Test site recommendations for Radiated Emissions testing.

David Mawdsley
Laplace Instruments Ltd

Abstract

Standard techniques for the measurement of emissions for most products require the use of an OATS (open area test site). In reality, very few organisations (excluding the Test Laboratories) have access to such facilities. However, an increasing number of organisations, particularly in Europe and increasingly in the US, are intent on conducting their own emissions checks, either for self certification or pre-test purposes.
A study of the measurement uncertainty associated with the checking of emissions on a typical test site shows that in general these sites will introduce massive errors, unrelated to the cost or complexity of the instrumentation. This situation has been largely ignored by the industry but it is hoped that this paper will open up discussion in this field. The sources of this uncertainty are discussed and a technique described for measuring and correcting for these errors.

INTRODUCTION

An increasing number of organisations, particularly in Europe and increasingly in the US, are intent on conducting their own emissions checks, either for self certification or pre-test purposes. The wish to conduct these tests is entirely understandable, given the cost and potential time saving that testing during the development phases of a new product can provide plus the avoiding of unnecessary (and embarrassing) visits to a test laboratory.
EMC standards specify that the techniques for the measurement of emissions for most products requires the use of an OATS (open area test site) or (semi) anechoic chambers.

In reality however, typical 'real life' test sites range from parking lots to loading bays and 'a corner of the lab'. Although we may officially condemn such activities, the reality for many organisations is that this is the best that they can do

Error Budgets

A flow chart for the emissions measurement process is shown in Figure 1. The error budgets for radiated emissions measurement in typical self test sites (or indeed any site) can be summarised as:

- Instrumentation and Transducer calibration. Analyser (receiver), antenna, amplifier, cable. All easy to quantify by reference to the relevant specification sheets. Errorswill generally be relatively minimal.
- Background radiation. A characteristic of the test site. 2 potential situations which can modify the reading of the signal from the EUT:
  - Strong narrowband signals.
  - Broadband signals

  The effect of each can be significant but will be reduced by increasing the dynamic range of the instrumentation. The degree of the problem of the masking of EUT signals by background will be dependant on the skill of the operator.
- Procedural. The integrity of emissions testing does depend on the correct procedures being followed. This must be related to training and management of the test process. In principle this should be reduced to zero error.
- EUT configuration. Again, depends on dedication of test personnel. This has an impact on the way in which the EUT radiates (aerial efficiency) and errors should be reduced to zero.

Test site: The real problem! See below..

The reality.

The following table is a summary of the typical measurement uncertainties that we have established from experience of approximately 80 site visits, plus published data from instrumentation suppliers and test houses.
The test laboratory figures are realistic norms and the 'non-OATS' figures assume lower cost equipment on a confined plot without height scanning. In both cases the test staff are assumed to have eliminated errors due to product configuration and orientation. The figures for errors due to the site for both test laboratory and 'self test' sites have been measured by using an Emissions Reference Source calibrated at the NPL (National Physical Laboratory) site in London, UK. This is, in effect, a transfer standard with a

Table 1. Error budgets

Error source	Test Lab (dB)	Self test sites (non-OATS) (dB)	
		Good	Typical site
Analyser	1	3	3
Antenna/pre-amp/cable	1	3	4
Background	1	2	2
Site	3	6	15
Procedural	0	0	0
Total	6	14	23

I

precisely known field strength at 3 metres. Errors are calculated from the deviation of readings from the known calibration data.
It is quite obvious that the test site is **the** real problem. This factor does introduce very large errors, unrelated to the cost or complexity of the instrumentation. (Although, obviously the use of unsuitable instrumentation can only make things worse). The figures may in fact be rather conservative.

At spot frequencies errors will be in the range 20 to 30dB on indoor sites. Figure 6 shows the errors measured on a typical 'office car park' (parking lot) site. These deviations are primarily due to:
(a) lack of height scanning and
(b) reflections from nearby cars and buildings.

It is no use simply dismissing such results on the basis that we 'professionals' would not use such sites for compliance testing. The fact is that the vast majority of product testing for emissions throughout Europe is done on such sites, largely due to a lack of appreciation of the problems, commercial pressures and the regrettably 'no problem' attitude of many EMC instrumentation suppliers.
Even if such sites are used for pre-compliance testing, it is important to understand and hopefully reduce the magnitude of error in order to make the testing as meaningful as possible.

Test Site considerations

The test technique for radiated emission measurement specified by most common EMC standards is the use of the OATS with ground plane and height scanning. The basis of this technique is the avoidance of 'unknown' reflections, i.e. all except the ground plane, and the need to normalise this ground plane reflection. It is apparent that unwanted reflections are the major issue. The one characteristic that 'typical' self test sites offer is the multiplicity of random reflections. Building structures, office equipment, metal framed furniture, metal cabinets, vehicles and wiring systems are commonly present to some degree. To show the extent of the problem, we have undertaken some simple analysis of the two extreme situations; the single ground plane and the completely screened room.

Effect of ground plane/height scanning

The need for a ground plane to ensure repeatability of measurement from site to site and from day to day is clear. However this maximises the subsequent error due to the ground plane reflection and makes the use of height scanning essential.
The ground plane 'effect' can be shown diagrammatically, see figure 2:

We can calculate the effect of this reflection and plot the results as deviation from true free space readings for a given fixed height antenna.

Figure 3 shows the results for a 3 metre site with antenna height as the horizontal axis and frequency as the vertical. Where the reflection is in phase (white areas), the signal strength is increased up to a maximum of about 5dB, but where the signals are out of phase (black areas), the cancellation exceeds 15dB.
It is a fact that almost all 'low cost' testing is done without height scanning.

Should we use a ground plane? It obviously introduces significant errors which can only be alleviated by using height scanning. Hence the importance of height scanning OR to put it another way, hence the importance of <u>avoiding</u> the use of a reflective ground plane!

The figure 3 plot shows the situation for just one reflection. Most 'real world' test sites have many reflections and, even worse, they include resonant artefacts such as metallic furniture frames and building structures. These will complicate and at some frequencies reinforce the degree of measurement error to the extent that they will exceed 20dB or more.

The screened chamber

This represents the 'worst case' site, with all six surfaces fully reflecting.
Fig 4 shows the approximate field strength distribution inside a 4 x 5 metre chamber from a centrally located source radiating at 500MHz. The vertical scale shows the deviation in dB from the free space level that should be measured at that point. For speed the calculations for these plots have been simplified, taking into account only the five most significant reflections. Nevertheless, they do show the extent of the problem.
For a signal at 500MHz, the measured level will be very dependant on the position of the antenna. At higher frequencies, position becomes more critical as the wavelength reduces. Note that the effect of resonances has not been calculated. These can only make the deviations worse.
Figure 5 shows the apparent field strength relative to a true free space level, as a function of the frequency of the source. The chamber dimensions in this case are a more typical 5 x 4 x 3 metre size and the EUT and antenna locations are on the centre line of the chamber, each one metre in from the end walls giving a 3 metre EUT/antenna distance. Again there are very substantial deviations from the true OATS results.
Both the above plots give an idea of the problems associated with screened rooms.

Most 'unofficial' test sites will have a performance somewhere between these two!

Actual results from car park and office 'test sites'

It is obvious that if measurements are to have any integrity the measurement uncertainty due to such sites must be substantially reduced.

Figure 6 shows how poor such sites can be. The site was outdoors, some 5 metres from nearby objects and buildings, with a damp asphalt ground surface. The EUT height was 0.8 metres and the antenna height was 1.1 metres.
In this particular case, the site was evaluated over the range 30 to 500MHz. Generally the results are low by up to 15dB, with an 'almost correct' reading around 280 - 300MHz. This result correlates well with the analysis for a ground plane effect shown in figure. 3
Given that such sites (and realistic alternatives) are not suitable candidates for a mathematical analysis, a more practical solution is called for.
Options are the use of alternative 'sites' such as a calibrated cell (GTEM or similar), a semi- or fully anechoic chamber or the 'calibration' of the existing site. Although cells and chambers may offer the easiest solution, the costs involved rule out this option for the vast majority of users. In addition, there are many 'products' that simply cannot be moved into a cell or room of any kind. On the other hand, calibration does offer a relatively low cost and, if integrated into the software of the measurement kit, simple solution.

Application of a reference source (ERS)

Reference sources are emitters which have been calibrated on an accredited test site such that the emission level at a prescribed distance (normally 3 metres) is accurately known and documented.
These ERS units are quite distinct from comparative signal generators and other comb generators which do not have any absolute calibration of emission level.
To understand how these ERS units operate, imagine one is used on a 'perfect' site and the full rigors of ground plane and height scanning are used. The results would exactly match the calibration data of the source.
Now take this ERS to an 'unofficial' site. The results may now differ considerably from the calibration data. The difference must be due to the effects of the site. If this difference is now used to correct the readings, we should obtain results that again match the calibration data and the site now behaves just like the 'perfect' site.

ERS limitations

Correction would be perfect for a product which was the same size and same aerial configuration as the ERS. Obviously in practice this is rarely the case. The degree of 'non-correlation' will depend on the nature of the site. The more 'open' the site, the lower will be the error due to EUT/ERS differences. In a 5 x 4 x 3 metre screened room, moving the source by 40cm produced 12 dB variation in signal strength at some frequencies, whilst on an open 'car park' site the variation for the same movement was only 1dB.
Even with the ERS it is clear that the test site configuration is still an important factor but (apart from the screened room situation) the technique does deliver substantial improvements in measurement accuracies. Testing various products on typical 'unofficial' sites has shown that measurement uncertainty has been reduced from generally 15 - 20dB to 6dB by using the ERS technique.
Although using the ERS in a manual mode is quite simple, to embody the technique in an automated software package is in practice not straightforward. All test sites suffer from relatively strong and unstable background radiation. Any technique must take this into account and avoid the trap of applying any corrections to the background signals.
The technique that is used in the Laplace automatic test site correction system involves several steps which include;

- Very precise measurement of each peak from the ERS using a precision spot frequency mode.
- Measurement at each of these spot frequencies with the ERS on and off to take account of background signals.
- Automatic computation of the correction data.
- A measurement process that normalises the background to a stable signature.
- Application of the correction data to the EUT emissions only, after cancellation of the background.

Comb vs. noise source

What would provide the best signal source?
Viable alternatives include 'comb' generators and impulsive and white noise sources. By definition, impulsive and white noise sources are broadband and measurements are therefore dependent on the I.F. bandwidth of the receiver/analyser. They will also be affected by the type of detector used and lack any distinctive frequency reference. The fact that they provide a continuous spectrum is in their favour, whilst comb generators can only offer a discrete series of points. However the comb generator does offer distinct measurement points, and a continuous narrowband signal This provides a source which is independent of I.F. bandwidth or detector type and can be absolutely calibrated at distinct frequencies. Another advantage is that most radiated emission 'problems' have a narrow band characteristic and a reference source having the same characteristics offers better correlation. The ERS is a comb generator with a 2MHz spacing, giving 485 measurement points over the range 30 to 1000 MHz. Each point is calibrated for vertical and horizontal polarisation on a perfect OATS using the full rigors of height scanning, ground plane etc...
The one potential disadvantage of the comb generator is the 'gaps' between the peaks which may

conceal any sharp test site characteristics. Measurements with a white noise type of source has shown that, except in screened rooms, the Q of a test site is never sufficiently high to cause errors of more than 3dB with a 2MHz resolution. Inside a small screened rooms, a resonance has been detected which would have given an errors up to 10dB if it fell exactly half way between two comb frequencies. This has been an exceptional instance and, in reality, this room would not have been suitable for any emissions measurements.

Conclusion

Non compliant test sites can introduce considerable error in the measurement of radiated emissions. The users of such sites are largely unaware of the causes and the significance of these errors. It is important therefore that the EMC measurement industry promotes discussion of these factors in order to increase general awareness amongst all those who are likely to be involved in EMC measurements. The use of devices such as the Emissions Reference Source can help to improve the integrity of these measurements, even on unsatisfactory sites.

About the Speaker

David Mawdsley is Managing Director of Laplace Instruments Ltd, a supplier of EMC test equipment. He has been instrumental in the development of a whole range of emissions test products, with the emphasis on practical solutions. During the past 5 years David has been involved in the measurement of emissions of practically every conceivable type of product in test sites and conditions of all kinds. This sobering experience has been the inspiration for this paper and the catalyst for the introduction of test site calibration techniques.

Figure 1 Measurement uncertainties

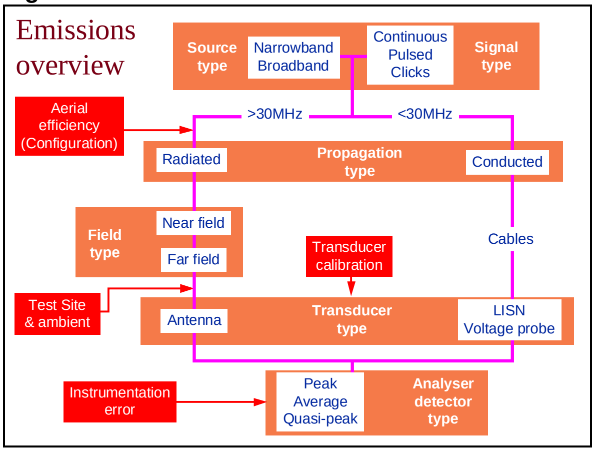

Figure 2 The reflection mechanism

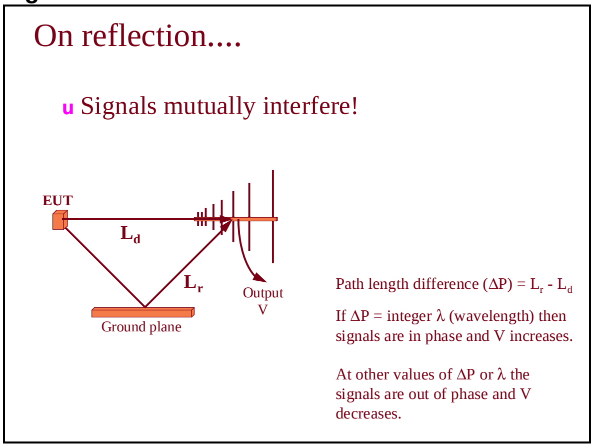

Figure 3 Antenna height effect

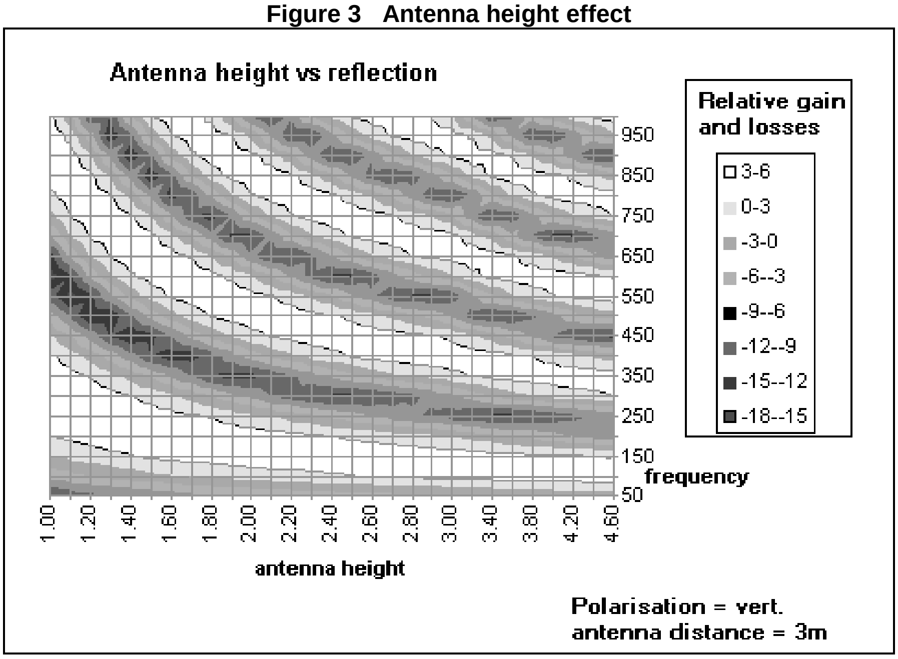

Figure 4. Spacial variation of field strength in screened room

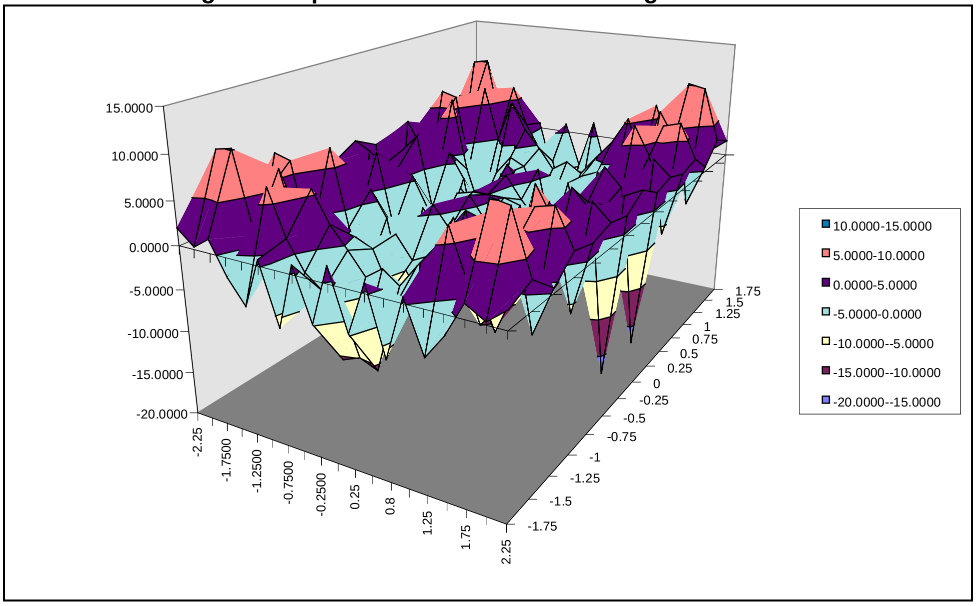

Figure 5. Variation with frequency.

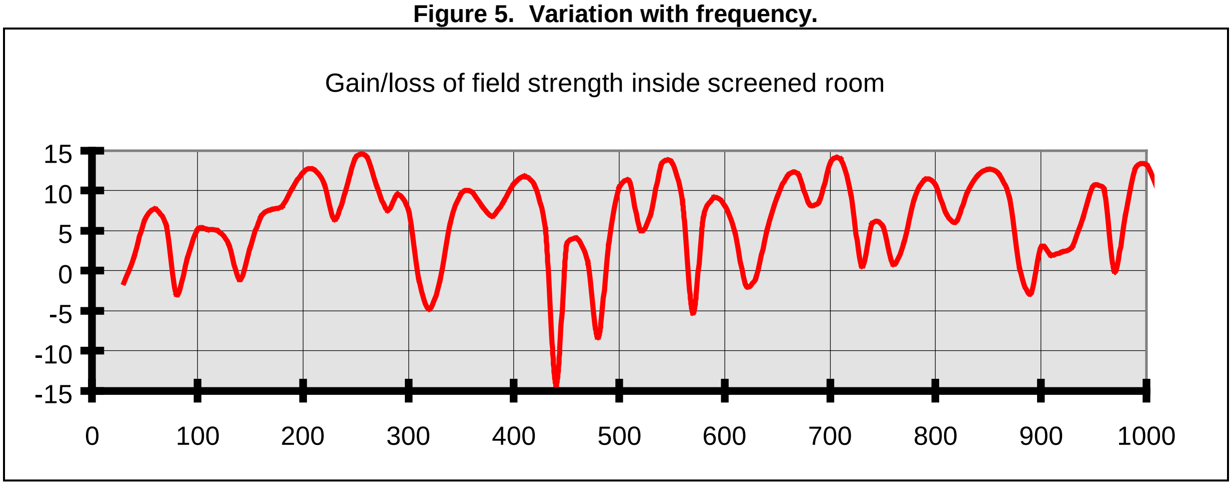

Figure 6 Actual 'parking lot' measurement error.