In: Horizons in World Physics. Volume 296 ISBN: 978-1-53614-125-2
Editor: Albert Reimer

Chapter 1

MAN-MADE ELECTROMAGNETIC RADIATION IS NOT QUANTIZED

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ABSTRACT

In this study I argue that the energy of man-made electromagnetic fields (EMFs) and corresponding electromagnetic radiation (EMR) with frequencies starting from 0 Hz and approaching the low limit of infrared (~3×10^{11} Hz) is not quantized, in contrast to molecular/atomic/nuclear (natural) EMFs/EMR (frequencies from infrared to gamma rays).

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Molecular oscillations, electron orbits in atoms, and nucleon vibrations are stationary states of bound microparticles with discrete/quantized energy levels. They emit radiation only during finite-time transitions between such levels, resulting in quantization of the emissions, and in discrete lines of the corresponding emission spectra since quantized transitions correspond to discrete single frequencies. But unbound electrons accelerating in electric/electronic circuits (producing all man-made EMR types) are definitely not in any stationary/quantized state, and thus emit EMR continuously during acceleration. Their motions and corresponding electromagnetic emissions are not periodic, and as such their parameters cannot be represented by Fourier series. These facts suggest - in contrast to what is suggested by quantum electromagnetism (QEM) or quantum electrodynamics (QED) and dogmatically claimed in all modern physics textbooks - that man-made EMR types are not quantized, and thus do not consist of photons. The study finds no facts forcing us to accept quantization of man-made EMFs/EMR, and shows how the founders of QEM/QED arbitrarily extrapolated the quantization rules from bound to free microparticles, and performed mathematically the "quantization" of EMF/EMR assuming periodic properties. Moreover, it finds no evidence for existence of microwave or lower frequency photons, in environmentally accounted conditions. I conclude we should consider man-made EMR as consisting of continuous waves like those described by classical electromagnetism. In such a case Planck's basic quantum mechanical formula connecting energy with frequency of the light quanta ($E = h\nu$), or the quantum mechanical rules for the energy quantization of bound microparticles in molecules/atoms/nuclei, do not apply to man-made EMFs/EMR. This in turn suggests that for interaction of man-made EMFs/EMR with matter (living or inanimate) different rules may apply than in the case of natural (quantized) EMR. Thus, this study may initiate a better understanding of both the nature of man-made EMFs and their interaction with matter, especially living matter.

1. INTRODUCTION

In a recent study (Panagopoulos 2015), I objected to the corpuscular aspect of light quanta (photons) and the wave-particle duality of light (Einstein 1905a; 1909a; 1909b), showing that the Photoelectric and Compton effects (Lenard 1902; Compton 1923a; 1923b), considered the ultimate proofs for the corpuscular aspect of photons and (consequently) of the wave-particle duality of light, bear alternative explanations considering photons simply as (divisible) wave-packets and not (indivisible) "particles" of light. I suggested a new wave-packet photon model, as "a bundle of adjacent radial, independently moving waves of a certain frequency, duration, length, phase, and polarization, which is spread discontinuously in multiple directions by increasing the distances between independent adjacent radial waves. Such a wave-packet is spread within a solid angle determined by the specific conditions of its atomic/molecular source during the transition-emission. The divergence solid angle remains constant when the photon propagates in the vacuum. This wave-packet is transmitted as a part of spherical surface with radius increasing with the velocity of light, and may be absorbed either partially or even as a whole depending on the degree of its spatial confinement. The total energy of the wave-packet is hv". I named this new photon model "Spatially Confined Wave Packet" (SCWP) (Panagopoulos 2015).

The reasons I introduced this new wave-packet photon model were that, a) the wave-particle duality of light and its corpuscular aspect seem unphysical to me, b) I wanted to provide a quantum mechanical explanation for the light interference effect with a physical meaning, in contrast to the unphysical explanation of the current quantum mechanical approach (Panagopoulos 2015).

Whenever a physical/causal explanation of an effect can be found, there is no need to adopt non-causal/unphysical explanations. I would say that the wave-particle duality of light is in my opinion a totally unphysical/non-causal explanation for the properties of electromagnetic radiation (EMR).

Therefore, in the present chapter, whenever I use the term "photon", I mean divisible, finite-length, plane-harmonic wave-packets of discrete frequency v and total energy hv, transmitted with the speed of light (Panagopoulos 2015).

Another claim of mainstream modern physics regarding electromagnetic fields (EMFs)/EMR that also seems unphysical to me, is that every form of EMF/EMR is quantized i.e., consists of photons (regardless of whether these photons be wave-packets or "particles of light") (Gross 1993; Grimes and Grimes 2005; Fox 2006). This claim was introduced by the founders of quantum electromagnetism (QEM) or quantum electrodynamics (QED) (Heisenberg 1925; Born et al. 1926; Dirac 1927; 1928a; 1928b; Heisenberg and Pauli 1929; Schwinger 1948; Feynman 1949), and is entirely based on postulations and mathematical formalization, not on experimental facts.

Although it is admitted that all man-made electromagnetic emissions from electric/electronic circuits can be perfectly described in terms of continuous electromagnetic waves, as those described by classical electromagnetism (Maxwell theory), all physics textbooks take for granted that these emissions consist of photons, each having energy given by the famous Planck equation $E = h\nu$. Yet the very same books do not use the quantum theory to describe these electromagnetic emissions, but use the theory of classical electromagnetism applying to continuous waves (Alonso and Finn 1967; Reitz and Milford 1967; Jackson 1975).

The development of the quantum theory of the EMF (QEM/QED) established the generalization that every form of EMF/EMR - regardless of the way it is produced - consists of photons, and that electromagnetic interactions are mediated by photons. QEM/QED formed a mathematical basis for this generalization, describing all electromagnetic phenomena by photon interactions. Certainly, the mathematical formulation of a theory is an indication that the theory may be correct, but does not prove that it really is. Especially when the mathematical formulation is invented in order to reach a desired result. Several eminent quantum physicists since the early years of the formulation of QEM/QED and until today have objected to the need for a quantum theory applying to every form of EMF/EMR, in other words they have objected to QEM/QED (Jaynes 1966; 1978; 1980; Lamb and Scully 1969; Hunter and Wadlinger 1989; Roychoudhuri et al. 2008; Roychoudhuri 2014).

QEM/QED was formulated mainly by Heisenberg (1925), Born et al. (1926), Dirac (1927), Heisenberg and Pauli (1929), who applied the Fourier theory to “quantize” the EMF as this was described by the Maxwell equations. The final step was made by Schwinger (1948) and

Feynman (1949) with the so called renormalization theory (Bialynicki-Birula and Bialynicka-Birula 2005)[1]. The whole procedure was strictly mathematical and there were no experimental facts that demanded the "quantization" of EMF/EMR.

Until our days, mainstream quantum physicists claim that "electromagnetic signals are always composed of photons, although in the circuit domain those signals are carried as voltages and currents on wires, and the discreteness of the photon's energy is usually not evident", in line with QEM/QED (Schuster et al. 2007). While they take for granted the existence of photons in the man-made frequency band closest to infrared called Radio Frequency (RF) or microwave band, they admit that single microwave photons have not been detected: "Verifying the single-photon output is a substantial challenge in on-chip microwave experiments. The simplest approach, that of looking for a photon each time one is created, is not currently possible; no detectors can yet resolve single microwave photon events in a single shot" (Houck et al. 2007). While the alleged evidence for existence of RF/microwave photons is highly controversial, there is absolutely no evidence for existence of lower frequency photons than RF/microwave, such as Very Low Frequency (VLF) ($\sim 3000\text{-}3\times10^{6}$ Hz), or Extremely Low Frequency (ELF) (0-3000 Hz) photons.

I introduce the opinion that man-made EMFs/EMR do not consist of photons but rather of continuous waves as described by classical electromagnetism. I shall attempt to support this by discussing specific aspects of EMFs/EMR, by re-examining related facts that led to the formulation of QEM/QED which may bear alternative explanations, and by showing that the "quantization" of EMF was strictly mathematical, based on arbitrary simplistic postulations, and not based on physical/ experimental data. [Like previously (Panagopoulos 2015), by "man-made EMFs/EMR" I refer to artificially produced electromagnetic emissions

[1] [After the late 1960's, QED was included in a more generalized theory unifying the electromagnetic, weak, and strong interactions, called the Standard Model (Burcham and Jobes 1995)].

with frequencies ranging from 0 Hz to the low limit of infrared ($\sim 3\times 10^{11}$ Hz)].

According to the *Fourier theory,* all periodic motions of any frequency can be represented as a sum of discrete harmonic oscillations with a basic frequency v, and its harmonic frequencies $2v$, $3v$, … etc. Non-periodic functions/motions may also be developed into Fourier series but then the Fourier series do not approach the initial functions. One of the three Dirichlet conditions in order for a Fourier series to approach the initial function, is that the initial function must be periodic. Therefore, non-periodic undulations cannot be represented as a sum of discrete harmonic terms. Except for the Fourier series, any continuous and integrable function periodic or not can be transformed by the Fourier integral/transformation into another continuous function consisting of infinite number of (non-discrete) harmonic terms (Stephenson 1973; Spiegel 1974). But a continuous function with no discrete terms is not "quantized". It seems that this simple mathematical conclusion (and the natural fact that represents) was overlooked by the founders of QEM/QED and their successors.

The total energy of a simple harmonic oscillator has a constant specific value according to classical physics, and may take a number of specific values according to quantum mechanics (Trachanas 1981). Since any periodic motion can be analyzed into a sum of harmonic oscillations, it comes that the energy of any periodic motion can only take discrete values, in other words it is quantized. All bound microparticles in matter are considered to be in perpetual periodic motion (or at least approximately periodic), and moreover at stationary states so that they do not lose energy, due to some unknown mechanism[2]. While this can be expected for particles that do not bear a net electric charge and assumed to constitute an isolated system with no friction forces exerted on them, it is inexplicable for charged particles in accelerated motion. The only way for bound microparticles to emit/absorb energy is to jump between different

[2] Such an unknown mechanism may be related to production of non-radiative standing (stationary) waves by the bound microparticles, and a continuous exchange of energy between the microparticles and the corresponding standing waves.

stationary levels/states. The energy difference between each two specific stationary states corresponds to a quantum of energy that is emitted/absorbed in the form of a plane harmonic wave-packet (photon) of discrete frequency, energy, polarization, and phase. Photon energy and frequency are connected according to Planck's formula (see Eq. 1 below). This is the reason why the emission spectra of all chemical compounds (atoms, molecules, ions) contain discrete lines/frequencies corresponding to transitions between discrete (quantized) energy levels (Herzberg 1944; 1950; Beiser 1987).

Obviously there is an intrinsic property of matter, in order to keep its stability, that the energy of its particles in a bound state can only take discrete values, in other words it is quantized. Atoms bound in a molecule, electrons bound in an atom, nucleons bound in a nucleus, are in constant periodic motions at stationary states (energy levels). Transitions from one discrete energy level to another are very fast (estimated to be on the order of $\sim 10^{-9}$ s for electrons) and during this time a wave-packet of certain frequency and length (~ 30 cm) is emitted/absorbed (Beiser 1987; Panagopoulos 2015). These nanosecond wave-packets are the photons. Photons produced by specific transitions (molecular/atomic/nuclear) have discrete frequencies, and thus give discrete lines in molecular/atomic/nuclear emission spectra (Herzberg 1944; 1950; Klimov 1975; Burcham and Jobes 1995). [Usually molecular and nuclear spectra appear as continuous with broadened lines, but in high resolution the discrete lines become visible].

In contrast to bound charged microparticles, free charged particles emit EMR continuously during acceleration, as predicted by classical electromagnetism (Alonso and Finn 1967). This is very different from a quantized emission. The continuous emission does not last for the short time of a transition ($\sim 10^{-9}$ s) and does not consist of discrete wave-packets of finite length, but of continuous waves emitted uninterruptedly for as long as the acceleration lasts. No matter if the continuous accelerated motion is periodic or not.

Even though the developed theory of QEM/QED mathematically predicts the existence of photons at all frequencies (both above and below infrared) (Gross 1993; Grimes and Grimes 2005), the following facts contradict the validity of such a prediction: 1) There is absolutely neither experimental proof nor any physical explanation for the existence of photons at frequencies below infrared, in environmentally accounted conditions. 2) There are no discrete lines in antennae spectra. 3) It is generally accepted that any interaction of man-made EMFs (from ELF to RF) with matter (both biological and inanimate) is very successfully studied by use of classical electromagnetism, not QEM/QED. 4) As will be shown below (section 6), the "quantization" of the EMF was strictly mathematical, not dictated by experimental facts, and performed by assuming simplified conditions of harmonic/periodic properties for the EMF. 5) While the existence of infrared/visible/ultraviolet/ionizing photons is supported by well documented phenomena such as excitation/de-excitation, the photoelectric, the Compton, or the pair production effects (Klimov 1975), there are no corresponding phenomena indicating production of photons at frequencies below infrared in environmentally accounted conditions.

Nevertheless, all modern physics textbooks - in line with QEM/QED - take for granted that all EMR types (including man-made EMR) consist strictly of photons, just like radiations produced by molecular/ atomic/nuclear quantized transitions. I believe it is time for this to be reconsidered.

2. Photons versus Continuous Waves

Continuous wave means that the emission of EMR is continuous/uninterrupted and the length of the wave increases infinitely as long as the emission lasts. This is different from the time-finite emission in the form of discrete wave-packets of finite length (photons).

A continuous harmonic (sinusoidal) wave contains a single frequency. A continuous periodic but not harmonic wave contains a basic frequency and its harmonics (multiples). A continuous non-periodic undulation/wave contains a continuous range of frequencies (Trachanas 1981). In any case, a continuous wave (periodic or not) can be of infinite length, corresponding to an emission of infinite duration (e.g., a perpetual accelerating motion of an unbound charged particle).

It is well-documented that natural forms of EMR with frequencies higher than the low limit of infrared (infrared, visible, ultraviolet, x-, and gamma-rays) consist of photons with energies corresponding to molecular, atomic, or nuclear transitions between different stationary energy levels. Individual sources of these natural forms of EMR (molecules/atoms/nuclei) produce spectra with discrete lines. EMR corresponding to the continuous part of x-ray spectra is emitted by retarding free electrons, and I suggest it should be reexamined whether it really consists of photons and not of continuous waves.

Cosmic microwave radiation is known to be of originally higher frequency (infrared/visible) which reaches the earth with lower frequencies due to the Doppler Effect taking place because of the cosmic expansion (Durrer 2008; Panagopoulos 2013). It is considered to be “a cooling black body radiation in an expanding universe that retains its black body spectrum form” shifted towards lower frequencies (Durrer 2008). Thus cosmic microwaves consist of photons, but these microwaves are actually very different from man-made microwaves in all other properties except frequency: They are not polarized in contrast to man-made which are totally polarized, and they consist of photons while man-made are continuous waves as I shall explain.

RF/microwave photons are produced in Nuclear Magnetic Resonance (NMR) and Electron Spin Resonance (ESR) spectroscopy in the presence of an intense static magnetic field (on the order of ~1 T) (Gautreau and Savin 1978; Poole 1983) (see section 7.2). But such strong static magnetic fields do not exist in electronic circuits that produce artificial RF/microwave EMR, neither in the natural human environment. The intensity of the terrestrial static magnetic field is ~ 0.5 G $= 0.5\times10^{-4}$ T which is much smaller (~ 20000 times) than the magnetic field in NMR/ESR spectroscopy. Even if we accept that RF/microwave photons can be produced naturally in certain environments (e.g., in stars) in the presence of strong static magnetic fields, this does not occur in man-made electronic oscillation circuits which generally do not operate in the presence of such fields. Electronic transitions between hyperfine energy splitting levels in atoms corresponding to RF photons are theoretically predicted. Yet, they do not occur naturally/spontaneously but only after stimulation (see section 7.3).

In addition, there are no effects in nature known to produce photons of lower frequency than RF, i.e., we do not know any effects producing VLF, or ELF photons. Ionic oscillations discovered in all living cells with ELF frequencies on the order of 0.01-0.1 Hz are continuous oscillations (Panagopoulos 2013) and thus emit continuous waves, not photons. Similarly, atmospheric discharges in the VLF and ELF bands, as well as all forms of EMR produced by all man-made electric/electronic circuits (e.g., power lines, antennas etc.).

Actually, the only proofs for the natural existence of photons are the discrete lines of atomic/molecular/nuclear spectra, and the undeniable ability of Planck's law to explain in terms of energy quanta the "black body" emission spectra (Panagopoulos 2015)[3]. All these spectra refer to natural electromagnetic emissions (infrared, visible, ultraviolet, x-ray line spectra, gamma rays). The "black body" continuous spectrum, as well as the emission spectrum of any natural object in terrestrial environmental conditions, do not contain frequencies lower than infrared.

Bohr's theory for the energy quantization of atomic matter which followed Planck's theory (Bohr 1913a; 1913b; 1914; 1928) and explained the experimentally observed facts of atomic spectra, refers to photon emissions in the visible, ultraviolet and x-ray bands, and is related to transitions between bound electron states. The same holds for the line spectra of molecular and nuclear transitions in the infrared and gamma bands respectively (Beiser 1987). The molecular, atomic and nuclear line spectra refer to frequencies higher than the low limit of infrared, and in no case to lower frequencies.

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[3] The photoelectric effect does not actually provide any proof for the existence of photons, in spite of opposite claims, since it can be explained by purely statistical/thermodynamical principles combined with the laws of classical electrodynamics (Richardson 1912; Lamb and Scully 1969).

Thus, it is important to emphasize, that all natural/spontaneous quantized electromagnetic emissions in environmental conditions have frequencies higher than the low limit of infrared (including the cosmic microwaves which were originally infrared/visible radiation as explained). As such they are very different from EMR types which produce continuous waves and have frequencies lower than infrared. This category includes all man-made EMR types.

3. Line versus Continuous Spectra

Continuous emission spectrum means that it does not contain discrete lines/frequencies, but a continuous range of frequencies.

Any continuous emission spectrum may be attributed either to a) Acceleration of unbound charged microparticles, such as free electrons/ions accelerated by an applied electric field, or b) Transitions of bound microparticles corresponding to a continuous range of photon frequencies resulting in this way in a seemingly continuous spectrum that even a spectrum analyzer with the highest resolution cannot discriminate the individual spectral lines, or c) a combination of both a and b cases.

The continuous emission spectra of sunlight, lamps, x-rays, RF/microwave antennas, cosmic microwaves, atmospheric discharges, should perhaps be attributed at least in part to accelerating free charged particles such as free electrons/ions which certainly exist in the above EMR sources, and not necessarily to quantized transitions (photons) exclusively.

One could undoubtedly clarify whether a certain continuous emission spectrum is due to accelerating free microparticles or quantized transitions (photons) of a continuous frequency range, were it indeed possible to detect discrete photons from the emission source. But it is not, in spite of opposite claims in modern physics texts. In fact what are really detected are “clicks” in photomultipliers (detectors). Each “click” represents the emission of a discrete photoelectron induced by the absorbed radiation, and this is erroneously interpreted and widely established as the absorption of a discrete photon (Roychoudhuri and Tirfessa 2008). But highly accurate photon counting experiments have recently shown that actually the simultaneous detection of multiple photons ("multiple units of *hν*") is necessary for the emission of a single photoelectron, and thus the production of a single "click" on a detector does not correspond to the detection of a single photon (Panarella 2008). Thus, in reality, single photons have not been detected, in spite of opposite claims in all modern physics textbooks (Roychoudhuri et al. 2008; Roychoudhuri 2014). Since photoelectron emission can also be induced by partial absorption of a (divisible) continuous wave, there is no way to verify beyond doubt the existence of photons by use of photomultipliers.

Therefore, we cannot undoubtedly verify the existence of photons in the continuous spectra, and it is actually only the line spectra that show the existence of photons with discrete frequencies, emitted by bound microparticles.

A single charged free microparticle accelerating in the vacuum due to an alternating applied voltage may move periodically and then its emission spectrum would (theoretically) contain only discrete lines/frequencies. But in electric/electronic circuits we do not have a single microparticle accelerating in the vacuum due to a perfectly alternating applied voltage. Instead we have innumerable microparticles (free electrons) moving not periodically (even in case of a perfectly alternating field), each one's individual period/frequency slightly differing from all others' due to the chaotic friction forces which are different for each individual microparticle, plus their random thermal motion which is also different for each one. This is why EMR produced by accelerating free charged microparticles gives continuous emission spectra.

In conclusion, bound charged microparticles produce photons and line spectra, while free charged microparticles during acceleration produce continuous waves and continuous spectra. This distinction/clarification is fundamental for understanding the arguments of the present study.

4. Differences between Natural and Man-Made EMFs/EMR

There are several important differences between natural and man-made EMFs/EMR, mainly regarding polarization, frequency, and bound versus unbound emission sources. These differences indicate that man-made EMFs should not be treated identically to natural ones, and their interaction with matter - especially living matter - should be given special attention. This is also in light of the widespread use of modern technology employing such fields and the consequent increase in health concerns in recent years. Let us briefly discuss these differences.

The first important difference regards *frequency* bands. Natural EMFs/EMR cover the higher frequency bands of the electromagnetic spectrum, from infrared to gamma rays. Sole exceptions are: a) The VLF/ELF EMFs of atmospheric discharges (lightning), which probably are the stimulus for the ELF ionic oscillations in all animal cells responsible for brain and cardiac activity as well as the animals' biological clocks. b) The terrestrial electric and magnetic fields which are basically static with ELF variations (Panagopoulos 2013; Panagopoulos and Balmori 2017). Man-made EMFs/EMR cover the lower frequency bands, from 0 Hz to the low limit of infrared (~ 3×10^{11} Hz).

Another important difference concerns *polarization*. Man-made EMR (such as ELF, VLF, RF) emitted by circuits/antennas, is totally polarized, most frequently linearly polarized, oscillating on a certain plane determined by the orientation and geometry of the antenna/circuit. In contrast, natural EMR (cosmic microwaves, infrared, visible, ultraviolet, gamma) is never polarized, and may only be partially polarized to a small degree under certain conditions. For example, in the case of natural light, each photon it consists of oscillates on a different discrete plane (Panagopoulos et al. 2015).

Last but very important difference concerns *bound versus unbound* emission sources. Natural EMR is produced by quantized transitions (excitations/de-excitations) of bound charged microparticles in molecules, atoms and nuclei, and consists of discrete wave-packets (photons). In contrast, man-made EMR types (and the above mentioned atmospheric/terrestrial/biological natural ELF/VLF EMFs), are produced by acceleration of free electrons/ions due to an applied EMF. Since this motion is continuous for as long as the EMF is applied and not periodic in general, the emitted electromagnetic waves do not consist of discrete wave-packets of finite length (photons), but of continuous waves like those described by classical electromagnetic wave theory.

5. Examination of Facts Related with EMF/EMR Quantization

5.1. Planck's Postulates and Interpretation of the "Black Body" Spectra

The concept of quanta or photons as the energy elements of a radiating body was first introduced by Max Planck in his 1901 legendary study on "black body" radiation[4]. Planck postulated that the emission of electromagnetic energy from a "black body" is quantized and that the energy element at any specific frequency is proportional to that frequency v (Planck 1901):

$$E = h \cdot v \tag{1}$$

($h = 6.625\times10^{-34}$ J$\cdot$s is the Planck's constant).

More specifically, Planck postulated that: a) The molecules on the walls in the interior of the "black body" cavity oscillate producing multiply reflected electromagnetic waves within the cavity, and these waves are

[4] A "black body" is an object that completely absorbs light falling on it, becoming a source of thermal radiation. A good example is a cavity with a small hole. The cavity absorbs light through the hole, traps it inside increasing its temperature, and emits secondary thermal radiation.

then emitted outside once they are emitted/reflected towards the cavity's hole. b) There is an energy element in the molecular oscillations (and the corresponding produced waves) at each individual frequency v. This energy element is given by hv, and the total energy E_n at frequency v is an integer multiple of this energy element: $E_n = nE = nhv$, (n an integer number).

Based on the above postulates and after mathematical/statistical operations, Planck found that the average radiating energy U of each resonator (oscillating molecule) at frequency v is described by the equation:

$$U = \frac{h\nu}{e^{\frac{h\nu}{kT}} - 1} \tag{2}$$

($k = 1.381\times10^{-23}$ J·K^{-1} is the Boltzmann constant, T the temperature in °K).

Multiplying U by the number of resonators per unit volume per unit frequency ($\frac{8\pi\nu^2}{c^3}$) he got the spectral energy density $u(v)$ of the emitted radiation (energy per unit volume per unit frequency) which is the famous Planck's law (Planck 1901; Trachanas 1981; Beiser 1987):

$$u(v) = \frac{8\pi h\nu^3}{c^3}\frac{1}{e^{\frac{h\nu}{kT}} - 1} \tag{3}$$

($c = \lambda v$, is the velocity of light in the vacuum/air, λ the wavelength).

Planck's law (Eq. 3) successfully explained the already known spectra of the black body radiation, and since its derivation was based on the assumption that the energy of each individual resonator at a given frequency v is an integer multiple of the elementary amount hv, his assumption was considered correct. Then Planck calculated the value of the constant h based on earlier experimental measurements on the black body radiation.

Planck's law implies that the *emission* of electromagnetic energy by individual oscillating molecules is quantized in integer multiples of the quantity *hv* at each individual frequency, and the unit of quantization is *h* (Planck's constant). The quantization of electromagnetic emission discovered/introduced by Planck clearly implied that the atomic/molecular energy is quantized as well, which was explicitly postulated by Niels Bohr twelve years later (Bohr 1913a; 1913b; 1914; 1928).

It should be underscored that Planck's finding was that *only the emission of light* (natural EMR) is quantized, not the absorption or the transmission, neither that EMR in general is quantized (Kuhn 1978; Tarasov 1980; Brush 2007).

The following remark and question arise from Planck's theory.

1. Remark: Obviously, the quantized emission of black body radiation is not due to the stationary molecular oscillations themselves, but to transitions between different stationary oscillation states. That was not known at the time Planck published his theory (1901), becoming known after Bohr's contribution (1913). While already oscillating at stationary states, molecules on the cavity walls of the black body become excited to higher energy levels by radiation absorption. Then de-excitation to the initial energy levels produces quantized electromagnetic radiation in multiples of *hv* at each individual frequency *v*.

2. Question: Since the black body emission is quantized, why is the spectrum continuous rather than consisting of discrete lines? A probable answer may be that the frequencies of the quantized emissions (photons) cover the whole range of the spectrum in such a dense way that even a spectrum analyzer with the highest resolution cannot discriminate the adjacent individual emission lines. Nevertheless, there is no such statement neither in the original publication (Planck 1901) nor in subsequent studies of the black body spectra (Gautreau and Savin 1978; Beiser 1987).

An alternative explanation may be that, in reality, the black body emission spectrum is a combination of discrete lines - as this is in agreement with the quantized emission - and a continuous background, in a way that the superposition of the two results in a seemingly continuous spectrum. The continuous background may be due to electrons/ions detached from the molecules of the cavity walls and accelerated as free particles due to thermal motion. Perhaps this possibility should be investigated by physicists specialized in acquiring high resolution emission spectra.

5.2. Quantization Rules for Bound Microparticles and Explanation of the Atomic Spectra

In order to explain the discrete lines of atomic emission/absorption spectra, and the stability of atoms despite the fact that electrons should constantly lose energy during their motions around the nuclei, Bohr postulated that the energies of the electrons bound in all atoms are quantized on discrete stationary levels, and electrons do not radiate while being on these stationary states despite their accelerated motion. [As suggested, they may produce non-radiative standing waves conserving their energy in this way]. Radiation is only emitted/absorbed during transitions from one stationary energy level to another, in the form of discrete energy amounts (quanta). This general postulate for the quantization of the electronic energies in all atoms was specifically applied by Bohr on the study of the hydrogen atom with a single electron in a cyclic orbit. The application was extended by Sommerfeld-Wilson for any periodic motion in a single-electron atom, and by Schroedinger for any periodic motion in the multi-electron atoms of all chemical elements. The Bohr-Sommerfeld-Wilson quantization rules allowed the calculation of the stationary energy levels in the hydrogen atom and in single-electron ions which really corresponded to the observed frequency lines of the corresponding atomic spectra. This fact proved correct Bohr's postulate for the energy quantization of electrons bound in atoms, and soon it was found that similar quantization rules apply to all bound microparticles not only in atoms, but also in molecules, and nuclei (Gautreau and Savin 1978; Tarasov 1980; Beiser 1987).

The energy quantization of all molecules, atoms, and nuclei explains their stability. The quantization implies that bound microparticles in molecules/atoms/nuclei cannot spontaneously jump from one stationary state to another, as that would require the absorption/emission of energy quanta (photons) corresponding to the energy differences between different stationary states. This perfectly explains the stability of matter. If bound electrons' energies were to take not only these certain values, the electrons would constantly lose energy due to their acceleration around the nuclei (with consequent emission of EMR), and inevitably would collapse and fall on the nuclei. In such a case, no matter would exist in the form of the chemical elements we know. A direct consequence of this is that molecules/atoms/nuclei emit and absorb only discrete amounts of electromagnetic energy (photons) corresponding to transitions between different distinct stationary energy levels (states). It was found that the energy differences between different stationary states in molecules/atoms/nuclei correspond to all known photon frequency bands of natural electromagnetic emissions (from infrared to gamma rays). More specifically, transitions between different molecular oscillation energy levels correspond to the emission/absorption of photons in the infrared band, electronic transitions in atoms correspond to photons in the visible, ultraviolet, and x-ray bands, and nuclear transitions correspond to photons in the gamma-ray band (Gautreau and Savin 1978; Beiser 1987).

No transitions were found to correspond to photon energies/ frequencies below infrared, except for photons in the RF/microwave band emitted after excitation and/or in the presence of a strong static magnetic field (as described in the Stern-Gerlach effect) manifested in the NMR and ESR spectroscopy and the maser microwave amplifiers (see sections 7.2, 7.3).

Bohr Rules for the Hydrogen Atom

From the empirically known combination principle in spectroscopy (Ritz 1908; Tarasov 1980), it was already known that the spectral line frequencies in the atomic spectra are differences between other frequencies called spectral terms. Thus, any spectral line (frequency) v can be written as:

$$v = v_m - v_n \tag{4}$$

where v_m, v_n are spectral terms (m, n integer numbers). Multiplying both parts of Eq. 4 by Planck's constant we get the corresponding photon energy for each spectral frequency:

$$hv = hv_m - hv_n$$
$$\text{or } hv = E_n - E_m \tag{5}$$
(Bohr's 1st rule)

$$\text{where } E_n = - hv_n \text{ and } E_m = - hv_m \tag{6}$$

Eq. 5 (Bohr's 1st rule) declares that the energies of the bound electrons in atoms are quantized, and the transition of an electron from a higher to a lower permitted energy level is accomplished by the emission of a photon corresponding to the energy difference between the two levels. Eqs. 6 declare that the permitted energy levels (stationary states) in the atoms correspond to the frequencies of the spectral terms (Bohr 1913a; 1913b; 1914; Tarasov 1980; Trachanas 1981). [These energy levels have to be negative (Eqs. 6) since we must supply energy in order to detach a bound electron and make it free with zero energy].

Considering the motion of the single electron in the hydrogen atom, its total energy (kinetic plus potential) is:

$$E = \frac{1}{2} m_o u^2 - k \frac{q_e^2}{r} \tag{7}$$

and for a perfectly cyclic orbit with constant angular velocity[5] around the nucleus,

$$k \frac{q_e^2}{r^2} = m_o \frac{u^2}{r} \tag{8}$$

---

[5] (which is the most simplistic case but still reasonable for a bound microparticle)

(m_o, q_e, u, r, the electron's rest mass, charge, velocity, and orbital radius respectively, $k = 1/4\pi\varepsilon_o$, $\varepsilon_o = 8.854\times10^{-12}$ $C^2/N\cdot m^2$ the vacuum permittivity).

Moreover, it was experimentally found by spectroscopic analysis, that the sequence of spectral terms (corresponding to the stationary energy levels) for the hydrogen atom satisfied the equation:

$$\nu_n = \frac{R}{n^2} \text{ with } n = 1, 2, 3, \ldots \tag{9}$$

(Balmer formula)

where $R = 3.27\times10^{15}$ s^{-1} is an empirical parameter called Rydberg constant.

Multiplying by h and combining with (6), we get:

$$E_n = -\frac{hR}{n^2} \tag{10}$$

The electron's orbital angular momentum l has the same units as h ($kg\cdot m^2\cdot s$), and in the case of a circular motion with a constant angular velocity it is $l = m\cdot u\cdot r$. In that case according to Eqs. 7, 8: $l = q_e^2 \sqrt{\frac{m_o}{2|E|}}$

Substituting the energy E by the quantized energy states provided by Eq. 10, we get:

$$l_{\mathrm{n}} = q_e^2 \sqrt{\frac{m_o}{2hR}}\, n \tag{11}$$

Applying the values of m_o, q_e, h, R, we get that:

$$q_e^2 \sqrt{\frac{m_o}{2hR}} = \hbar \ (= h/2\pi) \tag{12}$$

Combining Eqs 11 and 12, we get that the orbital angular momentum of the electron in the n^{th} stationary orbit of the hydrogen atom, is

$$l_n = n\ \hbar \tag{13}$$

(Bohr's 2nd rule)

This in brief is how Bohr was led by the spectroscopic data and simple mathematics/physics to the quantization of electron energy and orbital angular momentum in the hydrogen atom. Bohr's theory could explain very well the hydrogen spectrum, and the atomic stability (Bohr 1913a; 1913b; 1914; 1928; Tarasov 1980; Trachanas 1981).

The Sommerfeld-Wilson Generalized Quantization Condition

The success of Bohr's theory initiated the quest for a more general quantum condition which could apply not only to circular electron orbits in the hydrogen atom, but to any type of periodic electron motion, such as elliptical orbits, or harmonic oscillations.

A characteristic quantity for a closed orbit is the integral $\oint p \cdot dq$, with q any coordinate and p the corresponding momentum. This quantity has also the same units as angular momentum or h. In line with Bohr's second quantization rule, Wilson (1915) and Sommerfeld (1916) suggested the more generalized quantization condition:

$$\oint p \cdot dq = nh \tag{14}$$

The Sommerfeld-Wilson quantization condition (14) could explain more cases of a single charged bound microparticle in any periodic motion such as harmonic oscillations (e.g., atoms in diatomic molecules), or elliptical orbits (electrons in hydrogen atoms). Bohr's 2nd quantization rule (13) or even Planck's quantization formula (1) can be deduced as specific cases of this more general quantization condition.

The reason for this brief description of Bohr's and Sommerfeld-Wilson's quantization rules has been to show that until that point, quantum mechanics was strictly causal and provided an absolutely physical interpretation of the natural phenomena of the atomic/sub-atomic world known at that time. Although these rules could not explain very well the energy levels of the multi-electron atoms, they formed a strictly causal basis for the interpretation of the molecular/atomic world.

The Schroedinger Equation

In his attempt to find an equation to describe the energy of the electronic "matter-waves" (De Broglie 1924) of the many-electron atoms, Schroedinger took the classical wave-function

$$\xi(r, t) = e^{i(kr-\omega t)} \tag{15}$$

which describes a plane harmonic wave[6] of circular frequency $\omega = 2\pi v$ (v the frequency) and wave-number $k = 2\pi/\lambda$ (λ the wavelength), at distance r from its source along the direction of propagation [i is the imaginary unit ($i^2 = -1$)] (Alonso and Finn 1967).

Then he substituted ω and k by their corresponding quantum mechanical expressions (derived directly from Planck's and De Broglie's equations respectively):

$$\omega = E/\hbar \text{ and } k = p/\hbar$$

and derived what he called the quantum mechanical "wave-function" in direct analogy with the classical wave-function (Schroedinger 1926; Trachanas 1981):

$$\psi(r, t) = e^{i(pr-Et)/\hbar} \tag{16}$$

[6] The fact that Eq. 15 describes a plane harmonic wave comes from the Euler formula, $e^{i\theta} = cos\theta + isin\theta$ (Stephenson 1973), with the convention that physical quantities are obtained by taking the real parts of complex quantities (Jackson 1975). Thus, a physical wave described by Eq. 15 depends solely upon $cos\theta$ (which is a harmonic function of time) and therefore it is a plane harmonic wave.

The square of the wave-function ψ^2 supposedly describes the probability for the particle to be localized at the position *r* at a certain instant *t* (e.g., the probability for an electron to be found at distance *r* from the nucleus at a given instant). That was arbitrarily accepted, also in analogy with classical wave physics where the square of the oscillating quantity (wave function) is proportional to the energy density of the wave.

Thus Schroedinger identified the energy density of the matter-wave associated with the electron at a specific location around the nucleus, as the probability of finding the electron at this location.

Differentiating Eq. 16 with respect to *r* and *t*, we get correspondingly:

$$-i\,\hbar(\partial\psi/\partial r) = p\,\psi \tag{17}$$

and $$i\,\hbar(\partial\psi/\partial t) = E\,\psi \tag{18}$$

Eqs 17, 18 declare that the operator $-i\hbar(\partial/\partial r)$ corresponds to the momentum, and the operator $i\hbar(\partial/\partial t)$ to the energy of the particle.

In classical physics the total (conserved) energy value E of a particle with mass m and momentum p moving in a potential $V(r)$ is given by the Hamiltonian function

$$H(r, p) = p^2/2m + V(r) \tag{19}$$

and it is the sum of kinetic and potential energy. Thus, the equation

$$E = p^2/2m + V(r)$$

expresses the energy conservation law.

Since the wave-function $\psi(r,t)$ was introduced to represent the wave associated with the particle under study, Schroedinger demanded a-priori that it must satisfy the equation:

$$E\,\psi = (p^2/2m)\,\psi + V(r)\,\psi \tag{20}$$

Substituting in the last equation the energy and momentum by the corresponding operators from Equations 17, 18, we get:

$$i\,\hbar(\partial\psi/\partial t) = -(\hbar^2/2m)(\partial^2\psi/\partial r^2) + V(r)\,\psi \tag{21}$$

Thus, Equation 21 supposedly describes the energy conservation law for a "matter-wave" at position r and it is called the Schroedinger equation in one dimension.

For a particle/"matter-wave" moving in three dimensions the Schroedinger equation becomes:

$$i\,\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi + V(r)\,\psi \tag{22}$$

(where: $\nabla^2 = \partial^2/\partial x^2 + \partial^2/\partial y^2 + \partial^2/\partial z^2$ the Laplace operator)

With the introduction of the Schroedinger Equation, the defined trajectories of microparticles (considered in classical physics) are replaced by wave functions.

According to Eq. 22, the quantum mechanical wave-function cannot be a Real function since in such a case the first part of Eq. 22 would be imaginary and the second part real which is impossible. Thus, ψ does not represent a real wave that can be physically observed (measured/detected) as with classical waves in which the wave-functions are Real functions. It is a complex function possessing a real part and an imaginary part, and represents a "probability wave". Its square supposedly represents the probability density for finding the particle at a certain location a certain instant (Schroedinger 1926; Trachanas 1981; Beiser 1987).

As claimed by quantum physicists, the Schroedinger equation was successfully applied to describe the motion of bound elementary particles, such as the electrons in an atom. Its solutions are certain expressions for the wave-function. In the simplest case of the hydrogen atom with a single electron, the Schroedinger equation gives the orbital shapes corresponding to the energy values for the electron predicted by Bohr and Sommerfeld-

Wilson. The quantum numbers introduced by empirical spectral formulas and adopted by Bohr and Sommerfeld-Wilson to describe the stationary energy states of the electron in the hydrogen atom, can be deduced by solving the Schroedinger equation for this atom. Similarly, the shape of the electron "cloud" in the different stationary states (shape of the orbitals) can be deduced by solving the Schroedinger equation. Thus, it seems that the Schroedinger equation describes the hydrogen atom in the best possible way.

But as admitted, for multi-electron atoms the equation becomes too complicated to be solved and we have to accept that the electrons occupy successive electronic states/orbitals of the hydrogen atom. In this way, the many-electron atoms are described approximately with combinations of single-electron orbitals (Katakis 1976).

Nevertheless, it should be noted that despite the arbitrary assumptions made by Schroedinger in order to derive his equation (22), there was a causal reasoning in his methodology up to this point, and this is probably the reason why this equation seems to really work in describing the electronic states in atoms. But causality was about to be ruined in the next step…

5.3. Quantization Extrapolated from Bound to Free Microparticles

Although the Schroedinger equation was originally written to describe the energy of electrons bound in atoms (since they were described by harmonic wave functions with quantized energy), it was arbitrarily extrapolated for the case of a free electron/particle with zero potential energy [$V(r) = 0$] when it was also written by Schroedinger himself as,

$$i\,\hbar \frac{\partial \psi}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 \psi \tag{23}$$

But in such a case, how is it possible that a harmonic wave function (Eq 16) with quantized energy is attributed to a free particle? By doing this it was automatically assumed that any free particle can only have discrete energy values by itself, and regardless of whether this particle is in periodical motion bound in an atom, or not. This in my opinion is totally arbitrary, unphysical, and the start of a wrong direction that was to be followed… Causality was ruined by this step.

So, here is a *First general Remark*: The Schroedinger equation was introduced to describe the position of an electron *bound* in an atom. The energy of electrons bound in atoms is quantized as proved by Bohr who explained the discrete lines of atomic spectra. For this reason, a harmonic wave-function and quantized energy were utilized. How does it come that this equation is extrapolated to account for a *free* electron/particle for which there is absolutely no evidence (even today) that its energy is quantized? This totally arbitrary extrapolation was made by Schroedinger, and followed by Klein, Gordon, Dirac, Heisenberg and everybody else at that time, when they all adopted this equation to describe a free particle (!), and this was surprisingly accepted by everyone else in the quantum physics community until today without any objections.

5.4. The Relativistic Wave Equation for a Free Particle

Due to the relativistic speeds of the electrons bound in atoms, and the fact that all phenomena should be independent of any particular reference frame, the Lorenz transformations of special relativity should be incorporated in the Schroedinger equation (Gross 1993).

The Klein-Gordon Equation

Applying Schroedinger's transformations (17), (18) for energy and momentum in the relativistic equation

$$E = \sqrt{c^2 p^2 + m_o{}^2 c^4}$$

between energy and momentum where p and m_o the particle's momentum and rest mass respectively (Einstein 1905b), multiplying by the wave function ψ and ignoring the potential energy $V(r)$ (meaning that the whole operation refers to a free particle), Klein and Gordon reached the following relativistic form of Schroedinger's equation, called the Klein-Gordon Equation for a free particle (of zero potential energy):

$$-\hbar^2 \frac{\partial^2 \psi}{\partial t^2} = -c^2\hbar^2\nabla^2 \psi + c^4 m_o{}^2 \psi \qquad (24),$$

or $$(\nabla^2 - \frac{1}{c^2}\partial_t{}^2)\psi = \frac{m_o{}^2 c^2}{\hbar^2}\psi \qquad (25)$$

(where we used the notation: $\partial_t = \partial / \partial t$).

But there were problems with the interpretation of the Klein-Gordon equation arising from the fact that the particle's total relativistic energy $(i\hbar \frac{\partial}{\partial t})$ is squared and thus bears both positive and negative energy solutions, $E = \pm\sqrt{c^2 p^2 + m_o{}^2 c^4}$. The negative energy solutions have negative probability densities, and this would be rather unphysical…. (but what about the other unphysical postulation - ascribing periodic properties to a free particle - that was overlooked?)

The Dirac Equation

The problems with the Klein-Gordon equation led Dirac to search for an alternative relativistic wave equation in 1928, in which the time and space derivatives would be first order, so that one would not get negative probability densities. Dirac began by imposing this constraint and making the Klein-Gordon equation linear in $\partial/\partial t$ and in the space derivatives (Dirac

1928a; 1928b). One way to do this would be to factorise the operator in the left part of Eq. 25 into a square of some unknown new operator and apply the new operator to the wave function. Using the notation $\partial_t = \partial/\partial t$, $\partial_x = \partial/\partial x$, $\partial_y = \partial/\partial y$, $\partial_z = \partial/\partial z$, the following factorization

$$(\nabla^2 - \frac{1}{c^2}\partial_t{}^2) = (A\partial_x + B\partial_y + C\partial_z + \frac{i}{c}D\partial_t)^2 \tag{26}$$

can work with the right requirements on the coefficients A, B, C, D: They must be a) anti-commutative so that the cross derivatives disappear, and b) their own inverse ($A = A^{-1}$, $B = B^{-1}$, etc.), to preserve the second order derivatives. Thus he demanded that:

$$AB+BA = 0,\ BC+CB = 0,\ \text{etc. and } A^2 = B^2 = C^2 = D^2 = 1$$

The requirements are satisfied only if the coefficients are matrices as Dirac defined them:

$$A = i\gamma^1,\ B = i\gamma^2,\ C = i\gamma^3,\ D = \gamma^0 \tag{27}$$

The Dirac's gamma matrices are 4×4 hermitian matrices

$$\gamma^{\mu} = \begin{vmatrix} 0 & \sigma_\mu \\ -\sigma_\mu & 0 \end{vmatrix},\ \text{and}\ \gamma^0 = \begin{vmatrix} I & 0 \\ 0 & -I \end{vmatrix}$$

($\mu = 1, 2, 3$), built up of the Pauli matrices:

$$\sigma_1 = \begin{vmatrix} 0 & 1 \\ 1 & 0 \end{vmatrix},\ \sigma_2 = \begin{vmatrix} 0 & -i \\ i & 0 \end{vmatrix},\ \sigma_3 = \begin{vmatrix} 1 & 0 \\ 0 & -1 \end{vmatrix}$$

(I is the 2×2 identity matrix. The 0's in the matrices are 2×2 zero matrices).

Due to Eqs 27, and using the notation from special relativity $x^k = (x^0, x^1, x^2, x^3) = (ct, x, y, z)$, the operator in the right part of Eq. 26, becomes

$$(A\partial_x + B\partial_y + C\partial_z + \frac{i}{c} D\partial_t)^2 = (i\gamma^k \frac{\partial}{\partial x^k})^2 \quad (28)$$

Thus,

$$(\nabla^2 - \frac{1}{c^2}\partial_t{}^2) = (i\gamma^k \frac{\partial}{\partial x^k})^2 \quad (29)$$

Applying this operator to the wave function and substituting in Eq. 25, gives the equation, which is known as the Dirac equation for a free particle:

$$(i\gamma^k \frac{\partial}{\partial x^k})\psi = \frac{m_o\, c}{\hbar}\, \psi \quad (30)$$

Due to the mathematical tricks used by Dirac in order to acquire a desirable equation, he was criticized for blindly following a mathematical construct over physical intuition (Graham 2009).

Second general Remark: Apart from the fact that both Klein-Gordon and Dirac equations were derived from the Schroedinger equation for a free particle and thus both contain the same unphysical extrapolation from bound to free microparticles described by harmonic wave functions, additionally the Dirac equation shows how mathematics were changed in modern quantum physics. Instead of being the language describing the physical world through the observed phenomena as they were before, they became a tool of arbitrary tricks in order to acquire a desired result. But is it possible that nature works this way? I personally doubt it.

6. THE "QUANTIZATION" OF THE EMF BY MATHEMATICAL OPERATIONS

How did the dogmatic belief begin that every form of EMR, and the energy of any type of EMF, are quantized?

The reasoning of "quantization" is described by Dirac in his 1927 paper entitled "the quantum theory of the emission and absorption of radiation": "*Resolving the radiation into its Fourier components*, we can consider the energy and phase of each of the components to be dynamical variables describing the radiation field. Thus if E_r, is the energy of a component labelled r and θ_r is the corresponding phase (defined as the time since the wave was in a standard phase), we can suppose each E_r and θ_r to form a pair of canonically conjugate variables … satisfying the standard quantum conditions[7] $E_r\theta_r - E_r\theta_r = i\hbar$ … *this assumption immediately gives light-quantum properties to the radiation*" (Dirac 1927).

Two years earlier, Heisenberg was the first to attribute periodic properties to EMR and represent it by Fourier series which is the basis of "quantization" (Heisenberg 1925; Van der Waerden 1968). Born, Heisenberg and Jordan started working mathematically in this way to quantize the EMF in Maxwell's equations (Born et al. 1926). The difficulties in the quantization delayed for more than a year the completion of their work which resumed after Heisenberg managed "to eliminate the difficulties by means of a formal trick" (Pais 1986). At that time Dirac had already published his equation (Dirac 1928a; 1928b), and Heisenberg and Pauli adopted it in their quantum treatment for the interaction between the EMF and the electron in an atom (Heisenberg and Pauli 1929). Since they applied a "quantized" EMF on a particle the energy of which was also quantized (already in its initial form by Schroedinger), that was called "the second quantization", and it was the foundation of QEM/QED.

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[7] What Dirac calls "standard quantum condition" is Born's "law of commutation" (Born and Jordan 1925) for the pairs of so called "canonically conjugate variables" such as energy-time, or momentum-position.

This is how the dogma was founded… Heisenberg, Born, Jordan, Pauli, and Dirac resolved mathematically the radiation into its Fourier components… But according to the Fourier theorem as explained, this assumes that the function describing the radiation is periodical, which is totally simplistic to be assumed for any type of EMF/EMR. Moreover, even in case that it would have a physical meaning to "quantize" a randomly varying EMF in terms of the Fourier integral instead of the Fourier series, this would only be a mathematical transformation, not supported by facts or measurements. Therefore it is misleading to think that EMFs are quantized in general and all types of EMR consist of photons.

Interestingly, Dirac himself already since the early 1930s, was an active critic of QEM/QED and tried to develop alternative schemes. Later on he became dissatisfied with the method of renormalization - developed by Schwinger (1948) and Feynman (1949) to perform "highly accurate calculations" - and regarded it as a mathematical trick rather than a fundamental solution. Dirac died unreconciled with what, to a large extent, was his own creation (Dalitz and Peierls 1986). [This information is lacking both in university physics courses and in modern physics textbooks.]

Let us see how they "quantized" the EMF/EMR starting from its classical description by Maxwell's equations (Mandel and Wolf 1994; Walls and Milburn 2008). In the vacuum or the air and considering the free fields (without the presence of any electric charges or currents), Maxwell's equations are:

$$\nabla \cdot E = 0 \tag{31}$$

$$\nabla \cdot B = 0 \tag{32}$$

$$\nabla \times E = -\frac{\vartheta B}{\vartheta t} \tag{33}$$

$$\nabla \times B = \varepsilon_o \mu_o \frac{\partial E}{\partial t} \tag{34}$$

First they introduced a vector potential $A(r, t)$ which should satisfy the constraint, $\nabla \cdot A = 0$, and expressed the electric and magnetic field according to this:

$$B = \nabla \times A \tag{35}$$

$$E = -\frac{\vartheta A}{\vartheta t} \tag{36}$$

Then substituting Eqs 35, 36 into Eq. 34, it comes that $A(r, t)$ satisfies the wave equation (for $A(r, t)$ to be transmitted as a wave along the direction r with velocity c):

$$\frac{\partial^2 A(r,t)}{\partial t^2} = c^2 \nabla^2 A(r, t) \tag{37}$$

with $c = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$ the velocity of the electromagnetic wave.

Then, arbitrarily, they considered the vector potential to be a periodic function of time, and separated it into a sum of two conjugate complex terms

$$A(r, t) = A^{(+)}(r, t) + A^{(-)}(r, t) \tag{38}$$

where $A^{(+)}(r, t)$ contains all amplitudes which vary as $e^{-i\omega t}$ for $\omega > 0$ and $A^{(-)}(r, t)$ contains all amplitudes which vary as $e^{i\omega t}$, and $A^{(-)} = A^{(+)*}$. [By introducing this constraint (that $A^{(+)}$ varies as $e^{-i\omega t}$, and $A^{(-)}$ as $e^{i\omega t}$), it is implicitly assumed that $A(r, t)$ contains only harmonically varying terms, meaning it is a periodic function, which is totally simplistic and unphysical].

Since they had assumed the vector potential to be periodic, they expressed each term of $A(r, t)$ into Fourier series with a set of vector functions $u_k(r)$ corresponding to the frequencies ω_k, called "mode" functions describing the field restricted in a volume V in space:

$$A^{(+)}(r, t) = \sum_k c_k u_k(r) e^{-i\omega_k t} \tag{39}$$

(with c_k the Fourier coefficients).

The set of vector mode functions $u_k(r)$ were required to satisfy the wave equation, $(\nabla^2 + \omega_k^2 / c^2)\ u_k(r) = 0$ for harmonic waves (with a constant frequency/angular velocity)[8], the transversality condition, $\nabla \cdot u_k(r) = 0$, and form a complete orthonormal set:

$$\int_V u_k^*(r)\, u_{k'}(r)\, dr = \delta_{kk'}$$

[$\delta_{kk'} = 1$ for $k = k'$, and 0 for $k \neq k'$ (the "Kronecker's delta" function)]

Thus, they expressed the vector potential assuming it is periodic (and consequently any periodic EMF) as a sum of harmonic terms, which is finally transformed as:

$$A(r, t) = \sum_k (\hbar/2\omega_k \varepsilon_o)^{1/2} [a_k u_k(r)\ e^{-i\omega_k t} + a_k^\dagger u_k^*(r)\ e^{i\omega_k t}] \tag{40}$$

The Fourier amplitudes a_k, and $a_k^\dagger$, were arbitrarily chosen to be mutually adjoint operators which satisfy the commutation relations:

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8 [where $\dfrac{\partial^2 u_k(r)}{\partial t^2} = \omega_k^2\, u_k(r)$]

$[a_k, a_{k'}] = [a_k^\dagger, a_{k'}^\dagger] = 0, [a_k, a_{k'}^\dagger] = \delta_{kk'}$

Replacing the last expression of $A(r, t)$ into Eq. (36), we get for the electric field:

$$E(r, t) = i\sum_k (\hbar\, \omega_k/2\varepsilon_o)^{1/2}\, [a_k\, u_k\, (r)\; e^{-i\omega_k t} - a_k^\dagger\, u_k^*\, (r)\; e^{i\omega_k t}\,] \qquad (41)$$

and a corresponding expression for the magnetic field, which transform the Hamiltonian of the EMF, as:

$$H = \sum_k \hbar\omega_k\,(a_k^\dagger a_k + \frac{1}{2}) \qquad (42)$$

The last equation supposedly declares that the total energy of the EMF is the sum of the number of photons in each mode $a_k^\dagger a_k$, multiplied by the photon energy in this mode $\hbar\omega_k$, plus $\frac{1}{2}\hbar\omega_k$ representing the energy of the "vacuum fluctuations" in each mode (Mandel and Wolf 1994; Walls and Milburn 2008). [The product of operators $a_k^\dagger a_k$ was interpreted to represent the number of photons in each mode].

This is how the "quantization" of the EMF was performed. In reality, they "quantized" an ideal type of EMF consisting only of harmonically varying terms.

As explained already, even by application of the Fourier integral (Spiegel 1974) on a randomly varying EMF, so that it could be theoretically transformed into a continuous of an infinite number of (non-discrete) harmonic oscillators, this would be nothing more than a mathematical transformation. It would not actually mean that a randomly varying EMF is indeed a sum of discrete terms that could possibly be interpreted as photons. For what kind of "quantization" is this that transforms a continuous function into another continuous function with infinite number of non-discrete harmonic terms? Probably this is the reason why the founders of the EMF "quantization" applied the Fourier series instead of the Fourier integral: “We resolve the radiation into its Fourier components and suppose that their number is very large but finite” (Dirac 1927).

While according to classical electromagnetism, charged particles interact with each other instantly by Coulomb forces, according to QEM/QED they interact by the emission and absorption of virtual (imaginary) photons… transmitted at the speed of light, and the momentum transferred by the photons corresponds to the action of a force between the particles. This reasoning is, in my opinion, quite speculative and complicated.

Thus, a *Third general Remark,* is that they “quantized” the EMF by assuming that it is a sum of periodic functions of time and resolved the vector potential *A* into its Fourier components. This is, of course, an oversimplification. Most types of electromagnetic fluctuations in real life, both natural and man-made, are not periodic, and as such cannot be “quantized”, not even mathematically. Especially man-made EMR emitted by accelerating free electrons is never periodic. Avoiding the oversimplification by transforming the EMF in terms of the Fourier integral into a continuous of an infinite number of (non-discrete) terms (harmonic oscillators), does not actually constitute a “quantization”. “Quantization” implies discrete terms, not another continuous function. The above should have been emphasized from the beginning by the founders of QEM/QED. But they were not. As a result, everybody took for granted that every form of EMF/EMR (including those generated by free charges and man-made circuits) is quantized, and thus consists of photons, which is unnatural and misleading for the young scientists of succeeding generations.

A *Fourth general Remark* is that the so-called “quantization” of the EMF/EMR was strictly a mathematical procedure that was not dictated by experimental facts. Moreover, it was a procedure of fabricated mathematics in order to acquire the desired result.

7. Photons at Frequencies Below Infrared. Do They Exist?

7.1. Free Electron Acceleration in Metals due to an Applied EMF

The intensity I of EMR (in the vacuum or the air) emitted by an accelerating particle of charge q, moving with non-relativistic velocity, at any angle θ with the direction of motion and at distance r from the charged particle, is described by the equation

$$I(\theta) = \frac{q^2 a^2}{16\pi^2 \varepsilon_o c^3 r^2} \cdot \sin^2\theta \tag{43}$$

where α is the acceleration/retardation of the charged particle, ε_o the vacuum permittivity, and c the speed of light in the vacuum/air (Alonso and Finn 1967).

Eq. 43 declares that the intensity of emitted radiation by accelerating/decelerating free electrons in circuits/antennae depends upon the square of acceleration/deceleration α^2.

Since the acceleration α of an unbound particle is not quantized but it is a continuous function which may take any possible value, it follows from Eq 43, that the emitted radiation is not quantized either. Moreover, since the accelerating particle's motion is not generally periodic, the energy (and other parameters) of the emission cannot be represented by Fourier series as a sum of discrete terms, and thus the emission cannot be considered quantized, not even mathematically.

The dependence on $\sin\theta$, declares that the maximum intensity is emitted vertically to the acceleration/deceleration, e.g., in the case of free electrons oscillating in an antenna, the maximum radiation intensity is emitted vertically to the antenna (the vector of radiation intensity -

Poynting vector - lies upon a plane vertical to the antenna) as we indeed know, and can be verified by radiation measurements.

7.2. Microwave Generators

Microwaves are produced artificially by specially designed generators. Such generators are the Magnetron, the Klystron, and the Masers (Liolioutsis 1979). The Magnetron and the Klystron produce electromagnetic oscillations at microwave frequencies. This is accomplished by electron beams emitted by a cathode, and directed to pass through a series of positively charged metal cavities called “cavity resonators”. The frequency of the produced oscillations in the electron beam is determined by the cavities’ dimensions, and the beam’s speed. Such microwave generators are used in radars and in recent years in microwave ovens. The produced microwaves last for as long as the electrons accelerate within the cavities, and are thus continuous waves. They are produced by unbound electrons accelerated by an applied voltage just like in every electric/electronic circuit, and there is no reason to assume that they are quantized.

In the case of Masers (microwave amplification by stimulated emission of radiation), which are microwave amplifiers, the continuous microwaves produced by a Klystron or Magnetron, are amplified by microwave photons produced by some paramagnetic material such as NH_3, or crystals such as silicon (Si), after excitation by the continuous microwaves and in the presence of a strong static and spatially inhomogeneous magnetic field with intensity on the order of ~1T, according to the Stern-Gerlach effect.

The Stern-Gerlach effect indeed describes conditions of photon production in the RF/microwave band. It is related to the splitting of spin energy levels of uncoupled electrons or nucleons within a strong magnetic field (Gautreau and Savin 1978). It is the underlying effect in the ESR and NMR spectroscopies.

In the presence of a strong static magnetic field B, the electronic or nucleonic spins become parallel or antiparallel to the direction of the field. The energy difference corresponding to the splitting of the spins is:

$$\Delta E = g_s \frac{q\hbar}{2m} B \tag{44}$$

where q, m the particle's charge and rest mass respectively, and g_s (= 2.0023 for free electrons) is called the spectroscopic splitting factor.

The constant quantity $\frac{q\hbar}{2m}$ (= 9.27×10^{-24} J/T for an electron) is the elementary magnetic moment in the direction of the magnetic field, called Bohr's magneton.

The above energy difference corresponds to photons with microwave frequency v, and energy:

$$hv = g_s \frac{q\hbar}{2m} B \tag{45}$$

Particles may jump between the two spin levels with corresponding emission/absorption of photons in the microwave band. Thus, such photons may exist under the specific conditions.

But such strong static magnetic fields (~1T) do not exist in human environments. Moreover, the production of microwave photons cannot take place without simultaneous excitation by the artificial (continuous) microwaves. Thus, we do not expect to have microwave photons due to this mechanism in environmentally accounted conditions. In conclusion, microwave generators do not provide any general evidence that man-made microwaves are quantized, or that any microwave "photons" can exist in the environment.

7.3. Atomic Transitions in the RF/Microwave Band

There are atomic transitions due to hyperfine splitting of electronic energy levels in atoms, corresponding to photon energy in the RF/microwave band (typically of a few GHz). The hyperfine splitting is due to interaction of the nuclear magnetic moment with the electron magnetic moment, and is much smaller than the spin–orbit fine structure splitting. On such hyperfine transitions the function of "atomic clocks" is based. Although such hyperfine transitions are theoretically predicted to exist in atoms, in practice they do not occur spontaneously and need to be excited/triggered artificially in order to be detected.

In atomic clocks excitation of caesium atoms is achieved by periodical laser signals in a chamber at superconductive conditions (extremely low temperature very close to absolute zero). By de-excitation the caesium atoms emit a photon of a very precise microwave frequency. Other ways to excite microwave transitions in atoms involve magnetic resonance by an externally applied magnetic field (on the order of ~ 1 T) and artificial microwave radiation (see section 7.2). The resulting magnetic resonance is observed by changing the frequency and magnitude of the applied RF field (Major 2014; Kraus et al. 2014; Basdevant and Dalibard 2017)

The above facts on hyperfine atomic transitions constitute the strongest evidence for the generation of RF/microwave photons, but as explained, such emissions take place only under specific conditions not encountered environmentally.

7.4. Microwaves Produced by "Qubits"

In practice, the devices that are currently being developed to produce single microwave "photons" need to be operated at temperatures below 0.1K (Houck et al. 2007; Inomata et al. 2016). Until recently this would have meant using cryostats with liquid helium for cooling which is generally not possible in conditions outside of research labs. Rapid progress in cryogenics has already come to production of dry mechanical systems that only require a source of electricity to run (Radebaugh 2009). But still such conditions do not exist environmentally.

Recent claims that microwave/RF photons can be generated in electronic circuits also involve superconductive/cryogenic conditions. The so called "microwave photons", generated by special microwave oscillation circuits called quantum bits ("qubits"), are manifested as electromagnetic pulses. Qubits are integrated microcircuits made by lithography and containing capacitors (C) and inductors/coils (L) forming LC harmonic oscillators. They are the basic units of the so called "quantum computers" (Houck et al. 2007). A large amplitude trigger pulse generated by a conventional microwave pulse generator in the 'in' port excites the qubit which a few tens of nanoseconds later decays into the 'out' port by emitting a second pulse which is interpreted as a microwave "photon". With the circuit resistance approaching to zero in superconductive conditions, the generated pulses (interpreted as "photons") are practically harmonic (Houck et al. 2007; Schuster et al. 2007; Clarke and Wilhelm 2008).

In my view, like in conventional electric/electronic oscillation circuits emitting continuous classical waves in the microwave band, the so-called microwave "photons" emitted by qubits are not quantized transitions of bound microparticles (photons), but pulses of a continuous carrier wave at microwave frequency produced by the LC microcircuits. Even in case that we interpret these artificial microwave pulses as photons, they cannot exist in human environments (without superconductive/cryogenic conditions and without artificial excitation).

Thus, all present day "quantum" microwave emitters, a) need to be excited/triggered by artificial pulses, b) are cooled down to extremely low temperatures in order to increase emission efficiency (Houck et al. 2007; Kraus et al. 2014)

In conclusion, there is no evidence that the environmentally accounted microwave radiation types (as those used in modern telecommunications) transmitted by antennas, radars, satellites, etc. consist of photons.

7.5. Antennae Spectra

If every form of EMR were quantized, including man-made EMR (as QEM/QED suggests), then all antennae emission spectra anywhere in the whole band below the low limit of infrared ($0\text{-}3\times10^{11}$ Hz) would be line spectra consisting of discrete lines corresponding to the basic carrier frequency emitted by the antenna and its harmonics, plus the modulation frequencies. Although spectra may be very complicated and discrete lines may broaden due to a variety of reasons as is usually the case in molecular, x-ray and gamma-ray spectra, acquiring these spectra with increased resolution reveals their discrete lines. On the contrary, all antennae emission spectra do not display discrete lines regardless of resolution. Thus, antennae spectra are continuous spectra, even though antennas usually emit a periodic carrier signal.

Antennae spectra do not contain single emission lines corresponding to single frequencies, but continuous frequency bands around the main frequency peaks. This is because even though macroscopically the free electron cloud in the antenna circuit may perform a periodic motion at a certain carrier frequency v, the motion of each individual free electron is not periodic due to the chaotic friction forces which are different for each individual free electron plus the individual random thermal motion, as explained. The result is that instead of an individual emitted frequency, we have a continuous range of frequencies $\pm\Delta v$ around the carrier frequency v of the alternating voltage applied on the antenna circuit. In other words, instead of single lines we have peaks of frequency ranges. The argument of those who represent mainstream opinion may be that there are individual lines corresponding to individual frequencies and individual photons, but our spectrum analyzers do not have high enough resolution to discriminate single lines. My opinion is that even if we had the most sensitive spectrum analyzers, we would still get continuous antennae spectra for the reasons explained.

Therefore, the continuous spectra of antennae emissions, is an additional indication that man-made EMR emitted by all types of antennae and electric/electronic circuits is not quantized. In other words, it does not consist of photons, but of continuous waves as those described by classical electromagnetism.

Thus a *Fifth General Remark* is that, there are actually no facts showing photon existence at frequencies below infrared, in environmentally accounted conditions.

8. Energy Loss Mechanisms of Man-Made EMR

EMR in general (quantized or not) passing through inanimate matter can be absorbed by bound electrons in all materials and by free electrons in metals. The main mechanisms of interaction with electrons are: 1) *Excitations* (when the frequency of the radiation is close to one of the frequencies of the atomic spectra): Bound electrons absorb the necessary amount of energy in order to jump to a higher stationary energy level. The excited electrons are unstable, emit the absorbed energy in the form of photons in random directions and get back to their initial energy levels. 2) *Forced-oscillations*: Bound electrons in all materials and free electrons in metals are forced to oscillate at the frequency of the radiation, in addition to their initial motions. The energy of the forced oscillation is subtracted from the radiation and re-emitted by the electrons in all directions. This causes scattering of the initial waves (Alonso and Finn 1967). In all cases, the initial EMR is left with the same frequency but reduced intensity.

Man-made EMR has several orders of magnitude lower frequency than molecular/atomic/nuclear spectra, and thus, it is not expected to induce excitations or forced-oscillations on bound microparticles.

Forced oscillations induced on free electrons in metallic surfaces is the mechanism by which metals absorb EMR (quantized or not). In this case the absorption is so intense as to practically eliminate EMR in the interior of the metal body and shield other objects behind the metallic surface. This is how metals can insulate space from EMR.

The situation is different when the continuous polarized waves of man-made EMR pass through living matter. Living matter is composed by biological cells, and in all types of cells, except for the bound electrons in atoms/molecules, there are innumerable free (mobile) ions, water polar molecules, and polar macromolecules. The vast majority of biological molecules are either polar or carry a net electric charge (Alberts et al. 1994). Therefore, except for the above mechanisms of energy loss on bound electrons, there are induced forced-oscillations on every charged or polar molecule of the biological tissue. These forced-oscillations on ions and polar (macro)molecules are far more energy consuming than the induced oscillations on the bound electrons of the biological molecules, since the masses of the charged/polar particles are now several orders of magnitude (more than 10^4 times) bigger. The forced-oscillations induced by man-made EMFs/EMR in biological matter are parallel and coherent oscillations, since - as explained - these fields are totally polarized and of a single phase in contrast to natural/quantized EMFs/EMR (Panagopoulos et al. 2015).

A continuous polarized electromagnetic wave will induce a forced-oscillation of the same frequency, phase, and polarization on each charged or polar particle that it meets and will transfer to each of them a part of its energy. The induced oscillation will be most intense on the free (mobile) ions which carry a net electric charge and have smaller mass and higher mobility than other charged or polar molecules, and exist in large concentrations in all types of cells and extracellular aqueous solutions, determining practically all cellular/biological functions (Alberts et al. 1994; Panagopoulos 2013). The induced oscillation will be much weaker or even negligible on the polar macromolecules that do not carry a net electric charge, they have much larger masses, and in addition they are usually chemically bound to other molecules.

After each such event of interaction between the continuous polarized wave and a charged or polar particle, the remaining wave continues its way through the tissue with the same frequency but slightly reduced amplitude/intensity. After a countless number of such events, depending on the tissue’s mass, density, and the number of polar/charged molecules, any remaining wave leaves the tissue scattered and with reduced amplitude/intensity.

The total energy density W (energy per unit volume) in the simplest case of a plane harmonic electromagnetic wave (Alonso and Finn 1967) is described by the equation:

$$W = \varepsilon\varepsilon_o E^2 \tag{46}$$

Eq. 46 declares that when the amplitude/intensity E of the oscillating field/wave decreases after interaction with the charged/polar molecules of a medium, its energy decreases as well, transferred to these molecules. Thus the amplitude and energy of each individual continuous wave decrease, which differs from the accepted “all or nothing” interaction of photons where the intensity (number of photons per unit area) decreases without a corresponding decrease in the energy of individual photons given by Planck’s Eq.1. [Except if we accept that partial photon absorption (partial absorption of a divisible wave-packet) is possible (Panagopoulos 2015)].

In the case of man-made continuous waves, the most important difference from (natural) quantized EMR, is that man-made continuous waves have a discrete polarization and phase, while each photon of a quantized EMR has different polarization and phase from all other photons.

The energy loss in man-made electromagnetic waves may be manifested by temperature increase when they pass through matter (e.g., microwave heating), but no frequency reduction as e.g., in the Compton effect. Information-carrying microwaves do not change their frequency when passing through matter, but they can cause heating when they have sufficient intensity and frequency (e.g., microwaves in the GHz range with intensity around $1 mW/cm^2$ or higher).

Thus, man-made EMR types lose energy neither by losing a number of photons absorbed by the medium, nor by decreasing their frequency as in the Compton effect (by getting absorbed and giving rise to scattered photons of decreased frequency). This might explain why microwave radiation can cause larger temperature increases than ionizing radiation when absorbed by matter, although it has considerably lower frequency. Actually we talk about two different things: Ionizing radiation which is quantized and described by Planck's Eq.1 in terms of its energy, and man-made radiation which is not, and described by Eq. 46 in which the energy loss is not dependent on quantized (all or nothing) absorption, but on partial absorption from a continuous wave, inducing a continuous forced-oscillation on charged/polar particles. In this case, the energy loss transformed into heat may be larger even though the frequency is several orders of magnitude smaller.

But usually the important biological effects of man-made EMFs/EMR are the "non-thermal" ones with insignificant temperature increases within the exposed biological tissue. These are due to their totally polarized and coherent nature explained above. All individual waves oscillate on parallel planes, and individual waves emitted by a specific source are in phase between them. Thus, they induce parallel and coherent forced-oscillations on any charged/polar particle with energy well below the thermal level. Forces exerted by oscillating ions on electrosensitive ion-channel sensors can cause irregular gating (opening or closing) of ion channels on cell membranes and disruption of the electrochemical balance in all types of cells. This is the reason why EMR emitted by a mobile phone with average intensity ~ 10 $\mu W/cm^2$ on a human body may initiate biological effects, while ~ 10 mW/cm^2 (1000 times stronger) solar EMR with significantly longer exposure during the day, does not (Panagopoulos 2013; Panagopoulos et al. 2015).

Natural non-ionizing quantized EMR (infrared, visible light) also decreases in intensity (number of photons) when passing through biological matter by causing forced oscillations on charged/polar particles. But these oscillations are in random directions (each photon oscillates on a different plane) and not coherent. For this reason they only cause heating (increase in molecular random thermal motion) which is tolerated by living organisms if not excessive. Important adverse biological effects and cancer may be caused by (natural quantized) ionizing radiations through the breakage of chemical bonds in biological molecules. Thus, the mechanisms of harm are quite different between quantized and not quantized EMR, even though they may finally result in the same effects (e.g., DNA damage, cell death, cancer, etc).

9. Discussion and Conclusion

It seems that the tremendous progress of quantum physics during the first decades of the 20th century with the introduction of the idea of photons by Planck and the explanation of the black body radiation spectra, the photoelectric and the Compton effects, the explanation of molecular, atomic, nuclear spectra etc., seduced all physicists to take for granted that any form of electromagnetic emission, not only the natural forms that were already under study, but even those which were to come - as most types of man-made electromagnetic emissions not yet having been invented, or just invented but not yet deeply understood - consist of photons as well. It seems that after Planck's discovery (1901), physicists erroneously assumed that his theory refers not only to natural light but to any form of EMR. That conviction was soon to be sealed in the late 1920s with the mathematical "quantization" of EMF/EMR performed by the founders of QEM/QED. When during the following decades man-made EMFs gradually filled the remaining gap in the electromagnetic spectrum from 0 Hz to microwaves with increasing frequencies reaching in our days just an order of magnitude below the low infrared limit ($\sim 3\times 10^{11}$ Hz), everybody took for granted that these new radiation types consist of photons as well.

Nevertheless, there are some facts pointing in the opposite direction that cannot be overlooked. As explained in the present study, energy quantization is related to bound microparticles in molecules, atoms, nuclei. Quantized EMR is emitted during transitions of the bound microparticles between different stationary (quantized) energy levels. Such quantized energy levels do not exist for unbound (free) microparticles. EMR emitted by free charged microparticles during acceleration is a continuous process, not quantized.

As explained, man-made electromagnetic waves are produced by accelerating unbound charged microparticles in electric/electronic circuits, not by time-finite (nanosecond) transitions of bound microparticles. Since the electric circuits producing the artificial electromagnetic waves can operate continuously generating continuous electromagnetic oscillations, the produced electromagnetic waves are not in the form of finite-length wave-packets (photons), but of continuous waves, or pulses of a continuous carrier wave.

The outer (valence) electrons in all metals, loosely bound to their nuclei, are easily detached from their atoms and can move freely along a metal wire under the influence of an applied voltage. This is why they are called “free electrons” or “conduction electrons”. Since free electrons are detached from their atoms, their energy is no longer quantized, and once they accelerate due to an applied voltage in the circuit, they emit radiation according to Eq. 43. Their energy loss due to radiation emission is compensated by the energy provided by the applied field. Since their energy is not quantized during their motion along the metal wire, the radiation they emit is not quantized either (as described by Eq. 43), meaning it is emitted in the form of continuous electromagnetic waves (as those described by classical electromagnetism), and not as finite-length wave-packets (photons). This is the simplest reasoning concerning radiation emission by an antenna, and I believe the simplest is the most probable. There are actually no facts, except for the mathematical tricks used by the founders of QEM/QED, forcing us to accept that this radiation is quantized.

This is probably the reason why, while there is plenty of experimental evidence for the existence of photons in the case of natural EMR with frequencies above the low limit of infrared (Klimov 1975; Beiser 1987), corresponding experimental evidence for photons in the lower frequency bands of the electromagnetic spectrum ($0 - 3\times10^{11}$ Hz) is totally absent, with the reported exceptions in the RF/microwave band: a) RF transitions in atoms exist but they do not occur naturally in environmental conditions. They take place after stimulation by lasers or magnetic resonance, and at extremely low temperatures (cryogenic conditions). b) Microwave pulses emitted by LC microcircuits (qubits) interpreted as microwave “photons” are artificially generated, also in cryogenic environments. Even if we accept this highly controversial “evidence” for RF/microwave “photons” as valid in specific environments, there is absolutely no evidence regarding lower frequency photons (VLF, ELF, etc.).

Moreover, all antennae emission spectra are continuous spectra regardless of resolution. This is an additional indication that the reasoning described in the present study is correct, and man-made EMR types consist of continuous waves, not photons.

Recognition of the above facts may lead to a better understanding of the interaction of man-made EMFs/EMR with matter, especially living matter. The mechanisms of energy loss are different than with quantized EMR, because as explained, individual continuous waves passing through matter undergo attenuation in amplitude (intensity), in contrast to photonic radiations which are considered to attenuate in the number of photons but not in amplitude or energy ($h\nu$) of individual photons, since the frequency remains the same. Most importantly, man-made continuous waves emitted by an antenna/circuit each moment possess the same polarization and phase, in contrast to photons emitted by a quantized source each one having different polarization and phase than all the others. This unique property gives the potential to man-made EMFs/EMR to induce parallel and coherent forced-oscillations of charged molecules in biological tissue, which in turn may initiate biological effects.

In the present study, I examined the facts that led to the "quantization" of the EMF and the consequent belief that every form of EMF/EMR is quantized. I found at least five critical points that I believe need thorough re-examination by quantum physicists: a) The arbitrary extrapolation of the energy (Schroedinger) equation from bound to free microparticles without any corresponding change in the periodic wave function, b) the applied mathematics (especially in Dirac's equation) which were not discovered as the innate language of the natural world, but invented in order to acquire the desired equation, c) the attribution of periodical properties to free particles as EMF-sources and the use of Fourier series to represent any random undulation of free particles, d) the "quantization" of any EMF/EMR by strictly mathematical procedures that were not dictated by experimental facts, and e) the complete lack of facts denoting generation/existence of photons at frequencies below infrared in environmentally accounted conditions.

While the energy of an electron bound in an atom has to be quantized for energy conservation reasons as described by Bohr (1913a; 1913b; 1928), the situation is totally different for electrons not bound in atoms (such as the free electrons in metals), or any other unbound microparticles. This is key to understanding that man-made EMR types produced by circuits/antennas do not consist of quanta (photons), in contrast to EMR types produced by transitions of bound microparticles.

Nevertheless, QEM/QED treated both bound and unbound microparticles, and all EMF/EMR types, as quantized. This started when Schroedinger himself wrote his equation for a free particle (in zero potential), while the equation was introduced for electrons bound in atoms and described by harmonic wave functions. That was an unreasonable and unphysical extrapolation. Nevertheless, Klein, Gordon, Dirac, Heisenberg, Feynman, and everybody, adopted this unphysical idea to apply the quantized equation to free particles. In this way it was established that any microparticle's energy is quantized, no matter whether the particle is bound or not. Then they invented mathematics to describe this unrealistic situation, the "quantization" of a free particle's energy. Since the energy of any free microparticle was a-priori considered quantized, the corresponding emitted EMR by the microparticle would be quantized as well. That was fatal and misleading for the newborn QEM/QED.

Mathematics is the metrics of the natural world. They express the innate simplicity, harmony, symmetry and balance of the natural world. Like e.g., the harmony/balance in the motion of planets around the sun, the perfect geometry of solid state crystals, or the combined accurate functions of innumerable biological molecules in all living cells performing the miracle of life. That means mathematics exist already in nature and it is for the physicists and the mathematicians to discover them. That was the case in classical physics, and in early quantum mechanics. On the contrary, the mathematics of modern quantum physics (after Schroedinger) were not discovered, but invented in order to acquire a desired result. It seems to me that the founders of QEM/QED and their successors confused the physical reality by their mathematics. This was most evident in the formulation of the Dirac equation and the "quantization" of the EMF/EMR.

But inventing mathematics to acquire a desired equation has nothing to do with physical reality, and leaves little probability for that equation to describe something meaningful. This is probably the reason why modern quantum physics has nearly zero applications in real life. As admitted even by mainstream quantum physicists, nearly every technological application in our modern world of high technology is based on classical physics.

As mentioned, besides Dirac himself, several eminent quantum physicists of our times have strongly objected to QEM/QED stressing similar remarks: That it is based on untested assumptions, and is full of mathematical constructs devoid of physical reality (Jaynes 1966; 1978; 1980; Lamb and Scully 1969; Hunter and Wadlinger 1989; Graham 2009; Roychoudhuri et al. 2008; Roychoudhuri 2014).

The presented facts contradict the dogmatically spread information by all mainstream modern physics texts that the whole electromagnetic spectrum (including the part below infrared) consists of quantized emissions. Nevertheless, it is claimed that QEM/QED has yielded experimental confirmation and is considered by quantum physicists as the most precise theory in physics (Grimes and Grimes 2005). As an EMF-biophysicist, I may lack the expertise to test the validity of this claim. It is left to quantum physicists to re-evaluate this experimental "confirmation", taking into consideration the facts and arguments presented here. Certainly the microwave "photons" produced by qubits, the atomic clocks, or the "quantum computers" do not constitute such confirmation.

I understand that with the present study I object to basic principles of modern quantum physics. But as the famous quantum physicist Ed Jaynes declared back in 1966 when he among the first objected to QEM/QED, "*physics goes forward on the shoulders of doubters, not believers*" (Jaynes 1966). In a more recent study, the same eminent physicist criticized the general philosophical frame of modern quantum physics and the lack of connection between the theory and the real physical processes, which is exactly the point of the present study: "*Present quantum theory not only does not use, it does not even dare to mention the notion of a 'real physical situation'. Defenders of the theory say that this notion is philosophically naive, a throwback to outmoded ways of thinking, and that recognition of* *this constitutes deep new wisdom about the nature of human knowledge. I say that it constitutes a violent irrationality, that somewhere in this theory the distinction between reality and our knowledge of reality has become lost, and the result has more the character of medieval necromancy than of science*" (Jaynes 1980).

In conclusion, while the concept of photons applies very well for most types of natural EMR (except e.g., for the ELF/VLF EMFs of atmospheric discharges, or the ELF ionic oscillations in living tissue, and even possibly for other forms of natural radiations that produce continuous emission spectra such as the continuous spectra of x-rays), there is no evidence forcing us to accept that man-made EMR produced by electric/electronic circuits consists of photons as well.

I hope the ideas introduced by the present study concerning the non-quantized character of man-made EMR in contrast to the natural quantized EMR, may improve our understanding on the properties of man-made EMR and its interaction with matter, especially living matter.

"Dr Panagopoulos' study definitely brings out the reality that we must learn to distinguish between emission of EMR generated by (i) structurally quantized entities like nuclei, atoms and molecules, and (ii) various systems and devices that allow acceleration of charges that are not bound quantum mechanically, and are allowed to radiate pure classical waves. Since this differentiation is not made explicit in the prevailing modern physics texts, his study provides a valuable contribution.

By introducing the various mathematical jugglery in a simple and straight-forward way, he has also substantiated the fact that quantum mechanical formalism, in spite of its great successes, has failed to bring out the physical processes that guide the real physical transformations in nature. I have underscored this point in many of my articles and in my 2014 book."

Professor Dr. Chandrasekhar Roychoudhuri,
(Photonics Laboratory, Physics Department,
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ACKNOWLEDGEMENTS

Many Thanks to Dr C. Roychoudhuri, and Dr G. Fanourakis, for critical reading of the manuscript and valuable comments. Also Thanks to Daryl Vernon for language corrections.

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