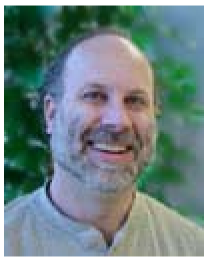
PACKET STATUS REGISTER



President's Corner

By Steven Bible, N7HPR, President, TAPR

Welcome to 2010 and it was another very busy quarter for TAPR.

In the HPSDR project, Magister was released. Magister operates very much like Ozy, but the interface to the SDR1000 was removed to keep costs down for a relatively low production run. For more information about Magister see http://openhpsdr.org/wiki/index.php?title=MAGISTER. Many thanks to Lyle Johnson, KK7P, for design and PCB layout, Nona Jurgens for purchasing and shipping, Dan Babcock, N4XWE, for testing and Scotty Cowling, WA2DFI, for manufacturing and testing.

Alex is progressing. What has been holding up Alex thus far has been the many toroids and their respective windings. TAPR wants to be able to sell assembled and tested units. That meant trying to source a contract manufacturer (CM) to purchase and wind the toroids. This has been the most challenging aspect of Alex's production.

Finally, an agreement has been reached with a CM. The brand of toroids changed making it necessary to qualify them, which also meant that the number of windings on each changed slightly. This took time. Alas, it is done; the toroids are on order. We hope to have toroids in hand by the end of March. Once we have them in hand, we can finalize the production of Alex. Many thanks to Graham Haddock, KE9H, and John Ackermann, N8UR, for the toroid testing.

Last quarter, Excalibur and Pennywhistle were released. Many thanks to Nona Jurgens for parts procurement, Graham Haddock, KE9H, for PCB design and layout, Walter Holmes, K5WH, for kitting, Steve Niles, N5EN, for kitting, and John Koster, W9DDD, for final kitting

We're also preparing for the Dayton Hamvention. We're taking inputs for talks during the TAPR Digital Forum on Friday morning. The joint TAPR and AMSAT Friday Night Banquet is being planned. Remember to sign up and pay for the banquet on the AMSAT web site beforehand. For more information, keep an eye on www.tapr.org/dayton.

And not sitting on our laurels, we are scouting a location for the 2010 Digital Communications Conference. We'll make an announce on the location and dates once a contract is signed.

As you can see, there are many people that make TAPR go. You don't have to be an officer or board member. We are always looking for motivated and energetic volunteers. You will find it a rewarding (and sometimes frustrating) experience. Won't you come join us?

– Steve, N7HPR

###

DCC Proceedings Are Now Online

By John Koster, W9DDD

Kudos to Ken Konechy, W6HHC.

Ken gathered information from the ARRL & TAPR Digital Communications Conference (DCC) proceedings for years 2006 through 2009. He then created a set of abstracts for each year which are now present on www.tapr.org. You can find links to them from www.tapr.org/pub_dcc.html.

He also created PDF files of each of the papers, which are linked from the abstract. This all allows search engines and therefore, you to find papers that might be of interest to you.

(Editor's Note: John, W9DDD, also deserves kudos for assisting Ken in this effort.)

###

Six DVDs of DCC Released

For the second year, ARVN has covered the DCC, and once again filled six DVDs with technical presentations from the three-day event. Topics include equipment design and construction, Software Designed Radio, AMSAT / ARISSat, Packet and D-STAR networking, advanced APRS, and Digital ATV.

Details and a free preview video at www.arvideonews.com/dcc2009/.

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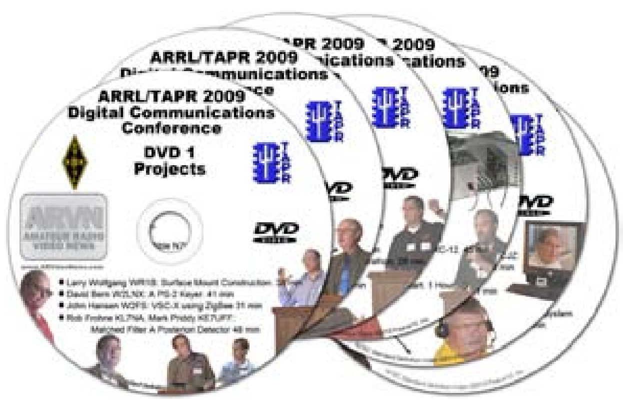


Write Early and Write Often

Packet Status Register (*PSR*) is looking for a few good writers, particularly ham radio operators working on the digital side of our hobby, who would like to publicize their activities here.

You don't have to be Vonnegut to contribute to *PSR* and you don't have to use Microsoft Word to compose your thoughts. The *PSR* editorial staff can handle just about any text and graphic format, so don't be afraid to submit whatever you have to wa1lou@tapr.org.

The deadline for the next issue of *PSR* is April 15, so write early and write often.

###

ADS-WS1 Weather Station

A Low-Cost, Integrated Solution for APRS Weather Monitoring

By Scott Miller, N1VG

Background

Several years ago, having just finished my paraglider pilot training, I decided it would be an interesting project to install a remote wind monitoring system at the local training hill so pilots could check conditions online before driving out to the site. When an old friend suggested APRS would be the best option for the data link, I was skeptical – the last time I'd looked at APRS, there was virtually no local activity and no local infrastructure.

I decided it was worth a shot, though, and dug up an old KPC-3 from the garage. Hooked it up to an even older FT-203R, dialed in '439' on the thumbwheels, and lo and behold, there was traffic! Not much of local origin, but I could hear two digis and hit an IGate a hop or two away.

Somewhere along the way I got distracted and started working on adapting the GPS data logger I'd built for my paraglider to work with the KPC-3 as an APRS tracker in KISS mode, and then revised the design to work as a stand-alone tracker without an external TNC, sold a few copies to other hobbyists to play with, made some more improvements, sold more kits, started a company, and eventually quit my day job to design and sell APRS gadgets full time.

The OpenTracker+ currently supports the AAG TAI8515 1-wire weather station and the Peet Bros Ultimeter II and Ultimeter 2000 series stations, and the Tracker2 adds support for the Davis VantagePro 2 and the LaCrosse WS-23xx series, but I've never been entirely happy with these solutions. The 1-wire station, at least until the TAI8515 was discontinued, was a low-cost solution for wind and temperature only, but adding extra sensors drove the cost up quickly. The wireless LaCrosse stations are reasonably cheap and complete, but have slow update rates for outdoor sensors and their reliance on AA batteries makes them unsuitable for remote sites. The Peet Bros and Davis stations work great, but with prices starting at roughly $400 for a complete station, not counting APRS gear, they're out of many hams' price range.

I'd wanted to design an all-in-one APRS weather station for a long time, but the wind sensors were always a problem – there just aren't many sources for inexpensive ones. The best known option was the TAI8515, and this was the route taken by the µWeather and TAPR T-238 kits – both good products, but the former lacking some features and polish in my opinion, and the latter being more complicated and expensive than I wanted.

I finally found an answer in China. In 2007 I made my first trip to Hong Kong and Shenzhen for a series of trade shows, and came across a manufacturer of home weather stations. Like the LaCrosse stations, these units featured a short-range transmitter and a touch-screen display – and were neither available for the US market due to lack of FCC certification nor directly usable for APRS because of their USB-only interface.

But since I was only after the wind and rain sensor assembly, containing no active electronics, this turned out not to be a problem. The factory was reluctant to sell partial sets, and negotiations took a couple of weeks by email, but eventually a deal was struck. Production took several weeks, and the trip across the Pacific another two, but eventually I had somewhere north of half a metric ton of anemometers, wind vanes, and rain gauges in my warehouse.

Most of this first batch actually got sold to two other hobby electronics companies while I was busy working on other projects, but I've got my second batch in now, and the increase in warehouse traffic let me justify the purchase of a forklift, which is now my second favorite toy – er, tool – in the shop, after the CNC milling machine.

Hardware

My original intent was to design a user-assembled kit based on the OpenTracker+, but after weeks of testing various sensors, ADCs, and instrumentation amps, I decided that sticking with easily soldered through-hole parts was going to make the kit larger, more complicated, and more expensive than I wanted. I scrapped the design, and started over with newer surface mount components. The new design wouldn't be suitable for hobbyists to assemble as a kit, but it shrunk the size, reduced cost and complexity, and let me add some extra features.

The end result is a 3.25" by 2.25" board containing the microcontroller, flash memory, and temperature, barometric pressure, and humidity sensors. The board is housed in a flange mount ABS enclosure, with the wind and rain sensors connected to internal RJ12 jacks and all other connections made through a 14-position pluggable screw terminal block.

The temperature/barometer sensor is a Bosch Sensortec BMP085, accurate to 0.25% and drawing very little power. The humidity sensor is a Humirel HTF3000LF, calibrated within 3% RH, with fast response and instantaneous de-saturation after long periods of saturation – a distinct improvement over many sensors in use on APRS stations today. Both of the sensors have digital outputs, reducing susceptibility to noise and simplifying the design.

Currently the flash memory has a capacity of 2 megabytes, but 4 megabyte parts are available and will probably be standard in the future.

The first batch of beta test units just shipped last week, and one more board revision is planned that will add support for an internal rechargeable battery to maintain timekeeping and allow data logging in the absence of external power.

Serial Ports

The ADS-WS1 has two RS-232 serial ports on the terminal block. Presently, only one of those is used and the output is fixed at 2400 baud, using Peet Bros data logger format. Later, the second port will allow two units to be connected together, one indoors and the other outdoors.

Presently the serial output is compatible with Virtual Weather Station, and it should work with any TNC that supports the data logger format.

A Dallas 1-wire bus is also provided, and the unit can optionally use an external DS18S20 temperature sensor. Other 1-wire sensors may be supported later.

APRS Features

While the ADS-WS1 will work with an external TNC, it's primarily intended to be connected directly to a radio. APRS settings are configured through a Windows-based configuration program that should be familiar to anyone who's used an OpenTracker or Tracker2. The same basic settings are there, and all of the same features, including battery voltage reporting.

A built-in 7-amp solid state relay can be used to control power to the radio, with a configurable pre-transmission delay. Switching off the radio when it's not in use can reduce the power consumption of the system drastically, simplifying solar power setups. The station itself draws about 20 mA and operates at 5 volts or higher. Once some power saving firmware features are implemented, power consumption should be reduced by at least half.

Voice

The addition of the 2 MB flash memory made it possible to add voice synthesis capabilities with very little increase in hardware cost. This feature is intended mostly for non-APRS users, including R/C flying fields, hang glider and paraglider flight areas, and yacht clubs. The vocabulary presently stands at over 200 letters, numbers, words, and phrases. For early testing, I used my own voice. After a week or two of listening to my synthesized self drone out weather readings every 30 seconds, I decided I'd had enough of that and hired a pro. The voice samples now loaded on the WS1 were recorded by the beautiful and multi-talented Emily Zuzik.

In the final firmware release, voice reports should be completely programmable – you'll be able to select their frequency, units, level of detail, and so on. For now, a couple of standard reports are included.

Availability

One more board revision is expected before full-scale production starts, and there's plenty of firmware work to be done, but the station should be available in February at a price of about $150, all sensors included. www.argentdata.com

###

Kitting PennyWhistle

By Walter Holmes, K5WH

We had a great time kitting up PennyWhistle and Excalibur.

The guys did such a great job of designing it, then spec'ing the parts for it, the least we could do was chip in to make certain there would be no hold up on the kitting part.

These two parts of the project were another great example of how well the TAPR concept works with a great team of enthusiastic volunteers that launch great ideas into the mainstream of everyday use in technology. Bringing the finest in great technology, down to cost levels for the everyday ham.

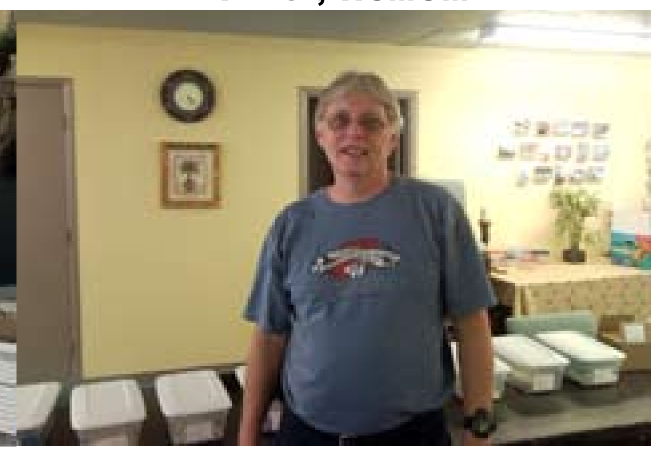
Since I have been involved with TAPR kits back to the TNC-1 days, it's been incredible to see how well this business model still works today.

###

Steve, N5EN

Teresa, W5MOM

Heather, KD5PZP



Walter, K5WH

2009 Midwest VHF/UHF Society Frequency Measuring Test

By John Ackermann, N8UR

Some of you may have noticed that I have an interest in precise frequency measurement. I've participated in the annual ARRL Frequency Measuring Tests since they were reinstated several years ago and have developed techniques that allow me to measure an HF signal off the air to a milliHertz or so if propagation permits. I'm not the only crazy one – there are quite a few hams throughout the US and the world with similar interests and capabilities.

We soon discovered that we were sometimes able to measure W1AW's frequency better than the League did. That's no slam on the ARRL, because the FMT was really designed to teach the basics and to remind people of the need to stay inside the band edges, rather than to feed the obsessive-compulsive behavior of the "fmt-nuts." In order to create a greater challenge, a few of the hams began running their own frequency measurement transmissions geared toward providing more stable and precisely measured signals. Connie, K5CM, in Oklahoma has been a leader in those tests.

History

In October 2007, I convinced some of the Midwest VHF/UHF Society (located in Dayton, Ohio) gang that we should also sponsor an FMT. Despite its name, the MVUS group is interested in just about any technical aspect of ham radio. The project fit well with our general tendency to over-engineer, and the club did not disappoint.

We operated from Mike, W8RKO's house. Mike has a 90-foot tower with tribander and wire antennas for the lower bands. Mike and Bruce, ND8I, did most of the RF engineering, converting three old Kenwood TS-520S transceivers into power amplifiers (as well as modifying one of the units so its PA would resonate on 30M). The idea was to feed the low-level frequency synthesizer output into the Kenwood driver and power amplifier stages. Mike also designed and built a computer-driven switching matrix to key the transmitters and provide CW ID. I provided most of the frequency generating and measuring gear. With large fans blowing on the tubes, we were able to run the Kenwoods at 100 watts output for the 30-minute test transmissions.

We used an Austron 1250A laboratory-grade crystal frequency standard as our reference. The Austron drove a TADD-1 distribution amplifier (see, this article has a TAPR connection after all!) whose six outputs were fed into PTS frequency synthesizers with 0.1-Hertz resolution. The frequency synthesizers each drove a small buffer amplifier whose output was coupled into the driver stage of the TS-520s. We measured the frequency standard against a GPS disciplined oscillator using a frequency counter with microHertz resolution and corrected the "dialed-in" synthesizer frequencies based on that.

The 2007 test was very successful, with 19 entries. We did a similar test in April 2008 with about a dozen entries.

New Ideas for 2009

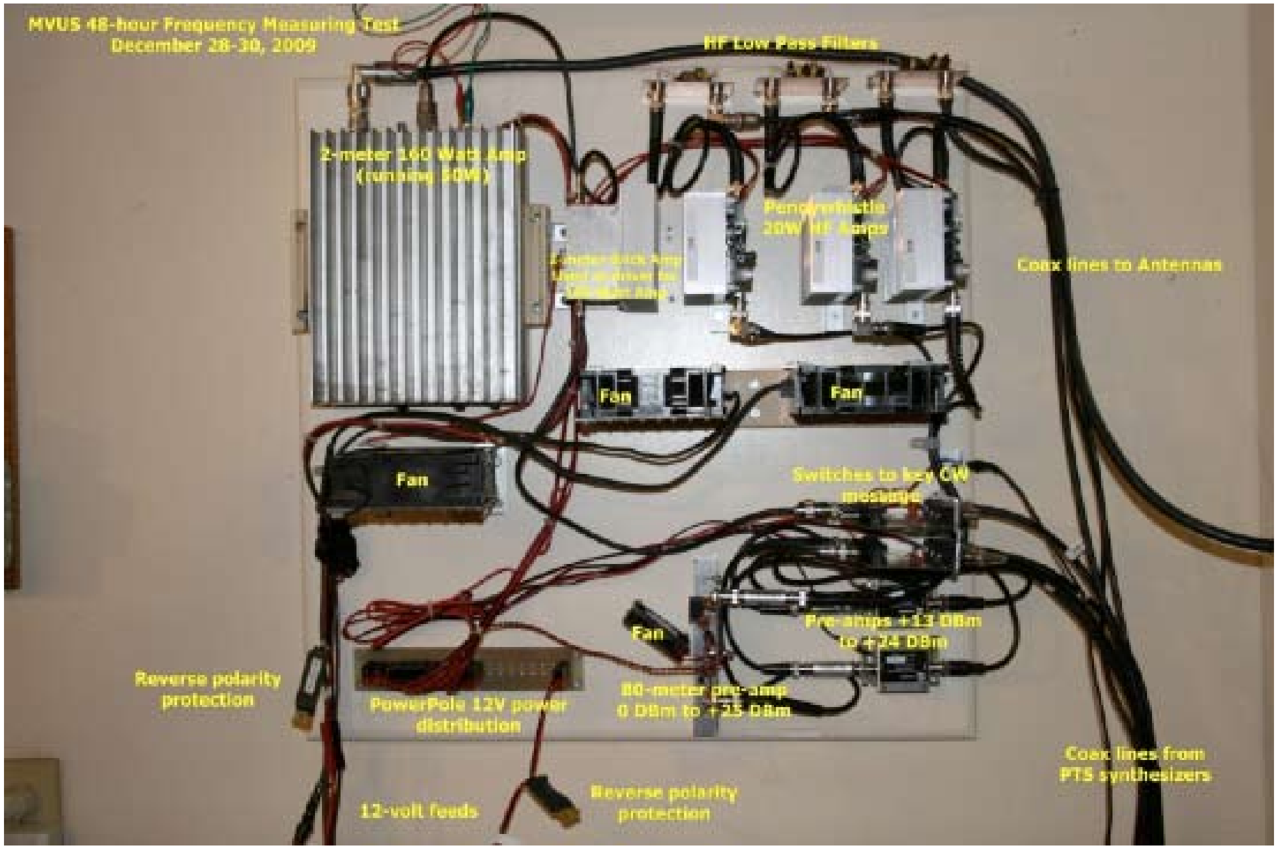
After 18 months off, we decided it was time to try again. This time, instead of a short transmission with moderate power, we tried a different approach: we would transmit for 48 hours at low power. The extended transmission time would allow measurements with long averaging times, would give more folks a chance to copy the signal, and would also allow for propagation experiments. The low power would keep us from burning up the amplifiers, and would also reduce QRM. We scheduled the test to begin at 1500 UTC December 28 and end at 1500 UTC on December 30, 2009. By operating during the holidays, we could transmit during the week to reduce interference to and from various operating activities (though we still managed to have a few problems in that regard).

The long, long key-down time made it impractical to use the Kenwood TS-520s with their hollow-state devices as the power amplifiers. We needed something else to increase the +10 dBm from the synthesizers up to at least 5 watts.

Coincidentally, the MVUS crew volunteered last year to do the kitting for 500 HPSDR LPU power supply kits, and as thanks TAPR donated three of the new HPSDR "Pennywhistle" solid state amplifier kits to the group. Rated at 16 to 20 watts output and with hefty heat sinks, these were perfect for our task. Daun, N8ASB, and Bruce, ND8I, built the three amplifiers, and Bruce designed and built low pass filters to follow them, as well as a buffer amplifier for the 80M position (the other bands used surplus 12 dB gain bricks as drivers; for some reason we needed a bit more gain to get equivalent power output on 80M).

In addition to 80M, 40M, and 20M on HF, we decided to provide a signal on 2M for the local community. Bruce, KA8EDE, provided a buffer amplifier and I loaned an old Tokyo Hi Power 160W amplifier. Together, they gave about 50 watts output fed to a discone antenna about 60 feet up; unfortunately we did not have an omnidirectional, horizontally polarized antenna available.

Mike integrated the amplifiers onto a two by two foot panel he mounted in his garage. Figure 1 is a picture of his excellent work, annotated to show the various bits that went into the system.



The transmitters worked flawlessly throughout the 48-hour key-down period, other than one minor problem depicted in Figure 2.

This resulted from using too small a wire gauge in a reverse-polarity protection circuit going to the 2M amplifier; the wire heated, softened its insulation, then shorted. Fortunately, only the Powerpole connector suffered before the fuse blew, and Mike quickly repaired the damage and got the 2M signal back on the air.

Signal Generation

An FMT starts with a very stable and accurate frequency source. In this test we used hardware similar to that of the earlier runs, but instead of a crystal oscillator we used a military surplus FTS 4100/S12 cesium beam frequency standard (a true "atomic clock") to drive the synthesizers. While the Austron oscillator we used before was very stable over short time periods, over 48 hours it could drift enough to be noticeable. The cesium standard wouldn't have that problem.

Since everyone has a GPS disciplined oscillator today, why not just use one of those to drive the frequency synthesizers? There are two reasons: first, it's impossible to tweak the GPSDO output frequency, and second, a GPSDO tends to be noisier over averaging times of 100 to a few thousand seconds than either a good crystal oscillator on its own, or a cesium standard. Additionally, using the atomic frequency reference seemed like a cool idea! Figure 3 is a picture of the FTS-4100/S12 frequency standard. It's not much to look at as it because the engineers designed it to mount inside a cabinet on a US Navy ship.

It may seem odd to deliberately offset the frequency standard. We did this so that the actual transmitted frequency would have enough non-zero digits to make measurement a challenge; remember that the frequency synthesizers can only be set to one-tenth Hertz. It's easiest to show this in an example:

Synthesizer Setting	No Offset	+5x10^{-8} Offset
7 055 231.5 Hz	7 055 231.500 000 000 Hz	7 055 231.852 761 575 Hz

With a perfectly accurate reference frequency, someone rounding to 0.1 Hertz could submit a completely accurate result. That would take all the fun out of the test, so offsetting the reference makes sure that rounding a low-precision reading doesn't result in an overly optimistic submission. With the crystal oscillator it was easy to get a large enough offset to avoid this problem.

Unfortunately the cesium standard has a much more limited tuning range and we were only able to get an offset of about 1.8x10-10, or just under 0.001 Hertz at 5 MHz. That turned out not be enough to avoid the rounding problem, and our actual frequencies had more zeros in them than we wanted. We could generate that larger offset using another synthesizer on the output of the frequency standard. The downside of that is increased phase noise and spurious signals, and because we wanted as pure a signal as we could obtain, we chose in 2009 not to use the additional synthesizer. That's a decision we will revisit before running another FMT.

As described below, we compared the cesium standard to the output of W8RKO's HP Z3801A GPS disciplined oscillator over the test period to make sure that offset was known as precisely as possible.

The output of the cesium standard went into a distribution amplifier and then fed the four PTS low-noise synthesizers shown in Figure 4. The synthesizers all have 0.1-Hertz resolution, and the three units used for the HF bands have a special option that provides significantly lower phase noise than the standard version.

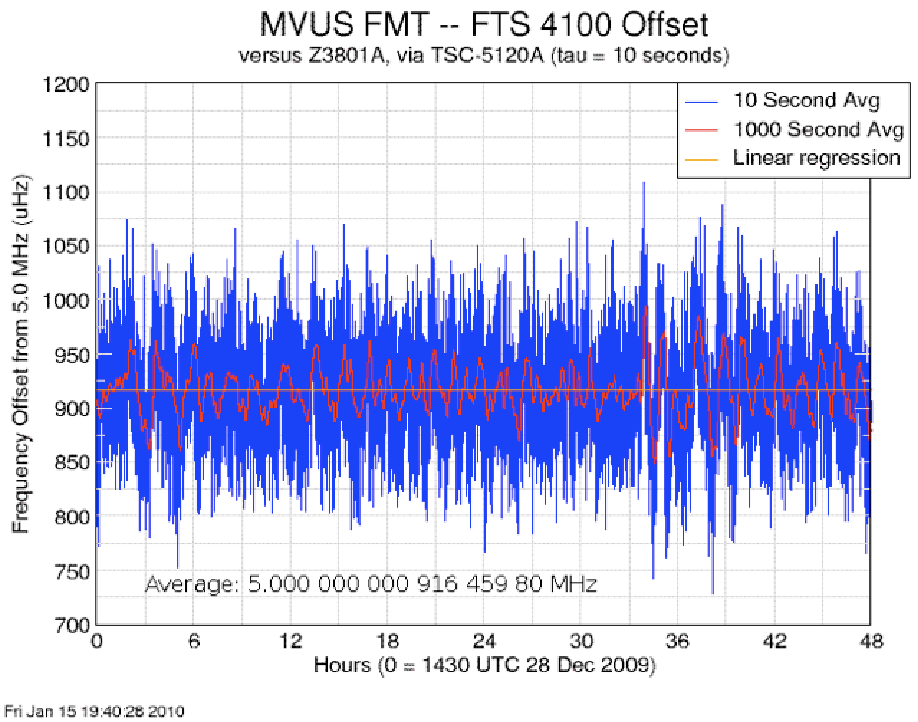
Signal Measurement

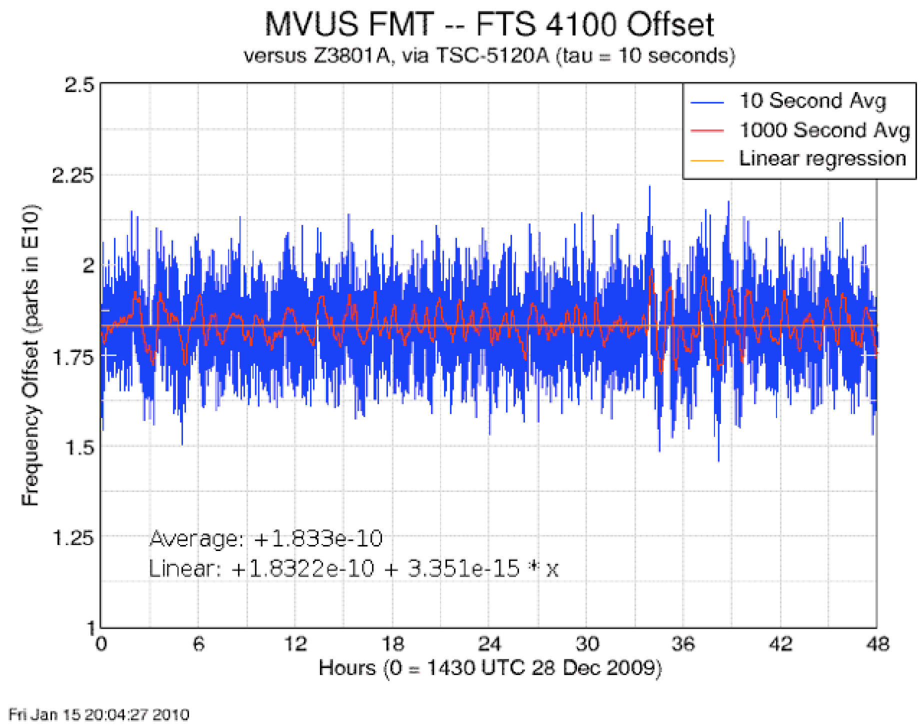
Part of the challenge for the people putting on an FMT is to measure the transmitted frequency locally as accurately as possible, to give the remote stations something to compare themselves against.

Since the U.S. Navy controls the frequency of the GPS timing signal very precisely, and compares it against the U.S. Frequency Standard run by the National Institute of Standards and Technology, using a GPS disciplined oscillator as a reference allowed us to measure the "true" frequency within a few parts in 1013 – in other words, to less than one microHertz at 5 MHz when averaged over 24 hours.

To make this measurement, we used a Symmetricom TSC-5120A stability test set which includes a frequency counter with up to 15 digits of resolution. It also outputs a stream of phase data (i.e., the time offset between the reference and unknown frequencies) that can be used to analyze the stability of the sources. The TSC box has a display, but is most useful when its data is captured via Ethernet. We used a laptop computer to log the frequency and phase data over the two-day transmission period. Figure 5 is a picture of the frequency measurement station with me at the controls.

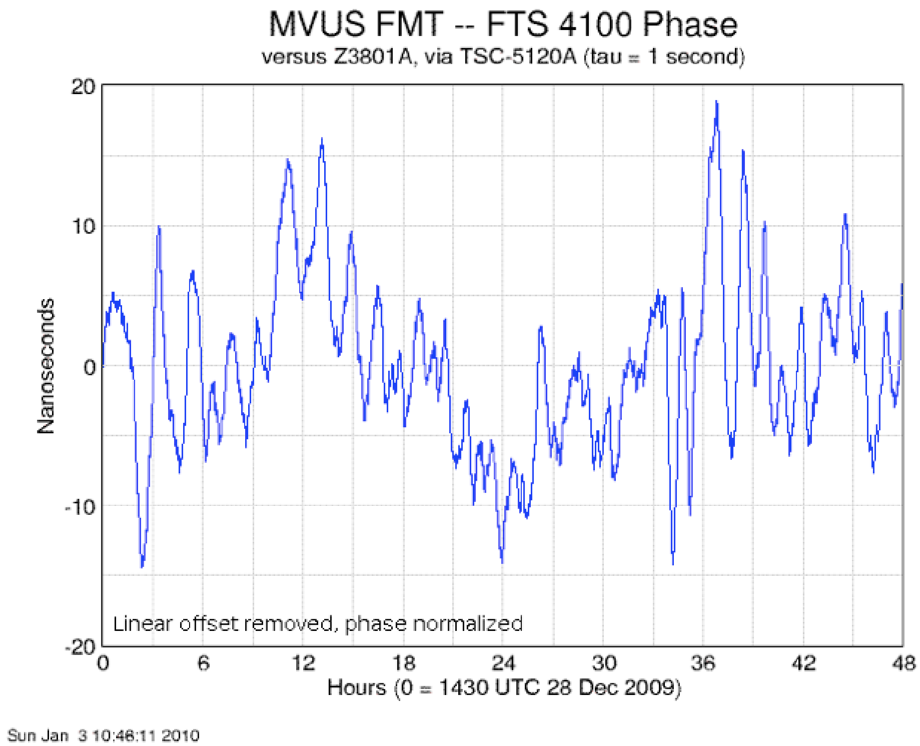
After the test, we plotted the logged data. Figures 6 and 7 show the frequency both in actual terms and as a fractional frequency offset (in other words, scaled to 1 Hz).



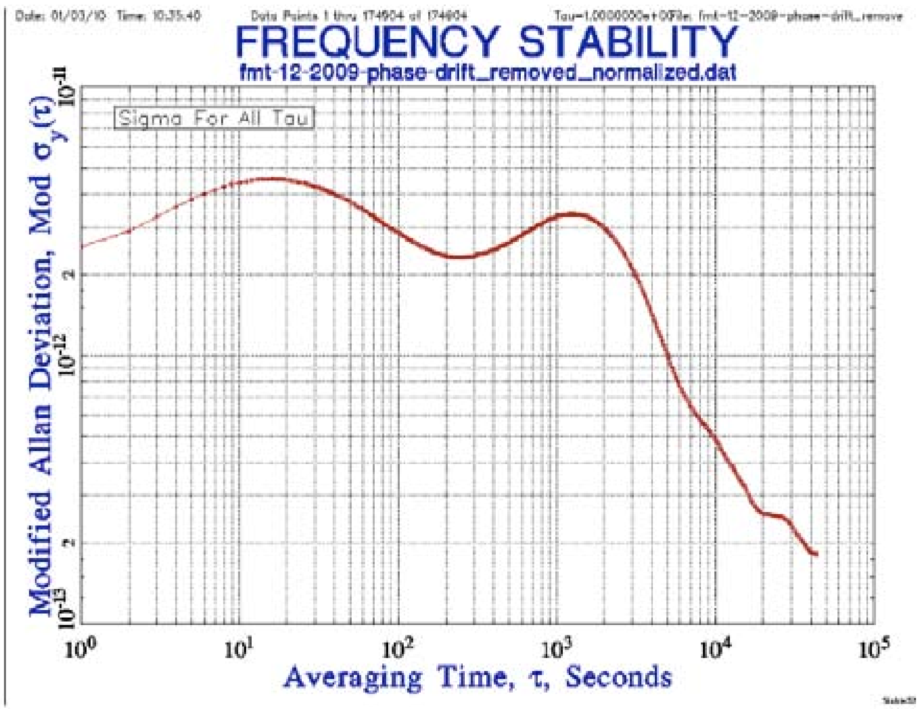


There are a couple of additional bits of analysis that help us understand the signal. First, we can use the phase data to look for jumps that would indicate a change in frequency. Since the cesium standard was deliberately offset from the correct frequency, a plot of the raw phase data would show a sloping line as the standard gained or lost time, and that slope would hide most of the detail. Figure 8 plots the phase after removing that offset. It shows that during the test period the jitter between the cesium standard and the GPSDO never exceeded about 20 nanoseconds.

It's important to note that all these measurements include noise from both the cesium standard and the Z3801A GPSDO. For example, if you look closely at the phase data you can see a 24-hour cycle in the data (note the peaks at 12 and 36 hours, and the minima at 24 hours). That is probably generated by the GPSDO; the orbital period of the satellites is just under one day, and GPS timing is slightly affected by periodicity. The GPS-derived signal is very accurate over the long run, but at any given instant may be less accurate than other sources. That's why we measured the cesium vs. GPS frequency over the full 48 hours.



Finally, we can apply statistics to the phase data to determine how stable the signals were when compared over various intervals from seconds to days. This measurement is called the Allan Deviation and it is similar to a standard deviation measurement – it shows the amount of noise in readings taken at different intervals. Figure 9 shows the Allan Deviation plot and from it we can see that the two signal sources were stable to better than 5 parts in 1012 – in other words, there was less than 25 microHertz of jitter or noise at 5 MHz over any measurement interval from one up to about 40,000 seconds.

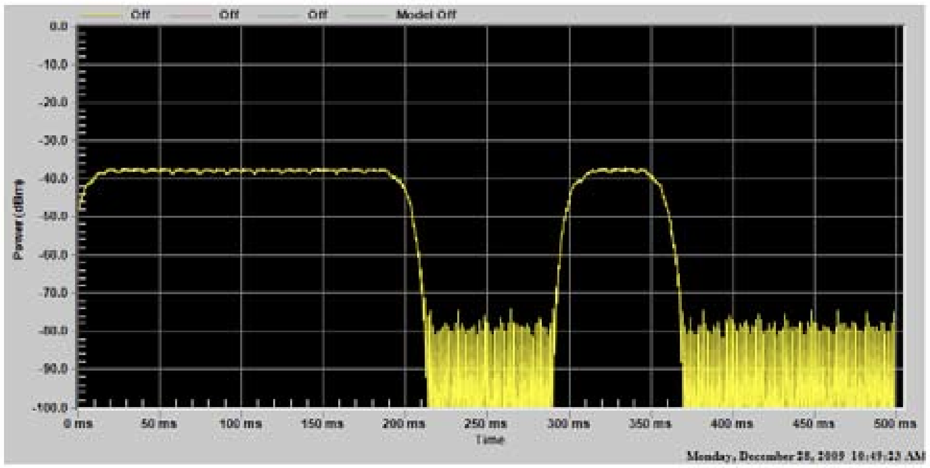


From all that data and analysis, we can confidently state the average frequency of the frequency standard over the 48-hour period to about 16 digits of resolution. To determine the actual frequency transmitted, we applied the measured offset (+1.833 x 10-10) to the frequency dialed in to each synthesizer. The resulting frequencies were:

80M	3 583 129	.	500 656 787	Hz
40M	7 054 683	.	701 293 123	Hz
20M	14 055 260	.	902 576 32	Hz
2M	144 274 286	.	426 445 4	Hz

To verify the results, I spot-checked the frequencies from my home station and my results matched these within about 0.001 Hertz. Given only a few minutes of monitoring time, and a systematic error in my measurement system that I haven't yet been able to track down, that's about as close as I can expect. It provides a sanity check that the readings taken at the transmitter site were valid.

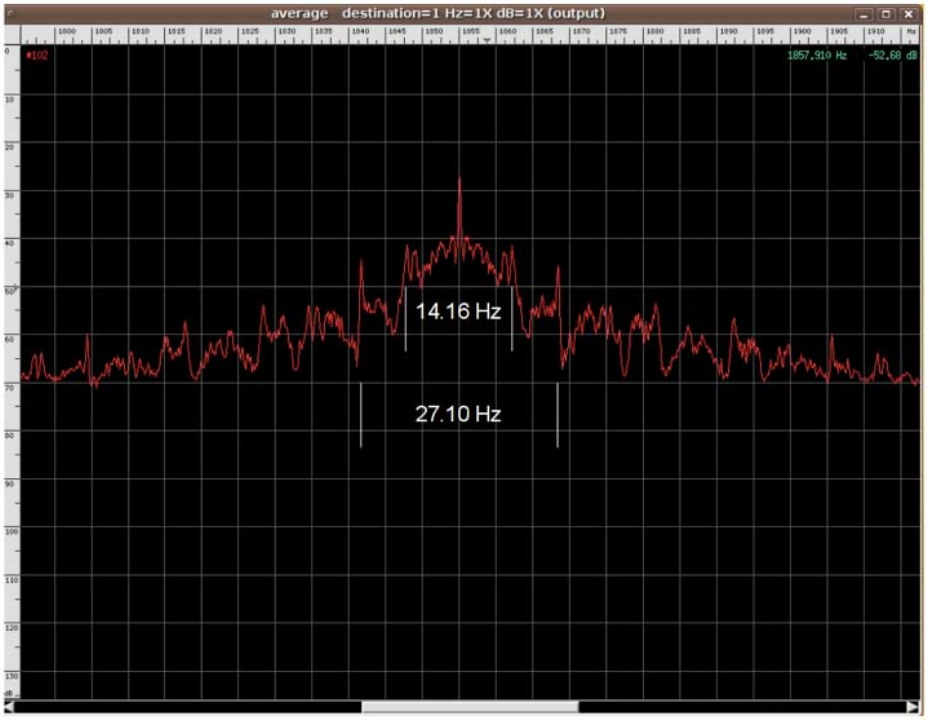
To verify the results, I spot-checked the frequencies from my home station and my results matched these within about 0.001 Hertz. Given only a few minutes of monitoring time, and a systematic error in my measurement system that I haven't yet been able to track down, that's about as close as I can expect. It provides a sanity check that the readings taken at the transmitter site were valid.



Keying Waveform

For extra credit, we also analyzed the waveform of the CW ID generated by Mike's software and keying matrix. Figure 10 shows an oscilloscope-like plot of the dits and dahs over a one second interval that N8ASB captured with his Agilent MXA spectrum analyzer.

I captured the signal over the full 3 minute ID period and averaged the results with a sound card spectrum analyzer program. That plot is shown in Figure 11.



This data shows that if anything the keying might have been a bit softer than necessary, which means that while the keying might have been a little mushy, it should not have generated key clicks.

(End of Part 1 – in Part 2, Tom, N8ZM, reviews the FMT entries and results.)

###

TAPR at Dayton Hamvention May 14-16, 2010

TAPR Dayton Hamvention Preliminary Schedule of Events:

Friday

8:00 AM - Outside Exhibits Open

9:00 AM - Inside Exhibits Open

9:15 AM - TAPR Digital Forum

6:00 PM - Exhibit Area Closes

6:00 PM - TAPR/AMSAT Dinner

Saturday

8:00 AM - Exhibit Area Opens

5:00 PM - Exhibit Area Closes

Sunday

8:00 AM - Exhibit Area Opens

1:00 PM - Exhibit Area Closes

Dayton Hamvention general information is available at Hamvention Web site (http://hamvention.org/).

TAPR has made arrangements with the Ramada Plaza Dayton to have a block of rooms available at a special rate for TAPR's members: $69.00 single/double. This special rate is good until April 12 or until the block of rooms is sold out, so book your rooms early!

Ramada Plaza Dayton

2301 Wagner Ford Rd.

Dayton, OH 45414

Tel: 937-278-4871

Fax: 937-278-0146

Internet: www.ramadaplazadayton.com

TAPR's Booth Space

See TAPR at booths 455-458, behind AMSAT. in the Ball Arena of the Hara Arena

TAPR Digital Forum

Schedule and Topics - TBD

TAPR Digital Bash Banquet

Joint TAPR/AMSAT Banquet at Dayton 2010. Details TBD

###

TAPR Twitter

Don't forget that TAPR has a Twitter account to keep TAPR members and digital enthusiasts aware of TAPR's events & activities.

You can access the TAPR Twitter account at: www.twitter.com/taprdigital

###

Rubidium Frequency Standard LPRO-101 in the Ham Shack

By Hans Hartfuss, DL2MDQ, and Juergen Sachtleben, DD6UJS

Introduction

The compact 10 MHz Rb atomic clock module LPRO-101 cheaply available on the surplus market has been integrated into an aluminium cabinet together with the necessary 24 V power supply, a converter stage to TTL and a subsequent fast driver.

The system built up has a sine wave output delivering about 6 dBm into 50 Ohm for frequency calibration purposes and has also a 50-Ohm TTL output which can be used as an external reference for a frequency counter system. Figures 1 and 2 give an impression of the size of the unit and how it has been integrated. Two *QEX* articles stimulated the experiments with the unit (7, 8). Our system differs by those described in these articles by the TTL-converter added.

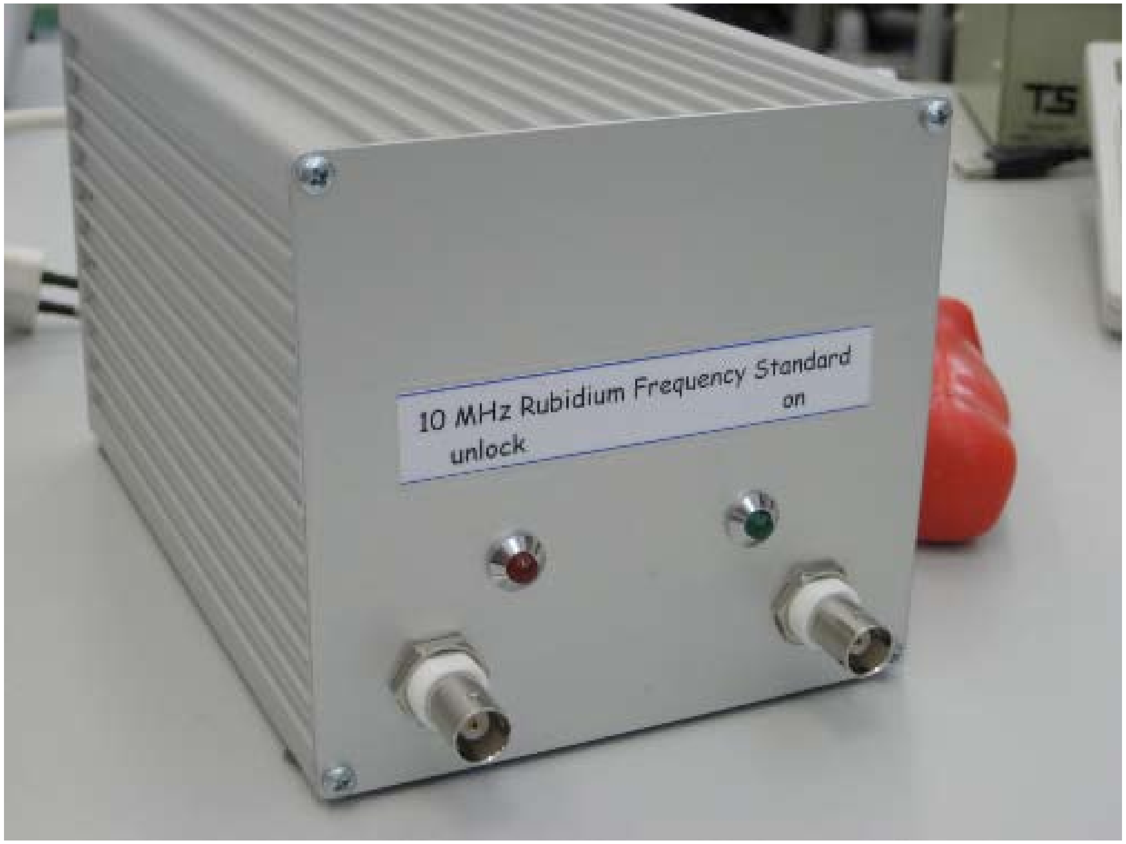
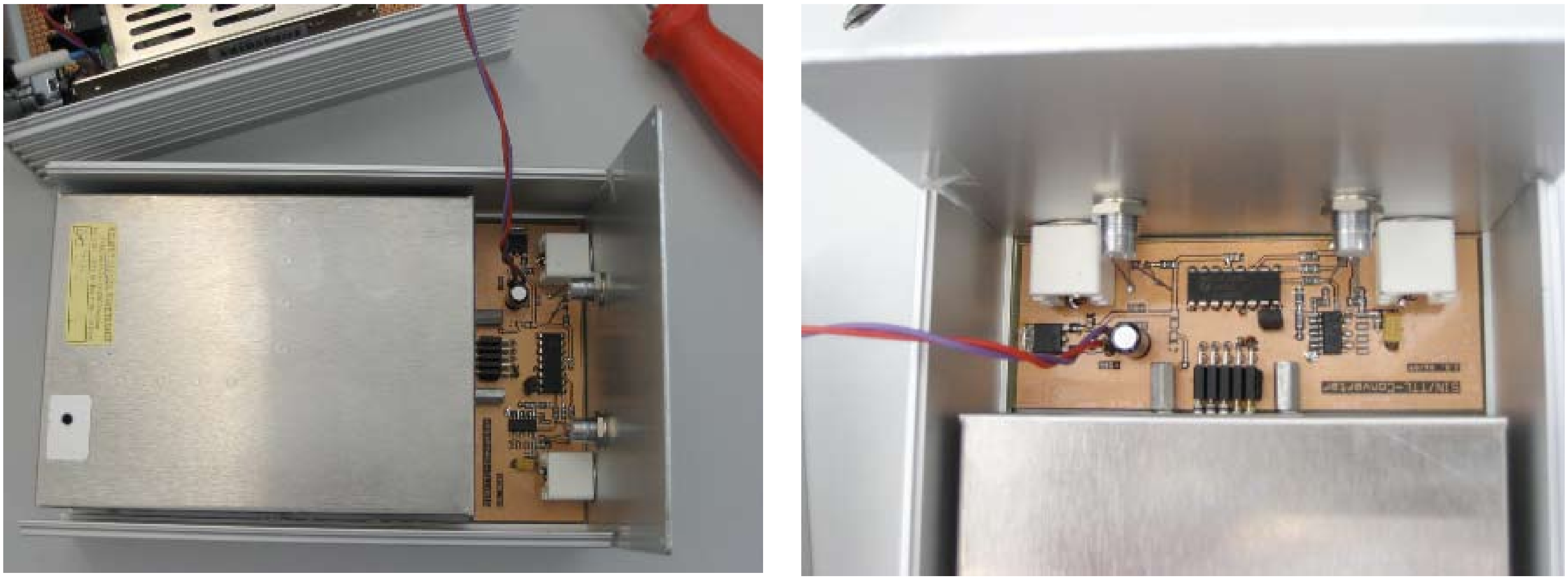


Fig.1: *The closed aluminium cabinet with the Rubidium frequency standard LPRO-101, a 24V switching power supply and a sine to TTL converter built in.*

Mechanics and Electronics



Figs.2: *The left photo shows the cabinet with its upper part containing the power supply removed showing the LPRO-unit with its metal shielding. All connections are via the small connector on the right side in the middle.*

The right photo shows in more detail the small printed circuit board developed providing the power connection to the LPRO-unit carrying also the TTL converter; Sine and TTL output signals are available on the BNC connectors left and right. The circuit is given in Fig.3.

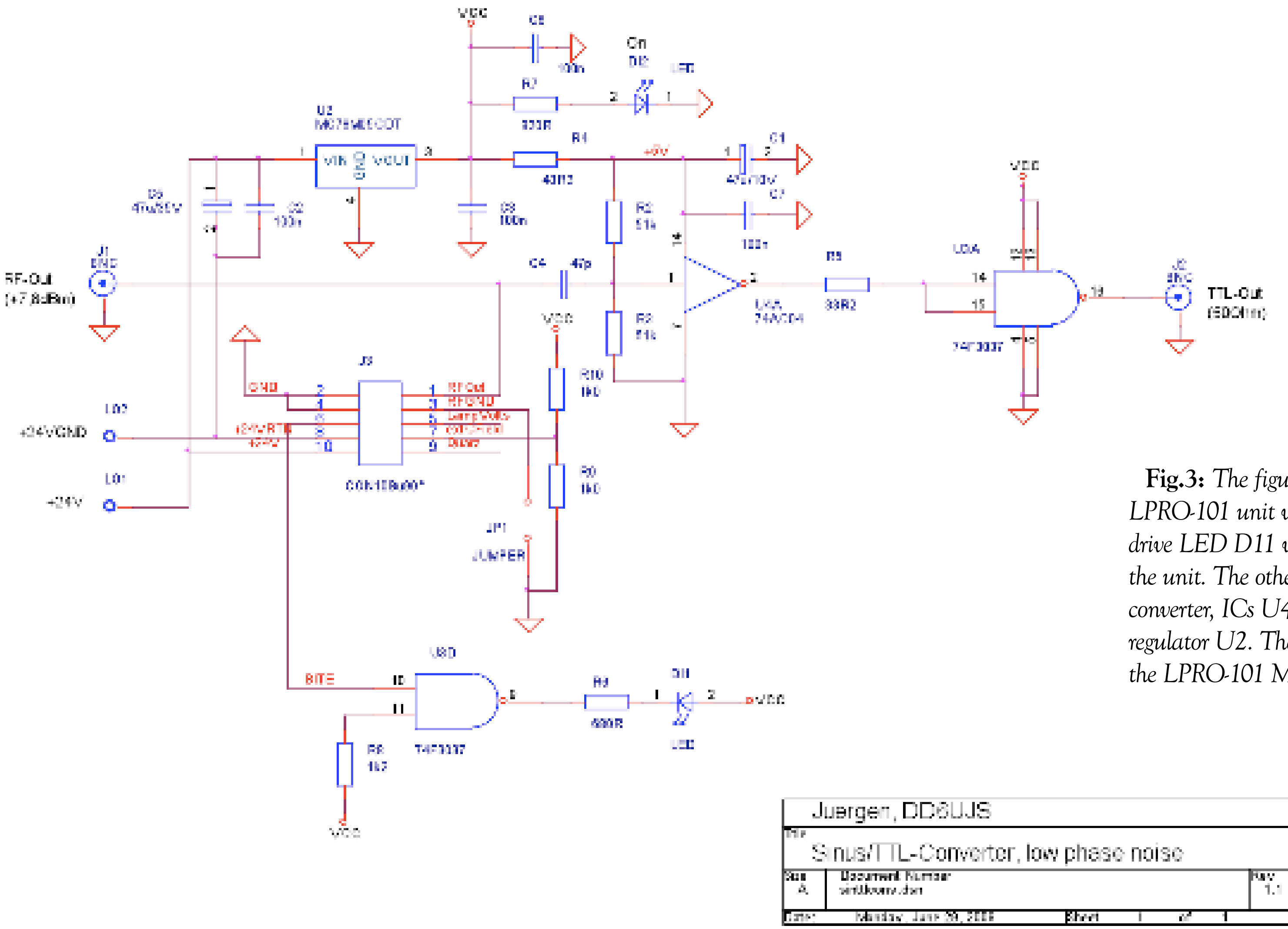


Fig.3: *The figure gives the circuit added to supply the LPRO-101 unit with 24 V via the connector J3 and to drive LED D11 via U3D to show the lock situation of the unit. The other components are used as a sine-to-TTL-converter, ICs U4A and U3A, and the corresponding regulator U2. The circuit is similar to what is described in the LPRO-101 Manual (6).*

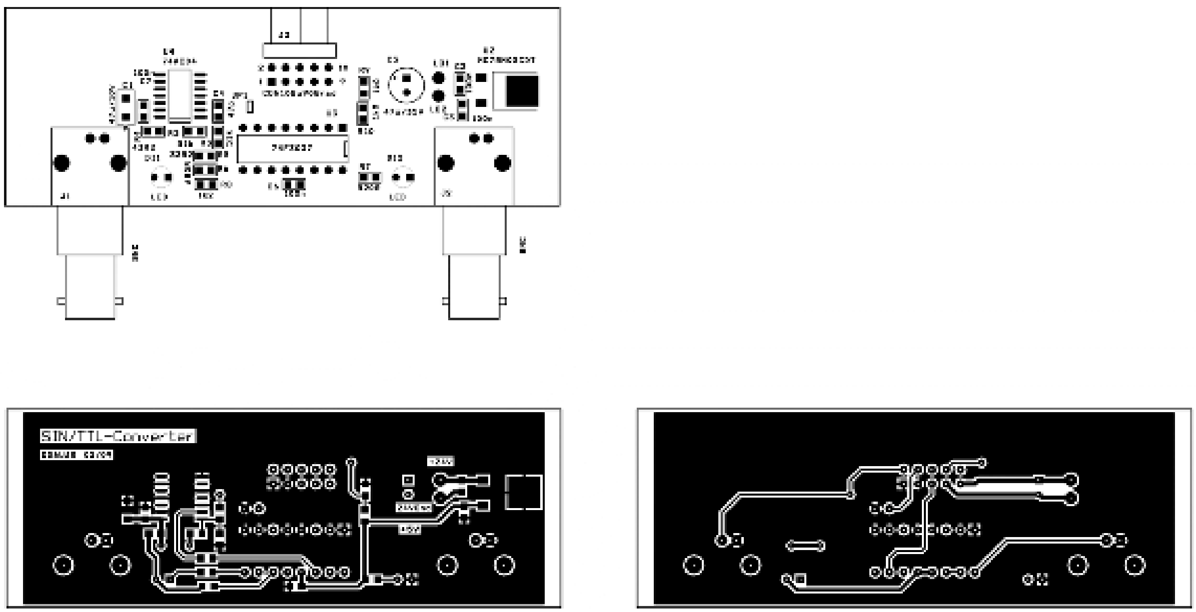


Fig.4: *The small printed circuit board carrying the circuit given in Fig.3.*

Physics Background

Before test measurements are being described, the physics background should briefly be outlined. We refer to the old articles from the late fifties and sixties, the time when the atomic standards have been developed (1, 2, 3, 4, 5) and describe the physics mechanisms as discussed in these papers as well as the overall realization in the LPRO-101.

In Rubidium (Rb) as in other atomic clock systems using Hydrogen or Caesium, the extremely stable and accurate hyperfine transition of the atomic ground state, typically in the GHz range of frequencies, is being used to phase lock a quartz oscillator delivering the output signal. In the LPRO-system a method called optical pumping is being applied rather than measuring directly the absorption of Rb-vapour in a gas cell at the transition frequency between the two hyperfine energy levels of the Rb ground state at 6.834684 GHz with reasons described below.

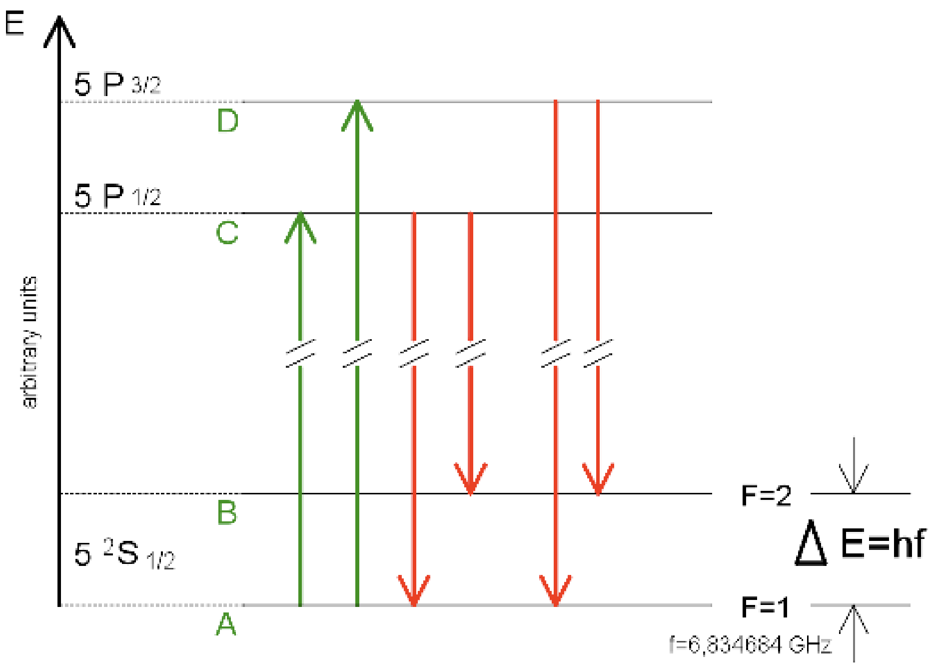


Fig.5: *Atoms have discrete energy states, which are usually given in a form as shown in this figure. The vertical scale is the energy scale. Upward transitions between states occur after absorption of electromagnetic radiation, correspondingly downward transitions are connected with the emission of radiation. The frequency of absorbed or emitted radiation is proportional to the energy difference of the energy levels involved.*

The figure gives the energy level diagram of the Rubidium atom. Only those levels important for the understanding of the physical processes are given. They are not given to scale, in particular the energy difference of the hyperfine levels F=1 and F=2 is largely increased. On the left the physics labelling of the energy levels of the Rb-atom are given. The principal quantum number is 5. P and S characterize the angular momentum of the n=5 electron, while the subscript 1/2 and 3/2 at the lower right give their total angular momentum including the electron spin. The number F results from considering in addition the nuclear spin. To avoid physics details, we count the various energy levels involved just by A, B, C, and D for simplicity.

Figure 5 gives the energy level diagram of Rubidium (see figure caption for more explanation of details). The hyperfine transition mentioned is the transition between the F=2 and the F=1 levels of the Rb-atom ground state, in physicist's nomenclature called a $5^2S_{1/2}$ state. These two levels correspond to the combination of the electron and the nuclear spins being parallel in the F=2 and anti-parallel in the F=1 state. The transition is being called a spin flip transition. It can be induced by the application of an rf-field at proper frequency f= 6.834684 GHz, so that the product hf corresponds to the energy difference ΔE=hf of the two states, the constant h being Planck's constant, $h=6.626*10^{-34}$ Js.

In case Rb-atoms are brought into a radio frequency field of exactly this frequency, the magnetic component of the rf-field induces transitions both upward and downward i.e. from the lowest state F=1 to the next higher state F=2 meaning upwards and vice versa downwards as well. In case there is no difference in the number of atoms in the two states no net absorption of the rf-field will take place. This means that under the influence of the rf-field equal numbers of atoms are changing their state per second by going upwards (absorption) or by going downwards (called stimulated emission). At room temperature and higher there is almost no difference in the numbers of atoms in the two states (Boltzmann factor =1). So no net effect is expected under these conditions, this means the mere application of a radio frequency field is not enough to allow the observation of any effect unless there is an inequality in the populations of the levels involved.

An unbalance in the number of atoms in states F=1 and F=2 is established, however, by the process called optical pumping. In this process line radiation in the near infrared (IR) at wavelengths 794.7 and 780.0 nm respectively from a Rb-lamp and properly filtered by a gaseous filter cell filled with the Rb isotope ^{85}Rb causes transitions mainly from the F=1 ground state of the ^{87}Rb vapour in the resonance cell (1). These transitions are given in green in the level diagram in figure 5 with arrows indicating the absorptive upward transition into the higher energy levels C and D of the Rb-atom. Atoms raised from the F=1 state (A) into the so-called P-states (labelled C and D in figure 5) will emit IR-radiation after a very short time when the Rb-atoms excited in this way relax by going back with equal probability into the atomic ground states F=1 and F=2 (A and B in figure 5). Theses transitions are marked in red in Fig.5. Since due to the proper preparation of the lamp radiation, pumping into higher states takes place almost exclusively from the lower F=1 state (A), the occupation number of the F=1 state as physicists say i.e. the number of atoms in that state, becomes therefore smaller under steady state conditions during the illumination by the Rb-lamp compared to the F=2 state (B).

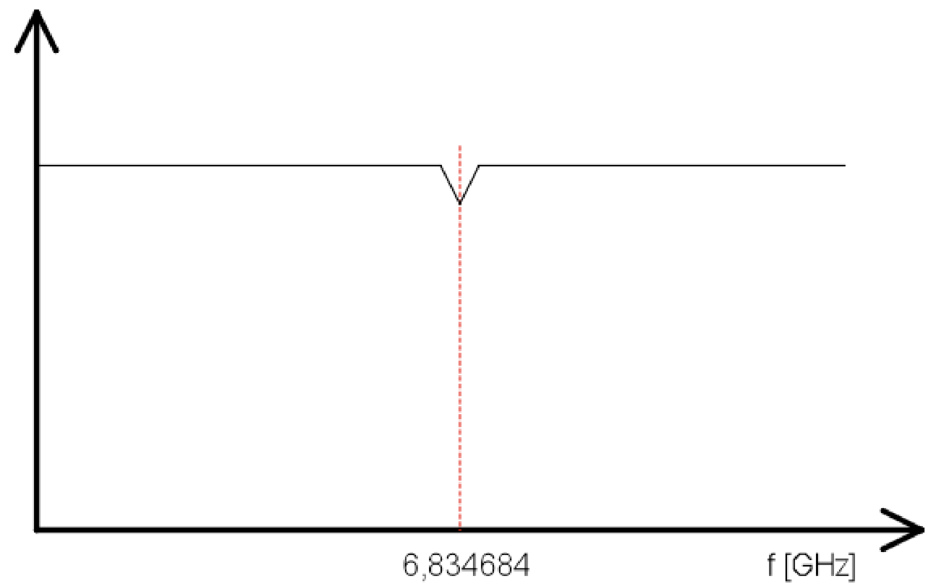


Fig.6: *The sketch gives the photocell signal as function of frequency applied to the Rb gas cell. In case the frequency f exactly corresponds to the hyperfine transition the absorption increases as explained in the text. An electronic control loop keeps the frequency locked to the dip (Fig.7). The dip is not deeper than about 1%.*

If now the microwave rf-field at the transition frequency 6.834684 GHz is being applied, more microwave transitions from F=2 to F=1 than vice versa are induced since more atoms are present in the upper F=2 state and less in the lower F=1 state due to the optical pumping process. The application of the rf-field then increases the number of atoms in the lower F=1 state.

As a result the absorption of the light from the Rb-lamp increases but only if the frequency of the rf-field applied exactly corresponds to the transition between the two hyperfine energy levels, f=6.834684 GHz. The absorbed IR-light is measured by a photo-detector. In case the right frequency is applied, the photo detector signal drops slightly as sketched in Fig.6.

LPRO Set-up

In the LPRO101-Rb frequency standard the frequency f is deduced in a complicated multiplier and mixing scheme from a 20 MHz voltage controlled quartz oscillator VCXO. This occurs in the block SYNTH. in Fig.7 (see LPRO manual (6) for more details). Here the 20 MHz signal is split into two paths. In the first the signal is multiplied by a factor of 3 then by a factor of 114 resulting in f_{VCXO} x 3 x114 = 6.840 GHz. In the second path it is multiplied by 17 and divided by 64 resulting in f_{VCXO} x 17/64 = 5.3125 MHz. The two signals are then mixed to give the difference frequency 6.84 GHz – 5.3125 MHz = 6.834688 GHz. To overcome the still existing small difference to the Rb resonance frequency, a weak magnetic field is applied to the Rb gas cell shifting the energy levels of the F=1 and F=2 states in a way that their difference equals Planck's constant h times the synthesized frequency, ΔE = h 6.834688 GHz.

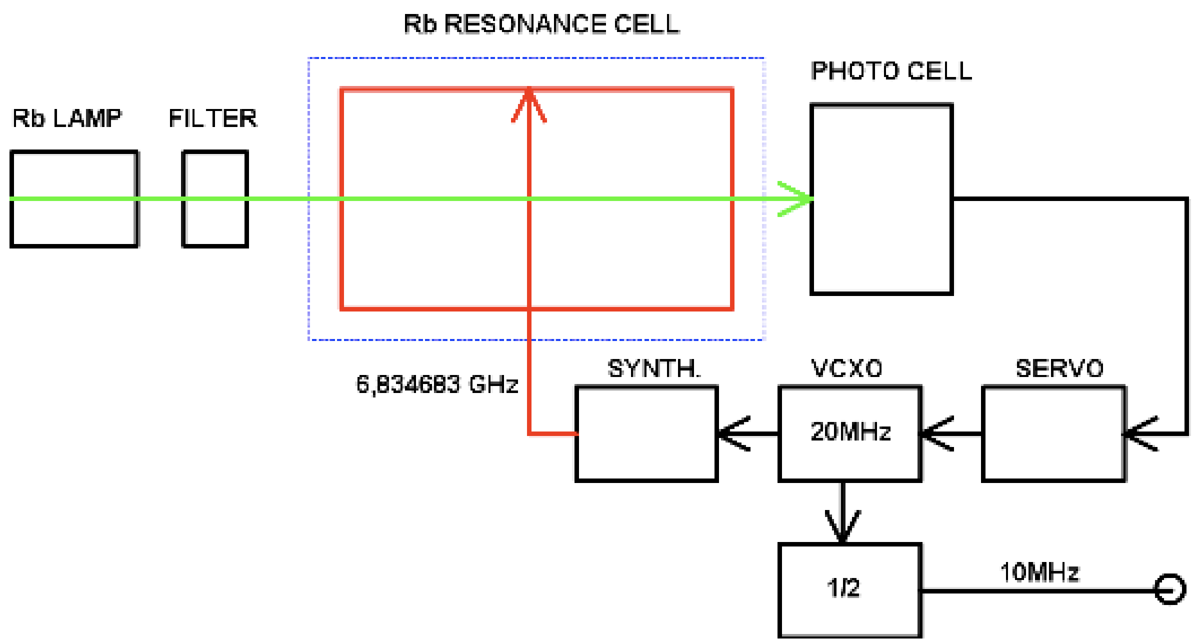


Fig.7: *The figure gives the block diagram of the overall arrangement. The filtered light from an ^{85}Rb lamp illuminates the Rb gas cell. A photocell measures the light passing the gas cell filled with ^{87}Rb atoms (green horizontal arrow). Simultaneously the microwave signal is applied (red vertical arrow). At the frequency of the hyperfine transition the light absorption in the cell increases. A servo loop controls the frequency of the microwave signal at maximum absorption making use of the high accuracy of this transition frequency in the Rb-atom. The frequency f=6.834683 GHz is derived in a complicated multiplier and mixing scheme from a 20 MHz VCXO at 20 MHz. Its frequency is kept constant at an accuracy determined by the transition frequency of the Rb-atom. For details of the synthesizer scheme see the LPRO-101 Manual (6).*

The VCXO is controlled such that a maximum of absorption of the IR-line from the Rb-lamp radiation occurs. The oscillator is locked to this absorption maximum corresponding to the dip in the photocell signal shown in Fig.6.

The manual says: „The dip in the photo detector current is used to generate a control signal with phase and amplitude information, which permits continuous regulation of the VCXO frequency. The servo section converts the photo detector current into a voltage, then amplifies, demodulates, and integrates it for high dc servo loop gain" (6).

Qualitatively it is accomplished by frequency modulating the synthesized microwave signal irradiating the gas cell by some 10^{-8} relative frequency sweep. This has the consequence that the absorption dip is periodically cycled resulting in a modulated photo detector signal with an AC component at the modulation frequency. Together with the modulating signal it is forming the input of a phase locked loop locking the VCXO to the zero crossing of the AC photodetector signal.

Test Measurements

Tests of the frequency accuracy of the surplus LPRO unit have been conducted by measuring the beat frequency respectively the beat period with a signal supplied by a modern commercial 10 MHz Rb frequency standard locked to GPS. Both output signals of the units to be com-pared are applied to an oscilloscope. Figure 8 gives the overall set-up while figure 9 gives a closer look to the oscilloscope's screen. The TTL-signal from the surplus unit is used (yellow) while the sine output of the reference standard (blue) is fed to a second input channel of the oscilloscope and is used as well to trigger the scope.

Fig.8: *Test set-up comparing the 10 MHz signal from a GPS locked Rb-standard (left) with the signal delivered by the surplus unit described before (centre). Both signals are applied to an oscilloscope to compare frequencies by measuring their beat period.*

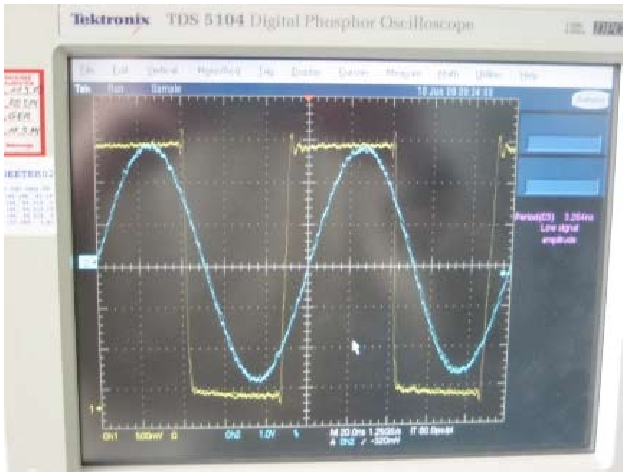


Fig.9: *The two signals from the reference 10 MHz standard (blue) and the LPRO unit (yellow) are applied to an oscilloscope. The horizontal scale is 20ns per division. The sine wave is used to trigger the scope. The frequency deviation between the two signals is causing a time dependent phase shift between the two. By measuring the time for a 360 degrees phase shift the frequency deviation can be quantified. Typically almost 1000 seconds are measured for 360 degrees.*

Since frequencies of the two devices to be compared are not exactly the same, the rectangular signal is drifting against the sine reference on the screen. The time necessary to shift by one period can be used as a measure of the frequency accuracy. It is found that after a warm-up period of about 20 minutes the time necessary for one period shift is almost 1000 seconds (Fig.10). This means that the deviation of the surplus unit is only about 10^{-3} Hz at a frequency of 10 MHz.

Assuming the GPS locked reference generator accurate to the order of 10^{-12}, the LPRO unit has a relative accuracy of almost 10^{-10}. For a more thorough analysis of the accuracy, see reference (8). This accuracy provided is by far good enough to check the accuracy of other ham shack equipment.

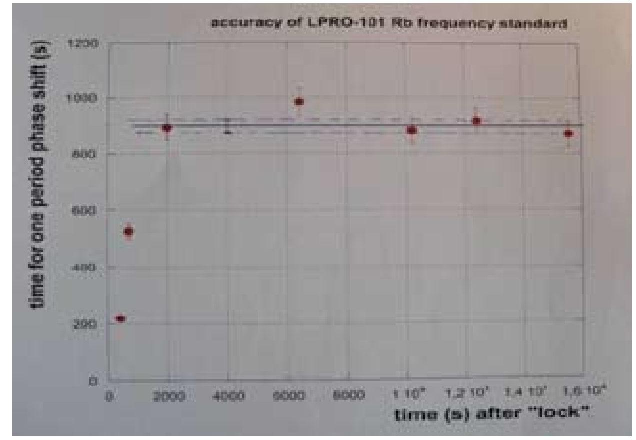


Fig.10: *To quantify the frequency accuracy of the LPRO surplus standard, its frequency has been compared with the frequency supplied by a modern commercial GPS locked Rb-standard. The comparison has been conducted by measuring the time needed for a 360 degrees phase shift between the two signals (see text for more details). The longer the time, the smaller the frequency deviation. A number of measurements have been done after switching on the LPRO unit given as red dots in the figure. After about 20 minutes the time needed approaches almost 1000 seconds, corresponding to a deviation of about 1/1000 Hz at 10 MHz.*

One first application was the comparison with an OCXO oscillator used as the clock source in an hpSDR system consisting of Mercury, Penelope, Ozymandias, and Atlas provided by TAPR (9). Instead of using the internal 10 MHz sources on the Mercury or the Penelope boards an external OCXO source has been built up using an OCXO purchased by the German Axtal company (figure 11). Another external accurate source is being provided by TAPR called Excalibur (10).

The PowerSDR software used to run the hpSDR system could easily be used to check the frequency deviation by applying the LPRO signal to the receiver and watching the phase difference in DSB reception mode (figure 12). Again the time was measured for a 360 degrees phase shift. It was found that this time is about 100 seconds corresponding to a deviation of 1/100 Hz compared to the surplus Rb-standard. At 10 MHz this corresponds to a relative accuracy of a few 10^{-9}.

Fig.11: *The photo shows the Axtal 10 MHz OCXO mounted on a small printed circuit board connected to the Atlas board of the hpSDR transceiver (9). It is used as the clock source in this fully digital transceiver system and determines its frequency accuracy and stability.*

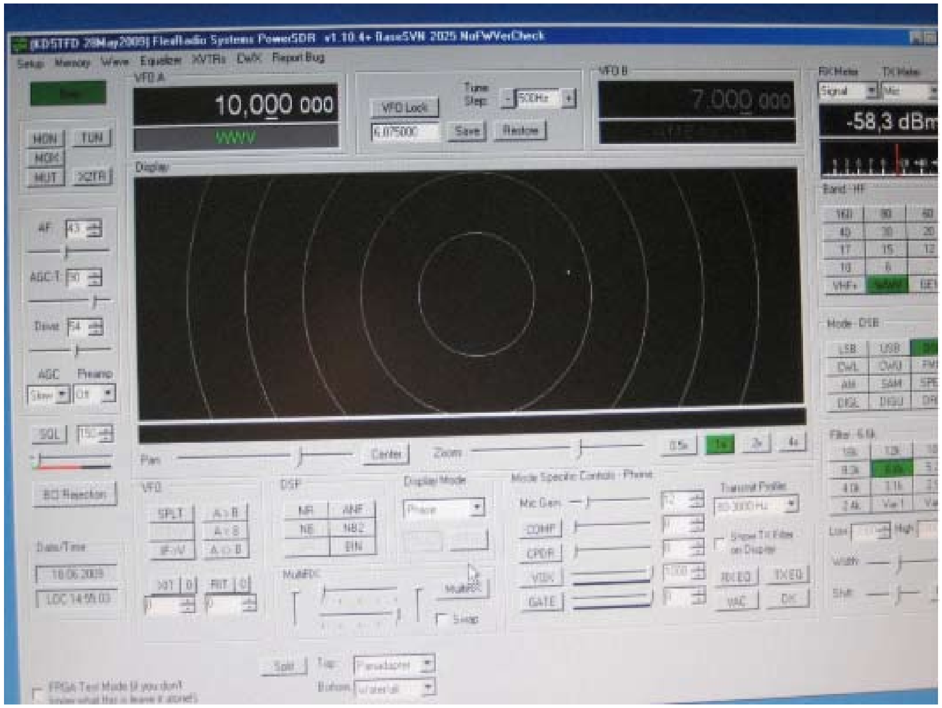


Fig.12: *The frequency offset between the ham shack LPRO 10 MHz standard and the 10 MHz clock source used in the hpSDR transceiver can easily be measured applying basically the same method as described before, by measuring the time needed for a 360 degrees phase shift. The screen shot gives a polar presentation of the phase, the small green dot between the inner two circles showing the phase wandering around. About 100 seconds are measured for one turnaround corresponding to 1/100 Hz deviation at 10 MHz.*

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8 B. Miller, *QEX* 256, 35 (2009)

9 http://openhpsdr.org/

10 http://openhpsdr.org/excalibur.html

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Hermes DDC/DUC HF Transceiver from OpenHPSDR

An Unofficial Introduction

By Ken Hopper, N9VV

"The new formula for innovation 'Pro-AM,' where passionate Amateurs do something for the love of it that strives for the best possible quality" – Charles Leadbeater

This document, diagrams, illustrations and all written material is presented for entertainment purposes only. This is my personal effort to share my excitement about the Hermes OpenHPSDR project.

This document was NOT sponsored or approved by OpenHPSDR; it is my personal UNOFFICIAL introduction.

Abstract

OpenHPSDR Hermes is a complex Software Defined Radio (SDR), high den-sity single board HF transceiver requiring only an antenna, power supply, and a USB connection to a computer. Software support for Hermes is cur-rently PowerSDR(R) or K.I.S.S Konsole (http://openhpsdr.org/wiki/index.php?title=KISS_Konsole) . It is anticipated that the proposed Athena software framework will point toward a client/server architecture in the future.

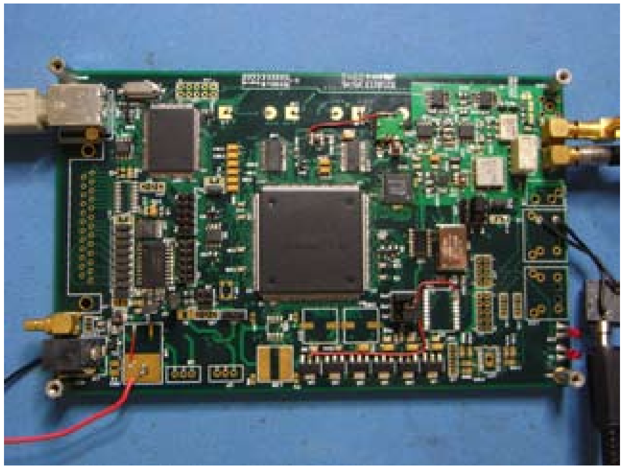
The OpenHPSDR Hermes is a full Digital Down Conversion (DDC) receiver, and a Digital Up Conversion (DUC) transmitter. The combination yields an exciting new HF transceiver (1,8Mhz – 55Mhz). The concept for Hermes was introduced by Kevin Wheatley M0KHZ, and through the collaboration of the HPSDR community, Hermes is now a reality (Team list on page 9).

Hermes is based on the successful OpenHPSDR Atlas + Penelope(Tx) + Mercury(Rx) + Ozymandias (control) designs. Kevin's proposed that OpenHPSDR could combine the receiver and transmitter processing re-quirements into a single FPGA on a single PCB in a compact design at a lower cost.

The DDC/DUC is new in Ham Radio. It was made possible by the reduction in price and dramatic increase in performance of Analog to Digital Conver-sion (ADC) chips for the wideband receiver (Mercury).

The Hermes concept is to use the state-of-the-art design to bring RF signals from the analog domain directly to the digital domain for computer process-ing in receive, and similarly in transmit. Hermes includes an audio PA for headphones and speaker connections (list of highlights on page 12).

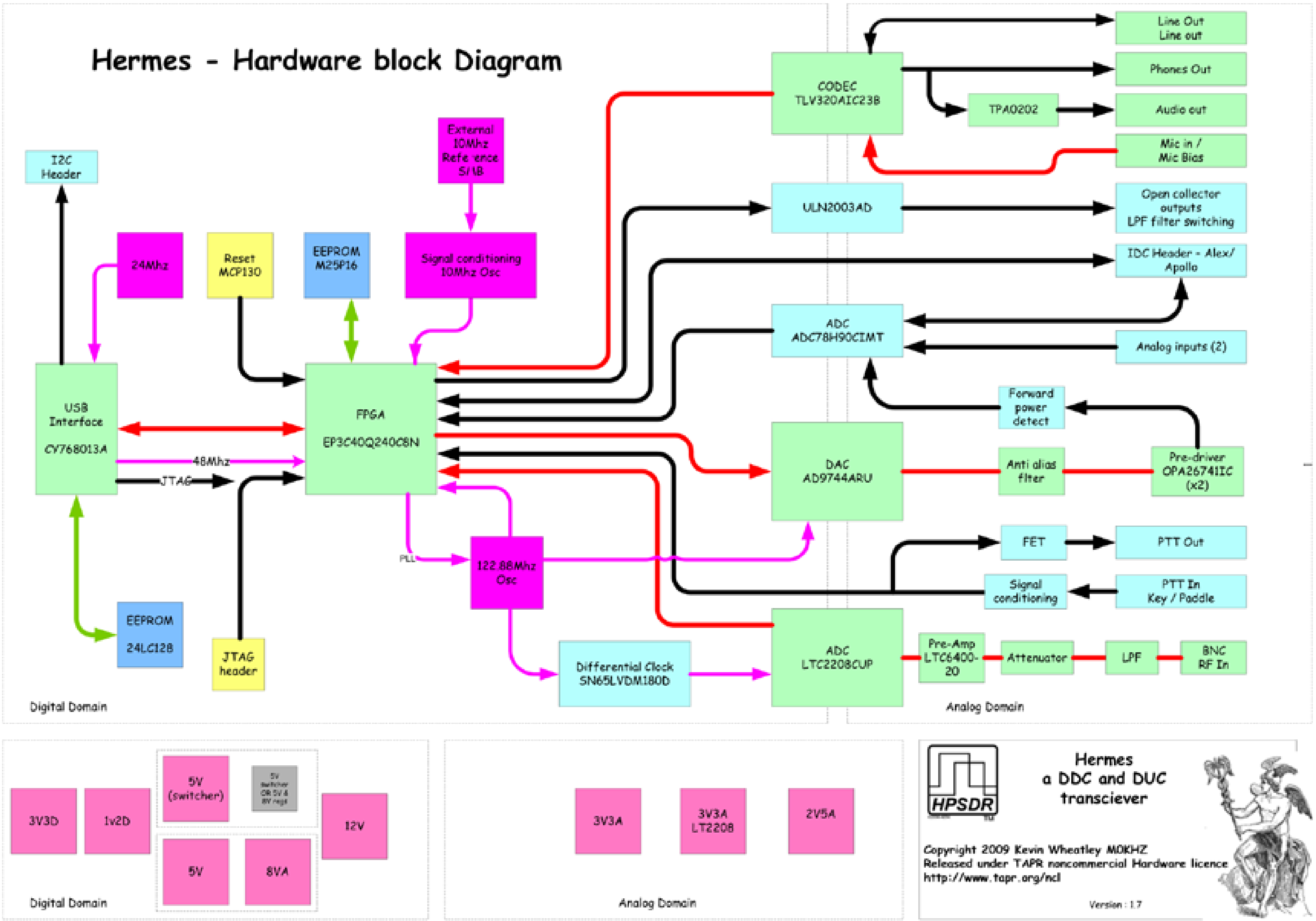
Digital signal processing has proven it's ability to surpass conventional ana-log designs while delivering exciting new communication technologies.



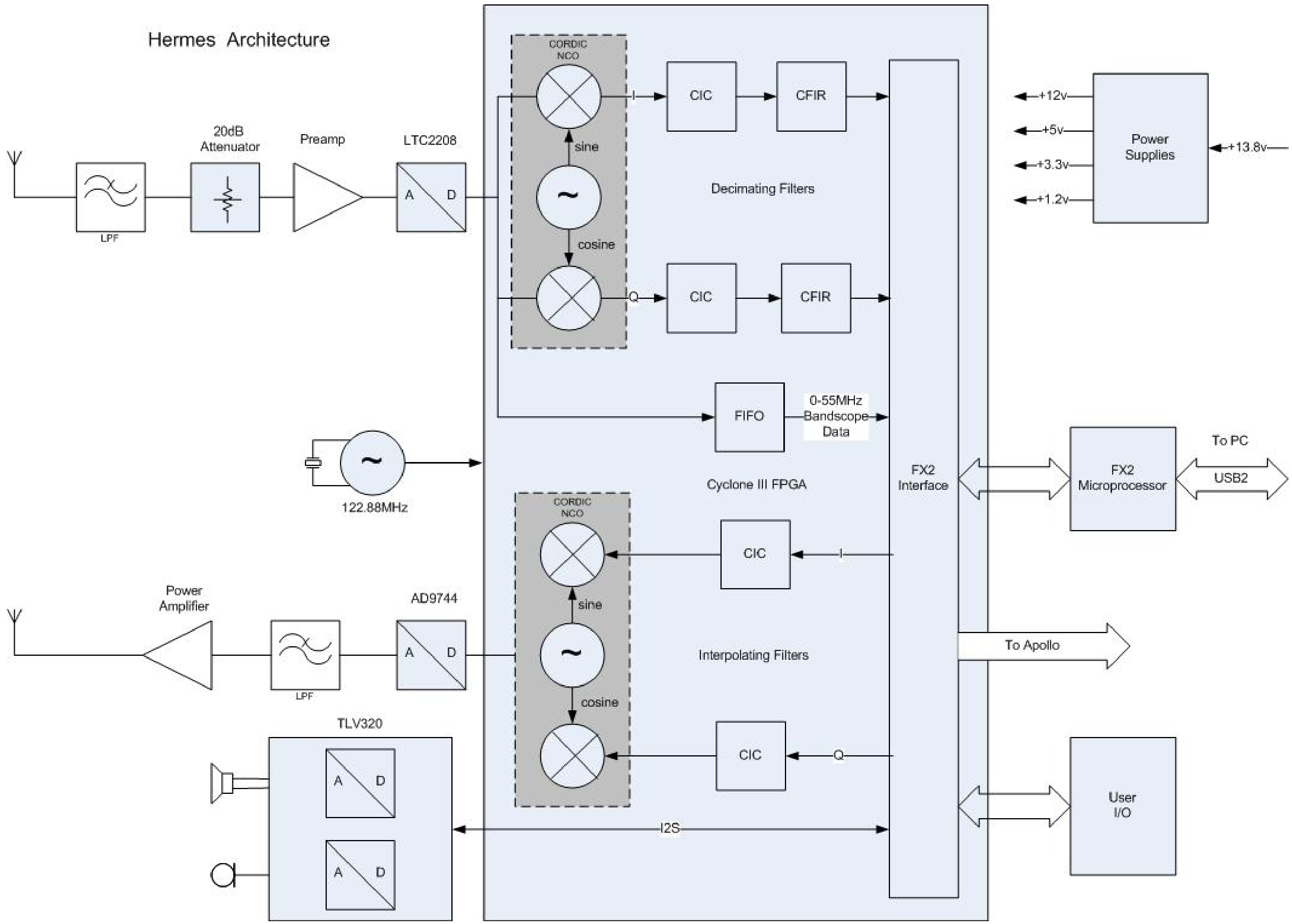
VK6APH Hermes Prototype, December 16, 2009

Hermes was the great Messenger of the gods in Greek mythology as well as an Olympian god.

The overall transceiver concept is explained here: Hermes Wiki (http://openhpsdr.org/wiki/index.php?title=HERMES).



Hermes Block Diagram (Courtesy Kevin Wheatley, M0KHZ)



Architecture (Courtesy Phil Harman, VK6APH, January 3, 2010)

Ham Radio is enjoying a period of tremendous change, adaptation, and evolution. We have crossed the chasm from rigs that you repair yourself to the rigs you can enhance yourself; from rigs you build out of parts, to rigs you build out of functional blocks; from rigs that are self contained trophy's of bent aluminum, to rigs that beat with an invisible heart of software. OpenHPSDR has given us Hermes as a link to this new era of Software Defined Ham Radio.

The OpenHPSDR Hermes transceiver is the mechanical base on which you can build your dream software defined radio. In the future with the Athena software framework, Hermes software can be morphed into any display you desire, on your favorite brand of computer.

Now it is up to us. We are no longer tied to the design, profit goals, and pri-orities of a manufacturer. You can dream about exotic and unique SWL features with imported European MF databases. You can dream about how you would layout multi-ple panadapters wiggling their FFT displays in front of your eager eyes. You can dream about the best Noise Blanker or Manual Notch Filter and you can homebrew any of the solutions.

Are you ready for the challenges of the software defined era of Ham Radio?

Introduction

There have been three significant generations of I and Q signal generation for Ham Radio; (a) Phasing Method, (b) QSD method, and (c) the new DDC/DUC Method.

(a) The first generation phasing method was successfully implemented in various Ham gear in the 1950's. "I" inphase and "Q" quadrature signals were of the highest analog quality in the advanced Central Electronics CE-100v. Many proud owners of the CE-100 and 200 models can be heard operating them on the bands today.

(b) The second generation Quadrature Sampling Detectors (QSD) and mixers were popularized by Dan Tayloe N7VE beginning in 1998. The first QSD Ham rig was in-troduced by Gerald Youngblood K5SDR in the his SDR-1000 QEX articles from 2002. The Flex-Radio website has a full collection of Gerald's articles and hundreds of other supportive technical material about the FLEX-5000 series equipment.

The original articles "A Software Defined Radio for the masses":

http://kb.flex-radio.com/article.aspx?id=10149

http://kb.flex-radio.com/article.aspx?id=10150

http://kb.flex-radio.com/article.aspx?id=10151

http://kb.flex-radio.com/article.aspx?id=10152

Tony KB9YIG has miniaturized and simplified a QSD design. Tony has sold more than 4000 of the inexpensive SoftRock QSD kits to a world-wide audience.

(c) The third generation of I and Q is now a reality as we follow the introduction of affordable high-speed analog to digital conversion integrated circuits. These amaz-ing ADC chips, like the LTC2208 (discussed below), are available to the experimenter to create new Software Defined Radios. The OpenHPSDR HPSDR and Hermes are state-of-the-art implementations that follows the true spirit of Ham Radio design where everything about the system is open and shared.

http://openhpsdr.org/wiki/index.php?title=FAQ

Description

The HPDR and Hermes transceiver follows the OpenHPSDR Mercury/Atlas/Ozy as one of the most advanced digital (DDC/DUC) transceiver board available for experimentation. Every chip and circuit has been chosen to offer the highest performance and value at an affordable cost. The DDC Hermes receiver features a Linear Technology

LTC2208 16 bit, 130 MSPS Analog Digital Converter (ADC) and an Altera EP3C40Q Cyclone III FPGA. Connectivity to the PC is through a high speed USB 2.0 interface. The general coverage Mercury receiver covers 15kHz through 55MHz in its standard configuration and can probably be used in under sampling applications in the VHF/UHF spectrum. The transmitter covers traditional HF Ham bands as defined by each ITU Region.

The Hermes transceiver uses approximately 30% of the FPGA capacity allowing extra room for future expansion. Multiple independent receiver chains sharing the ADC anywhere within the 15 kHz - 55 MHz range is one possibility. Three independent receivers have already been demonstrated by John Melton G0ORX/N6LYT, and 7 receivers have been demonstrated by Alex VE3NEA.

All the features of the Hermes transceiver benefited from the HPSDR Mercury + Ozy + Atlas project. Each new feature was selected to set it apart from any other DDC/DUC based software defined radios. Hermes transceiver is not a black-box de-sign. The Hermes transceiver is OPEN SOURCE. Open Source means that you can view, change, improve, and experiment with what is inside. The ability to see the internals of both OpenHPSDR Hermes and software programming gives you a special opportunity to study how a sophisticated DDC/DUC transceiver works.

In the old-days you could study a schematic, now you can study schematics AND dissect the software heart of the OpenHPSDR Hermes. Since the majority of the functionality is within the VHDL and computer software, a new, updated radio is only a download away.

The manufacturer of Hermes is expected to be announced shortly.

Who Are the Contributing Members of the Hermes Project?

- Kevin Wheatley, M0KHZ, who conceived the Hermes and is the Project Lead
- Tony Anthony Taylor, based in Singapore (no call sign) - Schematics & PCB layout.
- Phil Harman. VK6APH - Software & hardware development, especially the brain wave for maintaining full DAC bits while reducing power.
- Bill Tracey, KD5TFD - Component sourcing and kitting
- Lyle Johnson, KK7P - significant contributor to hardware development
- Scotty Cowling, WA2DFI – Parts procurement
- Graham Haddock, KE9H - Hermes PA improvements
- Plus numerous other contributors via the OpenHPSDR reflector.
- Apollo, a companion 20W PA, LPF and ATU, was conceived by Kjell Karlsen, LA2N

OpenHPSDR Hermes

http://en.wikipedia.org/wiki/Hermes The “Hermes” project that is part of the High Performance Software Defined Radio group’s ensemble of boards used in the original Atlas based backplane. The OpenHPSDR home is here: http://openhpsdr.org/

DDC

DDC is the abbreviation for the term Digital Down Conversion. DDC receivers are able to finally fulfill the dream that has been expressed in Ham Radio magazines for 50 years – to move the digital processing of analog RF information from the back of the receiver chain closer to the antenna. OpenHPSDR has created the Hermes and Mercury receivers to accomplish exactly that goal. The chip in this case is a very fast Analog to Digital conversion device from Linear Technologies the LTC2208 (more information below). The Hermes transceiver is designed to be supplemented by bandpass, attenuation, or pre-amp and PA circuits from the Alex or Apollo projects:

- Frequency Range (SMA LPF Input): 15 kHz to 55 MHz
- Input Impedance: 50 ohms
- Clipping RF Level: +9 dBm (~S9 + 80db)
- Maximum Display Bandwidth: 50MHz
- ADC Sampling Clock: 122.88 MHz (can be phase locked to an external 10MHz reference)
- I/Q Image Rejection: >110 dB
- MDS (500 Hz): -135 dBm @ 14 MHz (Preamp on)
- IP3: +50 dBm
- BDR: 125 dB
- Voltage: 12 - 15 VDC, 4A fused
- Current Draw: 500 mA (typ.)
- Connectors: SMA (RF IN LPF)
- LEDS: Power, FPGA loaded , Power Supplies (internal)
- Dimensions: 100x 160mm (3.299" x 3.940") (½ Eurocard size)

LTC2208

The Linear Technologies LTC2208 is a high speed, state-of-the-art, Analog to Digital conversion integrated circuit. The specifications for the LTC2208 (and it's cousin the 2209) can be found on the Linear Technologies website. The LTC2208 is just the beginning of the most exciting new era in Ham Radio. It offers us the ability to convert analog RF signals in the 15Khz to 55Mhz range to digital sig-nals. The conversions happen in the OpenHPSDR Hermes at the blazing rate of 122.88 Million Samples Per Second!

I realize that this is a difficult concept to grasp. Many hams have grown up in an Analog world. I am sure we all will all enjoy reading the OpenHPSDR explana-tions and analogies about how the Hermes transceiver architecture relates to designs that we understand. There is a great deal of helpful material available on the Inter-net and from various magazines and books. The ARRL DSP book written by Doug Smith KF6DX has several chapters devoted to various aspects of digital sampling of analog signals. Additionally, the SDR chapter in the RSGB Handbook (2010) was written by Phil Harman, VK6APH, one of the developers of Hermes, and covers a de-tailed explanation of the HPSDR project and its various modules.

New Linear Technologies devices allow hams to build affordable equipment that processes the digital representation of the entire RF spectrum throughout the HF ham bands (.05Mhz through 55Mhz). Digital processing gives us extraordinary fil-ters, AGC, MDS, BDR and demodulation that is far beyond any of our older analog circuit designs. The software doesn't change values as equipment heats up and im-age rejection is always at it's mathematically optimum value.

aThe ability of the LTC2208 to sustain 122.88 million samples per second cou-ples it to various algebraic and mathematical methods (CORDIC and digital division) that are processed easily inside a miniature logic circuit like the Cyclone-III FPGA. An CW signal on 3.552Mhz appears on the output pins of the LTC2208 among the stream of discrete numerical values ranging from -32768 to +32767 (216). The LTC2208 converts the RF impulses to decimal values using all sixteen bits of it's in-ternal circuitry. The selection of the LTC2208 16bit part is another illustration of the quality and versatility of the Hermes transceiver architecture.

During every tick of your wall clock, the 2208 presents over one hundred and twenty million samples of the RF spectrum at it's output pins. Each numerical sample is an aggregate value of the RF energy throughout the HF spectrum. It is the job of the logic elements in the Cyclone-III FPGA to interpret, divide, convert, and prepare the numerical values so that they can be post-processed by the PC Computer soft-ware. The I/Q data, once passed to an associated PC via a USB2 connection, uses PC software to convert the numerical data into human viewable and audible form us-ing the magic of algorithms such as the Fourier transform. The digital signals from the LTC2208 are passed without interference to the Cyclone-III FPGA in a continuous stream where they are processed in real time and in full duplex. The LTC2208 chip offers specialized randomization technology that can be selectively turned on to op-timize the signal to noise ratio of it's digital output.

You may wish to read some of the excellent digital signal processing material available at no cost on the World Wide Web. Terminology such as "time domain" and "frequency domain" will easily be related to oscilloscope patterns that we are all fa-miliar with. In addition to the ARRL and RSGB books, another popular text is The Scientist and Engineer's Guide to Digital Signal Processing By Steven W. Smith, Ph.D.

Altera Cyclone III

The Altera Cyclone-III EP3C40Q is an amazing device. First it is a field programmable set of electronic "gates" that can be combined to work like a very basic (and blazingly fast) computer. The Cyclone-III has the necessary mathematical primitives (such as multipliers) to do the Digital Down Conversion (DDC) and Digital Up Conversion processing simultaneously in parallel

The receive function of the Cyclone-III is to accept the digital data from the LTC-2208 Analog to Digital conversion chip and hammer it into shape using very sophisticated mathematical tools such as the "CORDIC" algorithm. The result is a stream of I and Q data that is fed to the USB interface and hence to a general purpose computer for the console display. The Cyclone-III EP3C40Q device has 39,600 logic elements, 1.6MB of RAM memory, and 126 multipliers. The Cyclone-III handbook is over 440 pages of highly technical material. It can be found on the Altera website. The Cyclone-III logic elements are arranged, directed, and formed into the desired functional blocks by programming in a high level Hardware Description Language called "VHDL" from Verilog.

Computers were first programmed using the most primitive instructions called the "assembler" language. The problem with assembler code is that it is difficult to maintain, modify, and repair. The answer was an explosion of higher level computer languages like Fortran, COBOL, and decades later we have modern languages such as C# and C++. Wikipedia currently lists more then 700 computer languages.

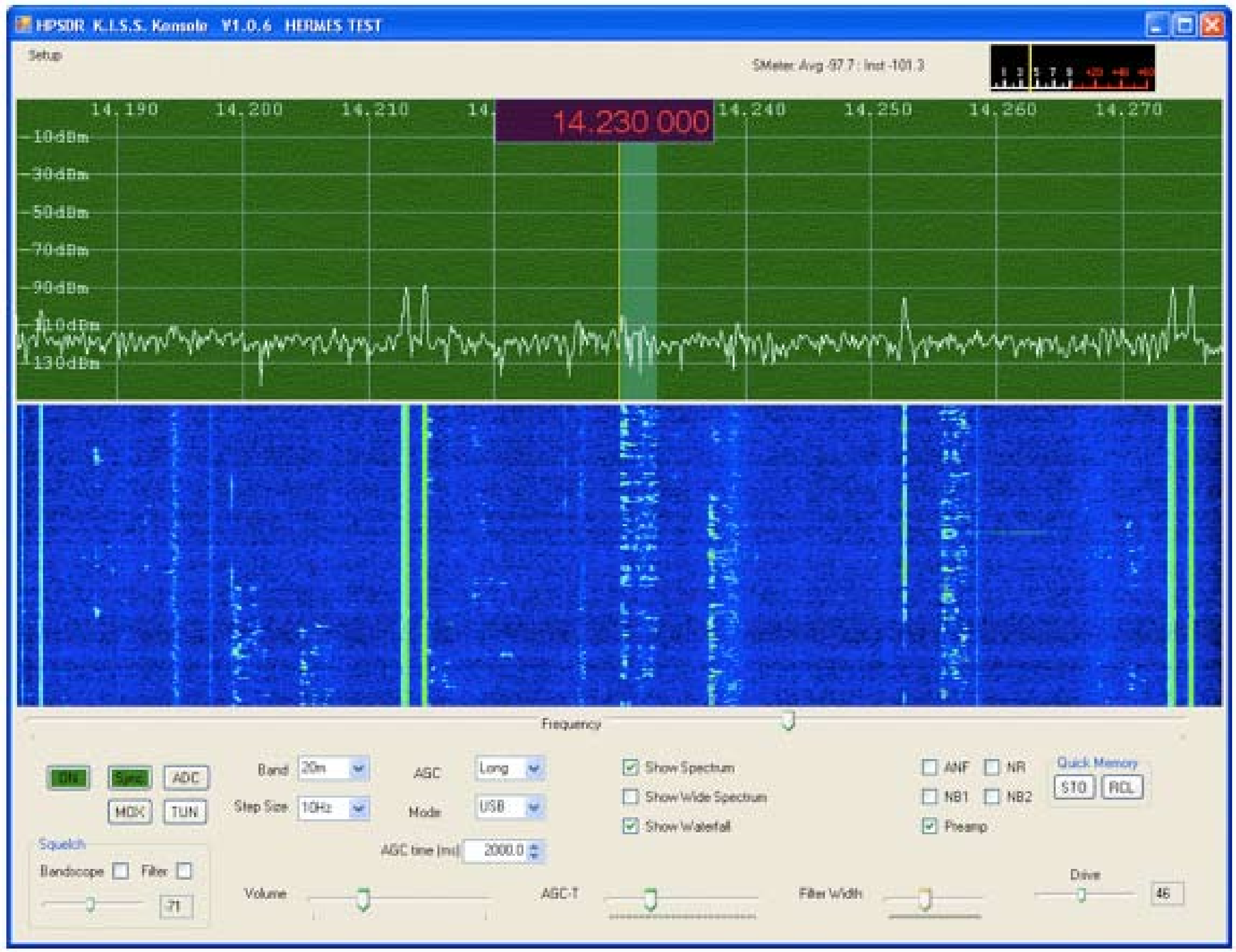
FPGA's are programmed or configured using the Verilog "VHDL" high level language that resembles the popular 'C' computer language. The Verilog compiler prepares logical element links within the Cyclone-III which is reprogrammable at any time. The advantages of Verilog is that it is maintainable, efficient, optimized, can be extended and repaired without unraveling the mysteries of the old opaque assembler style coding. FPGA coding is NOT trivial! We owe gratitude and praise for the OpenHPSDR Engineers who shared their skills and coded our FPGA chips.

• The logic elements of the FPGA are configured using Verilog programming. Be-cause the FPGA is such an agile device, the receiver logical elements and algo-rithms and the transmitter logical elements and algorithms are able to operate concurrently inside the FPGA chip. In receiving there are Decimating Filters and in the transmitter there are Interpolating Filters.

- The Decimating Filters reduce the sample rate from 122.88Msps to 192/96/48ksps as selected by the user. Decimation trades bandscope bandwidth for data rate; the lower data rates are necessary so a slower PC can undertake the rest of the neces-sary Digital signal processing tasks.
- The Interpolating Filters increase the sample rate from 48ksps to 122.88Msps to comply with the Nyqyist criteria.

You will find all the low level and high level files in the SubVersion (SVN) repository svn://206.216.146.154/svn/repos_sdr_hpsdr

Please refer to Appendix A for more information about the CORDIC algorithm and Appendix B for examples of Verilog programming.



Note: Live Hermes Test File, December 2009

New HPSDR K.I.S.S. Konsole from Phil Harman VK6APH for experimenters and new C# learners as well

http://openhpsdr.org/wiki/index.php?title=KISS_Konsole

K.I.S.S (Keep It Simple Stupid) Konsole is a straightforward PC program that will allow beginners in SDR and DSP programming to get their feet wet.

KK is intended as a learning experience and not as a competitor or replacement for any existing Console code. Where it goes and what features get added is up to you.

KISS Konsole is written in C# using the free VS 2008 IDE. The code is heavily commented and aimed at the newbie program-mer. It is straight line code with as simple a format as possible.

As a novice C# programmer myself my deep gratitude to Bill, KD5TFD, Dave, WA8YWQ and Joe K5SO for their invaluable as-sistance in getting KK released. We also owe Phil, N8VB our thanks for making his SharpDSP library available under GPL.

-- Phil Harman, VK6APH

- The code is written in C# using the free Microsoft Visual Studio C# 2008 IDE®

The code has been successfully tried using Mono on Linux.

- The code is simple linear code and well commented
- The code runs full duplex so you can see/listen to your transmitted signal as well as op-erate full QSK CW.
- More details here: http://openhpsdr.org/wiki/index.php?title=KISS_Konsole
- The GUI has deliberately been made to look as ugly as possible in an attempt to moti-vate users to improve it!!
- 48/96/192kHz wide bandscope with optional 55MHz wide 'full spectrum' bandscope
- Waterfall display synced to bandscope with AGC option that automatically sets the color of the baseline irrespective of actual band noise levels.
- Fully supports Ozy, Mercury, Penelope and Hermes. Automatically selects options based on boards present and prompts user for any required setting.
- Checks the release versions of all code in the various boards and prompts user when updates are available or required.
- User settings are saved in a simple text file for ease of programming and updating

K.I.S.S. Konsole Project contributors for High Performance Software Defined Radio

- Developed from original code Copyright 2006 © Phil Covington, N8VB
- Phil Harman, VK6APH
- David McQuate WA8YWQ
- Joe Martin K5SOGeorge Byrkit K9TRVMark Amos W8XR
- Gordon KA2NLM

GHPSDR3 Software Developed by John Melton, G0ORX/N6LYT

http://g0orx.blogspot.com/

(text from G0ORX Blog)

The HPSDR is mounted inside the Antec computer case in a similar may to the article on the Wiki by Ron Cox A complete HPSDR transceiver.

The computer is a PC Chips motherboard with an Intel dual core running at 3.4 GHz with 2 GB of memory. The graphics card is an NVidia GeForce

FX5500. The computer is running Ubuntu 9.10 64 bit although it does have an Ubuntu 9.10 32 bit partition that I can dual boot.

To the left of the keyboard is a completed PennyWhistle ready for testing. The large meter on top of the MFJ antenna tuner is a homebrew QRP dummy load and power meter. The meter itself is of surplus Russian origin.

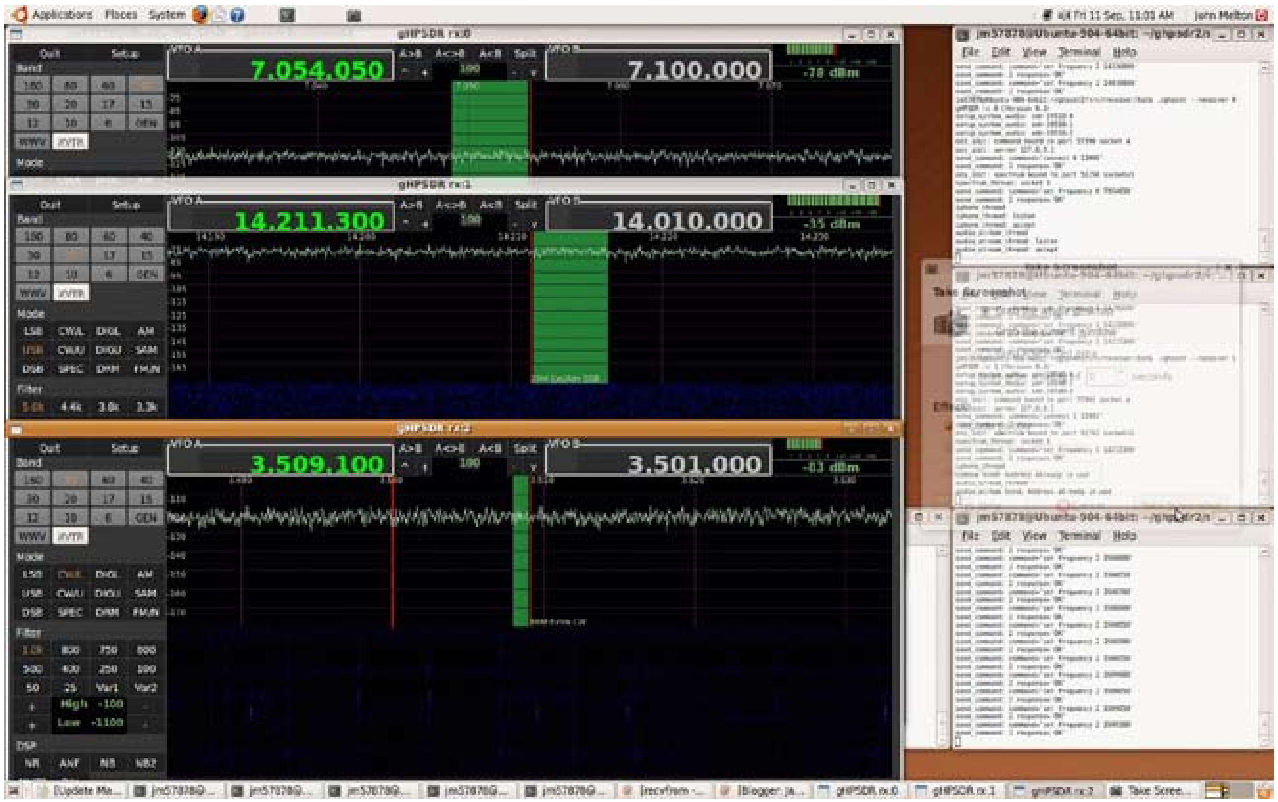
The latest version of ghpsdr now uses a client/server architecture to better support multiple receivers.

A server application handles the USB interface to the HPSDR Ozy board.

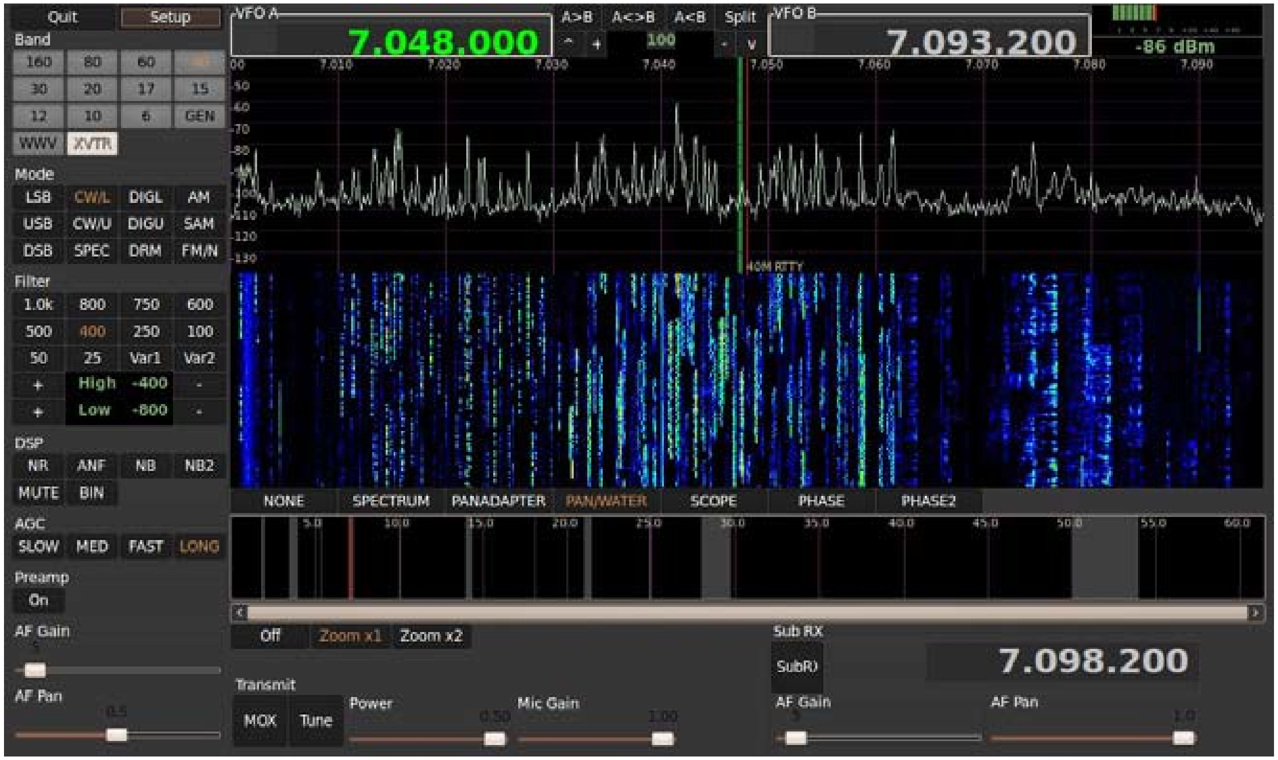
A client application makes a TCP connection to the server for sending commands to the server. The I/Q stream is sent from the server to the client using UDP.

The client can run on the same machine as the server or it can run across the network on another machine. The received audio can either be sent back to the server for playing out of the Mercury card or it can be sent to the local audio.

Screen pictures of John's work follows:



John Melton, G0ORX/N6LYT, Demonstration – Multiple RX on One Mercury Board



John Melton, G0ORX/N6LYT

Appendix A

The CORDIC mathematical algorithm used in the Cyclone-III FPGA

CORDIC - Wikipedia, the free encyclopedia:

http://en.wikipedia.org/wiki/CORDIC

CORDIC FAQ:

http://www.dspguru.com/dsp/faqs/cordic

CORDIC FAQ-II:

http://www.dspguru.com/info/faqs/cordic2.htm

CORDIC for Dummies:

http://www.jacques-laporte.org/cordic_for_dummies.htm

The CORDIC Algorithm:

http://www.andraka.com/cordic.htm

CORDIC:

http://www.nist.gov/dads/HTML/cordic.html

From Wikipedia, the free encyclopedia: "CORDIC (digit-by-digit method, Volder's algorithm) (for COordinate Ro-tation DIgital Computer) is a simple and efficient algorithm to calculate hyperbolic and trigonometric functions. It is commonly used when no hardware multiplier is available (e.g., simple microcontrollers and FPGAs) as the only operations it requires are addition, subtraction, bitshift and table lookup.

"The modern CORDIC algorithm was first described in 1959 by Jack E. Volder. It was developed at the aeroelectronics department of Convair to replace the analog resolver in the B-58 bomber's navigation computer,[1] although it is similar to techniques published by Henry Briggs as early as 1624. John Stephen Walther at Hewlett-Packard further generalized the algorithm, al-lowing it to calculate hyperbolic and exponential functions, logarithms, multiplications, divisions, and square roots.[2]

"Originally, CORDIC was implemented using the binary numeral system. In the 1970s, decimal CORDIC became widely used in pocket calculators, most of which operate in binary-coded-decimal (BCD) rather than binary. CORDIC is particularly well-suited for handheld calculators, an application for which cost (eg, chip gate count has to be minimised) is much more important than is speed. Also the CORDIC subroutines for trigonometric and hyperbolic functions can share most of their code."

Appendix B – Verilog and VHDL

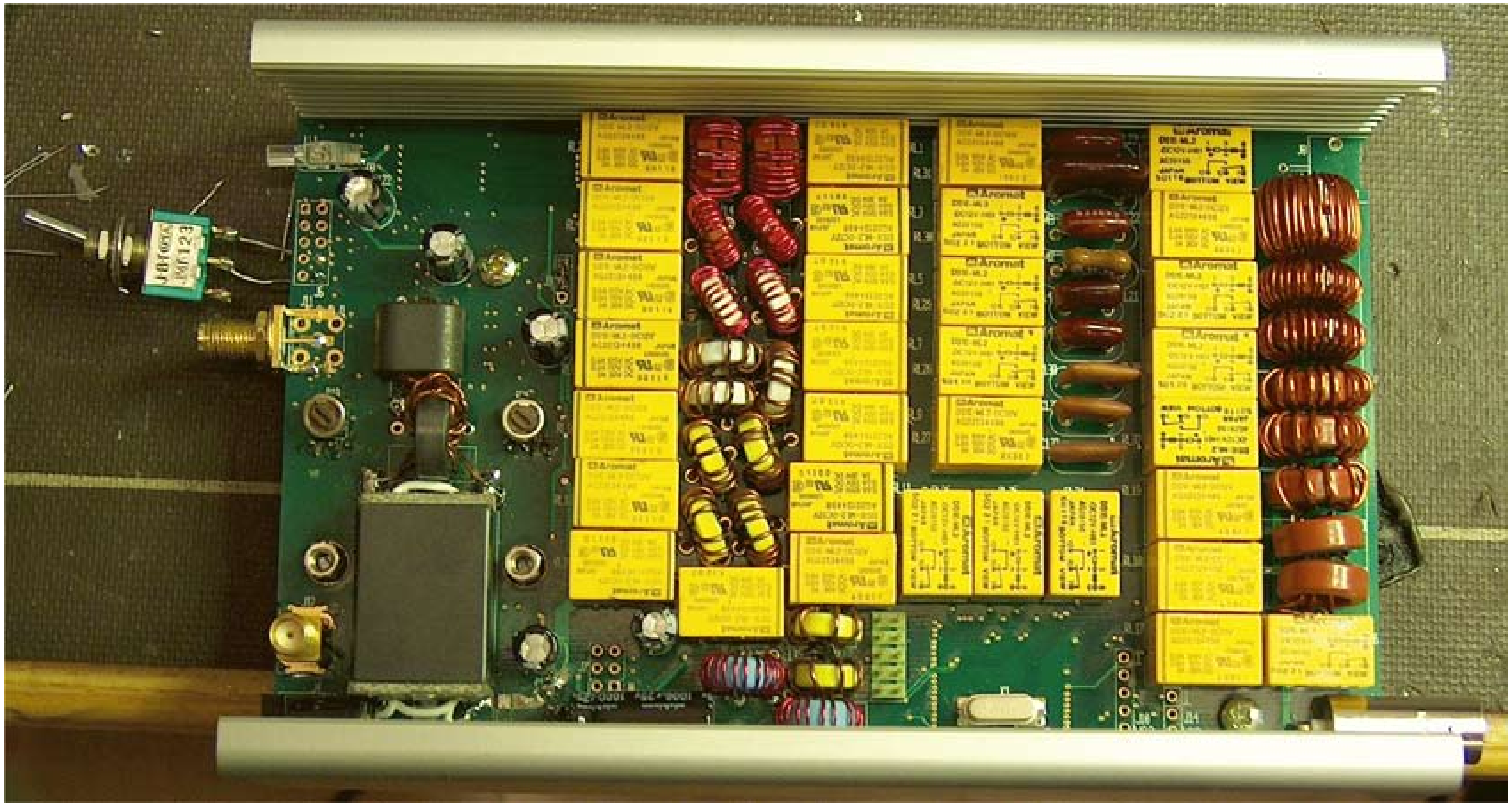
Verilog: http://en.wikipedia.org/wiki/Verilog

Verilog – tutorial learn by example: http://esd.cs.ucr.edu/labs/tutorial/

Verilog by example: http://www.ece.arizona.edu/~ece474a/resources/verilog_tutorial/index.html

```
================= Verilog programming example ==================

// Flash LED to indicate we have a clock selection error

module flash(
    input clock,
    input flag,
    output reg LED);

reg[19:0]error_count;

always @ (posedge clock)
begin
  if (flag) begin
   if (error_count > 1000000)begin
    error_count <= 0;
    LED <= ~LED;      // error so flash LED
    end
   else
    error_count <= error_count + 1'b1;
   end
  else begin LED <= 1'b1;    // no error so LED off
  end
end

endmodule
```

Appendix C



Apollo PA Prototype in Alpha Stage of Testing (Photo Courtesy Kjell Karlsen, LA2NI)

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PSR Packet Status Register Editor:

Stan Horzepa, WA1LOU
One Glen Avenue, Wolcott, CT 06716–1442 USA
phone 203–879–1348
e–mail wa1lou@tapr.org

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