Canada
PROVINCE OF QUEBEC
DISTRICT OF MONTREAL
No: 500-06-001018-197

Class Action
Superior Court

Tracey Arial et als.
Petitioners

Vs.

Apple Canada inc.,
Apple inc.,
Samsung Electronics Canada,
and Samsung Electronics co. ltd.
Respondents

AFFIDAVIT of Mr. PEDRO GREGORIO

1. I, Pedro Gregorio, B.Eng., M.Eng., ing., a Mechanical Engineer domiciled and residing at 7353 Dunver, Verdun Qc., solemnly affirm that the following Affidavit is truthful, objective and prepared solely for the purpose of enlightening the Court as set out in Art. 22 of the Quebec Code of Civil Procedure:

    a. *"The mission of an expert whose services have been retained by a single party or by the parties jointly or who has been appointed by the court, whether the matter is contentious or not, is to enlighten the court. This mission overrides the parties' interests. Experts must fulfill their mission objectively, impartially and thoroughly."*

(Code of Civil Procedure, 2014, c. 1, a. 22, http://legisquebec.gouv.qc.ca/en/showDoc/cs/C-25.01?&digest=)

CREDENTIALS

2. I, Pedro Gregorio, am a professional engineer, technology innovator and inventor with more than twenty-five years of professional engineering experience in fields ranging from automotive, consumer electronics, medical training and therapy, simulation-based training, robotics, space, and telecommunications products. I am named inventor on more than one hundred patents registered worldwide in fields including machines & mechanical design, computer algorithms, electronic circuits, control methodologies, and human interaction. In addition to my technical roles, I have also fulfilled non-technical roles including business development and Intellectual Property protection. Over an approximately six-year period, I built a worldwide team of applications engineers, and working with them to integrate directly our novel technologies into consumer products including automobiles and wireless portable devices. Our team developed and deployed proprietary technology with cellular handset manufacturers; which technology today ships on nearly every smartphone marketed worldwide.
3. In addition to work in the consumer space, I have a decade of engineering experience in the space field including two years of research with academic, industry, and government partners. I have worked directly with astronauts and I have designed and installed flight hardware onto space missions. More recently, over the past eight years, I have worked with my colleagues in

designing, assembling, integrating, and testing space systems including high-fidelity wireless microwave telecommunications payloads for commercial, military, and government satellites including dozens of spacecraft presently operating on-orbit.

4. My accumulated experience qualifies me to understand and parse specifications across a broad range of technical fields, affords me a perspective to understand the process of developing consumer products, and equips me with an experience to interpret business dimensions of technical product design decisions.

TESTING OF LICENSED PORTABLE DEVICES FOR RF EXPOSURE

5. This document provides an overview regarding radiofrequency emissions exposure testing processes of wireless portable devices marketed to the general public in Canada including Quebec. As many of Canada's regulations refer directly or indirectly to US and international standards of practice, some of these are also reviewed.

REGULATORY FRAMEWORK

6. In Canada (including Quebec) the licensing and regulation of Electromagnetic Field (EMF) emitting devices including Radiofrequency (RF) emitting devices such as mobile cellular consumer products are regulated by the federal government through ISED (formerly Industry Canada) according to human safety guidelines determined by Health Canada.
7. By this separation of responsibilities, Health Canada "establish[es] safety limits for human exposure to radiofrequency fields" (Health Canada, Safety Code 6 (2015), https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/pdf/consult/_2014/safety_code_6-code_securite_6/final-finale-eng.pdf) while ISED "sets out the requirements and measurement techniques used to evaluate radio frequency (RF) exposure compliance of radiocommunication apparatus designed to be used within the vicinity of the human body." (Industry Canada, RSS-102, Issue 5, March 2015, https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/rss-102-issue5.pdf/$file/rss-102-issue5.pdf)
8. Of note, the United States combines both these functions – human safety limits setting and apparatus testing and compliance – under a single entity, namely the Federal Communications Commission (FCC) thereby creating an apparent structural conflict of interest pitting "Protecting Consumers & Public Safety" (Strategic Goal #3) against "promot[ing] the introduction of new technologies" (Strategic Goals #1 & #2). (FCC Mission Statement, https://www.fcc.gov/about/overview)
9. While many of Canada's testing procedures and regulations (e.g. RSS-102) defer directly and interchangeably to the US FCC processes (FCC Knowledge Data Base), it is important to recall the distinct underlying regulatory frameworks between the two jurisdictions.
10. Furthermore, ISED in Canada and the FCC in the United States both in turn defer to the Institute of Electrical and Electronics Engineers (IEEE), a private non-governmental corporation, to recommend detailed practices and techniques for measurement of human RF Exposure; which practices (IEEE 1528) are not freely available for review by the public.

THE PHYSICAL NATURE OF ELECTROMAGNETIC RADIATION

11. All wireless communication – whether AM talk radio or digital satellite broadband internet – employs electromagnetic (EM) radiation to carry information between sender and receiver. EM radiation propagates by waves of coupled electric & magnetic fields that move through space (or another medium such as glass or copper wire) at the speed of light. A radio transmitter generates and broadcasts EM waves which are intercepted by receiving antennas. Information is encoded onto these waves by various methods and passes from sender to receiver where it is decoded.
12. As shown in Figure 1 below wireless communication represents only a portion of the non-ionizing EM Spectrum which also includes the entire visible spectrum (the rainbow) at higher frequencies and ionizing radiation at still higher frequencies.

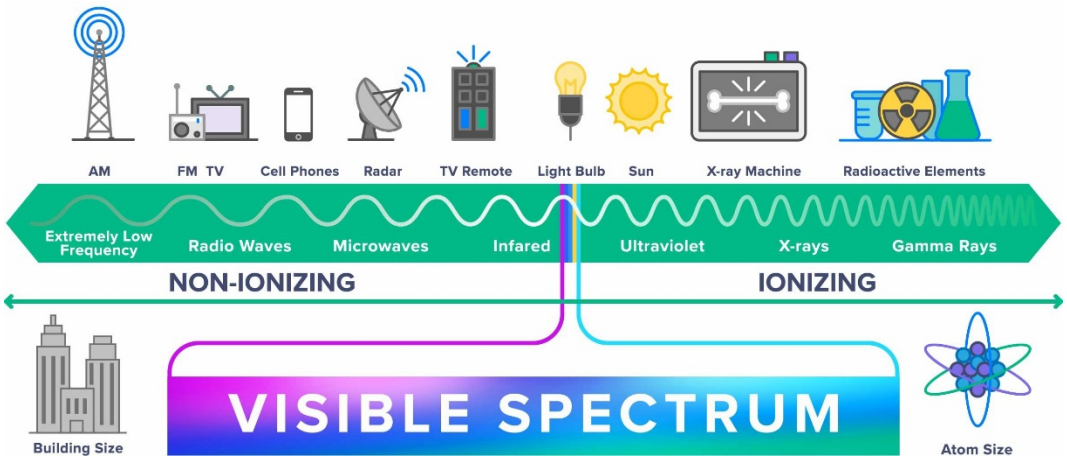

Figure 1: Graphical representation of the EM Spectrum and associated physical phenomena and technologies
https://www.defendershield.com/wp-content/uploads/defendershield-emf-visible-spectrum-infographic.jpg

13. Just as radio stations may be discriminated by their assigned frequency (Hz or number of oscillations per second), so too all EM radiation is uniquely distinguished by its frequency which also informs its preferred technological application. The EM spectrum stretches across a wide frequency range and accounts for a broad array of distinct physical phenomena. Nevertheless, all EM fields are comprised of the same building blocks: energetic photons whose energy directly depends on the frequency of the EM radiation. Higher frequency radiation means more energetic photons.
14. All told, the practical EM spectrum ranges across twenty orders of magnitude as shown in Table 1 below. Starting at Super low frequencies (household power wiring) past Medium (AM radio), High (short wave radio), and Ultra High (FM radio) broadcast frequencies, the spectrum next passes through Extremely High frequency (microwave ovens and microwave communications) before transitioning into the light spectrum. Light – another manifestation of EM radiation – straddles the ionizing danger zone with lower frequency thermal energy and the visible rainbow of light in the non-ionizing category, while higher frequency ultraviolet light – which may cause sunburn or skin cancer – marking the beginning of ionizing radiation frequencies that rise into X-rays (medical scanning) and on to Gamma rays (nuclear reactors) at the highest frequencies.
15. The photon energy of an EM Field depends only on its frequency in the same way that the energy of an object moving at constant speed depends only on its mass. To help understand the dizzying range of photon energies available in the EM spectrum, the last columns of Table 1 below lists objects scaled to corresponding EM radiation types. For example, if the photon energy of a low campfire (far infrared radiation) is compared to dropping a 100g billiard ball, then that same

photon at AM radio frequencies (1 million times lower) would compare to dropping a grain of salt. Similarly, increase that same photon to sunburn light frequencies and it now has the energy of a charging hippopotamus. The gamma rays emitted by a nuclear reaction would correspondingly have photon energies of a fully loaded freight train moving at the same speed. Extending the analogy to distinguish cellular communications frequencies, 1st generation networks (1G) is a rain drop; while upcoming 5th generation (5G) technology is a billiard ball.

Table 1: The Electromagnetic Spectrum. Phenomena, applications, classification, frequencies and Energy Scaling Analogy

Techology Application & Physical Phenomenon		Radiation Classification		Wavelength	Frequency [MHz]	Photon Energy [eV]	Energy Scaling Analogy Object (at constant speed)	Mass [kg]
	Nuclear Reactor	Ionizing	Gamma rays	10 pm	100,000,000,000,000	1E+05	Loaded freight train	1E+07
	Medical Imaging		Hard X-rays	100 pm	10,000,000,000,000	1E+04	Saturn V Rocket	1E+06
	DNA Damage		Soft X-rays	1 nm	1,000,000,000,000	1E+03	Cargo ship	1E+05
Light	Sunburn		Extreme ultraviolet	10 nm	100,000,000,000	1E+02	School bus	1E+04
				100 nm	10,000,000,000	1E+01	Hippopotumus	1E+03
	Rainbow	Non-Ionizing	Near ultraviolet, visible	1 µm	1,000,000,000	1E+00	Man	1E+02
	Heat		Near infrared	10 µm	100,000,000	1E-01	bowling ball	1E+01
			Mid infrared	100 µm	10,000,000	1E-02	basket ball	1E+00
			Far infrared	1 mm	1,000,000	1E-03	billiard ball	1E-01
Radio Waves	Microwaves		Extremely high frequency	10 mm	100,000	1E-04	9mm bullet	1E-02
			Super high frequency	100 mm	10,000	1E-05	penny	1E-03
	FM Radio		Ultra high frequency	1 m	1,000	1E-06	rain drop	1E-04
	ShortWave Radio		Very high frequency	10 m	100	1E-07	grain of rice	1E-05
			High frequency	100 m	10	1E-08	grain of sugar	1E-06
	AM Radio		Medium frequency	1 km	1	1E-09	grain of salt	1E-07
			Low frequency	10 km	0.1	1E-10		
			Very low frequency	100 km	0.01	1E-11		
			Ultra low frequency	1000 km	0.001	1E-12		
	Household Power		Super low frequency	10,000 km	0.0001	1E-13		
	Lightning		Extremely low frequency	100,000 km	0.00001	1E-14		

16. Ionizing radiation is characterized by photons energetic enough to free electrons from their atoms thus forming ions. In this way, ionizing radiation can directly break chemical bonds thereby altering matter. In the case of UV light this may mean breaking strands of DNA in skin cells and eventually causing cancer. In the case of Gamma rays this may knock metal atoms out of their lattice locations and compromise structures in nuclear installations. Ionizing radiation is universally understood to be dangerous and safety precautions must be observed, whether sunscreen & sunglasses at the beach, lead shielding for medical X-rays, or heavy metal cladding and restricted personnel access at nuclear power plants.

17. In addition to photon energy, EM radiation can be characterized by other properties such as power. Both a lit match and a raging forest fire may have the same photon energy, but the forest fire is more powerful and dangerous. Power level (measured in Watts) of EM radiation depends on "how many photons" are thrown at once. In the same way that an attack by ten archers is ten times more powerful even though each arrow has the same energy, a 100 Watt light bulb radiates 500 million-million-million photons each second. When considering the physical impacts of EM radiation we must consider the photon energy (which depends on frequency) as well as the radiated power. For radio frequencies, the size of the transmitter or the antenna roughly maps to its power. Thus, a small Bluetooth headset radiates less power than a cell phone which radiates less power than a WiFi router, and a deep space communications antenna radiates more power than a television transmission tower.

18. As in the case of the lit match and the forest fire, the effect of radiated power on the environment is also a function of distance. Get too close and the match will burn your finger. Stay far enough away and the forest fire will glow, but not heat you. So too with invisible microwave radiation, more distance reduces exposure. Thus, when characterizing the effect of radiofrequency exposure one must consider frequency, power, and distance from source among other parameters.
19. To harness the potential of EM radiation, communications technologies encode data by modulating the waves prior to transmission. Received waves can be demodulated and interpreted as voice, music, televised images, or internet search results. For telecommunications, higher frequency carrier waves can encode more information, thus microwaves are capable of transmitting at higher data rates than analog AM radio frequencies. Modulation techniques in and of themselves may elicit distinct physical responses in the environment regardless of the nature of the EM field carrying the signals. Analogously, pleasant music may elicit a different response than harsh noise even at the same power level. In some cases EM fields may be bioactive and interfere with normal biological processes which inherently employ natural electrical signaling and EM fields within the body.

ELECTROMAGNETIC RADIATION AND HUMAN HEALTH

20. Biological systems including the human body comprise multiple delicately balanced and interdependent processes including cellular reproduction, electrochemical signaling, biochemistry, and macroscopic mechanical action among others. Almost all biological processes rely on, or may be affected by EM fields. Whether neurological processing & signaling, endocrine regulation, DNA replication, cardiac pacing, or muscle contraction and control, the human body is fundamentally an electrical machine and as such our function and health may be affected by external electrical stimuli. In some cases EM or radio systems may offer therapeutic relief; in other cases, external EM stimuli are clearly harmful. In many cases, effects are more subtle and may only be perceived occasionally, anecdotally in certain individuals, or over long periods of chronic exposure or of careful observation. In general, biological studies do not lend themselves to the strict repetition and isolation of variables afforded the physical sciences. Rather, biological understanding advances deliberately by careful statistical analysis and interpretation of results from in-vitro (test tube) & in-vivo (animal model) experiments or from case studies (single individuals) & epidemiological studies (larger numbers of human populations). Complementary and replicated evidence across different study types reinforce understanding and advance the state of biological science.
21. As stated at para. 16, photon energies of ionizing EM radiation are sufficient to directly break chemical bonds including those that bind DNA molecules together. As such, ionizing radiation may lead to DNA replication errors (mutations) that can cause cancer. Ionizing radiation is therefore regulated to protect human health.
22. As discussed at paragraphs 14 and 17, microwaves in a cell phone and those in a microwave oven have the same frequency, but differ only in power level. The microwave oven is sufficiently powerful to heat popcorn (or human tissue), while the cell phone is designed and regulated to keep emitted power below the body's ability to dissipate excess heat. Exposure to excess microwave RF power levels are a clear health risk identified by regulators.
23. Beyond these clear-cut dangers of cumulative exposure to ionizing radiation and of acute exposure to excess power levels of thermal microwave RF emissions, there exists a vast peer-reviewed scientific literature studying health impacts of non-thermal microwave exposures.

24. In 2011 the World Health Organization (WHO) classified cell phone radiation as a Class 2B Carcinogen "possibly carcinogenic to humans" "based on an increased risk for Glioma, a malignant type of brain cancer" further warning "it is important to take pragmatic measures to reduce exposure such as hands-free devices or texting." (WHO Press release No 208, https://www.iarc.who.int/wp-content/uploads/2018/07/pr208_E.pdf).

25. In 2018 the US department of Health and Human Services published results of a National Toxicology Program (NTP) study that found clear evidence of tumors associated with exposure to RF radiation used by cell phones. (https://ntp.niehs.nih.gov/whatwestudy/topics/cellphones/index.html?utm_source=direct&utm_medium=prod&utm_campaign=ntpgolinks&utm_term=cellphone)

26. Also in 2018, Lennart Hardell, a leading RF health researcher and 2011 IARC Working Group Member, published a review of multiple health studies which "conclude[d] that there is clear evidence that RF radiation is a human carcinogen, causing glioma and vestibular schwannoma (acoustic neuroma). There is some evidence of an increased risk of developing thyroid cancer, and clear evidence that RF radiation is a multi-site carcinogen. Based on the Preamble to the IARC Monographs, RF radiation should be classified as carcinogenic to humans, Group 1." This proposed upgrade would classify cell phone radiation alongside Asbestos, Plutonium, Tobacco, and Gamma radiation. (https://www.spandidos-publications.com/10.3892/ijo.2018.4606)

27. Aside from potential carcinogenicity, myriad studies (some dating from the 1970s and earlier) have linked microwave RF radiation to various additional human health issues including: reproductive health, nervous system, blood and vascular disorders, enzyme and biochemical changes, metabolic disorders, and endocrine changes, and electromagnetic hypersensitivity among others. (https://www.magdahavas.com/wp-content/uploads/2010/06/Navy_Radiowave_Brief.pdf)

28. In 2015, 240 professional scientists and medical researchers "engaged in the study of biological and health effects of non-ionizing electromagnetic fields (EMF)" authored an international appeal to the United Nations calling for protection from non-ionizing electromagnetic field exposure based on numerous scientific publications showing "EMF affects living organisms at levels well below most international and national guidelines." (https://www.emfscientist.org/index.php/emf-scientist-appeal)

29. On the other hand, manufacture, testing and licensing of wireless communications devices worldwide (including in Canada) is predicated on regulations which assert that physical heating is the *only* mechanism of harm from microwave EM radiation, notwithstanding the body of published, peer-reviewed research stating the contrary. "The hypotheses of other proposed adverse health effects occurring at levels below the exposure limits outlined in Safety Code 6 suffer from a lack of evidence of causality, biological plausibility and reproducibility and do not provide a credible foundation for making science-based recommendations for limiting human exposures to low-intensity RF fields." (Health Canada, Safety Code 6 (2015), https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/pdf/consult/_2014/safety_code_6-code_securite_6/final-finale-eng.pdf)

30. While the human health question remains unresolved, there is substantial credible evidence linking microwave EMF to human health concerns. The question of biological effects is far more complex than simplified physical mechanisms of directly breaking chemical bonds (ionizing radiation), or heating a container of liquid (standard method for testing wireless devices). The simplified physical mechanisms approach to health imagines the human as a painting and asks "how can EM radiation damage a completed painting?" Meanwhile biological systems are dynamic; constantly adapting, interacting, healing, and rebuilding themselves. The more appropriate question is "how can EM radiation disturb the painter at his work?"

RADIOFREQUENCY COMMUNICATIONS TECHNOLOGIES

31. In its simplest form – unidirectional transmission – radiofrequency communication requires one sender (transmitter) and one receiver. Most transmission antennas broadly spread or cast signals over a wide area. Thus any receiving antenna located within range can access the signal. Thus Broadcast communications (AM or FM radio or television) consists of a centralized, high power transmission tower serving any number of audience members equipped with receivers (radios or television sets) tuned to a common frequency or station. The transmission antenna is typically mounted on a tall tower to avoid obstacles thus increasing broadcast range. Receivers may be fixed or mobile (e.g. car radio). A radio set equipped with a transceiver (portmanteau of transmitter and receiver) can be used for two-way communications such as citizens band (CB) radio with limitations of quality and range as generally both sender and receiver may be mobile and distances and terrain may vary. In CB, any number of users may share a non-private channel although only one may transmit at any time (push-to-talk).
32. Cellular mobile communications service private, two-way connectivity between lower-power mobile terminals (such as cell phones) by relaying radio signals across a network of fixed base stations sometimes called cell towers. Fixed cellular base stations are arranged in a roughly hexagonal grid each servicing a defined area – a cell – and employing a different frequency than neigbouring towers. A small set of distinct frequencies (3 or 4) are sufficient to service an arbitrarily large geography without interference while ensuring service quality. Since each mobile terminal communicates only with the nearby base station, transmission power may be reduced compared to CB radio, for example. Nevertheless, by relaying signals between base stations across the network any handset may connect to arbitrarily distant devices. Mobile terminals maintain communication with multiple nearby cellular base stations while they move.
33. As relative signal strength changes base stations may hand over service to a neighbouring tower. During handover, the mobile terminal seamlessly changes frequency without service interruption. A modern cell phone constantly monitors the control channel of up to 16 neighbouring base stations in order to moderate transmission power and negotiate handover when required. This constant control channel "housekeeping" communication is independent of phone calls or other data which are simultaneously carried on traffic channels. Mobile terminals will increase or decrease their transmission power depending on signal quality with the base station. Increased distance or obstructions (e.g. an elevator, tunnel, car or the user's body) can reflect or absorb radio emissions therby reducing signal quality. The mobile terminal (e.g. cell phone) constantly modulates transmission power to preserve link quality while maximizing battery life. In poor signal quality situations, cell phone transmitter power and radiated EMF increases.
34. Modern wireless communications systems take on many forms (e.g. cellular, Wi-Fi, Bluetooth, among others), but all generally follow similar principles to those described above. Communicating devices must first negotiate link protocols before communication can proceed. Thus, even when not actively communicating, cell phones monitor base station control channels and wireless smart meters periodically synchronize with their mesh networked neighbours. A modern cell phone may contain as many as eight different antennas each with a distinct function and each communicating on a separate network protocol, often simultaneously.
35. As seen in Figure 2 below, certain natural phenomena do emit radiofrequency EMF (the green band). However, the ubiquity, density, and variety of radio-enabled technologies in a modern city are such that ambient EMF levels today exceed natural background EMF by *18 orders of magnitude*. Repurposing the analogy of Table 1, if natural background EMF is a grain of salt, human-generated EMF in a modern city is the Giza pyramid. Moreover, as EMF has increased in

recent decades, ambient power levels are now cresting near ICNIRP safety guidelines. Radiofrequency EMF may be invisible, but nevertheless dominates the modern landscape.

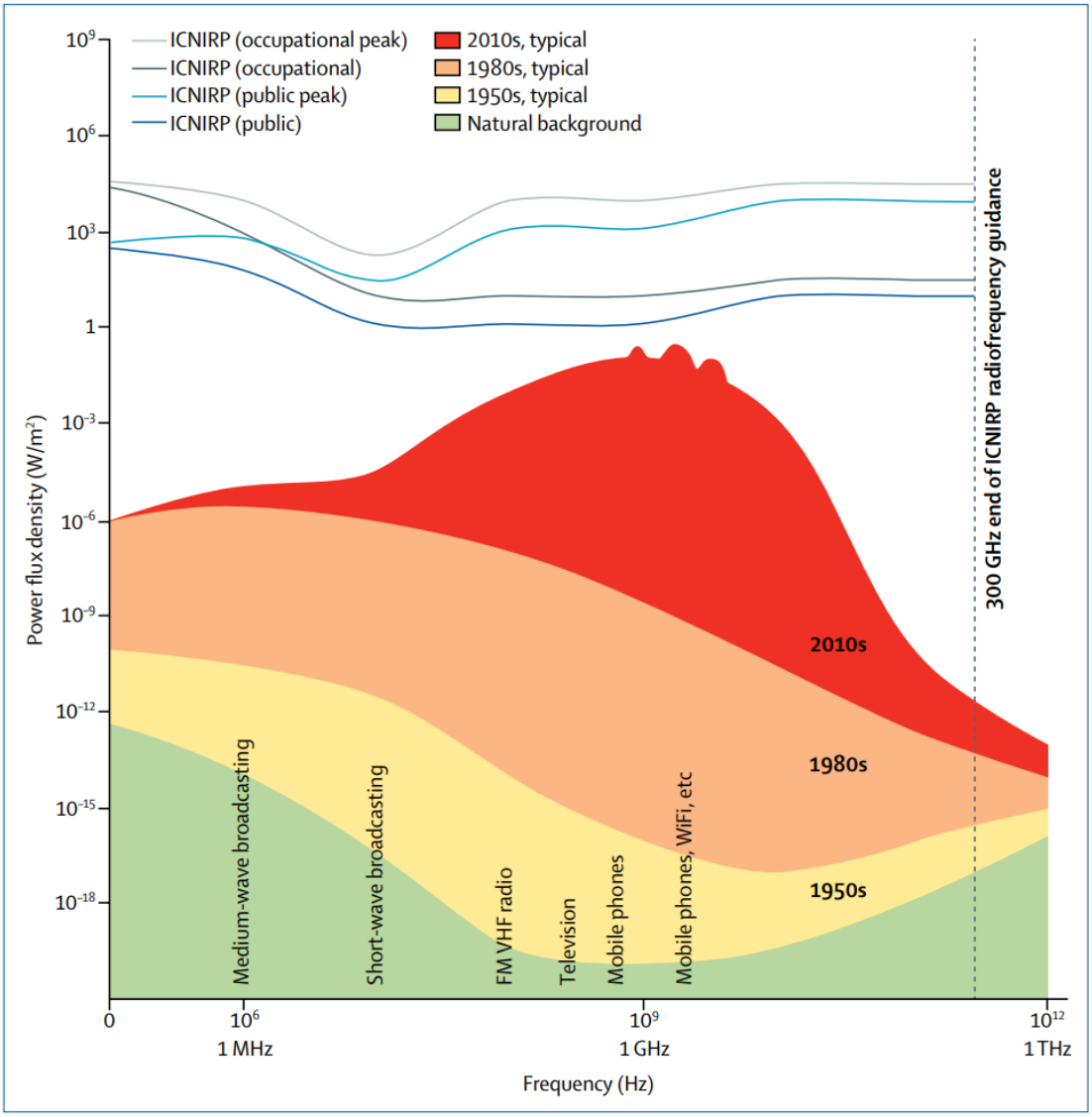

Figure 2: Typical maximum daily exposure to radiofrequency electromagnetic radiation from man-made and natural power flux densities in comparison with International Commission on Non-Ionizing Radiation Protection safety guidelines (https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(18)30221-3/fulltext)

REGULATING RADIOCOMMUNICATION APPARATUS

36. As discussed in the Regulatory Framework section at Paragraphs 6 - 10, above Health Canada has established basic restrictions, which are independent of testing methodologies, to protect citizens from *acute thermal-only* effects of RF emissions (6 minute reference period). For devices used close to the body (closer than 0.2m), restrictions apply to the Specific Absorption Rate (SAR) which measures the rate at which EM energy is absorbed into the body rather than being transmitted through the air and onto the base station. Three limits are declared: 0.08 W/kg over the entire body, 1.6 W/kg for any 1g of tissue in the head, neck or trunk, and 4 W/kg for any 10g

of tissue in the limbs (https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/limits-human-exposure-radiofrequency-electromagnetic-energy-range-3-300.html).

> Safety Code 6, 2015, p.3 para 5: *"Basic restrictions on peak spatially-averaged SAR have also been established in Safety Code 6 to avoid adverse thermal effects in localized human tissues (hot-spots)."*
>
> Safety Code 6, 2015, p.13 line 1: *"**basic restrictions**—Maximum allowable internal electrical quantities in the body, arising from exposure to incident external fields, that prevent the occurrence of all established adverse health effects."*
>
> Safety Code 6, 2015, p.4 line 2: *"For exposures in uncontrolled environments, the peak spatially-averaged SAR limits are 4.0 W/kg for the limbs and 1.6 W/kg for the head, neck and trunk."*

37. In turn, ISED "has adopted the SAR and RF field strength limits established in Health Canada's RF exposure guideline, Safety Code 6." Table 3 of RSS-102 sets out these limits for portable devices (https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01904.html):

Table 3: SAR Limits for Devices Used by the General Public (Uncontrolled Environment)

Body Region	Average SAR (W/kg)	Averaging Time (minutes)[20]	Mass Average (g)
Whole Body	0.08	6	Whole Body
Localized Head, Neck and Trunk	1.6	6	1
Localized Limbs	4	6	10

38. This Canadian standard is aligned with corresponding US FCC standards: (https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf)

> FCC OET Bulletin 65 p.6 line 3: *"Portable devices are evaluated with respect to SAR limits for RF exposure. The applicable SAR limit for portable transmitters used by consumers is 1.6 watts/kg, which is averaged over any one gram of tissue defined as a tissue volume in the shape of a cube."*

39. For devices further than 0.2m SAR is an impractical indicator of human exposure to RF EMF. For devices in this category including Wi-Fi routers, baby monitors, or cellular base stations, Health Canada specifies "external unperturbed field strength or power density measurements shall be carried out and the limits outlined in Section 2.2 shall be respected." For common wireless communications frequencies, Power Density reference levels peak at 10 W/m^2.

40. As discussed at paragraph 18, the effect of EM radiation is a function of frequency (photon energy), radiated power, and distance from the transmitter. Thus while it may be sufficient for assessing risk of heating to specify a basic restriction on SAR or Power Density measured at the body, from the perspective of evaluating, regulating, and licensing RF emitting devices, one must also specify the spatial relation between the device and said body during measurements. To this end, regulators in Canada and the US have defined mobile handset as "body-worn" devices and specify compliance testing no more than 5mm away from the body.

> RSS-102 p. 1, para 6: "***Body-worn (or body-mount) radio*** *is a wireless transceiver that is normally operated (or intended to be used) while it is placed in the pocket of a garment,*

or is maintained close to the body by means of a belt clip, holster, pouch, lanyard or similar mechanism."

RSS-102 p. 9, line 2: *"Body-worn devices that are designed to operate on the body using lanyards or straps shall be tested using a test separation distance of 5 mm or less."*

FCC KDB 447498 D01, section 4.2.2 c) : *"A conservative minimum test separation distance for supporting off-the-shelf body-worn accessories that may be acquired by users of consumer handsets should be used to test for body-worn accessory SAR compliance. … Devices that are designed to operate on the body of users using lanyards and straps or without requiring additional body-worn accessories must be tested for SAR compliance using a conservative minimum test separation distance ≤ 5 mm to support compliance."*
(https://apps.fcc.gov/kdb/GetAttachment.html?id=f8IQgJxTTL5y0oRi0cpAuA%3D%3D&desc=447498%20D01%20General%20RF%20Exposure%20Guidance%20v06&tracking_number=20676)

41. While "5 mm or less" may seem a sufficient specification of separation distance for device evaluation, it is noteworthy that SAR increases faster as the separation distance closes. Radiofrequency radiation intensity varies rapidly with separation distance especially for separation distances below 15 mm. SAR can increase 30% per mm of separation distance reduction below 5 mm separation distance per Gandhi, 2019.

    Gandhi OP, IEEE Access, April 2019, Microwave Emissions From Cell Phones Exceed Safety Limits in Europe and the US When Touching the Body: *"The increase in SAR for each millimeter of proximal placement of the wireless device varies from 10 to 30%"*
    (https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8688629)

42. According to the French government Agency for Food, Environmental and Occupational Health & Safety (ANSES), standard SAR testing practice of up to 5 mm separation distance for body-worn devices is inadequate as it does not capture the most conservative (highest) consumer SAR exposure scenarios. When tested as used (2mm separation distance or in contact with the body) almost all portable devices tested exceed regulatory SAR limits.

    ANSES 2019, section 3.1.3 *"…more than half of the mobile telephones tested were assessed with a maximum trunk SAR value in contact with the body above 2 W/kg [European standard]."*
    (https://www.anses.fr/en/system/files/AP2017SA0229EN.pdf)

43. Phones should be tested with no separation distance (Anses 2019)

    ANSES 2019, section 3.4.2 *"the [ANSES Expert Committee] CES recommends that the normative trunk SAR of mobile telephones be measured with the device in contact with the body, at a distance of 0 mm, in order to reflect a maximum but realistic exposure situation."*

    ANSES 2019, p. 15, para. 8 *"the Agency [French Agency for Food, Environmental and Occupational Health & Safety] recommends modifying the standard provisions relating to the distance of radio devices that can be placed close to the*

body to ensure that compliance verification measurements for SARs are carried out when the phone is in contact with the body (0 mm)."

44. For small transmitting devices such as mobile phones which are generally used very close to the body or in contact with the body, specifying the separation distance between the device under test and the user is not a comprehensive control. Because the transmitting antenna is very small compared to the device size, and because RF emissions change dramatically at different locations on the handset case, an almost limitless range of test positions is conceivable. Furthermore, the nature of RF radiation is that it is variously absorbed or reflected by nearby objects depending on their size, shape and composition thereby literally deforming and reshaping the ambient electromagnetic field. These changes can be dramatic. For example, as much as half of the energy emitted by a cell phone antenna may be absorbed into the user's head. Add a hand clasping the handset and the field dramatically changes again! Add metallic objects such as a wedding band or earrings and the EM field is again dramatically different.

45. Adding further complexity, a cell phone is not a passive device, but rather constantly adapts to its environment. Recall at paragraph 33 that a cell phone will modulate (increase or decrease transmission power) depending on signal strength. As the environment changes from free air, to head, to hand, to jewelry, the handset may increase its transmitter output to overcome power lost to absorption in order to maintain a stable link with the base station.

46. Thus, it is plain to see that reliably measuring SAR from a mobile device in the real world is fiendishly complicated. Ever more so as novel wireless products in myriad shapes and configurations come to market: smart watches, health monitors, wireless headsets, Bluetooth ear buds, and so on. Regulators and standards-setting bodies acknowledge the measurement challenge of SAR exposure evaluation since environment (e.g. nearby hand or metal objects) can significantly impact SAR readings, and they have all but given up on precisely defining real-world testing conditions beyond general guidelines requiring testers to identify the most conservative exposure cases (worst-case exposure).

> RSS-102 p. 2, para 6: *"**Separation distance (per the power exemption limits)** refers to the minimum test separation distance based on the smallest distance between the antenna and radiating structures or the outer surface of the device, according to the most conservative exposure condition for the applicable module or host platform test procedure requirements, to any part of the body or extremity of a user or bystander"*

47. Both FCC and Innovation, Science and Economic Development Canada acknowledge SAR variability as a *measurement* concern, but do NOT addressed this variability in terms of controlling *user exposure*. Since the human makes testing more complex, regulators allow device testers to substitute a mannequin for the human. Since an infinite array of test positions make testing complex, regulators allow device makers to test in a small set of pre-defined test positions.

> FCC OET Bulletin 65 p.10 para. 3: *"HANDSET AND OTHER TRANSMITTER TEST POSITIONS Because of near-field coupling effects, small changes in the positioning of a test device may sometimes lead to unexpected changes in energy absorption in the tissue medium. To address this matter, the SCC-34/SC-2 has developed specific test positions for testing handsets. These test positions are described in Appendix D. As explained in the SCC-34/SC-2 SAR measurement document, handsets should be tested on the left and right side of a head phantom in a range of test configurations to obtain a conservative estimate of the exposures expected by the user population."*

48. Despite the risk of "unexpected changes in energy absorption", rather than requiring a wide range of testing positions to capture maximum exposure scenarios, regulators allow makers to use three standardized test positions; namely two pairs for the head (Cheek and Tilt) and one for the body. Moreover, Regulators advise device makers may select a preferred separation distance for testing. Recently, Apple typically tests at 5 mm separation distance for iPhone products while Samsung generally tests their Galaxy handsets at 15 mm separation distance.

49. Very specific guidelines are required to define a reliable measuring system for SAR. Since defining precisely controlled phone positions during testing is beyond a regulator's expertise, Both the FCC & Industry Canada defer to the IEEE for specific guidelines. IEEE/IEC P62209-1528 measurement methodologies for specific SAR evaluation methods set out details for positioning the device under test (DUT) relative to a standardized Specific Anthropomorphic Mannequin (SAM) head phantom, and further specify testing, measurement, and data processing methods. Note that this document is not freely available to the public.

> RSS-102 p. 6, last paragraph: "SAR evaluations shall be made in accordance with the latest *version of IEEE 15288 and/or IEC 62209.9"*

50. Thus we have a circuitous and confused regulatory process which sets out to ensure licensed devices comply with basic SAR restrictions under all circumstances, but ultimately only samples compliance at 5 pre-defined positions and large separation distances that do NOT represent worst-case real-world use by consumers.

    a. Health Canada disavows all mechanisms of harm from RF exposure other than acute thermal heating
    b. Health Canada specifies Basic Restrictions on SAR to protect from acute thermal heating not to be exceeded under any circumstance
    c. ISED adopts Health Canada Basic Restrictions on SAR for licensing devices
    d. ISED stipulates testing must capture worst-case or most conservative exposure condition
    e. ISED defines mobile handsets as Body-Worn Devices and stipulates testing separation distance of 5 mm or less (devices designed to use lanyards or straps)
    f. FCC stipulates Devices that operate on the body of users without accessories must be tested using a conservative minimum test separation distance ≤ 5 mm
    g. FCC stipulates the risk of "unexpected changes in energy absorption" for small changes in test position and elects to pre-define testing positions
    h. ISED (& FCC) direct manufacturers to test per the IEEE 1528 Standard (5 defined positions)
    i. ISED allows handsets tested up to 15 mm separation distance

INCONSISTENCIES IN SAR COMPLIANCE TESTING OF MOBILE HANDSETS

51. On August 21st, 2019, the Chicago Tribune published a feature by Sam Roe "We tested popular cellphones for radiofrequency radiation. Now the FCC is investigating." The article reports on testing of certain popular cellular telephones at an FCC accredited laboratory revealing the devices exceed regulatory safety limits. (https://www.chicagotribune.com/investigations/ct-cell-phone-radiation-testing-20190821-72qgu4nzlfda5kyuhteiieh4da-story.html)

52. On or about May 10th, 2020, I was reviewing the Chicago Tribune article and began to investigate associated inconsistencies. After being advised by Mr. Roe of the failed tests and after reviewing the results, Apple protested evasively disputing "[the lab] had not tested the phones the same way

[we, Apple] do," and "[tests] were not performed in a way that properly assesses iPhones." However, Apple would not elaborate on "specifically what it thought was wrong with the Tribune's tests or reveal how the company measures its phones". Apple did not protest that the testing was incorrect, invalid, nor contrary to FCC regulations.

53. Based on these odd pronouncements I reviewed the Chicago Tribune report in more detail and also reviewed the FCC and ISED (Canadian) regulations regarding wireless device testing. From this review I concluded what is stated at paragraph 50 above. Namely, ISED and FCC regulations purport to ensure compliance to health standards (SAR limits) for the most conservative exposure cases. However, the compliance testing guidelines are so narrowly defined and only sample a few test positions that they miss worst-case exposure scenarios. Most obviously, allowing cell phone makers to select a separation distance up to 15 mm for SAR testing while many users carry phones in pockets or undergarments (0 to 2 mm separation distance) all but guarantees test results underestimate users' real-world RF exposure.

54. What specifically was the Chicago Tribune (CT) doing differently?

    a. **Handset orientation**: rather than following IEEE 1528, CT tested handsets at stated separation distance, but unconventional orientations. For example handset standing against the body (as one who is watching the screen while lying on his back) rather than lying against the body (as one who carries a phone in a pocket). (Figure 4)

    b. **Separation distance**: in addition to manufacturer's distance, CT also tested at 2 mm

    c. **Power-limiting trigger**: CT tested phones first against the head in the conventional manner, then again with a human hand holding the phone to trigger the power reduction feature (Figure 3 below)

    d. **Proprietary techniques:** some handset makers reported CT did not have access to special methods needed for testing

Figure 3: Sam Roe grasps an iPhone during retest (Sam Roe / Chicago Tribune)

55. As discussed at Paragraph 44 above, the orientation of a handset relative to the user (or test mannequin) may shift the transmit antenna closer to the subject even if the distance to the device is held constant. For example, if the antenna is at the bottom of the phone (typical location for contemporary smartphones), then holding the phone upside down against the head will bring the transmit antenna as much as 50 mm closer to the head even though the device separation distance is the same. Such a dramatic change in antenna position could certainly increase measured SAR as reported by CT and cause the device to exceed SAR limits.

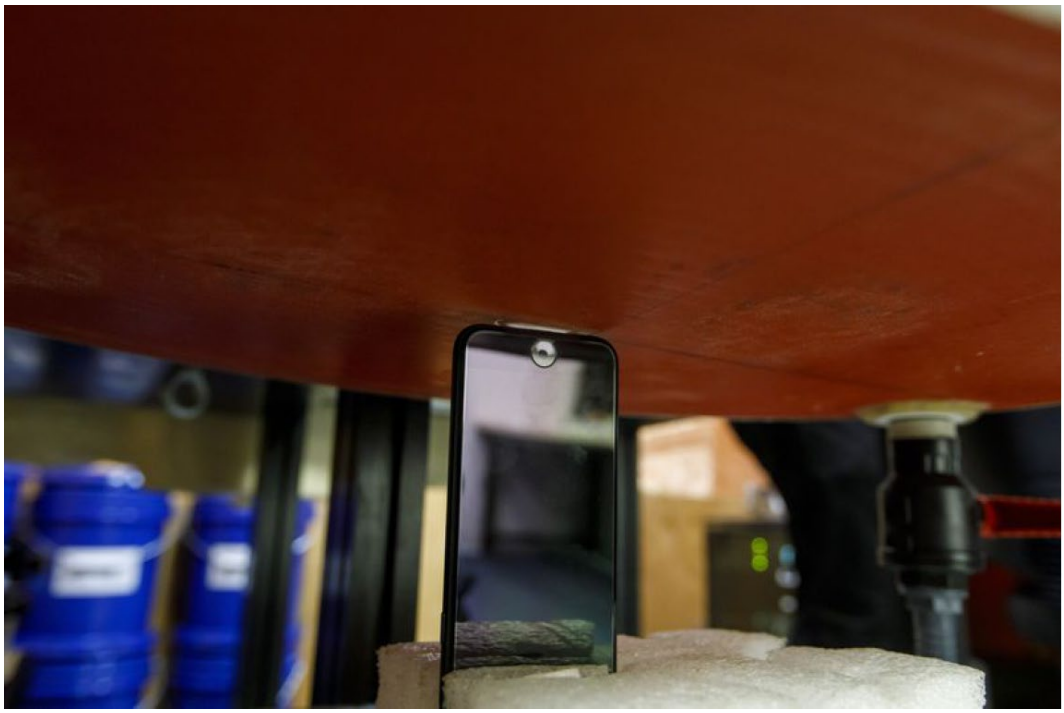

Figure 4: Apple iPhone is tested in unconventional orientation standing against the body mannequin (Brian Casella / Chicago Tribune)

56. As recommended by ANSES (paragraph 43) phones should be tested with no separation distance to best represent worst-case real-world usage. CT split the difference and tested at 2 mm separation distance. As expected, all seven Apple and Samsung handsets tested at this distance exceeded SAR limits since they had been manufactured and tuned to pass SAR testing at the larger separation distances (5 mm & 15 mm, respectively). Notwithstanding the larger separation distance during testing, both Apple and Samsung marketing messaging and promotional material actively show and encourage users to operate the devices close to or in contact with the body.

57. Manufacturers' advertising and promotional images (Figure 5, Figure 6) clearly demonstrate and message "body-worn" use configurations for these devices. Steve Jobs 2007 described the iPhone "Your life in your pocket" and "the Internet in your pocket for the first time ever." Consumers intuitively embrace the message and use mobile handsets in sometimes unconventional "body-worn" configurations without additional accessories (Figure 7)

58. Consumers grasp and operate phones in a variety of positions with a range of orientations and angles including in contact with the body (tucked into a bra or swimsuit). Such untested configurations are clearly demonstrated in manufacturers' marketing images, in the photos of the Chicago Tribune article, and in the Marketplace video, among others. On one hand, cell phone makers cultivate an image of body-worn devices operated in contact with the skin or in a pocket. On the other hand, they eschew testing with separation distances below 5 mm that would be consistent with their advertised use cases. Thereby, the testing configurations explicitly do NOT represent most conservative (worst-case) exposure scenarios.

Figure 5: Body-worn device - iPhone X -Studio in your pocket. Exhibit P-6

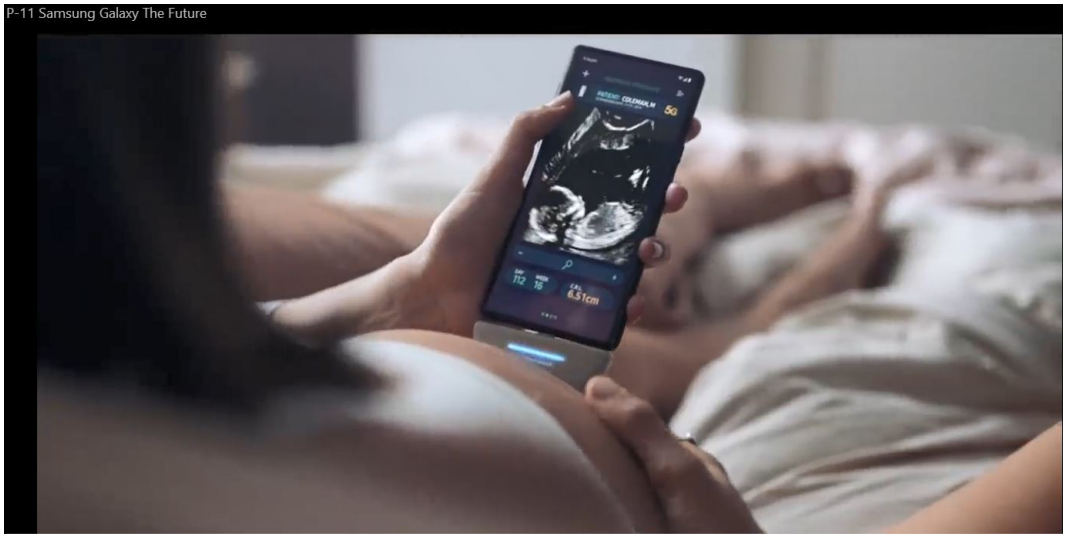

Figure 6: Body-worn device - Samsung Galaxy Sonogram. Exhibit P-11

Figure 7: Body-worn device - Chicago Tribune. Exhibit P-3A (Erin Hooley / Chicago Tribune)

59. Manufacturers (in some cases) falsely declare in their handset documentation that SAR exposure is tested at maximum transmission power; however, Chicago Tribune testing demonstrates power reduction techniques are used in the handsets.

> Apple iPhone 7 RF Exposure Information https://www.apple.com/legal/rfexposure/iphone9,3/en/: *"During testing, iPhone radios are set to their highest transmission levels and placed in positions that simulate uses against the head, with no separation, and when worn or carried against the torso of the body, with 5mm separation."*
>
> Samsung Galaxy S9 Health & Safety Information, Exhibit S-10, GH68-48856A_Rev_1.1 Page 19, Para 4: *"SAR tests are conducted using standard operating positions accepted by the FCC with the device transmitting at its highest certified power level in all tested frequency bands."*

60. In the case of Motorola handsets tested by CT, the handset maker confirmed that the first test results suggested power sensors in the phone designed to reduce power when near the head failed to detect the user. "[Motorola] speculated the test did not trigger the proximity sensors in that phone." Subsequent retest with a modified method yielded compliant results for all three Motorola handsets.

61. While it may sound like a "defeat device" (similar to that used by VW in testing their Diesel vehicles) for a phone to reduce its power output during testing and then only by application of a special, secret test method, it may not be inconsistent with regulations (at least not in the US). The latest FCC SAR Evaluation Considerations implicitly allow for such techniques that reduce transmitter power during SAR compliance testing. Whether permitted or not, such defeat devices

would run counter to disclosures in user manuals regarding highest power and highest transmission levels.

> FCC KDB 648474 D04, section 7: *"Smart phone manufacturers have implemented different power reduction techniques **to maintain compliance** [emphasis ours]. The maximum output power of transmitters operating in data mode is often reduced or can be pulse-modulated with a periodic duty factor to reduce the time-averaged power during simultaneous transmission to maintain voice call quality and SAR compliance. … power reduction mechanisms can become quite complex and dynamic. … These types of power and SAR reduction implementations for simultaneous transmission operations have continued to evolve with no clearly established industry standards."*
>
> *(https://apps.fcc.gov/kdb/GetAttachment.html?id=zCDu9bDcV8fcsumpj%2Bef3w%3D%3D&desc=648474%20D04%20Handset%20SAR%20v01r03&tracking_number=33853)*

62. Both Apple and Motorola evaded CT questions on how to configure the handsets for testing. "The Chicago Tribune's third-party lab was not privy to the proprietary techniques from Motorola necessary to elicit accurate results." Evasive responses from handset makers to CT investigators regarding testing methods run contrary to FCC and ISED regulations which require device makers to provide instructions to users (duty to inform):

> RSS-102 section 2.6: *"The applicant is responsible for providing proper instructions to the user of the radio device, and any usage restrictions, including limits of exposure durations. The user manual shall provide installation and operation instructions, as well as any special usage conditions (e.g. proper accessory required, including the proper orientation of the device in the accessory, maximum antenna gain in the case of detachable antenna), in order to ensure compliance with SAR and/or RF field strength limits. For instance, compliance distance shall be clearly stated in the user manual."*
>
> FCC KDB 447498 D01, section 4.2.2 d): *"All supported body-worn accessory operating configurations must be clearly disclosed to users, through conspicuous instructions in the user guide and user manual, to ensure unsupported operations are avoided."*
>
> (https://apps.fcc.gov/kdb/GetAttachment.html?id=f8IQgJxTTL5y0oRi0cpAuA%3D%3D&desc=447498%20D01%20General%20RF%20Exposure%20Guidance%20v06&tracking_number=20676)

63. Disclosures from the iPhone 7 and Samsung Galaxy S7 are less than instructive. Like the disclosures to CT, these statements demonstrate manufacturers' greater interest in protecting the validity of testing methods, testing results, and compliance status of products than in protecting consumers health in valid (if unorthodox) use cases.

> Apple iPhone 7 RF Exposure Information: *"To reduce exposure to RF energy, use a hands-free option, such as the built-in speakerphone, the supplied headphones, or other similar accessories. Cases with metal parts may change the RF performance of the device, including its compliance with RF exposure guidelines, in a manner that has not been tested or certified."*

(https://www.apple.com/legal/rfexposure/iphone9,3/en/)

Samsung Galaxy S7 Health & Safety Information, Exhibit S-8, Page 20, Para 5: *"SAR values for body-worn devices are measured when used with an accessory that contains no metal and that positions the device a minimum of X.X cm from the body."*

CONCLUSION

64. Manufacturers adjust transmitter power to ensure SAR limit compliance only in the three defined test positions. These test positions demand precise alignment, separation distance, and angle relative to test mannequins (specific anthropomorphic mannequin – SAM head, and flat body) to ensure repeatable SAR measurements. They choose one of the 3 IEEE 1528 test positions that gives worst-case SAR and adjust (tune) the transmitter power to ensure these values comply to the 1.6 limit. These tuning values for each transmission mode then become the standard for that model and are used for all units sold to consumers; but untested user positions may exist whereby the phone will likely exceed 1.6 W/Kg.
65. Testing by Marketplace, Chicago Tribune, ANFR, and Penumbra shows handsets available in the marketplace can exceed ISED, FCC, and European SAR limits especially when tested close to the body (separation distance below 5 mm). Other than commenting that such test configurations are not "standard", no handset maker or regulatory body has challenged the validity of these test results. In fact, such measurements are consistent with the spirit if not the letter of both ISED & FCC regarding most "conservative" test scenarios.
66. Regulatory guidelines require manufacturers to test "conservatively" ("Worst Case") including testing below 5 mm separation distance for "body-worn" devices. Manufacturers elect to only test in the very limited and tightly controlled positions (tilt, cheek, body separated) defined in by standards bodies (IEEE/IEC P62209-1528) and at maximum permitted separation distance. While manufacturers' user manuals and safety guidelines make no representations about use or SAR compliance outside tested configurations, their promotional materials actively display and encourage users to employ devices in a variety of untested configurations including worn on or close to the body.
67. Present testing methods and practices do NOT ensure consumers' real-world exposure remains below FCC limits or Health Canada Basic Restrictions during normal use.
68. Present testing method and practice does NOT represent most conservative (highest) consumer SAR exposure scenarios. When tested as used (2mm separation distance or in contact with the body) almost all portable devices tested exceed regulatory SAR limits.
69. Testing regimen is designed for repeatability and consistency of measurements rather than to assess maximum SAR exposure in real-world use scenarios. Mandate to test "Conservatively" (i.e. Worst Case) is not respected.
70. SAR compliance is therefore misrepresented to the consumer, who is given a knowingly misleading impression that the tested devices meet the 1.6 W/Kg limit. Where Apple and Samsung models are tested as actually used by the consumer, they still fail in all cases to meet the SAR limit. The purpose of such a deceptive testing regime is to hide from consumers the elevated level of non-ionizing radiation to which they are exposed. The inferred purpose of this deception is to hide intentionally undisclosed health risks from consumers.

71. While significant evidence exists in the scientific community challenging whether FCC and Health Canada SAR limits are adequate to ensure consumer safety, devices which exceed SAR limits during normal use cannot be considered safe.

72. This discovery is my own; to my knowledge, not previously published; constitutes innovative intellectual property; and is deemed to possess considerable financial value.

I, Pedro Gregorio, residing at 7353 Dunver, Verdun, Quebec, Canada solemnly affirm that the information presented above is, to the best of my knowledge, true.

AND I HAVE SIGNED AT MONTREAL
THIS 5th DAY OF FEBRUARY, 2021

Pedro Gregorio

SOLEMNLY DECLARED BEFORE ME AT MONTREAL THIS 5th DAY OF FEBRUARY, 2021

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