The Casimir Force and Heat Conduction Viewed as Exclusion of Natural Spatial Energy and Lateral EM Coupling between the Walls of a Waveguide

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Abstract— This is a deliberately different view of the Casimir Force and Casimir Heat Conduction. It is based on and supports the newly discovered physics of 'Lateral Electromagnetic (EM) Coupling (LEC)' which underpins the philosophy that in the final analysis "everything is, or can be shown to be, electromagnetic" [1–10]. It is not a quantum mechanical view.

Both Casimir effects are viewed electromagnetically as processes that take place between surfaces that form the walls of a (micro-strip) waveguide cavity.

The Casimir force is first considered as an imbalance of radiation pressure from 'Natural spatial energy'. 'Natural spatial energy' is excluded from the waveguide gap d up to a cut-off frequency $f_c = c/2d$. Natural spatial energy consists of thermal noise and Zero-Point-Energy, both of which have a white noise spectrum. Natural spatial energy is electromagnetic energy that exists in and is transported by the 'fabric of space', the 'ether' and it complies with the existence of free-space permeability μ_0 permittivity ε_0 and impedance $Z_0 = \sqrt{(\mu_0/\varepsilon_0)}$. A useful but novel view and model of antenna thermal noise is put forward based on existing antenna and new [11] noise measurements. ZPE is assumed to behave the same way as spatial thermal noise.

This simple 'radiation pressure' theory (like the virtual photon theory) predicts attraction and heat transport that is inversely proportional to the waveguide gap and both are much smaller than existing real measurements. Such radiation theories do not model any existing measurements with convincing accuracy.

When we introduce the properties of 'Lateral Electromagnetic Coupling' (LEM) coupling to the surfaces of the waveguide walls we find that we can apply a novel EM coupling formula [2]. This coupling formula saturates to unity at defined short distances and then any desired negative of distance may be selected. We can also define layered combination of higher inverse powers of distances at which the attraction and heat conduction saturates. In each layer (or region) a single distance power law dominates with on account of the newly discovered and universally applicable RSS (Root-Sum-of-the-Squares) process combination law [1–10].

It has been shown [2] that at room temperature photons below about 300 THz or longer in wavelength than about 1 μm are not stable particles and evaporate into plane waves that are not quantised [2]. Thus the model and theory used here is not quantum-mechanical. It does not use the concept of 'virtual photons'. The theory is consonant with and supports 'The Physical EM Model of Everything' [1].

1. INTRODUCTION

EM coupling is an essential concept for the Physical EM Model proposed as the basis for an Electromagnetic Theory of Everything (EMToE) [1, 8, 9]. It establishes the cut-off frequency of the waveguide cavity formed between two parallel surfaces, how much natural spatial energy is excluded between the surfaces and therefore the Casimir force between them. EM coupling also can explain heat conduction between the surfaces as discussed below in Section 4. The new part of EM coupling is better named as 'Lateral Electromagnetic Coupling' (LEM) as done for the first time here.

'Natural spatial energy' is taken to have two components both with a white noise (flat) spectrum. One is spatial thermal noise the other is the noise fluctuations of what can be called Zero-Point-Energy (ZPE). The relative magnitude of these is a function of temperature.

For reasons given below the ZPE process is preferred rather than the 'virtual photon' quantum process as the explanation for the Casimir force.

A previous paper showed that photons in free-space at room temperature are unstable below about 300 THz or one micron wavelength [10]). The stability frequency decreases as the square root of absolute temperature ($\sqrt{\mathrm{T}}$) down to an expected ZPE fluctuation limit that remains to be established, in principle by measurements of the two Casimir effects?

A waveguide with conducting walls has an effective high-pass cut-off frequency. Any noise or fluctuation energy below this frequency is therefore excluded from exerting an outward pressure between the plates. There is thus a nett attractive force between the plates. The excluded energy per unit area is proportional to the distance d and inversely proportional to the TE waveguide cut-off frequency. The reasons why this is not found in practice are discussed in Sections 5 and 6.

An initial assumption is that EM coupling impedance is the primary cause of excess heat conduction over radiant energy coupling. But the square of the EM coupling is found to vary with distance in the same way as the energy is distributed in an evanescent wave traveling on a surface. The same distribution, density with distance, formula can be assumed to apply. See Section 5.

2. ENERGY EXCLUSION MODEL

Figure 1 shows the natural energy exclusion process that occurs in the waveguide formed between two parallel surfaces.

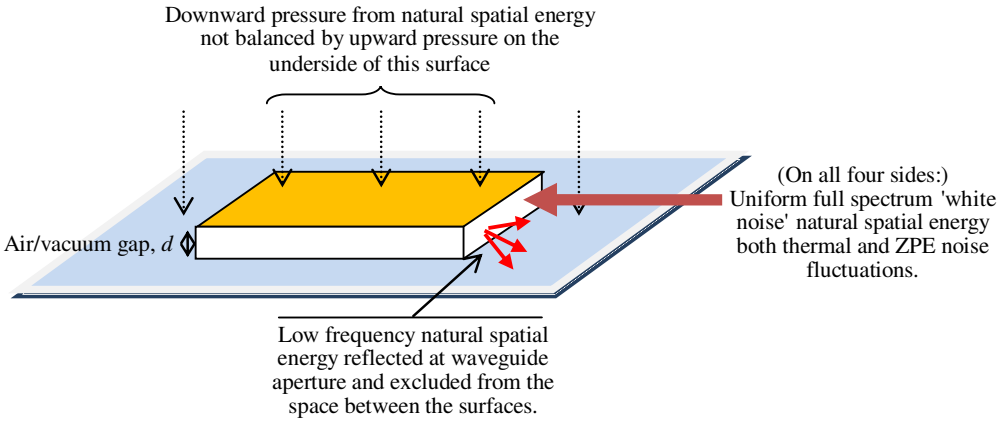

Figure 1: Casimir Force Model. A small (thin) surface on alarge surface at uniform height d are the two walls of a waveguide. Low frequency components of natural spatial energy noise spectrum are excluded from the waveguide by reflection at the small surface boundaries.

Transverse Electric (TE) or Transverse Magnetic (TM) waves can travel between two uniformly spaced finite parallel plane conducting plates in any direction in the plane. If energy is supplied uniformly into the gap d between the two planes from all directions energy is stored between the planes in the form of standing wave modes. All waveguide modes have a cut-off frequencies f_c below which energy does not propagate. This high-pass cut off frequency depends primarily on the spacing d between the waveguide walls. In general we have $f_c = c/2d$ where $c = 3 \times 10^8$ m/s is the free-space wave velocity.

The resistivity, permeability, conductivity and permittivity of the wall surfaces can cause small variations in the mode cut-off frequencies. Also edge effects depending on the size of the surfaces under investigation can be expected also to be detectable and measurable in the future. For the time being such second order effects can be neglected until sufficient measurements have been made for their measurement and detection.

The 'natural spatial energy' available for exclusion is assumed to be a combination of heat energy and 'Zero-Point-Energy' ZPE. Both forms of energy are assumed to have a uniform 'white noise' spectrum over the frequency range of interest. The origin and characteristics of these two types of energy are discussed further in the next Section 3.

The Casimir force is now assumed to be proportional to the reduction of radiation pressure between the surfaces by the exclusion of the low frequency part of the natural spatial energy spectrum. The force is proportional to the area of the upper plate surface if edge effects are neglected. The excluded white spectrum energy is proportional to the cut-off frequency $f_c = c/2d$. Thus on this basis the main component of the Casimir force is predicted to be inversely proportional to the spacing d. Significant deviations from this law at very close spacing are discussed in the next section.

3. NATURAL ENERGY IN THE SPATIAL ETHER

The 'natural spatial energy' available for exclusion is assumed to be a combination of heat energy and 'Zero-Point-Energy' ZPE. Both can be considered as being carried by of the electromagnetic ether. Here the ether is considered to be real and substantive. A good reason for positing the existence of a real ether is the fact that the velocity of light and EM waves is found to be the same anywhere in the universe, and as a consequence the permittivity ε_0, permeability μ_0 and impedance $Z_0 = \sqrt{(\mu 0/\varepsilon_0)}$ of free space have to be constant everywhere. Thus ε_0 and μ_0 are the main defining parameters of a real and substantive ether.

Heat energy (radiance) in space has a flat 'white noise' spectrum of spectral density per unit area of kT watts/Hz/m^{-2} (where k is Boltzmann's constant). This useful, and perhaps novel, statement has been derived from antenna noise theory and confirmed by measurements.

To avoid 'the ultra-violet catastrophe' thermal white noise has to have a high frequency noise cut-off frequency proportional to temperature. What this cut-off frequency is in practice has not yet been established.

ZPE white noise is also assumed to be white noise with a constant spectral envelope but one that is independent of temperature. In practice it is best to find the magnitude of ZPE white noise fluctuations empirically, for example by Casimir effect measurements. As yet there is no reliable theoretical prediction of its value.

4. CASIMIR HEAT CONDUCTION MODEL

Figure 2 shows inductive and capacitative coupling between two parallel surfaces. In both cases the coupling impedance varies proportional to the frequency and inversely proportional to gap distance d. Neglecting edge 'fringing' effects and assuming that heat can be represented by white noise we can argue that on this basis for a single frequency ω heat conduction distance law of ω/d and a full spectrum distance law of d^{-2}. But neither of these agrees with reported results or predictions. Higher order EM coupling mechanisms therefore have to be considered.

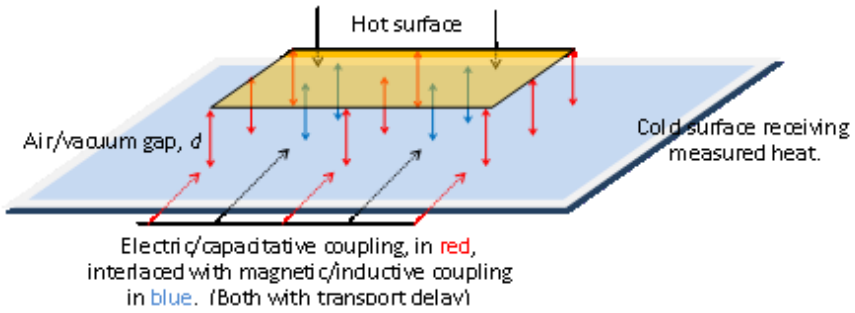

Figure 2: Casimir Heat Conduction Model. A small (thin) surface patch at uniform height d is coupled capacitatively and inductively (with a transport delay) to a lower larger surface. Significant coupling is predominantly at frequencies lower than the waveguide cut-off-frequency $f_c = c/2d$ but higher than the lowest resonant frequency of the patch.

5. ATOMIC LATTICE MATERIAL SURFACE MODEL

Figure 3 shows an idealised atomic lattice of the surface materials. The atoms are assumed to have a simple spherically symmetric structure consisting of an EM string loop 'substance' core surrounded by a 'potential' evanescent wave (non-radiating) atmosphere [9, 10]. Actually this model supports the existence of several concentric atmospheric layers of progressively less energy densities, larger radii and lower dominant EM spectrum line frequencies.

This EM particle model presumes that the core and its evanescent wave atmospheres has a dominant spectral line with frequency $f \sim mc^2/h$, where h is Planck's constant and m is the mass of the protons or neutrons of the surface atoms. For protons $f \sim 2.27 \times 10^{23}$ Hz or $\lambda \sim 1.32 \times 10^{-6}$ nm. For electrons $f \sim 1.24 \times 10^{20}$ Hz or $\lambda \sim 5.88 \times 10^{-3}$ nm. The electron orbital resonance frequency of a hydrogen atom is 2.88×10^{20} Hz corresponding to an orbit circumference of 1.04×10^{-3} nm. These wavelength distances appear to be much too small and the frequencies are much too high to have any significant effects for the distances over which the Casimir effects are operative.

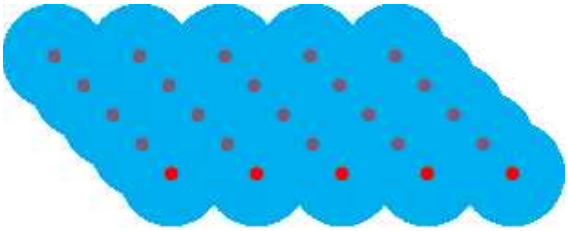

Figure 3: Lattice of surface atoms each consisting of (layered) core with surrounding atmosphere. The atmospheres of the atoms are regions where 'potential' dominates and so can be considered as 'dark matter'. Dark matter is not quantised, by definition. The potential regions overlap, coalesce and combine according to the Root-Sum-of-the-Squares (RSS) process combination rule that applies to non-coherent potentials.

However the 'lateral EM coupling distance' for these frequencies is within the region of interest and is therefore a candidate for further investigation.

6. LATERAL ELECTROMAGNETIC COUPLING DISTANCE AND PROFILE

Evanescent waves are non-radiating travelling waves on wires and surfaces. The wave energy is trapped and confined within a boundary distance that has been found to be inversely proportional to the square root of wave frequency as in Equation (1) below. The process that confines the wave energy is 'lateral' electromagnetic coupling. This is a concept that was first introduced in reference [2] and is a cornerstone of "The Physical Model of Electro-magnetism for a Theory of Everything" [1] and subsequent theory and developments from this model [3–11].

In [2] the 'Goubau distance' r_h was defined as the mean distance within which the coupling energy is confined. Here we equate r_h to the boundary distance d_0 to give

$$r_h = d_0 = (f_0/f)^{1/2} = (14\,\mathrm{MHz}/f)^{1/2}(\pm 10\%) \tag{1}$$

For the electron frequency of 1.24×10^{20} Hz we find $d_0 = 0.336$ nm. This is comparable with the silicon atomic lattice constant or atom spacing of 0.543 nm.

The profile with distance of lateral electromagnetic coupling κ_{11} for a given d_0 found from Equation (1), in reference [2] has been found to be

$$\left(\frac{\kappa_{11}}{\kappa_0}\right)^2 = 1 - e^{\frac{d_0^n}{nrd^n}} \tag{2}$$

where the coupling in [2] has here been squared to become a representation *energy* distribution.

Figure 4 gives plots of $(\kappa_{11}/\kappa_0)^2$ as in (2) for three different negative powers of distance $n = 1$, 2 and 3. For convenience and by inspection the limit of the saturation region where $\kappa_{11} = 1$ is taken as $d/d_0 = 0.5$. Mathematical justification for this is under investigation.

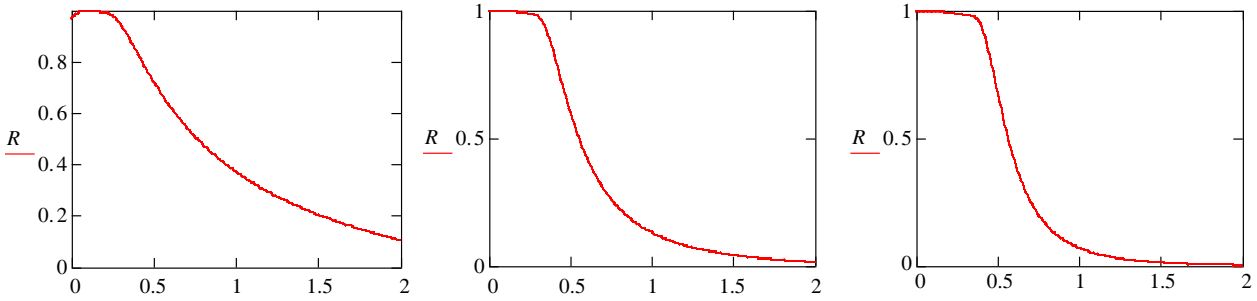

Figure 4: Plots of lateral EM coupling functions $(\kappa_{11}/\kappa_0)^2$ (vertical axis) against distance d (horizontal axis) using Equation (1) with negative powers of distance d with values n of 1, 2 and 3 going from left to right. Note saturation at small distances changing to a power law of $1/d^n$.

To obtain the *total* coupling it is necessary to integrate (2) with respect to frequency after inserting the frequency dependent $(1/\sqrt{f})$ value of d_0 together with the condition that a white noise spectrum is applied. The first term integral is simply f.

However the integration of the second term in (2) creates problems. No analytical solution in terms of known integral or transcendental functions has yet been found. On the other hand numerical integration is possible and it reveals that the second term integral only provides a small step addition to the first term integral.

The first term integral may thus be used on its own. Essentially it provides a $1/d$ additional slope to one of the distance laws shown in Figure 4. Which asymptotic power law should be chosen should be decided on the basis of best fit to measurements, when more accurate measurements become available. The measurements also should provide validation or not of the newly discovered physics process of 'electromagnetic coupling'.

7. CONCLUSIONS

Radiation pressure by either 'virtual photons' or 'natural spatial energy' is too small to be the primary explanation of the Casimir force. Also exclusion of energy in the waveguide formed by the gap between two parallel surfaces does not itself give a sufficiently high negative order polynomial for the distance law to represent what has been measured in practice.

The classical coupling between waveguide walls is likewise too small to account for Casimir Heat Conduction.

'Lateral Electromagnetic Coupling' is a cornerstone of "The Physical Model of Electro-magnetism for a Theory of Everything" [1]. Initial examination shows that Lateral Electromagnetic Coupling (LEC) between two surfaces can possibly explain both the Casimir force and Casimir heat conduction.

In fact more accurate measurements of these two Casimir effects could in the future be used to calibrate and validate the parameters of LEC over most of the accessible range of electromagnetic spectrum frequencies to strengthen its claim of being a necessary addition to Electromagnetic Theory.

The theory put forward here is not per se quantum-mechanical.

REFERENCES

1. Underhill, M. J., "A physical model of electro-magnetism for a theory of everything," *PIERS Online*, Vol. 7, No. 2, 196–200, 2011.
2. Underhill, M. J., "The phase noise spectrum and structure of photons?," *Proc. 16th EFTF-2010*, 8 pages, Noordwijk, Netherlands, Apr. 13–16, 2010.
3. Underhill, M. J., "Maxwell's transfer functions," *PIERS Proceedings*, 1766–1770, Kuala Lumpur, Malaysia, Mar. 27–30, 2012.
4. Underhill, M. J., "A local ether lens path integral model of electromagnetic wave reception by wires," *PIERS Proceedings*, 1005–1008, Moscow, Russia, Aug. 19–23, 2012.
5. Underhill, M. J., "Novel analytic EM modelling of antennas and fields," *PIERS Proceedings*, 1771–1775, Kuala Lumpur, Malaysia, Mar. 27–30, 2012.
6. Underhill, M. J., "Antenna pattern formation in the near field local ether," *PIERS Proceedings*, 1009–1012, Moscow, Russia, Aug. 19–23, 2012.
7. Underhill, M. J., "Wideband small loop-monopole HF transmitting antenna with implications for Maxwell's equations and the Chu criterion," *PIERS Proceedings*, 764–768, Taipei, Mar. 25–28, 2013.
8. Underhill, M. J., "Coupled electromagnetic wave propagation in space and around surfaces and interfaces," *PIERS Proceedings*, 394–398, Stockholm, Aug. 12–15, 2013.
9. Underhill, M. J., "Electromagnetic structures and inertias of particles including the higgs boson," *PIERS Proceedings*, 401–405, Taipei, Mar. 25–28, 2013.
10. Underhill, M. J., "The stability of EM particles and predicted mass ratios," *PIERS Proceedings*, 399–404, Stockholm, Aug. 12–15, 2013.
11. Underhill, M. J., "Discovery and theory of small antenna near-field dissipation and frequency conversion with implications for antenna efficiency, beverage antenna noise reduction, Maxwell's equations and the Chu criterion," *PIERS Proceedings*, Guangzhou, 2014.