

# Radio frequencies and health

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## **Abstract:**

Research on the potential health effects of an exposure to radio frequencies has apparently followed in the footsteps of advances in technology, with more or less of a lag and in a more or less organized manner. When mobile networks were being deployed during the first decade of this century, major questions were raised (chief among them: the risk that using mobile phones would cause brain tumors) and apparently settled — for a while. Findings from recent research along with the change of scale in “connectivity” (and thus of our exposure to electromagnetic waves) have made it necessary, once again, to assess risks. In particular, research on the relation between this exposure and the functioning of the brain, though not having detected any pathological effects, seems to open new approaches to understanding the interactions between electromagnetic fields and life.

On 16 July 2018, the government and ARCEP (Autorité de Régulation des Communications Électroniques et des Postes), the regulatory authority for electronic communications, presented a 5G roadmap for France.<sup>1</sup> This fifth generation of mobile (cellular) networks comprises all future connected uses ranging from “smart” cities to “connected” health, not to mention transportation and “factories of the future”. It has been described as a “*strategic issue for French industry, our economy’s competitiveness, innovation and renovated public services*”.<sup>2</sup> Following on the first generations of mobile telephones have come mobile networks, which include other roaming devices, such as tablets and various connected devices. The promoters of 5G see it as a breakthrough technology for bringing together all future forms of connectivity between things and networks in all fields of everyday life: at work, in leisure activities, for health, industry and transportation.

Apart from the problems of potential interference between simultaneous transmissions by a multitude of devices in a defined area, the future described by 5G operators will modify our exposure to radio waves. We thus wonder, quite naturally, about the eventual consequences of these foreseeable changes in exposure on our environment and, especially, our health.

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<sup>1</sup> This article, including quotations from French sources, has been translated from French by Noal Mellott (Omaha Beach, France). The translation into English has, with the editor’s approval, completed a few bibliographical references. All websites were consulted in October 2020.

<sup>2</sup> Press release of 16 July 2008 by ARCEP and the state secretariats of digital technology under the Prime Minister and the minister of the Economy and Finance, available via [https://minefi.hosting.augure.com/Augure\\_Minefi/r/ContenuEnLigne/Download?id=209561F1-FF9A-4F13-AAA9-DF6363488F31&filename=594%20-%20La%20France%20se%20dote%20d%E2%80%99une%20feuille%20de%20route%20pour%20la%205G.pdf](https://minefi.hosting.augure.com/Augure_Minefi/r/ContenuEnLigne/Download?id=209561F1-FF9A-4F13-AAA9-DF6363488F31&filename=594%20-%20La%20France%20se%20dote%20d%E2%80%99une%20feuille%20de%20route%20pour%20la%205G.pdf).

## Do radio frequencies have an impact on health? An open question?

The population has long been exposed to electromagnetic waves from man-made sources (such as transmitting and relay stations for radio and television that are relatively distant from each other) at levels higher than the exposure due to natural sources (Earth, Sun, stars). However the intensity of this exposure is low compared with the levels known to cause the short-term physiological effects clearly described in the literature. As the sources (such as microwave ovens) generating electromagnetic fields have come ever closer to people, the question of their impact on health has inevitably cropped up.

With the introduction of wireless and then mobile telephones, the sources transmitting radio waves are nearer to our bodies, even in contact with them. This calls for attention. After all, some sources are transmitting from the other side of the skin, namely the implants or capsules (to be swallowed) that transmit electromagnetic signals. Once the first receiving stations for portable telephones were installed — long before the prevalence of mobile phones, now used by 95% of the French population over the age of twelve (CREDOC 2019) — several research programs were conducted to examine the potential effects of this exposure due to telephones on health.

However the assessment of this new technology's potential risks to health and safety has very often run afoul of the calendar for its rollout in the marketplace. A prime difficulty is to have the equipment for simulating exposures to the signals transmitted by a device that is sometimes not yet available. For various forms of mobile telephone technology, studies cannot be imagined before the material needed to expose living cells (animal or human) to radio frequencies becomes available to researchers. This technology's pace of change makes it very hard for laboratories to keep up, since they must invest repeatedly in equipment soon to be obsolete.

One question for research on the impact of radio frequencies on health hinges on making a distinction between the possible effects on biological organisms of, on the one hand, the energy conveyed by radio waves and, on the other hand, of the timing of exposures to such waves (*i.e.*, modulations in the signals).

As technology has evolved, research teams have naturally taken an interest in the effects of signals with different modulations, whether GSM (Global System for Mobile Communications, the second generation of mobile phones) or UMTS (Universal Mobile Telecommunications System, the third generation). The findings have often been inconsistent. Effects on the functions of biological cells were sometimes found for exposures to GSM but not UMTS, or vice versa (TILLMANN *et al.* 2010, DANKER-HOPFE *et al.* 2011, ZENI *et al.* 2012, SMITH-ROE *et al.* 2019). Other studies focused on the hypothesis that biological cells and tissues might demodulate radio signals (SHEPPARD *et al.* 2008, DAVIS & BALZANO 2010, KOWALCZUK *et al.* 2010). However they have not shown that biological entities, on a small or large scale, can do this and, therefore, potentially have a reaction to the time form (pulses) of the signal rather than the energy conveyed. Except for Carrubba *et al.* (2010), who hypothesized that electric signals emitted by the brain ("*evoked brain potentials*") could be linked to an exposure to the low-frequency pulses produced by mobile phones (217 Hz, a frequency fundamental for GSM burst periods).

Another hypothesis about the action of electromagnetic fields could be imagined by focusing on the rhythm of repeated exposures, a much longer time scale (from a few minutes to a few hours) than the timing of pulses in radio signals and their modulation (of the magnitude of a millisecond). Electromagnetic hypersensitive people have advanced this hypothesis. In fact, several studies on animals have drafted protocols for experiments based on repeated exposures of variable duration (from a few minutes to several hours, several times a day). This repetition might be an additional source of stress. However, the heterogeneity of the findings from such studies, along with the diversity of the protocols used for measuring exposure, makes it hard, once again, to interpret the results.

## The effects on health

The penetration of radio waves in biological cells and tissues involves a transfer of energy from the wave to matter, at least for the part not reflected at the skin's surface. The conversion of electromagnetic into thermal energy has been clearly described (FOSTER & SCHWAN 1996). The nature of tissues and their variety determine how the heat thus produced spreads to the surrounding tissue, whether by conduction or radiation (FOSTER & GLASER 2007). In principle, this conversion takes place regardless of the intensity of the energy conveyed by the radio wave.

As long as the quantity of energy converted is low compared with the organism's thermoregulation, no macroscopic effect, local or systemic, has been observed. For a localized exposure when the heat produced cannot be evacuated, the temperature of the tissue increases. This effect is used in certain therapies (DEWEY *et al.* 2009). When a whole organism is exposed, the increase in energy can potentially exceed the organism's capacity for thermoregulation and thus have physiological effects due to the excessive temperature. To prevent effects of this sort, thresholds for exposure have been established and are now enforced.<sup>3</sup> Along with the increase in body temperature, behavioral modifications have, beyond the threshold, been observed in animals (D'ANDREA *et al.*, 2003).

Apart from this thermal effect, might the exposure to radio frequencies have long-term effects on health? For the short and medium terms, the question is of concern to the persons who claim to be electromagnetic hypersensitive (ANSES 2018). In the long run, several research programs have tried (for more than twenty years now) to detect the effects on health and identify the underlying processes. Studies in clinical epidemiological research programs have been made on animals, cell cultures and even plants, as well as on people.

Although mobile networks and relay antennas, in particular, have altered our electromagnetic environment in a short time, reports from simulations and observations of exposures to radio waves have pointed to a relatively limited increase in average exposure (in time and space) except for very local "atypical points", where the level of exposure is higher (ANFR 2019). The development of 4G and 5G might, however, significantly raise these averages. Besides, apart from persons who live far from sources of transmissions (in places poorly covered by television broadcasts and mobile networks), the whole population is exposed to electromagnetic fields to varying degrees. Since the gradient of exposure is rather low, it is not easy to conduct studies for assessing the incidence of pathologies and comparing the results between groups, namely the persons who are the most and the least exposed.

Furthermore, mobile telephones are a very special case. Among all sources of electromagnetic fields in our everyday environment, they are the source that, by far, accounts for the most intense exposure. This exposure is not permanent, like that from relay antennas; but it is much more intense. The ratio of the exposure due to a mobile phone held up to the ear is from one hundred to one thousand times higher than the exposure to radio frequencies from faraway sources in the environment (broadcasting towers, relay antennas, wireless media receiver boxes, etc.). For this reason, the potential effects of the exposure to radio waves from mobile telephones have been investigated for several years now. Other reasons also argue in favor of conducting this research: the closeness to the source of radio waves when a mobile phone is held near the brain, the extremely high number of users (many of them very young), and the speed at which the population has adopted mobile phones.

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<sup>3</sup> <https://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf>  
<https://eur-lex.europa.eu/legal-content/FR/TXT/PDF/?uri=CELEX:31999H0519&from=FR>  
<https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000226401&categorieLien=id>

## Carcinogenic effects

In its opinion on the effects of radio frequencies on health released in 2013, the French Agency for the Safety of Food, the Environment and Occupational Health (ANSES: Agence Nationale de Sécurité Sanitaire de l'Alimentation, de l'Environnement et du Travail) noted that it could not be excluded that, under certain conditions, the exposure to radio frequencies might boost oxidation or damage DNA — but without any permanent loss of the DNA's integrity, since the sometimes observed alterations seem to be quickly repaired. Other biological studies have not brought to light any processes that would support the hypothesis of a carcinogenic effect.

Since then, studies published about the long-term exposure of animals have been widely discussed. Falcioni *et al.* (2018) reported observations of heart tumors in rats after exposure to radio-frequency radiation. The National Toxicology Program in the United States published the final reports of its large-scale study in Chicago on the carcinogenicity of the exposure of rats and mice to radio frequencies (NTP 2018a & 2018b). The authors concluded that the evidence is ambiguous for brain tumors (malignant gliomas) in rats and limited for heart tumors (malignant schwannomas) in the case of exposures to the radio frequencies used for 3G. In this study, tumors were observed for high levels of exposure (SAR of the whole body at least 6 W/kg), but this does not correspond to real-life conditions for human beings.

Although it is not easy to interpret these various findings from so many studies, *in vitro* and *in vivo*, over a period of several years, all experts, national and international, now agree on dismissing the evidence that the exposure to radio frequencies is related to carcinogenesis in animals.

Meanwhile, several research programs in epidemiology have focused on the linkage between the use of mobile telephones and the risk of brain tumors. Mobile telephones generate an electromagnetic field corresponding to the highest level of exposure to radio waves (in intensity, duration, and number of persons concerned). Since mobile phones are mainly used by placing them in contact with the head, research has tried to find whether there is any relation to brain tumors. In 2010, the International Agency for Research on Cancer (IARC) drew the conclusion, after taking into account the findings of Cardis *et al.* (2011), of a possible linkage between the exposure to radio frequencies and an increased risk of gliomas. In its 2013 assessment of the health risks due to radio frequencies, ANSES also mentioned a possible carcinogenic effect on intensive users of mobile telephones, who accumulate more than 1.640 hours of exposure. This corresponds to the segment of the population at excess risk (CARDIS *et al.* 2011). An increase in the risk of rare sorts of gliomas (less than 20% of the increase in incidence) cannot be excluded in the subgroup of intensive users over a period of more than fifteen years (no data being available beyond this period).

## Effects on the central nervous system

Among the various hypotheses about the biological effects of an exposure to radio waves, a controversy has arisen about the permeability of the blood-brain barrier (BBB), which protects the brain, regulates its metabolism and controls the flow of blood to the brain. It initially stemmed from publications at the turn of the century that mentioned an alteration of the BBB. In the following decade, several research programs focused on this question. The outcome of all this work is that no neurotoxicity in the BBB has been clearly observed that can be set down to an exposure to radio waves.

On account of the proximity of mobile telephones with the head, and especially in the case of children, the eventual effects of radio frequencies on the functioning of the brain, its electrical activity as well as sleep and cognition, have been well explored. Cognition refers to attention and memory as well as the functions related to language, gestures and coordination.

A study of the EEGs (electroencephalographs) of people exposed to radio waves found evidence of some modifications (CROFT *et al.* 2010). A few studies on animals suggest that this exposure might modify cognitive functions and memory but — surprisingly — improve them (KUMLIN *et al.* 2007, ARENDASH *et al.* 2010). Several experiments have been made on people, in particular children. However differences in the conditions of these experiments, the tests conducted and the populations tested are so important that definitive conclusions can hardly be drawn. Nonetheless, a few experiments deserve attention that have reported EEG modifications during blind testing on the exposure to radio frequencies. These modifications of brain oscillatory EEG responses correspond to tasks related to attention, memory, emotions and sensations (KRAUSE *et al.* 2006, LOUGHRAN *et al.* 201). As for studies on sleeping while exposed to radio waves, they have not come up with evidence of an alteration of the length or quality of sleep; but once again, some studies do point to EEG modifications. These findings can be compared with those from the studies on exposures to low frequencies that have found a possible interference with the brain's electrical activity (CARRUBBA *et al.* 2010).

Till now however, evidence of any pathological incidence has not been reported.

### Other health effects

A characteristic of this research on the effects of electromagnetic fields on health is the proliferation of hypotheses and protocols, the multiplication of the sources of exposure, and the abundance of biological processes and effects that have been studied. Without going into the details about all the biological and health effects investigated, beyond those already discussed, I might mention a few major fields of research: neurological pathologies, auditory functions, circadian rhythms, the immune system, the endocrine system, reproduction and development, the cardiovascular system, and well-being. Depending on the specific interests of the researchers and, too, on the possibility of publishing results, research has covered these fields variably. In all cases, the data produced are disparate.

According to national and international experts, it is impossible to draw a conclusion about whether or not there are effects on health.

## Conclusion

While mobile telephone operators are preparing the rollout of 5G, 4G is still being developed. In December 2019, the ANFR's observatory of cellular networks reported more requests for authorizations to install 4G antennas.<sup>4</sup> At the time, the number of 4G transmitting stations was not very different from that of 2G and 3G stations combined, respectively about 211,000 and 234,000. As ARCEP's "digital barometers" show,<sup>5</sup> smartphones are being increasingly used, even for access to the Internet (instead of computers), including at home. They are also being more often used to view videos, not to mention the subscriptions to online platforms for video on demand.

The conditions are such that ever more data from mobile telephones are circulating. This will increase both the personal and environmental exposure to mobile phones. The increase in environmental exposure will be relatively high but will remain at levels low enough in absolute value, except for the aforementioned "atypical points", which might become more numerous. The increased consumption of energy and the environmental impact of these trends should be taken into account when planning how to develop cellular communication networks. The same holds for the increased level of the population's exposure.

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<sup>4</sup> ANFR (Agence Nationale des Fréquences, the National Frequency Agency) at <https://www.anfr.fr/gestion-des-frequences-sites/observatoire/actualites/actualite/actualites/observatoire-anfr-pres-de-49-500-sites-4g-autorises-par-lanfr-en-france-au-1er-decembre-2019/>

<sup>5</sup> An annual publication available at: <https://www.arcep.fr/cartes-et-donnees/nos-publications-chiffrees/numerique/le-barometre-du-numerique.html>

The stronger presence of telecommunication networks, in line with plans for territorial coverage and connectivity, necessarily comes into conflict with the demands for protection expressed by the electromagnetic hypersensitive, whose problems, blamed on radio waves, have to be taken under consideration. Research on the eventual effects of the exposure to radio frequencies is, therefore, worthwhile. However the difficulty of drawing conclusions from so many research programs with such varied objectives, not to mention the variable quality of the protocols used, should serve as arguments for better targeting these programs. Ideally, this research should be a matter of international cooperation so as to concentrate financial and human resources on the most troubling hypotheses. More than twenty years of research on how radio frequencies (in particular from mobile telephones) affect health should help us establish priorities. One priority would be to examine the latest controversial results on carcinogenesis. Another would be to study the effects on brain functions, given the proximity of mobile phones to the brain and the findings of previous studies.

The exposure of human beings to electromagnetic fields is going to undergo major changes as a result of 5G — owing to its higher frequency (in Europe: 3.5 GHz at first and then about 26 GHz) and to the evolution of mobile communications with a new distribution of exposure patterns in space and time, as antennas beam waves directly toward users. These changing conditions should be brought under consideration from the start — from the stage of designing protocols and systems — so as to anticipate the environmental effects and avoid underestimating the related questions.

The rollout of the Linky electricity meter in France has raised several questions and aroused anxiety about the possible effects of power-line communications (PLC) on health. As this experience has shown, it would be dubious to keep citizens out of the processes of information and deliberation associated with decisions about infrastructures. After all, an infrastructure, once installed, will necessarily have repercussions on the environment and potentially on our health, in the (more or less) long term.

The means should be mustered for an independent assessment of the potential effects on the environment and health. Beyond the potential effects closely linked to the exposure to electromagnetic fields, the effects on health in a broad sense, including the psychosocial effects of how digital devices are transforming our lifestyles, must also be taken into account and assessed.

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