Brief Historical Review and Bibliography for Intentional Electromagnetic Interference (IEMI)

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Abstract

In the late 1990s, concerns were raised that the advancement of solid state high power electromagnetic sources and more advanced antennas systems could allow terrorists, criminals and hackers to interfere with the operation of modern electronic systems. In particular there was great concern that the critical infrastructures (e.g. power, telecommunications, transportation, etc.) could be disrupted using new technologies. Scientists and engineers throughout the world began to evaluate potential threats and their ability to create upset and damage; this field of study was initially known as EM Terrorism, but was changed to the more encompassing term of Intentional Electromagnetic Interference (IEMI). This paper reviews the early history of this field and provides a bibliography of important papers covering the overall threat, the development of potential weapons, the susceptibility of equipment and systems, protection methods and standardization.

1. Introduction

Although there were a few early papers dealing with the subject of intentional interference of electronics [1], there were three separate, significant events in 1999 that were responsible for informing the technical community of the importance of the topic. These including a workshop on EM Terrorism at the EMC Zurich Symposium in February 1999 [2], the decision by the International Electrotechnical Commisssion (IEC SC 77C) to add IEMI to its standardization program in June 1999 and the decision by URSI to publish a "Resolution of Criminal Activities using Electromagnetic Tools" in August 1999 [3]. The term IEMI was coined at EMC Zurich in 2001 [4] to replace the term, EM Terrorism". Standards written by IEC SC 77C in later years also used the term IEMI [5]. In 2004 the IEEE EMC Society published a Special Transactions Issue on HPEM and IEMI that is a good reference for those who wish to understand the field [6].

In the past 15 years there have been literally hundred of papers written dealing with IEMI, and the purpose of this paper is to highlight some of the important papers covering the topics of the overall threat, the development of potential weapons, the susceptibility of equipment and systems, the development of protection methods and standardization in the field. Each of these topics is mentioned in separate sections with important references listed. Because of space limitations, we will not be able to list all important papers, but will try to reference those that are broad in their coverage.

2. The Overall Threat of IEMI

Some early papers are included here along with more recent publications. These papers discuss the possible scenarios that could used against commercial electronics along with a few cases where attacks were threatened or did occur.

- Loborev V. M., Parfenov Y. V. and Zdoukhov L. N., "The Modern Research Problems," AMEREM'96, Albuquerque, USA, May 27-31, 1996, p. 288.
- "City surrenders to £400m gangs", The Sunday Times, London, 2 June 1996.
- Gardner, R. L., "Electromagnetic Terrorism: A Real Danger," Proceedings of the XIth Symposium on Electromagnetic Compatibility, Wroclaw, Poland, June 1998.
- Sawyer, D., "20/20 Segment on Non-lethal Weapons," American Broadcasting Company (ABC), aired in February 1999.

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- Wik, M. W., Radasky, W. A. and Gardner, R. L., "Intentional Electromagnetic Interference (EMI) -- What is the Threat and What Can We Do About It?" Fifteenth International Wroclaw Symposium on EMC, 27-30 June 2000, pp. 896-897.
- Radasky, W. A. and Wik, M. W., "Overview of the Threat of Intentional Electromagnetic Interference (IEMI)," IEEE EMC Quarterly Magazine, August 2003, pp. 14-17.
- Thottappillil, R., et al., "Response of Civilian Facilities to Intentional Electromagnetic Interference (IEMI), with Emphasis on the Swedish Railway Network," EMC Europe Workshop, Electromagnetic Compatibility of Wireless Systems, Rome, Italy, 19-21 September 2005.
- Serafin, D. J. and Dupouy, D., "Potential EIMI Threats Against Civilian Air Traffic," URSI XXVIIIth General Assembly, New Delhi, India, October 23-29, 2005.
- Fortov, V., Parfenov, Yu., Siniy, L. and Zdoukhov, L., "Russian Research of Intentional Electromagnetic Disturbances Over the Past Ten Years," AMEREM 2006 Conference, Albuquerque, USA, 9-14 July 2006.
- Giri, D. V. et al., "A Preliminary Assessment of Radio Frequency Threats to Airports," EUROEM 2008, European Electromagnetics, Lausanne, Switzerland, 21-25 July 2008.
- Radasky, W. A. and E. B. Savage, "The Threat of Intentional Electromagnetic Interference (IEMI) to the Control of Supergrids," Electra Magazine, CIGRE, No. 261, April 2012.

3. The Development of Potential Weapons

The development of compact electromagnetic sources and antennas has been significant over the years especially in the area of broadband sources. The impulse radiating antenna (IRA) development allows the efficient launching of fast rising pulses. The IEC also has documented levels of source development dependent on the capabilities of those building them.

- Bohl, J., Stark, R. H. and Wollman, G., "RF Weapons for Non-Lethal Interference and Destruction of Communication, Information and Electronic Systems," 2nd European Workshop on Survivability, Netherlands, 23-25 March 2004.
- Baum, C., et al., "JOLT: a highly directive, very intensive, impulse-like radiator," Proceedings of the IEEE, Vol. 92, Issue 7, July 2004, pp. 1096-1109.
- Sabath, F., Bäckström, M., Nordström, B., Serafin, D., Kaiser, A., Kerr, B. and Nitsch, D., "Survey of Worldwide High Power Microwave Narrow Band Test Facilities," IEEE EMC Transactions Special Issue on IEMI, Vol. 46, No. 3, August 2004.
- Prather, D. P., Baum, C. E., Torres, R. J., Sabath, F. and Nitsch, D., "Survey of Worldwide Wideband Capabilities," IEEE EMC Transactions Special Issue on IEMI, Vol. 46, No. 3, August 2004.

4. The Susceptibility of Equipment and Systems

Great progress has been made over the years testing different types of commercial equipment against both narrowband and wideband electromagnetic field transients and conducted transients (due to both coupled fields and to injected voltages) to determine susceptibility levels for equipment. It is difficult to pick the "best" sets of data, but an attempt is made by the authors here. In addition the method of classifying narrowband and wideband waveforms was an important development for dealing with the IEMI threat [5].

- Bäckström, M., "HPM testing of a Car: A Representative Example of the Susceptibility of Civil Systems," 13th International Zurich Symposium Supplement, February 1999, pp. 189-190.
- LoVetri, J., Wilburs, A. T. M. and Zwamborn, A. P. M., "Microwave Interaction with a Personal Computer: Experiment and Modeling," Proc. 13th International Zurich Symposium on EMC, 1999, pp. 203-206.
- Radasky, W. A., Messier, M. A. and Wik, M. W., "Intentional Electromagnetic Interference (EMI) – Test and Data Implications," Zurich EMC Symposium, February 2001.
- Nitsch, D., Sabath, F., Schmidt, H.-U. and C. Braun, "Comparison of the HPM and UWB Susceptibility of Modern Microprocessor Boards," System Design and Assessment Note 36, 2002; Proc. 15th Int. Zurich Symposium on EMC, 2003, pp. 121-126.
- Giri, D. V. and Tesche, F., "Classification of Intentional Electromagnetic Environments (IEME)," IEEE EMC Transactions Special Issue on IEMI, Vol. 46, No. 3, August 2004.
- Bäckström, M. and Lövstrand, K.G., "Susceptibility of Electronic Systems to High-Power Microwaves: Summary of Test Experience," IEEE Transactions on Electromagnetic Compatibility, Vol. 46, No. 3, August 2004, pp. 396–403.

- Hoad, R., Carter, N., Herke, D. and Watkins, S., "Trends in EM Susceptibility of IT Equipment," IEEE Transactions on Electromagnetic Compatibility, Vol. 46, No. 3, August 2004.
- Parfenov, Yu., Zdoukhov, L., Radasky, W. and Ianoz, M., "Conducted IEMI Threats for Commercial Buildings," IEEE EMC Transactions Special Issue on IEMI, Vol. 46, No. 3, August 2004.
- Nilsson, T., Lundén, O. and Bäckström, M., "HPM Susceptibility Measurements on GPS and WLAN Systems," EMC Europe Workshop, Electromagnetic Compatibility of Wireless Systems, Rome, Italy, 19-21 September 2005.
- Arnesen, O.H., et al., "High Power Microwave effects on Civilian equipment," XXVIIIth General Assembly of International Union Radio Science (URSI), New Delhi, 23-29 October 2005.
- Månsson, D., Thottappillil, R., Bäckström, M. and Lundén, O., "Vulnerability of European Rail Traffic Management System to Radiated Intentional EMI," IEEE Transactions on Electromagnetic Compatibility, Vol. 50, No. 1, pp. 101-109, Feb. 2008.
- Månsson, D., Thottappillil, R., Nilsson, T., Lundén, O. and Bäckström, M., "Susceptibility of Civilian GPS Receivers to Electromagnetic Radiation," IEEE Transactions on Electromagnetic Compatibility, Vol. 50, No. 2, pp. 434-437, May 2008.
- Månsson, D., Thottappillil, R. and Bäckström, M., "Propagation of UWB transients in low-voltage power installation networks," IEEE Transactions on Electromagnetic Compatibility, Vol. 50, No. 3, pp. 619-629, Aug. 2008.
- Radasky, W. A. and Savage, E. B., "International Electromagnetic Interference (IEMI and its Impact on the U.S. Power Grid," Meta-R-323, January 2010.
- Palisek L. and Suchy L., "High Power Microwave Effects on Computer Networks," 10th Int. Symposium on Electromagnetic Compatibility (EMC Europe 2011), York, UK, September 26-30, 2011.
- Hagmann H. et al., "Application and Propagation of Transient Pulses on Power Supply Networks," 10th Int. Symposium on Electromagnetic Compatibility (EMC Europe 2011), York, UK, September 26-30, 2011.
- Parfenov, Y. V., Radasky, W. A., Titov, B. A. and Zdoukhov, L. N., "The Method for Evaluating the Probability of Failures of Digital Devices under the Influence of Short Electromagnetic Pulses," Asia-Pacific EMC Symposium, Singapore, May 2012, pp. 353-356.
- Savage, E. and Radasky, W., "IEMI Evaluation of Network Protectors," IEEE EMC Symposium, Denver, July 2013, pp. 407-411.
- Schmitz J., Camp M. and Jung M., "IEMI Effects of a TETRA Base Station as an Example of a Critical Infrastructure," Future Security 2013, Berlin, September 17-19, 2013.

5. Protection Methods

Protection methods for IEMI include classical electromagnetic shielding, cable protection and also detection of an attack. Papers covering these topics are included below.

- Eriksson, K. et al., "Microwave Shielding Effectiveness of a Large Mobile Military System and a Low Cost HPM-Indicator," RVK 02, Stockholm, 10-13 June 2002.
- Radasky, W. A. and Wik, M. W., "Intentional Electromagnetic Interference (IEMI) – Understanding the Threat and Developing Protection Concepts," Zurich EMC Conference, February 2003, pp. 111-114.
- Nilsson, T. and Jonsson, R., "Investigation of HPM Front-door Protection Devices and Component Susceptibility," FOI Technical Report, FOI-R-1771-SE, November 2005.
- Hoad, R. and Sutherland, I., "The forensic utility on detecting disruptive electromagnetic interference," Proceedings of the 6th European Conference on Information Warfare and Security (ECIW 2007), July 2007.
- Månsson, D., Thottappillil, R. and Bäckström, M., "Methodology for Classifying Facilities with respect to Intentional EMI," IEEE Transactions on Electromagnetic Compatibility, Vol. 51, No. 1, pp. 46-52, Feb. 2009.
- Månsson, D., Bäckström, M. and Thottappillil, R., "SafePowNet – Assessment and Mitigation of Risk for Disabling Control Centers of Large Power Networks by Intentional Radiofrequency Interference. Concluding Report," April 2011.
- Savage, E. B., W. A. Radasky and J. L. Gilbert, "Options for Mitigation of IEMI Induced Pulses on Commercial Building Cabling," 2011 Asia-Pacific International Symposium on EMC, Jeju Island, Korea, 16-19 May 2011.
- Adami, C. et al., "HPM Detection System for Mobile and Stationary Use," 10th Int. Symposium on Electromagnetic Compatibility (EMC Europe 2011), York, UK, September 26-30, 2011.
- Radasky, W. A. and Caruso, M., "HPEM Protection of Commercial Facilities," IEEE EMC Symposium, Denver, July 2013, pp. 411-415.

6. Standardization

Most of the standards published covering IEMI are from the IEC, however, the ITU-T, Cigré and the IEEE have also been active in the field. It should also be noted that many of the authors publishing in this field have been active in the standardization work of IEC SC 77C.

- Radasky, W. A. and M. W. Wik, "The Standardization of High Power Electromagnetic Transient Phenomena in the IEC," Fifteenth International Wroclaw Symposium on EMC, 27-30 June 2000, pp. 893-895.
- Wik, M. W. and Radasky, W. A., "Development of High-Power Electromagnetic (HPEM) Standards," IEEE Transactions on Electromagnetic Compatibility, Volume 46, No. 3, August 2004, pp. 439-445.
- IEC 61000-2-13, 2005-03, Electromagnetic Compatibility (EMC) – Part 2-13: Environment – High-power electromagnetic (HPEM) environments – Radiated and conducted.
- IEC 61000-4-33, 2005-09, Electromagnetic Compatibility (EMC) – Part 4-33: Testing and measurement techniques – Measurement methods for high – power transient parameters.
- Radasky, W. A. and Giri, D. V., "The Standardization of UWB Waveform Characteristics by the International Electrotechnical Commission," 28th General Assembly of URSI, New Delhi, India, 23-29 October 2005.
- IEC/TR 61000-4-35, 2009-07, Electromagnetic Compatibility (EMC) – Part 4-35: Testing and measurement techniques – HPEM simulator compendium.
- IEC/TS 61000-5-9, 2009-07, Electromagnetic Compatibility (EMC) – Part 5-9: Installation and mitigation guidelines – System-level susceptibility assessments for HEMP and HPEM.
- ITU-T K.81, "High-power electromagetic immunity guide for telecommuncation systems," November 2009.
- Radasky, W. A., "Application of IEC SC 77C Standards for the Protection of the Critical Infrastructures," Asia-Pacific EMC Symposium, Melbourne, Australia, May 2013.
- IEEE P1642, "Draft Recommended Practice for Protecting Public Accessible Computer Systems from Intentional EMI," October 2013.
- Cigré WG C4.206, "Protection Of The High Voltage Power Network Control Electronics Against Intentional Electromagnetic Interference (IEMI)," Draft Technical Brochure, January 2014.

7. Conclusions

Significant progress has been made over the years in the field of IEMI to understand the threat, the susceptibility of equipment and systems, and to develop protection methods that can be standardized. The problem is a large one and will require future work to fully understand the most cost-effective ways to protect against this threat.

8. References

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2. Workshop on "Electromagnetic Terrorism and Adverse Effects of High Power Electromagnetic (HPE) Environments", Proceedings of the 13th International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility, February 16-18, 1999.
3. "Resolution of Criminal Activities Using Electromagnetic Tools," International Radio Scientific Union (URSI) General Assembly, Toronto, 1999.
4. Wik, M. W., Radasky, W. A. and Gardner, R. L., "Intentional Electromagnetic Interference (EMI) -- What is the Threat and What Can We Do About It?" Fifteenth International Wroclaw Symposium on EMC, 27-30 June 2000, pp. 896-897.
5. IEC 61000-2-13, 2005-03, Electromagnetic Compatibility (EMC) – Part 2-13: Environment – High-power electromagnetic (HPEM) environments – Radiated and conducted.
6. Radasky, W. A., Baum, C. E. and Wik, M. W., "Introduction to High-Power Electromagnetics, Intentional Electromagnetic Interference (IEMI) and the Special Issue," IEEE EMC Transactions Special Issue on IEMI, 2004, pp. 314-321.