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A Heavyweight at 30g: The AirSpy HF+ Discovery

Radio User REVIEW Radio User

The new AirSpy HF+ Discovery is a small box, bursting with great ideas. **Nils Schiffhauer**, DK8OK, pricks up his ears and reviews this latest SDR.

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Just another SDR? Wait, this beast is different – not only in size and price but also in terms of its concept and performance. In common with some former models of AirSpy SDRs, the new AirSpy HF+ Discovery model (henceforth: 'Discovery') is a joint venture of Youssef Touil and his team at the Chinese ITEAD studio and ST Microelectronics. This smart team has already developed, for example, the ground-breaking AirSpy HF+, which is widely considered to be the top performer in its class. The Discovery continues this success story (Fig. 1).

If you remember the HF+, you will know that this exceptional SDR left few wishes open, and there was, arguably, little room for improvement.

The HF+ Discovery (Table 1) is an 18-bit SDR with a maximum HF bandwidth of 768kHz (660kHz of it alias-free). It takes advantage of the *Polyphase Harmonic Rejection Structure* (Fig. 2). This rather complex and advanced signal processing method results in a very efficient rejection of harmonics, and excellent performance when it comes to low noise and dynamic range.

https://tinyurl.com/yxt4zjwv

The Discovery SDR is housed in a very small, lightweight (30g), shielded plastic case. The model follows the same overall AirSpy architecture, but with noise reduction and dynamic range improved even more. This is especially important on HF, where signal strengths can be demanding at dusk.

Moreover, the Discovery introduces advanced (and tracking) HF preselection to reduce adverse effects (i.e. non-linearity) from the power of the combined signals from a good antenna.

Down In the Noise and Dummy Loads

At this point, you will come to see the comparably small HF bandwidth as a real advantage. In contrast to SDRs with a wider range, the Discovery needs to cope only with small(er) segments of the HF spectrum. This results in lower noise figures and a more usable dynamic range. The latter will be especially noticeable if you use performance (passive) antennas, under good propagation conditions and at dusk.

It is at that time, in particular, when the sum-signal can be challenging for the signal processing chain of some more conventional receivers, which may then respond with significantly higher noise levels and 'ghost' signals.

Compared to the AirSpy HF+, the Discovery features much-improved rejection of internally produced spurious signals. However, this comes to light only in the thicket under -125dBm. With an antenna connected, local and atmospheric noise usually masks signals at these depths, at least below 10MHz or so.

Therefore, to dig out very weak signals, I connected a dummy load to each of the antenna sockets. This made a dramatic difference when both receivers were connected to the same PC simultaneously (Fig. 3).

Where the new Discovery delivers a smooth and very low level of noise, the AirSpy HF+ exhibits largely the same basic noise level but shows a bunch of discrete signals.

The image in Fig. 4 shows the distribution of the noise: the average of the basic noise level is roughly 1dB better with the Discovery. However, 90% of the noise covers -141dBm to -145.5dBm (with the Discovery), compared to -138dBm to -144.5dBm (with the AirSpy HF+).

Regarding the maximum value on just one discrete frequency, the Discovery is more than 12dB better.

New Markets: The Professionals Join In

This is of vital importance, especially for professional signal acquisition and identification, which need to reliably dig out even minuscule signals. As Youssef Touil told *RadioUser*, *"Our professional customers use high-tech demodulators that dig into the noise, and they deploy advanced heuristics in the decision step. For this to work, they really need a deeper sampling of the RF signals.*

"Normally, we only need the RF noise to override the quantisation noise by 5dB, to get a sufficient SNR, but for more demanding professional applications, you may need up to 30dB. That's 30 dB less dynamic range available to the receiver to fight against strong signals."

Nearly all professional decoders make use of this technique; among them are the *go2monitor* by Procitec and the *CA100* of Rohde & Schwarz, to name just two examples.

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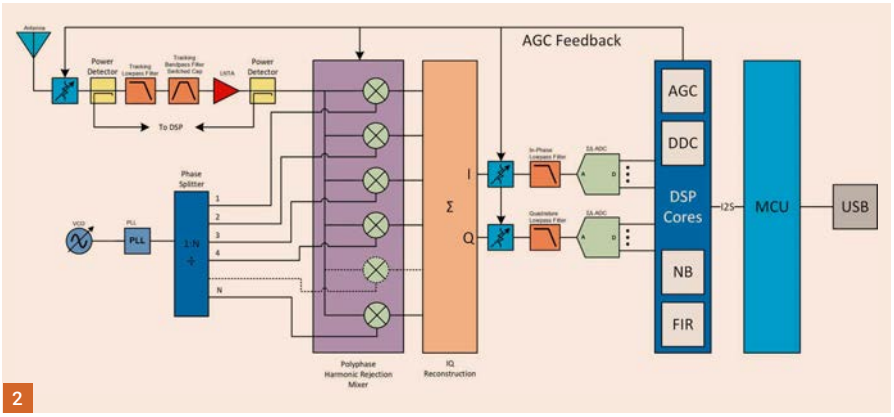

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The same is true, on the amateur level, in the case the modes provided by Joe Taylor's (K1JT) *WSTJ-X* suite of digital low-signal modes.

https://tinyurl.com/hg6rnxm

In this manner, the Discovery doesn't only open many new markets; the average listener too, benefits, as Youssef added: *"In a typical amateur setup, this translates into a more 'analogue-like' sound, because the human ear can still discern the differences up to 20dB below the peak of the noise floor; in extreme cases, this can be the difference between copy and no-copy."*

An AGC with More Bite

Keeping the low noise benefit is extremely difficult under today's signal and propagation conditions. For this to work, you need to keep a comfortable 'noise margin', as well as a comfortable dynamic range boundary, in case there is a blocker nearby.

The developers achieved these – seemingly contradictory – goals by using a less conservative – and more aggressive – approach to gain. The new AGC code pushes the gain of every stage very close to the saturation but without causing any distortion.

Youssef explained how they do that: *"We absolutely needed to relax the work of the RF AGC by attenuating the out-of-band blowtorch signals that would otherwise cause power estimation instability. This was achieved using low-order filters, providing both high linearity and low noise. In turn, these filters show stop-band attenuation of only between 20dB and 35dB."*

He also stated that the filters do not require more than 20dB of out-of-band rejection to get optimal reception. What might look counter-intuitive, actually results in a high performance level, not seen before in this size and form factor. In tests against a passive attenuator, the silicon attenuator built into the Discovery won't be overridden, even within a tough signal scenario.

Fig.1: The 'Discovery' (foreground) is a black beauty; the Airspy HF+ is in the background.
Fig.2: AGC feedback and tracking filters make the difference, compared to many other SDRs.

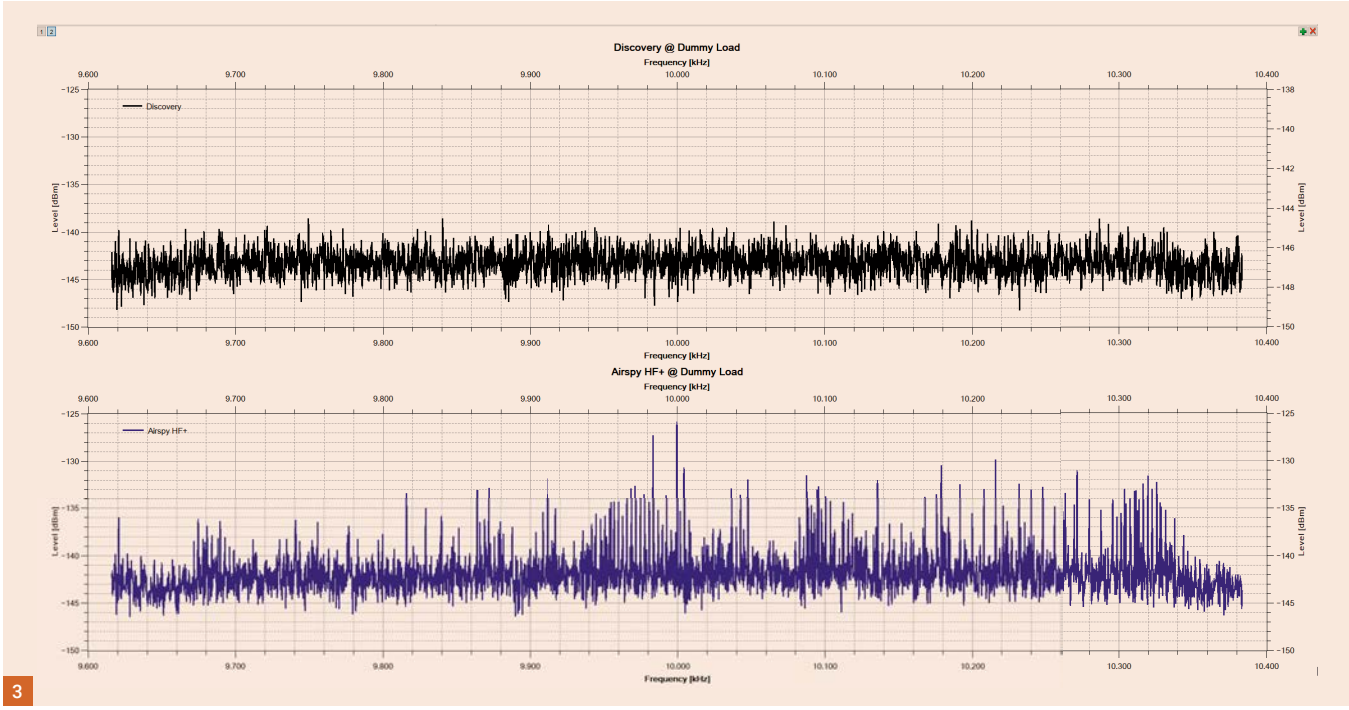
Tailored Software, But Open To Others

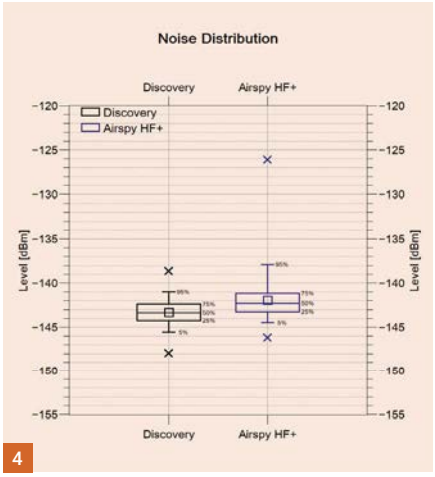
The receiver easily connects to any USB2.0 socket and is powered by it. Without the need to install any drivers or so, it instantaneously comes vibrantly alive with the *SDR#* software (Figs. 5a and b).

SDR# is, more or less, tailored to all SDRs of the AirSpy line. Don't forget to connect the receiver to an aerial, preferably, as Youssef

AirSpy HF+ Discovery: The Specifications

Receiver type: Passive mixer with Polyphase Harmonic Rejection structure; IF ADC with 4th-order multi-bit noise-shaping technology, DDC I/Q output with 18bit resolution and alias rejection performance of 108dBc
Frequency ranges: Range 1: 500Hz to 31MHz (HF); Range 2: 60MHz to 260MHz
Tuning resolution: 1Hz
Modes: depending on the software, e.g. AM, AMS, LSB, USB, CW, FM-N/-W
MDS (typ.): -140dBm (0.02µV/50Ω @15MHz at 500Hz bandwidth) -141.5dBm at 500Hz bandwidth in FM Broadcast Band (64MHz to 118MHz) -141.0dBm at 500Hz bandwidth in VHF Aviation Band (118MHz to 260MHz)
IP3: +15dBm on HF at maximum gain, +13dBm on VHF
BDR: 110dB on HF, 95dB on VHF
Phase Noise: -110dB/Hz at 1kHz separation on 100MHz
Frequency Stability: 0.5ppm
HF bandwidths: up to 768kHz (alias-free: ca. 660kHz)
Max. RF Input: +10dBm
Interface: USB2.0 (power source is USB socket)
Dimensions/Weight: 45 x 60 x 10 mm/30g
Temperature Range: -45°C to 85°C.





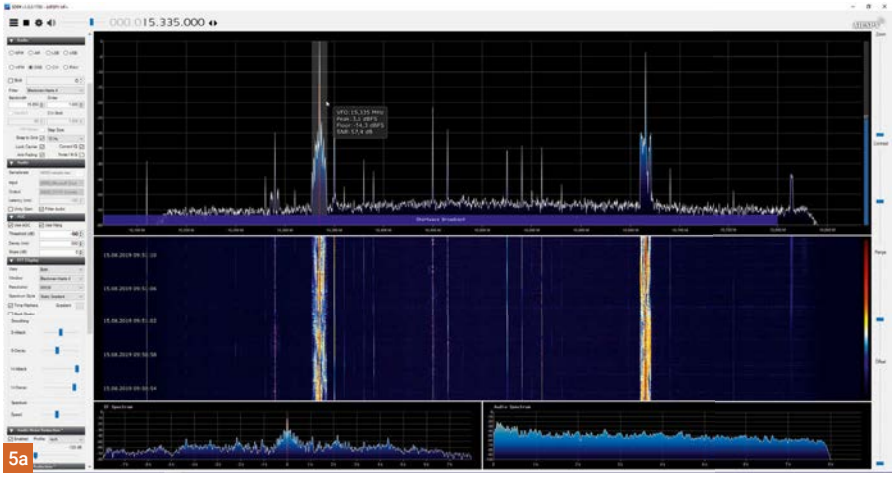


Fig. 3: At the top (Discovery) you can see the random noise expected from mainly natural sources; at the bottom (AirSpy HF+) is noise, plus internally-generated spurious signals. The differences occur below -125dBm/Hz – achieved here with dummy loads. Fig. 4: The noise distribution illustrates the difference you experience from Fig.3. On average, the Discovery is slightly better than the AirSpy HF+; on many discrete frequencies, there is a noticeable difference. Fig. 5a: In the 19m-band, with the software SDR#, and a full spectrum, including an SNR reading of China Radio International from Kashi, and a full spectrogram, plus IF spectrum and audio spectrum. Fig. 5b: A 24kHz-wide narrow spectrum, featuring the 'digital waterholes' in the 20m amateur radio band, to further optimize the SNR for connected decoders. Fig. 6: High quality on even the lowest of frequencies – a look onto the VLF/LF-range with loud signals in the clear, even from North Dakota (NML4, 25.2kHz) and Puerto Rico (NAU, 40.7kHz). Fig. 7: A recording of an overnight session around 7.3MHz, with plenty of strong signals.

recommends, a passive type, which delivers the best signal-to-noise ratio. There is one socket only for HF and VHF, making it easy to connect an active or passive broadband aerial.

The Discovery also runs with Simon Brown's *SDRC V3,* with *HDSDR, Studio1, GQRX, CubicSDR and GNU-Radio*, to name but a few. *SDR#* already contains a server software for Windows, and this is available for 32bit ARM boards, as well as Linux x64 and Linux x86. Additionally, there is a lot of third-party software available, among it decoders for ACARS, ADS-B and DAB/DAB+.

Developer resources consist of API libraries for Windows, Mac and Linux; all the software hitherto mentioned is free to download.
https://airspy.com/download/
https://tinyurl.com/y4dt8tx6

It can be piggy-packed onto a Windows' tablet, even to a budget model, like the Higole F1, retailing for considerably less than £200.

In my view, such a combination makes for a world band radio with outstanding performance and features.

On the Road

Comparing the AirSpy HF+ to the new Discovery is not easy. Even with an above-average antenna, like a quad-loop with 20m circumference, I found no eye-catching differences – not even during an overnight session (recorded) around 7.3MHz (Fig. 7). This is Europe's most challenging range with a

plethora of big, and many weak, signals.

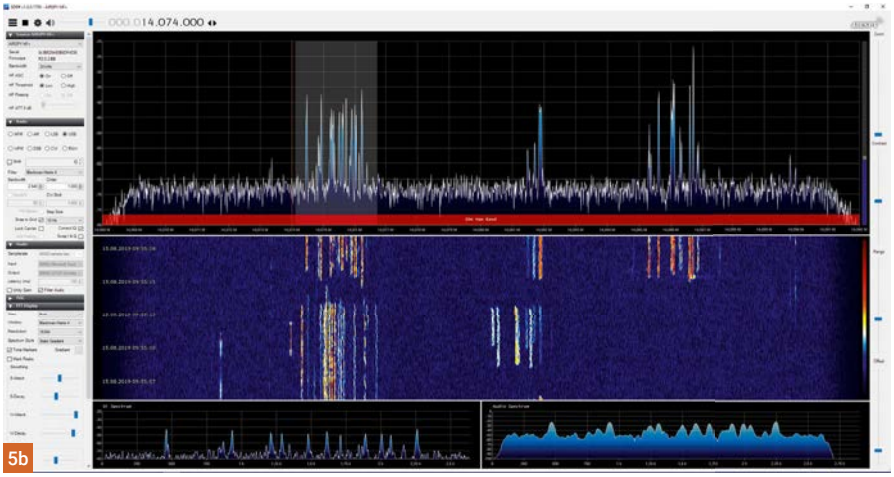
Moreover, if you pick out the really weak ones, with dull-modulated audio, you will soon be even more enlightened. Then the Discovery shines with less noise, and, astonishingly, less crackle. In at least 80% of these difficult cases, intelligibility with the Discovery is clearly better. With very few stations, this receiver will even make the difference between understanding the identification of a station and not copying it.

In August, I also tested the Discovery with the most 'demanding' band, the Very Low Frequency range (VLF). Here most SDRs – and certainly the majority of budget SDRs – reach their limits, lacking sensitivity and filling up the band with internally-generated signals. Thanks to a newly-developed input section to start at even 500Hz, this receiver shows outstanding strong and clean signals from as far as the US Navy in Australia (19.8kHz, Fig. [new]), North Dakota (25.2kHz) and Puerto Rico (40.7kHz, both Fig. 6).

Even better than that, the Discovery, in my view, maintains its stunning performance levels, when compared to SDRs with a price tag ten times higher (although the latter can provide a wider HF range for recording).

If you can live with the Discovery's 660kHz wide, alias-free, bandwidth, you will run into severe difficulties to find better performance at any price; a performance, at that, which can be realized in even an average (or slightly above-average) listening post or shack.

I simply have never seen a better performance at this price and, of course, these dimensions and this weight: 30 grams turned out, performance-wise, a true heavyweight.



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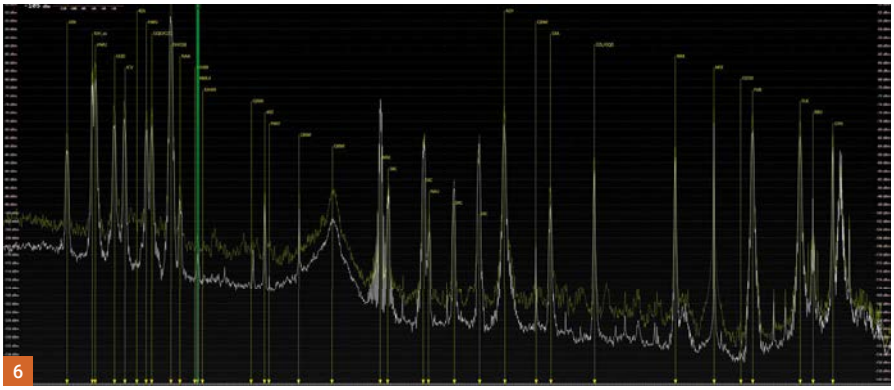
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Many thanks to Chris Taylor (Moonraker) for the loan of the review model. Special thanks also to Mike Devereux (Nevada), Peter Waters (Waters and Stanton), Youssef Touil (AirSpy) and Fernando Duarte (Fenu). The latter not only maintains a well-informed website around receivers and listening but also had some valuable input in the Discovery at the development stage.

https://airspy.com/airspy-hf-discovery
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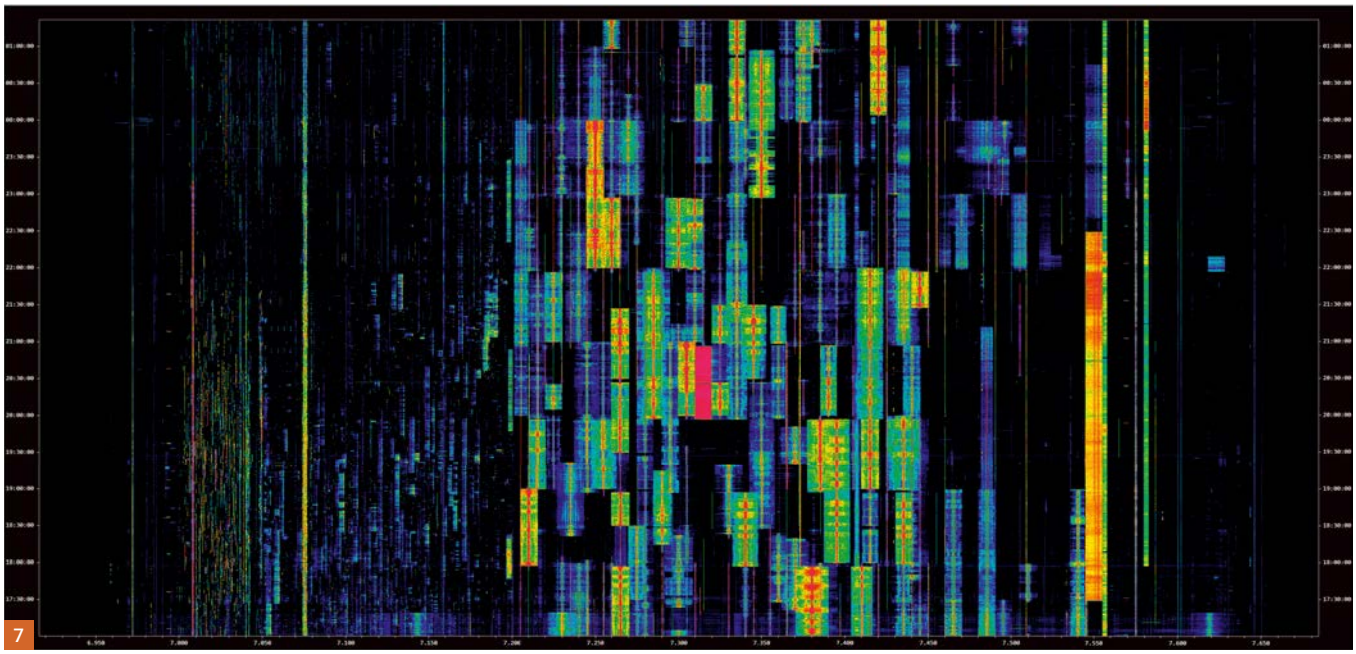
www.nevada.co.uk
https://tinyurl.com/y3o7um2d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