Mike Richards looks at the AOR AR-DV1 Digital Voice Receiver

AOR AR-DV1 Digital Voice Receiver

Mike Richards looks at a new product from AOR that (according to the company's publicity material) is, *"The first software defined receiver of its kind to receive and decode virtually ALL popular digital modes."*

The AOR AR-DV1 Digital Voice Receiver and SD card.

The future of mobile radio communications is clearly defined by digital voice and data systems. However, general coverage receiver technology has been lagging behind. The new AOR AR-DV1 Digital Voice Receiver reviewed here is set to change that because it is the first to deliver fully integrated digital voice decoding.

The AR-DV1 is a new development from AOR. It was initially released in the US at the Dayton Hamvention in May 2015; it is now available in the UK and is selling well. The AR-DV1 is primarily a base station/mobile receiver with continuous coverage from 100kHz through to 1.3GHz and employs software defined radio (SDR) techniques for its final intermediate frequency (IF) and demodulation.

Digital voice modes are identified and decoded automatically, which makes the AR-DV1 a powerful monitoring receiver. **Table 1** details the AR-DV1's compatibility with the stated digital voice modes and associated bandwidths.

In the couple of months prior to this review (which was undertaken in November 2015), the AR-DV1 received a number of important firmware updates, so I was keen to see how it performed.

Table 1: AR-DV1 Digital Voice Reception Modes
O = Decoded, X = Not Decoded.

DIGITAL MODE	BANDWIDTH	MODE	VARIOUS	COMPATIBLE VOCODER	ARD300 VOICE DECODING
D-STAR	12.5kHz			AMBE	O
ALINCO DIGITAL	12.5kHz	EJ-47 (voice mode F1E)		AMBE	O
YAESU DIGITAL	12.5kHz	V/D mode		AMBE+2	O
	12.5kHz	Voice FR mode			X
DIGITAL CR	6.25kHz		NON-ENCRYPTED	AMBE+2	O
	6.25kHz		ENCRYPTED	AMBE+2	X
NXDN	6.25kHz	REGULAR MODE	NON-ENCRYPTED	AMBE+2	O
		REGULAR MODE	DIGITAL SCRAMBLING (15 BIT)	AMBE+2	O
			ENCRYPTED		X
			TRUNKING		X
	12.5kHz				X
DPMR	6.25kHz	dPMR446		AMBE+2	O
	6.25kHz	TIER 1		AMBE+2	O
		TIER 2			X
		TIER 3			X
P25	6.25kHz & 12.5kHz	PHASE 1	NON-ENCRYPTED	IMBE	O
		PHASE 1	ENCRYPTED		X
		PHASE 2			X
DMR	12.5kHz	TIER 1	NON-ENCRYPTED	AMBE+2	O
			ENCRYPTED	AMBE+2	X
		TIER 2	NON-ENCRYPTED	AMBE+2	O
			ENCRYPTED	AMBE+2	X
		TIER 3	TRUNKING	AMBE+2	X

Chart courtesy of AOR, LTD.

Getting Started

The AR-DV1 is very easy to set up and use because there are very few external connections. The rear panel (**Fig. 1**) has a standard coaxial power socket that requires a nominal 12V DC at 750mA and a three-pin UK plug-top mains adapter was supplied with the review model. The choice of 12V is helpful because it makes

Fig. 1: The AR-DV1's rear panel.

Fig. 2: The AR-DV1's front panel.

the AR-DV1 easy to use with standard vehicle power supplies. The only other essential connection is the single 50Ω BNC antenna socket. With such a wide frequency coverage, it is unlikely that anyone will use a single antenna so you might need to budget for an external antenna switch if you do not already have one. The AR-DV1 was also supplied with a short telescopic antenna. However, to get the best from the receiver you should use an external antenna. Also on the rear panel was a 3.5mm external speaker jack that was set to disable the internal speaker automatically. Finally, a second 3.5mm jack provided a discriminator output that can be useful for specialist decoding systems.

The front panel (**Fig. 2**) featured three user connections – a standard 3.5mm headphone jack that disabled the internal and external speaker when a jack was inserted, a Micro-B USB jack that can be used for computer control of the receiver (more on this later) and a standard secure digital (SD) card slot. The SD card can be used to backup and restore the AR-DV1's internal memories, update the AR-DV1's firmware and to make audio recordings. A blank 4GB SD card was supplied with the review model, which is large enough for around 28 hours of audio recordings.

Because the receiver is so new, regular firmware (system) updates are being released. Therefore, I updated the review model as soon as I received it. This was a simple process, I downloaded the updated firmware (v1511B for the review), unzipped and saved it to the SD card and then followed the update menu to complete the operation.

Inside Story

Internally, the AR-DV1 uses an interesting mix of analogue and digital technology.

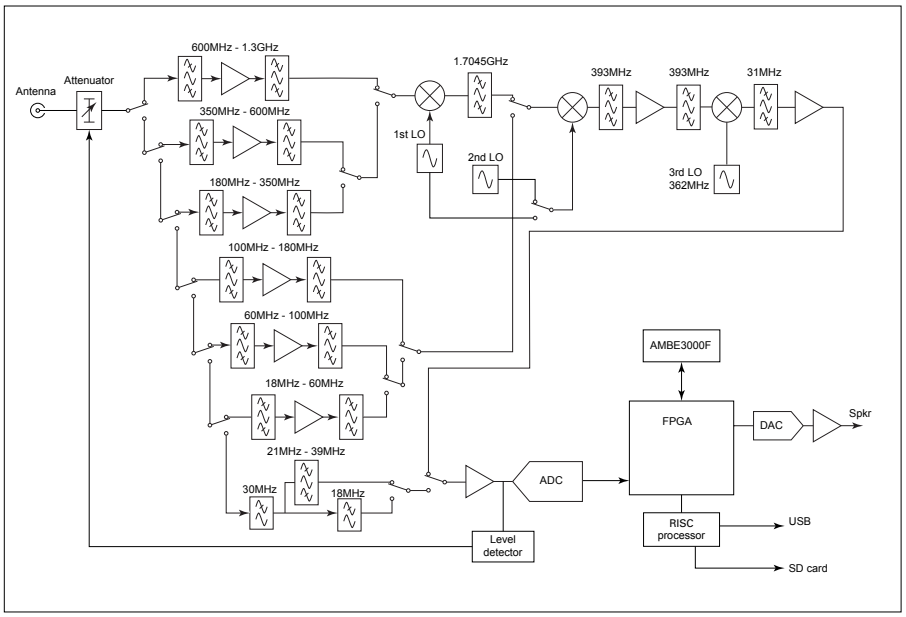

Fig. 3: A simplified block diagram of the AR-DV1.

Analogue superheterodyne techniques are used to translate the received signals down to the 31MHz digital IF. **Fig. 3** shows a simplified block diagram of the receiver. As you can see, the first stage is a PIN diode based automatic attenuator that controls the incoming signal level to ensure the analogue to digital converter (ADC) is not overloaded. The attenuator is controlled by a feedback path from a level detector that is connected directly to the ADC input. The wideband output from the attenuator is fed to a switching matrix where the signal is passed to one of the seven filter banks, according to the frequency range being tuned. For all bands above 30MHz, the filter combination includes a radio frequency (RF) preamplifier to provide some additional sensitivity. **Table 2** shows the filter bands. Frequencies from 350MHz to 1.3GHz are upconverted to a 1.7045GHz first IF, whereas the 18MHz to 350MHz bands miss that stage and are upconverted to the second IF of 393MHz. This second IF is filtered,

Table 2: AR-DV1 Front-end Band-pass Filtering

600MHz to 1.3GHz
350 to 600MHz
180 to 350MHz
100 to 350MHz
60 to 100MHz
18 to 60MHz
30MHz low-pass feeding 21 to 39MHz band-pass and 18MHz low-pass

amplified and filtered again before being applied to the final mixer that takes the signal down to the 31MHz (18MHz wide) final IF. All frequencies below 18MHz are applied directly to the ADC without any conversion, so are effectively direct digitally sampled (DDS). The ADC uses 14-bit sampling at 39.3216MHz to digitise the incoming analogue signals. Once digitised, all the signal processing and demodulation is carried out in the digital domain. An Altera Cyclone III field programmable gate array (FPGA) handles the decimation while a specialist digital signal processing (DSP) chip and a proprietary AMBE-3000F chip handle the digital demodulation. Virtually all the digital voice modes use advanced multiband excitation (AMBE) based speech encoding, so the AMBE-3000F chip plays a major role in the digital voice capabilities of the receiver. Once the incoming signal has been demodulated, it is converted back to analogue using a dedicated digital to analogue converter (DAC).

General control of the receiver (user controls, the display, SD card slot and USB connection) is handled by a dedicated reduced instruction set computing (RISC) processor. Frequency stability and accuracy was determined by a central master clock that fed a number of voltage controlled oscillator/phase locked loop (VCO/PLL) combinations.

As can be seen from **Fig. 4**, the internal construction of the AR-DV1 is excellent. Most of the electronics is mounted on a single printed circuit board (PCB) and there is good use of local screening to protect sensitive areas.

Fig. 4: An inside view of the AR-DV1.

Operation

The front panel has a clean layout with a distinctive styling due to the use of an off-white finish with a mid-grey flash. Fortunately, the finish seemed to be pretty robust and was easy to wipe clean. Manual tuning is via the large tuning knob to the right of the panel that controlled a 32-step rotary encoder. This encoder used soft detents, so the knob had a slightly notchy feel and the lightweight knob could not be spun. Nevertheless, I found it easy to tune quickly by making use of the finger dimple on the tuning knob. Closely associated with the tuning knob were the Up/Down buttons that were mounted directly above the tuning knob. These buttons increased or decreased the tuned frequency using the current tuning steps. Personally, I found the placement of these buttons was a little bit awkward and would have preferred to see them beneath the tuning knob. When casually tuning around, the AR-DV1 uses manual mode/step/bandwidth selection, so there was no inbuilt band plan to auto-select the appropriate band settings. In practice, this was not too much of a problem because most of the AR-DV1's frequency coverage is channelised and likely to be accessed via stored memories or searches.

As you will have seen in the introduction, the AR-DV1 offers a very wide range of receive modes. In addition to the digital modes shown in **Table 1**, the AR-DV1 is capable of demodulating amplitude and frequency modulation (AM/FM), upper and lower sideband (USB/LSB), synchronous AM (upper and lower sideband) and Morse (CW). Mode selection was achieved simply by pressing the Mode button and rotating the tuning knob or using the Up/Down buttons.

I found the AR-DV1's sensitivity across all bands to be very good. Wideband receivers often suffer from poor performance on HF. However, that is not the case with the AR-DV1, thanks mainly to the use of the digital final IF. With the final signal conditioning and demodulation in the digital domain, the listener benefits from tight DSP filtering and powerful demodulation techniques. During the review, I compared the AR-DV1 with a number of the popular SDR receivers as well as my Yaesu HF rig and the performance surprised me. I often use the Shannon VOLMET HF SSB signals for comparison tests because they provide a reliable signal source over a range of frequencies from 5 to 13MHz. When I compared the AR-DV1 with my FUNcube Dongle Pro+ on these frequencies, the sensitivity and signal to noise ratio (SNR) were very similar. However, the audio quality was very different because the output from the AR-DV1 is filtered to 'communications' quality with a sharp cutoff of the lower frequencies. Nevertheless, the result was very clear audio quality. Other useful features on the AR-DV1 include a timer and alarm system that can start unattended recordings and digital noise reduction, including an automatic notch filter.

Digital Voice

The AR-DV1 is the first and currently the only receiver that can handle most of the digital voice systems. As you can see from Table 1, there is a long list of modes, some of which you will not find in the UK. When choosing a digital mode to receive, you simply press the Mode button and then scroll through the list of modes using the Up/Down arrows or the tuning knob. For those unfamiliar with the characteristic sound of different digital

voice systems, the AR-DV1 includes a useful Auto mode. This automatically identifies digital signals and selects the appropriate mode. During the review, I used the Auto mode most of the time and found it to be very effective for digital signals.

Digital mobile radio (DMR) is by far the most common commercial digital mode in my area and these signals were correctly identified in a fraction of a second by the AR-DV1. One of the reasons the DMR system is so popular for commercial mobile radio is its spectrum economy. This is due to its ability to carry two completely independent conversations on the same frequency. The sharing is achieved by using a radio data rate that is twice as fast as necessary for a single contact and then splitting the data stream into discrete time slots. These time slots are then allocated to the two conversations in turn (**Fig. 5**). When receiving DMR signals with the AR-DV1, you clearly need to be able to select the appropriate time slot. The AR-DV1 handles this well, thanks to a recent firmware update. When I received single time slot DMR signals, the AR-DV1 automatically selected and decoded the active time slot. However, when both time slots were in use, I simply had to press the tuning knob and then rotate it to select the required time slot, completing the selection by pressing the ENT button. Assessing the demodulated voice quality is always a bit tricky because all the digital voice systems tend to have a robotic quality. This is due to the way in which speech is processed in the AMBE vocoders. In order to get a significant bit rate reduction, the speech is deconstructed in the transmitter and then re-assembled in the receiver. The net result is that everyone tends to sound very similar with the classic robotic quality. This is not a problem with the receiver but just the way modern AMBE-based vocoding works. The demodulated voice quality is also dependent on many factors at the transmitting station such as the environment, selected bit rate and equipment quality. During the review, I found the recovered voice from the AR-DV1 to be very clear with very low levels of background noise. When writing a review, it can be difficult to find a wide range of live digital voice transmissions. Nevertheless, I was able to receive the following systems successfully: Yaesu Fusion, D-STAR, dPMR446 and DMR (Tier 1 and 2). In each case, the mode was very rapidly identified using the AR-DV1's Auto mode.

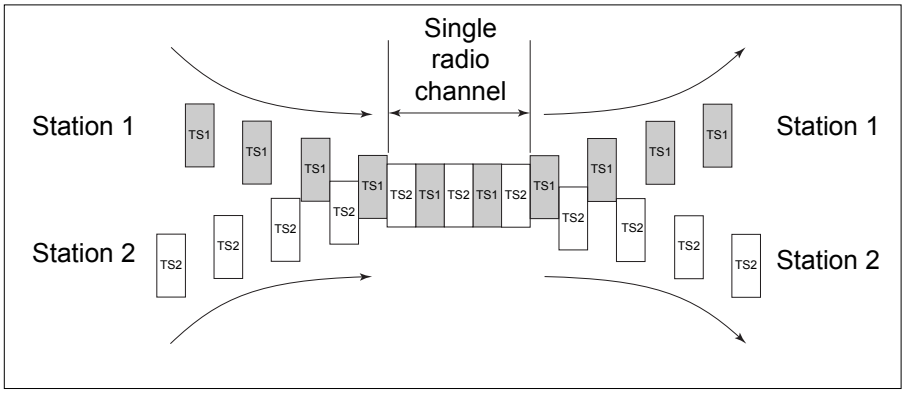

Fig. 5: DMR utilisation of time slots to support two independent conversations using a single carrier.

The AR-DV1 is primarily a digital voice receiver, so there is very little data decoding available in the current firmware build. In most cases, activating the 'Digital Decode' option simply displayed the callsign or other basic details of the current station.

Scanning and Searching

Although the AR-DV1 is promoted as a specialist digital voice receiver, it does include a useful range of scanning facilities. The search mode is a good way to find activity in a new band or location. Two search modes were provided – VFO Search and Program Search. The VFO Search was the easiest to use because it simply tuned between the frequencies shown in the AR-DV1's two main variable frequency oscillators (VFO). Toggling between the two VFOs required just a single press of the VFO button, thus making set up particularly easy. The more advanced Program Search facility lets you create and save up to 40 different search ranges, each of which can be labelled with a plain text title. Typically, you might have one for the airband, another for the marine band and so on.

The AR-DV1 also includes a custom bank-linking system where you can join banks together to make more complex search patterns. To give the user fine control over the search, the AR-DV1 has user controls to set how long it will wait on an active frequency and the time it will wait after the signal disappears. The AR-DV1 could also be set to store all the search hits automatically in memory bank 39, which was a useful feature.

Scanning with the AR-DV1 was again quite straightforward. The AR-DV1 included 2,000 memory channels arranged into 40 banks and one priority channel. In addition to storing the frequency, mode, step and so on, each memory channel could be given a plain text name tag. At the time of writing, the receiver architecture limited the available search and scan speeds to modest rates of around 13 steps per second for AM and FM (see *Stop Press*) and 2.5 steps per second for digital modes. One trick to increase the digital mode scan rate was to search in AUTO mode rather than preselect a digital mode. When you do this, the AR-DV1 actually searches in the much quicker FM mode and uses the AUTO mode detector to select the appropriate digital mode when a signal is detected. The net result is a much faster search than when using a single digital mode.

Versatile SD Card

The provision of an SD card slot on the front panel was well implemented and supported a number of useful features. The most obvious was to provide firmware updates. One of the many benefits of the AR-DV1's digital final IF and processor control is the easy addition of new features or bug fixes by installing new firmware. The AR-DV1 also features a record button on the front panel that starts a recording of the current audio with a single button press. This was great for making audio recordings on the fly. These recordings are saved as standard WAV files on the SD card. Finally, the SD card can be used to provide a useful backup and restore of the AR-DV1's internal memories.

External Control

For users that require serial port control facilities, the AR-DV1 is well equipped with the full command set available via a serial connection to the front-panel USB port. The AR-DV1 has a built-in USB-UART adapter, so a standard USB lead was all I needed to make the link to the computer. In addition to being able to control the receiver, the receiver's ID is configurable so a bank of AR-DV1s could be controlled from a single point. The command format was very straightforward and supported both read and write

Specification Summary

Frequency range:	100kHz to 1.3GHz
IF Filter bandwidths:	200Hz, 500Hz, 1.8kHz, 2.6kHz, 3.8kHz, 5.5kHz, 6kHz, 8kHz, 15kHz, 30kHz, 100kHz and 200kHz
Sensitivity 530kHz to 17.99999MHz:	0.71µV typ. for (12dB SINAD)
Sensitivity 18MHz to 1,300MHz:	0.32µV typ. (12dB SINAD)
VFOs:	3
Pass frequencies:	50 per bank or VFO
Audio output:	1.0W into 8Ω at 10 per cent total harmonic distortion
Dimensions (height, width, depth):	50 x 178 x 215mm
Weight:	1.5kg

Full specification is available on the AOR, LTD. website.
www.aorja.com/receivers/ar-dv1.html

operations. For example, to read the receiver's frequency you would send RF and the frequency would be returned in plain text. Similarly, to set the frequency to 98.2MHz you would send RF0098.20000. This simple format makes it very easy to write your own control software using Python or a similar programming language and so adapt the AR-DV1 for specialist applications. At the time of this review, the only commercial software available for the AR-DV1 was ARC-DV1 by BuTel. This is available to purchase or download as a time-limited trial. Despite being at an early development stage, the ARC-DV1 makes managing the AR-DV1's 2,000 memories so much easier. At the time of writing, the software provided management of all the AR-DV1 memories and included an option to import frequencies directly from the RadioReference.com online frequency database. Once the AR-DV1 becomes established, I am sure there will be other control solutions available.

summary

The AOR AR-DV1 breaks new ground for a wideband receiver by being the first to decode most of the unencrypted, digital voice modes in a single receiver. The use of SDR technology for the digital IF brings excellent filtering and tremendous flexibility for the future because new modes and features can be added simply by uploading new firmware. In its prime role as a digital voice receiver, it is unique but has the added advantage of a general coverage receiver combined with some useful scanning facilities. The external control facilities were also very comprehensive. Therefore, in addition to hobby radio enthusiasts, the AR-DV1 might well appeal to commercial operators that want a receiver to build into a custom, multi-receiver, surveillance system.

At the time of writing, the AOR AR-DV1 cost £1,199.95 including VAT at 20 per cent and was available from Waters & Stanton Ltd.

Waters & Stanton Ltd., Spa House, 22 Main Road, Hockley, Essex SS5 4QS.
Tel: 01702 206835
wsplc.com

My thanks to Waters & Stanton Ltd. for the loan of the review model.

Stop Press

A few days after Mike Richards submitted his review, AOR announced that firmware v1511C will provide faster scanning speeds for the analogue modes, with the narrow FM rate increasing to 37 steps per second. ●