RF Sources - Why Are Cell Phones Special?

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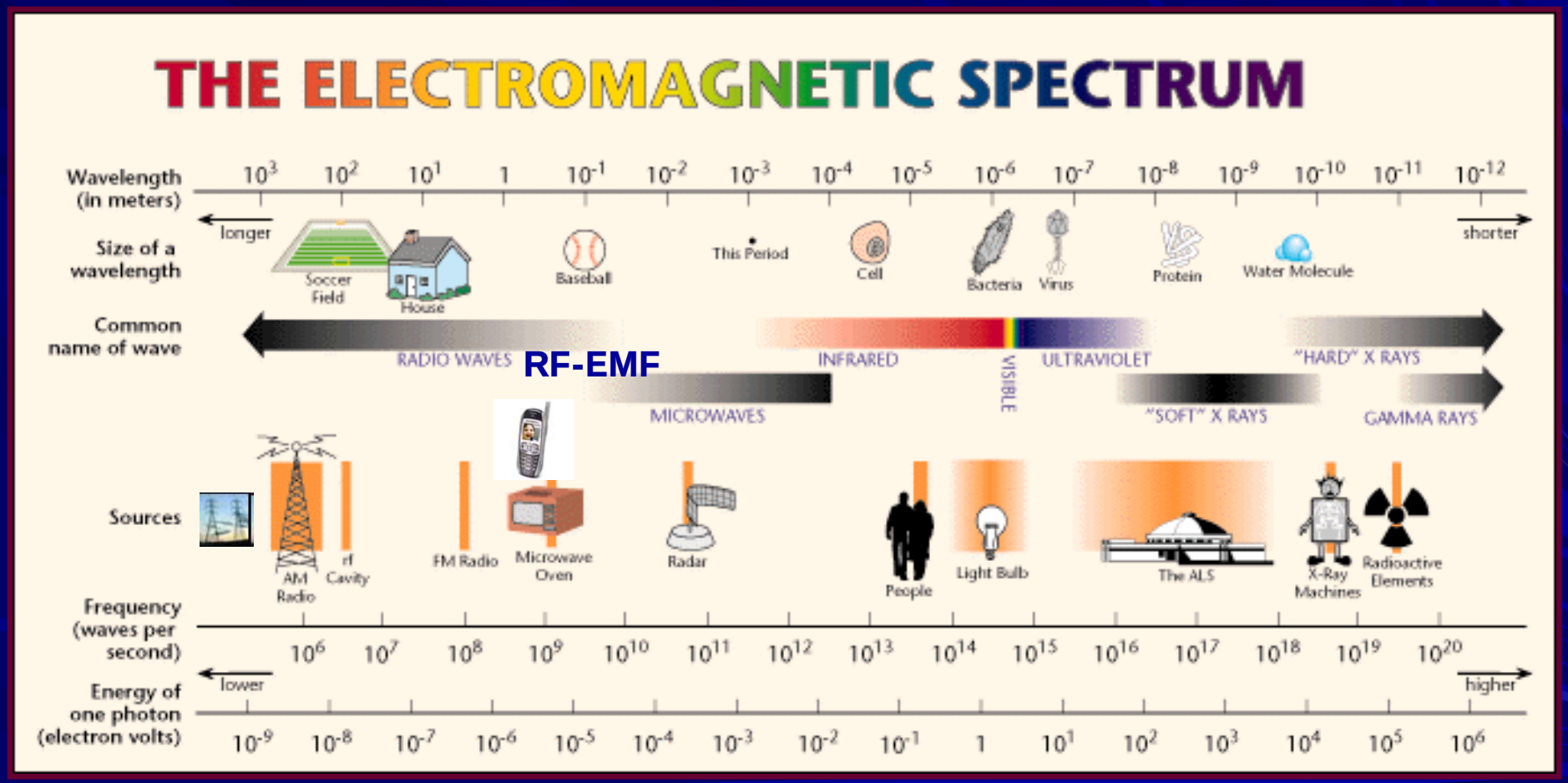
Radio Frequency Electromagnetic Fields (RF-EMF)



www.lbl.gov

History of Wireless Communications

- Prediction of Electromagnetic Waves - James C. Maxwell, 1865
- Experimental Confirmation - Heinrich Hertz, 1887
- Wireless Transmission - Guglielmo Marconi, 1895

- Radio Broadcasting Service, 1920
- Television Broadcasting Service, 1928
- Cellular Mobile Telephony, 1983 (1973)

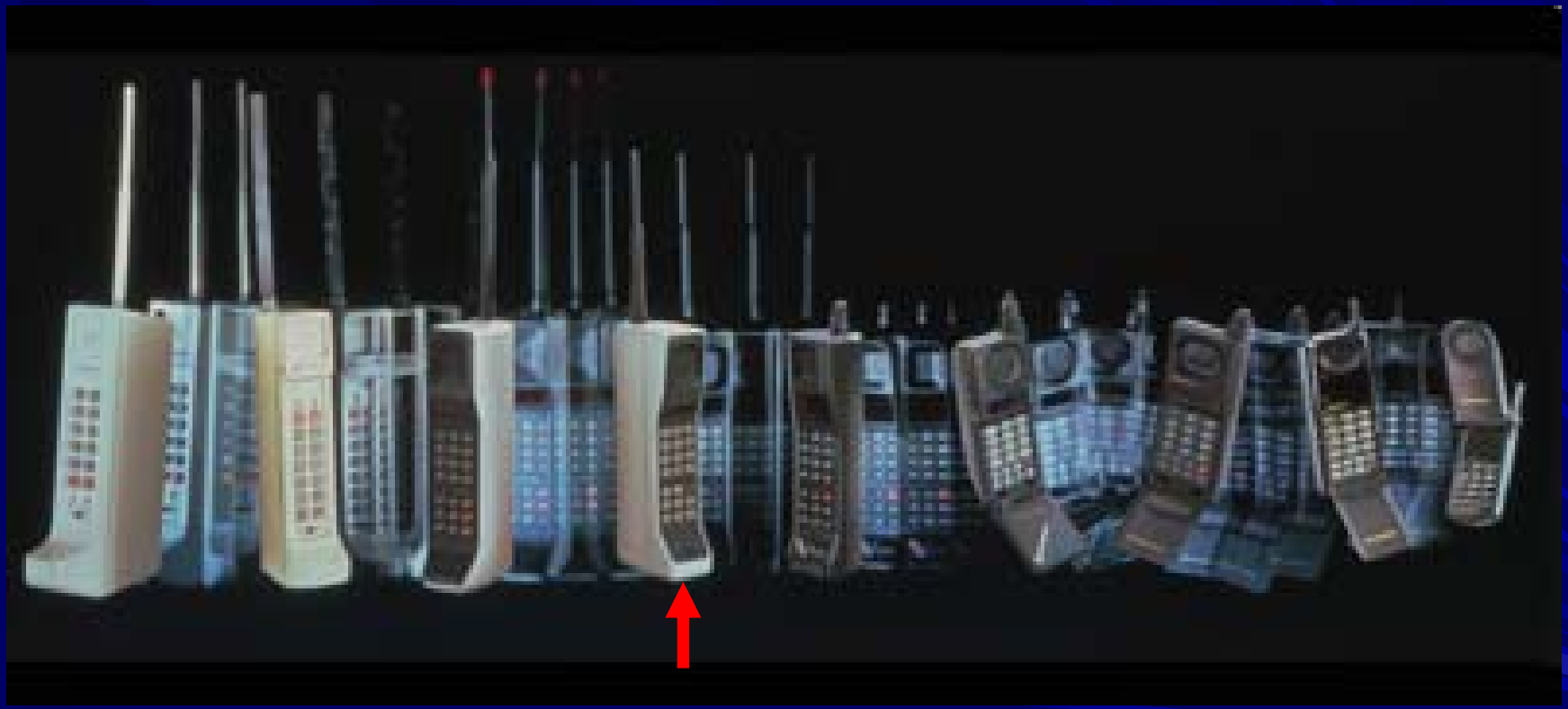
Bell's first telephone, 1875

First Portable Cellular Telephone

A "brick“ like 2 lb~1 kg phone, 1973

Commercial 1 lb~0.5 kg "DynaTAC" $4,000 phone, 1983
Cell-phone Subscribers reached 1 million by 1990 (1G)

The first quarter-century of Motorola handsets



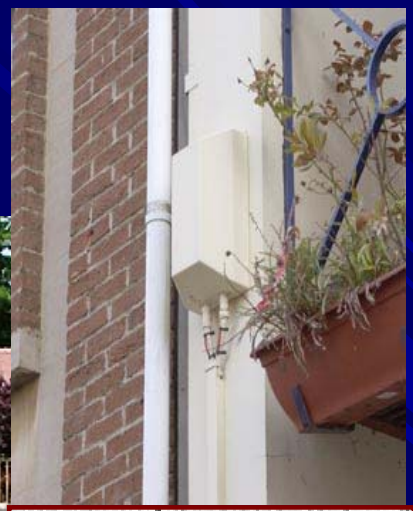
1973-1998

AM, FM and TV Broadcasting Towers

Fewer Numbers and Located on Mountain Tops and Huge Towers

Cell -Phone Base Station Antennas and Installations

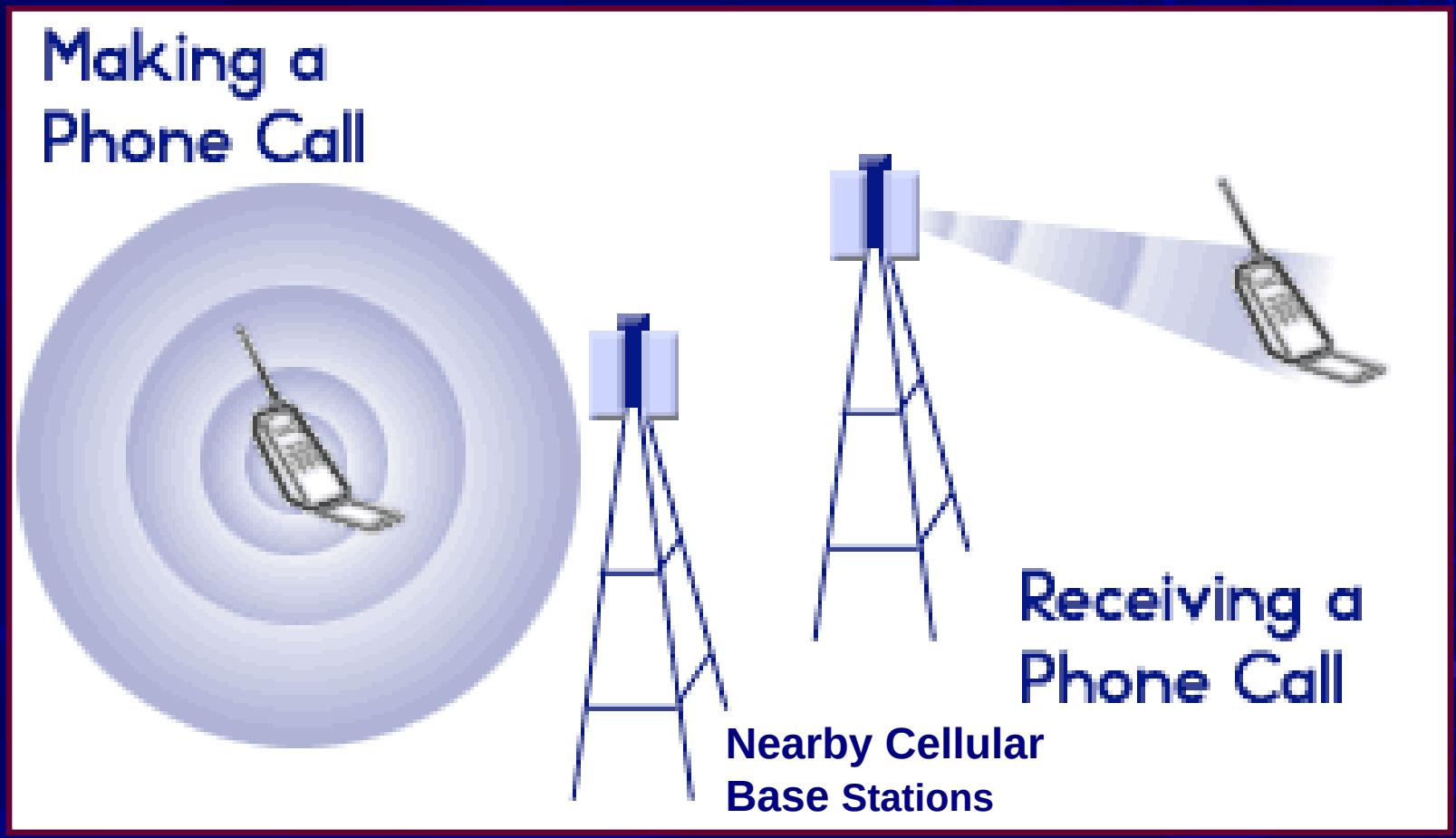
Many and
Widely Distributed



Broadcasting Technology & Operation

Cellular Mobile Telephony

Paradigm shift to personal and distributed access technology & operation



www.fda.gov

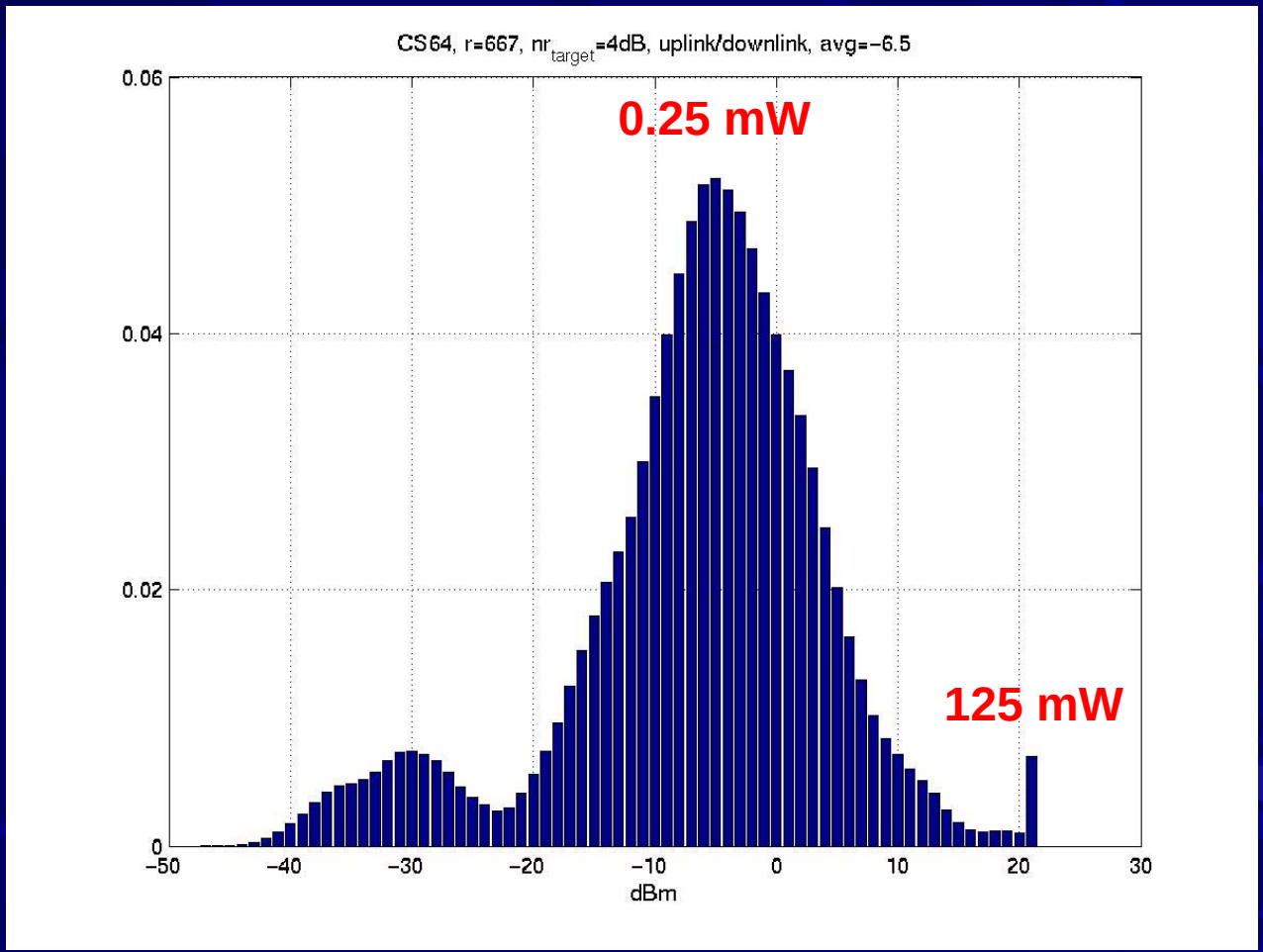
Cellular Mobile Communications

Cell-phone Subscribers reached 1 million by 1990 (1G)

- 2G – GSM and TDMA (1991)
  - **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)

Distribution of Handset Power in Urban Cell for W-CDMA System



Anderson

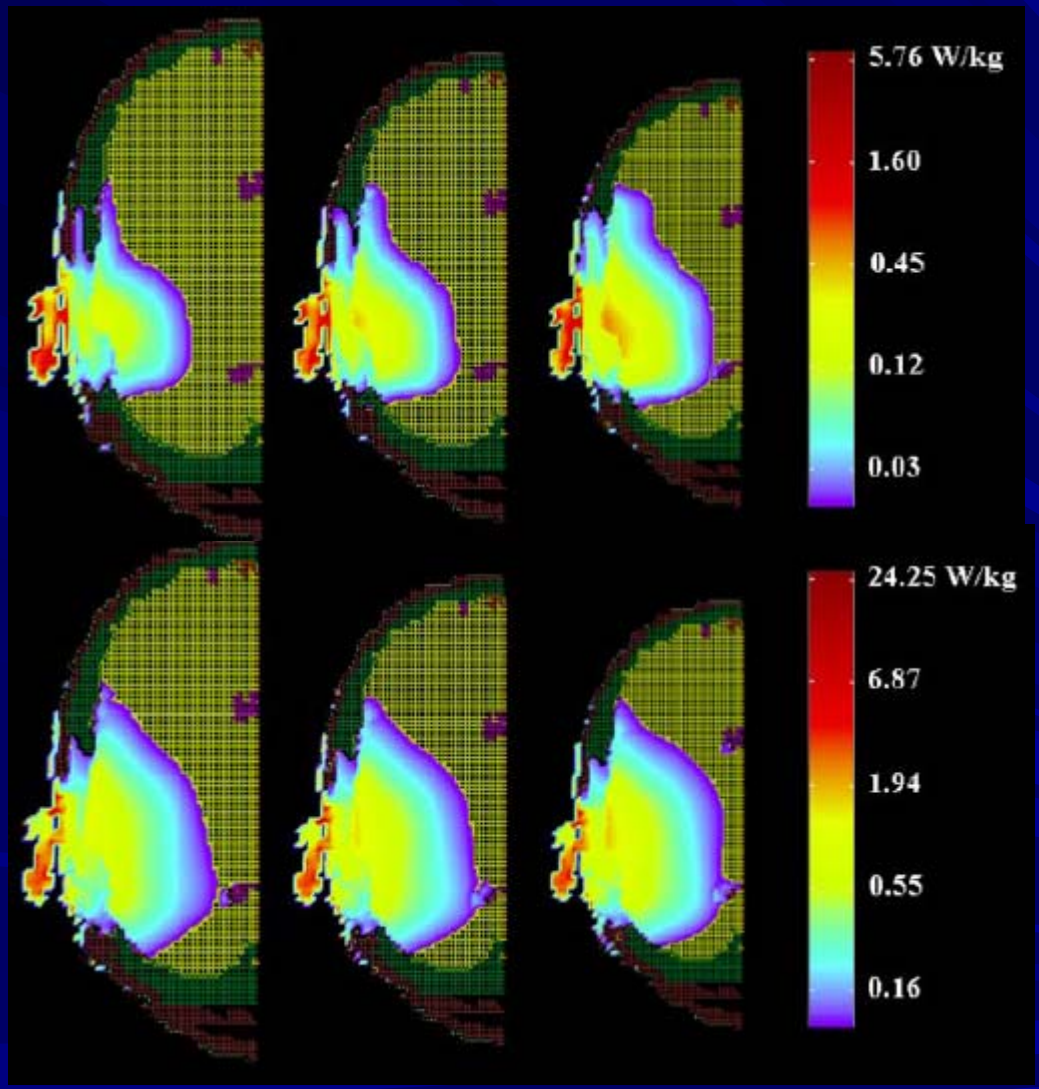
Causes for Resurgence of Interest in Human Health Protection

- Proliferation of Base-Station Antennas
- Rise in Popularity of Cellular Mobile Telephones
- RF Source Next to Many User's Head
  - First Time in Human History
- Potential for RF Interaction with Brain Tissue

SAR Distribution in Three Different Sizes of Human Head Exposed to Cell Phone

1900 MHz

835 MHz



Substantial Involvement of Tissues In the Head: Ear, Brain

Gandhi 2002

Mobile Terminals Devices - Transceivers

Wireless Local Area Networks

- **Wi-Fi (Wireless Fidelity)**
  - Data rate of 11 or 54 Mbit/s for 2.45 or 5 GHz at 100 mW
  - Access point, Hotspots, Ad-hoc systems allow mobility of terminals in home, cafe, hotel, airport, park, and campus

Wireless Local Area Networks

Standard	Description	Freq.	Data Rate	Prop. Year
IEEE 802.11	Original standard, exploiting the ISM band	2.4 GHz	2 Mb/s	1997
802.11b	Enhanced data rate	2.4 GHz	11 Mb/s	1999
802.11a	Fastest version, exploiting the UNII band	5 GHz	54 Mb/s	1999
802.11g	Same 802.11a speed, but in the ISM band	2.4 GHz	54 Mb/s	2003
802.11h	Modification of 802.11a for usability in Europe	5 GHz	54 Mb/s	2003

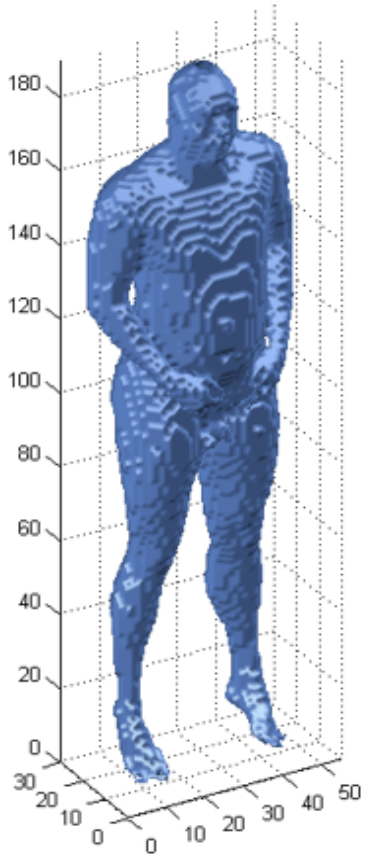
Wi-Fi Alliance certifies all IEEE 802.11 compliant devices
Most Wi-Fi on market are IEEE 802.11b.

Frequency Bands and Maximum Radiated Powers

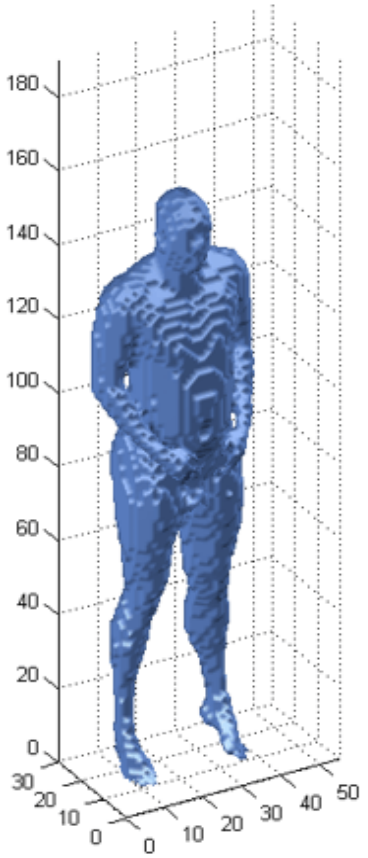
Freq. Band (MHz)	USA (FCC)		Europe (CEPT)	
	Radiated Power	EIRP	Radiated Power	EIRP
2400 - 2483.5	30 dBm	36 dBm	–	20 dBm
5150 - 5250	17 dBm	23 dBm	–	23 dBm
5250 - 5350	24 dBm	30 dBm	–	23 dBm
5470 - 5725	24 dBm	30 dBm	–	30 dBm
5725 - 5850	30 dBm	36 dBm	Unavailable frequency band	

Most Wi-Fi on market are IEEE 802.11b with a max EIRP of 100 mW (20 dBm).

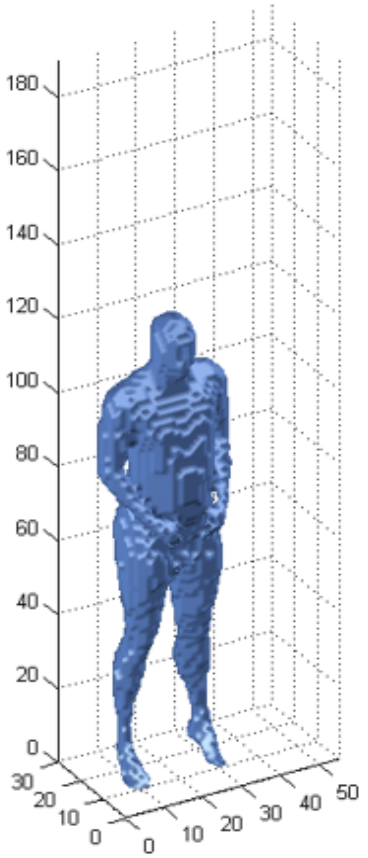
Scaled Human Body Models



Full Size Adult
W = 80 kg ; H = 188 cm



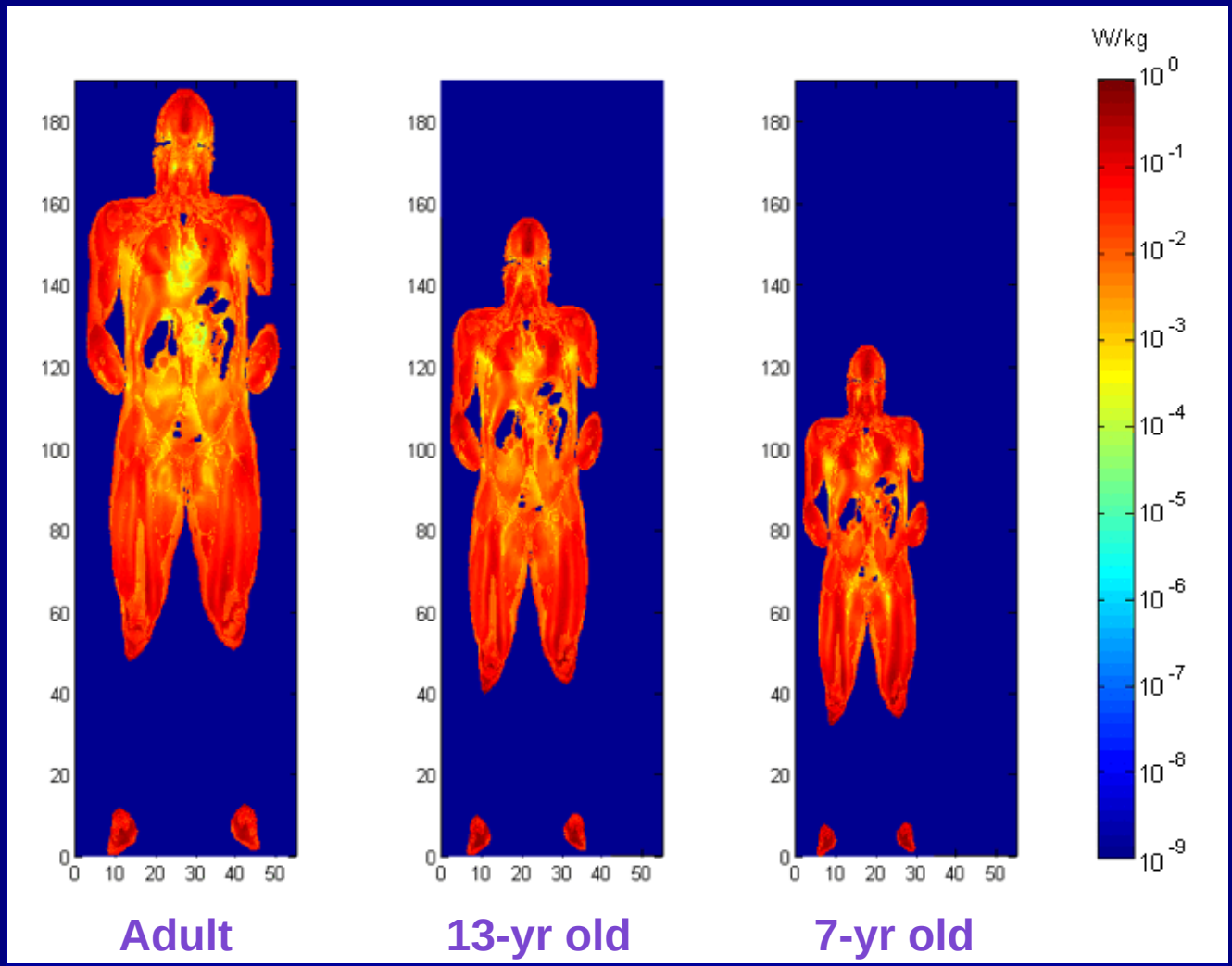
Reduced (13-year old)
W = 44 kg ; H = 156 cm



Reduced (7-year old)
W = 24 kg ; H = 125 cm

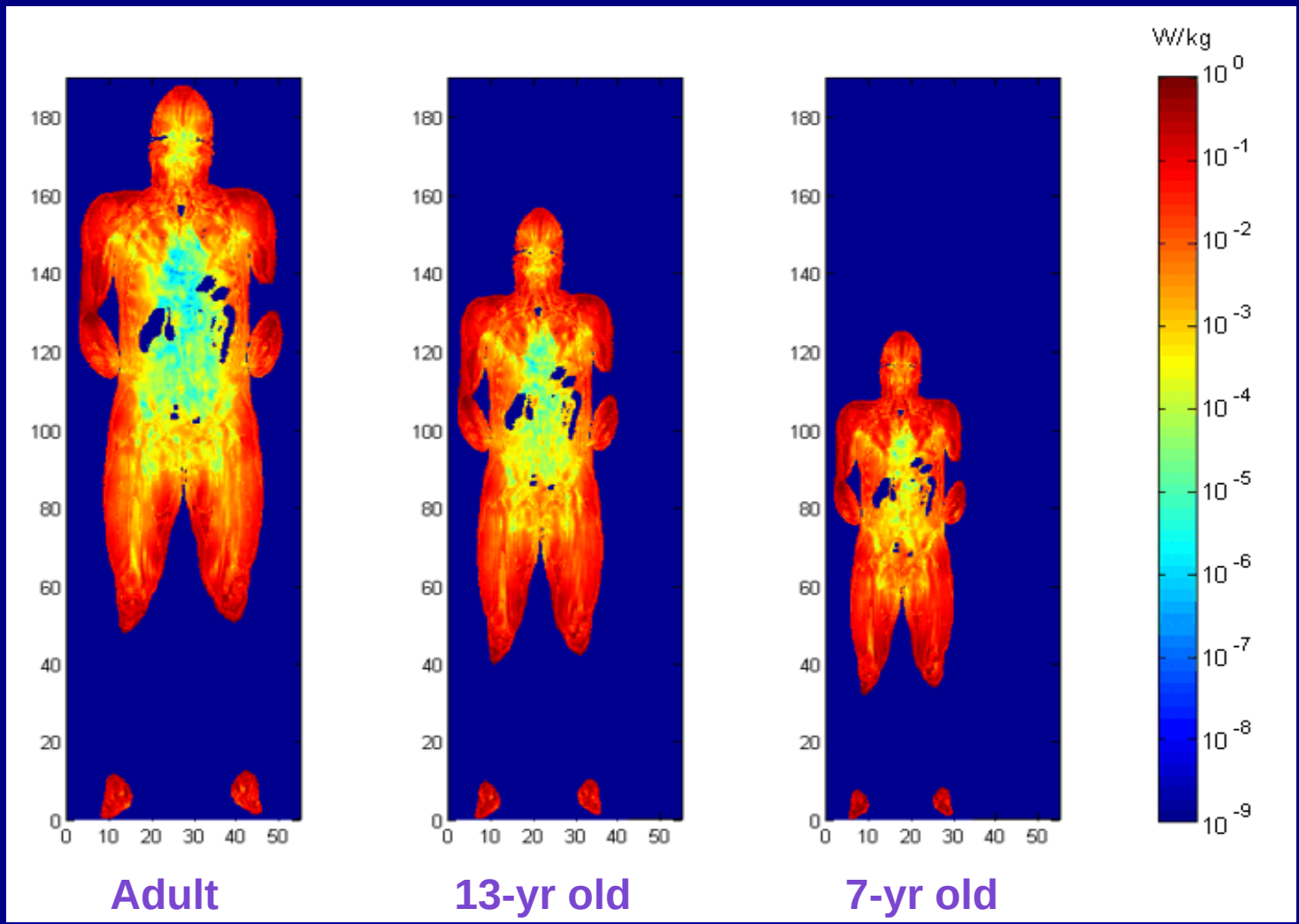
SAR Distributions for 3 Sizes of Scaled Human Bodies at 900 MHz

E_{inc} = 42 V/m Plane Wave



SAR Distributions in Scaled Human Bodies at 2.45 GHz

E_{inc} = 61 V/m Plane Wave



Far-field Indoor Exposures

System	Peak PD (W/m^2)	Ave PD (W/m^2)	ICNIRP (W/m^2)
GSM-900	0.082	0.026	4.5
GSM-1800	0.035	0.008	9.0
GSM-900+1800	0.101	0.034	6.3
Wi-Fi (2.45)	**0.017**	**0.004**	**10**

Values over a volume equivalent to the human body
30 W for GSM-900 and 20 W for GSM-1800 Base Station (BS)
Wi-Fi Access Point with 100 mW
Access Point (Wi-Fi) field is lower than in buildings located close to GSM BS **--** *P. Bernardi et al. EMC Europe 2004*

Near-field Exposure to Wi-Fi Field Radiated from A Laptop Computer

Frequency (GHz)	ε_r	σ (S/m)	1-g SAR (W/kg)	10-g SAR (W/kg)
2.45	39.2	1.80	2.82	1.61
5.25	35.9	4.71	1.64	0.53
5.80	35.3	5.27	2.10	0.59

100 mW Wi-Fi patch antenna placed 10 mm below planar phantom

Kang and Gandhi, IEEE EMC 2004

FCC 1-g SAR limit = 1.6 W/kg
ICNIRP 10-g SAR limit = 2.0 W/kg

Why Are Cell Phones Special?

- **Technology** from Broadcasting to Distributed Access;
- From Localized Single Transmitter to Many Networked Transmitters
- **Paradigm Shift** From Place to Person

- **Personalized** RF-EMF Exposure