SYNTHESIS REPORT

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CETIM

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NON-CONFIDENTIAL

ELECTROMAGNETIC COMPATIBILITY TESTING FOR VOLUME PRODUCTION

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Abstract

This project was initiated by the need of the European manufacturing industry to address the issue of ensuring the compliance of their manufactured products to the requirements of the European Directive on Electromagnetic Compatibility. The particular concern was that of volume manufacturers who were small and medium enterprises.

The project needed to review the basic method of characterizing the EMC performance of a product in particular its radiated and conducted emissions and its radiated immunity performance. A much smaller test environment was designed using computer modelling supported by practical assessment. This resulted in a near conformal test cell capable of testing a product up to the size of a single shelf in a 19 inch rack. The test cell was designed to be used in a production environment and therefore a control system was designed that provided a simple user interface. In addition a detailed methodology was developed that would enable the test system to integrated into the manufacturing environment.

1. INTRODUCTION

The specific industrial objective of the project was to provide European SME'S (Small and Medium Enterprises) manufacturing electronic equipment, with product test technology for Electromagnetic Compatibility (EMC), in response to the European Directive on EMC 89/336/EEC. The main emphasis of the project was to address the manufacturing environment as this would present future problems for all the electronics industry, as the directive requires all product to comply and not just the type approved unit,

Therefore developed technology aimed to reduce manufacturing costs, and increase product quality and inter-operability in an environment where the electromagnetic spectrum is under increasing pressure from the proliferation of electronic products.

The consortium of companies formed to support this project represented a spectrum of interests from component suppliers to end-users. This diversity shaped the project to ensure that a realistic set of industrial adjectives were specified.

The main technical objective of the project was to produce a small test environment, a ost conformal with the EUT (Equipment Under Test), and maintain the accuracy of measurement. The standards for emission and immunity test ng require the use of either a large Open Area Test Site (OATS), or a screened enclosure with= limit on the reflections, which normally involves the lining of the chamber with costly RF anechoic material. These test environments are normally many times the size of the EUT and therefore require considerable production area to house, and in addition will cost in excess of f50, 000 for the enclosure.

The project objective was to be achieved through the following activities:

- the development of a novel antetina array and enclosure design capable of measuring the radiated and conducted emissions from equipment under test in such a form as to allow comparison of the results with conventional test arrangements.

- the test cell should be capable of undertaking radiated and mains conducted emissions testing, and radiated immunity testing.

- to develop a test environment capable of evaluating product to the main requirements of the European Standards EN 50081-1 and EN50082-I, by referring the results to a "Gold Standard" for each product.

the development of a design for manufacture methodology for optimum EMC performance of high volume electronic assemblies and equipment.

to reduce the cost of EMC testing by 80% from using conventional test methods.

to characterise the cell performance to ensure reliable and repeatable performance.

The project was established with a two year research and development program me commencing in July 1994 and completing in June 1996. The consortium were keen to ensure that the project was able to provide a solution near to the date 1 January 1996, as this was the date of the full implementation of the European Directive on EMC. The project would research and develop the technology capable of meeting the objectives, and undertake exhaustive prototype testing to ensure the new test cell performed as required. The consortium would then take the technology and quickly develop it into a commercial product for the European market.

2. TECHNICAL DESCRIPTION

The developed technology consists of a novel test enclosure with an array of input and output signal and power connections. Supporting the test cell is an assembly of low cost test equipment under PC control, where the PC provides a graphical user interface for production environment testing. To enable the easy integration of the test cell technology into the production situation, a methodology was developed.

2.1 Requirement

The technical requirement of the project was significant, with the aim of condensing a normal RF (Radio Frequency) radiated emissions test site down from 10m x 4m x 5m to approximately 1.5m x 1 m x 1 m. This would present several problems including the interaction between the EUT (Equipment Under Test) and the antenna, control of reflections, and the understanding of the signal received in relation to that emitted by the EUT.

In order to provide the necessary parameters as to the form of this test cell, these were the shape and size of the environment, and the signal receive and launch mechanism; a series of computer models were developed by' the University of York.

At the start of the project, the consortium determined the outline specification, including the maximum EUT size that the developed technology would be required to test. This was determined as 0.6m x 0.5m x 0.3m (width x depth x height).

2.2 Organisation of the work

The three research organisations split the work to provide a complementary approach to completing the objectives of the project In summary, Pera was responsible for the project management, system design and integration, interface design and some correlation The University of York was responsible for the fundamental design of the test cell shape, antenna design, splitter and impedance matching. CETIM was responsible for some of the product evaluation and predominantly the methodology development.

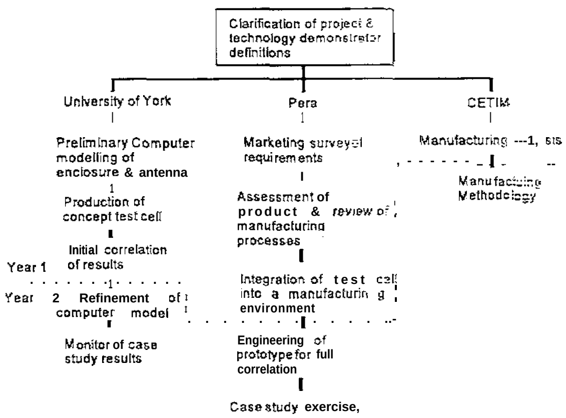

Figure 1: Overview of the project programme

2.3 Modelling work

The design was based on the details determined from the industrial survey, which defined the representative equipment under test (EUT) as having the dimensions 0.6m x 0.5m x 0.3m with one power cable and up to fifteen signal cables.

The electromagnetic design of the test cell was determined by the need to replicate, with adequate fidelity within the cell, the electromagnetic field structure at the surface of the EUT found in conventional EMC tests. That is to replicate the free radiating conditions found in open field test sites, and the incident field found in immunity measurements.

The first aim of the modelling programme was to determine the field structure and, if possible, the sensitivity of the EMC performance of the EUT to changes in the field structure. The remainder of the outline design was then concerned with the operation and observation of the EUT. As the electromagnetic design is passive and linear, the test monitor would be reciprocal, that is both immunity and emission measurements would be possible. The correlation of the measurements would however be different in each case.

The TLM (Transmission Line Matrix), described below, method was used to provide the backbone of the simulation work at the University of York with the NEC, described below, playing a model validation role, These models were used to determine the induced currents on the walls of the EUT when irradiated by a free-space plane wave, A similar model, but with the EUT enclosed in the measurement cell then enabled correlation between the two methods. The objective was that designs could be accurately modelled in a matter of hours and implemented or discarded as appropriate. Once the test cell was constructed, this prototype was used to validate the models, and calibration and correlation data was produced.

TLM (Transmission Line Matrix)

This modelling method is good for closed systems consisting of planes and blocks of material. This code maps the fields within the defined region as a function of time, Data can then be extracted in the form of electric or magnetic fields or vector currents as a function of time or frequency.

NEC Code

This is a thin wire model based on the Method of Moments. This package is suited to the solutions of free-space problems. Surfaces may be considered by replacing planes with crossed wires with a suitable element spacing.

2.3.1 Design aspects of the cell

One of the key aspects of the test cell design was the need to insert each EUT and its cables into the test cell in the same physical orientation. It was thought that the repeatability of the test performed in the test cell would be largely determined by the stability of the cable layout particularly as the volume occupied by the EUT and its cables would be a substantial fraction of the total test volume, This necessitated the use of a pallet into which the EUT would be inserted prior to testing. The pallet included a set of connections for attaching the EUT.

Once inside the monitor the cables on the pallet would be attached to the outside world via a series of filtered connectors. The electromagnetic energy would be coupled to/from the EUT by the use of a set of field sensors/generators inside the test cell. The test cell also required a screening function to exclude ambient energy from the EUT and to prevent threat energy incident on the EUT from leaving the test cell, thereby causing external interference.

A first prototype cell was constructed from mild steel, and measured 1.0 x 0.7 x 1.2m (wxhxl). The size was based on the maximum EUT size, the need to incorporate antennas, some form of RF signal damping/absorption, arid parts of the test equipment. These dimensions represented a significant saving over those that would be required by simply applying the one third rule which is observed by TEM and GTEM cells. This requirement would demand an overall size of approximately 1.8 x 2.5 x 3.0 m including the typical length associated with a taper section.

2.3.2 Modelling of the cell

Numerical simulation of a diverse range of test cell designs was undertaken using a TLM model.

The objective was to evaluate each design with respect to the control and to the alternative designs. The initial work concentrated on the frequency range 100 to 1000 MHz and on simple transmission line structures, This allowed the behaviour of individual components of the test cell such as the input section, use of absorber material and cell height to be examined.

The control was chosen to be a representative box EUT placed in free space and illuminated with an infinite extent planar wave incident normal to its front face. This choice was based on its equivalence to the situation of an EMC source/victim in its natural environment, This situation was also readily comparable with the standard reference techniques for examining the EMC performance (emissions/immunity) of a device and much work has gone into correlating free space results to measurements on an open area test site (OATS) or in a screened room,

The suitability of a given test cell design can be evaluated in terms of the correlation between the fields or surface currents developed on the surfaces of the EUT as compared to those produced in the case of free space illumination (Control). The predictive work used the representative EUT dimensions, The EUT was assumed to be constructed from ideal, planar, perfectly conducting walls which would induce the maximum' possible perturbation in the incident field,

Most of the structure behaved well showing some resonant behaviour at around 300 MHz and only very slight resonances at higher frequencies, The exceptions to this rule tended to be the fields of the lowest magnitude. The plot of the normalised minimum observed field values were less useful as many of the fields dropped to a value of zero due to the symmetry of the problem, This did serve however as a test that the model was accurately predicting the problem in that it indicated the location of field null points,

A diverse range of test ceil configurations were examined with the purpose of determining the most critical design parameters. In order to minimise the complexity of the models and to gain as much information on a specific element of general cell design, the initial cells under consideration were simple structures. These provided information on the four main problems associated with the design:-

- The design of the source region and excitation method,
- The effect of reducing the ratio of the cell height to EUT height ratio.
- The sensitivity of the internal field to the side wall reflection coefficients.
- The effect of breaking the system symmetry by attaching a wire bundle to the EUT.

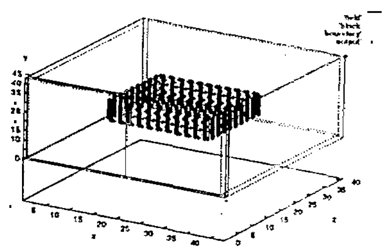

Figure 2: Model of control EUT in free space

The modelling work yielded a preferred structure for the antenna, and a theoretical method of matching the input impedance and the termination impedance.

2.3.3 **Modelling of the anechoic material**

One of the significant problems during the modelling phase was the accurate understanding of the behaviour of the Radio Absorbent Material (RAM} which was to be used to reduce overmoding. Manufacturers data did not yield sufficient information to be able to feed into the computer model. a combination of material testing and trials enabled a rough approximation of the performance of the RAM to be determined.

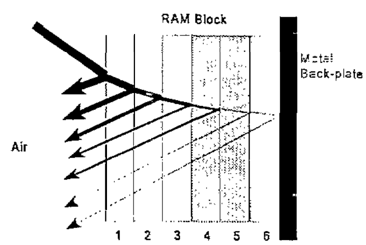

Figure 3: Structure of RAM showing first order reflections,

The RAM was successfully applied to the construction of the matched load in combination with a series of resistors which improved the low frequency response, This simple terminated cell configuration would however only be operable to a few hundred megahertz above which higher order waveguide modes would dominate giving unacceptably high field variations within the test volume. Further applications of the RAM within the test cell had a significant damping effect on those modes resulting in a more uniform field, and therefore extending the usable range of the cell to 1GHz. Although RAM is considerably cheaper than the other alternatives, it still adds a significant contribution to the cost of the system as well as to the weight and overall dimensions of the cell. Furthermore, surface and bulk waves may be setup within the RAM blocks which can degrade the system performance under certain circumstances.
The simulated response fell short of the manufacturer's quoted values by quite a significant amount especially at low frequencies. This was as a result of the large number of system unknowns (12) as well as the lack of information concerning the absorber response ie. only the magnitude information was provided. Even the application of a numerical minimisation routine failed to improve these values. The system was too complex for all but the most sophisticated routines.

2.3.4 **Excitation**

Using a simple transmission line model, an antenna array was developed and the number of elements optimised using the model. The objective being to achieve an even response within the required test volume.

A critical aspect of the cell design was the fabrication of a high quality broad band matched load on the far wall of the cell. This was necessary to prevent resonances developing in the transverse dimension of the guide reducing the field uniformity and operating volume of the cell.

Initially two methods of broadband matching the cell were considered using either ferrite tiles or a hybrid resistor - RAM combination, The former method was dropped due to the prohibitive cost of ferrite materials.

The use of a resistor - RAM hybrid is a standard technique adopted in the design of the GTEM cell. In this case however the overall length of the load is often in excess of 50cm and a return loss of better than 25dB can be achieved across the band. Most of the load length is due to the use of spiked RAM as well as the use of extended resistive elements. This dimension represents over 40% of the proposed cell length and is not acceptable by itself

Through experimentation a suitable combination of RAM and discrete resistors were found to produce a broadband load in an acceptable length.

2.4 **Preliminary results**

As part of the initial design and modelling work, the University of York carried out a series of measurements with the test cel as an emissions monitor and compared these results with **these** gained from a suitable control. In order to achieve this a number of dummy EUTS were used to simulate both varied physical dimensions and electromagnetic sources.

The objectives of this set of testing were to determine:-

- the linearity of measurements
- the sensitivity of the EUT position
- the ability of the cell to accurately measure varied EUTs
- the limitations and features of the cell design

A number of dummy EUTS were prepared for the purposes of the calibration exercise. Each design was chosen to test some feature of the test cell. The two main EUTS were the comparison noise emitter (CNE) and the generic EUT as described below.

- The CNE represented a small device which emitted over the entire proposed range of the cell (30 - 1000MHz). The CNE radiated via a small monopole antenna. Dimensions 18cm x 10cm x 12cm with monopole.
- Generic EUT brass box of dimensions 0.6m x 0.5m x 0.3m driven by the CNE in a number of modes (electrically or magnetically). This EUT represents< the maximum permissible EUT size for the

test cell.

The current standard technique for the measurement of electromagnetic emissions required the use of an Open Area Test Site, (OATS). The test procedure used to generate the preliminary results involved the use of a bilog antenna operating in the entire measurement range from 30 MHz to 1 GHz placed 3m from the position of the EUT, which was raised 0.4m from the ground plane by means of a dielectric support. The bilog antenna was fixed to a height adjustable mast which was scanned in height from 1 m to 4m above the ground plane and back down during the course of each measurement. The signal was recorded using an Anritsu spectrum analyser set in Peak-hold mode, The scan time of the analyser was considerably shorter than the time required for a complete height scan ensuring that true maximum field values were recorded.

Prior to each block of measurements a scan was carried out with no known sources active in order to establish a background level. For each EUT setup two measurements were carried out with the receiving antenna set to vertical and horizontal polarisations respectively. References to the EUT and antenna orientations are made with reference to co- and cross- polar directions, For any given case co-polar implies that the EUT source and the antenna are aligned in the same direction such that maximum coupling occurs between the two. The cross-polar direction is the reverse of this. This is only meaningful for measurements made with the CNE.

The scanning action used for standard OATS measurements was used in order to minimise the interference effects caused by the presence of the metal ground plane. The scanning had the effect of filling up the resonances especially for the case of vertical polarisation. The difference could be of the order of 10dB.

In each case the EUT was placed into the cell upon a polystyrene support in the appropriate position. The cell door was closed isolating it from the ambient environment and measurements were made using the Anritsu spectrum analyser as used for the OATS measurements, In most cases measurements of the response on the vertical and horizontal arrays were measured for each orientation of the EUT.

Polarisation response:
a vertically polarised CNE with monopole was measured using both the OATS and the test cell. The strength of the source was varied between measurements by inserting an attenuator of known value between the CNE and the radiating monopole. Attenuators of value 3, 6, and 10dB were used, The insertion of the attenuator also had the effect of introducing a resonance into the response at the top end of the frequency band for some of the plots. This effect was verified by using BNC connector pieces to simulate a device with the same dimensions as the attenuators used whilst producing no attenuation,

The results for a vertically and horizontally polarised CNE appeared to give good general agreement between the cell response ana the OATS responses however there seerned to be an anti-resonance around 30-1 00 MHZ which distorted the lower part of the spectrum. There were also features present on the cell measurements which were clearly representative of the cell volume. Figures 4 and 5 show the response for the vertically polarised CNE, and vertical polarisation response of the cell.

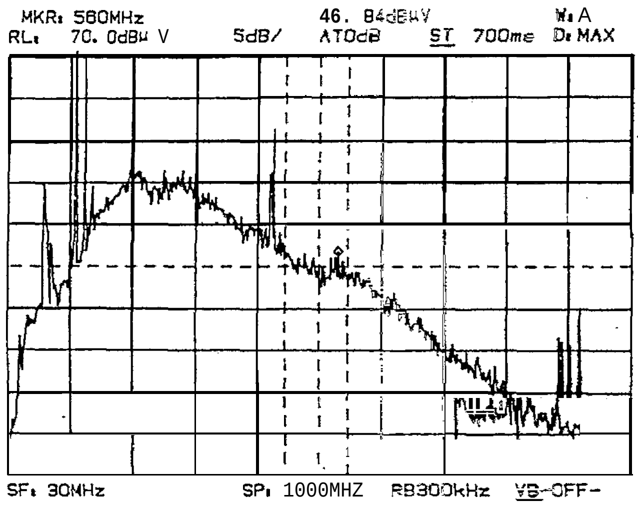

Figure 4: Vertically polarised CNE, vertical polarisation response, OATS measurement.

There appeared to be good agreement with respect to cross-polar levels with the co-polar signal being significantly less that the co-polar levels for both polarisations.

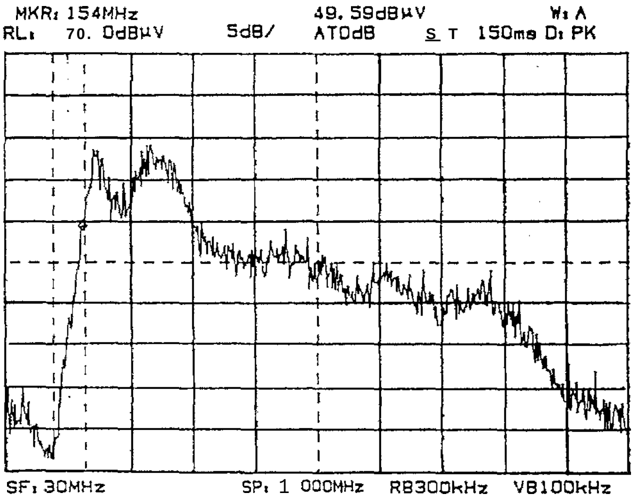

Figure 5: Vertically polarised CNE, vertical polarisation response, Cell measurement.

Position sensitivity

The location of the CNE was varied by 2cm in each direction in a horizontal plane. This procedure was repeated after raising and lowering the CNE by 2.5cm respectively, All responses were plotted onto the same axis and are given for vertical and horizontal polarisation in Figures 6 and 7.

The results showed a tight band of results which could be further improved by reducing the IF bandwidth of the measurement, The scan time used was 3 seconds which was much less than the time allocated to a measurement in the final cell, Even so, the results suggested that if the EUT can be contained within 1 or 2 cm, which should be possible using the palette system, then very repeatable results can be generated.

2.4.1 Conformal EUT measurements

The conformal EUT represented the maximum EUT size that was tested within the cell. The conformal EUT was a brass box with three of its sides formed from removable plates. This allowed the radiating mode of the EUT to be varied by using stand-off plates or slotted face plates. The stand-off was a metal plate raised

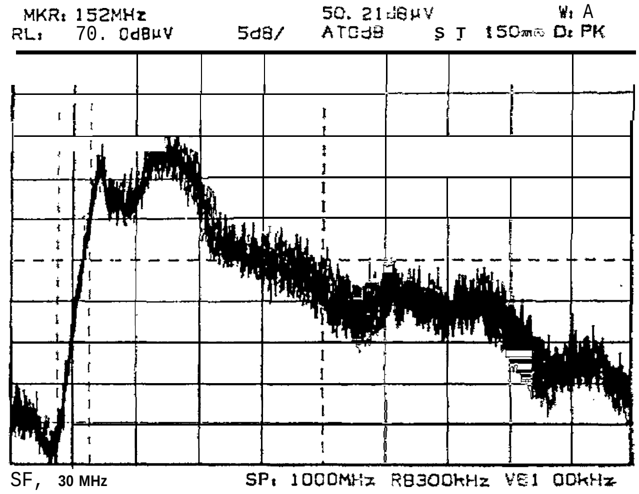

Figure 6: Vertical polarisation

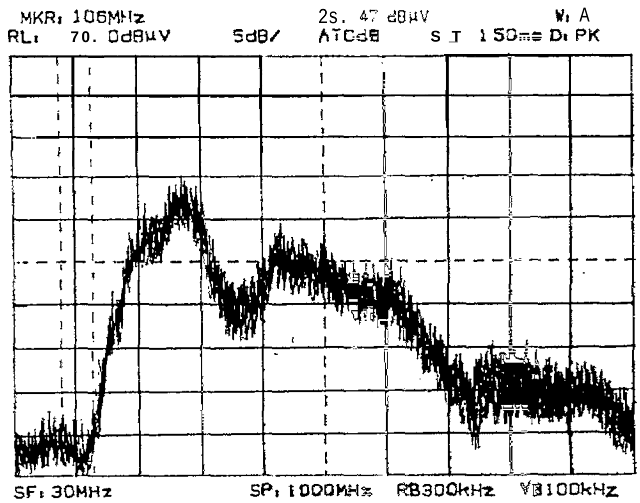

Figure 7: Horizontal polarisation

from the plane of the box wall by means of four short dielectric rods, When excited using an internal monopole an electric source was observed.

Excitation modes

In order to test for different excitation modes within the EUT a slot radiator and a stand-off were used, Both were powered using the CNE. The stand-off when excited with the CNE monopole behaved as an electric source whereas the slot when fed directly using the CNE behaved as a magnetic source.

Combinations of both individual sources as well as combinations of the two were examined.

Mode sensitivity
The EUT was driven in a way as to observe the effect of changing the relative output levels. There appeared to be good agreement between the data in all cases though the measured levels from the cell were somewhat lower than those from the OATS, This may not be a problem as OATS standard measurements are often taken on a 10m site which would result in a significant reduction in the observed signal level.

There were some slight differences in the data in terms of the positions of resonances and the relative levels of peak values, This was partially attributed to the effects of scanning the antenna smoothing out the response. This work provided a base demonstration of the general correlation between the measured cell voltages and the received signal from an antenna on the OATS.

There seemed to be good agreement with respect to the relative response of the vertical and horizontal signals measured in the cell when compared with those measured on the OATS. There could have been a problem with the low level of the signals measured in the cell but at the time this could have been improved by the use of a preamplifier or by further improvement of the input section of the cell.

2.5 Audit

The objective of the audit was to consider the production systems used by consortium members, and to review their design and support services in light of the need to meet the European Directive on EMC. This assessment would then provide information on how their processes impact on the EMC performance on their products.

At the request of the consortium a questionnaire was developed and sent out to over 50 UK companies to ascertain their view on meeting the EMC Directive. This was carried out over the period March to June 1995. Although the overall response was low, 20 replies, some interesting points were revealed as follows:-

i) Almost 90°A of the companies had been aware of the EMC Directive for at least year.

ii) 83% of companies believed that they had at least a reasonable understanding of the Directive.

iii) Only 28% of companies believed that they would have all of their products certified by 1 January 1996.

iv) In terms of perceived problems in meeting the requirements of the Directive the results were as foilo/fs:-
- 42% believed radiated emissions would be the main problem.
- 5% believed radiated immunity would be the main problem
- 5% believed conducted emissions would be the main problem.
- 37% found that simply understanding the Directive was their main problem.

v) 42% of companies were only considering EMC because of the legal requirements.

vi) 42°A of companies claimed to already posses pre-compliance EMC test facilities.

vii) Approximately half of the companies intended to rely on build quality to ensure consistent EMC performance. 29% of companies intended to test a sample of products coming off the production line. 18% of companies had not considered this problem.

viii) 35% of companies had at some time received a complaint about their products with respect to EMC.

[t was hoped that within the project budget there would be opportunity to re-run the questionnaire after the Directive's implementation date of 1 January 1996. This would have shown if changes in attitude had occurred. in addition a similar exercise for other European countries was planned but in both cases budget and time did not allow this exercise to occur.

2.6 Software development

One of the key elements of the project was to develop a system that was easily absorbed in to the production environment and used by staff not conversant with the details of EMC testing. To facilitate this a PC Windows$_{TM}$ based control system would be used. This would produce the man machine interface as well as the control and data processing.

The demonstrator software would provide the automation of the following functions:-

i Conducted emission measurements
ii Radiated emission measurements
iii Radiated immunity measurements

The software would provide a front end menu system to allow the user to select any of the above measurement functions. The menu would be initially presented to the user upon running the software, and may be later returned to from any of the measurement functions.

In addition to the measurement functions, a fourth option would be available from the menu. This option would allow a previously saved set of results to be reloaded, displayed and, if required, printed,

2.7 System Design

The project was conceived to use predominantly existing test equipment, preferably sourced through consortium members. There would by necessity be a requirement for a purpose designed interface box and RF coaxial switches. The objective would be to use conventional test equipment controlled by the use of the IEEE 488 protocol.

The main test equipment requirements were identified as follows:

Pc
Printer/ Plotter
PC Card
IEEE Relay Card
Spectrum Analyser
LISN (Line Impedance Stabilisation Network)
RF Signal Generator
RF Amplifier

2.8 Case studies

The case study exercise within the project was primarily aimed at providing confidence testing in the performance of the test cells, The trials by the consortium members would provide feedback on its operation and further support for the validation of its measurements. However, this exercise did not occur in its originally intended form, due to various events as detailed below. One unit was supplied to the French partner, who used it in support of the methodology development, and the exercise did provide useful feedback.

The case study exercise had not run as originally intended, but this had been due to combination of effects where effort had been expended on establishing the patent, delays with supply of parts for the case studies, and an emphasis within the industrial consortium to work towards a commercial product as soon as possible after the conclusion of the project. However the case study exercise did yield some very useful information that has been fedback into the construction of two more case study units and to the industrial exploitation of the project,

The requirement to gain confidence in its measurements was undertaken as a separate exercise between Pera and the University of York. This yielded a good set of data that showed very good performance in measuring the critical emissions of products.

The exercise was successful and yielded probably as much information as it was likely to if run in its entirety.

2.9 Methodology

The objective of this part of the project was to develop a methodology or understanding of how EMC was to be accounted for within the volume production environment using the developed test cell as the main assessment tool. One concern at the concept of this project was that an advanced EMC test equipment could be produced, but that it would not be effectively applied to the manufacturing environment.

The Methodology covered the following areas:

- Why companies should be involved in EMC
- What EMC is
- How companies should address EMC
- How EMC is involved in all stages from concept to after sales service

- How the EMC test cell is incorporated into the manufacturing facility.
- How the results are interpreted
- Quality assurance of the results

2.10 **Correlation**

Radiated Emissions

In order to increase confidence in the performance of the test cell, a series of tests were carried out by the University of York and Pera. These tests involved taking various equipments and testing them on a standard Open Area Test Site and then repeating the tests using the developed EMC test cell, located at Pera.

Each of the equipments was set-up in two different ways in order to measure a difference. The ability of the test cell to measure this difference would provide for the validation of the test method.

Test arrangement

Each unit was tested in both its operating conditions and using both antenna polarisations. Each unit was then rotated through 90 degrees to provide a basis for understanding any correlation between the OATS and the Test Cell.

The test arrangements conformed to the appropriate method for radiated emissions using an Open Area Test Site. Each test arrangement was photographed to maintain a record of the exact layout of cables, etc.

When the EUT was tested in the test cell, the centre of the EUT was positioned centrally to the array elements. The EUT was positioned on the appropriate height of polystyrene blocks above the pallet and cables were fixed in position.

Results

The results showed that generally across the frequency band 30 MHz to 1000MHz, there was very good correlation in measuring a difference between the two operating conditions for each equipment. In fact the test cell was much more accurate in detecting a specified 3dB change on the CNE than was the OATS.

Above 900 MHz there was a difference recorded in excess of 10dB, when testing the CNE, which was not obviously explained, Subsequent testing has been carried out to resolve this issue.

The majority of the EUTS were only producing signals below 200 MHz anc comparison was more difficult. However, the test cell measured the same frequencies of peak outputs as the OATS, which would ensure that a correct assessment in changes of performance could be detected.

Radiated Immunity

The testing for the RF immunity produced a compliant field strength of 3v/m using the RF amplifier supplied by Laumonier, using the vertical strips.

A series of tests were carried out at Pera to establish the uniformity of the radiated field within the test volume. The test was set up using an isotropic field probe and monitor linked to a PC to record the input level to an amplifier required to generate the necessary field strength of 3v/m and the data was then analysed to establish the maximum difference between any two positions of the rf field probe **on** each level. The levels were, for level 1 - the pallet surface, and for level 2- 19cm above the pallet surface. The results showed that on average the maximum field differences were less than 5dB, the specification requirement. The vertical polarisation was much better at obtaining a uniform field. The maximum excursion on the vertical polarisation was 11 dB on level 1, and for the horizontal plane the maximum excursion was 18 dB on level 2.

The results show a very good performance for such a small test volume, and the major excursions were confined to narrow frequency bands.

3. Results

The specification of the developed systems is:

Frequency Range:	
Radiated Emission	30 MHz - 1000 MHz
Radiated Immunity	27 MHz - 1000 MHz
Conducted Emissions	(Mains 110v/240v ac) 150kHz - 30 MHz
Radiated Immunity:	
Field Intensity	3V/m
Amplitude Modulation	80%
Field Variability	+6dB/-0dB (On average. Certain peaks exceed +6dB)
Test Volume:	
Max EUT Size	0.6m x 0.5m x 0.3m

Measurement Repeatability:	
Radiated Emissions	±2dB
Radiated Immunity	±2dB
Conducted Emissions	±2dB

4. Conclusions

The project set out with the main objective of developing an innovative testing technology for assessing the EMC performance of a manufactured product. This assessment would be of the form of a comparison against a "Gold Standard" product and the test system would detect deviations of the product causing the unit to fail. The project achieved its objective by producing an innovative technology capable of accurate and repeatable measurements in advance of anything on the market.

The technology developed is capable of testing the EUT in two planes without altering the orientation of the EUT in the test cell. The development is specifically geared for production testing with an easy pallet loading mechanism for each EUT to be tested. This will ensure repeatable positioning of the EUT and its wiring.

The results of the test cell's performance were generally in advance of that expected, with very good reception of signals and ability to generate an even field within the test volume.

The test time for a product is dependent on the number of tests to be undertaken and the complexity of the EUT installation on to the pallet, but a typical radiated emissions test is less than 5 minutes including the installation of the EUT.

The final cost of the prototype system was of the order of £28,000, this was using non-optimised or costed components, but did not include a sales mark-up. This cost was higher than originally desired, but is still cheaper than a comparable test system capable of testing the maximum size of EUT, which would be of the order of £120,000.

A significant amount of comparison testing between the test cell and conventions; test facilities was carried out to understand the performance of the cell. This showed a good set of results and reveals a very competent test cell. Further analysis of the data was not able to be undertaken due to lack of time, but extra work would lead to a very outline correlation factor between the cell and norms! test facilities.

The case studies was the most disappointing aspect of the project, in that time ran out in the last six months to achieve this activity as originally envisaged. Delays occurred in the delivery of components and parts, and there was a slight change in emphasis within the project at the 18 month point to look in more detail t the exploitation routes for the technology. In addition effort was expended on developing and applying for a Patent for the technology. All of this caused delays that could not be made up in the last quarter of the project.

The lack of case studies was counter-balanced by additional comparison testing undertaken by the University of York and Pera into how well the test cell performed, In addition, the development of the methodology by CETIM and various technical review meetings with the consortium yielded a significant amount of useful data that would otherwise have been generated by the case studies.

The project has been a positive exercise in working with other companies from various European countries. This has enabled different viewpoints on the requirements of the EMC directive to exchanged. The outcome of the project will enhance the position of the consortium members and will provide market opportunities for the technology in non-European markets.

5. **Acknowledgements**

The consortium acknowledge the support of the European Community under the Brite/Euram Programme.

CEC Contract N": BRE2-CT94-1 347
Project N°: CR-1 236-91

EXPLOITATION REPORT

CONFIDENTIAL

CONTRACT No: BRE2-CT94-1347

PROJECT No: CR-1236-91

TITLE: EMC TESTING FOR VOLUME PRODUCTION

PROJECT COORDINATOR: RAINFORD GROUP

PARTNERS:

RAINFORD GROUP
TECQUIPMENT LIMITED
I E PROMAX
AFEISA SA
PENTATRON SRL
WAYNE KERR ELECTRONICS LTD (Formerly Farnell Instruments Ltd)
MUIRHEAD VACTRIC COMPONENTS LIMITED
GEC MARCONI AVIONICS LIMITED
ATELIERS R LAUMONIER

PERA
UNIVERSITY OF YORK
CETIM

REFERENCE PERIOD FROM 1 JULY 1994 **TO** 30 JUNE 1996

STARTING DATE: 1 JULY 1994 **DURATION:** 24 MONTHS

PROJECT FUNDED BY THE EUROPEAN COMMUNITY UNDER THE BRITE/EURAM PROGRAMME

CONFIDENTIAL

1. Description of results

1.1 Results

The main results of the project areas follows:

- an innovative, near conformal test cell for evaluating the radiated emissions, conducted mains emissions, and radiated immunity performance of a product.
- a production line EMC (Electromagnetic Compatibility) test cell specifically designed to meet the needs of rapid and repeatable evaluation off manufactured product.
- a test cell capable of testing two polarisations without moving the EUT (Equipment Under Test).
- a software system and methodology aimed at production testing.
- *a series* of comparison tests between conventional test methods and the test cell enabling a detailed characterisation of the test cell's performance.

The state of the art as understood by the research organisations and the industrial members is as follows;

- EMC test cells have been brought onto the market during the life of this project. At project commencement the only products which were aimed at lower cost EMC testing were the G-TEM and TEM cells. These have limitations in the size of EUT that can be tested, their cost is high, and the skill required to use them is high when compared with the technology developed in this project.
- During the project a few test cells have been launched onto the market. These include the following: Chase EMC - EmCell
  MA Instruments - MAC Cell
  Euro EMC Services - EuroTEM
  Comtest - GStrip
  Rohde & Schwarz - S-Line

  All these cells are predominantly aimed at immunity testing with some claiming to undertake radiated emissions testing. None of the cells are specifically aimed at the production test environment, where quick turn round, and repeatable measurements are required.
- The developed technology has the distinct advantage of testing the product in two polarisations without moving the EUT. None of the other test systems are known to provide this.
- Considerable comparison testing has been done with conventional test facilities and this has given a high confidence in the performance of the cell.

1.2 New iterns for exploitation

The main item for exploitation is the test cell and associated equipment. This provides the production line test system. The system can be broken down into sub-sets depending as to whether the capability of testing all three criteria, that is radiated and conducted emissions and radiated immunity, is required.

The test cell itself can be used on its own, with other stand alone measurement equipment, to provide design support and a diagnostic tool.

1.3 Subject descriptors

The following are the selected subject descriptors to define the scientific fields to which the results could belong;

D32 Signal processing
E35 Product development
E36 Production control

2. Industrial applications

2.1 industrial applications for the results

The test system is aimed at production environments where large numbers of product are manufactured, which require either batch sampling or 100% testing. The system will be as applicable to large manufacturing companies as well as the small manufacturers. The system has been designed, together with its methodology, to provide a simple and repeatable test system.

The system would be useful to small companies who require to undertake design development as changes in the products performance, due to design enhancements, can be monitored by the test cell. The test ceil is therefore performing a dual role in a small company making it much more cost effective.

The availability of this technology will reduce development and manufacturing costs particularly for the small company. Small companies will have more control over their testing requirements, and although the developed technology does not provide an absolute result, the comparative results will provide confidence in how changes are affecting the product's performance. The capital cost of this system is equivalent to forty test house days of testing.

The software and methodology has been aimed to provide an easy entry into EMC and its requirements with regard to the legislation. Companies with very little knowledge can use this equipment, and through testing and effecting changes to the product, the companies will build up their own expertise.

2.2 Technological and commercial potential

The technology could be enhanced by introducing other EMC tests where a controlled environment is required, for example conducted immunity testing, bulk current injection, and by also increasing the field strength levels capable within the system. The test cell and its ancillary equipment would then become a very cost effective EMC test centre capable of being located in a normal laboratory or production environment.

The potential for using this equipment lies with any company producing electrical or electronic equipment, as it all needs to meet the terms of the EMC Directive. The main applications will be in the electronics industry associated with communication and computer products. These tend to be high value and high volume situations.

2.3 Commercial and industrial sectors

The following are the selected commercial and industrial sectors in which the results are most likely to find applications:

D23 Manufacturing technology
D25 Mobile communications
E11 Instruments, measuring equipment
E24 Radio/ Television/ Audio Equipment

2.4 Areas of intended development

The developed technology requires initial enhancement to make the system more commercial and to improve its aesthetics. A review of some of the component choices will also be made to reduce costs still further. This is particularly applicable in the interface box, where the technology demonstrator used expensive coaxial switches. The manufacturability of the test cell is a key point as the system is currently hand built with some complicated constructional parts.

The main enhancement to be considered in the short term is the increase in the radiated immunity test level to 10V/m as this is seen as being **more widely appealing** to industry, especially those requiring to meet the industrial limits. Future developments may include the following:

- addition of bulk current injection
- review of the absorber material used for an alternative

The short term objectives carry very little risk, and the bulk current injection application is of relatively low risk. The review of the absorber material impacts on the fundamental performance of the cell and therefore has significant risk and cost.

3. **Market analysis**

3.1 World market

This has not been quantified to any extent. However the needs to meet EMC standards that apply within Europe has a dramatic impact on supplier countries for example the USA and the Far East. The developed technology will be as applicable to the requirements &these other countries outside Europe as to those inside Europe. Many other non-European countries have EMC requirements of their own, for example, Australia, India and America, and many of these are moving towards those currently being formed in Europe. Therefore technology, such as developed in this project, has the opportunity to support much of the world market in assessing the performance of manufactured electronic products.

3.2 Potential and real market

The consortium are firstly considering selling into their own home markets in Europe. This will enable an understanding of the market reaction to such a product and ensure any operational problems are resolved at early stage. The consortium has considerable experience of the markets in Europe and will target certain industry sectors to establish a foothold.

4. Industrial and intellectual property rights

The consortium determined that the technology was sufficiently innovative and would have a large market potential, that they wished to protect the development by applying for a pate-$. A patent application was written, and was filed with the UK Patents office on 29 February 1996. The application number is 9604317.9. A copy of the letter confirming filing is contained in Annex 3. A full copy of the Patent Application is contained in the Final Technical Report.

The consortium is considering a Logo which will be common to all countries, but a final decision has not been made.

The consortium had developed a detailed Exploitation Agreement, stating the responsibilities of all the industrial partners. A copy of the agreement is contained in Annex'1.

5. Exploitation and marketing plan

5.1 Exploitation objectives of each partner

The provisional objectives of the individual partners is as follows;

Rainford Group:	Rainford are the lead partner within the project, and hold the patent application on behalf of the consortium. It is proposed that the engineering change control and supplementary funding is monitored by Rainford. This will provide a focus for the industrial consortium and ensure a uniform product. Rainford will be key in designing the commercialised product and producing the actual test cell. They will also be involved in putting systems together.
Tecquipment:	This company predominantly want to take the product and with agreement modify the system for teaching applications. This will involve Tecquipment in additional work to provide teaching manuals and possibly adjusting the software.
Afeisa SA:	This company wish to use one or more of the developed system, but their main intention is to supply the interface box. They will review the Pera design and condense the pcbs down to a more tailored system. This will ultimately reduce cost and space. Afeisa will also market the product in Spain.
Pentatron srl:	This company will supply and support the software for the system. Pentatron have put considerable effort into producing the software for the technology demonstrator and will continue to develop the applications available. Pentatron will also market the product in Italy.
Wayne Kerr:	This company has supplied the main items of support test equipment and aim to supply the same items as part of the exploitation.
Muirhead Vactric:	This company is purely an end user of the technology, and is interested in obtaining a number of the systems if the price is right.

GEC Marconi:	This company are keen to be involved in supplying tailored systems based on the general system as developed within the project. They may also use one or more systems to support their EMC test centre operations.
Ateliers R Laumonier:	This company aim to supply the contactor block and to system integrate the sub-system elements. They will also act as the marketing organisation within France.

5.2 Exploitation strategy

The consortium will continue to work together following the official end of the project, under the heading of Exploitation Coordination Board. The Rainford Group will act as the focal point.

The consortium intend to productionise the system during the third quarter o? 1996, with a possible product launch at the Rome 1996 EMC Conference. The consortium are looking at technical enhancements to increase the field strength level for radiated immunity testing, and methods of reducing the cost of the system.

A general publicity leaflet is being generated, an example of which is contained in Annex 2. This leaflet will provide a common basis for the marketing companies within the consortium to present a uniform profile on the product.

The consortium will review the necessity of the patent towards the end of 1996, when the patent will be due to go to the next stage. As significant costs will start to be incurred at that point, careful consideration will be given based on the market response at the time.

The consortium has requested Pera and the University of York to produce general articles to be submitted to journals. This will raise awareness of the product without giving away the technical issues. This exercise will be undertaken over the period August to October 1993.

5.3 Time-table for exploitation

In broad terms the exploitation timetable is as follows:

July - October 1996- Produce productionised prototypes of the test system.
August - October 1996- Produce general articles for journals.
August - October 1996- Review design and identify areas for cost savings
August 1996- Produce sales leaflet.
September 1996- Launch product at the Rome EMC Conference.
November 1996- First deliveries.

5.4 Supplementary investments

At this stage the consortium intend to fund any additional R&D and marketing activities through a common fund. They may consider future R&D funding from public money by approaching the individual countries Departments of Trade.

5.5 National technology transfer

At this stage there is no national technology transfer funding envisaged for developing any aspect of the technology developed.

6. Communication strategy

The consortium are determining their communication strategy, and in overview has the following main parts:

1. Publicity
   This will be achieved through general articles to be written by the research organisations and published in appropriate journals.

   An overview publicity leaflet will be produced introducing the new test system and technology.

   Consortium members will be responsible for publicity in their own countries and other countries as appropriate. This publicity will be aimed at presenting the opportunities and savings that this new innovative test system can give.

   Annex 4 contains an early model marketing plan which was produced for Rainford on behalf of the consortium, This plan was equally applicable to other countries and was produced to illustrate a strategy for marketing. This is currently being reviewed am' enhanced.

2. Papers
   The University of York are to present a paper related to this project at the Rome EMC conference in September 1996.

7. Annexes

Annex 1 - Exploitation Agreement

Annex 2 - Draft general publicity leaflet

Annex 3- Copy of letter indicating filing of patent application. (A full copy of the Patent Application is contained in the Final Technical Report)

Annex 4- Early marketing plan

Annex 1- Exploitation Agreement