A Multi-purpose Portable Setup

Working low-earth orbit satellites from any place

Ivo Klinkert, PA1IVO, pa1ivo@amsat.org

Only a relatively simple setup is necessary to use amateur radio low-earth orbit satellites. The design of a portable setup is described here, together with some experiences and rationale.

The current fleet of operational AMSAT satellites consists solely of low-earth orbit (LEO) satellites. Although high-earth orbit (HEO) satellites like AO-40 (and the upcoming P3E) delivers worldwide communication capabilities and interesting technical challenges, using LEO satellites is also interesting and fun, and has its own challenges to deal with.

This article describes a portable satellite setup for working LEO voice satellites. The setup was developed and optimized over several years, and the article mentions some rationale behind design decisions and practical experiences with the setup. Excellent results were achieved in terms of making QSOs via LEO satellites as a portable station.

The setup described here has the following main features:

✓ Truly portable. It is quick and easy to take in and out of an apartment, or a small tent on a campsite during holidays. The setup can also be carried entirely by one person, including the batteries to power it.

✓ Full-duplex capabilities. In the context of this article, full-duplex means the possibility of transmitting on one band, and receiving on the other band at the same time. When working QRP, listening to your own downlink is advantageous and increases chance of making successful QSOs.

✓ Satellite modes V/U and U/V are available, which are the main modes for the current fleet of LEO voice satellites. Also S-band reception capabilities are available (mode V/S, mode U/S also possible), after some small conversions in the setup.

✓ Multi-mode capabilities. Both FM and SSB can be used, including exotic combinations of modes (like the DSB up/ FM down previously used by AO-51).

With many new low-earth orbiting satellites scheduled to be launched in the coming years, the portable setup described here could be very interesting for many radio amateurs.

Overall Setup

The basic overall setup is shown in Figure 1. The figure shows two transceivers (in the carrying bag), a dual-band Arrow antenna, a small RF filter box, a Heil headset and a small battery for powering the transceivers. Figure 2

(Continued on page 20)

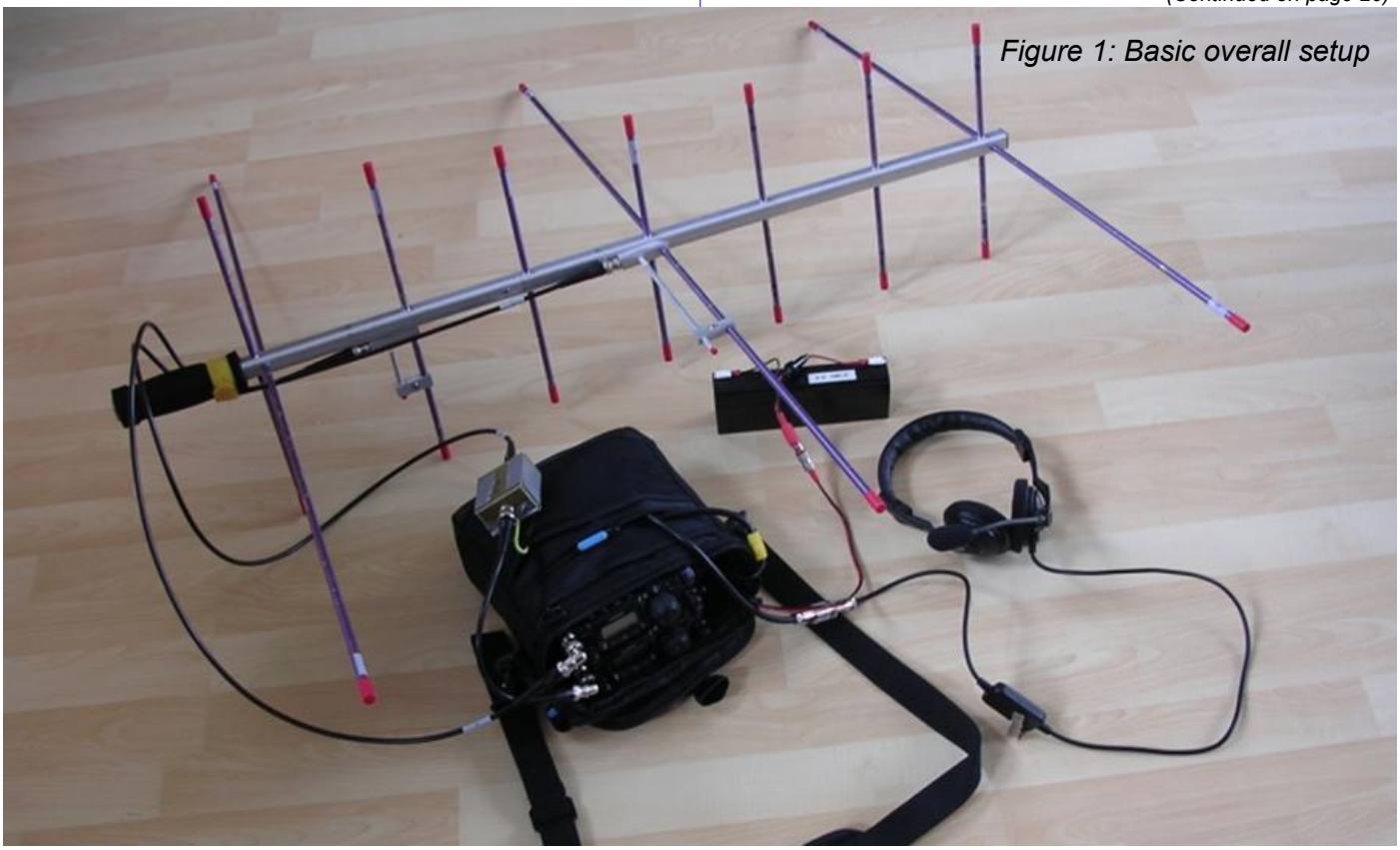

Figure 1: Basic overall setup

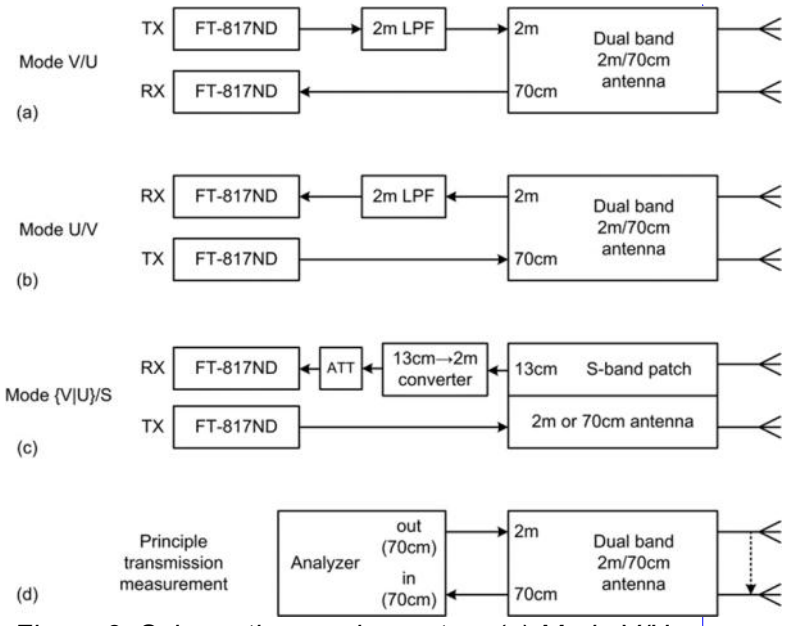

Figure 2: Schematic overview setup. (a) Mode V/U, (b) mode U/V, (c) mode V/S or U/S, (d) principle transmission measurement 2 m/70 cm dual band antennas.

(A Multi-purpose Portable Setup from page 19)

(a), (b) and (c) show configurations for four possible operation modes of the setup: Mode V/U in (a), mode U/V in (b) and mode V/S or mode U/S in (c). The different components in these four configurations are discussed separately in the text below.

Transceivers in a Box

The selection of a transceiver is first based on the type of satellite you want to use. LEO satellites for voice communication can generally be divided into two groups, (1) single channel FM repeaters and (2) linear SSB transponders. To work FM repeaters like SO-50 or AO-85, just a single dual-band FM handheld (preferably with full-duplex capabilities) can be used. Several lists of usable full-duplex handhelds can be found on the AMSAT bulletin board (at www.amsat.org). To work linear SSB transponders like FO-29 or AO-73, transceivers with SSB capabilities are required (often called 'all mode' transceivers) and these cannot be found as single handhelds. All mode desktop transceivers, such as the Icom IC-910, the Kenwood TS-2000, and the Yaesu FT-847, all have full-duplex capabilities and are in use by many satellite operators. These all mode transceivers are generally also capable of working the FM repeater satellites.

To be able to work both FM and SSB satellites with a truly portable setup, transceivers like the IC-910 are too heavy. For the setup described here, two Yaesu FT-817ND multi-mode portable transceivers are used. This small all-round transceiver has sufficient functionality and is small enough to form the base of the portable setup. The FT-817ND (further mentioned as '817') covers the amateur radio bands between 1,8 and 430 MHz; for this setup only the 2 m and 70 cm bands are used. A single 817 does not have full duplex capabilities, but two of them make an excellent full duplex combination. A setup with similar second-hand equipment, for example an FT-290R2 and an FT-790R2, is also possible, which will reduce the overall price of the setup.

Both 817 transceivers are externally powered from a single 2.2 Ah rechargeable sealed lead-acid battery[1], which is carried in a hip bag. One fully charged battery could be used for a couple of passes. On the 'KA7OEI FT-817 pages'[2] several useful tips about saving energy with the 817 can be found. The two most important tips are the use of the front antenna connectors and, when possible, turning the display backlight off. Another big energy saver is to leave the transceiver for TX switched off while you are waiting for the satellite to become audible at the start of the pass.

A custom-made box to hold both transceivers was designed to make the setup as rugged and portable as possible and fits inside the carrying bag (designed for photo equipment). Figure 3 shows four pictures of the equipment mounted into the box. The bare box consists of four main parts, made of 2 mm thick aluminium sheet.

Figure 3 a: FT-817NDs in the transceivers box: Bare box from front with the bottom FT-817ND mounted.

The first and largest is the U-shaped part

(Continued on page 21)

(A Multi-purpose Portable Setup from page 20)
that is mounted directly to the lower 817. A through hole is drilled through the U-shaped holder and one of the tabs on the rear housing of the 817, with a M3 nut and bolt used to hold the two together (yes, it takes some courage to drill even a small hole into your cute little 817). Figures 3 (b) and (c) show these bolts from both sides.

Figure 3 b: FT-817NDs in the transceivers box: Bare box from back with all parts mounted.

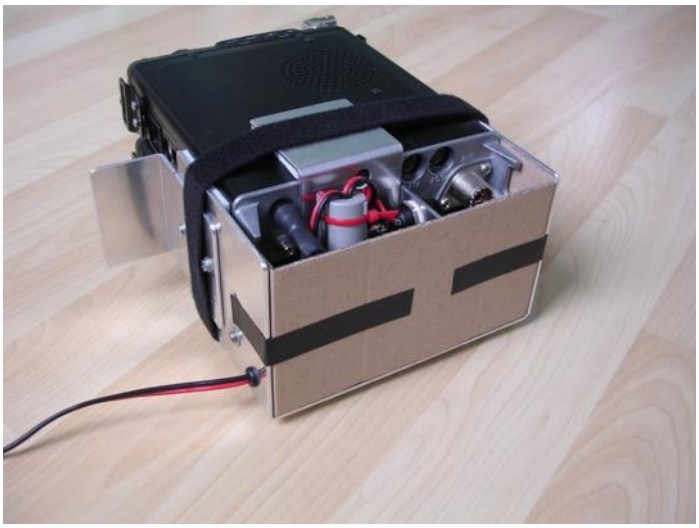

Figure 3 c: FT-817NDs in the transceivers box: Bare box ready to put in carrying bag, L-shaped audio cable bending protection at left.

The second part is a Z-shaped piece, which is mounted onto the middle of first part, in order to keep the upper 817 (which is not fixed to the box) against the lower 817, with both 817s separated by a piece of mouse pad (figure 3 (a)). Adhesive foam is used to prevent the box from scratching the 817s. A long piece of double-sided Velcro is used to firmly hold the two 817s together in the box, but also makes it very easy to remove the upper 817.

At the outside of the box, an L-shaped bracket is mounted to prevent the cabling at one side of the 817s from bending too much when the transceivers are in the carrying case (figure 3 (d)).

Figure 3 d: FT-817NDs in the transceivers box: Box mounted in carrying bag, space for audio cables visible, LPF clipped onto carrying bag.

The fourth and last part of the box is another L-shaped bracket to hold the four fuse holders, which is mounted to the U-shaped part (figure 3 (b)).

The exact dimensions of the four parts will be dependent on (1) the size of the carrying bag you want to use and (2) the thickness of the adhesive foam used between the 817s and the box, and some experimentation will be required.

Both 817s are powered by one power cable from the battery (figure 3 (c)). Fuses are present in the + and – lines, and each transceiver has an anti-parallel diode mounted to prevent damage from reverse polarity. The factory supplied ferrite clamps are mounted just before the power cables enter the 817s. Details of these components mounted in the box can be seen in figure 3 (b). A final cardboard protection is installed at the back of the box to protect the cabling when the box is inserted into the carrying bag.

At the back of the 817s there is space left to access the ACC connector, which can be used for Doppler correction in possible future projects. Also the data connector of the upper 817 is still accessible, so one 817 can be used with BPSK-31 on HF during holidays. At the front of the 817s angled BNC connectors are used to feed the antenna cables to the side so they are not in the way while operating the 817s.

(Continued on page 22)

(A Multi-purpose Portable Setup page 21)

Antenna Considerations

The main antenna for the setup is the well-known portable dual-band Arrow yagi antenna [3] for both 2 m (3 elements) and 70 cm (7 elements). For mode V/U and U/V either transceiver is connected to the corresponding antenna, using regular RG-58 with BNC connectors. The often-used small Arrow diplexer is not necessary here.

As a backup antenna, a portable dual-band HB9CV antenna[4] for 2 m/70 cm can also be used (figure 4). It is heavier than the ultra-light Arrow, and it needs an extra handle to point the antenna towards the satellite. The extra handle can easily be attached with the available screw thread in the boom of the HB9CV.

Figure 4: HB9CV dual band 2 m/70 cm portable antenna.

Another commercially available antenna specially designed for portable satellite operations is the dual-band Elk antenna[5], but the author does not own this antenna. The Elk is a log-periodic antenna with only one connector for both 2 m and 70 cm. For the setup described here, this would require an extra diplexer to be inserted (which is fortunately is not necessary for the Arrow and the HB9CV).

To compare the performance of these three antennas, Table 1 shows the approximate values for forward gain for both bands for all three antennas.

Forward gain	Arrow[6]	HB9CV[4]	Elk[5]
2 m	5,9 dBd	5,5 dBd	6,6 dBd
70 cm	8,2 dBd	5,5 dBd	7,0 dBd

Table 1: Approximate values of the forward gain for the Arrow, the HB9CV and the Elk dual-band antennas.

For 2 m the gains are almost equal. In practice, there is no noticeable difference between the Arrow and HB9CV. The almost 3 dB difference in gain between these two antennas for 70 cm is clearly noticeable as the downlink signals become undetectable at low elevations of the satellite. The best antenna to choose will actually depend on gain, price, weight, size, purpose, availability and, personal taste. Some people also build similar antennas themselves.

In some portable satellite setups, the Arrow antenna is mounted on a tripod, which will work fine. To have optimal and fast control of the antenna polarisation and pointing direction, I prefer to hold the antenna by hand.

Mode V/U Desensing

Using this setup in mode V/U in full-duplex, the receiver suffers in many cases from desensing, which is demonstrated by the loss of satellite reception during transmissions with the 817. The limited blocking dynamic range (BDR) of the 817, together with a large part of the transmitted signal entering the receiving 817, prevent the weak signals from the satellite from being detected.

The most common solution to this problem, but not effective here, is to add a so-called 'mode J' (old designation for mode V/U) filter in front of the 70 cm receiver. This mode J filter is a notch filter that prevents the strong 2 m signal from entering the 70 cm receiver (or preamp in many cases for a fixed station).

The desensing is caused by a strong third harmonic from the 2 m-uplink signal. The addition of a low-pass filter (LPF, in figure 2 (a)) that filters out the third harmonic on 70 cm solves this problem, which is shown in the basic calculations below. These calculations are performed for the worst-case scenario where the frequency of the third harmonic of the transmitted signal is close to the frequency of the signal received from the satellite. In order to determine what amount of unwanted signal is entering the receiver, the signal separation between the 2 m and 70 cm ports of the antenna is required and must be measured. A transmission measurement was performed (figure 2 (d)) with a handheld spectrum analyser (FSH3, Rohde & Schwarz, Germany) between the two connectors of the antenna, for both the Arrow as well as the HB9CV. Table 2 shows the results of these measurements. Although only the 70 cm numbers are relevant

(Continued on page 23)

(A Multi-purpose Portable Setup from page 22)
here, the 2 m results were also measured. It is remarkable that, although for the HB9CV the 2 m and 70 cm antennas are mounted in the same physical plane, the separation is still higher than for the Arrow.

Port separation	Arrow	HB9CV
2 m	45 dB	50 dB
70 cm	23 dB	8 dB

Table 2: Results of antenna port separation measurement.

After these measurements, the signal strength was calculated (1) without the LPF and (2) with the extra LPF added. The results are shown in Table 3. The values at the bottom of the table (in bold) show the minimal signal intensity that can be received on 70 cm while transmitting on 2 m. All values are approximate values, but this does not alter the principle.

These calculations show that in some cases it is impossible to receive weak signals without the extra LPF, such as signals from AO-51, which are between –105 and –117 dBm (from 'Calculating Link Budget for AMSAT-OSCAR 51', AMSAT-NA). It also shows that no desensing will appear when the extra LPF is added, which was verified in practice.

		Signal left	
	Value	Without LPF	With LPF
2.5 W output power FT-817ND (2 m)	34 dBm	34 dBm	34 dBm
Third harmonic suppression FT-817ND (70 cm)	60 dB	-26 dBm	-26 dBm
Extra attenuation LPF (70 cm)	50 dB		-76 dBm
Separation Arrow (70 cm signals)	23 dB	-49 dBm	-99 dBm
BDR FT-817ND receiver	60 dB	**-109 dBm**	**-159 dBm**

Table 3: Signal strength calculation for the minimum receivable signal in mode V/U in full-duplex.

The added LPF is based on a 2 m/70 cm diplexer design by HB9ABX, where only the 2 m part is used for the LPF. The schematic is shown in figure 5 (a). Adjustment was done with a dummy load and a VSWR meter. The LPF is home built and is shown in figures 5 (b) and (c). A clip made from thick copper wire makes it possible to clip the LPF onto the carrying bag (figure 3 (d)). Alternatively, the 2 m part of commercial 2 m/70 cm diplexers can be used as a LPF. When operating in mode U/V, the LPF can be mounted in the receiving path to limit the transmitted 70 cm signals flowing into the 2 m receiver, as shown in figure 2 (b).

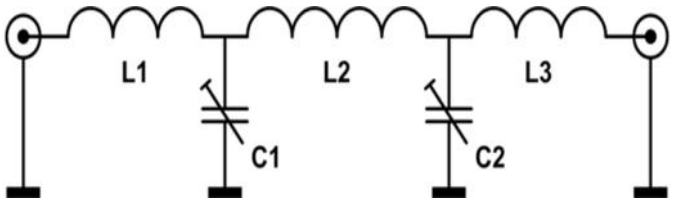

Figure 5 a: Home constructed LPF: Schematic of the filter [L1 = L3: 3 turns, L2: 4 turns, all Ø 6 mm, 1 mm Ag wire, C1 = C2: Foil trimmer capacitor 4 - 40 pF].

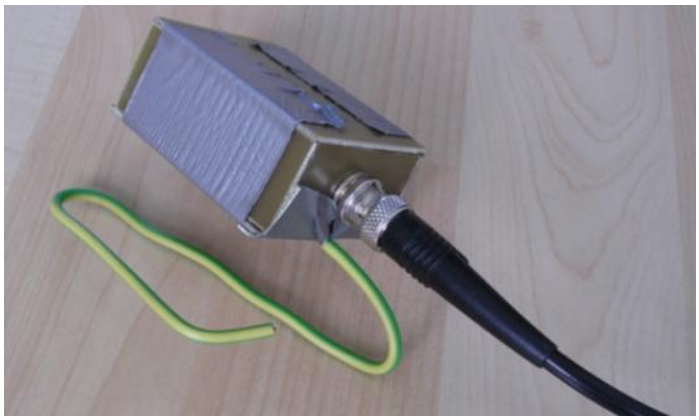

Figure 5 b: Home constructed LPF: Filter box.

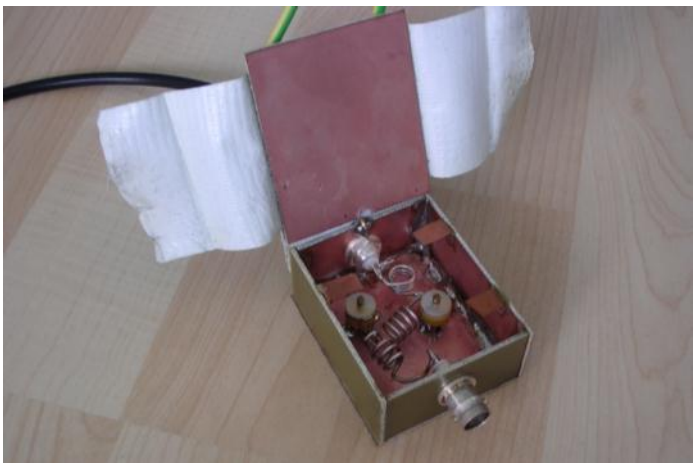

Figure 5 c: Home constructed LPF: inside of the filter box.

S-band Reception

S-band (2,4 GHz) receiving capabilities are made possible by means of a 2,4 GHz to 144 MHz down converter. The down converter (MKU LNC 24 OSCAR 2 TM, Kuhne electronic GmbH, Germany) was originally designed for AO-40, but was also capable for S-band reception of AO-51. The down converter is powered by means of a bias-T (KU BT 271 N, Kuhne electronic GmbH, Germany). An S-band patch antenna made by John G7HIA[7] (based on a design by K3TZ) is used, where the patch was mounted for Right Hand Circular Polarization

(Continued on page 24)

(A Multi-purpose Portable Setup page 23)
(RHCP). Figure 2 (c) shows the block diagram for S-band reception.

A creative method was used to mount the S-band reception parts all together onto the Arrow antenna, as can be seen in figures 6 (a) and (b). First an angled N-N connector is used to mount the patch antenna to the converter, and a strait N-N connector is used to mount the bias-T to the converter. From the bias-T to the receiving 817, regular RG-58 coaxial cable with BNC connectors is used. It is recommended to add an extra signal attenuator (around 20 dB) between the converter and the 817, because of the high gain of the down converter (or to reduce the gain inside the down converter box itself). After all S-band reception parts are mounted together, all this is mounted onto the boom of the Arrow antenna with the 70 cm part removed. A small piece of aluminium was used to mount the converter to the boom, where the existing mounting holes in both the converter and Arrow were used.

Headset and Audio

Using a headset instead of a hand microphone is highly recommended, because otherwise you need a hand for holding the microphone, a hand to operate the transceivers, as well as a hand to operate the antenna. For operation on SSB linear transponders, the VOX function of the 817 is used, because continuous manual tuning is required to find your own

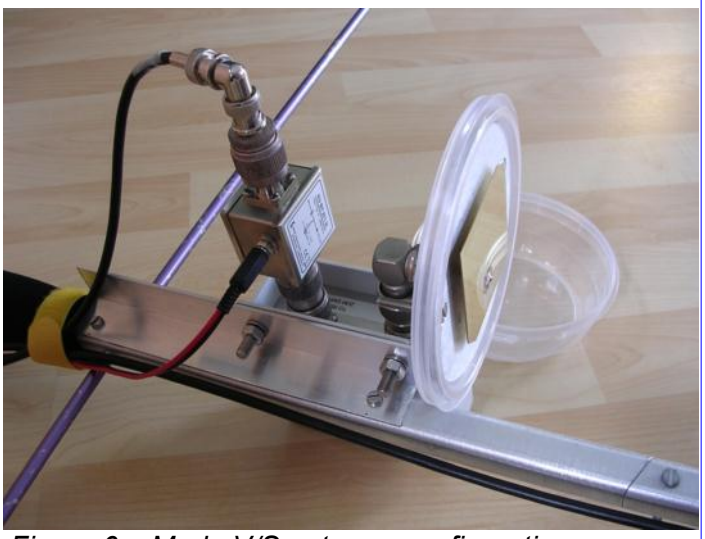

Figure 6a: Mode V/S antenna configuration: Detailed look on S-band reception parts.

downlink signal together with the necessary Doppler correction. I advise against the use of VOX for FM, as accidentally activating the VOX on FM (together with the VOX hang time) will certainly cause interference to other stations. This is less of an issue for SSB where no modulation means no signal transmitted. In practice, also strong wind or airplanes flying over can easily trigger the VOX.

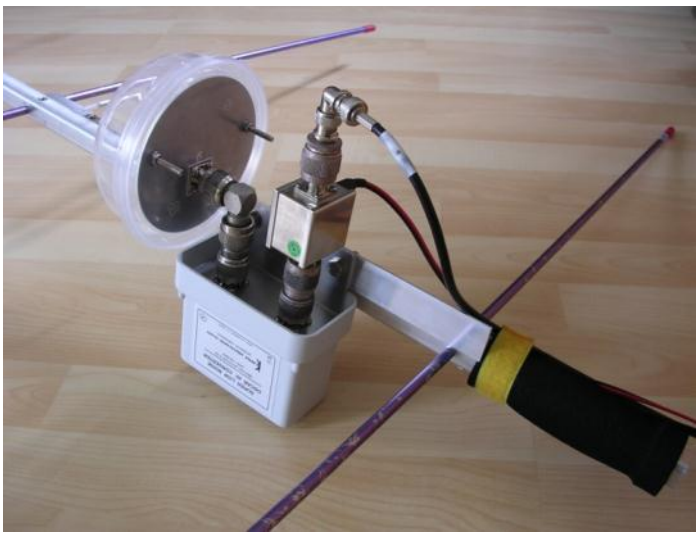

Figure 6b: Mode V/S antenna configuration: Overall mounting of the antennas for mode V/S.

The Heil Traveler dual headset works satisfactorily in this setup (this headset is discontinued by Heil, probably replaced by the ProMicro). No RFI is detected during transmissions, which is sometimes the case with cheaper computer headsets. The audio delivered by the microphone element sounds clear and powerful, a warm welcome when working QRP. PTT can be operated from the push button in the cable to the headset, and is used for FM repeater operation.

One expensive Heil adapter cable (HSTA-YM) is required to connect the headset to the 817. On the 817, the microphone/PTT are connected via a different plug than the headphone audio, so the two plugs of the HSTA-YM adapter cable can be plugged into corresponding connectors on the two transceivers.

A portable setup like this is ideal to show other people both the fun and technical achievements of AMSAT satellites. Full-duplex operation is highly recommended for successfully making QSOs, but it also prevents people from listening in to a QSO because of audio feedback. In an attempt to overcome this problem, the audio was also fed to a car radio FM transmitter (Tunecast II, Belkin) to let other people listen to the satellite signal on their iPod or similar devices. However, this was unsuccessful as the transmitter generates so much RF that all satellite reception is blocked completely. A more rigid way of letting people listen in is the use of a simple audio splitter (Rockstar, Belkin, figure 7) and separate head-

(Continued on page 25)

(A Multi-purpose Portable Setup from page 24)
phones for the extra listeners. A safe option is to use an extra audio splitter together with an audio extension cable (figure 7) so people do not have to stay very close to you, thus no harm is done to the equipment if they move one step away from you. When multiple headsets are connected to the audio output of the 817, the SP-PH switch can be set to SP to provide more audio power.

To be able to log the QSOs made, a small audio recorder is used (Zen Nano Plus, Creative, figure 7). This can be inserted in series with the headphone cable, or more conveniently connected in parallel with the audio splitter.

Figure 7: Audio multi splitter (Rockstar, Belkin), audio recorder (Zen Nano Plus), audio extension cable.

Experiences and Results

Many QSOs on the LEO satellites were made with this setup, both from my home QTH as well as from holiday locations in Denmark, Norway, and Scotland. In practice, the 817 together with an Arrow antenna has sufficient reception sensibility to receive the LEO satellites, although reception is difficult or impossible at low elevations (long distance to the satellite). The maximum 4 Watts output power is generally sufficient for a decent QSO, with the exception again when the satellite is at low elevations.

For single channel FM operation, is it convenient to use the multi-band memory capability of the 817, to have the Doppler correction pre-programmed for the entire pass. For SSB transponder QSOs, manual Doppler correction is required instead of using pre-programmed memories (as a starting point for manual tuning, a memory channel can be used to store the frequencies at the start of the pass). Memory programming can be performed with the 'FT817 Commander' software and a CT-62 (U) interface cable.

S-band reception while making a QSO with this portable setup is very challenging, due to the weight of the antenna and the Doppler shift. Almost continuous manual Doppler correction is required, especially near the time of closest approach (TCA) of the satellite pass. While both the uplink and the output of the converter were on 2 m, no interference between both was observed. The amount of noise in the 2,4 GHz band is enormous, with all wireless networks in the neighbourhood in the same band as the downlink signals from AO-51. Despite all this QRM, the signals from AO-51 were clearly readable.

Items are marked and labelled as much as possible, to make life easier when the setup is used outdoors, where small mistakes are more likely to be made than at home. The elements of the Arrow antenna are marked with the element sequence for fast mounting, all coax cables are marked with their frequency band to prevent wrong connection at the antenna or transceiver, and the transceivers are marked with 'RX' and 'TX' to indicate their function, together with different background colours of the displays.

Although the transceivers are marked with their function to be a receiver or transmitter, all memories are programmed both for reception (RX) and transmission (TX). In the case when a transceiver breaks down on RX or TX only, both transceivers can be exchanged to get the setup working again. In the case when one transceiver breaks down completely, the other one can still be used for working the FM satellites in half-duplex mode, which was also done successfully in the time when I owned only one FT-817ND.

Acknowledgements

A special thanks to Don Smith for the help with editing the original English text, and to PA0LEZ for making the antenna transmission measurements possible.

References

[1] For example Panasonic LC-R122R2PU, e.g. http://www.amazon.de

[2] The KA7OEI FT-817 pages, http://www.ka7oei.com/ft817pg.shtml

[3] Arrow II Satellite Antenna, model 146/437-10, http://www.arrowantennas.com

(Continued on page 26)

(A Multi-purpose Portable Setup from page 25)

[4] Dual band HB9CV, Order No. 18001, http://www.wimo.de

[5] Elk Model 2M/440L5, http://www.elkantennas.com/, available from http://shop.amsat.org.uk

[6] Antenna measurement results, originally at http://www.csvhfs.org/ant/CSANT09.HTML

[7] 2,4 GHz patch antenna, Radcom, November 2011, previously available from http://shop.amsat.org.uk

The article is used with permission from Ivo Klinkert, PA1IVO.

Figure 8: The setup ready for action on a campsite in Scotland.

4 June West Rand ARC Flea Market
5 June World Environmental Day
6 June Start of Ramadan
8 June World Ocean's Day
12 June Hammies ZS6 Sprint and SARL Youth Net
16 June Youth Day
16 to 19 June Calitzdorp Winter Festival
17 June World QRP Day
18 Highway ARC 20th birthday; ARRL Kid's Day
19 June Father's Day
20 June Winter Solstice
21 June Closing date for articles for the July Radio ZS
23 to 27 June SARL Top Band Contest
24 June All schools close
24 to 26 June Kirkwood Wildfees
24 to 26 June Ham Radio 2016, Friedrichshafen
30 June End of SARL Membership year

1 July Start of SARL Membership year
3 July ZS5 Sprint
6 July Eid-UL-Fitr
9 and 10 July IARU HF Championships
10 July SARL Youth Net
16 July Winter QRP Sprint
16 to 23 July Region 1 YOTA Summer Camp
18 July Schools open
24 July ZS2 Sprint
25 July Closing date for articles for the August Radio ZS
30 and 31 July Islands on the Air Contest

7 August SARL HF Phone Contest
9 August SARL YL Sprint
13 and 14 August International Lighthouse and Lightship Weekend
14 August SARL Youth Net
21 August SARL HF Digital Contest
28 August SARL HF CW Contest