Brillouin Precursors, a theoretical oddity or a real concern for 5G millimetre-wave bands to be used in future high-speed telecommunications?

Don Maisch PhD Discussion Paper July 21, 2022

In early 2002 the New York based technical publication, *Microwave News* published an examination of a rather arcane topic: Brillouin precursors. The issue at that time concerned the possibility of adverse biological effects from high-power and high-frequency radiofrequency (RF) radiation specific to the phased array PAVE PAWS radar facility at Cape Cod, Massachusetts, USA.

When an incoming radiofrequency wave enters body tissue it normally loses an amount energy with some of the energy absorbed in the body. The depth of penetration (absorption) depends upon the frequency. The lower the frequency, the further it penetrates, and vice versa. As waves shorten in length as the frequencies increase, penetration normally reduces, until, once the waves are short enough, penetration will be minimal but still can be sufficient enough to affect most skin structures. For example, With a millimeter wavelength of 0.65 mm at 42 GHz. The waves can penetrate into the human skin deep enough to affect most skin structures located in the epidermis and dermis.[1] However, these types of waves present other challenges. The first is that when most of the energy is focused in a small area, such as 5G antenna beam-forming, the risk of human tissue heating for anyone in the path of the beam will be increased.

The second challenge is that signals such as radar that are made of sharp pulses behave differently when they enter body tissue containing moving charges (such as potassium ions). Each incoming pulse generates a force that accelerates these moving charges, thereby causing them to become emitters of electromagnetic radiation (EMR). This additional radiation adds large spikes onto the leading and trailing edges of the original EMR pulse. The sharp transients, called "Brillouin Precursors" increase the strength of the original signal and reradiate EMR waves deeper into the body than predicted by conventional thermal models.[2]

The creation of Brillouin Precursors within the body by very short pulsed signals in the frequency of 10 GHz or more (millimeter wave bands) was described by Albanese et al in 1994. These authors predicted that the interaction of these signals with human tissue would cause disruption of

[1] Alekseev S., et al.,"Millimeter wave dosimetry of human skin", *Bioelectromagnetics* pp. 65-70, Vol. 29, No.1, Jan 2008.

[2] Scientists for Wired Technology, Introducing Brillouin Precursors, https://scientists4wiredtech.com/what-are-4g-5g/brillouin-precursors/

large molecules, and damage cell membranes leading to blood-brain barrier leakage.[3]

In the *Microwave News* interview, Professor Kurt Oughstun[4] explained how Brillouin Precursors are produced in biological tissue by the transients in the signals from phased array radar antennas. When asked, whether Brillouin Precursors are unique to PAVE PAWS radiation, Oughstun replied:

> *No - not at all. As data transmission rates continue to increase, wireless communication systems will approach closer to and may, at some time in the not-too-distant future, exceed the conditions necessary to produce Brillouin Precursors in living tissue.*[5]

On April 15, 2019 this writer sent an email to Oughstun and asked if there was a possibility of Brillouin Precursors being created by 5G technology. His detailed reply, dated May 5, 2019 said, in part:

> *This condition is likely not met, but again is close. A 10 Gbps (gigabits per second) data rate or higher would, however, be sufficient [to create Brillouin Precursors], and that would be worrisome.*[6]

The type of high-frequency electromagnetic signals that Albanese and Oughstun described as producing Brillouin Precursors are now, by implication, capable of being produced by 5G technologies that transmit pulsed waves at frequencies greater than 10GHz and/or peak download speeds of 10 Gbps or more.

In March 2021, the Global System Mobile Association (GSMA), the industry organisation representing the interests of mobile operators worldwide, published its policy position on the 5G spectrum. To quote, in part, from page 3:

> *5G is defined in a set of standardised specifications that are agreed on by international bodies – most notably the 3GPP and the ITU. The ITU has defined criteria for IMT-2020 – commonly regarded as 5G – and selected a set of compatible technologies which will support the following use cases: 1. Enhanced*

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[3] Albanese R., et al., "Ultrashort Electromagnetic Signals: Biophysical Questions, Safety Issues and Medical Opportunities," Aviation, Space and Environmental Medicine, 65 (Supplement), pp.A116-A120, May 1994

[4] Dr. Kurt Oughstun, Emeritus Professor of Electrical and Biomedical Engineering, University of Vermont, Burlington USA. He has done extensive work on the propagation of extremely short electromagnetic pulses through different types of materials, and is the author of more than 50 published papers, as well as the textbook Electromagnetic Pulse Propagation in Causal Dielectrics with G.C. Sherman (Berlin: Springer-Verlag, 1994).

[5] Slesin, L., *Brillouin Precursors 101* with Professor Kurt Oughstun, Microwave News, Vol 22, No. 2, March/April 2002, pp. 10-11, https://microwavenews.com/news/backissues/m-a02issue.pdf

[6] Email from Kurt Oughstun, May, 5, 2019.

mobile broadband: Including peak download speeds of at least 20 Gbps…[7]

Beyond 5G and its peak download speeds in the Gigabits range is 6G. According to a 2020 IEEE paper the future introduction of the next generation 6G communications will utilise much higher data speeds in the Terahertz band (0.3 THz to 10 THz), which the authors acknowledge "is the last unexplored band of the radio frequency (RF) spectrum".[8] This is a speed far in excess of what Oughstun called "worrisome" in relation to the generation of Brillouin Precursors.

It must be pointed out that little research has been carried out on the possibility of adverse biological effects from the creation of Brillouin precursors with 5G phased array antennas (let alone on 6G communications). Considering the high download speeds, which may have unintended adverse biological effects, this should be a priority.

Other damaging effects have been predicted in a paper published in *Health Physics* in December 2018 by Esra Neufeld and Niels Kuster. The paper suggests that permanent skin damage from tissue heating may occur even after short exposures to 5G millimetre wave pulse trains (where repetitive short, intense pulses can cause rapid, localised heating of skin). The authors stated that there is an urgent need for new thermal safety standards to address the kind of health risks possible with 5G technology:

Quoting from Neufeld and Kuster:

The FIFTH generation of wireless communication technology (5G) promises to facilitate transmission at data rates up to a factor of 100 times higher than 4G. For that purpose, higher frequencies (including millimetre-wave bands), broadband modulation schemes, and thus faster signals with steeper rise and fall times will be employed, potentially in combination with pulsed operation for time domain multiple access…The thresholds for frequencies above 10 MHz set in current exposure guidelines (ICNIRP 1998, IEEE 2005, 2010) are intended to limit tissue heating. However, short pulses can lead to important temperature oscillations, which may be further exacerbated at high frequencies (>10 GHz, fundamental to 5G), where the shallow penetration depth leads to intense surface heating and a steep, rapid rise in temperature…"[9]

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[7] GSMA, 5G Spectrum, GSMA Public Policy Position, March 2021, https://www.gsma.com/spectrum/wp-content/uploads/2021/04/5G-Spectrum-Positions.pdf

[8] Sarieddeen H., Saeed N., Al-Naffouri TY., Alouini MS., IEEE, *Next Generation Terahertz Communications: A Rendezvous of Sensing, Imaging, and Localization*, https://www.researchgate.net/profile/Hadi-Sarieddeen/publication/335990259_Next_Generation_Terahertz_Communications_A_Rendezvous_of_Sensing_Imaging_and_Localization/links/5eac534345851592d6b012f0/Next-Generation-Terahertz-Communications-A-Rendezvous-of-Sensing-Imaging-and-Localization.pdf

[9] Neufeld E., Kuster N., "Systematic Derivation of Safety Limits For Time-Varying 5G Radiofrequency Exposure Based on Analytical Models and Thermal Dose", December 2018, *Health Physics*, Volume 115, Number 6.

It is possible that this advice was in response to the ICNIRP draft guidelines (2019) as some changes were made to the final published guidelines. However, the changes did not conform to those suggested and it is not clear that the possibility of excessive heat absorption from these higher frequencies, which may result in pain, has been addressed in ICNIRP's current guidelines.

The need for reliable research

The necessity for more reliable research into possible damaging effects of pulsed millimetre waves used for 5G communications is also seen in an August 2021 paper by Foster and Vijayalaxmi. Their paper states:

> *This perspective considers 31 studies related to genetic damage produced by exposure to RFR at frequencies above 6 GHz, including at millimeter-wave (mm-wave) frequencies. Collectively, the papers report many statistically significant effects related to genetic damage, many at exposure levels below current exposure limits.*

However, the authors then point out that the findings in these studies in many cases are possibly non-replicable results. They suggest that any conclusions from these findings are limited and insufficient for giving health advice and setting exposure limits. In order to address this issue they have called for "improvements in study design, analysis and reporting in future bioeffects research to provide more reliable information for health agencies and regulatory decision makers".[10]

Uncertainties with ICNIRP's thermally based limits for millimeter wave emissions

Concerns over the lack of scientific data regarding possible biological effects of millimeter waves proposed for use in modern telecommunications have been raised by Nicholas Lawler et al. in *Biomedical Optics Express* (May 2022). The authors found that the studies cited indicate a strong power and dose dependence of millimeter wave induced effects at biologically relevant exposure levels such as those recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The authors state:

> *In conclusion, our findings demonstrate that high dose MMWs can induce characteristic transcriptomic and genomic modifications in primary human fibroblasts that are not associated with a typical cellular thermal response. We show that MMW-induced changes at the transcriptome level are distinct from a traditional cytokine-induced transition, and that they may be associated with alterations in DNA structural dynamics. These changes represent unique*

[10] Foster KR., Vijayalaxmi, "Needed: More Reliable Bioeffects Studies at "High Band" 5G Frequencies", *Frontiers in Communications and Networks*, August 2021, Vol. 2, Article 721925

interactions of MMWs with biological material and illustrate the importance of both power density and dose when determining safety margins for longer periods.[11]

The "take-home" message from the above mentioned papers is that we still do not have adequate research on 5G millimetre waves to be able to assure the public that the many thousands of 5G antennas, in many instances placed in close proximity to homes and workplaces, are without a possible health risk because the necessary research has not yet been conducted.

A potential risk for property owners

A German court ruling of July 2020 may portend future litigation risks for property owners and local governments who allow 5G millimeter wave antennas to be erected on their property, potentially setting a precedent for other nations as well.

The court determined in a lawsuit that property owners who rent space for base station antennas assume responsibility for possible health consequences of the activity. Although the emissions would be lower than the relevant official exposure standard (usually based on ICNIRP) this does not mean that the property owner is absolved of the responsibility of negative health consequences. The court ruled in part:

As even official bodies such as the European Parliament's Research Service (STOA) point out that the electromagnetic radiation limit values are too high by at least a factor of 10, the owner takes a liability when entering into an agreement with a mobile phone system operator in this regard. [12]

As far as this liability extends, the court also stated that property owners must be responsible for all new dangers and risks, which can be further strengthened through future upgrades and new mobile phone technology.[13]

Strengthening the German court decision, the head of the Office of Technical Assessment at the German Bundestag (German parliament), Professor A Grunwald stated that it is irresponsible to introduce new technology with significantly higher frequencies without prior investigation of the consequences.[14]

In the Australian and New Zealand context, even though the telecommunications carriers are themselves indemnified against the risk of

[11] Lawler NB, et al. "Millimeter waves alter DNA secondary structures and modulate the transcriptome in human fibroblasts", *Biomed Opt Express*, Apr 28, 2022, Vol.13 (5):3131-3144.
[12] The Swedish Radiation Protection Foundation, "German court finds property owners can be liable for health impacts from base station antennas on their property" June 5, 2022 https://www.emfacts.com/2022/07/german-court-finds-property-owners-can-be-liable-for-health-impacts-from-base-station-antennas-on-their-property/
[13] ibid.
[14] ibid.

possible harm that their facilities may cause, this apparently does not carry over to the owner of the property on which the facility is located.

Even though the risk for the property owner may be small the possibility of such a risk does exist, especially for new technology where questions still remain unanswered as to possible health hazards. Therefore the onus should be on the telecommunications carriers to acknowledge this risk in any rental agreement they present to prospective antenna site property owners.