Emission Reference Sources

The ERS is a source of precisely known emissions, very stable and completely defined. It is calibrated according to 'best practice' and traceable to NPL.

When would I use one?

If you are measuring radiated emissions from any product (EUT) for compliance or pre-compliance purposes, then the ERS becomes a valuable asset.

Why do I need one?

Most EMC standards that relate to radiated emissions specify an OATS as the test site in which to measure these emissions. (OATS = Open Area Test Site). This is because RF signals will reflect off any metallic surfaces and will be affected by many other types of material. Just walk round a test area and see how the human body affects the results! In particular, any metal in the vicinity of the test area can affect the way in which the site behaves. So the only way to ensure repeatability of measurements, independently of test site location, is to use an area free of anything that can affect RF propagation.

If you have such a site.. wonderful, and if it is calibrated…even better. Obviously, all test labs will have such sites, but manufacturers and others simply will not have the resources, or the space, or the budget to afford such a facility.

The standards specify limits, and these limits assume that the EUT emissions are measured as per the standard, ie are measured on an OATS. If the space that you are using is not an OATS, then one thing you can be sure of is that the measurements you take will not agree with those obtained on a true OATS.

What is the extent of the problem?

The key issue is reflections. To understand what actually happens, take a simple case. Even on the very best OATS, the ground is usually present (if not, we may have a long way to fall!). The ground will reflect RF. The amount that is reflected depends on the reflection coefficient of the ground, which varies according to the nature of the ground, and may vary with climate and local weather conditions. This means that there will always be at least 2 signals arriving at the antenna, that which has travelled the 'direct' route and that which has travelled the 'scenic' route, via the ground.

These 2 signals are coherent because they originate from the same source. This means that they will interfere with each other. The degree to which this occurs will depend on the phase relationship and the relative amplitude of each. If the signals are in phase the interference will be constructive (that is, they add together to produce a stronger signal). If out of phase the interference will be destructive in which the signal will be reduced.

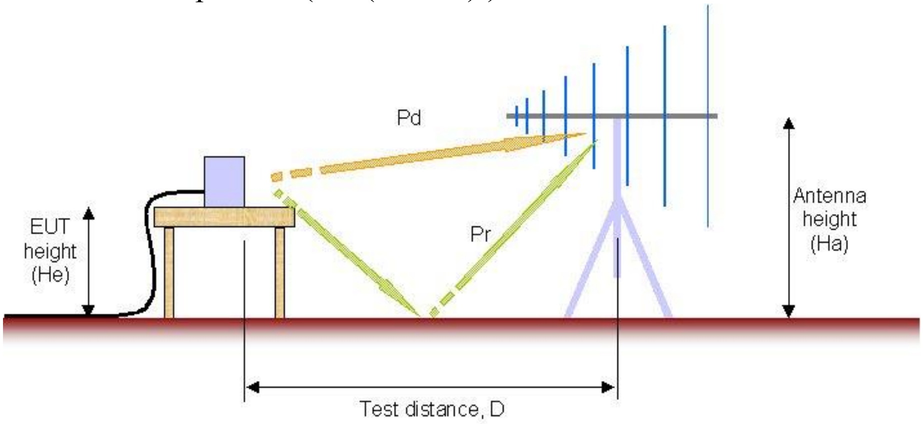
The phase relationship will depend on the difference in path length for the two signals. If the reflected signal travels further by half a wavelength, the two signals will be 180 degrees out of phase and will cancel each other.

We can calculate the path lengths using simple trigonometry:

Pd = Direct path = $\sqrt{(D^2+(Ha-He)^2)}$

and

Pr = Reflected path = $\sqrt{D^2+(Ha+He)^2}$



Where D = test distance,

He = EUT height

and

Ha = antenna height.

Path difference is Pr – Pd.

It's a relatively simple task to enter these equations into Excel and to try varying the factors.

For D = 3m, EUT height = 0.8m (as required by the standards) and antenna height = 1m

Then path difference is 0.492m, which is half wavelength for 304MHz

So if you have an emission at 304MHz, this will 'disappear' (actually it reduces by about 17dB, due to the fact that the reflected signal has travelled further and is therefore not as strong as the direct signal, so cancellation is not 100%).

This is clearly a problem. It accounts for the requirements in the standards which specify……

(a) a reflective (metal) ground plane should be used (which ensures repeatability between sites)

(b) the antenna should be 'height scanned' to find the maximum level for each emission frequency. At this point, the two signals should be in-phase and the level will be some 5dB above free space (ie no reflected signal) level. The limits take this increase into account. This means that if using an FAC, the limits need to be reduced by 5dB to account for the lack of reflection.

An Excel utility is available at http://www.laplace.co.uk/downloads/3/

Select 'RF Field Simulator'. Unzip ands run RFMEAS.xls This shows graphically the effect of height scanning and also shows the effect of varying the test distance. EMCROOMS.doc provides an explanation of the .xls files.

There are 2 issues that are now apparent.
Even if we have a 'perfect' site, we still suffer gross errors if height scanning is not performed. This height scan requirement covers a range 1m to 4m. This 'error' relates

to just one reflection. Imagine what may happen in a building where we are inevitably surrounded by the building structure, desks, filing cabinets, radiators, etc…. Even in a car park, we may have cars, metal fences and adjacent buildings.
Note that these issues apply regardless of the sophistication and accuracy of the instrumentation!
Obviously, accurate measurements of radiated emissions are an issue on typical 'pre-compliance' test sites.

How the ERS helps.

Because the ERS generates a precisely known emission level at 3m, as measured on a perfect site (NPL), using the full rigour of the techniques as prescribed in CISPR16, we can use this to measure the 'errors' related to our test site.
For example, we have an emission from our product at 304MHz, and we measure it to be 38dBuV/m. This is well within the limits for EN55022, class B which are at 47dBuV/m for a 3m test distance. So our emissions are apparently 9dB below the limit.. If however, we substitute the product for the ERS, ensuring that the ERS is in exactly the same position as the product was, we can now measure the 304MHz output from the ERS. Assume its level is measured at 56dBuV/m. Checking the calibration data for the ERS, it shows that the 304MHz peak should be at 68dBuV/m. So on this test site, at this frequency, any RF signal source at the location of the EUT will measure 12dB low. So the EUT emission at 304MHz must also be measuring 12dB low, in which case the actual measurement should be 38 + 12 = 50dBuV/m, which is over the limit.
This scenario is entirely typical. The use of an ERS clearly shows that in most typical non-compliant sites, errors in the range -16dB/+8dB are common, especially with indoor sites.

How it can be used.

There are two strategies that can be used with an ERS.

A. A manual technique as described above. This is generally the most accurate and can avoid the significant problem that may arise if the EUT is large and/or has cables connected to it. It can be appreciated that it is important to match the location of the ERS with the location of the source of emissions from the EUT. It is therefore good practice to use a near field probe to locate the 'real' source. This may not be the EUT itself, but a cable that is connected to it. Cables make excellent transmitting antennas, so if the cable is just the wrong length (¼ wavelength) it will radiate strongly, even if the apparent signal 'leaking' from the EUT is quite small.
B. The process can be automated if the appropriate facilities are available in the post processing software allied to the analyser. Prior to the measurement of the EUT, the ERS is placed at the EUT intended location. A scan over the full frequency range is acquired, first with the ERS switched off, then with it switched on. Ambient cancellation techniques may be used to cancel any significant ambient emissions. Because the ERS emissions are precisely located at 2MHz intervals, the scan could be arranged to step in 2MHz increments rather than perform a conventional sweep. Given that the RBW is 120KHz (CISPR16) this technique not only provides a much faster scan, it ignores the unwanted 1880KHz between each ERS peak, thus dramatically improving apparent s/n ratio. Once the scans have been acquired, the software could compare the results with the pre-loaded calibration data for the ERS.

The difference will be the 'site adjustment factor' which could be applied to the results received from the EUT. This could be entirely automated and applied as the scans are acquired. Note that this factor is only relevant to emissions whose source is located close to the location of the ERS. This means that the factor is not relevant to emissions from anywhere else (including ambients). So it is important to only apply the factor to the 'difference' trace (with the ambient subtracted). The Laplace system will have all this functionality built-in, thus providing a means for significantly improving measurement accuracy.

It is now obvious that current techniques for radiated emission testing is heavily dependent on the test site. The test site can (and will) introduce far greater errors than the instrumentation. The ERS provides a means for a complete end-to-end verification of the measurement. It includes not only the effect of the test site, but includes all other factors such as …

- Lack of height scanning
- Antenna characteristics
- Cabling
- Pre-amp (if used)
- Analyser and software.

A fundamental requirement when using an ERS is that once it is used… test site must remain stable. Any change will invalidate the correlation. One advantage is that the requirement for height scanning is nullified, but once the calibration is done, the antenna height must not be changed.

<u>Limitations of the technique.</u>

Even with the ERS, it is necessary to make the site as 'open' as practical. The more enclosed the space, the more critical source position becomes. In particular:

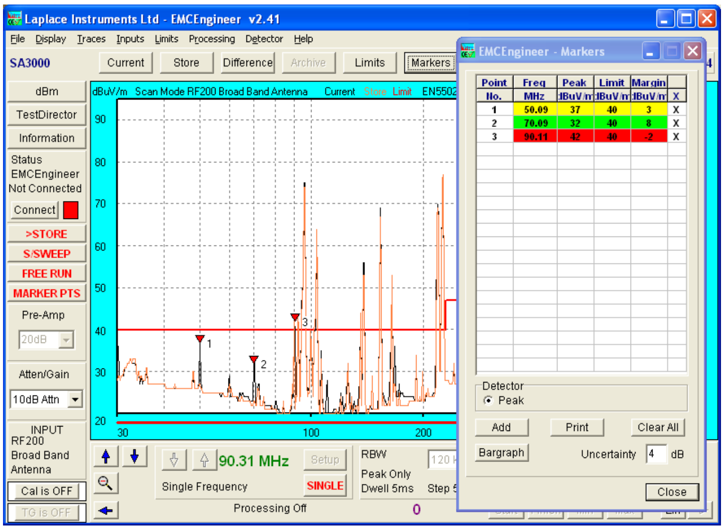
- never support the EUT on tables with any metal content.
- Locate the EUT away from metal surfaces.
- Ensure the EUT – antenna distance is at least 3m.
- Ensure that the test site is stable.

<u>A Real Example</u>

A 3m test site was established in the car park. A mobile *reflection device* (Volvo XC70) was used to check the effects of a typical reflection situation.

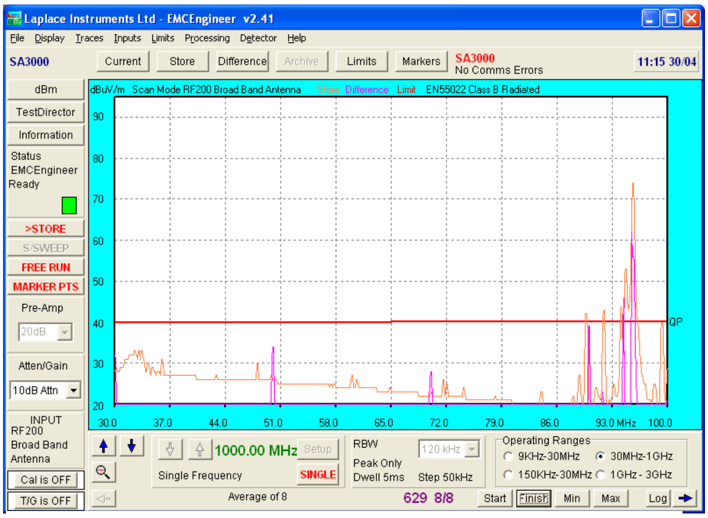
The EUT was a CMOS oscillator connected to a 0.8m wire, hung vertically (simulated mains cord).
No 'proper' ground plane was used.
Initial test was with the *reflection device* 'close'.
With the EUT switched off the ambient was first scanned using an averaging

technique to reduce the effects of ambient instability. Once this result had been stored, the EUT was switched on and the scanning repeated.
EUT emissions can be seen at 50, 70 and possibly, 90MHz. A peak at 110MHz also shows, but this is well down below the limit level.



Scan A1….Initial scan

The potential 90MHz peak is close to an existing FM frequency, so to check this, the scan is zoomed to see the relevant frequencies in more detail….



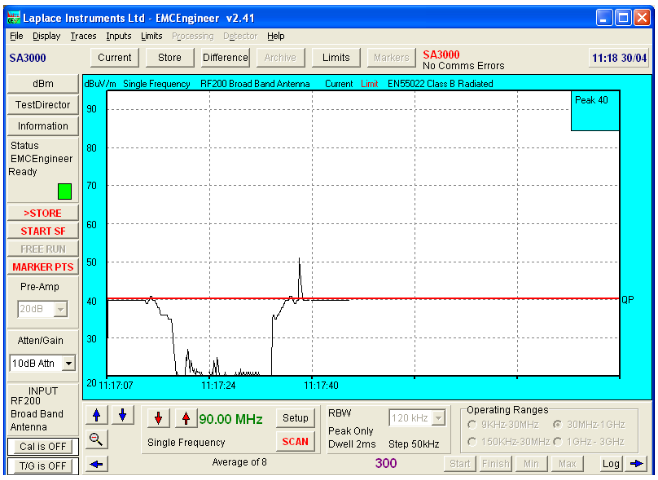
Scan B1….Zoomed scan, 30 – 100MHz

The difference trace is also invoked. This highlights the 50 and 70MHz peaks, and also shows a 90MHz emission plus some emissions in the 93 – 96MHz region. These latter are aligned with strong FM broadcast signals, and FM is by definition, a fluctuating signal.

To check that the 90MHz signal is on fact from the EUT, single frequency mode was used to monitor this frequency and the EUT switched off and on ….

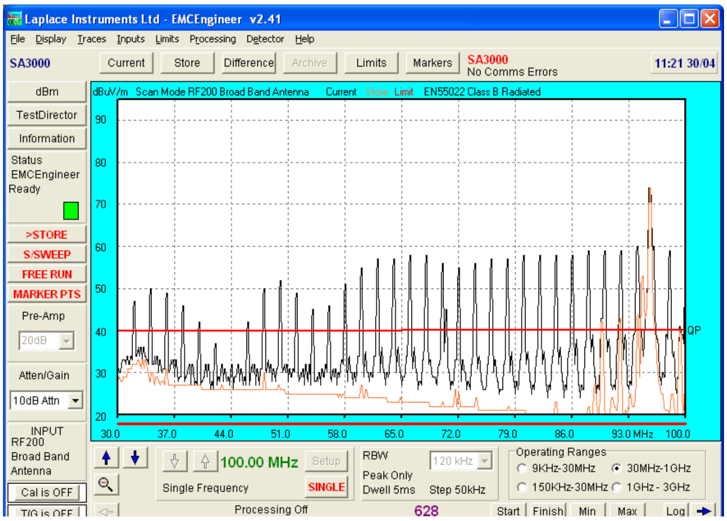
Single frequency mode plots the level of one frequency against time, so as we can see, the horizontal timebase shows current time.
The results are obvious! Between approx. 11:15:00 and 11:32:00 (17 seconds) the source was switched off.

Next step was to replace the EUT with an ERS. There needs to be a judgement as to where the ERS should be located. At a



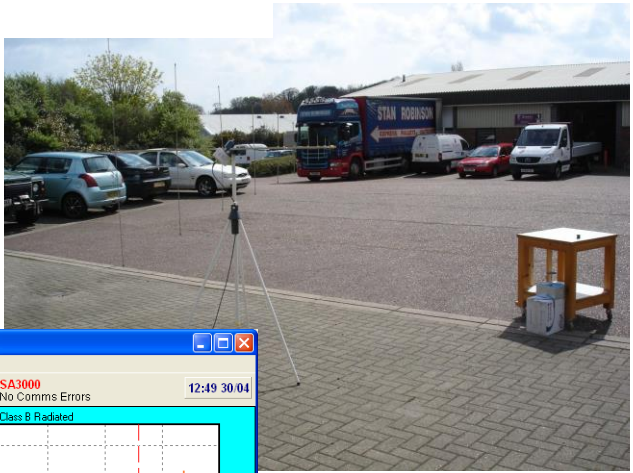
Single frequency plot at 90MHz

maximum emission frequency of 90MHz, wavelength is approx.3.4m, and quarter wavelength is 85cm. This correlates well with the wire extended from the EUT which was 80cm long. So it is obvious that the wire is the source of the emission. We therefore place the ERS at the 'centre of gravity' of the wire as shown in the photograph shown below.

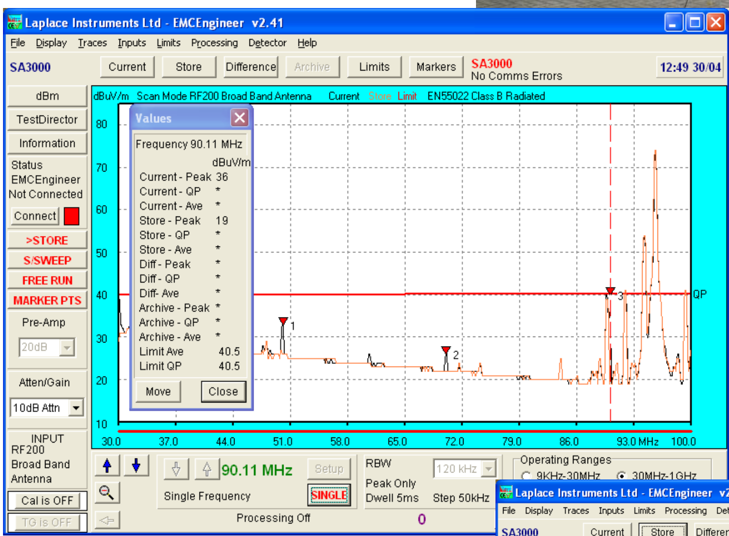


ERS results A

The frequency range of interest (30MHz – 100MHz was scanned with the ERS switched on….
The 2MHz interval between peaks are clearly seen and measurement of the amplitude at the relevant frequencies is a simple task.



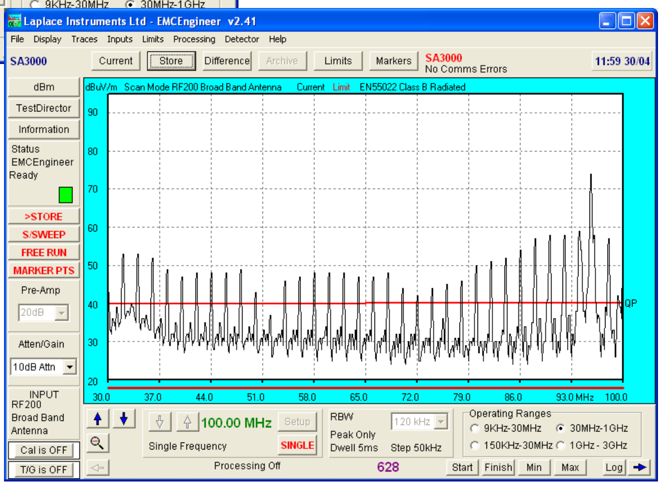
We then repeated the whole measurement process with the 'reflection device' removed to a remote location.



Scan B2, as scan A1, but with reflection removed

The 3 peaks are again observed and can be measured.

ERS results B



The measurement with the ERS was also repeated….

And finally the results were tabulated….

Frequency (MHz)	Calibration Data for ERS dBuV/m	Test 1 With reflection (dBuV/m)			Test 2 No reflection (dBuV/m)		
		EUT	ERS	**Corrected**	EUT	ERS	**Corrected**
50	53	35	52	**36**	28	44	**37**
70	57	29	56	**30**	18	44	**31**
90	59	39	59	**39**	36	58	**37**

The above results show that the ERS has been entirely effective in correcting the effects of the test site. The column labelled 'EUT' shows the wide variation between tests, but after the ERS correction has been applied, the results are all within 2dB.

Conclusion

This rather 'ad hoc' test does show:

- the significant effect that the 'reflecting device' has on the results.
- And that the ERS is capable of 'normalising' results even under adverse conditions.
- Accuracy is significantly improved and measurements becomes repeatable.
- And (incidentally) it all shows how the length of the wire affected the dominant emission frequency. Its no coincidence that at 90MHz the quarter wavelength is close to 80cm wire length.

Independent testing of the EUT had already shown that it was very close to the limit at 90MHz, and that is indeed what the above tests have shown.

The ERS represents a relatively small investment, but its effect on the level of confidence that can be attributed to any measurements is dramatic. Note that although the ERS is designed to counter the effects due to the test site, it also confirms and checks the operation and calibration of the whole measurement system including test site, antenna, cables, pre-amplifiers and analyser/receiver.
A key message is that all the above applies, regardless of the sophistication and 'quality' of the instrumentation.