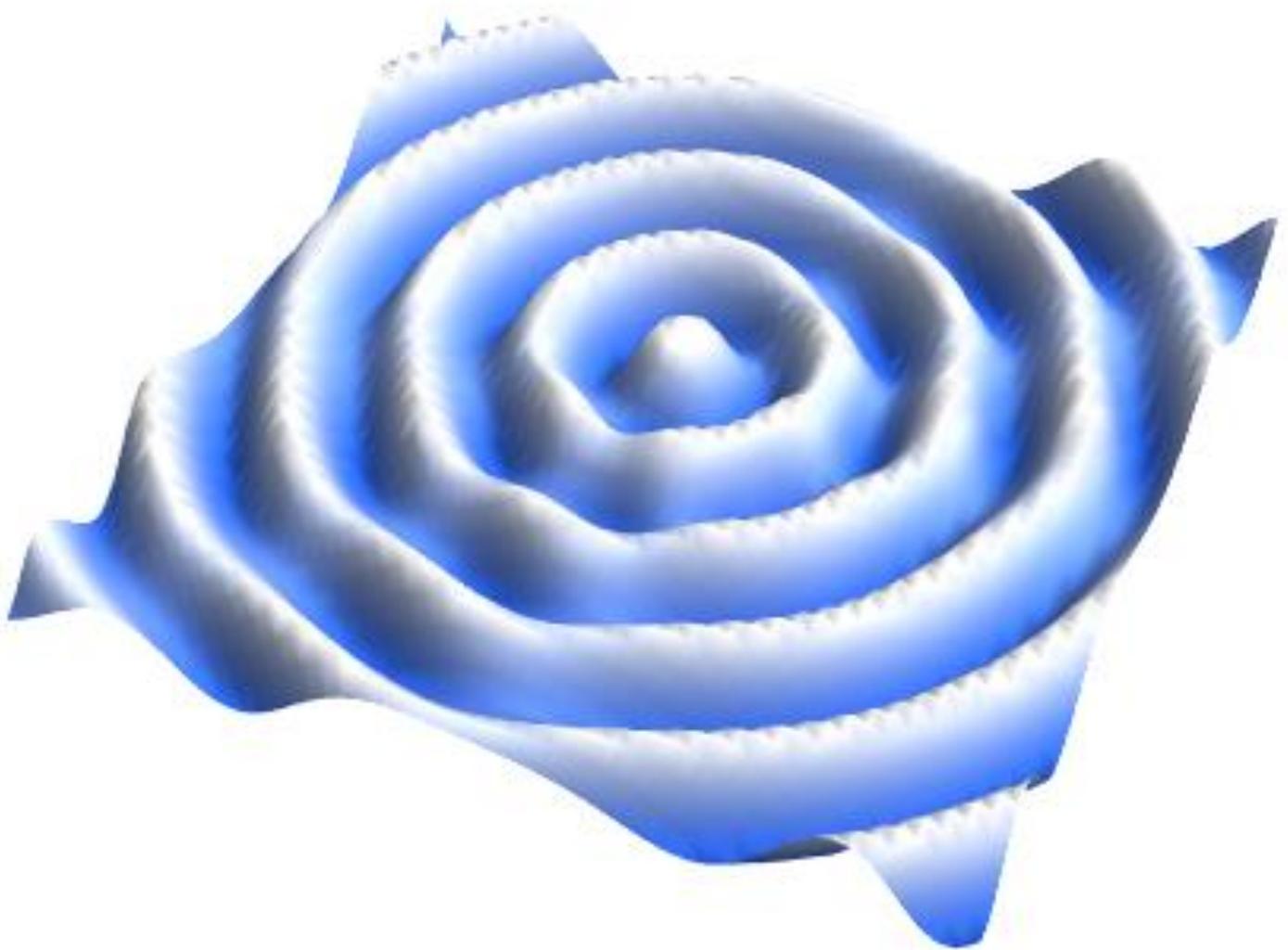


Radiofrequency and human health

An overview of the current evidence base



Disclaimer and notice

This report was commissioned by Mobile UK for Square Hammer Scientific Consulting Ltd to provide a contemporary overview of the current scientific evidence base around radiofrequency radiation and human health, and to provide independent assessment of frequently asserted claims on the subject in full context. Please note that the scientific evidence base changes constantly, and this report is current up to November 2021. This document is provided for guidance and consultation only.

Please note that relevant links to external organisations are hyperlinked for brevity, and full referencing for relevant scientific works is included. Note that the British English spelling of “ionising” has been employed in this document, but that the term “ionizing” is used when American reports are directly quoted. These should be taken as synonymous. Similarly, the British term “mobile” is generally employed herein, but the Americanisms of “cell” and “cellular” appear when international reports are quoted. These terms should accordingly be treated synonymously. The International System of Units is employed throughout unless otherwise stated in the text.

This report reflects the independent scientific opinion of the employees of Square Hammer limited consulting, based on the existing evidence base. Square Hammer Ltd are an independent scientific consulting organisation of qualified expert members with expertise and doctorates in relevant fields of biomedical science. All analysis herein is the independent scientific opinion of Square Hammer Ltd.

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Radiofrequency and human health

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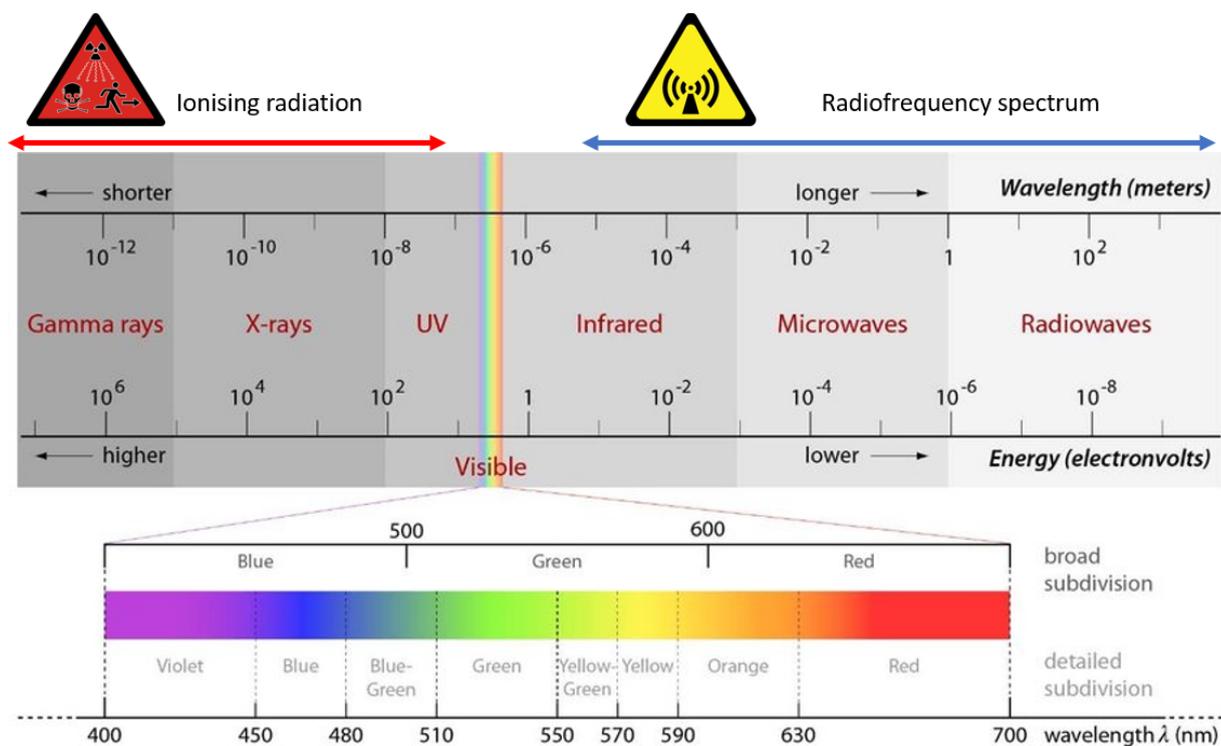


Figure 1: The electromagnetic spectrum (higher energy on the left, lower on the right)

Section I - Radiofrequency radiation

The electromagnetic spectrum

The word radiation is an often misunderstood one, and it is crucial to define it at the offset. Radiation refers to the transmission of energy in the form of waves of particles through space or a medium. Visible light itself is a prime example of electromagnetic radiation (EMR), which illuminates our world with every colour we can imagine. But visible light comprises only a tiny sliver of the vast electromagnetic spectrum, which encompasses light we cannot see, all travelling at the speed of light. The energies of these light particles, or “photons”, is proportional to their frequency, with higher frequency light carrying more energy. Conversely, energy is inversely proportional to wavelength, and higher energy EMR have shorter wavelengths¹.

The regimes of the EMR spectrum are illustrated in figure 1. At energies and frequencies beyond the visible light that illuminates our world exist the infrared, microwave, and radio-wave regimes - all of which have much lower energy than even visible light. At higher

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energies than visible light, there is ultraviolet, x-ray, and gamma ray, which possess higher frequency and shorter wavelength than visible light.

Ionising and non-ionising radiation

The amount of energy a photon carries has health ramifications that must be carefully considered. Light with high enough frequency has sufficient energy to liberate electrons, and is called ionising radiation. This is potentially carcinogenic, because it can lead to chemical changes that damage DNA, a prerequisite to many cancers². This is the reason why, for example, we limit our exposure to x-ray, a form of high-energy ionising radiation. Conversely, that which lacks the requisite energy to liberate electrons is referred to as non-ionising radiation. An illustration of where different common household radiation sources lie on the ionising and non-ionising dichotomy is shown in figure 2.

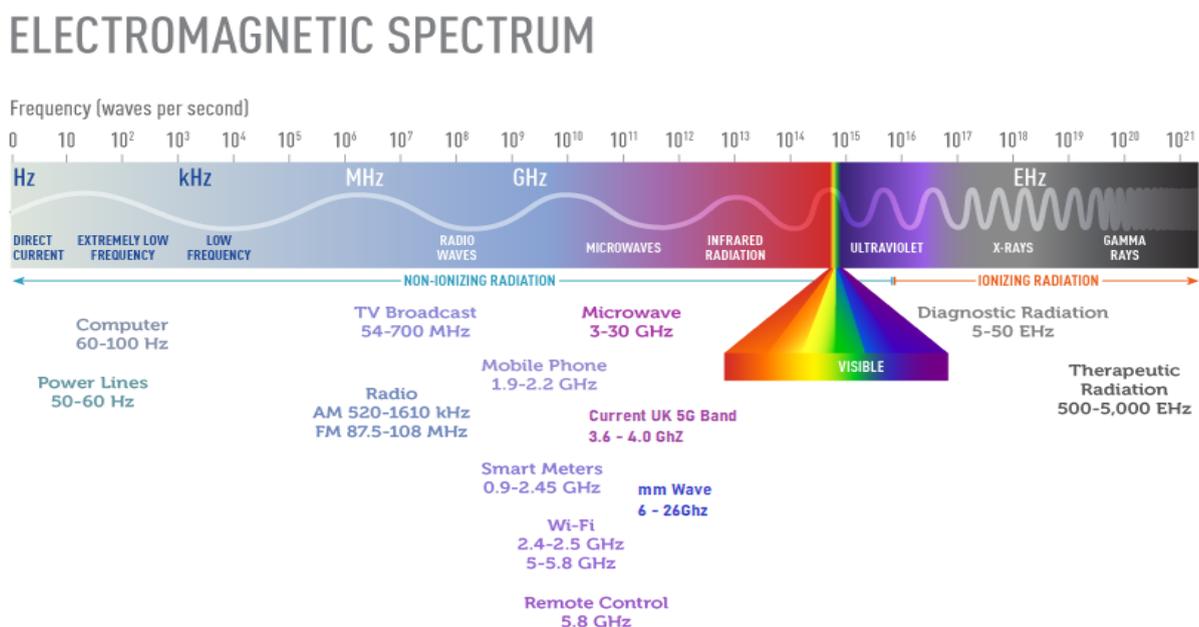


Figure 2: Common sources of ionising / non-ionising radiation (Image credit: modified from [National Cancer Institute](#) original image to include UK specific 5G spectrum (non-ionising))

Radiofrequency radiation on the spectrum

It is crucial to note that radiofrequency radiation (the spectrum of light used for radio, television, Wi-Fi, and mobile signals) is strictly non-ionising. To put it in context, radiofrequency (RFR) is much less energetic than even visible light (itself non-ionising). In reality, RFR is much less energetic than even visible photons we experience daily. In Europe, the 5G spectrum ranges from 3.6GHz to 26GHz³. This renders the most powerful RF photon

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over 15,000 times less energetic than lowest-energy visible light, with 5G mobile phone upper frequencies (6GHz) around 67,500 times less energetic than even visible light. In the UK, the current 5G band overlaps heavily with the existing 4G infrastructure, at around 3.6GHz. It is worth noting that the precise boundary at which radiation is considered "ionising" is not well defined, as different molecules and atoms ionize at different energies. A conservative threshold is 10eV^4 , corresponding to a photon of $\sim 124\mu\text{m}$, in the extreme ultraviolet end of the spectrum. Figure 3 shows the energy of the entire radiofrequency regime as a fraction of the ionisation threshold, illustrating that the radiofrequency regime is strictly non-ionising, at only a fraction of threshold.

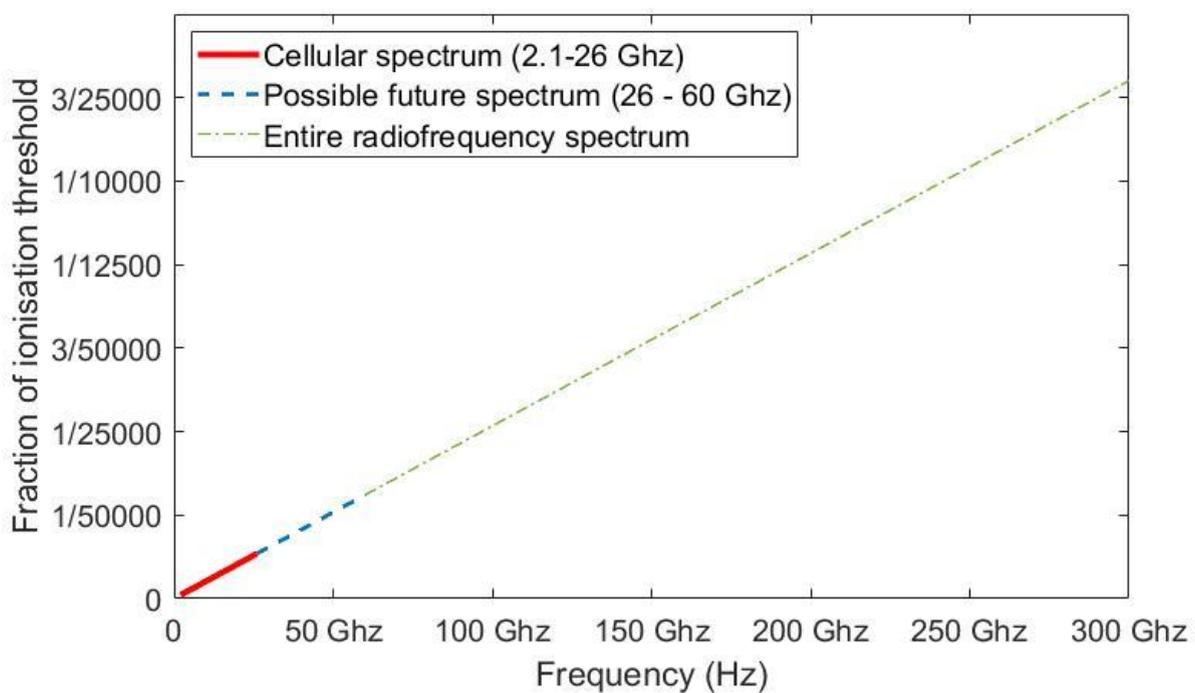


Figure 3: Radio-frequency energy as a fraction of the ionisation threshold. Mobile network region depicted in red for ease of contrast, potential future extensions in blue, derived from Ofcom discussions ([2017](#)). Sample calculations are given in the appendix.

Section II - Radiofrequency radiation and cancer

A common concern over RFR is whether it is a hazard for the onset of cancer, and if so to what degree does this risk hold. To answer this, it is worthwhile to look at both the mechanistic biophysical arguments, and the epidemiological evidence from animal and human data to date.

Biophysical considerations

High energy EMR can induce requisite DNA damage that can ultimately lead to cancer. However, for this to occur, the photons must be of sufficiently high frequency to ionise chemical bonds². As outlined in the previous section, RFR never comes remotely close to even a conservative estimate of the ionisation thresholds. At even the upper ends of the 5G spectrum, photon energy is less than 1/50000 of the energy required for a DNA damage event. It is also important to note that a subtle quantum mechanical consideration has to be taken into account here - one might reasonably ask if a higher intensity of lower energy photons might have the same bond-breaking effect. This will not however be the case - photons below the ionisation threshold will not carry requisite energy to overcome the chemical bonds, regardless of intensity. Accordingly, RFR cannot ionise and thus it can not cause the DNA damage needed for carcinogenesis.

It is often stated that all EMR above this threshold is carcinogenic, and all radiation below it is not. This is not strictly true, as ultraviolet radiation (UVR) on the periphery of the ionisation threshold, can also induce DNA damage and cancer. This is because higher energy UVR Photons have enough energy to raise DNA to an excited state. DNA is capable of rapid internal conversion, and dissipates most of these events to harmless heat in mere femtoseconds (million-billionths of a second) circumventing chemical reactions. When this process fails, incident UVB photons can form pyrimidine dimers. Even lower energy UVA photons can react with chromophores, yielding reactive oxygen singlets⁵⁻⁶. Yet even if the lower bound of UVA is taken as the ionisation threshold, this is still orders of magnitude above RFR energy levels.

To date, barring some unknown esoteric mechanism, there is no plausible biophysical rationale that would suggest RFR to be a cancer risk

“Photons below the ionisation threshold will not carry requisite energy to overcome the chemical bonds, regardless of intensity. Accordingly, RFR cannot ionise and thus it can not cause the DNA damage needed for carcinogenesis.”

Epidemiological data - monitoring projects

While known biophysical considerations do not support a link between low energy RFR and cancer, it is at least hypothetically possible that an unknown mechanism might cause harm. For this reason, health effects of RFR have been constantly monitored for several decades, and this monitoring is ongoing. There are several different agencies tasked with such monitoring. The World Health Organisation (WHO) runs the on-going International Electromagnetic field project ([EMF project](#)) an epidemiological undertaking to track potential effects of time-varying electric and magnetic fields in the frequency range 0-300 GHz. However, it should be noted this undertaking is not being performed based on any evidence of harm, but as a reasonable monitoring project. In the WHO's own words on the project, they state the following:

- ***“No major public health risks have emerged from several decades of EMF research..”***
- ***“There is no clear understanding if and how EMF at the low levels emitted by common appliances, might cause damage to cells.”***
- ***“If a common EMF exposure were found to cause a disease, it would likely be a rare one.”***
- ***“Demonstrating such a relationship would require complex population studies.”***

Crucially, the EMF project exists to monitor and synthesize existing and future research motivated by a proactive, precautionary stance. Its existence is not indicative of any proof of harm, given the EMF project themselves pointing to a lack of known mechanism for harm, and the rarity of any hypothetical illness related to RFR.

The International Agency for Research on Cancer (IARC) is an epidemiological body with a very specific remit. This is a branch of the WHO whose primary function is to ascertain potential cancer hazard of different agents, based on the strength of the epidemiological evidence linking exposure of an agent to potential carcinogenicity. Agents are classified under [4 distinct classes](#):

Group 1 : *The agent is carcinogenic to humans*: Agents with sufficient evidence of carcinogenicity in humans are placed in this group.

Group 2A : *The agent is probably carcinogenic to humans*: Agents with limited evidence of carcinogenicity in humans and sufficient evidence in experimental animals are classified here. Agents

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may also be classified as class 2A if there is inadequate human evidence but a known mechanism of carcinogenesis in human or animals.

Group 2B: *The agent is possibly carcinogenic to humans.* This is reserved for agents with limited evidence of carcinogenicity in humans and less than sufficient evidence in experimental animals. It is also deployed when an agent has inadequate evidence in humans and less than sufficient evidence in experimental animals but there is supporting evidence of carcinogenicity from mechanistic data. If a mechanism is known, an agent may also be classified in this category solely on this basis.

Group 3: *The agent is not classifiable as to its carcinogenicity to humans.* Reserved for agents where evidence is inadequate in humans and experimental animals. About 50% of all agents considered by IARC fall into this category.

Group 4: *The agent is probably not carcinogenic to humans.*

It is extremely important to note IARC exist not to classify degree of hazard, but only to determine strength of evidence for harm; for example, sunlight and smoking are Group 1 agents (solid evidence of carcinogenicity), but they have markedly different hazard rates, and it would be wrong to infer sun exposure is as dangerous as smoking. RFR is classified by the IARC as a Group 2B carcinogen, which in practice means there is no reliable evidence of carcinogenicity in human or animal models.

It is worth noting that confusion over these classifications is common, and the IARC system has [been criticised by science communicators](#) for confusion it induces. The inclusion of RF radiation as a class 2B agent has also been criticised, given the lack of quality evidence this designation typically requires. The IARC themselves tend to evaluate agents at far beyond reasonable levels, which in some instances is potentially misleading. The [most recent IARC communication](#) (2020) clarifies that there is no known risk from RFR. To summarise, while the WHO and IARC certainly do have projects and bodies tasked with evaluating potential EMF health effects, they are most certainly not stating any evidence of harm. In the [explicit words of the WHO](#),

“A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use.”

Epidemiological data - Human studies

It is also worth looking at human data to infer whether there is subtle evidence of harm. In this endeavour, large, carefully-controlled trials provide the most reliable data. Perhaps the most ambitious of these to date is the 13-country INTERPHONE study⁷ ([2010](#)), a case-control study where 2708 glioma and 2409 meningioma cases were matched with controls of similar background without brain tumours. The results of this study suggested there was ***“no increase in risk of glioma or meningioma was observed with use of mobile phones”***, although the researchers noted the potential for participant bias and unavoidable recall error.

A [2011](#) Danish cohort⁸ took data from Danes aged 30 and over, subdividing them into those who had subscribed to mobile networks since before 1995 and those who did not. In 10,729 records of central nervous system tumours, the data betrayed no indication of dose-response relation either by years use nor tumour location. A large prospective cohort study undertaken in the UK⁹ ([2013](#)) found no increase in incidence of central nervous system cancers related to RFR exposure in a large sample of 791,710 women. They did however initially detect an increase in acoustic neuroma incidence in long-term users, but this was subsequently shown to be an artefact that did not hold upon re-analysis¹⁰ ([2014](#)).

Aside from large scale studies such as these, a number of smaller scale studies have not found any replicable link between the use of phones and cancer across the world, from the United States to the Nordic countries¹¹⁻¹⁵ ([2000](#), [2001](#), [2005](#), [2009](#), [2012](#), [2014](#)). To date, a number of scientific and expert bodies have pooled the analysis of existing studies to ascertain any potential cancer risks from RFR. These collectively have yielded no discernable risk, and a non-exhaustive list of current scientific conclusions on carcinogenicity from radiofrequency radiation by major public health bodies is given in table 1 for brevity.

Table 1: Conclusions of recent health reviews by public health bodies worldwide

Public Health Body	Year	Evidence Base	Conclusions
International Commission on Non-Ionizing Radiation Protection (ICNIRP)	2020	Review of exposure guidelines dating from 1998, including a review of 39 relevant studies	No evidence of Cancer inducement in epidemiological studies.
US Food and Drug Administration	2020	Review of all relevant literature (dated 2008- 2018) on Radiofrequency & Cancer, including 125 125 studies of human and animal data	Insufficient evidence for causal association between RFR exposure and tumorigenesis, and lack of biological plausibility
Swedish Scientific Council on Electromagnetic Fields	2016 - 2019	Consensus report of relevant studies published up to 2019.	No causal relationship between EMF exposure and cancer risks established.
European Commission Scientific Committee on Emerging and Newly Identified Health Risks	2015	Expert consensus on studies published between 2009-2014	RFR exposure did not appear to increase risk of brain tumours, or childhood cancers.

Epidemiological data - In vivo studies (animal data)

It is also worthwhile to look at RFR studies with animal data, though caution must be taken when interpreting results for a wide variety of reasons. Animal studies for assessing possible adverse or other effects of RFR are very difficult to design, and typically employ whole-body exposures, itself not reflective of the human situation of localised exposure. For this reason, the FDA notes that strong epidemiological studies of human data tend to provide more accurate information regarding human health. Despite this limitation, the FDA review¹⁶ ([2020](#)) also consisted of 37 relevant animal studies but concluded that due to the inherent limitations of these experiments, that they demonstrate no reliable effect of RFR exposure and cancer initiation. One often cited study did claim to find an effect, but this has been refuted by experts, and is discussed specifically in section V.

Section III - RFR and electromagnetic hypersensitivity

Electromagnetic hypersensitivity (EHS) is a reported sensitivity to different types of electromagnetic radiation, typically including some or part of the RFR spectrum. The precise type of malaise reported is nebulous, with symptoms include fatigue, sleep disturbance, non-specific pain and even skin conditions. Yet despite the sincerity of these beliefs and the discomfort experienced by sufferers, there is zero evidence supporting the position that reported ill-effects of EMR are actually induced by such fields.

The strongest evidence of this comes from provocation studies, where self-identified sufferers are exposed to RFR sources (such as phones and routers) to gauge their response¹⁷. Yet tellingly, sufferers have been completely unable to identify when sources of EMR are present, and also reported negative effects when exposed to sham radiation. In one well known example from South Africa in 2010, residents complained of EHS symptoms following the construction of a new mast, only to be shown that the mast itself was not currently active.

“Sufferers have been completely unable to identify when sources of EMR are present, and also reported negative effects when exposed to sham radiation.”

The number reporting themselves as suffering from EHS varies markedly worldwide, and seems to be decreasing. A 2007 UK study of 20,000 people found that 4% of them self-attributed symptoms to EMR exposure¹⁹. In Taiwan, telephone studies suggested that self diagnosis has declined despite an increase in the prevalence of electronic devices²⁰, from 13% in 2007 to 5% in 2013. Similar declines were also noted in the Netherlands²¹ (7% in 2009 to 4% in 2011) and in Germany²¹ (10% in 2009 to 7% in 2013). Women appear more likely to self-report EHS than men. The non-RFR nature of these results have been replicated in several trials, strongly suggesting that the illness sufferers feel is psychological rather than physical, and that for some the belief one is allergic to EM radiation is enough to trigger an unpleasant psychosomatic reaction. Accordingly, the WHO and scientific bodies recognise that while EHS exists, it is not caused by EM fields; the WHO statement on this position is both sympathetic and unequivocally clear

“The symptoms are certainly real and can vary widely in their severity. Whatever its cause, EHS can be a disabling problem for the affected individual. EHS has no clear diagnostic criteria and there is no scientific basis to link EHS symptoms to EMR exposure.”

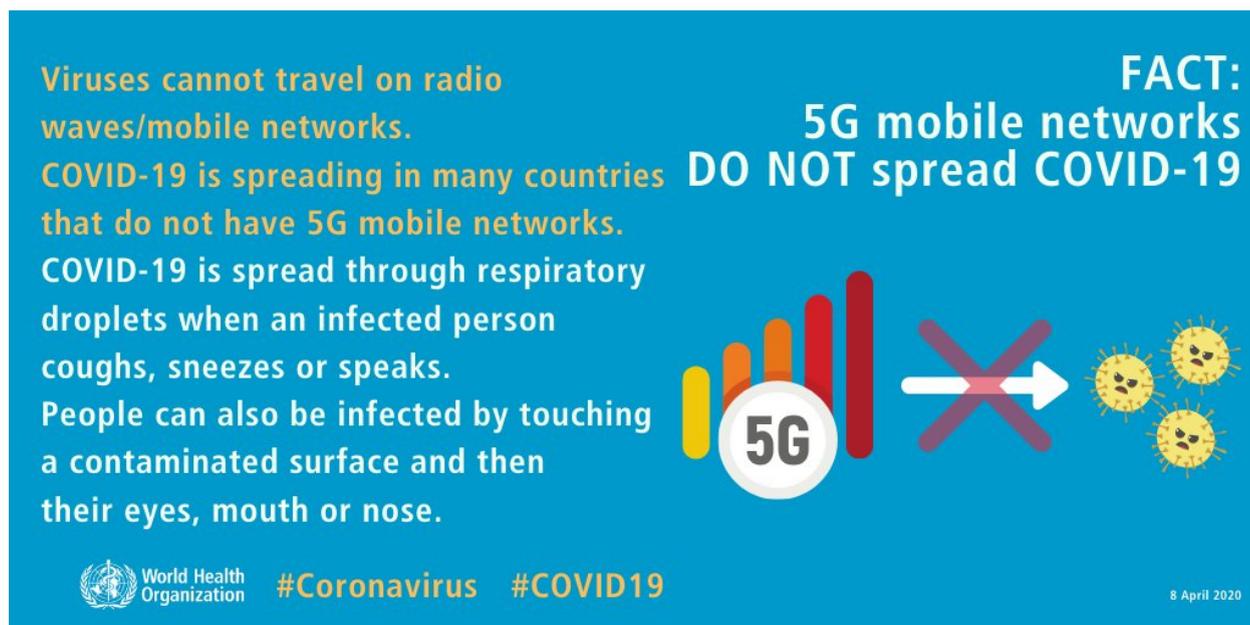


Figure 4: [WHO infographic](#) from April 2020 explaining that COVID-19 was completely unrelated to 5G.

Section IV - RFR and COVID-19

One especially unusual narrative that emerged around the novel coronavirus COVID-19 is that it was caused or exacerbated by exposure to 5G. The depth of feeling on this worldwide led to arson attacks on mobile-phone towers the world over. 5G radiation is, however, neither ionising nor capable of inducing a virus, a supposition which appears a biological impossibility. Prior to the advent of the novel coronavirus, opposition to 5G had already been firmly established worldwide, reciting long debunked myths, including deliberate disinformation²² campaigns originating in Russia.

Aside from biological implausibility, the COVID-19 / RFR assertion is a regurgitation and amalgamation of previously existing conspiracy theories, and is not in any way scientifically validated. One 2021 analysis²³ found that even if it had any biological merit, it would be virtually impossible for researchers, public health bodies, and telecoms companies to keep it suppressed. Accordingly, the 5G-COVID link is unambiguously a profoundly unviable and wrong-headed myth and deserves no further scientific or public consideration

Section V - Common misconceptions and avenues of confusion

RFR research is evolving and can be complicated, and it is not unusual that misunderstandings can arise, particularly in an area where misinformation (inadvertent falsehood) and disinformation (deliberate fictions) swirl constantly in discourse both online and off. There are also some scientific findings which quoted out of context or without reference to the full literature can seem positively misleading. In this section, a few of the prominently misrepresented and misunderstood pieces of evidence are considered in context.

The National Toxicology Programme study

As summarised in section II, the vast majority of in vivo experiments find no evidence to support a link between cancer and RFR exposure. One ostensible exception is a 2018 study by the National Toxicology Programme²⁴ (hereafter the NTP study). Briefly, the NTP study exposed pregnant rats to high doses of 900 MHz GSM- or CDMA-modulated RFR (beginning at Gestation Day (GD) 5) and continuing exposure to rat pups post birth until weaning on postnatal day (PND) 21. At this juncture, exposure of 90 pups per sex per group was continued for up to 106 weeks. RFR exposures were “conducted over a period of approximately 18 hours using a continuous cycle of 10 minutes on (exposed) and 10 minutes off (not exposed), for a total daily exposure time of approximately 9 hours daily.” Control rats were treated identically, except that they were not exposed to RFR.

The rats were grouped into either controls (no RFR exposure), or into GSM or CDMA groups (each subdivided into either 1.5 W/kg, 3W/kg, or 6 W/kg exposure levels). This is already a very high level of exposure, and after the experiment concluded, the experimenters looked to see if there was any increase in cancers for the rats exposed to different types of RF. The results from that study are shown in the table overleaf, and their interpretation is discussed thereafter.

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	Control	GSM			CDMA		
	0 W/kg	1.5 W/kg	3 W/kg	6 W/kg	1.5 W/kg	3 W/kg	6 W/kg
Number examined	90	90	90	90	90	90	90
Malignant glioma ‡	0	0	0	1 (1.1%)	2 (2.2%)	0	0
Glial cell hyperplasia	0	0	1 (1.1%)	0	1 (1.1%)	1 (1.1%)	1 (1.1%)

[§] Data presented as number of animals per group with lesions (percentage of animals per group with lesions).

[‡] Historical control incidence in NTP studies: 1/540 (0.18%), range 0-2%

The above table, taken from the paper in question, shows the results for male rats, where there was 1 malignant glioma in the highest exposed GSM group (6 W/kg) and 2 in the lowest exposed CDMA group (1.5 W/kg). For glial cell hyperplasia, there was one each in all the CDMA exposed groups and 1 at 3 W/kg in the GSM. This however must be cautiously interpreted - as other authors have noted, it does not seem to follow any dose-response curve; if RFR was the culprit for these malignancies, it should follow that increasing dose yields more occurrences, as is the case with other carcinogen exposure. That this did not transpire indicates these results are potentially flukes, especially as they only occurred in the male group. The study authors also noted the following:

“At the end of the 2-year study, survival was lower in the control group of males than in all groups of male rats exposed to GSM-modulated RFR. Survival was also slightly lower in control females than in females exposed to 1.5 or 6 W/kg GSM-modulated RFR. In rats exposed to CDMA-modulated RFR, survival was higher in all groups of exposed males and in the 6 W/kg females compared to controls.”

This is a curious result - namely that exposed rats lived significantly longer than their unexposed controls. This is more likely evidence of fluke results than any suggestion that RFR makes rats live longer. Upon [reviewing the preprint](#), Michael S. Lauer of the Office of Extramural Research at the Nation Institute of Health detailed a litany of problems with the research, stating that after a careful statistical analysis, he was “unable to accept the author’s conclusions”, elaborating:

“The low [statistical] power implies that there is a high risk of false positive findings, especially since the epidemiological literature questions the purported association between cell phone exposure and cancer.. I suspect that this experiment is substantially underpowered and that the few positive results found reflect false positive findings. The higher survival with RFR, along with the prior epidemiological literature, leaves me even more skeptical of the authors’ claims.”

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Since the release of this study, it has been shared widely by anti-RF groups the world over. But despite its popularity with anti-RFR and anti 5G groups, it does not provide reliable evidence of harm, and it would be equally ludicrous (but equally well-supported by the study data) to infer that RFR exposure increases male life expectancy by 8%. It is also worth noting that the technologies considered (GSM and CDMA) are old standards corresponding to 2G and 3G networks, rather than any specific argument against 5G as is often claimed by anti-RFR activists.

The low number of events and statistical issues are far from the only problems with this paper. A [February 2020 analysis by the FDA](#) noted a catalog of issues with the experiment¹⁶, including inadequate blinding and consideration of the thermoregulation of geriatric mice. They concluded, on the basis of this and other *in vivo* work,

“Overall, based on certain limitations, these studies have not produced any clear evidence that RFR exposure has any tumorigenic effect.”

Similar criticisms have emerged in both academic and [popular science literature](#). Perhaps more concise is the [2020 response](#) in the Journal of Health Physics from the International Commission on Non-Ionizing Radiation Protection (ICNIRP²⁵) which rebuts many of the claims and interpretations of the NTP study

“Although NTP (2018a) and Falcioni et al. (2018) both reported significantly elevated rates of carcinogenic outcomes in male rats, their results are not consistent with each other, nor with the NTP (2018b) mouse or female rat results, nor with the RF cancer literature generally (SCENIHR 2015; HCN 2016; SSM 2018). The NTP’s outlying finding is further complicated by important methodological limitations including the effect of the greater lifespans of the exposed rats on the statistical analyses, lack of blinding in the pathological analyses, and a failure to account sufficiently for chance in the statistical analyses. Collectively these two studies’ limitations preclude drawing conclusions about carcinogenicity in relation to RF EMFs.”

To conclude, the most likely explanation for the NTP study results is mere fluke, and it should be construed as evidence of harm. The refutations and weakness inherent in the work already render it suspect, and it is contradicted by a wealth of other data. Accordingly, despite the high status afforded to it by anti-5G activists, it is most explicitly not evidence of their position.

The Bioinitiative report

One apparent publication often cited by opponents of RFR is the Bioinitiative report, originally released to media fanfare in 2007 and updated in 2012. This appears to be a scientific position document which argues that RFR is linked with everything from cancer to neurological conditions. However, while it masquerades as a scientific document, it quite clearly does not base its conclusions on scientific evidence, and has been roundly condemned by scientists around the world for its fanciful and unsupported assertions.

To call this report a scholarly document would be an almost impressive misrepresentation - the Bioinitiative report is, in reality, one of the most wholly debunked texts on RFR ever produced. While a non-scholarly work, its alarming claims since 2007 have made it a mainstay of anti-RF activism. However, in stark contrast to the EHT claim²⁶, [the view of professional public health bodies towards the Bioinitiative report is grim](#):

"In view of the way the Bioinitiative report was compiled, the selective use of scientific data and the other shortcomings mentioned earlier, the committee concludes that the Bioinitiative report is not an objective and balanced reflection of the current state of scientific knowledge."

-Health Council of the Netherlands (2008)

"Overall, we think that the Bioinitiative report does not progress science and would agree with the Health Council of the Netherlands that the Bioinitiative Report is "not an objective and balanced reflection of the current state of scientific knowledge." As it stands, it merely provides a set of views that are not consistent with the consensus of science, and it does not provide an analysis that is rigorous enough to raise doubts about the scientific consensus."

-Australian Center for RF Bioeffects Research (2008)

"There is a lack of balance in the report; no mention is made in fact of reports that do not concur with authors' statements and conclusions. The results and conclusions are very different from those of recent national and international reviews on this topic . . . If this report were to be believed, EMF would be the cause of a variety of diseases and subjective effects."

-European Commission Scientific Committee on Emerging and Newly Identified Health Risks (2009)

"..the weight of scientific evidence in the RF bioeffects literature does not support the safety limits recommended by the Bioinitiative group. For this reason, Committee on Man and Radiation recommends that public health officials continue to base their policies on RF safety limits recommended by established and sanctioned international organizations such as the

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Institute of Electrical and Electronics Engineers International Committee on Electromagnetic Safety and the International Commission on Non-Ionizing Radiation Protection, which is formally related to the World Health Organization.” - Institute of Electrical and Electronics Engineers Committee on Man and Radiation (2009)

In conclusion, the Bioinitiative report is not a valid source of scientific information and should not be considered as one, particularly as its central claims are at best unsupported and at worst completely and utterly debunked.

5Gappeal.eu (Online petition)

Another commonly cited piece of apparent evidence of the alleged harms of RFR is the 5G appeal, a petition which at the time of this report has 417 signatories who claim that 5G may be harmful. This is mainly signed by people holding either medical degrees or doctorates, and some independent researchers. This might be superficially impressive, but there are major red flags with the whole premise:

- The first and most crucial of these issues is that science is not done by petition - scientific consensus is achieved on the basis of analysing the published research and assessing it for quality. The 5G appeal asserts that RFR has been “proven to be harmful”, which is at complete odds with the literature to date.
- A closer inspection of the 417 signatories reveals that almost none of them are experts in the field, nor have the vast majority published any research on RFR. Of those who have published, most occupy notably fringe views. This undermines the assertion that the petition reflects expertise, especially as it can be signed by any individual with a qualification, relevant or not.
- The individual behind the position holds a distinctly fringe scientific opinion, and methodological shortcomings of their RFR work have been noted [in US courts](#).
- No professional bodies, universities, or medical institutions support the petition nor have co-signed it.

In short, this petition is a far cry from scientific expertise, and is a fringe undertaking. It most certainly should not be interpreted as evidence or a barometer of expert opinion, as this would be a complete misrepresentation of both the petition and the strength of scientific evidence pointing very firmly in the opposite direction.

Section VI - Concluding remarks

RFR is both complex and ubiquitous. It is a subject beleaguered by persistent, long-standing misunderstandings, and disinformation. That apprehension exists in the public mind, particularly about issues of health, is completely understandable. As mobile phones have only been in common circulation for four decades, it is reasonable to be pragmatic and be mindful of potential emergent health-effects. However, it is important to note that both biophysical and epidemiological evidence to date show no evidence of dangerous RFR induced health effects.

In conclusion, assertions of RFR harm, particularly relating to ostensible cancer risks, are not supported by the totality of evidence. This remains the position of major health bodies, and it would take a huge shift in the current evidence base for this to alter significantly. Equally, claims of EHS being linked to RFR are not supported by evidence, and COVID-19 related claims about 5G and the RFR spectrum in general are firmly conspiratorial and non-evidence based. We conclude that the evidence to date suggests strongly that RFR does not carry any implication of severe adverse health effects.

“In conclusion, assertions of RFR harm, particularly relating to ostensible cancer risks, are not supported by the totality of evidence.”

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Appendix: Photon energy calculation

Photon energy is given by the Einstein-Planck relationship, where

$$E = h\nu = \frac{hc}{\lambda}$$

where h is Planck's constant ($6.62607004 \times 10^{-34}$ square metre kilogram per second), ν is photon frequency in hertz, c is the speed of light and λ is photon wavelength in metres.

Photon energy in the above identity is given in Joules, and from electron volts to joules is $1 \text{ J} = 1.603 \times 10^{-19} \text{ eV}$. The energy spectra for visible light (400 to about 790 Thz), millimetre wave (6-26Ghz) 5G mobile (3.6-4Ghz) are, as shown in the table below, orders of magnitude below the highly conservative 10eV threshold.

Light type	Fraction of 10eV threshold
Visible light (non-ionising)	1.65% - 32.67%
Millimetre waves (non-ionising)	0.000248% - 0.0011%
5G Mobile (non-ionising)	0.000148% - 0.0001654%



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