EMC SOCIETY of AUSTRALIA NEWSLETTER

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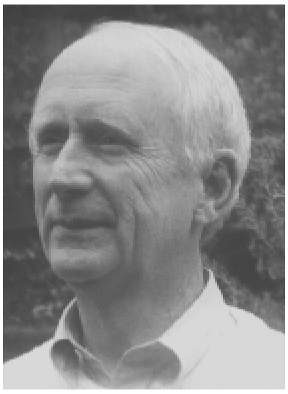
IEAust 11 National Circuit Barton ACT 2600

A SOCIETY OF THE INSTITUTION OF ENGINEERS AUSTRALIA

Issue Number 17 **February 2002**

MESSAGE FROM THE CHAIRMAN



2002 is the year of the outback and many of us city dwellers have a somewhat romantic picture of the outback. To some in the EMC community the idea of being remote from troublesome EMI emitters is appealing. Surely there can be no spectrum pollution in the vast expanse of the wide brown land? While the outback generally is not an area of dense RF emitters as some of our urban areas are, cases of interference do occur. Those who live in the outback rely on electric and electronic devices also, and particularly rely on radio for communication and safety.
Of course one of the disadvantages of living far from the population centres of the country is that many do not have communications services to suffer interference. I am reminded of the story of an outback resident who told a Government inquiry that she only had three requirements as far as telecommunications services were concerned:

1. A telephone
2. A telephone that worked
3. A telephone that worked all the time.

We also think of some of our members as in the "outback" as they live remote from our meeting places and are not able to attend our technical presentations. We hope to provide more contact for them in 2002.

Some exciting news is that the Society is planning an EMC Mini-symposium to be held in Melbourne on 15th August 2002. We are issuing a call for papers and our enthusiastic committee is busy planning the detail of the event. We look forward to welcoming members and others from government, industry, academia and the wider community to what promises to be a significant event for the discipline of EMC in Australia in 2002.We suggest you mark the date in your diary and watch for coming announcements. (If you don't see any let me know as I am responsible for media coverage!)

The winning paper in our 2001 Student Paper competition appears in this issue. Congratulations to the winner, who receives a $1,000 prize and to the runner-up who received an award of $250. We do not normally have a prize for runner-up but the judging committee faced a difficult task and recommended an acknowledgement prize for the runner-up also. The competition will be run again this year and we encourage students at all tertiary levels to enter. Graeme Richardson, our Student Paper Co-ordinator is looking forward to receiving many enquiries and entries. Information will be sent to numerous tertiary institutions around Australia.

Nine nominations were received for the nine positions on the EMC Society National Council. As a result, the members of the Council for 2002 will be John Hyne (Chairman), Kingsley McRae (Secretary and Treasurer), Jack Pluck, Emile Barco, Graeme Richardson, Steve Offer, David Sykes, Kevin Goldsmith, and Mark Mifsud. We welcome Mark to the Council and farewell Malcolm Mulcare who decided not to re-nominate. The Society thanks Malcolm for his service on the Council since the formation of the Society.
During 2002 Jack Pluck will continue as Newsletter Editor, Emile Barco as co-ordinator of technical presentations and John Hyne will handle media liaison. Stephen Brine continues as our NSW representative and Franz Schlagenhaufer our West Australian representative, while Kevin Goldsmith is our contact in South Australia.

Your council is working on the development of a new website which should allow us to provide more information to our members. Emile Barco will shortly hand over duties as Webmaster to Mark Mifsud.

John Hyne, MIEAust., CPEng.

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LETTER FROM THE EDITOR

This issue of the Newsletter starts the year off with a bang – lots of new ideas and events for year 2002. Nominations for the Council closed on 31st January and as there were only nine nominations for nine seats, no elections were necessary.

The student paper competition results for 2001 were announced. The winning paper being submitted by Joe Trinkle of the University of Western Australia and the runner-up was also from Western Australia in the person of Bert Wong of Curtin University of Technology. Joe's paper entitled "Damping of Resonant Modes Associated with Rectangular Power Supply Planes" appears in this newsletter. Bert's paper was entitled "The Impact of Transmission Line Terminations on Radiated Emissions" and will appear in a future edition of the Newsletter.

The student paper competition will be run again this year and carries a prize of $1,000-00. Details of entry for the competition are on page 14.

A competition for all readers is also announced and will be known as the "Editor's Prize" for the best technical paper or article on EMC accepted for publication this year. This prize is sponsored by Rohde & Schwarz and will be a signal generator.

An announcement of an EMC Mini-Symposium in August and a call for papers also appears in this issue.

A technical paper on "Finite Elemental Calculation of Two-Layered Magnetic Shields" is featured under our "Technical Brief." I extend our thanks to the authors Friederike Schulz, Andreas Binner and Karl Heinz Gonschorek of Dresden University of Technology for this article.

On behalf of myself and team of ready helpers I would like to thank all our readers who contributed articles for publication last year and wish them all the best and happy reading for 2002.

Jack Pluck
Editor

STUDENT'S PRIZE WINNING PAPER

The EMC society is pleased to announce the results of the Student Paper Competition run in 2001.
The winning paper was submitted by Joe Trinkle of the University of Western Australia and the runner-up in the competition was Bert Wong of Curtin University of Technology. Joe wins the cash prize of $1,000 and Bert receives $250.
Both papers addressed issues of radiated emissions from printed circuit boards, a topic of increasing interest to board designers and EMC compliance engineers.
Joe's paper was entitled "*Damping of Resonant Modes Associated with Rectangular Power Supply Planes*" and investigated the damping of resonant modes in power/ground planes associated with rectangular multi-layer printed circuit boards. The author states that the addition of a few well-positioned and correctly chosen resistors between the power and ground planes can achieve very good suppression of resonant behaviour.
The rapid increase of clock speeds in digital circuits is placing new requirements on the impedance of power supply systems. Wavelengths of clock harmonics are becoming comparable with dimensions of power supply planes used in multi-layered PCBs. Resonant modes associated with PCB dimensions, which previously were of no concern, are now appearing within the frequency spectrum of modern logic families.
J Pluck FIEAust CPEng
Editor

DAMPING OF RESONANT MODES ASSOCIATED WITH RECTANGULAR POWER SUPPLY PLANES

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ABSTRACT
The damping of resonant modes in power/ground planes associated with rectangular multi-layer printed circuit boards (PCB) is investigated. It is found that the addition of a few well-positioned and correctly chosen resistors between the power and ground planes can achieve very good suppression of resonant behaviour.

INTRODUCTION
The rapid increase of clock speeds in digital circuits is placing new requirements on the impedance of power supply systems. Wavelengths of clock harmonics are becoming comparable with dimensions of power supply planes used in multi-layered PCBs. Resonant modes associated with PCB dimensions, which previously were of no concern, are now appearing within the frequency spectrum of modern logic families.
Power supply planes not only provide dc voltage to the digital circuits, but also serve as a reference potential for switching. Any noise or ringing on the supply planes compromises signal integrity and reduces the reliability of the circuit. Such ringing also degrades the circuit's immunity to external electromagnetic disturbances and increases its emission. A good way to minimize the detrimental effect of resonant modes is to dampen them by placing resistors between the power supply planes.
The purpose of this paper is to explore the resonant modes associated with a rectangular PCB and to demonstrate the dampening that can readily be achieved by adding a few resistors between the planes.
THEORY

When a source current of 1A is applied between two closely spaced, highly conducting planes at the point (x_0,y_0), the resulting voltage between the planes is described by the two-dimensional Helmholtz equation [1],[2]:

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+k^2\right).V(x,y)=-j.w.m.d.d(x-x_0).d(y-y_0)\ ; \qquad (0.1)$$

$$k=w\sqrt{me}\,(1-j.(\tan d+g/d)/2)\ ; \qquad (0.2)$$

$$g=\min\left\{t,\sqrt{2/(w.m.s)}\right\}. \qquad (0.3)$$

In these equations w, m, e, $\tan g$, d, s denote the angular frequency, the permeability, permittivity and loss tangent of the dielectric, the skin depth and conductivity of the conducting planes, respectively. The thickness of the plates is *t,* and the spacing between them is given by ***d***, as shown in Figure 1.

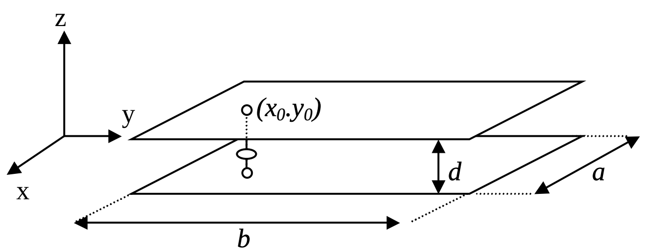


Figure 1: Power/ground system showing dimensions and current source at (x_0,y_0).

For the finite size rectangular PCB depicted in Figure 1, the solution of the wave equation (0.1) is subject to boundary conditions at the periphery. If fringing and radiation effects at the boundary are ignored, the homogeneous, orthonormal eigen functions of the wave equation are [1]:

$$n_{nm}(x,y) = \frac{C_n C_m}{\sqrt{a.b}}.\cos(k_{xm}.x).\cos(k_{yn}.y) \; ; \qquad (0.4)$$

$$k^2 = {k_{xm}}^2 + k_{yn}^2 \, . \qquad (0.5)$$

The values of k_{xm} and k_{yn} are given as

$$k_{xm} = \frac{mp}{a} \qquad k_{yn} = \frac{np}{b} \, , \qquad (0.6)$$

and n and m are integers. The coefficients C_n and C_m are chosen to normalize the eigen functions and their values are:

$$C_n = \begin{cases} 1 & \text{for n=0} \\ \sqrt{2} & \text{for n} \neq 0 \end{cases} \qquad C_m = \begin{cases} 1 & \text{for m=0} \\ \sqrt{2} & \text{for m} \neq 0 \end{cases} \qquad (0.7)$$

The solution of the wave equation (0.1) can be expressed as a linear summation of these eigen functions with weighting coeffients A_{mn}:

$$V(x,y) = \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} A_{mn} n_{mn}(x,y) \qquad (0.8)$$

Substituting (0.8) into the wave equation of (0.1), and multiplying by $n_{st}(x,y)$ and then integrating over the entire area of the PCB yields:

$$A_{st} = \frac{j.w.m.d\, n_{st}(x_0,y_0)}{k_{xs}^2 + k_{ty} - k^2} \, . \qquad (0.9)$$

Upon substituting the coefficients of (0.9) into (0.8) we get:

$$V(x,y) = j.w.m.d \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \frac{n_{mn}(x_0,y_0) n_{mn}(x,y)}{k_{mx}^2 + k_{ny}^2 - k^2} \, . (0.10)$$

Since this equation describes the differential voltage between the plates any (x,y) point for a 1A current source located at (x_0,y_0), it is an expression for the transfer impedance between a port at (x,y) and a port at (x_0,y_0). The input impedance is just the value of the voltage at the source port. ie $V(x_0,y_0)$. Thus these impedances can be written as the following modal expansions

$$Z_t(x,y \,|\, x_0,y_0) = j.w.m.d \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \frac{n_{mn}(x_0,y_0) n_{mn}(x,y)}{k_{mx}^2 + k_{ny}^2 - k^2} \, , \qquad (0.11)$$

$$Z_i(x,y) = j.w.m.d \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \frac{n_{mn}(x,y)^2}{k_{mx}^2 + k_{ny}^2 - k^2} \, , \qquad (0.12)$$

where $Z_t(x,y|x_0,y_0)$ is the transfer impedance between port (x,y) and port (x_0,y_0) and $Z_i(x,y)$ is the input impedance at port (x,y). In the derivation so far, infinitesimal ports port dimensions have been assumed. In reality, the ports over which the current enters the power planes have finite dimensions. If the ports are assumed to be square and have dimensions • *p*, equations (0.11) and (0.12) should be multiplied by the factor [1]

$$F_{mn} = \text{sinc}(k_{mx}\Delta p/2)^2.\text{sinc}(k_{ny}\Delta p/2)^2 \, . \qquad (0.13)$$

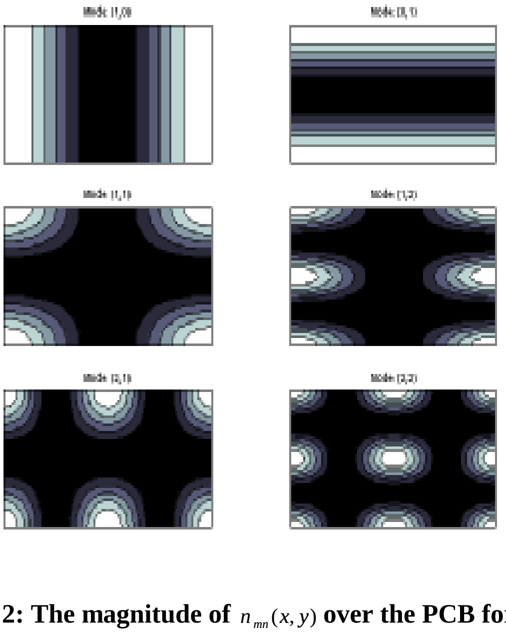


Figure 2: The magnitude of $n_{mn}(x,y)$ over the PCB for six different combinations of (m,n).

Interpretation of Modal Expansion

The eigen function expansions of (0.11) and (0.12) show the total value of transfer or input impedance as a summation of an infinite number of modes. The strength of each mode is determined by the frequency of excitation. Each mode has a unique value for $k_{mx}^2 + k_{ny}^2$ and when the frequency is such that k^2 is in the vicinity of this value, the mode will dominate and cause a 'peak' or resonance effect to be observed.

Placement of Damping Resistors

The frequency response of the input impedance exhibits peaks at these particular frequencies due to the reflections from the boundary of the PCB. This occurs because at particular frequencies, waves launched at the current source are reflected by the open circuit boundary and returned to the source to interfere constructively with the new wave being generated there.

In order to decrease the effect of the reflected wave, it would seem appropriate to add a distributed resistance around the periphery of the PCB to absorb the wave as is done in [3]. However, this is rather difficult to implement in practice.

By observing the voltage distribution associated with the modes in Figure 2, it is obvious that all modes will have maxima located at the corners. A single resistor placed at one corner alone will therefore have a dampening effect on all modes. In the next section we develop this idea and investigate the damping that is achievable by the use of a single resistor in one corner and how this can be further improved by using four resistors, one in each corner of the PCB.

EXAMPLE OF RECTANGULAR PCB

To demonstrate the theory and ideas presented so far, we choose a readily available double sided PCB with the following properties:

Length, *a*	0.3m
Width, *b*	0.25m
Copper thickness, *t*	35um
Plate separation, *d*	1.4mm
Dielectric constant	4.27
Loss tangent	0.02
Source location (x_0,y_0) *Port 1*	(4cm,8cm)

Table 1: Properties of PCB.

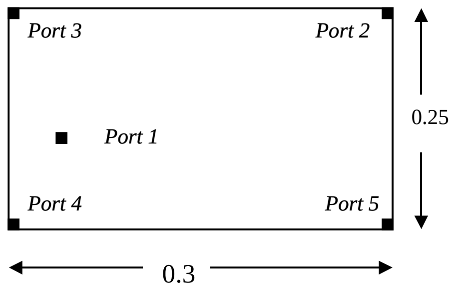


Figure 3: Port locations on PCB.

The source port (*Port 1*) was chosen to be in a non-symmetrical position so that all lower modes (<600MHz) will have an influence on the voltage/impedance at this port. Ports *2,3,4* and *5* are chosen to be at the corners of the board as shown in Figure 3.

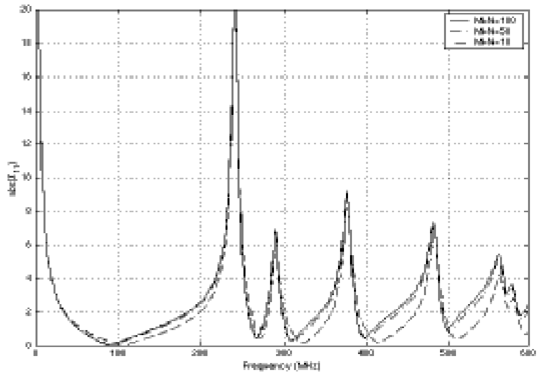
Using (0.11), (0.12) and reciprocity, we can evaluate the impedance matrix for the 5 port system of Figure 3 as:

$$[Z] = \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} & Z_{14} & Z_{15} \\ Z_{12} & Z_{22} & Z_{23} & Z_{24} & Z_{25} \\ Z_{13} & Z_{23} & Z_{33} & Z_{34} & Z_{35} \\ Z_{14} & Z_{24} & Z_{34} & Z_{44} & Z_{45} \\ Z_{15} & Z_{25} & Z_{35} & Z_{45} & Z_{55} \end{bmatrix} = \begin{bmatrix} Z_{11} & [Z_P] \\ [Z_P'] & [Z_M] \end{bmatrix} \qquad (0.14)$$

The matrices Z_P and Z_M are of sizes1x4 and 4x4 respectively.

Undamped Input Impedance at *Port 1*

When the four corner ports are open circuit, the input impedance at *Port 1* is simply Z_{11}. The magnitude of this impedance is plotted in Figure 4. The resonant behaviour at 242, 290, 378, 483, 564, 580 MHz can be attributed to modes (m,n) equal to (1,0), (0,1), (1,1), (2,0), (2,1), (0,2) respectively. These modes are shown in Figure 2. The summations in (0.11) and (0.12) are over an infinite number of modes. To evaluate this summation numerically we need to truncate it to upper limits M and N for m and n respectively. Figure 4 shows that if N=M=100 a sufficiently accurate answer is obtained. All future summations are truncated to these this value. Note that factor F_{mn} of (0.13) was included in the summations and that a typical port dimension of *1mm* was assumed.



summations with different truncation values.

Addition of Damping Resistors

The voltage at the 5 ports can be expressed as:

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{bmatrix} = \begin{bmatrix} V_1 \\ [V_M] \end{bmatrix} = \begin{bmatrix} Z_{11} & [Z_P] \\ [Z']_p & [Z_M] \end{bmatrix} . \begin{bmatrix} I_1 \\ [I_M] \end{bmatrix} \qquad (0.15)$$

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{bmatrix} = \begin{bmatrix} V_1 \\ [V_M] \end{bmatrix} = \begin{bmatrix} Z_{11} & [Z_P] \\ [Z']_p & [Z_M] \end{bmatrix} . \begin{bmatrix} I_1 \\ [I_M] \end{bmatrix} \qquad (0.16)$$

where positive currents are defined as flowing into the positive voltage terminal of the ports. If resistors ***R$_2$*, *R$_3$*, *R$_4$*, *R$_5$*** are connected to ***Ports 2, 3, 4, 5*** respectively, the voltage developed at these ports is given by

$$[V_M] = -\begin{bmatrix} R_2 & 0 & 0 & 0 \\ 0 & R_3 & 0 & 0 \\ 0 & 0 & R_4 & 0 \\ 0 & 0 & 0 & R_5 \end{bmatrix} . [I_M] = -[R_M].[I_M] \qquad (0.17)$$

Substituting (0.17) for V_M in the bottom equation of (0.15) and evaluating the current vector I_M gives:

$$[I_M] = -inv([R_M]+[Z_M]).\left[Z'_p\right].I_{11} \qquad (0.18)$$

Thus the new input impedance at ***Port 1*** can now be obtained by substituting (0.18) into the top equation of (0.15) as

$$Z_{11(new)} = Z_{11} - \left[Z_p\right].inv([R_M]+[Z_M]).\left[Z'_p\right] \quad (0.19)$$

When a single resistor, R_2 is connected to ***Port 2*** and the other ports are left open circuit, (0.19) reduces to:

$$Z_{11(new)} = Z_{11} - Z_{21}^2.inv(R_2 + Z_{22}) = Z_{11} - \frac{Z_{21}^2}{R_2 + Z_{22}} \qquad (0.20)$$

Figure of Merit

We now need to define what constitutes a "good" frequency response for the input impedance of the PCB. As explained earlier, large resonant peaks are very undesirable from signal integrity and EMC points of view. However, adding damping to reduce these peaks will be at the expense of raising other parts of the impedance frequency response. The figure of merit we choose here is the area under the graph of the magnitude of the impedance squared in the range from 100 to 600MHz. We choose the impedance squared as this emphasizes the peaks but does not neglect the regions between them. The lower part of the frequency response is ignored since the low frequency impedance is easily improved by adding de-coupling capacitance.

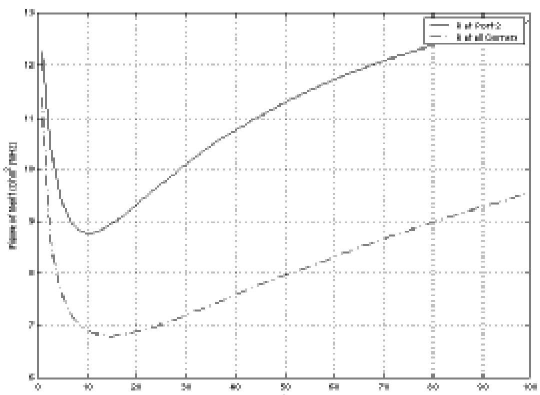


Figure 4: Figure of merit for different resistances.

We can calculate this figure of merit for various values of resistance connected (1) to *Port 2* alone using equation (0.20) , and (2) to all four corner ports using (0.19).

From Figure 5, the optimal value for damping for a single resistor is around 10• . When four corner resistors are employed, the best modal suppression is achieved for approximately 15 • in each corner. Figure 6 shows the frequency response obtained when these resistance values are added to the PCB.

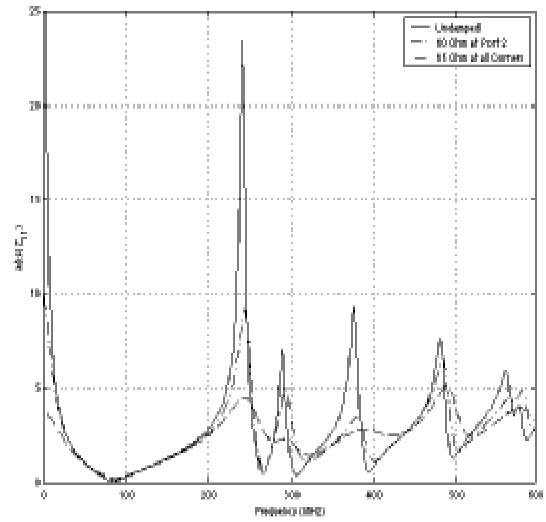


Figure 4: The improvement achieved theoretically by adding (1) a 10• resistor at *Port 2*, and (2) four 15• • resistors at the corners of the PCB.

MEASUREMENTS

The theoretical results of Figure 6 were confirmed by performing impedance measurements on a typical double-sided PCB cut to the correct dimensions. An SMA connector was mounted on the PCB at *Port 1* by drilling a hole and soldering the outer conductor to the top layer and the center conductor to the bottom layer. Comparing Figure 7 with Figure 6 shows excellent agreement between theory and measurement.

CONCLUSION

This paper has demonstrated theoretically and by measurement the optimum values and positions for damping resistors. A single resistor can already achieve a great reduction in resonant peaks of the impedance.

Four resistors located at the corners of PCB can offer a further improvement. In the example presented, the magnitude of the impedance remained below 5Ω over the entire 600 MHz frequency range considered.

The analysis here has been restricted to an unpopulated board. De-coupling capacitors and other components connected to the power planes will effect the modal voltage distributions. In this case the modal maxima may not be at the corners of the PCB but elsewhere and damping resistors should be placed at the new maxima locations for maximum effect.

Such damping may be a solution to applications where resonance effects are a problem and where more sophisticated solutions such as a distributed edge termination or the addition of losses elsewhere (eg copper or dielectric) proves uneconomical.

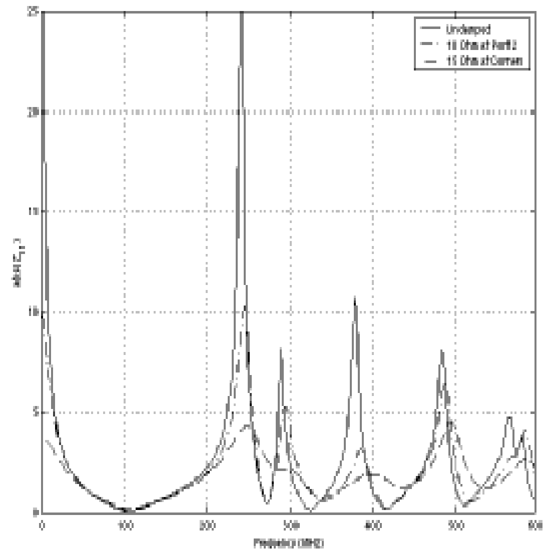


Figure 5: $|Z_{11}|$ obtained by measurement and it's improvement as damping resistors are added.

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TECHNICAL BRIEFS

FINITE ELEMENTAL CALCULATION OF TWO-LAYERED MAGNETIC SHIELDS

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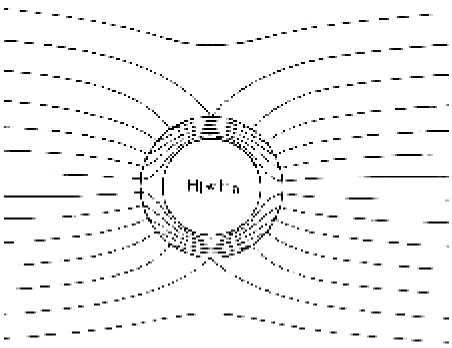
Introduction and description of the problem

Magnetic shielding protects electrical and electronic circuits from a functional degradation, caused by magnetic fields. There are two basic principles: redirecting the magnetic field through a shielding case (the so called Magnetostatic shields, Fig 1 and weakening the magnetic field by eddy currents (the so called eddy current shields).



At low frequencies, eddy currents do not provide a significant magnetic shielding. Therefore, Magnetostatic shields are applied. They are made of highly permeable materials being respectively expensive. These costs can be reduced by a shield construction of several layers increasing the shielding effectiveness in comparison to a solid shield using the same amount of material, especially for DC and low frequency applications [1].

A cylindrical (mainly) two-layered shield, composed of different ferromagnetic materials, is investigated to determine the influence on the shielding effectiveness, the so called shielding factor.

Previous research of magnetic shielding concentrates on constant permeability, that means linear magnetic behaviour, or on analytically solvable problems. Their results can only be used partially for ferromagnetic material, having nonlinear magnetisation characteristics [2]. Previous investigations, however, considering the nonlinear magnetisation characteristics, are restricted to one-layered shields. An exception is the topical research of magnetic shields for low frequency applications at the Università di Bologna. There, a shield consists of several layers of ferromagnetic material and aluminium, adjoining the neighbour layers directly [3].

Starting point and description of the model

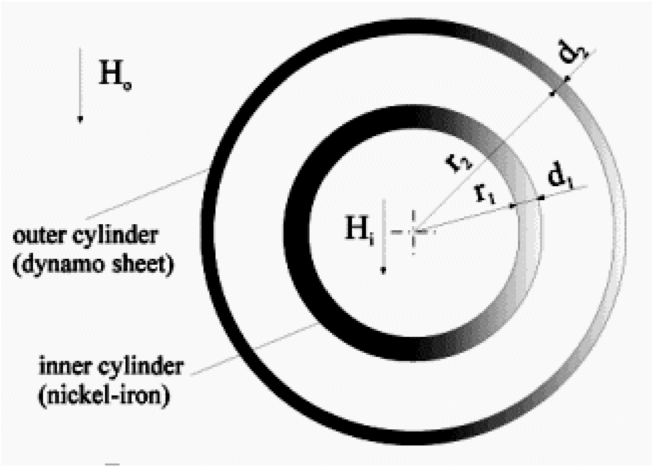
New about the magnetic shielding investigated in this paper is the multi-layered shield construction with consideration of nonlinear magnetisation characteristics. The influence of the material sequence and of the separation distance affects the shielding effectiveness.

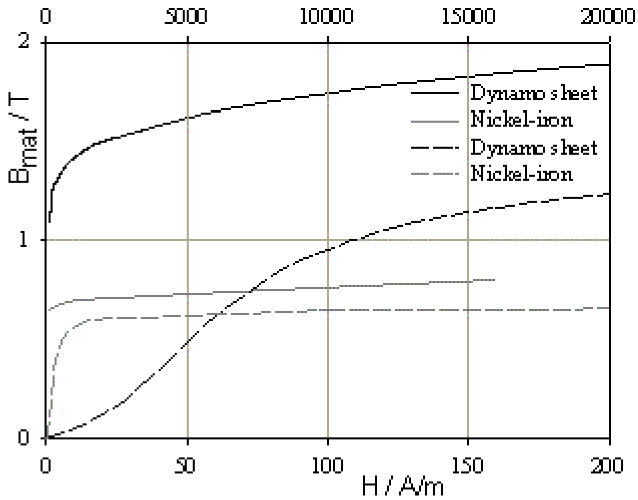
The calculations are based on the Finite Elemente Method (FEM), and, due to their complexity arising from the nonlinear magnetic characteristics, have been restricted to a magnetic DC field.

The cylindrical shield (Fig. 2) consists of two layers having a variable separation distance. Because of the cylindrical shape the inner magnetic field H_i is approximately homogeneous and therefore, the shielding factor S can be obtained by the equation

$$S = \frac{H_0}{H_i}.$$

The magnetic characteristics of the materials used for the shields are shown in Fig. 3, where the dashed curves refer to the lower H-scale and the solid curves refer to the upper H-scale.





Nickel-iron has a higher permeability than dynamo sheet for low magnetic fields but reaches its saturation for rather low field strength values. At higher field strength values nickel-iron is in saturation while dynamo sheet still maintains high permeability values. As a result dynamo sheet is better suited for the outer layer where the magnetic field is higher. The inner, nickel-iron layer is exposed to a weakened magnetic field and its higher permeability can then still be effective. A thicker layer of nickel-iron will provide increased shielding. The shielding due to the dynamo sheet must primarily be sufficient to reduce the magnetic field below the saturation point of the nickel-iron layer. Hence, the inner, nickel-iron layer having a wall thickness of 1 mm is thicker than the outer, dynamo sheet layer with thickness of 0.2 mm.

FEM-calculation

Proceeding

The FEM-calculation is performed by using the vector potential *A*. The equation

$$A = m_0 \cdot H_0 \cdot x = B_0 \cdot x$$

describes the external vector potential. The flux density B_0 is varied from 1 µT to 10 mT. The FEM requires boundary conditions and thus an artificial boundary for open problems must be introduced. A_l denotes the vector potential at the symmetry line (left boundary) and A_r the vector potential at the right boundary of the considered area (Fig: 4).

Due to symmetry the computation space can be reduced to a quarter of the total area (Fig: 4). The problem is treated as a 2-dimensional configuration with the vector potential constant along the axis of the shield (y-axis).

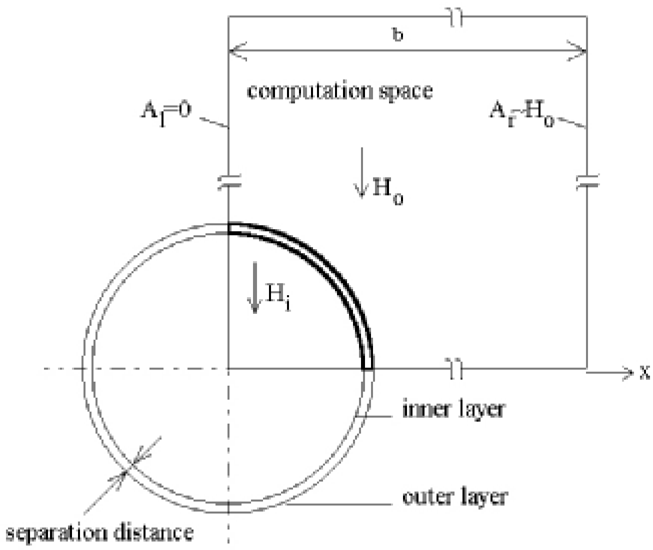


Fig. 4: Cross-section of the computation space

Meshing

The meshing, required for the FEM calculation, should have, on the one hand, as few elements as possible in order to reduce the calculation time, but, on the other hand, the elements must not exceed a certain size in order to produce precise results.
The solution of this objection is obtained by the following criteria:

1. Methods of generating the mesh:
    a) free meshing
    b) mapped meshing if possible, otherwise free meshing
    c) mapped meshing
2. Element type:
    a) Triangle
    b) Quadrangle
3. Density

There are two different types of regions to be meshed: the thin regions of the two layers and the significantly larger air regions inside, between and outside the shielding layers.

For the thin shielding layers the ‚free meshing‘ feature produces no precise mesh resulting in an incorrect distribution of the flux lines. Applying ‚mapped meshing‘ requires the manual generation of a new mesh for every geometry, i.e. different radii or layer thicknesses, whereas a combination of mapped and free meshing allows to specify the element density at critical locations, in this instance the shielding layers.

Within the shielding layers the flux lines are almost parallel (Fig 5), and quadrangular elements accommodate the flux line distribution best. So this type of elements is used for the thin layers regardless what type is used for the larger air regions. Common nodes then connect the air regions where the mesh is generated with the ‚free mesh‘ feature, with the ‚mapped meshed‘ layers, so that the meshes of different geometries can be easily reproduced.

Comparison of triangular with quadrangular elements in the air regions shows, that the calculated shielding factors are approximately the same for both element types, but triangles adapt better to the contour and build a more regular mesh (Fig 6).

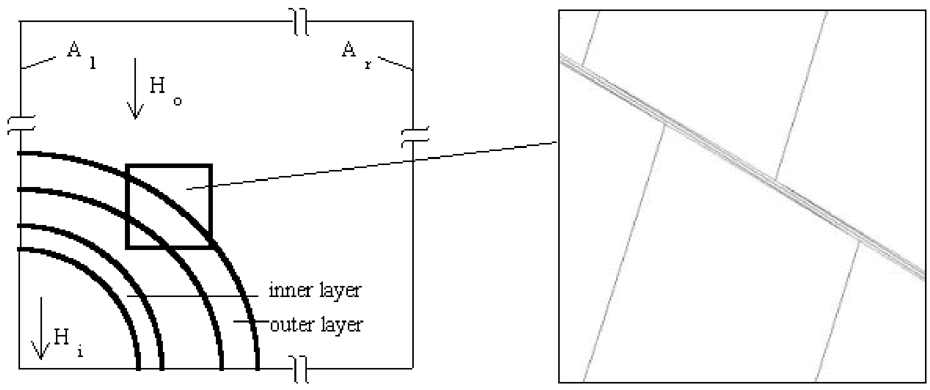


Fig. 5: Flux line distribution within a layer (here: within the outer layer)

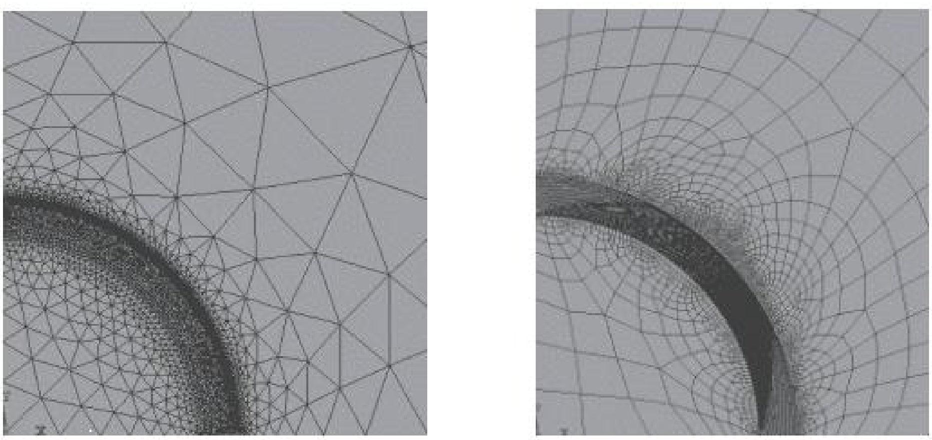


Fig. 6: Triangular (left) and quadrangular element (right) meshed air regions

Because of the uniform flux line distribution the mesh density within a layer is not important in contrast to the layer bound density in the air regions. When using quadrangular elements the calculated shielding factors depend on the mesh density in the air regions. By using triangular elements the influence of the mesh density on the shielding factors can be neglected.
As a consequence, the mesh will be realised by free meshed triangles in the air regions. The shielding layers are built of quadrangles; the mesh here can be rather coarse to reduce the required CPU resources while the accuracy of the results is still reasonable (Fig. 7).

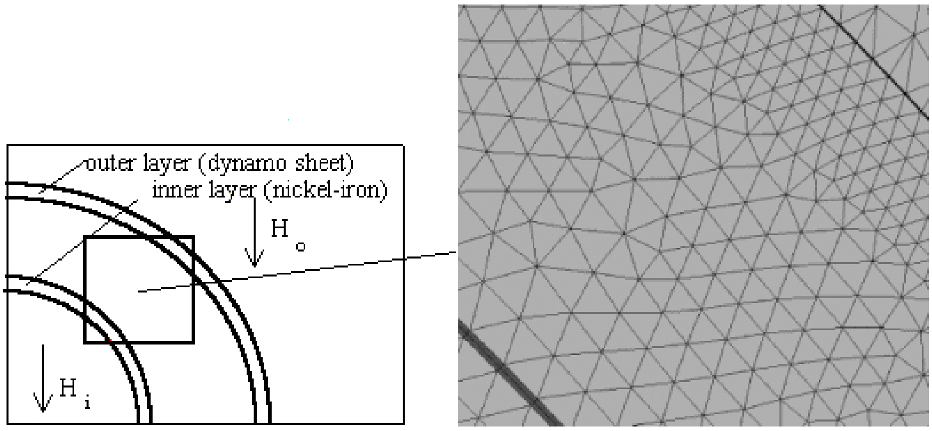


Fig. 7: Mesh detail – shielding layers and region between

Influence of the boundary

The artificial boundaries required by FEM may result in a large area to be calculated in order to reduce the influence of these boundaries. They have to be sufficiently far away from the shield under investigation to minimise their influence, but at the same time the total area should be as small as possible to minimise the required CPU and memory resources [2].
Investigations with different boundaries show that enlarging the computation space may lead to higher as well as to lower factors (Fig 8).

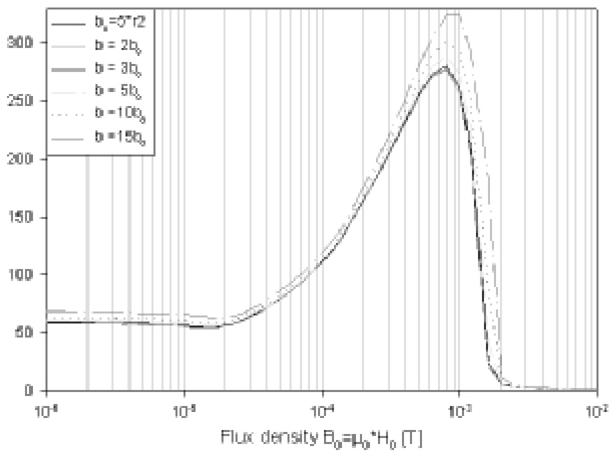


Fig. 8: Magnetic flux density vs shielding factor at different boundaries (b)

The variances are, however, less than 5 % except for the falling edge around 1 mT, when the computation space is between $b=5*r_2$ and $b=75*r_2$. The mesh generator of the used simulation software keeps the number of elements almost constant although the area width (b) changes. Thus, enlarging the computation space leads to larger elements and to more imprecise results. Enlarging the area may also result in a very uneven mesh, as Fig 9 exemplifies for an extreme value of $b = 500 \cdot r_2$.

On the base of all calculations the boundary is set to $b = 5 \cdot r_2$. This value guarantees both a sufficient distance of the artificial boundary from the area of interest, thus excluding any significant influence on the shielding factor, and a sufficient proximity to the investigated problem, so that the mesh generator produces a uniform mesh within the field area to be investigated.

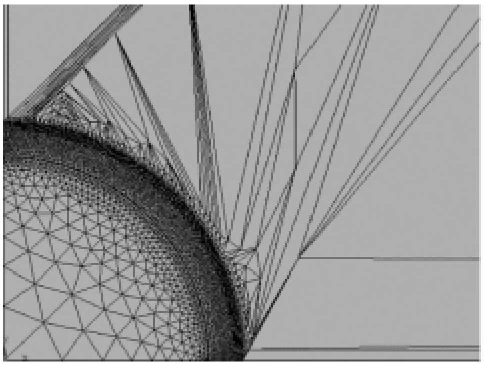


Fig. 9: Negative consequences of extreme values for the artificial boundary

Calculation results
Flux lines and shielding factor
Fig 10 illustrates the distribution of the flux lines between the two shielding layers and outside the shield. Each layer of the magnetic shield reduces the number of flux lines from the outside to the inside. Only a part of the flux lines penetrates the shield and continues on the inside. The remaining part follows a path within the shielding material for some distance, as shown in Fig. 1 exemplary. The fact, that magnetic field lines are closed loops, i.e. they do not start or stop at boundaries, and they do not cross each other, can be used as a plausibility check for the results.

The shielding factor depends strongly on the applied magnetic field strength or the flux density, respectively, (Fig 8) due to the non-linearity of dynamo sheet and nickel-iron. As soon as these materials reach saturation the shielding factor declines to low values. For the configuration under investigation this happens for a flux density between 1 and 2 mT.

Influence of the material sequence on the shielding factor
The statement, that the material nickel-iron is better suited to the inner cylinder and dynamo sheet is better suited to the outer cylinder, is supported by the results of Fig 11. In this figure only the layer materials are exchanged. In the case where dynamo sheet forms the outer layer the shielding factor has a maximum around 0.5 mT and drops for a flux density above 1 mT. When nickel-iron with its lower saturation flux density is on the outside the overall shielding factor is significantly lower and declines for a lower flux density of about 0.1 to 0.4 mT.

The cause of the effect of the material sequence can be explained by the following way:

The material layer collects flux lines around it (Fig 1). Hence, the flux density within the material (B_{mat}) is higher than the one in the environment (B). The equation

$$B_{mat} = B \cdot \frac{2r}{d}$$

where r is the radius and d the wall thickness of one layer, provides an estimate for the flux density B_{mat} within the material.

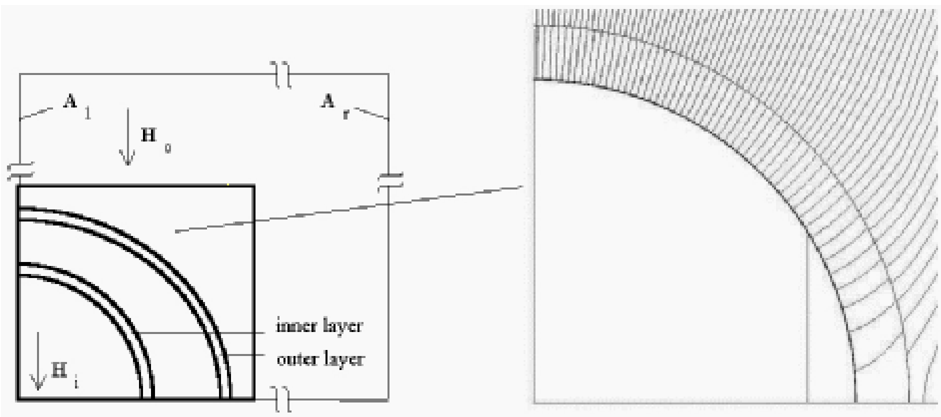


Fig. 10: Flux line distribution near shielded area at flux density B0=5 µT

The material having a higher permeability at the flux density B_{mat} provides the higher shielding factor at the respective external flux density B_o, if both materials have the same wall thickness. That means for the chosen problem the outer cylinder is preferably made of dynamo sheet for most magnetic field values. But there are external flux densities (in Fig.: at 1.5...4 mT), at which the material nickel-iron for the outer cylinder achieves a higher shielding factor.

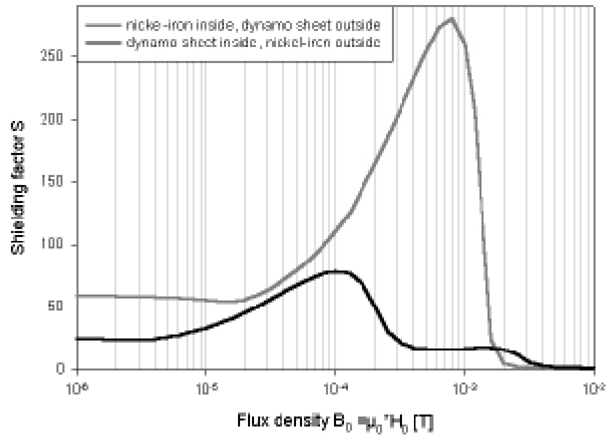


Fig. 11: Shielding factor of the two-layered cylinder at different material sequences

Influence of the layer distance on the shielding factor

The separation distance between the two layers is varied by changing the radius of the outer cylinder. In Fig 12 it can be seen that the shielding factor depends strongly on both, the flux density and the separation distance between the two layers. The maximum shielding factor appears around 0.5 to 0.8 mT.

A multi-layered shield provides a higher shielding factor than a solid shield where the layers are joined without separation distance. Increasing the separation distance increases the shielding factor, especially for small distances. Once the separation

Fig. 1: Redirection of a magnetic field through a shielding material (One layer shield) [1]

distance reaches about 40 mm a further increase affects the shielding factor only slightly.

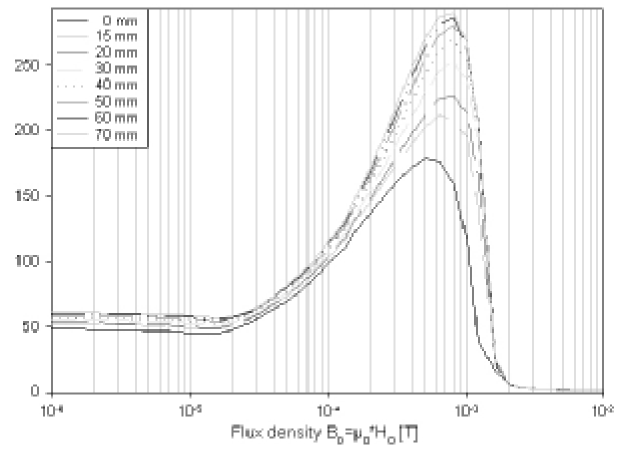


Fig. 12: Shielding factor at different separation distances

Consequences

Several layers increase the shielding effectiveness against magnetic DC fields in comparison to solid shields. The non-linear characteristic of ferromagnetic materials is the reason why the shielding factor depends strongly on the field strength the magnetic shield is supposed to protect from. The choice and sequence of the materials is to be taken into account and influences the shielding factor. A larger separation distance enhances the shielding effectiveness.

In most applications the material with the higher saturation flux density should be used for the outer layer.

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[1] Magnetische Abschirmungen. Firmenschrift. Vacuumschmelze. Hanau: 1988

[2] Lederer, D.: Simulation und Messung der Abschirmung niederfrequenter magnetischer Felder unter besonderer Berücksichtigung der magnetischen Hysterese. Berlin, Offenbach: VDE-Verlag, 1999. - ISBN 3-8007-2469-3.

[3] Sandrolini, L.; Massarini, A.; Reggiani, U.: Low-frequency multilayered magnetic shielding of circular loops. 14th Int. Symposoim on EMC, Zurich 2001, pp 17-22

[4] Neelakanta, P. S.: Handbook of Electromagnetic Materials: Monolithic and Composite Versions and Their Applications. Boca Raton, Florida: CRC Press, Inc., 1995. - ISBN 0-8493-2500-5.

2002 EMC SOCIETY STUDENT PAPER COMPETITION

Prize: $1000 for the best paper.

All entrants will receive a one-year membership to the EMC Society of Australia.

The EMC Society of Australia, a Technical Society of the Institution of Engineers Australia, is inviting Tertiary students to prepare a paper on any aspect of EMC technology. All papers will be considered for publication in the Newsletter of the EMC society.

Conditions:

The Entrant must be a student studying towards a recognised Award from an ustralian Tertiary Institution.

The paper must meet the publishing requirements defined in the EMC Society Web site: http://zap.to/emc.society.au.

Please download the following document Author Instructions.doc

All papers must be received or postmarked by 6:00pm on the 1st October 2002. A confirmation of receipt will be sent within 48 hours.

Papers should be submitted via email or on a CD in MS Word or pdf formats.

Via Post: EMC Student Paper Competition.

EMC Society Of Australia. (Secretary)

P.O. Box 254, Bayswater Vic 3153.

Via Fax: Attention EMC Society Secretary

+61 (0) 3 9762-8501.

The National Committee of the EMC Society will be responsible for judging the papers, and the committee's decision will be final. No correspondence will be entered into.

All Entrants will receive a critique of their paper by mail on or before 12th November 2002.

TECHNICAL PRESENTATION – DECEMBER 2001

Jack Pluck presents a memento to Geoff Hartwig

On the 6th December 2001, Mr. Geoff Hartwig, Assistant Manager Radio Communications Team, Australian Communications Authority, made a Technical Presentation to the Society: :REFLECTIONS ON THE AUSTRALIAN COMMUNICATIONS AUTHORITY'S (ACA) EMC SCHEME." The presentation was well attended and covered the evolution of the EMC Framework in Australia from Radio Communications Acts. Some attendees could remember contributing to the industry consultation surveys, when it came time to looking at the collated results. On a timeline, it followed Europe's implementation of EMC legislation which had significant trade implications. Australia's now world famous "C-tick" mark is a common sight on many consumer procucts. Mr Hartwig also spoke about the infrastructure that underpins the legislation. More recently the scheme was harmonized with New Zealand on the 7th November 2001.

The EMC framework was introduced on the 1st january 1995 and the legislation imposed the EMC phenomenon of radiated and conducted emissions on a wide range of electrical and electronic products.

Geoff also advised the meeting that according to market surveys, knowledge about the EMC framework was very high in the marketplace and the number of registered C-ticks was v\growing steadily each year. Currently, Immunity is not part of the test scheme as this is primarily viewed as a market place issue.

While industry perceived the effect of EMC as delaying product to market, most also reported product improvements resulting from improved engineering related to meeting EMC requirements. Most used external testing but there is a trend towards in house pre-compliance testing.

Further Geoff advised that recent changes had been approved:-

- 3 phase equipment connected to the general mains
- recognition of CISPR, EN and IEC standards
- Voluntary C-tick labelling for low risk devices

The EMC Society thanks the ACA and Mr. Hartwig for presenting the details on one of the most significant milestones in Australia's electro-technical history.

PRIZE FOR BEST TECHNICAL ARTICLE

SPONSORED BY ROHDE & SCHWARZ

Rohde & Schwarz have been generous in donating the prize a Rohde & Schwarz Signal Generator Model SML07 for the best technical paper or article on an EMC related subject accepted for publication in the Newsletter.

This prize, to be known as the "Editor's Prize," is to encourage our members and readers to submit for publication articles of general interest to the EMC community. The policy of the EMC National Council through the Newsletter is to provide a means whereby our readers are kept abreast of the latest developments in policy, design, research, testing or "this happened to me today" interesting incident.

Readers who wish to compete in this competition should nominate at the time of submission of their article. The cut off for submission of articles will be 31st December 2002.

<u>Editors Note:</u> This competition should not be confused with our Student Prize Competition which is limited to students currently studying at Tertiary level.

NEWS FROM ACA

ACA Approves Novel Uses of Radiofrequency Spectrum

Glove radar that can measure the speed of a ball as it hits a glove and automotive radar used as advanced cruise control systems in luxury cars have been approved for operation by the Australian Communications Authority (ACA).

The devices join a group known as low interference potential devices (LIPDs) and will be allowed to operate under a class licence. A class licence is free and does not require an individual application.

Glove radar is a low powered device currently used in the US to measure the velocity of a baseball or softball.

Automotive radar is already employed in advanced cruise control systems in luxury cars in the US and UK. These systems can activate a motor vehicle's brakes or accelerator to control the vehicle's distance separation from another vehicle.

Other devices authorised under the LIPDs class licence include garage door openers, remote electronic car door keys, home detention monitoring equipment and wireless microphones, among others.

ACA Chairman Tony Shaw said that the ACA was pleased to accommodate these innovative uses of the radiofrequency spectrum.

"While the intended uses of both devices is currently limited, it is likely that both devices will find additional markets", Mr Shaw said.

"For example, the technology of the glove radar could easily be transferred to cricket and other ball games. And, like other accessories that are first offered on luxury cars, it is likely that the automotive radar devices will eventually make their way to other models of cars."

Class licences authorise short-range or highly mobile devices such as mobile phones to operate in certain parts of the spectrum. These licences minimise expense and administrative burden and avoid the need for individual licences. Other devices that are authorised by class licences include cordless phones, remote controls and CB radios.

Trans-Tasman Agreement on Electromagnetic Compatibility

An important agreement recently signed by the Australian Communications Authority (ACA) and the New Zealand communications regulator will allow electrical and electronic equipment to be traded freely between Australia and New Zealand.

The ACA and the Radio Spectrum Management Group of the New Zealand Ministry of Economic Development have signed a Memorandum of Understanding setting out agreed principles to sustain the Trans-Tasman Mutual Recognition Agreement (TTMRA) on electromagnetic compatibility (EMC) regulation.

Speaking at the signing, ACA Chairman Tony Shaw said, "In the bigger picture, the Australia–New Zealand trans-Tasman relationship is central to the way we achieve our regional and global trade objectives. It ensures the world is open to our exports. It will give industry on both sides of the Tasman the opportunity to expand and mature, and will better position our industries to access markets in other regions."

The TTMRA is an agreement between the Government of Australia and New Zealand to develop an integrated trans-Tasman economy. It is intended to deliver to exporters on both sides of the Tasman Sea greater flexibility, low business compliance costs through mutual recognition, and harmonisation of product standards and regulatory arrangements. In general terms, it will allow goods to be traded between Australia and New Zealand with no regulatory impediment.

"In Australia, the EMC scheme is one of the largest regulatory arrangements administered by the Commonwealth and covers a wide range of electrical and electronic equipment. The 'C-tick' mark has become a world recognised EMC compliance mark, now appearing on many electrical and electronic products supplied to other regions of the world," Mr Shaw said. The harmonised EMC arrangement puts in place a common set of EMC standards, similar product conformity assessment, product labelling, public information material and administrative arrangements.

EMC is one of several programs listed in the TTMRA for trans-Tasman cooperation and is the first to attain harmonisation. The extent of cooperation between the ACA and the New Zealand regulator, signified by the Memorandum of Understanding, sets a benchmark for other regulators covered under the TTMRA program.

A joint EMC information booklet for suppliers is available by contacting the ACA on telephone: (03) 9963 6968, and from the ACA website.

PEOPLE IN THE NEWS

New Manager Appointed at EMC Technologies , Melbourne

EMC Technologies has appointed Mr Mark Mifsud to the newly created position of Manager of the Melbourne Branch of their NATA accredited Electromagnetic Compatibility (EMC) facilities. Mark is one of Australia's most experienced EMC and Tempest engineers with over 13 years concentrated EMC experience. He was formerly the manager of the EMC and environmental test facilities at the Army Engineering Agency (AEA) Maribyrnong, where he was responsible for the EMC, Tempest and Engineering testing and support services to the Army, Navy and Airforce.

Mark will be responsible for the management of EMC Technologies Melbourne facilities including the NATA EMC, EMR, SAR and Competent Body services. His role will also include the further development of EMC Technologies specialist EMC/ EMR and Tempest, consulting engineering services for the defence, aerospace and other industry sectors.

LETTER TO THE EDITOR

The August 2001 Issue of the EMC Society's Newsletter contained a report on Chris Zombolas' talk on Specific Absorption Rate Measurements (page 18) in Melbourne on 29 May, 2001. As Melbourne is quite far away from Perth I had no opportunity to attend the presentation, but the comment on the (lack of) confidence in computer modelling results compared to measured results set the trigger for my comment.

Contradicting the presenter I think, computer simulation, when done correctly, provides a very high level of confidence. There are a number of possibilities to check the results – consistency, meeting of boundary conditions, energy and power budgets, to name just a few. These checks can be compared with checking the calibration status of measurement equipment and ensuring that the equipment has been used according to its specification. With these checks, both measurement and simulation can give reliable results for field strength values in the model under investigation.

The measurement then predicts the field strength, produced by a particular source, in a certain liquid contained in a head-shaped enclosure. The inhomogeneity of the electric properties (conductivity, permittivity) is not considered in the measurement model. In the simulation this feature can be modelled to some extent, and the influence can be estimated, at least qualitatively.

Thermodynamic effects – the brain is usually cooled quite efficiently, in contrast to the skull or parts of the eye – are also not considered in the measurement model. The consideration in a computer simulation is not a trivial task.

Measurements are probably quite efficient to compare the results of different type of sources; whether the results have anything to do with the actual Specific Absorption Rate in a human head with its complicated composition is another question. What these SAR values, in the next step, mean in respect to increasing the temperature in certain areas of a still functioning human head, one can only guess.

Computer simulations can give a good insight in qualitative effects of details, however establishing whether results are correct and reliable is more difficult than checking the calibration stickers on field probes and receivers.

Franz Schlagenhaufer

Western Australian Centre for EMC Technology (WACET)

STUDENT MEMBERSHIP

The National Council of the EMC Society has announced that Student Membership of the Society is now free.
We invite all students undergoing study in tertiary education in associated disciplines, electronics or electrical technologies to join our society. Membership is not restricted to these specific fields and indeed, anyone who has an interest in EMC is encouraged to join.
Membership of the Society entitles members to receive free the quarterly newsletter, attend technical presentations and provide access to information and personnel who may assist students in their studies.
For more details please contact the secretary – Kingsley McRae – telephone 03 9762 6733 or kingsley@rfi-ind.com.au

CALENDAR OF EVENTS

2002

May 21 – 24

Sponsored by the Chinese Institute of Electronics (CIE)
2002 International Symposium and Technical Exhibition on EMC, Beijing, China
Professor Liu, Dayong
Phone: +8610 68283463 Fax: +8610 68283458
dyliu@public.bta.net.cn www.cie-china.org/emc2002/

June 25 – 28

16th International Wroclaw Symposium and Exhibition on EMC
(The conference language will be English)
General information: Mr. W.Moron, Mr. D.Wiecek
Phone: +4871 348 3051
Fax: +4871 3728 878 emc@il.wroc.pl
Post: EMC Symposium, Box 2141, 51-645 Wroclaw 12, Poland

August 19 – 23

IEEE EMC Symposium Minnesota
Hyatt Regency, Minneapolis
Dan Hoolihan +1 651 213 0966 d.hoolihan@ieee.org

September 9 – 13

EMC Europe 2002
Organised by the Associazione Elettrotecnica ed Elettronica Italiana, the University of Rome "La Sapienza", the University of L'Aquila, th eUniversity of Naples "Frederico II", Sorrento, Italy.
Massimo Iandolo Phone: +39 02 77790 218 / 230 Fax: +39 02 798817
emceurope2002@aei.it

IEEE Symposium on EMC 2003 – Tel Aviv, Israel

A number of international conferences and symposia on EMC are on the horizon, and the 'Calender of Events' in this newsletter regularly gives a good selection of the most important ones. Special attention deserves the IEEE Symposium for next year. In 2001 the Symposium was held outside the US for the first time, albeit one could argue, that most US Americans would probably consider Canada not really to be a foreign country. And the November 2001 issue of the Australian EMC Society Newsletter put a summary of the Symposium under the heading 'News from USA'.

Next year, in May 2003, the Symposium will, for the first time, leave the American continent and be held in Tel Aviv, Israel. There is little to say about the technical and scientific quality of the Symposium – after all, the IEEE Symposia are grown up and well established in the EMC community. The surrounding, however, promises to be a welcome change to the US cities hosting the Symposia so far. Tel-Aviv - one of Israel's largest cities, is a thriving vibrant metropolitan with an exciting and cosmopolitan mix of leisure activities. Tel-Aviv offers something for everyone – to be fully enjoyed in the ideal Mediterranean climate. Outdoor cafes, ethnic restaurants and cultural centers will compete for your attention with historic sites, open oriental markets and of course the Mediterranean coast and its golden beaches. And most important: this will be an opportunity to hear about the latest in EMC research and technology in an environment where you can use the bible as a guide book. In Israel, the world 'old' has definitely another meaning than in Australia.

As far as I am concerned I had the luck to visit Tel Aviv in 1998 for the International Conference on High-Power Electromagnetics (EUROEM '98) and I look forward for my next visit in 2003. A Website is already up and running containing more Information on the Symposium: www.ortra.com/emc2003.

Franz Schlagenhaufer
Western Australian Centre for EMC Technology (WACET)
e-mail: franz-s@ee.uwa.edu.au

NEW MEMBERS

For those who have not yet joined our EMC Society we would ask you to fill in our membership application form and encourage your colleagues to follow suit. If you have applied for membership but not yet received an invoice from IEAust, would you please fill in and submit a new application.

MAILBOX

We invite all our members and readers to participate in our quarterly newsletter. In order to produce a better newsletter and provide our readers with the information and items of interest looked for, we welcome your comment, advice and criticism. Particularly, we would look forward to receiving technical articles, amusing anecdotes and items of general interest to the EMC community.

CORPORATE MEMBERSHIP

The EMC Society offers corporate Membership to organisations who may wish to nominate up to three people for membership. It also provides an important source of funding to the Society and we would like to take this opportunity to recognise the 2000 corporate Members.

ADVANTEC ELECTRONICS Pty Ltd is a registered NATA test house with accreditations for testing to TS001, TS002, TS004, TS006 and TS008.
Contact: David Stocks (02) 9477 7757
DEPARTMENT OF DEFENCE Defence Communications Regulatory Affairs.
Contact: Neal Miller (02) 6265 0522
RITTAL PTY LTD
Contact: Lucy Krieg (02) 9525 2766
ROBERT BOSCH AUSTRALIA is a manufacturer of white goods and specialised electronic automotive products.
Contact: Steve Offer (03) 9541 5474
TENIX DEFENCE SYSTEMS is a manufacturer of specialised defence systems.
Contact: David Willetts (03) 9244 4134

The EMC Society would like to express gratitude to Advantec, Department of Defence, Rittal, Robert Bosch, and Tenix for their support in 2001.

Institutional Listings

The IEAust Electromagnetic Compatibility Society is grateful for the assistance given by the firms listed and invites application for Institutional Listings from other firms interested in the electromagnetic compatibility field.

Institutional Listings

An Institutional Listing recognises contributions to support the publication of **THE IE AUST ELECTROMAGNETIC COMPATIBILITY SOCIETY** newsletter. Minimum rates are $200.00 for a listing in one issue. Larger contributions will be most welcome. No agency fee is granted for soliciting such contributions. Inquiries, or contributions made payable to the EMC Society, plus instructions on how you wish your Institutional Listing to appear, should be sent to the Editor, EMC Society Newsletter, IE Aust, 11 National Circuit, Barton, A.C.T. 2600.