“Capacity Building and Strengthening Institutional Arrangement”

Workshop: “Environmental Impact Assessment (EIA) (for Assessors)”

Environmental Impact Assessement Models:

Electromagnetic Fields

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APAT

Agency for Environmental Protection and Technical Services

Environmental Reference Frame Non-Ionizing Radiation

- Normative aspects;
- Elements for the actual and future characterization;
- Impacts assessment

Environmental components and factors definitions by enclose I DPCM 27/12/1988

h) **Ionizing and Non-Ionizing:** considered either regarding the natural than the human environment;

The Enclose II of DPCM 27/12/1988
It gives the elements for the
"Characterization and analysis of the components and environmental factors"

Definitions:Non-Ionizing Radiations by enclose II DPCM 27/12/1988

The art.5 of the enclose II - D.P.C.M. 27 Dicembre 1988, consider that the environment quality characterization for the Ionizing and Non-Ionizing Radiation component, will have to allow the definition of the trasformation induced by the project, verifying the compatibility with the existing standards and with the prevenction criteria for environment and uman damage, by means of:

a) Medium and maximum radiation level description in the interesting area, for natural and antropic cause, before the project;
b) Sources and emission predictable level definition and characterization in consequence of the project;

Definitions:Non-Ionizing Radiations by enclose II DPCM 27/12/1988

c) The emitted quantitative definition in lapse of time and the final location of the material (keep into account the site's characteristic) in case of the project can produce radioactive material relase in the environment.

d) The predicted level definition in consequence of the project for the different kind radiations;

e) The definition of the resulting exposing scenario and their interpretation in the light of the rilevant reference parameters (standards, acceptability criteria, ect…);

Definitions: Non-Ionizing Radiations

by enclose III DPCM 27/12/1988

In particular the enclose III, in reference of any class of projects, specify that:

Thermic station and plants for the electric energy production (combustion plants, nuclear power plants and other nuclear reactors) Basing of art.5, comma 3, will have to describe and estimate the effects on the environment with reference to the electric infrastructures and electric transmission lines, as well as to the projectual choice and to the detecting attenuation mesures;

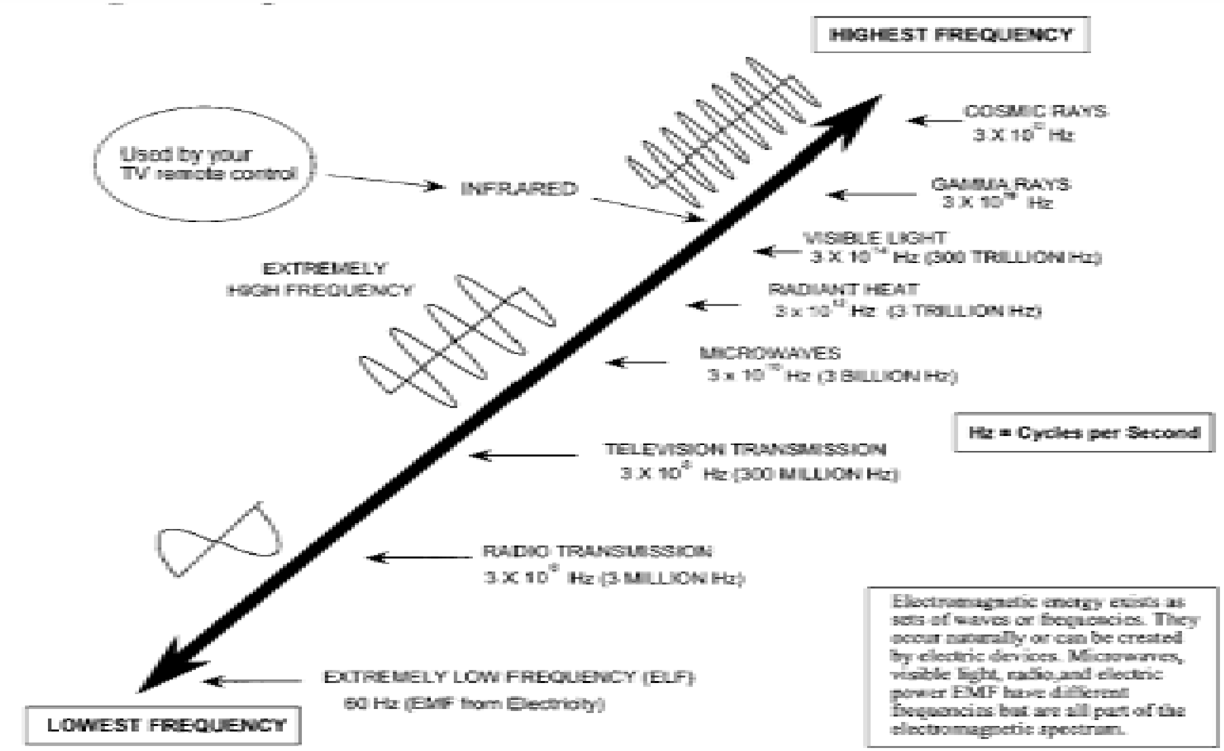
External aerial electric transmission lines for carrying out and distribuition of the electric power with operational voltage higher than 150 kV and length path higher than 15 km.

Impact Evaluation Ionizing and Non-Ionizing Radiation

The radiation (electromagnetic wave) can be classify, in relation to the ***frequency*** ad ***energy***, as “ionizing radiation” or “non-ionizing radiation (NIR)”

The ***Non-Ionizing Radiation*** belong to the part of electromagnetic spectrum where the fotonic energy is too much low to break the atomic bond and it basically produce thermical effects.

The ***Ionizing Radiations***, because their high energy, are able to break the cellular molecular bonds and they can induce genetic mutation.



Extracted picture by PSC Public Service Commition – State of Wisconsin (USA)

NIR include: Extremely Low Frequency fields (ELF, from 0 Hz to 10 kHz), Radio Frequency field (RF, from 10 kHz to 300 MHz) e MicroWave fields (MW, from 300 MHz to 300 GHz)

Current-State Characterization
Non-Ionizing Radiation

For the current-state characterization (before the project realization) the following factors are considered:

- Interesting area definition (type of receptors and their description and localization);
- Location and description of the electrical and physical parameters of sources in the interested project area (frequency, dimensional parameters, electric parameters, etc.);
- A catalog, with planimetric information, of possible electromagnetic field sources interfering with realizing project (as example electric transmission lines interfering with the railway lines, etc.);
- Electric, magnetic and electromagnetic field estimation in function of the distance from the source and the surrounding environment characteristic (electromagnetic bottom map before project),
- Computing algorithm type and version for electromagnetic field estimation (comply with normative CEI).

Analysis of the Project-Component Interation Non-Ionizing Radiation

The analysis of emitted radiation in the environment following up to project realization, is executed by:

- Location and description of the new electrical and physical parameters of sources in the interested project area (frequency, dimensional parameters, electric parameters, etc.);
- New interesting area definition (type of receptors and their description and localization);
- Esteem of total radiation levels taking in account of all connected and not connected sources to the project;
- Description of adaptation necessary for any interference resolution between sources (like electrical trasmission line) and project;
- Definition of the mitigation action necessary for the most sensitive and mainly exposed areas;
- Definition of the post-operam monitoring;

Impact Assessment Non-Ionizing Radiation

The evaluation of the insertion of the project in the environment pass throught:

- ***Impact prediction***, that is an esteem of the entity of the impact through the use of numerical, logic or other type models;

- ***Evaluation of the impact's entity***, that means a evaluation of "quality loss" of environment in consequence to:

  - human resources consumption (natural assets, projects);
  - risk of dangerous situations for human health and human activities.

The evaluation are facilitate by existing reference standards place by the law.

Impact Assessment
Properties of electromagnetic fields

The ***frequency*** represent a relevant parameter for the physical properties determination of the electromagnetic fields and it indicates how many time an event repeats in lapse of time. The wave frequency is the number of ripples to the second.

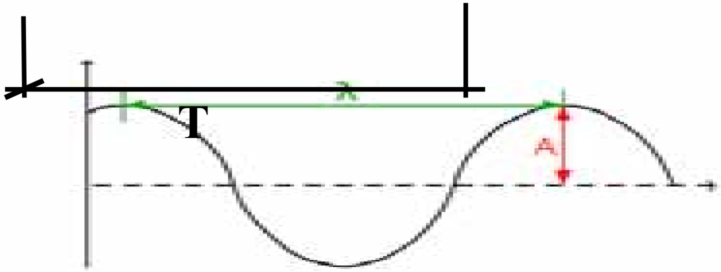
The wavelenght λ is the distance between two consegutive peaks of oscillating wave.

$c=\lambda/T$ or $c= \lambda f$

$f = 1/T$.

“c” is the speed of light in vacuum = 300.000 km/s

T is the period



Impact Assessment Properties of electromagnetic fields

- The Extremely Low Frequencies electromagnetic fields (ELF) have similar properties with statics fields (0 Hz), but their amplitude oscillates indipendently with the time. So that are named *quasi-static fields.*
  There are two quantities that physicists may refer to as the magnetic field, notated H and B. In a vacuum, they are equal. Although the term "magnetic field" was historically reserved for H, with B being termed the "magnetic induction". B is now understood to be the more fundamental entity.
  $B = \mu_0 H$ as μ_0 vacuum magnetic permeability.
  In SI units, B and H are measured in teslas (T) and amperes per metre (A/m), respectively and it's true the relation: 1 μT = 0.8 A/m.
- For high frequencies (RF-MW) the electromagnetic field may be described in terms of electromagnetic waves. Their propagation is associated to energy transfer from the source.
  Electromagnetic radiation can be imagined as a self-propagating transverse oscillating wave of electric and magnetic fields. This diagram shows a plane linearly polarised wave propagating from left to right.
  In the vacuum: E/H = 377 W
  377 W (ohm) is the impedance of the vacuum

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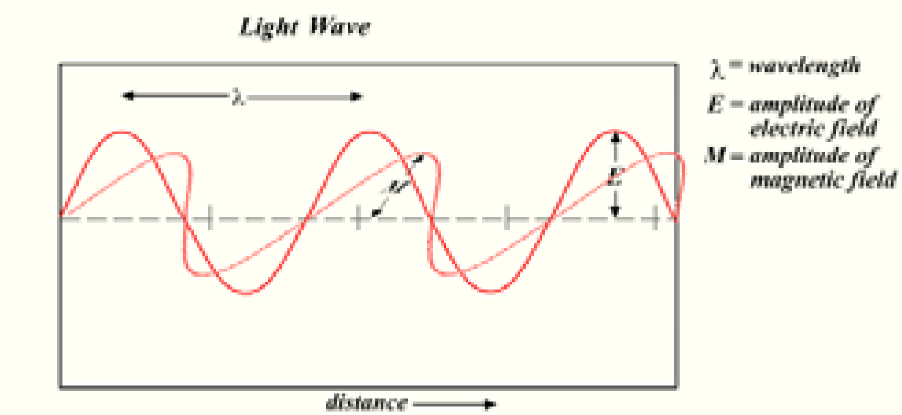


Impact Assessment Properties of electromagnetic fields

- In the ELF range, the fields E and B take indipendent values, so it is necessary to estimate both parameters to totally define the “electromagnetic enivornment”.
- For RF-MW radiation, it is enough to determine the electric field or the magnetic induction B cause the relation already seen.
- The mesure of the physical parameters E and B allow to determine the level exposion to the electromagnetic field. So, these parameters are named **exposion parameters**.

Impact Assessment Properties of electromagnetic fields

Near field

Short distance from the source (respect to source dimension and wavelenght) the electric and magnetic fields have complex distribution.

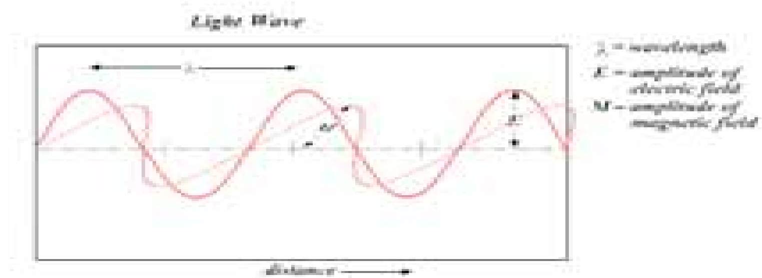
ELF (50 Hz) → λ=6000 km

Far field

For distances major of λ, the electric and magnetic fields have a regular trend and they travel energy far from the source. Moreover:

- they spread through spherical wave;
- they are perpendicular each other;
- they are in spatial and temporal phase;
- they have proportional intensity: E =377 ·H (in vacuum or air);
- they are a single entity named ***electromagnetic field.***

Mobile phone (900 MHz) → λ=30 cm



Impact Assessment Non-Ionizing Radiation

To evaluate electromagnetic impact is necessary make a distinct analysis respect to the radiation frequency.
The two DPCM (Decree of the President Council of Ministers) 8/07/2003 that put into effect the law 22/02/2001, n°36 – "Law about protection from the exposures to electric, magnetic and electromagnetic fields", regard:

- DPCM 8/7/'03 - "Establishment of exposure limits, attention values, and quality goals to protect the population against electric, magnetic, and electromagnetic fields at power frequencies (50 Hz) generated by power line"
- DPCM 8/7/'03 - "Establishment of exposure limits, attention values, and quality goals to protect the population against electric, magnetic, and electromagnetic fields generated at frequencies between 100 kHz and 300 GHz", for fixed sources ***(fixed telecomunication and radio-telecomuniction systems)***.
- For protection against exposure to fields in the frequency range 0 Hz – 100 kHz generated by sources unlike power lines and assimilated, the restrictions set out in the EU Recommendation of 12 July 1999 - published in the O.J.E.C. on July 30,1999 - are applied in their entirety.

DPCM 08/07/2003

"Establishment of exposure limits, attention values, and quality goals to protect the population against electric, magnetic, and electromagnetic fields at power frequencies (50 Hz) generated by power line"

	Electric field intensity E (V/m)	Magnetic Induction B (uT)
Exposure limits	5000 (rms values)	100 (rms values)
Attention values		10 (median of values recorded over 24 hours under normal operational condition)
Quality goals		3 (median of values recorded over 24 hours under normal operational condition)

Exposure limits **must not** be exceeded

Quality goal is adopted for the purpose of the progressively minimising exposures to electric and magnetic fields generated by 50-Hz power lines:

a) **In designing new power** lines in the:
- nighbourhood of children's playgrounds,
- residential dwellings,
-school premises,
-areas where people are staying for
-4 hours or more per day,

b) **In planning developments** in the proximity of existing electric power lines and installations, including the categories mentioned above.

Attention value is adopted in children's playgrounds, residential dwellings, school premises, and in areas where people are staying for 4 hours or more per day. Attention value represent a cautionary measure to protect against any possible **long-term effects** that might be related to power frequency (50 Hz) magnetic fields.

DPCM 08/07/2003

- To determine **right-of-way**, reference shall be made to the quality goal of Art. 4,

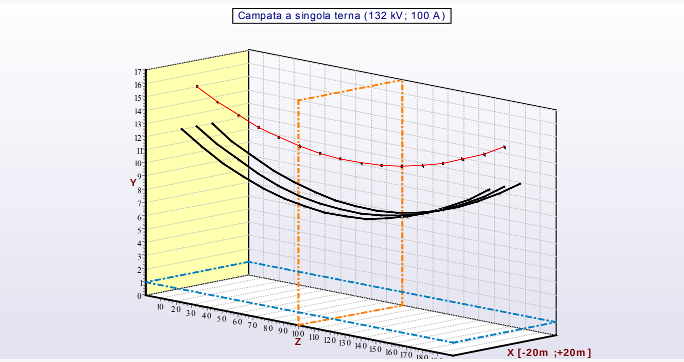
  and to the electric current load under normal operating conditions of the line, as

  defined by Standard CEI 11-60.

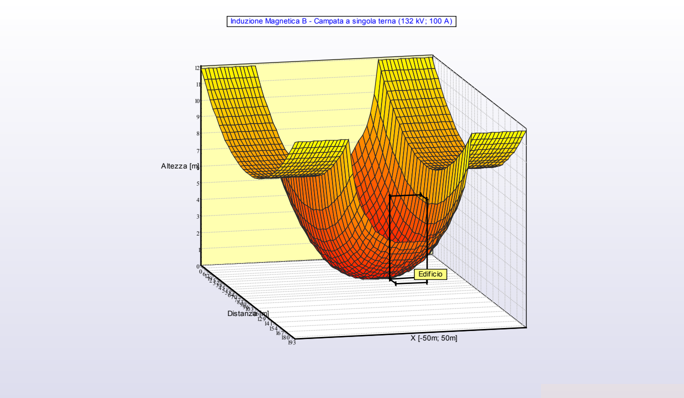
DPCM 08/07/2003

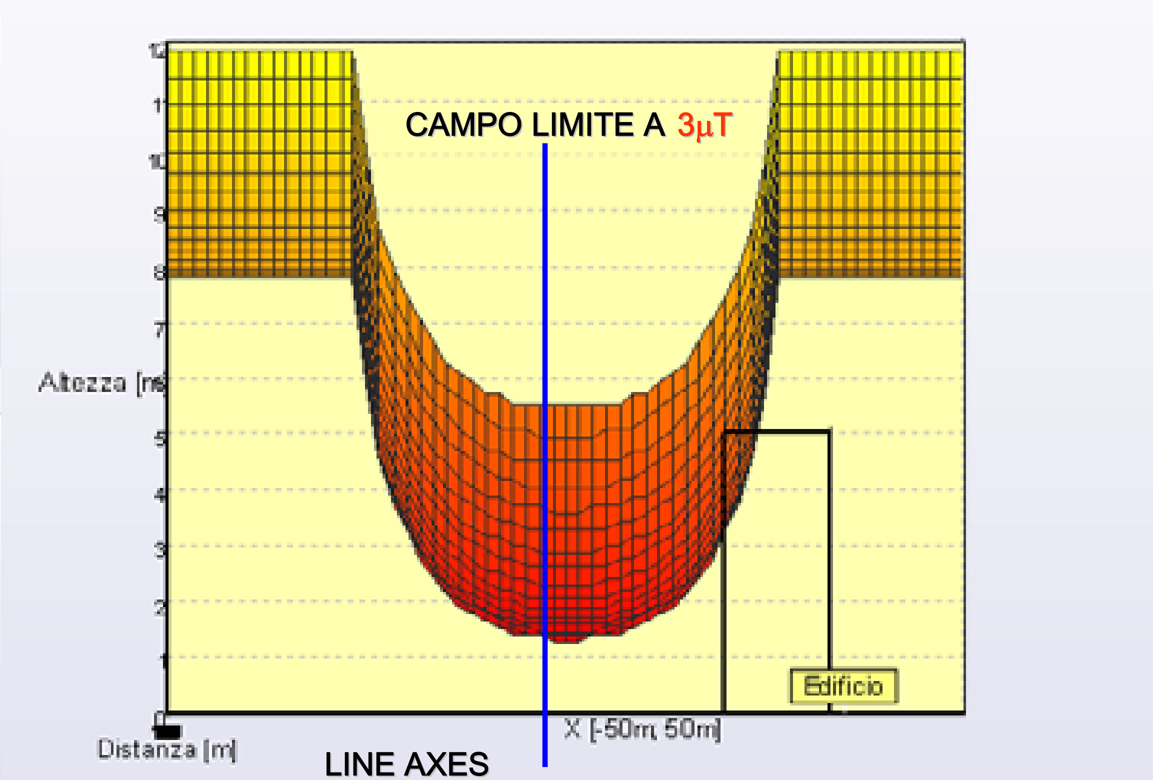
Art.6 – Parameters to determine right-of-way for power lines

CAMPATA DI 200 m, SINGOLA TERNA 132 kV; 100A



CAMPATA DI 200 m, SINGOLA TERNA 132 kV; 100A





Picture extracted by simulation software SteMa ver. 1.2 by Euronia

DPCM 08/07/2003

"Establishment of exposure limits, attention values, and quality goals to protect the population against electric, magnetic, and electromagnetic fields generated at frequencies between 100 kHz and 300 GHz"

Table 1	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)
Exposure limits			
0.1 < f = 3 MHz	60	0.20	-
3 < f = 3000 MHz	20	0.05	1
3 < f = 300 MHz	40	0.10	4

Exposure limits **must not** be exceeded

Table 2	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)
Attention values			
0.1 MHz < f = 300 GHz	6	0.016	0.10 (3 MHz - 300 GHz)

Attention value is adopted in children's playgrounds, residential dwellings, school premises, and in areas where people are staying for 4 hours or more per day as well as in outdoor annexes that may be used as residential environments, such as balconies, terraces, courtyards, but excluding roof pavings. Attention value represent a cautionary measure to protect against any possible **long-term effects** that might be related to exposure to fields in the frequency range 100 kHz-300 GHz.valori di CEM che non devono essere superati all'interno di edifici adibiti a permanenze non inferiori a quattro ore giornaliere e loro pertinenze esterne, che siano fruibili come ambienti abitativi quali balconi, terrazzi e cortili esclusi I lastrici solari. Essi costituiscono la misura di cautela ai fini della protezione da possibili ***effetti di lungo periodo***

DPCM 08/07/2003

"Establishment of exposure limits, attention values, and quality goals to protect the population against electric, magnetic, and electromagnetic fields generated at frequencies between 100 kHz and 300 GHz"

Table 3	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)
Quality goals 0.1 MHz < f = 300 GHz	6	0.016	0.10 (3 MHz - 300 GHz)

1. In order to progressively minimise exposure to electromagnetic fields, the calculated or measured values of fields that are the subject of the present decree, shall not, in highly frequented outdoor areas, exceed the values set out in Table 3. The values shall be averaged over any six-minute period in an area equivalent to the vertical cross-section of the human body.
2. Highly frequented areas shall include buildings or permanent structures employed for social, health, or recreational needs.

Impact Assessment The power lines

With the term "power line" is generally intended the set of the electric trasmission lines, the trasform substation and the electrical trasform booth (art.3 L. 22/02/2001, n°36).

The technique used to electric energy transfer was to utilize high voltages and low current for minimize the power loss and materials.

Classification of electric trasmission lines.

Type	Voltage (kV)	Current (A)
Transmission	380	1500
Transmission	220	550
Primary distribution	150	375
Primary distribution	132	
Low voltage distribution	<30	140
Low voltage distribution	0.380	

Impact Assessment Electromagnetic characterization of power lines

➢ *Electric field*

The electric field strenght generated from power line depends by:

- Operating voltage;
- Height of power wires from the ground;
- Conductors geometric configuration and their phases;
- Distance from metallic pylon structure;
- Lateral distance from the longitudinal axis of the line;
- Height from the ground of the interest evalueted point;

➢ *Magnetic field*

The magnetic field strenght generated from power line depends by:

- Instantaneous current in the phase conductors;
- Height of power wires from the ground (minimum height is indicated by DM 449/88 and further up-date DM 16/01/1991 and 05/08/1998);
- Conductors geometric configuration and their phases;
- Distance from metallic pylon structure;
- Lateral distance from the longitudinal axis of the line;
- Height from the ground of the interest evalueted point.

Impact Assessment:Electric field

Unperturbed field conditions

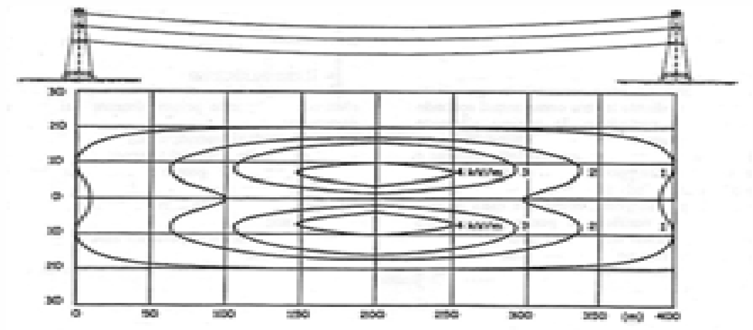


Figura 1 – Lateral profile of the electric field level curves (at 1 m from ground) under a typical power line span at 380 kV double-wire per phase. The vertical axes indicates the distance from the pylon's axes.

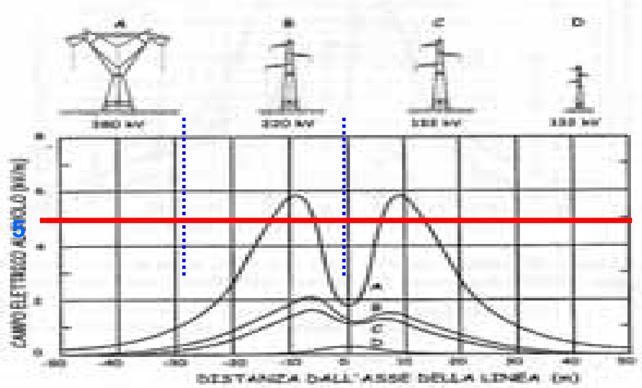


Figura 2 – Lateral profile of the electrical field at 1 m from ground for typical pylon and voltages.

The electric field is strongly prejudiced with the presence of obstacles that essentially produce two effects:

field deformation (relevant in the monitoring because the instruments probes can alterate the local trend of the electric field);

Strenght attenuation (screen effect of the construction structures).

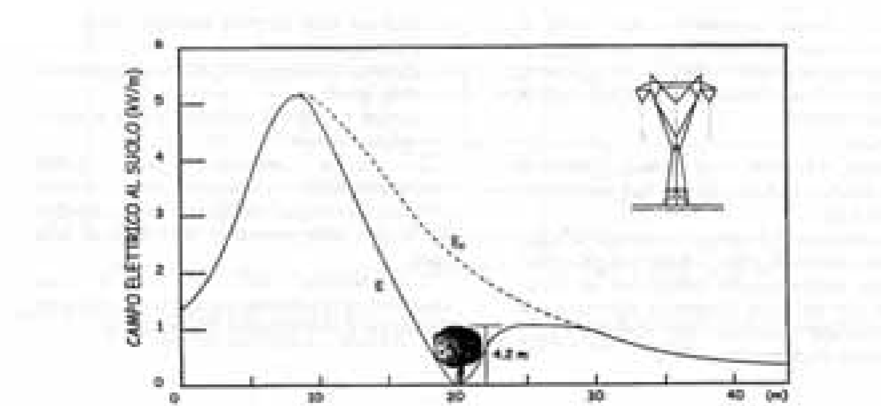


Figura 3 – Screening effect of a tree on electric field at soil. On x-axes the distance from the line axes.

Impact Assessment Magnetic field

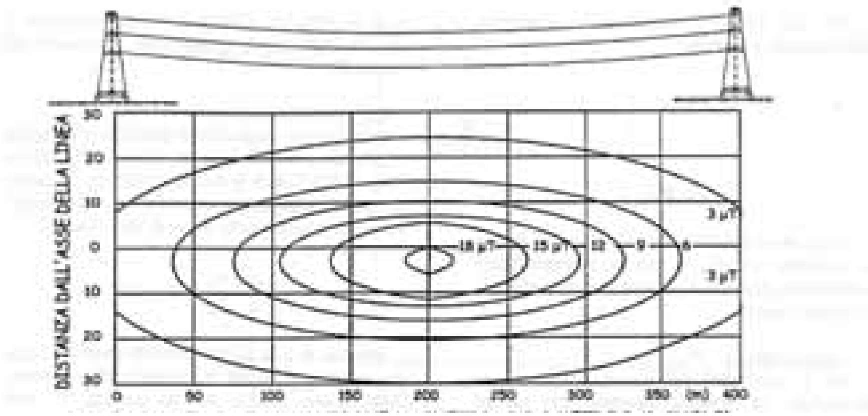


Figura 4 – Lateral profile of the magnetic induction B level curves (at 1 m from ground) under a typical power line span at 380 kV. The vertical axes indicates the distance from the pylon's axes

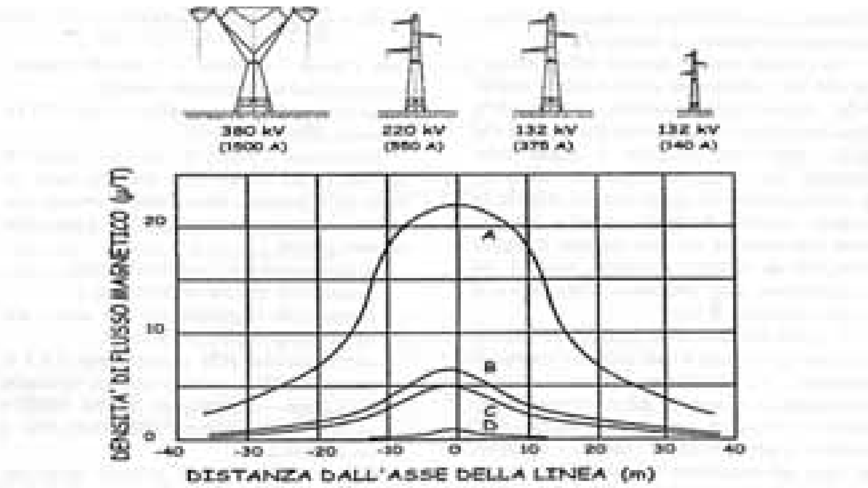
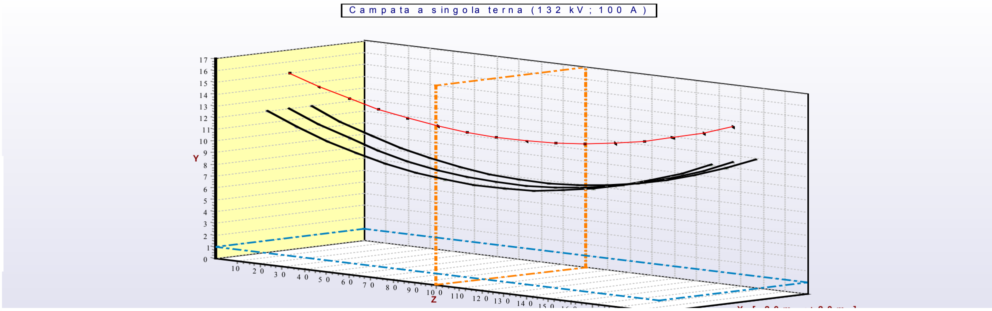
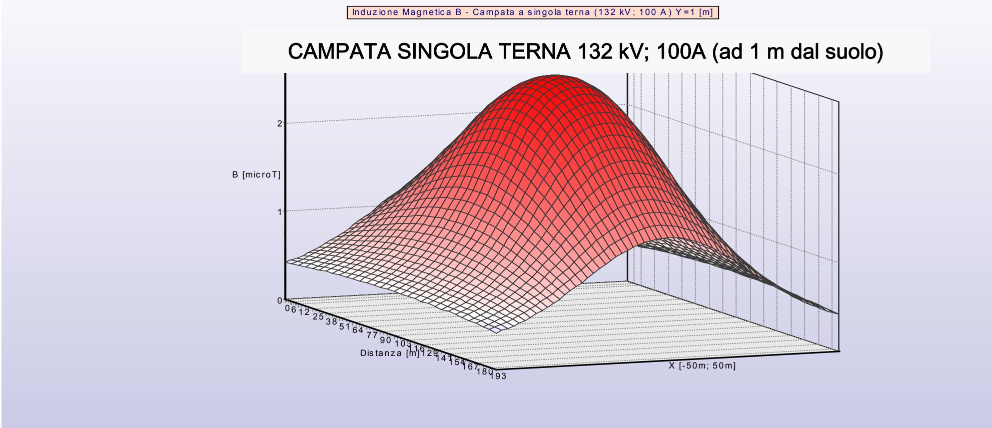


Figura 5 – Typical values of magnetic induction B generated by 380 kV, 220 kV, 132 kV, 20 kV power lines under normal operation conditions for different kind of pylons.

The magnetic field is not significantly screening by construction structures and the magnetic induction value remains bond to the current strenght and to the lines distance.





Pictures extracted from: "Campi elettromagnetici: tecniche di monitoraggio ambientale e principi dell'interazione biologica" di C. Bianchi, A. Lozito, A. Meloni e da simulazioni con il software SteMa ver. 1.2 di Euronia

Impact Assessment Previsional model

- **Electric field**

For electric field estimation exist either analytical model than numerical methods. Between analytical model the best for power line application is that image method based. This method consider:

-Three–phase lines as a set of infinity-lenght conductors;

- parallel conductor;

- land considered as infinity extension plane.

The boundary condition impose a zero potential on plane and than we can substitute the land-plan with charge distribution simmetric and opposite to the plane where the power line lie.

- **Magnetic field**

The magnetic induction B can be calculate as provided for technical norm CEI 211-4, with the method based on Biot.Savart law:

$$B=\frac{\mu_0}{2\pi}\frac{I}{d}u_l x u_r$$

where:

u_i the infinitesimal lenght of conductor carrying electric current;

u_r the unit vector to specify the direction of the vector distance r from the current to the field point.

Impact mitigation

- ***Delocalization***

It consist to detect an alternative path at the entire power line, so to reclaim the major exposed zone.

However, in overpopulation zone, it results difficult to realize because the danger is translate on other citizen the problems that have rendered the mitigation necessary.

- ***Move away the power line***

It consist to move away a part of the line.

Obviously, in the case of overpopulation, the difficulty is to realize the reclamation cause lack of space.

Impact mitigation

- ***Burrow the line***

This solution, usually required by citizens, consist to burrow the cables of the power line. This slution presents any problems:

- **In case of reclamation zone, an appropriate space is necessary to realize techonological structures that allow the transition from aerial line to burrow cable and vice versa.**
- **High cost for the underground power cables;**
- **High costs for installation and maintenance;**
- **High electromagnetic level produced by burrow line in correspondence of the line.**

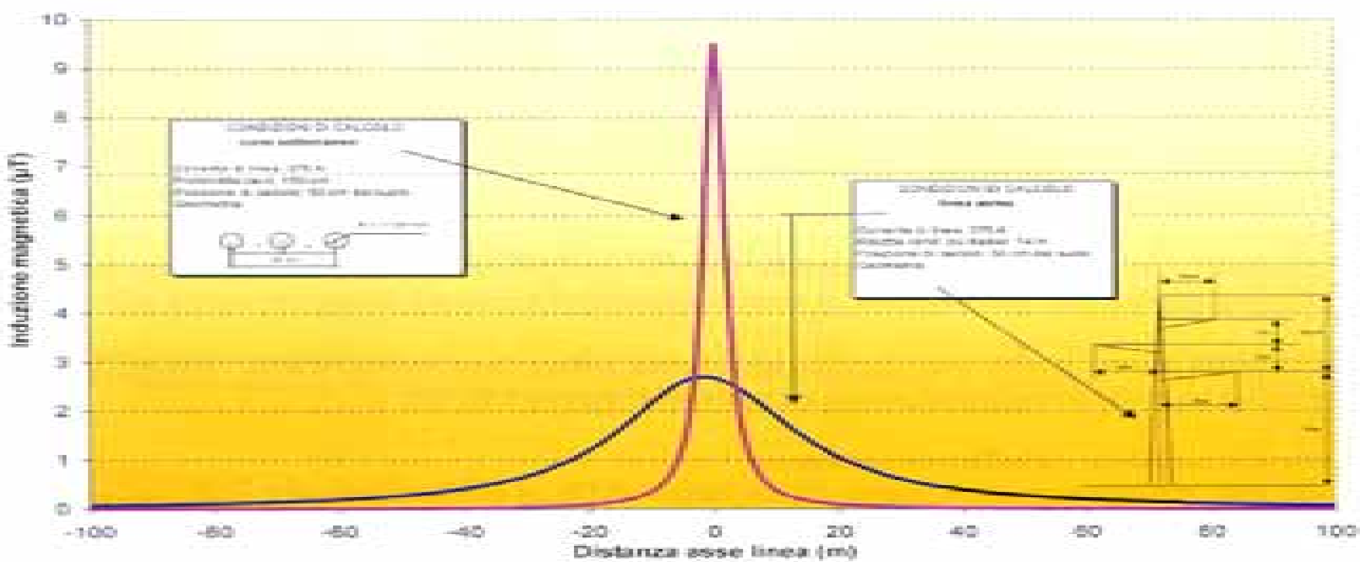


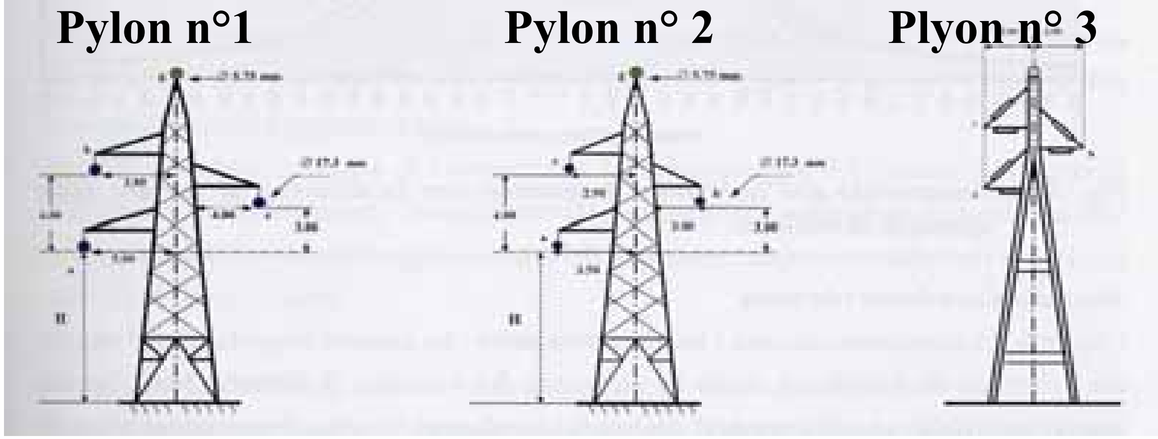
Figura 6 – Comparison between magnetic induction strenght produced, at the same distance from line axes, by burrow power line and aerial power line when the same currents are flowing. (picture extracted from acts of Conference "Elettrosmog: le ultime novità" organizzato da ANPA e Associazione Ambiente e Lavoro, 2000)

Impact mitigation

- ***Modification of the phase-conductors geometry in the powerline***

This hypothesis previews to modify the type of the supports to realize a mitigation of the levels of field B taking advantage of the effect that has the position of the conductors in producing actions of compensation of the total magnetic field in the surrounding space.

The high-voltage power line is constituted from three conductors who generate three magnetic field whose combination produces a reduced totally field, for a compensation and mutual effect. This effect is as well as more obvious as much as the conductors are near.



Picture extracted from acts of Conference “Elettrosmog: le ultime novità” organizzato da ANPA e Associazione Ambiente e Lavoro, 2000

Impact mitigation

From the diagrams we can see that the pylon n°3 that is the “triangle compact support” that has the nearer conductors, introduces inferior values of field regarding the others two supports but it has the disadvantage of having a more fragile structure, and it consequently involves limitations on the height of the conductors from earth and smaller length of the catenaries.

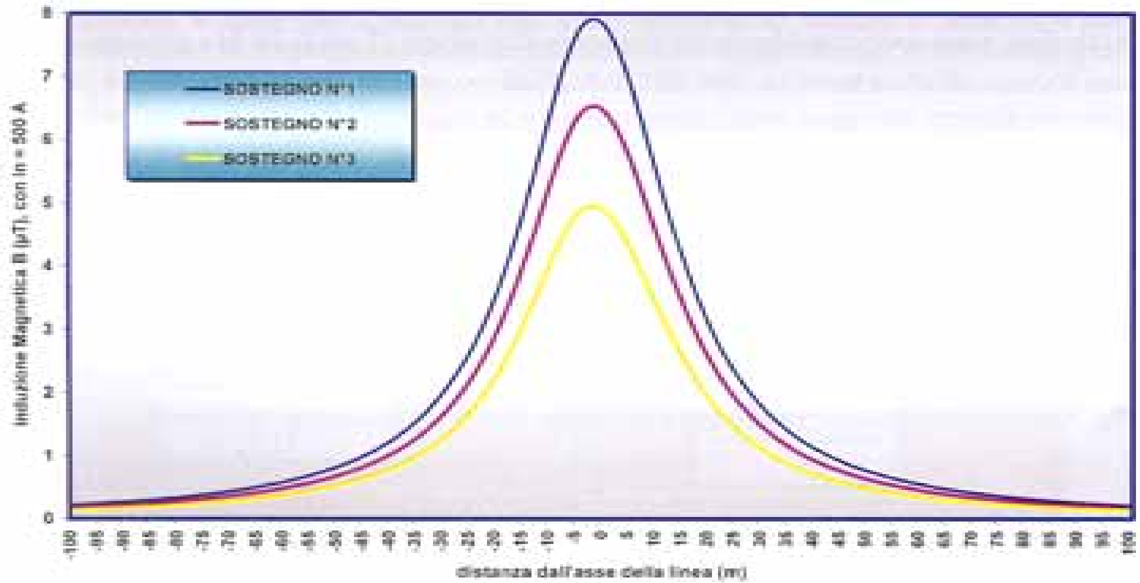


Figura 7 – Magnetic induction trend in function of the distance varying the kind of pylon (picture extracted from acts of Conference “Elettrosmog: le ultime novità” organizzato da ANPA e Associazione Ambiente e Lavoro, 2000)

Impact mitigation

➢ *Height from earth of the phase-conductor*

The height of the conductors from earth is an other parameter that is important in the case of the receptors are near to the power line. Since the catenary possesses a trend with at the center a ventre of minimal distance from the land, in case of the used model does not allow to consider such variability, then the use of the minimal distance of the conductors from the land makes cautelative the esteem carried out with such model.

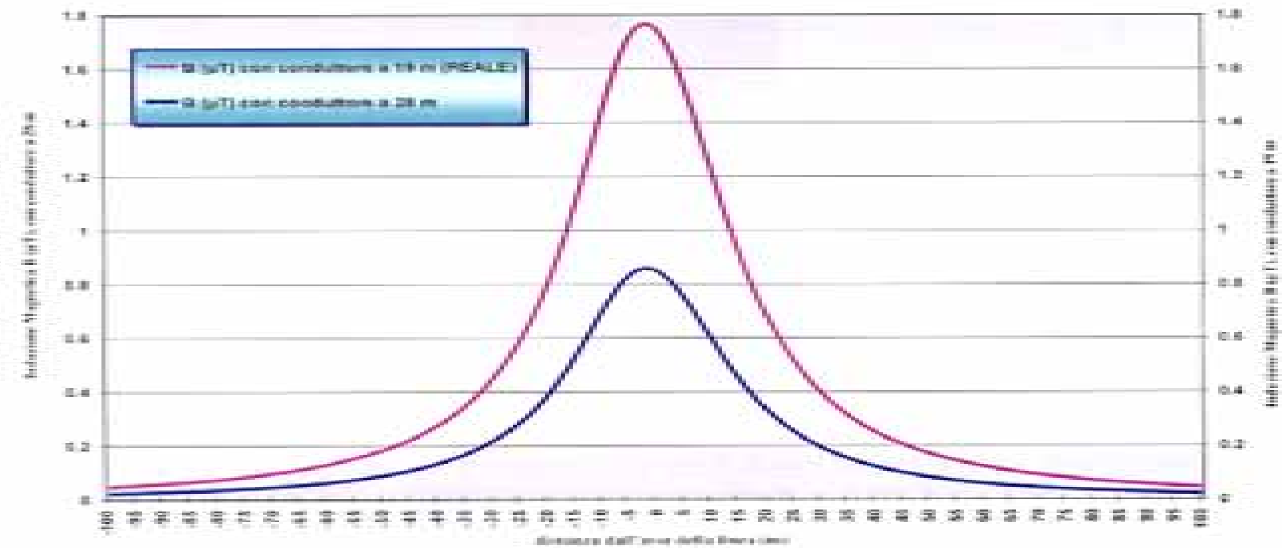


Figura 8 – Magnetic induction trend in function of different height of the conductors (picture extracted from acts of Conference "Elettrosmog: le ultime novità" organizzato da ANPA e Associazione Ambiente e Lavoro, 2000).