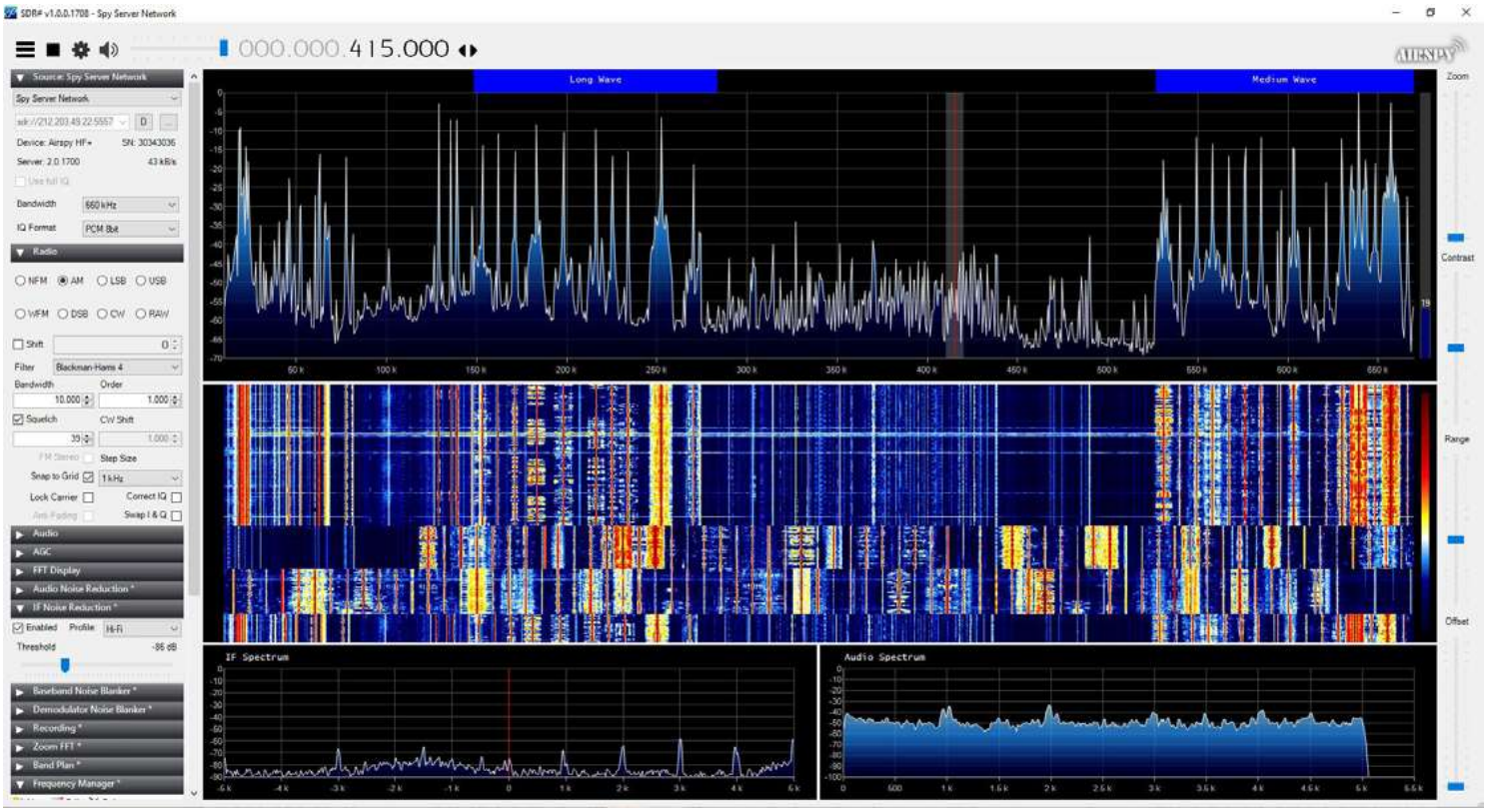


Reception on longwave and medium wave from central Europe using the HF+ Discovery prototype. (Courtesy: Fenu-Radio)

TSM Reviews:

AirSpy HF+ Discovery: It's a Whole New World of Radio

By Larry Van Horn N5FPW and Gayle Van Horn W4GVH

My motto has always been: "Give me a shortwave radio and I can monitor the world." But the world of shortwave radios is not the same one that I started with in the hobby many years ago.

The world of radio receivers and its associated electronics has undergone quite an evolution over the last 130 years or so that they have been around. As technology has advanced, so has the capability, spectrum coverage, and utility of the receivers that we use in our radio monitoring hobby.

The warmth and glow of tube radios were starting wane in the late 1950s and early 1960s with the introduction of radio circuits that used tiny chips of germanium known as transistors. Due to temperature concerns, germanium was soon replaced by silicon-based transistors. Consequently, most major radio manufacturers started producing transistor-based receiver designs that didn't need a tube checker anymore.

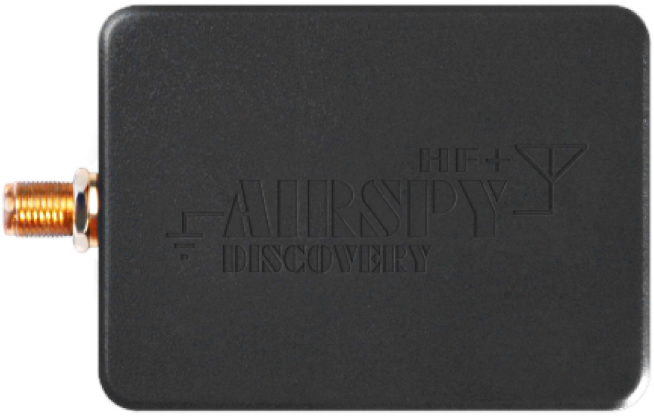
Most radio old-timers (including the authors) still have found memories of those boat anchor days, you can usually see a collection of those wonderful old tube-based radio bargains at your local hamfest flea market or junk in the trunk.

It was even the humble transistor that launched the public safety scanner market. They started out as tunable analog dial radios, then migrated to crystal-controlled radios. With the invention of integrated circuit (IC) chips, the revolutionary phase locked loop (PLL) circuit was born that propelled the scanner industry to produce the high technology programmable scanners we use today.

It is the integrated circuit that has created the personal computer/smart devices boom, a marketplace that continues evolve even as this piece is being written.

Shhh! – It's All About the SDRs

While the term digital radio has been around since the 1970s in US government circles, it wasn't until 1984 that the term software radio first surfaced. At first, many old-timers in the radio hobby scoffed at the idea that any radio that didn't have a tuning knob and all the circuitry associated



Weighing slightly more than one ounce, this small package delivers huge HF+ performance. AirSpy HF+ Discovery ($169) covers .5 to 31 MHz plus 60-260 MHz. (Courtesy: Airspy)

Weighing 65 pounds, the R-390A/URR was a go-to receiver for many shortwave listeners for decades. Above is the Stewart-Warner Electronics version. (Courtesy: Universal Radio)

with it wasn't a real radio. People pushing a computer-based technology were on the outside looking in as far as major manufacturers were concerned. It did not take long for those whispered words, software-defined radio, or SDR, to come out of the shadows and be embraced by the radio hobby industry.

In 1991 a little-known Australian company known as WiNRADiO leveraged computer technology to launch their first software-defined radios. They were soon followed by another industry giant, Icom, and their PCR series SDRs.

Founded in 2003, FlexRadio Systems in Austin, Texas, was a pioneer in the design and development of SDRs for the amateur radio market. Many in the industry will admit that FlexRadio' s innovative approach to SDRs and its supporting software has changed the face of amateur radio as we know it today.

Even in its heyday our beloved old *Monitoring Times* magazine had a Computer and Radio column written by John Catalano that covered many of the early battles between hardware-based radios and the early SDRs as they were.

All these new technologies have led the way to a whole new generation of radios, that wouldn't have even been thought of just three decades ago.

One of those new SDR radios now available is the focus of this review—the AirSpy HF+ Discovery.

What is SDR Technology?

In order to appreciate the marvel that is the software defined radio like the Airspy, a brief primer is in order.

The software-defined radio is a technology that offers a simple alternative to bulkier analog radios, adding more flexibility and performance in a much smaller case. You may not realize it but SDRs are everywhere, from your cell phone to your wireless headset and even your cable modem.

In a nutshell, an SDR is a radio where the components that have been traditionally implemented in hardware (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded system.

A basic SDR system may consist of a personal computer equipped with a sound card, or other analog-to-digital converter, preceded by some form of radio frequency (RF) front end. Significant amounts of signal processing are handed over to the general-purpose processor, rather than being done in special-purpose hardware (electronic circuits).

The SDR software performs all the demodulation, filtering (both radio frequency and audio frequency), and signal enhancement (equalization and binaural presentation).

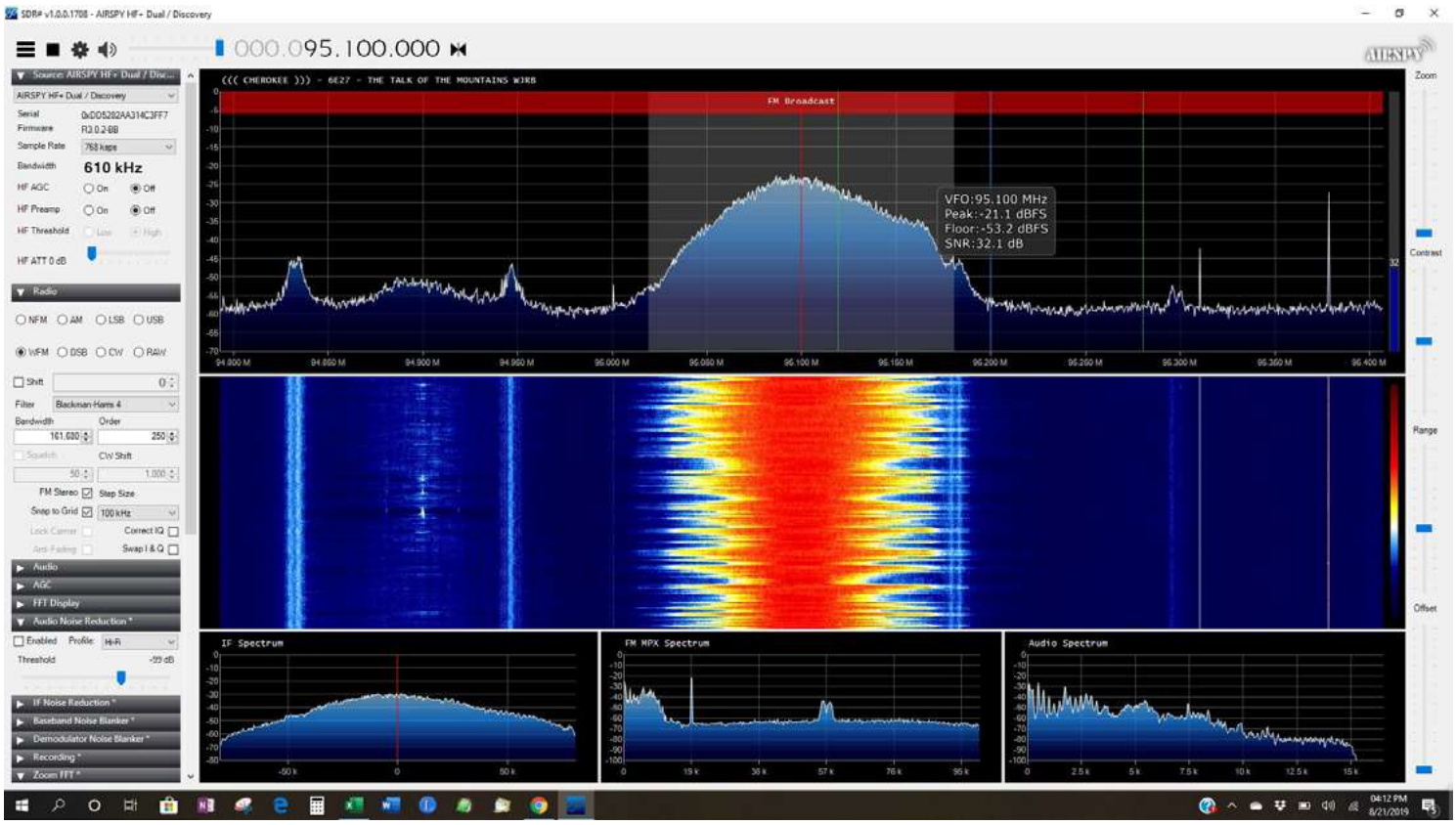
SDR usages include every common amateur modulation: Morse code, single sideband, frequency modulation, amplitude modulation, and a wide variety of digital modes such as RTTY, SSTV, packet radio, and many others. SDRs are also being used to demodulate Digital Radio Mondiale (DRM) broadcast streams without the need to purchase a hardware-based receiver. Listeners using this method can use the DREAM open-source project that decodes the coded orthogonal frequency division multiplexing (COFDM) technique to listen to DRM transmissions.

The bottom line on decoding various digital modes and modulation schemes is this. The days of the hardware decoder are over. Now with an SDR, in order to receive a new modulation or digital mode, you only need to upgrade a software package or firmware in the radio instead of replacing the whole hardware-based unit as we have done in the past.

The Airspy SDRs

Airspy is a line of popular SDR receivers developed and designed to achieve high performance at an affordable price. They accomplish this using some innovative combinations of digital signal processing (DSP) and RF techniques. Youssef Touil, the owner of Airspy and the developer of the company SDRs and their software support, was the hardware engineer for the HF+ Discovery project, the SDR we are reviewing.

In our online interview with Youssef, he stated, "My goal with this new SDR was to incorporate a built-in pre-



DXing the AM and FM bands on the Airspy HF+ Discovery shows great detail of the actual signal on the scope. This is WJRB-FM from nearby Chattanooga, Tennessee. Note RDS data in upper left under the frequency. (N5FPW photo)

selector and build a smaller and cheaper SDR compared to the HF+ at a cheaper price." Based on our initial testing we agree that he has accomplished those goals with the HF+ Discovery.

Initial Testing

In the interest of full disclosure, Airspy is an advertiser in *The Spectrum Monitor*. In keeping with *TSM* editorial guidelines, our test unit was purchased by the authors from Airspy US. The results of our tests were not reviewed by the manufacturer prior to publication.

We received prompt and courteous service from the company. The unit was shipped from their New Jersey location via USPS Priority Mail., It was well packaged and arrived in good shape.

Normally, prior this section in my reviews, is the part where I would tell you what is in the box. That is quite simple in this case – the HF+ Discovery unit itself and a shielded micro-USB-to-standard-USB connector. A complete set of specifications for this unit can be found in Table One.

Let me make this clear from the onset, there are no instructions or manuals included in the box. You will need to interface with the AirSpy website for installation and additional operational information (see the links listed in Table Two).

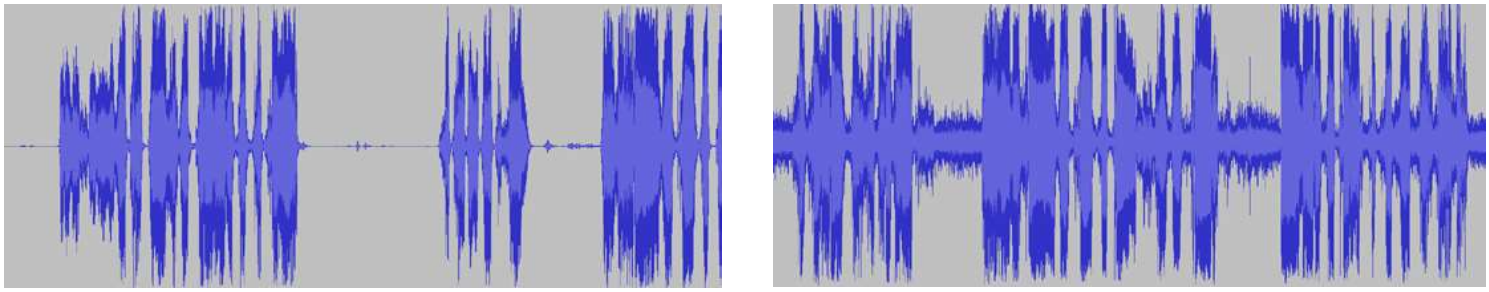
The first test I ran was in the VHF/UHF spectrum. A quick check of the seven NOAA nationwide weather frequencies showed activity that was consistent with stations regularly heard at our location. Six out of seven frequencies were received with signal strengths I normally see on my other radios in the shack that cover these frequencies.

The next big test was in the FM broadcast band. While I specialized in HF utility and all band military monitoring, I still DX my radio roots and prowl the AM/FM bands looking for new stations so I am very familiar with the AM/FM bands as received here in Brasstown.

As I started tuning up of the bottom of the FM broadcast band, I managed to snag two new FM stations – KRLE-FM 89.7 Carbon Hill, AL (182 miles) and WMAB-FM 89.9 Mississippi State in Starkville, MS (277 miles). These two were heard using my roof mounted Grove Scantenna. While I didn't have dead band conditions during this part of the test (probably some locally enhanced tropospheric bending), both stations were very strong, and the software even decoded the two stations radio broadcast data system (RBDS) streams.

The HF+ Discovery's excellent FM performance is achieved by the receiver using signal paths composed of band filters; high linearity low noise amplifiers (LNA) with a stepped automatic gain control (AGC) and a harmonic rejection mixer and intermediate frequency (IF) filters that have been optimized for the FM broadcast band. The amplifier gain is switchable in 3 dB-steps and fully controlled by the AGC function running in the DSP module. Extended VHF/UHF (118-260 MHz) coverage uses a second tuner, but it does have reduced performance.

Radio tours through the 2-meter ham band, VHF-public safety band, the civilian aircraft bands produced similar



Left: An audio signal without processing. Right: Same audio signal noted as noisy but now with using the Airspy digital noise reduction processing (courtesy Airspy)

and acceptable results. I was very pleased not to see any FM band interference in any of the other VHF bands I checked.

HF Bands and Below Circuitry

Airspy HF+ Discovery achieves excellent HF performance by means of a low-loss preselection filter, high linearity LNA, high linearity tunable RF filter, a polyphase harmonic rejection (HR) mixer that rejects up to the 21st harmonic and multi-stage analog and digital IF filtering. Harmonic rejection can be a key issue in some wide-band HF SDR receivers because of the large signal bandwidth of the input signal.

The 6-dB stepped AGC gain is fully controlled by the software running in the embedded DSP module which optimizes the gain distribution in real time for optimal sensitivity and linearity.

Once the received signal leaves the IF-filter it is digitalized by an IF analog to digital converter (ADC) for further signal processing in the digital circuitry.

This IF ADC uses 4th order multi-bit noise shaping topology that has a very high dynamic range and linearity. One of the critical specifications of any SDR is the IF-ADC sampling rate. It is determined by a control algorithm running in the receiver's embedded DSP.

Airspy uses an advanced technique that adjusts the sampling rate depending on the tuning frequency with the goal of avoiding spurs and other unwanted signals by the switching discrete sections of the IF-ADC.

Once the IF signal is digitalized, the high sample rate I/Q (I is In-phase and Q is Quadrature) stream is then frequency translated and processed to the decimation stages. After every stage, the sample rate is reduced, and the resolution increased. The final signal at the output has 18-bit resolution and an alias rejection performance of 108 dBc. The data is then scaled to 16-bit and sent to the micro-controller for streaming through the USB port to the control software.

So How Does It Work Below 31 MHz?

The big problem of the low-budget receivers is strong signal overload due to many, sometimes very strong, summed signals on the shortwaves. Unfortunately, most the low-priced SDRs have never been preselected, mostly for cost reasons, and will suffer strong signal overload especially in high RF areas (urban/metro areas).

Without exception, these devices usually have major problems with the antennas that radio hobbyist use. They overload very quickly, which makes serious reception on long, medium and shortwaves rather difficult.

The HF+ Discovery is the big exception. Despite its small size, it has a built-in preselector, that consists of several low and high pass filters. The difference is noticeable when I compared it to several other SDRs we own. Again, regardless of the antenna we used there was zero overloading issues noted during our test.

During the test we used an 80-meter G5RV, a 100-foot long wire, and a Kiwi medium wave amplified loop, I did not notice any overloading issues from the long or medium wave in the VLF or longwave spectrum. Likewise, I saw no indication of overloading anywhere in the shortwave radio spectrum. That is pretty good performance for a radio package weighing in at just one ounce.

Noise Reduction Processing

During our online chat, Touil touted their work with this unit in noise reduction. "We spent a lot of time understanding RF noise, its structure, and how it interacts with legitimate signals," Youssef said.

"Today, we have one of the most flexible and acoustically pleasant noise reduction algorithms of the market. The applications range from high-fidelity hiss removal for broadcast FM signals, to unburying weak SSB signals from the noise floor. Our algorithm doesn't kill the highs to give you a false impression of loudness, yet it doesn't have the typical high tone artifacts that plague popular noise reduction algorithms like LMS and spectral subtraction."

This, in my opinion, is where the HF+ Discovery really shines. We have seen in our area over the last few years a gradual rise in noise levels on all bands. Everything from noise generated by our inhouse Wi-Fi system, the electric company meter monitoring system, to electric fences in the area. All these and more have contributed to a rise in our general noise levels which directly impact radio listening.

For me this was going to be the make or break area of this review. I can honestly say that the Airspy HF+ Discovery was not only up to the task, but it exceeded my wildest

expectations.

Whether it was in the VLF, long-medium wave, shortwave or VHF/UHF bands, this unit's noise reduction really does work. Using the SDR# software you have four separate noise functions that can be implemented as the operator wants or needs: Audio and IF noise reduction that uses the HF+ Discovery noise circuitry, and a broadband and demodulator noise blankers.

But don't take my word for this. I have two examples that have been posted to the Airspy website. First, at **https://airspy.com/downloads/dnr_ssb.mp3**, is a recording of a very weak SSB signal in the 40-meter ham band, with and without the Airspy's digital noise reduction circuitry. They also have another recording made during an 80-meter ham band pileup at **https://airspy.com/downloads/Csete_80m_20171118_231457Z_3765000Hz_AF.mp3**.

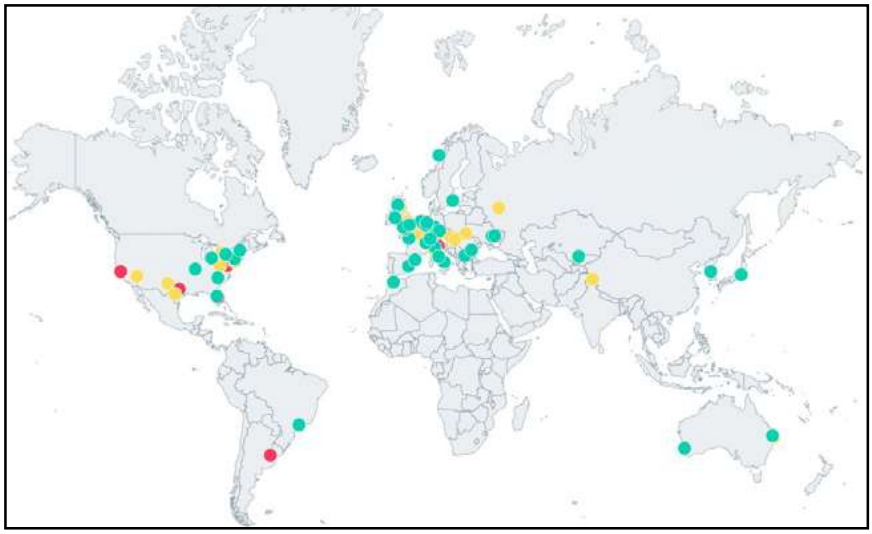
During our noise test (see my comments earlier regarding my noisy neighborhood), I managed to log a new military utility station on 9-MHz near high noon EDT.

While making a run in the 31-meter band for shortwave broadcast stations, with the IF noise reduction feature on, I noted a very strong RTTY signal on 9830 kHz. At first, I thought it might have been a harmonic or other unwanted signal showing up where it wasn't supposed to be. Further investigation revealed it was a new station for me, a Department of Defense station at Davidsonville, Maryland, (near Andrews AFB) that was transmitting a Stanag 4481, 850/50, KG-84 Crypto RTTY signal. This one has been around for a while but has been well hidden in my local noise floor till now. Imagine a receiver with noise reduction circuitry that really does work at your monitoring post. Job well done Airspy.

Streaming your Airspy on a local network or the Internet

We have two radio hobbyists in this household who like to DX, usually at the same time. So, do we go out and buy two of everything? Not with the AirSpy HF+ Discovery.

With the AirSpy SDRs they have concentrated their state-of-the-art DSP and networking techniques into their SpyServer software that will allow multiple users to stream high quality I/Q data from the same receiver at the same time. No compromises in the quality were made like you usually see in most web SDR interfaces. You get actual I/Q data you can process on your computer from your AirSpy receiver. If you have an Internet connection on both ends, you can set it up in a remote site and stream that I/Q to any location on a local network or to a remote site. You can even use all the available free plug-ins available for the SDR# software and digital decoding software from your remote operation since you are streaming true I/Q via the server software.



Airspy's online SDR network lets viewers explore the world of HF as seen from these locations. (Courtesy: Airspy)

The server software is highly scalable and can run on computers as small as the $7 Orange Pi Zero to top end 64-bit servers with multiple core CPUs, including the popular Raspberry Pi series.

AirSpy has its own web-based network of AirSpy radios you can use. All you have to do is download the free SDR# software, launch a browser to **https://airspy.com/directory**/, enter the SDR address/port number in the source menu option and you have a great worldwide network of receivers at your fingertips.

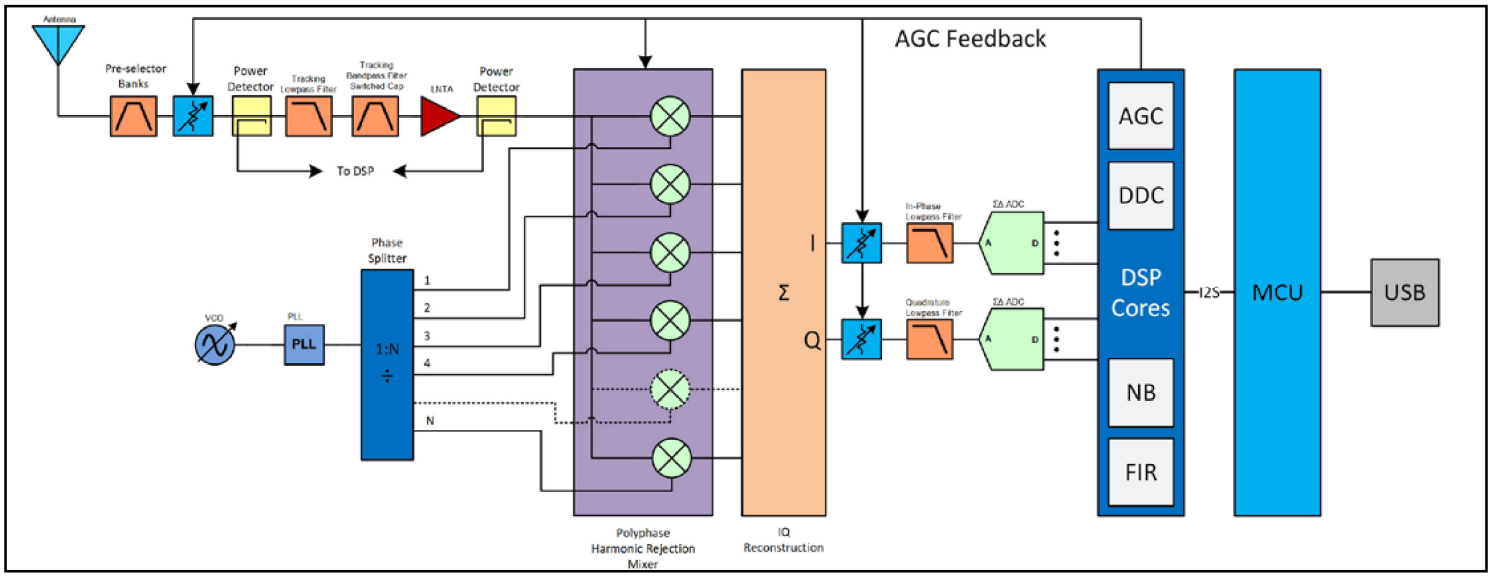
If you would like to get a test of what this new SDR can do. One of the early prototypes is streaming in the Airspy network. It is on-the-air courtesy of Fernando Duarte (more on him and this radio later). It is in central Europe and you will be amazed at what it hears. Initiate the IF noise reduction software and take a tour of the longwave-mediumwave spectrum from that location. I am sure you will as impressed as I was. That address is sdr://212.203.49.22:5557 and it is currently using a Datong AD370 active dipole.

Finally . . .

One of Europe's most respected reviewers and a beta tester for Airspy, Fernando Duarte aka Fenu, recently posted a review of a HF+ Discovery prototype that did not have all the preselectors that the production release now has.

On his review page you will find audio samples, screen grabs, interior pictures of the unit and a lot more (see table two). What made this review so special is that he also owns the $2000 WiNRADiO G33DDC Excalibur Pro. He put the two radios head to head, and his conclusions are nothing short of amazing.

The final paragraph of Fenu's review: "The Airspy HF + Discovery (the "he" in this article) delivers in a head to head race with one of the best SDR! ... Striking is the very low noise, which ensures a relaxed lis-



Airspy HF+ Discovery architecture. (Courtesy: Airspy)

tening. In some situations, it outperformed the WiNRADiO G33DDC in terms of low noise and sensitivity. On usual hobby antennas, it delivers exceptionally good reception on VLF, long, medium and shortwave with minimal overloading symptoms. Also, the VHF / UHF range gave good results. With its preselection and sophisticated software, Airspy offers with the HF+ Discovery the best tuner based SDR for shortwave listening for little money. A small drawback is the hard to adjust noise blanker SDRSharp what the nearby pasture fences could not filter properly from the audio. The Airspy HF+ Discovery is a real find! Excellent price to performance ratio."

A copy of that review is available at **https://www.fenu-radio.ch/Airspy_HF-Plus_Discovery-en.htm**

Some Final Thoughts

The Airspy line has a very fine reputation in the radio hobby. In reviews published in Gayle Van Horn's 2018 Global Radio Guide and the 2019 World Radio TV Handbook, the Airspy HF+ received high marks by the testers and a "Best Value" rating. The Airspy HF+ Discovery has built on its predecessor's architecture and improves the unit's reception ability in the area of noise and signal handling capability.

We hope to have a more extensive review that will include the testing the Airspy HF+ Discovery using the W6LVP amplified receive-only magnetic loop antenna in our Winter 2018-2019 Global Radio Guide. That should be available prior to Christmas.

In the meantime, you can get an in-depth review of the Airspy HF+ and W6VLP loop by Loyd Van Horn W4LVH, in the Summer 2018 International Shortwave Broadcast Guide (Kindle format) at Amazon.

The Airspy HF+ Discovery has set a new standard in terms of reception performance with the extra pre-selectors for all the supported bands, a new DSP core that optimizes gain distribution, and advanced real time noise filtering to let you dig deeper in the noise for those elusive signals.

Based on our testing, the Airspy HF+ Discovery has no equal at its price point. You will find world-class performance and an amazing piece of hardware wrapped up in a package smaller than a matchbox.

Table One: Manufacturer Technical Specifications
Cost: US$169 plus shipping

Receiver Frequency coverage:
ELF-HF 500 Hz (0.5 kHz) - 31 MHz; VHF 60 - 260 MHz.
ADC (2): Up to 36 MSPS (2 - High Dynamic Range Sigma Delta ADCs)

Automatic Gain Control: Smart AGC with real time optimization of gain for best SNR

Band Pre-Selectors:

- HF Pre-selector (4 filter banks) with cutoff (corners) at DC, 5, 10, 17 and 31 MHz
- VHF Pre-selector (Air, Ham (2 meters), Commercial and Military VHF)
- FM Broadcast Pre-selector (Japan, US, EU, OIRT)

Blocking Dynamic Range (BDR): HF 110 dB; VHF 95 dB

Clock (Low phase noise) accuracy: 0.5 ppm

Combined selectivity (hardware + software): 150 dB

Digital Down Converter (DDC): Embedded 18-bit, 22-bit resolution at 3 kHz channel using DDC (SDR# and SDR-Console

Frequency adjustment capability: 1 ppb

Filters: High pass filters at 0, 5, 10, and 17 MHz; Low pass filters at 5 and 31 MHz; Bandpass filters at 60-118 and 118-

260 MHz; and polyphase tracking bandpass filters for close range interference suppression.
I/Q Output 660 kHz at 768 k/samples per second Image

Rejection (software): 120 dB

Maximum RF input: +10 dBm

Minimum Discernible Signal (MDS)/Sensitivity (smallest receivable signal over the noise floor)

- 140.0 dBm (0.02 µV / 50 ohms at 15 MHz) MDS typical at 500 Hz bandwidth in HF
- 141.5 dBm MDS typical at 500 Hz bandwidth in FM broadcast band (64-118 MHz)
- 141.0 dBm MDS typical at 500 Hz bandwidth in VHF/UHF bands (118-260 MHz)

Noise Reduction: State of the art software algorithms.

PLL: Very low phase noise -110 dBc/Hz at 1kHz separation at 100 MHz, Third Order Input Intercept Point (IIP3): HF +15 dBm; VHF +13 dBm. IIP3 both measured at maximum gain.

Operating Modes: AM, SAM, LSB, USB, CW, FM or software dependent

Spectrum Bandwidths: 16/24/32/48/64/96/128/192/256/384/768 kHz (SDR# V1.0.0.1708) or software dependent

Antenna: Single RF SMA female connector input.

Covers all bands with high linearity switching that improves input matching down to virtually DC.

Receiver Output to Computing Device: Micro USB port to standard USB cable (supplied)

Operating Voltage: 5V (via USB socket)

Industrial Operating Temperature: -45°C to 85°C

Case size: 1.8-inches (45 mm) x 2.3-inches (60 mm) x .4-inch (10 mm)

Weight: Slightly more than one ounce.

Minimum hardware requirements: 1GHz Pentium or ARM; 1GB of RAM (to run your own OS, HF+ barely needs 1MB of memory); High speed USB 2.0 controller; Fully Open-

Source driver; Open source, multi-platform user mode driver libairspyhf on github

Operating System: Windows Vista, 7/8/8.1/10, No drivers required -100% plug-and-play, Linux; BSD; and OSX.

Supported Hardware: Intel compatible PC; Raspberry Pi 2 and 3; Odroid C1, C2 and XU4l Many other Single Board Computers (SBC)

Supported Software: SDR# (SDR Sharp); SDR-Console; Linux and Mac: GQRX; Network server for use with SdrDx for Mac, AirspyHF+ Mac Server; All ExtIO based software (HDSDR, Studio1, etc.) via ExtIO by Hayati Ayguen and Andrea Montefusco. Signals Analysis and Decoding Suite Krypto500/Krypto1000. Check the full list of tools on the Airspy download page. VHF Radio; Ham Radio (HF + 2m); Short Wave Listening (SWL); AM DX; FM DX; VHF-L TV DX; Remote Telemetry Radio Receiver.

Table Two: Internet Reference Guide

Airspy US **https://v3.airspy.us**

Nils Schiffhauer DK8OK HF+ Discovery Review **https://dk8ok.org/2019/08/02/new-dimensions-air-spy-hf-discovery**

RTL-SDR (great SDR resource) **http://RTL-SDR.com**

RTL-SDR Tutorial: Decoding DRM Audio **https://www.rtl-sdr.com/tutorial-drm-radio-using-rtl-sdr**/

SDR Console Software **https://www.sdr-radio.com**/

SDR Sharp Users Guide **https://www.rtl-sdr.com/sdrsharp-users-guide**

Airspy product reviews in *The Spectrum Monitor*
SpyVerter2 review by Bob Grove *The Spectrum Monitor* November 2017

Airspy HF review by Bob Grove *The Spectrum Monitor* January 2018

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