Cognition and safety awareness of non-ionising radiation

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ABSTRACT: The aim of this study was to better understand non-ionising radiation (N-IR) and non-ionising radiation pollution (N-IRP). As a result it should be possible to determine how to reduce N-IRP harm and how to make better use of N-IR. Maxwell's electromagnetic theory underpins N-IR. An oscillating electric dipole (OED) was chosen as a representative N-IR model. With this model, the OED radiation curve and surface travelling wave graphs were simulated. The simulation diagrams show: the near field strength is strong; in the distance, the field strength becomes weak rapidly. The N-IR field has a strong directionality; in the horizontal direction of vertical axis, the field strength is relatively strong while along the shaft the field intensity is weak. For the far field, OED radiation can be seen as transverse electromagnet (TEM) waves in space. The N-IRP sources were divided mainly into the two categories of power frequency field source and radio frequency (RF). By analysing all kinds of N-IR sources in daily life and considering N-IRP safety standards, the conclusion was N-IR is everywhere, but it is controllable.

INTRODUCTION

Non-ionising radiation (N-IR) refers to the radiation with energy too low to ionise atoms or molecule. For example, ultraviolet, infrared, laser and microwave are all N-IR. Radio frequency (RF) and microwave electromagnetic waves have frequencies within the range 100kHz - 300GHz.

Since N-IR cannot ionise substances, its harm to humans is less obvious than that from ionising radiation. However, N-IR could change the rotation and vibration of molecules or atoms or alter the valence shell electron orbit state. Hence, it might still have some impact on living tissue. Especially, given the popularity and development of radio and TV broadcasting, wireless mobile communications, radar, remote sensing, etc, the number of RF systems is increasing substantially, and the trend, for some, is to use them at higher power levels [1].

The N-IR in human environments has increased sharply. In many places the electromagnetic environment has reached a level where it is able to cause harm to humans. Since N-IR has the characteristics of being invisible, colourless, tasteless and able to penetrate materials, the harm from non-ionising radiation pollution (N-IRP) should be more seriously regarded. While the N-IR effect on living tissue has attracted some attention in recent years and some countries have established their own N-IR limits for health safety, more publicity should be given to N-IRP and more work should be undertaken in related fields.

How is N-IR generated? How does it spread? How can people effectively prevent N-IRP in their daily lives both at work and otherwise, without affecting the full use of the dissemination information function of electromagnetic waves? This knowledge is urgently required and should be widely available.

NON-IONISING RADIATION THEORIES

The N-IR is characterised by the electromagnetic field strength, which is closely related to the electromagnetic wave power, frequency and the medium in which the electromagnetic waves propagate.

The most representative radiation model is the oscillating electric dipole (OED). The OED can be regarded as a changing elementary current, with outward spreading, varying and mutually interacting electric and magnetic fields. The waves propagate in free space on their own. A small part of the wave can be considered as a plane harmonic wave.

Figure 1 shows the radiation field diagram for an OED. The OED moment $p = p_0 \cdot \cos\omega t$ has amplitude p_0, OED is at the origin of a spherical co-ordinates system with p the polar axis, the electric and magnetic fields strengths at time t as [2]:

$$E = E_\theta = \frac{\omega^2 p_0 \sin\theta}{4\pi\varepsilon_0 c^2 r}\cos\omega(t - \frac{r}{c})$$
$$H = H_\varphi = \frac{\omega^2 p_0 \sin\theta}{4\pi c r}\cos\omega(t - \frac{r}{c}), \quad (1)$$

Where, θ and φ are the polar and azimuth angles, the magnetic field oscillating along the weft; and the electric field, the meridian.

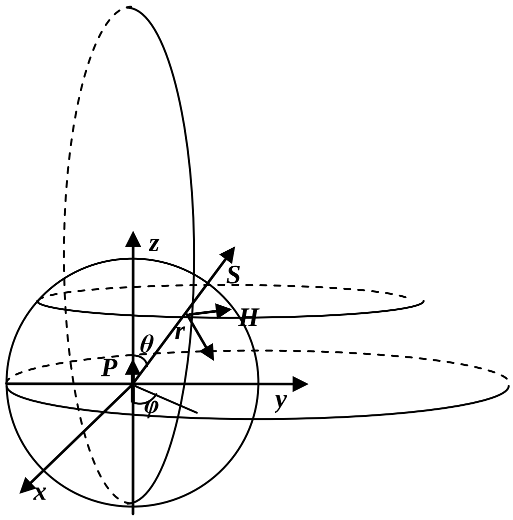


Figure 1: An OED radiation field diagram.

From Formula (1), the electromagnetic wave emission can be simulated. Simulation results are displayed in Figure 2.

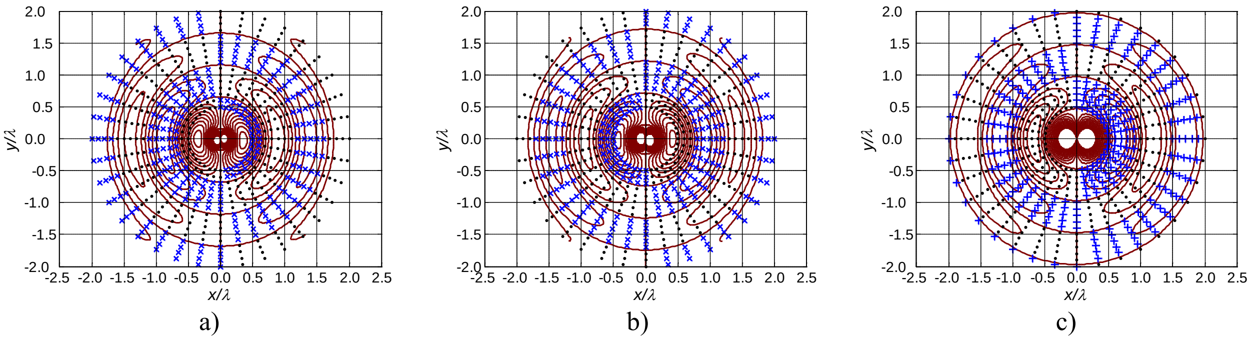


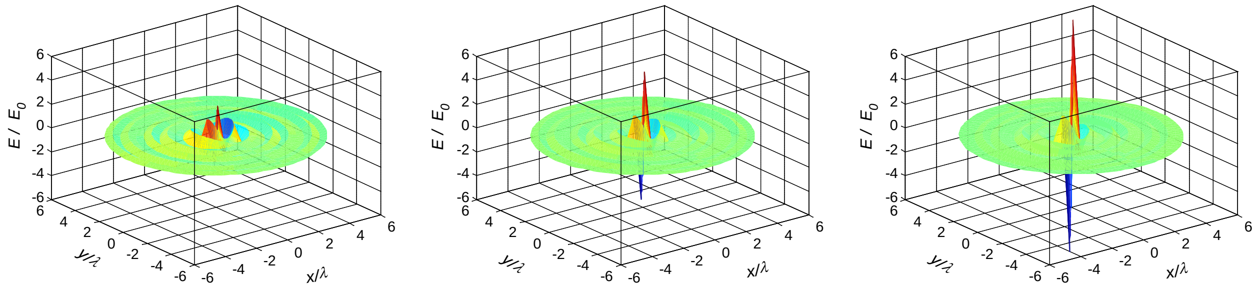
Figure 2: OED N-IR simulation map: a) screenshot at time t_1; b) screenshot at time t_2; c) screenshot at time t_3.

In Figure 2, the N-IR is depicted by the diagram. The *fork* and *dot* indicate the magnetic field strength perpendicular to the paper, inward and outward respectively. The closed curves represent the electric field intensity identified by contour lines. The circular curve in Figure 2c represents the zero line. The magnetic induction lines are the circles around the polar axis; the isoline indicating magnetic field intensity always has a transverse direction. The density of the contour-line indicates the field strength.

The simulation diagrams also show that close to the OED the field strength is strong but weakens rapidly with distance. In the horizontal direction on the vertical axis, the field strength is relatively strong; while along the shaft, the field intensity is weak. In addition, the N-IR simulation diagrams show that the contour lines start from the centre, then spread to the surroundings.

For the far field, the high order term of 1/R can be omitted and the waves from OED radiation are transverse electromagnetic (TEM). Moreover, using Formula (1), the OED electric or magnetic field intensity can also be displayed by curved surfaces; the simulated results for the electric field are shown in Figure 3.

Near the centre, as the wave amplitude is large, there is a very high peak or valley. Wave peaks and troughs are created and launched out continually. Away from the centre, the field strength gradually weakens. The magnetic field and electric field change in synchronisation and have identical characteristics.



a) b) c)

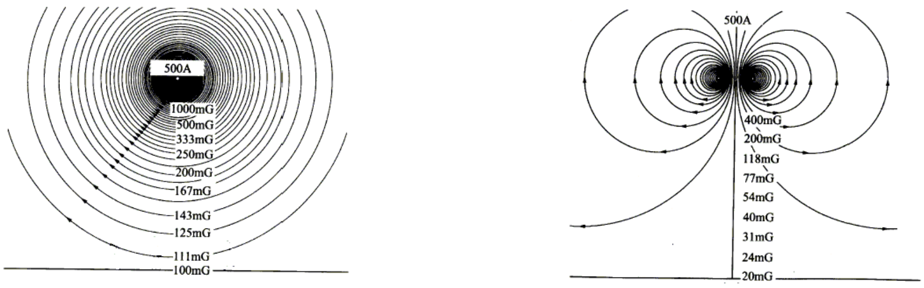
Figure 3: Curved surface simulation for the radiated electric field strength from an OED: a) screenshot at time t_1; b) screenshot at time t_2; c) screenshot at time t_3.

THE SOURCES OF NON-IONISING RADIATION POLLUTION

The N-IRP sources can be divided into two categories of power frequency field source and radio frequency (RF).

With the power frequency field source, there is no electromagnetic wave radiation, but there are strong electromagnetic fields in the neighbourhood, such as transformers, generators and AC high voltage power lines. The magnetic field near 500A power lines were listed in the Nanjing Normal University course *Electromagnetics Applications*, as shown in Figure 4.

Figure 4a reveals the magnetic field distribution around a 500A power transmission line 10m above the ground; Figure 4b shows the magnetic field distribution from two parallel 500A currents, carried by single-phase power transmission lines 10m off the ground. The magnetic field generated by the single transmission line is much stronger than that generated by the double transmission lines. In addition to the magnetic field near the power lines, there is also an electric field [3]. Reference [4] provides the measured electric field near 220kV double split level lines. The measurement was done in Jiaozuo City, Henan Province, on July 15, 2008, and is shown in Figure 5.



a) b)

Figure 4: The magnetic field distribution near 500A transmission lines: a) a single transmission line; b) two parallel transmission lines.

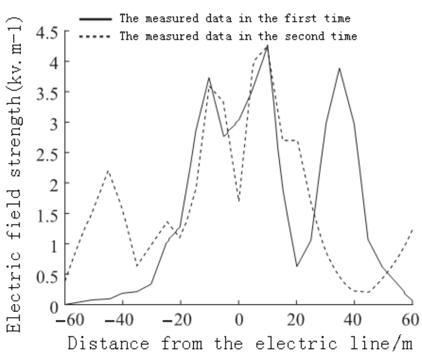


Figure 5: The electric field distribution near 220kV transmission lines [4].

The RF source: RF fields are produced when various kinds of RF equipment, such as radio, television, communication, radar and navigation are operated. Their frequencies cover a wide range, over large distances. The RF electromagnetic waves are N-IR. The total radiation power is proportional to the square of the wave frequency. The general RF radiation frequency is between 100kHz - 300GHz; 3MHz - 300MHz is referred to as high-frequency, and above 300MHz is called microwave.

The unit indicating the strength of the RF is the μTesla (μT). Radiation over 0.4μT on the human body is strong radiation and can be hazardous. This is especially true for long-term exposure of children, e.g. it doubles the risk of leukaemia compared to not exposed children. Radiation between 0.3 to 0.4μT is a warning value for children with long-term exposure; it increases the risk of leukaemia by 75% compared to children who were not exposed. The RF electromagnetic power unit is microwatts/cm^2 (μW/cm^2). Radiation higher than 10μW/cm^2 will cause harm to humans; less than 10μW/cm^2 is safer. The state regulations for non-ionising radiation protection states that in the living environment, non-ionising radiation should not exceed 40μW/cm^2 (conversion factors 100μW/cm^2 = 10 milligauss = 1μT).

NON-IONISING RADIATION HAZARDS

Safety Standards for N-IRP

According to the regulations for N-IR protection in the People's Republic of China (GB8702-88) [1][3], the basic limit for N-IR safety protection is that anyone who has an occupational exposure during any continuous 6 min period in an 8h work period must have a whole body averaged specific absorption rate (SAR) of less than 0.1W/kg. Furthermore, anyone who has a public exposure during any continuous 6 min period in a 24h period must have a whole body averaged specific absorption rate (SAR) of less than 0.02W/kg.

According to the People's Republic of China standard GB16203-1996 - *Health Standard for Power Frequency Electric-Fields in Workplace*, the maximum permissible level for the power frequency electric-field strength in the work environment during an 8h period is 5kV/m. According to the power industry standard DL/T799.7-2002, 0.1mT is the maximum allowable power frequency magnetic field in the workplace. For HF RF wave and VHF electromagnetic waves, there are also special health standard limits.

Given the above, more attention should be paid to these aspects of N-IRP: radiation field intensity, frequency, time and cycle of the radiation, distance from the radiation source, ambient temperature and humidity in work place, gender and age of workers [5]. As well, adaptation and the accumulated effect should be considered.

Learning About the N-IRP in the Environment

First, is the recognition that the action of N-IR on the human body can have biological effects. Magnetically induced effects on humans can lead to a temperature rise in human tissue and organs, causing irreversible damage. The N-IRP microscopic mechanism affects humans in the following ways: electron transfer is affected; it influences the activities of free-radical and protein enzymes; it affects biological semiconductor functions; it causes genetic changes and it changes the biological metabolic processes, etc. This can lead to body cells or organ tissue lesions resulting in adverse impacts on the reproductive, immune, sensory, endocrine and central nervous systems [6].

Finding out about common radiation sources and appropriate precautions:

- Microwave ovens: use a microwave of 2.45 GHz, the correct wavelength to interact with the water molecule. According to the US Electric Power Research Institute, the average value 10m Gauss (mG) or 1μT of N-IR was measured 65cm in front of the microwave oven; even at a distance of 2m away, there was still 1mG.
- Induction cooker: the measured value was 840mG 10cm above the cooker. Even at a distance of 100cm from the cooker the strength was still up to 4.5mG, much higher than the safety standard of 2mG.
- Electric blanket: the observed reading of N-IR exceeded 100mG.
- Hair dryer: for a 1200W hair dryer, 50mG 15cm away.
- Electric shaver: when a rechargeable AC shaver is turned on, the measured maximum electromagnetic waves intensity can be up to 15,000mG, 3cm away from the razor blade.
- Computers: the computer monitor and the host are two of the largest sources of radiation. Frequent users of computers should have a 15-minute break every hour and not use a computer more than 32 hours per week.
- Mobile phones: near a mobile phone antenna within a wavelength range is called the *edge near boundary*. When a phone is close to the ear, the head is just at that location. The output power of radiation is largest as the mobile phone signal is just turned on. The recommended distance from the body is 2.5cm [7].
- TV set: when watching TV, the distance from the TV set should be at least 6 times the TV screen size and continuous watching of TV should be restricted to less than 3 hours.

IMPLICATIONS FOR ENGINEERING AND TECHNOLOGY EDUCATION

Since numerous non-ionising radiation sources come from the electrical and electronic equipment around us, product design and product research-development (R&D) need to consider electromagnetic radiation safety limits. The control of electromagnetic radiation should be included in the content of products and technical personnel need to be considered. Therefore, to meet the needs of future development, entrepreneurs and technology workers should take the lead in understanding the characteristics of non-ionising radiation pollution and try to reduce the electromagnetic radiation from products.

Also they should carry out the R&D and manufacture electromagnetic radiation pollution protection materials and devices. Electromagnetic information should be marked on electronic products. Scientific and technological workers should take the initiative to strengthen the publicity and educational efforts regarding electromagnetic radiation and to promote the public's environmental awareness.

Chinese authorities attach great importance to electromagnetic radiation pollution protection. At the end of 2012, the National Electromagnetic Radiation Control Materials Engineering Technology Research Center was formed at the University of Electronic Science and Technology of China. Setting up the centre conforms to the state development need for a high-end electronic information materials industry and national defence. This effectively supports the development of high density electronic integration technology and is of great significance in promoting the rapid rise of electromagnetic radiation control materials within the international electronic information industry.

CONCLUSIONS

On the one hand, it is correct to be alert to N-IRP, but there is no need to be alarmist about it, because the word *radiation* can cause fear. Unlike ionising radiation, N-IR has no cumulative effect. In addition, the normal human body has some abilities of self adjustment and self protection. Generally, as long as the amount of radiation received is kept within safety limits, there will not be a health hazard. Provided the characteristics of N-IR are understood and its features fully grasped, corresponding measures can be taken to effectively control and reduce the harm to humans. Working in special places may require particular N-IRP protection. In addition, it is most important that science and technology workers play a major role in electromagnetic protection.

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