



Review

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Summary of seven Swedish case reports on the microwave syndrome associated with 5G radiofrequency radiation

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Abstract: The fifth generation, 5G, for wireless communication is currently deployed in Sweden since 2019/2020, as well as in many other countries. We have previously published seven case reports that include a total of 16 persons aged between 4 and 83 years that developed the microwave syndrome within short time after being exposed to 5G base stations close to their dwellings. In all cases high radiofrequency (RF) radiation from 4G/5G was measured with a broadband meter. RF radiation reached $>2,500,000$ to $>3,180,000 \mu\text{W}/\text{m}^2$ in peak maximum value in three of the studies. In total 41 different health issues were assessed for each person graded 0 (no complaint) to 10 (worst symptoms). Most prevalent and severe were sleeping difficulty (insomnia, waking night time, early wake-up), headache, fatigue, irritability, concentration problems, loss of immediate memory, emotional distress, depression tendency, anxiety/panic, dysesthesia (unusual touched based sensations), burning and lancinating skin, cardiovascular symptoms (transitory high or irregular pulse), dyspnea, and pain in muscles and joints. Balance disorder and tinnitus were less prevalent. All these symptoms are included in the microwave syndrome. In most cases the symptoms declined and disappeared within a short time period after the studied persons had moved to a place with no 5G. These case histories are classical examples of provocation studies. They reinforce the urgency to inhibit the deployment of 5G until more safety studies have been performed.

Keywords: base station; 5G; radiofrequency radiation; electromagnetic sensitivity; microwave syndrome; health

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Introduction

The fifth generation, 5G, for wireless communication has been implemented in Sweden as well as in many other countries since 2019/2020. 5G antennas emit radiofrequency (RF) radiation and so far the 3.5 GHz frequency has been used as carrier wave for 5G in city environments. When 5G is installed, previous generations such as 2G and 3G are dismantled (<https://www.pts.se/sv/privat/telefoni/teknikskifte/informationsmote-om-avveckling-av-2g-och-3g-nat/>; in Swedish). 5G uses MIMO technique, multiple-input and multiple-output, with the use of multiple antennas at the transmitter and receiver. 5G is so far broadcasted in combination with 4G+, and will send data up to 100 times faster than previous technology (<https://projectgoliath.eu/emf-5g/>). According to preliminary pilot investigations in France, 5G exposure varies considerably with number of users in the vicinity of the base station and the size of data transfers (<https://www.anfr.fr/fileadmin/mediatheque/documents/5G/20200410-ANFR-rapport-mesures-pilotes-5G-EN.pdf>).

Concerns were raised by many scientists before the rollout that 5G would lead to a massive increase in the general public's exposure to RF radiation (www.5Gappeal.eu). It was noted that RF radiation was already proven to be harmful to human health at levels encountered in the environment before the deployment of 5G. These concerns also highlighted that there was no previous research on the effects on humans and the environment from the new 5G RF radiation exposure, including new higher frequencies, modulations, intense fast pulsing and perhaps most importantly the expected much higher RF radiation exposure. In addition, in a report to the European Parliament in 2019 it was noted that 5G exposure will be more complex than previous systems: "Although fields are highly focused by beams, they vary rapidly with time and movement and so are unpredictable, as the signal levels and patterns interact as a closed loop system." (https://5gfree.org/wp-content/uploads/2020/07/IPOL_IDA2019631060_EN.pdf).

Several appeals have requested better protection against harmful effects from RF radiation due to known risks for human beings and the environment. The 5G appeal asked

for a moratorium of 5G deployment already in 2017 (www.5gappeal.eu), see also (www.emfcall.org, www.emfscientist.org). These appeals are to date largely ignored by the responsible governmental agencies, politicians and the telecom industry. The progress of this technique continues at its own pace, apparently driven by considerable economic interests within the telecom industry.

It is clear from measurements made so far that the implementation of 5G has indeed caused a massive increase in human and environmental exposure to pulse-modulated RF radiation [1–8].

Limits for maximum exposure

Most countries use extremely high and outdated guidelines by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for maximum allowed exposure to RF radiation. The first guidelines were published in 1998 [9], and were updated in 2020 [10]. The US Federal Communications Commission (FCC) has adopted similar maximum limits set by the Institute of Electrical and Electronics Engineers (IEEE) (https://docs.fcc.gov/public/attachments/FCC-19-126A1_Rcd.pdf).

ICNIRP is a private organization based in Germany. New members are elected by existing members and most of them have historically had both economic and/or personal ties to the telecom industry [11, 12]. ICNIRP's limits are based only on heating (thermal) effects from RF radiation that appear when the RF radiation is so intense that it causes acute thermal effects within an hour. For chronic full body exposure to 5G at 3.5 GHz the ICNIRP limit is $10,000,000 \mu\text{W}/\text{m}^2$ averaged over 6 min [9], or 30 min [10]. The ICNIRP thermal-based limits do not protect against any effect caused by non-thermal acute or chronic exposure in spite of growing evidence for such effects. Therefore the ICNIRP and the FCC limits are criticized for their inability to protect against a long range of known health effects based on substantial and increasing scientific evidence [13–15]. In fact, RF radiation was already in 2011 evaluated by the International Agency for Research on Cancer (IARC) at WHO to be a possible human carcinogen, Group 2B [16, 17]. In spite of further evidence of the carcinogenicity indicating that RF radiation now may be classified as a human carcinogen Group 1 [18], a new evaluation has not been made by IARC.

The ICNIRP approach appears to be of large importance for the telecommunication industry since these guidelines for exposure to RF radiation allow them to deploy 5G according to their plans. A major example is that 5G roll out would be “*difficult or impossible*” if the limits were lowered 100 times according to a leading 5G infrastructure provider (https://www.itu.int/en/ITU-T/Workshops-and-Seminars/20171205/Documents/S3_Christer_Tornevik.pdf). Yet another example of the

importance of these limits to the industry is a promotional brochure about the ICNIRP 2020 limits from the telecommunication operator's organization GSMA (https://www.gsma.com/publicpolicy/wp-content/uploads/2021/10/GSMA_International_EMF_Exposure_Guideline_Oct21.pdf).

The microwave syndrome

Microwaves are frequencies between 300 MHz and 300 GHz within the radiofrequency spectrum and it is within the microwave frequency range that the 5G and previous generations of mobile phone technology carrier waves operate. Evidence of negative health effects from RF/microwave radiation were published already in the 1960s and 1970s in Eastern European countries in studies of exposed workers [19–21]. Common symptoms were headache, fatigue, concentration difficulty, insomnia, emotional distress, irritability, dysesthesia, skin lesions including burning sensation, cardiac and lung symptoms. These are included in the microwave syndrome or illness that comprises a variety of clinical and physical symptoms. It was observed that in general women appeared to be more sensitive than men and that the individual sensitivity varied.

A review of these studies, as well as studies on animals, concluded that “*a surprisingly wide variety of neurological and physiological reactions are to be expected*” because of exposure to non-thermal levels of RF/microwave radiation [19].

Other term for the illness was radiofrequency sickness syndrome [22]. The non-thermal effects depend primarily on the modulation and/or pulsation of the signal and also on the peak and average intensity. Pulsed signals and simultaneous exposure to several frequencies caused more effects and were thus considered more hazardous. The observed effects increased with longer time of exposure [20]. Today the population is exposed simultaneously to a multitude of frequencies from various wireless technologies. The signals are pulsed and modulated and the exposure is chronic.

It was also observed that, in general, the symptoms declined after the exposure had ceased. According to Marha et al. (see page 31) “*at a certain time after exposure had ended (sometimes as long as several weeks or more), the organism usually returns to its original physiological state and all subjective and objective complaints vanish*” [21].

The results of these early observations have been confirmed during the last two decades in investigations on health effects among inhabitants near mobile phone masts or base stations. Some of these recent studies have investigated prevalence of symptoms identified within the microwave syndrome, others have investigated other outcomes such as cancer or effects on biochemical parameters, for

instance hormones or indications of genetic damage [23]. One study from France has studied frequency of ALS [24]. According to a review in 2022 of most of these studies, 17 of 23 studies showed evidence for radiofrequency sickness or the microwave syndrome, 10 of 13 reported increased cancer risks and six of eight studies found changes in biochemical markers among people living in the vicinity of masts or base stations [23].

5G studies so far

The literature is sparse on health effects caused by exposure to 5G radiation. So far, according to our knowledge, no long-term effects have been studied and there are only a few short term animal studies and one human laboratory study. None of the laboratory studies have used exposure corresponding to real life 5G exposure [25–29].

There were at the start of the roll-out of 5G no studies available on biological effects on humans from exposure to the 5G frequencies around 3.5 GHz.

Thus, no study had investigated exposure similar to that encountered by millions of people now exposed to radiation from 5G antennas in combination with 4G technology.

A few animal studies have investigated effects on animals after exposure to 3.5 GHz RF radiation at levels below the ICNIRP limits. Studies exposing animals to the 3.5 GHz frequency (not real-life 5G signals) have found negative effects such as oxidative stress in the liver, kidneys, the plasma, degenerated neurons in the brain as well as oxidative stress in muscles and negative effects on bone strength. Further, modified behavior after fetal exposure has been reported [25–28].

Human laboratory studies

A study published in September 2023, investigating effects on human brain waves, exposed 34 healthy young volunteers to GSM pulse-modulated 3.5 GHz at a mean level between 1.5 and 2 V/m or up to 10,610 $\mu\text{W}/\text{m}^2$ during only 26 min. The estimated peak power density (PD) was calculated to 680,000 $\mu\text{W}/\text{m}^2$. The authors reported “*an overall non-significant difference in beta, alpha, theta, and delta brain oscillations relative to 5G exposure. However, a few electrodes in the baseline-corrected exposure and post-exposure periods exhibited significant modulation corresponding to the eye condition only in the alpha, theta, and delta rhythms, which did not survive the posterior statistical correction.*” [29].

Some changes in human brain waves were thus observed. However the signal was GSM modulated and consequently not representative of real 5G exposure. The exposure lasted only

26 min and was thus not representative for effects of chronic real life exposure. In addition, real life exposure includes simultaneous exposure to several other signals, for instance to 4G.

Case studies of human real life 5G exposure

We have previously published seven case reports on health effects in humans exposed to 5G RF radiation [1–7]. The studies were performed during 2021–2023 and investigated health effects previously described to be associated with exposure to RF radiation among a total of 16 persons. Measurements of RF radiation were also made.

Aim of this study

The aim of this study was to make a summary of our seven case reports [1–7]. One purpose was to investigate the severity and any pattern of different diseases/symptoms based on the total material.

Materials and methods

All seven case studies were initiated after contact from persons who developed symptoms identified within the microwave syndrome shortly after installation of 5G antennas close to their dwellings. The participating persons were asked to answer questions on the prevalence of different symptoms related to the microwave syndrome. The structured questionnaire was adapted after Belpomme et al. [30]. A 10-grade scale for severity was used, grade 0=no symptoms, grade 10=unbearable pain and/or discomfort. The questionnaire included in total 41 symptoms/health issues. No clinical examinations were performed. The studies also included measurements of RF radiation exposure.

We did an aggregation of all the results from these individual seven case studies. Five groups of symptoms were used based on anatomical site including diseases of the nervous system and sense organs (n=18), Table 1, diseases of the cardiovascular and respiratory system (n=9), Table 2, diseases of the skin and musculoskeletal organs (n=6), Table 3, diseases of the digestive and urinary system (n=4), Table 4, and diseases of the ear and vestibular system (n=4), Table 5.

The sum of the reported grade of severity for each disease/symptom was calculated for all study subjects. Minimum and maximum grade for each item is reported as well, and the calculated mean and median grades for the total material.

Table 1: Diseases/symptoms of the nervous system and sense organs grades 0–10. Grade 0=no symptoms, 10=unbearable pain and/or discomfort. Total number of replies was based on 16 persons or otherwise given (n). Number of persons reporting minimum grade 0, or maximum grade e.g. 10 are given within parentheses. Number of persons reporting other grade than the maximum (e.g. 2 to 9) are not displayed in the table.

Nervous system and sense organs	Min	Mean	Median	Max	Total
Sleeping difficulty					
– Waking night time (n=12)	0 (1)	6.58	7	10 (5)	79
– Early wake-up (n=14)	0 (3)	6.33	7	10 (5)	76
– Insomnia	0 (3)	6.25	7	10 (7)	100
Fatigue	0 (3)	5.75	7	10 (3)	92
Headache	0 (4)	4.88	5	10 (3)	78
Irritability (n=15)	0 (3)	4.73	4	10 (3)	71
Emotional (n=15)	0 (4)	4.47	4	10 (4)	67
Concentration/attention deficiency	0 (7)	3.69	4	10 (1)	59
Loss of immediate memory	0 (9)	3.19	0	10 (2)	51
Dysesthesia (unusual touched based sensation)	0 (7)	3.13	1	10 (1)	50
Dizziness	0 (8)	2.38	1	10 (2)	38
Depression tendency	0 (5)	2.38	2	8 (1)	38
Anxiety/panic	0 (9)	2.19	0	10 (1)	35
Global body dysthermia	0 (11)	1.81	0	7 (1)	29
Ocular deficiency	0 (10)	1.63	0	8 (1)	26
Light sensitivity (n=11)	0 (9)	1.36	0	8 (1)	15
Confusion	0 (11)	1.25	0	10 (1)	20
Suicidal ideation	0 (16)	0	0	0 (0)	0

Table 2: Diseases/symptoms of the cardiovascular and respiratory system grades 0–10. Grade 0=no symptoms, 10=unbearable pain and/or discomfort. Total number of replies was based on 16 persons or otherwise given (n). Number of persons reporting minimum grade 0, or maximum grade e.g. 10 are given within parentheses. Number of persons reporting other grade than the maximum (e.g. 2 to 9) are not displayed in the table.

Cardiovascular system	Min	Mean	Median	Max	Total
Heart					
– Irregular pulse	0 (12)	2.31	0	10 (2)	37
– Transitory high pulse	0 (12)	2.13	0	10 (2)	34
– Slow pulse	0 (16)	0	0	0 (0)	0
Blood pressure high/low (n=14)	0 (11)	0.81	0	5 (2)	13
Nose bleeding	0 (11)	1.75	0	10 (1)	28
Respiratory system					
Dyspnoea	0 (8)	2.69	1	9 (2)	43
Cough	0 (11)	1.50	0	10 (1)	24
Chest squeeze (n=12)	0 (8)	1.42	0	10 (1)	17
Chest pain (n=9)	0 (8)	1.11	0	10 (1)	10

In most studies the device Safe and Sound Pro II broadband RF meter was used for measurement of RF radiation [1–5, 7]. The true response detection range is

Table 3: Diseases/symptoms of the skin and musculoskeletal organs grades 0–10. Grade 0=no symptoms, 10=unbearable pain and/or discomfort. Total number of replies was based on 16 persons. Number of persons reporting minimum grade 0, or maximum grade e.g. 10 are given within parentheses. Number of persons reporting other grade than the maximum (e.g. 2 to 9) are not displayed in the table.

Skin	Min	Mean	Median	Max	Total sum
– Face, arms, legs	0 (8)	3.19	1	10 (1)	51
– Burning, lancinating skin on hands and arms	0 (8)	3.19	2	10 (2)	51
– Bruises, hemorrhages	0 (13)	0.75	0	6 (1)	12
Hair loss	0 (13)	0.31	0	3 (1)	5
Musculoskeletal organs					
Arthralgia	0 (9)	2.75	0	10 (2)	44
Myalgia	0 (9)	2.31	0	10 (1)	37

Table 4: Diseases/symptoms of the digestive and urinary systems grades 0–10. Grade 0=no symptoms, 10=unbearable pain and/or discomfort. Total number of replies was based on 16 persons or otherwise given (n). Number of persons reporting minimum grade 0, or maximum grade e.g. 10 are given within parentheses. Number of persons reporting other grade than the maximum (e.g. 2 to 9) are not displayed in the table.

Digestive system	Min	Mean	Median	Max	Total
Diarrrhea (involuntary)	0 (11)	2.31	0	10 (1)	37
Abdominal pain (n=8)	0 (6)	2.00	0	8 (2)	16
Nausea (n=9)	0 (5)	1.89	0	10 (1)	17
Urinary system urgency (n=11)	0 (9)	1.00	0	10 (1)	11

Table 5: Diseases/symptoms of the ear, vestibular system. Clinical symptoms grades 0–10. Grade 0=no symptoms, 10=unbearable pain and/or discomfort. Total number of replies was based on 16 persons. Number of persons reporting minimum grade 0, or maximum grade e.g. 10 are given within parentheses. Number of persons reporting other grade than the maximum (e.g. 2 to 9) are not displayed in the table.

Ear and vestibular system	Min	Mean	Median	Max	Total
Balance disorder	0 (9)	2.00	0	10 (1)	32
Ear heat/otalgia	0 (13)	0.50	0	5 (1)	8
Hyperacusis (noise sensitivity)	0 (12)	0.44	0	5 (1)	12
Tinnitus	0 (10)	0.38	0	6 (2)	22

between 400 MHz and 7.2 GHz. It was calibrated by the manufacturer and has an accuracy of ± 6 dB. Peak levels or RF radiation were recorded (<https://safelivingtechnologies.com/products/safe-and-sound-pro-ii-rf-meter.html>). A detailed description of the methods can be found in all publications. In one of the seven studies [6] the GigaHerz Solution HF 59B was used for measuring the frequency range 0.7–3.3 GHz, and

the GigaHerz Solution HFW 59D for the frequency range 2.4–10 GHz.

The Narda broadband field meter NBM-550, with the probe EF-1891, measuring frequencies between 3 MHz and 18 GHz, was also used in one study [5] in addition to the Safe and Sound Pro II broadband RF meter. This latter meter as well as the GigaHerz Solution meter show peak levels of RF radiation whereas the Narda meter shows results in root mean square (RMS) for minimum, maximum, and average.

The 5G case studies

In the following a summary is given of our seven case studies.

Study [1]: two previously healthy persons, a man aged 63 years and a woman aged 62 years, developed symptoms of the microwave syndrome after installation of a 5G base station for wireless communication on the roof above their apartment. A base station for previous telecommunication generation technology (3G/4G) was present at the same spot since several years. Very high RF radiation with maximum (highest measured peak value) levels of 354,000, 1,690,000, and $>2,500,000 \mu\text{W}/\text{m}^2$ were measured at three occasions in the bedroom located only 5 m below the new 5G base station. Maximum (peak) level of $9,000 \mu\text{W}/\text{m}^2$ was measured prior to the 5G deployment. The rapidly emerging symptoms after the start of 5G were typical for the microwave syndrome: fatigue, sleeping difficulty, emotional distress, nose bleeds, tinnitus, dizziness, skin disorders, concentration problems, balance disorder, impaired short-term memory, confusion, heart and lung symptoms (palpitations, feeling of heaviness in the chest) and a feeling of warmth in the body. The symptoms were more pronounced in the woman. Due to the severity of symptoms, the couple left their dwelling and moved to a small office room with maximum (peak) RF radiation of $3,500 \mu\text{W}/\text{m}^2$. Within a couple of days, most of their symptoms alleviated or disappeared completely.

Study [2]: in this case study we describe two men, case 1 and case 2, working in three office rooms close to base stations situated on the roof above their office. After the deployment of 5G, both men developed symptoms typical for the microwave syndrome, e.g., fatigue, headache, tinnitus, dizziness, concentration and attention deficiency, and balance disorder. RF radiation after the 5G deployment was measured in the three offices. In office one, only 3 m below the nearest 5G base station, maximum (peak) RF radiation during 1 min varied from 463 to $1,800,000 \mu\text{W}/\text{m}^2$, in office two from 6,230 to $501,000 \mu\text{W}/\text{m}^2$, and in office three, from 13,700 to $61,000 \mu\text{W}/\text{m}^2$. The symptoms disappeared in both men within a couple of weeks (case 1) or immediately (case 2)

after leaving the office for other offices and living spaces with much lower maximum peak RF radiation emissions, maximum for case 1= $16 \mu\text{W}/\text{m}^2$, and for case 2= $2,920 \mu\text{W}/\text{m}^2$. The clinical pictures in both men were clearly related to the exposure.

Study [3]: in this case report we presented a woman aged 52 years who developed health problems consistent with the microwave syndrome after installation of a 5G base station facing her apartment at 60 m distance. These symptoms consisted of e.g., headache, dizziness, concentration difficulties, fatigue, arrhythmia, skin burning and nose bleeding. High RF radiation levels were measured in her apartment especially in the part closest to the base station. At the window in her living room peak levels of RF radiation from 17,500 to $758,000 \mu\text{W}/\text{m}^2$ were obtained during 10 measurements, each over 1 min. By the sofa in the living room peak levels from 36,800 to $222,000 \mu\text{W}/\text{m}^2$ were measured. Very high radiation was measured at the balcony facing the base station where all 10 measurements yielded within 10–15 s peak levels $>2,500,000 \mu\text{W}/\text{m}^2$. After temporally leaving the apartment for another dwelling with much lower RF radiation, $96\text{--}2,810 \mu\text{W}/\text{m}^2$ peak levels, almost all symptoms disappeared within a short time. After moving back to her own apartment the symptoms reappeared.

Study [4]: in this study we examined a family of three persons living at distances to two 5G base stations of about 50 and 70 m, respectively. The base stations are located on the top of two 6-floor buildings and the antennas are directed towards the family's apartment on the fourth floor on the opposite side of the street. Measurements in the apartment were made 10 times at every place, each measurement during 1 min. Highest levels were measured close to the two windows in the master bed room varying from 320,000 to $1,200,000 \mu\text{W}/\text{m}^2$. High levels were also found at the window of the son's room, 121,000 to $490,000 \mu\text{W}/\text{m}^2$, and the daughter's room $34,800$ to $166,000 \mu\text{W}/\text{m}^2$. Somewhat lower levels were found at the place of the pillow in the bed for all family members. The family members reported symptoms included in the microwave syndrome to varying self-estimated degrees. The daughter had the most severe health issues, for example sleeping problems, headache, concentration and memory problems, skin disorders, irregular heartbeat, light sensitivity, anxiety and panic attacks.

Study [5]: in this case report a 49-year old previously healthy man was described. After a 5G base station was installed 20 m from his apartment, he rather immediately developed a variety of symptoms that are part of the microwave syndrome. Most severe were headache, dysesthesia (abnormal sensation), loss of immediate memory, high and irregular pulse, chest squeeze, burning and lancinating skin. Very high RF radiation was measured in his apartment. The

levels measured with the Safe and Sound Pro II meter reached the maximum peak measureable level of the used Safe and Sound Pro meter, $>3,180,000 \mu\text{W}/\text{m}^2$, within 10–15 s for each of the 10 measurements made during 1 min in the living room. In the man's bedroom, measured levels at pillow in the bed ranged from 105,000 to 240,000 $\mu\text{W}/\text{m}^2$. Follow-up measurements were also made with a Narda-550 broadband meter showing results in root mean square (RMS) for both maximum and average values. The highest maximum RMS level in the apartment was 1,368,021 $\mu\text{W}/\text{m}^2$. Highest maximum RMS level in the living room was 571,624 $\mu\text{W}/\text{m}^2$. After moving to another apartment with low RF radiation the symptoms decreased or disappeared within a short time period but they reappear whenever he returns to his apartment with high 5G RF radiation.

Study [6]: this study included a woman aged 82 years with electromagnetic hypersensitivity (EHS) since almost four decades. After deployment of two 5G base stations, 528 and 489 m from her house respectively, she developed worse symptoms with e.g., fatigue, dysesthesia, dizziness, balance disorder, light sensitivity, and skin disorders that all are included in the microwave syndrome. Also her 83 years old husband was affected, although to a minor extent. The GigaHerz Solution HF 59B and the GigaHerz Solution HFW 59D were used for the measurements. High levels of maximum peak RF radiation levels were measured in the kitchen 166,700 $\mu\text{W}/\text{m}^2$ and in the living room, 147,100 $\mu\text{W}/\text{m}^2$.

Study [7]: in this case report a previously healthy family including a man, a woman and their three children was studied. The family members rapidly developed symptoms of the microwave syndrome after arriving at a summer cottage located at 125 m distance from a 24 m high mobile phone tower with 5G antennas. The most severe symptoms for the adults were sleeping problems, headache, tiredness, and irregular heartbeat. The children got sleeping problems, diarrhea, stomach pain, skin rashes, headache, and emotional symptoms. All symptoms disappeared and health was restored when the family returned to their own house at another place with no 5G base stations in the vicinity. No measurements were available inside the cottage during the time the family stayed near the mast. Later measurement showed that the radiation level varied from 9,000 to 43,400 $\mu\text{W}/\text{m}^2$ outside the cottage on the 5G base station side, compared with 2,500 $\mu\text{W}/\text{m}^2$ at most within their regular home without a 5G base station nearby. It can be reasonably assumed that the RF levels were considerably higher at the time the family stayed at the cottage during high vacation season when the nearby camping area was full of people. The area was nearly empty when the measurements were performed. The number of users and size of data transfers influence the RF radiation emitted from 5G base stations.

Results

Diseases/symptoms of the nervous system and sense organs: most prevalent were sleeping problems, Table 1. Thus of the 16 included subjects all but three reported insomnia. All three children aged 8, 6 and 4 years suffered insomnia grade 10, which is the worst category. All but one of the 12 responding persons reported waking night-time and 11 of 14 included had early wake-up. These symptoms were most severe in the children.

Other severe symptoms were headache, emotional distress, and irritability. Fatigue was prevalent, but may also be associated with the sleeping problems. Suicidal ideation was the only symptom that was not reported by any participating person.

Diseases/symptoms of the cardiovascular and respiratory system: transitory high pulse was reported by one man (grade 10) and three women (grades 5, 9, and 10, respectively), Table 2. One man (grade 10) and three women (grades 9, 8, and 10, respectively) reported irregular pulse. No person reported slow pulse. Blood pressure variability was reported by two men (grades 5 and 3, respectively) and one woman (grade 5).

Nose bleeding was reported by two men (both grade 5) and three women (grades 5, 10, and 3 respectively). Five out of 10 male cases reported dyspnea (grades 1 to 9) as well as three of six women (grades 4 to 9). Also chest squeeze, chest pain and cough were reported although to a minor extent.

Diseases/symptoms of the skin and musculoskeletal organs: among the most prevalent symptoms were those affecting face, arms and legs, Table 3. Thus this was reported by five men (grades 1 to 8) and three women (grades 6 to 10). Also burning and/or lancinating skin on hands and arms was common among in total four men (grades 3 to 10) and four women (grades 2 to 10). Hair loss was reported to a minor extent; three men (grades 1 to 3), but no woman.

Three men and four women reported myalgia (grades 3 to 8, and grades 2 to 10, respectively). Arthralgia occurred among four men (grades 5 to 10) and three women (grade 2 to 6).

Diseases/symptoms of the digestive and urinary system: among six men two reported nausea (grades 3 and 1, respectively), Table 4. The corresponding results for women was two of three respondents (grades 10 and 3, respectively). Six persons reported no abdominal pain. No man had urinary urgency compared with two of five women (grades 10 and 1, respectively).

Diseases/symptoms of the ear and/or vestibular system: one man noted ear heat and/or otalgia (ear pain; grade 5) compared with two women (grades 1 and 2, respectively), Table 5. Tinnitus was reported by three men (grades 6, 5, and 1, respectively) and three women (grades 6, 2, and 2,

respectively). Only one man noted noise sensitivity (hyperacusis) compared to three women (grades 2, 1, and 4, respectively).

Balance disorder was reported by three men (grades 2, 1, and 3 respectively) and four women (grades 7, 10, 2, and 7, respectively).

RF radiation

Measurements of RF radiation peak maximum levels are displayed in Table 6. Measurements were made only in one of our studies in the studied apartment before the deployment of the 5G base station [1]. In that case study a base station for 3G/4G was located at the same spot since several years. The radiation increased from $9,000 \mu\text{W}/\text{m}^2$ with 3G/4G to $>2,500,000 \mu\text{W}/\text{m}^2$ with 5G (peak maximum). The couple had lived in the same apartment for many years without health issues associated with the 3G/4G base station. However, 5G caused severe symptoms within a couple of days. The study persons had to leave the apartment definitely.

In two of our other studies very high RF radiation was also measured that reached over 2 million $\mu\text{W}/\text{m}^2$ (on balcony) [3] or 3 million $\mu\text{W}/\text{m}^2$ [5]. In these cases the study persons also quickly developed severe symptoms of the microwave syndrome within a few days that became so intolerable that the persons could not stay in their respective apartments.

In study [7] unfortunately no measurements were made during the days the studied family of five persons (two adults and three minor children) spent a long week-end at the house near a 5G mast. Also in this case study the studied persons developed severe symptoms within a few days that vanished when the family returned to their home with much lower RF radiation exposure.

The measured levels in all these case studies were considerably lower than the ICNIRP guidelines for RF radiation, but at the same time also considerably higher than the recommendations from other experts, as shown in Table 7. In one of our studies [5], measurements were also made with Narda-550 broadband meter with results in RMS averaged over 2 min that are more comparable with ICNIRP limits averaged over 6 or 30 min. In that study, a man aged 49, developed within a week very severe symptoms that he considered life threatening (symptoms from the heart). He therefore left the apartment definitely. The RF-radiation in the living room averaged over 2 min was $135,983 \mu\text{W}/\text{m}^2$ (Narda-550 broadband meter), which is considerably lower than the ICNIRP limits of $10,000,000 \mu\text{W}/\text{m}^2$ averaged over 6 or 30 min. The maximum peak level measured with another meter (Safe and Sound Pro II) was $>3,180,000 \mu\text{W}/\text{m}^2$, which is extremely much higher than the maximum levels recommended by EuropaEM EMF guidelines of $100 \mu\text{W}/\text{m}^2$ [31]. All the measurements of 5G radiation in all case studies showed levels very much higher than the levels recommended by EuropaEM EMF guidelines and also by the Bio-Initiative Group 2012 [31, 32].

Table 6: Levels of measured RF radiation in the seven case studies.

Case study	Highest measured RF radiation in bedroom	Highest measured RF radiation in $\mu\text{W}/\text{m}^2$	Meters to 5G base station	Placement of 5G base station	Place of max measured levels
[1]	$>2,500,000^a$	$>2,500,000^a$	5	Above on roof	Bedroom
[2]	$501,000^a$ $613,000^a$	$1,180,000^a$	3	Above on roof	Office for work
[3]	616^a	$>2,500,000^a$	60	On roof of opposite building, slightly higher height	Balcony
[4]	$374,000^b$ $89,600^b$ $58,500^b$	$1,200,000^b$	50 and 70	On roof of two opposite buildings, slightly higher height	By window in sleeping room
[5]	$240,000^b$ $30,483^c$ $13,668^f$	$>3,180,000^b$ $1,368,021^c$ $135,983^f$	20	On roof of building opposite side of street, same height	Living room
[6]	$19,600^d$	$166,700^d$	538 and 489	One mast (538 m) and one base station on roof of building (489 m)	Kitchen
[7]	Not measured	$43,400^e$	125	On a mast 24 m high	Outer side of house

^aSafe and Sound Pro II meter with max $2,500,000 \mu\text{W}/\text{m}^2$; ^bSafe and Sound Pro II meter with max $3,180,000 \mu\text{W}/\text{m}^2$; ^c Narda 550 m, max value in RMS; ^dGigahertz Solution HFW 59D; ^eSafe and Sound Pro II. Measurements made two months after the family's holiday at the house; ^fNarda 550 m, average value in RMS (over 2 min).

Table 7: Measured levels of RF radiation in $\mu\text{W}/\text{m}^2$ in the seven case studies compared with recommended maximum limits from EuropaEMF Guidelines [31] and ICNIRP 1998 [9] and 2020 [10].

Case study	Highest measured RF radiation in bedroom	Highest measured RF radiation	EuropaEMF guidelines 2016	ICNIRP 1998/2020
[1]	>2,500,000 ^a	>2,500,000 ^a	0.1–100 ^g	10,000,000 ^h
[2]	501,000 ^a 613,000 ^a	1,180,000 ^a	0.1–100 ^g	10,000,000 ^h
[3]	616 ^a	>2,500,000 ^a	0.1–100 ^g	10,000,000 ^h
[4]	374,000 ^b 89,600 ^b 58,500 ^b	1,200,000 ^b	0.1–100 ^g	10,000,000 ^h
[5]	240,000 ^b 30,483 ^c 13,668 ^f	>3,180,000 ^b 1,368,021 ^c 135,983 ^f	0.1–100 ^g	10,000,000 ^h
[6]	19,600 ^d	166,700 ^d	0.1–100 ^g	10,000,000 ^h
[7]	Not measured	43,400 ^e	0.1–100 ^g	10,000,000 ^h

^aSafe and Sound Pro II meter with max 2,500,000 $\mu\text{W}/\text{m}^2$; ^bSafe and Sound Pro II meter with max 3,180,000 $\mu\text{W}/\text{m}^2$; ^cNarda 550 m, max value in RMS; ^dGigahertz solution HFW 59D; ^eSafe and Sound Pro II. Measurements made two months after the family's holiday at the house; ^fNarda 550 m, average value in RMS (over 2 min); ^gMaximum levels (not averaged); ^hAveraged over 6 [9] or 30 [10] minutes.

Discussion

The microwave syndrome is a set of symptoms identified since 50–60 years as effects of exposure to RF radiation or microwaves at so called “low levels” or non-thermal levels [33]. Non-thermal levels are below the ICNIRP limits (FCC limits in the USA) that do not cause heating effects. Consequently, the microwave syndrome is known to appear below the ICNIRP and FCC limits [13, 31]. A majority of the countries over the world have nevertheless adopted those very high limits that are increasingly criticized for being insufficient for health protection [11–13]. However they are important for the telecom industry and in particular for the roll out of 5G. These limits based on thermal effects are not only promoted by the industry itself but also by the WHO since 1998. The WHO has previously received funding for this work from telecom organizations such as GSM Association and Mobile Manufacturer's Forum [34].

In repeated previous studies on health in people living near mobile phone masts and base stations, the prevalence of symptoms identified within the early studies on the microwave syndrome or the radiofrequency illness has been explored. Several of these studies have found that symptoms such as sleeping problems, headache, dizziness, fatigue and cardiovascular problems were more prevalent near the base stations compared to prevalence among people with less

exposure or larger distance to the base stations [23]. These studies have investigated effects on the earlier generations of mobile phone generations, such as 2G and 3G. Our seven case studies are so far, to our knowledge, the first to have explored the health effects on people living near 5G base stations.

In our seven case studies [1–7] we found that persons who got 5G base stations or masts at various distances ranging from 3 to 538 m from their dwellings, Table 6, developed a range of symptoms known as the microwave syndrome or radiofrequency sickness. In all seven case studies, antennas for 3G/4G were active before the change to 5G and most study persons appeared to have tolerated the radiation from these previous generations. However, after the deployment of 5G most of the study persons rapidly developed severe symptoms of the microwave syndrome, which indicates that 5G is more harmful than previous generations of telecommunication. In cases [1, 3, 5] the symptoms were so severe that the persons left their apartment within a week. In case [7], the symptoms became severe within a few days, but the persons had only rented the house for a short vacation. In this latter case, after that the two adults and the three children returned to their home with no 5G base stations within sight, their health was restored. In all cases except cases [4, 6], the symptoms disappeared when the persons left the apartment, house or office for a dwelling with considerably lower RF radiation. Cases [4, 6] did not move from their dwellings. Thus, short-term health effects often occur within days of 5G RF radiation exposure and may disappear after a short time when exposure from 5G antennas has been avoided or substantially reduced.

The observations from these case studies confirm early reports from Eastern Europe when studies on occupational exposure concluded that after exposure has ended the health is restored, although for some individuals it may take some time, sometimes as long as several weeks or more [21]. The most prevalent symptoms in these early studies were also, like in our case studies, symptoms related to the central nervous system. It was noted that the effects on nerve functions from low-intensity exposure to RF radiation were characterized by an exhaustion syndrome (asthenia) [19, 21]. Fatigue was one of the symptoms that got the highest score in our present study, see Figure 1.

In our seven case studies [1–7], comprising 16 individuals of various ages from 4 to 83 years, sleeping problems, fatigue, headache, increased emotional symptoms, irritability, and concentration/attention deficiency were the most common early effects from exposure to 5G RF radiation. In fact most subjects reported some grade of these symptoms, Table 1, see also Figure 1. Cardiovascular and respiratory system diseases/symptoms were reported

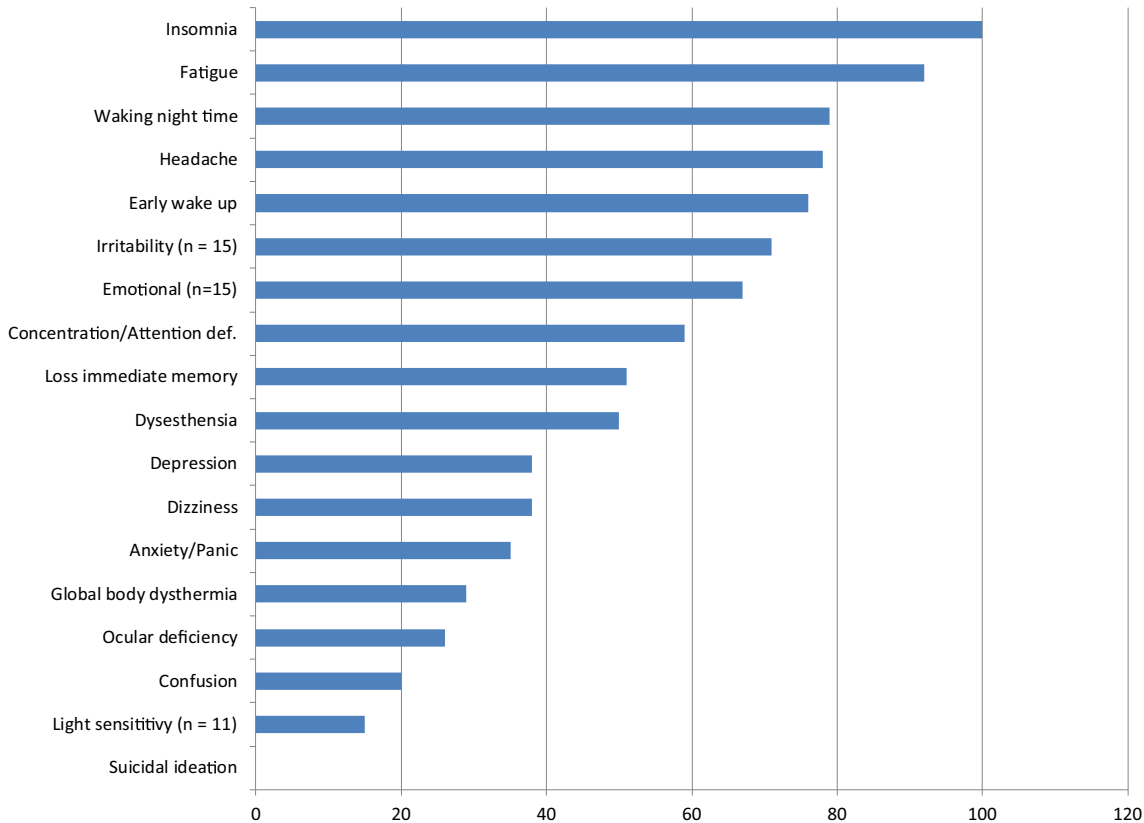


Figure 1: Total grade for clinical symptoms in the nervous system and sense organs among 16 persons or otherwise given (n). Grade 0 to 10 for each symptom was reported by the different individuals.

by $\geq 50\%$ of the study persons, Table 2. About 50% of the persons reported some skin problem, Table 3. Less common were diseases/symptoms of the digestive or urinary tract, Table 4, and ear or vestibular system, Table 5. It is noteworthy that most subjects did not report tinnitus.

It would have been interesting to analyze if there was a correlation between highest exposure and symptoms. However, the total number of study persons is very limited. Furthermore, there appears to be a large variation of sensitivity [33] between different individuals which makes the result of a correlation analysis uncertain. It should also be noted that the reporting of symptoms and their severity is self-assessed, and the evaluation of the severity is subjective with individual variation.

There seemed to be a somewhat higher mean grade for symptoms from the nervous system and sense organs, cardiovascular and respiratory systems among the subjects with highest exposure. However, due to low numbers this must be interpreted with caution (data not in table). A larger study group would be necessary.

In a review of all epidemiological studies on health effects in people living near mobile phone base stations of previous

generations [23] similar symptoms as in this study were also common among the subjects. However, the measured RF radiation was in those previous studies on earlier generations of telecommunications technologies such as GSM, very much lower than in our 5G case studies. For instance, measurements in 2001 of RF radiation in the bedrooms of 94 persons living close to GSM base stations in Spain found a maximum of $4,420.28 \mu\text{W}/\text{m}^2$. The median value was $31.57 \mu\text{W}/\text{m}^2$ [35]. In 2006 a study from Austria reported highest maximum RF radiation of $4,100 \mu\text{W}/\text{m}^2$ in the bedrooms of 336 persons [36]. A German study obtained in 2009 an average value of $3,631 \mu\text{W}/\text{m}^2$ ($1.17 \text{ V}/\text{m}$) at the homes of 82 persons living within 200 m from GSM base stations [37].

Conclusions

Our seven case studies, comprising 16 persons, on health effects from real 5G RF radiation exposure, showed that the study persons developed the microwave syndrome after installation of 5G base stations in the neighborhood of their dwellings. Most prevalent were symptoms of

the nervous system: sleeping problems, headache, fatigue, irritability, emotional symptoms and concentration/attention deficiency. Very high RF radiation levels, although much lower than limits recommended by ICNIRP and the FCC, were measured with the broad band meter. Some of the studied persons developed severe symptoms. Most persons could move to another settlement without 5G, whereby the microwave syndrome alleviated and disappeared within short.

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