A Global Survey and Comparison of Different Regulatory Approaches to Non-Ionizing RADHAZ and Spurious Emissions

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ABSTRACT — A worldwide survey of regulations and standards in 235 countries reveals different approaches associated with RADHAZ and spurious emissions. These are primarily divided into regions regulated or influenced by Europe or by North America, each applying different limits to cellular base stations, utility power lines and spurious emissions. Generally, the American and Japanese permitted exposures are more lenient, whereas the European are stricter. Several interesting examples are discussed.
Index terms— ANSI standards, electromagnetic compatibility, IEEE standards, radiation effects, radio spectrum management, risk analysis, standardization.

I. EXPOSURE LEVELS: CELLULAR BASE-STATIONS AND POWER LINES

The limits of the 'International Commission on Non-Ionizing Radiation Protection' ICNIRP [1] (p. 511, table 7) and the European Community EC [2] (Annex III, table 2) are identical. The ICNIRP levels have been endorsed by the Commission's Scientific Steering Committee. Table I specifies the exposure limits from cellular base stations and power lines.

TABLE I ICNIRP AND EC REFERENCE LEVELS FOR EXPOSURE

Frequency range	Electric field strength (V/m)	Magnetic field strength (A/m)	Equivalent plane wave power density S_{eq}(W/m^2)	Magnetic Flux Density (μT), B
25-800 Hz	250/f	4/f	-	5,000/f
400-2000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	f/200	$0.0046\ f^{½}$
2-300 GHz	61	0.16	10	0.2

The ICNIRP level for magnetic flux density at 50/60 Hz is 5,000/f (last column in Table I). The same formula is adopted in Europe and North America; therefore, it is 100 μT for 50 Hz Europe, and 83,3 μT for 60 Hz North America.

Table II, see [3] (p.67), specifies the official US thresholds for base stations.

TABLE II FCC EXPOSURE LIMITS

Frequency Range (MHz)	Electric Field (E) (V/m)	Magnetic Field H (A/m)	Power Density (S) (mW/cm^2)
30-300	27.5	0.073	0.2
300-1500	--	--	f/1500
1500-100,000	--	--	1

The IEEE permissible exposure, see [4] (p. 25, table 9), was updated in 2005 and is shown in Table III.

TABLE III THE UPDATED IEEE PERMISSIBLE EXPOSURE

Frequency Range MHz	Electric Field (E) (V/m)	Magnetic Field H (A/m)	RMS power density (S) (W/m^2)
100-400	27.5	0.073	2
400-2000	--	--	f/200
2000-5000	--	--	10

The levels of IEEE C95.1-1991 [5] and C95.1-2005 [4] standards for exposure at 100-400 MHz did not change (0.2 mW/cm^2= 2W/m^2). The IEEE C95.1-2005 level for 400-2000 MHz (typical cellular RF bands) is now 4/3 more stringent (new f/200 W/m^2) relative to IEEE 1991 (f/1500 mW/cm^2 = f/150

W/m^2); the updated value is identical (not to FCC nor ANSI present levels) to the ICNIRP level (f/200 W/m^2); the units now are also the same.
Table IV, see ITU-R BS.1698 [6] (p. 67, table 9[1]), compares the power density levels from the renowned institutions. Table IV clearly depicts that the levels in power exposure limits of the US are 4/3 (=200/150) higher than ICNIRP and Europe.

TABLE IV DERIVED LEVELS, POWER DENSITY (W/m²): ICNIRP AND USA

Frequency range	ICNIRP	ANSI (USA)
	General Public	General Public
400 - 1,550 MHz	f /200	f /150
1,550 - 2,000 MHz	f /200	f /150[2]

Table V, see [7] (p. 195), specifies the *human hazards* power density of less tolerant countries, with more stringent thresholds relative to the ICNIRP level, 5W/m^2 at 1GHz; see column 4 in Table I.

TABLE V COUNTRIES LESS TOLERANT OF RISK

Country	**Power Density**, Relative to **ICNIRP**
Switzerland	0.01
Italy	0.02-0.2
Poland	0.02
Luxembourg	0.05
China	0.08
Israel	0.1
Bulgaria	0.12
Italy	0.02-0.2
Russia	0.2
Belgium	0.25
Greece	0.8

Switzerland and Italy apply up to 0.01 ICNIRP reference level for cellular phone base stations, acting against 'proven' adverse health effects. Additionally, Switzerland also implements precautionary emission limitations (the most stringent in the world), so-called Installation Limit Values (ILV), at places of sensitive use, such as apartment buildings, schools, hospitals, permanent workplaces and children's playgrounds. Poland reduces the level by 50 times for public exposure, Luxembourg by 20 times and China is 12.5 times stricter. The compliance with environmental guidelines in Israel stands at 10% (indoors) or 30% (outdoors) of ICNIRP levels.

The World Health Organisation WHO source[3] also details the national magnetic fields thresholds. Relative to the ICNIRP threshold, again Switzerland, Israel, Russia, Italy, Poland and Greece are the countries least tolerant of magnetic fields; i.e., of radiation from power lines, electricity pylons, generators and transformers. The following countries have indicated that they follow ICNIRP levels: Austria, Czechoslovakia, France, Finland, Germany, Holland, Ireland, Netherlands, New Zealand, Singapore, Taiwan and UK. Table VI, see [7] (p. 196), indicates only the countries that apply different limits relative to the ICNIRP level[4]. It specifies the *human hazards* magnetic flux of less tolerant countries, with more stringent magnetic thresholds, relative to the ICNIRP level.

[1] The same values appear also in the ITU-R 2004 Report ITU-R BS. 2037, p. 66.
[2] The value at http://www.who.int/docstore/peh-emf/EMFStandards/who-0102/North_America/USA_files/table_us.htm 30/09/09 is 10 W/m^2; for f=1,500 MHz; 1500/150=10.
[3] See http://www.who.int/docstore/peh-emf/EMFStandards/who-0102/Worldmap5.htm 30/09/09
[4] 5,000/f μT; f: 50 Hz for Europe and 60 Hz for America; see column 3 Table I.

TABLE VI COUNTRIES LESS TOLERANT OF MAGNETIC RISK

Country	Magnetic Flux Density relative to ICNIRP
Switzerland	0.01
Italy[5]	0.03 (daily mean, for more than 4 hours); 0.1 (for designed lines)
Slovenia	0.1 (for new installations)
Israel	0.1 (proposed in occupational)
Russia	0.1 (Indoor); 0.5 (Outdoor)
Poland	0.75
Greece	0.8

Table VII, see [7] (p. 196), indicates only the tolerant countries, with less precautious.

TABLE VII
COUNTRIES[6] MORE TOLERANT OF EMF RISK

Country	Power Density Relative to ICNIRP
Canada	1.33
Japan	1.33
USA	1.33

Exposure Levels- Conclusion: The value of exposure levels is reducing with time. The same countries (Italy, Switzerland and Poland) are un-tolerant to cellular base stations and utility power lines.

II SPURIOUS EMISSIONS

Spurious emissions are unwanted RF transmissions on a frequency, and the level of which may be reduced without affecting the corresponding emission of information. The *spurious emissions* are elementary in regulating RF systems, as their levels affect the appropriate introduction of any new system; the adjacent licensed receivers may be interfered. Therefore, *spurious emissions* need the most attention from the regulator; lower unwanted emissions reduce the uncertain risk: the RF interference. The study compares the regional and national limits of *spurious emissions* domain. The ITU Radio Regulations (RR Appendix 3; a treaty level text) specify the attenuation values used to calculate maximum permitted *spurious emissions* levels. The ITU-R Recommendation on *spurious emissions* [9] is widely used in Europe (e.g. ETS 300 328 November 1996, CEPT/ ERC/ Recommendations 74-01 and 02-05) as well as by the USA type approvals of the FCC, Japan's (e.g. ARIB TR-T12-34.926), and various national regulators and international standardisers (such as 3GPP TR 34.926). A significant difference among regions and states is the allowance of RF *spurious emissions*. Category B, C and D are examples of more stringent spurious domain emission than Category A limits. Table VIII defines the four categories of spurious domain emission.

TABLE VIII CATEGORIES OF SPURIOUS EMISSIONS LIMITS

Category A	The attenuation values used to calculate maximum permitted spurious domain emission power levels. **RR Appendix 3** is derived from Category A limits.
Category B	Limits are defined and adopted in **Europe** (all Europe not only EC) and used by some other countries.
Category C	Limits are defined and adopted in the **US and Canada** and used by some other countries.
Category D	Limits are defined and adopted in **Japan** and used by some other countries.

[5] See the 8/7/2003 Italian Presidential Decree http://www.who.int/docstore/peh-emf/EMFStandards/who-0102/Europe/Italy_files/table_it.htm 30/09/09.
[6] UK (NRPB) level was 8.2 ICNIRP's threshold; after Pr. Stewart report [8], UK follows ICNIRP levels.

VI COMPARATIVE ANALYSIS

Table IX, [7] (p. 30) derived from [9], indicates the different limits of RF *spurious emissions* adopted.

TABLE IX COMPARATIVE SPURIOUS EMISSIONS LIMITS

Type of equipment	Category A: All Countries	Category B: Europe	Category C: USA, Canada	Category D: Japan
	Attenuation (dB) below the power (W)			
Land mobile service	All services except those services quoted: 43 +10 log *P*, or 70 dBc, whichever is less stringent	mobiles and base stations: –36dBm for 9kHz≤ *f*< 1 GHz –30dBm for1GHz ≤ *f*<300GHz	150-174 MHz and 421-512 MHz whichever is less stringent 50+10 log *P* or 70 dBc for 12.5 kHz channels	Analogue systems for portable/auto-mobile telephones 60 dBc for *P* < 50 W
Fixed service		–50[7] dBm for 30 MHz ≤ *f* < 21.2 GHz –30 dBm for 21.2GHz ≤ *f* <300 GHz	As in Category A	30MHz < f_0 ≤ 335.4 MHz; 60 dBc for *P* < 50 W
Broadcasting at HF	50 dBc and the absolute mean power level of 50 mW should not be exceeded		80 dBc	Like Category A, for all Broadcasting: HF and FM
Broadcasting at FM	46+10 log P, or 70 dBc, whichever is less stringent; the absolute mean power level of 1 mW should not be exceeded	FM broadcasting, 87.5 ≤ *f* ≤ 137 MHz: –36 dBm for *P* < 9 dBW; 75 dBc for 9 ≤ *P* < 29 dBW; –16 dBm for 29 ≤ *P* < 39 dBW; 85 dBc for 39 ≤ *P* < 50 dBW; –5 dBm for 50 dBW ≤ *P*	43 + 10 log *P* or 80 dBc, whichever is less stringent	

Category A (all countries) and B (Europe) include a thorough regulation on the *spurious emissions* of low power device radio equipment in Category A, and Short Range Devices in Category B. North America and Japan, as a policy, refrain from regulating these licence-exempt devices[8]; Europe **does** control them. However, the US and Canada are the only countries to apply limits in spurious domain emissions in the 1,559-1,605 MHz band to protect their strategic GPS transmission. Table X, see [7] (p. 31), compares the limits for typical systems. The power and RF values were chosen in order to compare the limits in the different regions.

[7] Fixed Service- Terminal stations (stations with subscriber equipment interfaces) are more relaxed: –40 dBm.
[8] According to [9] SM. 329, not to FCC CF7 47, PART 15, e.g.

TABLE X COMPARATIVE SPURIOUS EMISSIONS VALUES(dBm) FOR VARIOUS SYSTEMS

Type of equipment	Category A: All Countries	Category B: Europe	Category C: USA, Canada	Category D: Japan
Portable, 465 MHz, 1 W, 12.5 kHz channels	-13	-36	-20	-30
Fixed Service[9], 325 MHz, 10 W	-13	-50	-13	-20
HF Broadcasting, 100 kW	17	17	0	17
FM Broadcast, 100 MHz, 10 kW	0	-15	-10	0

Except for the HF broadcasting examples, in all the other cases Europe is more stringent than the US and Canada. For the fixed service, a striking discrepancy is indicated, of up to 37 dB, i.e. the US allows spurious levels up to 5,000 times higher in power than in Europe. Japan is the most tolerant in FM broadcast: 10 dB more tolerant than the US and Canada, and 15 dB more than Europe.

Spurious Emissions- Conclusion: there is significant diversity among the different categories. Each grouping represents a compromise between lower *spurious emissions* and the cost of equipment. Europe is the most stringent in its limits and protection of the natural RF resource. North America and Japan are more sensitive to the market needs. Europe also regulates the *spurious emissions* of unlicensed Short Range Devices, whereas North America and Japan do not (according to ITU-R SM.329). However, the US is very keen to protect its exclusive GPS.

III RF THRESHOLDS - CONCLUSION

The permitted levels of EMF and *spurious emissions* disclose the national risk tolerability. The study shows a regulatory convergence toward two hemispheres: the European – regulated by CEPT and EC, versus the American standards, led by the US (and Canada). Table XI, see [7] (p. 32), compares Europe versus North America. The table highlights the divergence between the two hemispheres.

TABLE XI STANDARDS AND THRESHOLDS: EUROPE VERSUS NORTH AMERICA

Standard	*Main Power*	*Spurious Emissions & Human Hazards*
Europe	50 Hz	Stringent
North America	60 Hz	Flexible

Europe and North America apply different levels of RF *human hazards* and *spurious emissions*. A "central planning" Europe is more inclined to adopt a precautionary principle in *human hazards* and to protect its congested RF spectrum by enforcing stringent *spurious emissions*. North America prefers a more *laissez-faire* policy, in order to lower prices of wireless equipment.

The RF levels of *human hazards* are becoming more stringent worldwide; due to globalisation, the thresholds may converge to the universal levels of ICNIRP. Universal thresholds (*human hazards* and *spurious emissions*) will avoid a Babylon tower of thresholds that confuse suppliers, operators and users.

[9] According to CEPT/ERC/74-01 table 1.1, the same limits apply also for fixed receivers.

IV SUMMARY

This talk surveys the diversity in regulatory thresholds worldwide, which was obtained through a rigorous academic study of 235 countries. Different approaches towards *human hazards* and towards *spurious emissions* are pointed out, and two major philosophies are identified - the more conservative European approach, regulated by CEPT and EC, and the more liberal American approach, led by the US and Canada.

The presented study reveals that the US, Canada, and Japan are more tolerant to RF exposure limits from cellular base stations and define higher allowable limits for these. It further shows that these regions are also more lenient with regards to *spurious emissions*. Details of the diversity in thresholds, published by the leading standard and health institutions, are provided, pointing questions like: why do Switzerland and Italy adopt ultra-low permitted emission levels for cellular towers and electricity (1% of ICNIRP 98 level), whereas for other populations, having different approach to *human hazards*, such as Canada, Japan and USA, the factor is 4/3 (of ICNIRP level)? In general, "central planning" Europe is shown to be more inclined to adopt a precautionary approach in *human hazards* and also to protect its congested RF spectrum by enforcing stringent spurious emission limits, whereas North America generally prefers a more '*laissez-faire*' policy, in order to stimulate economic growth. [7] explains the different tolerability to risk in Europe and the US by distinctive legal origin (Civil Law versus Common Law) and religion (Catholicism versus Protestantism).

REFERENCES

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[2] *EC General Council Recommendation 1999/519* "On the Limitation of Exposure of the General Public to Electromagnetic Fields, 0 Hz to 300 GHz", 1999

[3] *FCC OET Bulletin 65C* "Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions", 2001

[4] *IEEE 2006 Standard C95.1-2005* "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz", 2005

[5] *IEEE 1991 (and ANSI 1992) C95.1-1991* "IEEE Standard C95.1 for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz", 1991

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[7] H. Mazar *An Analysis of Regulatory Frameworks for Wireless Communications, Societal Concerns and Risk: the Case of Radio Frequency (RF) Allocation and Licensing*, Boca Raton Fl.: Dissertation.Com, 2009 http://eprints.mdx.ac.uk/133/2/MazarAug08.pdf

[8] W. Stewart *Mobile Phones and Health,* Chilton[UK] IEGMP (Independent Expert Group on Mobile Phones), 2001

[9] *ITU-R Recommendation SM.329-10* "Unwanted Emissions in the Spurious Domain", 2003

A Global Survey and Comparison of Different Regulatory Approaches to Non-Ionizing RADHAZ and Spurious Emissions

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Purpose / Motivation

- Why are there so many different thresholds worldwide for Radiation Hazards (RADHAZ)?
- The topic is of great public interest
- 1996 Santa Rosa ITU-R (International Telecommunications Union) Study Group 1 meeting on Spurious Emissions has triggered my personal interest
- A worldwide survey of regulations and standards in 235 countries (PhD research)

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Outline

- The different approaches in applying **RADHAZ** limits worldwide for Cellular Base Stations and Utility Power Lines
- The different approaches in applying **Spurious Emission** limits worldwide
- A survey of the differences
  - What are they? - Comparison tables
  - Why? - culture and geography

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RADHAZ: Quantities and Units

Quantity	Symbol	Unit	Unit-Symbol
Frequency	f	Hertz	Hz
Magnetic flux density*	B	Tesla	T
		Gauss	G
Specific Absorption Rate	SAR	Watt per kilogram or milliWatt per gram	W/kg or mW/g
Power density or power flux density	S	Watt per square metre	W/m^2
		mWatt per square cm	mW/cm^2

*** to convert from microtesla (µT) to milligauss (mG), multiply by 10.**
1 µT = 10 mG; 0.1 µT = 1 mG.

An error in this conversion resulted in the delay of 3 years in populating an administrative building in Jerusalem.

ICNIRP and EC Levels for RADHAZ

Frequency range	Equivalent plane wave power density S_{eq} **(W/m^2)**	Magnetic Flux Density (μT), B
25-800 Hz	-	**5,000/f**
400-2000 MHz	**f/200**	0.0046 $f^{½}$
2-300 GHz	10	0.2

Same formula adopted in Europe and North America:
100μT for 50Hz Europe, and 83.3μT for 60Hz North America.

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Differences ICNIRP versus USA (FCC)

Power Density Limits (W/m^2)

Frequency range	ICNIRP	ANSI (USA)
	General Public	Uncontrolled
400 - 1,550 MHz	f /200	f /150
1,550 - 2,000 MHz	f /200	f /150

- **IEEE C95.1-2005 exposures at 400-2,000 MHz is now 4/3 more stringent (new f/200 W/m^2) relative to IEEE 1991 (f/1500 mW/cm^2 = f/150 W/m^2)**
- **The updated IEEE value (2005) is identical (not to FCC nor ANSI present levels) to the ICNIRP level (f/200 W/m^2)**

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Tolerability to EM Risk, relative to ICNIRP1998

- **US, Canada and Japan** are more tolerant of risk - 133% ICNIRP
- Countries **less** tolerant of risk, with more stringent thresholds:

Country	*Power Density Relative to ICNIRP*
Switzerland	1%
Italy	2%- 20%
Poland	2%
Luxembourg	5%
China	8%
Israel	10%
Bulgaria	12%
Russia	20%
Belgium	25%
Greece	80%

See WTO http://www.who.int/docstore/peh-emf/EMFStandards/who-0102/Worldmap.htm

Tolerability to Magnetic Risk, relative to ICNIRP1998

Countries Less Tolerant to Magnetic Risk

Country	*Magnetic Flux Density Relative to ICNIRP*
Switzerland	1%
Italy	3% (daily mean, for more than 4 hours); 10% (for 'designed lines')
Slovenia	10% (for new installations)
Israel	10% (proposed in 'occupational' area)
Russia	10% (indoor); 50% (outdoor)
Poland	75%
Greece	80%

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Considerations in Setting Thresholds

- Tradeoff - **cellular coverage and electricity infrastructure** vs. human hazards
- Scandinavian economy; Northern population is more tranquil and restrained; essentiality of wireless communications
- Levels in Switzerland and Slovenia were influenced by Italy due to geographical (and linguistic) vicinity
- Italian instability, topography and FM pirates
- Trusting styles may lead to less precaution; less precaution is typical to the 'innocent until proven guilty' way of thinking: there are no hazards to humans until the risks are scientifically proven
- Common law vs Civil law; Protestantism vs Catholicism (Max Weber: “either eat well or sleep well”); Colonialism; Worldviews
- None of the English-speaking countries applies more restricted limits than ICNIRP levels

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RADHAZ Trends

- The allowed exposure levels are reducing with time (UK, Singapore)
- The same countries (Italy, Switzerland and Poland) are intolerant to excessive emissions both from cellular base stations and from utility power lines
- Cultural differences and mentality may explain the different approaches
- A need to manufacture and to circulate the same cellular handsets all over the world; Globalization leads to **harmonization** in SAR limits for handsets

ITU Categories for Spurious Emissions Limits

Category A	Spurious emissions of **ITU Radio Regulations** Appendix 3
Category B	Limits are defined and adopted in **Europe**
Category C	Limits are defined and adopted in the **US and Canada**
Category D	Limits are defined and adopted in **Japan**

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Comparison of Spurious Emission Categories

Type of equipment	Category A: All Countries	Category B: Europe	Category C: USA, Canada
Land mobile service	43 +10 log *P*, or 70 dBc, whichever is less stringent *Actually - 43 dBW=* *-13dBm*	mobiles & base stations: –36dBm for 9kHz≤ *f*< 1 GHz –30 dBm for1GHz ≤ *f*<300GHz	150-174 MHz and 421-512 MHz whichever is less stringent 50+10 log *P* or 70 dBc for 12.5 kHz channels
Fixed service		–50 dBm for 30 MHz ≤ *f* < 21.2 GHz –30 dBm for 21.2GHz ≤ *f* <300 GHz	As in Category A

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Spurious Emissions (dBm) for Various Systems

Type of equipment	Category A: All Countries	Category B: Europe	Category C: USA, Canada	Category D: Japan
Portable, 465MHz, 1W	-13	-36	-20	-30
Fixed Service, 325MHz, 10W	**-13**	**-50**	**-13**	**-20**
HF Broadcasting, 100 kW	17	17	0	17

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Conclusions: Spurious Emissions

- Significant diversity among the different regions
- Tradeoff - **spectral purity** vs. **equipment's cost**
- Europe is stringent in protecting the natural RF resource
- N. America and Japan are more sensitive to market needs (compare also UWB Europe/US/Japan)
- Europe also regulates the spurious emissions of unlicensed SRDs, whereas N. America and Japan do not
- But the US is very keen to protect its exclusive GPS: strict emission limits applied for 1.575GHz

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Conclusion (1/2)

Standards and Thresholds: Europe vs. North America

Standard	*Main Power*	*Spurious Emissions & Human Hazards*
Europe	50 Hz	Stringent
North America	60 Hz	Flexible

- US, Canada, and Japan are more tolerant to RF exposure limits from cellular base stations
- These countries are also more lenient with regards to spurious emissions
- "Central planning" EC adopts a precautionary principle in human hazards and protects its congested RF spectrum by enforcing stringent spurious emissions
- N. America prefers *laissez-faire* policy, in order to lower prices of wireless equipment

Conclusion (2/2)

- Universal thresholds (human hazards and spurious emissions) will avoid a Babylon tower of thresholds that confuse suppliers, operators and users
- Variations reflect the societal concerns, social amplification, the acceptance of the precautionary principle, obedience and the national tolerability to risk
- A convergence to 2 hemispheres: Europe regulated by CEPT and EU; American standards, led by the US (and Canada)
- Book covering the topic and correlating the differences in tolerability to risk in Europe and the US with distinctive legal origin (Civil Law vs. Common Law) and religion (Catholicism vs. Protestantism):

"An Analysis of Regulatory Frameworks for Wireless Communications, Societal Concerns and Risk" / Dr. Haim Mazar

http://www.moc.gov.il/new/documents/frequences/MazarThesisOct08.pdf

http://www.universal-publishers.com/book.php?method=ISBN&book=1599427109

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Backup: Comparison Cellular Handsets, SAR (W/kg)

10 MHz–10 GHz Portables; General Population

ICNIRP	European Community	FCC- USA
2.0; averaged over 10 g tissue		1.6; averaged over 1g tissue

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