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Mathematical Structure for Electromagnetic Frequencies that May Reflect Pilot Waves of Bohm's Implicate Order

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Abstract

The mathematical basis for the earlier reported spectrum of discrete electromagnetic field (EMF) frequencies that were shown to affect health and disease is substantiated and generalized in the present paper. The particular EMF pattern was revealed by a meta-analysis of, now, more than 500 biomedical publications that reported life-sustaining as well as life-decaying EMF frequencies. These discrete eigenfrequency values can be related to supposed bio-resonance of solitons or polaron quasi particles in life systems. Bio-solitons are conceived as self-reinforcing solitary waves that are constituting local fields, being involved in intracellular geometric ordering and patterning, as well as in intra- and inter-cellular signalling. Literature search, revealed very similar frequency patterns for wave resonances of nucleotides in aqueous solution, for a candidate RNA-catalyst, as well as for sound-induced vibrations evoked in thin vibrating membranes. This collective evidence points at a generalized biophysical algorithm underlying complexity in nature, evidently manifest in both animate and non-animate modalities. The detected EMF eigenfrequencies could be arithmetically scaled according to an adapted Pythagorean tuning. The mathematical analysis shows that the derived arithmetical scale exhibits a sequence of unique products of integer powers of 2, 3 and a factor $\sqrt{2}$. This generalized semi-harmonic frequency spectrum may reflect a discrete pilot-wave structure that can be interpreted as a, so called, hidden variable in Bohm's causal interpretation of quantum field theory.

Keywords

Life Algorithm, Quantum Mechanics, Bohm, Fröhlich, Philolaus, Pythagoras

1. Introduction: Mathematical Structure as a Form-Inducing Modality?

Why does mathematics exhibit such effectiveness in describing the physical world [1]? In general, the question should be asked whether reality that we as humans observe, has a priory physical structure or it means that physicists have increasingly been able to make mathematical sense of the material world. Some even claim that our universe is a mathematical structure perse: a set of objects having interrelations [2] [3] [4]. Tegmark proposes that mathematics is an invented language since humans define its format and symbols, yet he claims that independent of human thought mathematical structures exist that underlie the fabric of reality. An integral mathematical matrix, containing entangled information patterns, could provide a physical basis for a universal knowledge domain and even a universal type of consciousness [5] [6] [7]. The nature of "reality" was discussed in such terms by mathematicians, such as Barrow, who stated "Where there is life there is a pattern, and where there are patterns there is mathematics" [4]. Once that germ of rationality and order exists to turn a chaos into a cosmos, then so does mathematics. Penrose framed it in an ontological context of the math-matter-mind triangle. The triangle suggests the circularity of the view that math arises from the mind and the mind arises out of matter, and that matter can be explained in terms of math. The latter can take the form of a limited collection of geometrical bodies that may underlie the wave world of reality but also the archetypes of mind [8] [9].

A bio-soliton model based upon patterns was earlier proposed by us on the basis of a spectrum of EM frequency bands that appeared to produce striking biological effects in living cells. Both endogenously measured and in particular exogenously applied electromagnetic fields indicate states of quantum coherence in living systems [10] [11]. The soliton model enabled to predict which eigen-frequencies of non-thermal electromagnetic waves are life-sustaining and which are, in contrast, detrimental for living cells. The particular effects were exerted by a range of electromagnetic wave eigen-frequencies of one-tenth of a Hertz till Peta Hertz that clearly show a pattern of twelve EM frequency bands, that is, if positioned on an acoustic-like frequency scale. This algorithm showed to be applicable over a much broader frequency window, being distributed over multiple scales and could be based on the ancient knowledge of Pythagoras, which intervenes: ratios of frequencies ordered at 2:3 are approaching harmonic like properties. To further understand this algorithm mathematically, the principles of scaling have been studied, including the history of the development of tone scales that in fact started the knowledge of arithmetics in general.

Arithmetic is part of mathematics that consists of the study of patterns of numbers, especially the properties of the traditional operations between them: addition, subtraction, multiplication and division. A number is a mathematical object used to count, measure, or label. The first historical finding of an arithmetically defined nature is a fragment on a clay tablet Plimpton (ca. 1800BCE) and contains a table of different numbers and “Pythagorean triples”. The Greek philosopher and scientist Philolaus (ca. 420BCE) studied numbers and argued that number one represents the generation of a first unity and that all objects in the universe basically result from a combination of limited and unlimited aspects, that are fitted together by harmony. Philolaus in his time conceived harmony as constructed according to a number ratio scale, as was considered by Pythagoreans, and later by Plato. In the following, we will discuss the knowledge of scales in relation to order and disorder in nature and stipulate that more detailed insight into the knowledge of scales is in principle ground breaking and can be scientifically included in current science. First of all a description is given of Philolaus’ and Plato’s work made by Huffman, McKay and McKirahan [12] [13] [14] [15] and will be discussed in the next session.

1.1. Philolaus and Plato

Philolaus presupposed a scale with an unlimited continuum of pitches (musical tones), that should be limited in some way, in order for a very scale to arise. In Philolaus' system the fitting together of “limiters and un-limiters” involves their combination, in accordance with a certain ratios of numbers. He choose a scale in which the ratio of the highest to the lowest pitch amounts 2:1, which produces the interval of a so-called octave. That octave can, in turn, be divided into a fifth and a fourth, which exhibit the ratios of 3:2 and 4:3 and if added, make a complete octave. The fifth can be further divided into three whole tones, each corresponding to the ratio of 9:8 and a remainder (small non-fitting rest value) with a ratio of 256:243; the fourth can be divided into two whole tones with the same remainder [12]. Similarly, it was argued that the entire cosmos and the constituting individual objects in the cosmos cannot arise by a random combination of so-called “limiters and unlimiters”, but instead follow distinct ordering ratio’s. Philolaus formally demonstrated that ratios are expressed in numbers and that the many forms of numbers in fact represent different types of ratios [13]. He did not provide many specific examples of mathematical relations that control physical phenomena, which is not surprising given the scientific capabilities of the time period at stake. Within this apparent order, Philolaus inferred a discrete scale and described that the number “one” yields the generation of the first unity of “limiter and unlimited” [14]. A same type of scale structure has been discussed later by Plato, and it seems that Philolaus somehow anticipated Plato's calculations in the Timaeus [15].

1.2. Quantum Mechanics

It is now generally known that living organisms are able to generate and receive electromagnetic pulses that are transferred and processed at a non-thermal level. According to Cifra, chemical and electrical interaction within and between cells is well established and the most probable candidate for a form of cellular interaction is the electromagnetic field [16]. Living organisms are affected by patterns of electromagnetic waves that reflects a "biological order" [10] [11]. It has been shown that electrons, photons, solitons (polarons) represent electromagnetically vibrations that travel along proteins, microtubules and DNA [17] [18] [19] [20]. They locally induce an endogenous electromagnetic field in cells and in this manner interfere with local resonant oscillations by excitation of neighboring molecules and macromolecules. In relation to this, we found biological evidence for the studies of Fröhlich in 1968, showing that living cells employ coherent acoustic like waves, called polarons for constructive interference with electromagnetic fields [18] [21]. Cellular functions are sensible to low-level sinusoidal-modulated signals of different frequencies and pulse modulations. In many biological studies, windowing, both with regard to frequency and amplitude domains, has been found and decoherent modulations of signals have a greater influence on biological properties than unmodulated signals [22].

Coherence is defined as the physical congruence of wave properties within a wave packet and it is a property of stationary waves (i.e. temporally and spatially constant) that enables a type of wave interference, known as constructive. The particular processes are called highly coherent when the variability of the phase differences between the signals is relatively small, whereas the wave processes are defined as incoherent, the phase difference has a high degree of variability. Constructive interference of wave patterns occurs in cellular domains of variable size, that is based on arithmetic rules [10] [17]. Next to highly coherent domains, typical decoherent (non-coherent) and chaotic domains can be discerned. The same features are in principle valid in the framework of quantum mechanics. In quantum mechanics, particles such as electrons behave like waves and can be described by a wave function. As long as there exists a definite phase relation between different states, the system is said to be coherent. This coherence is a fundamental property of quantum mechanics, but also quantum decoherence plays a role, that is loss of quantum coherence.

In a similar vein, Müller proposed an arithmetic fractal scaling models of harmonic oscillators, in which natural numbers greater than one can be written as unique products of prime numbers. Resonant oscillations can be understood as a forming-mechanism of fractal structures and fractals show a spectral compression and decompression of high and low density structure areas inside a medium. Yet the author did not find a link or interaction between the elements of a particular oscillating system [23]. Coherent topological structures have been studied for musical data and can be made visible by distance functions. Even small details of distance functions have influence on the global structure of the described space. Consonant intervals can be formed by frequency ratios of integers and represented by products of prime numbers [24]. The Tonnetz (German: tone-network) is a coherent topological structure and can represent a toroidal lattice diagram, that pictures a tonal space, as first described by Leonhard Euler in 1739. This space has been further described by Chew, who introduced a spiral array model involving arrays of concentric helices, representing perceptions of pitches, chords and keys in a geometric space [25]. The spiral array model wraps up a two-dimensional Tonnetz into a three-dimensional lattice, and models higher order structures such as chords and keys in the interior of the lattice space.

One of the fundamental questions in developmental biology is how the complex range of linked vibratory patterns in bio-molecular structures, that we observe in nature, emerges. It is postulate that coherent interactions and entanglement of waves are keys in the setting of a finite number of parameters, and can be described by corresponding arithmetic equations.

Coherence or non-randomness of quantum resonances has also been discussed by Einstein and Infield (1961) for the so-called "prequantum modes". And it was Schrödinger who recognized that coherent interaction of waves is coupled to entanglement as "the characteristic aspect of quantum mechanics" and suggested that "eigenstates" are able to survive interaction with the environment. Einstein-Podolsky and Rosen (EPR) discovered nonlocal correlations in quantum phenomena in 1935. Two systems, which are in an entangled state, even if separated as far as you like from each other, retain correlations, which do not decrease with increasing separation. Bohm proposed that the particle positions are the "hidden variables" in a causal interpretation of the quantum mechanics. These particle positions are independent of the wavefunction and exhibit their own dynamical motion [26]. The term quantum potential represents an informational effect shared by the surroundings particles and waves that depends on its form and shape [27] [28].

1.3. A 12-Number Scale

Research in the framework of electromagnetic pulses in and on living cells has been systematically undertaken the past eighty years. About 25.000 biological/physical reports are available, of which a part is dealing with non-thermal biological effects on cells. Influences of electromagnetic waves causing thermal effects on biological systems are relatively well understood, yet the knowledge about non-thermal effects of electromagnetic waves is rapidly increasing. The Polaron model of Fröhlich (1968) and the Soliton model of Davydov (1973) describe both the effects of coherent states of waves for inanimate as well as animate systems. Polarons are quasi-particles in which an electron is dressed with one or phonons and are also called solitons. Solitons, as self-reinforcing solitary waves, have been shown to interact with biological phenomena in the framework of cellular self-organisation [6] [18] [21]. It is proposed that stabilisation of cell states occur at typical discrete frequencies, described by particular wave functions, in which either each type of cell or bio-molecule or even a well-defined part of the bio-molecule will exhibit their own eigen-frequencies. The particular life-sustaining effects analysed are exerted by a range of electromagnetic wave eigen-frequencies of one-tenth of a Hertz till Peta Hertz that show repeating patterns of twelve bands, and can be positioned on a "coherent scale of 12 numbers" [11] [19] [29].

The stability and life times of these waves depend upon the extent of thermal decoupling of the stable state(s) of cells from the heat bath. Yet, in order to maintain stability of bio-molecules in living systems, also external coherent information is at stake. Locations receiving resonance transfer in the case of living cells are the surrounding domains of ion water clathrates, nucleic acids and ion-protein complexes [19] [20]. Various cell-types are sensible to low-level sinusoidal-modulated signals of different frequencies and to a spectrum of frequency bands in both frequency and amplitude domains and is called "windowing" [22] [30] [31]. Electromagnetic fields can have a direct influence on DNA [17] and circular polarized wave modalities as well as decoherent modulations of signals can have a greater influence on biological properties than unmodulated signals [22] [31] [32].

An earlier analysis of 254 articles from 1950 to 2015, dealing with effects of electromagnetic waves on in vitro and in vivo life systems has been reported before [10]. In the present paper these preliminary data are complemented by a further analysis of another 128 papers, and in doing so detected a striking agreement with the earlier observed frequency pattern. The stabilizing (beneficial) and destabilizing (detrimental) frequencies for living cells can be positioned in a set of reproducible frequency bands of two 12-number scales, as pictured in **Figure 1**.

On the whole, a spectrum with a consistent pattern of frequency bands can be observed, with only some exceptions in the first and third elliptical bands from the left. Some clusters of frequency values of the separate bands seem to be very close to each other. This could be related to the choices made by the particular investigators in following earlier published frequency data, instead of performing a primary random screen to find optimal values. The ordered beneficial EM field values may induce Fröhlich condensate states in cells through resonant communication. The meta-analysis of more than 500 biomedical studies thus revealed an obvious 12-number frequency scale, that shows a marked predictive value for biological effects that either stabilize or de-stabilize living cells. It is striking that just in between the stabilizing frequency bands, 12-bands with destabilizing frequency bands could be identified that were experimentally shown to be detrimental for living cells.

Also a likely relation exists between quantum mechanics and the proposed 12-number scale. Quantum behaviour and coherence has been found not only for micro states, but also for macro processes such as photosynthesis, magneto-reception in birds, the human sense of smell as well as photon effects in vision, all showing a non-trivial role for quantum mechanisms throughout biology [30] [33]. It can be concluded that stabilizing (beneficial) frequencies for living cells showing quantum behaviour like the light-dependent reactions of photosynthesis and the quantum resonances of a candidate RNA-catalyst can be positioned in the same 12-number scale [10] [11]. A correlation between the proposed coherent scale and the "hidden variables" as described in the theory of

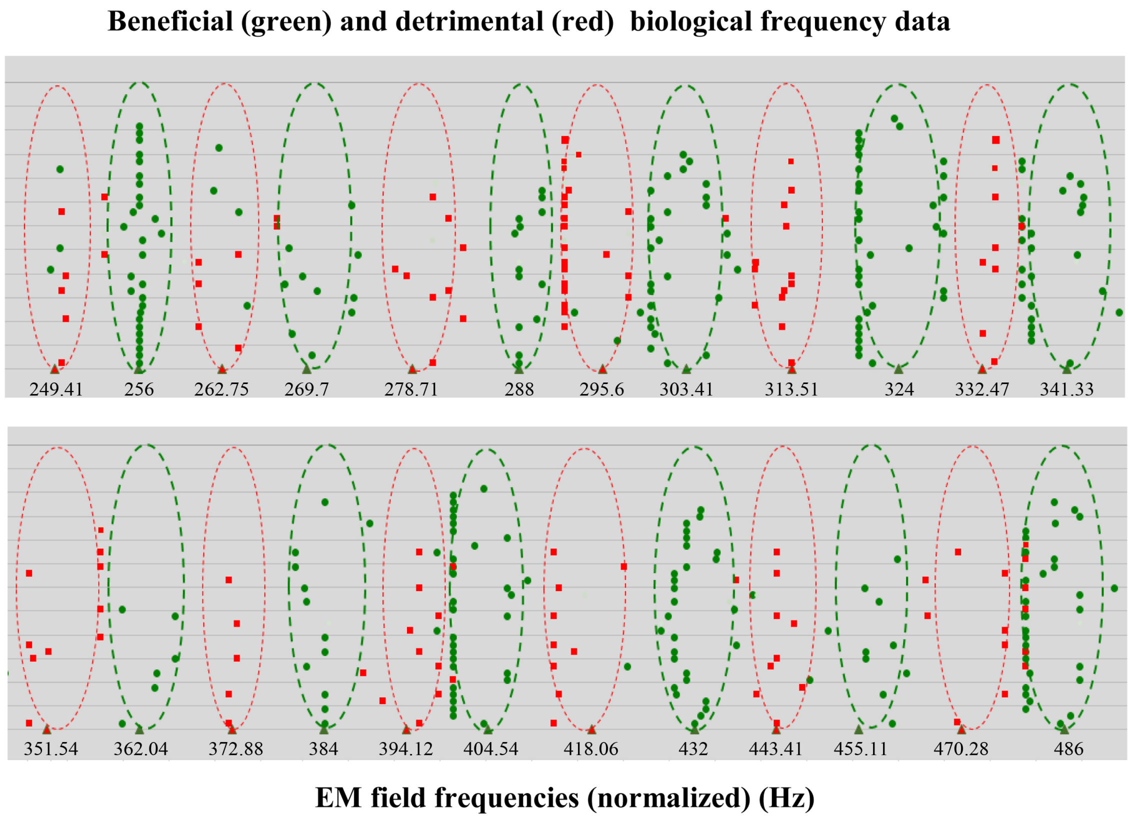

Figure 1. Measured frequency data of living cells systems that are life-sustaining (green points) and detrimental for life (in red squares) versus calculated normalized frequencies. Biological effects measured following exposures or endogenous effects of living cells *in vitro* and *in vivo* at frequencies in the bands of Hz, kHz, MHz, GHz, THz, PHz. Green triangles plotted on a logarithmic x-axis represent calculated life-sustaining frequencies; red triangles represent calculated life-destabilizing frequencies. Each point indicated in the graph is taken from published biological data and are a typical frequency for a biological experiment(s). For clarity, points are randomly distributed along the Y-axis.

Bohm maybe at stake. The quantum potential, indicated as hidden variable, is an informational effect shared by the surroundings particles and waves that depends on its form and shape, that is derived from the ψ-field [27] [28]. Apparently, nature makes use of wave information to induce and stabilize biological order using the coherence principle combined with energy minimization.

Conclusion: These observations provided clues for the existence of a specific pattern of electromagnetic frequencies and quantum resonances that affect the viability of life systems and may be involved in the functional structuring and self-organisation of bio-molecules within cells through organizing them at the lowest possible energy level. The combination of multiple discrete frequencies could tentatively even be considered as a potential algorithm of life.

Interestingly, there is also an analogy between the found coherent patterns of electromagnetic waves in living organisms and a so called Tonnetz (German: tone-network) in music theory. In the Tonnetz systematic the parameter pitch refers not only to the perceived frequency of sound, but in addition describes the distance between repeated elements in a musical structure possessing translational symmetry. Pitch/space relationships typically use distance parameters to model the degree of relatedness of closely related pitches, placed near one another, and less closely related pitches placed farther apart; for example: triangular lattices (major third, minor third and fifth ratio's). Edge-adjacent triads that share two common pitches, are expressed as a motion on the Tonnetz, which wraps the planar graph into a torus at different helix angles [34]. The Tonnetz can be expanded to torus and spiral like representations considering subsequent tone scales and circularity due to enharmonic properties of tones [24] [35].

Chew took the interior-point approach to model higher-level structures using spiral configurations of a harmonic network, see **Figure 2** below.

On the basis of this research, some obvious questions arise: what are the mathematical principles behind these ordered data, and is it possible to calculate and predict the frequencies of the "macroscopic wave function" as proposed by Fröhlich. A further point of interest is the relation with number theory that is also based on knowledge of Philolaus, Pythagoras, Archytas and Plato.

2. Arithmetical Approach of a Universal Number Scale for Organization of Natural Processes

The basic scale unit of ancient Greece was the tetrachord meaning four strings. The first and fourth music notes of the tetrachord were tuned to the interval of a fourth (3:4) but the tuning of the other strings depended on the genus and mode of the music. The diatonic genus comprised the tuning of intervals with three whole tones and a semitone. The chromatic genus comprised a minor third (three semitones) and two semitones. In this theory, the enharmonic mode comprised a major third (two tones) and two quarter tones. The Pythagoreans devised a musical system of tuning based solely upon the interval of a fifth (2:3), that was regarded as the next most consonant interval after unison (1:1) and the octave (1:2). They discovered that a musical scale can be constructed by continuing through the spiral of fifths (2:3), which means that all subsequent tones in

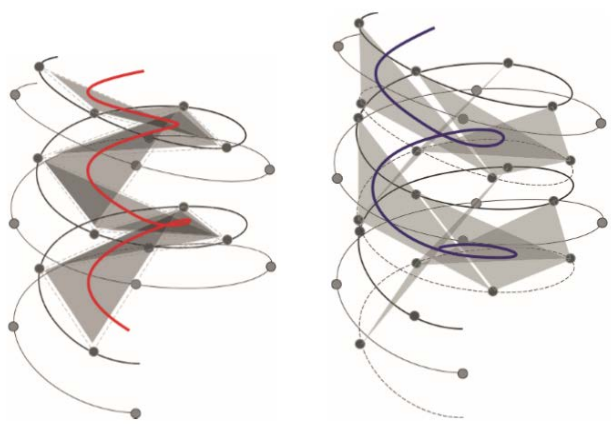

Figure 2. Representations in the spiral array of major and minor keys (Chew, 2013).

the serial scales obey mutual relations with ratios of 2:3 and 1:2. The Pythagorean arithmetical scales were not only used to design musical scales, but, interestingly, also used in studies to describe the ordering of the cosmos [13]. It is known that Pythagoras and the Pythagoreans were actively involved in the science of harmonics, which was separately studied from the practical art of music. In other words, the diatonic descending Pythagorean tone scale may not have solely been used in actual music, but also in the broader context of a mathematical representation of a basic tuning procedure [35]. Philolaus made clear that the octave (2:1) is made from the unequal intervals of the fourth (3:4) and the fifth (2:3) and followed the tuning procedure known as the method of "concordance" to construct a whole tone as difference between the fourth and the fifth with a ratio of 9:8. He recognized that the tones do not fit equally into these intervals: the fourth (3:4) represents in fact two whole tones plus a left-over called a leimma (256:243) and the whole octave consists of five tones and two leimma's [36] [37] [38]. In the middle ages a seven tones diatonic descending Pythagorean scale was practised using pure fifths (3:2) and showed the ratio structures of 9:8, 256:243.

The twelve tones Pythagorean system was developed by medieval music theorists using the same method of tuning in perfect fifths and there is no evidence that Pythagoras himself went beyond the tetrachord [39]. This scale was a chromatic scale and not be equally tempered [40]. The resultant twelve notes are roughly equal spaces and every note has a reasonable tuned upper and lower perfect fifth, and may be regarded as chromatic. The principle of twelve-tone equal temperament was articulated in Europe by Mersenne in 1635 and its invention over thousand years probably earlier by the Chinese [41]. This type of chromatic scale is cross-cultural, but not universal [42].

The Pythagorean twelve tone scale shows two sizes of semitones: the diatonic and the chromatic semitone. By considering these semitones, it was known that the "circle of fifths" (ratios of 2:3) does not fit within an octave (ratios of 1:2), and an ongoing discussions raised how to divided 12 tones within a ratio of 1:2. Eventually in music, musicians settled on using just the twelve notes, and tuning them in many different ways. Major and minor thirds (4:5 and 5:6) became more important in music, but the thirds were never used as a harmony in medieval music, and later the extremely sharp third in Pythagorean tunings was unacceptable to musicians and different "well temperaments" were developed. Composers of the past (for example Bach, Mozart, Beethoven, and Brahms) favored different tunings other than this kind of Pythagorean tuning [43].

2.1. Calculation of the Proposed 12-Number Scale Proposed in the Present Study

A mathematical eigenfrequency model is proposed after analysing the biophysical experiments in the framework of electromagnetic pulses in and on living cells related to discovered intervals that approach ratios of 2:3 [10] [11]. A more precise mathematical development of the 12-number scale, containing 12 numbers, is derived by considering the following conditions:

1) Resonance vibrations that oscillate in a manner such that standing wave patterns can be formed at a semi-harmonic way are of interest, for example being present in a vibrating string or in a membrane. Philolaus and Plato studied preferably the harmonic scales [11] [44]. In these scales important ratios are the octave hierarchy (1:2), the quint hierarchy (2:3), and the so-called means and fourthly some higher harmonics. Plato described a diatonic scale using repeated seven numbers of which four numbers are harmonic: 1, 3/2, 4/3, 9/8, added with subsequent tone distances of 8:9 and 243:256, see **Figure 3**. The scale contains two means: the harmonic and the arithmetical mean: 3/2 and 4/3 (see later).

A harmonic scale is defined as a "just" musical scale, allowing extended just intonation. In music, just intonation or pure intonation is any musical tuning in which the frequencies of notes are related by ratios of small whole numbers. Pure intervals are important in music because they correspond to the vibrational patterns found in physical objects, that also correlate to processes involved in human sound perception [45]. A harmonic series is also the sequence of tones, represented by sinusoidal waves, in which the frequency of each tone is an integer multiple of the fundamental, being the lowest frequency. A way of characterizing the harmony in music is found by Partch and called a harmonic limit number that is a term to give an upper bound on the complexity of harmony; the larger the limit number, the more harmonically complex and potentially dissonant the intervals of the tuning are perceived, (see later 3-limit tuning) as also discussed by Wolf [46].

Philolaus applied a harmonic scale derived from the concept of overtones, that show first, second, third and some higher harmonics: 1, 3/2, 4/3, 9/8, 16/9. It is proposed to apply these harmonics in a so called 12-number descending Pythagorean scale, that is based upon 2:3 ratios. A scale constructed through Pythagorean tuning uses only ratios of 3:2, and can be constructed "upwards" by wrapping a chain of perfect fifths around an octave, but it can also be constructed "downwards" by wrapping a chain of perfect fourths around the same octave. By juxtaposing of these two slightly different scales, it creates a so-called enharmonic scale that proceeds quarter tones. When ascending from an initial pitch for example the note C by a cycle of justly tuned perfect fifths (ratio 3:2), wrapping twelve times, one eventually reaches a pitch approximately seven whole octaves above the starting pitch. If this pitch is then lowered precisely

	8:9	8:9	243/256	8:9	8:9	8:9	243/256
1	9/8	81/64	4/3	3/2	27/16	243/128	2
2	9/4	81/32	8/3	3	27/8	243/64	4
4	9/2	81/16	16/3	6	27/4	243/32	8

Figure 3. Plato's diatonic scale (The Timaeus; R. D. Archer-Hind, 1888).

seven octaves, the resulting pitch is a very small amount higher than the initial pitch. This microtonal interval is called a Pythagorean comma and amounts a ratio of about 1.0136. The enharmonic scale is a scale that proceeds by quarter tones (**Appendix 1**) and the interval (or comma) existing between two enharmonically notes such as C and B♯, or D♭ and C♯ is equal to the Pythagorean comma.

2) A slight adaptation of the descending Pythagorean semi-harmonic scale is of interest. In this scale most ratios of numbers are 2:3 ratios, some are approaching closely 2:3, and contains harmonic ratios, discussed at as the first condition: 2:3, 3:4, 8:9, 16:9. Using this scale, a good fit with frequency patterns of the earlier mentioned 486 different published independent biological electromagnetic frequencies could be found [10] [11] [19].

3) Three different so-called mean structures are of interest in the proposed scale due to the fact that ratios of 1:2 are precise, but not all ratios of 2:3 are exact. The so-called Pythagorean mean structures are the arithmetic mean of 3:2, the harmonic mean of 4:3 and the geometric mean of $\sqrt{2}$ (see for the definitions **Table 1** and [10] [38]). These means are appropriate for situations when average of rates is desired and concave symmetries play a role.

Based on these conditions a deterministic 12-number arithmetic scale can be derived making use of a combination of the following principles: Partially harmonic ratios, Pythagorean tuning, one is unity and fits in a 12-number scale, and the three mathematical means. The scale can be further extended from a single scale to 54 scales with overall ratios of 1:2, and contains 648 different numbers for ordered data and 648 different numbers for disordered data. The proposed 12-number scale shows harmonic intervals with ratios of 2:3, 3:4, 8:9, 16:9, shows whole tones distances in relation to six limma distances. The limma can be calculated as follows: an octave (1:2) has 12 semitones, and a perfect fifth (2:3) has 7 semitones, moving up three octaves equals 3 × 12 = 36 semitones, and moving down five fifth equals 5 × 7 = 35 semitones. Moving up three octaves and moving down five fifths equals 36 − 35 = 1 semitone, and can be expressed: $2^3/(3/2)^5 = 2^8 3^{-5} = 256/243 = 1.0535$. The proposed 12-number scale contains six Phytagorean limma's and three means: the geometric, arithmetic, and harmonic mean (see **Table 1**). The combined 12-number scale approaches the principle of the Pythagorean diatonic tetrachord in a descending order, and is built on intervals of 8:9, 9:8, 256:243, and shows principles of the scale of Philolaus and Plato [47] [48]. The 12-number scale starts with one and shows 3-prime-limit tuning (products of integer powers of 2 and 3), with the exception of the 7th

Table 1. Definition of the means.

Name	Formula	Solution	Mean of octave (2/1)
Arithmetic	a − b = b − c	b = (a + c)/2	B = 3/2 (perfect fifth)
Geometric	a/b = b/c	b = $\sqrt{ac}$	b = $\sqrt{2}$ (tritone)
Harmonic	(a − b)/a = (b − c)/c	b = 2ac/(a + c)	b = 4/3 (perfect fourth)

number. The scale is mainly composed of just fifths (3:2) and intervals between scale notes have ratios that can be expressed as 2^a3^b. The proposed tuning is partially a form of just intonation, and these tones are rational (a rational number is any number that can be expressed as the quotient p/q of two integers), such as the semitone 256/243. Based on these typical scale properties twelve frequencies of the scale can be calculated: 1.0, 1.0535, 1.1250, 1.1852, 1.2656, 1.3333, 1.4142, 1.5000, 1.5803, 1.6875, 1.7778, 1.8984. The differences between the proposed coherent scale of 12 numbers, coined the GM-scale, a descending Pythagorean scale, an equal tempered scale and a harmonic scale are listed in **Table 2**. The GM-scale proposed in the present paper, is quite similar to the descending Pythagorean scale that we used earlier [10], except for the 1.4142 value.

The 12-number-scale can be further extended to larger dimensions by multiplying with 2^m (m = < −4 till > 50), thereby producing a universal frequency scale, see **Table 3** and **Appendix 3**.

The numerical ratios, that are semi-harmonic (harmonic and non-harmonic) are further shown in **Appendix 2**; the calculation of the non-coherent-scale, of which the parameters are logarithmically located just in between the coherent parameters of the semi-harmonic scale are derived and shown in **Appendix 4**.

2.2. In Summary

The present mathematical analysis shows that the derived arithmetical scale exhibits a sequence of unique products of 12 × > 54 integer powers of 2, 3 and a factor $\sqrt{2}$. The proposed scale for life-sustaining frequencies is shown to contain a core of twelve eigenfrequency functions as expressed: $2^03^02^m$, $2^83^{-5}2^m$,

Table 2. Proposed coherent GM-scale of 12 numbers, Pythagorean scale descending, equally tempered scale and harmonic scale.

GM-scale	**1.0**	**1.0535**	**1.1250**	**1.1852**	**1.2656**	**1.3333**	**1.4142**	**1.5000**	**1.5803**	**1.6875**	**1.7778**	**1.8984**
Desc. Pyth.	1.0	1.0535	1.1250	1.1852	1.2656	1.3333	1.4047	1.5000	1.5803	1.6875	1.7778	1.8984
Equal temp.	1.0	1.0595	1.1225	1.1892	1.2599	1.3348	1.4142	1.4983	1.5874	1.6817	1.7818	1.8877
Harmonic	1.0	1.0667	1.1250	1.2000	1.2500	1.3333	1.4000	1.5000	1.6000	1.6667	1.7778	1.8750
Harm. ratios	1.0	16/15	9/8	6/5	5/4	4/3	7/5	3/2	8/5	5/3	16/9	15/8

Table 3. Proposed universal coherent scale of 12 numbers extended to more than 54 octaves (m = < −4 till > 50).

$F_m(coh.1) = 2^03^02^m$	$F_m(coh.7) = 2^{0.5}2^m$
$F_m(coh.2) = 2^83^{-5}2^m$	$F_m(coh.8) = 2^{-1}3^12^m$
$F_m(coh.3) = 2^{-3}3^22^m$	$F_m(coh.9) = 2^73^{-4}2^m$
$F_m(coh.4) = 2^53^{-3}2^m$	$F_m(coh.10) = 2^{-4}3^32^m$
$F_m(coh.5) = 2^{-6}3^42^m$	$F_m(coh.11)= 2^43^{-2}2^m$
$F_m(coh.6) = 2^23^{-1}2^m$	$F_m(coh.12) = 2^{-7}3^52^m$

$2^{-3}3^{2}2^{m}$, $2^{5}3^{-3}2^{m}$, $2^{-6}3^{4}2^{m}$, $2^{2}3^{-1}2^{m}$, $2^{0.5}2^{m}$, $2^{-1}3^{1}2^{m}$, $2^{7}3^{-4}2^{m}$, $2^{-4}3^{3}2^{m}$, $2^{4}3^{-2}2^{m}$, $2^{-7}3^{5}2^{m}$ being valid for a broad range of adjacent frequency spectra for the integer values of m = 0, 1, 2, 3, ⋯, up to overall >54 self-similar 12-number octave scales. The scale shows a small adaptation of the scale proposed in 2016 [10] [11] for the seventh factor, due to the fact that a slightly adapted descending Pythagorean scale has been calculated (the seventh factor: 1.4142 instead of 1.4047). The proposed algorithm scale is based upon calculated frequency values, and not on positions of apparent frequency bands, that were found by the first statistically approach (calculated approach: 1.0000, 1.0535, 1.1250, 1.1852, 1.2656, 1.3333, 1.4142, 1.5000, 1.5803, 1.6875, 1.7778, 1.8984, versus statistical approach: 1.00, 1.05, 1.13, 1.18, 1.26, 1.32, 1.42, 1.50, 1.57, 1.68, 1.78, 1.89) [11].

Thus it is proposed to apply: 1) *A Pythagorean descending tuning with the adaptation of the 7th ratio as the geometric mean of* 1 *and* 2: $\sqrt{2}$ *in a* 12-*number scale*, 2) *to expand this* 12-*number scale from* 1 *to* > 54 *octaves*/*scales*, *that overall affords* 648 *numbers and* 3) *each scale contains five harmonics and six limma*'*s to unite ratios of* 1:2 *with* 2:3.

2.3. A Coherent-Scale for Electromagnetic Frequencies of Living Cells in Hertz Frequencies

Quite surprisingly we detected in literature, that next to living cells also the same principles are valid for inanimate materials such as optical parametric oscillators used to show Bell's inequality, ordered water molecules and thin metal membranes, that all show typical frequencies that comply with the calculated 12-number scale expressed in Hertz frequencies. A typical characteristic frequency of this membrane is 96 Hz that can be expressed as $2^{5}3^{1}$ [11]. Water molecules have typical resonances at Hertz frequencies, and a typical frequency can be expressed in 3-prime-limit tuning. A calculated typical frequency of a water molecule, with a molecular weight M = 18 g·mol^{-1}, is 54 Hz ($2^{1}3^{3}$) according to Henry [49]. A typical frequency of a water molecule can be derived by using the mass-energy equivalence coupled to the Planck-Einstein relationship:

$$M \cdot c^2 = h \cdot f \Rightarrow f\left(\text{Hz}\right) = 2.981 \cdot \text{M}\left(\text{g} \cdot \text{mol}^{-1}\right)$$

(M is molecular weight of water molecule, c = 299,792,458 m/s, h = 6.62606959 × 10^{-34} J·s, f is the frequency of a water molecule).

So ordered number scales are able to represent geometric measures and are able to describe biological as well as physical processes. Therefore it is proposed to apply a 12-number-reference-scale expressed in Hertz, and is as follows: 1, 1.0535, 1.1250, 1.1852, 1.2656, 1.3333, $\sqrt{2}$, 1.5000, 1.5803, 1.6875, 1.7778, 1.8984, 2 Hz. The reader is referred to the appendices 2 and 3, and for the mathematical definition of the coherence inducing scale, to appendix 4 for the non-coherence inducing scale, while **Appendix 5** provides an example of calculation results with the given equations. As mentioned before, all typical frequencies of living cells, cell systems and bio-molecules, from sub Hertz till Peta Hertz, can be further derived by multiplying each parameter of the reference scale by

2^m, of which m is an integer (see examples in **Appendix 5**). Twelve coherent acoustic frequencies, twelve coherent colours (nm) and the different interval distances are respectively calculated in **Appendices 6-8**.

3. Support for the Proposed GM Model on the Basis of Reported Frequencies Describing Bio-Molecular Stabilization and De-Stabilization of Applied EM Frequencies

The earlier mentioned analysis of about 500 articles from 1950 to 2017, dealing with endogenously measured and exogenously applied EM field frequencies in tissues, cells and biomolecules, thus shows patterns of *beneficial* biological effects related to electromagnetic waves on in vitro and in vivo life systems, and can be positioned from sub Hertz till Peta Hertz into the GM-scale. Frequencies just between the beneficial frequencies are related to patterns of detrimental biological properties, (see **Figure 1** and **Appendices 9-13**).

A total of about 315 independent endogenous and exogenous *beneficial* biological frequency data of electromagnetic waves ranging from tenth of Hz till PHz, were normalized to a 12-number scale frequency scale by multiplying or dividing by multiples of 2 and can be positioned in the coherent-scale together with the calculated discrete beneficial frequencies (see the green points in **Figure 1**). The mean deviation of the 293 measured frequency data, relative to the calculated different beneficial frequencies according to the 12-number is 0.34%, that is equal to about one third of the Pythagorean comma, so extremely low.

Totally about 171 independent endogenous and exogenous *detrimental* biological frequency data of electromagnetic waves ranging from tenth of Hz till PHz were also normalized to a 12-number-scale by multiplying or dividing by multiples of 2 and can be positioned in the non-coherent-scale together with the calculated discrete detrimental frequencies (see the red squares in **Figure 1**). The mean deviation of these measured frequency data, relative to the calculated different beneficial frequencies is 0.42%, that is less than half of the Pythagorean comma. It can be concluded that all independent 536 data of biological properties can be described by the proposed 12-number scale with a high precision. The accuracy, expressed in mean ratio differences, is less than a ratio of 1.0045.

It is of interest that very different examples of ordered coherent data reported in (bio)-physical literature can be positioned in the chosen scales:

1) *biological electromagnetic data expressed in Hertz* [10] [12] [17] [19] [29].

2) *spectrum of terahertz frequency patterns of oligonucleotides in aqueous solutions* (**Appendix 13**)

3) *quantum resonances of a candidate RNA-catalyst expressed in Hertz* [10] [12]

4) *vibrating patterns in membranes expressed in Hertz* [17]

5) *coherent colours expressed in nanometre wavelengths* [12]

Disordered data can be accommodated too:

1) *biological electromagnetic data expressed in Hertz* [12] [17] [19] [29].

2) *distorted patterns in sound induced geometric patterns on flat membranes, expressed in Hertz* [17]

Are there other examples of number systems that underlie natural processes? There is not yet a consensus about the construction of the genetic code and how to explain it has been the subject for a lot of studies during many decades. Wohlin [50] proposed number-based arithmetic correlations for the mass distribution of amino acids on codon domains. The parts in that big scheme: 384, 576, 216 and 324, are all numbers present in the 12-number scale. Other aspects on the mass distribution and numbers of nucleons in the code have earlier been shown possibly related to Pythagorean and Plato numbers [51] [52]. These findings show that many of these data comply with the proposed 12-number scale.

Of note, a striking resemblance has also been found between the proposed coherent scale and a spectrum of measured terahertz frequency patterns of oligonucleotides and the protein albumin in aqueous solutions, see appendix 13 and [53] [54]. Finally, a similar range of frequencies has been found for a candidate RNA-catalyst that may have been instrumental in the evolutionary initiation of first life [11] [17].

Summarized: The proposed universal semi-harmonic code of nature shows frequency ratios and stabilizing frequencies of living cells from sub Hertz till PHz and is able to predict frequencies of nucleotides, frequencies of a candidate RNA-catalyst and there are some indications to describe the ordering of the genetic code.

4. General Conclusions of the Present Study

In the present paper a set of 12-number scales and sequences thereof have been revealed that describe coherent as well as non-coherent (non-coherent) eigen frequency functions. The scales are able to predict where typical numbers are positioned that are coherent, non-coherent, or chaotic. The coherence promoting scale of frequencies has been mathematical calculated and biologically verified for 12 × 54 = 648 different frequency in Hertz detected in living cells, nucleotides, a candidate RNA-catalyst, a thin vibrating membrane and presumably also in the genetic code. The non-coherence inducing scale has also been calculated for 12 × 54 = 648 different frequency values detected in destabilized living cells and in a thin vibrating membrane. The power of the proposed 12 number-scales could be directly demonstrated by data presented in about 500 biological studies. The particular EM field pattern, in our opinion, may have a close relation with the study of solitons, that are self-reinforcing solitary waves, and are supposed to interact with complex biological phenomena such as cellular self-organisation. Solitons in the cells are able to constitute local fields that both can be involved in intracellular geometric ordering and patterning, as well as in intercellular communication. The presently proposed mathematical calculations therefore complement the earlier proposed “macroscopic wave function” of the soliton models of Davydov [10] [55] and Fröhlich [18] [21]. The scale has a relation with tonal structures positioned in spiral configurations by E. Chew [25] [35].

The theoretical background of the found regularities of standing wave patterns, not only in biological properties of living cells, but also in inanimate materials and in thin vibrating membranes systems, might be that nature organizes its components at a highly coherent semi-harmonic way. Therefore the 12-number scale might be tentatively called a universal scale. The underlying mechanism is evidently instrumental in the unification of first, second, and third harmonics, as described by a Pythagorean descending scale and octave hierarchy. Possibly nature make use of this scale at the lowest possible energy level operating within a broad range of coherence inducing frequencies from sub Hertz till PHz, as was biologically verified. Of note, even much lower and higher frequencies can be probably considered, starting from sub Hertz to frequencies of Higgs particles.

The present analysis of the frequencies can be regarded as Fröhlich condensate frequencies and may have a possible correlation with the quantum potential as described in the theory of Bohm. The proposed model has also been based upon the knowledge of Philolaus, who was probably the first person to write down Pythagoras's ideas and teachings [56]. To the Pythagoreans, the entire universe was mathematical and all music represented an exact numerical science and all musical notes were regarded as mathematical numbers and ratios.

Inferred Postulates:

1) Nature organizes animate and inanimate components at a highly coherent way, able to unite first, second, third and higher harmonics of waves within a semi harmonic scale, described by a slightly adapted semi-harmonic Pythagorean scale using arithmetic, geometric and harmonic means. The arithmetical 12-number scale uses 12 sequences of unique products of integer powers of 2, 3 and a factor $\sqrt{2}$ and can be regarded as eigenfrequency functions. The biological verified scale acts at a frequency distance from about < 0.01 Hz till > PHz (10^{15} Hz).

2) The discovered frequency patterns can be interpreted as hidden variables in Bohm's causal interpretation of quantum mechanics theory.

3) In preliminary work, we inferred that the here proposed eigenfrequency functions may also fit in the EPR (Einstein-Podolsky-Rosen) argument, considering the particular measurements reported with regards to the testing of Bell's theorem (Geesink, 2018).

Future plans: A first approach has been made into analysing the involvement of toroidal geometric structures, while applications of the concept have been described recently in cancer research [7] and the study of human and universal consciousness [29]. It remains to be established whether the coherent number parameters of the wave-function can be positioned in a toroidal geometric structure. In such a geometric model the decoherent parameters are conceived as waves that are able to distort the toroidal positions of the proposed coherent parameters [7]. It is further envisaged that the discovered "coherent wave pattern" may represent "hidden variables" in Bohm's causal interpretation of quantum mechanics and the EPR (Einstein-Podolsky-Rosen) argument may fit in the proposed eigenfrequency functions concerning the measurements centred around the testing of Bell's theorem [57] [58]. The present findings, potentially, may have an impact on the study of electromagnetic bio-fields in quantum biology as well as the design and operation of modern diagnostic and therapeutic technologies in the near future.

5. Final Considerations

In this last section, we want to put our mathematically based hypothesis in a somewhat broader perspective of information and mathematics, since at least four of its aspects are quite striking: 1) the algorithm shows not only constructive frequencies but also, intermediate, deconstructive elements, 2) the revealed coherent number system seems to accommodate both animate and inanimate systems related to certain atomic cascade transitions, 3) the frequency pattern is compatible with ancient music theory and the apparent pattern suggests the influence of a pilot-wave steering mechanism that reminds us of the implicated order interpretation of quantum physics by Bohm, 4) the link between external fields and the ultra-structure of cells is provided by a dedicated resonating bio-photon/phonon/soliton system, picturing an interactive discrete field system that is probably energy and information dissipative.

1) Coherent (constructive) and non-coherent (destructive) EM frequencies

Constructive and destructive interference of light was first shown in 1801 by Thomas Young, who sent sunlight through two narrow slits and showed that an interference pattern could be seen on a screen placed behind the two slits. The interference pattern was a set of alternating bright and dark lines, corresponding to where the light from one slit was alternately constructively and destructively interfering with the light from the second slit (see **Figure 4**).

This also makes use of Huygen's principle: the principle that each point on a wave can be considered to be a source of secondary waves. Applying this to the

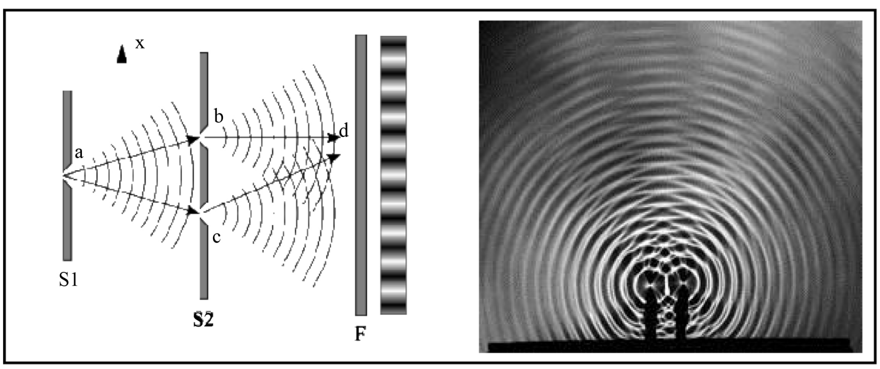

Figure 4. Young's interference experiment (ref. Ángel S. Sanz).

two slits, each slit acts as a source of light of the same wavelength, with the light from the two slits interfering constructively or destructively to produce an interference pattern of bright and dark lines. The principle of superposition of waves states that when two or more propagating waves of same type are incident on the same point, the resultant amplitude at that point is equal to the vector sum of the amplitudes of the individual waves. If a crest of a wave meets a crest of another wave of the same frequency at the same point, then the amplitude is the sum of the individual amplitudes—this is constructive interference. If a crest of one wave meets a trough of another wave, then the amplitude is equal to the difference in the individual amplitudes—this is known as destructive interference (see Figure 5).

Our meta-analysis of more than 500 biomedical studies shows sets of opposing frequency spectra that are constructive and deconstructive, and that can be related to be beneficial and detrimental for life conditions. Do these separate modalities have an implicit relation with a geometry? It has been proposed that 12 different interfering constructive states and octaves thereof (ratios of 1:2) fit in coherent wave patterns with typical geometrical structures and sub-structures on a torus of which these states have their "zeros" at a single point. The torus model we propose accommodates properties of various types of localized states, similar to the states of semi-harmonic oscillators, which are maximally localized in phase space. The states on this torus have many properties in common with coherent states on a string, on a plane, on a sphere, and on Platonic solids [59]. In this sense, the term constructive means that these states are able to stabilize a geometry of waves that constitute a torus. On the contrary, waves that preferably do not fit in this torus geometry are considered as destructive.

2) Number systems valid for animate and inanimate systems

It is proposed that Life Systems are resembling typical coherent resonances of atomic cascade transitions of materials used to show Einstein-Podolsky-Rosen's argument, and Bell's theorem that should be placed by a local realistic process in space-time. Potentially, these informational frequencies are linked with the zero point energy field, through resonances leading to phase-locked cellular information attractors, that are functionally separated by non-coherent wave activity [7] [60]. The latter could explain the function of interwoven "coherent" and

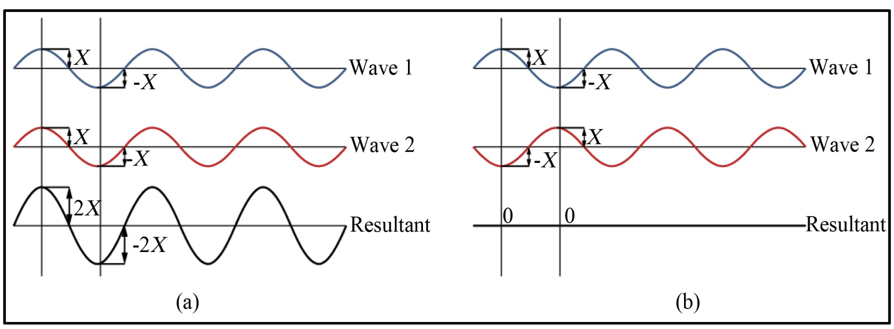

Figure 5. Constructive and destructive interference of waves.

"non-coherent" EM/quantum values and the presence of trajectories corresponding with initial vibrational energies of molecules and atoms equal to their measured vibrational zero-point energies. A morphogenetic aspect, that is observed in animate (life) systems (spectral properties of proteins and nucleotides) as well as in inanimate models may indicate that a generalized bio-physical principle is at stake that is involved in morphogenetic ordering and guided organization and replication. Scientists have also observed self-replication in non-living systems. According to research led by Marcus, vortices in turbulent fluids spontaneously replicate themselves by drawing energy from shear in the surrounding fluid [61]. Brenner presents theoretical models and simulations of microstructures that self-replicate. These clusters of specially coated microspheres dissipate energy by roping nearby spheres into forming identical clusters [62]. Mandelbrot's fractal theory is capable to describing and generating figures of infinite scale invariant complexity [63]. Such a layered structure is compatible with David Bohm's notion of the implicate order, that is a powerful concept. But until now it lacks a formal physical representation as well as a verified mathematical background that expresses the so called quantum potential as defined by Bohm in relation to this concept.

3) Steering mechanism based on Bohm's pilot theory

The concept of rational control of shape by soliton-waves and the proposed "coherent wave pattern" observed in physical and biological experiments, the GM-model, shows an analogy with Bohm's quantum potential. Bohm's interpretation of the quantum mechanics is nonlocal, and causal. He makes use of the term quantum potential that is an informational effect shared by the surroundings particles/waves that depends on its shape and is derived from the ψ-field [27] [28]. It is considered that the GM-scale describes the entangled states of typical inanimate materials as used to demonstrate Bell-nonlocality. This means that there might be a relation with the Bohm's vision that there is entanglement of all kinds of frames within a certain reference, in which Bell's theorem can be placed by a local realistic process in space-time. One part of the GM-scale is an acoustical like scale that is related to the coherent ordering of music tones. Bohm discusses the experience of listening to music and postulated that listening to music provides a way to experience the implicate order. He argued that the sense of movement and change that constitutes the experience of the music relies on notes both from the immediate past and the present being held in the brain at the same time. Bohm does not view the notes from the immediate past as memories but as active transformations of what came earlier.

4) Potential link between GM-scale and energy/heat

A further step in developing a morphogenetic mechanism has been achieved by also taking dissipation into account. Dissipation is possible when the interaction of a system with its environment is considered. Vitiello described how the system-environment interaction causes a doubling of the collective modes of the system in its environment [64]. This yields many differently coded vacuum states, offering the possibility of many memory contents without overprinting. Eventually, a life system arrives at a state of maximum entropy called "thermodynamic equilibrium," in which energy is uniformly distributed. Self-replication (or reproduction, in biological terms), the process that drives the evolution of life on Earth, is one such mechanism by which a system might dissipate an increasing amount of energy over time. As England recently put it: from the standpoint of physics, there is an essential difference between living things and inanimate clumps of carbon atoms [65].

The authors support these ideas, but stipulate that a potential electromagnetic energy source should be more differentiated with regard to its frequency spectrum. We argue that the overall complexity of cells requires a fine-tuned set of input energies including coherent and damping frequencies, and that only a concerted action of the combined frequencies can be instrumental in the mathematical construction of extremely complex animate and inanimate systems.

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix 1 (Table A1)

Table A1. Notes and Mutual Ratio's according to an Enharmonic Pythagorean Scale.

Note	Ratio	Note	Ratio
C	1:1	Fies	729:512
Des	256:243	G	3:2
Cies	2187:2048	As	128:81
D	9:8	Gies	6561:4096
Es	32:27	A	27:16
Dies	19,683: 16,384	Bes	16:9
E	81:64	As	59,049:32,768
F	4:3	B	243:128
Ges	1024:729	C	2:1

Appendix 2. Calculation of Numerical Ratios of the Proposed 12-Number Scale of Coherent Frequencies (Tables A2-A4)

The calculated different numerical ratios of the 12-number; F1 till F12 stand for the twelve numbers of the Coherent-scale, that show harmonic, non-harmonic and irrational parameters.

Table A2. Mutual relations of the 12 numbers.

Harmonic part	Non-harmonic	Irrational
$F1 = 1$	$F2 = \Lambda\ F1$	$F7 = \sqrt{2}$
$F3 = 2^{-3}3^{2}\ F1$	$F4 = \Lambda\ F3$	
$F6 = \Lambda\ F5$	$F5 = 2^{-6}\ 3^{4}\ F1$	
$F8 = 2^{-1}3^{1}\ F1$	$F9 = \Lambda\ F8$	
$F11 = \Lambda\ F10$	$F10 = 2^{-4}\ 3^{3}\ F1$	
	$F12 = 2^{-7}\ 3^{5}\ F1$	

Table A3. Substituted equations from **Table 3**.

Harmonic part	Non-harmonic	Non-harmonic
$F1 = 1$	$F2 = 2^{8}3^{-5}$	$F7 = \sqrt{2}$
$F3 = 2^{-3}3^{2}$	$F4 = 2^{5}3^{-3}$	
$F6 = 2^{2}3^{-1}$	$F5 = 2^{-6}3^{4}$	
$F8 = 2^{-1}3^{1}$	$F9 = 2^{7}3^{-4}$	
$F11 = 2^{4}3^{-2}$	$F10 = 2^{-4}3^{3}$	
	$F12 = 2^{-7}3^{5}$	

Table A4. Calculated number ratios of the Table 4.

Harmonic part	Non-harmonic	Non-harmonic
F1 = 1	F2 = 1.0535	F7 = 1.4142
F3 = 1.1250	F4 = 1.1852	
F6 = 1.3333	F5 = 1.2656	
F8 = 1.5000	F9 = 1.5803	
F11 = 1.7778	F10 = 1.6875	
	F12 = 1.8984	

Appendix 3. The Calculation of the Generalized Scale of Coherent Frequencies (Table A5)

The GM-function can be written as twelve unique combinations of $2^p \cdot 3^q$, multiplied by 2^m, where p = 0, −1, 2, −3, 4, −4, 5, −6, 7, −7, 8, $\sqrt{2}$, q = 0, 1, 2, 3, 4, 5, −1, −2, −3, −4, −5, and m are integers from 0 till 54.

Table A5. Proposed universal coherent scale of 12 numbers extended to 54 octaves (m = 0 till 54).

$F_m(\text{coh.1}) = 2^0 3^0 2^m$	$F_m(\text{coh.7}) = 2^{0.5} 2^m$
$F_m(\text{coh.2}) = 2^8 3^{-5} 2^m$	$F_m(\text{coh.8}) = 2^{-1} 3^1 2^m$
$F_m(\text{coh.3}) = 2^{-3} 3^2 2^m$	$F_m(\text{coh.9}) = 2^7 3^{-4} 2^m$
$F_m(\text{coh.4}) = 2^5 3^{-3} 2^m$	$F_m(\text{coh.10}) = 2^{-4} 3^3 2^m$
$F_m(\text{coh.5}) = 2^{-6} 3^4 2^m$	$F_m(\text{coh.11}) = 2^4 3^{-2} 2^m$
$F_m(\text{coh.6}) = 2^2 3^{-1} 2^m$	$F_m(\text{coh.12}) = 2^{-7} 3^5 2^m$

Appendix 4. The Calculation of the Generalized Scale for Non-Coherent Frequencies Calculation of the Non-Coherent Universal Scale (Table A6)

A non-coherent-scale can be calculated based upon the finding that decoherent parameters are located logarithmically just in between the coherent parameters and can be calculated as follows (m = 0 till 54):

Table A6. Decoherent-scale extended to 54 octaves (m = 0 till 54).

$D_m(\text{decoh.1}) = 10^{(0.5\log F1 + 0.5\log F2)}$	$D_m(\text{decoh.2}) = 10^{(0.5\log F2 + 0.5\log F3)}$
$D_m(\text{decoh.3}) = 10^{(0.5\log F3 + 0.5\log F4)}$	$D_m(\text{decoh.4}) = 10^{(0.5\log F4 + 0.5\log F5)}$
$D_m(\text{decoh.5}) = 10^{(0.5\log F5 + 0.5\log F6)}$	$D_m(\text{decoh.6}) = 10^{(0.5\log F6 + 0.5\log F7)}$
$D_m(\text{decoh.7}) = 10^{(0.5\log F7 + 0.5\log F8)}$	$D_m(\text{decoh.8}) = 10^{(0.5\log F8 + 0.5\log F9)}$
$D_m(\text{decoh.9}) = 10^{(0.5\log F9 + 0.5\log F10)}$	$D_m(\text{decoh.10}) = 10^{(0.5\log F10 + 0.5\log F11)}$
$D_m(\text{decoh.11}) = 10^{(0.5\log F11 + 0.5\log F12)}$	$D_m(\text{decoh.12}) = 10^{(0.5\log F12 + 0.5\log F13)}$

Appendix 5. Calculated Examples of Beneficial Frequencies from Sub Hertz till PHz for Living Cells (Table A7)

Table A7. Examples of coherent frequencies; $F(x) = Fn, m \cdot 2^m$ (n from 1 till 12, m from 0 till +54).

Factor	F1, m	F2, m	F3, m	F4, m	F5, m	F6, m	F7, m	F8, m	F9, m	F10, m	F11, m	F12, m
m = 0	1.0000	1.0535	1.1250	1.1852	1.2656	1.3333	1.4142	1.5000	1.5803	1.6875	1.7778	1.8984 Hz
m = 1	2.0000	2.1070	2.2500	2.3704	2.5312	2.6666	2.8284	3.0000	3.1606	3.3750	3.5556	3.7968 Hz
m = 2	4.0000	4.2140	4.5000	4.7408	5.0624	5.3332	5.6568	6.0000	6.3212	6.7500	7.1112	7.5936 Hz
m = 3	32.000	33.712	36.000	37.9264	40.4992	42.6656	45.2544	48.000	50.5696	54.000	56.8896	60.7488 Hz
m = 8	256.00	269.70	288.00	303.41	324.00	341.33	362.04	384.00	404.54	432.00	455.12	486.00 Hz
m = 12	4.0960	4.3151	4.6080	4.8546	5.1839	5.4613	5.7926	6.1440	6.4729	6.9120	7.2819	7.7759 KHz
2^24	16.777	17.675	18.874	19.884	21.233	22.370	23.726	25.166	26.513	28.312	29.827	31.850 Hz
2^32	4.2950	4.5248	4.8318	5.0904	5.4357	5.7266	6.0739	6.4425	6.7873	7.2478	7.6356	8.1536 Hz
2^40	1.0995	1.1583	1.2370	1.3031	1.3915	1.4660	1.5549	1.6493	1.7376	1.8554	1.9547	2.0873 Hz
2^48	281.47	296.53	316.66	333.60	356.23	375.29	398.06	422.21	444.81	474.99	500.41	534.35 Thz
	532.5	*505.6*	*473.4*	*449.3*	*420.8*	*399.5*	*376.6*	*710.1*	*674.0*	*631.3*	*599.1*	*561.0* nm

Appendix 6. Calculated Frequencies of Twelve Coherent Musical Tones (Hertz) at m = 8

An acoustic coherent scale at m = 8: 256, 269.70, 288, 303.41, 324, 341.33, 362.04, 384, 404.54, 432, 455.12, 486 Hz.

Appendix 7. Calculated Wave Lengths of Twelve Coherent Colours (nm)

Colours												
	561.0	599.1	631.3	674.0	710.1	376.6	399.5	420.8	449.3	473.4	505.6	532.5 nm

Appendix 8. Calculated Different "Tone-Distances" of the Coherent 12-Number Scale

The 12-number GC-scale is positioned between a ratio of 1:2 and contains five whole "tone" distances of 9/8 and twelve half "tone" distances of three different types of half tones: six Limma's ($2^8 3^{-5} = 1.0535$), four Apotomes ($3^7 2^{-11} = 1.0679$) and two means of a Limma and an Apotome (1.0607); 1, 1.0535, 1.1250, 1.1852, 1.2656, 1.3333, $\sqrt{2}$, 1.5000, 1.5803, 1.6875, 1.7778, 1.8984, 2.

The calculated mean of all fifth's (ratios of 2:3) is:

$$\sqrt[12]{2^7}$$

Typical fifths are distributed as follows, see Table A8:

Table A8. The different fifth's in the 12-number coherent scale.

$8^{th}/1^{th} = 1.5000$	$14^{th}/7^{th} = 1.4899$
$9^{th}/2^{th} = 1.5000$	$15^{th}/8^{th} = 1.5000$
$10^{th}/3^{th} = 1.5000$	$16^{th}/9^{th} = 1.5000$
$11^{th}/4^{th} = 1.5000$	$17^{th}/10^{th} = 1.5000$
$12^{th}/5^{th} = 1.5000$	$18^{th}/11^{th} = 1.5000$
$13^{th}/6^{th} = 1.5000$	$19^{th}/12^{th} = 1.4899$

The 12-number scale has a closed circle of fifth's, which means that the defined fifth's fit in a ratio of 1:2. The brokenness of the circle (the fact that pure fifth's do not fit in a ratio of 1:2), as defined by the Pythagorean comma ($(3/2)^{12}/27 = 1.0136$), has been redistributed over two fifth's. The means of all fifths over a total of 54 scales amounts:

$$\sum_{m=0}^{54}\sum_{n=1}^{12}\frac{F_{(12m+n+7)}}{F_{(12m+n)}} = 12(m+1)\sqrt[12]{2^7} \tag{A1}$$

Formulae (A1): The mean of all fifth's in all scales from n = 1 till 12, m = 1 till 54.

Typical mutual ratios of the numbers in the scale are, see Formulae (A2):

$$\frac{F_{(12m+n)}}{F_{(12m+n-12)}} = 2 \tag{A2}$$

$$F_{(12m+8)} \cdot F_{(12m+6)} = F_{(12m+7)}^2$$

$$\frac{F_{(12m+7)}}{F_{(12m+1)}} = \sqrt{2}$$

$$\frac{F_{(12m+6)}}{F_{(12m+1)}} = \frac{4}{3}$$

$$\frac{F_{(12m+8)}}{F_{(12m+1)}} = \frac{3}{2}$$

$$\frac{F_{(12m+3)}}{F_{(12m+1)}} = \frac{9}{8}$$

Formulae (A2): Typical mutual relations of numbers for n = 1 till 12, m = 1 till 54.

The mutual distances of the subsequent 12 numbers are: 1.0535, 1.0678, 1.0535, 1.0678, 1.0535, 1.0607, 1.0607, 1.0535, 1.0678, 1.0535, 1.0678, 1.0535, whereas all mutual distances of an equal tempered scale are 1.0595. And all individual sequences of quint ratios of the scales in the frequency range from sub Hertz till PHz approach 1.498 at 0.00% - 0.07%, with the exception of the quint's related to a so-called Wolf-interval (the Wolf interval is in music theory a particularly dissonant musical interval spanning seven semitones). Strictly, the term refers to an interval produced by a specific tuning system, widely used in the sixteenth and seventeenth centuries: the quarter-comma meantone temperament).

When the numerical differences of the frequencies of all intervals of quarts and major thirds are calculated, than the mean of this differences approximates ϕ (1.618) at 0.38%:

$$\sum_{m=0}^{54}\sum_{n=1}^{12}\frac{F_{(12m+n+9)}-F_{(12m+n+4)}}{F_{(12m+n+4)}-F_{(12m+n)}}=\sim 12m\phi \qquad (A3)$$

Formulae (A3): Arithmetical sequences that approach phi from n = 1 till 12, m = 1 till 54.

Appendix 9. Published Electromagnetic Frequencies of Endogenously Measured and Exogenous Applied Beneficial EM Field Effects

The different biological studies related to endogenous and exogenous frequencies of electromagnetic oscillations are listed in alphabetical order below:

Activation of the extracellular signal-regulated kinase signal pathway
Anti-proliferative effects on tumour cells
Biological membranes
Brain activity
Brain stimulation, spinal cord stimulation
Changes in gene expression in neural stem cells and mesenchymal stem cells
Chromatin remodelling and pro-neuronal gene expression
Decrease of inflammatory cells
Depressive disorders and neurological defects
Entorhinal-hippocampal interactions
Improve of cognitive function
Improvement of attention
Increase of bone growth
Increase of fibroblast proliferation
Influence on fibroblast morphology
Influence on memory tasks
Influence on transcriptome and genetic networks
Inhibition of tumour growth
Foci in differentiated cells
Genetic expressions
Genome-wide methylation
Ion-channel proteins
Light-harvesting complexes from bacteria, and bioluminescence
Microtubular proteins
Muscle regeneration
Neurogenesis
Neuro-regeneration

Neuro-stimulation, restore of neurological disorders
Neutrophil calcium homeostasis
Neuronal communication
Oligonucleotides
Osteogenic differentiation of human bone marrow-derived mesenchymal stem cells
Pigment-protein complexes
Prefrontal and parietal human cortex
Promotion of proliferation of human mesenchymal stem cells
Protein synthesis by cells, increase of endothelial cells
Protein folding
Receptors in human neutrophils endogenous electric fields
Reduced and repression of tumour growth, improvement of memory
Reduction of diabetic peripheral neuropathy
Reduction of Parkinson
Regeneration of cells
Restore of spectrum of disorders such as traumatic brain injury
Rhythmic neuronal synchronization
Self-assembly of microtubulins
Skin healing
Stimulation of angiogenesis, granulation of tissue formation
Synthesis of collagen
Transcranial magnetic stimulation
Tubulin protein molecules
Wound healing

Appendix 10. Published Research Objects in Which Biologically Detrimental EM Frequencies Were Reported

The experiments in these studies were described in the areas of:

Alteration of protein conformation
Angiogenesis, inhibition of cell growth
Antigen-antibody interaction
Cancer
Cardiovascular effects
Cardiovascular responses
Chromosomal instability
Cognitive impairment
DNA single-strand breaks
Effects on blood pressure
Gene expression
Genotoxicity
Induction of spermatogenic germ cell apoptosis
Influence on alkaline phosphatase activity

Influence on behaviour
Influence on sleeping
Influence on specific brain rhythms
Influence on teratogenic potential
Influence on the permeability of the blood-brain barrier
Influences on sperm parameters
Learning and memory alterations
Maculopathy
Phototoxic effects on human eye health
Phototoxic effects on human eye health, and on the retina
Skin healing
Tumour growth

Appendix 11. Reference to Authors that Performed Biological Experiments that Generated Data of Beneficial and Detrimental Biological Effects at Sub-Hz, Hz, KHz, MHz, GHz, THz, Phz EM Frequencies

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Appendix 12. Reported EM Field Frequencies in Bio-Medical Experiments that Generated Data for Beneficial and Detrimental Biological Effects

Coherent frequencies that stabilize living cells and calculated acoustic reference frequency.

Hz:

1) Moore, 1979: 0.3 Hz > 307.2 Hz
2) Persinger, 2015: 0.445 Hz > 455.7 Hz
3) Persinger, 2015: 0.473 Hz > 484.4 Hz
4) Persinger, 2015: 0.482 Hz > 493.6 Hz
5) Persinger, 2015: 0.499 Hz > 255.5 Hz
6) Kole, 2011: 0.6 Hz > 307.2 Hz
7) Fröhlich F., 2014: 0.750 Hz > 384.0 Hz
8) Yu L., 2015: 0.952 Hz > 487.4 Hz
9) Mayrovitz, 2004: 1.000 Hz > 256 Hz
10) Sanchez-Vives: 2. 000 Hz > 256 Hz
11) Hartwich, 2009: 1.000 Hz > 256 Hz
12) Gapeyev, 1999: 1.000 Hz > 256 Hz
13) De Mattei, 2006: 2.000 Hz > 256 Hz
14) Ricci, 2010: 2.000 Hz > 256 Hz
15) Hartwich, 2009: 2.000 Hz > 256 Hz
16) Hartwich, 2009: 3.200 Hz > 409.6 Hz
17) Hartwich, 2009: 4.000 Hz > 256 Hz
18) Fadel, 2005: 4.500 Hz > 288 Hz
19) Selvam, 2007: 5.000 Hz > 320 Hz
20) De Mattei, 2009: 5.000 Hz > 320 Hz
21) Sancristóbal, 2014: 6.000 Hz > 384 Hz
22) Lisi, 2008: 7.000 Hz > 448.0 Hz
23) Ross, 2015: 7.500 Hz > 480 Hz
24) Kang 2013: 7.5 > 480 Hz
25) Leoci, 2014: 8.000 Hz > 256 Hz
26) Kole, 2011: 8.2 Hz >262.4 Hz
27) Belyaev, 1998: 9.000 Hz > 288.0 Hz
28) Kole, 2011: 9.4 Hz > 300.8 Hz
29) Golgher, 2007: 10.00 Hz > 320 Hz
30) Hood, 1989: 10.00 Hz > 320 Hz
31) Fröhlich, F., 2014: 10.00 Hz > 320 Hz
32) Bellossi et al. 1988: 12 Hz > 384 Hz
33) Eusebio, 2012: 20.00 Hz > 320 Hz
34) Kole, 2011: 10.7 Hz > 342.4 Hz
35) Golgher, 2007: 13.50 Hz > 432 Hz
36) Kole, 2011: 10.7 Hz > 342.4 Hz
37) Murray, 1985: 15.00 Hz > 480 Hz
38) Lei, 2013: 15.00 Hz > 480 Hz
39) Ross, 2015: 15.00 Hz > 480 Hz
40) Aaron 1989: 15.00 Hz > 480 Hz
41) Ciombor 1993: 15.00 Hz > 480 Hz
42) Blackinton 1992: 15.00 Hz > 480 Hz
43) Hopper 2009: 15.00 Hz > 480 Hz
44) Dutta, 1994: 16.00 Hz > 256 Hz
45) Belyaev, 2001:16.00 Hz > 256 Hz
46) Mayrovitz, 2004: 16.00 Hz > 256 Hz
47) Hartwich, 2009: 17.10 Hz > 273.6 Hz
48) Loschinger, 1999: 20.00 Hz > 320 Hz
49) Chen, 2007: 20.00 Hz > 320 Hz
50) Prato, 2013: 30.0 Hz > 480 Hz
51) Kang 2013: 30 Hz > 480 Hz
52) Seeliger, 2014: 33.00 Hz > 264.0 Hz
53) Cane, 1993: 37.50 Hz > 300 Hz
54) Ceccarelli, 2014: 37.50 Hz >300 Hz
55) Singer, 1999: 40.00 Hz > 320 Hz
56) Joliot 40 Hz > 320 Hz
57) Sheer, 40 Hz >320 Hz
58) Steriade, 40 Hz >320 Hz
59) Rouleau and Dotta: 40 Hz >320 Hz
60) Desmedt, 1994: 40.00 Hz > 320 Hz
61) Llinas, 1993, 1994: 40.00 Hz >320 Hz
62) Bastos, 2014: 40.50 Hz > 324 Hz
63) Golgher, 2007: 40.50 Hz > 324 Hz
64) Reite, 1994: 42.70 Hz > 341.6 Hz
65) Pasche, 1996, 2003: 42.70 Hz > 341.6 Hz
66) Blackman, 1985: 45.00 Hz > 360 Hz
67) Kang 2013: 45 Hz > 360 Hz
68) Kim 2015: 45.00 Hz > 360 Hz
69) Wei, 2008: 48.00 Hz > 384 Hz
70) Cheing, 2014: 50.00 > 400 Hz
71 Reale, 2014: 50.00 Hz > 400 Hz
72) Segatore, 2014: 50.0 Hz > 400 Hz
73) Battini, 1991: 50.00 Hz > 400 Hz
74) Marchionni, 2006: 50.00 Hz > 400 Hz
75) Iorio R, 2011: 50.00 Hz > 400 Hz
76) Delle Monache 2008: 50 Hz > 400 Hz
77) Golgher, 2007: 54.00 Hz > 432 Hz
78) Blumenfeld, 2015: 60.00 > 480 Hz
79) Braun, 1982: 72.00 Hz > 288 Hz
80) Yoon, 2015: 60.00 Hz > 480 Hz
81) Tabrah, 1990: 72.00 Hz > 288 Hz
82) Luben RA, 1982: 72 Hz > 288 Hz
83) Elliott, 1988: 72 Hz > 288 Hz
84) Varani, 2002: 75.00 Hz > 300 Hz
85) De Mattei, 2006: 75.0 Hz > 300 Hz
86) Wang, 2016: 75.0 Hz > 300 Hz
87) Veronesi, 2014: 75.0 Hz > 300 Hz
88) Reed, 1993: 76.00 Hz > 303.6 Hz
89) Singer, 1999: 91.00 Hz > 364 Hz
90) Singer, 1999: 100.0 Hz > 400 Hz
91) Wen, 2011: 100.0 Hz > 400 Hz
92) Menteş, 1996: 100.0 Hz > 400 Hz
93) De Mattei, 2006: 110.0 Hz > 440 Hz
94) Douglas, 2001: 120.0 Hz > 480 Hz
95) Buhl, 2003: 150.0 Hz > 300 Hz
96) Cheron, 2004: 160.0 Hz > 320 Hz
97) Chrobak, 2000: 200.0 Hz > 400 Hz
98) Schmitz, 2001: 200.0 Hz > 400 Hz
99) Kole, 2011: 242.6 Hz >485.2 Hz
100) Mayrovitz, 2004: 300.0 Hz > 300 Hz
101) Foffani, 2003: 300.0 Hz > 300 Hz
102) Ceccarelli 2013: 769.2 Hz > 384.6 Hz

kHz:

1) Pelling 2004, 2005: 1.63 KHz > 407.5 Hz
2) Pelling 2004, 2005: 0.87 KHz > 435.0 Hz
3) Pohl, 1986: 33.00 KHz > 257.8 Hz
4) Conner-Kerr, 2015: 35.00 KHz > 273.4 Hz
5) Pitt, 2003: 70 KHz > 273.4 Hz
6) Kirson, 2004: 150 KHz >292.96 Hz
7) Hernández-Bule, 2014: 448.0 KHz > 437.5 Hz

MHz:

1) Kyung Shin Kang, 2013:0.500 MHz > 488.3 Hz
2) Ritz, 2009: 0.658 MHz > 321.29 Hz
3) Kyung Shin Kang, 2013: 1.000 MHz > 488.3 Hz

4) Takebe, 2013: 1.000 MHz > 488.3 Hz
5) Bandyopadhyay, 2014: 1.000 MHz > 488.3 Hz
6) Ritz, 2009: 1.315 MHz >321.05 Hz
7) Usselman, 2016: 1.4 MHz > 341.30 Hz
8) Yamashita, 2010: 1439 MHz > 343.08 Hz
9) Kyung Shin Kang, 2013: 1.500 MHz > 366.2 Hz
10) Takebe, 2013: 3.000 MHz > 366.2 Hz
11) Zou, 2007: 5.000 Mhz > 305.2 Hz
12) Ritz, 2004: 7.0 MHz > 427.25 Hz
13) Pokorny, 2009: 8.000 MHz > 488.28 Hz
14) Fadel, 2016: 10.0 MHz > 488.28 Hz
15) Hinrikus, 2016: 450 MHz > 429.15 Hz
16) Gerner, 2010: 1800 MHz > 429.15 Hz
17) Bandyopadhyay, 2014: 20.00 MHz > 305.2 Hz
18) Stolfa, 2007: 21.20 MHz > 323.5 Hz
19) Zong 900 MHz > 429.15 Hz

GHz:

1) Ozlem Nisbet, 2012: 1.8 GHz > 429.15 Hz
2) Cao, H. 2015: 1.8 GHz > 429.15 Hz
3) Hirose, 2006: 2.1425 GHz > 255.41 Hz
4) Sekijima 2010: 2.1425 GHz > 255.41 Hz
5) Beneduci, 2005: 46.00 GHz > 342.7 Hz
6) Fröhlich, ref. G. Schmidl 46 GHz > 342.7 Hz
7) Beneduci, 2005: 51.05 GHz > 380.4 Hz
8) Makar, 2006: 61.22 GHz > 456.13 Hz
9) Fröhlich, ref. G. Schmidl 61.2 GHz > 456.0 Hz
10) Radzievsky AA. 2004: 61.22 GHz > 456.1 Hz
11) Kalantaryan, 2010: 64.50 GHz > 480.6 Hz
12) Beneduci, 2005: 65.00 GHz > 484.3 Hz

THz:

1) Sukhova, 2007: 0.129 THz > 480.6 Hz
2) Fedorov, 2011: 2.300 THz > 267.8 Hz
3) Sergeeva, 2016: 2.300 THz > 267.8 Hz
4) Kirichuk, 2013: 3.680 THz > 428.4 Hz
5) Tang M 2015: 0.326 THz > 303.61 Hz

Nm:

1) Finkel, 2013: 9.3 nm > 458.10 Hz
2) Henry, 2016: 100 nm.
3) Hamblin, 2012: 254 Hz > 268.4 Hz
4) Rahnama, 2010: 280 nm > 486.89 Hz
5) Rahnama, 2010: 335 nm > 406.95 Hz
6) Almeida-Lopes, 2001: 393 nm > 346.9 Hz
7) De Sousa, 2013: 395 nm > 345.1 Hz
8) Gungormus, 2009: 404 nm > 337.5 Hz
9) Rezende, 2007: 415 nm > 328.5 Hz
10) Hawkins, 2007: 415 nm > 328.5 Hz
11) Hussein, 2011: 445 nm > 306.4 Hz
12) Reddy, 2003: 452 nm > 301.6 Hz
13) Silveira, 2011: 452 nm > 301.6 Hz
14) Pereira, 2002: 452 nm > 301.6 Hz
15) Chlorophyll b: 453 nm > 308.2 Hz
16) Fushimi, 2012: 456 nm > 299.0 Hz
17) Carotenoid: 450 nm >303.0 Hz
18) Ueda, T., 2009: 465.0 nm >
19) Hu, J., 2014: 466.0 nm > 292.5 Hz
20) Adamskaya, 2011: 470 nm > 290.1 Hz
21) Cheon, 2013: 470 nm > 290.1 Hz
22) Meyer, 2010: 515 nm > 264.7 Hz
23) Palacios, 1997: 503.96 nm >270.5 Hz
24) Palacios, 1997: 505.86 nm > 269.5 Hz
25) Meyer, 2010: 525 nm > 259.7 Hz
26) De Sousa, 2010: 530 nm > 257.3 Hz
27) Fukuzaki, 2015: 532 nm > 256.26 Hz
28) Shrivastava: 535 nm > 254.82 Hz
29) Weng, 2011: 532 nm > 256.3 Hz
30) Fukuzaki, 2015: 532 nm >256.3 Hz
31) Lee MW, 2003: 532 nm > 256.3 Hz
32) Kuchimaru, 2016: 562 nm > 485.16 Hz
33) Phycoerythrin: 565 nm > 482.6 Hz
34) Weiss, 2005: 590 nm > 462.1 Hz
35) Shrivastava: 605 nm >450.68 Hz
36) Komine, 2010: 627 nm > 434.9 Hz
37) Tada, 2009: 629 nm > 433.5 Hz
38) Adamskaya, 2011: 629 nm > 433.5 Hz
39) Huang, 2007: 630 nm > 432.8 Hz
40) Yu, 1997: 630 nm > 432.8 Hz
41) Rabelo, 2006: 632.8 nm >430.9 Hz
42) Carvalho, 2006: 632.8 nm > 430.9 Hz
43) Fahimipour, 2013: 632.8 nm > 430.9 Hz
44) Naeser, 2011: 633 nm > 430.9 Hz
45) Hu, 1996: 632.8 nm > 430.9 Hz

46) Maiya, et al. 2006: 632.8 nm > 430.9 Hz
47) Schindl, 2000: 632.8 nm > 430.9 Hz
48) Yu H.S., 2003: 632.8 nm > 430.9 Hz
49) Lim WB, 2011: 635 nm > 429.39 Hz
50) Fushimi, 2012: 638 > 427.4 Hz
51) Oron 2012: 660 nm > 403.9 Hz
52) Chlorophyll a: 675 nm > 403.9 Hz
53) Reis, 2008: 670 nm > 407.0 Hz
54) Lacjaková, 2010: 670 nm > 407.0 Hz
55) Lanzafame, 2007: 670 nm > 407.0 Hz
56) Quirk 2012: 670 nm > 407.0 Hz
57) Moore, 2005: 675 nm > 403.9 Hz
58) Kuchimaru, 2016: 677 nm > 402.75 Hz
59) Ameral 2001: 685 nm > 398.0 Hz
60) Viegas, 2007: 685 nm > 398.0 Hz
61) Sousa, 2010: 700 nm > 389.5 Hz
62) Choi, 2012: 710 nm > 384.0 Hz
63) Saikin 2014: 749-750 nm > 363.78 Hz
64) Kereıche, 800 nm > 340.82 Hz
65) Titova, 2013: 800 nm > 340.82 Hz
66) Fukuzaki, 2014: 808 nm > 337.5 Hz
67) Murayama, 2012: 808 nm > 337.5 Hz
68) Oron, 2007: 808 nm > 337.5 Hz
69) Assis, 2012: 808nm > 337.5 Hz
70) Oron, 2012: 810 nm > 336.62 Hz
71) Xuan, 2013: 810 nm > 336.62 Hz
72) Xuan, 2014: 810 nm > 336.62 Hz
73) Ando, 2011: 810 nm > 336.62 Hz
74) Ando, 2011: 810 nm > 336.62 Hz
75) Streeter, 2004: 810 nm > 336.62 Hz
76) Huang, 2013: 810 nm > 336.62 Hz
77) Khuman, 2012: 810 nm > 336.62 Hz
78) Vatansever, 2012: 830 nm > 328.51 Hz
79) Ameral, 2001: 830 nm > 328.51 Hz
80) Kereıche, 850 nm > 320.78 Hz
81) Correa, 2007: 904 nm > 301.62 Hz
82) Biolase, 940 nm > 290.06 Hz
83) Lobo 2015: 940 nm > 290.06 Hz
84) Lee MW, 2003: 1064 nm > 256.26 Hz
85) Lin CC, 2008: 4050, 5480, 6300, 8000 nm
86) Lin TC, 2015: 4050, 5480, 6300, 8000 nm
87) Chen CH, 2017: 4050, 5480, 6300, 8000 nm
88) Peidaee, 2013: 3600 nm > 302.96 Hz

***Decoherent* frequencies that destabilize living cells and calculated acoustic reference frequency**

Hz:

1) Puharich, 6.600 Hz > 422.4 Hz
2) Pfluger, 1996: 16.7 Hz > 267.2 Hz
3) Minder, 2001: 16.7 Hz > 267.2 Hz
4) Gye, 2012: 33 Hz > 264.0 Hz
5) Cecconi, 2000: 33 Hz > 264.0 Hz
6) Ghione, 1996: 37 Hz > 296.0 Hz
7) Lee J.S., 2004: 60 Hz > 480 Hz
8) Kim Y.W., 2009: 60 Hz > 480 Hz
9) Kim H.S., 2014: 60 Hz > 480 Hz
10) Kim J., 2012: 60 Hz > 480 Hz
11) Loja, 2014: 125 Hz > 250 Hz
12) Ahmed, 2013: 200 Hz > 400 Hz
13) Ahmed, 2013: 250 Hz > 250 Hz
14) Ahmed, 2013: 350 Hz > 350 Hz
15) Ahmed, 2013: 400 Hz > 400 Hz
16) Ahmed, 2013: 500 Hz > 250 Hz
17) Loja 2014: 625 Hz > 312.5 Hz

KHz:

1) Sausbier, 2004: 5 KHz > 312.5 Hz

MHz:

1) Curley 2014: 13.56 MHz >
2) Brown-Woodman, 1988: 27.12 MHz > 413.82 Hz
3) Tofani, 1986: 27.12 MHz > 413.82 Hz
4) Bawin et al., 1973: 147 MHz > 280.38 Hz
5) Jauchem and Frei 1997: 350 MHz > 333.78 Hz
6) Bellossi, 1988: 460 MHz > 460 Hz
7) Dore, 2015: 462 MHz > 440.60 Hz
8) Vedruccio, 2011: 462 MHz > 440.60 Hz
9) Vedruccio, 2004: 465 MHz > 443.46 Hz
10) Gervino, 2007: 465 MHz > 443.46 Hz
11) Dore, 2015: 465 MHz > 443.46 Hz
12) Sanders, 1980: 591 MHz > 281.8 Hz
13) De Pomerai, 2000: 750 MHz > 357.6 Hz
14) Mashevich 2003: 830 MHz > 395.78 Hz
15) Maskey, 2014: 835 MHz > 398.21 Hz
16) Donnellan, 1997: 835 MHz > 398.2 Hz
17) Maskey 2010: 835 MHz > 398.16 Hz
18) Mashevich 2003: 830 MHz > 395.77 Hz
19) Luukkonen, 2009: 872 MHz > 415.8 Hz
20) Zmyslony, 2004: 930 MHz > 443.5 Hz
21) Dore, 2015: 930 MHz > 443.46 Hz
22) Maes, 1997: 935.2 MHz > 445.9 Hz
23) Pavicic, 2008: 935.0 MHz
24) Johnson and Guy, 1972: 918 MHz > 437.7 Hz
25) De Pomerai, 2003: 1000 MHz > 476.81 Hz
26) Lu, 1992: 1250 MHz > 298.0 Hz
27) Jauchem and Frei 2000: 1000 MHz > 476.8 Hz
28) Oscar and Hawkins, 1977: 1300 MHz > 310.0 Hz
29) Wake, 2007: 1500 MHz > 357.6 Hz
30) Schirmacher, 1999: 1750 MHz > 417.2 Hz
31) Iyama, 2004: 2000 MHz > 476.8 Hz
32) Aydogan, 2015: 2100 MHz > 250.3 Hz
33) Grin AN, 1974: 2375 MHz > 283.1 Hz
34) Shandalal, 1979: 2375 MHz > 283.1 Hz
35) Taylor and Ashleman, 1975: 2450 MHz > 292.1 Hz
36) Chou et al., 1978: 2450 MHz > 292.1 Hz
37) Lai et al, 1987, 1988: 2450 MHz > 292.1 Hz
38) Switzer and Mitchell, 1977: 2450 MHz > 292.1 Hz
39) Kesari KK, 2010: 2450 MHz > 292.1 Hz
40) Shokri S. 2015: 2450 MHz > 292.1 Hz
41) FigueiredoI, 2004: 2500 MHz > 298.0 Hz
42) Thomas et al., 1982: 2800 MHz > 333.8 Hz
43) Frei and Jauchem, 1989: 2800 MHz > 333.78 Hz
44) Albert EN, 1977: 2800 MHz > 333.8 Hz
45) Gandhi, CR., 1989: 2800 MHz > 333.8 Hz
46) Siekierzynski, 1972: 2950 MHz > 351.7 Hz
47) Grodon, 1970: 3000 MHz > 357.61 Hz
48) Tolgskaya, 1973: 3000 MHz > 357.6 Hz
49) Pu, 1997: 3000 MHz > 357.61 Hz
50) DÁndrea et al, 1994: 5600 MHz > 333.8 Hz
51) Jensh, 1984: 6000 MHz > 357.6 Hz
52) Goldstein and Sisko, 1974: 9300 MHz > 277.2
53) Zhang Y, 2014: 9417 MHz > 280.7 Hz
54) Jauchem and Frei 2000: 10000 MHz > 298.0 Hz
55) M. Porcelli, 10400 MHz > 309.9 Hz
56) FigueiredoI, 2004: 10500 MHz > 312.9 Hz
57) Hao, 2012: 916 MHz > 436.8 Hz
58) Deshmukh, 2015: 2450 MHz > 292.1 Hz
58) Bin, 2014: 2576 MHz > 307.1 Hz
59) Copty, 2006: 8500 MHz > 253.31 Hz
60) Zhang, 2014: 9410 MHz > 280.4 Hz
61) Sharma, 2014: 10000 MHz > 298.0 Hz
62) Senavirathna, 2014: 2000 MHz > 476.8 Hz
63) Paulraj, 2012: 16500 MHz > 245.9 Hz
64) Mashevich, 2003: 830 MHz > 395.8 Hz

GHz:

1) Bellorofonte, 2005: 1.395 GHz > 332.59 Hz
2) Dore, 2015: 1395 GHz > 332.59 Hz
3) Imai 2011: 1.95GHz > 464.92 Hz
4) Jain S. 2015: 2.1 GHz > 500.68 Hz
5) Jain S. 2015: 2.3 GHz > 274.18 Hz
6) Marcickiewicz, 1986: 2,450-MHz >
7) Johnson, 1999 (2.45 GHz; > 292.06 Hz
8) Guy et al., 1985: 2.45 GHz > 292.06 Hz
9) Johnson, 1984: 2.45 GHz > 292.06 Hz
10) Lai and Singh 1995: 2.450 GHz > 292.06 Hz
11) Johnson EH, 1999: 2.45 GHz > 292.06 Hz
12) Kesari, 2010: 2.45 GHz > 292.06 Hz
13) Roszkowski, 1980: 2.45 GHz > 292.06 Hz
14) Jain S., 2.6 GHz > 309.94 Hz
15) Millenbaugh NJ, 2008: 35 GHz > 260.8 Hz
16) Roza K. 2010: 35 GHz > 260.8 Hz
17) Shock, 1995: 35 GHz > 260.8 Hz
18) Kesari KK, 2009: 50 GHz > 372.5 Hz
19) Tafforeau M, 2004: 105 GHz > 391.2 Hz
20) Frei 1998: 2.45 GHz > 292.06 Hz
21) Lerchl, 2014: 1.97 GHz > 469.69 Hz
22) Tillmann et al. 2010: 1.97 Ghz > 469.69 Hz
23) Qureshi 2016: 3.31 GHz > 394.58 Hz

THz:

1) Homenko et al. 2009: 0.1 THz > 372.5 Hz
2) Kirchuk et al., 2008: 0.24 THz > 447.0 Hz
3) Webb and Dodds, 1968: 0.136 THz > 253.3 Hz
4) Cheon H., 2016: 1.67 THz > 388.83 Hz
5) Wilmink et al., 2010: 2.52 THz > 293.4 Hz
6) Kitchel E., 2000: 689.18 THz > 313.4 Hz

7) Glazer-Hockstein, 2006: 689.18 THz > 313.4 Hz
8) Algvere PV, 2006: 689.18 THz > 313.4 Hz
9) Marshall J, 2006: 689.18 THz > 313.4 Hz
10) Tomany S.C, 2004: 689.18 THz > 313.4 Hz
11) Smick K, 2013: 689.18 THz > 313.4 Hz

Nm:

1) De Gruijl, 1993: 293 nm > 465.3 Hz
2) Belloni, 2005: 308 nm > 442.63 Hz
3) Setlow, 1993: 365 nm > 373.5 Hz
4) Setlow 1993: 405 nm > 336.6 Hz
5) Kitchel E., 2000: 435.0 nm > 313.4 Hz
6) Smick K, 2013: 435.0 nm > 313.4 Hz
7) Setlow 1993: 436 nm > 312.7 Hz
8) Gomes Henriques, 2014: 660 nm
9) Sperandio, 2013: 660 nm
10) Frigo, 2009: 660 nm > 413.12 Hz

11) Frigo, 2009: 660 nm > 413.12 Hz
12) Sperandio 2013: 660 nm > 413.12 Hz
13) Gomes Henriques, 2014: 660nm > 413.12 Hz
14) Optic phototoxic blue 435 nm: 689.18 > 313.4 Hz
15) Oron, 2012: 730 nm > 373.51 Hz
16) Sperandio, 2013: 780 nm > 349.56 Hz
17) Sperandio, 2013: 780 nm > 349.56 Hz
18) Moore, P. 2005: 810 >336.6 Hz
19) Oron, 2012: 980 nm > 278.22 Hz

Coherent frequencies able to inhibit and retard cancer

1) Zhang X. et al. 2002, 0.16 Hz
2) Nuccitelli et al. 2006, 3.33 MHz
3) Fadel, 2015 0.5 Hz
4) Fadel 2015: 0.7 Hz
5) Yin, S. 2014, 10 MHz and 0.5 Hz
6) Emara et al. 2013, 0.9 Hz
7) Tuffet et al. 1993, 0.8 Hz
8) Seze et al. 2000, 0.8 Hz
9) Novikov, 2005, 2009: 1 Hz; 4.4 Hz; 16.5 Hz
10) Tatarov et al. 2011: 1 Hz
11) Chang et al. 1985: 1.0 Hz
12) Ruiz-Gómez 1999, 2002: 1Hz
13) Zhang X. et al, 2002: 1.34 Hz
14) Emara et al. 2013: 3 Hz
15) Wu S. 2013: 4 Hz
16) Fadel, 2010, 2011: 4.5 Hz; 10 MHz
17) Smith, 1986: 4.5 Hz
18) Ghannam, 2002: 5Hz
19) Buckner, 2015: combinations of 6 Hz and 25 Hz
20) Nie, Y. 2013: 7.5 Hz
21) Feng, 2013: 8Hz
22) Miyagi, 2000: 10 Hz
23) Bellossi, 1991:12 Hz
24) Crocetti, 2013: 20 Hz
25) Ruiz-Gómez: 25 Hz
26) Yamaguchi et al. 2006: 25 Hz
27) Hu et al. 2010: 25 Hz
28) Rannung, 1993: 50 Hz
29) Hisamitsu et al. 1997: 50 Hz
30) Simkó et al. 1998: 50 Hz
31) Pang, 2001: 50 Hz
32) Tofani et al. 2002, 2003: 50 Hz
33) Traitcheva, 2003: 50 Hz
34) Santini et al. 2005: 50 Hz
35) Morabito et al. 2010: 50 Hz
36) Berg, 2010: 50.00
37) Filipovic, 2014: 50 Hz
38) Chen YC, 2010: 60 Hz
39) Vincenzi, 2012: 75 Hz
40) Jian et al. 2009: 100 Hz
41) Wen et al. 2011: 100 Hz
42) Williams, 2001: 120 Hz
43) Jiménez-García, 2010: 120 Hz
44) Cameron et al. 2014: 120 Hz
45) Omote, 1990; 200 Hz
46) Bellosi, 1991: 460 Hz
47) Vincenzi, 2012: 1300 Hz
48) Agulan, 2015: 3.3 MHz
49) Ren Z., 2015: 10 MHz and 0.5 Hz
50) Wang, J. 2012: 10 MHz and 0.5 Hz
51) Chen X. 2012, 2014: 10 MHz, 33.3 MHz, 0.5 Hz, 1.0 Hz
52) Yao, 2008: 10 MHz, 1 Hz
53) Garon, 2007: 50 MHz
54) Buttiglione 2007: 900 MHz
55) Wu S., 2013: 7.2 GHz
56) Yoon, 2011: 18 GHz
57) Beneduci, 2005: 46.00 GHz
58) Beneduci, 2005: 51.05 GHz
59) Radzievsky, 2004: 61.22 GHz
60) Beneduci, 2005: 65.00 GHz
61) Liu YH, 2004: 808 nm
62) Murayama 2012: 808 nm
63) Fukuzaki, 2014: 808 nm
64) Peidaee, 2013: 3600 nm
65) Peidaee, 2013: 3800 nm

Decoherent frequencies that can initiate and promote cancer

66) Beniashvili, 1991: 50 Hz
67) Löscher, Mevissen et al. 1996, 1999: 50 Hz
68) Ahlbom, 2000: 50 and 60 Hz
69) Greenland, 2000: 50 and 60 Hz
70) Kheifets, 2010: 50 and 60 Hz
71) National Cancer Institute Electromagnetic fields and cancer, 2016: 50 and 60 Hz
72) Soffritti, 2016: 50.00 Hz combined with harmonic distortions 3%
73) Soffritti, 2016: modulated 50.0 Hz
74) Stuchly, 1992: 60 Hz

75) Cain, 1993: 60 Hz
76) Loja, 2014: 125 Hz
77) Loja, 2014: 625 Hz
78) Repacholi, 1997: modulated 900 MHz
79) Wyde ME, 2016: modulated 900 MHz

89) Chou CK, 1992: modulated 2.45 GHz
90) Johnson EH, 1999: 2.45 GHz
91) Prausnitz and Susskind 1962: pulsed 9270 MHz
92) Sperandio, 2013: 780 nm
93) Frigo, 2009: 660 nm

80) Wyde ME, 2016: modulated 1900 MHz
81) Tillmann et al. 2010: modulated 1.97 GHz
82) Lerchl, 2014: modulated 1.97 GHz
83) Roszkowski, 1980b: 2.45 GHz
84) Szudzinski, 1982: 2.45 GHz
85) Guy, 1985: modulated 2.45 GHz
86) Marcickiewicz, 1986: 2,450-MH
87) Szmigielski, 1982: 2.45 GHz
88) Balcer-Kubiczek, 1989: 2.45 GHz

94) Gomes Henriques, 2014: 660 nm
95) Sperandio, 2013: 660 nm
96) Setlow, 1993: 436 nm,
97) Setlow, 1993: 405 nm
98) Belloni, 2005: 308 nm
99) Setlow, 1993: 365 nm
100) Popp, 1976: 380 nm
101) De Gruijl, 1993: 293 nm

Appendix 13. Measured Coherent EM Frequencies of Oligo-Nucleotides and Bovine Serum Albumin

1) Terahertz spectroscopy of oligonucleotides, Mingjie Tang, Qing Huang 2015. (Figure A1)

1) 326 GHz > 303.61 Hz
2) 410 GHz > 381.84 Hz
3) 622 GHz > 289.64 Hz
4) 703 GHz > 327.36 Hz
5) 908 GHz >422.82 Hz
6) 1.38 THz > 321.31 Hz
7) 1.64 THz > 381.84 Hz
8) 1.88 THz > 437.72 Hz
9) 2.08 THz > 484.29 Hz
10) 2.14 THz > 498.26 Hz
11) 2.25 THz >261.94 Hz
12) 2.55 THz > 296.86 Hz
13) 1.29 THz > 300.35 Hz
14) 1.97 Thz > 458.68 Hz
15) 2.20 THz > 256.11 Hz
16) 2.32 THz > 270.08 Hz
17) 2.47 THz > 287.55 Hz

2) Terahertz measurements model Bovine Serum Albumin in watery solution, Ilaria Nardecchia et al. 2017. (Figure A2)

1) 0.314 THz > 292.44 Hz
2) 0.278 Thz > 258.91 Hz
3) 0.285 THz > 265.43 Hz
4) 0.308 THz > 286.85 Hz

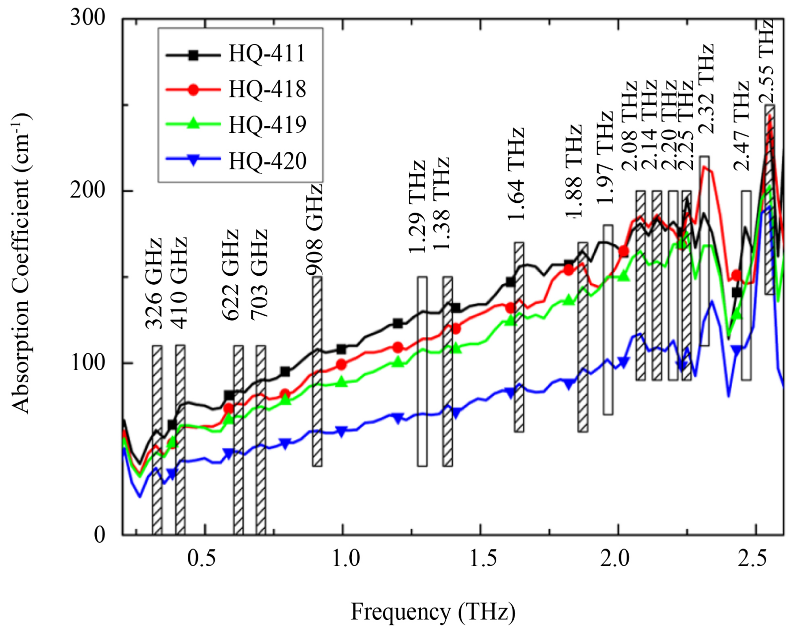

Figure A1. THz absorption spectra of oligo-nucleotide samples. Blank and patterned bars with a width of 30 GHz (spectral resolution) are depicted, respectively indicating similar and different absorption peaks of the four oligonucleotide samples.

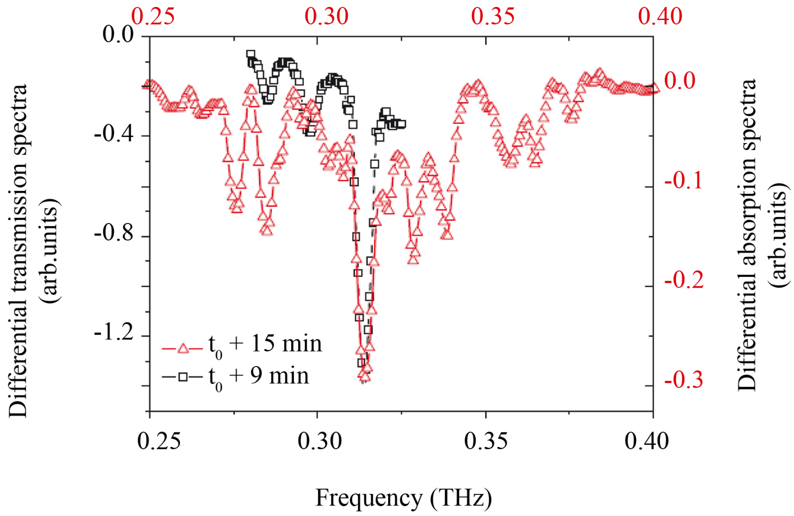

Figure A2. THz transmission and absorption spectra as functions of the model protein Bovine Serum Albumin.