



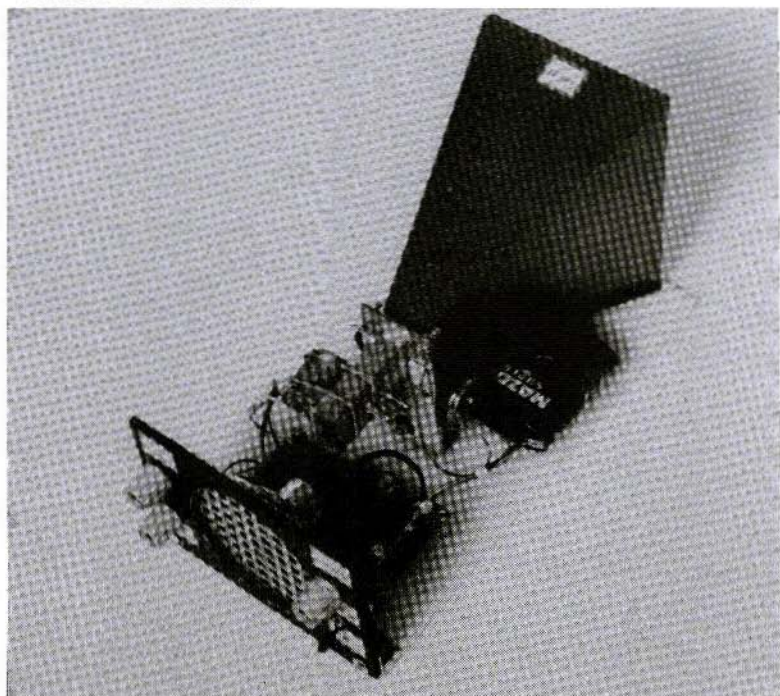
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**André Jamet**



**10 GHz Super-Regenerative Receiver**

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André Jamet, F9HX

# A 10 GHz Super-Regenerative Receiver

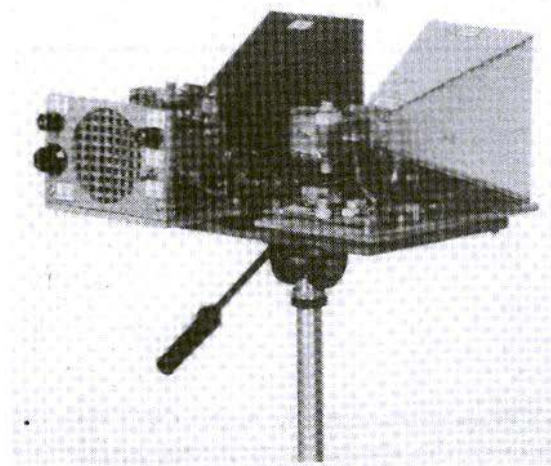
## 1. INTRODUCTION

In 1996 when you are hearing people talking about super-regenerative reception, you think they are old hams regretting their young days! However

this kind of reception is still much used professionally: millions of units a year are produced for miscellaneous applications as remote control, supervision, alarms, medical apparatus, etc., with contributions of new techniques as surface resonators (SAW) and up-to-date semiconductors. Indeed, very simple and low consumption devices are valuable for those applications.

We have shown recently [1] that super-regeneration could be still useful for amateurs. Without wishing to compete with conversion reception, results up to 1296 MHz, are not uninteresting as you can see in table 1.

We are going to discover that super-regeneration can be also useful at SHF at 10 GHz.



10 GHz Transmitter-Receiver



	144 MHz	432 MHz	1296 MHz
CW	MDS	150nV	200nV
	with BFO S/N=10dB	600nV	1mV
AM	MDS	150nV	300nV
	S/N=10dB	1V	1.5mV
Bandwidth	50 kHz	150 kHz	500 kHz

**Table 1: Measured Sensitivities of VHF and UHF Receivers**

## 2.

### A REVISION of THEORY

A super-regenerative detector is based on the repeated build-up and decay of oscillation in an oscillator, which is caused to operate intermittently by means of a quenching signal supplied from a separate low frequency oscillator, or from a low-frequency relaxation of the oscillator itself. Those two modes are respectively called "separated quenching" and "self-quenching". After each quenching, during the starting and the build-up of oscillation, the device shows successively a positive resistance behaviour, then zero and finally a negative resistance. When the negative resistance is reached the device is oscillating. But during the period of the exponential build-up of oscillation, it shows a tremendous amplification of up to one million! When no external signal is present at the input the amplification applies to the basic noise. Demodulation of the HF wave, or using the audio or video component in the device producing the negative resistance gives an amplified noise. In phone you can hear the typical and well known rushing

sound called hissing or mush-noise. If a signal at the oscillator frequency is applied, the oscillation is started in advance as the starting level of the exponential is higher than the noise alone. This advance gives an increase of the current oscillator, proportional to the signal, but highly amplified.

In the beginning the electronic tube was used as oscillator, but now evidently it is the transistor. Nevertheless, other components are able to produce a negative resistance, for example the unijunction transistor and the tunnel diode. Also, and it was at 10 GHz already, during the Forties, a 723 A/B Klystron [2] showed a 150  $\mu$ V sensitivity! At that time during World War II an intensive use of super-regenerative devices in VHF and UHF was made by both Allied and German forces, IFF for example.

The final super-regeneration purpose is of course the reception of modulated signals. CW demodulation is very simple, as the transistor current increases when a signal is on, seeing that the oscillation starting is advanced. For AM that current varies as the carrier magnitude. BLU needs a re-established-carrier as shown in [1].

FM demodulation is obtained by detuning the SR at one slope of its selectivity curve. Owing to the relatively poor SR selectivity, bad demodulation is obtained with NBFM. But at 10 GHz it is frequent practice to use a much larger modulation, for example with Gunn diode transmitters. Under these conditions FM reception is possible with a poorer quality. A much more correct demodulation could be obtained with a more sophisticated device, but we do not make HI-FI and it is workable. Phone tests were done, that by means of audio signals; it could be possible to demodulate video with a sufficient quenching frequency. Shannon will remember us to increase the quenching frequency to at least twice the highest signal frequency !

---

### 3.

## CIRCUIT DESCRIPTION

---

For this 10 GHz device (3 cm wavelength), it was considered to use the self-oscillator ATV transmitter described in [3].

A lack of frequency stability was stated for phone work at the various ambient temperatures, especially in portable conditions. So, a more efficient solution using a dielectric stabilised oscillator has been retained. We can make this DRO [4], [5], [6], [7], [8], but it is easier to find it free! Indeed you can find LNBS in antenna shops: out of use LNBS because the DRO is not often considered reusable, or LNBS replaced

by a more up to date device. A professional directory, a telephone, a bit of patience and you are able to find those LNBS, in order to check and then modify them.

As the DRO is used as the local oscillator its frequency varies upon the received frequency range and the intermediate frequency. Usual frequencies are 9.75, 10 and 10.475 GHz. As the phone traffic is usually done at 10.368 GHz, we need to shift the DR frequency.

As shown in the above-mentioned articles you can increase the frequency by abrading the DR with sandpaper to decrease its height, or to increase it by adding a piece of ceramic in order to lower the frequency. Our attempts showed up better using the first method in preserving the relatively low temperature coefficient. On the contrary, adding a piece of ceramic impairs the stability. Indeed to sufficiently lower the frequency needs a great thickness of low permittivity ceramic adding; on the contrary if the permittivity is high, the thickness will be lower but the ceramic temperature coefficient is very high usually. In both cases the DR original coefficient will be modified and the DRO frequency will drift off several megahertz for indoor temperature variations and a far too much for portable use. An answer is to use a piece taken from another DR which is sacrificed for that.

The overall DRO temperature coefficient depends not only on the DR but also on the case dilatation, adjustment screw and transistor parameters. An equalisation has been reached by the

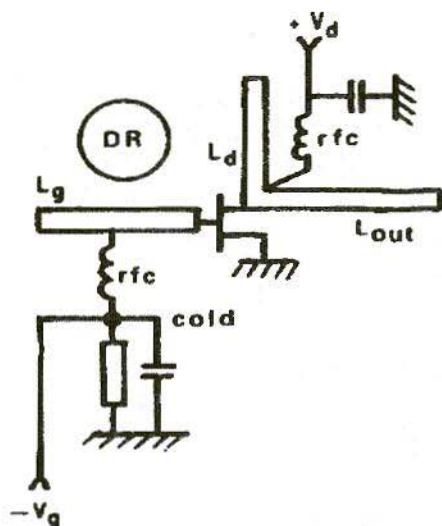


Fig.1: DRO with Gate side cold point

manufacturer and the balance could be upset by our modifications, and then damage the stability. Moreover, those modifications do not have to bring the

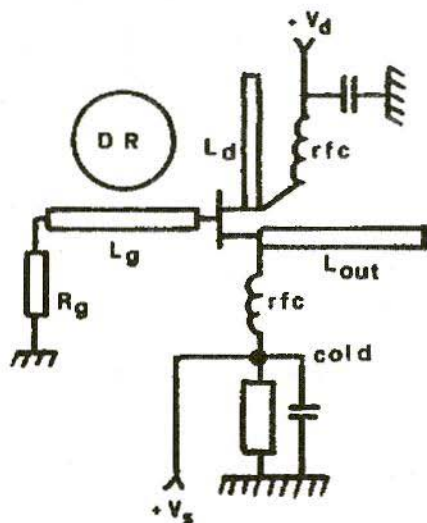


Fig.2: DRO with Source side cold point

screw nearer to the DR as the Q factor would be weaker, which means increased losses and gives a more stringent adjustment.

It is profitable to carry out one or two ageing cycles after a DRO modification in order to stabilise components which were mechanically stressed and require a stable state. That could be obtained by a one hour curing in an oven at 40° Celsius. The oldest LNBs which are the most available have a 9.75 GHz local oscillator. It is very easy to shift them to 10.368 with only a little patience [5].

Making a self-quenching super-regenerator with a DRO requires the addition of a resistor into the drain circuit to pick-up the audio signal and to produce the quenching oscillation. Gate-source voltage control will state the operating point, which is quite critical, to obtain the highest super-regenerative sensitivity. Several configurations are used for DRO as with all kinds of oscillators.

The DR can be placed gate side, drain side, between gate and drain, etc. Some experiment showed it is possible to make them generally working as SR more or less easily. But two cases appear to inject the gate-source voltage at an originally cold point to avoid a DRO modification. Upon the instance a negative voltage will be injected gate side or a positive voltage source side. Figures 1 and 2 show typical diagrams for both cases. That voltage is brought through a 0.8 mm hole very close to the cold point.

An audio amplifier is all that is required after the SR with a low-pass filter in order to remove the quenching frequency, which could disturb the ampli-

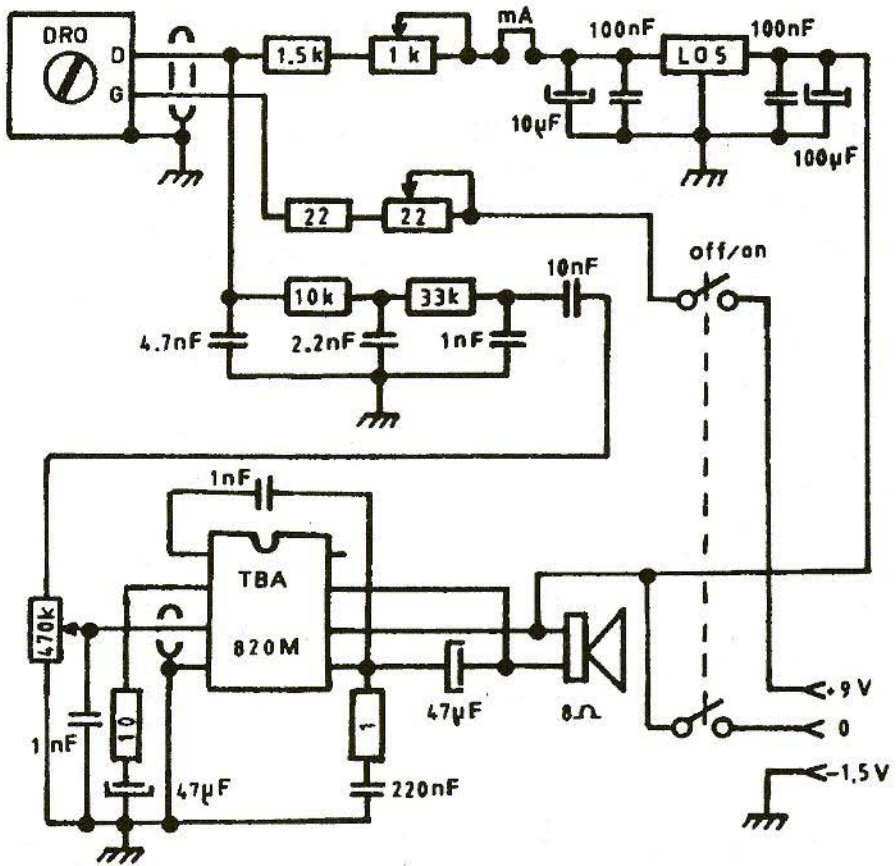


Fig.3: 10 GHz Regenerative Receiver

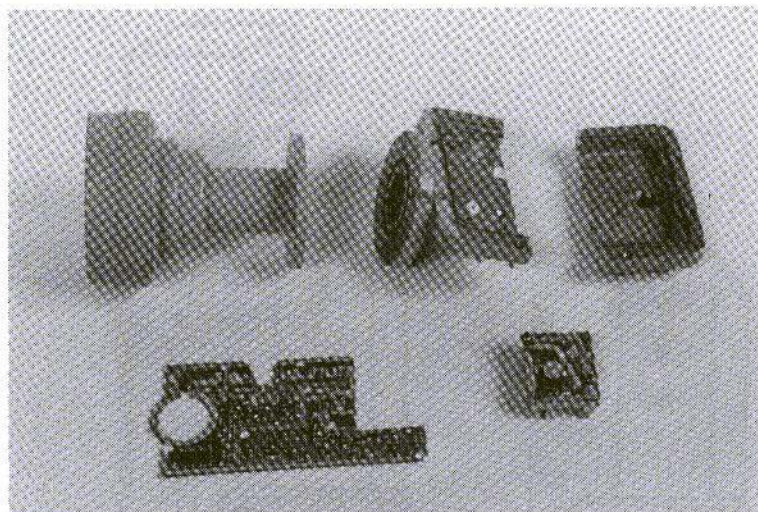
fier even into inaudibility. A regulated power supply is needed for the DRO as its frequency varies appreciably with the supply voltage. For an oscillator the drift is about 1 to 2 MHz per volt in the 4.5 to 5 volts range.

Figure 3 shows the complete diagram. The DRO used required a negative voltage gate-source so a 1.5 V battery has been added to the two 4.5 V batteries for the positive supply.

#### 4. CONSTRUCTION

The photograph and figure 4 show the layout. At first you have to separate the DRO from the LNB by sawing out the case, screens, printed circuit, etc. That gives a small screened box with the original screw for frequency adjustment. After that, the DRO is placed against a





**10 GHz LNB sawn into its component parts**

waveguide WR90/R100 in which a slot has been made. That slot lets into a small piece of Teflon insulated wire (a 5 millimetre coaxial cable with removed braid) connected at the DRO output. The slot allows the DRO to be installed at the optimum place, slides with blocking screws or a rubber ring are used to fix it in position.

Two setting screws have been provided in order to round off the impedance matching. The DRO original screw will allow you to tune the SR at the wanted frequency, for example 10.368 GHz.

A small piece of ball pen body is glued to the bolt head to make the adjustment easier. The waveguide is attached through a flange to a 20 dB horn made in epoxy-glass as sized in [9].

---

## 5.

### MEASUREMENT RESULTS

---

Measurement was carried out with the following equipment:

- Tektronix 465 oscilloscope to show the quenching wave
- Hewlett-Packard 141T spectrum analyser with 8555A 18 GHz rack and 8552B IF rack
- frequency meter made of a new LNB with 9.75 GHz LO in front of a 2.4 GHz frequency meter. Although all of the various filters are not tuned on the input and the intermediate frequencies, sensitivity is enough for frequency measurement

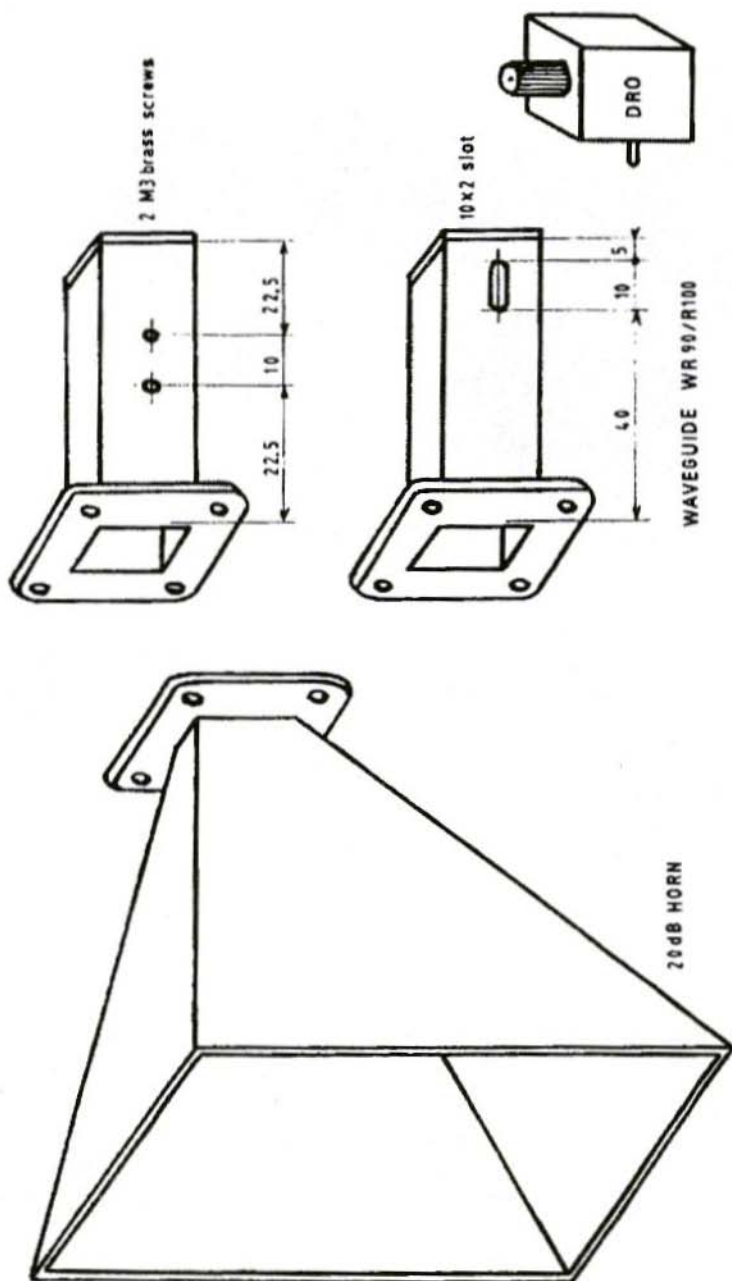


Fig.4: Mechanical design including waveguide front and rear views



- 2.4 GHz frequency meter with a 12 GHz pre-scaler as describe in [10]
- Polarad G711 hyper frequency generator tunable from 6.950 to 11 GHz. That equipment is too old to allow sensitivity measurement at the current levels as its leakage is enough to insure reception at several meters! It was necessary to place the generator in a separate room, to use a coaxial cable connection and to add an extra attenuator
- Yupiteru receiver, wide coverage from 430 kHz up to 1650 MHz, connected to LNBS for comparative sensitivity measurement
- two DROs settled around 10.368 GHz, frequency modulated. Settings and measurements are the following.

The drain current is settled by both gate-source polarisation and variable resistance in the drain circuit. SR behaviour is insured in average from 0.8 to 2mA upon the components DRO charac-

teristics. There is no super-regenerative action below, but only regeneration. Above the device is always oscillating without usable reception.

The maximum sensitivity is obtained barely beyond the hissing appears. Quenching frequency increases as for any kind of self-quenching SR proportionally to the fixed drain current and when the received signal is growing. The selected values gives a frequency of about 20 to 200 kHz. Figure 5 gives the wave form at the drain cold point.

The SR bandwidth depends on the quenching frequency (to see the level up reference [1]). Selectivity measurement confirmed that statement and gave from 150 kHz to 2 MHz upon the setting. That measurement was done by two unmodulated DROs as shift frequencies generators. To give information, the SR radiated spectrum is shown by figure 6. It is similar to the pulse radars one [12], but asymmetrical as the train of waves growing and decreasing are different.

Our measurement resources did not allow us to work out absolute sensitivity values. But comparisons were done between different equipments.

Even with the dubiousness of measurement, SR shown a sensitivity practically alike to a classical conversion receiver using a 1N23 diode, an Gunn diode as LO, a FI of about 85 MHz and a frequency demodulation. That receiver was pro-

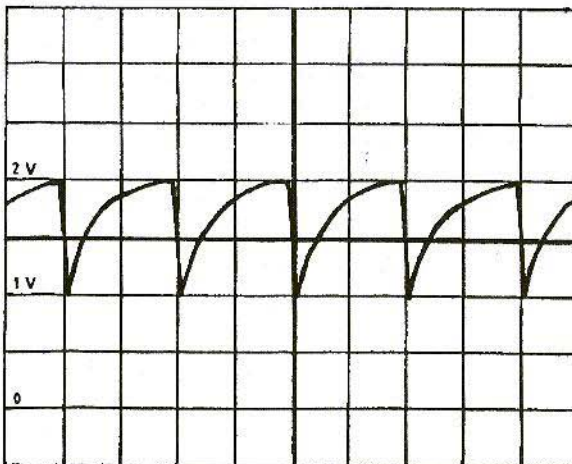
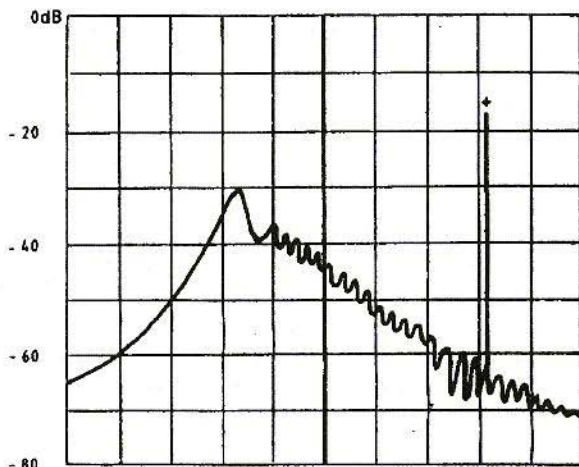


Fig.5: Drain Cold Point Waveform



**Fig.6: Supr-regenerative Receiver Spectrum**

**Scan width: 2 MHz/div**

**Scan time: 0.5 s/div**

**Bandwidth: 10 kHz**

**+ received signal added to spectrum at the analyser input**

vided with the same 20 dB horn as for the SR.

An LNB followed by the Yupiteru receiver shows a very variable sensitivity as the case may be. If the input and output filters have been modified the sensitivity is much better, which is not surprising owing to the premium transistors used on the 10 GHz side.

With an unmodified LNB with a 9.75 GHz LO, the sensitivity is better than the SR one. On the contrary, for an unmodified LNB with a 11.475 GHz LO, the sensitivity is very poor as the filters are too far from the needed frequencies.

## 6. SUCCESSFUL CONTACTS

Table 2 gives an extract of the F9HX's log book concerning worked contacts at 10 GHz by that time of writing. It shows that it is possible to make contacts in receiving conditions we were expecting from sensitivity measurements. It is not great DX but by proper paths one certainly could do much better. In all cases the receiver was the one described here. When the correspondent had got a receiver, a two-way contact was established with an F9HX/P transmitter

comprising a FM modulated DRO and a 20 dB horn as for the receiver. All communications were done in or nearly in sight. It is certainly possible to make contacts by reflection, refraction and/or diffusion as is readily done, but it was not carried out before writing this article.

## 7. CONCLUSIONS

As it was computed in the article conclusions [1], the 10 GHz SR work was easily obtained. Obviously results are not those of a 10 GHz modified LNB for the ham band, but they are



Date	Call	QTH	ASL	TX	Mod	QTH	ASL	QRB	QRK	QSO
1996		JN25	(m)			JN25	(m)	(km)	0-5	
15/08	F11FI/P	MS	202	DRO	1 kHz	MS	202	1	2	--
28/08	F11FI/P	MS	206	DRO	1 kHz	MS	264	3.1	5	--
31/08	F1CDT	MR	234	GUNN	PHONE	MR	234	0.1	5	YES
07/09	F11FI/P	LS	200	DRO	1 kHz	LT	310	6.1	5	--
07/09	F11FI/P	LS	200	DRO	1 kHz	MS	264	7.5	5	--
12/09	F1FDY	JT	330	DRO	PHONE	MS	264	20	5	--
13/09	F1CDT	MR	234	GUNN	PHONE	MR	234	4	1	--
18/09	F1CDT	MR	234	GUNN	PHONE	LR	230	5.1	5	YES
19/09	F1CDT	MR	234	GUNN	PHONE	IO	318	25.6	4	YES
27/09	F1CDT	MR	234	GUNN	1 kHz	GJ	1250	48	0/3*	YES

Output power in all cases +20dBm; \* with QSB

**Table 2: Extract from F9HX's log showing some successful contacts**

very close to those obtained with a converter using a 1N23 diode as mixer and a Gunn diode as LO. It is certainly possible to obtain a better sensitivity for the device as only a few trials were done for impedance matching

between the DRO and the waveguide. Output DRO is probably not the best input for the signal. A very low noise transistor (less 1dB at 10 GHz), as used at the LNB input, would be surely better than the DRO one as its purpose is to deliver enough power to the mixer. More, FM demodulation by detuning is not very efficient. With AM, result would be much better. But, who is doing AM anymore? The chief interest lies in simplicity and low cost of implicated means: only one transistor and an audio amplifier! Nevertheless you cannot minimise the need for a good theoretical and practical SHF knowledge because great difficulty is on the way to get a result. So, an attempt to use the same DRO to make a transceiver is not yet successful: a significant frequency deviation is

stated between RX and TX owing to the transistor drain current and gate-source polarisation differences. We need to compensate that frequency deviation by a varicap acting on a DRO coupled line. Professionally, there are interesting references but the achievement seemed to be difficult for us if we want to have both power to transmit and sensitivity to receive. Therefore wait and we will speak about it again. For the most audacious, there is an open way for experimentation at higher frequencies: 24, 47, 76 145 and 241 GHz (241 GHz that means 1.2 millimetre wave-length!). Indeed, components will probably be accessible for astute amateurs owing to the advent of radars used in luxury cars for protection against running into things whilst reversing, as those equipments are working above 50 GHz.

F9HX would like to show especially gratitude to F1CDT thanks, for his competent and devoted help for test, measurement and QSOs.

E and OE!



8.

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Wolfgang Schneider, DJ8ES

# VHF, UHF and SHF Measuring Methods Using a PC

## Part-3: 0.9 - 1.5 GHz Synthesizer

The frequency synthesizer can be thought of as one of the cornerstones in the structure of an amateur radio enthusiast's measuring equipment. Even just a 23cm signal to balance the pre-amplifier, an oscillator for the new 2m mixer module. All the frequencies which are of interest to amateur radio enthusiasts should be covered, at the lowest possible cost.

It is obvious that all these wishes can not be granted right away with just one piece of equipment. At least, not at a reasonable cost and with the measurement options normally available!

---

### 1. GENERAL

---

The following article, "0.9 - 1.5 GHz Synthesizer", describes the core of such a unit, the tunable oscillator (VCO) with the phase control circuit (PLL). In addition to the VCO, the synthesizer module and its programming are of vital importance in this context (Fig.1).

Other modules required, such as mixer assemblies for additional frequency ranges and PIN diode controllers to adjust the output power, will be the

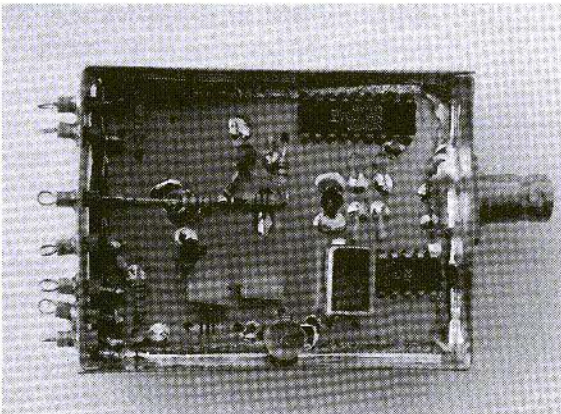


Fig.1:  
Experimental Rig  
for 0.9 - 1.5 GHz  
Synthesiser

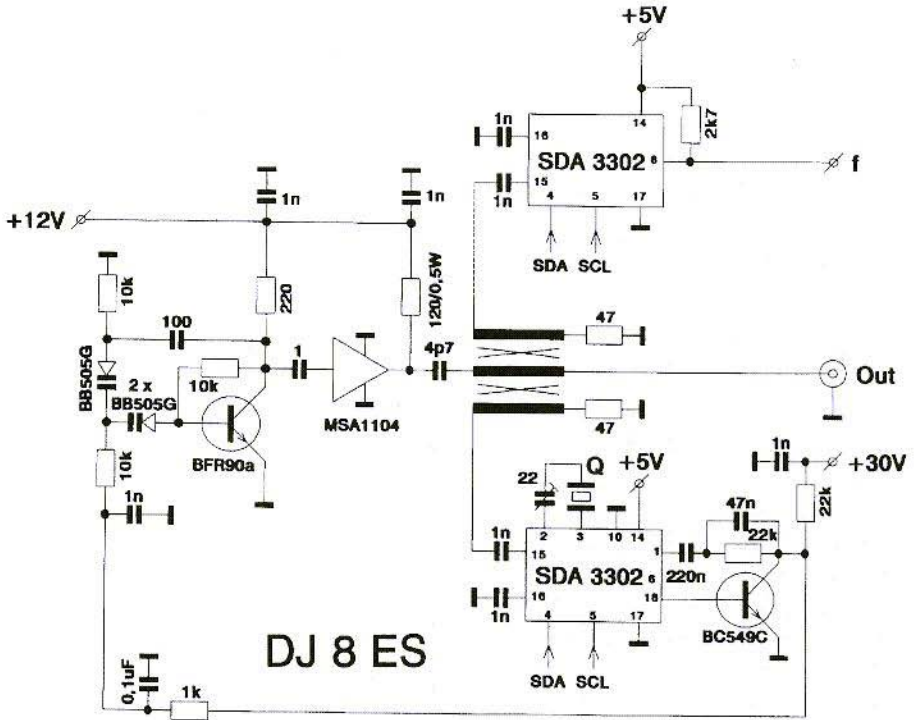


Fig.2: Circuit Diagram for 0.9 - 1.5 GHz Frequency Synthesiser

subject of articles to be published in future editions of VHF Communications.

## 2. CIRCUIT

The 0.9 - 1.5 GHz synthesizer was created on the basis of the FM-ATV transmitter for the 23cm band [1], details of which were published at that time. The only new feature is the SDA3302 programmable synthesizer module in the circuit (Fig.2).

The tunable oscillator (VCO) covers the entire frequency range, with a tuning voltage of +30V, in one sweep. The article referred to above contains any details required in connection with the assembly and operation of the circuit.

The frequency information is transferred to the integrated circuit through a special log on a 2-conductor bus (I<sup>2</sup>C bus). The lines distinguish between CLOCK and DATA.

Günter Sattler (DJ4LB), among others, has made the functioning of such synthesizer modules clearer for us, as amateur radio enthusiasts, in [2] and [3]. Fig.3 merely shows once again the





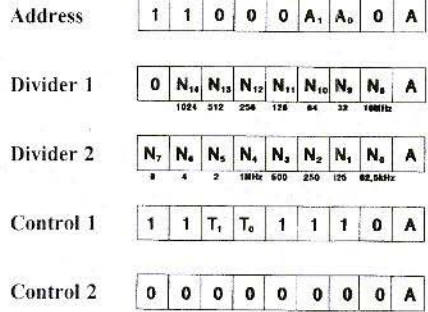
structure of the data elements for the programming of the SDA3302 as a synthesizer.

There is also an addition to the complete circuit here, in the shape of an MSA1104 broad-band amplifier. The output power is thus app. 50mW over the entire tuning range (Fig.4). Moreover, the amplifier acts as a buffer stage for varying loads at the output.

A further SDA3302 IC is wired up in the experimental rig for my own experiments, this time as a frequency divider. The I<sup>2</sup>C bus controls both circuits!

### 3. SOFTWARE

The entire data log is transferred to the SDA3302 PLL IC for each frequency setting. The I<sup>2</sup>C bus forms the link. In this way, the chip address and all frequency and control parameters are transferred to the module integrated within special start / stop conditions.



**A Acknowledge (log. 0)**

**N Frequency Divider**  
 (z.B. 1296 MHz: N<sub>14</sub> , N<sub>12</sub> , N<sub>8</sub> = 1)

Chipadresse	A <sub>1</sub>	A <sub>0</sub>	CAU (Pin 10)
0	0	0	OV
0	1	1	offen

Funktion	T <sub>1</sub>	T <sub>0</sub>	
0	0	0	PLL
1	0	0	Divider

Fig.3: Data Formats for Programming the SDA 3302 as a Freq Synthesiser

DJ4LB describes the details and, in particular, the temporal sequences for the data transfer very graphically in [2] and [3].

Another program is available which is

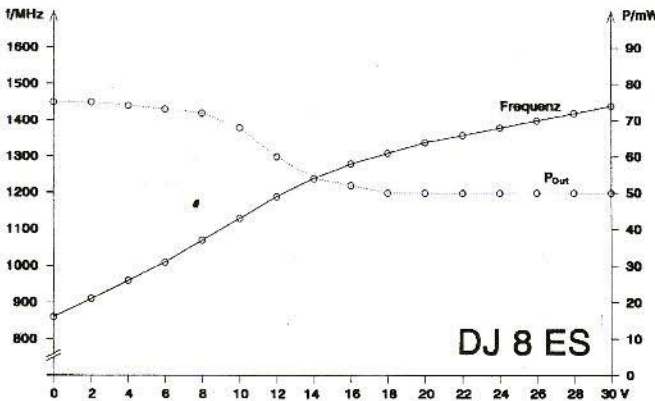


Fig.4: Output Power and Frequency plotted against the Tuning Voltage



**Fig.5:**  
**The Assembled**  
**VCO, shown**  
**greatly Magnified**

suitable for 0.9 - 1.5 GHz frequency synthesisers, and is written in Turbo-Pascal 7.0. It contains all the components for the frequency synthesiser, but not for the frequency divider! Additional information required for operating the program is contained in the READ.ME file on the associated diskette.

Once started, the program sets the frequency of 1,296.0000 MHz as the default value. Other frequencies can be set through direct entry by means of the keyboard, or else using the cursor control keys. The minimum step width is 62.5 kHz, determined by the system.

---

#### 4.

### ASSEMBLY INSTRUCTIONS

---

The entire circuit is constructed on an epoxy printed circuit board, coated on both sides, with the dimensions 54 x 72mm. It therefore fits into a standard tinplate housing with the dimensions

55.5 x 74 x 30mm. The holes are to be milled on the earth side using a 2.5mm drill. Only the earth contacts remain in existence.

The assembly of the VCO (Fig.5) and the subsequent broad-band amplifier is described in detail in [1]. As always in higher frequency ranges, special attention must be paid to creating a structure suitable for high frequencies. Short connecting wires are an absolute must!

Further details can be found in the equipment diagrams for the foil side (Fig.6) and the earth side (Fig.7). Moreover, the rig can be copied without any special problems for the person assembling it.

#### 4.1. Components list

IC1	SDA3302 (Siemens)
IC2	SDA3302 (Siemens), optional
IC3	MSA1104 (Avantek)
D1, D2	Varicap diodes BB405G
T1	BFR96 (Valvo)
T2	BC549C (Valvo)
4	4 MHz crystals (HC18U or HC25U)

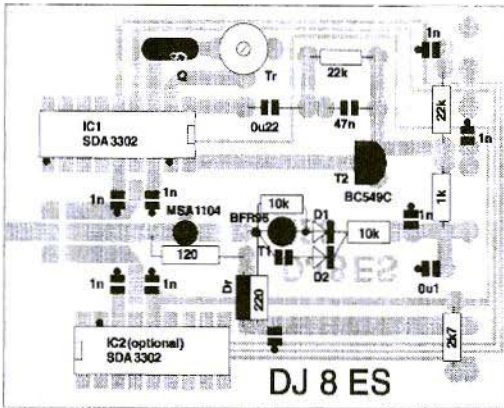


Fig.6:  
Only a few Components on  
the Foil Side

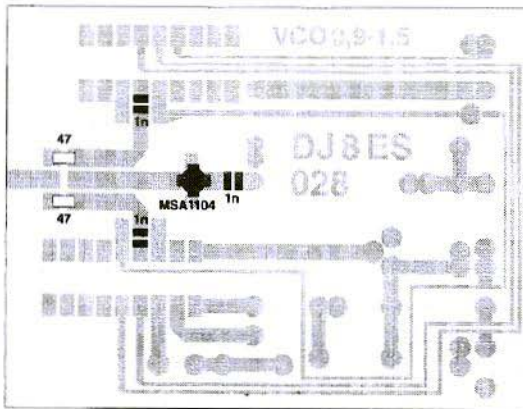


Fig.7:  
Layout of Elements on  
Component Side

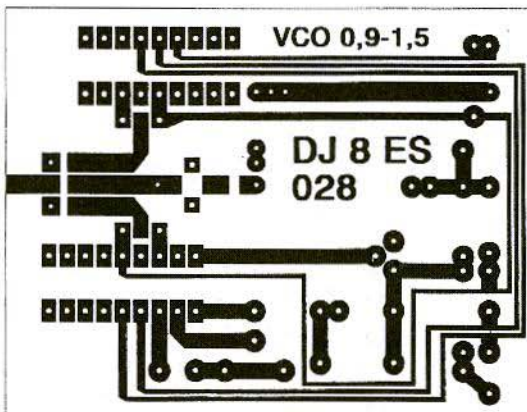


Fig.8:  
DJ8ES 028 Printed Circuit  
Board. Reverse Side passing  
through Earth

Dr	$\lambda/4$ choke, 5 turns on 3mm diam rod, 0.1mm Cu lacquered wire
1	22pF foil trimmer Valvo, green
1	MKT capacitor 47nF, 7.5mm basic grid
1	MKT capacitor 0.1 $\mu$ F, 7.5mm basic grid
1	MKT capacitor 0.22 $\mu$ F, 7.5mm basic grid
1	carbon film 120 $\Omega$ / 1W, 12.5mm basic grid
7	Teflon bushings
1	BNC jack UG290 A / U
1	tinplate housing 55 x 74 x 30mm.
1	PCB DJ8ES 028

1/8 Watt, 10mm basic grid resistors

1	220 $\Omega$
1	1k $\Omega$
1	2.7k $\Omega$
3	10k $\Omega$
3	10k $\Omega$
2	22k $\Omega$

Ceramic disc capacitors, 2.5mm basic grid

1	100pF ceramic disc
7	1nF ceramic disc

And in SMD format

(1206 / 0805 construction)

2	47 $\Omega$
3	1nF

#### 4.2. Putting into operation

The assembly group forming the 0.9 - 1.5 GHz frequency synthesiser must operate as soon as the operating voltages:

+ 5V (PLL), + 12V (VCO with amplifier stage) and + 30V (tuning voltage) are applied. A power level of app. 50mW (cf. Fig.4) and a frequency somewhere between 0.9 and 1.5 GHz can now be measured at the output jack.

The PC is now connected up. The Centronics adapter card described in Part 1 acts as interface. In this connection, d7 is the data line (SDA) and STROBE is the clock (SCL).

The standard address for the Centronics interface is LPT1. For other ports, the data can be adapted in the SYNTHESI.CFG file.

The READ.ME file on the diskette has additional information, especially with regard to installation. It should be read before the equipment is put into operation.

If the SYNTHESI.EXE program is now started, the frequency 1,296.0000 MHz must be set at the output of the assembly. Fine balancing can be carried out using the 22pF trimmer at pin 2 of IC1 (SDA 3302). A "Help" function is available through function key F1, as for the mW meter.

## 5. LITERATURE REFERENCES

- [1] Wolfgang Schneider DJ 8 ES (ex. DD2EK); FM-ATV Transmitter for the 23cm Band  
VHF Communications, no. 1/89,  
pp. 25-30



- [2] Günter Sattler DJ4LB; SDA 3202 - New PLL-IC up to 1.5 GHz  
VHF Communications 1/86,  
pp.18-22
- [3] Günter Sattler DJ4LB; Crystal-Stable VCO Frequencies for ATV Processing  
VHF Congress Weinheim 1991  
Congress Proceedings, pp. 173
- Synthesiser
  - Wobbler
  - mW meter and
  - Spectrum analyser

Issues 2 and 3/97 of VHF Communications will contain a complete description of the assembly of all the elements.

### *Note on Series of Articles:*

The aim of the series of articles on VHF, UHF and SHF measuring methods using a PC is to enable us amateur radio enthusiasts to gain entry into this new and interesting area of discussion.

After the initial preparations and practical tests (cf. Centronics interface, mW meter and synthesiser), the next step is the development of a universal measuring apparatus for the amateur radio enthusiast.

This PC-controlled measuring apparatus for the 10 - 1,400 MHz frequency range combines the following functions:

In addition, the experimental mW meter and synthesiser set-ups already presented are being revised and turned into a more efficient version of what is a constituent part of the measurement equipment.

Thus, for example, the resolution in the  $\mu$ W range for the mW meter has been increased by two powers of ten, while the output power in the synthesiser has been largely kept constant, and the frequency range has been extended to cover the necessary minimum of 700 - 1,400 MHz.

Wolfgang Schneider, DJ8ES

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## *VHF Communications Magazine on the World Wide Web*

*Please note that effective April 1st 1997 the VHF Comms WWW site will no longer be available at Eolas*

*The VHF Comms WWW site is now:*

*<http://www.clearlight.com/~vhfcomm>*

Walter Zwickel, OE2TZL

## Pre-Mixer for 23 and 13cm

The measuring equipment available to private operators is often limited to 500 MHz or below, and is thus not fully satisfactory for the 70cm band. If you nevertheless wish to include the next highest bands, 23cm and 13cm, in your measurement system, either new measuring equipment has to be obtained, or the existing equipment has to be extended by appropriate additions.

---

### 1. INTRODUCTION

---

Supplementary equipment is described below which increases the measurement capacity of spectrum analysers and test transmitters in the 1,000 - 1,500 MHz and 2,000 - 2,500 MHz ranges.

As radio shacks often contain elderly test transmitters giving results which are fine in themselves, but unfortunately cover only a restricted frequency range of just 500 MHz, this addition, which covers the 23cm and 13cm bands, together with their processing frequencies, brings about a welcome expansion

in the possibilities of measurement. Existing wobble transmitters also expand their useful frequency range to cover these two areas. The same applies to simple spectrum analysers such as Hameg and the like. ATV amateurs can thus evaluate their output signal directly for band width, modulation symmetry, tone lowering, etc.

If you assemble two units of this kind, and if you have the appropriate tracking generator, you can also carry out wobble measurements at 23 and 13cm. The logarithmic representation and the a dynamic range of app. 60dB come fully into their own here.

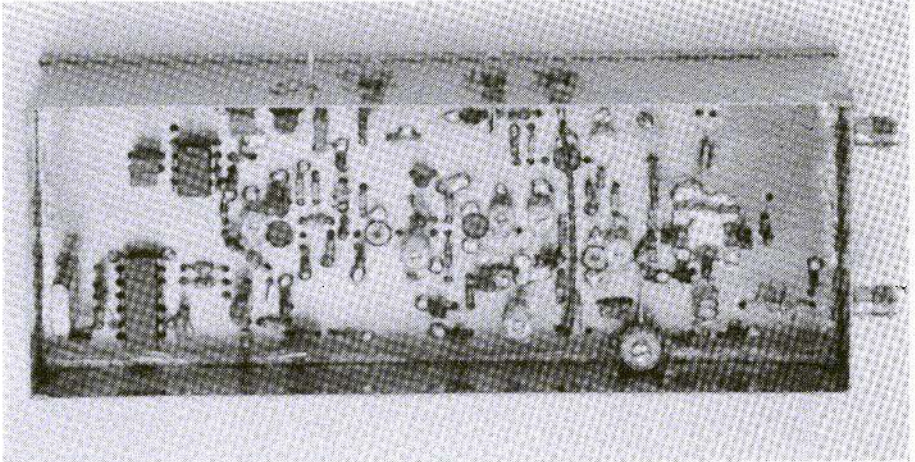
With directional couplers which can be set to these frequencies, even matching measurements are no longer a problem.

---

### 2. SUMMARY

---

A VCO for 1 GHz is stabilised by a PLL. After a buffer stage, the signal divides into a 1 GHz fraction and a 2 GHz fraction. Both paths are selectively boosted to app. 10dBm and fed alterna-



**Fig.1: Prototype of Pre-mixer for 23 cm. and 13 cm**  
**a. Component Side with Continuous Earth Surface**

tively to a ring mixer through a PIN diode switch. This keeps the high frequency input signal and transmits the spectrum ranging from 0 to 500 MHz at its output. Moreover, the input and output are exchangeable, so that you can obtain upward or downward mixing, depending on the application.

---

### 3. CIRCUIT DESCRIPTION

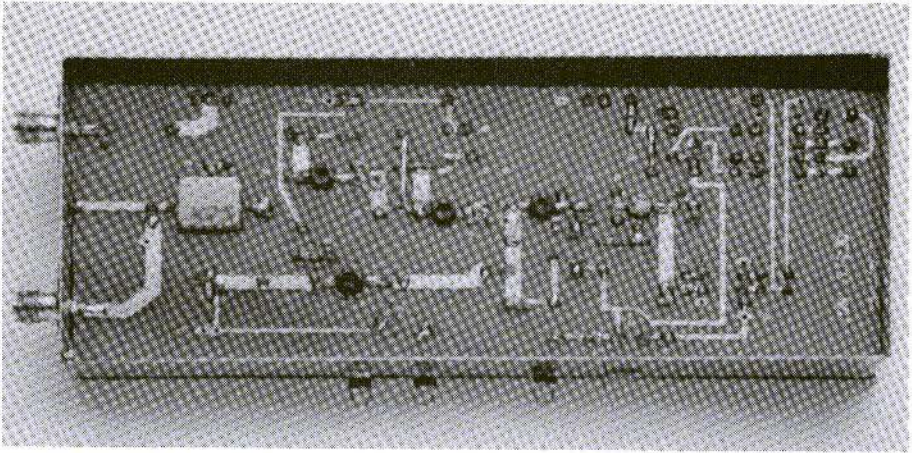
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#### 3.1. VCO

The VCO oscillates directly at 1 GHz with a PNP transistor, so that the collector circuit can be directly earthed. Loose decoupling is provided at the emitter through 220 Ohms (Fig.2). To ensure a stable conversion value for 1 or 2 GHz, a simple PLL circuit is used, which is completely adequate for the purpose in hand. In addition, some HF

is decoupled for the divider: 64 at a collector circuit tap. The type used, U664B, is highly sensitive at 1 GHz and requires only a few mV of input voltage; hence the small coupling capacitor and the tap. The weaker the connection, the less feedback through the divider!

The output signal from the pre-divider controls an integrated SO42 mixer, which has a crystal oscillator circuit at the second mixing input. The difference frequency and the sum frequency of the two signals are available at the output (pin-2). The sum signal is attenuated through the subsequent loop filter. In the case of parity of frequency between the divided VCO frequency and the crystal frequency, a DC voltage comes about as the control voltage for the capacitance diode on the VCO (mixing at frequency 0 Hz). Should discrepancies occur - due, for example, to changes in temperature or voltage - this control voltage always pulls the VCO back to the rated frequency.



**Fig.1b: Foil side with Transistors**

The VCO is followed by a booster stage, equipped with a BFR91, since this type created the least feedback of any of the UHF transistors tested. There is already about 2mW power available at the output. This power is now divided into two paths:

- a. To the final booster with T5, which is already generating just 10mW, enough to control the C-3 integrated mixer.
- b. To the doubler with T3. The BFG types are indispensable here, since the low-inductive earth connection can be created only through the two emitter lugs. This is vital for high efficiency duplication.

### 3.2. Booster for 1 GHz

To obtain better harmonic suppression, the 1 GHz branch is again selectively laid out. This is also the reason why no MMIC's are used here. However, it is

generally not a simple matter to obtain 1 GHz or 2 GHz alternatively with the same processing, since the PIN diodes used for switching no longer display ideal characteristics. For this reason, there is a switching diode in the collector circuit of this stage, which tunes out the output circuit in 2 GHz mode. If this stage is not needed, the operating voltage is also switched off as well.

Naturally, the second harmonic is relatively strong, due to the moderate quality of the strip-line resonators. However, a PI filter, fitted as an experiment to reduce the harmonic, had only a very modest success and was therefore dispensed with.

The spectrum purity obtained for the 1 GHz mixing signal overall is just 40dB. If more is required, we can not do without separate assemblies, since even within the housing selection is restricted by parasitic coupling.





### 3.3. Doubler and Booster for 2 GHz

A standard single-phase doubler is used in the 2 GHz branch. Even with the small amount of control available, a low bias makes it possible for the doubler to operate reasonably well. At the output, a bandpass filter, together with a suction circuit, provides for the necessary selection. But the suction circuit (idler circuit) also improves the efficiency of the doubler.

If you also incorporate a second suction circuit, as described in the "Setting-up" section, the spectrum purity of the mixing signal looks considerably more favourable. With optimum setting-up, 60dB can be attained.

A booster stage, which also has a BFG91 transistor, provides for the level of almost 10 mW required. This output is needed so that, even after the lossy PIN diode switchover, there is still a high enough level available to control the mixer.

### 3.4. Change-over Switch and Mixer

The BA479 PIN diode can still just be used in this range, but the track resistance is already clearly traceable, particularly at 2 GHz. The relevant diode is therefore located directly at the high point of the circuit, without burdening the latter excessively. A connection leg from the other diode is bent round to the 1 turn choke, and thus reduces the drain of 2 GHz signal capacitive coupling.

The C-3 SMD mixer needs an oscillator power of 7dBm (5mW). This type is given preference here because, firstly, it can be obtained at a reasonable price,

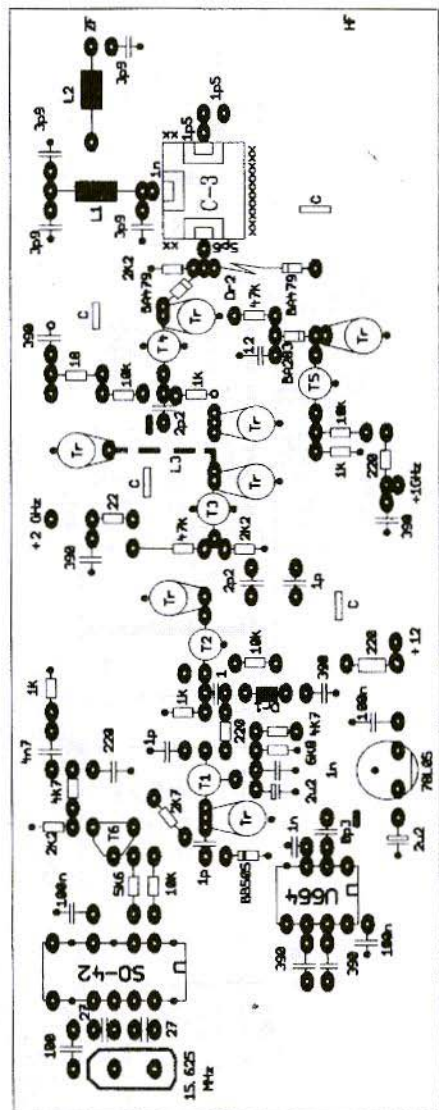


Fig.3: Pre-mixer Layout, 1:1

and secondly, because it can safely be used at 3 GHz. Let's not conceal that it has a disadvantage as well. Compared with the well-known ring mixers in the metal housing, its matching behaviour is markedly worse.



#### 4. ASSEMBLY

The equipment should be assembled step by step, in functional blocks, so that each circuit component can be functionally tested as soon as it is completed. This procedure is described in Chapter 5 - Setting-up.

A printed circuit board (Fig.3) with dimensions of 148 x 54 mm., which can be incorporated into a standard tinplate housing, has been developed for the circuit.

The double-sided board has a continuous earth surface as its top. The holes on the top are slightly countersunk in the usual fashion, using a 3mm drill bit, in order to avoid short-circuits.

No holes need be created for the component connections with links to earth. Instead, these are soldered directly onto the earth surface. These soldering points are indicated by small solid circles on the component diagram.

The integrated circuit connections are an exception. The earth connections also have 0.8mm holes, but they are not countersunk. The IC earth connections are to be soldered onto the component side (Fig.4). No bases should be used for the IC's. The transistors T1 to T5 are placed in 5mm holes, so that the shortened terminal lugs lie flat on the track in question and can be soldered (see Fig.1b). Be careful how you mount the transistors! For T1, the lettering should face toward the soldering side, for T2 to T5 the lettering should face toward the earth surface in each case.

For T2 to T5, the small emitter legs should be bent sharply upwards and soldered on the earth side. The trimmers, Tr, are of the green SKY type. The thin, flexible little terminal lug is bent sharply through 90 degrees and soldered to earth. In each case, the round pin goes through the hole to the oscillator circuit connection.

As test assemblies of the suction circuit with L3 as a strip line were of insufficiently high quality, this circuit was executed as a wire strap on the soldering side.

After a great deal of consideration, I opted for resistors in the 1/8 or 1/10 W format. 1/3 Watt resistors can hardly be obtained in capless format now, and are thus unusable for assemblies in the GHz range. SMD resistors were not used, to make the structure easier to reproduce.

The SMD mixer is inserted into a rectangular recess, flush with the earth surface. The soldering connections face the components side. Two narrow strips and one wide strip, made of copper foil, act as the earth connection from the mixer to the continuous earth surface (identified with xxx).

One leg of each of the coupling capacitors is inserted into the corresponding board hole, and the other leg is soldered directly to the square soldering surface of the mixer. These three coupling capacitors have not been shown in the components drawing, as it is difficult to depict them. The band pass filter coils are soldered to the earth surface, with a clearance of 1mm.

The tinplate housing - dimensions 55 x 111 x 30mm - is prepared with two



high-frequency jacks, preferably SMA or SMC, and three feedthrough capacitors.

The fully-assembled and pre-balanced board can now be firmly soldered all around into the housing. With regard to the fitting height, make sure that the jack pins lie directly on the tracks in question. The earth connection for the high-pass strip line, near the high-frequency input jack, is soldered directly to the tinplate housing.

---

## 5. SETTING-UP

---

When the voltage controller, the two IC's, the T1 and the passive components have been assembled, a thin measuring cable is soldered onto the position of the T-2 base - still vacant - and connected to a frequency meter which measures values up to 1 GHz.

The current consumption should measure app. 60mA at +UB 12V, stabilised, with the lion's share of this, 45mA, going to the pre-divider.

If the VCO is oscillating, it should be possible to bring about a latched condition with the trimmer on T1, which is signalled on the meter by a stable reading of 1 GHz.

A DC voltage of 2 to 8 Volts is applied at the test point, TP. If the VCO has not been locked, an AC voltage can be measured here, using the oscilloscope, the frequency being the difference between the divided VCO frequency and

the crystal frequency. Should there be locking problems, first check that the crystal oscillator is oscillating satisfactorily, using an anti-capacitance high-frequency probe. The : 64 divided frequency of the VCO can then be checked at pin-6 or 7 of the U664B.

Buffer stages are now assembled around T2, and the 1 GHz section around T5. A sensitive milliwatt meter is connected at the PIN diode switch through a 3.9pF capacitor. Control voltage is now fed to + UB and subsequently to the 1 GHz switching input. A maximum of over 5 milliwatts can be achieved with two new trimmers added. Check again to find out whether the VCO is actually locked. If necessary, restore this condition through a small correction to the first trimmer.

The components around T3 and T4 supplement the frequency synthesis for 2 GHz. For setting-up, couple the milliwatt meter to the diode switch again, and apply control voltage at - UB and also at the 2 GHz switching input. The remaining trimmers are adjusted to give a maximum 2 GHz signal. This is the case for trimmers which are almost switched off.

The suction circuit for 1 GHz can not be correctly balanced except with a spectrum analyser, as even without it the reduction in the unwanted signal is already better than 30dB. It is of assistance if this trimmer is also balanced to a maximum 2 GHz signal, since this circuit markedly improves the doubler efficiency.

Anyone who has the appropriate measurement equipment for setting-up can also incorporate a second suction circuit - dimensioning as L3 - on the collector

circuit of T4. This circuit operates considerably more efficiently than the first one, as the filtering is carried out directly at the output to the switching diode, and thus parasitic couplings of the 1 GHz signal no longer create any interference. In this way, if setting-up is carefully done, following incorporation into the housing, a spectrum purity of almost 60dB can be attained for the 2 GHz signal. This circuit can not be adjusted except with a spectrum analyser which can, as a minimum, represent the 1 GHz signal directly. For this reason, it was not incorporated into the layout either.

Finally the SMD mixer is incorporated, as described.

After incorporation into the housing, carry out a final re-setting-up of the VCO setting at a mean control voltage of approximately 5 Volts.

---

## 6. COMPONENTS LIST

---

T1	BF979
T2, T5	BFR91, BFR91A
T3, T4	BFG91, BFG91A
T6	BC2328B or similar, NPN type
D1	BB505 Varicap diode
D2, D3	BA479 PIN diode (379 if necessary)
D4	BA283 switching diode
Mixer	C-3, SMD ring mixer for 7dBm
Tr	5pF SKY trimmer, green

C 100 - 150pF ceramic disc capacitor or trapezoidal capacitor, small format capacitors, soldered into slots in the board, ceramic, 50V, basic grid 2.5mm / 5mm

Electrolytic capacitors: Tantalum 16V

- Dr 1 2 windings on 2.5mm core rod, 0.6mm CuAg
- Dr 2 1 winding, 2mm diameter, made of diode connecting wire BA479
- L1, L2 3 windings on 3.5mm core rod, 0.6mm CuAg
- L3 Strap app. 15mm long, CuAg 0.8mm on soldering side, with 3mm clearance from board

Resistors: 1/10 or 1.8 Watt, capless

---

## 7. TYPICAL APPLICATIONS

---

The pre-mixer described above was hooked up to a spectrum analyser as per DBINV.

Fig.5 shows an FM-modulated ATV signal at 2,410 MHz, together with a sound sub-carrier, at 6.5 MHz. It can also be clearly recognised that the modulation symmetry is imperfect, conditioned by the characteristic of the capacitance diode in the ATV control transmitter.

In this case, the spectrum analyser output signal was fed to two A/D converters in the PC, to make it easy to save and print out test certificates.

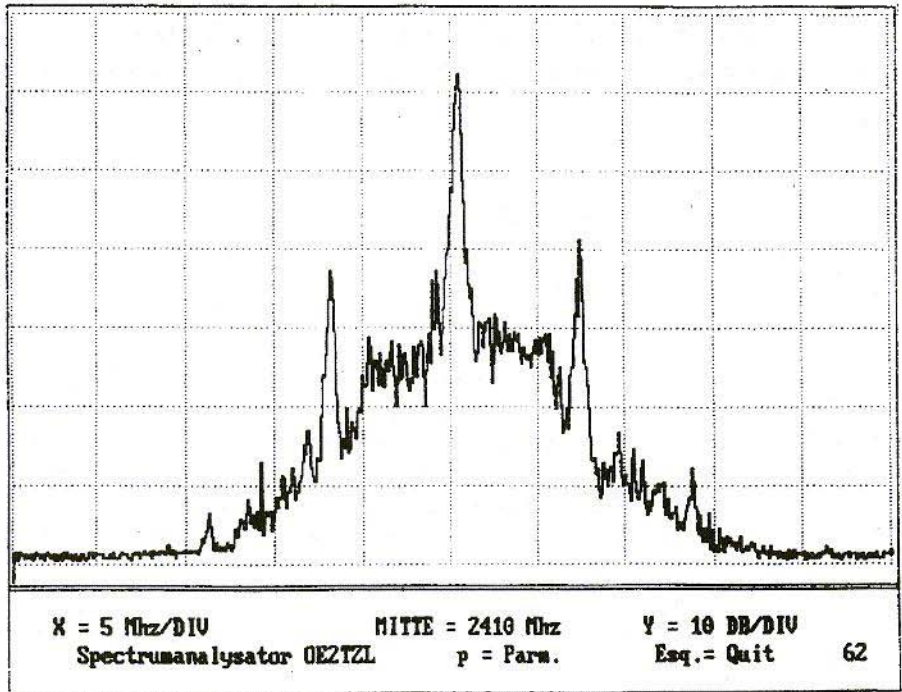


Fig.5: Example of FM-ATV Signal, at 2,410 MHz, with 6.5 MHz sound carrier

## 8.

### LITERATURE

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Transceiver  
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Congress, 1992

[2] J.Jirmann, DB1NV; Broad-band  
Tunable Voltage-Controlled  
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VHF Communications, 3/1986,  
pp. 214-221

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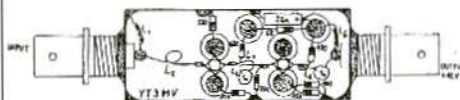
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Gunthard Kraus, DG8GB

# Design and Realisation of Microwave Circuits

## Part-2

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### 5. THE AUXILIARY EQUIPMENT

---

The aim here is to give a brief sketch of the equipment needed for the "microwave workshop", so that even a beginner can have the opportunity of finding out about the most important things. Not only do microwave circuits behave differently to short-wave circuits - or VHF

circuits - they usually also need a different mechanical structure. Precision mechanics is often a pre-requisite here for good electrical measurement results.

#### 5.1. The Auxiliary Mechanical Equipment

We have already referred in the introduction to the need to use SMD technology for the entire assembly. Fig.1 shows the most important auxiliary equipment:



Fig.1: Appropriate Aids make the Work Easier

- Temperature-controlled soldering irons with very narrow replaceable soldering tips
- Extra-fine watchmaker's tweezers
- Stereo magnifying glass in form of spectacles
- Set of SMD chip resistors from 10 Ohms to 1 MOhm, component size for beginners: 1206 (3mm x 1.5mm); component size for those more experienced: 0805 or 0604 (2mm x 1.25mm or 1.5mm x 1mm)
- Set of SMD chip capacitors from 1pf to app. 100nf - the capacitors from 1pf to 220pf should be size 0805, suitable for microwaves (e.g. "ultra-stable NPO" from Philips / Valvo, or in the Siemens "COG - Class 1")

- Roll of SMD solder (100g is enough!) with 0.5mm wire diameter
- Pivoted precision vice with ball and socket joint or printed circuit board holder.

Upright drilling machines, vices, files and taps, or perhaps a small lathe, will be ideal for the mechanical operations.

## 5.2. Electronic Auxiliary Equipment

The electronic auxiliary equipment includes, for example, digital multimeters, and at least one adjustable DC voltage power pack with adjustable current limiting. Something new is the requirement for a PC - if possible from a 386SX upwards, with a coprocessor and Windows. (Why Windows? All will be explained...)

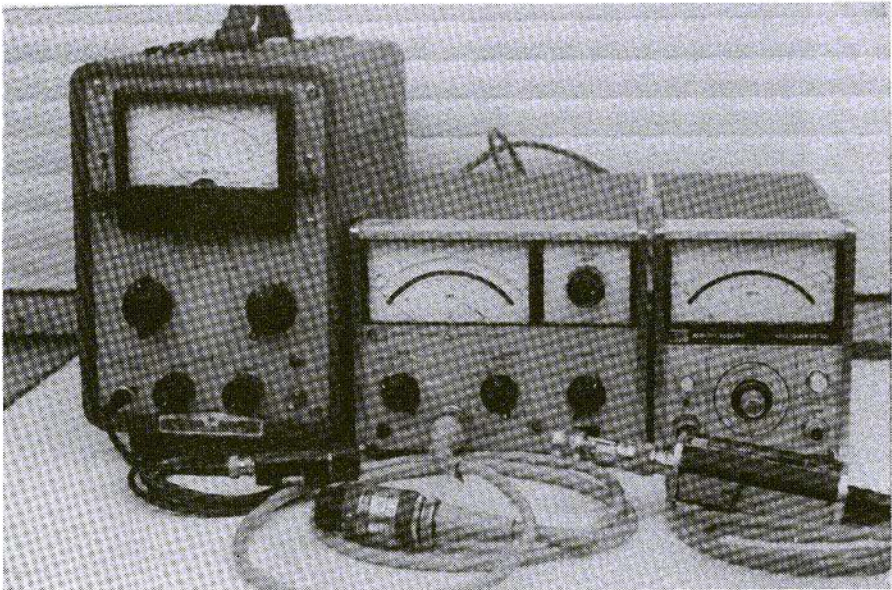


Fig.2: Examples of Relatively Old High-Frequency Measuring Equipment



The following are useful aids for the microwave measuring equipment:

- a. Test transmitter for the intended measurement range, from 50 Ohms upwards, with a 50 Ohm internal resistance. It's quite OK if the test transmitters date from the valve era, but they should be equipped with a good reducer covering a wide range of levels - e.g. 120dB.
- b. People like to use the wobbler range from Hewlett-Packard, which sell in large numbers. They are easy to maintain in working order, and it is also easy to obtain documentation about them. These units can also be used as test transmitters in the "CW" position.
- c. At least one microwave power meter - but better two, with measuring head for up to, for example, 12 GHz. They can be used to obtain very precise measurements of input and output power levels, and thus of the amplification or attenuation brought about by a module (i.e. our S-parameter S21).

Fig.2 shows examples of the most widely used equipment - from left to right.

- The HP430A (to 430C) is undoubtedly the "grandmother" of entire generations of wattmeters. Although developed back in the fifties, it is precise enough. One unpleasant fact is that this "bolometer meter" can be used to measure only very low power levels of about -20dBm (20mV can be measured at 50 Ohms).

- The next generation of meters, 431 and 432, are already greatly improved. The measuring heads have temperature compensation and the zero point can be corrected.
- The well-known Powermeter 435A has a chopper amplifier in the measuring head for the minute DC voltage output of the detector. Using a thermo-element instead of a thermistor, we can now measure as far as -65dBm.
- d. It is scarcely possible to operate without high-frequency plug connectors, adapters and high-frequency cables of various lengths. Here one should stock up with appropriate materials covered by the "N" and "SMA" standards, in which context preference should be given to used or corroded MIL quality instead of high-gloss nickel-plated Taiwanese products. Naturally, equipment may sometimes have to be bent back into shape during cleaning, to restore a good earth contact again.

SMA connectors are very good for operating up to 18 GHz, but nevertheless attention should be paid to the following points:

- In practice, an SMA connection is made only once, and here the union nut is tightened at 56Ncm, using a special dynamometric key. Thus the manufacturers do not see it as a connection which can frequently be undone.
- For this reason, if they are being used in experimental rigs (with a lot of screwing processes), they should

be treated with great care. Check them regularly for damage, and clean them even more regularly.

- e. You can't do without a small set of coaxial moving loads, short-circuits and attenuators, with values between 3dB and 30dB. "N" type formats are good but bulky. In contrast, "SMA" formats are incredibly small. Special attention should be paid to good quality here, as otherwise you'll be puzzling over the reasons for poor matching values in the measuring rig later.
- f. For those also wishing to measure reflection factors, there is the not exactly cheap directional coupler, with 20dB decoupling attenuation and a directivity exceeding 30dB. Luckily these articles can usually be picked up as surplus material, with N or SMA plug connectors.
- g. Just one more thing, learned from personal experience. You work hard and long and very successfully with the equipment referred to above. But inevitably there comes a day when you decide that you can't get any further without a spectrum analyser with a frequency range, for example, up to 18 GHz. Only the price scares you off! However, there are two possibilities here - either buy a used SA, or create a DIY apparatus, following the assembly instructions of - for example - J.Jirmann, DB1NV.

## 6.

### METEOSAT CONVERTER APPLICATION PROJECT

A specific project makes it possible:

- To plan a system and lay down specifications
- To draft circuits and analyse them, with the aid of appropriate microwave software (e.g. Puff)
- To develop the final current cycle plan and convert it into printed circuit boards, using CAD software if necessary (e.g. Geddy-CAD shareware)
- To design and manufacture appropriate housings, suitable for microwave work, for the assemblies
- To dimension the individual modules and the apparatus as a whole, and to document the measurement readings

Using the new design aids naturally offers other options as well. The modules created step by step in this way can also be put together extremely rapidly in a rather different way - one thinks of a 1,296 MHz assembly, or an assembly for the GPS receiver. The additional development cost would then extend over only a few stages, which would have to be "re-dimensioned". In most cases, this is done by calling up the appropriate Puff file and entering new design data.

It is also possible to put together a complete circuit from individual part-circuits already developed, which can then be fitted onto an overall printed circuit board.





### 6.1. Framework Conditions

Fig.3 shows the overall circuit diagram for the Meteosat converter. The only striking feature here is that the two MMIC amplifiers (described below) are identical.

Fig.4 shows the specimen rig for the complete converter. In the test layout, the converter was housed in the vicinity of an offset mirror with a DIY exciter. It was remotely powered through a coaxial cable, about 10m long, connected to the output.

The following pre-conditions apply to the module design:

- The individual stages are housed in milled aluminium housings with screw-on tops, have 50 Ohm input or output resistors, and are fitted with SMA jacks on the narrow sides.
- The smallest printed circuit board size is 30mm x 50mm, with a

housing measuring 35mm x 55mm x 15mm high. If this can not be achieved, the board size can go up to 30 x 95mm and the housing size to 35 x 100mm. The fixing system on the board consists of 4 M2.5 x 8 screws, each screw being 3mm from the edge of the board (this gives a "bore pattern" of 24 x 44mm).

- The operating voltage is fed into the interior of the housing through a feedthrough capacitor, to an SMD voltage stabiliser (type 78L05).
- The internal core of the SMA jacks must be fed through the housing wall so as to "match" the impedance level, and must then be connected to the board using a 50 Ohm microstrip line, with as little reflection as possible.

Fig.5 shows a blow-up view of these details on the pre-amplifier module.

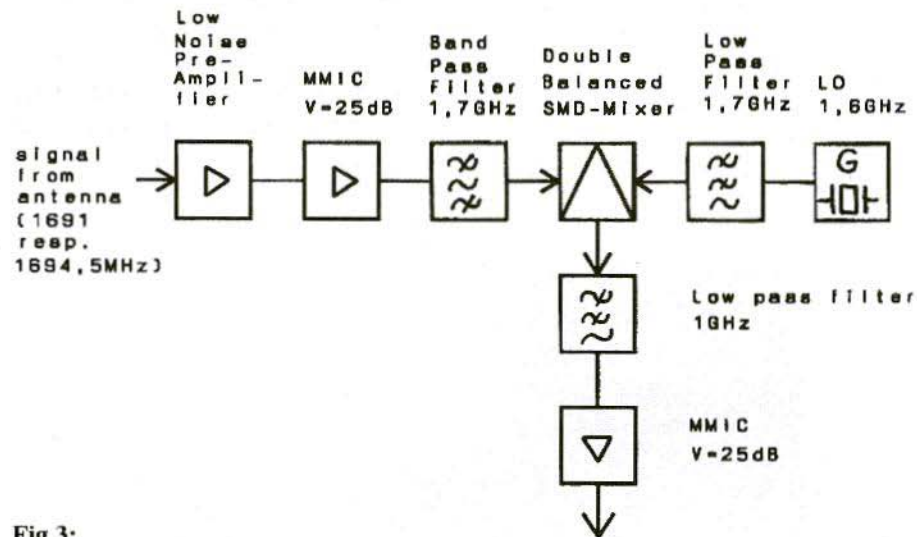
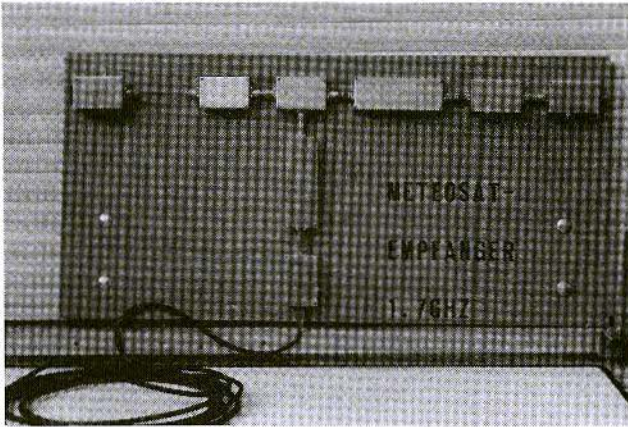


Fig.3:  
Project Block Diagram:  
Meteosat Converter

IF-signal (91 resp. 94,5MHz)  
to IF- and demodulator unit



**Fig.4:**  
Specimen Converter  
System Assembly

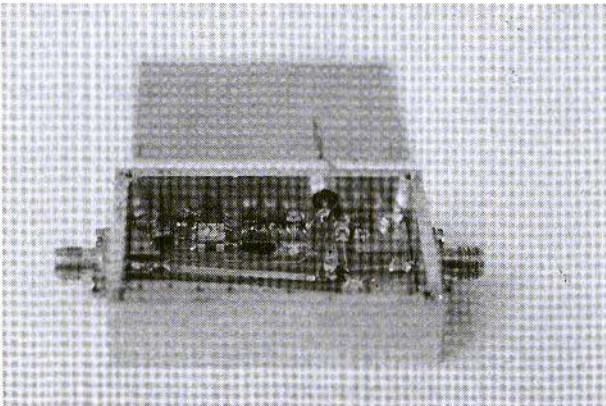
## 6.2. The first Assembly: LNA for 1.7 GHz

### 6.2.1. The Basic Circuit of the LNA

To obtain a low overall noise factor, the noise factor of the input amplifier must be kept as low as possible, and the amplification factor must be as high as possible, so that the subsequent stages can not have a stronger effect. The state of the art here is the GaAsFET, and the choice fell on the CFY30, for reasons of price. We can learn from its data sheet, or from the semi-conductor data CD-ROM from Siemens, that a minimum

noise factor of 1 to 1.2dB is possible at 1.7 GHz. Associated with this, of course (see Fig.6, left-hand diagram), is a "source resistance" at 1.7 GHz of  $Z_i = 100 \text{ Ohms} + j150 \text{ Ohms}$ .

The right-hand diagram of Fig.6 shows, for the 4 GHz frequency, how accurately this transformation must be carried out to keep the noise low. Thus, if you imagine the central point of the concentric circles at our point, 100 Ohms, being displaced by only  $+j150 \text{ Ohms}$ , you obtain the circumstances at 1.7 GHz.



**Fig.5:**  
Details of  
Pre-Amplifier  
Assembly



At this point, we should mention something else which can have a significant influence on design. If the exciter does not give an internal resistance of precisely 50 Ohms at 1.7 GHz, then the transformation circuit is displaced in relation to our start point. Things become dramatic if the aerials and the amplifier input are connected by coaxial cable! In that event, the start point actually moves - depending on the cable length - around a circle centred on the centre of the diagram. It is easy to imagine how far you can suddenly go from the Fmin point. The craziest thing about all this is that the noise factor will suddenly periodically oscillate between 1 and 10dB if you alter the cable length.

Once the aerial resistance has been established at - hopefully - exactly 50 Ohms, we have to try to make this into 100 Ohms + j150 Ohms at the gate of the FET. This can be done in several ways. One thinks of stubs, transforming L/C networks, strip lines wired in series, etc.. After tests on the various possibilities using Puff, and in view of their influence on the frequency cycle, however, the following solution was selected.

The 50 Ohm resistance of the aerial is initially transformed to 100 Ohms with a lambda/4 strip line. For this purpose, the strip line must have a wave resistance of:

$$Z_{\text{strip}} = \sqrt{(50\Omega \cdot 100\Omega)} = 70.7\Omega$$

At 1,700 MHz, the missing j150 Ohms call for a coil with 15nH. There are lovely, tiny little SMD inductances for this, size 0805 (i.e. 2mm x 1.25mm). At this frequency, the coil quality is given as "min. 50", so it is completely

adequate.

We can naturally not leave the gate connection in limbo, so we feed the required DC, in a known fashion, into a further highOhm  $\lambda/4$  line, short-circuited at the end (with a wave resistance of at least 100 Ohms). Due to the transformation into an open circuit, the FET, hopefully, does not notice what we have done.

For higher amplification, the output side of the FET is subjected to communications adaptation. To do this, the drain DC is fed in through an SMD inductance, the reactive impedance of which is high, as against the internal resistance of the FET. 47nH was selected, giving j470 Ohms. With an appropriate transformation circuit - e.g. a strip line, once again - you must also ensure that the reflection factor is zeroed on the SMA output jack. Puff can be of assistance here.

The basic circuit from Fig.7 is thus slowly crystallising, and we can risk our first simulation using Puff.

## 6.2.2. S-Parameter Files

To simulate a given circuit, we need the S-parameters of the semi-conductors used. In our example, this means the specifications for the recommended operating point from the data sheet (e.g. drain voltage 3.5V, drain current 15mA) and a file with the S-parameters for this operating point. We can come at this in two ways:

- a. We can obtain the appropriate diskettes with S-parameters for all standard semi-conductors - here then,

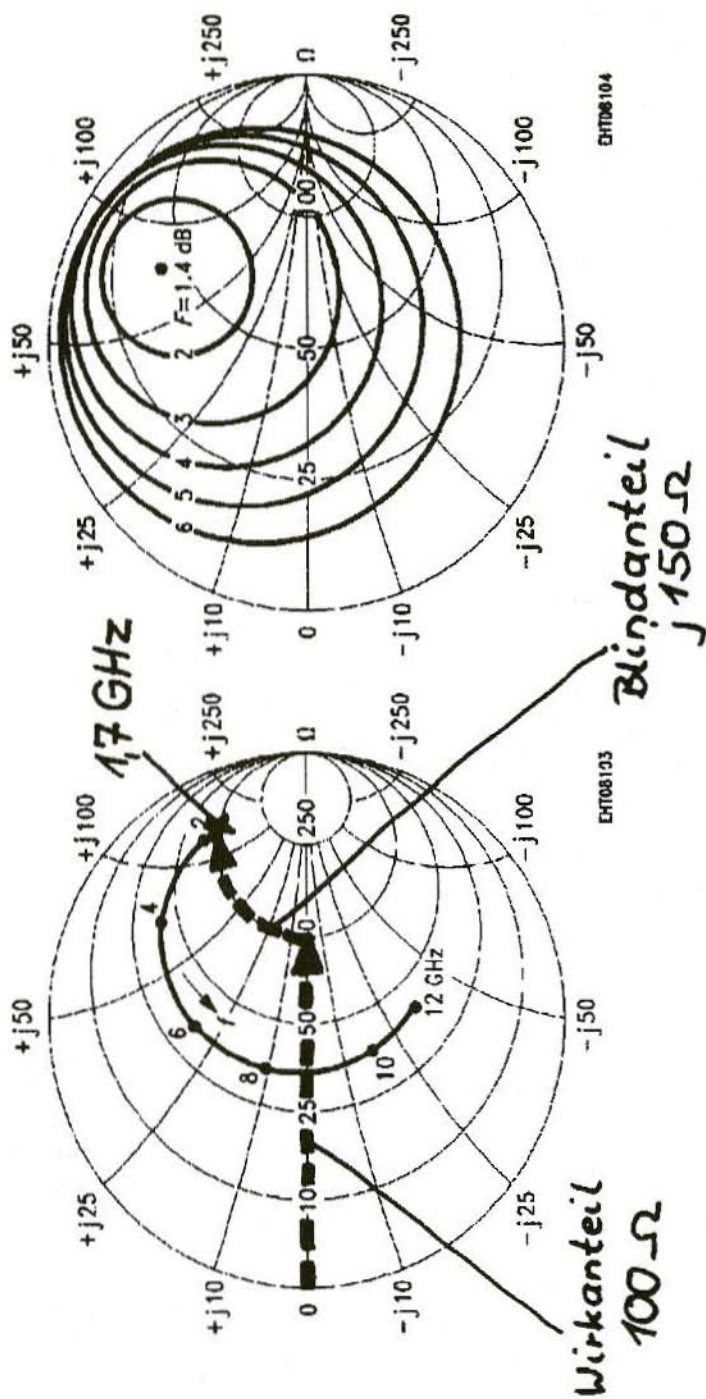


Fig.6: Diagrams  
 Wirkanteil = Active Fractions; Blindanteil = Reactive

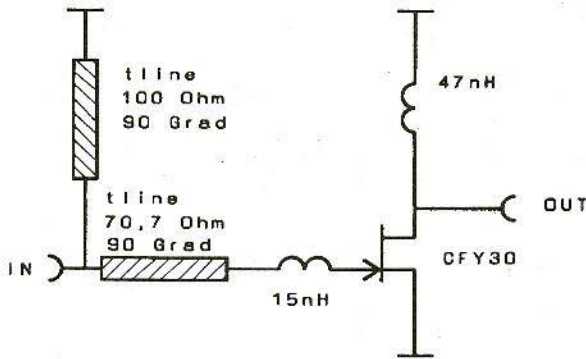


Fig.7:  
Base Circuit of LNA

the Siemens high-frequency transistors. The data for the semiconductor in question - here the CFY30 file - still have to be adjusted, as the data are usually supplied in "touchstone format" (identification: \*S2P), which Puff can not read. There is a conversion program for Siemens data, which is also supplied on the Puff diskette.

- b. There are also data on CD-ROM - e.g. from Siemens. This CD-ROM also contains a table with S parameters, in the appropriate data sheet. These data must also be adjusted. The simplest way is using a word processor. Any kind of "device file" supplied with Puff with the ending "\*\*dev" is loaded into the word processor, and this is used as a pattern for how such a file must be structured. Thus, you simply modify all the specifications for the CFY30, the S values always being: first amount, then phase angle. Finally the file is saved into the "Puff" directory, here with the name "CFY30.dev".

N.B.: Most touchstone files do not have any values for the "zero Hertz" fre-

quency. There is no alternative to estimating them, on the basis of the other values, and entering them into the tables subsequently! Puff otherwise sends an error message and goes on strike when the simulation should begin at zero Hertz.

### 6.2.3. The Printed Circuit Board material

Now all we need for the first simulation are the data on the board material used. On grounds of price, and since we are still operating below 2 GHz, the "FR4" fibreglass epoxy material was selected - photo-coated on both sides with a thickness of 1.5mm and a 35mm copper deposit.

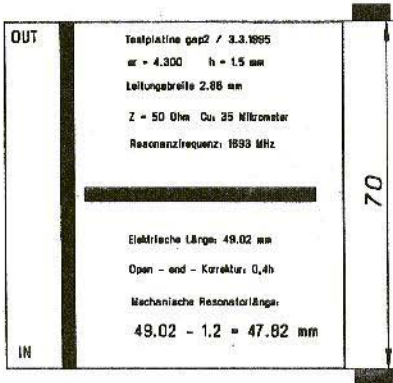
Of course, there were considerable difficulties at first:

- No values relating to the dielectric constants for this material could be obtained from the supplier. In the specialist literature, we found the value "5.5", so a small aerial intended for 1.7 GHz was designed for the test. To our amazement, the resonance frequency turned out to be

f	S11		S21		S12		S22	
0	1	0	2.23	180	0.01	90	0.69	0
1	0.98	- 18	2.23	157	0.024	74	0.69	- 15
2	0.95	- 39	2.22	136	0.045	57	0.66	- 30
3	0.89	- 64	2.21	110	0.068	40	0.61	- 45
4	0.82	- 89	2.23	86	0.085	23	0.56	- 62
5	0.74	- 115	2.19	61	0.099	7	0.49	- 80
6	0.65	- 142	2.11	36	0.107	- 10	0.41	- 98
7	0.58	- 171	2.05	11	0.113	- 26	0.32	- 119
8	0.51	155	1.99	- 15	0.117	- 41	0.23	- 147
9	0.50	120	1.85	- 40	0.115	- 56	0.16	167
10	0.51	90	1.62	- 65	0.110	- 69	0.17	118
11	0.53	65	1.44	- 86	0.107	- 80	0.25	84
12	0.55	41	1.34	- 107	0.107	- 92	0.31	60
13	0.59	17	1.20	- 130	0.104	- 105	0.38	35
14	0.64	- 3	1.03	- 153	0.099	- 118	0.45	16
15	0.68	- 19	0.86	- 170	0.092	- 131	0.51	- 1

**Table:** Here is an S-Parameter File as an Example  
**CFY30 GaAsFET in SOT143 package**  
**V DS = 3.5V, I D = 15mA, Z 0 = 50 Ohm**  
**frequency f in GHz**

- almost 2 GHz, so this value could never be correct. Moreover, the static capacity of the large printed circuit board supplied was measured with a capacity measuring bridge, and the dielectric constant was determined from this as being 4.8.
- The next trial using the 1.7-GHz aerial still produced unacceptable discrepancies, so once again we looked for the reasons. There follows a summary of the results:
  - FR 4 material has a dielectric constant of 4.8 at low frequencies;
  - This value decreases, from about 1 GHz upwards, first slowly, but then faster and faster; for 1.7 GHz, it is only 4.3.
  - The losses likewise rise slowly from 1 GHz, but then faster and faster. At 1.7 GHz, we can expect a value of 0.015 for the loss factor.
  - Unfortunately, the dielectric constant varies by up to 3 per cent from delivery to delivery. In critical applications, such as resonators or aerials, for every new board material delivery, the dielectric constant variation must first be determined, and must be taken into account in the Puff layout, on a percentage basis, when the value is pre-set.
  - Anyone for whom this is too expensive should immediately change to a decent microwave printed circuit board material with a Teflon or ceramic basis, such as RT-Duroid, etc.. These materials conserve their characteristics practically unaltered



**Fig.8:**  
Aerial for 1.7 GHz as Test Rig

*Testplatine* = Test board; *Leitungsbreite* = Line width; *Mikrometer* = Micrometres; *Elektrische Länge* = Electrical length; *Open-end-Korrektur* = Open end correction; *Mechanische Resonatorlänge* = Mechanical resonator length

up to and above 10 GHz, and the manufacturer's specifications can be transferred unchecked into the Puff simulation.

If, on the contrary, you stay with FR4, then you can first engrave yourself a test circuit - for example, as per the specimen in Fig.8. In the test circuit, a stub cable at no-load is connected through a small 0805 chip capacitor to a continuous 50Ohm line, which is closed off at 50 Ohms. For all  $\lambda/4$  resonances of the stub cable, this forms a short-circuit, and thus dramatically worsens the otherwise good input reflection factor. At the same time, the layout acts as a band barrier at this frequency. Using these two effects, it is then possible to work backwards over the mechanical length of the stub cable to determine the actual dielectric

constants at this frequency.

#### 6.2.4. Entering Puff

Now we come to Puff. The procedure is explained step by step.

1. Start Puff by calling up the "PUFF-BAT" file.

Hopefully, this will also put the "Code Page 437" into operation (command "chcp 437"), to change over to the American code set with the Ohm and degree signs. If not, the line

```
DEVICE=C:\DOS\DISPLAY.SY
CON=(EGA,,2)
```

must be added in CONFIG.SYS and the lines

```
C:\DOS\NLSFUNC
MODE CON CODEPAGE
PREPARE=((850 437)
C:\DOS\EGA.CPI)
MODE CON CODEPAGE
SELECT=850
```

must be added in UTOEXEC.BAT. Of course, the three lines must be set in AUTOEXEC.BAT as far as possible at the beginning, or else before the driver for the keyboard, CD-ROM, etc..

2. Press key F3 to arrive in the "Components Window".
3. The components required in the circuit are now entered one after another.
  - Discrete components always start with "l(umped)", followed by the component value

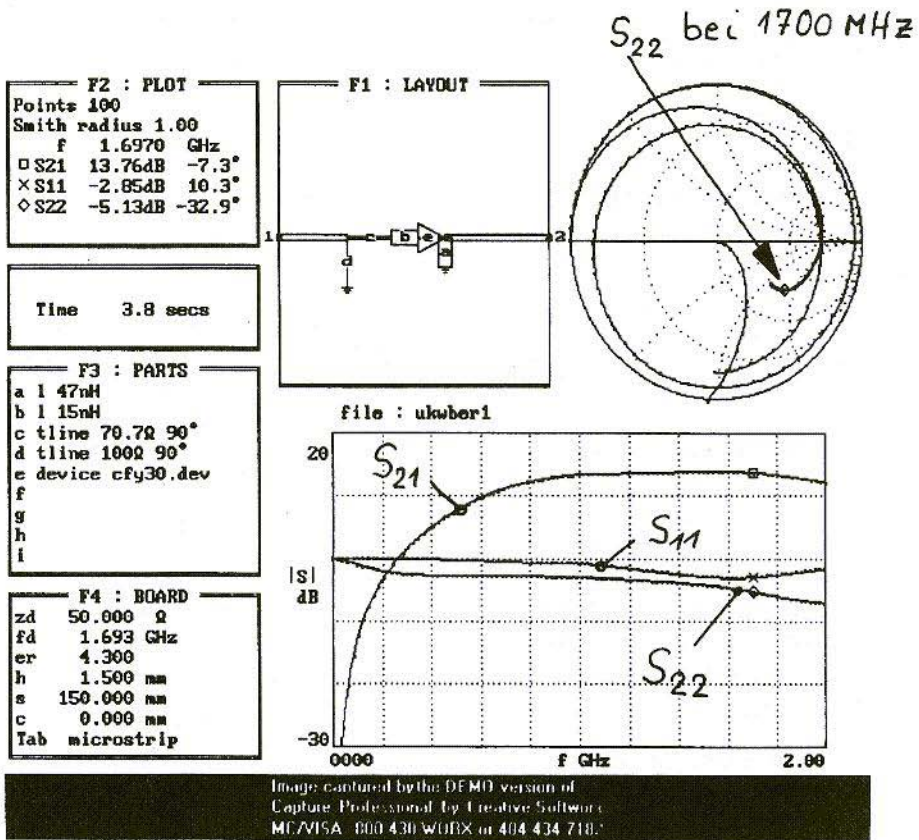


Fig.9: Puff Screen Print-Out; Bei = At

- Strip lines begin with “t(line)”, followed by the impedance level and the electrical length in degrees
- Active components are entered using “device \*.dev”

Fig.9 shows how the complete list for the specimen circuit should look.

4. Next, press key F4 and enter the values for impedance level (50 Ohms), mean frequency (1.693 GHz), dielectric constant (4.3) and board thickness (1.5mm). 150mm should be the board size selected.

5. The key F1 takes you to the layout window, i.e. to the board. If an old design can still be seen there, it can be deleted using “CTRL e”. The “start cross” is then displaced by pressing the change-over key and moving the appropriate cursor key slightly to the left, to obtain space for the circuit.

If you now press key “c”, this component (it is the 70.7Ohm transformation line) is active, and can be placed, using the appropriate cursor key.





This continues to the end of the procedure, during which:

- A wrongly positioned or superfluous competent can simply be deleted again by pressing the change-over key and "Cursor Key in Opposite Direction"
- You can travel round the circuit already "plotted" with the cursor at any time without any consequences, and
- Upon completion, press "1" to connect up to the input jack
- Press "2" to connect up to the output jack

But take care; within the circuit, the cursor must also actually be at the input or output point of the circuit when the corresponding key is pressed, otherwise you will connect up some point or other of the circuit. In the worst case, you can delete the circuit using "CTRL e" and begin again.

6. Activate key F2 to branch into the calculation program. First you preset, for example, 100 calculation points, and select only sizes S21 and Sss. At the other S parameters, you need only delete the index, so that they are "switched off". Use the "Up" or "Down" cursor key to get back to the axes of the diagram in which the results are displayed. On the frequency axis, you key in, e.g., "0" and "2.0 GHz", and on the vertical axis the values "-30dB" and "+ 20dB" are shown.

If everything is now in order, press "p"

to obtain the screen as in Fig.9. If problems arise, compare the values for all the windows of the print-out with those on your own screen. You'll soon find the errors. You can see the beautifully even amplification curve given by the cycle of S21, going from 1 GHz almost all the way to 2 GHz.

Now, of course, we still need to adjust the power at the output. For this, you should cast a glance at the Smith diagram of the print-out and have a look at the cycle of S22. The curve runs to the right below the mean point. This means that the internal resistance of the FET exceeds 50 Ohms and has a capacitive blind fraction.

It can be transformed to 50 Ohms only by means of a strip line, which has:

A resistance considerably exceeding 50 Ohms, and:

Is considerably shorter than 90 degrees, so that you are in the vicinity of the 50Ohm point in the Smith diagram.

Thus, as an experiment, you might enter a strip line having a value of  $Z = 120$  Ohms and a length of 30 degrees, which you position between the FET output and the output terminal "2" into field F3. Moreover, the 47nH SMD choke coil must still be connected somewhere on the drain connection of the CFY30 subsequently, at size 1206 a gigantic component in comparison to the FET. So we also need a small piece of strip line here, with as high an impedance level as possible (that gives greater inductance) and a length of app. 5mm. But things more or less have to stop at  $Z = 135$  Ohms, since then the width of the line is already falling below 0.3mm.

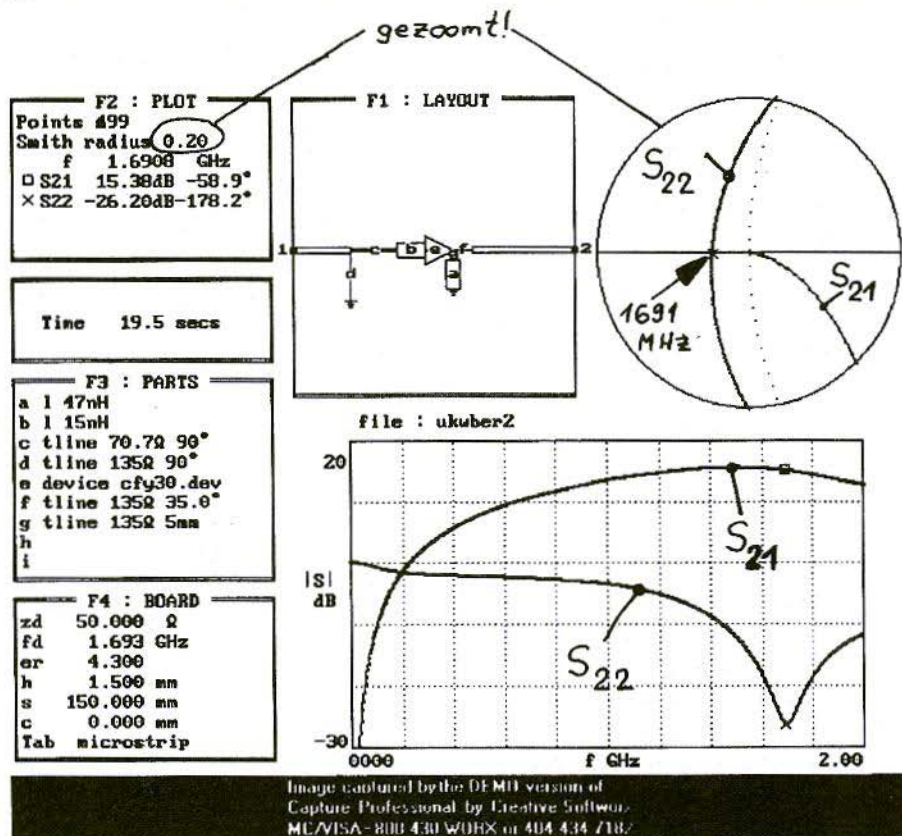


Fig.10: Optimised Circuit Data; Gezooamt = Zoomed

(Even for the gate pre-voltage for the operating point, we therefore select this 135 Ohms as impedance level for the  $\lambda/4$ )

We now go back to field F1 and incorporate the changes just made into the circuit. Next, we need only to make a new plot, to examine the results in the diagrams, and to correct the line length in the direction of point 2. The entire process will need to be repeated a few times, until you can get practically as far as possible from the mean point (= 50 Ohms) at 1,700 MHz in the Smith

diagram and are simultaneously on the vertical axis. S22 will then display a minimum value! If the S22 curve finally runs past the 50 Ohm point to the left, then the transformation resistance must be slightly increased again. If, on the contrary, it runs past to the right, then the resistance must be slightly decreased.

One other recommendation here - you should "zoom out" the mean point of the Smith diagram, so that you can fiddle around until the S22 curve is as near to this point as possible, and thus the best



possible matching is precisely at 1,693 MHz. For this, we need not only to reduce the "Smith radius" in field F2 right down to 0.5, or even 0.2, but we should also increase the number of plot points (absolute limit: 499). Hopefully, your PC has a coprocessor. Otherwise, with circuits of considerable size, the calculations will take a very long time.

Fig.10 shows the data for a circuit optimised in such a way.

Before continuing, we must not forget to carry out an essential Puff check. Change the frequency range scanned into "0 to 10 GHz" and carry out another plot. You now need razor-sharp eyes to investigate the cycle of S11 and S22 in the bottom frequency diagram, as the values of S11 and S22 must never exceed 0dB anywhere.

Those would mean reflection factor values exceeding 1, and these are unfortunately associated with negative resistance values for the input resistance and also for the output resistance. But in most cases anything like that causes the amplifier to oscillate.

Now one more observation which I have recently made concerning the print screen function:

It has become clear that, of the printer drives supplied on the Puff diskette, only the "Epson version" functions without any problems on all printer versions at all times. Printing with HP Deskjets and Laserjets has proved to be very much the biggest headache in the past. Part of the screen was always missing, and there was no way to eliminate the errors. Even a letter to the software authors in America resulted only in an

answering letter containing the priceless final sentence: "...let us know if you find a solution, because this is a common problem...".

The lengthy searching and experimentation has borne fruit, for I can now offer an almost perfect solution. By chance, in a sub-category on a CD-ROM belonging to my children (111 Windows Games), I found a "Screen Capture Shareware Program" named "Capture". This was the solution to the problem, and printing out became child's play.

Install Puff using Windows (as a DOS application by means of the program manager) and start it up from there. If you are working with Puff and you press the "Printscreen" key as usual, the screen is copied into the intermediate filing (= Clipboard). Go back to Windows, call up "Capture" and load the intermediate file into this program. The many processing options now on offer make it a pleasure to invert (to eliminate the black background), convert into a black and white image, balance the half-tones, rotate the diagram, and much more.

You can save the end result as a "Bitmap file" and print out immediately, using the PC system's Windows printer. Naturally, I prefer to fetch the image into a "graphics frame" in my word processing program (Winword 6.0) and then cut the bottom 2cm off, as that's where the tiresome reference to the shareware version appears.

You should now become familiar with the first Puff operating commands. Unfortunately the original English manual does not contain a list of all possible commands and operations. Since one is



really helpless without this reference work, I have compiled the following "Alphabetical Keyword Catalogue for Operating with Puff".

### 6.2.5. Alphabetical Keyword Catalogue for Operating with Puff

#### Command Keyword

Indicate dimensions of components or lines:

Load American code set (to access Ohm sign, etc.)

Place component (in layout F1)

Delete component (in layout F1)

Enter component values (in F3)

#### Key Combination

Go into field F3, move cursor to corresponding component line and press "="; data then appear in information field

Before calling up PUFF.EXE: "cd c:\puff", then "chcp 437" (N.B.: First change AUTOEXEC.BAT and CONFIG.SYS!)

Change to field F1, move cursor to intended connection point and select component by keying correct letter in (see list for field F3!). Then place component by pressing corresponding cursor direction key.

Change to field F1, move cursor to start of component and delete it with key combination "Shift + cursor direction key"

Change to field F3, move cursor to list empty space in list and key in: "l(umped)". The components can be entered individually, as a series circuit, or as a parallel circuit. For Ohmic resistors, either "Ohms, kiloOhms, etc." or values standardised on the system resistance ( $1z$ ", " $0.3z$ ", etc.) are permissible as units for Ohmic resistors. Blind elements, on the other hand, can be given directly with the correct unit (e.g. pf, mH), or as imaginary resistance values (" $+j10$ "), or as imaginary resistance values standardised on the system resistance (" $-j5z$ "). Example for series circuit: " $2+j4-j3z$ ".



Expand component list F3,  
because points a...h are not  
sufficient

Component sweep

Press F3, then activate tab key

A component from the component list can be varied in its value through the program, whilst the other components and the frequency are kept constant. In this way, a circuit can be optimised. To do this, first go to field F3 and insert a question mark in front of the component value.

Example:

lumped ?10pF

or tline 50          ?90°

After the change to field F2, the sweep limits for the variation of the component are set on the axes of the frequency cycle diagram - for example, 5pF to 15pF for the capacitor or 70° to 110° for the stripline.

Insert coupled lines

Enter in component field F3 with "clines" or just "cl", followed by values of "even" and "odd" resistance, if impedance level of coupled lines is different from system resistance. Then enter electrical length. If impedance levels of system and coupled line are the same, only one of the two resistance values is to be entered (either "Even" or "Odd" can be used). Puff then calculates the absent second value and enters it in the \*puf file.

Load file of a draft

Change to field F3, "CTRL r", enter file, then "Return".(N.B.: File must have extension \*puf. But this extension does not have to be indicated.)

Save file of a draft

Change to field F2, then "CTRL s", key in file name, "Return".

Change board material

Go into field F4, then enter new thickness value under menu point "h"



Print out draft layout	Change to field F2, then "CTRL a" (Enlargement factor p must have already been set again, if necessary, through word processing, directly in circuit file *puff!)
Load printer driver	Before calling up PUFF.EXE: "cd c:\puff", then e.g. "vga2pro.com" for IBM Proprinter; then "puff.exe"
Degree sign (°) for entering angles for components, e.g. for electrical lengths of line units	In field F3 "Alt d"
Request help	Press key "F10"
Trigger pulse answer	In field F2 "i"
Micro-sign (e.g. for micro-Henry)	In field F3 "Alt m"
Use micro-stripline with dispersion and attenuation	Insert tline! instead of tline. N.B.: Before Puff is loaded, the file in question (or the set-up file, for a new start) must be called up with a text editor, and the board thickness, the thickness of the Cu layer, the surface roughness and the loss factor for the intended draft frequency must be entered and saved. Example: values for FR 4 material for the frequency 1,700 MHz $\epsilon_r = 4.3$ loss tangent = 1.5 E-2 Board thickness s = 1.5mm Conductor thickness = 0.035mm Surface roughness = 0.001mm
Jump to next node in layout	In field F1 "CTRL n"
OHM sign	In field F3 "Alt o"
Delete one component on board	Change to field F1, move cursor to start of component and delete it using key combination "Shift + cursor direction key"
Delete complete circuit on board	Change to field F1, then "CTRL e"



Parallel sign for discrete component combinations	In field F3 "Alt p"
Board: Change interval of	Change to field F4, then key in new portpins value under menu point "c"
Board: Change external dimensions	Change to field F4, then key in new value under menu point "s"
Board: Change thickness	Change to field F4, then key in new value under menu point "h"
Board: Change dielectric constant of material	Change to field F4, then key in new value under menu point "er"
Board: Create earth connection at a circuit point	In field F1 "="
Change number of plot points	Change to field F2, move cursor to "Points" and enter number of calculation steps (max. 449) manually
Start plot procedure (including calculation)	In field F2 "p"
Start plot procedure after change and also show old cycle	In field F2 "CTRL p"                      a
Connect portpin to layout	Change to field F1; move cursor to corresponding end point of circuit, key in number of portpin, then "Return"
Load Puff	Suggestion: Batch file "PUFF.BAT" into basic directory c: otherwise: "chcp 437", "cd c:\puff", "vga2pro.com", "puff"
Leave Puff	Press "ESC" twice in succession
Smith diagram: Change cut-out radius	Change to field F2, move cursor to "Smith radius", then key in desired radius. (Values between zero and infinity are permissible. Values smaller than 1 give a "cut-out enlargement".)
Smith diagram: Switch over to "Screen filling"	Change to field F2, then enter "Alt s"
Smith diagram: Print screen	Press "Printscreen" key (N.B.: This is not effective unless a printer driver - e.g. VGA2PRO.COM has been loaded before the start.)



Smith diagram: Switch back from "Screen filling" to "Small representation", with separately represented frequency cycle curve:

In field F2 "ALT s"

Smith diagram: Displace frequency markers

See under "Frequency markers". Displacement with "Page Up" or "Page Down"

Smith diagram: Switching over from resistance representation to electric conductance representation

Go into field F2, then activate "Tab" key

Trigger jump answer

In field F2 "s"

Change start frequency for plot procedure and calculation

Change to field F2 and move cursor key ("Up" or "Down") until cursor is on start frequency of lower diagram (for frequency cycle). Key in new start frequency, then start new plot procedure with "p".

Change stop frequency for plot procedure and calculation

Change to field F2 and move cursor key (up or down) until cursor is on stop frequency of lower diagram (for frequency cycle). Key new stop frequency in GHz in, then start new plot procedure with "p".

Select S parameter for calculation and plot procedure

Change to field F2, go down in field F2 with cursor key and key in desired parameter after letter "S" (e.g. S11)

### 6.2.6. Expansion of Basic Circuit to full Wiring Diagram

To obtain a circuit which can be assembled, the following requirements must also be met:

- The drain source DC voltage must be + 3.5V, the drain current must be 15mA
- The gate must have a negative voltage, app. 0.35V for this current,

against the source connection

- The source connection itself must be at earth potential for high frequencies
- The mains supply voltage for the FET amplifier should be +5V, and is obtained from "Remote power supply at +12V" by means of an SMD fixed voltage regulator (type 7805 / SMD)

There are now 2 options for setting the operating point via the Gate voltage:





1. An SMD switching controller (7660) is used to generate a negative voltage of -5V, which is used to power both the known lambda / quarter line and the gate, through a read-out potentiometer. The source can now be directly connected to the earth.
2. The gate connection is put directly at earth potential through the lambda / quarter line. But here a 22 Ohms resistance is needed in the source feed, on which the desired negative gate pre-voltage is set. This is the

simpler solution, but it causes considerable difficulties for broad-band, lowOhmic earthing of the source connection at up to 2 GHz using appropriate capacitors.

To investigate these influences in detail, I simply set both options up and then took measurements.

Fig.11 shows the assembled circuit with negative pre-voltage. Fig.12, on the other hand, shows the solution using the source resistance.

(To be continued)

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Mike Wooding, G6IQM

# SPLASH

## *a Review*

The radio spectrum is a precious resource, with everybody after a slice. Consequently, rigid spectrum management is required by both legislator and designer alike. One method for the designer of accomplishing this task is to produce expensive prototypes and test, redesign and test, and so on. This method is time consuming and can be very costly. One of the many tools now available to the designer to help with this problem is SPLASH.

SPLASH by Phasor Design is the name of their Spectral Occupancy Prediction Software package. The program performs mathematical simulations of radio transmission systems, which makes it an excellent aid for design engineers working in this field.

Using Fast Fourier Transform (FFT) techniques the parameters of a transmitter which determine the spectrum generated are modelled and a spectrum analyser type display produced on the screen. The FFT procedures convert from time domain to frequency domain and back again as required to model the modulation.

The key aspects of SPLASH are:

- Simulates modulation of radio transmitters, displaying spectrum in detail
- AM or FM analogue or digital signals
- Works with standard B32 format files, with an in-built text editor for producing/modifying such files
- 16 MHz sweep in 1 kHz resolution in 3 seconds on a 486/66 system
- Waveform display both before and after baseband processing
- Spectra graphed in a form comparable with that produced by a spectrum analyser
- Simulates the ideal Double Side band spectrum
- Simulates the FM spectrum
- Simulates the compressed spectrum resulting from 3rd and 5th order intermod.
- SPLASH is file compatible with WaveWorks Pro (Pragmatic Instruments). Waveforms created by WaveWorks Pro may be imported

into SPLASH and the spectral density predicted, compared with actual measurements of a transmitter driven by an arbitrary waveform generator.

## 1. HOW SPLASH WORKS

Note: rather than reinvent the wheel, I have reproduced this section from the SPLASH user manual and documentation supplied by Phasor Design.

### 1.1 Wave Base Band Data

Wave Base Band (WBB) files describe a section of time of a waveform. The section repeats indefinitely, setting the period and frequency resolution as the reciprocal of the period. WBB files are in binary form and are stored as floating-point values, with four bytes per sample. SPLASH displays the file length as the original data size.

SPLASH loads the WBB file and internally expands it to a textual form for editing. Editing is performed as with any other text editor, but note that on conversion back to binary form any non-numeric characters are lost. Conversion also adds marker numbers to assist editing.

When generating a WBB file, first decide the period/resolution needed. Then decide how many samples are needed, based on the criteria that the sample frequency must exceed twice the highest modulation frequency. Use FIX/ADD/SCALE/SINEWAVE to describe the new waveform. Note that it is not

necessary to carefully shape the waveform to model restricted frequency response (shaping) as these effects are applied by SPLASH during DSB calculation.

### 1.2 Double Side Band (DSB) Calculation

The FFT transforms the WBB data to the frequency domain where shaping is applied. As the final range of frequencies after modulation will be much greater than for the original signal, the data is expanded nominally by a factor of 10. This expansion is by interpolation and can be set to optimise performance between speed and dynamic range.

Interpolation has two effects:

A frequency response loss occurs due to the aperture error; this is automatically corrected.

Aliasing spurs appear in the  $-90\text{dBc}$  area. These spurious signals can be reduced by increasing the expansion factor.

Frequency domain processing is applied to:

- a) correct the aperture error of interpolation.
- b) add emphasis by including the effect of a pole/zero network.
- c) restrict the range accepted, either in a low-pass or band-pass way.
- d) add shaping by applying an ideal roll-off characteristic affecting amplitude only. Note that this is applied to the range selected.



### 1.3 Frequency Modulation

To model FM the calculated DSB data is:

- a) frequency phase modified; this also removes the DC component
- b) transformed to the time domain by the FFT.
- c) interpreted as wide-angle phase modulation with constant amplitude.
- d) transformed back to the frequency domain by the FFT.

### 1.4 Compression

To model compression the calculated DSB is:

- a) translated to a frequency offset.
  - b) transformed to the time domain by the FFT.
- c) compressed according to the third and fifth order power laws.
- d) transformed back to the frequency domain by the FFT.
- e) artificial spurious frequency components are removed.

---

## 2.

### USING SPLASH

---

The hardware requirements for running SPLASH are:

- IBM or compatible PC, 486 or better
- MS Windows 3.1 or 95
- Printer Port (for the program key)

SPLASH comes with an A5 ring-bound manual, the software on a single 3.5 inch disc and a dongle. The dongle is for software security and must be attached to the 1st printer port (LPT1) at all times for complete program functionality.

Installing the software was simple - just copy the files into a new directory. Copy the SPLASH.exe file to the desktop for an iconised click-to-go facility, attach the dongle to LPT1 and thats it. Double click on the icon and splash runs.

The fact that SPLASH is written as a Windows package (rather than a DOS package that will run under Windows) helps a great deal. It has the immediate feel of a user-friendly system, with all the usual GUS features - drop-down menus, iconised tool bar, multi-window presentation, context-sensitive help files, etc. (OK, I apologise now to all the non-Windows users or Windows haters out there - obviously I am neither of them!).

The user-manual is basic and assumes to some extent that you know what you are doing. I suppose that if you buy the package then you probably do - however, to some degree in relation to this sort of work I dont! That aside, the manual gives basic guidelines on how to install and run the software and has a section detailing some of the examples included with the package. , but that is about it. The main user guide is the Help file.

As with all good Windows packages the help file is dual-fold:

- Firstly, there is the main Help menu,

which allows you to search through an index for specific subjects, or gives an overview of general subjects.

- Secondly, there is the all-important context-sensitive help. This, to the uninitiated, is a system whereby one selects context-sensitive help by clicking on the toolbar icon and then just by clicking on the point on the screen which needs clarification or help with the help system opens up a dialogue box with the answer.

The user manual I found to be of little value to me essentially a novice - the help file got me going in quite a short time.

Experimenting with the on-board specimen data files I was soon negotiating the package and producing oscillograms and spectra with ease.

Dealing with a subject I am quite familiar with, i.e. a video waveform, and because I am not quite up to generating my own data files yet (!), I have reproduced here plots made on my system from an example WBB data files included with the package.

Video is a complex waveform, which these days contains monochrome (luminance) and colour (chrominance) information. To model this complex waveform separate shaping is necessary. Consequently 2 WBB files are used, one for each component. Firstly the monochrome information is shaped and processed, the resultant spectrum shown in Fig.1. Then in Fig.2 is the same for the chrominance information. Fig.3 shows the FM spectrum of the combined processed parts, the chrominance proc-

essed file having been imported into the luminance file, and then the combined file processed.

*Note:* These figures reproduced here are unfortunately in monochrome, the actual print output from SPLASH is available in colour, thus simulating the plots one would obtain from a pen-plotter.

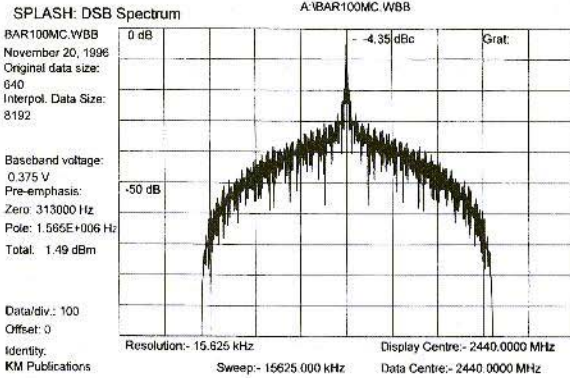
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### 3. CONCLUSIONS

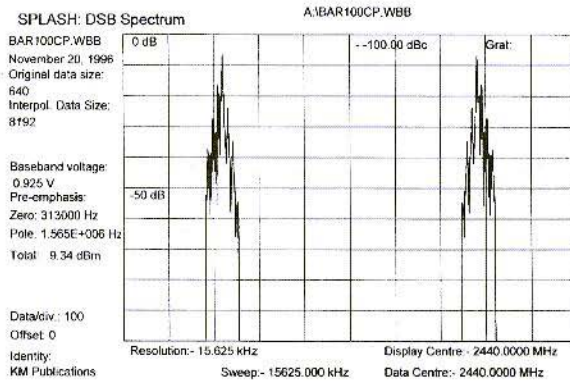
---

As I said earlier, I am no expert in the field of spectrum management or transmitter design. However, I imagine that if I were, then SPLASH could be a good aid to the design process. The package is simple to use, being Windows based, and with a minimum of effort meaningful results can be obtained. My only complaint, and that is based on the fact the essentially I did not entirely know what I was doing!, is that the user manual could have a lot more information on how to use the software. That aside, the on-board help files more than compensated for the lack of printed material. The assumption has been made by the software developer(s), and this of course may be somewhat invalid, that any potential user of SPLASH must be Windows and computer literate. I personally know of many engineers who are neither.

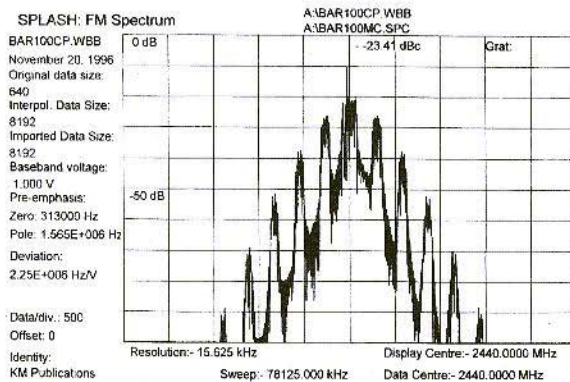
I wish to thank Phasor Design for the loan of the review package. The system used in the review was a 133 MHz Pentium based PC with a GraphixStar 600 video accelerator and an NEC SuperScript 660 GDI Laser printer.



Phasor Design +44(0)1858 432148 Fax: 432109 email: splash@phasor-design.uk.com **Fig.1**



Phasor Design +44(0)1858 432148 Fax: 432109 email: splash@phasor-design.uk.com **Fig.2**



Phasor Design +44(0)1858 432148 Fax: 432109 email: splash@phasor-design.uk.com **Fig.3**

In the UK SPLASH is available from S.J.Technologie, 183 Station Road, Burton Latimer, Kettering, NN15 5NY, UK. Tel: (0)1536 420163; Fax: (0)1536 420174. The introductory price (valid until 1st April 1997) is £325 (US \$490).

Overseas orders and for further technical information contact Phasor Design, 16 Blenheim Way, Market Harborough, LE16 7LQ, UK. (0)1858 432148; Fax: (0)1858 432109

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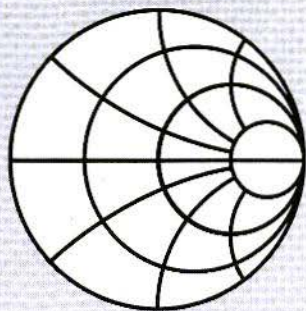
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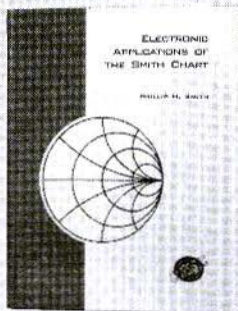
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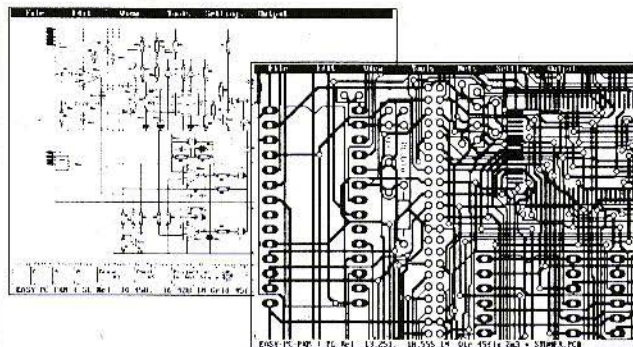
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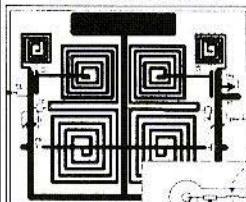


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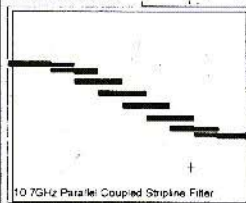
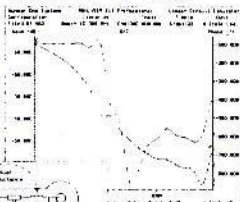
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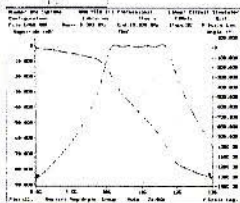
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