ΔΗΜΟΚΡΙΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΡΑΚΗΣ

ΤΜΗΜΑ ΗΛΕΚΤΡΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ & ΜΗΧΑΝΙΚΩΝ ΥΠΟΛΟΓΙΣΤΩΝ

ΕΡΓΑΣΤΗΡΙΟ ΜΙΚΡΟΚΥΜΑΤΩΝ

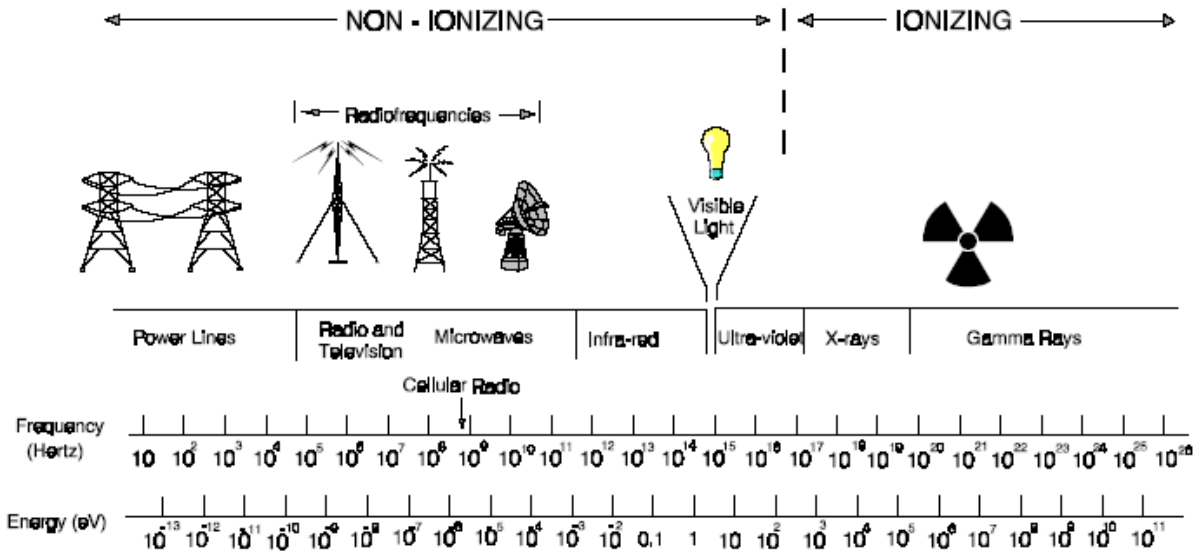
Καθηγητής Γ. Κυριακού

67 100 ΞΑΝΘΗ, Τηλ. 25410-79593, Fax : 25410-79503, Κιν. 6974196173

E-mail : gkyriac@ee-duth.gr,

ΑΚΤΙΝΟΒΟΛΙΕΣ

ΕΚΘΕΣΗ ΑΝΘΡΩΠΩΝ ΣΕ ΗΛΕΚΤΡΟΜΑΓΝΗΤΙΚΑ ΠΕΔΙΑ



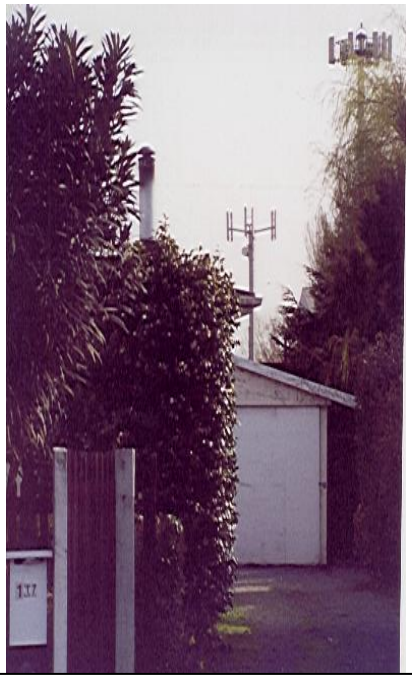
ΔΕΚΕΜΒΡΙΟΣ 2007

Hidden Dangers of Electromagnetic Radiation from Communication Towers, Power Lines and Cellphones

Commissioned by Ralph Ross, Chairman, and Terry Wilkinson, Committee, Member of Christchurch Combined Residents Assn.

The frogs stopped
croaking
dead fish lay
floating
no more ladybirds
on the grass
damn and blast the
microwave mast
platelets lessening
heart pump quaking
technological advancement
human contaminant
radiated toys for boys
in my head the
high pitched noise
this land I carved with
flowers of joy
is this the kiwi
money curse
must some dear souls
drop dead first
will I see Val's
auricula
Burnt Butterscotch
bloom by fall
do human beings
count at all?
by Jenny Barrer

(Who lives 100 metres from the microwave tower)



http://canterbury.cyberplace.co.nz/ouruhia/

By Penny Hargreaves
& Denise Ward

Recommendations by
Dr Neil Cherry

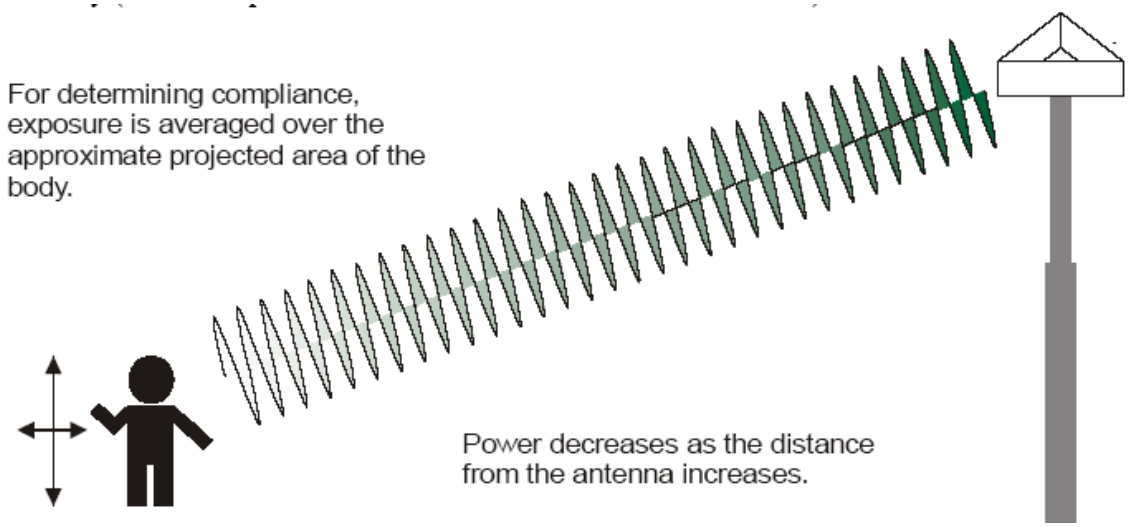
Health Database Contact
Diana Pennell
Email dp.emr@hotmail.com

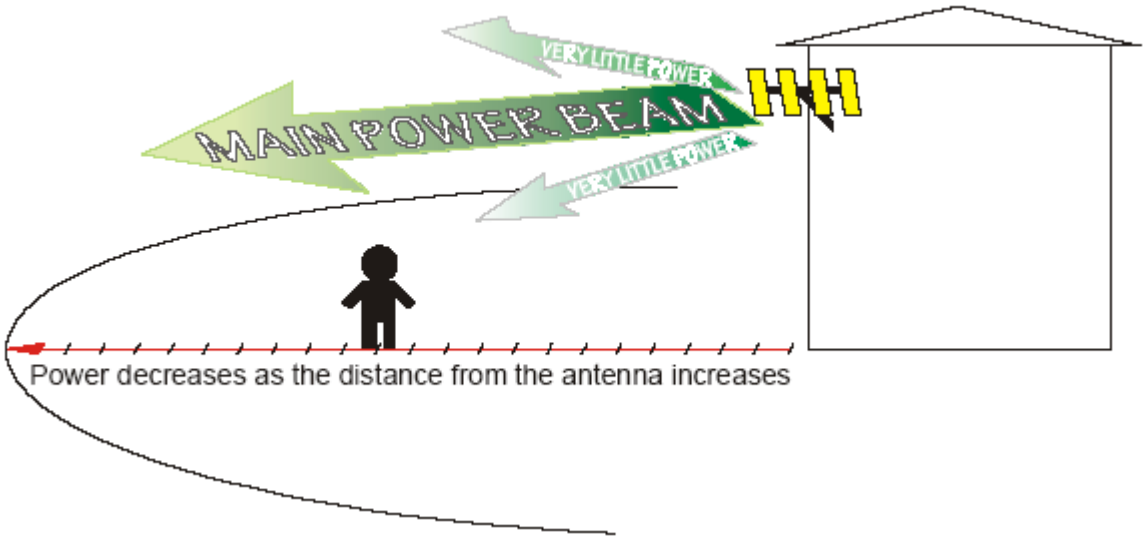
Καταστροφή κεραίας κινητής τηλεφωνίας στην Πολυτεχνειούπολη

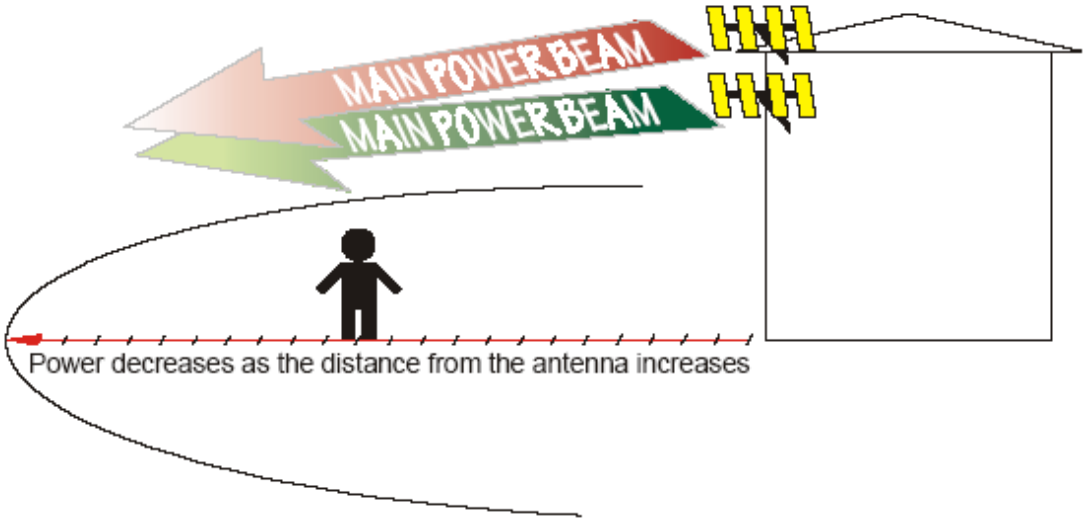
από **Αναρχικοί** *1:52μμ, Τρίτη 17 Οκτωβρίου 2006*
(Τροποποιήθηκε 1:52μμ, Τρίτη 21 Νοεμβρίου 2006)

Καταστροφή κεραίας κινητής τηλεφωνίας στην Πολυτεχνειούπολη

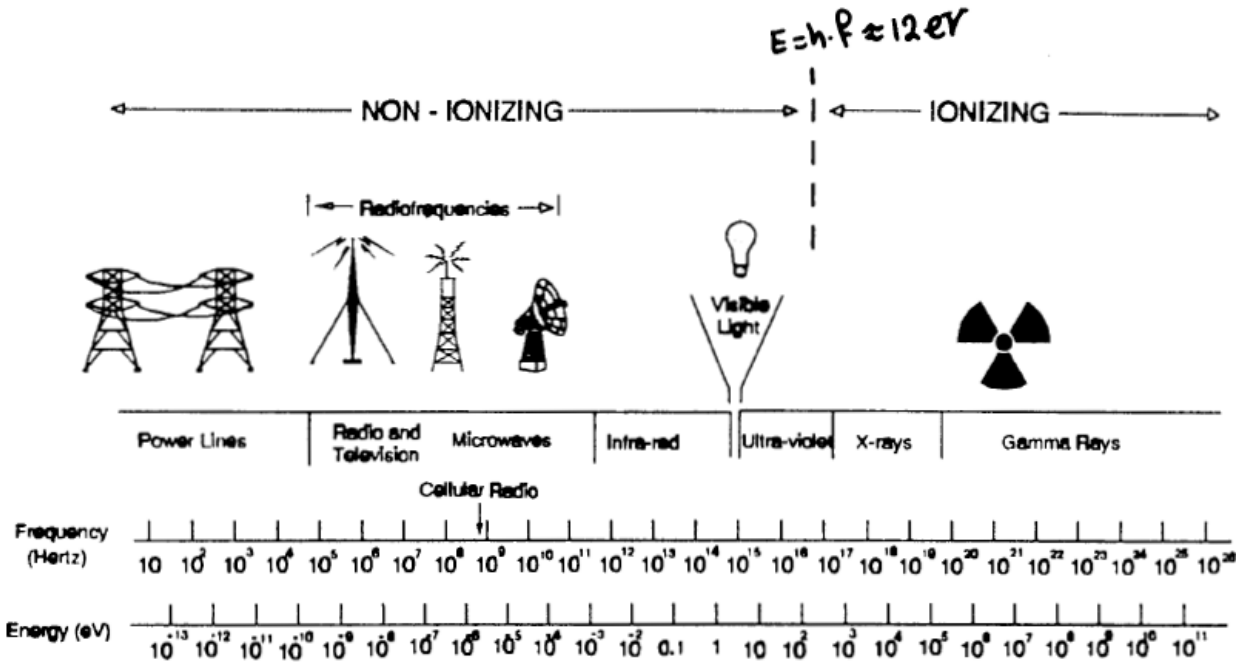
Καταστράφηκε σήμερα το πρωί κεραία κινητής τηλεφωνίας που είχε στηθεί σε ΧΑΜΗΛΟ κτήριο των νέων εστιών στην Πολυτεχνειούπολη, ακριβώς απέναντι και στο ίδιο ύψος με τα υπόλοιπα σπίτια των εστιών.


For determining compliance, exposure is averaged over the approximate projected area of the body.
Power decreases as the distance from the antenna increases.

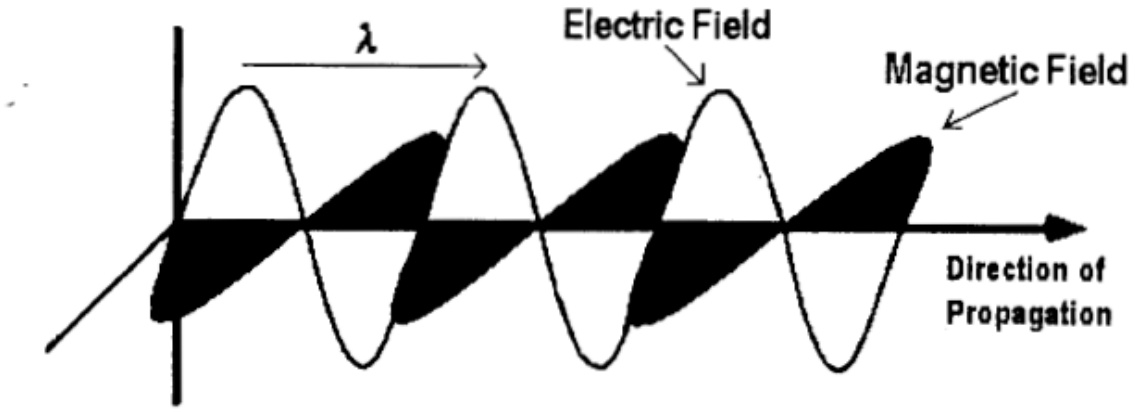

VERY LITTLE POWER
MAIN POWER BEAM
VERY LITTLE POWER
Power decreases as the distance from the antenna increases


MAIN POWER BEAM
MAIN POWER BEAM
Power decreases as the distance from the antenna increases

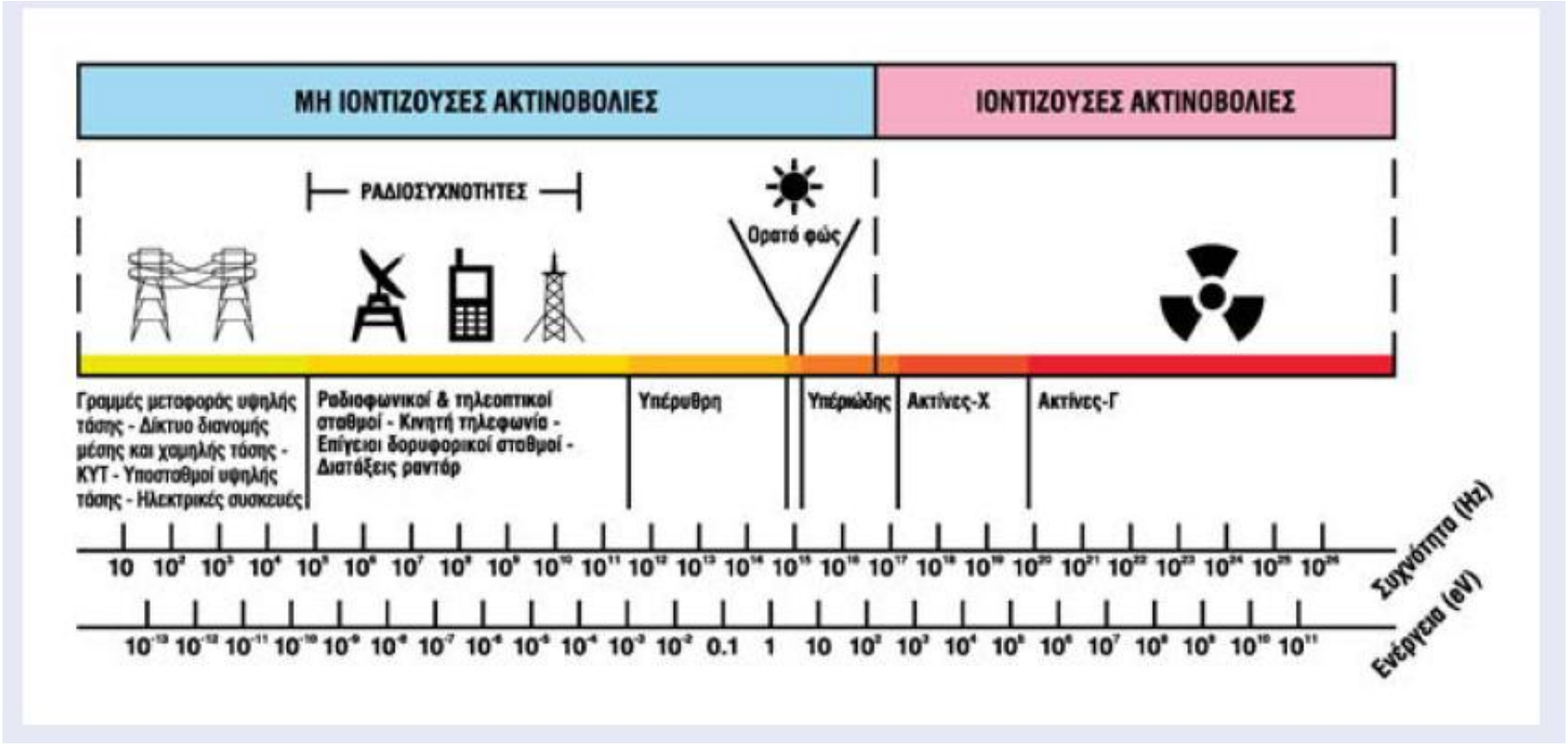
The Electromagnetic Spectrum -1



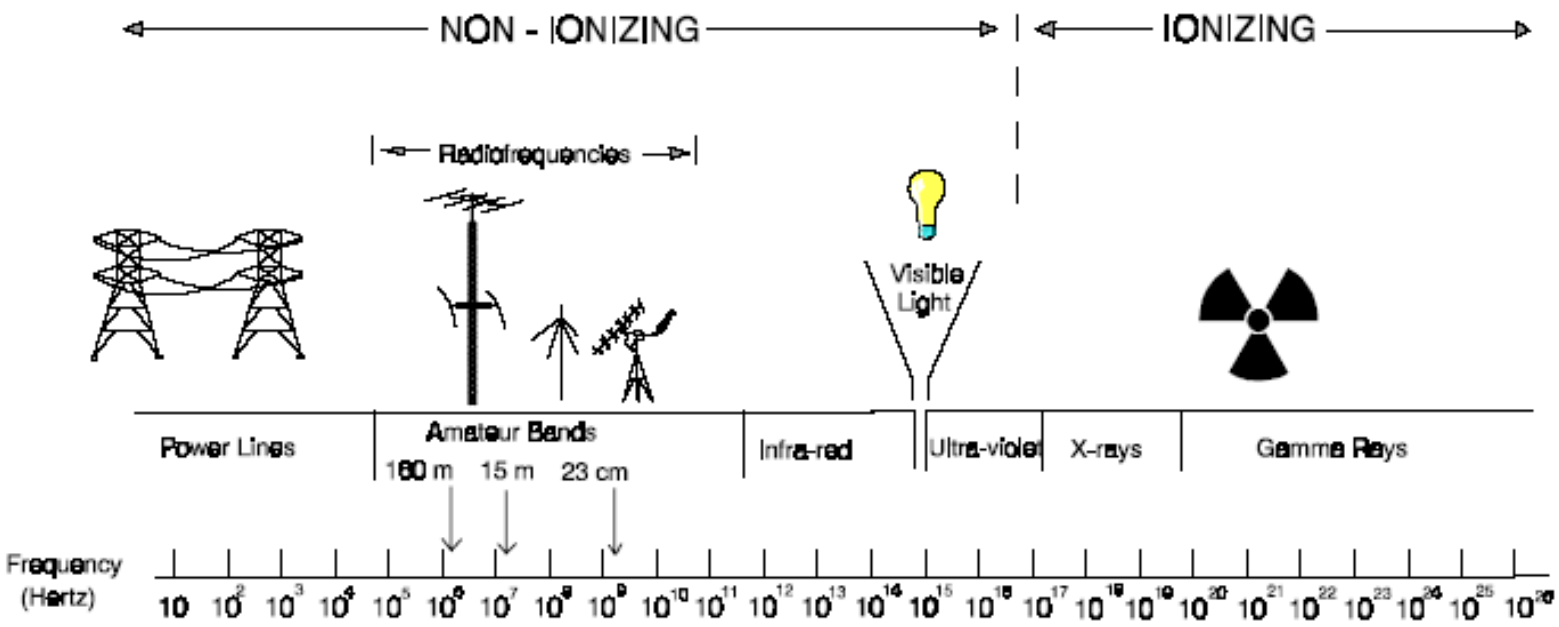
The Electromagnetic Wave.



ΗΛΕΚΤΡΟΜΑΓΝΗΤΙΚΗ ΑΚΤΙΝΟΒΟΛΙΑ

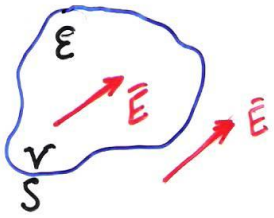


The Electromagnetic Spectrum -1



Ενέργεια Φωτονίου που προκαλεί Ιονισμό: **E_{ion} > 12 eV**	Ιονισμός: **f > E_{ion} / h = 3.10^{15} Hz = 3000 THz** **Πάνω από το Υπεριώδες**
Νόμος του Plank **E = h.v = h.f**	Plank's constant **h = $6.626196.10^{-34}$ Joule.sec= $4.1357.\ 10^{-15}$ eV/Hz**
Φωτόνιο Μικροκυμάτων **Έστω f = 10 GHz, => E = $41.357.10^{-6}$ eV = 0.000041357 eV.**	

ΘΕΡΜΑΝΣΗ ΜΕ ΜΙΚΡΟΚΥΜΑΤΑ - ΡΑΔΙΟΣΥΧΝΟΤΗΤΕΣ



"Αποθηκευόμενη" Ηλεκτρική Ενέργεια W_e

$$W_e = \frac{1}{4} \cdot \mathrm{Re} \iiint_V \bar{D} \cdot \bar{E}^* \, dV$$

$\bar{D} = \varepsilon \cdot \bar{E}$ $\quad \varepsilon$ = ηλεκτρική διαπερατότητα.

$$\varepsilon = \varepsilon(\omega) = \varepsilon_0 \cdot \varepsilon_r \cdot (1 - j\tan\delta) = \varepsilon_0 \varepsilon_r \cdot \left(1 - j\frac{\varepsilon_r''}{\varepsilon_0 \varepsilon_r} - j\frac{\sigma}{\omega \varepsilon_0 \varepsilon_r}\right)$$

$\omega = 2\pi f$

$\varepsilon'' \Leftrightarrow$ Απώλειες - Κατανάλωση ενέργειας λόγω αδράνειας του ατομικού σύστήματος - στοιχειωδών διπόλων. → Μετατροπή σε θερμότητα.

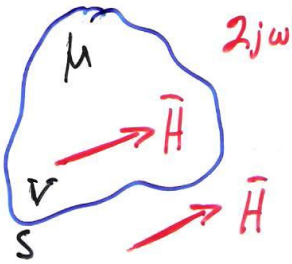
σ = Αγωγιμότητα υλικού $\Leftrightarrow$ απώλειες Joule μετατροπή σε θερμότητα

$$W_e = \frac{1}{4} \varepsilon_0 \varepsilon_r \cdot \iiint_V |\bar{E}|^2 \cdot dV \leftarrow \text{Αποθ. Ηλεκτρ. Ενέργεια.}$$

$2j\omega \cdot W_e$

$$P_{Le} = \frac{1}{2} (\omega \varepsilon'' + \sigma) \cdot \iiint_V |E|^2 \cdot dV \leftarrow \text{Καταναλισκώμενη ενέργεια}$$

→ Θέρμανση.



$2j\omega W_m$ = "Αποθηκευόμενη" Μαγνητική Ενέργεια.

$$W_m = \frac{1}{4} \mathrm{Re} \iiint_V \bar{B} \cdot \bar{H}^* \, dV$$

$\bar{B} = \mu \bar{H}$ $\quad \mu$ = μαγνητική διαπερατότητα

$\mu = \mu(\omega) = \mu' - j\mu''$ $\quad \mu'' \Leftrightarrow$ Απώλειες λόγω αδράνειας ατομικού συστήματος

$$P_{Lm} = \frac{1}{2} \omega \mu'' \cdot \iiint_V |\bar{H}|^2 \cdot dV$$

R.E. Collin, p. 9-10

Safety Levels for Radiofrequency Energy

What levels of radiofrequency (RF) energy are considered safe?

- Countries set their own national standards for exposure to electromagnetic fields.
- The majority of these national standards draw on the guidelines set by the ***International Commission on Non-Ionizing Radiation Protection (ICNIRP).***
- ***ICNIRP*** is a non-governmental organization that evaluates scientific results from all over the world and is formally recognised by the ***World Health Organisation*** (***WHO***).
- ***Europe*** uses guidelines developed by the International Commission on Non-Ionizing Radiation Protection (***ICNIRP***).
- Currently, the World Health Organization is working on a framework for international harmonization of RF safety standards.
- ICNIRP has identified ***a whole-body Specific Absorption Rate (SAR) value of 4 watts per kilogram (4 W/kg) as a threshold level of exposure after which harmful biological effects may occur***.

$$SAR = (\sigma/\rho).E^2$$

- σ = electrical conductivity of the tissue;
- ρ = tissue density;
- E = effective electric field strength in V/m.

- In addition, guidelines vary depending on the frequency of the RF exposure.
- This is due to the finding that whole-body human absorption of RF energy varies with the frequency of the RF signal.
- The ***most restrictive limits*** on whole-body exposure are in the ***frequency range of 30-300 MHz*** where the human body absorbs RF energy most efficiently.
- ***ICNIRP Limit:*** This is a guideline for the maximum permitted power density of nonionizing radiation for public exposure.
- The guideline is frequency dependent and is currently defined as:

Frequency	ICNIRP Limit
Less than 400MHz	2W/m²
400MHz to 2GHz	(f / 200)W/m², where f is frequency in MHz
2GHz to 300GHz	10 W/m²

ΘΕΡΜΙΚΕΣ ΕΠΙΔΡΑΣΕΙΣ

R. Kitchen p. 47-48.

> Συσχέτιση Ειδικής Απορρόφησης SA : Specific Absorption και Θερμοκρασίας T

- Χειρότερη Περίπτωση (worst case) ⇔ NRPB-240, Dec. 1991.

↳ Αγνοώντας τη ψύξη λόγω ΘΕΡΜΟΡΥΘΜΙΣΤΙΚΩΝ ΜΗΧΑΝΙΣΜΩΝ

$$T = \frac{SA}{C \cdot 4180}$$

T (°C)

$C \approx 0.85$ σχετική Θερμοχωρητικότητα

$$SA\ (Joule/kg) = SAR\ (\tfrac{W}{kg}) \times \text{Χρόνος έκθεσης (sec)}.$$

Παράδειγμα:

$SAR = 2\ W/kg$

Χρόνος έκθεσης $= 30\ min$

⇒ Αύξηση Θερμοκρασίας $T = 1^{\circ}C$

> Θερμορυθμιστικοί Μηχανισμοί:

- Κυκλοφορία αίματος
- Εφίδρωση

«Απαιτούν την εκλυόμενη θερμότητα μέχρι κάποιο όριο»

↳ Πέρα απο αυτό αυξάνει η θερμοκρασία των σώματος ή ιστών. ⇒ Υπερθερμία.

> Η αύξηση της Θερμοκρασίας των ιστών $\gtrsim 43^{\circ}C$

⇔ Μη αναστρέψιμες βλάβες ↔ Καταστροφή Κυττάρων.

> Ellis etal. Medical Research Council, London, Special Rep. 298:

«Στις κλινικές εφαρμογές λαμβάνεται ως όριο μια αύξηση θερμοκρασίας κατα $2.2^{\circ}C$ π.χ. $36.6^{\circ}C \rightarrow 38.8^{\circ}C$»

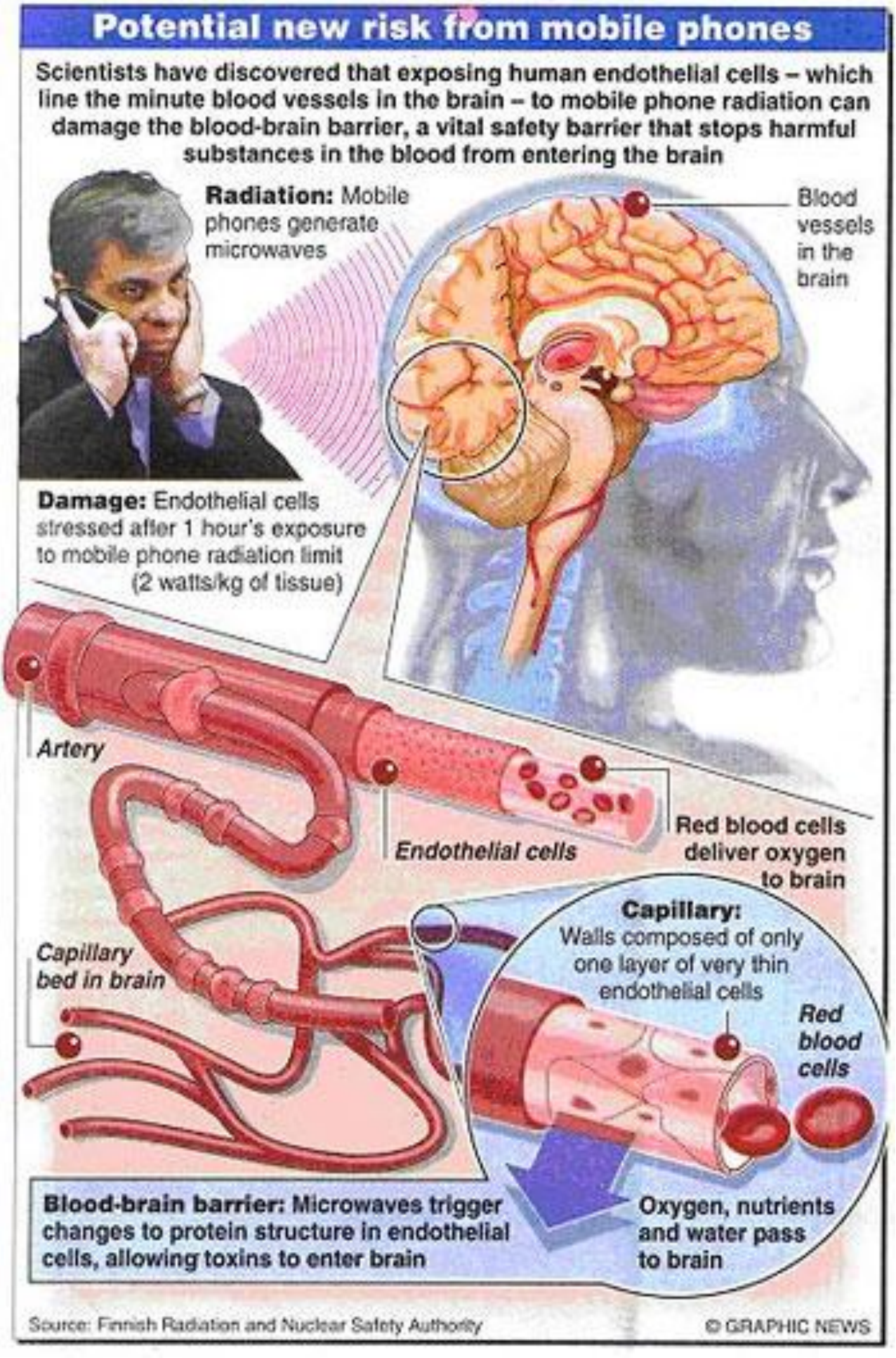
> Επιδράσεις RF Ακτινοβολίας: Λαμβάνεται ως όριο μια αύξηση θερμοκρασίας κατά $1^{\circ}C$

> Τα δυτικά Πρότυπα βασίζονται σε ένα $SAR = 4\ W/kg$

⇔ Τα πειραματόζωα στα ματιών τις πολύπλοκες λειτουργίες

⇔ Συντελεστής Ασφάλειας $= 10$ (⇐) $SAR = 0.4\ W/kg$

⇔ Έκθεση κοινού: Επιπλέον Συντελεστής Ασφάλειας → 5.


Potential new risk from mobile phones
Scientists have discovered that exposing human endothelial cells – which line the minute blood vessels in the brain – to mobile phone radiation can damage the blood-brain barrier, a vital safety barrier that stops harmful substances in the blood from entering the brain
Radiation: Mobile phones generate microwaves
Blood vessels in the brain
Damage: Endothelial cells stressed after 1 hour's exposure to mobile phone radiation limit (2 watts/kg of tissue)
Artery
Endothelial cells
Red blood cells deliver oxygen to brain
Capillary bed in brain
Capillary: Walls composed of only one layer of very thin endothelial cells
Red blood cells
Blood-brain barrier: Microwaves trigger changes to protein structure in endothelial cells, allowing toxins to enter brain
Oxygen, nutrients and water pass to brain
Source: Finnish Radiation and Nuclear Safety Authority
© GRAPHIC NEWS

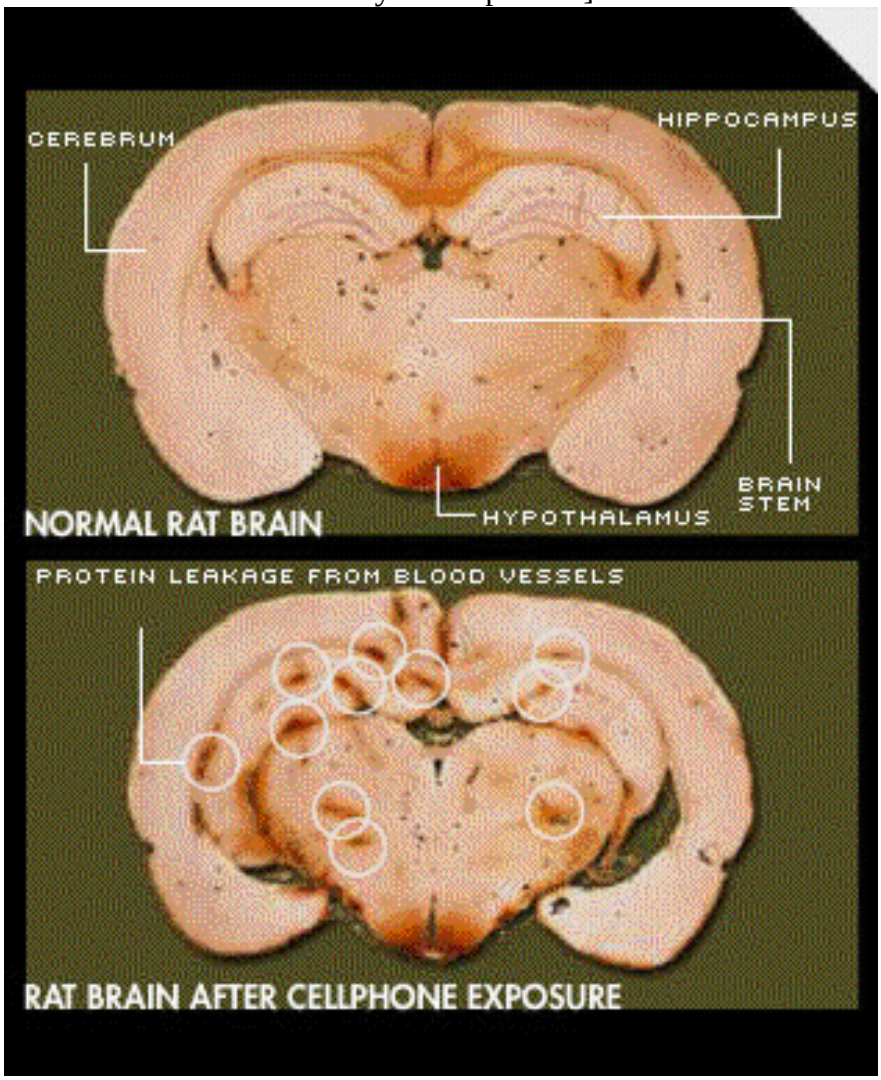
CELL PHONES EXPOSE BRAIN CELLS TO BLOODSTREAM POSIONS

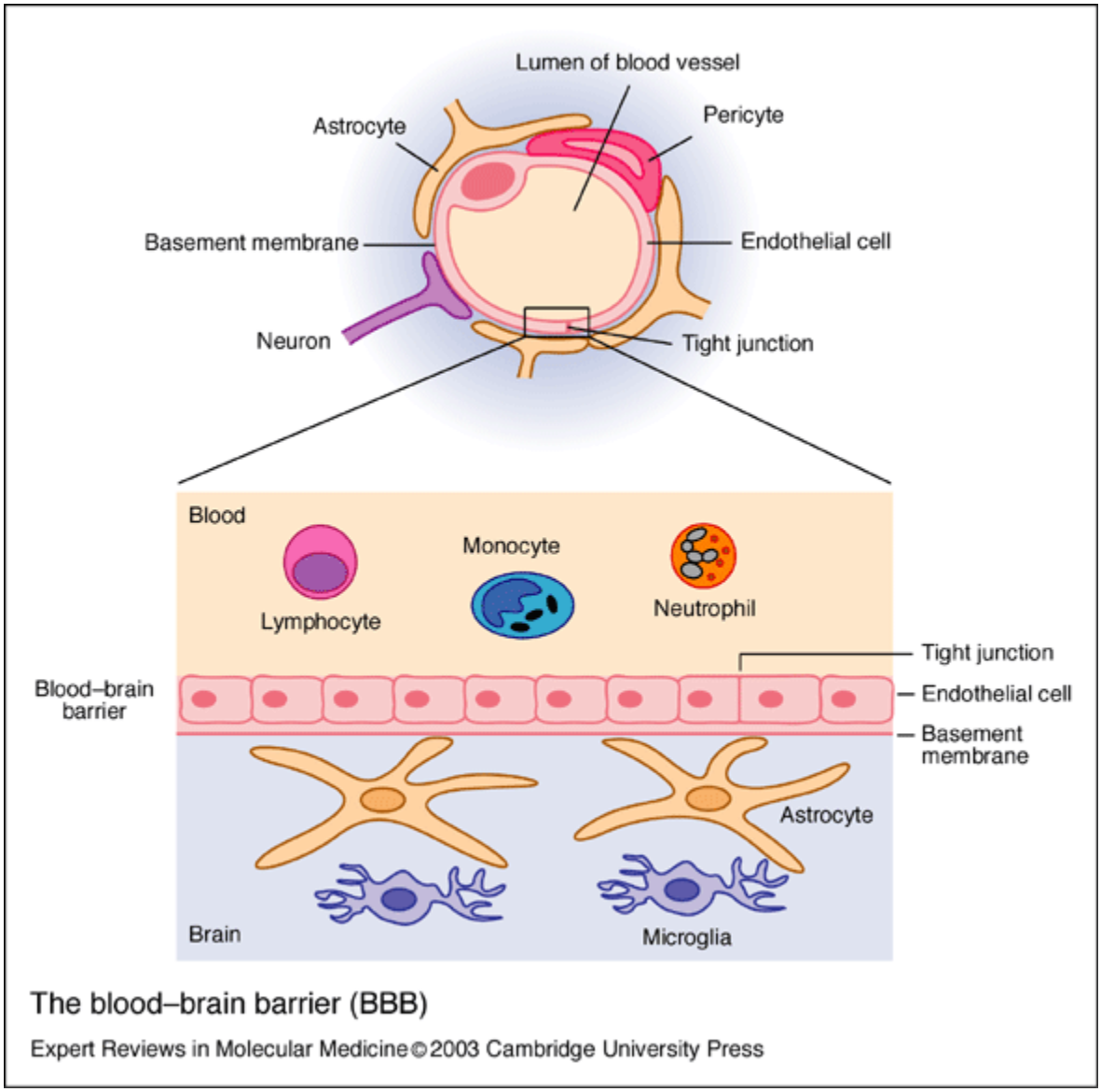
A study by Finish scientist Darius Leszczynski published in the journal Differentiation shows that several hundred chemicals operating in a certain type of human brain cells could be altered by the weak microwaves broadcast by mobile phones.

The blood-brain barrier normally keeps toxins and microorganisms circulating in the blood out of the brain. But Prof Leszczynski found that at the legal limit for mobile radiation, a blood-brain barrier protein named HSP 27 became ineffectual in keeping blood poisons out of brain cells. [The Guardian June20/02]

Proteins found in the blood can, if they get to the brain, cause autoimmune diseases such as Fibromyalgia and Multiple Sclerosis. Damaged nerve cells could also lead to dementia, premature aging, and Parkinson's disease. Brain cells inflamed by cell phone conversations are also indirectly be linked to Alzheimer's disease.

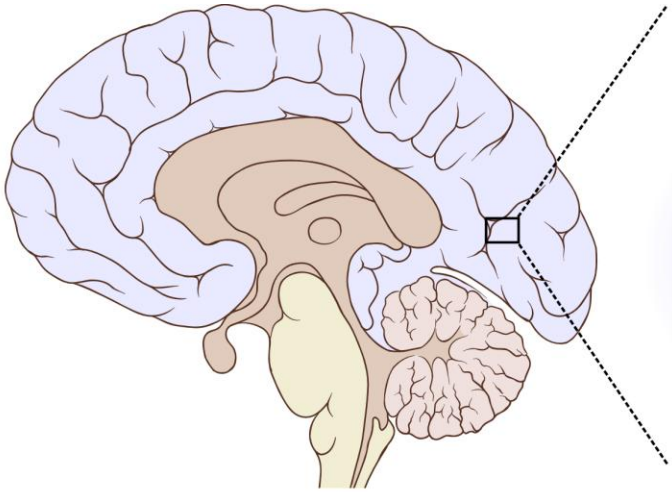
In addition to these potential personal disasters, medication that under normal circumstances wouldn't be able to penetrate the blood-brain-barrier could do so and cause damage. [British Library Net Sept14/03]

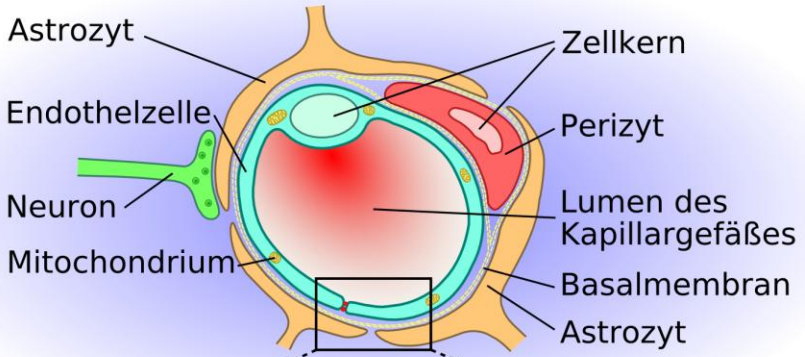


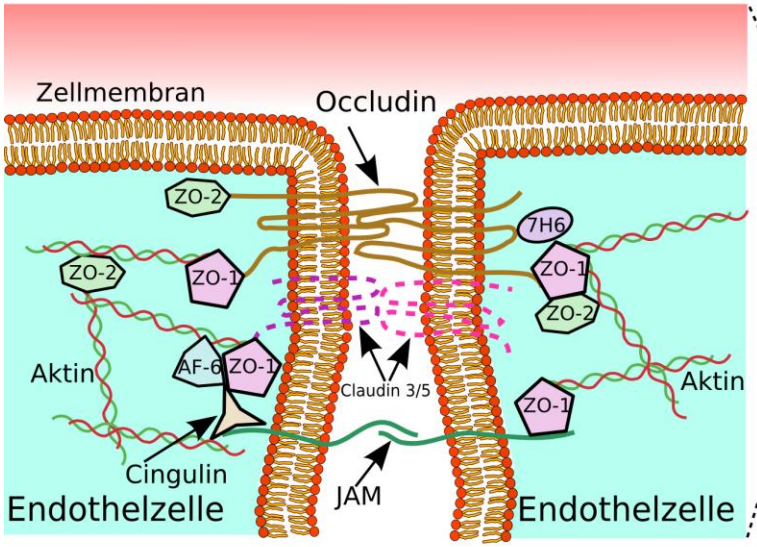


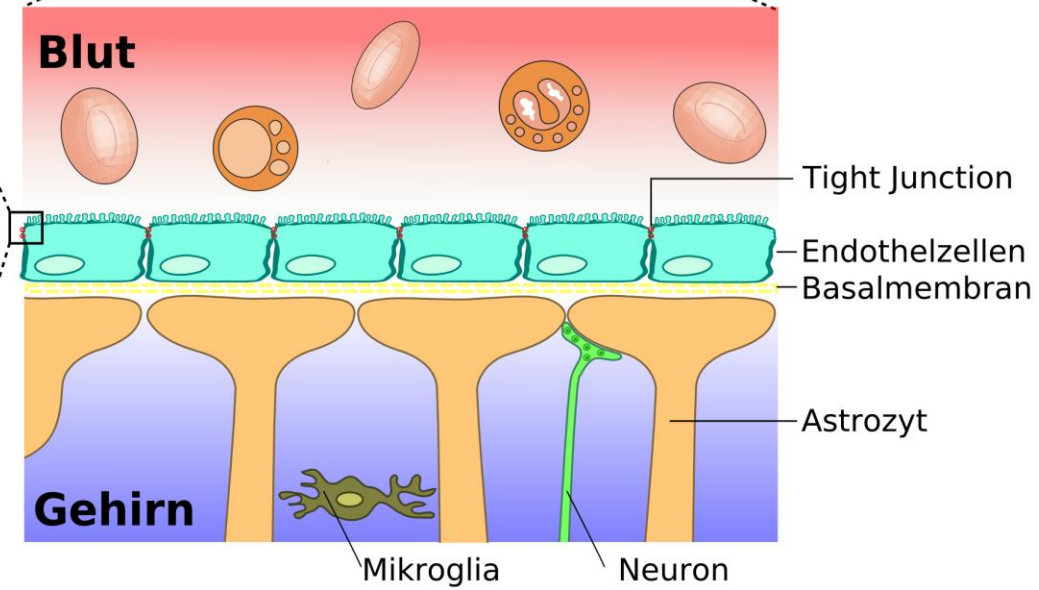
The blood–brain barrier (BBB). The BBB is created by the tight apposition of endothelial cells lining blood vessels in the brain, forming a barrier between the circulation and the brain parenchyma (e.g. astrocytes, microglia). Blood-borne immune cells such as lymphocytes, monocytes and neutrophils cannot penetrate this barrier. A thin basement membrane, comprising lamin, fibronectin and other proteins, surrounds the endothelial cells and associated pericytes, and provides both mechanical support and a barrier function. Thus, the BBB is crucial for preventing infiltration of pathogens and restricting antibody-mediated immune responses in the central nervous system, as well as for preventing disorganisation of the fragile neural network. This, together with a generally muted immune environment within the brain itself, protects the fragile neuronal network from the risk of damage that could ensue from a full-blown immune response. On rare occasions, pathogens (e.g. viruses, fungi and prions) and autoreactive T cells breach the endothelial barrier and enter the brain. A local innate immune response is mounted in order to limit the infectious challenge, and pathogens are destroyed and cell debris is removed, a vital process that must precede tissue repair

Blood-brain barrier









ΟΡΙΑ ΕΚΘΕΣΗΣ

ΕΥΡΩΠΑΪΚΗ ΝΟΜΟΘΕΣΙΑ

• Σύσταση του Συμβουλίου της Ευρωπαϊκής Ένωσης L 199 (1999/519/EC), 30-7-1999.

«Περί του περιορισμού της έκθεσης του κοινού σε ηλεκτρομαγνητικά πεδία (0Hz – 300GHz)»

ΕΛΛΗΝΙΚΗ ΝΟΜΟΘΕΣΙΑ

• Κοινή Απόφαση υπ' αριθ. 53571/3839

των Υπουργών Ανάπτυξης, Υ.ΠΕ.ΧΩ.Δ.Ε., Υγείας και Πρόνοιας, Μεταφορών και Επικοινωνιών (ΦΕΚ 1105/Β/6-9-2000) με θέμα

«Μέτρα προφύλαξης του κοινού από τη λειτουργία κεραιών εγκατεστημένων στη ξηρά»

με την οποία εισάγονται στην Ελληνική Νομοθεσία

- τα όρια της Ευρωπαϊκής Ένωσης για την έκθεση του κοινού σε ηλεκτρομαγνητική ακτινοβολία και
- ορίζονται μηχανισμοί ελέγχου για τα επίπεδα της ηλεκτρομαγνητικής ακτινοβολίας που εκπέμπεται από τους σταθμούς κεραιών όλων των ειδών.

• Νόμος 3431 (ΦΕΚ 13/Α/3-2-2006)

«Περί Ηλεκτρονικών Επικοινωνιών και άλλες διατάξεις», άρθρο 31

«Ρυθμίσεις σχετικά με την εγκατάσταση κεραιών».

Σύμφωνα με το άρθρο τα Ελληνικά όρια για την έκθεση του κοινού τίθενται στο:

- **70%** των ορίων της Ευρωπαϊκής Ένωσης για τους σταθμούς κεραιών που βρίσκονται σε απόσταση μεγαλύτερη των 300 μέτρων από την περίμετρο των κτιριακών εγκαταστάσεων σχολείων, βρεφονηπιακών σταθμών, νοσοκομείων και γηροκομείων και στο

60% των ορίων της Ευρωπαϊκής Ένωσης για τους σταθμούς κεραιών που βρίσκονται σε απόσταση μικρότερη των 300 μέτρων από τις εγκαταστάσεις αυτές.

ICNIRP

Διεθνής Επιτροπή για την Προστασία από τις Μη Ιονίζουσες Ακτινοβολίες
International Commission on Non Ionizing Radiation Protection
ICNIRP

Επίσημα αναγνωρισμένη, μη κυβερνητική οργάνωση από:

- την Παγκόσμια Οργάνωση Υγείας,
- το Διεθνές Γραφείο Εργασίας και
- την Ευρωπαϊκή Ένωση.

Έχει ως μέλη διεθνώς αναγνωρισμένους επιστήμονες που καλύπτουν τις επιστημονικές περιοχές της ιατρικής,της βιολογίας, της επιδημιολογίας, της φυσικής και της μηχανικής.

Πως προέκυψαν τα όρια της ICNIRP;

Η ICNIRP,

- Εξέτασε το σύνολο των δημοσιευμένων ερευνών σχετικά με τις βιολογικές επιδράσεις της ηλεκτρομαγνητικής ακτινοβολίας ραδιοσυχνοτήτων,
- Κατέληξε ότι οι μόνες επιδράσεις που θα μπορούσαν να χρησιμοποιηθούν ως βάση για την θέσπιση ορίων έκθεσης των ανθρώπων είναι αυτές που οφείλονται στην αύξηση της θερμοκρασίας των ιστών από την απορρόφηση της ηλεκτρομαγνητικής ενέργειας από το σώμα.
- Θεωρήθηκε ότι οι δυσμενείς βιολογικές επιδράσεις προκύπτουν με την αύξηση της θερμοκρασίας του σώματος κατά $1^{o}C$.

1. Η αύξηση αυτή γίνεται με την απορρόφηση ενέργειας από το ανθρώπινο σώμα με ρυθμό μεγαλύτερο από 4W/kg.
2. Δηλαδή, για έναν άνθρωπο 80kg με ρυθμό 320W.

Λαμβάνοντας υπόψη ότι

1. Ενδεχομένως κάποιες ομάδες πληθυσμού να είναι πιο ευπαθείς και ότι
2. Δεν αποκλείεται η έκθεση να λαμβάνει χώρα σε ήδη επιβαρημένους χώρους με αυξημένη θερμοκρασία ή υγρασία ή κατά την διάρκεια έντονης άσκησης,

επέλεξαν έναν συντελεστή ασφαλείας 50

στη θέσπιση των ορίων έκθεσης του κοινού.

Έτσι, προέκυψε

ο βασικός περιορισμός για την έκθεση του κοινού σε 0,08W/kg,

δηλαδή για έναν άνθρωπο 80kg το όριο του ρυθμού απορρόφησης ηλεκτρομαγνητικής ακτινοβολίας είναι 6,4W.

ICNIRP

Για να μηνυπάρχουν περιοχές του σώματος στις οποίες να εμφανίζεται τοπικά υψηλή απορρόφηση ενέργειας προβλέπονται οι

Περιορισμοί και για τον μέγιστο τοπικό ρυθμό απορρόφησης

1. **σε 2W/kg για το κεφάλι και τον κορμό και**
2. **σε 4W/kg στα άκρα του σώματος.**

Σε παρόμοια συμπεράσματα και όρια για την έκθεση στην ηλεκτρομαγνητική ακτινοβολία έχουν καταλήξει και άλλοι διεθνείς επιστημονικοί φορείς, όπως

- Το IEEE (Institute of Electrical and Electronic Engineers – Ίδρυμα Ηλεκτρολόγων και Ηλεκτρονικών Μηχανικών),
- το NRPB (National Radiological Protection Board – Εθνικό Συμβούλιο Ραδιολογικής Προστασίας) της Μεγάλης Βρετανίας.

Πίνακας. Βασικοί περιορισμοί της Σύστασης της Ευρωπαϊκής Ένωσης για την απορροφούμενη ενέργεια στο σώμα ενός ανθρώπου που κατατάσσεται στο γενικό κοινό.

Φυσικό Μέγεθος	Όρια ΕΕ (W/kg)	Ελληνικά όρια[1]	
		70% ορίων ΕΕ (W/kg)	60% ορίων ΕΕ (W/kg)
Μέσος ρυθμός ειδικής απορρόφησης (SAR) ολόκληρου του σώματος	0,08	0,056	0,048
Τοπικός ρυθμός ειδικής απορρόφησης (SAR) στο κεφάλι και στον κορμό	2	1,4	1,2
Τοπικός ρυθμός ειδικής απορρόφησης (SAR) στα άκρα	4	2,8	2,4

1. Στο περιβάλλον σταθμών κεραιών

1. Η ICNIRP είναι μια μόνιμη επιτροπή που παρακολουθεί συνέχεια τις εξελίξεις σχετικά με τις επιδράσεις της ηλεκτρομαγνητικής ακτινοβολίας στον άνθρωπο.
2. Τα όρια αυτά ισχύουν όταν η έκθεση στην ηλεκτρομαγνητική ακτινοβολία είναι συνεχής και μόνιμη.
3. Οι τιμές των ορίων αναφέρονται ως χρονικός μέσος όρος οποιουδήποτε εξαλέπτου έκθεσης.

Basic restrictions and reference levels

Basic restrictions

- In many documents, the ***basic limits ("basic restrictions")*** are expressed in quantities such as the specific absorption rates (SAR),
  - since these are intended to be closely related to the biological impact.

Σύσταση Συμβουλίου Ευρώπης, 1999/519/ΕΚ

(Όρια για το γενικό πληθυσμό)

Βασικοί περιορισμοί για ηλεκτρικά, μαγνητικά και ηλεκτρομαγνητικά πεδία (0 Hz — 300 GHz)

Ζώνη συχνοτήτων	Πυκνότητα μαγνητικής ροής (mT)	Πυκνότητα ρεύματος (mA/m^2) (rms)	Μέση ταχύτητα ειδικής απορρόφησης για όλο το σώμα (W/kg)	Τοπική ταχύτητα ειδικής απορρόφησης (κεφάλι και κορμός) (W/kg)	Τοπική ταχύτητα ειδικής απορρόφησης (άκρα) (W/kg)	Πυκνότητα ισχύος S (W/m^2)
0 Hz	40	—	—	—	—	—
>0-1 Hz	—	8	—	—	—	—
1-4 Hz	—	8/f	—	—	—	—
4-1 000 Hz	—	2	—	—	—	—
1 000 Hz-100 kHz	—	f/500	—	—	—	—
100 kHz-10 MHz	—	f/500	0,08	2	4	—
10 MHz-10 GHz	—	—	0,08	2	4	—
10-300 GHz	—	—	—	—	—	10

Σημειώσεις

1. f είναι η συχνότητα σε Hz.

2. Ο βασικός περιορισμός της πυκνότητας ρεύματος αποσκοπεί στην προστασία από τις επιπτώσεις της άμεσης έκθεσης στους ιστούς του κεντρικού νευρικού συστήματος της κεφαλής και του κορμού του σώματος και εμπεριέχει έναν παράγοντα ασφάλειας. Οι βασικοί περιορισμοί για τα πεδία ELF βασίζονται στις διαπιστωμένες δυσμενείς επιπτώσεις που έχουν στο κεντρικό νευρικό σύστημα. Οι οξείες αυτές επιπτώσεις είναι σχεδόν ακαριαίες και δεν υπάρχουν επιστημονικές ενδείξεις που να συνηγορούν υπέρ αλλαγής των βασικών περιορισμών για τη βραχυχρόνια έκθεση. Επειδή όμως αυτοί αναφέρονται σε δυσμενείς επιπτώσεις στο κεντρικό νευρικό σύστημα, ο συγκεκριμένος βασικός περιορισμός μπορεί να επιτρέπει και μεγαλύτερες πυκνότητες ρεύματος σε άλλους ιστούς του σώματος υπό τις ίδιες συνθήκες έκθεσης.

3. Λόγω της ηλεκτρικής ανομοιογένειας του σώματος, οι πυκνότητες ρεύματος πρέπει να εκφράζονται ως μέσος όρος επί διατομής εμβαδού 1 cm^2 κάθετης προς τη διεύθυνση του ρεύματος.

7. Η τοπική SAR υπολογίζεται ως μέσος όρος επί μάζας 10 g παρακειμένων ιστών. Η μεγαλύτερη SAR που προκύπτει κατ' αυτόν τον τρόπο πρέπει να αποτελεί την τιμή που χρησιμοποιείται για την εκτίμηση της έκθεσης. Τα εν λόγω 10 g ιστού υπονοούν συνεχόμενη μάζα ιστού με σχεδόν ομοιογενείς ηλεκτρικές ιδιότητες. Αναγνωρίζεται ότι η έννοια της συνεχόμενης μάζας ιστού είναι χρήσιμη για τους δοσιμετρικούς υπολογισμούς αλλά παρουσιάζει δυσκολίες όσον αφορά τις άμεσες φυσικές μετρήσεις. Επιτρέπεται να χρησιμοποιούνται απλά γεωμετρικά σχήματα, π.χ. κυβικά μέρη ιστών, αρκεί οι υπολογιζόμενες δοσιμετρικές ποσότητες να έχουν συντηρητικές τιμές σε σχέση με τις κατευθυντήριες γραμμές για τα επίπεδα έκθεσης.

Reference levels

- ***In order to simplify compliance testing, these biologically effective quantities are converted into external field levels and power densities ("reference levels"),***
  - These are based on ***dosimetry and worst case situations***.
- Thus, compliance with these reference levels ensures that also the basic restrictions are complied with.
- Failure to comply with the reference levels, on the other hand, does not necessarily mean that the basic restrictions are not complied with - this must then be investigated.
- Having in mind the distances involved (compare figure 6), only reference levels will be discussed here.
- In some documents (e.g. from Italy), limits are only expressed in external field levels.

Επίπεδα αναφοράς για ηλεκτρικά, μαγνητικά και ηλεκτρομαγνητικά πεδία (0 Hz — 300 GHz, σταθερές τιμές rms)

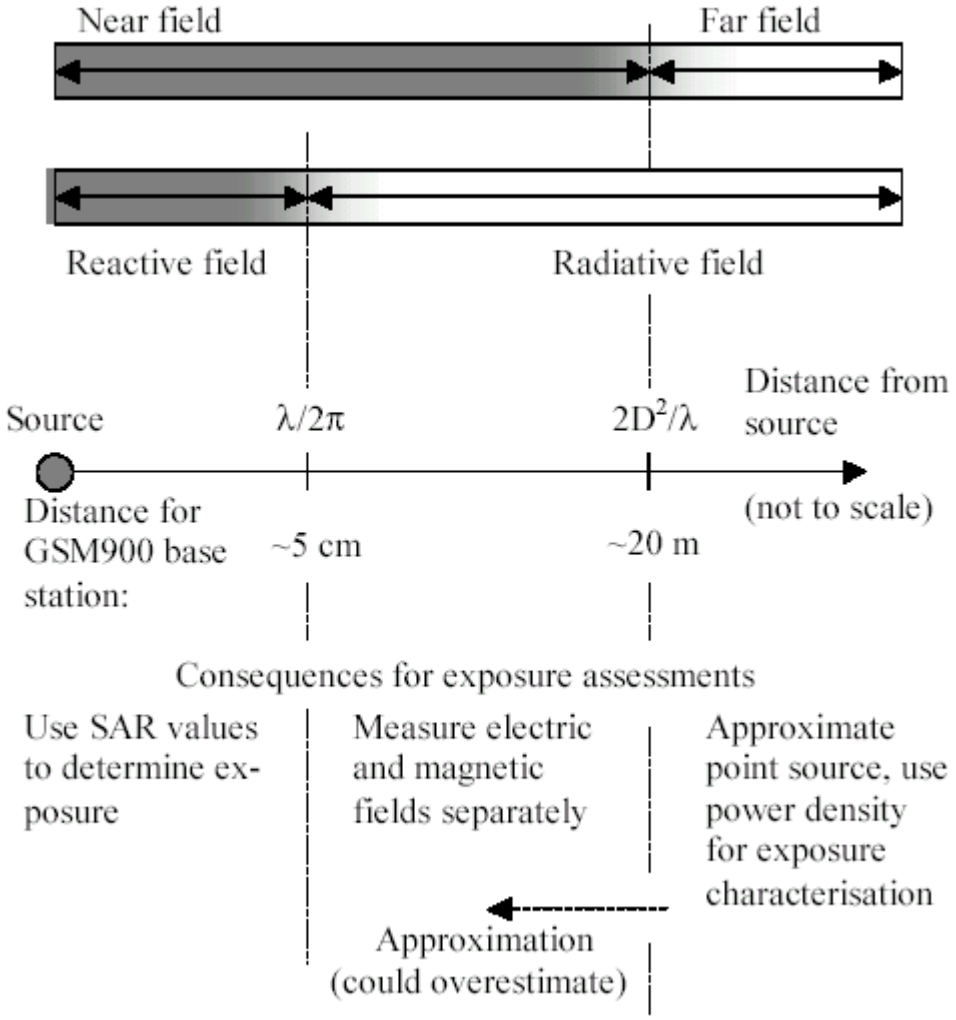
Ζώνη συχνοτήτων	Ένταση ηλεκτρονικού πεδίου-E (V/m)	Ένταση μαγνητικού πεδίου-H (A/m)	Πυκνότητα μαγνητικής ροής πεδίου-B (μT)	Ισοδύναμη πυκνότητα ισχύος επιπέδου κύματος S_{eq} (W/m²)
0-1 Hz	—	$3,2 \times 10^4$	4×10^4	—
1-8 Hz	10 000	$3,2 \times 10^4/f^2$	$4 \times 10^4/f^2$	—
8-25 Hz	10 000	4 000/f	5 000/f	—
50 Hz	5000	80	100	
0,025-0,8 kHz	250/f	4/f	5/f	—
0,8-3 kHz	250/f	5	6,25	—
3-150 kHz	87	5	6,25	—
0,15-1 MHz	87	0,73/f	0,92/f	—
1-10 MHz	$87/f^{1/2}$	0,73/f	0,92/f	—
10-400 MHz	28	0,073	0,092	2
400-2 000 MHz	$1,375\ f^{1/2}$	$0,0037\ f^{1/2}$	$0,0046\ f^{1/2}$	f/200
2-300 GHz	61	0,16	0,20	10

2. Για συχνότητες από 100 kHz έως 10 GHz, τα S_{eq}, E^2, H^2 και B^2 πρέπει να εκφράζονται ως μέσος όρος για κάθε χρονική περίοδο διάρκειας έξι λεπτών.

3. Για συχνότητες που υπερβαίνουν τα 10 GHz, τα S_{eq}, E^2, H^2 και B^2 πρέπει να εκφράζονται ως μέσος όρος για κάθε χρονική περίοδο διάρκειας $68/f^{1,05}$ λεπτών (f σε GHz).

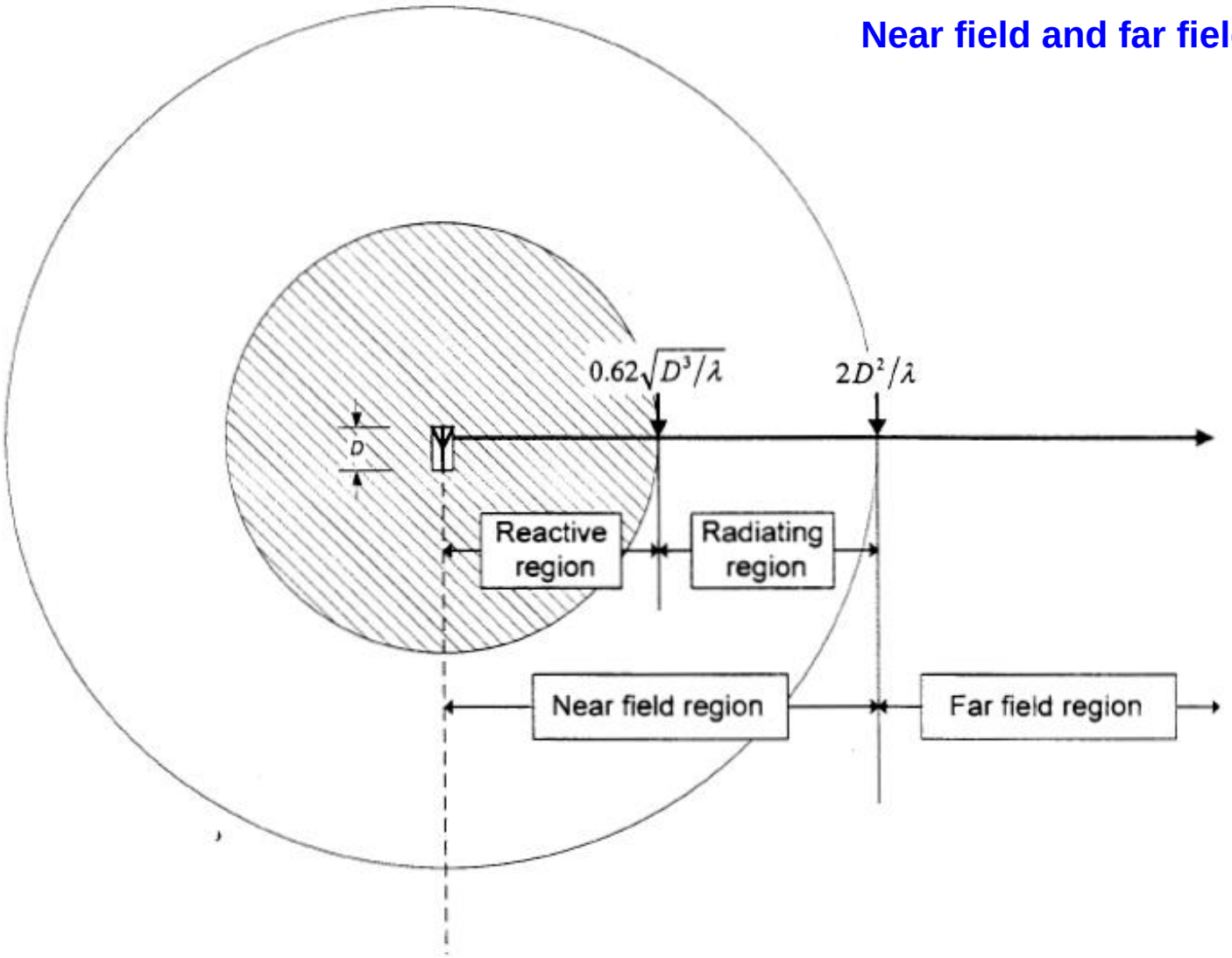
4. Δεν ορίζεται τιμή πεδίου E για συχνότητες <1 Hz, που είναι στην πραγματικότητα στατικά ηλεκτρικά πεδία. Για τους περισσότερους ανθρώπους, η ενοχλητική αίσθηση επιφανειακών ηλεκτρικών φορτίσεων δεν γίνεται αντιληπτή σε πεδία με ένταση μικρότερη από 25 kV/m. Πρέπει να αποφεύγονται οι εκνευριστικές ή ενοχλητικές εκκενώσεις σπινθήρων.

Near field and far field situations



- The physics of electromagnetic emission from an antenna produces different circumstances for measurements depending on the distance **R** from the source.
- For practical purposes, this is commonly described as the existence of three zones
- Figure 6. Illustration of three zones:
- ***Reactive near field,***
  - ***$R < \lambda/2\pi$***
- ***Radiative near field***
  - ***$\lambda/2\pi < R < 2D^2/\lambda$***
- ***Radiative) Far field***,
  - ***$R > 2D^2/\lambda$***
- D = largest dimension of
- λ = wavelength (33 cm for 900 MHz)
- . SAR = Specific Absorption Rate.

Near field and far field



Comparison of limits for radio-frequency fields (COST-244)

- Figure 8 describes graphically the ***general public limits*** of the reviewed documents for the electric field strengths between 0.1 MHz and 300 GHz.

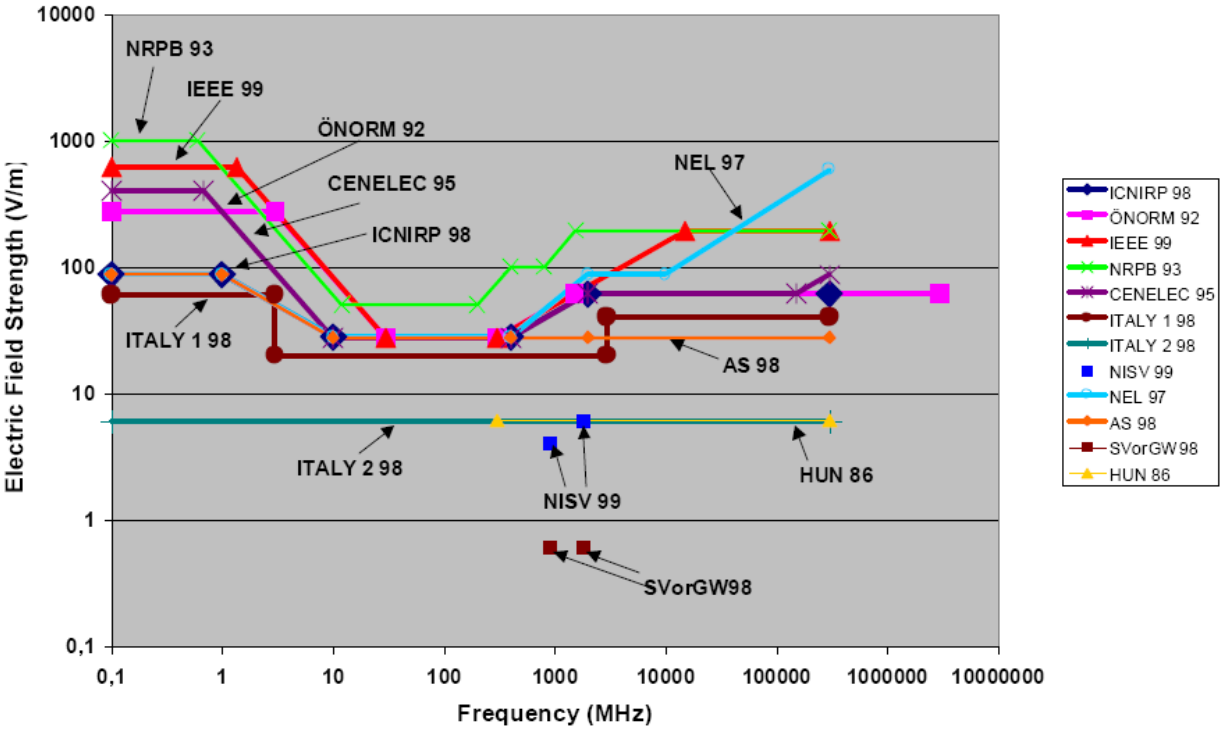


Figure 8: Overview on limits of the electric field strength reference levels for the general public from 0.1 MHz up to 300 GHz.

-

Table 3. List of guidelines for general public exposure reviewed in this report

Country or organisation	Type	Reference
International / International Commission of Non Ionising Radiation Protection	Guidelines	ICNIRP 1998
International / IEEE	Standard	IEEE 1999
European / CENELEC / Technical Committee 211	Prestandard (withdrawn)	CENELEC 1995
Australia / Standard Association of Australia	Standard	AS/NSZ 1998
Austria - national / Österreichisches Normungsinstitut	Prestandard	ÖNORM 1992
Austria - local / Salzburger Sanitätsrat	Report	S vorGW 1998
Hungary / Hungarian Standard Institution	Standard	Hungary, 1986
Italy / Ministry of Environment	Decree	Italy 1998
Netherlands / Health Council of the Netherlands	Report	NEL 1997
Switzerland / Schweizer Bundesrat	Regulation	NISV 1999
United Kingdom / National Radiation Protection Board [a/]	Report	NRPB 1993

[a/] The UK has recently decided to adopt the ICNIRP/EU recommended limits.

Comparison of limits for radio-frequency fields (COST-244)

- Figure 9 describes graphically the ***general public limits*** of the reviewed documents for the electric field strengths between 100 MHz and 10 GHz.

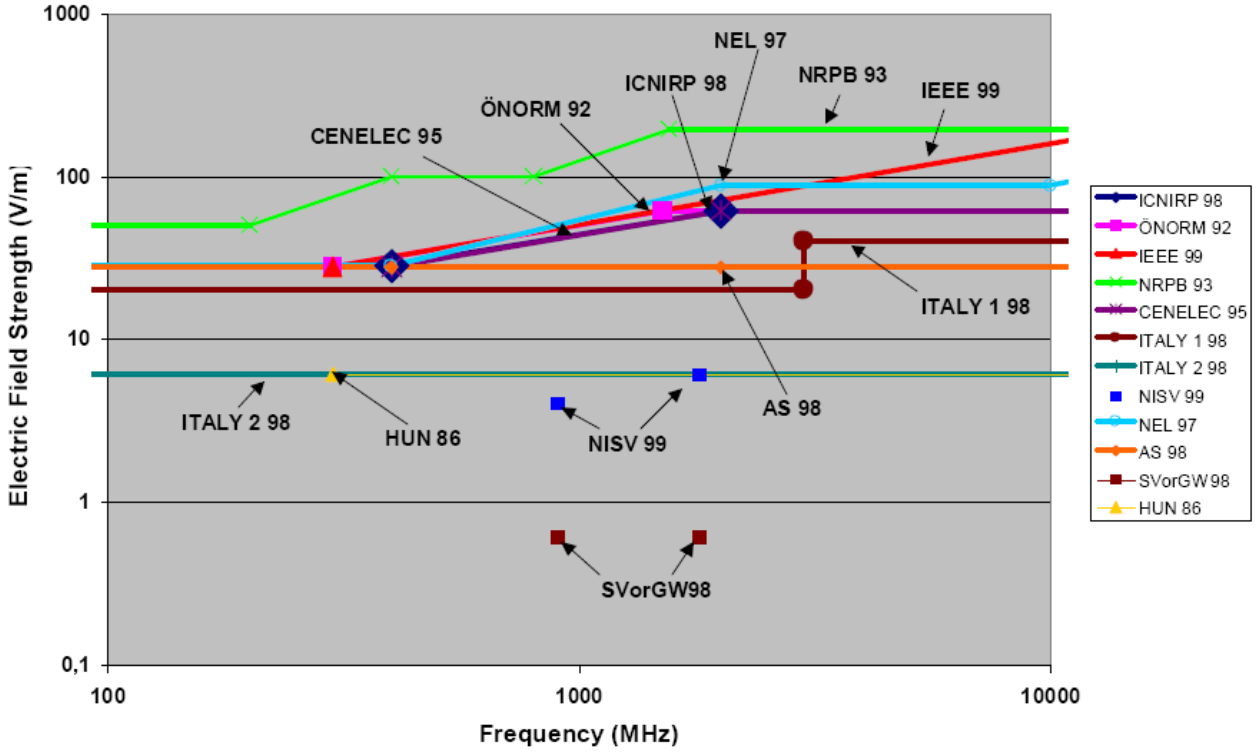


Figure 9: Overview on limits of the electric field strength reference levels for the general public from 100 MHz up to 10 GHz.

- As seen in figures 8 and 9, there is a substantial frequency variation in these levels in some guidelines.
  - Essentially those that are primarily based on restricting the SAR levels.
- Across the frequency range between 100 kHz and 10 GHz, this basic restriction in SAR is the same exposure according to ICNIRP, 1998:
  - 0.08 W/kg fore general public
- But the ***coupling of the external field*** (=the ability for a field level to cause a certain SAR level) ***is at its maximum between some 20 MHz and some few hundred MHz – the so-called resonance range.***
- Accordingly, most reference levels shown in figures 8 and 9 are at a minimum at these frequencies, and do increase at lower and higher frequencies, where the ability of the external fields to pass into the body diminishes.

Comparison of limits - Different Countries (COST-244)

- Comparing in figure 8 the electric field strength limits of different document in the intermediate frequency range from 0.1 to 1 MHz, ***differences of up to three orders of magnitude*** can be found.
  - This is mainly caused by ***different protection concepts*** applied by the different national authorities or committees.
- **A central distinction is that between:**

A. Exposure limits based on scientific evaluation of health based data,

B. Other documents based on social and political considerations

  - such as the ones issued by the Italian Ministry of Environment (Italy 1 98 and Italy 2 98), which applied another protection concept largely based on social and political considerations resulting in much lower limits.

- **A second distinction is that between those:**

C. Guidelines intended to restrict a biologically relevant exposure parameter (e.g. SAR levels) – and where as a consequence the reference levels vary with frequency (see above),

D. Guidelines where the primary objective is to restrict the external field levels.

Different Countries

- In **Italy**, two limits for the general public are in force based on the concept that additional precautionary measures have to be applied in buildings used for periods of more than four hours:
  - **Italy 1, 98**, general limits, periods less than four hours
  - **Italy 2, 98**. periods of more than four hours
- UK has recently adopted guidelines based on the ICNIRP (1998) recommendations
- However, in UK, 1993 the National Radiation Protection Board (NRPB, 1993):
  - took short term effects as a basis for his limits;
  - have not, in contrast to e.g. ICNIRP (1998) limits, introduced additional reduction factors for general public exposure,
  - but uses the same levels as for occupational exposure – which in principle are a factor 5 higher in power density (and a factor of $\sqrt{5} \approx 2.2$ higher for electric fields)

Typical Exposure Levels

- The strongest power frequency electric fields commonly encountered are beneath high voltage transmission lines.
- Strongest magnetic fields at power frequency are normally found very close to motors and other electrical appliances, specialized medical equipment, etc.

Source: Federal Office for Radiation Safety, Germany 1999

Typical electric field strengths measured near household appliances at a distance of 30 cm		**Typical magnetic field strength of household appliances at various distances.** Appliances operated on electricity at a frequency of 50Hz. Normal operating distance is in bold.		
Electric appliance	Electric field strength(V/m)	3 cm distance(μT)	30 cm distance (μT)	1 m distance (μT)
Stereo receiver	180	-	-	-
Iron	120	8 – 30	**0.12 – 0.3**	0.01 – 0.03
Refrigerator	120	0.5 – 1.7	**0.01 – 0.25**	<0.01
Mixer	100	-	-	-
Toaster	80	-	-	-
Hair dryer	80	**6 – 2000**	0.01 – 7	0.01 – 0.03
Colour TV	60	2.5 - 50	0.04 – 2	**0.01 – 0.15**
Coffee machine	60	-	-	-
Vacuum cleaner	50	200 – 800	**2 – 20**	0.13 – 2
Electric oven	8	1 – 50	**0.15 – 0.5**	0.01 – 0.04
Light bulb	5	-	-	-
Electric shaver	-	**15 – 1500**	0.08 – 9	0.01 – 0.03
Fluorescent light	-	40 – 400	**0.5 – 2**	0.02 – 0.25
Microwave oven	-	73 – 200	**4 – 8**	0.25 – 0.6
Portable radio	-	0.8 – 50	**0.15 – 3**	0.01 – 0.15
Washing machine	-	0.8 – 50	**0.15 – 3**	0.01 – 0.15
Dishwasher	-	3.5 – 20	**0.6 – 3**	0.07 – 0.3
Computer	Usually 1 -10	0.5 – 30	**< 0.01**	-
Guideline limit value	**5000**	For most household appliances the magnetic field strength at 30 cm is well below the **guideline limit for the general public of 100 μT at 50Hz.**		

Note:

- Magnetic field strength around all appliances rapidly decreases the further you get away from them.
- Most household appliances are not operated very close to the body.
- At a distance of 30 cm the magnetic fields surrounding most household appliances are more than 100 times lower than the given guideline limit of 100 μT at 50 Hz (83 μT at 60 Hz) for the general public.
- Field strength does not depend on how large, complex, powerful, noisy a device is.
- Magnetic field strengths vary between makes of hairdryers, etc due to product design.

ICNIRP Limit:

- Electromagnetic field levels vary with frequency in a complex way so one can not sensibly list every value in every standard and at every frequency.
- The following table lists ***exposure guidelines*** for the three areas of public concern: electricity ***in the home, mobile phone base stations and microwave ovens.***

Summary of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) exposure guidelines					
	European power frequency		**Mobile phone base station frequency**		**Microwave oven frequency**
Frequency	**50 Hz**	**50 Hz**	**900 MHz**	**1.8 GHz**	**2.45 GHz**
Exposure Limits:	Electric field	Magnetic field	Power density	Power density	Power density
Public	5000 V/m	100 μT	4.5 W/m^2	9 W/m^2	10 W/m^2
Occupational	10000V/m	500μT	22.5W/m^2	45 W/m^2	

ICNIRP, EMF guidelines, Health Physics 74, 494-522 (last updated in April 1998)

Typical maximum public exposure of common sources

- The following table lists most common sources of electromagnetic fields
- All values are maximum levels of public exposure – normal exposure is likely to be much lower.

Source	Typical maximum public exposure of:	
	Electric field (V/m)	Magnetic flux density (μT)
Natural fields	200	70 (Earth's magnetic field)
Mains power (in homes not close to power lines)	100	0.2
Mains power (beneath large power lines)	10 000	20
Electric trains and trams	300	50
TV and computer screens (at operator position)	10	0.7
	Typical maximum public exposure of Power Density (W/m^2)	
TV and radio transmitters	0.1	
Mobile phone base stations	0.1	
Radars	0.2	
Microwave ovens	0.5	

Source: World Health Organisation Regional Office for Europe

Note:

1. World Health Organisation literature states there is no specific level beyond which exposures become instantaneously and immediately hazardous – rather the potential risk to human health gradually increases with higher exposure levels. ie guidelines indicate that, below a given threshold, electromagnetic field exposure is safe according to scientific knowledge. However, it does not automatically follow that, above the given limit, exposure is harmful.
2. **Guidelines are set for the average population and do not address the requirements of a minority of potentially more sensitive people**. For example, air pollution guidelines do not take into account the needs of asthmatics and electromagnetic field guidelines are not designed to protect people from interference with implanted medical electronic devices such as pacemakers.

ΕΞΟΠΛΙΣΜΟΣ ΜΕΤΡΗΣΕΩΝ

ΚΙΝΗΤΑ ΤΗΛΕΦΩΝΑ

Πότε ακτινοβολούν τα κινητά τηλέφωνα;

1. Τα κινητά τηλέφωνα εκπέμπουν ηλεκτρομαγνητική ακτινοβολία μόνο κατά την διάρκεια της τηλεφωνικής μας επικοινωνίας.
2. Επίσης, όταν ένα κινητό βρίσκεται σε κατάσταση αναμονής (stand by),εκπέμπει, περίπου ανά κάποια λεπτά, ένα βραχύ παλμό προς το δίκτυο κινητής τηλεφωνίας

Πόσο ακτινοβολούν τα Κινητά Ασύρματα τηλέφωνα;

Συνήθεις μέγιστες τιμές εκπεμπόμενης ακτινοβολίας από το ασύρματο τηλέφωνο είναι 0,01 W και από τη βάση του 0,12W.

	Τυπική ισχύς εκπομπής	Συχνότητα
Κινητό τηλέφωνο	10 mW έως 500 mW	900 MHz, 1800 MHz, 2100 MHz
Ασύρματο τηλέφωνο	έως 10 mW	1900 MHz (DECT)
Bluetooth	1 mW	2450 MHz

Εξαρτήματα αποδέσμευσης των χεριών (hands free) – ακουστικών

1. Μειώνουν τα επίπεδα ακτινοβολίας που δεχόμαστε από το κινητό τηλέφωνο;
2. Μικρή αύξηση της απόστασης του κινητού τηλεφώνου από το σώμα μας μειώνει σημαντικά την έκθεσή μας σε ηλεκτρομαγνητική ακτινοβολία.
3. Να μην χρησιμοποιούμε τα εξαρτήματα αυτά έχοντας το κινητό τηλέφωνο κολλημένο στο σώμα μας.
4. Τα ασύρματα εξαρτήματα τεχνολογίας Bluetooth εκπέμπουν πολύ μικρότερη ακτινοβολία απ’ ότι ένα κινητό τηλέφωνο

ΠΡΟΛΗΠΤΙΚΑ ΜΕΤΡΑ

Για την μείωση της ακτινοβόλησης κατά την χρήση του κινητού τηλεφώνου

1) Η συνομιλία να είναι όσο το δυνατόν πιο σύντομη.

- Όποτε μπορούμε να χρησιμοποιούμε σταθερό τηλέφωνο.

2)Προμήθειας κινητού τηλεφώνου με χαμηλό SAR.

- Οι καταναλωτές μπορούν να ενημερωθούν για τον SAR από τα έντυπα που συνοδεύουν τα κινητά τηλέφωνα και τα εγχειρίδια χρήσης τους.

3) Να χρησιμοποιούν τα εξαρτήματα αποδέσμευσης χεριών (hands free).

- Απομακρύνοντας ταυτόχρονα το κινητό τηλέφωνο από το σώμα.
- Έστω και μικρή αύξηση της απόστασης της συσκευής από το σώμα ελαττώνει κατά πολύ την ένταση της ηλεκτρομαγνητικής ακτινοβολίας.

4) Να αποφεύγονται οι συνδιαλέξεις το κινητό τηλέφωνο έχει κακό-χαμηλό σήμα

(Σε εσωτερικούς χώρους, Ανελκυστήρας, Υπόγειο, Αυτοκίνητο)

1. Να προτιμώνται οι εξωτερικοί χώροι ή έστω τις θέσεις κοντά στις εξωτερικές πόρτες και τα παράθυρα των κτιρίων όπου γενικά υπάρχει καλύτερο σήμα.

5)Η χρήση του κινητού τηλεφώνου κατά την οδήγηση αυτοκινήτου αυξάνει τους κινδύνους οδικού ατυχήματος.

2. Αυτό ισχύει ακόμα και αν χρησιμοποιείται το εξάρτημα αποδέσμευσης χεριών (hands free).
3. Τα ατυχήματα αυτά αποδίδονται περισσότερο στην απόσπαση της προσοχής του οδηγού από την οδήγηση λόγω της συνομιλίας του στο κινητό και όχι στη δυσχέρεια οδήγησης λόγω του χειρισμού της συσκευής.

Χρήση κινητών τηλεφώνων από παιδιά

Υπάρχουν ενδείξεις ότι τα μικρά παιδιά είναι πιο ευαίσθητα από τους ενήλικες σε ότι αφορά την έκθεσή τους σε ηλεκτρομαγνητικά πεδία.

Διεθνείς φορείς π.χ. (NRPB - National Radiological Protection Board - Εθνικό Συμβούλιο Ραδιολογικής Προστασίας)

1. Τα παιδιά κάτω των 16 ετών να αποθαρρύνονται από την χρήση των κινητών τηλεφώνων. διότι:
2. Έως την ηλικία των 16 ετών περίπου, το νευρικό σύστημα του ανθρώπου αναπτύσσεται.
3. Συνεπώς, δεν αποκλείεται (δεν έχουν ολοκληρωθεί ακόμα οι σχετικές επιστημονικές έρευνες) κατά τις ηλικίες αυτές τα άτομα να είναι πιο ευαίσθητα σε κάποιους παράγοντες απ' ότι αργότερα.
4. Τα άτομα μικρής ηλικίας έχουν στατιστικά μεγαλύτερο χρόνο ζωής.

Χρήση κινητών τηλεφώνων από άτομα με καρδιακό βηματοδότη.

1. Η ηλεκτρομαγνητική ακτινοβολία του κινητού θα μπορούσε να επηρεάσει την λειτουργία ενός καρδιακού βηματοδότη αν λειτουργεί πολύ κοντά σε αυτόν.
2. Για τον λόγο αυτό προτείνεται στα άτομα που έχουν βηματοδότη να μην τοποθετούν το κινητό τηλέφωνο κοντά στο βηματοδότη.
   (τσέπες των πουκαμίσων ή στις εσωτερικές τσέπες από το σακάκι)
3. Τα διάφορα μοντέλα βηματοδοτών μπορεί να διαφέρουν πολύ μεταξύ τους, αν έχετε βηματοδότη, συμβουλευτείτε το γιατρό σας και τον κατασκευαστή για τη συμβατότητα του βηματοδότη σας με τη χρήση κινητών τηλεφώνων.

Χρήση κινητών τηλεφώνων στα αεροπλάνα και στις εντατικές μονάδες των νοσοκομείων.
Απαγορεύεται η λειτουργία κινητών τηλεφώνων;

4. Η ακτινοβολία των κινητών τηλεφώνων μπορεί να προκαλέσει παρεμβολές σε ευαίσθητες ηλεκτρονικές συσκευές.
5. Επειδή τα αεροπλάνα και οι εντατικές μονάδες των νοσοκομείων έχουν τέτοιες συσκευές και επειδή κάποια παρεμβολή σε αυτές θα μπορούσε να έχει ολέθρια αποτελέσματα.
6. Συστήνεται η απενεργοποίηση των κινητών τηλεφώνων σε αυτούς τους χώρους.

Mobile phone technology and health.

The UK Government's Research.

- At the request of the Minister for Public Health, an independent committee, under the chairmanship of Sir William Stewart, was set up to ***report on Mobile Phones and Health. The Stewart Repor****t*, published in May 2000 (available at www.iegmp.org.uk),
- This was the most comprehensive in the world and concluded that:
- The balance of evidence to date suggests that exposures to emissions of radiation from mobile phones, at levels below the National Radiological Protection Board or the International Commission on Non-Ionizing Radiation Protection ***(ICNIRP)*** guidelines do not cause adverse health effects to the general population.
- There is now scientific evidence, which suggests that there may be biological effects occurring at exposures below these guidelines.
- A precautionary approach to the use of mobile phone technologies, particularly by children and young people, should be adopted until much more detailed and scientifically robust information on any health effects becomes available. **(See Recommendations A2 and 3, C2)**
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- The ***Stewart Report proposed*** that more research was needed on:
    1. effects on brain function
    2. impact, if any, of pulsed signals
    3. improvements in dosimetry
    4. possible impact on health of sub-cellular and cellular changes induced by radiofrequency radiation
    5. psychological and sociological studies related to the use of mobile phones
    6. epidemiological and human volunteer studies.

Fields from Mobile Phone Systems

- The RF power from a phone is mainly transmitted by the antenna together with circuit elements inside the handset.
  - The antenna is usually a metal helix or a metal rod a few centimetres long extending from the top of the phone.
  - Neither type is strongly directional, although more power is radiated in some directions than others.

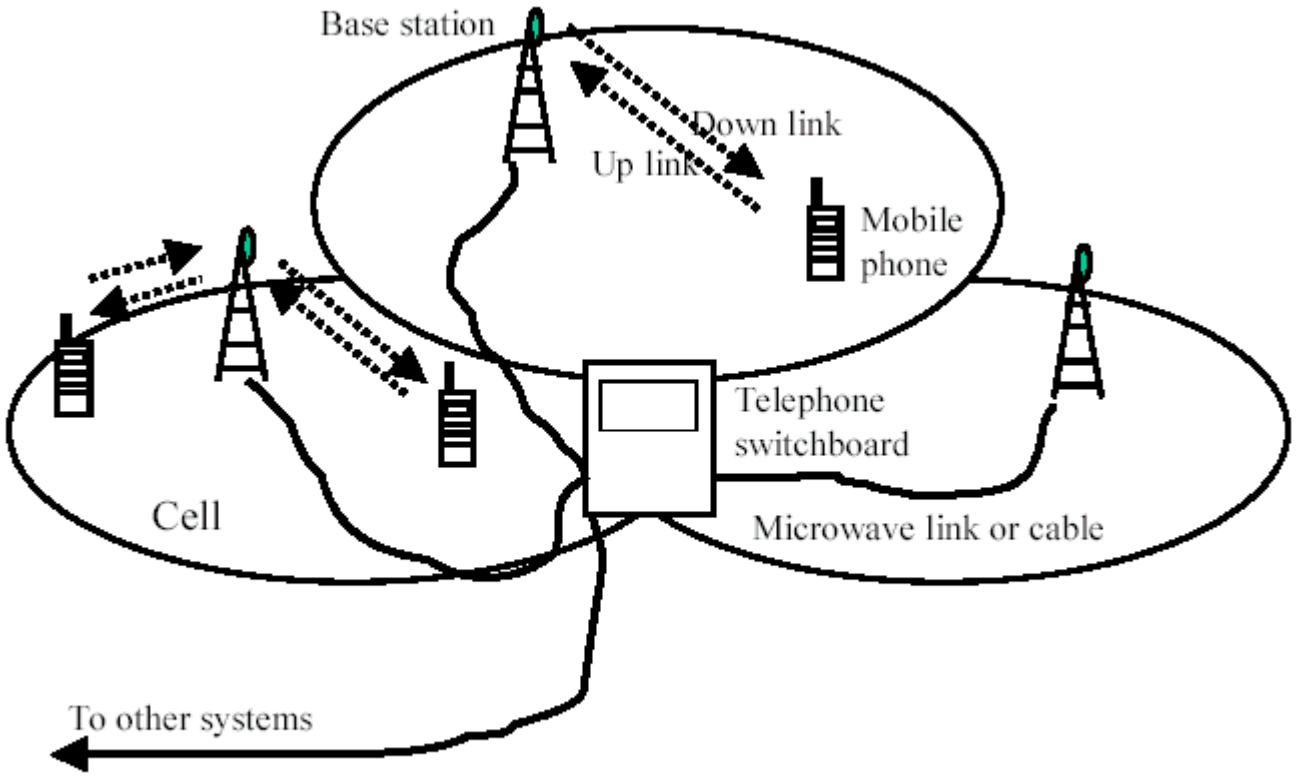
Fields and intensities when the antenna is a long way from the head or body.

- At points 2.2 cm from an antenna (the distance at which calculations were made), ***the maximum values of the electric field are*** calculated to be
  - about 400 V/m for a 2 W, 900 MHz phone and
  - about 200 V/m for a 1 W, 1800 MHz phone and
- ***The maximum magnetic field*** is calculated to be
  - about 1 μT for both phones*.
- For both 2 W, 900 MHz phones and 1 W, 1800 MHz phones the ***maximum intensity (power density) at 2.2 cm from the antenna is very roughly about 200 W/m^2***.
  - This is about one-quarter of the intensity of the Sun's radiation on a clear summer day (***800 W/m^2)*** , although the frequency of the emission from a phone is a million or so times smaller).

Fields and intensities when the When the antenna is near the body,

- ***The radiation penetrates the head or the body it but the fields inside are significantly less, for the same antenna, than the values outside***.
- For example, the largest maximum fields inside the head when its surface is 1.4 cm from the antenna are calculated to be
  - ***about three times smaller than the values given above***.
- The average field values are all appreciably less than these maximum values for the reasons explained earlier.
- As well as these RF fields, that are pulsed at 8.34 Hz and 217 Hz, there are magnetic fields near to the phone that oscillate at these same frequencies, and are a few μT in magnitude.
- These are generated by currents flowing from the battery which are switched on and off at these frequencies as a result of TDMA.
- ***The largest values of electric field E inside a model of a head whose surface is 1.4 cm from the antenna were also computed and are***
  - ***about 120 V/m for a 900 MHz antenna radiating 2 W and***
  - ***about 70 V/m for a 1800 MHz antenna radiating 1 W.***

Description of the mobile telephone system, (COST-244)

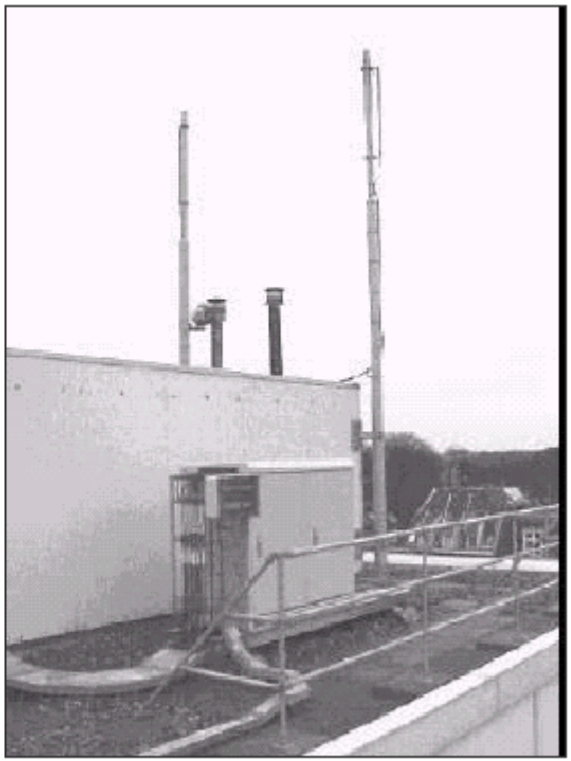


- The mobile (cellular) phone system works as a network containing base stations.
- Within each cell, a base station (with an antenna) can link with a number of handsets (mobile phones).
- The mobile phones and the base stations communicate with each other, sharing a number of operation frequencies.

Figure 3. ***The structure of the mobile telephone system (here with three cells).***

- Other transmission links connect this base station with switches connecting to base stations in other cells, or with switches connected to conventional phones.

Photographs of GSM Base Stations.



- Figure 1. A base station; right: two of the three masts with an antenna at the top;
  Foreground: the equipment cabinet; left: one of the masts with an antenna and
  A dish antenna for the microwave link.

TELEPHONE MAST BASE STATION

(A close view}

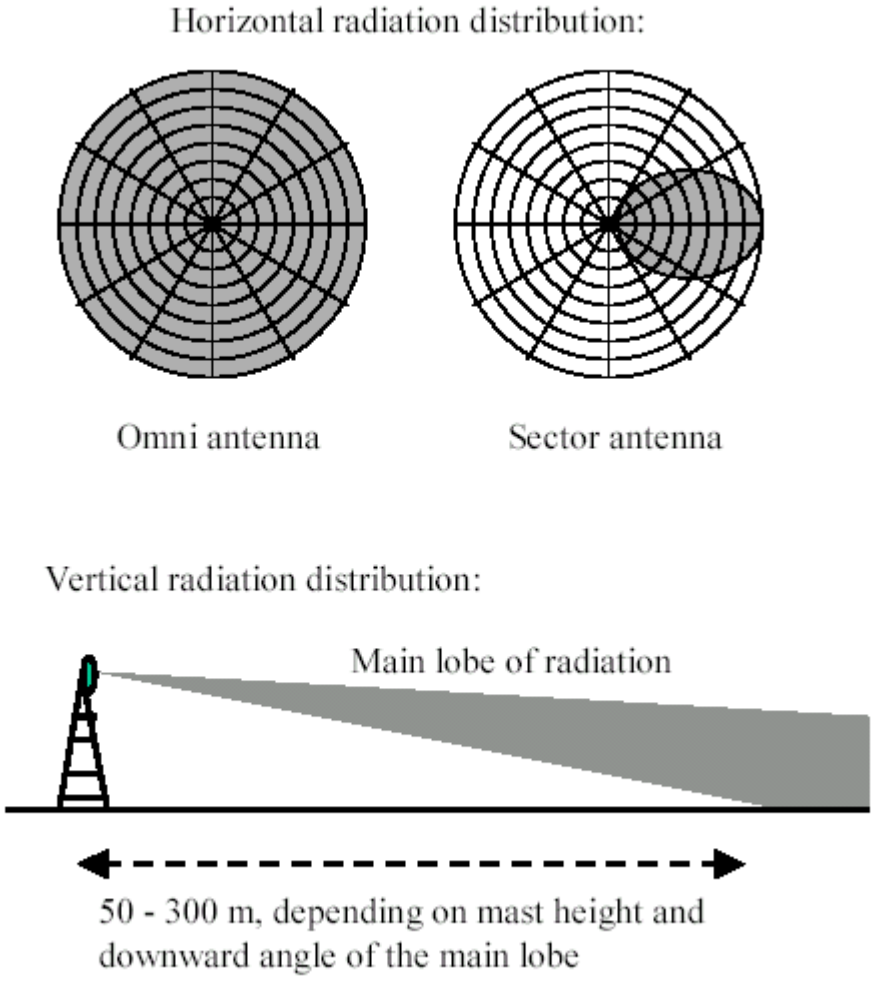
Description of the mobile telephone system, -2.

- The cell exists in order to permit re-use of frequencies – the same frequency can be used in different cells (given a sufficient distance).
- The links (uplink from handset to base station, downlink from base station to handset) employ high frequency electromagnetic fields.
- ***The outdoor base station antennas may be mounted on the roof or walls of buildings or on free standing masts***.
- The size of the cells may vary, from several kilometres (in rural areas with low traffic density) down to some 10-100 meters (in high traffic density areas in cities).
    - Small indoor cells occur, using either normal mobile telephone systems such as GSM–900MHz, – GSM–1800 MHz (DCS), or systems for cordless telephony (e.g. DECT).
    - In these systems, several users can use the same frequency, since each transmission is digitalised and compressed to fit into one of 8 time slots.
    - A new system, the UMTS, is currently being introduced, and will use codes to separate the calls.
- The ***typical power emitted from outdoor antennas is between 5 and 10 W per channel***, which means that the ***total power from a base station could amount to some 50 W*** depending on the number of channels and varying with time.
- In the GSM systems, each link is allocated a bandwidth of 200 kHz (0.2 MHz). Thus, the allocated spectrum could theoretically encompass 124 (GSM 900) or 374 (GSM 1800) different channels (pairs of links).
- One channel (the control channel) from each base station is always transmitting with essentially a constant power, regardless of the traffic intensity.
- However, the re-use of the same frequency limit the number of possible channels to be used in each cell, and thus also the total emitted power, from a minimum of10 W up to a maximum of 50 W.

Exposure variations with distance from the base station, Antenna Characteristics.

- An antenna does generally have some directionality.
    - Omni antennas radiate in every direction (seen horizontally), while
    - Sector antennas effectively only radiate in a (horizontal) sector, see figure 5.
- This will permit increased re-use of frequencies, as it will reduce interference – accordingly, most base stations in high traffic density areas such as cities are of the sector type.
- ***The preferred sector antenna gain is between 10 and 20 dBi***.
    - This means that the emitted power may be between 10-100 times stronger in the intended directions compared to an omni antenna, while
    - It will be correspondingly weaker in other directions.
    - For example, the exposure behind a sector antenna could be 300 times weaker than in the main lobe (Ramsdale and Wiener, 1999).
- ***Tilt down (between 3^o to 6^o):*** In addition to this horizontal directionality, the antenna lobe will also have a strong vertical directionality, with a fairly narrow beam, which is often tilted slightly downward (see figure 5).
- At a sufficient distance from the antenna (of at least 10-15 meters) the EMF exposure levels can be characterized by the power density in W/m^2.
- In the main lobe, and disregarding attenuation by other objects ("free space"), this power density will decrease with the square of the distance.
- At larger distances, where (often) buildings or hills will interfere, attenuation and/or reflections will cause an even faster overall decrease in the power density, but also cause substantial variation. A decrease of power density with distance as $1/r^{3.5}$ has been found to be useful for e.g. base station power calculation (ETSI, 1996).

Exposure variations with distance from the base station, Antenna Characteristics –2.

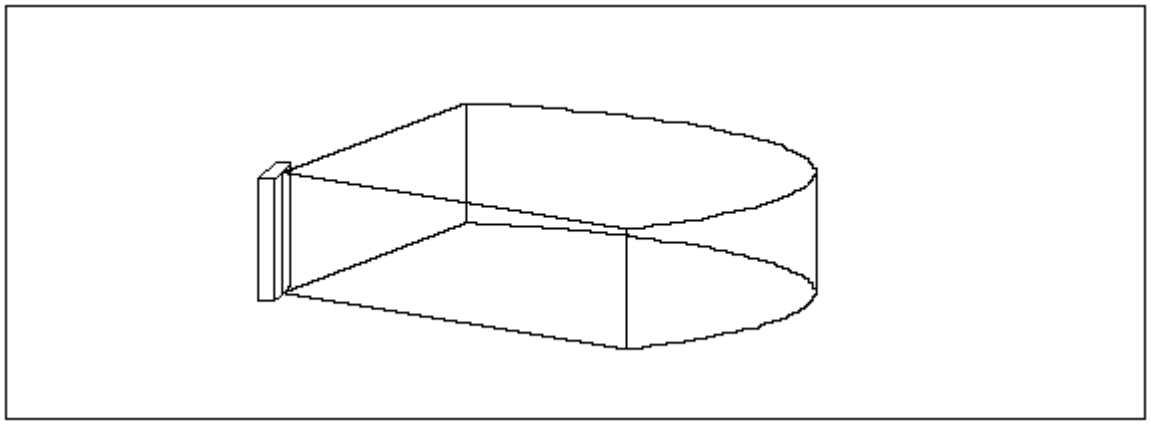


- ***The preferred sector antenna gain is between 10 and 20 dBi***.
- ***The horizontal half power beam-width of the sector antenna is 120^0***
- ***The main-beam is vertically Tilted downwards between 3^o to 6^o:***
- ***Typical antenna dimension D=1.8m***
- Antenna boxes consist of a plastic casing between 1m and 2.5 m in height, containing a number of dipoles
- Typical mast height: 20m to 35 m
- At distances greater than at least 10-15 meters from the antenna the EMF exposure levels can be characterized by the power density in W/m^2.

Figure 5. The direction of main radiation (main lobe) from base station antennas, both in the horizontal direction (above) and in the vertical direction (below).

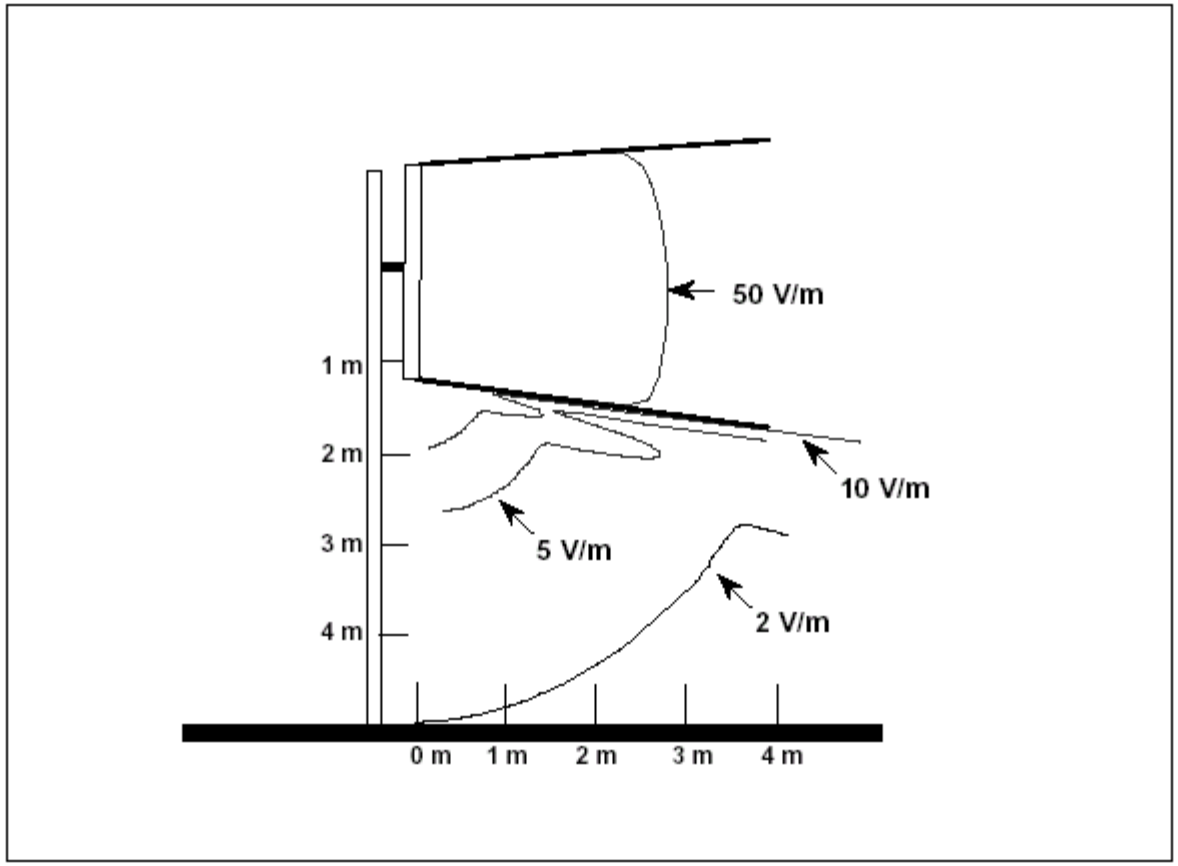
Typical Antenna boxes for GSM base stations

- The antennas transmit the electromagnetic fields mainly in a forward horizontal direction in which the beam is targeted at a downward angle of between 3 and 6 degrees.
- In the most usual construction of a base station there are three antennas.
- In such a case the beam from each antenna has a horizontal spread of 120^{o} (Figure 4), such that the three antennas cover an entire circle.



- Antenna boxes consisting of a generally right-angled plastic casing between 1m and 2.5 m in height, in which a number of dipole antennas are enclosed.
- In thinly populated areas the antennas are often placed on a free-standing purpose built mast of between 20 and 35 m in height.
-

Field strength within and outside the beam



- Figure 5 provides a schematic representation of the calculated field strengths for an antenna with a radiated power of 20 Watts,
- The exposure limit for the general public can only be exceeded within the beam and at a distance of no more than 3 metres from the antenna.

- Figure 5 ***Schematic representation of the field strengths near a GSM 900 MHz antenna with a radiated power of about 20 W.***

Field strength within the beam

- The field strength within the beam depends upon the power of the antenna and the distance from the antenna.
- For the antennas most typically used at base stations, the near-field remains limited to a distance of several metres from the antennas.
- Simple calculations reveal that for an antenna with a radiated power of about 20 Watts, ***The exposure limit for the general public can only be exceeded within the beam and at a distance of no more than 3 metres from the antenna.***

Field strength outside the beam

- The field strengths outside the beam are considerably lower than those in the beam and the exposure limits are not exceeded (see also Figure 5).
- From measurements that have been carried out at various locations near GSM 900 and DCS 1800 antennas, it is clear that outside the beam at a distance of 1 to 1.5 m underneath the beam and at a distance of less than about 3 m from the mast the field strength is not greater than 3 V/m.
- At distances further from the beam and the antenna the field strength is inversely proportional to the distance.
- At most of the accessible places on the roof, the field strengths are generally lower than 1 V/m.
- As a consequence of the protective effect of roof constructions, the field strength in the space underneath the roof is lower than that on the roof surface.
- A variety of different measurements reveal this to be lower than approximately 0.2 V/m.
- At distances further from the antenna (for example at street level) the field strength will also be considerably lower than 1 V/m.
- ***In all cases the exposure level lies considerably below the exposure limit.***

Dish antennas

- A dish-shaped antenna that provides a microwave link with another base station.

Main beam characteristics

- The antenna transmits electromagnetic fields at a frequency of between 24 and 40 GHz within a very narrow beam.
    - The opening angle is not more than about 3o.
    - The beam is therefore comparable to the light beam from a laser.

Field strength within the beam

- The power of the dish antenna used at base stations is not more than approximately $\mathbf{P_t = 130\ mW.}$
- The maximum power density for such antennas is four times the quotient of the available power and the surface (**A)** of the antenna. $\mathbf{S = 4\ P_t / A}$
    - This maximum occurs within the main beam at a distance from the antenna corresponding to one eighth of the far-field distance.
    - The far-field distance varies between 14.4 m at 24 GHz and 24 m at 40 GHz.
    - The maximum power density therefore occurs within 1.8 to 3 m from the antenna.
- For an antenna with a diameter of D=30 cm and a maximum power of 130 mW:
    - The maximum power density is $\boldsymbol{7.4\ W/m^2}$,
    - Which corresponds to an electric field strength of 52.7 V/m.
- ***For the general public, the exposure limit is 20 W/m^2, or at least 106 V/m*** (for a 24 GHz transmitter).
- ***Even within the beam, the exposure limit is not exceeded***.
- Furthermore, the likelihood of someone being present within the beam is small, as the beam is narrow, and in the usual position (affixed to a mast) it remains out of the reach of the general public.

Dish antennas

Field strength outside the beam

- Outside the beam, the field strength at all points is considerably lower than within the beam and thus also considerably lower than the exposure limit.
- For distances from the dish antenna greater than half of the far-field distance, the electric field originating from the antenna is inversely proportional to the distance from the antenna.
- The electric field strength is simple to calculate in this case.
- Table 4 shows the result of a calculation of the field strength outside of the main beam and at a distance of 4 m from the dish antenna.
- ***For the general public, the exposure limit is 20 W/m^2, or at least 106 V/m*** (for a 24 GHz transmitter).

Table 4 Electric field strengths outside the main beam at a distance of 4 m from a dish antenna with a capacity of 130 mW.

number of degrees outside the main beam	electric field strength (V/m)
5°	< 3.6
20°	< 1.5
50°	< 0.5
100°	< 0.15

Evaluating Mobile and Portable Devices, (FCC OET Bulletin 65)

- The new FCC guidelines differentiate between devices according to their proximity to exposed persons.
- In that regard, ***"portable"*** devices are defined as those devices that are designed to be used with any part of the ***radiating structure of the device in direct contact with the body of the user or within 20 cm of the body of the user under normal conditions of use***.
- This category would include such devices as ***hand-held cellular telephones*** that incorporate the radiating antenna into the handpiece.
- ***"Mobile"*** devices are defined by the FCC as transmitting devices designed to be used in other than fixed locations that would ***normally be used with radiating structures maintained 20 cm or more from the body of the user or nearby persons***.
- In this context, the term ***"fixed location"*** means that ***the device is physically secured at one location*** and is not able to be easily moved to another location.
- Examples of ***“mobile devices”***, as defined above, would ***include transportable cellular telephones ("bag" phones), cellular telephones*** and other radio devices that use vehicle-mounted antennas and certain other transportable transmitting devices.
- Evaluation of exposure from a ***portable or mobile*** device depends on how the device is to be used.
- With respect to ***portable*** devices, both the 1992 ANSI/IEEE standard and the NCRP exposure criteria, upon which the FCC guidelines are based, require that such ***devices comply with the limits for specific absorption rate (SAR)***.For portable devices ***SAR evaluation is routinely required*** by the FCC ***prior to equipment authorization or use.***
- Therefore, portable devices, as defined by the FCC, ***are to be evaluated with respect to SAR not MPE limits***.
- For most consumer-type devices, such as hand-held cellular telephones, ***the appropriate SAR limit is 1.6 watt/kg as averaged over any one gram of tissue***, defined as a tissue volume in the shape of a cube

Evaluating Mobile Devices

- The selection of the ***20-cm value for differentiating between "portable" and "mobile" devices*** is based on the specification in the 1992 ANSI/IEEE standard that 20 cm should be the minimum separation distance where reliable field measurements to determine adherence to MPEs can be made.
- Therefore, although at closer distances a determination of SAR is normally a more appropriate measure of exposure, for ***"mobile" devices, compliance can be evaluated with respect to MPE limits***, and the generic equations of this section.
- ***Evaluation prior to equipment authorization or use is routinely required*** for the following mobile transmitters:
    - If the operating frequency is 1.5 GHz or below and the effective radiated power (ERP) of the station, in its normal configuration, will be 1.5 watts or greater, or
    - If the operating frequency is above 1.5 GHz and the ERP is 3 watts or more.
- At this time routine evaluation for compliance is not required for devices such as "push-to-talk" portable radios and "push to talk" mobile radios used in taxicabs, business, police and fire vehicles and used by amateur radio operators.
    - These transmitting devices are excluded from routine evaluation because their duty factors (percentage of time during use when the device is transmitting) are generally low and,
    - For mobile radios, because their antennas are normally mounted on the body of a vehicle which provide some shielding and separation from the user. This significantly reduces the likelihood of human exposure in excess of the RF safety guidelines due to emissions from these transmitters.
- Duty factors associated with transmitting devices that are ***not "push-to-talk"*** such as transportable cellular telephones ("bag" phones) or cellular telephones that use vehicle-mounted antennas, would be generally higher, and these ***devices are subject to routine evaluation***.

Evaluating Portable Devices, based an SAR

- With respect to evaluating portable devices, various publications are available that describe appropriate measurement techniques and methods for determining SAR for compliance purposes.

ANSI/IEEE C95.3-1992 :

- American National Standards Institute (ANSI), "Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave." ANSI/IEEE C95.3-1992. Copyright 1992, The Institute of Electrical and Electronics Engineers, Inc. (IEEE), New York, NY 10017.

and ***NCRP Report No. 119:***

- National Council on Radiation Protection and Measurements (NCRP), "A Practical Guide to the Determination of Human Exposure to Radiofrequency Fields," NCRP Report No.119, 1993. Copyright NCRP, Bethesda, MD 20814.

- For purposes of evaluating compliance with localized SAR guidelines, portable devices should be tested or evaluated based on normal operating positions or conditions.
- A sub-committee sponsored by the IEEE has been recently formed to develop specific and detailed recommendations for experimental and numerical evaluation of SAR from portable devices.
  - IEEE Standards Coordinating Committee 34 (IEEE SCC34), sub-committee II.
- For portable devices operating ***at frequencies above 6 GHz*** special considerations are necessary.
- The localized SAR criteria only apply at operating frequencies between 100 kHz and 6 GHz.
- For portable devices that operate above 6 GHz (e.g., millimeter-wave devices) localized SAR is not an appropriate means for evaluating exposure.
- ***At these higher frequencies, exposure from portable devices should be evaluated in terms of power density MPE limits instead of SAR***.
- Power density values can be either calculated or measured, as appropriate.

ICNIRP Statement: (Health Physics 1996)

HEALTH ISSUES RELATED TO THE USE OF HAND-HELD RADIOTELEPHONES AND BASE TRANSMITTERS

kg^{-1} for 1.8 GHz radiation. This implies that the IEEE basic limit of 8 W kg^{-1} averaged over 1 g mass will be exceeded for duty cycle weighted powers greater than 1.7 W for 900 MHz radiation and 1.0 W for 1.8 GHz radiation.

In the case of hand-held radiotelephones, however, the exposure distance for the user is less than $2D^2/\lambda$, and the RF field contains significant reactive components that interact strongly with objects and with people. This may result in a localised pattern of absorption produced from the resulting anisotropic field. Demonstration of

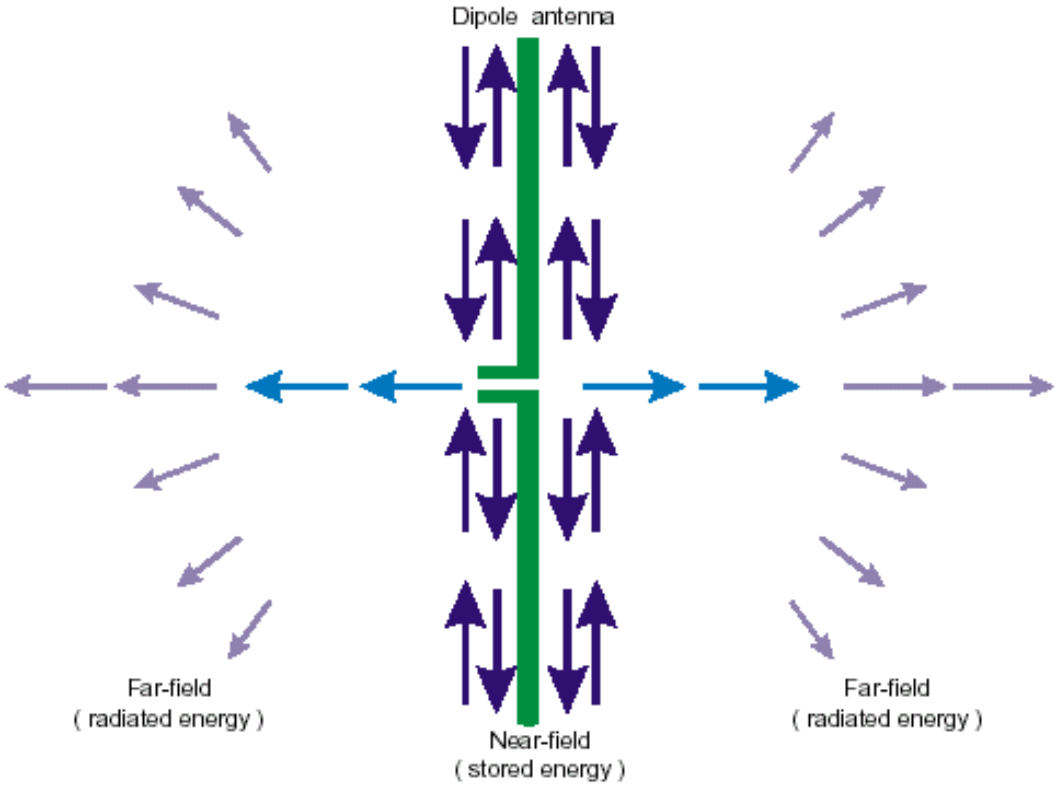
Most of the established biological effects of exposure to RF fields are consistent with responses to induced heating, resulting in rises in tissue or body temperature of greater than 1°C (UNEP/WHO/IRPA 1993). Most stud-

mass. A calculation of temperature increase for a realistic finite element model of the eye (Scott 1988) has yielded a maximum rise of about 1°C from the absorption of 10 W kg^{-1} throughout the eye.

While ICNIRP is formulating comprehensive guidelines on exposure limits, the basic limits for localized exposure have been agreed upon. ICNIRP recommends a localized SAR limit of 10 W kg^{-1} averaged over any 10 g mass of tissue in the head for occupational exposures and 2 W kg^{-1} averaged over any 10 g mass of tissue in the head for general public exposure.

Fields from Mobile Phone Systems

- Figure 4.4, which shows the directions in which most of the energy flows.
  - The electric field directions are in the plane of the paper and perpendicular to the directions of energy flow, while
  - The magnetic field directions are perpendicular to the paper.
- Far from the antenna, the energy flows outwards. However,
- Near to the antenna, most of the energy is stored around the antenna,
  - flowing to and fro along its length, and only a small proportion is radiated outwards.



- Figure 4.4 Electric dipole antenna showing the directions in which most of the electromagnetic energy flows.
- In the near-field region,The amount of power being radiated outwards is the same as that in the far-field region, but near to the antenna a considerable amount of electromagnetic energy is also being stored.
- So as well as the net radiated energy flowing outwards, there is additional energy that oscillates to and fro.
- These oscillating flows occur perpendicularly to the outward direction from the antenna as well as along it so the net energy flow is tilted with respect to the outward direction.
- The E-field and B-field are still at right angles to each other and to the direction in which the energy is being carried, but they are no longer in phase and their values can differ appreciably from the simple expressions that apply in the far-field region.

Stewart's Report.

The UK Government's Research.

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- This was the most comprehensive in the world and concluded that:
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    9. improvements in dosimetry
    10. possible impact on health of sub-cellular and cellular changes induced by radiofrequency radiation
    11. psychological and sociological studies related to the use of mobile phones
    12. epidemiological and human volunteer studies.

Cellular phone technologies –1.

GSM mobile phones.

- ***The maximum powers that GSM mobile phones are permitted to transmit by the present standards are 2 W (900 Hz) and 1 W (1800 Hz).***
- Nevertheless it seems possible that some older phones might still be in use whose maximum powers are 3.56 W (900 Hz) and 1.78 W (1800 Hz).
- However, ***because TDMA is used, the average powers transmitted by a phone are never more than one-eighth of these maximum values (0.25 W and 0.125 W, respectively)***
  - Usually these powers are further reduced by a significant amount due to the effects of adaptive power control and discontinuous transmission.
- ***Adaptive power control (APC) means that the phone continually adjusts the power it transmits to the minimum needed for the base station to receive a clear signal.***
  - ***This can be less than the peak power by a factor of up to a thousand if the phone is near a base station.*** Although the power is likely to be appreciably more than this in most situations.
- ***Discontinuous transmission (DTX)*** refers to the fact that the power is switched off when a user stops speaking either because he/she is listening or because neither user is speaking.
  - So if each person in a conversation is speaking for about half the time, he/she is only exposed to fields from the phone for that half of the conversation.
- In summary, the largest output from a phone occurs if it is mainly used at large distances from the base station or shielded by buildings, etc.
- In this situation, the peak powers could approach the values of 2 W (900 Hz) and 1 W (1800 Hz) and the average powers could approach the values of 0.25 W (900 Hz) and 0.125 W (1800 Hz).

TETRA (digital)

- The new TETRA (Terrestrial Enhanced Trunk Radio System) technology is not intended for public systems connected to the telephone network. It is designed for closed groups (eg for communication within an organisation or company) and is coming into use for the emergency services and some commercial applications.
- Frequency bands are available at about 400 MHz and 900 MHz. The modulation method is complex. The main features, however, are a 25 kHz band divided into four frequency channels, each of which is divided into 56.7 ms frames containing 4 time slots. So the transmission is pulsed at 17.6 Hz (1/56.7 ms).

Cellular phone technologies –1.

UMTS/IMT-2000 (digital)

- A third generation of mobile telecommunications technology has now been agreed and will be introduced in the next few years. In Europe this is called UMTS (Universal Mobile Telecommunication System) and worldwide it is known as IMT-2000 (International Mobile Telecommunications - 2000).
- The frequency bands identified for this system are 1885–2010 MHz and 2110–2200 MHz
- The specifications allow some choice in the modulation to be used but it is expected that the main choice will be CDMA (Code Division Multiple Access).
- The frequency channels will have 5 MHz bandwidths and, as in GSM, each can be used by a number of users at the same time. However, in CDMA, a transmission is “labelled” by a coding scheme that is different for each user.
- Since all the transmissions occur at the same time, ***the changes in amplitude of the carrier wave are essentially random (noise-like)***.

DECT (digital)

- Cordless phones are used at very short ranges between a base station located at the telephone socket outlet ***within the house or office*** and the cordless phone handset.
- Earlier cordless phones used analogue technology and are now being replaced by a digital system, DECT (Digital Enhanced Cordless Telecommunications) which has performance advantages in terms of privacy and protection against interference.
- DECT is now in widespread and increasing use and operates at similar ***frequencies, around 1850 MHz***, to cellular mobile phones.
  - There are ten channels with a spacing of 1.728 MHz.
  - In each channel there are 24 time slots within a 10 ms frame and the transmission within a slot uses a form of frequency modulation.
  - So a particular phone emits a pulse every 10 ms (100 Hz) during one of the time slots.
- ***Since the maximum power emitted is 250 mW, the average power emitted is about 10 mW.*** Possibly, DECT technology may form part of an overall UMTS system.

Fields from Mobile Phone Systems

- The RF power from a phone is mainly transmitted by the antenna together with circuit elements inside the handset.
  - The antenna is usually a metal helix or a metal rod a few centimetres long extending from the top of the phone.
  - Neither type is strongly directional, although more power is radiated in some directions than others.

Fields and intensities when the antenna is a long way from the head or body.

- At points 2.2 cm from an antenna (the distance at which calculations were made), ***the maximum values of the electric field are*** calculated to be
  - about 400 V/m for a 2 W, 900 MHz phone and
  - about 200 V/m for a 1 W, 1800 MHz phone and
- ***The maximum magnetic field*** is calculated to be
  - about 1 μT for both phones*.
- For both 2 W, 900 MHz phones and 1 W, 1800 MHz phones the ***maximum intensity (power density) at 2.2 cm from the antenna is very roughly about 200 W/m^2***.
  - This is about one-quarter of the intensity of the Sun's radiation on a clear summer day (***800 W/m^2)*** , although the frequency of the emission from a phone is a million or so times smaller).

Fields and intensities when the When the antenna is near the body,

- ***The radiation penetrates the head or the body it but the fields inside are significantly less, for the same antenna, than the values outside***.
- For example, the largest maximum fields inside the head when its surface is 1.4 cm from the antenna are calculated to be
  - ***about three times smaller than the values given above***.
- The average field values are all appreciably less than these maximum values for the reasons explained earlier.
- As well as these RF fields, that are pulsed at 8.34 Hz and 217 Hz, there are magnetic fields near to the phone that oscillate at these same frequencies, and are a few μT in magnitude.
- These are generated by currents flowing from the battery which are switched on and off at these frequencies as a result of TDMA.
- ***The largest values of electric field E inside a model of a head whose surface is 1.4 cm from the antenna were also computed and are***
  - ***about 120 V/m for a 900 MHz antenna radiating 2 W and***
  - ***about 70 V/m for a 1800 MHz antenna radiating 1 W.***

Output from base stations

- The base station antennas serving macrocells are either mounted on free-standing towers, typically 10–30 m high, on short towers on top of buildings, or attached to the side of buildings.
- In a typical arrangement, each tower supports three antennas, each transmitting into a 120° sector.
- A large proportion of the power is focussed into an approximately horizontal beam typically about 6° wide in the vertical direction and the rest goes into a series of weak beams (called side lobes) either side of the main beam.
- The main beam is tilted slightly downwards (Figure 4.5) but does not reach ground level until the distance from the tower is at least 50 m (usually 50–200 m).

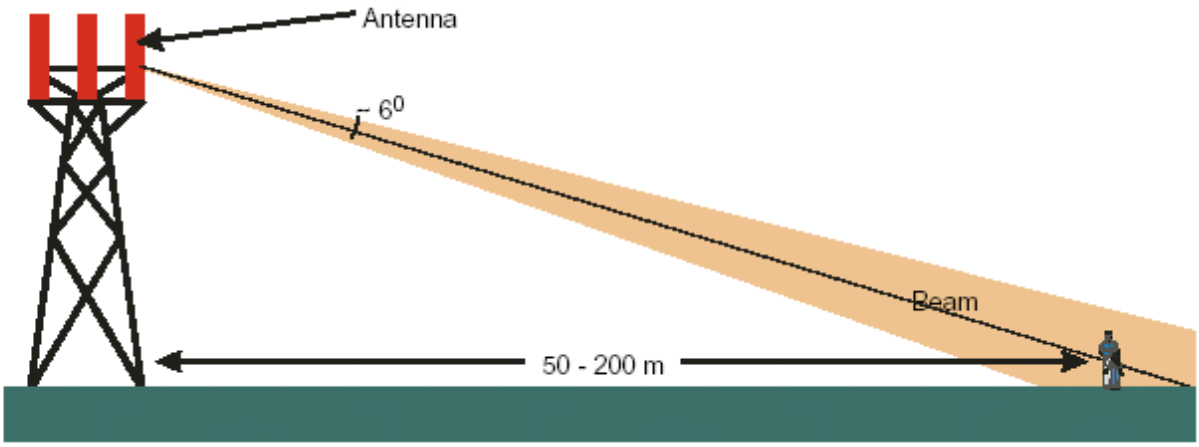

Figure 4.5 ***Main beam from an antenna mounted on a tower. The beam is in fact less well defined than that shown here and there is a series of weak side lobes either side of it***

- The base station antennas transmit appreciably greater power than the phones.
- The limit to the power is formally set by the need to avoid RF interference and defined by a licence issued by the Radiocommunications Agency.
- This does not directly limit the total power emitted but does so indirectly by fixing the maximum intensity (power density) that an antenna can transmit into the main beam.
- This is done by ***defining the maximum "equivalent isotropically radiated power" (EIRP) that can be transmitted***.

Fields from GSM Base Stations

- The EIRP is the power that would have to be emitted equally in all directions to produce a particular intensity (power density).
- In fact, as already noted, the antennas used are very far from isotropic, with most of the power being emitted into the main beam, and ***the ratio of the EIRP to the total power output is called the gain of the antenna***.
- ***For a 120° sector antenna the gain is usually between about 40 and 60.***
- ***The licence sets the maximum EIRP at 1500 W per frequency channel corresponding to a maximum total radiated power of about 30 W per channel (= EIRP/gain)***.
- It also limits the number of channels per antenna to 16 (for 1800 MHz) and 10 (for 900 MHz).
- However, we have been told that in practice the number of channels is typically:
  - less than 4 for 1800 MHz and radiated power = 120 W
  - 2 to 4 at 900 MHz (FEI, 2000), radiated power = 60–120 W

which would correspond to maximum radiated powers of less than 120 W and 60–120 W, respectively.

- Similarly, the total radiated power emitted from an antenna is generally limited by the characteristics of the equipment to somewhat under 70 W (FEI, 2000), and a figure of 60 W will be assumed in this report.
- It needs to be stressed that the number of channels used, and hence the total radiated power, is limited by technical rather than legal requirements, which would in fact permit significantly larger powers to be radiated.
- ***As with a phone, and for largely the same reasons, the average power transmitted by a base station is normally less than the maximum power***, although in this case it could rise to the maximum at times (rather than to one-eighth of the peak power in the case of a phone).
- By the inverse square law, ***the maximum intensity*** (power density). in the main beam at a point on the ground 50 m from a 10 m tower carrying an antenna transmitting 60 W into a 120° sector ***is about 100 mW/m^2*** *.
- This corresponds to oscillating electric and magnetic fields of about 5 V/m and 0.02 μT, respectively,
  - very roughly about 50 to 100 times smaller than those 2.2 cm from the antenna of a phone.

Comparing Fields from GSM Base Stations and mobile Phones

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- ***The heating effects that these fields would produce will vary with the intensity and are about 5000 times smaller than the maximum value 2.2 cm from the antenna of a mobile phone***.

The RF intensity (power density) on the ground

- The RF intensity on the ground is not zero outside the main beam, because of the power emitted into the side lobes.
- Its value will depend on the design of the antenna.but it seems unlikely that it could ever be significantly more than that within the beam.
- So the values given above should be reasonable indications of the maximum intensity and fields that would be present on the ground around a base station.
- The intensity (power density) will, however, become appreciably larger as the antenna is approached, as it might be by maintenance workers.
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