Smart Metering Issues

Alfonso G. Tarditi
Electric Power Research Institute
52nd Annual Rural Energy Conference
February 12-14, 2014, La Crosse (WI)
Acknowledgments

The previous efforts, guidance and expertise of EPRI colleagues, Doug Dorr, Rob Kavet, Brian Seal, are gratefully acknowledged.
Take-Home Message

EPRI Involvement in Electromagnetic Safety Issues
• EPRI conducts independent, non-profit research in the interest of the public
• Documented, in-depth involvement in EM fields health effects research

EPRI studies on Smart Meter EM Emissions
• Several studies with testing in actual residential installations
• Laboratory measurements to characterize worst case scenarios
Take-Home Message

EPRI position within the wide range of approaches in tackling the Smart Meter EM Emission Effects and EM Field Health Issues
Contents

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
Background: the Smart Grid

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
Background: the Smart Grid

The *Smart Grid* Big Picture

- In a recent roadmapping publication (*), the IEC also observes that the *smart grid* has become more a *marketing term*, rather than a technical definition.

- The current *technical consensus* and de facto trends indicate that the current evolution of the power grid monitoring is leading toward a widespread integration of digital communication (both wired and wireless) and processing technology.

- In principle, this would allow a *capillary monitoring* of the grid status and the ability to perform real-time or as-needed optimization of generation, power delivery paths, and characteristics of overall end-user electrical load.

- This *technology upgrade* that ties together generation, distribution, and utilization is commonly referred to as “*smart grid*”.

Background: the Smart Grid

The Smart Grid: enhanced interaction among different components of the electric power system

- Top level: generation level, the proper response to the load variations needs to be in place
- Intermediate level, the transmission and distribution infrastructure, represents the key of ensuring this functionality
- Bottom level, utilization, the customer must be provided with a nominal level of power, dependable service, and a fast recovery from power outages
Background: the Smart Grid

Power grid evolution: new technologies and **EM Compatibility issues**

Internet of (Power Grid) Things

© 2014 Electric Power Research Institute, Inc. All rights reserved.
Background: the Smart Grid

The *Smart Grid* Big Picture

- The communication to and from the consumer level is critical for the overall planning and managing of the grid operations.
- **Need**: the ability to collect timely data on the end-usage levels and their patterns
- **Solution**: an adequate *Information Technology infrastructure*
  - telecommunication
  - data storage/processing
  - data analytics
- **IT infrastructure** allows for “intelligent” resources management improving
  - reliability
  - energy efficiency
  - customer satisfaction (quality of service and economy)
Background: the Smart Grid

IT Smart Grid Mesh-Network Infrastructure

- Infrastructure already designed, tested
- In many areas is implemented and operational
- Large number of smart meters to operate and communicate in a mesh-network environment.

Picture credit: http://www.infraxinc.com/media/content/smart-metering-lg.jpg
Background: the Smart Grid

IT Smart Grid Mesh-Network Infrastructure

• Smart meters “mesh network” communication:
  – directly with a receiving concentrator node
  – or with another smart meter present in its neighbor

• Communication path depending on the radio wave propagation condition that may favor one connection versus another.

• Mesh network design allows for
  – **maximum flexibility** in the deployment and installation of the network
  – **high reliability** for communication in both high-density urban environments and rural, sparsely populated areas.
Background: the Smart Grid

Smart Meters with Wireless Communication

- In the United States, the typical implementation of this network relies on wireless communication, organized in a similar fashion to the cellular telephone network.
- Within this large-scale picture, the smart meters—the upgraded version of the revenue meters—represent the natural interface with the large number of customer installations.

Picture credit: http://www.landisgyr.com
Background: the Smart Grid

Smart Meter Radios

• The smart meters designed for this application utilize radios operating in the high-frequency region of the radio spectrum, near the frequencies allocated for cellular telephones.

Picture credit: http://www.lbl.gov/images/MicroWorlds/EMSpect.gif
Issues with Smart Meters

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
Issues with Smart Meters

• “Smart meters” radio emissions
  (health concerns)
• Cost, benefits and drawbacks
  (interface w/ smart grid, new technologies, EMC)
• Smart meters getting too smart?
  (cybersecurity, privacy)
• Alternatives and future outlook
  (power line communication, optical fiber, directive antennas)
Issues with Smart Meters

Concerns

• EM emissions impacting human health
  – Known thermal effects
  – Other unspecified effects
• Proximity to living areas due to wall installation
• Not having a choice

The EPRI Approach

• All safety concerns are taken very seriously
• Unfiltered, unbiased research
• Work in the interest of the public
Current EM Exposure Safety Standards

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
Current EM Exposure Safety Standards

ICNIRP Guidelines

GUIDELINES FOR LIMITING EXPOSURE TO TIME-VARYING ELECTRIC, MAGNETIC, AND ELECTROMAGNETIC FIELDS
(UP TO 300 GHz)

International Commission on Non-Ionizing Radiation Protection

INTRODUCTION

In 1974, the International Radiation Protection Association (IRPA) formed a working group on non-ionizing radiation (NIR), which examined the problems arising in the field of protection against the various types of NIR. At the IRPA Congress in Paris in 1977, this working group became the International Non-Ionizing Radiation Committee (INIRC).

In cooperation with the Environmental Health Division of the World Health Organization (WHO), the IRPA/INIRC developed a number of health criteria documents on NIR as part of WHO’s Environmental Health Criteria Programme, sponsored by the United Nations Environment Programme (UNEP). Each document includes an overview of the physical characteristics, measurement and instrumentation, sources, and applications of NIR, a thorough review of the literature on biological effects, and an evaluation of the health risks of exposure to NIR. These health criteria have provided the scientific database for the subsequent development of exposure limits and codes of practice relating to NIR.

PURPOSE AND SCOPE

The main objective of this publication is to establish guidelines for limiting EMF exposure that will provide protection against known adverse health effects. An adverse health effect causes detectable impairment of the...
“Overall, these incidence data from the United States based on high-quality cancer registries do not provide support for the view that use of cellular phones causes brain cancer.”
“An examination of all generally accepted and proposed mechanisms...shows that in the frequency range from several megahertz to a few hundred gigahertz..., the principal mechanism for biological effects, and the only well-established mechanism, is the heating of tissues.”
Current EM Exposure Safety Standards

Applicable Standards
• EM exposure standards
  – ICNIRP
  – IEEE
  – FCC

Previous Investigations
• EPRI Reports
• EPRI workshop
About EPRI

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
About the Electric Power Research Institute

EPRI’s Focus

- Scientists and engineers working on nearly every area of electricity generation, delivery and use, management and environmental responsibility
About the Electric Power Research Institute

EPRI’s Business

• The Electric Power Research Institute, Inc. conducts research, development and demonstration (RD&D) relating to the generation, delivery and use of electricity for the benefit of the public

• An independent, nonprofit organization: “To promote, engage in and conduct research in both the pure and applied sciences for the advancement and betterment in the public service of the production, transmission and distribution of electric power” [excerpt from EPRI articles of incorporation]

EPRI conducts independent, non-profit research in the interest of the public [www.epri.com]
EPRI Research on EM Exposure Safety

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
Health and Safety

Rapid expansion of wireless technologies in the electricity industry, coupled with the inherent safety risks associated with electricity, requires stakeholders to understand and assess their impacts on the health and human safety of society.

EPRI’s research works to understand and reduce scientific uncertainties associated with potential health effects of electric and magnetic fields (EMF), radio-frequency (RF) emissions, and air toxics and pollutants including public health risks of general electric power industry operations. Our research also examines workplace injuries to improve employee health and manage labor-related costs through injury and illness trend analyses, ergonomic interventions, and assessments of new health issues unique to the electric utility workplace environment.

Spotlights

EMF and Your Health
EPRI’s public information brochure characterizes everyday EMF exposures and reviews the latest health research and its findings.

Smart Grid and Your Health
Two expert workshops and an international review team identified key issues and knowledge gaps relating to RF emissions from smart grid technologies.

Worker Safety Research
A new research project will facilitate a forum for improving worker safety performance for the electric power industry.

Contact
For more information please contact:

Chris Mahoney
Communications Manager
Phone: 704-595-2653
Email: cmahoney@epri.com

http://www.epri.com/Our-Work/Pages/Health-and-Safety.aspx
EPRI Research on EM Exposure Safety

EPRI Reports #1024737 and #1023105
EPRI Research on EM Exposure Safety

Electric and Magnetic Fields and Radio-Frequency Health Assessment - Program 60


Electric and Magnetic Fields and Radio-Frequency Health Assessment and Safety - Program 60

EPRI Research on Smart Meters Emissions

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
EPRI Research on Smart Meters Emissions

- EPRI Comments: A Perspective on Two Smart Meter Memoranda - EMF and RF Health Assessment and Safety, EPRI, Palo Alto, CA: 2012. 1024952.

Summary: EPRI Research Reports 2010-2014
EPRI Research on Smart Meter Emissions

- General discussion of Automatic Metering Infrastructure (AMI) presented as a summary white paper.
- Analysis defining
  - the typical operational conditions at low duty cycles,
  - the expected level of exposure in comparison with the FCC guidelines
- Comparison with EM emission from other common devices (like cellular telephones).

EPRI Research on Smart Meter Emissions

• Summary of the EPRI perspective on smart meters
• Focus on two main research activities:
  – analysis of the amount of RF energy deposited in persons exposed to smart meter emissions
  – study of RF emissions from one particular type of smart meter model, under controlled conditions at the manufacturer’s facility.
EPRI Research on Smart Meter Emissions

- General discussion of Automatic Metering Infrastructure (AMI) presented as a summary white paper.
- Analysis defining
  - the typical operational conditions at low duty cycles,
  - the expected level of exposure in comparison with the FCC guidelines
- Comparison with EM emission from other common devices (like cellular telephones).

EPRI Research on Smart Meter Emissions

- Report on RF emission data collection on smart meters carried out in a laboratory setting and at residences in the states of California and Washington.
- Analysis of the EM emission vs. FCC standard
- Results indicate emissions always less than 1% of the FCC maximum permitted exposure (MPE) for typical duty-cycle operating conditions.
- Emissions at 100% duty cycles were measured and were found at a level less than the FCC limits.
- Indoors shielding effect from typical home construction materials reduces the field level by an additional order of magnitude compared with the one measured outdoors.

EPRI Research on Smart Meter Emissions

• Measurements on typical indoor values of the RF fields for six residential locations in the service territory of the PG&E electric utility company.
• Measurements of the composite RF field environment from arrays of smart meters installed and operating next to each other in three different apartment complexes (including one with 112 co-located smart meters).
• Analysis of data transmissions from 88,296 smart meters, collected via the PG&E data-management system, was utilized to provide a statistical distribution of meter duty cycles to be included in the determination of time-averaged potential exposure.

EPRI Research on Smart Meter Emissions

• Summary of two workshops that were conducted to study the electromagnetic environments created by emerging technologies and on their potential health effects associated with radio-frequency (RF) emissions

• Conclusions indicate that there is a lack of relevant findings about “non-thermal” effects

• Open questions related to the risks from heavy cell phone use and to the consistent observation of slightly altered brain-wave activity in human subjects exposed to radio-frequency fields under laboratory conditions.
**EPRI Comments: A Perspective on Two Smart Meter Memoranda - EMF and RF Health Assessment and Safety, EPRI, Palo Alto, CA: 2012. 1024952.**

- Memorandum addressing the specifics of the debate about the radio-frequency (RF) electromagnetic fields emitted from smart meters and related health risks.
- In all the reported studies, smart meters EM emission levels in typical conditions of utilization and exposure have been found well below both the thresholds from officially recognized safety standards (IEEE, FCC, and, ICNIRP).
- Smart meter emissions lower than the ones from other common sources of EM field to which the public is exposed.
EPRI Research on Smart Meter Emissions

- This technical report presents the results of electromagnetic (EM) emission measurements in the radio frequency (RF) range from advanced metering infrastructure (AMI) utility meters (smart meters) employed by CPS Energy in its territory of operation.

- The study is focused on the determination of the maximum possible level of emissions, the typical population exposure conditions, and a comparative set of measurements from other (EM) sources that are present in a common household.

- The results indicate that human exposure would mostly occur at RF electric field pulses levels about 10%, or less, of international standard safety guidelines for continuous exposure.

- Smart meters emissions also compare favorably to those from other devices to which consumers are typically exposed, from power frequency to microwaves.

Characterization of Radio Emissions from Advanced Metering Infrastructure Revenue Meters (Smart Meters) in CPS Energy Residential Installations

Final Report


EPRI Project Manager
A. G. Tartiti

© 2014 Electric Power Research Institute, Inc. All rights reserved.
EM Field Primer

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
EM Field Primer

Relevant Characterizing Parameters

• Amplitude of Electric (E) and Magnetic field (B) components
  – Why they matter: the coupling issues
  – The impacts on living tissue
  – Near- and Far-field

• Radiated Power vs. Reactive Power

• Frequency
  – Propagation through matter
  – Absorption and energy conversion

• Time of Exposure
Electromagnetic waves

Credit: http://hyperphysics.phy-astr.gsu.edu/hbase/waves/emwavecon.html

Applet: http://www.cabrillo.edu/~jmccullough/Applets/Flash/Optics/EMWave.swf
EM Field Primer

Electric and magnetic field components

- Generation
- Propagation

Credit: http://www-antenna.ee.titech.ac.jp/~hira/hobby/edu/em/smalldipole/smalldipole.html
EM Field Primer

Measuring the EM Field

- High-frequency instruments

- Low-frequency instruments
Smart Meter Emissions 2013 Project

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
Smart Meter Emissions 2013 Project

Characterization of Radio Emissions from Advanced Metering Infrastructure Revenue Meters (Smart Meters) in CPS Energy Residential Installations

• Three different smart meter models currently utilized or planned for installation in the CPS Energy service territory in San Antonio, Texas
• Measure the EM emissions generated by the radio transmitter installed to provide two-way communication capabilities.
• Obtain an accurate characterization of these emissions
• Provide a relative term of comparison with other common sources of EM fields to which the public is exposed.
Smart Meter Emissions 2013 Project

Project Scope

• Focus on characterization of smart meter emissions in actual and planned residential installations

• The study not focused on actual impact of EM fields on the human body, or on biologic material in general,

• Safety-related considerations relying on internationally recognized and most stringent guidelines for human exposure to EM fields from the International Commission on Non-Ionizing Radiation Protection (ICNIRP).
Smart Meter Emissions 2013 Project

Characterization of Radio Emissions from Advanced Metering Infrastructure Revenue Meters (Smart Meters) in CPS Energy Residential Installations

• Three different smart meter models currently utilized or planned for installation in the CPS Energy service territory in San Antonio, Texas

• Measure the EM emissions generated by the radio transmitter installed to provide two-way communication capabilities.

• Obtain an accurate characterization of these emissions

• Provide a relative term of comparison with other common sources of EM fields to which the public is exposed.
Smart Meter Emissions 2013 Project

Project Scope

• Focus on characterization of smart meter emissions in actual and planned residential installations

• The study not focused on actual impact of EM fields on the human body, or on biologic material in general,

• Safety-related considerations relying on internationally recognized and most stringent guidelines for human exposure to EM fields from the International Commission on Non-Ionizing Radiation Protection (ICNIRP).
Smart Meter Emissions 2013 Project

Project Highlights

• Project with high general relevance in the context of current AMI technology development
• Data have been collected with a particular focus on actual utility installation
• Measurements performed on smart meters in operating residential installations
• More extensive laboratory tests were conducted to cover different models that are currently in the utility smart meter installation plan
Pictorial representation of the measurements data for the worst-case (continuous transmission) scenario of EM emissions in the radio-frequency range from the tested smart meters. The field level is shown compared to the maximum permitted exposure (MPE) as defined in the ICNIRP international standard.
Qualitative comparison of EM emissions for different sources present in common households vs. typical exposure time (both axes are on a logarithmic scale).
# Smart Meter Emissions 2013 Project

<table>
<thead>
<tr>
<th>Device</th>
<th>Smart Meter</th>
<th>Microwave Oven</th>
<th>DECT Phone</th>
<th>Smart Phone</th>
<th>Wi-Fi Router</th>
<th>CFL Bulb</th>
<th>TV Antenna</th>
<th>Baby Monitor</th>
<th>Video Game</th>
<th>Cell Tower (Near)</th>
<th>Cell Tower (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Approx. Frequency (MHz)</strong></td>
<td>900</td>
<td>2400</td>
<td>1800</td>
<td>900</td>
<td>2400</td>
<td>0.15</td>
<td>400</td>
<td>900</td>
<td>2400</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td><strong>ICNIRP Peak E-field Limit (V/m)</strong></td>
<td>58</td>
<td>86</td>
<td>82.5</td>
<td>58</td>
<td>86</td>
<td>123</td>
<td>40</td>
<td>58</td>
<td>86</td>
<td>58</td>
<td>58</td>
</tr>
<tr>
<td><strong>Typical Use Peak Electric Field (V/m)</strong></td>
<td>5</td>
<td>50</td>
<td>10</td>
<td>9</td>
<td>3</td>
<td>30</td>
<td>0.6</td>
<td>6</td>
<td>0.08</td>
<td>6</td>
<td>0.0002</td>
</tr>
<tr>
<td><strong>Approx. % ICNIRP Limit</strong></td>
<td>10</td>
<td>60</td>
<td>15</td>
<td>10</td>
<td>3</td>
<td>25</td>
<td>0.01</td>
<td>10</td>
<td>0.001</td>
<td>10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Typical Exposure Time (s)</strong></td>
<td>&lt;0.1</td>
<td>10</td>
<td>&gt;10^2</td>
<td>10^3</td>
<td>&gt;10^3</td>
<td>&gt;10^4</td>
<td>10^4</td>
<td>&gt;10^3</td>
<td>&gt;10^3</td>
<td>&gt;10^3</td>
<td>&gt;10^3</td>
</tr>
</tbody>
</table>
Smart Meter Emissions 2013 Project

Smart Meter
- Measured: less than 5 V/m at the one meter (3 ft) from the front surface of the smart meter case

Microwave Oven
- Measured: 52 V/m at the door surface

DECT Phone
- Measured: 15 V/m at the surface. Peak measurement of 111 dBµV/m=0.355 V/m at 1.8 GHz at 3 m. Extrapolated at 0.3 m to 3.5 V/m.
  http://stakeholders.ofcom.org.uk/binaries/research/technology-research/a1-a6.pdf, Figure 58, page 130

Smart Phone
- Measured: 9 V/m near the antennas

Wi-Fi Router
- Measured: 34 V/m near the antennas, less than 3 V/m at 1 m.

CFL bulb
- Measured: 30 V/m near the surface

UHFTV Antenna Tower
- A digital signal strength in a residential area can be found from http://transition.fcc.gov/mb/engineering/dtvmaps/. Here a typical signal of -21 dBm corresponding to 0.58 V/m is considered

Baby Monitor
- Estimated considering a worst-case scenario of a 900 MHz transmittter at 100 mW (20 dBm) at 30 cm producing 5.77 V/m (isotropic radiator) from http://www.qsl.net/pa2ohh/jsvpm.htm

Video Game
- XBox 360 Core system. Tested in normal operating mode – Using a demo game that exercises the CPU, graphic cards and input and output ports. Peak measurement of 98 dBµV/m=0.079 V/m at 3 m, 2.4 GHz. Extrapolated at 0.3 m to 0.79 V/m.
  http://stakeholders.ofcom.org.uk/binaries/research/technology-research/a1-a6.pdf, Figure 56, page 127

Residential Power Distribution
- Measured: near indoor wiring

Cell Phone Tower (near)
- Assume 10 W power, 20 dB antenna, 30 m distance. This corresponds to an effective radiated power $P_{ERP}=1000$ W and a power density (at 30 m) of $p_{ERP}=\frac{1000}{(2\pi^2)}=0.088$ W/m$^2$. The corresponding electric field is found then from $E = \sqrt{Z_0 p_{ERP}}=5.77$ V/m, where $Z_0=377$ Ω.

Cell Phone Tower (average)
- A 4-bar Android signal at -91 dBm corresponds to 0.00018 V/m, or 0.18 mV/m.

Reference Electric Fields - Basis of Estimate
Smart Meter Emissions 2013 Project

Following the Proper Procedure

• Cross-correlation time domain and frequency domain

• Verification of measurements vs. theory
  – Field level from TX power and antenna pattern
  – Field trend vs. distance

• Near-field vs. far-field effects

• Consistency with previous reports

• Error analysis

Low-accuracy Requirements

• Safety guidelines are…just guidelines, not precise limits

• Large margin to include worst case scenarios

Can We Trust the Numbers?
Conclusions

1. Background: the Smart Grid
2. Issues With Smart Meters
3. Current EM Exposure Safety Standards
4. About the Electric Power Research Institute
5. EPRI Research on EM Exposure Safety
6. EPRI Research on Smart Meters Emissions
7. EM Field Primer
8. Smart Meter Emissions 2013 Project
9. Conclusions
Conclusions

Results from EPRI 2013 project consistent w/previous research

- For any possible exposure conditions smart meter EM field always less than the maximum permitted exposure (MPE) levels specified by the ICNIRP safety standard.
- This comparison holds in the most unfavorable conditions where the pulsed emission level is compared with the level allowed for a continued exposure over a period of six minutes.
- For typical consumer exposure in residential operating conditions, are one order of magnitude less, or lower, than the ICNIRP MPE (results are also consistent with previous studies)
- Smart meters generate the lowest EM emissions in terms of combined exposure time and field intensity when compared to common devices that generate EM fields.
Together…Shaping the Future of Electricity
Backup Slides
Rationale for a Power Utility EMC Program

Electric grid rapid technology transition
- Closer integration of power and control electronics, data processing, and telecommunication technologies.

Increasingly complex EM environment
- Large current and voltage components, sensitive electronics, digital signals, and analog waveforms all coexist and interact.

A new environment for the electric power grid
Smart Meters, Smart Grid and EMC

EMC improves PQ

- EMC-conscious design and testing of power grid components, less disturbances, outages, improving PQ

Smarter Grid, more EMC

- Fully integrated Smart Grid: co-existence of power lines, sensors, data communication and processing, all requiring stricter EMC guidelines

Ya’ll need EMC anyway

- EMC fixes are generally more costly and less effective than preventive design and testing
**Relationship between EMC to PQ**

**EMC Events**
- Typically involving small, stray signals coupling to sensitive equipment

**PQ Events**
- Typically manifest themselves on the power lines/systems
- Require compatible power levels to be generated

**PQ relates to the perturbation of a power system and that typically requires another power system**
The Power Utility New Look

- Ubiquitous spreading of control electronics, sensors and data communication channels creates a new level of electromagnetic vulnerability
- Similarly to what happened in Aerospace and Defense: final goal of the EMC integration in the electric power industry would be the creation of an “EMC Standard for the Electric Utility”
- Including the relevant aspects of Smart Grid technology
Energized Objects

- Basic scenario: a conductor is energized with a given AC potential with the respect to ground
- Equivalence to a monopole antenna and, by image theory, to a dipole antenna
The Near-Field Region

• An antenna with length $L$ much smaller than the wavelength $\lambda$ is referred to as “electrically short” (typically $L << \lambda / 50$)

• The EM emission pattern of electrically short antennas is much like that of an infinitesimal (ideal) dipole

• For an ideal dipole the maximum radiated and reactive powers are the equal at a distance $R = \lambda / 2\pi$

• The boundary $r < R$ defines the near field region. The far field region is considered for $r >> R$. A transition region is defined for $r > R$ but still not $r >> R$ (there is no sharp transition in between any of these regions)
The Electric Field from a Dipole

Electric field lines of force generated in a small dipole

$V_{AC}$

$t=0$

$t=T/2$

$t=T$: field lines that were generated in $t=0$ are forced to close