

Mike Richards takes a look at the ELAD FDM-S1 which, in addition to continuous coverage from 20kHz to 30MHz, can also receive any 30MHz band up to 200MHz using super-Nyquist sampling.

ELAD FDM-S1



The ELAD FDM-S1 direct sampling SDR receiver.

The ELAD FDM-S1 receiver offers a low cost entry to the world of direct sampling software defined radio (SDR) receivers. In addition to providing continuous coverage from 20kHz through to 30MHz, the receiver can be used in undersampling mode for extended coverage up to 200MHz. The receiver software includes demodulators for all the usual modes found on long wave, medium wave and HF, along with a built-in Digital Radio Mondiale (DRM) decoder and stereo FM! The FDM-S1's specification is shown in Table 1.

In the Box

The presentation is excellent, with a very smart metal alloy case. The FDM-S1 is supplied with an SMA to BNC adapter, a USB cable, a soft pouch and a CD-ROM with the receiver software and drivers. The FDM-S1 is a very low power device, which consumes just 2.2W and takes its power from the USB port. The only other essential connection is the antenna and that used a miniature SMA connector. In addition, there was an optional 9-pin D-type connector on the rear panel and I'll cover that later.

Installation was straightforward and

followed the usual pattern of installing the software before connecting the FDM-S1 to the USB port. The installation process installed all the drivers, the control software and an additional in-phase and quadrature (IQ) file editor. Once the installation was complete, the FDM-S1 was connected to the computer's USB port and I was ready to start listening. Please note, when connecting devices that take their power from a USB port, it's important to make sure the port has sufficient capacity. For a high bandwidth, USB powered device such as the FDM-S1, the safest bet is to connect directly to a USB port on the PC and to avoid external hubs altogether. However, a good quality powered port should be able to cope but you still need to beware of mixing high bandwidth devices on the same hub.

The ELAD software is undergoing continual improvement, so I visited the ELAD Yahoo! Group to get the latest release. As a result, this review relates to software version 3.27.

http://groups.yahoo.com/group/elad_sdr_en

Under the Lid

During the review, I made contact with ELAD to better understand the inner workings of the FDM-S1 and I've shown a simplified block diagram in Fig. 1. Here you can see that, following some electrostatic protection, the signal passes via a switchable 30MHz low-pass filter, an attenuator and then on to the Texas Instruments analogue to digital converter (ADC). The role of the ADC is to convert the entire 20kHz to 30MHz band into a digital format. This is done by measuring and recording (sampling) the voltage on the input terminals at regular intervals. In the case of the FDM-S1, the sample rate is 61.44 million samples per second (MSPS), which aligns neatly with the Nyquist requirement to sample at more than double the highest frequency.

The Texas ADC employed in this design produces 14-bit parallel data samples, which results in a stream of parallel data arriving at a rate of 61.44MSPS! Processing this amount of data is not for the faint hearted and certainly not suitable for passing directly to a PC. As with all the direct sampling

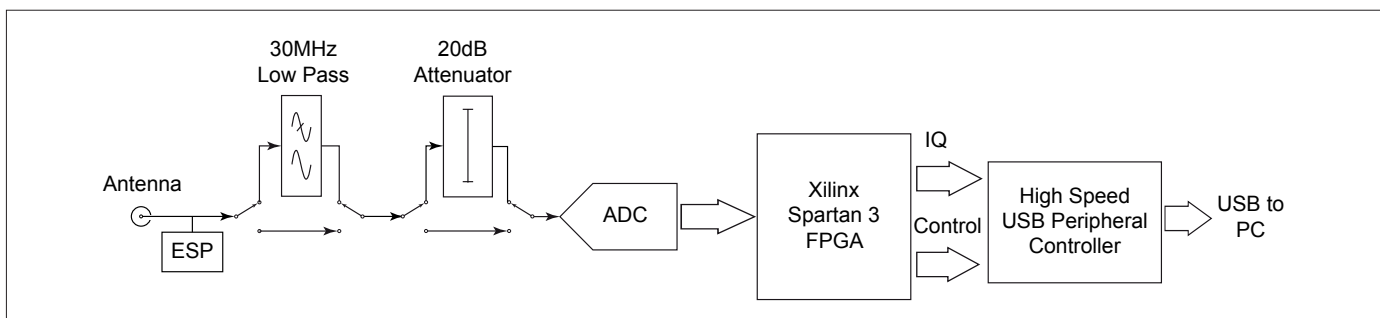


Fig. 1: A simplified block diagram of the ELAD FDM-S1

receivers I've encountered so far, the FDM-S1 uses a field programmable gate array (FPGA) to provide the high-speed digital signal processing (DSP) muscle. Not only are FPGAs very quick but they also operate in parallel mode, so many different functions can be executed simultaneously.

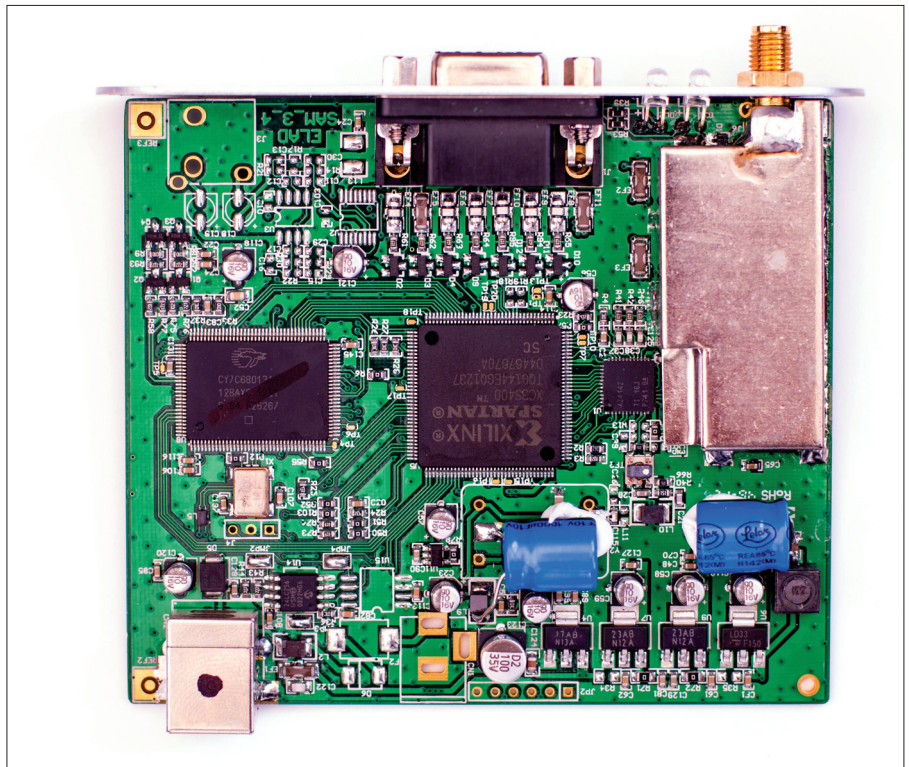
The FDM-S1 uses a Xilinx Spartan-3 FPGA and its primary function is to extract a narrow slice (between 192kHz and 6MHz wide) from the full 30MHz bandwidth and to deliver that slice as an IQ data stream. This process is known as decimation and is roughly equivalent to a mixer, local oscillator and intermediate frequency (IF) filter in an analogue receiver. The FDM-S1 has six preset IQ bandwidths available as follows: 192, 384, 768, 1536, 3072 and 6.144kHz.

Linking everything together is a Cypress high speed USB peripheral controller. This is a highly integrated chip that has its own built-in microcontroller. In the FDM-S1 application, the peripheral controller manages the serial control signals and combines these with the decimated digital IQ stream to create the USB link back to the software on the host PC.

Operation

When first fired-up, the FDM-S1 displays the main receiver panel but with the receiver offline. A press of the software power button and the receiver springs to life and displays three separate screens. The main screen contains all the receiver's control systems as well as the primary spectrum and waterfall displays. In addition, there were secondary spectrum and waterfall displays for the audio frequency (AF) and IF signals.

The main display is where you'll find all the action, so let's start with that. As with most SDR receivers, the FDM-S1 has multiple tuning methods. Point and click tuning with the mouse is available across both the waterfall and spectrum displays. This is my favoured SDR tuning technique because signal selection becomes a visual process once you're accustomed to the waterfall fingerprint of different signals. For larger frequency changes, the FDM-S1 had one of the best tuning systems I've seen so far. Immediately below the spectrum display on the main screen there are three tuning ribbons marked with different frequency scales (see Fig. 2). The bottom scale displays



An inside view of the ELAD FDM-S1.

almost the entire 30MHz frequency range, while the centre ribbon shows a 6MHz wide slice and the upper ribbon is the frequency scale for the spectrum and waterfall displays. In addition, the centre ribbon has a highlighted section that aligns with the current spectrum/waterfall width. For major frequency changes, I simply dragged the lower ribbon with the mouse so that the desired frequency was centred in the display. I could then complete the tuning using the two finer ribbons combined with point and click tuning on the desired station. The explanation might sound a bit cumbersome. Nevertheless, in practice, it was a very slick system that worked extremely well. When tuning with a wide IQ spectrum it could be difficult to spot individual signals, so I used the FDM-S1's zoom facility to take a closer look. For fine tuning, the FDM-S1 allows scrolling with the mouse wheel

and the scroll steps can be adjusted from 1Hz to more than you'd ever want! The settings panel even includes the facility to preconfigure scroll steps to particular frequency bands which was useful. Direct frequency entry was also supported by double clicking on the frequency display at the top of the screen or pressing the space bar. I could also use the + key as a shortcut to enter three 0s.

The remaining receiver controls were located in a panel to the right of the main display. This section started with tick boxes to enable or disable the 20dB attenuator and 30MHz low-pass filter. The filter should always be activated for normal HF operation because it prevents signal degradation from aliasing products. The software also includes a useful overload warning for the ADC that flashes if the ADC starts clipping the signal. In case of overload, the 20dB

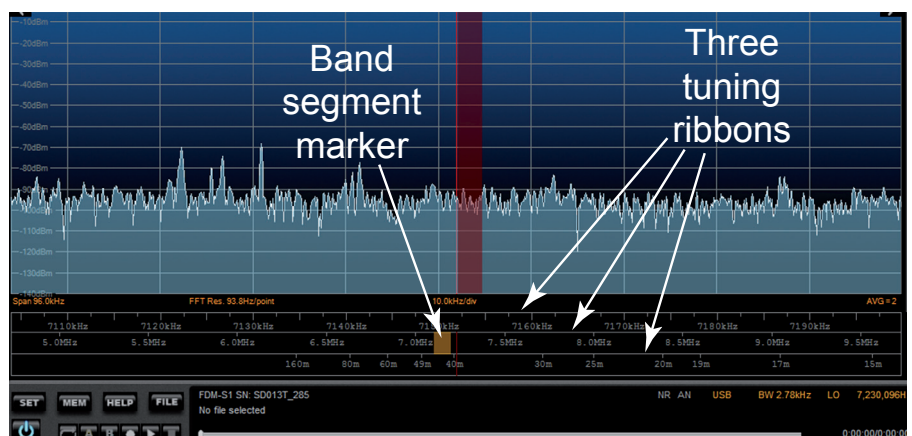


Fig. 2: The clever multi-ribbon tuning system.

attenuator could be switched in to tame the signal.

The range of demodulation modes included was excellent and included synchronous amplitude modulation (AM), double sideband (DSB), wideband frequency modulation (FM) and DRM as well as the usual single sideband (SSB) and Morse (CW) options. Inclusion of a DRM decoder was a very welcome extra and the decoder included a display of programme information and signal status – see Fig. 3.

The demodulator bandwidth was adjustable in 1Hz steps either using the filter entry panel or by dragging the spectrum in the IF spectrum panel. Another thoughtful extra was the provision of two independently controlled audio output streams. I was able to make good use of these with one feeding my data software and the other driving the PC speakers. The separate controls let me alter the speaker volume without interfering with the levels to the data decoder. Noise and unwanted signal reduction were covered with a variable noise reduction unit, noise blander, variable auto notch filter and two separately controlled IF notch filters.

In its default setup, the FDM-S1 displays a 6MHz slice of the 30MHz bandwidth but this can be changed at start-up to one of the six preset bandwidths as mentioned earlier. While the 6MHz bandwidth could be useful, the downside was lower resolution on the spectrum display when I zoomed-in close enough to be able to recognise signal characteristics. The solution was to choose a narrower IQ bandwidth for detailed work. This cannot be done 'on the fly', so I had to restart the software and select the bandwidth from the hardware setup menu. This was a very simple process, once the option had been enabled in the Advanced Setup panel. I found the 384kHz and 768kHz IQ bandwidths to be the most useful. The separate IF and AF spectrum screens were also useful for signal analysis.

Memory Integration

The FDM-S1's memory system was very well implemented with a number of useful options. The first was a conventional user database file where you could store all your favourite stations. You could have as many files as you like and the system is only limited by the available disk space. The second option was to use the EiBi international list of broadcast stations.

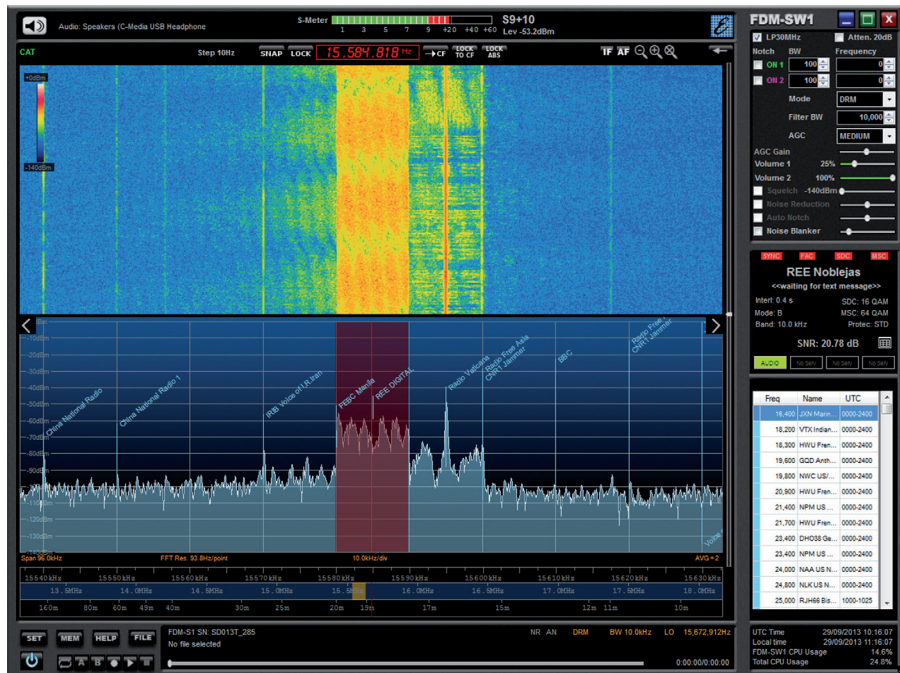


Fig. 3: A full screen display while receiving DRM.

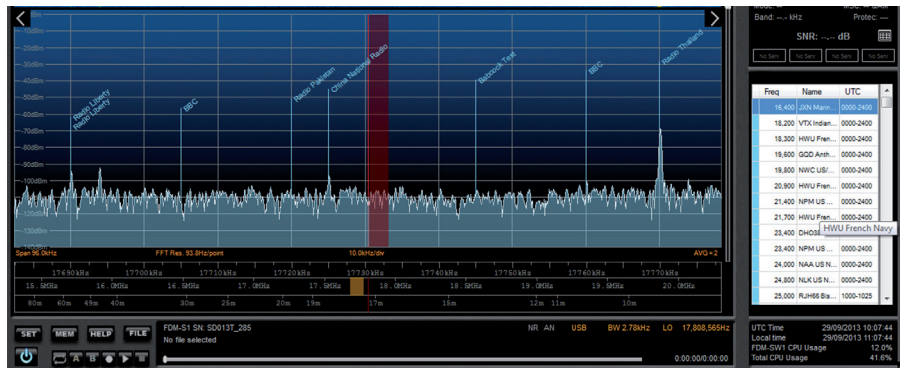


Fig. 4: Station names can be included in the spectrum display.

This is readily downloadable via the internet and lists global broadcast stations and is obviously very useful for broadcast listeners. When using the EiBi system, a database panel appears at the bottom right of the main display where you can scroll through the entries and a single click will retune to that station.

www.eibispace.de

Finally, the FDM-S1 can link to your favourite DX Cluster. This makes it very easy to spot new and interesting amateur activity.

One rather good feature of the software is the facility to display the station names on the spectrum display as shown in Fig. 4. This applies to all three memory systems and worked very well.

Spectrum Recording

Both IQ and audio recording were fully integrated with the FDM-S1 software and it was very easy to use. A single click of the record button started a recording using a preset naming convention and file type. The format and naming system

could be changed via the Settings menu if necessary. Once a recording had been made, I could replay and loop it using the main FDM-S1 software. Where you have multiple files recorded in a chain, you can use the supplied SDRWave software to edit and join the files.

Undersampling

You will have noted that the FDM-S1 is described as a sampling receiver, so let's see what that means. As the entire RF spectrum is presented directly to the ADC stage of the receiver you can do rather more than just tune to stations in the specified 20kHz to 30MHz range. Many readers will be have heard of the Nyquist-Shannon sampling theorem which, in simple terms, says you should sample at twice the highest frequency in the signal (f). The same work also states that frequency bands higher than 2f can be sampled at a rate that's twice the bandwidth you want to capture. The higher frequency bands then appear reflected in the 0 to 30MHz range as

aliasing products. Normally, you would use a 30MHz low-pass filter to remove the higher frequencies and prevent these aliasing products. However, where the ADC has a suitably wide frequency response, you can make use of the aliasing products by adding a 30MHz high-pass filter.

The ADC chip used in the FDM-S1 is specified to work up to 200MHz, so you can use the sampler in aliasing mode to receive any 30MHz wide band up to 200MHz. The technique employed for this is known as under, band-pass sampling or super-Nyquist sampling. For this to work properly, you need to add band-pass filters for the segment you want to receive or you will receive out of band aliasing products. However, I found that you can use the FDM-S1 to listen to VHF/FM broadcasts in strong signal areas without extra filtering because the VHF/FM signals are so much stronger than the unwanted HF signals. For more serious VHF/FM monitoring you could build your own filters or use the matching ELAD PDC-V1 VHF preselector and downconverter. For a more detailed look at undersampling, see *Undersampling Applications* on the Analog Devices website.

www.analog.com/static/imported-files/seminars_webcasts/3689418379346Section5.pdf

Advanced Features

The rear panel of the FDM-S1 features a configurable EXT I/O port that uses a standard 9-pin D connector. This can be configured using the Settings tab to control external equipment and accessories. The range of settings available was comprehensive and it would be easy to use this interface to switch filters, preamplifiers, antennas and so on. ELAD also makes a couple of experimenters' boards that can be used to integrate your own preamplifiers, preselection filters or other electronic goodies. These boards can be controlled via the EXT I/O port and there is also a matching case available so you can keep your project looking smart.

External rig control has also been made available via OmniRig, which allows the ELAD to control up to two additional rigs. Incoming computer aided transceiver (CAT) control is also supported and the FDM-S1 uses a subset of the Yaesu FT-897 commands.

One final but very important feature is the sharing of the hardware application

programming interface (API) details. As a result, the FDM-S1 can be controlled by most of the popular SDR software packages including SDR-Console Beta 2.1, HDSDR and SDR#.

In addition, those that crave a mechanical tuning knob will be pleased to know that the FDM-S1 software is fully compatible with the Tmate and Tmate2 controllers.

Performance

For the review, I used the FDM-S1 with a Wellbrook ALA1530S+ Imperium antenna. This combination worked extremely well for me. The computer was a Pentium Q8300 32-bit quad core unit running Windows 7. I tried the FDM-S1 connected directly to the PC and via a good quality USB Hub (Exsys 7-port) and didn't suffer and bandwidth problems, including using the full 6MHz IQ bandwidth.

When you look at the specifications, you might notice that the FDM-S1's sensitivity is slightly lower than that of many other HF receivers, with the quoted figure of -114dBm (0.45µV) for CW about 8dB worse than some. However, for the vast majority of listening the sensitivity loss is insignificant when you consider the very high noise floor on the HF bands these days. In comparative tests during the review, there was very little to choose between the ELAD and other better specified receivers. In addition, it's also worth noting that the built-in noise reduction worked extremely well and provided a good 6db signal to noise improvement. Nevertheless, the Wellbrook antenna might also have aided the subjective performance because the current model features a relatively high output level. Despite this, the FDM-S1 coped well with very strong medium wave and HF broadcast signals with no signs of ADC clipping.

As I mentioned earlier, having a wide

summary

The ELAD FDM-S1 is a great little receiver and makes a very attractive entry point to direct sampling SDR receivers. The supplied software was particularly impressive with all the controls you need and a very good user interface. The three ribbon tuning system was exceptionally good and the inclusion of a fully featured DRM decoder was very welcome. The configurable I/O port will make the FDM-S1 attractive to those who enjoy homebrew because adding and controlling filters, downconverters, preamplifiers and so on would be easy.

The ELAD FDM-S1 is available from **ML&S Martin Lynch & Sons** and costs £349.94 including VAT, with free carriage for *RadioUser* readers until the end of November 2013.

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www.hamradio.co.uk/fdms1

My thanks to ELAD for their technical support and to Martin Lynch & Sons for the loan of the review model.

choice of demodulation bandwidths is great but when you've decided the band you want to monitor, it's worth changing to a narrower bandwidth because this makes visual signal recognition very much clearer. One of the main benefits of the wider IQ bandwidths is the facility to record huge chunks of spectrum that you can replay and analyse at your convenience.

The three-ribbon tuning system used in the receiver software proved to be excellent and certainly one of the best SDR tuning systems I've encountered. The ribbons enabled me to scoot around the bands very quickly but also made fine tuning a pleasure. ●

Table 1: The ELAD FDM-S1 Specification

Frequency coverage:	20kHz to 30MHz (up to 200MHz via undersampling)
Configuration:	Direct sampling
A/D conversion:	61.44MSPS at 14-bits per sample
Sensitivity:	Typical -114dBm (CW, BW 500Hz, 10dB (S+N:N))
3rd order intercept:	+25dBm at 14MHz
Noise floor:	<-124dBm at 14MHz, CW, BW 500Hz
Receive modes:	CW, CW SH+, CW SH-, USB, LSB, DSB, AM, Sync AM, FM (Stereo + RDS decoder), RTTY, DRM
Digital USB Streaming sampling rate	
IQ channel 32-bit samples:	192, 384, 768, 1536 and 3072kHz
IQ channel 16-bit samples:	6144kHz