GSM RF Application Board
Version 1.0

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1. OVERVIEW

1.1 GSM mobile design

A GSM radio consists of a radio part and an advanced baseband part. Strategy is to move more and more intelligence like filtering and adjusting from the RF into the digital logic. The base band computing power can be used to customise the mobile with additional features like answering machine, SMS or userfriendly MMI.
A State of the Art RF part chipset and its application is described in this document.

1.1.1 Block diagram using Integrated Circuits

A GSM handset implemented using the SIEMENS GOLDplus baseband chipset and RF chipset would be as shown in Figure 2: Physical Partitioning of the GSM Handset.

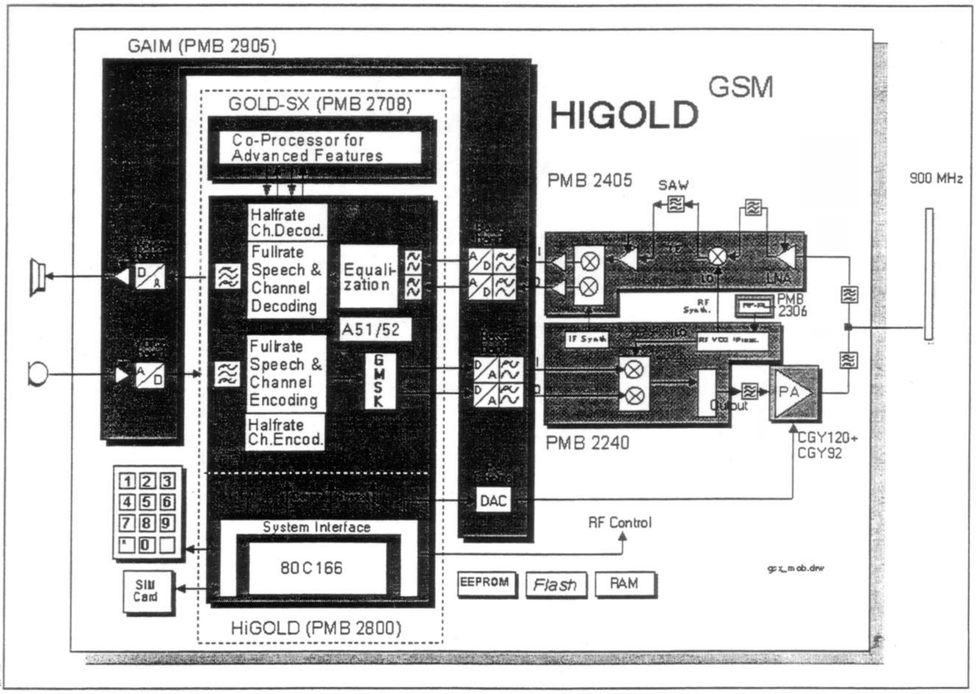


Figure 1 - 1 : Physical Partitioning of the GSM Handset

1.2 RF design

GoldSMith is a PCB which demonstrates SIEMENS state of the art GSM RF IC solution. The PCB is a classical implementation of a class IV, 4.8Volt Primary GSM small mobile terminal. Documentation of the RF unit , its mechanics, performance, (both static RF and dynamic GSM performance) are detailed in this document together with sufficient information enabling the user to use this PCB for a rapid start to GSM development in conjunction with the GOLDplusX baseband board.

The GoldSMith board enables simple testing and validation of the SIEMENS GOLDplus ICs with minimal effort in connection and required level of input. Furthermore, the PCB comes complete with a set of test results associated with the PCB and typical board measurements[1]. The measurements demonstrate the capability of the IC's to be designed into an RF module and be conformable with the GSM 11-10 specification.

The GoldSMith radio board is based upon the GOLDplus chip set from SIEMENS, consisting of the PMB2240 transmitter and PMB2405 receiver (RF ICs), and the PMB2306 synthesiser integrated circuit. It is a technology demonstrator and reference design. To enable complete operation the board should be used with the GOLDplusX baseband demonstrator board (also available from SIEMENS).

The PMB2240 integrates the 1LO oscillator, dual modulus prescaler, 2LO synthesiser, transmit mixer and modulator.

The PMB2405 integrates the LNA, receive mixer, programmable IF amplifier, 2LO oscillator, demodulator and the baseband operational amplifiers.

One primary feature of the PMB2240 & PMB2405 is that most of RF and base-band signals are balanced with respect to ground. With appropriate peripheral circuit design and careful PCB layout, this can significantly reduce the effects of radiation and unwanted coupling reducing the risk associated with RF layout.

The GoldSMith utilises distributed PCB elements where possible, in a combination of microstrip and stripline forms. This allows considerable design flexibility and a highly cost effective end result.

[1] Reference PCB retained by SIEMENS

1.2.1 Block diagram of RF Part

The architecture of the GoldSMith RF PCB is shown in Figure 3, the board uses a number of components which are predominantly available from SIEMENS Semiconductor or SIEMENS & Matsushita[2].

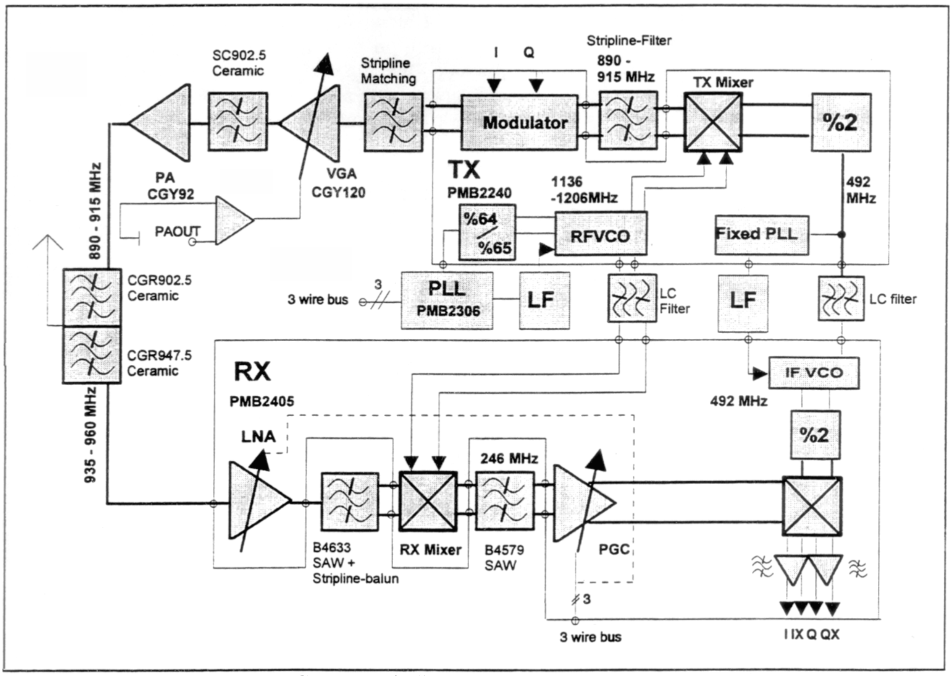


Figure 1 - 2: RF Block diagramm

Frequency generation

The transmit and receive chains are inter-linked though the use of two common VCOs (herein after called 1LO and the 2LO: 1LO refers to the high frequency VCO and 2LO the lower frequency oscillator). Synthesised frequency generation on board uses a 13 MHz VCTCXO module for the reference oscillator, each synthesiser receiving its own buffered supply. The 1LO forms the channel switching synthesiser whilst the other is fixed at the 2LO frequency of 492MHz.

Transmitter

Transmit mode combines the 1LO and the 2LO to form the on frequency component and a number of other unwanted spurs; which have to be reduced with suitable filtering. The transmitter RF frequency is a product of mixing the 1LO and 2LO synthesisers according to the following equation:

$$RF = 1LO - \left(\frac{2LO}{2}\right) \qquad (1)$$

2 Please ask your local SIEMENS representative. See Appendix A.

The filtered carrier is modulated by the on-frequency IQ modulator element. This is a fully balanced IQ modulator and requires the use of filtered differential baseband signals. These are provided by the GOLDplusX baseband board (more explicitly the GAIM [GSM Analog Interface Module, PMB2905]). The modulator utilises a frequency doubler and digital divider circuit to obtain the quadrature carriers at the RF frequency. This approach is accurate and repeatable, requiring no external phase-shift elements.

Subsequent to the modulator the signal level is increased by the CGY120 and the CGY92 amplifier blocks, these are both GaAs devices, which generate an output signal level in excess of 34.5dBm. This power level is sufficient to guarantee that the specification GSM11-10 is satisfied at the antenna port. A part of the transmit filtering is done in a ceramic type filter SC902.5 between CGY120 and CGY92 to prevent unwanted emission from further amplification.

The mechanism for power control is through the CGY120 and a full closed loop implementation using a loosely coupled diode detector at the output of the Power Amplifier. The power control dynamic range is approximately 40 dB. Closed loop control of the power amplifier reduces AM in the slot and so corrects for modulator set-up inaccuracies. Clearly with this arrangement the diode characteristic must be determined in order to generate the required baseband control for the closed loop operation.

The output of the power amplifier is connected to the duplexer unit via a low pass filter. The low pass filter is designed in distributed microstrip components. The duplexer has been designed using two discrete 2 pole coaxial ceramic resonator filters, one for the receive band type CGR947.5 and the other for the transmit band, type CGR902.5. Optimising the phase length between the two filters and the antenna port will ensure a reasonable performance from the duplexer, to minimise the size this is done with the aid of lumped elements. The antenna port is a 50 Ω connection.

Receiver

The receiver uses the same frequency sources (the 1LO and 2LO) as the transmitter albeit 45 MHz difference in the 1LO frequency due to the duplex separation of the Tx and Rx bands. The receiver RF frequency is calculated in the same way as for the transmitter, using equation (1) above. The signal flows from the duplexer to the Low Noise Amplifier block.

The LNA has a high gain and a low noise figure, hence the system noise figure is largely defined by this block (unless there are high subsequent losses). The LNA gain can be switched to low gain by the receiver's 3-wire bus control. The output of the LNA feeds the RF Rx SAW filter B4633 which in combination with the duplexer gives all of the required filtering for receiver wideband blocking.

Down conversion to the IF of 246MHz is performed in the PMB2405 with a Gilbert cell type mixer circuit. The output of this block like many others is differential. The mixing process will combine any inferior 1LO noise and the signal; this process of reciprocal mixing leads to a demanding performance specification for the local oscillator signal. The subsequent channel filtering is fulfilled through the use of an IF SAW filter B4579 at 246MHz. This filter is balanced and has a high impedance level so design in this area is critical. The SAW filter on the GoldSMith board provides a high degree of filtering at the adjacent channel.

After channel selection in the SAW filter the signal is processed by the Programmable Gain Control (PGC). This block provides 80dB of dynamic range (maximum gain 70 dB) in 2dB steps. The output of the PGC is connected internally in the PMB2405 to the IQ down conversion mixer. The down conversion requires quadrature carriers (like the modulator), these are generated by suitable division and conditioning of the 2LO frequency source. The differential baseband signals generated by the down conversion operation are filtered by second order active low-pass filters. The combination of the IF SAW filter and the second order active LPF provide nearly all of the required filtering to satisfy GSM 11-10 performance requirements. Final channel filtering is done outside of the GoldSMith board on the recommended GOLDplus X base band board.

1.3 PCB design

The radio is constructed on a 4-layer FR4 PCB of 1.2-mm total thickness. Layer 1 of the PCB is defined to be the back of the assembly, and a height limit of 4mm exists for components fitted to this side. Layer 4 is considered the top side, and a height limit of 2.3mm applies. With reference to the diagram below, the following rules are applied to the usage of layers:

* Layer 1 tracking is used for both signal and power as required. RF tracks are considered microstrip structures, and referenced to layer 3 ground. Some areas of layer 1 are used as ground plane for stripline on layer 2.
* Layer 2 tracking is used for both signal and power as required. RF tracks are considered stripling structures, and where possible ground plane cover on layer 1.
* Layer 3 is ground plane with maximised copper area. Vias connecting to the ground plane are provided with thermal relief to improve solderability. Vias passing through to the other side of the board are given a minimum of clearence. There are no tracks on this layer.
* Layer 4 tracking is used for both signal and power as required. RF tracks are considered microstrip structures, and referenced to layer 3 ground.

Note: Layer 1 microstrip will have parameter 'h' (substrate height) double that of layer 4 microstrip microstrip. This must be considered when calculating track widths. Some areas of layer 2 stripline have little or no layer 1 ground plane cover, due to the presence of tracks and component pads on layer 1. This will mean that the TEM model of the stripline is incorrect, and track impedance will vary considerably where this happens.

1.3.1 PCB Structure

The PCB used for the GoldSMith design has a specification as defined in Table 1 - 1.

Characteristic	Specification
Number of layers	Four layer
Thickness	Total - 1.2mm Pre-preg -0.4mm Base board - 0.4mm
Conductor	Copper - 5um
Via size	Ø = 0.3mm plated (0.35mm drilled)
Via type	No Blind via, no buried vias
Dimension	102.5mm x 53.5mm
Dielectric constant	4.4 ± 0.3
Dielectric loss	$\tan \delta = 0.02$
Finish	All exposed conductor gold plated with thickness 0.05 um over a nickel base layer of 3um. Edge of PCB gold plated. Solder resist.

Table 1 - 1: RF PCB parameter

The board structure is as shown in Figure 1 - 3.

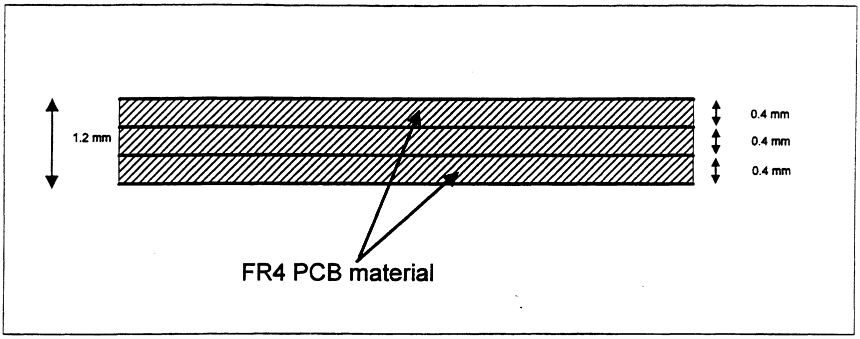


Figure 1 - 3: RF PCB layer definition

1.4 The GoldSMith GSM RF Application Board

Figure 1 - 4 and figure 1 - 5 are showing the realised GoldSMith GSM RF Application Board.

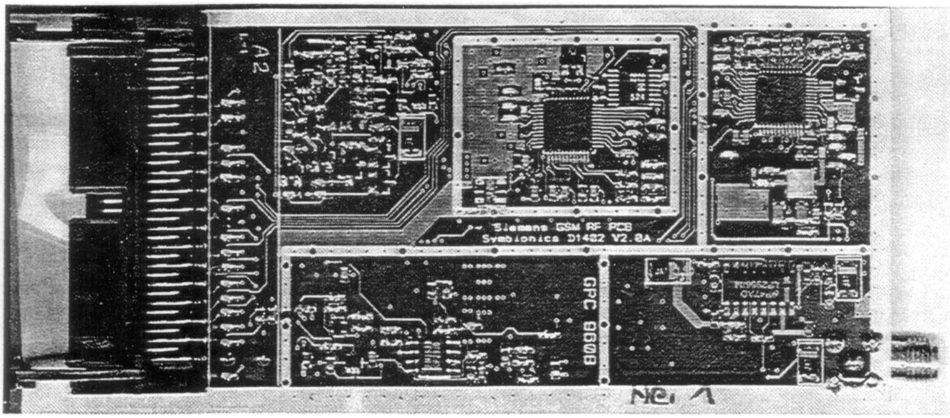


Figure 1 - 4: The Top side of the GoldSMith Board

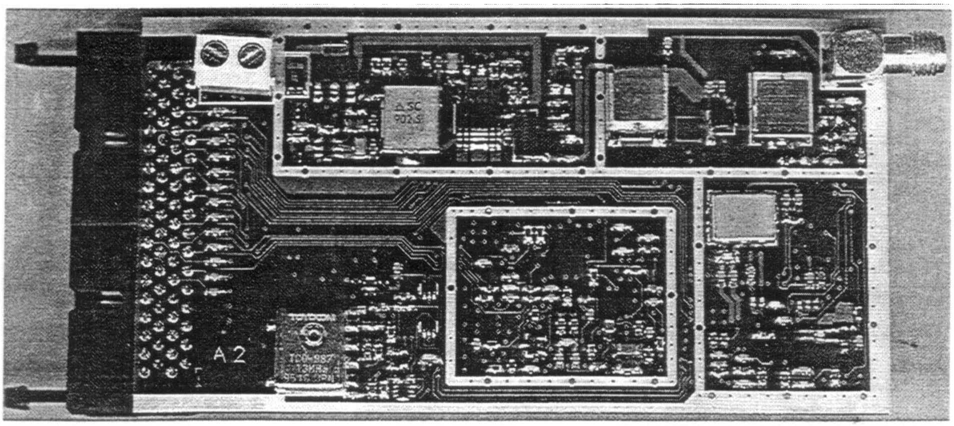


Figure 1 - 5: The assembly side of the GoldSMith Board

2. SYSTEM ISSUES

GSM, like many other digital communications standards has associated problems with its design and implementation. The GSM RF design brings with it many issues, many of these at a system level as opposed to an implementation issue. The following sections deal with some of these issues and the implementation of the system to circumvent these.

2.1 Phase noise

Phase noise from the oscillators affects both the transmit and receive strips in a number of ways. Some are common to both paths and some are quite different. The implications are complicated by the fact that the transmit and receive architectures make use of the same frequency generation elements. Hence the specification of the VCO phase noise performance must involve both calculations.

2.1.1 Transmitter

The transmitter phase noise requirements are defined outside the band ±400 kHz, which is where the phase noise dominates over the emissions due to modulation. Table 2 - 1 shows the requirements assuming that the 1LO and the 2LO both contribute to the combined figure, the ratio of the two contributions will be considered later in this document.

Frequency Offset (kHz)[3]	Power level at Δf(dBc)[4]	Res BW (kHz)	Phase Noise requirement	GSM Spec.5.05
400 - 1800	-60	30	-105dBc/Hz	4.2.1
1800 - 3000	-53	100	-113dBc/Hz	4.2.1
3000 - 6000	-65	100	-115dBc/Hz	4.2.1
6000 - 10000	-71	100	-121dBc/Hz	4.2.1
10000-20000	-67dBm	100	-150dBc/Hz	4.3.1
20000-45000	-79dBm	100	-162dBc/Hz	4.3.1
1805MHz-1880MHz	-71dBm	100	-154dBc/Hz	4.3.1

Table 2 -1 :Phase Noise requirements for Transmit

It is obvious that in order to obtain the required phase noise characteristic in the Rx band this will not be possible with the oscillator design alone. Therefore additional filtering will be required in the Rx- band.
The GoldSmith PCB design uses a filter in the TX path after the PA and hence subsequent calculations assume this.

The factors affecting the noise on transmit result from a number of sources :

Noise figure of the Power Amplifier

Noise floor of the IQ modulator

Phase noise of the local oscillators

Linearity of the transmit strip

The ideal duplexer gives rejection as defined in Table 2 - 2.

Frequency Offset (kHz)[1]	Rejection of Duplexer (dB)
400 - 1800	0
1800 - 3000	0
3000 - 6000	0
6000 - 10000	0
10000-20000	4
20000-45000	13
1805MHz-1880MHz	25

Table 2- 2: Duplexfilter specification

It can be concluded from an analysis of these criteria that the required specification for the transmit phase noise is as shown in Table 2 - 3. Assumptions made here are :

The IP3 of the CGY120/93 is 45dBm

IQ modulator noise floor -140dBc/Hz

A given, ideal duplexer

Frequency Offset (kHz)[2]	Power level at Δf (dBc)[3]	Res BW (kHz)	Rejection of Duplexer (dB)	IQ mod Phase noise (dBc/Hz)	Carrier Phase Noise requirement (dBc/Hz)
400 - 1800	-60	30	0	-140dBc/Hz	-105dBc/Hz
1800 - 3000	-63	100	0	-140dBc/Hz	-113dBc/Hz
3000 - 6000	-65	100	0	-140dBc/Hz	-115dBc/Hz
6000 - 10000	-71	100	0	-140dBc/Hz	-121dBc/Hz
10000 - 20000	-67dBm	100	4	-140dBc/Hz	-126dBc/Hz
20000 - 25000	-79dBm	100	13	-140dBc/Hz	-129dBc/Hz
1805MHz-1880MHz	-71dBm	100	25	-140dBc/Hz	-129dBc/Hz

Table 2 - 3: Phase noise requirements with SIEMENS Duplexer and IQ modulator

[1]Unless otherwise denoted

[2]Unless otherwise denoted

[3]Unless otherwise denoted

2.1.2 Receiver

For the close in phase noise specification, the requirements on the local oscillators is dominated by the reciprocal mixing in the receiver. In this section these values will be calculated.

Blocking

The GSM specification GSM 05.05 section 6.3 details that for close in channels the following figures for Adjacent channel interferers must be rejected :

Channel	C/I Level
m±1	-9 dB C/I
m±2	-41 dB C/I
m±3	-49 dB C/I

Table 2 - 4: Adjacent channel performance requirements

The level of phase noise on the carrier must such as to produce a co-channel product of 9dB C/(N+I) after reciprocal mixing takes place.

Further removed from the carrier is the following blocking specification..-

Frequency Offset kHz	Interferer level
600 - 800	–43dBm
800 - 1600	–43dBm
1600 - 3000	–33dBm
3000 +	–23dBm

Table 2 - 5: Wideband blocking performance requirement

The carrier is at -99dBm and the required C/I is set at 12dB. Therefore in a 200 kHz bandwidth the following table is constructed for carrier Phase Noise.

Frequency Offset kHz	Interferer level	Req'd carrier phase noise
600 - 800	-43dBm	-121dBc/Hz
800 - 1600	-43dBm	-121dBc/Hz
1600 - 3000	-33dBm	-131dBc/Hz
3000 +	-23dBm	-141dBc/Hz

Table 2 - 6: Wideband blocking performance requirements

In-band phase noise

The inband phase noise requirements affect the following parameters :

Receive sensitivity
Receive performance with C/I
Receiver demodulator performance with phase error
Transmitter rms phase error

GSM 11-10 specifies an rms phase error of 5 degrees, typically the radio design should be well within this figure. A detailed analysis of these quantities reveals that for a given rms phase error of 2.6 degrees the noise spectrum is as shown in Figure 2 - 5, the following assumptions are also made :-

Inband noise density is -74dBc/Hz

PLL loop break frequency is 13khz

Roll off of noise spectrum is 20dB/decade

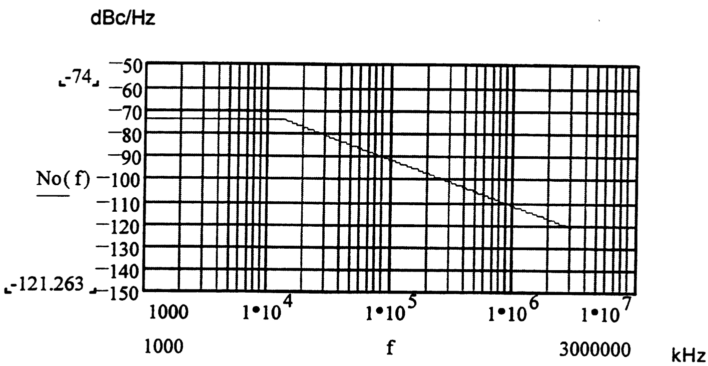


Figure 2 - 5: PLL output noise spectrum

2.1.3 1LO phase noise specification

The phase noise requirements of the high frequency oscillator 1LO is given in the table below :-

Frequency Offset (kHz)[4]	Carrier Phase Noise requirement (dBc/Hz)
Inband	-76dBc/Hz
300 - 600	-112dBc/Hz
600 - 1600	-121dBc/Hz
1600 - 3000	-131dBc/Hz
3000 - 6000	-141dBc/Hz
6000 - 10000	-141dBc/Hz
10000-20000	-141dBc/Hz
20000-25000	-141dBc/Hz
1805MHz-1880MHz	-141dBc/Hz

Table 2 - 6: 1LO performance requirement

[4]Unless otherise denoted

2.1.4 2LO phase noise requirement

The phase noise requirements of the 2LO is given in table below :-

Frequency Offset (kHz)[5]	Carrier Phase Noise requirement (dBc/Hz)
Inband	-76dBc/Hz
300 - 600	-109dBc/Hz
600 - 1600	-119dBc/Hz
1600 - 3000	-129dBc/Hz
3000 - 6000	-139dBc/Hz
6000 - 10000	-139dBc/Hz
10000-20000	-139dBc/Hz
20000-25000	-139dBc/Hz
1805MHz-1880MHz	-139dBc/Hz

Table 2 - 8: 2LO phase noise specification

2.2 Sensitivity

GSM 11-10 completely defines the required performance of the transceiver unit, including the modem performance. The modem performance (Base Band) is at least as critical as the RF unit itself, the equaliser performance is not covered within this report. Therefore for the puposes of this document we assume that the Signal to noise ratio (SNR) required at the radio baseband output is 9dB.
The sensitivity of the GoldSMith PCB is dependant on a number of parameters associated with the design of the receiver. In summary the prime contributors are :

Noise figure of the receiver
Demodulator performance
Noise bandwidth
Ambient temperature

These factors are now considered in more detail with the tacit assumption that there is no front end overload and/or blocking of the receiver by and interferers. These conditions are covered by other sections. The major contributions to the cumulative noise figure are the :-

On channel interferers
Adjacent channel interferers
Wideband blocking

These factors will be dealt with in more detail in the following section, some references are made to the phase noise specification derived in other sections. Specifications for the performance requirements with respect to blocking are clearly stated in Section 2.1.2.

2.3 Blocking and receive signal path

The receiver is tested for a number of parameters, one of the most crucial and difficult to meet is called the blocking tests. Blocking refers to one or more interfering signals either on channel or at a frequency away from the required signal, these signals are generally at a level considerably higher than the wanted signal and represent the harsh environment that handsets are expected to operate in whilst they are in the field. The blocking may be split into three discrete categories.

[5] Unless otherwise denoted

These factors will be dealt with in more detail in the following section, some references are made to the phase noise specification derived in other sections. Specifications for the performance requirements with respect to blocking are clearly stated in Section 2.1.2.

2.3.1 On channel interferers

Filtering on the RF module has little effect on the integrity of an on channel interfering signal, though for obvious reasons, the wanted signal quality might be degraded by the on channel filtering (ie. the SAW filter). This in-band filtering may reduce the performance of the system in the presence of the on-frequency interferer and must be dealt with accordingly. It should be noted that the receiver section of the GOLDsmith PCB introduces some distortion of the wanted signal in both amplitude and group delay. The equaliser will remove this distortion only at the expense of system performance in a fading environment.

2.3.2 Adjacent channel

Two effects are of concern with adjacent channel interferers, these being filtering of incident adjacent channels and the effect of reciprocal mixing due to the local oscillators. The latter is dealt with in other sections. The adjacent channel rejection of the IF filtering is the former concern and this is provided by the SAW filter and the low pass filters at the output of the baseband. The GoldSMith PCB provides all of the required rejection, no additional filtering is needed. Table 2 - 9 and figure 2 - 6 show the signal levels throughout the receiver.

	i/p[dBm]	Duplexer	LNA	SAW	Mixer	IF SAW	PGC	PGC filter	LPF
Wanted	-99	-101	-95	-98	-91	-94	-26	-26	4
-200kHz	-90	-92	-86	-89	-82	-93	-25	-26	-6
+200kHz	-90	-92	-86	-89	-82	-93	-25	-26	-6
-400kHz	-58	-60	-54	-57	-50	-85	-17	-20	-10
-400kHz	-58	-60	-54	-57	-50	-85	-17	-20	-10
-600kHz	-43	-45	-39	-42	-35	-80	-12	-17	-7
+600kHz	-43	-45	-39	-42	-35	-80	-12	-17	-7
-800kHz	-43	-45	-39	-42	-35	-80	-12	-20	-26
+800kHz	-43	-45	-39	-42	-35	-80	-12	-20	-26
-1600kHz	-33	-35	-29	-32	-25	-70	-2	-18	-33
+1600kHz	-33	-35	-29	-32	-25	-70	-2	-18	-33
-3000kHz	-23	-25	-19	-22	-15	-60	2	-23	-38
+3000kHz	-23	-25	-19	-22	-15	-60	2	-23	-38
-20000kHz	0	-20	-14	-34	-27	-72	-4	-64	-79
+20000kHz	0	-20	-14	-34	-27	-72	-4	-64	-79

Table 2 - 9: Adjacent channel interference (values in dB unless otherwise noted)

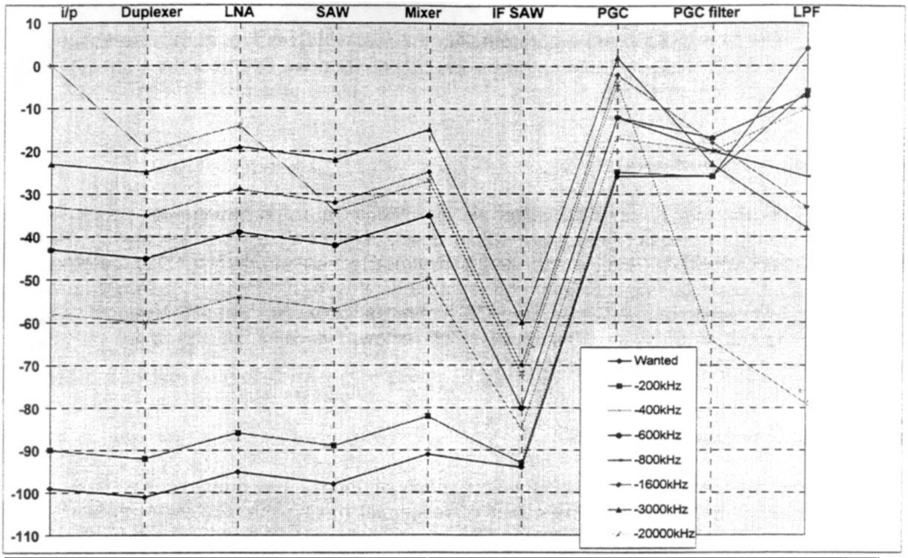


Figure 2 - 6: RX signal level [dBm] in the GoldSMith PCB vs. receiver stage

2.3.3 Wideband

The wideband blocking case is influenced by the RF filtering, it is covered in Table 2 - 9 and Figure 2 - 6.

2.4 Receive Intermodulation

The receiver is also susceptible to other forms of interference, one of these is third order distortion in the receiver front end and is best explained by means of a diagram.

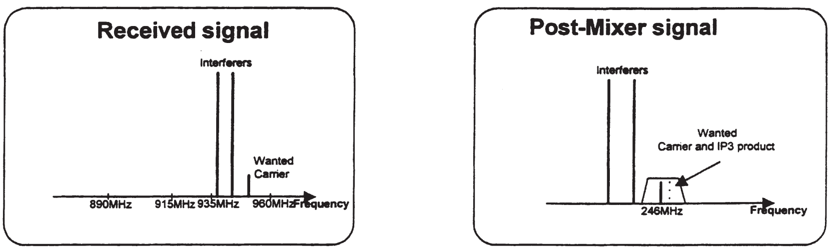


Figure 2 - 7: Intermodulation process

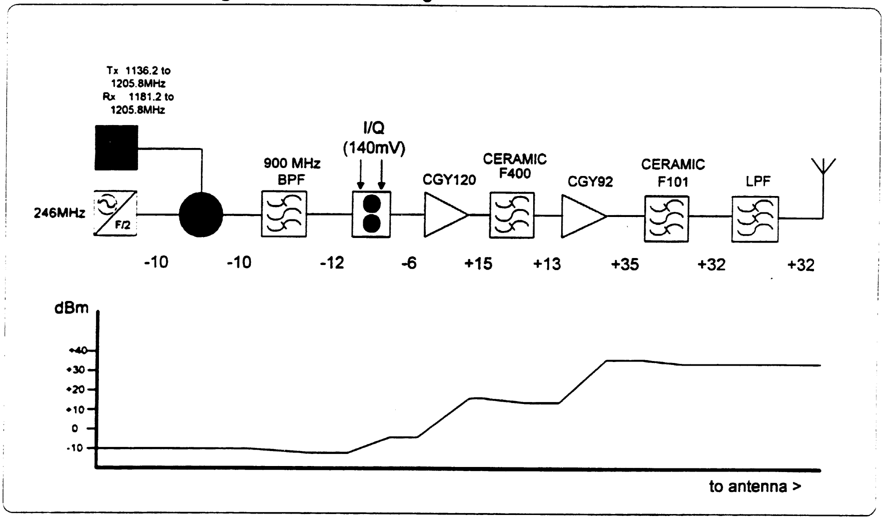
There is nothing that post mixer filtering can help with as the signal is generated prior to IF selection. Furthermore, there is no possibility that RF filtering can help as the signals could be separated from the carrier by 2 times the channel spacing (i.e. 400kHz).

The main factor that determines the performance in this area except for the specification is the LNA gain, the mixer third order intercept point and to a small of degree the third order intercept point of the LNA.

2.5 Transmitter signal path

The transmit signal path has a simple gain distribution and the signal levels are as shown in

Figure 2 - 8: Transmit signal levels vs. transmit blocks



The gain of the transmit control loop in this case is set to the maximum value, useful control of the power level at this stage is approximately 50dB.

2.6 Transmit power ramping

Transmit power ramping for the handset is very important to maintain low spurious due to the AM emissions in the channels close to the carrier. The GSM specification 11-10 recognises the importance in doing this and the specification is difficult to meet. The emissions are minimised by careful selection of the ramping characteristics which in turn also has to meet the template defined by GSM 05.05.

2.7 Transmit linearity and Spectral spreading

Linearity of the transmit circuitry is a function of the modulator and the power amplifier. Non-linearity's within the modulator will cause the generation of unwanted spurii which in turn indicate that the signal has become of non-constant envelope. Subsequent non-linear amplification will cause intermodulation and the signal will undergo spectral spreading in the frequency domain. The modulation mask for GSM is difficult to meet, hence particular attention must be paid to the signal levels within the modulator and power amplifier. The signal level (baseband I & Q) at the modulator input is very important as overload of the modulator is easily done and cannot be rectified easily.

The modulator output can be tested through the transmission of an FCB (Frequency Correction Burst - a function normally associated with a basestation). Typical performance of the modulator in FCB mode is seen in Figure 2 - 9 with a baseband modulating voltage of 200mV.

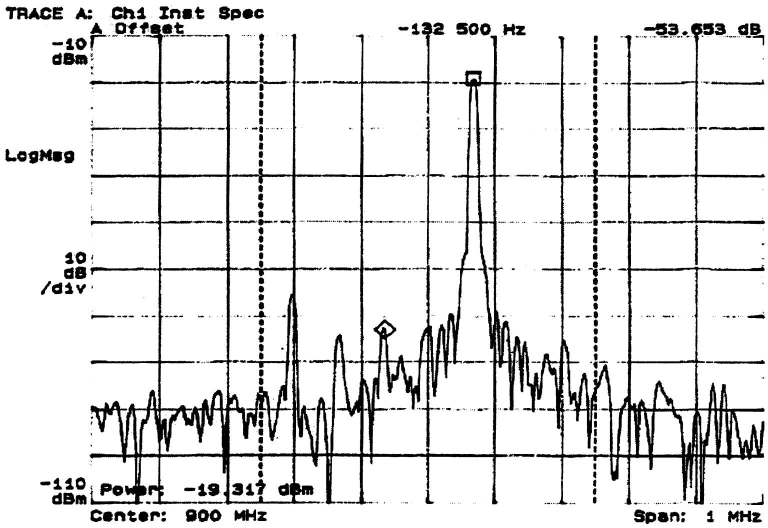


Figure 2 - 9: Modulator output spectrum (200mVpp differential IQ amplitude)

Increasing the modulating voltage to 400mV gives rise to higher order products as see in Figure 2- 10.

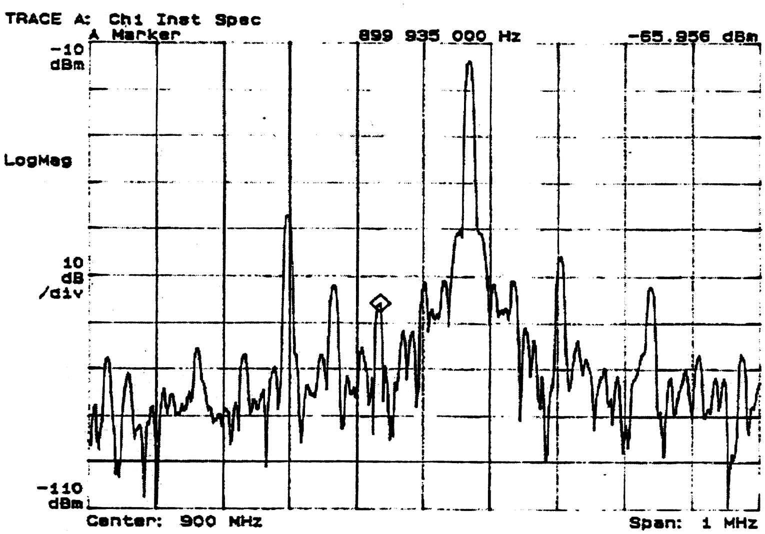


Figure 2 - 10: Modulator output spectrum (400mVpp differential IQ amplitude)

3. CIRCUIT BLOCKS

3.1 Overview

Please refer to RF Block diagram Figure 1 - 3 and circuit schematics in Appendix B.

3.2 Voltage Controlled Oscillators

The 1LO and 2LO synthesisers use voltage controlled oscillators implemented as balanced microstrip structures. Active devices are provided within the RF IC's for this purpose. The two oscillators are similar in design, being essentially of Hartley type, utilising a tapped inductance to obtain feedback.

The 1LO oscillator must be tuneable from 1.13 GHz to 1.21 GHz, with a tuning voltage range of ~0.5 to ~3.1V. For this reason the additional tuning range available from the Hartley configuration is a considerable advantage over more traditional Colpitts circuits, thus allowing 'headroom' for tolerancing, so the typical GoldSMith LO1 tuning range is 1.08 Ghz to 1.25 Ghz. The 2LO is required to operate at a fixed frequency, but here, the balanced Hartley is a simple and compact choice, so it is easy to achieve a frequency tuning range of +/-5% for the LO2.

The 1LO oscillator requires good phase noise performance. 1LO phase noise will contribute to receive band noise during transmitter operation, and is the primary cause of reciprocal mixing during receiver operation. The balanced Hartley oscillator configuration used provides certain advantages in this area due to inherent cancellation of some types of noise contribution. Varactor tuning diodes will reduce resonator Q, and thus degrade the phase noise performance. They will also actually introduce additional noise if care is not taken over the method of biasing. The varactor tuning diodes here are biased at the DC ground side using stripline, which has a very low impedance to low frequencies (the frequency of interest being around 0.1 to 30 MHz) and so reduces their noise contribution. The 2LO uses resistive biasing of the varactor diodes, which is acceptable due to its less stringent phase noise requirement. The 2LO contributes to the RF frequency only after division by 2, and so its noise contribution for both transmitter and receiver operation is reduced by 6dB.

The resonator centre tap is used as a DC bias point, and the varactor diode centre connection is used to apply the tuning voltage. Both of these points may be described as 'virtual grounds', having little or no RF voltage present. For this reason RF decoupling is not required, and additionally, the absence of decoupling at the resonator centre tap is thought to improve phase noise.

3.2.2 1LO VCO Measured Phase Noise

Below 3 MHz offset a direct measurement using HP 8590 spectrum analyser, was done, however above 3 MHz the carrier was notched out by a filter. This explains the phase noise step between 2 and 3 MHz.

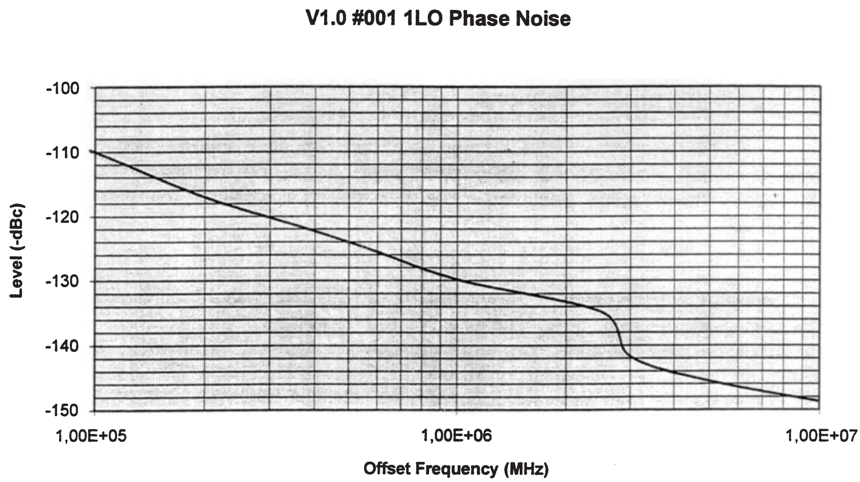
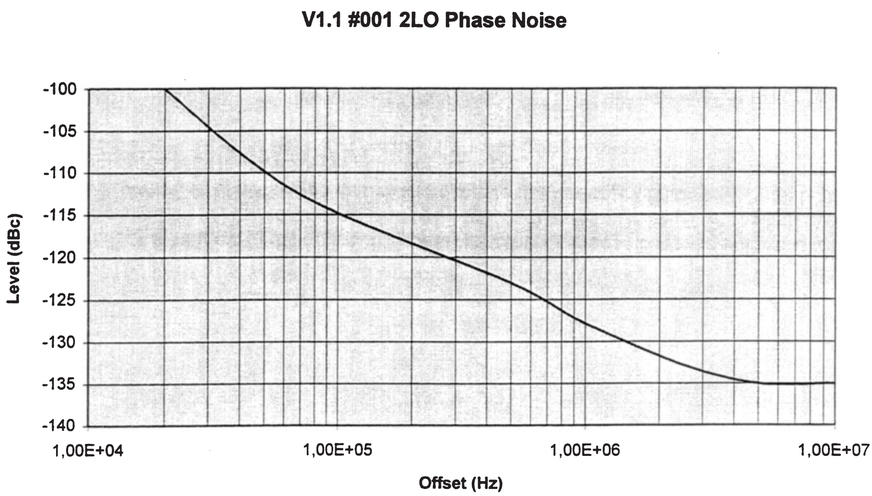


Figure 3 - 1: Measured Phase Noise of LO1

3.2.4 2LO VCO Measured Phase Noise

This Phase Noise is directly measured using HP8590 spectrum analyser.



3.2.5 Tolerancing

Investigation of the sensitivity of circuit parameters and component values on the 1LO highlighted the varactor diode, and C211 (varactor padding capacitor) as the worst contributions to a yield analysis. For this reason, C211 has been specified as an AVX ACCU-F type, with a tolerance of 0.05 pF. The tolerance of the varactor diode could be improved by specifying selected parts. This investigation produced the surprising result that PCB dielectric constant has virtually no effect on oscillator frequency. This is a lucky coincidence of the fact that εr variation causes an equal and opposite effect on account of characteristic impedance and guided wavelength, for the particular physical microstrip parameters in use.

3.2.6 1LO Voltage Regulator

The 1LO oscillator has its own dedicated voltage regulator. The voltage reference and control amplifier are integrated within U201, but an external series pass transistor is required.. Since the regulated voltage is 3.3V nominal and the requirement to operate at 3.6V (for a 3 cell battery) is an important consideration. For this reason an optimised series pass device is required. The device chosen is a fifth generation MOSFET from International Rectifier, the IRLML6302. It has a low on resistance of just 0.25 ohm, a threshold voltage of 1.4V maximum, and is packaged as an SOT23. It can be driven adequately by the control amplifier without additional circuitry, and provides superior performance. The modified circuit achieves a drop out voltage of just 30mV.

3.3 Synthesisers

3.3.1 1LO

The 1LO synthesiser is comprised of the 1LO VCO described above, the controller chip U202, loop filter, and dual modulus pre-scaler (integrated within U201). The reference input, provided by VCTCXO U200, is at 13 MHz. This is fed to the controller chip via the 13 MHz distribution amplifier, where it is divided by a programmable 'R' divider to 200 KHz and applied to the phase comparator. The 1LO VCO is buffered and fed to the dual-modulus prescaler, then transferred to U202 and further divided by the main programmable divider before being applied to the phase comparator. The effective 'N' division ratio is calculated using:

$$N = M \times P + A \qquad (2)$$

Where 'P' is the normal division ratio of the pre-scaler (64), 'A' is the controller counter used to toggle the pre-scaler ratio, and 'M' is the main divider ratio.

The passive loop filter is a lead-lag design with an additional pole to suppress reference frequency spurii. The component values are calculated using Siemens application software, with a target loop ω_n of 10 kHz. The capacitors used in the loop filter are of C0G dielectric, which is known to have a superior transient settling characteristic compared to X7R.

All counter values are programmed via the serial data interface.

3.3.2 1LO PLL, Locked, Close to Carrier Phase Noise Profile

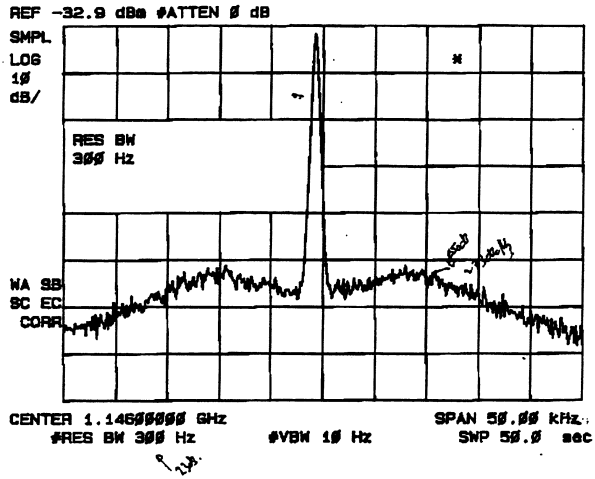


Figure 3 - 2: LO1 Close to carrier Phase Noise Profile measured with HP8590

3.3.3 1LO Lock Transient, Receive to Tansmit

This is a measurement for a frequency step of LO1 from receive to transmit.
It is frequency deviation vs. time measurement.

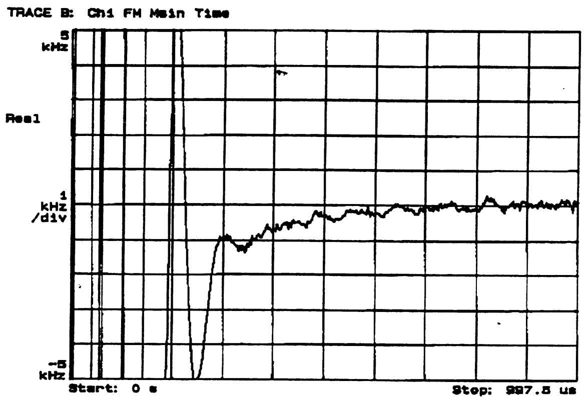


Figure 3 - 5: 1LO Lock in behaviour

3.3.4 1LO Lock Transient, Transmit to Receive

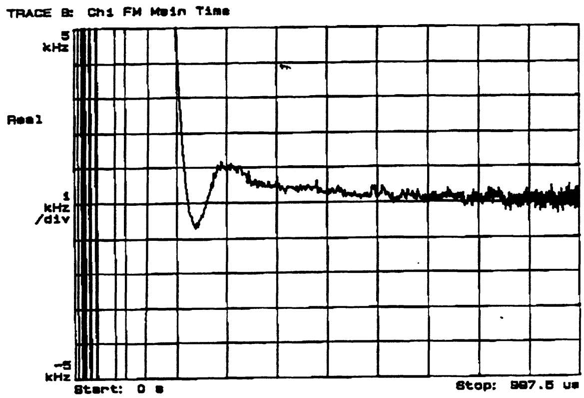


Figure 3 - 5: 1LO Lock In transient from transmit to receive

3.3.5 1LO TXONPA Disturbance, Frequency Effect

To investigate coupling effects of LO1 from supply or radiation, the PA was turned on to full power and off again, the frequency deviation vs. time was measured.

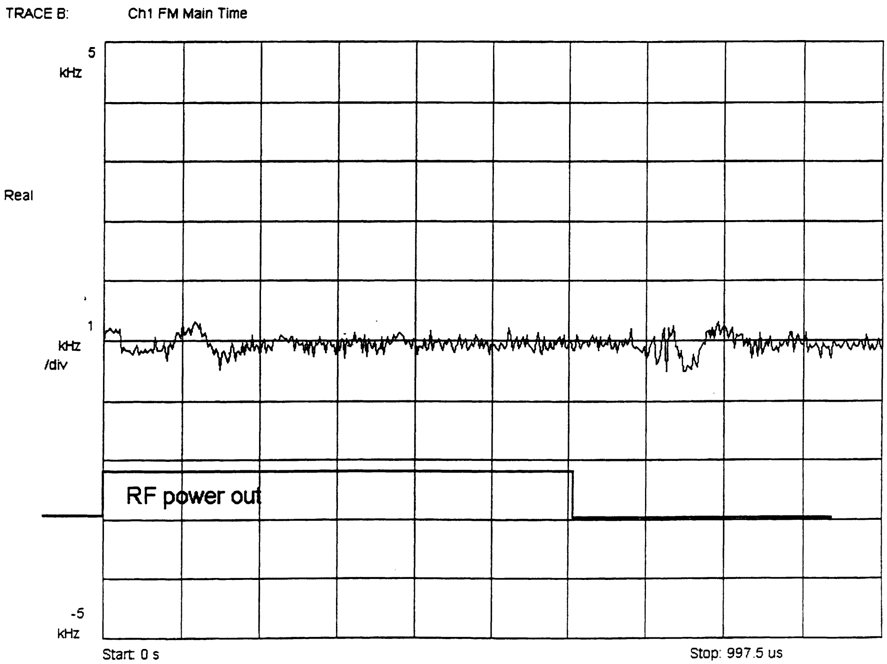


Figure 3 - 6: 1LO TXONPA disturbance in frequency domain

3.3.6 1LO TXONPA Disturbance, Phase effect

To investigate coupling effects of LO1 from supply or radiation, the PA was turned on to full power and off again, the phase deviation vs. time was measured.

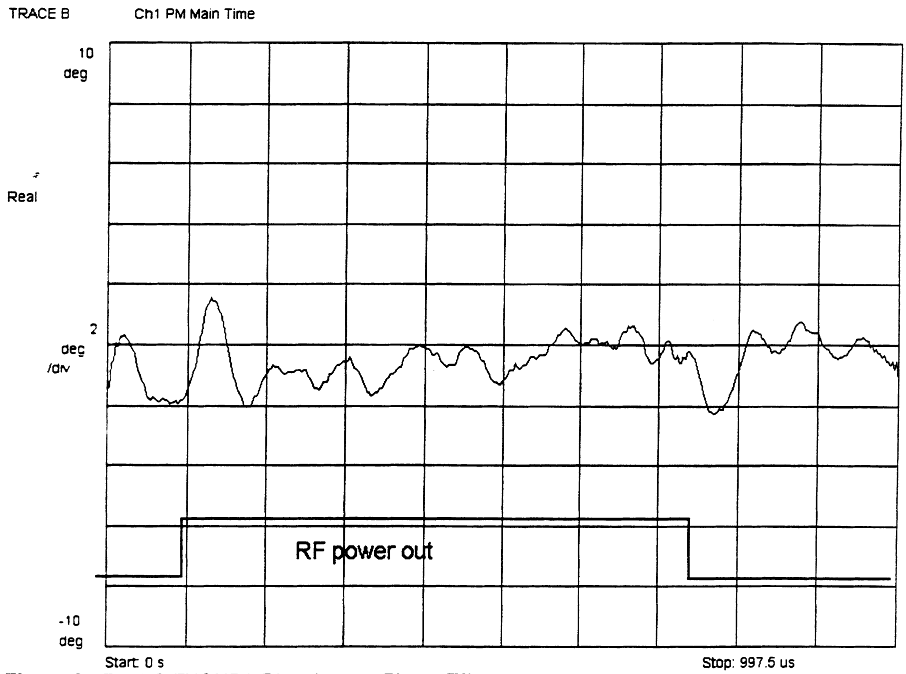


Figure 3 - 7: 1LO TXONPA Disturbance, Phase Effect

***Note** - the timing of the burst is not exactly that of a typical normal burst, this is as a result of the test method.*

3.3.7 2LO

The 2LO is a fixed frequency synthesiser, operating at 492 MHz. It is comprised of the 2LO VCO and buffer within U300, dividers and charge pump within U201, and a passive loop filter. The VCO is buffered then fed from U300 to U201 via a balance feeder where a fixed ratio divider of modulo 492 feeds the resulting 1 MHz signal to the phase comparator. The reference input at 13 MHz is applied to U201 where a modulo 13 divider feeds the resulting 1 MHz to the phase comparator. The passive lead-lag loop filter has an extra pole to suppress reference frequency spurii. Component values for the loop filter were calculated using Siemens application software, with a target loop ω_n of 20 kHz. As for the 1LO, C0G dielectric capacitors are specified for the loop filter components. This is known to improve the transient settling characteristic as compared to X7R types, although this is less critical than for the 1LO since the 2LO is faster locking anyway.

3.3.8 2LO, Locked, Close To Carrier Phase Noise

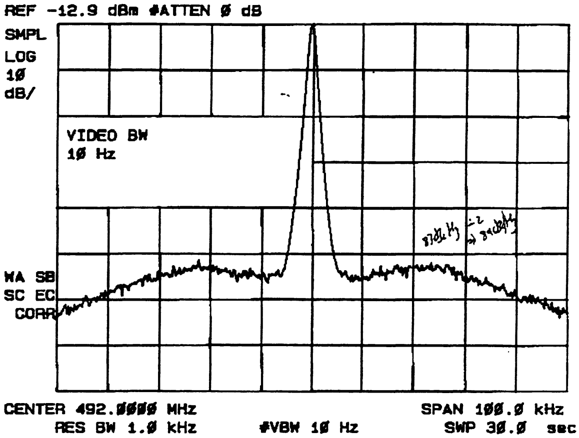


Figure 3 - 8: 2LO Locked Close to Carrier Phase Noise measured with HP8590

3.3.9 2LO TXONPA Disturbance, Frequency Effect

To investigate coupling effects of LO2 from supply or radiation, the PA was turned on to full power of 2W and turned off again, the frequency deviation vs. time was measured.
Date: 06/03/96 Time: 10:52

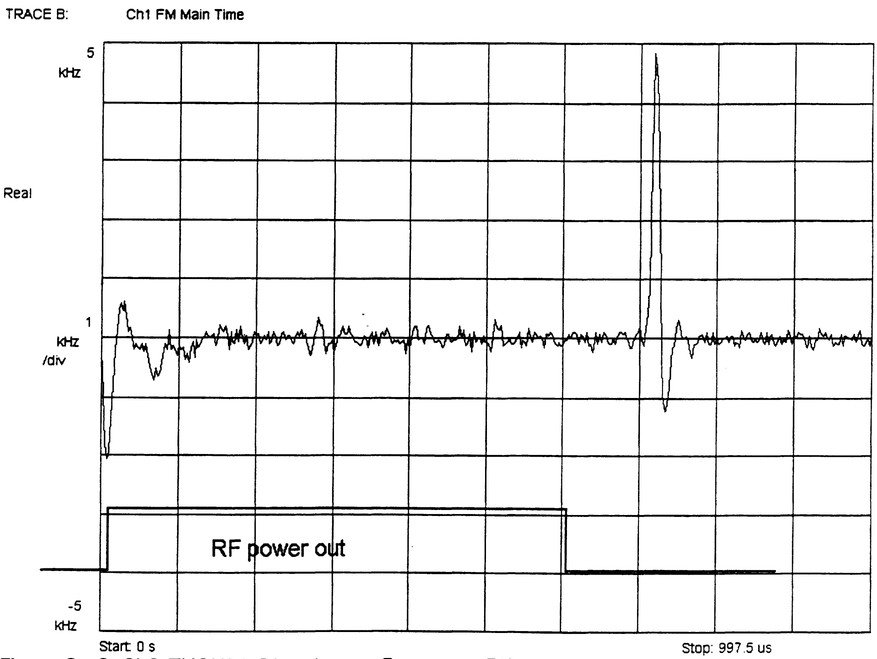


Figure 3 - 9: 2LO TXONPA Disturbance, Frequency Effect

3.3.10 2LO TXONPA Disturbance (Phase effect)

To investigate coupling effects of LO2 from supply or radiation, the PA was turned on to full power of 2W and turned off again, the phase deviation vs. time was measured.

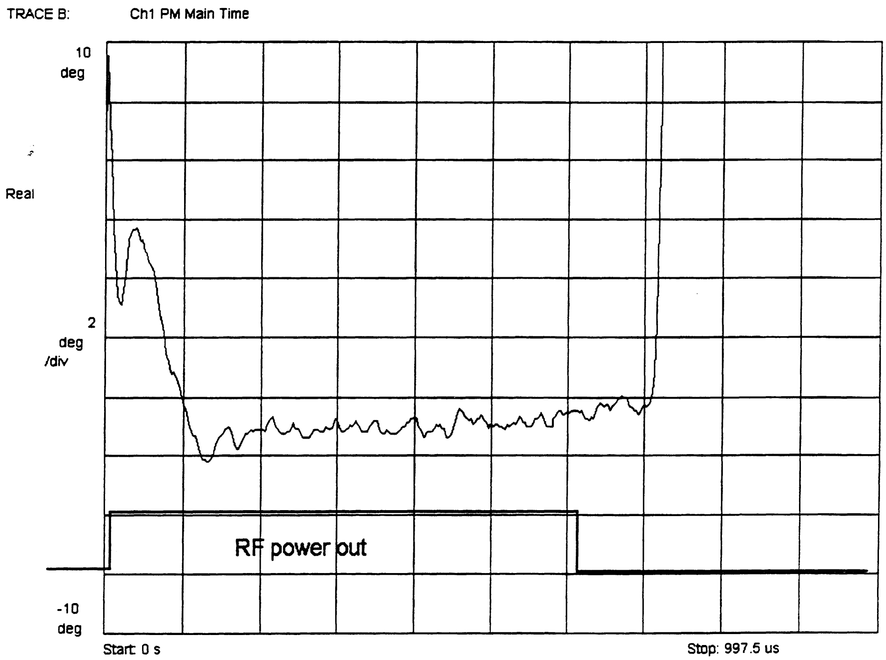


Figure 3 - 10: 2LO TXONPA Disturbance, Phase Effect

3.4 Transmitter Base-band Filter

The modulator base-band inputs PMB2240 (U201, I/IX Q/QX) are filtered by a single pole RC filter at each pin. This filtering is important, as any unwanted signals entering at this point will modulate the carrier, and cannot subsequently be removed. However, the filtering must allow the base-band modulation through with no appreciable effect, the bandwidth of these filters is therefore 3.6 MHz.

3.5 Transmitter Up-conversion Filter

3.5.1 Printed Filters

The GoldSMith Board utilises a printed stripline filter between the transmit mixer (MO/MOX) and the modulator LO input (LO/LOX). This filter is required to pass the transmit frequency band of 890 MHz to 915 MHz, while attenuating the 1LO frequency range of 1136 MHz to 1161 MHz. Pass-band insertion loss of less than 10 dB is desired, with >55 dB stop-band rejection. The stop-band rejection requirement was determined experimentally, and is known to strongly affect modulation accuracy. The attenuation achieved on the GoldSMith Board is >65 dB with <4 dB insertion loss..

3.6 Printed Baluns

Baluns perform the dual task of impedance matching and balanced to unbalanced conversion. They have been implemented using low cost printed stripline structures. This technique allows baluns to be designed over a wide range of impedance ratios, although the bandwidth is limited. The balun at E/EX may be viewed as coupled resonators, where the coupling is mixed mode. The degree of coupling, and the asymmetry of capacitor values at the unbalanced side are factors used to control the impedance ratio. The overall length of the coupled section is not particularly critical, but will influence the bandwidth since a loading capacitor is used at the balanced side to tune the line to resonance. A shorter line, and hence lower inductance, implies higher 'Q' and less bandwidth.

3.6.1 Printed Balun at Transmitter E/EX

It provides a match between the ~1kohm balanced source impedance PMB2240 (U201, E/EX pins) and the 50 ohm unbalanced load for the SAW filter B4632 (F200). This structure is also used to feed DC bias at the centre of the primary coupled line to the PMB2240 (U201) E/EX outputs . Gain variation is approximately 1 dB across the transmit band, with >11 dB return loss.

. The parallel resisitor across E/EX R221 sets the maximum open collector load impedance and improves the impedance matching for the SAW filter.

3.6.2 Measured Input Return Loss of E/EX Balun

This measurement of return loss is done from the output of the balun, where it is connected to the SAW filter B4632 (F200).

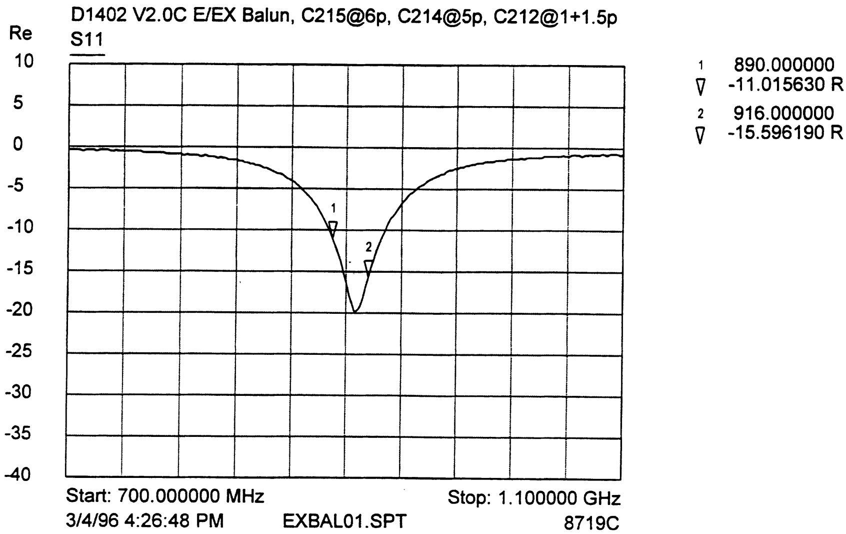


Figure 3 - 11: Input return loss at the output of E/EX strip line balun.

3.6.3 Measured Amplitude Ripple of E/EX Balun

This measurement of amplitude ripple is done in a Peak Hold measurement with the HP 8595E spectrum analyser, while tuning the output frequency.

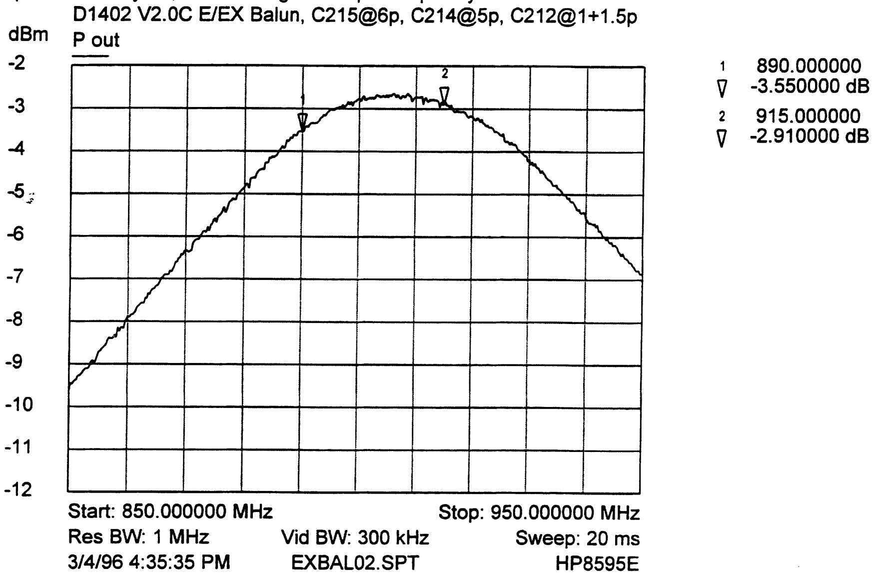


Figure 3 - 12: Amplitude ripple of E/EX balun

3.6.4 Printed Balun at Receiver (SI/SIX)

The SI/SIX balun required a fundamentally different approach due to the much lower impedance levels present. This balun may be viewed simply as a power divider with phase shifters at the outputs. One output port has a phase lead on account of capacitive coupling, the other has a considerable phase lag caused by a loaded stripline resonator. The net effect is that approximately 180 degrees is observed between the two outputs. The input impedance is brought close to 50 ohms by choosing appropriate circuit values.

Used on the GoldSMith this balun provides a match from a 50 ohm unbalanced SAW B4633 (F300) to 30 ohm balanced load at PMB2405 SI/SIX pins (U300).

3.6.5 Measured Performance of SI/SIX Balun, in Circuit

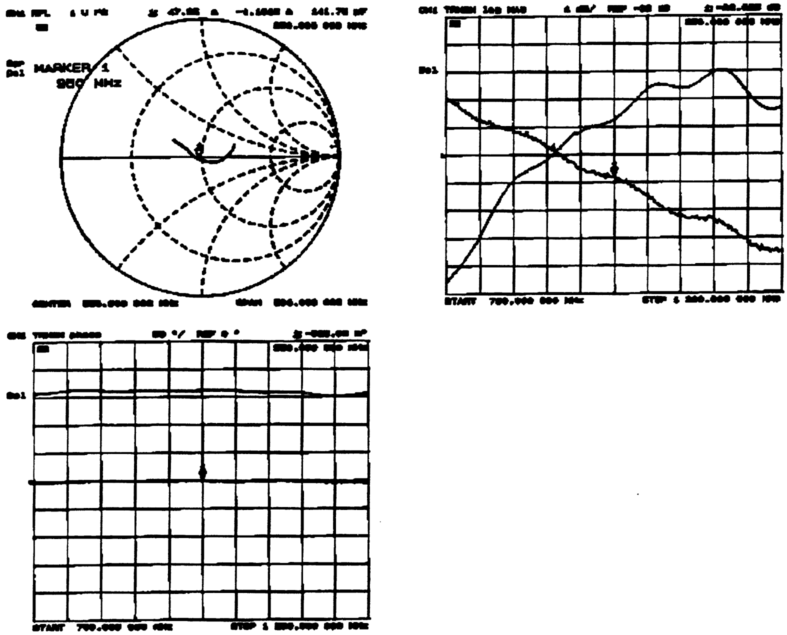


Figure 3 - 13: Measured Performance of SI/SIX balun.

3.7 RF SAW Filters

The transmitter was originally designed with a SAW filter B4632 at the output of the modulator (F200). During testing of the transmitter it has been observed that the presence of this filter makes little difference to the observed spectral purity, and it's insertion loss (2-3dB) is a disadvantage. Although the mounting pads have been left on the PCB, the filter is not fitted on the final version of GoldSMith boards, and therefore the input and output pads are linked with a wire.

The receiver utilises a SAW filter B4633 of a very similar type after the LNA (F300), which is required in order to achieve the required blocking performance.

Both are 3mm S+M type with 50 ohm input and output impedances. As is usual with SAW filters, matching is critical to performance. Severe degradation of the response will result from poor matching.

3.7.1 RX RF SAW Filter B4633 (F300)

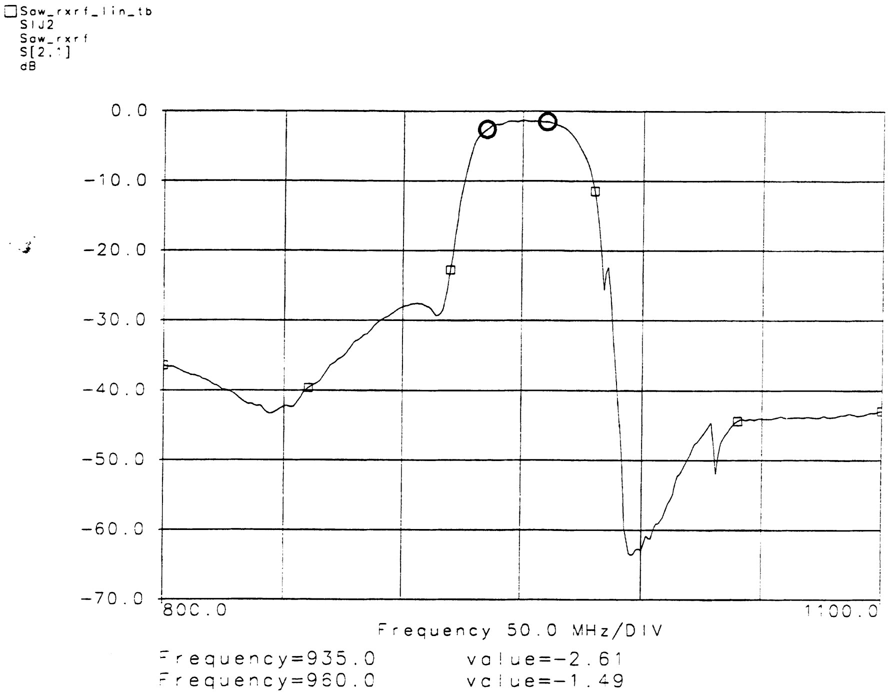


Figure 3 - 14: Measured transfer function of RX SAW B4633 (F300)

3.8 13MHz Distribution Amplifier

The distribution amplifier for the 13 MHz reference has been designed to achieve maximum isolation from input to output, and from output to output. The reference is used for both 1LO and 2LO synthesisers, the negative/positive rail converter, and the base-band processor section. Any reference modulation is multiplied particularly by the 1LO PLL and added directly to the RF output of the radio. This influence is critical on account of the very stringent phase accuracy required of the radio, and requires that the 13 MHz reference is very stable.

Cascode output stages have been utilised to obtain high isolation at each output, and implemented using double transistors in the highly compact SOT 363 package. This is combined with a dc coupled approach to the overall design, and a resulting low passive component count. Despite the apparent complexity of the distribution amplifier schematic, it occupies a minimal area of the PCB. Future optimisation of this area could result in an further integration.

3.9 LNA

The LNA active device is integrated within PMB2405 (U300), but requires external matching and bias feed components. The gain is switchable under software control, the high gain state being 23 dB. The actual noise figure is about 5 dB, but no further attempt was made in the current version to optimise matching for better noise figure. Bandwidth is approximately 170 MHz, or 18% of centre frequency.

3.9.1 Measured Transfer Function of LNA

This tranfer function was measured using a network analyser.

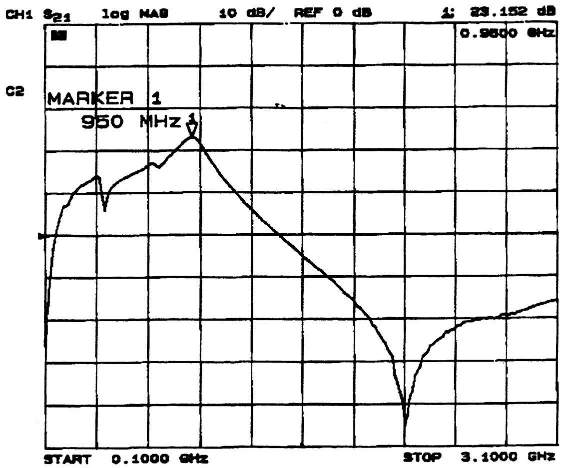


Figure 3 - 15: LNA tranfer fuction (S21)

3.9.2 Measured LNA Input Matching (S11)

This impedance was measured using a network analyser.

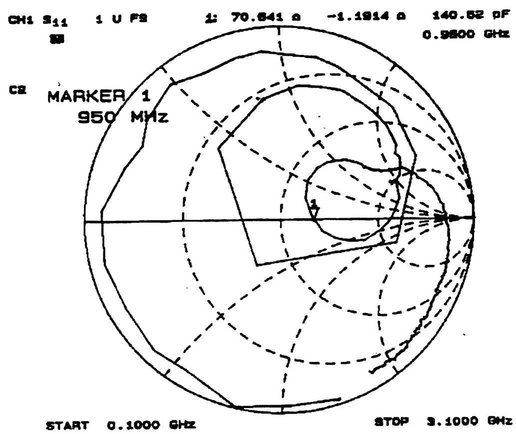


Figure 3 - 16: Input impedance of LNA

3.9.3 Output Matching of LNA (S22)

This impedance was measured using a network analyser.

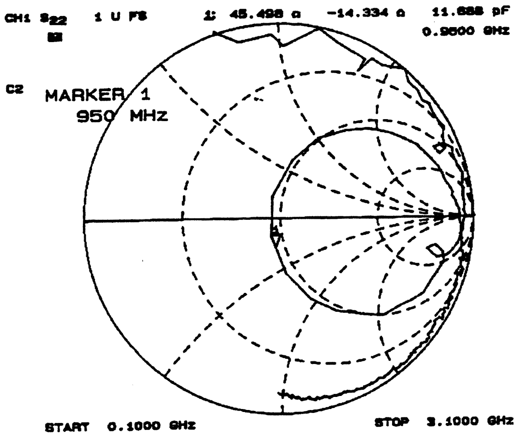


Figure 3 - 17: Output impedance of LNA

3.10 Receiver IF Filter

The receive IF filter is a SAW device of approximately 180 kHz bandwidth. As is usual with SAW devices, input and output terminating impedances are critical to filter performance. Severe degradation of both amplitude and phase response will occur if the matching is less than optimum. The correct impedances were established by measurement and computer simulation, then component values were subsequently optimised during test.

The S+M filter B4579[1], here used, is designed for balanced application, with input and output impedances of approximately 400 ohms. At the input side, this must be matched to the mixer output MO/MOX of PMB2405 (U300) of approximately 2K ohms. At the output side, it must be matched to the IF amplifier input IF/IFX (U300) at 20 ohms. Single section lumped matching networks are used at both sides in the present design. At the input side, the high impedance level requires the use of high 'Q' inductors, and therefore a Coilcraft wound type is specified. The circuit must also allow a DC feed to be applied to the PMB2405 (U300) outputs and is arranged accordingly. At the output side, the lower impedance level does not require the use of a high 'Q' inductor. At both sides however, the impedance match ratio is large, and the single section circuit provides a rather limited bandwidth. This could represent a component tolerancing issue for high volume manufacturing. If so, a wider bandwidth could be provided by a circuit using 2 matching sections at each side.

Note:
[1] From SIEMENS MATSUSHITA are further 246 MHz IF SAW filters with different I/O impedances and different pass band characteristics available. Please call your local SIEMENS office for futher information.

3.10.1 Measured IF Filter Performance

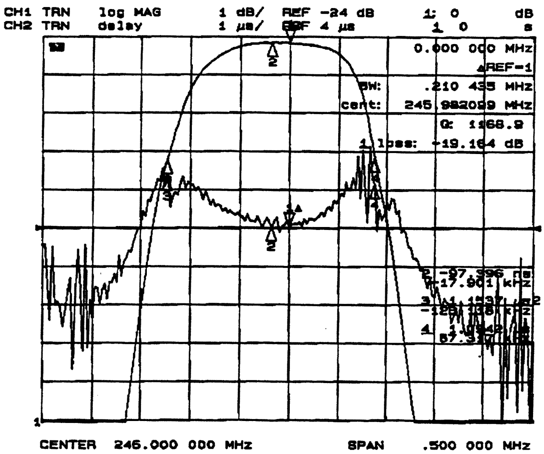


Figure 3 -18: IF SAW filter transfer funtion and group delay.(Matched)

3.11 Receiver Base Band Filter

The receiver output is balanced quadrature base-band. Filtering is provided to enhance the adjacent channel filtering provided by the receive IF SAW. The 2 pole filters utilise balanced output op-amps within PMB2405 (U300), provided for the purpose. The current design has a 3 dB bandwidth of 91 kHz. Optimisation of this area may be required in the future.

3.11.1 Schematic for Simulation of Receiver Base Band Filter

The following schematic represents either the I or Q channel. The differential output op-amp has been represented by two standard op-amps, with one providing an inverting function. The resistor values set the required voltage gain to 30 dB, and the capacitors set the filter roll - off. In particular, C3 below can be used to lift the response at the corner frequency of the filter, and has been chosen to give a good pass-band flatness.

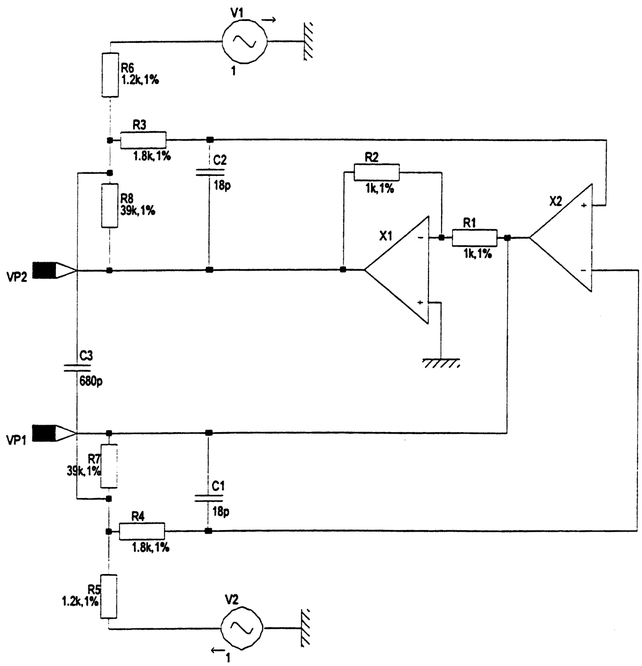


Figure 3 - 19: Schematic of simulated RX baseband filter

3.11.2 Simulated Performance

The circuit given above has the following amplitude and phase response. Although the amplitude response is very flat, the baseband equaliser will have to correct for the phase response.

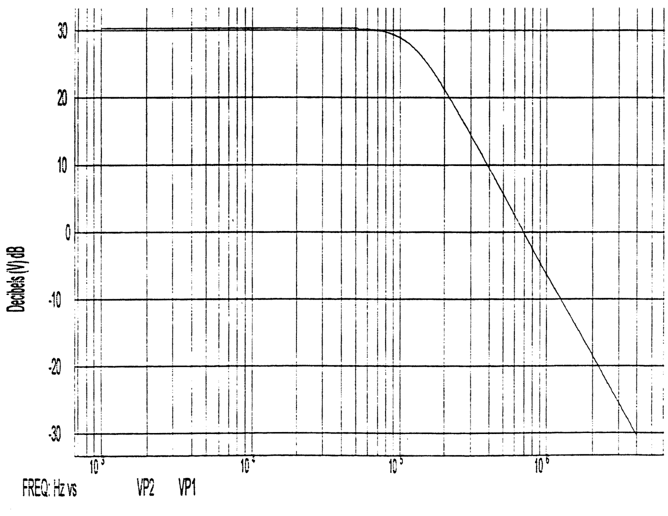


Figure 3 - 20: Amplitude response of RX baseband filter

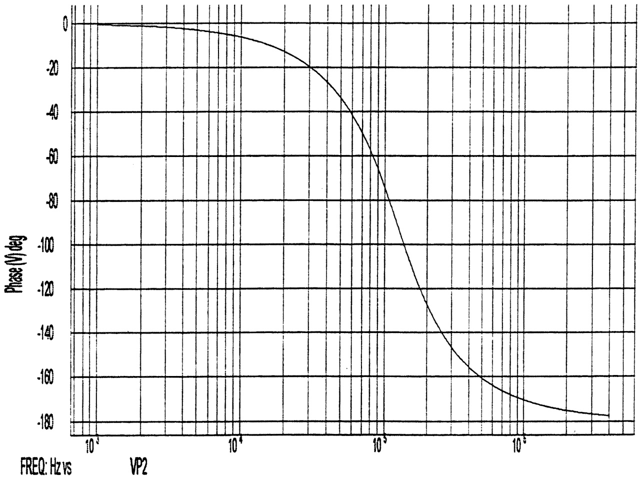


Figure 3 - 21: Phase response of simulated baseband filter

3.12 Duplexer

The duplexer has been constructed from standard ceramic filters since Siemens + Matsushita do not currently produce a ceramic duplexer. The system design requires approximately 20 dB rejection in the receive band when passing signals through the transmit port. The target loss should be better than 3 dB at the band edge, and ideally around 2 dB on the transmit path. In addition, the transmit to receive port isolation needs to be better than 35 dB to avoid receiver damage, and this must account for a range of antenna mismatch conditions. On this design, the solution adopted was to fit a PIN diode switch to the receiver input.

The CGR902,5 (F101) and CGR947,5 (F100) are two - pole filters, which have an acceptable insertion loss for this application, but the receive band rejection is only 8 dB. Because they have a secondary response at 3x and 5x their wanted passband frequencies, a low pass filter has been added to the design to achieve the harmonic and receiver blocking specifications. This filter begins to roll off at 1.5 GHz, with a null at just under 3 GHz.
The receive path from the antenna to the input of the LNA is shown below. The PIN switch has increased the loss by about 1 dB to a total of approximately 4 dB.

3.12.1 Duplex Filter Performance

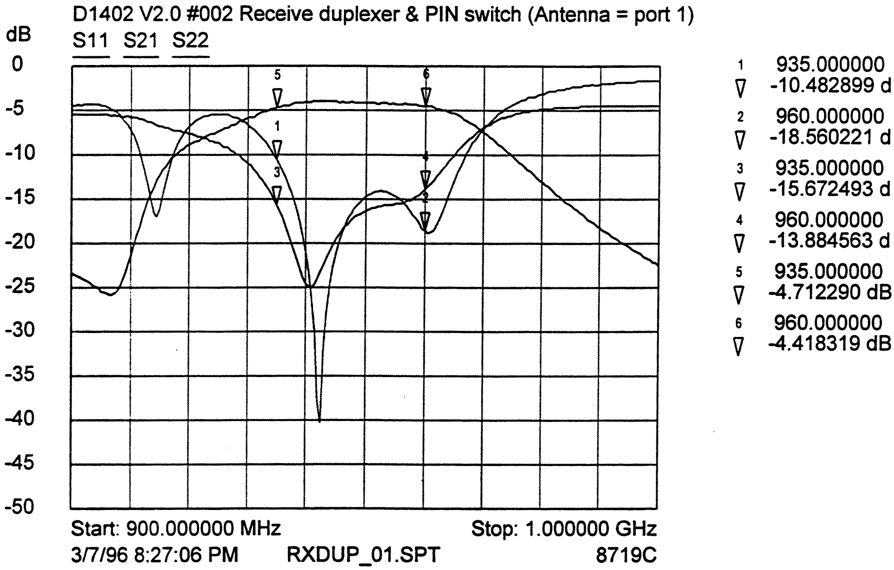


Figure 3 - 23: Receive path of Duplexer

The transmit path has a lower loss than the receive path, but the system requirement is more demanding. The PA produces slightly more than 35 dBm and the target power at the antenna is 33 dBm (31 dBm minimum). The loss at 915 MHz is the worst case position because the duplexer crossover is not particularly sharp. At 915 MHz, maximum output powers in the range 31 to 32 dBm are all that can be achieved due to the duplexer loss.

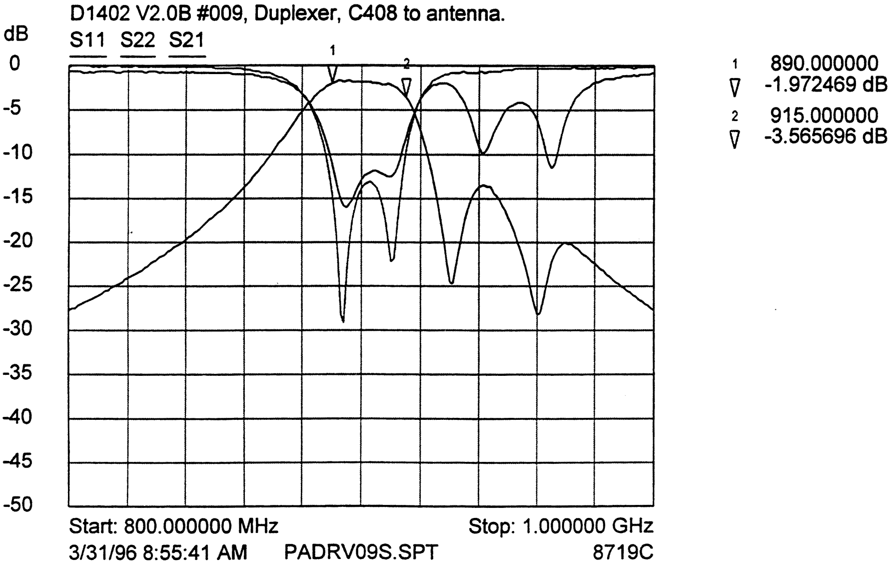


Figure 3 - 24: Transmit path of duplex filter

3.13 PIN Diode Switch

The receive LNA is sensitive to input overload, and may be permanently damaged if the input level exceeds 0 dBm. The duplexer performance is inadequate to ensure attenuation of the transmitter output to this level, and therefore an additional attenuator must be inserted during transmitter operation. This is achieved using a PIN diode switch of combined series/parallel configuration. The switch is activated automatically during transmitter operation by deriving diode bias current from the TXON1 control signal.

It was not possible to use a single diode for this application. A single shunt diode is capable of around 20dB attenuation in a 50 ohm system, but unfortunately the output impedance of the duplexer is quite low, around 3 ohms, and so a shunt diode provides little attenuation. Conversely, a single series diode would be inadequate due to the LNA input impedance being close to 50 ohms.

3.14 Power Amplifier

The power amplifier supplies a minimum of 35 dBm into the duplexer in order to achieve Class 4 output at the antenna port of 33 dBm nominal. At the input, -6 dBm is expected from the PMB2240 (U201) transmit chip. The active devices are a CGY120 driver (U401), followed by a CGY92 PA chip (U400). Both are GaAs FET MMICs. Between the devices is a ceramic filter OF SC-type B69812-N9026-A720, which passes 890 - 915 MHz. This is used in conjunction with the duplexer to suppress spurii produced by the PMB2240 (U201). At the output of the amplifier is a coupler and detector, used to monitor the output power level.

Minimal matching of the devices is required for 50 ohm operation. C407 at the output of the CGY92 (U400), and C419 at the drain of the first stage inside the CGY92 (U401) are the only components used for matching.

3.14.1 Biasing of Power Amplifier

The current drawn by the CGY92 (401) requires that it be operated under pulse conditions to avoid overheating. Since supply voltage must be maximised to the device to achieve maximum power, a very low "on" resistance FET BSP319 (Q400) is used to switch the supply to the PA. This is switched on by a +7V output (PA DC ON) derived from the negative rail circuit. A delay of 50 us is introduced between the -4V rails (VNEG) and PA DC ON (Q102, R117, C120) to ensure that the gates of the RF FETs are sufficiently negative before the drain voltage is applied.

The drain current required by the CGY92 (U401) is internally set when V_{tr} is pulled up to 0 V. This pin is driven from the power level control circuit described below.

The drain current required by the CGY120 (U401) is set by an external bias chip BCR400W (Q401). R415 senses the drain current and sets the gate voltage at pin 1 to achieve 75 mA. The time constants of the biasing resistors and decoupling capacitors are chosen to allow for the interaction which occurs between the $V_{control}$ and V_g pins. Interaction occurs because the FETs inside the CGY120 (U401) are dual gate types, and altering $V_{control}$ also alters the drain current, which causes the BCR400W (Q401) to compensate by altering V_g to maintain the target drain current value. A compromise has been reached here which allows biasing and level control to co-exist without bias circuit or levelling loop oscillation.

3.14.2 Power Control

The output power is adjusted through the $V_{control}$ pin on the CGY120 (U401). Sufficient control range is available from the CGY120 (U401) to set the power level at the antenna between +5 and +33 dBm, and to provide power ramp shaping down to about -5 dBm. Further attenuation is provided by controlling the V_{tr} pin on the CGY92 (U400), enabling the "off" power to be less than the -54 dBm GSM specification. Q402, R418, R406 are used to set the relationship between the CGY92 and CGY120 power control mechanisms. For levelling loop stability, the CGY92 (U400) turns on fully at output powers above -10 dBm, i.e. before the CGY120 (U401) reaches its active region.

3.14.3 Directional Coupler and Detector

The coupler has approximately a 15 dB coupling factor, and is constructed in microstrip. For compactness, it is less than a quarter wavelength long (10 mm length). The coupling flatness slope is corrected using L401 and C409, which also serve to attenuate the third harmonic of the amplifier output. The detector uses a twin - diode arrangement, where one of the diodes in the pack is used for biasing the other to the correct operating point. The arrangement also provides temperature compensation, since the bias point alters with temperature to correct for sensitivity changes. This is helped by the thermal contact between the two diodes provided by the common package.

3.15 Leveling Loop

The levelling loop is a single integrator type, functionally this is represented as in Figure 3 - 25. U402 is a dual op-amp, where the device at pins 1, 2 and 3 is used as an error amplifier and the device at pins 5, 6 and 7 is used as the integrator. The sum of the (negative) detector output and the PACONTROL signal (0 to +2 V) from the baseband appears at the inverting input pin 2 of U402. This is compared with the voltage at pin 3 (7.9 mV) and feedback via R413 creates a virtual earth at the inverting input. Pin 3 is offset from ground to allow the PACONTROL signal to turn off the RF output by applying 0 V even with input offset errors and tolerance considerations. The second op-amp in the package integrates the error voltage produced by the first op-amp. Therefore, the loop settles when the error voltage (pin 1) is zero. The output at pin 7 of U402 drives the $V_{control}$ pin of the CGY120.

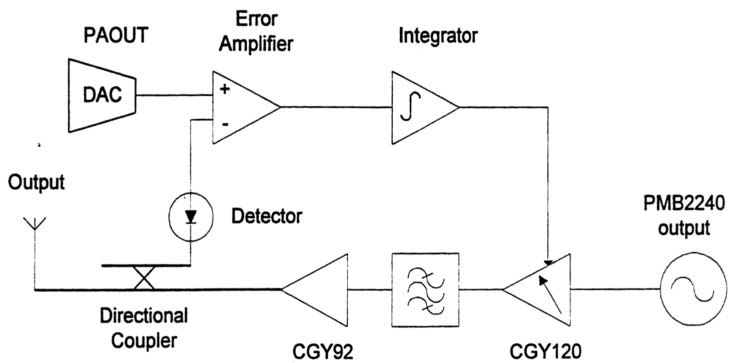


Figure 3 - 25: Block diagram of leveling loop

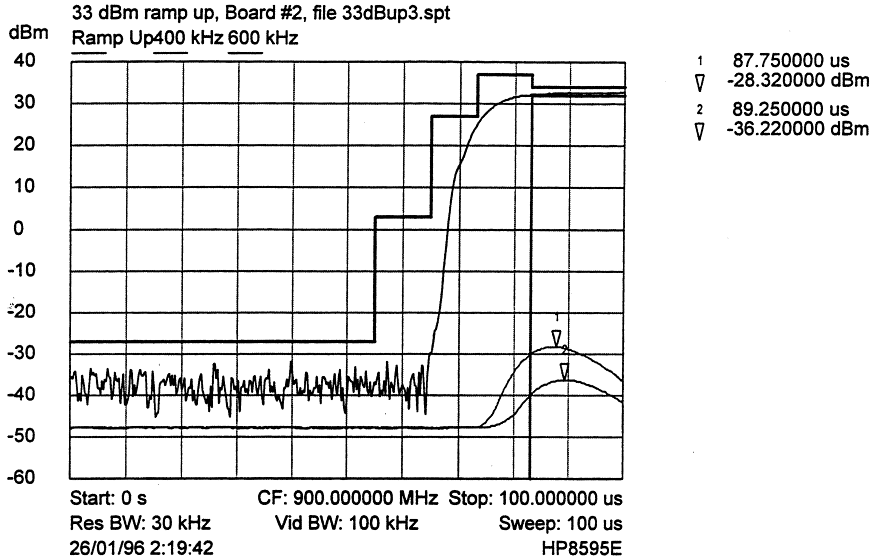


Figure 3 - 26: Rising edge of power ramp

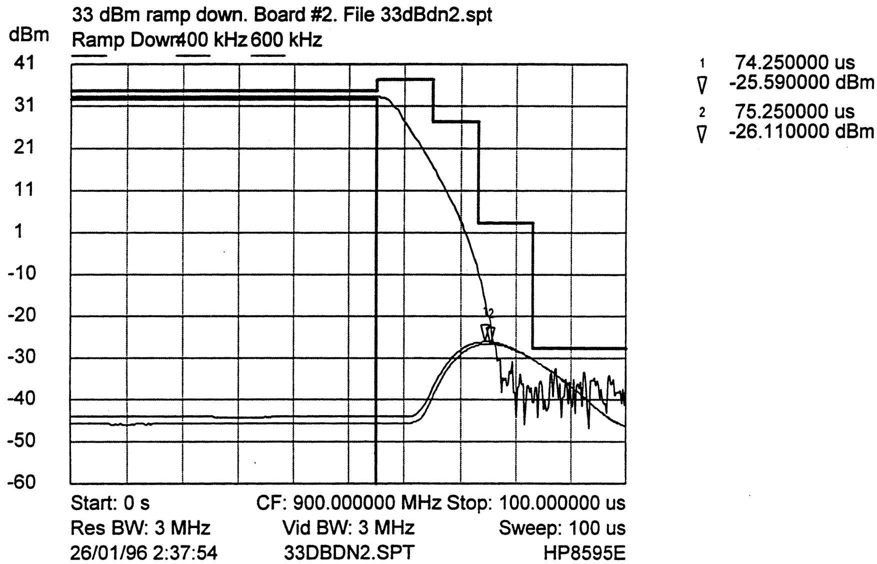


Figure 3 - 27: Falling edge of power burst

Note: The additional graphs in Figure 3 - 26 and 3 - 27 is the transmitted power in 400 and 600kHz offset from the carrier.

3.16 RF Lowpass Filter

The RF low-pass filter is required to reduce the level of harmonics produced in the transmitter power amplifier. It will also improve the blocking performance of the receiver, and so is placed between the antenna socket and duplexer. It has an elliptic response shape, with the notches placed at the transmitter third harmonic frequency. The filter is implemented in microstrip technology, which is both cheap and predictable.

3.16.1 Measured Performance of RF Lowpass Filter

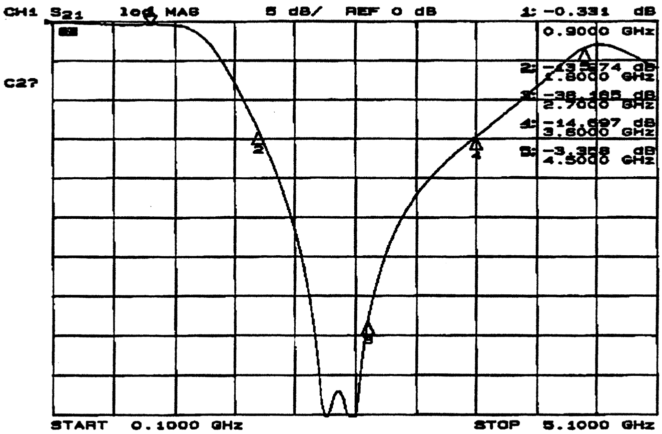


Figure 3 - 28: Measured performance of RF lowpass filter

4. SYSTEM MEASUREMENT

4.1 Transmitter

The transmitter performance on the GoldSMith board falls short of GSM compliance in the following ways:

* The output power at upper edge of transmit frequency band is too low due to the poor duplexer performance

* Transmitted noise in the receive band. This is caused insufficient duplexer attenuation in the the receive band. The noise floor is initially attenuated by band-pass filtering in F400, but intermodulation in the final power amplifier re-generates the noise and subsequently the duplexer must remove it.

Complete system measurements on the reference board are included in Appendix C.

4.2 Receiver

The receiver performance falls short of GSM compliance in the following ways:

* Blocking at 3MHz offset. This is caused by reciprocal mixing due to 1LO phase noise. Improvements to the 1LO oscillator will be required, although it is not known if adequate performance is possible using the on-chip oscillator. An external oscillator module would be an alternative. For this purpose a different version of the PMB2240 is available.

Complete system measurements on the reference board are included in Appendix C.

5. GETTING STARTED

5.1 Overview

The GOLDsmith PCB can be operated in a number of modes, these differing modes are changed depending on the type of measurements to be made. Two set-ups were shown here :-

Static testing

Dynamic testing

5.2 Testing the Board

The board contains sensitive RF circuits. Testing the board requires professional RF knowledge, inproper use may cause hardware damage !

5.3 Static testing

For static testing a PC program is available by request from your local SIEMENS office. (See Appendix A)

It uses the parallel port of a PC and allows static frequency programming and gives control over powerdown functions and PCG programming. **It does not allow any power amplifier measurements !**

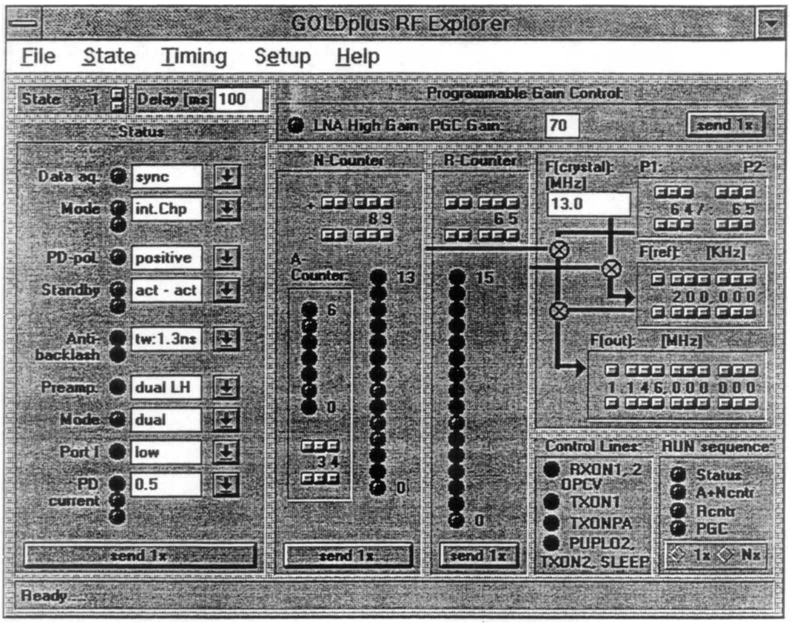


Figure 5 - 4: Screen shot of Goldplus RF Explorer

To use the program please connect the 25 pin D-Sub connector pin with referring GoldSMith connector as in table 5 - 1:

2: Clock	6: Test-Bit 4 (PUPLO2, TXON2, SLEEP)
3: Data	7: Test-Bit 5 (TXONPA)
4: Synth Strobe	8: Test-Bit 6 (TXON1)
5: PGC Strobe	9: Test-Bit 7 (RXON1, RXON2, OPVC)
19: Ground (GND)	

Table 5 - 1: Interconnection Parallel Port to GoldSMith board

Important Notes for static tests:

1 **Be sure using a resistive voltage divider from 5V to 3.6V at the control lines** for not damaging the RF chips operating on 3.6V supply.

2 **Do not try to get the PA to work. It can only operate in a precise switched mode due to its power dissipitation**

3 **The program is for test purpose only, so it will be delivered as it is.**

5.3 Dynamic tests

For dynamic testing, highlighted in this capter, the GOLDplusX board can be ordered supplied with a entry level software and additional documentation.
Please ask your closest SIEMENS office for support. The adress and phone number can be found in Appendix A.

Overview

For ful dynamic tests and operation the GoldSMith Board is connected to the GOLDplusX Board. This combination helps you verifying the functions of GoldSMith board and GOLDplusX board. They can serve as starting point for your own software and hardware development.

The test software runs on the GOLD-µC C166 controller on GOLDplusX board. The software has to be downloaded from PC using a RS232 serial link between GOLDplusX board and the PC. To control the GOLDplusX board and for downloading and running the test software a monitor has to be installed on the PC.

Required materials and equipment

GoldSMith board

GOLDplusX board

An IBM compatible PC running Microsoft Windows 3.1 or Microsoft Windows for Workgroups is required for running the monitor. An RS232 serial interface is required for communication to GOLDplusX board.

The GOLDplusX board comes with GOLDplusX tools from Dr. Kaneff Engineering Consultants. The monitor with this tool package will be used for downloading and running the test software. You will have to install the monitor software on your PC and connect your PC to GOLDplusX board.

The monitor EPROM labeled rdt_mon.hex is already inserted on the shipped version of GOLDplusX board. If not ask your local representitive for an update.

Test software

The test software is written using standard C and has been compiled and located using KEIL professional development kit. To run the tests no compiler or linker/locator is required. For modifications of the test software a suitable C166 development tool from KEIL or BSO/TASKING is required.

Setting up the boards

Make sure to perform the following steps carefully else malfunction may occur, which can lead to the destruction of the GoldSMith power amplifier stage.

GOLDplusX to GoldSMith connector

Make sure to use *only* the 68 pin connector cable delivered with GoldSMith board and *not* the one delivered with GOLDplusX board. The cable delivered with GoldSMith board is marke with RF on one end and with BB on the other end. Make shure to insert the end marked BB into GOLDplusX board and the end marked RF into GoldSMith board.

Power supply

The supply voltage has to be supplied to GoldSMith board only, GOLDplusX board is supplied via the GoldSMith board interface connector. The GOLDplusX board power supply is to be used only in stand-alone mode. GoldSMith board requires a DC supply voltage of 4.8 to 5.0 V.

Before applying power make sure to have set up everything else to avoid destruction of the power amplifier due to overload.

Reference Clock

The reference clock for the GOLDplusX board has to be supplied by GoldSMith board. For this purpose jumper CLKSRC on GOLDplusX board will have to be set as shown below.

Description of tests

Please find the start up tests in the GOLDplusX getting started manual.

6. INTERFACE DEFINITION

6.1 Interface Specification

The interface connector on the RF board to the baseband board is through a Thomas & Betts 311-068072E connector, this has 2 rows of pins with a total of 68 connections and a pitch of 1.27mm. Connection of this to the baseband is through a ribbon cable. The interface connections on this cable are as defined in table 7 - 1.

Name	Description
Vbat	4.8 V supply from RF board to GoldPlus-X board
GND	0 V or signal ground
VTCXO/VCC	3.0 V supply to GAIM, used to derive 13 MHz VTCXO tuning voltage
PUPLO2	Power up LO2 (1 = on)
SLEEP/RF	Power up LO1 (1 = on)
TXON1	Power up Tx modulator and mixer (1 = on)
TXONPA	Power up Power Amplifier (1 = on)
OPVC	Power up Rx baseband op-amps (1 = on)
RXON1	Power up Rx LNA and mixer (1 = on)
RXON2	Power up Rx IF stage (1 = on)
OCE	Sample and hold control (1 = sample)
PGCSTR	Programmable Gain Control strobe (active high)
TXON2/PD	Power up LO2 PLL phase detector and dividers (1 = on)
SYNSTR	LO1 synthesiser strobe (active low)
SYGCDT	synthesiser and gain control serial data
SYGCCL	synthesiser and gain control serial clock
VTCXO	13 MHz 1.1 V pk/pk output to GoldPlus-X baseband board
SLEEP/PR	Power up 1LO synthesiser prescaler (1 = on)
TREF	Voltage reference output to GAIM (1.35 V typical)
AFC	Fine tune input for 13 MHz VTCXO (0 to 3 V)
PAOUT	Tx output power control voltage (0 V = off, 2 V = 33 dBm)
IT	Tx modulator input. (140 mV pk-pk)
IXT	Tx modulator input. (140 mV pk-pk)
QT	Tx modulator input. (140 mV pk-pk)
QXT	Tx modulator input. (140 mV pk-pk)
IR	Rx demodulator output
IXR	Rx demodulator output
QR	Rx demodulator output
QXR	Rx demodulator output
CTRL1	Power up RF board regulators (0 = on)

Table 7 - 1: Interface connections

6.2 GoldSMith RF Board connector Pinouts

The baseband connector SK500 has the format as defined by

Direction	Name	Pin	Pin	Name	Direction
in	*Vbat*	1	2	*Vbat*	in
in	*Vbat*	3	4	*Vbat*	in
out	*VTCXO/VCC*	5	6	*GND*	in/out
in/out	*GND*	7	8	*GND*	in/out
in	*PUPLO2*	9	10	*SLEEP/RF*	in
in	*TXON1*	11	12	*TXONPA*	in
in/out	*GND*	13	14	*OPVC*	in
in	*RXON1*	15	16	*RXON2*	in
in	*OCE*	17	18	*GND*	in/out
in/out	*GND*	19	20	*PGCSTR*	in
in	*TXON2/PD*	21	22	*SYNSTR*	in
in	*SYGCDT*	23	24	*SYGCCL*	in
in/out	*GND*	25	26	*GND*	in/out
in/out	*GND*	27	28	*VTCXO*	out
in	*SLEEP/PR*	29	30	*GND*	in/out
in/out	*GND*	31	32	*TREF*	out
in/out	*GND*	33	34	*GND*	in/out
in	*AFC*	35	36	*PAOUT*	in
in/out	*GND*	37	38	*GND*	in/out
in	*IT*	39	40	*IXT*	in
in	*QT*	41	42	*QXT*	in
in/out	*GND*	43	44	*GND*	in/out
out	*IR*	45	46	*IXR*	out
out	*QR*	47	48	*QXR*	out
in/out	*GND*	49	50	*GND*	in/out
in/out	*GND*	51	52	*no connection*	
in/out	*GND*	53	54	*GND*	in/out
	no connection	55	56	*no connection*	
	no connection	57	58	*no connection*	
	no connection	59	60	*CTRL1*	in
in/out	*GND*	61	62	*GND*	in/out
in/out	*GND*	63	64	*GND*	in/out
in/out	*GND*	65	66	*GND*	in/out
in/out	*GND*	67	68	*GND*	in/out

Figure 6 - 1: Connector Physical Layout

Supply connector BAT500

Pin 1 4.8V supply
Pin 2 0V Ground

During each transmission burst, the power amplifier requires a peak of 2 A from the supply. The average current requirement is approximately 0.5 A. Depending on the transient behaviour of the power supply, it may be necessary to fit a 1000 µF capacitor between the terminals of BAT500.

6.3 Timing of Control signals

6.3.1 Overview

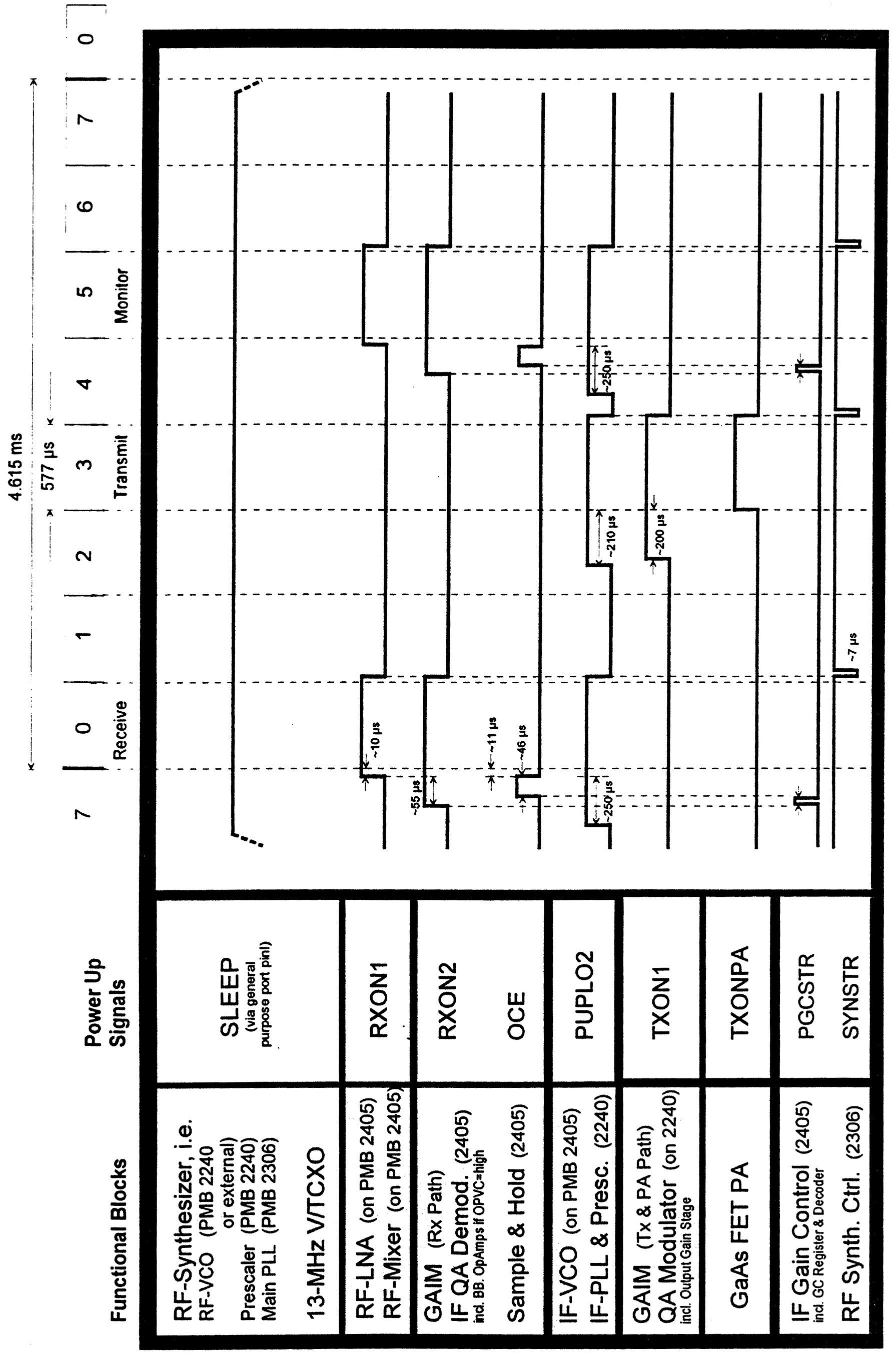


Figure 6 - 2: Timing Diagram (Overview)

6.3.2 Detailed Receive and Transmit Timing

Receive Timing Diagram

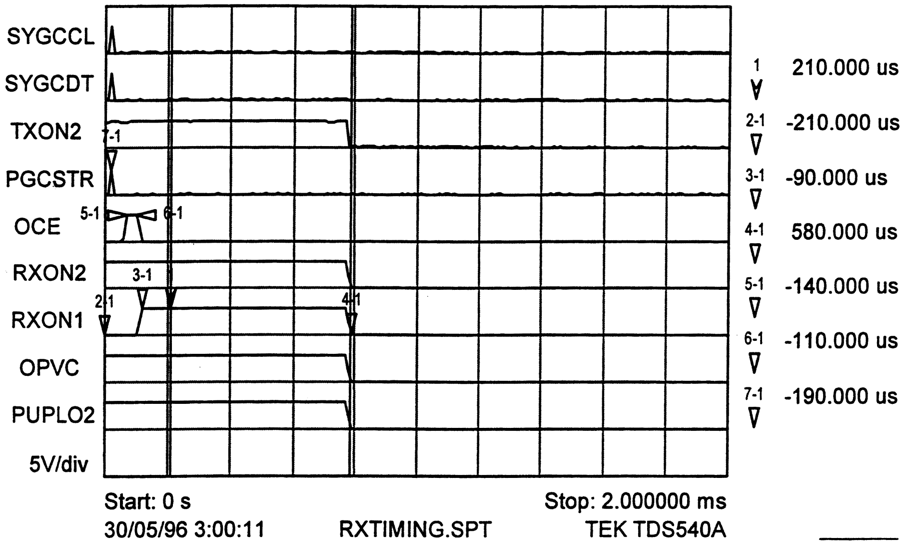


Figure 6 - 3: Detailed receive timing diagram

Transmit Timing Diagram

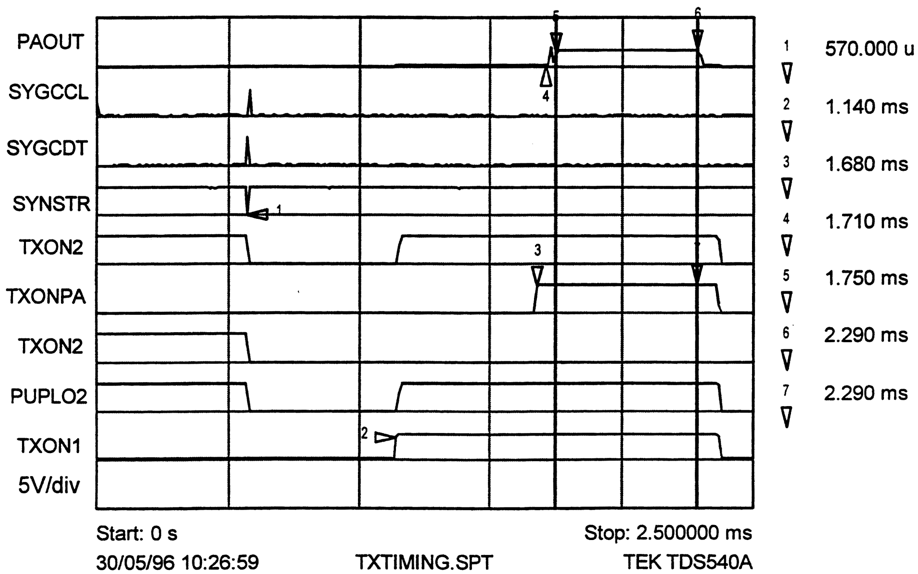


Figure 6 - 4: Detailed transmit timing diagram

7. REFERENCES

(1) Global System for Mobile communications (GSM)
European digital cellular telecommunications system (Phase 2)

from:

ETSI

European Telecommunications Standards Institute

ETSI Secretariat

F-06921 Sophia Antipolis CEDEX - FRANCE

Tel. + 33 92 94 42 00

Fax + 33 93 65 47 16

9. APPENDIX B

9.1 Place plan of GoldSMith Board

Please find it on page 57.

9.2 Mechanical information

Please find it on page 58.

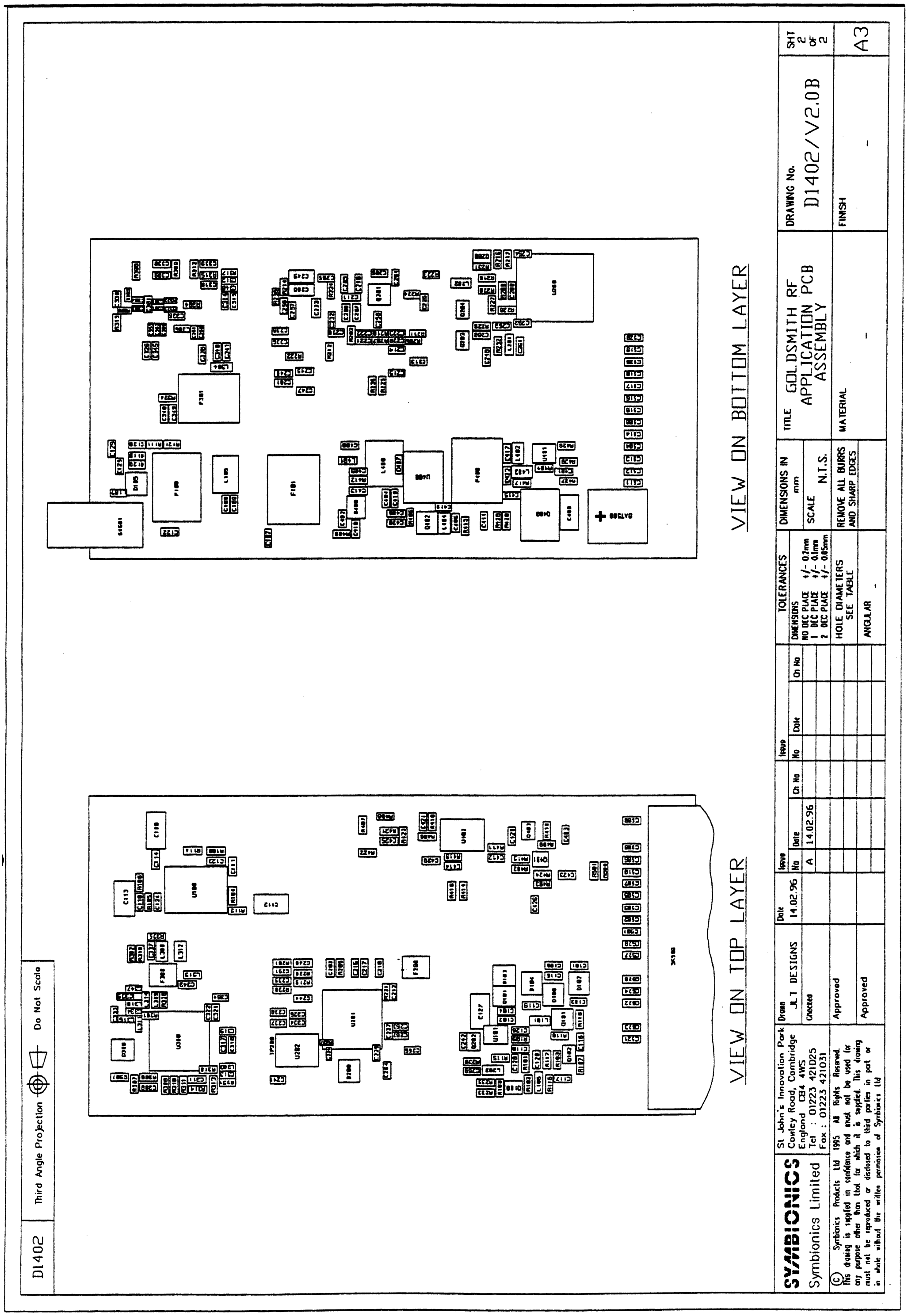
9.3 Bill of Material

Please find it from page 59 on.

9.4 Circuits schematics

Please find 5 pages from page 65

Note: Length of stripline is measured in thou.
1 thou is 0.00254 mm


VIEW ON BOTTOM LAYER
VIEW ON TOP LAYER
D1402
Third Angle Projection
Do Not Scale
SYMBIONICS
Symbionics Limited
St John's Innovation Park
Cowley Road, Cambridge
England CB4 4WS
Tel : 01223 421025
Fax : 01223 421031
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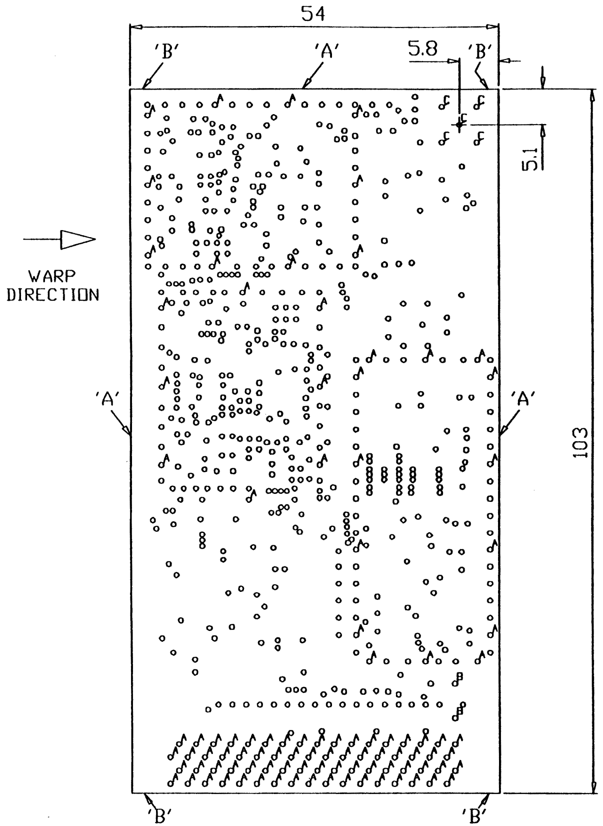
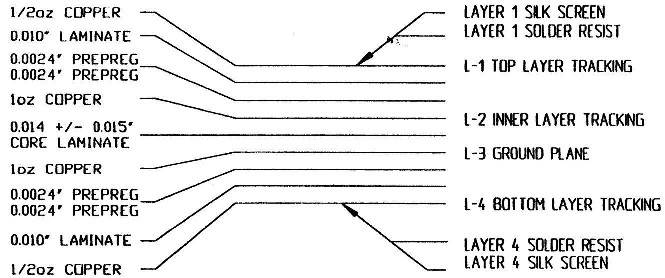
Drawn JLT DESIGNS
Checked
Approved
Approved
Date 14.02.96
Issue No A
Date 14.02.96
TOLERANCES
DIMENSIONS
NO DEC PLACE +/- 0.2mm
1 DEC PLACE +/- 0.1mm
2 DEC PLACE +/- 0.05mm
HOLE DIAMETERS SEE TABLE
ANGULAR
DIMENSIONS IN mm
SCALE N.T.S.
REMOVE ALL BURRS AND SHARP EDGES
TITLE
GOLDSMITH RF
APPLICATION PCB
ASSEMBLY
MATERIAL
DRAWING No.
D1402/V2.0B
FINISH
SHT 2 OF 2
A3

D1402 | Third Angle Projection | Do Not Scale





BOARD LAYER ARRANGEMENT

HOLE DETAILS

REF.	PARTICULARS OF HOLES	QTY	PLATED THRO
UNSPEC	Φ0.3 +0/-0.1	570	YES
A	Φ0.8 +0.13/-0	100	YES
B	Φ1.2 +0.13/-0	2	YES
C	Φ1.6 +0.13/-0	5	YES

NOTES:

1. MANUFACTURE IN ACCORDANCE WITH BS9761
2. MATERIAL:
   1.2 THICK MULTI-LAYER FR04 LAMINATE TO BS4584 (4 LAYERS) CLAD WITH 1/2oz COPPER ON OUTER LAYERS AND 1oz COPPER ON INNER LAYERS
3. FINISH:
   BLACK OXIDE ON INNER LAYERS
   BARE COPPER ON OUTER LAYERS
   THROUGH HOLE PLATING TO BS6221 PART 6
   IMMERSION GOLD
   PHOTO IMAGEABLE SOLDER RESIST
   WHITE SILK SCREEN
4. GOLD EDGE PLATING ON 3 EDGES 'A'. BOARD TO BE HELD IN 4 BREAK OFF POINTS 'B' DURING EDGE PLATING

SYMBIONICS Symbionics Limited

St John's Innovation Park
Cowley Road, Cambridge
England CB4 4WS
Tel : 01223 421025
Fax : 01223 421031

Drawn	Date	Issue No	Date	Ch No
JLT DESIGNS	14.02.96	A	14.02.96	
Checked				
Approved				
Approved				

TOLERANCES: DIMENSIONS NO DEC PLACE +/- 0.2mm; 1 DEC PLACE +/- 0.1mm; 2 DEC PLACE +/- 0.05mm. HOLE DIAMETERS SEE TABLE. ANGULAR -

DIMENSIONS IN mm. SCALE N.T.S. REMOVE ALL BURRS AND SHARP EDGES

TITLE: GOLDSMITH RF APPLICATION PCB

DRAWING No. D1402/V2.0B

SHT 1 OF 2

MATERIAL: SEE NOTE 2

FINISH: SEE NOTE 3

A3

Bill Of Materials of GOLDSMITH RADIO

Item	Quantity	Reference	Part
1	1	BAT500	BATTERY CONNECTOR L1007 RS 426-042
2	5	C100,C112,C113,C127,C400	10uF 10V 20% CASE B2 Tantalum NEC L1004
3	9	C101,C102,C103,C105, C115,C128,C242,C259,C260	100pF 50V 10% 0603 C0G Murata L1001
4	11	C104,C110,C111,C114, C118,C119,C124,C126, C200,C403,C423	10nF 50V 10% 0603 X7R Murata L1001
5	8	C107,C122,C212,C227, C229,C264,C320,C409	2pF 50V 0.25pF 0603 C0G Murata L1001
6	5	C108,C209,C210,C348,C349	6pF 50V 0.5pF 0603 C0G Murata L1001
7	3	C109,C405,C413	33pF 50V 10% 0603 C0G Murata L1001
8	17	C116,C117,C120,C123, C235,C238,C250,C252, C253,C312,C326,C404, C406,C411,C412,C415,C425	1nF 50V 10% 0603 X7R Murata L1001
9	70	C125,C129,C130,C201, C205,C213,C216,C217, C218,C220,C221,C222,C223, C225,C232,C236,C237,C239, C244,C245,C248,C261,C308, C309,C310,C311,C324,C325, C345,C346,C401,C402,C408, C410,C417,C418,C420,C421, C422,C426,C428,C429,C500, C501,C502,C503,C504,C505, C506,C507,C508,C509,C510, C511,C512,C513,C514,C515, C516,C517,C518,C519,C520, C521,C522,C523,C524,C525, C526,C527	22pF 50V 10% 0603 C0G Murata L1001
10	12	C202,C256,C265,C307, C317,C318,C319,C321, C322,C340,C341,C407	10pF 50V 0.5pF 0603 C0G Murata L1001
11	5	C204,C240,C251,C258, C414	100nF 50V 10% 0603 X7R Murata L1001
12	4	C207,C208,C214,C419	4pF 50V 0.25pF 0603 C0G Murata L1001
13	1	C211	1pF 50V 0.05pF 0603 ACCU-F AVX L1001
14	1	C215	5pF 50V 0.25pF 0603 C0G Murata L1001
15	1	C233	1nF 50V 10% 0805 C0G Murata L1044

Bill Of Materials of GOLDSMITH RADIO

Item	Quantity	Reference	Part
16	4	C234,C257,C300,C305	22pF 50V 10% 0402 C0G Murata L1040
17	1	C241	100pF 50V 0.5pF 0603 C0G Murata L1001
18	1	C246	2.2nF 50V 10% 1206 C0G Murata L1045
19	2	C247,C337	220pF 50V 10% 0603 C0G Murata L1001
20	2	C266,C249	4.7nF 50V 10% 1206 C0G Murata L1045
21	1	C254	47pF 50V 10% 0603 C0G Murata L1001
22	3	C255,C338,C339	470pF 50V 10% 0603 C0G Murata L1001
23	2	C262,C263	1.5pF 50V 0.25pF 0603 C0G Murata L1001
24	1	C301	6.8pF 50V 0.5pF 0603 C0G Murata L1039
25	2	C303,C304	47pF 50V 10% 0402 C0G Murata L1040
26	1	C306	10pF 50V 0.5pF 0402 C0G Murata L1040
27	1	C313	18pF 50V 10% 0603 C0G Murata L1001
28	2	C315,C314	22nF 25V 10% 0603 X7R Murata L1001
29	1	C330	120pF 50V 10% 0603 C0G Murata L1039
30	2	C333,C335	22pF 50V 10% 0603 C0G Murata L1039
31	1	C334	33pF 50V 10% 0603 C0G Murata L1039
32	1	C336	10pF 50V 0.5pF 0603 C0G Murata L1039
33	1	C343	3pF 50V 0.25pF 0603 C0G Murata L1001
34	1	C347	1nF 50V 10% 0603 X7R Murata L1039
35	2	C351,C350	3pF 50V 0.25pF 0402 C0G Murata L1040
36	2	C352,C353	100pF 50V 10% 0402 C0G Murata L1040
37	1	C354	1pF 50V 0.25pF 0603 C0G Murata L1001
38	1	C528	N/F 50V 10% 0603 C0G Murata L1001
39	1	D100	BAS40-04 SOT23 SIEMENS L1029
40	3	D101,D102,D103	BAV99 SOT23 SIEMENS L1029
41	1	D104	5v1 350mW SOT23 ITT L1030 BZX84C5V1
42	1	D105	BAR63-04 SOT23 Siemens L1029

Bill Of Materials of GOLDSMITH RADIO

Item	Quantity	Reference	Part
43	2	D200,D300	BBY51 SOT23 SIEMENS L1029
44	1	D400	BAS70-07 SOT143 SIEMENS L1026
45	1	F100	CGR947.5 SMD S+M L1011 CERAMIC FILTER
46	1	F101	CGR902.5 SMD S+M L1010 CERAMIC FILTER
47	1	F200	B4632 DCC6 S+M L1012 3mm Saw Filter
48	1	F300	B4633 DCC6 S+M L1012 SAW RXRF FILTER
49	1	F301	B4579 QCC10 S+M L1009 SAW IF FILTER
50	1	F400	B69812-N9026-A725 SMD S+M SC CERAMIC FILTER
51	1	L101	4u7 30mA 20% 0805 LK Taiyo Yuden L1014 LK 2125 4R7
52	1	L105	8nH SMD Spring Coilcraft L1005 A03T
53	1	L106	1u5 30mA 20% 0805 LK Taiyo Yuden L1014 LK 2125 1R5
54	2	L107,L303	22nH 5% 0603 HK Taiyo Yuden L1013
55	3	L201,L202,L203	3u9 30mA 20% 0805 LK Taiyo Yuden L1014 LK 2125 3R9
56	1	L304	47nH 5% 0805 HK TAIYO YUDEN L1014
57	1	L306	4.7nH 10% 0603 HK TAIYO YUDEN L1013
58	2	L308,L312	56nH 10% 0805 COIL CRAFT L1033
59	1	L309	100nH 20% 0603 LK TAIYO YUDEN L1043
60	1	L310	27nH 5% 0603 HK TAIYO YUDEN L1043 HK 1608 12N
61	1	L311	15nH 5% 0603 HK TAIYO YUDEN L1043
62	1	L313	5.6nH 10% 0603 HK TAIYO YUDEN L1013
63	1	L314	27nH 5% 0603 HK TAIYO YUDEN L1043
64	1	L315	10nH 5% 0603 HK TAIYO YUDEN L1043
65	1	L400	43nH SMD Spring Coilcraft L1006 B10T
66	1	L401	12nH 5% 0603 HK TAIYO YUDEN L1013 HK 1608 12N
67	1	L402	27nH 0805 Coilcraft L1033 0805CS-270XMBC
68	1	L403	22nH 0805 Coilcraft L1033 0805CS-220XMBC

'Bill Of Materials of GOLDSMITH RADIO

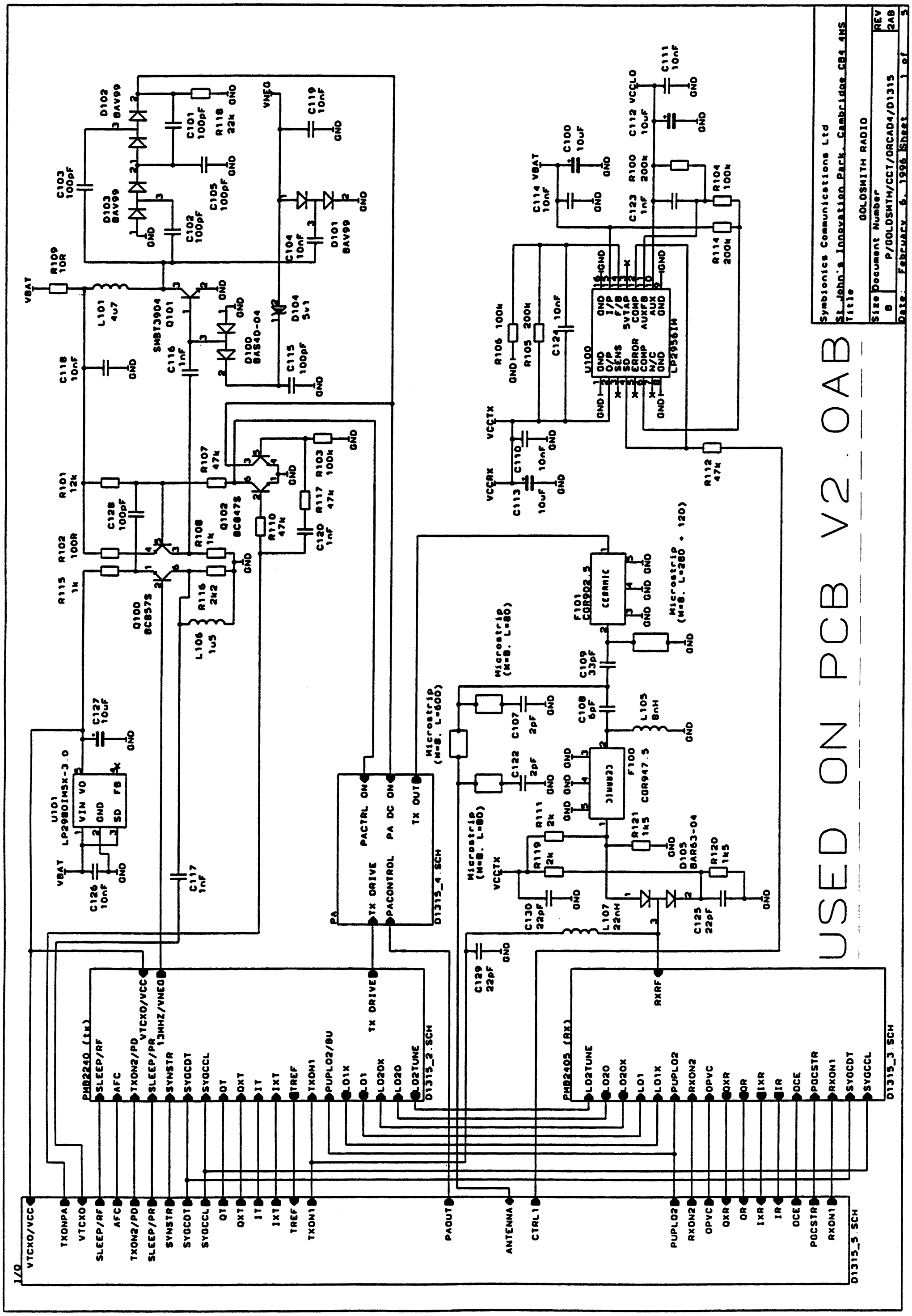
Item	Quantity	Reference	Part
69	1	L404	27nH 0805 Coilcraft L1033 0805CS-220XMBC
70	6	Q100,Q200,Q202,Q203, Q204,Q403	BC857S SOT363 SIEMENS PNP DOUBLE TRANSISTOR
71	1	Q101	SMBT3904 SOT23 SIEMENS L1029 NPN
72	1	Q102	BC847S SOT363 SIEMENS NPN DOUBLE TRANSISTOR
73	1	Q201	LRLML6302 SOT23 International Rectifier L1029
74	1	Q400	BSP319 SOT223 SIEMENS L1027 SIPMOS FET
75	1	Q401	BCR400W SOT343 Siemens Bias Regulator TRANSISTOR
76	1	Q402	BC848B SOT23 SIEMENS L1029 NPN
77	3	R100,R105,R114	200k 0603 L1020
78	1	R101	12k 0603 L1020
79	6	R102,R222,R226,R227, R230,R419	100R 0603 L1020
80	7	R103,R104,R106,R409, R410,R416,R418	100k 0603 L1020
81	9	R107,R110,R112,R117, R216,R403,R404,R424,R501	47k 0603 L1020
82	6	R108,R115,R200,R233, R402,R426	1k 0603 L1020
83	11	R109,R201,R212,R224, R225,R235,R302,R317, R318,R325,R415	10R 0603 L1020
84	6	R111,R119,R206,R207, R210,R211	2k 0603 L1020
85	6	R116,R215,R221,R231, R412,R500	2k2 0603 L1020
86	1	R118	22k 0603 L1020
87	2	R121,R120	1k5 0603 L1020
88	1	R202	91R 0603 L1020

Bill Of Materials of GOLDSMITH RADIO

Item	Quantity	Reference	Part
89	1	R205	240R 0603 L1020
90	1	R214	4k3 0603 L1020
91	1	R217	33k 0603 L1020
92	2	R219,R423	6k8 0603 L1020
93	1	R220	9k1 0603 L1020
94	1	R223	4R7 0603 L1020
95	2	R232,R228	470R 0603 L1020
96	1	R229	330R 0603 L1020
97	11	R234,R236,R238,R239, R321, R405,R406,R408, R420,R421,R422	10k 0603 L1020
98	1	R237	560R 0402 L1042
99	2	R300,R303	10k 0402 L1042
100	1	R301	22R 0603 L1041
101	2	R414,R304	220R 0603 L1020
102	5	R305,R310,R311,R316, R411	1k2 0603 L1020
103	4	R306,R309,R312,R315	1k8 0603 L1020
104	4	R307,R308,R313,R314	39k 0603 L1020
105	1	R319	10k 0603 L1041
106	1	R320	560R 0603 L1020
107	2	R322,R323	N/F 0402 L1042
108	1	R324	3k6 0603 L1020
109	1	R400	68R 0603 L1020
110	2	R407,R413	4k7 0603 L1020
111	1	R417	510R 0603 L1020
112	2	R427,R429	N/F 0603 L1020

Bill Of Materials of GOLDSMITH RADIO

Item	Quantity	Reference	Part
113	1	R428	0R 0603 L1020
114	1	SK500	SK L1008 RS 449-635
115	1	SK501	85SMA-50-0-1/111 SUHNER L1015 SMA 90° female PCB
116	1	TP200	TEST L1038 Printed Test Pad
117	1	U100	NS LP2956IM L1025 Double Low Dropout Reg.
118	1	U101	LP2980IM5X-3.0 National Semi L1019 5V Low-Dropout Reg
119	1	U200	TCO-987 SMD TOYOCOM L1032 13 MHz VCTCXO
120	1	U201	PMB2240 P-TQFP-48 SIEMENS L1031 GSM TX CHIP
121	1	U202	PMB2306 TSSOP16 SIEMENS L1018 PLL CHIP
122	1	U300	PMB2405 P-TQFP-48 SIEMENS L1031 GSM RX CHIP
123	1	U400	CGY92 MW12 Siemens L1016 GSM PA IC
124	1	U401	CGY120 MW6 Siemens L1017 GSM Driver Amp IC
125	1	U402	OP291G SO8 PMI L1023 Dual Op-amp
126	32	Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8, Z9,Z10,Z11,Z12,Z13,Z14, Z15,Z16,Z17,Z18,Z19,Z20, Z21,Z22,Z23,Z24,Z25,Z26, Z27,Z28,Z29,Z30,Z31,Z32	GNDVIA L9010



Symbionics Communications Ltd
St John's Innovation Park, Cambridge CB4 4WS
Title
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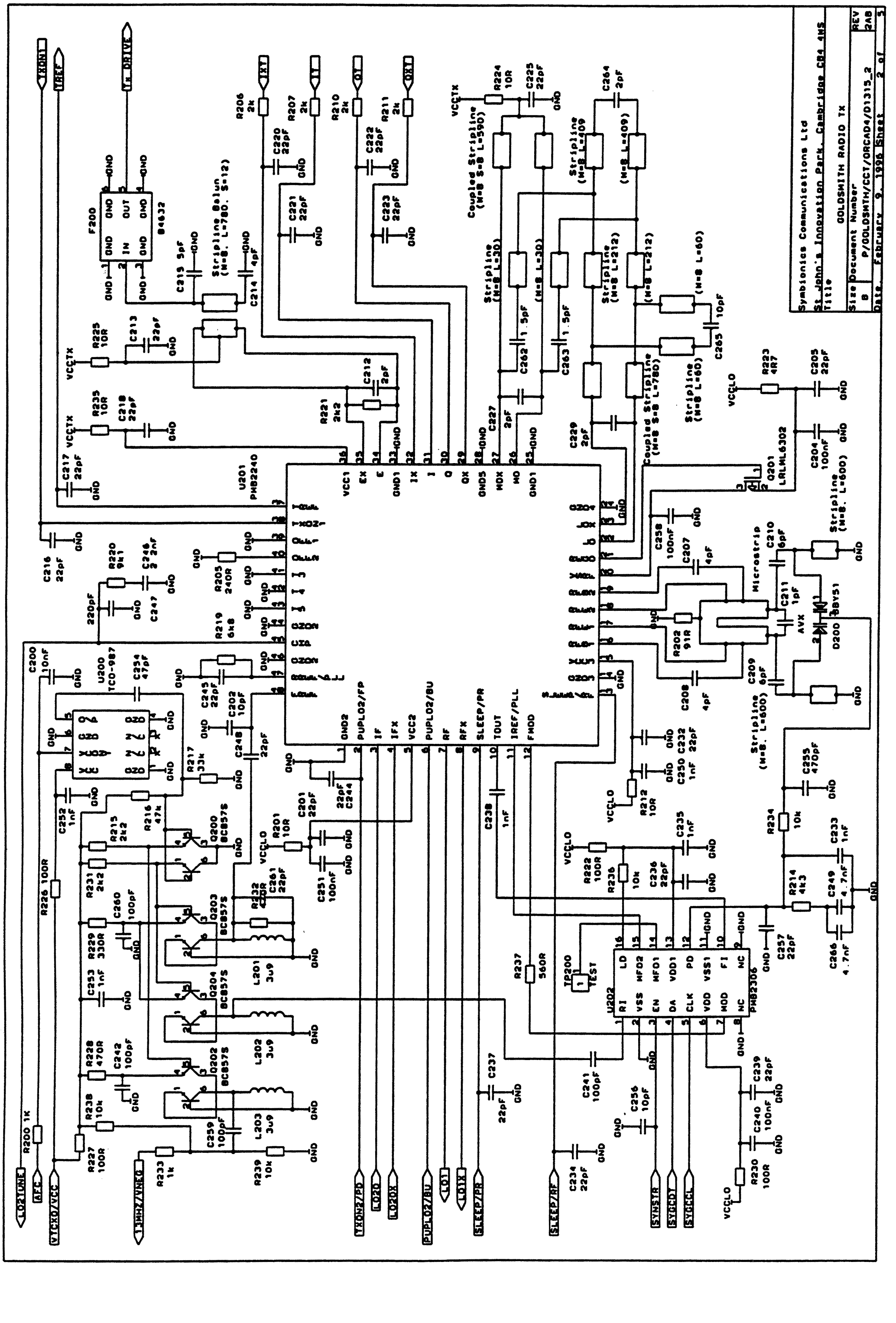
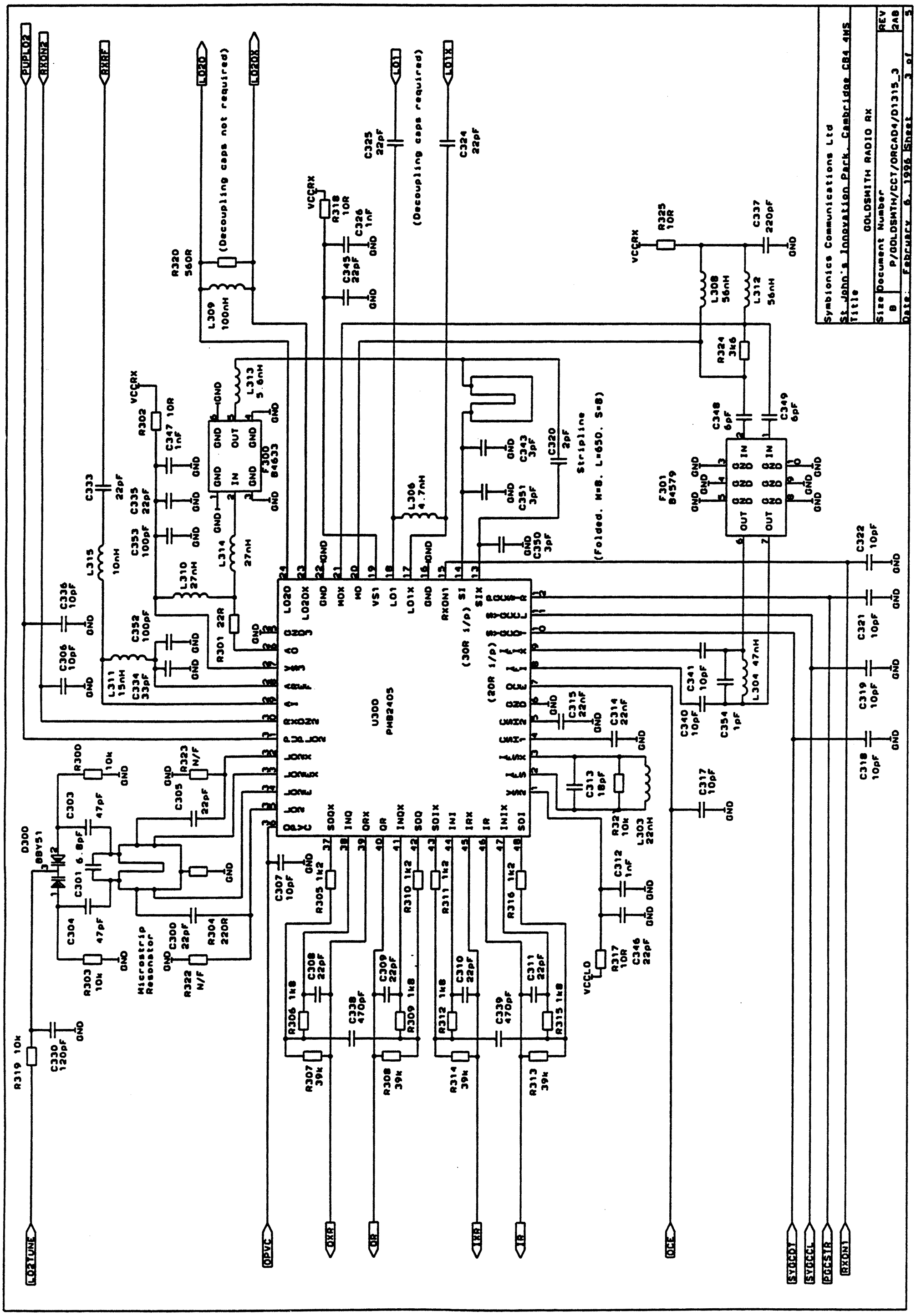
Size B
Document Number
P/GOLDSMITH/CCT/ORCAD4/D1315
REV 2AB
Date: February 6, 1996 Sheet 1 of 5
USED ON PCB V2 OAB


Symbionics Communications Ltd
St John's Innovation Park, Cambridge CB4 4WS
GOLDSMITH RADIO TX
P/GOLDSMTH/CCT/ORCAD4/D1315_2
February 9, 1996
U201 PMB2240
U202 PMB2306
U200 TCO-987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St John's Innovation Park, Cambridge CB4 4WS
Title
GOLDSMITH RADIO RX
Size B
Document Number
P/GOLDSMTH/CCT/ORCAD4/D1315_3
REV 2A8
Date: February 6, 1996 Sheet 3 of 5
U300
PMB2405
F300
B4633
F301
B4579
D300
BBY51
Microstrip Resonator
Stripline
(Folded. W=8, L=650, S=8)
(Decoupling caps not required)
(Decoupling caps required)
PUPLO2
RXON2
RXRF
LO2D
LO2DX
LO1
LO1X
LO2TUNE
OPVC
OQR
QR
IRR
IR
OCE
SYGCDT
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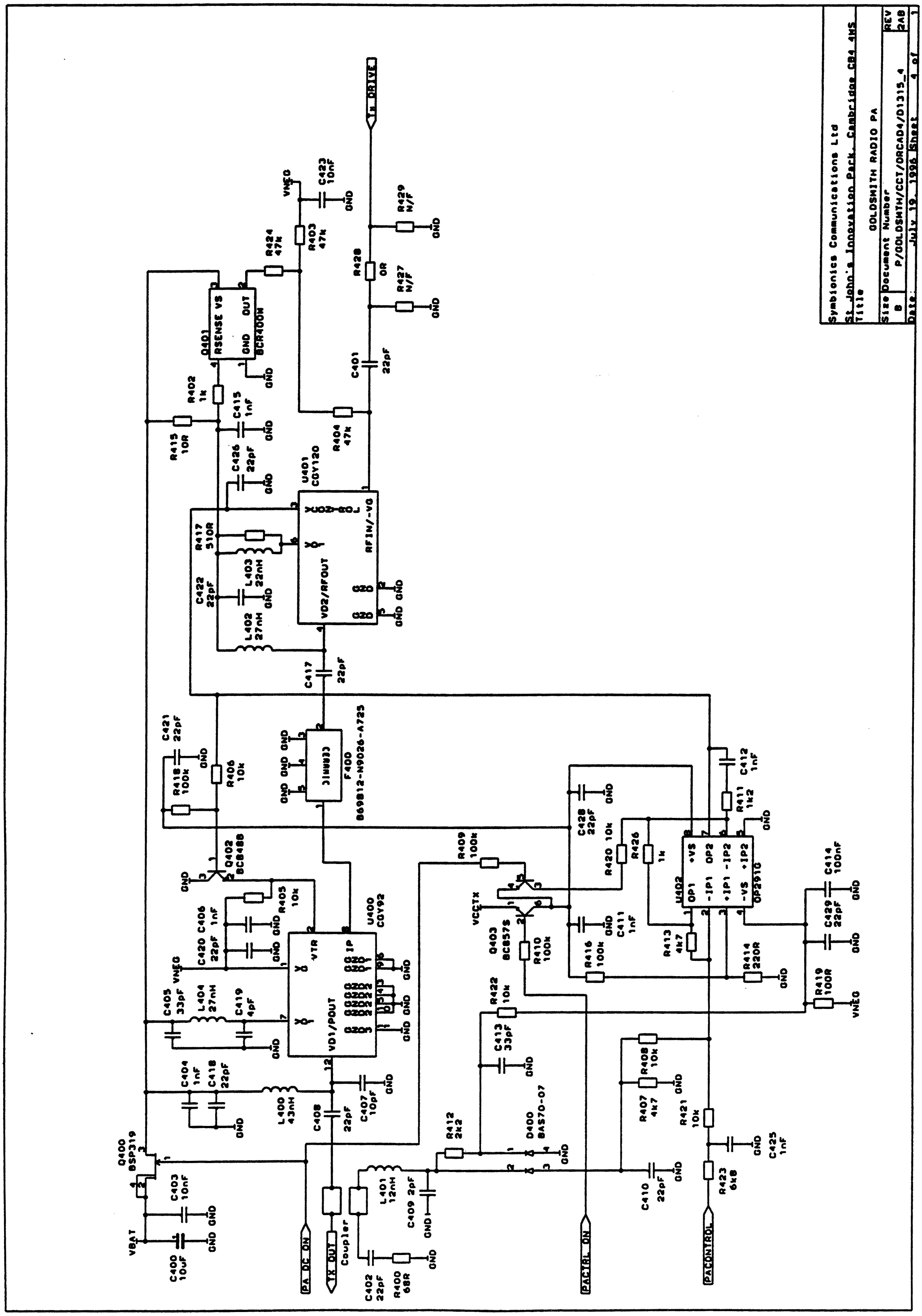
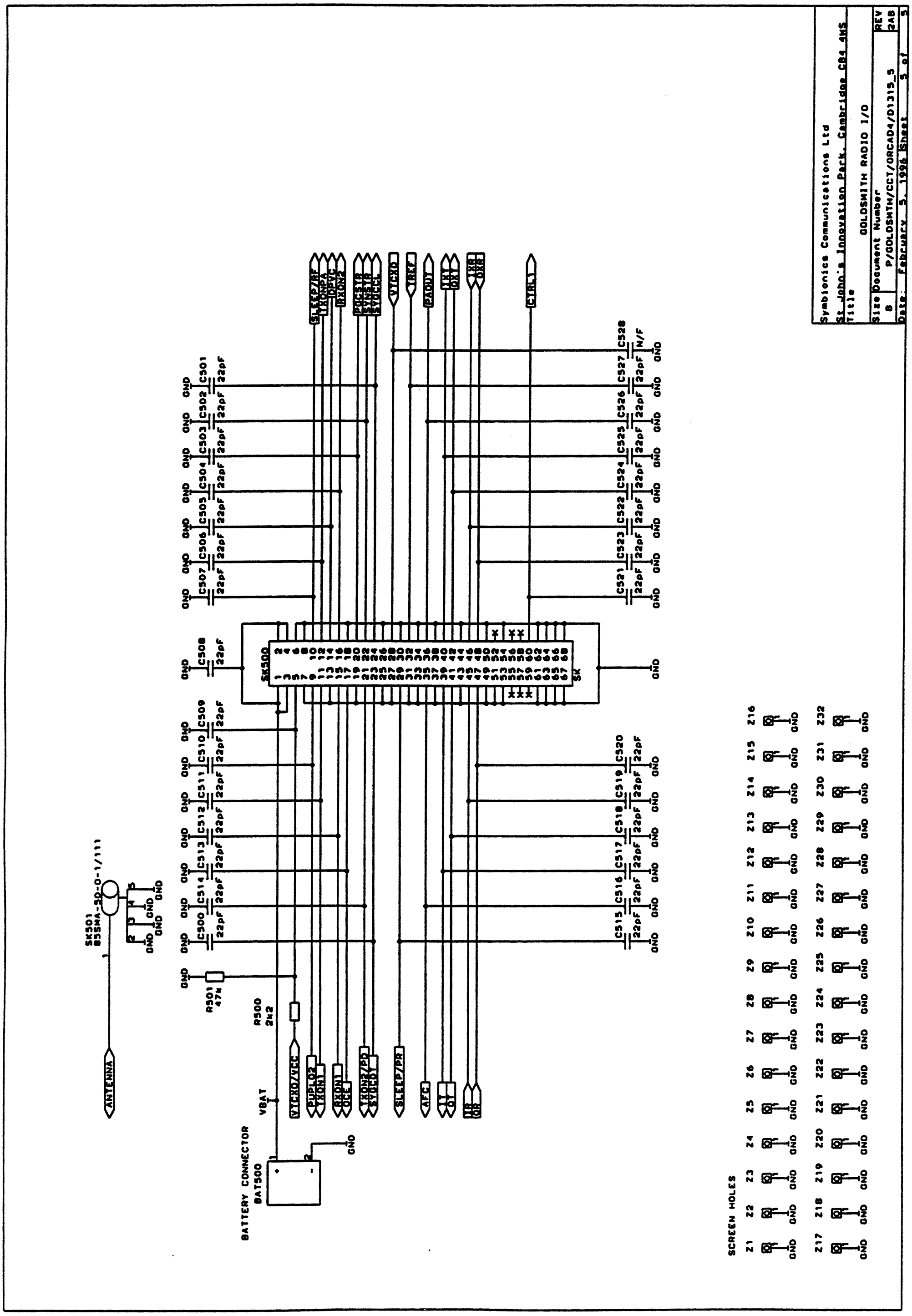
RXON1
VCCRX
VCCLO
GND


Symbionics Communications Ltd
St John's Innovation Park, Cambridge CB4 4WS
Title
GOLDSMITH RADIO PA
Size
B
Document Number
P/GOLDSMTH/CCT/ORCAD4/D1315_4
REV
2AB
Date:
July 19, 1996


Symbionics Communications Ltd
St John's Innovation Park, Cambridge CB4 4WS
Title
GOLDSMITH RADIO I/O
Size Document Number REV
B P/GOLDSMTH/CCT/ORCAD4/D1315_5 2AB
Date: February 5, 1996 Sheet 5 of 5
SCREEN HOLES
BATTERY CONNECTOR
BAT500
ANTENNA
SK500

10. APPENDIX C SYSTEM MEASURENTS OF REFERENCE BOARD B6

10.1 TEST SHEET

Serial No	B6	Supply Voltage	5V
Date	May 1996	Temperature	room temperature

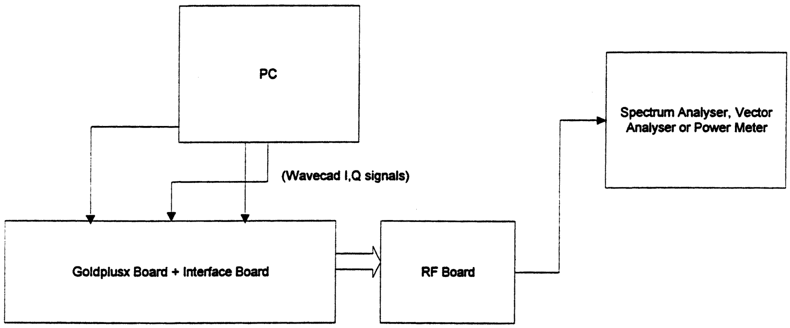
Test	Section Ref	Conditions	Specification	Channel			Pass/ Fail
				1	63	124	
Tx Power	5.1.2	Level 5	+33 dBm ± 2 dB (± 2.5 dB under extreme conditions	32.0	32.8	31.2	P
		Level 12	+19 dBm ± 4 dB		19.9		P
		Level 19	+ 5 dBm ± 6 dB		5.3		P
Burst Profile	5.1.2	Level 5	P/F	P	P	P	P
Mod Spectrum	5.1.3	Level 5	± 400 kHz: -60 dBc	P	P	P	P
Transients*	5.1.4	Level 5	-1.8 MHz: -24 dBm		-30.0		P
(power ramp			-1.2 MHz: -21 dBm		-39.0		P
sidebands)			-600 kHz: -21 dBm		-31.0		P
			-400 kHz: -19 dBm		-21.8		P
			+400 kHz: -19 dBm		-21.6		P
			+600 kHz: -21 dBm		-32.0		P
			+1.2 MHz: -21 dBm		-38.0		P
			+1.8 MHz: -24 dBm		-31.0		P
Spurious Emissions	5.1.4	Level 5	0.1 - 1 GHz: -36 dBm		P		P
			1 - 12.75 GHz**		P		P
Frequency	5.1.5	Level 5	± 90 Hz	NA	±60	NA	P
		Level 19	± 90 Hz	NA	NA	NA	P
RMS Phase	5.1.5	Level 5	5°	4°	4°	4°	P
		Level 19	5°	4°	4°	4°	P
Peak Phase	5.1.5	Level 5	20°	17°	14°	17°	P
		Level 19	20°	17°	18°	17°	P
Blocking	5.2.1	± 600 kHz: -43 dBm	9 dB S/(N+I)		12		P
		± 1.6 MHz: -33 dBm	9 dB S/(N+I)		12		P
		± 3 MHz: -23 dBm	9 dB S/(N+I)		8		F
Intermod-ulation	5.2.2	+800 kHz, +1.6 MHz	9 dB S/(N+I)	13	13	10	P
		-800 kHz, -1.6 MHz	9 dB S/(N+I)	13	13	10	P
Sensitivity	5.3.2	-102 dBm	9 dB S/N	-104	-103	-102	P
Adjacent Channel	5.3.3.1	± 200 kHz	-6 dB S/(N+I)		8		P
		± 400 kHz	-12 dB S/(N+I)		13		P

*The specification originally typed in this table for this measurement was as per GSM 05.05, the more correct specification adopted here is as per GSM 11.10 section II.3.4.2
**Measured to 6.5 Ghz

10.2 MEASUREMENT SET-UPS

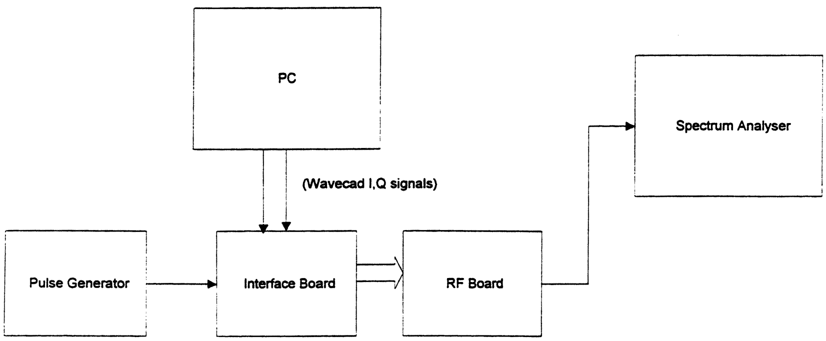
Three measurement set-ups were used:

1)Transmitter Dynamic set-up
This was used on all the above transmitter measurements except modulation spectrum and spurious measurements



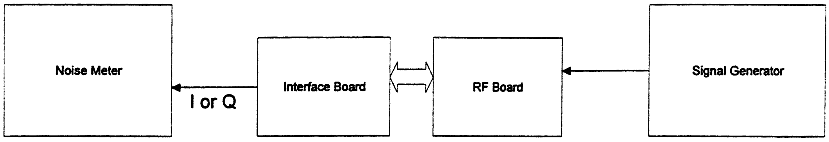
The interface board contains a circuit that converts the I,Q signals from unbalanced to balanced signals. It also connects through all the control signals from the baseband board except VBAT, V5V, APCS, SWIC, SWIA, SWID, SWIB and the transmit and receive I/Q signals GSM pulse width and duration are used.

2)Transmitter Static with Pulsed PA Control set-up
This was used for modulation spectrum and spurious measurements (section 4 above)



The interface Board converts unbalanced I/Q signals to balanced as above in 1). Also it provides the following static (high) signals: PUPLO2, TXON1, TXON2, SLEEP/RF, SLEEP/PR, and the following pulsed signals: TXONPA and PAOUT, pulsed at 30ms pulse width and 10% pulse rate.

3) Receiver tests Static set-up
This was used for all receiver tests, and is a fully static measurement.



The interface board converts the receive balanced I/Q signals (IR,IRX,QR,QRX) to unbalanced, and either signal is used to measure the signal to noise ratio. The interface board also provides the following static signals: PUPLO2, RXON1, RXON2, TXON2, SLEEP/RF and SLEEP/PR. OCE is provided as pulsed signal at a pulse duration of about 1ms once per second

10.3 BURST PROFILES

The following plots show the burst ramp up and ramp down (with the GSM power time template), and the full burst at power levels 5 (33dBm), 12 (19dBm) and 19 (5dBm) for channel 63 (902.6MHz), channel 1 (890.2 MHz) and Channel 124 (914.8MHz). These plots also show the 400KHz and 600KHz switching transients ,measured using 'maximum hold' measurement.. The measurements are made at the antenna connector output, using a spectrum analyser in zero span mode. The ramps are adjusted by controlling the step sizes in the control signal PAOUT.

Figure 10 - 1: Full power ramp up at 902 MHz center frequency

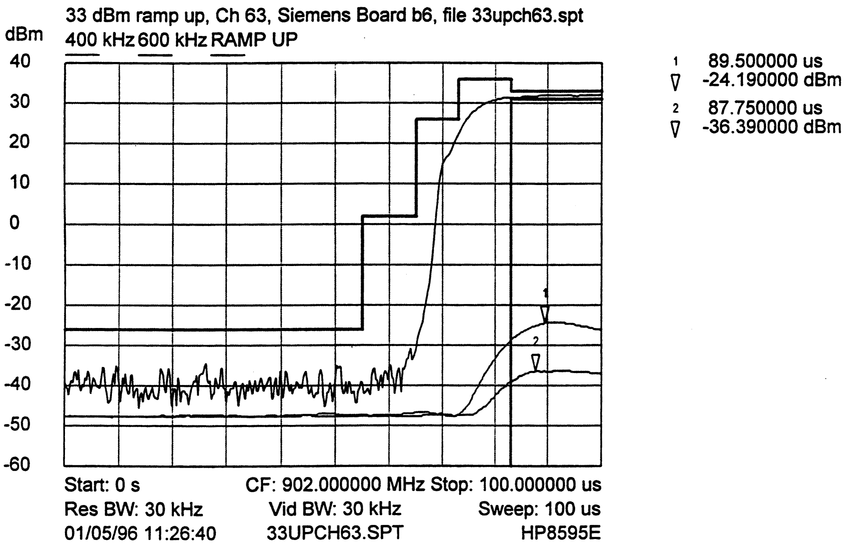


Figure 10 - 2: Full power ramp down at 902MHz center frequency

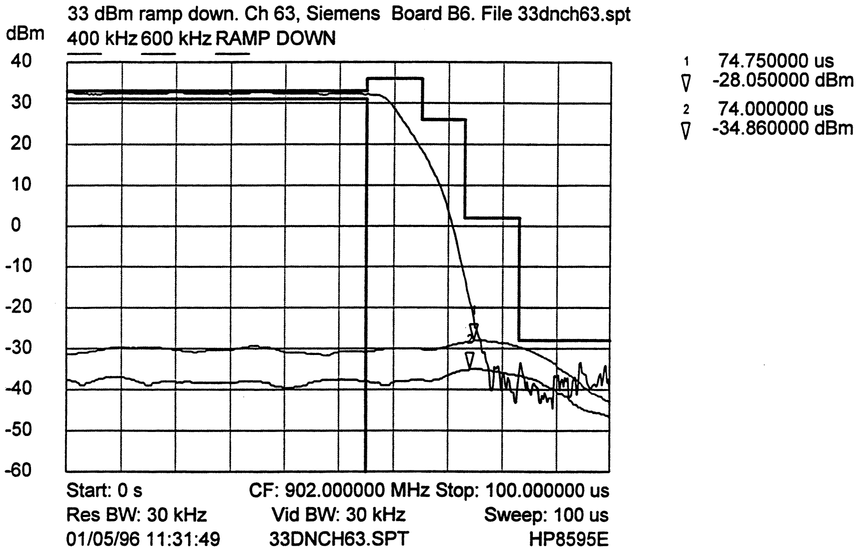


Figure 10 - 3: Full power GSM burst at 902 MHz center frequency

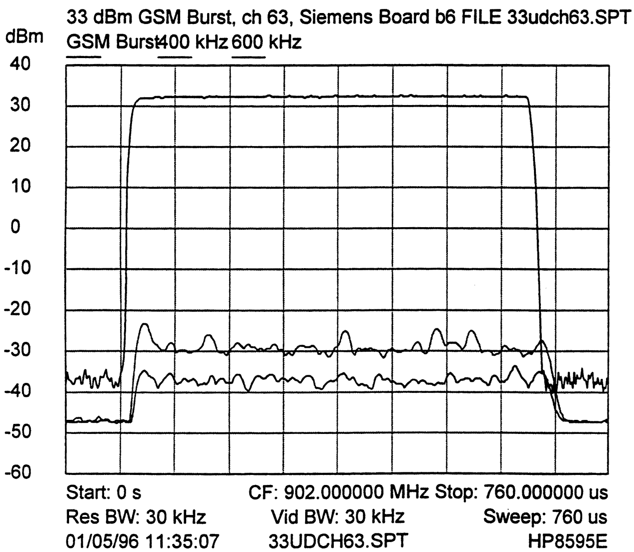


Figure 10 - 4: Full power ramp up at 889.2 MHz center frequency

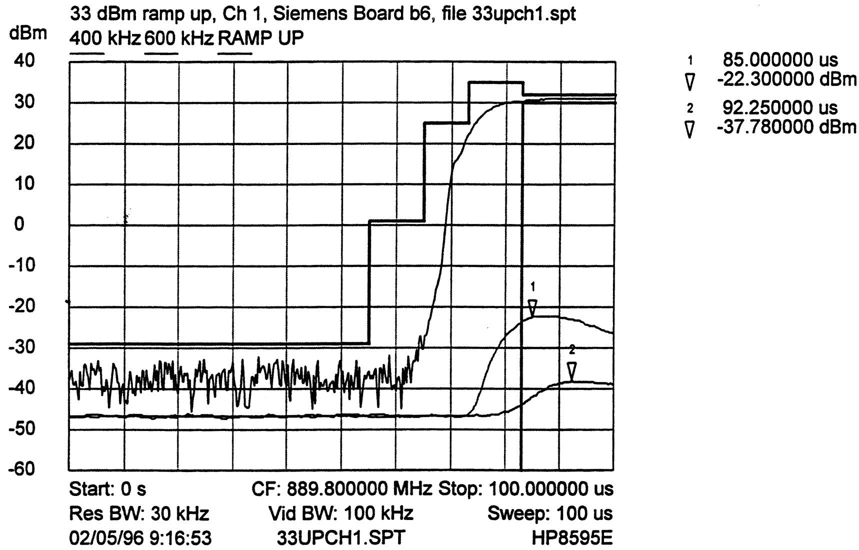


Figure 10 - 5: Full power ramp up at 889.2 MHz center frequency

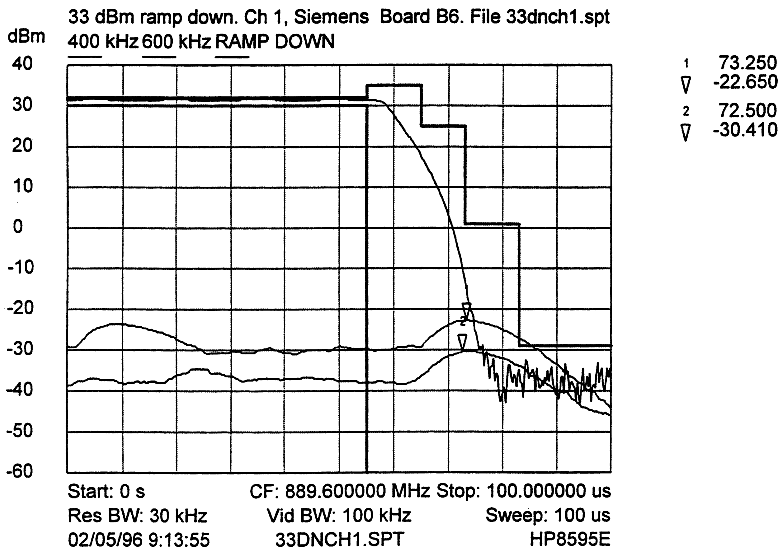


Figure 10 - 6: Full power GSM burst at 889.6 MHz center frequency

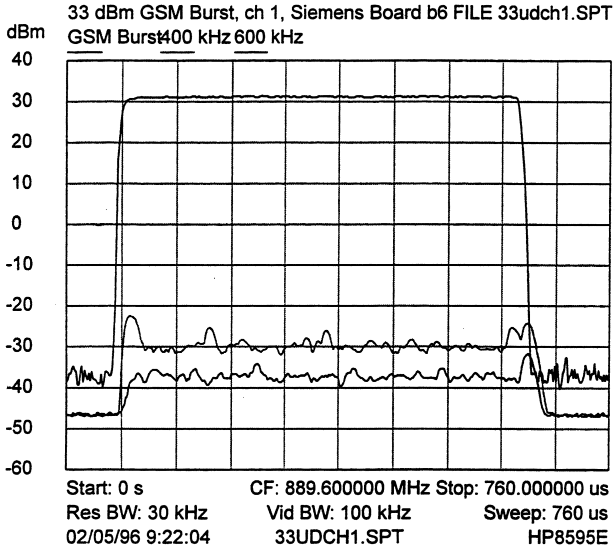


Figure 10 - 7: Full power ramp up at 914.2 MHz center frequency

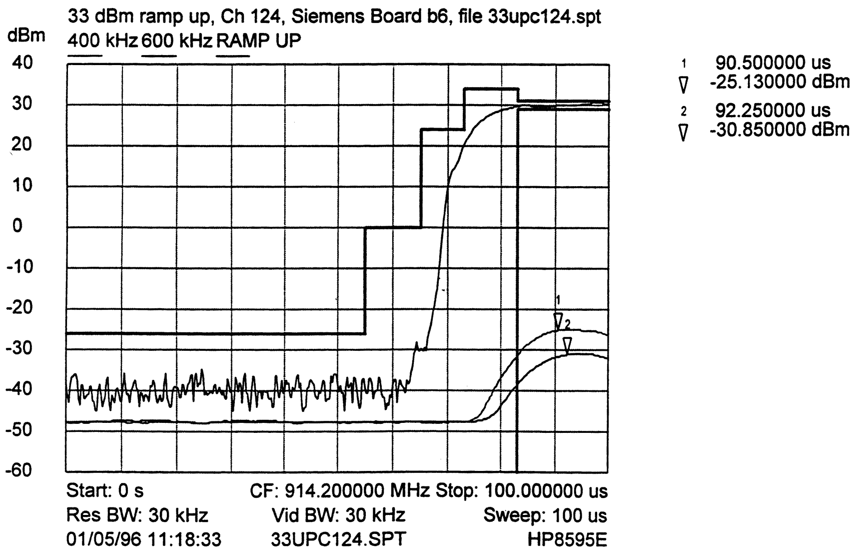


Figure 10 - 8: Full power ramp down at 914.2 MHz center frequency

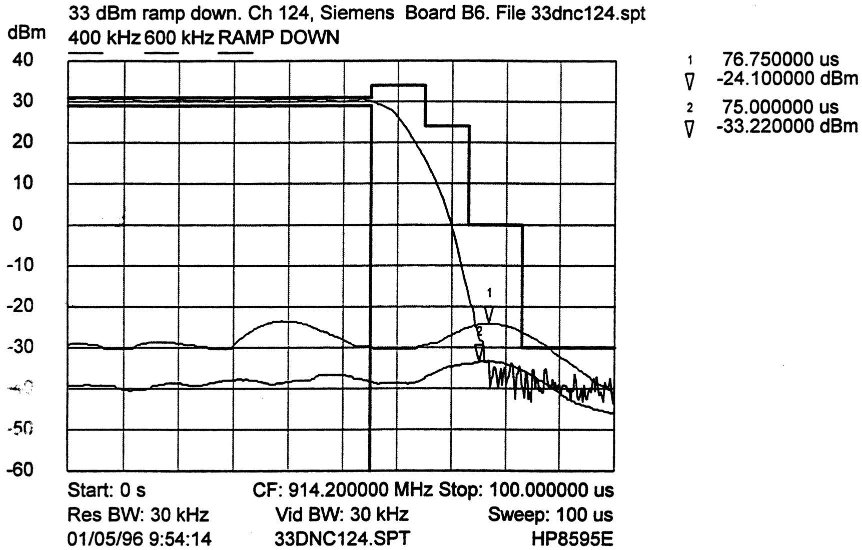


Figure 10 - 9: Full power GSM burst at 914.2 MHz center frequency

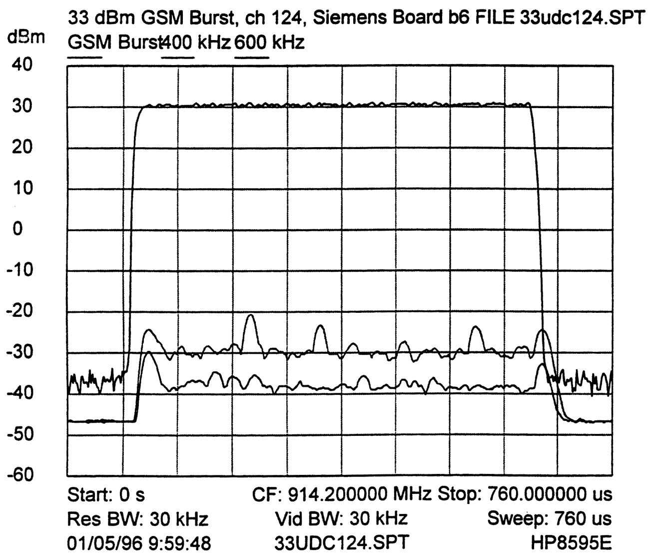


Figure 10 - 10: 19 dBm power ramp up at 902 MHz center frequency

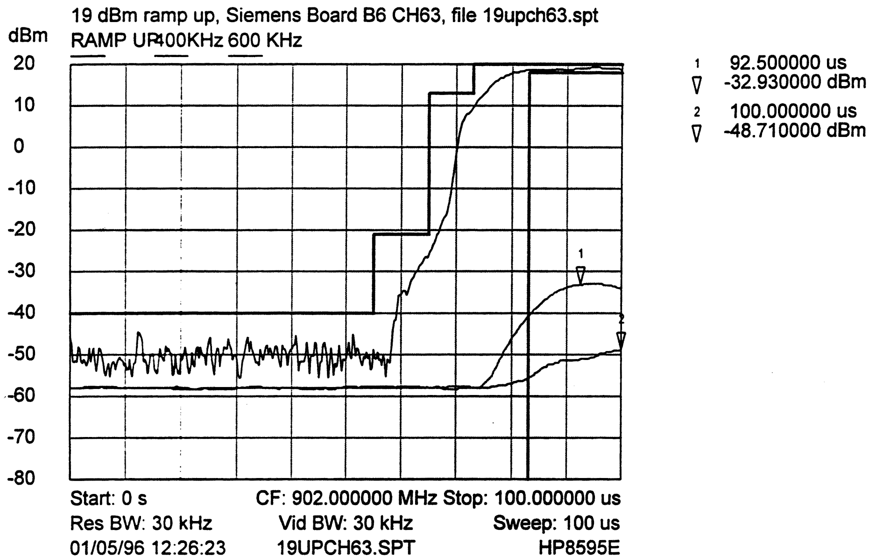


Figure 10 - 11: 19 dBm power ramp down at 902 MHz center frequency

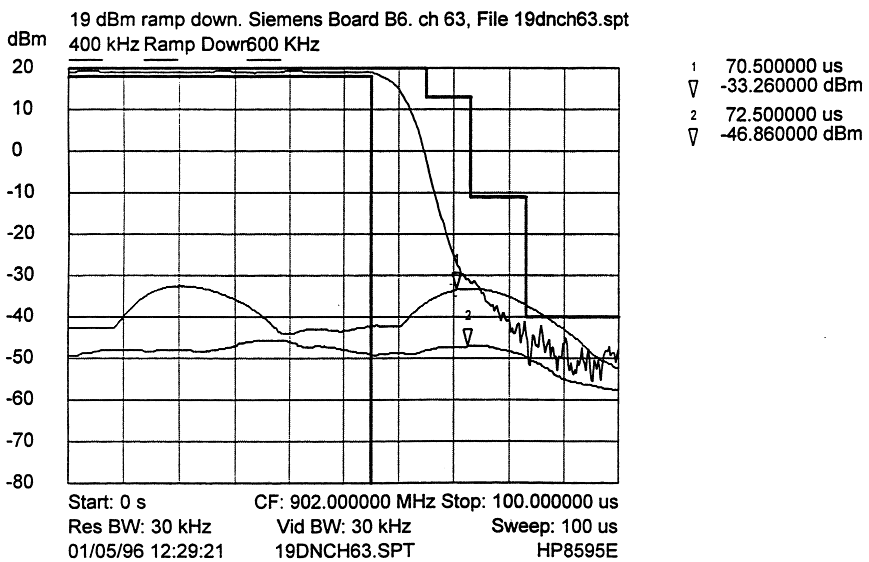


Figure 10 - 12: 19 dBm power GSM burst at 902 MHz center frequency

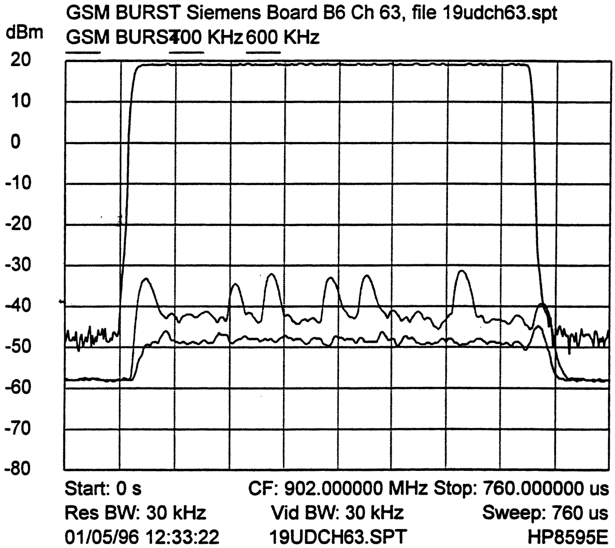


Figure 10 - 13: 19 dBm power ramp up at 889.2 MHz center frequency

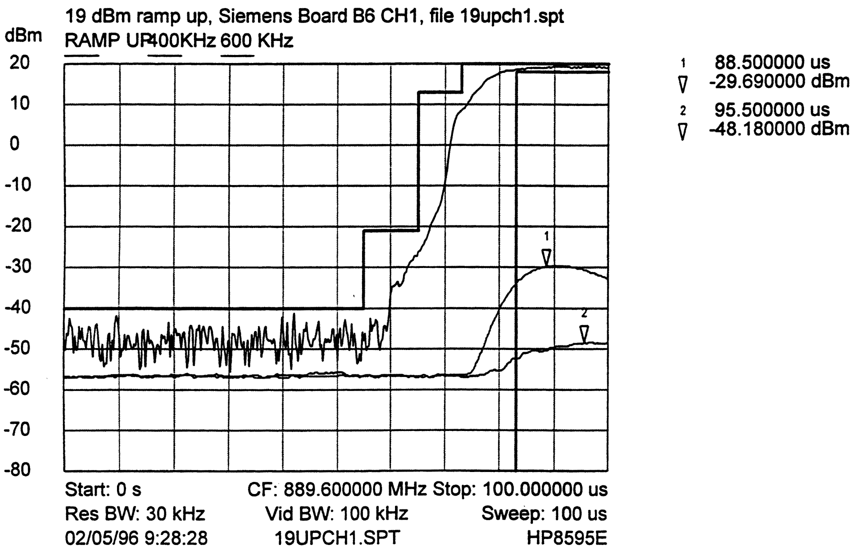


Figure 10 - 14: 19 dBm power ramp down at 889.6 MHz center frequency

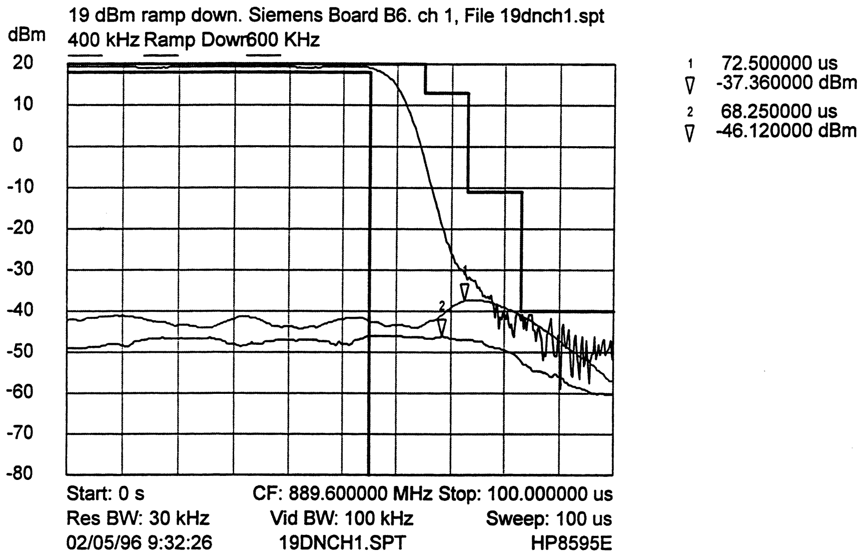


Figure 10 - 15: 19 dBm power GSM burst at 889.6 MHz center frequency

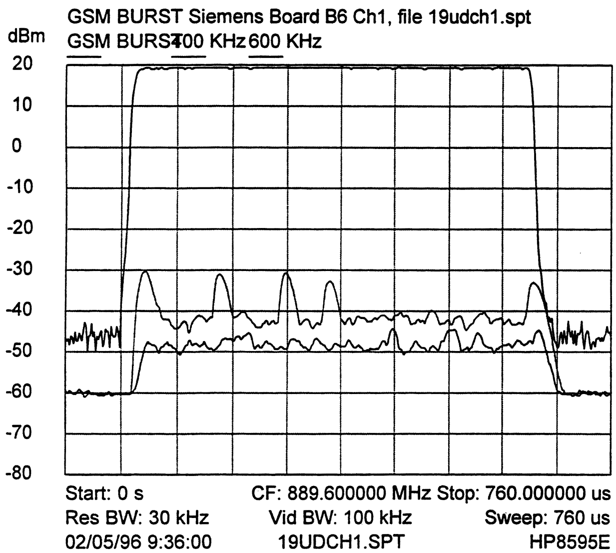


Figure 10 - 16: 19 dBm power ramp up at 914.2 MHz center frequency

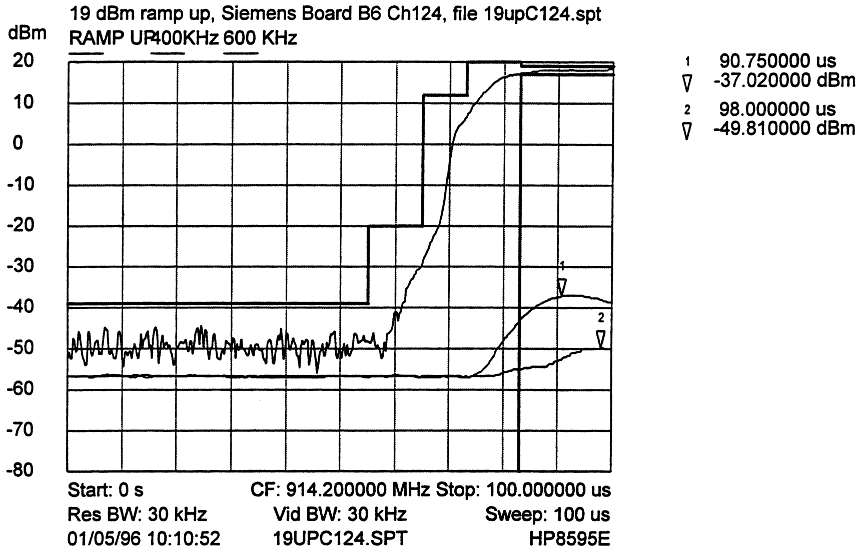


Figure 10 - 17: 19 dBm power ramp down at 914.2 MHz center frequency

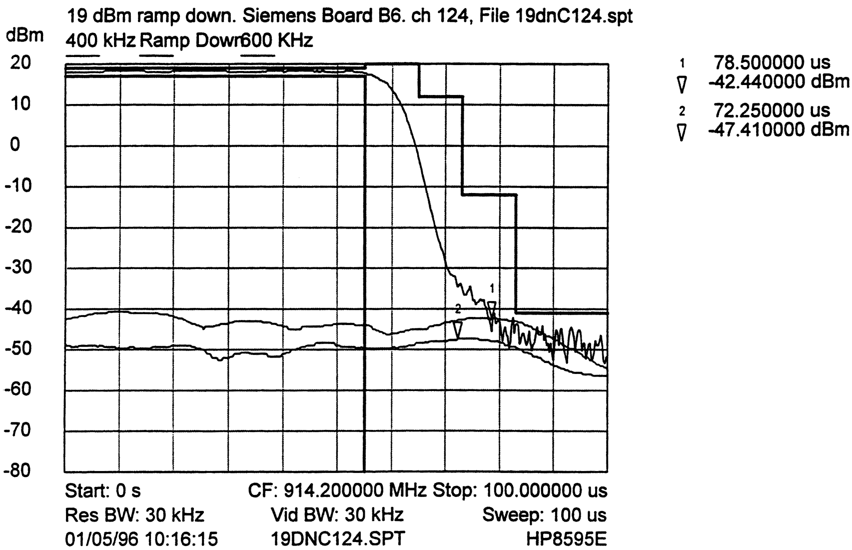


Figure 10 - 18: 19 dBm power GSM burst at 914.2 MHz center frequency

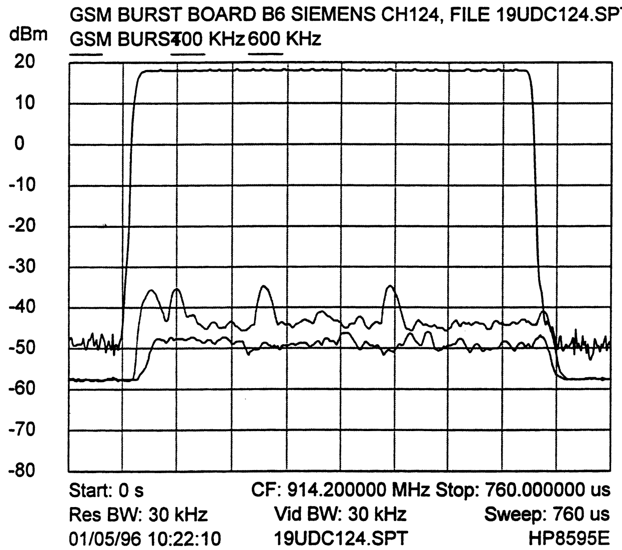


Figure 10 - 19: 5 dBm power ramp up at 902 MHz center frequency

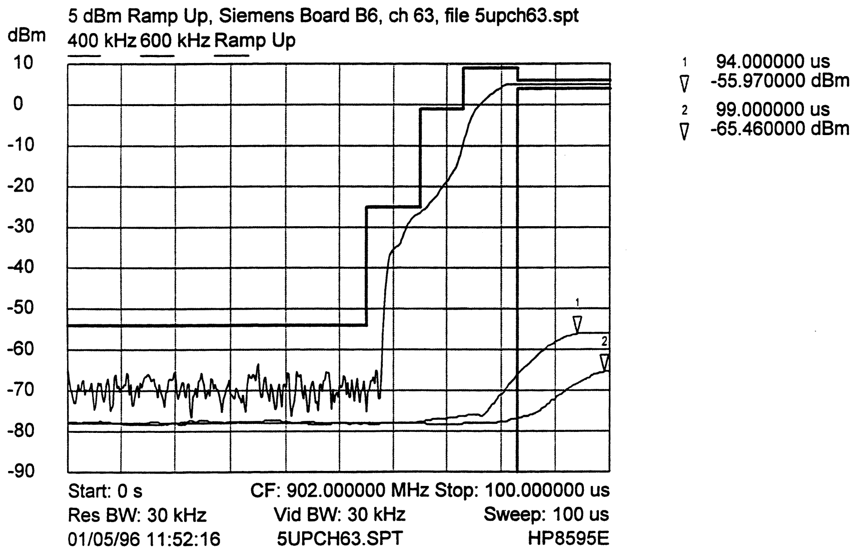


Figure 10 - 20: 5 dBm power ramp down at 902 MHz center frequency

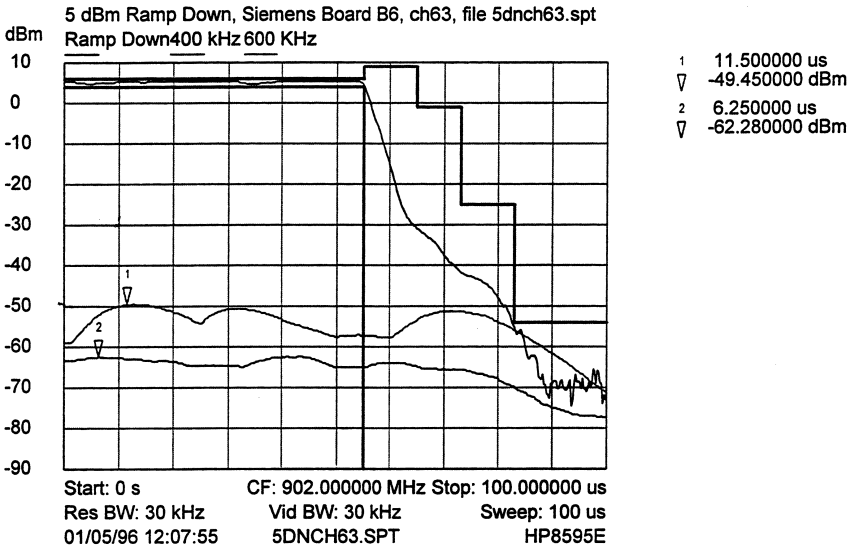


Figure 10 - 21: 5 dBm power GSM burst at 902 MHz center frequency

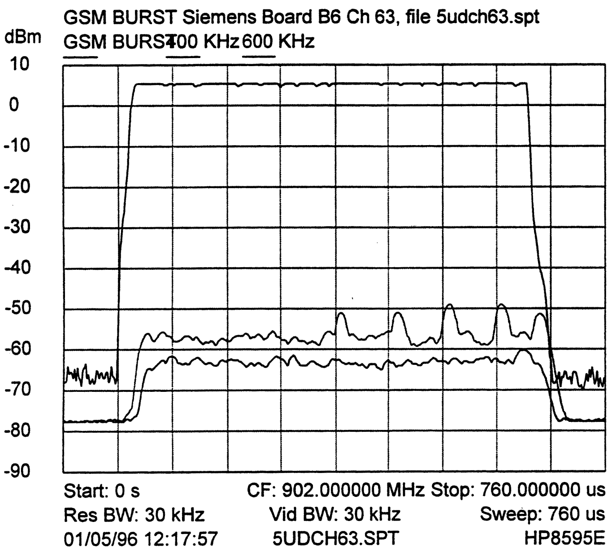


Figure 10 - 22: 5 dBm power ramp up at 889.6 MHz center frequency

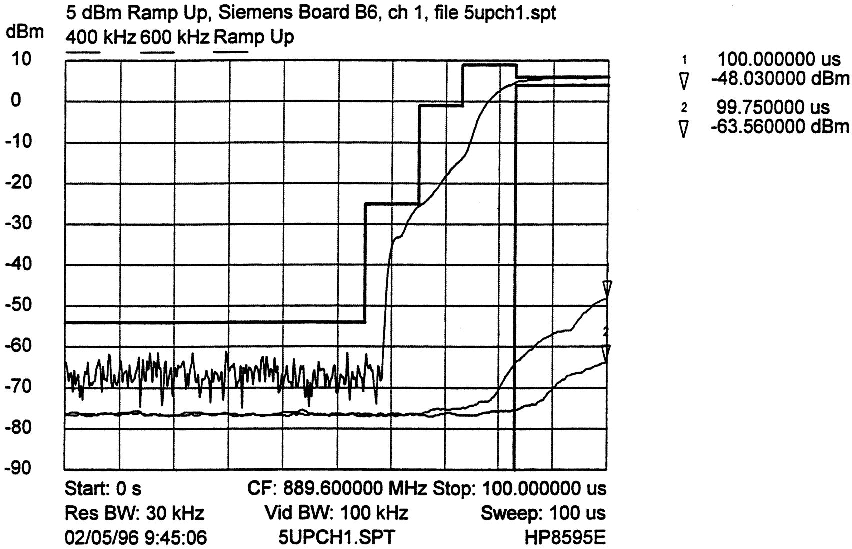


Figure 10 - 23: 5dBm power ramp down at 889.6 MHz center frequency

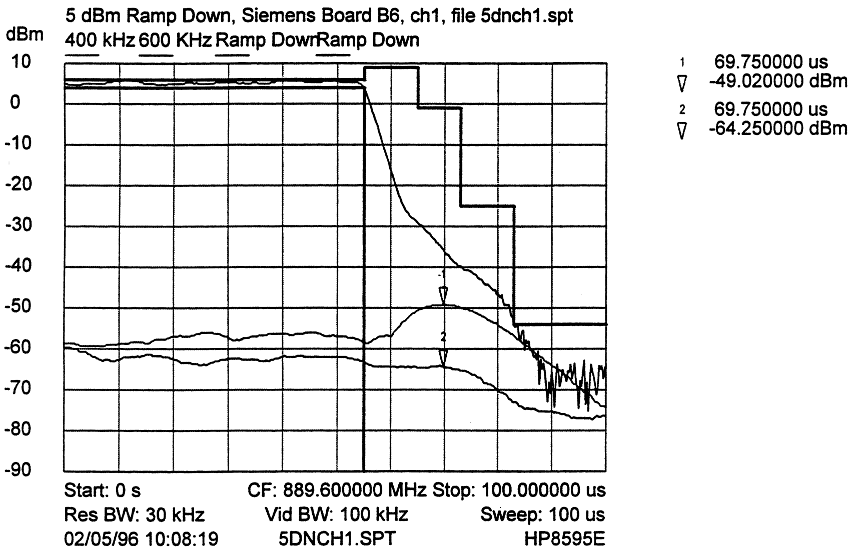


Figure 10 - 24: 5 dBm power GSM burst at 889.8 MHz center frequency

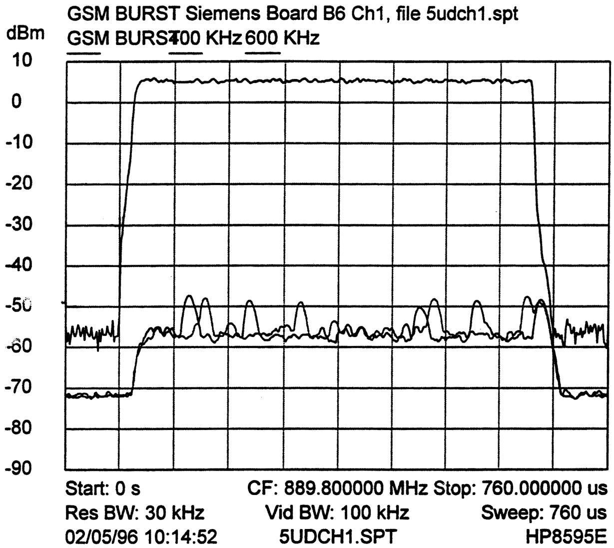


Figure 10 - 25: 5 dBm power ramp up at 914.2 MHz center frequency

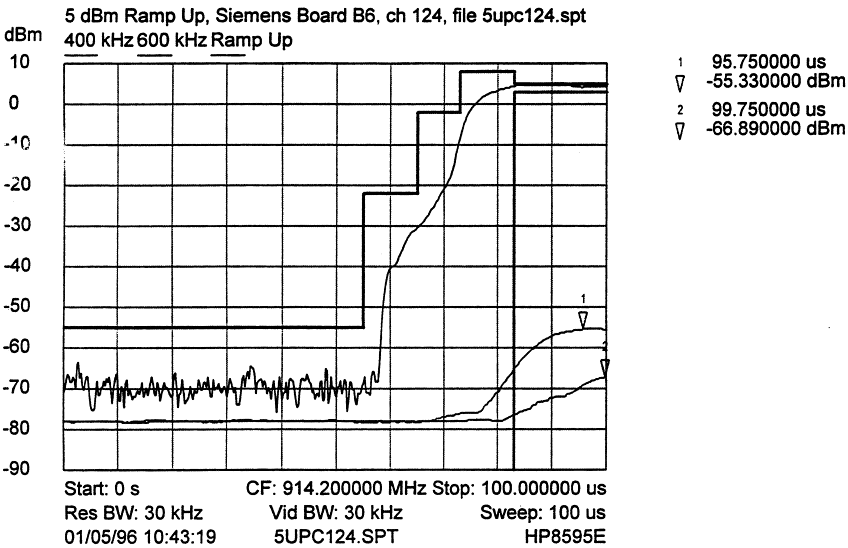


Figure 10 - 26: 5 dBm power ramp down at 914.2 MHz center frequency

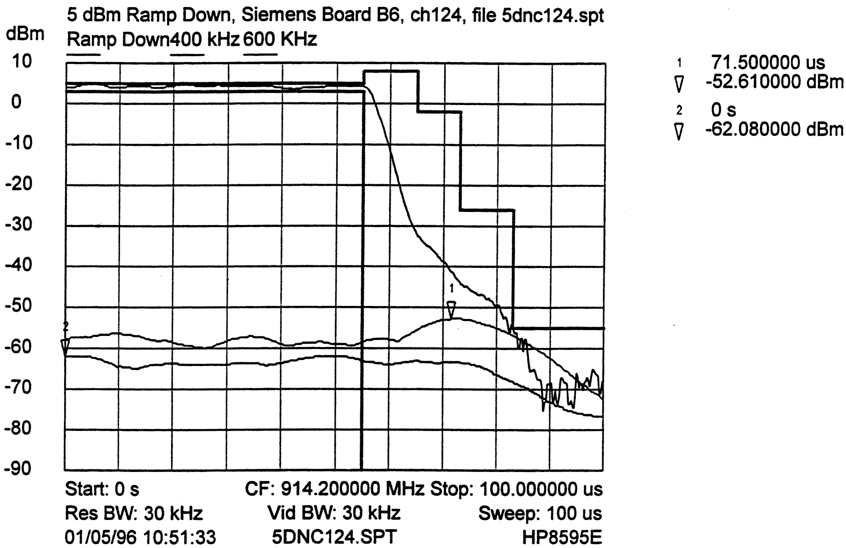
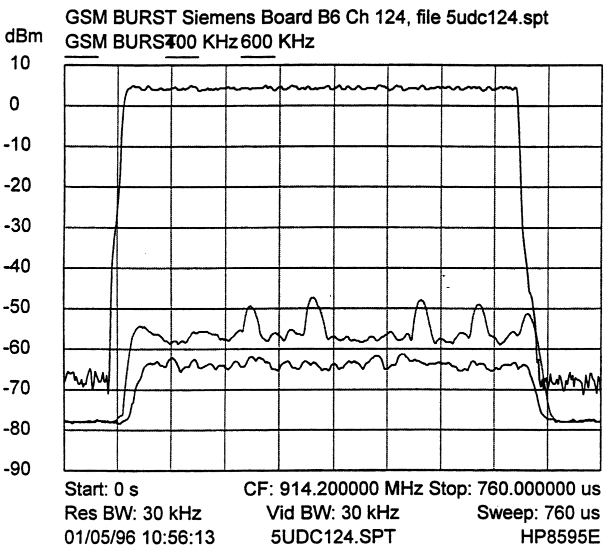


Figure 10 - 27: 5 dBm power GSM burst at 914.2 MHz center frequency



3. TRANSMIT MODULATION

The following plots show the transmitter modulation measured at the antenna connector output, at channel 63 (902.6MHz), on a vector signal analyser. They show the I/Q vector constellation, eye diagram, phase trellis, and the error table. The error table shows the phase error (rms and maximum values), the frequency error, and the IQ offset measured over the number of symbols shown, here 100 symbols.

Figure 10 - 28: TRANSMIT MODULATION, ANTENNA CONNECTOR OUTPUT, 33 dBm CH 63

Date: 02/05/96 Time: 11:46

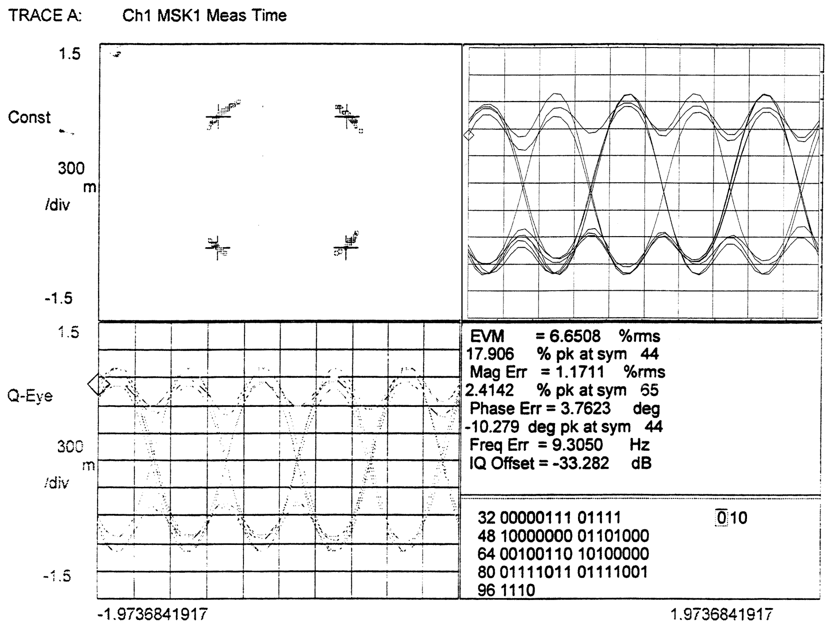


Figure 10 - 29: I/Q constellation diagram

Date: 02/05/96 Time: 11:47

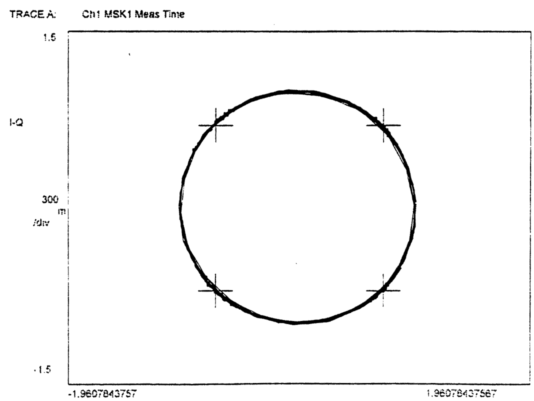


Figure 10 - 30: Eye diagram

Date: 02/05/96 Time: 11:48

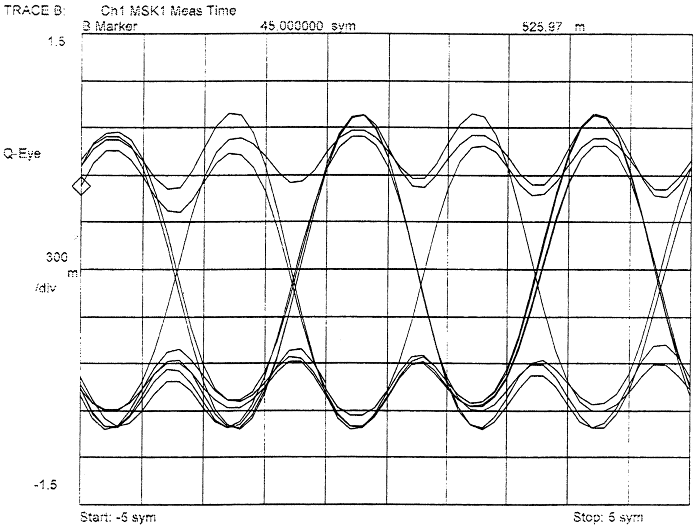


Figure 10 - 31: Phase trellis diagram

Date: 02/05/96 Time: 11:49

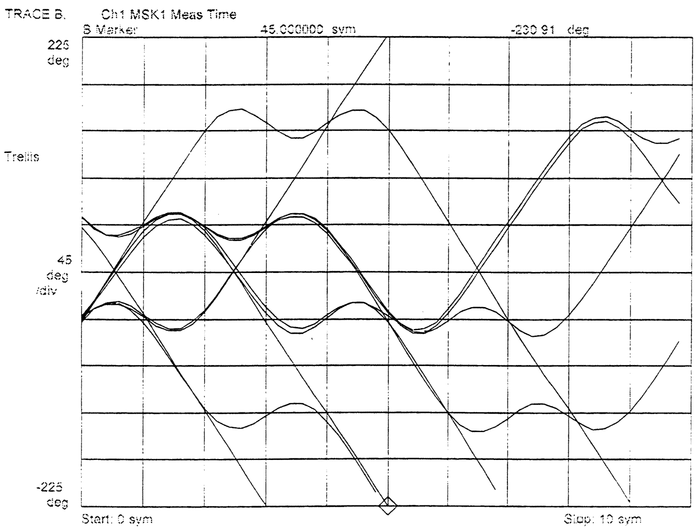


Figure 10 - 32: Error table

Date: 02/05/96 Time: 11:49

TRACE D: Ch1 MSK1 Syms/Errs
D Marker 45.00000 sym 0.0000

EVM	= 6.0580	%rms	16.408	% pk at sym	0
Mag Err	= 1.0078	%rms	-2.8111	% pk at sym	56
Phase Err	= 3.3421	deg	9.4427	deg pk at sym	0
Freq Err	= 45.762	Hz			
IQ Offset	= -31.18	dB			

0 11110010 00111100 10100001 01110110 10011001 00010 [0]11
48 00100110 10010111 11111011 10011001 10110001 11001101
96 1111

4.MODULATION SPECTRUM AND SPURIOUS EMISSIONS

The following plots are measured at the antenna connector output.
The plots of figure 10 -33, 10 - 34 and 10 - 35 show the modulation spectrum measured at channel 1, channel 63 and channel 124. The template shown is derived from the modulation transient specification GSM 11.10, section II.3.4.
Figure 10 - 36 shows a plot of the spurious emissions over a 10 MHz bandwidth.

Figure 10 - 33: Modulation spectrum at channel 1

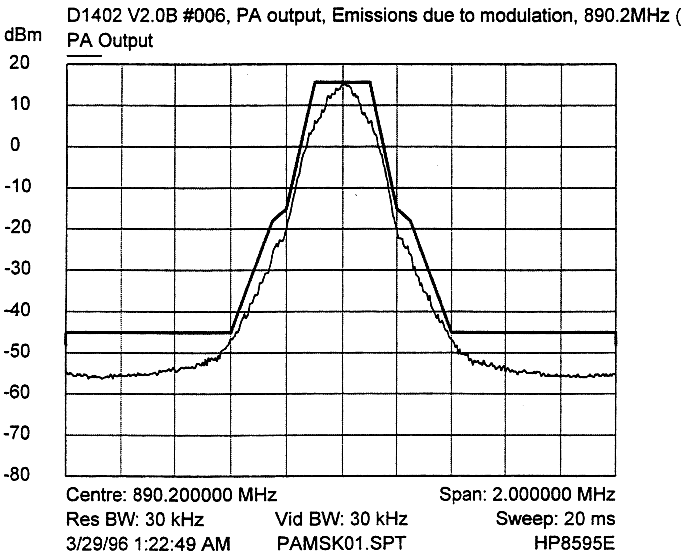


Figure 10 - 34: Modulation spectrum at channel 63

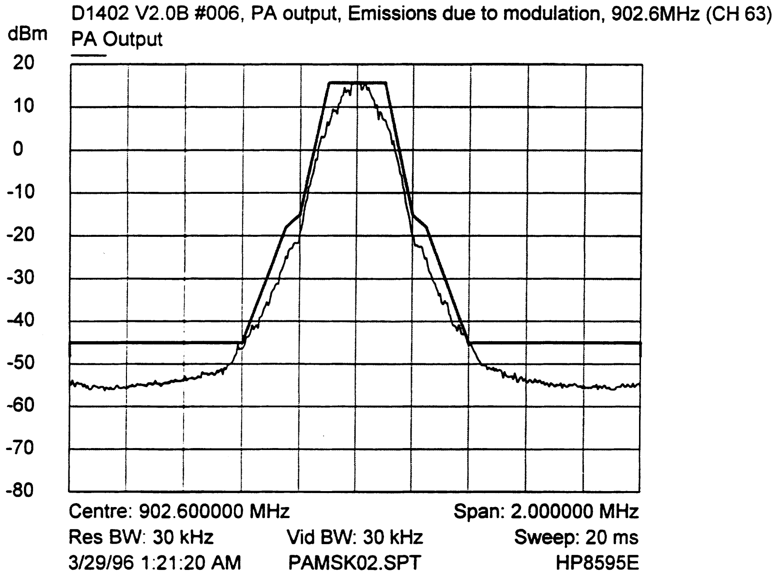


Figure 10 - 35: Modulation spectrum at channel 124

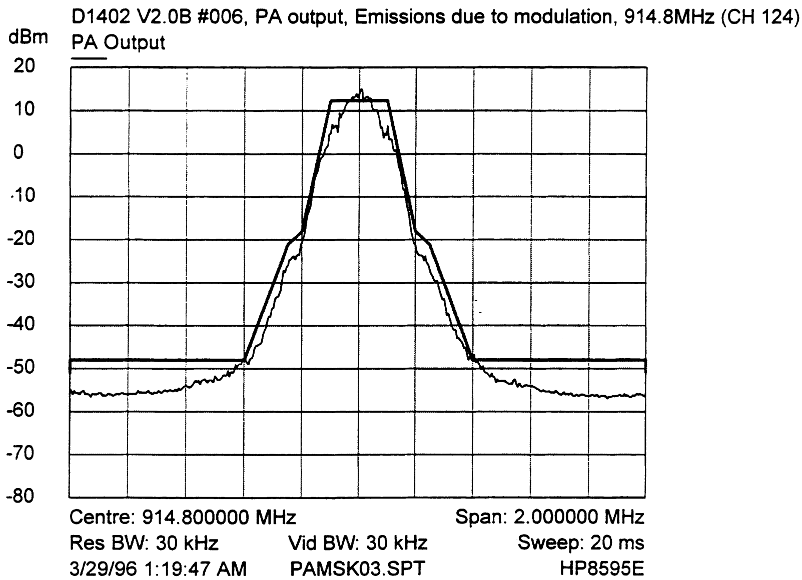


Figure 10 - 36: Spurious emmissions over 10 Mhz