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The doublet de-mystified

Some basic information on this most versatile of antennas

Left: The doublet at G3GKG.

The doublet is the most versatile and trouble-free all-band aerial for use on the amateur HF bands. My own installation is shown in the photograph above.

It offers the facility to achieve perfect matching, ie an SWR of 1:1 (or, as I prefer to express it, zero reflected power), with high forward power efficiency, anywhere in the entire HF spectrum. Add to this the fact that, provided its inherent balance is maintained by feeding it from a properly-balanced matching unit, it also gives maximum immunity against interference, either incoming or outgoing. It is obvious why, wherever space considerations allow, experienced operators eventually abandon all other compromises and/or gimmicky aerial solutions, and adopt the simplicity and perfection of the doublet.

BASIC INFORMATION

In its simplest and most all-round efficient manifestation, it consists merely of two equal lengths of wire, forming a top section of any convenient length, coming together in the centre, with spacers attached, so as to create a similarly random length of twin feeder. For maximum efficiency as a radiator, the actual length of the top section does, of course, matter and it should be at least equal to an electrical half-wavelength at the lowest frequency of intended use (so that the current maxima will then be in the top, rather than in the feeder). If space is restricted, bending the ends down (by no more than 90°) will have very little effect on the efficiency. Similarly, height above ground and orientation will be determined by whatever will fit the location and, on the lower frequency bands at least, will have little influence on the effective polar diagram; for inter-G working it's the signal that goes *upwards* that counts.

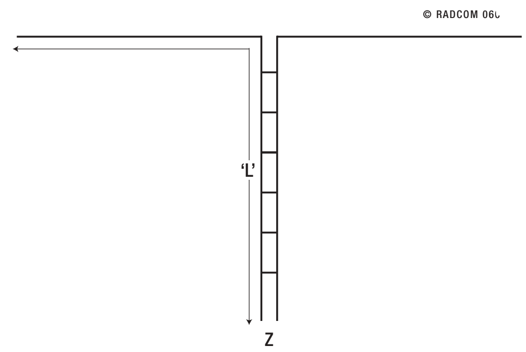
Whatever the individual lengths of the top section and the feeder, the natural fundamental resonance of the system as a whole is determined by the length, L (**Fig 1**), measured from either end of the aerial to the bottom of the feeder. It will, of course, be at a much lower frequency than the required band, but that is of no practical consequence. The noteworthy fact is that the impedance, Z, at the feed-point, ie at the bottom end of the twin feeder, will also depend on this same length. Neither the impedance at the centre of the top nor the nominal impedance of the feeder are of any real significance.

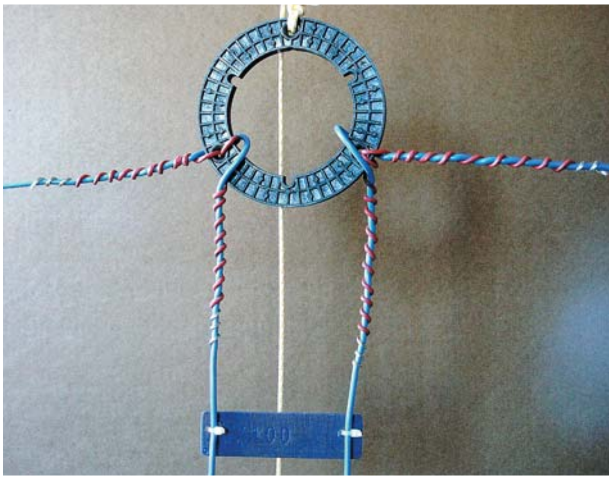
Actually *at* the resonant frequency, the impedance 'seen' by the transmitter or ATU, would be purely resistive and low in value but, at all other frequencies, the feed-point resistance itself is increased and reactance is introduced. As the operating frequency is moved away from resonance, both the resistive and reactive components of the impedance increase more and more rapidly (the reactance being capacitive (-j) if the frequency is lowered and inductive (+j) if it increases) until a frequency is reached where the total impedance is at a very high value (thousands of ohms) and, again, becomes purely resistive. Beyond this maximum, the sign of the reactance (j) suddenly reverses and the impedance decreases, quite quickly at first and then more gradually, until it is again low and purely resistive when, L is equivalent to three-quarters of one wavelength ($3\lambda/4$). At still higher frequencies, there will be any number (and parts) of such cycles.

So, if the doublet is to be used over a wide range of frequencies, the feed-point impedance in the shack, at any given frequency, may comprise any combination of resistance and reactance. It is important to realise that, at all frequencies, there will be standing waves along the entire length of both aerial and feeder. The only constant factor is that, at the far end of each half of the aerial there will be a voltage maximum and the standing waves could be plotted right back from there to the feed-point. Moreover, nothing done in the way of tuning or impedance matching at the bottom of the feeder will affect

Fig 1: The basic doublet configuration.

Fig 1





Above: The method used to support the bend. The centre insulator is a bit of DIY improvisation, being the hub from an NAB reel-to-reel tape spool. The spacers are likewise, using the packing pieces employed by plastic window installers.

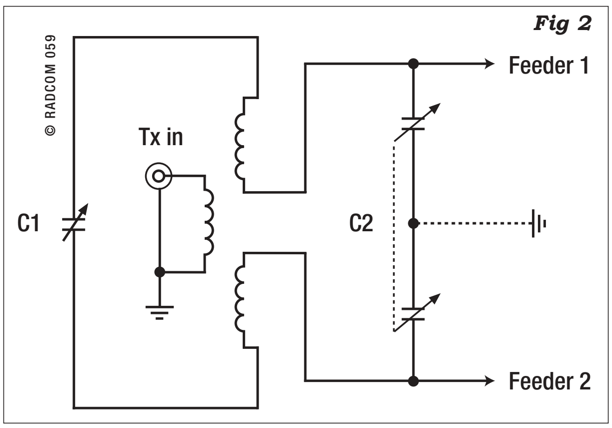
either the standing waves or the actual impedance at that point. The purpose of the matching circuit is to convert that balanced, random impedance so that the transmitter sees it as an unbalanced, resistive load of, say, 50Ω. If both the feed arrangement and the disposition of the two halves of the aerial maintain a true balance, the currents on the two legs of the feeder will always be in anti-phase and radiation from them, and pickup of any external interference on them, will cancel out.

My own doublet is constructed using just two 83ft (25.3m) lengths of heavy-duty, stranded, PVC-insulated wire, the centre of which is shown in the photograph above. The two outside ends are completely sealed against water ingress and the nearer 15ft (4.8m) of the two legs form the feeder, which comes right into the ATU; thus there are no joints or connections exposed to the weather.

BALANCED MATCHING

Although the two extremes of impedance mentioned in the above discussion correspond to the situations often referred to as requiring 'current feed' on the one hand and 'voltage feed' on the other, it is quite possible to make a matching unit that will cope with any combination of reactance and resistance to be found in any aerial which is suitable (ie long enough) for the band in use, provided the physical attributes of the actual components used are adequate. For several years, I have been using an aerial matching system (ATU) which I devised in about 1993, only to discover subsequently that, although generally neglected, it had appeared in print at various times as far back as 1955, and probably very much earlier. I have also more recently noticed that the same circuit appears to be quite a favourite of Pat Hawker, G3VA.

Fig 2: The matching unit.



The basis of this design, shown in **Fig 2**, is a sort of link-coupled, balanced π-coupler that does not require any tedious setting of taps on the coil. It uses one variable capacitor, C1, to tune the network and a second one, C2, to 'tune out' any reactance at the feed point and match the overall impedance - effectively performing the functions of both the second capacitor and the movable taps of the well-known ARRL circuit. The two controls do interact but it is very easy to obtain a perfect match by rotating them alternately.

Tune-up initially using low power; rotate each control until a decrease is observed in the reflected power (or SWR) reading. Then continue, slowly, in order to reduce reflected power to a minimum. With practice (and safecracker's fingers in some situations, see the next paragraph), it is possible to obtain zero reflected power, coincident with maximum forward power.

In general, the lower the impedance of the load the more capacitance will be required in C2 and, as the two capacitors are effectively in series as regards resonating the inductor, the lower will be the capacitance of C1. For either capacitor, the lower the capacitance when loaded, the higher will be the voltage across it at any given frequency and power. Also, the lower the reactance in the load, the broader will be the tuning - it is only with very high impedance and highly reactive loads that the tuning becomes quite sharp and critical.

PRACTICAL CONSIDERATIONS

There are three possible arrangements of the two variable capacitors. Either C1 or C2 can be a twin-gang type with the frame earthed, to provide a centre about which the feeders are balanced, or both can be single-gang types, completely isolated from earth so that the whole of the secondary circuit, including the aerial system itself, is floating. In virtually all amateur installations, the aerial will be more or less unbalanced anyway so there is a strong argument for using the floating method and letting the whole aerial/feeder system find its own 'balance'. (In either case, high-value resistors should be connected to earth from each side of the feeder to prevent static voltage build-up.)

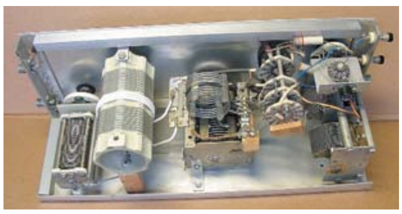
C1 will need to be fairly wide-spaced, but of reasonably low capacitance, whereas, provided steps are taken to avoid the higher feed-point impedances (at or near voltage maxima), C2 can often be an old-fashioned, close-spaced receiving type. It might be advantageous to use a twin-gang capacitor, with or without the earth connection to the frame, so that the two sections are in series (so as to double the voltage rating) but that, of course, reduces the capacitance swing to half that provided by one section. In any event, at the lower frequencies, particularly if the feed-point is at or near a current maximum (low impedance), the value of capacitance required can be quite high - necessitating either a multi-gang component with the sections in parallel, extra fixed capacitors to be switched in, or both. (However, the voltage rating of those particular fixed capacitors could be relatively low.)

It is well worth giving some consideration to the total length of the feeder/aerial combination so as to avoid both extremes of feed-point impedance. However, if the aerial is intended to be used on all the amateur HF frequencies, it might well prove virtually impossible to avoid having a high impedance (and hence voltage) feed-point on one or more bands. Rather than going to extremes with ridiculously wide-spaced capacitors and switches when using relatively high power, there is a useful dodge which has, in fact, sometimes been proposed as the *sole* method of matching. That is, to add a few extra feet of feeder, which could be 300 or 450Ω, plastic type (rolled up in the shack) to be inserted in series on the troublesome band(s).

AS USED AT G3GKG

Fig 3 shows the ATU that I use. An inside view is shown in the photograph below. Details of the two coil assemblies are: LF (used for 80, 60 & 40 m bands) – (9 + 9) turns of 16SWG tinned copper wire on 2.25in-diameter former, with 3-turn link of PTFE-coated wire; HF (used for 20 to 10m bands) – (4 + 4) turns of B&W 1.75-in stock with 1-turn link between windings. The ceramic switch assembly a, b, c, d is a large, 4-gang, 6-way device. On one or more bands, the total capacity of C2, required to suit the particular aerial, is made up by switching in an extra fixed capacitor, the value of which is determined to suit the aerial by temporarily substituting a variable capacitor, and using low power. C2 itself needs only to be capable of providing coverage of each of the individual bands. The design could be simplified somewhat by using single-section tuning capacitors for both C1 and C2, when the frames would have to be well-isolated from the chassis/earth. Even when using a twin-gang variety, C2 should be treated similarly so as to give the option of balanced or floating output, as in my circuit.

This 'all-band' model uses only two coils to cover from 80 to 10m and avoids switching the 'hot' ends by having separate tuning capacitors for each inductor. The low frequency coil is wound on one of those old Eddystone ceramic formers with ribs which determine the turn spacing at about 1 turn's width. The two



Below right: Inside view of the ATU. The toroid/ switch assembly (top right) is to cater for an alternative, aperiodic feed directly to the receiver.

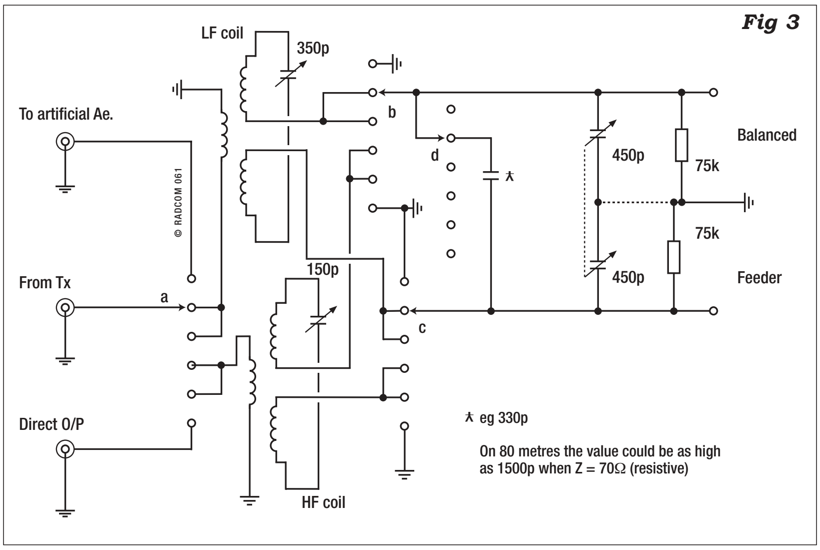


Fig 3: Schematic circuit of G3GKG's 'all-band' ATU. See the text for details of the two coil assemblies.

main windings are spaced as far apart as the former allows, so that there is a gap about an inch wide between them in which the link is close-wound using thicker, PTFE insulated wire. Even at that, the coupling is closer than it needs to be and indeed, *must* be kept fairly loose so as to minimise capacitive coupling (which can produce in-phase current in the feeder). For virtually complete elimination of the capacitive effect, an earthed Faraday shield around the link could have been arranged.

TWO-BAND VERSION

This is a 40/80m tuner, shown in the photograph on the right, in which the only switching is performed by a ceramic, 2-pole switch which just adds the padding capacitors across *both* variable capacitors on 80m. By that expedient, the single-gang, wide-spaced variable capacitors are reduced to reasonable values and the only 'earth' connection is to the high value static bleed resistors.

It uses a slightly smaller ceramic former from one of the TU 6 type of wartime tuners and an optimised number of turns, 11 + 11, with a 3-turn link. To avoid trying to drill holes in the ceramic, and to provide anchor points for the inner ends of the windings, I devised a method I hadn't tried before, but which worked very well (see the photograph, right). It consisted of preparing a strip of fibreglass PCB cut to fit closely into one of the flutes in the former, with all the copper removed except for lands used as anchor points. It is fixed in place by solder tags held under screws using the two existing threaded holes in the former. The ends of the main windings are soldered to the copper anchor points on the PCB, leaving sufficient extra wire to form the connections to the capacitors.

A strip of thin polythene sheet (cut from the lid of a redundant 'Tupperware' box!) was wrapped around the interwinding space and held in place with polythene adhesive tape before winding the link over it using heavy duty, PTFE-insulated , silver plated stranded wire. The ends of this winding were twisted together before slipping a short length of heat-shrink tubing over them, as close to the former as possible, and applying a thin coat of acrylic varnish to fix it in place.

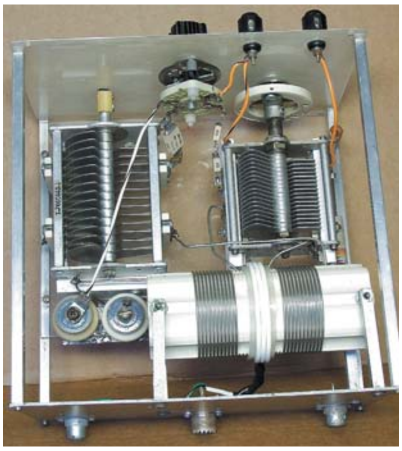
[I did a bit of experimenting using some of the larger iron-dust toroidal cores, eg T 300-2, for the inductor and had very promising results, which I passed on to the late G3IPZ. Dave developed the idea very successfully for even larger units, working on 40, 80 and 160m, but I'm afraid his findings died with him.]

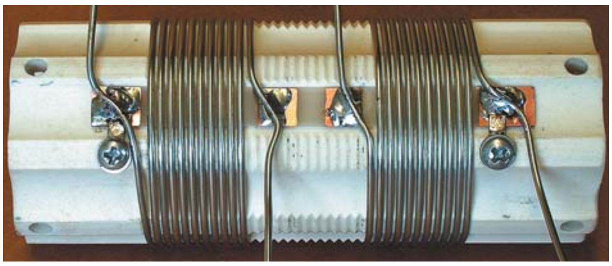
Having somewhat alleviated the problem of finding suitable variable capacitors, the next problem, although possibly less acute, may now be in finding appropriate fixed components. There are numerous types of capacitor available which claim to have high kilovolt ratings, but *beware* - a lot of them (eg the red and blue ones in the photograph below) are meant only to be used in pulse applications and will soon break down if subjected to the sort of high RF voltages likely to be encountered here. Other types (the ceramic disc and 'door-knob' types shown) may or may not stand the voltage strain, but are only intended for coupling and decoupling situations and are prone to large capacitance changes with temperature.

I have in the past had some unfortunate experiences with the old, wartime, moulded mica capacitors, from the American TU units (y'know, the ones we used to swear by!) rated at up to 5kV. On examination, I found the internal construction to be of an appalling standard, but there are now occasionally to be seen mica ones of more recent manufacture, with voltage ratings up to 3kV. Some of these do seem to be suitable, at least for medium-power units but one or two, even of the 3kV ones, have expired spectacularly when used at the full legal limit.

I am told that the tuning capacitors now being used in the so-called 'smart tuners' are rated for RF up to 6kV and come in a large range of fixed, binary-related values required by that application. I have no knowledge regarding the type of construction or, more importantly, where to obtain them.

The best ones to look out for are the large 'mushroom' types of capacitor specifically designed for RF and rated at about 10kV, made by Plessey and TCC among others, which come in values between 10 and 1300pF to my knowledge, but I've only found them at rallies, usually amongst the silent key 'junk'. They are ideal for any power up to at least the legal limit but, by the time you get up to 1000pF or so, they are *huge*. Another glazed-ceramic-encased type, which I have used in both my ATUs, came in two sizes, rated at 1kV and 2kV *RF*. They are very stable, produce no perceivable heat at full power and give no trouble whatsoever; the only two snags are that I only ever came across them once, at a rally some years ago (I think on Birkett's stand) and the only values were around 500pF, so parallel or series combinations are usually required. ◆





From top:

The two-band version of the ATU, interior view.

Securing the coil windings in the two-band version.

Capacitors. Left and centre: suitable types. Right: the ones to avoid.