RADIOFREQUENCY ELECTROMAGNETIC FIELDS

A Review of Public Exposures to Radiofrequency-emitting Sources

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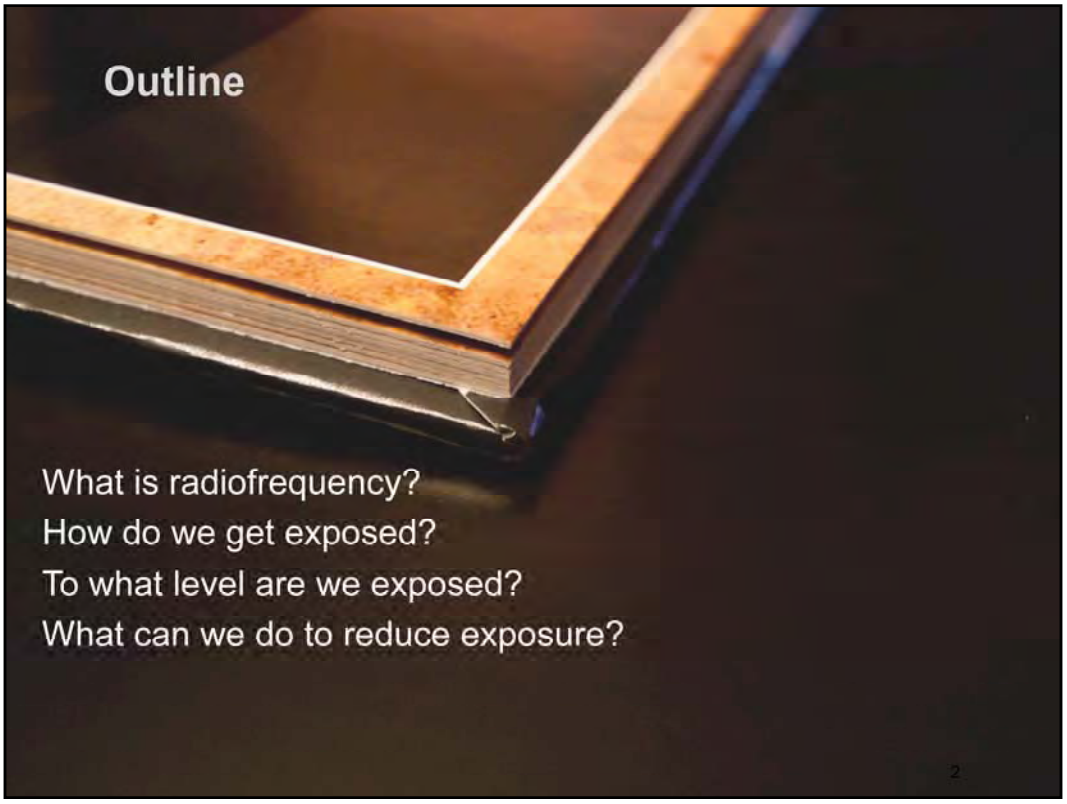
Outline
What is radiofrequency?
How do we get exposed?
To what level are we exposed?
What can we do to reduce exposure?
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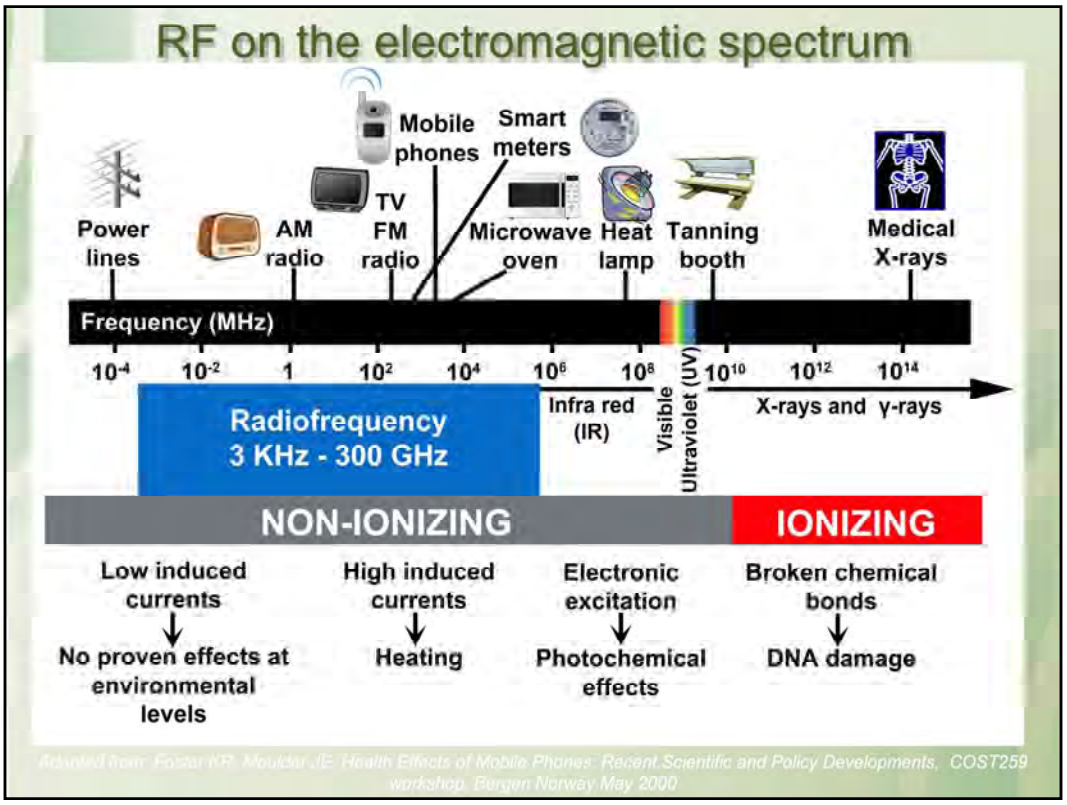
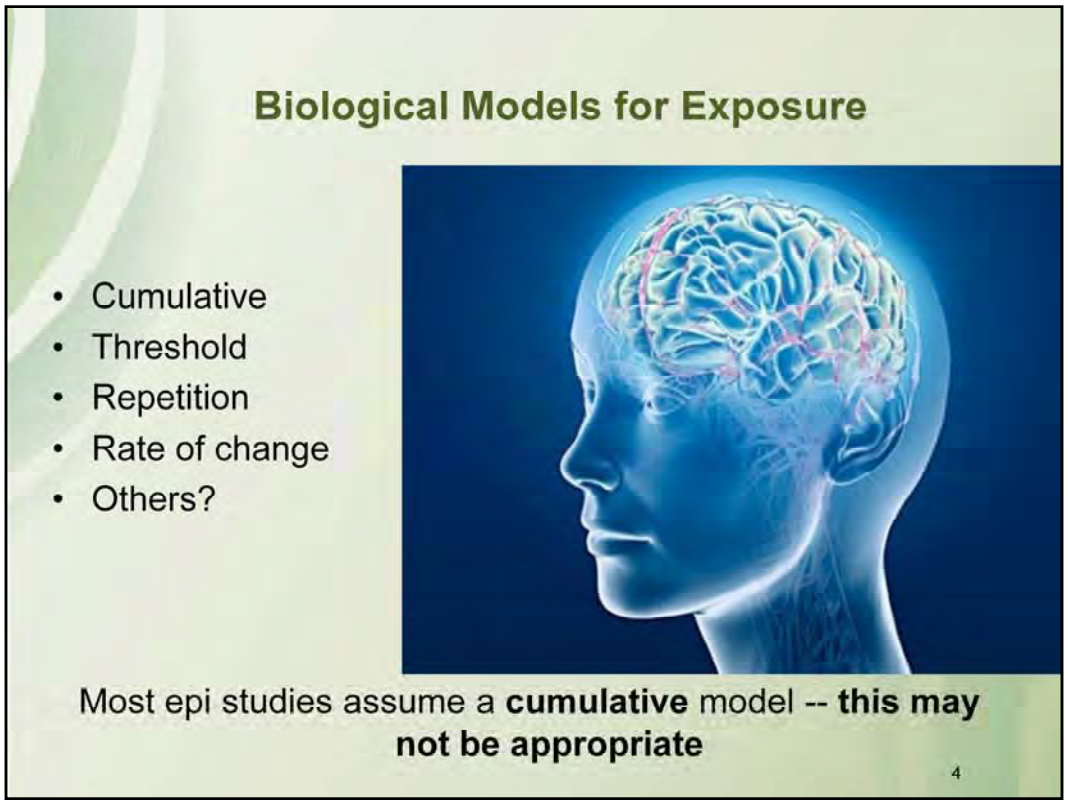


•The range of RF spans 3 KHz (3000 Hz) to 300 GHz (300 million Hz)

•Frequencies of RF devices range from the low frequency AM broadcasts (80 MHz) to higher frequency mobile phones (1900 MHz) smart meters (2.45 GHz) & microwave ovens (2.45 GHz)

•RF is non-ionizing and therefore cannot damage DNA directly, unlike higher frequency devices, such as medical X-rays



•In assessing intensity of exposure, an understanding of possible biological mechanisms informs the exposure assessment strategy

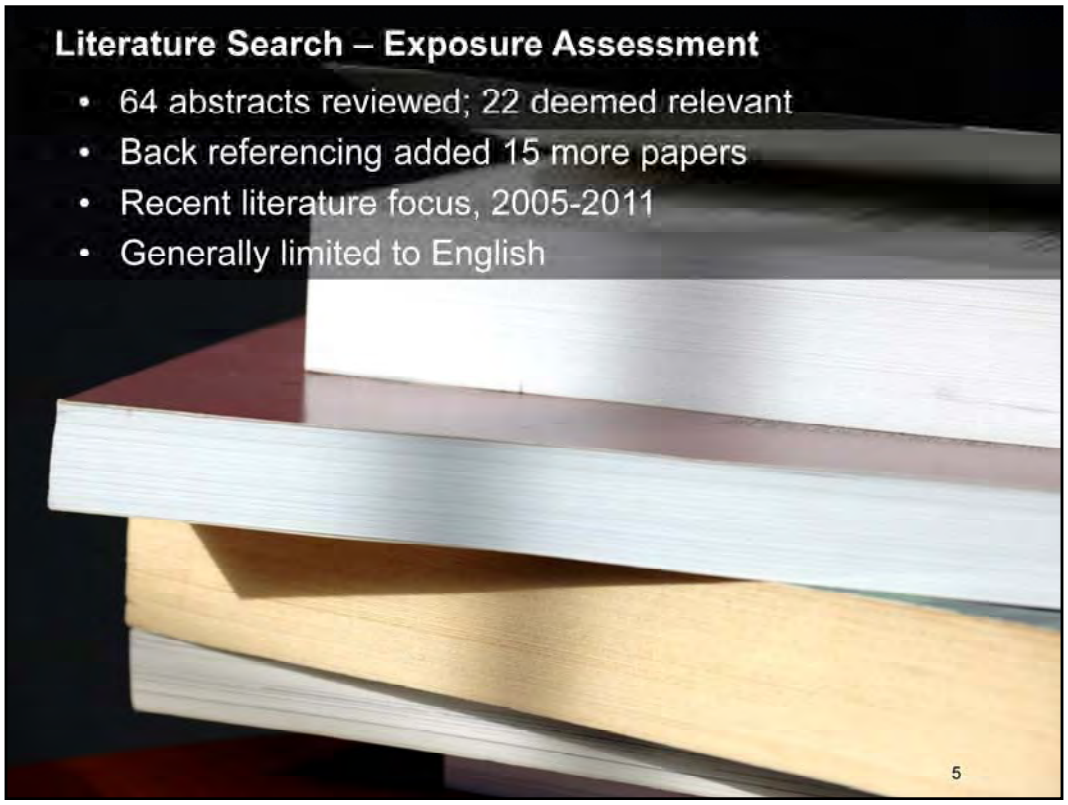
•*Cumulative exposure* – assumed by most epidemiological studies (e.g. using total duration of calls as a measure of exposure)

•*Repetition model* – also commonly used (e.g. number of events of RF exposure)

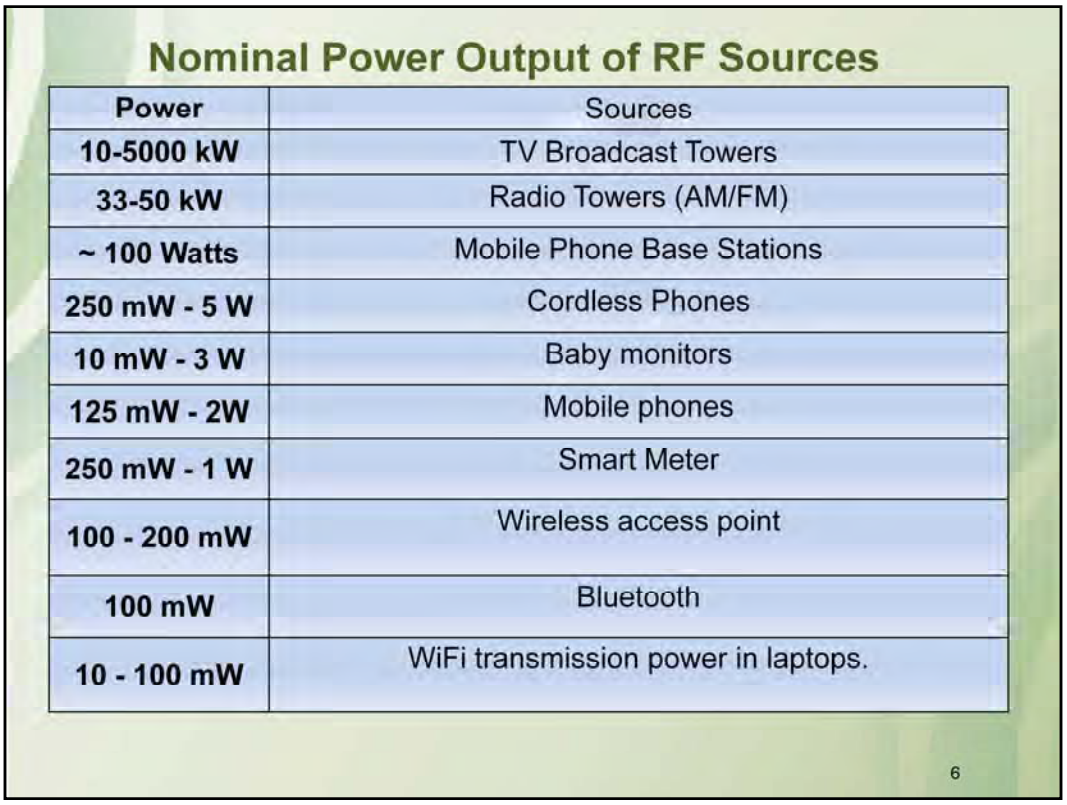
•But a criticism of using cumulative or repetition models is that they do not differentiate between low intensity and high intensity exposures. For example, using a cumulative model would not be appropriate when assessing temperature and duration of immersing a hand in water, as health effects would be expected at 100°C for one minute but not at 20°C for five minutes, even though the cumulative exposure would be the same

•*Threshold dose response* – critical level added to dose-response model

•*Rate of change* - how fast you go from a low to a high or a peak to a valley



•The literature search was mainly on more recent papers on RF exposure assessment, and yielded 37 pertinent publications



•Nominal power output is a device's maximal power level at the source

•The RF power output at the source ranges from the low values for WiFi transmission power (10-100mW, 1 mW=1/1000 W) to a high for TV Broadcast towers (10-5000 kW; 1 kW =1000W)

•Note that peak power is a more appropriate measure for continuous transmission & does not take into account duty cycle; e.g. a smart meters only transmit data several times a day for milliseconds at a time

•Distance from the RF device (e.g. Radio or TV Broadcast Towers are in the distant far-field) reduces exposure

Microwave Oven	Mobile phone	WLAN terminal	Smart Meter	Mobile Phone Base Station	Radio TV/Broadcast Station
					
Frequency					
2450 MHz	900 MHz, 1800 MHz	2.4-5 GHz	900 MHz, 2400 MHz	900 MHz, 1800 MHz	Wide spectrum
Distance					
2 inches	At ear	3 feet	3 feet (1W, 5% duty cycle)	10s to 1000s of feet	Far from source
RF-EMF power density (mW/cm^2) (Source: EPRI)					
~5	1-5	0.000005-0.0002	0.002	0.000005-0.002	0.001 (highest 1% of population)

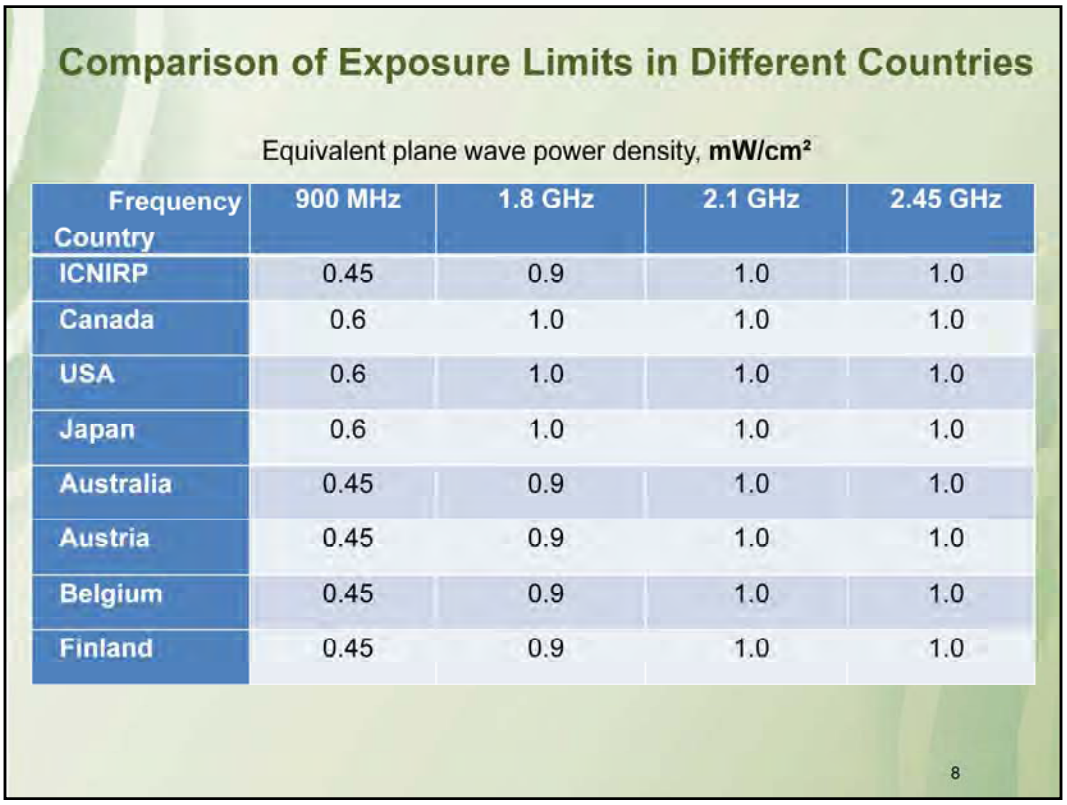
•Examples of RF devices are given at various frequencies. Measurements vary from close to the device (near-field, e.g. mobile phone) to much further away (far field, e.g. Mobile phone base station)

•You can't measure exposures in the near field close to the antenna using broadband meter or narrow spectrum meter, because readings are very inaccurate

•SAR is used to determine what the absorption could be to tissue and is done in the near field

•The near field for phones is a few centimetres depending on antenna size

•WiFi - if the antennas are 5-10 cm in size, radiating near field extends to no more than 16 cm at 2.4 GHz and 33 cm for 5 GHz

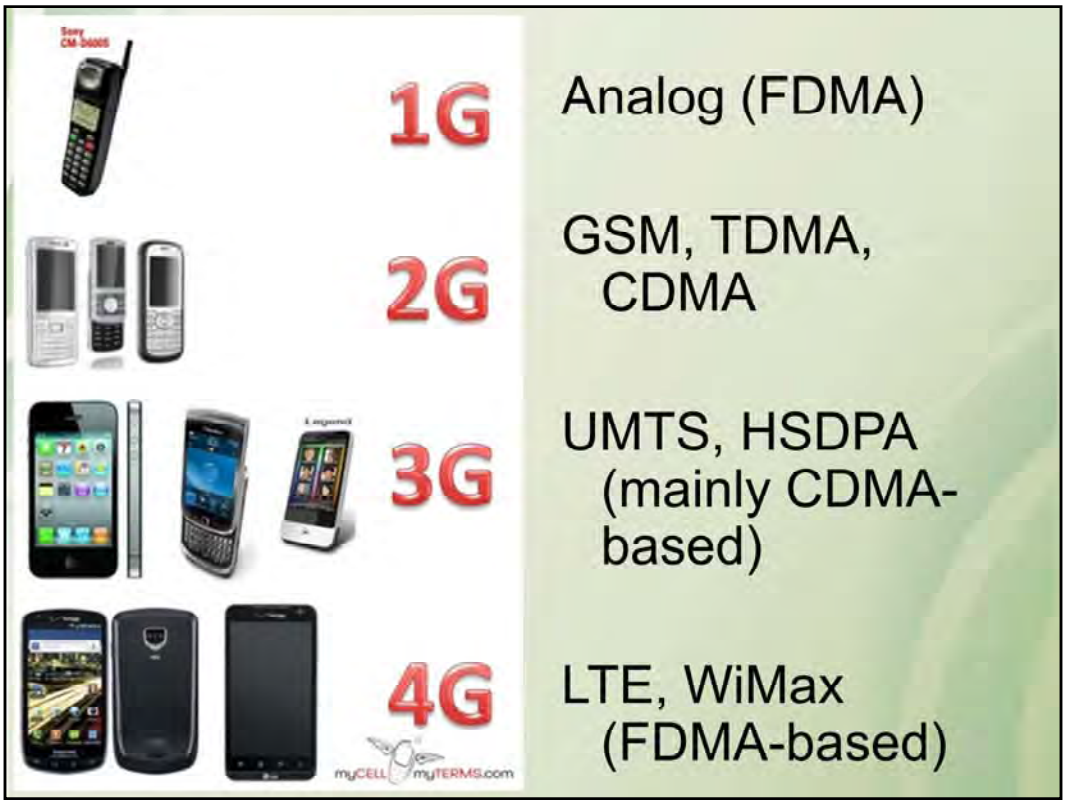


ICNIRP – International Commission on Non-ionizing Radiation Protection

•Exposure limits for Canada, US and Japan are somewhat higher for the lower RF frequencies

•900 MHz and 1800 MHz is typical of GSM mobile phones and base stations, and some smart meters

•2.45 GHZ is the frequency of RF from Microwave ovens



1G - FDMA-Frequency division multiple access - gives users an individual allocation of one or several frequency bands

2G - TDMA - Time division multiple access – allows several users to share the same frequency channel by dividing the signal into different time slots

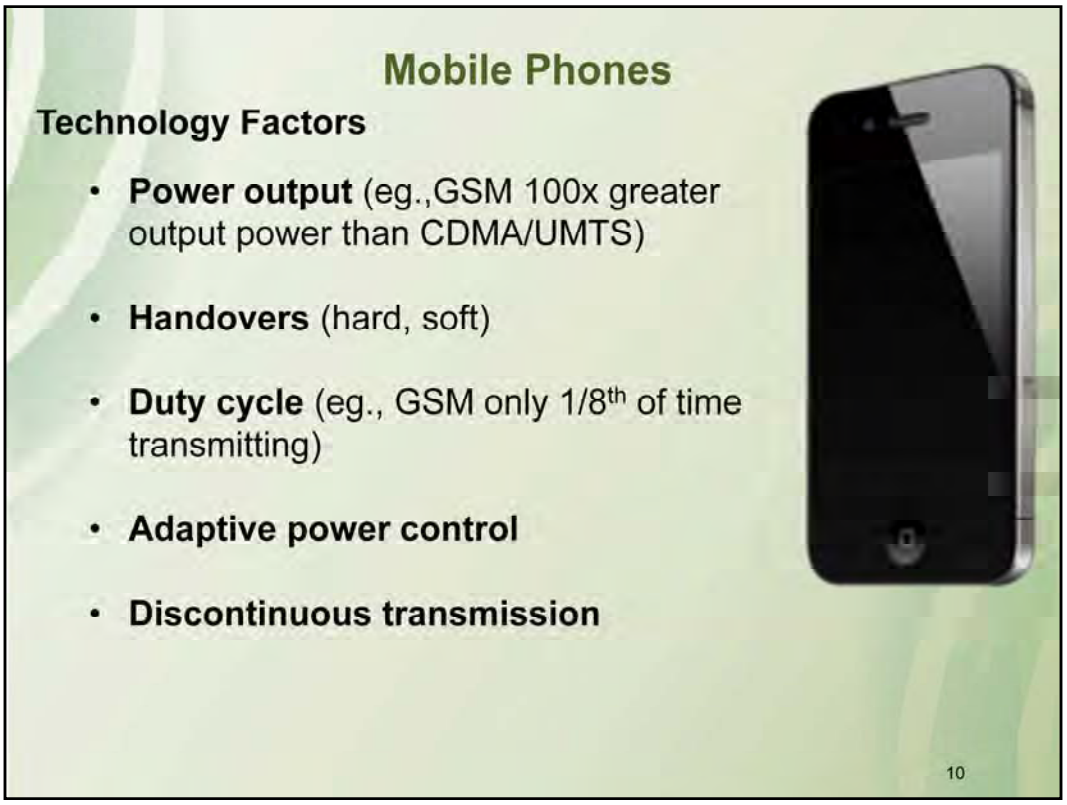
GSM –Global system for mobile communications pulsed (all other generation phones are continuous)

CDMA – Code division multiple access

3G – UMTS – Universal Mobile Telecommunications system – most common uses W-CDMA as underlying air interface

4G - LTE – Long Term Evolution: upgrading UMTS technology

WiMax – Worldwide Interoperability for Microwave Access



•Power output - peak output power, maximum output power, or actual output power. Peak output power is the phone's maximum possible power level, whereas maximum output power is the phone's maximum power level within a network. For instance, the peak output power of GSM can be 1W or 2W, but because GSM only transmits for 1/8th of the call time and every 26th pulse is omitted, the maximum output power is 120mW or 240 mW.[11] For CDMA and UMTS technologies, the transmission is continuous, and therefore the peak and maximum output power are the same at 250 mW

•Handovers - handover or handoff refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another

•'Hard' handover - phone transmits at peak power each time there is a handover of the signal from one base station to another

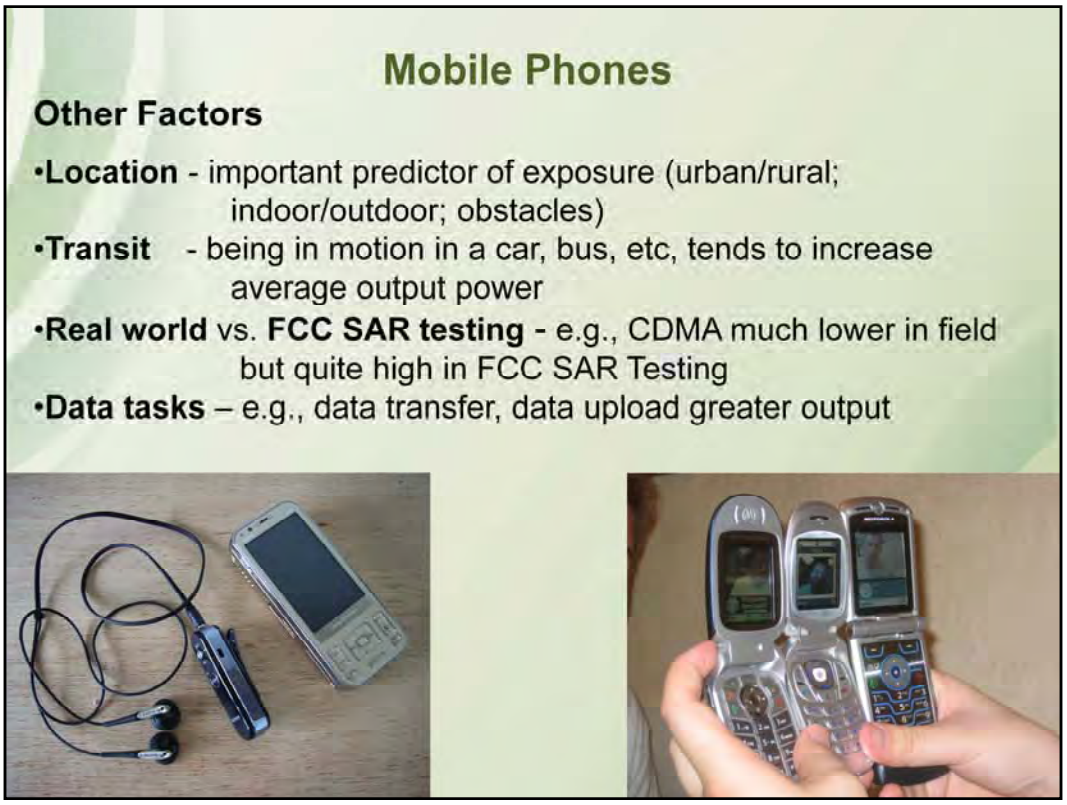
•'Soft' handover – devices which connect with more than one base station at a time during handover means they can avoid maximum power emissions when handover occurs

•Duty cycle – ratio of the transmitted signal's on-the-air time to the total operating time

•Adaptive control - Actual output power is usually lower than maximum output power due to adaptive or power control (which reduces RF power of mobile phones to a minimum level compatible with voice quality for a conversation). Some studies report that adaptive control for GSM phones can decrease RF output by 50% of the maximum output power levels.

•Analogue phones didn't have adaptive power control and thus transmitted at max power continuously.

•Discontinuous transmission with CDMA or WCDMA technology - when the user is not speaking, the mobile phone runs at less (1/2 or 1/8)of maximum output power



•**Location**: is an important predictor of exposure - output power levels of mobile phones used in rural areas are higher than in urban areas, likely due to lower base station densities in rural locations.[8]Average emitted power is usually greater indoors compared to outdoors as building features interfere with signals

•**Transit:** For GSM mobile phones, being in motion while in a car or other mode of transportation tends to increase average output power due to handover. Also for UMTS phones. Being in transit (particularly in trains or buses) produces the highest total ambient field exposures which also may be due to the high use of wireless devices on trains and buses

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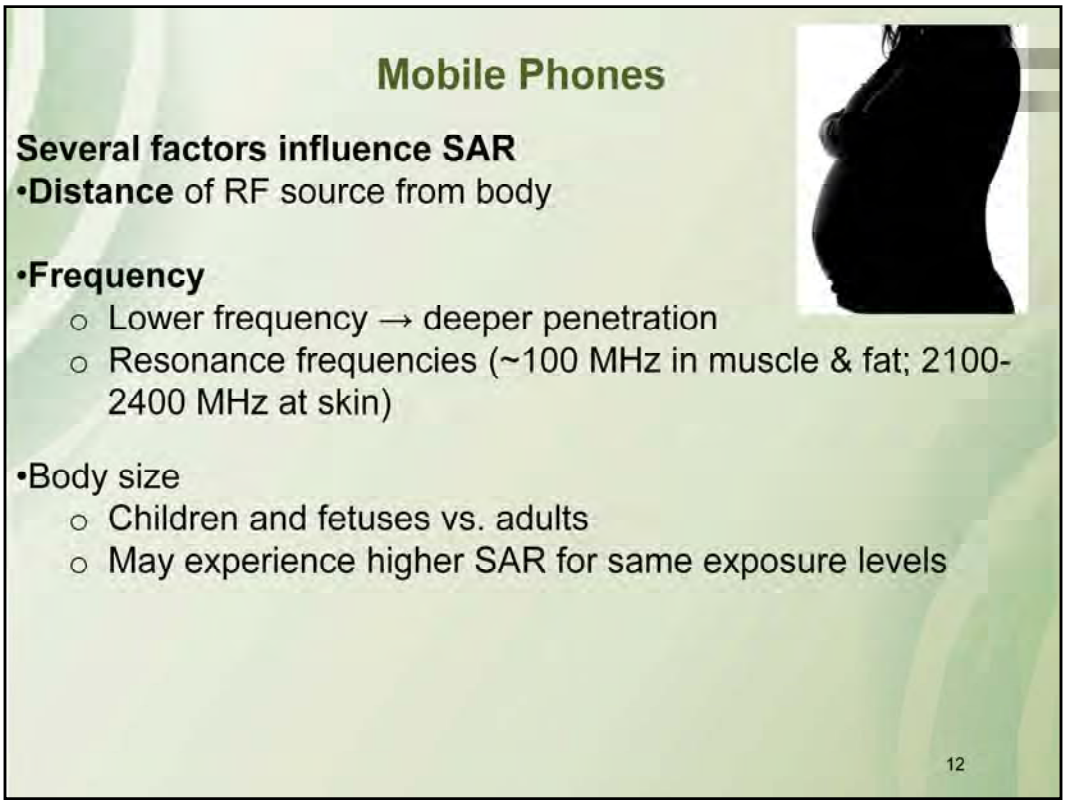
•**Data transfer** results in up to a four times increase in output power than for voice for wCDMA technology; **data upload** shows even high increases in output power

•Also, mobile phones continue to transmit when on, but not in active use



•Distance of the RF source from the head is an important factor to consider. The absorbed power for a mobile phone placed 10 cm from the head decreases more than 10 times than when it is held close to the ear. At 40 cm from the head, the maximum SAR over 10g is close to 1% of the SAR obtained by touching the phone to the head

•Lower frequency RF tends to penetrate more deeply into brain tissue

•However, there are two resonance frequency ranges where more absorption in tissue occurs: between 2100-2400 MHz there is greater RF absorption at the skin, whereas at a lower resonance frequency of ~100 MHz, RF is absorbed more in the muscle and fat, resulting in higher SAR values in these regions

•However local SAR (without spatial 10g averaging) for children showed higher exposure of some tissues and organs such as sub-regions of the brain and in the eye due to closer distance to the phone, whereas other head regions were lower than adults

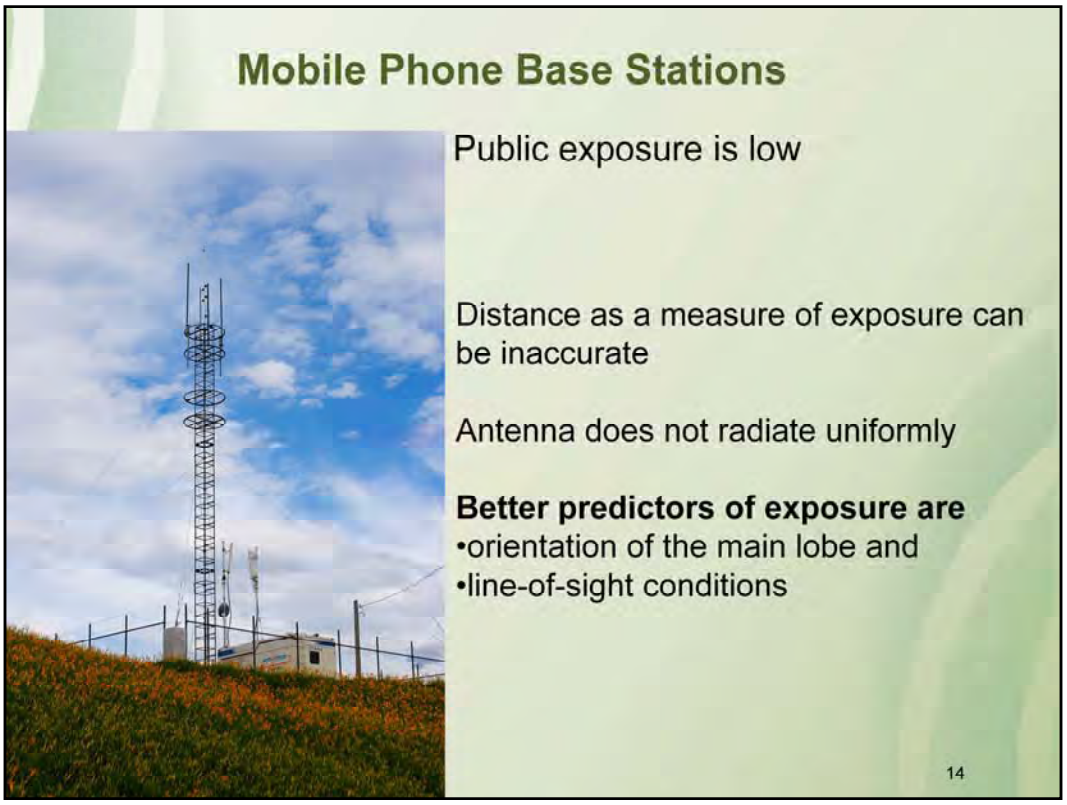
•DECT phones produce pulsed emissions. A 10 millisecond frame is divided into 24 time-slots

•When no calls are in progress, the base station transmits a brief pulse every 10 milliseconds. In certain models, the base station never transmits when the handset is placed in the cradle

•The peak output power for DECT phones is 250 mW, but because the transmission is pulsed, the average output power is lower, typically 2 mW

• Cordless phones (DECT) do not usually implement power control like most modern mobile phones

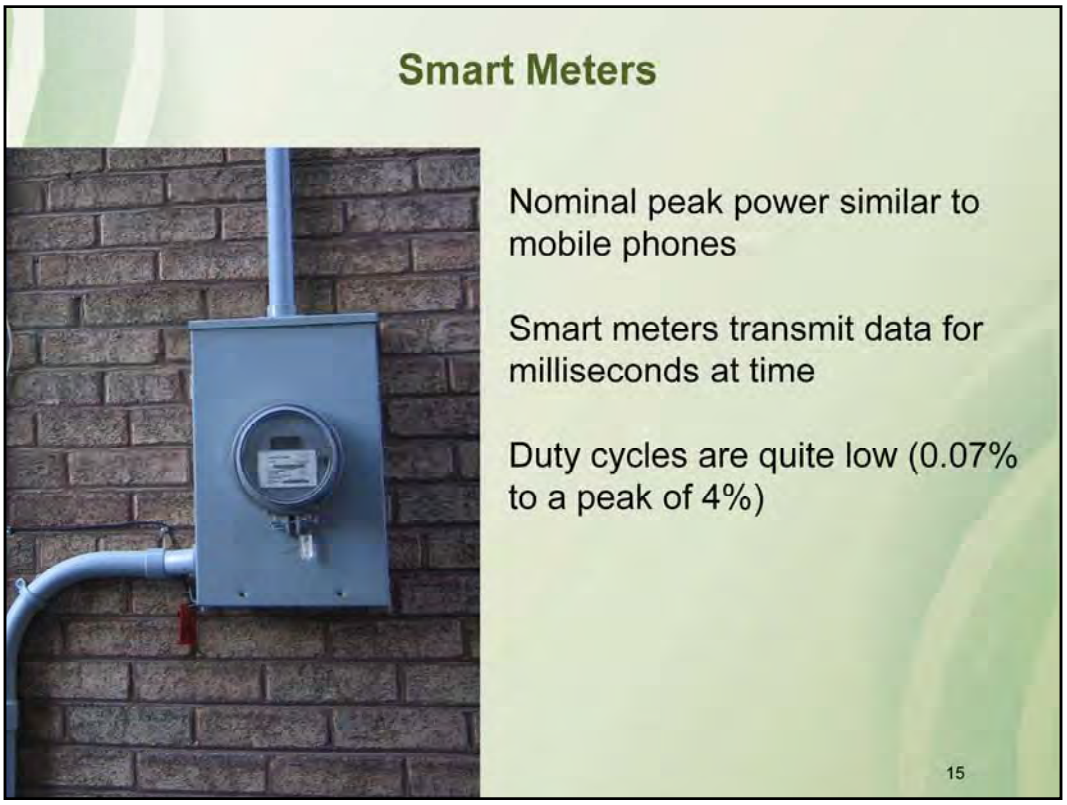
• For this reason, SAR from cordless DECT phones can be higher than SAR from UMTS phones (but can be up to five times lower than GSM phones)



•Using distance from a base station as a surrogate of exposure is inaccurate as the antenna does not radiate uniformly. There is a main lobe with side lobes of RF and null areas

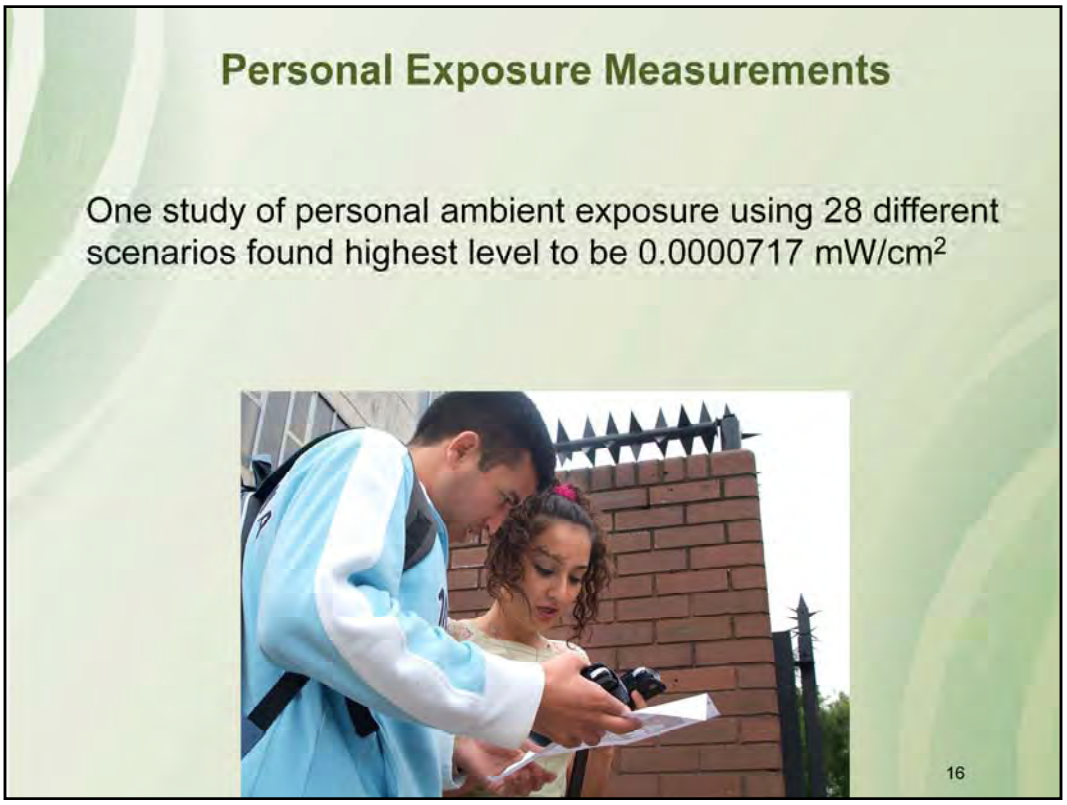
•As many base stations are located well above ground level, the areas immediately adjacent to the base station may be in null areas

•Better predictors of exposure are orientation of the main lobe and line-of-sight conditions



The smart meters transmit data four to six times a day for milliseconds at a time, therefore the duty cycles are quite low (0.07% to a peak of 4%)

So, if you think about putting smart meters into context, they don't transmit very often, about a minute a day, and the peak output power (the most it can go to) is similar to that of cell phones. So when my mother asked me if she should be concerned about the smart meter they just put outside her window, I told her it's like someone standing outside your window making a phone call for a few seconds at a time a few times a day – that's the equivalent exposure

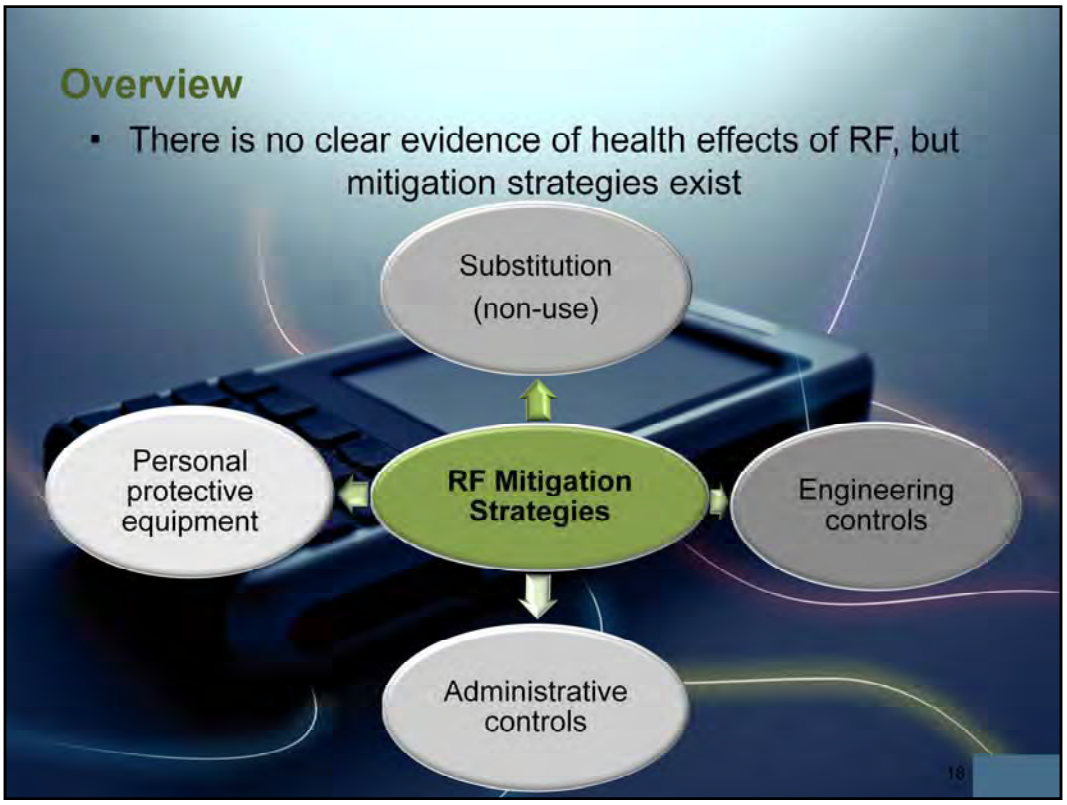


Joseph et al. (2008) conducted PEM for 5 hours for each of 28 different realistic exposure scenarios (combinations of outdoors/indoors, rural/urban, standstill/moving, night/day) in Ghent, Belgium. The highest outdoor exposures were due to downlink signals of GSM (up to 0.0000717 mW/cm^2) and they generally found values, based on conversion of PEM data to SAR (specific absorption rate) of close to 100,000 times below exposure limits

Exposure Reduction

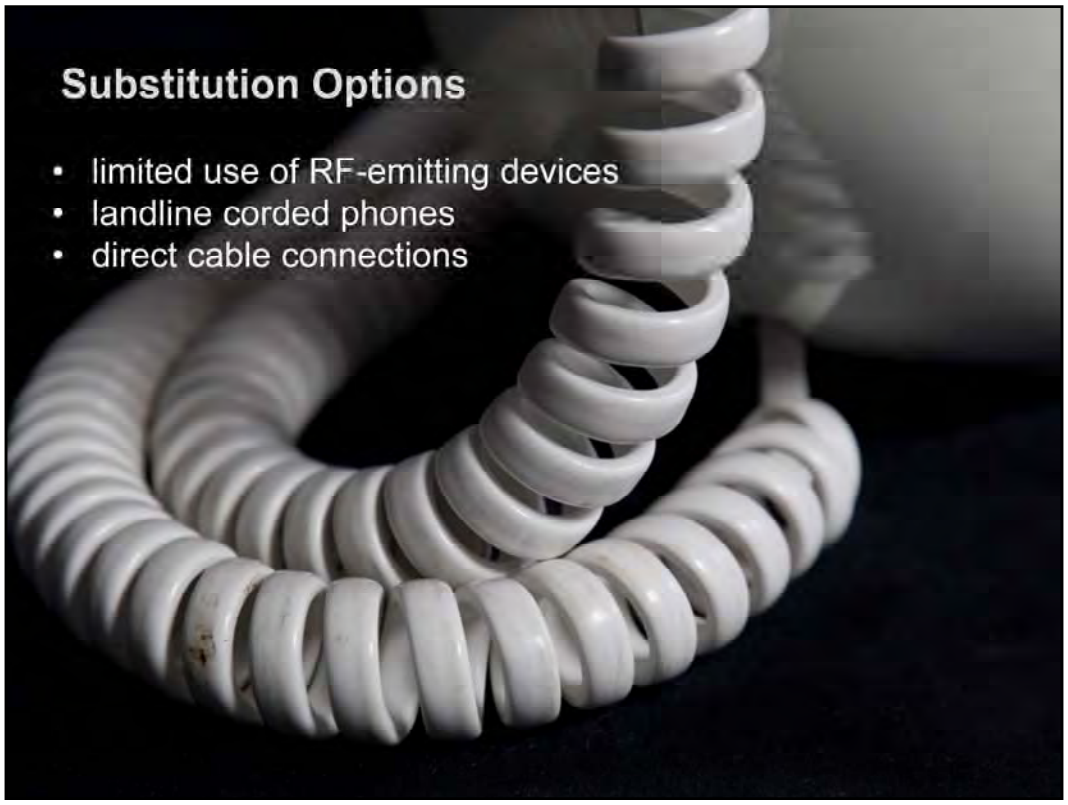
How can we reduce our exposure to RF?

What are mitigation strategies?



•RF devices have benefitted society - Use of mobile phones has promoted safety and saved countless lives by allowing remote communication

•In occupational hygiene, the hierarchy for exposure reduction includes substitution, engineering controls, administrative controls, and personal protective equipment. In the case of reducing RF exposure to the general public, similar strategies include non-use, technology and design changes for RF-emitting devices, distancing and limiting use, and exploration of shielding measures



•Avoid use of devices that result in the highest personal exposures such as mobile phones placed against the head

•Landline phones - result in a loss of flexibility in communication

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•Cabled connections are possible (e.g. for WiFi) but the effective reduction to total RF is minimal

•A lower SAR FCC rating does not necessarily translate into lower real-world SAR as contemporary mobile phones do not often reach or maintain maximum output power levels in the field

•Compared to GSM mobile phones, the technologies of CDMA/wCDMA and UMTS)produce lower RF power measurements by not transmitting as often at maximum power. More research is needed to assess the newer technologies associated with 4th generation mobile phones using LTE or WiMax to determine what RF output power levels they produce in real-world situations

•Living further away from base stations (e.g., in a rural area with poor base station coverage), does not necessarily decrease overall exposure for mobile phone users as the mobile phone needs to increase output power levels to maintain a good connection. Good base station coverage applies to WiFi and cordless phones, too

Engineering Controls – Cordless Phones

RF exposure from cordless phones can be reduced by

- ✓ a power-saving function, and
- ✓ a system that does not intermittently signal when handset is off and placed in base station cradle

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- Low duty cycles, transmitting RF for only milliseconds
- Plates that reduce RF transmission into house
- Banks of smart meters communicate with a single controller one at a time

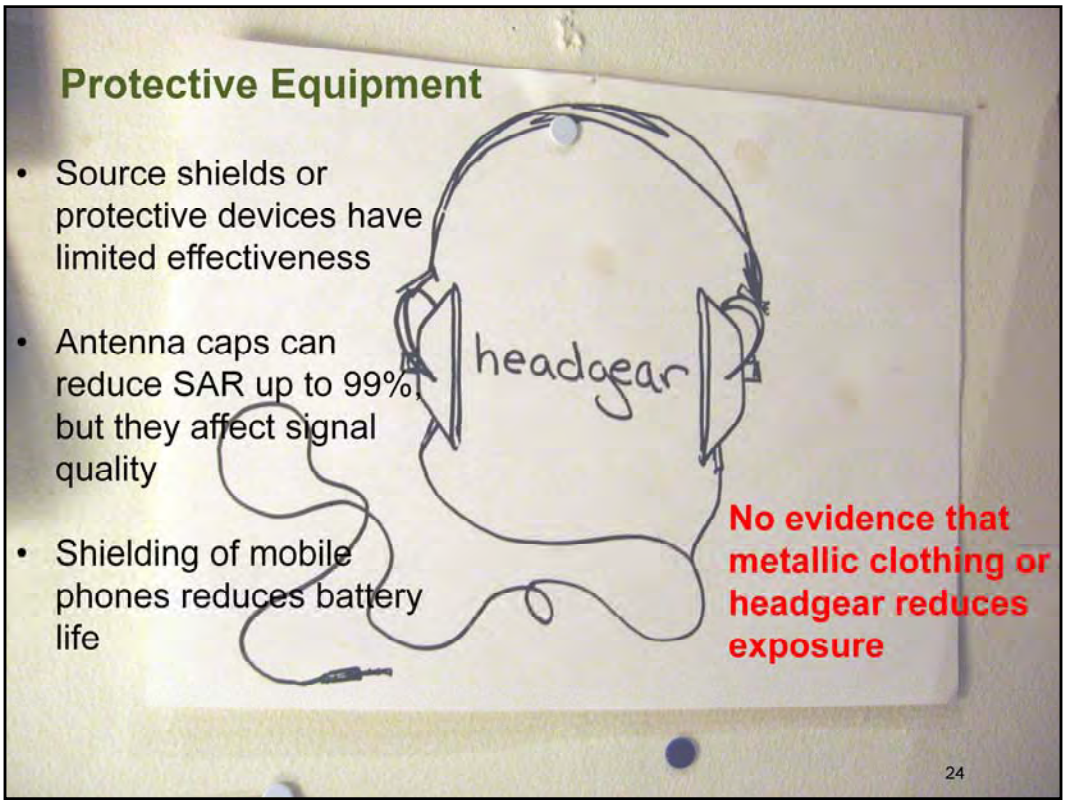
•Smart meters have back plates that reduce RF transmission into the house (as does the house wall)

•Communication one at a time with a single controller eliminates the possibility of exposure to multiple signals simultaneously

•**Handsfree kits** -e.g.,wired headsets are effective in reducing exposure

•SAR measurements at the head are 8-34 times lower when using a wired hands-free kit than when using the phone at the ear

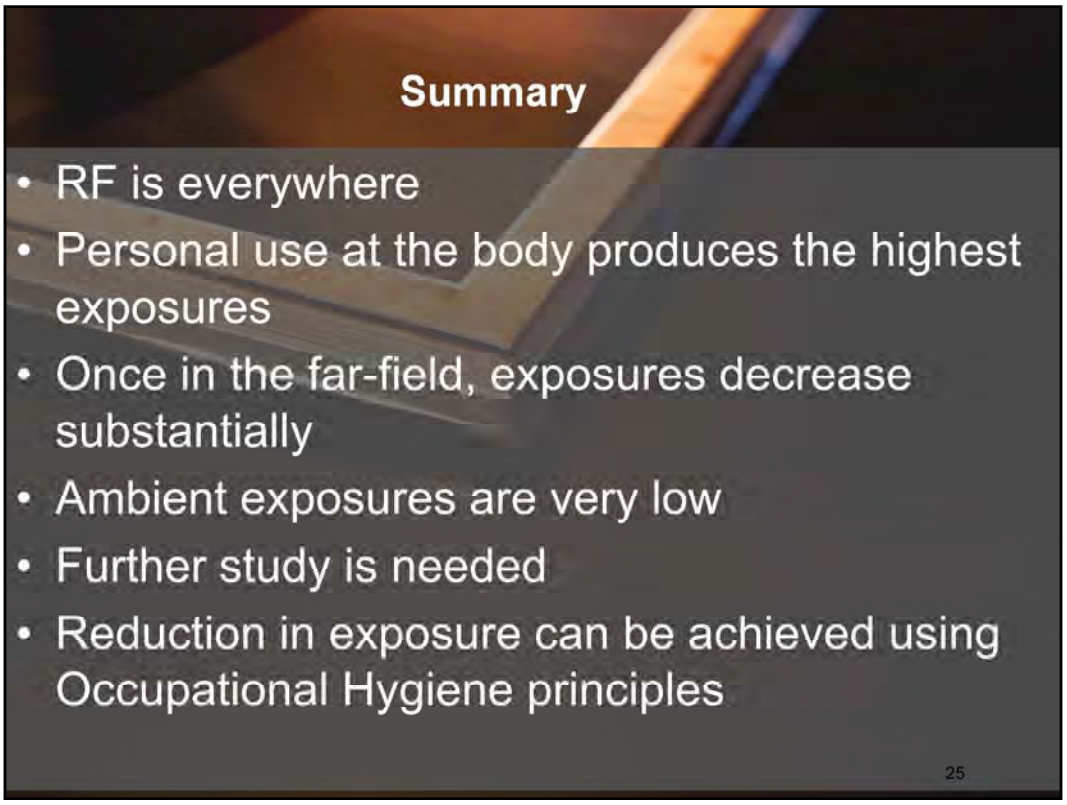
•Although WLAN access points can be placed far from WLAN terminal devices, this can result in a poor connection, thus increasing output power



•A small opening will reduce the shielding effect even of a complete metallic cage

•A shield to reduce ambient levels of RF may cause any RF-emitting sources indoors (e.g., mobile phones) to generate resonances, producing higher local exposures

•Shields for mobile phones are available, but when tested, earpiece pads and shields did not affect SAR substantially and may increase the transmit power to compensate for interference with the signal



•There are many new and emerging sources of RF for which very little exposure information is available

•Other uses of RF such as for aesthetic purposes (e.g., RF facials) have been documented, but as of yet, no exposure studies have been conducted

5G?


It's a sunny day.
Good morning
Hot keys
E-mobile
Schedule
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Thank You

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References

- The list of references is available in Sections 5 and 14 of the Radiofrequency Toolkit, published on the BC Centre for Disease Control (BCCDC) website

- http://www.bccdc.ca/healthenv/ElectromagFields/RadioFrequency/default.htm

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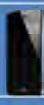	http://en.wikipedia.org/wiki/Mobile_phone	Wikipedia	Mobile phone	
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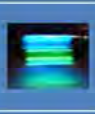	http://www.flickr.com/photos/9937638@N02/6486716555/	mahela1993	PWM - high duty cycle	
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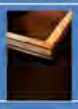	http://www.flickr.com/photos/jexweber/5098828459/	Jexweber.fotos	Review libro fotográfico Hoffmann	
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