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A simple SMD project

A Panoramic Adapter Tap (PAT) for your radio, using surface mount technology

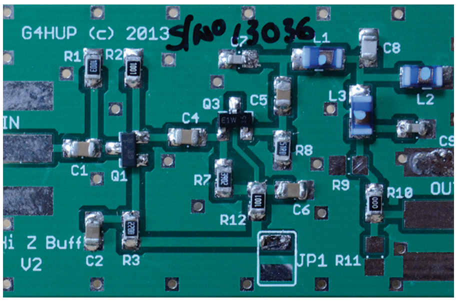

PHOTO 1: Assembled PAT board.

INTRODUCTION. This project has come directly from my 'Surface Mount for the Terrified' presentation and workshop at the 2013 RSGB Convention and (at the time of writing) I plan to repeat and update the workshops at the 2014 Convention, with this and other newer projects available as the 'build' options.

Over the last few years, software defined radio (SDR) technology has made enormous inroads into amateur radio products and operating practices. Routinely we now place the majority of the 'hard work' of our communications in the PC rather than in the radio, with filtering and demodulation being performed in software. But there are still many 'conventional' radios being used and giving very good service without the benefits of SDR. However, there is one over-riding advantage to having SDR capabilities that is not generally available even on most of the main manufacturers 'conventional' radio products: a real-time, panoramic view of part of the band we are working on, giving us a whole new operating experience.

WHY DO YOU NEED AN SDR ON YOUR RIG? Although, increasingly, the 'traditional' radio manufacturers are including elements of SDR in their products, there is only one rig/product that I am aware of that gives the full benefits of SDR technology – and even then it requires an optional purchase to achieve it. Many radios have a spectrum display or band scope of some form, ranging from early, rather crude first attempts on low-res character LCDs to the magnificently detailed displays of the current mid- to top-of-the-range offerings from the major suppliers. But, as any serious weak-signal VHF or microwave operator already knows, the great value of SDR technology lies not in the fully adjustable filter cut-offs and the spectral displays, but in the waterfall display. This is by far the most useful aspect of SDR for the identification of weak signals. Signals that are too low to stand out in the spectrum display will just blend in with the random noise, or 'grass' at the bottom of the display – they are invisible. But, turn on the waterfall and you will start to see faint traces down the screen as the consistency between the 'random samples' is established over the integration period. Where there is noise, you will see no correlation – but where there is a faint signal, it is plainly obvious.

In **Figure 1** you can see three beacon signals received via an SDR. As displayed, this screen shot is taken with a high degree of integration of the signal, compressing the visible noise level against which the signal appears. The centre signal (GB3MHX) and the left signal are both large enough to see even when there is no integration, but the signal to the right of GB3MHX would be essentially invisible in the spectral display – in the waterfall, the trace is clearly visible. Thus the advantage of having the display is that you are able to see where there are weak signals around you in the band.

ADDING SDR CAPABILITIES TO RADIOS. Almost any radio can have this magic capability added to it – all that is needed is an output at the intermediate frequency (IF) and an SDR to connect it to. A simple buffer board can be installed and your choice of both SDR product (within the confines of the IF used, of course) and operating software can be added. The Panoramic Adaptor Tap (PAT) described here provides this solution as far as the IF connection is concerned.

No gain is required in the PAT buffer – its job is to isolate the IF of the rig from anything that may be connected externally. The boards have a gain of about 1dB in practice; see **Table 1**.

CONSIDERATIONS IN SPLITTING THE IF. There are two main requirements: the need to extract signal without causing any degradation of the forward path through the radio and the need to ensure that there is no risk of feeding 'extraneous' signals back into the rig's IF path. Some SDRs, especially simple quadrature mixer types such as the SoftRock variety, have relatively high levels of their own local oscillator present at their inputs. When attached directly to an antenna, they may radiate a little, but this does not degrade the performance. However, if that signal gets fed into your existing receiver's IF, it may cause all kinds of issues and distortion and give a worse performance than you perceived without the SDR!

Looking around the internet, there are a number of ways that amateurs have taken an IF output for purposes such as this. Some are as simple as a single capacitor. Given the foregoing paragraph, the real need is for a high impedance input buffer, which will avoid loading the IF and reducing the signal levels passed through to the detector stages. Furthermore, to avoid feed-in problems, the buffer also needs a high reverse isolation, so that any signals presented to the output of the buffer are not propagated back to the input.

THE PAT BOARD. The PAT board has been designed and developed with the previously noted considerations in mind. It also fulfilled other objectives, including being small enough to fit in almost any rig and being simple enough to present a worthwhile entry-level project to surface mount construction. Although there are a wide variation of rig models and types, they can all be served by some simple variations in the PAT builds.

Amateur transceivers tend to have internal regulated rails for both the Rx and Tx functions. Portable rigs, such as the FT-817, have a nominal +5V RxB. As a generalisation, base rigs have voltages between +8V (Icom, Yaesu) and 13.8V (Kenwood, as in TS-2000). This variation is catered for by a single resistor change on the PAT board. The other difference is in the IF used. But again, there are a few nominal ranges. Depending on the rig architecture, either the first IF or the second IF may be the more appropriate to use (discussed later). There is nothing in the buffer amplifier stages that is frequency dependent, but I do recommend having a low pass filter to avoid any other signals from the rig getting passed through – this will help to minimise the risk of any high side local oscillator

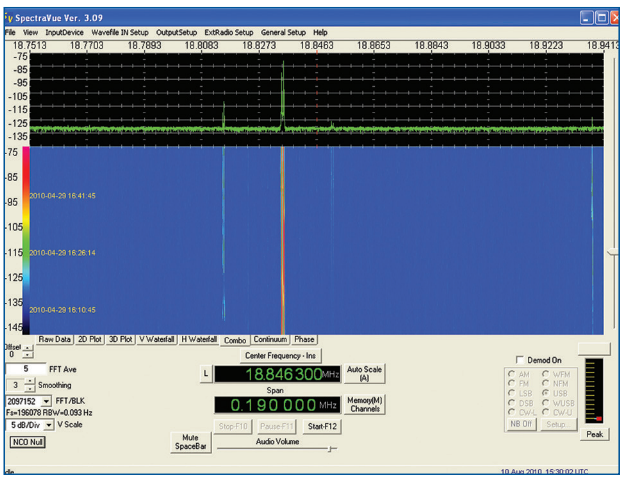

FIGURE 1: Reception of 10GHz beacons using SDR.

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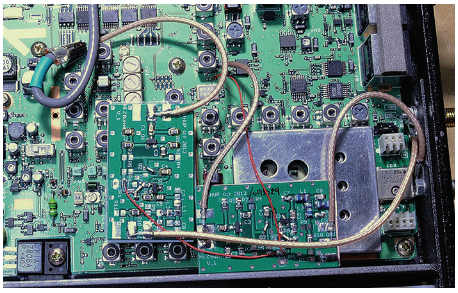

PHOTO 2: Two PATs installed in an FT-897.

remnants that have got through the mixer causing strong signal issues in the SDR. Typical LPF frequencies are 6, 12, 15, 50, 70 and 140MHz. Other frequencies can be accommodated easily.

INSTALLING IN RIGS. The PAT board (see **Photo 1**) is 25mm x 40mm – it fits snugly in an FT-817, and can be 'lost' in the majority of larger rigs. The best mounting option is to use double sided adhesive tape to stick it to the top of one of the screening cans, in a convenient position close to the IF pick up point and the rear panel. Exactly where this is will vary from rig to rig. Example installation instructions for a number of popular radios are available on the PAT website **[1]**. Even if yours is not amongst them, it is worth checking these to pick up tips for dealing with you own installation.

You will need to locate a suitable place to pick up the IF signal – this could be on the input side of the filter or on the output side of the filter (a narrower view, but cleaner outside the wanted range). I have found that with a 15kHz wide first IF roofing filter, a useful SDR display of between 30 and 50kHz can be seen, which is enough for many applications.

Figure 2 shows the output from my TS-2000 during a 6m Sporadic-E opening in June. The display is of the CW segment of the band, around 50.100MHz. Displayed bandwidth is approximately 33kHz: in fact, a satisfactory display up to about 50kHz wide can be obtained, although signals towards the edge of the display will show at lower levels, due to being on the slope of the IF filter.

The best pickup point may not be on the filter itself. There is another issue that needs to be considered here. In many rigs the IF is 'bi-directional' – it is part of the IF chain for both Rx and Tx. In satellite-capable rigs (eg FT-847, TS-2000) this is not the case, but in most others it is. It is preferable not to allow Tx path IF signals into the SDR, as they are likely to be rather larger than Rx signals, and may cause overload in the SDR. Radios with bi-directional IF filters usually have a diode switch arrangement around the filter; it is better to collect your signal from an Rx path outside the diode switch in such cases. I still also recommend powering PAT from a switched RxB line, giving additional protection against feeding Tx signals into the SDR.

Miniature coax or a short single wire may be used for the input connection – if you use coax, only ground the braid at the PAT end.

Finally, you need to get the output signal from PAT out of the radio. If there is sufficient real estate on the back panel, mounting a small socket (eg SMA) is a good method – but this may mean taking a drill to your radio. In many cases there are rear panel ventilation slots and, while these are there for a purpose, most radios can easily stand having a small bit of this space blocked off by an SMA or similar small socket mounted across it. Alternatively, a flying lead can be brought out through the slot, or a hole, and terminated in a cable end plug.

Power for the board must be available, and the RxB line is the recommended choice. Usually, this can be a single positive connection, since the shield connection on the output coax will provide the ground connection for the supply. However, where a flying lead cable exit is used, it will also be necessary to provide a separate DC ground to the PAT board.

WHICH SDR TO USE? The only real consideration is that the SDR must cover the transceiver's IF. Of course, different SDR products use different software, and some of them are proprietary. There are many hardware and software options for the SDR: it really is about deciding what works for you.

At the cheapest end, especially for the higher IFs, the ubiquitous RTL DVB dongles (with appropriate software, such as *SDR#*) can be very effective **[2]**. The only issue is that they can be prone to overload, so strong signals may cause some distortion. An alternative is the FUNcube Dongle Pro+, which has much better inbuilt filtering and can be used with more 'conventional' SDR software such as *SpectraVue*, as well as *SDR#* and other programs.

For lower IFs the SDR-IQ is an excellent radio, although expensive. A SoftRock makes a really cheap solution that could be dedicated to this service alone.

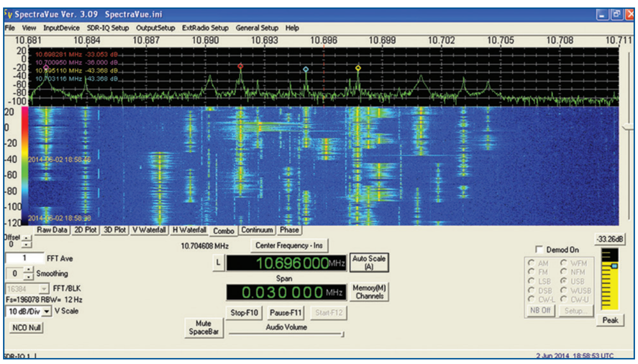

FIGURE 2: Output from TS-2000 during 50MHz Es opening, June 2014.

OTHER METHODS OF USE. The foregoing has focussed on using the PAT board to extract the IF. However, there are actually three ways if may be connected, depending on what you want.

The following comments are principles to help you decide how you want to use the external SDR function. I should sound a note here that due to modern construction methods used in our rigs, not all of the points that we may identify from the circuit diagram as being ideal for making the connection we want may actually be accessible inside the rig! Very often, in deference to compactness, many of the components and connection points are on the underside of PCBs, or within sealed screened enclosures. In this respect, older rigs can be easier to work on than some of the latest.

Application 1 – visibility of the segment around the tuned frequency of the radio. If all you want is to see the 30 to 50kHz of spectrum immediately around the frequency you are tuned to, then the original installation concept is for you – connect the PAT input to the output of the 1st (or in some cases 2nd) IF filter. The SDR must be set to the appropriate IF of the radio and, as you tune your radio, the signals will move through your visible 'window' on the screen. As you change bands, what is on your screen will track what you do with the radio, without any further intervention on the SDR. This is how I set things up in Figure 2.

Application 2 – wider spectral visibility around the tuned frequency. If you want a wider view, you can try to pick up the *input* of the filter. In all other respects, the behaviour should be the same as Application 1. It should be possible to achieve visibility of the whole band (depending on your SDR setting) but of course, the display will still 'tune' with the rig, so not all the signals you see will necessarily be in the band. Also note that since you will be looking between the mixer and the filter, you will also be likely to see some extraneous 'signals' due to mixer products, which would be removed by the filter for normal reception. Often these signals will 'tune' in the opposite direction to main movement of the display as you change the frequency on the rig.

Application 3 – visibility of the band – second independent receiver function. This method will give effectively the same result as Application 2, but the SDR display will be completely independent of the Rx tuning. This may have some advantages, however it is not achievable on all rigs. By picking up the Rx signal before the first mixer, it only has the processing of the rig's bandpass filters and any amplification applied to it: the signal is still at the antenna frequency. This means that you must tune your SDR to the band you want to receive/monitor and the signals will not track the rig as you change frequency. Using this method, it is quite likely

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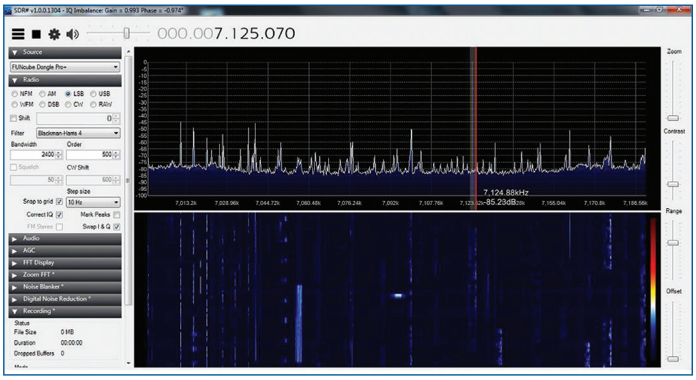

FIGURE 3: 40m band as 2nd Rx function, using a FUNcube Dongle Pro+ and *SDR#*.

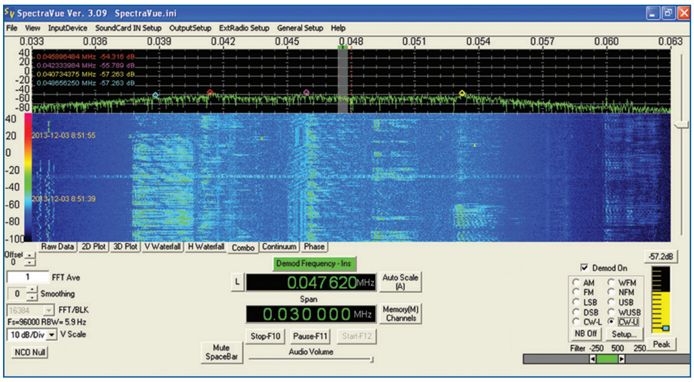

FIGURE 4: 40m band SSB segment as IF tap, with FUNcube Dongle Pro and *Spectravue* 3.09.

that you will also use the SDR to demodulate some of the signals – it's much quicker than tuning the rig to an interesting-looking signal. As many modern radios use 'block' filtering (eg 1-2MHz, 2-4MHz, 4-8MHz, 8-16MHz, and 16-32MHz) you may be able to monitor frequencies other than the currently-selected amateur band. For instance, when the rig is set to 40m and using its 4-8MHz bank, you could have the SDR Rx monitoring any other segment within that filter passband – eg the 5MHz allocations. Or using the 8-16MHz block, when on 20m, you could be monitoring 30m as well.

SUITABLE TRANSCEIVERS. You can fit the PAT to almost any radio, but you may not be able to see all bands in the case of HF/VHF/UHF rigs. This is due to the architecture used by the manufacturers. Yaesu, for example, tend to bring all the various input stages to a common point, then starting the mixing process – this is great, since it means there is one place to connect the PAT, and you will see on your SDR the band of choice anywhere between 1.8MHz and 435MHz. The FT-817, 847, 857, and 897 all use this approach.

Kenwood and Icom do not consistently use this approach – for example, in the TS-2000 the first point at which all the bands (including 23cm in the X version) meet in the signal path is at the second IF (10.695MHz). They have used a very similar architecture in the TS-790 series. The Icom IC-910 also uses different first IFs for the different bands.

In summary, if it's an HF or HF/6m radio you're dealing with then it is almost certain that the 2nd Rx function is feasible. If you have a full coverage (HF/VHF/UHF) radio other than Yaesu, then probably not. It would still be possible to put in a PAT for a specific band, but if you can't see everything it's a bit limiting. Several versions of the PAT are available for different configurations, IFs and so on; the differences are relatively minor and mainly concern whether any filtering is included and, if so, on what frequency.

FITTING A PAT. Detailed fitting procedures for a number of radios can be found on the G4HUP website [1]. As an example, I fitted *two* PAT boards to my FT-897, at the first and second IF, for comparison purposes. **Photo 2** shows the general arrangement and **Photo 3** shows how I mounted SMA output sockets in the ventilation slots, as mentioned earlier. The first PAT, seen on the lower right of the photo, was installed on top of the large screening can. The second, which gets its input signal from J1003, where the Rx signal enters the PCB from the PA Unit, was also attached to a (smaller) screening can. Both boards share the same power connection, derived from the RxB line, so both outputs are self muting on Tx.

Operating Comparisons. **Figure 3** and **Figure 4** provide a useful comparison of the capabilities of the two options, in spite of being acquired with different SDRs and software. These pictures are both captured off the FT-897 seen in Photo 2.

Figure 3, from the 2nd Rx PAT, shows almost the whole band. The SDR is set roughly to the band centre (in this case). You can see a wide variety of signals across the band, from the CW segment at the left hand end through data and into the shared SSB segment towards the right. Any signal can be clicked on and demodulated on the PC – just remember to select the appropriate demod/filters in the control panel area. By adjusting the SDR settings, the width of the display (in spectrum terms) can be reduced, showing more detail, so you could focus in on just one frequency range or mode segment. The display is flat across the spectrum, demonstrating equal sensitivity at all points.

As an experiment, I tried looking at bands on the SDR that I wasn't tuned to on the radio. With the FT-897 I could see 30m, 20m and 17m on the SDR when the radio was switched to any one of them – ie the relevant block filter covers from below 10MHz to over 18MHz.

TABLE 1: PAT gain at different intermediate frequencies.

Intermediate frequency	Reverse isolation	Net gain
12MHz (eg TS-2000)	>60dB	0.7dB
45MHz (eg FT-840, 847, TS-440)	>40dB	1.1dB
70MHz (eg FT-450, 817, 857, 897, IC-706 etc)	~40dB	1.3-1.5dB

Figure 4 shows the view using the IF tap facility, providing a span of about 30kHz across the screen in this case, although slightly wider views are possible. The response is clearly declining at the outer edges of the sweep, due to the filter passband. The frequency display does not reflect the actual IF of the rig. As a FUNcube Dongle is being used as the SDR, the separate *FCHiD* utility controls the frequency in *Spectravue*; that is not an artefact of the PAT approach, but is a function of the SDR/software architecture.

CONCLUSIONS. Whether you use the PAT as a 2nd Rx or IF tap depends what you prefer, or what you find most useful in terms of visibility. I find the 'narrow' view of the IF filter system adequate in cases such as 6m Es, where I prefer to sit in the CW segment. The SDR only needs to cover the IF of your rig. However, on a crowded HF band, the wider view of the 2nd Rx can help to spot the quiet parts of the band – or where the activity is – but your SDR must cover at least the same frequency range as your radio. You can also quickly demodulate the signal on the PC to confirm what is happening. Just remember to net the Tx before trying to reply…

Another use for the 2nd Rx function is at the IF output of transverters (28 or 144MHz). Installing the PAT in the transverter Rx path would allow connection to a suitable SDR to display a large part of the band. In this way there is no need to get inside your rig.

Full operation and construction details of the PAT board can be found on the author's website [1]. You can also purchase kits for PAT and, although this is really intended as an SMD construction project, assembled and tested boards are available too.

WEBSEARCH

[1] http://g4hup.com/PAT.htm

[2] G0CHO, *RadCom*, December 2013

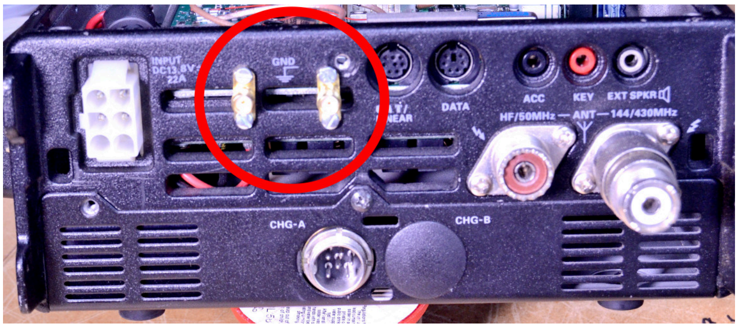

PHOTO 3 (missing from original article): two SMA sockets installed on the rear of an FT-897.