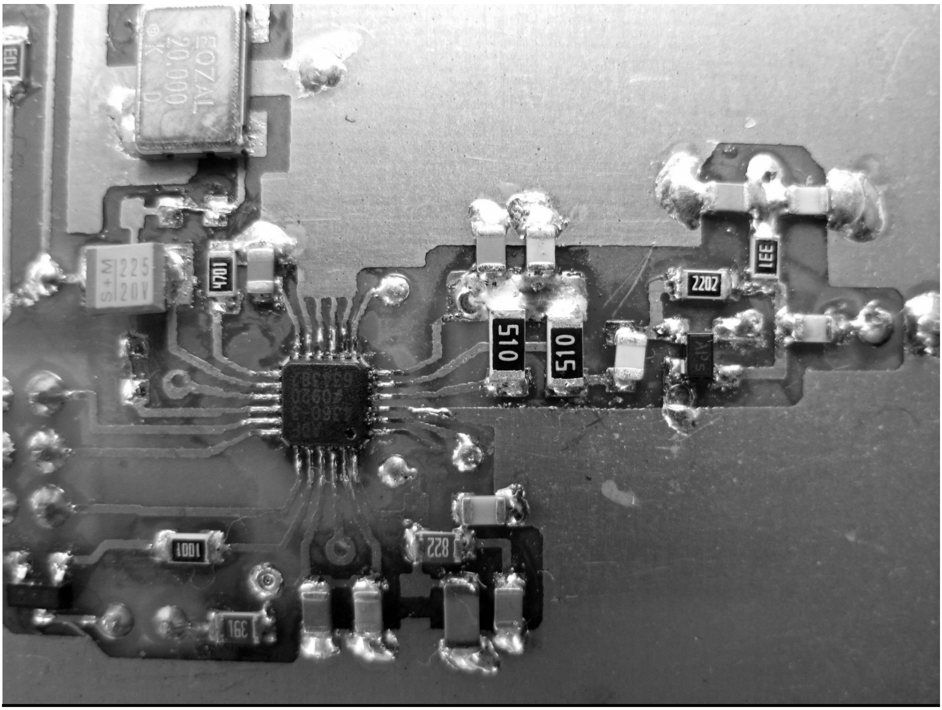
A Publication for the Radio Amateur Worldwide

Especially Covering VHF, UHF and Microwaves

VHF COMMUNICATIONS

Volume No.42 . Winter . 2010-Q4 . £5.35



An interesting component: ADF 4360 from Analog Devices

Hubertus Rathke, DC1OP

Contents

A lot of articles in this issue so I hope there is something for everyone. I need more new articles for 2011. If you have something that you think would make a good article, please let me know. Please remember to subscribe for 2011. The number of subscribers continues to fall, at the present rate it will hit the break even point in about 2 years so tell all of your friends to subscribe to keep the magazine going.

Merry Christmas and a Happy New Year73s - Andy

K M Publications, 63 Ringwood Road Luton, Beds, LU2 7BG, UK

Telephone / Fax +44 (0)1582 581051, email : andy@vhfcomm.co.uk

web : http://www.vhfcomm.co.uk

André Jamet, F9HX agit@wanadoo.fr

Trials and Tribulations of 1.990xxx Crystals

1.0 Introduction

The DFS for SHF beacons [1] is based on the Fig 1 arrangement. The frequency stability of the auxiliary oscillator working at around 2MHz is an important part of the final stability. The output will be multiplied by 96 to get to the 10 368.xxxMHz beacon frequency.

To obtain a good stability in spite of temperature variations, the crystal is maintained at +45°C by a simplified device. It is not really an OCXO and the crystal must have a good stability in spite of the rather poor temperature regulation.

After months of crystal trials and tribulations, here is a summary of them.

2.0 Crystal Beckman curves

When I did the DFS design and after tests, I didn't understand that is was not easy to find appropriate crystals to get the result I wanted. In theory, it is quite easy to make an adequate crystal because a family of curves named Beckman's curves shows the frequency drift versus temperature for an AT cut crystal (Fig 2). A judicious cut angle provides the upper turning point, that allows a very flat slope at this point, at the desired working temperature.

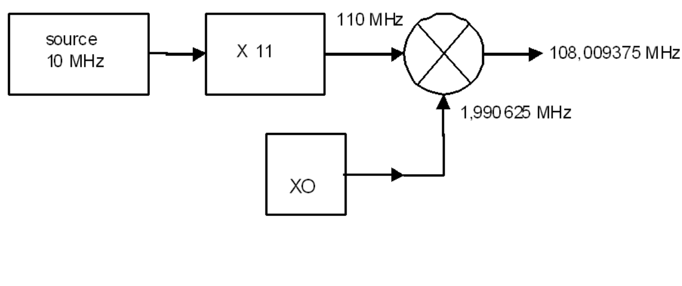


Fig 1: Block diagram of a DFS with auxillary oscillator.

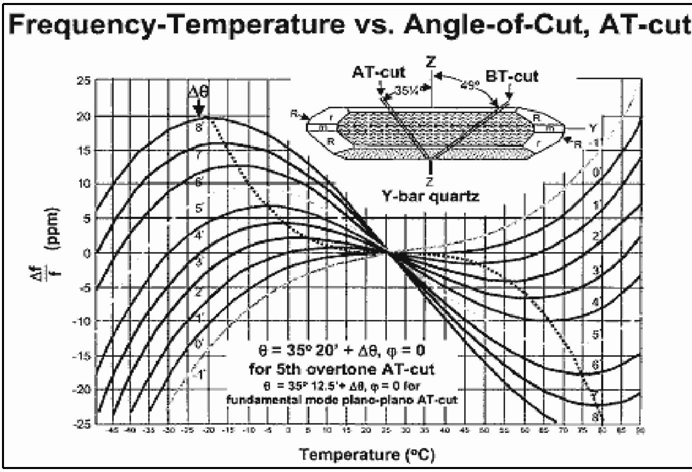


Fig 2: Beckman curves for AT-cut crystals.

3.0

Tribulations

I prepared a precise "wish list" and I sent it to several manufacturers in Europe, Asia and the States:

- 1.990xxx frequency at + 45 °C (the upper turning point must be at that temperature)
- Fundamental mode, 30pF load
- HC49/U holder

Unfortunately, 2MHz seems to be a low frequency limit of manufacture as we can see on the manufacturer's data. For some, their limit is 1.8432, 2MHz or even much more. Some manufacturers want to make the crystal in a larger holder instead of HC49. I said yes.

It is important to known that the ESR (equivalent series resistance) is quite high for such low frequency crystals. They require a relatively high positive reaction to oscillate.

I ordered crystals from manufacturers having a positive answer. I have made very professional tests with a device as shown Fig 3.

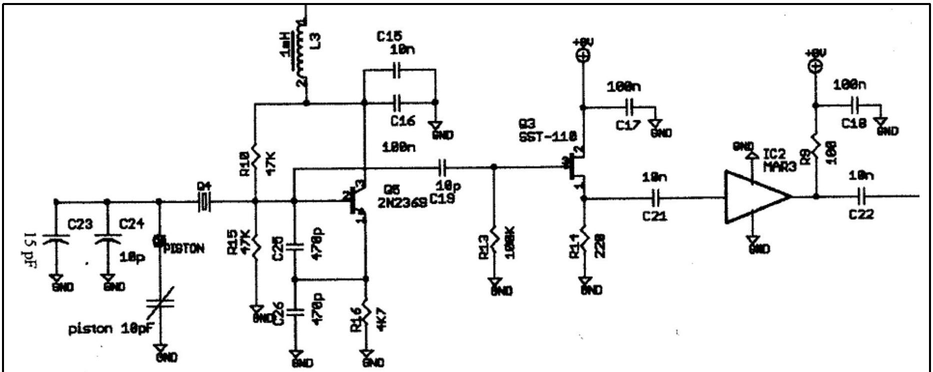


Fig 3: Test device circuit diagram.

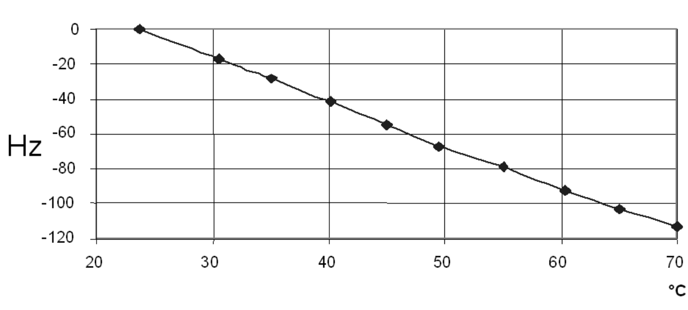


Fig 4: Unacceptable crystal, very high slope of 2.4Hz/°C.

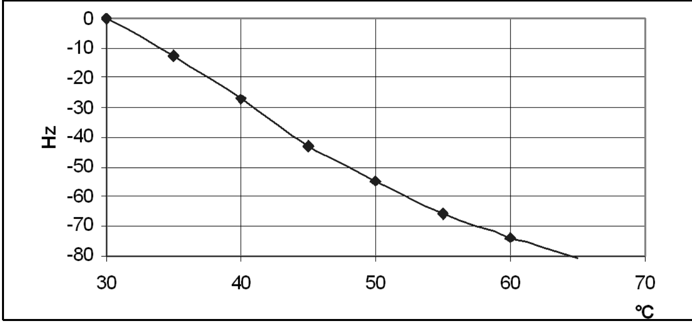


Fig 5: Unacceptable crystal.

The test device comprises:

- A Colpitts oscillator followed by buffers, power supply 8V ± 10^{-3} V, at the ambient temperature
- An oven for the crystal under test (temperature adjustable from ambient up to at least +70°C)
- A calibrated type K thermocouple sensor to measure the crystal case temperature
- A frequency meter locked by GPS.

The test procedure is:

- The device is ON for at least 24 hours with oven at +45°C.
- Then, the adjustable capacitor is set to get the nominal frequency.
- Then, the crystal holder temperature is varied from the ambient up to around 65°C.

The frequency drift is measured for different temperatures. The duration of each step of temperature is at least 15 minutes.

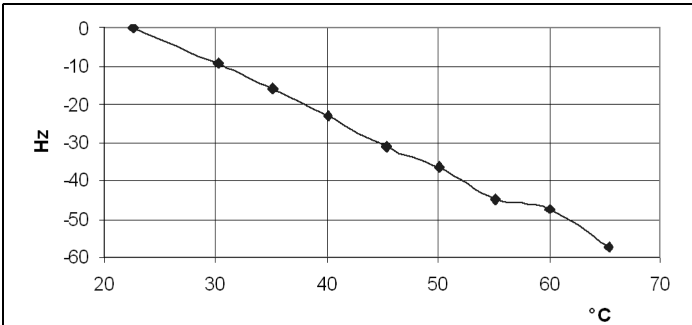


Fig 6: Unacceptable crystal, very high slope of 1.34Hz/°C.

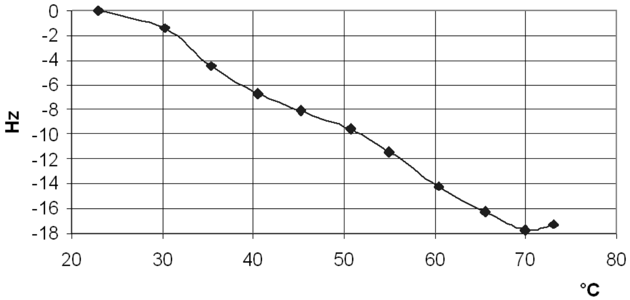


Fig 7: Upper turning point is too high, slope 0.36Hz/°C.

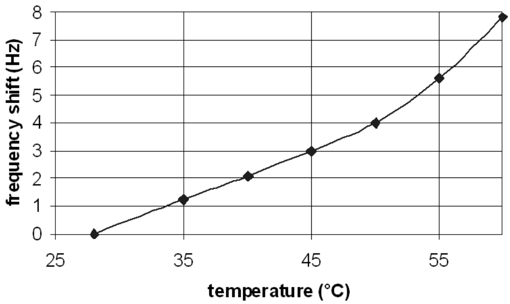


Fig 8: Acceptable crystal but no turning point in the frequency range.

Figs 4, 5, 6 and 7 show curves of inadequate crystals. In Fig 7 we can see the curve of a crystal having a too high upper turning point. In Fig 8 there is no turning point in the temperature range, but this crystal is acceptable with compensation with a negative temperature coefficient capacitors in the oscillator.

Only one is acceptable as shown Fig 9.

As almost all the received crystals were completely out of spec, I asked their manufacturers what had happen. They said they are not able to get quartz blanks with the required angle. As I am a radio amateur they thought it was acceptable for me. Of course, I am displeased with that answer.

To end, I took an off-the-shelf standard 10MHz crystal and I made the same measurements. As the Fig 10 shows, this crystal has a splendid upper turning point at around 50°C.

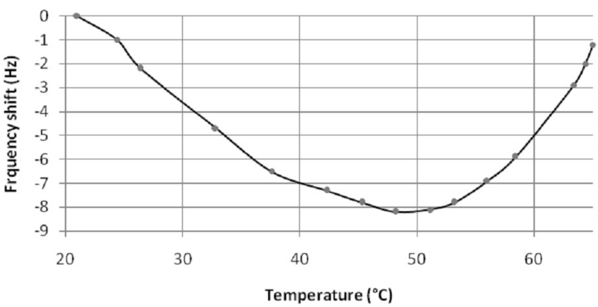


Fig 9: Crystal adequate, flat curve at around +45°C.

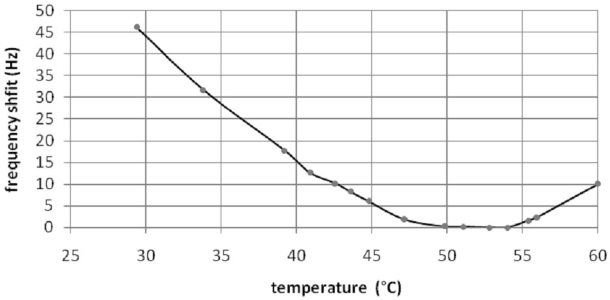


Fig 10: Standard 10MHz crystal.

4.0 Conclusion

At this point, the positive outcome is that I am able to buy adequate crystals from one manufacturer. The negative outcome is the cost. In spite of a reasonable list price, when I added shipping/delivery, taxes and customs, I reached about 100 Euros.

Fortunately, there is a solution. Change the oscillator frequency to 9.995xxx with a more affordable and adequate crystal. Change the output sine wave into logic levels and divide by 5 with a counter. Then with a low pass filter, we can get a 1.99xxxMHz sine wave as required.

We can parody and proclaim: ***Sic transit gloria 1.99xx crystal mundi!***

5.0 References

[1] DFS for Microwave Beacon Direct Frequency Synthesiser with Auxiliary Oscillator, André Jamet, F9HX, VHF Communications Magazine 4/2009 pp 194 - 202

Hubertus Rathke, DC1OP

An interesting component: ADF 4360 from Analog Devices

The trend for miniaturisation, with increasingly higher integration of functions into ever-smaller packages, has continued by the chip manufacturers for years. The package size is ultimately only determined by the number of necessary connections. This article describes such a miniature component used with traditional amateur radio working practices.

1.0 Basics

Free running oscillators are usually used to produce a stable and clean LO frequency from approximately 200MHz. This is stabilised using a Phased Locked Loop (PLL) to lock it to a quartz crystal oscillator. A digitally divided version of the oscillator signal is fed to a frequency/phase comparator that compares it with a quartz crystal oscillator signal. In the case of a deviation between the signals a control signal is produced to correct the oscillator to reduce the deviation to zero.

2.0 Introduction

The task for this article was to produce an LO signal in the range 1750MHz to 1800MHz for a receive converter. The frequency should be adjustable in 1MHz steps and the operating voltage of the module should be in the range of 6 to 8V; a remote supply was planned. This meant that a 12V supply could be used for the stabilised supply for the LO module.

The solution began with an Internet search for a PLL component that could provide all the necessary functions including the VCO. It should also allow programming of the working frequency over a standard interface.

The search led finally to the PLL ICs from Analog Devices Inc. [1]. The ADF 4360 was found with VCO and PLL integrated into the same package. The component is offered in 10 different versions as ADF 4360-0 to ADF 4369-9 to cover the frequency range from 1.1MHz to 2725MHz.

The data sheet [1] shows that the operating voltage is only 3.3V with a power input of approximately 40 to 50mA. It is controlled by a serial 3-wire bus. The 24-pin Lead Frame Chip Scale Package [VQ_LFCSP] is 4mm × 4mm. This Very

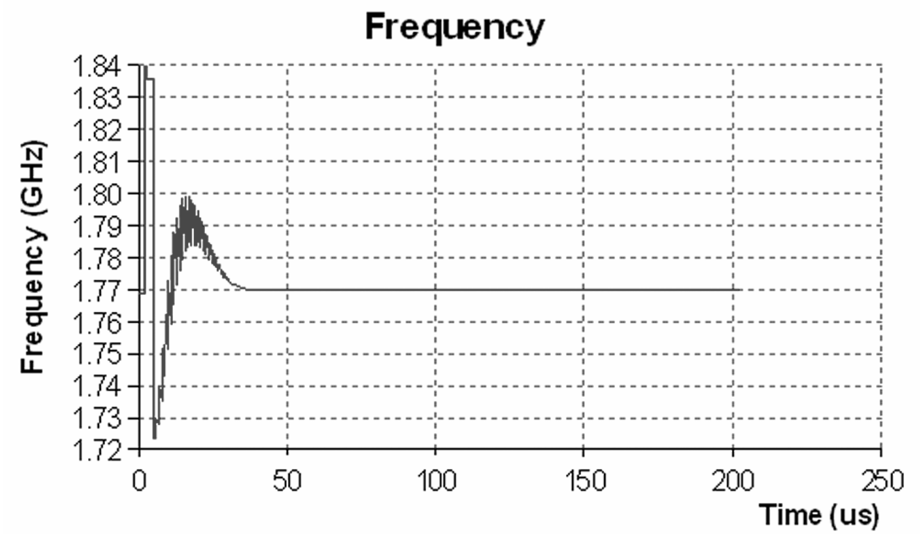


Fig 1: Simulation from ADIsimPLL showing the transient behaviour of the PLL after switching on.

Thin Quad (CP-24-2) was a concern for hand soldering with 24 connections around the 4mm square package. Additionally there is a 2.5mm a square metallised heat sink on the lower surface of the package that should be connected to the printed circuit board for heat dissipation from the chip. The IC was available in all version from [2] for a single item price of approximately $6 in October 2009.

3.0

Circuit Description

To support application developers, Analog Devices provides a CAD tool for PLL components called ADIsimPLL that can be downloaded free from their web site [1]. The core of this tool is a PLL simulator with a network of parameters and tables. The downloaded tool also contains tutorial to instruct the user on the various facilities.

After selection of the appropriate PLL component, the desired goal parameters, the type of loop filter (16 types selectable), VXO and component characteristics the standard values are computed. The results show the PLL behaviour and a graphical view of the frequency against time (Fig 1).

The suggested values can be changed by manual input in order to adapt the characteristics of the PLL to the application or to permit only the use of E24 components.

Once a satisfactory design is found the programming bytes required and the values, including the three division factors and the values for the components, are read off from the values computed by ADIsimPLL.

4.0

Experimental setup

To examine whether the component

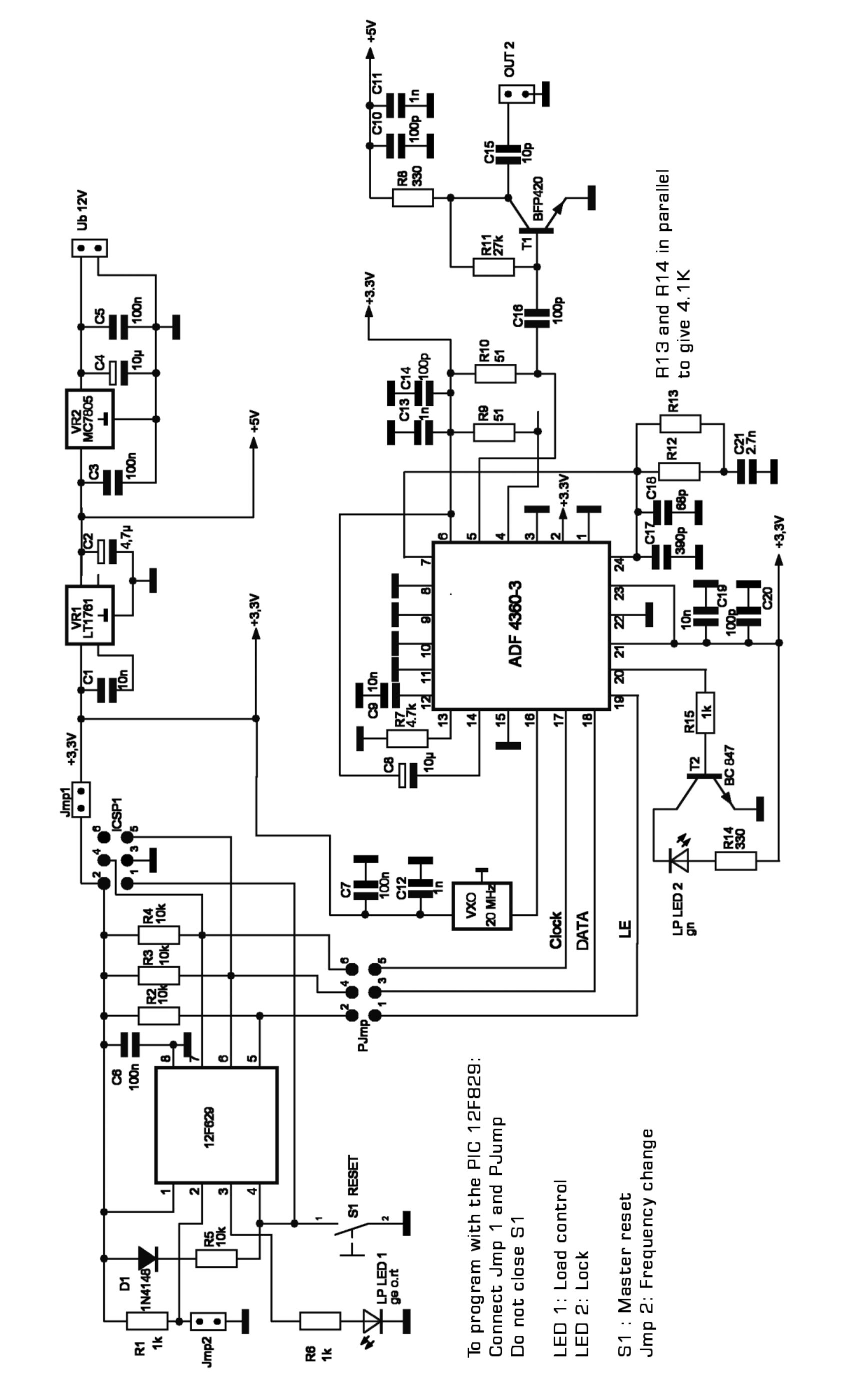


Fig 2: Circuit diagram of the test circuit.

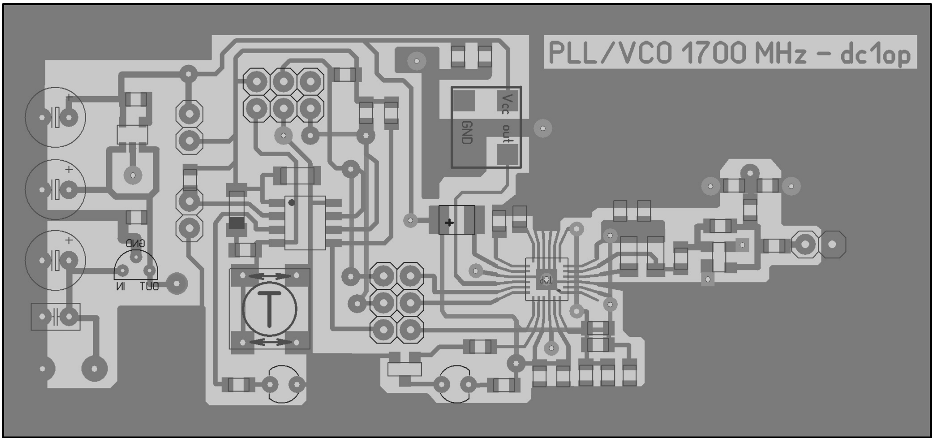


Fig 3: PCB layout of the prototype.

could actually be hand soldered and the required LO signal could be produced an experimental PCB was sketched for the circuit shown in Fig 2.

The mating surface for the ADF 4360 looks tiny. The small copper surface was defined as a central ground for the PLL/VCO corresponding to the IC heat sink. This ground is plated-through on the component side of the printed circuit board. All plated-through holes for the experimental board were made with hollow rivets. This gave a small problem because the rivets under the IC heat sink of the ADF 4360 were not completely flat with the soldering surface. It was also planned to put some ground pins plated-through to the ground surface. In retrospect that appears to be unnecessary because the central ground at the IC heat sink is sufficiently low impedance. The IC heat sink does not have any internal chip connection and is considered Not Connected (NC).

The output signal of the ADF 4360 is a differential signal on two adjacent pins. The data sheet offers some wiring possibilities the simplest version using a 50Ω termination resistor was selected. An output level of –3dBm should be attainable. To decouple the PLL/VCO from the following systems a simple buffer amplifier stage was used on the experimental PCB.

Pin 20 of the ADF 4360 is a multiplexed output that can be selected by programming for different signals. For the experimental circuit the PLL lock signal was selected that changes from 0 to 1 when the PLL locks. The following transistor switches an LED to make the condition visible.

5.0
Control

The control programme for the ADF 4360 is loaded via the 3-wire serial data bus using a 12F627 PIC from Microchip [3].

The signals required are LE (load enable), CLK (serial clock input) and DATA (serial DATA input). The CE (chip enable) signal is hard wired. Altogether 3 x 3 bytes are transferred, in order to set all necessary operating parameters of the ADF 4360.

The sequence of the bytes is: R Counter Latch (3 byte), control Latch (3 byte), N Counter Latch (3 byte). The individual

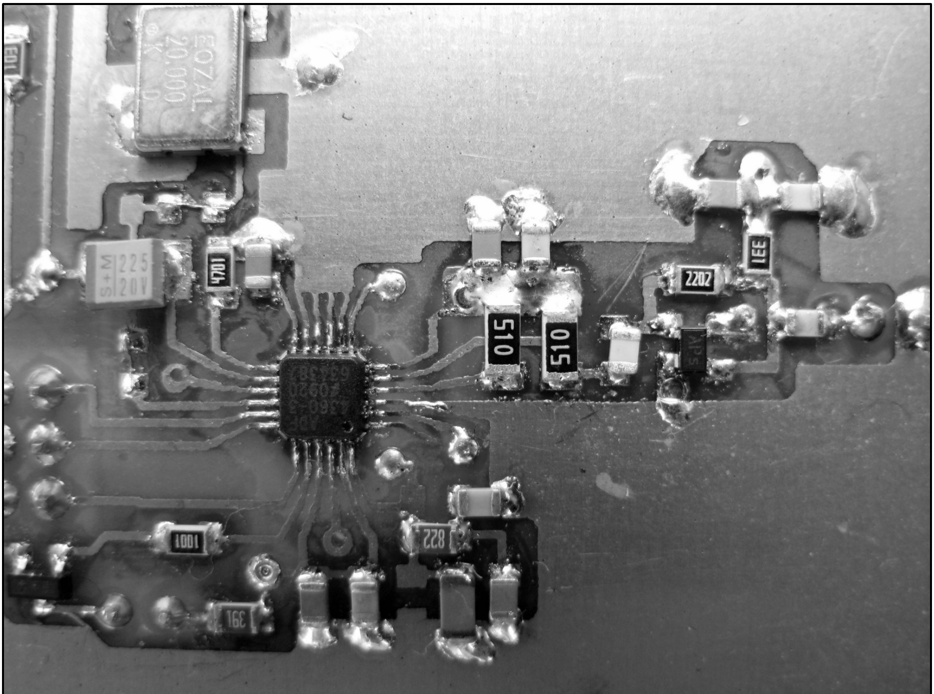


Fig 4: A closeup of the experimental circuit with the ADF 4360 almost in the centre. To the left and above the ADF 4360 is the VXO (5mm x 7mm), to the right is the amplifier/buffer stage. The two holes for the additional plated-through connections to the ground can be seen.

values of the individual bytes are determined with the help of the data table in the data sheet and the values given by ADIsimPLL.

In the experimental circuit it is possible to switch to second frequency by setting the jumpers and resetting.

6.0

Construction

The printed circuit board was sketched with Sprint layout 5.0 as double-sided PCB (Fig 3) and printed using an ink jet printer at 600 dpi onto a coated transparent foil. The PCB was successfully produced using a standard exposure and etching technique. The fine tracks near the ADF 4360 (0.3mm conductors spaced at 0.5mm) did not turn out completely accurate but did not have any bridges or breaks so were sufficient for an experimental setup. The SMD components were assembled using “No Clean” SMD flux [4] that flows at approximately 220°C.

The ADF 4360 was assembled using the following procedure: Fit the 0.8mm hollow rivet into the central ground area. Coat the legs and heat sink area of the IC with an economical layer of flux. Align the IC using a magnifying glass and “tack” two diagonally opposite legs using a very fine soldering iron tip to secure the IC. Now solder the ground plated-through holes from the component side until the hollow rivets run full with solder. Conduction of the hollow rivet heats the flux on the IC heat sink and this flows after a few seconds. Now the remaining legs of the IC can be soldered, with a steady hand, using the magnifying glass. It is important that the solder flows cleanly. Finally excess flux and possible solder beads between the legs and tracks can be carefully removed with a needle. A visual inspection completes this process; the finished article is shown in Fig 4.

7.0

Testing

Once the PIC was programmed the supply voltage was connected and the input power measured. With the experimental setup the ADF 4360 only drew half the current that was expected and showed no lock signal. The voltages at the IC connections were checked and it was apparent that some legs were not connected to the tracks. These legs were re-soldered and after that the power input was correct. Also the lock signal announced that the PLL was working and the expected frequency was produced at the output.

The problems with the IC connections were mainly caused by the rivets on the heat sink area of the IC not being perfectly flat with the tracks. The small distance between tracks and the IC legs plus the bad thermal conductivity of the 0.3mm tracks caused the first soldering attempt to be unsuccessful. Proper plated-through holes particularly for the central ground area of the IC heat sink would solve this because the IC could rest directly on the tracks. A tinned printed circuit board would be better for soldering.

8.0

Conclusion

This description should encourage the use of such tiny components The assembly of these such delicate ICs can be carried out with conventional assembly procedures a steady hand, a lit magnifying glass, suitable materials and much patience.

9.0

References

[1] www.analog.com

[2] www.digikey.de

[3] www.microchip.com

[4] www.reichelt.de

Gunthard Kraus, DG8GB

Radio engineering - basic knowledge. Investigating Signals

Part 2, continuation from 3/2010

4.0 Modulation

4.1. Principle of amplitude modulation (AM)

It is probably the oldest type of modulation that enabled the transmission of language and music approximately 100 years ago following on from Wireless Telegraphy using a Morse key. The basic idea is simple: Audio signals have wavelengths that are far too large to be radiated wirelessly using antennas with acceptable efficiency. Therefore a high frequency carrier signal was used so that a smaller antenna could be used and the information loaded onto the carrier for problem free transmission. The amplitude of the carrier is changed in sympathy with the information. Mathematically this is a multiplication and addition of two different signals. The secret of this is shown in Fig 18:

The top trace shows the constant 10kHz carrier with a peak value of 1V. Below that is the information that is a 500Hz sine wave with a peak value of 0.5V. If these two signals are multiplied the result is a signal at the carrier frequency where:

- The amplitude follows the information signal but:
- When the information signal voltage goes negative the phase reverses.

This multiplication is called the Modulation Product shown in the third trace. If this is added to the unmodulated carrier signal the total voltage becomes larger if the modulation product is in phase with the carrier. Likewise it becomes smaller if the modulation product and carrier are out of phase. The bottom trace is the AM signal where the signal amplitude varies in sympathy with the information.

Now the question is: how many different frequencies are involved because this is no longer a constant sine wave? With the carrier signal it is simple because it is a constant sine wave with only one spectrum line. The modulation product already has a mathematical formula for the multiplication of two sine signals:

$$\cos(\alpha)\cdot\cos(\beta)=\frac{1}{2}\left[\cos(\alpha+\beta)+\cos(\alpha-\beta)\right]$$

The products are the sum and difference frequencies of the two cosine signals. The carrier and information frequencies are not present.

The simulation in 3.1.2 uses the Behavioural Voltage (bv), this has the necessary tools to simulate the multiplication of the two signals. This is confirmed in Fig 19 showing:

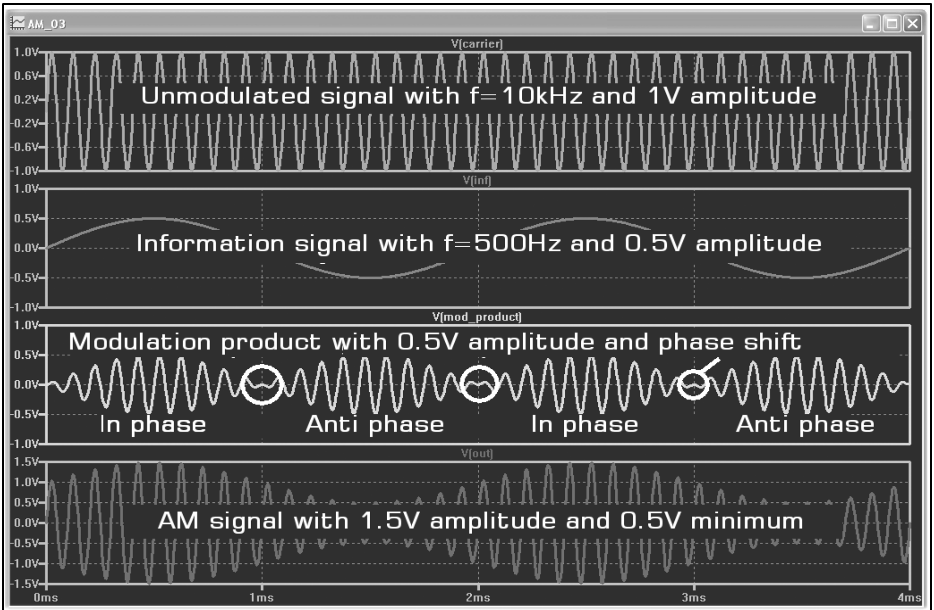


Fig 18: This shows all the parts of an AM signal. If the unmodulated carrier is added to the modulation product, this gives the complete AM signal.

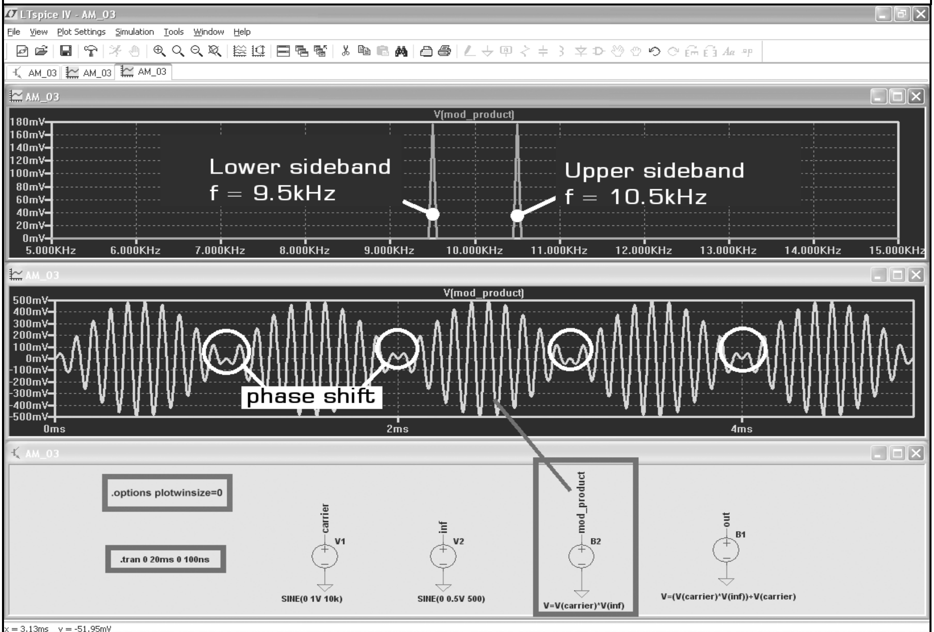


Fig 19: The modulation product in detail. The simulated spectrum shows that it consists of two single signals.

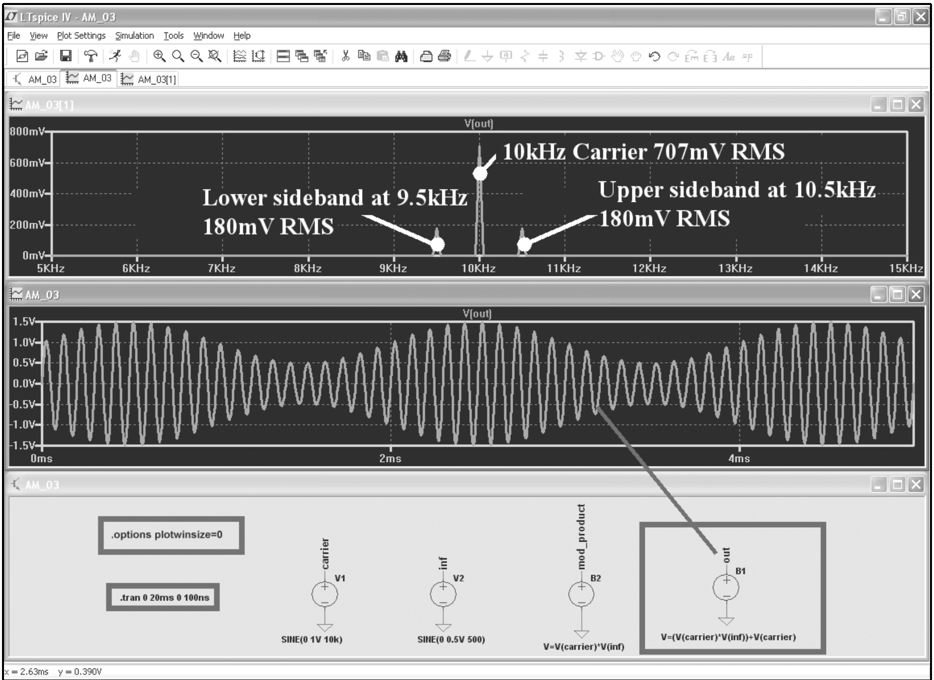


Fig 20: If the unmodulated carrier and the modulation product are added, the complete AM signal is produced. The associated spectrum is self explanatory.

- The sum frequency, 10kHz + 0.5kHz = 10.5kHz
- The difference frequency, 10kHz - 0.5kHz = 9.5kHz

They are called upper and lower side-bands having equal amplitudes. The peak value of both signals amounts to 50% of the information signal thus 250mVs. In the spectrum display this is 180mV because of the RMS representation.

For the complete AM signal the carrier signal is added. This can be simulated using the bv source as shown in Fig 20.

Note:

Usually several frequencies or a complete frequency band are involved in the information signal. These are called the lower and upper sidebands, the Lower Side Band is the LSB and the Upper Side Band is the USB of the AM signal.

4.2 Amplitude Shift Keying (ASK)

The good old Morse key gave just “Open” and “Closed”. This simple method still has its place today in as a modern transmission technique, the logical levels are simply assigned to the two conditions “Zero” and “One“. This works amazingly well and is reasonably interference-proof (if additional limiting is used). In addition the circuits required are fairly simple.

The bv source is used again for the simulation multiplying the carrier with a 1kHz symmetrical square wave information signal. The smallest voltage level is zero V, resulting from “Key open”. The maximum voltage is 1V resulting from “Key closed”.

A carrier signal of 455kHz was selected for this example. Fig 21 shows the simulation circuit with the output signals

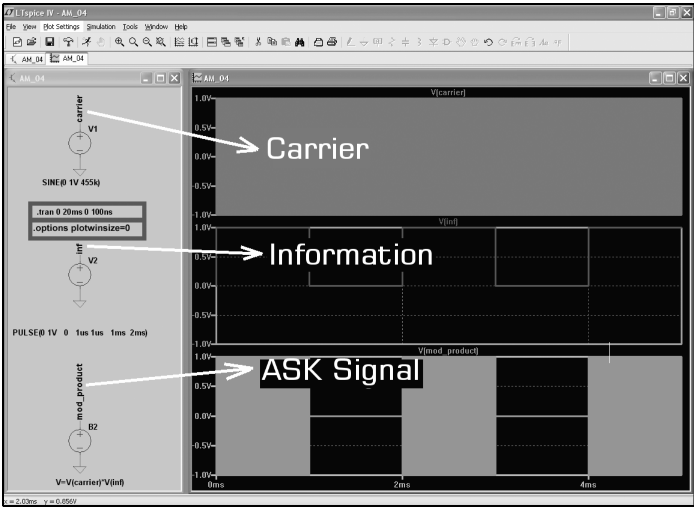


Fig 21: Both signals for the ASK simulation, a square wave does the switching.

of the three voltage sources used with a peak value of 1V or 0.707V RMS. The spectrum of the ASK signal is shown in Fig 22, it shows what was to be expected. The symmetrical square wave information signal contains the 1KHz fundamental and all odd number harmonics. The result is LSBs and USBs with all these spectral lines of the information signal that spread to the left and right of the carrier.

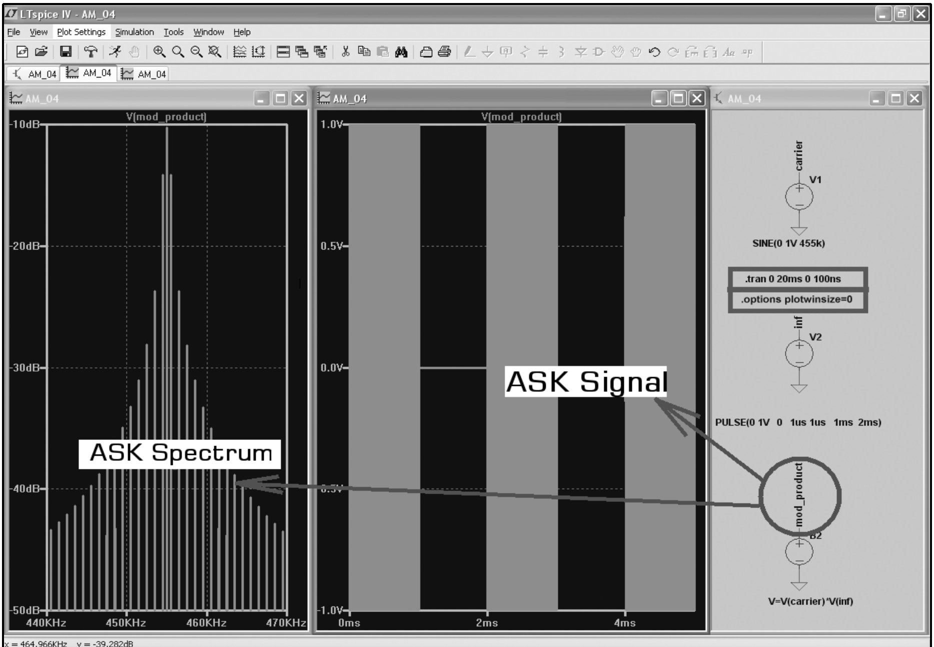


Fig. 22: The spectrum of the ASK signal is interesting because the harmonics of the square wave form the sidebands (to the left and right of the carrier).

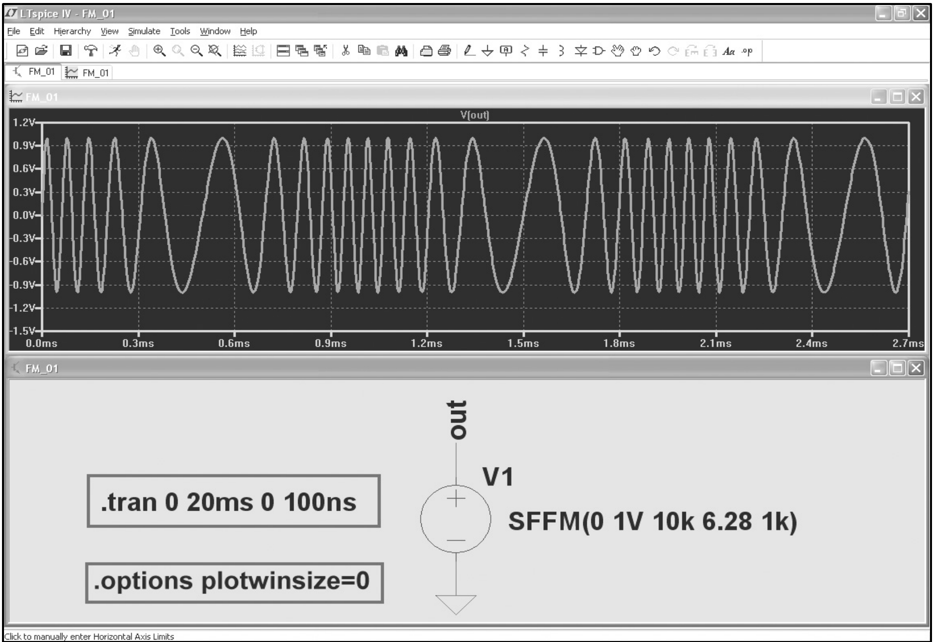


Fig 23: A frequency modulated signal can be produced very easily. Unfortunately the modulating signal voltage cannot be shown separately.

4.3 Frequency modulation

This is a refinement because this time the amplitude of the carrier is not used. Yes, it is completely unimportant and in an FM receiver a limiter removes all fluctuations and glitches. The carrier frequency is changed in the sympathy with the information signal. That costs more and clearly requires substantially higher technical expertise. Success is convincing, it can be heard by listening to good music received on a VHF receiver.

It is good that LTspice has three components available:

- One can be used to switch the voltage supply to produce FM (SFFM). A sinusoidal carrier is produced and sinusoidal information signal is automatically superimposed.
- There is a complete FM-AM generator with a modulate function that can be found in the Special Functions section. It is suitable for information signals with different waveforms.
- Finally the same FM-AM generator exists in a “modulate2” version that produces quadrature outputs (two separate outputs with a 90 degree phase shift between the carrier signals).

4.3.1. Production of an FM signal using the voltage supply

Take a close look at Fig 23. The frequency of the signal increases during the positive half wave and decreases during the negative half wave of the information signal. Unfortunately the modulating signal cannot be shown on a separate diagram in this mode. Data compression is switched off as usual. It is simulated over 20ms (100ns resolution) but for clarity only a short section is shown. The rest can be seen from the SFFM source programming. The line:

SFFM (0 1V 10k 6.28 1K)

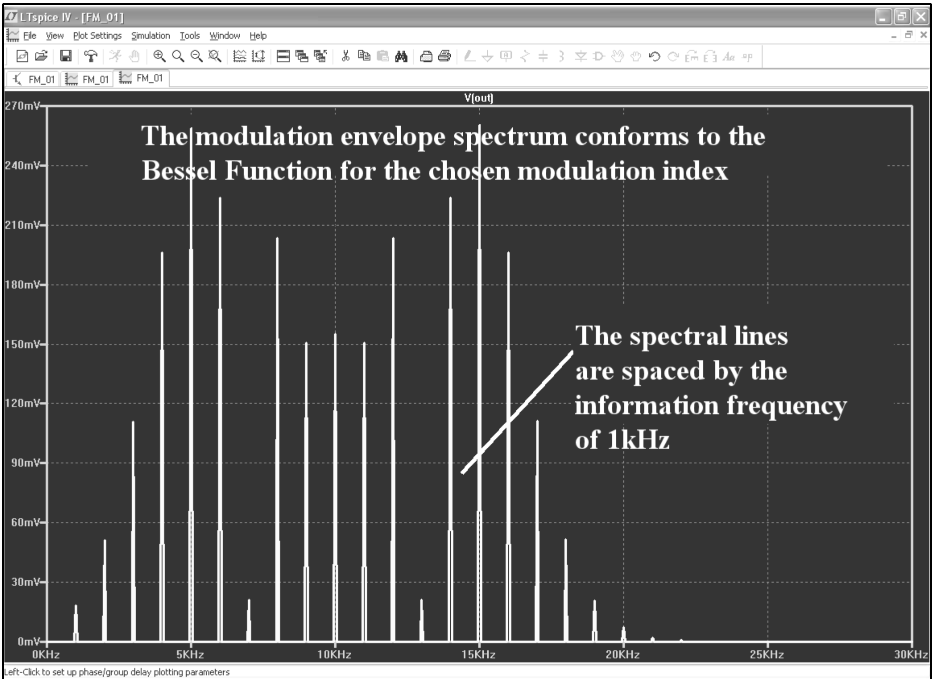


Fig 24: An FM spectrum is sometimes confusing. There are many spectral lines spaced by the information frequency and their amplitudes do not change logically but in accordance with a Bessel functions.

means:

- 0 = no DC portion
- 1V = peak value of the carrier
- 10k = 10kHz unmodulated carrier frequency
- 6.28 = modulation index
- 1k = 1kHz sinusoidal information signal

The modulation index needs an explanation. If the carrier frequency increases it can be interpreted as advancing the phase in relation to the unmodulated signal. Similarly a lower frequency means a reduction of the phase in relation to the unmodulated signal. The modulation index expresses this change of the phase. It represents the maximum phase shift in relation to the steady state with the phase deviation measured in radians.

For the example the modulation index of 6.28 represents the peak phase deviation in relation to the steady state with the phase deviation measured in radians. For example the modulation index of 6.28 represents the phase shift of a circle with a radius of 1. A complete circle is 360 degrees or 6.28 radians. It is really simple.

Fig 24 shows a FFT spectrum of this signal using 131,072 samples. The entire spectrum is occupied with lines spaced at a distance of the information signal frequency. The amplitude distribution envelope can be described using Bessel functions. It is difficult to understand the detail of this but simply the frequency range occupied by the FM signal increases with the modulation index but the envelope and the number of spectral lines obey the Bessel function. In an extreme case increasing the modulation index, the unmodulated carrier would be zero in the spectrum for a moment.

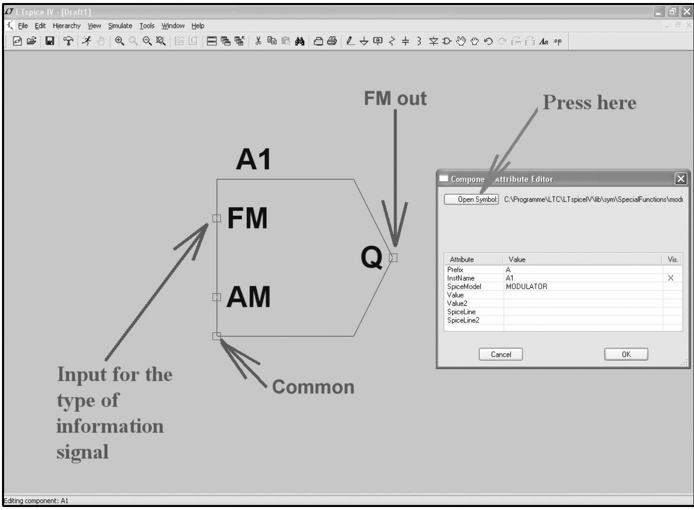


Fig 25: It is pretty simple to make an FM signal generator but programming requires some work (see text).

The peak frequency deviation indicates the maximum deviation of the instantaneous frequency in relation to the unmodulated signal and this naturally related to the modulation index.

As an example the VHF broadcast stations from 88 to 108MHz use a peak frequency deviation of 75kHz. That seems small but it cannot be more otherwise the maximum permissible channel spacing (300kHz) would be exceeded and the transmitter on the adjacent channel would be disturbed.

As a guide:

- Channel bandwidth = 2 x (peak frequency deviation + information signal frequency)

For interest the phase deviation (= modulation index in radians) can be calculated from the frequency deviation and the information signal frequency as follows:

- modulation index = (peak frequency deviation) / information signal frequency

So the differences between frequency modulation and phase modulation are:

- For frequency modulation the peak frequency deviation is held constant. From the formula the modulation index and thus the peak phase deviation must then decrease with rising information signal frequency. Unfortunately this worsens the signal signal-to-noise ratio for high tones.
- For phase modulation the modulation index (= peak phase deviation) is held constant. According to the formula the peak frequency deviation increases with increasing information signal frequency. This increases the frequency range occupied.

4.3.2. Frequency Shift Keying (FSK)

Frequency Shift Keying is a digital mode that assigns the two conditions, “logic 0” and “logic 1” to two different frequencies. The origin of this mode comes from the days of teleprinter technology. The only things that remain from that technology are the two names, “Mark” for the higher frequency and “Space” for the lower frequency. These are required to programme the FM-AM generator “modulate” function in LTspice.

Unfortunately some work is needed. When the VCO (Voltage Controlled Oscillator) is selected the basic adjustment is missing. In order to correct this, click the right mouse button on the circuit symbol and open the “Component Attributes Editor”. Click on the “Open Symbol” button to change to the actual

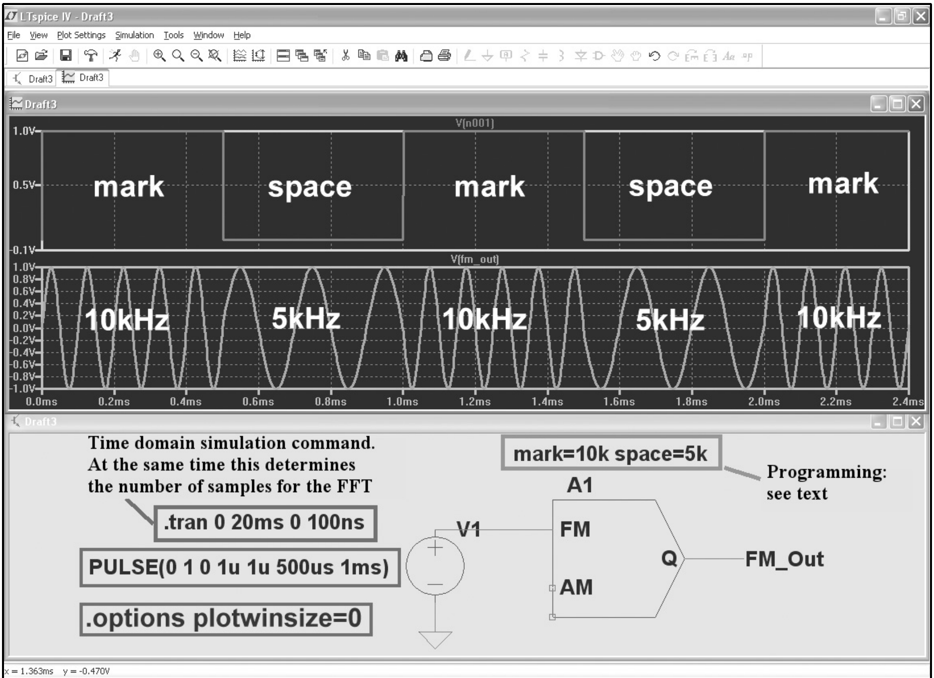


Fig. 26: The result of the simulation is good. Also the information signal voltage can now be seen.

symbol editor (recognised by the small red circles at the ends of the individual lines that emerge in the circuit symbol and represent connection points). The path "Edit/attributes/Edit Attributes" leads to the "Symbol Attribute Editor" as shown in Fig 25. In the line "Value" enter "mark=10k" and "space=5k" as the control characteristic of the VCO to give:

- For 0V at the FM input the output frequency will be the space value of 5kHz.
- For 1V at the FM input the output frequency will be the mark value of 10kHz.

For a beginner this entry is somewhat complicated: First click on the line "Value" and then type "mark=10k space=5k" in the window above the table. Click OK to make the entry - however it is not shown on the screen. Now select the path: "Edit/Attributes/Attributes Window" again and click on "Value" in the table then click OK and the cursor changes to "Mark Space Programming" so that it can be can placed on the circuit symbol. Now this changed symbol must be stored in the component library with a path like: "LTspiceIV/lib/sym/Special Functions/modulate". Now this VCO will be available but only if all windows are closed the program restarted. Otherwise the program does not know anything about the changed symbol.

Fig 26 shows the symbol being used with a 1kHz pulse with Vmin = 0V and Vmax = 1V connected to the FM input and the simulated output (FM_Out). To ensure that the additionally voltage information is shown, right mouse click on the diagram and use the "Add Plot Pane/Add trace". For the following FFT simulation enter the attributes "20ms simulation

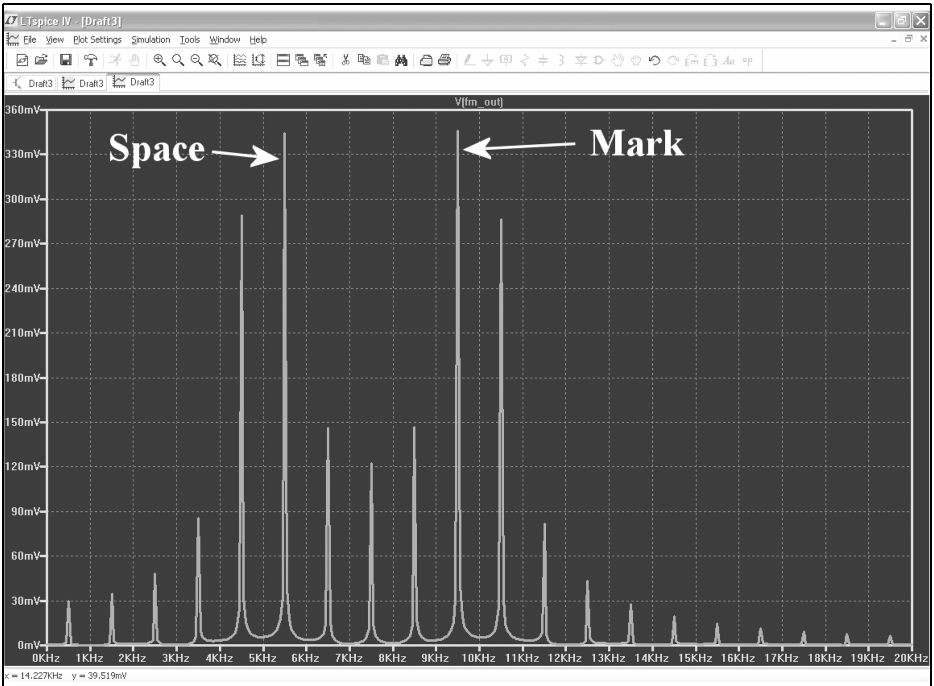


Fig. 27: Correctly, as if from a text book: an FSK signal with sqaure wave modulation gives two maxima, in each case "Mark" (around 10kHz) and "Space" (around 5kHz).

time" and "maximum time step 100ns" in order to receive 200,000 genuine samples. Also no data compression should be used.

The linear frequency spectrum simulated with 131,072 samples is shown in Fig 27. It exhibits two maxima, one for "Mark" and one for "Space". This is a well-known fact that can be found in technical literature. It occupies a considerable frequency range, probably 20kHz.

For interested readers who have access to a computer there are some additional exercises:

- Change the minimum and maximum pulse amplitude at the input. Examine if negative voltage levels are permissible.
- Use a 1kHz sine wave information signal in place of the pulse. Select the amplitude similar to "Mark" and "Space". Also us an offset for the sine wave. Compare the frequency range now occupied to the pulse simulation example.
- Use triangle information signal with the same frequency of 1kHz.

5.0

Literature

[1] To download LTspice go to the Linear Technology home page: www.linear.com

[2] Simulation of RF circuits with LT-spice. Part 1, Gunthard Kraus, DG8GB, VHF Communications Magazine, 2/2010 pp 75 – 89

Gunthard Kraus, DG8GB

An interesting program: Simulation of RF circuits with LTspice IV, Part 2

Continuation from issue 2/2010 4/2009

In part of 1 the circuit of a 137MHz LNA was simulated. The operating point was determined, the S parameters were determined and the noise figure simulated. In this part of the article the stability will be investigated and a simulation in the time domain will be used to determine the IP3 intercept point. Then two other circuits will be investigated; a double balanced mixer and a bandpass filter.

4.3.4. Stability control with LTspice

Modern RF simulation programs usually have the facility to simulate for the gain stability factor "k". The S parameters have already been simulated ("k" can be computed from them), it must be possible to write a function to carry out the mathematics necessary.

The correct formula can be found in modern books on microwave engineering, e.g. from [3]:

$$k = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |S_{11} \bullet S_{22} - S_{12} \bullet S_{21}|^2}{2 \bullet |S_{12}| \bullet |S_{21}|}$$

A simple text editor (like Notepad) can be used to edit the "plot.defs" and enter this formula in a form that LTspice will understand.

Note: The letter "k" is already reserved for other purposes; therefore another label must be chosen e.g. "klinear".

The formula must be converted into a SPICE function and then stored in the LTspice "plot.defs" file. It is laborious and great care is required during input but otherwise there are no problems. With patient analysis of all the brackets it can be seen that this SPICE function represents the above formula:

```
.func klinear (S11, S21, S12, S22)
{(1-abs(S11(v2))*abs(S11(v2))-abs(S22(v2))*(S22(v2))+abs(S11(v2)*S22(v2)-S12(v2)*S21(v2))*abs(S11(v2)*S22(v2)-S12(v2)*S21(v2)))/(2*abs(S12(v2))*abs(S21(v2)))}
```

This function must be entered as a string of characters as shown with no additional spaces or control characters. After storing the function in the LTspice "plot.defs" file the program must be restarted so that it is recognised.

The S parameter simulation is repeated as described in 4.3.2 and Fig 14. A right mouse click on the result diagram gives the option "Add Plot Pane" to add a new empty diagram. Use the "Add Trace" option and enter "klinear (S11, S21, S12, S22)" and press OK as shown in Fig 21. With some changes to the axes (linear representation, amplitude range of k = 0 to k = 5) the result shown in Fig 22 gives k = 1.5.

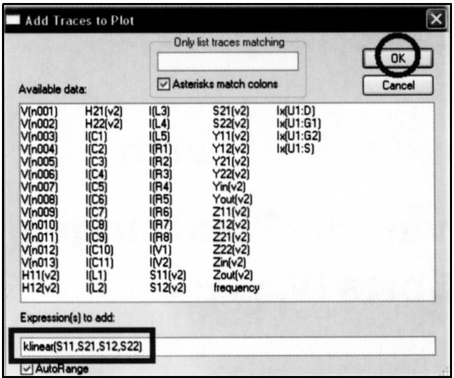


Fig 21: Working with an additional function was shown in Fig 19. For the stability simulation the simulated S parameters must also be handed over to the function.

(The line width was increased to show the curve. This attribute is hidden on the "Control Panel", it is the hammer shaped button on the "Waveforms" tab. Choose "plot Data with thick lines".

An Ansoft Designer SV simulation of the LNA gives a similar value of k = 1.0 instead of k = 1.5 from this simulation.

For those who want to be sure that there will be no instability in the practical amplifier, insert a small inductance between the source resistor and the MOSFET as an "oscillation stopper". A value from 1.5 to 2nH is enough to make "k" a minimum value of 2, this is confirmed by an Ansoft simulation.

4.3.5. Simulation in the time domain: A 137MHz signal at the input

So far only the frequency domain has been used with the circuit. This is normal for S parameter simulation programs if the appropriate S parameter file is available. The most important basic characteristic of SPICE is simulation in the time domain to determine voltage and current values.

For this apply a sine signal (f = 137MHz, peak value = 30mV) to the circuit and examine the RF voltages expected in the circuit. The following changes are necessary:

- The input source is changed to "Sine" with f = 137MHz and V = 30mV
- Simulate the first 200ns with a large time step of 0.1ns. The simulation command is:
  .tran 0 200ns 0 0.1n

All other directives and commands can be deleted.

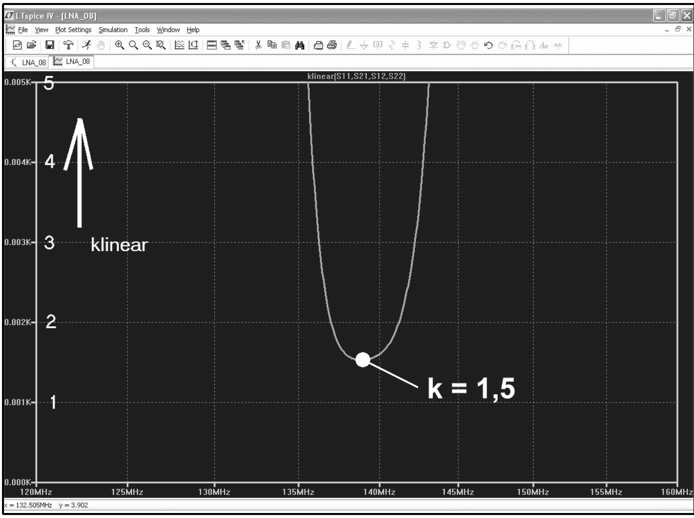


Fig 22: The result of the work is the stability factor "klinear".

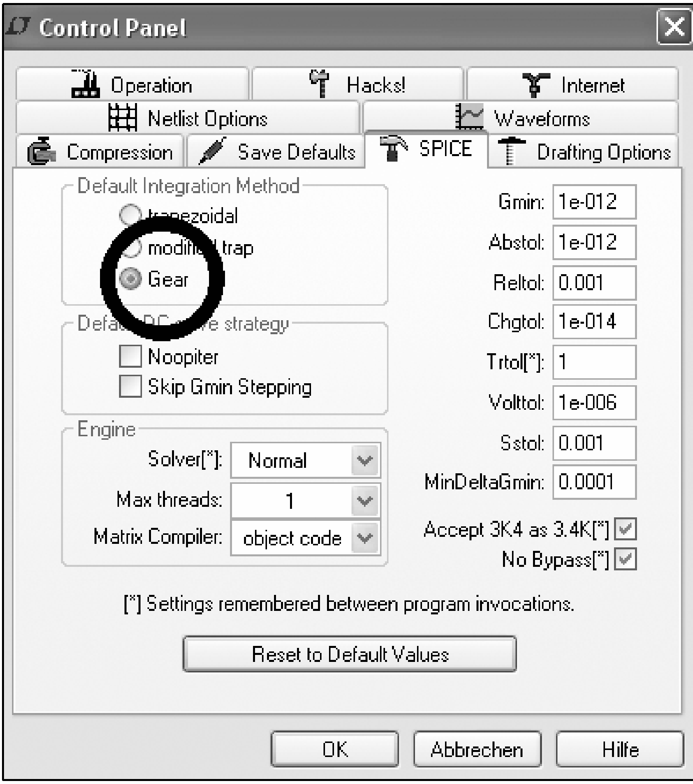


Fig 23: Without this basic adjustment feature of Spice, necessary for high frequencies, there would be problems.

Now for the most important thing:

Click on the "Control Panel Button" (Button with the hammer) and go to the SPICE tab (Fig 23). Select "Gear" as the integration method because the other two methods cause problems with RF simulations.

This check should be done as often as possible because this setting is sometimes changed by the program without a warning (e.g. caused by changes of the component values or when a new drawing is made or when extending a drawing or on a computer restart).

The results for the four RF signals that can be measured are shown in Fig 24. V2 is the voltage source with a peak value of 30mV, the actual input signal 0.5 x V2 because of the internal resistance R9.

4.3.6. Determination of the IP3 intercept point

Simulation of the "Third Order Intercept Point" provides information about the distortion behaviour of the stage with increasing input level. The IP3 point is the point at which the third order distortion is the same as the signal (limiting begins before this point is reached). The amplifier is fed with two "in band" signals in the centre of the pass band with only a small frequency difference, the level must be quite high to expect intermodulation (for this type of amplifier it is usually somewhere between -30 and -10dBm, Veff = 7mV to about 70mV at the input).

For simulation two input voltage sources are connected in series and programmed as follows:

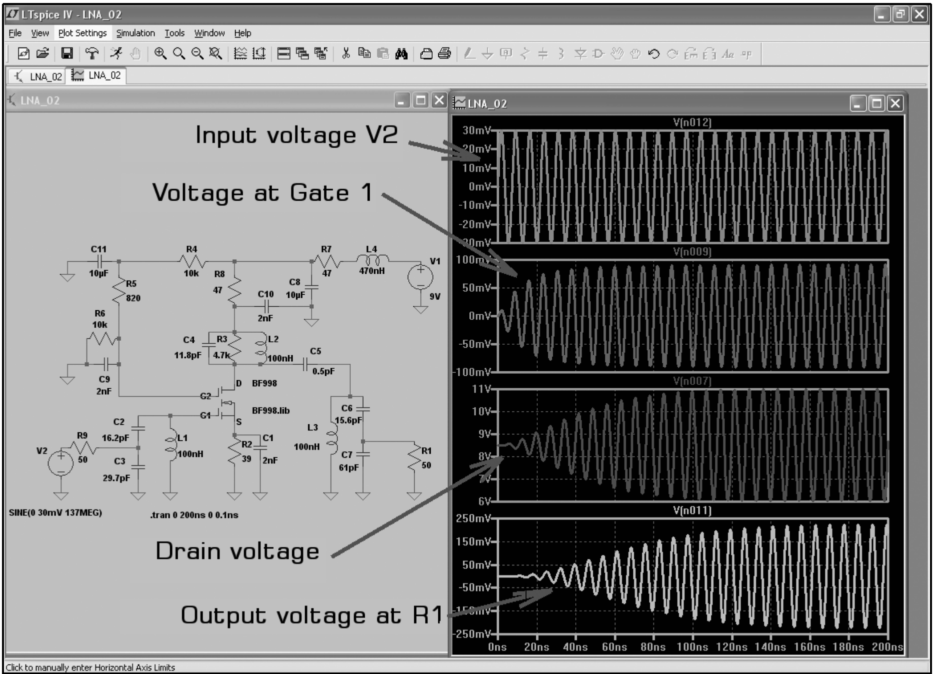


Fig 24: This looks like a measurement of the finished circuit with a good oscilloscope. There ar four interesting voltages displayed together for f = 137MHz.

- V2 supplies a sine wave with a peak value of 20mV and f = 137MHz.
- V3 supplies a sine wave with a peak value of 20mV and f = 137.5MHz.

Caution is required when choosing the simulation command because the basic rules of FFT system theory must be considered:

- The resolution and thus the smallest frequency step represented in the spectrum is specified by the "total simulation time".

If a resolution frequency of 50kHz is required, the simulation time must be greater than:

$$t_{Simulation} = \frac{1}{50kHz} = 20\mu s$$

The "Maximum Time Step" represents the time between two sequential points of sample and corresponds to the period of the sample frequency. The minimum sample frequency is given by:

f_{sample} = 1/Maximum Time Step

this must be substantially higher than the highest frequency occurring in the signal (preferably twice as high). Otherwise there will be "Aliasing distortions" that invalidate the result causing much annoyance and cannot be eliminated.

Thus the sample frequency determines the highest signal frequency usable without errors in the spectrum. But not only that, according to the relationship:

$$Samplenumber = \frac{Simulationduration}{MaximumTimeStep}$$

A certain number of samples must be used. The FFT program requests the

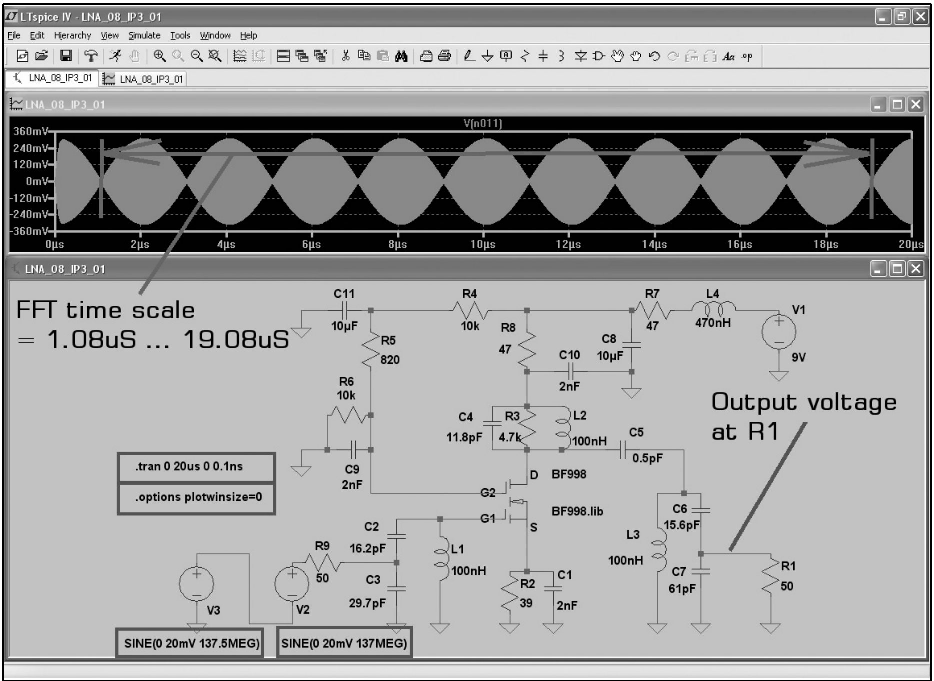


Fig 25: The circuit with the necessary attributes and the simulation result of the intermodulation test in the time Domain. Very nice but it takes a lot of computing time.

number of points on the curve to be used to compute the spectrum. Naturally there can be no more values than actually simulated and this causes unexplainable errors or deviations or increased "background noise" or long computation times (In each case this causes annoyance).

The number of samples for the FFT must be a power of two, the program defaults to a suitable values of 65,536 samples. To be more precise select double this value (131,072). Therefore 200,000 samples must be supplied by specifying the smallest time step as follows:

Maximum Time Step = Simulation Time/200,000 = 20µs/200,000 = 100ns

LTspice automatically reduces the size of the result file using data compression that is not required in all cases. This can be switched of using "Edit/Spice Directive" to enter the SPICE directive:

.options plotwinsize=0

The integration method should be set as shown in Fig 23 using the button shaped like a hammer and then selecting "Gear" on the "SPICE" tab.

Fig 25 shows the simulation circuit with all the commands and directives and the time domain display of the simulated output voltage. The series connection of the two input voltage sources can be seen. This is simple with SPICE but in practice two separate input signal generators require considerable expense and additional circuitry (see [4]).

The output signal shows important information but it is important to avoid things that may falsify the FFT result:

- Always use only the "steady state range" of the output signal and avoid the start up process of the circuit.

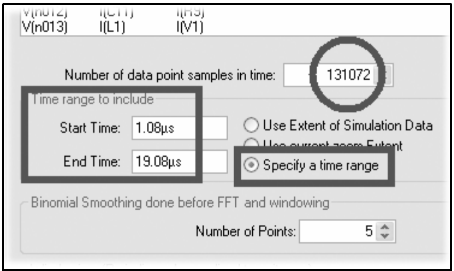


Fig 26: The time slot for the FFT is programmed as 18µs. Please remember to select the number of samples first (see text).

- The FFT simulation time should be chosen to be between two zero crossovers on the curve. The period of 1.08µs to 19.08µs (these are exact zero crossover points selected using the cursor) should be selected, there is still enough data for 131072 samples. Fig 26 shows the necessary attributes on the FFT menu. Select the number of samples of 131072 first and then select the associated time interval, do not do this the other way because the input will not be accepted.

With the FFT result zoomed to the range from 135 to 140MHz as shown in Fig 27 the signal and the two third order intermodulation products can be seen. These are used to calculate the IP3 using the following information:

The difference in level between each of the two signals and the associated third order intermodulation products is approximately 32dB.

Thus the IP3 point can be determined as follows:

IP3 in dBm = (level of the signal) + 0.5 (difference in level to the IM3 product)

There is a choice between two representations, the IP3 related to the input (IIP3) or related to the output (OIP3). The two values differ by the gain of the stage.

The input:

The voltage range of both sources has a peak value of 20mV. The associated RMS value is smaller by a factor of 0.707 giving 14.14mV. With an input impedance of 50Ω the input voltage is half this value. This gives an input signal of 0.707mV corresponding to a level of:

$$20 \cdot \log\left(\frac{7.07mV}{224mV}\right) = -30dBm$$

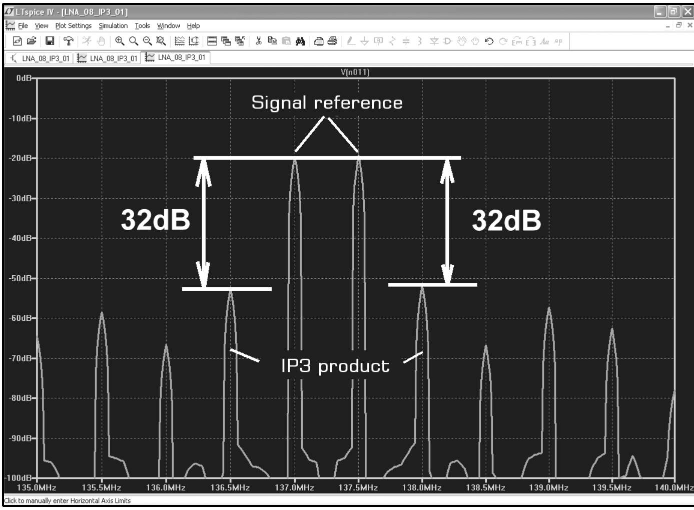


Fig 27: The result we want is found in the frequency range from 136 to 138MHz. This is the important information about the signal-to-intermodulation ratio to define the IP3 (see text).

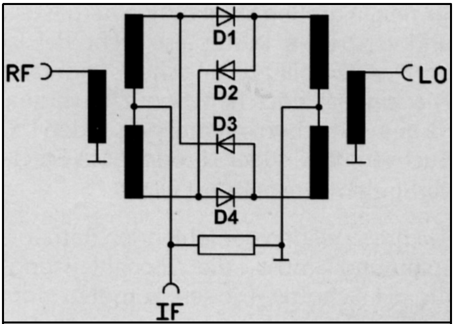


Fig 28: This is it - the basic circuit of the famous Double Balanced Mixer or ring modulator dating back to 1930.

The remainder is now simple, the input IP3 is:

IIP3 = -30dBm + 0.5 (32dB) = -30dBm + 16dB = -14dBm

The gain of the stage is approximately 23 to 24dB (see the simulation in the previous chapters) giving and output IP3 of:

OIP3 = IIP3 + (23… 24dB) = -14dBm + (23 to 24dB) = +9dB to +10dBm

This is the value usually given in Application Notes for LNAs using MOSFETS found on The Internet.

This information about the LNA is interesting and more extensive that expected. The mixer will now be examined.

5.0. The Double Balanced mixer (ring modulator)

5.1. Basics

This familiar communications circuit can be used to change the frequencies of signals without the information suffering (frequency conversion). The circuit of the ring modulator or Double Balanced Mixer (DBM) has two inputs and an output:

- The input for the signal whose frequency is to be converted (RF - radio frequency signal). It must always be a small amplitude signal.
- The input for the signal that causes the frequency conversion (LO - local oscillator signal). It must always be a large amplitude signal.
- The output where the converted signals are available (IF - intermediate frequencies)

Importantly:

In principle this is a circuit that multiplies the two input signals with one another. The mathematical formula is:

$$\cos(\alpha)\cdot\cos(\beta)=\frac{1}{2}\left[\cos(\alpha+\beta)+\cos(\alpha-\beta)\right]$$

Looking at the right hand side of the formula it can be seen that:

After going through this circuit the two input signals have disappeared at the output but the sum and difference frequencies are present.

The LO signal is usually a symmetrical square wave (or a sine wave with an amplitude large enough to act like a square wave). The effect is:

It is known that a symmetrical square wave is the sum of sine wave signals. The fundamental is present as well as the odd harmonics i.e. three, five, seven, nine etc. times the fundamental with decreasing amplitudes compared to the fundamental. The third harmonic has an amplitude of 1/3 of the fundamental, the fifth harmonic an amplitude with 1/5 of the fundamental etc. All of these harmonics are multiplied by the RF signal in the DBM to produce composite signal at the output with the sum and difference frequencies. The user selects the required signal from

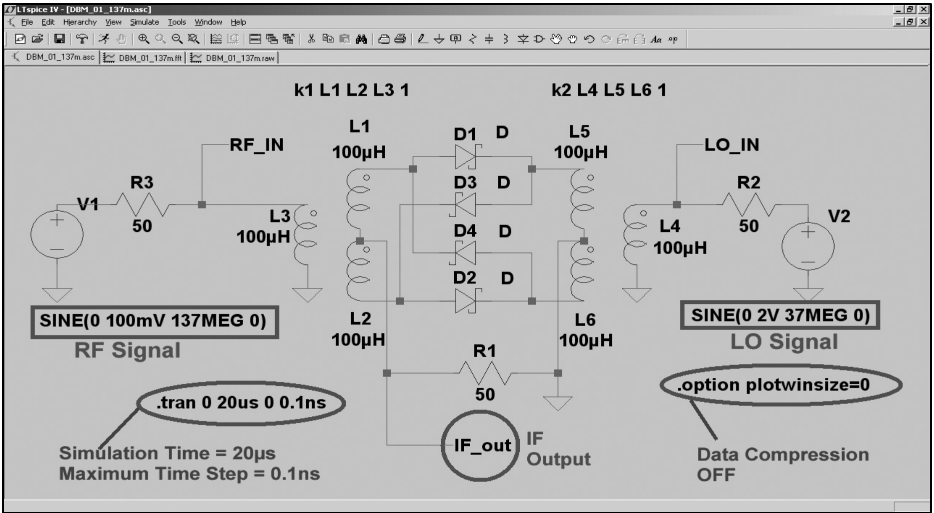


Fig 29: It is a little complex to draw the circuit of the DBM and program everything correctly.

this mixture using a suitable filter.

This component is indispensable in all communication systems in either a passive or active form. The passive version is shown in Fig 28. It consists of a ring of 4 fast Schottky diodes (note: they are not connected the same as a bridge rectifier) and two transformers. Each transformer has three windings. The two secondary windings are connected with the centre tap used. The multiplication takes place as follows:

For the positive half wave of the large LO signal - an amplitude of "+1" - the two diodes D2 and D4, that are connected in series, are switched on. For the negative half wave - an amplitude of "-1" - the two diodes D1 and D3 are switched on. Thus the RF signal is connected from either the upper or lower transformer windings to the IF output. Because the two secondary windings are anti phase the desired switching of the RF signal in sympathy with the LO signal is achieved. Thus the sine wave is multiplied by the square wave.

The advantages are: very low distortion. When constructed correctly they can be very wide-band (e.g. from zero to 5GHz and for special versions to over 50GHz). Free from adjustment problems. No supply voltage is needed however all ports must match the system resistance of 50Ω as closely as possible. Many manufacturers manufacture them in large quantities so they are low cost. They are often supplied fitted with RF connectors (BNC, N or SMA) ready to use as a plug in component.

The disadvantages are: because there is no supply voltage the LO signal must overcome the turn on voltage of the Schottky diodes so quite a large LO signal level is necessary to fast switch the diodes. No gain is possible therefore the component is an attenuator (typical between 5 and 8 dB) therefore the noise performance of a system is degraded. The consequence of this is that more preamplifier gain is required in a receiver.

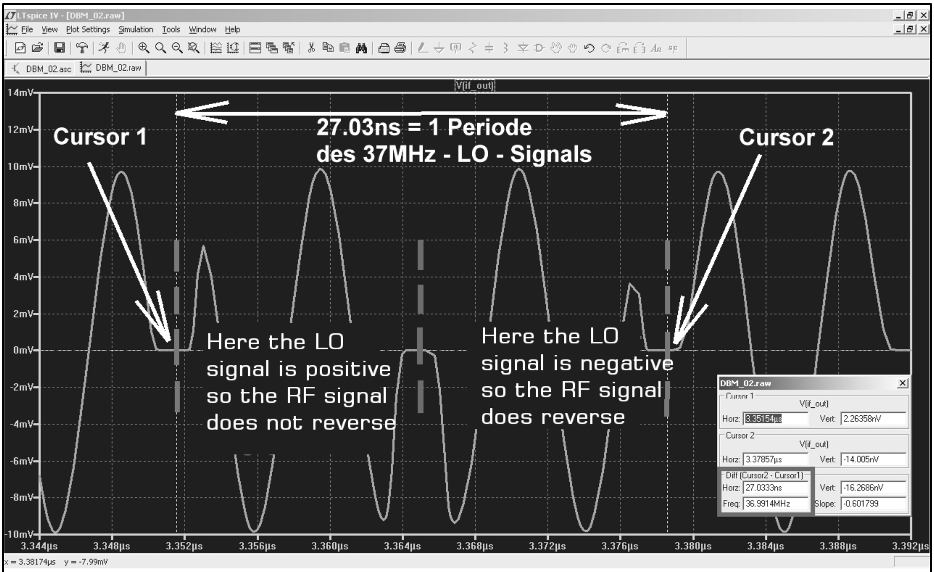


Fig 30: This is a view successfully showing the Schottky diodes working.

5.2. Simulation of the DBM with LTspice

5.2.1. Circuit for the LTspice simulation

It is good because all components necessary are already in the component library to make the new circuit shown in Fig 29. The diode symbol is labelled "schottky" the transformers are made from the symbol "ind2", the symbol has a small circle to mark the polarity for the three identical inductances. In practice the inductance is usually selected so that the inductive reactance is at least three times the system resistance of 50Ω at the lowest frequency to be used (100µH use for this example).

A SPICE directive is used to define the magnetic coupling that makes a transformer from the three individual coils. For the left hand (RF input) transformer it is:

k1 L1 L2 L3 1

The coupling coefficient k1 = 1 makes an ideal transformer. The same directive is used for the right hand (IF output) transformer.

The left input (RF) is fed the antenna signal in the finished converter. This is already amplified by the previous stage by approximately 20dB. Therefore an RF sine wave voltage with a peak value of 100mV and a frequency of 137MHz is selected for the mixer simulation in order to match a real system.

The right input of the mixer is supplied with the LO signal. For an intermediate frequency of 100MHz an oscillator signal of 37MHz and a peak value of 2V is required for distortion free operation.

The IF output delivers the desired intermediate frequency, it is terminated with a 50Ω load.

5.2.2. Simulation of the mixer characteristics

A time scale of 20µs gives a frequency resolution of 1/20µs = 50kHz. If the

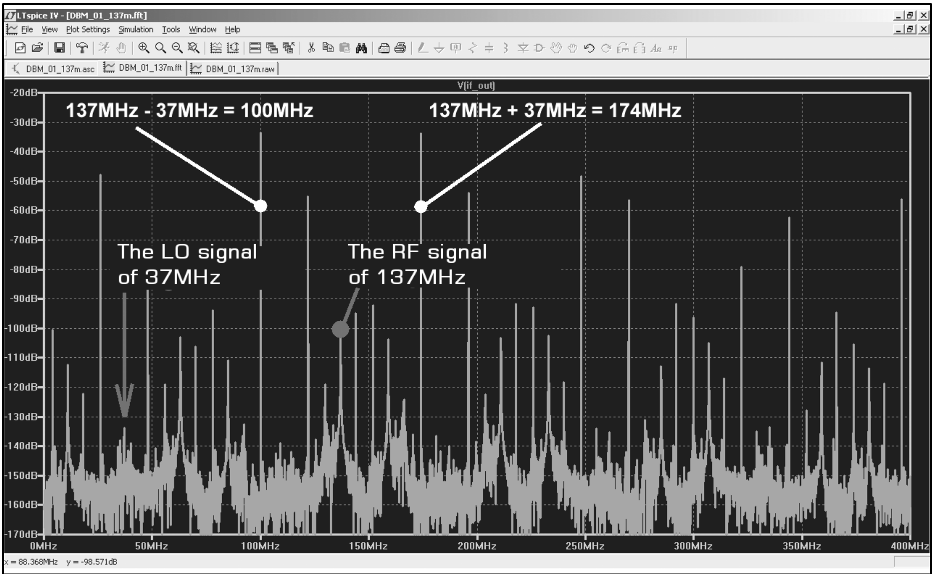


Fig 31: At first sight this is a little confusing, a mixer output spectrum showing the peak outputs is dB.

maximum time step of 0.1ns is used then at least 20µs/0.1ns = 200,000 samples are computed. Thus the FFT can be supplied with up to 131,072 samples.

In addition the noise floor is reduced in spectral plots. Quantisation errors can occur because the digital signals are stepped levels to simulate an analogue signal. Secondly a peculiarity of LTspice is that it does not use a constant sample frequency, only the “maximum step size” is used giving the minimum sampling rate. But for difficult signal transitions LTspice will vary its sample rate so that the effect is a “non foreseeable frequency change” e.g. a noise modulation. If the maximum time step is decreased the frequency change for this noise modulation portion of the noise floor becomes smaller. If these frequency changes happen regularly additional unknown spectral lines are suddenly produced causing a puzzle).

The data compression should be switched off using .option plotwinsize=0 before the simulation is started. Fig 30 shows the result of the IF signal, the switching process of the RF signal by the LO signal can be seen. Do not forget to check the “Gear” attribute.

An FFT simulation with 131,072 samples and a zoom range from 0 to 400MHz is shown in Fig 31. It is easy to identify the sum and difference frequencies of the RF and LO signals. The suppression of the two input signals is quite good but a great many unwanted spectral lines are produced during the switching process caused by the nonlinear characteristics of the diodes. With less than 0.4V across each switching diode their characteristic is no linear causing a short part of the signal to be missing. This causes distortion; this effect can be seen in Fig 30. The developers of such mixers deserve our respect because they must find solutions for this linearity problem.

By a simple change of the diagram axes the insertion loss can be found. Change the right hand axis to “linear” as shown in Fig 32. This shows the RMS value of the sum frequency (20.8mV) and the

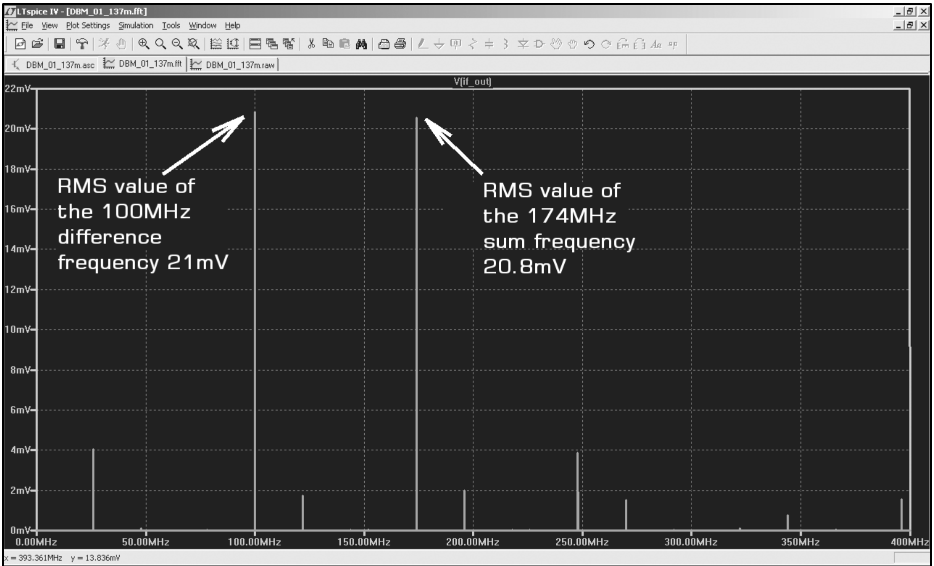


Fig 32: Using linear representation the whole thing looks much clearer and the attenuation can be calculated (see text).

difference frequency (21mV). The following calculation for the difference frequency difference of 100MHz:

The peak value of the RF signal voltage source is 100mV corresponding to an RMS value of 70.7mV. The input signal is half this amplitude thus 35.35mV, it appears at the mixer output as only 21mV at 100MHz. Thus the insertion

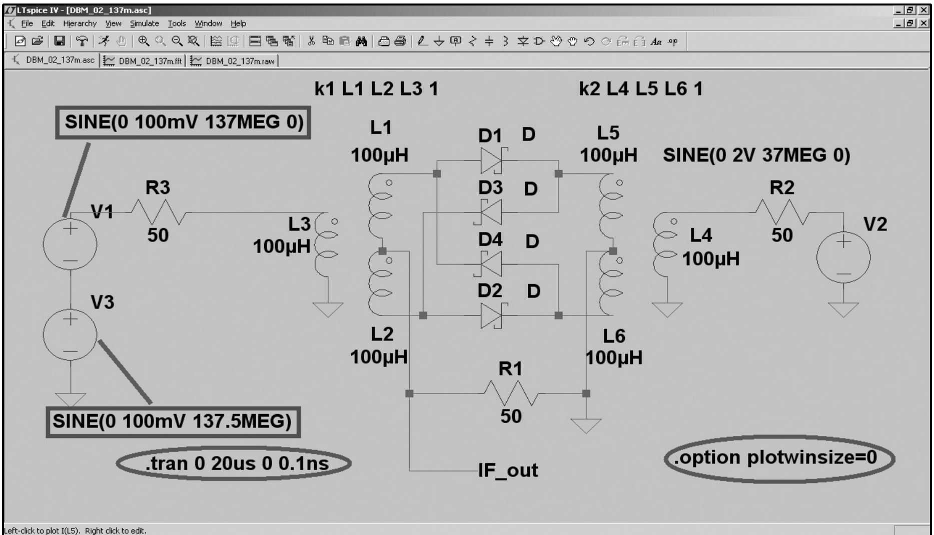


Fig 33: The circuit with the two input signals for IP3 measurement.

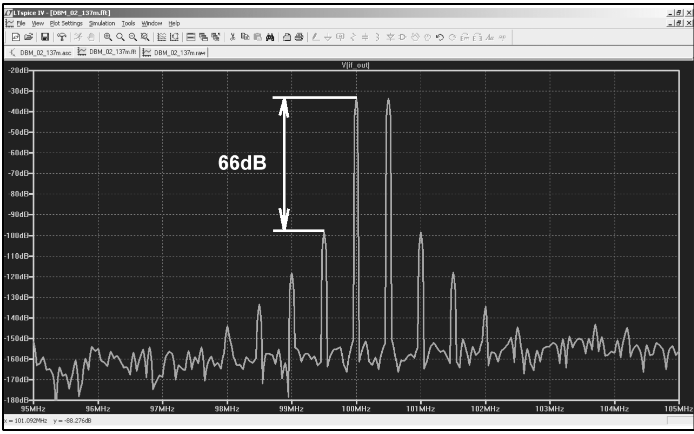


Fig 34: A nice result, the IP3 point can be easily determined.

loss amounts to:

$$a = 20 \cdot \log \frac{35.35mV}{21mV} = 4.5dB$$

This is only valid for ideal transformers; unfortunately the loss may be 5.5 or 6dB in practice. An additional loss has been seen for the sum frequency. This is due to the switching performance of the Schottky diodes with increasing frequency. This adds to the loss in the transformers so the insertion loss can increase rapidly. The IP3 intermodulation behaviour of the circuit must be considered. Two "in band" signals are used i.e. 137MHz and 137.5MHz with a peak amplitude of 100mV (Fig 33). The output spectrum now has the third order intermodulation products as well as the two IF signals (100MHz and 100.5MHz) that are attenuated by approximately 66dB (fig. 34).

Now the IP3 calculation can start.

The level at the RF input has an amplitude of 35.35mV at the fundamental: This gives a power level of:

$$20 \cdot \log \frac{35.35mV}{224mV} = -16dBm$$

and therefore the IP3 point can be calculated to:

IP3 = input Level + 0.5(Level difference between Input and Third order distortion product)

$$IP3 = -16dBm + 0.5(66dB) = +17dBm$$

The output IP3 point of the preamplifier that feeds the mixer is +10dBm therefore it is not the mixer that determines the limiting level of the converter.

6.0

The bandpass output filter

6.1. Description

The simulated mixer output spectrum is terrible, see Fig 31; this requires a good bandpass output filter with a steep cutoff. A centre frequency of 100MHz and a passband of less than 5MHz requires high quality components and a good circuit design. A good narrow bandpass filter (in Ansoft Designer SV it is called "Coupled Resonator Bandpass") has the following requirements:

- All inductors must have the same value (100nH is suitable for fo = 100MHz)

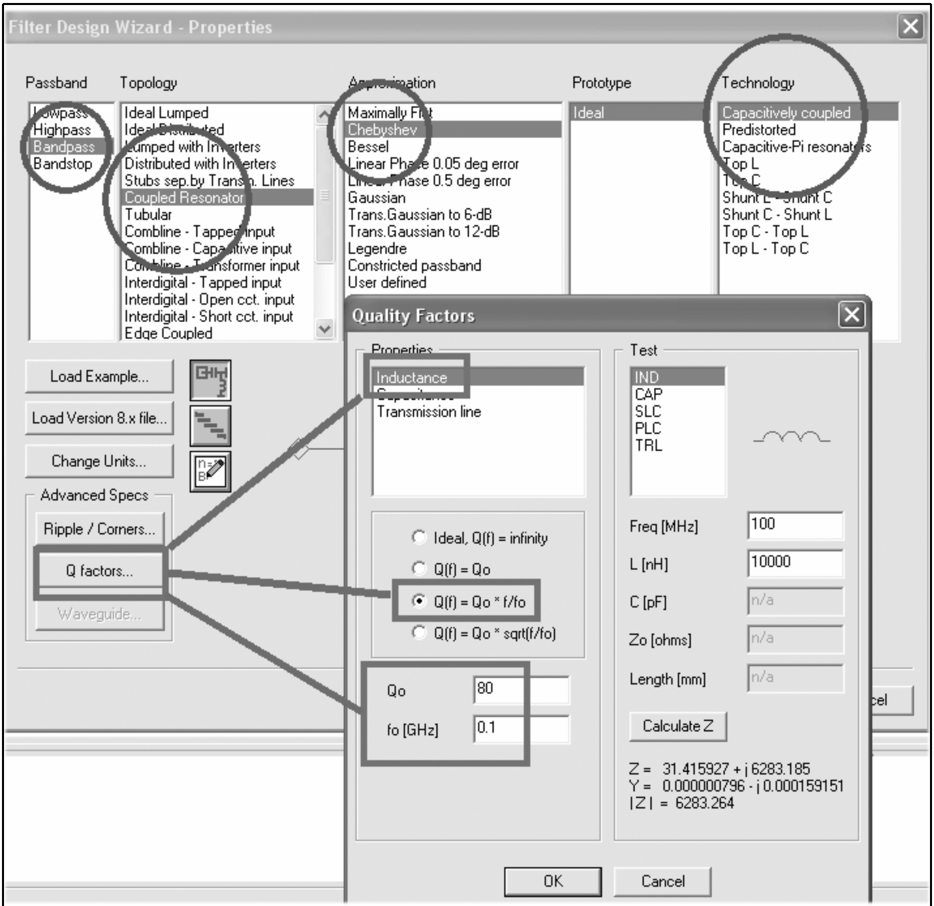


Fig 35: Very good menu guidance of the filter Calculator. Nothing can be forgoten.

- The coupling capacitor should be an as interdigital design requiring no additional components.
- The passband should be more than 5MHz, but at 10MHz away from the centre frequency an attenuation of approximately 70dB is required.
- The high frequency attenuation at 1GHz should not be less than 70dB.
- Use in a 50Ω system must be possible without problems.

The procedure for designing such a 100MHz bandpass filter was described in [5], it was simulated but the practical design required further development. A prototype was made with the following specification:

- Type of filter Tschebyschef band-pass filter, Coupled Resonator Bandpass type
- System resistance Z = 50Ω
- Filter degree of n = 5
- Centre frequency 100MHz

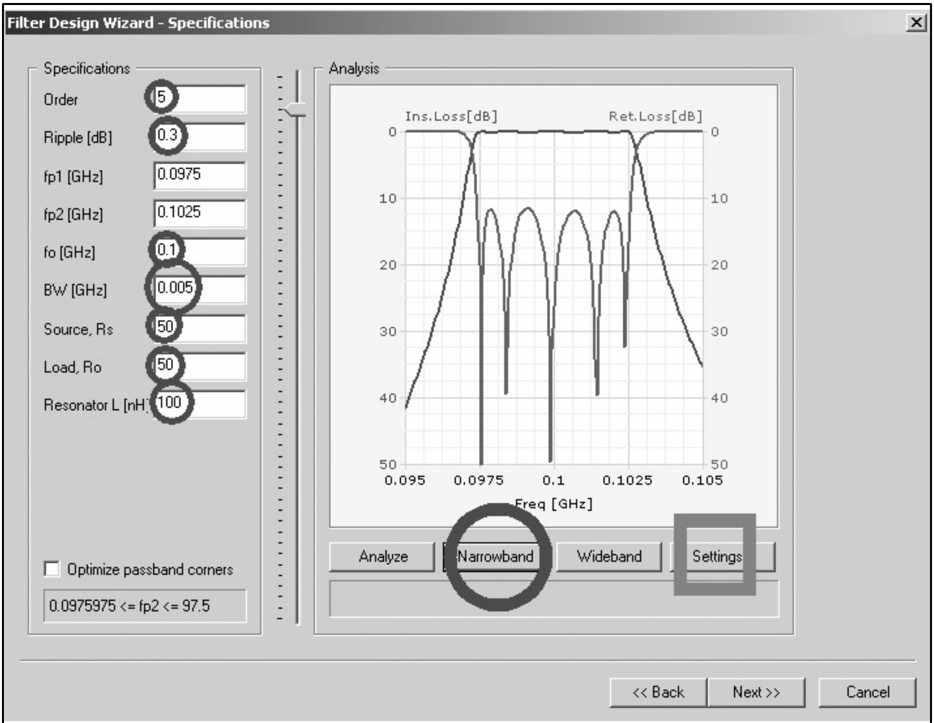


Fig 36: The list of input parameters required (see text) and a simulation result for the ideal circuit.

- Passband Ripple 0.3dB
- Passband bandwidth 5MHz
- Capacitors SMD 0804, Material NP0
- Inductors Neosid Helix filter in silvered screening cans. L = 100nH, Q = 80, measured at 100MHz
- Coupling capacitor printed inter-digital design
- PCB material, Rogers RO4003, thickness = 32MIL = 0.813mm, 35µm copper, εr = 3.38

6.2. Circuit design using Ansoft designer SV

Once again Ansoft must be praised for their software because as well as the complete linear S parameter simulation including hundreds ready made component models there is an outstanding filter calculator and it is all free.

Designing an interdigital capacitor is also easy but it does require some cheating to reach the exact value of the coupling capacitor and to separate it from the other parallel capacitors in the circuit because the program only simulates the S parameters of the components. The procedure is described in [6].

The filter design using Ansoft Designer SV is a pleasure. Once the program is started select “Insert Filter Design” under “Project”. The data for the filter is entered (bandpass filter/Coupled Resonator Band/Chebychev/Capacitively coupled) and “Q Factor” pressed (Fig 35). This ensures that the inductors have a Q = 80 at 100MHz with a linear frequency re-

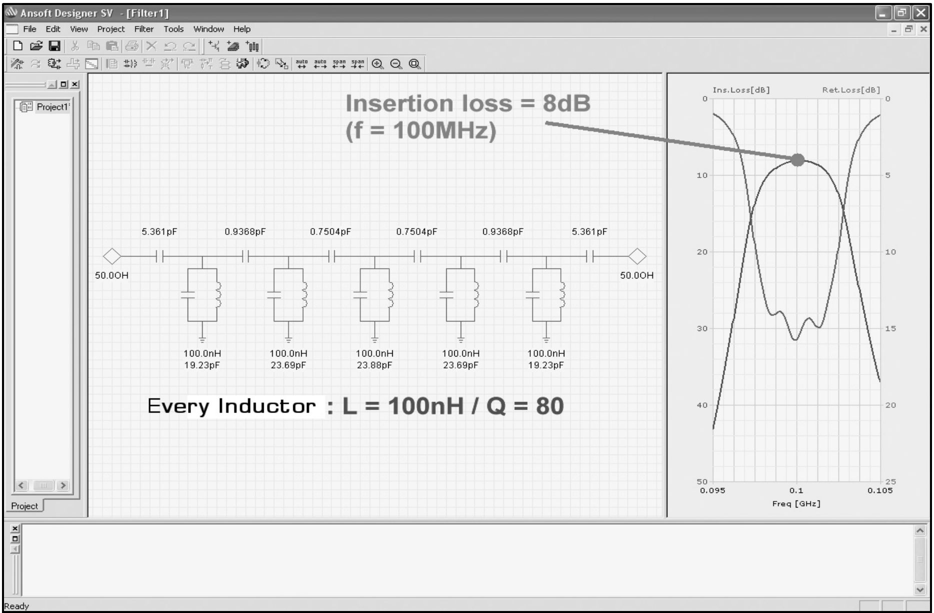


Fig 37: This shows the practical result: the simulated circuit with losses. The coil Q was included into the simulation.

sponse. A further press produces the list of filter parameters (Fig 36). The user must enter the following:

- Filter degree: 5
- Ripple: 0.3dB
- Centre frequency f_o 0.1GHz
- Bandwidth BW 0.005GHz
- Source resistance RS 50
- Load resistance R_o 50
- Resonator L (inductance) 100nH

The program computes the cutoff frequencies fp1 and fp2 from the centre frequency and the given bandwidth and enters them automatically in the associated fields if "narrowband" is selected. Then equivalent S parameters for the circuit are produced however this is for an ideal circuit without losses. If losses are to be included (a must in practice), click on "Settings" and check "Include Q factor losses in the response". With a further click on "Finish" the complete filter circuit shown in Fig 37 including S11 and S21 is produced. Typically for a narrow band filter there is an insertion loss of approximately 8dB because of the coil losses.

The result is examined with LTspice. The circuit is drawn and an S parameter simulation made for the same frequency range with the coil quality included. The coil quality is represented by a resistor in series with each coil with the value:

$$R_{series} = \frac{2\pi \cdot f \cdot L}{Q} = \frac{2\pi \cdot 100MHz \cdot 100nH}{80} = 0.758\Omega$$

The result of the S parameter simulation is shown in Fig 38. The values of the discrete capacitors were rounded to the values after the decimal place and produce using parallel-connected SMD components. The result is acceptable compared with Fig 37.

The practical result using proven micro-

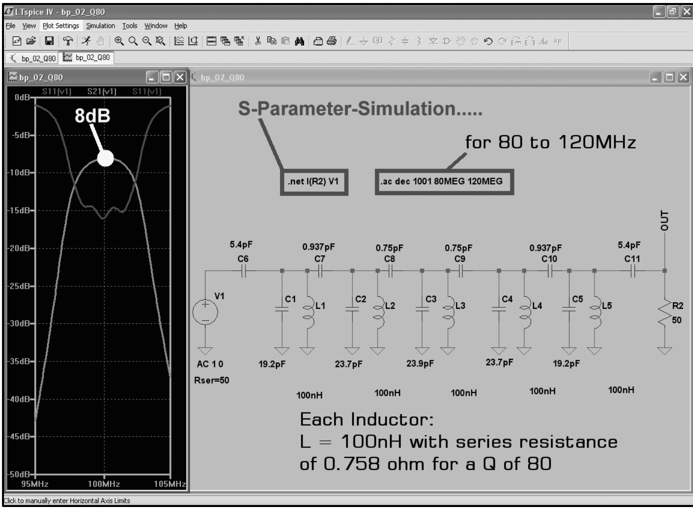


Fig 38: LTspice completely agrees with Ansoft designer SV for the filter characteristics.

wave construction techniques is shown in Fig 39. The RO4003 PCB is mounted under the SMA sockets in a milled aluminium housing. The usual work is: a separate ground area with many plated-through holes (by 0.8mm rivets) for each coil, SMD capacitors for each resonant circuit and interdigital capacitors for coupling. This gives good agreement with the simulations.

To be continued.

X. Literature for part 2

[3] Microwave Circuit Design using linear and Nonlinear Techniques, George D. Vendelin, Anthony M. Pavio, Ulrich L. Rohde, Wiley Interscience, New York, page 48.

[4] Measuring IP3, Agilent Design Tip from the Internet by Bob Myers

[5] Practical Project: Design and construction of a high quality 100MHz bandpass filter, Gunthard Kraus, DG8GB, VHF Communications Magazine 4/2003, pp 208 - 225

[6] Ansoft Designer SV project: Using microstrip interdigital capacitors, Gunthard Kraus, DG8GB, VHF Communications Magazine, 2/2009, pp 78 - 95

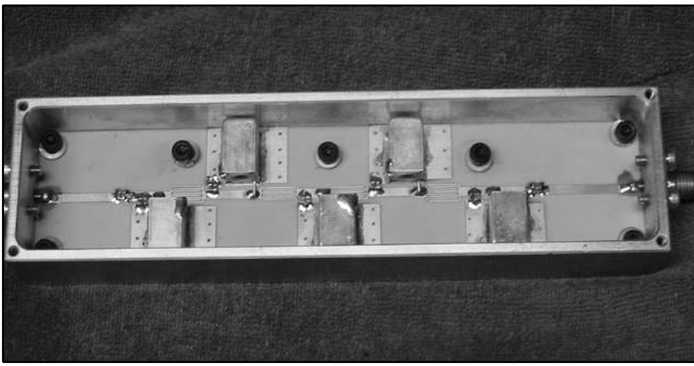


Fig 39: The prototype bandpass filter in a milled aluminium housing. The ground areas have plated through holes for the helical coils, SMD resonant circuit capacitors and an interdigital coupling capacitor.

Michael Kuhne, DB6NT

60 Watt amplifier for the 23cm Amateur Band

1.0 Introduction

Modern power MOSFETs make it possible to realise single stage power amplifiers with relatively few components. However these transistors need a 27V supply instead of 12V. With a few additional circuit modifications a 60 Watt power amplifier can be developed for the 23cm amateur band. Just build, switch on and align the RF circuits. Very small SMD components are used so some experience of construction with these components is required.

2.0 Circuit description

The complete circuit of the 23cm amplifier is shown in Fig 1. The heart of the amplifier is the UGF 9060F MOSFET from CREE with a 27V DC supply and a gain of approximately 14dB. The supply voltage is fed to the transistor via a 5A fuse, a transient protection diode, filter capacitors and a choke.

The output power monitor uses a strip line coupler feeding a voltage divider to give an output on the "MON OUT" connection.

The development paid special attention to reliability and reproducibility of performance e.g. overvoltage protection and reverse polarity protection.

The external control voltage (+12 - 14V DC) feeds a 5 V regulator via a protection diode. A voltage divider and trimmer feed the gate via a choke and stopper resistor.

This control voltage (TX or PTT) turns the transistor on to draw full current and it produces full power. With no control voltage the amplifier is in standby mode.

3.0 Short description of construction

A basic knowledge of RF technology is required to setup and align the amplifier. Experience with SMD components is essential; this should not be your first SMD project because the components used are very small. Different components, like MOSFETs are very sensitive to static, it is strongly recommended that ESD preventive measures be used during construction. A grounded and temperature controlled SMD workstation with a

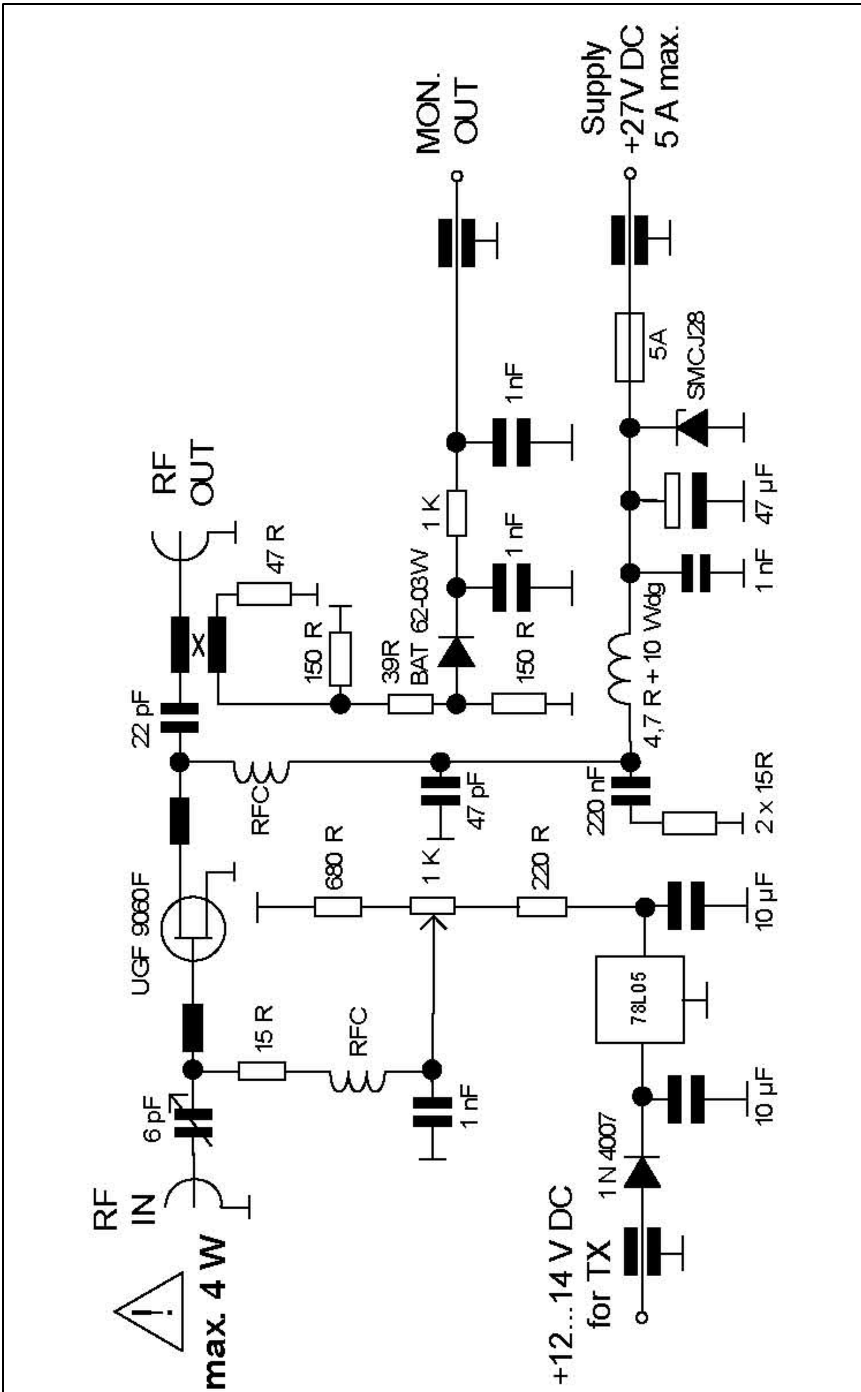


Fig 1: The circuit diagram of the 60 W transistorised amplifier for the 23 cm amateur band.

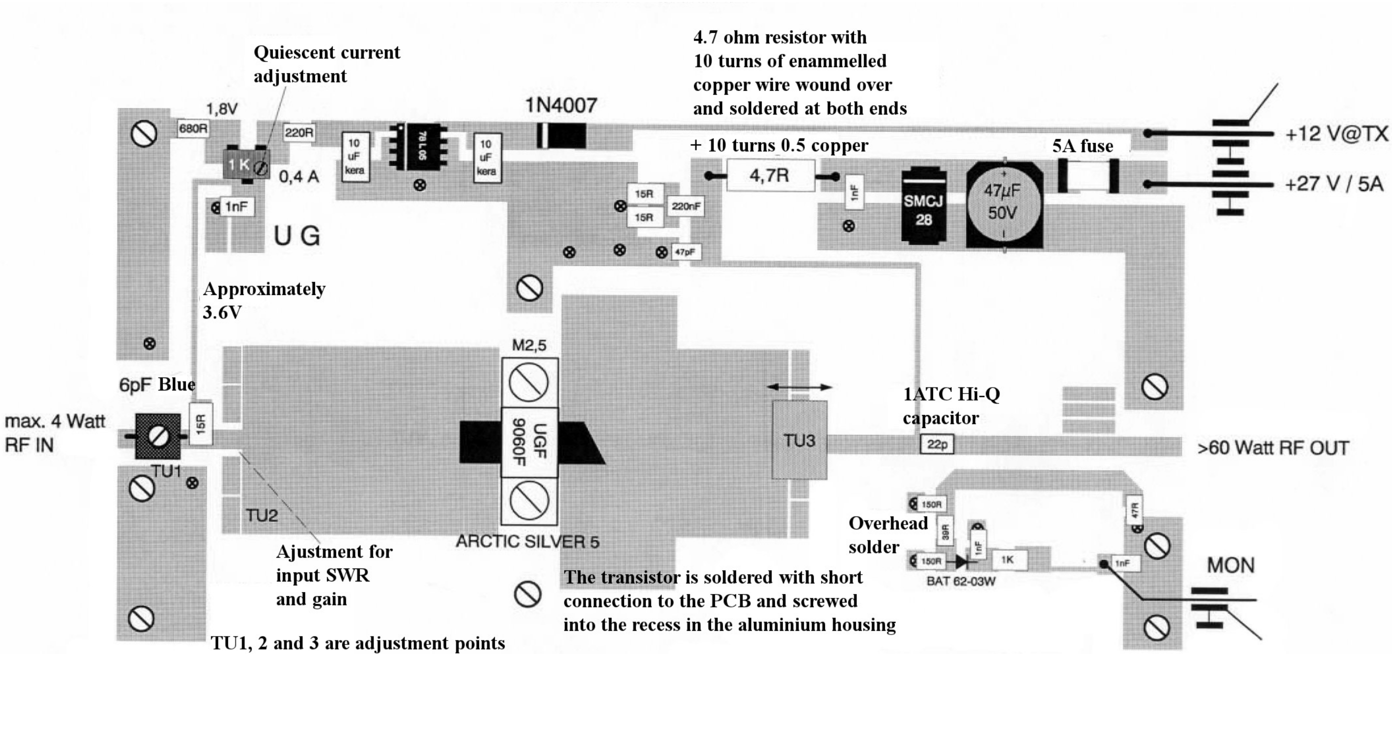


Fig 2: The component layout for the transistorised 60 amplifier for the 23cm amateur band.

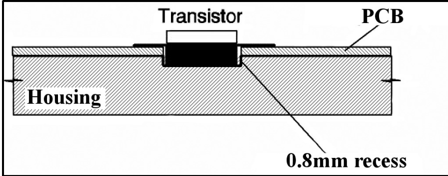


Fig 3: Detail of the assembly of the MOSFETs on the PCB and in the recess in the aluminium housing.

grounded work area should be used.

The printed circuit board is fitted into the milled aluminium housing using M2 screws. Silver loaded adhesive should be used between the printed circuit board and the housing. It is important that no adhesive is used near the connections at the edge of the printed circuit board or MOSFET because this could cause a short circuit between the tracks and the ground connection of the SMA sockets.

The adhesive is hardened at a higher temperature as described by the manufacturer. Following this the SMD components are soldered as shown on the component layout (Fig 2) and in the parts list (Table 1). SMA sockets are used for the RF input and output. The centre pin of the sockets goes through the housing wall and connects to the 50Ω strip line of the printed circuit board. SMA sockets with a long Teflon collar are used; the holes in the housing are the appropriate diameter for the collar. The SMA sockets are fitted and soldered into the aluminium housing.

Before the MOSFET is fitted the DC supply should be tested:

- Connect 12V to the control voltage input and adjust the gate voltage to its lowest value (approximately 1.8V)

Fit the MOSFET using thermal compound (ARCTIC SILVER V is the best). It should be used sparingly, ensure that no paste spreads between the tracks because this would risk a short circuit. The transistor is secured with M2.5 screws in the recess of the printed circuit board and the aluminium housing (Fig 3).

4.0

Adjusting the quiescent current

The amplifier module should be fitted to a suitably large heat sink. A sizing guide is shown in [2].

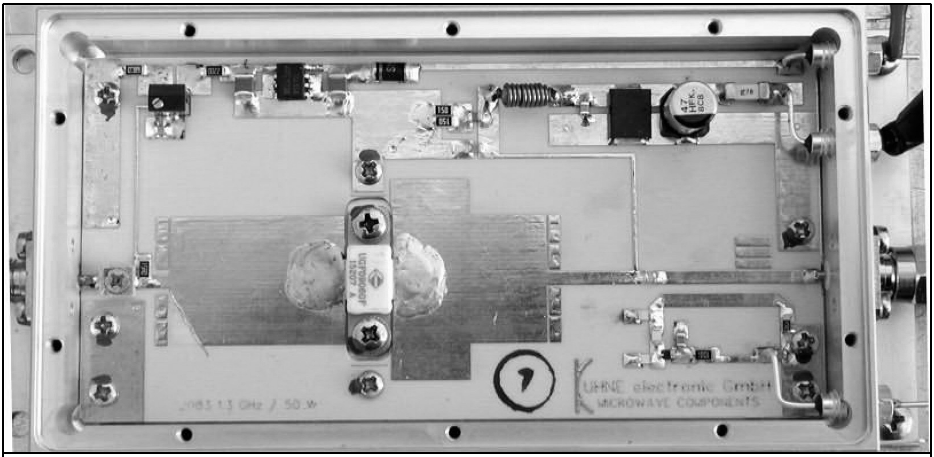


Fig 4: Assembled amplifier for 1296MHz, showing adjustment of the input strip line on the left.

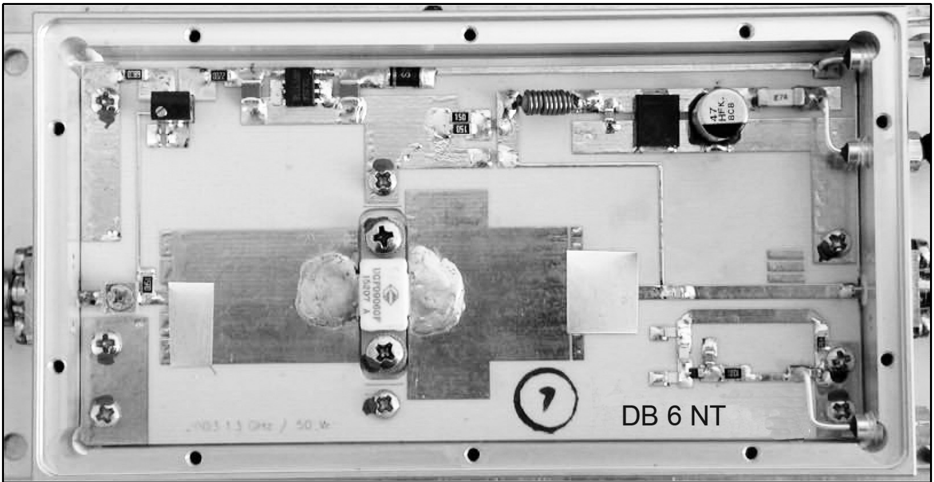


Fig. 5: Assembled amplifier for 1270MHz showing adjustment of the strip lines on the left and right.

- Connect a suitable 50Ω power meter to the output socket and a 50Ω dummy load to the input socket.
- Connect the 27V supply via an ammeter. The power supply used should have a current limit set to 0.6A.
- Connect the 12V control voltage and adjust the bias voltage to give a quiescent current of 0.4A.

5.0

RF alignment

Set the current limit of the 27V power supply to 4.5A.

Connect a RF input signal of approximately 1W to the input of the amplifier; the power drawn by the amplifier will increase. An RF output power of more

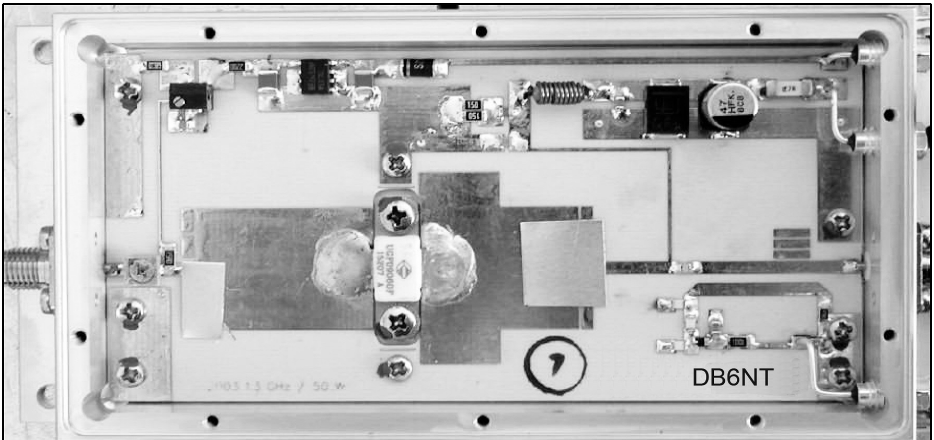


Fig 6: Assembled amplifier for 1250MHz showing adjustment of the strip lines on the left and right.

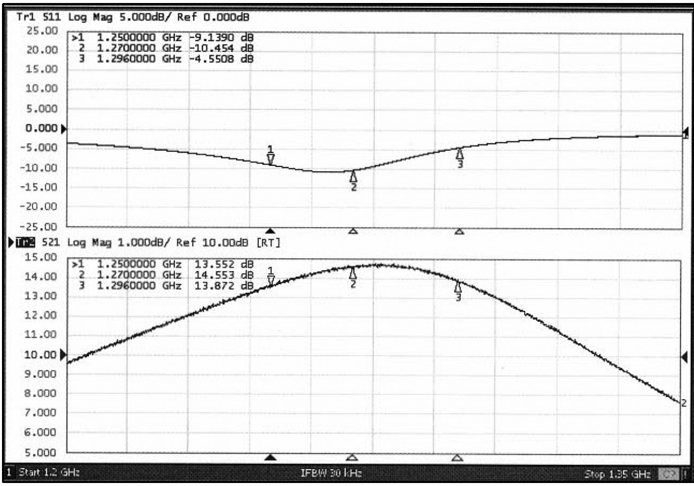


Fig 7: The measured gain for am amplifier tuned for 1270MHz.

than 10W should be measured at the output. Depending on operating frequency the input stage of the amplifier must be aligned. The frequency range from 1240 to 1300MHz should not be exceeded under any circumstances. The trimmer capacitor is adjusted to maximum gain and the strip line shortened by attaching copper tags to give maximum power output and optimal input adjustment, see Figs 4 to 6.

The input signal power is increased gradually to a maximum of 4W.

The output strip line is aligned using a copper tag for maximum power output. A power output of approximately 60W should be achieved.

Warning:

An input signal power of more than 4W will cause the immediate destruction of the MOSFET.

The SWR of the antenna should be better than 1:1.8. A sequencer that controls the amplifier and the antenna relay is essential.

Some examples of the tuning for appropriate frequencies are shown in Figs 4 to 6. It is also possible to tune for wideband operation but this reduces the power output. It is a compromise between power output and gain.

6.0

Example measured results

Gain and input adjustment for an example amplifier tuned for 1270MHz are shown in Fig 7; more details shown in Table 2.

7.0

Availablity

This article describes a kit (MKU PA 1360). The kit and other accessories e.g. housings, thermal compound and a heat sink are available from:

Kuhne Electronics GmbH,
Scheibenacker 3,
95180 Berg, Germany
Telephone: 0049 (0) 9293 – 800 939,
E-Mail: info@kuhne-electronic.de
Internet: www.db6nt.de

Table 1: Parts list for the 60 W transistorised amplifier for the 23cm amateur band.

1	PCB	DB6NT-PA 23-60
1	MOSFET transistor	UGF 9060F
1	trimmer capacitor	6pF blue
6	SMD resistors	1206
4	SMD resistors	0805
1	trimmer potentiometer	SMD 1K
2	Capacitor	10µF/20V
6	SMD capacitor	0805
1	ATC Hi-Q capacitor	22pF
1	wire wound resistor	4.7Ω with 10 turns of enamelled copper wire
1	Transient protection diode	SMCJ28
1	Schottky diode	BAT62-03W
1	Voltage regulator	78L05
1	Electrolytic capacitor	47µF/50V
1	SMD fuse	5A
2	SMA socket	4 hole flange
3	Feedthrough	1.5nF 8/32UNC
2	Solder tags	3mm
8	High-grade steel screws	M2 x 4
2	High-grade steel screws	M2.5 x 5
2	Lock washers	M2.5
8	High-grade steel screws	M2 x 3

Also required:

1	Aluminium housing with all necessary holes and threads	
1	Thermal compound	ARCTIC SILVER V
1	Heat sink	SK300-62
1	Fan	60 x 60 24V
1	Power supply unit	S 150 W 27

Table 2: Measurements for the amplifier.

f/MHz	P_{in}/Watt	P_{out}/Watt	I/A	MON./V
1296	2.2	50	3.80	3.7
1270	1.4	50	3.66	3.6
1250	1.5	50	3.82	3.7
1296	3.9	60	4.33	4.1
1270	3.1	60	4.20	4.0
1250	3.2	60	4.34	4.0

P_{1db} for 1296MHz: 61 Watt

Harmonic suppression at 1296MHz: approximately 40dB

IM_3 at 1296MHz: 31dBc for 30W PEP

Roy Stevenson

The American Museum of Radio and Electricity, Bellingham, Washington.

Every year thousands of amateur radio and communications aficionados visit the American Museum of Radio and Electricity in the small town of Bellingham, Washington, just south of the Canadian border, to see buzzing, humming, and spinning artifacts that span four centuries. Located in the middle of the bustling downtown area, the museum is a radio enthusiast's nirvana with a collection featuring many rare and historic objects that even the Smithsonian Museum has shown interest in.

The museum's 12,000 artifacts include unusual items like 18th century Leyden Jars (the first objects used to store electrical charges), Tesla coils, early 20th century Fleming Valves (the grandfather of the modern Triode vacuum tube), De Forest Audion amplifying vacuum tubes (that made radio and long distance telephone possible), electric lamps invented by Thomas Edison in the 1880's, the 1920 Westinghouse Model RADA (the first commercial radio receiver ever designed), and the RCA Radiola Model 30 (the first AC powered radio). Other rarities include original documents from Gilbert, Newton, Galileo, Benjamin Franklin, and Marconi, and a full size replica of the wireless room in the Titanic, complete with authentic Marconi wireless apparatus - the same as the one installed on the Titanic. It's like walking through a pantheon of the history and evolution of radio and electricity, with all sorts of rare and bizarre artifacts that capture your attention and imagination.

The first gallery introduces The Dawn of the Electrical Age, with devices showing how electricity was produced in the early days - things that you probably did in high school using materials like resin, wax, and glass tubes to generate static electricity. Influence machines produced electricity by using glass plates spinning in opposite directions. You'll have a shocking time in the Static Electricity Learning Centre as you attract large currents of energy from the Van de Graaff generator. The small metal electrical sportsmen are particularly fascinating. These French ornamental novelties, dating from the late 1700's, worked by discharging the electrical build up from Leyden Jars. The base of these 6-inch tall hunting sportsmen is held in your hand and the barrel of the rifle is moved near the electrode of the charged jar. The jar discharges into the Sportsman with a loud crack, while a flash appears at the rifle barrel. Great stuff!

You'll see an early Volta Cannon, invented by Alessandro Volta (1745-1827) who used methane swamp gas as the explosive agent in this experimental gun. When ignited with a rudimentary spark plug, a lead ball was ejected 20 feet across the room. Although never used as

Fig 1: View of the radios on display in the museum.

a weapon, Volta's invention led to the creation of the internal combustion engine, and Volta was honored by having the measure of electric potential, the volt, named after him, the volt.

The second gallery, Electricity Sparks Invention, is even more intriguing. You'll see early electromagnets, electric motors, dynamos, and an excellent series of displays that show how electric lighting was developed. Early Edison Lamps and Nernst Lamps show the evolution and experimentation with different lighting filaments. German scientist Walther Nernst (1864-1941) experimented with ceramic rods, and Thomas Edison (1847-1931) tried bamboo and wire filaments. Here, you learn how Edison invented the screw-in socket base for light bulbs. Early light sockets were held in place on the ceiling by a small thumbscrew, but the screws had a tendency to come loose and the lamp would fall from the light socket. Edison fiddled with the threaded lid on a nearby can of kerosene and declared, "This most certainly can make a bang-up socket for the lamp", and thus was born the screw-in lamp base!

The enigmatic genius Nikola Tesla (1856-1943) is also featured in this gallery. Tesla, an immigrant from Croatia, worked first for Edison, but did not get along with him, then switched over to working for George Westinghouse (1846-1914). Tesla invented a system of motors and generators that operated by alternating current and Westinghouse, a savvy businessman, quickly realised the value and uses of the AC motor. He built AC generating plants that could send power over a much greater distance than Edison's generators, thus putting a spanner in Edison's corporate works. The museum presents dozens of interesting examples of early corporate competition, development, and subterfuge from these exciting times, and museum President and CEO, John Jenkins, is only too happy to tell you these stories.

The museum's roots go back to 1985, with the antique radio and vintage magazine and manual collection of Jonathan Winter, under the name The Bellingham Antique Radio Museum. Its floor to ceiling display of antique radios soon attracted like-minded radio buffs. Then, in 1995, John Jenkins, general manager of worldwide sales and marketing for Microsoft Corporation, also an avid collector of electrical and communications artifacts, discovered the museum, teamed up with Winter, and funded its expansion into its current, larger location. The museum became a non-profit 501(c) organization in 1998. With its new mission of turning the museum into a world-class

Fig 2: The Deforest long plate audion.

display of all things electric, it was renamed the American Museum of Radio and Electricity.

Jenkins started his extensive personal collection when he was 13 years old, inspired by an old radio he discovered in his grandparent's basement. He pored through the pages of Morgan McMahon's book "Vintage Radio", dreaming that someday he might own some of these radios. During the next 40 years he brought together thousands of artifacts and books beginning in the 16th century about electromagnetism, the telegraph and telephone, electric light, and wireless technology. In his book, "Where Discovery Sparks Imagination", Jenkins says he founded the museum because, "I wanted to recreate for people that sense of magic and discovery that I felt as a child when I sat down with McMahon's Vintage Radio: a sense of appreciation for the amazing minds and hands of the scientists, inventors and craftsmen whose dedication, persistence and plain hard work have made our modern world possible".

A large number of exhibits in the Electricity Sparks Invention gallery show the development of the Telegraph, the progenitor of wireless communications. We learn that the first electric telegraphs were made in the early 18th century using static electricity, but when the battery was invented in 1800, telegraph inventors knew that a continuous electric current would be ideal for telegraph transmission. Then in 1821 Hans Oersted (1777-1851) discovered electromagnetism, and over the next ten years William Sturgeon (1783-1850) and Joseph Henry (1797-1878) developed the electromagnet, which sparked a flurry of experimentation and further development of the telegraph.

As a result, many varieties of telegraphs were invented: Needle telegraphs, ABC and Dial telegraphs, and Printing Telegraphs. And then, of course, along came Samuel Morse's Telegraph system and the telegraphic transmitting key. The museum contains one of the largest collections of early telegraph apparatus in the world.

The logical innovation to follow the telegraph was the telephone, and the development of the telephone is a fascinating story and the museum's array of early telephones is superb. Most people credit Alexander Graham Bell (1847-1922) with inventing the telephone - he did, after all, report the electrical transmission of speech for the first time in 1875. But, another inventor, Elisha Gray (1835-1901) had independently invented the telephone around the same time as Bell. Both lodged their patents on 14 February 1876, but it is believed that Grey lodged his patent first, by a few hours. Bell prevailed in a court case, however, and went on to hit the big time while Gray doggedly continued his work, lodging 70 patents for his inventions including the "teleautograph", a precursor to the fax machine, and the "telephote", a primitive close-circuit television. What is not commonly known is that industrial espionage may have played a hand in Bell's triumph. His lawyer somehow heard about the liquid mercury microphone transmitter devised

Fig 3: A replica of the Titanic radio room on display at the museum.

by Gray, and cunningly inserted a description of it into Bell's patent, without Bell even having a liquid transmitter at the time!

The "Hush-A-Phone" is a classic piece of telephone paraphernalia with a great story; it's a small rectangular baffle that fits over the mouthpiece of a telephone, with an opening just big enough to place your lips into. The party at the other end of the line can hear the speaker clearly, but no one else in the room can hear a sound. This invention precipitated a court case that changed the way we do business today. In the late 1940's, AT & T sued the Hush-A-Phone company, claiming that it had added something on to their phone, which Hush-A-Phone clearly had done. However, the case was ruled in favor of the Hush-A-Phone company, which had now set a legal precedent for inventors to add other things on to someone else's invention. Think of all of the inventions that have been approved as a result of this "add-on" ruling; the computer mouse, and computer software are great examples. Eventually this ruling would lead to the break up of AT & T and the development of the public Internet.

Radio enthusiasts will no doubt be fascinated by these stories, gadgets, and inventions, but the real radio action starts in Gallery Three: "The Wireless Age". Covering the era from 1863 to 1920, these exhibits show the evolution of electromagnetic waves. James Maxwell (1831-1879) described the theoretical propagation of electromagnetic waves and a first edition of his paper titled "On a Dynamical Theory of the Electromagnetic Field" is stored in the museum's library. His mathematical formulae predicted that radio waves existed and that varying the amplitude of the electrical current in a wire could create them. At this stage of your visit to the museum you start to get an appreciation of how far ahead of their time these inventors really were - and it's a humbling experience.

On now to Heinrich Hertz (1847-1894), who was the first to send and receive radio waves. He's the granddaddy of modern radio, and radio wave frequencies are rightly named after him, although they were quaintly called "Hertzian waves" back in the day. You'll see a parabolic Hertzian set from the early 20th century, an 1885 Hertzian-Wave Test Bench, and an unusual cohearer that detects a radio pulse, causing a magnet to

Fig 4: A Marconi 11F on display at the museum.

fire an attached pistol.

Next up in the museum's radio hall of fame is Guglielmo Marconi (1874-1937) who was the first to develop wireless transmission for practical use. Marconi's dream was to bypass landlines by using radio waves. After being rejected by the Italian and British governments, Marconi worked with William Preece, the Chief Engineer of the British Post Office. Marconi patented his invention in 1896, and formed the Marconi Wireless Telegraph Company. Amazingly, Marconi's device was designed primarily for ship-to-shore communications, and completely overlooked the device's potential for popular entertainment broadcasting!

The displays show a plethora of Marconi's inventions, from a 1922 Marconi MC1 1.5KW Ship Set, a 1915 Marconi Type 16 Balanced Crystal receiver, a 1920 Marconi Type 11 Direction Finder, and a 1920 Marconi 1/2KW Quenched Multiple Spark Transmitter. The full-scale diorama of the Titanic's radio room is painstakingly reproduced from a photograph, and displays the exact same type of Marconi wireless set that was used while the Titanic was sinking. You can listen to the spark transmitter's final message sent from the Titanic, on that night of April 14, 1912, "SOS SOS CQD CQD Titanic. We are sinking fast. Passengers are being put into boats. Titanic".

Some other unique wireless apparatus displayed include a 1907 apparatus for receiving space signals made by Stone Tel & Tel Co, Boston, a 1908 two-coil syntonizer from De Forest Radio Telephone & Telegraph Co, a 1917 shipboard receiver, and 1910 Model D Tuner from United Wireless Telegraph Co.

The sad story of A. Frederick Collins (1869-1952) is told here. Collins invented a Wireless Telephone in 1898, and a Wall Street promoter Cameron Spear, guided the 1909 merger of Collins Wireless Telephone Company into the Continental Wireless Telegraph & Telephone Company based on this invention. In 1911 Collins, Spear, and other company officials were indicted for using the mail to defraud in selling worthless stock. Collins was also charged with giving a fraudulent demonstration of his wireless telephone at Madison Square Garden two years previously. Despite demonstrations that his apparatus worked, Collins served a year in jail. By the time he resumed his work, rapidly improving technology like Lee De Forest's (1873-1961) vacuum tube left Collins behind. In the years that followed he wrote nearly 100 books, including "The Radio Amateurs Handbook" in 1922, which is still a staple of every radio hobbyist, now in its 85th edition.

The military was quick to use the radio - it's previous signals methods had been runners, flags, carrier pigeons, smoke signals and wired telegraphy. The Radio Goes to War section display features a number of military signals artifacts including a 1917 CW-938A Short Range Transmitter/Receiver, and a British 1914 Field Radio Set signed Marconi's Wireless Telegraph Company Ltd.

Gallery Four, "Radio Enters the Home", illustrates early public broadcasting, the famous Zenith Radio Corporation, portable radios, RCA music makers, and the Atwater Kent Open Receiving Sets. Charles Herrold (1875-1948) began broadcasting music in San Jose in 1906. He made the distinction between "narrowcasting", a transmission aimed at a single receiver, and "broadcasting" aimed at a general audience. Early radios were ugly and inefficient affairs, small black boxes with wires sticking out, and poor selectivity. With radio broadcasts covering news, comedy and drama, the radio moved into the living room, which meant that radios took on a new look.

Radios became decorative furniture and thus was spawned "The Golden Age of Radio" described in Gallery Five. There were only 5,000 radio sets in the USA in 1920, and by 1924 there were three million! There were literally hundreds of radio manufacturers. The museum's collection of furniture radios from the 1930's through the 1960's is superb, and many are rare collectors items worth tens of thousands of dollars. A few of the museum's radio showpieces include the 1936 Crosley Cathedral Tabletop Receiver, the 1937 Emerson Duo-Vox AC-DC Receiver Model 107, the art deco 1940's De Forest-Crosley Console Radio Model SD 992 looking like a miniature Empire State Building, and the 1937 Scott pointer-Dial Philarmonic Console Radio Model 20A.

There are far more surprises that await you at the museum. These then are just a few of the highlights of the fascinating and captivating artifacts and stories at the American Museum of Radio and Electricity. There's enough to interest radio techies, radio historians, and those just looking for high drama, intrigue and espionage. Above all else, the exhibits remind us that historically speaking, these discoveries took place only yesterday.

The American Museum of Radio and Electricity
1312 Bay Street
Bellingham, WA 98225

Phone: 360.738.3886

Hours: Wednesday through Saturdays from 11 a.m. to 4 p.m., Sundays noon to 4 p.m., and by appointment.

Admission: $5 for adults and $2 for children 11 and under.

All photographs supplied courtesy of John Jenkins and his book "Where Discovery Sparks Imagination - A Pictorial History of Radio and Electricity (AMRE, Bellingham, WA 2009)".

Andy Barter, G8ATD

Backpacking on 23cm

My home QTH is in a valley, to the East is a range of hills rising 150 feet so the chance of working DX in Europe on 23cm from home is nil. There are some good locations locally to work portable, the best one is only accessible on foot, so I began to think of ways to backpack. My thoughts were to build a small transverter that could be mounted at the top of a portable extendable mast with a reasonable sized antenna. The transverter would be driven by an FT817 on 2m and the whole lot should fit into a backpack, including a battery to run the station for 2 - 3 hours of contest operation.

1.0 Searching for a transverter

There are not many designs for 23cm transverters and fewer available as kits. I investigated at two kits:

- Down East Microwave [1]
- Mini Kits [2]

The Mini Kits 23cm transverter kit looked the best option with 4 modules available to construct a complete 23cm transverter

- EME65B - LO with a 95.9MHz crystal for an IF of 145MHz to avoid local QRM on the IF
- EME72B - Transverter producing 10mW output
- EME162-1200 - Low power amplifier to raise output to 800mW
- RA18H1213GPA - PA using a Mitsubishi RA18H1213 MOSFET module to give about 12W output

The Mini Kits web site shows these modules built into a pair of RS aluminium chassis boxes. This looked a good idea giving isolation between the transverter and the PA but I wanted to mount the transverter up the mast so a weatherproof enclosure was required. I found a diecast box on the Farnell [3] web site that looked ideal. Using the same idea of using two enclosures I decided to use two diecast boxes mounted back-to-back.

The kits were ordered from Mini Kits and I waited for them to arrive from Australia, they arrived in about a week. A block diagram of the complete backpack station is shown in Fig 1.

2.0 Constructing the transverter

The kits from Mini Kits were well presented with full documentation and all

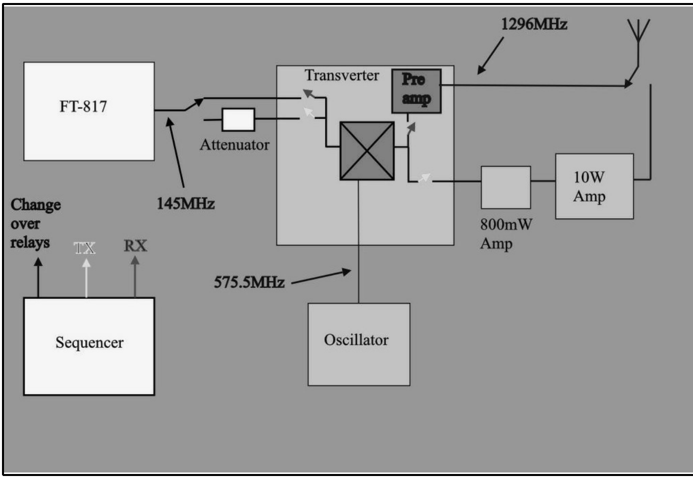


Fig 1: Block diagram of the 23cm backpacking transverter.

components well identified, all SMD parts were taped to identification sheets. Fig 2 shows the transverter kit as it arrived.

Construction was straightforward. Each module, except the PA, uses SMD components so experience with SMD construction techniques and anti static precautions are required. The LO and transverter were fitted into their own tinplate

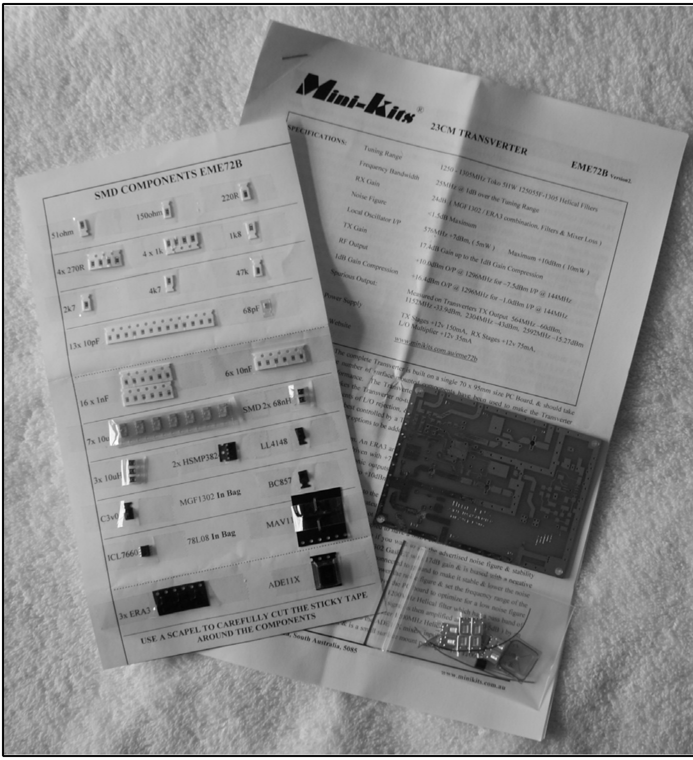


Fig 2: Picture of the tranverter kit as it arrived from Mini Kits. The components were well identified and a full set of assembly and testing instructions were included.

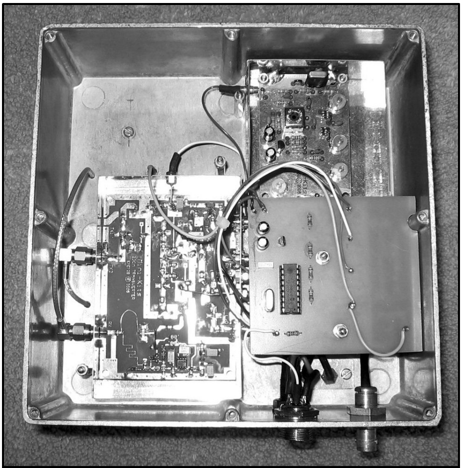


Fig 3: Picture of the transverter, LO and sequencer fitted in one half of the twin diecast box enclosure.

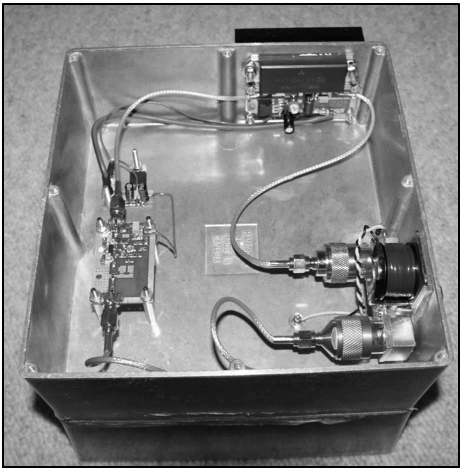


Fig 4: Picture of the power amplifiers and aerial changeover relay fitted in one half of the twin diecast enclosure.

boxes, Fig 3 shows them mounted in one half of the twin diecast box enclosure.

2.1 Testing

The first module to be switched on was the LO, this proved to be a bit tricky to set up. The instructions suggest adjusting the tuned circuit in the crystal oscillator stage without the crystal in circuit, this was good advice but the remaining stages could not be persuaded to produce the specified 10mW output. My kit had a modification consisting of back-to-back diodes across the oscillator tuned circuit; this was supposed to reduce the spurii. When these were removed the specified output could be achieved and the output could be setup with care using a spectrum analyser.

The transverter was the next to test; this worked first time and tuned up perfectly. Unfortunately the second time it was powered up the receive side did not work; this was traced to a blown up FET in the input stage. A replacement blew up immediately so there was a problem. The FET has an automatic bias circuit that worked fine at steady state but I concluded that at switch on the negative bias was not established in time to stop the FET destroying itself. A simple solution was to fit a diode between the negative bias and ground thus preventing the bias from going too far positive during switch on. It has not failed since.

The two power amplifier stages worked first time; the first increases the 10mW output of the transverter to about 800mW that is sufficient to drive the RA18H1213 MOSFET module to about 12W. Fig 4 shows these two amplifiers mounted in the second half of the twin diecast box enclosure.

2.2 Sequencer

A sequencer was required to control the transverter when switching from receive to transmit and back again. Mini Kits do sell a sequencer but I decided to build my own using a PIC. The circuit is shown in Fig 5. It uses 4 dual (one N and one P channel in a single SMD package) MOSFETS to switch the supply to the relevant circuits; a timing diagram is shown in Fig 6. The changeover relay for the 2m IF is a small PCB mounted coax relay fitted on the sequencer PCB. There is also an attenuator in the transmit feed to the transverter to reduce the 200mW minimum output power of the FT817 to suit

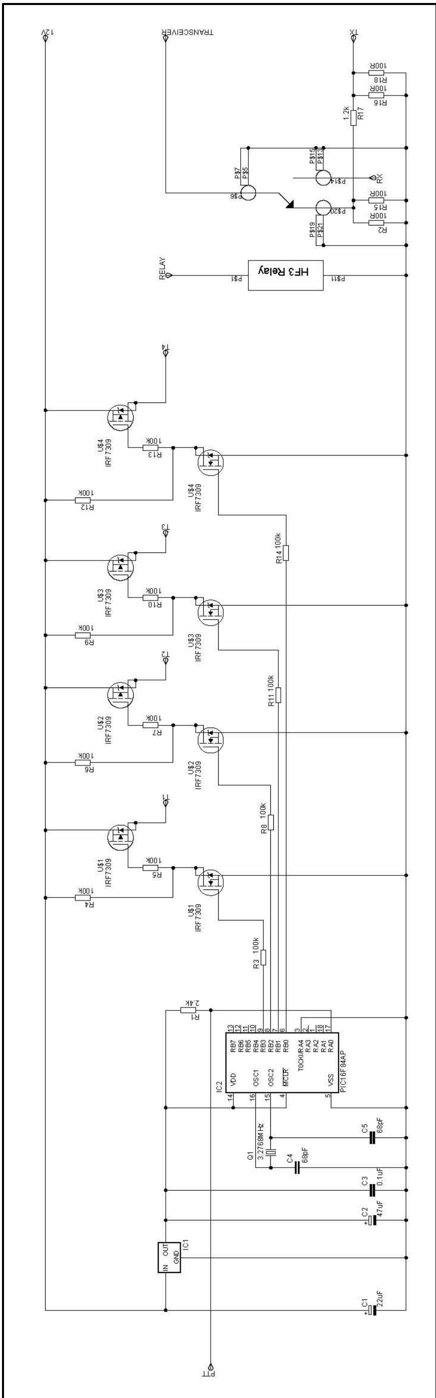


Fig 5: Circuit diagram of the sequencer.

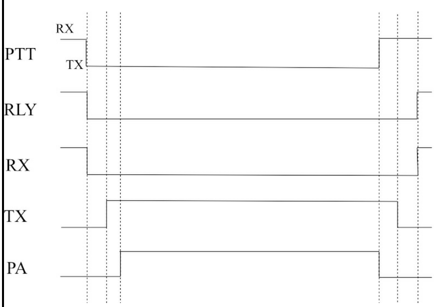


Fig 6: Sequencer timing diagram.

the input of the transverter. The sequencer board can be seen in Fig 3.

2.3 Fitting the transverter into its box

Now that it was all working it had to be fitted into its box. The two diecast boxes were bolted together and the gap sealed with silicon sealant. A Tohtsu CX-520D changeover relay was fitted in the top of the PA side and a BNC socket in the bottom of the transverter side. Power and control is fed in via a 5 pole socket with a “fools” diode fitted after an input fuse to prevent damage if the power is connected the wrong way round. A simple mast clamp was fitted and it was ready to go. The finished transverter is shown mounted to the mast in Fig 7.

3.0

Getting ready to go backpacking

Everything needed to operate must be carried to site, the list that I take is:

- Transverter
- FT817
- Battery
- Battery connection leads

Fig 7: Transverter mounted on it's mast with the 19 element 23cm Yagi.

- Antenna
- Extendable mast
- Guy ropes
- Stakes
- Hammer
- Connecting cables – DC supply, control, antenna
- Headset
- Microphone connection adapter and PTT switch
- Log book and pen
- Garmin GPS receiver set to maidenhead mode to confirm QRA locator
- Spanners
- Spare fuses

3.1 Mast and antenna

I use a four section extendable mast from Sandpiper [4]. This is just over a metre when collapsed and will extend to 3.5 metres with two sets of guys on rotating guy rings. The antenna is a 19-element Yagi from Sandpiper [4], this has 17.1dBi gain and in practice is a very nice antenna for portable use. It is 1.5 metres long so when strapped to the mast with the stakes and a hammer it makes a good walking pole.

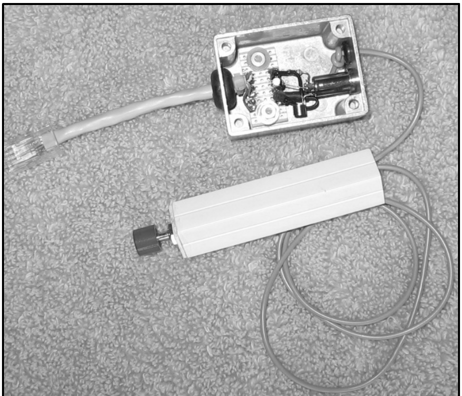


Fig 8: FT817 microphone and PTT switch adaptor.

3.2 Battery and connection leads

The battery that I use is a 13Ah sealed lead acid battery. It will run the station for 3 hours and it is small enough to fit in the backpack with the other equipment. I believe in having everything as fool proof as possible so I use a plug and socket connectors for all the connections, the only exception to this are the spade connectors that fit onto the battery. They go to a small distribution box with a socket to connect to the transverter down lead and a fly-lead to supply the FT817.

3.3 The FT817

The FT817 is ideal for portable use, it is a bit fiddly to use but once the buttons and menus have been mastered it does everything required. The only addition I have made is an adaptor to connect a standard headset microphone and latching PTT switch. The FT817 uses an RJ11 socket for the microphone so a short length of CAT5 cable with an RJ11 plug fitted fed into a small box gives room to fit a 3.5mm jack socket for the a standard microphone and a fly-lead with a latching push switch for PTT. Fig 8 shows this adaptor.

Fig 9: The 23cm backpacking station set up on my local hill.

4.0

In action

Fig 9 shows the station set up on my local hill, it takes about 20 minutes to erect the antenna and get everything connected, then it is ready to go. My first experiences showed that the receiver was a bit deaf compared to the transmit capability. That was easily solved with the addition of a Mini Kits preamplifier. This uses and identical circuit to the front end of the transverter so my modification to the bias circuit was fitted before I switched on and it worked first time. The only problem was that it was a bit too lively when connected to the transverter so a 6dB attenuator was fitted between the preamplifier and the transverter. The result was very pleasing with good reports on transmit quality and best DX achieved to date at 475km.

5.0

References

[1] Down East Microwave - http://www.downeastmicrowave.com/

[2] Mini Kits - http://www.minikits.com.au/

[3] Diecast box from Farnell - http://uk.farnell.com/hammond/1590f/box-diecast-ip54-188x188x63mm/dp/930040

[4] Sandpiper antennas - http://www.sandpiperaerials.co.uk/

John Fielding, ZS5JF

John’s Mechanical Gems

Number 12, Wind loading – Is my antenna system safe?

Radio amateurs often erect large antenna systems without considering if they will survive abnormal wind conditions. On a calm day they appear to be safe but come the first winter storms the amateur starts to worry if it will all come crashing down!

1.0 Wind Loading Calculations

Calculating wind loading on certain antenna types is simple but on others it is not so easy. A parabolic antenna with a solid surface is a simple antenna to analyse; it behaves the same as a flat plate with the same surface area. Many countries have building codes or standards that civil and structural engineers use as the basis for stress calculations. In the UK the most common document is BS 6399 - Part 2 of 1997. This covers a wide variety of structures and has recommended wind speeds for the calculations.

A flat plate of $1m^2$ surface area experiences a force of 44kg when subjected to a wind velocity of 80km/hr. At 160km/hr the force per square metre is 88kgf. (160km/hr is almost the same speed as the old standard of 100mph, 162km/hr).

Let us make some calculations for a 5m diameter parabolic antenna with a solid surface, later we will consider mesh covered dishes and see the differences. A 5m diameter dish has an effective wind loading surface area the same as a 5m diameter flat plate when pointed into the wind. The surface area is πr^2 and this gives an area of $19.63m^2$.

When subjected to a wind of 80km/hr the force acting on the dish is 19.63 x 44 = 863.72kgf, almost 1 tonne. The steady state wind is not what normally causes damage but the gusty wind which rises and falls about a certain speed is the main culprit as the supporting structure experiences varying forces that causes it to oscillate, causing fatigue to occur in the members. It is the buffeting by the wind that causes most antenna structures to fail due to metal fatigue. Very low ambient temperatures also can cause weakening of some materials, particularly aluminium and its alloys. Fig 1 is a diagram showing forces acting on the structure due to wind

At 160km/hr the force on our 5m dish is over 1.6 tonne and this is transmitted through the mounting points to the supporting structure. If the structure is a lattice tower, of say, 5m in height, this causes a bending moment to be experienced at the base. Assuming the lattice

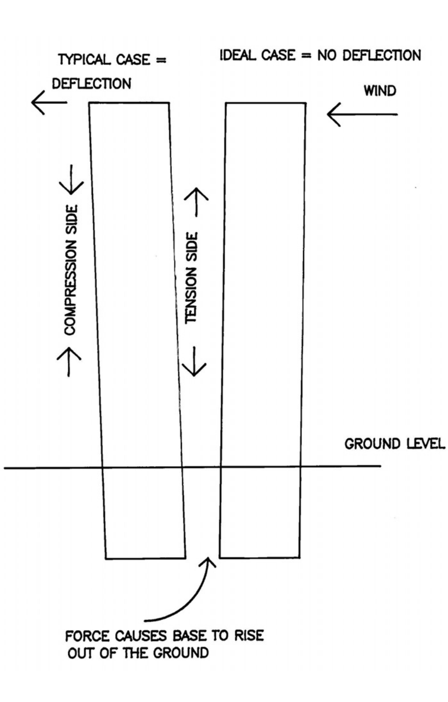


Fig 1: Diagram showing forces acting on the structure due to wind.

tower does not deflect but is extremely rigid then all this force is now acting on the base foundations. The applied force is multiplied by the height of the tower and causes a torque on the base of 863kgf x 5m = 4318kgf-m, over 4 tonne of torque pressure for an 80km/hr wind. For the 160km/hr wind condition the force is doubled to 8.6 tonne.

For a taller tower the torque pressure is even greater, for a 10m high tower the torque pressure is double that of a 5m tower. The foundations and the soil need to resist this force, if it cannot then the bottom of the base is caused to rise out of the ground and the tower topples over. The mass (dead weight) of the foundations do not significantly affect the stability, rather it is the "purchase" the foundations have to the soil. For dry, sandy ground the foundations need to be more complex than for ground with heavy clay. For heavy clay type soil the foundations can also be shallower than for dry, sandy soil.

In the normal scenario the lattice tower does deflect to some extent and absorbs some of the load, but not by any significant amount. The vast majority is transferred to the foundations and the soil as in the perfect case. So the foundations and the soil are the overall determining factors as to whether your structure is safe in abnormal winds.

2.0

Mesh Covered Dish

If we now examine a mesh surfaced dish we see that we can alleviate much of the wind loading for a large dish. If a fairly large aperture mesh is chosen we suffer some loss of gain. Generally, the aperture of the mesh should be not more than λ/10 to minimise the gain loss. For 23cm the mesh should not exceed 23mm aperture. For this mesh with 1mm wires the gain loss is only about 0.5dB for a 5m diameter dish, (which is about 30dB gain) so relatively insignificant and can be ignored. Smaller aperture mesh can cause the wind loading to approach that of a solid surface dish, especially if the mesh is filled with ice during winter.

Assume the mesh aperture is λ/10 for a 5m diameter dish for 23cm and there is no icing. The effective wind loading surface area falls to about 15% of a solid dish and consequently the wind loading is considerably reduced even for the 160km/hr condition. A small loss of 0.5dB is not as important as a reduction in the wind loading of 85% against the solid surface case.

3.0

Wind Loading of Round Tubes

A round tube is a special case for wind loading. This behaves as a "double-sided aerofoil" when the wind strikes it side on. The wind passing either side causes a partial vacuum to exist on the leeward side that reduces the apparent surface area. Generally, the wind loading calculations consider the round tube to have a loading of 0.67 of the same surface area as a flat plate structure.

It is the partial vacuum developed on the leeward side that causes the round tube to deflect more than a flat plate structure and consequently the round tube bends more against the wind loading. Hence, more guying is required with a small diameter round tube than a lattice tower of the same surface area for a given wind speed.

However, a round tube is a stronger section than any other shape and consequently it can be a smaller diameter to support the same wind loads, so reducing the effective surface area even more. In practice a round tube can have a similar surface area loading as a lattice tower of larger section so reducing the overall wind loading.

As an indication how stiff a round tube supporting structure can be, consider the data analysed on the proposed Durban University of Technology 7.5m diameter mesh covered antenna for the Indlebe Enkulu radio telescope (meaning Big-Ear in zulu). The supporting column is a 5.8m tall 406mm OD steel tube of 6mm wall thickness. With the predicted 15% fill factor for the chosen mesh covering the dish surface the analysis showed a predicted "sway" or deflection of only 2mm at the top of the support tube in a 160km/hr wind.

A round vertical tube can be analysed as an infinite number of vertical members with integral bracing between each vertical member. As the number of vertical members increases the wall thickness and thickness of the bracing members can be reduced in thickness. Beyond about 24 vertical members the structure behaves as a thin walled round tube. The deflection due to wind loading acting on the top portion is much less than a similar lattice tower of 4 sides.

The side of the round tube facing into the wind experiences stress in tension, whereas the leeward side is in compression. If the forces on the tube are high enough the leeward side begins to kink and the tube collapses inwards leading to catastrophic failure.

Any tube couplers, to increase the height by adding two or more tubes in series, are potential weaknesses that need to be carefully considered. The tube may be adequately strong but the interfaces between sections can cause failure when highly stressed. The interface can behave like a hinge if it is unable to resist the bending moments. In the Durban radio telescope design the supporting column is made in two pieces and connected by round flanges with gussets. This interface is a potential weak point, but analysis showed that the joint was in fact nearly twice as strong as the round tube for the column. The reason for selecting a two piece assembly is simply due to the mass of the column. If it were made as a single piece it would be nearly 500kg and would present a problem in transporting and erecting it on site.

Gunthard Kraus, DG8GB

Internet Treasure Trove

The Basics of Patch Antennas - updated

This Application note from the Orban Company was originally published 2005. Due to many letters and notes it has been fundamentally revised and extended with great success. Thus it is obligatory reading for everyone who would like to train into this topic.

Address:
http://www.rfglobalnet.com/download.mvc/Technical-Article-The-Basics-Of-Patch-Antenna-0001

Orban Microwave

The homepage the Orban Company has further interesting downloads to offer. For example there is "The Basics of Antenna arrays" or "Introduction to GPS Low Noise Amplifiers".

Address:

http://www.orbanmicrowave.com/technical-articles/

Mathematical models for the simulation of wave propagation

This team work on the free University of Berlin forum and have produce a beautiful summary of the basics that are necessary for simulation and understanding of wave propagation. It is very clear and should be read.

Address:

http://cst.mi.fu-berlin.de/teaching/SS06/19554-S-TI/Florian%20Deinert%20-%20Mathematische%20Modelle%20zur%20Wellenausbreitung%20fuer%20die%20Simulation%20drahtloser%20Netze.pdf

Alan `s Laboratory

Behind this inconspicuous title lays a tremendous number of documents and calculators for wireless technology and amateur radio. From antennas to receivers and up to transmitters: clearly sorted into categories and in each category there is an average of 30 articles. Where do some people find the time? For the techno freak this is a treasure chest.

Address:

http://www.vk2zay.net/category/8

Amanogawa.com

This is a small collection of on-line calculators. Particularly aimed at antennas.

Address:

http://www.amanogawa.com/index.html

Engineering Toolbar

This tool box contains a very extensive and continuously updated collection at Application Notes, patent information, standards, data bases etc. Very interesting for RF engineers.

Address:

http://www.globalspec.com/engineering-toolbar/install?frmtrk=tbhome

em talk

This is a collection of tutorials and tools for RF and microwave engineering. Highly interesting needing quite a while to examine everything.

Address:

http://www.emtalk.com/tutorials.htm

NXP's RF manual

The text on the homepage reads:

"NXP`s RF manual - one of the most important reference tools on the market for today's RF of designers".

The data book has so many block diagrams and explanations that make reading informative and always worthwhile.

Address:

http://www.nxp.com/acrobat_download2/other/discretes/nxp_rf_manual_14th_edition.pdf

OML Millimeter Wave test equipment

This homepage offers a wide spectrum of products plus many other documents. As an example there is "Harmonic mixer Application Notes". Please try the search.

Address:
http://www.omlinc.com/map.htm

Note: Owing to the fact that Internet content changes very fast, it is not always possible to list the most recent developments. We therefore apologise for any inconvenience if Internet addresses are no longer accessible or have recently been altered by the operators in question.

We wish to point out that neither the compiler nor the publisher has any liability for the correctness of any details listed or for the contents of the sites referred to!

VHF COMMUNICATIONS

A Publication for the Radio Amateur Worldwide

Especially Covering VHF, UHF and Microwaves

Volume No.42 Winter Edition 2010-Q4

Publishers

KM PUBLICATIONS,
63 Ringwood Road, Luton,
LU2 7BG, United Kingdom

Tel: +44 (0) 1582 581051
Fax: +44 (0) 1582 581051

Email:
andy@vhfcomm.co.uk

Editor

Andy Barter G8ATD

VHF *COMMUNICATIONS*

The international edition of the German publication UKW-Berichte is a quarterly amateur radio magazine, especially catering for the VHF/UHF/SHF technology. It is owned and published in the United Kingdom in Spring, Summer, Autumn and Winter by KM PUBLICATIONS.

The 2010 subscription price is £21.40, or national equivalent. Individual copies are available at £5.35, or national equivalent each. Subscriptions should be addressed to the national representative shown in the next column. Orders for individual copies of the magazine , back issues, kits, binders, or any other enquiries should be addressed directly to the publishers.

NOTICE: No guarantee is given that the circuits, plans and PCB designs published are free of intellectual property rights. Commercial supply of these designs without the agreement of the Author and Publisher is not allowed. Users should also take notice of all relevant laws and regulations when designing, constructing and operating radio devices.

Translated using Translution translation software: www.translution.com

Printed in the United Kingdom by: Printwize, 9 Stepfield, Witham, Essex, CM8 3BN, UK.

AUSTRALIA - Mark Spooner c/o, W.I.A SA/NT Division, GPO Box 1234, Adelaide, SA 5001, Australia Tel/Fax 08 8261 1998

BELGIUM - UKW-BERICHTE, POB 80, D-91081 BAIERSDORF, Germany. Tel: 09133 7798-0. Fax: 09133 779833. Email: info@ukwberichte.com Web: www.ukwberichte.com

DENMARK - KM PUBLICATIONS , 63 Ringwood Road, LUTON, LU2 7BG, UK. Tel: +44 1582 581051. Fax: +44 1582 581051. Email: andy@vhfcomm.co.uk

FRANCE - Christiane Michel F5SM, Les Pillets, 89240 PARLY, France
Tel: (33) 03 86 44 06 91, email christiane.michel.s5sm@orange.fr

FINLAND - KM PUBLICATIONS , 63 Ringwood Road, LUTON, LU2 7BG, UK. Tel: +44 1582 581051. Fax: +44 1582 581051. Email: andy@vhfcomm.co.uk

GERMANY - UKW-BERICHTE, POB 80, D-91081 BAIERSDORF, Germany. Tel: 09133 7798-0. Fax: 09133 779833. Email: info@ukwberichte.com Web: www.ukwberichte.com

GREECE - KM PUBLICATIONS , 63 Ringwood Road, LUTON, LU2 7BG, UK. Tel: +44 1582 581051. Fax: +44 1582 581051. Email: andy@vhfcomm.co.uk

HOLLAND - KM PUBLICATIONS , 63 Ringwood Road, LUTON, LU2 7BG, UK. Tel: +44 1582 581051. Fax: +44 1582 581051. Email: andy@vhfcomm.co.uk

ITALY - R.F. Elettronica di Rota Franco, Via Dante 5 - 20030 Senago, MI, Italy. Fax 0299 48 92 76 Tel. 02 99 48 75 15 Email: info@rfmicrowave.it Web: www.rfmicrowave.it

NEW ZEALAND - KM PUBLICATIONS , 63 Ringwood Road, LUTON, LU2 7BG, UK. Tel: +44 1582 581051. Fax: +44 1582 581051. Email: andy@vhfcomm.co.uk

NORWAY - WAVELINE AB, Box 60224, S-216 09 MALMÖ, Sweden. Tel: +46 705 164266; GSM: 0705 16 42 66, email info@waveline.se

SOUTH AFRICA - KM PUBLICATIONS , 63 Ringwood Road, LUTON, LU2 7BG, UK. Tel: +44 1582 581051. Fax: +44 1582 581051. Email: andy@vhfcomm.co.uk

SPAIN & PORTUGAL - JULIO A. PRIETO ALONSO EA4CJ, Donoso Cortes 58 5° -B, MADRID 15, Spain. Tel: 543 83 84

SWEDEN - WAVELINE AB, Box 60224, S-216 09 MALMÖ, Sweden. Tel: +46 705 164266; GSM: 0705 16 42 66, email info@waveline.se

SWITZERLAND - KM PUBLICATIONS , 63 Ringwood Road, LUTON, LU2 7BG, UK. Tel: +44 1582 581051. Fax: +44 1582 581051. Email: andy@vhfcomm.co.uk

UNITED KINGDOM - KM PUBLICATIONS , 63 Ringwood Road, LUTON, LU2 7BG, UK. Tel: +44 1582 581051. Fax: +44 1582 581051. Email: andy@vhfcomm.co.uk

U.S.A. - ATVQ Magazine, Mike Collis, WA6SVT, P.O. Box 1594, Crestline, CA, 92325, USA,
Tel: (909) 338-6887, email: wa6svt@atvquarterly.com

ELSEWHERE - KM PUBLICATIONS, address as for the U.K.

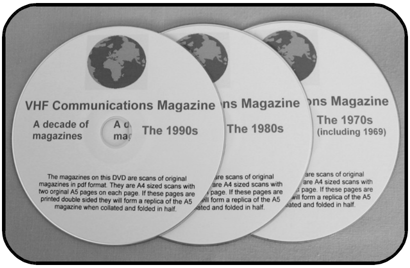
Web: http://www.vhfcomm.co.uk

ISSN 0177-7505

Back Issues on DVD

VHF Communications Magazine has been published since 1969. Up to 2002 it was produced by traditional printing methods. All these back issue have been scanned and converted to pdf files containing images of the A4 sheets that formed the A5 magazine when folded in half. These have been put together on DVD in decade sets.

From 2002 the magazine has been produced electronically therefore pdf files are available of the text and images. These have been used to produce the 2000s decade DVD.

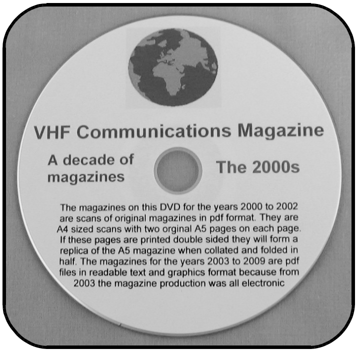


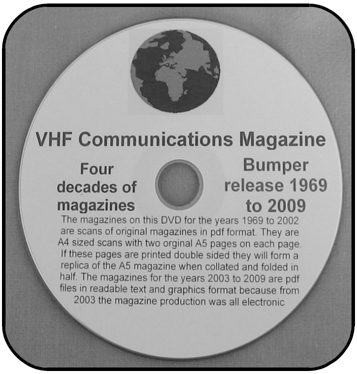
1970s - 1980s - 1990s

These three DVDs cover the first 3 decades of the magazine. The 1970s DVD contains all magazines from 1969 to 1979 (44 magazines) the 1980s and 1990s DVDs contain 40 magazines for the decade. The DVDs are £20.00 each

2000s

This DVD contains magazines from 1/2000 to 4/2001 in scanned image format and from 1/2002 to 4/2009 in text and image format. This DVD is £35.00





Bumper 4 decade DVD

This DVD contains all magazines from 1969 to 2009. That is 164 magazines. It also contains the full index for those 41 years in pdf and Excel format so that you can search for that illusive article easily. This DVD is just £85.00 - just 52 pence per magazine.

To order, use one of the following:

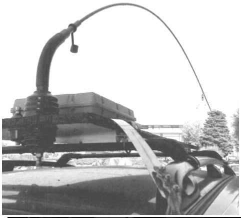
- Use the order form on the web site - www.vhfcom.co.uk
- Send an order by fax or post stating the DVD required (1970s, 1980s, 1990s, 2000s, Bumper)
- Send the correct amount via PayPal - vhfcomms@aol.com - stating the DVD required (1970s, 1980s, 1990s, 2000s, Bumper) and your postal address

Add £1.00 for air mail postage in Europe or £1.50 for air mail postage outside Europe

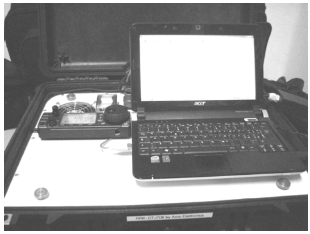
arno elettronica

Via Leonardo da Vinci 13 56033 Capannolli PISA Italy PH/Fax +39 0587 607390

www.arnoelettronica.com assistenza@arnoelettronica.com



Special professional equipments and fitting outs: We design, supply, install and support satellite and radio voice/data Communication Systems We realize base and mobile systems (Terrestrial, maritime and avionic) and we implement existing installations



RRK-DTJ Ready Radio Kit Data Terminal This case includes all the necessary to operate in all modes, PACTOR included. It fits in a quadriband RTX, an SCS Modem and a Netbook PC. Supply is automatically selected (100-240VAC and/or 13VDC) . A compact automatic antenna tuner completes the mobile station. All you have to do is connect the antenna and the power supply and you are "**Ready to go**"! You may send an e-mail to assistenza@arnoelettronica.com for any further information We will be glad to answer!

Our company is also present in the radioamateur market since year 2000. We design and manufacture some of the products, while we trade others chosen as what we deem best quality at best price.

I.E. We manufacture multi band wire "**OFF CENTER FEED DIPOLE Antenna**" presently available in two versions: "**OC6L4/1K**" for **10, 12, 17, 20, 40** and **80** meter bands "**OC3L2/1K**" for **10, 20** and **40** meter bands Power rating 1 KW SSB Perfect for temporary or steady installations No ATU required Wide bandwidth High quality UV resistant materials BalUn: Dual core Guanella (Current) Treated and protected with urethane transparent film Very light and robust

The wee **RX WIRE** Receiving antenna adaptor designed and manufactured to couple 50/75 Ohm impedance coaxial lines with wire antennas Only for receiving High S/N ratio 50KHz—30MHz large band (Can be used even further) Low noise High efficiency In/output stage DC short-circuited Box in PVC Completely waterproof (Epoxy filled) IP 67

Aspis Cobra and **Venus** mono band vertical antennas Small Very efficienct Large bandwidth High S/N ratio Pre tuned and ready to install **All details featured on our web**

Moreover, a wide selection of whatever you need to build your antennas Including special cables, coaxial lines, PVC and ceramic isolators, guy lines, GRP masts, toroid cores, ladder line spreaders and all sorts of stainless steel AISI316 odds and ends **Not just Ham equipment Also professional and nautical equipment Technical service**

We speak English French and German You may browse our website and contact us via e-mail for whatever need We'll be glad to help you ! Don't forget our website www.arnoelettronica.com ..... Saluti from Julie!