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## AOR AR6000

Professional grade, super wideband multimode receiver reviewed

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■ Mike Richards looks at the new AOR AR6000 super wideband multimode receiver

Mike Richards takes a close look at the latest professional grade, super wideband multimode receiver from AOR Japan.

# AOR AR6000

**AOR has maintained a strong reputation in the professional scanning world for many years, with its AR5000 series receivers being particularly popular.** The new AR6000 follows in the footsteps of the much-loved AR5000 series but extends the frequency coverage and adds some new features.

The AR6000 provides continuous coverage of the radio frequency (RF) spectrum from 9kHz through to 6GHz. The tuning resolution is 1Hz for all frequencies up to 3.15GHz and 2Hz from 3.15 to 6GHz. In addition to operating as a wide range, standalone receiver, the AR6000 includes software to provide full control using a PC.

The AR6000 also features an optional in-phase and quadrature (IQ) output facility. This allows the receiver to be used with the supplied AR-IQ-II software, which brings all the usual benefits of software defined radio (SDR) such as sharp, continuously variable filters, point and click tuning and IQ recording. The demodulation modes are comprehensive and include a video decoder for monitoring analogue closed-circuit television (CCTV) links.

## What You Get

The AR6000 is housed in a sturdy steel enclosure with a speaker mounted beneath the top panel. The side panels have rubber feet on one side and a carry handle on the other, which makes the receiver easy to transport for fieldwork. In addition, using an optional kit, the receiver can also be 19in rack mounted.

The rear panel is bristling with connections, including two high quality N-Type connectors for antennas – see **Fig. 1**.

Power requirements are 10.6 to 16V DC at 2A, making it very easy to power from a vehicle supply. The AR6000 was supplied with a good quality 12V power supply using a standard UK power plug for mains operation.

The review model also included the optional IQ output board and AR-IQ-II software that provides an SDR interface to the AR6000.

I've included a brief specification for the AR6000 in **Table 1**. The full specification can be found on the AOR Japan website.

www.aorja.com/receivers/ar6000.html

The AOR AR6000 super wideband multimode receiver.

Fig. 1: AR6000 rear panel connections.

## Technicalities

Designing a receiver with continuous

### Table 1: Brief Specification for the AR6000

| | |
|---|---|
| **Frequency Range:** | **9kHz to 6GHz** |
| Frequency Resolution: | 1Hz (2Hz above 3.15GHz) |
| Receive Modes: | USB, LSB, CW, AM, FM, WFM, FM-Stereo, APCO P-25 (Option) |
| VFOs: | 5 |
| Memory Channels | 2000 (40 banks of 50 channels) |
| Scanning Speed | 100 channels/steps per second (typical) |
| Dimensions | 304 (D) x 220 (W) x 97 (H) mm |
| Weight | 5kg |

### Table 2: AR6000 Superheterodyne Stages

| Frequency Band | Conversion type |
|---|---|
| 9kHz to 25MHz | Direct conversion |
| 25 to 220MHz | Double conversion |
| 220 to 360MHz | Triple conversion |
| 360MHz to 3.15GHz | Double conversion |
| 3.15 to 6GHz | Down conversion |

coverage as wide as that of the AR6000 is not an easy task. To achieve such wide coverage, it is necessary to combine the best analogue RF technology with the latest in digital processing. In very simple terms, the AR6000 uses RF up and down conversion techniques, as shown in **Table 2**, to convert the incoming RF to a 45.05MHz final intermediate frequency (IF). This IF signal is then applied to an analogue to digital converter (ADC) to create a digital representation of the signal that is processed by a field programmable gate array (FPGA) to complete the signal processing and demodulation – see **Fig. 2**. In addition, HF signals up to 25MHz are band filtered and direct sampled. In practice, the signal path is rather more complex, so let's take a closer look at how it's done.

Much of the additional complexity of the AR6000 is due to the use of switched local filters to control the output from the mixer stages and to reduce the level of out of band signals. In cheaper, less sophisticated designs, you will find that much of this filtering is absent.

In **Fig. 3** I've shown a simplified block diagram of the AR6000. Starting at the top end of the frequency range, signals between 3.15 and 6GHz via Ant 1 are applied to a downconverter board to bring them below 2GHz. Two mixers are employed for this process, one for 3.15 to 3.8GHz and a second for the 3.8 to 6GHz range. Each mixer is preceded by band pass filters and the output is filtered with low pass filters to remove any unwanted mixing products. Next, the signal path is split into five broad bands as follows: below 1GHz, 996MHz to 1.5GHz, 1.5 to 2GHz, 2.0 to 2.5GHz and 2.5 to 3.2GHz. Signals above 1GHz are applied to a mixer and converted to a first IF of 294.5MHz. Signals below 1GHz undergo further filtering with seven banks of filtering. Signals in the range 220 to 360MHz would clash with the 294.5MHz IF frequency, so these are mixed up to 1.7045GHz before mixing down again to 294.5MHz. Signals between 25MHz and 1GHz are then converted to the 294.5MHz IF, where they are amplified and filtered before being sent to the final mixer. This brings the signals down to 45.05MHz. Here they are further amplified and filtered before being passed to the analogue to digital converter (ADC).

Signals via Ant 2 take a slightly different route because this input is designed to cover 9kHz to 3.15GHz. Signals below 25MHz use a direct digital route via a switchable attenuator and on to a bank of eight band pass filters as follows: 40 to 500kHz, 500kHz to 1.6MHz, 1.6 to 3MHz, 3 to 5MHz, 5 to 10MHz, 10 to 15MHz, 15 to 20MHz

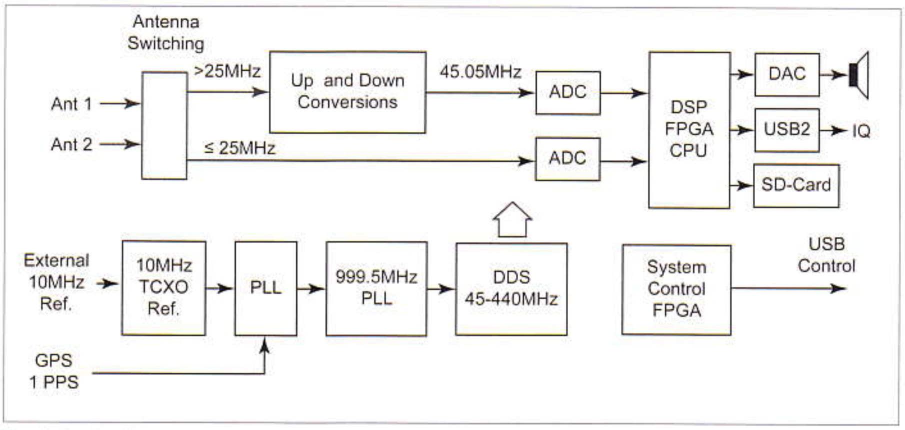



**Fig. 2: A simplified block diagram for the AR6000.**

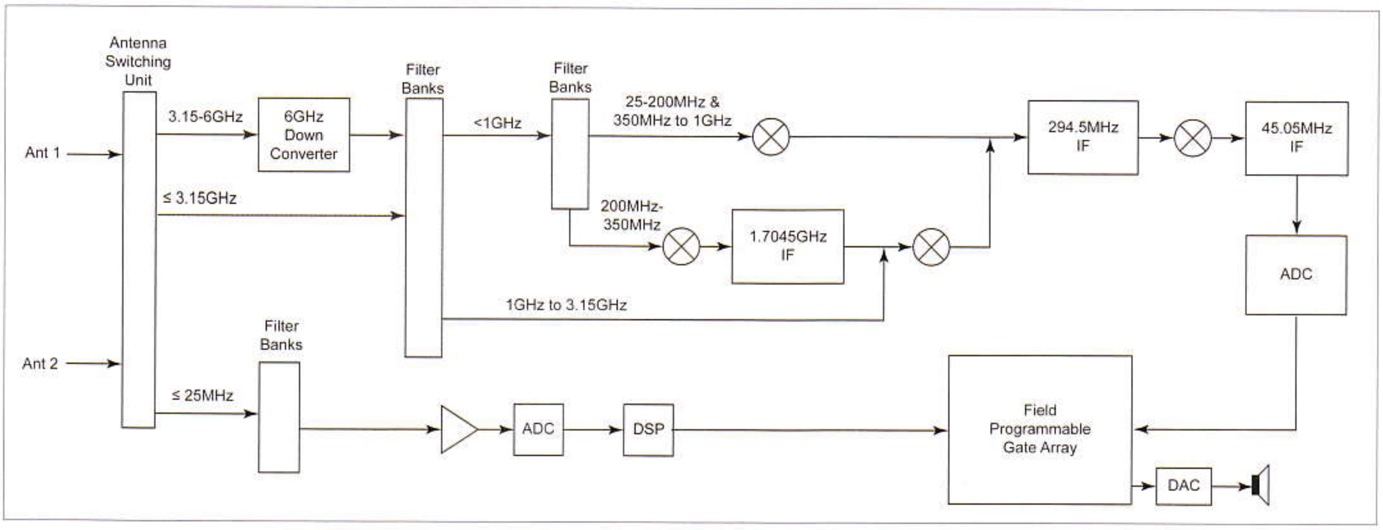



**Fig. 3: A block diagram of the AR6000 signal path.**

Fig. 4: Front view of the AR6000 showing the spectrum scope display.

and 20 to 25MHz. The output from the filter bank is applied to a 25MHz low pass filter, amplified and passed directly to a separate ADC running at 65 Mega samples per second (Msps). This in turn feeds a specialist digital signal processing (DSP) device that feeds the main CyclonII DSP FPGA. This FPGA handles all the final filtering and demodulation requirements of the receiver. FPGAs are used in this position because of their high processing speed and flexibility. Signals from Ant 2 between 25MHz and 3.15GHz follow the same conversions as Ant 1, ending up feeding into the FPGA.

With the complex mixing arrangements within a receiver like the AR6000, a rock solid local oscillator is essential. The AR6000 employs a 10MHz temperature controlled crystal oscillator (TXCO), with a basic stability of 0.1 parts per million (ppm). This oscillator provides the reference for the 999.5MHz phase locked loop (PLL) and the 45.05MHz to 440MHz direct digital synthesiser (DDS).

For many professional applications such as direction finding and special modulation systems, frequency stability to ± 0.1 ppm is not sufficient. Therefore, the AR6000 can accept a 10MHz external reference or the 1 pulse per second (PPS) from a global positioning system (GPS) receiver to provide improved frequency stability to ± 0.01 ppm.

Management of the internal switching and local oscillator functions is handled by a second FPGA which is also a CyclonII running a SuperH reduced instruction set computer (RISC) architecture.

More flexibility is provided through the use of a buffered 45.05MHz final IF output with a bandwidth of 15MHz (± 7.5MHz). The output level at this point is calibrated to be +10dB with respect to the RF signal input, so is ideal for connection to custom measuring instruments or demodulation systems.

The optional IQ module provides a USB output with an IQ stream that's 900kHz wide but I'll cover more on this later.

As you can see, the AR6000 is a sophisticated beast and a lot of care has been put into optimising the mix of analogue and digital technologies.

The full specification for the AR6000 can be found on the AOR Japan website. www.aorja.com/receivers/ar6000.html

## Operation

Despite the complex infrastructure of the AR6000, operation is remarkably straightforward and follows the conventions of previous receivers in the line.

The front panel has a traditional look with a large rotary tuning knob, keypad, analogue level meter and a large liquid-crystal display.

The tuning knob drives a rotary encoder with approximately 20 steps per revolution. However, the steps are not evident in the rotation, which was very smooth. Personally, I would have preferred a bit more weight to the knob so that it could be spun but this is a minor point.

The keypad provided easy access to the wide range of features and all the keys had a positive feel with a subtle beep to confirm operation. Operators have a love-hate relationship with beeps and you'll be glad to hear that the AR6000 can be adjusted from silent to a very loud beep via an 8-step adjustment!

For manual tuning, I found the best technique was to key in the required frequency and then use the tuning knob to complete the process. Keypad entry worked exactly how it should, that is you just have to type the significant digits and hit Enter. For example, to enter the marine VHF Channel 16 distress frequency, you just type 158.6 Enter (MHz button). Tuning to any frequency in the incredible range was instantaneous, so you could go from 60kHz to 6GHz in an instant. The AR6000 also has five variable frequency oscillators (VFO) that can be set to different frequencies anywhere in the 60kHz to 6GHz range.

One of the problems associated with such a wide tuning range is antenna selection. As I mentioned earlier, the AR6000 has two antenna inputs one of which handles the full range up to 6GHz, while the other handles a reduced range but offers direct sampling of the HF band. Antenna section can be set via front panel control, computer interface or automatically. In auto mode, antenna switching is determined by the tuned frequency but is user configurable, so you can set the changeover point between Ant 1 and 2 to suit your antenna system. For installations that are more complex, the optional AS5001 automatic antenna switch unit is available.

The configuration of the AR6000 enables reception of up to three separate frequencies simultaneously. To achieve this, one frequency has to be below 25MHz and the other two have to be above 25MHz, within 5MHz, less than 100kHz bandwidth and using the same receive mode.

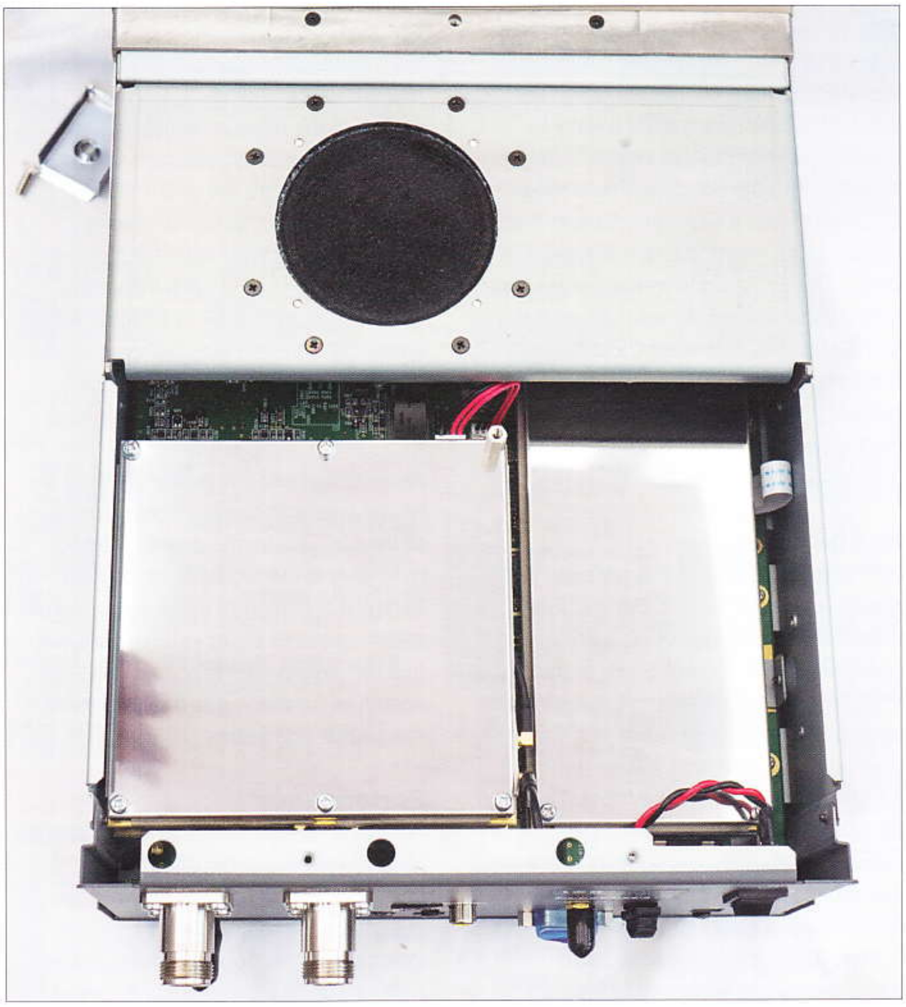
One very powerful tuning option on the AR6000 was the built-in spectrum scope (**Fig. 4**). This was activated by pressing and holding the Func button for a couple of seconds. When activated, the spectrum display shows a spectrum width that's adjustable from 400kHz through to 10MHz wide. The refresh rate was very fast so I could study band activity in real-time, which was a great way to check for local activity.

## Scanning and Searching

The AR6000 receiver includes all the standard scanning and searching options you would expect to find on this type of receiver. The memory banks can be linked to create advanced scanning patterns and individual memories can be excluded where necessary. Priority scan is included, so you can keep an eye on a favourite channel while searching out other activity elsewhere. The search function was particularly easy to use because the search range could be set by putting the start frequency in VFO A and the end frequency in VFO B.

The AR6000 also has what's known as a Cyber search. This is able to search at 100 channels per second and stores the hits in signal strength order, with the strongest stations first.

The receiver also includes decoding of continuous tone-coded squelch system (CTCSS), digital-coded squelch (DCS), dual-tone multi-frequency (DTMF) signalling and voice inversion descrambling.



**Inside the AR6000 with the lid removed.**

A large memory capacity is important with this type of receiver and the AR6000 has internal space for 2000 channels. These are segregated into 40 banks of 50 channels each to help with the memory organisation. In addition to holding the frequency and mode, each memory can store all the main receiver settings along with CTCSS/DSC tones and a 12-character comment.

Programming memories from the front panel was very easy. All I had to do was tune to the required frequency, press and hold the Enter key and the receiver automatically selected the next available memory. At this point, I could easily choose a different bank/memory number if necessary.

You will note from the photographs that the AR6000 features a secure digital (SD) card slot on the front panel. This can be used to hold more memory channels or to make audio recordings, thus further expanding its capabilities. The audio recording facility worked well but could have been so much better if it had been linked to the squelch, so that the recording could pause between transmissions.

## Computer Control

Software for direct computer control of the AR6000 is available free of charge from the AOR support site. This software is based on that provided for the earlier AR5001D and AR2300 range of receivers but with options changed to match the AR6000's features. The software is standalone but I found I had to run it in Windows XP compatibility mode on a Windows 8 system.

Control of the AR6000's features is achieved using a number of separate windows, including one that shows the full spectrum display with a very good refresh rate.

While PC control is very useful, one of the main benefits of the software is for memory management because it makes the process so much simpler. The use of a PC also gives virtually limitless memory capacity. In a practical situation, you could use the control software in the office to load the AR6000 with all the memory and search data necessary for a particular project.

In addition to enabling full control of the AR6000 via a connected computer, the control interface makes it easy to create your own custom software for the AR6000. To help with this, the receiver is supplied with a separate manual that describes all the available commands in detail. The commands were all plain text based, for example, to set the frequency to 136MHz you just send CF136 over the serial interface. Using the control manual, I was able to reconfigure one of my Python band occupancy programs to use the AR6000 in no time at all.

### IQ SDR Software

As I mentioned earlier, the review model was supplied with the optional IQ output board and the AR-IQ-II software package. The IQ output board extracts a 1.125Msps IQ stream from the AR6000's main DSP device and sends this via a standard USB port with a data rate of 72 Megabits per second (Mbps). This IQ stream is then used by the AR-IQ-II software to provide a 900kHz wide spectrum slice that's centred on the AR6000's dial frequency.

The AR-IQ-II software has been produced by Microtelecom in Italy, so it uses a very similar interface to their Perseus SDR receiver. The software was supplied on disk and is a standalone product that can be placed in a directory of your choice. Also included on the CD-ROM were the software drivers for the interface and the installation process was very well covered in the supplied printed manual.

Operation of the software was very straightforward and followed the conventions used by most of the popular SDR software packages. The screen display was dominated by the spectrum/waterfall display and included measurement markers, so it was easy to use the mouse cursor to make frequency and signal level measurements.

Tuning around within the displayed spectrum was best done using the mouse cursor, where a double click tuned the receiver to that point. The spectrum bandwidth could be set to one of nine preset values between 3.5 and 900kHz, with the narrower bandwidth being particularly helpful for signal analysis.

Just below the main display is a secondary spectrum display that shows a closer view of the currently tuned signal. Here you can adjust the demodulator bandwidth in preset steps or you can use the mouse cursor to drag the bandwidth to the desired setting.

One of the most powerful features is the IQ recording because this can be used to record the entire 900kHz spectrum to disk as an IQ stream formatted as a WAV file. The software is configured to limit each WAV file to a maximum of 2GB (3 minutes 40 seconds) with new files being created automatically as the limit is reached. Recorded IQ files can be played back through the same software and I particularly liked the facility the drag the replay cursor to the appropriate section of the file. The main advantage of IQ recording is the facility to repeatedly examine a portion of the spectrum. The major agencies make extensive use of this technology and record swathes of spectrum for automatic analysis using mainframe computers.

### Performance

Assessing the performance of such a wide range receiver is something of a challenge and I can't possibly assess everything it does, so I've chosen to look at the most popular activity areas. Antenna choice is also difficult and at least two antennas are required for this frequency range. For the review, I used the new Wellbrook ALA1530S+ Imperium for frequencies below 30MHz and a discone for everything above that. When you get into the higher UHF/microwave frequencies, you really need to move onto specialist antenna systems.

At low frequency, the **60kHz MSF** transmission came booming in and the tuning accuracy appeared spot on. A look through the long and medium wave broadcast bands in the evening showed that the AR6000 can handle strong signals extremely well. The high gain Wellbrook antenna can deliver signal levels of around 30mV at the antenna terminals and the AR6000 handled this with no sign of overload problems. Similar conditions apply on the lower frequency broadcast bands in the evening and again the AR6000 handled them with ease. However, the most likely use of the AR6000 is for signals interception and this is where it's searching, scanning and spectrum analyser features come into their own. For HF signals, I compared the AR6000 to my dedicated amateur radio kit using an A/B switch and the performance was always at least as good in terms of sensitivity and noise and in some cases slightly better. The variable width, built-in, spectrum display was particularly helpful for locating band activity.

Moving on to the VHF and UHF bands, the Cyber search was a real favourite of mine. Not only did it search very quickly (100 channels or steps per second) but it also produced a log file that showed the number of hits for each frequency and the signal level of the last hit. This was best used with the computer control software and the result was a very clear indication of the active frequencies in any given search band. Sensitivity on the higher bands was excellent and compared favourably with other top-end receivers that I've reviewed in *RadioUser*.

### summary

As you can see, the AR6000 is bristling with features and I only have space for what I think are the most significant and interesting. The combination of full computer control with IQ recording and an excellent front panel interface makes the AR6000 a very attractive receiver that will appeal to many different users. The frequency range is one of the widest available in a single receiver and I was impressed by its performance across that range. In addition to the control facilities, the IF and IQ outputs along with the facility to use an external frequency reference or GPS receiver further extend the AR6000's usefulness in professional applications.

The AR6000 is available from Waters & Stanton and retails for £5699.95. The following options are available, the IQ5001 IQ output board and software costs £549.95, the AS5001 automatic antenna switch unit costs £134.95 and the GP5001 GPS receiver for improved frequency stability to ± 0.01 ppm costs £349.95. All prices include 20% VAT and delivery to a UK mainland costs £11.00.

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**Telephone: 01702 206835**
www.wsplc.com

My thanks to Waters & Stanton for the loan of the review model and to AOR Japan for generously supplying technical support for the review. ●