

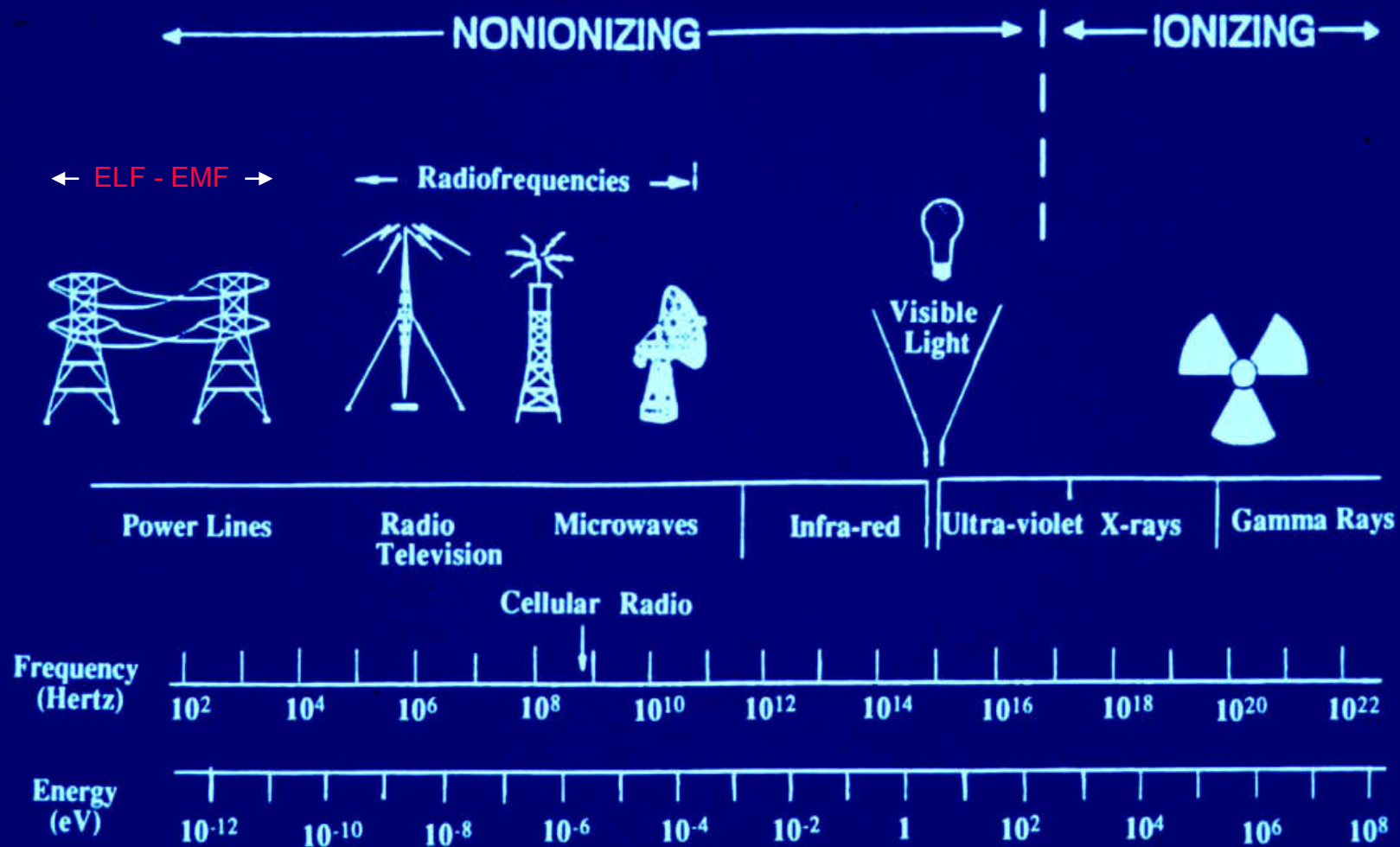
OVERVIEW

ELF Electromagnetic Radiation
(30 Hz - 300 Hz)

Cytogenetics Studies

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ELECTROMAGNETIC SPECTRUM



One Herz (Hz) equals one cycle per second

ELF ELECTROMAGNETIC RADIATION

We can not imagine life without electricity.
Consequence of Electricity Production,
Transmission Through Power Lines & its Use
Chronic Exposure to
Extremely Low Frequency Electromagnetic Fields

Recommended Exposure Limits:

(based on electric currents induced by power frequency fields to $< 10 \text{ mA/m}^2$)

	<u>General Public</u>		<u>Occupational</u>	
	Cont.	Short-term	Cont.	Short-term
ICNIRP - 50, 60 Hz	100 μT	1000 μT	500 μT	5000 μT
NRPB - 60 Hz	1330 μT		1330 μT	
NRPB - 50 Hz	1660 μT		1660 μT	

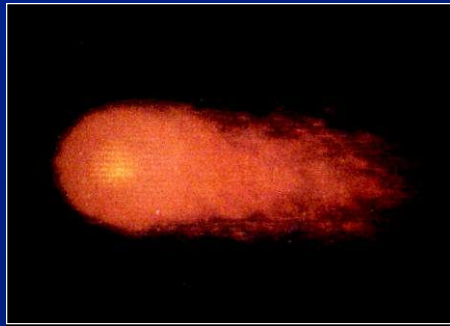
Cytogenetic Investigations

Most genotoxic agents are **CARCINOGENS**

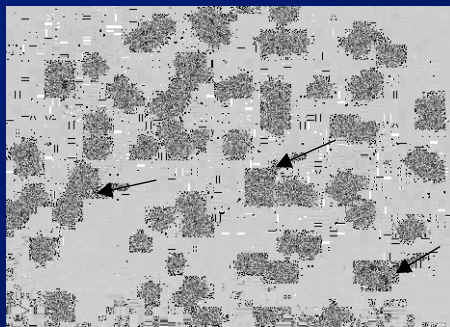
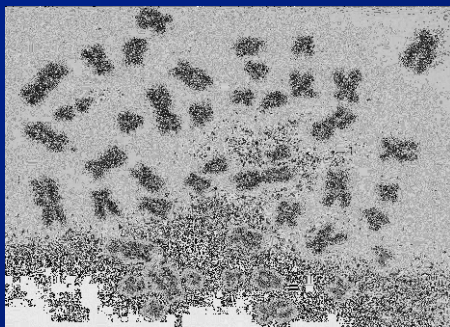
Non-genotoxic agents (which do NOT cause damage by themselves) can also contribute to carcinogenesis by enhancing the damage induced by known genotoxic agents, i.e.,
EPIGENETIC EFFECT

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DNA Strand Breaks
SSB / DSB



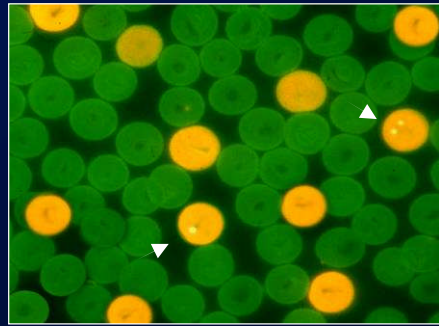
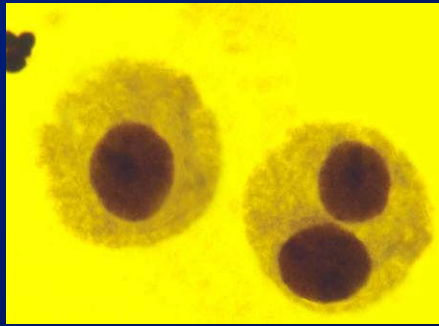
Chromosomal Aberrations
CA



Sister Chromatid Exchanges
SCE



Micronuclei
MN



ELF - EMF

GENOTOXIC EFFECTS

and / or

EPIGENETIC EFFECTS

Literature Overview

1990 - 2003

63 Publications

Vijayalaxmi & Obe, Bioelectromagnetics., 26, 412 – 430, 2005

DNA Strand Breaks / Repair

	First Author	Year	ELF-Hz	Modulation	Flux Density (mT)	Exposure (m/h/d/w/y)	Experiment	Cells	End-Point
Whole - Body Exposure : Animals									
1	Lai	1997a	60 Hz	MF	0.1, 0.25, 0.5	2 h	In vivo	Rat - WB	SSB / DSB
2	Lai	1997b	60 Hz	MF	0.5	2 h	In vivo	Rat - WB	SSB / DSB
3	Singh	1998	60 Hz	MF	0.5	2 h	In vivo	Rat - WB	Crosslinks
4	Svedenstal	1999a	50 Hz	EMF	0.008	11, 20, 32 d	In vivo	Mice - BCx	DSB
5	Svedenstal	1999b	50 Hz	Sin MF	0.5	2h, 5d, 14 d	In vivo	Mice - BCx	DSB
6	McNamee	2002	60 Hz	MF	1.0	2 h	In vivo	Mice - BCe	SSB
In vitro – Human Cells									
1	Fiorani	1992	50 Hz	EF, MF, EMF	0.0002, 0.002, 0.02, 0.1, 0.2	1, 4, 6, 12, 24 h	In vitro	HTC	SSB
2	Ahuja	1997	50 Hz	MF	2, 3, 5, 7, 10	1 h	In vitro	HBL	SSB
3	Ahuja	1999	50 Hz	MF	2, 3, 5, 7, 10	1 h	In vitro	HBL	SSB
4	Pacini	1999	-	Static MF	200	5 – 120 m	In vitro	HNC	Mol Alt
5	Kindzelskii	2000	50 Hz	P-EF, DC	?	30, 45, 60 m	In vitro	HBN	SSB
6	Maes	2000	50 Hz	MF	0.06 – 0.25	48 – 72 h	In vitro	HBL	SSB
7	Ivancsits	2002	50 Hz	Sin EMF	0.02 – 2.0	24 h	In vitro	HSF	SSB / DSB
8	Ivancsits	2003a	50 Hz	Sin EMF	0.02 – 1.0	1 - 24 h	In vitro	HSF	SSB / DSB
9	Ivancsits	2003b	50 Hz	Sin EMF	1.0	1 - 24 h	In vitro	HSF	SSB / DSB

Vijayalaxmi & Obe, Bioelectromagnetics., 26, 412 – 430, 2005

CA, MN, SCE - 1

	First Author	Year	ELF-Hz	Modulation	Flux Density (mT)	Exposure (m/h/d/w/y)	Experiment	Cells	End-Point
Whole - Body Exposure : Animals									
1	Zwingelberg	1993	50 Hz	MF	30.0	24 h/d - 7d, 28d	In vivo	Rat- BLym	SCE
2	Singh	1997	50 Hz	Sin MF	2.0, 10.0	72 h	In vivo	Mice - BEry	MN
3	Svendenstal	1998	50 Hz	Sin Mf	0.014, 0.015	2 h/d - 1, 2, 4, 90 d	In vivo	Mice - BEry	MN
Whole - Body Exposure : Humans									
1	Cicccone	1993	Occup	EMF	?	?	In vivo	HBL	CA
2	Skyberg	1993	Occup	EMF	0.5 - 10.0	9 - 12 y	In vivo	HBL	CA, SCE
3	Khalil	1993	Occup	EMF	?	3- 19 y	In vivo	HBL	CA, SCE
4	Valjus	1993	Occup	EMF	?	5- 10 y	In vivo	HBL	CA, MN, SCE
5	Skyberg	2001	Occup	EMF	1.9	?	In vivo	HBL	CA

Vijayalaxmi & Obe, Bioelectromagnetics., 26, 412 - 430, 2005

CA, MN, SCE - 2

	First Author	Year	ELF-Hz	Modulation	Flux Density (mT)	Exposure (m/h/d/w/y)	Experiment	Cells	End-Point
In Vitro Exposure : Animal and Human Cells									
1	Garcia-Sagredo	1990	4.4 kHz	P-EMF	1, 2, 4	48 h	In vitro	HBL	SCE
2	Garcia-Sagredo	1991	4.4 kHz	P-EMF	1, 2, 4	24 h	In vitro	HBL	CA
3	Khalil	1991	50 Hz	P-EMF	1.05	24, 48, 72 h	In vitro	Mice - BEry	CA, SCE
4	Livingston	1991	60 Hz	P-EMF	?	72 h	In vitro	HBL	SCE
	Livingston	1991	60 Hz	P-EMF	?	24 h	In vitro	CHO	MN, SCE
5	Nordenson	1994	50 Hz	MF	0.03, 0.3	72 h	In vitro	HAB	CA (CA-intmt)
6	Scarfi	1994	50 Hz	P-EMF	2.5	48, 72 h	In vitro	HBL	CA, MN
7	Antonopoulos	1995	50 Hz	EMF	5.0	48 – 72 h	In vitro	HBL	SCE
8	D'Ambrosio	1995	50 Hz	AM-MW	?	10 m	In vitro	HBL	MN
9	Galt	1995	50 Hz	Sin MF	0.03	72 h	In vitro	HAC	CA
10	Paile	1995	50 Hz	Sin MF	0.03, 0.3, 1.0	48, 67 h	In vitro	HBL	CA, MN, SCE
11	Jacobson-Kram	1997	?	P-EF, P-EMF	3000 - 9000	24 h	In vitro	CHO	CA
12	Scarfi	1997a	100 Hz	P-MF	1.3	72 h	In vivo	HBL	MN
13	Scarfi	1997b	50 Hz	P-MF	2.5	72 h	In vitro	HBL	MN (TurSynd)
14	Scarfi	1997c	50 Hz	Sin-MF	1.0	72 h	In vitro	HBL	MN
15	Simko	1998a	50 Hz	EMF	0.1, 0.3, 0.5, 0.8, 1.0	24, 48, 72 h	In vitro	HTC	MN
	Simko	1998a	50 Hz	EMF	0.1, 0.3, 0.5, 0.8, 1.0	24, 48, 72 h	In vitro	HAC	MN
16	Scarfi	1999	50 Hz	Sin-MF	0.05, 0.25, 0.5, 0.75	72 h	In vitro	HBL	MN
17	Zeni	2002	50 Hz	P-MF	2.5	72 h	In vivo	HBL	MN

DNA Strand Breaks / Repair +/- Known Genotoxic Agents

	First Author	Year	ELF-Hz	Modulation	Flux Density (mT)	Exposure (m/h/d/w/y)	Experiment	Cells	End-Point
In Vitro Exposure : Animal and Human Cells									
1	Frazier	1992	60 Hz	EF, MF, EMF	0.05, 0.6, 1.0	20, 60, 180 m	In vitro	HBL	SSB repair
2	Fairbairn	1994	50 Hz	EMF	5.0	1, 24 h	In vitro	HTC, HBC	SSB
3	Cantoni	1995	50 Hz	EF, MF, EMF	0.0002 – 0.2	5 – 60 m	In vitro	CHC	SSB repair
4	Cantoni	1996	50 Hz	Sin-EF, MF, EMF	0.0002, 0.002, 0.2	20 - 300 m	In vitro	CHC	SSB repair
5	Miyakoshi	2000	50, 60 Hz	P-MF	5.0, 50, 400	30 m	In vitro	HTC	SSB
6	Zmyslony	2000	50 Hz	Static, P-MF	7.0	3 h	In vitro	RBL	SSB
Vijayalaxmi & Obe, Bioelectromagnetics., 26, 412 – 430, 2005									

CA, MN, SCE +/- Known Genotoxic Agents

	First Author	Year	ELF-Hz	Modulation	Flux Density (mT)	Exposure (m/h/d/w/y)	Experiment	Cells	End-Point
In Vitro Exposure : Animal Cells									
1	Okonogi	1996	?	Static MF	4700	6 h	In vitro	HBLCHLC	MN
2	Lagroye	1997	50 Hz	EMF	0.1	24 h	In vitro	RTEC	MN
3	Yaguchi	1999	50 Hz	MF	5.0, 50, 400	42 h	In vitro	MESC	SCE
4	Yaguchi	2000	50, 60 Hz	MF	5.0, 50, 400	40 h	In vitro	MESC	CA
5	Simko	2001	50 Hz	MF	1.0	24, 48, 72 h	In vitro	SHEC	MN
6	Nakahara	2002	-	Static MF	????	18 h	In vitro	CHC	MN
In Vitro Exposure : Human Cells									
1	Scarfi	1991	50	P-MF	2.5	72 h	In vitro	HBL	MN
2	Scarfi	1993	50	Sin EF	?	72 h	In vitro	HBL	MN
3	Hintenlang	1993	60 Hz	MF	0.5, 1.0, 1.5	48 h	In vitro	HBL	CA
4	Tofani	1995	32, 50 Hz	MF	0.075, 0.15	72 h	In vitro	HBL	MN
5	Simko	1998b	50 Hz	MF	1.0	24, 48, 72 h	In vitro	HAC	MN
6	Simko	1999	50 Hz	EMF	1.0	24, 48, 72 h	In vitro	HAC	MN
7	Maes	2000	50 Hz	MF	0.06 - 205	48, 72 h	In vitro	HBL	CA, SCE
8	Heredia-Rojas	2001	60 Hz	Sin MF	1.0, 1.5, 2.0	72 h	In vitro	HBL	SCE
9	Hone	2003	50 Hz	EMF	0.223, 0.47, 0.7	12 h	In vitro	HBL	CA
10	Cho	2003	60 HZ	EMF	0.8	24 h	In vitro	HBL	MN, SCE
11	Verheyen	2003	50 Hz	MF	0.08 – 0.8	72 h	In vitro	HBL	MN

SUMMARY - 2003

Test System	Number of Studies Indicating Damage			Total
	Increase	No Increase	Inconclusive	
DNA Strand Breaks / Repair				
Whole-Body: Animals	5	1	0	6
In Vitro: Human Cells	6	3	0	9
In Vitro: EMF +/- Known Genotoxic Agents	0	4	2	6
CA, MN & SCEs				
Whole-Body: Animals / Humans	0	6	2	8
In Vitro: Animals / Human Cells	2	9	6	17
In Vitro: EMF +/- Known Genotoxic Agents				
Animal Cells	1	1	4	6
Human Cells	0	5	6	11
Total	14	29	20	63
	22%	46%	32%	

Variables in Investigations

Exposure Facility

Flux Density

Temperature

Duration of Exposure

Type of Exposure: Continuous / Intermittent

Cells: Stimulated / unstimulated / Quiescent / Growing

Cell Types: Human / Rodent / Primary & Cultured Cells

End-points: SSB / DSB / CA / MN / SCEs

Controls: Sham / Unexposed / Positive

Blind

Statistical Methods

Majority of the Investigations
ELF Electromagnetic Fields
No Significant Genotoxic Effect

< 1.0 mT Flux Density
(safety standard)

Scientific Weight of Evidence



NO INCREASE IN DAMAGE

Experimental protocols were described
in detail for independent verification

Larger sample size

Independent investigators

Independent laboratories

“Replication” & “Confirmation” studies

INCREASED DAMAGE

Interpretation of data was hypothetical

Observations were NOT confirmed by
SAME investigators in subsequent
experiments / studies

Independent investigators could NOT
confirm the original observations

Future Research

Co-ordinated

International

Multi-center

Exposure (single laboratory) → 50 or 60 Hz

Temperature Controls

Validated Dosimetry

Flux Density → 1 – 10 mT

End-points → SSB / DSB, CA, MN & SCE

Cell Types → HBL, HSF, Tumor Cells, Inherited Syndromes
etc, etc.



THANK YOU
Questions / Comments !

