EMC Society of Australia NEWSLETTER

*The official newsletter of the Electromagnetic Compatibility Society of Australia*
*ENGINEERS AUSTRALIA 11 National Circuit Barton ACT 2600*

*Issue Number 25* A SOCIETY OF **ENGINEERS** AUSTRALIA *March 2004*

# NEW CHIEF EXECUTIVE FOR ENGINEERS AUSTRALIA

Peter Taylor FASCE FIPWEA FIEAust CPEng has been appointed as Engineers Australia's new Chief Executive. He took up his appointment in February 2004. A civil engineer, Peter Taylor has worked with the Royal Australian Engineers. His military appointments include operational service in Vietnam and attendance at the Defence Services Staff College in India. After leaving the army in 1977, his career has been in local government, initially as works engineer with the City of Hobart and until recently chief executive officer of Toowoomba City Council. Taylor has been involved with Engineers Australia since joining as a student member in 1967. He has been a Fellow since 1987 and has served on several National Task Forces and Committees.

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# TECHNICAL PRESENTATION TUESDAY, 23 MARCH 2004

## INTERFERENCE-FREE PROFESSIONAL AUDIO SYSTEMS

Keith Armstrong Partner, Cherry Clough Consultants
Tony Waldron, Technical Manager, Cadac Electronics Ltd

The design of large professional audio (pro-audio) systems was never trivial, but the recent increases in the use of digital, switch-mode and wireless technologies have worsened their interference problems. This situation, increasing EMC regulation, and the poor EMC practice of single-point grounding commonly used in the pro-audio industry, encouraged the Audio Engineering Society (AES) of the UK, to set up working group SC-05-05 to create a standard on cable shield termination. Two shield termination methods for EMC are discussed in this paper - direct bonding at one end with capacitive bonding at the other, and direct bonding at both ends. The effects on the EMC performance of a large professional audio system of applying single-ended, and both-ended shield bonding using capacitive or direct methods are discussed and test results given. Practicality and costs are also discussed. This paper was first presented at the IEEE International EMC Symposium in Minneapolis, August 2002. Keith graduated in electrical engineering from Imperial College London in 1972, majoring in analogue circuit design. Much of his working life has involved controlling real-life interference problems in high-technology products, systems, and installations, so that they would work properly and make money for their manufacturers and users. Keith formed Cherry Clough Consultants in 1990, an independent company which helps manufacturers, installers, and users achieve cost-effective control of interference, and compliance with the EMC and other EU Directives. Cherry Clough Consultants is a founder member of the EMC-UK association. Keith has been a Chartered Electrical Engineer since 1978, a Group 1 European Engineer since 1988, and has written and presented a great many papers on EMC. He is the past chairman of the IEE's Professional Group (E2) on Electro-Magnetic Compatibility, and currently the chairman of the IEE's new Working Group on 'EMC and Functional Safety'.

Engineers Australia Auditorium, 6:30PM
21 Bedford Street
North Melbourne (Melway 43 F5)

## EMC AT AUSTRALIAN UNIVERSITIES

Received from Dr. Franz Schlagenhaufer (franz-s@watri.org.au)
Western Australian Telecommunications Research Institute (WATRI)

Are there any EMC activities at Australian Universities? And if yes: who is doing what and where? A quick search through the web-sites of Australian universities produced the following list of dedicated EMC lectures:

- Adelaide University;
- Monash University (Melbourne);
- Royal Melbourne Institute of Technology (RMIT);
- The University of South Australia
- The University of Western Australia.

Queensland University of Technology offers an EMC lecture, to my knowledge, but I could not find a reference on the University's web site. The EMC lecture at The University of Western Australia is included as part of the unit 'High Frequency Electronic Systems'. A number of universities address EMC aspects in one form or the other in lectures on related topics.

**Australian National University:**
- Large scale Electromagnetic Compatibility Analysis

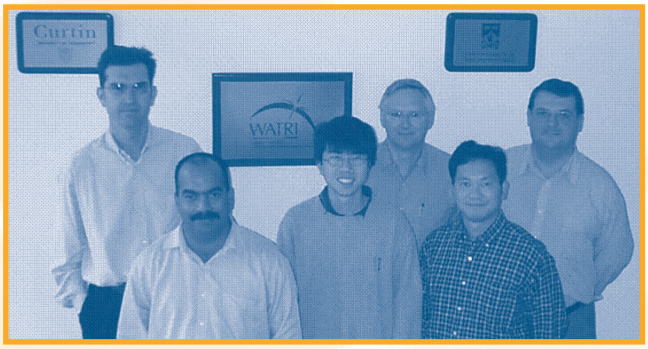
**Queensland University of Technology**
- EMC Emission Measurement and Data Acquisition System

**Western Australian Telecommunications Research Centre (joint venture of The University of Western Australia and Curtin University of Technology**
- EMC in Printed Circuit Boards
- EMC in Interconnect systems
- EMC on Transmission lines
- EMC in enclosures and shielding design

There are a few other activities I am aware of, but of which I could not find a trace on the web sites. At Melbourne University, a PhD project is done on FDTD modeling and combination with non-linear Spice models. A PhD project in Adelaide (I think at The University of South Australia) investigates reverberation chambers. The Walter and Eliza Hall Institute of Medical Research (affiliated with Melbourne University) is looking at biological effects of 50 Hz fields. The University of Western Sydney is dealing with EMI and power quality and Numerical solution of electromagnetic fields. At Latrobe University work is done in the area of EMC compliant PCB design.

The search I did on the university web sites was, admittedly, only short, and the activities listed above are certainly not complete. I also might have got some details wrong: my apologies for that.

EMC is only beginning to make its way into the curricula of electrical engineering courses on the university level. The vast majority of graduated engineers had only a marginal (if any at all) exposure to EMC issues during the study. Experienced engineers usually have picked up bits and pieces of EMC expertise from colleagues, during painful sessions in the EMC lab when failing compliance tests, from books and magazines, or from seminars and workshops. What is very often lacking is a comprehensive and well structured introduction and overview of the subject. Seminars and workshops to industry can certainly help to some degree to fix urgent problems. In the long term, however, EMC must become a fundamental and integral part in the education process of engineers.
(For more information about the EMC lecture at The University of Western Australia see the 'Technical Corner' at: http://www.acett.org.au)




*The staff of WATRI*

## FCC ACKNOWLEDGES HUNDREDS OF THOUSANDS WHO HAVE COMPLAINED ABOUT SUPER BOWL HALFTIME SHOW

Washington, DC — The FCC acknowledges the hundreds of thousands of Americans who have registered their complaints about the broadcast of this year's Super Bowl halftime show. The FCC has received more than 200,000 complaints on this subject. On February 2, the day after the Super Bowl, FCC Chairman Michael K. Powell issued a statement "I am outraged at what I saw during the halftime show of the Super Bowl. Like millions of Americans, my family and I gathered around the television for a celebration. Instead, that celebration was tainted by a classless, crass and deplorable stunt. Our nation's children, parents and citizens deserve better. "I have instructed the Commission to open an immediate investigation into last night's broadcast. Our investigation will be thorough and swift.". While it is impossible to respond to each individual complaint, the Commission will issue a decision that will be posted on its' Web site at www.fcc.gov at the conclusion of the investigation.

Scientists were rated as great heretics by the church, but they were truly religious men because of their faith in the orderliness of the universe. — *Albert Einstein*

## AEEMA

AEEMA is the peak industry association representing local and international companies in the electrical, electronic and information and communication technologies (ICT) industries. AEEMA's objective is to strengthen the competitive position of the Australian electrical, electronic and ICT industries and promote value-adding by those industries wherever possible, in both domestic and international markets. The Association was established in 1969 to serve the interests of Australian electrical and electronics industries. With the convergence trend between the electrical, data and telecommunications markets, AEEMA's role has gradually extended to cover the ICT industries. With the growing internationalisation of the Australian economy and the rapidly changing regulatory and policy environment, AEEMA deals with an ever-expanding range of issues and activities on behalf of its some 400 members. The vast majority of companies - both national and international - are involved in the design, development and production of the electronic, electrical and ICT products and systems in Australia. Operating through nationally-based divisions, serviced by the secretariat, AEEMA provides a point of liaison between the industry, its customers and government. With its secretariat based in Canberra, AEEMA is ideally placed to access key decision-makers and takes an active role in influencing and shaping public policies. AEEMA publishes an E-Bulletin fornightly, in the issue of Monday 16 February 2004, the following discussion of the recent Free Trade Agreement appeared.

**FREE TRADE AGREEMENT:** NOT A PANACEA, BUT SETS UP OPPORTUNITIES. While voters Australia-wide were coping with hot and sticky conditions early last week, they received the very big news that a deal had been done on the Australia-US Free Trade Agreement (FTA). By the end of the week, their elected representatives were agreeing (well, almost) to free up generous entitlements to superannuation. One wonders what a year-long heatwave in Canberra might really achieve!

As an active participant in the FTA process, the week's events and discussions have been illuminating. At a National Press Club convened by the Australian Services Roundtable (of which AEEMA is a member a growing number of our members are focused on product-related services), Minister Mark Vaile reminded the audience that the FTA agreement represented a landmark in improving Australia's trade relationship with the world's most dynamic and richest economy, a third of the world's GDP, and the world's largest merchandise and services exporter and importer. Minister Vaile made two important points that were not picked up by the media. The FTA deal is a dynamic agreement; it will allow change and fine-tuning as approved by both parties. The FTA also sets in place a trading framework, well ahead of our ability to supply. The FTA is not a panacea or guarantee to success for Australian exporters in a tough market place such as the US, but it sets up the opportunities. Through its work in establishing supporting linkages and relationships with kindred, influential US trade associations, and its strong support for the Electronics Industry Action Agenda, AEEMA has been actively building on the back of the FTA pathway. We are also aware, however, of the need to continue to build similar linkages to the North Asian powerhouse economies, which themselves are inextricably linked with the US marketplace. There is no doubt Australian manufacturers in the automotive industry will benefit immediately, with the elimination of US tariffs for auto parts exporters. Given the established linkage with our electronics industry, this represents a significant boost to our industry. AEEMA's tariff policy states that we must be prepared to consider supporting concessions to the General Tariff for individual bilateral trade agreements as a negotiating measure for the freeing up of access to new markets; these measures include non-tariff and technical barriers to trade.

*Minister for Trade, Mark Vaile*

AEEMA's support of the Australia-US FTA is totally consistent with this policy. The details of the agreement will be available in a few weeks' time; examining these will enable us to ensure that attention is being paid to the removal of any non-tariff and technical barriers. Only experience in the market place will establish that the promised US commitments to ensure non-discrimination against Australian service suppliers will be delivered. Consistent with stated Howard Government policies, AEEMA's tariff policy is to support removal of the three per cent tariff on business inputs – particularly for materials and components. This tariff is an impost on Australian manufacturers; AEEMA has consistently lobbied for its removal in general dealings with the Australian Government and through opportunities presented in bilateral trade liberalisation measures. This has been achieved for the Australia-US FTA. With the current tariff scheme now so full of holes, it presents an opportunity for us to argue that the scheme should be removed altogether: we will continue our efforts to achieve this outcome. As for the week ahead, who knows what will emerge in this February hot-house environment. Mark Latham has hinted a move to attack politicians' perks in free air travel. If successful, who knows what impact such a bold move might have on the domestic airline industry. At least it might open up more opportunities for low-fare airlines wishing to expand their operations out of Canberra!
**Angus M Robinson, Chief Executive, AEEMA.**

For more information on AEEMA and its activities visit http://www.aeema.asn.au/.

## INDUSTRY BRIEFS

### AUSTRALIA JOINS INTERNATIONAL ANTI-SPAM CAMPAIGN

The Australian Communications Authority (ACA) is urging Australian businesses to take responsibility for eliminating spam as part of a ground-breaking international campaign aimed at reducing the practice. Australia joins 37 agencies in 26 countries in Operation Secure Your Server being launched by the United States' Federal Trade Commission today. Operation Secure Your Server encourages businesses to help reduce the flow of spam by preventing their computing systems being used by spammers to disguise the origin of unwanted emails. Spammers operate by routing their messages through the servers of other organisations, potentially damaging the reputations of these organisations.

As part of the ongoing campaign, tens of thousands of businesses worldwide, including many in Australia, will be contacted warning them of their vulnerability to becoming unwitting spammers. Acting ACA Chairman Allan Horsley said Australia had recognised the importance of addressing the problem of spam in a global context and was pleased to be a co-sponsor of Operation Secure Your Server. "We are very keen to be a part of an international coalition of like-minded organisations trying to eliminate the problem of spam," Mr Horsley said. "Around the world, governments are introducing legislation to combat spam although each country has its own objectives driving these laws. However all these laws have a common goal, so it is important we also unite globally to coordinate efforts against spam." International coordination is one of the strategies being implemented by the ACA in the fight against spam. The others are codes of practice for ISPs and direct marketers, use of technology, and consumer practices. Education and awareness are key aspects of all strategies.

The Federal Parliament has enacted legislation to regulate unsolicited commercial electronic messages, also known as 'spam': the *Spam Act 2003*; and the *Spam (Consequential Amendments) Act 2003.* The ACA has been given the task of enforcing the new anti-spam laws which were passed by Federal Parliament in December last year. The *Spam Act 2003* comes into effect on 11 April 2004.

The Spam Act will prohibit unsolicited commercial electronic messages with an Australian link from 11 April 2004. It will also require all commercial electronic messages to contain accurate sender information and a functional unsubscribe facility. The legislation provides for the development of codes of practice for the e-marketing industry and for the internet industry, which will detail and supplement the basic prohibitions. Under the spam legislation, the ACA is concerned with unsolicited commercial email (and other electronic messages) whether or not the content is itself legal or illegal. However, much email also carries content which is itself illegal under other laws—for example, it is fraudulent, offensive or carries a computer virus. The ACA will be working closely with other regulators and law enforcement agencies on the problem of spam. The ACA has also prepared a list of Frequently Asked Questions; available at http://www.aca.gov.au/ & http://www.aba.gov.au/.

### WANTED: A FEW GOOD ENERGY CONSERVATION DESIGNS

From the IEEE in the USA
BY KATHY KOWALENKO

Students with ideas about how to build a more efficient electric motor or a way to link alternative energy sources to the existing power system could win US$35,000 in the 2005 International Future Energy Challenge competition. Although the final judging won't be held until 15 Aug. 2005 in Washington, D.C., USA, proposals are due 10 April 2004. Student teams from colleges with recognized engineering programs may compete. Winners in the 2003 competition came from Seoul National University of Technology, Korea; Bangladesh University of Engineering and Technology, Dhaka, and the Illinois Institute of Technology, Chicago, USA.

"The competition has significant interest for the student's community and the world in general because the topics have a global perspective," says IEEE Member Steve Pekarek, the competition's chair and an associate professor of electrical and computing engineering at the University of Missouri, Rolla, USA. "Power engineering gets to the heart of many problems. Solutions require diverse thinking and even though students have to understand some power engineering, they don't have to be power engineering experts," Pekarek explains. "We expect to have students with mechanical, electrical, and even policymaking skills." Each design category offers $35 000 as the top prize. One category is for a single-phase adjustable speed motor drive and the other is for an interactive inverter system for small distributed power generators.

**Efficient Motors**

Electric motors consume 75 percent of all electric power in the United States. Reducing the energy consumption of motors and motor drives could yield deep cuts in the cost of running home appliances. Teams may not spend more than $40 on hardware for a combination motor, driver, and controller. The motor must operate from a single-phase residential source, deliver a rated shaft load of 0.75 horsepower or 500 watts, at 1500 revolutions per minute. It must have a useful speed-control range of at least 150 to 5000 RPM, and a power efficiency of at least 70 percent for loads ranging from 50 W to 500 W at a specified speed.

Human beings, vegetables, or comic dust, we all dance to a mysterious tune intoned in the distance by an invisible player. — *Albert Einstein*

## INDUSTRY BRIEFS

**Inverters**

An inverter allows new alternative energy systems like fuel cells to link to the existing power grid, notes Pekarek. Entries for inverter systems for small distributed generators must operate at typical voltage and frequencies, grid-connected or stand-alone. No more than $200 can be spent for an inverter that operates from a dc input voltage of between 30 and 60 volts, with input power varying from 250 to 1000 W. It must plug into a single-phase 110/240-V utility line at 50Hz/60 Hz. The inverter must have an efficiency of at least 90 percent.

**Submission details**

Teams may enter only one of the design areas. Those with proposals deemed to have merit will be notified by 15 May 2004. The teams can then begin building their prototypes. Writing progress reports is also part of the project. Interim reports are due 1 November 2004 and 1 February 2005, a final report on 1 May 2005. Finalists will be chosen by 15 May by judges affiliated with the organizations sponsoring the competition. Sponsors include, from the IEEE, the Power Electronics, Industry Applications, Industrial Electronics, and Power Engineering societies, the U.S. National Renewable Energy Laboratory, and several corporations. Funds will be available to help teams travel to the finals. Prizes, ranging from $1000 to $5000, will also be awarded for best engineering design, best technical documentation, and best presentation. For more information, visit http://www.energychallenge.org/.

## IEEE ONLINE EXHIBIT TAKES AIM AT WORLD WAR II TECHNOLOGY

From the IEEE USA
BY PEG GALLOS

That human technological innovation is both a curse and a blessing is clear from "World War II: How War Impacted Technology; How Technology Impacted War," the new exhibit from the IEEE Virtual Museum. World War II was an epic of destruction unprecedented in world history mainly because of major technological advancements, according to the exhibit. And, by contrast, the very same human ability to innovate formed the response to the violence of warfare and cut it short. The particular strength and weaknesses of weapons such as tanks, aircraft carriers, and submarines made a significant difference in defeats and victories for both sides, a visitor to the site will discover. Equipping tanks with especially sturdy armor, developing communication devices enabling tank commanders to talk while the battled raged, and improving the maneuverability of these vehicles by enhancing their off-road capabilities—these advances helped the German "Blitzkrieg" or lightning war decimate Western Europe early on. Yet another kind of technical achievement, mass-production, enabled the Allies to fight back. The United States manufactured Sherman tanks in huge numbers with the help of Ford Motor Co. and later Chrysler Corp. Through their sheer numbers, Allied tanks eventually overwhelmed the Germans on the battlefields of North Africa.

The exhibit's discussion of submarine technology offers the startling statistic that at one point in 1942, Germans were sinking Allied ships in the North Atlantic at the rate of one every four hours. "Enigma" encoding machines wrought this havoc because they enabled encrypted messages about ship positions to be relayed by another communications advancement, radio, which enabled them to transmit this information to German submarine commanders. Great Britain quickly learned the value of radar when its famous Chain Home radar system helped stave off the Germans during the 1940 Battle of Britain, according to the exhibit's section entitled "War as a Technological Watershed." It explains that two British engineers [*Sic. Australian, Sir Mark Oliphant, also contributed. Editor.*] developed the cavity magnetron vacuum tube that generated the radar signals. Eventually, this development led to the creation of the legendary Massachusetts Institute of Technology's Radiation Lab. There, researchers developed 100 specialized radar systems by 1945.

The exhibit also illuminates the contribution of women's mathematical and technological skills. In the United States and Britain, women became human computers, calculating the long, intricate equations that were used to help gunners aim artillery on the battlefields. A profile of Grace Hopper, a Naval officer and computer software developer, explains how she became one of the first programmers of the Navy's Harvard Mark I, an early electronic computer. Visit the Virtual Museum exhibit at http://www.ieee-virtual-museum.org/.

## EMC SOCIETY COUNCIL

The EMC Society is a technical and learned society within **Engineers** Australia, established to promote the science and practice of Electromagnetic Compatibility throughout Australia and the region.

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# Vulnerability of Electronic Circuits to Electromagnetic Pulses with Spectral Components above 1 GHz

Dipl.-Ing. Michael Camp, Prof. Dr.-Ing. Heyno Garbe
Institute for Electrical Engineering and Measurement Science, University of Hannover, Germany
E-mail: camp@ieee.org, garbe@ieee.org

## 1 Introduction

Electronic circuits are of vital importance for the function of traffic systems, security systems and modern communication. A malfunction in one of these areas may cause casualties and economic disasters. Nowadays pulse generators with fast rise times ($t_r$ < 100 ps) and very high amplitudes can be bought by everyone. Taken the aspect of electromagnetic terrorism into account a system with fast rise time $t_r$ and short pulse length $t_{fwhm}$ (cp. Fig. 1.1) could be a very dangerous weapon, because it can be built in a very small volume due to the low energy content of the pulse. Typically the pulse shape character of very high amplitude generators is double exponential as well known from ESD, EMP or UWB shown in Fig. 1.1. Therefore the susceptibility of electronics to pulsed electromagnetic fields like EMP and UWB pulses is of great interest.

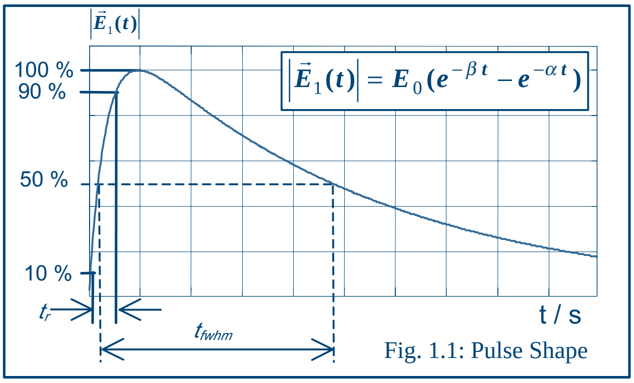


Fig. 1.1: Pulse Shape

## 2 Definitions

### 2.1 Failure Rates

To describe the different failure effects of electronic circuits after impact of pulsed electromagnetic fields, two quantities have been defined (Table 2.1). The Breakdown Failure Rate (BFR) has been defined as the number of breakdowns of a system, divided by the number of pulses applied to it. A breakdown means no physical damage is done to the system. After a reset (self-, external- or power reset) the system is going back into function. The Destruction Failure Rate (DFR) of the device under test has been defined as the number of destructions divided by the number of pulses applied to the system. Destruction is defined as a physical damage of the system so that the system will not recover without a hardware repair.

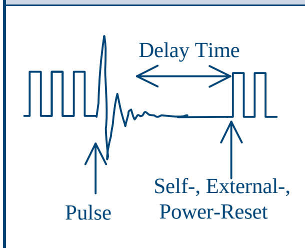
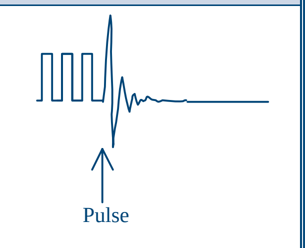
| Breakdown | Destruction |
|---|---|
|   |   |
| Breakdown Failure Rate | Destruction Failure Rate |
| $BFR = \frac{No.\,of\;Breakdowns}{No.\,of\;Pulses}$ | $DFR = \frac{No.\,of\;Destructions}{No.\,of\;Pulses}$ |

Table 2.1: Failure Rates

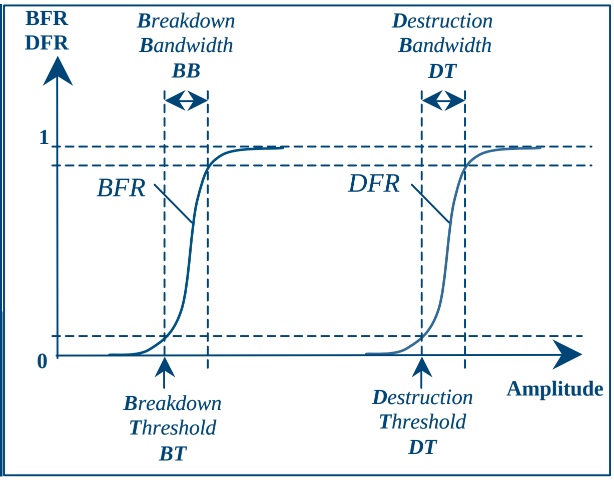


Fig. 2.1: BFR, DFR - principle behavior and definitions

### 2.2 Principle Behavior of BFR and DFR

The BFR and DFR behaves in principle as shown in Fig. 2.1. As important parameters for the description of the susceptibility of a system four quantities were defined. The Breakdown Threshold (BT) specifies the value of the electrical field strength, at which the BFR reaches 5% of the maximum value. The Breakdown Bandwidth (BB) is defined as the span of the electrical field strength, in which the BFR changes from 5% to 95% of the maximum. Äquivalent definitions were done for the destruction failure rate DFR (cp. Fig. 2.1).

## 3 General Measurement Setup

### 3.1 Waveguides

The measurements were carried out with two different waveguides shown in Fig. 3.1. Waveguide 1 is an open area test simulator with a maximum heigth of about 23 m located at the armed forces scientific institute for protection technologies in Munster, Germany [1]. Waveguide 2 [2] is an open waveguide inside a shielded room surrounded by absorber walls.

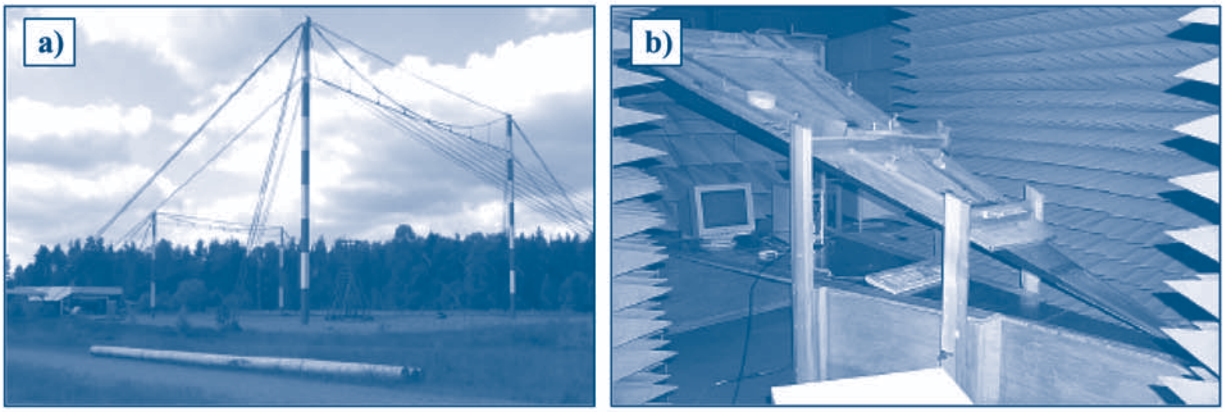



Fig. 3.1: open area test simulator (a) and indoor waveguide (b)

### 3.2 Test Setup

To apply the different pulses to the electronic circuits a modular setup has been realized (Fig. 3.2). Separate channels were built with a combination of differently printed circuit boards. The circuit boards were combined with ribbon cables to realize different coupling lengths at the input and output pins of the devices under test. In Fig.3.2 a NAND test setup consisting of ten separate channels with 20 cm ribbon cable length at the input pins and ≈ 0 cm ribbon cable length at the output pins of the test devices is shown. The power supply is realized with ten different accumulators. DIP switches were implemented to the power supply unit to adjust arbitrary bit patterns at the input pins. LEDs and resistors were used as loads to observe the operating states of the devices.

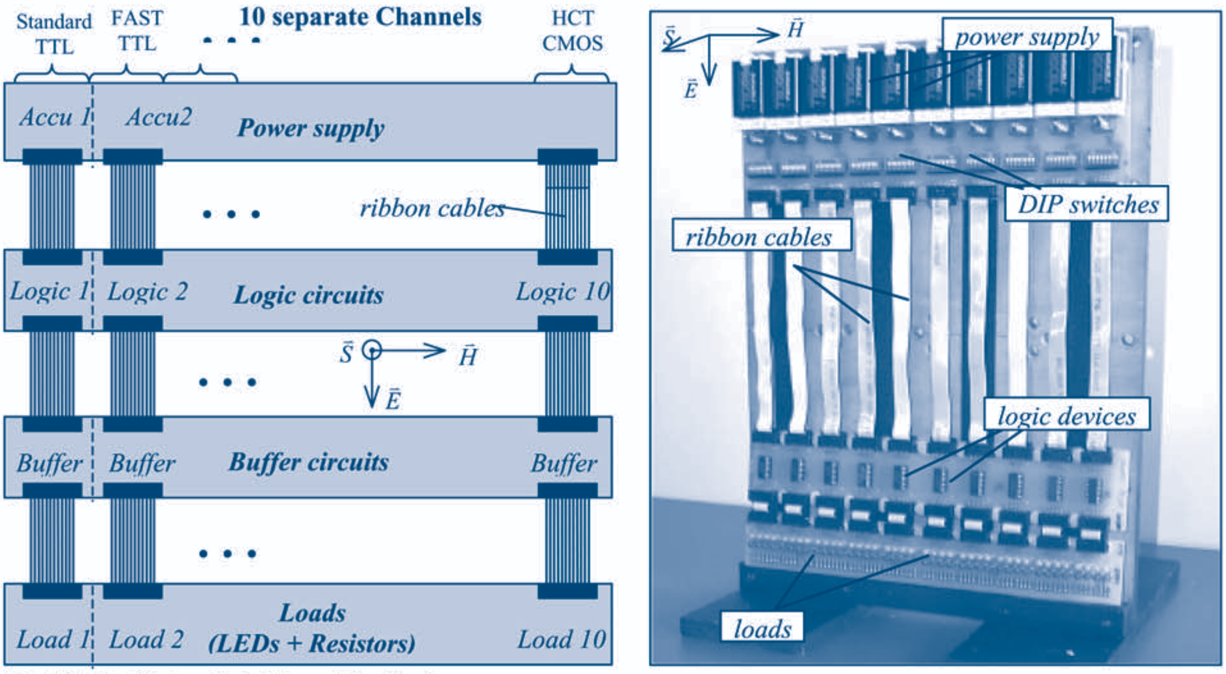



Fig. 3.2: Test Setup - Principle and Realization

## 4 Equipment under test

During the investigation different electronic circuits have been tested. Simple logic devices (NANDs, Inverter), generic array logic devices and shift registers were choosen to observe the influence of the technology on the failure effects. Microcontrollers, shift registers, industrial microprocessorbaords and personal computer systems were chosen to determine the effect of different clock rates, operation line lengths, program and operation states as well as the influence of different pulse shapes.

## 5 Measurement Results

### 5.1 Influence of the circuit technology

During the investigations ten different semiconductor technologies (six TTL-, four CMOS-families) have been tested (Table 5.1) concerning the susceptibility to EMP and UWB pulses. As a first result it can be noticed, that CMOS-devices first are affected by reversible breakdowns which can be fixed by switching the power off and on. At much higher field amplitudes destructions occur. This effect can be explained by a parasitic thyristor (latch up effect) as a result of the vicinity of complementary n- and p-channel transistors in CMOS devices described in [4]. Fig. 5.2 shows the *BFR* and *DFR* of NAND-devices built in four different CMOS technologies after Impact of an Ultra Wide Band pulse with a rise time $t_r \approx 100$ ps and a pulse length $t_{fwhm} \approx 2.5$ ns . The comparison of CMOS- with TTL-NAND-devices shows, that the destruction thresholds are similar, but that TTL-NAND-devices only are affected by non reversible destructions and at lower field amplitudes no breakdowns occured in contrary to the behavior of CMOS-NAND-devices. Fig. 5.1 shows the Breakdown- (*BT*) and Destruction threshold (*DT*) of NAND-devices built in ten different technologies (cp. Table 5.1). The same effects were observed during the investigation of other electronic circuits.

| TTL-Families | | | | | |
|---|---|---|---|---|---|
| Standard | Schottky (S) | Low Power Schottky (LS) | Advanced Schottky (AS) | Advanced Low Power Schottky (ALS) | Fairchild Advanced Schottky (FAST) |

| CMOS-Families | | | |
|---|---|---|---|
| High Speed (HC) | High Speed TTL-compatibel (HCT) | Advanced (AC) | Advanced TTL-compatibel (ACT) |

Table 5.1: Circuit technologies

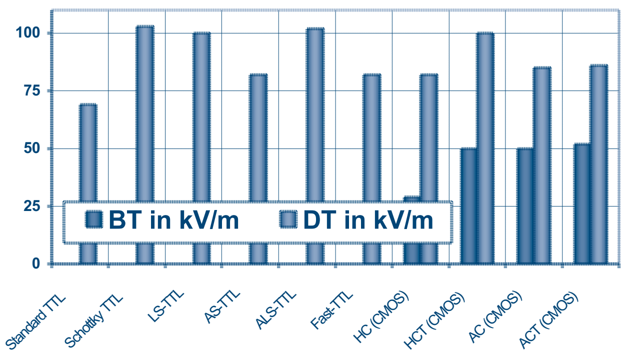



Fig. 5.1: Breakdown (BT) and Destruction (DT) Threshold of CMOS and TTL NAND Devices

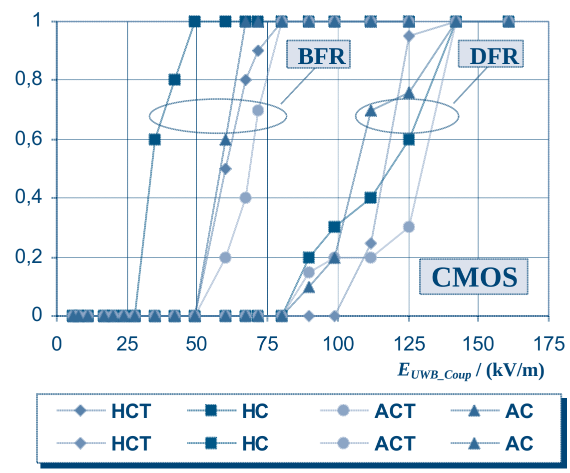



Fig. 5.2: Breakdown (BFR) and Destruction Failure Rate (DFR) of CMOS NAND Devices

### 5.2 Influence of circuit parameters

The effect of an alteration of circuit parameters is shown for different microcontroller circuits e.g.. Three different microcontrollers with a different number of I/O-ports, have been investigated. The microcontrollers were exposed to an UWB pulse (cp. Fig. 1.1). The features of the microcontrollers are: *-RISC Architecture, High-speed CMOS Process Technology, 32 x 8 General Purpose Working Registers , Flash on Board, EEPROM on Board*. The influence of different data-, quartz-, reset- and power supply-line lengths has been tested, as well as a variation of the clock rate. Four microcontrollers of the same type have been tested simultaneously to observe any difference. The microcontroller circuits were placed vertically on a wooden wall (Fig. 5.3) which has been placed in the waveguide. The different states of the I/O-ports are monitored via different coulored led´s. The variation of the data-, quartz- and power supply-line length was done with ribbon cables. During the test a program was running on the microcontrollers which can get into two different states. In status 1 two ports are high and two ports are low to observe this state. After a switch the program moves to the second state in which the microcontrollers were exposed to the pulses. The intention is to observe a self reset of the system by changing from status 2 back to status 1. Without the implementation of two states a self reset cannot be observed due to the fast reset action. In status 2 the I/O-Ports are changing from low to high to investigate the influence of the portstatus on the susceptibility.

### 5.2.1 Effect of I/O-Portstate

As a first result it can be noticed, that the susceptibility of microcontrollers depends on the states of the I/O-ports. The amount of influence depends on the different parameters and the type of microcontroller but is always low. Therefore in the following results the BFR is shown for low as well as for high I/O-port status.

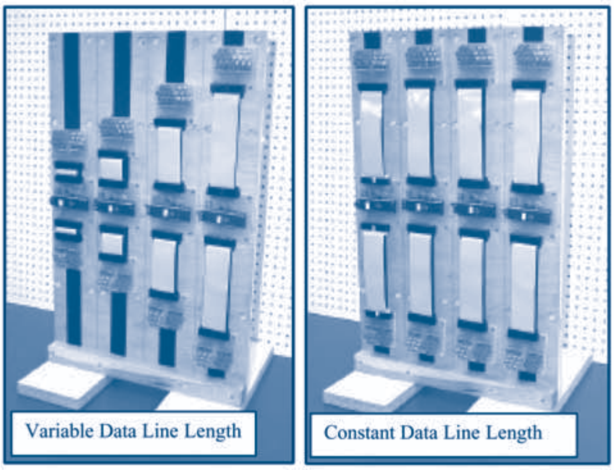



Fig. 5.3: Microcontroller test setup

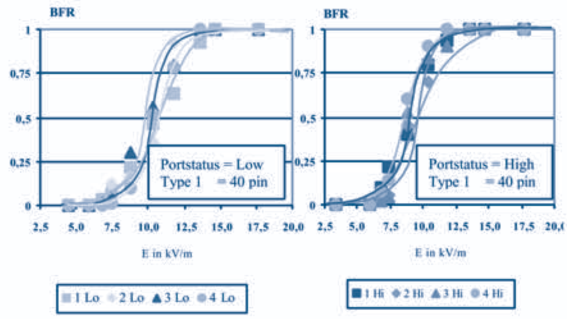



Fig. 5.4: Breakdown Failure Rate for microcontroller type 1 (40 pin) at basic setup

### 5.2.2 Results for Basic Setup

As the basic setup a state with quartz-, data-, reset- and power supply lines at minimal length and a clock rate at 1 MHz was defined. Figure 5.4 shows the results for a certain microcontroller in portstate low and high. The breakdown parameters BT and BB of the microcontroller circuits do not much vary by different devices of the same type of microcontroller, but are well influenced by the microcontrollertype. In the following analysis the breakdown parameters BT and BB have been determined as the average of four microcontrollers of the same type.

### 5.2.3 Effect of varying operation line length

Fig. 5.5 - 5.7 shows the behaviour of the BT for three different microcontrollertypes at different data-, quarz- and power supply line lengths for I/O-portstatus low and high. The Breakdown Threshhold (BT) is weakly influenced by the data line length. The amount of the BT is decreasing by about 1kV/m from minimal data line length to 20 cm data line length as shown in Fig. 5.5. The effect on the BB is of minor character.

The effect of the quartz line length on the BT is much higher than the effect of the data line length. The amount of the BT is decreasing by about 3 kV/m from minimal quartz line length up to 20 cm quartz line length as shown in Fig. 5.6. Further there is a influence on the BB by the quarz line length. The amount of the BB is decreasing by about 1.5 kV/m from minimal quartz line length up to 20 cm quartz

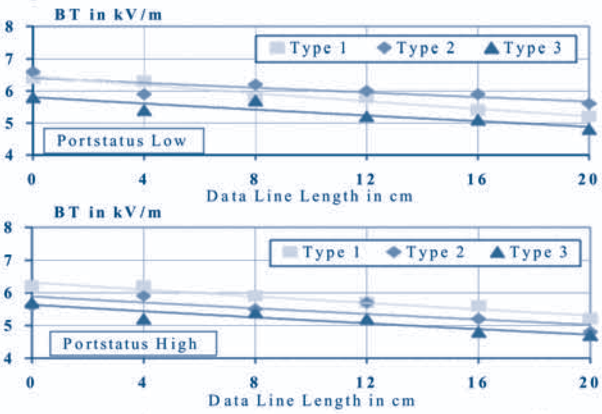



Fig. 5.5: BT for three different microcontrollers at different data line lengths in portstatus Low and High

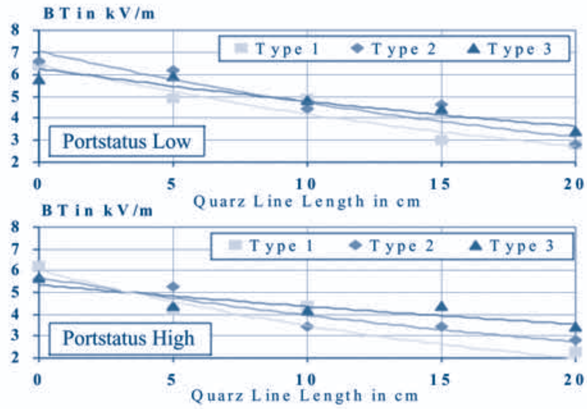



Fig. 5.6: BT for three different microcontrollers at different quarz line lengths

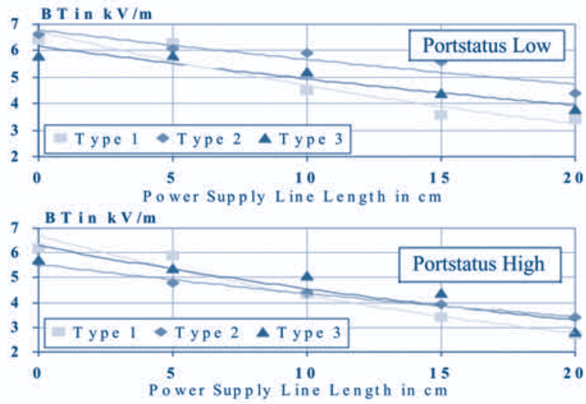



Fig. 5.7: BT for three different microcontrollers at different power supply line lengths

line length. The Breakdown Threshhold BT also strongly depends on the power supply line length as shown in Figure 12. The value of BT is decreasing by about 3 kV/m from minimal up to 20 cm power supply line length. The value of BB is decreasing by about 2 kV/m from minimal up to 20 cm power supply line length.

5.2.4 Effect of the Clock Rate

The Breakdown Threshold BT as well as the Breakdown Bandwidth BB of the tested microcontroller circuits are not influenced by a variation of the clock rate up to 8 MHz (Maximum permissible clock rate of the tested systems).

5.2.5 Results

The BT of the tested microcontrollers was generally much influenced by the quarz- and power supply line length as shown in Fig.5.6 and Fig. 5.7, little influenced by the data line length as shown in Fig. 5.5, very much influenced by the reset line length, not influenced by the clock rate and low influenced by the microcontrollertype. The BT is approximately linear decreasing by a variation of the operating lines, while the line length is not longer than 20 cm. The BB is generally little influenced by the quartz line length, medium influenced by the power supply line length, not influenced by the data line length and clock rate and strongly influenced by the microcontrollertype and reset line length (Table 5.2).

| | Reset Line Length | Data Line Length | Quarz Line Length | Power Supply Line Length | Clock Rate | Type of Controller |
|---|---|---|---|---|---|---|
| **BT** | High | Low | High | High | None | Low |
| **BB** | High | None | Low | Medium | None | High |

Table 5.2: Influence on BT and BB

### 5.3 Effect of different pulse shapes

As a first result it can be noticed, that the Breakdown Threshold BT strictly depends on the rise time and therefore on the energy distribution of the pulse spectrum. Fig. 5.8 shows the Breakdown Failure Rate of an industrial microprocessorboard for a rise time of 100 ps (UWB) and 1.5 ns (EMP) of the applied pulses. Using the UWB pulse the BT value is approximately 12 kV/m and for the EMP pulse approximately 30 kV/m. A second result of this investigation is, that there is only a narrow BB (≈1kV/m) if a UWB pulse generator is used, but a broad BB (≈20 kV/m) of the electrical field strength if an EMP pulse generator is used.

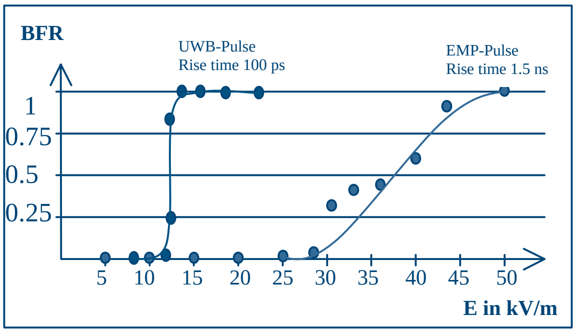



Fig. 5.8: BFR of a Rocky-518 HV board with a Pentium MMX CPU 233 MHz at different rise times

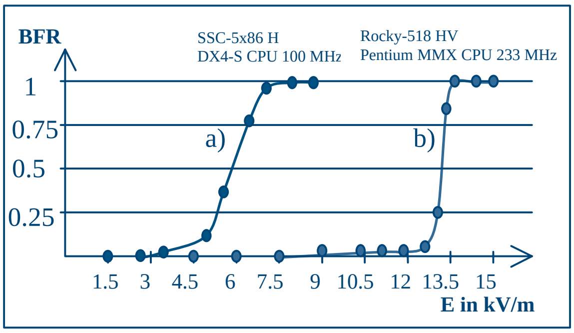



Fig. 5.9: BFR due to an irradiation with the UWB a) SSC-5x86 H board b) Rocky-518 HV

In a second test the behaviour of two different boards with approximately the same physical dimensions has been examined. Therefore the size of the coupling structures on the board is comparable. It was observed that the BT`s of the boards are different (Fig. 5.9). For a Rocky-518 HV board with a Pentium MMX$^{tm}$ CPU at 233 MHz irradiated with the UWB pulse the BT is approximately at 12 kV/m. For a SSC-5x86 H board with a DX4-S CPU at 100 MHz the BT is at approximately 4 kV/m. The different behavior of the boards is based on the different susceptibility of the on board devices and the different layouts of the boards [3].

### 5.4 Microscopical analysis of the destruction effects

5.4.1 Destruction Effects

The microscopic analysis of the destructed devices generally shows three different damaging effects (Fig. 5.10). At lower field strengths only electronic components like diodes or transistors on the chip, mostly as a result of flashover effects, were damaged (Fig. 5.10a). If the amplitude of the electromagnetic pulse increases by about 50 %, additional onchipwire destructions (this means melting of pcb tracks without flashover effects) and multiple component destructions occured (Fig. 5.10b). Further increase of the amplitude leads to additional bondwire destructions (Fig. 5.10c) and multiple component- and onchipwire-destructions.

Figure 5.11 shows an TTL NAND device with multiple component- onchip- and bondwire destructions after impact of an EMP with $t_r = 7.5$ ns, $t_{fwhm} = 180$ ns and an amplitude of about 1300 kV/m electrical field strength. The ribbon cable length at the input pins was ≈ 20 cm. At the output pins ≈ 0 cm ribbon cable length was realized.

Simular results were observed during the investigations of TTL-Inverter devices. Fig. 5.12 shows the destruction failure rate (DFR) of TTL-Inverter devices, separated to component-, onchipwire- and bondwire-destructions. At the lowest field level component destructions occured. A further rising of the field strength resulted in onchipwire- and bondwire-destructions.

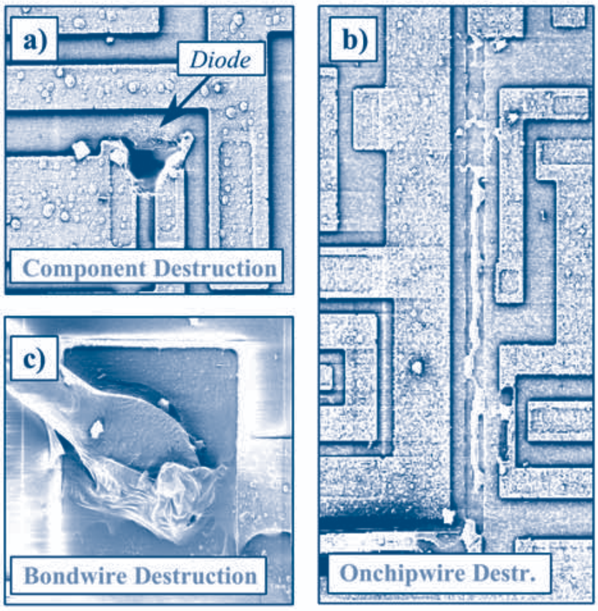



Fig. 5.10: Destruction effects on chip level

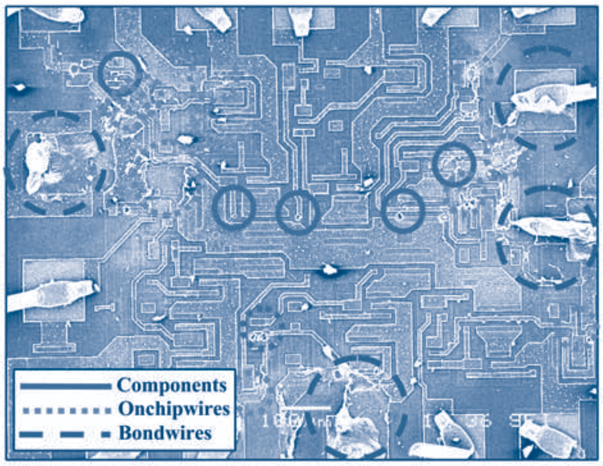



Fig. 5. 11: NAND Device with multiple Destructions

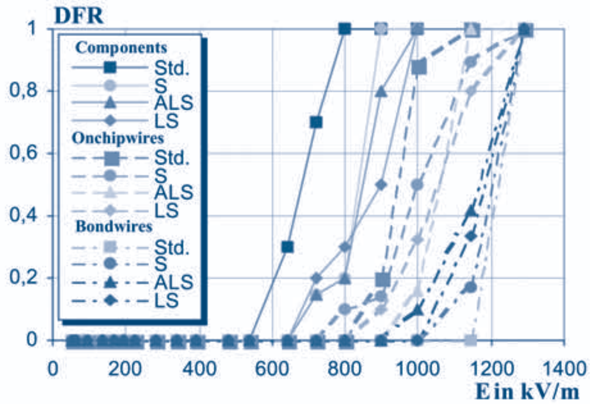



Fig. 5.12: DFR of TTL-NAND-Devices separated into Component- Bondwire- and Onchipwire-Destructions

## 5.4.2 Component Destructions

Depending on the technology and the manufacturer, different component destruction effects have occured. Fig. 5.13 for example shows an 74S00 TTL NAND device with four component destructions after the impact of an EMP ($t_r = 7.5$ ns, $t_{fwhm} = 180$ ns, amplitude = 650 kV/m). All bondwires and onchipwires are intact.

Type 74xx00 devices are composed of four separate NAND gates with combined VCC and Ground pins. NAND 1 and 2 as well as NAND 3 and 4 are manufactured with symmetry to the x-y axis. At NAND 1 and 2 as well as NAND 3 and 4 the same components have been destructed. In Fig. 5.14 for example the damaged areas of NAND 1 and 2 is shown. Between point P1 and point P2, marked in Fig. 5.14 and 5.15, a flashover has occured and as a result the metallic structure at the top layer directly around two distributed resistors (R1 and R2 in the depth of the material, not visible) has been destroyed and affected the two resistors.

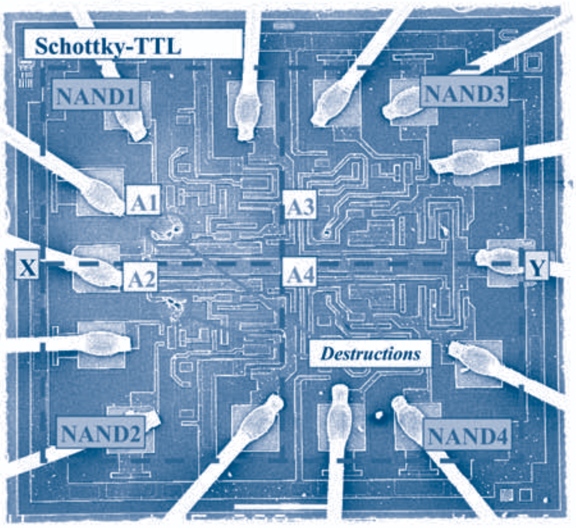



Fig. 5.13: Schottky-TTL NAND with Component-Destructions

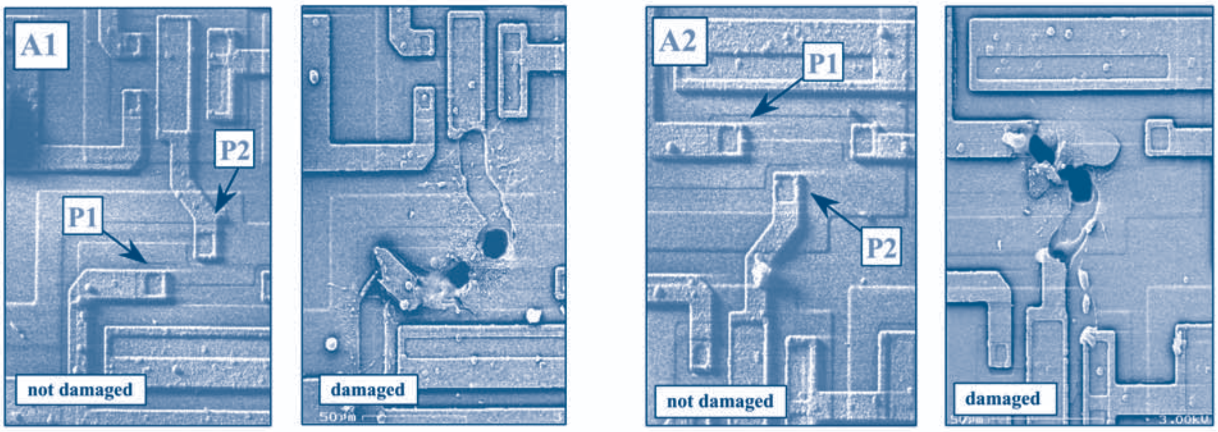


Fig. 5.14: Schottky -TTL NAND - Destruction in Detail

The fact, that always this area was damaged first, leads to the conclusion, that the damaged zone shown in Fig. 5.14 is the most susceptible area of the Schottky-TTL-NAND in this configuration and layout. Fig. 5.15 shows the basic schematic of a Schottky TTL NAND device and the area where the flashover has occured. At lower field strengths the resistors R1 and R2 have always been destructed first.

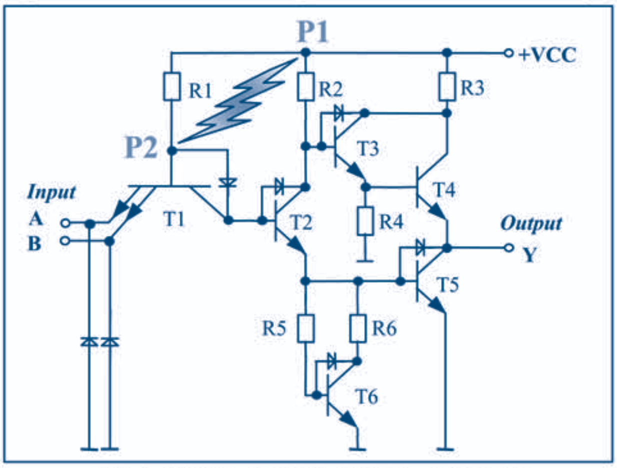


Fig. 5.15: Schottky TTL NAND - Schematic

Similar effects were observed with the other technologies. The components on the chip, which were damaged first if the amplitude of the electromagnetic pulse was increased, are depending on the layout of the chip (and therefore on the manufacturer) as well as on the technology. Transistors, diodes and resistors were damaged similarly.

### 5.4.3 Onchipwire Destructions

A further rising of the amplitude of the electromagnetic pulse resulted in onchipwire destructions. Fig. 5.16 shows different onchipwire destructions after the impact of an EMP with $t_r = 7.5$ ns, $t_{fwhm} = 180$ ns and an amplitude of about 900 kV/m electrical field strength.

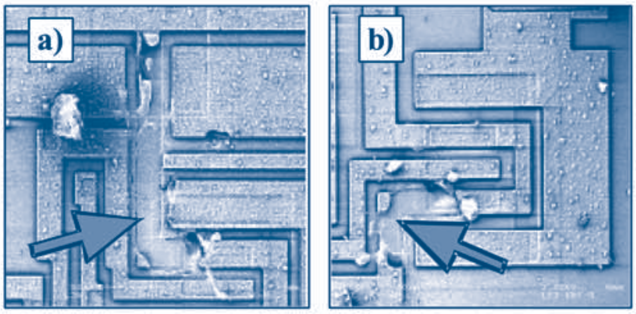


Fig. 5.16: Destruction of Onchipwires

### 5.4.4 Bondwire Destructions

Bondwire destructions always occured at higher pulse amplitudes than onchipwire destructions due to the fact, that onchipwires normaly has much lower cross sections than bondwires. The destructions occured by melting of the material similar to onchipwire destructions. Fig. 5.17 shows two destructed bondwires and pads.

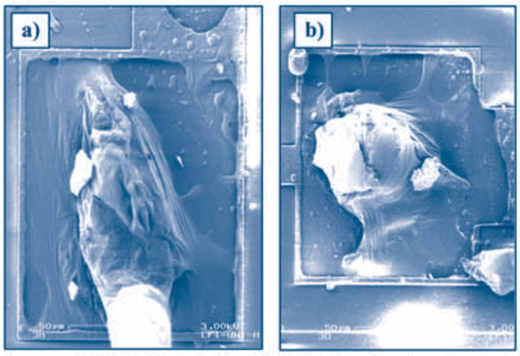


Fig. 5.17: Destructions of Bondwires

The energy to destruct bond- or onchipwires can be calculated via the equation [4]

$$Q = \rho \cdot A \cdot l \cdot c \cdot (T_{melt} - T_{sur}) \qquad (1)$$

with $A$ = cross section, $l$ = length of wire, $\rho$ = density of material, $c$ = specific heat capacity, $T_{melt}$ = melting temperature and $T_{sur}$ = surrounding area temperature. Equation 1 shows that the melting energy strictly depends on the cross section, if the same material is used for bond- and onchipwires under the constraint heat transfer into the surrounding area is neglectable (valid due to short pulse impact). Drawing an energy balance results in equation 2 which allows to make a rough estimate of the current which was responsible for the bondwire destruction.

$$I = \sqrt{\frac{\rho \cdot \kappa \cdot c \cdot \pi^2 \cdot d^4 \cdot (T_{melt} - T_{sur})}{16 \cdot \Delta t}} \quad (2)$$

With $\kappa$ = electrical conductivity, $d$ = diameter of the bondwires and the assumption that the duration of the current is approximately equivalent to the pulse length, a current of $I \approx 400$ A can be calculated via equation 2 if bondwires made of aluminium were implemented.

## 6 Summary

The investigation of the susceptibility of logic devices built in ten different semiconductor technologies (NANDs and Inverter) to EMP and UWB pulses has shown, that CMOS devices first gets reversible breakdowns and at much higher field amplitudes non reversible destructions occur. The destruction thresholds of TTL and CMOS devices are similar but TTL devices always gets non reversible destructions. The breakdown- (BT) and destruction-thresholds (DT) decreases much by extending the ribbon cable length or usage of pulses with faster rise times.

The susceptibility of microcontrollers was in general much influenced by the clock- and power supply line length, little influenced by the data line length, not influenced by the clock rate and very much influenced by the reset line length and pulse shape.

Further the susceptibility field strength levels of different microprocessor boards were determined. The different boards failed at 4 kV/m or 12 kV/m fieldstrength of the applied UWB pulse. The susceptibility vs pulses with slower rise times was lower (about 30 kV/m vs a fast NEMP). The investigation of two different boards with nearly the same dimensions showed that the devices on the board are of vital importance for the breakdown effects.

The destruction effects can be separated into component- onchipwire- and bondwire-destructions. First, at lower field amplitudes, component destructions, mostly as a result of flashover effects, occur. If the amplitude increases also onchipwire destructions appear. Further increase of the amplitude is leading to additional bondwire destructions and multiple component- and onchipwire-destructions.

This investigation is part of the study "Susceptibility of Electronics to EMP and UWB, Phase II", commissioned by the Armed Forces Scientific Institute for Protection Technologies - ABC-Protection (Munster, Germany).

## References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[2] C.Braun, "*Aufbau eines breitbandigen Wellenleiters für NEMP Modell Simulationen*", INT Bericht Okt. 84

[3] D.Nitsch, M.Camp, *"UWB and EMP Susceptibility of Modern Microprocessorboards"*, EMC Europe, Brugge, Sept. 2000

[4] M.Camp, "*Empfindlichkeit von Elektronik gegen EMP und UWB - Phase II*", WIS Report, Armed Forces Scientific Institute for Protection Technologies, Munster, Germany, Okt. 01, AN:005.H-0 A064, AG:UT 243-C


*Biographical notes*

**Michael Camp** was born in Celle, Germany in 1968. He received the Dipl.-Ing. degree in electrical engineering from the University of Hannover (Germany) in 1999. He is currently pursuing the Ph.D. degree at the Institute for Electrical Engineering and Measurement Science at the University of Hannover. His research areas cover high frequency measurement techniques, electronic circuit design under EMC considerations and the susceptibility of electronics to fast transient pulses (UWB). Mr. Camp is a student member of the IEEE Electromagnetic Compatibility (EMC), Antennas and Propagation (AP), Instrumentation and Measurement (IM), Microwaves Theory and Techniques (MTT) societies and author or coauthor of more than 20 scientific papers.

**Heyno Garbe** was born in Germany in 1955. He received his Dipl.-Ing. and Dr.-Ing. from the University of the Federal Armed Forces, Hamburg, Germany, in 1978 and 1986 respectively. Currently he is a Professor at the University of Hannover, Germany. From 1974 to 1986 he served as an officer in the German Army. He holds the rank of a LtCol.(retired). From 1986 to 1991 he was with the Asea Brown Boveri Research Center in Baden, Switzerland. From 1991 to 1992 he was the Research Manager for EMC Baden Ltd. Since 1992 he has been with the University of Hannover where he holds a professorship in the department of electrical engineering and information technology. In addition to lecturing on basic electrical engineering, measurement technology, and EMC, he has developed an active research program related to electromagnetic field effect modelling, testing, and measurement as applied to EMC. Prof. Garbe is also very active in several EMC related national and international standardisation committees. Beside others he is the convenor of the Joint Task Force CISPR/A and TC77B on "TEM Waveguides". He is a member of URSI Com. E, VDE and a Senior Member of IEEE. Beside this Prof. Garbe is the counsellor of the IEEE student branch at the University of Hannover and an associate editor of the IEEE Transactions on EMC.

# Power density in the near field of aperture antennas
## Validation of the ACA Prediction Procedure

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## 1 Introduction

Transmitters generate electromagnetic fields, and certain limits must be observed for these electric and magnetic fields. The relevant Australian standard for limit values and measurement procedures is AS/NZS 2772. Limit values are specified for the electric field E, the magnetic field H and for the power density S, which is defined as:

$$\vec{S} = \vec{E} \times \vec{H} \,. \qquad (1)$$

All quantities in equation (1) are vectors and the x stands for the cross product. In a distance of several wavelengths, or of several times the largest dimension of the antenna – whichever is greater – all three vectors are perpendicular to each other, with S pointing away from the antenna, and E and H are related by the intrinsic impedance $Z_0$ of free space:

$$\left|\vec{E}\right| = Z_0 \left|\vec{H}\right| \quad \Rightarrow \quad \left|\vec{S}\right| = \frac{\left|\vec{E}\right|^2}{Z_0} = Z_0 \left|\vec{H}\right|^2 \quad \left(Z_0 = 377\Omega\right). \qquad (2)$$

The power radiated from an antenna can be considered to pass through a sphere with the antenna in the centre. The surface area of the sphere is given by $4\pi r^2$ (r is the radius of the sphere), and from this it can be derived that the power density S decreases with $1/r^2$.

$$S \propto \frac{1}{r^2}. \qquad (3)$$

If we double the distance from the antenna, we are on a sphere with 4-times the surface, i.e. the radiated power will pass through 4-times the area, and hence the power density will drop to one-fourth.

The fact that actual antennas do not radiate equally in all directions but show a more or less pronounced directivity is described by the antenna gain and the 'equivalent isotropic radiated power' EIRP. These terms are explained quite well in an ACA publication [1].

For practical reasons, it is desirable to predict maximum levels for the electric and magnetic fields, and the power density based on easily accessible parameters, such as EIRP, antenna gain, and radiation diagrams, without the need for expensive measurements. This is not a problem in the undisturbed far field, where equation (2) can be applied safely. Where the far field is disturbed, e.g. due to reflections on large conducting surfaces, for instance the ground, or in the near field of antennas it is a bit more difficult. Some methods to do this are described in [1] in an easy to follow manner.

## 2 Ground reflections

According to [1] ground reflections are taken into account by an increase of the electric field strength to 1.6 times the incident field, equivalent to a reflection coefficient of ±0.6. Exposure limits are often based on the specific absorption rate, which is given by

$$SAR = \frac{E^2}{\sigma} \quad \left(\sigma : \text{electric conductivity}\right). \qquad (4)$$

Thus a 1.6 fold electric field will lead to a $1.6^2 = 2.56$ fold value for the SAR in a conductive material, for instance a human body, in front of the reflecting surface.

The power density S of the propagation wave is a different matter. A reflection coefficient of 0.6 gives a average power density for the reflected wave of $0.6^2 = 0.36$ times the incident wave. Thus, if 100% of power flows towards the reflecting surface (the ground that is), 64% will be absorbed and 36% will be reflected.

# 3 Near Field Power Density

## 3.1 Beam forming region

Equation (3) describes the dependency of the power density in the far field of antennas, where the field propagates as spherical wave. In the beam-forming area near the antenna the power density decreases, in a simple approximation, with 1/r for rectangular aperture antennas, and stays constant for circular aperture antennas, according to [1] and other literature [2, 3].

The idea behind this is that for rectangular aperture antennas the beam propagates as cylindrical wave for some time, before transforming in a wave of spherical shape. Thus the surface area increases proportional with distance first, before going following equation (3) further away (Fig. 1). From this model it can be concluded that this behavior can only be expected for aperture antennas of a distinguished rectangular shape, i.e. where one dimension is considerably larger than the other.

In the case of circular aperture antennas, the wave is assumed to propagate within a tube of constant diameter first, resulting in constant power density (Fig. 2). Further away from the antenna, the wave spreads out in a spherical shape.

## 3.2 Power density simulation results

These assumptions shall now be validated with computer simulations based on a Method-of-Moments program, CONCEPT [4]. Two variants of a rectangular aperture antenna are investigated (Fig 1). In both cases a 7-element dipole array is placed in front of a reflector in a distance of 8 cm. The reflector is a flat rectangle, 0.68 m by 2.4 m, in the first case, and a rectangular reflector 0.6 m by 2.4 m bent in a parabolic curve in the second case. The excitation voltages of the dipoles are: 0.383 $V_0$, 0.707 $V_0$, 0.924 $V_0$, 1.000 $V_0$, 0.924 $V_0$, 0.707 $V_0$, and 0.383 $V_0$, starting at the lowest dipole, the total length of the dipole array is 1.8 m. The feeding voltage $V_0$ is scaled to result in an EIRP of 1kW. The frequency was chosen to be 820 MHz.

The model for the circular aperture antenna is a parabolic dish antenna with two dipoles as excitation (Fig. 2). Both dipoles are fed with $V_0$, with $V_0$ again scaled to achieve an EIRP of 1kW. The dipoles are 9 cm ($\lambda/4$) apart from each other, about 0.5 m in front of the parabolic dish, approximately in its focal point. The radius of the dish is 0.8 m and 1.4 m, respectively.

The models are shown in Figs. 1 and 2 with the resulting current densities. In Fig 3, the 2-dimensional radiation patterns are shown for the four antenna arrangements. The rectangular reflectors result in fairly wide-spread horizontal beams, while the vertical radiation diagrams show a much smaller angle. The parabolic dishes focus the beam in both horizontal and vertical direction in a similar manner. Some parameters for the antennas are listed in Table 1.

In Fig. (4) the power density is shown for the four antenna arrangements along the direction of maximum radiation, in a distance of 0.1 m to 100 m, where 0 m is the location of the dipole arrays, not the reflectors. The power density has been calculated according to equation (1), based on both, electric and the magnetic fields. In the far field the power density is the same for each case, as the same EIRP has been used, and drops with $1/r^2$. Closer to the antennas the dependency deviates from the $1/r^2$ formula.

**Table 1:** Gain and 3-dB angles for the four antenna configurations

| | Rectangular flat reflector | parabolic reflector | Parabolic dish (0.8 m) | Parabolic dish (1.4 m) |
|---|---|---|---|---|
| Gain | 15.2dB | 19.1dB | 23.2dB | 25.5dB |
| Horizontal 3dB-angle | 110° | 45° | 18° | 13° |
| Vertical 3dB-angle | 15° | 15° | 21° | 18° |

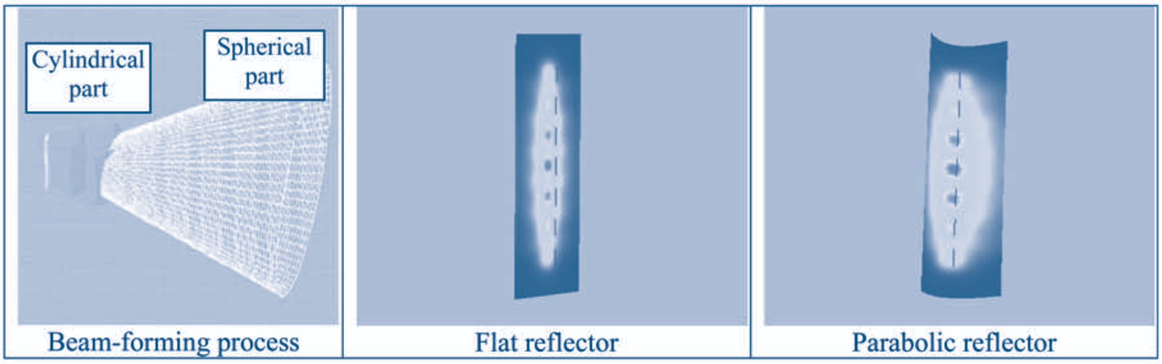



**Figure 1:** 7-Element dipole array with rectangular reflector

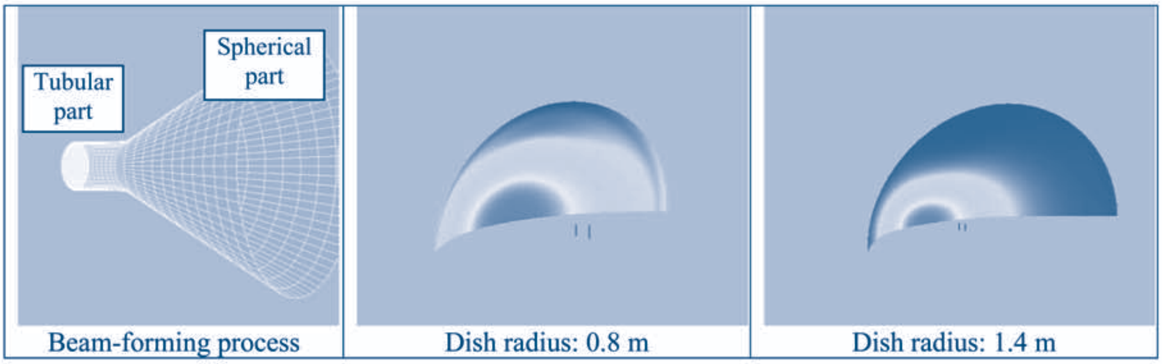



**Figure 2:** 7-Element dipole array with parabolic dish reflectors

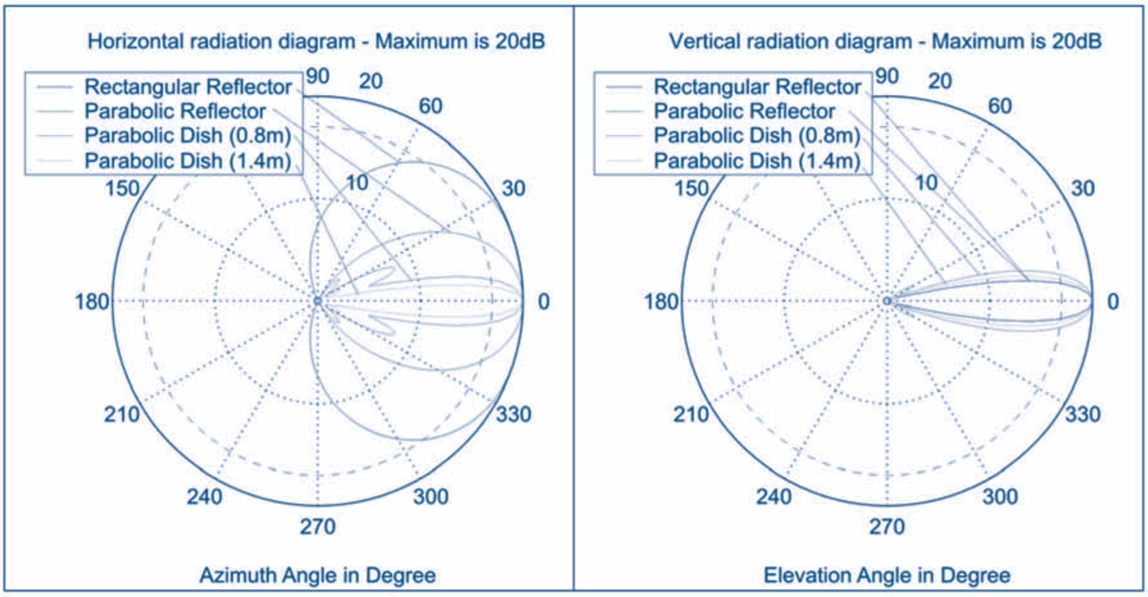



**Figure 3:** Horizontal and vertical radiation diagrams

In the case of the parabolic dish antennas the power density actually drops with decreasing distance, before it again rises sharply. This sharp rise, however, is at a distance very close the actual source dipoles, which are placed at -5cm and 5cm. Not regarding this critical point, it can be said that the larger parabolic dish results in a significant smaller maximum power density.

In Fig. 5 values for the power density are shown when calculated exactly according to equation (1) and only from the electric field strength values according to equation (2). Only very close to the parabolic dish antennas, a difference can be observed.

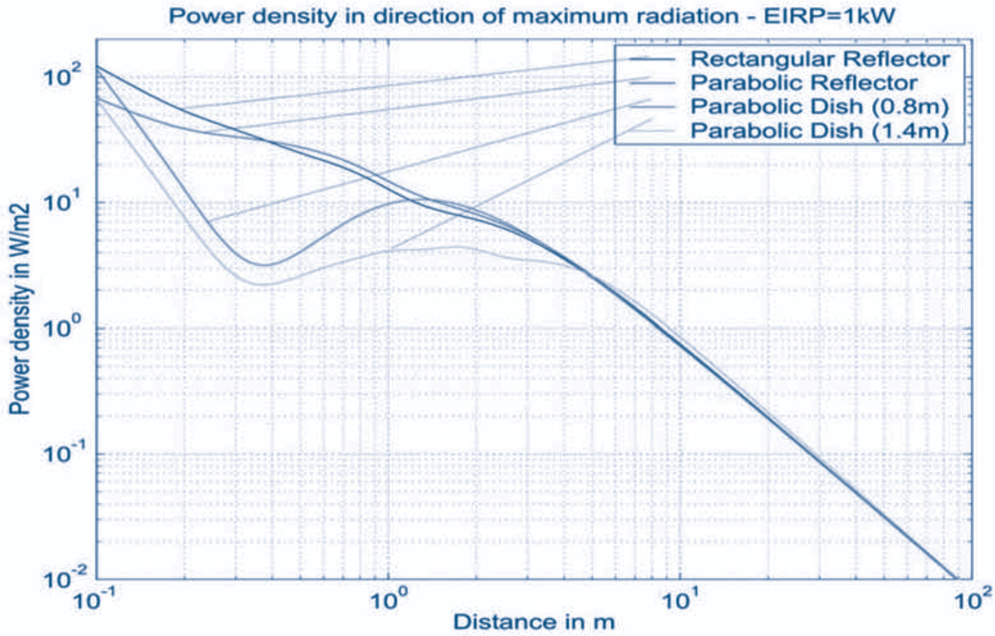



**Figure 4:** Power density comparison for equal EIRP

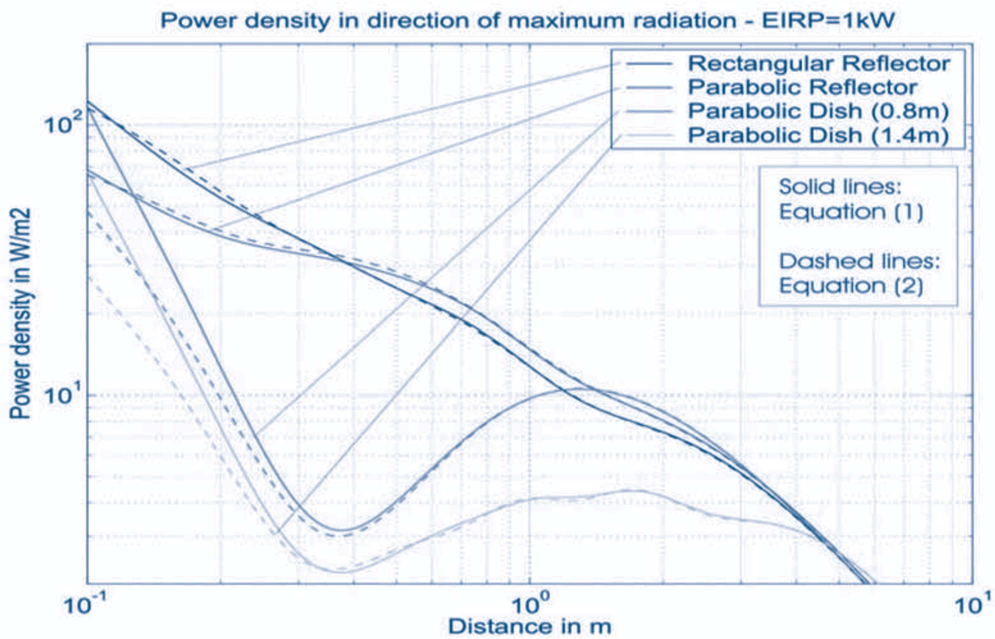



**Figure 5:** Power density according to equation (1) and (2)

### 3.3 Near field power density approximation

Both reflectors for the 7-Element dipole arrays have a largest diagonal dimension of D=2.5 m, the parabolic dish antennas have diameters of 1.6 m and 2.8 m, respectively. The wavelength related to the transmitted frequency of 820 MHz is 0.37 m.

According to [1, section 2.3] the transition point between the 1/r near field dependency and the $1/r^2$ decrease for the power density is, for rectangular aperture antennas, at:

$$R_{T-R} = \frac{0.5D^2}{\lambda} \approx 8.45\, m. \tag{5}$$

For circular aperture antennas the transition point is at:

$$R_{T-C} = \frac{0.16D^2}{\lambda} \approx \begin{cases} 1.11\, m & (D = 1.6\, m) \\ 3.39\, m & (D = 2.8\, m) \end{cases} \quad . \tag{6}$$

Equations (5) and (6) are now applied, and the results are added to the exact graphs for the power density in Fig. (6). Shown as a dashed line is the simple approximations of a 1/r decrease for a distance less than 8.45 m, according to a rectangular aperture antenna of 2.5 m diagonal dimension. There is a good correspondence between the approximation and the exact results, but the transition point seems to be chosen a bit too far away from the centre, and the approximations are slightly below the actual power density values.

In Fig. 1 the current densities are shown for the two reflectors. It can be seen that no significant current flows along the edges of the reflectors. So they do not contribute to the beam-forming process and the effective reflector area is smaller than the physical dimension.

In the case of parabolic dish antennas the estimated values (dashed lines) are well above the actual values for the 0.8 m dish, and slightly above the 1.4 m antenna. The transition point could have been chosen according to equation (12) [1] – $R_{T-12} = D^2 f / 900$ – which would lead to slightly more than double the distance, to 2.33 m and 7.14 m, respectively. That would leave the approximation for the 0.8 m dish in the safe region above the actual values. The

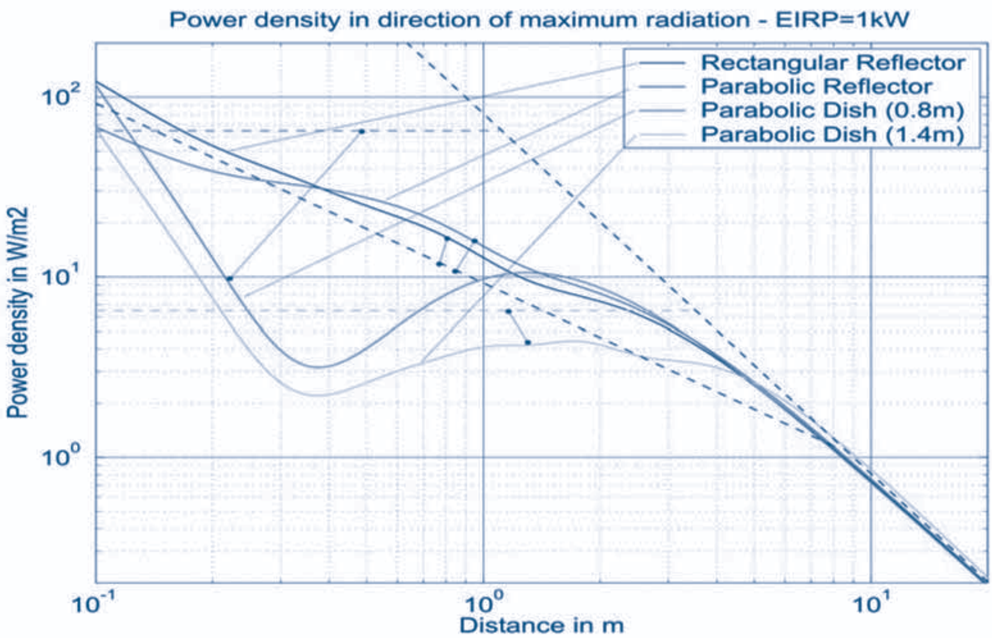



**Figure 6:** Power density – Exact values and ACA procedure

approximation for the 1.4 m dish would come down slightly below the actual values. The explanation is the same as for the rectangular reflectors: only the centre part of the larger parabolic reflector is electromagnetically effective, as can be seen from the current densities in Fig. 2.

## 4 Conclusion

The near field approximation method as described in [1] yielded good results in the example investigated in this paper. In the direction of main radiation the correspondence between power density and the electric field follows closely that for plane waves and free space. Only very close to the actual radiating elements, i.e. the source dipoles in this paper, deviations from the approximated curves must be expected.

It is important that the correct dimensions for the aperture antennas are used. Only parts that contribute to the beam-forming process, i.e. parts that carry significant currents, are to be considered.

## 5 References


[1] Australian Communications Authority: *'Guidelines on the assessment of installations against electromagnetic radiation (EMR) exposure limits'*, http://www.aca.gov.au/consumer_info/issues_alerts/self_assessment.htm

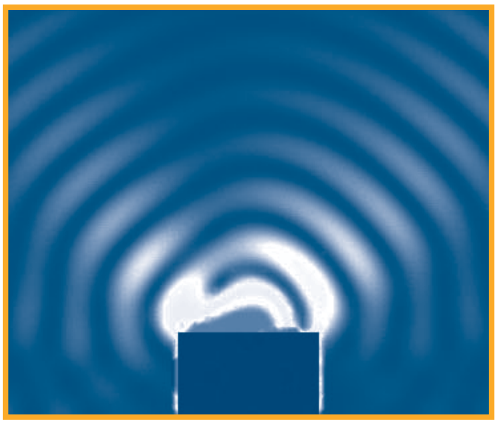
[2] F. Las-Heras, T. K. Sarkar: 'Efficient Near-Field to Far-Field Transformation Techniques for Antenna Measurements' http://www.techonline.com/community/ed_resource/feature_article

[3] Quirino Balzano, Antonio Faraone: 'Human Exposure to Cellular Base Station Antennas', IEEE International Symposium on EMC, 1999, pp. 924-927

[4] CONCEPT Homepage: http://www.tet.tu-harburg.de


Additional graphic representations of field distributions and animated radiation patterns can be found in the 'Technical Corner' on the ACETT webpage at: http://www.acett.org.au.

*The Australian Centre for Electromagnetic Compatibility Technology Transfer (ACETT) is part of the Western Australian Telecommunications Research Institute (WATRI), a co-operation of the University of Western Australia (UWA) and Curtin University of Technology, and is located on the UWA campus in Perth. ACETT has been established with financial support from the Australian Commonwealth Government and involvement of EMC Technologies Pty Ltd as industry partner. The purpose of the centre is to collect and maintain expertise in the area of Electromagnetic Compatibility (EMC) and make it available to industry under the Commonwealth Government's Technology Diffusion Program. ACETT will diffuse leading edge tools and techniques to enable Australian electronic design and manufacturing engineers to meet EMC requirements in the initial design phase. This will make the Australian electronics industry more competitive internationally and help to avoid lengthy and costly trial-and-error approaches. ACETT will provide services to increase the skill level among electronic designers regarding EMC requirements. This means that manufacturers of electronic and electrical products will be able to quickly assess the regulations they must meet for their chosen markets; be able to design their products to meet the necessary requirements right from the start; have a design process that caters for EMC issues at each stage of the product life cycle.*



## Antenna Solution for Automotive Applications (10kHz to 18GHz)

Prepared by
Vicente Rodriguez Ph.D.
RF Engineer
ETS-Lindgren L.P.
1301 Arrow Point Dr.
Cedar Park, TX 78613

### I. Introduction.

Immunity applications in automotive EMC standards call for the generation of very high fields. Over the Years ETS-Lindgren has developed a series of High Power antenna to address these issues. This document proposes a solution that the ETS-Lindgren Field Generation Group staff believes to be suitable for the 10kHz to the 18GHz range.

The main Standards that this solution addresses are the following:

ISO 11451-2
SAE J551-11
95/54 EC Annex VI

All these standards have similar wording. The SAE and the ISO are virtual copies of each other and they both require a highest severity level of 100V/m. ISO contemplates an additional level of severity to be agreed between the test house and the manufacturer. This document assumes that additional level as an internal requirement of the customer that does not fall within the standard. The present solution concentrates on field levels lower than 100V/m. If the Customer is interested in field levels higher than 100V/m the ETS-Lindgren Field Generation Group Staff should be consulted prior to offering this solution.

Additionally the Solution assumes that the field uniformity requirements are those stated in the standard. These requirements are (for SAE and ISO) that the required field level be generated at a reference point located 1m above the ground on to which the vehicle rests (2m for vehicles higher than 3m) and at two points 75cm on either side of the reference point. At these points the field level should be within 3dB of the reference point level. For 95/54 EC the points are 50cm on either side and the highest level of severity is 24V/m with 80% AM modulation. For 95/54 EC the field at the adjacent points must be at least half of the field at the reference point.

For SAE and ISO the Field Uniformity requirement applies over 200MHz for 95/54 EC it applies above 20MHz. Both polarizations can be tested if so required in the test plan.

### II. Solution

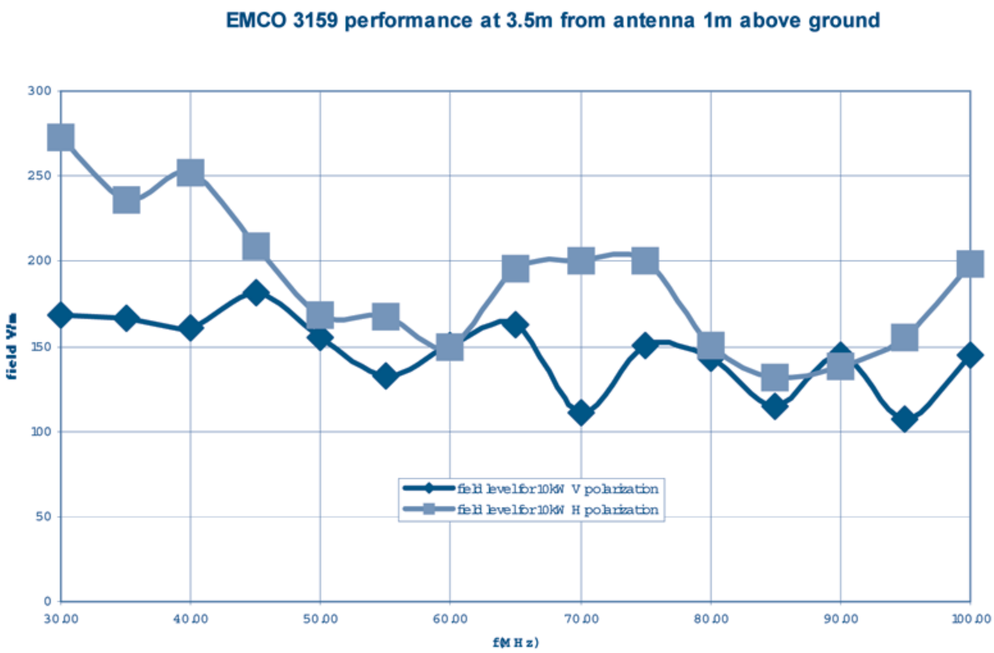
Based on the setup mentioned above the ETS-Lindgren Solution for the 30MHz to 1GHz range is to propose the use of two antennas. A high power biconical antenna, the EMCO 3159, for the 30MHz to 100MHz range and a double ridge guide horn, the EMCO 3112, for the 100MHz to 1GHz are the proposed antenna solution.

For frequencies under 30MHz the Field Generation Group at ETS-Lindgren suggests the use of a stripline/TEM wire approach. The TEM device approach is discussed below in this document. For Frequencies above 1GHz, the double ridge horn approach can be used or instead a collection of Standard Gain Horns or Octave Horns can be proposed.

## III. EMCO 3159 for 30MHz to 100MHz.

The EMCO 3159 is a biconical type antenna with a high power balun and construction.

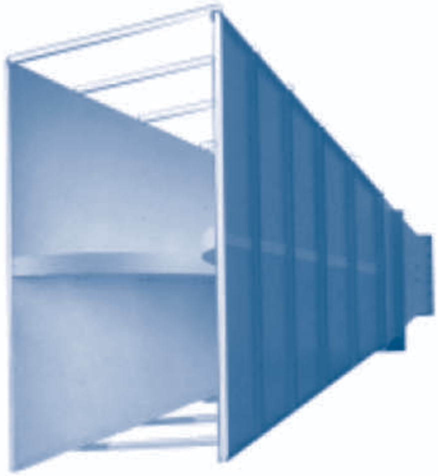
The antenna is designed to accept a 10kW input level and it has been field tested at those high power levels.




The graph above shows measurements that were performed with the antenna on its positioning device 1.8m above ground and 3.5meters from the reference point. The reference point was located 1m above the ground. At 2 meters distance it is expected that a power level less than 10kW is necessary to develop the required field levels. The EMCO 3159 comes with a positioner that allows for polarization of the antenna.

## IV. EMCO 3112 for 100MHz to 1000MHz.

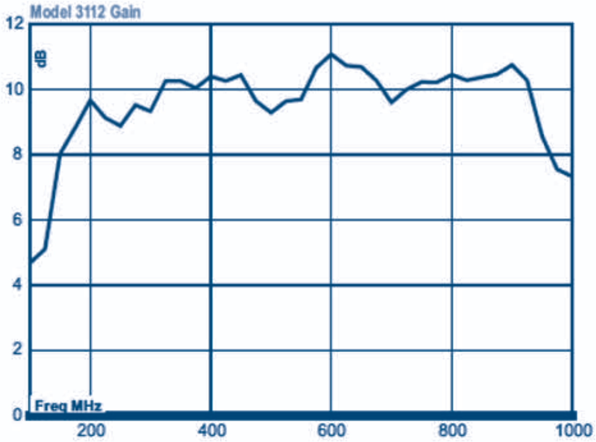
The EMCO 3112 is a scaled up version of the popular EMCO 3106 dual ridge horn. The EMCO 3112 brings the excellent gain characteristics of the 3106 down to 100MHz.



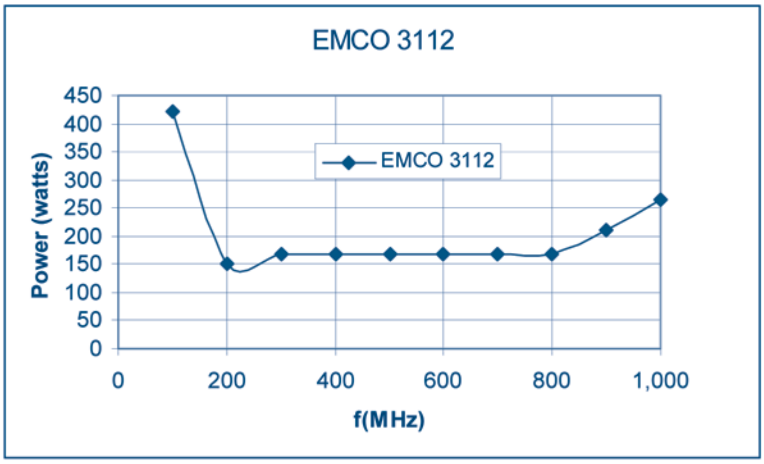
*ETS-Lindgren's Model 3112 Double-Ridged Waveguide Horn*

The gain of the 3112 at the lowest end of its operational range is about 5dBi. The gain improves to a level higher than 8dBi at about 150MHz. The gain stays higher than 9dBi up to 950MHz where it drops down to 7dBi at 1GHz.

**Model 3112 Gain**




Using the gain values it is possible to derive the required power to attain 100V/m at 2 meters distance (2m is the minimum distance between the reference point and the antenna phase center according to all the standards). The computation shows that 500Watts is all that it is needed to obtain the required 100V/m CW field levels at a distance of 2m from the aperture. (NOTE: the computed data does not take into account the losses in the cables but it gives a general idea of the power requirements of the antenna).

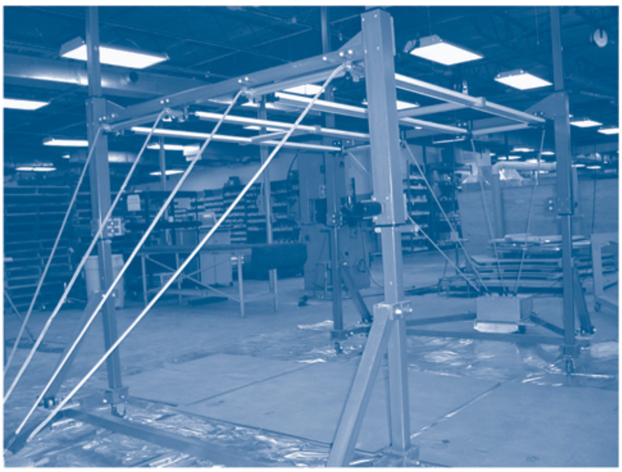



The EMCO 3112 is a large antenna having the following dimensions: 80 inches (2.03m) wide, 55 inches (1.39m) in height, and 72 inches (1.82m) in depth. The antenna would be provided with a supporting mechanism that allows for polarization change.

## V. Below 30MHz Testing.

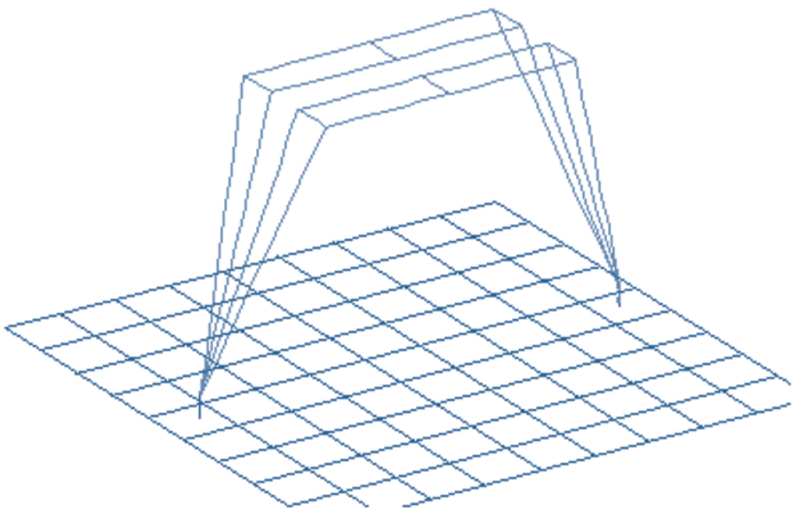
For Frequencies below 30MHz manageable size antennas are not very efficient. Wavelengths get in the order of tens of meters and half wavelength resonant radiators become too large to be inside a chamber. All the above-mentioned standards allow for the use of transmission line systems or TLS.

The Field Generation Group at ETS-Lindgren has over the years developed solutions for testing at the low frequency range (100kHz to 30MHz). Among them are variable height E-H field generators that are suspended from the ceiling of the chamber and whose supporting frame can be nested in to the absorber treatment when not in use. The Field Generation Group at ETS-Lindgren however suggest a less expensive solution using a fixed height self supported TEM transmission line based on its successful E/H generator for the Belcore Standard.



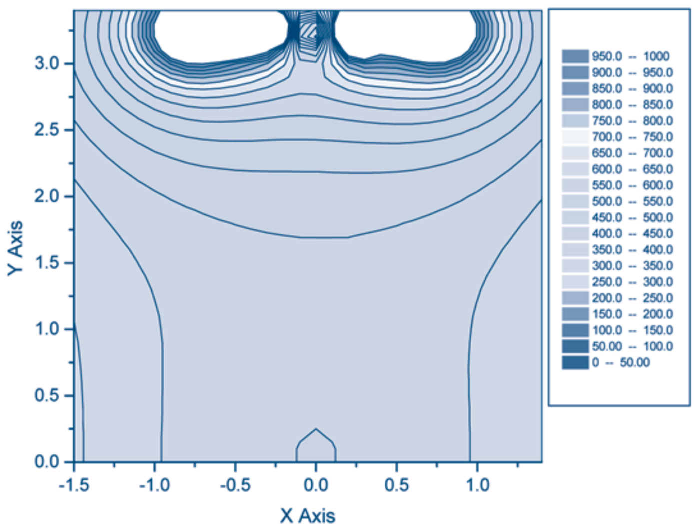
The TLS solution for automotive that ETS-Lindgren suggests is a 10kW fixed height Stripline. Hence, the Belcore system is simplified by having only a single height setting and also by taking away the H-field generation mode. Scaled data from measurements on the Belcore system suggests that 3.5kW of power is enough to generate the 100v/m required for the highest severity level.

However the automotive TLS recommended solution will operate at a height of 3.25m, this allows for vehicles up to 2.75meters in height to be tested. All of the above mentioned Standards call for 50cm of minimum distance between the TLS and any part of the vehicle.

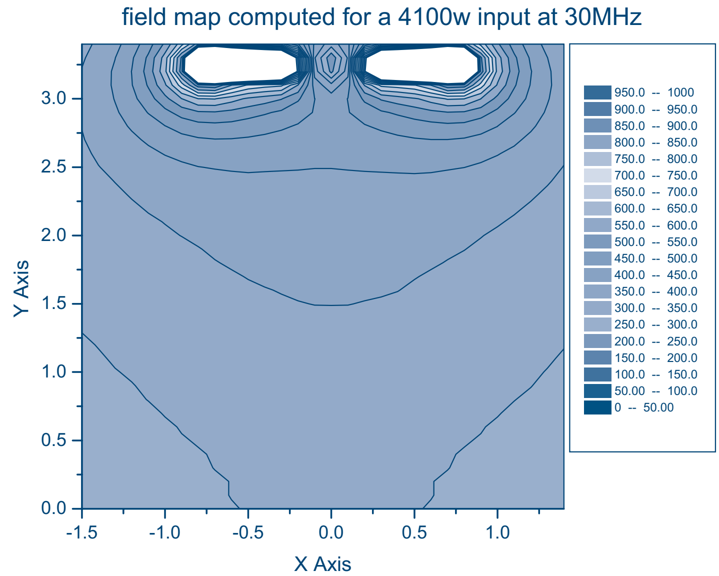


Numerical models suggest that the fields obtained at 1m above ground with an input of 6500kW are in the order of 400V/m

Field map computed for a 6500W input for the TLS at 10kHz



The model does not take into account losses in the unum or any resonant behavior in the chamber that may require additional power levels to obtain the needed field. Additionally the structure is fed with a 50 ohm to 100 ohm unum impedance transformer. The wire structure has a characteristic impedance of 75 to 123 ohms over its frequency range. Some VSWR losses are expected. The results are for CW and do not take in to account the need for 80%AM modulation. For these reasons the Field Generation Group at ETS-Lindgren suggest the use of a 10kW amplifier although a 5kW amplifier may be sufficient at most of the frequencies in the range.




The length of the structure is 3m, however longer structures can be used to illuminate longer vehicles without affecting the performance of the TLS.

*Please note that a discussion paper presents a discussion around, or abstraction of, the papers title and should be treated as informative only.*

## THE DAWN OF EMC REGULATION

Received from Dr. Franz Schlagenhaufer (franz-s@watri.org.au) Western Australian Telecommunications Research Institute (WATRI)

EMC is no invention of modern times, and EMC regulations were put in place as early as 1892. In article 12 of the 'Gesetz über das Telegraphenwesen des Deutschen Reichs' (Telegraph Act for the German Empire) of April 6, 1892, Kaiser Wilhelm declared how to deal with cases of interference in electrical installations. The relevant paragraph 12 states:

*'Electrical installations, if they cause or are feared to cause a disturbance to an already existing conductor, must be designed, as far as possible, in such a way, at the expense of that party which is cause for the disturbance by a later installation or by later modifications to an existing installation, that the conductors do not disturb each other.'*

There are a number of interesting points in this bureaucratic lingo:

- The act supports the 'polluters pays' principle, i.e. the party which comes later and disturbs an existing interference-free environment is responsible for fixing the problems, compared to the modern principle of compatibility;
- Conductors are explicitly mentioned as source and victim of potential interference;
- There is a softener in form of the 'as far as possible' to give lawyers a change to also make a living.

Reichs-Gesetzblatt.

№ 21.

Inhalt: Gesetz über das Telegraphenwesen des Deutschen Reichs. S. 407

(Nr. 2015.) Gesetz über das Telegraphenwesen des Deutschen Reichs. Vom 6. April 1892.

Wir Wilhelm, von Gottes Gnaden Deutscher Kaiser, König von Preußen &c.

verordnen im Namen des Reichs, nach erfolgter Zustimmung des Bundesraths und des Reichstags, was folgt:

§. 1.

Das Recht, Telegraphenanlagen für die Vermittelung von Nachrichten zu errichten und zu betreiben, steht ausschließlich dem Reich zu. Unter Telegraphenanlagen sind die Fernsprechanlagen mit begriffen.

§. 12.

Elektrische Anlagen sind, wenn eine Störung des Betriebes der einen Leitung durch die andere eingetreten oder zu befürchten ist, auf Kosten desjenigen Theiles, welcher durch eine spätere Anlage oder durch eine später eintretende Aenderung seiner bestehenden Anlage diese Störung oder die Gefahr derselben veranlaßt, nach Möglichkeit so auszuführen, daß sie sich nicht störend beeinflussen.

§. 15.

Die Bestimmungen dieses Gesetzes gelten für Bayern und Württemberg mit der Maßgabe, daß für ihre Gebiete die für das Reich festgestellten Rechte diesen Bundesstaaten zustehen und daß die Bestimmungen des §. 7 auf den inneren Verkehr dieser Bundesstaaten keine Anwendung finden.

Urkundlich unter Unserer Höchsteigenhändigen Unterschrift und beigedrucktem Kaiserlichen Insiegel.

Gegeben im Schloß zu Berlin, den 6. April 1892.

(L. S.) Wilhelm.

Graf von Caprivi.

Wisdom is not a product of schooling but of the life-long attempt to acquire it.
— *Albert Einstein*

## CHANGE IN UK REGULATORY BODIES

Ofcom is now the regulator for the UK communications industries, with responsibilities across television, radio, telecommunications and wireless communications services. Ofcom exists to further the interests of citizen-consumers as the communications industries enter the digital age. To do this Ofcom shall:

* Balance the promotion of choice and competition with the duty to foster plurality, informed citizenship, protect viewers, listeners and customers and promote cultural diversity.
* Serve the interests of the citizen-consumer as the communications industry enters the digital age.
* Support the need for innovators, creators and investors to flourish within markets driven by full and fair competition between all providers.
* Encourage the evolution of electronic media and communications networks to the greater benefit of all who live in the United Kingdom.

Ofcom will inherit the duties of the five existing regulators it will replace - the Broadcasting Standards Commission, the Independent Television Commission, Oftel, the Radio Authority and the Radiocommunications Agency. More information can be found at http://www.ofcom.org.uk/.

## NEW PRODUCT

### NEW RF SURVEY METER FOR SAFETY MEASUREMENTS

Cedar Park, Texas, February 1, 2003 — ETS-Lindgren introduced the HI-2200 RF Survey Meter, the newest addition to its Holaday line of EMF Measurement Instruments. A simple solution for basic RF safety measurements, the HI-2200 RF Survey Meter provides a compact measurement system including interchangeable probes. The HI-2200 System is a lightweight, easy to hold instrument for less accessible measurement locations such as towers and ladder access situations.

The HI-2200 covers the 100 kHz to 5 GHz frequency range, providing broad coverage for common telecommunication and broadcast applications. The survey meter's broad dynamic range — as low as 0.3 volts/meter to over 800 volts/meter without range changing — covers all common safety limits. The display module has easy to use Spatial and Temporal Averaging. Additional features include data logging capability, user selectable readout units, an adjustable alarm threshold, and an RS-232 data interface.

ETS-Lindgren is an international manufacturer of components and systems to measure, shield, and control electromagnetic and acoustic energy. The company's products are used for electromagnetic compatibility (EMC), microwave and wireless testing, electromagnetic field (EMF) measurement, radio frequency (RF) personal safety monitoring, and control of acoustic environments.

ETS-Lindgren is headquartered in Cedar Park, Texas, with manufacturing facilities in the USA, Europe and Asia. The company is a wholly owned subsidiary of ESCO Technologies (symbol ESE), St. Louis, Missouri, a New York Stock Exchange (NYSE) listed company. htpp://www.emctest.com/.

*The EMC Society does not necessarily endorse this product, this information is presented because of its general industry interest.*

## STUDENT PROJECT GRANT

The EMC Society could make up to $1,000 available to one Electrical or Electronic Engineering student project. The grant is to be made to the project that in the opinion of the National Council has a novel objective that would most benefit from the conquering of a unique electromagnetic compatibility aspect. It is expected that this offer would be most suitable for final year or postgraduate students. The overall project need not be on the subject of EMC itself. Students are required to identify how the grant will be used to resolve the particular EMC issue to expedite the project's primary technical outcome. The announcement of this grant is usually made at the start of the academic year to encourage students and supervisors to formulate an appropriate avenue of electrical or electronic engineering development especially in response to this opportunity.

Students should submit a 750 word or less application as follows:

* A brief description of the project and its primary technical outcome.
* An outline of the particular EMC facet of the project.
* An engineering plan of how the grant could be used to resolve the particular EMC issue and thus enhance the outcome of the overall project.
* How use of the grant would reduce the overall engineering risks associated with the project.
* An estimate of the costs involved.
* All submissions should include the endorsement of the project supervisor.

There is no set format for grant applications, but the points listed above should be covered. Typical use of the grant may be as follows:

* Enable and determine compliance to a real world EMC specification as a project objective.
* Calibrate an unusual E or H field transducer or link.
* Commission a site survey to better understand the EM environment in which the project is destined.
* Hiring of specialised equipment to measure a radiated or conducted EM parameter.
* Development of a specialised enclosure for an instrument designed to operate in a hostile field.

Students should ensure that where external commercial goods and services are required that the cost is commensurate with the grant, as no extensions can be made. Payment of the grant is made to the winner's Engineering faculty. Submissions can be sent to to enquiries@emsca.org.au. At the conclusion of the project, a brief report is required and an article on the project may be featured in the EMC Society's Newsletter.

## STANDARDS UPDATE

### NEW USER-FRIENDLY CISPR 16 PUBLISHED

A restructured and far more user-friendly version of CISPR 16, one of the most popular IEC series of standards, was published in November 2003 by the International Electrotechnical Commission. The revamping of the publication, covering all aspects of radio disturbance and immunity measuring apparatus and methods, was developed over the past two years by an ad hoc committee of CISPR A, the IEC subcommittee of CISPR* in charge of radio interference measurements and statistical methods.

One of the main reasons behind the decision to reorganize the publication was the voluminous content and page count of each of the four parts that composed the original CISPR 16. The sheer volume of each part was felt to hinder a proper tracking down of the specifications it contained, thus making it not sufficiently user-friendly. Don Heirman, chairman of CISPR A explained that "too-frequent amendments resulted ultimately in too-frequent new editions. This led to standards users having to buy new editions far too often if they wished to keep up to date."

The task given the ad hoc committee was to create smaller, subject-related, self-contained publications that would provide users with all they needed on one subject. All specifications that were part of the old set are included in the restructured version. Heirman added that "standards that have been newly voted upon are also included to avoid re-balloting all the material." Numbering for the publications will be 16-1-X, 16-2-X, 16-3 and 16-4-X, where the "X" values will range from 1 to 5 depending on the subject matter. The table below describes the old and new structure of CISPR 16:

- CISPR 16-1-1 Measuring apparatus
- CISPR 16-1-2 Ancillary equipment - conducted disturbances
- CISPR 16-1-3 Ancillary equipment - disturbance power
- CISPR 16-1-4 Antenna calibration test sites for 30 to 1 000 MHz
- CISPR 16-1-5 Conducted disturbance measurements
- CISPR 16-2-1 Conducted disturbance measurements
- CISPR 16-2-2 Measurement of disturbance power
- CISPR 16-2-3 Radiated disturbance measurements
- CISPR 16-2-4 Immunity measurements
- CISPR 16-3 CISPR technical reports
- CISPR 16-4-1 Uncertainties in standardized EMC tests
- CISPR 16-4-3 Statistical considerations in the determination of EMC compliance of mass-produced products
- CISPR 16-4-4 Statistics of complaints and a model for the calculation of limits
- CISPR 16-4-2 Measurement instrumentation uncertainty

Visit http://www.iec.ch/ for more information.

## EMC TRAINING COURSES

### EMC COURSES FEBRUARY - APRIL 2004

Presented by European Engineer Keith Armstrong
Hosted by EMC Technologies Pty Ltd

Euro-engineer Keith Armstrong will be visiting Australia-New Zealand February-April 2004 to present a series of EMC courses to industry and the public, sponsored by EMC Technologies. The courses will be presented in each capital city of Australia, plus Auckland and Christchurch, and will be presented in convenient modules ranging from introductory to advanced level. They all use plain English and simple mathematics to describe practical methods proven to have great benefits for quickly achieving EMC at low cost. There will be an emphasis on emerging EMC and signal integrity design challenges associated with the latest types of ICs and co-located wireless data communications.

Keith graduated from Imperial College London in 1972 with an Honors degree in electrical engineering. He has been a member of the IEE since 1977, a U.K. Chartered Engineer since 1978, a European Engineer (Group 1) since 1988 and a member of the IEEE's EMC society since 1997. Cherry Clough Consultants was started by Keith in 1990 to help companies reduce costs and project timescales whilst also complying with the EMC Directive and other regulations world-wide, using very practical and well-proven methods. Keith has solved very many EMC problems in industries ranging from consumer appliances through automotive and IT to large industrial plant using low-cost techniques.

Keith has written many articles, presented many professional papers, demonstrations, and training courses on EMC. He has chaired the IEE's Professional Group on EMC, now chairs the IEE's Working Group on "EMC and Functional Safety" and is a member of the IEC 61000-1-2 (EMC and functional safety) committee, a consultant member of the EMC Test Labs Association (EMCTLA), and a member of the EMC Industries Association (EMCIA). He Co-authored "EMC for Systems and Installations" (Newnes, 2000) with Tim Williams (Elmac Services, U.K.). Has written a great many articles on EMC in professional journals and trade magazines, including 3 annual series with 6 parts each for the EMC & Compliance Journal: "Design for EMC" (1999), many parts of which have been presented in this newsletter, "EMC for Systems and Installations" (2000), and "EMC testing" (2001).

*Keith Armstrong*
*BSc(Elec Eng)*

Visit www.emctech.com.au for course content, venues, dates, costs and registration.

# ENGINEERS AUSTRALIA
## Electromagnetic Compatibity Society
## Membership Application Form

Please return this form to:

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Date of Birth

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Alternate Address

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Employer Position

FEES (Including GST & applicable to year commencing 1st July)

| | | |
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| (a) | EA Member, other than a student | $ 88.00 |
| (b) | Non EA Member | $ 93.50 |
| (c) | Corporate Member | $ 550.00 |
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| (e) | Student | FREE |

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Signature ________________ Amount $ ________

## CORPORATE MEMBERSHIP

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

**ADVANTECH ELECTRONICS Pty Ltd** is a registered NATA test house with accreditations for testing to TS001, TS002, TS004, TS006 & TS008.
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## INSTITUTIONAL LISTINGS

An Institutional Listing recognises contributions to support the publication of the **ENGINEERS AUSTRALIA** EMC SOCIETY Newsletter. Minimum rates are $250.00 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; or, sent to newsletter@emcsa.org.au.

## CAD SYSTEM THAT WAS A CAD

An engineering company invested heavily in a networked computer-aided design (CAD) system. However, the system's many advantages were overshadowed by the all too regular problems it suffered. The system would crash unexpectedly, sometimes hours of work were lost or corrupted and circuit failures seemed to be almost a monthly event. At first these were assumed to be just "teething troubles" but as time went on, and design work slipped further and further behind schedule, relations with the system's supplier became increasingly difficult. Only when one of the engineering team read an article in a professional journal, did they realise that the problem might not be the system, but the environment. They soon observed that the system's failures coincided with the operation of a large drawing copying machine, which was injecting switching transients onto the ring main. *(Furse Electronic Systems Protection Handbook, 1996, page 15)*

More on this topic...
Transient faults (in computer systems) are triggered by environmental conditions such as power-line fluctuation, electro-magnetic inter-ference, or radiation. These faults rarely do any lasting damage to the component affected, although they can induce an erroneous state in the system. According to several studies, transient faults occur far more often than permanent ones, and are also harder to detect. Curiously, most computer failures are based on either software faults or permanent hardware faults, to the exclusion of the transient and intermittent hardware types. Yet many studies show these types are much more frequent than permanent faults. The problem is that they are much harder to track down. *(IEEE Spectrum, August 1999, pages 50 and 51,"Fault injection spot-checks computer system dependability" J V Carriera, D Costa, and J G Silva)*

And yet more...
Late last year, lightning struck in the car park area of a UK Building Society's town centre headquarters. Large voltage surges knocked out the security cameras, and were transmitted to other electronic equipment in three buildings via the connecting cables. Once they had entered the building's electrical systems, the voltage surges damaged the security system, fire alarm and distributed computer equipment. Latent damage was also caused to the interface between the fire alarm and the radio tag-operated automatic door system, but this went unnoticed at the time. The problem was identified only when a fire alarm went off some weeks later and staff were unable to exit through the automatic doors. Fortunately it was a false alarm. *(Electrical Review, Vol 227 No 12, 10-30 June 94, page 90, "Don't lose your data in a flash" by Tony Harrison)*

The ideals that have lighted my way and time after time have give me new courage to face life cheerfully, have been Kindness, Beauty and Truth. — *Albert Einstein*

## IN HOBART

Hobart in Tasmania suffered an unusual blight. Residents all over town found themselves trapped in their garages when the remote controls that operate the garage doors suddenly failed to function. Roll-a-door companies were flooded with calls from angry garage owners and were at first completely nonplussed by the problem. Then the explanation emerged: the aircraft carrier USS Carl Vinson had just cruised majestically into the town's docks, equipped with navigational radar employing the same frequency as the remote controls for the town's garage doors. According to the local newspaper The Advocate, an apologetic Lieutenant Dave Waterman, the ship's public affairs officer, said that the problem would only occur when the ship was arriving and leaving. *(New Scientist, 24th April 1999, page 100)*

**EXCHANGE RATES**

| | |
|---|---|
| USA | 0.7920 |
| EURO | 0.6268 |
| UK | 0.4227 |
| YEN | 84.10 |

## POWER SHOWER

A (CE marked) portable PC carried up the stairs in a domestic household whilst operating, reliably caused the "power shower" in the bathroom to turn itself off if it was in use at the time. *(Personal communication in 1997)*

## WHO LET THE CAT OUT

Computers used in a room close to a door fitted with a high-technology (magnetic) cat flap caused the latches on the cat flaps to rattle continuously whenever Windows was loaded or a Windows application run. *(From the New Scientist magazine, 7th May 1997)*

## EMC WITHOUT IMMUNITY IS NOT EMC

The current Australian regime (for EMC compliance) only covers emissions requirements, but there has been extensive discussion about whether immunity should also be made mandatory. ...a submission from a major telecommunications network company (Telstra) outlined difficulties it has experienced in dealing with customer equipment susceptible to interference. The ACA mandates interoperability, safety, and emissions standards but telecoms carriers have little control over the EMC quality of equipment connected to their network. *(Chris Zombolas of EMC Technologies Pty Ltd: "Australian framework comes under review", Approval, Sep/Oct 2000 pp7-8.)*

If we knew what it was we were doing, it would not be called research, would it? — *Albert Einstein*

**The information on this page is not verified fact; it is intended to provoke interest in, and an understanding of, Electromagnetic Compatibility.**