Assembly Manual

VHF Receiver For Weather Satellites

Cat No. **K 3226**

by Jim Rowe

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KIT

Here's a compact, low-cost 2-channel VHF FM receiver for pulling in weather satellite signals in the 137-138MHz band. It has good sensitivity and adjustable RF gain, combined with the correct bandwidth for weather satellite APT signals. You can also operate it from either a plugpack or a 12V battery, for greater flexibility.

WHILE YOU CAN use a standard VHF scanner or communications receiver to pick up weather satellite signals, the results are often disappointing. The reason for this is that most scanners and communications receivers only provide a choice of two bandwidth settings for VHF FM reception: "narrow" and "wide". The narrow setting gives a bandwidth of ±15kHz or less, which is fine for NBFM reception. However, it is too narrow for undistorted reception of the weather satellite signals which need a bandwidth of at least ±25kHz.

By contrast, the wide bandwidth setting usually gives a bandwidth of about ±100kHz, so this is the setting that must be used. Unfortunately, this is really too wide for weather satellite signals and, as a result, the demodulated audio level is relatively low. At the same time, the wider reception bandwidth allows more noise through, so the signal-to-noise ratio can become quite poor.

In short, for best results you really need a receiver with an effective bandwidth of ±30kHz, or not much more. This type of specialised VHF receiver is available but they are not very thick on the ground and those that are available are fairly pricey. Hence the motivation for developing the low-cost weather satellite receiver described here.

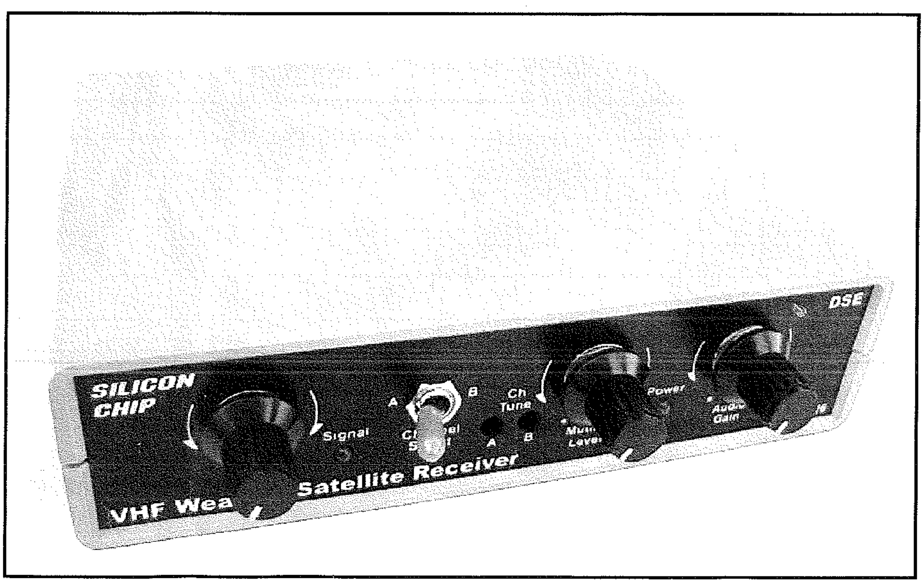
As you can see from the photos, the receiver is built into a very compact plastic instrument box. All of the circuitry is mounted on a double-sided PC board, so it's quite easy to build. It has switch tuning between two preset frequency channels, for ease of use. There are RF Gain, Audio Muting and Audio Gain controls and the receiver can drive a small monitor speaker or headphones, as well as providing a line level signal to feed into your PC for recording and decoding.

The sensitivity is quite respectable, at about 0.7μV for 12dB of quieting. At the same time, the effective bandwidth is approximately ±35kHz, which is quite suitable for weather satellite reception.

Bear in mind though that for good reception of these signals, you really need to use a masthead preamp as well. The receiver provides 12V DC at the antenna connector, for "phantom powering" such a preamp. We'll describe a matching preamp later on in the article along with an easy to build turnstile/reflector antenna for 137.5/137.62MHz.

Circuit description

At the heart of the receiver is an SA605D IC, which is described by



Receiver Parts List

1 PC board, code 06112031(ZA1048), 117 x 102mm (double-sided, with plated through holes)
1 small instrument case, 140 x 110 x 65mm
1 front panel
1 rear panel
2 5.5MHz ceramic filters, Murata SFTRD5M50AF00-B0
2 RCA sockets, 90° PC-mount
1 2.5mm concentric power socket, PC-mount
1 3.5mm stereo headphone jack, PC-mount
1 SPDT miniature toggle switch
7 PC board terminal pins
1 TO-220 heatsink
3 small skirted instrument knobs.
1 coil former.
1 F16 ferrite slug.
1 4-pin former base and screening can
1 short length of 0.25mm enamelled copper wire for RFC1
1 F29 ferrite bead (for RFC1)
1 short length of 0.8mm tinned copper wire for L1
1 length of 0.8mm enamelled copper wire for L2, L3
1 RF Choke 10µH (100K / .100)
1 RF Choke 68µH (680K)

Semiconductors
1 SA605D mixer/IF amplifier/FM detector (IC1)
1 TL072 / LF353N dual op-amp (IC2)
1 LM386 audio amp (IC3)
1 7812 / LM340T-12 + 12V regulator (REG1)
1 78L05 / KA78L05+5V regulator (REG2)
1 BF998 dual-gate MOSFET (Q1)
1 PN100 NPN transistor (Q2)
1 5.1V 400mW zener diode 1N4733 / BZX85C5V1 (ZD1)
1 3mm red LED (LED1)
1 3mm green LED (LED2)
1 ZMV833ATA varicap (VC3)
1 1N4004 1A power diode (D1)

Capacitors
1 2200µF 16/25V RB electrolytic
1 470µF 25V RB electrolytic
1 330µF 16V/25 RB electrolytic
3 10µF 16/25V RB electrolytic
1 10µF 25/35V TAG tantalum
1 470nF MKT metallised polyester
9 100nF multilayer monolithic ceramic
1 47nF MKT metallised polyester
1 22nF MKT metallised polyester
5 10nF multilayer monolithic ceramic
1 4.7nF MKT metallised polyester
7 2.2nF monolithic or ceramic
1 1nF disc ceramic
1 1nF MKT metallised polyester
1 390pF NPO ceramic
2 15pF NPO ceramic
2 10pF NPO ceramic
2 3-10pF trimcaps blue (VC1, VC2)
2 2.2nF SMD ceramic capacitor

Resistors (0.25W 1%)

1 470kΩ	1 1.8kΩ
1 390kΩ	1 1.5kΩ
1 150kΩ	1 1.2kΩ
1 110kΩ	4 1kΩ
1 100kΩ	1 360Ω
1 47kΩ	1 300Ω
1 39kΩ	1 240Ω
3 22kΩ	1 220Ω
2 10kΩ	2 100Ω
1 5.6kΩ	1 47Ω
1 4.7kΩ	1 22Ω
2 2.2kΩ	1 10Ω

Potentiometers
1 50kΩ linear pot (B50K), 16mm PC board mount (VR1)
1 25kΩ linear pot (B25K), 16mm PC board mount (VR2)
1 50kΩ log pot (A50K), 16mm PC board mount (VR3)
2 50kΩ 10-turn trimpots (503), PC board mount (VR4,VR5)

Miscellaneous
Screws, nuts & washers, tin plate shield, BNC socket, solder and instructions.

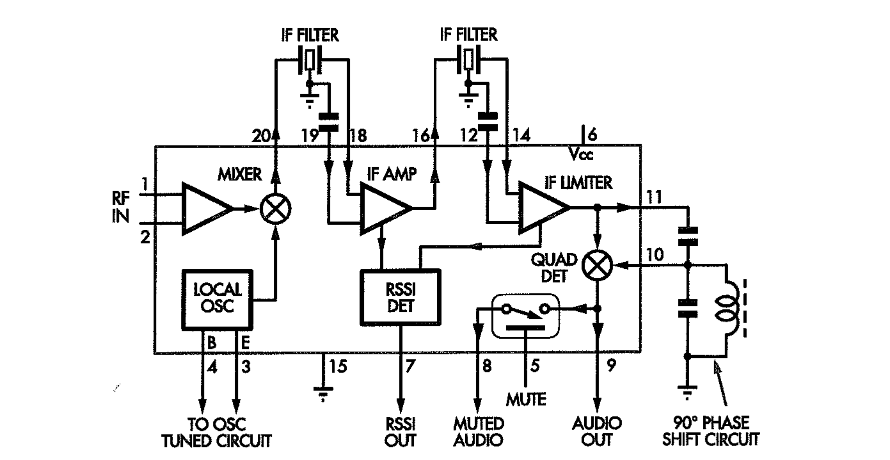


Fig.1: block diagram of the Philips SA605D low-power FM mixer and IF system. It contains a local oscillator (LO) transistor, a balanced mixer, a high gain IF amplifier and IF limiter, a received signal strength (RSSI) detector, an FM quadrature detector and an audio muting circuit.

Main Features

- Two presettable channels in the 137-138MHz band
- Sensitivity: 0.7µV for 12dB of quieting
- Bandwidth: ±35kHz (approx.)
- Plugpack or battery powered
- Provides 12V DC phantom power to power a masthead amplifier

Philips as a high-performance low-power FM mixer and IF system. As you can see from the block diagram of Fig.1, it contains a local oscillator transistor and balanced mixer, plus a high-gain IF amplifier and IF limiter, a received signal strength (RSSI) detector, an FM quadrature detector and finally an audio muting circuit.

The local oscillator transistor can operate at frequencies up to about 500MHz in an LC circuit, or up to 150MHz with a suitable crystal. The mixer can operate up to 500MHz as well, while the IF amplifier and limiter can operate up to about 25MHz with a combined gain of about 90dB.

That's not bad when you consider it's all packed inside a 20-pin small outline SMD package!

Fig.2 shows the complete circuit details. In this receiver, we're using the SA605D in a fairly conventional single-conversion superhet configuration, with the IF amplifier and limiter working at 5.5MHz. This allows us to take advantage of high selectivity 5.5MHz TV sound IF ceramic filters to provide most of our bandwidth shaping. The two filters in question are CF1 and CF2, which are both Murata SFT5.5MA devices.

As shown in Fig.2, CF1 is connected between the mixer output and the IF amplifier input, while CF2 is connected between the IF amplifier output and the limiter input. The resistors connected to the filter inputs and outputs are mainly for impedance matching, while the 10nF capacitors are for DC blocking. The 90° phase shift required for IC1's quadrature FM detector is provided by coil L4 and its parallel 390pF capacitor, which are tuned to 5.5MHz.

The local oscillator transistor inside IC1 is connected in a Colpitts circuit. This includes coil L3, together with the two 15pF capacitors (which provide the emitter tap) and a 10pF capacitor in series with varicap diode VC3.

Varicap diode VC3 is the receiver's tuning capacitor. Its tuning voltage for each of the two channels is set by 10-turn trimpots VR4 and VR5, with switch S1 selecting between them. We can tune the receiver simply by changing the local

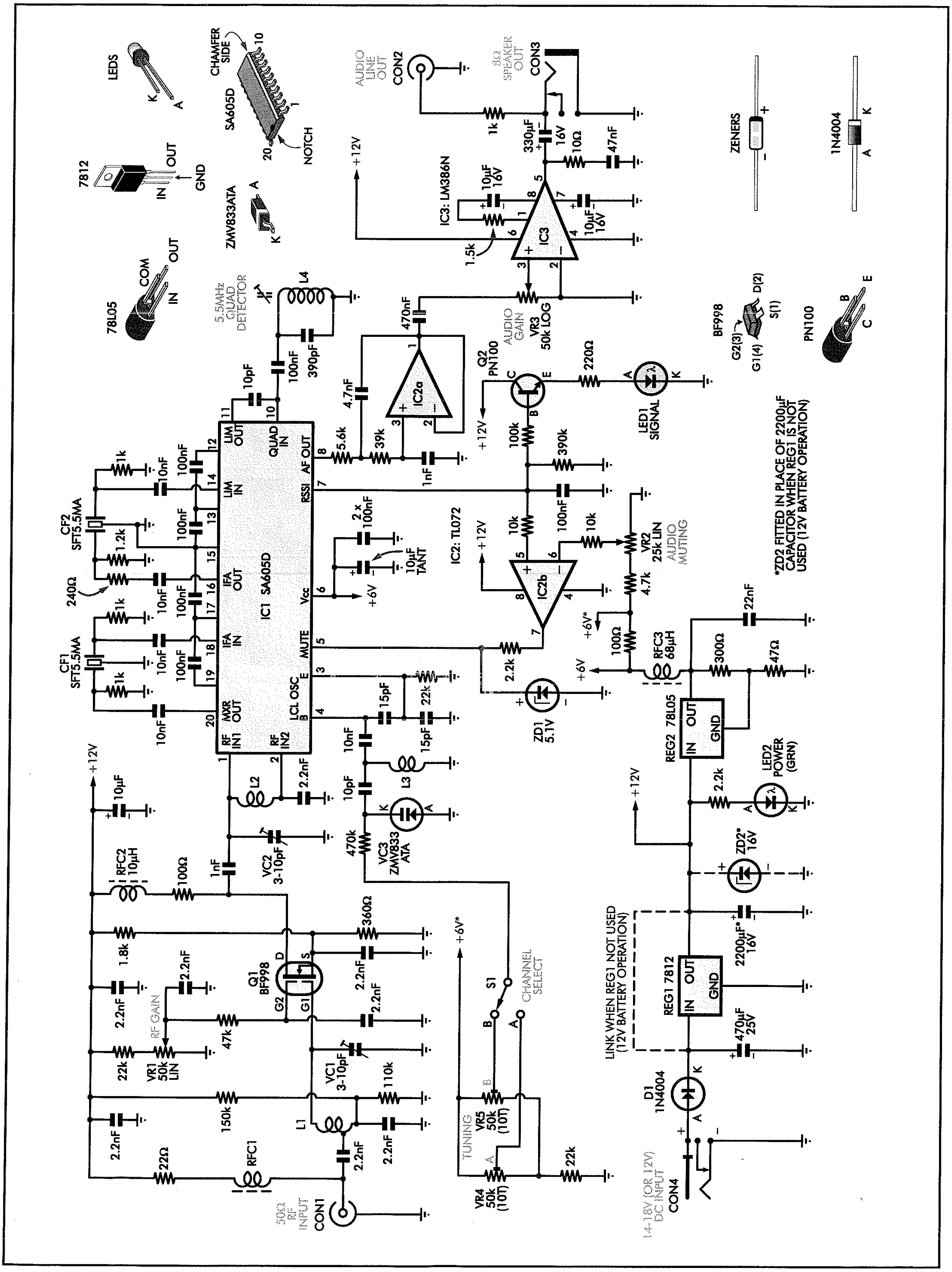


Fig.2: the complete circuit diagram for the VHF Weather Satellite Receiver. Dual-gate MOSFET Q1 functions as an RF amplifier stage with adjustable gain. Its output is fed into IC1 and the demodulated output from IC1 fed to low-pass filter stage IC2 and then to audio output stage IC3. The local oscillator (LO) inside IC1 is tuned using VR4, VR5 and varicap diode VC3.

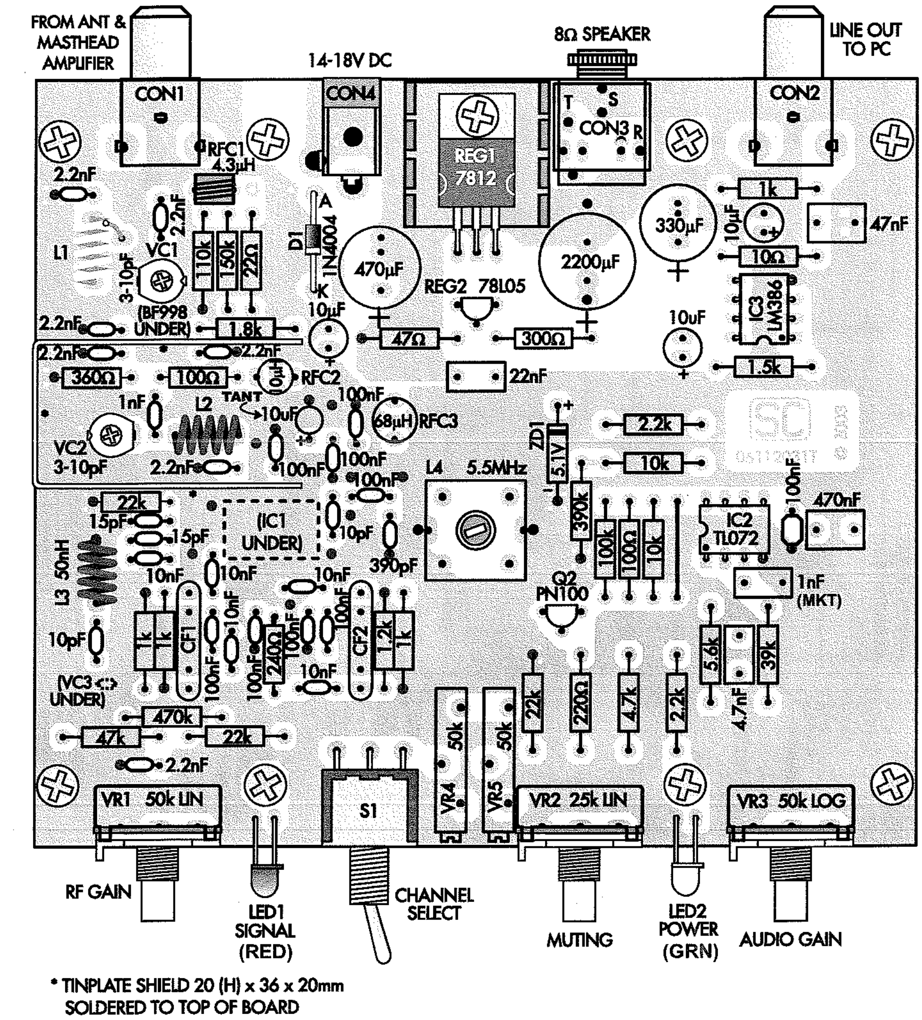


Fig.3: install the parts in the top of the PC board as shown here. Note that S1 is not directly soldered to the board but is instead connected to three PC stakes using flying leads (Refer also to Fig.9).

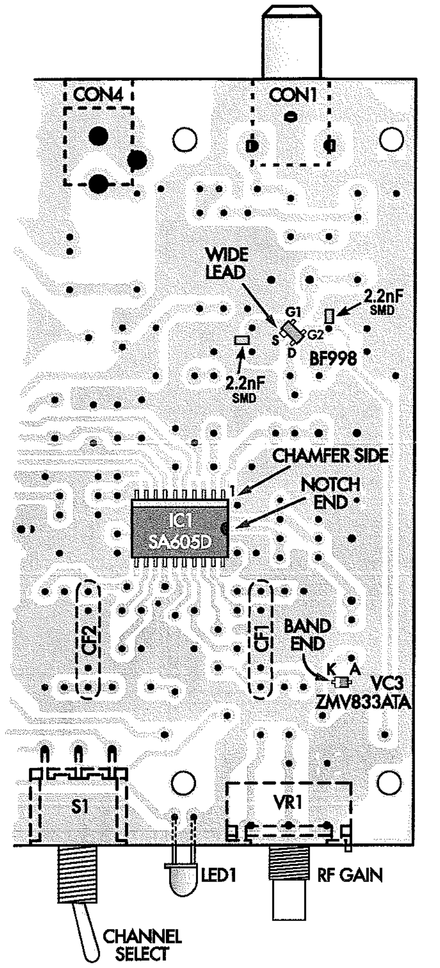


Fig.4: here's how to install the five surface mount devices - SMD's (Q1, IC1, VC3 & two 2.2nF capacitors) on the underside of the board. Q1, VC3 & the capacitors can be held in position using epoxy resin to make soldering easier - see text.

oscillator frequency because we only need to tune over a relatively small range (ie, 137.3 - 137.85MHz maximum), which is within the selectivity curve of the "front end" tuned circuits.

Moving now to the front end, this uses a BF998 dual-gate MOSFET (Q1) connected in a standard cascode amplifier configuration. The incoming VHF signals are fed into a tap (for impedance matching) on antenna coil L1, which is tuned to about 137.55MHz using trimmer capacitor VC1. The signal from the top of this tuned circuit is then fed directly to gate 1 of Q1, while gate 2 is bypassed to ground but also fed with an adjustable DC voltage via VR1 for RF gain control.

The amplified VHF signal on Q1's drain is fed to pin 1 of IC1 via a 1nF coupling capacitor. Additional RF selectivity is provided by coil L2 and trimmer capacitor VC2, which are again tuned to about 137.55MHz. The 100Ω resistor and 10μH RF choke form an untuned high-impedance load for Q1.

Notice that as well as being coupled to the tap on L1 via a 2.2nF capacitor, the antenna input is also connected to the +12V supply line via RFC1 and a series 22Ω resistor. As you may have guessed, these components are there to provide "phantom" DC power for the masthead preamp.

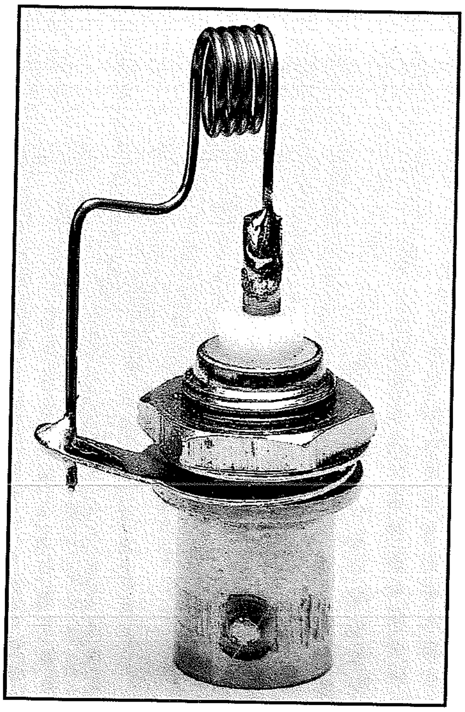
At the output end of IC1, we take the demodulated APT signals from the "muted audio" output at pin 8. This allows us to take advantage of the SA605's built-in muting circuit, which works by using comparator stage IC2b to compare IC1's RSSI output from pin 7 (proportional to the logarithm of signal strength) with an adjustable DC control voltage from muting pot VR2. When the RSSI voltage rises above the voltage from VR2, IC2b's output switches high and this is fed to pin 5 of IC1 via a 2.2kΩ series resistor to unmute the audio. ZD1, a 5.1V zener diode, limits the swing on pin 5 of IC1 to less than 6V.

Transistor Q2 and LED1 form a simple signal strength indicator. This also uses the RSSI output from IC1. In operation, the voltage across the 390kΩ resistor and 100nF capacitor rises from about +0.26V under no-signal conditions to about +5V with a very strong input signal. So with Q2 connected as an emitter follower and LED1 in its emitter load, the LED current and brightness are made to vary quite usefully with signal strength.

Low-pass filter

The demodulated APT signal from pin 8 of IC1 is first fed through op amp IC2a, which is configured as an active low-pass filter. This has a turnover frequency of 5kHz and is used for final de-emphasis and noise reduction.

From there, the signal is fed to audio gain control VR3 and then to audio amplifier stage IC3. This is a standard LM386 audio amplifier IC, configured for a gain of about 40 times. Its output is fed to both the monitor speaker socket



You can make a sniffer coil for your frequency counter by winding four turns of 0.8mm enamelled copper wire on a 5mm drill shank. Its ends can then be soldered to a BNC socket which is then connected to a plug on the end of a coaxial cable. The other end of the cable is then connected to the frequency counter

and to a line output socket for connection to your PC's sound card.

Power supply

Most of the receiver's circuitry operates from +12V, with the exception of IC1 which needs +6V. As a result, the power supply circuitry includes REG1 to provide a regulated and smoothed +12V supply from an external supply such as a 14.5-18V plugpack. This is followed by 5V regulator REG2 which has its output "jacked up" using 300Ω and 47Ω resistors to provide close to +6V for the SA605D (IC1).

Note that if you want to run the receiver from a 12V battery, this can be quite easily done by replacing REG1 with a wire link. In addition, the 2200µF capacitor should be replaced with a 16V zener diode (ZD2) for over-voltage protection.

Construction

Construction is straightforward with virtually all of the parts mounted on a small PC board coded ZA1048 / 06112031 (117 x 102mm). The board is double-sided but the top copper pattern is used mainly as a groundplane. This means that the board doesn't need to have plated-through holes but there are quite a few component leads which do have to be soldered on both sides of the board, if a plated-through hole PCB is not supplied.

Fig.3 shows the assembly details. As shown, the various input and output connectors are mounted along the rear edge of the board, while the controls and indicator LEDs mount along the front edge. The only component not actually mounted on the board is S1, the channel select toggle switch. This mounts on the front panel, with its three connection lugs wired to PC board terminal pins directly underneath using very short lengths of tinned copper wire.

Start the assembly by fitting these three terminal pins first & then fitting another two terminal pins at each led termination. Now fit the the project's only wire link, which goes on the righthand side of the board just to the left of IC2. **Note that this link must be insulated using some heatshrink tubing supplies, as it carries +12V and passes over ground plane copper.**

Next, fit the four connectors CON1-CON4 along the rear edge, followed by the resistors. Table 1 shows the resistor colour codes but it's also a good idea to check each value using a digital multimeter before soldering it in position. All resistors are fitted to the top of the PC board. There is no need to solder any of the components to the top side of the board as the PCB comes with plated-through holes. Soldering is only required from the bottom side.

Once the resistors are in, the small ceramic capacitors can now all be installed on the lefthand side of the board. Once they're in, install the MKT capacitors and the electrolytics, making sure that the latter are all correctly orientated.

Now for trimmer capacitors VC1 and VC2. These should be fitted so that their adjustment rotors are connected to earth (this makes it much easier to align the receiver later). It's simply a matter of orientating them on the board as shown in Fig.3.

RF chokes RFC2 and RFC3 are both supplied pre-wound (10µH and 68µH respectively) but RFC1 needs to be wound on an F29 ferrite bead. It's very easy to wind though, because it requires only two turns of 0.25mm enamelled copper wire.

Winding the coils

At this stage, it's a good idea to wind and fit the remaining coils. Table 3 gives the winding details. As shown, L1-L3 are air-cored types, each consisting of five turns of 0.8mm dia-meter wire wound on a 5mm mandrel. Note, however, that L1 is wound using tinned copper wire, while L2 and L3 are both wound using enamelled copper wire. Don't forget to scrape off the enamel at each end, so they can be soldered to the board pads.

L1-L3 should all be mounted so that their turns are about 2mm above the board. After you've fitted L1, don't forget to fit its "tap" connection lead as well. This can be made from a resistor lead off-cut, since it's very short. It connects to a point 1/3 of a turn up from the "cold" (earthy) end of the coil – ie, just above half-way up the side of the first turn.

The final coil to wind is quad detector coil L4. Unlike the others, this is wound on a 4.83mm OD former with a base and a copper shield can. It's wound from 20 turns of 0.25mm enamelled copper wire and tuned with an F16 ferrite slug.

Once L4 is wound, fitted to the board and covered with its shield can, you can fit the two ceramic filters CF1 and CF2. These devices can be fitted either way around but make sure that their pins are pushed through the board holes as far as they'll go before you solder them underneath.

The next step is to fashion and fit the small tinplate shield at the location shown in the overlay diagram – ie, around L2, VC2 and most of the components in the drain circuit of Q1. This shield is U-shaped and measures 20mm high, with the front and back "arms" 36mm long and the side section 20mm long. The bottom edges of all three sides are soldered to the board's groundplane in a number of places, to hold it firmly in position and to ensure it stays at earth potential. For further details refer to Fig. 7.

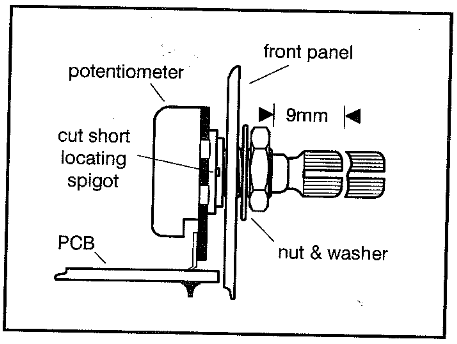
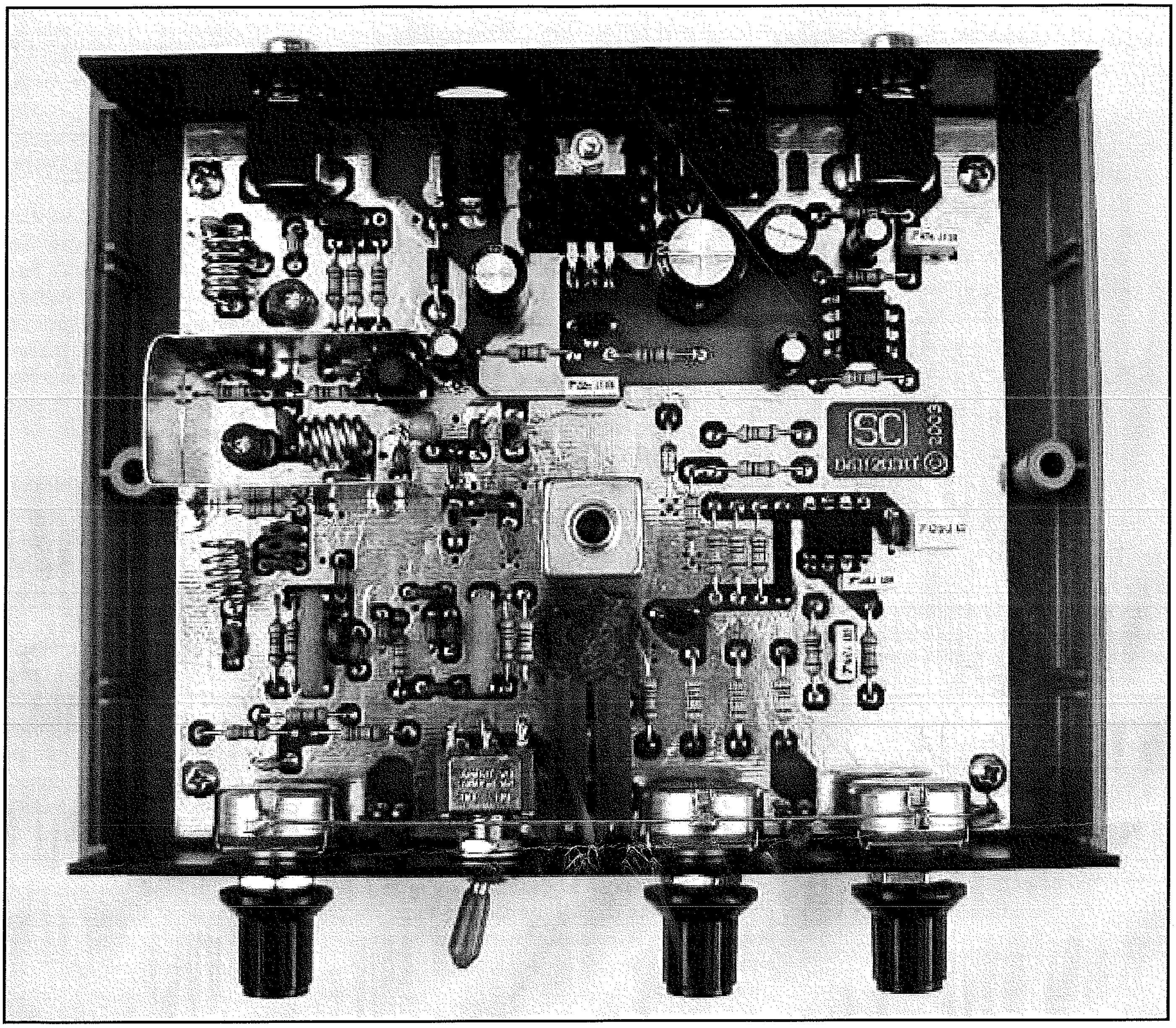


Fig.8: Before mounting the pots onto the front panel trim their spindle length to about 9mm. This will allow the knobs to sit closer to the front panel giving the project a more professional look. Also the locating spigot on each pot is not required and can be trimmed short and removed with a pair of side cutters.

Text and illustrations courtesy of Silicon Chip



This is the view inside the assembled receiver. Note that a tinplate shield is fitted around L2, VC2 and most of the components in Q1's drain circuit (see text). Note also that the metal bodies of the potentiometers are connected together using tinned copper wire and then connected to the groundplane copper on the PC board.

Fitting the pots

The two 10-turn trimpots (VR4 and VR5) can now be soldered in position at the front-centre of the board. They can then be followed by the three main control pots, which are all 16mm dia-meter types. Trim each pot's spindle length to about 9mm before fitting it and make sure you fit each one in its correct position as they are all different. In particular, note that VR1 and VR3 both have a value of 50kΩ but VR1 is a linear pot while VR3 is a log type.

After fitting the pots, it's a good idea to connect their metal shield cans together and then run a lead to the board's top copper to earth them. This is done using a length of 0.5mm tinned copper wire, with a short length of insulated hookup wire then connecting them to the board copper at front right (see photos). Note that it will be necessary to scrape away the passivation from the pot bodies in order to get good solder connections.

Mounting the semiconductors

Now you should be ready to fit the semiconductor devices – or at least those that go on the top of the board. Begin by installing diode D1, 5.1V zener diode ZD1 and transistor Q2.

That done, install regulator REG1 (if you're using it) and its associated heatsink, as shown in Fig.3. These parts are secured to the board using a 10mm-long M3 screw, nut and lockwasher.

Next, fit regulator REG2, followed by IC2 (TL072) and IC3 (LM386).

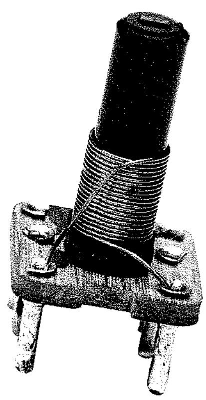
The two LEDs (LED1 & LED2) are both mounted horizontally on PCB stakes so that they later protrude through matching 3mm holes in the front panel. Note that they are both fitted with their cathode leads towards the left. Trim their leads to about 5mm from the LED bodies, then solder them in position so that the axis of each LED is in line with the front panel hole.

The final components to fit are the surface-mount parts, which all fit underneath the board – see Fig.4. We're talking here of varicap diode VC3 (ZMV833ATA), the BF998 dual-gate MOSFET (Q1), the SA605D IC (IC1) and the 2.2nF SMD capacitors. The first two in particular are in very tiny packages and need very careful handling.

In fact, these very small devices are not easy to hold in position while you solder them but there is a way around this. The trick is to mix up a small amount of 5-minute epoxy resin cement (Araldite or similar) and then apply an extremely small "dot" of epoxy to the underside of the board at each component position (if you use the end of a

Text and illustrations courtesy of Silicon Chip

Table 3: Coil Winding Details	
L1	5 TURNS OF 0.8mm TINNED COPPER WIRE, 7mm LONG (WOUND ON 5mm DIAMETER MANDREL). TAP AT 0.3 TURNS. AIR CORED, MOUNTED 2mm ABOVE BOARD
L2	5 TURNS OF 0.8mm ENAMELLED COPPER WIRE, 9mm LONG (WOUND ON 5mm DIAMETER MANDREL) AIR CORED, MOUNTED 2mm ABOVE BOARD
L3	5 TURNS OF 0.8mm ENAMELLED COPPER WIRE, 8mm LONG (WOUND ON 5mm DIAMETER MANDREL) AIR CORED, MOUNTED 2mm ABOVE BOARD
L4	20 TURNS OF 0.25mm ENAMELLED COPPER WIRE, TIGHT WOUND ON 4.83mm FORMER WITH F16 TUNING SLUG AND SHIELD CAN
RFC1	2 TURNS OF 0.25mm ENAMELLED COPPER WIRE WOUND ON AN F29 FERRITE BEAD



resistor or diode lead offcut as the cement applicator, this should apply about the right amount). It's then just a matter of using tweezers to carefully place each component in its correct position over the epoxy "dots", with the correct orientation.

When you're satisfied that they're all located accurately, carefully put the board aside for 10 minutes or so to let the adhesive cure. After this, you can solder their leads to the PC pads without having to worry about them moving.

IC1 can be mounted in the same way if you like but it's not nearly as small as the other two parts and so isn't as difficult. The main thing to watch out for here is that you don't create solder bridges when you're soldering its leads, as they're spaced at just 1.25mm. Make sure you use a clean fine-tipped soldering iron for this job and work quickly so that you don't overheat either the IC or the copper pads on the board.

After soldering all three SMD devices in place, it's a good idea to inspect them very carefully using a magnifying glass. Check that all joints have been made correctly and that there are no solder bridges.

Final assembly

The completed PC board is housed in a low-profile plastic instrument case. If you purchase a kit, this will probably come with all holes predrilled. If not, you will have to drill the front and rear panels yourself using Fig.6 as drilling template.

Once the panels have been prepared, you can mount switch S1 on the front panel and connect three short lengths of tinned copper wire to the three pins on the PC board via. That done, the front panel can be mated with the PC board by positioning it on the three pot ferrules and doing up the nuts. The three leads from the PC board pins can then be trimmed and soldered to the switch lugs.

The rear panel is not attached to the board assembly. Instead, it simply slips over CON1 and CON2 and is then slid into the rear slot when the assembly is fitted into the bottom half of the case. Finally, the completed assembly is fastened in place using four 6mm-long 4-gauge self-tapping screws.

Does it work?

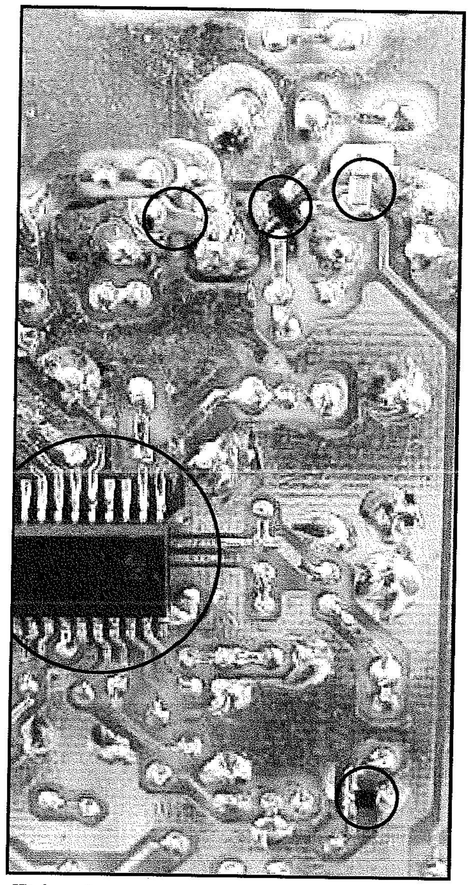
Now for the final checkout, to make sure it's working properly.

First, turn all three front-panel pots fully anticlockwise, then apply power from a suitable 14-18V DC plugpack (or a 12V battery). Check that the green power LED immediately begins glowing.

If it does, check the voltage on REG1's output lead (ie, the righthand lead) with your DMM – it should be very close to +12V with respect to ground. Similarly, the voltage at REG2's (righthand) output pin should measure very close to +6V.

If you now plug an 8Ω speaker into CON3 and then turn up audio gain control VR3, you should hear a small amount of hiss and noise. When you turn up the RF gain control VR1 as well, this noise should increase a little further but LED1 shouldn't begin glowing except only very faintly when VR1 is turned fully clockwise.

Now turn VR1 fully anticlockwise again and use your DMM to measure the DC voltage at the top of the 390kΩ resistor located just behind transistor Q2 (ie, to the right of 5.1V zener diode ZD1). The voltage across this resistor should be less than 0.30V and preferably about 0.26V. If it's any higher than 0.30V, the IF amplifier in IC1 may be unstable.



This view of the underside of the PC board shows the locations of the three surface-mount devices (SMDs). Refer to the text for the mounting details.

Assuming that your receiver has passed all these tests, it should be working correctly and is now ready for alignment.

Receiver alignment

A final "touch up" alignment of the receiver is best done with a satellite signal. However, you need to give it a basic alignment first so that you can at least find the signal from a satellite when it's within range.

For the basic alignment, you'll need access to a frequency counter capable of measuring up to 150MHz and an RF sig-

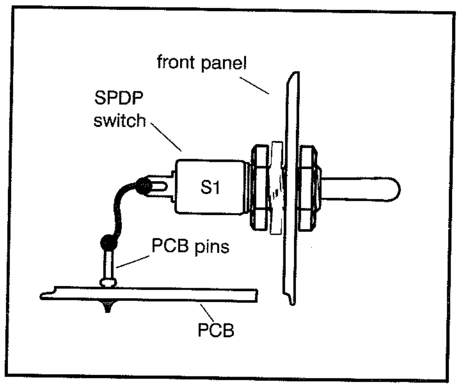
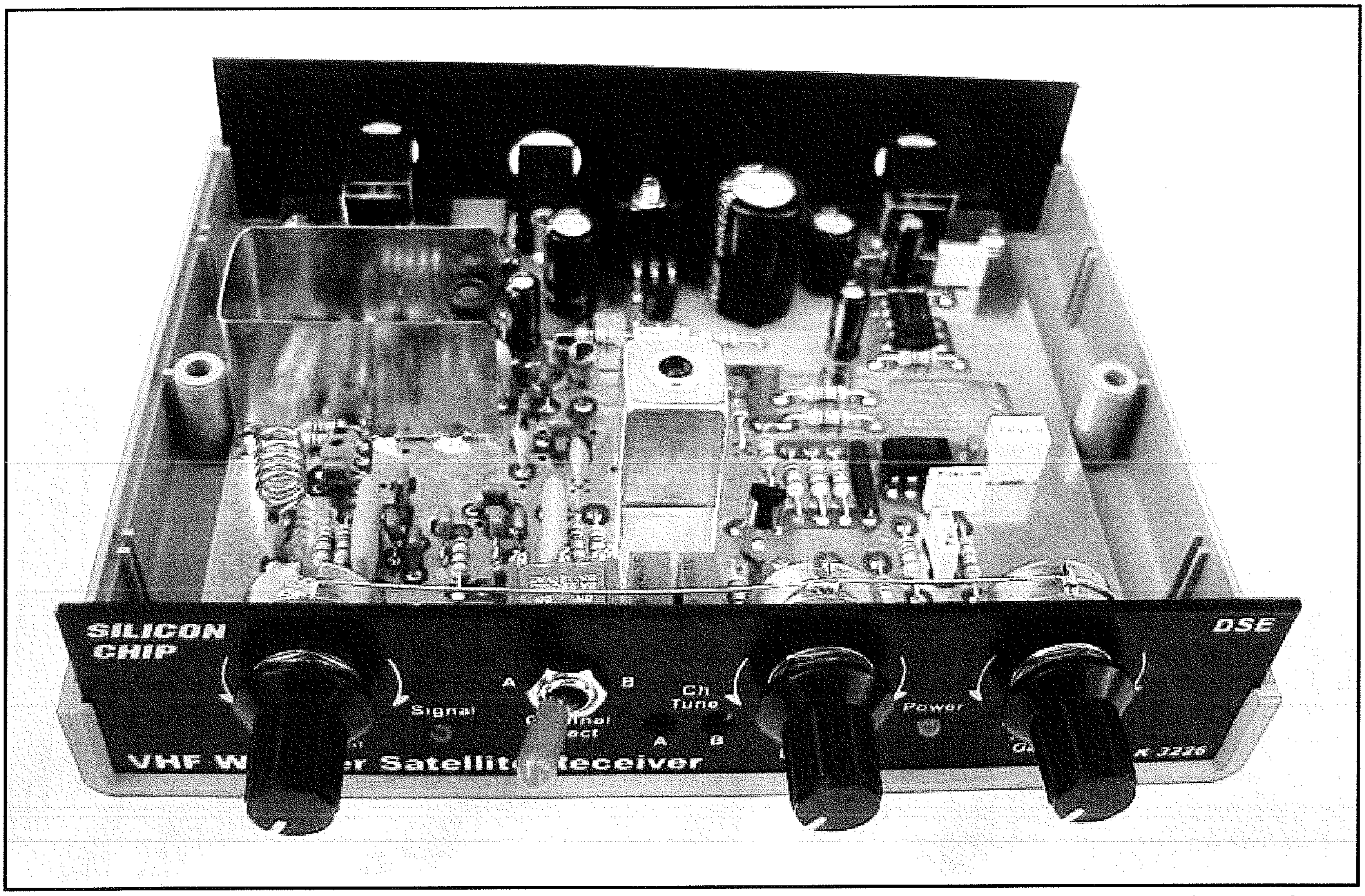


Fig.9: Secure switch (S1) to the front panel then using short lenghts of tin copper wire terminate each of the three switch terminals to the adjacent PCB (printed circuit board) pins.



The receiver is easy to drive, with just four front-panel controls. These are (from left to right): RF Gain, Channel Select, Muting Level and Audio Gain. In addition, there are two holes in the front panel to provide screwdriver access to the 10-turn pots (VR4 & VR5) during alignment.

nal generator which can be set to give an output at 137.50MHz and at 137.62MHz. It should be able to provide either unmodulated (CW) output or frequency modulation, with a modulating frequency of 2.4kHz and a deviation of ±25kHz or thereabouts.

If the generator can't be accurately set to the above frequencies, you'll need to use the frequency counter to help set its frequency. You'll also need your DMM during the "tuning-up" process, to monitor received signal level.

The first step is to set the local oscillator frequencies for the two reception channels. This is done by adjusting trimpots VR4 and VR5 respectively, while measuring the oscillator's frequency with the frequency counter. The oscillator signal is coupled to the counter via a "sniffer" coil which is connected to the end of a coaxial cable. The other end of this cable is then connected to the counter's input.

Note that there is no direct physical connection between the oscillator coil and the counter's sniffer coil. Instead, the sniffer coil is placed about 9mm in front of oscillator coil (L3) and roughly on-axis (ie, just in front of the 10pF capacitor).

The sniffer coil can be made by winding four turns of 0.8mm enamelled copper wire on a 5mm drill shank. Its ends can then be soldered to a BNC socket

Table1: Resistor Colour Codes

Value	4-Band Code (1%)	5-Band Code (1%)
470kΩ	yellow violet yellow brown	yellow violet black orange brown
390kΩ	orange white yellow brown	orange white black orange brown
150kΩ	brown green yellow brown	brown green black orange brown
110kΩ	brown brown yellow brown	brown brown black orange brown
100kΩ	brown black yellow brown	brown black black orange brown
47kΩ	yellow violet orange brown	yellow violet black red brown
39kΩ	orange white orange brown	orange white black red brown
22kΩ	red red orange brown	red red black red brown
10kΩ	brown black orange brown	brown black black red brown
6kΩ	green blue red brown	green blue black brown brown
4.7kΩ	yellow violet red brown	yellow violet black brown brown
2.2kΩ	red red red brown	red red black brown brown
8kΩ	brown grey red brown	brown grey black brown brown
1.5kΩ	brown green red brown	brown green black brown brown
1.2kΩ	brown red red brown	brown red black brown brown
1kΩ	brown black red brown	brown black black brown brown
360Ω	orange blue brown brown	orange blue black black brown
300Ω	orange black brown brown	orange black black black brown
240Ω	red yellow brown brown	red yellow black black brown
220Ω	red red brown brown	red red black black brown
100Ω	brown black brown brown	brown black black black brown
47Ω	yellow violet black brown	yellow violet black gold brown
22Ω	red red black brown	red red black gold brown
10Ω	brown black black brown	brown black black gold brown

Table2: Capacitor Codes

Value	mF Code	EIA Code	IEC Code
470nF	0.47µF	474	470n
100nF	0.1µF	104	100n
47nF	0.047µF	473	47n
22nF	0.022µF	223	22n
10nF	0.01µF	103	10n
4.7nF	0.0047µ	F472	4n7
2.2nF	0.0022µ	F222	2n2
1nF	0.001µF	102	1n
390pF	–	391	390p
15pF	–	15	15p
10pF	–	10	10p

Text and illustrations courtesy of Silicon Chip

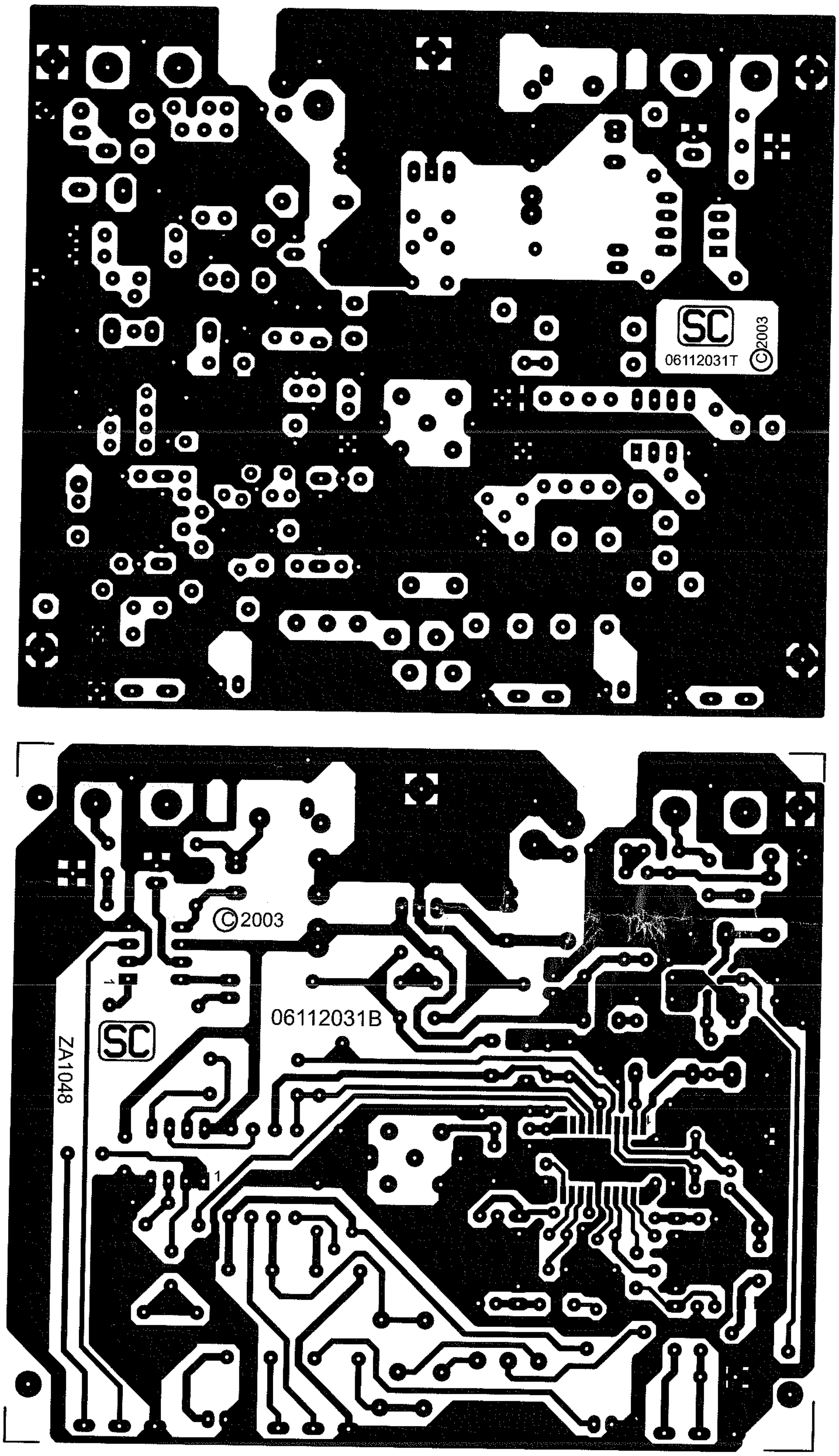


Fig.5: here are the full-size (top and bottom) etching patterns for the PC board.

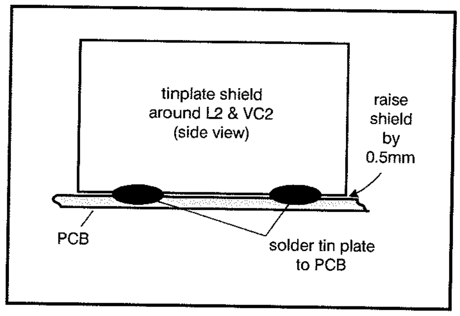


Fig.7: Once the tinplate shield is shaped as described in the text, position the shield so that the bottom edges are soldered to the board's groundplane at a number of places. To avoid any shorts between the top-plane component pads and the tin plate, raise the shield by about 0.5mm off the groundplane before soldering.

which is then connected to the end of the counter input cable (see photo). This arrangement picks up enough oscillator energy to give reliable counter readings, without needing to be any closer to L3 (to avoid "pulling" the frequency).

Assuming you want to receive the NOAA satellites, set the oscillator frequency for channel A to 132.0MHz (using VR4), and the frequency for channel B to 132.12MHz (using VR5). These correspond to reception frequencies of 137.5MHz for NOAAs 12 & 15 and 137.62MHz for NOAA 17. If you want to try for other satellites, you'll need to find out their APT frequency and set the oscillator frequency to 5.5MHz below that figure instead.

Peaking the RF stage

Once the oscillator frequencies have been set, the next step is to peak up the RF stage tuned circuits. This is done by setting your RF signal generator to produce an unmodulated (CW) signal at 137.5MHz, initially with a level of about 30mV. That done, connect the generator's output to the antenna input of the receiver, **using a series DC blocking capacitor if the generator doesn't have one (so that the generator doesn't short out the +12V phantom power for the masthead amplifier).**

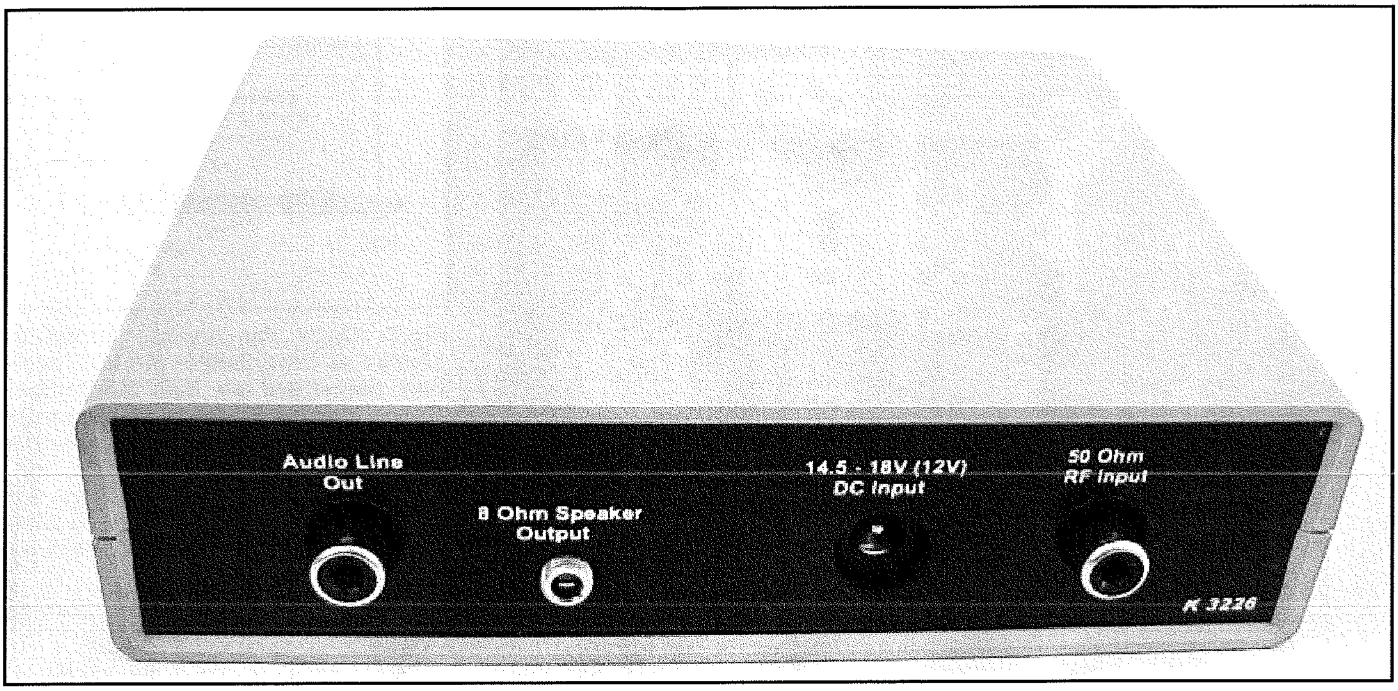
Next, connect your DMM (set to the 5V DC range) across the 390kΩ resistor just behind Q2 and make sure switch S1 is set to the channel A position. Now turn up RF gain control VR1 to about midway and use an alignment tool or a very small jeweller's screwdriver to adjust trimcap VC2 until you find a peak in the voltage reading on the DMM. If you can't find a peak, you may have to pull the turns on coil L2 slightly further apart to reduce its inductance.

Once the peak is found, adjust VC2 carefully to maximise the DMM reading (the DMM is reading the RSSI voltage from IC1, so it's essentially showing the received signal strength).

When you're happy that the L2/VC2 circuit is tuned to 137.5MHz, check the actual voltage reading of the DMM. If it's more than 2.5V, reduce the output level from the RF generator until the DMM reading drops to about 2.0V.

You're now ready to peak the receiver's input tuned circuit – ie, L1 and VC1. This is done in exactly the same way as for L2 & VC2. Just adjust VC1 slowly until the DMM indicates a peak and then carefully set VC1 for the maximum peak reading. If you can't find another peak, you may need to pull the turns of L1 slightly further apart as before.

Peaking the quadrature coil



This view shows the rear panel layout. There are two RCA sockets (one at each end) for the antenna and audio output signals, a 2.5mm DC power socket and a 3.5mm stereo jack socket for the loudspeaker.

The final alignment step is to set the slug in quadrature detector coil L4 to the correct position for optimum FM demodulation of the 5.5MHz IF signals. This is done by first switching the signal generator so that it's still producing a 137.5MHz signal but this should now be frequency modulated – preferably with a 2.4kHz tone and a deviation of about ±25kHz.

That done, connect an 8Ω speaker to the receiver's speaker socket (CON3) and turn up the audio gain control (VR3) to about the 10-o'clock position. You may not be able to hear the 2.4kHz modulating signal at this stage but in any case, slowly and carefully adjust the slug in L4 using a non-magnetic alignment tool. Sooner or later you'll start to hear the 2.4kHz tone and you should also be able to tune the coil for maximum audio level and minimum distortion and noise.

Once this has been done, the basic alignment of your weather satellite receiver is finished and it's ready for final alignment using the signals from a weather satellite. But before you'll be able to do this, you'll need to build a suitable antenna and masthead preamp, as described in the next part of the article.

Antenna & RF preamp

As MENTIONED earlier, you don't need a high-gain tracking antenna to receive the 137.5MHz or 137.62MHz APT (automatic picture transmission) signals from the polar orbiting weather satellites. A fixed antenna will do the job but you do need one with an approximately hemispherical reception pattern. It also needs to be capable of receiving circularly-polarised signals, because the signals from the weather satellites use this format.

There are three main antenna types that meet these requirements but two of them – the quadrifilar helical (QFH) antenna and the Lindenblad – are not at all easy to build. The antenna we're describing here is the third type which is usually described as a "turnstile/reflector" (T/R) or "crossed dipoles with reflector" antenna. In fact, we decided to go with this type after building a Lindenblad and getting quite disappointing results.

As a bonus, the T/R antenna is much easier to build than the other two types and is also less critical about the type of roof it's mounted above - although it should still be mounted as high as possible, so that it has the largest possible unobstructed view of the sky in your location.

As you can see from the photo, the antenna is fairly simple. The "active" elements consist of two horizontal half-wave dipoles which are crossed (ie, at right angles to each other), with their feed points connected together via an electrical quarter-wave length of 75Ω coaxial cable. This introduces a 90° phase shift at the reception frequency and it's this phase shift that allows the antenna to receive circularly-polarised signals.

The active elements are mounted roughly 0.3 of a wavelength (0.3λ) above a pair of matching crossed reflectors in a square frame. These reflectors give the antenna a roughly hemispherical reception pattern, which can be modified to some extent by varying the spacing between the reflectors and the active elements. Reducing the spacing gives more gain directly upwards and poorer coverage at lower angles. Conversely, increasing the spacing reduces the vertical gain – eventually to a null – and also gives other lobes and nulls.

We used 10 x 3mm aluminium strip to make the active elements and also to make the frame that's used to secure the reflectors. The reflectors themselves were made from slightly stronger 16 x 3mm aluminium strip. The construction details should be fairly clear from the diagrams – see Figs.10 & 11.

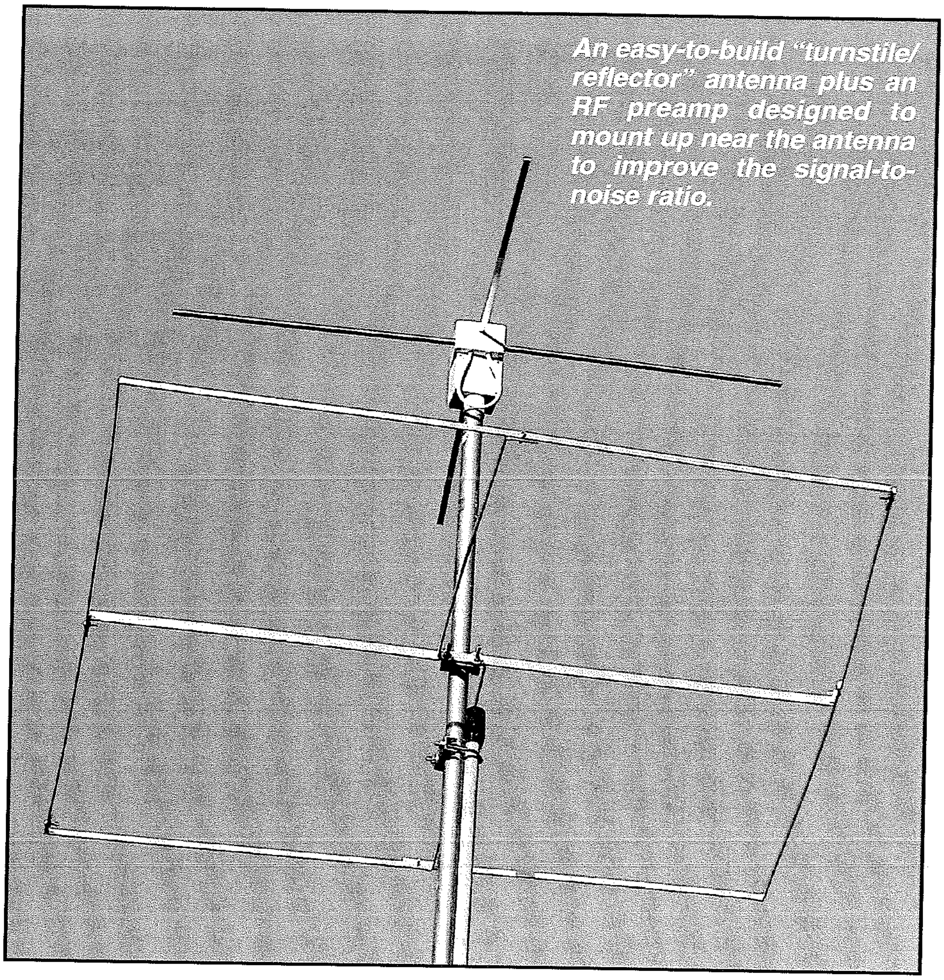
As shown on Fig.10, the active elements are all 500mm long. This gives dipoles a whisker (1.5%) shorter than they should theoretically be for an end-corrected half-wavelength at 137.5MHz. However, it also means that all four elements can be cut from a standard 2m length of the aluminium strip. The difference is not significant in practice.

The inner ends of each dipole element are mounted on a 73 x 75mm rectangular plate of 3mm perspex sheet, which is cut into a "fat" cross shape and drilled as shown. The 3.5mm holes are used for mounting the dipoles on the perspex plate (using 12mm x M3 screws and nuts) and also for mounting the complete assembly inside an 82 x 80 x 55mm polycarbonate box. The box specified

Antenna Parts List

The hardware bits as listed in the "Antenna Parts list" (below) to construct the antenna system are not supplied in the kit. These optional parts can be purchased from your local hardware store.

- 4 500mm lengths of 10 x 3mm aluminium strip
- 1 82 x 80 x 55mm polycarbonate sealed box
- 1 75 x 76 x 52mm PVC junction box with one inlet
- 1 PVC conduit thread adaptor
- 1 73 x 75mm rectangle of 3mm perspex sheet
- 4 25mm long untapped spacers
- 4 32mm long M3 machine screws
- 8 M3 x 10mm machine screws with nuts & lockwashers
- 4 M3 solder lugs
- 2 2470mm lengths of 10 x 3mm aluminium strip
- 2 1300mm lengths of 16 x 3mm aluminium strip
- 1 U-clamp and V-block assembly
- 1 2.4mm length of 32mm OD gal mast pipe (optional)
- 6 M4 x 12mm machine screws with nuts & lockwashers
- 1 360mm length of 75Ω coaxial cable (phasing loop)
- 1 360mm length of 50Ω coaxial cable (matching section)
- 1 75Ω coaxial 'TV' plug, line type (Belling-Lee)
- 1 75Ω coaxial 'TV' socket, line type (Belling-Lee)
- 1 length of 75Ω coaxial cable (to suit)



An easy-to-build "turnstile/reflector" antenna plus an RF preamp designed to mount up near the antenna to improve the signal-to-noise ratio.

has a sealing groove and strip around the lid for weatherproofing.

The complete assembly is held inside the box using four M3 x 32mm machine screws, which mate with the threaded inserts moulded in the bottom of the box. Untapped spacers 25mm long ensure that the assembly sits so that the active elements leave the box (via small slots cut in the centre of each side) with their top surfaces very close to the top edge of the box sides. Then just before the box lid is fitted, small strips of neoprene or rubber are placed on the top of each element, so the box sealing is preserved.

The larger 6.5mm holes in the perspex plate are to accept the two ends of the cable phasing loop, along with the end of the 50Ω matching cable section. Because the phasing loop is a little too long to be coiled up inside the box, it loops out and back in again through a pair of holes drilled in the bottom of the box (about 40mm apart). The holes should be made only just large enough to accept the 75Ω phasing cable, so it won't be easy for moisture to find its way in. You might also like to seal around the cables with neutral-cure silicone sealant when the

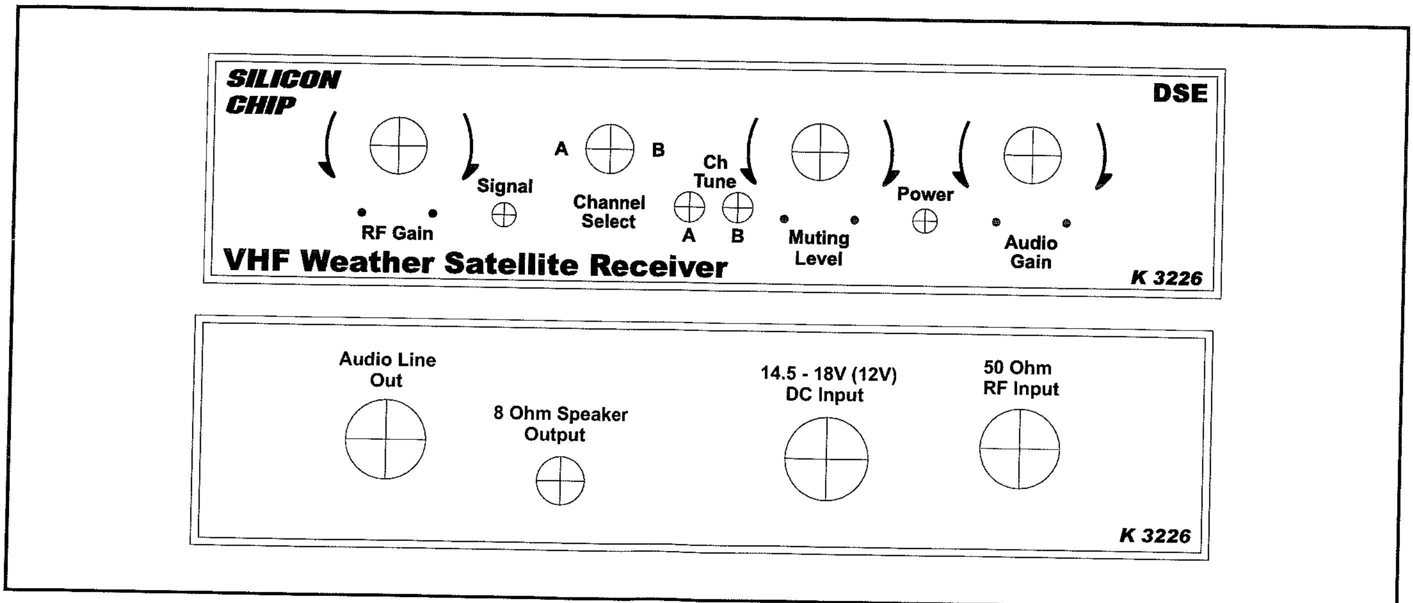


Fig.6: these are the two full-size artworks for the front and rear panels.

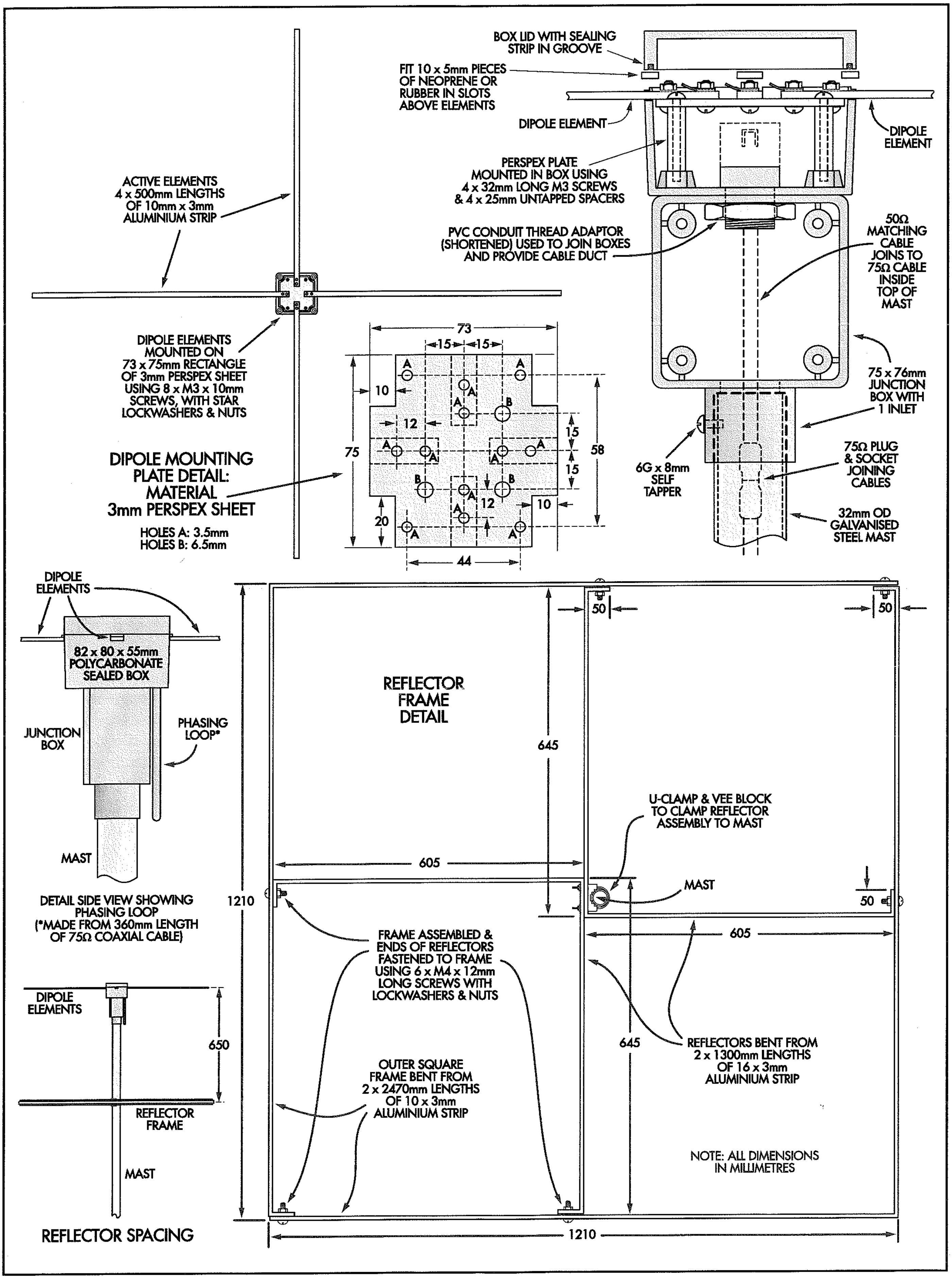


Fig.10: follow this diagram to manufacture the parts and assemble the turnstile/reflector antenna.

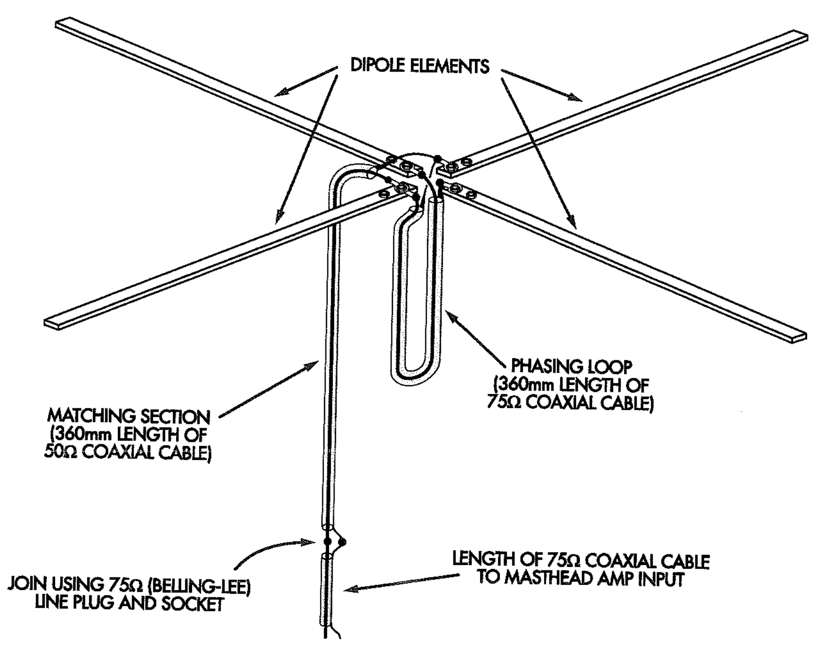
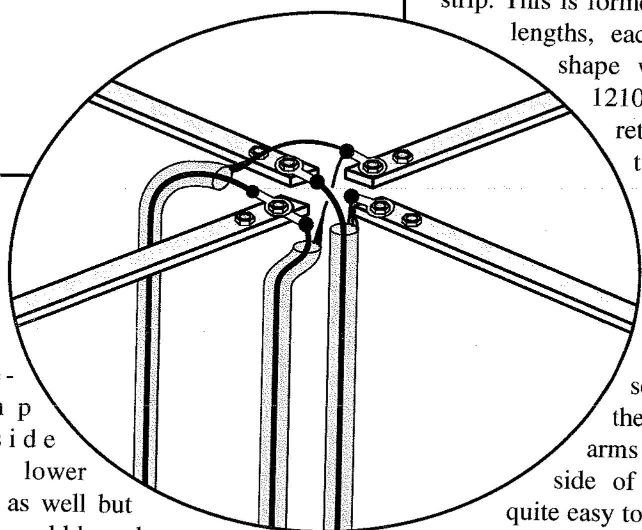


Fig.11: this diagram and the insert at right show how the matching section and the phasing loop are connected to the dipole elements.



antenna is complete.

Like the phasing loop, the matching cable section is 360mm long. This represents a quarter wave at 137.5MHz, corrected for the cable's velocity factor (0.66). However, the matching section is cut from 50Ω cable, which makes it act as an impedance transformer. The 37.5Ω impedance of the two dipoles in parallel is thus transformed into an effective 75W impedance, so that the signal can be fed down to the preamp or receiver via standard 75Ω cable.

The 50Ω matching cable doesn't exit from the box through another external hole but instead passes down through a shortened PVC cable thread adaptor. This adaptor is also used to couple the top box to a 75 x 76 x 52mm single inlet plastic junction box, used in turn to mount the combination on the top of the 32mm mast. It also provides an "access hatch" to the 75Ω connectors which couple the 50Ω matching cable to the main 75Ω downlead, just down inside the mast.

Initially, we were going to mount the pre-amp inside this lower box as well but this would have been a very tight squeeze. It would also have meant trying to coil up the 50Ω matching cable inside one or other of the two boxes, which would be tricky as well.

Note that the PVC cable thread adaptor which is used to couple the two boxes together is shortened by cutting off most of the sleeve section which is normally cemented over the end of a conduit. By cutting this section off, you're left with a large-diameter hollow PVC "bolt", with a mating PVC nut.

As shown in Fig.10, the reflector elements are bent up from two 1300mm lengths of the 16 x 3mm aluminium strip. Each piece is bent into an "L" shape, with main arms 605mm and 645mm long and 50mm return arms at each outer end. The two longer arms are then overlapped in the centre and both drilled with a pair of 6.5mm holes, to take the threaded ends of a standard U-clamp bolt.

This bolt and its matching V-block are then used not only to hold both reflector sections together but also to clamp the complete reflector assembly to the 32mm mast at the desired spacing below the active elements.

To strengthen the reflector assembly and also to partially enhance the reflectors for lower reception angles, the reflectors are enclosed in a 1210 x 1210mm square of 10 x 3mm aluminium strip. This is formed from two 2470mm lengths, each bent into an "L" shape with the main arms 1210mm long and a 50mm return at one end. The two halves are then assembled into a square using two 12mm x M4 screws plus nuts and lockwashers, while four more 12mm x M4 screws are used to bolt the ends of the reflector arms to the centre of each side of the square. It's all quite easy to build and assemble.

Mounting the antenna

As mentioned before, the completed antenna should be mounted as high up off the ground as you can manage, so that it gets the largest unobstructed view of the sky. The 137.5MHz weather satellite signals are not particularly strong and are attenuated even more if they have to pass through heavy cloud, tree canopies, etc.

In some cases, you might be able to attach the mast of the weather satellite antenna to the upper part of your TV antenna's mast, to get extra height. This can be done using another pair of U-clamp/V-block assemblies.

If your receiver isn't going to be too far away from the antenna, you could now try running the main 75Ω antenna downlead directly to the receiver's input. Provided the cable losses aren't too high, you just might get quite acceptable results from this direct connection.

On the other hand, the results might be disappointing, in which case you'll want to build up the RF preamp and fit it into another weatherproof box at the base of

Table 3: Resistor Colour Codes

Value	4-Band Code (1%)	5-Band Code (1%)
150kΩ	brown green yellow brown	brown green black orange brown
110kΩ	brown brown yellow brown	brown brown black orange brown
100kΩ	brown black yellow brown	brown black black orange brown
47kΩ	yellow violet orange brown	yellow violet black red brown
33kΩ	orange orange orange brown	orange orange black red brown
1.8kΩ	brown grey red brown	brown grey black brown brown
360Ω	orange blue brown brown	orange blue black black brown
47Ω	yellow violet black brown	yellow violet black gold brown

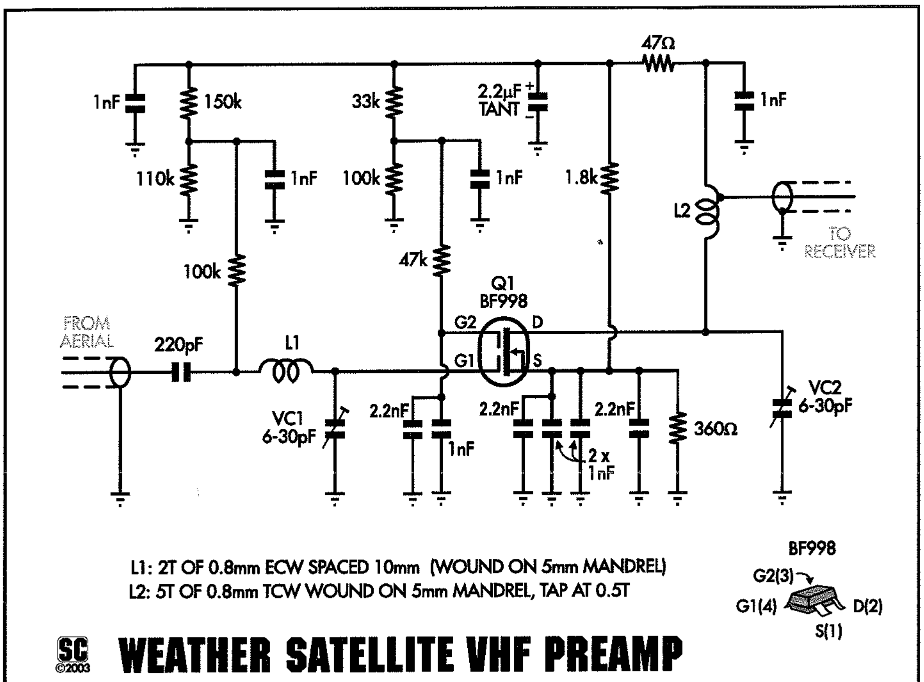


Fig.12: the VHF preamplifier circuit is based on a BF998 dual-gate MOSFET and is powered from a 12V DC supply which is fed up via the down-lead.

the mast. That way, it can boost the strength of the signals before they go down the main downlead to the receiver, thus improving the signal-to-noise ratio quite significantly.

OK, let's now move on to describe the RF preamp.

The RF preamp

The main requirements for this type of preamp are that it should provide around 15-20dB of stable amplification at 137.5/137.62MHz, with a low noise figure. It should also be capable of operating from a 12V DC supply which is fed up the downlead cable from the receiver.

This may all sound easy enough but it's trickier than you might think. In fact, we tried out a number of different configurations in developing this project but in most cases they gave unsatisfactory results. Basically, they either didn't provide enough gain and/or were too noisy, or they were too hard to keep stable.

One simple design we tested used a Mini Circuits MAR-6 microwave amplifier IC, as used in many masthead amplifiers for TV. This was stable enough but it didn't provide enough gain and for this type of application it was relatively noisy as well.

We also tried a design based on a BF998 dual-gate MOSFET that was very similar to the RF stage in the Weather Satellite Receiver described last month. This gave enough gain and was much quieter as well but it was very difficult to "tame" – it would oscillate at the drop of a hat, despite all kinds of shielding and extra bypassing.

Eventually, after much web research, experimenting, frustration and tearing of hair (what little hair the author has left!), we finally arrived at the configuration shown here. It still uses a BF998 MOSFET but has a somewhat different input coupling circuit which allows the preamp to be peaked up for quite acceptable gain and a low noise figure (below 1dB), while at the same time being much more stable.

As shown in Fig.12, the BF998 is used as a cascode RF amplifier. The incoming RF signal (from the antenna) is fed to gate 1 via a 220pF input coupling capacitor and then via L1 and VC1, which form an input tuning/matching network. Gate 1 is also fed the correct DC bias voltage via the 100k resistor and a voltage divider consisting of 150kΩ and 110kΩ resistors.

Gate 2 of Q1 is biased to achieve maximum gain. Its bias voltage is derived from a 33kΩ/100kΩ voltage divider and this is fed to gate 2 via a 47kΩ decoupling resistor. Q1's source is also provided with the correct bias voltage via a 360Ω self-bias resistor and this is fed with some additional current via a 1.8kΩ resistor.

Q1's output is tuned by L2 and VC2 in the drain circuit. The RF output from the preamp is then derived from a tap near the "cold" (to RF) end of L2, to provide an approximate match for the 75Ω output cable to the receiver. At the same time, the tap delivers the +12V DC supply to run the preamp, which is fed from the receiver via the down-lead.

Note that there are quite a few 1nF and 2.2nF bypass capacitors throughout the circuit. These ensure that points like the "G2" and "S" leads of Q1 and the "cold" end of L2 are held firmly at ground potential for RF, which is necessary for

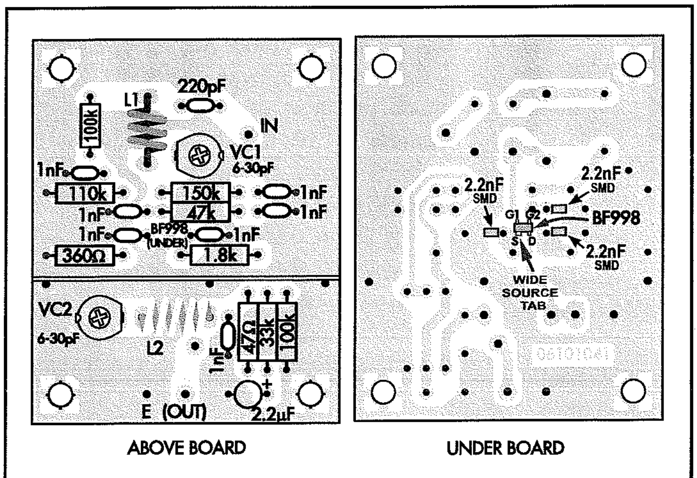


Fig.13: the PC board assembly has the board supplied with plated through holes, therefore component leads need only be soldered from the bottom side.

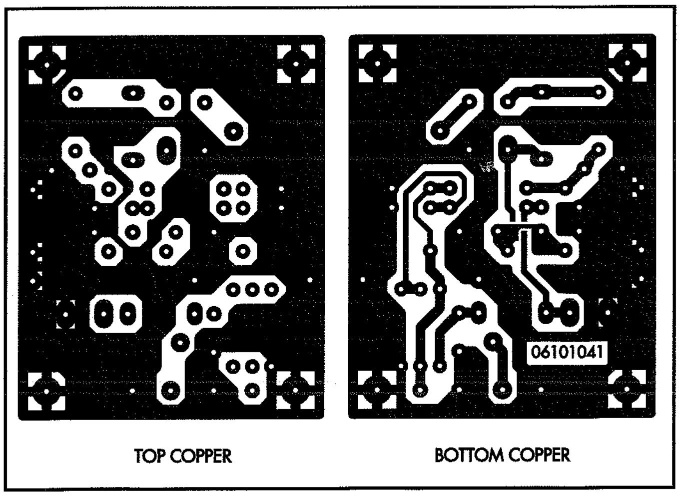


Fig.14: check your PC board against these full-size etching patterns before installing any of the parts.

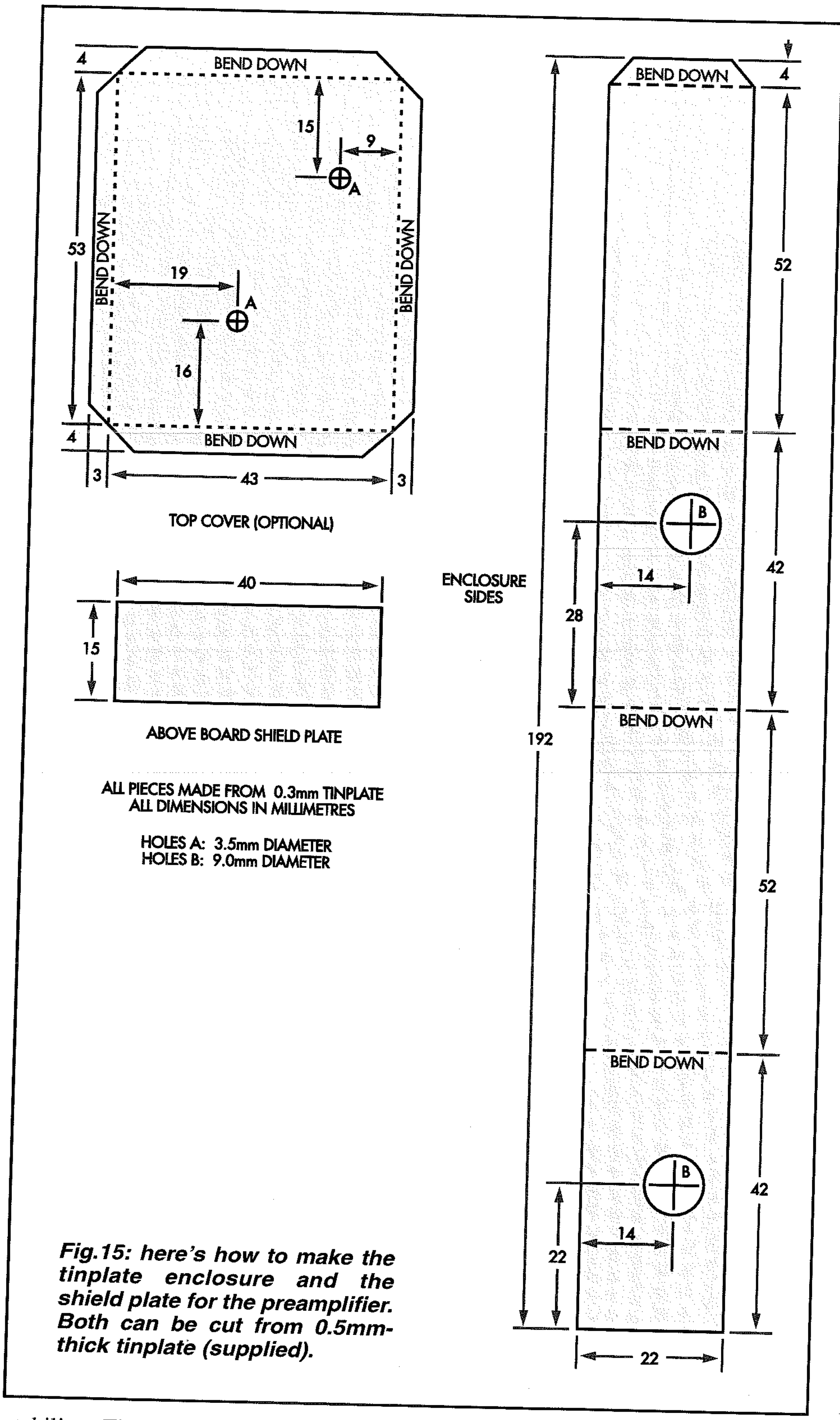


Fig.15: here's how to make the tinplate enclosure and the shield plate for the preamplifier. Both can be cut from 0.5mm-thick tinplate (supplied).

stability. These capacitors should be either disc ceramic or multilayer monolithic ceramic types and their leads should be kept as short as possible.

Building the preamp

The preamp is built on a very small double-sided PC board coded 06101041 (ZA1048B) and measuring 41 x 51mm. All parts except the BF998 MOSFET are mounted on the top of the board, while the MOSFET mounts underneath because it's a surface-mount device. The location and orientation of all parts is shown in Fig.13.

Both L1 and L2 are air cored but are wound on a 5mm drill shank or similar 5mm OD mandrel. L1 is wound using 0.8mm enamelled copper wire (ECW) and has only two well spaced turns, while L2 is wound using 0.8mm tinned copper wire (TCW) and has five spaced turns. The tap on L2 is spaced half a turn from the end that is "cold" for RF – ie, the end furthest from VC2.

The only other coil in the circuit is RFC1 and this is wound on an F29 ferrite bead, using only a single full turn of 0.25mm ECW.

To ensure stability, a shield plate should be fitted across the top of the board in the position shown. This plate is cut from 0.5mm tinplate and measures 40 x 15mm. You'll find that the PC board has three 1mm diameter holes in this location, to take 1mm PC board terminal pins. Fit these first, then use the pins as "posts" to support the shield plate when it's soldered to them.

The board also has holes for: (1) a terminal pin at the preamp's input, (2) a pin for the tap wire for L2 and (3) a pin for the preamp's output. You can use these pins for connecting coaxial cables directly to the board, if you wish.

However, as you can see from the photos, it's also possible to enclose the four sides of the preamp with a simple box made of tinplate, which provides some shielding and also supports a pair of panel-mounting 75Ω "TV" sockets (ie, the type formerly known as "Belling-Lee" sockets). These make the input and output connections a little more convenient.

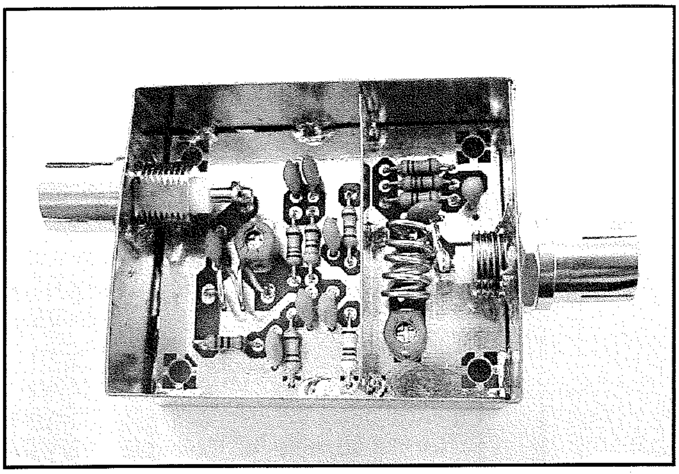
Tinplate enclosure

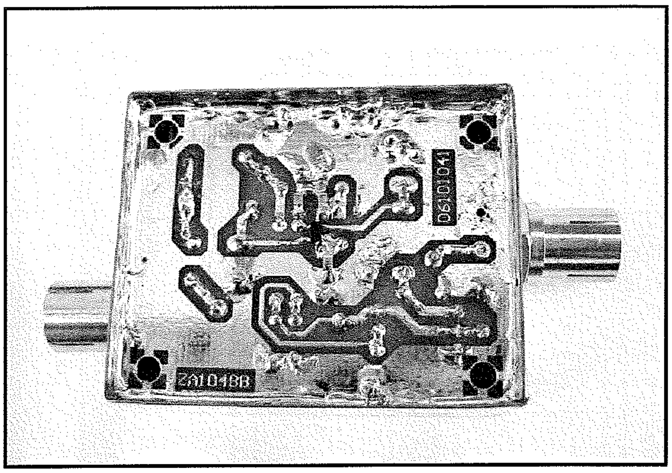
The dimensions of the tinplate enclosure are shown in Fig.15, along with the hole locations and sizes for the two sockets. Notice that both sockets are mounted in the ends of the enclosure by soldering their outer threaded sections directly to the box ends, on the inside of the tinplate. This is done for two reasons: (1) it gives a more reliable earth connection; and (2) there isn't room to fit the nuts inside the enclosure anyway.

Note also that the nut for the output socket is actually fitted to the socket and tightened firmly before the socket is soldered into the enclosure, to act as a spacer. This ensures that this socket doesn't protrude inside the case by its full threaded length.

The centre pin of both sockets is cut short, to make sure they clear other components. The input socket's centre pin is then soldered directly to the PC board terminal pin marked "IN", while the output socket's pin can be connected directly to coil L2 via a very short length of tinned copper wire, to make the tap connection (in this case, the "OUT" pin is not fitted to the board at all).

If you elect to provide the preamp with this simple tinplate enclosure/socket support, fit the board into the enclosure so that the top of the shield plate is level with the top of the enclosure sides. That done, run a fillet of solder along the edges of the board on both the top and





These two views show the completed VHF preamplifier housed inside its tinplate enclosure and fitted with 75Ω TV sockets for the input and output connections. Note the short wire link connecting directly from the centre pin of the rightband (output) socket to the tap on coil L.2 (ie, the tap is not taken to a terminal pin if the socket is fitted).

bottom, to bond the tinplate to both of the board's earthy copper layers. This not only holds it all together but also helps ensure stable operation.

Checkup & tuning

When your preamp is complete, connect its output to the input of the receiver with a length of 75Ω coaxial cable. That done, turn on the receiver and quickly check a few voltages in the preamp with your DMM, to make sure it's working correctly. You should be able to measure about +11.8V at the cold end of L2 and also at that end of the 22Ω decoupling resistor.

You should also be able to measure about +4.7V at the junction of the 150kΩ and 110kΩ bias resistors for G1, and +4.9V or thereabouts at the top of the 360Ω source resistor. Finally, you should get about +8.8V at the junction of the 100kΩ, 33kΩ and 47kΩ resistors (ie, feeding G2 of Q1).

If all of these voltages are close to the values given, your preamp should be working correctly. Assuming that's the

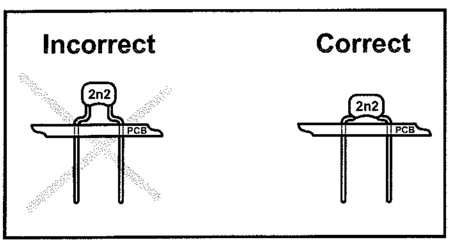


Fig.17: the monolithic capacitors supplied for the kit have pre-formed leads. In this circuit it is important that all components (unless specified) are mounted as close as possible to the board. Therefore, in some cases it is necessary to re-shape the leads to allow the component body to sit close to the board as shown above.

case, switch the receiver to one of the two satellite reception channels (ie, 137.5MHz or 137.62MHz), then connect the preamp's input to your signal generator via a suitable cable and set the generator to the same frequency.

Now connect your DMM (set to the 5V DC range) across the 390kΩ RSSI load resistor in the receiver, so you can use it as a signal strength meter. The signal generator can then be set for about 2-3μV of output.

Next, turn up the receiver's RF gain control to about halfway. You may not be aware of any signal at this stage but try adjusting trimmer VC2 in the preamp slowly using an insulated alignment tool. Listen carefully for a signal and also watch the DMM carefully to monitor the signal level.

Somewhere near midway in the trimmer's adjustment range, you should find the signal and be able to set VC2 for a peak in both the received tone and the DMM reading. If the DMM reading rises much above 2.5V, you may need to reduce the signal generator's output to bring it down below this level again.

When the correct setting has been found for VC2, leave it alone and turn your attention to VC1. By adjusting this carefully (again using an insulated alignment tool), you should be able to find another signal peak and a minimum for the accompanying noise.

Once you have set VC1 carefully for this second peak, your preamp is tuned up and ready to be connected into the antenna downlead at the base of the mast. We suggest that you fit the preamp into another small polycarbonate box – ie, the same type as used for the antenna's active elements, so it can be sealed to keep moisture out.

Preamp Parts List

1 PC board, code 06101041 (ZA1048B), 41 x 51mm (double sided, plated through)
1 short length 0.8mm enamelled copper wire for L1
1 short length 0.8mm tinned copper wire for L2
5 PC board terminal pins, 1mm diameter
2 75Ω coaxial "TV" sockets (Belling-Lee), panel mount
1 80 x 50mm piece of 0.5mm tinplate for top shields (trim to size)
1 192 x 22mm piece of 0.5mm tinplate for enclosure

Note, trim shield plates to the sizes required. Also refer to individual demensions as shown on page 15 (Fig. 15).

Semiconductors
1 BF998 dual-gate MOSFET (Q1)

Capacitors
1 2.2μF 35V TAG tantalum
7 1nF disc ceramic
1 220pF disc ceramic
2 6-30pF trimcaps green (VC1, VC2)
3 2.2nF SMD ceramic capacitor

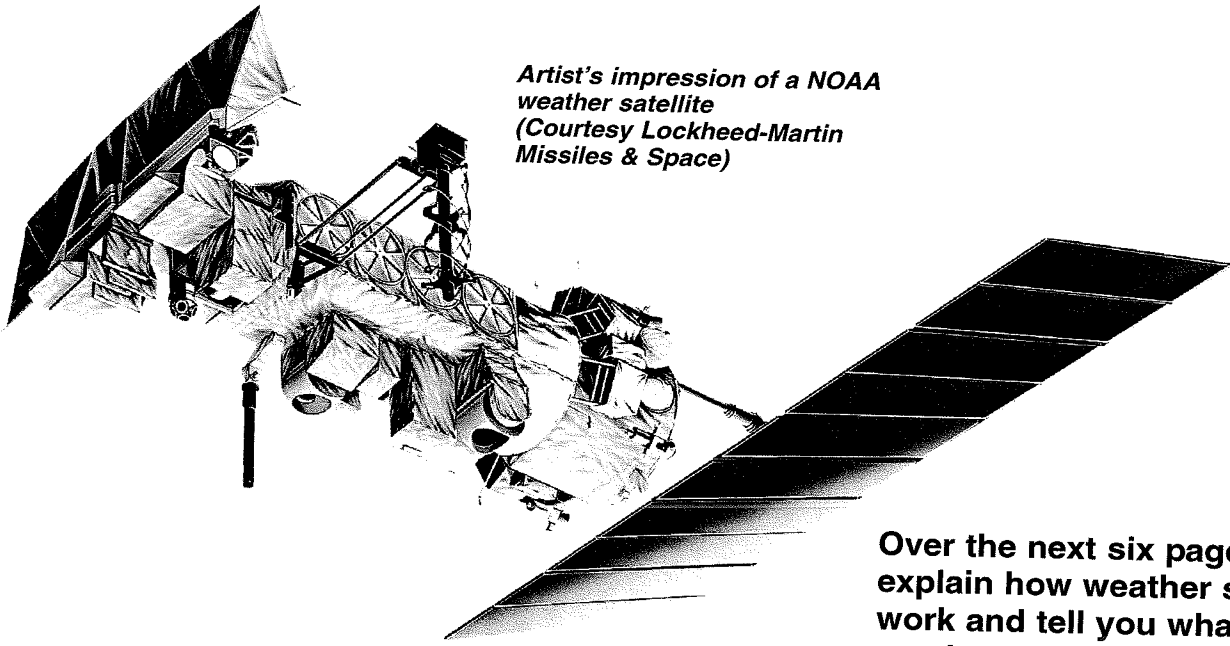
Resistors (0.25W 1%)

1 150kΩ	1 33kΩ
1 110kΩ	1 1.8kΩ
2 100kΩ	1 360Ω
1 47kΩ	1 47Ω

Both the input and output cables should pass through close-fitting holes drilled in the bottom of the box, to reduce the likelihood of moisture finding its way inside. As before, it's a good idea to run some neutral-cure silicone sealant around both cable exits, to ensure that the moisture is really kept out.

Happy weather satellite signal reception!

YES, IT'S TRUE that you can see weather satellite images (or computer enhanced graphics derived from them) on the TV evening news and you can also download images of "special weather events" like cyclones from sites on the Internet. But there's nothing quite like



Artist's impression of a NOAA weather satellite (Courtesy Lockheed-Martin Missiles & Space)

Over the next six pages , we explain how weather satellites work and tell you what you'll need to receive their images.

the satisfaction of receiving them yourself directly from the satellites, as many radio amateurs and other enthusiasts have been doing for decades. And as it happens, this is now a lot easier to do than it has ever been before.

Only a few years ago, you not only needed a suitable receiver and antenna to receive the weather satellite signals but a special decoder box as well, before the signals could be displayed on a PC (using a specially written program). But now, providing your PC is reasonably up to date and has a decent sound card, the decoder box is no longer needed. Instead, you simply feed the audio signals from the receiver into your sound card and record them on your hard disc.

That done, they can be decoded and displayed in one operation, using software that's freely available on the Internet.

So if you'd like to try your hand at receiving weather satellite signals, it's now all fairly straightforward and can be done at low cost (provided you already have a PC).

In this article, we'll give you a quick introduction to weather satellites, describe how they work and describe the kind of receiver, antenna and masthead amplifier you'll need to receive their signals. We'll also discuss the kind of PC you'll need and tell you about some of the software that's available to both track the weather satellites (so that you can be prepared when one comes within range) and then decode their signals after you've received them.

About weather satellites

Weather satellites have been orbiting the Earth for over 43 years now, providing valuable information on the world's weather and other environmental events on a 24-hour basis. The first of these satellites was Tiros 1, launched by NASA for the US National Oceanic and Atmospheric Administration (NOAA) in April 1960. Since then, there has been not only a continuous series of NOAA satellites but also many broadly similar satellites launched by the former USSR, Japan, India and the People's Republic of China.

So you mightn't have been aware of them but at any time in the last few decades there have been quite a number of weather satellites orbiting above us and sending down a constant stream of images and other meteorological data.

There are still quite a few satellites in orbit, although some of them (like the Russian Meteors) seem to have reached the end of their operating life and are no longer sending down any pictures. But there are still at least two fully operating NOAA satellites, for example, providing weather images at least twice and sometimes three or four times a day virtually anywhere in the world.

By the way, there are two rather different types of weather satellite. One type are in equatorial orbits (ie, around the Equator) at an altitude of about 35,800km, so they rotate in synchronism with the Earth itself and are therefore described as "geostationary". Each of these satellites constantly views a fixed "disc" of the Earth, with its centre point on the equator directly below it.

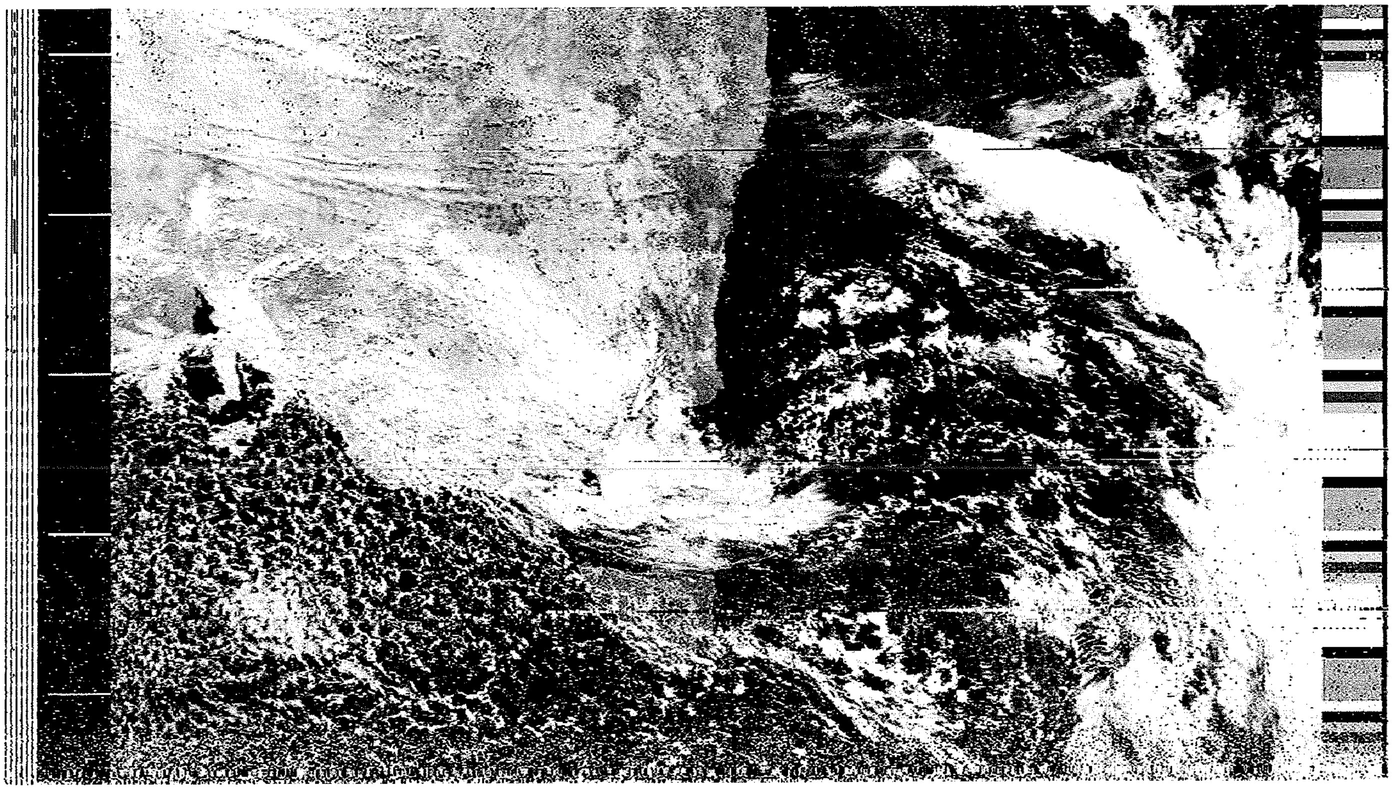
Signals from a geostationary satellite can be received continuously from anywhere inside its field of view. However, receiving their signals isn't easy because they only transmit in the UHF S-band (typically at 1.691GHz) and the signals are quite weak because they're coming from so far away. You need a fairly large dish antenna with a low noise down-converter (LNC) just for a start.

The other kind of weather satellites are in close to polar orbits (ie, passing over the poles) and orbit at a much lower altitude – ie, around 850km. In other words, they're "Low-Earth Orbiting" or "LEO" satellites and each circles the Earth many times a day and passes over (or at least near) any particular point a couple of times a day.

The NOAA satellites are of this type and typically orbit the Earth about 14.1 times a day, or about once every 102 minutes. For example, the NOAA17 satellite currently passes over New Zealand and Australia a number of times during each morning, while the NOAA12 satellite passes over a number of times in the late afternoon or early evening.

Since these satellites "precess", or slowly move around the Earth as they orbit, their "passes" don't follow the same path every time. However, there is usually at least one pass (and sometimes two or three passes) by each satellite that can be received each day, to provide interesting weather pictures.

Another big bonus with the LEO satellites is that they not only transmit weather images in the UHF band (usually on 1.698GHz or 1.707GHz) but also in the VHF band on frequencies such as 137.50MHz and 137.62MHz. And although you need a steerable dish and LNC to track the satellites and receive



This false picture from NOAA17 shows extensive cloud over the southeastern corner of Australia. The vertical band at farleft shows the sync pulses, while the adjacent vertical black band carries the minute markers (this picture was received over a period of about five minutes). The vertical band at far right represents undecoded telemetry data, which conveys the status of various systems on-board the satellite.

their UHF signals, the VHF signals are much easier to receive. For VHF, all you need is a fixed antenna with a roughly hemispherical reception characteristic, plus a masthead amplifier and a suitable VHF receiver.

So the polar orbiting LEO weather satellites are of much greater interest to amateur weather satellite enthusiasts, because their VHF signals are a lot easier to receive. And NOAA's satellites 12, 15 and 17 are of particular interest at present, because they're the ones that are currently in operation.

The NOAA satellites

The latest generation of NOAA satellites are fairly large "birds", powered from a large solar cell array which is attached to one end (see artist's drawing). They are equipped with quite a range of scanning and sensing subsystems, including microwave and IR sounders, an alpha particle sensor and the main source of meteorological images: the Advanced Very High Res-olution Radiometer/3, or "AVHRR/3" for short.

The data from these sensors is transmitted back to Earth (along with housekeeping telemetry data) via a number of communications links. In fact, each NOAA satellite has no less than 14 antennas, nine transmitters and various receivers (for receiving command data).

The AVHRR/3 is mounted at the opposite end of the satellite from the solar array. It is a continuous imager, which uses a rotating mirror scanning system to scan the path beneath the orbiting satellite in "lines" which are perpendicular to the path and stretching from the horizon on one side to the other.

The scanning mirror rotates at 120RPM, giving 120 lines per minute – chosen because as the satellite moves in its orbit, this provides the vertical deflection, so each scanning line butts against the last for contiguous scanning. The radiometer's sensors have quite a small field of view (1.3 x 1.3 milliradians, or about .075° x .075°) and the sensor outputs are sampled on the spacecraft at a rate of 39.936kHz, so there are essentially 2048 samples per sensor per scanned line.

There are a total of six sensors in the AVHRR/3 radiometer, three scanning at visible wavelengths near the infrared and three at thermal IR wavelengths. The outputs from any five of these sensors can be transmitted back to Earth at any time on the UHF (1.7GHz) channel.

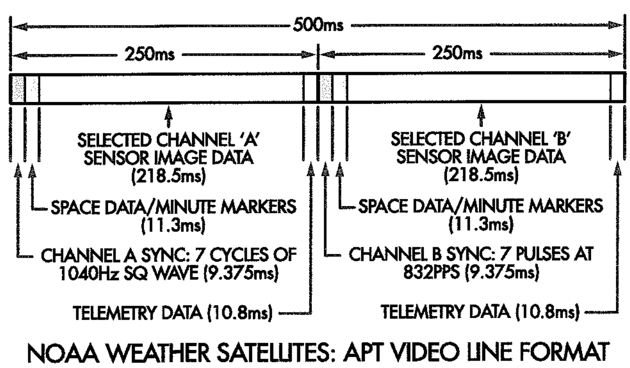
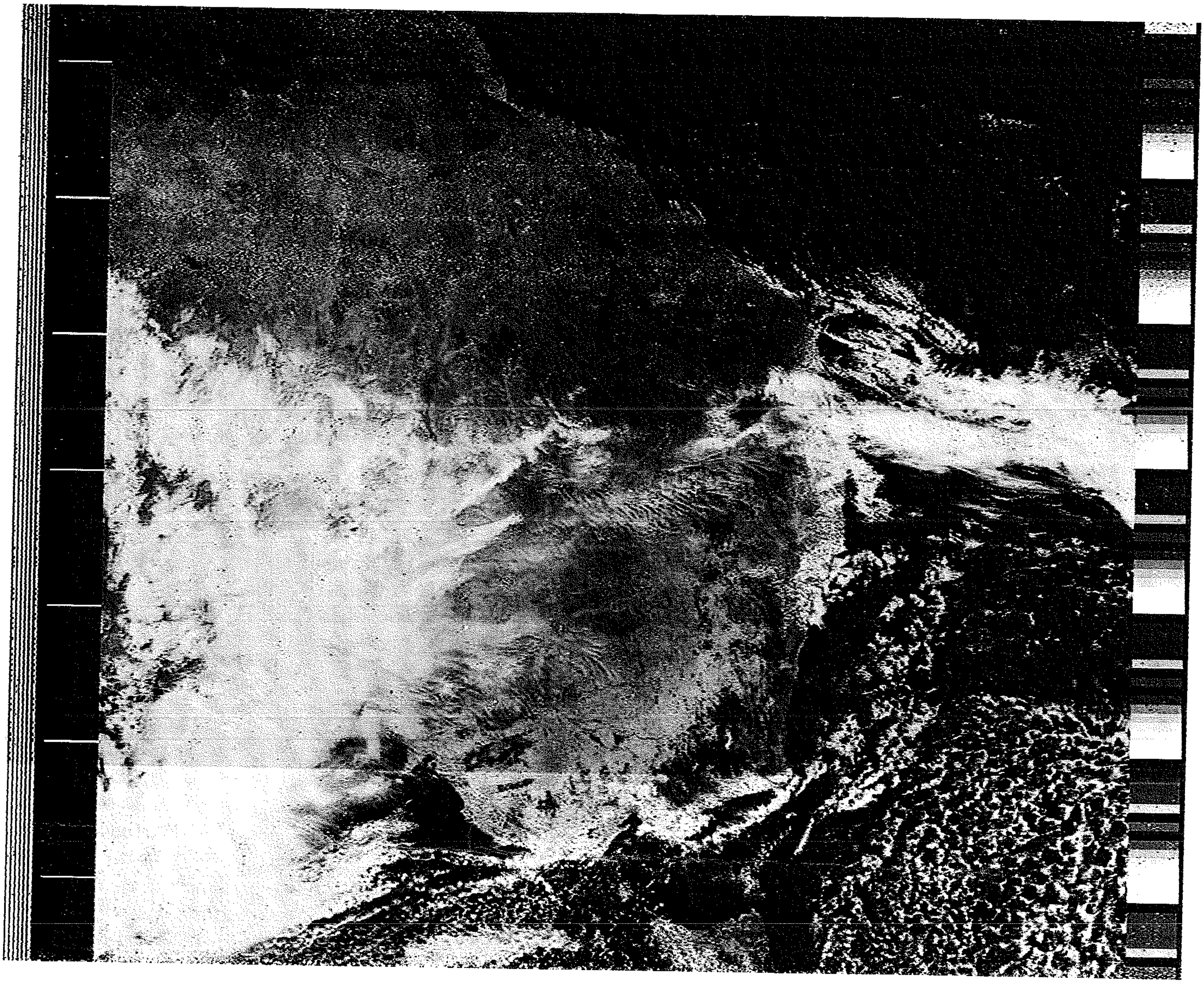


Fig.16: an APT transmission line starts with a sync pulse burst. This is followed by an 11.3ms section allocated to "space data" and minute markers, then a 218.5ms section with 909 pixels of image data from the Channel A sensor, and then 10.8ms of telemetry data. This 250ms-long data format is then repeated for the Channel B sensor.



This is another false picture from NOAA17, this time received over a period of about seven minutes and showing a large part of eastern Australia extending from the Gulf of Carpentaria down to Tasmania. The sudden change in the picture towards the bottom is result of turning up the RF gain control on the receiver at this point during signal reception.

However, the satellite's APT (automatic picture transmission) signals provided on VHF (137.5MHz or 137.62MHz consist of down-sampled versions of the signals from two of the AVHRR/3 sensors, selected by commands uplinked from NOAA's control centres.

During the part of each satellite's orbit that is in daylight, each APT line contains data from one visible light sensor and one IR sensor. By contrast, at night the visible light data is replaced by data from a second IR sensor to provide more useful information.

The down-sampled APT data derived from the two selected AVHRR/3 sensors is converted back to analog form and then used to amplitude modulate a 2400Hz audio subcarrier, together with synchronisation and timing pulses and other telemetry data. The 2400Hz subcarrier is then frequency modulated onto the VHF carrier signal, for transmission down to Earth via a 5W FM transmitter and helical antenna.

APT signal format

Fig.1 shows the basic format of the signals conveyed in one APT transmission line (lasting 500ms). The line starts with a sync pulse burst of seven cycles of a 1040Hz square wave. This is then followed by an 11.3ms section allocated to "space data" and minute markers, then a 218.5ms section with 909 pixels of image data from the channel A sensor, and finally 10.8ms of telemetry data.

The second half then starts with a second sync pulse burst of seven pulses at 832Hz, followed by a second space data and minute marker section of 11.3ms. Then comes another 218.5ms section with 909 pixels of image data from the channel B sensor and finally another 10.8ms of telemetry data.

It's this format that gives the signal a characteristic "tick-tock" sound when you listen to the received 2400Hz audio via a speaker or earphones.

Receiving antenna

The VHF APT signals from NOAA satellites are strong enough not to require a high-gain tracking antenna. Instead, a low-gain fixed antenna can be used, although it does need to have a hemispherical or "flattened hemispherical" reception characteristic so that it picks up the signals with much the same sensitivity as the satellite passes over.

Note that because the signals are transmitted from the satellite via a helical antenna, they are also righthand circularly polarised. This means that the antenna must also be able to pick up signals with this type of polarisation.

There are three main types of receiving antenna which meet these requirements: (1) the crossed-dipole or "turnstile" antenna (either alone or combined with a reflector to become a turnstile/reflector); (2) the Lindenblad antenna; and (3) the quadrifilar helix antenna or "QFHA". Of these, the QFHA probably gives the best performance but is not easy to build because it's essentially a truncated double helix.

The Lindenblad gives reasonable performance but is still fairly difficult to make because it consists of four dipoles in a square array, with each dipole tilted at 30°. It also doesn't perform well unless it's mounted very high off the ground and well away from metal roofing.

In fact, the author built and tested a Lindenblad antenna for the receiver described elsewhere in this issue but after a lot of frustration, I finally scrapped it and built a turnstile/reflector instead. This was quite easy to make and also gives surprisingly good reception at my location.

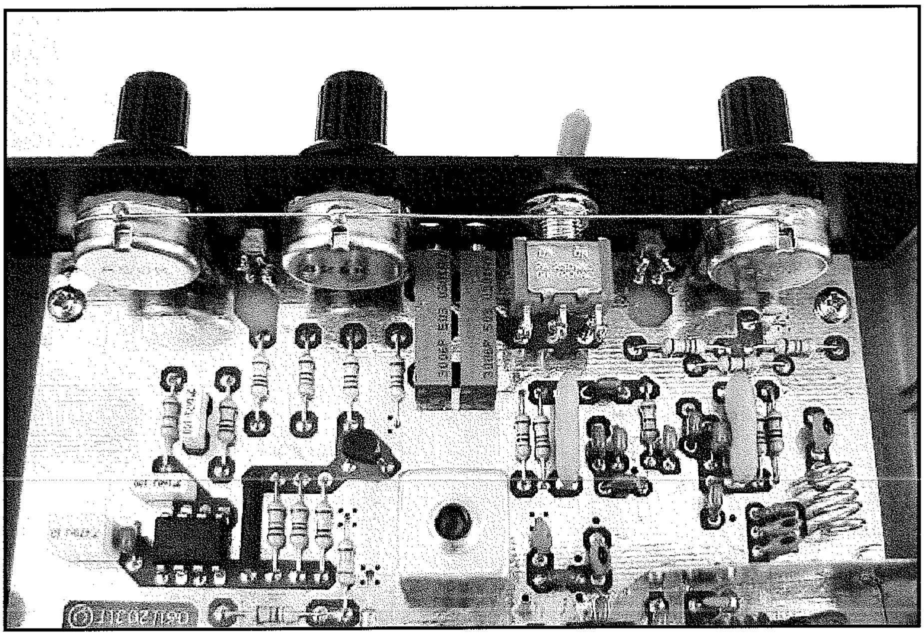
Now although the VHF NOAA signals are strong enough to be received using this type of fixed antenna, they're still pretty weak. After all they're coming from a 5W transmitter which is still more than 800km away even when the satellite is passing directly overhead. The transmitting antenna is also propagating this power in a solid angle of 63°, so by the time it does reach the ground below, the effective path loss is quite high.

From a practical point of view, this means that most VHF receivers simply aren't sensitive enough and don't have a good enough noise figure to give good reception of the weather satellite signals by themselves. In short, you also need a low-noise masthead preamp, to boost the signals as close to the antenna as possible – and certainly before they have to pass down through any significant length of coaxial cable to the receiver (which introduces losses).

So as well as describing an easy-to-build turnstile/reflector antenna in coming months, we'll also be describing a suitable masthead preamp. Stay tuned!

The receiver

Since the NOAA signals are in the 137MHz VHF band and use FM, you'd expect that almost any VHF communications receiver or scanner would be suitable for receiving them. However, while it's true that you can receive them reasonably well with some receivers, the results are often disappointing.



That's mainly because the 2400Hz satellite subcarrier signal is modulated with an FM deviation of ±17kHz, so it has a bandwidth of about ±25kHz. This bandwidth is quite a bit wider than that used for narrow-band VHF FM communications but at the same time, it's much narrower than that used by broadcast FM stations. So a VHF scanner or communications receiver can't be set to its narrow bandwidth, because this is too narrow to receive the signals without severe distortion. Instead it must be set to WFM (wideband FM), even though this gives a relatively low audio output level and often a fairly poor signal-to-noise ratio.

The ideal type of FM receiver to use for the APT signals is one with a bandwidth of about ±30kHz, or not much more. There are specially designed weather satellite receivers with this bandwidth available commercially but they're fairly expensive. Because of this, we've developed a small 2-channel VHF FM receiver which has a bandwidth of about ±35kHz and is therefore quite suitable for receiving the APT signals.

This receiver is described in this issue in a separate article, so that you can build your own at a reasonable cost.

As you've probably guessed already, it's the 2400Hz subcarrier "audio" signal from the receiver that contains the APT information as amplitude modulation. As a result, it's this signal which is fed into your PC via the sound card, to be initially stored on the hard disk and then decoded and displayed using the appropriate software.

PC requirements

You don't need a particularly hot PC to record and decode the APT signals. Almost any reasonably up-to-date machine will do, as long as it's running Windows 98SE or better, has a sound card and also has a reasonably fast and capacious hard disk so you can record mono audio signals sampled at 11.025kHz (16 bits). Most Pentium II, III and IV machines should be quite suitable, as should many of the machines using Celeron and Athlon processors.

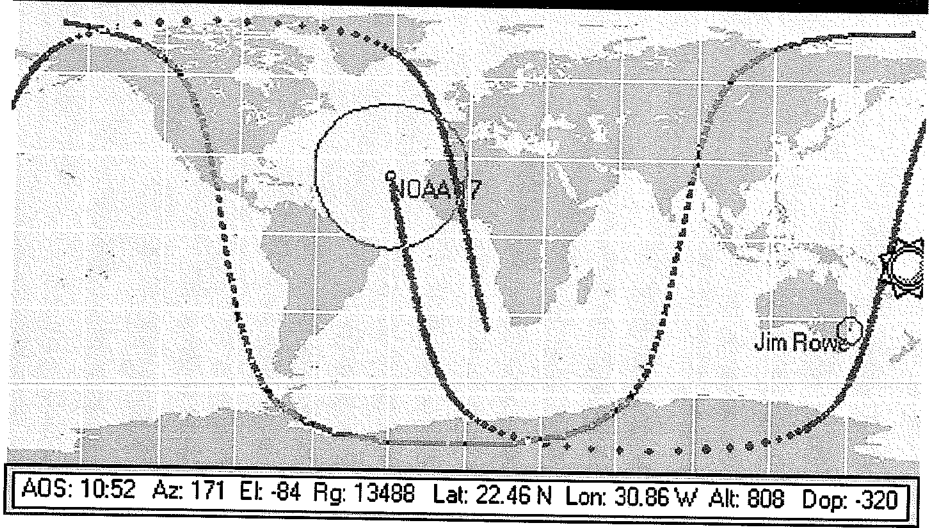
Of course, your PC also needs to have a modem and an Internet connection, so you can get on the Internet to download the software you'll need for both satellite tracking and weather image decoding. You'll also need the Internet connection to download the orbit update information for the satellites you want to track.

Tracking software

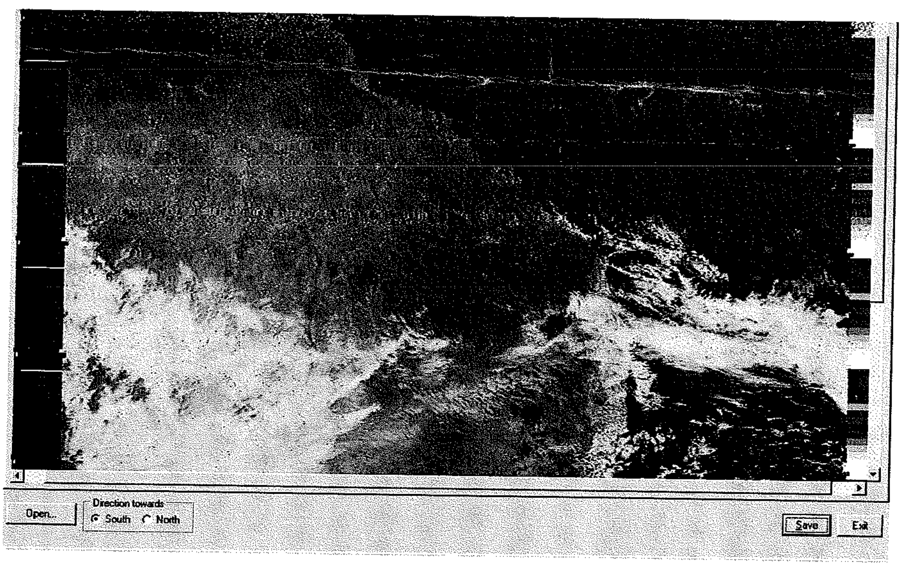
Because the polar-orbiting satellites move in very well defined orbits, the position of each one can be calculated at any time based on the so-called Keplerian elements (orbit definition parameters) for that satellite. This is done by tracking software, which can also predict when that satellite will pass within your antenna's field of view, once it knows your longitude and latitude. This calculation is done completely "off line"; you don't need your weather satellite receiver to be working.

There are quite a few freeware and shareware satellite tracking programs available on the Internet. We tested and can recommend WinOrbit 3.6, written by American radio amateur Carl Gregory, K8CG. Once you provide it with the orbital information on the satellites you want to track, it can not only plot their positions at any time on a world map but also predict the next useful pass of any nominated satellite together with the local time, the satellite's range and ele-

Tracking And Decoding Software



WinOrbit 3.6 is a "predictive freeware satellite tracking program that can be downloaded from www.amsat.org/amsat/ftp/software. This readout, taken over a 2-hour period, shows the path and current location of NOAA17, with the large circle indicating the satellite's current field of view. The readout also indicates the dark and sunlit areas of the Earth. The Sun symbol (ie, all areas in the middle of the "U" were in the darkness when this plot was made). The program can predict the time of the next useful pass of the nominated satellite for a given location and shows lots of other data as well.



SatSignal V4.04 is a freeware APT decoder that works quite well. You can download it from www.satellitescience.com or from www.satsignal.net.

vation and so on.

WinOrbit 3.6 is freeware, and you can download it as a single zipped file (WINORB36.ZIP – 478KB) from various sites, including **www.amsat.org/amsat/ftp/software.** However, we plan to make a copy available on the SILICON CHIP website, so look for it there first.

Two other popular satellite tracking programs are L. Hamilton's "Footprint V2.08" which can be download-ed from **www.riglib.demon.co.uk/footprint.htm** and "WXTrack V3.4.0" which is written by David Taylor of Edinburgh, Scotland and can be downloaded from his website at **www.satsignal.net.**

Which ever program you decide to use, you'll need to provide it with the tracking data for the satellites you want it to track (ie, their Keplerian elements). This tracking data can be downloaded as a text file from various Internet sites. For example, you can get the data for the NOAA satellites from **http://celestrak.com/NORAD/elements –** it comes as a text file called "noaa.txt". This is then simply renamed with a "2li" extension instead of "txt", after which it can be used by the tracking program.

Using the tracking program, you'll be able to find out when the satellite you're interested in will next be in range. You'll then be able to receive its signal at the expected time and record it on your PC's hard disk using an audio recording program. You can use CoolEdit (which can be downloaded from the Internet), for example, or Creative Recorder which comes with most Sound Blaster audio cards.

By the way, most weather satellite decoding programs seem to want the signals recorded as WAV files, in mono (left channel), with 16-bit resolution and a sampling rate of 11.025kHz. So that's the recording format to use and it's much more economical when it comes to disk space than recording in 44.1kHz stereo.

APT decoding software

Once you have the signals recorded on your hard disk, you can fire up the decoding program and process them to produce the actual images. So if you don't have a decoding program as yet, the next step is to download one of the freeware or shareware decoders available on the Internet.

There are quite a few weather satellite decoding programs available for free downloading; eg, from sites such as **www.satellitescience.com.** One of the most popular programs is WXSAT 2.59e, written by Christian Bock. It's free for schools and private/amateur use and has good documentation. It's also fairly easy to use, although sometimes it seems to have trouble decoding signals where the subcarrier has been Doppler shifted in frequency.

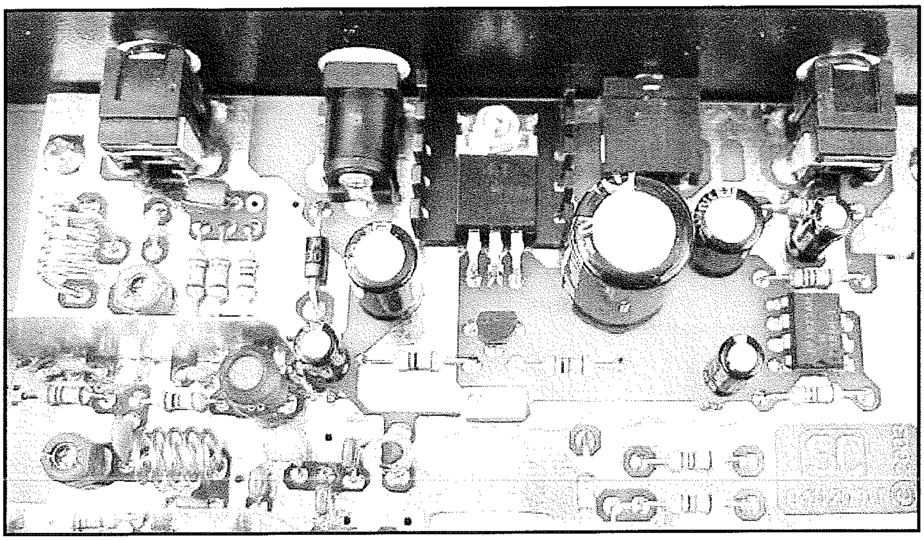
After testing several programs, we eventually settled on SatSignal V4.04, written by David Taylor. You can download this program from www.satellitescience.com or directly from David Taylor's own website at **www.satsignal.net.** All of the weather satellite images shown here were decoded using SatSignal V4.04, incidentally.

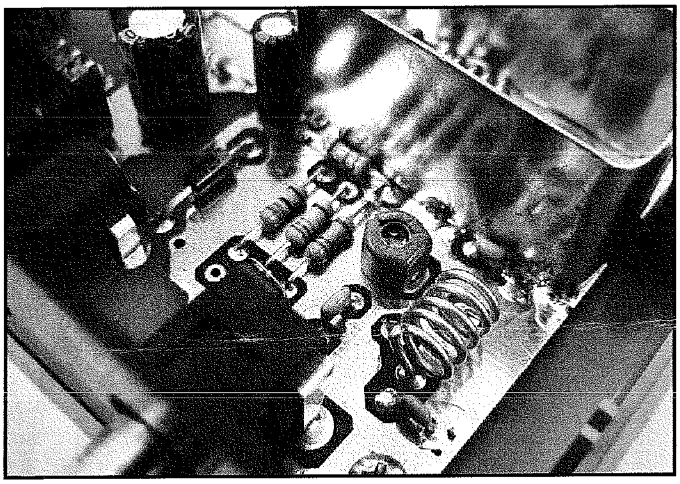
By now, you should have a good understanding of how weather satellites work and how you can receive images from them using a suitable receiver, a PC and freeware software from the Internet.

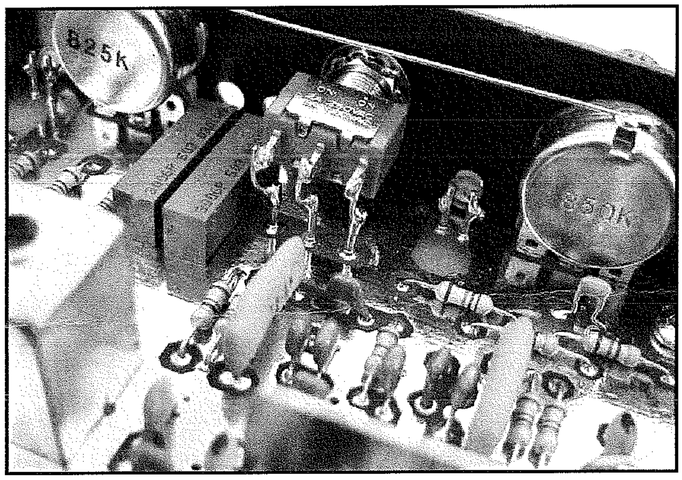
Useful Websites

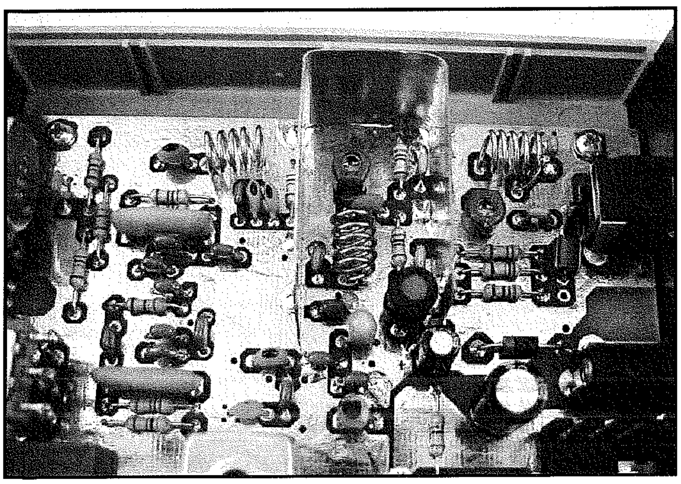
If you'd like to get some more information on weather satellites, or to download some satellite tracking or decoding software, here are some useful websites and documents:

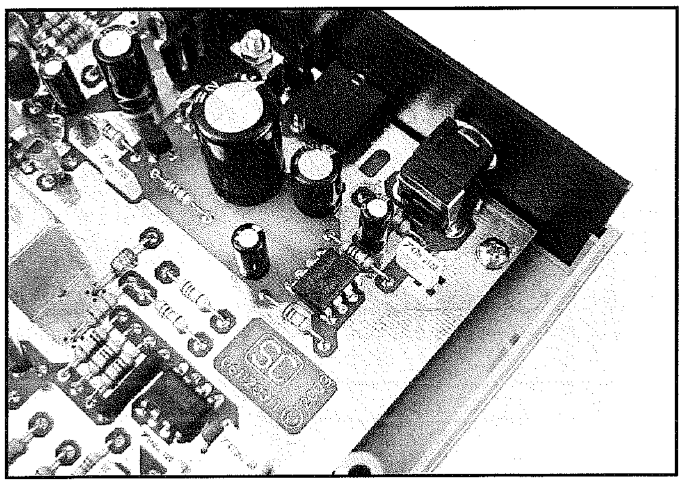
www.amsat.org
http://celestrak.com/NORAD/elements/
www.david-taylor.myby.co.uk/software/
www.drig.com
www.geocities.com/SiliconValley/2504/wx.htm
www.noaa.gov
www2.ncdc.noaa.gov
www.oso.noaa.gov
www.riglib.demon.co.uk/index.htm
www.satellitescience.com
www.satsignal.net
http://sattrackhouston.com
www.telecable.es/personales/ealbcu/kepsen.htm
www.time-step.com/apt











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