MITEL SEMICONDUCTOR

AN4700

SL6619 Application Set-Up Procedure

Application Note

AN4700 - 1.1 February 1997

1. Introduction

This application note describes the correct set-up procedures and considerations to ensure that optimum performance is achieved when using the SL6619 Direct Conversion FSK Data Receiver. The analysis outlined has been based on the development by Mitel of an ***SL6619 reference pager receiver board*** which operates at 323MHz. Full details relating to the design and construction of this board are provided to give maximum assistance to customer evaluation and design using the SL6619. Factors which may potentially limit the performance of the receiver are described and suggestions are made to help isolate and overcome these issues.

The work on the SL6619 reference pager receiver board underlines how the SL6619 IC can be used to successfully obtain highly competitive performance in small form factor pagers; giving the user the well known cost benefits of direct conversion receiver methods.

2. SL6619 receiver board set-up procedure

The following is a procedure that should be followed to ensure the best possible performance is achieved in a receiver board using SL6619.

The initial set-up should be performed with the antenna and matching circuitry disconnected and replaced with a matched 50ohm input from a signal generator. See Fig. 2 (a) SL6619 reference pager receiver board schematic.

2.1. Setting the trade off between receiver sensitivity and receiver interferer performance

The local oscillator (LO) drive level and LNA gain can be set-up by the user to achieve the optimum trade off between receiver sensitivity and receiver interferer performance.

Sensitivity can be increased by increasing the LNA gain but this causes a subsequent reduction in receiver interferer performance. However, by increasing the LO drive level and reducing the LNA gain (to keep the same overall gain to the SL6619 test points TPI and TPQ) the receiver interferer performance can be improved while maintaining practically constant receiver sensitivity performance.

For the SL6619 reference pager receiver board, this was noted to be true for LO signals in the range 10mVrms to 50mVrms as measured at the SL6619 LO input pins LOIP I and LOIP Q when using the measurement technique outlined in 2.1.1. below.

The trade off between receiver sensitivity and receiver interferer performance is shown in Fig. 1(a) and Fig. 1(b). This gives results for the SL6619 reference pager receiver board with the antenna circuitry disconnected and replaced with a matched 50ohm input from a signal generator.

Fig. 1(a) and Fig. 1(b) indicate the receiver gain should be set such that the levels at the test points TPI and TPQ are 300mVpp +/-10%. Mitel suggest the LNA gain and the LO drive level in an SL6619 application should be set to give this level at the test points TPI and TPQ. The work on the SL6619 reference pager receiver board typically used a LNA gain to the mixer input pins MIXIP A and MIXIP B of approximately 18dB with a 2dB noise figure.

2.1.1. SL6619 LO drive level measurement

The amplitude level at the SL6619 LO input pins LOIP I and LOIP Q can be measured with a high impedance RF FET probe with an adjustment made for the FET probe loading. A spectrum analyser is used to display the measured voltage in dBm, assuming a 50ohm impedance level. It is highlighted that the result will not be the true LO drive level to the SL6619 as the impedance at the SL6619 LO input pins LOIP I and LOIP Q is not 50ohm.

The level at the SL6619 LO input pin LOIP I can be measured as follows:

Note: It should be ensured that the LO frequency is the same as the intended carrier frequency (for the SL6619 reference pager receiver board this is 323MHz).

i. Apply an RF input from a signal generator which is equal to the LO frequency plus the deviation frequency and is at -73dBm. If the SL6619 audio AGC circuitry is used in the application, it must be disabled by directly connecting pin GTH ADJ to pin VREG but leaving all existing circuitry connected to pins GTH ADJ and VREG.

ii. With an oscilloscope, measure the signal level at the pin TPI, call this level TPI1.

iii. With a high impedance RF FET probe measure the level at the pin LOIP I. Measure the new level at pin TPI, call this level TPI2.

iv. LO drive level (V) is:
FET probe measurement(V) * [TPI1(V) / TPI2(V)]
(Note: Making appropriate conversions for units)

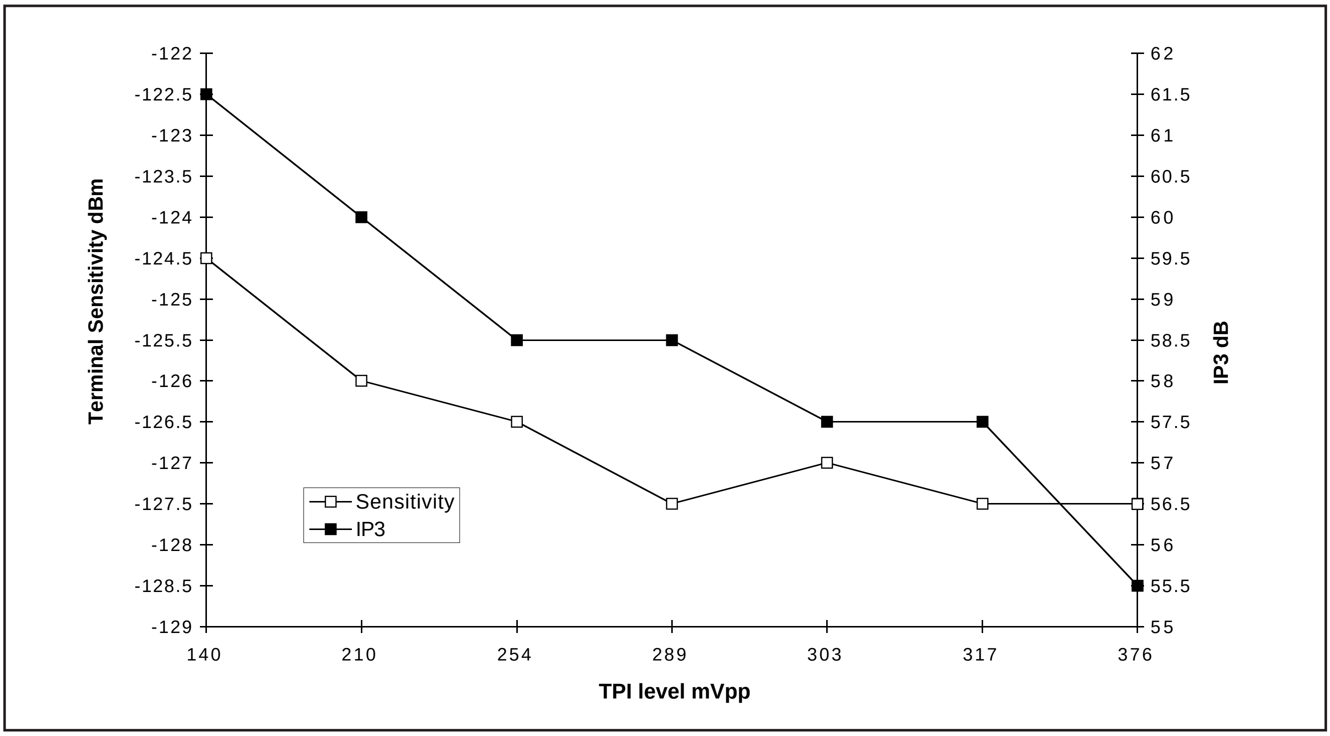


Fig.1(a) Sensitivity, IP3 vs TPI level

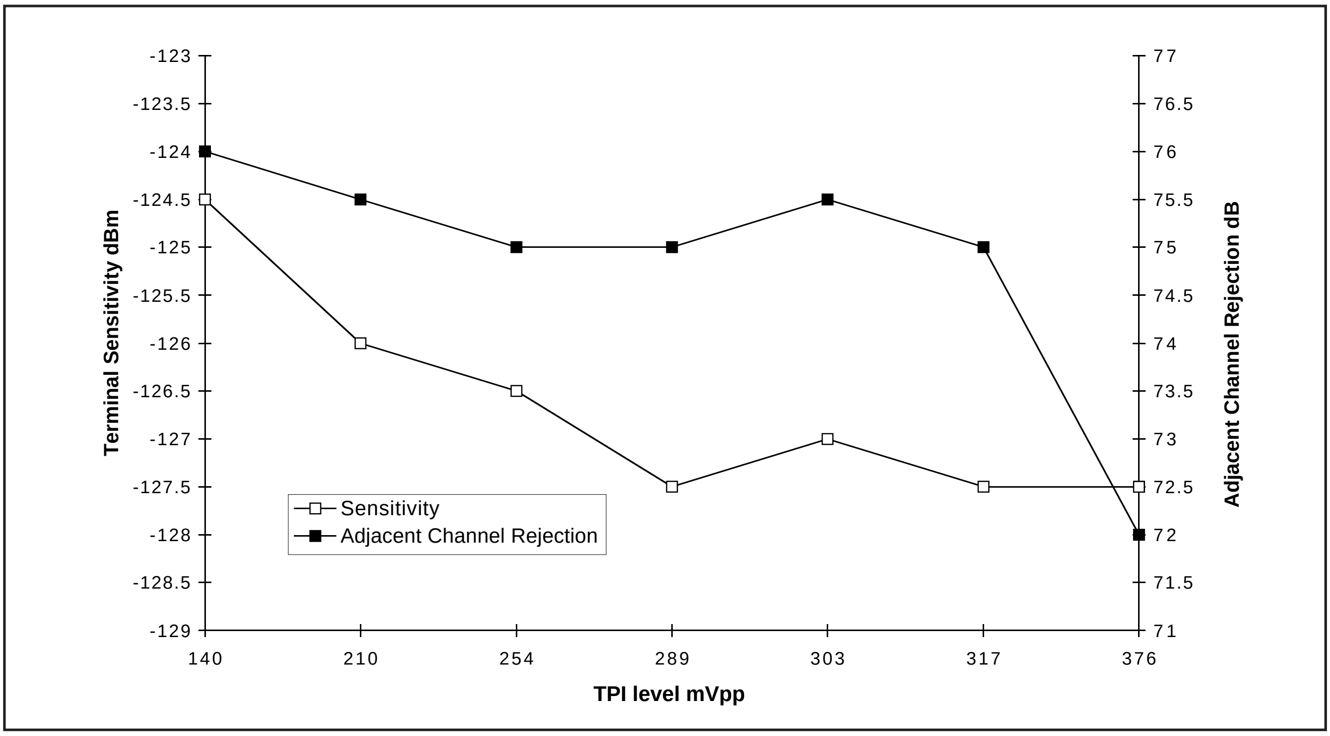


Fig.1(b) Sensitivity, Adjacent Channel Rejection vs TPI level

An example calculation is then as follows:

FET probe LOIP I measurement = -20dBm (50ohm system)
TPI1 = 280mVpp
TPI2 = 232mVpp

Actual LOIP I level:
= -20dBm + 20 log (280/232)
= -18.37dBm (50ohm system)
= 27mVrms

The LO drive level correction procedure for FET probe loading used above assumes that the SL6619 LO inputs are still being driven in their linear region, i.e. a 1dB increase in LO drive level producing a 1dB increase in receiver gain.

2.1.2. SL6619 Receiver gain measurement

The SL6619 audio AGC function must be disabled before undertaking the gain measurement described in this section. To disable the audio AGC function, connect pin GTH ADJ to pin VREG but leave all existing circuitry connected to pins GTH ADJ and VREG.

Note: It should be ensured that the LO frequency is the same as the intended carrier frequency (for the SL6619 reference pager receiver board this is 323MHz).

i. Match the receiver RF input to 50ohm.

ii. Apply an RF input from a signal generator which is equal to the LO frequency plus the deviation frequency and is at -73dBm.

iii. Using a 10:1 oscilloscope probe, measure the levels at pins TPI and TPQ. The suggested level to be set up at pins TPI and TPQ is 300mVpp - see 2.1. above. The difference in levels between the signals at TPI and TPQ should be less than 10% and should be in quadrature to within an accuracy of 10%. The signals should also be sinewaves at the same frequency as the RF input deviation frequency.

2.2. Ensuring good noise performance - SL6619 Signal To Noise Ratio Measurement

The measurement outined below can only be made on the I channel as there is no corresponding pin to TP LIM I on the Q channel.

The Signal to Noise ratio can be measured as follows:

Note: It should be ensured that the LO frequency is the same as the intended carrier frequency (for the SL6619 reference pager receiver board this is 323MHz).

i. Match the receiver RF input to 50ohm.

ii. Apply an RF input from a signal generator which is equal to the LO frequency plus the deviation frequency and is at -99dBm.

iii. With a 10:1 scope probe measure the gain at pin TP LIM I. The amplitude measured should be 120mVpp ±10mV if the receiver gain is set such that the levels at the test points TPI and TPQ are 300mVpp as outlined in 2.1 above.

iv. Turn off the RF source connected to the receiver RF input, ensuring that the receiver RF input is still terminated in 50ohm.

v. Using a 1:1 scope probe measure the amplitude of the noise at pin TP LIM I. If the receiver gain is set such that the levels at the test points TPI and TPQ are 300mVpp as outlined in 2.1 above, the maximum noise level should be less than 12mVpp. Note that this is a measurement of the absolute peak of the waveform.

Optimum sensitivity will not be achievable if the noise exceeds the expected value. See section 3. Possible Noise Problems below to try to reduce this noise level to the correct level.

vi. The receiver's RF input should now be connected and matched to an antenna and placed in a TEM cell.

vii. Assuming that the gain of the antenna in the chosen TEM cell is known, it will be possible to calculate the TEM cell RF input level that is equivalent to the -99dBm signal applied in step ii. above. Apply this level and check that the same level is observed at pin TP LIM I as in step iii. above.

Extreme care has to be taken to ensure that any connections made to the circuitry in the TEM cell have a minimum affect. If the TP LIM I signal level is not correct, it is likely that the antenna is not correctly matched to the receiver RF input, or that the LNA is oscillating (or is close to oscillation) via the antenna.

viii. Switch the TEM cell RF signal input off, and repeat step v. above, measuring the noise at pin TP LIM I. If the noise level is too high it is likely that the excess noise is being picked up by the antenna. See section 3. Possible Noise Problems below to try to reduce this noise level to the correct level.

Note: If the SL6619 receiver gain has been set such that the levels at the test points TPI and TPQ are different to the recommended 300mVpp as outlined in 2.1 above, the measured values of signal and noise at pin TP LIM I will need to be adjusted accordingly.

3. Possible Noise Problems

Great care should to be taken to minimise noise which adds to the received signal. This is because of the very low RF signal levels that a paging receiver is required to work with. The SL6619 has been designed to be a very low noise device, but care has to be taken to ensure that the pcb layout and external circuitry does not become the major noise source.

3.1. Power Supply Noise

The SL6619 is a direct conversion receiver and so the RF signal is down-converted to baseband when still at a low amplitude. Excessive noise on the power supply lines can degrade the receiver signal to noise ratio. Noise in the frequency range 500Hz to 25kHz should therefore be minimised. This can be achieved by:

- Careful supply decoupling. RC low pass power supply filters are recommended.

- Careful choice of voltage doubler/regulator to supply Vcc2. Supply filtering can be most effectively achieved if all frequency components of the voltage doubler lie outside the frequency range 500Hz to 25kHz.

- The SL6619 reference receiver board was designed to correspond with the common practice of pager manufacturers where two separate boards are constructed; the receiver board and a separate board for digital circuitry. It is preferable to place the voltage doubler/regulator circuitry on the digital board.

- Careful pcb grounding. A continuous ground-plane for good RF performance is strongly advised. Care should be taken with signal and power supply grounding. Power supply decoupling should be placed as close as possible to the SL6619 IC. RF decoupling capacitors should be placed as close as possible to the appropriate RF circuit nodes.

- Antenna grounds should be joined at one point to the ground plane. The ground plane should not run underneath the antenna.

3.2. Digital Noise Pickup.

Because of the low RF signal levels that the SL6619 receiver is required to receive, noise generated at the RF frequency by harmonics of digital signals can degrade the receiver performance by coupling in the LNA circuitry directly or via the antenna. Particular care should be taken with the SL6619 data output pin DATA OP. This problem can be minimised by:

- Using a continuous RF ground plane.

- Careful pcb layout to ensure that digital signal pins and track routing are kept away from the sensitive receiver RF front end components and the antenna.

- Using low pass filters (e.g. a capacitor) to reduce the level of the higher harmonics on digital tracks.

- Incorporating good RF decoupling on the digital board power supplies and data tracks.

- The digital decoder and LCD driver circuits can also generate harmonics that are at the same frequency as the RF frequency. The affect of this problem can be minimised by implementing a pager design where the receiver and digital circuitry are constructed on two separate boards. It is also good practice to have as much of the digital circuitry inactive during the RF paging message reception period. An example would be to delay writing to the LCD display until after the end of the RF paging message reception.

3.3. LO Re-Radiation.

In a direct conversion receiver such as SL6619, the LO frequency is the same as the incoming RF frequency. The receiver antenna is therefore tuned to the LO frequency and can easily pick up the LO signal and feed it into the receiver's RF input. This signal will then be mixed in the SL6619 with the LO signal applied directly to the SL6619 LO input pins LO IP I and LO IP Q. If the LO pickup at the RF receiver input is too large, the sensitivity of the receiver will be degraded. Both the phase and amplitude of the LO picked-up at the RF input will affect the level of receiver degradation. With worst case phasing, the level of LO signal picked up at the LNA input must be kept below -65dBm (as measured using a high impedance RF FET probe), if the receiver performance is to be unaffected.

The following guidelines should be followed to minimise LO pickup at the receiver RF inputs:

- Use a good continuous RF ground plane.

- Position the LO circuitry away from the antenna and the LNA circuitry.

- Keep the LO circuitry on the pcb as compact as possible and minimise the lengths of the tracks connecting the LO output to the receiver LO input pins LO IP I and LO IP Q.

- It is strongly recommended to use a grounded screen to cover all of the LO components.

- Ensure that there is no AM modulation on the LO caused by power supply noise. This can be achieved by powering the LO circuitry using the 1V regulator function provided on the SL6619 (pins VREG, REG CNT) and effective RF power supply decoupling. It should be ensured that decoupling is made to the appropriate AC ground, e.g. Vcc1, GND or VREF.

3.4. LNA Oscillation.

Oscillation of the LNA near the upper frequency limit of the LNA transistors can occur. This frequency is typically in the region of 1GHz to 5GHz, much higher than the received RF signal frequency. This can be caused by inadequate RF decoupling or too much circuit gain near the transistor upper frequency limit. The latter can usually be cured by adding a small capacitor to the LNA circuitry to reduce the gain near the upper frequency of the LNA transistor. On the SL6619 reference pager receiver board this is C9. This type of oscillation can be detected by observing the SL6619 mixer input pins MIX IP A and MIX IP B with a spectrum analyser that is capable of observing the 1GHz to 5GHz frequency range.

Oscillation of the LNA at the RF input frequency can occur either when the RF receiver input is connected to a 50ohm input or when an antenna is connected. If oscillation of the LNA is suspected when the RF receiver input is connected to a 50ohm input, it can usually be confirmed by checking the input match with a network analyser. If a good 50ohm match cannot be achieved it is likely that the LNA is oscillating or very close to oscillating.

If good RF receiver performance and a good RF input match are obtained when the receiver RF input is connected to a 50ohm input, but sensitivity with an antenna is slightly below the expected performance, it is possible that the LNA is oscillating, or very close to oscillating, through a feedback loop via the antenna. This is possible because the antenna and LNA output load circuitry are tuned to the RF input frequency.

The symptoms below indicate that the LNA is oscillating via the antenna:

- The receiver large signal interferer measurements (e.g. IP3) with an antenna connected are significantly worse (e.g. >2dB) than when measured with the receiver RF input matched to a 50ohm signal generator.

- The expected gain to the test points TPI and TPQ in the TEM cell is significantly different (usually higher) than that expected from the same gain measurement with the receiver RF input matched to a 50ohm signal generator input.

To minimise the possibility of LNA oscillation via the antenna, the LNA output circuitry should be placed as far as possible away from the antenna.

4. Antenna considerations

Antenna gain increases with larger enclosed loop area. Antenna gain also increases with frequency of operation. Therefore, using a larger antenna for the same frequency or the same antenna at a higher frequency should result in an improved TEM Cell Sensitivity. This assumes that the Terminal Sensitivity remains constant and that the TEM Cell Sensitivity does not become limited by an antenna noise pick-up problem such as LO re-radiation or Data O/P spikes. If such a noise problem exists then increasing the antenna loop area will make no difference to the TEM Cell Sensitivity as the Signal to Noise Ratio remains the same.

Any losses due to Low-Q components in the antenna matching network will result in a direct loss in TEM Cell Sensitivity. It is recommended to use only capacitors in the antenna to LNA matching network.

The antenna gain is also very dependant on the loop resistive loss, and at RF this resistance is dominated by skin effects. It is therefore important that the antenna is made from, or coated with, a low resistivity metal. (e.g. silver).

4.1. Measurement of antenna gain

Antenna gain can be measured with reasonable accuracy by tuning the antenna matching circuit to 50ohm and measuring the power output with the antenna mounted on the pager board and in the TEM Cell. The antenna gain is the TEM Cell input power minus the antenna output power.

For the SL6619 reference pager receiver board fitted with the larger dual-loop antenna option, this gain is approximately -20dB in the Elena ETC150F TEM Cell.

With this antenna power matched to the LNA (with no losses) the SL6619 reference pager receiver board with a terminal sensitivity of -127.5dBm (tone only) should attain a TEM Cell sensitivity of -87.5dBm assuming there are no additional noise problems introduced.

5. Audio AGC Problems

If the loop gain of the Audio AGC circuit is made too great it is liable to break into oscillation at certain input signal levels.

This usually occurs just as the PIN diode turns on, typically about 25dB above the sensitivity level. An oscillation of around 400Hz will be visible at pin TP LIM I. The loop gain can be decreased by reducing the value of R5 in Fig. 2. Note that R1 in Fig. 2 softens the turn on of D1.

6. SL6619 reference pager receiver board

Comprehensive details relating to the design and construction of the SL6619 reference pager receiver board are provided to give maximum assistance to customer evaluation and design using the SL6619. Fig. 2(a) and (b) show the circuit schematic and component list. Fig. 3 (a) to (e) shows the 3 layer pcb layout and silkscreens.

The SL6619 reference receiver board has been designed to accomodate 2 antenna options as shown in Fig. 4 (a) and (b).

The TEM Cell Sensitivity of the SL6619 reference receiver board is antenna limited. Sensitivity is noted to improve with an increase in antenna loop area.

6.1. Key points: SL6619 reference pager receiver board layout and construction

Specific points to note on the pcb layout and construction of the SL6619 reference pager receiver board are as follows:

- Careful RF layout and positioning on the pcb. Care was taken with the ground plane connections of the capacitors directly associated with the antenna circuitry.

- The use of a three layer PCB with the middle layer used exclusively to provide a continuous RF ground plane.

- The compact LO circuitry layout; short track length of the LO signal lines to pins LOIP I and LOIP Q. Provision for a full screen over the LO circuitry. The LO circuitry has been powered using the 1V regulator function provided on the SL6619.

- LNA output load circuitry has been positioned away from the antenna.

- The output track from the data output pin DATA OP is positioned away from the antenna.

- Special attention to RF decoupling.

- Antenna grounds joined to one ground plane point.

6.2. SL6619 reference pager receiver board performance

The typical performance of this board is shown in Table 1. below. The measurements were carried out at room temperature and with the following operating voltages:

i. Vcc1 1.5V
ii. Vcc2 3.0V

Different operating conditions will cause minor changes to the results obtained.

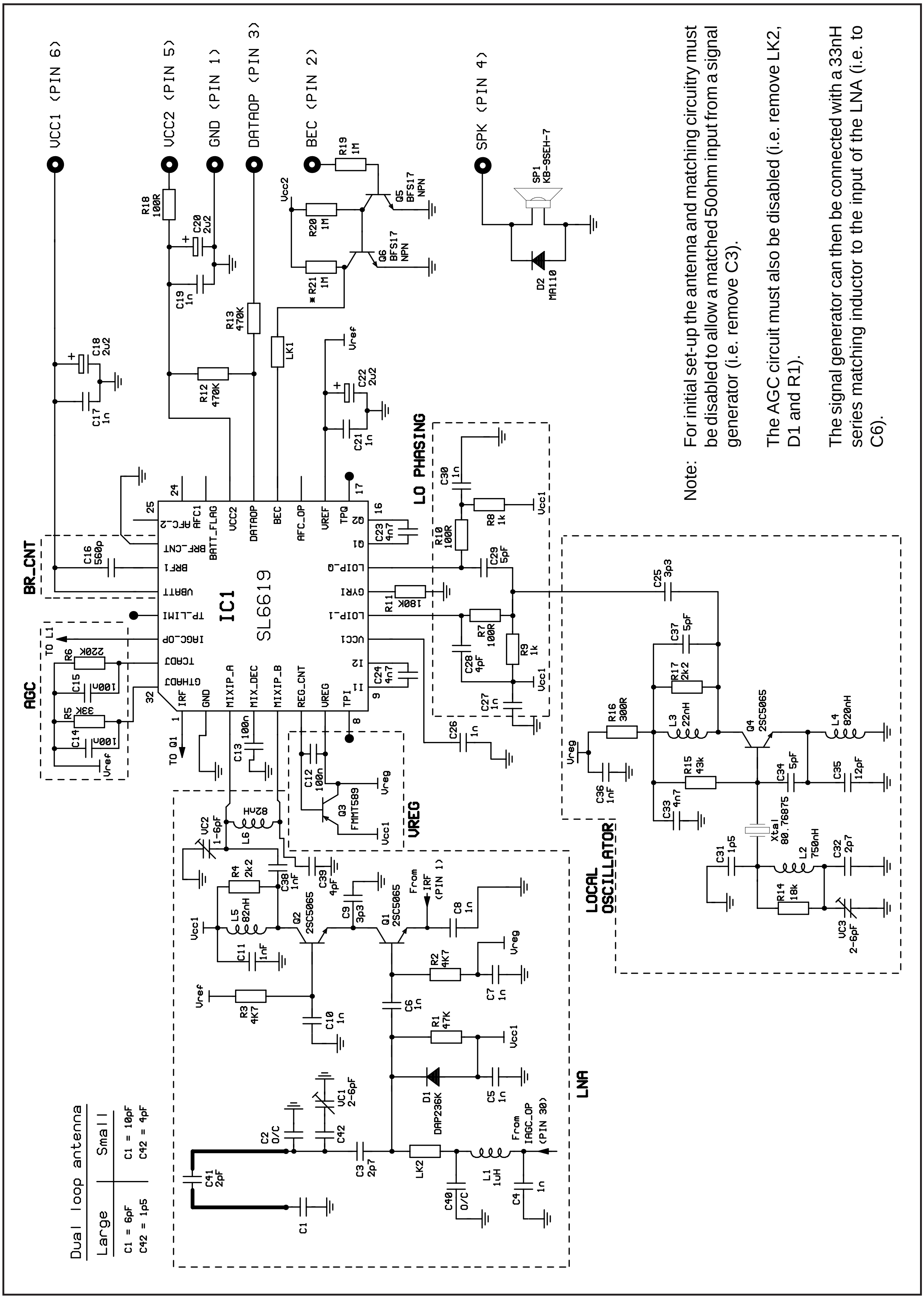
The measurements used an Elena ETC150F TEM cell with the SL6619 reference pager receiver board fitted to a digital board of a standard pager design. The Elena ETC 150F TEM cell system has a 20dB attenuator connected to the TEM cell input and the TEM cell power inputs quoted below are the values before the 20dB attenuator. The level applied to the actual TEM cell is therefore 20dB lower. The TEM cell calibration allows for a 6dB body effect.

Measurement Conditions:

Frequency 323MHz, Deviation Frequency 4.5kHz, Data Rate 1200bps, Vcc1 1.5V and Vcc2 3.0V.

Measurement		**Matched 50ohm Sig. Gen Input No AGC**	**Dual Loop Antenna - see Fig.4(a)**	**Comments**
Sensitivity		-127.5dBm	a) -88.5dBm b) -88.0dBm	Antenna performance includes correction for 6dB body effect. 15 charecter message. a) No AGC b) With AGC
IP2	above below	60dB 58.5dB	59dB 58dB	AGC connected.
IP3	above below	59dB 58dB	58dB 57dB	AGC connected.
Adjacent Channel Rejection	above below	75.5dB 74.5dB	74.0dB 73.5dB	AGC connected.
Centre Frequency Acceptance	above below	2.7kHz 2.7kHz	2.7kHz 2.7kHz	AGC connected.
Deviation Frequency Acceptance	above below	2.8kHz 2.5kHz	2.8kHz 2.5kHz	AGC connected.
Level at pin TPI (see section 2.1.2.)		289mVpp		RF input level of -73dBm, with the RF offset from the LO frequency by 4.5kHz. Antenna removed and the receiver RF input matched to 50ohm signal generator output. AGC function disconnected.
Level at pin TPQ (see section 2.1.2.)		284mVpp		RF input level of -73dBm, with the RF offset from the LO frequency by 4.5kHz. Antenna removed and the receiver RF input matched to 50ohm signal generator output. AGC function disconnected.
LO Drive Level at pin LOIP I (see section 2.1.1.)		27mVrms	27mVrms	
LO Drive Level at pin LOIP Q (see section 2.1.1.)		27mVrms	27mVrms	
Level at pin TP LIM I (see section 2.2.)		120mVpp		RF input level of -99dBm, with the RF offset from the LO frequency by 4.5kHz. Antenna removed and the receiver RF input matched to 50ohm signal generator output. AGC function disconnected.
Peak noise measured at pin TP LIM I (see section 2.2.)		11.9mVpp		Signal generator output switched off but still terminated in 50ohm. AGC function disconnected.
Level at pin TP LIM I (see section 2.2.)			100mVpp	Elena ETC150F TEM Cell system input level of -64dBm (corresponds to xxxuV/m actual field strength). AGC function disconnected.
Peak noise measured at pin TP LIM I (see section 2.2.)			9mVpp	Antenna and matching circuitry connected. AGC function connected.

Table 1. Typical performance of the SL6619 reference pager receiver board.



Note: For initial set-up the antenna and matching circuitry must be disabled to allow a matched 50ohm input from a signal generator (i.e. remove C3).

The AGC circuit must also be disabled (i.e. remove LK2, D1 and R1).

The signal generator can then be connected with a 33nH series matching inductor to the input of the LNA (i.e. to C6).

Fig.2(a) SL6619 reference pager receiver board schematic

Component List SL6619 reference pager receiver board.

Side of pcb is indicated.

Component	Value	Comments
C1 (bottom)	*6pF	Antenna tune circuit
C2 (top)	O/C	Antenna tune circuit
C3 (top)	2p7	Antenna matching
C4 (bottom)	1nF	Decoupling
C5 (top)	1nF	Decoupling
C6 (top)	1nF	DC block
C7 (top)	1nF	Decoupling
C8 (top)	1nF	Decoupling
C9 (top)	3p3	LNA stabilizing
C10 (top)	1nF	Decoupling
C11 (bottom)	1nF	Decoupling
C12 (top)	100nF	Vreg capacitor
C13 (top)	100nF	Mixer decouple
C14 (top)	100nF	AGC circuit
C15 (top)	100nF	AGC circuit
C16 (top)	560pF	Bit rate filter
C17 (top)	1nF	Decoupling
C18 (bottom)	2m2	Decoupling
C19 (top)	1nF	Decoupling
C20 (bottom)	2m2	Decoupling
C21 (top)	1nF	Decoupling
C22 (bottom)	2m2	Decoupling
C23 (top)	4n7	ACR filter (Q chan)
C24 (top)	4n7	ACR filter (I chan)
C25 (bottom)	3p3	LO matching
C26 (top)	1nF	Decoupling
C27 (bottom)	1nF	Decoupling
C28 (bottom)	4pF	LO phase shift network
C29 (bottom)	5pF	LO phase shift network
C30 (bottom)	1nF	Decoupling
C31 (bottom)	1p5	LO stabilizing
C32 (bottom)	2p7	LO circuit
C33 (bottom)	4n7	Decoupling
C34 (bottom)	5pF	LO circuit
C35 (bottom)	12pF	LO circuit
C36 (bottom)	1nF	Decoupling
C37 (bottom)	5pF	LO circuit
C38 (top)	1nF	DC block
C39 (top)	4pF	Mixer i/p LC network
C40 (top)	O/C	(AGC circuit 1nF)
C41 (bottom)	2pF	Antenna match
C42 (bottom)	*1p5	Antenna match
L1 (bottom)	1uH	LNA AGC inductor
L2 (bottom)	750nH	LO circuit
L3 (bottom)	22nH	LO circuit
L4 (bottom)	820nH	LO circuit
L5 (bottom)	82nH	LNA inductor
L6 (bottom)	82nH	Mixer i/p LC network
VC1 (bottom)	2-6pF	Antenna match
VC2 (bottom)	2-6pF	Mixer i/p tune
VC3 (bottom)	2-6pF	LO frequency tune

Component	Value	Comments
R1 (top)	47k	AGC circuit
R2 (top)	4k7	LNA bias
R3 (top)	4k7	LNA bias
R4 (top)	2k2	LNA gain adjust
R5 (top)	33k	AGC circuit
R6 (top)	220k	AGC circuit
R7 (bottom)	100R	LO phase shift network
R8 (bottom)	1k	LO phase shift network
R9 (bottom)	1k	LO phase shift network
R10 (bottom)	100R	LO phase shift network
R11 (top)	180k	Gyrator current adjust
R12 (top)	470k	Data o/p pull up
R13 (top)	470k	Data o/p series resistor
R14 (bottom)	18k	LO circuit
R15 (bottom)	43k	LO biasing resistor
R16 (bottom)	300R	LO biasing resistor
R17 (bottom)	2k2	LO o/p level adjust
R18 (top)	100R	Reduce Vcc2 noise
R19 (top)	1M	Battery Economy
R20 (top)	1M	Battery Economy
R21 (top)	1M	Battery Economy (short to Vcc2 for test)
Q1 (top)	2SC5065	LNA transistor
Q2 (top)	2SC5065	LNA transistor
Q3 (top)	FMMT589	Vreg PNP transistor
Q4 (bottom)	2SC5065	LO transistor, Toshiba
Q5 (top)	BFS17	npn transistor
Q6 (top)	BFS17	npn transistor
XTAL (bottom)	80.76875MHz 3rd o/t crystal	
D1 (top)	DAP236K	AGC diode
D2 (top)	MA110	Speaker diode
LK1 (top)		Link (Bat Econ circuit)
LK2 (top)		Link (AGC circuit)
SP1 (bottom)	KB-9SEH-7	Speaker
IC1 (top)	SL6619	32 pin TQFP
CONN 1 (bottom)		6 pin male connector block, 2mm, Gold plate

* Small dual loop antenna, C1 = 10pF, C42 = 4pF

Fig.2(b) Component List SL6619 reference pager receiver board

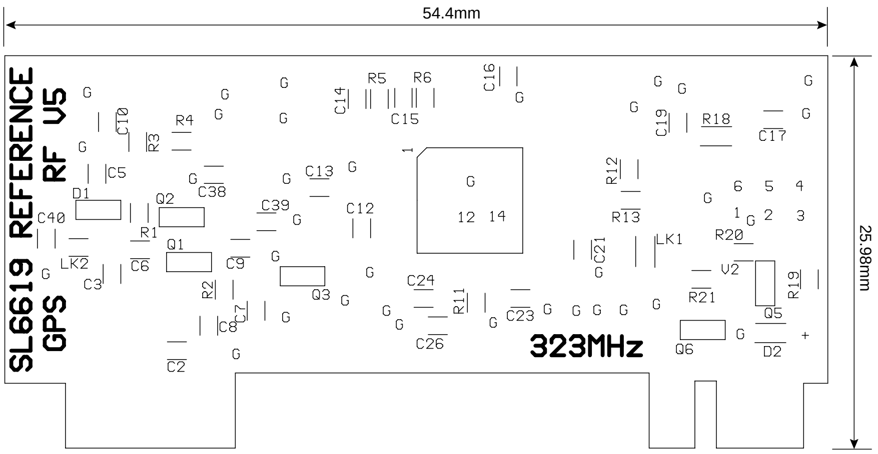


Fig.3(a) SL6619 reference pager receiver board - Top silkscreen
(NOT SHOWN TO SCALE)

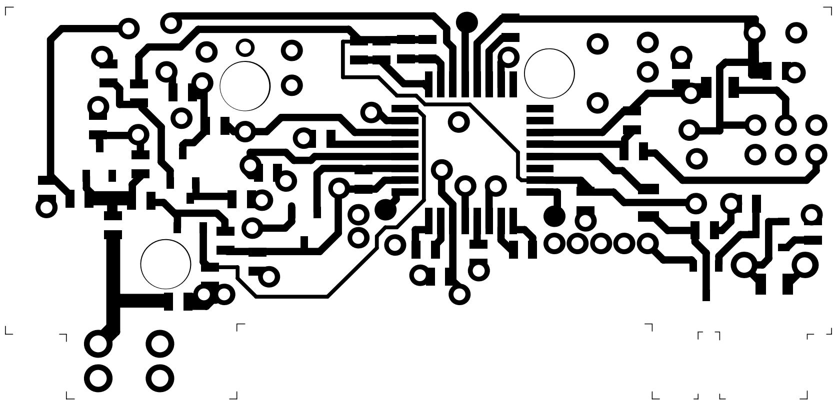


Fig.3(b) SL6619 reference pager receiver board - Top copper
(NOT SHOWN TO SCALE)

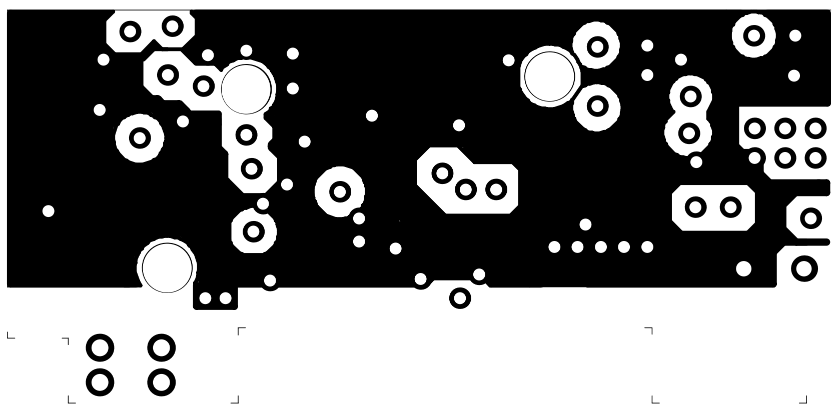


Fig.3(c) SL6619 reference pager receiver board - Centre ground
(NOT SHOWN TO SCALE)

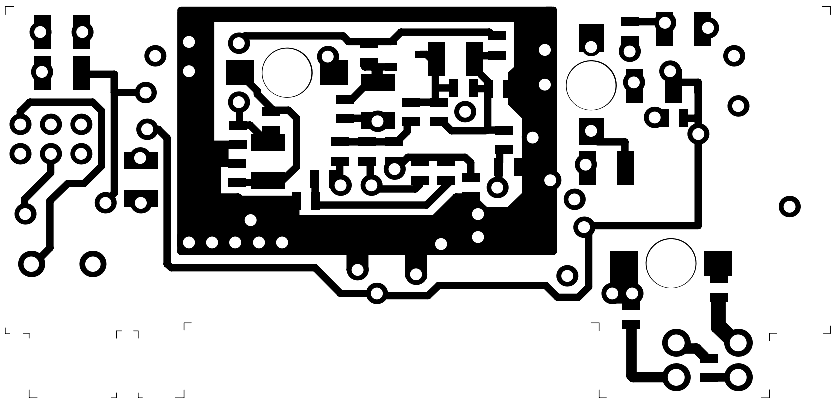


Fig.3(d) SL6619 reference pager receiver board - Bottom copper
(NOT SHOWN TO SCALE)

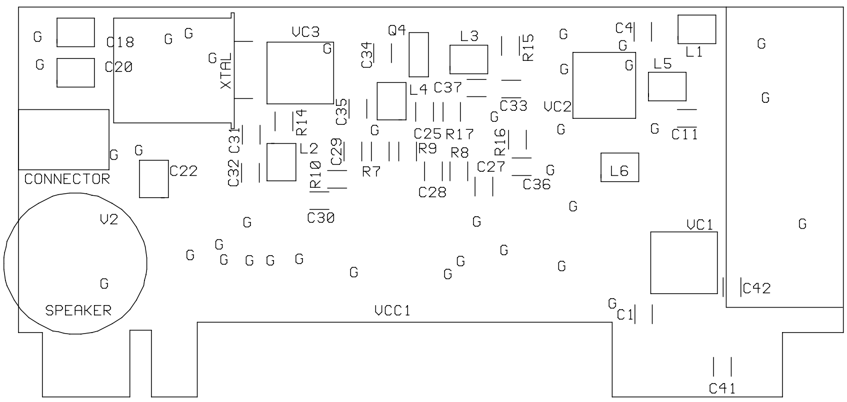
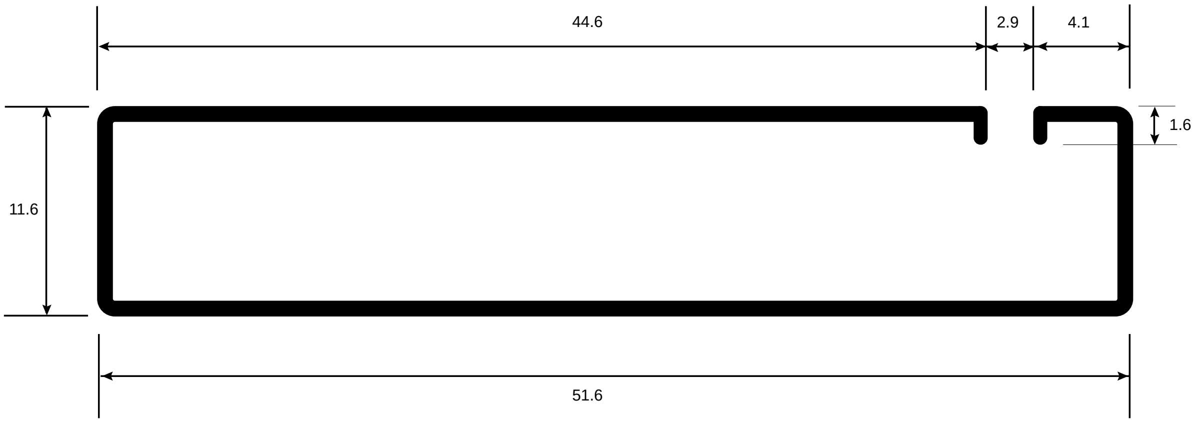
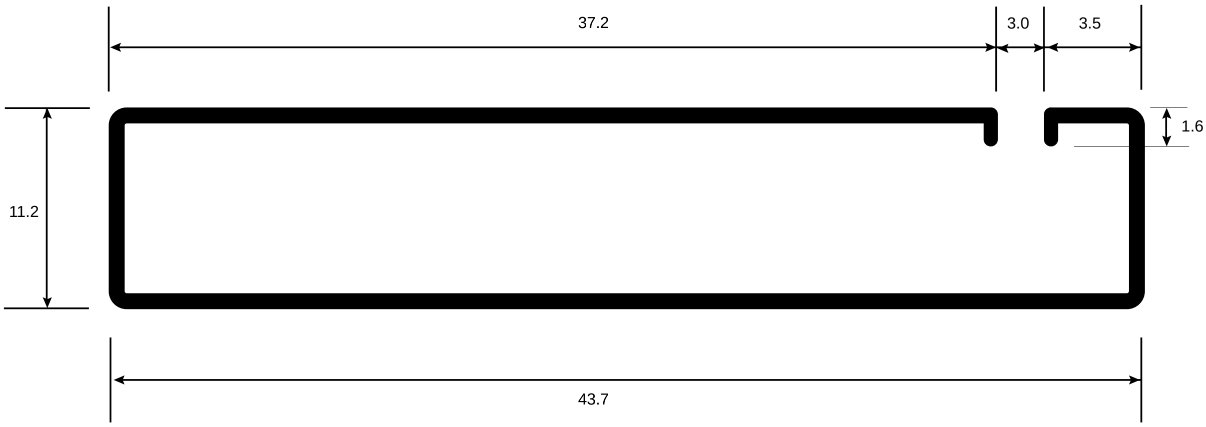


Fig.3(e) SL6619 reference pager receiver board - Bottom silkscreen
(NOT SHOWN TO SCALE)



Both loops are the same size.
Dimensions: mm
Material: 1mm diameter copper wire, Gold plated.

Fig.4(a) Large dual loop antenna



Both loops are the same size.
Dimensions: mm
Material: 1mm diameter copper wire, Gold plated.

Fig.4(b) Small dual loop antenna

HEADQUARTERS OPERATIONS
MITEL SEMICONDUCTOR
Cheney Manor, Swindon,
Wiltshire SN2 2QW, United Kingdom.
Tel: (01793) 518000
Fax: (01793) 518411

MITEL SEMICONDUCTOR
1500 Green Hills Road,
Scotts Valley, California 95066-4922
United States of America.
Tel (408) 438 2900
Fax: (408) 438 5576/6231

Internet: http://www.gpsemi.com
CUSTOMER SERVICE CENTRES

- **FRANCE & BENELUX** Les Ulis Cedex Tel: (1) 69 18 90 00 Fax : (1) 64 46 06 07
- **GERMANY** Munich Tel: (089) 419508-20 Fax : (089) 419508-55
- **ITALY** Milan Tel: (02) 6607151 Fax: (02) 66040993
- **JAPAN** Tokyo Tel: (03) 5276-5501 Fax: (03) 5276-5510
- **KOREA** Seoul Tel: (2) 5668141 Fax: (2) 5697933
- **NORTH AMERICA** Scotts Valley, USA Tel: (408) 438 2900 Fax: (408) 438 5576/6231
- **SOUTH EAST ASIA** Singapore Tel:(65) 3827708 Fax: (65) 3828872
- **SWEDEN** Stockholm Tel: 46 8 702 97 70 Fax: 46 8 640 47 36
- **TAIWAN, ROC** Taipei Tel: 886 2 25461260 Fax: 886 2 27190260
- **UK, EIRE, DENMARK, FINLAND & NORWAY**
  Swindon Tel: (01793) 726666 Fax : (01793) 518582

These are supported by Agents and Distributors in major countries world-wide.