March 2012
Volume 12, Issue 9

ANODE

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Anode Editor's Comments

Volume 12, Issue 9
March 2012

SARL Field Day Contest
11 - 12 February 2012

Storytelling and creative writing has never been my strong point. Unlike a task such as reverse parking I will certainly not be remembered for my writing ability as part of my 'super hero' skills.

It would however be unfair to everyone who took the time and made the effort to contribute, support and took part in the West Rand Club (ZS6WR) field day contest effort. Everyone who built the station, help made contacts, made food, gave advice away, gave points away and packed up again.

This is a big thank you to you all!

The West Rand Club is again champions and the results speak for themselves.

I'm looking forward to the next leg of this exciting contest as part of the winning team in September. Well done all!

Results:
The February leg of the 2012 SARL National Field Day was held on 11 and 12 February and 20 logs were received.

Class A - Multi Operator Field Station:
1st West Rand ARC, ZS6WR, 117 240 points.
2nd Bloemfontein ARC, ZS4BFN, 64 044 points.

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duplexers: theory and tune up

Note
This article is also available in it's original Adobe PDF format. You will need the Adobe Acrobat Reader to use the PDF format.

background
From the amount of questions we have received on the web page, I saw a need for an article to demystify the subject of duplexers and cavity filters. Duplexers and their cousin the Diplexer (note they are not the same thing) are electrically simple filters. They allow us to transmit and receive on the same antenna at the same time, reject unwanted signals and in the case of the Diplexer feed two different signals to the same antenna.

Electrically a duplexer is a device using sharply tuned resonate circuits to isolate a transmitter from a receiver. This allows both of them to operate on the same antenna at the same time without the transmitter RF frying the receiver. Note that there must be a separation of the transmit and receive frequency. This is called the "split." On two meters the split is 600 kHz. On 70 cm the split is a much easier to do 5 MHz.

(Continued on page 2)

Special points of interest:

- **Contact details on back page UPDATED 2011-11-14**
- **Ham-Comp Latest on web site. Still under construction...**

duplexers: theory and tune up

(continued from page 1)

Diplexers are often mistakenly called duplexers. The common application for a diplexer is to connect a dual band mobile radio's two antenna connections to a common feed line and antenna. Diplexers are completely different and much simpler to build devices then a repeater duplexer. While duplexers use narrow pass-bands and notches to work their magic, a diplexer is a simple high and low pass filter connected together.

types of duplexers

There are several different ways to build a duplexer. The hybrid ring, cavity notch and band pass/ band reject design are all found commercially. Each design has its advantages. The hybrid ring is rarely seen in Amateur service. It uses a combination of both cavities and phasing lines. The ARRL Handbook has a excellent explanation of how it works if you are interested.

For many years the Handbook also had plans for a six cavity notch duplexer. The Handbook has an excellent explanation of the theory behind this design. I have built these and they do work. I have also found this design to be extremely difficult to tune, noisy and not all that stable. I do not recommend it. Yes, I know some have been built, but there are better and easier to tune designs available now.

My all time favourite duplexer design is the Wacom four cavity Band Pass/Band Reject model with 8" cavities. Their only flaw is their expense (close to $900 at this writing). By using larger high Q cavities and a better design, Wacom was able to get the performance of the six cavity notch duplexer using only four cavities.

wacom description

Examination shows that two of the cavities are in series with the transmitter output, and two in series with the receiver input. The two "halves" are joined together with a "T" connector and connected to the coax line to the antenna (see fig. 1).

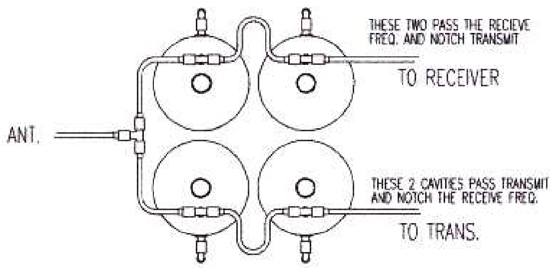

FIG. 1 FOUR CAVITY BP/BR DUPLEXER CONNECTIONS

Each cavity has two functions. First it must pass the desired signal (the "bandpass" or pass band). Second, it must stop as much as possible of the undesired signal (the band re-

(Continued on page 3)

duplexers: theory and tune up

(Continued from page 2)

ject or notch). In figure 2 I show the ideal response curve of a typical transmitter cavity. Note that is passes almost all of the signal on the transmit frequency of 145.37. And that it has a deep (30 dB+) narrow notch at the receive frequency 600 kHz. lower.

The two receiver cavities are exactly the same except that they have their pass band tuned to 144.77 the receive frequency. Their notch or Band Reject frequency is on the transmitter frequency of 145.37. Thus the transmitter cavities keep the wide band RF noise from the transmitter out of the receiver, and the receiver cavities keep the RF power from the transmitter out of the receiver.

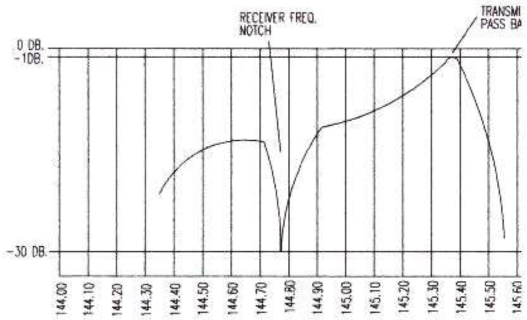

FIG. 2 TRANSMITTER CAVITY ATTENUATION CURVE

Note at this point that transmitters do not put out all of their energy on just the desired frequency! They also put out wide band white noise (hiss) for a considerable distance from the centre frequency. If your transmitter (this is a rare problem) puts out excessive white noise, you may not be able to notch out it all out. Some transmitters radiate less white noise then others. A few very early solid state transmitters produced so much noise that they could not be used on repeaters.

how they work

How do they do this apparent magic of letting you transmit and receive at the same time? Surprisingly, a duplexer cavity is simply two carefully tuned resonate circuits! Electrically they are very simple. One tuned circuit sets the pass band, the other sets the frequency of the notch. That's all there is! Two cavities are used in series simply to provide more isolation between the transmitter and receiver. One cavity isn't enough to do the job.

The duplexers complexity comes from the mechanical design required. To make things simpler, lets just look at one cavity since they are all the same. A cavity is simple tuned circuit. Look at figure 3. The body of the cavity and tuned line inside make up the parallel tuned circuit consisting of L1 & C1. Coupling of the RF energy into the cavity is done by L2 and C2.

Now why do we have to use a big cavity when a coil and capacitor tuned circuit for two meters can be made very tiny? The answer is in the quality of the tuned circuit, that is, its "Q." Our little coil and capacitor has a low Q, far too low to work as a duplexer. That is, it does not tune sharply enough. Its band pass peak would be too broad, and its notch too wide and shallow.

Now an interesting thing happens as we make the coil larger in diameter and reduce it turns. When we increase the value of C1 so it still tunes to the same frequency, the Q increases and the tuning becomes sharper. If we continue this evolution, our coil becomes a tuned line 1/4 wave long. The capacitor is replaced by a large metal tank (cavity). The larger the tuned line and cavity (in reason) the higher the Q. An 8" diameter cavity has a higher Q then a 3" cavity would and works better on the air.

Thus our tuned circuit becomes a cavity (figure 4) 25" long and about 8" in diameter. The tuned line inside is a copper tube 1 3/8" in diameter that can be varied in length between 18 to 23 inches. Varying the length of this tube (often called the plunger) sets the band pass frequency the cavity is resonate on.

Look back at figure 3. We still have to couple RF energy into our resonate cavity. L2 becomes a "loop" of copper wire or strap that dips down

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duplexers: theory and tune up

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into the cavity from the top. The size or the loop and its position determines the amount of coupling of energy into the cavity. One last refinement is the loop resonating capacitor C2. It sets the frequency of the cavities notch. Together L2 and C2 form a series tuned resonate circuit.

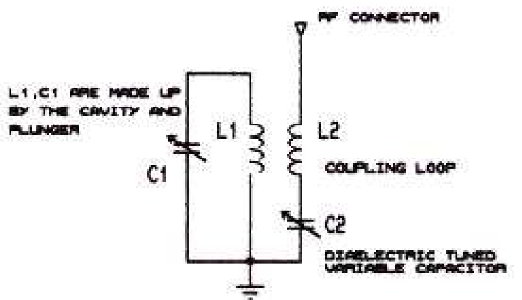

FIG.2 BP/BR CAVITY SCHEMATIC

is there a plumber in the house?
So we now have a very simple electrical design! All of our problems from here on out are mechanical in nature. First of all, we have to fabricate the body of the cavity. Copper, aluminium or brass all will work well. Just as long as the top can be in one piece of electrically low loss material. It has to be closed on the bottom end. A simple plate pop riveted in place would work.

The tuning plunger can be a 18" piece of ordinary 1 3/8" O.D. copper water pipe. Inside of it a 20" long tuning shaft made of 1/4" threaded rod screws in and out a 6" section of 1" O.D. copper pipe. The only real problem here is the electrical conductivity of the plunger. The joint between the two pipes has to be made of a springy bronze contact material called "finger stock."

Then all of the pieces are silver plated. The silver plating is ultra important! Bare copper alone is too lossy at two meters to make a practical cavity. Plus the surface of the copper (where the RF travels) oxidises making a even poorer connection between the fixed and moving section of the tuning plunger. The result is often a cavity that is almost impossible to tune due to the noise generated by the moving contact.

The tuning plunger, finger stock and all RF parts inside the cavity must be silver plated. Plating really makes a difference. Remember that you have to keep total losses in your duplexer to less than 3 dB. Small improvements in efficiency are very important.

The last item is capacitor C2. A simple air variable would be too critical to tune. Wacom solved this problem by using a cleverly designed capacitor that works by varying the dielectric constant! Going back to your basic theory, remember that two things determine the value of a capacitor. One the size of the plates, the other is the dielectric constant (quality) of the insulating material between them.

The Wacom capacitor consists of a 11" section of 1/2" I.D. brass tube making up one plate of the capacitor. The other plate is a 1/8" O.D. copper rod inside the tube. A plastic tube slides into the 1/2" brass tube and over the interior 1/8" rod. Varying its position, changes the dielectric constant of the capacitor and thus its capacitance (you are varying the amount of plastic dielectric replacing the air dielectric and no the device is not air tight).

This capacitor and the coupling loop make up a series resonate circuit (refer back to figure three). The resonate frequency of this circuit determines the frequency of our cavities notch (or as Wacom calls it, the "Band Reject"). The great beauty of the Wacom design is simple smooth adjustment of the notch frequency by this clever variable capacitor. In other duplexer designs I have worked with (for example the Handbook six cavity notch design) the tuning of the passband and notch are very difficult.

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temperature stability

Another problem is temperature stability. If the duplexer is in an area that is not temperature controlled, the metal will expand and contract with temperature changes. This could possibly detune the cavity slightly. Wacom gets around this problem by using a tuning rod made of a special and very expensive alloy called INVAR that compensates for the temperature changes. We do not have a source of these rods.

If you do build a homebrew duplexer and it is kept in a temperature controlled environment, then there is no need for self compensation. If you tune the duplexer at 72 degrees and keep it close to that temperature, then NO PROBLEM! In practice, we have found that our homebrew duplexers do work well in an unheated building. Or at least well enough that the users have not complained.

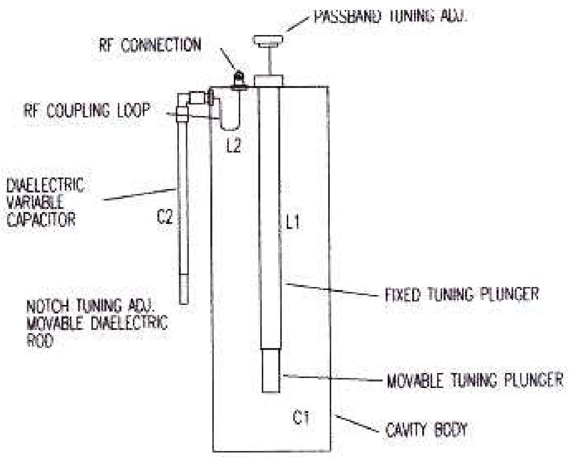

FIG. 4 BP/BR CAVITY CONSTRUCTION

coupling

The next issue on duplexer design is the coupling of the RF between the various components. This is done with electrical 1/4 wave coax lines. If you are working with surplus cavities that were used in the high end public service band you may have to replace the coupling cables with longer ones. Tune the cavities and test them on the air. If you can not get sufficient isolation, contact the manufacturer for their recommendations. Or you can go ahead and fabricate a new set of cables yourself.

A RF wave travelling in coax is shorter than one travelling in free space. The difference between free space length and the wave length in coax is called the velocity factor. The ARRL Handbook has charts giving the velocity factor of various coaxes and explains how to calculate the correct length for the 1/4 wave lines.

I have had duplexer connecting lines go bad on older duplexers so it is useful to know how to replace them. I've also found that when I determine the length of the lines experimentally they came out a little different than the Handbook calculations led me to believe they would be. The lesson here is that if you are not sure, make some tests!

The choice of connecting cable is important. The coax must be the double shielded type with 100% coverage. It does not have to be solid heliax (that would be pretty hard to work with). If you can locate it, double shielded mil-spec Teflon coax is the best. The new Times coax with a metalised mylar shield works very well. The coax does not have to be large diameter if you are running under a couple of hundred watts. The lengths are so short that losses are not a consideration.

connectors

Pay careful attention to the duplexers connectors. Most of the mysterious noise problems I have heard in repeaters have been traced to the coax connectors. My favourite Wacoms do use UHF connectors on them. I have had minor problems with noise that was easily cured by cleaning and tightening the UHF connectors.

If I had a choice, I would use N or BNC connec-

(Continued on page 6)

duplexers: theory and tune up

(Continued from page 5)

tors on any new duplexers. N series connectors are the best and well worth the extra money. They are lower loss and I have never had a noise problem with one. Be sure that the connectors you use are U.S. made and silver plated! There is a difference in connector quality. Be super careful of UHF elbow connectors. We have had very serious problems with imported elbow connectors. Most work better as RF chokes then connectors. Avoid using any of them if you can. Some we tested introduced severe losses in the system.

tuning

Tuning of the band pass/band reject design duplexer is easy compared to conventional notch duplexer. The cavity plunger sets the passband frequency. Here you want as much RF to pass through the duplexer as possible. The tuning capacitor C2 sets the notch frequency. Clearly mark the pass and reject (notch) frequencies on each cavity. Remember that they are opposite for transmit and receive!

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EXAMPLE:
RECEIVER CAVITIES Pass 144.77 MHz Reject 145.37
TRANSMITTER CAVITIES Pass 145.37 MHz Reject 144.77
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The easiest way to tune cavities is with a FM service monitor equipped with a tracking generator and a spectrum analyser. If at all possible, contact someone with this type of test equipment to do the tuning for you. If this is not possible, do not despair. Simpler amateur methods are possible and will work just fine. You just have to take more care.

You are going to need some kind of stable signal source and method to measure RF amplitude. A old fashioned tunable RF signal generator that can put out at least a volt of RF is very useful. You can use to sweep the cavities for initial passband tuning. For a stronger signal source a HT will work.

With the HT your passband indicator can be a RF watt meter. For the finer job of tuning the reject (notch) frequencies, a simple RF voltmeter will work. You could also use a "S" meter equipped receiver with a step attenuator in front of it. This would be perfect for fine tuning the notches. Just be careful how much RF you inject into the duplexer while tuning, you would not want to fry your receiver front end when you hit the correct passband!

If you are going to build your own RF voltmeter probe, see the ARRL Handbook for details. Build it in a connector that you can attach directly to the duplexer connecting cables. For the RF voltmeter use a old fashioned analogue moving needle meter like a VTVM or a simple micro amp meter. Its much easier to tune for peaks and notches with a analogue then a digital meter.

one at a time

Start with just one cavity connected. Turn the RF output up all the way on the generator and sweep up and down the band till you see a peak on your RF voltmeter or S meter. Remember that turning the plunger in lowers the pass frequency. Turning the plunger out raises the pass frequency. Set the output of the generator to keep the meter in the linear portion of the scale.

All we are doing is a rough tuning first, so don't try to get things perfect. Connect the next cavity in the chain and repeat the process to put it on the pass frequency. Then set the second set of cavities to their pass frequency. Here is where it is easy to get confused and why it is important to have the frequencies clearly marked on the cavities. Doing that will save you a lot of trouble.

With both the transmit and receiver cavity sets rough tuned to the pass frequency, connect all of the cables on the duplexer set. Connect a watt meter and a dummy load as in Figure 5 to the antenna connection. Set your HT on simplex to the pass frequency of the transmitter cavity set. In my example this is 145.37 MHz. Key the HT and tune the cavities

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duplexers: theory and tune up

(Continued from page 6)
for the maximum amount of power output.

Connect the HT to the receiver cavities and set the HT frequency to 144.77 MHz simplex (- 600 split from the transmit frequency in this ex- ample). Repeat the process of tuning the pass- band plungers for maximum RF on the watt-meter. Note that if by accident the reject frequency is too close to the pass band you may not be able to tune a cavity prop- erly. If you suspect this, move the reject fre- quency adjust rod a short distance and try the passband tuning again.

tuning notches
Tuning notches is a little more difficult. You need a vastly more sensitive detector than the watt meter used so far. If your signal gen- erator can put enough RF into the cavities, a simple RF voltmeter probe will work. Re- move the watt meter and replace it with a T connector. Connect the RF probe to the open port of the T. Your cavities will now be prop- erly terminated with a 50 ohm load and you will be able to measure the RF voltage across that load.

It is critical that your RF source be dead on frequency. A old fashioned tunable genera- tor will not work. If your HT has a low power position, you can start with that. Warning! The HT will not be seeing a 50 ohm load when its signal is notched out. If you are un- certain if the HT can sustain high SWR's, don't use it.

Key the transmitter and adjust the first cavity for the proper notch frequency. You may have to increase the meter sensitivity or RF power to clearly see the notch. It should be quite sharp. Then repeat the process on the next cavity. Other than changing frequency, the process should be the same for the other set of cavities.

If everything went well you should be 99% in tune at this point. Go back and touch up the passband tuning and the notches one more time. Calculate the pass frequency loss across the re- ceiver and transmitter cavities.

It should be less than 2 dB and no more than 3 dB. If the loss is excessive, check your tuning again. If that is not the problem, check the loss of each of the cables and connectors.

The main reason I like the band pass/band re- ject design so well is the ease of tuning. They also rarely need retouching when connected to the repeater. In some rare cases you may want to touch up the notch adjustment to eliminate the last trace of de-sense white noise from the re- ceiver. You need a weak unmodulated off the air signal to do this and a AC voltmeter connected across the repeater monitor speaker.

I use a whip antenna on my service monitor out- put to supply the weak signal. Adjust the output till you have about 10 dB of quieting with the squelch open. Turn the transmitter on and off (you do have a local service switch don't you?) and observe the difference in the background noise. Any additional hiss is that is heard when the transmitter is on the air is white noise from the transmitter. If you feel the noise level is ex- cessive touch up the notches.

white noise
Most repeaters I have heard do have some audi- ble white noise on the receiver. Perfection is hard to achieve in the real world. Worry about it only if the noise level is so high that it obscures the weakest modulated signal that you could normally expect to communicate with.

For example, lets say that you can clearly hear a .25 uV signal on your receiver with the trans- mitter off. With the transmitter on the noise level increases 2 dB. This you could accept after final tuning. If the same signal disappears completely when the transmitter is keyed, then the de-sense is excessive and there are still problems in the

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duplexers: theory and tune up

(Continued from page 7)
system.

building your own
Can you build your own duplexers? The answer is yes, but it is not easy. Nor is this intended to be a construction article. You can't find all the materials at the local hardware or plumbing store. You have to be able to do some simple lathe work and other metal fabricating. And you need the proper test equipment and tools.

As I said before, silver plating of the internal components is very important. I do silver plating on a regular basis and it is not difficult. I am not going to publish instructions on the web due to the extreme toxicity of the cyanide compounds used in the baths. Actually the process is quite safe, but I don't want some idiot killing his family by pouring the plating bath in the orange juice. If you are interested in electroplating, go to your local library and research the subject. Jeweller supply houses sell the plating baths and supplies. Check the Yellow Pages.

Nor can I give technical details or tuning procedures for all of the duplexers on the market. The smartest thing you can do is to contact the manufacturer and buy the manual! Its a small expense for the trouble it will save you.

correspondence
This article is the product of the mind of David Metz, WA0AUQ. If you have questions or want further information, you can email Dave. davemetz@muscanet.com

To SEITS Homepage
http://www.seits.org/index.html

February 6, 1998

March 01	ZS6YE	Heather Holland	Partner of ZS6YOT Jess Hawes
March 03		Cynthia	Spouse of ZS6CAA Viv Wells
March 03		Gail	Spouse of ZR6NPH Noel Hammond
March 04	ZS6YOT	Jess Hawes	
March 07		Lynda	Spouse of ZR6LY Peter Hasert
March 07		Gill	Spouse of ZS6TF Richard Dismore
March 12		Antoinette	Spouse of ZS6AVH Andrew van Heerden
March 13	ZR6DCP	Stewart da Costa Pereira	
March 14		Wojciech	Child of ZS6RQM Boleslaw/Teresa Halas
March 15	ZS6EF	John Williscroft	
March 19		Barosz	Child of ZS6RQM Boleslaw/Teresa Halas
March 20		Elizabeth	Child of ZS6WL John Brock
March 21		Maureen	Spouse of ZS6NJV Nico Vorster (Snr)
March 21		Andre Truter	
March 26	ZS6SAV	Albertus Vermeulen	
March 29	ZS6JAQ	Jaqueline	Spouse of ZS6OPC Christo Snyman
March 29	ZS4AU	Dirk Beukman	
March 29		Ettiene	Child of Edgar/Cornelia Wallace

Anode Editor's Comments

(Continued from page 1)
3rd Magalies ARC, ZS6MRK, 60 840 points.

ZS6PVT - Phillip van Tonder

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VHF/UHF Contest Frequencies .. Next Weekend
[From The 2012 SARL Contest Manual - Blue Book, Issue 10 — Pages 35-36 of 73]

Frequencies
50.150 CW
50.200 -- 50.250 MHz SSB
50.250 -- 50.300 MHz Digital
50.350 -- 50.400 MHz FM
51.400 FM

70.090 CW
70.100 -- 70.150 MHz SSB
70.150 -- 70.175 MHz Digital
70.200 -- 70.275 MHz FM

144.100 CW
144.200 -- 144.250 MHz SSB
144.250 -- 144.300 MHz Digital
144.350 -- 144.400 MHz FM
145.500 - 145.575 MHz FM

432.100 CW
433.200 -- 433.250 MHz SSB
433.250 -- 433.300 MHz Digital
433.350 -- 433.400 MHz FM

1296.195 CW
1296.200 -- 1296.250 MHz SSB
1296.250 -- 1296.300 MHz Digital
1296.350 -- 1296.400 MHz FM

Higher frequencies as per band plan
NOTE: The 70 MHz band is a shared band; please avoid QRM to commercial users.

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Powerful, wallet-sized Raspberry Pi computer sells out in SECONDS
http://www.theregister.co.uk/2012/02/29/
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Anode Editor's Comments

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raspberrypi_mania/

The first batch of 10,000 ARM-powered Raspberry Pi computers went on sale at 6 am GMT on Wednesday - and sold out within minutes.

According to distributor Premier Farnell, there were at least 600 orders, visits or pre-orders every SECOND, producing a 300 per cent hike in web traffic. The electronic component sales site was knocked for six by the surge in demand for the $35 GNU/Linux-powered gizmo.

BUT!

Raspberry Pi buyers face delay after factory mistake
http://www.bbc.co.uk/news/technology-17311146
[Ok, I admit, it is very hard to tell the difference from the pictures.]

{—}

A Developer after my own Heart!
From: http://www.freewebs.com/g1hbe/signalhound.htm
"Copper pipe-caps are not exactly cheap, so I decided to build a filter with a Toast Topper tin instead. I'm sure Mr Heinz would approve. Sadly, a quick trawl of all three of our local supermarkets drew a blank on the TT front, so I chose a small tin of tomato puree instead. After using the puree in a Bolognese, I cut the tin down to about 23 mm in height and carefully drilled a hole in the end for the tuning screw. A good fluxing and a hot iron saw a nut soldered over the hole."
http://www.freewebs.com/g1hbe/

Microsoft's Azure cloud leap-day meltdown [It seems Y2k has been forgotten!]
[Everyone makes mistakes, but for Microsoft to make a killer leap day blunder with its Azure cloud service is inexcusable]
http://www.zdnet.com/blog/open-source/microsofts-azure-cloud-leap-day-meltdown/10482?alertspromo=&tag=nl.rSINGLE

Facebook uses bgsound to see if you opened an e-mail
http://www.zdnet.com/blog/facebook/facebook-uses-bgsound-to-see-if-you-opened-an-e-mail/10003

Anonymous tricked into installing Trojan
http://www.zdnet.com/blog/security/anonymous-tricked-into-installing-trojan/10452?tag=nl.e539

Up to 900 tropical bird species could 'go extinct'
http://www.bbc.co.uk/nature/17212765

Shakira attacked by sea lion who mistook BlackBerry for a 'fish' [My sympathies are with the Sea Lion!]
http://www.theregister.co.uk/2012/02/14/shakira_blackberry_seal/

Celebrating Colossus, the code breaking computer
http://www.bbc.co.uk/news/technology-17237494

The West Rand Amateur Radio Club
Established in 1938
KG33XU 26.14122 South - 27.91870 East

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Weltevreden Park
1715

Phone: 083 267 3835 (Chairman)
Email: zs6wr.club@gmail.com
Web page: www.zs6wr.co.za

Bulletins (Sundays at …)
11h15 Start of call in of stations
11h30 Main bulletin start

Frequencies
Output: 439.000 MHz 7.6 MHz split
Input: 431.4 MHz (West Rand Repeater)
145,625 MHz (West Rand Repeater)
(HF Relay when possible)

Radio Amateurs do it with more frequency!

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Secretary	Rory Crouch	ZS6RBJ	082 448 4445	rorycrouch@mweb.co.za
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Member	Johan van Vuuren	ZS6JVV	082 558 5811	johanvv@absamail.co.za
SARL Liaison (PIO)	Willem Weideman	ZS6WWJ	082 890 6775	willem@zs6wwj.co.za
Club Manager & Groundsman	Nico Vorster	ZS6NJV	082 221 1266	zs6njv@gmail.com

West Rand members - we need your input!

To make this the best ham radio magazine in South Africa we need your input. Please submit articles, comments, suggestions etc.

Please send plain text with no formatting to the email address below.

See Club website at www.zs6wr.co.za for all ANODE back issues.

We need your input! Email us articles, comments and suggestions please.
zs6wr.club@gmail.com