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Non-chemical signatures of biological materials: Radio signals from Covid19?

Yogendra Srivastava [ID][a], Elisabetta Sassaroli[b], John Swain[c], Allan Widom[c], Meenakshi Narain[d], and Georges de Montmollin[e]

[a]Department of Physics and Geology, University of Perugia, Perugia, Italy; [b]Department of Radiology, Brigham and Women's Hospital, Boston, MA, USA; [c]Physics Department, Northeastern University, Boston, MA, USA; [d]Physics Department, Brown University, Providence, RI, USA; [e]Lenr-Cities Suisse Sárl, Neuchatel, Switzerland

ABSTRACT
All therapeutic methods dealing with coronavirus (past and present) are based on chemicals. We test for it (positive or negative) chemically and hope to cure it with a future vaccine (some complicated chemical preparation). If and when the virus mutates, another set of chemical protocols for its testing and a hunt for new chemicals as a vaccine shall begin again and again. But the history of modern (western) medicine tells us that our biotechnology is not so limited. Copious scientific evidence for sonic and low energy electromagnetic signals produced by all biological elements (DNA, cells, bacteria, parasites, virus) exists; in turn, the biological elements are affected by these non-chemical signals as well. A careful analysis and a catalogue of the spectrum of these non-chemical signals are proposed here as a unique *biophysical* signature.

Introduction

Standard paradigm for intercellular communication is via chemical reactions. However, *physical* non-chemical means such as sonic and electromagnetic signals from various life forms have been shown to exist for a long time. The best-known example of a *non-chemical communication* is of course via light signals. In fact, F. Popp showed that ultra-weak bio-photon emission by living cells is a universal phenomenon that is involved in cell regulation (Popp 1998) (Light signaling is fairly common amongst plants and mammals). The intensity of the emitted electromagnetic light signal is not necessarily linear with number; for example, intensities of the emitted radiation are remarkably different for cancer versus normal cells (Alvermann et al. 2015; Popp 1998).

It is of obvious practical interest to investigate the biochemical possibilities of producing and absorbing sonar and electromagnetic signals from various life forms at larger wavelengths. Sound (vibrational) waves from cells of *Bacillus subtilis* were detected with sensitive microphones, showing approximate peaks at frequencies of [8.5, 19, 29 and, 37 kHz] (Matsuhashi et al. 1998). Also, beaming continuous sine waves at similar frequencies by a speaker or those emitted by *B. subtilis*, promoted colony formation by another *Bacillus carboniphilus* when the latter was under severe stress such as high temperatures and high KCL concentrations. Thus, it was deduced that physical (sound

waves) rather than chemicals can and do function as a growth-regulatory signal between cells (Matsuhashi et al. 1998), (Norris and Hyland 1997).

For an excellent review about when sonic and other low-frequency EM signals (*microbial conversations*) might become physical, see Reguera (2011).

In 2000, Babincov'a *et al.* (Babincov'a et al. 2000) hypothesized that viruses could be inactivated by generating the corresponding resonance ultrasound vibration of viruses that is in the GHz region. Thus, began an intensive theoretical and experimental research on the vibrational modes of variously shaped virus in this frequency range (Balandin and Fonoberov 2005; Dykeman and Sankey 2008, 2010; Ford 2003; Saviot et al. 2004; Sun et al. 2017; Tsen et al. 2006; Yang et al. 2015).

The proposal to do resonant energy transfer from ultrasound for the destruction of HIV virus made in (Babincov'a et al. 2000) was taken up to use efficient energy transfer from microwave radiation against the influenza A virus and it was mapped out in detail in (Yang et al. 2015). The resonant peak frequency was found to be 8.2 GHz with a width of about 4 GHz. As microwave energy can be dangerous to humans and animals, it is only thanks to resonant energy transfer that the needed power was reduced by about a factor of 15 and be below the IEEE safety threshold value so that microwave power could be employed to disinfest open spaces from this virus (Yang et al. 2015). Sun *et al.* (Sun

et al. 2017) have studied another rod-shaped virus WSSV (white spot syndrome virus) that is dangerous to marine life (shrimp, crab, crayfish, etc.) and find a strong microwave absorption peak on WSSV at a frequency (6.5 ± 1) GHz. Termite (Termiditiae) control has been demonstrated with 2.45 GHz microwave radiation (Yanagawa et al. 2020).

Direct electrical bio-signaling between communities of bacteria have been studied in Yuzvinsky et al. (2011), Prindle et al. (2015), Humphries et al. (2017), Liu et al. (2017), where further references can be found. Through these works, one can follow the natural evolution from nanowire microbial connections (Yuzvinsky et al. 2011) to wireless cellular communications (Humphries et al. 2017; Liu et al. 2017; Prindle et al. 2015). Just as our home computers have evolved from an early *hard wired modem* connection to present-day *wireless communications* from afar, so it would seem has been the fate of the living state on earth.

To properly discuss and theoretically understand the above experimental results, one is faced with an obvious difficulty of large difference in the length scales involved since the length of the *emitter* (say a bacterium) is so much smaller than the length of the *emitted signal* (that is, the wavelength of say a radio wave).

Consider a long thin biomaterial of (effective) length L. The classical dipolar sonar radiation frequencies are given by Sun et al. (2017)

$$\nu_{n,cl}(L) = (\frac{\nu}{L})(2n+1); n = 0, 1, 2, 3, \ldots;$$

$$\nu_1 : \nu_2 : \nu_3 \ldots = 1, 3, 5, 7, \ldots; \qquad (1)$$

where ν is the speed of sound in the medium.

On the other hand, there are also quantum mechanical-free electron motion along the effective perimeter of the material. The quantum mechanical electromagnetic (EM) transition frequencies are given by (Swain et al. 2013; Widom et al.)

$$\nu_{n,qm}(L) = (\frac{\pi\hbar}{mL^2})(2n+1); n = 0, 1, 2, 3, \ldots;$$

$$\nu_1 : \nu_2 : \nu_3 \ldots = 1, 3, 5, 7, \ldots; \qquad (2)$$

where m is the mass of the electron. The presence of the Planck's constant in the frequency tells us that this is a truly quantum mechanical (and not a semi-classical) effect. As emphasized in (Widom et al.), the electron can skip rungs as it goes up and down the length of a DNA say, thus $L_{eff} < L$.

For the model in consideration, we have for the same length

$$\left[\frac{\nu_{n,cl}(L)}{\nu_{n,qm}(L)}\right] = (\frac{\nu m L}{\pi \hbar});$$

$$\approx 1.1 \times (\frac{\nu}{2km/sec.}) \times (\frac{L}{200nm}); \qquad (3)$$

For densely packed bio-materials of interest, we expect $\nu \approx (1.5 \div 2.5)$ km/s. The two frequencies become equal $(11.1 \pm 1.5$ GHz$)$ for a narrow length-band around (180 ± 25) nm. Thus, there should be an *internal* balance between the two sets of mode for this length.

On the other hand, for $L \leq 180$nm, the EM transition frequencies are higher than the internal sonar frequencies, and *vice versa*, for $L \geq 180$ nm, the EM transition frequencies are smaller than its sonar counterpart.

Let us consider the rod-shaped virus WSSV studied in (Sun et al. 2017). If we assume its mean length to be 300 nm, and the mean speed of sonar propagation as $2km/sec.$, its peak sonar frequency would be 6.66 GHz, that matches very well with the peak frequency of 6.5 GHz observed in (Sun et al. 2017). For the internally generated EM mode frequency for this virus to be the same as the sonar frequency, we need to assume $L_{eff} \approx 0.78L = 234$ nm. The experimental data for this virus seem to be amenable to a satisfactory theoretical analysis using standard methods.

Unfortunately, such is not the case for the data presented in (Matsuhashi et al. 1998) for *B. subtilis* of length $L = 10$ microns $= 10^4$ nm. Using Eq.(1) with $\nu = 2km/sec.$, the sonar frequency is 200 MHz and through Eq.(2), the (internally generated) EM frequency is estimated to be 3.64 MHz. These are several thousands of times larger than the measured frequency range $(8 \div 40)$ kHz (Matsuhashi et al. 1998) and the authors themselves note that the mechanism producing such frequencies is unknown. See also Norris and Hyland (1997). Below we shall try to understand this conundrum.

It is important to remember that the sonar and EM radiations are not decoupled. The vibrational motion that generates sonar frequencies implies a separation of charges and thus a change in the dipole moments inducing EM effects. So long as the coupling between the two interactions is weak, they can be treated as independent and the arguments presented above are adequate. But when the coupling becomes large, there is a strong interaction between the two and in fact at a critical value of the coupling, the system enters a *super radiant* Dicke-Preparata phase and a *zero* frequency mode develops.

Let ν_s be the sonar frequency; ν_{em} the EM frequency and ν_{int} the frequency with which the two are coupled. After diagonalization, the (two) resultant frequencies $(\nu_\pm)$ are given by

$$2v_{\pm}^2 = \left[(v_s^2 + v_{em}^2) \pm \sqrt{(v_s^2 - v_{em}^2)^2 + 16v_{int}^2 v_s v_{em}} \right]$$

As v_{int} is increased to a critical value

$$v_{int} \equiv v_{critical} = (1/2)\sqrt{(v_s v_{em})};$$

$$v_- \to 0;$$

and a zero frequency mode develops. For $v_{int} > v_{critical}$, the system undergoes a phase transition and enters into a super-radiant phase.

For the problem at hand, $v_s = 200$ MHz; $v_{em} = 3.64$ MHz; so that $v_{critical} = 13.5$ MHz. To obtain an experimental peak frequency say 40 kHz, $v_{int} \approx v_{critical} \sqrt{1 - \left(\frac{40}{3640}\right)^2}$, exceedingly close to the critical value. Optimistically, we note that the measured frequencies seem to be consistent with our selection rule for the ratios $1 : 3 : 5 : 7$. If our conjectured mechanism is valid, the system is very near the critical phase and thus expected to be metastable.

At present, it is of great practical interest to investigate into the nature of electromagnetic signals emitted by the virus SARS-Cov-2 (the disease is technically Covid-19, commonly called coronavirus). The physical characteristics of this virus are well known, see, for example Cascella et al. (2020). For our immediate interest, we may recall that the diameter of the corona (circular or elliptic) $D \sim (60 \div 140)$ *nanometers* and that this positive-strand RNA coronavirus typically contains $[(26 \div 32) \times 10^3$ bp], so that we may infer that in absolute units they are $[(8.84 \div 10.8) \times 10^{-4}$ cm] long. The mean length 10 microns of CV-19 virus is the same as that of *B. subtilis* studied in Matsuhashi et al. (1998) and theoretically discussed above. Were the length the dominant factor fixing the value of the frequency, then to a first approximation, there would be a clash between the calculated sonar and internally generated EM frequencies and the experimentally reported values in Matsuhashi et al. (1998). *Mutatis mutandis* critical coupling between the two modes would have to be invoked with a resulting meta stability implied also for CV19. It is difficult to estimate theoretically the resultant frequency without further assumptions. In a later section, we shall describe experimental methods for a future determination of this important frequency.

Measurements of the characteristic frequencies

Here we briefly mention an ancient but tried method (Houck and Gaw 1961) that could be readily adapted for measuring the frequency spectrum of a biological specimen that is radiating at a low intensity. The device sometimes known as *gate dip meter* measures the radiation frequency of a specimen without *disturbing* it since the meter is not directly coupled to the biosample.

The essential idea of how the meter works can be stated in its simplest form as an LC-circuit with a tunable (and thus known angular) frequency Ω_M. Suppose the meter is brought near the sample so that it gets (weakly) inductively coupled to the sample. Then, as one sweeps Ω_M and it hits (one of the characteristic frequencies) ω_s of the sample, there would be a resonance and the meter would lose power to the sample and its own current would dwindle and hit a minimum; this explains the word *dip* in the name of the meter. A similar situation exists in the capacitive coupling mode. The central point being that as Ω_M gets close to ω_s there is the maximum dip in the current. Modern-day instruments are properly calibrated so that the data about the frequency spectrum can be digitally read.

It is natural to assume that as a virus (say) mutates, its natural frequencies would change also. Thus, a careful measurement of its time-dependent frequency spectrum should provide a *signature* or fingerprint of the same in real time. Ideally, we might hope that in parallel with the highly useful (but static) biogenetic structural information that the genome archive provides, in the future we would also have biophysical (dynamical) information at the genetic level through its frequencies and the latter's evolution in time. Hence, our proposal is to augment the Genome with a Bio-digital frequency catalogue. We shall return to this subject and present further details in another study elsewhere.

Dielectric properties of water and of bacteria in water

Water is quintessential to all life forms (certainly those terrestrial). Biochemistry admits this fact but does not explain it. In any event, both low-frequency sonic and EM signals from biological materials such as cells, bacteria, virus, etc., have been observed only in the presence of water (Matsuhashi et al. 1998; Reguera 2011). Thus, it is natural to ask whether water possesses low energy excitations of its own. In the following, we shall briefly discuss theoretical considerations and experimental evidence supporting their existence.

Insertion of transverse modes inherent in QED to polar liquids – such as water – have led to remarkable results such as a laser-like activity (Del Giudice et al. 1988; Preparata 1995) along with a ferroelectric domain structure in water (of radius $R \sim 10^{-5}$cm) at room temperature (Sivasubramanian et al. 2005). One implication

is the dramatic rise in the permittivity of water at low frequencies (Angulo-Sherman and Mercado-Uribe, 2011; Rusiniak 2000, 2004). For example, the real part of the dielectric constant at 100 Hz is $(3.5 \div 4.5) \times 10^3$, whereas it falls to its traditional textbook value 80 when probed at higher frequencies [10 kHz–10 MHz]. Also, when sufficiently confined, water permittivity can attain values even higher than 10^7 at say 5 Hz. In a phenomenological fit of the data (Rusiniak 2000), two resonant frequencies, one between $(3.5 \div 10)$ Hz (attributed to oxygen) and a higher frequency mode $(40 \div 80)$ Hz (attributed to hydrogen) were employed.

There are substantial changes in the permittivity of water even for small additions of biomolecules. For example, at a concentration of only 0.05% polymerized DNA (of molecular weight 3×10^6), the static dielectric constant of the solution reaches a high value of 40,000(Takashima and Schwan 1991). Because of the large size of the biomacro-molecules, the dielectric dispersion occurs at very low frequencies $(5 \div 8)$ Hz.

An important message here is similar both for sonic and EM resonance signals: a signal can be *sympathetically* excited by a nearby (external) system possessing a common frequency and *vice versa*: the external system can be excited by it provided a commonality of frequencies exists.

Information capacity and memory of DNA and water

The discovery of (small) ordered ferroelectric domains in water (at standard temperature and pressure) clarified the previously confusing role of memory in water (Widom et al. 2010). Just as ferromagnetic ordering is routine for storing memory information on computer disks so does Nature use ferroelectric ordering in water for data storage. Moreover, wireless connections are an everyday living proof and reminder that information can be manipulated via EM signals with sources far removed from the information storage site.

To estimate the information capacity of water as well as that of DNA, the polymer most studied with regard to memory, we proceed first to relate information I to entropy S (Khinchin 1957) and then use statistical thermodynamics to relate S to other physically measurable quantities (Widom et al. 2010). If Ω denotes the number of states in a system, then the information memory capacity N in *bits* is defined in information theory as follows (Khinchin 1957):

$$N = log_2 \ \Omega;$$

$$\Omega = 2^N \tag{4}$$

On the other hand, in statistical mechanics, the entropy S is defined as (Landau and Lifshitz 1999)

$$S = k_B ln\Omega;$$

$$(Boltzmann's \ constant) k_B = 3.80 \times 10^{-23} \ Joules/Kelvin; \tag{5}$$

Thus, the memory capacity of a system is related to the entropy of the system via

$$\left(\frac{N}{bit}\right) \equiv \left(\frac{8I}{bytes}\right) = \left(\frac{S}{k_B ln2}\right)$$

$$\approx \ 1.443 \left(\frac{S}{k_B}\right) \tag{6}$$

where I denotes the memory capacity in bytes.

To illustrate thermodynamic reasoning about information and entropy let us first consider a DNA molecule. The normal coiled state of the DNA molecule can become uncoiled. It is experimentally possible to hold two points of a long molecule apart with optical tweezers and measure the molecular tension τ.

If the length L denotes the distance between the two points, then the DNA molecular-free energy F at temperature T obeys

$$dF = -SdT + \tau dL = -(k_B ln2)NdT + \tau dL;$$

$$\left(\frac{\partial N}{\partial L}\right)_T = -\left[\frac{1}{k_B ln2}\right]\left(\frac{\partial \tau}{\partial T}\right)_L;$$

A remarkable feature was discovered by two groups simultaneously (Smith et al.) (Cluzel et al. 1996): that at a force of about 65 picoNewton, the DNA lengthens by a factor about two without any additional force (Marko and Siggia 1995) (JPK instrument application note). This is called an *over-stretching transition*. If we model this phase transition regime as

$$\tau \approx (TT_o)\tau_c, \tag{7}$$

we may estimate the approximate DNA information capacity per unit length (in units of bytes per meter) as given by the right-hand side of Eq. (8) to be

$$\frac{\tau_c}{(8ln2)(k_B T_o)} \approx \ 2.8 \ Gigabytes/meter;$$

$$for \ \tau_c = 65 \ picoN; \ T_o = 300K, \tag{8}$$

a satisfactory estimate.

We can also estimate the information capacity of one water molecule (N^*) using a similar tactic (Widom et al. 2010). During the phase transition of liquid water into steam at $T = 100^o$ Celsius $(T^* = 373$ Kelvin), the heat of

evaporation of steam is 2, 260 Joules/gm. [This is equivalent to a latent heat $q^* = 6.79 \times 10^{-20}$ Joules/molecule = 0.42 eV/molecule]. This anomalously large latent heat is due to ordered domains. Water contains electric dipole ordered domains of size $(R \sim 100$ nm) due to a condensation of photons interacting with the molecular dipole moments (Del Giudice et al. 1988) (Sivasubramanian et al. 2002) (Del Giudice and Vitiello 2006).

The analogue of Eq.(8) is given by the vapour pressure coexistence equation

$$\left(\frac{dP}{dT}\right) = \left(\frac{\Delta s}{\Delta v}\right) = \left(\frac{q^*}{T^*\Delta v}\right) = \left(\frac{(k_B ln2)N^*}{\Delta v}\right);$$

$$N^* = \frac{q^*}{(k_B T^*)ln2} \approx 19 \; bits/molecule, \qquad (9)$$

showing that water has an exceedingly high degree of memory storage capacity: about 6.3×10^{23} bits/cm^3.

A evolution from nanowire microbial connections to wireless cellular communications

In this subsection, we briefly note that just as our home computers have evolved from an early *hard wired modem* connection to present-day wireless communications from afar, so has been the fate of the living state on earth.

In (Ntarlagiannis et al. 2007), using saturated sand columns and a metal-reducing bacterium *Shewanella oneidensis* MR-1, they showed electrically conductive appendages called *microbial nanowires* that are directly associated with electric potentials. Furthermore, SEM imaging revealed a network of nanowires linking cells to cells and cells to mineral surfaces, *hardwiring* the entire column.

They also show that these nanowires serve as conduits for the transfer of electrons from bacteria in the anaerobic part of the column to bacteria at the surface that have access to oxygen, thus functioning akin to a *bio-geo-battery*. These results advance our understanding of the mechanism of electron transport in subsurface environments and of how microorganisms cycle geologic material and share energy.

Natural evolution has brought about the living state from a previous hard nanowired set of biocommunities to the later more evolved oxygen-rich biocommunities that were able to communicate wireless with others at a distance; both sonically and through EM signals of low frequency.

Conclusions

In this paper, we have tried to delineate non-chemical signatures of a generic biological object. To be concrete, in the present pandemic, when a chemical analysis is mute about an asymptomatic carrier of CV19, our study to hunt the identity of the virus through its non-chemical expression(s) assumes a more than academic role.

To facilitate this enormous task, we have touched upon a variety of related problems. For example, a model has been presented that gives us a reasonable description of experimental data on the frequency spectrum of Escherichia Coli K 12. If we assume a simple scaling law, we should expect CV19 to have its fundamental frequency around $(3 \div 5)$ MegaHertz (By way of comparison). Obviously, an experiment is needed to test this estimate.

This brings us to the sad fact that to this date no generally agreed upon experimental procedure exists that guarantees a uniform set of measurements of the parameters that quantify the non-chemical signals. To bring this to the fore, we have considered the important case of the permittivity of water. Every textbook tells us that the dielectric constant of water is a constant and that its value is about 80. Of course, this statement is only true if the water is probed at a frequency of 10 kHz or higher: at 100 Hz its value is about 4000 and when water is narrowly confined this constant can be as large as 10^7 at very low frequencies (the precise value depends crucially upon the state of water). We can not overstress how important truly confined water or excluded zone (EZ) water (Pollack 2013) (Widom et al. 2015) is for biology as all living matter is in water that has also a large permittivity.

Since the manner of communication of any object is obviously anchored upon the memory storage capacity of the object, we have quantitatively estimated the information capacity both of a DNA and a water molecule. The astonishingly high value of the information capacity of water is the true key to an understanding as to why water is quintessential to life.

Evolution led life forms from nanowire microbial connections to wireless cellular communications each with a unique frequency spectrum in analogy to the atomic spectrum, the nuclear data table or the compendium of hyperfine structure.

Hence, our proposal is to augment the Genome that is a purely (static) biochemical catalogue with a catalogue or register of the frequency spectrum of basic living forms. These may provide our only hope to judge over cases classified asymptomatic through chemical analysis.

ORCID

Yogendra Srivastava ⓘ http://orcid.org/0000-0002-7293-561X

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By way of comparison, let us recall that *ultrasound* waves in medicine are employed with frequencies in the range of (2÷15) MHZ.1000.

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