate the board, fitting firstly the four through board links, C24, C51, C53, C54, R24, R25 and then the IC sockets.

Cut the tails on Sk1 so that they are as long as possible consistent with both not touching adjacent track and mounting Sk1 hard up to the board edge. Solder quickly into place without melting the insulation. Fit all other components and the two links on the track side. The earthy ends of C24, C26-C46, R45 and C54 are soldered to the ground plane only and do not pass through the board. Depending on the size of your decoupling capacitors, C26-C46 may be better fitted diagonally. X1 lies flat on the board to reduce height.

Soldering in the transistors needs a steady hand. You may find it easier to leave short tails on their leads on the copper side (especially the grounded emitter lead) - and solder them to the track a short distance from the holes.

Make off the three flying leads as illustrated. The RF sense lead is wired in miniature coax; the Cmd and Ref lines preferably in miniature audio cable. They are routed in/outside the enclosure as illustrated and made off under the board.

Do not fit IC4-IC6 in their sockets at this stage.

TESTING THE LOGIC BOARD

AT THIS POINT it is possible to verify basic operation of the PIC and its memory.

After the usual checks, connect a short 'antenna' to the inner of the RF sense lead and loosely couple it to your receiver antenna - on one of the LF bands. Plug in IC2 and IC3 and then apply 12v to the board - between the +12v pins and ground.

Immediately on powering up you should be greeted with the following message in CW:-

HI de PicATUne AR K

The text of the message has been read from memory verifying that the PIC and memory are at least basically functional. At the end of the message, the 'READY' LED should light.

If you enjoyed that, try dabbing the inner of the Cmd lead on and off IC4 socket, pin 16 (+5v) - simulating the operation of your Command Switch. You should hear:-

M U S I C

which is the main menu. Its significance will be fully discussed later. Suffice it at this stage that you hear the CW message. Should you hear actual music, then something is badly wrong.

RELAY WIRING

FIRSTLY, YOU NEED a mating connector to fit SK1 on the logic board.

I 'manufactured' a free plug by soldering a 28-way SIL plug (Pl1) to a piece of 0.1" pitch stripboard. The stripboard is 28 strips wide by 4 holes high with the SIL plug at one edge, the opposite edge copper cut back to avoid earthing - and with the wires soldered to the middle of each strip. The purpose of the stripboard is to add some marginal mechanical strength and to give you something to push against when mating with Sk1.

The relevant tracks for the relays are routed to a central location on the main PCB. I used SIL plugs and sockets to make off wire leads on the component side, but it is an unwarranted luxury. You might just as well solder the wires directly to the board since there is a connector at the other end of the leads anyway.

Either way, cut 20 lengths of hook-up wire, 17cm long and bare both ends. Some colour variety is useful. Make off all the leads on the main PCB. Use one wire for the common +12v lead.

I then passed all 20 leads through an old PA balun core to tidy them together and perhaps offer some reluctance to RF. I would doubt if it does much.

With the logic board assembly tack soldered in position and Pl1/Sk1 lightly mated, start from the RL9 (C1) end of the connector (the shortest lead). Use a continuity meter to locate the correct lead, cut it to length (with little excess) and make

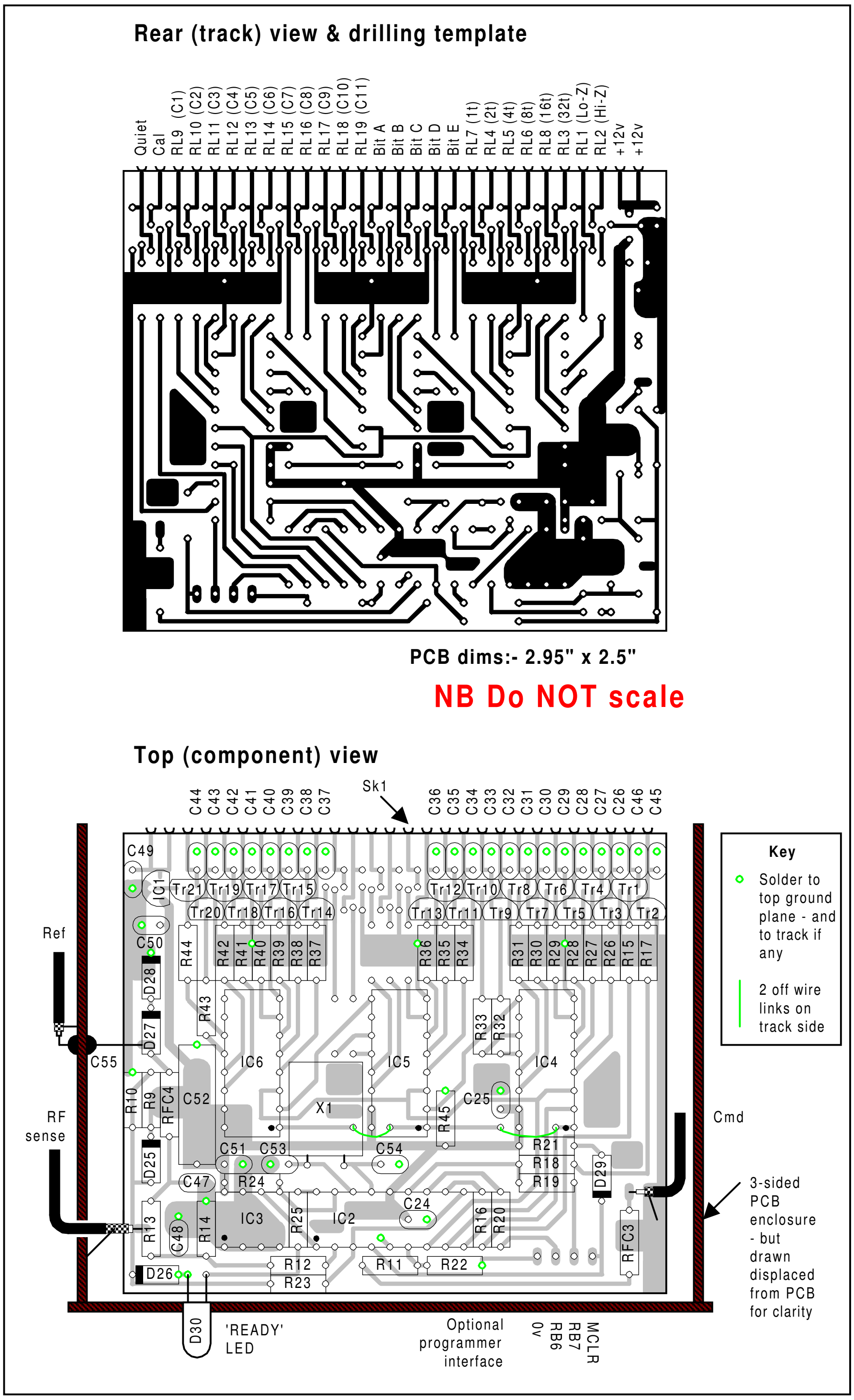

Fig 20: Logic board PCB. This is a double-sided PCB with the component side of the board completely unetched, providing shielding and ground connections. Note four through board links adjacent to R40, R36, R28 and pin 5 of IC2 - which bring ground through to the track side of the board. The PCB is shown etched for the optional bit outputs - but illustrated unpopulated.

off its end on Pl1.

Proceed along the plug remembering to leave a 5 pin gap near the middle (Bits A-E). Note also that the relays are not in any 'obvious order' and it is vital to get this right first time. Subsequent diagnostics if you get your wires crossed will be next to impossible, so check and check again. At the same time, check that all the protective diodes are fitted the right way round.

You will be left with one wire, the common +12v feed to the relays. Leave this free at this stage since it is needed for capacitor building.

BUILDING THE CAPACITORS

THESE ELEVEN CAPACITORS are built up on the copper side of the board. As a preliminary, finish cutting and drilling the clamp plates for C3-C11. Trial fit them all at the same time and using an indelible pen, write "C3", "C4" etc on each plate so that you will always fit the same clamp plate the same way round subsequently.

INTRODUCTION

The two smallest capacitors, C1 and C2 are air-spaced. The remainder use a polyethylene dielectric as illustrated in **Fig 21**.

Now for the science bit. Although the capacitor values follow the binary series 1, 2, 4 .... 1024pf, you must not attempt to build to those values. This is because two forms of stray capacitance will conspire to foil you.

There are general strays which you can observe just by watching a capacitance meter while waving your hand around inside the casing. Every effort has been made to minimise these but there is an irreducible minimum which you get between any two lumps of conductor in the same box.

Then there are the insidious switched strays. These are mostly the capacitance across the open relay contacts in series with the capacitors. These strays have the interesting property of progressively disappearing as the relay contacts are closed - and largely don't even exist until the capacitors have been built.

The build process described removes potential errors from both these sources provided only that you stick to this simple rule:-

The measured value of any one capacitor when switched in on its own .... must always be greater than .... the measured value of all its smaller valued capacitors when switched in at the same time.

For example C4 must be greater than (C1+C2+C3). Note that (C1+C2+C3) is not the sum of their individual values. It is the single value of them acting collectively - which, because of the strays, is different.

The rule arises because when the software sends out the bits to demand an increase or decrease in capacitance, it has to assume that the opposite has not actually happened!

Doubtless this sounds complicated, but in practice it is very simple. The process and rule were hard won - and if you don't observe them your ATU may well not work. So don't abuse them.

SETTING UP

Before starting the build my general advice to you is to have a good clean up and vacuum thoroughly. You don't need clean room conditions or to positively pressurise your shack, but conversely the dielectric properties of the odd dog hair are somewhat unpredictable.

Establish three distinct working zones. One for handling the polyethylene, one for the brass shim and one for assembly.

In the latter, stand the ATU on its edge, having first removed the logic board, its base plate and ground link.

Make up a test lead with an eleven way (or more) SIL socket - all pins joined together - and connect it to the -ve lead of a 12v supply. Connect the +ve supply lead to the common +12v feed to the relays. Note that you can now energise any one relay by mating this socket at right angles to Pl1 - or you can energise any consecutive number of relays at the same time - by mating the connectors in the usual way but with an appropriate offset. The 'rule' is falling into place.

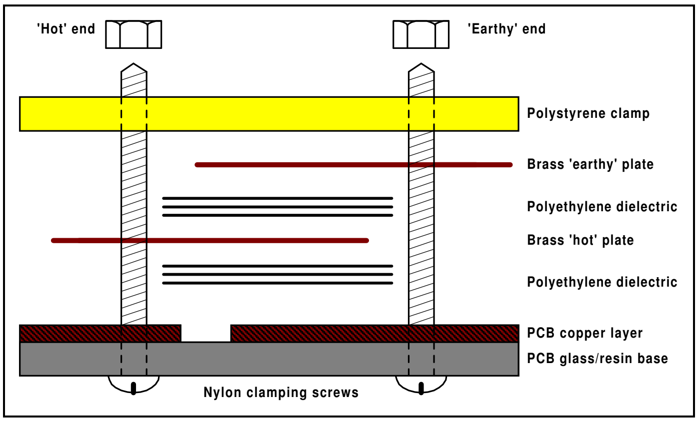

Fig 21: Generalised form of capacitor construction for C3-C11. Note that the PCB copper always forms one earthy plate. This is therefore a 3-plate capacitor (ie 2 layers of dielectric). Three layers of polyethylene film are illustrated per dielectric layer. The brass plates are soldered to each other and/or the PCB copper layer at their respective ends.

Connect your capacitance meter, one lead to the counterpoise terminal, one temporarily soldered to the bus-bar running along the capacitor switching relay bank.

In the polyethylene zone, set up a cutting surface at least 30cm square. Glass over newsprint (to give optical contrast) is ideal and old kitchen worktop works well. Do not use grained wood. Use some anti-static cleaner if you have some.

Remove the polyethylene bags from their box and cut off about the first five which will have been marked by the freezer ties provided - and return them to kitchen stock. Never attempt to tear bags along the dotted line. Only cut them with a sharp blade - or sharp scissors for coarse work. Never use the portion of the bag with the white contents and date label, nor the hard crease at the edges of the bag. Always inspect by eye and reject any film with obvious inclusions. I never found any! Small creases and stretch marks are OK.

Apply a film of DC4 grease to the glass. Squeeze out about 1cm from the tube and spread it using a flexible spatula. The long edge of a credit card is ideal. Try to get the grease film even and just wetting the surface.

Cut some strips of polyethylene about 70mm wide. Lay one film thickness on the grease. Now apply a wetting layer of grease to the film and it should become practically invisible. If not, there are probably two layers of film and an air gap. Lay a further layer of film on top - roughly aligned - and grease that also. Repeat for a third layer. That establishes some base stock of dielectric with three layers of film. You are now ready to trim dielectric to size - which is easier done when greased first. Trim the strip width down to 40mm (long edges roughly parallel) - which is the size needed for C7-C11.

In the brass zone, you need the brass shim stock, a 4mm drill, some soft wood, fine wet & dry and a vice. Also some cleaning solvent (I used cellulose thinners) and a lint free rag. To cut the brass either use a pair of tin snips or buy a cheap pair of scissors from the market and be prepared to write them off.

To drill a hole in the shim, mark the hole by eye, clamp it in the vice and drill against soft wood backing. Do not attempt mass production because you will end up with mass twisted shim instead.

The order of events is to cut the plate, drill the hole, radius the corners, rub down flat any sharp edges (most of them) and clean. The size of the plate, all right angles etc can be judged perfectly well by eye. Anything more subtle is a waste of time and you will be there for weeks.

GENERAL TECHNIQUE

See **Fig 22** for a view of the finished result. The film width is cut to clear the two clamping holes. Use the clamping plate to judge the other dimension. Lay one edge of the film into the capacitor, line everything up and 'roll' it into place. Smooth out any wrinkles or bubbles with a finger tip.

Then prepare a plate. Line it up with a screw through the hole and press it onto the dielectric. It should stick to the grease. Quickly tack solder it at the screw end. Press the centre with the plastic end of a screwdriver to get a rough measurement.

Proceed applying alternate layers of dielectric and plate (alternate ends). When you get close to the desired value, apply the clamping plate before taking a measurement.

The clamping plate is secured with M3 nylon screws and nuts. Torque them up finger tight only on the nut or you will strip the thread. When you get near to the desired value, go over the top and then trim back the final plate - unsoldered to start with. Also consider slipping in an extra layer of film to pull the value back somewhat.

COARSE BUILD SEQUENCE

The main purpose of this step is to crudely

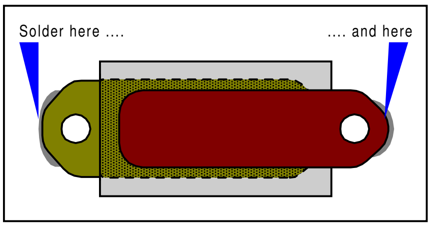

Fig 22: PCB plate construction viewed from below. The critical parameters are:- 1) the plate corners are arbitrarily radiused, 2) the dielectric is larger than the plate overlap zone by at least 3mm in all dimensions, 3) the cut edges of the plates are rubbed smooth and 4) the plates are different widths so that the long edges are not aligned. Thereafter, the absolute size and shape of the plates is completely unimportant.

build up the larger capacitance values (not observing the 'rule' yet) - so that the strays are established.

At switch on, you should be looking at about 15-20pf of residuals.

C1 and C2 are air spaced and it is easiest if these are crudely built first. Cut a full sized plate for C2 (about 27x12mm) and solder it to the 'hot' end with about 20mm overlap on the copper ground plate. Slide a piece of 2mm wire between the plates and use it to bend the shim so that the plates are roughly parallel and about 2mm apart. Repeat for C1, but with a shorter plate giving only about 8mm overlap.

Now for the big ones, starting with C9, 10 and 11. These can share common dielectric layers, at least to start with. They could also share shim ground plates, but the latter is more trouble than its worth.

Energise RL17 (C9) only and build up C9, C10 and C11 - applying the same number of plates to each - until C9 measures about 200-300pf. Clamp up C9.

Energise RL18 (C10) only and build up C10 and C11 - applying the same number of plates to each - until C10 measures about 500-600pf. Clamp up C10 and C11.

Energise RL15 (C7) only and build up C7 and C8 - applying the same number of plates to each - until C7 measures about 50-80pf. Clamp up C7 and C8.

Trim some 3-layer dielectric to 25 x 70mm and lay it across C3-C6. Without soldering them, add one full sized 'hot' plate each to C5 and C6 - one full width, half length plate to C4 - and one half length, half width plate to C3 - clamping up each one in turn.

You now have some sort of capacitor bank with the larger values (C6-C11) under sized and the smaller values somewhere near. A good start.

FINE BUILD SEQUENCE

From now on observe the rule! Draw up a table along the lines of **Table 1**. Date stamp it for your records. The table also shows the actual values achieved on my capacitor bank. For each row, the 'Alone' column is the value of a single capacitor. The 'Cumulative' column shows the value of that same capacitor - and all the smaller ones - all engaged at the same time.

The 17pf value represents the minimum capacitance achievable - and 2472pf is the maximum value with the full bank engaged. The theoretical maximum is just over 2000pf, so there is 400pf of excess - ie useful safety margin - in there somewhere. I doubt that it would be possible to build an air spaced variable to this specification.

So, applying the 'rule', the 'Alone' value of every capacitor must be greater than the 'Cumulative' value in the previous row. Obviously, the 'Alone' and 'Cumulative' values in the first two rows must be equal.

The next question is, if the value must be greater, how much greater? The answer for the smaller values is definitely 1pf. For the larger ones, some 2-5% but not critical.

You are trading off gaps in the capacitance range if you add too much - versus risk of breaking the 'rule' if there is any drift.

If you look at my C8, you will see that it observes the rule, but needs watching since if there is any drift the rule is at risk. By inspection, the safety margin could be improved by slightly reducing C7 and/or C6 and by increasing C8 by about 5pf. In the event, C8 drifted a few pf higher after a few days of use (they never drift lower) and all was well.

The 'Alone' value is measured by mating the connectors at right angles. The 'Cumulative' value, by in-line mating with the appropriate offset. In this case, always measure the voltage across the relay coils to make sure they are all energised, since with the connectors gently mated, it is possible to miss some.

	Alone	Cumulative
None	17	17
C1	18	18
C2	19	21
C3	22	25
C4	26	33
C5	36	50
C6	55	86
C7	94	162
C8	164	311
C9	320	615
C10	624	1228
C11	1251	2472

Table 1: Format of table for building capacitor bank - and my achieved values.

Start at the top of the table and work down. C1 needs to be 1pf more than your base residual value. Bend the plate to achieve this. Write in the actual measured value. Then C2 needs to be 1pf more than C1. Again bend the plate of C2. With both C1 and C2, you shouldn't let the gap fall below about 2mm or there is some risk of subsequent flashover.

Now energise both C1 and C2 and write the result in C2 cumulative. Add 1pf to it and pencil it in as the target for C3. Energise C3 alone and achieve the target with the clamping plate fitted, erring on the high side if anything - and write in the achieved 'Alone' value. Now energise C1 and C2 and C3 - write the result in C3 cumulative and the result plus 1pf as the C4 target .... and so on .... until you finish C11.

SOME TIPS AND OBSERVATIONS

• If you get too much grease on the dielectric, the capacitor will tend to drift higher in value over time as the excess grease distributes - and ultimately gets squeezed out of the edges.

• One approach to speeding up this drift if it is serious is to clamp up the capacitor with metal screws and nuts and leave it overnight. This is good practice at the end of a day's work anyway - and then just touch up the values next morning.

• Otherwise, regard the clamp plates as mere dust covers. Ideally the capacitance value should not change with or without the clamp plates and irrespective of the applied torque. These are not compression trimmers! In practice, and especially on the higher values, you can indeed alter the torque to trim the value by a few pf.

• Another trick is to apply a few extra layers of dielectric to the middle of the clamp plate - to increase the pressure on the plate overlap zone.

• Revisit the capacitors after about a week and repeat the full set of measurements. Correct any serious drift and keep good records so you can spot any trends. One of mine had moved quite a lot and I actually had to remove a whole plate to get it back. The others had barely moved at all. Thereafter there has been no significant movement - and believe me, it has seen a lot of use.

• You need to form a judgement as to how often you need to check the values, but in my experience, once they settle down, they stay settled. Whatever happens, if it all works, don' t touch it!

• Once you are happy, run a trivial drop of epoxy resin under an edge of C1 and C2 to hold the spacing - and apply some non-setting thread locking compound to the M3 screws.

COMPLETING THE WIRING

BEFORE REFITTING the logic board take the opportunity to fabricate a top cover. Use either brass shim with external lips or oversized double sided PCB.

Drill a small hole for D30 in the top cover (to let the light escape!) and orient the LED. Do not fit the cover at this stage.

Refit the logic board base and its earth lead. Place the logic board assembly in position and solder it to the bottom plate at no more than three points. Connect up the three flying leads and the Cal and Quiet leads to the sensor section, and a short link to the two +12v pins. Dress the longer leads along the casing wall, next to the dummy load.

Fit a spark gap across the two output terminals, either across the coax output socket or external to the casing. Adjust it for a few thou trivial gap at this stage - and you are ready to go!

COMMISSIONING

AT THIS POINT the entire project is built and fitted - with the exception of IC4-IC6, cover plates and environmental sealing.

Connect a 100Ω 2W carbon resistor across the ATU antenna and counterpoise terminals. Connect your Tx/Rx via your SWR bridge to the Command Unit with 50Ω coax. Run a further length of coax from the Command Unit to the RF input connector of the ATU. Put your Tx/Rx on one of the LF bands. Connect the supply (13-14v DC) to the Command Unit.

Immediately on powering up the Command Unit the Quiet and Cal relays will energise and you should hear the greeting message as previously described.

The relays will then de-energise and the ' READY' LED will light.

PHASING T1 AND T2

Power off PicATUne. Connect a high impedance voltmeter or ' scope to the Ref line at C55 (the feedthrough), looking for a few hundred mV DC. Switch on PicATUne and only while it is sending the greeting message, apply about 10W of carrier on 80m. The voltmeter should read 150mV or less. If substantially more, swap over the winding leads of either T1 or T2 (but not both) and repeat.

Your SWR head is now sensing reflected (as opposed to forward) power.

USING PicATUne's MENUS

The operation of your Command Switch depends on the type of switch fitted. If a toggle or slide switch, a command is issued by changing it to the opposite position. If a non-latching push button, then a press and immediate release is required. For the sake of brevity the term "Press the Command Switch" should be read as "Issue a command according to the type of switch fitted." So, without further ado, press the Command Switch.

The relays will energise again and you will hear:- '**M U S I C**' which is the main menu. Its significance will be fully discussed later.

Transmit a brief carrier at about the 2W level. Note that there is some reflected power and that the 100Ω resistor gets hot. This verifies that the Tx is connected through to the dummy antenna.

On key-up, PicATUne may well respond with '**X K**' continuously repeated, which simply means it has searched for a pre-stored matching solution and, not surprisingly, has failed to find one. Acknowledge and cancel any XK sequence by pressing the Command Switch.

Now for a menu selection command. At this stage you are being invited to test the system by rote and not to understand much about what is going on. That will follow.

So, press the Command Switch to bring up the main **MUSIC** menu again - and as you hear the second (or first) dash of the **M** press the Command Switch again.

PicATUne will respond with '**R M**' , which means roger, got your command, **M** was selected. '**M**' will be continuously repeated. For your interest, you have now entered the "Match from Scratch" mode.

Transmit a carrier at about the 5-10w level (in bursts of no more than 3 seconds) and note that your SWR bridge shows something close to 1:1 SWR. This verifies Quiet match operation - with the vast majority of the Tx power being routed to PicATUne' s dummy load - and not to the dummy antenna. On each key-up, PicATUne will send '**M**' continuously which means, again - not surprisingly - that you have not been transmitting long enough for it to find a matching solution. Given that IC4-6 are not yet fitted, it never stood much chance! Press the Command Switch to cancel the M sequence.

On the sockets for IC4 and IC6, connect one end of a jumper lead to pin 16 (+5v) and then dab the other end on pins 4-7 and 11-14 in turn. One relay should energise each time, and it might be wise to check it is the correct and only one. Repeat for IC5' s socket, but for pins 4-6 only. Do not proceed if there are any issues here.

All being well, power off, wait a few minutes, fit IC4-6 in their sockets and power back on again.

And now for the next tune .....

MATCHMAKER, MATCHMAKER ...

... make me a match! Get back to repeated '**M**' s as just described but this time when you supply a carrier, let PicATUne actually find the match for your 100Ω dummy antenna. During this process you will hear an amazing rattling of relays, much like a Gatling gun. When the relays all start to bang on and off at about 1Hz - and the Command Unit LED is flashing at the same rate - key up and PicATUne will send you '**R K**' . Your first match achieved!

Then transmit a brief burst of carrier and note that the SWR is acceptable. The power is being matched into your dummy antenna at this stage and it will heat - and maybe overheat if you are not quick.

If you experience anything unusual here, monitor the Ref line (at C55 in practice) using an oscilloscope with a high impedance probe, set to DC using 200mV sensitivity and the timebase on 10mS. As PicATUne searches for a match, you should see a triangular waveform moving up and down on a varying DC pedestal. The DC level represents the reflected power and PicATUne is attempting to minimise it.

At the end of the matching process - and after key up and down again - it should go to the lowest value you (and it) observed.

As a final confidence test, power off, wait 20 seconds and power on again. After you hear the greeting, supply a brief burst of carrier. PicATUne should leap to the matching solution - as soon as you key up.

REFERENCES

[7] http://www.qsl.net/ei9gq/

PicATUne

- an intelligent antenna tuning unit

Part five, by Peter Rhodes, BSc, G3XJP

Issue 7.0 Nov 8

IN THIS LAST part, the architectural considerations behind PicATUne's design are covered, culminating in specific detail of the operator interface - and finally some ideas on installation.

ARCHITECTURAL DESIGN

THE SYSTEM, hardware and software thinking that went into PicATUne is briefly discussed here since if you understand some of the background thinking, the operator instructions which follow will make more sense in that context.

Also, it is a relatively simple task to design different ATU hardware to use with my software - or your own software with my hardware - or you could be inspired to design your own tuner from scratch for your specific operational needs.

Or, if you are thinking of buying a commercial offering, this may inspire some aspects to look out for.

SYSTEM CONSIDERATIONS

There are a number of gross options in conceiving how to automate an ATU.

QST published a basic design [8] which is representative of the KISS approach. It is billed as 'easy to build' - which certainly looks likely - and 'makes time-consuming knob twisting and roller cranking a page in your station's history book.' It uses low voltage capacitors and only has a coax output socket, which makes me somewhat suspicious. What it certainly does *not* do is remember the matching solutions. It has to re-discover them from scratch each time you change frequency. This seems a pity, because even us humans write down the settings of a manual ATU on a piece of paper. However that does remove a lot of systems complexity - such as the need to measure frequency - and it may represent a good compromise for some. But to pick another tune, "A KISS is just a KISS .....".

From the outset, I decided that committing solutions to memory for later use was money well spent - but I did expend a lot of effort trying to keep the memory size (and cost) down.

The issue is this. If you want to cover the *entire* HF spectrum, then a lot of memory is needed to retain the full detail of unique solutions at sufficiently small frequency intervals. So much so, that there are architectural implications. It may be easier to settle for storing a limited number of solutions - or partial solutions, but then refining them in real time - every time - during the first few seconds of operation on a given frequency. Since this latter has to be done quickly to be effective, you probably need phase detection to tell you instantly which way to go; and certainly full VSWR measurement since you cannot rely on a steady carrier to match on. Maybe the bigger memory works out cheaper?

If, however, you are designing exclusively for the amateur then the total HF allocation only adds up to some 5MHz (if you are generous) which immediately divides memory needs by six. But more significantly, it does allow retention of the full exact matching solution at frequent intervals - with no topping up required - at an acceptable price.

Having spent weeks trying various data compression techniques - and encoding 11 bits of capacitor settings into an 8-bit byte (by sacrificing resolution at higher capacitances), you can imagine my language when the latest catalogue from a well known UK distributor arrived showing the price of 32k EEPROM to be less than that for 16k the year before. That's progress! What I had actually saved was about 20% of my software from being devoted to the memory interface alone.

HARDWARE ASPECTS

The great debate was whether to put the intelligence (ie PIC) at the shack end - or out there in the remote ATU.

The former has the great virtue of making the operator interface easy to implement since switches and LEDs are readily to hand. The difficult aspect is the need for a data link - probably serial in practice - for the relay switching commands; and the need for some decoding at the far end. A two PIC solution was implemented (one at each end of the link) to handle the communications as well as the ATU application. It worked well until any serious level of RF was applied - and then it collapsed in a heap of tangled '0's and '1's on the link.

The philosophical issue was that if it were necessary to run even one extra wire up to the ATU (for power or data) then one might as well run many extra cores. But I badly wanted to get to a simple and convenient installation (ie only a coax link) and without all the inherent hazards of adjacent logic and RF signals.

So I built a version with no user interface at all (and no incremental features). It relied on detection of a carrier running for 5 seconds as the cue to go and find a match - which works fine unless you want to use a data mode - and you were never quite sure when it had finished the matching process.

Then serendipity struck. By chance I miscoded the Tx frequency measuring software which left it still running on receive - and noted a broad band spectrum of tones on my receiver as the counting gate opened and closed.

Twenty minutes later, the remote PIC was sending CW - simultaneously on all frequencies in the HF spectrum. Complete flexibility to send any messages back down the coax - and with licensed HF operators as the target audience, well, no problems there. And thanks to Keith, G3OHN for explaining the Fourier maths needed to get the required spectral distribution.

Multiplexing the DC power up the coax presented few problems either. The remaining issue was how to get operator commands up to the remote ATU.

I briefly toyed with the idea of asking you to send CW to it. I think I could have made it work, but whereas it is fair to expect anyone to copy slow machine-sent CW with a restricted set of possible short messages, expecting people to send it might well have limited the appeal. And without a lot of software (for which there is no space) a PIC is very unforgiving of scruffy CW. Especially when it also has to ignore real CW QSOs. Anyway, it was all very clumsy and unfriendly.

The idea of interrupting the power to the PIC was inspired immediately after one of the frequent power failures round here. This provides exactly one command - no more, no less - so it soon developed to the concept of using that one command to pick choices from a PIC-driven menu.

I was now only short of one signal back from the ATU to denote completion of the matching process - which can't be CW since the Tx/Rx is on transmit at the critical moment. I first implemented it by pulsing on and off a small mismatch - which could be observed on the shack SWR bridge, but eventually settled for continuously toggling all the relays and detecting the resultant regular current pulses in the shack.

At the end of the day, this flexible user interface allowed the project to proceed to fruition at all, since I was able to exploit it for software development. One of the issues with PIC development on the cheap is that unless the application has a means of communicating with you, it is difficult to make much progress. Trying to peer at some LEDs through a pair of binoculars at night - and climbing on the roof to upload the latest software from my laptop by day - is not an easy development environment!

SOFTWARE ASPECTS

It would be nice to think that the software development proceeded classically. That is, understand the problem, develop a solution, code and test. Nice theory!

In real life I started off developing some chunks of code to perform utilities I just knew I would need. The ability to measure frequency, VSWR, detect phase, to read and write from memory - and above all, a fast matching algorithm. Then I struggled to integrate these into a working system at the same time as coping with radical shifts in ideas on hardware architecture. The software, the hardware and I were going round in endless loops for weeks.

As with all software development, coding is a pretty mechanistic task. It is understanding exactly how you want the system to behave in *all* circumstances that is the real issue.

Ironically, it was my wife (who has never written a line of code in her life) who sorted it out. By the simple expedient of sitting me in front of a manual ATU and saying "... show me exactly how a human does it. Why do you turn that knob first? Why do you overshoot the minimum reflected power when using that knob?" And, tellingly, "... how did you manage without a phase detector thingy?" Ah well, a lesson learned! The moral is, you don' t have to understand ' software' . You don' t even much have to understand the solution. But you do have to understand the problem.

It also goes to illustrate that even if you have never written software for a living and you are not being paid by the hour, you can still get there if you are persistent and enjoy the challenge.

For your interest - and especially if you want to write your own - **Table 2** shows how much code it finally took to implement the functionality.

MATCHING ALGORITHMS

A few words about the process of finding a match are in order. Although once the installation is stable this may never be needed again, it is certainly critical in getting to that point.

Any matching algorithm is some trade-off of speed versus the certainty of finding the best solution. There are exactly 526,400 relay combinations to try. The software could get round these in a few milliseconds each were it not for the need to allow for a relay settling time of about 15mS. So the ' try everything' approach would, by simple multiplication, take about 3 hours to find the solution. But it would definitely find the best one!

It might be thought that a quick coarse pass through each of the four impedance options - looking for any sort of SWR dip - would then determine which was the best impedance, thus quartering the size of the problem. In practice this does not work because you can find some sort of SWR dip - especially for an already near 50Ω load - for all four impedance options. Some of these dips are due to spurious resonances and some are down to the fact that the solution is truly on the borderline. Some are wide shallow dips, some are narrow, deep and easy to miss. In fact they come in all shapes and sizes. But the only way to find which is the right impedance is to pursue its dip in detail to the best match.

My final algorithm of many does just that. It finds the best match for each impedance by using first coarse steps to find any dips. Picking the best one, it then alternately dithers the L and C values up and down to find the required direction to produce a better match. If the match starts to get worse, that direction is quickly abandoned. If there is no change (which is what happens most of the time) that direction is pursued - since you never know when a dip is just around the corner. But little settling time is allowed for the relays, relying on the hardware to smooth the resultant DC reflected power level. However as soon as any hint of improvement is noted, the algorithm slows down to allow full relay settling. And once the bottom of the dip is passed, its all over!

There are other subtleties but the result of all of this is the best solution for each of the four impedance options - and the best one of all is the winner. The time to do this varies with the load but is typically somewhere about 20 seconds.

This is a necessary improvement on 3 hours but must carry some inescapable risk. The risk occurs early on; that in going for the best dip after the coarse pass the wrong one is picked. This risk is minimised by keeping the coarse steps small - which, of course, in the limit takes you back up towards 3 hours again.

22	PIC general overheads
19	General timing
93	Memory & bus management
66	CW send routines
55	Frequency measurement
48	Frequency to memory mapping
20	Reflected power measurement
63	' Restore from Before'
260	' Match from Scratch'
69	Menu management
107	Mode U utilities (QED)
120	Status reporting
71	Optional Bits (A-E)
1013	**Total**

Table 2: Lines of code to implement PicATUne functionality. Divide by 10 to give percentage.

I have tested the algorithm against a wide range of reactive dummy loads - and real antennas - at different frequencies. The algorithm does not always produce the same result (there are often two or more genuinely good answers), but it has never got it truly wrong yet. If it should happen to you, my suggestion would be to let it try again, perhaps at a slightly different (and preferably higher) power level. By its nature I can' t anticipate the problem; if I could I would code it out.

But for sure, if your Tx contains any significant spurii (harmonic or otherwise) then although it will always indicate unity SWR into a dummy load, it will play havoc with any reflected power measurement into a real antenna.

Peter Hart reviewed the SGC SG-231 Smartuner [9] using a 100W light bulb as a dummy load. As he points out, this varies in impedance between 50Ω and 500Ω with increasing applied power. The SG-231 passed the test of matching it, but I suspect PicATUne would not - except by luck. My algorithm does not anticipate the antenna changing impedance with applied power - on the contrary, it assumes that the antenna impedance remains constant at any given frequency.

The same load was used to judge internal heat dissipation and hence efficiency. Without any implication that the SGC is less than efficient (I have never tested one) it is worth pointing out that any ATU will be efficient into this sort of load. As the graphs in Part 1 show, the real stress areas into real antennas do not lie around the 500Ω region for an L-match. Nor do they for any other configuration.

OPERATIONAL USE

PicATUne HAS ONE NORMAL default mode of operation (and 8 other modes used variously for training and maintenance). Each mode is named for the CW character sent when first switching to it - and that letter is also a prompt for its function.

NORMAL USE - MODE K

Entered at power on, this is the default mode for operational use. Whenever you hear a **K**, it means - unsurprisingly - over to you. All other modes revert to K on completion. Once you have a stable installation, you need never leave this mode.

In Mode K, PicATUne constantly monitors the frequency of your transmission - and repeatedly fetches the pre-stored solution from memory for that frequency - and applies it immediately on a break in transmission. A morse dot or a snatch of SSB speech is sufficient; merely pressing the PTT switch is often enough. This process is called ' Restore from Before' .

In practice, a ' break in transmission' occurs when the SSB waveform takes a dip at normal speech frequencies ie roughly every 10mS. An actual pause in speech is not needed. On CW, the gap between morse elements is used.

During each such brief burst, the software measures the frequency - twice normally, but four times if a change is detected - and only if it gets the same result each time, looks up the matching solution in memory for that frequency. If none is found, it searches both up and down from that centre frequency till it finds the nearest solution - or the band edge(s). This entire process is essentially instantaneous in human time frames - and of course, if you haven' t actually changed frequency there is no net effect.

The software contains a zero crossing detector which minimises relay switching under load. It waits for the brief break - and was implemented purely as a means of making the relays affordable. So, if you are using a constant carrier mode, eg a data mode or FM, you absolutely must send a quick burst after you change frequency to allow switching.

Following any change in band you will hear **R K**. Thereafter no further status is reported while you remain on that band - but a different solution will be applied as necessary should you change frequency within the same band.

Note that PicATUne makes no judgement about the quality of the solution. As a matter of design philosophy, you are in total control; and it is up to you to decide if the SWR is too high - and to train PicATUne to a better solution for that frequency (assuming one exists).

If - very unusually - there is no stored solution for any frequency in the band then PicATUne will send a constant and annoying **X K** sequence. This sequence ceases on pressing the Command Switch.

USER SELECTABLE MODES

THESE MODES ARE made available by pressing the Command Switch while in Mode K. PicATUne responds by sending the user selectable mode letters **M U S I C** - an easily remembered acronym. If none of these characters is selected, operation continues in Mode K.

To summarise what follows, the modes and their initials are:-

- **M**atch from Scratch
- **U**tilities
  - **Q**RS or **Q**RQ
  - **E**rase solutions
  - **D**ummy load
- **S**tatus
- **I**nhibit
- **C**onfigure

MODE M

' Match from Scratch' . This is the mode you use to command PicATUne to find and remember a new matching solution.

On entering Mode M, PicATUne sends **R** to acknowledge your command followed by **M** continuously repeated.

You then supply a steady carrier for about 20 seconds. The time varies depending on the nature of the load. As for power level, 10W is ideal. 5W is acceptable and 2W will often produce a result. Anything over 40W risks saturating the detector, especially on the LF bands - which will merely have the effect of prolonging the matching time. PicATUne is in ' quiet tune' during matching so for 10W in, you will be radiating 40mW. This is not much, but it is not nothing!

Whatever power level you use, *do not alter it during the matching process*. If you should get the power level badly wrong, immediately stop transmitting - which aborts the process - and start again. (You can do this deliberately while setting the power level in the first place.)

After detection of the carrier, PicATUne finds the best match and stores the resultant solution against the frequency in use. Throughout the matching process you will note that your SWR bridge reads close to unity - and the intensity of the Command Unit LED varies. When it starts to flash at about 1Hz, you know matching is complete and you can stop transmitting.

PicATUne then reverts to Mode K with the matching solution applied - and you will hear **R K**. If you have not held the key down long enough, you will hear **M** continuously repeated. You need to either re-apply carrier for long enough to find the solution - or you can press the Command Switch to abort and return to Mode K.

Up to 1,000 different solutions may be stored, sufficient for a potentially different solution every 5kHz throughout the 9 bands 160m through 10m - (slightly larger band allocations than the present USA allocations are assumed). If you use PicATUne outside these allocations, the results are not predictable.

MODE U

Utilities mode brings up **R U** followed by **QED**, the initials of the three utility modes.

Mode Q (QRS or QRQ) allows you to toggle CW speed between about 12wpm and about 20wpm. On first use, PicATUne is set to the slower speed. Even if your CW is truly appalling, this will soon seem very slow. When you select Q, the speed will immediately change and operation reverts to Mode K. Your speed selection is remembered even after powering off.

Mode E Erase memory contents mode. This erases all stored matching solutions. Use it if you change your antenna installation, thus invalidating the solutions.

Before erasing, you will be asked to confirm - **CFM** - by pressing the Command Switch. If you do, you will hear four **E**s, at about one second intervals, one for the successful erasure of each 8k memory block. There is no way back!

Mode D Dummy load mode is for your general convenience - and that of other operators. It switches in the dummy load with the L-match and antenna grounded to give vanishingly small radiation.

The character **D** is sent continuously while Mode D is activated - and is exited to Mode K by pressing the Command Switch.

MODE S

Status mode reports the current PicATUne settings. It uses binary values, with a dit representing a ' 0' and a dah representing a ' 1' . The most significant bit is sent first.

Besides obvious value in commissioning the L, C and Z information is useful in determining if PicATUne is matching in a ' risky' region. More about that later.

L	**6 bits**	which L1 turns in use
C	**11 bits**	which capacitors in use
Z	**HI LO ONLY L ONLY C**	
FREQ BITS	**13 bits**	frequency ÷ 5
BIT A	**ON** or **OFF**	
BIT B	**ON** or **OFF**	
BIT C	**ON** or **OFF**	
BIT D	**ON** or **OFF**	
BIT E	**ON** or **OFF**	

Fig 23 allows you to perform an approximate conversion of L1 turns to inductance.

The frequency bits have the normal binary weighting but need multiplying by five to give the answer in kHz. Some examples are:-

3.7MHz	00010	11100100
14.2MHz	01011	00011000
28.5MHz	10110	01000100

Note that this is not a frequency standard in any real sense. Its sole purpose is to let you check that PicATUne is getting the frequency about right.

Pressing the Command Switch at any time aborts Mode S and PicATUne reverts to Mode K with **AR K**.

MODE I

Inhibit mode. This mode inhibits all activity and explicitly prevents PicATUne from changing the matching solution.

In this mode the PIC chip itself goes to SLEEP and ceases all activity including its 4MHz clock, thus preventing the possibility of any internally generated noise finding its way into your receiver. Since all the serious PIC activity occurs while you are transmitting, this latter is not a realistic risk - but better safe than sorry.

This mode is particularly useful if other strong transmitters are in the immediate vicinity, since there can be enough pick-up on your antenna to cause PicATUne to react to a strong inbound received signal.

Pressing the Command Switch gets you back to Mode K.

MODE C

Configure mode allows you to specify the behaviour of the five optional output bits. Why you might want to is covered in a moment.

Of these, Bit A is a simple on/off toggle switch. Firstly, you will hear **BIT A** followed by **ON** or **OFF**. If you select it, the switch immediately toggles and PicATUne reverts to Mode K. The switch setting is remembered during power off.

If you make no selection against Bit A, PicATUne will then play out 4 bits (B-E) against each of 9 bands, in the sequence 160m-10m. A typical ' line' is:-

20m N Y N N

This example states that if you were to operate on 20m, Bit C would be set.

To alter a given setting, simply select it as it goes past and PicATUne will toggle it Y/N and then replay the entire line for confirmation before continuing. Thus to change all four settings (in any order) you would make four passes through the line.

There are a total of 36 settings (9x4) to provide maximum flexibility for your application. The net result of altering any of these 36 configuration settings is first applied after the next burst of transmission. They are all remembered during power off.

SWR PROTECTION

An inherent problem with any auto-ATU is that of presenting your Tx with SWR spikes when changing bands. For example, if you are operating on 80m and change to 40m, the 80m solution is likely to present a very high SWR to your Tx on 40m. This only lasts for a few milliseconds while the ATU measures that something radical has happened - and fetches and applies the 40m solution. But during that few milliseconds, your PA transistors can exhibit their fuse-like properties.

I am not aware of any commercial auto-ATU which does other than rely on SWR protection in your Tx to save the day. Ironically, if it works to shut down the PA quickly and hard, then there may not be enough RF energy reaching the ATU to allow measurement of the new frequency.

PicATUne has two defence mechanisms:-

1. If very high reflected power is measured in normal use, PicATUne will switch instantly to its dummy load. This in turn allows your Tx to develop full power - allowing PicATUne to measure the frequency, find the solution, apply it and then remove the dummy load. This all takes milliseconds and unless you have a hard fault on your antenna, you are unlikely to be aware of it.

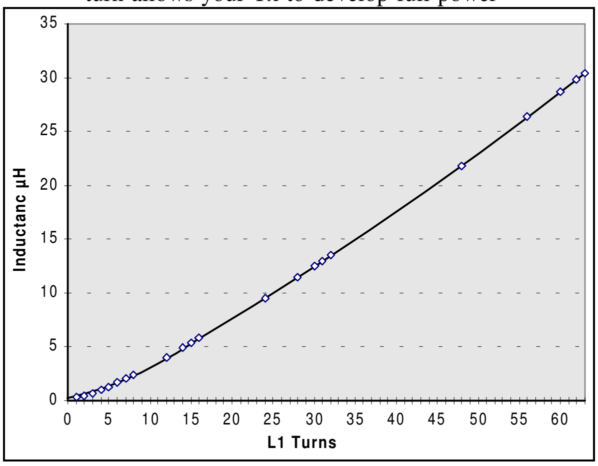

Fig 23: Measured inductance of my coil. Yours may vary from this, but the difference is unlikely to be significant in plotting your operating point on the graphs in Part 1.

2. If your PA is unprotected - or you don' t wish to rely on it every time you change bands, proceed as follows:-

- Change bands on your Tx/Rx but before transmitting, press the Command Switch to bring up the MUSIC menu.
- Transmit a morse dot or utter a brief word. You are on dummy load, so nobody will hear you. Immediately key-up.
- If you continue to hear the main menu, then you have not transmitted enough power even to be noticed. If you hear a succession of **T**s, then you have not applied enough power for long enough for accurate frequency measurement. Apply more, and the Ts will cease. (Or press the Command Switch to escape completely.)
- Normally however, you will hear **R K** and you will have changed bands without ever presenting your Tx with other than 50Ω - even for an instant. Nor will you have radiated. For both these reasons, this is the preferred way to change bands.

GENERAL INTERFACE ISSUES

Although PicATUne is simple to use, there are some issues to watch out for:-

- If you make a mistake in menu selection, the simple rule is - do nothing! PicATUne will find its own way to a stable situation - normally Mode K.
- If you want to hear CW messages from PicATUne, you must be listening! PicATUne cannot tell if your Tx/Rx is on receive - or on Tx but with no output. If you are operating SSB without VOX or CW without break-in, you will miss any message sent at key-up time if you do not lift the PTT line briefly.
- If you are using a narrow Rx filter, PicATUne' s CW note may fall outside your passband.
- An interesting phenomenon arises operationally when you are by chance on a frequency that is spot on the transition between two different solutions. You may find PicATUne flips back and forth between them, especially on SSB where your actual voice frequencies of the moment determine the transmitted frequency. This is not a problem and can be safely ignored. But if you are within earshot of PicATUne, the noise of relay switching can be a nuisance. You can always engage Mode I (Inhibit) to stop it happening. Equally this *may* be evidence that you have got too many closely spaced - and unnecessary matching solutions.

PIC YOUR ANTENNA

THE OPTIONAL BIT outputs provide a unique and powerful means of automatic remote antenna selection. They are designed to drive external relays - though a few extra ones could be judiciously accommodated within the PicATUne enclosure. It is up to you to use relays which can stand the strain in your application.

Bit A is switched directly from the Command Unit, providing remote *manual* antenna swapping. It is designed to drive a relay which diverts the coax input to the L-match instead to a further coax socket and thence to an already well matched alternate antenna. The L-match is thus bypassed, but will continue to be set. So when you switch back to the matched antenna, it will be instantly available.

If this ' alternate' antenna is in fact the only one you want to use on a given band, it would be better to configure one of the four frequency sensitive bits (Bits B-E). You would then *automatically* switch to this antenna whenever you used that band.

Here are a other few ideas for those frequency sensitive bits:-

- Nested mono-band Quads or Yagis. Feed them with one coax run up to PicATUne near the masthead and then configure the bits to route a separate short coax lead to each antenna - as a function of frequency.
- A mast with both beam and wire antennas. Much as above, you can specify which antenna is to be selected on which band.
- On any band (particularly the LF bands) if PicATUne has not enough matching range, you can arrange to selectively switch in some external reactance to improve the match.
- Many antennas benefit from different earthing arrangements or counterpoise lengths on each band. These too can be switched in automatically.

This feature is very versatile, but suffice it to say if you have no interest in it, all you have to do is ignore it.

BALANCED ANTENNA OPTION

IF YOU WANT to feed balanced loads - yet still retain an unbalanced capability - you need to insert a choke balun in the coax feed from the SWR head to the L-match input. This is made possible because the whole L-match is floating at RF - except for the braid of this coax.

I taped together four 3/8" ferrite rods, 145mm long to form a square(ish) cross section and then wound 23 turns of RG58 round this. This assembly fits in the space on the copper side of the RF deck sensor section - between the SWR head and the casing.

Another approach - but for balanced configurations only - is to fit an external 1:1 balun at the antenna and counterpoise terminals. This practice is employed by the commercial ATU manufacturers, but I confess doubts about its effectiveness. Such baluns do not work well in the presence of a reactive component.

FIRST USE

CONNECT UP any antenna of convenience to PicATUne and place it where you can see and hear it. Keep your power level to no more than about 10W and set the spark gap to a few thou until you gain confidence.

Run through all the menu options to gain familiarity. Specifically try out the erase mode (Mode E) since you may well not want to do so later once you have some real matching solutions stored.

Then use Mode M to find some matching solutions - preferably on different bands - and practice subsequent band changing.

TRAINING PicATUne

ONCE YOU ARE confident PicATUne is functional, mount it in its target location and connect up the antenna(s). Choose a pleasant day and fit PicATUne not weatherproofed to give you access to the spark gap. Remember to use Mode E first to get off to a clean start.

Starting on the lowest HF band of interest, check that you can obtain a reasonable match on all the HF bands. If you have any problems, pay particular attention to the quality of your counterpoise or ground plane or RF earth - depending on the type of antenna you are using.

Ultimately if your antenna is too short PicATUne will not be able to match it. A possible way round this was just discussed.

If your antenna system is near half wave resonant and end-fed - or full wave and centre fed - there may be portions of the band which will not produce a good match. See Part 1, Fig 1. Altering the antenna length slightly either way should fix it - and in general, longer is better.

For each band, start at the band bottom edge and use Mode M to 'Match from Scratch'. Then move up the band, checking the SWR. As soon as it starts to become unacceptable, use Mode M again to find a new solution. Repeat until you get to the top band edge. With some antennas, the same match will cover the whole band. With others, especially if the antenna is naturally near resonance, you will need many different - potentially radically different - solutions.

Then (using Mode S) plot your operating points onto the graphs provided in Part 1. Alternatively, the Mode S data may be entered directly into the QBASIC utility. This vital step ensures you are not operating in a danger zone - or at least that you understand and accept the limitations.

All the above caution is wise practice but in reality there are few issues unless you want to push the power to (but not beyond) the design limits.

As a final check, turn your power up to the normal operating maximum and check that there is no flashover on the spark gap at any frequency. You will be able to see the arc at night from a distance and hear it on any broadcast receiver. If there is, open up the gap as little as you need to, but to absolutely not more than 75 thou (2mm) - ie 1.5kV. If the spark gap is flashing over you will generate substantial TVI and BCI. So you must check that there is no evidence of this at full power - on all the bands.

Finally, complete the weatherproofing and enjoy!

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