EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Smart Metering Issues

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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

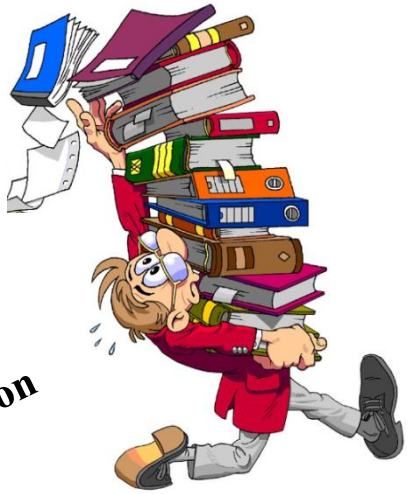
EPRI Involvement in Electromagnetic Safety Issues

- 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
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Background: the Smart Grid

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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".

(*) International Electrotechnical Commission, *IEC Smart Grid Standardization Roadmap*, Edition 1.0 (2010), www.iec.ch/smartgrid/downloads/sg3_roadmap.pdf.

Background: the Smart Grid

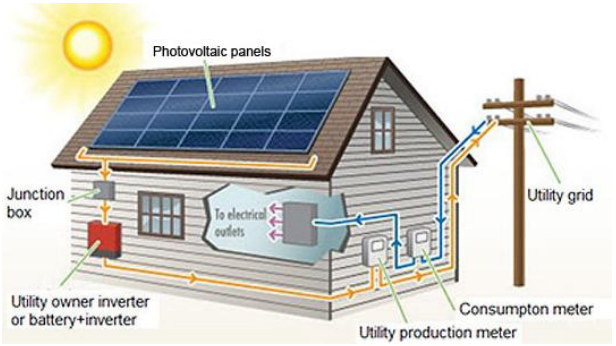
The *Smart Grid:* enhanced interaction among different components of the electric power system

- Top level: generation level, the proper response to the load variations needs to be in place

Generation

Transmission & Distribution

- Intermediate level, the transmission and distribution infrastructure, represents the key of ensuring this functionality

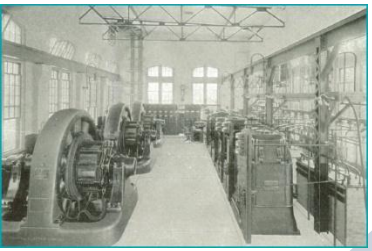


End User

- 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

EMC



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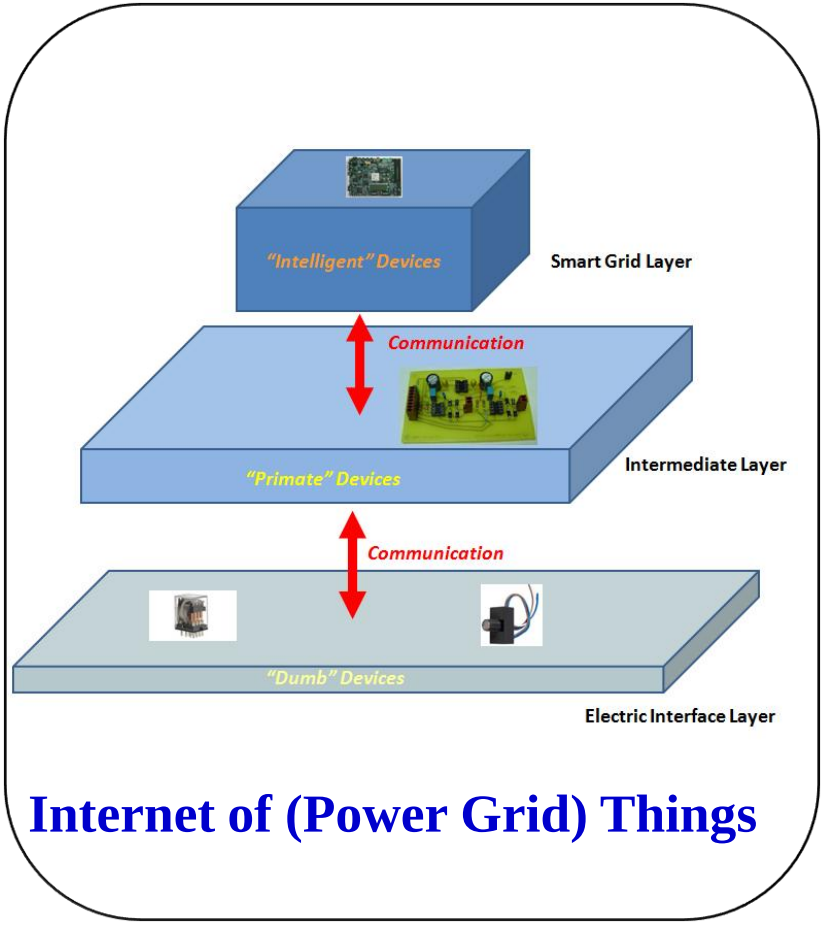


Internet of (Power Grid) Things

Power grid evolution: new technologies and EM Compatibility issues

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Background: the Smart Grid

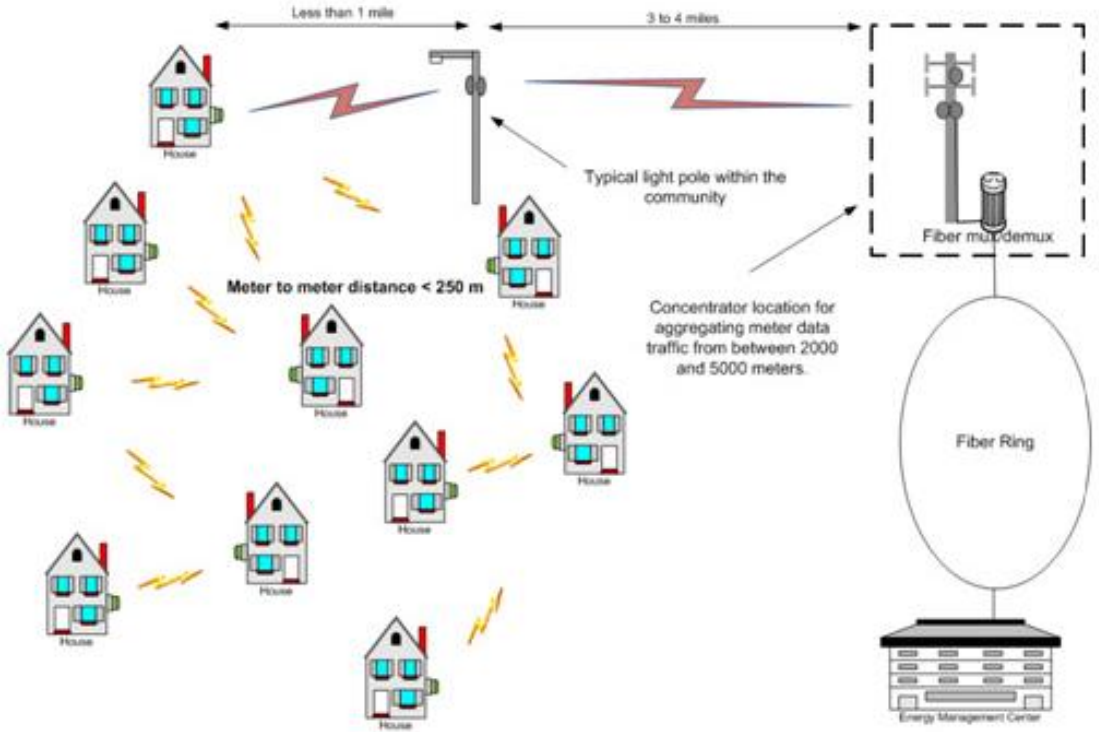
The *Smart Grid* Big Picture

- 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

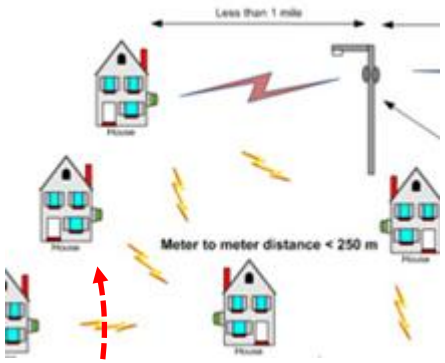
IT Smart Grid Mesh-Network Infrastructure

- 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.

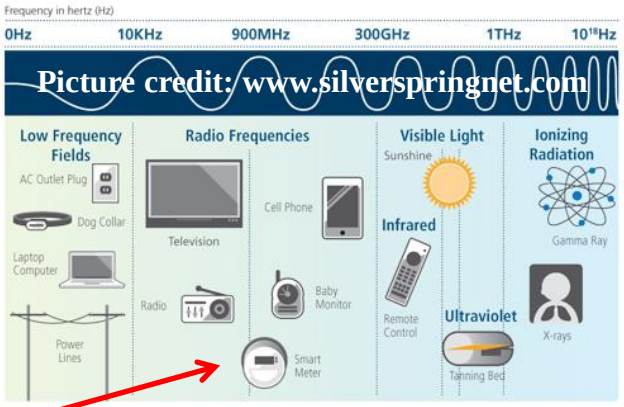
Background: the Smart Grid

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.

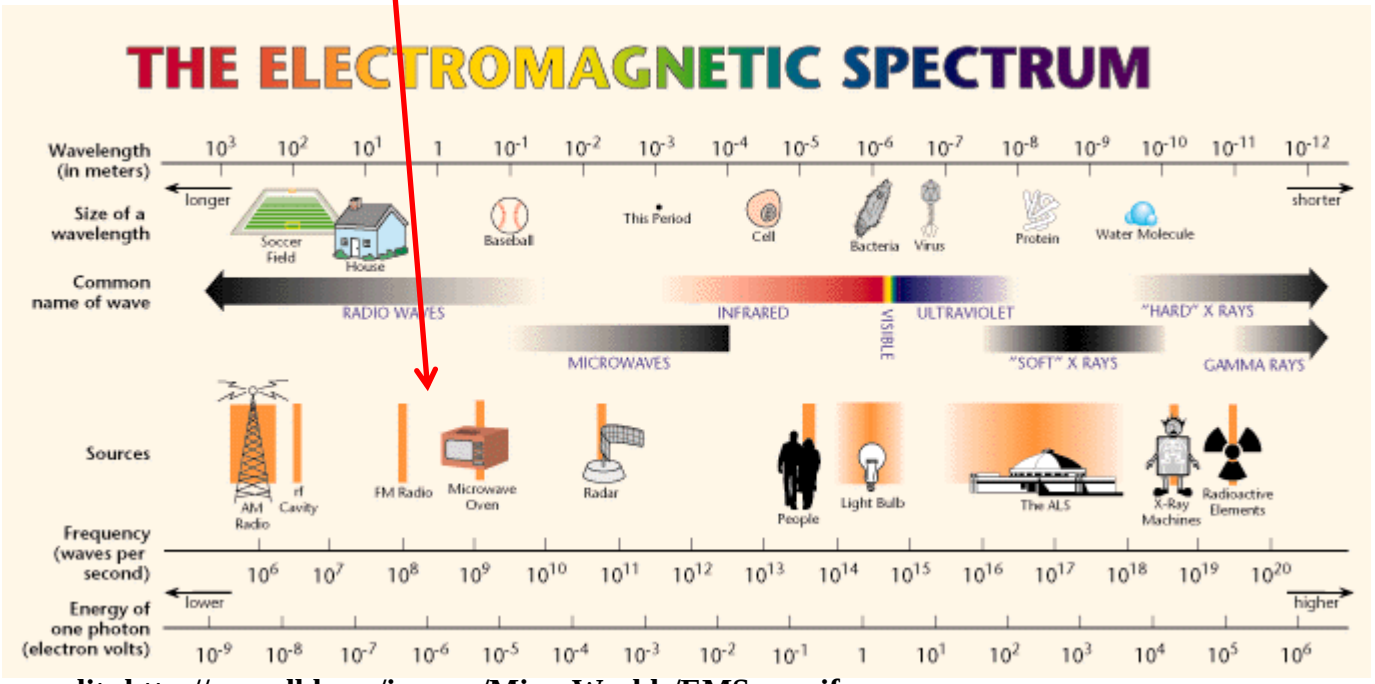
Picture credit: http://www.landisgyr.com

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/EMSpec.gif

Issues with Smart Meters

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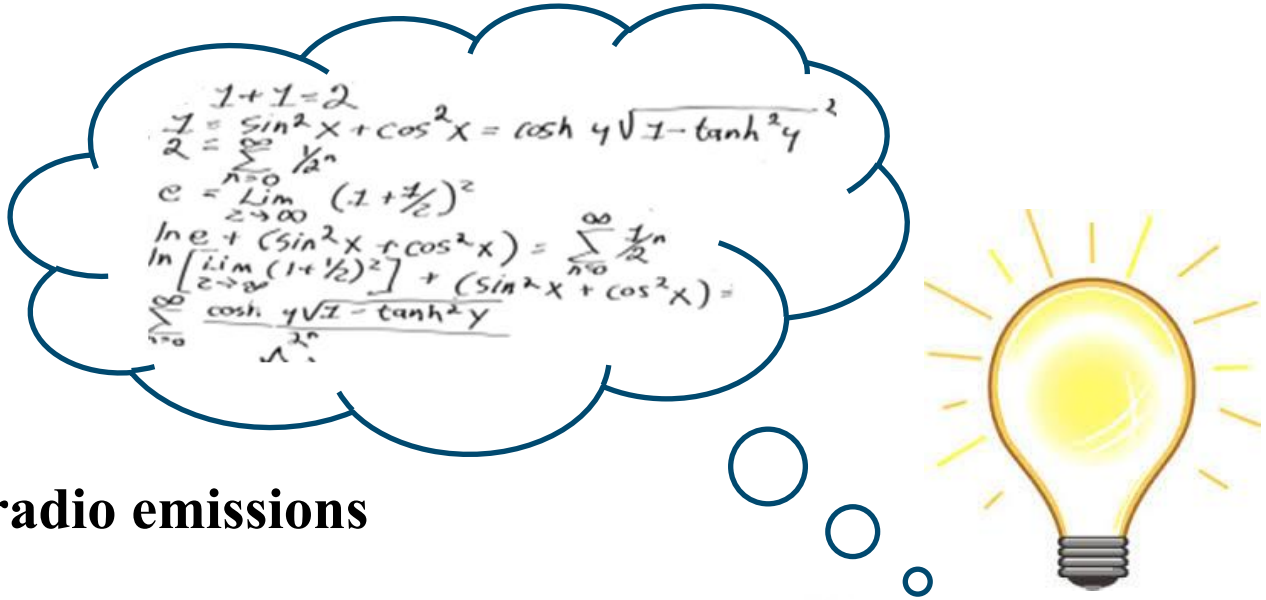
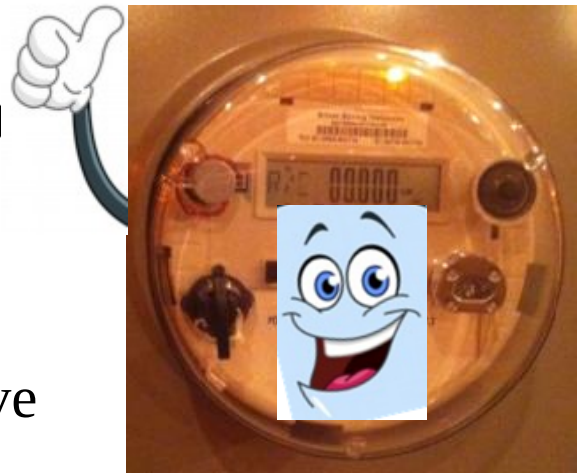
Issues with Smart Meters



- **“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 healt
  - 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

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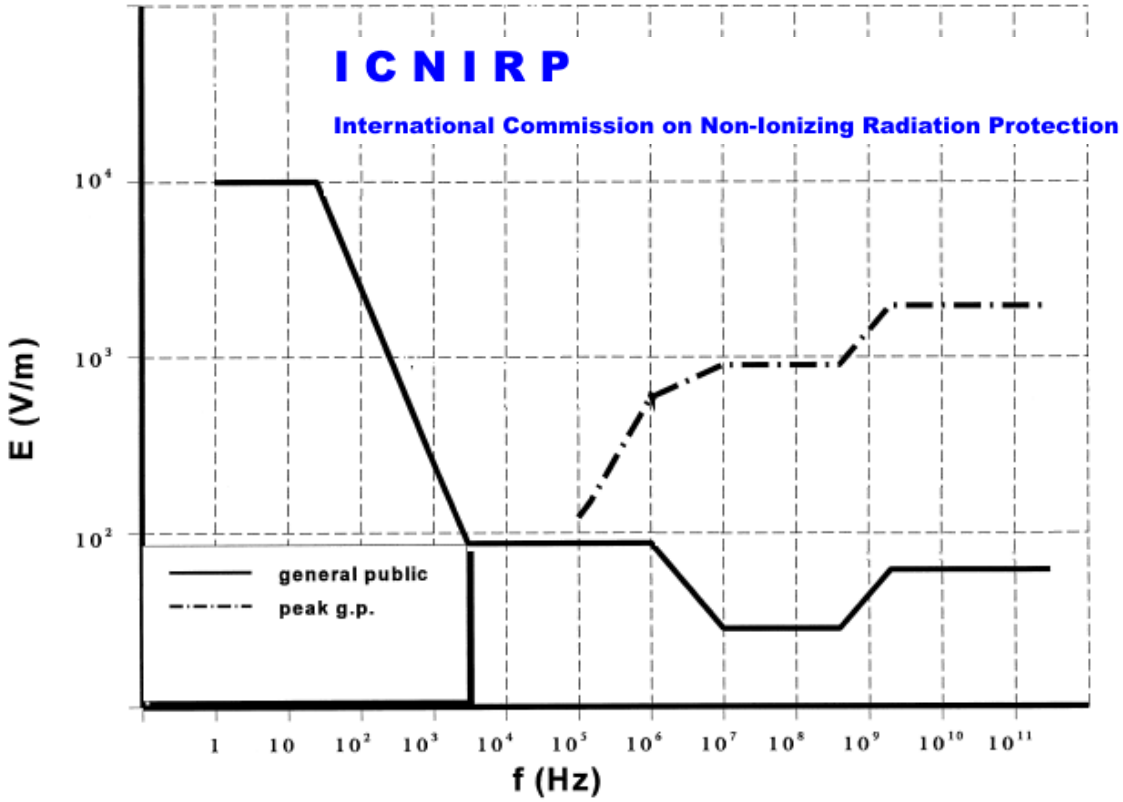
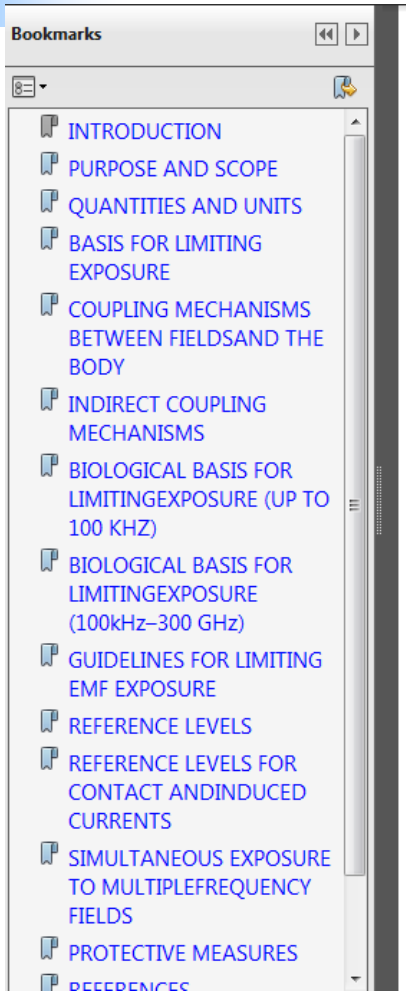


"Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)". Health Phys. 74, 494, 1998.

Current EM Exposure Safety Standards (



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.

At the Eighth International Congress of the IRPA (Montreal, 18–22 May 1992), a new, independent scientific organization—the International Commission on Non-Ionizing Radiation Protection (ICNIRP)—was established as a successor to the IRPA/INIRC. The functions of the Commission are to investigate the hazards that may be associated with the different forms of NIR, develop international guidelines on NIR exposure limits, and deal with all aspects of NIR protection.

Biological effects reported as resulting from exposure to static and extremely-low-frequency (ELF) electric and magnetic fields have been reviewed by UNEP/WHO/IRPA (1984, 1987). Those publications and a number of others, including UNEP/WHO/IRPA (1993) and Allen et al. (1991), provided the scientific rationale for these guidelines.

A glossary of terms appears in the Appendix.

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

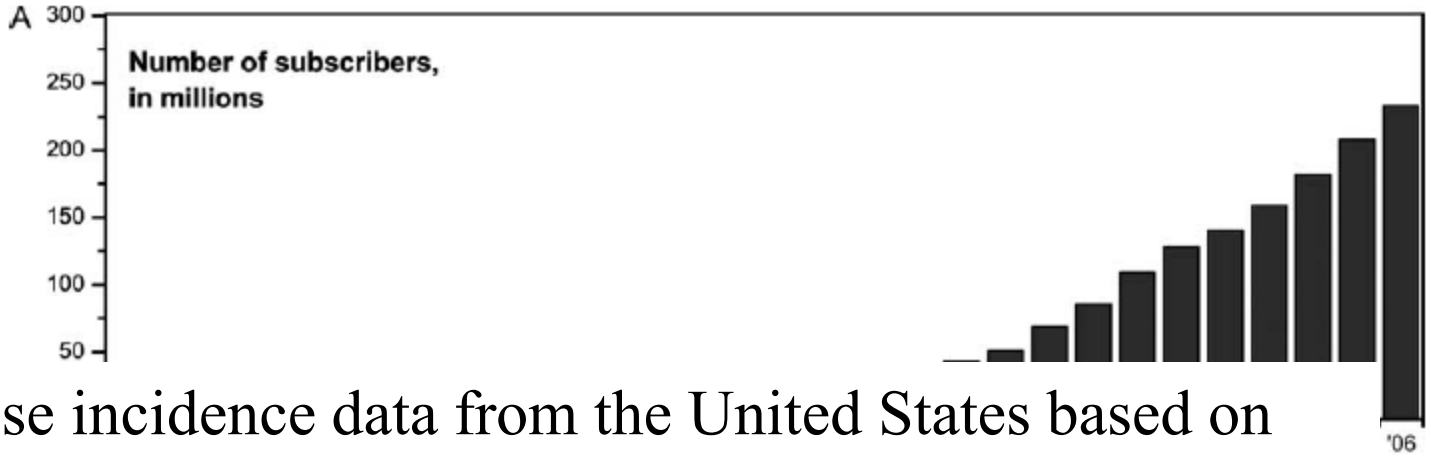
http://www.icnirp.de/documents/emfgdl.pdf

Current EM Exposure Safety Standards

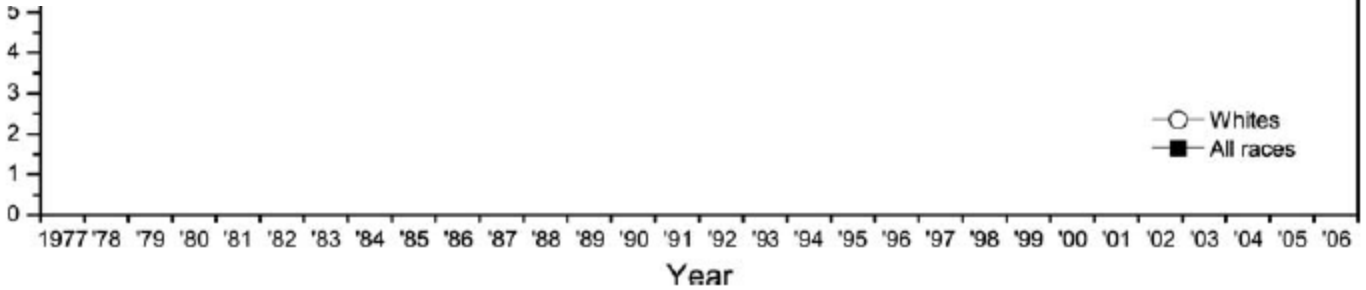
Neuro-Oncology
doi:10.1093/neuonc/noq077

Brain cancer i
cellular teleph

Peter D. Inskip, Robert N.
Division of Cancer Epidemiology
Bethesda, Maryland (P.D.I., R.N.H



"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."



Current EM Exposure Safety Standards

Health Physics, 2008

Review Article

QUANTITATIVE EVALUATIONS OF MECHANISMS OF RADIOFREQUENCY INTERACTIONS WITH BIOLOGICAL MOLECULES AND PROCESSES

Asher R. Sheppard,* Mays L. Swicord,† and Quirino Balzano‡

"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

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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

Generation

Nuclear

Environmental

Distribution & Utilization

Needs

Solutions

Needs

Solutions

Needs

Solutions

Needs

Solutions

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

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EPRI Research on EM Exposure Safety

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Health and Safety

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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:

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http://www.epri.com/Our-Work/Pages/Health-and-Safety.aspx

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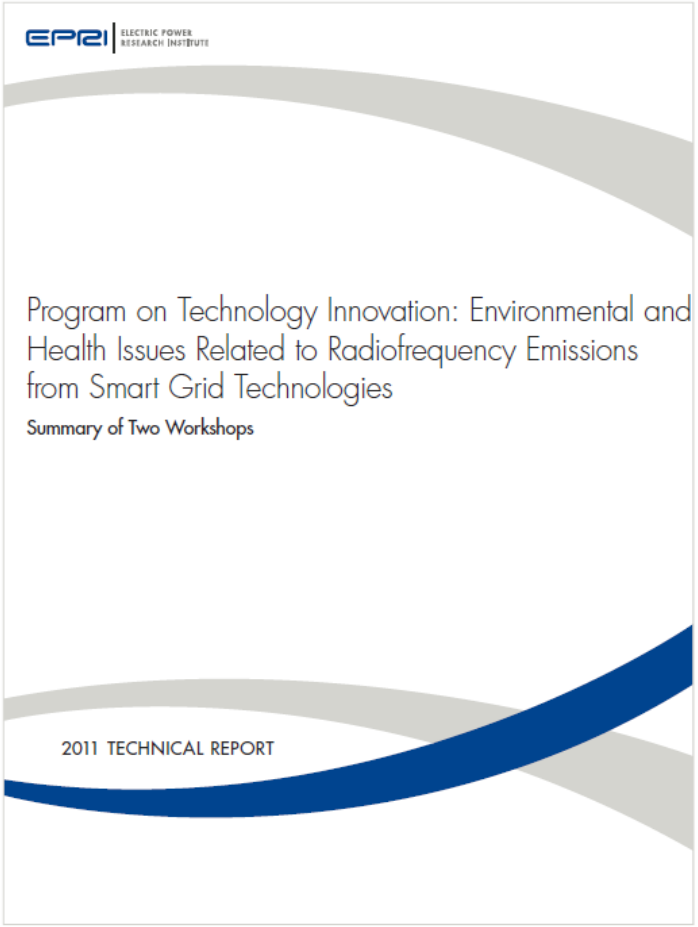
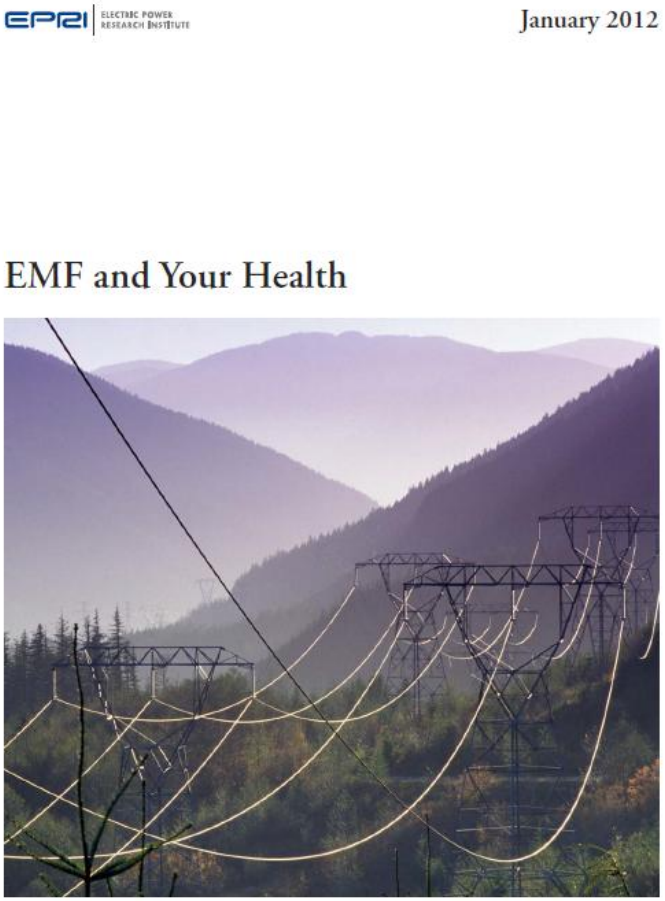
EPRI Research on EM Exposure Safety





EPRI Reports #1024737 and #1023105

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EPRI Research on EM Exposure Safety

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

http://mydocs.epri.com/docs/Portfolio/P2014/2014_P060.pdf

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

http://mydocs.epri.com/docs/Portfolio/PDF/2013_P060.pdf

EPRI Research on Smart Meters Emissions

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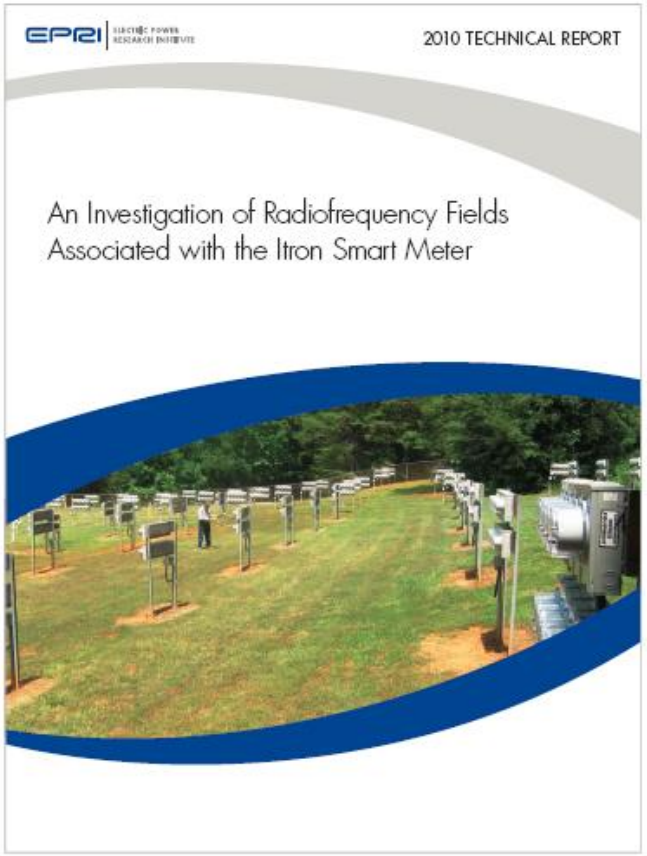
EPRI Research on Smart Meters Emissions

- *A Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading*, EPRI, Palo Alto, CA: 2010.1020798.
- *An Investigation of Radiofrequency Fields Associated With the Itron Smart Meter*, Palo Alto, CA: 2010. 1021126.
- *Radio-Frequency Exposure Levels From Smart Meters: A Case Study of One Model*, EPRI, Palo Alto, CA: 2011. 1022270.
- *Characterization of Radio Frequency Emissions From Two Models of Wireless Smart Meters*, EPRI, Palo Alto, CA: 2011. 1021829.
- *Program on Technology Innovation: Environmental and Health Issues Related to Radiofrequency Emissions from Smart Grid Technologies - Summary of Two Workshops*, EPRI, Palo Alto, CA: 2011. 1024737.
- *EPRI Comments: A Perspective on Two Smart Meter Memoranda - EMF and RF Health Assessment and Safety*, EPRI, Palo Alto, CA: 2012. 1024952.
- *Characterization of Radio Emissions from Advanced Metering Infrastructure Revenue Meters (Smart Meters) in CPS Energy Residential Installations*, EPRI, Palo Alto, CA: 2014, to be published.

Summary: EPRI Research Reports 2010-2014

EPRI Research on Smart Meter Emissions

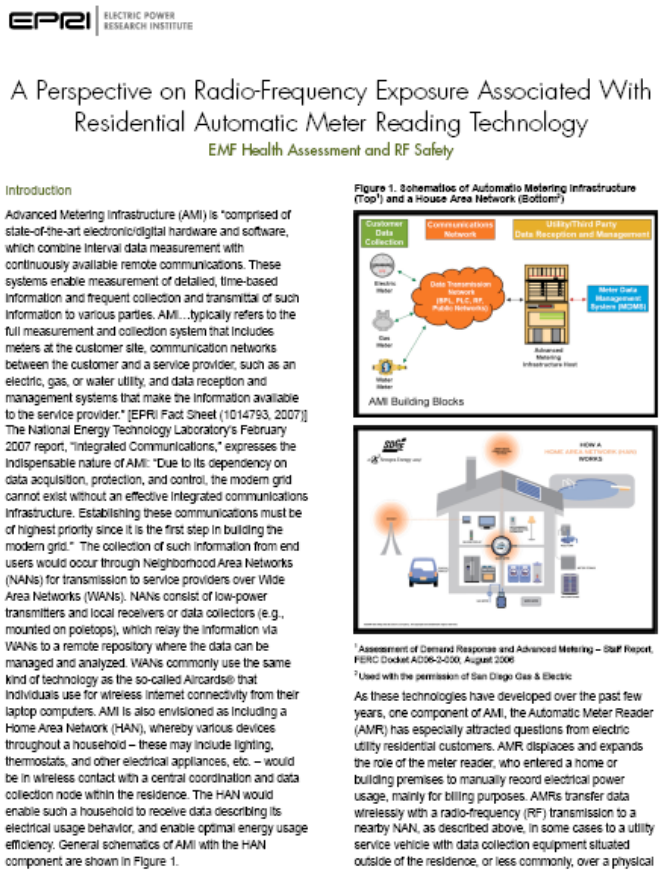
- General discussion of Automatic Metering Infrastructure (AMI) presented as a summary white paper.
- Analysis defining
  - the typical operational conditions at low duty cycles,
  - the expected level of exposure in comparison with the FCC guidelines
- Comparison with EM emission from other common devices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



***An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter*, Palo Alto, CA: 2010. 1021126.**

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.



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A Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading Technology

EMF Health Assessment and RF Safety

Introduction

Advanced Metering Infrastructure (AMI) is "comprised of state-of-the-art electronic/digital hardware and software, which combine interval data measurement with continuously available remote communications. These systems enable measurement of detailed, time-based information and frequent collection and transmittal of such information to various parties. AMI…typically refers to the full measurement and collection system that includes meters at the customer site, communication networks between the customer and a service provider, such as an electric, gas, or water utility, and data reception and management systems that make the information available to the service provider." [EPRI Fact Sheet (1014793, 2007)] The National Energy Technology Laboratory's February 2007 report, "Integrated Communications," expresses the indispensable nature of AMI: "Due to its dependency on data acquisition, protection, and control, the modern grid cannot exist without an effective integrated communications infrastructure. Establishing these communications must be of highest priority since it is the first step in building the modern grid." The collection of such information from end users would occur through Neighborhood Area Networks (NANs) for transmission to service providers over Wide Area Networks (WANs). NANs consist of low-power transmitters and local receivers or data collectors (e.g., mounted on poletops), which relay the information via WANs to a remote repository where the data can be managed and analyzed. WANs commonly use the same kind of technology as the so-called Aircards® that individuals use for wireless internet connectivity from their laptop computers. AMI is also envisioned as including a Home Area Network (HAN), whereby various devices throughout a household – these may include lighting, thermostats, and other electrical appliances, etc. – would be in wireless contact with a central coordination and data collection node within the residence. The HAN would enable such a household to receive data describing its electrical usage behavior, and enable optimal energy usage efficiency. General schematics of AMI with the HAN component are shown in Figure 1.

Figure 1. Schematics of Automatic Metering Infrastructure (Top[1]) and a House Area Network (Bottom[2])

AMI Building Blocks

[1] Assessment of Demand Response and Advanced Metering – Staff Report, FERC Docket AD06-2-000, August 2006

[2] Used with the permission of San Diego Gas & Electric

As these technologies have developed over the past few years, one component of AMI, the Automatic Meter Reader (AMR) has especially attracted questions from electric utility residential customers. AMR displaces and expands the role of the meter reader, who entered a home or building premises to manually record electrical power usage, mainly for billing purposes. AMRs transfer data wirelessly with a radio-frequency (RF) transmission to a nearby NAN, as described above, in some cases to a utility service vehicle with data collection equipment situated outside of the residence, or less commonly, over a physical

***A Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading*, EPRI, Palo Alto, CA: 2010. 1020798.**

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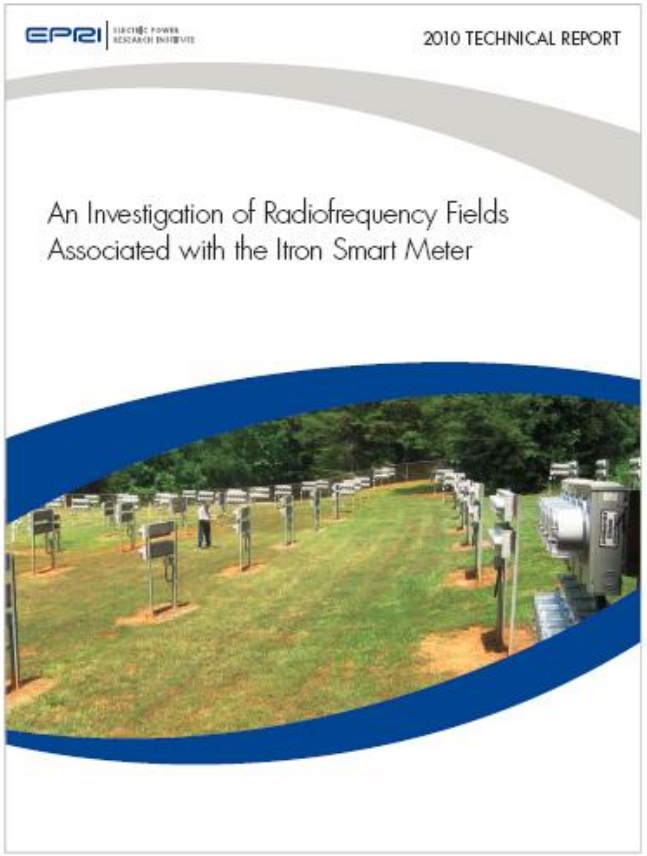
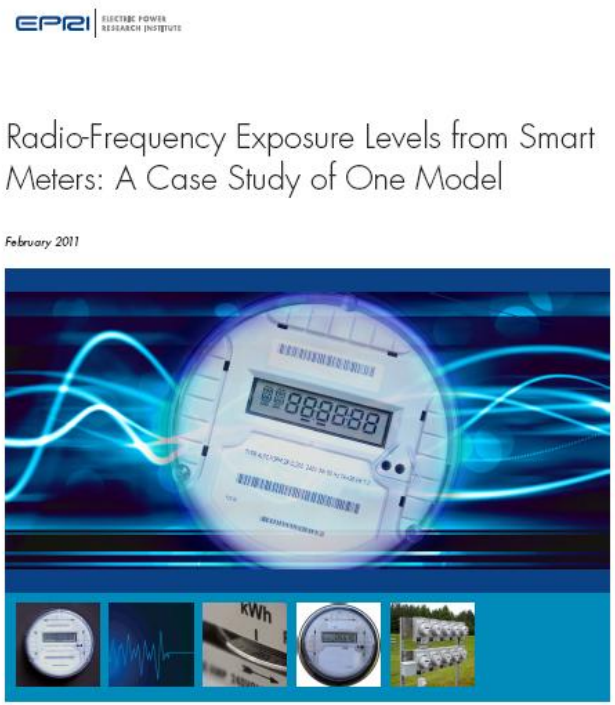


***An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter*, Palo Alto, CA: 2010. 1021126.**

EPRI Research on Smart Meter Emissions

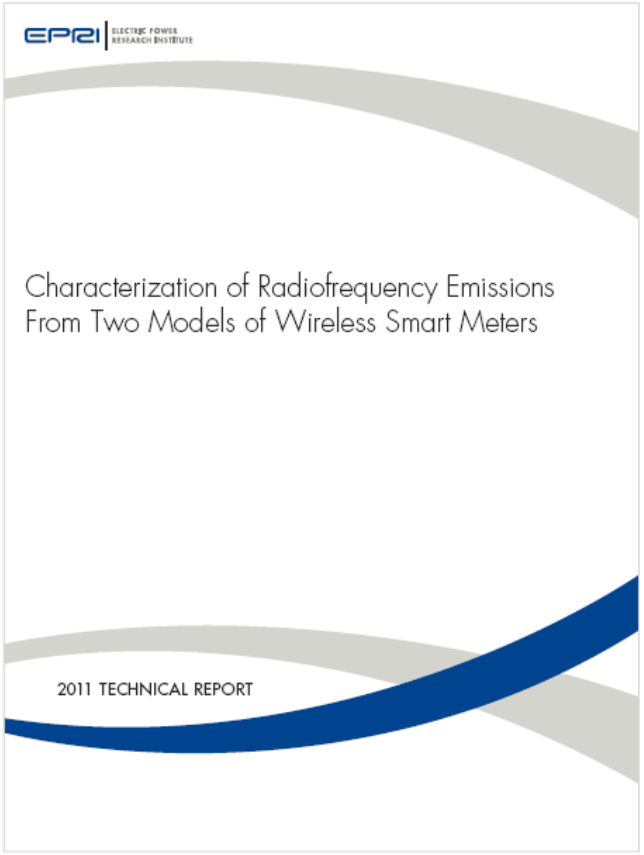
- Report on RF emission data collection on smart meters carried out in a laboratory setting and at residences in the states of California and Washington.
- Analysis of the EM emission vs. FCC standard
- Results indicate emissions always less than 1% of the FCC maximum permitted exposure (MPE) for typical 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.



Radio-Frequency Exposure Levels From Smart Meters: A Case Study of One Model, **EPRI, Palo Alto, CA: 2011. 1022270.**

EPRI Research on Smart Meter Emissions

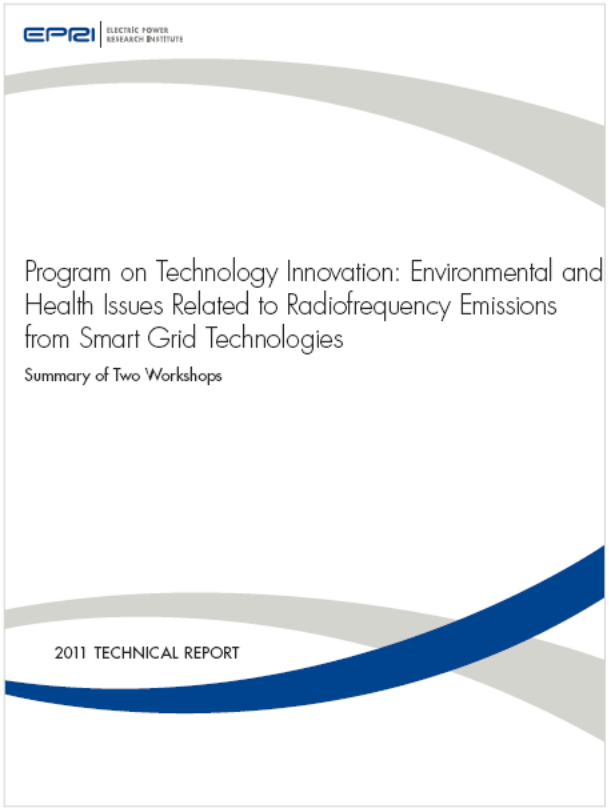
- Measurements on typical indoor values of the RF fields for six residential locations in the service territory of the PG&E electric utility company.
- Measurements of the composite RF field environment from arrays of smart meters installed and operating next to each other in three different apartment 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



***Characterization of Radio Frequency Emissions From Two Models of Wireless Smart Meters,* EPRI, Palo Alto, CA: 2011. 1021829.**

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.



***Program on Technology Innovation: Environmental and Health Issues Related to Radiofrequency Emissions from Smart Grid Technologies - Summary of Two Workshops*, EPRI, Palo Alto, CA: 2011. 1024737.**

EPRI Research on Smart Meter Emissions

- 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.

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EPRI Comments: A Perspective on Two Smart Meter Memoranda

EMF and RF Health Assessment and Safety

Introduction

In January 2012, two separate memoranda – one from the Santa Cruz (CA) County Health Officer[1] and another from the American Academy of Environmental Medicine (AAEM)[2] – were issued indicating views that the radio-frequency (RF) electromagnetic fields emitted from smart meters pose a health risk. The purpose of these EPRI Comments is to offer additional perspectives on the issues raised in these two memoranda.

The two memoranda assert that the Federal Communications Commission (FCC) rule issued in 1997 (see FCC OET Bulletin 65[3] and Code of Federal Regulations 47 CFR § 1.1310) that sets enforceable limits on human RF exposure is protective of only adverse thermal effects, and does not address non-thermal effects. Neither the Santa Cruz nor the AAEM documents took into account the vast wealth of research on RF conducted over nearly half a century, as well as the "weight-of-evidence" approach taken by any number of expert groups and panels convened over the years to evaluate the RF health science literature.

Background

By way of historical perspective, the 1997 FCC rule was adopted from two previous guidelines, one published by the National Council on Radiation Protection and Measurements (NCRP Report No. 86) in 1986, and the other by the Institute for Electrical and Electronic Engineers (IEEE C95.1) in 1991. Both had extensively reviewed the biological and health literature, regardless of whether or not the research had been conducted at non-thermal levels of exposure. NCRP and IEEE both concluded that the only established effects were associated with tissue heating, and that there were no confirmed adverse effects from RF exposure levels below an exposure threshold associated with an elevation in body temperature of about 1 degree centigrade (1.8 degrees Fahrenheit).

Prior to its publication, the FCC rule received endorsements from the U.S. Environmental Protection Agency (EPA), the U.S. Food and Drug Administration (FDA), and the U.S. Occupational Safety and Health Administration (OSHA). The EPA reaffirmed its opinion in letters written in 1999 and 2002. The expanding body of scientific evidence concerning potential health effects from RF exposure has been re-visited since the FCC rulemaking, but the basic conclusions have remained consistent with the position taken by the FCC in 1997. The International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998 reaffirmed in 2009) and the IEEE (2005) published exposure limits very similar to the FCC's following a comprehensive review of the scientific literature.

References to reviews and comments about RF health by a variety of scientific and governmental institutions are included at the end of this commentary. They reflect a consensus that adverse effects from RF exposure have not been established below the thresholds that serve as the basis for published exposure limits.

Concerns about RF exposures received significant visibility in Spring 2011 when the International Agency for Research on Cancer (IARC) released the results of its expert panel's evaluation of potential cancer risks from radiofrequency exposures.[4] Based on "limited"[5] epidemiologic evidence in studies of cell phones and "limited"[6] evidence from a small

[1] http://scccounty01.co.santa-cruz.ca.us/bos/Govstream/BOSvData/non_legacy/agendas/2012/2012012/24/PDF/041.pdf

[2] http://aaemonline.org/images/CaliforniaPublicUtilitiesCommission.pdf

[3] http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf

[4] http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf

[5] "A positive association has been observed between exposure to the agent and cancer for which a causal interpretation is considered by the Working Group to be credible, but chance, bias or confounding could not be ruled out with reasonable confidence." (from: IARC)

[6] "The data suggest a carcinogenic effect but are limited for making a definitive evaluation because, e.g. (a) the evidence of carcinogenicity is restricted to a single experiment; (b) there are unresolved questions regarding the adequacy of the design, conduct or interpretation of the studies; (c) the agent increases the incidence only of benign neoplasms or lesions of uncertain neoplastic potential; or (d) the evidence of carcinogenicity is

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

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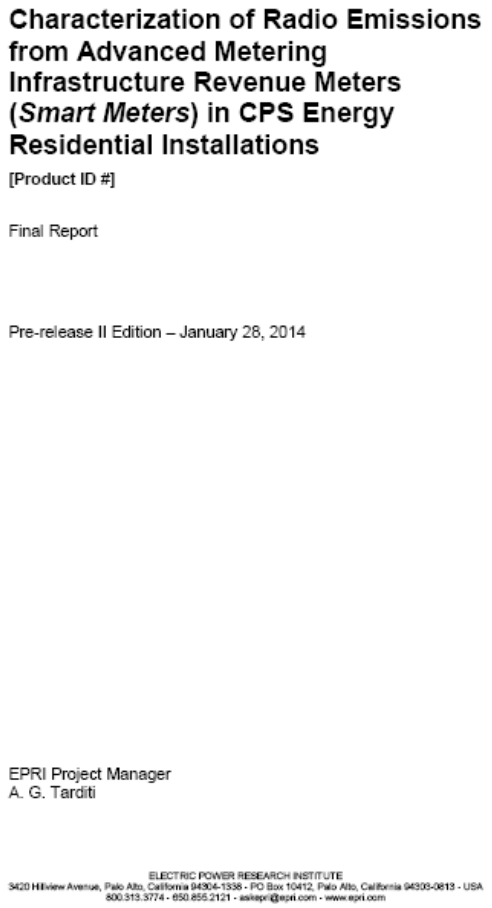
EPRI Research on Smart Meter Emissions

- 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

[Product ID #]

Final Report

Pre-release II Edition – January 28, 2014

EPRI Project Manager
A. G. Tarditi

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***Characterization of Radio Emissions from Advanced Metering Infrastructure Revenue Meters (Smart Meters) in CPS Energy Residential Installations*, EPRI, Palo Alto, CA: 2014, to be published.**

EPRI ELECTRIC POWER RESEARCH INSTITUTE

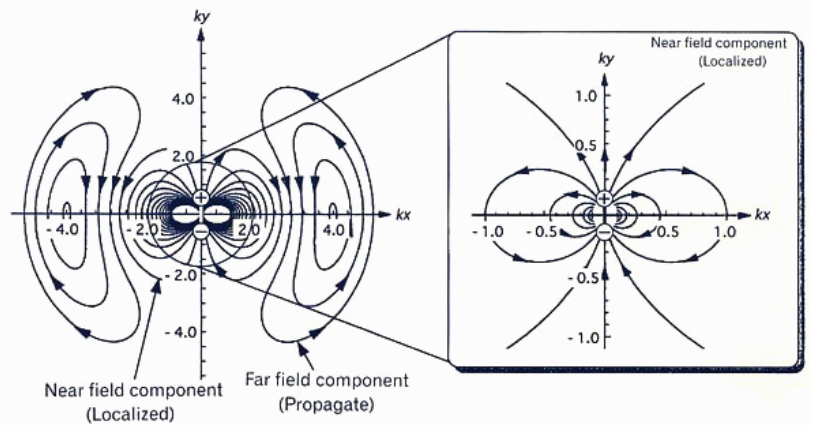
EM Field Primer

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

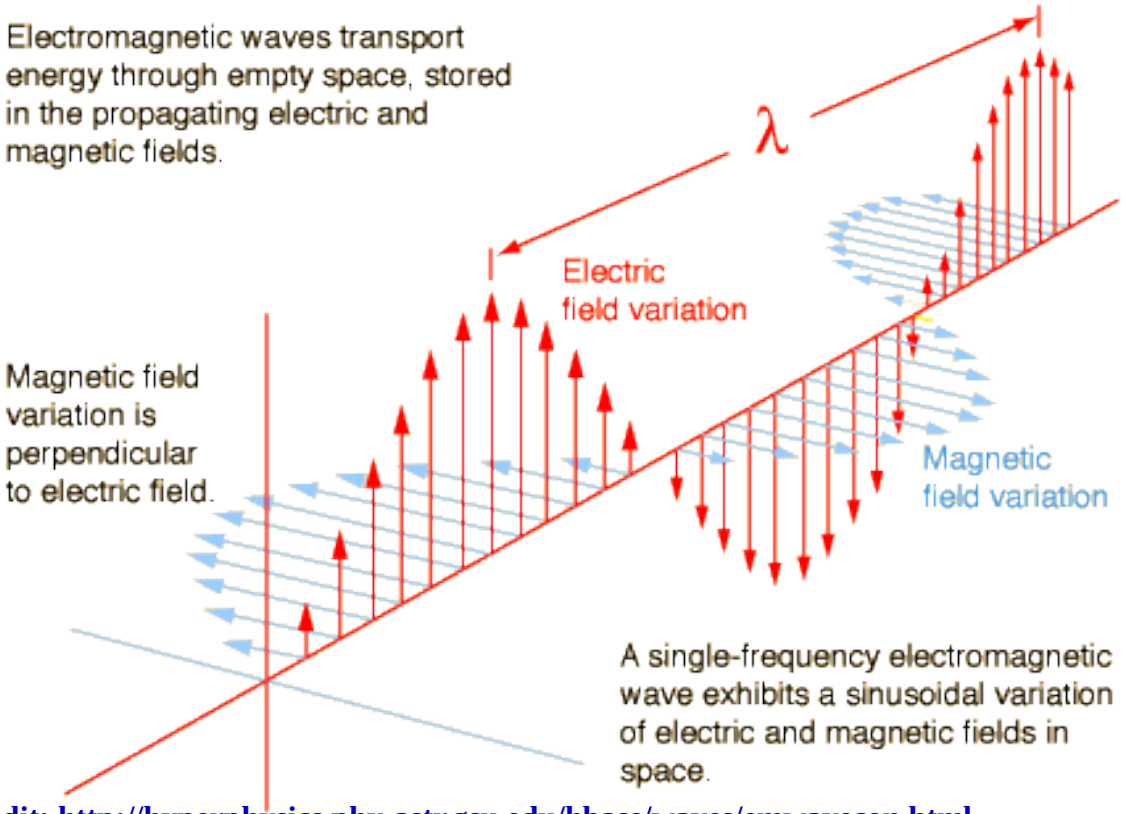
- Amplitude of Electric (E) and Magnetic field (B) components
  - Why they matter: the coupling issues
  - The impacts on living tissue
  - Near- and Far-field



- Radiated Power vs. Reactive Power
- Frequency
  - Propagation through matter
  - Absorption and energy conversion
- Time of Exposure

EM Field Primer

Electromagnetic waves



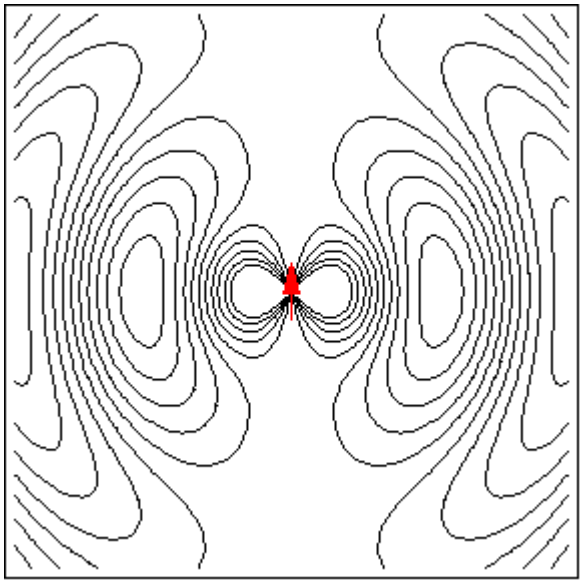
Credit: http://hyperphysics.phy-astr.gsu.edu/hbase/waves/emwavecon.html

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

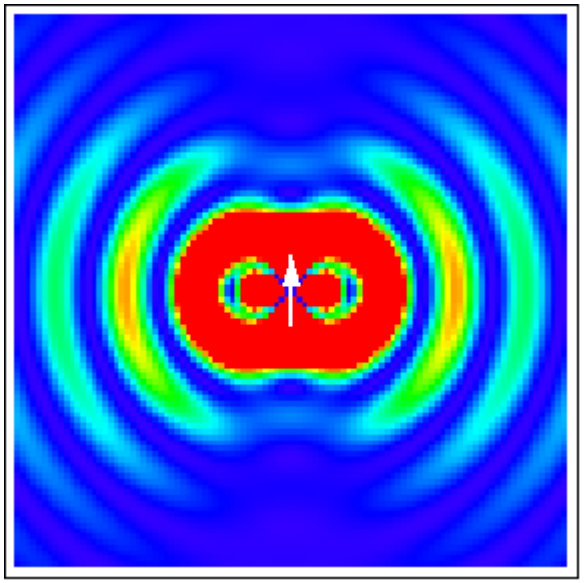
EM Field Primer

Electric and magnetic field components

- Generation
- Propagation



Dipole antenna electric field lines



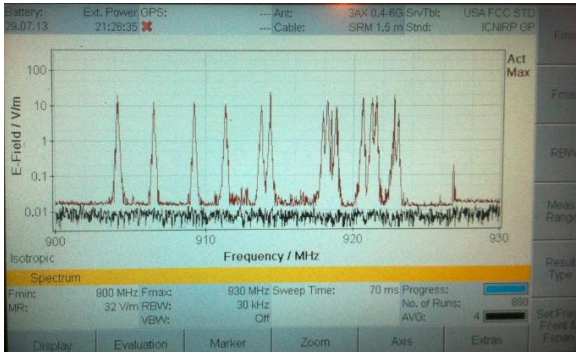
Dipole antenna electric field energy

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

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Smart Meter Emissions 2013 Project

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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).

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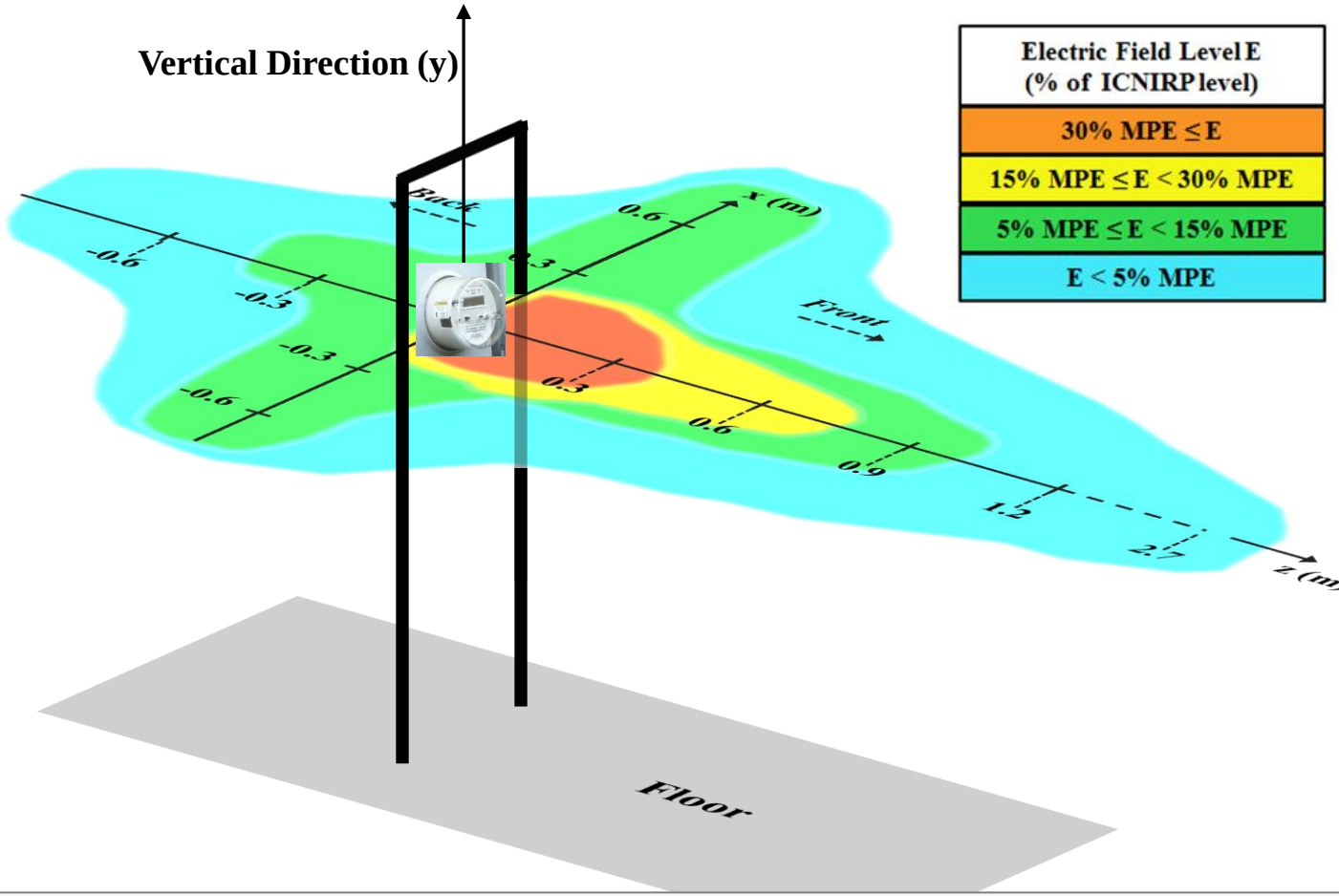
Smart Meter Emissions 2013 Project

Project Highlights

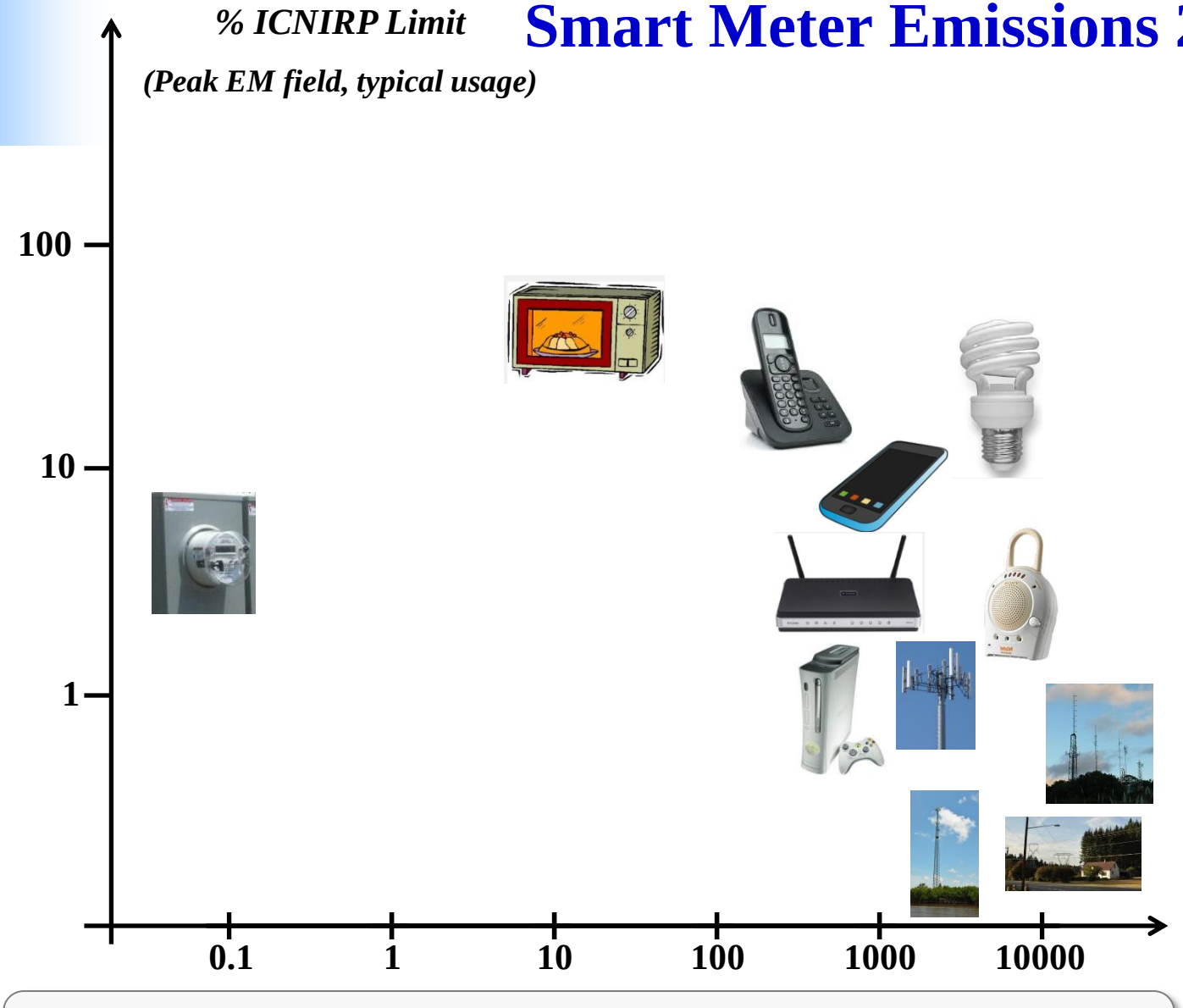
- Project with high general relevance in the context of current AMI technology development
- Data have been collected with a particular focus on actual utility installation
- Measurements performed on smart meters in operating residential installations
- More extensive laboratory tests were conducted to cover different models that are currently in the utility smart meter installation plan

Smart Meter Emissions 2013 Project



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

Smart Meter Emissions 2013 Project



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

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

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.

Reference: M. Ganley et al. "Permitted Noise Above 1 GHz: Final Report", ERA Technology Report 2006-0450 (2006) 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

UHF TV 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.

Reference: M. Ganley et al. "Permitted Noise Above 1 GHz: Final Report", ERA Technology Report 2006-0450 (2006) 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 $p_{ERP}=1000/(2\pi d^2)=0.088$ 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

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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.

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Together…Shaping the Future of Electricity

Backup Slides

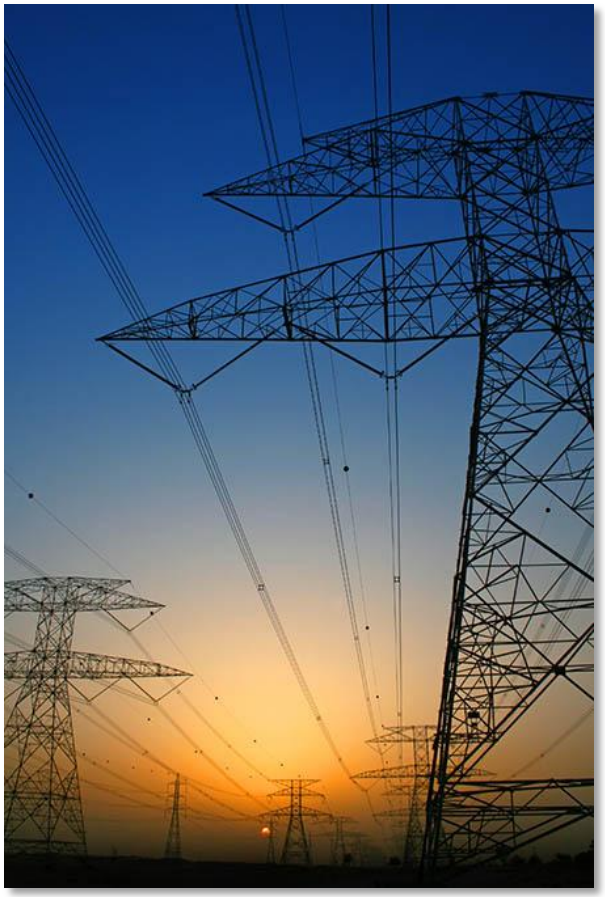
Rationale for a Power Utility EMC Program

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

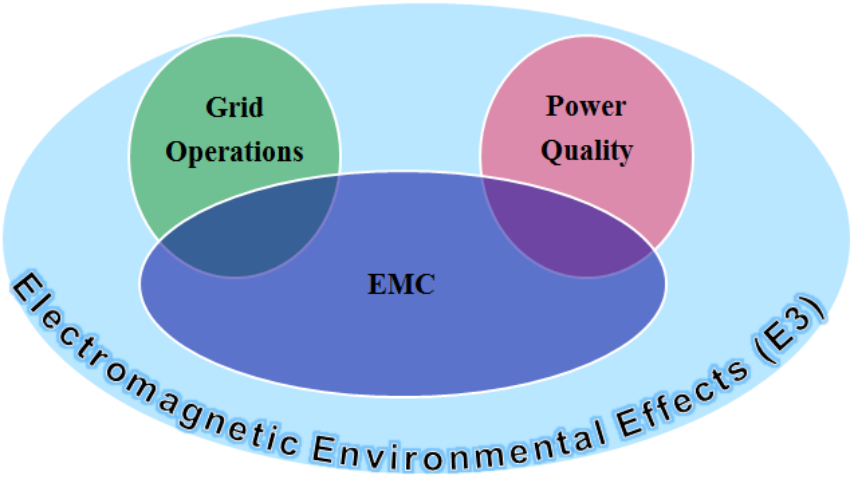
- Fully integrated Smart Grid: co-existence of power lines, sensors, data communication and processing, all requiring stricter EMC guidelines

Ya'll need EMC anyway

- EMC fixes are generally more costly and less effective than preventive design and testing

The Need for EMC

Relationship between EMC to PQ



EMC Events

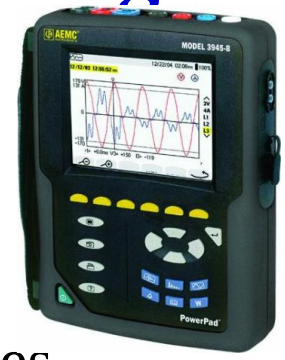
- Typically involving small, stray signals coupling to sensitive equipment

PQ Events

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

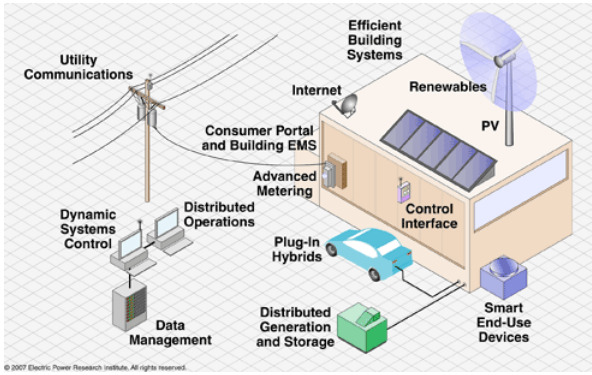
PQ relates to the perturbation of a power system and that typically requires another power system

EMC New Role in an Old Engineering Sector



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



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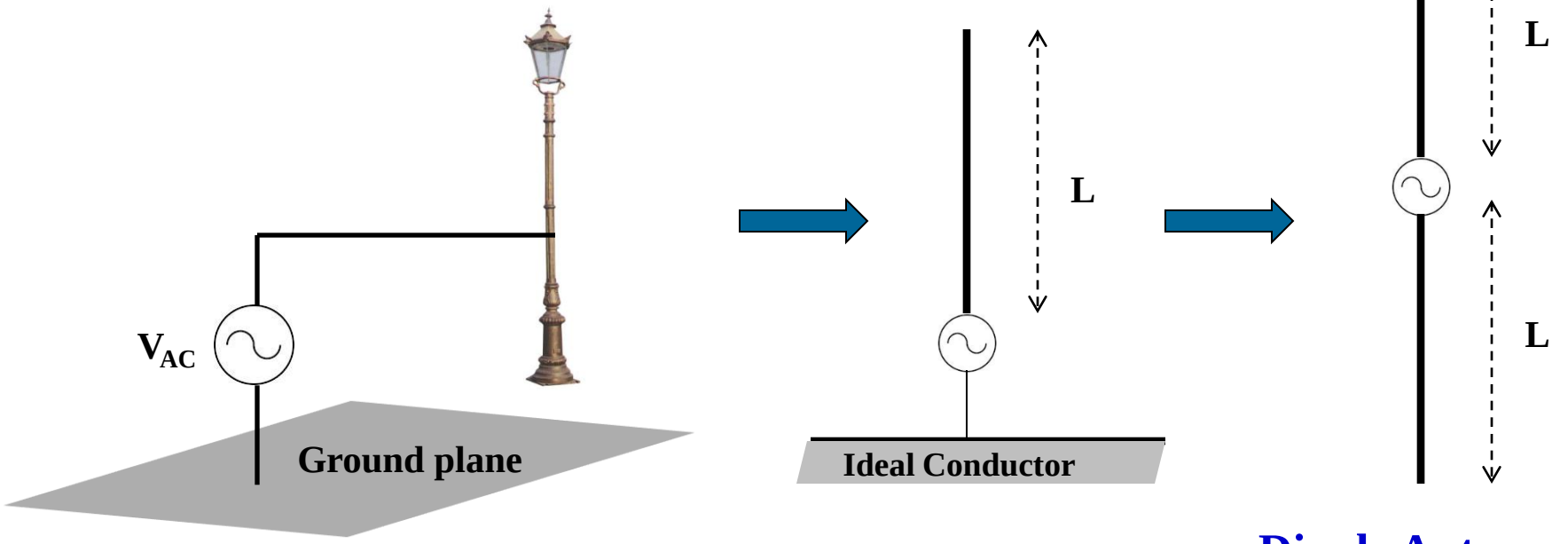
Energized Objects

- 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

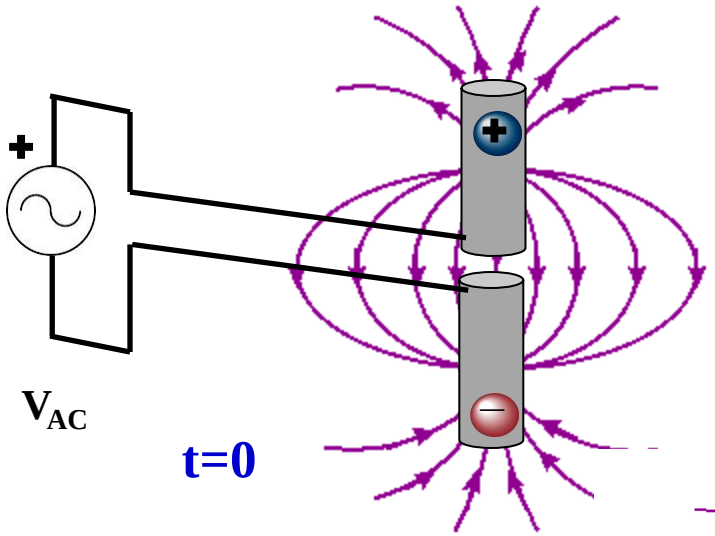


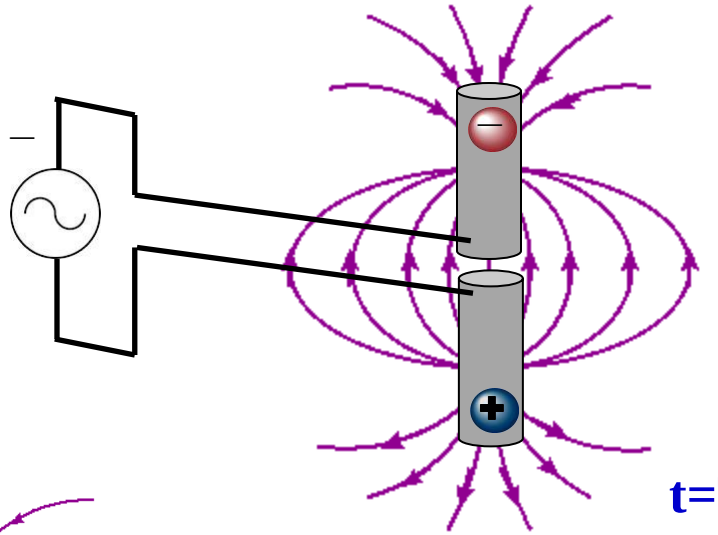
The Near-Field Region

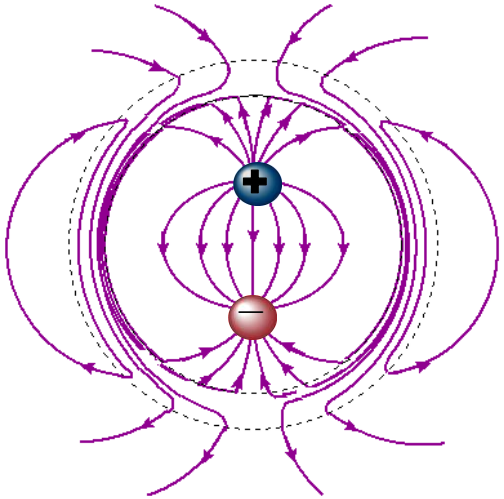
- An antenna with length L much smaller than the wavelength λ is referred to as "*electrically short*" (typically $L << \lambda/50$)
- The EM emission pattern of electrically short antennas is much like that of an infinitesimal (ideal) dipole
- For an ideal dipole the maximum radiated and reactive powers 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







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