

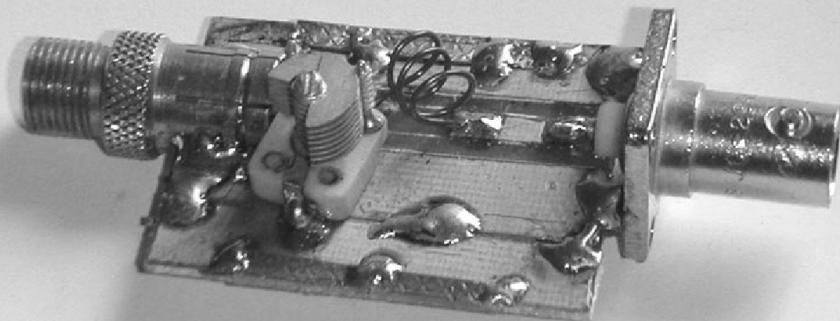


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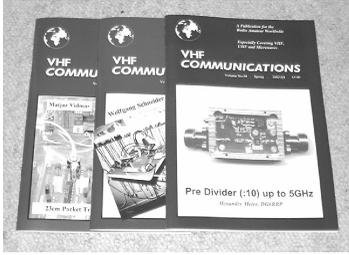
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**The noble art of piping power
to an antenna**

Carl Lodsrtöm, KQ6AX and SM6MOM

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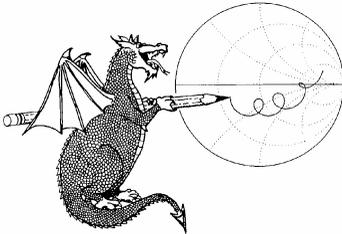
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I had a good visit to The Ham Radio Exhibition in Friedrichshafen and met several subscribers and authors of articles.

I shared a stand with Franco Rota and that has resulted in a new regular article, Franco's Finest, that will describe one of the products that can be adapted for use by radio amateurs.

73s - Andy



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

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

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Carl G. Lodström, KQ6AX & SM6MOM

The noble art of piping power to an antenna.

To RG-59 or to RG-58, that is the question. Maybe nobler to stand the losses and reflections than to never build the network.

1.0

Background

For 100W of SSB on HF I am using some 25m of RG-59 cable to feed a wire dipole. In the midpoint of the wire dipole hangs a full transformer on a toroid core. It is only some 3-4cm in diameter. Seven turns (that is what filled the little core's length) on each winding for a 1:1 ratio, also giving galvanic isolation. I am only operating on 20m and shorter wavelengths, and this little core did not even get lukewarm in a test with a power meter and 100W for a few minutes! Amazing! So for the fairly long feed, I opted to spool off some "TV cable", RG-59, that I had laying around. With its 75Ω characteristic impedance it is of course a good match to a 72Ω antenna, and the rig (a Ten-Tec 580 Delta) did not seem to mind too much either, although the SWR meter displayed the reflection from the approximately 75Ω load. It probably does not matter and the antenna works remarkably well.

2.0

Concept

It is an interesting technical "problem" though. If I remember correctly, without resorting to the literature, the RG-59 is optimised for "minimum loss", whereas other types can handle maximum power or voltage or whatever. It may not be appreciated within the Ham Community how much lower loss the RG-59 really has, especially at higher frequencies. Do not get fooled by its low cost! The reason for this may be that light-years of it that are used for all kinds of TV installations. The shield is an aluminium foil under a sparse copper braid. The connectors (F-connectors) are also very low cost. 100 connector bodies, a cable stripping tool and the crimping tool, all together cost less than a handful of BNC connectors, see Fig 1. So, there are good reasons to take a closer look at this cable, and another look at a simple matching network for to make the 75Ω cable look good to 50Ω equipment, although that part is probably not so important.

The loss indicated, for example at 146MHz 2.6dB, for the matching filter + cable is surprisingly almost entirely due to the cable! When I move the output in the model, from where it is on the schematic, to before the cable, the net-



Fig 1: Examples of F connectors.

work alone results in a 0.025dB loss! Even though the network is realized with “real” components. The program is told to use a Q of 333 for the capacitor and it is aware of the 0.5mm dia. Cu wire in the coil, and the length of it.

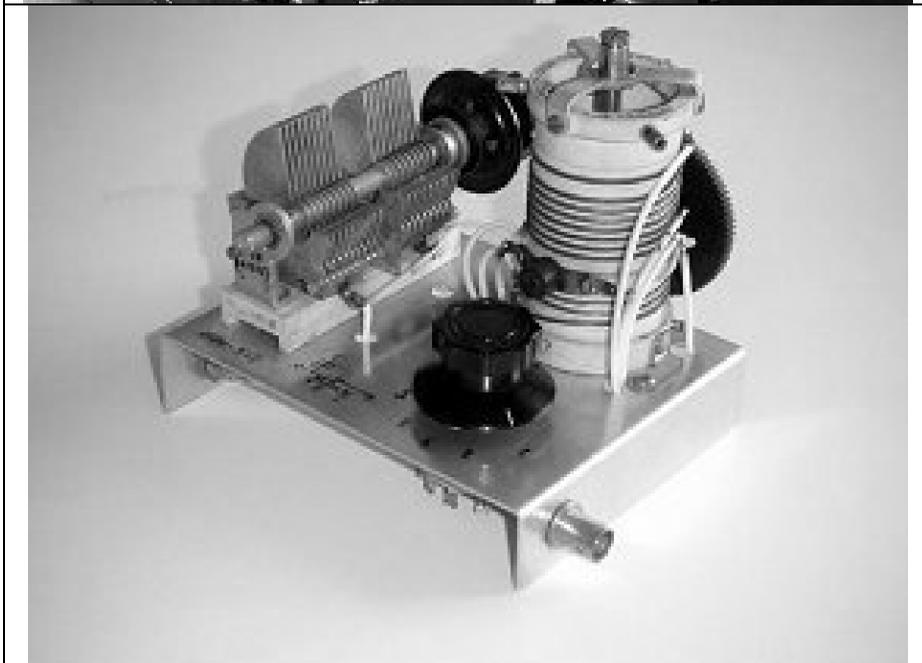
For comparison, I tested RG-6 and RG-8 in the model at 146MHz. After re-optimization, that gave slightly different L and C, 25m of RG-6 had a loss of 2.06dB and RG-8 had 1.58dB. So the good old RG-8 was slightly better, but the RG-59 had only 2.6dB!

3.0

Analysis

In the Eagleware GENESYS program I played around with some simple net-

works, and I let the program optimize the circuit. I used the programs models of cable and set it to a length of 25m (82ft). For HF the loss of either cable is so low that it is not worth experimenting with. Although one reason to build the matching network could be if the radio wants to see “something better”. Another reason could be that the low-pass nature of the match will cut down on harmonics and thereby potential TVI and/or other problems. Fig 2 and 3 show pictures of this fantastic network that gave a match so good that the SWR meter on my Tx does not even move anymore! This version has a variable inductor and capacitor. One advantage, of many, with the GENESYS is that it can simulate physical air core inductors very well! It can also optimize the circuit by tweaking the coil parameters. So, the solutions for HF are all on a 25mm (one inch if you like!) former, the turns are integer numbers



Figs 2 and 3: Pictures of the HF matching unit.

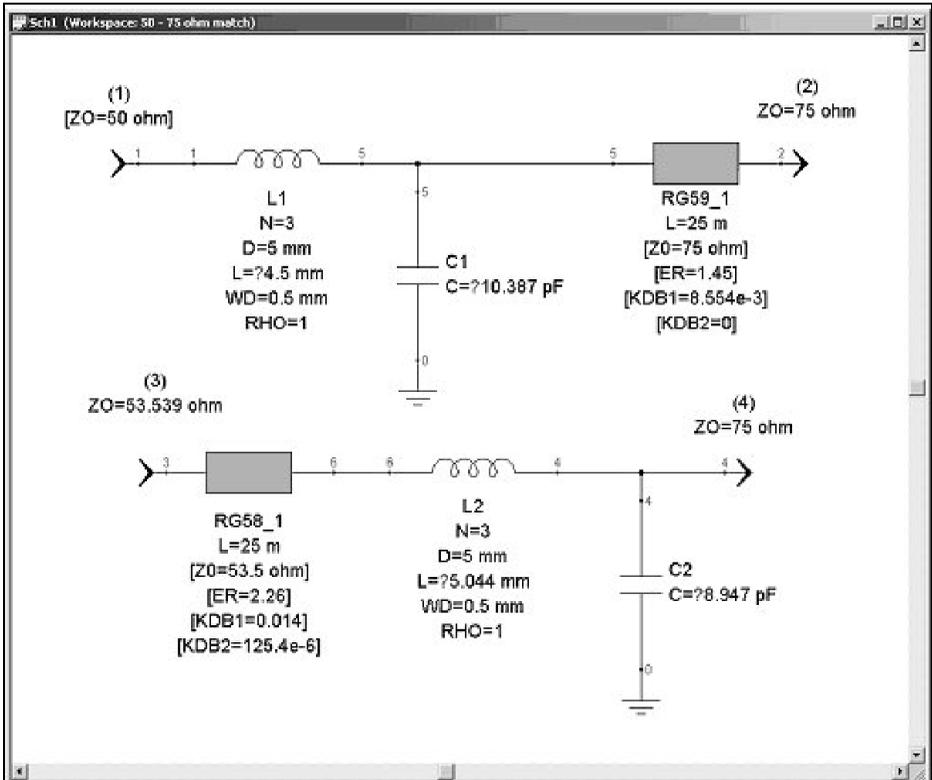


Fig 4: A view of the networks optimised for 146MHz From a 50Ω load 25m remote. Two low pass solutions:

Top: Matching network + 25m RG-59 cable + 75Ω load.

Bottom: 25m RG-58 cable + matching network (essentially the same) + 75Ω load.

Note: the component values may differ slightly from the ones in Table 1 and 2 since the program stops optimising when the targets are reached.

(there are no half turns in the “magnetic world”!), with 1mm Cu wire, so I let the program tweak the lengths of the coils. The inductance is very sensitive to the length, so it is a good object for tweaking. Tables 1 and 2 show the dimensions for the regular HF bands, there is a solution for each of them, but the focus of this article is on the higher frequencies, where cable loss easily becomes a real problem.

For VHF and UHF the coil diameter has to be smaller than 25mm, so I arbitrarily picked 5mm (0.2 inches), using 0.5mm wire, see Fig 4. If you have silver-plated wire, use it!

Since the characteristic impedance for RG-58 is slightly different from 50Ω, approximately 53.5Ω, the resulting values in the two networks are slightly different as well. To make life easier, the

**Table 1: List of dimensions and values for the case of 50Ω to network + RG-59 match.**

Frequency (MHz)	Diameter (mm)	Turns	Length (mm)	Capacitance (pF)	dB loss 25m (RG-59)
3.5	25	8/9	15/22	432	0.43
3.9	25	8	18	389	0.45
7.1	25	6	19	185	0.6
14.3	25	4	16	105	0.84
21.4	25	3	11.5	69	1.0
29	25	3/2	19.5/3.4	52	1.18
137.6	5	3	4.2	10.8	2.5
146	5	3	4.7	10.2	2.6
435	5	2	7.2	3.4	4.5
915	3	2	6.5	1.66	6.5
1296	2.1	1	0.5	1.2	7.7

RG-58 is driven by a matched, 53.5Ω, source.

Tables 1 and 2 show the results. One is for the case where a 25m long RG-58 is to be matched to 75Ω by the network at the far end. The other is for where a 50Ω device is to be matched to the 25m long RG-59 by the same network at the near

end. In both cases the termination at the far end is 75Ω

For realistic results I have chosen Q = 333 on the capacitors, and GENESYS considers a real world condition for the inductors, so they get a realistic Q value automatically. What this value is depends on is the coil form ratio, frequency, wire

Table 2: List of dimensions and values for the case of RG-58 to 75Ω match.

Frequency (MHz)	Diameter (mm)	Turns	Length (mm)	Capacitance (pF)	dB loss/25m RG-58
3.5	25	8/9	16/23.5	388	0.68
3.9	25	8	19.5	342	0.73
7.1	25	6	20.6	209	0.97
14.3	25	4	17	92	1.38
21.4	25	3	13	61	1.7
29	25	3/2	21/4	46	1.97
137.6	5	3	4.5	9	4.5
146	5	3	4.9	9.8	4.6
435	5	2	7.8	3.0	8.7
915	3	2	7.1	1.43	13.3
1296	3	1	0.5	1.03	16.5

Note On the 29MHz line above, the 3/2 turns and 21/4 mm lengths means that you can use 3 turns and 21mm length *or* 2 turns and 4mm length. Naturally there are other solutions, not the least using different coil diameters.

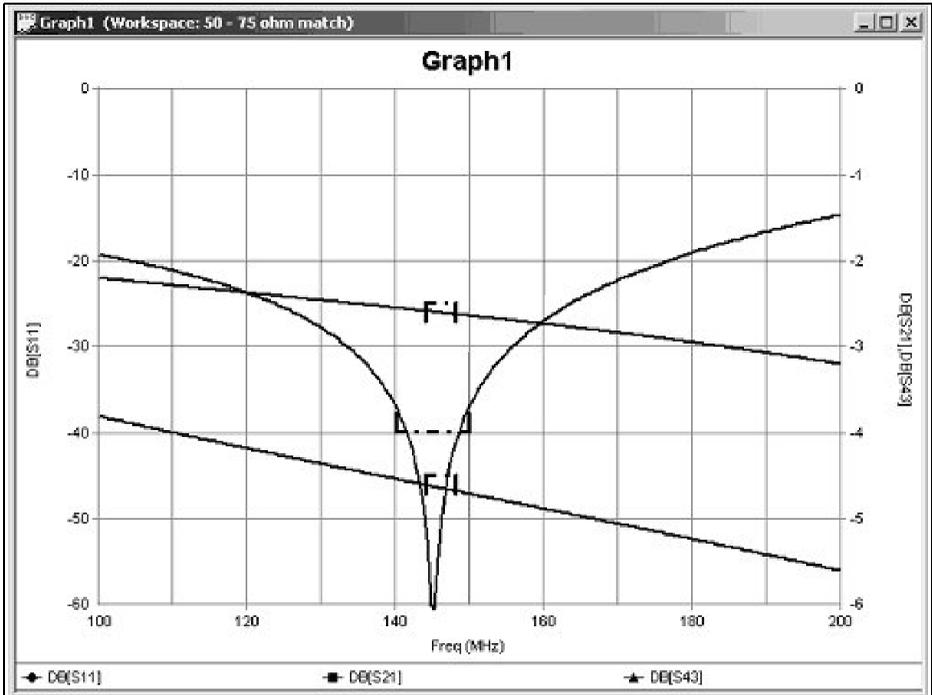


Fig 5: Performance of the optimised network for 146MHz.

diameter and material.

Optimisation is made not only for a good match (which results in a “perfect” match) but for minimum insertion loss (network and cable together) as well. In each case the Target for S_{11} was set to a value just out of reach, so the program really had to work at it. Once a target is reached, it focuses on other targets, or if all are reached, it is done and stops.

4.0

Results

So, not only do the addition of this simple network allow for a smaller loss, and the use, of a less expensive cable, it also allows for the direct and simple match to dipoles. The 1:1 balun you

should have anyway as it is nasty to feed a dipole with a coax! Or at least: put a ferrite collar around the cable near the antenna. Furthermore, if the L and the C of the network are slightly adjustable, they will allow for a “perfect match” even if the load at the far end is off by a little.

When done, the match often results in a better than 40dB Return Loss over the band! See Fig 5. It is so good that few hams would have the equipment to even measure it. Already a 40dB RL corresponds to VSWR of 1.02:1. It should be noticed that just because the VSWR (or “SWR”) instrument may have a meter with a face, where 1.02 possibly can be read, it does not mean that the instrument has such accuracy! The insertion in the transmission line of the most common types will cause a reflection of much more than this! One should also keep in

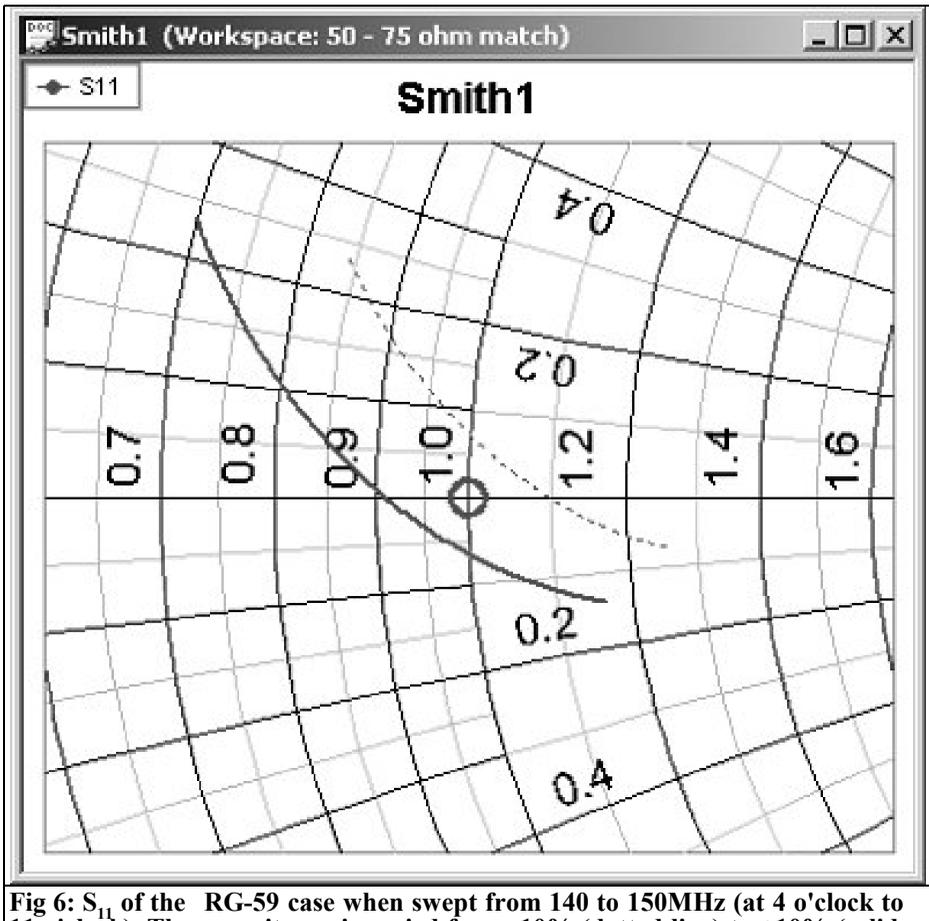


Fig 6: S_{11} of the RG-59 case when swept from 140 to 150MHz (at 4 o'clock to 11 o'clock). The capacitance is varied from -10% (dotted line) to +10% (solid line). The perfect match for 146MHz is of course in between the two.

So, varying the capacitor will not tune the circuit over frequency! The same effect, but to a lesser % per variation of length, is observed when varying the coil.

mind that even a “horrible” 14dB of RL (i.e. VSWR 1.5:1 of the 50Ω – 75Ω mismatch) is not the end of the world; the loss from mismatch would be only 0.18dB.

If you are more comfortable with units of VSWR than Return Loss, the graph in Fig 7 should speak loudly!

It should not be hard to make a simple matchbox with “plug-ins”, using fixed

value components, one plug for each band maybe. The old valve sockets in the Junk Box are suddenly beginning to look good... A VSWR of less than 1.4 over an octave is not bad either!

Only a small part of the coil had to be selected by the rotary switch for match at 14.3 MHz, so the entire coil is probably enough for operation down to 80m band!

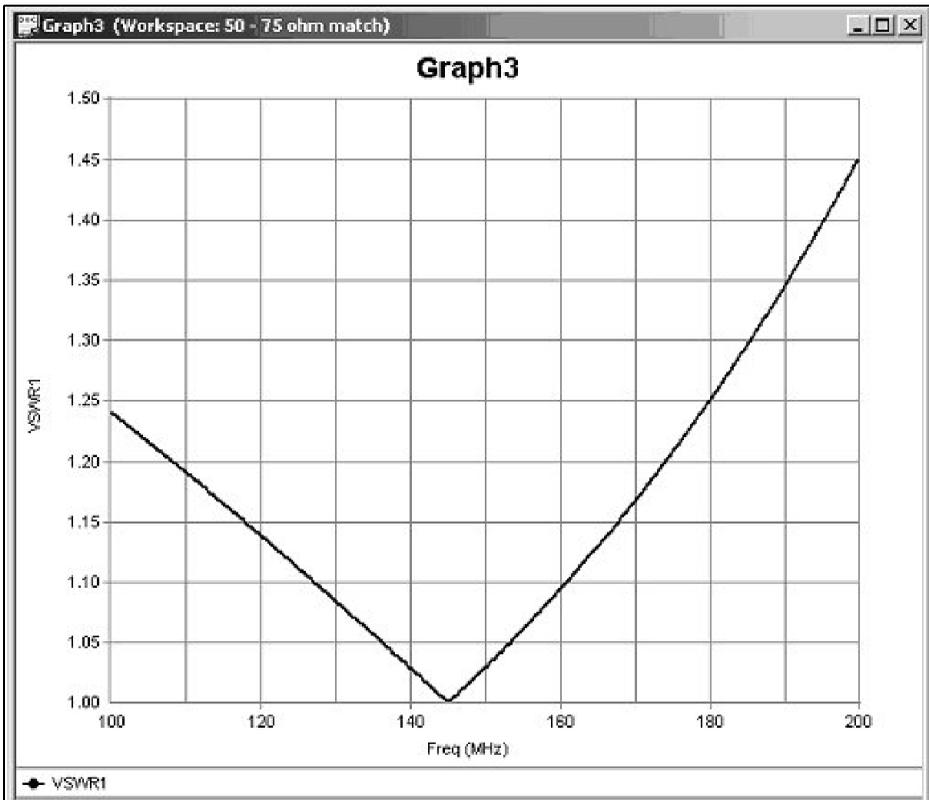


Fig 7: The match in units of VSWR.

5.0

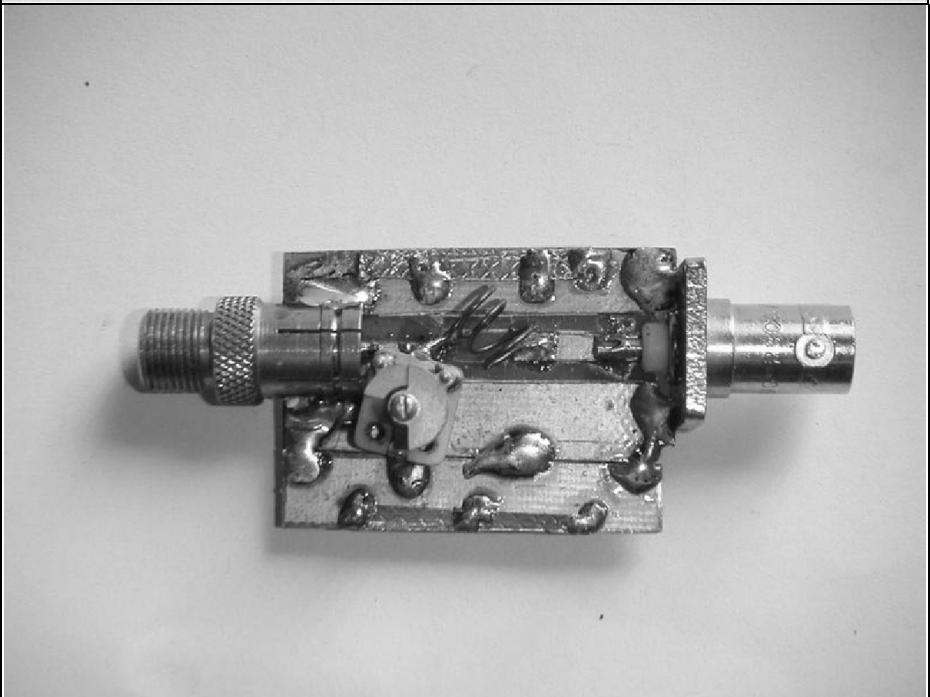
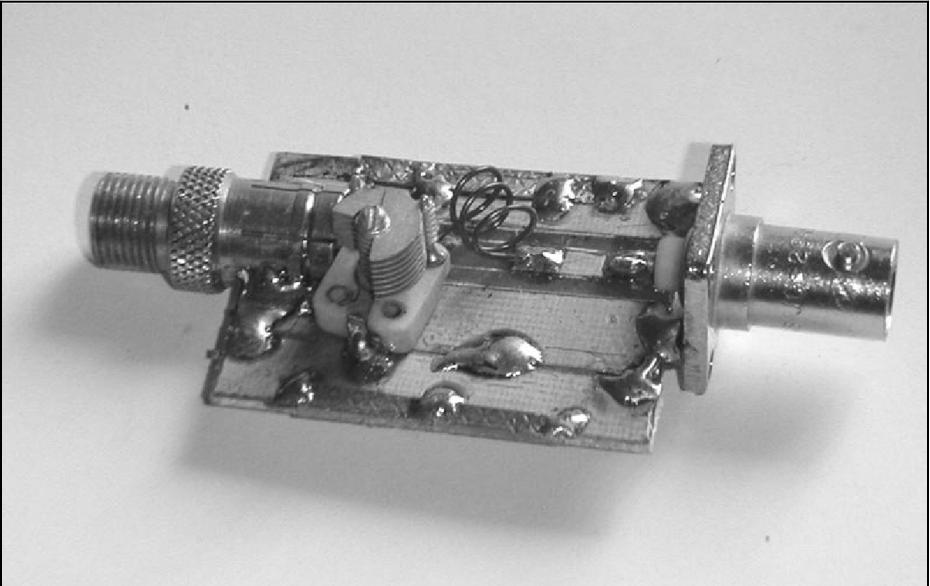
Conclusion

The beneficial nature of a truly low cost cable, such as RG-59 (and probably RG-6 as compared to RG-8) has been demonstrated (in theory). A simple, reproducible, network that will match the 75Ω characteristic to 50Ω devices has been suggested. Prototype circuits for HF (Figs 2 and 3) and VHF (Figs 8 and 9) have been built and work as predicted by modelling.

The network described “extends” the range for which one may consider using

coaxial cable, given some acceptable loss. This network also allows for DC to be fed up the line to power pre-amps and LNAs. A further benefit from the network is that it cuts down on harmonic content in the signal and that one can also tune out small imperfections in the load.

A possible, additional, benefit, especially for reception, can be that the LNA on the receiver input may not have its lowest NF under matched condition. By tuning the L and C around it may be possible to squeeze out a little lower NF! Especially for satellite reception a few 1/10th of a dB may make a difference.



Figs 8 and 9: Pictures of the VHF matching unit.



Sigurd Werner, DL9MFV

Low noise, high performance amplifiers for 76GHz

Various amplifier modules were constructed using the CHA1077 MMIC from United Monolithic Semiconductors (UMS). The results for the single chip model gave an antenna gain of 18dB, a noise factor of 7.9dB and a saturation power of precisely 10dBm. When the version with two identical chips in series was used, an amplification of 35dB was measured, with a noise factor of 11.3dB, with the same maximum power. Special characteristics of the assemblies (e.g. parasitic oscillations, etc.) were measured paying particular attention to the noise factor. The appendix contains the assembly instructions for a two chamber filter with a resonant frequency of 76.032GHz.

1. Introduction

In the Autumn of 2003, United Monolithic Semiconductors (UMS) launched a Wband amplifier chip (CHA1077) for the 76/77GHz frequency range. The data [1] for the MMIC (a P-HEMT) are described

as follows: noise factor approximately 4.5dB (!), amplification approximately 15dB and maximum output 10dBm.

Thus this (three stage) semiconductor would fulfil all the prerequisites that are needed for the assembly of a very low noise receive amplifier in the 76GHz band.

I have already described a signal amplifier for these frequencies in this magazine a year ago [2]. In the two stage models, a chip from the Fraunhofer Institut, IAF (MAP7710) was used. The amplification of 24dB and a maximum output of 10dBm certainly qualified it as a low power transmit amplifier, and yet the noise measurements (the values were between 12 and 14dB) made it clear that these assemblies were not suitable as receive amplifiers.

The aim in this new article is to use the new chip from UMS to assemble an amplifier especially for receive purposes.

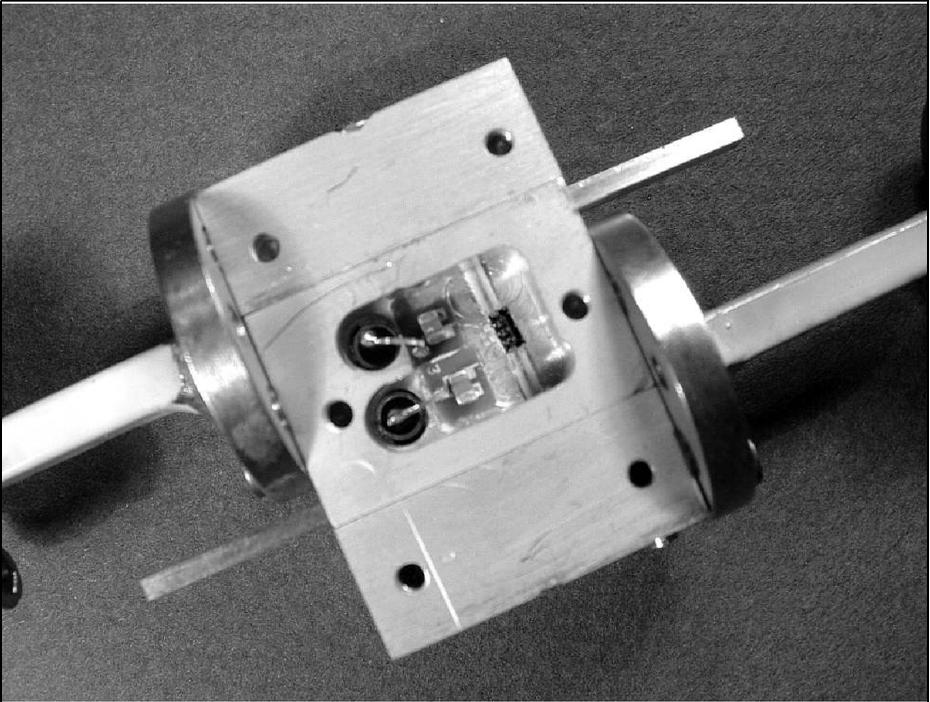


Fig 1: View of the single chip 76GHz amplifier showing the layout of the feed. The attenuation mats were fitted in this cavity.

2. Mechanical and electrical assembly

The housings were milled out from brass and then gold plated.

Semiconductors and ceramic substrates were fitted into the cavities milled out at various levels in order to balance out the different component heights.

Radio frequency power was fed to and from the semiconductors from the WR 12 waveguide using 50Ω striplines. The choke piston fitted at right angles to the housing optimised this transmission process. The chips were connected to the

substrates by means of an $18\mu\text{m}$ gold thread using bond engineering (Hybond, Model 572). The DC voltages were fed through the housing base using feedthrough capacitors. The DC circuits were blocked using 100pF single layer capacitors mounted directly on the semiconductor, followed by 100nF ceramic capacitors. The microstrip impedance matching required was provided, as described [3], by fitting small gold flags.

To measure the power of the test rig, two thermistor heads (ANRITSU MP716A) were used in conjunction with a 3dB directional coupler (MILLITECH, 34dB). In order to measure very low power levels of less than -17dB , calibrated, adjustable attenuators were used (MILLITECH and FRX, Inc.).

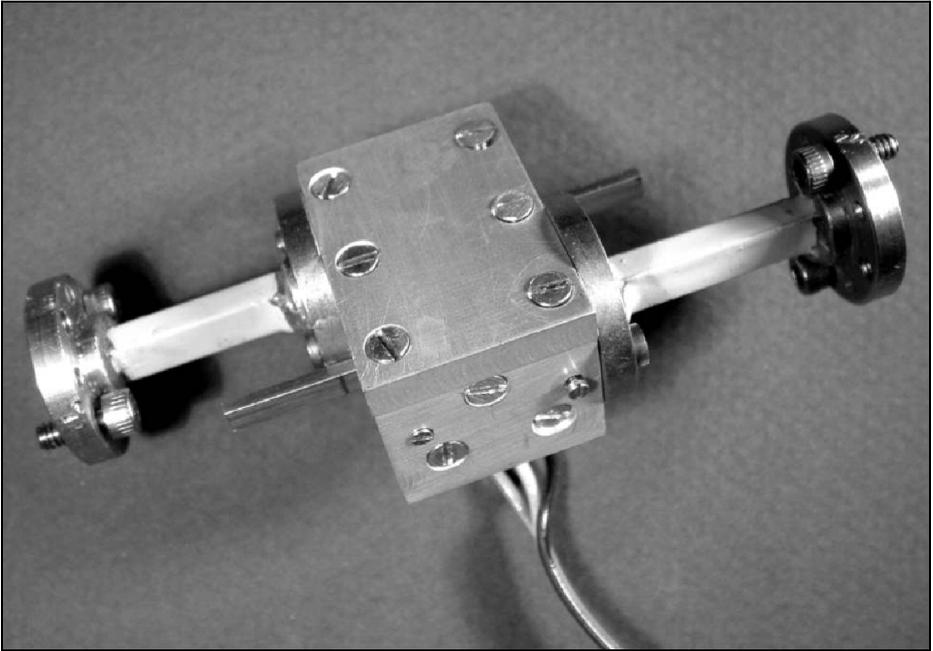


Fig 2: View of the completed single chip 76GHz amplifier with the 4mm thick lid fitted.

The noise measurements were carried out in a professional HF laboratory (IAF, Freiburg). They covered a frequency range between 76 and 78GHz.

A: Amplifier module with one chip (CHA1077)

The dimensions of the housing, which consisted of three blocks, were 31mm x 20mm x 15mm (L,B,H). The lid was 4mm thick. The dimensions of the cavity were 8.6mm x 8.0mm, and it was 5.0mm. deep. The details of the assembly can be found in Figs. 1 and 2.

B: Amplifier module with two chips (CHA1077) in series

The housing was again formed from three blocks (38mm x 20mm x 15mm (L,B,H). The cavity (15.6mm x 12.0mm, and 5.0mm. deep) was divided into two chambers by a thin partition wall, the compartments being connected by a 4.4mm. long stripline (see Figs. 3 and 4). The housing lid was 4mm. thick.

3. Results

A: Amplifier module with one chip

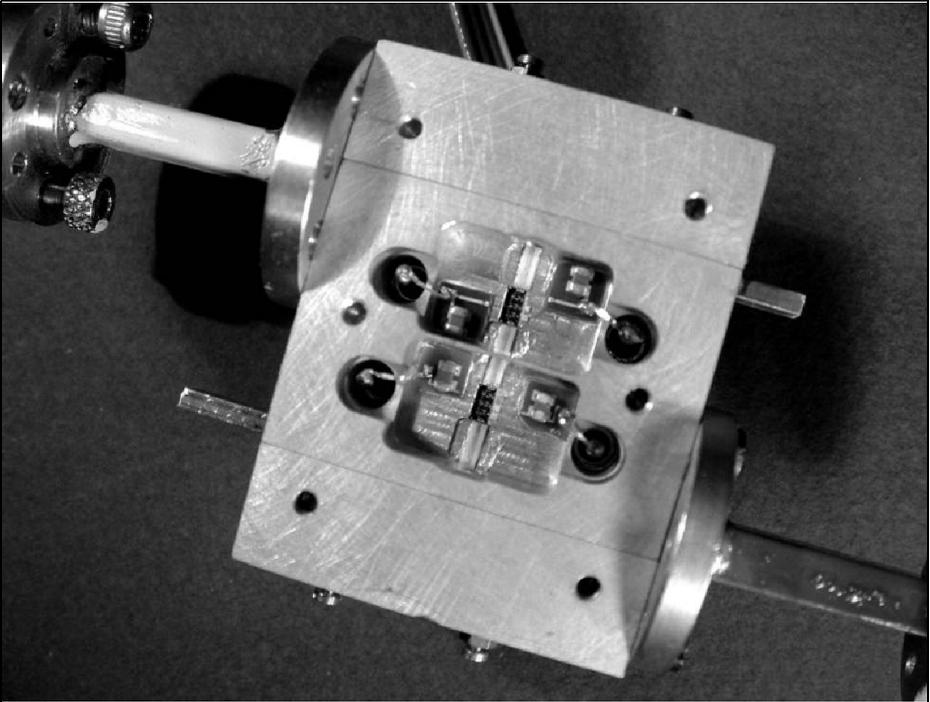


Fig 3: View of the two chip 76GHz amplifier. The 4.4mm stripline connecting the two chips can be seen.

Once the gate voltages were applied (minus 4.45V at 5mA and plus 4.45V at 50mA) without feeding the radio frequency power, a relatively high degree of oscillation was observed (approximately 2mW power). When attenuation mats were fitted tightly into the cavity (in particular, on the output side), these feedback effects can be suppressed. The gain and the output of the amplifier at various input levels can be seen in Fig. 5. The test frequency was always 76.032GHz.

The maximum gain measured, happily, amounted to 18dB (details in data sheet: 11 to 19dB – typical result 15dB). For input signals $> -10\text{dBm}$ the values obtained rapidly decreased. The saturation power was precisely 10dBm.

The output was also plotted against the frequency. The result was naturally dependent on the degree of impedance matching for the waveguide feeds. The 3dB bandwidth extends from 74.7 to 76.5GHz (1.8GHz).

The result of the noise measurements in the range from 76.0 to 77.0GHz is illustrated in Fig. 7. In accordance with the specification of the chip (actual frequency 76 - 77GHz [1]), the lowest values were in the “mid band” at 7.77dB. At the frequency of use of 76.032GHz, a noise factor of 7.9dB was measured. Changes in the DC voltages had no effect, except on the second decimal place.

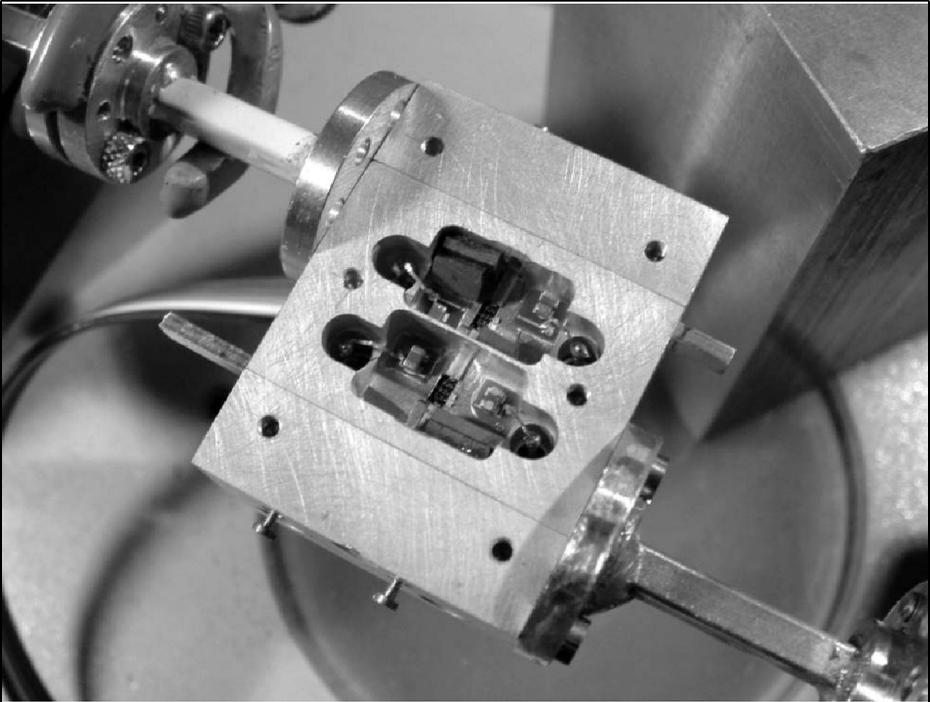


Fig 4: View of the revised two chip cavity with a wall isolating the two chips to help prevent self oscillation.

B: Amplifier module with two chips in series

In the initial assembly, the two MMICs were stuck to the base of the cavity, one directly behind the other (approximately 70 μ m apart). There was already a high degree of oscillation when the DC voltages were applied (output approximately 4mW!). In spite of the massive application of attenuation material, these “wild oscillations” could not be controlled.

So in the next assembly the semiconductors were isolated in two separate chambers. The chips were connected by means of a short stripline that went through a short passage in the thin partition wall.

This resulted in much reduced oscillations, which were prevented by means of glued in carbon mats. When the housing lid was put on, these problems returned. The oscillations that occurred were finally reliably prevented by the insertion of a 2.5 mm thick attenuation mat into a milled recess in the lid.

The maximum gain for the module was determined as being 35dB (!) at 76GHz. The saturation power was again 10dBm (Fig. 6).

The noise factor of the double chip amplifier was 11.3dB at the nominal frequency (Fig. 8). The -3dB bandwidth of the output power extended from 73.0 to 77.6GHz (.6GHz).

To summarise, the measured data allow

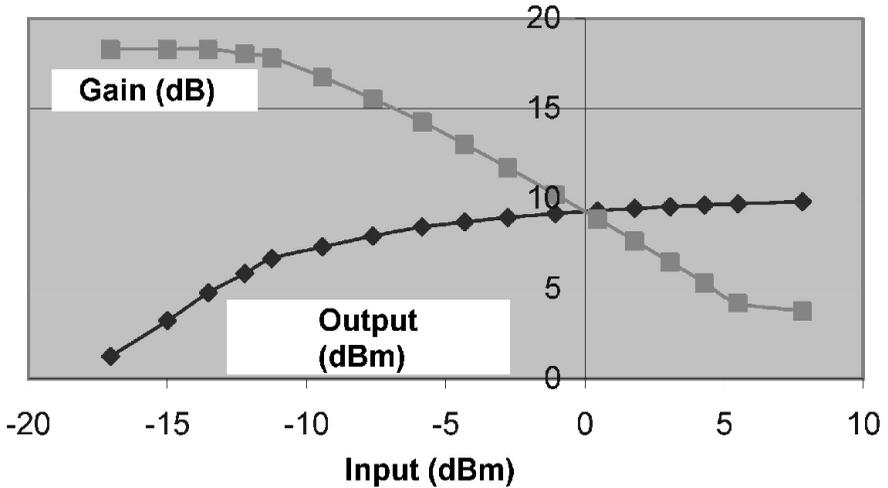


Fig 5: Gain and output characteristics of the single chip 76GHz amplifier.

us to make the following preliminary assessment of the two modules:

The amplification of the double chip module [2] had been improved by more than 10dB.

The premise that a module used as a receive amplifier might have a noise factor approximately 3dB better than the mixer involved (approximately 10dB, see [2]) was almost accomplished in the single chip version. This aim will undoubtedly soon be achieved through a further improvement in the amplifier.

However, there is still a significant discrepancy between the noise factor specified for the MMIC by the manufacturer of 4.5dB (typical!) and the value obtained from the assembly of 7.9dB. At the moment, I have no explanation for the unsatisfactory noise factor in the double chip model (11.3dB). The big

difference between the values from module A and module B is striking - an absolutely unexpected result. Simple measurement errors are rather unlikely here, and moreover M. Kuhne (DB6NT) obtained very similar results from his own assemblies [4].

Since in this project the “matching” has to be done largely “blind” (the noise measurement was not done until later), the next objective is to find a way of being able to optimise on the minimum noise level even when assembling the amplifier. The maximum amplification and the minimum noise do not necessarily have to coincide. A start has been made on the construction of a waveguide noise source for 76GHz (noise diode NC406; 18 to 110GHz).

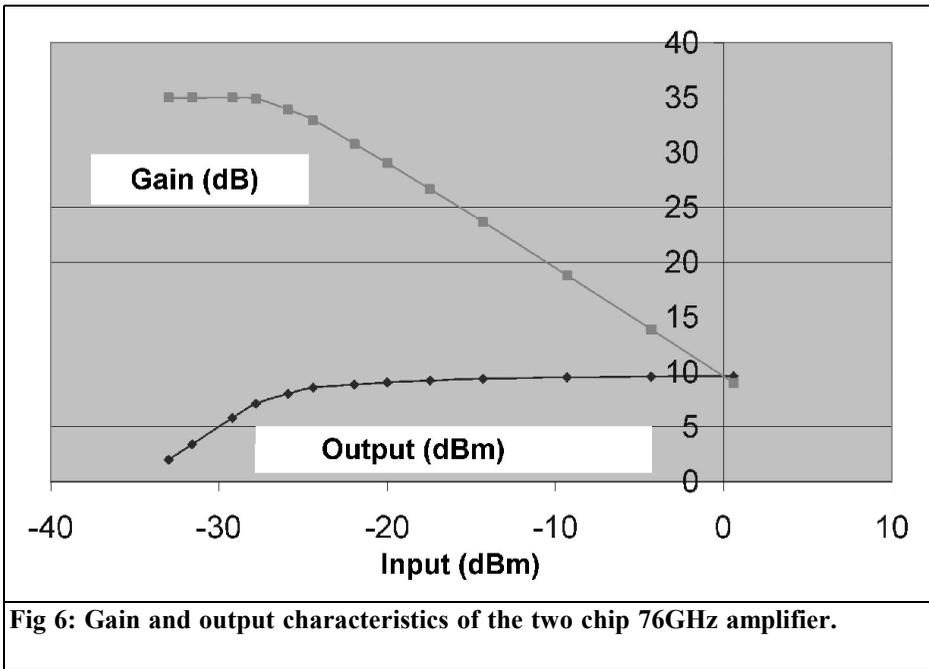


Fig 6: Gain and output characteristics of the two chip 76GHz amplifier.

4. Appendix: 76GHz filter

Special filters are available to remove unwanted signals at 76GHz (e.g. the sidebands arising in mixers). Since I have been frequently asked for design data regarding chamber filters in recent weeks, the assembly notes below should be helpful, especially as not all hams have the option of using frequency wobbling in this range.

The popular two chamber filter from OE9PMJ [5] serves as the basis for the assembly.

The housings (20mm x 20mm x 12.3mm) consist of three brass blocks screwed together, which are then gold plated. The central metal block contains the two cavities (see Fig. 9). One important factor

affecting the specification of this filter (assembled in this way!) is that the frequency of resonance measured in the end is approximately 600MHz lower than the calculated value [6]. This “correction factor” has already been taken into account here. It has also been established that the clearly asymmetrical transmission curve of this filter is improved through the use of two additional adjusting screws (two on each side, i.e. four in all).

Filter assembly data:

- Diameter of cavities: 5.7mm
- Height: 3.55mm;
- Diameter of iris to waveguide: 1.35mm

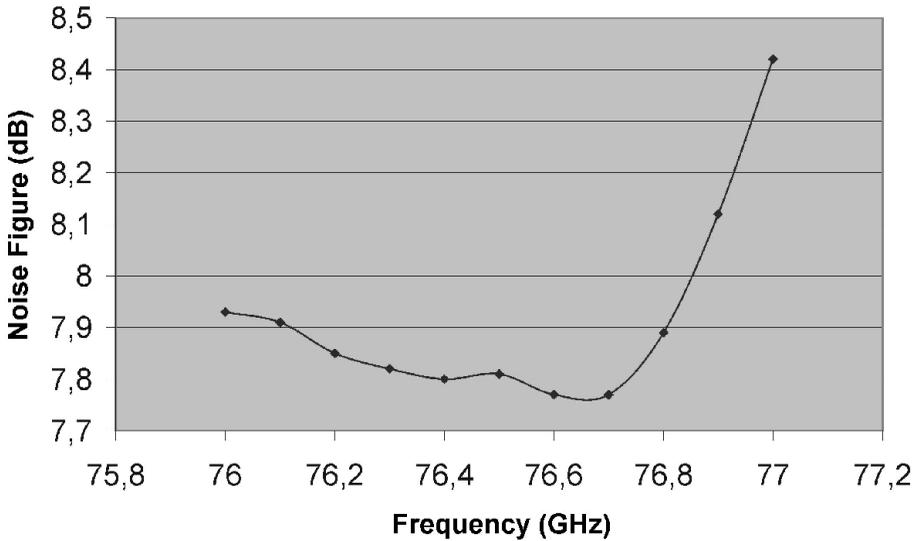


Fig 7: Noise figure characteristics of the single chip 76GHz amplifier.

- Diameter of iris between the cavities: 1.0mm
- Ratio $(d/l)^2 = 2.6$
- Frequency of resonance (hollowed out M2 screws) approximately 76.0GHz
- Insertion attenuation: 4.6 to 9dB, for different assemblies
- Coupling slightly over damped

From the wobbling measurements initially carried out in the range from 70 to 80GHz, two additional spurious resonances were fixed at 80.8GHz ($1.06 \times f_0$) and 71.9GHz ($0.94 \times f_0$), but in comparison with the main resonance these were suppressed by approximately 30dB.

The transmission curve of the filter can be seen in Fig. 10 as the result of a

narrow band wobbling at 76.032GHz with ± 720 MHz. A signal deviating from the nominal frequency by 288MHz (e.g. generated by addition of an intermediate frequency of 144MHz) is attenuated by approximately 40dB.

Assessment: whilst the filter displays good edge steepness in frequency dependent transmission behaviour, at the relatively high insertion attenuation levels there is still a clear need for action. Work is being done on improvements in this area.

The measurements were carried out using a wobble generator (HP8350B with an 86290B insert), in conjunction with a network analyser (HP8757A), a home-made frequency octupler [7] and a diode measuring head (Pacific Millimeter Prod-

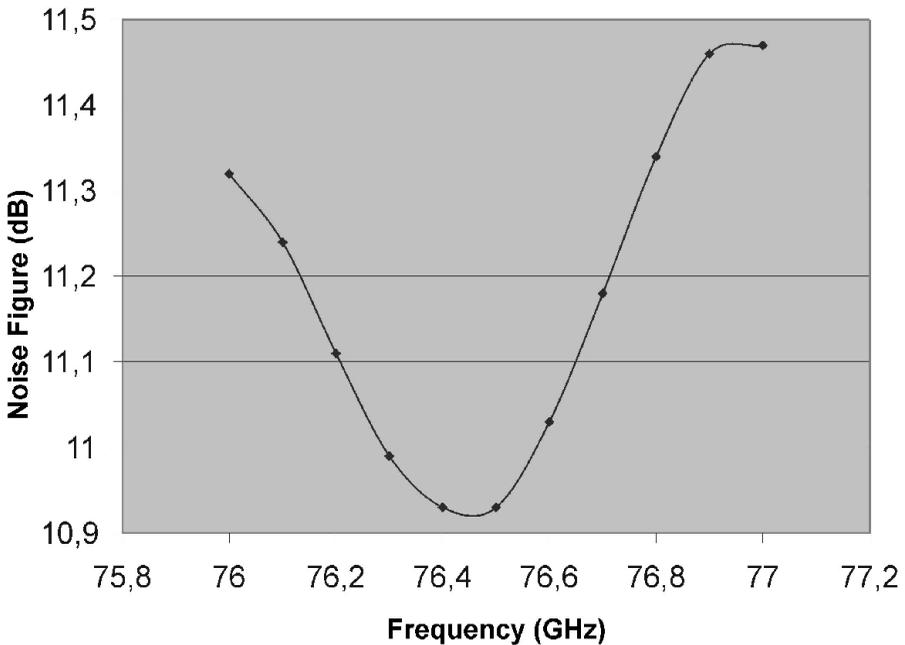


Fig 8: Noise figure characteristics of the two chip 76GHz amplifier.

ucts Model VDH) with a diode adaptor (HP 11664C).

5. Acknowledgments

I am particularly grateful to Dr. H. Massler of the Fraunhofer Institute for applied solid state physics (IAF = Institut für angewandte Festkörperphysik) in Freiburg. He provided me with rapid assistance with noise measurements, without a lot of red tape.

My thanks also go to Dr. R. Jünemann (DK7AH) and Dr. Hechtfisher

(DG4MGR), both of Rohde & Schwarz, Munich, for checking through my manuscript. My self-effacing “comrade-in arms”, J. Ehrlich (DF3CK), supported me with positive criticism and helped solve the mechanical problems involved in manufacturing the filter.

6. Literature references

- [1] Data sheet from Monolithic Semiconductors, S.A.S., Ref. DSCHA10773155, 04 June 03
- [2] Sigurd Werner, DL9MFV; 76GHz

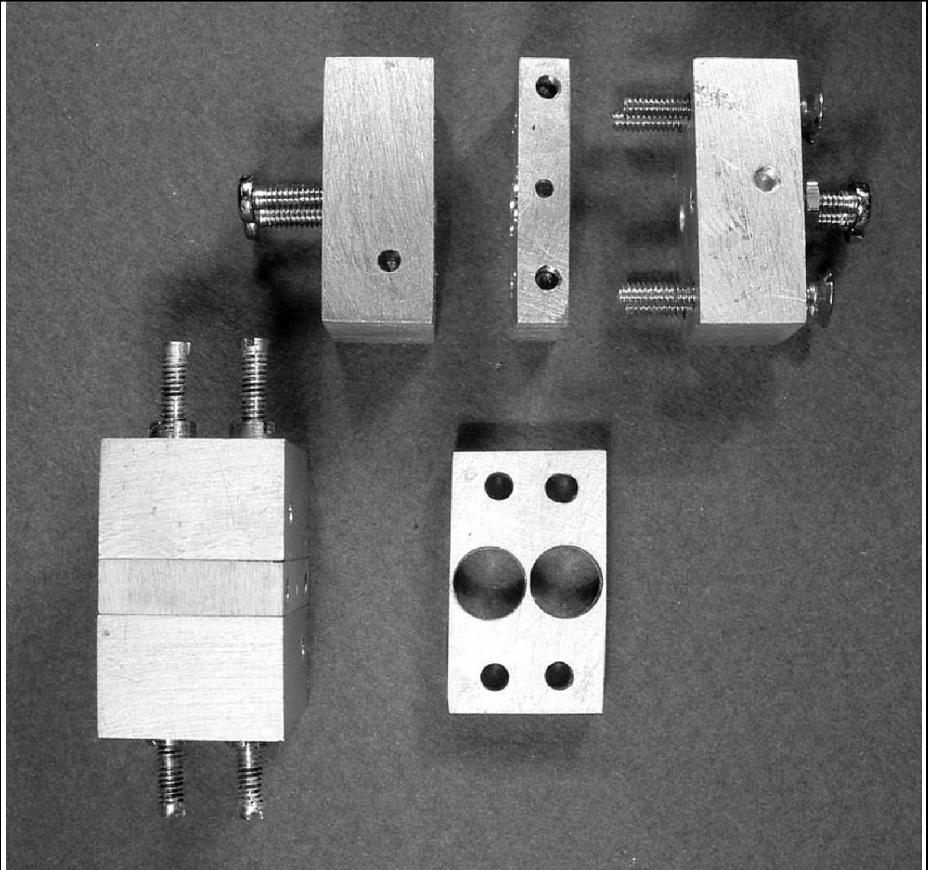


Fig 9: View of the mechanical parts used to make the 76GHz filter.

amplifier, VHF Communications 3/2003, pp. 163 - 169

[3] Sigurd Werner, DL9MFV; A simple concept for an efficient 76GHz transmitter, VHF Communications 2/2003, pp. 77 - 83

[4] Michael Kuhne, DB6NT, personal information. See also Proceedings of 27th GHz Congress, Dorsten 2004.

[5] Peter Riml, OE9PMJ, 47GHz waveguide filter, Proceedings, Dorsten 1992

[6] Filters and Cavities, pp 180 and ff., In: Microwave Engineer's Handbook, Vol.1, Th. S. Saad, ed., Artech House, Inc., 1971

[7] Sigurd Werner, DL9MFV, Frequency multipler for 76GHz with an integrated amplifier, VHF Communications 1/2003, pp.35 - 41

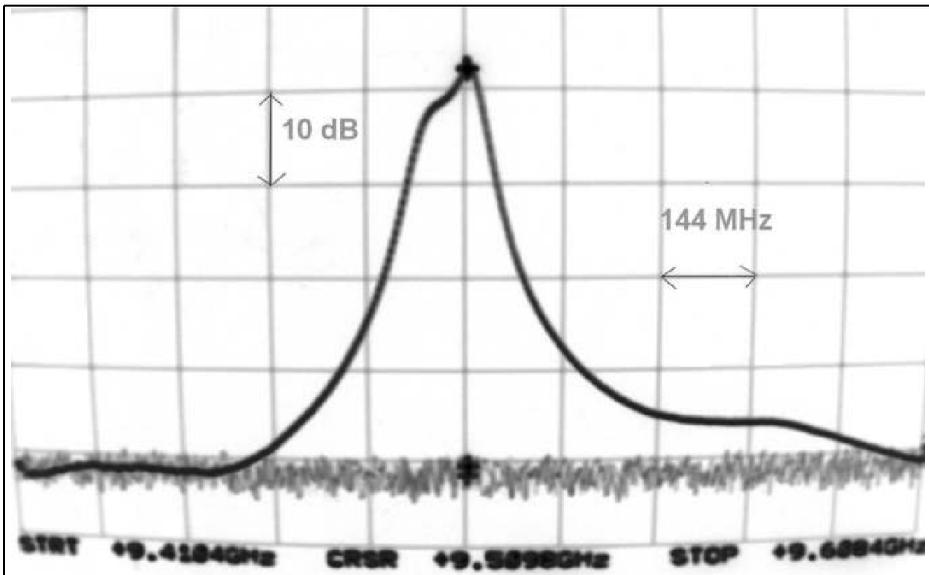


Fig 10: Transfer characteristics of the 76GHz filter. Wobble frequency 76032MHz +/- 720MHz.

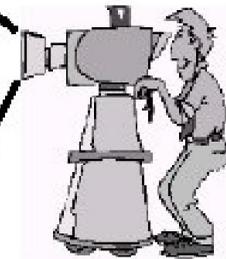
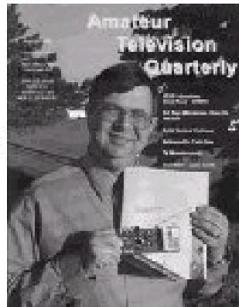
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Sigurd Werner, DL9MFV

Frequency doubler for 76GHz with 130/160mW output

The CHU3277 chip from United Monolithic Semiconductors (UMS) has been put to use in a module again. The outputs from four parallel driven MMIC's were fed into a WR 12 waveguide at intervals of $1\lambda_g$. The outputs obtained were 132mW (with a DC voltage of 5.05V) and 160mW (at 5.75V). The problems occurring in relation to this special design are discussed.

1. Introduction

Various options for power addition have recently been investigated in order to increase the output of 76GHz generators [1]. One effective solution that emerged involved twin parallel feeds into the waveguide using two striplines $1\lambda_g$ apart. When this admittedly narrow band, (approximately 1GHz) method was used, an output of 90mW could reliably be obtained using two chips (CHU3277 from UMS) [1].

To increase the output signal further, it

was suggested that two identical modules should be wired together, for example by means of a simple T junction in the waveguide, or through a, so called, magic T.

The latter procedure proved effective. The reason for this was clearly that additional matching possibilities were provided by the magic T's differential port being calibrated at minimum output. Yet even if a so called "matched magic T" (HUGHES) was used, the output obtained corresponded to only a single module.

Only when two additional E-H tuners were used (BAYTRON and HUGHES) in the addition legs of the waveguide was the (expected) 160mW measured (at 5.75V). This corresponds to a loss of only approximately 10%, but at what a cost! It's clear that this can only be obtained in a laboratory set up (see Fig. 1).

A further disadvantage of this solution lies in the expensive dual drive for the module at 38GHz using an output divider and a phase changer. All these unfavourable circumstances could be avoided us-

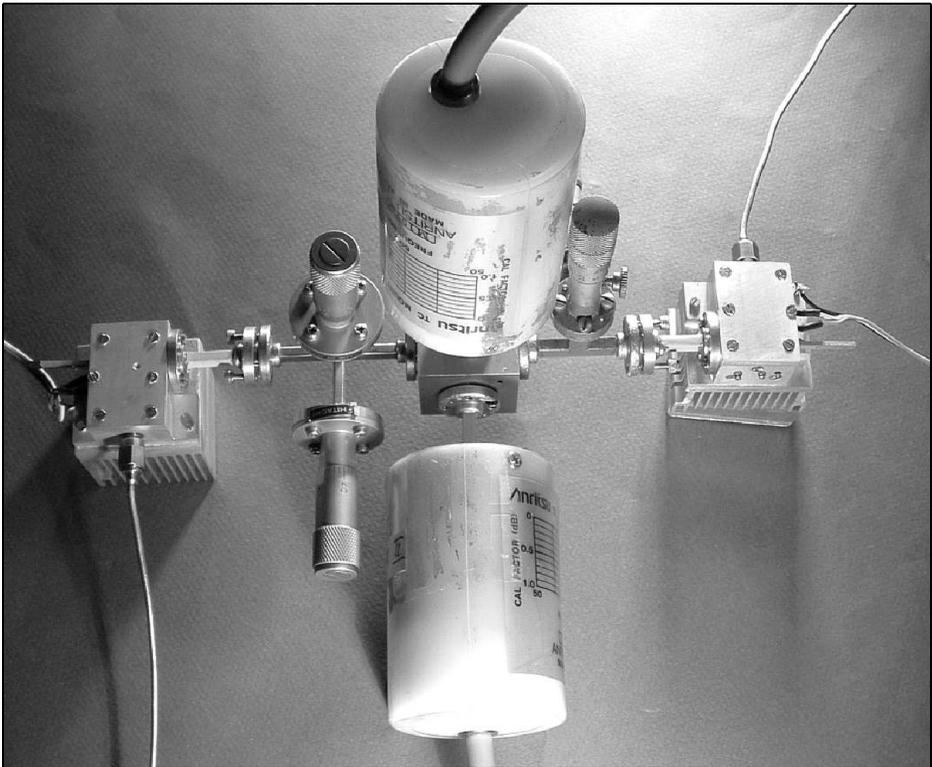


Fig 1: The laboratory set up of the "Matched Magic T" experiment.

ing what was at the same time an extremely compact construction, with four parallel feeds into the waveguide.

However, for a set up like this the following four questions must be answered in the affirmative :

- Does it make sense, with a relatively large number of couplings, to create them in the E plane in the manner shown here? Until now (e.g. [2]), the stripline has mainly been powered in a position rotated through 90 degrees.
- Can the choke piston still generate discrete maxima in these conditions?
- Does this design still provide an efficient output yield? Where is the limit beyond which the output obtained is achieved at too great a cost?
- How big is the drive signal loss (38GHz) with a relatively branched network with several Wilkinson dividers?

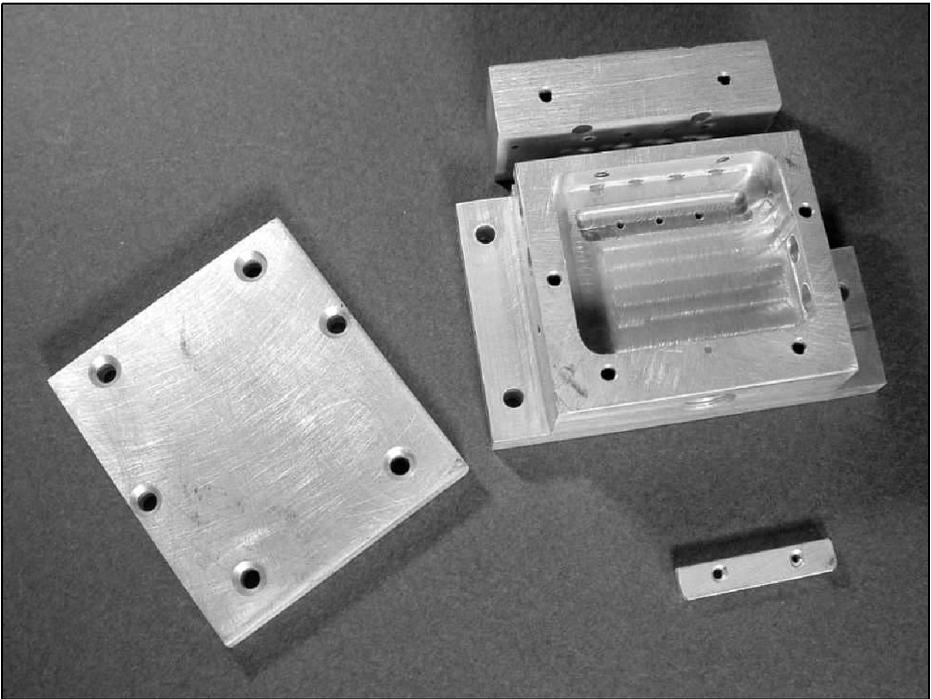


Fig 2: View of the mechanical components manufactured for the housing of the 4 MMICs frequency doubler.

2. Mechanical and electrical assembly

The housing with dimensions 40mm x 36mm x 15mm was milled out of brass and gold plated. The other details of the assembly essentially correspond to module 3, already described [1]. The design details can also be obtained from Figs. 2, 3 and 4.

The chips (4 x CHU3277) were mounted on a 4mm wide brass strip (2mm thick) and this was screwed into a milled recess on the edge of the cavity.

A heat sink (with a blower, if at all

possible) is absolutely necessary to extract the heat generated (6 - 7W!). There was a certain problem in feeding in the 38GHz drive signal with as low a loss as possible. To this end, a home made ceramic board (Al_2O_3) was manufactured with three Wilkinson dividers (see also Figs. 3 and 4).

The linking of the MMIC's and substrates using bonding technology and the DC supplies has been described [1].

3. Results

The output readings were obtained using

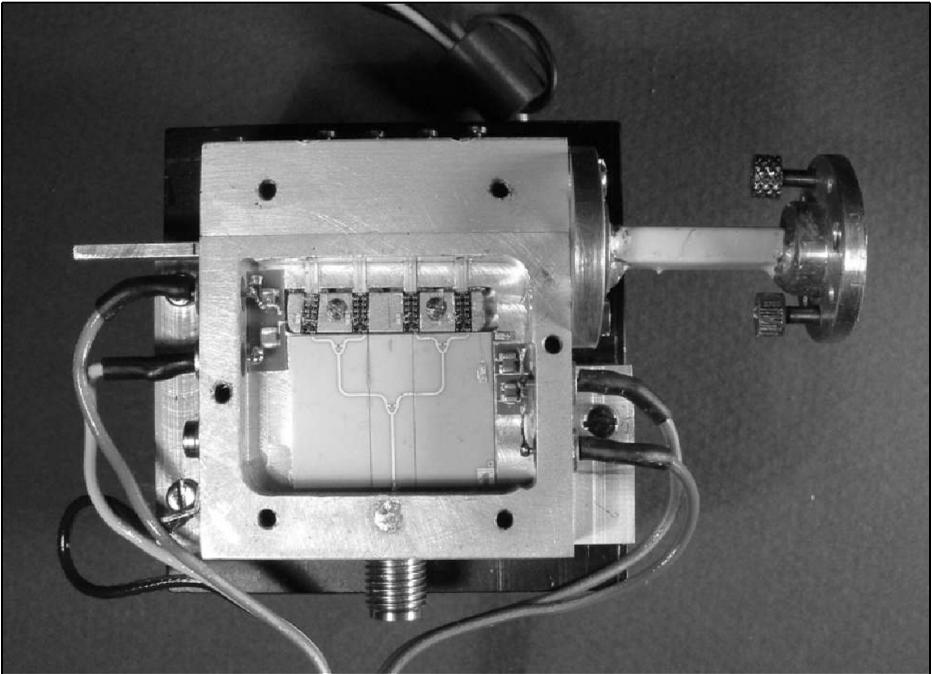


Fig 3: View of the part completed assembly showing the Wilkinson divider, 38GHz input and 4 MMICs.

a sensor from ANRITSU (MP716A). With signal strengths exceeding 130mW, a calibrated waveguide attenuator (10dB) was connected in series.

With supply voltages of 5.05V (currents of 270mA positive and 7.5mA negative per chip), a 76GHz output of 132mW (21.2dBm) was obtained. When each of the voltages was increased to 5.75V (currents of 305mA positive and 8mA negative per chip), the signal could be increased to 160mW (22dBm).

The interval between the various striplines, which are fed into the waveguide in parallel at an interval of $1\lambda_g$, is critical. The estimated value of $1\lambda_g$ in the WR 12 waveguide ($f = 76032\text{MHz}$) amounts to 5.12mm [3]. In practice, a lower value between 5.0 and 5.1mm (tendency to-

wards 5.0mm) appeared optimal. Strict adherence to this parameter is essential for a good result.

The coupling of the striplines in the E plane practiced here makes a simple mechanical solution possible. The efficiency of this power combination method is thoroughly comparable with that previously used.

As regards the action of the phase changer, I had expected the setting of the maxima to be more critical and thus sharper (individually for $\lambda/4$, $5\lambda/4$, $9\lambda/4$, $13\lambda/4$). In fact, the adjustment distances for two feeds moved within the 0.1mm range, whilst for four couplings the range was expanded to approximately 0.5mm.

A similar phenomenon was observed for the impedance matching of the striplines.

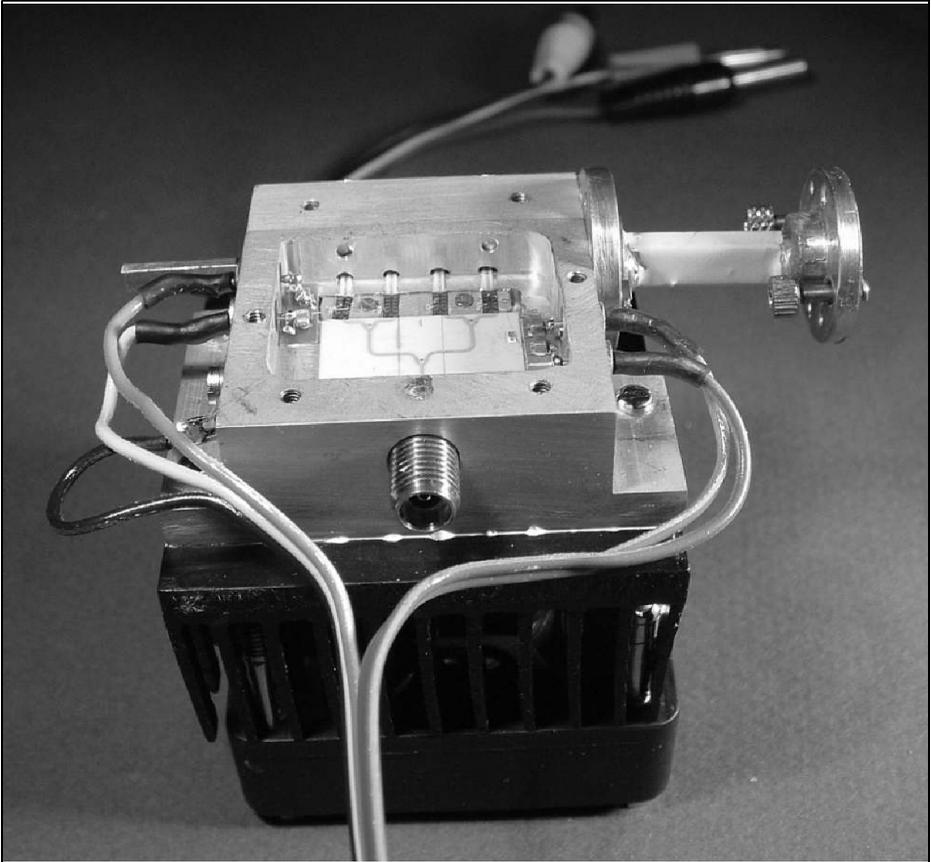


Fig 4: View of the completed unit showing the heat sink and the four feeds at $1\lambda g$ spacing.

The possibility of obtaining a sharp output maximum decreases as the number of inputs increases (You can get by with fewer stubs!) On the whole, these reduced adjustment possibilities are still at the expense of the output yield.

The output efficiency (compared with a one chip model [4], which is set to 100%) amounts to 181% with two chips and 310% with four chips. Thus the limit for sensible development would be reached, at the latest, with an 8 chip module. This has less relevance for the 38GHz feeds. The drive outputs needed

are 3mW (1 chip, [4]), 8mW, (2 chips. [1]) and 20mW (4 chips).

4. Outlook and acknowledgments

In order to obtain a further increase in output in the 200 to 300mW range, two of these 4 chip modules can be wired together using a magic T. The difficulties to be expected here have already been mentioned in the introduction. As an



alternative, a design using 8 parallel MMIC's could also be investigated. However, I leave it open here if this actually represents a clear improvement. The urgent objective now is to check the behaviour of the various modules "in practice" e.g. as components in transverter assemblies.

My thanks go to the employees of Rohde & Schwarz (Munich), and in particular W. Hohenester and Dr. Hechtfisher (DG4MGR). I am particularly indebted to Dr. R. Jünemann (DK7AH), who not only supported me with valuable discussions but also provided guidance as to the manufacture of the 38GHz substrate. My thanks go to my friend Jochen Ehrlich (DK3CK) for his constant support.

solutions discussed, VHF Communications 1/2004, pp. 13 - 19

[2] Sigurd Werner, DL9MFV, A simple concept for an efficient 76GHz transverter, VHF Communications 2/2003, pp. 77 - 83

[3] M.M. Brady, Tables of constants for standard rectangular waveguides. In: Microwave Engineer's Handbook, Vol. 1, pp. 38 and ff., Artech House 1971

[4] Sigurd Werner, DL9MFV, New transmitter with higher output for 76GHz, VHF Communications, 4/2003, pp. 194 - 198

5.

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[1] Sigurd Werner, DL9MFV, Combining power at 76GHz: Three possible



Gunthard Kraus, DG8GB

An Interesting Program

SonnetLite 9.51

The free “Lite” version of SONNET has already featured here many times. It has now been made more attractive to use compared to the previous versions, since some of its features are now finally being given away. This article presents solutions to a comprehensive set of problems based on actual practice.

1.

A brief description

Description:

EM simulator for the analysis of planar arrays and antennas using a modified “moment method”. It analyses the structure to be investigated in a rectangular metal box with a lid. The field distribution inside is known and can easily be calculated.

Following the download and installation, we are initially given a working memory of only one megabyte. If we register via email, we receive a free licence to use 16 megabytes for the PC in question, but this procedure can be repeated at any time for additional computers in the same household (e.g. for the notebook).

The good news:

- Outstanding user guidance about the preparations for simulation, together with excellent documentation in the form of manuals which are also supplied as PDF files.
- The program calculates S, Y and Z parameters and if requested will provide the values for usable spare parts for a SPICE simulation.
- The accuracy of simulation is satisfactory.
- Also available is the representation of the current distribution as an animation (using a “current density viewer”).
- Finally a massive reduction in the calculation time needed for EM simulators – down to a few minutes due to the refined “ABS” (adaptive band sweep).
- Comprehensive collection of application Notes, FAQ’s with answers, technical principles and advice, etc., in a “Knowledge Base” which can be used free of charge.
- Very competent support, including committed support from the numerous SonnetLite users all over the world.



And the bad news:

- The limit of 16 megabytes is usually reached faster than you expect. When this happens the project has to be restructured and simplified until it fits into the “cage” again.
- One unfortunate aspect is the antenna patterns – but we’ll come back to that later...

Bugs or gross calculation errors detected:

Nothing found, even using WINDOWS XP or WINDOWS 2000.

Desirable improvements:

There’s only one more heartfelt wish which the numerous SonnetLite community all over the world would like to see granted:

JUST LET US HAVE FREE USE OF THE FARFIELD VIEWER FOR SIMULATED ANTENNAS!

Download and file size:

Approximately 23 megabytes as a compressed file from the Sonnet homepage – see end of article.

On the other hand, application notes, technical information, FAQs etc. from the knowledge base must be downloaded separately and then filed away using a

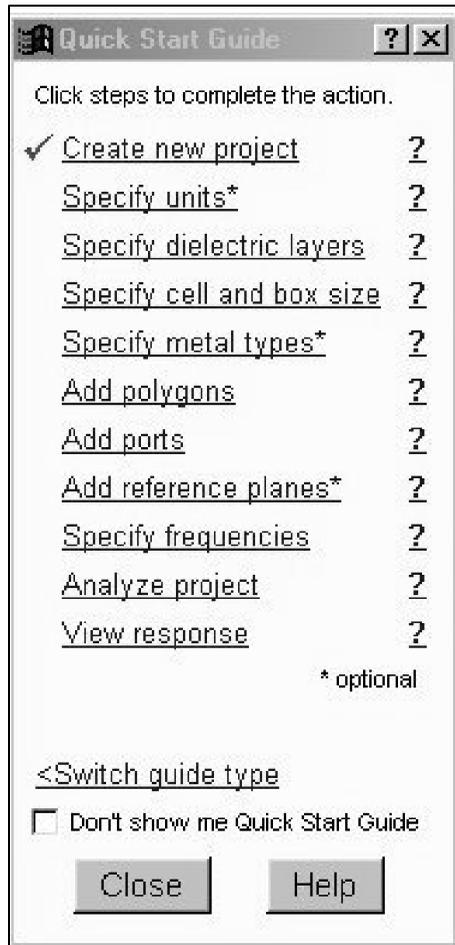


Fig 1: Quick start guide menu.

good system. This is very much recommended!

2. What are the main points?

SONNET has been known for some years, but it has changed in the course of its “evolution”.

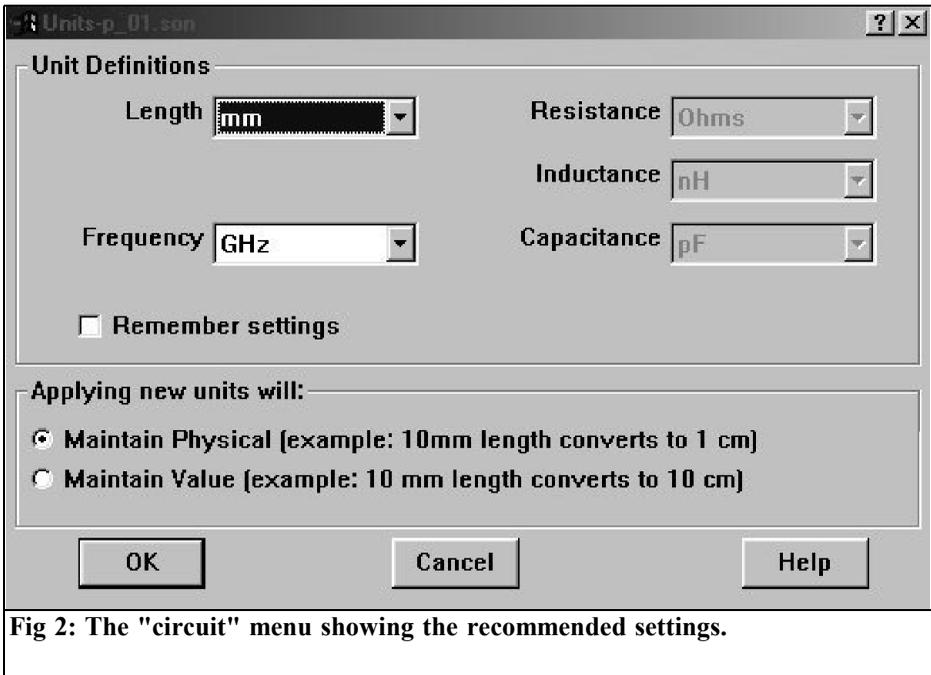


Fig 2: The "circuit" menu showing the recommended settings.

What hits you straight in the eye following the start and the selection of "New Geometry" is the "Quick Start Guide", together with a checklist, obtained by clicking on "Draw manually in Sonnet" (Fig. 1).

This is NOT a menu driven operation, but a genuine checklist: if you miss an item (when calling up the corresponding menu), it is automatically checked off. The list runs from "Create New Project" to "View Response" and is extremely helpful, right down to the obtaining a dummy routine for operating the program. So it's not a bad idea to print out this "Quick Start Guide" and keep it near the PC - otherwise this list keeps concealing parts of the geometry drawn and then has to be pushed to one side. Naturally, you can make it disappear completely with one click, but then if you really need it later on....

Another very practical point is the "A-

daptive Band Sweep (ABS)" option. It resembles "wobbling" when determining frequency responses of any type, and it saves calculation time. You just need to enter the start and stop frequencies for the selected frequency range. The program then automatically determines the minimum quantity of simulation points for a correct representation and thus the simulation time can be measured in mere minutes, instead of hours.

But the most important novelty is the availability of ports WITHIN a structure (previously these were only on one wall of the box, so you had to keep adding one more line to create the structure). This means that, for example, it's now possible to power patch antennas directly on one edge and have the input resistance prevailing there plotted into an SIP file. Or you can work with an "inserted feed" somewhere inside the patch, which is powered from below (from the continuous earthing surface). This point will be considered in greater detail later, with the

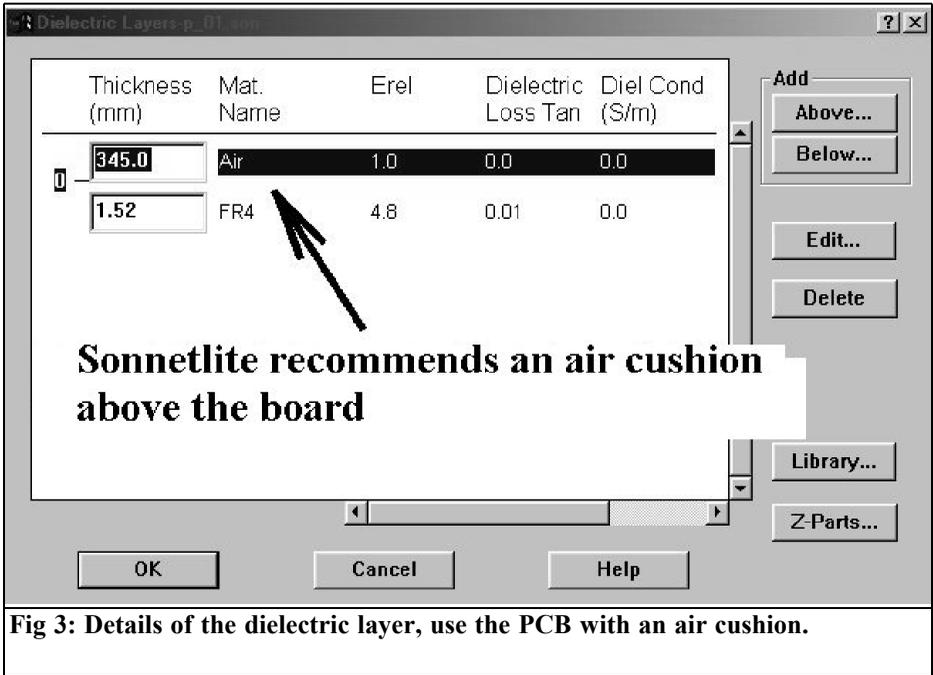


Fig 3: Details of the dielectric layer, use the PCB with an air cushion.

help of some examples.

The accuracy of simulation has also clearly been improved once again. But the author must admit that it's only now that he's discovered the section on "Attainable levels of accuracy" in the massive manual supplied with the program. The formulae listed there relating to the connection between the selected numerical values and the errors which result from them in the simulation of microstrip structures have not been used in practice until now.

The small changes or improvements made over time will naturally not become apparent until you start making more intensive use of the program. They can't all be listed here, but they can be found in a corresponding list on the SONNET homepage.

3.

First practical example: Investigation of a patch antenna for 435MHz

3.1. Background

The best stories are taken from life. This example springs from everyday experience.

The current SONNET accuracy of simulation and operator friendliness were put to the test in a different way.

Another radio ham I know was looking for a patch antenna for the 70cm band, which had to be really beautifully flat and could be easily hung on the wall behind a curtain in his home without projecting out too much. On grounds of

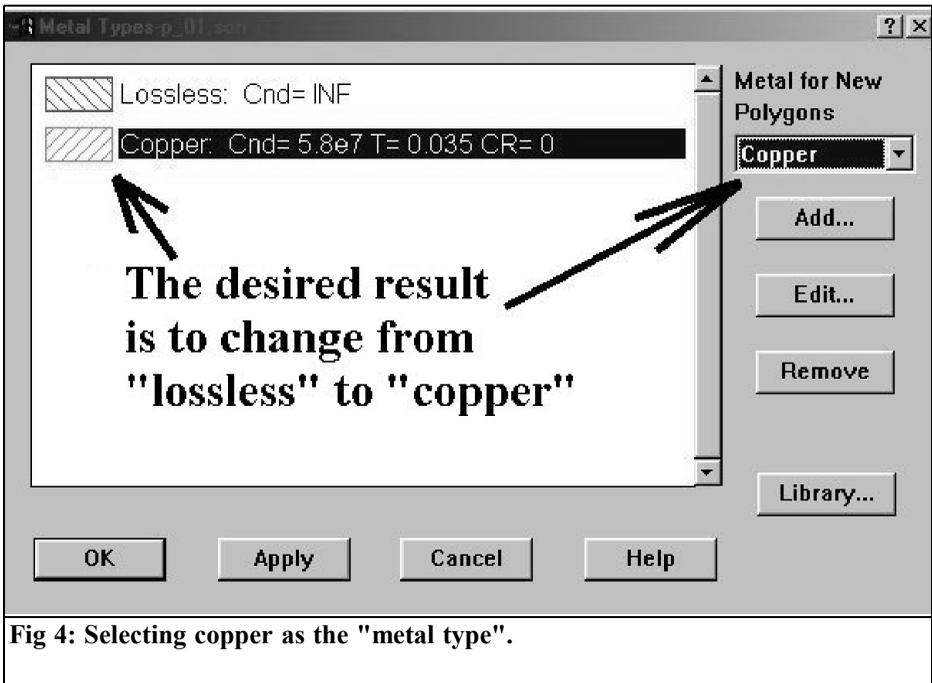


Fig 4: Selecting copper as the "metal type".

price, and because the efficiency and the small bandwidth of the antenna weren't so important, he used simple FR4 material 1.52mm thick.

So a prototype was designed, using the "PATCH16" program from the Internet, based on the following material data

- relative permittivity, $\epsilon_r = 4.8$
- Dielectric loss factor 0.01 (corresponding to a quality of $Q = 100$)
- Carrier material used was an FR4 board, copper coated on both sides size DIN A4 (210mm x 29 mm)
- Patch dimensions were 154.18mm x 228.6mm
- Midband frequency was 435MHz.

Note: the patch length of 154.18mm approximately corresponds to half the wavelength and determines the natural

resonance of the antenna. The 228.6mm represents the patch width and is derived from the requirement for a low radiation resistance, together with as big a bandwidth as possible.

An SMA flange bush was soldered on the underside, i.e. on the continuous earthing surface, its internal conductor being connected to the radiating patch edge on the upper surface.

Measurements using the HP8410 network analyser yielded the following results:

- Resonance frequency: $f_0 = 465\text{MHz}$
- The minimum input reflection factor valid there was: $r = -0.1$

The requirement for the use of SonnetLite can now be formulated as follows:

The antenna measurements supplied by the "PATCH16" program were to be

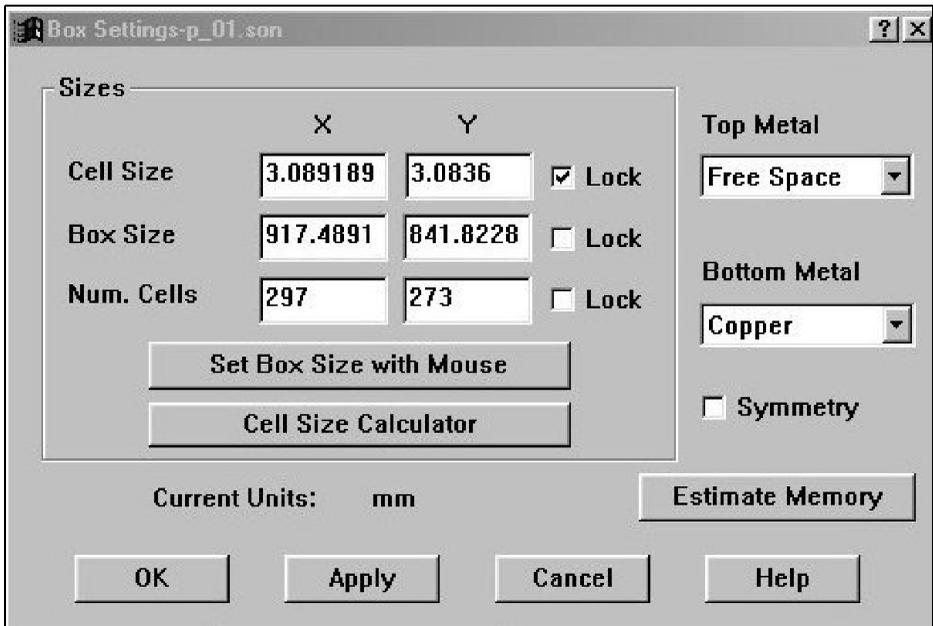


Fig 5: Results of setting the box dimensions.

verified using a SONNET simulation.

The origins of the big differences observed between theory and practice were to be discovered. Finally, SONNET was to be used to give the antenna new dimensions. Then it was to be assembled and checked using the network analyser.

Just for interest and for comparison purposes, a check simulation was to be carried out by standard means (say, with PUFF).

3.2. Investigating the antenna above using SonnetLite

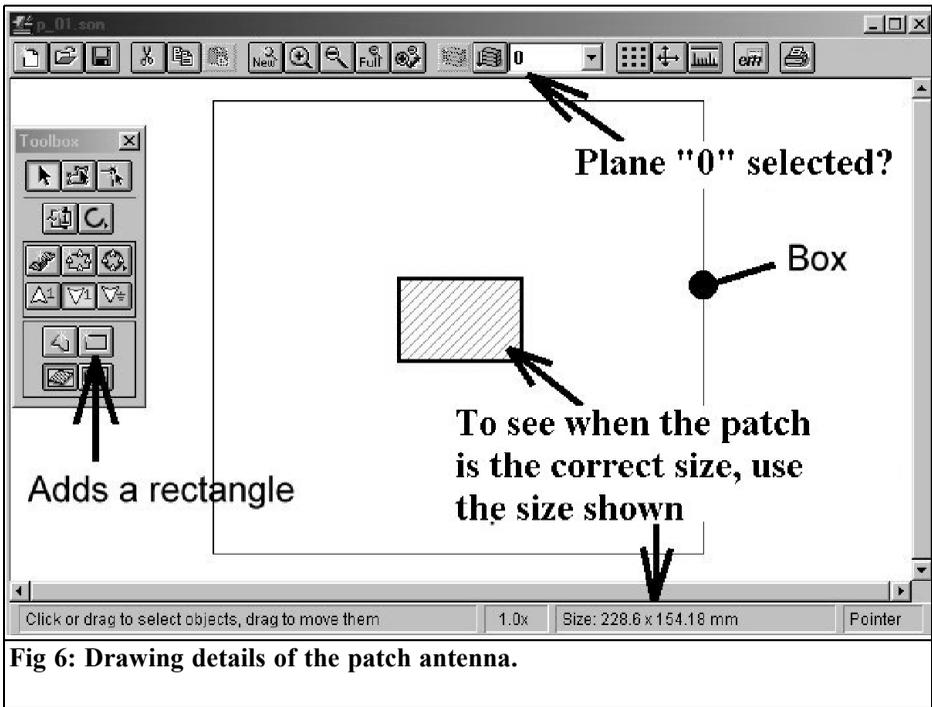
The procedure used the “Quick Start Guide”.

1st step:

Open “New Geometry” in the SONNET task bar and immediately save the project under a suitable name (here: p_01) in a new file to be set up.

2nd. step:

The “Circuit” menu includes all the required settings as follows: Under “Units”, we check whether “mm” and “GHz” have already been entered (Fig. 2). In addition, a tick should be entered, so that the selected length will still be retained, even if the units are changed.

**3rd. step:**

We then move on to "Dielectric Layers". See Fig. 3, which supplies the detailed information required. Apart from the data for the FR4 base material, an insulating air cushion should be entered (as recommended by the manufacturer) above the board, approximately half the thickness of the wavelength, for 435MHz that makes 345mm. Air, of course, has a relative permittivity of 1 and no losses. To enter the material characteristics, we simply click on the selected line and do the rest with "Edit".

4th. step:

Instead of using the "Quick Start Guide", we prefer using the option "Metal Types", since this saves some work and

time. We see immediately that initially only "lossless" is provided, and we immediately add copper to this ideal case in the selection list. You must keep very strictly to the following "click series":

First click on "ADD" then "Select Metal from library", then "Global Library". A selection list appears, in which "copper" is marked. Use "Edit" to obtain the list with its characteristics, in which we check and/or enter the "Thickness" of 0.035mm Confirm this using "OK". We then return to "Global Library", where we click on the "OK" panel, and if we click on "OK" again Fig. 4 should appear on the screen. But please don't forget that "Metal For New Polygons" has also been set to copper.

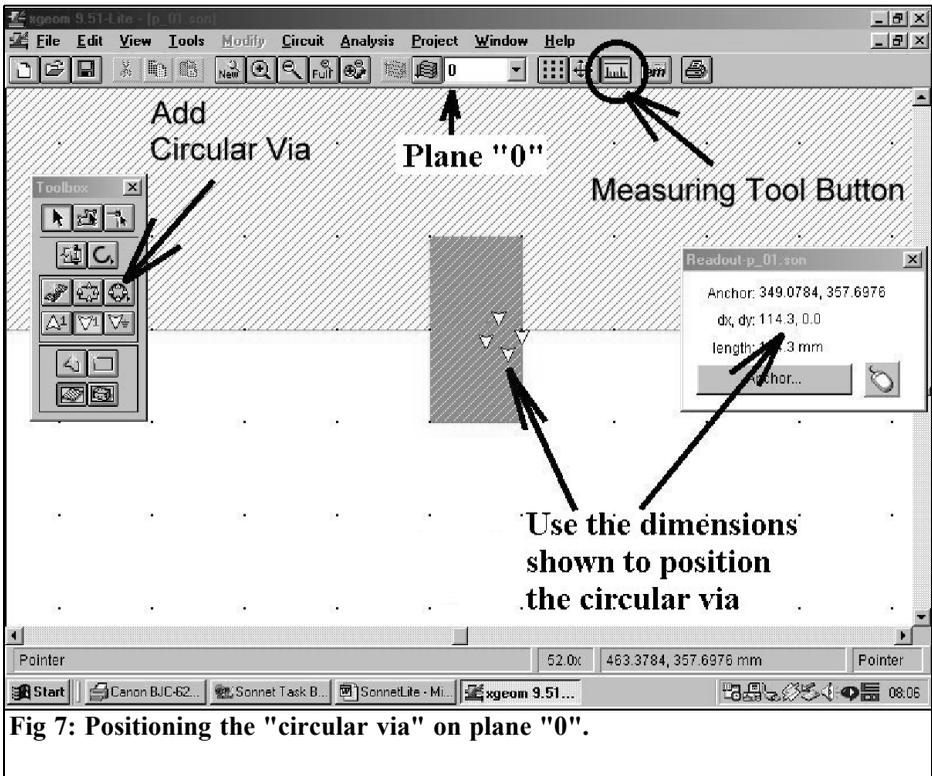


Fig 7: Positioning the "circular via" on plane "0".

5th. step:

Now it gets really interesting, because we now select the cell size (decisive for the accuracy of simulation) under "Box". A value of approximately 1% of the wavelength for the length or width of a cell is a good compromise in relation to calculation time, accuracy of simulation and storage space requirements. Because of the limitations of the SonnetLite version, this doesn't always work, but the "accuracy of simulation pain barrier" lies at approximately 5% of the wavelength. In most cases, that should suffice. The cell length, Λ_y , and the cell width, Λ_x , can naturally not be the same, but the difference between them should not be extreme (e.g. not more than a factor of 10).

This is what we do next:

- We know that the patch length of 154.18mm corresponds to about 50% of the wavelength. So we need only divide this value by 50 to obtain $\Delta_y = 3.0836\text{mm}$.
- If we divide the patch width of 228.6mm by this value, then we get 74.134129 cells, which we round down to 74 cells. Thus we obtain $\Delta_x = 228.6\text{mm} / 74 = 3.0891892\text{mm}$.
- In antenna simulations, SONNET recommends that a distance of at least one wavelength should be maintained from all edges to the metal walls of the simulation box. So in the X direction we now need about $2 \times 345\text{mm} + 228.6\text{mm} = 918.6\text{mm}$. We divide that by $\Delta_x = 3.0891892$ and we get about 297 cells.
- Then we do the same thing in the Y direction. The sum there runs: $2 \times$

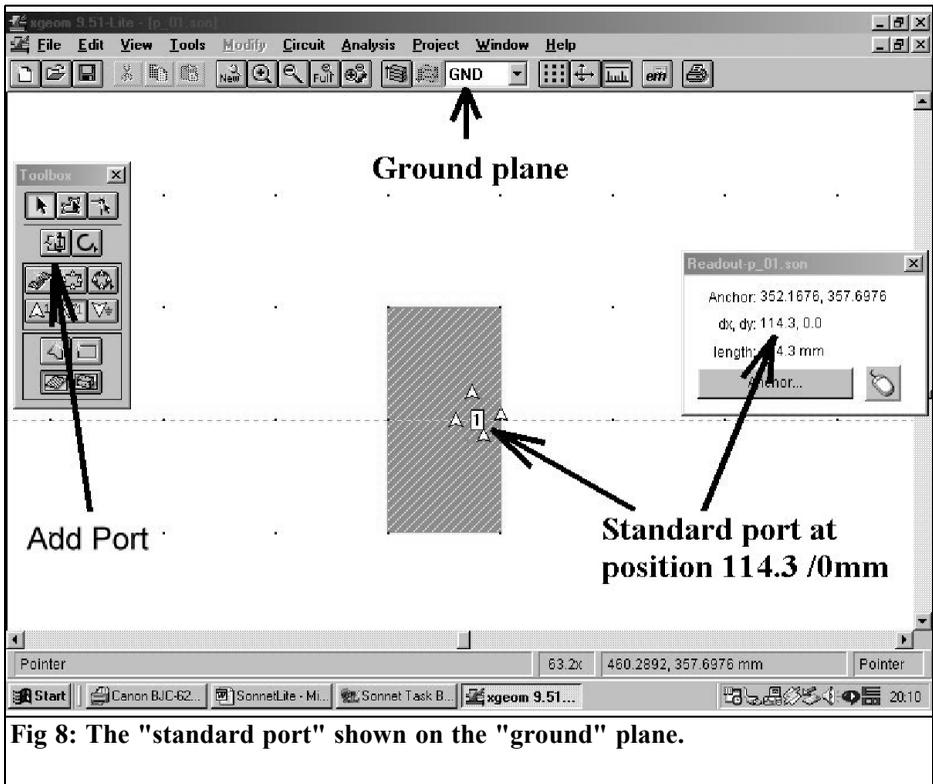


Fig 8: The "standard port" shown on the "ground" plane.

$345\text{mm} + 154.18\text{mm} = 844.18\text{mm}$.
Divide by $\Delta_y = 3.0836\text{mm}$, and we
get approximately 273 cells.

So now we go into the BOX menu. Fig. 5 shows what the final result should look like. Please don't forget to add a tick immediately after entering Δ_x or Δ_y at "Lock" in the same line, otherwise this dimension is not retained if you change the number of cells. Two very important entries are, of course, "Free Space" for the box lid (the antenna should finally release its energy to the free space) and "Copper" for the base of the simulation box.

6th. Step

Now we draw the antenna (Fig. 6). First please check whether plane "0" is actually activated and whether "Toolbar" is present on the screen. To make it easier to do the drawing, you can zoom out of the central area of the simulation box a little and then immediately click on "Add a rectangle". You can now use a known technique (Drag and Drop) to hold the mouse button down and draw the patch. Its dimensions can very easily be checked at the point indicated. If the patch area afterwards with green cross-hatching, copper is being used as the metal. Now reduce the simulation box to its old size again and, if applicable, push the patch across the screen with the mouse until it is in the middle of the box.

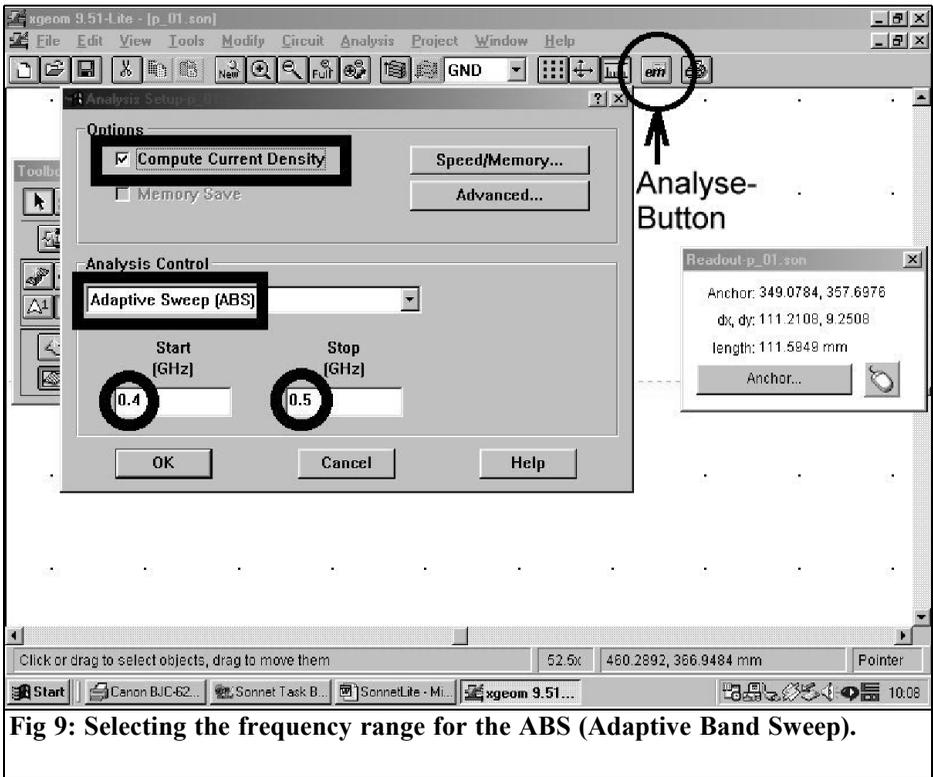


Fig 9: Selecting the frequency range for the ABS (Adaptive Band Sweep).

7th. step:

Use “View” (or the marked button) to obtain the “Measuring Tool” on the screen. Then zoom the patch out and make it as big as possible, click on the mouse symbol in “Measuring Tool” and then move the mouse very precisely to the bottom left hand corner of the patch. Now left click on the mouse and this corner suddenly becomes the reference point. This is exactly what we need for a “Circular Via” to earth, which should be in the middle of the bottom patch edge. This should, in fact, later become the exciter port; we provide a “Via” diameter of 1.27mm for connecting the internal conductor of the SMA bush. Now we activate “Circular Via” in the toolbox, enter this diameter in the menu that appears and position it precisely in the

centre of the bottom patch edge at 114.3mm (Fig. 7).

8th. Step

We now create a port at the “Via” position. Here again, we begin by enlarging the picture detail as much as possible, to make the positioning easier. This new port is then activated by clicking on the mouse and placing it precisely in the centre of the via (at position 114. 3 / 0mm).

Nothing seems to have happened, for at first nothing can be seen on the picture. It’s only when you change from plane “0” to “Ground” that the port connected up by the via appears on the screen, identified as “1” (meaning port no. 1). Fig. 8 shows the final result, greatly

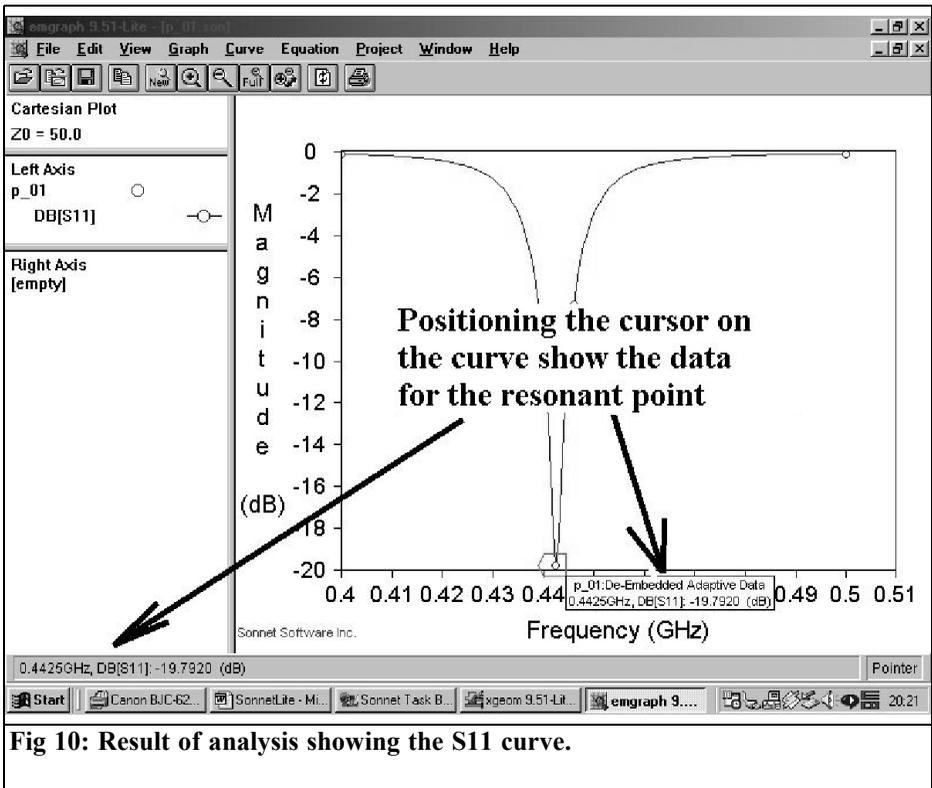


Fig 10: Result of analysis showing the S11 curve.

magnified, for the “Ground” plane.

Note:

The combination of “Via” and “Port” makes it possible to include the inductance of the internal conductor of the energising SMA bush into the simulation, because this is precisely how a measurement is carried out using the network analyser. The SMA bush is actually soldered by its flange to the metallised underside of the board and the internal conductor must pass through the entire board thickness to go all the way to the patch edge.

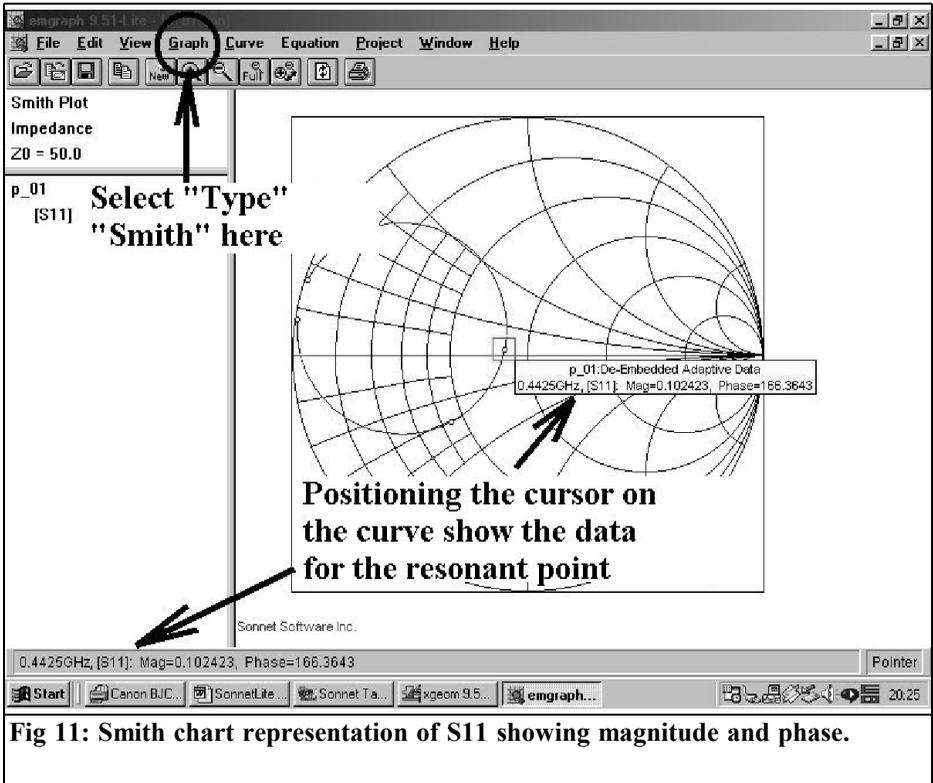
If, on the other hand, we wish to measure the impedance directly on the patch edge, without any trade offs, then we merely position an “Autoground Port” there.

9th. Step

Now things are getting serious, the simulation is prepared. Select “Setup” in the “Analysis” menu and then, as in Fig. 9, select a frequency range of 400 to 500MHz, “Adaptive Band Sweep” and “Compute Current Density”. Then press the “Analysis” button.

10th. Step

The program now prompts you to save the project. Right, so now it’s a good time to have a coffee break, while the PC does it’s work. When it has finished saving the simulation, simply close the



“Analysis” screen (small cross in top right hand corner) and instead click on “View Response” in the “Project” menu and “Add to Graph”. The desired result finally appears. Click on the curve with the mouse and then use the cursor key to travel to the resonance point. We can very clearly see the data that are valid for the resonance (see Fig. 10):

- Frequency of resonance = 442.5MHz
- S11 = -19.8dB.

The reflection factor here amounts to approximately 10%, as is also confirmed by a measurement using the network analyser. The SONNET frequency of resonance is not at 435MHz (as pre-set in the “PATCH16” program), but rather higher, at 442.5MHz. But this difference amounts to just 2%. So there is still a big difference in the measurement

(465MHz), and eliminating it is the objective of the next section.

By the way: if you prefer to look at a Smith chart, go into “Graph” then “Type” and “Smith”. Then you’ll get Fig. 11 and, following a click on the curve, the relevant values will emerge once more.

If you’re also interested in the current distribution on the patch, just go to “Project” and call up “Current View” and then enter the desired frequency. Fig.12 shows a greatly magnified zoom result for the frequency of resonance. It’s a pity that the varied colours can’t be reproduced in the article.

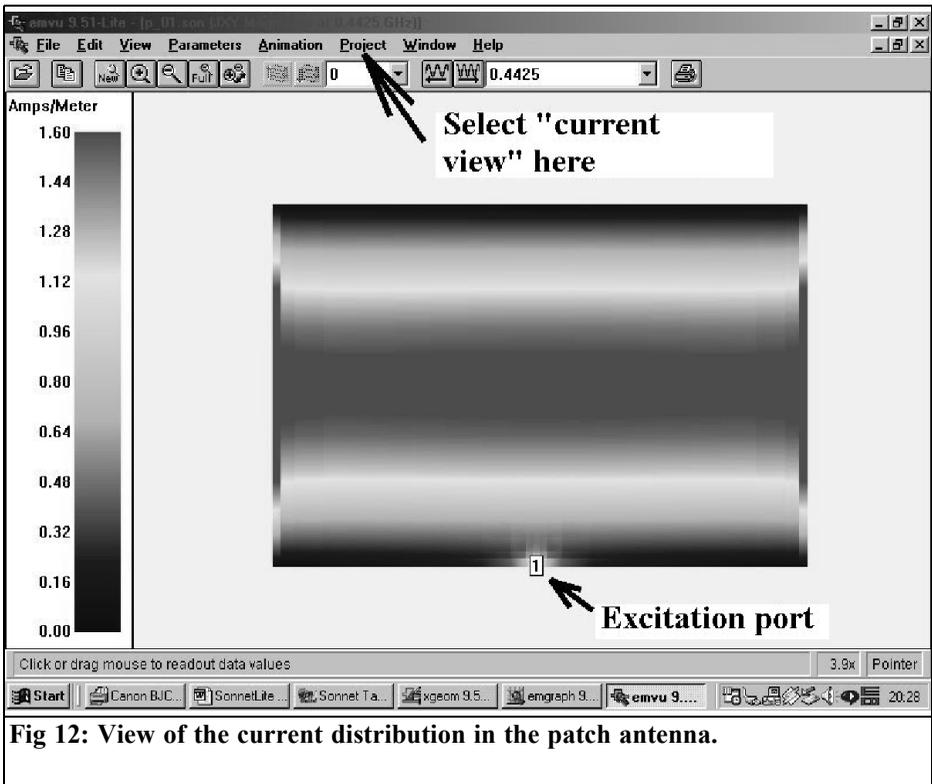


Fig 12: View of the current distribution in the patch antenna.

3.3. New antenna calculations using SonnetLite

The reason for the frequency deviation is plainly and simply a relative permittivity of 4.8, which is too high, and which goes right back to the data sheet for the FR4 material. So we just go into the “Dielectric Layers” menu and reduce the value entered there to

$$\left(\frac{442.5\text{MHz}}{465\text{MHz}} \right)^2 \cdot 4.8 = 4.35$$

(I’m sure you remember that when wavelengths are shortened on a line with a dielectric there’s a root involved...).

If we then repeat the simulation, we do actually get the measured frequency of

resonance of 465MHz. And now we’re moving rapidly down the final straight – and a small pause for reflection can help us on a bit:

If we simply increase the previous patch length of 154.18mm in the ratio (465MHz / 435MHz), the resonance should fall from 465MHz to 435MHz. This requires a new length of 164.8mm. We immediately divide this by 50 and obtain a new cell length for the SONNET check simulation of $\Delta_y = 3.296\text{mm}$.

Unfortunately, things now get a little tedious, since if we change the cell length we have to delete the old structure completely and draw everything again (including “Via” and “Port”!).

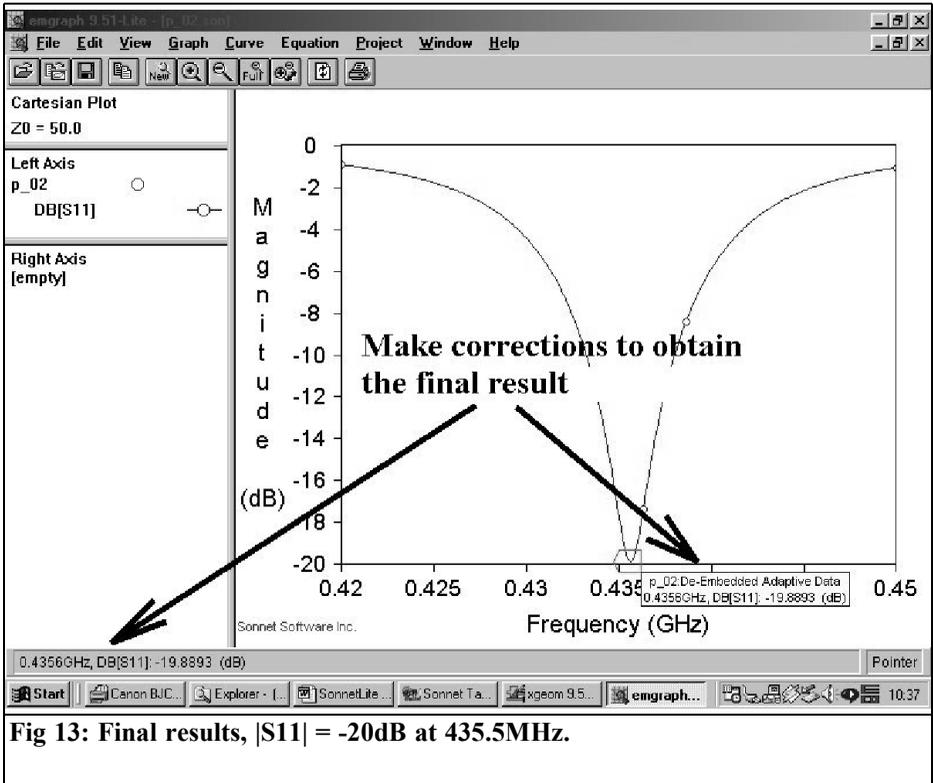


Fig 13: Final results, $|S11| = -20\text{dB}$ at 435.5MHz.

Note:

When entering the new value of 3.296mm for “y”, please don’t forget the lock, and also remember to reset the number of cells in the Y direction to 273, they’ll change themselves! Also does the window for the box base still show “Copper”?

You should also run another check in “Metal Layers”, since unfortunately when changes are made the setting likes to jump back from “copper” to “lossless”.

If everything is OK, we can run a new simulation and the result can be analysed. It seems that we have almost acquired the desired frequency of resonance now, but the carrier material losses do not yet match (as S11 is coming out as too

good). So keep on correcting until you get the data shown in Fig. 13.

These include a patch length of 164.8mm, a patch width of 228.6mm, a relative permittivity of $\epsilon_r=4.35$, a new dielectric loss factor of 0.0125 and a copper coating with a thickness of 35 microns.

3.4. PUFF check and the moment of truth

For this purpose, we first need another simulation using SonnetLite:

Once we assume that the carrier material

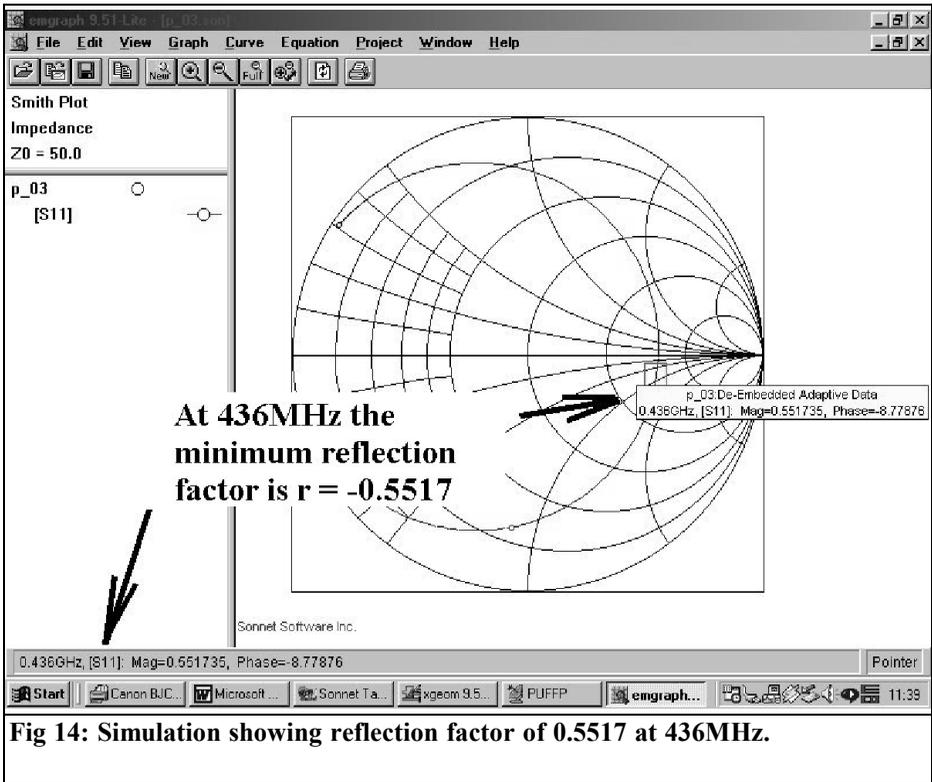


Fig 14: Simulation showing reflection factor of 0.5517 at 436MHz.

and the metal components used are completely lossless, the simulation result you obtain is the pure radiation resistance of the antenna on the patch edge!

So it's back to work: delete the old structure, reset all metals (in the box and under "Metal Types") to "lossless", set the loss factor of the dielectric to zero and finally re-draw everything (including "Via" and "Port").

The reward for our toil can be seen in Fig. 14: a simulated reflection factor of +0.5517 at 436MHz gives an input resistance of

$$R_{in} = \frac{1+r}{1-r} \cdot 50\Omega = \frac{1+0.5517}{1-0.5517} \cdot 50\Omega = 173\Omega$$

Thus we have 346Ω on each patch edge

acting as a radiation resistance, and this can also be observed in the PUFFP simulation, which should also be carried out straight away.

First, the PUFFP setup file is opened with an editor, and a relative permittivity is entered with $\epsilon_r = 4.35$, together with a dielectric loss factor of 0.0125. The design frequency of 435MHz = 0.435GHz can be entered. Then open PUFFP (are you already working with the new batch file, "PUFFP_XP.bat") and delete the old setup layout screen F1. In the list F3, we first enter the radiation resistance as 346Ω and then we have to reproduce the patch in the form of a very wide and also low resistance microstrip. Keep changing its impedance level until you obtain the desired width of 228.6mm. The mechanical length, on the other hand, is entered directly and can be

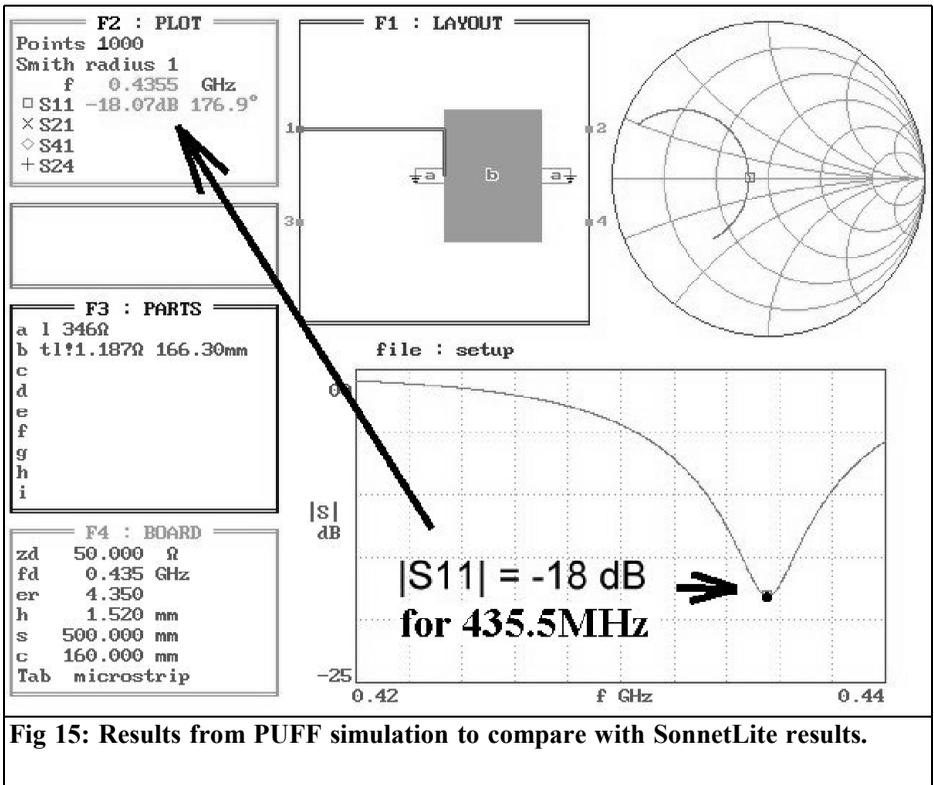


Fig 15: Results from PUFF simulation to compare with SonnetLite results.

calculated in advance. To the 164.8mm we add the open end extension on each side. With a wide line like this, it is approximately half the board thickness – that comes to approximately 0.75mm. on each side. So we arrive at approximately 164.8mm + 1.5mm = 166.3mm. And that’s what we enter in the F3 file (after a few trial attempts – you know, you change the impedance level, then press the equals sign and check the width):

tl ! 1.187 166.3mm

The simulation result can be seen in Fig. 15 and the only real difference from SONNET is that the value of S11 (i.e. the input reflection) is predicted, rather too pessimistically, as only -18dB. (PUFF arrives at higher losses for the transformation circuit, and only a slightly smaller dielectric loss factor of 0.012 would give

the precise value of S11 = -2 dB here as well).

No doubt everyone is already dying to hear the test result for the antenna manufactured using the new dimensions (patch 228.6mm x 164.8mm on FR4 carrier, 210mm x 297mm, board thickness = 1.52mm).

Here it is:

- The resonance measured was 438MHz, with a minimum input reflection factor of -0.1.

Well, there you are, then! It shouldn’t be too difficult to correct this residual error, the patch length of 164.8mm is increased again by the factor (438MHz / 435MHz), another antenna is manufactured with a length of 165.93mm, and then everything

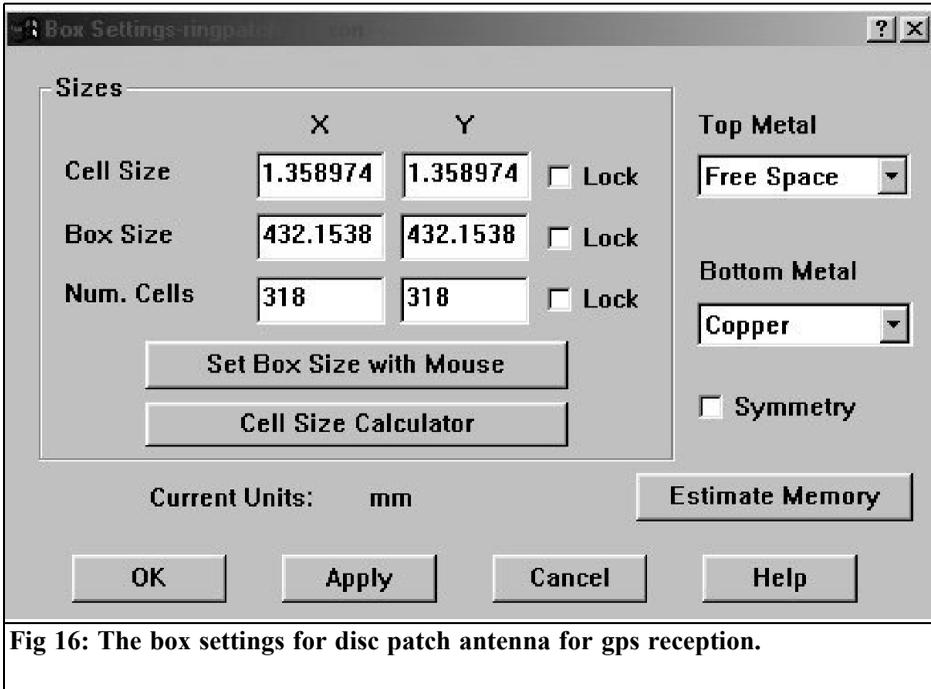


Fig 16: The box settings for disc patch antenna for gps reception.

should be all right.

4. Second typical demo: Disc form patch for GPS reception

Another actual case where another radio ham friend handed me a sketch and asked me to check whether it was really a GPS patch antenna.

The carrier material, once again, was FR4, with a thickness of 1.52mm. The underside was continuously coated, and on the top side there was a circular copper area with a diameter of 53mm. 16mm away (measured from the outer edge of the circle), the feed could be seen, in the form of an SMA flanged bush, soldered on from the bottom up. So this was a similar problem to our earlier

example – but this time it was round! So now SONNET had to show us what it could do.

The data for the FR4 material (relative permittivity = 4.35 and dielectric loss factor = 0.0125) cannot simply be taken from the previous example, for as the frequency rises the carrier material losses increase. And if we also study various manufacturers' documents in detail (e.g. from ROGERS), then there is usually an increase in the "loss tangent" with the root of the frequency. Thus at 1,575MHz, you actually have to simulate using a new loss factor of

$$lt = \sqrt{\frac{1575MHz}{435MHz}} \cdot 0.0125 = 0.02378$$

We naturally retain the "Copper" setting for the metal surfaces.

As regards the selection of cell size, it became clear that with approximately 44

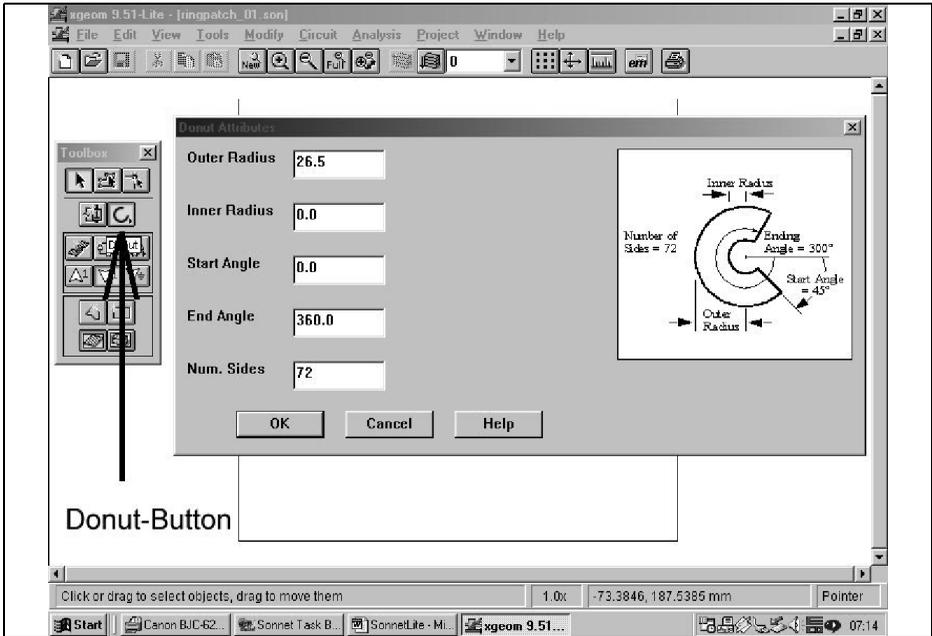


Fig 17: Setting up the circular patch using the "Donut" button.

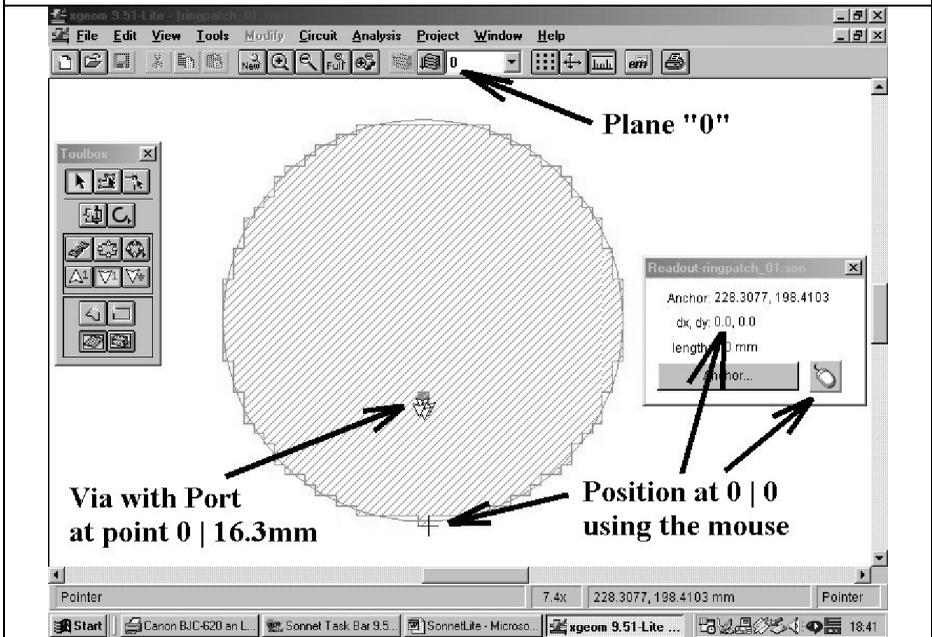


Fig 18: Positioning the via and port.

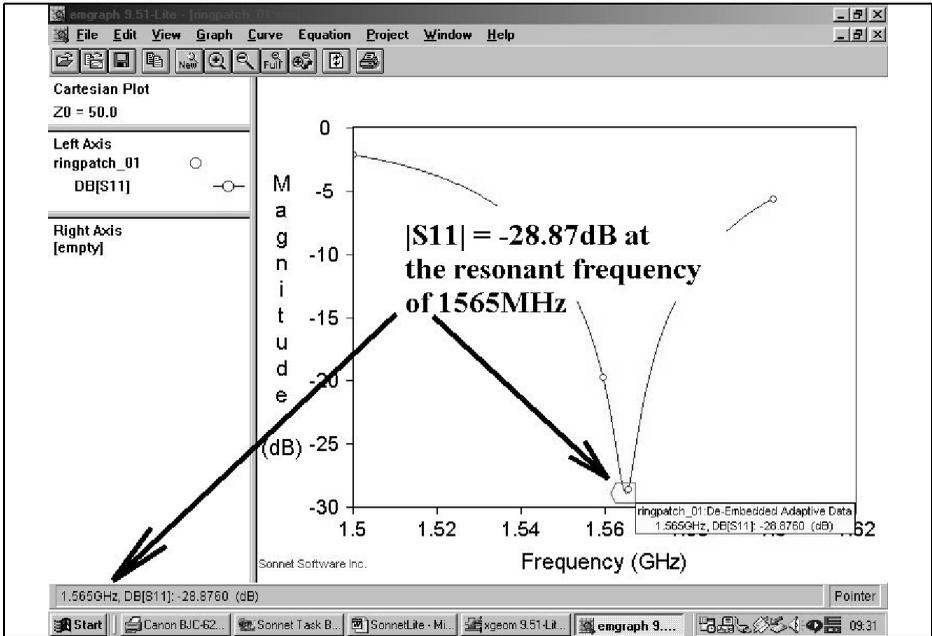


Fig 19: Simulation results showing S11 for the circular patch antenna.

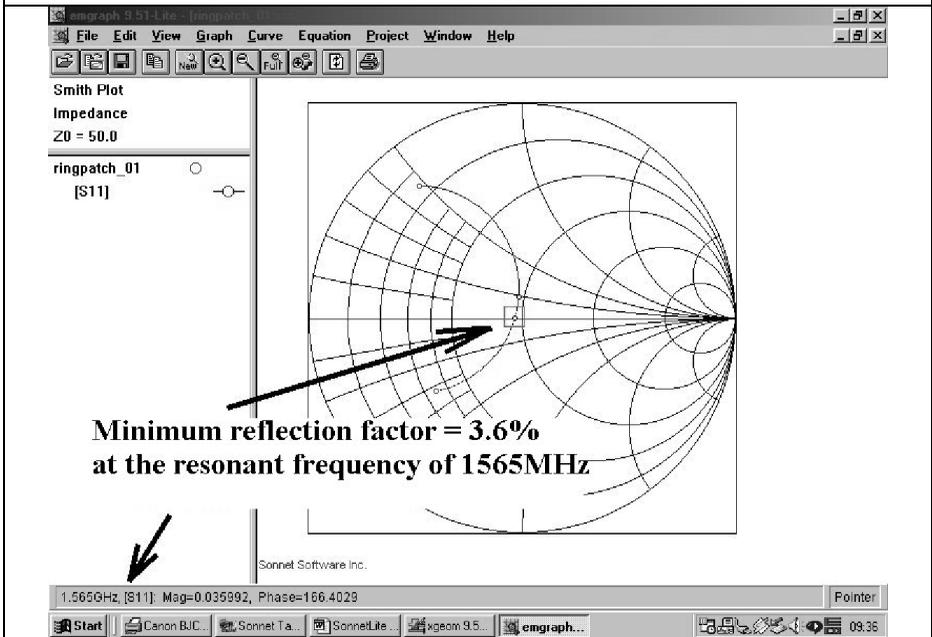


Fig 20: Smith chart representation of S11 showing magnitude and phase.

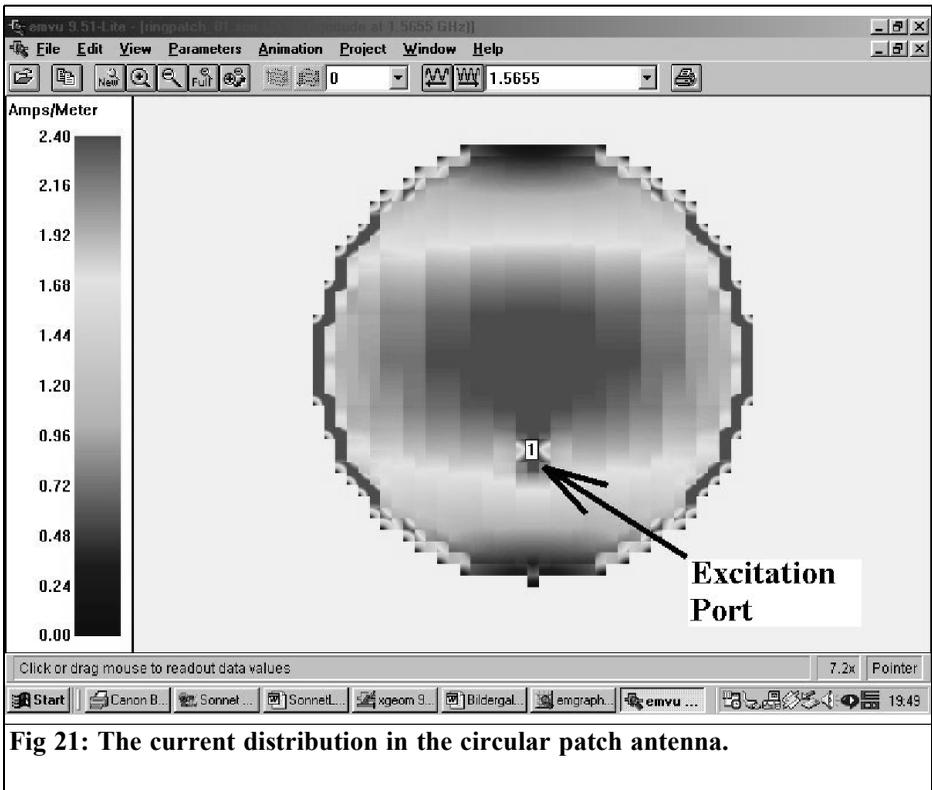


Fig 21: The current distribution in the circular patch antenna.

cells in every direction, the storage space occupied was still less than 16 megabytes. Fig. 16 shows the box settings finally selected and used to start drawing the structure. To set up the circular patch, we need only the “Donut” option from the toolbar. Fig. 17 shows precisely how it can be used to create a circle from the plain washer using suitable settings. This circle is then positioned, using what is now a familiar procedure, and a “Via” and a standard port are created. Fig. 18 very neatly demonstrates how the program for the desired circle is put together from the many individual cells. Apart from this, the “Via” and the port are positioned at a distance of about 16mm. (in relation to the lowest patch edge) with the help of the measuring tool.

The simulation results can be seen in Fig. 19 and Fig. 20 (S11 in the frequency

range of 1.5 to 1.6GHz), the test piece is truly an antenna! But if it’s a radiating antenna, this should be visible from the current distribution at the frequency of resonance. So we obtain a greatly enlarged zoom of this (Fig. 21) and it naturally resembles the result from the rectangular patch in Fig 12.

5. Summary and acknowledgments

At this point, I would like to express my special thanks, once again, to Dr. Volker Mühlhaus in Witten, who, as SONNET’s representative in Germany, has shown

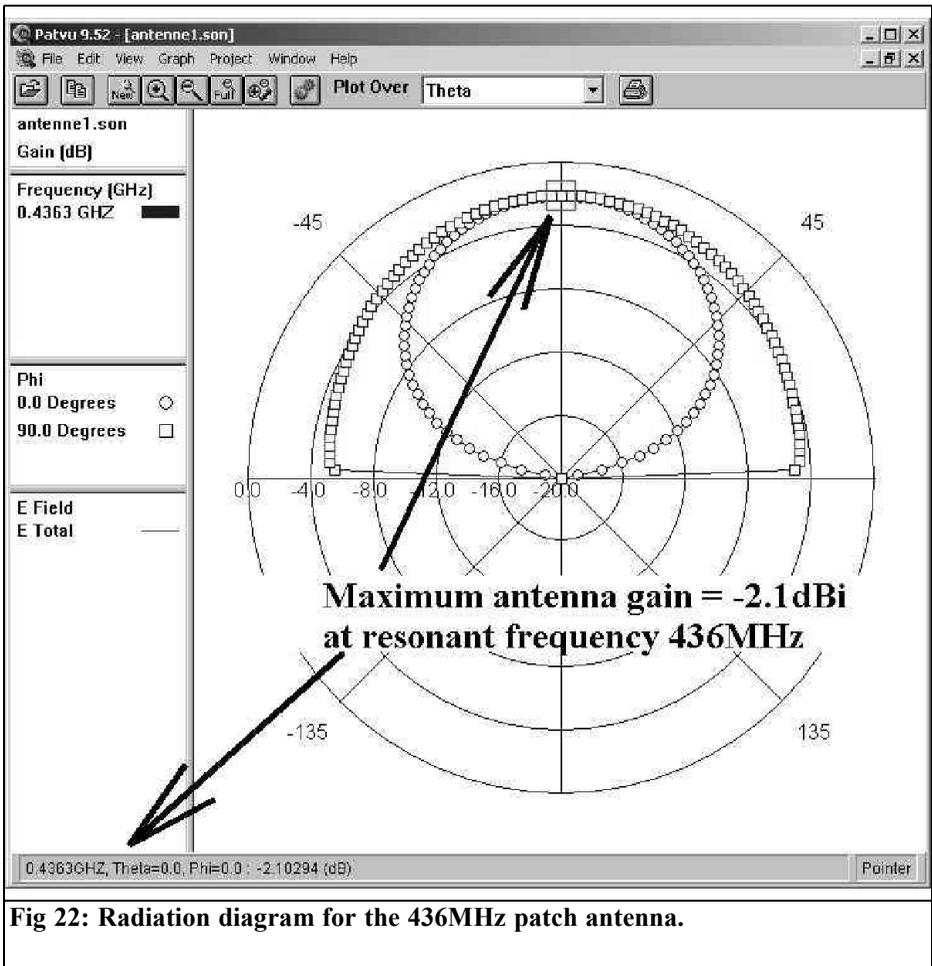


Fig 22: Radiation diagram for the 436MHz patch antenna.

himself to be extremely competent and co-operative with respect to all questions and problems (and no wonder: after all, he's a radio ham as well...).

His contribution to this article, which also provides a "consolation prize" can be seen in many places, for instance, in Figs. 22 and 23, namely the highly desirable simulations of the radiation diagrams for the rectangular and round patches (not available using the "lite" version under discussion)..

Both antennas naturally display similar

response patterns, but the most important point does not become apparent until you take a closer look, at 400MHz, FR4 itself can hardly be used for this purpose any longer, and its losses have grown so high that for both antennas the gain has slumped from the theoretical +5.5 to +6.5dBi down to 0 to -2dBi! The only consolation is that this has increased the bandwidth, which makes the use of such antennas (as already mentioned) appear pointless except with connections over short paths and with small to medium transmission power.

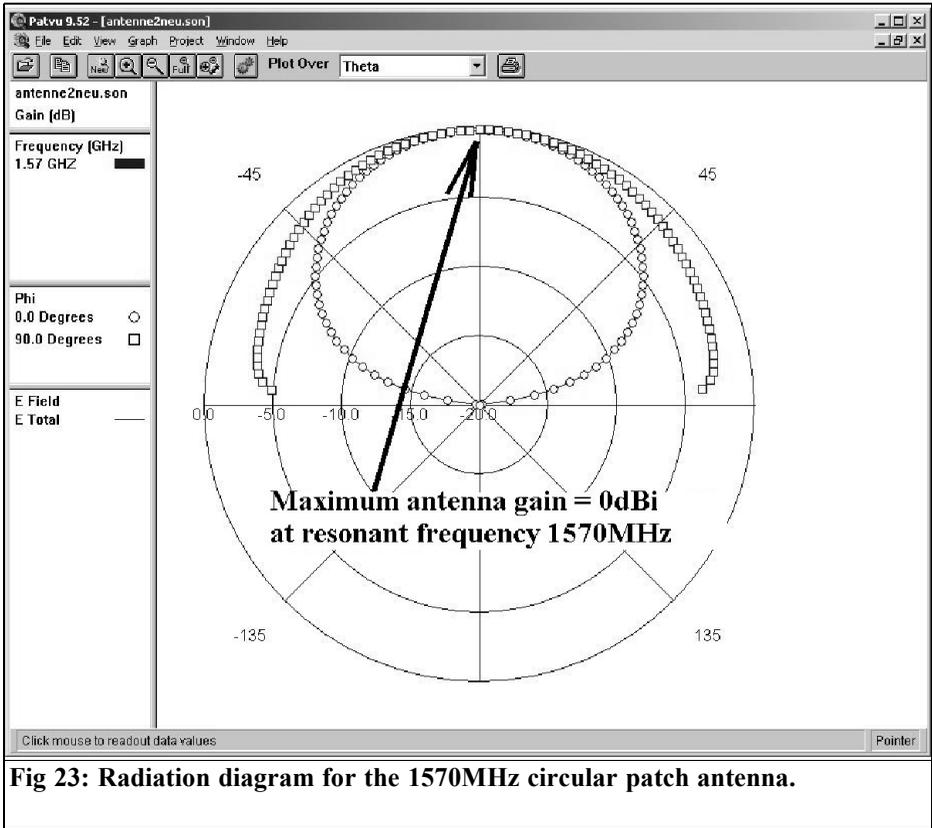


Fig 23: Radiation diagram for the 1570MHz circular patch antenna.

Fig. 24 shows another extract from the SONNET manual with the co-ordinate system that shows both the response patterns. The normal direction and angle definitions for antenna engineering can clearly be seen, together with the determination of E_{ϕ} and E_{θ} .

using a key to index the observation angle, in steps of 5 degrees, and in this way we can easily observe how the individual response patterns for E_{ϕ} or E_{θ} come into existence. (Very much recommended, even for specialists!).

Here's a tip for anyone who still has some problems, get hold of the "m-strip40" program already discussed in "VHF Communications", install it and upload one of the patch antenna examples supplied with it, say "Demo2". Then call up the pattern menu, select first "Kos" and then "Pattern 2D". You'll be overjoyed to find that the results are almost exactly the same as those in Fig. 22 or 23.

To summarise:

The present version of SonnetLite 9.51 offers both the hobbyist and the professional considerably expanded options in relation to the development and investigation of new projects. But the best compliment that you can make a free program is the introductory comment: "...There's only one more heartfelt

But we now have the additional option of

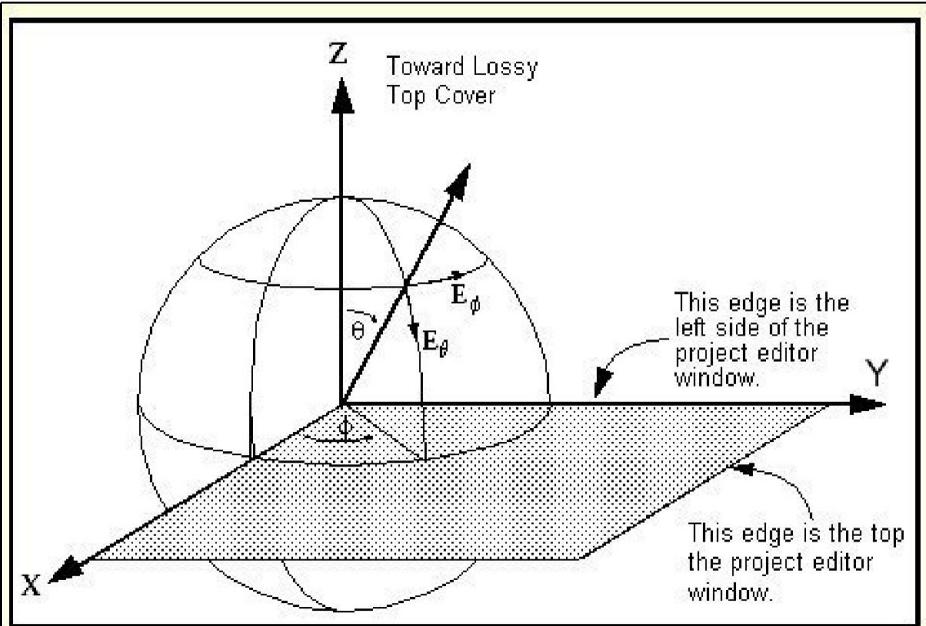


Fig 24: SonnetLite co-ordinate diagram.

wish...". And I'd just like to repeat that here.

6.0

References

To obtain the program: Internet address of SONNET: <http://www.sonnetusa.com>

German agent and advice centre: Ingenieurbüro Dr. Volker Mühlhaus, Witten (<http://www.muehlhaus.com>)



Alexander Meier, DG6RBP

A simple detector to estimate the immission from GSM mobile phone base stations: Part 1

In contrast to your own mobile telephone you can't switch off the base stations in your local area. The worries about the health effects of this permanent radiation lead to the demand for field strength measurements. Exact measurements with a spectrum analyser are very expensive, that is why estimated measurements were introduced using a wide band detector with an integrated filter for the GSM frequencies.

1.

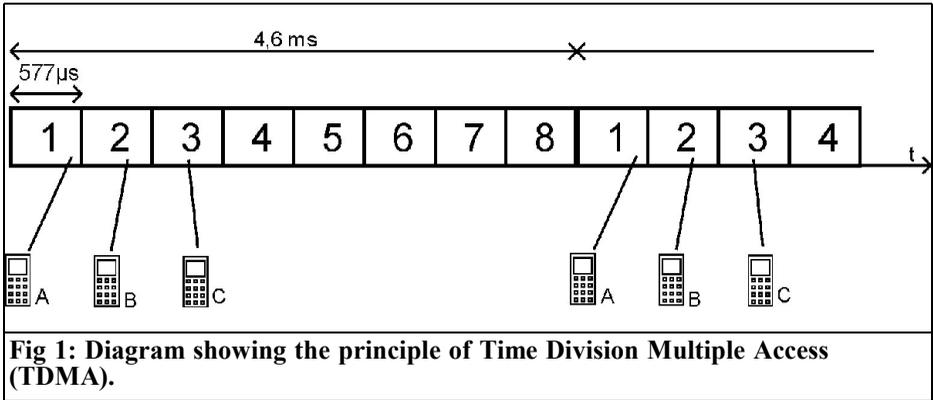
The GSM System (global system for mobile Communication)

The location of a mobile phone base station is often used by several network suppliers. Every one of them uses their own antenna, either an omni-directional antenna or more sector antennas in order to give preference to certain directions or to increase the number of subscribers. If the surrounding is divided into different zones (usually $3 \times 120^\circ$) using sector antennas, then they are also using different frequencies (frequency channels) and work separately from each other.

Each antenna of a base station sends out general data, like network labelling or the frequency of surrounding base stations, on a control channel (CCH). The actual conversations are handled by traffic channels (TCH).

The transmit frequencies for the base stations (Downlink) are 935MHz up to 960MHz for GSM 900 (accordingly 925 - 960MHz for the enhanced GSM 900) and 1805MHz to 1880MHz for GSM 1800. The frequency channel separation is 200kHz. The mobile phones transmit on a duplex band of 45MHz (GSM 900) as well as 95MHz (GSM 1800) below the base station frequencies.

Several telephones use a frequency channel simultaneously using Time Division Multiple Access (TDMA). Each frequency channel is subdivided into frames of 4.6ms, each of these is split into eight time slots of $577\mu\text{s}$. The conversation data from up to eight portable phones is transferred within a framework one after the other time wise, each portable phone is assigned to a time slot (Fig 1). Using this technique, the simultaneous handling of eight conversations is possible on a single frequency. The transmit power for a frequency channel is between a few watts up to about 50 watts according to the size of the mobile radio cell. The transmit power is zero for short periods between each time slot.



The single time slots (traffic channels) of a traffic only frequency channel are activated by the base station dependant on the conversation flow. The transmit power is regulated separately for each time slot dependant on the connection quality to the mobile phone. A distinctive pulse frequency of $n \cdot 217\text{Hz}$ is generated according to number "n" of the activated time slots. In order to avoid fading due to unfavourable reception conditions, the base station operator can activate optional frequency hopping. If this happens the conversation is transferred to another frequency channel after each time slot.

One frequency channel of the base station is subdivided like the traffic only frequency channels into eight time slots. A minimum of one slot is required for control purposes (control channel) so that there is capacity for up to seven additional telephone conversations (traffic channels). In contrast to the traffic only frequency channels, this one sends constantly with all eight time slots activated and with maximum power for every slot! Because the transmission power is only zero for a short period between the time slots, a not distinctive pulse frequency of 1736Hz is generated.

The mobile phones themselves send every 4.6ms for 577μs, therefore a pulse frequency of 217Hz is generated by the hand appliances.

1.1. Immission measurement around a GSM base station

To measure immissions we use either E the rms value of the electric field strength [V/m] or the power density S in watts per square metre [W/m^2]. In the far field of the antenna, which begins a few metres from the antenna at these frequencies, both measurements are related by the impedance of free space, so that they can be converted easily:

$$S = \frac{E^2}{Z_0} \quad \text{with} \quad Z_0 = 377\Omega$$

The combination of all frequency channels within a frequency range (GSM 900 or GSM 1800) must be added up quadratically to determine the total electrical field (accordingly the power densities has to be simply added).

$$E_{ges} = \sqrt{E_1^2 + E_2^2 \dots E_n^2} \left[\frac{V}{m} \right]$$

$$S_{ges} = S_1 + S_2 + \dots S_n \left[\frac{W}{m^2} \right]$$

The total field strength at the measurement point fluctuates because of the dynamic traffic only frequency channels. This makes measurements very difficult.



In order to get more reproducible measurement one normally decides the "worst case" power density. This occurs in the most unfavourable case, i.e. if the network is fully employed to capacity and the connection quality to all mobiles is the worst. Then all traffic only channels would also transmit with all time slots activated and maximum power. To measure the "worst case", only the power densities of the frequency channels which contain a control channel are measured with a spectrum analyser, because they are at full power for all time slots. Afterwards one adds up the multiplications of every measurement of a control channel with the respective number of traffic only frequency channels to determine the entire power density. For this one requires the exact information about the base station, i.e. the number of respective traffic channels for each control channel. Since the network is rarely fully employed the mean power density is actually only approximately 30% of the "worst case".

A wide band detector is introduced to make direct estimated measurements of the present power density. In contrast to many other wide band detectors, it has a switchable filter for both GSM frequency bands, so that separate measurements can be made. The filter also suppresses measurement errors due to foreign signals, e.g. from mobile phones, radio stations or other radio services. For most cases this simple rough measurement of immission is sufficient.

The measurement point (x,y,z) should be chosen carefully because the field strength can vary due to reflections. The vertical polarisation of the transmitted field can also be rotated. The field strength should be investigated, in a living area for example. Walk around, rotate the antenna and alter the height of the antenna until the maximum field strength is found. A minimum distance of 50cm should be kept to walls, basement, blanket, cupboards or similar objects.

A suitable antenna for GSM field strength measurement is a log periodic directional antenna. They are wide band and encompass both GSM frequencies. The directivity of the antenna can be used to determine the direction of the incident radiation and locate a hidden base station, which are mounted on a chimney or installed in a billboard etc. If the measurement location is surrounded by several base stations from different directions, or if radiation will be received from different directions due to reflections, the directional antenna will not receive all radiation and hence those will not be estimated. A quasi-isotropic measurement with an omni-directional antenna (e.g. dipole) has its advantages in this situations. For doing this, the antenna has to be located orthogonal at the same measurement point in the x, y and z direction. Afterwards the particular field strength will be added up quadratically (accordingly the power densities have to be simply added up).

1.2. Limits

The limit of the allowable total immission for a frequency band at maximum system utilization ("worst case") that cannot be exceeded is in accordance with the 26th Bundes-Immissionsschutzverordnung [1].

GSM 900:

$$E_{\max} = 42.0V/m \quad S_{\max} = 4.7W/m^2$$

GSM 1800:

$$E_{\max} = 58.4V/m \quad S_{\max} = 9.1W/m^2$$

Please note these limits are for Germany only.

In the practice, such intensities are not



normally reached. If one looks at the actual average immission instead of the "worst case", it is well below these levels. Typical measurements in cities and communities for momentary immission are in the order of 10 to 100 microwatts per square metre. Only rarely are field strengths of several milliwatts per square meter measured.

For a long time it has been disputed that low levels of radiation can endanger health. Many scientists speak of no danger at levels of a few microwatts per square metre but mobile radio opponents regard this as risky. The question of the health effects should not be discussed further here.

On the internet one can find a recommendable and objectively correct webpage about "electro-smog" from Ralf-Dieter Wölfle [2].

If someone feels there is a problem with radiation, screening can be used to reduce the radiation intensity in the living space. Usually most radiation enters through the windows, since these are bad shields in the comparison to concrete and bricks. Metalised windows are better for screening.

1.3. Other radio services

Beside GSM mobile radio there are many other other radio services, like radio stations and TV stations or the new UMTS mobile radio system.

People usually have the most intensive radiation source in their house, e.g. wireless networks (WLAN) or cordless telephones. In a standard DECT digital telephone system, the base station sends a beacon signal to the handset even if the telephone is not being used! The output

power is 250mW peak or 10mW average. Such a base station in an apartment (or neighbouring apartment) generates more radiation than all the GSM base stations in the surroundings!

X.

Literature

[1] 26. Bundesimmissionsschutzverordnung BImSchV, Verordnung über elektromagnetische Felder

[2] Elektromog-Informationssseite of Dipl. Ing. Ralf Dieter Wölfle,

<http://www.ralf-woelfle.de/elektromog/index.htm>

To be continued



Gunthard Kraus, DG8GB

PUFF with Windows XP: “Wonderful”

This is often how the winners describe the result of a game of football, but there’s something of an ongoing mood of jubilation after any successful struggle. There’s a similar mood among the supporters of “PUFF”, following the new problems that have suddenly developed with Windows XP.

1.0

To take things in order

Let’s just go back briefly to the outbreak of hostilities:

Following the successful revival of PUFF simulation software at the time of XP (See [1] and [2]), it suddenly became clear that Microsoft essentially wanted to have all old stuff off the market and had thus also deleted the screenshot option under XP for DOS programs, even when they had successfully been made to run again. This makes printing was almost impossible. But the call for help in recent issues of VHF Communications and UKW Berichte did not go unanswered, a veritable flood of emails and suggestions came pouring in. So please forgive me if I can’t express my sincere thanks to everyone personally for their trouble. I’d

just like to thank everyone involved here and now. But I am also extremely satisfied to be able to point out that there’s no need for anyone to be uneasy that there’s a lack of new blood in our field (RF and microwave DIY). The solution presented and advocated below was proposed by one of my students. This clever lad (an RF enthusiast and a computer freak in one, combined with an attitude to Microsoft which is best described by saying that he’s the technical equivalent of Michael Kohlhas) remembered something from his early days using DOS and kept searching until he could submit a watertight solution. Just to defy Microsoft. Here it is:

It requires a DOS program resident in the memory and called “pcxgrab” (it was called a TSR program when used with DOS). It is loaded before PUFFP and automatically de-installed when you exit from PUFF. A batch file, “PUFFP-XP.BAT”, controls this process. When you need a PUFF screenshot, press the key combination “ALT” + “G” An attractive ringing tone demonstrates that a copy of the current screen is being made and is being saved as a PCX file in the PUFF directory. If we repeat the procedure again later to record the next important step in the circuit development, then your friendly computer generates a new PCX file and the old one is NOT overwritten. The rest is simple and already

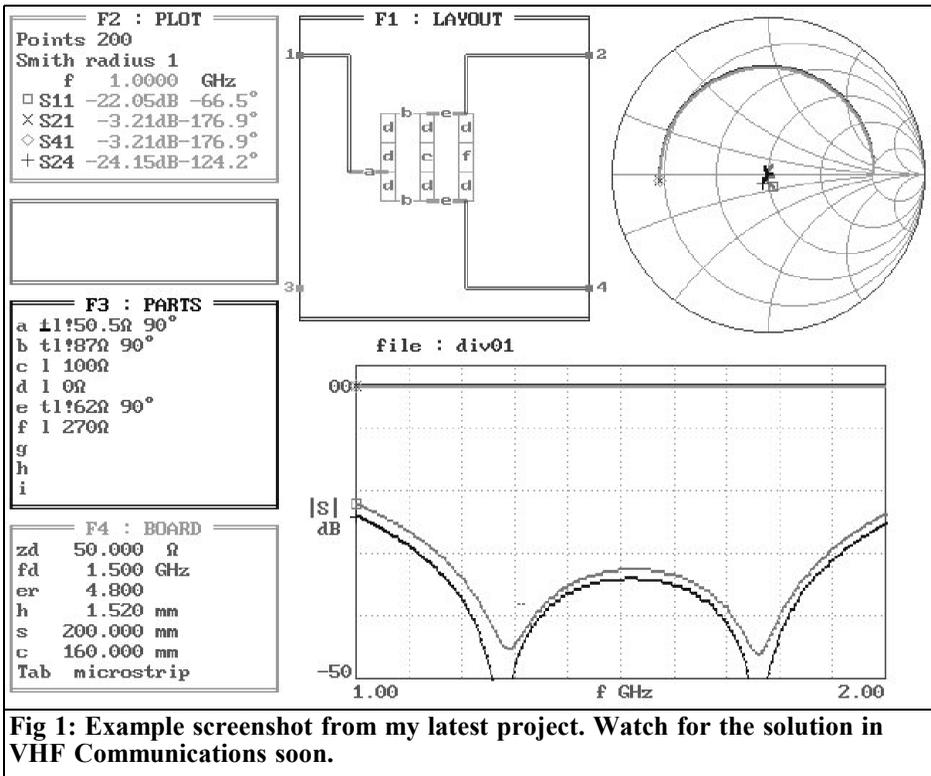


Fig 1: Example screenshot from my latest project. Watch for the solution in VHF Communications soon.

familiar, and involves using a modern graphics program (IRFAN-VIEW, Paintshop Pro, etc.). And for the freaks, you can even find references to “PCXGRAB.ZIP” on the Internet and download it, but who would know this in advance? It’s true there are also quite a lot of useful articles, notes and applications – but they are in Russian!

All the necessary files have been summarised in a “PUFFP-XP service pack”, which can be downloaded from my homepage:

www.elektronikschule.de/~krausg

However, the following notes are useful:

The batch file has essentially been written in such a way that, for reasons that have already been explained several

times, you are always working with “PUFFP.EXE” (i.e. with the protected mode version of PUFF). Thus theoretically the entire pack has to be copied in, whereas with PUFF the two files “PUFFP-EXE” and “RTM.EXE” are stored. To make things simpler, and for security reasons, the service pack also has these two files. They are therefore also copied automatically and that should make the material even easier and more reliable to work with.

Naturally the old PUFF icon must be deleted from the WINDOWS starting screen, and a new link must be created to the file “PUFFP_XP.BAT”. But it’s very easy to recognise this new file in the Puff directory by it’s icon with the little gears. Once you click on this icon, all the procedures are then automatic. And another practical tip, please don’t start all your new projects in the same PUFF



folder, because after a little while this means things get into an unbelievable mess. A new folder is simply started for any new development, and PUFF21 is just copied into it, together with the service pack. Once the development is done and dusted, then only the result is saved and the associated "development folder" is at some point just deleted.

So on to new developments or challenges with fresh courage, PUFF's help is available once again. But just to encourage us all, myself included, here's a riddle. A brand new XP screenshot is shown in Fig 1. It is my most recent practical project, which happens to be in the final PUFF phase. Certainly, I'm not revealing the subject, but maybe you can guess... The solution will probably be appearing in an article in one of the next few issues of VHF Communications.

Just one more thing occurs to me before I go: the service pack naturally also functions excellently with WINDOWS 95, 98 and ME.....

2.0

Literature

[1] Gunthard Kraus, DG8GB: Problems with running PUFF on WINDOWS 98, WINDOWS ME and WINDOWS XP, and how to eliminate them. VHF Communications, 4/ 2002, Page 229 - 231

[2] Gunthard Kraus, DG8GB: Let's try again with PUFF. VHF Communications, 3 / 2003, Page 179 - 180



The UK Six Metre Group

www.uksmg.org

With over 1000 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 60-page quarterly newsletter 'Six News' and through its web site www.uksmg.org, 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 Iain Philipps GORDI, 24 Acres End, Amersham, Buckinghamshire HP7 9DZ, UK or visit the web site.



Gerard Galve, F6CXO

Franco's Finest

Low priced 10GHz preamplifiers described by F6CXO

Franco Rota runs an RF component supply company in Italy called R F Elettronica. His main objective is to sell bulk components such as SMD parts to the electronics industry. He attends some radio rallies in Europe and often has interesting items for sale that can be used or adapted by radio amateurs for use on the amateur bands. This is the first article of a regular series that will describe one of Franco's products with details of its use by radio amateurs. If you require more details about the products you can contact VHF Communications or Franco – rf.elettronica@tiscalinet.it

1.0

Introduction

Franco sells the PCB described in this article for €3 (Fig 1). The board was initially purchased to salvage the 4 NE 32584's. After examination, I realised it was fairly rare to find satellite boards with preamplifiers which are so well aligned and so suitable for modifications.

Fig 2 shows a close up of the two preamplifier circuits. Preamplifier No. 1

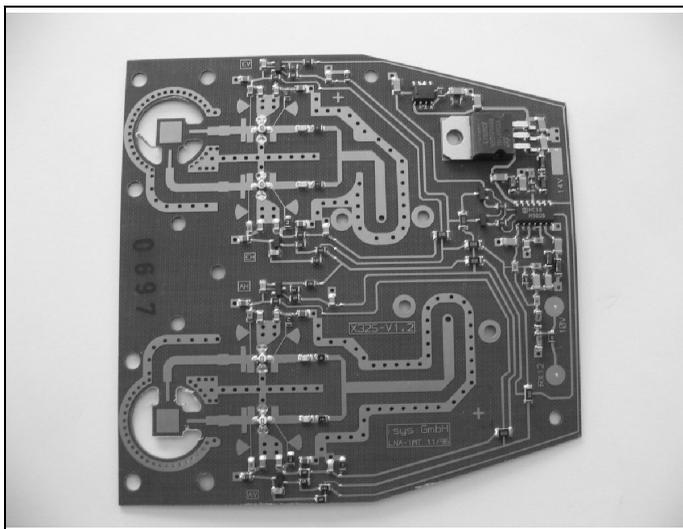


Fig 1: Picture of the amplifier PCB available from Franco Rota for €3.

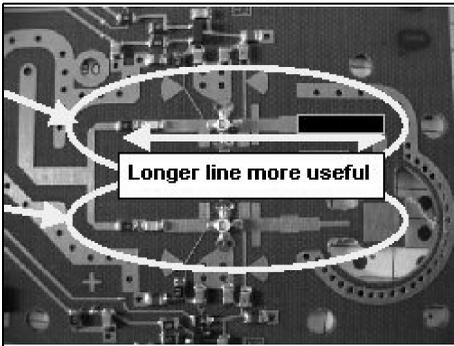


Fig 2: View of one pair of amplifiers. The top circuit is referred to as preamplifier No1 in the text, the bottom one is preamplifier No2.

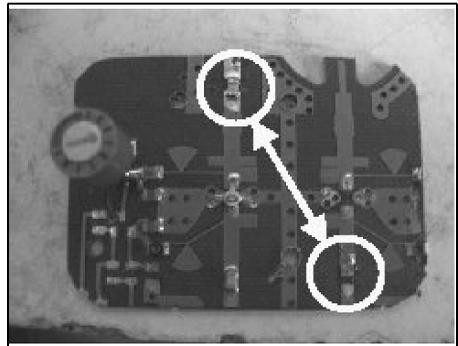


Fig 4: Connecting two amplifiers together.

can be adapted to a wider range of enclosures. The input track can be cut at any point throughout the black area.

Fig 3 shows that if you are careful, you can even salvage 2 preamplifier circuits on this board, use the output capacitor of one as the input for the other. You could just salvage transistors (that was the original idea). Fig 4 shows how the output capacitor of the right hand preamplifier is connected to the input of the left hand one. The negative feed potentiometer can be fitted on the existing printed circuit.

It is that easy, the hardest part is to find a housing that suits the length of the

printed circuit board. Just use your imagination and see what might be available at the back of some old drawer. Figs 5 and 6 show the authors example.

2.0 Performance

Let's see what this box of tricks can do.

- Noise Figure 0.7dB without the lid, 0.8dB with the lid.
- Gain 14dB from 10,368 to

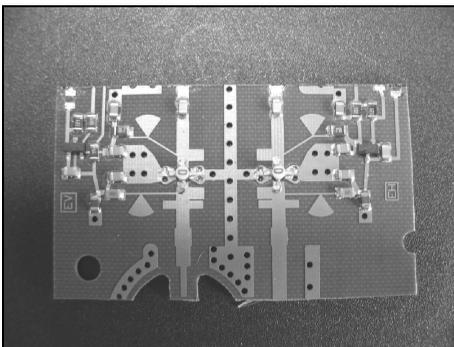


Fig 3 : How to use two amplifier circuits.

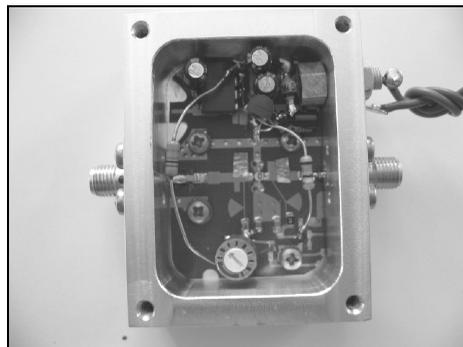


Fig 5: Example housing.



Fig 6: Example housing.

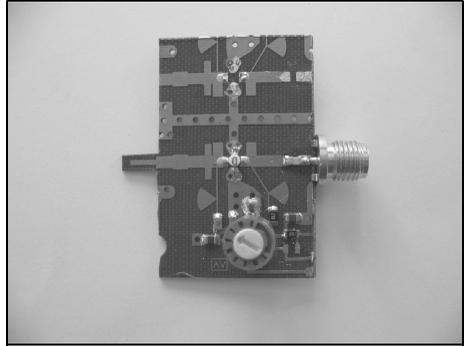


Fig 7: Using preamplifier No2 with direct waveguide input.

10,450MHz.

That's pretty fantastic for €1.5.

original design (Fig 7).

3.0

Alternative use

Circuit No. 2 is a little too short to position a capacitor at the input. It can be used very easily with the input line directly in the waveguide as used in the

4.0

Circuit diagram

The original diagram is in the box shown in Fig 8. The power supply was made very simple with wiring "in the air". The ICL 7660 is upside down and the components are soldered directly onto the pins. The drain current should be set to 10mA.

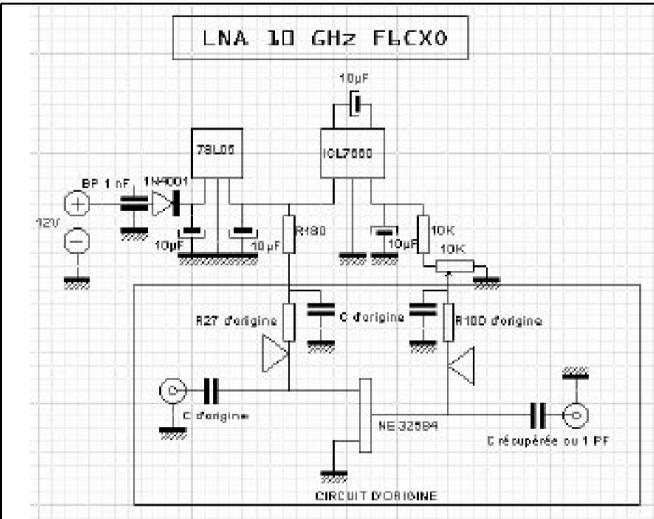


Fig 8: Circuit diagram of the preamplifier and the power supply used.



Gunthard Kraus, GD8GB

Internet Treasure Trove

MACOM

Microwave and millimetre wave IC products...that's what it says in the publicity. A very nice homepage, recently revised, done by someone I know well. In addition to comprehensive data sheets and basic information, you can also find some interesting new application notes here.

Address:

http://www.macom.com/tech_app_resources/techapp_app_note.jsp?i=0

PENTEK

Technical development marches on – and that includes receiver technology too. Digital receivers, loosely referred to as “software radio”, are in the vanguard. Anyone wishing to read up on this new technology and get some idea of the concepts involved might like to download the “Digital Receiver Handbook” from Pentek. The principles, characteristics and advantages of this new technology are very nicely explained here – and, best of all, direct comparisons are made with standard analogue receiver

technology.

If you explore the homepage in a little more detail and download the company's main catalogue onto your home computer, you'll get another surprise. Chapter 2 includes a very interesting collection of miscellaneous tutorials dealing with this area!

Address:

<http://www.pentek.com/sftradcentral/Overview.cfm>

Software Radio Resource Page

Something else on this subject in the form of every possible link which is relevant to it. Once you really get into it, you'll soon lose track of the time...

Address: [http://www-](http://www-sop.inria.fr/rodeo/personnel/Thierry.Turletti/SoftwareRadio.html)

[sop.inria.fr/rodeo/personnel/Thierry.Turletti/SoftwareRadio.html](http://www-sop.inria.fr/rodeo/personnel/Thierry.Turletti/SoftwareRadio.html)

SYNERGY

An old acquaintance that supplies every



possible type of microwave module. The homepage has been re-designed and, most importantly, there is now a much wider range of articles and application notes. Of particular interest is the documentation on offer in relation to synthesisers and microwave oscillators.

Address:
<http://www.synergymwave.com/Articles/Articles.htm>

Amateur Radio Soundblaster Software Collection

This homepage, which is run by Dr. Oliver Welp (DL9QJ), deals with the use of the PC sound card for all possible purposes and operating modes in amateur radio. A very comprehensive collection, especially the enormous number of links to other pages and topics.

Address:
<http://www.muenter.de/~welp/sb.htm#analyzer>

Electronics for physicists

The University of Kiel is behind this site, and it's really great how teaching materials are designed and prepared nowadays. In particular, you should just take a look at the topics that cover our own area (AM, FM etc.). But there's some interesting new stuff here even for specialists — just call up subjects like “Types of Modulation” or “Noise and Noise Suppression”. I guarantee that you won't be bored.

Address:
<http://www.ieap.uni-kiel.de/plasma/ag-piel/elektronik/>

Downconverter page

It's both amusing and comforting when you come across sites run by other “mad D.I.Y. people”. Steve Blackmore has a day job as an electronics specialist, but it clearly doesn't take up all his energy. So he goes in for decoding digital transmissions in a big way. He has generously made available his experience in relation to weather satellite reception, and you should work your way through all the cross-references of his homepage, where you'll find all sorts of interesting things. Here's a tip: there's also a page (it's a bit hard to find) that deals with quadrifilar helix antennas.

Address:
<http://www.pilotltd.net/downconv.htm>

ATMEL

It's good to know that the well-known microcontroller manufacturer is also going into the HF market for WLAN, Smartcard, Bluetooth and the rest in a big way. Consequently, as well as containing data sheets relating to the IC's the company manufactures, the homepage also has application notes and some good articles on the principles. Highly recommended: “A Tutorial on WLAN”, which also contains easy-to-understand information on spread spectrum technology.

Address:
http://www.atmel.com/dyn/products/app_notes.asp?family_id=657



CHIPCON

This company is from the far North – it's head offices are in Oslo. But the product range (RF transceiver IC's) is really first class. So it also comes as no surprise to find a very wide-ranging collection of application notes and other documentation. You can even take part in a "Wireless Quiz", and win prizes.

Address:

http://www.chipcon.com/index.cfm?kat_id=3

Linear Technology

It must be because of the time of year, new products are sprouting in HF companies. The homepages have new products and the document collections are being extended. If you haven't seen the new version of this site yet, you might find it all a bit overwhelming when you make your net visit.

Address:

http://www.linear.com/new/design_tools.html

Z-Communications

A specialist in VCO's and PLL's, with a very attractive range of products for the HF and gigahertz sectors. Also very attractive is the documentation on offer, including a lot of interesting application notes.

Address:

<http://www.zcomm.com/home.htm>

Note

Because of the fast-moving nature of the Internet and because Internet addresses or sub-directories can change at any time in ways which cannot be monitored, it is impossible to reflect the current situation at all times.

We therefore apologise for any inconvenience if Internet addresses listed in any "Internet Treasure Trove" articles are no longer available, or are altered at short notice by the operators in question.

However, the editors and/or the author will be happy to assist in finding the new addresses for the sites in question, or in obtaining the documents desired. The links available on the web site – www.vhfcomm.co.uk - include all of the companies mentioned in Internet Treasure Trove and are updated when broken links are reported

We would also like to take this opportunity to point out that the author and the publishers accept no responsibility for the accuracy of any information listed here or indeed for the contents of the sites referred to!



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Tel: +44 1582 581051
Fax: +44 1582 581051

Email:
andy@vhfcomm.co.uk

Editor

Andy Barter G8ATD

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BELGIUM - UKW-BERICHT, POB 80, D-91081 BAIERSDORF, Germany. Tel: 09133-77980. Fax: 09133-779833
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DENMARK - KM PUBLICATIONS, 63 Ringwood Road, LUTON, LU2 7BG, UK. Tel: +44 1582 581051.
Fax: +44 1582 581051. Email: vhfsubs@vhfcomm.co.uk

FRANCE - Christiane Michel F5SM, Les Pillets, 89240 PARLY, France
Fax: (33) 03 86 44 08 82 Tel: (33) 03 86 44 06 91

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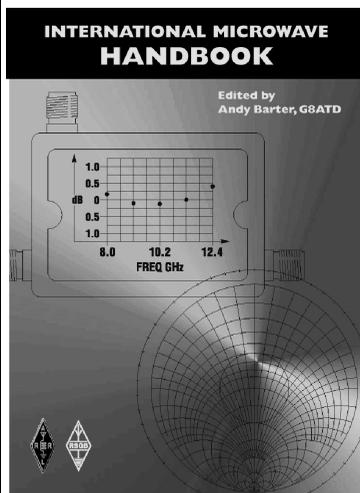
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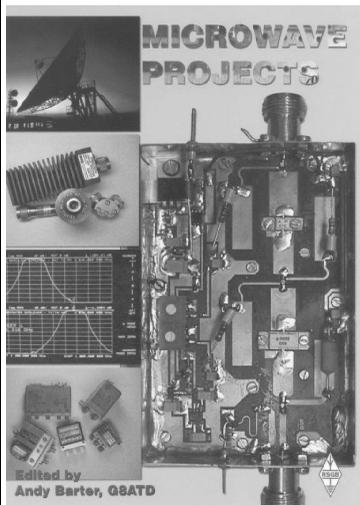
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