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IX International Conference – Industrial Engineering And Environmental Protection (IIZS 2019)

Zrenjanin, 3rd-4th October 2019.

University of Novi Sad
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Proceedings

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IX International Conference - Industrial Engineering and Environmental Protection (IIZS 2019)

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The Conference is supported by the Ministry of Education, Science and Technological Development and Autonomous Province of Vojvodina, Provincial Secretariat for Higher Education and Scientific Research, Republica Srbija

ISBN: 978-86-7672-324-9

CIP - Каталогизација у публикацији
Библиотеке Матице српске, Нови Сад

62:005.3(082)(0.034.4)
502/504(082)(0.034.4)

INTERNATIONAL Conference Industrial Engineering and Environmental Protection (9 ; 2019 ; Zrenjanin)
Proceedings [Elektronski izvor] / IX International Conference Industrial Engineering and Environmental Protection (IIZS 2019), Zrenjanin, 3rd-4th October 2019 ; [organizer Technical Faculty "Mihajlo Pupin", Zrenjanin]. - Zrenjanin : Technical Faculty "Mihajlo Pupin", 2019. - 1 elektronski optički disk (CD-ROM) : tekst ; 12 cm

Nasl. sa naslovnog ekrana. - Bibliografija uz svaki rad.

ISBN 978-86-7672-324-9

а) Индустријско инжењерство -- Зборници б) Животна средина -- Заштита – Зборници

COBISS.SR-ID 330863111

RADIATION OF HIGH FREQUENCY ELECTROMAGNETIC FIELDS BIOLOGICAL EFFECTS AND HEALTH CONSEQUENCES

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Abstract: The sources of radio frequency radiation (radio and TV transmitters, radars, microwave ovens, portable radio transciever equipment) are presented first. The absorption factors of radio frequency and microwave emissions by human body are also presented. The basic structure and operating principles of GSM equipment (mobile stations, system of basic stations, network and communication systems) are given. The interaction between mobile phone and human tissue, i.e. absorption of radio frequency energy emitted by mobile phone is described. Advices for safer usage of mobile phones are given.
Key words: electromagnetic fields, radio frequency, mobile phone

INTRODUCTION

Electromagnetic radiation consists of waves of electric and magnetic energy moving together (that is, radiating) through space at the speed of light. Taken together, all forms of electromagnetic energy are referred to as the electromagnetic spectrum (Fig. 1). Radio waves and microwaves emitted by transmitting antennas are one form of electromagnetic energy. Often the term electromagnetic field or radiofrequency (RF) field may be used to indicate the presence of electromagnetic or RF energy. An RF field has both an electric and a magnetic component (electric field and magnetic field), and it is often convenient to express the intensity of the RF environment at a given location in terms of units specific for each component [1].
For example, the unit "volts per meter" (V/m) is used to measure the strength of the electric field and the unit "amperes per meter" (A/m) is used to express the strength of the magnetic field.
RF waves can be characterized by a wavelength and a frequency. The number of cycles per second is known as the frequency, which is measured in Hertz (Hz).
There are different kinds of radiation with different wavelengths all around us, inside us, everywhere, they flow continuously, changing each other, coinciding and colliding. We have just started to realize their variety, understand that our ideas about the surrounding and penetrating into us radiation are fragmentary and insufficient, about its key role in the processes encircling us.

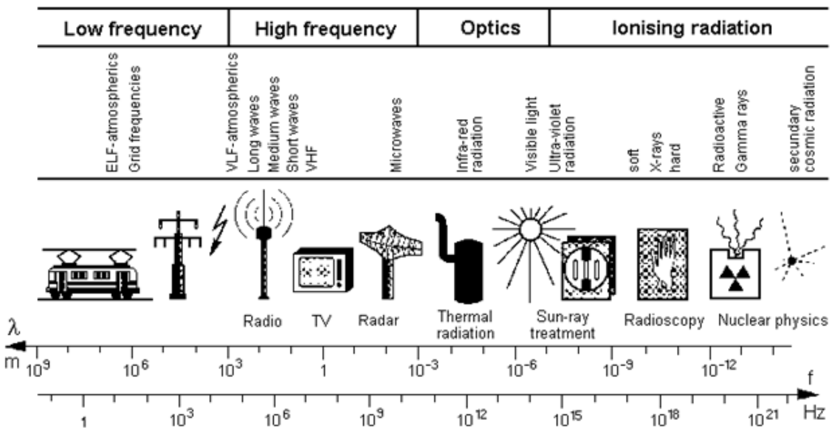

Figure 1. Electromagnetic Spectrum

Nowadays, this idea became even more relevant since the purposeful use of electromagnetic energy in various areas of human activity has resulted in the fact that existing electric and magnetic fields of the Earth, atmospheric electricity, solar and galaxy radio radiation were added by an artificial

electromagnetic field. Its level considerably exceeds the level of natural electromagnetic background. Every ten years world energy resources are doubled and within this period specific gravity of electromagnetic field variables in power industry has thrice increased.
Electromagnetic radiation sources, which include overhead high voltage and extra high voltage transmission lines, radio broadcasting, TV, radio relay and satellite communication equipment, radar and navigation systems, laser beacons and etc. have significantly influenced the natural electromagnetic background.

The effect of mobile phone radiation on human health is the subject of recent interest and study, as a result of the enormous increase in mobile phone usage throughout the world. Mobile phones use electromagnetic radiation in the microwave range. Other digital wireless systems, such as data communication networks, produce similar radiation. Many scientific studies have investigated possible health symptoms of mobile phone radiation. These studies are occasionally reviewed by some scientific committees to assess overall risks [2].

THE SOURCES OF RADIOFREQUENCY RADIATION

Radiofrequency (or RF) Radiation refers to electromagnetic fields with frequencies between300 kHz and 300 MHz, while - Microwave (or MW) Radiation ‖ (Fig. 2) covers fields from 300 MHz to 300 GHz. Since they have similar characteristics, RF and MW radiation are usually treated together. As well, the lower-frequency boundary of RF radiation is often extended to 10 kHz, or even to 3 kHz, in order to include emissions from commonly used devices. The sources of radio frequency radiation are: radio and TV transmitters, radars, microwave ovens, microwave radio systems, transceivers, handheld radio transceivers, amateur radio transceivers, mobile phones.

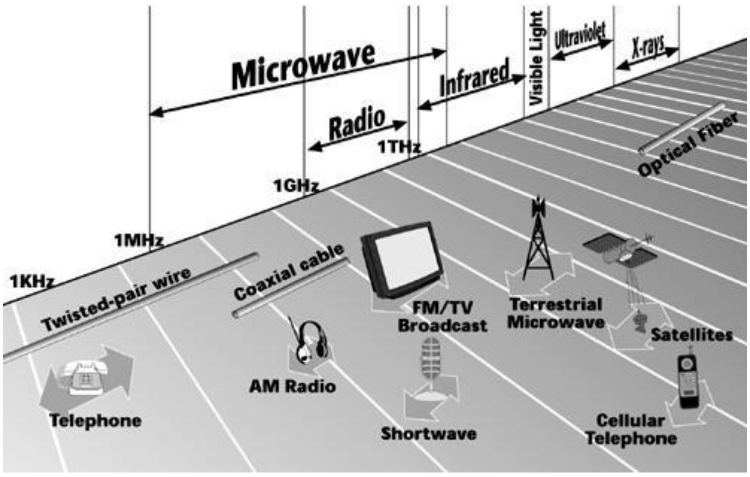

Figure 2. Microwave devices, radio frequency and microwave spectrum

In electronics and telecommunications a transmitter or radio transmitter is an electronic device which, with the aid of an antenna, produces radio waves. Microwave radio networks are systems used for digital transmission of TV images and tones, wireless internet, data transmission between computer networks at various locations, as well as systems for wireless transmission of other electrical information in digital form. Fig. 3 shows a typical architecture of Wi -Fi systems as well as broadband microwave radio systems.

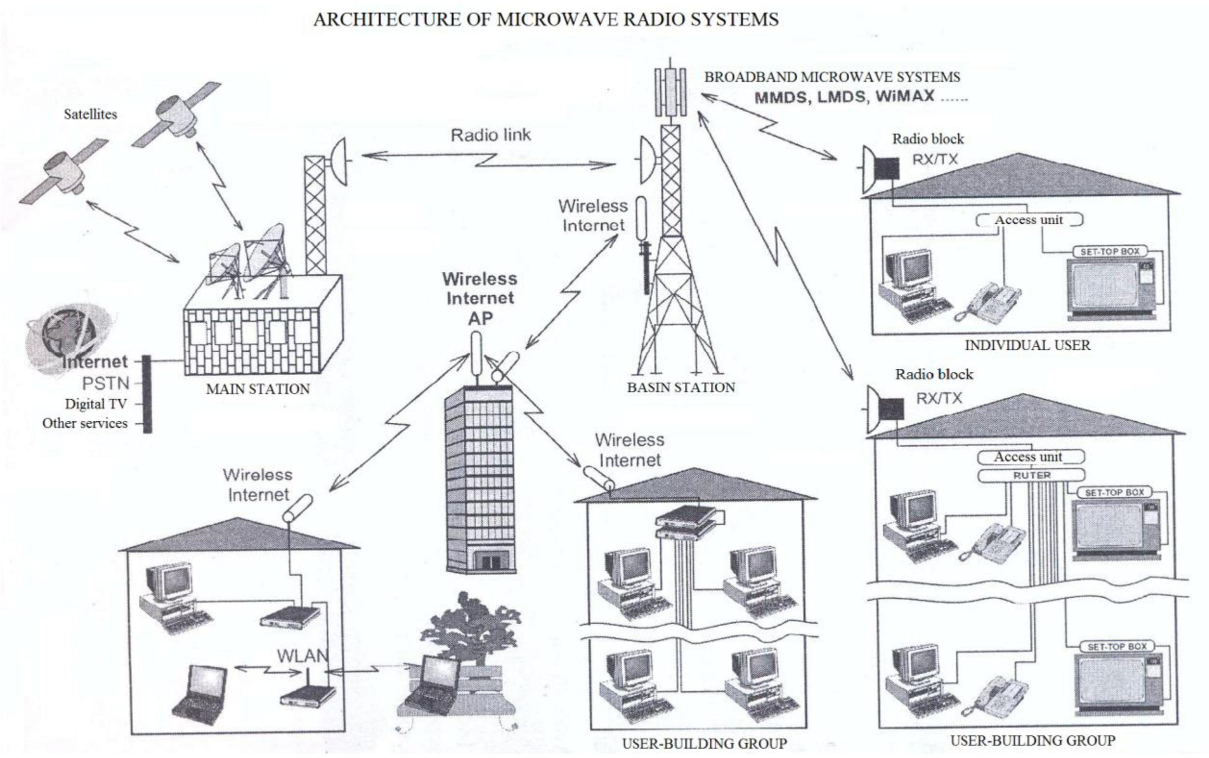

Figure 3. Architecture of microwave radio systems

GSM NETVORK ARCHITECTURE ELEMENTS

GSM (Global System for Mobile Communications) architecture can be divided into three broad functional areas: the Base Station Subsystem (**BSS**), the Network and Switching Subsystems (**NSS**), and the Operations Support Subsystem (**OSS**). Each of the subsystems is comprised of functional entities that communicate through various interfaces using specified protocols [2].

Figure 4 shows a general **GSM** architecture to illustrate the scope and the entities that comprise the three subsystems.

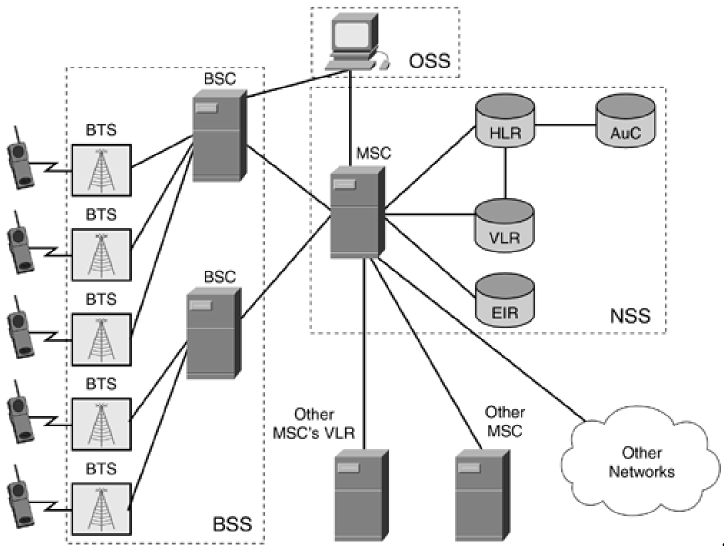

Figure 4. General GSM Architecture, Including the Three Main Separations in the Network

The **GSM** network architecture as defined in the **GSM** specifications can be grouped into four main areas:

- Mobile station (**MS**)
- Base-station subsystem (**BSS**)
- Network and Switching Subsystem (**NSS**)
- Operation and Support Subsystem (**OSS**)

Mobile station

There are a number of elements to the cell phone, although the two main elements are the main hardware Mobile Equipment (**ME**) and the Subscriber Identity Module (**SIM)** (Figure 5).The hardware (**ME**) itself contains the main elements of the mobile phone including the display, case, battery, and the electronics used to generate the signal, and process the data receiver and to be transmitted.

The **SIM** or Subscriber Identity Module contains the information that provides the identity of the user to the network. It contains are variety of information including a number known as the International Mobile Subscriber Identity (**IMSI**).

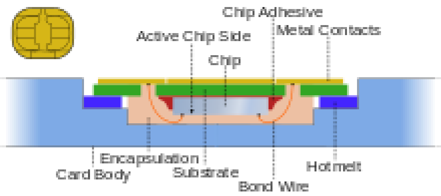

Figure 5. SIM chip structure and packaging

The block diagram in Fig. 6 provides a simplified description of the mobile station. A microphone captures the sound, which is sampled in a numerical format, compressed, coded, and modulated. A high-frequency oscillator translates the modulated signal to a valid transmission frequency. The received signal (less than 1mV) is amplified before down-conversion to a low-frequency, demodulation, decoding, and sound reconstruction [2].

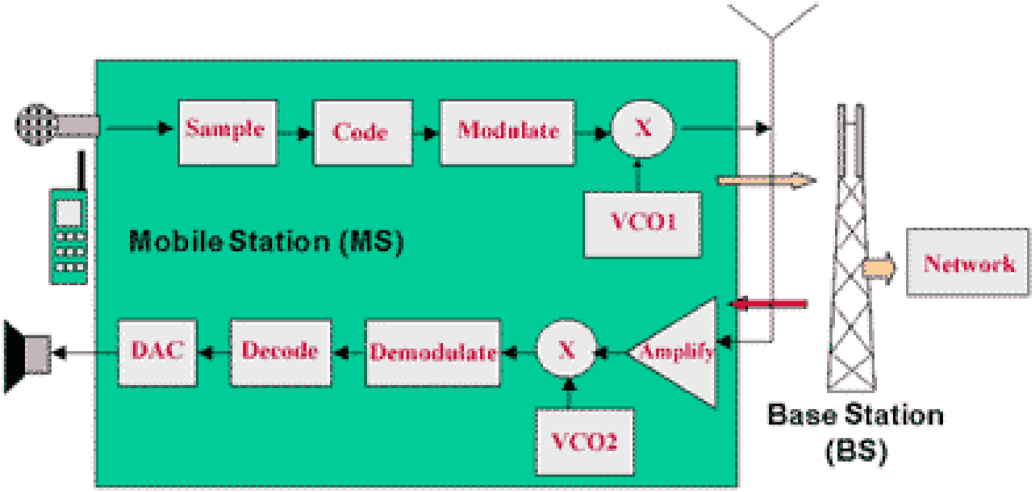

Figure 6. Block diagram of a mobile station

Base Station Subsystem (BSS)

The Base Station Subsystem (**BSS**) section of the **GSM** network architecture that is fundamentally associated with communicating with the mobiles on the network. It consists of two elements:

Base Transceiver Station (**BTS**): The **BTS** used in a **GSM** network comprises the radio transmitter receivers, and their associated antennas that transmit and receive to directly communicate with the

mobiles. The **BTS** is the defining element for each cell. The BTS communicates with the mobiles and the interface between the two is known as the Um interface with its associated protocols.
Base Station Controller (**BSC**): The **BSC** forms the next stage back into the **GSM** network. It controls a group of **BTS**s, and is often co-located with one of the BTSs in its group. It manages the radio resources and controls items such as handover within the group of BTSs, allocates channels and the like [2].

Network Switching Subsystem (NSS)

Its main role is to manage the communications between the mobile users and other users, such as mobile users, ISDN users, fixed telephony users, etc. It also includes data bases needed in order to store information about the subscribers and to manage their mobility.

Mobile Switching services Centre (**MSC**): the central component of the **NSS**. The **MSC** performs the switching functions of the network. It also provides connection to other networks.

Home Location Register (**HLR**): The **HLR** stores information of the subscribers belonging to the coverage area of a **MSC**; it also stores the current location of these subscribers and the services to which they have access.

Visitor Location Register **(VLR**): contains information from a subscriber's **HLR** necessary to provide the subscribed services to visiting users.

Authentication Center (**AUC**): It serves security purposes; it provides the parameters needed for authentication and encryption functions. These parameters allow verification of the subscriber's identity.

Operation and Support Subsystem (OSS)

The **OSS** or operation support subsystem is an element within the overall **GSM** network architecture that is connected to components of the **NSS** and the **BSC**. It is used to control and monitor the overall GSM network and it is also used to control the traffic load of the BSS. It must be noted that as the number of BS increases with the scaling of the subscriber population some of the maintenance tasks are transferred to the BTS, allowing savings in the cost of ownership of the system (http://www.radio-electronics.com).
The **OSS** consists of Operation and Maintenance Centers (**OMC**s) that are used for remote and centralized operation, administration, and maintenance (**OAM**) tasks. The **OSS** provides means for a service provider to control and manage the network [2].

HEALTH EFFECTS FROM RADIOFREQUENCY ELECTROMAGNETIC FIELD

The basics of EM interaction with materials were elucidated over a century ago and stated as the well-known Maxwell‘s equations. The application of these basics to biological systems, however, is very difficult because of the extreme complexity and multiple levels of organization in living organisms, in addition to the wide range of electrical properties of biological tissues.
There are many factors to be taken in determining how the RF / MT energy absorbed in the body, such as:
- Dielectric compositions
- The size of the body,
- The shape and orientation of the body and polarization fields,
- The complexity (similar to zones) RF / MT field

Interaction of electromagnetic field (EMF) with environment and with tissue of human beings is still under discussion and many research teams are investigating it. Biological tissues are modeled by their permittivity and conductivity. The complex permittivity of a biological tissue is given by:

$$\underline{\varepsilon} = \varepsilon_r \cdot \varepsilon_0 + j\frac{\sigma}{2\pi f} \qquad (1)$$

where, σ (S/m) is the conductivity of tissue in siemens per meter and $\varepsilon_0 = 8{:}854\text{x}10^{-12}$ F/m.

Electrical conductivity and permittivity vary with the type of body tissue and also depend on the frequency of the applied field [1].

Table 1. Electrical conductivity of body tissue

	Conductivity (S/m)			
Tissue type	**150 MHz**	**450 MHz**	**900 MHz**	**1,800 MHz**
Muscle	0.73	0.81	0.94	1.3
Skin (wet)	0.56	0.69	0.85	1.2
Blood	1.2	1.4	1.5	2.0
Grey brain matter	0.60	0.76	0.94	1.4
White brain matter	0.35	0.46	0.59	0.92
Fat	0.07	0.083	0.11	0.19
Bone	0.070	0.096	0.14	0.28
Liver	0.53	0.68	0.86	1.3

Each object, whether it is a case or a living being, when found in the RF / MW field, can under certain conditions, to enter into resonance with the source of such a field. If the object is a person, its resonant frequency is primarily dependent on the height of the body.
Three different cases:
- when the body is less than the size of the wavelength,
- when they are approximately equal in their size and
- when the body is much larger than the size of the wavelength.

In cases where a body size smaller than the wavelength (Fig. 7-a), there is little absorption. When the wavelength is approximately equal to the size of the body (Fig. 7-b), it appears the greatest absorption of the unequal distribution of power. Therefore, it may appear " hot spots" in certain parts of the body. When the wavelength is smaller than the size of the body (Fig. 7-b), the absorption is smaller, while the heating is limited to the irradiated surface.
At RF and microwave frequencies, electromagnetic fields penetrate into human body. These fields interact with biological tissue in several ways. The most important interaction can be explained in terms of energy transfer from the electromagnetic field to the tissue material. One measure of this macroscopic effect is the time-averaged absorbed power.

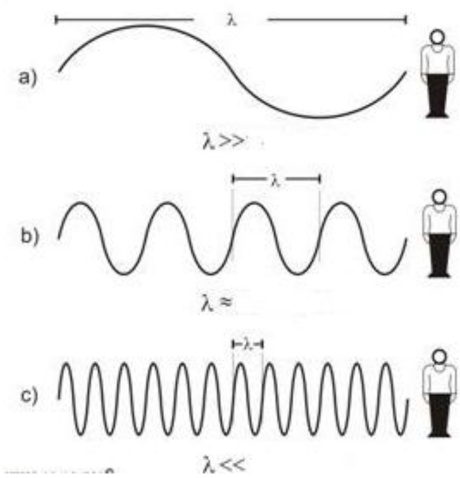

Figure 7. Size of the human body in relation to the wavelength of the electromagnetic wave [1].

Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field; although, it can also refer to absorption of other forms of energy by tissue.
A quantity usually used is known as SAR and has dimension W/kg. SAR can be defined as:

$$SAR = \frac{1}{2} \cdot \frac{\omega \varepsilon_0 \varepsilon_r}{\rho} |E|^2 \tag{2}$$

with ω the angular frequency, ε_0 the permittivity of free space, ε_r the imaginary part of the relative complex permittivity, ρ the tissue density in kg/m3 and E is the peak value of the total field inside the tissue material.

We can see that the SAR depends on dielectric parameters therefore the materials of phantoms have to have similar dielectric parameters as human tissues. The human head consists of several tissues, which have different electrical characteristics and form complex-shaped boundaries. The electrical characteristics of human tissues are very different from the normal propagation medium (air), but not so different between each other. For values of SAR are recommended maximum values by committee INCRIP, this value is 2 W/kg in EU (SSI'S Independent Expert Group on Electromagnetic Fields) [1].

In the past few years, very rapid development in mobile cellular communication has drawn attention to possible health risks of the electromagnetic energy (EM) emitted from the transmitters of hand-held phones [3]. The interaction between a human head and a hand-held phone under various conditions should be quantitatively evaluated in order to establish the safety in cellular mobile communication systems [4].

Beside public biological concerns in cellular mobile communication system, there is also a great demand to know the deterioration of the antenna performance because of the existence of human head. This is an important feedback for antenna designers to develop better structures. Analyzing possible range of variations of the induced field strengths in various tissues requires an extensive effort, since local field strengths strongly depend on various parameters [3]. Among the others : operational frequency and antenna power, mutual positions of the between device and head, design of the device, size and the shape of human head, distribution of tissues within the head and electrical properties of the tissues can be listed as important parameters which strongly affect the SAR distribution. Since some of the listed parameters are different for various individuals and can even change with time, analytical formulations (even the approximate ones) in SAR distribution calculations are extremely difficult.

The SAR distributions in a human head exposed to EM fields from hand-held cellular phones have been estimated through experimental [5], and numerical calculations [6]. The models used in these studies are quite different where from simple to enhanced geometries and from a few to many different tissue types are taken into account with different electrical properties. Moreover, quite different values have been used in some of these studies [7], parallel to more accurate measurements of human tissues [6]. For example, there are more than hundred percent differences in some of the tissue parameters in [7].

CONCLUSION

High frequency radiation exists in free space around us from an increasing number of sources and cover a wide range of the electromagnetic spectrum. The most important use for RF energy is in providing telecommunications services. Radio and television broadcasting, cellular telephones, radio communications for police and fire departments, amateur radio, microwave point-to-point links, and satellite communications are just a few of the many telecommunications applications. By for the most important and rapidly expanding source is the mobile phone base stations. Fortunately, the radiated power densities around these base stations are below the standard limits set by the different world organizations. It is important to take care in the design of new base stations to meet the guidelines set for the antennas and their mounting so that the minimum required distance can be observed for the public access. New trends in the design of such antennas such as the smart antenna concept, can be applied in order to further reduce the radiation power levels.

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