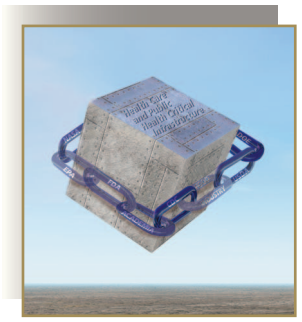

Electromagnetic Interference Risk Analysis

A Necessity for Resilient Medical Infrastructure

BY PAUL ROBERT HAYES, EISUKE HANADA, AND CRAIG BAKUZONIS

Electromagnetic interference (EMI), whether intentional or not, causes a wide spectrum of difficulties including momentary, minor inconveniences to system failures in electronic devices [7], [26]. Within a hospital environment, electronic devices must reliably perform or fail gracefully, including telecommunications infrastructure through basic instrumentation [1]. Lack of comprehensive EMI risk data has caused some facilities to ban wireless devices altogether for reducing risk from inadvertent emitters and yet relinquishing the possible lifesaving benefits [2], [3]. Often, the bans rely heavily on good-faith compliance with minimal or no detection and mitigation strategy. With increasing reliance on electronic medical records, timely access to patients' treatments, medications, and allergens, and timely communications with medical personnel can be critical, especially during disaster events [3].

Significant work has covered cellular and mobile phone emitters within the hospital and near critical medical instrumentation [5], [6]. These studies have resulted in improvements of device susceptibility including shielding and improved understanding of the more common EMI emitters. Standards have aided greatly in electronic device designs: IEC60601-1-2 recommending immunity to 1 V/m (80 MHz–1 GHz) and 10 V/m for critical systems above 800 MHz; IEC61000-4-3 recommending that medical devices should work normally in 3 V/m, and life-sustaining devices should work normally in 10 V/m (80 MHz–2.5 GHz). A great wealth of work has been focused on common, low-power continuous wave (CW) or pulsed CW emitters, as these will more likely be encountered in a daily routine [5]–[8]. Relatively less data are available for pulsed, high-power emitters and extraordinary weather. Much work remains in the consideration of inadvertent and intentional EMI (unknown risk) where no control is possible over the emitter, CW, or pulsed, to ensure resilient systems.

Structural factors in facilities (topography, materials, architecture) play a significant role in environmental protection plans. During design and maintenance, significant consideration is given to local weather phenomena, soil, environmental, and structural factors based on historical data as a quantifiable risk [24], [25]. As shown in Figure 1, EMI simulations, test, and analysis also quantify risk during building design and maintenance [10], [20], [21]. Developing cost-effective, broad spectrum shielding (including building design) aids in daily EMI management. Monitoring and mitigating risk in adverse EMI incidents is a necessity [11] along with continued development of resilient medical instrumentation, communication, and information technology (IT) infrastructure.

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Inadvertent EMI

On a daily basis, medical facilities, networks, and instrumentation experience a wide range of EMI from locally geographic sources (radar, television, radio), portable sources (cell phones, mobile radios), weather-related sources, and medical instrumentation [7], [12]. Many physical tests, improved designs, and studies have yielded significant improvements for device EMI immunity as well as the reduction in power levels of emitters (e.g., cellular phones).

Distributed antenna systems for cellular phones have reduced the emissions and yielded benefits from the timely response of personnel. Wireless networking has also provided timely access capability for electronic medical records. Electromagnetic environment simulation before installing wireless communication systems should be required because radio wave irradiation in hospitals without any protection might interfere with medical devices [19], [20]. Some research indicates that installation of a wireless network increases the resiliency of IT infrastructure [10]. With increasing access and reliance on these systems, there is also a vulnerability and a responsibility to ensure their resilient operation [7].

Reliance on a distributed antenna system (installed to reduce cellular phone emissions) for rapid communications will yield time delays, if the systems fail to respond. Critical systems, including common-off-the-shelf (COTS) computer access points, should be designed with extra resiliency to have robust failure mechanisms and with rapid, progressive restoration. One spectrum management solution is to have a reasonable supply of spare electronic components stored on site and readily available (network switches, wireless access points, disks, computers). Should the facility experience an EMI disruption, the affected components could be quickly restored after mitigating the source EMI. Thus, a critical need

arises in determining if the EMI remains active before installing the replacements.

Intentional EMI

Electromagnetic environment analysis, testing, and design are not new by any measure as evidenced by the quantity of research in electromagnetic pulse (EMP) and high-power microwave (HPM). Significant portions have been focused on critical installations and thankfully rare events (nuclear EMP) yielding robust (80 dB) and resilient protection. However, it is unlikely that the broad range of medical facilities will have the resources to implement such costly shielding measures.

Intentional EMI sources can range from low-tech COTS radar sources that can produce narrow-band CW more than 100 V/m at kilometer distances through high-tech impulsive radiating antennas [26]. Spectrum content through and above 2.5 GHz as well as spectral density above 10 V/m is certainly achievable with present-day technology. These systems could be placed within the hospital grounds, in a nearby parking facility, or at some distance and cause disruptions to medical facility electronics. Should these disruptions occur during disaster events, the timely response of medical personnel and life-saving information would be impaired.

Physical Testing

To quantify the risk to medical devices and electronic systems in a hospital environment, on-site testing is important; however, it does not cover all possible scenarios. Even before testing, the electromagnetic environment around medical devices should be checked. An electromagnetic environment may consist of CW electromagnetic fields (irradiated radio waves or signals), static magnetic field (MRI), residual magnetization, quality of groundings (noise, low-power impulsive), surge (thunder, static electricity), electric power supply quality, and others [12], [14]. Several EMI environment test methods have shown viability in hospital facilities [13]–[16]. Electronic system characterization is also important in a controlled environment; radio wave irradiation to the medical devices, for example, aids in determining susceptibility of the device to EMI and in quantifying its own emissions. If wireless communication systems are planned to be installed, regular electromagnetic compatibility (EMC) checks or references to the test results should be required [16], [17].

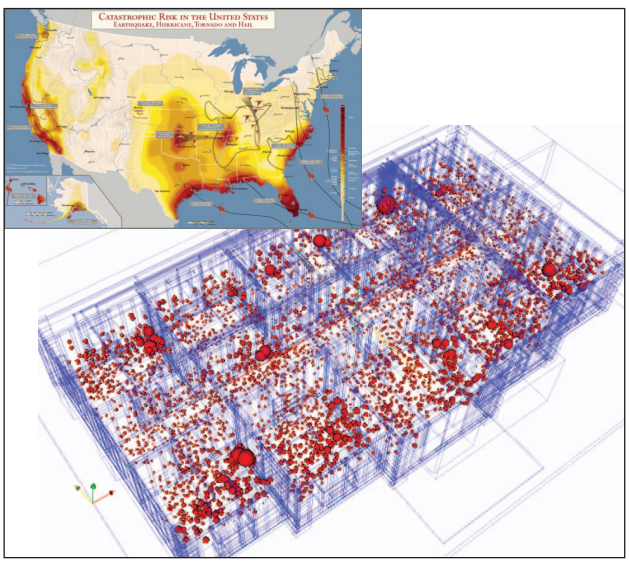

Fig. 1. Simulations and analyses combined with targeted physical testing can generate EMI risk maps for a wide range of daily and unexpected emitters yielding cost-effective shielding metrics. Catastrophic risk analysis for earthquake, hurricane, tornado, and hail yields structural metrics for building design. (Image courtesy of Risk Management Solutions, Inc. (www.rms.com).)

Simulations and Analysis

Simulations can aid in the design of intentional emitters for maximum coverage internally with minimal coverage external to the building. Some of these emitters are in static locations (wireless access points, distributed cellular antennas), and others can be moving (patient worn telemetry, cell phone users, mobile instrumentation such as infusion pumps or diagnostic ECG devices). Ideally, deployment and protection should seek to minimize external disruption to these systems. Fixed location external intentional emitters (such as aviation, cell, emergency response, etc.) whose internal penetration may need to be suppressed, or at times, for emergency response need to be available within the building. Along with physical design considerations, this point can also be the start of, or the extension of, a spectrum management plan within the facility.

Numerous simulation systems for the electromagnetic fields have been developed, and, among them, finite-difference time-domain (FDTD) is one of the more recognized methods. In medical facilities, comparisons between simulation results and measurements under real conditions have shown accuracy [18]. For rapid analysis, two-dimensional (2-D) simulation yields reasonable model fidelity. Expanding into three-dimensional (3-D) simulation to calculate can be a significant undertaking because of the computational requirements and new model details [10]. For example, a 1 m^2 simulation in 2-D with 5 mm^2 cells needs 40,000 cells. In contrast for 3-D, a 1 m^3simulation with 5 mm^3 cell needs 8,000,000 cells. For full facility studies, 3-D simulations may be as time and cost prohibitive as full spectrum physical testing, albeit less intrusive. However, just as in physical testing, simulations can be deployed in a multilevel approach in which zoned higher-resolution 2-D analyses are pursued on a per-floor basis and lower-resolution 3-D models are studied for the full facility. One major challenge is the model data entry for the existing and new designs (wiring, heating, ventilating, and air-conditioning, structural shape, materials, etc.), which can be a large time and cost commitment.

Simulations and analysis (S&A) can play a role in pretest planning and post-test analysis of medical devices and facilities as complete full-spectrum physical testing can be cost and time prohibitive. S&A has resulted in a more comprehensive understanding of the physical mechanisms of the interaction leading to more cost-effective shielding [9], [10]. Development of EMI environment descriptors along with statistical analysis of the deterministic physical and simulation results has yielded mappable results to new facilities [22]. Timely, cost-effective electromagnetic environment simulation is one of the most promising techniques being developed especially in the rapidly evolving area of intentional EMI where physical testing is cost- and time-prohibitive [23].

Conclusions

Daily mitigation of and planning for intentional or unintentional EMI should be a part of a medical facilities ongoing spectrum management just as annual condition and risk

assessments are performed at other facilities. A reasonable supply of spare electronic components should be stored safely on site and readily available (network switches, wireless access points, disks, computers, instrumentation). Although some planning can rely on good-faith compliance, protection and planning for noncompliance and electronic device failure is a necessity.

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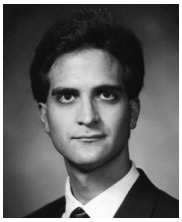

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