THE WEST RAND AMATEUR RADIO CLUB

June 2006
Volume 6, Issue 11

ANODE

Inside this issue:

Special points of interest:

- Contact details on back page (updated)
- New email address for Anode and ZS6WR. See back page

Editor's Comments

June 2006
Volume 6 Issue 11

TYPICAL 'HAMSTER' STUPIDITIY

Two ARRL members from California are dead after the vehicle in which they were riding during a mobile hidden transmitter hunt May 27 went over a cliff in rugged terrain near Lake Isabella in Kern County. They were identified as Michael G. Obermeier, K6SNE, of Anaheim, and David A. Gordon-Ross, N6IDF, of Yucaipa. Obermeier, an ARRL Official Observer in Orange County, was 46. Gordon-Ross was 35.

"Mike and Dave were some of the best T-hunters in the biz," said Scott Press, N6SAP, calling both "true assets to this hobby." In his role as an OO, Obermeier reportedly had participated in the infamous Jack Gerritsen radio jamming case in the Los Angeles area.

According to media accounts, a Kern County Sheriff's Department search-and-rescue team located the victims early Monday, May 29. Obermeier was driving the 1991 4-wheel-drive Jeep Cherokee that apparently went out of control on Cook Peak Road while the pair was proceeding to the next hidden transmitter site. After caroming off a rock wall, the vehicle crossed the road and plunged down a 900-foot cliff.

(continued on page 2)

Multi-band, Direct Conversion Receiver

Novel application of low cost components result in a unique receiver design for the h. f. amateur bands. By Hannes Coetzee, ZS6BZR. From the February 1998 Electronics & Wireless World

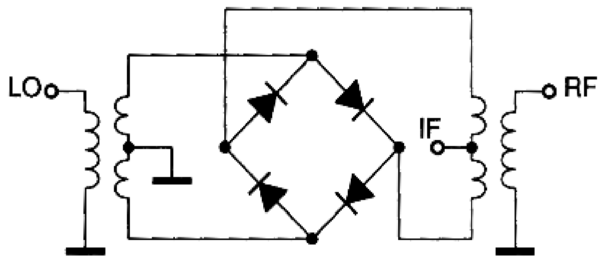

Fig. 1. In the typical diode-ring mixer, the switching signal needs to be significantly higher than the signal being switched.

Today's listeners ask a lot from a radio receiver. Among other things, it is expected to be able to demodulate a very weak signal - sometimes with some very strong local transmissions only a few kilohertz away. This has made the distortion free dynamic range of the receiver very important, along with selectivity and, for vhf receivers, noise figure.

For a high-frequency receiver, the distortion-free dynamic range is to a great extent determined by the mixer, or mixers, used.

(continued on page 3)

Editors Comments & News

(continued from page 1)
They were reported missing after failing to check in with T-hunt organizers.

Greg Pitta, KF6DBJ, reports Obermeier and Gordon-Ross were on a half-day multiple-transmitter T-hunt. "Both K6SNE and N6IDF were expert transmitter hunters, each with hundreds of hunts completed, ranking with top scores in most," he said.

ARRL Amateur Radio Direction Finding (ARDF) Coordinator Joe Moell, K0OV, knew both men. He notes that Obermeier had suffered a sports-related spinal cord injury that left him a paraplegic. "He did all the adaptive work on his vehicles, of which he had quite a few that he used over time for RDF," Moell said. Despite his physical limitations, Obermeier also enjoyed foxhunting from his wheel chair.

Moell says Gordon-Ross had been a proficient mobile T-hunter for many years. He took a brief hiatus after his first child was born in April 2005 (his wife, Melanie, is KF6GWV), but he recently became active again.

According to Moell, the mobile transmitter hunts take place on the fourth Saturday of each month on 2-meter FM simplex, starting out from a hilltop in Rancho Palos Verdes. He says it's not uncommon for the main hidden transmitter to be hundreds of miles away--175 highway miles in this instance. The 147.435 Amateur Radio Repeater System is collecting donations to help Melanie Gordon-Ross, a stay-at-home mom. It also will donate all proceeds from its 16th annual 435 Chili Cook-off June 10. Visit the 147.435 Web site http://www.435online.com for additional information.

[Please take note of the above, those of you wanting to take part in the upcoming fox hunts.]

If you want to list to the SARL bulletin on the Internet…
Browse to :-
http://www.pirateradionetwork.com/
Note the 'pie rat' radio network! H.I.

Why didn't it work?
There are several reasons the product has failed to meet your expectations.

1 you have likely installed it upside down.
2 Your antenna is defective, the product is not meant to be used with a defective antenna.
3 Exposure to weather has nullified your warranty.
4 There is an improved replacement product available and you may wish to upgrade at a special price.

de W8CCW John

So you think you have problems with your neighbours…
Browse to :-
http://www.youtube.com/watch?v=aC_EeWSKJII

JB 2006-06

Multi-band, Direct Conversion Receiver

(Continued from page 1)

Mixer using an analogue switch

The heart of this direct-conversion receiver is a low-cost 74HC4066 c-mos analogue switch implemented as a double-balanced mixer. The switching speed of high-speed c-mos makes it possible to use this logic family right through the h.f. spectrum, i.e. from 3 to 30MHz.

The switches in the 74HC4066 IC replace the diode switches found in a conventional diode-ring mixer, Fig. 1. In the conventional normal diode mixer. Local-oscillator, r.f. and intermediate-frequency signals are coupled to the diode ring via two r.f. transformers. Two local oscillator signals that are 180° out of phase are fed to the diode quad by the r. f. transformer.

Phase shift is accomplished with the aid of a radio-frequency transformer, causing two pairs of diodes to alternately conduct on the positive and negative cycles of the local-oscillator signal. The conducting diodes thus switch the rf signal to the intermediate-frequency port at the rate of the local oscillator signal.

For a diode to function satisfactorily as a switch, the switching signal needs to be much more powerful than the signal being switched. For this reason some high level diode ring mixers make use of a +27dBm, i.e. 500mW, local oscillator level to provide good strong-signal handling capability.

Even then a diode is not a perfect switch due to the transfer function of the diode not being 100% linear. This is one of the causes of the unwanted mixing products that become a big problem when strong signals from the antenna are present at the rf input port. With a half-watt local oscillator signal radiation also needs some special considerations.

In the mixer to be described, the diodes are replaced with the analogue switches of a 74HC4066. The gates of a 74HC04 hex inverter are used to split the local-oscillator signal into two signals with a 180° phase difference.

This device also converts the local-oscillator signal to a square wave. Using the inverter allows one of the mixer r.f. transformers required by the diode-ring mixer to be replaced with an inexpensive c-mos integrated circuit. Only the r.f. signal needs to be transformer coupled into the mixer.

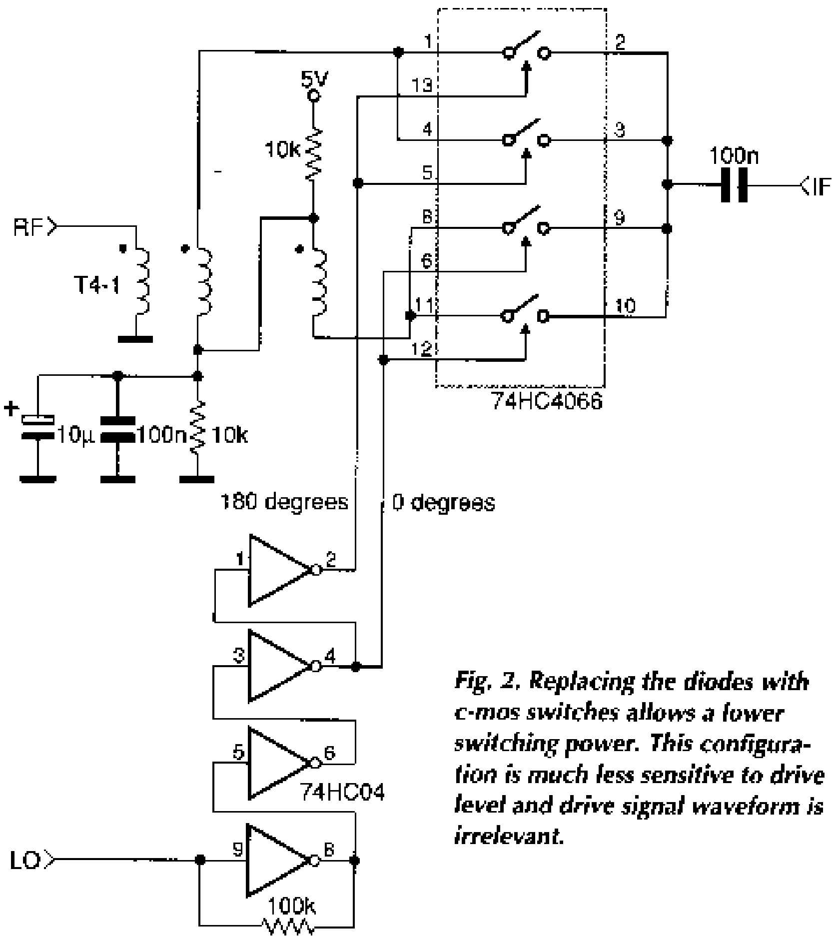

Fig. 2. Replacing the diodes with c-mos switches allows a lower switching power. This configuration is much less sensitive to drive level and drive signal waveform is irrelevant.

(Continued page 4)

Multi-band, Direct Conversion Receiver

Direct-conversion receiver performance summary				
Frequency (MHz)	**Bandwidth (kHz)**	**Minimum discernable signal (dBm)**	**Test tone Spacing (20kHz)**	**Distortion-free dynamic range (db)**
7.020	2.4	-128	20	105
14.040	2.4	-109	20	101
21.060	2.4	-112	20	100
28.080	2.4	-104	20	90

The theoretical noise floor in a 2.4kHz bandwidth is at -140.2dBm. The measured -128dBm minimum discernible level at a 7MHz rf input represents a receiver noise figure of around 12dB in 2.4kHz bandwidth. This is made up by the mixer's 7dB insertion loss, 1dB through the r.f band-pass filter and 3dB contributed by the image that is also mixed down to base band. The measured and calculated values correlate fairly well for a change.

(Continued from page 3)

Two switches are used in parallel to reduce the on resistance with Vcc/2 dc bias applied via the rf transformer, Fig. 2. As long as the input level is high enough to activate the Schmitt trigger, the mixer is insensitive to the drive level and wave form of the local oscillator signal.

Square wave switching signal has a not so obvious, but very useful characteristic: the mixer responds to harmonics of the local-oscillator signal, although with reduced performance. This harmonic mixing technique is often used by microwave engineers for the down conversion of a microwave signal to a more manageable frequency.

When the mixer is used in a direct conversion receiver, for example at 7MHz, signals on 14, 21, 28MHz, etc., will also be mixed down to base band.

Fortunately, the above-mentioned frequencies are all harmonically related amateur bands. A suitable band-pass filter between the antenna and the mixer is all that is needed to select the band of interest. It is thus possible to use the same local oscillator for a multi-band, direct-conversion receiver.

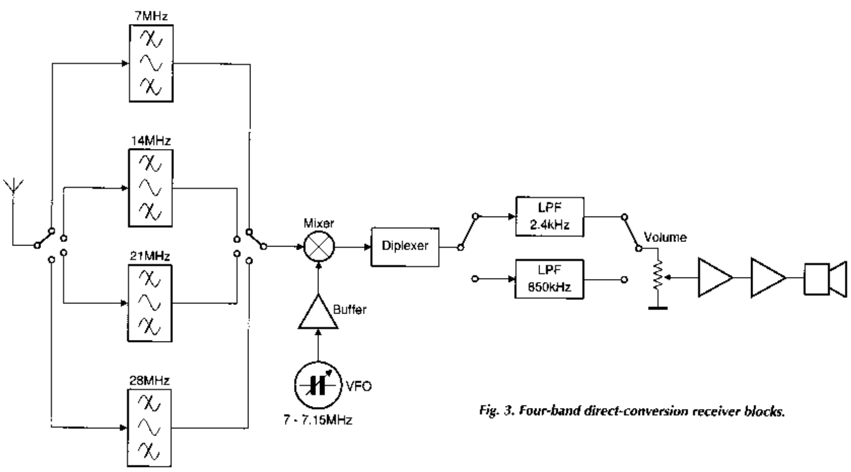

Fig. 3. Four-band direct-conversion receiver blocks.

But unfortunately, there are tradeoffs. The penalty for multi band operation is increased insertion loss through the mixer and reduced dynamic range when operating on the harmonics. Fortunately though, the sensitivity can easily be improved by an r.f. pre-amplifier ahead of the mixer.

The c-mos analogue switches used in the mixer are very linear when switched on and give

(continued on page 5)

Multi-band, Direct Conversion Receiver

(Continued from page 4)

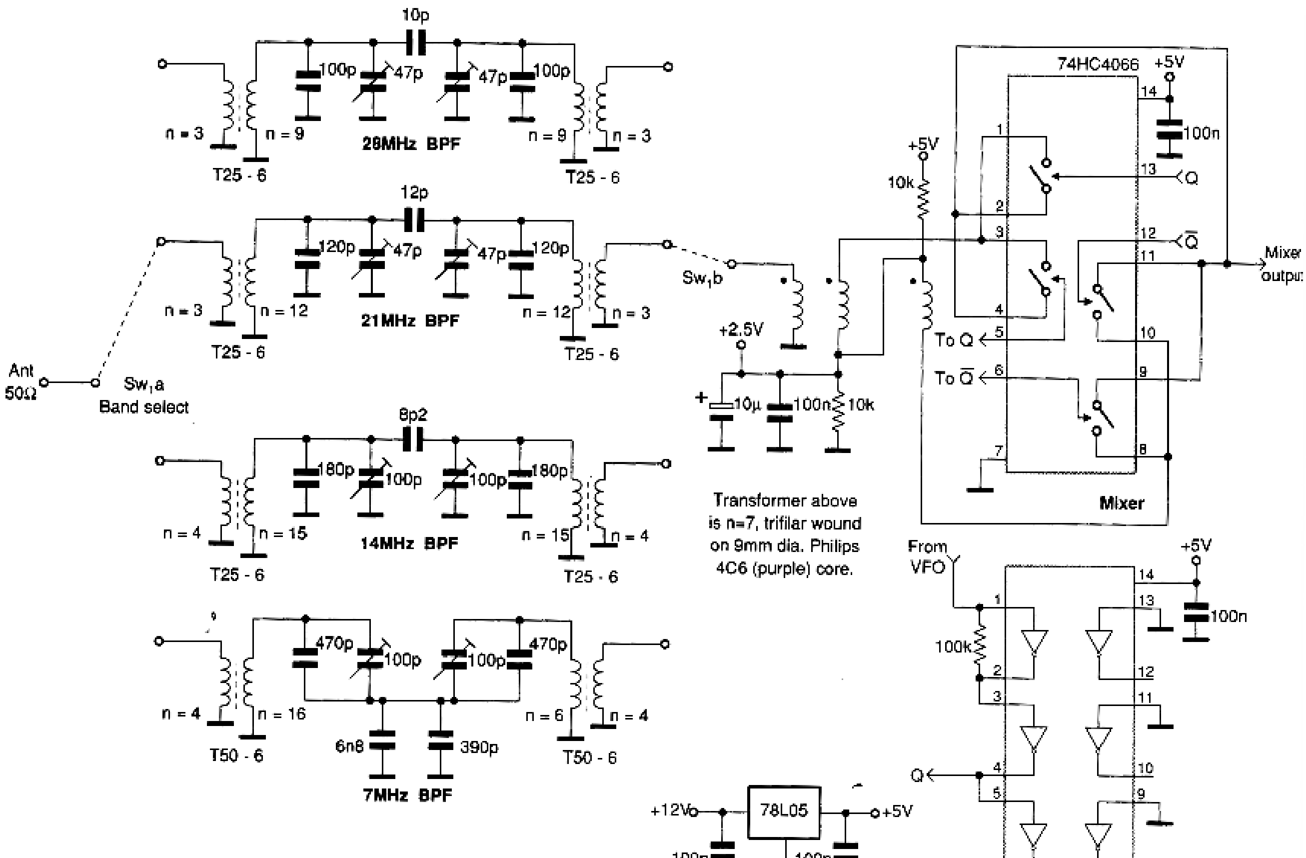

Fig. 4. RF front end showing the four switch-selected band-pass filters and the mixer.

good isolation when switched off, resulting in a mixer with good strong signal handling capabilities. This is reflected in the very good dynamic range of the receiver.

Receiver

Shown in block form in Fig. 3 and in full in Fig. 4, the receiver is a fairly conventional direct conversion (homodyne) design. (refs 2,3,4)

The received signal is mixed down to base band, i.e. 300Hz to 3kHz, with the aid of the local oscillator running at very nearly the same frequency as the received signal. This enables Morse code continuous-wave and single side band signals to be received. Even amplitude-modulated transmissions can be demodulated if the local oscillator is tuned to the same frequency as the received signal.

Note that a nasty whistle results when the local-oscillator and received frequencies differ too much, i.e. by more than about 300Hz.

Receiver selectivity is determined by selecting either a 2.4kHz passive low pass filter for ssb, or a passive 850Hz low-pass filter for c.w.

Audio frequency amplifiers are used to increase the signal to an adequate level for driving headphones or a loudspeaker. In this receiver automatic gain control is not implemented to keep the design simple.

(Continued on page 6)

Multi-band, Direct Conversion Receiver

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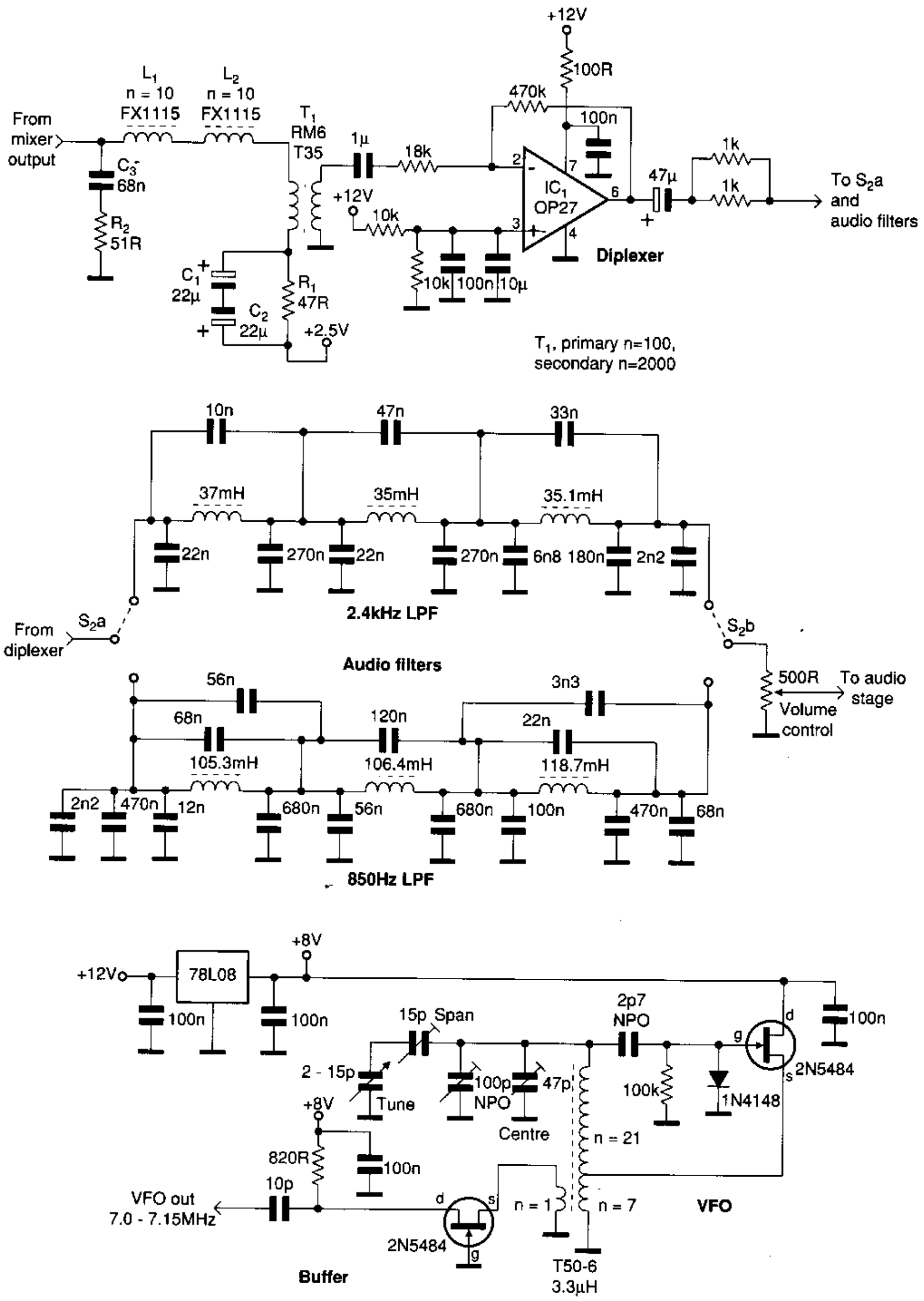

Fig. 5. Diplexer presents a 50Ω load to the front end, converts it to several kilo-ohms ready for the op-amp filter. Two subsequent passive filters allow selection of 2.4kHz or 850Hz low-pass filtering of the audio signal from the op-amp. Also shown is the 7 to 7.15MHz variable-frequency oscillator.

Designing the band-pass filters

The band of interest is filtered out with the aid of second-order band-pass filters preceding the mixer. If better rejection of the other amateur bands is required, higher order filters can be implemented. With the current low of the solar cycle, the second-order filters proved to be quite adequate.

(continued on page 7)

Multi-band, Direct Conversion Receiver

(Continued from page 6)

A Butterworth response with a q0 of 14.142 was selected out of Zverev -the bible of filter design. The theoretical insertion loss is just less than a decibel, which adds little to the noise figure of the receiver.

The inductance value used for the 7MHz filter is 1uH, requiring, approximately 520pF to resonate at 7MHz. Coupled loops are used to improve the attenuation of the unwanted 14MHz response.

Coupled loops cut off at a higher rate on the high side, while coupled nodes attenuate better on the low side of the filter.

An inductor Q of 180 is realisable on an Amidon T50-6 toroid (stocked in UK by Cirkit). Twenty turns provide approximately 10uH of inductance. The loaded Q of the resonator is 15, resulting in a MB filter bandwidth of 665kHz. Note that the number of turns on a toroid is determined by the number of times that the wire passes through the hole of the toroid.

For the 14MHz band-pass filter, use is made of Amidon T25-6 toroids. The inductor Q for an inductance of 620nH is 170. I chose a loaded filter Q of 23, resulting in a MB filter bandwidth of 853kHz.

The 50 Ohm filter termination resistance is transformed to 1490 Ohm across the resonators by the transformer action between the coupling windings and those forming the inductor.

The inductance value used for the 21MHz filter is 389nH. Twelve turns on a T25-6 toroid provide the necessary inductance, which resonates with 148pF. A resonator Q of 14 is realisable, which results in a 3db filter bandwidth of 2.1 MHz.

On 28MHz, the inductor Q comes down to 100 for an inductance of 240nH on a T25-6 toroid. The 3dB bandwidth of the filter is 3.974MHz, representing a loaded resonator Q of 10.

If you want to achieve the 1dB theoretical insertion loss of the filters, it is vital that you only use capacitors with a low insertion loss at r.f. Good choices are NPO ceramic capacitors for the fixed values and Philips trimmer capacitors for the variable types.

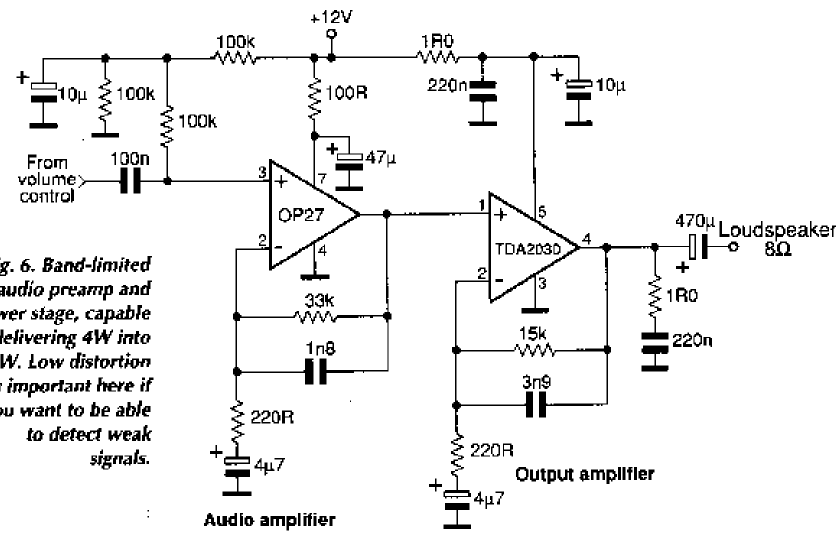

Fig. 6. Band-limited audio preamp and power stage, capable of delivering 4W into 8W. Low distortion is important here if you want to be able to detect weak signals.

Local oscillator options

Many suitable designs for a variable frequency oscillator covering approximately 7-7.15MHz have been published over the years.

In this receiver, a classic Hartley configuration implemented with a 2N5484 junction-fet is used.

To ensure a clean output signal, the jfet must be prevented from operating in the pinch-off region. In a junction fet with a high IDSS, such as the J310, this is accomplished with a source resistor bypassed by a suitable capacitor.

The IDSS of a 2N5484 is very low and individual samples are fairly well matched. This makes the use of a source resistor to set the drain current unnecessary.

Coupling between the resonator and the amplifier (jfet), must

(continued on page 8)

Multi-band, Direct Conversion Receiver

(Continued from page 7)

be as light as possible to prevent degradation of the resonator's Q. This is accomplished with a small value NP0 capacitor.

Output is buffered by a common gate 2N5484 junction-fet amplifier inductively coupled to the resonator. This effectively isolates the variable-frequency oscillator from the rest of the circuitry. Both the variable-frequency oscillator and the buffer get their dc supplies from a well regulated, low noise 78L08 regulator.

It is good practice to build the variable-frequency oscillator and associated circuitry in a separate, shielded enclosure.

In my prototype, the span and centre frequencies were adjusted using trimmer capacitors. Once the settings were correct, l replaced them with fixed-value NPO capacitors of the same value. This greatly improved the oscillator's stability. After a ten-minute warm-up period, the drift of the oscillator was found to be low enough for monitoring ssb and cw signals.

A multimeter capable of measuring capacitance is adequate for matching the fixed and variable capacitor values

To resolve ssb and morse code signals easily, the tuning rate must not exceed 30kHz per revolution of the tuning knob. When the receiver is operated on one of the harmonics, at 14, 21, 28MHz, the tuning rate of the oscillator is also increased - four times on 28MHz for example. The receiver then tunes from 28.0 to 28.6MHz.

To comply with the 30kHz per revolution criteria on 28MHz, the tuning rate at 7MHz needs to be 4.25kHz per revolution. This is difficult to implement, and a compromise might be needed. A large tuning knob helps a lot to improve matters on the higher bands.

On the prototype, a variable capacitor with a reduction gearbox was used, but this can be replaced with variable capacitance diodes and a multi-turn potentiometer.

A band-spread capacitor used in conjunction with the main tuning capacitor is probably the best solution.

Diplexer details

It is very important that the mixer must be terminated into a 50+j0 load from dc to at least 30MHz to prevent degradation of the mixer characteristics. This is accomplished with the aid of a low-pass, band-pass, high-pass diplexer.

Components R1,2, C1, C29 C3, TI, L1,2 and IC, form the diplexer. For frequencies from 0 to 300Hz, the copper resistance of the primary winding of the audio transformer, TI, of around 4~2, together the 47Q resistor R,, terminates the mixer.

Low-pass. The low-pass action is accomplished with two 22pF capacitors, C1,2 in series. These represent an unpolarised 11pF capacitor with a reactance of 50 Ohms at 300Hz - the low pass section's cross over frequency.

Filtering of frequencies below 300Hz also helps to reduce microphonics, which is sometimes an annoying problem associated with direct conversion receivers.

Band-pass. The band pass section not only terminates the mixer correctly, but also feeds the wanted received signal to the rest of the receiver chain. Generally available, low-noise op-amps attain their lowest noise figures when they are fed from a source with an impedance of several kilo-ohms

An audio transformer turns the 50 Ohm impedance needed to match to the mixer, into the several kilo-ohms to suit the op-amp. This transformer has dual advantages of voltage gain coupled with virtually no added noise. This helps to keep the overall noise figure of the receiver the same as the input stages, namely the band-pass filter and mixer.

Although winding a transformer is at the best of times a pain, the benefits really make it worth the while. The transformer is wound on an ungapped, RM6 core without a

(continued on page 9)

Multi-band, Direct Conversion Receiver

(Continued from page 8)
mounting hole through the centre.

Siemens manufactures this type of core in a T35 material.

The primary consist of a 100 turns while the secondary comprises 2000 turns - or as many as you can fit on. Both the primary and secondary are very carefully and patiently wound with 0.06mm enamelled copper wire. A mechanical winder will help a lot.

On the high-pass side, which lets through frequencies from 46kHz to more than 30MHz, the mixer is terminated as follow into 50 Ohms.

The inductance of the two ferrite bead inductors in series, L1,2, is 170ptH. Using XL=2nFL shows that a load of +j50Q is presented at 46810Hz. A 68nF capacitor, C2, provides the necessary -j50Q reactance to cancel it. In this way, from 46 8 1 0Hz up to many megahertz, the 5 IQ resistor, R2, terminates the mixer.

Low-pass filters

Seventh-order, passive elliptical low pass filters terminated in 500 Ohms provide excellent selectivity.

Suitable designs have been published using off-the-shelf 33mH and 100mH inductors. (refs 2,3) Unfortunately these components are not freely available in South Africa.

I designed 850 and 2400Hz low-pass filters incorporating hand-wound inductors using Zverev. (ref 5) These inductors were wound on couple of P14/8 pot cores made from 3B7 material, which is now obsolete (try 3F3). The AL value of this material is 350nH / (winding)^2. The number of turns required by each inductor was calculated and the pot cores were assembled with a very small amount of epoxy used to keep the two halves together.

Fortunately many modem multimeters can measure inductance, which makes confirming the inductance values at audio frequencies a piece of cake.

High quality capacitors are a must for this application. Polystyrene, Wima and MKT are all suitable. Using capacitors with a tolerance of around 10% results in an unknown amount of ripple in the pass band of the filter. This is totally acceptable for speech and morse code applications.

The theoretical insertion loss of an equally terminated filter is 6dB. I measured an insertion loss of less than 7dB on the filters used in the prototype receiver.

Although modem switched capacitor filters give the same pass-band response as the above passive filter - and sometimes even better - the dynamic range is limited to about 85db. This is not enough for the main filter of a modem h.f. receiver.

For the narrow c.w. filter, I implemented a low-pass response in favour of a band-pass response. The human ear needs some background noise to aid in the decision making process of decoding a weak morse code signal. (ref 10) Electronic detection on the other hand measures the energy in a certain bandwidth, which necessitates a band-pass response.

The narrow c.w. filter also helps to reduce one of the more serious principle defects of a direct conversion receiver - namely image response.

Audio amplification

Low-noise op-amps provide the majority of gain. The low-pass filter is fed via a 500 Ohm termination resistor from the op-amp output stage of the diplexer.

Output of the elliptical low-pass filter feeds a non-inverting amplifier with a voltage gain of 4MB. Input impedance of this amplifier is defined as 500 Ohm by the volume potentiometer, which also terminates the filter.

A 6V bias voltage is applied to the input of the amplifier by the three 100k. Q resistors. The output of this stage feeds the power op amp output stage.

Capacitor Cp, in parallel with the feed back resistor Rp, forms a first order low-pass filter with a MB cut off frequency

(continued on page 10)

Multi-band, Direct Conversion Receiver

(Continued from page 9)

of close to 2.7kHz. This reduces the high-frequency noise generated in this stage.

Capacitor C, in series with the voltage divider resistor Rs to ground performs two duties. First of all it blocks dc. Secondly, it forms a first-order high-pass filter to reduce the effects of microphonics.

Output amplifier

A low-distortion output stage is very important to prevent weak signals from sounding fuzzy. This problem is typical of the majority of audio amplifier ICs. The class B output stage used in these ICs just isn't good enough.

I found a good compromise between current consumption and high-fidelity audio was m the TDA2030 power op amp. At 38mA, its quiescent current is relatively low, yet it is capable of driving a 8Q loudspeaker.

The prototype receiver is frequently used at campsites for demonstrations to groups of young people interested in radio. The receiver is powered from a rechargeable sealed-gell battery, which makes the current consumption of the receiver important when a loudspeaker is used.

If you do not need to drive a loudspeaker, the output stage can be replaced with an op-amp capable of driving 600Q headphones. The TDA2030 is supplied in a T0220 package and will need a heat sink.

To ensure stability of the output stage and to prevent any r.f. feedback from creating havoc, the output is terminated for high frequencies via a series connected IQ resistor and 220nF capacitor to ground.

The two resistor/capacitors pairs in the feed back path perform the same function as those in the preamplifier.

Housing the receiver in a metal enclosure avoids problems with r.f. pickup and emissions. I built my prototype on plain un-etched pcb.

In summary

in common high-performance hf receivers, only the first mixer is a very' high performance type, incorporating for example switched junction fets. The cost driven assumption is made that the first intermediate-frequency filter will limit the frequencies that the following mixers are exposed to.

During a c.w. contest for example, there are sometimes quite a few strong signals present in the pass bands of the various IF filters. This can be the source of intermodulation distortion in following mixers in an otherwise excellent receiver.

In my direct conversion receiver, closely spaced signals are not a problem since only a single, high-performance mixer is used. Even with very closely spaced signals the spurious free dynamic range remains very good, probably only being limited by the phase noise of the local oscillator. Although the presented receiver is fairly simple and easy to implement especially when you make use of ready-wound inductors - the performance can rival many expensive commercial h.f. receivers.

Design improvements

From the performance summary of the receiver, it is clear that the sensitivity can be improved when operating on the harmonics of the local oscillator frequency, i.e. 14, 21 and 28 MHz. An r.f. preamplifier that can be switched in and out as needed will improve the situation quite a bit. A gain of 10 to 20 dB will probably be adequate.

It is important that such a preamplifier must not degrade the dynamic range of the receiver too much. This is accomplished with a high standing current through the pre-amplifier's transistor.

In general, high dynamic range and low current consumption do not go hand in hand. I suggest using a noiseless feedback design with bipolar transistors or a broadband junction FET amplifier. Although I have not tried this, suitable designs can be found in references 8 and 9.

(continued on page 11)

Multi-band, Direct Conversion Receiver

(Continued from page 10)

Dynamic range of the mixer can in most instances be improved by a few decibels by running the 74HC4066 from an 8V supply. For c-mos, the switching point is normally at Vcc/2, for an 8V supply, making it 4V. When run from a 5V supply, the 74HC04 output can swing to 4.9V, which is normally adequate for switching the 74HC4066. This modification will also decrease the insertion loss by nearly 0.5dB, due to the lower on resistance of the switches. The mixer described in this article is highly suitable for implementation in a phasing or Weaver type ssb receiver. A quadrature local oscillator signal can be digitally generated with the aid of a dual D type bistable IC. The dynamic range will be improved by 6dB due to the 3dB reduction in noise figure and the dividing of the r.f. input signal to the two mixers.

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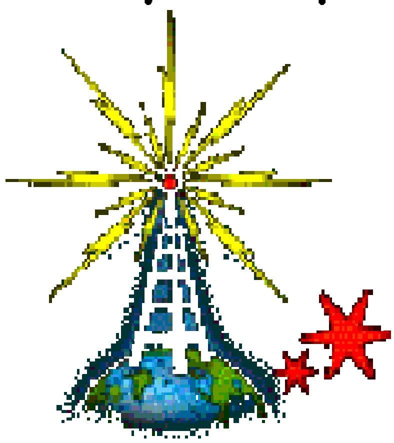
West Rand members - we need your input!

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.

In July 2003, we re-published an Anode Compendium on CD. It has the issues from July 2000 until June 2005. This included the new Adobe reader. It has been updated, check with the chairman for details.



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