18 The Great Outdoors

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One aspect of amateur radio that has seen huge growth in recent years is that of outdoor operating. By this we mean the use of a portable or mobile station without recourse to mains power and where the station is carried in its entirety to the intended location by the operator. This style of operating includes Summits on the Air (SOTA) [1] activations, Worked all Britain [2] operations from remote areas and even long-distance backpacking with amateur radio.

A number of factors have led to this rise in popularity. Amongst them are the availability of small multiband radios, the success of the SOTA programme and perhaps the difficulty many face in operating a radio station effectively in a modern urban environment. It is an excellent way to combine two hobbies. A love of walking and the countryside enhances the operation of the radio station and vice versa. Whether this is a local walk to your nearest hill, a night spent in the mountains while climbing bigger SOTA summits or backpacking along one of our National Trails with a radio for company, the enjoyment can be immense.

Whatever the reason for its popularity, this style of operating poses many interesting challenges to the technically-minded. It presents numerous opportunities for the construction of equipment that would perhaps be bought from commercial sources given more normal operating constraints.

Inevitably, when weight is the most serious consideration, compromises in performance may have to be made. It is the balance between performance and weight and it's effect on the engineering of an effective station that we will discuss in this chapter.

RELIABILITY

It may seem perverse to commence this chapter with a section on reliability but whilst having to close down at home due to an equipment malfunction is always annoying, for this to happen on a summit after a long car journey and several hours walking would be annoying to say the least. Worse, if this were to happen in mid-contact, it's entirely possible that the unexpected silence could initiate an unnecessary callout of a Mountain Rescue team.

Survivability

This topic falls more under the heading of operating philosophy, but resolving this dilemma may determine your approach to engineering the station. It is always possible to take duplicate equipment to guard against failures but this approach could dramatically increase the load that has to be carried. A reasonable compromise might be to take a small handheld and halfwave vertical as a backup for the main station. I have invoked the use of my backup station on several occasions when the weather conditions made it impossible to erect the main station. This approach can be made to cover many eventualities and many of the physical challenges thrown at the outdoor operator. Resolving this multi-dimensional jigsaw puzzle is the first task.

Failure Assessment

In attempting to minimise the chances of a failure halting operations, it is sensible to review each piece of equipment subjectively and decide what the likelihood and consequence of a failure would be to the station. Then it can either be re-engineered to reduce the possibility of a failure or backup provided that would at least allow operating to continue. It has to be said that the most common causes of failures known to me are those involving microphone leads and home-made coaxial and control cables. These are potentially fragile items anyway, but using them 'in the field' dramatically increases the chance of a failure.

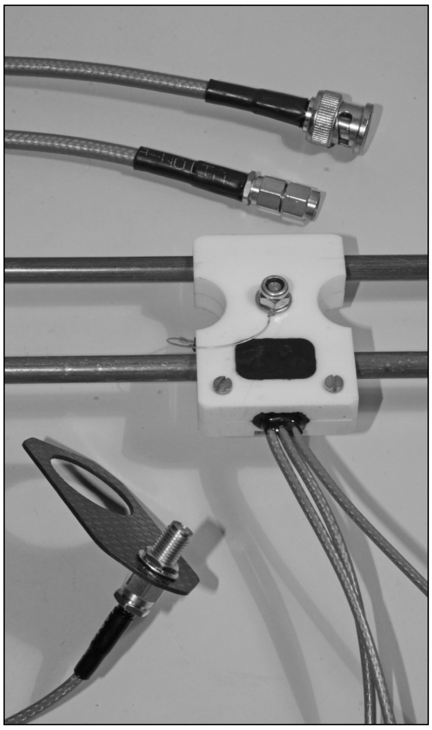


Fig 18.1: Strain relief applied to antenna components. From the top: 1) Stiff Raychem Viton heat-shrink sleeving has been applied to the crimped connections on the coax. This is glued in place using special RT125 two-part epoxy adhesive. 2) The coax balun joints and cable exit from the folded dipole have been encapsulated using RT125. 3) A carbon fibre strain relief plate has been added to prevent the weight of the coax downlead from damaging the more fragile RG316 of the dipole feed

Techniques

The topic of reliability is high on the agenda in military, aerospace and in motor racing circles and it is not surprising that similar techniques are used in all three.

These techniques are mostly based on applying strain relief and waterproofing to both cables and equipment. Damage caused by tension on cables, or corrosion caused by water ingress are two very common causes of failure. Equipment designed for use in the home shack or car is unlikely to have been designed to survive the climatic extremes of outdoor operating. They may need a little help in this respect. Here, small engineering changes can make a major improvement to reliability. Even the layout of the station can be important. For example, a black rig operating in full sun on a calm day can easily overheat. Using your body as a shield against the sun can solve this particular problem.

Fig 18.1 shows several instances where strain relief has been applied to antenna components. **Fig 18.2** shows how control and other cables can be engineered to last.

General Reliability Comments

Generally, crimped connectors are more reliable than the soldered equivalent *if done correctly* and are usually lighter. Solder joints generally fail at the sharp transition between the solder joint and wire. Kynar sleeving placed over a joint can dramatically reduce the chance of a failure.

When planning a system, consideration should be given to ensuring as far as possible that a particular type of connector is only used once thus avoiding cross-connection mistakes.

Fig 18.2: Strain relief applied to control cables. 1) Top centre shows how the cable into the centre of this paddle key is trapped and held by the Tufnol block. Each connection has a small length of Kynar heatshrink sleeving covering the solder joints. 2) Top left and right are examples of heatshrink boots being used to protect the cable exits from connectors. 3) A headphone splitter made from three moulded cables. The splice contains sleeved, Kynar-covered joints with repair loops and there is a heatshrink covering for overall protection of the split. 4) Bottom left is an example of 'repair loops' - a small loop allowing the wire to be stretched slightly without damage. Note the crimped pins. 5) Deutsch Autosport connector and Raychem boot prior to shrinking. The connector is the intended housing for the crimped pins to their left

Military and motorsport applications guard against mismating of connectors by using connector families that provide different orientations and polarities. These connectors are relatively expensive so an alternative approach is to, use different types of connectors for each application and to ensure that it is not possible to inter-mate them. If duplication is inevitable, label the connectors to minimise the risk of a mistake.

If a free choice of connectors is possible, it is worth considering whether they are 'scoop-proof'. In other words, the pins in the mating halves cannot ever touch until the connector is correctly mated. This is particularly important for power connectors. Imagine that during station assembly an earth connection already exists between two units via a control cable. A power connector is mated last in the sequence. Two of the pins accidentally touch but they carry opposite polarities. This could cause serious damage. The FT817 external power supply is particularly fragile in this respect, having a common-mode choke on its input. Fitting fuses in both sides of the supply to any transceivers or amplifiers is the only way to guard against such an occurrence and even so, there is a chance that a narrow PCB trace will blow before a fuse. Good quality connectors are a better defence - and probably a lighter solution than the addition of fuses.

Heatshrink sleeving is an exceptionally useful product for protecting and strain-relieving electrical interconnections. It should, however, be used with care. In its intended environment it is used with matching high-temperature wires and cables. It should be used carefully with PVC cables where the heat that is required to shrink the sleeving can also cause the PVC to melt and the wires to fuse together. If a sound is heard when the cable is flexed after assembly, this is a good indication that it has been damaged.

SAFETY AND WALKING EQUIPMENT

The outdoor operator is probably at much greater risk than the average hill walker. There are several reasons for making this statement and some are listed below:

- A higher risk of hypothermia due to the length of time spent stationary.
- A higher danger from thunderstorms.
- Instability caused by carrying a larger, heavier and perhaps less well-balanced load.
- The distraction caused by an intense concentration on the radio.
- A greater than normal determination to reach a summit whatever the conditions.

To this list should be added the hazards facing the more 'normal' hill walker such as trips, navigation and the vagaries of the British weather.

This section attempts to indicate 'best practice' and to show what equipment is available to help reduce the risks to a minimum. Following this to the letter will not guarantee your safety. Experience built up over increasingly challenging expeditions, backed by formal training or tutoring by a mentor is probably the best way to learn safely.

Clothing

"There is no such thing as bad weather, only the wrong clothes " says the old proverb. The importance of using the correct clothing cannot be stressed enough. The marketplace is full of outdoor garments of different types and a discussion of the various options could fill a book in its own right. If you intend heading off into the great outdoors for the first time you are strongly recommended to read the specialist walking magazines available from high street newsagents. They publish excellent reviews of equipment and offer good advice. What follows here are no more than a few hints.

- Go to a specialist outdoor shop and ask for their advice. Most such shops are staffed by knowledgeable enthusiasts.
- Don't be tempted to wear Denims - ever. At best, they restrict leg movement and waste energy. Worse, they get wet and stay wet, leading to heat loss.
- Always take spare layers, even when the weather shows no sign of it being necessary. In particular, take a spare hat and gloves. Loss of a glove could result in frostbite.
- Good supportive boots are essential - despite what you might read. We are hikers - not fell runners!
- Buy the best you can afford. The best will keep you warmer or will be lighter - or both.
- Look after your investment. Apart from the cost of replacement, it could be important for your continued wellbeing.

Here are some of my favourites:

Extremities Sticky Windy Gloves. They will allow you to write, operate a rig and even assemble SMAs. Not as warm as some, though. Take them as your spare pair.
Montane Atomic Pants and Jacket. They weigh very little, pack up into tiny stuff sacks and whilst not as breathable as some waterproofs still work very well.
TrekMates Merino T-shirt. A great base layer - especially for long treks where the wool's anti-odour properties are appreciated.
Scarpa Ranger GTX boots. A good hill walking boot. Having leather uppers, they require more care and maintenance than others. They will take a Grivel G10 Crampon for short periods despite their rating.
Lowa Renegade GTX Lo trail shoes. Excellent for backpacking on defined paths.
Balaclava. It will stop your face from freezing and so will help prevent a Q4 report on SSB!

Fig 18.3: A selection of navigation tools: The newer Etrex Vista HCx on the left has a colour screen and higher sensitivity receiver than the older Summit on the right. The small Silva compass below it may be adequate as a backup. The Silva Ranger 3 on the right is preferable

Navigation

In the UK we are extremely lucky to have the most incredibly detailed maps at our disposal. The Ordnance Survey's 1:25,000 series maps are a treasure trove of information for the trained eye to use. When used in conjunction with a compass, a GPS receiver and even satellite imaging, it helps the outdoor operator to understand and anticipate the terrain. There have been one or two cases where SOTA activators have activated the wrong summit due to errors in navigation so quite apart from making sure you get back safely, accurate navigation is very important.

A selection of navigation tools is shown in Fig 18.3. Their correct use requires practice and details of training courses can be found in the walking magazines.

Maps and compass

GPS receivers usually provide a compass facility - examples can be seen in Fig 18.3. Some work by using your GPS-calculated direction and some have built-in Hall-effect sensors. They all use electronics.

It is a wise precaution to take a traditional compass based on a magnetic needle and to know how to use it in conjunction with a map. Silva manufactures a good range of plastic-bodied compasses of varying sizes from the tiny to the classic Silva Ranger 3.

Even when your GPS receiver is still working, there can be occasions when a map and compass are preferable. A compass can be operated in arctic conditions when fingers pushing buttons would freeze in seconds.

GPS

Many personal computing devices incorporate a GPS receiver these days, however none is waterproof and most do not have the features that are available in devices specifically aimed at the walker.

This is not the place to discuss the workings of GPS, so this section concentrates on the basics, on those features that matter most and how to get the best from a receiver.

A GPS receiver calculates its location by clever mathematics based on the time taken for time-critical signals to travel from satellites in known locations in space. It could be viewed as DF in reverse. It is unaffected by cloud cover - or even rain, the system working at 1.6 GHz. It is important to have a clear view of as many satellites as possible to get the most accurate calculation of position.

Tree cover used to be a big problem however the latest high sensitivity receiver chip sets are very much better than the older generation ones, which lost lock very easily. Whilst users have been known to place their GPS receiver in their hats, a more normal and more readily accessible location is on a rucksack strap where the top part of the unit can see the sky. Garmin sell a carrying case which has a useful clip. If the receiver is supplied with a lanyard, it is a good idea to attach it to the rucksack to prevent its accidental loss.

Most GPS receivers run on two AA cells and the life is often no more than 20 hours. The receiver then automatically switches off when its preset end voltage is reached. Often a large percentage of the cell's capacity is wasted. Although they have a lower initial voltage, rechargeable NiMH cells will give longer use than Manganese Dioxide non-rechargeable cells due the poor slope of the latter's discharge curve. The latest receivers allow the user to select the type of battery that has been fitted and this should help to maximise the life of a set of cells.

Typically, the user will decide on some key points on a map that define the intended journey (track junctions, turns, landmarks etc). These waypoints are then linked to form a route which is downloaded to the receiver. Whilst it is possible to enter all this information directly into the device, this is time-consuming to say the least. Most come with a PC interface and software which allow this to be done more efficiently. With the route downloaded, the receiver is then told to follow it from one waypoint to the next. In so doing, it records a log of the actual path taken (a so-called breadcrumb trail). This can be used later in the walk to allow the user to re-trace his steps or it can be downloaded to the PC for analysis. It is fascinating to overlay a tracklog on an OS map and see the exact route.

In choosing a receiver there are several important features to consider.

- Sensitivity. The latest generation receivers such as Garmin's Vista HCx are infinitely better in tree cover than older models such as the Etrex Summit.
- Routes. Some units are able to store a maximum of only 20 routes. For a long multi-summit expedition this may be a problem.
- Reversible routes. Both the Summit and the Vista allow you to follow a route in either direction however the Vista is less intuitive to set up and is less well-documented.
- Maps. Later units like the HCx can store and display real maps if a micro-SD card is installed. Cross-referencing the GPS position to a location on a paper map is made much simpler.
- Tracklog memory. Older devices record into a limited-size internal flash memory. Depending on the logging mode chosen, this is generally adequate for a weekend expedition but would not cope with a Long Distance Path walked over a period of a week. Modern units like the Vista have the ability to log onto a micro-SD card. The same weekend expedition that would fill two-thirds of the internal flash memory would use only 100kB of a 1GB card.

Rucksacks and Waterproofing

Another difference between the outdoor operator and the average hill walker is in the type of equipment he needs to carry and the relative fragility of this equipment. These factors have a bearing on the choice of a suitable rucksack.

The primary specifications you will see for a rucksack are its capacity and its weight. The term Daysack is applied to something generally less than 25 litres and usually without a waist strap. A waist strap adds stability and transfers weight to the hips, making a large or heavy sack more comfortable to carry. For a single activation or even a day's expedition, a Daysack is usually big enough, although the wearer's shoulders may suffer when carrying a heavy load. A 30 litre rucksack could be adequate for an overnight stop but this is specialist ultra-light territory and probably not for beginners. A 45 litre rucksack is a better bet. Again, for the ultra-lightweight enthusiast a 45 litre rucksack could be adequate for longer expeditions but 55 litres would be less spartan.

Whatever the application, the quality of the material is important. Here, it is very much a case of "if it feels strong enough, it is". For this reason it is best to visit a good outdoor shop and see for yourself - especially if straying into ultra-lightweight territory. The nature of the loads to be carried could result in damage to some of the fabrics used in ultra-lightweight rucksacks. That said, recent advances in materials and design techniques mean that even a strong 45 litre rucksack can now weigh less than 1kg.

When choosing a rucksack for outdoor operating, the following questions are worth asking yourself.

- What type of expeditions do I want to cover?
- Has it got attachment points for antennas?
- Can I mount a GPS receiver in a convenient place?
- Has it got lots of separate compartments? This helps with segregating radios from walking necessities.
- Is the back system going to protect me from awkward-shaped objects? Will it be difficult to pack?

Fig 18.4: Rucksacks suitable for different radio uses: (left) Deuter Speed Lite 30 litres, 830g. Hardwearing and just large enough to cope with an overnight stop if you are a minimalist.
(middle) Osprey Exos 46 litre, 1030g. Slightly less robust. Shown ready for a week's expedition with camping equipment, FT-817 and spare batteries. The 'R'-Clip Special and mast are in the bag opposite the walking poles.
(right)) Blacks Velocity 20 litre Daysack, 700g. Really strong with lots of compartments. Excellent for a single activation

Generally-speaking rucksacks are not waterproof. It is normal practice to stow any critical items inside specialist waterproof bags which can be bought from outdoor shops. They are useful for larger items like sleeping bags or maybe a transceiver but the outdoor operator will need to carry many small articles - such as coax adaptors, batteries etc and these are best organised into several small, separate groups. A cheap way of doing this is to use Baco Zip'n' Seal freezer bags. They are readily available, cheap, will last many activations before needing replacement whilst coming in a range of sizes. For the outdoor operator, the added advantage of keeping radio items in waterproof bags is that the bags help protect the rucksack from damage due to sharp corners. When the bag is worn it can be cheaply replaced.

Fig 18.4: shows three rucksacks that have proved suitable for different types of expeditions.

Weight

The most valuable piece of equipment the outdoor operator can acquire is a good set of digital scales. Using these, the activator can keep a check on the weight of his load. I maintain a spreadsheet listing the weights of every piece of equipment I intend carrying and from this can calculate the overall weight of the rucksack. The weight that can be carried depends on your own physique, level of fitness and the nature of the expedition. Some activators will happily carry 15kg all day. I am of slight build and have found my limit to be around 12kg for a moderately strenuous expedition or 13kg for backpacking.

Safety Equipment

In addition to the clothing and navigation equipment mentioned in the preceding sections, it is wise to carry several other safety-related items in case of emergencies.

Hypothermia is a real possibility at altitude even in summer. Any form of shelter will make a big difference to your chances of survival should you be unfortunate enough to suffer a forced stay on a summit. Survival bags come in different sizes but Vango's one-person Storm Shelter 100 weighs 380g and its deployment promotes an instant increase in body temperature thanks to the shelter it provides from a chilling wind. The alternative is to carry a small tent that can also be used for more extended operating periods as well as for emergencies. It should be said, however, that an exposed summit is not the best environment for a tent. Merely putting in the guys may be impossible on rocky terrain. The best of the lightweight tents is Terra Nova's Laser Competition at 990g. The material is relatively fragile and care is needed to avoid damage - especially on rocky ground.

To summon help should it be needed, a whistle should always be carried - and possibly a mobile phone as well. Six blasts on the whistle is the universal distress call and this should always be tried first before 'phoning for help. Mobile phones often have no coverage and should never be relied upon. It is also best to leave them switched off unless they are needed as battery drain is drastically increased when areas of poor coverage are entered.

Walking after dark in an urban environment is relatively easy. There is usually so much light pollution. This is not the case in the mountains and navigating on a cloudy night can be completely disorientating. For emergency use, it is a good idea to carry a small head torch such as the Petzl Tikka Plus. It weighs 80g and has four LEDs which run on AAA cells. Whilst it could never be used for fell running, it is fine in an emergency (and ideal for in-tent use at night). If a night-time walk is contemplated, a more powerful and versatile torch will be required. For mountain marathons or night time activations, then something similar to Black Diamond's Icon is more appropriate. It runs on three AA

Fig 18.5: A selection of safety-related items for the hill walker: Laser Competition tent, Storm Shelter 100, two head torches and a carabiner with a whistle, mini-compass and single LED torch

cells and has both a single 3W LED and four additional LEDs for a choice of high intensity spot or broad beam. As battery changing on any equipment in the dark is difficult, I also carry a small single LED torch to help in such situations. Naturally, spare cells should always be carried. **Fig 18.5** shows a selection of safety-related items.

ANTENNAS

This is one aspect of outdoor operating where the keen constructor can make a significant difference to the efficiency of the station. Antennas intended for long-term use at home are likely to be far too bulky and heavy for the outdoor operator to carry. Efficient antennas for all the amateur bands can be constructed that will be far lighter than anything available from the usual commercial sources. This section explores a selection of designs that have been proven to work. Brief descriptions and constructional details are given for each type along with approximate weights and performance figures.

HF

Two types of HF antenna dominate lightweight portable operation: the inverted-V and the inverted-L (there's more about these in the chapter on practical HF antennas). The latter normally requires the use of some form of antenna matching unit and probably a counterpoise as well. It has the advantage that it can be fed directly with only a short length of coax and the mast can be used as part of the antenna. It does, however, require a matching unit. The inverted-V needs no counterpoise or matching unit and so potentially promises the lighter solution. It is also less susceptible to changes in tuning caused by variations in ground conductivity.

Space can be a problem in some situations and this may make the inverted-L a more attractive proposition, however the radiation from an inverted-V is predominantly high-angle and this is ideal for most outdoor operations where the majority of listeners are in Europe. The high-angle radiation particularly favours 60m with its NVIS properties and this largely explains the success that SOTA has enjoyed on this band.

On 80 and 160m, the space required to erect an HF antenna is often a problem but by using loading coils the overall length may be reduced at the expense of a reduction in bandwidth. For many types of outdoor operation such as SOTA and WAB, specific frequencies are used and so this lack of bandwidth is unlikely to cause a problem since the antenna can be pre-tuned for the desired part of the band.

A shortened multiband inverted-V

The two most popular HF bands for SOTA use are 40 and 60 metres. Antenna sizes are reasonable and one or other band can normally be relied upon to produce enough contacts to qualify a summit. This proven design covers both bands with provision to extend it for 80m use. In common with most lightweight antennas for HF, it ignores the accepted and normally correct practice of feeding the antenna via a balun. In this instance the dipole legs are connected directly to the coax.

Apart from ease of deployment, a shortened antenna is most useful in situations where space is limited - which is often the case on mountain tops. It needs approximately 30% less real estate than a full-sized antenna, thanks to the loading coils. The reduction in bandwidth that these cause is small on 40m but more noticeable on 60m. If necessary, tuning can be achieved by adding short plug-in extensions to the ends.

The centre of the inverted-V is supported on a glass fibre pole 6m above ground. The height of the centre is not particularly critical to the tuning, but the height of the ends and hence the capacitance of the ends to ground has a large effect. The antenna should be tuned for the anticipated height of the ends above ground allowing for droop. The dipole centre can be seen at the bottom of **Fig 18.6**. The cup fits over the top of the mast making for quick attachment.

The loading coils are wound on 50mm lengths of 22mm diameter hot water pipe. This material appears to have excellent RF properties even up to VHF, thanks to a mix that includes PTFE. The coils comprise 55 turns of 0.56mm (24AWG) enamelled copper wire. Note the stirrup-shaped 18SWG tinned copper wire pigtails used for attachment of the antenna wire. These pass through 2mm holes drilled in the sides of the tube. Glued heatshrink sleeving is used to ruggedise the potentially fragile junctions between the coils and the dipole wires.

Band selection is achieved by means of the links that can be seen in Fig 18.6. They are connected to achieve 60m operation and left open for 40m. Each link comprises a 2mm plug and socket pair - again, ruggedised using glued heatshrink. When open, the ends of the active part of the dipole carry high voltages and the small insulators shown in the photograph are essential. These blocks are made from 22 x 12mm pieces of 6mm thick acrylic sheet although Tufnol or Perspex could equally well be used. The holes in these insulators are countersunk and deburred on both sides to reduce the possibility of a failure in the

Fig 18.6: Components of the compact multiband inverted-V linked dipole

Dipole centre to loading coil:	4.4m
Loading coil to 40/60m link:	1.6m
60m leg:	1.4m
Guy:	2.5m

Table 18.1: Critical dimension of the multiband inverted-V

wires caused by sharp edges. There is a 2mm socket at the end of the 60m legs to allow an 80m extension to be added.

The wire is standard 7/0.2 plastic-covered equipment wire. Different colours have been used on either side of the dipole to aid deployment should a tangle occur. To a large extent this annoyance can be minimised by careful winding of the dipole onto a suitable 'former' when not in use and the author's example can be seen at the top of the photo. It is a 300mm length of a glass fibre tube with the ends slotted. A piece of hardboard is equally suitable - if heavier.

The antenna is fed via 7m of RG316. Whilst loss is not significant on HF, the RG316 is used in preference to RG174 due to its higher voltage specification. This becomes important at higher powers but RG316 is also mechanically superior and so is to be preferred.

The dipole centre comprises a 40 x 20mm piece of insulating material which is attached using a single M4 screw to an aluminium cup. In operation, this is held onto the mast by gravity. Note the method of securing the wires to the dipole centre in a fashion that helps prevent failure at this point due to flexing.

The guy ropes shown in the photo are 2.5mm woven polypropylene cord. As an alternative, Liros manufacture a range of 2mm cords in high visibility colours that stand out well when buried amongst vegetation. The completed antenna weighs 282g including the coax, storage former and titanium guy pegs.

Tuning a trapped dipole from scratch can prove frustrating and simulation programs such as *EZNEC* do not accurately model the end capacitance, making the task doubly difficult. With this antenna, the no-traps design means that setting up the lengths is simply a matter of tuning the length for the highest band then adding in the links and cutting the next lowest band legs to length. A network analyser - even a simple one will make this an easy task.

Should such a device not be available, the dimensions given in **Table 18.1** should prove very close and certainly in-band, allowing the SWR indication in a transceiver to be used to complete the operation. To allow for variations on-site, the kit could include pairs of small lengths of wire each fitted with 2mm plugs. These need be no more than 200mm long to have a significant effect on the resonant frequency.

VHF/UHF

A diverse range of antenna designs can be used on the VHF bands. They all fall into one of two categories - beams and omnidirectional verticals.

Verticals are simple to erect and are often rucksack-mounted for ease of use and lightness. The handheld / 'rubber duck' antenna combination is the ultimate expression of this approach. Beams include both Yagis and quads (see the chapter on practical VHF antennas) although the latter are a heavier and more bulky solution.

The choice of a suitable antenna, of course, is entirely down to the philosophy of the operator and, in the SOTA context, the difficulty of qualifying a summit. This section offers a range of antennas from both groups which should satisfy most situations and tastes in operating styles. Having a range of antennas available allows the weight-conscious operator to choose the most appropriate solution for a particular expedition. Whilst the handheld / 'rubber duck' approach may well allow a summit qualification in some parts of the country, it is unlikely to succeed in more remote areas where a high-gain beam and 50 watts would be more suitable.

Yagis

Without doubt, the Yagi is the most appropriate antenna for the VHF and UHF bands when system performance is important. Not only will a beam mounted on a mast have more gain than a vertical, its directional properties may prove beneficial on sites where there are co-located commercial transmitters and the receiver is in danger of being overloaded.

Most commercial Yagi designs intended for home use are generally bulky and heavy - they have to survive the ravages of our climate for long periods. For the outdoor operator, weight and ergonomics are the most important factors. The designs presented in this section have proved their worth in countless outings and despite their lightweight construction, perform at least as well as the equivalent commercial design.

A 6-element Yagi for 2m

This no-compromise design has survived several hundred outings without a breakage and gives outstanding performance for an antenna weighing 0.5kg. The design criteria were:

- Lightweight
- Driven element can be used alone
- Quick assembly / disassembly (no nuts)
- Rugged - to survive the occasional crash-landing.
- High but stable forward gain.
- Readily-available materials.
- No part longer than 1m.

Having had considerable success with Yagis based on DL6WU's double taper principle [3], this was used as the starting point for the electrical design. It was optimised using *EZNEC* within the physical constraints defined above. Conventional designs use a reflector of greater than 1m in length. However ,suitable tubing is not easily available and so a reduction in front-to-back ratio was accepted in order to maintain this goal. The azimuth plot of the finished design is shown in **Fig 18.7**.

The elements are all insulated from the boom. This removes any possibility of a variation in performance caused by an intermittent contact in this important area. The passive elements are held to the boom using Terry clips. Nylon bushes on each element locate and insulate them from the boom. This method

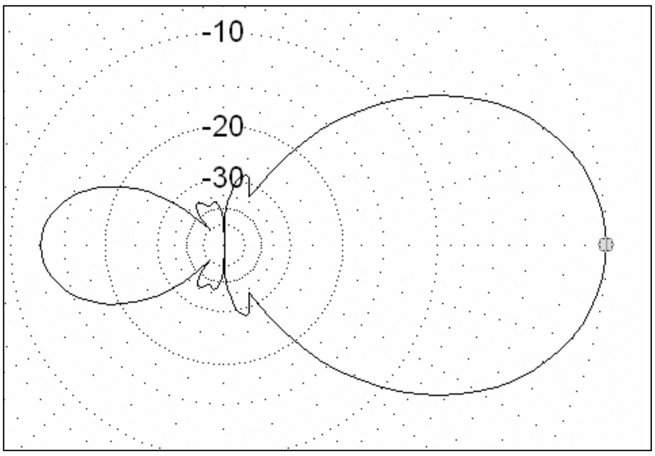


Fig 18.7: *EZNEC* simulated polar plot of the 6 element 2m Yagi. Predicted gain is 9.1dBd, F/B 12.6dB and -3dB beamwidth 50º

Element	Position (mm)	Length (mm)
R	0	1000
DE	450	930 (see text)
D1	700	920
D2	1050	900
D3	1450	890
D4	1980	880

Table 18.2: Dimensions for the 6 element 2m Yagi

of attachment provides for very quick assembly and allows them to come free in the event of an accident - the elements simply popping off the boom.

The driven element (DE) is a folded dipole. An increase in weight has been accepted here in order to achieve a near-50-ohm match. This allows it to be used alone when conditions dictate - perhaps due to high winds on a summit. The mounting for the DE is replicated on the mast clamp to permit a direct fit without using the boom.

Dimensions for the antenna are shown in **Table 18.2**. The folded dipole has an overall length of 930mm and the two sides have a centre-to-centre spacing of 30 mm.

Aluminium for the antenna elements and boom can be obtained from larger DiY stores in 1m lengths. The boom comprises two lengths of 10mm square tube and the elements are all constructed from 6mm tubing. Each passive element has a pair of nylon bushes bonded in place at its centre. Two different lengths (4mm and 6mm) are needed to exactly match the 10mm boom. As an alternative, they can be machined as one piece from nylon. Initially, they are held in place with a drop of superglue. Once this has set, a bead of Araldite should be placed around the junction between the nylon flange and the tube. Application of a small amount of heat using a heatgun will flow the glue and help it form a better joint.

Fig 18.8 shows assembly details of the passive element mount. The passive elements clip onto the boom using 8mm Terry clips. These fit into recesses in the boom and are held in place using 2.5mm (3/32") rivets. The recessed mounting protects the clips and the semicircular details in the sides of the boom locate the element accurately. These semicircular cutouts are machined using an 8mm ball-nosed cutter. Below the boom

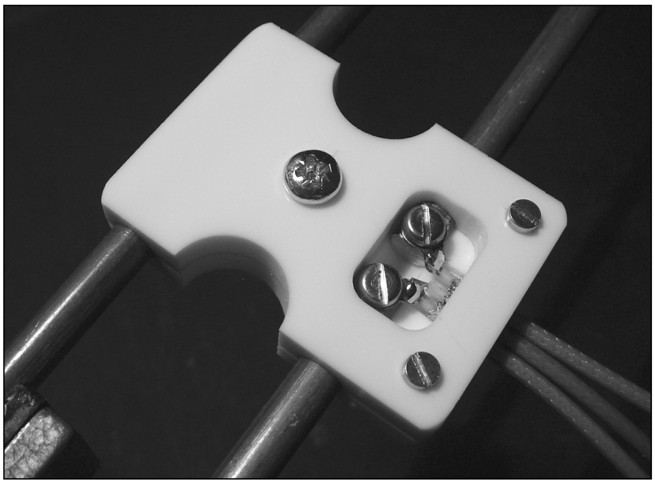


Fig 18.9: Fully-insulated dipole centre

can be seen a strengthening plate. The original design did not use these and the soft aluminium of the boom eventually suffered after a fall. The plate was added to passive elements one and two and this has since proved reliable despite many mishaps. Both the bushes and clips are available from Farnell - one of the UK's major mail-order electronics companies [4].

The driven element is a folded dipole fed via a 4:1 coaxial balun for a near-50-ohm match. It is insulated from the boom by the plastic housing and secured to it by a titanium stud and 'R' clip which fits through a hole in the end of the stud. The distance quoted in the table is from the reflector to the mounting hole at the centre of the DE.

Construction of the balun housing is shown in **Fig 18.9** and an assembly drawing in **Fig 18.10**.

In this particular case, a solid rod is used and the balun attached using M3 stainless steel screws and solder tags into threaded flats on the ends of the DE. The insulator comprises two pieces of 36mm x 51mm 6mm thick acrylic plate. The elements are located 30mm apart in semicircular grooves machined in each half using a 6mm ball-nosed cutter. The two halves are held together by two M2.5mm screws (seen at the bottom of the photo) and the titanium locating stud. (The temporary fixing in the photo shows an M4 standard screw.) A 10mm wide longitudinal

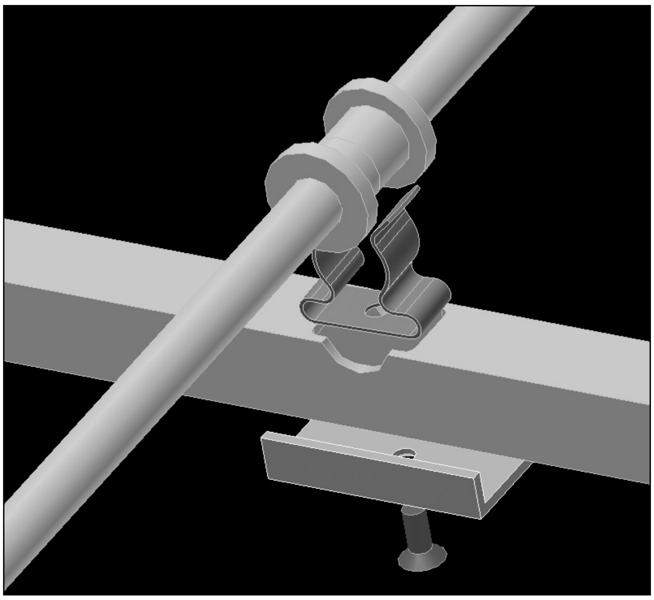


Fig 18.8: Assembly drawing of the passive elements

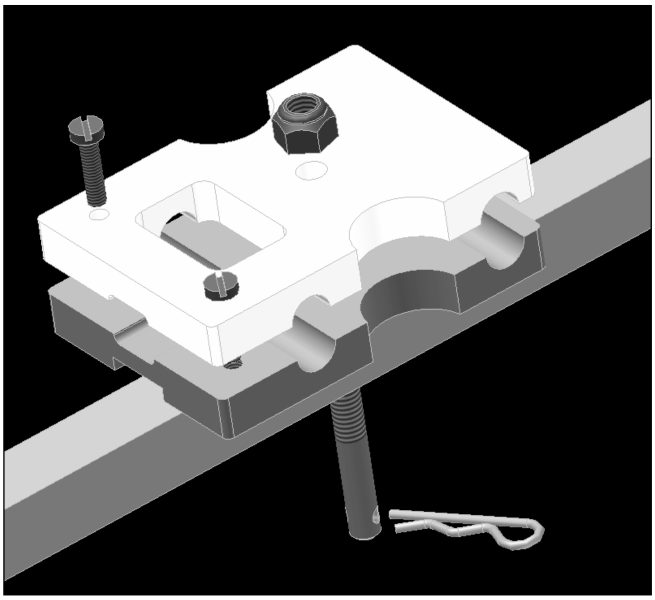


Fig 18.10: Assembly drawing for the dipole centre

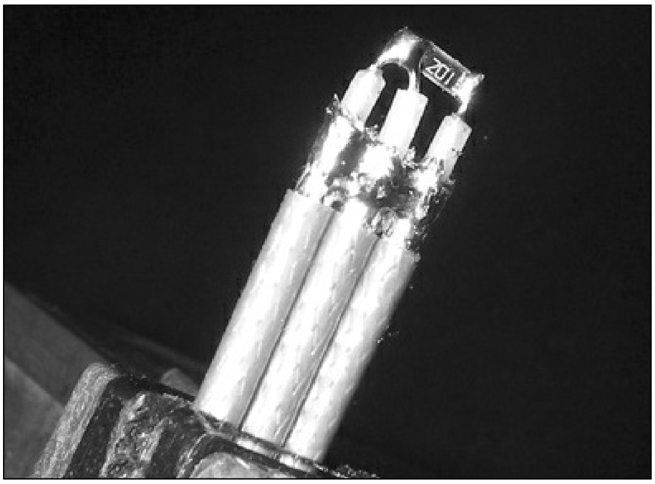


Fig 18.11: Adjusting the balun for lowest VSWR

groove on the bottom stops the driven element from rotating with respect to the boom. Once the performance has been verified, the cavity is filled with Araldite to achieve both waterproofing and mechanical strength.

The 'R' clip that locates the DE on the boom is held captive to the DE using a short length of fishing line. In case of loss due to breakage of the line, I take a spare. To date, this has not been needed.

The 4:1 balun comprises a halfwave of RG-316 connected as shown in Fig 18.9 and **Fig 18,11**. It does not matter whether the coaxial connection is located in the centre of the balun or to one side. Allowing for the velocity factor, the length of the coax forming the balun is approximately 700mm. A diagram of the balun arrangement can be found in the chapter on practical VHF/UHF antennas.

The only tuning that is required is to cut the coaxial balun for the desired frequency. This can be done prior to connecting it to the dipole. Attach a 200-ohm surface mount or other non-inductive resistor as shown in Fig 18.11. Using an antenna analyser or other return loss indicator, adjust the length of the balun for best match at the desired centre frequency (usually 145MHz). Once this is done, the balun and feed can be attached to the dipole as shown in Fig 18.9 and the assembly potted.

A 4-element compact Yagi for 2m - the 'R' Clip Special

There are occasions when carrying a one metre-long bundle of poles and antenna elements is inconvenient. Having struggled to maintain control over both antenna and rucksack when using public transport, I developed this solution. The entire antenna and mast fit in a small stuff sack measuring 550 x 150mm. This can be carried in one of the side pockets on a rucksack - one that would normally carry trekking poles. The antenna and 3m mast in its bag weigh 672g. A separate bag containing the guys, pegs and coax weighs a further 160g.

The antenna has a forward gain of 7.3dBd which compares well with its larger cousins whilst offering a substantial saving in weight and bulk. **Table 18.3** shows the dimensions.

Conventional high-performance Yagi designs place great emphasis on the electrical integrity of the elements at their centres where the currents are highest. An inescapable consequence of a design that dismantles into parts shorter than one metre is the scope for poor contacts in this important area. The outdoor operator can take advantage of the transient nature of his operations and ignore the major source of this problem - corrosion. In this design, the act of assembling the antenna causes the electrically mating surfaces to be wiped clean of any surface build-up. In this case, the elements are all held in place using 'R' clips and whilst fiddly to assemble, this design has proved its worth on long treks where minimising weight and bulk are the primary considerations.

Element	Position (mm)	Length (mm)
R	0	1015
DE	450	980
D1	700	961
D2	1050	913

Table 18.3: Dimensions of the 'R'-Clip Special

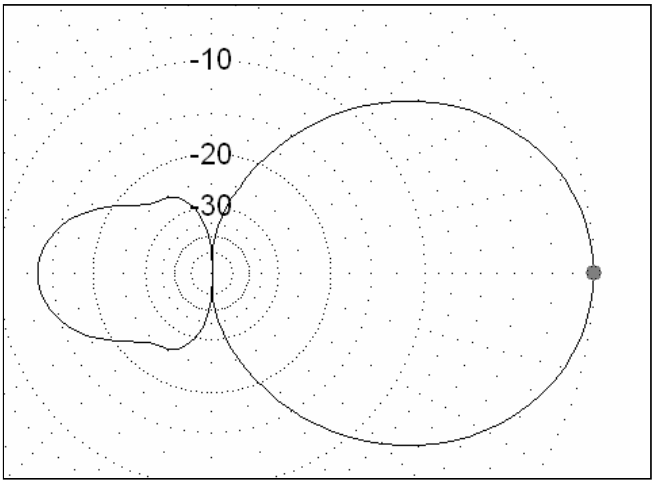


Fig 18.12: Simulation of the polar pattern for the 'R'-Clip Special. Predicted gain is 7.3dBd, F/B 13.5dB and -3dB beamwidth 57º

This four-element Yagi employs a folded dipole as the driven element and so, like the 6-element version in the previous section, the DE can be used in isolation should conditions dictate. In this design, the passive elements are electrically connected to the boom. The design was optimised using *EZNEC* to give the highest stable gain using boom and element lengths that would fit inside the available sack. After simulation, the element lengths were corrected for the 10mm boom material. The EZNEC polar pattern is shown in **Fig 18.12**.

The elements are 4mm aluminium rod and the boom 10mm square-section tubing as can be seen in **Fig 18.13**. Both types of material are readily available in the larger DIY shops although

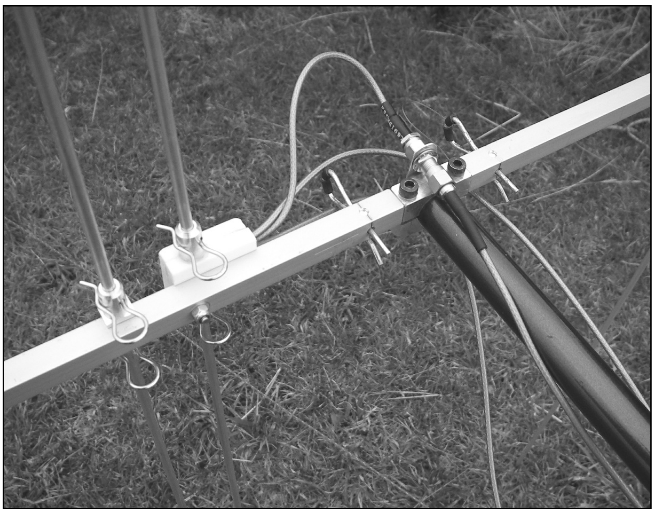


Fig 18.13: The 'R'-Clip Special driven element and mast clamp

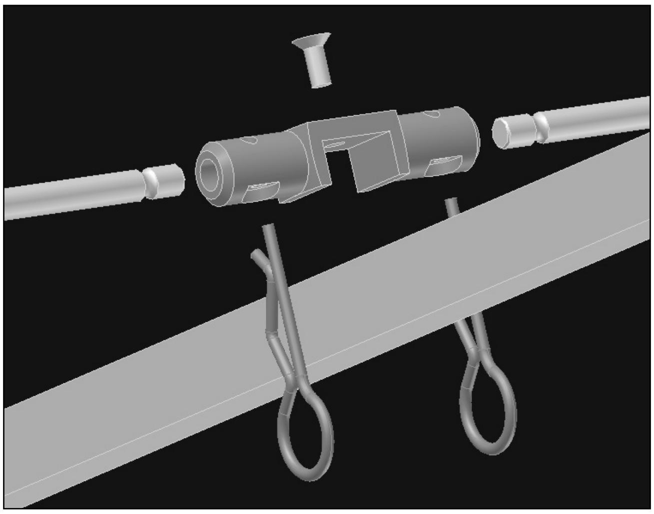


Fig 18.14: Assembly drawing showing the passive element mounts

better quality rod that is easier to machine would be an improvement. Referring to Fig 18.14 the element rods are held captive in their aluminium mounts by 'R' clips and are located by radial grooves. The mounts are riveted to the boom using M2.5 rivets. M3 countersunk screws could equally well be used.

The driven element follows similar principles to the design of the 6-element but in common with the passive elements uses the 'R' clip method of attachment. Two small machined bushes provide the transition between the rods and the coax of the balun and feeder. The fully insulated assembly is potted in Araldite whose properties are adequate for short-term exposure to moisture.

As supplied, the 'R' clips have sharp ends which can dig into the aluminium. It is worth spending time with a needle file chamfering them to smooth their passage through the mounts and past the grooves in the elements.

Tuning of the assembly is identical to that of the 6-element design above and the reader is referred to this section.

A 12 element Yagi for 70cm

Whilst considerably smaller than its 2m relatives, a 70cm Yagi is still too bulky to be carried with the elements attached to the boom and for this reason a design using similar principles to those described for the 6-element 2m design is presented here. It is based on the DJ9BV series of 70cm Yagis [5] which in turn can trace their roots back to the work done by DL6WU, originally published in 1977 [3].

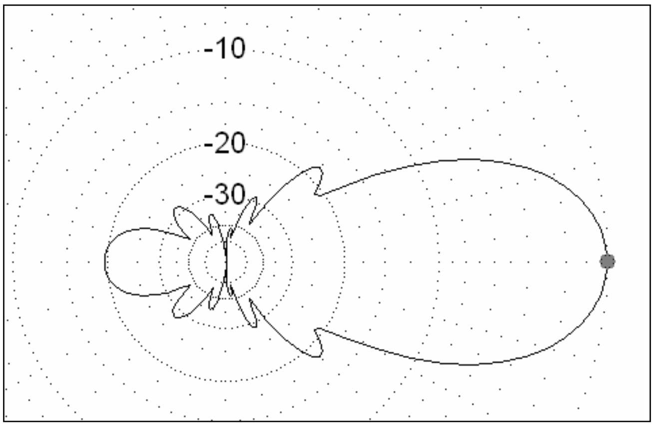


Fig 18.15: Simulated polar pattern of the 12 element 70cm Yagi. Predicted gain is 13dBd, F/B 20.6dB and -3dB beamwidth 33º

Element	Position (mm)	Length (mm)
R	0	341
DE	133	324
D1	193	312
D2	317	304
D3	460	296
D4	625	293
D5	832	292
D6	1034	289
D7	1246	288
D8	1488	285
D9	1736	283
D10	1981	282

Table 18.4: Dimensions of the 12 element 70cm Yagi

It has a total of 12 elements with dimensions as shown in Table 18.4. All are insulated from the boom which breaks down into two sections of approximately 1m length for ease of transportation. As Fig 18.15 shows, the gain is approximately 13dBd with a F/B ratio of around 20dB (noticeably better than the 2m version, thanks to the lack of restriction in the length of the reflector). It weighs 385g without the mast clamp which is common to the 2m versions.

Unlike the 2m version, the elements in this design are made of 4mm solid rod, however the boom still uses 10mm square tube. The nylon bushes used to insulate the elements are all 5mm wide and are used in pairs to straddle the boom. In this case, the semicircular locating details in the boom are machined using a 6mm cutter. Notice that both elements and boom are labelled to avoid time being wasted during assembly of the antenna.

The driven element is 324mm overall in length and the two sides are spaced by 30mm from centre-to-centre. It can be made from a single rod (Fig 18.16).

The balun and feed are attached to the DE via small solder tags and M2.5 screws which fit into tapped holes. The distance quoted from the reflector to the DE is to the centre line of the side to which the balun is attached.

The coaxial cable used for the balun and for the feeder exit is RG-316. The total length is 250mm. Allowing 5mm at each end for termination, this gives an active length of 240mm.

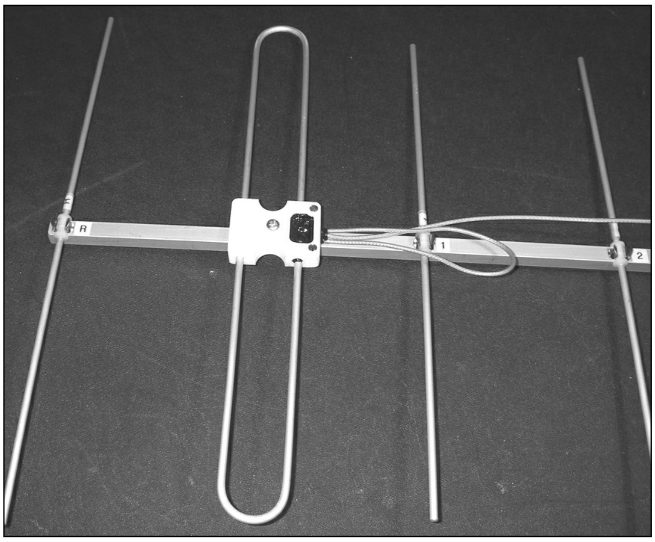


Fig 18.16: Showing the construction of the first four elements of the 70cm Yagi

Verticals

Those venturing to more remote areas need to consider vertical antennas somewhat more seriously. Whilst the standard ‘rubber duck’ type of antenna supplied with all handheld radios is useful, the efficiency is poor in comparison with a resonant antenna such as a quarter-wave ground plane or collinear. For those who do not wish to carry a beam or specifically want omnidirectional radiation from their antenna, some of the options are described in this section.

Although it is not in the same league as a beam, a rucksack-mounted vertical can at least be used in almost any weather conditions. It can also be used whilst on the move to keep in touch with other expeditions; I have made numerous contacts with stations on other summits by this means. It is necessary, however, for the user to remember that he is carrying it when approaching trees! A useful secondary effect of using a halfwave vertical is that a reduction in IMD products may be noticed thanks to the frequency selectivity created by using a resonant antenna and its matching network.

A rucksack-mounted vertical for 2m

This variation on the halfwave theme employs a standard telescopic antenna salvaged from a broadcast radio as the radiating element. A length of around 3/8 wavelength or 700mm is ideal, resulting in a practical Q in the tuned circuit and easier matching than with a full halfwave. A 50 ohm match to the transceiver can be achieved by adding a tap part-way up the coil as shown in **Fig 18.17**.

Telescopic antennas often have a hinged joint and this can be employed to good effect to achieve a polarity change. In my example, a modification was required to allow the whip to be locked in the vertical position, the normal friction lock proving inadequate. This was achieved by adding a small aluminium collar that slides down over the joint locking it solid. This collar can be seen in **Figs 18.18 and 18.19.** A small modification in a lathe was also required to the whip section to produce a parallel end to the lower section.

The matching network is housed in a small aluminium enclosure whose lower portion fits over one of the mast sections which is in turn mounted on the rucksack. It is necessary to prevent the whip from rotating with respect to the housing as this would cause the connection to the matching network to fail. This is achieved with a small insulating block which is a tight fit inside the housing. The whip is attached by a screw which locates in a tapped hole in the block. Under the head of the screw (sized to match the hole in the whip) is a solder tag which is the top connection for the parallel tuned circuit. The whip is insulated from the housing by a PTFE bush which is an interference fit in the housing. A second solder tag and screw at the base of the housing connects the opposite end of the matching network to ground.

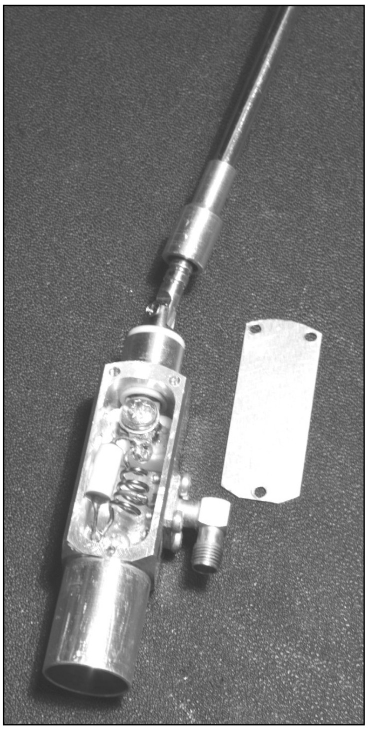


Fig 18.19: Close-up of the mount and matching network

The capacitor is a 22pf tubular ceramic of surplus origins. The inductor comprises four turns of 1mm enamelled copper wire wound on a 5.0mm former and in my version is tapped one and a half turns from the bottom. Exact values will depend on the construction and the length of the whip. A fixed capacitor is used in preference to a variable type as these can have a tendency to creep with repeated temperature cycling or with vibration.

The cavity is covered by a small 0.7mm thick aluminium plate. The assembly is waterproofed using a small amount of non-corrosive sealant. A detailed diagram of the housing is shown in **Fig 18.20**. The completed antenna weighs 72g and the RG316 coax a further 21 grams. Measurements on a test range indicate a gain approaching 6db over the type of antenna typically fitted to handheld units. **Fig 18.21** shows the SWR plot.

Assuming a similar length of whip is used, tuning of the assembled antenna should consist of adjusting the spacing of the turns on the coil for resonance. In my version, the plate made no difference to the tuning and so this procedure can be carried out with the lid removed. A non-conductive tool should be used to adjust the spacing. A useful adjusting tool can be made from a short length of FR4 PCB material with the copper foil removed.

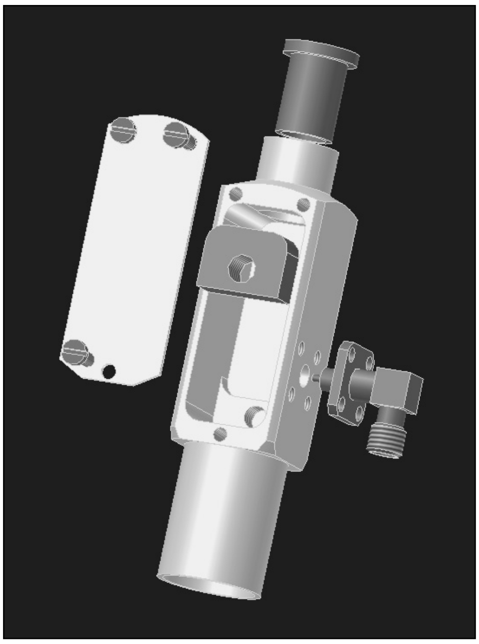


Fig 18.20: Exploded view of the mechanical assembly

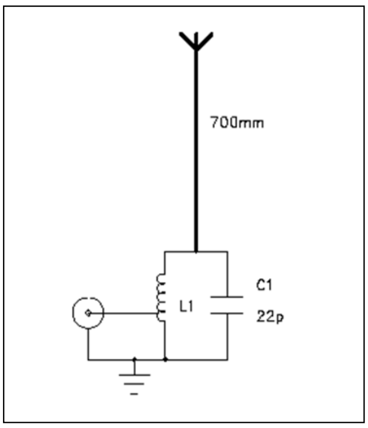


Fig 18.17: Circuit representation of the rucksack antenna

Fig 18.18: The mount and matching network

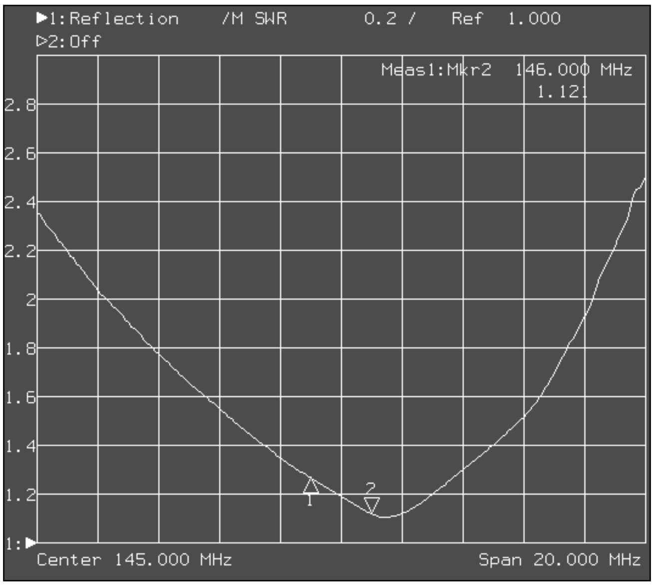


Fig 18.21: SWR plot of the finished 2m vertical

Collinears and J-poles

Other possibilities in this category are a collapsible collinear antenna constructed from coaxial cable, and the J-pole. Of the two, the J-pole is much more compact and can easily be mounted on a small mast. Suitable designs that can be adapted for use by the outdoor operator may be found in the chapter on practical VHF/UHF antennas. A ready-made version is available from MFJ.

A 4m ground plane antenna

The length of a resonant 4m antenna renders it impractical for the outdoor operator to carry without it being broken down into shorter lengths which then require assembly on site. A traditional rigid antenna is also likely to prove heavy. Wishing to participate in the activity on 4m FM, I put together the collapsible antenna shown in **Fig 18.22**. It is a quarter-wave ground plane with the elements comprising lengths of 16/0.2 hookup wire soldered to an SMA connector. The antenna is suspended from the top of a fibreglass mast using a hook fabricated from a short length of heavy gauge tinned copper wire. The hook is electrically isolated from the antenna thanks to the insulation on the PVC-coated wire and it is held in place by a short length of heatshrink tubing. By experimentation, the best lengths for the elements were found to be 940mm and 920mm for the radiating element and ground plane elements respectively. When deployed, the ground plane elements are allowed to hang down from the SMA connector. The complete antenna weighs 31g.

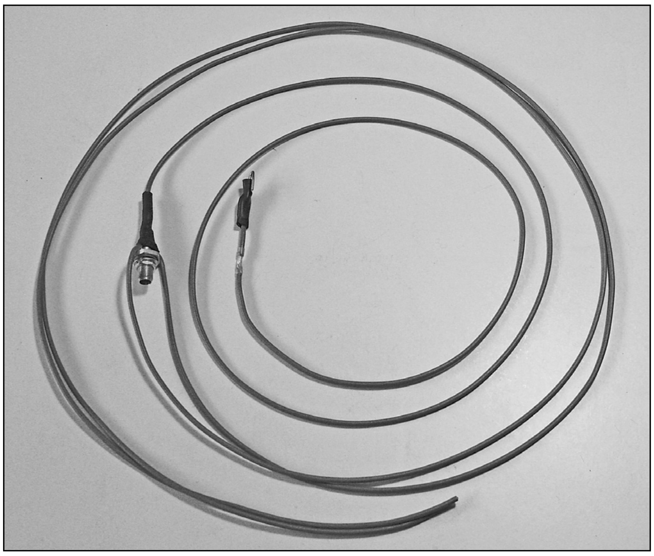


Fig 18.22: The 4m ground plane antenna

Microwave

Nowhere is there more scope for optimisation of antenna systems than on the microwave bands. Normal portable operation on the bands above 13cm generally involves the use of a dish. Here weight is an advantage as it counters the effects of the wind on an antenna whose -3dB beamwidth is usually in single figures. Unfortunately there is no substitute for size in the quest for gain and when a lightweight system is to be constructed, compromises will have to be made.

This section explores different approaches to what is a relatively new area of outdoor operating (the author and G3CWI having made the first 3 and 6cm SOTA QSOs as recently as 2008).

Yagis

On 23cm and above, Yagis become small enough to be transported with the elements in place. Unfortunately, the dimensional tolerances become difficult to maintain and so 13cm is probably the practical limit for their use. Above 13cm most microwave operators have switched to dishes and so reference designs for Yagis are not available.

Dishes

A parabolic reflector (or dish) is the standard antenna for use on the microwave bands. On 3cm, the 60cm satellite TV offset-feed dishes are widely used - as are surplus 2ft dishes from Andrew Corporation [6] and others. Both of these are impractical for portable operations due to their bulk and weight. Probably the practical limit is the small portable metallised plastic dish sold as part of caravan TV systems. These are approximately 30cm in diameter, yielding a gain of approximately 26 dBd - some 6dB less than a 2ft dish. Beyond this size, carrying the antenna on a rucksack would prove difficult. Experience has shown that even a dish this size can prove difficult to align when mounted on a lightweight mast in typical summit conditions. Perforated dishes are the traditional answer to this problem but none of a suitable size currently exists. There is plenty of information available on the construction and use of dishes and I would recommend reading the *International Microwave Handbook* [7] as a starting point.

Horns

At present, the horn antenna offers the most effective solution on 3 and 6cm and whilst low in gain compared with the 30cm dish, is robust and lighter. By packing system components inside the mouth of the horn for transportation, the overall volume can be kept to a minimum.

A 6cm horn and coax transition

Whilst the use of horns was common in the early days of 3cm and Gunn oscillators, they have fallen out of use except for dish feeds. These designs are not optimised for gain but for the specific F/D ratio needed for the dish. The design presented here is intended for use on 6cm where it has a gain of approximately 15dBd. Tapering it further down to WG-16 waveguide dimensions would allow it to be used on 3cm, where it would yield a gain of approximately 20dBd.

The purpose of a horn is twofold. Firstly it must give gain, and secondly it must smooth the transfer of the RF from waveguide to free space. Thus it acts as an impedance transformer. Whilst it is

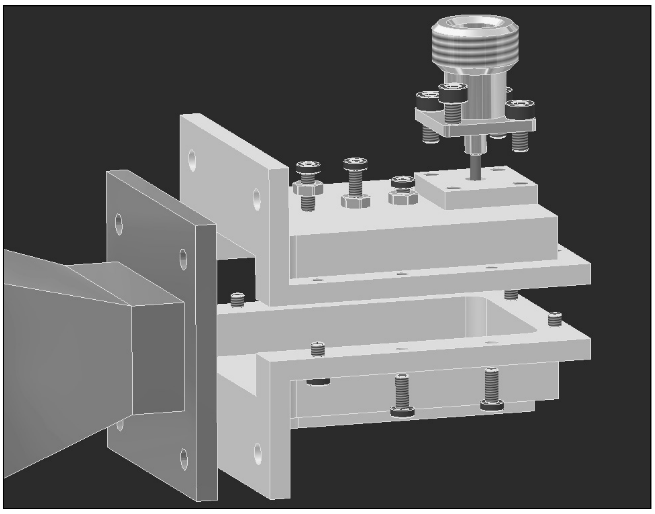


Fig 18.23: Mechanical assembly of the WG-14 transition

possible to use a shorter horn, the angle affects the efficiency of this transition. Too great an angle incurs a loss of gain. Too small an angle does little other than increase the weight and volume. This design is the best compromise between gain and weight.

The coax transition provides a second translation - this time from the 50-ohm impedance of the transverter to that of the waveguide. Despite a free choice of waveguide dimensions in this design, those for WG-14 were chosen to allow standard test equipment to be used. RF is launched into the waveguide by a probe attached to the centre pin of the 'N'-type connector. Matching is achieved by the three M2.5 screws seen inline with the connector (**Fig 18.23**).

The antenna and transition are mounted onto the aluminium mast coupler and the transverter mounts directly to the transition. The complete antenna with its mast clamp weigh 352g.

The horn was fabricated from a single piece of 1mm aluminium sheet with the joint welded. The walls were then welded to a flange to complete the antenna. The slot in the flange is 34.8 x 15.8 mm - the dimensions of WG-14. The mouth of the horn measures 150 x 115 mm and the length of the taper is 160mm. The finished unit is shown in **Fig 18.24**.

As an alternative, the horn could be constructed from 1.6mm copper-clad FR-4 PCB material or sheet brass with the joints soldered. A brass plate could be used for the flange. Suitable brass can be obtained from model shops.

The transition comprises two pieces of aluminium bolted together with eight M2.5 screws around the perimeter. Whilst not ideal from the RF point of view, this method of construction has been verified in back-to back experiments. The probe comprises

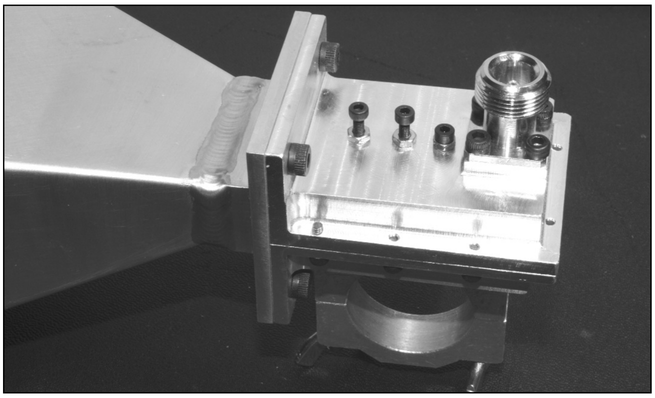


Fig 18.24: The finished 6cm antenna and mount

Probe to end wall: 7.0mm
Probe to first tuning screw: 4.0mm
Tuning screw spacing: 9.5mm

Table 18.5: Critical dimensions inside the cavity of the horn

Cable	Weight (g) of 4m	Loss (dB) 144MHz	Loss (dB) 432MHz	Loss (dB) 1296MHz	Max power (W) 432MHz
RG-174	34	1.68	3.43	Forget it!	26
RG-316	46	1.68	2.96	Ditto	210
RG-58C	100	1.10	2.22	High	90
RG-400	256	0.72	1.43	2.82	1050
RG-214	500	0.44	0.92	1.92	330
FSJ1-50A	280	0.29	0.52	0.94	610

Table 18.6: Coax cable characteristics for typical lengths

a length of 2.0mm brass rod that projects 12.4mm into the cavity. Critical dimensions inside the cavity are given in **Table 18.5**:, see the materials section below for suitable specifications of metals. A 3cm version of the transition could be manufactured on similar lines. For dimensions, see [7].

Patch antennas

A potential source of cheap ready-made lightweight antennas for 6cm is the Wi-Fi market. For example Solwyse advertise a 200mm square patch antenna whose specification shows a gain of 17dBd and a weight of 500g. It is believed that these antennas will handle powers up to 5W. More on patch antennas can be found in the chapter on microwave antennas.

Feed Systems

Whilst feeder runs are relatively short in most outdoor applications, the correct choice of coaxial cable is still important. An inappropriate choice could either add unnecessary weight to the system or waste valuable RF power. There is little point in carrying a higher power station only to lose a large percentage of that extra power in the feeder.

Cable

Table 18.6 gives the characteristics of some commonly-used cables. For such short lengths, the loss can be ignored on the HF bands but it becomes significant on VHF and above. As an example, putting 50 watts of FM on 2m through RG-316 causes a noticeable increase in temperature of the coax - which is not surprising since 30% of the power is wasted as heat. The loss figures in the table relate to a 4m length - which is typical of outdoor systems. The weights quoted are just for the coax. Whilst it would appear that RG-174 is a serious candidate, it is not a cable that I would consider; the voltage rating is too low for high power operation and it is mechanically inferior to RG-316.

RG-58 is a sensible choice. However, if UHF operation is contemplated the lower-loss RG-400 will give better performance but at over twice the weight. At 23cm FSJ1-50A Heliax is a good choice although it is mechanically stiff and more difficult to use.

Connectors

The choice of connectors may well be dictated by whatever transceiver is to be used. Unfortunately, most commercial transceiver manufacturers persist in fitting SO-239 sockets for the HF bands. Many do at least fit an 'N'-type for VHF and above. Whilst there are now good quality clamp-style PL-259 plugs available for RG-58 and RG-400 cables, I still prefer to use a BNC adaptor and a crimped BNC plug on the cable. This gives a mechanically-superior solution. Clamp-type connectors have a habit of coming loose over time, eventually causing a failure of the braid connection. Correctly assembled, a crimped connector is far superior - and lighter.

The FT817 offers the choice of two RF connectors and although the front panel-mounted BNC is less convenient operationally than the SO-239 rear socket, it is to be preferred from both the weight and reliability aspects.

Where a free choice is available, I always use crimped SMA connectors and reinforce the screen crimp with a length of heat-shrink sleeving. If the socket is mounted on a plate as shown in Fig 18.1, I find it easy to mate the free plug even with cold or gloved hands. Microwave connectors are discussed above. Despite it often being described as a microwave band, coaxial cable is normally used on 23cm to connect the antenna to a ground-mounted transverter. If FSJ1-50A is to be used then BNC or 'N'-type connectors are really the only viable options.

Supports

Whatever the antenna, and not withstanding the fact that the station may be on top of a mountain, some form of antenna support is generally needed. There are exceptions to the rule and the rucksack-mounted vertical is one - provided the operator is prepared to stand whilst operating. Where HF antennas or any form of directional VHF/UHF antenna is to be used, a mast of some description will be needed. The traditional amateur mast involves aluminium tubing and whilst a possibility for outdoor operating, it is a heavy solution. Two very different solutions are offered in this section. One follows the minimalist approach compromising height and functionality in exchange for lightness. The other is a traditional portable mast engineered for the lightest solution commensurate with ease of use and performance.

The ‘walker's approach’

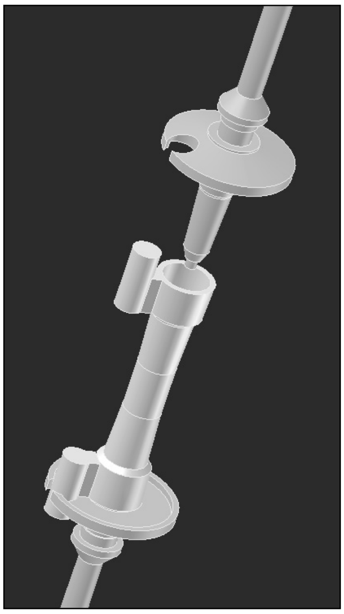
There is an adage that says that: "nothing weighs less than nothing". Many walkers use a pair of walking poles to aid stability and ease the load on hard-worked knees etc. The average walking pole is approximately 1.35 metres in length when fully extended and so two poles end-to-end with a suitable joiner can be used as a compromise mast. For 60m in particular, this may be an adequate height for the centre of an inverted 'V' dipole. When erected over poor ground such as is found on many summits, the difference in performance between 2.7m and the average 6m mast is small. For the minimalist approach, all that is required other than the poles is a small coupler to connect them end-to end and a set of guys. The wrist loop on the top pole can be used as an attachment point for the centre of the dipole and for the guys. A more ergonomic solution is to fit an inverted cup over the top pole's grip to which are attached the antenna and guys.

Many summits afford such an excellent take-off that this solution can also be used on VHF. It does, however, assume that the terrain at the summit is known in advance.

The coupler: The bottom section of most poles is tapered. The length of this tapered section varies between models so it is worth choosing ones with a longer one if this technique is to be used. In its simplest form, the coupler can comprise a short length of tubing, the resultant flexibility in the centre of the ‘mast’ being accepted as part of the compromise. A better solution is to machine the coupler from solid, matching the taper on the end of the poles to tapers inside the coupler. This will achieve a straight mast but will not necessarily prevent the top one from rotating on its own when it is used for supporting a Yagi in windy conditions.

Most walking poles have a basket just above the tip and there is often a cutout in it's perimeter. By arranging pegs to locate in these holes, an anti-rotation mechanism can be made. A suitable design weighing 39g is shown in Fig 18.25.

Fig 18.25: A coupler for two walking poles



Attaching a Yagi or other directional antenna to the top of the ‘mast’ is more of a challenge and the solution is very much dependant on the type of pole. A small bracket clamped just below the grip of the upper poles is the most secure answer.

Whilst they are very strong, the use of walking poles in this manner may in exceptional circumstances cause them damage, rendering them useless for the return journey. The risks should be considered before adopting this approach.

Modified ‘roach poles’

For a no-compromise solution to the problem of supporting antennas, there is no better starting-point than the 7 and 9m glass fibre fishing rods known as ‘roach poles’. These are readily available from a number of suppliers and they provide an excellent source of lightweight material. They can be used in their unmodified form, but it is worth bearing in mind that the sections lock together by friction alone. That works well in their intended application as fishing rods where the pole is close to horizontal. When used vertically they have a tendency to collapse. The greater the head load and the larger the antenna the greater the chance.

For transportation, the rods retract into the handle section, making a package that is around 1.2 m long. In my opinion, this is a bit long and when attached to a rucksack makes it prone to getting caught in overhanging branches or on rocks when descending steep mountainsides.

This design discards the handle (which is heavy anyway) and uses six middle sections from two rods, all reduced to 1m in length - or the length of an element of a 2m Yagi.

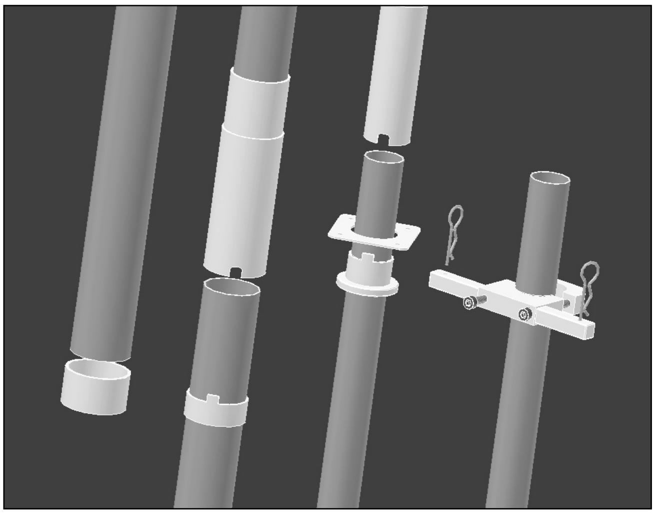


Fig 18.26: Exploded view of the mast components

For VHF usage, the antenna is mounted at the top of the fourth section, locating the antenna 4m above ground. For HF, the remaining two sections are added, bringing the height up to nearly 6m. The first four sections lock using small spigots to allow the beam to be turned. The remaining two are left free to swivel. The mast is guyed at the top of the third section, where a square carbon fibre plate sits on top of a collar on the coupler.

The glass fibre pole sections fit together using aluminium tubes and locking rings (**Fig 18.26**). The tubes prevent the glass tubing from splitting and protect the bottom ends from damage on rocks. When made out of good quality aluminium, the wall thicknesses can be reduced to 1mm without fear of damage in use. A collar at the base of the mast protects the bottom pole where it touches the ground. The guying plate sits on top of a collar formed on the locking ring on the third pole. Space is left above the boom clamp on the fourth pole to allow the fifth and sixth sections to be added for HF operation.

The aluminium rings and tubes are bonded to the glass fibre poles using Araldite. Prior to bonding, the epoxy paint is removed from the poles to expose the bare glass fibre tubing and all parts are degreased using Methylated Spirit or Methanol.

The mast and boom clamp weigh 460g when used in the VHF configuration and 600g when extended for HF. The 8mm square spigots either side of the boom clamp form a universal fixing that can take any VHF or UHF antenna that uses the 10mm square tubing as a boom. The halves of the antenna boom are slid onto the spigots and secured using 'R' clips. This makes for very rapid assembly and allows a polarisation swap in just a few seconds (the boom has holes in both planes).

Guys and pegs

It is true that a mast will stay erect with only three guys but in my experience, the addition of a fourth greatly increases both the stability and ease of erection of the mast. The angles between the guys are much less critical and uneven terrain causes much less of a problem. The weight of the fourth guy is negligible and the fourth peg comes ‘for free’ since a spare would always have to be carried with a three-guy system to cater for accidental loss. A target weight for a complete four-guy system is 80g.

In this context, guy ‘rope’ is hardly an accurate description - and would lead to confusion when enquiring in boating shops. The term cord is more appropriate for the 2 to 3mm guys which are perfectly adequate for use with outdoor masts and antennas. The most readily available and cheapest rope is 2.5mm diameter polypropylene cord. This is usually available in 50m reels. Whilst the breaking strain is not quoted, it has proved adequate with the loads presented by the 6-element 2m antenna in high winds. It does, however, have a tendency to stretch in use so some re-tightening of guys may be necessary.

The best is the 2mm diameter Dyneema-based cord produced by Liros. This has a specified breaking strain of 240daN and very low stretch of less than 3%. It has proved highly abrasion-resistant in use. It is available in a fluorescent yellow or blue. The added visibility of the yellow is an advantage, highlighting the location of such thin guys. To some extent, the nightmare of the tangle can be overcome by the addition of short lengths of low-temperature heatshrink sleeving over the knots - as shown in **Fig 18.27**. These help prevent the loose ends catching.

In my experience there is only one type of guy peg to consider and that is the 1/8" (3.2mm) diameter Titanium pegs that are often available from the high street retailer Blacks in sets of six. They do not bend, retain their points and have an incredible capacity to find their way into cracks between rocks on the stoniest summit without damage. As supplied, the loops are rather open which could lead to a guy slipping off the peg. It is possible to close them up slightly in a strong vice but this must be done with the utmost care to avoid injury should one escape during the process. A set of four pegs weighs 28g. Aluminium and steel pegs are more readily available but neither has the same strength and they are nearly twice the weight. Whichever pegs are chosen, it is a good idea to add short lengths of yellow heatshrink sleeving to aid recovery if one is accidentally dropped. They can be very difficult to spot even in the shortest of vegetation and usually end up some considerable distance from where dropped.

Fig 18.27: Lightweight guy set including the guying plate, peg loops and guy pegs. An example of the fluorescent yellow chord is shown at the bottom

A guying plate is important to allow the mast to rotate smoothly when required and not to damage the guys. Fig 18.27 shows a 42mm square, 1mm thick carbon fibre plate that has been carefully deburred to prevent chafing of the guys. Even after several hundred activations, the guys are unmarked.

RADIO EQUIPMENT

There are many factors to consider when making a choice of transceiver for outdoor operating. These include:

- Weight
- Size
- Modes and bands of interest
- Output power
- Ruggedness
- Power requirements

There is no correct answer to the often-discussed question of which transceiver is best. Yaesu's FT-50, FT-847 and FT-817 plus Icom's IC-706 are all possibilities. On a remote summit the extra power of the FT857 may be useful - but not if the expedition is also a camping trip when weight and volume become the overriding consideration. A specific SOTA expedition to an outlying mountain will usually warrant taking a spare transceiver as a backup. This might be impossible when backpacking. Anyway, in this case radio might not necessarily be the primary objective!

Transceiver	Wt (kg)	Int batts	RX current (A)	Bands	Input voltage (V)
IC-706 Mk1	2.63	No	1.36	HF/2m	11.7 - 15.8
FT-817	1.53	Yes	0.304 (min)	HF -70cm	8.0 - 16.0
FT-857	2.36	No	0.522 (min)	HF-70cm	11.7 - 15.8
FT-50	0.36	Yes	0.082	2m/70cm FM	4.0 - 16.0

Table 18.7: Comparison of popular transceivers for portable use

Table 18.7 provides a comparison between some of the transceivers currently in use by SOTA operators. It focuses on parameters of interest to the outdoor enthusiast. Receive current was measured on SSB (or FM for the handheld) at a comfortable audio level into a headset. This was done with the radio powered by an external 13.8V PSU. Note that the weights quoted for the FT-857 and IC-706 include CW filters at approximately 20g.

The IC-706 consumes 1.55A on receive. This can be reduced to a slightly more manageable 1.36A if the display contrast is set to low. At this current, operating time will be noticeably less than with the FT857.

Both the FT-817 and FT-857 allow the operator to choose the colour of the display backlight. The factory setup for the FT-817 results in a receive current of 333mA on external batteries. If the backlight is switched to ‘off’, this can be reduced to 304mA. Similarly, the FT-857 takes 594mA. The default setting is actually one of the lower current colours. Some will increase this to 630mA. By changing the display mode to ‘Auto1’, the consumption can be reduced to 522mA until a button is pressed when it temporarily increases. That represents a useful saving.

One of the most popular HF bands for SOTA use in the UK is 60m (for which a Notice of Variation is required at the time of writing). All three of the above HF radios can be modified to cover this allocation.

The FT-817, FT-857 and FT-50 can be configured to display the supply voltage on the front panel. I find this invaluable. Given a knowledge of the discharge curve of the battery pack being used, the state of charge of the pack can be established. This estimation is accurate enough to determine when to change the battery pack or call a halt to operating. It can also help guard against either damaging the rig with the low voltage or the battery pack by a deep discharge. Information on battery performance is given in a later section.

The transceivers mentioned above are all general purpose multi-band devices however none covers one of the emerging bands in the SOTA world - four metres. A 5W handheld, the Wouxun KG-699E/4m, has now opened up easy access to the FM portion of the band. The use of an external antenna is recommended and a suitable lightweight design can be seen in Fig 10.26. As an alternative to this handheld, I have pressed a Tait T199 crystal-controlled mobile transceiver into service. This aluminium-cased unit is roughly the size of an FT-857 and weighs 1.6kg. It will happily generate 15W on transmit. From a well-located summit, it is advisable to ensure that at least two working channels are available in addition to the FM calling channel of 70.45 MHz.

Signal Quality

The potential effect that a ‘sagging’ generator can have on a contest station is well-known and although outdoor operations tend to last for much less than the average day’s contesting, it is still our responsibility to ensure that the signal being radiated is clean. This is particularly so on VHF and above where the station is likely to radiate a considerable distance and where, in many cases, it is co-located with commercial radio stations.

If access to a spectrum analyser is not possible, simple on-air tests with a local station should be able to confirm the quality of the signal. These tests should be carried out using the complete station including the intended battery pack in varying states of charge to establish what happens when the pack becomes depleted. Ideally, apply a two-tone audio signal to the microphone input of the transceiver and monitor the RF signal on a spectrum analyser. Reduce the power supply voltage and repeat the measurements. I found that there was no noticeable change in transmit IMD performance with either the FT-857 or the IC-706 when the voltage was taken down to 10V.

ANCILLARY EQUIPMENT

Despite the maxim that "less is more", there are several ancillary items that the outdoor operator is likely to need.

Lightweight Morse Key

On HF and on the microwave bands, CW is a very popular mode - and indeed is often essential for microwave operating. Most modern transceivers have an inbuilt keyer, but a standard paddle key intended for the home station is generally fragile in construction and difficult to use if not placed on a stable surface. They are usually made intentionally heavy to impart further stability when sending high-speed Morse. A neat solution to the fragility of the paddles is to make them retractable for transit. The stability needed to operate a conventional paddle key can be achieved by putting the transceiver's metallic case to good use and embedding magnets in the base of the paddle.

Unless you are intending to send Morse at over 20WPM, the solution in Fig 18.28 may appeal. By reverting to the up-down motion of a straight key much more stability will be achieved, and by using the rig's built-in keyer Morse can be sent at a reasonable speed, even with a gloved hand. I am no CW expert but I find this type of key much more usable in adverse weather conditions. It is also light, weighing in at 100g including 0.5m of cable.

The base comprises a 50 x 78mm piece of 5mm aluminium plate which is lightened by machining pockets a shown. A layer of tape on the underside helps prevent it from moving laterally during use. The paddles are 14 x 66mm plates of 0.8mm brass and they are held in blocks made of Tufnol or any other insulating material. Grooves are milled in the lower block to clamp and locate the paddles and to prevent them rotating. Five 2.5mm holes in the base are tapped at M3 to take the two paddle stops, the screws to hold the insulator blocks and an M3 solder tag for the earth connection. Further tags are soldered to the underside of the paddles and used to make electrical connections. The three soldered connections to the cable are reinforced with short lengths of Kynar sleeving. The cable is located in a hole through the bottom insulator block and is glued in place, strain-relieving the cable connections. Once adjusted, the screws are locked in place using M3 nuts.

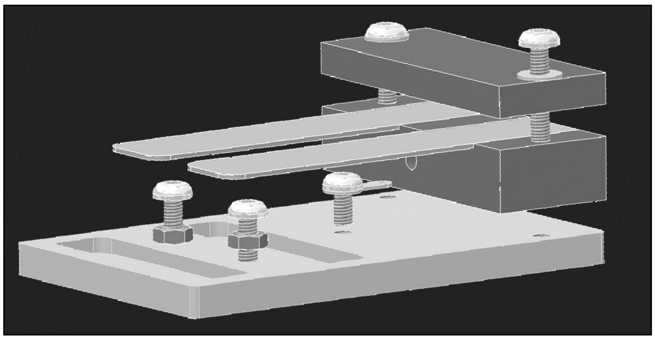


Fig 18.28: Mechanical assembly of the paddle key

Fig 18.29: A selection of logbook solutions

As an aside, it is worth remembering how to switch the transceiver between its keyer and straight key modes when operating on the microwave bands. The key is normally used to send a series of long dashes during the process of antenna alignment.

Logbook

Unlikely though it may sound, considerable effort has been expended by many outdoor operators over the years in pursuit of the lightest and most ergonomic logging method. Only when an attempt has been made to operate a rig and rotate a mast by hand, whilst simultaneously trying to stop a logbook flying away in the wind does the difficulty become apparent.

Short of taking a table or other substantial flat surface the outdoor operator will inevitably be balancing the logbook on an unstable surface. Fig 18.29 shows three very different solutions.

At the top are two versions of a conventional paper logbook. In both cases, the log sheets are the same and comprise a number of laser-printed 100gsm sheets cut and bound using salvaged wire binding. The slightly shiny finish on this paper repels the occasional drop of rain long enough for it to be removed. Under most conditions a ballpoint pen can be used but when temperatures are excessively low or humidity is exceptionally high, a 2B pencil is more useful and water-resistant. Take both so that each acts as a spare for the other.

To the left is the minimalist approach using a thin aluminium sheet as the backing. Measuring 95 x 125mm, it is too narrow to rest conveniently on most surfaces but as it weighs 55g, it is ideal for the long distance backpacker. The QSO start time can be taken from any number of devices that have a clock built-in - eg mobile phone, camera, GPS etc. To the right is a heavier and larger, but more ergonomic, solution. It weighs 105g without the stopwatch. The extra size of the backing allows it to rest more securely in your lap. As an alternative to standard Laser printer paper, some outdoor operators use waterproof paper and the accompanying writing implements. 'Toughprint' [8] from Memory Map and 'Rite in the Rain' [9] are two of these.

Below the paper logbooks are two completely different solutions. To the left is a small MP3 recorder weighing a total of 64g. With this, it is possible to log the audio during the activation, making sure to speak the time at the start of each recording. Given that these devices are stereo, microphone audio could be recorded on one side and rig audio on the other rather than trying to capture both sides of the contact using its internal microphone.

At least one experienced outdoor operator uses a Windows CE-based PDA for logging. I have been very tempted to try this route but have so far failed to find a device I consider sufficiently robust. Attempts at simulating data entry in a real environment have also not been very successful, paper logging proving much quicker. As a PDA often has a voice recorder built in, this may be a useful backup when time is short. Some devices store data into battery-backed RAM and so a flat battery could result in data loss. It is worth checking this before deciding on a purchase. The device in Fig 18.28 weighs 122g.

Headphones

If it's windy you should use headphones to help you hear over the noise. If it isn't, you should wear headphones out of courtesy to other walkers.

In the former case, headphones will make a big difference to the overall S/N ratio. For the minimalist, earpieces of the type that come with an MP3 player are adequate. Slightly more ergonomic are a set of lightweight stereo 'phones. These are generally fragile and the plastic has a tendency to fracture - especially in very cold weather. The TM-201 headset from Maplin has swivelling earpieces which allow it to stow flat, reducing the chances of damage in transit.

Microphones and Headsets

In the context of ultra-lightweight backpacking, to carry a fist microphone weighing 170g makes little sense - and that is the weight of the MH-31 unit that comes with the FT-817. Inside this bruiser of a mic is a steel weight, which when removed, reduces it's weight to 147g. This is still over 10% of the weight of the radio.

The headset shown in Fig 18.30 was developed specifically for backpacking, but it has proved generally useful on VHF SOTA activations in adverse conditions when a beam antenna, a logbook, a microphone and an umbrella would have been too much for one pair of hands. The finished headset weighs 36g and should prove reliable if built along the principles described at the start of this chapter.

It is based on the BEP-55NC In-ear Headset Microphone available in the UK from Maplin [10]. This has a noise-cancelling insert which can be improved further by adding a foam sock as shown in Fig 18.30. The PTT comprises a standard SPST toggle switch. I would normally prefer a momentary switch but in this application there is little danger of it being accidentally left on transmit. This microphone is not directly compatible with the FT-817 and so several discrete components are needed both to set the level and to prevent the RF feedback that was prevalent on HF prior to their inclusion. These components are all hidden in the heatshrink transition between the RJ-45 connector and the headset / PTT cables.

The circuit of the headset is shown in Fig 18.31. L1 and C1 form a LPF that prevents the RF feedback that was noticed when operating on HF whilst seated directly under the antenna.

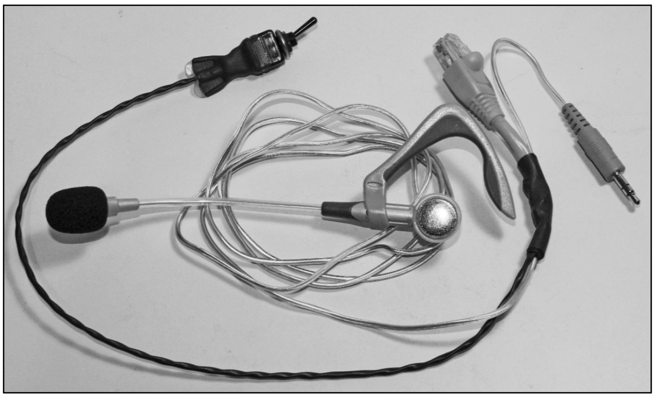


Fig 18.30: Lightweight headset for the FT-817

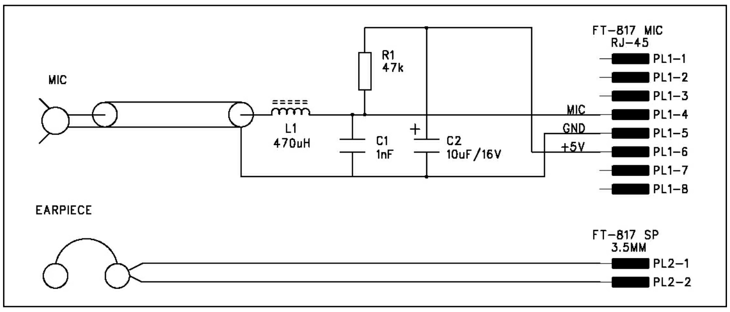


Fig 18.31: Circuit diagram of L/W FT-817 Headset

Resistor R1 is used to apply DC bias to the microphone insert and its value can be used to control the microphone gain. Values between 22k and 68kΩ were found to give a large adjustment range. Capacitor C2 provides decoupling of the +5V supply, preventing noise on this line from being fed into the microphone.

The BEP-55ND headset conductors comprise cores constructed of self-fluxing multi-strand enamelled copper wire and there is no conventional insulation between them so care must be taken not to damage this by applying too much heat. Tinning the wires quickly with a hot soldering iron was found to give good results. For reliability, the moulded 3.5mm plug that was part of the original headset was re-used and for the same reason, an RJ-45 cable with stranded wires was used for the connection to the FT-817's microphone input.

Filters

The VHF-orientated outdoor operator is likely to find himself co-sited with all manner of radio installations. Many of these services have the potential to overload the front end of the transceiver. Particularly vulnerable are those with a broadband receiver such as can be found in most handhelds, and in extreme cases the radio is rendered useless. A model with bandpass filtering at its input is much less likely to be susceptible to this overloading.

In the UK, a major cause of receiver overload is the pager traffic located just above the 2m band. Being so close in frequency, it is not an easy task to design a bandpass filter that is sharp enough to reject out-of-band signals whilst having reasonable passband loss in a package that is manageable for the outdoor operator. For excellent immunity, a filter such as the DCI 2m BPF is needed. At 300 x 150 x 75 mm and weighing 1.37kg, this is a little large and heavy for the outdoor operator to carry.

Since these services are vertically polarised, the use of a directional, horizontally polarised antenna with SSB will often solve the problem. For the determined FM operator, there is some hope. The MFJ-713 is a compact 2m filter for use with low power rigs that may provide some protection. This unit overcomes the problem by RF-switching the filter out of circuit on transmit. An external power source is required..

HOMEBREW HF EQUIPMENT

Listen for a while on 7.032MHz and it will become apparent what success can be obtained by using low power CW into an inverted-V antenna. Whilst the FT-817 is very popular, a number of outdoor operators are using home-built QRP transceivers.

One possibility here is the design sold in kit form by K1SWL under the name Small Wonder Labs [11]. The SW40 is a 2.5W output CW transceiver covering up to 40kHz of the 40m band. When boxed, it would be approximately half the volume and a fraction of the weight of an FT-817. With a receive current of 20mA, it would last twice as long on a set of batteries. The limited selectivity may cause it to struggle on 40m at weekends but during quieter periods, it may be an ideal backpacker's radio.

MICROWAVE EQUIPMENT

Traditional designs and equipment for the bands above 13cm have been relatively bulky and heavy. Bearing in mind the usual need for a talkback station as well, this amounts to an unacceptable load for the outdoor operator.

The separate talkback station permits full duplex cross-band operation during setup and dramatically reduces the time spent in this phase of the contact. When battery life and the effects of adverse weather on the hilltop activator are taken into account, this has to be the best method.

My combined 2m and microwave station fits into a 30 litre rucksack and the overall weight is approximately 13kg including all safety equipment, food and water for an expedition. Battery life is adequate for over one hour's operating. This station comprises an FT-857 on 2m running 50W to a 6-element Yagi and an FT-817 as the prime mover for a 3 or 6cm transverter. The FT-817's output is reduced to 0.5W to drive the transverter and so it runs on its own internal battery for the duration of the activation. Two NiMH battery packs are taken. One powers the transverter and the other the FT-857. At 'half-time' the packs are swapped to equalise usage. A headphone splitter cable feeds audio from the transceivers to separate earpieces. Arranging the transceivers so that the LH earpiece corresponds with the LH rig helps avoid potential confusion. Also, it is probably worth labelling the microphones if they are identical!

Compact transverters for 3 and 6cm

At present, SOTA operators on the microwave bands are using transverters based on the Kuhne Electronics [12] modules by DB6NT (see the chapter on microwave transmitters and receivers). Whilst it is possible to buy some of the units as kits at a lower price, they are normally supplied aligned and ready to use. A glance at their catalogue will show a vast array of equipment for all of the microwave bands.

From a decent site, the basic transverter with around 200mW output and a 20dBd horn will allow many contacts to be made, however adding a 2W PA will vastly improve the range and put the station equipment on a par with many home stations. In considering an enclosure for the basic transverter, it is worth allowing room for a PA module to be added at a later date.

The transverters and modules come with full instructions and circuit diagrams so this description is limited to a few overall comments. Fig 18.32 shows the inside of the 3cm unit. The two large modules are the transverter and 2W PA. Transmit/receive switching is performed by the microwave coaxial relay below the PA (the black rectangle). All microwave connections use RG-402 coax, the antenna connection being the 'N'-type right of centre.

The PCB that can be seen bottom right provides power supplies for the 28V relay and provides sequenced switching between transmit and receive. This is necessary to ensure that

Fig 18.32: Completed 3cm 2W DB6NT transverter

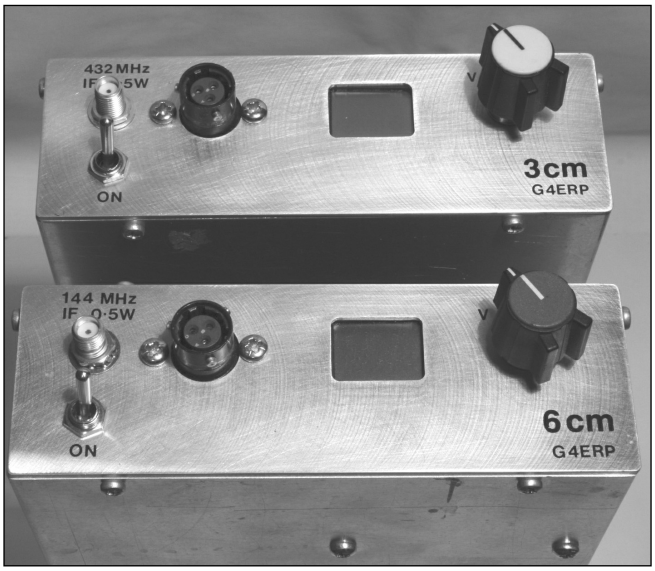


Fig 18.33: 3 and 6cm transverter front panels

there is no damage caused to the sensitive receive semiconductors or to the PA transistor during switchover. If just the basic transverter is used, this is not necessary. A suitable comparator-based design can be found in [7]. The board is my own design but Kuhne electronic sell a similar sequencer.

The transverter cases shown in **Fig 18.33** comprise rigid front and rear panels machined from solid aluminium and a case bent from 0.8mm sheet. Front panel metering shows battery voltage, RF output and current drawn. Each complete assembly weighs 705g.

The mast-mounted transverter, microwave horn and VHF antenna are shown in **Fig 18.34**.

Fig 18.34: Transverter and horn mounted on the mast, aligned with the 2m talkback antenna

POWER SOURCES

For outdoor operating, power sources almost inevitably mean batteries - perhaps augmented by on-site recharging using solar or wind power. Recent developments in chemistries now provide us with a bewildering array of batteries to choose from. For more information, see the chapters on principles and power supplies.

The capacity of a battery is quoted as current multiplied by time in hours. The units are either mAh for small batteries or Ah for larger ones. Manufacturers often quote the capacity assuming that discharge takes place over 10 hours. Batteries that provide sufficient voltage to power transceivers such as the FT-817 will comprise several cells in a series and possibly parallel combination. The configuration of such a pack is often described in advertisements using shorthand terms such as 3S, 4S or maybe 4S2P. In the above examples, 3S and 4S describe battery packs made of 3 and 4 cells in series. 4S2P describes a pack of two 4S stacks in parallel to increase the capacity.

Battery Chemistries

Battery technology is split between those types that can be recharged and those that are used once and then thrown away. Both environmentally and financially, rechargeable types are to be preferred but there are good reasons why the non-rechargeable types occasionally have a place in the outdoor operator's rucksack. For example, I use Lithium AA cells in my GPS unit when backpacking due to the problem of recharging sufficient batteries using solar power while away for long periods.

There is a vast range of rechargeable batteries but they all fall into one of three basic types which are explored here.

Lead acid

In their wet form, as used in cars, they are not very attractive for outdoor operating, but when the electrolyte is contained in a gel to form the Sealed Lead Acid (SLA) battery they are more interesting. Unlike the wet variety, these batteries can be used in almost any orientation and cannot leak unless damaged. (If you wish to use one inverted, check the data sheet to ensure that this is allowed.) There are subtle differences in their construction based on the intended application which can range from starting cars to stand-by lighting. The manufacturer's data sheets should mention this.

In all cases, the individual cell voltage is a nominal 2V. Commonly available capacities range from 2Ah to 40Ah and whilst single cells are available, the most common format is the 12V pack. Generally speaking, they will happily source high currents for short periods but the internal resistance is such that the terminal voltage droops under load. As can be seen in **Fig 18.35**, the discharge curve of an SLA battery has a greater slope than the other types and so some of the capacity may be wasted if the voltage drops below the minimum allowable voltage for the transceiver. It is also the heaviest of the three types.

Lead acid batteries do not take well to being stored. Those that are used regularly and reasonably hard, tend to last the longest. A brand new battery that had been stored and top-up charged to the manufacturer's specification proved completely useless when attempts were made to bring it into service. In general an SLA battery has a life of about three years from manufacture. After this period, the available capacity may be seriously reduced. This means that for the occasional activator, SLA is probably a poor choice.

Nickel

The first rechargeable battery packs that appeared in handheld transceivers used Nickel Cadmium cells (NiCd). In recent years, Nickel Metal Hydride (NiMH) cells have all but replaced NiCd, and recent legislation relating to disposal of used cells will probably

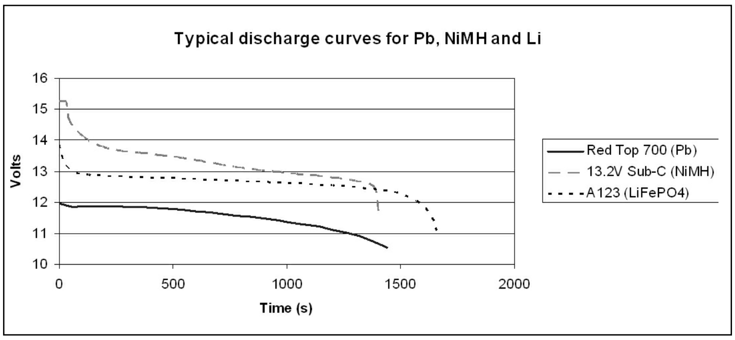


Fig 18.35: Typical battery discharge curves

soon spell the end of NiCd technology. We will concentrate on NiMH cells here. They are very similar in their characteristics to NiCd - if a little more difficult to charge correctly.

NiMH cells are available in an array of sizes and capacities. An individual cell has a nominal 1.2V terminal voltage and common capacities range from 200mAh to 4Ah. They are readily available in sizes from button cells up to 'D' cells. Considerable development has gone into the sub-C cell for high current radio control applications and these characteristics make them equally good for powering transceivers. Although available in lower capacities than SLA packs, the internal resistance is lower and so they can deliver higher relative currents without the voltage drooping. The energy density is also higher and so Nickel has been the choice of Radio Control enthusiasts for many years.

After an initial dip, the discharge characteristic is relatively flat. It then drops rapidly when the battery is depleted so most of the energy is available at a sensible terminal voltage. When the end-point is reached, it is necessary to cease operating immediately to prevent damaging the battery by a deep discharge.

Unlike SLAs, NiMH batteries do not mind being stored. They have a low self-discharge rate and so can be stored for several days after charging without significant loss of capacity. They should be stored fully charged and if unused for a longer period, given a top-up charge before use. For longer periods of inactivity, it will be necessary to check them regularly - say every two months - and recharge them. They can be destroyed by a deep discharge and should never be taken below 0.8V per cell.

Lithium

Lithium cells have been the biggest growth area in battery technology in recent years. It is the lightest technology currently available and cells with capacities of several Ah are now available. This performance comes at a cost in terms of their user-friendliness. Their SOA (safe operating area) is much smaller than for other types and they are capable of failing spectacularly if abused. If, however, their characteristics and limitations are understood and respected, they offer by far the best performance for the outdoor operator and they are perfectly safe. The different chemistries within the Lithium family of cells have slightly different voltages but all are in the range 3.3 to 3.8 V. Those at the upper end of the range pose potential problems when used with popular mobile transceivers.

The discharge curve for Lithium is similar in characteristic to that of Nickel but it is even flatter which means that more of the cell's energy can be used. The end-of-use knee is very abrupt and so considerable care must be used to ensure that operation stops before this point is reached. Again, a deep discharge below this point will almost certainly destroy the cell.

All forms of Lithium cells are excellent at retaining their charge when stored. Unlike Nickel packs which require checking every couple of months, they can be safely left for probably six months without attention. This is only true when talking about the basic cells. Any battery pack with active electronics inside it should be checked as often as possible since this electronics draws current, eventually flattening the pack.

It is not a good idea to store Lithium batteries fully-charged as subjecting them to cold in this condition can cause damage to the cells. The capacity of a Lithium cell is proportional to temperature and so cooling a cell that has been fully-charged at room temperature will result in an effective over-charge. Transportation of cells over a certain capacity by aircraft is problematical and strictly controlled by law. If they are to be stored or transported, then they should be discharged to a 50% SOC (state of charge). Most modern intelligent chargers have a function to discharge a pack to a user-defined SOC.

Three types of Lithium batteries are of interest:

Lithium Polymer (LiPo) is the lightest, most available and least stable of the variants. Compared with the equivalent NiMH battery, it is approximately two-thirds of the weight whilst having a similar volume. It requires careful charging and a specialist charger should always be used. Most of the packs that are available are intended for Radio Control applications where they are used in electrically powered vehicles. Many of the alarmist comments that have been made about these cells relate to the after-effects of crashes. They can be discharged at very high rates but can only be charged relatively slowly. Being careful and sympathetic users, SOTA operators have found them to be perfectly safe.

Lithium Ion (LiIon) cells are most commonly found in the laptop PCs, cameras and any number of portable consumer appliances that can be found around the home. Most consumer packs have built-in electronics to safeguard the cells. One other major application for LiIon cells is set to outstrip all others in volume - HEVs (Hybrid Electric Vehicles). Here, large banks of cells in series / parallel totalling many hundreds of volts are used to store energy under braking using an onboard motor /generator. That energy is then used to help power the car under acceleration. LiIon cells have been chosen for this application because of the high charge and discharge rates they can withstand. In Formula 1 motor racing, KERS (Kinetic Energy Recovery Systems) packs are typically 3Ah capacity. The cells are charged and discharged at around 400A for short periods. SOTA operators are now starting to use LiIon cells as the voltage is more attractive than that of LiPo.

Lithium Iron Phosphate (LiFePO4) is not as light as LiPo or LiIon but it is much more user-friendly. The cell voltage is also slightly lower than the others and so a pack comprising four cells is ideal for use with most transceivers. Until recently, they were not readily available and some users resorted to salvaging cells from the battery packs supplied with cordless drills. These particular cells are universally referred to as A123 but this is actually the name of the company. There are two part numbers that you may see - 18650 and 26650. The latter is the more common and is the useful one for powering transceivers. Capacity is 2.3Ah which is marginal for most outdoor operations but I carry two or more packs which is in keeping with my policy on failure management (see below for details of charging).

Lithium Polymer packs and mobile transceivers

While LiPO packs are undoubtedly attractive for powering mobile transceivers such as the FT-857, the discharge curves in **Fig 18.36** show that a 3S pack gives too low a voltage and a 4S pack exceeds the maximum voltage specification of the radio when fully charged. The Yaesu specification is quoted as 13.8V ±15% (or 11.7 to 15.9 V) and the 100% SOC voltage for a 4S LiPo pack is approximately 16.8V.

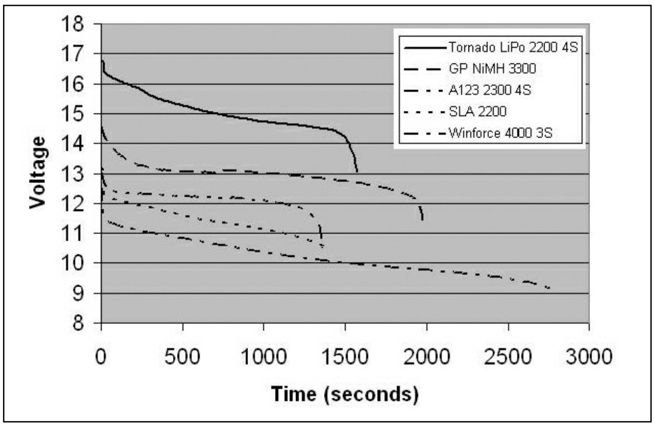


Fig 18.36: Typical battery discharge profiles

A number of outdoor operators have overcome this problem by using the forward voltage drop of silicon diodes to reduce the input voltage of the transceiver. The preferred configuration is to use two bridge rectifiers connected as shown in **Fig 18.37**. Each bridge rectifier contributes a voltage drop of approximately 0.75V at low current depending on the specification of the device. The second rectifier is simply linked or switched out of circuit once the pack voltage has fallen to a safe level. Although it may seem desirable to be able to switch out both bridge rectifiers, having one permanently in circuit guards against an operational error.

This technique does have a cost in terms of weight and an estimate including a suitable heatsink is 50g. This puts the complete power pack on a par with a LiFePO4 battery. A simpler solution is to limit charging to 80% SOC where the voltage is within limits and to accept the wasted capacity.

Non-rechargeable Cells

Non-rechargeable cells still have a place in the outdoor operator's rucksack but their applications are very specific and are restricted to AA and AAA cells. I carry spare batteries of this type for use in my GPS navigation device and my headtorch. There are two reasons for this: Firstly, non-rechargeable cells have a very long shelf life and hence only need checking periodically. Secondly, if the main rechargeable cells fail due to some external influence such as very low temperature, having cells of a different chemistry as spares guards against a double failure.

There are two types of non-rechargeable cell chemistries that are of interest namely Alkaline and Lithium. The best known of the first type is sold under the Duracell name and Lithium cells are manufactured by Energizer under the Ultimate Lithium brand (L91 and L92). Lithium cells have better overall performance particularly at higher discharge currents where they have over twice the capacity. They are also considerably lighter. The FT-817 comes with an AA cell carrier and these are the obvious choice. **Table 18.8** gives their weights.

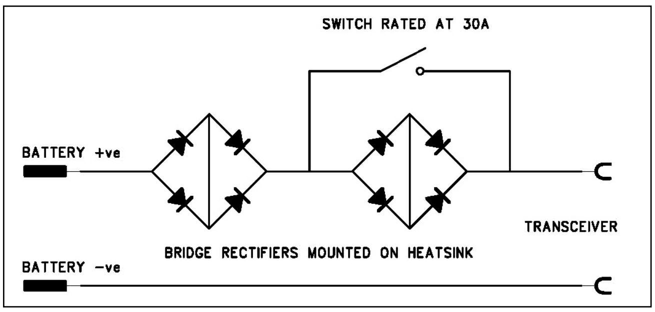


Fig 18.37: Voltage reducing circuit for LiPo 4S packs

Type	Alkaline Weight per cell (g)	Lithium Weight per cell (g)
AAA	12	7
AA	25	14.5

Table 18.8: Non-rechargeable cell weights

	Lead Acid	NiMH	Lithium
Cell voltage	2.0V	1.2V	3.5V approx
Capacity	2Ah - 40Ah	0.2Ah - 4Ah	0.3Ah - 20Ah
Weight	Heavy	Medium	Lightest
Discharge curve	Sloped	Flat	Flat
Charging	Easy	Medium	Complex
Safety (relative)	Good	Medium	Care

Table 18.9: Battery performance compared

Battery Selection

Batteries are probably the heaviest single item that the outdoor operator has to carry. There is no obvious answer to the question of which battery is correct for a particular application but a correct choice will have a significant impact on the overall weight of the station. This section explores some of the factors to consider and **Table 18.9** summarises these. The first and most important consideration is the voltage range of the equipment that will be powered from the battery. Check the specification carefully to establish both the upper and lower limits. The input voltages specified in the handbooks of some commonly-used transceivers were shown earlier in Table 18.7 as a guide. Too high an input voltage could damage a transceiver. Too low a voltage could be responsible for poor transmitted signal quality, and in some cases failure of the PA. The discharge curves in Fig 18.42 will help with this decision and the higher initial voltage of a newly-charged pack needs to be taken into account. When it comes to deciding which cells to use for a pack, NiMH is the most versatile technology. With a cell voltage of 1.2V it is easy to assemble a pack whose voltage is within the range of the transceiver.

Formerly, my choice for powering a mobile transceiver such as the FT-857 is a pack comprising 11 NiMH Sub-C cells. The fully-charged voltage is approximately 15.2V and for the entire usable part of the charge, the voltage is well over 12V. One such pack is shown in **Fig 18.38**. Experience shows that a 3.3 Ah pack weighing 720g will last over 45 minutes on SSB at 50 watts. More recently, many SOTA activators (including myself) have moved to Lithium battery packs and all three variants are now in regular use on the hills. This change was hastened by the availability of new A123 cells and sources of reliable, high capacity LiIon and LiPo packs from the Far East. I now use different packs for one-day outings and for multi-day backpacking trips. Experience has shown that a single 4S LiFePO4 will last over 30 minutes on SSB at 50W, so for a day's multi-summit outing I take three packs. For backpacking trips I take a 3S 4Ah LiPo pack.

Charging is an important but often overlooked part of the battery selection process. In order to maximise the energy available and the longevity of a battery, it is necessary to ensure that charging is carried out correctly. For optimum battery life and performance, a specialist charger is a must. At present, most LiPo cells come with a warning about safety when charging and with a suggestion that they should not be left unattended. One particular manufacturer suggests that they should be charged outdoors on a concrete block. Whilst this may be excessively cautious, I do not feel confident enough to leave a used LiPo pack recharging in my car whilst away on an activation whereas it is my normal practice with NiMH packs.

Fig 18.38: Selection of batteries for outdoor operations. Clockwise from the bottom left: 4.0 Ah 3S LiPo pack (265g); 2.2 Ah 4S LiPo pack (242g); 3.3Ah 13.2V NiMH Sub-C pack (796g); 2.2Ah 12V SLA battery (824g); 2.3Ah 4S LiFePO4 pack (314g); 2.6Ah 9.6V NiMH AA cell pack (258g). It is no coincidence that of the six batteries shown, half are based on Lithium. For robustness and ease of use, NiMH is still to be preferred, but for the ultimate in performance, LiPo is the clear favourite. The two packs at the front are intended for use with the FT817 - indeed the one to the right uses the FT817's AA cell carrier. The voltage of the 3S LiPo is ideal for the FT-817 and this pack will power the rig for a multi-summit expedition without needing to be recharged. The remaining packs are for use with mobile transceivers such as the FT-857 which can be powered directly from all but the 4S LiPo pack. Here, the 100% SOC voltage exceeds the maximum voltage specified by most equipment manufacturers and so the diode dropper described earlier in this section should be used.

Fig 18.39: A selection of intelligent battery chargers. The two chargers at the rear are mains-powered units specifically for SLA batteries. The large unit to the right is a Yuasa YCP4A12 three-stage charger delivering 4A. The Mascot plugtop unit to the left is for smaller batteries and charges at a maximum of 0.5A. On these units, LEDs indicate the status while charging. The two 12V-powered chargers at the front will cope with a range of chemistries. Both will cope with Lithium, NiMH and NiCD batteries however the unit to the right will also charge SLA batteries and all three types of Lithium batteries. Note the ferrite chokes that have been added to the leads on the Kokam unit to reduce spurious emissions. Most chargers of this type have a small alphanumeric display which is essential for their setting up and operation.

Care, Use and Testing

Having made a significant investment in suitable batteries, it obviously makes sense to look after them and this section shows how to maintain them in the best possible condition.

Charging

Just as it is possible to damage a battery during use, it is possible to do so when re-charging. Although sometimes difficult to find amongst their advertising information, the manufacturers data sheet will usually provide the correct parameters. Data sheets for many common batteries can be found on the Farnell website [4]. What follows here are generic comments relating to each type of chemistry.

It is now easy to find specialist chargers for the different chemistries - indeed many chargers will cater for all three types if not all sizes of battery and these units are strongly recommended. A selection of chargers is shown in Fig 18.39.

Lead-acid chargers

The method of charging all lead acid batteries is the same but SLAs require additional care to prevent overcharging which can cause venting of the cells. An intelligent charger for a 12V battery will have several stages to the charge. These are:

- A bulk charge where the current is limited to a suitable value for the capacity of the battery. This is usually 0.25C so the 4A charger in Fig 18.34 would be ideal for a 16Ah battery.
- When the voltage rises to 14.5V, the current is allowed to decrease and the voltage held at 14.5V.
- When the current drops to a low value the battery is fully charged.
- The charger then lowers its voltage to 13.8V and continues to trickle charge the battery. It can be left indefinitely in this state.

In the absence of a specialist charger, the above procedure can be executed using a current-limited bench PSU. Not all PSUs like being used in current-limit for extended periods so this technique should be used with care.

NiMH chargers

The cheap plug-top chargers that come with so many portable devices are trickle-chargers that will take many hours to charge a pack. Because of the voltage that they give and method they use, there should be no chance of overcharging. The Radio Control fraternity have been fast-charging NiCd and NiMH cells for many years and there are a number of 12V-powered units available that will speed up the charging process. In this category are the Kokam and Overlander chargers shown in Fig 18.45. Most are multi-chemistry chargers that can be programmed for the desired current and then left to complete the charge unattended.

Whilst handy in an emergency, fast charging a battery is likely to shorten its life. Most cell manufacturers define a ‘fast charge’ as one that is greater than 0.5C - or 1.5A in the case of a 3Ah pack - and so this is my preferred setting for my Sub-C cell packs. A glance at the data sheet for the Ansmann AA and AAA cells indicates that a standard charge is 0.1C and 0.2C is referred to as a quick charge. I use the quick charge rates for my AA and AAA cells.

Trickle charging is usually carried out at 1.5V per cell, current limited to 0.1C, a full charge taking around 12 hours. Fast charging requires a specialist charger to detect when the cell reaches full charge. This point is indicated by a small drop in terminal voltage and an increase in temperature. The voltage drop is detected by the charger periodically removing the charge current and measuring the terminal voltage. Some chargers also measure the temperature rise although this is not a common feature.

Lithium chargers

All multi-cell packs can become unbalanced to the point that some of their potential capacity is unavailable. This happens when one cell becomes fully charged before the others and charging has to stop at that point. With Lithium cells, it is critical that this is detected. Unless each cell's voltage is measured, it is possible to overcharge some of the cells in a pack, leading to damage and possible thermal runaway.

For this reason, it is advisable to use a charger with this cell balancing facility. The small LiPo batteries in Fig 18.38 have two connectors. The smaller is a multi-way connector which allows the charger to access the individual cell voltages. By this means it is possible to re-balance a pack. The pack is charged then individual cells are discharged until they all have the same terminal voltage. The battery can then be re-charged to its full capacity. At the very least, a charger that monitors the individual cell voltages should be used to prevent overcharging.

Load testing

As has already been noted, batteries do not last forever. A regular check of their capacity should be made to determine when they should be replaced. There are two methods of doing this. One involves a complete charge-discharge cycle. The other involves the application of a load whilst measuring the cell voltage. Both are described in this section.

In both cases, similar equipment is needed and examples are shown in Fig 18.40. On the left is a homebrew load comprising a range of power resistors with values between 0.47 ohms and 100 ohms. These are mounted on an aluminium plate with 4mm sockets. This method also requires external current and voltage meters, and fans will be required to keep it cool if a discharge test is to be performed. On the right is an Electronic Load of the type that sometimes appears on the surplus market. It can be used in a variety of modes but the constant current setting is of interest in this application. The instrument varies its impedance to maintain a constant current regardless of applied voltage - something that cannot be done with a fixed resistor. Having a fixed current makes capacity checking much simpler since no additional equipment is needed. A fully hands-off test can be performed if the voltage is recorded using a data logger such as a PicoScope [13] to detect the end voltage.

Capacity test

The battery is fully charged and allowed to settle for a few hours. A representative load is then applied and the voltage logged against time. The battery state must be monitored carefully and the procedure stopped immediately the battery reaches its end voltage. The capacity *at that load current* is calculated from the area under the curve of the resulting time / current graph.

$$Capacity = \sum (I * \delta t) \text{ aH}$$

If a measurement is taken every 30 seconds, the capacity in Ampere Hours is the sum of all the individual current and time measurements.

A glance at the data sheet for any cell will show that the measured capacity is related to the load. For this reason, the test should be carried out at a representative current. As experience shows that a 4.3Ah pack gives approximately 45 minutes of operating, I use 6A as my test current.

The disadvantage of this method is that in doing the test, one charge cycle is used up. However, if done on an annual basis and interspersed with the step method described in the next section, this overhead is probably acceptable. A series of tests showing how the capacity of a battery pack degrades with time and usage can be seen in Fig 18.41. (The pack was first used in July 2006 but this data is not available.)

Fig 18.40: Battery health monitoring equipment

Step test

The health of a battery can also be determined by applying a known load to a battery for a short period and measuring the quasi-steady voltages before loading and when the load is applied. This gives a measure of the internal resistance of the battery and hence its state of health. Unfortunately, few manufacturers supply data for their cells and so the only way to use this technique is to measure a battery when it is new and use this data as a benchmark for future tests.

With careful measurement, good correlation with discharge test results can be obtained. It should be noted that this technique is not suitable for use with packs that contain thermal or other protection circuitry as the characteristics of these components tend to dominate in the calculation. In order to get accurate results, it is essential to use exactly the same procedure each time. In particular, the timing of the three phases is critical and for this, a data logger such as a PicoScope will allow the voltage for the entire test to be recorded. The data for the calculation can then be extracted after the test has been completed.

If neither of the above methods can be followed, it is possible to get an approximate idea of the health of a pack by using the calculation built into chargers such as the Kokam unit shown in Fig 18.45. This displays the charge that has been applied to the pack. However, it should be noted that this value is optimistic as it includes the time taken to detect the end point and this is beyond the point where the battery is fully-charged.

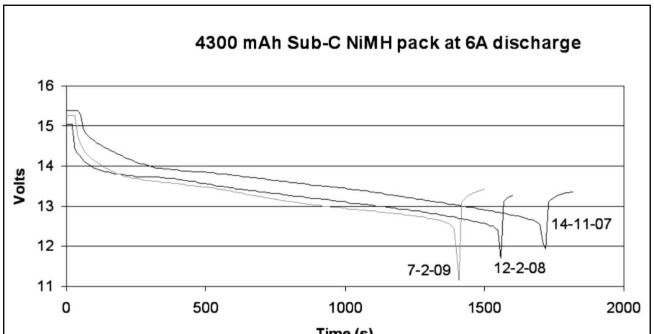


Fig 18.41: Typical NiMH pack discharge test results showing the capacity loss with use

Solar Power

For the serious backpacker wanting to recharge batteries during a multi-day outing, solar power would seem to offer the ideal solution. It is a technology that is attracting plenty of development and interest at present, so although the performance is currently a little disappointing, this may change over the course of the next few years.

A solar panel converts light into electricity. In simple terms, the number of solar cells dictates the maximum terminal voltage but the light level has a big influence on the actual voltage and current that is available. As a result, solar power is highly unlikely to be a viable energy source on it's own but it can be used to recharge the primary power source when it has become discharged.

The alternative to solar-powered charging, of course, is to carry additional battery packs and not worry about recharging the used ones. For a weekend expedition, this may be the sensible approach, but for a longer outing, this may be impractical. Let us compare the merits of the two options.

The major deciding factor is the amount of available sunlight. Practically, if you can't see a distinct shadow it's not worth getting it out of the rucksack. On many American Long Distance Trails, sufficient sunlight can be guaranteed to make solar-powered charging a realistic option. In the UK, where the climate can best be described as variable, it is a less attractive proposition. Many backpackers mount a solar panel on their rucksack whilst walking to maximise the available time for charging. In order for this to be practical, the size of the solar panel needs to be carefully considered as does the method and flexibility of the mounting so that output can be optimised. On a linear walk where the backpacker's relationship to the sun is reasonably constant, it is possible to benefit from solar charging from this technique.

A search on the web will indicate a variety of devices. Some can immediately be discounted for portable use unless the application is purely to recharge a couple of AA cells for a GPS unit, a head torch or an MP3 player. If the intended use is the recharging of batteries for powering radio equipment in the field, then a realistic recharge time has to be achieved. Panels with an output of at least 5W should be considered.

Currently there are three units available for the hiking market that are worthy of consideration: the Flexcell [14] Sunpack 7W and the Reware Powerpocket 6.5W and 12W Folding Solar Panels. The former weighs 700g but appears sturdy and capable of being successfully mounted on a rucksack. It rolls up into a cylinder of approximately 35 x 6cm. The latter units weigh 200g and 360g respectively but the 12W version is too large for rucksack mounting and so would need to be used statically during an activation to recharge an already spent pack or during the evening after the day's operating is finished. I have successfully used the PowerPocket 6.5W on multi-day trips (**Fig 10.42**) and the results presented here were obtained with this unit.

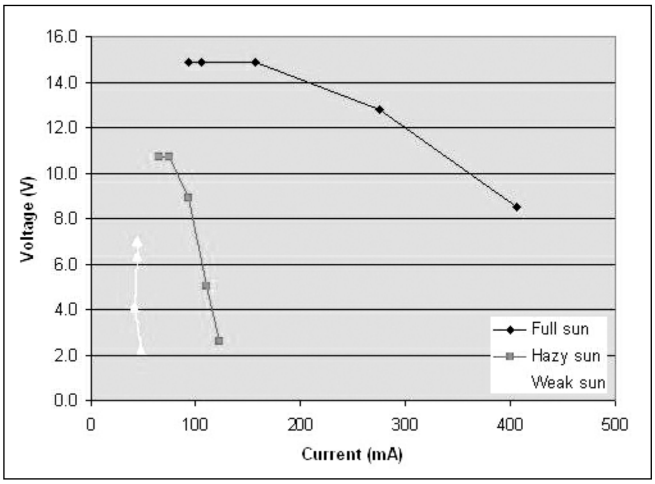


Fig 18.43: Solar panel output curves showing output power at different light levels

Solar panel performance

So, what can you expect in the UK? The Reware 6.5W PocketPower solar panel data sheet specifies a maximum output of 433mA maximum at 12V. Can this be achieved?

The output of a panel is strongly dependant on light level and whilst hazy sun will provide enough power to charge a couple of AA cells, if the object is to replenish a discharged battery pack for the FT-817 then sunlight bright enough to give a strong shadow will be needed. The graph of **Fig 18.43** indicates that the maximum output that could be obtained in full sun in the south of England was 406mA but at this current draw, the voltage had dropped to 8.5V (an output of 3.45W). The best performance curve will only be achieved if the entire panel is in full sun and nothing must be allowed to mask the active area. The panel must also be kept pointing at the sun. If the error is kept to less than 30 degrees, almost full output will be obtained.

Charging batteries from solar power

In the UK, it is safe to say that there is one application that is ideally suited to solar charging. The FT-817 is the ideal radio for backpacking trips where summit activations are spaced over the

Fig 18.42: Solar power being used to float charge a LiPo battery

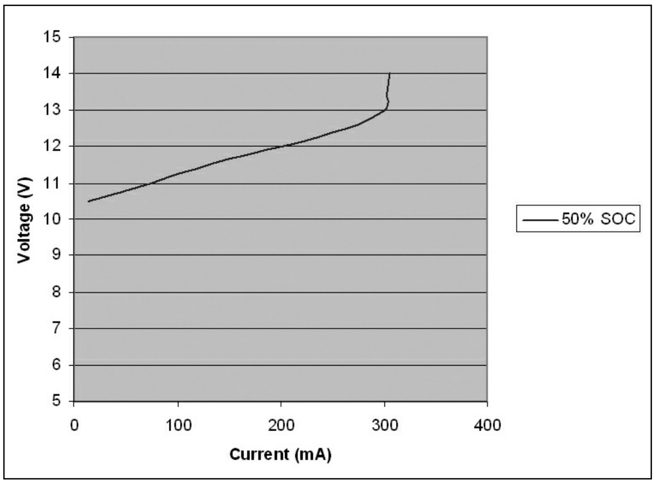


Fig 18.44: FT817 charge curve

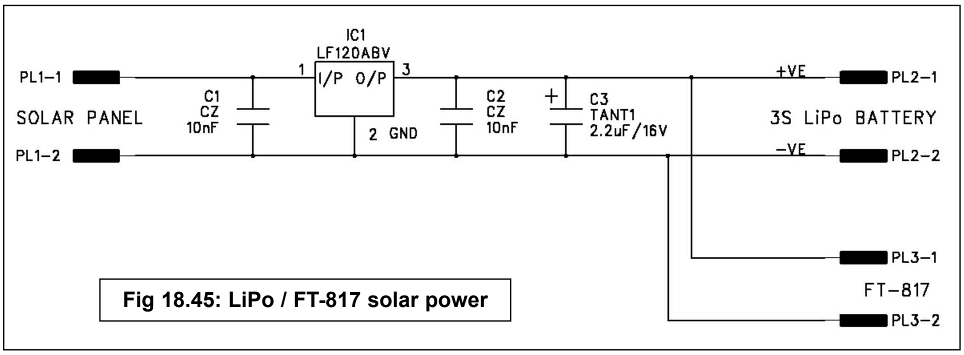


Fig 18.45: LiPo / FT-817 solar power

course of several days. Maintaining charged batteries under these conditions using solar power is a practical proposition given reasonable weather.

Charging the FT-817. Tests on an FT-817 indicate that the internal charger limits the current into the battery at 300mA but that a useful charge is still achieved at lower voltages. These tests were performed with the battery at a 50% SOC. (See Fig 18.43) Comparing the graphs in Fig 18.49 with that of **Fig 18.44**, it will be seen that in full sun, a charge current of over 250mA will be achieved.

Charging LiPo packs. My preference when using the FT-817 is to power it from an external higher voltage battery whilst the internal NiMH pack is kept as a spare. The current-limited 400mA output of the panel is ideal for charging a 4Ah LiPo 3S pack. All that is then required is a low voltage dropout linear regulator to limit the charging voltage to a safe level. While it would be possible to 'push the limits' and charge at the LiPo maximum allowable voltage of 12.6V, there is little to be gained and so a fixed voltage regulator is used. The specification for ST's LF120ABV indicates a maximum voltage drop of 350mV at 400mA load but experience shows that in full sun, a charge current of around 250mA will be achieved.

I used the circuit shown in **Fig 18.45** for this purpose. It allows the battery to be float charged during an activation as well as on the move. If there is insufficient sun, the FT-817 is then powered from the battery alone. The system is shown in **Fig 18.46**. The LDO regulator is potted into the boot of the connector to the right of the solar panel using RT-125 (see the Heatshrink section), construction being 'dead-bug' style with strain-relief on all the wires. The FT-817 power connector can be seen at the bottom of the photo.

By way of a demonstration of its effectiveness, I used this system on a six-day walk with five SOTA activations. Thanks to topping up the battery using solar charging I was able to maintain a 75% SOC.

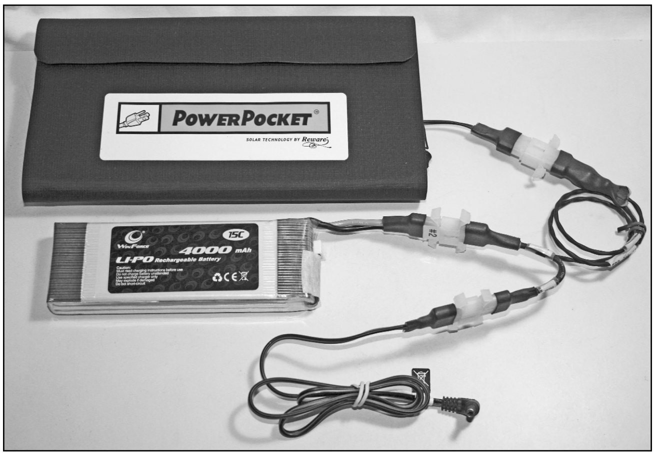


Fig 18.46: Solar float charging of 3S LiPo

When there is insufficient sunlight to charge the LiPo battery due to the reduced terminal voltage, ancillary items such as phones and cameras can still be charged. For this, I have built similar adaptors and these are shown in **Fig 18.47**. The adaptor at the top allows a compact camera LiIon battery to be charged (it is held in place using the rubber band). The potting on the top of the nylon housing conceals a TO-220 voltage regulator. The contacts are spring-loaded terminals salvaged from a handheld radio microphone sideclip connector. The second adaptor is for charging a mobile phone and uses a regulator salvaged from a commercial car charger.

MATERIALS

In the context of engineering the ultimate lightweight station, the choice of materials is critical. Thanks mostly to research in the field of aerospace, there is now a huge selection of advanced materials available. Knowing their properties is the first stage to the ultimate in station engineering.

Taking aluminium as an example, the range of strengths available from different grades is large and achieving the same durability in the weakest grade may require a part that is twice as heavy as using the strongest. VHF antennas, of course, are primarily aluminium and so considerable weight savings can be made here by the correct choice of grade.

Composites

Composites is the generic term for a large range of materials that are produced by combining widely differing substances. Examples include carbon fibre, glass fibre, chipboard, plywood and MDF. In each of these cases, resin is used to lock fibres in a defined orientation to each other, imparting a strength to the final product that is greater than that of the constituents.

When working with composite materials and carbon in particular, it is advisable to take precautions to avoid inhalation of dust. Any splinters should be removed immediately as the resins can cause the onset of an infection.

Carbon fibre

Carbon fibre materials have limited use in outdoor stations. However, in certain applications they are an appropriate choice. In the raw state, it is supplied as woven sheets impregnated with adhesive. When laid into a mould and baked in a vacuum, it can produce a 3D part that is incredibly strong and much lighter

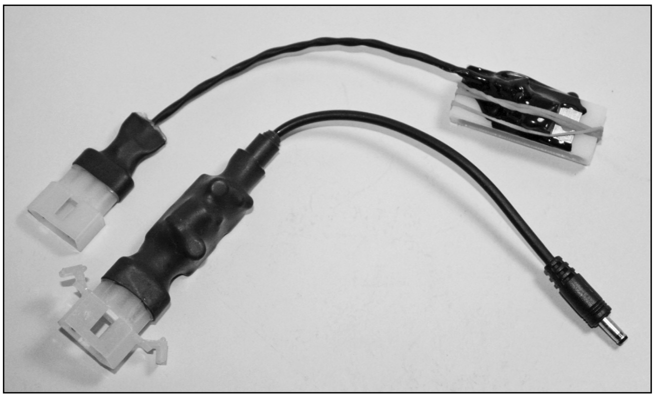


Fig 10.47: Ancillary charge adaptors

than the fabricated equivalent. Another application where carbon fibre is an appropriate material is as a microwave antenna such as a dish where it is covered in aluminium foil. Carbon fibre could be used to manufacture an ultra-light and dimensionally stable antenna.It can be bought in sheet form, ready-cured. As flat sheet, it is still stiffer and slightly lighter than the aluminium equivalent and so I have used it for logbook backings and coax cable supports.

Carbon fibre tubing is also available - at a cost - and weight-for-weight it is stiffer than a glass fibre equivalent. Be aware that many plastics have been made to look like carbon by clever printing. Carbon fibre is very hard on cutting tools. Top quality files and drills last well, but lesser quality tools are likely to have a very short life.

Glass fibre

Glass fibre materials come in many forms but one is particularly useful for the outdoor enthusiast looking for a lightweight antenna support. A 7m Roach Pole is a useful source of cheap, lightweight material. It is not as strong as a carbon equivalent but it is much less expensive and is readily available. These poles are mostly covered in an epoxy-based paint which should be removed prior to any bonding operation. This can be done by using a sharp, flat file followed by fine abrasive paper.

Metals

Steels

Being generally heavy and prone to corrosion, steels would not normally find a place in the construction of lightweight equipment and if strength is required, titanium is generally a better option.

If the superior strength of steel is required then my favourite is EN24. This is reasonably easy to machine and is more commonly available than the stronger grades that have higher EN numbers. Mild steel has no practical use for the outdoor station.

Aluminium

Most of the aluminium offered in DiY shops and at engineering shows is of indeterminate grade and generally soft. As such, it is a poor choice for most applications but it is ideal for antenna element construction since a small bend can more easily be straightened in the field.

For machined parts, there is nothing better than HE15. This is a high-strength alloy that can be reduced to a wall thickness of 1mm or less without worry about its longevity. My 1mm thick mast couplers have withstood numerous encounters with rocks over the years without sustaining any damage. There are several other specifications that describe the same material, so offcuts stamped with L168 or 2014A are equally valuable. As an even tougher alternative, L160 or 7075 can be used. None of these can be welded. If machined parts are to be welded, such as might be the case for the flange and walls of a microwave horn antenna, then HE30 is the preferred grade. Equivalents are L111 or 6082. It is possible to weld many types of aluminium sheet that can be found on the surplus market, but for the best results, the NS4 specification sheet is preferred and gauges down to 1mm can be worked reasonably easily.

Titanium

Titanium is an exceptional material that has the strength of steel, does not rust yet is approximately the density of aluminium. As with other metals, there are many grades.

For machined parts, Ti6-4 is the most common material and it can be machined reasonably easily. For sheet metal work, it is essential to remember that there are two distinct grades. BSTA2 can be bent whereas BSTA10 (Ti64) definitely cannot.

Brass

Despite its habit of tarnishing, its high density and its lack of strength, brass is still an exceptionally useful material for small components where weight is less of a problem. It can be machined easily, takes threads well and does not corrode. It is ideal for small bushes and studs. It is also easy to soft solder.

Ropes

There are three types of rope. Those that stretch and are supposed to, those that stretch and are not supposed to and ropes that do not stretch. For guying portable antennas, Liros Dyneema-based Magic Gold is the author's favourite. It has a guaranteed stretch of less than 3% and has good abrasion resistance. The 2mm cord has a breaking strain of 240daN which has proved adequate, surviving some severe mountain-top conditions. It is available in a highly-visible luminous Neon Yellow which helps the thin cords stand out against most backgrounds. It can be obtained from most yachting shops.

Tendon supply similarly well-specified cords for the climbing market. These start at 4mm diameter and are available from outdoor shops.

Shock cords are elastic ropes and they are very useful for the outdoor operator or backpacker. The author uses 3mm diameter shock cord in conjunction with button-operated toggles to hold together bundles of poles and antenna elements and to secure loads to rucksacks etc. The cord can be obtained from many sources, including caravanning and outdoor shops. Good outdoor shops also hold stocks of spare toggles in different colours.

Sealants and Adhesives

When used appropriately, both adhesives and sealants have an important part to play in the construction of the outdoor station. A visit to any DiY shop will reveal shelves full of tubes containing different compounds intended for different purposes.

Tubed sealants

In general, there are two families of sealants - those that use acetic acid as a solvent and those that do not. Those which are often referred to as Silicone Sealants and which have the unmistakable smell of pear drops should be used near any metallic part with caution. They will often cause severe corrosion. Steels are particularly badly affected - even plated ones. Their main advantage is a faster cure time but, however tempting, that feature should be ignored.

Sealants are useful in a number of applications, including waterproofing box lids - such as the tuning network on the 2m vertical described earlier. As they do not form an adhesive bond, the parts can be relatively easily dismantled when needed.

When used to seal a box, a thin uniform layer should be applied - just enough to fill the largest gap. Gentle, slow tightening of the screws should then cause the two surfaces to extrude any excess which can then be cleaned away.

Applying a blob of sealant between a wire or a wire bundle and a solid surface such as an enclosure wall will help prevent a vibration-induced fatigue failure of a solder joint by damping any motion.

In the commercial world, Dow Corning's RTV744 has been proven to be compatible with all types of electronic equipment and metals. A more readily-available alternative is Unibond's Waterproof All-Purpose Sealant which also has reasonable adhesive properties. It causes a slight reaction with brass, producing a Verdigris-looking deposit after an extended period.

Thread locking

Outdoor equipment is subjected to repeated thermal cycling and vibration in a way that home equipment never is. In the long-term, this can cause threaded components to come loose. Thread lock compound applied to the parts during assembly will prevent this problem. The most commonly used compounds are made by Loctite [15] who produce a range of products for different applications. For general low-temperature use, their 242 (Nutlock) compound is ideal. It does not require heat to permit disassembly. For applications that require a small amount of gap-filling, 641 can be used to good effect.

Conformal coating

By far the best way to protect PCBs is to apply a conformal coat such as Concoat's HumiSeal 1B31 (available from Farnell etc). This can be carefully applied using a small artist's brush, covering small components as well as the board. Apart from preventing corrosion, it will wick under parts, damping any movement due to vibration. It is a good idea to avoid applying the coating to any open-frame connectors as these same wicking properties can cause problems.

Adhesives

Adhesives do not generally like being subjected to moisture for long periods but for the length of the average outdoor operation, this is not a problem and so they can be used for bonding many types of materials together. Aluminium mast couplers can be bonded to glass fibre poles. Nylon bushes can be bonded to aluminium rods.

The most readily-available adhesive is Araldite which is a two-part epoxy. Provided the surfaces are cleaned and de-greased first, the resultant bond will last well. Adhesives work best where the parts overlap, giving a large bond area. Butt joints usually fail.

Hot melt adhesives of the type that are readily available in DiY shops are widely used in the manufacture of battery packs where they are used to hold the cylindrical cells together. They have many other uses in the outdoor station but should be used sparingly to avoid adding unnecessary weight to the assembly.

Heatshrink

The reader who has made it thus far, will have probably have realised that I am a big fan of heatshrink sleeving. No longer a specialist material, anyone looking in a distributor's catalogue will note the large variety of types that are now available.

Unless heatshrink sleeving is to be used with the companion high temperature wires and cables it is wise to use the low temperature types. These are usually cheaper and have higher shrink ratios anyway. They are more versatile whilst being less likely to cause damage to PVC insulation. The Pro-Power range of 3:1 tubing available from Farnell shrinks at about 100°C compared with Raychem's DR-25 at 175°C.

If Raychem [16] 44 or 55 Specification wire - or indeed any high temperature wire - can be acquired, then the ultimate in lightweight flexible control and audio cables can be made by twisting the wires together by hand then covering in heatshrink. In this case DR-25 heatshrink can be used as this provides the toughest jacket. To use this properly with the matching boots, it is necessary to glue the parts together using a two-part adhesive such as ResinTech's RT-125. These are the techniques that are used to manufacture the ultra-light yet robust looms that are used on racing cars.

An alternative to using plain heatshrink boots and two-part adhesives is to use pieces of adhesive-lined heatshrink to join sleeving to connectors and to cover inline splices. This is not as durable, but is quick to implement and does not require such specialist techniques.

For the protection of the soldered joints of in-line splices, Kynar semi-rigid sleeving is recommended. The complete splice is then further covered with adhesive-lined tubing to strengthen the transition. Heatshrink products should be used in a well-ventilated area as small amounts of fumes are released during the shrinking process.

SUPPLIERS

Aluminium - antennas: .....Major DiY shops (B&Q etc)
Carbon sheet: ....Demon Tweeks
'R' Clips: ....Trident Racing Supplies [17]
NiMH packs: ....Overlander Technologies
SLA packs; ....DMS Technologies
Cyclon SLA cells: ....Farnell [4]
Ropes: ....Cotswold Outdoors [18]
Glass Roach poles: ....SOTA Beams [19]
Coax cables ....Times [20]

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About the Author

***Richard Marshall, G4ERP**, has had a passion for radio from an early age. After many years of successful contesting on VHF and above, his interest turned to the Summits on the Air programme and he is one of a select band to have achieved the coveted Mountain Goat award. After 17 years in defence electronics he has spent the last 22 as Head of Electronics or Chief Electronics Engineer for the Renault F1 Team.*