RF test kits and SA1000 analyser and Software

User Guide

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LAPLACE INSTRUMENTS LTD

WARNING

EMC emissions measurements and the use of RF spectrum analysers require specialist expertise and users must be aware of several 'non-obvious' precautions. Unless you are already familiar with these specific topics it is most important to read this instruction manual fully before using the equipment otherwise erroneous or misleading results many be obtained.

LAPLACE INSTRUMENTS LTD
3B Middlebrook Way
Holt Road, Cromer
Norfolk, NR27 9JR

Tel: +44 (0) 1263 515160
Fax: +44 (0) 1263 512532

Website: http://www.laplace.co.uk
e-mail: tech@laplace.co.uk

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12.0 INDEX

STOP!

YOU MAY BE KEEN TO START USING YOUR NEW EMC TEST SYSTEM AND HAVE NO WISH TO SPEND ‘WASTED’ TIME READING THIS MANUAL.....

HOWEVER....

BEFORE YOU BEGIN TO USE THE EQUIPMENT, READ THE SECTIONS LISTED BELOW AS AN ABSOLUTE MINIMUM. IT WILL SAVE TIME AND FRUSTRATION LATER ON!

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1.0 Specification

SA1000

HARDWARE

Frequency range	10KHz - 1100MHz
Start & stop frequencies	Infinitely variable
Sensitivity	> -90dBm (17dBuV)
With SA1020 pre-amp	> -105dBm (2dBuV) at 500MHz
Flatness	±4dB
Max. RF input (50R)	3dBm (110dBuV)
Spurious responses	>40dB down from fundamental
Scan rate	Variable, min 10secs
Overload:	Overload detector at input.
Input protection	Diode clamped, 1.6V pk-pk max.
Bandwidth - narrow	9KHz (<30MHz)
- wide	120KHz (>30MHz)
Input dynamic range (no compression)	HF range: 70dB min LF range: 70dB min
RF attenuator	0, -10, -20, -30dB
Modes	Spectrum: instantaneous, average, quasi-peak and peak Single freq.: Instantaneous, average and quasi-peak.
Calibration output:	10MHz @ 30dBuV square wave
Horizontal scale modes	Frequency (Log and Lin scaling), Time trend (single freq mode)
Special modes:	Site attenuation calibration in conjunction with ERS.
Audio demodulator	Slope demodulation Internal loudspeaker
Control interface:	PC serial interface on rear panel
Control software:	Windows application software, Compatible with any colour screen PC running Windows
Connectors:	BNC RF input BNC calibration signal output
Indicators:	Power on LED
Input power	230V 50Hz, 40W
Factory set option	115V 60Hz.
Physical	
Dimensions 305 wide x 270 deep x 115 mm	
Weight	5kg

SA1020

Bandwidth (nom)	10KHz - 1GHz
Gain	20dB
Gain accuracy	±3dB
Noise*	3dB (degradation of S/N Ratio)
Max. safe input	0dBm (220mV)
Input impedance	50R
Max. Output into 50R	0.5 volt pk-pk
Output impedance	50R
Power	9V PP3 battery
Consumption	35mA

* typical

PC Software, additional functions:

Scaling:	Vert:	dBuV, dBm, dBuV/m, dBuA
	Horiz:	Spectrum mode: KHz, MHz (variable), Log or Lin scale Single freq mode: mSec, sec (variable)
Traces:		Current (signal currently acquired) Stored (background copied from current) Difference (Current - Stored) Archive (Any trace from disk) Limit (All common limits included)
Cursor readout:		Digital readout of all traces with level and frequency.
Background nulling:		Automatic. In either average or peak processing modes.
Limits		EN55011/14/15/22, EN50081, EN60945, FCC and NZ/AS limits User may enter own limits (Automatic interpolation)
Compensation:		Antenna factor compensation for all Laplace accessories User may enter own compensation data.
ERS correction		Mode to enable ERS to calibrate for site attenuation
Analyser controls:		Start/stop frequency (cursor or numeric entry) Bandwidth (automatic) Detector: Peak, Average or Quasi-peak Attenuator setting Sweep resolution (100, 250, 500 points) Single frequency mode (inst. Ave, QP) Single frequency control Single frequency update rate (0.05, 0.1, 0.2 sec)
Analyser status:		Operating: Active, overload, calibrating, busy, ERS calibration Error: Not connected, not active, fault
Output:	To disk:	All measurements stored in file with standard ASCII format.
	Printer:	Standard Windows printer interface, mono and colour printers supported.
	Other:	Clipboard to other applications. Screen dump. Read files into spreadsheets etc...

LISN16A1P

Max current:	16A continuous
Max Voltage:	264V, AC to 400Hz
LF Resistance:	135 mohm
Power outlet:	National mains outlet socket plus 4mm shrouded sockets.
Impedance Network:	to CISPR16
I/P Imp. Variation:	±20% 150KHz-30MHz (CISPR 16 Spec.)
Measurement cct. Attenuation:	-30dB Nom. Calibration factor ±1.5dB variation 150KHz - 30MHz
Source selection:	By connector
Pre-amplifier:	External.
Gain:	30dB.
Power:	Separate mains plug-top supply.
Output RF Connector:	50R BNC
Artifical hand:	220pF + 500R

Physical:	Weight:	3.5kg
	Size(mm):	300 x 180 x 90

RF100 Near field probes

H field loop antenna

Type:	Balanced faraday loop
Diameter:	50mm

E field antenna

Type:	Monopole
Monopole length:	10mm
Overall length:	250mm

Common specifications

Insulation rating:	240v
Connector:	50R BNC

RF200 Broadband antenna

Frequency range:	30MHz - 1GHz.	
Antenna Factor:	Similar to tuned dipole. Curve issued with each antenna. Data pre-loaded into SA1000 software supplied with Laplace EMC kits	
Calibration:	Tested at NPL free space antenna test facility.	
Ancillaries:	SA1020 Pre-amplifier.	
Type:	Modified Log periodic.	
Size:	Length	1.7m.
	Max. width	1.6m.

Stand:

Construction	Tubular Fibreglass/epoxy supports and moulded plastic fittings.
Adjustable Height:	1.1m to 2.1m.
Antenna orientation:	Vertical or Horizontal

RF300 Large Loop antenna

Fully compliant with EN55015 (CISPR15)

No. of loops:	3 orthogonal axes
Loop diameter	2 metres
Frequency range	10KHz - 30MHz
Antenna factor	Supplied with each RF300.
RF pickup	Transformer coupled
Loop selection	Via patch panel
Includes	Wooden frame All cables and output lead Qty 3 current transducers User guide

RF400 RF absorbing clamp

Fully compliant with EN55014 (CISPR16)

Frequency range	30 MHz - 1GHz
Internal diameter	18mm
Core type	Split, sprung both sides Individually replaceable
Motion	100mm dia rubber wheels
Includes	5 metre output cable 6 metre mains cable User guide Antenna factor correction data

RF500 Dipole

Antenna Type:	Tuned Dipole
Tuned Freq. Range:	80MHz - 265MHz
Adjustment:	Telescopic
Output:	50R BNC
Stand:	Tubular steel, adjustable.

RF600 FM band filter

In line BNC - BNC notch filter unit

Filter band	70 - 120MHz (3dB points)
Stop band Attenuation	>40dB (80 - 105MHz)
Pass band attenuatn	< 2dB
Power	Non required
Size	30 x 30 x 90 (over connectors)
Connectors	BNC socket - BNC plug

RF700 Low frequency rejection filter

In line BNC - BNC high pass filter unit

Cut-off frequency	30MHz (3dB point)
Stop band Attenuatn	>60dB (<10MHz)
Pass band attenuatn	< 2dB (>35MHz)
Power	Non required
Size	30 x 30 x 90mm (over connectors)
Connectors	BNC socket - BNC plug

RF800 Band B selector filter

In line BNC - BNC band pass filter unit

Pass band:	150KHz - 30MHz
Stop band Attenuatn	>40dB (<50KHz, >50KHz)
Pass band attenuatn	< 2dB
Power	Non required
Size	135 x 40 x 35mm (over connectors)
Connectors	BNC socket - BNC plug

RF900 and RF910 Band B Pre-selectors

Manual and automatic multi-band pre-selectors

Type	RF900	RF910
Operation	manual Push buttons	Automatic via serial port
Range	150KHz-30MHz	150KHz-30MHz
Bands	7	8
In/Out impedance	50R	50R
In/Out connectors	BNC	BNC
Insertion loss	4dB	4dB
Stop band atten.	>40dB	>40dB
Filter slope	5 + 9 pole	5 + 5 pole
Indication	Switch tell tales	LED indicators
Power	None required	12Vdc (mains adapter supplied)
Size	31 x 11 x 26cm	31 x 11 x 26cm

PLIP Power line interference probe

Voltage probe with safety isolation and amplifier

Frequency range	150KHz - 30MHz
Nom. Insertion loss	0dB
Correction data	Supplied with each unit
Isolation rating	400V
Input connections	Safety croc. Clips
Output	BNC (50ohm)
Filter	HF rejection filter (>30MHz)

Amplifier

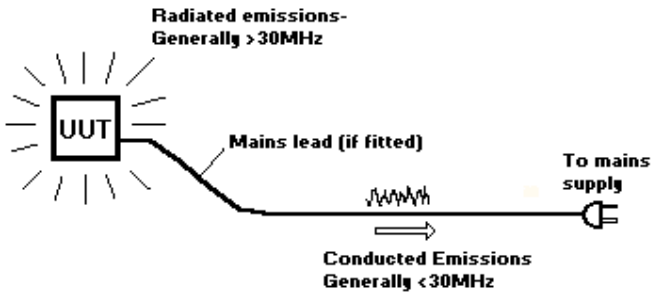
Gain	30dB (150KHz - 30MHz)
Connectors	BNC
Power	via mains adapter

2.0 Introduction

Throughout Europe legislation was introduced in 1996 which requires that all electrical and electronic products sold within the EC complies with the EMC directive. This specifies limits for emissions which in general can only be checked by measurement of the emissions from the product. Although the directive allows use of a Technical Construction File, self certification has proved to be the choice of route to compliance for the majority of manufacturers. Although testing is not mandatory, it is usually the only way to ensure limits are not exceeded. Testing in the past has been treated as a specialist task undertaken by test houses. However purpose designed test kits such as the Laplace system now enable users to conduct their own testing at their own convenience. It is clear that the integrity of EMC test results depends more on the test conditions (test site, background radiation etc...) than on the test equipment. Therefore, provided the test environment is suitable, users can and do use this type of test equipment for self certification without resorting to test house visits.
Two types of emissions are recognised by the directives and specified by the standards. These are conducted and radiated emissions. The RFG-xx kits have been designed specifically for the EMC measurement of both.
These kits at the very least enable the user to minimise and control the use of expensive test houses.

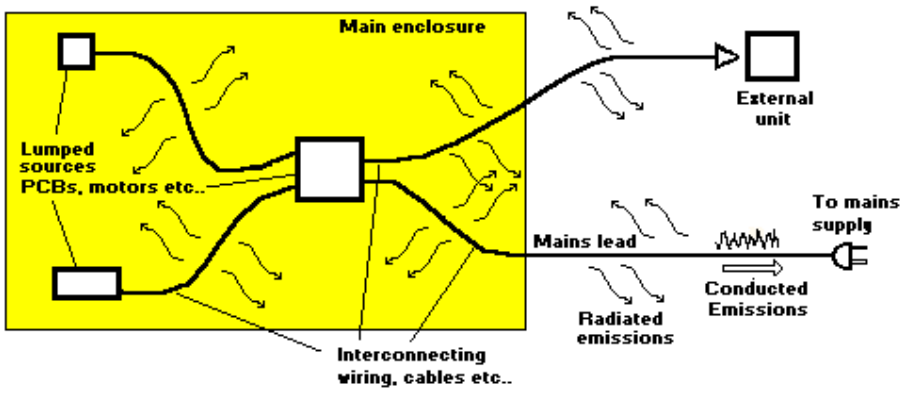
In general conducted emissions limits apply only to those which the EUT (Unit Under Test) transmits back down the mains lead. See Fig 1. Some standards do apply limits to other cables connected to the EUT and the are plans to make the testing of 'other terminals' more widespread.
Radiated emissions are those which are broadcast directly to the surrounding environment.

Fig 1 Simplified view of emissions



In practice the situation is not quite so simple as shown above.
The mains lead often acts as an efficient aerial for the radiation of signals sourced from within the EUT. This means that the radiation as measured in free space varies considerably as a result of changes in configuration of the mains cable. Where systems have detached parts connected by cables, again the precise configuration of these cables can affect the radiation to a substantial degree. Even cabling and wiring within enclosures will act as aerials, inducing RF signals onto other parts of the system which may subsequently be re-radiated by external cables.
See Fig 2.
EMC emissions problems can be quite complex, often requiring a trial and error technique to find the best solution. This is difficult if not impossible at a test house. The advantages of having an in-house test kit become overwhelming at this stage.
The main problem associated with in-house measurements is related to the test site (or lack of one). Typical users simply do not have access to a test site and have to use a laboratory, loading bay, assembly workshop etc... Such 'sites' will introduce massive errors if measuring radiated emissions in the far field! To cater for this problem, Laplace test kits can be supplied with an ERS (Emissions Reference Source) which can quantify these errors and hence allow the user to correct the results to true levels.

Fig 2 Typical emission situation



In many instances, the users are engineers who have not been involved with RF measurements before and the prospect of becoming 'experts' at EMC measurements at short notice can be daunting. For this reason, the SA1000 software is designed for ease of use and, where possible, operation is relatively intuitive.

The SA1000 based test kits can:
(a) Provide accurate mains conducted emissions measurements.
(b) When using an ERS reference source to quantify measurement errors generally due to test site imperfections, measurements of radiated emissions can be performed with a high degree of confidence and should provide adequate information to justify self-certification without further use of test houses.
(c) Provide the means by which you can 'see' problem emissions and locate sources and leakage paths
(d) Provide the capability for comparative measurements. These may be before/after checks when circuit or screening refinements are being tested, testing one product against another, measuring the effectiveness of screening, checking production units for consistency and trend.
(e) Help ensure that a product is as good (EMC-wise) as possible before submitting it to a test house, if using the test house strategy, thus maximising the chances of passing first time.
(f) Provide a facility to perform relative tests such as insertion loss tests as required by EN55015 Because these test do not require measurement of field strengths, the results are dependable.
(g) Perform production testing on a go/no go basis. The standards require testing of all products as they leave the production line so as to ensure that the EMC performance does not significantly change from that measured on the unit used for the initial qualification approval testing.

The Laplace range of EMC test kits may be used to replace the use of test houses, thus repaying their cost many times over in saved test house bills, reduced project timescales and improved product performance. In addition, by testing in-house, your engineering team will gain useful experience in EMC control techniques which may result in shorter project timescales and costs on future products.

Note that it is most important for the user to obtain copies of the relevant EN standards to ensure that the proper procedures and test techniques appropriate to the product under test are used.

3.0 Packing list

Check that all the items relevant to the kit specified on your order are included in the delivery. If any parts are missing, contact your supplier immediately.

Table 1 Component parts common to all kits

All kits	*RFG...*
SA1000	**P**
SA1020 with PP3 battery	**P**
Serial lead (9 pin dee connectors)	**P**
RF100 E and H field probes	**P**
SA1000 software (3½" disk)	**P**
User manual	**P**
Qty 1 BNC-BNC leads	**P**
Mains lead (UK only)	**P**
EMC for Product Designers (Book)	**P**
BNC-BNC adapter (with RF100 probes)	**P**

Table 2 Additional items for specific kit options

Options	*..4*	*..5*	*..6*	*.B*	*.C*	*.A*	*.L*	*.F*	*.H*	*.J*	*.P*	*.R*
With 16A LISN (and pre-amp)	**P**											
With 150A LISN		**P**										
With PLIP + 2085 amplifier			**P**									
RF200 + stand				**P**								
ERS reference source					**P**							
RF400 RF Absorbing clamp						**P**						
RF300 Large Loop Antenna							**P**					
FM band stop filter								**P**				
LF reject filter (30MHz HP)									**P**			
Band B filter (0.15-30MHz)										**P**		
RF900 Preselector (Manual)											**P**	
RF910 Preselector (Auto)												**P**

Other options will become available in time. Check with Laplace for current range

4.0 Emissions Testing... background

Ensuring compliance with EC directive 89/336/EEC requires the measurement of emissions from any product that falls within the scope of the directive to ensure that they do not exceed limits specified in relevant standards. The scope of the directive covers virtually everything that has 'electric' in it, except certain products that are covered by specialist standards such as medical equipment, radio transmitters...etc.

It must be clearly stated from the outset that it is imperative that the user obtains a copy of the standards relevant to their products. These notes, the user guide and the SA1000 software are not substitutes for the standards.

In order to ensure compliance it is necessary for the user to ensure that the correct procedures are followed as specified by the standards. Use of the accompanying text book will help decide which standard is relevant to your product. See section 10.11 for additional sources of information.

4.1 The Standards

Of those products within the scope of the directive, certain product groups are covered by product specific standards. Any products not covered by one of these standards must comply with the appropriate 'generic' standard. Each standard not only specifies the emission limits, but also specifies the test technique to be used. The following table 3 summarises the most common basic standards and relates each to the product group and test technique. As can be seen, there are 6 possible basic techniques. Each requires the use of specific test equipment although the analyser is common to all. The Laplace range covers all the possible hardware items and software facilities to enable any of the techniques to be addressed.
A more comprehensive coverage of standards is included in the TestDirector facility built into the SA1000 software. (See section 7.6)

A study of the standards table (Table 3) shows that the generic standards refer to the product specific standards (the basic standards) for limits and test techniques. Note how the type of emissions (continuous or discontinuous) needs to be considered. In this instance it is the presence of 'clicks' that is the key issue here. A discussion about clicks and measurement requirements is given in section 4.2 but if there is a need to test for these, refer to standard EN55014 for full details.

4.2 Types of Emission signals

For the purposes of EMC there are 3 types of signals that can cause interference. These are continuous, Discontinuous and Clicks.
An understanding of these types is required because in some cases, the type of signal influences the testing that is required. For conducted emissions, the standards call for an averaging and a 'quasi-peak' measurement techniques. Both are provided on the SA1000 analyser together with a third type, peak, for fast scanning. These measurements are specified in order to accommodate the different signal types.

4.2.1 Continuous

This means a signal that is steady state and is not interrupted in time. If it was displayed on an oscilloscope, it would display a continuous, unbroken signal. This type of signal will give the same result whether measured with an average, peak or a quasi-peak detector.

4.2.2 Discontinuous

This is a signal which is interrupted or pulsed with time. These signals are repetitive and regular. An example is the signals from switched mode power supplies or light dimmers. These use solid state devices to switch power at repetition rates typically 100Hz for mains dimmers to several KHz for switched mode power supply units. Each time the power is switched, a pulse of emissions is created. This pulsed signal may have a duty cycle down to fractions of one percent. This type of signal can give significantly different results between average, peak and quasi-peak.

Table 3. Summary of standards and test techniques

	Main Standard	Classification		Conductd/ radiated	Transducer	Notes	Test Type
		Group	Sub group				
1	55011	Group 1	Class A	Cond	LISN/PLIP		A
2	Equipment			Rad	RF200	No limit adjstmnt for distance	B
3	that		Class B	Cond	LISN/PLIP		A
4	intentionally			Rad	RF200	No limit adjstmnt for distance	B
5	generates RF	Group 2	Class A	Cond	LISN/PLIP		A
6	internally or			Rad	RF200	No limit adjstmnt for distance	B
7	externally. (eg		Class B	Cond	LISN/PLIP		A
8	RF welders)			Rad	RF200	No limit adjstmnt for distance	B
9	55014	Electric	<700W				C
10	Domestic	tools	700-1kW	Cond	LISN/PLIP	Special measurements reqd	C
11	appliances,		>1kW			for non-continuous signals.	C
12	power		<700W			Click rate must be	D
13	control		700-1kW	Rad	RF400	measured and quasi-peak	D
14	equipment		>1kW			limit level adjusted	D
15		Others		Cond	LISN/PLIP		C
16				Rad	RF400		D
17	55015	Fluorescent lamps	Power freq<100Hz	Insertion loss	Special	150KHz - 1.605MHz	E
18	Luminaires	All lights	Power freq. <100Hz	Cond	LISN/PLIP	Note: freq. range 10KHz to 30MHz	A
19			Power freq >100Hz	Rad	RF300	Use 2m loop limit line Freq.range 10KHz-30MHz	F
20		Incandescent	Power freq. <100Hz	No emission testing required			
21	55022		Class A	Cond	LISN/PLIP		A
22	Information technology			Rad	RF200	Limit adjstmnt for distance allowed	B
23	equipment		Class B	Cond	LISN/PLIP		A
24				Rad	RF200	Limit adjstmnt for distance allowed	B
	Generic standards						
25	50081-1	Continuous interference		Cond	LISN/PLIP	Refer to 55022, class B, cond	A
26	Domestic & commercial equipment	Discontinuous interference			LISN/PLIP	Refer to 55022, class B, cond and refer to 55014 for click criteria and limit adjustment	C
27				Rad	RF200	Refer to 55022, class B, rad	B
28	50081-2	Continuous interference		Cond	LISN/PLIP	Refer to 55011, Group 1, class A, Cond	A
29	Industrial equipment	Discontinuous interference			LISN/PLIP	Refer to 55011, Group 1, class A, Cond and refer to 55014 for click criteria and limit adjustment	C
30				Rad	RF200	Refer to 55011, Group 1, class A, rad, Limit adjstmnt for distance allowed	B

Table 4 List of test techniques

Test Type	Transducer	General description
A	LISN/PLIP	Mains, continuous emissions
B	RF200	Standard radiated emissions, broadband antenna and optionally the ERS
C	LISN/PLIP	Mains, discontinuous emissions, needs true Q-P measurements and click rate adjustment
D	RF400	Radiated measurement using mains lead.
E	Special	Insertion loss test. Needs extra equipment supplied by user (Sig Genny etc..)
F	RF300	Large loop antenna for luminaires, radiated emissions

4.2.3 Clicks

Clicks are essentially the type of interference caused by contactors, relays or switches as they are operated. These tend to be intermittent operations. The standards recognise that the 'nuisance' value is dependant of the frequency at which these clicks occur. Clearly one click per minute (even if it was quite strong) is not as irritating as clicks occurring at one second intervals. The standard therefore requires an analysis of the EUT to calculate the 'click rate' which is the number of clicks per minute with the EUT operating normally. EN55014 gives full details of the definitions of clicks and how they are evaluated. Basically, if clicks occur less than 6 times per minute, they can be disregarded. If they occur at more than 30 times per minute, then they must fully comply with the relevant standard limit levels. Between 6 and 30 times per minute a sliding scale applies.

4.3 Testing Fundamentals

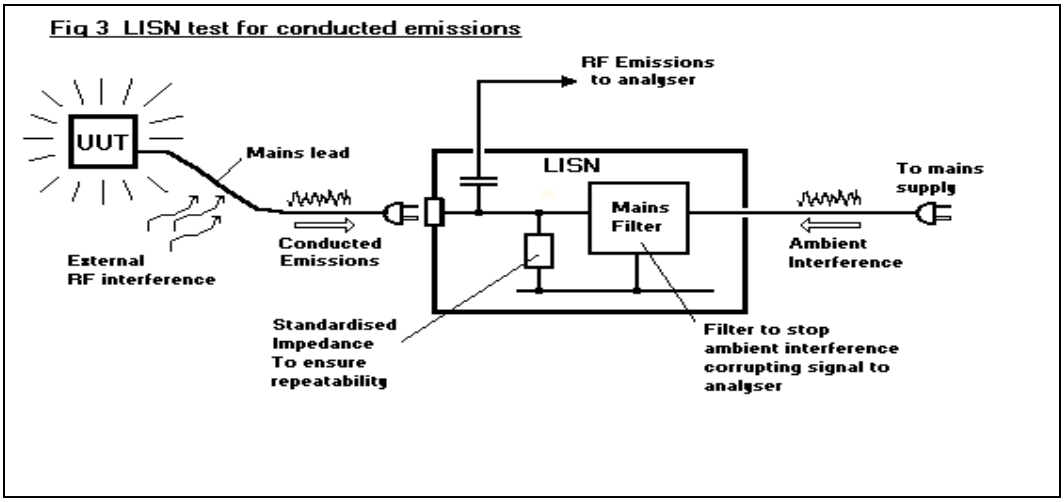
4.3.1 Basic test requirements

EMC testing can be broken down into three basic categories. These are conducted tests, radiated tests and special tests. In the above table 4 types A and C are the conducted tests, types B, D and F are radiated tests and E is a special test.
In general, conducted tests cover frequencies below 30MHz and radiated tests cover frequencies above 30MHz. Thus 30MHz is a key start or stop frequency for most standards.

4.3.2 Conducted tests

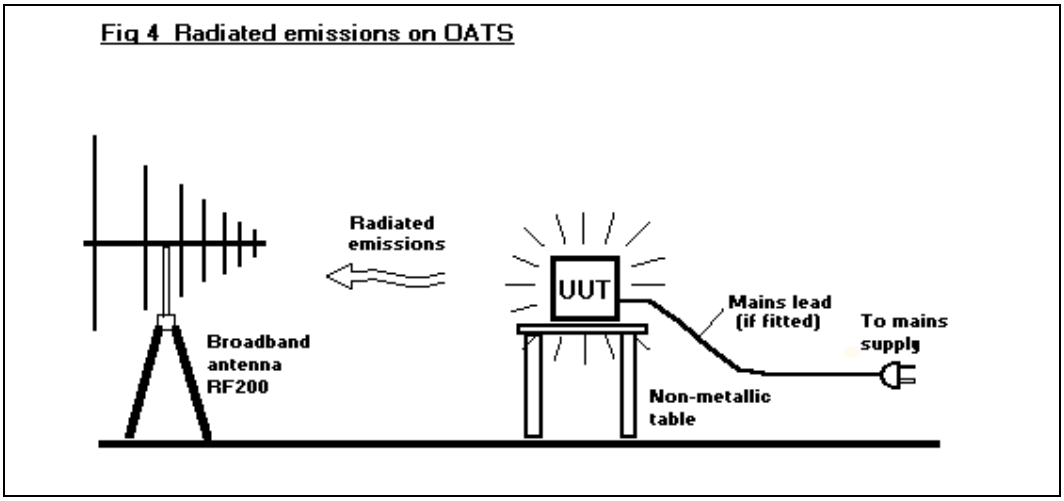
Conducted tests require the use of a transducer to 'pick up' the RF from the relevant cable, usually the mains lead. The transducer used should ideally be a LISN (line impedance stabilisation network). Alternatively a 'voltage probe' can be used. This is recommended by the standards for use on high current circuits (>50A per phase) or in cases where a LISN would be difficult to connect in circuit. Note that Laplace can offer LISNs up to 150A. The LISN or voltage probe (PLIP) intercepts the RF from the EUT and conditions the signal so that it is suitable to be connected to an analyser. (See fig 3) Note that there is the possibility that ambient RF will be induced into the mains lead leading to false readings. Care is needed to identify these emissions as not originating from the EUT. The difference between test types A and C are in the techniques used in the analyser to make the measurement. These differences are due to the absence (type A) or presence (type C) of discontinuous emissions.

Conducted emissions can be strong, and in particular, can be 'broadband'. Broadband emissions are typically caused by commutator motors and impulsive sources such as phase angle controllers. Although the spectral level (i.e. the amplitude as measured with a spectrum analyser) may not be particularly high, the overall amount of energy within the signal may be very high. This may cause the analyser to be overloaded, distorting the results. The recommended technique for avoiding this is to use a 'pre-selector'. These are in fact specified by CISPR16 for all measurements, but they only make a significant contribution where analyser overload may be a problem.
The Laplace range includes two pre-selectors, manual and automatic.



4.3.3 Radiated tests

Radiated tests differ in the type of antenna used to 'pick up' the emissions. Type B tests use what is effectively a conventional aerial located at a distance from the product on an Open Area Test Site (OATS). See Fig 4.



Type D testing achieves the same measurement by picking up the RF on the mains lead using an RF Absorbing clamp as shown in Fig 5. This clamp is mounted on wheels allowing it to be moved along the length of an extended mains cable, detecting the peak of any standing waves which may be present on the cable. The Laplace RF400 is a fully compliant RF absorbing clamp.

Fig 5 Radiated emissions using absorbing clamp

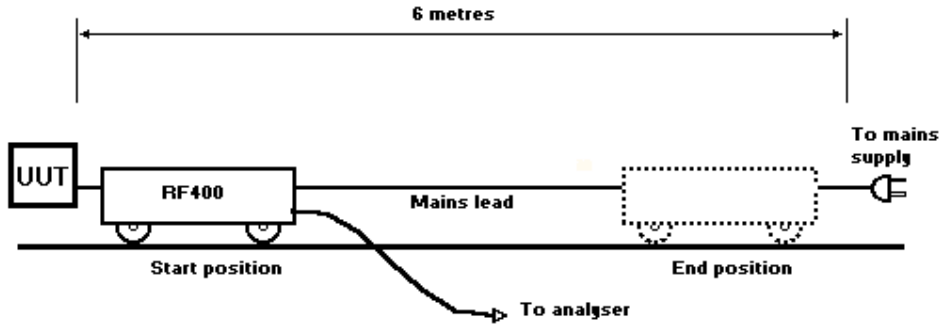
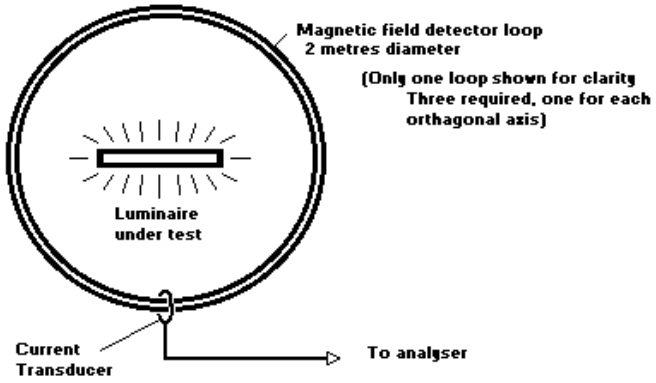


Fig 6 Radiated testing of luminaires



Type F testing is applied only to luminaires and is non standard in the sense that the frequency range covered is from 10KHz to 30MHz. This test requires the use of a Large Loop Antenna (RF300) which measures the magnetic field produced by the luminaire. These loops are produced in groups of 3 set to cover the horizontal and two vertical axes. Each is measured in turn and all three must be below the relevant limit line.

4.3.4 Insertion Loss

The special test E relates to the measurement of the attenuation characteristics of the RF filter fitted to fluorescent lamp ballasts.

4.4 Measurement Equipment

All EN test techniques require the use of an analyser or receiver to make the measurement. The signal input to this measurement instrument is obtained from a 'transducer' which is specified by the standard to be used. This transducer converts the radiated field strength or conducted power or disturbance voltage to a signal suitable for the measurement instrument. Transducers include antennas, LISNs and RF Absorbing clamps.
In general, the reference document CISPR16 specifies the precise characteristics of both the measurement instrument and the transducers. (Where not specified by CISPR16, the item is specified by the relevant EN standard)
Any instrument or transducer that meets the specification given in CISPR16 or a standard is said to be 'compliant'. All Laplace transducers except the RF500 are compliant and calibrated.
CISPR16 also specifies the test environment. In particular, many standards call for an Open Area Test Site (OATS) for radiated emissions testing. This site is obviously under the control of the user and, in general, will be non-compliant and the major source of measurement errors. See section 8.1.1. However, use of the Emissions Reference Source (ERS) will quantify the measurement error due to the site and hence enable reliable measurements to be made.
The measurement instrument specified by CISPR16 is a 'tuned receiver' or 'measuring receiver'. This is a highly specialised and generally expensive instrument with certain characteristics which enable it to make accurate measurements even under worst case conditions. The SA1000 is a spectrum analyser, a fundamentally different instrument from a tuned receiver. In order to reliably make accurate measurements with the SA1000, the differences between a spectrum analyser and receiver must be understood and the associated pitfalls avoided. Note that when an RF900 or RF910 pre-selector is used when measuring band B (150KHz - 30MHz) the SA1000 is effectively acting as a receiver.

4.4.1 Tuned receivers vs spectrum analysers

The main difference between the two types of instrument is that a tuned receiver has a built-in 'pre-selector'. The pre-selector is a variable frequency narrow band pass filter right at the 'front-end' of the instrument. This ensures that only signals at the frequency of interest enter the receiver detection stages, all other frequencies are filtered out. A spectrum analyser does the filtering function at a later stage (after the input amplifier and first mixer stages). This means that the input amplifier and first mixer have to cope with **all** the frequencies in the original signal. In many 'real' circumstances, the frequency of interest may be at a low level amplitude, say 20dBuV, but other frequencies may be present at levels of say 80dBuV, some 60dB higher. (60dB represents a 1000:1 signal level difference!) With a tuned receiver, the pre-selector filters out the stronger unwanted signals so that the receiver sensitivity can be matched to the 20dBuV signal of interest. With a spectrum analyser, the first stages must have the sensitivity set to cope with the 80dBuV signals in order to avoid overload which means that it becomes difficult to measure accurately the small signals of 60dB lower amplitude. The key parameter which determines the effectiveness of a spectrum analyser is the linear dynamic range. This is a measure of the maximum difference in signal level that the analyser can cope with without overloading or distorting the signal. The SA1000 dynamic range is 70dB, thus able to cope with the above example. However, it is most important to match the signal level to the analyser dynamic range by careful setting of the input attenuators. This is where great care must be observed when using a spectrum analyser, not necessary with a tuned receiver. Note that this matching of the signal amplitude to the available dynamic range of the analyser becomes particularly critical when pulsed or non-
continuous emissions are to be measured. It is the peak level of the pulsed emission that must be within the dynamic range of the analyser. Given that the duty cycle of pulsed emissions may be as low as 1% or less, obtaining the correct settings on the analyser is not a trivial task. To aid this requirement, the SA1000 is fitted with a fast overload detector at the input which can be used to ensure optimum setting of the input attenuator. Note that CISPR16 requires a margin of at least 43dB between the measured quasi-peak level and the overload (linear) limit of the receiver/analyser. That means that for signals with a pulsed nature, the maximum quasi-peak reading should not exceed a level that is 43dB down from the top of the screen (or about 2½ divisions up from the base line)

4.4.2 SA1000 structure

The SA1000 is basically a spectrum analyser. However it is fitted with peak, quasi-peak and average detectors at the front end and provides specialist facilities tailored to EMC measurements. Peak detection enables relatively fast sweeping of the full EMC spectrum to be made initially, speeding the identification of problem frequencies (if any). Once frequencies of interest are established, the analyser

can be progressively 'zoomed' into these areas then the quasi-peak and/or average detectors can be used to produce results which can be directly compared to the limit levels in the standards. Finally the analyser can be switched to a 'single frequency' mode in which only one frequency is analysed (as with a tuned receiver) and again an averaging or Quasi-peak detector can be selected. These detectors are matched to the CISPR16 specifications and are implemented digitally, using a high speed processor and fast ADC coupled to a peak hold input stage which guarantees to capture any fast transients that may exist on the input signal.
When in initial (peak detector) frequency scanning mode, a peak hold facility is used to monitor the input as the frequency is shifted from one measurement frequency up to the next measurement point. This ensures that the resultant spectrum will always show any peaks even if they fall between measurement frequencies, regardless of the frequency resolution of the sweep. This is known as 'no gap' scanning. See section 4.5.2.

The single frequency mode is ideal for monitoring a particular emission frequency whilst modifications are tested on the product. Any changes are shown immediately, saving considerable time and effort to continually re-sweep the spectrum.
Thus the SA1000 combines the ease and speed of use of a spectrum analyser with the measurement accuracy of a tuned receiver....and some more.

4.5 SA1000 Measurement Technique

The SA1000 spectrum analyser operates in three modes, peak scan mode, true measurement mode and single frequency mode.

Table 5 Measurement modes

Mode	Detector	Speed	Accuracy	Notes
Peak scan	Peak	Fast	Take care with pulsed signals	Use for fast initial scanning. Will not miss peaks between measured freq. points
CISPR scan	Quasi-peak and average	Slow	High, results can be compared with limits	True measurement mode. Can miss peaks between points Up to 500 points/sweep
Single frequency	Quasi-peak and average	Fast	High, results can be compared with limits	Levels can be monitored in real time, but only one frequency at a time.

4.5.1 Frequency resolution.

In any frequency scanning mode, the analyser is set by the operator to scan the input signal from a start frequency to a finish frequency. The user can also select the number of frequency points to measure within the scan, 500, 250 or 100. The fewer the number of points, the faster the sweep. Note that when scanning a wide scan range, (say 1GHz) at 500 steps per scan, each step must be 2MHz apart, assuming linear frequency scaling. Given the correct CISPR16 bandwidth of 120KHz, some 1880KHz of the sweep will apparently be 'missed' This will be even worse the lower resolution of 250 and 100 steps.

4.5.2 No Gap Scanning

The SA1000 uses a unique 'no gap' scanning technique in which, even at the coarsest frequency resolution, ensures no intermediate peaks are missed. This is achieved by scanning the range from one step to the next with a peak hold detector in operation to capture the highest peak and hold it until the next step is reached. It is the value of this peak hold buffer that is reported back to the PC. Figure 7 shows the principle.
The resultant spectrum gives a true representation of the signal (emission) levels in cases where the emissions are continuous. Many conducted emissions however are discontinuous and these must be measured with an average and a quasi-peak detector. For radiated emissions quasi-peak is the specified detector but for conducted, both measurements are required and each should not exceed the relevant limit level. Note that many radiated emissions are continuous and will give the same results with either peak or quasi-peak detectors.

4.5.3 Testing strategy

Because the peak detector always gives worse case (highest) readings, and gives the fastest sweep, standard practice, regardless of the type of analyser or receiver, is to use the peak detector first and compare the results with the average limit level (or Quasi-peak if no average limit is specified). If the peak results shows that all emissions are below the limit, then the EUT is judged be compliant. Only if the results are over this limit need the CISPR Quasi-peak and average detector modes be used.

Note that the quasi-peak and average modes do not feature 'no gap scanning' and thus will detect at only the measurement frequency points as determined by the scan range and the number of steps and so care is required in order to avoid peaks falling between measured points. The Peak (fast scan) mode will always show any peaks so this can be used as a check. CISPR scan mode can show either true average or true quasi-peak levels. Frequency scanning can be set to logarithmic or linear, continuous scanning or single sweep.

Single frequency mode continuously measures one frequency and displays the result in chart recorder style on screen. This enables a problem emission to be continuously monitored in true quasi-peak or average or instantaneous modes, ideal when investigating possible modifications. Frequency selection can be set to either fixed, allowing the user to step the frequency up or down to find the peak level, or peak tracking, in which case the analyser will automatically latch onto any close spectral peak and track the peak, even if it drifts in frequency.

5.0 Quick start information:

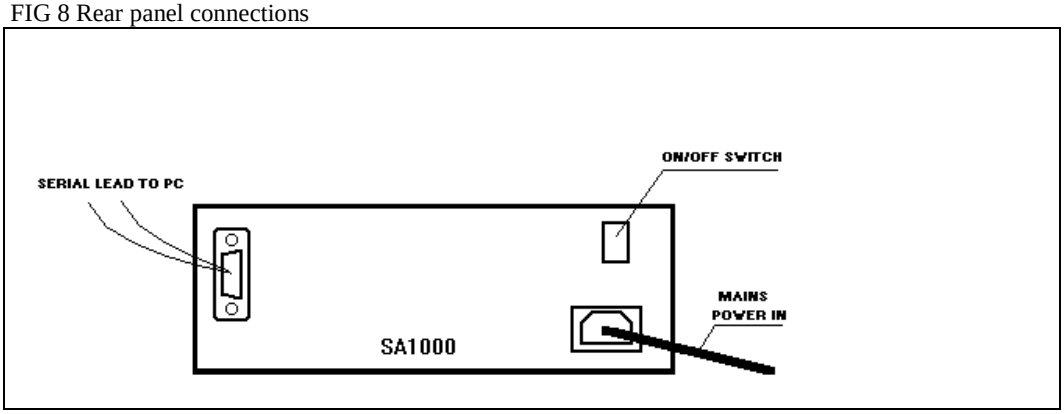
5.1 Setting up.

1. Unpack all items and check against the packing list in section 3 to ensure no items are missing.

2. Install the PC software on the PC as described in Appendix 1.

3. Connect mains lead to analyser and link the analyser to the PC with the serial lead as shown below .

FIG 8 Rear panel connections



4. Connect an input lead to the 50 ohm input socket. Initially for a quick check, this can be a plain length of unscreened wire which will act as a simple aerial.

5. Ensure the audio level switch is set to OFF (Centre position)

6. Switch the SA1000 on. (Rear panel).
Check that the green power indicator on the front panel is ON

7. Run the SA1000 software on the PC. If error messages are displayed, see NOTE in appendix 1 for more information.

8. Check the **Port...** menu and ensure that the correct port (**com1** or **com2**) is ticked. (On the first occasion the software is run, a warning message regarding 'analyser not present' or 'SA1000 not responding' may be displayed. Clear these messages and check the **Port** menu to select the correct com port (1 or 2).

9. Check that the analyser status 'box' is showing OK. If not, click on the status box.

10. Click on the **S/Shot** button and the analyser status should change to 'scanning' and a trace progress indicator should appear at the bottom of the trace area, gradually tracking across to the RH edge where it will stop.
This shows that the system is now working correctly and measurement can begin.

5.2 Radiated emissions:

1. Connect an antenna (RF200, RF300 or RF400) to the input using the supplied long lead. If using the RF200 install the SA1020 pre-amplifier at the antenna end, mounted on the 'platform', using the supplied velcro pads to hold it in place. See section 9.3.1 for antenna assembly.

2. If using the SA1020, install the battery. Note that the SA1020 is supplied with a battery, located in the battery compartment. Ensure this battery is unwrapped and connected to the battery leads.

3. Orientate the antenna to suit (Elements vertical for vertical polaristion, horizontal for horizontal polarisation). If using the RF200 broadband antenna, place it about 3 metres from the product and pointed towards it ('sharp' end forward!). Switch the pre-amplifier ON. Leave the EUT switched off.

4. Check the frequency range of the analyser. Click on the **High** button in the frequency selection area (see fig 9 over). The horizontal axis should show the range 30MHz to 1100MHz. (Or 30 - 1000MHz if Log Frequency axis)

5. Under **Input....** menu, select the appropriate antenna. Select the **Pre-amp** to show a cross in the clear field if the pre-amp is in use. Note that selection of the RF200 broadband antenna automatically selects the pre-amplifier. Check that the **Current** trace is active. Traces are selected on/off by clicking on the buttons shown below. Active traces are identified by name in the space immediately above the graphical trace screen. The colour of the text identifies the colour of the trace.

6. Select **S/Shot**. The trace will build up the spectrum of the background radiation as received by the antenna, plotted as amplitude vs frequency.

7. The sensitivity of the analyser must be matched to the signal strength at the input. The idea is to reduce the **attenuator** setting to the minimum such that the compression (overload) warning just appears intermittently. It is quite possible that even if the attenuator is set to 0dB (the most sensitive setting) the overload does not appear. This is good, it shows that the environment is relatively quiet and the analyser can be left at this most sensitive setting., If the overload is permanently flagged even with the attenuator at the 30dB setting, the background must be very strong indeed. The options then are:

- Check for any single or group of strong peaks. If such a group appears at 86 - 106MHz, this is the FM broadcast band. The RF600 is specifically designed to overcome this problem.

- If no one peak or group of peaks is particularly strong, try an RF700 30MHz high pass filter between the antenna and the pre-amplifier. Sometimes the problem is energy below 30MHz, outside the scan range in use and therefore not visible, but still causing the input to be overloaded.

- Normally, one or more of the above steps will fix the problem. If however it still persists, the location must be abnormally noisy and the source should be evident. (E.g. a plastics welding factory next door!) In this case either:

  (a) use a 'quieter' location for EMC testing. If the product (EUT) is small, try the back garden at home!

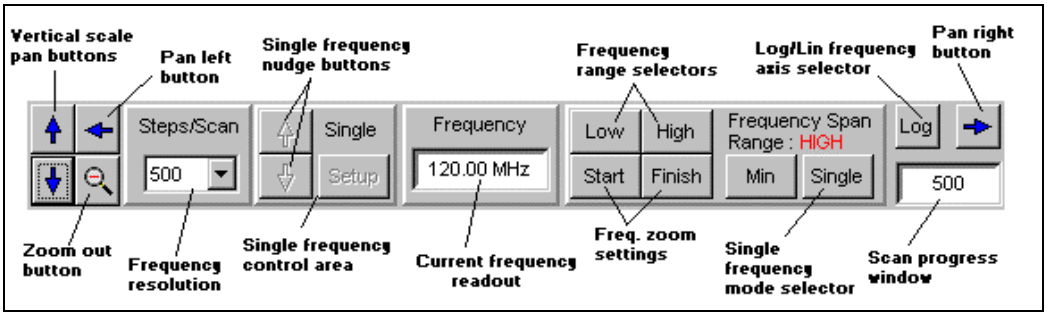
  (b) if the product is less than 30cm cube, use a test cell such as the LaplaCell300

  (c) use a screened room, not normally advisable except in extreme circumstances (see section 8.1.2)

8. Having set the attenuator, do a single sweep (S/SHOT) to show the background spectrum. If outdoors or in a relatively unscreened indoor area, the FM transmissions between 86 - 108MHz may be clearly seen as a cluster of peaks. To confirm, check you are in **lin**(ear) frequency axis mode and use the cursor to 'pull' the LH and RH edges of the spectrum display so that the start frequency is about 80MHz and the stop frequency is about 120MHz. Scan again to see the FM band in detail. Select **Min** Span and a 10MHz scan width will be selected with the start frequency unchanged from the previous setting of about 80MHz. This 10MHz scan width can be moved up or down in frequency in 5MHz steps by using the left or right frequency shift buttons each side of the frequency axis. Finally select **single** frequency mode and a frequency select cursor will appear. Position this line on a peak of interest and click. A selection window will appear enabling the user to select the detector type. For the moment select '**Instantaneous**' and '**Fast'** update rate. The analyser is now set at a single frequency which can be fine tuned up and down in frequency using the single frequency **shift**

buttons. Switch the audio demodulator on the front panel of the analyser into the up or down position and the signal will be demodulated and output at the internal loudspeaker. By fine tuning the signal can be clearly identified as a broadcast station. The accurate frequency of the transmission can be read off the current frequency readout display. Set the analyser back to the original settings by clicking on the **span** button and clicking on **High** frequency before continuing. This will set the frequency scan width back to 30MHz - 1100MHz.

Fig 9. Analyser frequency controls



7. The presence of emissions from a product can be crudely tested by switching the EUT on in the vicinity of the antenna. If there are any 'heavy' emissions, these will show up as increases in the spectral levels. In general, emissions from most products are minimal and to 'see' these amongst the background, a more sophisticated approach is required to null out the background.

8. Because the background is generally unstable, switch the EUT off and select **Peak hold** or Averaging from the **Processing...** menu. Use **Run** to sweep the spectrum continuously. Peak has the effect of applying a peak hold function at each frequency point across the spectrum, thus acquiring the peak level of the background emissions and the screen will eventually show a stable result. The length of time this takes depends entirely on the nature of the background at your particular location. This may vary between 5 minutes and 20 minutes. When no more changes to the result can be observed, stop the scanning by clicking on the **STOP** button

   Averaging will display the average of 8, 16.... sweeps, building up the average with each sweep and automatically stopping when the target number of sweeps has been completed.

   When the above has been completed, copy this result to the STORE trace by clicking on the **>STORE** button. This action turns the Store (red) trace on and observation will confirm that it will be identical to the current (black) trace.

9. Turn the EUT on. Click either **RUN** or **S/SHOT**. Remember that the analyser will still be in peak hold or average mode unless the processing is intentionally switched off. Any continuous emissions from the EUT will be shown up on the first sweep, but any discontinuous emissions from the EUT may take several sweeps for the envelope of emissions to be fully shown.

10. If using peak hold with the **RUN button**, click on the **STOP** or **CANCEL** buttons to stop the sweeping, The screen will redraw and any new signals (i.e. those from the now operating EUT) will appear as black traces above the red background (stored) trace. Use the difference trace to show the field strength of the EUT emissions. Turning both the current and stored traces off will make the difference trace easier to observe. Save to result to disk or note the approximate frequencies so that they can be examined in detail at the next step.

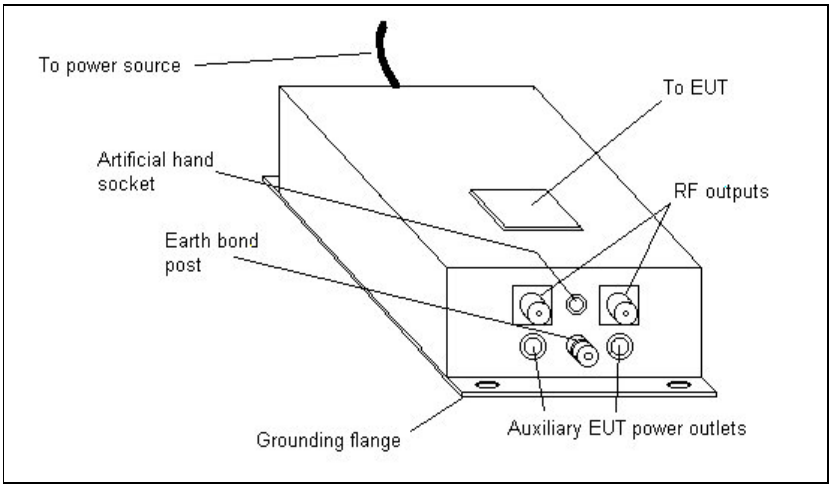
11. Examine the suspect peaks by 'zooming in' to the suspect area with the frequency select cursors. Note that the background (stored) trace is also zoomed and remains valid. However, if preferred the background can be renewed for the zoomed area by repeating the procedure with the acquisition of the background trace, copying it to the stored trace then switching the product ON to see the product emissions.

See section 8.3 on software operation for measurement of absolute levels and comparison with limit lines.

5.3 Conducted emissions

Connect the LISN mains lead to the mains supply. Ensure that the supply is NOT fitted with an RCB (Earth leakage trip). If it is, use an isolation transformer of adequate rating for the EUT between the mains supply and the LISN.
Plug the EUT into the mains socket on the top of the LISN. Note that this socket is not switched by the LISN, so it will be live if the incoming mains is live.

Fig 10 LISN connections



1. Connect the LISN to the ground plane with a short, thick bonding strap.
2. On the PC software, set **Low** frequency range (see fig 9) and wait 30 seconds.
3. Click on Input menu and select ....**LISN**
    1. Insertion loss… **30 dB** if using standard Cranage LISN
    2. LISN source = **live** or **neutral** (or **phase**) as required
4. Click on Detector menu and select **Detector...Peak (Fast scan)**
5. Switch analyser input **attenuator** to 30dB (see field at LHS of screen).
6. Set Pre-amp window to **0dB** and do not use pre-amp initially.
7. Connect the appropriate LISN RF output to the analyser signal input with a short BNC lead.

In the following procedures, ***reduce attenuation*** means switching attenuation down by 10dB. This can be accomplished by a combination of the following to give an end result which equals a 10 dB reduction in attenuation (ie a 10dB increase in sensitivity)

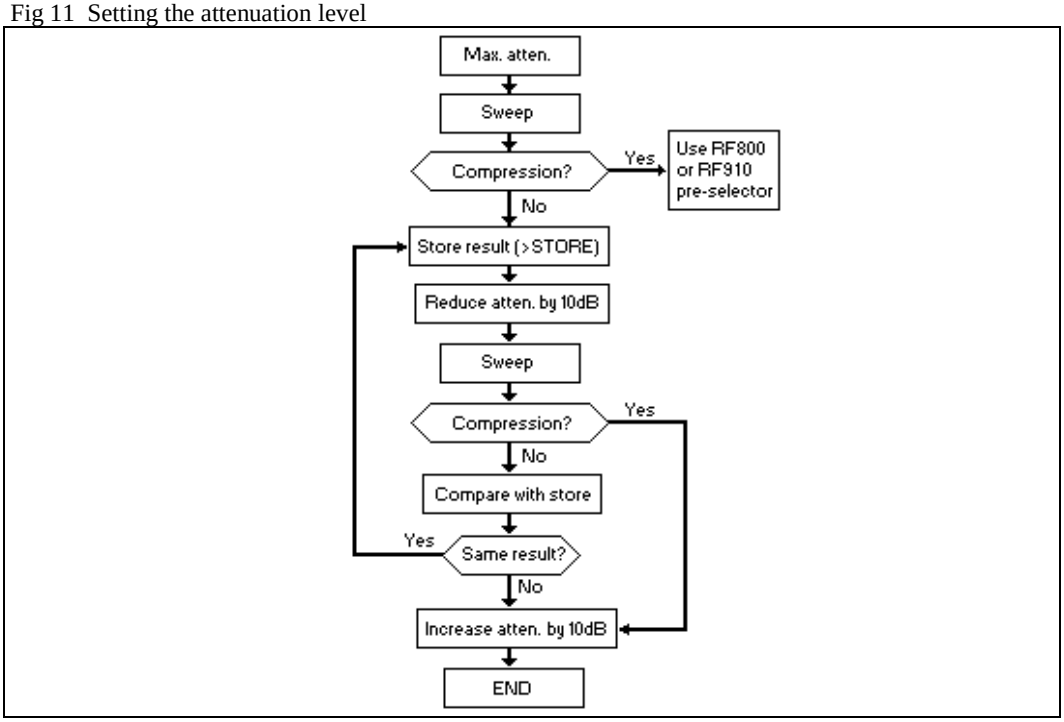
- analyser attenuator, (30 > 20 > 10 > 0dB)
- use of pre-amplifier (which has the effect of reducing attenuation by 20dB or 30dB depending on which is used). Ensure pre-amplifier status window on screen shows correct indication.

Increase attenuation means increase attenuation by 10dB using the same facilities in reverse as listed above.
See attached flow diagram, fig 11.

8. Click on **S/SHOT** and observe the signal on the screen.
9. If no compression warnings occur (red bands on the trace progress bar),
    ....use **>STORE** button to store result
    ....reduce attenuation (ensuring on-screen indications are correct) and
    ....repeat step 8
10. If intermittent compression warnings occur,
    ....compare current trace with stored trace.
        If current trace is same as the stored trace at all frequencies, then go to step 11.
        If current trace is significantly less than stored trace, ***increase attenuation*** **and go to step 11**

11. This is the best result. Make sure that the software switches match the settings on the LISN, analyser and pre-amplifier and proceed with the next stage.
12. If the signal is particularly strong, use an RF800 filter or an RF900 series pre-selector.

Fig 11 Setting the attenuation level



Then the 'proper' measurements can be taken USING THE SAME SETTINGS.

Sweeping the complete range 150KHz to 30MHz will show any significant emissions. Remember that the peak detector is in use which will always produce the highest reading of any of the detectors. If a limit line has been selected, it will be showing the average limit. This is the lowest limit level. Only if the trace shows any results close to, or above the limit, is there any need to use average or quasi-peak scanning.
Average and quasi-peak detectors are slow! If only a small number of peaks require further measurement, use the single frequency mode. This enables measurement with these detectors in real time. It plots the measured level against time as the horizontal axis, just like a chart recorder. Click on the Single button and position the special cursor at the frequency of interest. The frequency readout window will display the cursor position as it is moved. When the cursor is at the desired frequency, click the mouse. A window will appear in which the detector can be selected. An option is offered to enable 'Auto peak tracking'. Use this if the signal to be analysed has a distinct narrow band peak, otherwise leave this disabled. Auto peak tracking will find the relevant peak and track it even if it drifts.

If peak tracking is not used, the frequency can be fine tuned with the and nudge buttons in the frequency control section. Whilst Single frequency mode is running, the measured value is displayed in the top RH corner. When the measurement is completed, click on **STOP**. To return to the scan screen, click on the button marked **Scan** (lower RHS). To change the single frequency setup (eg to change the detector, click on **Setup** in the Single frequency control area at the bottom of the screen.

If a scan is preferred rather than single frequency, use 100 steps and zoom to the frequency band of interest. This will enable quicker results to be obtained.
Select **Detector...average** and **S/SHOT** The true average measurement will now be taken. Note that this will take some time, 10 minutes for 100 steps.

Repeat above with **Detector....Quasi-peak** selected.

This procedure is essential if the EUT has pulsed emissions and should always be followed for conducted emissions.

If the emissions are continuous, the above two tests will produce the same results and these will match the Peak (fast scan) mode.

6.0 SA1000 SPECTRUM ANALYSER

6.1 Description

The SA1000 is an all-analogue, digitally controlled conventional triple IF spectrum analyser covering the range 10KHz to 1.1GHz. It has a digital control interface built in to provide a PC interface. This interface is designed to work in conjunction with any standard PC running Windows 3.1, 3.11, or Win 95 with all the control and display functions provided by PC software supplied with the analyser.
EMC specific features, in particular average and quasi-peak detectors to comply with CISPR requirements are implemented.
Connection between the analyser and the PC is by standard serial interface. To aid display calibration and setting, the analyser generates a zero frequency marker and has a 10MHz calibration signal available.

6.1.1 Analyser Power

The analyser requires 240V or 110V 50/60 Hz ac mains supply. Note that all analysers are configured for 240V at the factory unless specifically ordered otherwise. If required to change the mains voltage setting the analyser must be returned to Laplace Instruments.
The power ON/OFF switch is located on the rear panel next to the mains input socket.
b

6.1.2 Analyser - Controls

Full control of the analyser is provided via the serial interface from the SA1000 software running on a standard PC. The only control provided on the analyser itself is the audio demodulator volume control. This is a three position rocker switch with a centre off position. Switch down for half volume and up for full volume.

6.1.3 Analyser frequency range

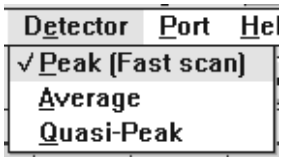
The SA1000 is specified over the range 10Khz to 1.1GHz, therefore exceeding the frequency range required by most published EC standards which specify the range 150KHz to 1GHz.
The analyser splits the full range into 2 sections to match the standards. i.e. A low frequency range from 10KHz to 30MHz and a high range from 30MHz to 1.1GHz. The low range uses a 9KHz bandwidth IF and the high range a 120KHz IF. The required range is selected by click buttons on the control screen. Note that when the range is changed, a delay will occur whilst the analyser reconfigures.

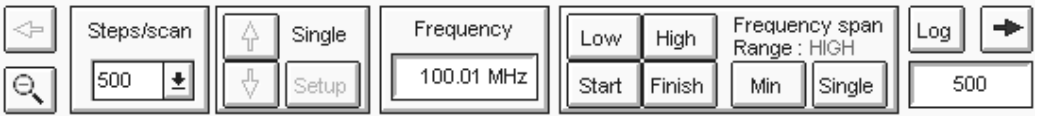
6.1.4 Scan control

The scanning of the analyser is controlled entirely from the PC.

The parameters set by the PC are:

Scanning mode:	- spectrum
	- single frequency
Detector type:	- peak (Fast scan)
	- quasi-peak
	- average
Start frequency	
Stop frequency	
Single frequency	
Number of steps	
Scan type:	- log
	- linear





6.1.5 Scanning Modes

The SA1000 can scan frequencies as a conventional spectrum analyser, running from a Start frequency up to a Stop frequency. Either 500, 250 or 100 frequency points can be measured during the scan.
Three modes are available, fast scan, average and quasi-peak scan.
Fast scan uses a peak detector and scans the frequency spectrum without any gaps. (No gap scanning, see section 4.5.2). This means that any peaks that fall between frequency measurement points will be shown.
The quasi-peak and average detectors measure individual frequency points.
Alternatively, the analyser will work in single frequency mode, in which the analyser is tuned to one frequency only and no scanning occurs. The frequency for this mode can be manually tuned from the PC or can be set to 'peak track' in which case the analyser will automatically track the maximum of any adjacent peak, thereby retaining a true maximum reading even if the frequency of the peak drifts with time.

6.1.6 Analyser bandwidth

The IF filter bandwidth in the SA1000 analyser is switched between 9KHz (Narrow) and 120KHz (Wide). These correspond to the filter bandwidths specified in the standards for emissions measurements.
9KHz is used for frequencies in the range 10KHz to 30MHz (conducted) and 120Khz is used for radiated emissions in the range 30MHz to 1GHz.
Note that the standards call for a 200Hz I.F. bandwidth below 150KHz. This is not provided by the SA1000. However the use of the 9KHz I.F. bandwidth in this frequency range will result in measurements that are always higher than if the 200Hz filter had been used. The degree to which the measurement is increased depends on the nature of the signal. If it is narrowband, the increase will be negligible. If it is wideband, the increase may be substantial. In either case, if the measurements are within the limit levels, the product must be OK.

6.1.7 Audio demodulator

The audio output on the analyser can be used to identify broadcast and other background transmissions, to identify emissions sources (some have characteristic sounds) and to aid source location. In order to use the audio output, tune to the frequency of interest and select single frequency mode. You now have a receiver tuned to that frequency. Slope demodulation is used, effective for both AM and FM signals.
Note that there are two volume settings, down for half output, up for full output.

6.1.8 Input attenuator

The purpose of the attenuator is to match the sensitivity of the analyser to the strength of the input signal. It is most important to avoid overloading the analyser by having too little attenuation whilst ensuring that not too much attenuation is used. To aid this important setting the analyser is fitted with a high speed input overload (Compression) warning circuit which will display a warning on the PC screen if one should occur. Thus the procedure is to start with maximum attenuation, then decrease it in 10dB steps until the compression warning shows. When this occurs, increase the attenuator by 10dB. In many instances, even at 0dB attenuation, no overloads will be flagged. In this case, leave the attenuator set at 0dB and, only if necessary, introduce a pre-amplifier into the signal path. See fig 11 and section 6.3.

6.1.9 Calibration signal

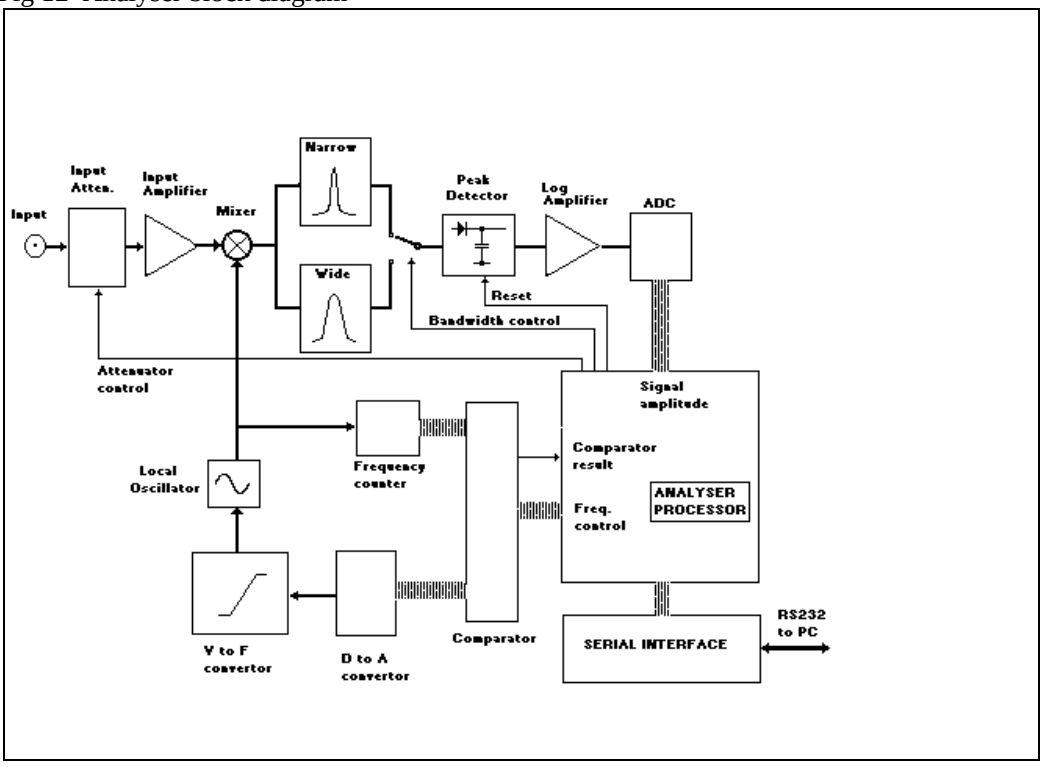
The right hand BNC is an output for a calibration signal. This can be used to check the correct operation of the analyser by feeding the signal direct from the calibration output to the input. It also provides a useful check of the operation of any external pre-amplifiers or attenuators by feeding the calibration signal via these and back to the analyser input.
The calibration signal is 30dBuV and 10MHz. All low harmonics of 10MHz will be present, at undefined amplitudes.

The main purpose of this signal is to provide a confidence check of the system. If necessary, the small hole to the left of the calibration signal output gives access to a gain trimmer which adjusts the sensitivity of the analyser.

6.2 Analyser Operation

The SA1000 is an essentially conventional, analogue RF spectrum analyser.
Any signal connected to the input is first amplified and mixed with a local oscillator signal. The resultant difference signal is extracted by a low pass filter (the I.F. filter). This filter allows only a narrow range of frequencies to pass through. The width of this narrow range is either 9KHz or 120KHz, depending on the frequency range in use. The output from this filter represents the magnitude of the signal at the filter frequency. This is converted to a logarithmic magnitude then passed to an A-D converter to digitise the signal to be read by the internal analyser processor. Note that this description is grossly oversimplified and that the actual system is far more complex.
The frequency being measured at any instant in time is dependant on the local oscillator frequency. This is controlled by the internal processor and continuously monitored to ensure the correct and accurate operation. Two fundamental modes of operation are provided. The analyser can either sweep a band of frequencies (between a Start frequency and a Stop frequency) or can remain fixed at one frequency (single frequency mode). In sweep modes the processor steps the local oscillator frequency to match the commands from the PC. These steps can be spaced either linearly or logrithmically in frequency and the number of steps per sweep can be varied. At each step the peak level output from the selected IF filter is measured and passed to the PC. In single frequency mode the input is repeatedly measured very quickly and the analyser processor performs either averaging or quasi-peak processing of the resultant data. This processed measurement is passed to the PC at a user selected interval.

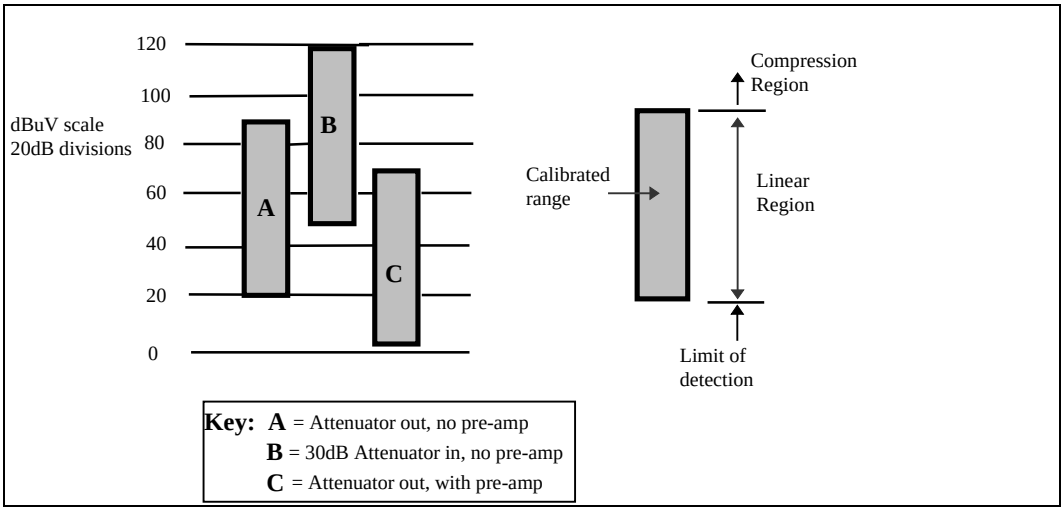
Fig 12 Analyser block diagram



6.3 Analyser Dynamic Range

The term Dynamic Range for an analyser is a measure of the range of input signal levels which can be accurately displayed. At the low amplitude end, a signal below a certain minimum level will be lost in the noise floor. At the high end, above a certain level the input will start to saturate or go into compression. The range between the low end limit and the high end limit is the dynamic range and is expressed in dB. The linear dynamic range of the SA1000 is 70dB, a range of just over 3000:1. In addition to this range, the input attenuator provides an additional 30 dB in 10dB steps for high level signals and the pre-amplifier gives another 20dB for low level signals giving a total dynamic range of 120dB.
See fig 13.
Spectrum analysers will give false readings if used outside the linear dynamic range. You have been warned! They are very sensitive instruments with inputs that respond to uV and must be handled with care. It is important to match the input signal level with the linear portion of the analyser's dynamic range.

Fig 13 Analyser dynamic range



Please take note of the 3 traps for the unwary listed below.

Overload
Linearity
Distortion

6.3.1 Analyser overload

Be aware that there are two kinds of 'overload'.

Compression: This is the situation when the signal is strong enough cause distortion at the input amplifiers. Although this is well within the capability of the analyser to accept, the distortion causes false harmonics and other distorting effects which corrupt the resulting spectra displayed on the screen. See linearity and distortion below.

Overload: The situation where the input may be subject to damage. If directly connecting the analyser to signal sources such as a LISN or PLIP or via 'scope probes to circuitry, be aware that the maximum signal level allowed is 220mV with the attenuator switched to its maximum of 30dB. ***Signals larger than this may cause damage to the analyser. In particular, this restriction applies to transients so beware of switching 'glitches' etc***.
When using antennas or near field probes signal levels are very unlikely to exceed dangerous levels.
The analyser inputs are protected and will withstand levels of 2V or greater. The actual protection level depends on signal source impedance and duration. If using the LISN, always have the attenuator on the LISN switched to either -10dB or -20dB, never 0dB. Also, set the 150KHz filter IN unless specifically requiring to measure frequencies below 150KHz.

If using a third party LISN, be aware that most are not fitted with either the switchable attenuator or transient limiter as fitted to the Laplace LISN. An external voltage limiter is highly recommended. Great care must therefore be taken with any LISNs to avoid overload.

6.3.2 Analyser linearity

It is important to be aware that the magnitude of a signal on the display will differ from the true magnitude under certain conditions. Spectrum Analysers use a broadband mixer which has a linear range (in terms of output level vs signal strength) but at higher inputs the output starts to saturate. This effect is called **compression** because higher input levels are 'compressed' into a limited range.
The linear dynamic range of the analyser detector is 70dB (over 3000:1) for both the high frequency and the low frequency range. That means that the maximum difference between the largest signal and the smallest signal that can be measured is 70dB. The attenuators must be set such that the largest signal is not causing compression. This then defines the lowest signal that can be measured. Signals below this level cannot be observed without reducing the attenuation, but this may cause compression.

As a guide, always ensure that the analyser is not running in compression (compression is indicated by a warning message on the PC screen and red sections on the trace progress bar). Adjust the input attenuator/pre-amplifier combination so that the compression warning flashes intermittently when scanning. This is the ideal situation.. A further check if strong signals are suspected even if the compression warning bar does not indicate, is to store the current trace to store (**>Store**), increase the attenuator by 10dB, acquire a new current trace and check for differences between the stored and current trace. If significant changes are observed, these may be due to compression and the less sensitive settings should be used.

6.3.3 Analyser distortion

If the detector is running near or in the compression region, cross-modulation and harmonic products will be generated within the analyser giving false readings. If it is, increase the attenuator and/or take the pre-amplifier out of circuit.
Note that the full frequency band must be checked. It is no use just checking say 0 - 100MHz on the basis that this is the only range you intend to use today. A strong signal at 300MHz could be causing the detector to go into compression and affecting the 0 - 100MHz range.

6.3.4 Avoiding the problems of compression

- A situation can exist where a strong signal below 30MHz can force the analyser into compression when on the high frequency range, even though this range starts at 30MHz. This would be apparent if the compression warnings are given when no significant peaks are visible in the 30 - 1100MHz band. Should this happen, fit a 30MHz high pass filter (RF700) at the transducer, before the pre-amplifier (if used).
- Many products exhibit broadband or high level emissions on the mains supply. Obviously these will tend to push the analyser into compression. Broadband signals such as created by power controllers, motor commutators etc.... may be a particular problem, causing compression even with maximum attenuation switched in. The solution (as specified by CISPR16) is to use a pre-selector. This is a special filter unit that is placed between the source (tpically a LISN) and the analyser.This splits the band (150KHz - 30MHz) into several narrow bands, allowing only one band at a time through to the analyser. Se sections 9.4.4 and 9.4.5.

7.0 SA1000 software

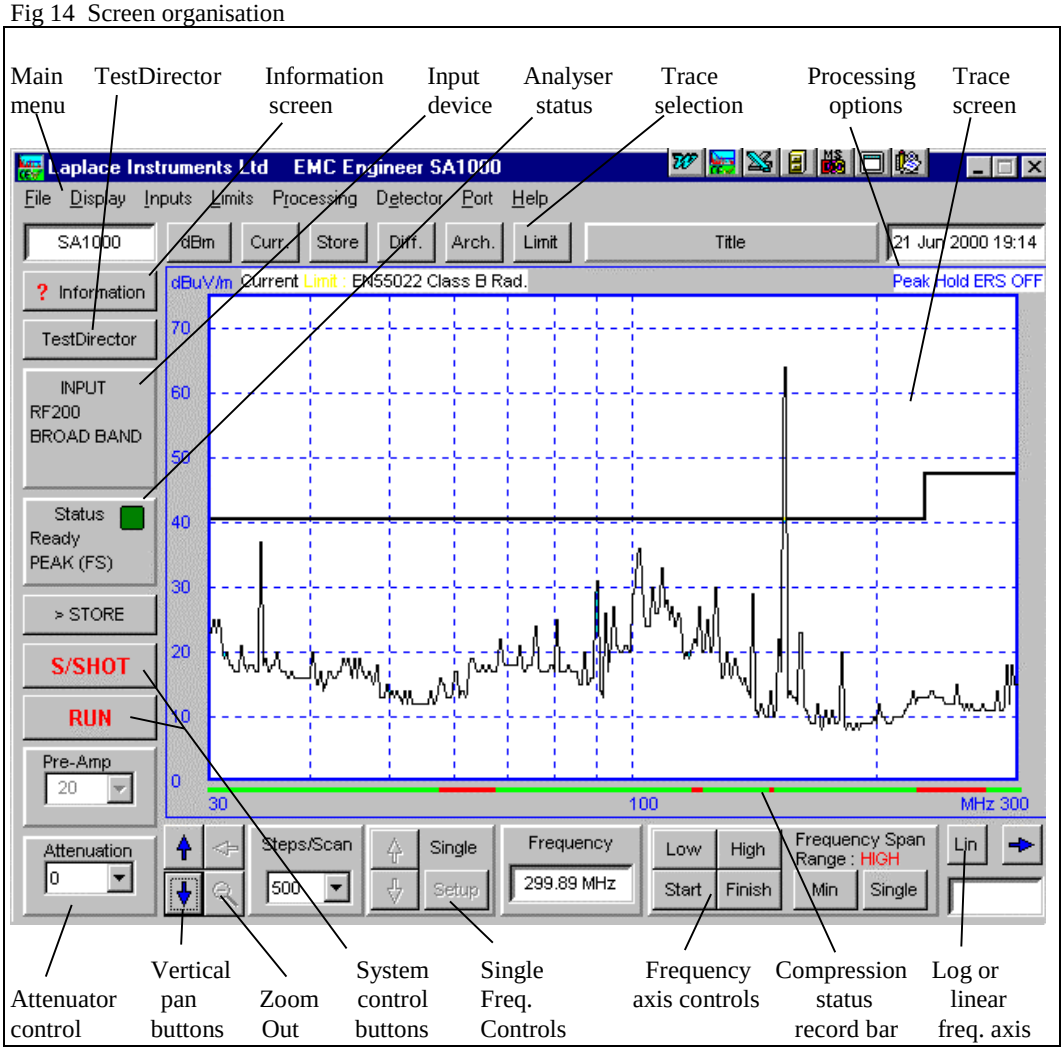
The SA1000 system comprises the SA1000 software and an SA1000 spectrum analyser.
Note that text appearing in **bold** type refer to screen controls or buttons or menu items.

7.1 Screen organisation

The screen is organised into the following areas:
Trace screen. The graphical area in which the spectrum, limit lines and other traces are displayed.
Menu bar. The banner across the top of the screen which carries the headings for the main menus.
Trace selection buttons. Toggles traces ON/OFF
Left hand group: System control buttons. Control the scanning of the analyser.
Input device identification area. Displays the selected transducer (Aerial, LISN,...etc.)
Analyser configuration group... pre-amp, attenuator.
Analyser status panel.

Lower edge: Frequency axis controls....mode, start & stop frequencies, Lin/log scaling, zoom.
Single frequency control area
Steps/scan (frequency resolution)

Fig 14 Screen organisation

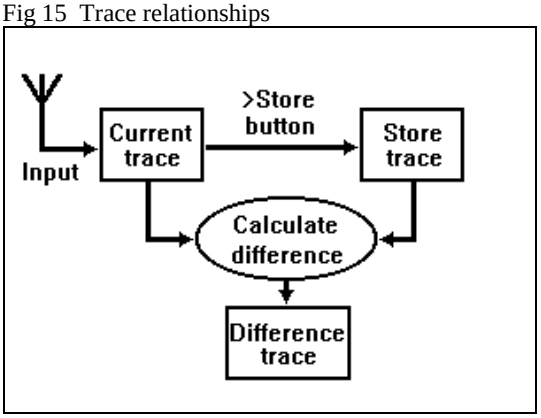


7.1.1 Mouse/key operation

The software would normally be driven with the mouse. However, if a mouse is not available the software can be driven from the keyboard.
Each 'active' button is highlighted. This highlight can be moved from group to group with the TAB key. Within each group the highlight can be moved using the cursor keys and a selection made by pressing the space key. To select a main menu press ALT+(the letter underlined in the menu title).
Other groups or choices can be selected by just pressing the letter only.

7.1.2 Trace organisation

Fig 15 Trace relationships



The incoming signal is always displayed as the 'Current' trace. All processing functions such as average, peak hold and antenna factor correction are applied to this trace.
The 'Store' trace is always a copy of the current trace and is copied when the **>Store** button is clicked.
The 'Difference' trace is the difference between the current and stored traces. There are two techniques for calculating the difference (emissions and insertion loss) and these are described fully in section 7.3.2.4

If the ERS correction is technique is used, the correction is applied to the Difference trace.
The 'Archive' trace is always used for displaying traces recalled from disk, although any other trace can also be used for this purpose.

7.2 Analyser Controls

7.2.1 Scan controls

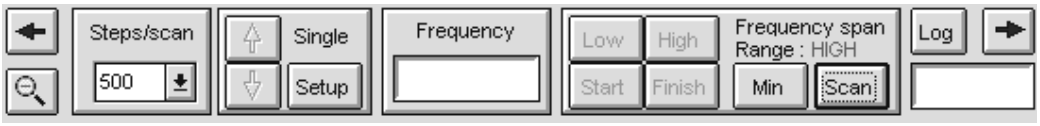
The two main control keys '**S/SHOT'** and '**RUN**' are bi-functional and the button legend will change according to the operating mode of the analyser.

S/SHOT - Stop - Stopping
Takes one scan from the analyser and updates the screen once. When the analyser is scanning, STOP causes the analyser to stop ***when it reaches the end of the current scan***.

RUN - Cancel
RUN causes the analyser to scan the signal and update the screen continuously. Cancel causes the analyser to stop immediately, even if it is only part way through a scan,

>STORE
Copies the current trace to the stored trace. Any data already in the stored trace will be lost. This is used to copy a background reading into the store so that the difference trace can be used for instance to null out the background by subtracting the stored trace from the current trace.

7.2.2 Frequency controls



The area below the trace screen contains all the controls for setting the frequency range to be scanned and/or single frequency controls.

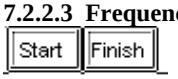
7.2.2.1 Steps/scan

Controls the frequency resolution of the analyser. This sets the number of frequency points measured per scan. Note that whilst in Linear sweep mode, the spacing is linear, in Log sweep mode the spacing is set to give constant screen resolution and a true log scan. The maximum number of steps is 500. Selecting any higher number would have no benefit as there are only 500 pixels across the trace screen.

7.2.2.2 Frequency range

These set the frequency range to be scanned. Low range covers 10KHz to 30MHz. High range covers 30MHz to 1100MHz. The selected range is shown just to the right of the buttons.
Changing the frequency range causes the analyser to enter a self calibration mode which takes 30 seconds.
The I.F. bandwidth is automatically changed when the range is changed. For Low range, I.F. bandwidth is 9KHz. For High range, I.F. bandwidth is 120KHz.

7.2.2.3 Frequency start/finish



These set the start (low frequency end) and stop (high frequency end) frequencies of the scan. They cause a frequency entry window to appear enabling the chosen frequency to be keyed in MHz. If the Start button is clicked, the software will automatically show the Stop entry window after the Start frequency has been entered.
On the low frequency range, the entry is XX.XX MHz. On the high frequency range, only integer numbers are allowed.
Software logic will ensure that the 30MHz boundary is not crossed.
Note that when in Log sweep mode the frequency start/stop parameters cannot be changed.

A full list of techniques for setting the scan range is as follows:

1. The cursor can be used to zoom into a narrower frequency range than currently displayed. This technique works with Lin frequency axis only, not Log. The system works by using the cursor to 'pull' each edge to the desired position. To do this, position the cursor on the trace screen within 1 division of the LH edge, hold the left mouse button down and drag the LH edge to the desired frequency then release the button. Repeat for the right hand edge of the trace screen.

2. The keyboard can be used to type in the desired start and stop frequencies by clicking on either the Start or Stop buttons.

3. The frequency axis can be 'shifted' left or right by half the screen width using the or buttons immediately below the trace screen.

4. The frequency axis can be 'zoomed out' by clicking on the button. Each time this is clicked the frequency coverage will double.

5. The frequency axis can be reset to the full frequency span (30 - 1100MHz or 10KHz - 30MHz) by clicking on the Low or High buttons.

6. If in Log frequency axis, or will switch between alternative ranges.
   If in High range, the alternatives are 30 - 300MHz span and 30 - 1000MHz span.
   For low range the corresponding alternatives are 10KHz - 30MHz and 100KHz - 30MHz.

7.2.2.4 Frequency axis scaling

Log/Lin button

The frequency axis can be displayed in linear or logarithmic scaling. Note that the logarithmic scaling is limited to 30 - 1000MHz and 30 - 300MHz or 10KHz and 100KHz - 30MHz. depending on the frequency range selected at the time. If in log frequency scaling or will switch between alternative spans.

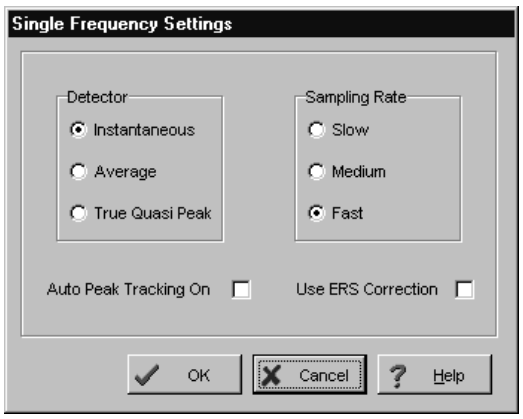
The logarithmic scaling causes the analyser to step logrithmically in frequency, thus providing an even resolution across the screen.

7.2.2.5 Min frequency span

This sets the scan width to the minimum permissible and, if in low frequency range, selects 100 steps per scan. The start frequency is unchanged from the previous sweep.
The purpose of this mode is to show maximum spectrum resolution.
In Low frequency range, the scan width is 500KHz.
In High frequency range, the scan width is 10MHz.

7.2.2.6 Single frequency mode

Enters single frequency mode. This enables one frequency to be constantly monitored and the level plotted against time. Any one of the three detectors may be selected.
Clicking on this button causes a 'tuning' cursor to appear on the trace screen. Note that the Frequency window will display the selected frequency as the mouse is moved. Position this at the frequency of interest and click the left mouse button. This selects the single frequency to be measured. A further selection window will appear to enable sampling interval, detector type and tracking mode to be selected.



Detector sets the analyser in the corresponding mode.

Sampling Rate is the rate at which readings are transmitted to the PC. It does not refer to the input sampling rate of the analyser. Thus if average detection and Fast sampling rate are selected the input is sampled continuously at maximum speed to derive a true average level. Every 100mS the analyser transmits the current average value to the PC and continues sampling.

Medium corresponds to an interval of 0.5 sec and Slow to an interval of 1 second**.**

Auto Peak Tracking mode can be used where the signal of interest is a distinct peak. Selecting this mode and positioning the cursor over the peak or at a frequency slightly higher than the peak will cause the analyser to lock on to the peak and continually track the frequency of the peak, always returning the peak value to the PC. If the peak drifts in frequency, the analyser will track it. The frequency is constantly measured and is displayed in the frequency window.
Note that if the signal is interrupted for even a short period, the peak tracking system will lose track and hunt downwards in frequency, picking the next lowest peak.

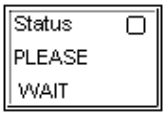
If the signal is broadband, (no distinct peak) then leave **peak tracking** off. The frequency will be fixed by the position of the single frequency cursor on entry into this mode. Once running, the frequency can be adjusted with the and buttons with the current frequency displayed in the frequency window.

If **Use ERS Correction** is selected then the difference trace, corrected with the ERS correction system, will be displayed. Note that this item will only be available if ERS correction is valid.

When running in the single frequency mode the current measured value is displayed in the top right hand corner.
Once running in single frequency mode, **STOP** causes the measurement to cease.

Setup enables the single frequency parameters to be changed and clicking on **Scan** (near lower RH side of the screen) switches the screen back to normal frequency scanning mode.

7.2.3 Status area



This shows the current status of the analyser and the serial communications link with the analyser. If there are any problems with this link, or the analyser itself, a message will be reported here.

The coloured indicator shows:

Green, OK, waiting for commands
Blue, OK, analyser working
Red, Compression occurring or Comms link fault, message gives details of the fault.
Magenta, Analyser in ERS calibration setting mode
White, Analyser undergoing reset.

If the system appears to 'hang up', select **Disk...hardware reset**. This forces a complete communications reset and may clear the problem.

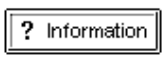
7.2.4 Input Attenuator

The input on the SA1000 analyser is fitted with a switchable 0, 10, 20, 30dB attenuator. These are used to extend the dynamic range of the analyser for large input signals. This automatically adjusts the vertical scaling of the display.
If overload warnings occur, increase the attenuation setting until the overloads cease. See section 6.3.

7.2.5 Pre-amplifier

If the SA1020 pre-amplifier is used to increase the signal level to the analyser, the preamplifier options box should be clicked to show the gain in the window. This will then automatically adjust the vertical scaling to match the increased gain of the system.
The nominal gain of the SA1020 pre-amplifier is 20dB.
NOTE: When using the RF200 antenna and invoking the RF200 under the input menu, the pre-amplifier setting will be automatically set to 20dB as the pre-amplifier must always be used with the RF200.

7.2.6 Information screen



This shows all the current settings, the contents of the notes fields and limit line and AF data plot. If ERS correction is being used, a plot of the correction data will also be shown.

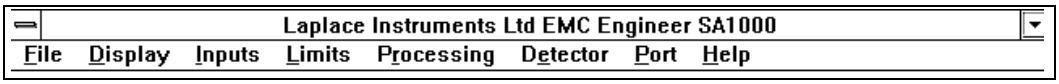
7.2.7 TestDirector

Clicking on this button triggers the entry into the TestDirector expert system.
See section 7.6 for more details.

7.2.8 dBm/dBuV button

The vertical scaling of the spectrum amplitude can be switched between dBm and dBuV. For EMC emissions applications, dBuV is commonly used. For other general RF analyser work, dBm is frequently used.
Note that when an input device such as the RF200 is selected, the vertical units are in the appropriate units such as dBuV/m, dBpW or dBuA and the **dBm/dBuV** button is deactivated.

7.3 Main menus



7.3.1 FILE menu

File...Open...
Loads data from a previously saved file.
An 'options' selection window is opened to enable considerable control of the way in which trace data is loaded.
The key selection is the 'Import all screen settings?' switch. If this is checked, the imported data will set the displayed frequency span and configuration. If this is not checked, the imported data will be matched (as far as possible) to the existing screen setup.
All traces are stored in the saved file. (Current, Stored, difference and Limit) Options control the way in which these traces are loaded. This allows considerable flexibility so that results of different tests can be compared. The screen will retain any existing trace that is not loaded during the Open command. Thus if you need to compare a current trace with a previously saved current and stored trace, load the previous file with Current loaded as store and Store loaded as archive.

The result will be a stored and an archive trace showing the 'old' data and the current trace showing today's data.
If the difference trace from the file is required, you can either load it as an archive trace or load both current to current and store to store then having loaded them, enable the difference trace.
Note that if the 'Import screen settings' is not checked the loaded data will be 'fitted' as accurately as possible to the current frequency scaling even if the two traces where acquired with differing setup conditions.
If you need to use the difference function between a current trace and a trace stored on disk, load the previously saved trace as the store trace.

If the Import screen settings is selected, the ERS correction data used at the time that the file was saved can also be imported. Note that this overwrites any ERS correction data currently in use. This 'loaded' correction data can be used for correction on any subsequent tests, although this is not recommended as there is no certainty that the test site has not changed.
If the file had been saved with single frequency data, this is loaded with the spectral data and can be viewed by switching to the single frequency mode in the usual way.

Other options allow selection of directory and drive.

File...Setup...

Allows selection of baud rate and file delimiter.
The baud rate will normally run at 38,400. If there are problems with the communications link, try setting this to a lower option. Note that when the RF910 pre-selector is in use, the baud rate will be fixed at 9600 baud.
The file delimiter is used when saving data to disk and when loading data. It can be changed, if necessary, to match the requirements of third party software such as spreadsheets.

File...Save as...

Saves the results currently on screen to disk.
The data saved includes:

- Date and time
- Set-up conditions
- Current trace data
- Background trace data
- Difference trace data
- Limit line data
- Comments
- Title
- ERS correction data

If the system is in single frequency mode, the single frequency data will be saved as well as the associated spectrum. The file format is simple ASCII with a header for the set-up data. See Appendix 2 for file format details.
The default extension is .EMC
The options include entry of file name, selection of directory and disk drive.

File...Save

As above, but assumes same file name as previously saved file. Will display confirmation message on screen warning of file overwrite before proceeding.

File...Printer setup...
Standard Windows printer setup selection screen which allows control of printer type, format (landscape or portrait), paper size, printer port etc...

File...Print
Prints a hard copy version of the current screen data.

File...Printer Colours...
Enables individual traces and grid lines to be allocated alternative colours.
A default button sets all the colours back to the default set. (All black).

File...Screendump
Sends a copy of the screen direct to printer.

File...Title...
Enables entry of the title field, shown above the trace screen and reproduced as the title on any hardcopy. Double clicking on the title field has the same effect.

File...Notes...
Enables up to 8 lines of notes to be appended to the results. These notes are saved to disk and reproduced on any hardcopy. They can be viewed by using the ? Information screen.

File...Hardware Reset
Resets all settings on the analyser to startup conditions, including 30dB attenuation. Also all traces, notes, title, filenames etc.. back to null or default values. All information will be lost. The analyser will be reset to the high frequency range.

Exit
Exits from the SA1000 program. All data currently not saved to disk will be lost.

7.3.2 Display menu

The Display menu enables the user to control which traces are visible. These can also be switched by using the buttons at the upper edge of the graphic display (see below). Note that the active traces are listed in the colour of the respective trace along the top edge of the trace screen. Up to 5 traces can be displayed on the screen at any one time. These are:
Current. This is the current input signal
Store. This is a trace copied from the current trace. Normally used for background nulling.
Difference. This is a plot of Current - Background trace.
Archive. This trace can be created by loading a previously saved file
Limit. Shows the selected limit line.

7.3.2.1 Instant display toggle keys

Clicking these buttons will toggle the corresponding trace on or off

7.3.2.2 Display...Current

The Current trace (default colour black) is the spectrum of the current signal input to the analyser. All processing functions (averaging and peak) are applied to this trace. This trace may be copied to the stored trace by using the **>STORE** button.
Selection of this item on the Display menu toggles the Current trace ON/OFF.
Toggling the trace OFF will not cause loss of data.

7.3.2.3 Display...Stored

The Stored trace (default colour red) is used for recording the background emission level or for comparing two traces. Data can be transferred to this Background trace from the Current trace (using the **>STORE** button) or loaded from disk from a previously recorded file.
This trace is used to compute the Difference trace.
Selection of the **Display...Stored** menu item toggles this trace ON/OFF.
Toggling the trace OFF will not cause loss of data.

7.3.2.4 Display...Difference

The Difference trace (default colour magenta) is a computed difference between the Current trace and the Stored trace.
There are three different modes for calculating the different trace:

- Emissions: The main purposes of this trace is to enable measurement of radiation from a product in the presence of background radiation, as will be the case on any open field test site.
- ERS correction If using the ERS auto correction facility, the corrections are always applied to the difference trace. This avoids 'correcting' the background.
- Insertion loss: This is a measure of the characteristics of a filter, or amplifier plotted as attenuation (or gain) vs frequency.

Choice of difference trace mode is selected under the processing menu.
Each technique requires a different process for calculating the difference between the current and stored traces. These are detailed below.
Note that each frequency point along the frequency axis is calculated individually by processing of the relevant traces at that frequency point.
The processing techniques are:

7.3.2.5 Emissions

Selected by the **Processing....Difference: emissions** item.
Because the data is in logarithmic values, simple subtraction is the equivalent of dividing the current trace by the stored trace. This is clearly not what is required if using the trace for background subtraction. Therefore to obtain a true subtraction each value is antilogged first to convert to linear units, then subtracted, then logged to convert back to log scaling. This technique should be used when subtracting background radiation in radiated emissions testing.
Logarithmic scaling has the effect of making small differences between current and stored traces appear as relatively large peaks on the difference trace. In order to work with a relatively 'clean' difference trace, the use of averaging or peak detection is essential.
Note that if there are points at which the stored trace is greater than the current trace, the resultant is negative and will not appear on the screen. If a difference trace is required for a case when the stored trace is the greater of the two traces, save the results to disk first, then open the file, recalling the traces with the current and stored traces reversed. See **File...Open** for details.

7.3.2.6 ERS Correction

This mode is entered by selecting **Processing....Difference: emissions** and **Processing.....Apply ERS correction - Vertical (or Horizontal).**
Note that if the ERS calibration sequence has not been previously run or loaded from file during this current session, the Apply ERS correction options are not available and are greyed out.
This technique calculates the emissions difference trace as described in the section above and then applies the ERS correction data to that trace. See section 8.4 for full details.

7.3.2.6 Insertion loss

This is effectively simple linear subtraction. This technique is only used in the special case when measuring insertion loss or filter attenuation or amplifier gain.
Selected by the **Processing ..... Difference: Insertion loss** item.
Because insertion loss is a log valued parameter, simple subtraction gives the correct result.
The results for insertion loss can routinely be positive or negative and so a special scale up the Right hand side of the trace screen is used. This applies only to the insertion loss parameter and provides a range of -30dB to +40dB.

Selection of the **Display...Difference** menu item toggles this trace ON/OFF.
Toggling the trace OFF will not cause loss of data.

7.3.2.7 Display - Archive

This trace is only active after loading an archive trace from file. It cannot be used directly for difference trace calculations. The default colour is green.

7.3.2.8 Display - limit

The Limit trace (yellow) will display the currently selected limit values on the screen.
The limit line is selected under the Limits menu.
Selection of the **Display...Limit** menu item toggles this trace ON/OFF.
Toggling the trace OFF will not cause loss of data.
The limit line will be scaled and adjusted to suit the current display settings. Note that Limit traces are only displayed if an appropriate **Input** device has been selected. Eg. A conducted limit trace will not be displayed unless a LISN or PLIP has been selected as the input device. This interlock prevents invalid comparisons between measurements and limit levels.

7.3.2.9 Display...Clear

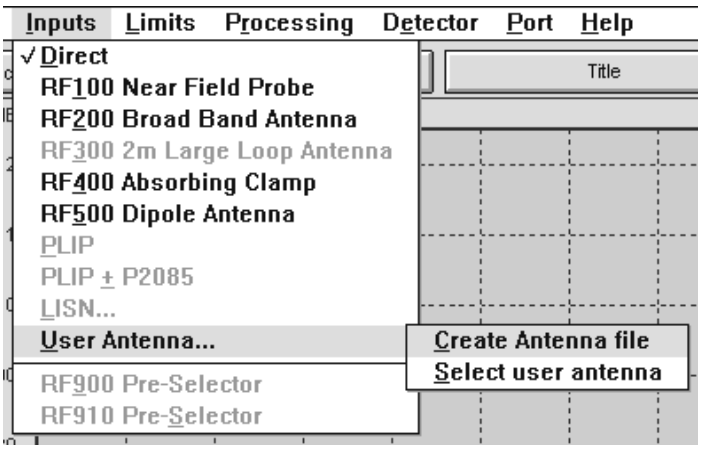
Clears all input data from the current, stored and difference traces. Resets the Averaging and Peak arrays and sets the LIMIT trace to OFF.

7.3.2.10 Display...Information... Displays the information screen. See para. 7.2.6

7.3.2.11 Display...Colours... Enables the colours of the traces and grid lines to be changed.

7.3.2.12 Display...Values... Actives a cursor readout window. See section 7.4.

7.3.3 Input Menu



The Input menu allows the user to specify the source of the signal to be input to the analyser. The software will automatically adjust the scaling of the display to match the source. For instance, if the RF200 is selected, the antenna factor correction for the RF200 antenna will be implemented and the display will read directly in dBuV/m field strength.

The Input Device information area to the left of the trace screen shows the current selection. See fig 14. In the case of the LISN, the LISN settings are displayed. To change LISN settings, double click on the input device information area.

If a 'straight' readout of the signal received at the analyser is required, use the Direct item.
Note that any input devices not relevant to the frequency range selected will be greyed out. Thus for instance you cannot select the RF200 broadband antenna if the low frequency range (10KHz - 30MHz) is selected.

7.3.3.1 Input - Direct

This item should be used if connecting directly to any signal source or simply wishing to ensure that the software does not apply any corrections to the incoming data in any way, other than scale adjustment for pre-amplifier and input attenuator. Processing functions are treated separately.

7.3.3.2 Input - RF100

This item displays and stores the data from the analyser without processing or applying any antenna factor compensation. The RF100 near field probe set cannot be used for absolute field strength measurements, it can only be used for comparative and qualitative work. For most work, use the SA1020 pre-amplifier. However for strong sources the SA1020 may not be necessary.

7.3.3.3 Input...RF200

The RF200 broadband antenna from Laplace is a 30MHz to 1GHz antenna with a known antenna factor. This antenna factor is loaded with this SA1000 software and when this item is selected the antenna factor is automatically used to display field strength as measured by the antenna. Although these readings will be correct (within the ±6dB error budget of antenna + analyser) for field strength as received by the antenna, test site conditions have to be very carefully controlled if these readings are to have any meaning. To greatly improve the accuracy and integrity of readings the ERS (Emissions Calibration Source) can be used.

NOTE When using the RF200 antenna, it must be assembled as specified in the instructions in section 9.3.1 with the SA1020 pre-amp installed at the head of the antenna**.**

Antenna distance

This is the distance from the EUT and the antenna. It is measured in metres from the outer surface of the EUT and the effective centre of the antenna (the centre mounting boss).
This parameter must be accurately entered into the SA1000 software when selecting antenna type if comparison with limits is to be achieved. The allowable range is 1 to 30 metres. **The Standards suggest that a minimum distance of 3metres should be used. The ERS is calibrated for a distance of 3 metres.**
The field strength from any point source is inversely proportional to the distance from the source. The limit levels are specified by the standards at a specified distance from the EUT (usually 10m or 30m). If measurements are undertaken in the presence of background radiation as on an OATS, it is normal practice to considerably reduce the antenna distance (i.e. to less than 10 or 30m) so that the radiation from the EUT is increased relative to the background. Having reduced the antenna distance, the limit levels should be adjusted (increased) to take into account this reduced distance. The SA1000 software will automatically calculate the new limit levels to conform with the entered antenna distance.
Some users prefer to reduce the signal level instead of increasing the limit level. This alternative technique has the advantage of showing the limit at the level prescribed by the standards although the technique is incorrect. If this alternative technique is preferred, click the right mousebutton on the Antenna Factor graph in the **Information** screen. This will display a confirmation screen and will invoke the alternative technique. To switch back to the standard technique, use the same sequence of clicks.

7.3.3.4 Input... RF300 Large loop antenna

This item corrects the readings over the range 10KHz to 30MHz for use with the RF300 antenna.
For details of the operation of this antenna, see the separate RF300 user guide.

7.3.3.5 Input... RF400 RF absorbing clamp

Select this item if using the RF400. The antenna factor compensation for the RF400 will be automatically applied. Note the requirement to search along any cable for maxima closest to the EUT.
For details of the operation of this clamp, see the separate RF400 user guide.

7.3.3.6 Input...RF500

The RF500 tuned dipole can be tuned to frequencies between 80MHz and 300Mhz by adjusting the element lengths to ¼wavelength. See Dipole section 9.3.4. The readings are NOT subjected to any antenna factor correction because the RF500 is not calibrated.

7.3.3.7 Input...PLIP

Selects the correction factor for the PLIP. If using the SA1020 pre-amplifier, ensure that the corresponding check box on the SA1000 screen is checked appropriately.
Do not use this item if using the P2085 pre-amplifier.

7.3.3.8 Input...PLIP + P2085

Selects the correction factor for the PLIP and pre-amplifier. Note that the pre-amplifier check box on the SA1000 screen should NOT be checked unless using the SA1020 pre-amp in addition to the P2085.

7.3.3.9 Input...LISN

Use this item if measuring conducted emissions with any standard LISN. The software will activate the LISN control box on the screen allowing entry of the LISN settings. Once the LISN is selected the settings can be changed by clicking on the Input information area.
The settings are source (Live or Neutral), and insertion loss setting. The software will use these settings to set the scaling of the screen.
NOTE: Spectrum analyser inputs are very sensitive. Great care must be taken not to overload the input, especially when connected to the LISN. It is normal RF analyser practice to disconnect the analyser input whilst switching/connecting the EUT to the mains. The Laplace LISNs have a built-in transient limiter to protect the analyser.
If using a pre-amplifier, set the pre-amp gain in the **pre-amp** window.
Other LISNs

- If using any other LISN, fit a voltage (transient) limiter in the signal lead.
- Check the insertion loss of both the LISN (should be quoted in the user manual) and transient limiter. Many LISNs have zero dB attenuation, but transient limiters often have a 10dB attenuation. Select the appropriate attenuation in the LISN selector box. In the above example, the 10dB attenuation selection would be correct.

7.3.3.10 Input...user antenna

This section is provided so that 3rd party antennas can be used with this system.

Secondary options allow either:

- The entry of a new antenna factor data file.
  The data is entered as a series of nodes specifying sensitivity vs frequency. There is no limit to the number of nodes. The software will compute straight line interpolation between the entered nodes.
  If the antenna is used for radiated emissions, clicking the Radiated item will activate the 'enter antenna distance' query when the antenna is used.
  When all the data is entered, use the **File...** menu to save the data to disk.

Several A.F. data sets may be entered and each will be automatically filed under a user specified 'name'. Each antenna factor file is stored in a separate file called 'name'.ant.

- The selection of an existing user entered antenna factor.
  When an antenna factor data set is invoked, the software will display field strength on the vertical axis and automatically compensate the incoming spectrum.

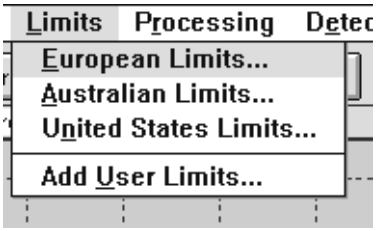
7.3.3.11 Input...RF900 Pre-selector

Select this item when the RF900 pre-selector is in use. This will cause the required band setting to be shown in the small window above the information button on the screen and the PC to beep when the next band is to be selected. More information is given in the RF900 User Manual. **7.3.3.12**

Input...RF910 Pre-selector

Selection of this item enables the automatic control of the RF910 pre-selector via the serial port. Once selected, the appropriate commands are sent to the serial port and the operation of the RF910 can be confirmed by checking the indicators on the front panel of the pre-selector.

7.3.4 Limit Menu



Select country specific limits

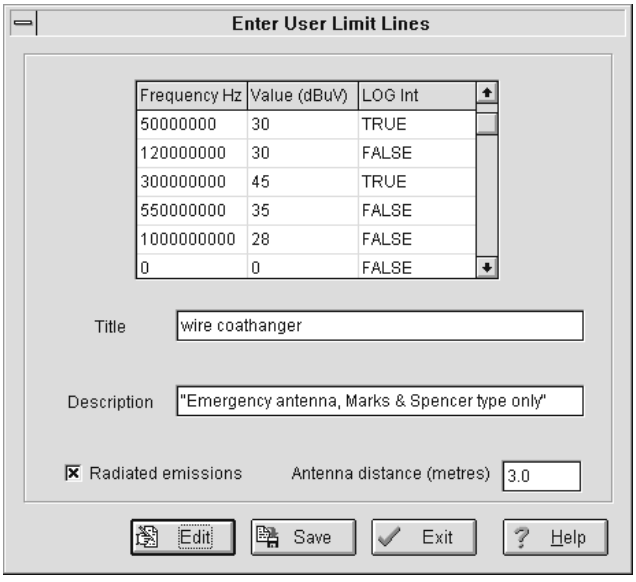
Limit lines, as specified by certain EN standards, Australian/New Zealand standards and FCC (US) standards can be displayed on screen. The Limits menu allows selection of the appropriate limit.
The limit line will be scaled and adjusted to suit the current display settings.

WARNING
The limits will be at the correct level according to the current settings. (i.e. pre-amplifier, antenna distance, LISN settings etc...) Any errors in the set-up conditions will cause corresponding errors in limit line comparisons with the signal traces.
In particular:

- Limit lines must not be used with near field probes.
- When used with a far field antenna, large loop antenna or absorbing clamp, compensation for antenna factor must be made. (This is automatic if the correct device is selected under the Input menu)

Allowances for test set-up and test site calibration must be made.

Limits...Add User Limits...

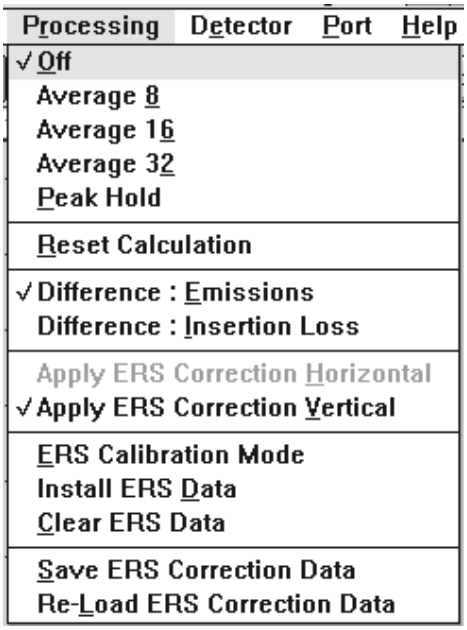


Enables the user to input new limit lines. An entry screen is provided into which frequency vs level (dB units) data can be typed. A third column selects logarithmic or linear scaling vs frequency for the interpolation between points. This is entered as TRUE (log interpolation) or FALSE (linear interpolation) and controls the way in which the interpolation applies to the next frequency point entered. Other fields are for a **description** which appears on the information screen and hardcopy, **title** which appears on the European Limits menu list. Note that if the Radiated emissions check box is clicked, the reference distance for the antenna must be entered as XX metres. The reference distance is the distance at which the limit data applies.

When all the fields are entered, click on **save** and enter a filename. The limit line data will now be saved as a file.

Existing limit lines can be loaded and edited by clicking on the Edit button. The list of limit lines will be displayed so that the required file can be opened for editing.
To use a 'user limit' when it has been entered, select **Limits....User limits....Load user limit**
The user limits will be listed for selection

7.3.5 Processing Menu



This menu controls any additional processing of the current trace on each scan as it is received from the analyser. Note that this menu does not affect the antenna factor compensation of the results.

7.3.5.1 Current Trace processes

Off: Displays the data as received from the analyser. (No processing applied)
This selection automatically applied when the Detector is set to average or Quasi-peak.

Peak Hold: The spectrum display on the PC applies a peak hold function to each frequency point so that if many scans are performed, the trace will show the maximum value obtained during all the scans. The clear window at the lower RHS of the screen shows Pk and the number of scans completed in this mode. This mode is useful when acquiring spectra from pulsed emissions and for acquiring background emissions.

Average:
The average selection includes an averaging number, 8, 16 or 32. The software applies an average to the measured value at each frequency point averaged over the selected averaging number of scans. If 8 scans are selected, the first scan is plotted as received, the second plot shows the average of 2, the third the average of 3.... and so on. When the 8th scan has been plotted showing the average of 8, the scanning will cease.

Reset Calculation:
Resets the peak hold and average results to zero.

7.3.5.2 Difference trace processing

Difference - emissions The difference trace is calculated as a true power difference.

dB(diff) = dB(curr) - dB(stored)

This is not a simple subtraction as these are log values and subtraction is equivalent to division. Therefore the difference is calculated by taking the anti-log of both current and stored traces, subtraction, then re-logging the result. For example, when the difference is equal to the stored value, the current trace is 6 dB higher.

i.e. dB(diff) = dB(curr) - dB(Stored)
therefore dB(curr) = dB(stored) + dB(diff) = 2 * dB(stored).
Doubling a power is a 6dB increase.

Difference - insert. loss Insertion loss a measure of the attenuation of a circuit or device measured in dB. This is expressed as a ratio, output power/input power. Subtracting the two dB values of stored from current produces this parameter directly. Hence this option implements a simple subtraction technique.

7.3.5.3 ERS Options

These options all relate to the auto-correction feature for measurement of radiated emissions on non-calibrated sites. The logical progression starts with the lowest item on the menu and works upwards.

Clear ERS Data
Use this if updating the ERS calibration data. This will be required if using a different ERS unit (i.e. a different serial number) or if updating the data following a re-calibration of the ERS.

Install ERS Data
Transfers ERS calibration data from a floppy disk to the hard drive. Subsequent screens lead you though the process. Ensure the serial number is entered correctly.

ERS Calibration Mode
This items initiates the procedure for calibrating a test site and generating the correction data which can subsequently be used to correct measurements of emissions from the EUT. Each polarisation (Vertical and Horizontal) should be calibrated separately, requiring two runs in calibration mode. Full details of this process are given in section 8.4.

Apply ERS Correction Vertical/Horizontal
Once the correction data has been obtained by using the Calibration Mode outlined above, it can be applied to the difference trace obtained when measuring the EUT. This correction can be applied either after or during the process of measuring the EUT. Full details are given in section 8.8.

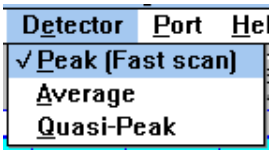
7.3.5.4 Save ERS Correction data

The current ERS correction data can be saved to disk. Only one set of correction data is saved. Any previously saved will be overwritten.

7.3.5.5 Re-load ERS Correction data

Enables previously saved ERS correction data to be loaded and used. Note that any changes to the test site would render this corretion data invalid.

7.3.6 Detector Menu



These options set the type of detector implemented in the analyser.

Detector...Peak (Fast scan)
The analyser measures the instantaneous peak of the signal as it is scanning. A peak hold circuit at the analyser 'front end' ensures that no peaks are missed between measurement points. See 'no gap scanning', section 4.5.2. This mode permits fast scanning but may give false results in the presence of non-continuous emissions.
This should not be confused with **Processing...Peak** which applies a peak hold function to the display only.

Detector... Average
This implements an average detector in the analyser. Although this mode is slower than the peak mode, it produces accurate average results which can be compared directly with the average limit levels. Selection of this option disables any **Processing... menu** functions.

Detector... Quasi-peak
This implements a quasi-peak detector in the analyser. Although this mode is slower than the peak mode, it produces accurate Q-P results which can be compared directly with the Q-P limit levels.
Selection of this option disables any **Processing... menu** functions.

7.3.7 Port

Menu item which allows selection of the serial port to be used for communication with the SA1000 analyser.
Selection is either COM1 or COM2
The default is COM1.
Note that this default can be changed by using the inifile.exe utility. See appendix 1.

7.4 Cursor Readout

A cursor can be invoked which will enable a direct readout of the value of all traces at one frequency. A readout window will appear on the trace screen, giving values of all the active traces, and a frequency readout.

- To invoke the readout window, use the <alt><up arrow> key combination or the **Display...values** menu

- To invoke the cursor, click on any part of the trace screen.

- The cursor is represented by a vertical yellow line which can be moved using the <alt> <left arrow> or <alt> <right arrow> combinations. Initially, the cursor will be at the LH edge of the screen, so use <alt><right arrow> to bring it into view.

- To deselect the cursor readout, use <esc>.

7.5 Power up defaults

All the program defaults are saved in a file called SA1000.INI located in the SA1000 directory. This is a simple text file which can be edited with any standard word processing software. Every time the EMC software is run, the program reads this file and invokes the settings defined in it. The file is fully explained in Appendix 2. Default settings such as Port selection, limit line selection, analyser configuration etc.. may be set to suit your own circumstances.

7.6 TestDirector

The TestDirector button opens a series of windows which will assist the user to make the correct decisions when beginning a test.
This system is essentially self explanatory...simply answer the questions and follow the instructions!
There are three main phases:

1. The selection of the correct standard and test technique.
2. Advice on test ancilliaries required and test setup,
3. The selection of the relevant limit level.
4. Automatic initial setup of the analyser.

At any stage the system can go back to the previous step if a mistake has been made or this mode can be exited.

Standards currently covered by this system are:

EN standards	**As/NZ standards**
55011	
55013	1044
55014	1053
55015	2064.1/2
55022	2557
55025	3548
50081-1	4051
50081-2	4251.1
60945	

8.0 Emissions testing - Operating notes

This chapter describes the actual measurement procedures for radiated and conducted emissions.

It is important to realise that the actual procedures adopted for a particular EUT, site situation and circumstances will need to be developed from these basic guidelines in order to achieve optimum results. Every product and test site is different and the ability to adapt and improvise your test strategy is fundamental.
In order to achieve this flexibility, an in-depth knowledge of the test techniques and the behaviour of RF is important. For that reason, the chapters 4 and 10 in this manual are recommended reading!

Radiated emissions testing using OATS technique.
Suggested procedure (consult sections 8.1 to 8.9 for the details)

1. Set up the test site and equipment ready for the measurement.

2. Use the near field probes (RF100) to scan the product. (SECTION 8.2.1) Take sweeps right up against any part of the product, or especially any attached cables, that may radiate emissions. Take care to note any peaks found when the probe is away from the EUT, these are background! Particularly note the location on/around the EUT that produces the strongest signal. The purpose is to identify the most likely source of emissions. Bear in mind the fact that any cables on which you detect RF signals will be strong radiators of RF even if the level as measured by the near field probe is relatively low.(See sections 10.3 and 10.4)

3. Save the resulting 'signature' to file (xxx.emc). LOOK at the signature! Note any distictive features such as..... are the emissions broadband or narrowband? What is the highest frequency of any significant emissions?, if so, make a note. Are they all concentrated in one particular frequency range?, if so, make a note.

4. Prepare the test site and connect the RF200 antenna to the analyser. Leave the EUT to one side, well out of the test area. Place the ERS at the location which will be occupied by the position of the source of emissions, see (2) above.

5. Run the ERS calibration procedure. (See section 8.4). When completed.....

6. Under the **Processing** menu, select **Apply ERS Correction**, (Vert or Horizontal as appropriate)

7. Remove the ERS and install the EUT, leave it switched off.

8. Set the input device and limit line as appropriate. Use TestDirector if preferred.

9. Set the frequency range to match the range of emissions detected in step 3 above. (No point in scanning for signals that do not exist)

10. Scan the background remembering to check the pre-amplifier batteries and to switch it ON! and adjust the input attenuator setting for optimum results (compression detector on intermittantly, see section 8.3.2). NOW YOU ARE READY TO BEGIN THE ACTUAL MEASUREMENT

11. Set **Processing... Peak Hold** and then **RUN** for continuous sweeping. (SECTION 8.5) This will gradually build a stable signature of the background. Generally after 5 sweeps the display should be stable (no more additional peaks appearing). The counter in the RH lower corner of the sceen indicates the number of sweeps completed. When content, **STOP** the sweeping.

12. Copy the current trace to store trace. (See section 7.2.1)

13. Switch the EUT on. Make sure that it is settled into the normal operating mode.

14. Use **S/SHOT** to sweep. (SEE SECTION 8.7)

15. Switch Diff trace ON and stored trace OFF. The diff trace will show all signals which exceed the stored (background) trace. These new signals may be from the EUT, or may be changes in the background.

16. Use the **File...open** command to open the xxx.emc file previously saved with the near field probe results. Under Open settings select current trace to archive, store trace to 'do not import' and deselect 'Import all screen settings', 'Import single frequency data' and 'Import difference as Archive'. The near field result will now appear as an archive trace overlaid on the screen.

17. Use the correlation between the archive trace and the difference trace to establish which peaks are due to the EUT. These can now be measured in dBuV/m.

18. If desired, zoom to the frequencies of the EUT emissions and investigate product orientation and operating mode variations to find the worst case levels. Use of single frequency mode may help to speed up the process.

8.1 Radiated emissions testing...details

In order to ensure repeatability and consistency of measurement, the techniques used to measure radiated emissions are carefully defined (in theory!!)

Techniques for Far Field radiated testing are set down in the Standards which propose 2 alternative techniques:

* Open field test site: Literally do the measurements in an open space, well away from interfering sources or any structures that could give rise to reflections.

  In practice, radiated emissions are difficult to measure accurately. To minimise the variability of measurement, emissions are measured in the 'far field', far enough away from the unit under test to avoid field distortions immediately in the vicinity of the source and to avoid the need to distinguish between E or H field sources.

  An alternative for those who have the facilities is the use of an anechoic chamber or test cell (such as the LaplaCell300).. A chamber comprises a totally screened room fitted internally with RF absorbent materials to prevent reflections. This eliminates background radiation but is an expensive solution. Also be aware that all chambers need calibration.
  Simple 'screened rooms' are NOT a good idea as the reflections cause massive measurement errors.

* RF Absorbing clamp.: A relatively straightforward technique that overcomes most of the problems associated with the 'far field' test discussed above. Unfortunately, this technique is specified only for EN55014. If your product has to comply with any other standard then you cannot use the absorbing clamp. For measurement technique, see the RF400 user guide.

8.1.1 Open Area Test Site (OATS)

Sometimes called an Open Field Test facility

The technique specified by the EC standards for measuring RF emissions is to measure the far field radiation (field strength) at a specified distance.
There are two major problems to be addressed:

- Background radiation.
- Test site distortion.

An OATS is literally an 'open' field i.e. an area free of any metal objects or structures which could cause reflections. Being an 'open' field, the site will have a level of ambient (background) radiation comprising mainly of broadcast stations and other transmitters. Any emissions measurement system needs to be able to measure the amount of background radiation and differentiate it from signals emitted from the EUT.

Even if the site is free of reflecting objects, there will always be some reflection off the ground. See section 10.6 The standards use ground planes and 'height scanning' to overcome the problem that the ground causes. *A metal ground plane should be laid on the ground between the product and the antenna. This should be such that it provides a totally reflecting surface (whereas ordinary 'ground' e.g. soil, will have an indeterminate reflection coefficient which will vary with weather and time of day)*. Having a reflecting ground plane may give consistent results but the reflected radiation itself causes other problems. The antenna will 'see' the resultant field strength due to the combination of direct radiation and reflected radiation. If the difference in distance travelled by the direct and reflected radiation is half wavelength then the two signals will cancel at the antenna location and the analyser will measure a level far below the true figure. *In order to overcome this effect, the standards specify use of an antenna mounted on a mast such that it can be adjusted in height up to 4 metres and, at each frequency of interest, the antenna height is adjusted until a peak level is found. At this point the direct and reflected signals are in phase and sum together*. In order to overcome all these variables and indeed to allow testing in non-compliant sites, the ERS (Emissions reference source) has been developed. This is now available as a standard option with all kits intended for use on an OATS. The ERS enables the effects of all the above problems to be quantified and subsequently corrected. See section 8.4.

8.1.2 Test cell

This comprises a totally screened room or cell fitted internally with RF absorbent materials or designed to to prevent reflections.

Note that a simple screened room not fitted with any RF absorbing features may be the worst option because the RF radiated by the unit under test will reflect from the walls/floor/roof of the room, summing in some positions and cancelling in others, making any true measurements virtually impossible. However, use of a calibration source (see ERS, section 8.4) will enable the room to be calibrated and a correction factor calculated for all frequencies of interest, provided that the EUT is small relative to the size of the room.
Screened rooms may be used to identify emission frequencies as a first stage test before moving to an OATS to measure the actual field strength. This two stage technique has the advantage that the need to search for emissions in noisy backgrounds is avoided.

8.2 Radiated testing strategy:

If using the RF300 large loop antenna (for EN55015) or RF400 RF absorbing clamp (EN55014), careful testing will produce results that can be compared directly with then limit levels with a high degree of confidence. See the user manual supplied with each of these devices.
If using the RF200 broadband antenna to perform radiated emissions measurement, the strategy must allow for the fact that accuracy of far field measurement with any broadband antenna is very dependant on the test site. Any testing must take into account the following variables which should be investigated to ensure worst case emissions are measured:

Antenna polarisation, EUT operating mode, EUT orientation

If possible, testing can be staged as follows:

- Simple initial measurements. Locate frequencies being radiated and track the source. No attempt to measure absolute levels, main purpose is to minimise emission levels by comparative measurements (before/after modifications). The initial tests enable the user to gain an overall picture of the emission levels and to spot any potential 'problem' frequencies. Note that the EUT should be rotated to find which side emits the highest levels of interference. (Vertical emissions from the top of the EUT are not covered by the standards and do not need measurement!)
- Pre-compliance tests. Use auto site correction technique with ERS to obtain relatively accurate emission level measurements. If any strong emissions are detected, the near field probes can be used to locate the hot spots or leakage paths corresponding to these problem frequencies. Once a product has been 'refined', the far field test can be repeated to quantify the effect of the improvement and to ensure that new problem frequencies have not appeared. Note that the combination of near and far field testing is essential.
- Final compliance checks and documentation. Use manual ERS techniques to obtain highest level of measurement integrity.

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Near field testing enables you to track down the source and to 'fix' it. Measurements can only be relative and will not bear any defined relationship with the far field measurements. Strong 'hot spots' as

measured by the near field probes will not necessarily produce strong far field 'peaks'. This is why near field probes when used in isolation are of limited value.

8.2.1 Near Field measurements.

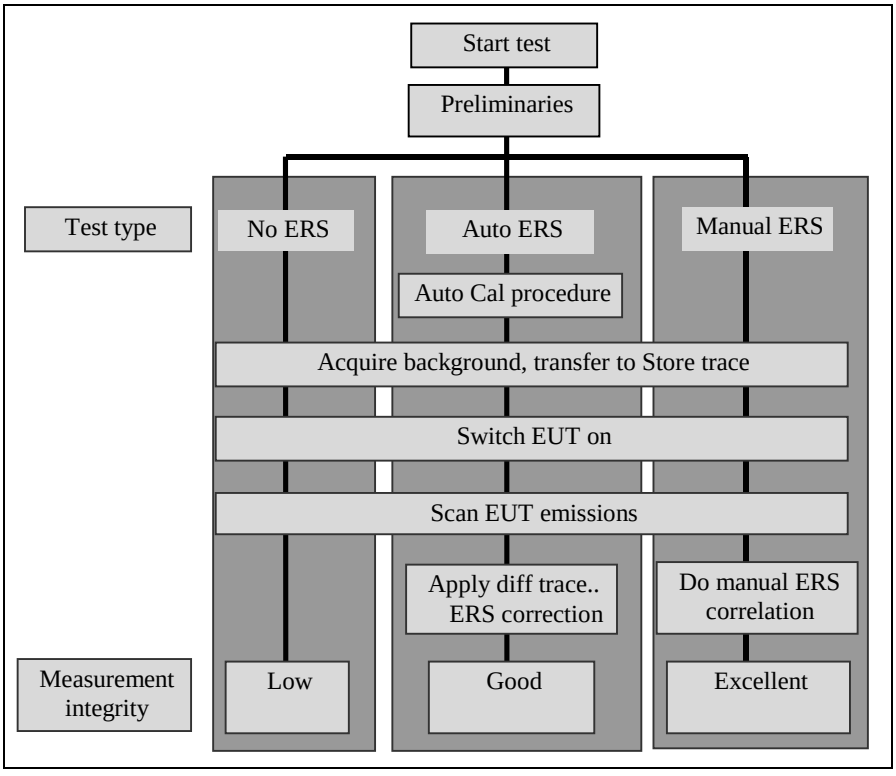
The RF100 Near field probe set enables you to detect the location of radiation sources precisely. Note that the output from these probes will reflect the intensity of the source. This often does NOT correspond to the peak frequencies as measured by the far field antennas. See Field types section 10.2. The far field strength is a function of source intensity and (more importantly) the efficiency of the 'aerial' The aerial in this case being the cable, wire, PCB track or whatever conductor is radiating the signal. The efficiency of this aerial will depend on many factors, including the electrical length (approx. the physical length) in comparison with the wavelength of the radiated signal. An 'efficient' aerial will cause a strong field strength in the far field even if the 'source' is relatively weak. Bearing in mind that it is only the far field that matters (because that is what the standards are based on), you must use the far field results to identify the 'problem' frequencies and then concentrate on just these frequencies when in near field mode.

The probes can initially be used with the analyser set to cover a broad spectrum to get an idea of the emission levels at specific points outside and inside the EUT. Because the levels are totally dependant on the proximity of the probe to the source, any measurement of absolute field strength is quite meaningless.

Note that experience shows that the significant emission frequencies normally do **not** correspond to clock frequencies because clocks are usually very low power circuits and much of the digital circuitry is driven at harmonics or sub-multiples of the basic clock frequency.

8.3 Radiated test techniques

Fig 17 Radiated test techniques



The following sections describe the steps involved in measuring radiated emission levels. The diagram shown in Fig 17 shows the three techniques listed in the preceding sections, and the steps associated with each. If no ERS is available only the 'no ERS' technique can be used and ample uncertainty

margin will have to be allowed. The degree of uncertainty will depend heavily on the 'quality' of the test site and the procedures used. See the requirements in EN55022.
To execute a particular test technique, simply follow the relevant steps as indicated in the above diagram. Each step is individually described in the next sections

8.3.1 Preliminaries

8.3.1.1 General guidelines

* Both horizontal and vertical polarisations need to be tested.
* Once the test has started, the environment must be kept stable. No objects should be moved and no persons should approach the EUT whilst scanning is in progress.
* The EUT should be configured so as to maximise emissions.
* The emissions should be measured from all angles by rotating the EUT.

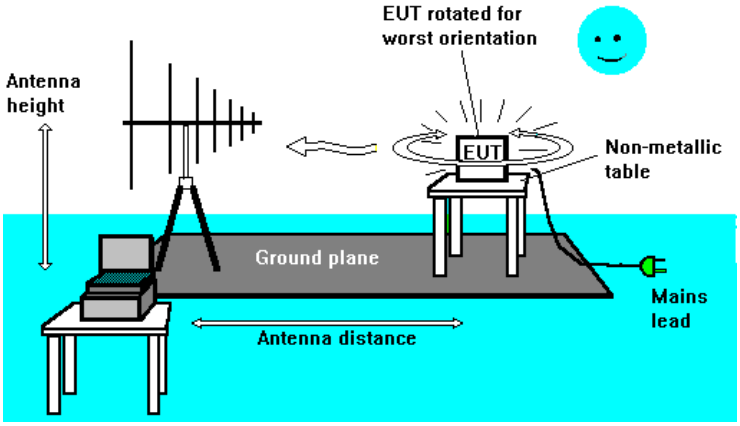
8.3.1.2 Test Site

As the previous sections have stated, establishing a suitable test site is of prime importance. Guidance is given both in this manual, books such as written by Tim Williams and Chris Marshman and as specified in the Standards themselves.
For the purposes of this section, we will assume that a site has been established that at least attempts to match the basic requirements of an OATS in respect of using an area free of reflecting metal surfaces.

8.3.1.3 Configuration

If the product is table top mounted, it must be placed on a non-conductive table 0.8m high, connected as specified in the appropriate Standard.
The antenna (RF200) should be placed at a known distance from the product in vertical or horizontal polarisation and pointed at the product. This distance is measured from the central boss on the antenna to the closest point on the EUT. For most applications, the minimum distance of 3m can be used.

Fig 18 OATS

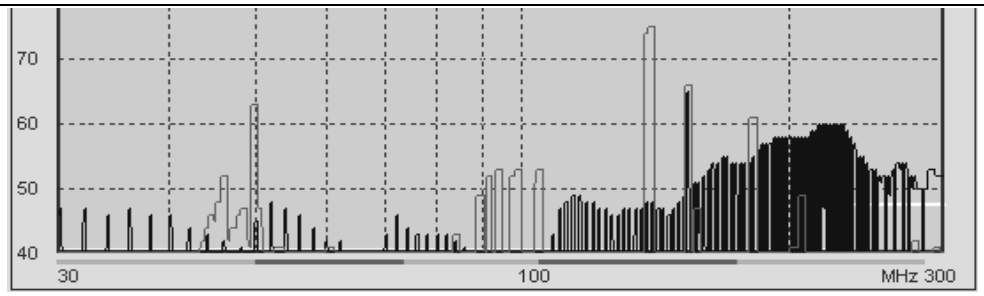


Establish the analyser and PC as far as practicable off to one side of the antenna.
Couple the pre-amp input to the antenna and the output via coax cable to the analyser.
Use only the current trace for the moment.
Switch the pre-amp on ,
Set **Steps/scan** to 500.
Set **High** frequency range and **Log** scaling (log scaling is the convention for EMC work).
Set 0dB **attenuator**.
Under the **Input** menu, select the appropriate antenna **RF200** and enter antenna distance.
Set the limit level by selecting the relevant standard under the **Limits....** menu

8.3.2 Check background

Set **Detector ... Peak**.(Fast scan) This is the fastest scan.
Set **Processing....Difference: emissions**

With the EUT switched off, click **S/Shot** and check the spectrum on the PC. There will be an indicator bar just under the horizontal axis on the trace screen. This generally shows the progress of the sweep with a green bar. If there are any compression (overload) conditions, the bar will turn red at the instant of the overload and a warning message in the analyser status area will appear. Transient overload indications may be caused by 'glitches' from equipment or traffic in the close vicinity. These can be ignored. The example given in figure 19 shows substantial compression indications over 30% of the sweep.
* If there is significant compression indications, sweep again with the **attenuator** increased by 10dB.
Check the sweep is clear of significant compression.
If this is the case, repeat from *.



Red compression condition indications

Fig 19 Compression status bar

If there is significant compression with the attenuator set at 20 or 30dB then the source of the strong signal should be identified. There are some signals which can be dealt with quite simply:
- If the highest peaks are the FM broadcast signals (85-106MHz) then the RF600 filter unit will attenuate these signals and permit testing to continue.
- If there are no particularly high peaks observed on the scan, the problem may be signals below 30MHz and thus invisible to the user when scanning the HF range. This could be the case if no signals in the HF band above 30MHz are of significant amplitude. The RF700 high pass filter is effective in these circumstances.

It could be that the test site is simply unsuitable due to high background emissions and an alternative needs to be found (your back garden at home, for instance). Although no particularly high peaks may be present, high broadband emissions, sometimes found at frequencies below 100MHz may be the cause of compression. These are typically due to sources within or close to a building and the best solution is to re-site the test away from that building.

If the attenuator reaches 0dB and still no overloads, then use the 0dB setting.
The ideal is to have the analyser giving intermittent compression warnings. This shows that it is running at an optimum setting,, receiving the largest possible signal consistent with no significant distortion (or compression).

8.3.3 Background signals

Backgrounds vary from location to location but usually the major frequencies can be identified. Not all the list below will be visible, but it would be most unusual if non of the list where present.

Each of these frequencies can be tuned to and by selecting single frequency mode, they can be demodulated and listened to.

Table 6 Common Ambient signals

Frequency (MHz)	Source	Notes
75	Aero ILS	May be intermittent
85 - 108	FM broadcast stations	Often the strongest signals in the spectrum
108 - 136	Aviation	Ground - air ATC voice comms
136-156	Land mobile	Emergency services, taxis etc..
138	Pagers	Can be strong if close to a repeater
153	Pagers	Can be strong if close to a repeater
156 - 165	Marine	
165 - 220	Land mobile	Emergency services, taxis etc..
418, 459, 464	Low power telemetry	
470 - 853	TV	
853 - 960	Mobile phones	Vodaphone, Cellnet
960 - 1215	Aero DME	
1030, 1090	ATC Transponders	

8.4 ERS site calibration

8.4.1 The principle

The ERS is always used by substitution with the EUT so that the site attenuation between the precise location of the EUT and the antenna can be measured and compared with that which would be obtained on a perfect test site.

The ERS radiates signals at 2MHz intervals from 30MHz to 1000MHz. Each 2MHz signal has been carefully measured using test conditions and procedures that exactly match the requirements of the standards. It must follow then that if the ERS is measured on any other site that also matches the standard requirements, the results would be in agreement and there would be zero difference. On any site that is not absolutely 'correct', the results would differ. This difference is a measure of the 'distortion' of that site. For example, if at 120MHz, the readings from the ERS are 8dB less than the calibration data, that site must be reading 8dB low at 120MHz and any emissions from the EUT at 120MHz must have a correction of plus 8dB added in order to 'normalise' the readings to the level which would have been measured on a perfect test site, using strictly correct procedures.

Factors which must be taken into account are the two polarisations (vertical and horizontal) and background signals.

8.4.1.1 Calibration integrity

At frequencies where the signal from the ERS is much stronger than the background or noise floor, the calculation of the correction factors will be accurate. At some frequencies, the ERS signal may be 'buried' in strong background, or may be so weak (due to high site attenuation) that it is barely above the noise floor. In these situations the calculation will not be dependable and the results cannot be trusted. This happens when the ERS signal is less than 6dB higher than the reading with the ERS switched off. The frequencies at which this happens are 'marked' with an integrity status bar. This is the black/white bar across the bottom of the screen. The corrected difference trace at those frequencies which coincide with the white band should be ignored. The other sections of the trace, against the black band, will be accurate.

8.4.2 The procedure

This procedure needs to be followed for either or both polarisations, depending on the needs of the current test. Note that any ERS corrections derived during this procedure are 'volatile' i.e. will not be retained once the program is exited unless they are saved to disk. See section 7.3.5.4. However, when a result is saved to disk, any ERS correction data is saved also. When Opening a file, the option is offered to reload the ERS correction data is made available. In addition, the Processing menu has items for saving ERS data and reloading it independantly of the results files.

8.4.2.1 Install ERS data

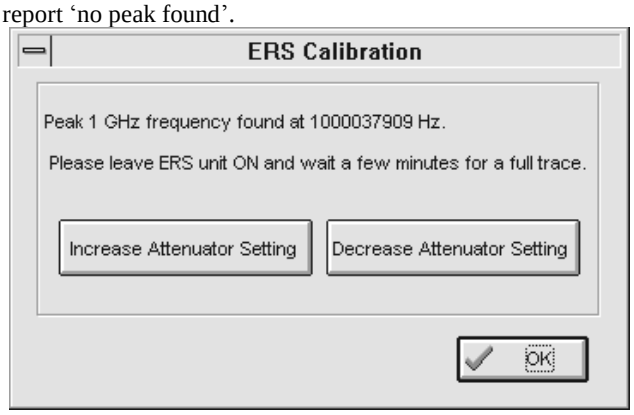
The ERS calibration data is supplied with each ERS on a 3.5" disk. This data is transferred to the PC using the **Install ERS data** under the **Processing** menu.
This only needs to be done once. Once the data is installed, it is retained in a file on the default drive.
Only when this step has been completed will the next options in the Processing menu become active.

8.4.2.2 ERS Calibration Mode

Once a test site is established and ready for use, the ERS is positioned at the location of the product to be tested (if the product is small it is removed from the site for the purposes of this test , if too large to remove, make some initial measurements in the far field to find significant emission frequencies, then use the near field probes to locate the source of these frequencies. Position the ERS as closely as possible to the location of this source) , set for either vertical or horizontal polarisation (adjusting the receiving antenna to correspond).
The next step is to set the attenuator such that the analyser is not in compression when the ERS is switched on.
Switch the ERS on and scan with the attenuator set to 30dB.
* Transfer the current trace to store trace with the >Store button.
Reduce the attenuator by 10dB and scan again. Compare the current and stored traces.

If they are essentially the same (within 3dB) repeat from *.
If they are different, increase the attenuator by 10dB and continue below.

Select **Processing....ERS Calibration Mode.**
Check the serial number of the ERS and select the required polarisation.
A message will remind you to have checked for compression as detailed above.
Switch the ERS on and confirm on the screen.
The analyser will now search for the 1GHz signal from the ERS. This will take a few seconds. On completion, the screen will indicate either that the peak has been found, and will report its precise frequency, or it will report 'no peak found'.

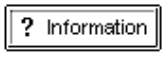


If the peak has been found, confirm OK to proceed.

If no peak was found it means that either the ERS or Pre-amp were not switched on, or that the site attenuation at 1GHz is so high that the 1GHz peak has been lost in the ambient noise. If this occurs, temporarily reduce the attenuator setting by 10dB)or more) and try again.. Once the peak has been found and the frequency measured, use the 'increase attenuator setting' button to restore the attenuator to the 'proper' level before confirming OK to proceed.

The analyser will now automatically measure every 2MHz peak from 30MHz to 1GHz very precisely. This takes approximately 7 minutes.When the sweep has finished, switch the ERS off and confirm on the screen. A prompt will appear requesting a 'S/SHOT'. OK this message and click on S/SHOT. The analyser will now repeat the sweep, measuring background signals. This will again take approximately 7 minutes. At the end of this second sweep, the software will automatically calculate the correction factors necessary to make the test site behave like a perfect site.
This process should be repeated to cover both vertical and horizontal polarisations, changing the ERS and the receiving antenna accordingly.

Note: the resulting correction data is volatile. It will NOT be retained by the system once the SA1000 software is closed unless the Save ERS Correction procedure is invoked. This is intentional to avoid the temptation to re-use the same correction factors for subsequent tests when test site conditions may have changed.

The correction data may be viewed in the 

screen.
The correction data is applied to the difference trace. This difference must be derived from the store (background) trace and a current trace which includes the EUT emissions.

8.5 Acquire Background

In typical test sites, the background is quite unstable. However a stable background 'signature' is essential if the background is to be effectively nulled out. This is accomplished by using **Processing... peak hold** or **Processing...Average...**. Both these techniques tend to stablise the background. The choice of which to use depends on local conditions. Experiment with each and use the one which gives best results. If using Peak hold, continuous sweeping using the **RUN** button will eventually capture any intermittent transmissions or fluctuating signals and show them as part of the signature. Observe the trace and when no more changes are seen, use STOP to end the process. The sweeping will stop when it gets to the end of the current sweep.Averaging will simply average the spectrum. The greater the averaging the more potent the effect. This will automatically stop when the required number of sweeps has been performed.
So set **Processing....Peak hold** or **Averaging** and use **RUN** to establish a stable display, When stopped, click the **>STORE** button. The store trace will now be active, showing the background signature in red.

8.6 Switch EUT on

Ensure the EUT is located and configured correctly, and that it is running in the chosen mode.

8.7 Locating problem frequencies

- If using Average mode, check the processing menu and ensure averaging is still active then click on **RUN**. If using peak hold mode this will be turned off automatically and just use **S/Shot**. Any new signals received by the antenna will now show up as an increase over the background signature. At the end of the sweeps the new signals are immediately obvious as black peaks above the red background.
- If the emissions are intermittent, run the analyser for some time in Peak hold mode to acquire the frequency envelope of the emission pulses.
- Enable the difference trace to show the field strength of the 'new' emissions by clicking on the Diff trace button. Switch off the store trace to show the difference trace more clearly.
- Having identified any peaks which originate from the EUT, note their frequencies and/or store the results to disk/hardcopy.
- Bear in mind the fact that when covering such a wide frequency span (30-1100MHz) discrete narrow band emissions may be difficult to detect especially in a test site that suffers from high background levels. In this situation, reduce the span to sweeps of approx. 200MHz wide and repeat the tests.

8.7.1 Measurement of emission level.

Zoom to the frequency of interest. Generally a 100MHz scan width would be appropriate. To speed scanning, you can set the **steps per scan** to 250 or 100 steps. The stored background trace will still be valid provided that the test setup or environment has not been changed.

- Set **Processing...off (to cancel peak hold)**
- Switch the EUT on.
- Click on **RUN**.
- Any emissions due to the EUT should be clearly visible.
- Switch the EUT on and off to confirm that the emissions are from the EUT rather than some background phenomenon.

Use the current trace to indicate the magnitude of the emissions from the EUT and compare this level with the limit level bearing in mind the margin of uncertainty due to the instrumentation and antenna (±6dB) and the test site (??dB). Use of the ERS calibrator will considerably reduce this uncertainty.

8.8 Use of the ERS Auto Calibration function

Select **Processing...Apply ERS correction Vertical/Horizontal** (as appropriate)
The corrections as computed during the ERS calibration procedure will now be applied to the difference trace.
Note the black/white 'integrity' bar across the bottom of the screen and disregard any results which are at frequencies shown as having poor integrity. See section 8.4.1.1.

8.9 Manual ERS correction

Whilst the analyser is zoomed into the area of interest, use the near field probe to locate the position of the source:

Stop the scanning
Set **Detector....Peak (fast scan)**
Set **Input....RF100**
Disconnect the pre-amp input from the RF200 antenna and connect the H field loop probe to the pre-amp using the supplied BNC-BNC adapter.
Remember that low level sources on long leads (Eg. mains cables) will act as a better source than a relatively strong source not connected to any long leads.
RUN the analyser and 'sniff' with the probe around the EUT, paying particular attention to any cables, leads or other conductors (if external) and slots or other unscreened areas.

Once the location of the source is identified, the EUT should be removed and the ERS located at the same position in space, orientated to provide the appropriate (vertical or horizontal) polarisation.
Measure the emissions from the ERS by reconnecting the RF200, selecting RF200 on the Input menu and scanning. Note the amplitude at the frequency of interest. By comparing this with the corresponding amplitude stated in the ERS calibration data, the errors due to the test site will be apparent and the correction calculated.
Modify the original reading from the EUT by the correction factor.

Repeat for vertical polarisation and other EUT configurations and directions.

8.10 Problem assessment and monitoring modifications

Many sources are found to be related to cables and any other wiring that exits the EUT, including the mains lead, if fitted. The near field probe will help track this down.
Once the source is located, steps can be taken to reduce the emissions, either by PCB redesign, circuit changes, filtering or screening.
The effect of any changes to the product can be noted in real time using the single frequency mode of the analyser. Set this to the frequency to be monitored, select the appropriate detector type, fine tune the analyser to find the peak and the trace will display a continuously updating reading of level plotted against time.

When you have completed 'improvements' to the EUT, repeat the scanning measurements to check that the improvements have been sufficient and to ensure that no other peaks have been created or made worse as a consequence of the changes to the circuitry/screening.

8.11 CONDUCTED EMISSIONS

For all mains powered equipment, the standards call for the amount of interference conducted back up the mains cable to be limited.

8.11.1 Preliminaries

The SA1000 and LISNs are designed to cover these emissions, from 10KHz up to 30MHz as specified by EN standards.
Measurement of RF on a mains supply cable introduces specific problems. In particular these are:

(A) High voltage (115 or 240V, 50/60Hz)
(B) Presence of interference from other sources coming 'up' the mains.
(C) Variable impedance as seen by the EUT (Equipment Under Test) looking back down the mains lead. The source impedance of the mains varies considerably at RF frequencies from one location to another, making repeatable measurement impossible.

To overcome these problems, CISPR have specified a Line Impedance Stabilisation Network (LISN) to be used for all mains interference measurements. The construction and components are clearly specified so that all conforming LISNs will give the same results. In circumstances where a LISN cannot be used (due to high EUT current requirement or difficulty in connecting a LISN) the standards allow the use of a 'voltage probe'. The Laplace PLIP (Power Line Interference Probe) is such a probe.
A common feature of the signals on the mains is their broadband nature, particularly if the EUT is a power control device using phase angle switching (e.g. light dimmers) , includes electric motors with commutators or variable speed drives. Switched mode power supplies can also cause these broadband signals. These signals can cause compression in spectrum analysers which will lead to false results. The solution is to use a pre-selector. The RF900 or RF910 pre-selectors are designed for this specific application.

NOTE

When first beginning a test with the LISN, ALWAYS start with the LISN attenuator (if fitted) set to -20dB, 150KHz filter (if fitted) switched IN and the SA1000 attenuator switched to 30dB. Do not use a pre-amplifier to begin with. Check the full span of the analyser to ensure that there are no compression warnings and that no peaks are greater than 100dBuV. Only if this is true, reduce the SA1000 attenuator and check the full span again. If still OK gradually reduce the attenuator down to 0dB. If still no compression warnings and no peaks are greater than 80dBuV, connect a pre-amplifier and adjust the pre-amp gain field as appropriate. Only if there are still no compression warnings, reduce the LISN attenuation (if switched). The whole point to this exercise is to ensure that the analyser is working in its linear range.

8.11.2 Non continuous emissions

Many emissions output from equipment down the mains lead are pulsed in nature. Often these will pulse at 100Hz, caused by zero-crossing and phase angle control circuitry. These pulsed emissions will modulate the frequency scan of the analyser to produce apparently random peaks especially when using the low frequency ranges. This is a well known problem that affects all conventional spectrum analysers and is overcome by using the 'average' or 'Quasi-Peak' detectors.

8.11.3 Quasi-peak analysis

Most standards call for 'quasi-peak' detection. This technique will give a lower reading spectrum than the 'peak' technique for pulsed emissions. The reduction actually depends on the repetition rate of the pulses and is shown graphically on page 55 of Tim Williams' book (Page 65 in the second edition). This shows that for 100 Hz repetition rate, the difference between peak and quasi-peak is 7dB for the frequency range below 30MHz and 12dB for the frequency range above 30MHz. At higher repetition rates the differences reduce. The graph also shows how Average readings relate to Peak.
Quasi-peak is a technique which aims to measure the 'annoyance' value of an interference signal. The faster the repetition rate, the more annoying the interference. Thus a repetition rate of 1 second produces a much lower reading than the same pulse repeated 100 times per second.

8.12 Conducted testing - Procedure

The overall procedure summary:

1. **Establish test environment.**
2. **Set the signal level.** Set the level of attenuation and pre-amplifier such that maximum sensitivity is obtained without compression.
3. **Measure and store any background signals.**
4. **Measure the emissions from the EUT:**
    - **Use peak detector initially**
    - **Only if results shown emissions close to or exceeding the average limit level, proceed to Quasi-peak and Average detection.**

8.12.1. SETUP

Establish a test environment as prescribed by the relevant standard. This will normally involve mounting the EUT on non-metallic table, itself stood on a ground plane and with a vertical reference plane 0.4m from the EUT. The LISN should be positioned on the ground plane with a short ground bond between them.

Connect the LISN to your mains supply.

NOTE: The mains supply must NOT be fitted with an RCB (earth leakage breaker) as the LISN will immediately cause this to trip. This is not a fault, all LISNs have this feature. If a non-RCB supply is not available, use a 240/240V (or 110/110V) isolation transformer of a current rating to match your product.

IMPORTANT: READ SAFETY INSTRUCTIONS IN LISN MANUAL

You are about to connect an exceptionally sensitive instrument (the analyser) with a full scale input of only 22mV to the mains!!! Follow the instructions listed below carefully. Avoid becoming too 'casual' when conducting these tests.

1. Check that the software settings match the LISN and pre-amp situation.
2. In the software, set **LOW** frequency range.
3. Input settings: **Input....LISN (or PLIP)**
   LISN Insertion loss as appropriate
4. Select **Detector...Peak (Fast scan)**
5. Switch analyser input **attenuator** to 30dB
6. Select **Log** frequency axis (this is normal convention)
7. Select the appropriate limit from the list under the **Limits** menu
6. At the start, do not use the pre-amplifier between LISN and analyser. Set Pre-amp to 0dB
7. Connect theappropriate LISN RF output or PLIP output to the analyser signal input with a short BNC lead.

8.12.2 Set signal level

In the following procedures, ***reduce attenuation*** means reducing the attenuation by 10dB. This can be accomplished by a combination of analyser attenuator, LISN attenuator (if fitted), use of pre-amplifier (which has the effect of reducing attenuation) to give an end result which equals a 10 dB reduction in attenuation. Always ensure that the LISN and Pre-amplifier check boxes on the PC screen match the actual configuration of the hardware. If using a PLIP, follow the same procedure but disregard the LISN references.

NOTE: If using a LISN with switched attenuation, never switch it to the 0dB position!!

Increase attenuation means increase attenuation by 10dB using the same facilities as listed above.

Switch the EUT on.
Switch the LISN source to L (L1)

1. Click on **S/SHOT** and observe the signal on the screen.
2. If no significant compression warnings occur (red bands on the trace progress bar),
   ....use >**STORE** button to store result
   ....reduce attenuation and
   .... click on **S/SHOT** and observe the signal on the screen.
3. Compare current trace with stored trace.
   If no compression indications and current trace matches stored trace, repeat from step 2.
   If intermittent compression indications and current trace is within 2dB of the stored trace at all frequencies, then go to step 4.
   If current trace deviates significantly from the stored trace, ***increase attenuation*** and go to step 4**.**
4. This is the best result. Make sure that the software switches match the settings on the LISN, analyser and pre-amplifier and proceed with the next stage.

See the flow diagram, fig 11.

Then the 'proper' measurements can be taken USING THE SAME ATTENUATOR SETTINGS.

It may be that compression is evident even with maximum attenuation used and/or that results are inconsistent. Broadband emissions from switching devices are particularly liable to create such a situation. The solution is to use a pre-selector such as the RF900 or RF910.

8.12.3 LISN - Background interference

Despite using the LISN, background signals will normally be present. The voltage probe will be particularly susceptible to background noise. These are due to signals either from the mains supply, 'leaking' past the LISN input filter or broadcast signals, typically LW (long wave) and MW (medium wave) radio signals picked up on the mains lead between the LISN/probe and the EUT. At some locations, low frequency (<100KHz) artefacts may appear, even when no EUT is connected to the LISN/probe. These will occur if the mains supply has such a high harmonic content that the filtering in the LISN is unable to attenuate it fully. Using the 150KHz high pass filter on the LISN will help, but this is really a symptom of very poor local mains supply conditions.

To check these background levels, leave the EUT connected, but switch it off at the EUT on/off switch. If no switch is fitted, disconnect the mains at the terminal block inside the EUT. The aim is to leave the connections intact between the LISN/probe and the EUT so that any pickup of broadcast emissions will be observed.
Use **RUN** or **S/SHOT** to sweep the spectrum and capture the background. This can then be transferred to the store trace with the **>STORE** button.

8.12.4 Measure emissions from EUT

The initial test is to check whether the peak emission level exceeds the Average limit line. With Peak (Fast Scan) detector selected, the limit line automatically shows the average limit level.
Switch on the EUT. **RUN** the analyser.

- Observe several sweeps. If the spectrum remains stable and is below the limit level, **STOP** the analyser and save/record the results to file/hardcopy. Repeat for Neutral (L2). Test completed!
- If the spectrum appears to be unstable, select **Processing...peak hold** and **RUN** again. Let the analyser sweep until the spectrum appears to be stable. If the results are below the limit, **STOP** the analyser and save/record the results to file/hardcopy. Repeat for Neutral (L2). Test completed!
- If the results show peaks above the limit, both the average and Quasi-peak detectors should be used and the results compared with the respective limit levels. There are two methods for taking these measurements.

    * **Single frequency:** Fast, but only one frequency measured. Ideal for narrowband emissions. Peak tracking facility will automatically lock on to and track the peak. If frequency of peak drifts, peak tracking will follow it. Use Setup button to switch between Average and Quasi-peak detectors.

    * **Scan:** Slow, but produces a complete spectrum of the emissions. Ideal for broadband emissions. Each step takes 6 seconds. Note that the measurements are taken at step increments only. Frequencies between the steps are not measured.

Steps/scan	Time
100	10 minutes
250	25 minutes
500	50 minutes

NOTES:
A. When using a LISN with a switched attenuator, NEVER use the OUT position on the LISN (This is provided so that the LISN can be used as a means of injecting RF onto the mains.
B. ALWAYS select the OFF position on the LISN source selector switch, or disconnect the RF output lead before switching your product ON and OFF. This is just good discipline and avoids any possibility of damaging the analyser or Pre amp with transients.
C. Only switch out enough attenuation to obtain usable readings. Do not attempt to obtain readings greater than absolutely necessary as this may lead to errors due to the impulsive nature of many mains borne emissions.

8.13 Insertion loss

Part of the requirements of certain directives (e.g. EN 55015) includes a measurement of 'insertion loss'. This is a measure of the effectiveness of an RF filter and requires the measurement and comparison of both the input signal to the filter and the output signal from the filter, the difference between the two being the 'insertion loss'. Conventionally, this is measured at many discrete frequencies using a sine wave signal generator and an RF voltmeter, a time consuming and far from ideal technique.

With the SA1000 and PC interface the complete insertion loss characteristic can be measured easily and accurately for all frequencies in the required range, instead of just a few discrete frequencies.

The test will require a set-up as defined in the standard 55015, section 4.1, section 5 and figs 1 - 4 plus either a swept sinewave signal generator or a 'white' noise source covering the frequency range 150KHz to 1605KHz to act as the test signal source.

1. Connect the RF terminals of the dummy lamp to the test signal source. This can be either a broadband noise generator (ideally) or a swept sine wave generator. The sweep may be automatic or manual. The signal input level must be set to the level specified in the standards.
2. The output of the luminaire is then measured. Connect the analyser to the mains terminals. Using the analyser attenuator and signal generator level controls, set the analyser to read a level of around 1 - 2 divs up from the screen baseline. If using a swept sine wave then use **Processing.....Peak hold** and sweep the source very slowly. Expect to take many scans to complete the spectrum. Too fast a sweep will result in obvious gaps in the spectrum on the screen. If sweeping manually, monitor the screen to check progress. If using a broadband noise source then use 8 averages. This builds up a spectrum of the output from the circuit under test..

   Copy the resultant spectrum to the stored trace. (**>STORE**)

3. The input to the analyser is now connected to the RF terminals on the dummy lamp and the measurement repeated except that the new spectrum, once acquired, is not copied to the stored trace. Note that it is recommended to fit a 20dB 50ohm attenuator in line to the analyser. This will make the signal level more closely match that of the first run and ensure that the results are not affected by dynamic range limitations. Add 20 dB to any resultant insertion loss values.
4. Select Diff trace on and select **Processing...Difference: Insert. loss** and the insertion loss characteristic is immediately shown across the whole range of frequencies tested. The scaling is shown on the right hand side of the screen.

9.0 Accessories

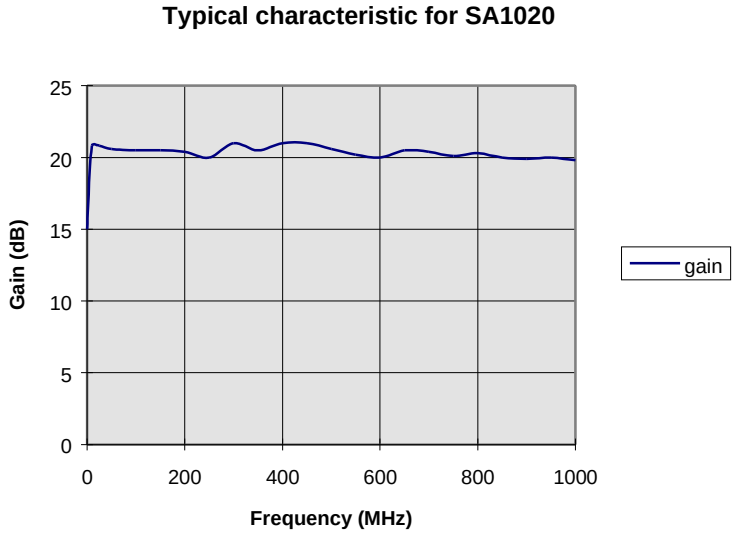
The Laplace accessories listed in this section are:
1. SA1020 Preamplifier
2. RF100 Near field probes
3. RF200 Broadband antenna
4. RF300 Large loop antenna (separate user guide supplied with item)
5. RF400 RF Absorbing clamp (separate user guide supplied with item)
6. RF500 Dipole antenna
7. RF600 FM band filter
8. RF700 30MHz high pass filter
9 RF800 150KHz - 30MHz band pass filter
10. RF900 and RF910 pre-selectors (separate user guide supplied with item)
11. LISN1600 (separate user guide supplied with item)
12. PLIP (separate user guide supplied with item)
13. ERS Emissions Reference Source (separate user guide supplied with item)

The analyser can be used with any other third party input device as long as the calibration data (antenna factor) is known. This can be entered into the software and the correction factors automatically applied. See section 7.3.3.10

9.1 SA1020 Pre-amplifier

9.1.1 Description

The SA1020 is a small self contained amplifier intended to provide in-line signal amplification for low level RF signals such as output by radio or EMC antenna and near field probes, and to provide an output suitable for RF spectrum analysers, oscilloscopes or other measurement or recording instruments.
In order to maintain high signal to noise ratio and to offer maximum operational convenience, the unit is internally battery powered with a standard PP3 battery. This may be either primary cell type, or rechargeable (e.g. NiCad).
Fig 20 Typical gain characteristic.



Note that this characteristic is included in the RF200 antenna factor curve. See section 9.3.1

9.1.2 Battery installation

Suitable batteries are any PP3 type such as alkaline or rechargeable types such as NiCad.

To fit the battery, push off the moulded battery cover as indicated on the rear of the SA1020. This will reveal the battery compartment and the battery connector. Ensure that the ON/OFF switch is set to OFF before connecting the battery to the connector and that the connector is correct orientation before pushing the contacts home. Check that the contacts are both fully engaged before inserting the battery in the battery compartment. Clip the battery cover back in place.

Make sure that the battery is not discharged by checking the battery voltage with a meter before fitting the battery cover. With the battery connected to the SA1020, and the unit switched ON, the battery voltage should not be less than 8V

With a fully charged battery, the amplifier should run for the following periods:

Battery type	Capacity	Duration
NiCad	110mAH	5 hour
Alkaline	200mAH	10 hour
Zinc-Air	1000mAH	50 hour

Avoid using 'cheap' batteries. They are a false economy!

9.1.3 Operation

Important notes

1. The amplifier is intended to be used with low level signals, of uV amplitude rather than Volts amplitude. The input is therefore very sensitive and , although protected, may be damaged if input voltages exceed the specified values. When used with the SA1000 analyser and to ensure linear operation, input signal amplitude should not exceed 22mV rms in the frequency range above 5KHz. For signals with frequencies below 5KHz the internal ac coupling permits higher input voltages. The slope of this characteristic is 3dB/octave which gives a max. voltage input of 2.2V at 50Hz.
2. If the input is subject to overload voltages, a diode clamping network will protect the amplifier. However, this network has limited current capacity so that the degree of protection and the overload voltage which the unit will withstand depends on the source impedance of the signal.
3. During use, monitor the condition of the battery. Low battery condition is manifested by a reduction in output signal. This occurs quite abruptly if using NiCad cells.
4. When not in use, switch the amplifier off to preserve battery life. If the unit is not to be used for any significant period, disconnect the battery. This avoids batteries being drained inadvertently.
5. Two SA1020 amplifiers may be cascaded in series. For optimum results, fit a 3dB attenuator between the two amplifiers and after the second. This gives an overall gain of nominally 32 dB.
6. Dispose of used batteries properly.

9.2 RF100 Near Field Probe set

Near field probes can be used for the location of emission sources and for monitoring the effectiveness of design changes, circuit improvements and screening.

They should not be used to assess emission levels as required by the legislation because this requires measurement of the far field.

Sources of radiated emissions may be current or voltage in nature. Low impedance sources will be current sources and generate magnetic fields (H field). High impedance sources generate electric fields (E field). Most electronic circuits exhibit H field radiation because the sources are allied to current flow.

The H field loop and the E field stub antenna are included in the near field probe set so that both types of sources can be traced. The output signal level of both are very dependant on proximity to the source. Generally, more than a few centimetres from the source and the output from the probes will drop to virtually zero. This makes the probes ideal for use in noisy 'laboratory' environments and for accurate pin-pointing of sources.

Some sources can be related to lengths of cable or internal wiring. Often the user will find nodes and anti-nodes (standing waves) along the length of these conductors, the E and H fields being in antiphase. Therefore when checking conductors, it is important to check along the length of the conductor to ensure detection of a node.

Note that the level of signal picked up by the near field probe does not give any indication of the field strength in the far field. The probes respond to source intensity and do not take into account how well that source is coupled to the environment.

9.3 Antennas

For measurement of field strength (far field emission level) an antenna is required which will act as a transducer, converting field strength (mV/m) to mV signals output down a coax cable.
Antennas to cover the wide frequency ranges required by the legislation are not simple devices! The standards call for the use of a 'tuned dipole'. Whilst this is simple to manufacture and produces a easily definable output, it will only work at one frequency, the tuned frequency. Dipoles are tuned by adjusting the length of their elements, see Dipole. For serious emissions measurement work, the constant retuning of the antenna for each peak of interest is time consuming, hence the introduction of 'broad band' antennas that cover a wide spectrum without the need for any retuning. These include log periodic, bi-conical, bi-log and other specialist types such as the RF300 large loop antenna and the RF400 RF absorbing clamp. All suffer from variation of sensitivity with frequency and need a correction chart so that the appropriate adjustment can be made to the signal. This correction chart is called the antenna factor.
The Laplace RF200 broadband antenna has a relatively ripple free antenna factor characteristic, close to the optimum.
Selection of the RF200 item in the input menu automatically applies the RF200 antenna factor correction to the spectrum.

9.3.1 RF200 Broadband antenna

The broadband antenna will allow the user to detect and measure radiation over the frequency range 30MHz to 1GHz.
This is shipped in a 'knocked-down' form to ease packaging and to minimise the potential for damage in transit. Assembly is straightforward but must be done with care.
The basic design of the antenna consists of a central main beam, itself comprising two parallel aluminium sections spaced apart by insulators. Equal length pairs of stainless steel rods form the antenna elements, these mounted on the main beam in order of length, the shortest at the end at which the output lead is attached. An insulating block provides attachment for the stand with facilities for horizontal and vertical mounting. The non-metallic stand allows adjustment of antenna height and direction.

Antenna assembly (see fig 21)

1. The stainless steel elements are secured to the central beam using the M4 nuts and washers provided. An M4 nutspinner is also included to facilitate assembly. These elements are mounted in equal length pairs with the shortest at the end of the central beam where the output cable is attached.
2. Alternate the element direction as shown in Fig 21, so that for each side of the central beam, the elements alternate up, down, up, down...etc. until element 9 which is out-of-sequence and is mounted same side as element 8. Element 10 is alternate to element 9 as shown in the diagram.
3. The number of elements should match the number of hole pairs along the central beam.
4. Each element is mounted by running a nut right to the end of the thread, add a shakeproof washer and insert the element in the beam. Then add a shakeproof washer and finally a second nut. A short length of threaded element will be left protruding on the opposite side of the beam to the element.
5. A pre-drilled plastic block is supplied to form a central mounting block and pre-amp support. This is screwed to both beams using the supplied nylon screws.

Fig 21 RF200 Assembly

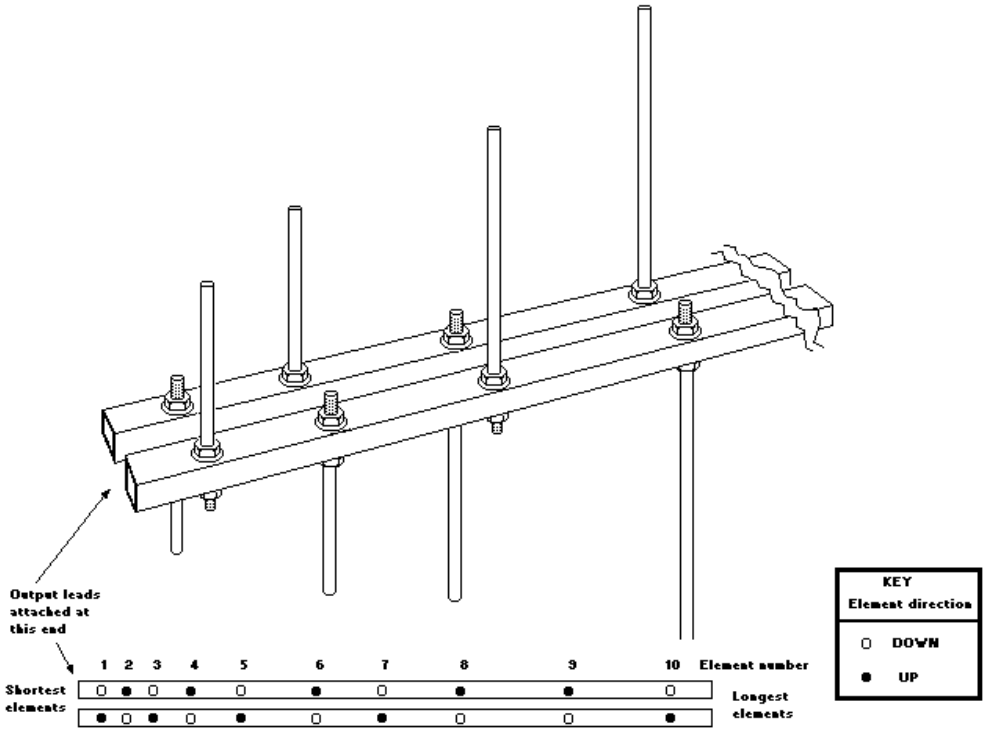
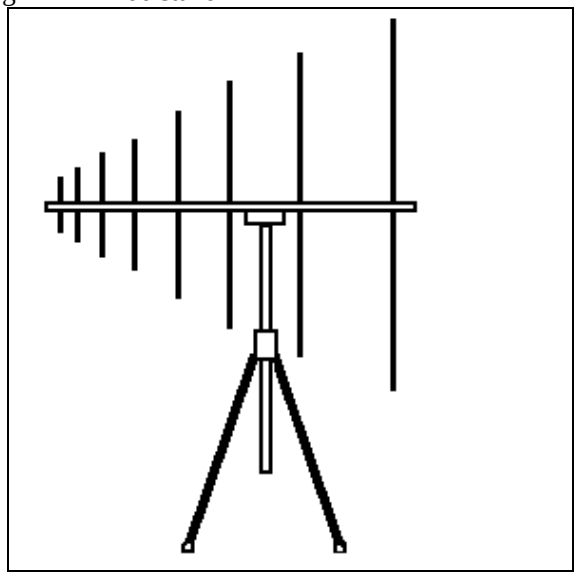


Fig 22 RF200 stand



RF200 Stand assembly

This is supplied as a central vertical support fitted with a leg attachment moulding and three legs.
The legs are a push fit into the leg attachment moulding.
The vertical support has a friction slide fit in the leg attachment moulding so that the antenna can be adjusted in height over the full length of the vertical support.

The antenna is located on the stand by locating the central support block on the top of the vertical support in either the horizontal or vertical polarisation position. Nylon bolts are provided so that the antenna can be clamped in position
If used outdoors in strong wind conditions, the stability of the antenna can be considerably increased by filling a bag with sand, soil or stones and supporting it by cord tied round the leg attachment moulding.

In use
Connect the SA1020 pre-amplifier directly to the antenna output lead and secure the pre-amp to the central pivot block with the velcro strips.
Point the antenna, sharp end forward, at the EUT. Note that the antenna is directional but full sensitivity is maintained over a wide angle either side of 'dead ahead'. Orientate the elements to match the polarisation required (vertical or horizontal).
The height of the antenna can be changed by sliding the vertical support up or down within the leg attachment moulding. If this friction fit is too slack or tight, **slightly** adjust the nylon bolt to suit. Note that antenna height may be a critical factor in obtaining valid results. See section 10.6
The main feature of the polar plot of the antenna (i.e. its directional properties) is a sharp null at 90º on either side. This can be used to null out any strong background emission for instance from an FM radio transmitter IF using a true open field site. Note that the null is very sharp and care has to be taken to find the right angle. Attenuation of up to 20dB is possible under the right conditions. In the presence of buildings etc., these emissions will be affected by reflections and will not be unidirectional, making them impossible to null out.
When using the RF200 in conjunction with the SA1000 Windows software, the antenna factor for this antenna can be invoked in the software to give a display of field strength. See section 7.3.3.3 Note that when used in this mode, the Pre-amp YES/NO buttons on the PC screen will default to YES as the antenna factor data loaded in the software includes the effect of the pre-amplifier.

Antenna Factor
The sensitivity of any antenna will vary with frequency. i.e. it will be more sensitive at some frequencies and less sensitive at others. A plot of sensitivity vs frequency is called the Antenna Factor.
The SA1000 Windows software has the antenna factor for the RF200 broadband antenna ready installed. Selecting this item in the INPUT menu automatically applies the appropriate conversion to read out in absolute field strength.
Table 7 RF200 Antenna Factor tabular data

Freq(MHz)	A.F. (dB/m)	Freq(MHz)	A.F. (dB/m)	Freq(MHz)	A.F. (dB/m)
30	0	220	-3	460	4
40	-1	240	-2	480	5
50	-2	260	-4	500	5
60	-3	280	-5	550	6
70	-5	300	-3	600	7
80	-7	320	-2	650	8
100	-9	340	-1	700	9
120	-9	360	0	800	10
140	-8	380	1	900	11
160	-7	400	2	1000	12
180	-6	420	3		
200	-5	440	3		

These figures include the SA1020 and 5 metres co-ax cable

WARNING: Although the conversion is valid, the field strength measured by the antenna is subject to your test site conditions and configuration and may be subject to gross errors. Reception of emissions radiated from the EUT depend on the test conditions, the test site, reflections, ground plane, background radiation, EUT to antenna distance etc..etc.. Be very wary about relating field strengths to limit lines unless you have some known test results to act as a reference.

Fig 23(a) RF200 Antenna factor, linear frequency scaling.

Note. Antenna factor includes SA1020 Pre-amplifier and 5 metres co-ax cable.

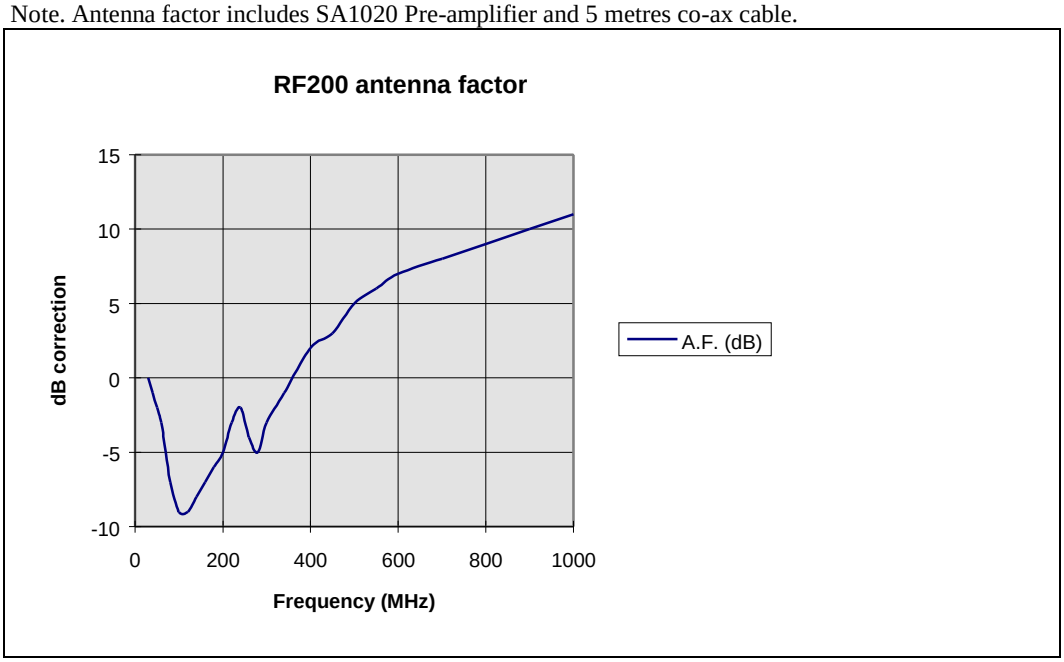
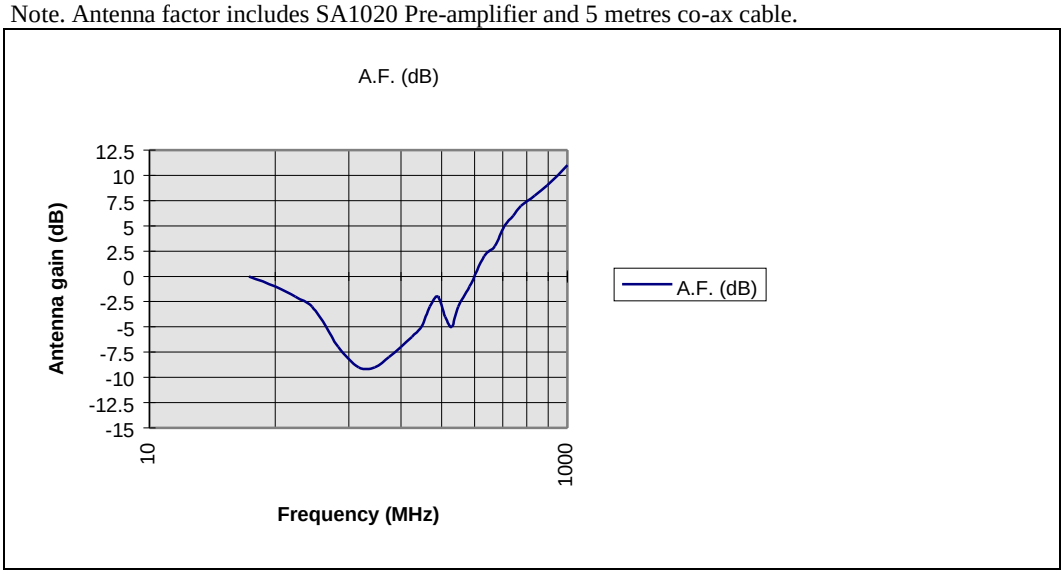


Fig 23(b) RF200 Antenna Factor, Log frequency scaling

Note. Antenna factor includes SA1020 Pre-amplifier and 5 metres co-ax cable.



9.3.2 RF300 Large Loop Antenna

This antenna complies with EN55015 and should be used when testing luminaires.
See separate user guide supplied with the RF300 for details
Note that the antenna factor for the RF300 is included with the SA1000 software.

9.3.3 RF400 RF Absorbing Clamp

This clamp is required for testing to EN55014.
See separate user guide supplied with the RF400 for details.

9.3.4 RF500 Dipole

EN50022 specifies that a tuned dipole be used as the antenna for radiated emissions testing. The problem with dipoles is that, although the calculation of the output for a given field strength is relatively straightforward at the tuned frequency, it needs to be tuned for each and every frequency. Tuning is a matter of adjusting the element lengths to ¼wavelength. In practice, this is time consuming, hence the use of 'broadband' antennas which respond to frequencies over a wide range without adjustment.
Note that the Q of the dipole is relatively low. Although maximum sensitivity is reached at the tuned frequency, the dipole can be quite effective as a broadband antenna and so for pre-qualification testing and all comparison checks, It has been found in practice that reasonable results are obtained if 5 or 6 elements are extended to view the complete spectrum from 30MHz to 500MHz in one sweep.

The relationship between element length and tuned frequency is shown in table 8.

Table 8. Dipole tuning

Element length	Tuned frequency	Wavelength
Minimum (1 section)	263MHz	1.14m
2 sections	174MHz	1.72m
3 sections	132MHz	2.28m
4 sections	106MHz	2.84m
5 sections	88MHz	3.40m
Max. (6 sections)	75MHz	4.0m

9.4 Filters

9.4.1 RF600 FM Band Filter

This filter provides a notch filter which attenuates the band of frequencies used for FM broadcast transmitters. These are often a major source of problems when using outdoor sites. The RF600 reduces the signal; strength of the band between 85MHz and 108MHz by >30dB without affecting other frequencies. It should be fitted between the antenna and the pre-amplifier. No power is required.
Locate the filter before the pre-amp on the antenna.
This filter does not need any action with the SA1000 software.

9.4.2 RF700 30MHz High Pass Filter

On some test sites, particularly indoors, the analyser exhibits compression when set to measure radiated emissions even if there is no apparent high signals in the spectrum. These circumstances can be caused by high levels of interference below 30MHz, and thus out of 'sight' on the high range spectrum. Fitting the RF700 will eliminate these signals and cure the problem.
Locate the filter before the pre-amp on the antenna.
This filter does not need any action with the SA1000 software.

9.4.3 RF800 Band B filter

Used for conducted emissions testing, in situations in which out-of-band signals are causing compression. Effective only in certain conditions but a low cost alternative to using a pre-selector. Recommended use when sensitivity needs to be improved by just 10dB before onset of compression.
Fit the filter between the transducer (LISN or probe) and the analyser or pre-amp (if fitted)
This filter does not need any action with the SA1000 software.

9.4.4 RF900 Manual Pre-Selector

The RF900 is connected in series with the lead from the LISN/probe to the analyser or pre-amp, if fitted. The **RF900** item must be ticked on the **Input** menu.
As the analyser sweeps the current required setting of the pre-selector will be shown in the small window at the top LH corner of the screen.

Band	1	2	3	4	5	6	7
Frequency(MHz)	0.15 - 0.3	0.3 - 0.6	0.6 - 1.2	1.2 - 2.5	2.5 - 5	5 - 12	12 - 30

Before starting a sweep, ensure that pre-selector is set to the appropriate start band. Each time the band needs to be changed, the PC will beep. Use two fingers to change the range so that the old one is switched out as the new one is switched in simultaneously.
See the RF900 User Guide for full details.

9.4.5 RF910 Automatic Pre-Selector

The RF910 is connected in series with the lead from the LISN/probe to the analyser or pre-amp, if fitted. The **RF910** item must be ticked on the **Input** menu.
As the analyser sweeps, the software will control the pre-selector via the serial port so that the appropriate band is automatically selected.
See the RF910 User Guide for full details.

9.5 LISN

LISN stands for Line Impedance Stabilisation Network.
The LISN provides the 'transducer' for measurement of RF conducted back down the mains from the Unit Under Test (EUT).
It is located in the mains feed to the EUT and primarily provides a known calibrated load impedance at RF frequencies for RF emitted by the EUT back down the mains lead.

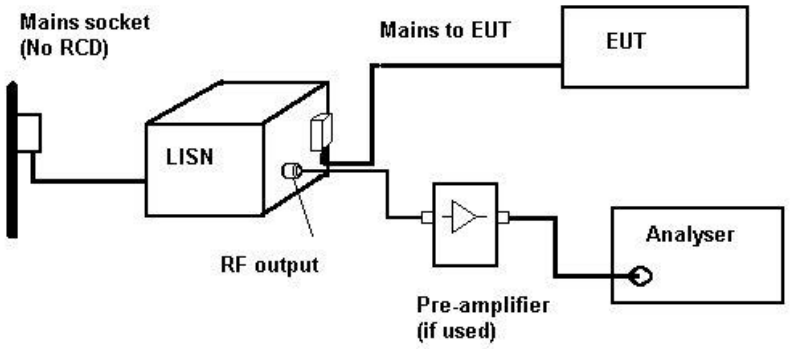
Additional facilities included with Laplace LISNs are:

- Transient limiter included.
- Artificial hand outlet.

9.5.1 LISN - Connections

NOTE: Before using LISN, read safety instructions in LISN manual

Fig 24 LISN connections



Mains ... The mains lead from the EUT is plugged into the mains socket on the front or top of the LISN. The mains lead from the rear of the LISN is connected to a mains supply. Note that there is no mains ON/OFF switch on the LISN so that the front panel socket is always live when the LISN is connected to a live supply.
LISNs will always trip RCB (earth leakage) breakers. If no supply is available without an RCB, use a isolation transformer with an appropriate rating for the EUT.

Signal...Then RF signal is taken off the appropriate front panel BNC connector. This should be connected to the analyser input via a coaxial cable. Note: If the LISN is fitted with a switched attenuator, always start with this switch to maximum attenuation and NEVER use the 0dB position.

If greater sensitivity is required use a preamplifier in series between the LISN and analyser.
The 'Cranage' LISN often supplied with the Laplace test kits has an insertion loss of 30dB. This should be selected when setting the Input device on the SA1000 software under the Input menu. The pre-

amplifier supplied with the LISN provides a 30dB gain. If used, 30dB should be selected on the Pre-Amp selector located on the left hand side of the screen.

9.5.2 LISN Calibration

LISNs are shipped with calibration data. This includes the insertion loss, ie the relationship between the amplitude of any RF signal on the mains and the amplitude at the RF output BNC for frequencies from 150KHz to 30MHz.
Proper use of the settings in the LISN control box on the SA1000 screen will ensure that the readings will be accurate whatever the LISN attenuator is switched to.

9.6 PLIP (Power Line Interference Probe)

Full details are given in the instruction booklet supplied with the PLIP

Set the input menu to PLIP or, if using the 30dB pre-amplifier set it to PLIP + P2085

Note that the pre-amp selector setting should remain at 0 when using the P2085 unless an additional pre-amp is used as well.

10.0 Background Topics

10.1 EMC

EMC stands for **E**lectro **M**agnetic **C**ompliance.
In plain English, this is a measure of the product's ability to cause interference (Emissions) and its ability to withstand interference (Susceptibility).
Interference is a BAD thing. At the 'trivial' level it causes annoyance on radio and TV channels. In other circumstances it can cause life threatening 'incidents', such as interference to aircraft control or navigation systems.
Unfortunately, interference is a fact of modern life. All electrical/electronic systems (from the National grid to an electronic wristwatch) radiate interference at some level. Therefore, the ability of a product to work properly in the presence of 'normal' interference is just as important as having its emissions limited.
So there are two parts to EMC, **Susceptibility** and **Emissions.**

10.1.1 Emissions

Emissions are any form of electrical/electronic signal emitted by the product but which is not an intended function. This covers radiated interference (radiated emissions) and interference transmitted along any cables or wires connected to the product, including mains leads (mains conducted emissions).

In general, all the above relates to frequencies in the range 9KHz to 30MHz for conducted (i.e. transmitted back down the mains lead) and 30MHz to 1GHz for radiated.

10.1.2 Susceptibility

Susceptibility is a measure of a product's ability not to malfunction when subject to any form of electrical interference. This includes:
» radiated interference (radio etc.),
» conducted interference (along mains cables, signal and control leads etc.)
» electrostatic discharge (such as may happen if you walk across a carpeted floor and touch the product).

10.2 Radiated field types

Radiated fields (or interference) are electromagnetic waves emitted from a conductor (PCB track or wire) acting as an **aerial** which is being driven from a **source**. The source is generally an electronic circuit or component generating ac signals or having fast edges with high frequency components. A source in isolation cannot create any significant radiation unless it is connected to an aerial.
For an aerial to be effective, it must have dimensions approaching ¼ wavelength of the frequency emitted.
Conductors acting as aerials may be low impedance (current) sources or high impedance (electrostatic) sources. Open circuit conductors will be the latter and circuit interconnections, including power rails on PCBs will be the former. In fact, the bulk of emissions from electronic circuits tend to be from low impedance (current) sources. These give rise to magnetic (or H) fields in their immediate vicinity. Electrostatic sources create corresponding E fields. The RF100 Near Field Probe kit includes both E and H field probes, each designed to be sensitive to the high local field strength immediately adjacent to a source. This region is known as the Near Field.
As a field radiates away from a source it undergoes a transition to an alternating E and H field (electro-magnetic) wave which has an impedance corresponding to that of free space (377ohm). In this condition, it is called Far Field radiation. The transition from near to far field takes place gradually, but it is generally accepted that the borderline occurs at a distance of approximately $\lambda/_6$ (one sixth of a wavelength). At 100MHz this is 0.5m.

10.2.1 Field Strength

This is the parameter that is used as a measure of the level of emissions from a product. Usually, it is be measured in free space at some distance from the source in order to avoid the unavoidable distortions that occur close to the source. It is measured in dBuV/m which is related to the intensity of the electric component of the radiation. uV/m is a simple voltage gradient parameter and dB (log) scaling is used so that a wide range of field strengths can be plotted sensibly on one scale.

In the far field (i.e. when the energy alternates equally between magnetic and electric fields), there is a fixed relationship between the two field types (defined by the free space impedance). This means that measurement of the electric field gives a reliable figure for the total energy in the radiation. In the near field, the relationship is undefined and measurement of the electric field would not give a reliable result. Hence the importance of measuring emissions using far field techniques.
Some standards specify alternative methods for measuring these emissions which overcome some of the difficulties allied to the above method.
EN55014 specifies the use of an absorbing clamp to measure the level of energy radiated down the mains lead from the product. It makes the assumption that the mains lead is the primary 'aerial'.
EN55015 measures the radiated emissions over the range 10KHz to 30MHz from luminaires. This assumes that the source is primarily H field in nature.

10.3 Wavelength

An awareness of wavelength is very useful in EMC work. Frequency and wavelength are inversely proportional and an easy number to remember is that the wavelength at 100MHz is 3 metres. So 50MHz has a wavelength of 6 metres and 300MHz has a wavelength of 1 metre.

Effective transmitters have a length of quarter wavelength so a cable or PCB track 250mm long will radiate effectively frequencies around 300MHz. This effect is sometimes seen when, for instance, digitally clocked signals are present on a data bus. Although the clock frequency may be 12MHz, emissions apparently peak at 300MHz. The reason is that although a complete spectrum of odd harmonics of 12 MHz is present on the bus, the physical length of the tracks provides effective radiation only at 300MHz.
This example highlights one reason why far field testing rather than near field measurements are the basis for the standards. With a near field probe, the whole spectrum of harmonics would be detected, probably showing highest levels at the fundamental and lower harmonics. The 300MHz peak may not be apparent even though this is the main problem in terms of radiated interference. Near field probes respond to source intensity, not radiation effectiveness.

10.4 Practical considerations - radiated emissions

Any radiation having a significant field strength in the far field will require 2 factors to be present:

- **the source**
- **an aerial (antenna)**

Of these two, the aerial is the dominant factor. i.e. a strong source without an aerial will not produce as much field strength as a weak source with a good aerial.
The source may be a microprocessor clock or data bus, fast switching devices or logic, motor commutator etc....
The aerial may be a mains cable, signal lead, ribbon cable, internal wiring, PCB track, in general a conductor that is connected directly or indirectly with the source.
Aerial efficiency is dependant on physical length and wavelength. An ideal aerial (one which will radiate a maximum level for a given input signal) has a length that equals ¼ wavelength. If a conductor has a length of 75cm, it will radiate very effectively at 100MHz (which has a wavelength of 3 metres) So it is important to consider the physical dimensions of any product and relate these to potential problem frequencies. This simple technique will often lead to important insights into how interference is radiated.
When using near field probes, check potential aerials (long conductors) Even a small signal on a relatively long conductor or enclosure slot may cause high far field signals.
In a typical example, an offending frequency of 80MHz gave a reading of 65dB when the probe was located on top of a memory chip, but only 32dB when close to the mains cable. In spite of this differential, the 'problems' ceased when the mains cable was properly filtered.

10.5 Dealing with strong background peaks

Sometimes an otherwise acceptable site has high ambient FM signals or one large peak in the background which is powerful enough to push the analyser into compression when the input attenuator is switched out. This peak may be due to proximity to an FM broadcast station or BT paging service (153.5MHz) for instance. Another cause of compression is when signals below 30MHz are present. These can overload the analyser even though they are outside the scanned range and therefore not visible. If any of these occur, all is not lost!

Discrete peaks

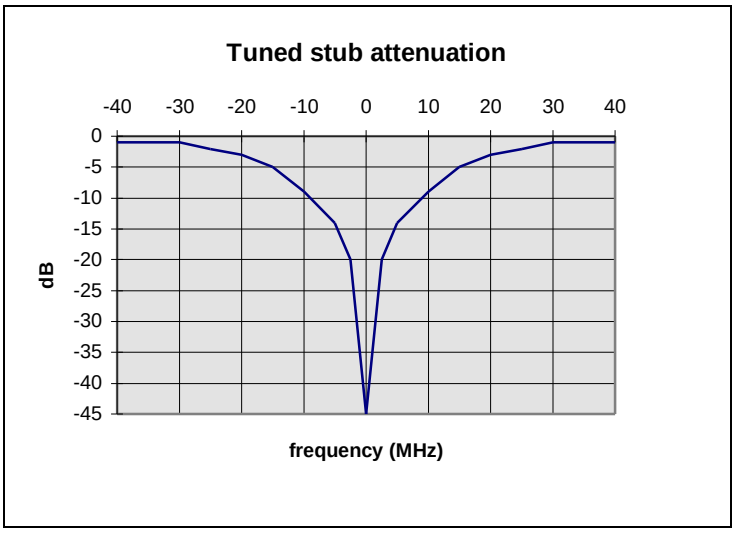
For single peaks above 150MHz, a trick well known by radio amateurs is to use a 'tuned stub' as a notch filter. These filters give a very sharp attenuation to just one frequency (and odd multiples). Attenuation factors over 40 dB can be achieved over a narrow bandwidth without affecting the levels in the passband. See fig 25.

To make a 'stub', use a BNC Tee adapter in the antenna lead to join a length of co-ax to this lead. This co-ax should be cut to ¼ wavelength of the problem peak and left open circuit at the free end. The best way to do this is to initially have a length too long and gradually snip bits off, observing the results on the screen, until the desired frequency is reached. Note that the actual length will differ from the calculated length due to the characteristics of the co-ax.

FM band (85MHz - 106MHz)

If the FM broadcast transmissions are a problem, these cover such a wide frequency range (85MHZ - 106MHz) that a tuned stub is not effective. In these circumstances, the RF600 FM band filter will reduce these signals by 35dB without affecting any other frequency. This small module is connected between the antenna and the pre-amplifier, reducing the FM signals before being amplified.

Fig 25 Attenuation characteristic for tuned stub



Low frequency interference

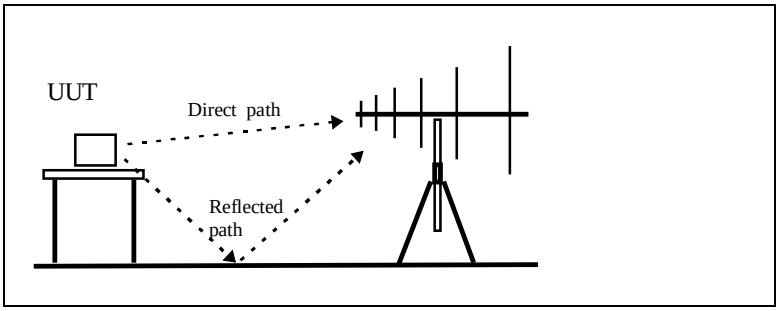
This can cause confusion due to the fact that the source of the problem is not apparent. The solution is to use an RF700 30MHz high pass filter available from Laplace. This attenuates all frequencies below 30MHz and thus overcomes the problems.

10.6 Ground plane

In general, any EUT will emit radiation in all directions. Some of this will impinge on the ground which will partially reflect this radiation.

When measuring emissions in the far field, the signal received by the antenna will comprise a direct signal and a signal which has been reflected from the ground. (Assuming that the test site has been chosen so that no other reflections are present).

Fig 26 Ground plane reflection



The amount of this reflected signal depends on ground conditions and may vary very considerably in amplitude. On 'soft' ground such as earth (soil) the reflection will vary from day to day as conditions change. This means that the integrity and consistency of the results will be variable. To overcome this problem, the standards require a test site to have a metal ground plane consisting of a continuous metal sheet (or equivalent) under the EUT and between the EUT and the antenna. This gives a consistent 100% reflection. This is in one sense 'worst case' because the effect of the reflection will be maximised, but at least it will be consistent.

The effect of the reflection will depend on frequency and the difference in path length between the direct path and the reflected path. If this difference is equal to half a wavelength at the frequency of interest, the two signals will be 180° out of phase and will cancel, producing up to 20dB reduction in signal strength.

Fig 27 Ground plane effect

Conditions:	Product height:	0.8m
	Antenna distance:	3m
	Polarisation:	Horizontal
	Ground plane:	Metal sheet (ideal)

To overcome this effect, the standards call for the antenna to be mounted on a mast so that it can be varied in height over a range of 1 to 4 metres. For each frequency there will be a height at which the two signals are in phase and additive. This is the height at which that frequency is measured.

Fig 27 shows the relationship between frequency, antenna height and signal gain/attenuation. The white areas correspond to gain and the dark areas represent attenuation.

If using an open field site on dry soil, the reflection will be small and the gain/attenuation effect will be minimal. However, if any metal surface is in the vicinity (filing cabinet for instance) this chart gives some idea of the consequences! Note that the chart is correct for the conditions listed only. If for instance the polarisation is changed to vertical the plot will completely change.

10.7 Test Site Calibration

Any area or test cell used for far field radiation testing should be calibrated. Purpose made cells such as a G-TEM cells are supplied ready with a calibration sheet which defines the characteristic relationship between EUT emissions and cell output vs frequency.

If using a an open field test site, this should also be calibrated. The ground plane reflection alone can have a significant effect on the test results. One way of achieving a rough calibration is to test a product with known emissions (i.e. one which has already been tested at a test house) on your test site under exactly the same conditions as applied during the test house measurement. By correlation of your results with the test house results, an approximate calibration of the site can be derived. The problem with this technique is that it can only work for the frequencies at which the product had emissions. In general this will leave the vast majority of the frequency band uncalibrated. A better technique is to use a calibrated noise emitter.(ERS). Details of this are given in section 8.4. Note that if the site is outdoors, it will need a calibration check every time it is used because weather conditions can affect the site significantly.

10.8 The Legislation

EC legislation is embodied in Council Directive 89/336/EEC which is intended to limit the interference caused by electronic and electrical products. A series of EN Standards define limits for emissions and the levels of interference (RF radiation, mains disturbances and static discharge) for susceptibility tests. If a product can be proved to comply with these standards, the product can be issued with a compliance certificate and a CE label attached. This certification has legal validity throughout the EC and in those countries which used to be part of the EFTA group.

After 1st January 1996, all products offered for sale within the EC which fall within the scope of the directive must have an EMC compliance certificate. Failure to do so will result in the product being removed from the market and possible conviction of those responsible. The consequences of false certification can be severe!

The responsibility for obtaining certification rests solely with the person/organisation placing the product on the market within the EC. If the product is imported from outside the EC, liability still rests with whoever is placing it on the market in the EC, not the manufacturer. Note that the supplier cannot pass the responsibility to a 'test house'. The function of a test house is simply to take the measurements, it is up to the responsible person to make the final decision regarding compliance.

10.9 Scope.....What products are affected?

Any product which uses electricity in any form is included, except those which "have no intrinsic function".
This means that the only items excluded are those which, on their own, are completely passive and serve no function. These include components such as resistors, integrated circuit chips, relays and connectors.
However, any assembly, such as an assembled printed circuit board, which is sold as a separate item, must conform. This means that any adapter cards and plug-in cards for PCs must be certified.
Items such as electric motors which are sold only as a component part for inclusion into other products still must conform because they are sold as a product with an intrinsic function.

When are they affected?
The rules state that when a product is 'placed on the market' or 'put into service', it must be compliant. The person/organisation responsible for the compliance is that person/organisation that 'places it on the market' or 'puts it into service'. If you do not sell it, but make
it yourself and use it within your own factory (e.g. some process control equipment or an electronic test unit) then it still must comply.

10.10 Certification

Most manufacturers have a choice of two routes, **self certification** and **TCF (Technical Construction File).**
The TCF is provided for those products that cannot be tested in the conventional way or for which no specific standard applies. Such products may be power stations and other large installations. A file is created which covers all the design considerations, calculations, protective features, test results, component specifications etc. which would justify a claim for compliance. This has to be audited by a 'competent body' (an organisation approved by NAMAS to fulfil this function) who will charge you for the privilege. The TCF route is likely to be both time consuming and expensive.
Self certification is exactly what the name implies. **You** issue a certificate that states that product XYZ complies with the relevant directives and **you** sign it. Of course, before doing that you should take all reasonable steps to ensure compliance (in terms of product design) and make any appropriate tests for compliance as a check. What these tests should comprise is at your discretion. At the end of the day, you must be prepared to stand up in court to argue your case but, provided that you had acted in such a way as to show due diligence, you should have nothing to fear.

10.11 The Standards

In the UK the Standards are published and issued by BSI Standards. Assistance in deciding which Standards apply to your particular product can be obtained from the DTI and/or your local EMC Club
Contact points: DTI Tel: 0171215 5000
Fax 0171 215 1529/2909
Guidance booklet from Europe Hotline 0117 944 4888

BSI Tel 0181 996 9000 Source of Standards in the UK

As a very rough guide, the current EMC standards for Emissions which have been issued are:

Cenelec Reference	**Equipment covered**
EN55011	Industrial, Scientific and Medical Equip. (ISM)
EN55013	Sound & TV broadcast receivers
EN55014	Household appliances and portable tools
EN55015	Fluorescent lights and Luminaires
EN55022	Information Technology Equipment (ITE)
EN55025	Automotive
EN50065-1	Mains signalling equipment
EN50081-1	Generic standard - Light industrial and domestic
EN50081-2	Generic standard - Heavy industrial (generally 3phase)

If your equipment is not covered by any of the product specific standards, use the Generic Standards.

10.12 Production testing

For any products produced in quantity to a standard design, the legislation requires the establishment of a testing regime to monitor and ensure that the product continues to comply to the standards. In other words, a single 'type' test is not sufficient.
These standards specify a requirement to ensure that statistically at least 80% of the product conforms to the limits with an 80% confidence factor. EN55022 and other standards give full details.
This requirement can be achieved by testing a specified percentage of random samples of the production on a pass/fail basis. The Laplace test kits can provide a cost effective means of accomplishing these emission tests, particularly if the 'background' trace is made to act as a limit line. This limit line can be derived from a 'marginal' pass product or from calculated data input either as a series of nodes in the Limit menu....User limits .... facility or via a spread sheet using knowledge of the test data file format.

10.13 Pre-Compliance testing

Pre-compliance test equipment is not intended to provide the complete solution for checking that products meet the standards. As the name suggests, the aim is to be able to measure and roughly assess EMC emissions performance before using a test house or more specialised equipment for the definitive testing.
However, there are circumstances where the use of pre-compliance test kits can be judged adequate to justify self-certification.

Laplace test equipment can provide accurate and reliable conducted emissions test results. This is because the kits use fully compliant LISNs, designed to meet the requirements of CISPR16 and which give a calibrated output. So, in terms of mains conducted emissions, these test kits are adequate to judge the compliance of your produce, within an error margin of typically 5dB.
All our test kits include near field probes. These are essential for locating the sources or leakage paths of troublesome emissions, but cannot be used to judge far field radiation levels. The EN standards specify that compliance must be judged on far field radiation levels because only these measurements are repeatable in controlled conditions.
Far field measurements are where test kits can be prone to gross errors if measuring absolute field strength.
The problem is not the really the equipment, but the environment.
In other words, even if you had a fully compliant, top-of-the-range analyser and antenna your results may still be grossly in error because:

(a) metal objects (e.g. steel building frames, filing cabinets) in the vicinity are causing reflections.
(b) Ground plane reflections.
(c) Antenna factor errors.
(d) Background interference.
Some of these error sources can be minimised by testing away from reflecting surfaces (literally in a open field or large empty car park), using a calibrated antenna and compensating for the antenna factor in software and measuring and then subtracting background interference levels. Even so, variability of ground plane reflection, errors inherent in low cost antennas and practical limitations of antenna positioning will mean that error budgets of the order of 10dB would be appropriate. An effective solution to these problems is to use an ERS (emissions reference source) to quantify the errors due to the test site.
Testing in a shielded room is not recommended. Although background radiation may be reduced, internal reflections would make sensible testing impossible. Test cells lined with RF absorbent materials or GTEM cells are ideal, but these are expensive.
The only effective solution is to use an ERS to calibrate the measurements. This overcomes the errors and distortions due to the test site.

10.14 CISPR

This stands for *International Special Committee on Radio Interference* which is a technical committee set up by the IEC (International Electrotechnical Commission).
The function of CISPR is to define unified limits and measurement techniques that can be adopted by European and National legislation.
Most EN standards have CISPR equivalents or quote CISPR measurement techniques (e.g. CISPR16)

10.14.1 CISPR16

This is a document issued by CISPR which precisely defines many of the measurement techniques and equipments required by the EN Standards.
Example topics covered are:
* Full constructional details of the LISN to be used for mains conducted interference measurement.
* Receiver bandwidth to be used for all emissions measurements

APPENDIX 1

Software Installation

Compatibility

The SA1000 software will run on any PC compatible with Windows, running Windows 95, 98, NT, 2000 and having a VGA monitor as a minimum.
The interface will connect to the standard serial port, either COM1 or COM2. The appropriate port must be selected in the Port menu before acquiring data.

Installation

The software is provided on a 3½" disk in compressed format. This software will automatically self install and place the programme in a directory called SA1000
To install this software on your PC:

1. Load the disk into drive a:
2. Type "a:\setup" {enter}. (Or run setup.exe from Windows file manager)
3. This will place the appropriate files in your Windows system directory and create a new directory "c:\SA1000".
4. If the software is being installed for the first time, a window will appear offering a selection of com 1 or com 2 serial ports. It is important to select the correct port and to ensure that this port is not used by any other device such as a mouse or modem. The com port selection is saved to a .ini file so that whenever the program is run, the correct port will be accessed.
5. If you are updating an existing installation, the existing .ini file will be retained.
6. The SA1000 icon will now be installed, although you may have to adjust its position to make it visible in the program group window.

UPGRADE
This section is only valid if upgrading an existing version of SA1000 software with a later release.

Use setup.exe the new supplied disk.
This overwrites all old program files that need changing in the SA1000 directory.

If upgrading from an e-mail version of the upgrade, unzip (using WinZip) the file into any convenient temporary directory. Then run setup.exe as above.

NOTE
When the software is started, it will check the selected serial com port to see if an analyser is connected. The selected com port (com 1 or com 2) is stored in the sa1000.ini file. When the software is first installed, the install program will prompt you for the number of the com port to use and write this to the sa1000.ini file. If for any reason, the wrong com port is selected and some other device occupies that port (mouse, modem etc...) the software may crash and indicate multiple 'block too small' error messages.

If this occurs, reboot the computer and run the inifile.exe utility supplied with the software. Make sure that this program is located in the SA1000 directory.

This will allow you to change the com port setting in the .ini file without running the main program. This utility does not check or test the com port in any way, simply provides a method of changing the default setting.

APPENDIX 2

Data File Format

All files written to disk are in ASCII format

Line Number	Typical entry	Explanation
1	1.50 3rd April 1997	Software Version used
2	2 Apr 97 15:15	Date of test
3	Title	Title of test
4	TRUE	If TRUE then single frequency data stored
5	TRUE	If true then PRE-AMP Checked
6	20000	Start Frequency
7	30000000	Finish frequency
8	100	Number of steps used for scan
9	FALSE	If true then log scale used
10	FALSE	If true then dBm vertical scale used
11	3	Antenna Number (See Note 1)
12	;	File delimiter used
13	30	Attenuation Used (dB)
14	TRUE	If TRUE then Current trace displayed
15	FALSE	If TRUE then Store trace displayed
16	FALSE	If TRUE then Difference trace displayed
17	FALSE	If TRUE then Archive trace displayed
18	TRUE	If TRUE then Limit trace displayed
19		Line for "NOTES" comments
20		Line for "NOTES" comments
21		Line for "NOTES" comments
22		Line for "NOTES" comments
23		Line for "NOTES" comments
24		Line for "NOTES" comments
25		Line for "NOTES" comments
26		Line for "NOTES" comments
27	1218	ERS unit serial number
28	50	Single frequency interval (msec)
29		Spare
30	4	Limit Number
31	30000000	Frequency of any SF Trace (Hz)
32	11:21:26	Single frequency Time label
33	11:21:32	Single frequency Time label
34	11:21:38	Single frequency Time label
35	11:21:44	Single frequency Time label
36	11:21:51	Single frequency Time label
37	1	Detector (See Note 2)
38	TRUE	Insertion loss flag
39	2	LISN settings (attenuator)
40	1	Calculations setting (Averaging/peak hold)
41	1	Limit country
42		ERS style (1=hor, 2=vert, 0=none)
43		Spare
44		Spare
45		Spare
46	finish	End indicator
47	FREQUENCY ; CURR....	Column Headers
48	20000; 0; 0; 200; 0	Data for up to 500 rows (See Note 3)
..	.....	
..	-6,0	501 lines of ERS correction data and ERS integrity flag (0
..	..	or 1) This data only written if ERSstyle is 1 or 2.

Note 1

Value	Antenna used
1	RF100
2	RF200
3	RF300
4	RF400
5	RF500
6	PLIP
7	PLIP+P2085
8	DIRECT INPUT
9	LISN
10	USER

Note 2

Value	Detector
1	Peak (Fast Scan)
2	Average
3	Quasi Peak

Note 3

There are 500 rows of data each
consisting of integer numbers separated by a delimiter .

Each column is headed by its label: Frequency, Current, Store, Limit, Single.
Frequency is the frequency in Hz of the step in the scan.

Current & store are those values in dBuV.
Limit is the value of the limit at the specified frequency in dBuV.
Single is the Current value in dBuV stored at the single frequency.
Single does not refer to the frequency in column 1, but to time, with row 1 being the oldest.
If there are less than 500 steps in the trace, empty values are always zero

SA1000 EMC Engineer INI file format (SA1000.INI)

Line Number	Typical entry	Explanation
1	16776960	Value of screen colour
2	12632256	Value of Border colour
3	16711680	Value of Grid colour
4	0	Value of Current trace colour
5	255	Value of Store trace colour
6	16711935	Value of Difference trace colour
7	32768	Value of Archive trace colour
8	65535	Value of Limit trace colour
9	0	Value of printer Grid trace colour
10	0	Value of printer Current trace colour
11	0	Value of printer Store trace colour
12	0	Value of printer Difference trace colour
13	0	Value of printer Archive trace colour
14	0	Value of printer Limit trace colour
15	TRUE	If TRUE then log scale else linear scale
16	TRUE	If TRUE then dBm vertical scale else dBuV
17	FALSE	If TRUE then COM1 is used
18	TRUE	If TRUE then COM2 is used
19	;	File delimiter used
20	30	Attenuation Used (dB)
21		Spare
22	FALSE	If true then High Range in use
23		Spare
24	1218	ERS serial number
25	c:\SA1000	Default path
26	FALSE	‘Alternative’ antenna distance correction applied if TRUE.

APPENDIX 3

Clipboard

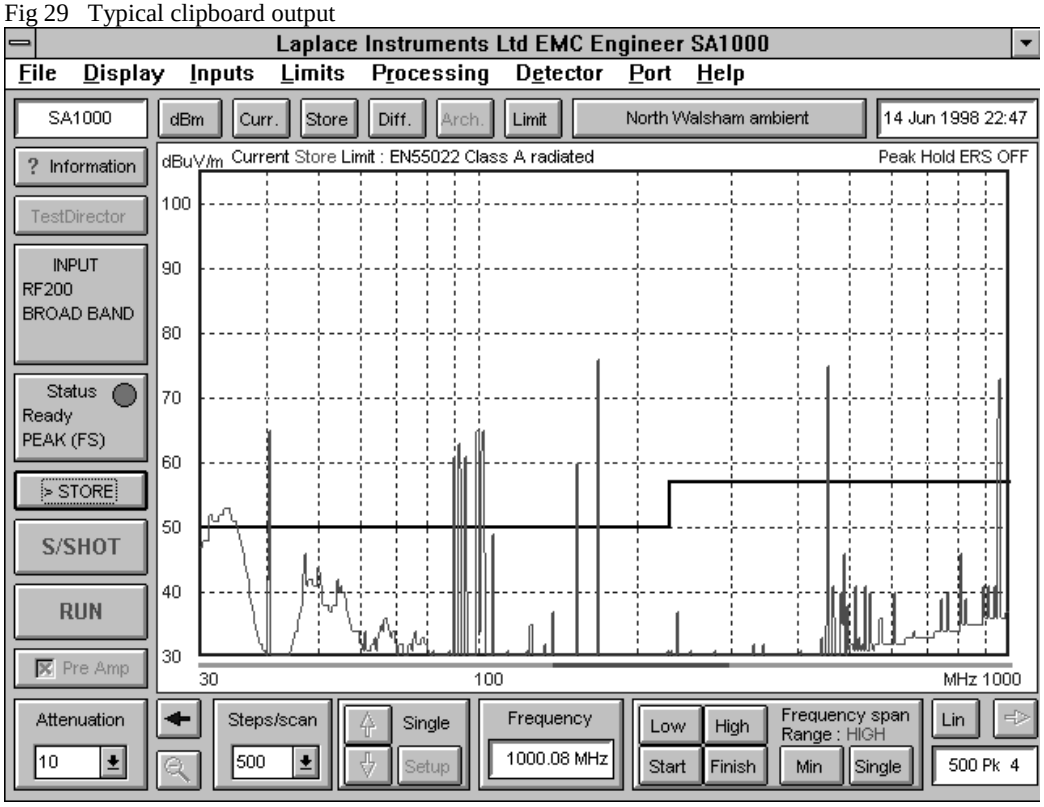
SA1000 software is fully Windows compatible and has full Clipboard facilities. This means that you can ‘capture’ any screen and copy it direct to your word processing document which can be running in the background. Thus you can build up your test documentation whilst conducting the tests.

To copy the screen to the clipboard, press **ALT+Printscreen**.

To switch between SA1000 software and your document, use **ALT+TAB**.

To copy the screen into your document, use paste **(CTRL+V)** in many applications.

Fig 29 Typical clipboard output



APPENDIX 4

Checklist

1. Check the condition of the SA1020 pre-amplifier battery
2. Ensure that the LISN attenuator is never in the 0dB position and the 150KHz filter is IN.
3. Check the analyser is NOT working in compression.
4. If measuring emissions against a limit line.....take great care to ensure that the test conditions as required by the standards are meticulously observed.
5. When using the RF200 always use it with the SA1020 pre-amplifier at the head.

APPENDIX 5

Troubleshooting

Symptom	Cause	Cure
PC hangs-up	Disrupted serial comms	Click on Status box to reset comms link.
Intermittent and/or random peaks on trace	Pulsed or intermittent emissions from product	Use averaging or Quasi-peak modes under Detector menu
PC fails to acquire any trace	Wrong COM port selected	Check COM port settings under PORT menu
Peak readings not as expected	Analyser input in compression	Increase attenuation on input (use attenuator or insert external attenuator. Check peaks drop by corresponding level.
Peak readings not as expected	Settings on PC incorrect	Check LISN, antenna distance & pre-amp settings
Lower than expected signal level	Flat battery in pre-amp	Replace battery
FM broadcast signals too strong	Proximity to transmitter	Use RF600 FM band filter
'Noisy' signal from LISN even when no output mains lead connected	Poor mains supply, probably heavy harmonic distortion	* Find clean mains supply * Use 150KHz HP filter * Add additional HP filters
'Noisy' signal from LISN even when EUT switched off	Interference picked up by mains lead between LISN and EUT	* Use short mains lead * Use screened room * Find quieter test site
No signal received	Pre-amp connected wrong way round (Output connected to antenna)	Reverse connections on Pre-amp.
Compression indications of High range, although no strong peaks evident on the sweep.	Strong signals present below 30MHz	Use RF700 30MHz high pass filter

APPENDIX 6

EMC Declaration

DECLARATION OF CONFORMITY

We, Laplace Instruments Ltd

of

Tudor House, Grammar School Road, North Walsham, Norfolk,

declare under our sole responsibility that the product:

SA1000 Spectrum analyser

SA1020 RF pre-amplifier

to which this declaration relates is in conformity with the following standard(s) or other normative document(s)

EN50081-2
EN50011 Group 1 Class A
EN60555-2/3

Following the provisions of

EC Council Directive 89/336/EEC

North Walsham
8th January 1996

Signed.....

David Mawdsley
Managing Director.

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