Section 3

Sources of Radiofrequency Electromagnetic Fields

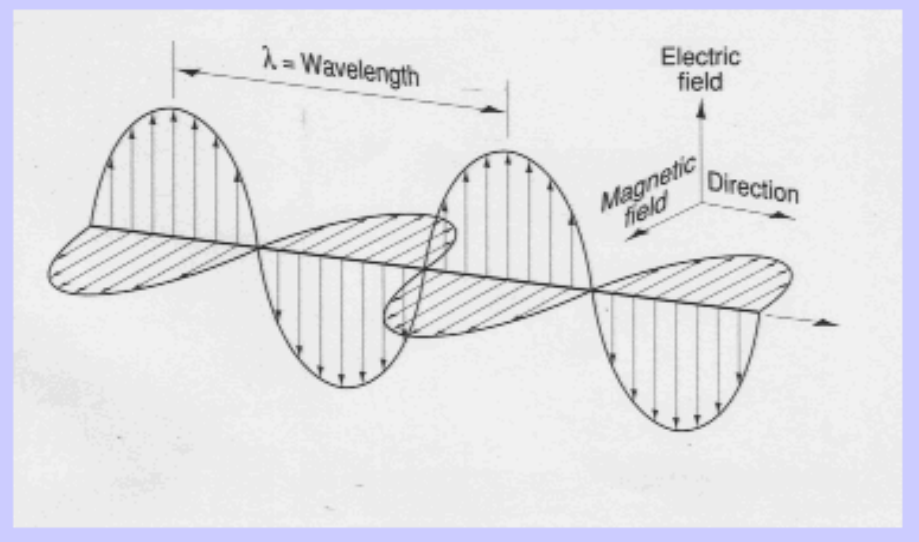
Table of Contents

3.1 Radiofrequency Electromagnetic Waves

What Is a Radiofrequency (RF) Wave?

RF waves are electromagnetic (EM) waves used for radio transmission. They carry electromagnetic energy as they propagate in free air and dense media.

A changing electric field will create a changing magnetic field, and a changing magnetic field will create a changing electric field.[1]



"TEM wave" courtesy of Wikibooks (CC BY-SA)

What Is a Continuous RF Wave?

RF wave(s) with:

- successive identical oscillations
- constant height (amplitude)
- constant repetition (frequency)
- constant output power equal to the average power
- varying sinusoidally with time.[2,3]

Examples: power supplies, plasma etching, welding/cutting arcs, continuous wave NMR, antennas, mobile phone communication, cordless phones, AM and FM broadcasting, anti-theft devices, RF heat sealers, portable radio systems, burglar alarms, microwave ovens, etc.

What Is a Pulsed RF Wave?

RF waves that are pulsed:

- The transmitter is pulsed, i.e., "on" for a short time and turned "off" for a longer time.
- Best example: radar
- Common radar frequencies: 50–330 MHz, 300–1,000 MHz, 1–2 GHz, 2–4 GHz, 4–8 GHz, 8–12 GHz, 12–18 GHz, 18–27 GHz, 27–40 GHz, 40–100+ GHz[4,5]
- Human exposures to radar systems are from police speed control radar, airplane and ship radar, meteorological precipitation monitoring, and ground-penetrating radar for geological observations.
- Examples of pulsed RF devices: keyless entry pulsed NMR systems, analog or digital radar from airports, ships, speed detection, military devices, satellites, electronic test equipment, etc.

What is the "microwave hearing effect"?

An ability of some people with normal hearing to perceive pulsed RF fields.[6]

Natural Sources of RF

Natural RF emitters:

- earth
- sun
- thunderstorm activity
- the ionosphere
- deep-space extraterrestrial sources

Thunderstorm RF:

- 30–300 MHz
- Very High Frequency (VHF)[7-9]

Characteristics of Natural RF:

- Does not pass through hills or large structures
- Cannot be transmitted beyond the horizon
- Does not bend readily around the earth's curvature
- Is reflected from the atmosphere.

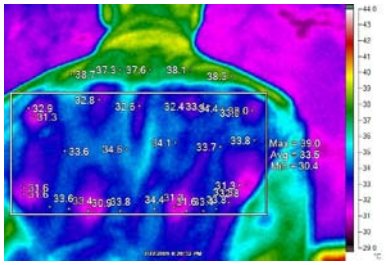
RF Utility: Little use has been made of naturally generated VHF fields.

Biological Sources of RF/EMF

Humans and mammals emit EMF energy

A human body, at 37˚C, emits an EMF of:

- Frequency: 31 THz *(31,000 GHz)*
- Wavelength: 9.66 µm



"Thermal image" courtesy of Dhama InnovationsPvt. Ltd., Wikimedia (CC BY-SA)

3.2 Consumer Products

Wireless Phone Evolution

First generation (1G) mobile phones – 1980s[10]

- Frequency: 450 MHz, 800–900 MHz
- Radiated power: 600 mW (0.6 W)
- Analogue circuit-switched technology

"History of mobile phones" courtesy of Marus, Wikipedia (CC BY-SA)

Second generation (2G) mobile phone systems – 1990s

- Frequency: 800, 900, 1500, 1800, 1900 MHz (US)
- Pure digital technology
- Caller identity and text messaging

"Cell Phone Cameras" courtesy of compujeramey, Flickr (CC BY)

Third generation (3G) mobile phone systems – 2001

"Mobile phone" courtesy of Irfan Nasir, Wikipedia (CC BY-SA)

- Frequencies: 1885–2025, 2110–2200 MHz
- Added broadband internet and high-tech video calls
- Able to use 2G and 2.5G networks where the 3G service unavailable[11]

Wireless Phones

- Frequencies: 850 MHz, 900 MHz, 1700 MHz, 1800 MHz, 1900 MHz, 2100 MHz
- Power emitted: maximum power transmitted 1 to 2 watts
- RF exposure is below HC SC 6 when radiating structure is 2.5 cm away from body
- RF exposure: When **less than** 2.5 cm from the body (excluding hands, wrists, feet, and ankles), the potential for exceeding Specific Absorption Rate (SAR) limit depends on the operating configurations and exposure conditions of the device
- Phones emit **less power** when close to base station.[12]

"charade #47 answer" courtesy of ndrwfgg, Flickr (CC BY)

Mobile Phone Base Stations

- Emit less RF than non-cable television transmitter
- Are low-power, multi-channel, two-way radios
- Antennae transmit ~ 60 watts of RF power
- Public exposures **at several meters from antennae** are typically **3000 to 1,000,000 times below HC SC 6**
- Dead zones occur when handset or mobile site is blocked by hilly terrain, excessive foliage, physical distance, or excessive cell phone use[13-16]

Baby Monitors

- Frequencies: 16 MHz, 9.3–49.9 MHz, 900 MHz, 2.4 GHz
- Range: up to 300 m[17,18]
- Power: 0.010 W to 3 W

"Baby Monitor" courtesy of Jpsammy, Wikipedia (CC BY-SA)

Bluetooth Devices

- Frequencies: 2.4 to 2.485 GHz – Industrial, Scientific and Medical (ISM) band
- No license required
- Range: short range of 5–100 m
- Power at head: 100 mW[19]
- Bluetooth products: Over 500 products including hands-free calling, GPS navigation, portable music players, wireless headsets, wireless speakers, wireless hands-free car systems, printers, laptops, cameras, health and fitness device computers, heart rate monitors, phones, home security systems, etc.

"Bluetooth Earbud" courtesy of topgold, Flickr (CC BY)

DECT, Digital Enhanced Cordless Telecommunication

- Frequencies: 902–928 MHz, 1880–1900 MHz, 1920–1930 MHz
- Range: 91 m in open area[20-22]

Cordless Phones

- Frequency: 43–49 MHz, 900 MHz, 2.4 GHz and 5.8 GHz
- Range: 12–75 m, 20–200 m, 60–450 m, 90–600 m
- Long Range: Up to 10 km
- Power: 1–5 watts[23]
- Emitted Power: 0.2–1.0 mW/cm^2
- Older cordless phone constant power: 10 mW
- Digital cordless phones – millisecond transmissions, average power: 0.01 mW

"Cordless Phone" courtesy of JDB Photos, Flickr(CC BY-NC-SA)

Wireless Head Phones

- Frequency: 86–108 MHz, 863 MHz, 900 MHz, 913.5 MHz, 914 MHz, 914.5 MHz, 925 MHz, 926.0 MHz, 926.5 MHz, 2.4 GHz
- Range:
  - Home use: 1–3 m, 3–9 m, 10 m +
  - Industrial: 6–100 m[24]

Uses: listening to music, watching a video

"Wireless Stereo Headset H3070" courtesy of audiovisualjunkie, Flickr (CC BY-NC-ND)

Wireless Home Security

- Frequencies: 43–49 MHz, 433 MHz, 902–928 MHz, 2.4 GHz–2.4835 GHz, 5.725 GHz and 5.850 GHz
- Typical output power: 10 to 100 mW (0.01–0.1 watts)
- RF emissions: 0.1% of HC SC 6 allowable exposure limits[25]

Wi- Fi Systems

- Frequency: 2.4 GHz, 915 MHz, 5.8 GHz
- Power density: <0.003 W/m^2 to 0.03 W/m^2
- Typical exposures: 1.8–4.6 V/m
- HC SC6 exposure limit: typical exposures 0.03% to 0.3% of HC SC6 limits
- Health Protection Agency: typical exposure 100 mW (0.1 W)[26-30]

Smart Meters

- Frequency: 902–928 MHz
- End point power: ¼ Watt or 0.25 W
- Maximum power (cell relays): <0.5 W
- Instantaneous power density: at 30 cm: 0.02 to 0.04 W/m^2 (2 to 4 μW/cm^2)
- Typical accumulated emission duration: approximately 60 seconds per day
- RF emissions from Smart Meters[31,32]: Far below HC SC 6 exposure limits at 900 MHz: 600 μW/cm^2

Example of measured instantaneous peak power densities from Smart Meters:

- One Smart Meter at 30 cm–3.2 μW/cm^2
- One Smart Meter at 1 m–2.0 μW/cm^2
- One Smart Meter at 3 m–1.2 μW/cm^2
- Ten operating Smart Meters at 30 cm–4.0 μW/cm^2

  Ten operating Smart Meters at 1 m–2.6 μW/cm^2

  Ten operating Smart Meters at 3 m–1.8 μW/cm^2

"Smart Meter" courtesy of Duke Energy, Flickr (CC BY-NC-ND)

Source: http://www.bccdc.ca/NR/rdonlyres/43EF885D-8211-4BCF-8FA9-0B34076CE364/0/452012AmendedReportonBCHydroSmartMeterMeasurements.pdf

AM Radio, FM Radio, and TV Transmissions

- Amplitude modulation (AM) radio frequency: 550 to 1600 kHz
- Frequency modulated (FM) radio frequency: 88 to 108 MHz
- Airborne television (TV) transmission frequency: 300 to 400 MHz
  - Humans absorb up to five times more RF from FM radio and TV than from mobile phone base stations[33]
  - SC 6 exposure limits exceeded 1–2 m from AM radio antennae
  - SC 6 exposure limits exceeded 1–2 m from FM radio antennae
  - High powers present danger of electrocution with contact[34]
  - WorkSafeBC regulates permissible exposures to workers[35]

(left) "Superturnstile Antenna" courtesy of Hans-Peter Scholz, Wikipedia (CC BY-SA)

(middle) "ENOME Anywhere!" courtesy of Coolmitch, Flickr (CC BY-NC-ND)

(right) "broadcast antenna" courtesy of HerPhotographer, Flickr (CC BY-NC-SA)

CB and FRS Radio

- Frequency: CB – 27 MHz**,** Family Radio Service (FRS) – 462/467 MHz
- Power: CB: 4 W; FRS: 500 mW–2 W[36]

"Amateur Radio Rig" courtesy of Joshua Fuller, Flickr (CC BY-NC)

Microwave Ovens

"Microwave" courtesy of DerekL, Flickr (CC BY-NC-SA)

- Frequency: home 2.45 GHz; industrial 915 MHz
- Power: home 400–1400 W
  - o Typical microwave oven leakage: up to 1 mW/cm^2
  - o Average microwave oven leakage 0.17–0.52 mW/cm^2[37,38]
  - o Physical/structural damage of microwave may result in RF leakage

Table of power densities from common RF sources

- "Power density," in units of microwatts per square centimeter (μW/cm^2), may be converted to watts per square meter (W/m^2)
- Table 1 describes the typical RF emissions from various RF sources[39]

Table 1. RF source, frequency, power, and power density

RF Sources	Frequencies	Power	Typical Average Power Density Exposure
Mobile Phone	GMS 850, 1900 MHz	0.3–3 W	1000 to 5000 μW/cm^2 (at ear)
Microwave Oven	2450 MHz	400–1200 W	5000 μW/cm^2 (at 5 cm)
WiFi	2.4 GHz and 5.0 GHz	less than 1.0 W (FCC) less than SC 6 (HC)	0.001–20 μW/cm^2 Max average RF exposure level 0.232% of SC 6 limits
TV Broadcast VHF	54–216 MHz	10–100 kW	0.005–1.0 μW/cm^2
TV Broadcast UHF	470–698 MHz	500–5000 kW	0.005–1.0 μW/cm^2
Smart Meter at 1 m	902–928 MHz	0.25 W	0.0001–0.002 μW/cm^2
FM AM	88–108 MHz 535 kHz–1.7 MHz	FM 33 kW AM 50 kW	0.005 to 1 μW/cm^2 500 μW/cm^2

3.3 RF Sources Used in Industry

"CalStateArch_PreservationLab6"
courtesy of vlasta2, Flickr (CC BY-NC-ND)

- Frequencies: 135–6 MHz, 27.12 MHz, and 40.68 MHz[40,41]
- Heat sealer power: 1,500 W to 60,000 W
- Exposures: Unprotected worker exposures are often five to eight times above allowable exposure limits
- Body to ground currents: >200 mA

WorkSafeBC regulates permissible exposures to workers

Induction Heating (IH) Cooking Hotplates

"Pressure Cooker on Induction Burner"
courtesy of Dinner Series, Flickr (CC BY)

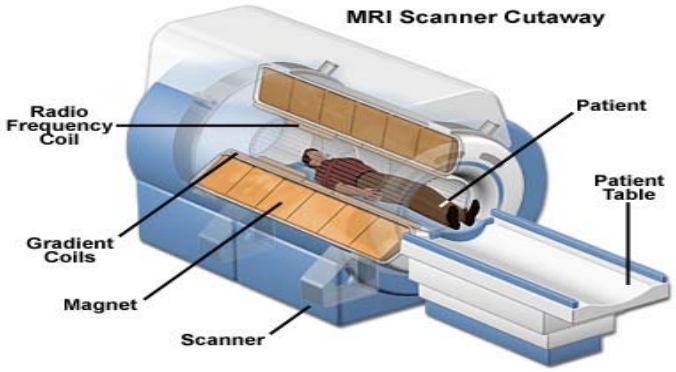
- Frequency: 20–50 kHz, 26.1 kHz
- Power: commercial hobs: 1–3 kW
- Electric field strength: 10–20 V/m at 10 cm. Induced currents lower than HC SC6 guidelines[42]

3.4 EMF Sources Used in Medicine

Magnetic Resonance Imaging (MRI) in Radiology

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to visualize detailed internal structures. An MRI machine uses three different fields to generate images:

- A static magnetic field (average magnetic flux density of 1.5 to 3 Tesla) produced by a large magnet for the alignment of hydrogen nuclei (protons) inside the body.
- Low power time-varying magnetic field gradients (100 Hz to 1 kHz) generated by small magnets in three orthogonal directions to provide the spatial position of the protons. These MF gradients allow image slicing by focusing on the patient body part under examination.
- RF fields (10 to 400 MHz) to excite the protons (in the body) and cause them to emit radio waves for the acquisition of anatomical images.



"MRI Scanner" courtesy of onlinedocturs, Flickr (CC BY)

RF Ablation in Interventional Cardiology

Cardiac ablation is a procedure that can correct heart rhythm problems (arrhythmias).

It works by scarring or destroying tissue in the heart that triggers abnormal heart rhythms.[43,44]

- Frequency: 485 kHz, 915 MHz
- Power: 40 W, 50 W, 150 W

Physiotherapy: Short- Wave Diathermy

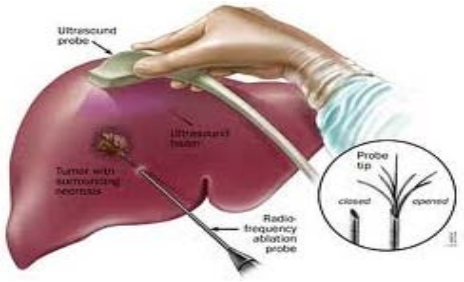
- Frequency: 27.12 MHz
- Power: 500 W

In diathermy, the heat generated by RF waves increases blood flow and speeds up metabolism and the rate of ion diffusion across cellular membranes. The fibrous tissues in tendons, joint capsules, and scars are more easily stretched when subjected to heat, thus facilitating the relief of stiffness of joints and promoting relaxation of the muscles and decrease of muscle spasms.[45]

"DA-ST-84-02519" courtesy of expertinfantry, Flickr (CC BY)

RF Tumour Therapy

- Frequency: 461 KHz
- Nominal power: 200 W
  - o Radiofrequency ablation – treats tumours in lung, liver, kidney and bone
  - o Needle-like RF ablation probe placed inside tumour
  - o RF waves increase temperature and destroy tumour
  - o May be combined with chemotherapy treatment[46,47]



"Radiofrequency ablation (RFA) in liver cancer (hepatocellular carcinoma)" courtesy of Hopkins Medicine.org (CC BY-NC)

Table 2. RF sources: frequency, power, and power density[48-55]

RF Medical Source	Frequencies	Power/Strength
Magnetic Resonance Imaging (MRI)	0 Hz	Main Magnetic Field operating field 1–7 Tesla
	100 Hz to 1 kHz	Gradient Magnetic Field 1–5 mT (millitesla)
	Radiofrequency fields 10–400 MHz	Up to a few KW Not radiative
Cardiac Ablation	485 kHz, 915 MHz	40, 50, 150, 200 W
Shortwave Diathermy	27 MHz	500 W
Tumour Therapy	461 kHz	200 W

3.5 References

1. National Weather Service. Electromagnetic waves. Fort Worth, TX: National Oceanic and Atmospheric Administration; [cited 2012 Nov 29]. Available from: http://www.srh.noaa.gov/jetstream/remote/remote_intro.htm

2. National Radiation Protection Board. Mobile phones and health 2004: report by the board of NRPB. Chilton, Didcot, Oxfordshire: NRPB; 2004. Available from: http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1194947333240

3. RFCom.ca. EMF primer - technical glossary. Terms used in wireless technology. Ottawa, ON: University of Ottawa; [cited 2012 Nov 29]. Available from: http://www.rfcom.ca/glossary/technical_glossary.shtml

4. Fuhs AE. Radar cross section lectures. Reston, VA: American Institute of Aeronautics and Astronautics. Available from: https://www.aiaa.org/PubDetail.aspx?id=2595&terms=radar%20waves

5. Airborne Early Warning Association. Online library - Radar frequency bands. Reston, VA: American Institute of Aeronautics and Astronautics; [cited 2012 Nov 28]. Available from: http://www.aewa.org/Library/rf_bands.html

6. Frey AH. Auditory system response to radio frequency energy. Technical note. Aerosp Med. 1961 Dec;32:1140-2.

7. Jacobson AR, Cummins KL, Carter M, Klingner P, Roussel-Dupré D, Knox SO. FORTE observations of lightning radio-frequency signatures: prompt coincidence with strokes detected by the National Lightning Detection Network. Los Alamos, NM: Los Alamos National Laboratory; 1999 Contract No.: LA-UR-99-870. Available from: http://www.forte.lanl.gov/science/publications/1999/Jacobson_1999_1_FORTE.pdf

8. Encyclopedia Britannica Online. VHF. Chicago, IL: Encylopedia Britannica. Available from: http://www.britannica.com/EBchecked/topic/627147/VHF

9. Yasuda Y, Ida Y, Goto T, Hayakawa M. Interferometric direction finding of over-horizon VHF transmitter signals and natural VHF radio emissions possibly associated with earthquakes. Radio Sci. 2009;44(2):RS2009.

10. Mobile Phone Directory. Glossary of terms - First generation. [cited 2012 Nov 29]. Available from: http://www.mobile-phone-directory.org/Glossary/F/First_Generation.html

11. Literral M. What are 1st, 2nd and 3rd generation mobile phones?2008; (Jun 30): Available from: http://www.articlesbase.com/technology-articles/what-are-1st-2nd-and-3rd-generation-mobile-phones-467075.html

12. Means DL, Chan KW. Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields. Washington, DC: Federal Communications Commission, Office of Engineering and Technology; 2001 Jun. Available from: http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65c.pdf

13. Stewart SW. 4. Radiofrequency fields from mobile phone technology. Mobile phones and health. Chilton, Didcot, Oxfordshire: Independent Expert Group on Mobile Phones,; 2000. p. 27-39. Available from: http://www.iegmp.org.uk/documents/iegmp_4.pdf

14. Whirlpool. Mobile phone frequencies. Australia: Whirlpool. Available from: http://whirlpool.net.au/wiki/mobile_phone_frequencies

15. Arvidson E. Why do cell phones have dead zones?2008: Available from: http://www.ehow.com/info_8352576_do-cell-phones-dead-zones.html

16. Cambridge Dictionaries Online. Dead zone. Cambridge, UK: Cambridge University Press; [cited 2012 Nov 29]. Available from: http://dictionary.cambridge.org/dictionary/british/dead-zone

17. Anonymous. Baby monitor buying guide: Yonkers, NY; 2012 Nov. Available from: http://www.consumerreports.org/cro/baby-monitors/buying-guide.htm

18. HowStuffWorks.com. Can anyone hear my baby monitor? Atlanta, GA: HowStuff Works; [cited 2012 Nov 29]. Available from: http://home.howstuffworks.com/question333.htm

19. Bluetooth. Technical information. Kirkland, WA: Bluetooth SIG; [cited 2012 Nov 29]. Available from: http://www.bluetooth.com/Pages/Tech-Info.aspx

20. Avaya. 1.9 GHz DECT™ 6.0. The new standard in wireless technology. Basking Ridge, NJ: Avaya; 2007 Mar. Available from: http://downloads.avaya.com/css/P8/documents/003940257

21. Radio-Electronics.com. DECT frequencies and frequency bands. Radio-Electronics.com; [cited 2012 Nov 29]. Available from: http://www.radio-electronics.com/info/wireless/dect/frequency-frequencies-bands.php

22. Kowalk W. The DECT standard. Oldenburg, Germany: Rechnernetze [Computer Networks]; [cited 2012 Nov 29]. Available from: http://einstein.informatik.uni-oldenburg.de/rechnernetze/seite24.htm

23. Shop-WiFi.com. Wireless communication products. New Taipei City, Taiwan: Shop-WiFi.com,; [cited 2012 Nov 29].
Available from: http://www.shop-wifi.com/cordless.html

24. Sennheiser. Wireless headphone systems. Pointe Claire, QC: Sennheiser; [cited 2012 Nov 29].
Available from: http://www.sennheiser.ca/live/senn/groupe/en/40/1

25. Health Canada. Limits of human exposure to radiofrequency electromagnetic energy in the frequency range from 3 kHz to 300 GHz. Safety code 6 (2009). Ottawa, ON: Health Canada, Healthy Environments and Consumer Safety Branch; 2009.
Available from:
http://www.rfsafetysolutions.com/PDF%20Files/Health%20Canada%20Safety%20Code%206%20Standard_2009.pdf

26. Moonblink. 802.11b WiFi channels. Sunnyvale, CA: Moonblink; [cited 2012 Nov 29].
Available from: http://www.moonblinkwifi.com/2point4freq.cfm

27. Office of the Telecommunications Authority. Radiofrequency radiation measurements. public Wi-Fi installations in Hong Kong. Wan Chai, Hong Kong: Office of the Telecommunications Authority; 2007 Oct. Available from:
http://tel_archives.ofca.gov.hk/en/report-paper-guide/report/rp20071012.pdf

28. Health Protection Agency. Health effects from radiofrequency electromagnetic fields. London, UK: HPA; 2012 Apr.
Available from:
http://www.hpa.org.uk/webw/HPAweb&HPAwebStandard/HPAweb_C/1317133826368

29. Verloock LF, Joseph WF, Vermeeren G, Martens L. Procedure for assessment of general public exposure from WLAN in offices and in wireless sensor network testbed. Health Phys. 2010 Apr;98(4):628-38.

30. Foster KR. Radiofrequency exposure from wireless LANs utilizing Wi-Fi technology. Health Phys. 2007;92(3):280-9.

31. British Columbia Centre for Disease Control. Measurement of RF emissions from BC Hydro's smart meters. Vancouver, BC: BCCDC; 2012 Jan.
Available from: http://www.bccdc.ca/NR/rdonlyres/43EF885D-8211-4BCF-8FA9-0B34076CE364/0/452012AmendedReportonBCHydroSmartMeterMeasurements.pdf

32. BC Hydro. Radio frequency & smart meters. Vancouver, BC: BC Hydro; [cited 2012 Nov 29].
Available from:
http://www.bchydro.com/energy_in_bc/projects/smart_metering_infrastructure_program/faqs/radio_frequency.html?WT.mc_id=rd_metersafety

33. British Columbia Centre for Disease Control. BCCDC Field Measurements of FM & AM radio station electromagnetic field emissions (not published). 2002.

34. Federal Communications Commission. Radio frequency safety - frequenty asked questions (FAQs). Washington, DC: FCC; [cited 2012 Nov 29]. Available from: http://transition.fcc.gov/oet/rfsafety/#sec3

35. WorkSafeBC. Legislation and regulation. Vancouver, BC: WorkSafeBC; [cited 2012 Dec 1]. Available from: http://www.worksafebc.com/regulation_and_policy/legislation_and_regulation/default.asp

36. Industry Canada. CPC-2-0-03 - Radiocommunication and broadcasting antenna systems. Ottawa, ON: Government of Canada, Spectrum Management and Telecommunications; 2007 Jun, Issue 4. Available from: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08777.html

37. British Columbia Centre for Disease Control. BCCDC Measurements of electromagnetic radiation - microwave ovens (not published).

38. Department of Justice Canada. Radiation Emitting Devices Regulations (C.R.C., c. 1370). Last amended 2006-06-01. Ottawa, ON: Government of Canada. Available from: http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.,_c._1370/page-4.html#h-7

39. Industry Canada. Case study: measurements of radio frequency exposure from Wi-Fi devices. Ottawa, ON: Government of Canada, Spectrum Management and Telecommunications; 2012 May. Available from: http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/Wifi-e.pdf/$FILE/Wifi-e.pdf

40. Stuchly MA, Repacholi HM, Lecuyer DW, Mann R. Radiation survey of dielectric (RF) heaters in Canada. J Microw Power. 1980 Nov;15(2):113-21.

41. Rosenquist S. Why RF gluing continues to grow. The woodworker's guide to radio frequency gluing. Available from: http://www.rosenquistllc.com/images/Gluing_Guide.pdf

42. Suzuki Y, Taki M. Measurement of magnetic field from an induction heating hob and estimation of induced current density in human body. IEEJ Trans Fund Mater. 2005;125(5):427-33. Available from: http://www2.iee.or.jp/ver2/honbu/14-magazine/log/2005/2005_05a_05.pdf.

43. International Commission on Non-Ionizing Radiation Protection. ICNIRP statement on EMF-emitting new technologies. Health Phys. 2008 Apr;94(4):376-92.

44. Lencioni RA, Allgaier HP, Cioni D, Olschewski M, Deibert P, Crocetti L, et al. Small hepatocellular carcinoma in cirrhosis: randomized comparison of radio-frequency thermal ablation versus percutaneous ethanol injection. Radiology. 2003 Jul;228(1):235-40.

45. Stuchly MA, Repacholi MH, Lecuyer DW, Mann RD. Exposure to the operator and patient during short wave diathermy treatments. Health Phys. 1982 Mar;42(3):341-66.

46. Assenheim HM, Hill DA, Preston E, Cairnie AB. The biological effects of radio-frequency and microwave radiation (NRCC No 16448). Ottawa, ON: National Research Council Canada, Committee on Scientific Criteria for Environmental Quality; 1979.

47. National Council on Radiation Protection and Measurements, Wilkening GM, Barnes FS, Bowman RR, Guy AW, Illinger KH, et al. Radiofrequency electromagnetic fields - properties, quantities and units, biophysical interaction, and measurements (NCRP Report No. 67). Bethesda, MD: NCRP. Available from: http://www.ncrponline.org/Publications/Press_Releases/67press.html

48. Fuchs VR, Sox HC, Jr. Physicians' views of the relative importance of thirty medical innovations. Health Aff (Millwood). 2001 Sep-Oct;20(5):30-42.

49. Center for Integration of Medicine & Innovative Technology. Medical device "Plug-and-Play" interoperability program. Cambridge, MA: Center for Integration of Medicine & Innovative Technology; [cited 2012 Dec 1]. Available from: http://www.mdpnp.org/

50. Hornak JP. Chapter 9. Imagine hardware The basics of MRI. Rochester, NY: Rochester Institute of Technology, Center for Imaging Science. Available from: http://www.cis.rit.edu/htbooks/mri/chap-9/chap-9.htm

51. Brady M. Basics of MRI [lecture]. Oxford, UK: Oxford University; 2004. Available from: http://www.robots.ox.ac.uk/~jmb/lectures/medimanallecture1.pdf

52. Quick HH. Seven Tesla MRI from technical developments to imaging applications. Diagnostic Imaging Europe. 2011 Apr:10-2.

53. Wong SL, Edwards MJ, Chao C, Simpson D, McMasters KM. Radiofrequency ablation for unresectable hepatic tumors. Am J Surg. 2001 Dec;182(6):552-7.

54. Laufer Y, Zilberman R, Porat R, Nahir AM. Effect of pulsed short-wave diathermy on pain and function of subjects with osteoarthritis of the knee: a placebo-controlled double-blind clinical trial. Clin Rehabil. 2005 May;19(3):255-63.

55. Babilas P, Schreml S, Szeimies RM, Landthaler M. Intense pulsed light (IPL): a review. Lasers Surg Med. 2010 Feb;42(2):93-104.