

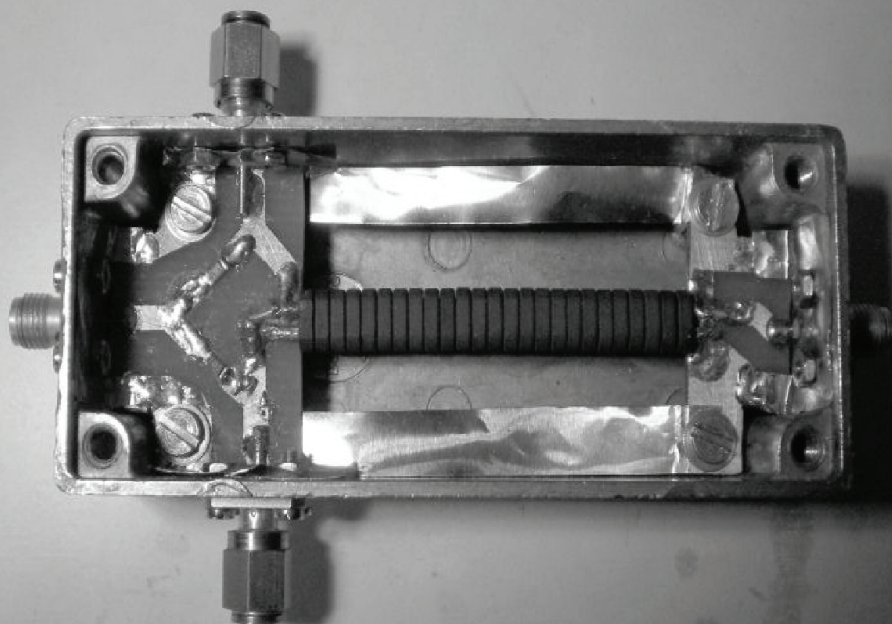


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Practical tips for building a return loss bridge

Andrea Daretti, IZ2OUK

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This was the most difficult issue that I have prepared. When I started in early July I only had two new articles from Andrea Daretti and Vincenzo Mendola plus one article that I had not published from UKW Berichte. I had been working on a project myself that I quickly converted into an article. At almost the last minute Carl Lodström and Gunthard Kraus saved the day with their articles. I hope that the result is an interesting magazine.

It has made me very aware that the magazine can only continue to be published if I can find more new articles so I have enclosed a flyer with this issue to ask for help from all subscribers. I hope it is successful otherwise I can see the end of the magazine.

73s - Andy



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Andrea Daretti, IZ2OUK

Practical tips for building a return loss bridge

This is my contribution for return loss bridge enthusiasts. There is no need for an article on how to build or use a return loss bridge because there are plenty of articles available on The Internet. Most of these are well written and contain designs, tutorials and warnings. The thing that I could not find were tricks to use to achieve the specifications predicted, I could only find these out the hard way. This article describes my findings.

return loss bridge projects, from very simple to high performance designs with a zillion dB of directivity for frequencies up to γ rays and even able to make coffee.

It seemed to be simple, and it is...after some trials!

After reading many articles I froze my minimum specification to: 30dB directivity at 1300MHz. Everybody seemed to be able to do it, why not me?

1.0

Introduction

Everything happens by chance; recently I built a helical antenna for radio astronomy. It has a typical impedance of 140Ω therefore an impedance transformer to 50Ω was required. I made a microstrip $\lambda/4$ transformer but it left me with some doubts because cutting a 87.7Ω microstrip (geometric mean between 50Ω and 140Ω) was problematic, since with my PCB techniques I was only able to manage $\pm 1/10\text{mm}$ (at best!). This means a variation from 77Ω to 91Ω that is far too inaccurate. So I needed a tool to measure and validate hence the return loss bridge.

Surfing The Internet I found a variety of

2.0

Construction

Recently I became better at producing PCBs and using SMD components, so I said to myself "With my modern technology I will do it even better " and I started.

I began by selecting a metal box from my junk drawer (more of a trunk than a drawer), and I found a good rectangular Eddystone aluminium box (93mm x 34mm x 30mm) that I bought in Friedrichshafen from a British seller. It was perfect for my project: see Fig 3.

A side note: it is incredible how something very simple can become almost impossible. Everyone who is able to drill

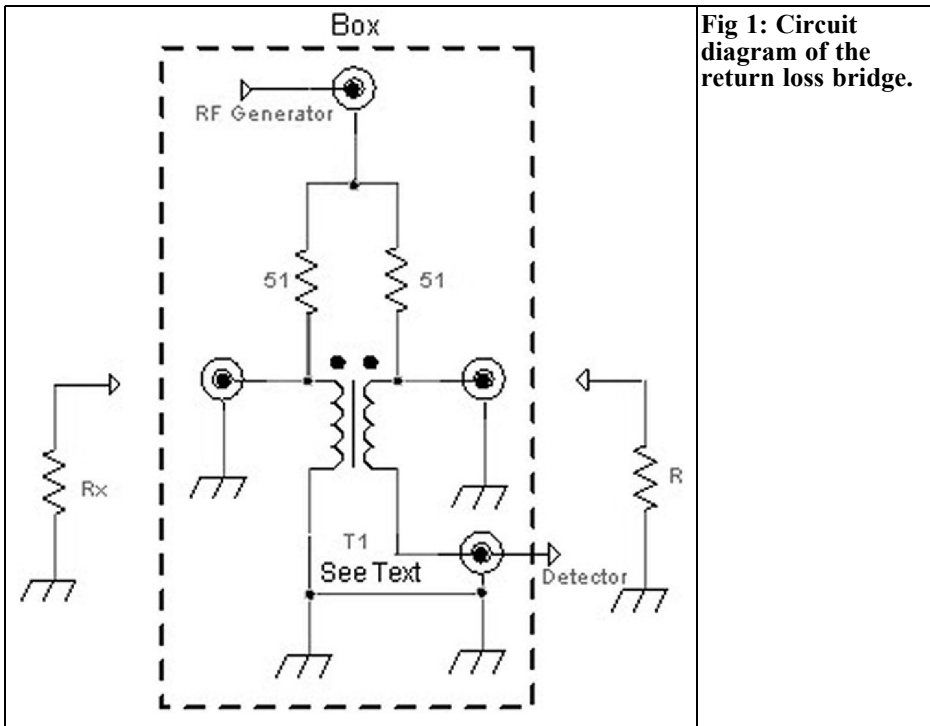


Fig 1: Circuit diagram of the return loss bridge.

the 5 holes necessary for a four hole SMA flange perfectly the first time should raise their hand. But don't worry: I won't bother you with sad stories. I'll just skip to conclusion.

I selected the design of bridge with a balun transformer output to be able to detected from an unbalanced device: see Fig 1.

I designed a small PCB for the RF input to support two 51Ω SMD resistors to reduce parasitic inductance and be as symmetric as possible. It is placed at one end of the box to give more space for the balun transformer. At the far end I positioned a second small PCB that is just a support for the balun transformer and the SMA output to the detector (in my case a spectrum analyser) see Fig 3.

The balun was a very mysterious type of transformer; I couldn't understand how it works. But all of a sudden I had a vision

while reading a Siemens application note and I understood. Once understood it was easy to build although not so easy to make it working properly.

So, not to offend your electronic knowledge I will not describe how it works, just how I made it see Fig 2

Back to the bridge; from the RF input the generator signal goes to the two 51Ω SMD resistors and then to the two SMA connectors for Rx and 50Ω load.

From these two SMA connectors the RF goes to the two arms of the balun transformer. This is made from two lines, one is a simple copper conductor, and the other is a small Teflon coaxial cable inserted into a set of (25 in my case, but not critical) binocular ferrite cores. The first arm is a simple copper conductor tunnelling through all binocular cores and ending at the ground connection of the detector SMA connector. The second

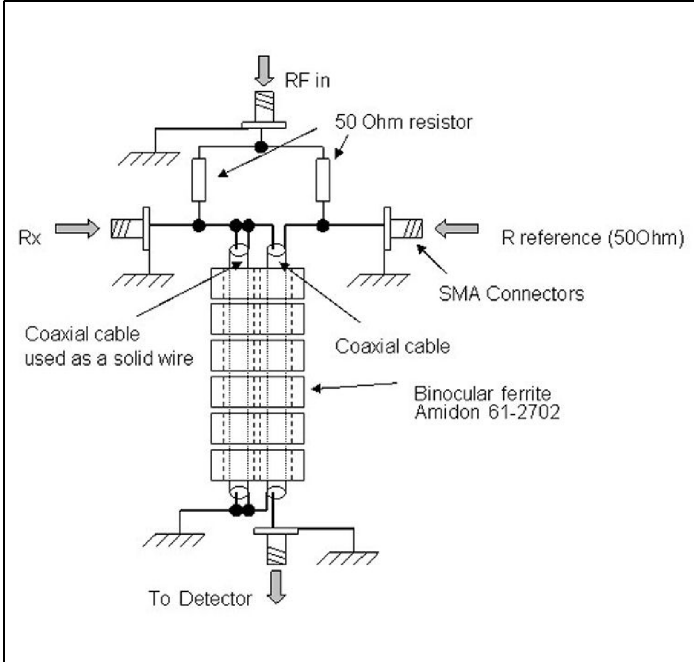


Fig 2: Return loss bridge layout showing the balun transformer.

arm is the coaxial cable, slim enough to fit into the binocular ferrite cores. On one end it has the centre conductor soldered to the adjacent copper conductor and the braid to the central pin of the 50Ω load SMA connector. The other end of the coaxial cable, next to the detector SMA connector, has the centre connector soldered to the centre pin of the detector SMA connector and the braid to the end

of the other arm that is connected to the ground connection of the detector SMA connector see: Fig 2.

This seems easy and you can find all of this on some Internet sites. It is easy for everybody building it ...the second time, but vast majority of people will make it just once, unless they are a serial sinner.

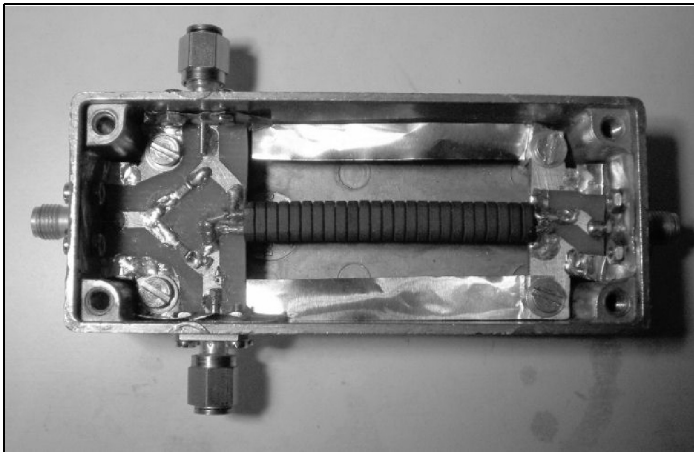


Fig 3: Top view of the return loss bridge.



3.0

Tricks

Here is the difference from many articles that you can find on The Internet. I intend to tell you the tricks I had to invent and friend's I had to hear to make my bridge fulfil the design specification.

Initially it didn't pass 400MHz at 30dB. Only after the applying the following catalogue I did get it to full specification.

Here is the catalogue of RL Bridge dirty tricks, not in order of importance:

- I used SMD resistors but a friend suggested that using normal 1/8W resistor (not inductive!) mounted a bit above the support. By displacing them a little could help to compensate for some asymmetry at higher frequencies.
- I used SMA connectors because of my box size but other connectors can be used: N, SMB, BNC (F is 75Ω, so no applicable).
- As an OM told me, the guideline to design should be "symmetry" of the two arms more than "no parasitic elements" (impossible). Pay attention to this as much as possible.
- Initially I used a 1.5mm silvered copper wire as the conductor arm through the binocular ferrite cores. An OM suggested that in the interest of symmetry; instead use a length of the same coaxial cable as the other arm with the inner and outer connected together to behave as a single conductor with the same geometry.
- I used 25 Amidon 61-2702 binocular ferrites (these can be found in the R F Elettronica catalogue [1]) but the quantity is not critical. The more used, the better the performance at low frequencies. I even tried ferrite beads, but it seems that the binocu-

lars keep the flux more confined.

- A crucial point has been the effective ground connection. This is a very important point. Initially I thought that the connector screws were a good enough ground connection. Not true, or not enough. A step forward came when I redesigned all ground links and added a copper leaf around all connectors. Then I linked the two internal box ends with two 5mm copper strips to directly ground the input and output test areas.
- PCBs. In the picture (Fig 3) you can see the two very small PCBs. These were mainly to support the SMD resistors, but there is no real advantage in having them. I haven't even added the PCB layout because they depend too much on the box available.
- The coaxial cable I used was Teflon insulated cable that fitted smoothly into the binocular ferrite cores. Initially I used a nylon-insulated coaxial cable. It melted when soldering and shorted in a way that took quite some time to spot it.
- The 51Ω resistors were selected from a bunch of ten using a 4 wire digital ohmmeter. The criteria was to select for close value rather than close to 50Ω.
- When the bridge is balanced it presents a 50Ω load to the generator. Not so when it is not balanced. In the worse case ($R_x = 0$) it presents 30Ω. This has to be taken into account for the precision of the measurement. Using attenuators is recommended.

I don't know if these suggestions are good for the eyes of big guns; but at least it represents the collection of my personal and some Ham friend's experience. In the end the results speak for themselves because I achieved my target. Fig 4 shows the bridge under test. The performance that I reached was:

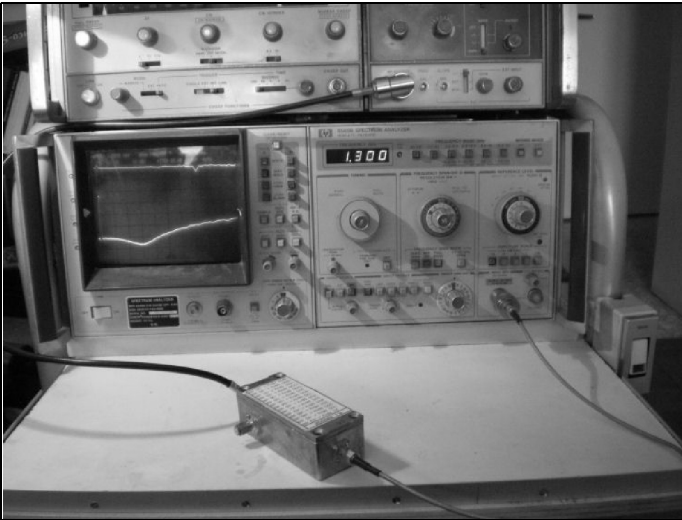


Fig 4: The return loss bridge under test.

- Directivity: 32dB @ 1300MHz
- Directivity at higher frequency see Fig 5
- Insertion Loss: 14dB @ 100MHz; 15dB @ 500MHz; 15dB@ 1GHz; 16dB@ 1.5GHz
- RL (open Rx) detector port: >22dB.

reproducible enough. Enjoy building it.

4.0

References

[1] R F Elettronica catalogue - <http://www.rfmicrowave.it/>

I only built one sample, so I don't know how reproducible it is but since I built and rebuilt it several times, I believe it is

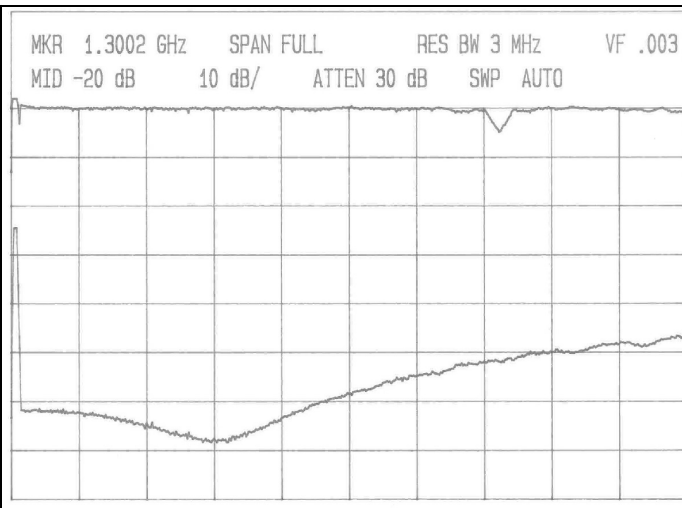


Fig 5: Plot of the return loss bridge performance.



Vincenzo Mendola, IW2KSZ,

How to realise a simple and cheap dummy load

The dummy load is used in all kinds of RF and microwave measures and is an essential accessory in every shack if you have a state of the art spectrum analyser, network analyser and oscilloscope or only few very simple and old instruments; a dummy load is essential.

Often we forget what a dummy load is: a non-inductive power resistor specifically designed to have a VSWR very closed to 1 over a very wide range of frequencies. To achieve high power handling the core of the dummy load, the non-inductive resistor, is mounted on a heat sink. The outside of this device is very simple, it looks like a heat sink with a connector, generally an N type.

A very wide range of dummy loads of every power and frequency range can be

found on the market. They are generally not a cheap accessory due to the high specification requirements (high power and wide frequency range with an excellent return loss). A good dummy load can be made without investing lots of money by just using a high power non-inductive 50Ω chip resistor. A good variety of non-inductive chip resistors can be found on the R.F. Elettronica web site.

The power non-inductive chip resistor is a thin film resistor, generally made using a substrate of AlN and BeO, with a copper flange, a beryllium copper tab and an alumina cover. The wide range of power and frequencies available allows us to realise every kind of dummy load that we need in a very cheap way. We just need the adequate resistor for our application requirements in terms of

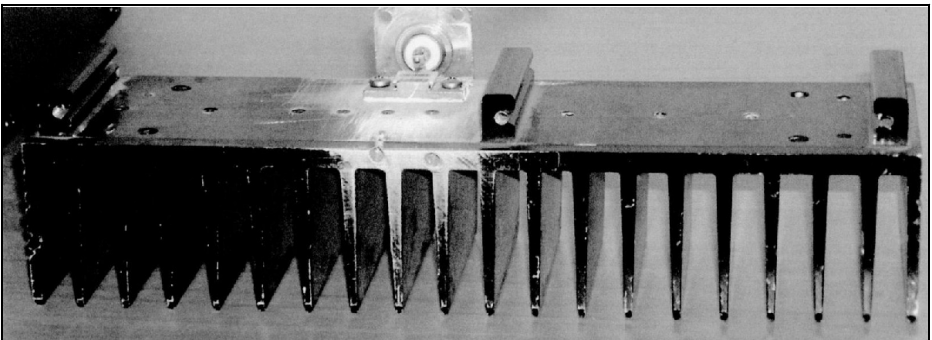


Fig 1: 250W DC - 2GHz dummy load.

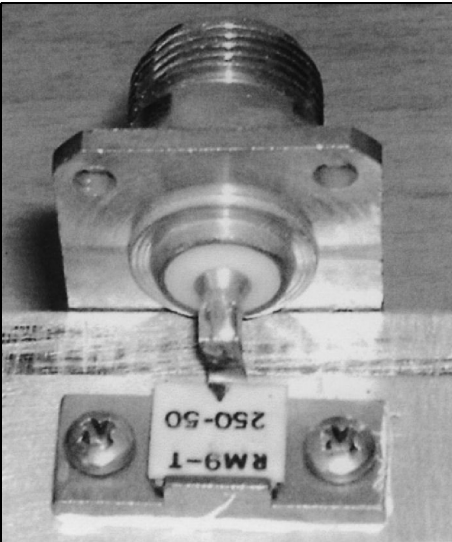


Fig 2: Detail of the dummy load.

power and frequency, a heat sink big enough, a flange mount connector of the kind that we need (BNC, N, etc.), 2 screws to fit the connector and some thermal silicon grease.

Figs 1 and 2 show a simple but very useful example of a dummy load made with a 50Ω chip resistor, capable of handling power up to 250W in the range DC - 2GHz, with a VSWR very close to 1.

References

[1] R. F. Elettronica -
www.rfmicrowave.it



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With over 700 members world-wide, the **UK Six Metre Group** is the world's largest organisation devoted to 50MHz. The ambition of the group, through the medium of its 56-page quarterly newsletter '**Six News**' and through its web site www.uksmg.com, is to provide the best information available on all aspects of the band: including DX news and reports, beacon news, propagation & technical articles, six-metre equipment reviews, DXpedition news and technical articles.

Why not join the UKSMG and give us a try? For more information contact the secretary: Dave Toombs, G8FXM, 1 Chalgrove, Halifax Way, Welwyn Garden City AL7 2QJ, UK or visit the website.



Andy Barter, G8ATD

Construction Project: Elektor RF Sweep Frequency Generator / Spectrum Analyser

I take Elektor magazine and marvel at some of the projects that they print. When the October 2008 issue arrived I quickly spotted an article by Gert Baars who described an RF sweep frequency generator / spectrum analyser [1]. It covers 0 – 450MHz and looked a very interesting project to build over the winter. This article describes my experiences in building this project, I hope it will contain some useful information for anyone else who wants to build either this project or a similar project involving modern SMD components.

My second reason for writing this article is that the supply of articles for the magazine is drying up so if you think you could write a similar article please let me know.

1.0

The Project

Fig 1 shows a block diagram of the project and Figs 2 and 3 show the circuit diagram. It consists of a microprocessor

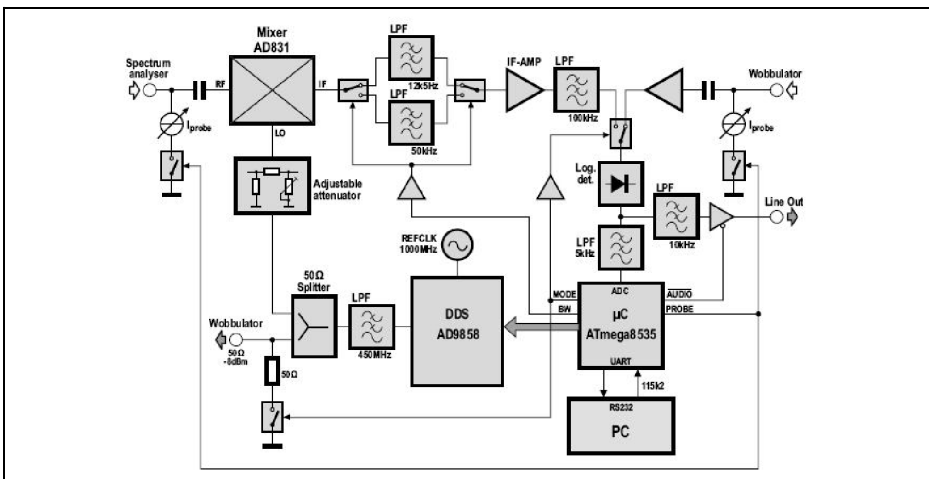


Fig 1: Block diagram of the RF Sweep Frequency Generator / Spectrum Analyser.

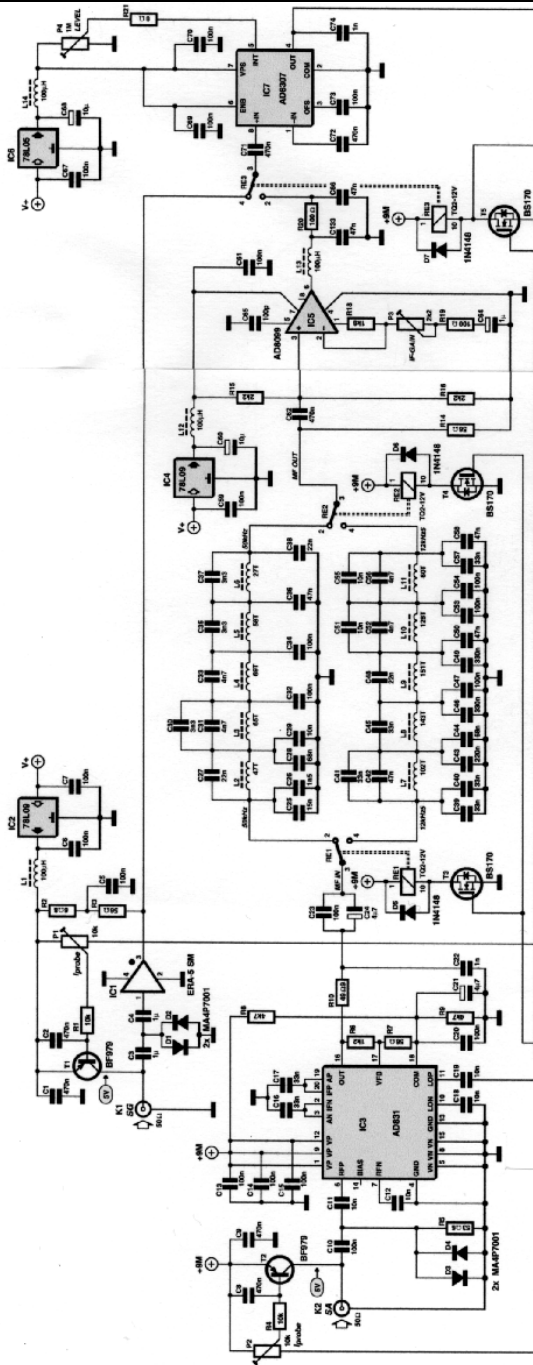


Fig 2: Circuit diagram of the RF Sweep Frequency Generator / Spectrum Analyser.

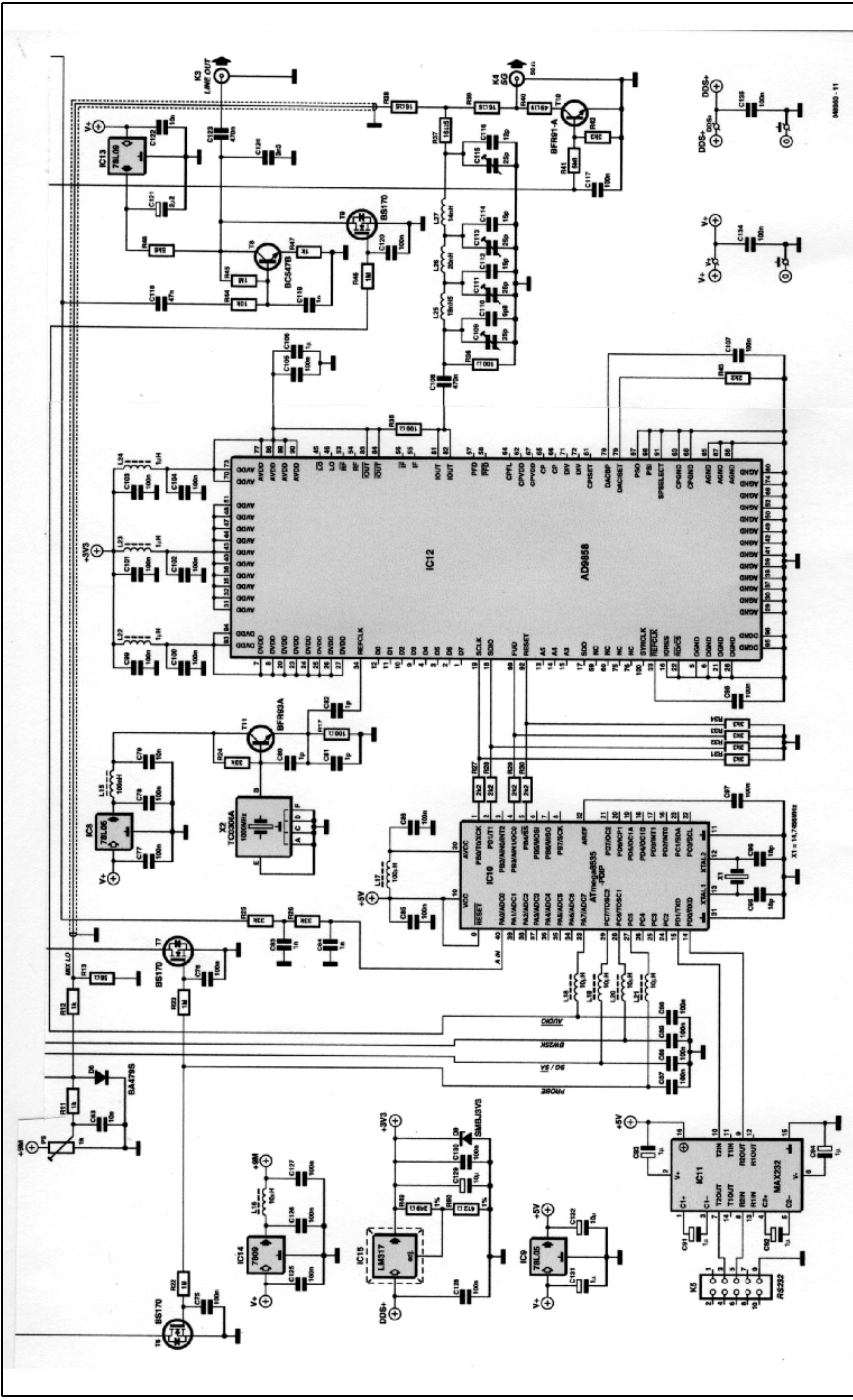


Fig 3: Circuit diagram of the RF Sweep Frequency Generator / Spectrum Analyser.



controlled Direct Digital Synthesiser (DDS) using an Analog Devices AD9858. The output from this synthesiser is split between a front panel wobulator (sweep frequency) output and a Local Oscillator (LO) input to an Analog Devices AD831 mixer that is the input stage of the spectrum analyser. The output of the mixer can be fed via one of two filters to an Analog Devices AD8307 Log detector to provide a line output or a digitised output via the Analogue to Digital Converter (ADC) in the microprocessor. There is also a wobulator input that can be switched via the Log detector so that the output of test objects fed using the wobulator output can be displayed. The digital output from the microprocessor is fed via an RS232 port to a PC running a program supplied by Gert Baars [2].

I purchased a PCB for the project via The PCB shop [3] and a programmed microprocessor from the Elektor shop [4]. Then the fun began to first locate and purchase all of the parts required and then assemble the PCB.

2.0 Finding the parts

The first problem was that Elektor did

not print a parts list. There is a supplementary document [5] that is supposed to contain all of the additional information required for the project but in many places it leaves more questions than answers. I have spoken to the editor at Elektor and discovered that the supplementary document now contains the parts list, it was added some time after the document was available. My first task was to produce a parts list from the circuit diagram this is shown in Table 1. A full list by component number is shown, this makes assembly easier. There is a summary by component type for ordering purposes.

My junk box contains most axial resistors and capacitors but has virtually no SMD parts. A search on eBay found the Fast-components Electronic Kits shop [6], they sell kits of SMD resistors and SMD capacitors quickly giving me a supply of nearly all the passive SMD parts needed for the project plus a nice stock in my junk box. The remaining non-standard SMD resistors and capacitors were purchased from Farnell [7], R S Components [8] and Cricklewood Electronics [9]

All of the active devices are readily available, the only ones I had difficulty with were D1 – D4, MA4P7001 but a suitable alternative is BAR64-03W.

The one component that I could not source was the 1GHz Surface Acoustic

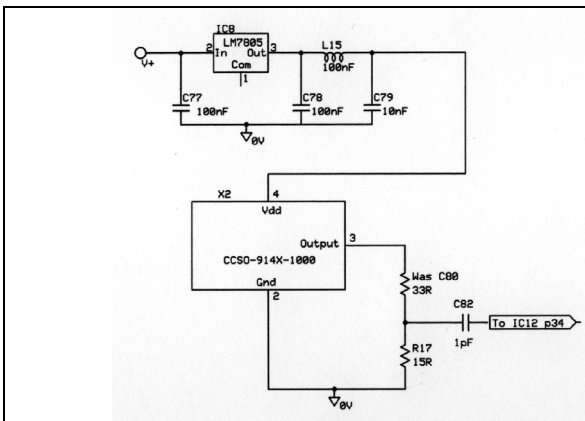


Fig 4: Circuit of SAW oscillator in place of SAW resonator.

T11, R24 and C81 are not fitted. R17 is 15Ω and C80 is replaced with a 33Ω resistor. IC8 is an LM7805 and the +5V is fed to the SAW oscillator.

**Table 1: Parts list for the RF Sweep Frequency Generator / Spectrum Analyser.**

IC1	ERA-5		R17	100Ω	15Ω if using alternative SAW oscillator
IC2	78L09				
IC3	AD831		R18	1.8kΩ	
IC4	78L09		R19	100Ω	
IC5	AD8099		R20	100Ω	
IC6	78L05		R21	0Ω	
IC7	AD8307		R22	1MΩ	
IC8	78L06	78L05 if using Crystek oscillator (see text)	R23	1MΩ	
			R24	33kΩ	Not fitted if using alternative SAW oscillator
IC9	78L05		R25	33kΩ	
IC10	Atmega8535-PDIP	From Elektor [4]	R26	33kΩ	
IC11	MAX232		R27	2.2kΩ	
IC12	AD9858		R28	2.2kΩ	
IC13	78L09		R29	2.2kΩ	
IC14	7809		R30	2.2kΩ	
IC15	LM317		R31	3.3kΩ	
			R32	3.3kΩ	
X1	14.7456MHz		R33	3.3kΩ	
X2	TC0306A 1000MHz	Alternative CCSO-914X-1000 (see text)	R34	3.3kΩ	
			R35	100Ω	
			R36	100Ω	
			R37	16.5Ω	Use 2 x 33Ω in parallel
T1	BF979		R38	16.5Ω	Use 2 x 33Ω in parallel
T2	BF979		R39	16.5Ω	Use 2 x 33Ω in parallel
T3	BS170		R40	49.9	Use 2 x 100Ω in parallel
T4	BS170				
T5	BS170		R 41	6.8kΩ	
T6	BS170		R42	3.3kΩ	
T7	BS170		R43	2.2kΩ	
T8	BC547B		R44	10kΩ	
T9	BS170		R45	1MΩ	
T10	BFR91-A		R46	1MΩ	
T11	BFR93A	Not fitted if using alternative SAW oscillator	R47	1kΩ	
			R48	5.6kΩ	
D1	MA4P7001	Alternative BAR64-03W	R49	249Ω	Select from 330Ω
D2	MA4P7001	Alternative BAR64-03W	R50	412Ω	Select from 560Ω
D3	MA4P7001	Alternative BAR64-03W			Ratio R49/R50 = 0.604
D4	MA4P7001	Alternative BAR64-03W			
D5	1N4148		P1	10kΩ	Horizontal skeleton pot.
D6	1N4148		P2	10kΩ	Horizontal skeleton pot.
D7	1N4148		P3	2.2kΩ	Horizontal skeleton pot.
D8	BA479S		P4	1MΩ	Horizontal skeleton pot.
D9	SMBJ3V3		P5	1kΩ	Horizontal skeleton pot.
R1	10kΩ		C1	470nF	
R2	6.8kΩ	Use 10Ω	C2	470nF	
R3	56Ω	Use 82Ω	C3	1uF	
R4	10kΩ		C4	1uF	
R5	53.6Ω	Use 2 x 100Ω in parallel	C5	100nF	
R6	1.2kΩ		C6	100nF	
R7	56Ω		C7	100nF	
R8	4.7kΩ		C8	470nF	
R9	4.7kΩ		C9	470nF	
R10	49.9Ω	Use 2 x 100Ω in parallel	C10	100nF	
R11	1kΩ		C11	10nF	
R12	1kΩ		C12	10nF	
R13	56Ω		C13	100nF	
R14	56Ω		C14	100nF	
R15	2.2kΩ		C15	100nF	
R16	2.2kΩ				



C16	33nF		C81	1pF	SAW oscillator used
C17	33nF				Not fitted if alternative
C18	10nF				SAW oscillator used
C19	10nF		C82	1pF	
C20	100nF		C83	1nF	
C21	4.7uF	Electrolytic	C84	1nF	
C22	1nF		C85	100nF	
C23	100nF		C86	100nF	
C24	4.7uF	Electrolytic	C87	100nF	
C25	15nF		C88	100nF	
C26	1.5nF		C89	100nF	
C27	22nF		C90	100nF	
C28	68nF		C91	1uF	Electrolytic
C29	10nF		C92	1uF	Electrolytic
C30	3.3nF		C93	1uF	Electrolytic
C31	4.7nF		C94	1uF	Electrolytic
C32	100nF		C95	18pF	
C33	4.7nF		C96	18pF	
C34	100nF		C97	100nF	
C35	3.3nF		C98	100nF	
C36	47nF		C99	100nF	
C37	3.3nF		C100	100nF	
C38	22nF		C101	100nF	
C39	33nF		C102	100nF	
C40	33nF		C103	100nF	
C41	33nF		C104	100nF	
C42	47nF		C105	100nF	
C43	220nF		C106	1uF	
C44	68nF		C107	100nF	
C45	33nF		C108	470nF	
C46	330nF		C109	25pF	Trimmer
C47	100nF		C110	6.8pF	
C48	22nF		C111	25pF	Trimmer
C49	330nF		C112	15pF	
C50	47nF		C113	25pF	Trimmer
C51	10nF		C114	15pF	
C52	4.7nF		C115	25pF	Trimmer
C53	100nF		C116	12pF	
C54	100nF		C117	100nF	
C55	10nF		C118	47nF	
C56	4.7nF		C119	1nF	
C57	33nF		C120	100nF	
C58	47nF		C121	2.2uF	Electrolytic
C59	100nF		C122	10nF	
C60	10uF	Electrolytic	C123	470nF	
C61	100nF		C124	3.3nF	
C62	470nF		C125	100nF	
C63	10nF		C126	100nF	
C64		Not used	C127	100nF	
C65	100pF		C128	100nF	
C66	47nF		C129	10uF	Electrolytic
C67	100nF		C130	100nF	
C68	10uF	Electrolytic	C131	1uF	Electrolytic
C69	100nF		C132	10F	Electrolytic
C70	100nF		C133	47nF	
C71	470nF		C134	100nF	
C72	470nF		C135	100nF	
C73	100nF				
C74	1nF		RE1	TQ2-12V	Mouser 769-TQ2-12v
C75	100nF		RE2	TQ2-12V	Mouser 769-TQ2-12v
C76	100nF		RE3	TQ2-12V	Mouser 769-TQ2-12v
C77	100nF				
C78	100nF				
C79	10nF		L1	100uH	
C80	1pF	Fit 33Ω if alterantive	L2	47T on 4C65 core (120cm 30 swg)	



L3	65T on 4C65 core (165cm 30 swg)	
L4	69T on 4C65 core (175cm 30 swg)	
L5	58T on 4C65 core (145cm 30 swg)	
L6	27T on 4C65 core (68cm 30 swg)	
L7	102T on 4C65 core (255cm 30 swg)	
L8	143T on 4C65 core (360cm 30 swg)	
L9	151T on 4C65 core (380cm 30 swg)	
L10	128T on 4C65 core (320cm 30 swg)	
L11	60T on 4C65 core (150cm 30 swg)	
L12	100uH	
L13	100uH	
L14	100uH	
L15	100nH	
L16	10uH	
L17	100uH	
L18	10uH	
L19	10uH	
L20	10uH	
L21	10uH	
L22	1uH	
L23	1uH	
L24	1uH	
L25	19.5nH	20mm 1mm silver plated wire
L26	20nH	21mm 1mm silver plated wire
L27	14nH	15mm 1mm silver plated wire
K1	50 BNC	Mouser 523-31-5640-1010
K2	50 BNC	Mouser 523-31-5640-1010
K3	50 BNC	Mouser 523-31-5640-1010
K4	50 BNC	Mouser 523-31-5640-1010
		Note order fixing nuts separately
K5	10 pin	Header with socket with link to 9 Pin Din (Fig n)
PCB	040360-1 from Euro Circuits [3]	
L2 -11	14.5mm 4C65 cores, Farnell 180-008	

0805 SMD resistors

Qty	Value	Comment
1	0Ω	*
1	10Ω	*
1	15Ω	*
6	33Ω	*
3	56Ω	*
1	82Ω	*
6	100Ω	*
1	330Ω	* Select (see text)
1	560Ω	* Select (see text)
3	1kΩ	*
1	1.2kΩ	*
1	1.8kΩ	*
7	2.2kΩ	*
5	3.3kΩ	*
2	4.7kΩ	*
1	5.6kΩ	*
1	6.8kΩ	*
3	10kΩ	*
3	33kΩ	*
4	1MΩ	*

* Fastcomponents [6] 0805 SMD resistorr pack

0805 SMD capacitors

Qty	Value	Comment
3	1pF	*
1	6.8pF	*
1	12pF	RS 211-3120
2	15pF	*
2	18pF	RS 648-0935
1	100pF	*
5	1nF	*
1	3.3nF	*
6	10nF	*
3	33nF	*
3	47nF	*
44	100nF	RS 264-4416
9	470nF	RS 264-4444
3	1uF	RS 264-4450

* Fastcomponents [6] 0805 SMD capacitor pack

Axial Ceramic capacitors

Qty	Value	Comment
1	1500pF	Maplin WX70M
3	3300pF	Maplin RA41U
5	4700pF	Maplin RA42V
4	0.01uF	Maplin RA44X
3	0.022uF	Maplin RA45Y
5	0.033uF	Maplin RA46A
4	0.047uF	Maplin RA47B
2	0.068uF	Maplin RA48C
6	0.1uF	Maplin RA49D
2	0.22uF	Maplin RA50E

Axial Electrolytic capacitors

Qty	Value	Comment
5	1uF	Maplin VH16S
1	2.2uF	Maplin VH18U
2	4.7uF	Maplin VH20W
4	10uF	Maplin VH22Y

0805 SMD inductors

Qty	Value	Comment
1	100nH	
3	1uH	
5	10uH	
5	100uH	

Wave (SAW) resonator (X2) used as the signal source for the DDS. I contacted all the listed stockist with no luck. I then contacted the manufactures to find that they produce these in batches and there were no new batches planned. The Internet then came into full use and I found a company called Crystek Crystals who manufacture a range of oscillators that use SAW resonators, with the CCSO-914-1000 being ideal for this application [10]. The package is small enough to fit in the area used for the original SAW resonator and with a few easy circuit

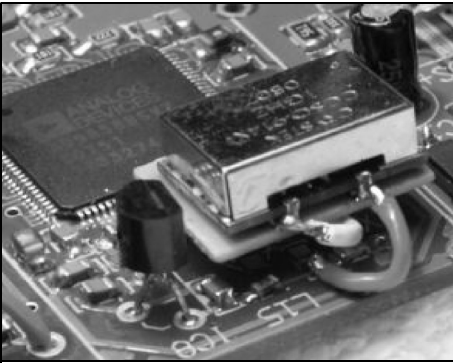


Fig 5: SAW oscillator fitted in place of SAW resonator.

changes shown in Fig 4 plus a small piece of Teflon laminate used to support the oscillator it was job done. Fig 5 shows the oscillator in place. Fortunately Mouser Electronics [11] stock the 1GHz oscillator at a very reasonable price, they also solved another problem which was a source for the Amphenol PCB mounting BNC sockets used for this project. Amphenol wanted a fantastic price for these sockets but they are very reasonable from Mouser, the only thing that I did not realise is that the fixing nuts have to be purchased separately. Fortunately I found that the fixing nuts for some 20mm fuse holders in the junk box were the correct size thus saving an expensive order of nuts from the USA.

The inductors for the post mixer filters are wound on 14.5mm 4C65 cores using 30swg enamelled copper wire with the number of turns shown in the parts list. I have included the approximate length of wire used to wind the coils.

3.0

Construction

3.1 The main PCB

With all the parts on the way it was time to start the construction. When the PCB

arrived I was a bit dismayed to see that the component silk screen was not really legible, not really surprising with such a compact design. Unfortunately Elektor did not publish a component layout so I contacted The PCB Shop [3] who supplied the PCB to see if they could supply me with a copy of the silkscreen artwork. By return email I had the artwork as shown in Fig 6. Construction could now start.

The first three ICs to mount were the most difficult. The AD9858, IC12 being the most difficult because it has 100 legs on 0.5mm pitch plus it has a square conductive heatsink pad in the centre that must be soldered to the feedthrough pads to conduct the heat generated in the IC to the outside world. The other two difficult ICs are IC3 an AD831 and IC5 an AD8009. I have a friend who works at a local electronics manufacturer so I went to see if he could help. The reply was that he could not but he knew a man who could. Their PCBs are all assembled a specialist PCB assembly company who have all of the equipment needed to handle such small IC packages. It turned out the assembly company had never dealt with ICs like the AD9858 with its heatsink pad, so it became a challenge to try. In a few days I had a call to say that my PCB was ready to collect with the three ICs mounted. Now all I had to do was mount the remaining components.

In my experience SMD assembly has to be taken slowly and with a bit of preparation. For this task I used a tray lined with aluminium cooking foil as the work area. The foil would keep the static at bay and the sides of the tray would catch any stray SMD components that tried to escape.

The golden rule when handling SMD components is to leave them in their packaging until you are about to solder them in place. Most are not marked so if you loose track of which one is which there is little hope of using that component. There is no particular order of

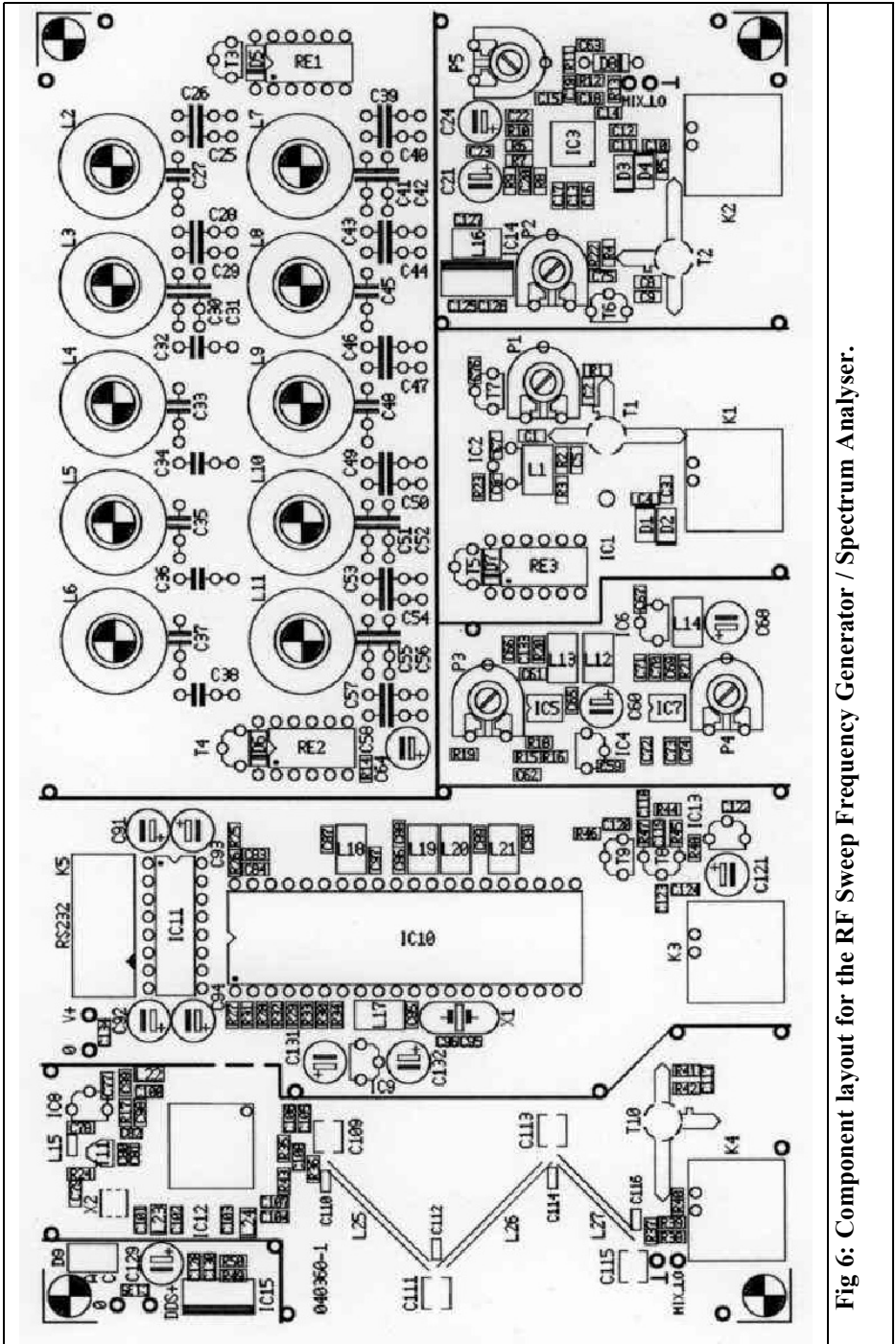


Fig 6: Component layout for the RF Sweep Frequency Generator / Spectrum Analyser.

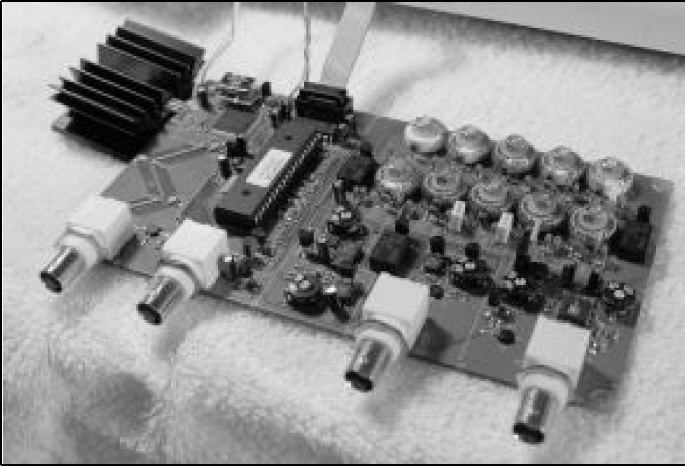


Fig 7: Completed main PCB for the RF Sweep Frequency Generator / Spectrum Analyser.

assembly but I found it best to fit all of the SMD resistors and capacitors first because some of the larger components would make positioning the small parts very difficult. The completed PCB is shown in Fig 7.

3.2 Power supply

The circuit diagram of the power supply is shown in Fig 8. It is straightforward and was constructed on strip board with a simple aluminium plate to hold the transformers.

3.3 The active probe

An active probe is part of this project; the circuit diagram is shown in Fig 9. It gives a high impedance input for either the wobulator of spectrum analyser inputs and is powered by a current source on the relevant input circuit. I constructed it on a small piece of Teflon PCB as shown in Fig 10 and mounted in a pen case that had been supplied to me as a sample from a promotional products company. The advantage of this pen case is the metallic coating that provides good

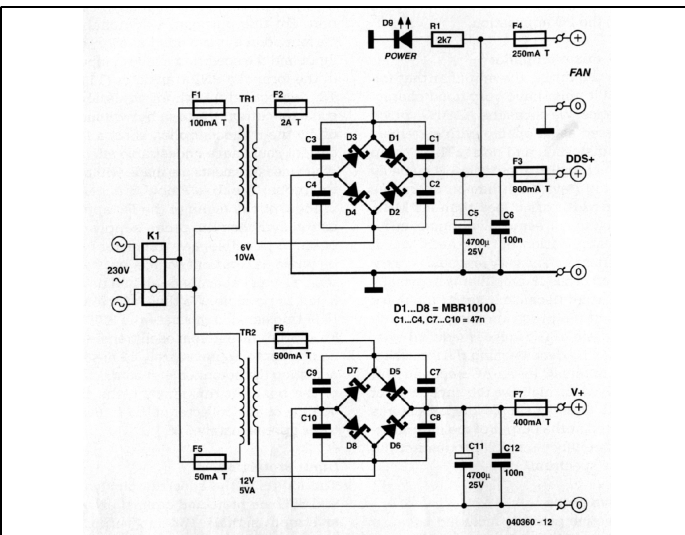


Fig 8: Circuit diagram of the power supply for the RF Sweep Frequency Generator / Spectrum Analyser.

I did not use a fan to cool the unit.

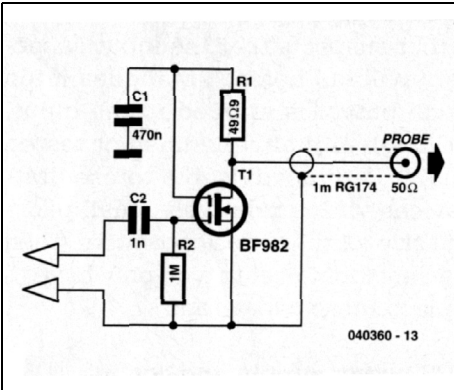


Fig 9: Circuit diagram for the active probe.

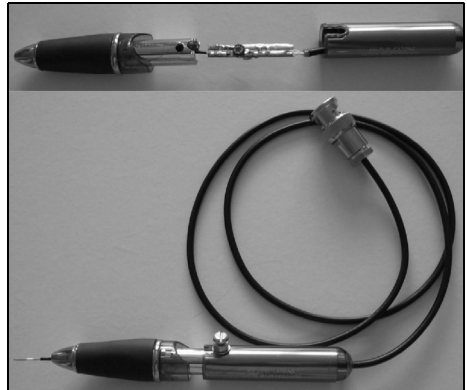


Fig10: The active probe constructed in a pen case.

screening for the probe.

3.4 Final assembly

The completed PCB and power supply were mounted in a simple two-part case from Maplin Electronics [12]. I wanted to make the front panel look good and investigated using photosensitive sticky

backed card. This is quite expensive and would require a suitable size UV exposure unit, which I do not have. I tried an alternative. Using a free front panel design program downloaded from the Internet [13] I produced a panel design printed on an A4 sheet of paper. I then laminated the paper using a standard

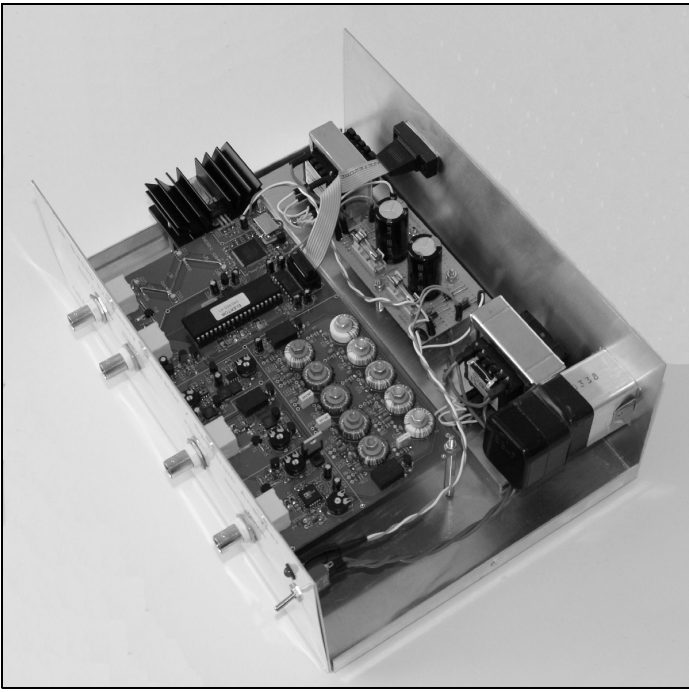


Fig 11: Internal view of the completed RF Sweep Frequency Generator / Spectrum Analyser.

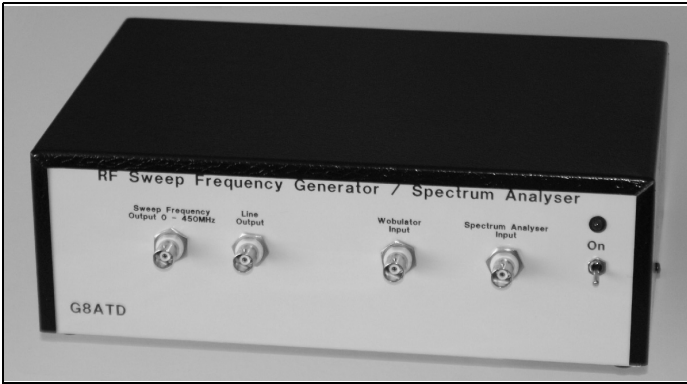


Fig 12: Front view of the completed RF Sweep Frequency Generator / Spectrum Analyser.

heat-sealing laminator and carefully fitted it to the front of the unit using double-sided sticky tape. The completed unit is shown in Figs 11 and 12.

4.0

Testing

The first test was to check the voltage regulators to ensure that they were producing the correct supply voltages. The most critical being the 3.3V supply for the AD 9858 DDS IC, this is generated by and LM317 with a voltage divider comprising two non standard value resis-

tors (R49, 249Ω and R50, 412Ω). In fact I hand selected two resistors to give the correct ratio of 0.604 from 330Ω and 560Ω resistors. To ensure that the voltage was correct I connected the input to a variable voltage source and slowly raised the input voltage while monitoring the 3.3V supply line to ensure that it stabilised at about 3.3V. The remaining supply voltages are generated with fixed voltage regulator ICs so they are less critical but it is still worth checking.

Once these initial checks are made the unit must be linked to a PC running the program downloaded from the Internet [2]. The link is a simple 3-wire RS232 link; the connections are shown in Fig 13. After the program is loaded (Fig 14) there is a simple hardware test and setup procedure. This is my version of the setup procedure shown in the supplementary document [5]:

- Select “Com Port” from the “Settings” menu
- Set the parameters to COM1 or COM2 depending on the port available on your PC, Baud rate 115200, 8 data bits, 1 stop bit, no parity and no flow control
- Now select “Test HW” from the “Settings“ menu, if all is well you will get a message to say that the hardware is OK

Next the DDS output filter should be aligned:

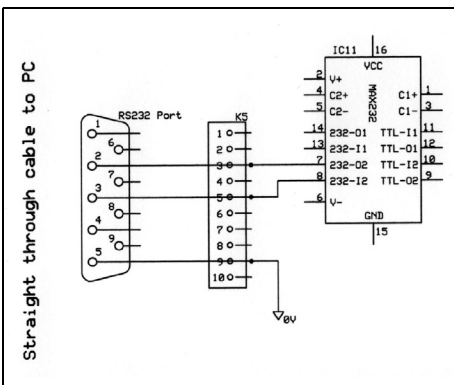


Fig 13: RS232 connections from the RF Sweep Frequency Generator / Spectrum Analyser to a PC.

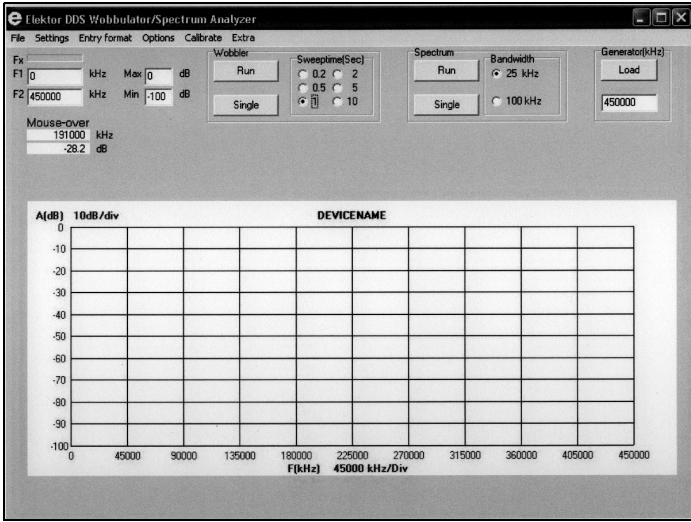


Fig 14: The wobulator screen.

- Ensure that the probe is not enabled on the “Options” menu
- Connect the sweep generator output (K4) to the Wobulator input (K1) with a short length of 50Ω coax
- Select “F1,F2” and “Megahertz” on the “Entry Format” menu
- Enter “0” and “-100” for dB values
- Select “Adjust LPF” on the “Options” menu
- Enter “0” and “500” for the values of F1 and F2 respectively
- Select “0.2s” for a sweep time
- Click “Run” for the Wobulator
- This will display the response curve for the DDS output filter, adjust P4 to set the highest point of the display on the 0dB line
- Adjust trimmers C109, C111, C113 and C115 until the line is as flat as possible with a steep fall off at about 450MHz. The best that I could achieve is shown in Fig 15
- Once the best adjustment has been made, stop the sweep by clicking “Stop” for the Wobulator

Next the spectrum analyser level should be set:

- Deselect “Adjust LPF”
- Disconnect the cable connecting K1 and K4
- Select “100kHz BW” for the spectrum analyser
- Connect a signal generator with a 50Ω output to the spectrum analyser

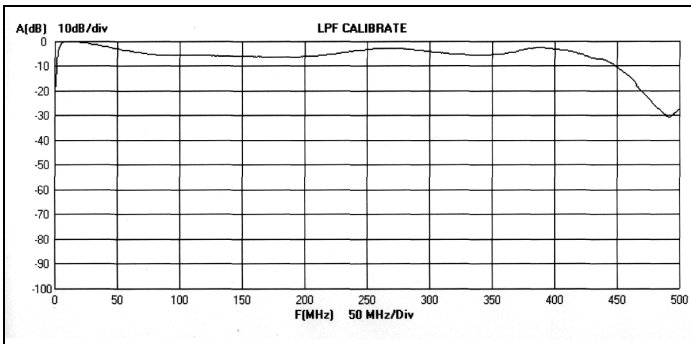


Fig 15: Calibrating the low pass filter on the output of the DDS.

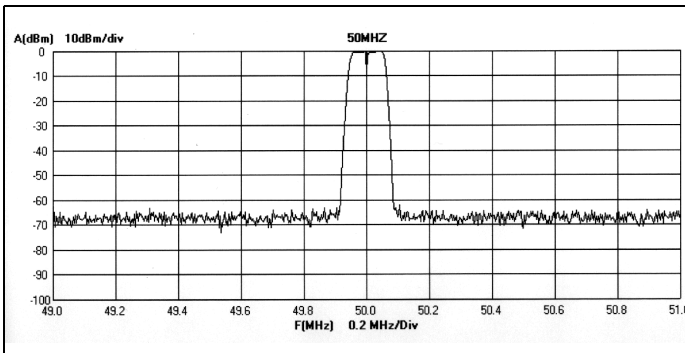


Fig 16: Setting the 0dB level with a 50MHz signal from a signal generator.

input (K2) and set the frequency to 50MHz with a level of 0dBm

- Enter “40” for F1 and “60” for F2 and click “Run” for the Spectrum analyser, the display will look like Fig 16
- Adjust P5 to set the tip of the signal to 0dBm
- Reduce the signal generator level to –30dBm and adjust P3 to set the tip of the signal on the –30dB line
- Stop the spectrum analyser by clicking “Stop” for the Spectrum analyser

Next the sweep generator level should be calibrated

- Connect the sweep generator output (K4) to the Wobulator input (K1) with a short length of 50Ω coax
- Select “0” and “450” for F1 and F2 respectively
- Select “0” and “-100” for the min and max dB levels
- Check “Level” on the “Calibration” menu. If this option is already ticked, click to un-tick it and a second time to enable the level setting once a single sweep has been made
- Click “Single” for the Wobulator. This will calibrate the level and store the relevant values in file that is loaded each time the program is run. The fact that the level has been calibrated is shown with a tick against the “Level” option on the “Calibrate” menu

There is a calibration procedure to for the frequency of the signal generator but I did not need to use that because the frequency output was close enough for all my requirements.

Finally the probe should be calibrated:

- Connect the probe to the spectrum analyser input (K2)
- Select “Use probe” in the “Options” menu
- Measure the DC voltage at the collector of the current source transistor (T2) and adjust P2 to give 5V
- Now connect the probe to the wobulator input (K1) and measure the DC voltage at the collector of the current source transistor (T1) and adjust P1 to give 5V
- Select “F1,F2” and “Megahertz” in the “Entry Format” menu
- Enter “0” and “450” for F1 and F2 respectively
- Enter “0” and “-100” for the max and min dB values
- Connect the signal generator output to a 50Ω termination with the hot end of the termination accessible to the probe (I used a BNC “T” piece)
- Connect the probe to the hot end of the termination
- Select “Probe level” on the “Calibrate” menu
- Click “Single” for the Wobulator. This will calibrate the level and store the relevant values in file that is loaded each time the program is run.

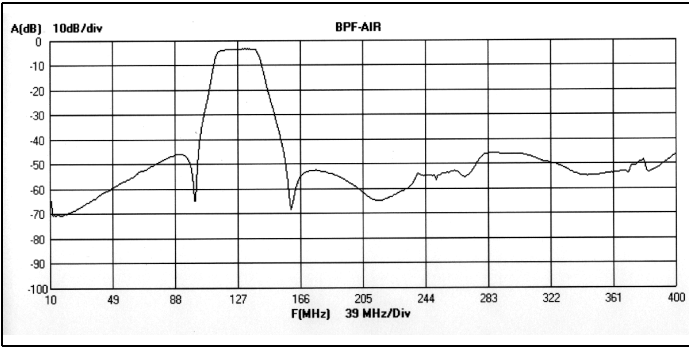


Fig 17: Measuring the frequency response of an air band filter using the wobulator function.

The fact that the level has been calibrated is shown with a tick against the “Probe level” option on the “Calibrate” menu

The unit is now calibrated and ready for use.

5.0

In use

The software is easy to use making swept frequency measurements over any range from 0 to 450MHz very easy. The full range of facilities is quite comprehensive:

- Making a swept frequency measure-

ment of such things as filters. Fig 17 shows the frequency response of an air band filter with the filter connected between the sweep generator output (K4) to the Wobulator input (K1).

- Making a spectrum scan of a signal source. Fig 18 show a scan from 0 to 450MHz with a signal generator set to 100MHz. The fundamental plus several harmonics can be seen. Moving the mouse over the display area show the frequency and attenuation at the mouse cursor. Click and hold the mouse button on the fundamental then dragging the mouse to the first harmonic makes a delta measurement as shown.
- Using the sweep generator as a VFO. By selecting “VFO” from the “Ex-

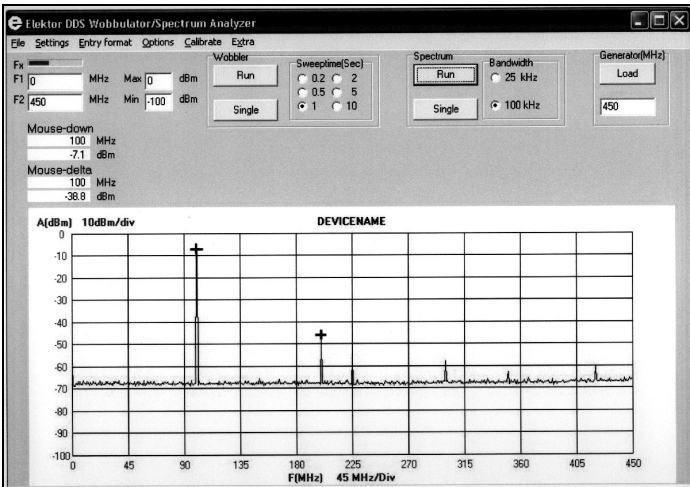


Fig 18: Measuring the harmonics of a 100MHz signal.

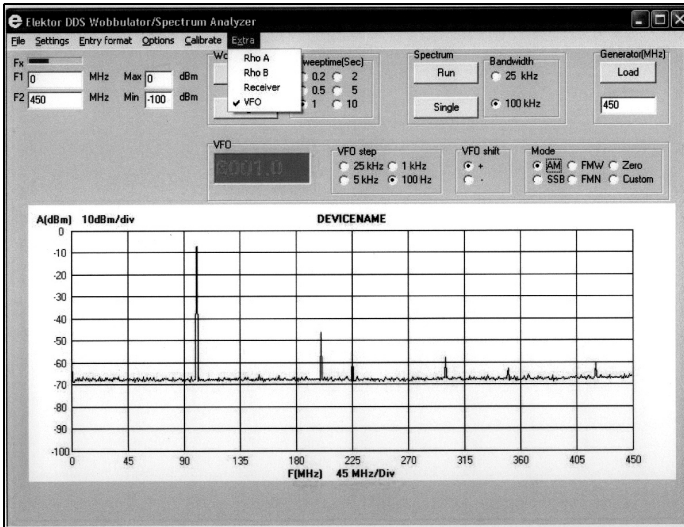


Fig 19: Using the VFO function.

tras” menu displays a panel to set the frequency in kHz, the output of the sweep generator (K4) is set to that frequency at an output of -8dBm . Using the mouse wheel increments or decrements the frequency by the step size chosen as shown in Fig 19.

- Using the unit as a Direct Digital Synthesis (DDS) receiver. By selecting “Receiver” from the “Extras” menu displays a panel to set the frequency in kHz, the output of the sweep generator is set to that frequency and the Line Output (K3) is enabled. This is not a very sensitive receiver but I note that Gert Baars has a design for a 2m preamplifier in the July/August 2009 issue of Elektor. Don’t expect this to be a communications receiver.
- VSWR measurement, there are two options on the “Extras” menu to measure Rho-A and Rho-B. These are to be used with an external VSWR bridge to make measurements. I have not tried these yet and the descriptions to construct a VSWR bridge in the supplementary document [5] are a bit vague and the relevant diagrams are missing.

6.0

Conclusion

This was an interesting and challenging project to construct. The end result is a very useful piece of test equipment for the radio amateur. It is not a precision instrument but the accuracy is quite sufficient to use for various measurement tasks up to 70cm. My thanks to Elektor, portions of this article are copyright© of Elektor International Media and reproduced with the permission of the Editor. The original article may be downloaded at www.elektor.com/040360

There is an active group of followers in the Netherlands [14]. The link is rather long so I will out it on the VHF Communications Magazine web site.

7.0

References

- [1] RF Sweep Frequency Generator / Spectrum Analyser, Gert Barrs, Elektor,



October 2008. Download article from www.elektor.com/040360

[2] Wobulator software can be downloaded from www.elektor.com/040360 then select Free Downloads and choose Software

[3] PCB Shop follow the link from the page www.elektor.com/040360 to order bare PCB. PCB manufactured by Eurocircuits – www.eurocircuits.com

[4] Programmed microcontroller, follow the link from the page www.elektor.com/040360 to order the Programmed Controller Atmega 8535 part number 040360-11

[5] The extra information can be downloaded from www.elektor.com/040360 then select Free Downloads and choose Extra Info

[6] Fastcomponents Electronic Kits is the name of an eBay shop. To find the shop use the Advanced Search facility on the eBay main page and search for a shop with Fastcomponents in the name

[7] Farnell components – www.farnell.com

[8] R S Components – www.rs-components.com

[9] Cricklewood Electronics – www.cricklewoodelectronics.com

[10] Crystek Crystals CCSO-914X-1000 - www.crystekcrystals.com/crystal/spec-sheets/clock/CCSO-914X.pdf

[11] Mouser Electronics – www.mouser.com

[12] Maplin Electronics – www.maplin.co.uk

[13] Front Panel Designer 3.50 – www.frontpanelexpress.com

[14] Dutch Elektor forum - <http://www.elektor.nl/forum/forum/algemene-forums/alle-hens-aan-dek/hoog-frequentwobulator-elektor-oktorber-2008.697891.lynkx?highlight=wobulator&pageStart=1>

Note this link is on the VHF Communications Magazine web site - www.vhfcomm.co.uk



Wolfgang Schneider, DJ8ES

Experimental board for the ATmega128 microcontroller

Experience shows that using an experimental board to develop circuits with microcontrollers can save time and money in the long run. The board should be as versatile as possible and have as many circuit variants as possible. The most frequently used interfaces are; relay drivers, real-time clock, a serial interface like the standard RS232. Also it must use different types of microcontroller.

1.

Introduction

The most important characteristic of an experimental board is that it should be universal. It should be able to use as many different interface circuits as possible. It should be downward compatible with similar microcontrollers; these must have the same capabilities as all smaller versions (derivatives) from its product family if possible. It must be possible to differentiate different peripheral interfaces such as parallel and serial interfaces. It is most important to differentiate between the standard RS232 serial interface and the I²C Bus. Important standard microcontroller circuits are relay drivers and high current drivers. The AT-Mega128 microcontroller from Atmel

meets these criteria. Apart from the many ports there is a plentiful supply of software for this well used microcontroller. There is also plenty of technical literature available.

2.

Circuit description

Fig 1 shows the circuit diagram for the ATMeaga128 experimental board. The main item is the ATmega128 microcontroller (IC1) from ATMEL. This component is in a 64-pin SMD package with plenty of input and output ports to connect peripheral controls. The 128kByte ROM gives enough space for extensive application software. At first sight the clock frequency of 9.216MHz is unusual compared to the more normal 8, 12 or 16MHz but it was chosen with the serial interface bit rates in mind. A 4 line by 20-character display is available to display current data, measured values or other data. This display is connected to port C on the microcontroller via a 10-pin connector K7. The pin connections for this connection are shown in Fig 2. Port F of the ATmega128 has an Analogue to Digital Converter (ADC) with 10-bit resolution. This can be used to measure analogue signals using addi-

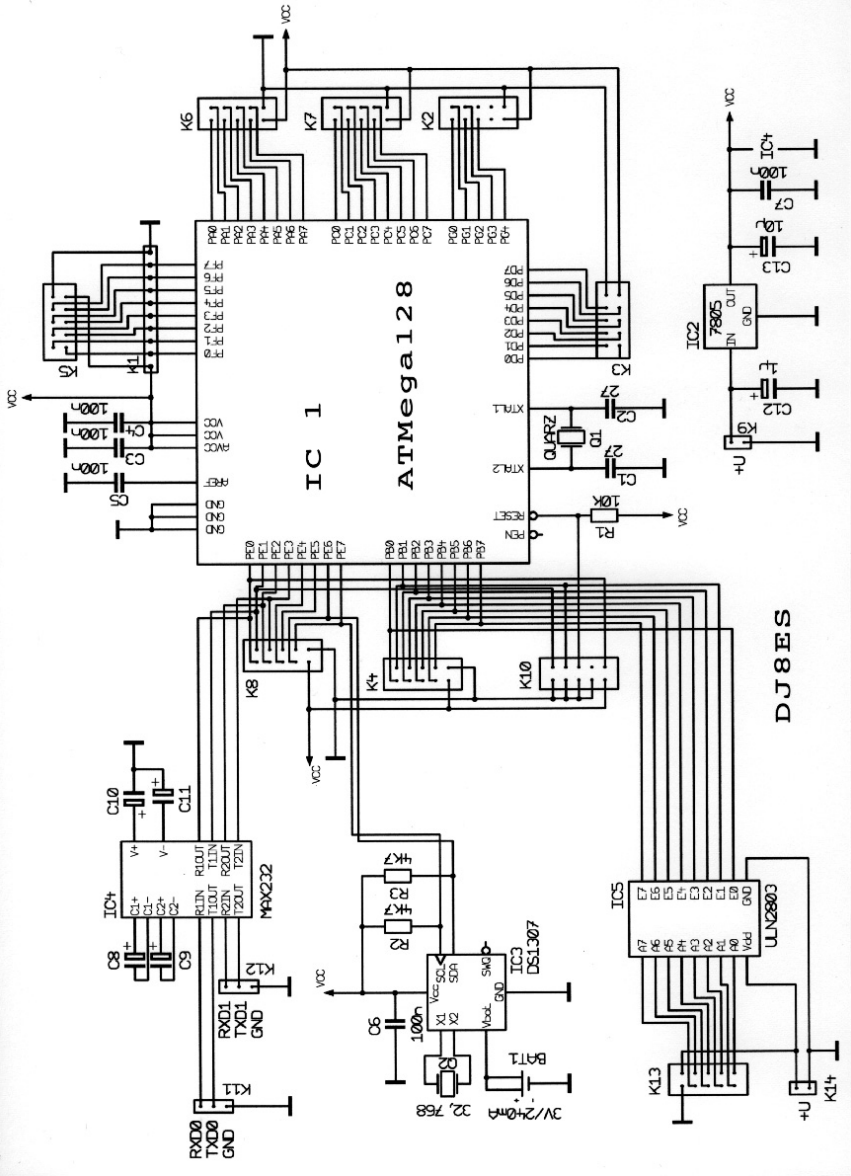


Fig 1: Circuit diagram of the ATmega128 experimental board.

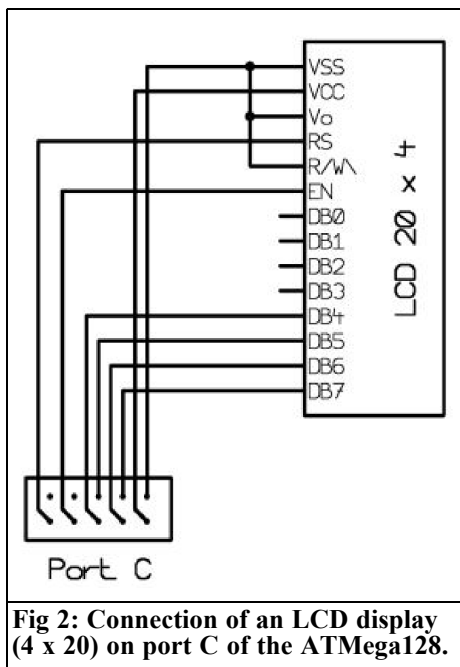


Fig 2: Connection of an LCD display (4 x 20) on port C of the ATmega128.

tional resistor wiring on contact strip K1. The circuit shows a special driver (IC5, ULN 2803) on port B. This driver makes it possible to connect up to 8 relays with higher current contacts. All other ports are digital input or output ports and free to use. The two serial interfaces, standard RS232 and the I²C Bus, are connected to port E. Both interfaces are separately addressed. The ATmega128 microcontroller has an integrated real-time clock on the chip. However to ensure compatibility with smaller microcontrollers without this facility, an external clock (IC3, DS1307) is used to provide the Real Time Clock (RTC).

3.

The ISP interface for the programming of the microcontroller

Microcontrollers with integrated flash

memory, like the AVR microcontroller from ATMEL usually offer facility for In Systems Programming (ISP). This uses a programming device to program the microcontroller while it is connected to the existing circuit. Memory can be also selected using the same mechanism. This microcontroller has a Serial Peripheral Interfaces (SPI) that is an interface with three connections:

- MOSI: Master Out, Slave in (program data bits)
- MISO: Master in, Slave Out (selected data bits)
- SCK: Clock pulse (clock to transfer the data bits)

The connections from the microcontroller for this interface are fed to the appropriate plug contacts. These connections depend on the ISP adapter used. There are different versions of programming adapters for a parallel PC interface. The electronics necessary is usually fitted in the plug.

4.

The real-time clock DS1307

An important auxiliary component experimental board for the ATmega128 is the DS1307 (IC3) real time clock. The DS1307 is in an 8-pin package and is almost ideal for the function required. It has an integrated clock, calendar and 64 bytes of static RAM with about which 56 bytes free for the user (the clock needs 8 bytes) and most important it is very inexpensive. With an external battery (CR2032) this IC will run for at least 30 years. This 3V battery connected to pin 3 of IC3 and continues to supply the device if the supply voltage is switched off. In standby the power required is a maximum of 500nA. The DS1307 is addressed over an IC-bus, also know as TWI (twin Wire) -bus. It is connected to

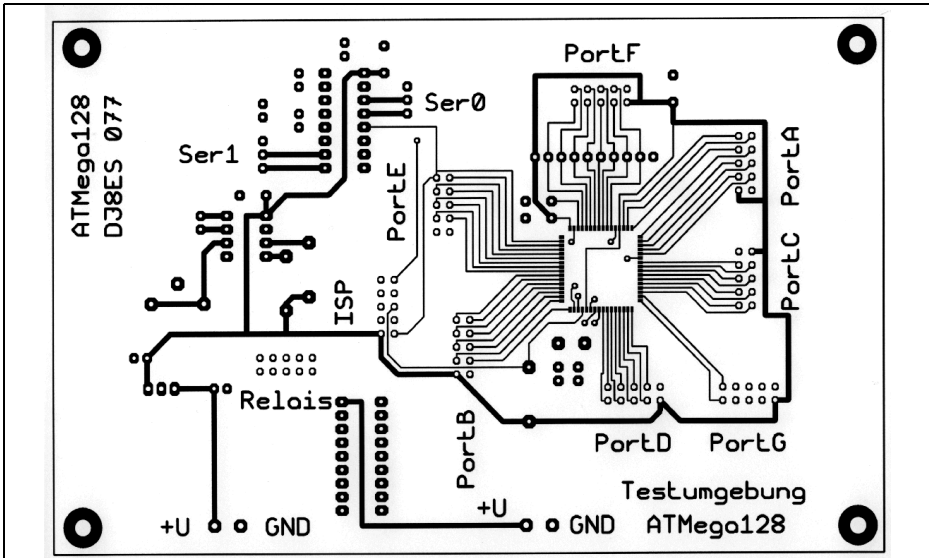


Fig 3: Layout of the component (top) side of the PCB.

the microcontroller by pin 5 (SDA, Serial Data) and pin 6 (SCL, Serial Clock). The other external component is a miniature 32.768kHz clock crystal connected to pin 1. It provides for the accuracy of the clock.

possible to operate individual drivers in parallel to be able to switch higher currents. However the total power dissipation of the device should not exceeded 1.3W.

5. The ULN 2803 relay driver

The ULN2803 (IC5) is an amplifier circuit to control relays or light emitting diodes with high current requirements. Up to 8 devices can be controlled. The ULN series was developed to illuminated displays with high supply current requirements and as relay drivers. This device contains 8 Darlington transistors. Each output is an open collector. All gates can be operated independently. The inputs are suitable for TTL or CMOS signal levels. The outputs have internal protection diodes for inductive loads and can switch peak currents of 600mA. It is

6. The standard RS232 serial interface

The transmission method of RS232 was originally developed for data communication over a voice grade channel. It uses a simple asynchronous serial procedure for the data communication. Serial means that the individual bits of the to be transmitted are pushed successively over one data line. A typical bit rate is 9600 Bit/s. Asynchronous means that there is no clocking line to tell the receiver of the data exactly when the next bit is on the data line. Such a procedure can only work if the transmitter and receiver use exactly the same internal clock and if the

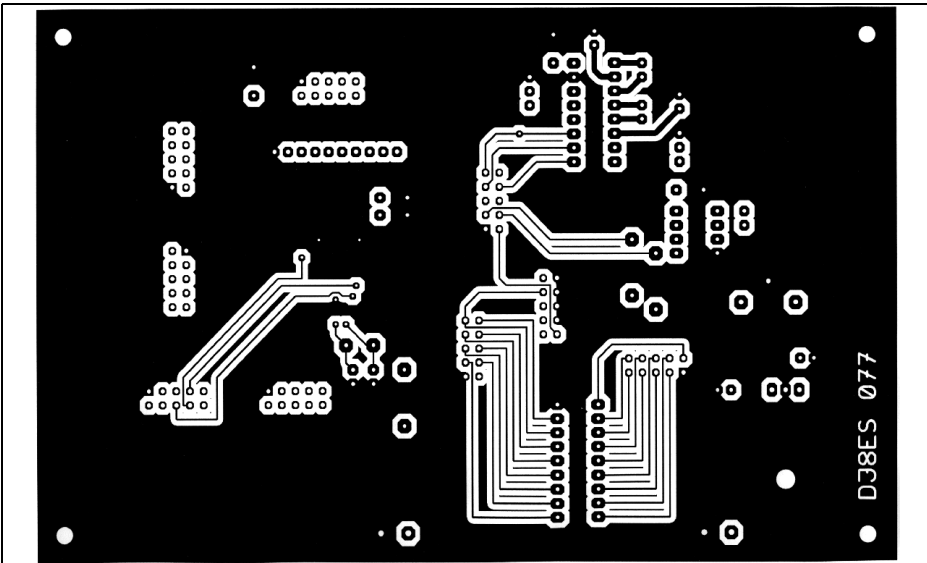


Fig 4: Layout of the track (bottom) side of the PCB.

receiver is told exactly when the first bit begins (synchronisation). It was defined that 8-bits would transfer a data byte. Additionally at the beginning a start bit is

sent that marks the beginning of a byte. At the end of a byte an additional stop bit is sent i.e. 10 bits are sent per data byte. The interface was originally designed for

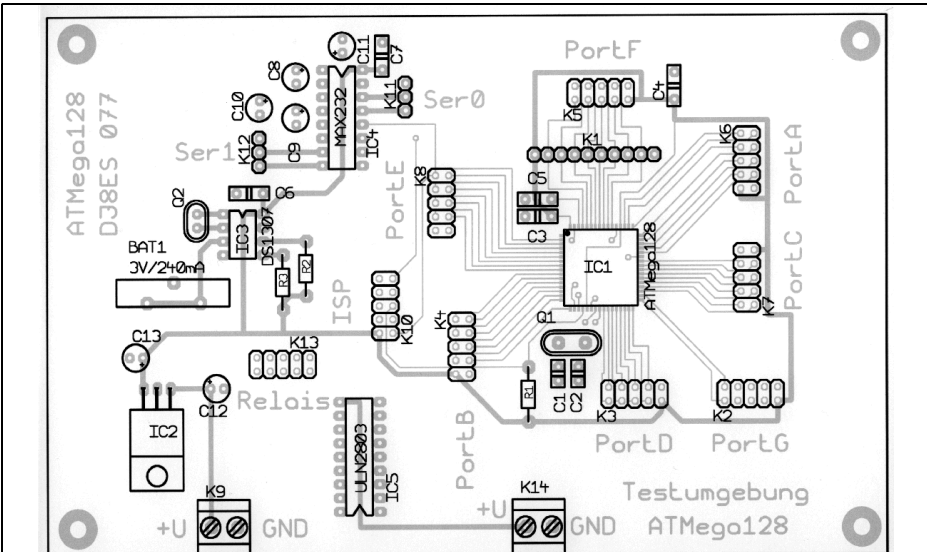


Fig 5: Component layout for the ATmega128 experimental board. All components are fitted on the component side.



Table 1: Parts List for the AT-Mega128 experimental board.

IC1	ATMega128, ATMEL microcontroller
IC2	7805, voltage regulator
IC3	DS1307, Dallas real time clock
IC4	MAX232A, serial port
IC5	ULN2803, relay driver
Q1	9.216MHz crystal, RM 5mm
Q2	miniature 32.768kHz clock crystal

Resistors:

R1	10k, 1/4W, RM 10mm
R2, R3	4k7, 1/4W, RM 10mm

Ceramic Capacitors:

C1, C2	27pF, RM 2.54mm
C3 - C7	100nF, RM 5mm

Electrolytic Capacitors 25V, RM 2.54mm:

C8 - 9	1 μ F
C10 - 12	1 μ F
C13	10 μ F

Single row connectors RM 2.54 mm:

K1, K4	10-pin
K2	14-pin
K3, K8	2-pin
K5	3-pin
K6	5-pin
K7	4-pin
Bat1	Battery CR2032 lithium backup battery
1	LCD display 4 x 20
2	connecting terminal 2-pin, RM 5mm
2	pinboard 3-pin, RM 2.54mm
1	pinboard 10-pin, RM 2.54mm
8	contact strip 2 x 5-pin, RM 2.54mm
1	printed circuit board DJ8ES 077

the RS232 interface do not need these modem specific signals and just use Received Data (RXD), Transmit Data (TXD) and Ground (GND). All RS232 signals (with exception of the ground wire) work with the voltage levels +12V (for logic 0) and -12V (for a logic 1). 5V to 15V are permitted and the receiver often accepts +3V for 0 and less than -3V for 1.

The RS232 serial port uses a standard MAX232A (IC4) chip. This takes care of all the level transformation and the IC produces all necessary voltages.

7.

Construction

The ATMega128 experimental board is a 100mm x 160mm (Euro card format) double-sided epoxy printed circuit board (PCB). The PCB should be commercially manufactured because some plated-through holes are close to very thin tracks. The PCB layouts for the upper and lower sides are shown in Fig 3 and 4. Experienced home constructors could use these to make a PCB. The circuit and PCB layout produced with TARGET are available as a data file from the author.

The component layout is shown in Fig 5. The 7805 (IC4) 5V voltage regulator and the associated components should be assembled first and the 5V supply checked before any other assembly is carried out. The ATMega128 (IC1) microcontroller is assembled next followed by the sockets for the input and output ports. Because these are relative close to the solder connections of the microcontroller care should be taken not to disturb these when soldering the sockets. The circuit layout was designed to give comparatively generous space. There should be no particular assembly problems for the less practiced constructor.

operation by modems (modulator demodulator) and contains some signals for that purpose. Applications like communication between microcontrollers that use

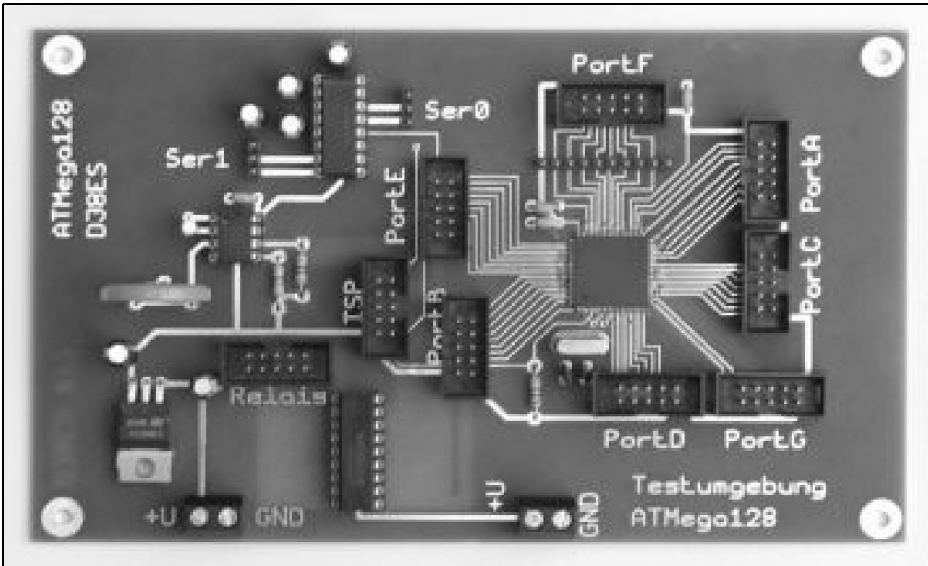


Fig 6: The completed ATmega128 experimental board ready to use.

8.

Set up

Fig 6 shows the completed ATMegas128 experimental board. Once assembly is complete it should be examined carefully. Connecting the LCD display completes construction, this only requires about 35mA. The operating voltage of the experimental board is between 8V and 15V. Importantly, the real-time clock (IC3, DS1307) must be programmed with the current date and the time, after this it can run with the external backup battery (CR2032) for over 30 years.

9.

Programming of the AT-Mega128 microcontroller

There are various alternatives available to program the ATMeaga128 microcon-

troller. One option for the beginner is BASCOM. BASCOM is a complete basic development environment for the AVR controller from ATMEL. It offers a large user friendly and efficiency development environment. A free demonstration version is available on the Internet; it can be used by anyone to produce code up to 4kB in size, which can use the all the memory of an AT90S2313. BASCOM AVR contains a great many finished functions to make addressing external components (e.g. LCD displays) very simply. The demo version does not have any restrictions compared to the full version. The demonstration version can be downloaded from the manufacturer's web site [2].

10.

Example of uses

A possible practical application for the ATmega128 experimental board is to

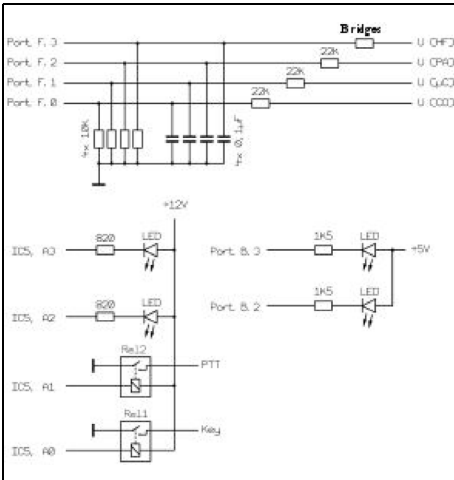


Fig. 7: With only a few external components the ATmega128 experimental board can be used for controlling a beacon.

control a beacon. The hardware and software necessary for this were described in detail in [3] using an AT-Mega32 microcontroller. The measured values for operating voltage and power output are connected to port F (K5) of the ATmega128 microcontroller as shown in Fig 7. The analogue inputs of the microcontroller can measure up to 5V. The measured values must be standardised using resistive voltage dividers. The two relays for the PTT and Key are connected

to the ULN2803 (IC5) relay driver (K13). Two LEDs are also connected for control purposes. All ports are LOW active, i.e. switched to ground.

The outputs of the microcontroller can directly feed LEDs; these should be low current LEDs that operate with only 2 - 4mA. The current limiting resistors should have the appropriate values.

11. References

- [1] Data sheet Atmega128, Atmel, <http://www.atmel.com/>
- [2] Bascom AVR, MCS Electronics, <http://www.mcselec.com/>
- [3] Beacon controller using an AT-Mega32 and BASCOM, Wolfgang Schneider, DJ8ES, VHF Communications Magazine 3/2008, pp 178 - 186

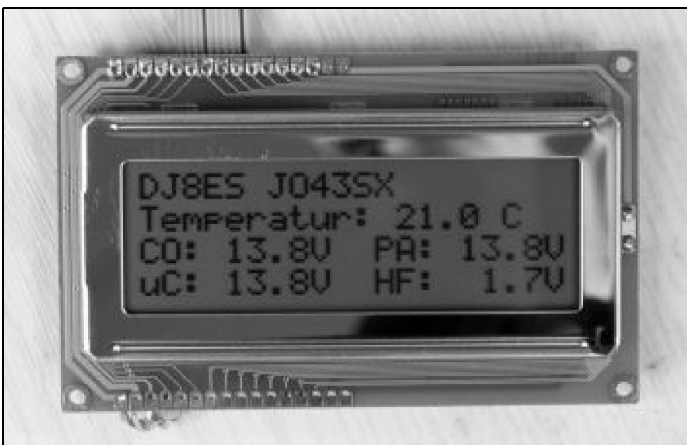


Fig 8: The LCD display shows all important operating parameters of the beacon



Carl Lodström, KQ6AX, SM6MOM

The noble art of checking your SWR meter

1.0

Introduction

The key part in an SWR meter is a Directional Coupler or an SWR bridge. For either there are two couplers and a meter that can be switched between them or they each have one meter separately indicating the forward and reverse power. The sensitivity of the meters is varied until the forward meter shows full reading and the reading of SWR is done on the other meter.

It is also possible, and more practical, to have two couplers, one for forward and the other for reverse power. The sensitivity of both meters (if two couplers) is adjusted to full deflection on the forward coupler when the normal full power is available. SWR is read off the other meter.

There are bi-directional couplers that provide the coupled reference (the forward) as well as the reflected (the reverse) signal at the same time. The forward coupler is used all of the time to provide reference for the value of full power. A coupler like the one in Fig 5 can be made dual and bi-directional.

A Slotted Line (with detector and an instrument like the HP415E) can perform very accurate SWR measurements, but it

is not direct reading and not in real time. Otherwise it is a great instrument for the lab and more accurate than just about any regular SWR meter! The maximum error, given by GR and HP for their regular slotted lines, are 1.04:1 or 34dB RL.

We now suspect that a poor coupler will make a poor SWR meter!

We also suspect that a good coupler can be tested with a good load!

Looking in the data sheets for Directional Couplers, we see a property called “Directivity”. That is how well the coupler can tell the difference of the coupled signal between waves travelling one way and the other.

30dB is not a bad number. 40dB is very good. If we use the SWR meter (with a coupler like this) to judge how good, or bad, a load is, we can obviously not make measurements beyond the directivity of the coupler.

2.0

Testing the Directional Coupler

To test the SWR meter we want a mismatch of known magnitude.

If we have a total mismatch, short or

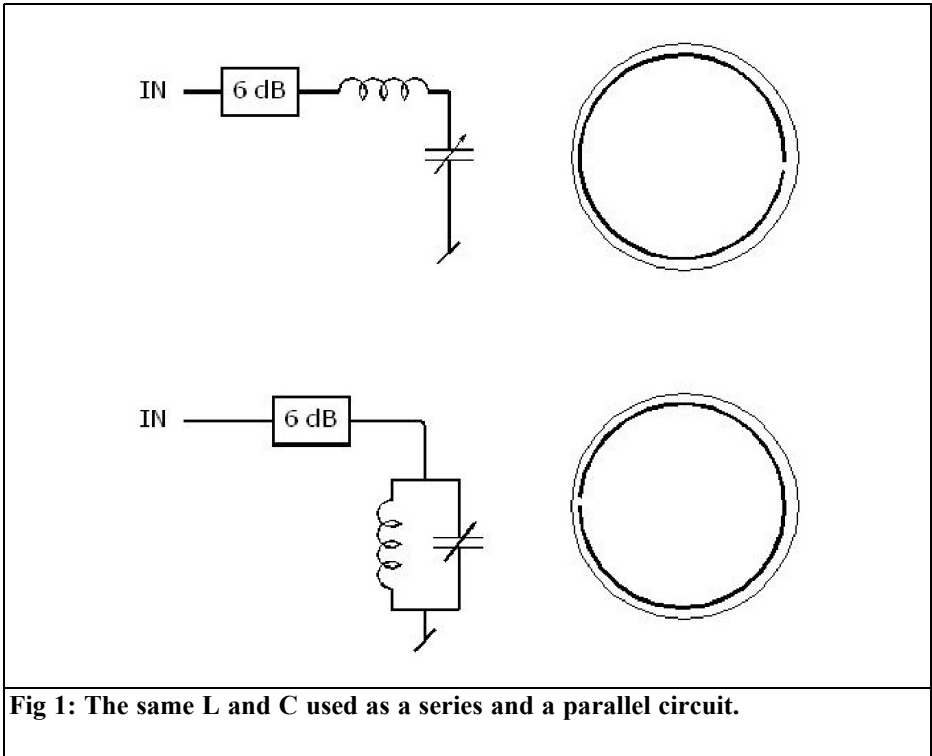


Fig 1: The same L and C used as a series and a parallel circuit.

open circuit (notice that any pure reactance will give a total reflection as well) on the line, there will be a total reflection. No energy consumed, it all comes back!

If a 10dB attenuator is connected between the output and the total reflection, it will improve the reflection by twice its value, as seen from the source. The signal is attenuated by 10dB on the way out, reflected and attenuated again on the way back, total attenuation of 20dB. This is the same thing as a RL (Return Loss) of 20dB. Compared to the out-bound power only 1/100 of the power comes back! That makes the bad load look very good, SWR = 1.222:1 or better.

No matter what we have on the far end, with a 10dB attenuator, the reflection will be no worse than -20dB.

3.0

Making a load for calibration!

Let us assume that an attenuator is put in the line, after the meter, in front of a very, or totally, mismatched load! Say the attenuator is 6dB. To begin with, the incident (outgoing) signal is attenuated, so in this case the signal is attenuated by 6dB when going out, totally reflected by the load, and attenuated again by another 6dB coming back. Thus, as seen from the source, the reflection is at least 12dB below the outgoing signal. (Called: "a 12dB Return Loss" which is somewhat of a good load = SWR 1.671:1). Thanks to the attenuator, this is "Worst Case", as bad it can get. No matter what we do to the load end, it cannot get any worse! The reflection from this load assembly is

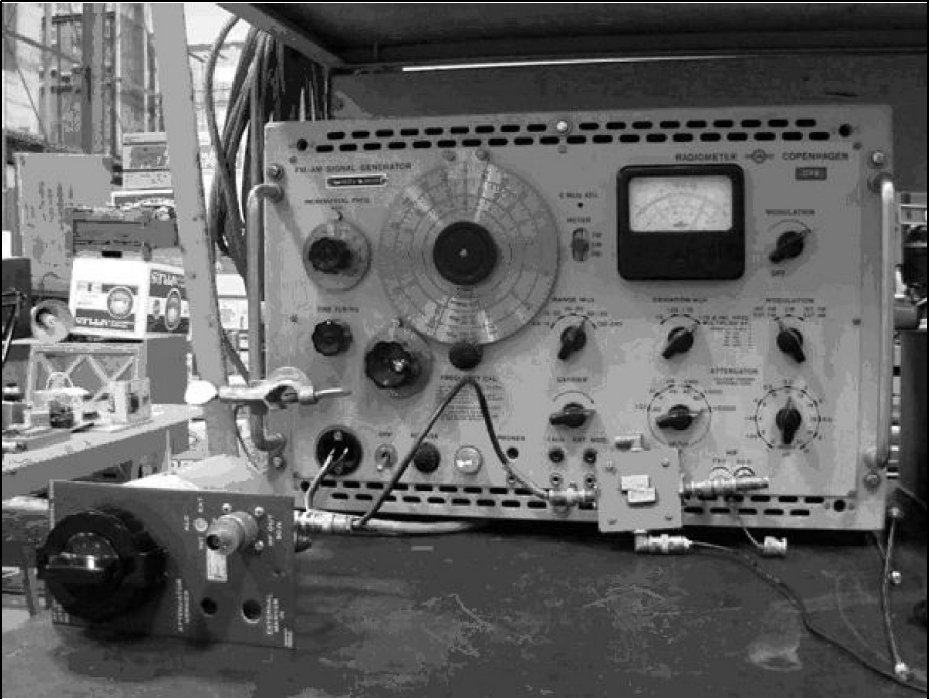


Fig 2: The SWR meter setup. From left: a variable attenuator, signal generator and double directional couplers. A DMM is outside the picture.

12dB below the outgoing signal. That would actually not be a very bad load, but it is of course all thanks to the attenuator. If the actual load is not all reflective, it will be “improved”, from whatever it is, by another 12dB thanks to the attenuator. We can use this for calibration, or evaluation, of any SWR meter.

By very simple means, we can make a load with an argument that can be rotated continuously by *almost* 360°. The Series LC version shown in Fig 1 will easily go through the 180° argument and almost reach 0° from either direction. The Parallel LC version shown in Fig 1 will just barely reach the opposite loci, at 0°, from the 180° loci, in either direction.

As they are real, not ideal, L and C have some losses, therefore the arcs they produce will be just inside the periphery of the Smith Chart where perfectly reflect-

ing loads are located.

Fig 1 shows the case at series resonance. The circle, with an inscribed arc, represents the periphery of a Smith Chart where the arc symbolises the possible locations that the reflection from a resonant circuit can occupy. It does not include the 3 o'clock location but almost all the rest. It is exaggerated here. In reality, the arc is closer to the circle, the periphery of the Smith Chart, and the loci of perfectly reflecting loads.

The signal source plus SWR meter under test, connected to “IN”, should show an infinite SWR even if the frequency is varied so the resonator goes into, through and out of resonance. The attenuator with a total reflection and with this resonator are the basic test of the SWR meter. In place of varying the frequency, the C (or L) can be varied a little back and forth while looking for small variations. There

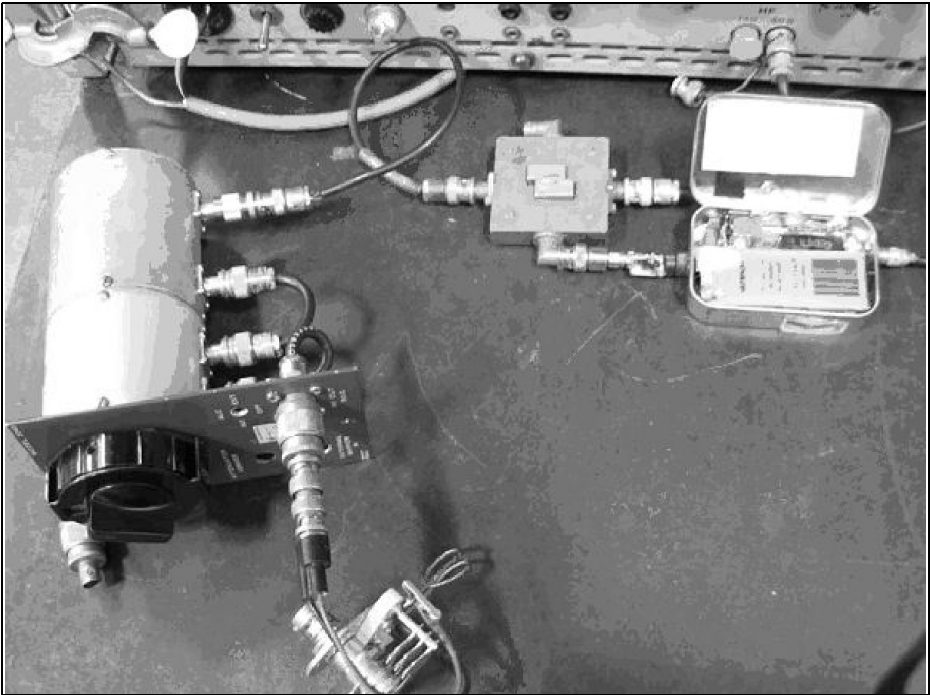


Fig 3: Closer view of the SWR setup. Clockwise from 7 o'clock: LC resonator, the variable attenuator, the double directional couplers and the AD8307 logarithmic output RF detector. A DMM is outside the picture.

should not be any if the meter is good. It may be practical with rotor grounded.

In preparation for this article I tested this with the setup shown in Figs 2 - 4 but got no effect at all. This could be because the Mini Circuits couplers are so good. I have a lot of my stuff packed away because of a move but am finally able to unpack it in a local storage space. The available supply of couplers to test was limited.

4.0

How coupled lines work

To understand how coupled lines works we need to take a closer look at what constitutes a wave in Fig 5. Looking at

the electric and magnetic field around the main conductor, in the direction of power flow, there is an electric and a magnetic vector, both perpendicular to the direction of the flow of power, the \mathbf{P} , vector. This is also called the Poynting Vector. When \mathbf{E} and \mathbf{H} are multiplied according to the rules for vector multiplication, the result is a \mathbf{P} vector such that \mathbf{E} rotated 90° clockwise to \mathbf{H} results in \mathbf{P} into the paper. The magnetic coupling and the electrostatic coupling (small capacitors) are indicated in Fig 5

In Fig 5 RF is fed into the Main Line (the heavier) from the left side and a load on the right side is absorbing the signal (in the attenuator) more or less.

If the attenuator is set to 20 or 30dB, the absorption is near total, making a near perfect load, no matter what is on the far side.

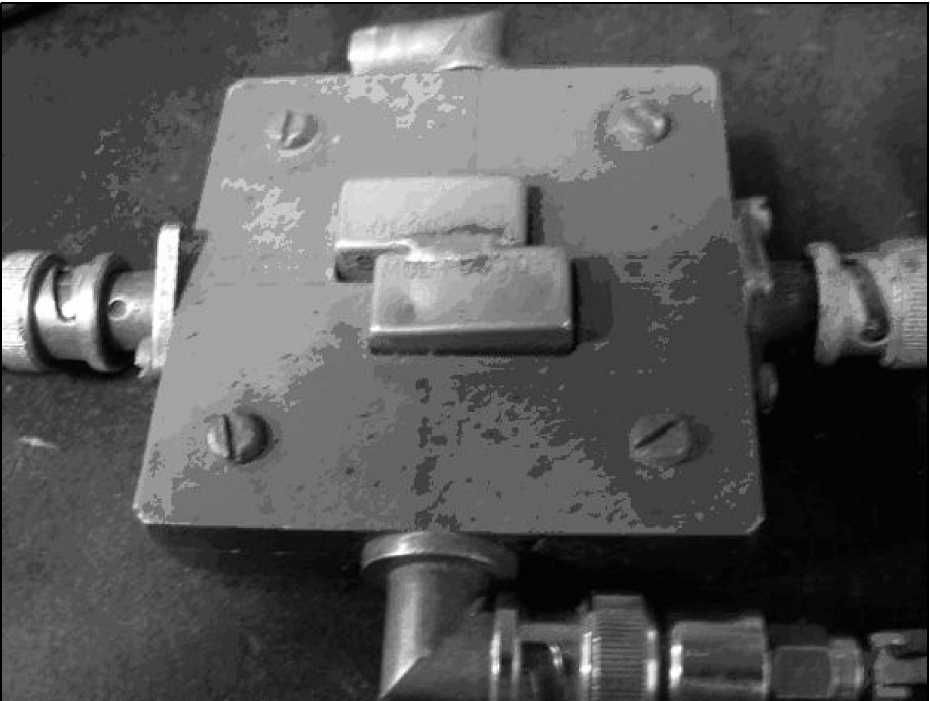


Fig 4: The dual Mini Circuits PDC-10-1 Directional Couplers.

If it is set to 10dB, there is a reflection, “Return Loss”, of twice -10dB , 20dB Return Loss. This is still a good match but a decent SWR meter should pick it up; 1:1.222. The remaining, small, reflection can be rotated with one of the LC circuits after the attenuator and the reading on the meter should not move!. Either a series or a parallel circuit will give the rotation of the reflection through 360° .

The coupled lines are also the basis for a directional coupler. A short line runs for a $\frac{1}{2}$ wave or so in parallel with the main line. This couples the short line both capacitively and inductively to the “main” line. A lesser signal, the “Coupled Signal” is developed in this short line. One end of the shorter line is terminated *with the characteristic impedance of this smaller line*, not necessarily 50Ω . If the line is a piece of thin wire, it may well be 100Ω . The other end of this

line is the Coupled RF output, where the coupled signal can be detected. If two such coupled lines are laid next to the “main” line, in opposite directions, a “Bi-Directional Coupler” is formed and an SWR meter can easily be built.

In SWR meters, these thin lines probably have a higher impedance than 50Ω . This does not matter; it may actually be an advantage, as they usually are feeding crystal diode detectors. It may even be an advantage as the crystal detector impedance is more than 50Ω !

Professional Directional Couplers usually have coupled ports as close to 50Ω as possible. They are then terminated with just a 50Ω resistor at the far end. If you have any doubt about your couplers, just measure the termination of the coupled ports with a regular Ohmmeter!

Referring to Fig 5, and 6, the coupling

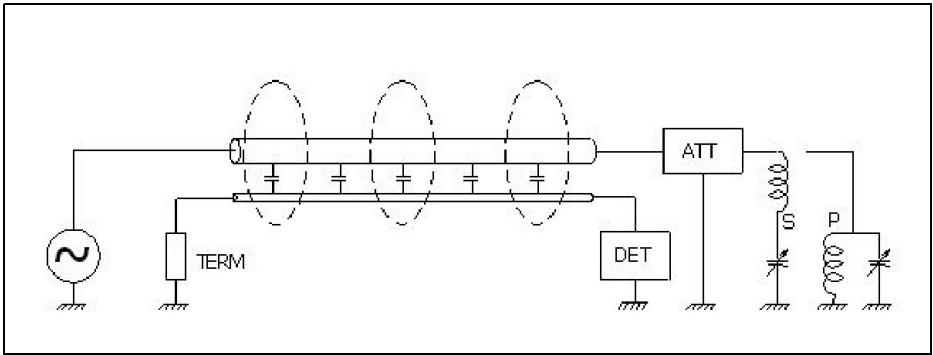


Fig 5: The SWR meter with a test load.

section is the parallel lines. The coupled line is usually made of a thinner conductor.

The capacitive coupling between them is indicated by the small capacitors between the lines. The magnetic coupling is indicated by the dotted ellipses encircling both lines. The terminations of these lines determine the direction of the waves coupling to the sidelines. The coupled energy is directed away from the terminations. There can be one on each side of the main line, or two after each other. The coupled line must be terminated with its own characteristic impedance, Z_c , (often not 50Ω) on one end and a detector on the other. For a plain wire Z_c is probably in the 100Ω range. If we use a detector like AD8307 on the other end, life becomes beautiful! It has some 1100Ω input impedance, so it is easy to put it on the end of the line and a surface mount resistor in parallel!

Lack of attention to the termination of these lines, 110Ω or whatever they may be, is how the SWR detector, or bridge, can have different sensitivity to reflections with different arguments! So this is where the method described becomes useful for trimming the terminations of these coupled lines for a good response. Vary the argument of the load, by tuning the C (easier than tuning the L) and adjust the pick-up line load for a constant reading at all arguments! Besides trim-

ming the resistor value, there may have to be a small reactance added to either end of the line!

The two, coupled, lines can each go to one detector and to meters where the SWR can be read out.

5.0

The Detector

Traditionally, the detectors are Ge diodes, such as 1N34. This works well for up to some 500MHz and at reasonable power levels, around a mW or so. Microwave couplers can use 1N21 or 1N23 up to 10GHz. A shortcoming, when used with low power levels and a when measuring a reasonably good match; the signal to the detector for reflected power will of course be very weak. If this signal goes below -50dBm the diode may not produce a useable output. The difference between forward and reflected signals, as detected, will then begin to look as if the SWR is infinitely better than it is.

Consider that the coupling to the detector line may be some -15 to -20dB , so the -50dBm to the diode may occur for signals with a level of -30dBm and reflected wave from a good load even at 0dBm .



Fig 6: The logarithmic detector AD8307 in its box with battery and output amplifier as described in VHF Communications 1/2004.

Nowadays we have the means to break with this tradition and limitation. The added complication is not serious: two logarithmic detectors for some \$12 each. For example AD8307 up to 900MHz or AD8313 working up to 2.4GHz. A small, stabilised, supply with a +5V regulator (78L05 or similar) is needed for the log detectors. The great advantage with these detectors is that their outputs are DC and proportional to the logarithm of the RF signal amplitude. The reward is a direct reading of RL from the difference between these two signals!

Therefore, the difference in DC output from the detectors is greatly independent of the RF level of the “main” signal level over a wide range! Another great advantage is that these detectors are more sensitive by far than the best diode detector, typically registering -70dBm , even up to 2.4GHz. In addition, they are frequency independent, better than the usual diode can ever be!

A simple, non-stabilized, ± 12 or 15V supply can drive a couple of OP amps or even better: an Instrumentation Amplifier, subtracting the two DC voltages from the detectors, providing a direct reading RL meter, in dB! The positive side of the 12 - 15V can supply the

78L05 regulator as well.

If we use the logarithmic detectors in our SWR meter, a total reflection will of course result in equal DC signal on both outputs! A case of $\text{SWR} = 1.0:1$ or $\text{RL} = 0\text{dB}$.

The directivity of a directional coupler is finite AND will ultimately play it's part. Even with a perfect load, when the reverse directional coupler should register nothing, it may provide a small signal in error. The termination that will result in no signal from the coupler may be a slight mismatch. If the coupler is specified as having 30dB directivity, then that (-30dB) may be the worst case of a mismatch that cannot be detected

In Fig 7 the AD8307 or AD8313 detectors, in the small package, connected to a pickup loop along the main line. It is terminated with a resistor (100Ω) at the left end. Both inputs have DC blocking capacitors on their pins. The inputs are DC biased internally, using the differential inputs in a single mode. With two such lines and detectors, one on each side, the ratio between the signals can be calculated and the actual RL can be displayed directly. SWR you may have to look up in a conversion table or calculate.

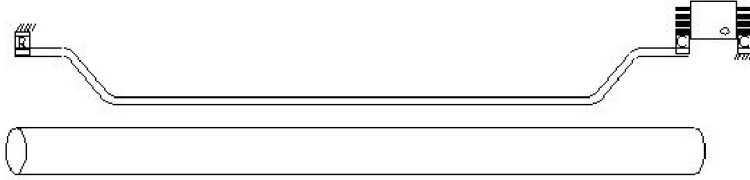


Fig 7: A coupled line and its detector.

These days RL is a more relevant measure of mismatch than SWR.

Using my 30 year old PDC-10-1 Mini-Circuits Directional Coupler and a signal generator with 10mV output I made the plot shown in Fig 8.

The bump at 35dB RL is certainly my mistake during the measurements, and not the response of the logarithmic detector AD8307, here operating at 80MHz. We see an excellent linearity of the response all the way down to a RL of 50dB! Remember that this is done with

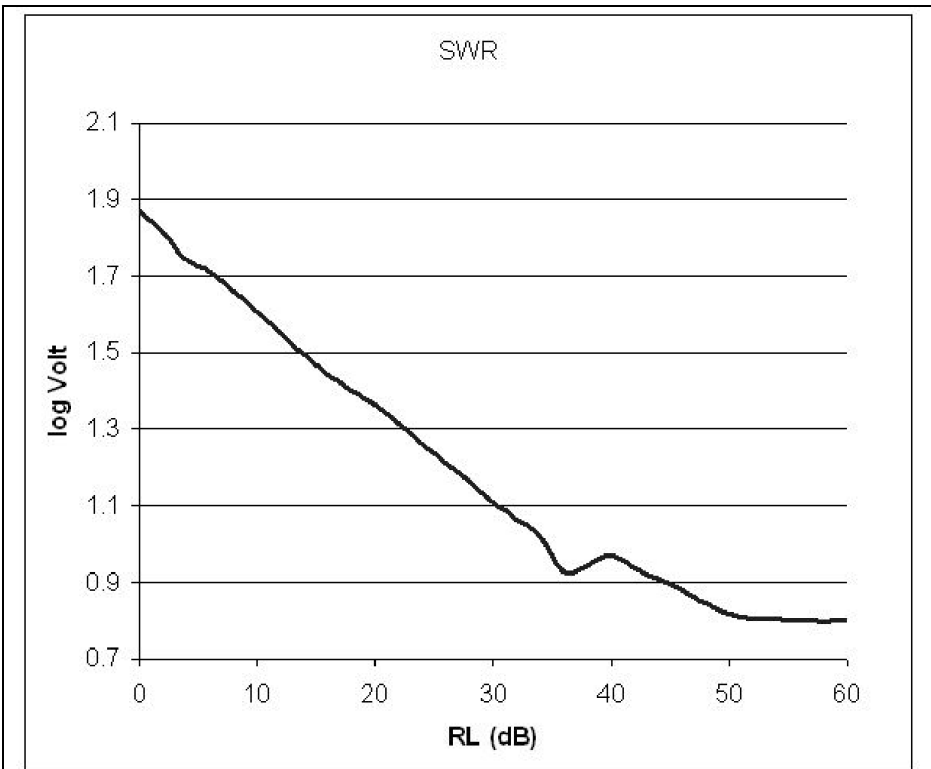


Fig 8: The beautiful performance of the RL meter!

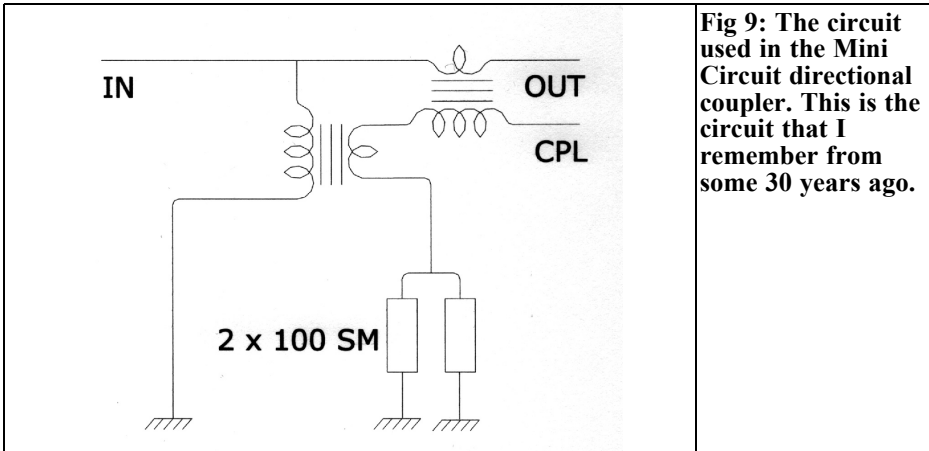


Fig 9: The circuit used in the Mini Circuit directional coupler. This is the circuit that I remember from some 30 years ago.

10mV from a signal generator! This is not a measurement to be relied on as a measurement of RL. It is maybe fortunate that it looks so good! Experience with a meter that you build will reveal how useful it is for very small returns. So a log detector certainly has a place in the future reflectometers!

As a matter in fact, if the RF power is kept constant, the forward coupler and detector can be replaced with a small potentiometer. In my case I got 1.8V dc from the detector with the load removed ($RL = 0$) for a total reflection. The 5V stabilized supply can drive a trimmer potentiometer of a k or so. The load is removed, making the reflected signal maximum and the trimmer is set to balance the output of the log det on the reflected signal coupler. The reading of the difference is possible with an Instrumentation Amplifier and the meter can be calibrated in dB RL directly. At 0dB RL the difference is zero so the meter can start on the left end and go as far as one wants to go on one range, but it seems to me that 0 – 50 (or - 60) dB is nice and would agree with many meter dials.

This is a very large range, one that probably exceeds the directivity of the coupler. 0 - 40dB would satisfy, and probably exceed, most needs and the capacity of the coupler.

I cannot find my notes about the type of Directional Couplers that Mini Circuit use. I even built some about 30 years ago and I had them on my finger tips. That was then!

Fig 9 shows what I remember, they were two transformers, usually one “binocular” ferrite core, sensing the current and voltage of the through line. The voltage was transformed into a current and the current was transformed into a voltage. These currents and voltages, and a 50Ω resistor (the 100Ω resistors shown in parallel making a good 50Ω resistor), formed the coupled port. Therefore these couplers can be made to have a wide bandwidth, whereas coupled lines, as in Fig 5. have a “sweet range” where the lines are about $\frac{1}{2}$ wavelength long.

The author wishes to thank Mr José Geraldo Chiquito for his very valuable suggestions and help with keeping my scattered thoughts and ideas on a line, straight enough to merit, and perhaps deserve publication. Any remaining errors are in spite of his efforts.



Gunthard Kraus, DG8GB

Possibilities and limits of circuit simulation for radio amateurs

Revised version of the lecture to the UKW conference 2009 in Bensheim

1.0

Sense and purpose of circuit simulation

Everyone who has already developed circuits knows the questions that torment those who do this work:

- How do I find out how the circuit functions?
- How do I create the data required?
- Will I find the optimum?
- What things that I have not considered could affect the results?
- Will the circuit work “cleanly” without oscillating?
- Do component and manufacturing tolerances affect the results?
- Do I have alternatives if the solution chosen leads to a dead end?
- etc.

Circuit simulation can answer most of these questions before a prototype is manufactured or a soldering iron is touched. However exact knowledge of the desired circuit behaviour is absolutely necessary. Working with the simulation as well as any changes are ALWAYS the responsibility of the developer

- no program can replace your specialised knowledge (even if the advertisement suggests otherwise).

The use of circuit simulation always means precious work time is saved. Also alternative ideas can be examined quickly or a prototype can be optimised.

2.0

The different types of simulator program

The differences are:

- Simulators that work in the time Domain. These are in principle all SPICE and PSPICE programs. “SPICE” stands for Simulation Program with Integrated Circuit Emphasis and “PSPICE” is simply SPICE for the PC.

They provide all the information about stability and starting behaviour. The response to signals with arbitrary waveforms is determined by splitting the signal behaviour into very short, but practically linear sections. Additionally all nonlinearities in the circuit are identified.

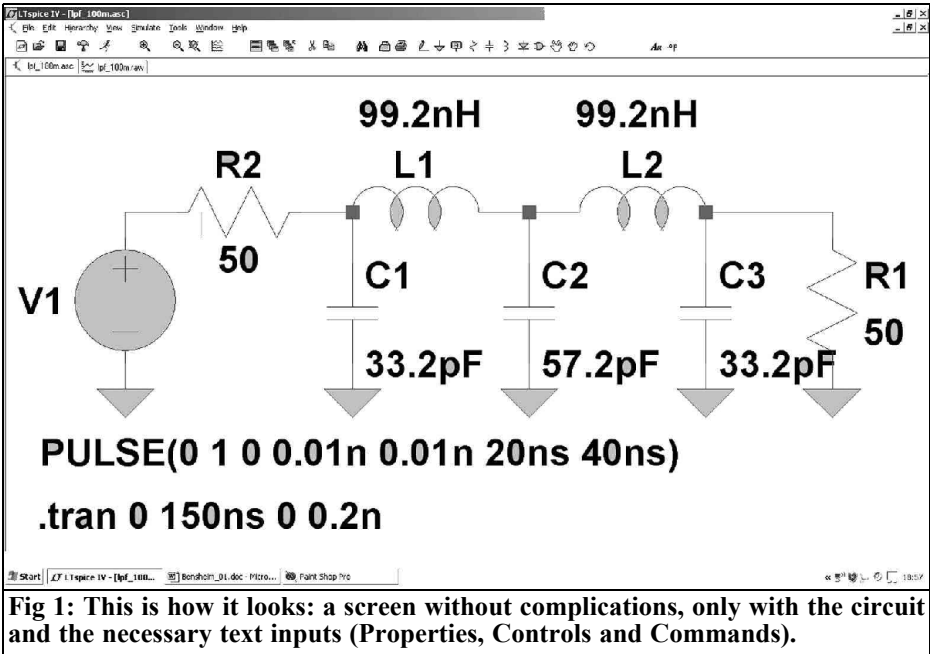


Fig 1: This is how it looks: a screen without complications, only with the circuit and the necessary text inputs (Properties, Controls and Commands).

Other options are the AC-Sweep (wobulator to determine the frequency response), noise simulation and the FFT (Fast Fourier transformation) for the analysis of a signal in the frequency domain (spectral representation). Thus they offer the most comprehensive possibilities, but the simulation accuracy always depends on the quality of the SPICE models. These are supplied with the software or by the component manufacturers. In reality they specify exactly how the simulation and reality will agree.

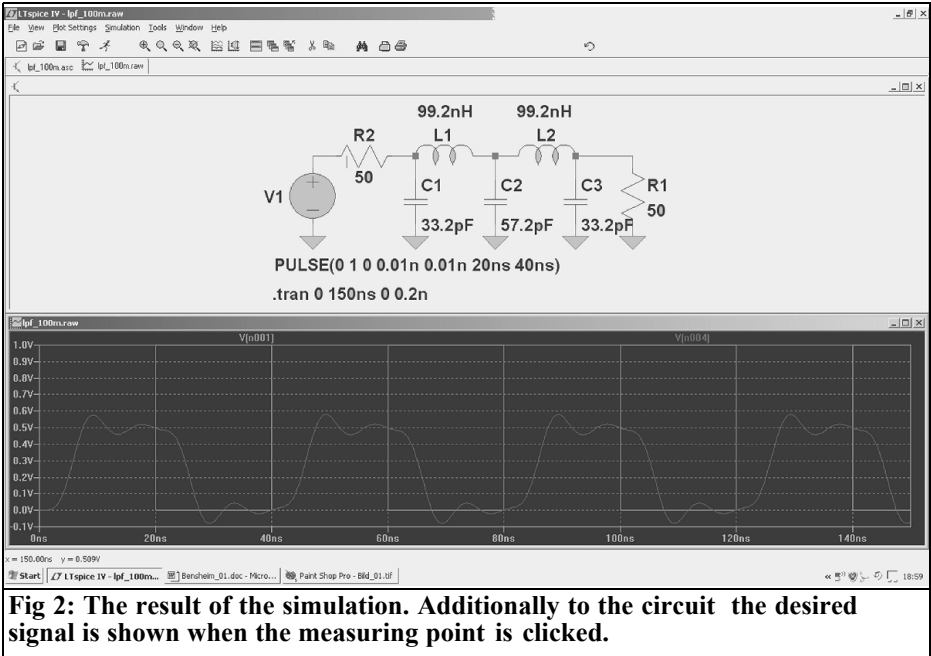
- Simulators that work in the frequency domain, these often use S-Parameters (some also convert Y-Parameters to S-Parameters). So vector network analysers can be used to check the simulation or to gain the necessary component properties for the simulation itself. This achieves a good agreement between simulation and prototype. A disadvantage with this in the RF and microwave area (to over 100GHz) is that it is principally

a linear simulation (a small signal system). Information about distortion with large signals is usually only available with cheats that the program may offer (e.g. using harmonic balance) and these are normally secrets of the software vendors.

- EM simulators use the distribution and the relationships of the electrical and magnetic fields around “structures” for analysis. They can be divided in two groups:

For things with surfaces (Patch antennas, couplers, stripline filters etc.) The complete structures are divided into very small rectangular or triangular “cells”. The individual fields for each cell are computed and finally all added together.

For wire antennas (or similar wire objects) these are known as “NEC”. The structure is also divided into small elements, in this case short pieces of wire with linear current and power distribution. These elements



can be examined more easily to calculate the total behaviour of the arrangement by addition of all individual calculations.

include EMV simulation and also a simple SPICE simulation (e.g. Target).

3.0 SPICE simulation for the radio amateur

The situation is very much relaxed because the restriction “for the amateur” usually means reduced price. It is not a problem to spend €50,000 on simulation software, these are enormous machines that can be used to design the associated printed circuit board and examine the EMV behaviour etc. For the private person money is replaced by time. In practice that means a reduction of comfort as well as a separating the simulation from the PCB CAD. There are already affordable solutions for PCB design that

The large SPICE software manufacturers always supply free demonstration versions of their products, but these make you grind your teeth in the middle of a simulation with a message like: “all components used” or “MEMORY restricted in this version”. Above all because, unfortunately, the design started can never be transferred to a more complex (and more expensive) program variant.

A program for amateur purposes (or training purposes!) should have the following features:

- Little or no cost
- No restrictions or limitations, thus fully functional
- An easy import of new component models from the Internet
- A good user group removing the

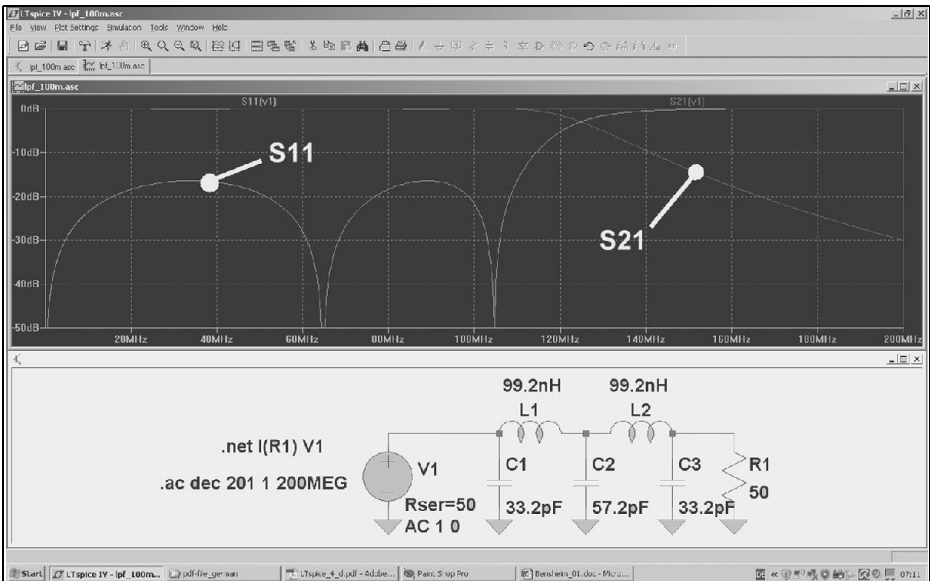


Fig 3: The simulation of S-parameters requires a different spice directive and a new simulation command.

dependency on expensive support for questions or problems solving

Fortunately the company Linear Technologies has made a free version of their PSPICE software LTSpice IV available to engineers on their homepage [1]. There is no problem to download the software, even the registration before download can be refused. Importing new models from the Internet is problem free and there is an easy to use symbol editor.

The only drawback in using the software is that it has a very simple user interface and it takes some time to become familiar with the mixture of keyboard and mouse commands required.

Note: there is a Tutorial (in German or English) for this program on my homepage [2] that can be downloaded free of charge. It contains an extensive collection at practical projects for training.

The use of LTSpice will be demonstrated using the example of an 110MHz Tscheytschef low pass filter for a characteristic impedance of 50Ω driven with a 25MHz square wave signal. The screen shown in Fig 1 is produced.

Beside the circuit there is the facility to include additional text lines this requires some explanation:

The line "Pulse..." below the circuit defines a square wave signal with $V_{min} = 0V$ and $V_{max} = 1V$. The rise and fall times are 0.01ns with a pulse length of 20ns and a period of 40ns. The signal begins immediately at the time $t = 0s$.

The line ".tran..." defines the time period, in the time domain, that will be simulated. The time period is 0 to 150ns that will be divided into maximum 0.2ns time steps.

After the simulation is started the screen is divided and an empty result diagram



appears for the simulation (Fig 2). Clicking the mouse on the point of interest in the circuit immediately displays a diagram of the signal at that point (from the initially starting point of the circuit). Using different mouse clicks and sub-menus the result can be adjusted until the desired results are achieved (e.g. several diagrams, different values or different colours for the curves...).

For an S-Parameter simulation the internal resistance of the source (50Ω) must be set in the "Property" menu and an AC Sweep programmed with a SPICE simulation COMMAND (Wobulator from 1Hz to 200MHz with 201 points per decade, decade sweep). The Spice directive ".net I (R1) V1" specifies an S-Parameters display. The final result is shown in Fig 3.

4.0

S-Parameter simulation for the radio amateur

4.1. Some basic information about S-Parameters

System descriptions and computation start from approximately 1MHz upwards with the highest frequencies (today more than 100GHz) easily measured. These require a completely different model:

Everywhere in the system the same system resistance is used (usually 75Ω for entertainment electronics or video technology and 50Ω for most other areas). This defines the internal resistance of the signal sources, the output resistance of the modules used, the characteristic impedance of all cable connections and all terminating resistors.

The principle of this technique is perfect power matching ($R_i = R_a$) everywhere in the system.

Using suitable measuring instruments (directional couplers) the deviations of the ideal resistance are measured at the input and output (technical term: "Ports") to calculate the "reflection factors" (S-Parameters S11 and S22).

The power output can be calculated from the input power multiplied by the "forward transmission factor" (S-Parameter S21).

The effect of a component from the output back to the input is the "reverse transmission factor" (S-Parameter S12).

A complete system has many components connected in line. Using suitable software the total behaviour can be easily determined.

4.2. Using PUFF

This well-known DOS program available from [9] is probably the standard program used by radio amateurs for nearly 20 years and has not retired yet. It is low priced, has minimum memory requirements, high stability and simulation accuracy. It is simple to operate using key commands with the most important basic models available. Clear screen layout makes it the RF pocket calculator for the developer making it easy to quickly test new ideas. In addition it has been upgraded again and again and even made compatible with Windows XP.

Note: my homepage [2] contains all documents required and help (including a detailed list of the control commands with explanations and a guidance plus a "PUFF_XP-Servicepack" for trouble free operation under Windows-XP - sorry but only in German.

The complete PUFF simulation of the

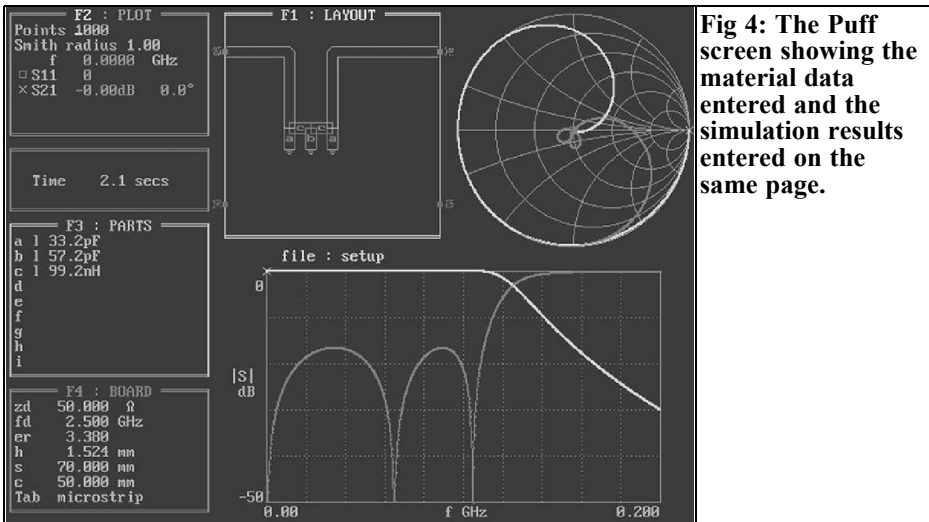


Fig 4: The Puff screen showing the material data entered and the simulation results entered on the same page.

110MHz low pass filter is shown in Fig 4:

The screen shows component input, results by Smith Chart or graph, PCB layout and most importantly the material data.

The disadvantages are not too bad: both input and output of diagrams is dated (particularly expressions). Using PCX output for diagrams and screen shots helps. Important models for failure areas are missing e.g. for micro strip lines etc. It has not been changed for Windows Vista. Nevertheless for fast testing of an idea, the speed and operation are unbeatable with the same accuracy as large expensive simulators. The restrictions must simply be accepted.

4.3. ANSOFT Designer SV

This uses the most modern simulation techniques. It is one of the best Windows programs with all conceivable facilities. Hundreds of components and failure area models cover all conceivable applications up to waveguide. An integrated filter calculator saves the search for a suitable external filter calculation program. The complete linear simulation of the expen-

sive ANSOFT product is included without restrictions for study purposes in the Student Version (SV), it is free of charge and can be downloaded from [4].

This is a well thought out marketing strategy; if students learn to know and love such a program they will want to use the same with greater security in a later job. Thus the limitations are set accurately where it would cause problems to a company that tries to use it secretly. The direct creation of a draft PCB is missing, the very good, and patented, nonlinear simulator is missing and the automatic optimiser is restricted.

However this is ideal for amateur radio use but I have some nostalgia for PUFF. A complex program such as ANSOFT Designer SV with so many fascinating possibilities clearly requires more training and operator effort. The input and simulation are separate and some work is needed to produce the output required. There is nothing that cannot be shown; there are stability values, S-Parameter, noise figures etc....

Note: an extensive Tutorial (in German or English) can be downloaded free of

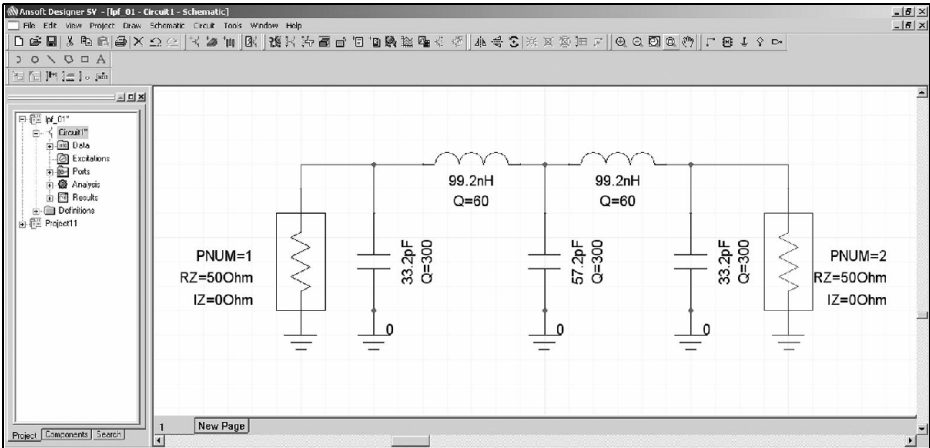


Fig 5: The input screen for an ANSOFT project, the designer must spend time producing this data.

charge from my homepage [2]. It contains many a projects with active or passive components. The first part of a project is shown in Fig 5 i.e. the input of the circuit for the simulation. A screen display of S11 and S22 in graph form as shown in Fig 6 can be displayed if required after the simulation under “Results”

5.0

EM simulation for the radio amateur

5.1. Simulation of flat structures with SONNET Lite

The comments about the good marketing

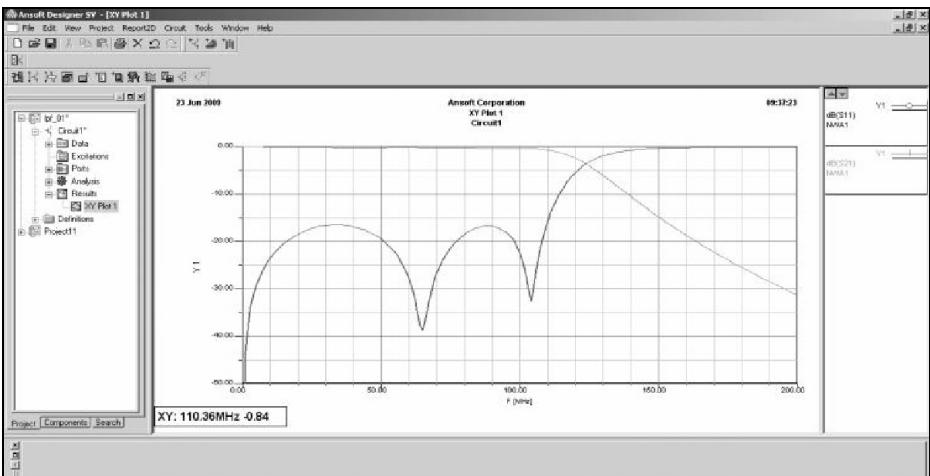


Fig 6: The results after simulation shown after choosing the required display.

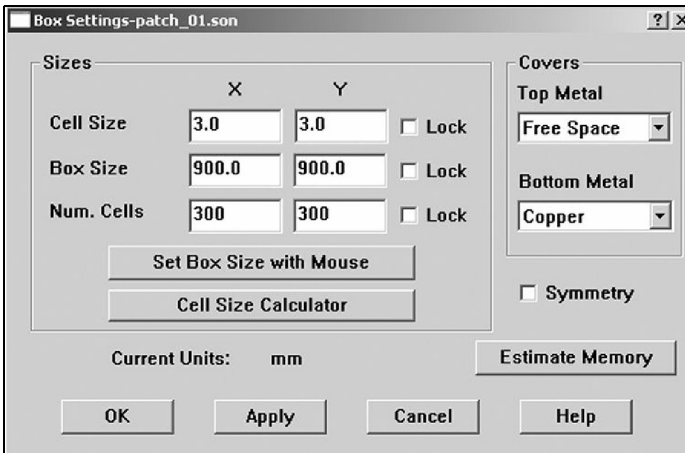


Fig 7: The most important part of a SONNET simulation is correct definition of the box characteristics.

strategy by ANSOFT also apply to the Sonnet Company. With this program a definite limitation is made for the maximum useable storage, that gives somewhat greater inaccuracies in the final result of the simulation but these are still quite acceptable.

The following applies:

- If you just download the free program and install it you get 1Mb of storage.
- If you register on line after installation and request a free licence you can suddenly use 16Mb.

Since improvements in the simulator are incorporated in the Lite version it becomes more efficient saving on the use of storage.

Training for this subject is clearly more difficult than for PSPICE or PUFF. It can be done by specifying the surfaces, the individual cells sizes and the different materials used. Then the signal injection must be made correctly. Again and again the storage used must be controlled.

Note: There is a list of my publications in UKW Berichte (The German version of VHF Communications Magazine – generally all articles published in UKW

Berichte appear 2 issues later in VHF Communications Magazine, if you cannot find an article there is a full index for VHF Communications Magazine in the web site [9]) on my homepage [2].

An interesting program, SONNET Lite 9.51 was published in VHF Communications Magazine issue 3/2004. It contains exact instructions for using the program and two different patch antenna simulation sample applications. This guidance can still be used for the most modern program version.

For training and assistance with problems there are a great many examples, application notes and tips on the homepage [5], the FAQ section is really first class, or on the Internet.

Generally everything is great, but one thing does cause pain; the simulation of the radiation patterns as well as the antenna gain computation are intentionally missing. Unfortunate....

As an example the simulation of a square patch antenna made from FR4 material for the frequency $f = 435\text{MHz}$ will be used. The input impedance of the antenna is determined relative to the patch edges. The following must be considered:

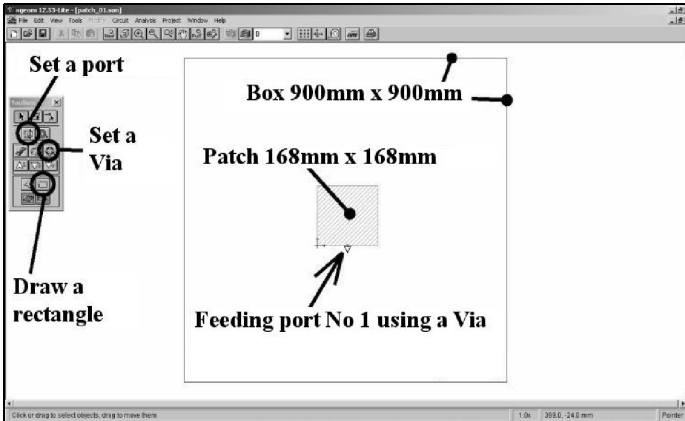


Fig 8: The antennas structure designed with a feed port Using a Via all inside the box.

SONNET is only an analyser and NOT a design program. It only tests the finished ideas of the user.

Thus the basic design of the antenna must be produced e.g. with the free DOS program “patch16” that can be found easy on the Internet (enter “patch16.zip” into a search engine). It is excellent because it is simple and easy to use. An A4 (210mm x 297mm) double-sided copper clad FR4 laminate board 1.52mm (0.06 inch) thick is used. The dielectric constant is 4.35 and the dissipation factor tand is 0.01. The Patch program gives 6.61inch x 6.61inch = 168mm x 168mm as antenna dimensions to be taken forward to SONNET for simulation.

The PCB material is entered with the metals involved and “the box” data as shown in Fig 7. SONNET uses a rectangular box, with the PCB to be analysed inside, as basis of the simulation. The field distribution in such a box is well known and calculable. The user must program the details.

The first step is to enter the box dimensions (with half a wavelength distance between the structure to be examined and the walls in each direction). The length and width as well as the number of cells that the structure is divide into must be specified. The cell width or length may

not be more than 5% of the wavelength otherwise the accuracy suffers. It should not be much less as 1% for the same reason. The optimum is between 1 and 2%.

The screen shown in Fig 8 is the SONNET screen after completion of the input work; it should then be stored under a suitable name.

Next the sweep frequency range is programmed - here a reasonable setting is 400 to 500MHz. Now the simulation can start but as usual with large programs there is NOTHING to see. Programming the presentation of the results has its own procedure (View Response/Add to graph) and produces the screen shown in Fig 9.

The resonant frequency of the antenna can be seen easily and is still approximately 7MHz too low. But it cannot be seen from this presentation if the input impedance (made up from the parallel connection of the resonant element, the radiation resistance and the losses of the PCB material) is larger or smaller than 50Ω . A Smith Chart is required and there is a button “graph” in the menu border for this purpose. When this is selected there is a question; “Cartesian” or “Smith”, the remainder is automatic.

The actual input impedance is not shown

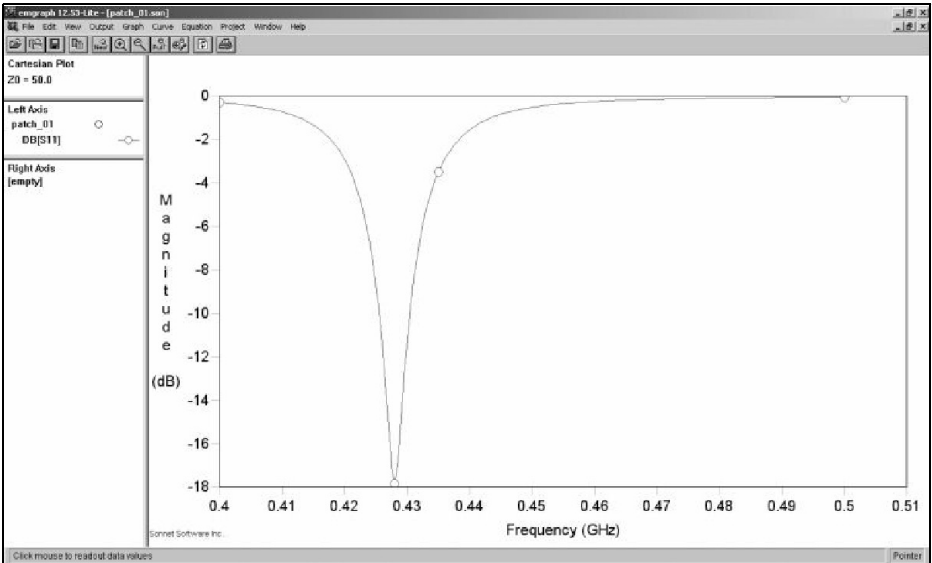
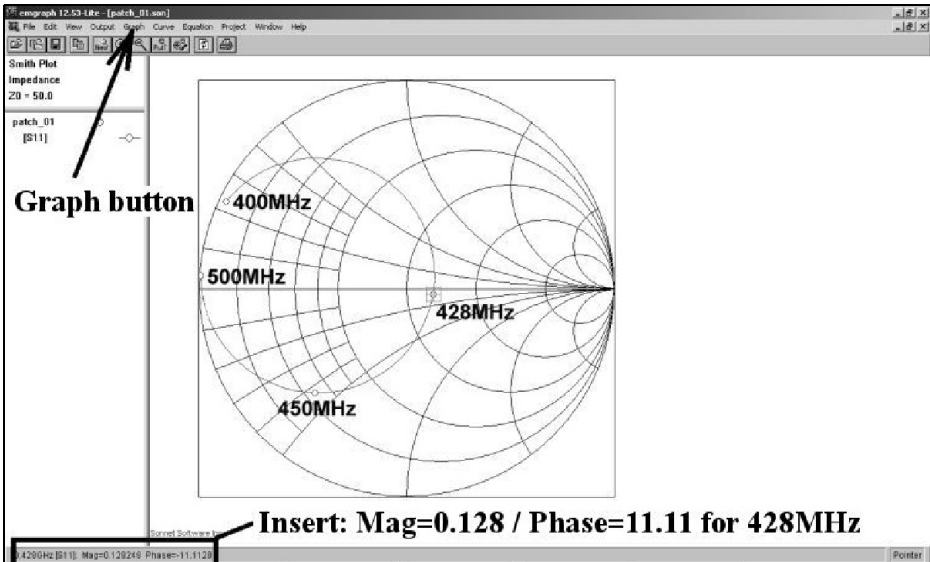


Fig 9: The first result to show is the reflection factor S11 that shows the resonant frequency of the antenna.

in Fig 10; it takes some of work to determine from the input impedance at the feed point:

We have to use the reflection factor r (“Mag”) of approximately +0.128. The following operation is performed using pocket calculator:



Graph button
Insert: Mag=0.128 / Phase=11.11 for 428MHz

Fig 10: The Smith Chart is indispensable to calculate the exact input impedance - see text.

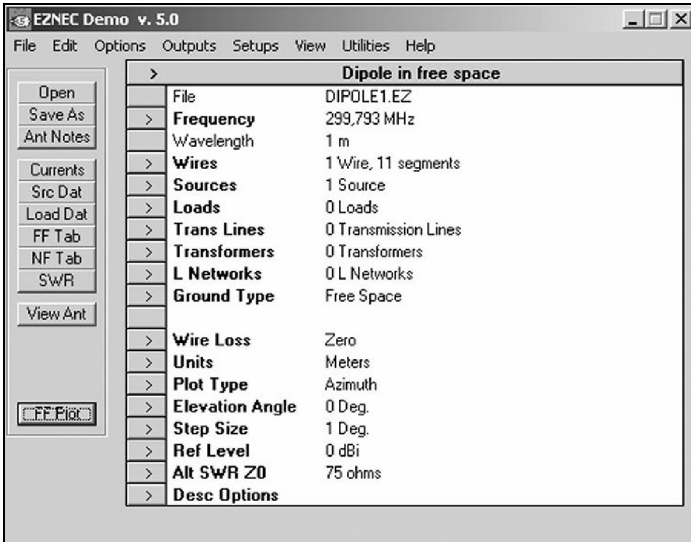


Fig 11: The input form of EZNEC will automatically load the last design that can just be re-worked.

$$R_{IN} = 50\Omega \cdot \frac{1+r}{1-r} = 50\Omega \cdot \frac{1+0.128}{1-0.128} = 64.67\Omega$$

To see the pure radiation resistance at the patch edges the simulation must be repeated with the PCB losses set to zero and the metal losses set to “lossless”. Only then is the radiation lossless.

The great thing is that experience shows that the simulation agrees quite exactly with the results of measurement made on a prototype. The resonant frequency is always somewhat high (usually between 1 and 3%), that is unfortunately typical for all EM simulators.

But this isn't a serious problem: manufacturing a sample PCB determines the deviation from the desired value and dimensions are corrected using a pocket calculator. If the dimensions are larger this results in a larger wavelength and therefore a lower frequency.

We can only wait and hope for the calculation of the radiation patterns for the antenna...

5.2. Simulation of wire antennas with NEC

The Lawrence Livermore laboratory developed a simulation method for wire antennas called NEC (Numerical Electric Code) in 1981 for the Navy. The antenna is divided into very short pieces = “segments”, where the current and the voltage change is (nearly) linear (see SPICE). Thus amazingly exact simulation can be accomplished.

The standard used in a great many free application software packages is NEC2.

The development continued and the weaknesses of NEC2 e.g. wrong computation of structures close to or crossing wires buried in the soil were corrected by NEC4, but:

NEC4 was, until recently, not available and was considered in former times as secret. Today it is available outside of the USA but costs a lot of money (normally between \$2,000 and \$4,000).

The private individual (small purse) must be content with NEC2 and the only problem is the choice from the selection

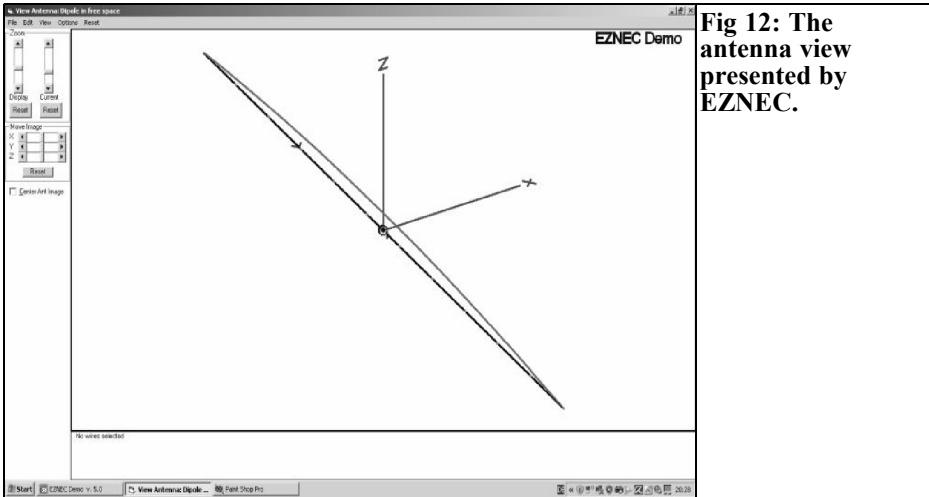


Fig 12: The antenna view presented by EZNEC.

available on the Internet. It is reasonable to select something that:

- Is already in common use
- Has good input and output facilities
- Has an easy to understand output
- Is regularly and well maintained
- Gives Near and Far Field simulations
- Has many examples, help and support on a forum.
- Has a good manual and help
- Does not cost too much

For these reasons many radio amateurs and antenna developers have used EZNEC by Roy Lewallen, [8] for years. It has a fair current price of \$89 with direct Download and payment by credit card.

Fig 11 shows a view of the operator interface of the newest version 5.0. The data is for a simple 299.793MHz half-wave dipole that is one of the examples supplied. This only shows a row of buttons and screen with input lines. The reason for this is:

EZNEC does not use the philosophy that

shows an empty sheet when starting, but always shows the last loaded example. Simply retrieve a suitable antenna from the archives and change the appropriate lines of the menu. For investigation your own antennas you should collect a large supply of different simulated antenna types. This proceeding is somewhat differently, i.e. re-engineering, but it is not bad.

Fig 12 shows the screen after clicking on “View Antenna “. The antenna wires are shown in a coordinate system arranged in moveable segments using the controls located on left of the screen.

Clicking on “FF Plot” (FF stands for Far Field) produces the radiation pattern (Fig 13), the cursor can be used to read off the curve. A different elevation view can be selected under “Setups” in the main menu, there is even the option “Near Field”.

Tip: For those who would like to see the radiation pattern in 3D and in colour, get yourself the program “4nec2” from the Internet.

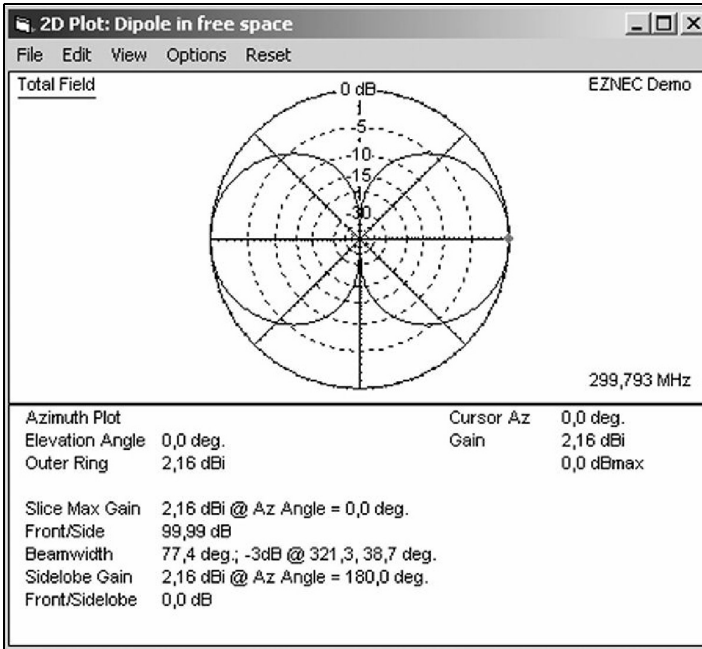


Fig 13: The simulated horizontal Far Field diagram for the antenna.

6.0 Other antenna simulators

On the Internet there are antenna simulation programs that work with approximation formulae. The program "patch16" has already been mentioned in the SONNET chapter, but there is a DOS program on the Web that can show the dimensions of many types of antenna (wire and patch antennas, log periodic antennas, antennas with parabolic reflectors and horn antennas) on the screen by entering the requested data. This free "Jack of all trades" is called "pcaad21.zip" and even as a DOS version does not loose its attraction.

Now have much fun and success with the design of your own projects and simulations. But also use the programs for error analysis, fine tuning and finishing development work.

7.0 References

- [1] Linear Technologies, homepage for LTSpice IV, www.linear.com
- [2] Gunthard Kraus, DG8GB, homepage under Tettngang Electronic School, www.elektronikschule.de/~krausg
- [3] Reader service UKW Berichte, www.ukw-berichte.de
- [4] Homepage of ANSOFT, www.ansoft.com
- [5] www.sonnetsoftware.com
- [8] www.ez nec.com
- [9] VHF Communications Magazine web site, www.vhfconn.co.uk



John Fielding, ZS5JF

John's Mechanical Gem No. 7, Antenna element holders

The writer has an old 2m Yagi that was made by the defunct KLM Company. Over the years the UV has broken down the plastic parts and with strong winds and large birds sitting on the ends of the elements some had broken. Trying to epoxy the parts back together was not successful and some pieces had gone missing. The elements are all 3/8-inch diameter alloy tubing (10mm) and the driven element consists of 4-elements fed in a Log Cell to give wider bandwidth. The antenna basically needed 4 new driven element insulators and 4 other for the other directors. Several of the director elements were broken and these were replaced with new elements using the old pieces as a pattern. Pictures of the original element holders are shown in Fig 1 & 2.



Fig 1: Element insulators for the KLM Yagi. The driven elements use the larger insulators

1.0

Making new element holders

It was decided to make the insulators from wood and a piece of hardwood (meranti) was obtained. This was 20mm square and matched the width of the original insulators. The first task was to carefully measure the two original insulators and make a sketch of the critical dimensions. On the driven elements the spacing between the two inner ends of the dipoles was found to be 50mm. The boom consisted of 1-1/2-inch tube (38mm) diameter. The various steps to make the new insulators are described below.

- Pieces of wood were cut to length, allowing a little over length for



Fig 2: Another view of the element insulators. The top insulator is banana shaped due to UV exposure.



Fig 3: Machining the semicircular element cutouts.

final trimming to size.

- An angle plate was set up on the

table of the milling machine so it was square to the table. This angle



Fig 4: Machining the boom cutout in the bottom of the insulator. The edges of the angle plate allow simple alignment so everything is square.

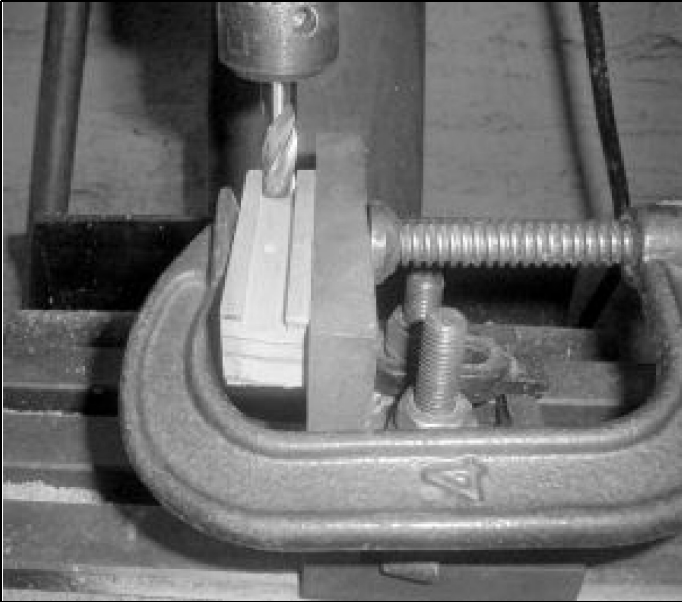


Fig 5: Machining the 10mm wide slot for the director insulators.

plate is used for all the machining operations with the wood clamped to it using G-clamps.

- The centre hole through which the securing screw to the boom passes was marked and drilled in each piece. The pieces of wood were next clamped onto the angle plate and the first machining operation set up. This was the semicircular

cutout in the ends of the driven element insulator. These were 5mm deep in the wood so half the element stood above the insulator so the feed zigzag transmission lines could be attached.

The angle plate edge is used to line up with the edge of the wood ensuring the wood is truly vertical. The cutter being used is a 10mm diameter 4-flute slot



Fig 6: Completed element insulators ready for varnishing.

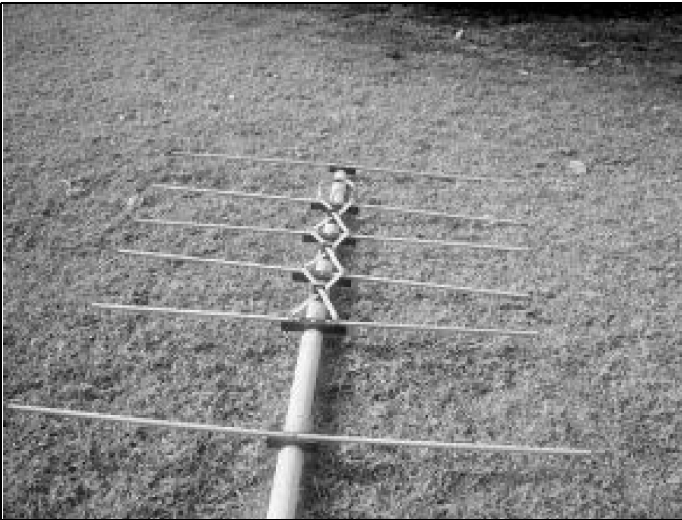


Fig 7: The repaired Yagi.

drill. An alternative could be made from a short 10mm drill by grinding the end off square to form a routing cutter, or a wood routing cutter could be purchased.

The second phase cuts the boom-locating cutout in the bottom of the insulator. This is done using a 38mm hole-saw with the wood clamped to the angle plate. The pilot drill of the hole saw is lined up with the insulator mounting hole to ensure the insulator lies in the correct plane when fastened to the boom.

The element fixing holes are jig drilled using the original insulator as a pattern.

The second set of element insulators are made in a similar manner. Instead of cutting a rounded channel for the element tube, for which a round nose cutter would be needed, the 10mm slot drill was used to form a square slot along the wood 5mm deep. When this was completed the piece of wood was turned over and the 38mm hole saw used to form the boom-locating cut out.

After all the machining was completed the pieces of wood were cut to the final length and sanded to remove any burrs.

The insulators were soaked in a wood preservative over night to seal the pores

of the wood and left to dry in the sun. They were then given two coats of yacht spar polyurethane varnish to protect them from the weather.

Reassembly was straightforward and all joints were cleaned with Scotchbrite™ cloth before tightening the screws. When assembled all the joints and nuts/screws were liberally coated with yacht spar polyurethane varnish to protect them from the weather.



Gunthard Kraus, DG8GB

Internet Treasure Trove

EME

The abbreviation means Earth Moon Earth it is a specialist part of our hobby; QSOs with the moon as reflector. Everything concerned has to be at the forefront of technology and technical know-how because the transmitter powers are limited not much signal arrives at the receiving antenna or the following LNA. This homepage presents the current state of the art information to give an idea of the requirement including the financial ones needed to succeed.

Address:
<http://www.hb9bbd.ch/index.php3>

SETI

Another exotic abbreviation that stands for: Searching for Extraterrestrial Intelligence. This web site has all the information about the many interesting spin aspects; this is sometimes at the edge of physical technology.

Address: <http://setiathome.berkeley.edu/>

Noise Figure Measurements

For those who are interested in or develop low noise amplifiers the Central States VHF Society has a league table of the best results achieved each year. It shows what other amateurs have achieved so that you can see how your efforts compare. Studying the lists will cause the genuine developer to think about their own projects.

Address:
<http://www.csvhfs.org/csvhfnf.html>

Microwaves101

For anyone who does not understand a term then this encyclopaedia is the place to look for the answer. There are many things to discover.

Address:
<http://www.microwaves101.com/encyclopedia/index.cfm>

EZNEC Model files

EZNEC is a simulation program for wire antenna simulation in the frequency



range up to 1GHz. It can save many unnecessary prototypes and tests. The program does not give complete building and assembly instruction, but the simulation results are so good that usually only fine adjustments are necessary. EZNEC is a good low cost entry into simulation. To save re-inventing the wheel it is a good idea to look at finished projects. This helps to learn how the software works and secondly an existing project can be adapted. Here is a source of such small project.

Address: <http://www.cal-av.com/2d-40-models.html>

Also this site has an interesting offer at the end to download an antenna collection:

<http://www.voacap.com/antennas/squeezing-decibels-out-of-dipole/>

ADIsimRF

This is a free program from Analog Devices that sounds very mysterious. It enables various components (filters, mixers, amplifiers...) to be connected in cascade to form a complete system. The program can then simulate the overall gain, the noise figure, IP3, P1db etc. To use the program you must be registered.

Address:
http://forms.analog.com/form_pages/rfcomms/adisimrf.asp?ref=ASCPR-066

Direct Conversion of Receivers

This is an interesting technology that demands high demands on design and construction. It is always interesting to study and see the solutions that other people have achieved. Here are several interesting examples:

Address:
<http://kd1jv.qrpradio.com/dcrx/dcrx.HTM>

<http://www.arrl.org/tis/info/pdf/9208019.pdf>

<http://www.qsl.net/ik2pii/lf/dcrx136.htm>

<http://www.njqr.org/sop/schematic%20rev%20b.html>

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!



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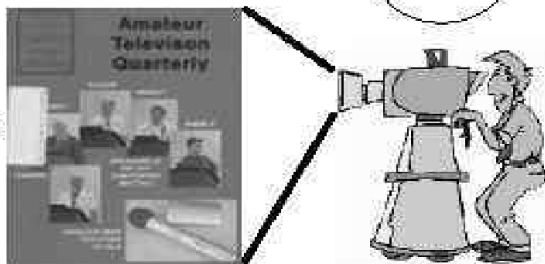
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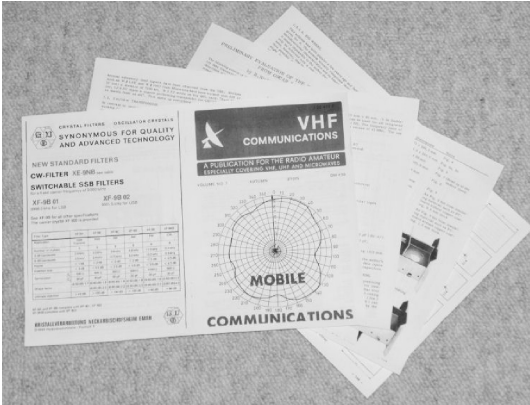
Mike Collis, P.O. Box 1594, Crestline, CA 92325

<http://atvquarterly.com>



New for 2009

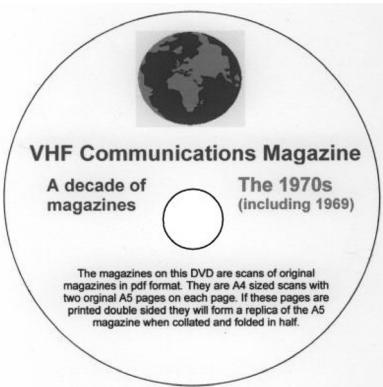
Back issues on DVD



For a number of years the back issues that are not available as real magazines have been available as photocopies. All issues for the 1970s (including 1969), 1980s and 1990s have now been scanned and stored as pdf files. The magazines have been opened up and scanned as A4 pages containing two A5 magazine pages. All pages for a magazine have been stored in a pdf file that can be accessed using a pdf file reader, they are in image format not text format.

They can be printed double sides and folded to make a replica of the original magazine.

Three DVDs are now available, each one contains a decade of magazines in pdf format. Each DVD is £20.00 - just 50p per magazine. The 1970s DVD contains all magazines from 1969 - 1979 (44 magazines) and the 1980s and 1990s DVDs contain 40 magazines for the decade. The price includes postage in the UK and surface mail for overseas. The additional price for air mail postage is £0.60 for Europe and £1.00 outside Europe,



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- Send an order by fax or post stating the DVD required (1970s, 1980s or 1990s)
- Send the correct amount via PayPal - vhfcomms@aol.com - stating the DVD required (1970s, 1980s, 1990s) and your postal address



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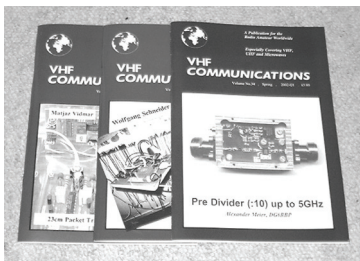
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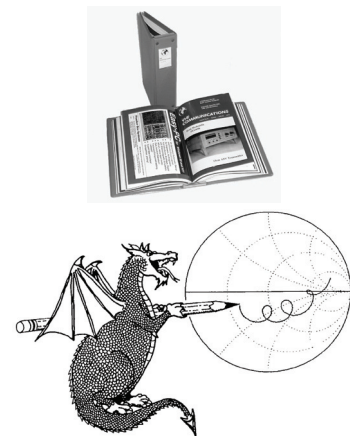
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