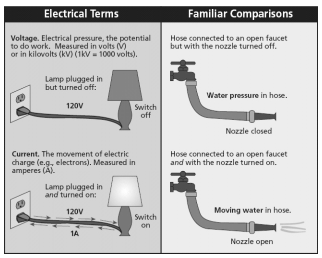
전자기파와 생체 관련성

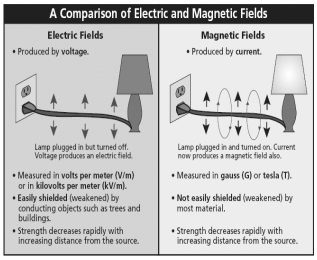
김 남
충북대학교

Electric and Magnetic fields



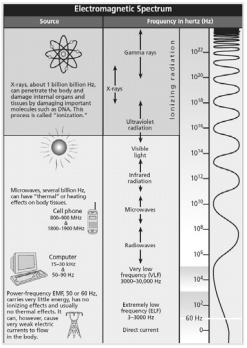
- Electric fields
  - produced by voltage
  - Increase in strength as the voltage increases
  - Unit : volts per meter (V/m)
- Magnetic fields
  - result from the flow of current through wires or electrical devices
  - Increase in strength as the current increases
  - Units : gauss(G), tesla(T)

Electric and Magnetic fields



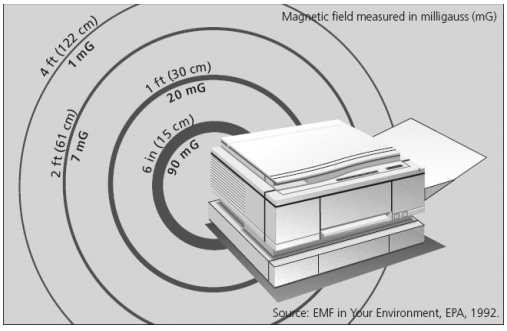
- Electric fields
  - Easily shielded by conducting objects
    ex) tree, building, human skin
  - Strength decreases rapidly with increasing distance from the source
- Magnetic fields
  - Not easily shielded by most material
  - Strength decreases rapidly with increasing distance from the source

Electromagnetic Spectrum



Frequency	Band	Applications
3 – 300 Hz	ELF/SLF	Detection of buried metal objects and Communication with submerged submarine/electric power
300-3000 Hz	ULF	Telephone audio range
3-30 kHz	VLF	Navigation, sonar
30-300 kHz	LF	Navigation, radio beacon
300-3000 kHz	MF	AM, maritime radio, direction finding
3-30 MHz	HF	Facsimile, SW radio, citizen's band
30-300 MHz	VHF	TV, FM, police, mobile radio, air traffic control
300-3000 MHz	UHF	Radar, TV, navigation, Cellular phone, PCS phone, IMT-2000, WLAN, RFID, ISM
3-30 GHz	SHF	Radar, satellite communication
30-300 GHz	EHF	Radar, space exploration

Magnetic Field strength vs. Distance



Influence of EMF exposure

- DC electric power does not induce electric currents in human
- AC electric power produces electric and magnetic fields that create weak electric currents in human ⇒ **Induced currents**
  - Electric fields
    - A person standing directly under a high-voltage transmission line may feel a mild shock when touching something that conducts electricity
    - These sensations are caused by the strong electric fields from the high-voltage electricity in the lines
  - Magnetic field
    - Alternating magnetic fields produced by AC electricity can induce the flow of weak electric currents in the body
    - However, such currents are estimated to be smaller than the measured electric currents produced naturally by the brain, nerves, and heart

전자기장에 의한 인체노출 영향

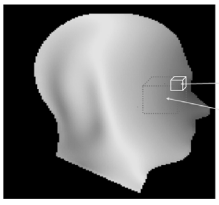
- 열적효과 : 고주파 대역의 전자파가 인체에 흡수될 경우 체온이 상승하는 효과
- 자극효과 : 저주파 대역의 전자파가 인체에 흡수될 경우 체내에 유도전류가 발생하여 신경에 자극
- 비열적효과 : 미약한 전자파가 장시간 인체에 흡수될 경우 나타나는 효과
- 쇼크 및 화상 : 대전체와의 접촉 및 방전으로 발생

SAR Computation-1

- SAR : Specific Absorption Rate

$$SAR = \frac{\sigma}{2\rho}|E|^2$$

σ = conductivity of body tissue (s/m)
ρ = density of body tissue (kg/m³)
E = rms value of electric strength in the tissue (v/m)



	SAR 기준 [W/kg]			
	직 업 인		일 반 인	
	전신	국부	전신	국부
FCC	0.4	8.0	0.08	1.6
ICNIRP	0.4	10.0	0.08	2.0

- FCC : 1 g 평균 (미국, 한국, 캐나다 등)
- ICNIRP/CENELEC : 10 g 평균 (유럽, 일본 등)

SAR Computation-2

- 측정온도
  - 18°C ~ 25 °C ±2°C
- 측정환경
  - Environment Noise : 0.012 W/kg 이하
  - 무선장치는 구내 이동망과 상호작용하여서는 안됨
  - 주위 전자기 발생원이 SAR 측정에 심각한 영향을 미치지 않게 함


ESSAY-3, EMF Safety Inc


DASY4, Speag Inc

IARC 및 IARC Monographs란?

About IARC

The International Agency for Research on Cancer (IARC) is part of the World Health Organization. Its mission is to coordinate and conduct research on the causes of human cancer, the mechanisms of carcinogenesis, and to develop scientific strategies for cancer control. The Agency is involved in both epidemiological and laboratory research and disseminates scientific information through publications, meetings, courses, and fellowships.

ABOUT THE IARC MONOGRAPHS

What are the IARC Monographs?

The *IARC Monographs* identify environmental factors that can increase the risk of human cancer. These include chemicals, complex mixtures, occupational exposures, physical and biological agents, and lifestyle factors. National health agencies use this information as scientific support for their actions to prevent exposure to potential carcinogens. Interdisciplinary working groups of expert scientists review the published studies and evaluate the weight of the evidence that an agent can increase the risk of cancer. The principles, procedures, and scientific criteria that guide the evaluations are described in the Preamble to the IARC Monographs.

Since 1971, more than 900 agents have been evaluated, of which approximately 400 have been identified as **carcinogenic or potentially carcinogenic** to humans.

WHO-IARC WG 회의 결과-1

International Agency for Research on Cancer

World Health Organization

PRESS RELEASE
N° 208

31 May 2011

IARC CLASSIFIES RADIOFREQUENCY ELECTROMAGNETIC FIELDS AS POSSIBLY CARCINOGENIC TO HUMANS

Lyon, France, May 31, 2011 -- The WHO/International Agency for Research on Cancer (IARC) has classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B), based on an increased risk for glioma, a malignant type of brain cancer[1], associated with wireless phone use.

Background

Over the last few years, there has been mounting concern about the possibility of adverse health effects resulting from exposure to radiofrequency electromagnetic fields, such as those emitted by wireless communication devices. The number of mobile phone subscriptions is estimated at 5 billion globally.

WHO-IARC WG 회의 결과-2

From **May 24–31 2011, a Working Group of 31 scientists from 14 countries has been meeting at IARC in Lyon, France, to assess the potential carcinogenic hazards from exposure to radiofrequency electromagnetic fields**. These assessments will be published as Volume 102 of the IARC *Monographs*, which will be the fifth volume in this series to focus on physical agents, after **Volume 55** (Solar Radiation), **Volume 75** and **Volume 78** on ionizing radiation (X-rays, gamma-rays, neutrons, radio-nuclides), and **Volume 80 on non-ionizing radiation (extremely low-frequency electromagnetic fields)**.

The IARC Monograph Working Group discussed the possibility that these exposures might induce long-term health effects, in particular an increased risk for cancer. This has relevance for public health, particularly for users of mobile phones, as the number of users is large and growing, particularly among young adults and children.

The IARC Monograph Working Group discussed and evaluated the available literature on the following exposure categories involving radiofrequency electromagnetic fields:

- occupational exposures to radar and to microwaves;
- environmental exposures associated with transmission of signals for radio, television and wireless telecommunication; and
- personal exposures associated with the use of wireless telephones.

International experts shared the complex task of tackling the **exposure data, the studies of cancer in humans**, the **studies of cancer in experimental animals**, and the **mechanistic and other relevant data**.

- List of WG of 31 scientists
  - Bruce Armstrong, University of Sydney, Australia
  - Igor Y. Belyaev, Cancer Research Institute, Slovak Academy of Science, Slovak Republic
  - Carl F. Blackman, USA
  - Maria Blettner, University of Mainz, Germany
  - Elisabeth Cardis, Center for Research in Environmental Epidemiology, Spain
  - Clemens Dasenbrock, Fraunhofer Institute for Toxicology and Experimental Medicine, Germany
  - Etienne Degrave, Belgian Ministry of Defence, Belgium
  - René de Seze, INERIS (Institut National de Environnement industriel et des RISques), France
  - Jean-François Doré, INSERM (Institut national de la santé et de la recherche médicale), France
  - Lennart Hardell, Örebro University Hospital, Sweden
  - Peter D. Inskip, National Cancer Institute, USA
  - Jukka Juutilainen, University of Eastern Finland, Finland
  - **Nam Kim, Chungbuk National University, Republic of Korea**
  - Dariusz Leszczynski, STUK – Radiation and Nuclear Safety Authority, Finland
  - Simon Mann, Health Protection Agency, United Kingdom
  - David L. McCormick, IIT Research Institute, USA
  - James McNamee, Health Canada, Canada
  - Ronald Melnick, Ron Melnick Consulting, USA
  - Meike Mevisse, University of Bern, Switzerland
  - Junji Miyakoshi, Kyoto University, Japan
  - Christopher J. Portier, Centers for Disease Control and Agency for Toxic Substances and Disease Registry, USA
  - David B. Richardson, University of North Carolina at Chapel Hill, USA
  - Martin Röösli, Swiss Tropical and Public Health Institute, Switzerland
  - Jonathan M. Samet, University of Southern California, USA
  - Tomoyuki Shirai, Nagoya City University, Japan
  - Jack Siemiatycki, University of Montreal, Canada
  - Malcolm Sim, Monash University, Australia
  - Stanislaw Szmigielski, Military Institute of Hygiene and Epidemiology, Poland
  - Luc Verschaeve, Scientific Institute of Public Health, Belgium
  - Vijayalaxmi, University of Texas Health Science Center, USA
  - Niels Kuster, IT'IS Foundation for Research on Information Technologies in Society, Switzerland(Specialist)
  - Anders Ahlbom, Karolinska Institute, Sweden (withdrew his participation)

- IARC Monographs

Classification	Volumes	Title (Year)	Note
Ionizing radiation	Vol. 75	Ionizing Radiation, Part 1: X- and Gamma (g)-Radiation, and Neutrons (2000)	x-ray, gamma-ray, and neutrons
	Vol. 78	Ionizing Radiation, Part 2: Some Internally Deposited Radionuclides (2001)	radionuclides
Non-ionizing radiation	Vol. 55	Solar and Ultraviolet Radiation (1992)	Solar radiation
	Vol. 80	Non-Ionizing Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields (2002)	ELF-EMF
	Vol. 102	in progress	RF-EMC

WHO-IARC WG 회의 결과-3

IARC CLASSIFIES RADIOFREQUENCY ELECTROMAGNETIC FIELDS AS POSSIBLY CARCINOGENIC TO HUMANS

Results

The evidence was reviewed critically, and overall evaluated as being *limited*[1] among users of wireless telephones for glioma and acoustic neuroma, and *inadequate*[2] to draw conclusions for other types of cancers. The evidence from the occupational and environmental exposures mentioned above was similarly judged inadequate. The Working Group did not quantitate the risk; however, one study of past cell phone use (up to the year 2004), showed a 40% increased risk for gliomas in the highest category of heavy users (reported average: 30 minutes per day over a 10-year period).

Conclusions

Dr Jonathan Samet (University of Southern California, USA), overall Chairman of the Working Group, indicated that "the evidence, while still accumulating, is strong enough to support a conclusion and the **2B classification**. The conclusion means that there could be some risk, and therefore we need to keep a close watch for a link between cell phones and cancer risk."

"Given the potential consequences for public health of this classification and findings," said IARC Director Christopher Wild, "it is important that additional research be conducted into the long-term, heavy use of mobile phones. Pending the availability of such information, it is important to take pragmatic measures to reduce exposure such as hands-free devices or texting. "

WHO-IARC WG 회의 결과-4

The Working Group considered hundreds of scientific articles; the complete list will be published in the Monograph. It is noteworthy to mention that several recent in-press scientific articles[4] resulting from the **Interphone study** were made available to the working group shortly before it was due to convene, reflecting their acceptance for publication at that time, and were included in the evaluation.

A concise report summarizing the main conclusions of the IARC Working Group and the evaluations of the carcinogenic hazard from radiofrequency electromagnetic fields (including the use of mobile telephones) will be published in **The Lancet Oncology in its July 1 issue, and in a few days online.**

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[2] '***Limited evidence of carcinogenicity***': A positive association has been observed between exposure to the agent and cancer for which a causal interpretation is considered by the Working Group to be credible, but chance, bias or confounding could not be ruled out with reasonable confidence.

[3] '***Inadequate evidence of carcinogenicity***': The available studies are of insufficient quality, consistency or statistical power to permit a conclusion regarding the presence or absence of a causal association between exposure and cancer, or no data on cancer in humans are available.

[4] a. 'Acoustic neuroma risk in relation to mobile telephone use: results of the INTERPHONE international case-control study' (the Interphone Study Group, in Cancer Epidemiology, *in press*)
b. 'Estimation of RF energy absorbed in the brain from mobile phones in the Interphone study' (Cardis et al., Occupational and Environmental Medicine, *in press*)
c. 'Risk of brain tumours in relation to estimated RF dose from mobile phones – results from five Interphone countries' (Cardis et al., Occupational and Environmental Medicine, *in press*)
d. 'Location of Gliomas in Relation to Mobile Telephone Use: A Case-Case and Case-Specular Analysis' (American Journal of Epidemiology, May 24, 2011. [Epub ahead of print].

WHO-IARC Classification

Group 1 Carcinogenic to Humans	Group 2A Probably Carcinogenic to Humans	Group 2B Possibly Carcinogenic to Humans	Group 3 Not Classifiable	Group 4 Probably not Carcinogenic to Humans
Evidence that an agent is "proven" to be associated with human cancer	Limited evidence of an association with cancer in humans, but sufficient evidence of cancer in experimental animals	Limited evidence of an association with cancer in humans, but insufficient evidence of cancer in experimental animals	Evidence indicates that it is not possible to classify an agent based on the available information	Evidence to prove agent is "not associated" with human cancer
107 Agents including: • Alcoholic Beverages • Asbestos (all forms) • Arsenic • Benzene • Formaldehyde • Ionizing Radiation (all types) Tobacco smoking, smoke and smokeless • Painter (occupational exposure) • Sunlight (solar radiation)	**59 Agents including:** • Hairdresser or barber (occupational exposure) • Petroleum refining (occupational exposure) • Shift work that involves circadian disruption (disruption to normal sleep patterns)	**266 Agents including:** • Coffee (urinary bladder) • Diesel fuel, marine • Dry cleaning • (occupational exposure) • Firefighter (occupational exposure) • Styrene • Textile manufacturing industry (work in) • Magnetic Fields (ELF) • Pickled Vegetables	**508 Agents including:** • Acrylic acid • Chlorinated drinking water • Hair coloring products (personal use of) • Fluorescent lighting • Electric Fields (ELF)	**1 Agent:** • Caprolactam ***Note:*** *Caprolactam is toxic although not carcinogenic.*

WHO-International EMF Project

- 1996년 - 2007년 동안의 전자기장 문제에 대한 국제적인 조사 및 연구 프로젝트
- 정적 및 시변 전기장, 자기장의 노출에 의한 건강영향의 가능성에 대한 과학적인 해명이 필요
- 주파수 범위 : 정상계(0 Hz), 극저주파수(ELF, 0 - 300Hz), 중간주파수(IF, 300 Hz - 10 MHz), 무선주파(RF, 10 MHz – 300 GHz)
- 가장 우선적으로 RF 대역에 대한 연구 수행
  - 900~2000 MHz의 주파수 대역에 대해 연구 집중
  - 세포실험(in vitro) 및 생체실험(in vivo) 연구 중심
- 극저주파(ELF) 대역에 대한 연구 수행
  - 일부 역학조사가 송전선 근처에 거주하는 소아의 백혈병 발병률 증가 제시
- 참여 기관 : 8 international agencies, 7 WHO collaborating centers, over 40 national authorities (UNEP, IARC, ILO, ICNIRP, IEC, EC, NATO, NRPB, NIEHS, NIOSH, BfS, NIES, 44개국)

- Project schedule
  - 1996년 : 연구착수
  - 2001년 : Static 및 ELF field의 발암성 평가
  - 2002년 : Static 및 ELF field의 암이외 질병의 건강 위험성 평가
  - 2003년 : RF field의 발암성 평가
  - 2004년 : RF field의 암이외 질병의 건강 위험성 평가
  - 2005년 : ICNIRP(국제비전리방사선보호위원회) Guideline의 수정사항 권고
- Static (0 Hz), ELF(>0-100 kHz) and RF (100 kHz- 300 GHz)

EMF Policies I

- Adoption of National Guidelines
  - In December 1999, the article 47-2 of the "Radio Wave Act" was revised and then proclaimed in January 2000.
  - In December 2000, MIC(now, KCC) announced officially four separate ordinances:
    - Exposure limits for EMF and SAR
    - Measurement method for EMF
    - Measurement method for SAR
    - Installations and devices to which the exposure limits apply
  - They were enforced from 1 January 2002.
  - Precautionary policies are not adopted
  - were in effective from 1 January 2002.
  - The ordinances are not mandatory regulations, but recommendatory

EMF Policies II

- New Mobile-Phone Policies
  - SAR values for each mobile phone available on the market were measured and then the results were published by the end of 2000
  - A mandatory rule to restrict the use of mobile phones in moving vehicles has been adopted
  - Hands-free devices should be applied while driving from 1 July 2001
- Generation of a New National EMF Research Project
  - In 2000, a five-year EMF research project funded mainly by the government has been started
  - The total amount of the budget was reached about $8.5m for the duration of the project
  - Main research topics are as follows: dosimetry, in vivo and in vitro studies for middle frequency (MF) and radio frequency (RF) exposures, epidemiological studies.
  - Several other research projects such as health effects for the extremely low frequency (ELF) exposures have been investigated

EMF Standards I

- Exposure Limits for EMF Intensities
  - Regulate maximum permissible level of electric field, magnetic field, or power density, generated by stationary installations, appliances, etc.
  - Frequency range: 0 – 300 GHz
  - Two-tier standard: General public/Workers
  - Exceptions:
    - Mobile radio stations
    - Installations operated in an emergency or a natural disaster
    - Facilities installed in the area such as mountains where the general public do not enter frequently
    - Low-power devices

EMF Standards II

- Exposure Limits for EMF Intensities (continued)
  - Closely follows the ICNIRP guideline
  - Limits for induced current, contact current, and pulsed EMF are not included.
- Exposure Limit for SAR
  - Regulates maximum permissible level of spatial peak SAR in local exposure environments.
  - Frequency range: 100 kHz – 10 GHz
  - One-tier standard: General public only
  - Applies only to mobile telephones
  - Based on the IEEE/ANSI guideline

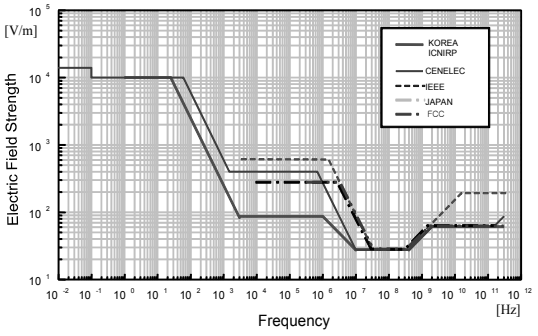
일반인에 대한 국내 전자파강도 기준

주파수 범위	전기장강도(V/m)	자기장강도(A/m)	자속밀도(μT)	전력밀도(W/m^2)
1㎐ 이하	-	3.2×10^4	4×10^4	
1㎐ 이상 ~ 8㎐ 미만	10,000	$3.2\times10^4/f^2$	$4\times10^4/f^2$	
8㎐ 이상 ~ 25㎐ 미만	10,000	4,000/f	5,000/f	
0.025㎑ 이상 ~ 0.8㎑ 미만	250/f	4/f	5/f	
0.8㎑ 이상 ~ 3㎑ 미만	250/f	5	6.25	
3㎑ 이상 ~ 150㎑ 미만	87	5	6.25	
0.15㎒ 이상 ~ 1㎒ 미만	87	0.73/f	0.92/f	
1㎒ 이상 ~ 10㎒ 미만	$87/f^{1/2}$	0.73/f	0.92/f	
10㎒ 이상 ~ 400㎒ 미만	28	0.073	0.092	2
400㎒ 이상 ~ 2,000㎒ 미만	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	f/200
2㎓ 이상 ~ 300㎓ 미만	61	0.16	0.20	10

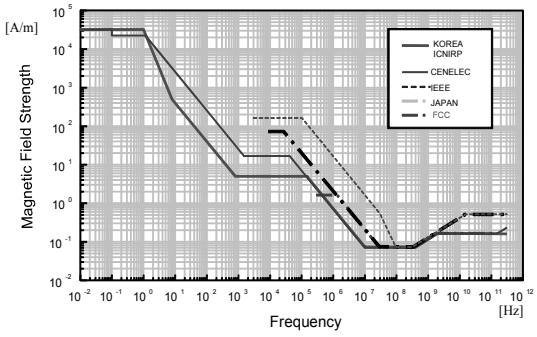
직업인에 대한 국내 전자파강도 기준

주파수 범위	전기장강도(V/m)	자기장강도(A/m)	자속밀도(μT)	전력밀도(W/m^2)
1㎐ 이하	-	1.63×10^5	2×10^5	
1㎐ 이상 ~ 8㎐ 미만	20,000	$1.63\times10^5/f^2$	$2\times10^5/f^2$	
8㎐ 이상 ~ 25㎐ 미만	20,000	$2\times10^4/f$	$2.5\times10^4/f$	
0.025㎑ 이상 ~ 0.82㎑ 미만	500/f	20/f	25/f	
0.82㎑ 이상 ~ 65㎒ 미만	610	24.4	30.7	
0.065㎒ 이상 ~ 1㎒ 미만	610	1.6/f	2.0/f	
1㎒ 이상 ~ 10㎒ 미만	610/f	1.6/f	2.0/f	
10㎒ 이상 ~ 400㎒ 미만	61	0.16	0.2	10
400㎒ 이상 ~ 2,000㎒ 미만	$3f^{1/2}$	$0.008f^{1/2}$	$0.01f^{1/2}$	f/40
2㎓ 이상 ~ 300㎓ 미만	137	0.36	0.45	50

Guidelines of E-field strength



Guidelines of H-field strength



Recent researches-1

- Prevalence of symptoms and relation between hearing and symptoms (Dr. Jae-wook Choi, Korea University)
- Biological Effects of 20 kHz MF Exposure (Dr. Yun-sil Lee, Ewha Womans University)
- Biological Effects of combined RF-EMF Exposure: *In Vitro* studies (Dr. Jae-seon Lee, Korea Institute of Radiological & Medical Sciences)
- Biological Effects of 915MHz RFID Exposure – in vivo study (Prof. Young-Hwan Ahn, Ajou University)

Recent researches-2

- Biological effect in Placenta of radiated by 1.765 GHz microwave (Prof. Jongyun Hwang, Kwangwon Univ.)
- Maternal mobile phone use during pregnancy and children's health (Prof. Mi-na Ha, Dankook Univ.)
- Computational Dosimetry for Whole Body exposure (Dr. Ae-kyoung Lee, Electronics and Telecommunications Research Institute)
- ELF EMF Policy and Research in Korea (Dr. Sung-Ho Myoung, Korea Electrotechnology Research Institute)
- EMF Research in KOREA (Prof. Seung-Cheol Hong at Inje University and Prof. Youn-Shin Kim at Hanyang University)