بسم الله الرحمن الرحيم

Protection against non-ionizing radiation

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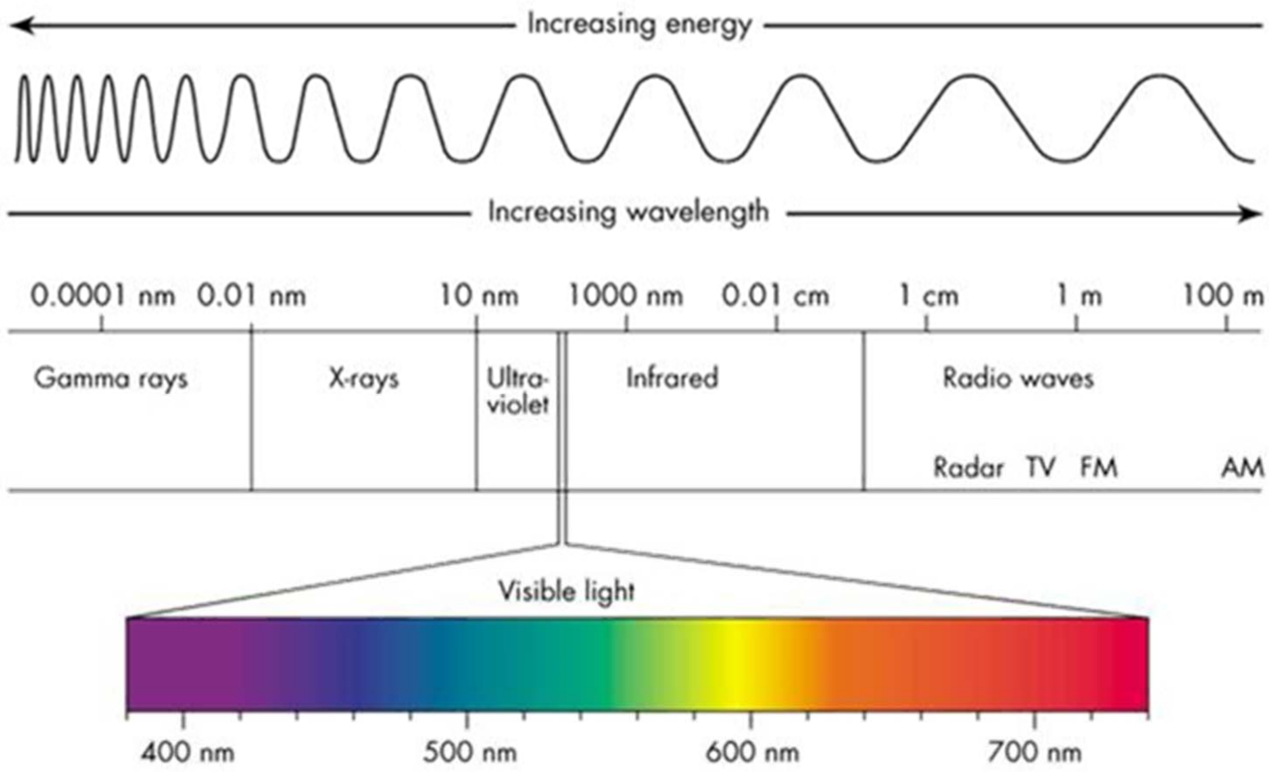
Electromagnetic spectrum



Coupling mechanisms between fields and the body

- Human and animal bodies significantly perturb the spatial distribution of a low frequency electric field.
- At low frequencies, the body is a good conductor, and the perturbed field lines external to the body are nearly perpendicular to the body surface.
- Oscillating charges are induced on the surface of the exposed body and these produce currents inside the body.
- The electric field induced inside the body is considerably smaller than the external electric field, e.g., Five to six orders of magnitude at 50 – 60 Hz;
- For a given external electric field, the strongest fields are induced when the human body is in perfect contact with the ground through the feet (electrically grounded), and the weakest induced fields are for the body insulated from the ground (in "free space");
- The total current flowing in a body in perfect contact with ground is determined by the body size and shape (including posture) rather than tissue conductivity;
- The distribution of induced currents across the various organs and tissues is determined by the conductivity of those tissues;

Key features of dosimetry for exposure of humans to low frequency magnetic fields

- For magnetic fields, the permeability of tissue is the same as that of air, so the field in tissue is the same as the external field. Human and animal bodies do not significantly perturb the field.
- The main interaction of magnetic fields is the Faraday induction of electric fields and associated currents in the tissues.
- The induced electric field and current depend on the orientation of the external magnetic field to the body.
- Generally induced fields in the body are greatest when the field is aligned from the front to the back of the body, but for some organs the highest values are for different field alignments;
- The weakest electric fields are induced by a magnetic field oriented along the principal body axis;
- And the distribution of the induced electric field is affected by the conductivity of the various organs and tissues.

Ultraviolet UV

Portable UV lamp

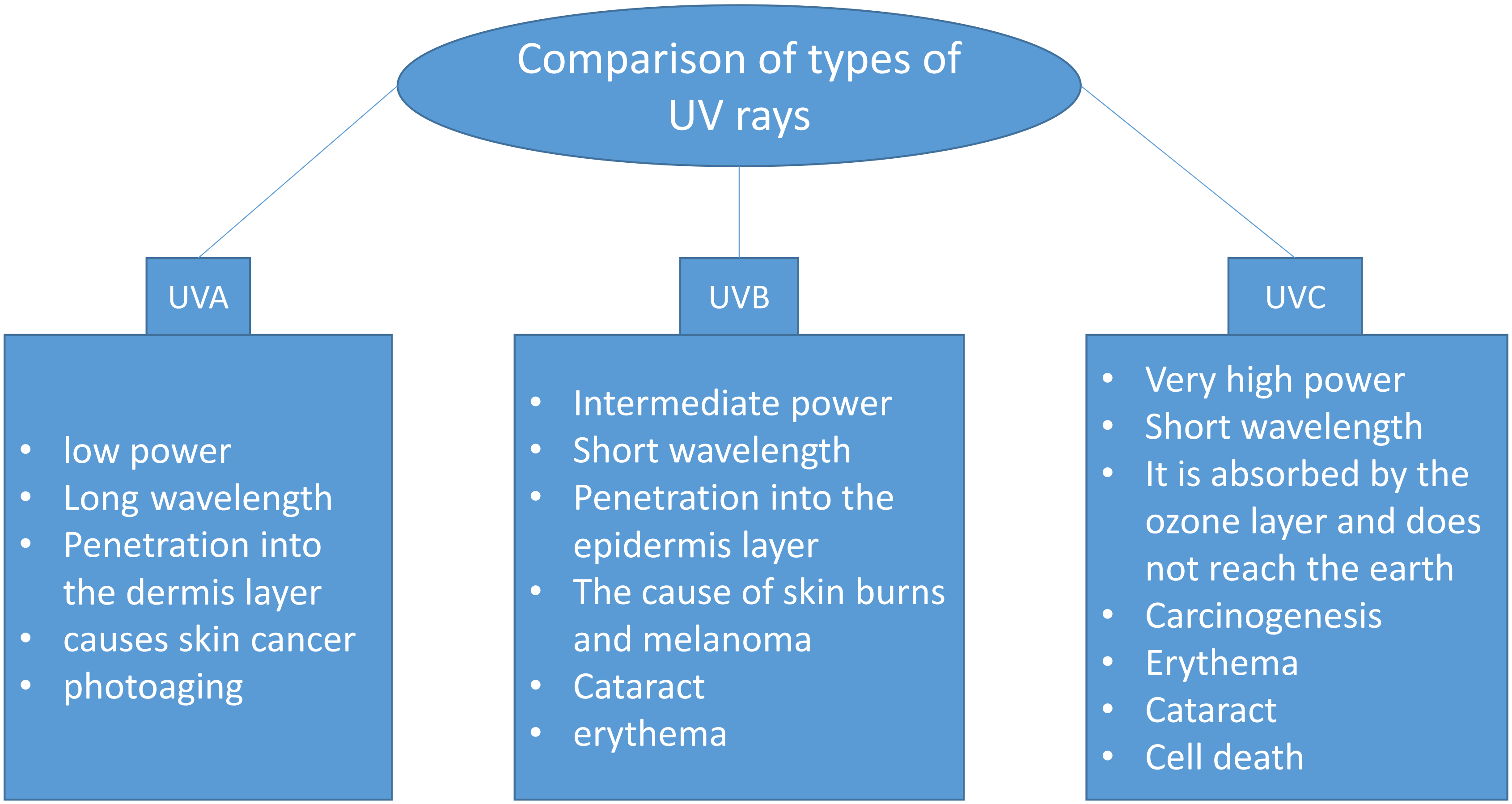
Wavelength in the range of 100 to 400 nm

Classification of ultraviolet radiation

3.10 – 3.94 eV	315 – 400 nm	UVA
3.94 – 4.43 eV	218 – 315 nm	UVB
4.43 – 12.4 eV	100 – 218 nm	UVC

Some UV Sources

Sunlight, black light lamps, carbon arcs, dental polymerization devices, mercury lamps, disinfectant lamps, metal halide lamps, plasma welding, printing ink polymerization, tanning devices, welding arcs and...


Comparison of types of UV rays
UVA
low power
Long wavelength
Penetration into the dermis layer
causes skin cancer
photoaging
UVB
Intermediate power
Short wavelength
Penetration into the epidermis layer
The cause of skin burns and melanoma
Cataract
erythema
UVC
Very high power
Short wavelength
It is absorbed by the ozone layer and does not reach the earth
Carcinogenesis
Erythema
Cataract
Cell death

Bioeffects of Ultraviolet Radiation

The usefulness and necessity of a low amount of ultraviolet radiation

- Destroy some bacteria
- Converting some chemicals on the surface of the skin to vitamin D

High amount of ultraviolet radiation

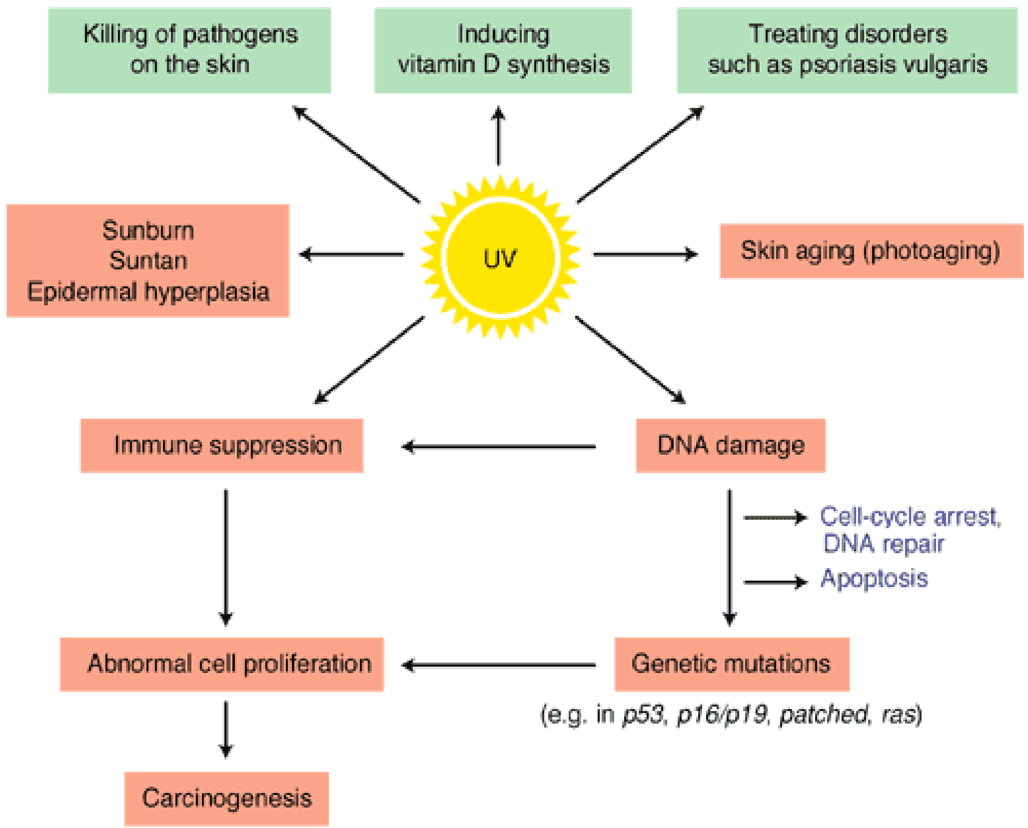
Skin

- redness, dryness, burning of the skin
- Premature aging, dryness and wrinkles
- Blisters, burns and wounds
- skin cancer

Eye

- Dry eyes
- Cataracts at a young age
- Metabolic disease in the eye at a young age

Effective Irradiance (w/m2)	**Maximum permissible Exposure**
0.001	8 hours
0.008	1 hour
0.05	10 minutes
0.5	1 minute
3	10 seconds
30	1 second
300	0.1 second

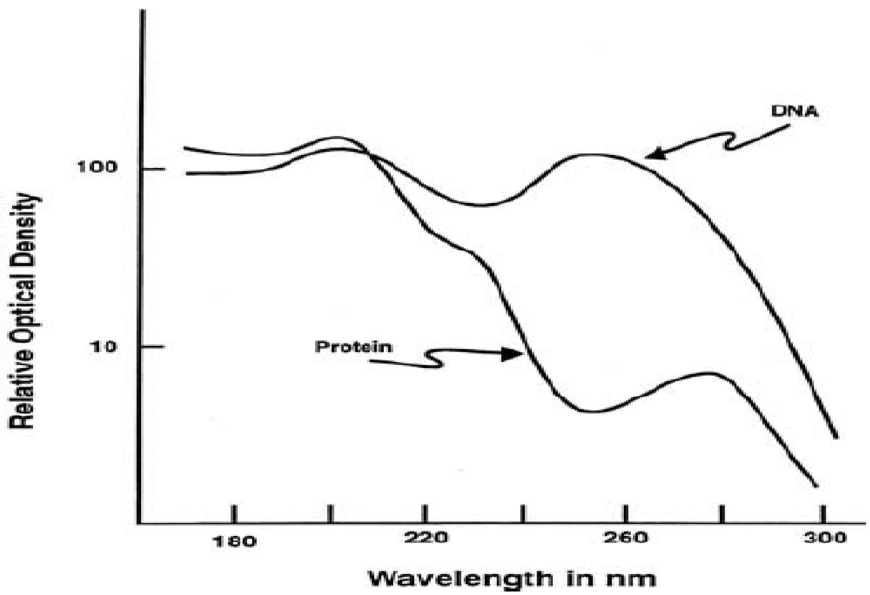


Summary of the effects of UV irradiation on skin

Harms of UV rays in pregnancy

- Melasma
- Hyperthermia
- Dehydration
- Fetus defect
- Fever
- Folic acid deficiency
- Increased risk of brain lesions in the fetus

The ultraviolet absorption of DNA and a typical protein



Ultraviolet-Visible

UV-Vis spectroscopy

Absorption wavelength 100 to 700 nm

spectroscopy

The measurement and interpretation of electromagnetic radiation emitted or absorbed when ions, atoms, or molecules in a sample move from one energy state to another.

Ultraviolet-visible spectroscopy

It is a type of absorption spectroscopy that uses radiation in the UV range and the visible range.

Types of ultraviolet-visible detectors

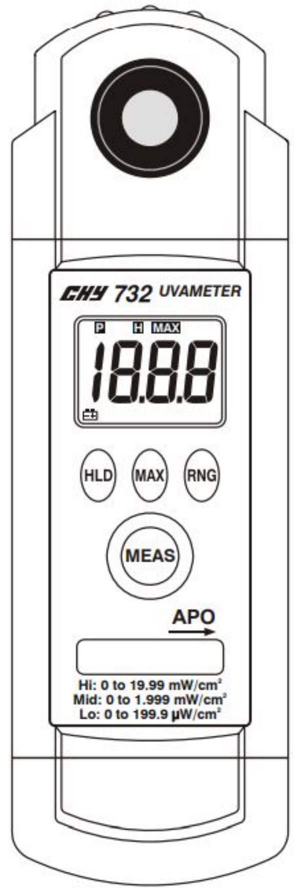
The function of detectors: converting light into electrical signals

Spectrophotometer answer

Detectors used in UV-Visible spectroscopy

1. **Photomultiplier tube**
2. **Phototube**
3. **Diode array detector**

UV Meter



FEATURES:

CE-Mark Approval.
Auto power off function.
Portability and simplicity one hand operation.
Three Ranges: 199.9 μW/cm^2
1.999 mW/cm^2
19.99 mW/cm^2
With MAX/DATA HOLD function.
With pocket hook.
Hand-Held lightweight design.
Ultra-violet irradiance measurement for UVA.
UV detector spectrum from 320nm to 400nm.

SPECIFICATIONS

Display: 3½ digit liquid crystal display (LCD) with a maximum reading of 1999.
Polarity: Automatic, positive implied.
Low battery indication: The "[battery symbol]" is displayed when the battery voltage drops below the operating level.
Operating environment: 0°C to 50°C at<75% R.H.
Storage temperature: -20°C to 60°C, 0 to 80% R.H.with battery removed from meter.
Accuracy: Stated accuracy at 23°C±5°C, <75% R.H.
Battery: 1.5V x 3 pcs AAA size.
Dimensions: 155mm(H) x 48mm(W) x 24mm(D).
Weight: Approx. 2.9 oz. (81.2g) including batteries.

UVA

Sensor: UV Photo diode
Range: 199.9 μW/cm^2
1.999 mW/cm^2
19.99 mW/cm^2
Accuracy: ±(4% FS ± 2 dgts), (FS: full scale)
UV Sensor Spectrum: Band pass 320 to 400nm

Quantities of ultraviolet radiation

Amount of Exposure (E)

In fact, it is equivalent to the power or energy of ultraviolet rays received at a certain level and is expressed in watts per square meter.

$$E=P/A$$

E: radiation power density in watts per square meter

P: output power of the radiation source in watts

C: cross-sectional area of the source in square meters

Dose (H)

The amount of ultraviolet ray energy received in a certain period of time. In fact, the received dose is in one period and is expressed in joules per square meter.

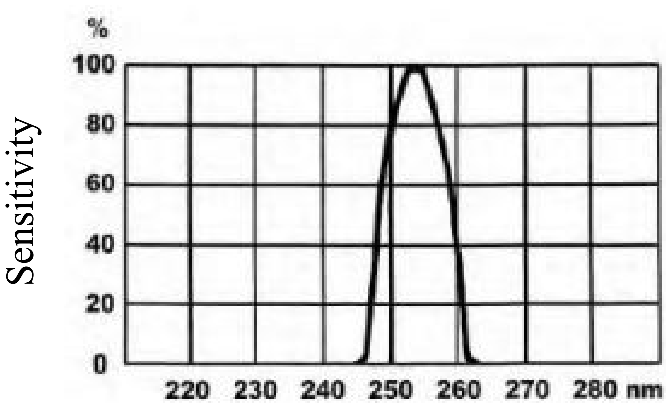
$$H=E * t$$

Limits of exposure to ultraviolet rays

- It is a condition under which workers may be exposed to radiation repeatedly without any harmful effects on their health. Spectral radiant flux density. The first step in evaluating UV radiation sources is to determine their effective radiation.

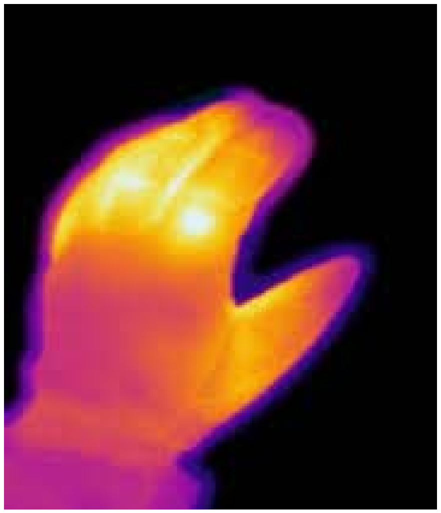
- $E_{eff} = \sum E(\lambda) * S(\lambda) * \Delta\lambda$
- E_{eff} is the effective radiant flux density related to a monochromatic source with a wavelength of nm
- $E(\lambda)$ spectral radiant flux density with wavelength λ in $W/cm^2.nm$
- $S(\lambda)$ (relative spectral efficiency) without units
- $\Delta \lambda$ is the bandwidth in nm.
- The amount of daily exposure to ultraviolet rays based on the effective irradiance is equal to $0.003\ j/cm^2$ based on this, the maximum allowed radiation time is obtained from the following relationship:
- $T_{max} = 0.003 / E_{eff}$

Example of ultraviolet spectro-radiometer device



UVC(μW/cm²)	UVB(μW/cm²)	UVA(μW/cm²)	طول زمان پرتوگیری در روز
۰/۱۰	۰/۱۲	۳۴/۷۲	۸ ساعت
۰/۲۰	۰/۲۳	۶۹/۴	۴ ساعت
۰/۴۰	۰/۴۷	۱۳۸/۹	۲ ساعت
۰/۸۰	۰/۹۴	۲۷۷/۸	۱ ساعت
۱/۷۰	۱/۸۸	۵۵۵/۵	۳۰ دقیقه
۳/۳۰	۳/۷۷	۱۱۱۱/۱	۱۵ دقیقه
۵	۵/۶۶	۱۶۶۶/۷	۱۰ دقیقه
۱۰	۱۱/۳۳	۳۳۳۳/۳	۵ دقیقه
۵۰	۵۶/۶۶	۱۶۶۶۶/۷	۱ دقیقه
۱۰۰	۱۱۳/۳۳	۳۳۳۳۳/۳	۳۰ ثانیه
۳۰۰	۳۴۰	۱۰۰۰۰۰	۱۰ ثانیه
۳۰۰۰	۳۴۰۰	۱۰۰۰۰۰۰	۱ ثانیه
۶۰۰۰	۶۸۰۰	۲۰۰۰۰۰۰	۰/۵ ثانیه
۳۰۰۰۰	۳۴۰۰۰	۱۰۰۰۰۰۰۰	۰/۱ ثانیه

Infrared (IR)



Wavelength in the range of 400 nm to 1 mm

- Molecular vibrations will absorb in this area.

- Every substance has its own infrared spectrum, and like a fingerprint, it is specific to the same molecule.

In the absorption process, frequencies of infrared rays that match the natural vibrational frequencies of the target molecule will be absorbed, and the energy absorbed will be used to increase the range of vibrational movement of the connection in the molecule.

0.7 – 1.4 um	IR – A
1.4 – 3 um	IR – B
3 – 1000 um	IR – C

Biological effects of infrared radiation

The usefulness and necessity of the appropriate amount of infrared radiation

- Medicine, industry, sports, etc
- Night vision, military applications, food industry, etc

High amount of infrared radiation

Skin :

Burns, redness, dryness

Eye :

Thermal damage to the cornea, iris and lens of the eye, increasing heat and cataracts

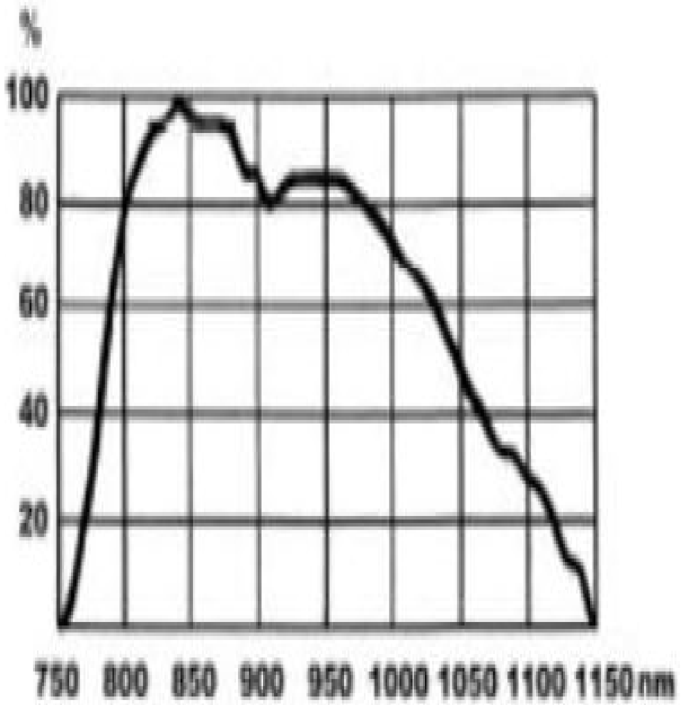
The strongest absorption by the retina is at the very shortest IR wavelengths

Protection against IR

- Eyes: Protection with proper filters and glasses
- Skins: Protection with aluminium cloth (because of high reflectance), plastic and water circulation
- (The thickness of the material is not important and only the reflectance is needed)

Infrared Detector

Hanger EC1



Occupational exposure limits in some infrared waves

ناحیه طیفی	طول موج (nm)	زمان پرتوگیری (t) برحسب ثانیه	حد مجاز مواجهه شغلی
IR-B & C	۱۴۰۱-۱۵۰۰	$۱۰^{-۳}$ تا $۱۰^{-۱۴}$	۰/۱ j/cm^2
	۱۴۰۱-۱۵۰۰	۱۰تا $۱۰^{-۳}$	۰/۵۶ $t^{۰/۲۵}$ j/cm^2
	۱۵۰۱-۱۸۰۰	۱۰تا $۱۰^{-۱۴}$	۱/۰ j/cm^2
	۱۸۰۱-۲۶۰۰	$۱۰^{-۳}$ تا $۱۰^{-۱۴}$	۰/۱ j/cm^2
	۱۸۰۱-۲۶۰۰	۱۰تا $۱۰^{-۳}$	۰/۵۶ $t^{۰/۲۵}$ j/cm^2
	۲۶۰۱-$۱۰^{۶}$	$۱۰^{-۷}$ تا $۱۰^{-۱۴}$	۱۰mj/cm^2
	۲۶۰۱-$۱۰^{۶}$	۱۰تا $۱۰^{-۷}$	۰/۵۶ $t^{۰/۲۵}$ j/cm^2
	۱۴۰۰-$۱۰^{۶}$	۱۰تا $۳×۱۰^{۴}$	۱۰۰mw/cm^2

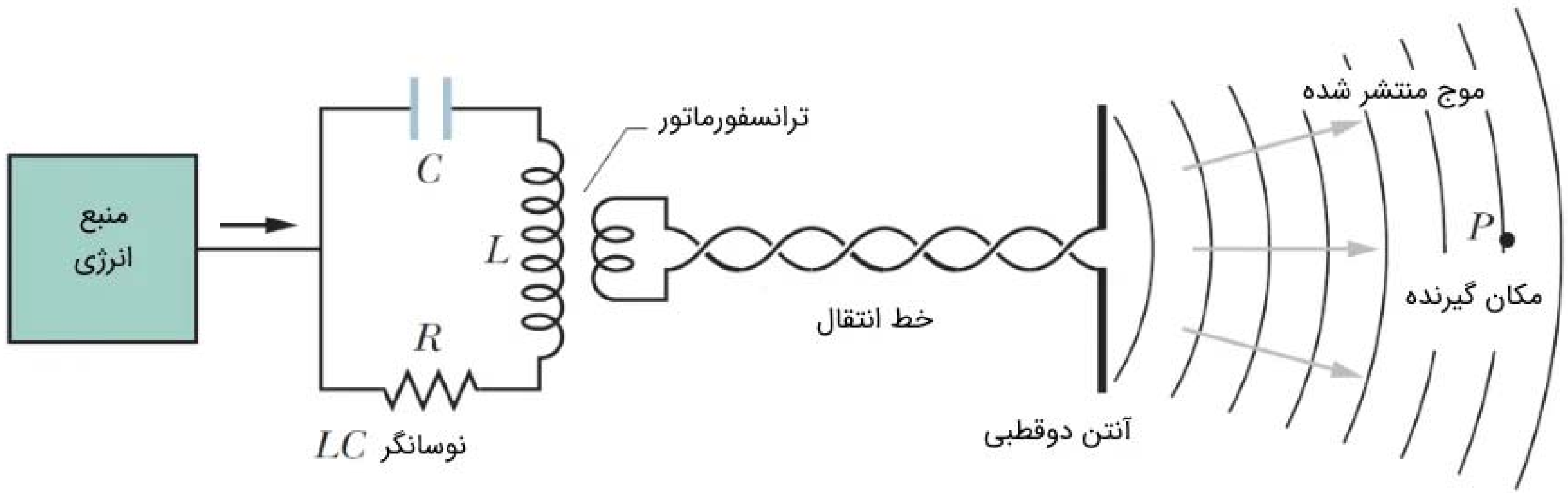
Radiofrequency (RF)

Wavelength in the range of 1 mm to several kilometers

- Radio waves are produced naturally by lightning and asteroids.
- Artificial radio waves are used in fixed and mobile telecommunication systems, radar and other navigation systems, satellite communications, computer networks and many others.

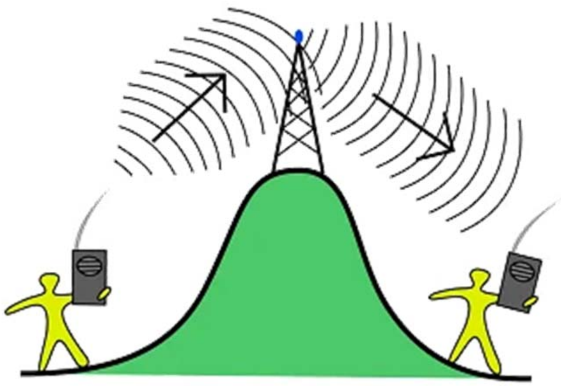
Radiofrequency (RF)

Radio waves are the result of the movement of accelerated electric charges, including time-varying electric currents.



A simple schematic of the operation of an antenna

Biologic effect of Radio-waves



- Radio waves do not have enough energy to separate electrons from atoms or molecules or break chemical bonds.

- Exposure to these waves does not damage the DNA structures.
- These fields create an electric field in the body and affect the movement of ions, heat, nerve and muscle stimulation and various effects.

High exposure to radio waves

Eye :

Looking at the source of high-power radio waves at a very close distance causes the lens of the eye to heat up, which itself leads to damage and the occurrence of cataracts.

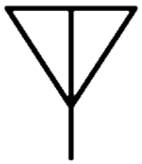
Cancer :

Acceptable evidence from the International Center for Cancer Research has been published that long-term use of mobile phones and waves with similar frequencies increases the risk of cancer.

- Others:
- The effect of electromagnetic radiation on sleep and memory disorders
- Increased permeability of the blood-brain barrier caused by magnetic and electromagnetic fields

Types of radio wave detectors

Antenna symbol in circuits and maps



Antennas

- In simple terms, antennas are converters that convert the electrical signal of radio waves into electromagnetic waves of the same frequency.

- To exchange information, they must be sent and received, so radio communication will need both receiver and transmitter antennas.

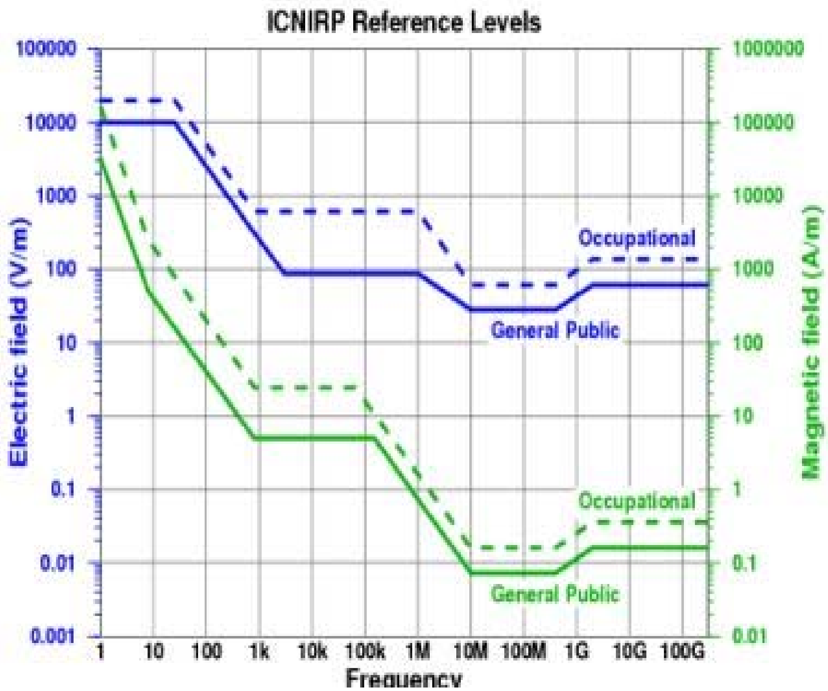
- The radiation power density of the waves decreases with increasing distance from the production source based on the law of the inverse square of the distance

D = the largest linear dimension of the parabolic reflector of the antenna in meters

$$W = \frac{16P}{\pi D^2} = \frac{4P}{A} \ (nearfield)$$

$$W = \frac{GP}{4\pi r^2} = \frac{AP}{\lambda^2 r^2} \ (farfield)$$

Radio-wave Detectors



شدت میدان مغناطیسی، H (A/m)	شدت میدان الکتریکی، E (V/m)	چگالی توان، S (W/m²)	فرکانس
۱۶۳	۱۸۴۲	–	۳۰ KHz —۱۰۰KHz
۱۶/۳ /f	۱۸۴۲	–	۱۰۰ KHz —۱ MHz
۱۶/۳ /f	۱۸۴۲/f	–	۱ MHz —۳۰ MHz
۱۶/۳ /f	۶۱/۴	–	۳۰ MHz —۱۰۰ MHz
۰/۱۶۳	۶۱/۴	۱۰	۱۰۰ MHz —۳۰۰ MHz
–	–	f /۳۰	۳۰۰ MHz —۳ GHz
–	–	۱۰۰	۳ GHz —۳۰ GHz
–	–	۱۰۰	۳۰ GHz —۳۰۰ GHz

Summary of in vivo and in vitro studies on the role of EMFs in induction of DNA damage and oxidative stress.

Summary of in vivo and in vitro studies on the role of EMFs in induction of DNA damage and oxidative stress.

Type of study	EMF parameters	Duration of exposure	Type of cells/animals	Results	References
in vivo	50 Hz (0.97 mT)	50/100 days	rats	long-term exposure induced oxidative DNA damage	Yokus, B. et al. (2005)
in vitro	935 MHz	1 min	human lymphocytes	no effect on DNA strand breakage	Stronati, L. et al. (2006)
in vitro	50 Hz (0.23, 0.47, 0.7 mT)	1,2,3 h	human lymphocytes	no effect on chromatid damage	Hone, P. et al. (2006)
in vivo	60 Hz (14.6 mT)	5 min on and 10 min off during 4 h	Salmonella enterica subspecies	no effect on DNA strand breakage	Williams, P. et al. (2006)
in vivo	834 MHz	7.5 h × 6 days	rats	no effect on induction of oxidative stress	Ferreira, A. et al. (2006)
in vivo	400 and 900 MHz	2 and 4 h	duckweed Lemna minor L.	EMF induced oxidative stress	Tkalec, M. et al. (2007)
in vitro	50 Hz (1 mT)	4 h (1 and 45 days)	Wistar rat tibial bone marrow cells	EMF demonstrated genotoxic potential	Erdal, N. et al. (2007)
in vitro	50 Hz (0.4 mT)	2,6,12,24,48 h	human lens epithelial cells	EMF is capable of inducing DNA double-strand breaks	Du, X. et al. (2008)
in vitro	900 MHz	1 h × 30 days	Sprague-Dawley rats	EMF induced oxidative stress	Ursache, M. et al. (2009)
in vitro	1.8 GHz	4,6,24 h	human trophoblast HTR-8/SVneo cells	high frequency EMF affects DNA integrity	Franzellitti, S. et al. (2010)
in vitro	900 MHz	5,10,20 min × 14 days	primary rat neocortical astroglial cell culture	low-intensity EMF induces ROS production and DNA damage	Campisi, A. et al. (2010)
in vitro	20,50,75 Hz	15 and 90 min	Escherichia coli bacteria	EMF affects bacterial transposition	Giorgi, G. et al. (2011)

					(2011)
in vivo	900 MHz	6 min	insect Drosophila melanogaster	EM radiation retards ovarian development in insects	Panagopoulos, D. J. (2012)
in vivo	1800 MHz	15 min/day x 7/14 days	rabbits	RF-EMF exposure led to an increase of lipid peroxidation	Guler, G. et al. (2012)
in vitro	50 Hz (1 mT)	16 min	AT478 murine squamous cell carcinoma cells	EMF induced oxidative stress and DNA damage	Buldak, R. et al. (2012)
in vitro	1800 MHz	1 h and 24 h	6 types of different cell lines	RF-EMF induces DNA damage in a cell type-dependent manner	Xu, S. et al. (2013)
in vitro	100 Hz (5.6 mT)	45 min	Vero cells	EMF had a genotoxic effect on Vero cells	Mihai, C. et al. (2014)
in vitro	50 Hz (1, 2,3 mT) and 1800 MHz	24 h	mouse spermatocyte-derived GC-2 cells	ELF-EMF (50 Hz) did not induce DNA damage. RF-EMF (1800 MHz) caused DNA strand breaks	Duan, W. et al. (2015)
in vitro	1800 MHz	1 h	mouse embryonic fibroblasts	RF-EMF induced significant DNA single-strand and double-strand breaks and activated repair mechanism	Sun et al. (2016)
in vitro	50 Hz (18.5 μT)	30, 60,120 min	human amniotic (FL) cell line	EMF increased mitochondrial ROS	Feng, B. et al. (2016)
in vitro	50 Hz (10 and 30 μT)	24 h	neuroblastoma and glioma cell lines	genotoxic effect and induction of oxidative stress	Kesari, K. et al. (2016)
in vitro	50 Hz (100 μT)	24 h	human SH-SY5Y neuroblastoma cells	EMF exposure can alter the G1 checkpoint response (cell cycle)	Luukkonen, J. et al. (2017)
in vivo	900 MHz	5–12 days	chick embryo	EMF caused structural changes in liver and DNA damage	D'Silva, M. et al. (2017)
in vitro	1950 MHz	50,100,150,200 h	human glioblastoma cell lines	EMF does not cause chromosomal damage	Al-Serori, H. et al. (2017)
in vitro	1951 MHz	20 h	Chinese hamster lung fibroblast cells	EMF exhibited dose-dependent genotoxicity	Sannino, A. et al. (2017)

Specific Absorption Rate (SAR)

- SAR = σE 2 /ρ
- Calculation of SAR and temperature change (ΔT) for the general public through assessment of electric field

Tissue type	Density ρ [kg/m^3]	Frequency [MHz]	Conductivity, σ [S/m]	Electric field strength, E [V/m]	SAR [W/kg]	Temp. change δT [K]
Nerve	1040	800	0.16	38.89	0.232	0.022
		850	0.17	40.08	0.262	0.025
		900	0.18	41.25	0.294	0.028
		950	0.19	42.38	0.328	0.032
		1000	0.195	43.48	0.354	0.034
Brain	1040	800	0.54	38.89	0.785	0.077
		850	0.58	40.08	0.895	0.088
		900	0.62	41.25	1.014	0.099
		950	0.65	42.38	1.122	0.110
		1000	0.67	43.48	1.217	0.119
Eye	1170	800	0.82	38.89	1.059	0.104
		850	0.88	40.08	1.208	0.118
		900	0.93	41.25	1.352	0.132
		950	0.97	42.38	1.489	0.146
		1000	1.01	43.48	1.631	0.160

Specific heat, C = 3664 [J/(kg K)] ** Time duration, t = 360 sec.

Calculation of SAR and temperature change (ΔT) for the occupational worker through assessment of electric field

Tissue Type	Density ρ [kg/m^3]	Frequency [MHz]	Conductivity, σ [S/m]	Electric field strength, E [V/m]	SAR [W/kg]	Temp. change δT [K]
Nerve	1040	800	0.16	84.85	1.107	0.108
		850	0.17	87.46	1.250	0.122
		900	0.18	90.00	1.401	0.137
		950	0.19	92.46	1.561	0.153
		1000	0.195	94.86	1.687	0.165
Brain	1040	800	0.54	84.85	3.738	0.367
		850	0.58	87.46	4.265	0.419
		900	0.62	90.00	4.828	0.474
		950	0.65	92.46	5.343	0.524
		1000	0.67	94.86	5.797	0.569
Eye	1170	800	0.82	84.85	5.045	0.495
		850	0.88	87.46	5.753	0.565
		900	0.93	90.00	6.438	0.632
		950	0.97	92.46	7.087	0.696
		1000	1.01	94.86	7.767	0.763

* Specific heat, C = 3664 [J/(kg K)] ** Time duration, t = 360 sec.

محدوده فرکانس	نوع کاربرد
در حدود 40 MHz	دزدگیر، کنترل از راه دور
40 - 50 MHz	تلفن‌های بی‌سیم متداول
در حدود 72 MHz	هواپیماهای کنترل از راه دور
در حدود 75 MHz	ماشین‌های اسباب‌بازی کنترلی
2.4 GHz	بلوتوث
2.45 and 5.3GHz	شبکه‌های بدون سیم (WiFi)
2.45GHz	گرم کن مایکروویو
960 - 1215 MHz	رادارهای کنترل ترافیک هوایی
1227 - 1557 MHz	سیستم‌های موقعیت یاب جهانی
900 MHz /1800MHz	تلفن‌های همراه

Everyday things we see in the world

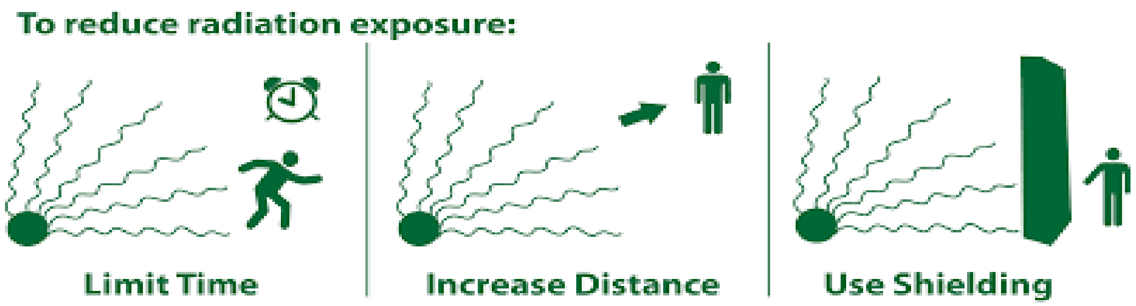
Suggestions about mobile phones

- Shortening the time of calls
- Using the hands-free system
- Using SMS
- Avoiding conversations in places with low antenna coverage
- It is better to connect with a mobile phone outdoors or near a window if possible.
- Avoiding unnecessary calls
- Keep mobile phones away from the body
- Turn off the mobile phone when not in use, especially at night and in places without an antenna
- Limiting the use of mobile phones during pregnancy

Radiation protection against non-ionizing radiation

The principles of radiation protection against non-ionizing radiation are the same as ionizing radiation:

- Reduction of irradiation time
- Increasing the distance from the source
- Use of radiation protection



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www. doe.ir://http.

Guidelines.Protection Radiation ionizing -Non on Commission International.

Health Radiation optical Incoherent Band -Broad to Exposure of Limits on 1997, 3 Number, 73 Volume. physics in Fields Electromagnetic Radiofrequency to Exposure Human of Limits.