

New EMF Technologies - A Challenge for Radiation Protection?

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Is New EMF Technology a Challenge for Radiation Protection?

To Answer ...

Look at Some Numbers

- **Nearly half of the world population
~ 3.5 billion have access to cellular
mobile telephones**
- **About 20% world's population live
without electricity and its services**
- **At current rate of cell phone growth
more of the world's population will
have access to mobile phone
services than to electricity**

Potential Exposure of Entire Population: Young and Old

Large-Scale Deployment and Popularity result in **huge numbers of individuals** at workplace and in public being exposed to RF fields

Moreover, there are...

- Increasing number of **new devices and systems** emit RF-EM energy at broad range of wireless frequencies
- **Total level of exposure** rises because of superposition of EM fields emitted by new and existing sources
- Questions on health effects from exposure to new and existing systems and devices persist

- Highlight **new technologies** under development or recently or soon-to-be deployed
- Assess **exposures** and **research needs** to evaluate their NIR safety and health implications

Specific Topics

- **Mobile Wireless Communication Technologies**
 - Cellular Mobile Devices and Systems
 - Wireless Networks & Devices (*Bluetooth, WiMAX*)
- **Rapidly Developing and Emerging Technologies**
 - Radio Frequency Identification (RFID)
 - Ultra-Wide-Band (UWB) Systems
 - Adaptive Vehicular Cruise Control
 - TeraHertz (THz) Security Technology
 - Induction Heating Devices and Appliances
 - High-Field and Interventional MRI
- **Current and Future Challenges**

Cellular Mobile Communications

■ 2G – GSM and TDMA

- **Major Breakthrough** in cellular mobile communication
- GSM at 900 and 1800 MHz (TDMA at 835 and 1900 MHz), 250 kHz **bandwidth**, and 9.6 kbit/s **data rate** with constant envelope, access frequency of 217 Hz and **power control** and system signals at 2 and 8 Hz.
(250 – 600 mW handset power).

■ 3G UMTS-WCDMA (ITU-IMT-2000)

- 1900-2170 MHz with 5 MHz **bandwidth**, “chiprate” of 3.84 Mbit/s, **power control** at 1500 Hz, but non-constant envelope feature give power spectral peak at 3.84 MHz.
(125 mW Max; 0.25 mW handset power in Urban Cell)

*Base
Station*

Wireless Local Area Networks

■ Bluetooth

- Short-range (1-10 m) wireless cable replacement at 2.45 GHz.
- Small LAN as Piconets, with point-to-multipoint at 1 Mbit/s
- Headset, Mouse, Office Equip, A/V Comps (0.25 -- 100 mW Max)

■ DLNA (Digital Living Network Applications)

- **Digital home of the future** and beyond - DLNA-compliant products launched already for in-home
- Wireless and Wired networks to share digital content: photos, music, and videos through consumer electronics, game players, PCs, and mobile devices via Wi-Fi compliant Universal Plug 'n' Play using IEEE 802.11.

4G Wireless IP Broadband Networks

- Direct internet service to laptops (w/o AP) with seamless roaming like cell phones for data, text, voice, photo, music, video, and mobile TV
- ITU goals of **100 Mbit/s** for mobile environments and **1 Gbit/s** for fixed
- Exposure is expected to be at or below 3G applications but with different modulation (OFDMA and SC-FDMA) Schemes

■ Two Competitor Air Interfaces for Combined Fixed and Mobile:

■ WiMax – Current Leader and Under Test Deployment

- IEEE 802.16 (WiMAN/WiMax) air interface to support “Last Mile”, “Internet Everywhere” and MiMo using **2 and 11(66) GHz** [toward 2.3, 2.5 and 3.5 GHz] bands (1.25-20 MHz bandwidth) for browsing,
Performance: 50 Mbit/s at 110 km/h AND 10 Mbit/s at 10 km range

■ LTE - Long Term Evolution

- An evolution of UMTS from 3GPP; Spec Complete in 2008
- **Performance: 90-160 Mbit/s at 15 – 120 km/h for 700 MHz at 5-30 km coverage**
- **EVDO (Evolution Data Only); Available at 1.8–3.1 Mbit/s through Card for laptops or built-in**
- **3G IP (internet protocol) version of CDMA2000 from 3GPP2**

Radio Frequency Identification (RFID)

- RFID systems consist of RF tags and RF readers or interrogators.
 - **Active RF tags with batteries** - relatively high-strength RF signals
 - **Passive RF tag systems** - low power with applications in large numbers
- Types of Passive RF Tags:
 - Card-type RF tags are popularly used in **automatic ticket**
 - Adhesion-sheets for apparels and books
 - Heat-resistive type for dry cleaning
 - Glass-encapsulated implantable type for animals,
 - **Outdoor types for vehicles** and transportation containers,
- Types of RF Readers
 - Tunnel or **Gate in factories or highways**
 - Gate in stores and libraries for Electronic Article Surveillance (EAS)
 - **Panel on counters**
 - **Handheld for logistic**, inventory, and customer management
- Impact of the inductive coupling RFID systems, EAS, and security systems described in ICNIRP Statement, 2004 *Health Physics*.

RFID Systems

- Frequencies: 100 kHz to ISM (2.45 GHz and 5.8 GHz)
- For 13.56 MHz or lower - Inductive Coupling Mode
 - Short range (< 1 m) and high throughput
 - Card-type tag, ISO/IEC 15693-2 (0.15 – 5 A/m at 13.56 MHz)
 - ICNIRP reference level is 0.073 A/m for general public.
 - Intermittent Fields rapidly decrease with distance, spatial and temporal average should be applied when evaluating exposure.
 - Numerical simulation - induced current density in human body in a gate-type reader (EAS) is lower than ICNIRP basic restriction,
Gandhi and Kang 2001 (PMB)
- For UHF above 1.0 GHz - Propagation Coupling Mode
 - Longer range (1-5 m)
 - Output power of readers from several 100 mW to several watts
 - Lower than base station but higher than that of a cellular phone
 - Local SAR required for comparing with the ICNIRP basic restriction for RF reader in proximity of human body

Ultra-Wide Band Technology

- **US FCC Definition** of UWB Device & Operation:
 - Fractional bandwidth > 0.20 for lower frequencies
 - Occupies 0.5 GHz of spectrum for higher freq
- Center frequency > 2.5 GHz must have a -10 db bandwidth of at least 500 MHz
- Center frequency < 2.5 GHz must have fractional bandwidth of at least 0.20
- **High Data Transfer Rate: Maximum of 1 Gbit/s**
with low power limits
- **No Specification** for Physical Layer or Access Scheme for Communication Use

Ultra-Wide-Band (UWB), also called Digital Pulse

Wireless Communication Devices and Systems

Applications of UWB Technology

- High Bit Rate/Short Range Applications
 - Wireless Personal Area Networks (WPAN) for multimedia
 - Cable Replacement such as wireless USB
 - Wearable Devices, e.g., wireless Hi-Fi headphones

- The Low Bit Rate/Medium-to-Long Range Uses
 - Sensor networks such as indoor/outdoor distributed surveillance systems
 - Non-real-time communication, e.g., e-mail and text messaging

- Multi-Band (MB) frequency hopping with OFDM (MB-OFDM)
WiMedia focus on PC-centric W-USB application: 50 Mbit/s, 242 ns pulse (528 MHz BW over 3 bands within 3.1 -10.6 GHz)

- Direct-Sequence UWB, or DS-UWB, preserving original UWB pulse
CWave focus on Consumer Electronics: 500-890 Mbit/s, 750 ps pulse (1.35 GHz BW for 4 GHz carrier)

Imaging and Sensing Systems

Applications of UWB Technology

- Ground Penetrating Radars (GPRs)
 - Low frequency imaging systems with (-10 dB) bandwidth, below 960 MHz
- Medical imaging of Tissue Dielectric Permittivity Changes
 - Low frequency with (-10 dB) bandwidth for below 1.0 GHz
- Through-wall imaging and Surveillance Systems
 - Mid frequency with (-10 dB) bandwidth within 1.99-10,6 GHz
- Indoor Systems and Handheld UWB devices anywhere
 - High frequency with (-10 dB) bandwidth within the frequency band 3.1-10,6 GHz.
- Vehicular Radar for Proximity Braking and Control
 - Center frequency > 24.075 GHz with (-10 dB) bandwidth within 22-29 GHz

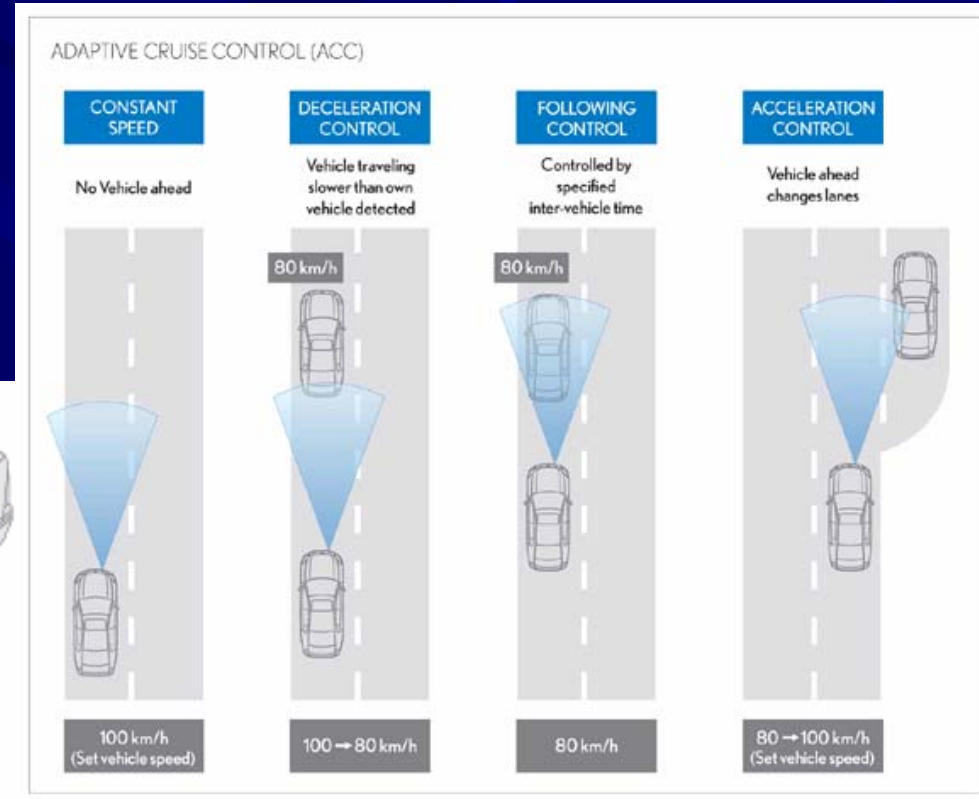
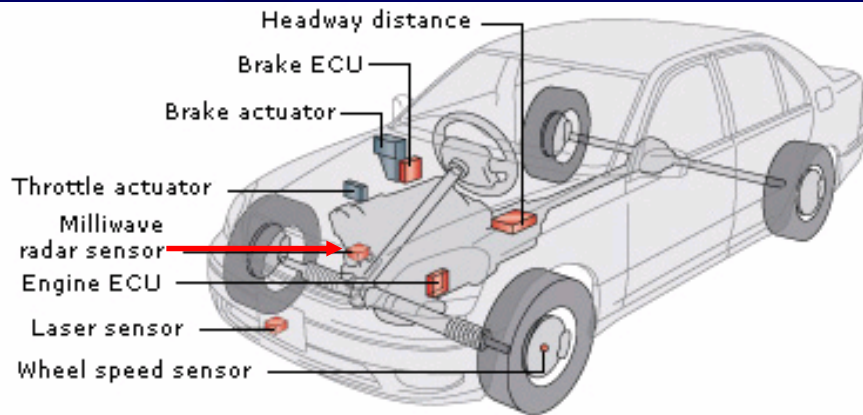
Average Emission Limits for UWB Systems

Frequency Band (MHz)	Imaging below 960 MHz	Imaging Mid Frequency	Imaging High Frequency	Communication Indoors	Handheld Transceiver In + out	Vehicular Radar
0.009-960	-41.3	-41.3	-41.3	-41.3	-41.3	-41.3
960-1610	-65.3	-53.3	-65.3	-75.3	-75.3	-75.3
1610-1990	-53.3	-51.3	-53.3	-53.3	-63.3	-61.3
1990-3100	-51.3	-41.3	-51.3	-51.3	-61.3	-61.3
3100-10600	-51.3	-41.3	-41.3	-41.3	-41.3	-61.3
10600-22000	-51.3	-51.3	-51.3	-51.3	-61.3	-61.3
22000-29000	-51.3	-51.3	-51.3	-51.3	-61.3	-41.3
Above 29000	-51.3	-51.3	-51.3	-51.3	-61.3	-51.3

EIRP in dBm with 1 MHz resolution bandwidth. **-41.3 dBm/MHz = 75 nW/MHz.**

Adaptive Vehicular Cruise Control

mm Wave Radar Sensing



Vehicle Setup

Functionality

Radar Cruise Control with All-Speed Tracking Function

To work in two speed ranges – low (0-30 km/h) and high (40-100 km/h)

Technical Requirements for Short Range Devices (SRD)

- **Frequency Band: 76-77 GHz**
- **Applications: Automatic Cruise Control; Collision Warning System**
- **Max Output Power:**
 - < 37 dbm EIRP, Vehicle in Motion;
 - < 23.5 dbm EIRP, Vehicle Stationary
- **FCC Requirements: Part 15 or EN 301 091**

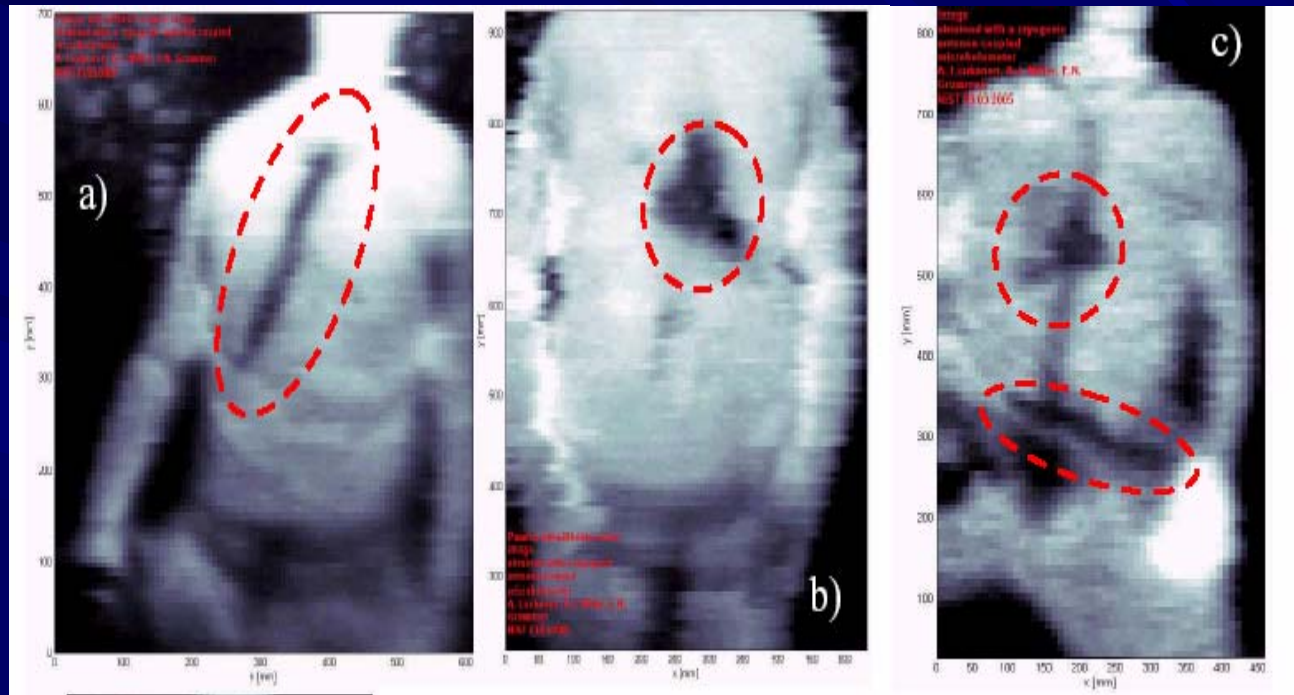
Potential Health Issues to Better Define System

- Biological Effects of 76-77 GHz Radar Fields
- Power Limits (1-3 W) Realistic or Thresholds?
- Large-Scale Deployment and Adoption could result in large numbers of pedestrians being exposed to RF fields

TERAHERTZ TECHNOLOGY

- **Frequency Range: 100 GHz to 10 THz**
- **Wavelength: 3 mm to 30 mm (MM Wave)**
- **Applications with Human Impact:**
 - **Passive/Active Security Scanning/Imaging**
 - **Biomarker Detection and Chemical Sensing (explosives and drugs)**
- **Key Enabling Technological Advances:**
 - **Sources: Quantum Cascade Laser & Smith-Purcell THz Source (mW)**
 - **Detectors: Antenna-Coupled Microbolometer & Hot-Electron Bolometers (1°K)**
- **Bioeffects: Safety of Human Exposure (?)**
 - **It's Nonionizing Radiation, But**
 - **Exploitation of Protein Interaction Mechanism**

Passive Indoor THz Images of Gun and Ceramic Knife Under Clothing



Passive images in 100 GHz to 1 THz band. Integration time 100 ms/pixel, Scanning time for each image 30 minutes. The ceramic knife is circled with oval, while gun is marked by circles. Items were hidden under two cotton shirts.

ThruVision T5000 camera picks up Terahertz Radiation or T-rays through clothing



L3 ProVision Active Millimeter Wave Whole-Body Imager



Source:

Two Rotating Antennas
0.1 – 10 THz, 10 – 60 μ W

Scan Time:

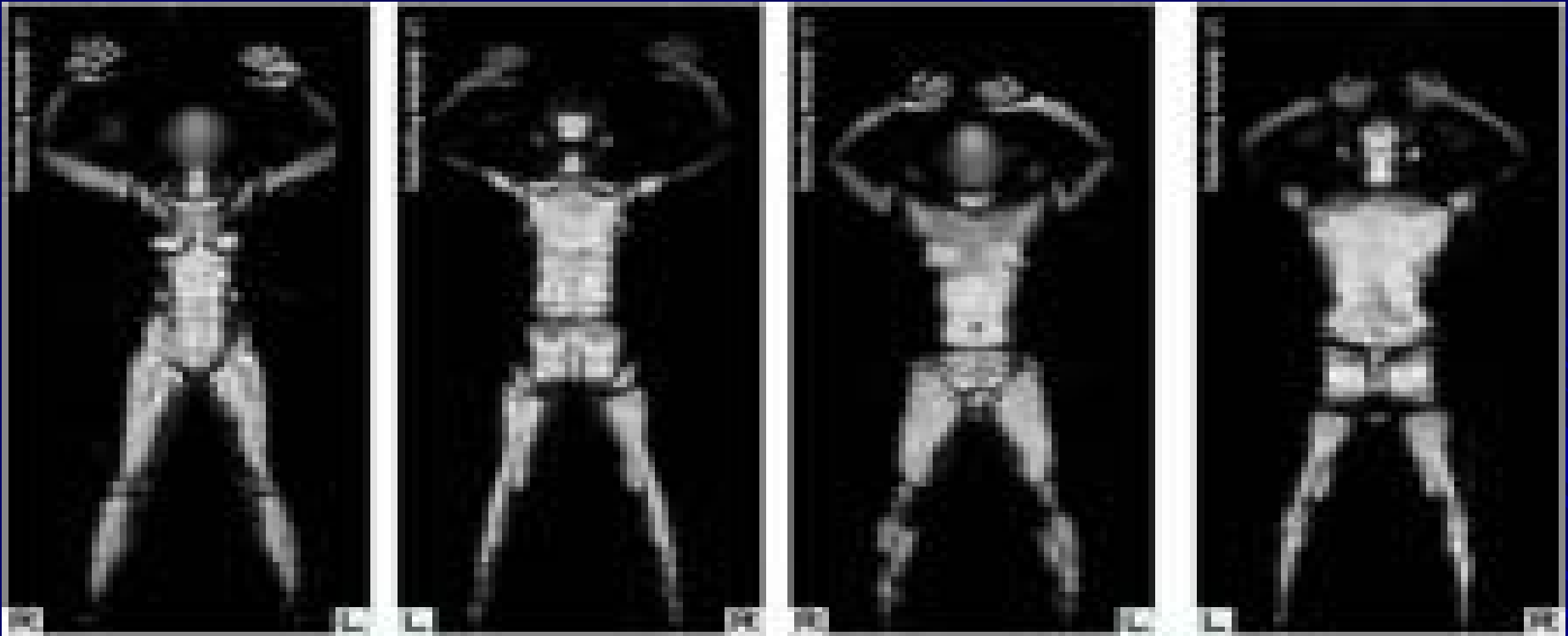
2-s scan time (real time) for
complete multi-directional view

Capability:

Detects liquids, gels, plastics,
metals, ceramics, etc.

And
weapons, standard and home-
made explosives, drugs,
money, documents, etc.

L3 ProVision Active Millimeter Wave Whole-Body Images



- Potentially Large Numbers of People May be Exposed to mm Wave RF fields
- Biological Effects are Unknown from Lack of Scientific Research

Induction Heating Applications

- Electromagnetic Heating of Conducting Materials at Intermediate Frequency (IF) for Controlled, Rapid, and Non-contact Heating - **Eddy Current**
- Industrial Metal Heating, Melting, Sealing, Welding (150 W to 600 kW at 1 kHz to 3 MHz)
- Induction Heating (IH) Kitchen Appliances **Gaining Popularity in Japan and Europe** (20-100 kHz modulated at 100/120 for 50/60 Hz)
 - Commercial Catering (5-10 kW)
 - Household Appliances (1-3 kW)
- **Exposure depend on user position**
May exceed the reference levels

Interventional and High-Field Medical MRI

ISSUES

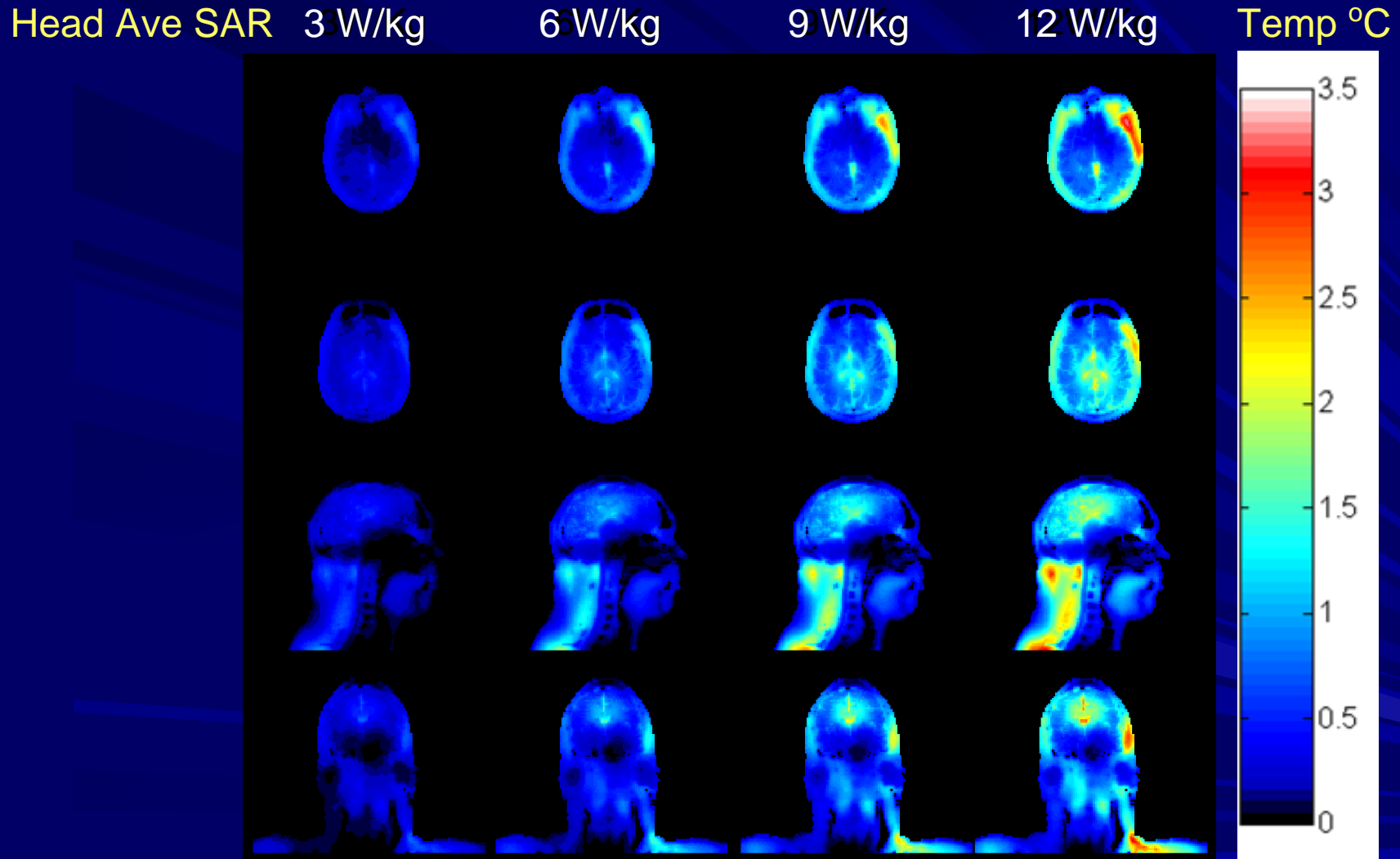
- Image Guided Interventional Procedures use 1.5-T MRI clinical scanners
- High-Field MRI -- Diagnostic imaging standard migrating from 1.5 to 3 T, and whole-body scanners at 7 T and above now available.
- Exposure of technicians, engineers, radiographers, and medical staff to stray magnetic field of conventional and high-field MRI
- Effects on Cognition, perception, neurobehavior, and performance
- Occupational exposure of the head, torso, and limbs to gradient fields
- Exposure condition may exceed current safety guidelines, especially for gradient fields

Interventional and High-Field Medical MRI

Effect of Whole-Body Exposure to Stray Magnetic Field

- Exposure of Whole Body to 1.5, 3.0 and 7 T MRI affect visual perception and hand-eye coordination at $dB/dt = 100$ to 300 mT/s (de Vocht)
- Vertigo from induced currents by $dB/dt = 2$ T/s on hair cells (7-T scanner)
- Postural sway at a field-gradient product of 1 T²/m (Glover)

Temperature Increase ($^{\circ}\text{C}$) after 30-min inside 7-T TEM MRI Head Coil



Change $1^{\circ}\text{C} <$ at 3 W/kg - Maximum allowed by the FDA

Conclusions

- The number of **new devices and systems** emit RF-EM energy at broad range of wireless frequencies are increasing
- **Total level of exposure** rises because of superposition of EM fields emitted by new and existing sources
- **Questions on health effects** from exposure to new and existing systems and devices persist
- If it transpires that EMFs have harmful health effects at relatively low exposure levels, this would have **huge societal and economic impacts**
- **Research needed** to evaluate their NIR effects, safety and health implications; existing data limited and inconsistent