Life Imitating "Art": Flux Capacitors, Mach Effects, and Our Future in Spacetime

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Abstract. The results of an experiment designed to produce small amounts of "propellantless" thrust using Mach effect mass fluctuations produced by an alternating electric field in high voltage capacitors in conjunction with an externally induced alternating magnetic flux in their dielectric cores are described. Small effects of the sort expected were detected. Several tests to exclude spurious signals were performed.

INTRODUCTION

When inertial reaction forces that arise in response to the action of "external" accelerating forces are taken to be caused by the gravitational action of chiefly distant matter in the Universe – that is, the weak form of "Mach's principle" obtains – is combined with the constraint of relativistic invariance and the strong form of Mach's principle – that the inertial and "active" gravitational masses of objects are induced by the gravitational action of the chiefly distant matter on their "passive" gravitational masses – it is possible to recover a field equation for the gravitational action of that distant matter on an accelerated local object that has the form:

$$\nabla^2\phi - \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} = 4\pi G\rho_0 + \frac{\phi}{\rho_0 c^2}\frac{\partial^2\rho_0}{\partial t^2} - \left(\frac{\phi}{\rho_0 c^2}\right)^2\left(\frac{\partial\rho_0}{\partial t}\right)^2 - \frac{1}{c^4}\left(\frac{\partial\phi}{\partial t}\right)^2 . \tag{1}$$

ϕ is the scalar potential of the gravitational field that produces the inertial reaction force that acts through the object on the accelerating agent, c the speed of light, G Newton's constant of universal gravitation, ρ_o the proper (frame of instantaneous rest) matter density of the test object, and the other symbols have their customary meanings. (The derivation of this field equation can be found in Woodward, 1995; 1997; and 2003a.) For practical purposes, the important feature of this field equation is the time-dependent source terms on the RHS that have non-vanishing values when the proper matter density of the accelerating test body changes during the acceleration. This occurs whenever internal energy changes accompany accelerations induced by external forces. Formally, the mass fluctuation arising from the first and normally largest transient term on the RHS may be written as:

$$\delta\rho_0(t) \approx \frac{\phi}{4\pi G\rho_0 c^4}\frac{\partial^2 E_0}{\partial t^2} . \tag{2}$$

The relationship $\rho_o = E_o/c^2$ has been used here (E_o being the proper local energy density).

Capacitors excited by an alternating voltage are one system (among several) where large, rapid fluctuations in E_o can easily be affected that should produce periodic mass fluctuations δm_o (the integral of Equation (2) over the volume of the capacitors) that might be put to use to generate stationary forces. To generate such forces one acts on the capacitors with a second periodic force that pushes on the capacitors in one direction when δm_o is large, and the

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opposite direction when δm_o is small or negative. Since the reaction forces during the two phases are not equal, a time-averaged net force on the object results. Formally, the time-averaged force may be stated as:

$$<F> = -4\omega^2 \delta l_o \, \delta m \sin(2\omega t) \sin(2\omega t + \varphi), \tag{3}$$

where ω is the angular frequency of the voltage that produces the mass fluctuation in the capacitors, and δl_o the amplitude of the excursion produced by the second force, the reaction to which has a stationary, non-zero value when the cosine of the relative phase of δl_o and δm is non-zero, for:

$$<F> = -2\omega^2 \delta l_o \, \delta m \cos \varphi, \tag{4}$$

follows from Equation (3) when trigonometric identities are applied and all time-dependent terms are suppressed because they time-average to zero.

THE MACH-SLEPIAN SYSTEM

There are several ways to produce the second force that "shuttles" the dielectric material in the capacitor where a periodic mass fluctuation is driven by the application of a strong, alternating electric field **E**. The simplest shuttling method is the application of direct mechanical excursions induced by some suitable exterior electromechanical device. This method, however, is far from ideal, for the mass fluctuation induced by the electric field in the dielectric occurs effectively instantaneously throughout the dielectric, whereas the effect of mechanical shuttling

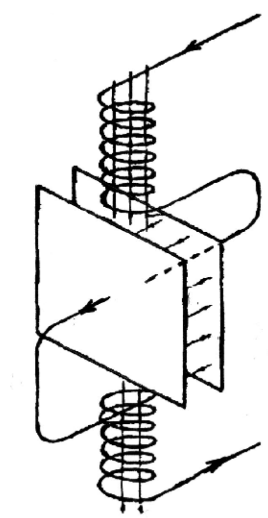


FIGURE 1. A Schematic Diagram of a "Slepian" Inductive-Capacitive Circuit (after Corum, *et al.*, 1999).

forces propagate through the dielectric at sound speed. Coordinating the two effects, as a result, is problematic. Another way to produce the desired shuttling that avoids this problem is by the application of a suitable magnetic flux **B** generated by an inductor located close to the capacitor, as in Figure 1. Since changes in the **B** flux, like changes in the **E** field, occur essentially instantaneously everywhere in the dielectric, coordinating their effects in the dielectric is simple.

If the capacitor has a simple parallel plate configuration, the induced **B** flux is perpendicular to the **E** field between the plates, and the fields have the same frequency and an auspicious relative phase, then the magnetic part of the Lorentz force, the second term in the RHS of

$$\mathbf{F} = q[\mathbf{E} + (\mathbf{v} \times \mathbf{B})], \tag{5}$$

where **v** is the velocity of the lattice ions imparted by the action of the **E** field, will generate a stationary force like that described by Eq. (4). Such a stationary force, however, can only arise in a system of this sort without violating "momenergy" conservation if Mach effect mass fluctuations actually occur, physically coupling the system with the chiefly distant matter in the universe.

H. Brito (2003) has claimed to see very small thrusts in in a device modeled on the circuit of Figure 1. His device, however, is configured to optimize the interplay of the **E** and **B** fields by the use of the toroidal geometry shown in Figure 2. Others who have investigated "Slepian" type circuits [so-named for one of their early discussants; see Corum, *et al*., 1999] have tried to extract a stationary thrust from them by appeal to the so-called "Heaviside" force – the time-derivative of the Poynting vector that appears in the analysis of this subject that must be "subtracted out" to preserve momenergy conservation [see Panofsky and Phillips, 1962, and Woodward 2003b]. Since the Heaviside force, being periodic in all systems of interest, time-averages to zero, Brito instead bases his claim to a stationary

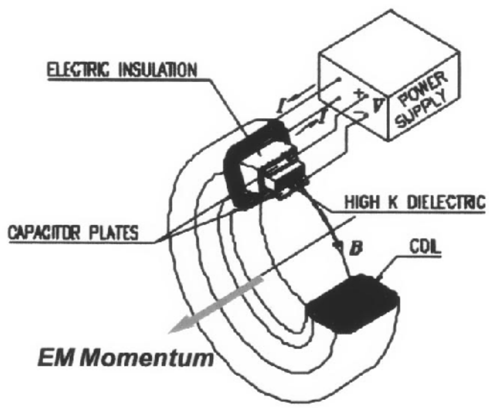


FIGURE 2. H. Brito's Schematic Diagram of his "Electromagnetic Stress Tensor" Device.

force on the **v** X **B** part of the Lorentz force. This leads Brito to the following expression for the time-averaged force generated by a device like that shown in Figure 2:

$$\langle F \rangle = \frac{\varepsilon_r \omega\, nIV d}{2c_0^2} \sin\varphi\,, \tag{6}$$

where ε_r is the dielectric constant of the capacitor core material (4400 in Brito's devices), ω the operating frequency (39 kHz), *n* the number of turns of the inductor (900 per device), *I* the amplitude of the current in the inductor, *V* the amplitude of the voltage across the capacitor (200 volts), *d* the length (or height) of the capacitor (8 mm), and φ the relative phase of the voltage in the capacitor and the current in the inductor (90 degrees). With devices of this sort (three operated in tandem) Brito claims to have detected thrusts on the order of a dyne. Not much; but if true, either a violation of momenrgy conservation (as he notes), or evidence suggesting the presence of a Mach mass fluctuation effect.

I will not consider seriously the possibility that conservation of momenergy is violated. That eliminates all purely electromagnetic claims to the generation of stationary thrusts in devices like those in Figures 1 and 2 (and Brito's preferred explanation thereof). So we now must consider Mach effects to see if they really do make possible the production of measurable thrust in Slepian devices [which I shall call Mach-Slepian devices]. In particular, Equations (1) and (2) above lead to the prediction that the action of a periodic electric field **E** on the dielectric core material should produce a Mach effect mass fluctuation. Since the first time derivative of the proper energy density E_o is just the power density; and when integrated over the volume of the dielectric core that becomes the total power delivered to the capacitor, which instantaneously is just the product of the voltage and current applied to the capacitor, we see that the mass fluctuation predicted will occur at twice the frequency of the voltage applied to the capacitor (because the product of two sinusoids of the same frequency is another sinusoid with twice the frequency). So, for Mach effects to allow the production of a stationary thrust two things must be true. First, the magnetic field **B** with the same frequency as the voltage applied to the capacitor must produce a "shuttling" force with twice the frequency of the **E** and **B** fields. Second, the Mach effect mass fluctuation must take place in such a way that the combined action of the external **B** field and lattice stresses induced thereby lead to the production of a stationary thrust.

In the simplest circumstances, the second requirement is satisfied if the mass fluctuation and **B** field peak when the velocity of the ions in the dielectric owing to the action of the **E** field peaks too. That is, the dielectric core of the capacitor is treated as a tethered propellant accelerated by the **B** field when its mass is, say, larger than normal due to the action of the **E** field. The force produced by the **B** field on the dielectric core is communicated to the whole device via the reaction to the force that acts through the **B** field on the inductor(s). As the dielectric begins to move due to the action of the **B** field, lattice forces are excited that act to restore the initial configuration. They, however, act on the dielectric *later* when it is in (more nearly) its normal massive state. If this cycle is repeated periodically, the result is a time-averaged net force on the device where the momentum change is communicated via the gravinertial field induced by the mass fluctuation excited by the **E** field.

Turning to the first requirement, it is straight-forward to show that the magnetic part of the Lorentz force [the second term on the RHS of Equation (5)] will have a frequency that is twice that of the applied magnetic field. **v** in this term arises from the action of the **E** field, and the equation of motion – $q\mathbf{E} = \mathbf{F} = m\mathbf{a}$ – for the ions in the lattice of the dielectric is easily integrated with respect to time to give a formal expression for **v**. If initial conditions are chosen so that the position and acceleration of the ions are sines of the angular frequency ω and time t, then **v** turns out to depend on the cosine of ωt. Since **v** and **B** are orthogonal by design, their cross-product is just their simple product, and the product of two sinusoids of the same frequency returns a sinusoid of twice that frequency (and a phase dependent term) as required. So shuttling ions in which Mach effects are driven by the application of a suitable **E** field by applying a **B** field of the same frequency with an auspicious phase may actually work if the mass fluctuations coincide with the part of each cycle induced by the **E** field where the velocity, irrespective of whether its direction is positive or negative, is a maximum.

To show that the Mach effect mass fluctuation peaks when **v** due to the action of the **E** field peaks, we first note that the impulse Mach effect is proportional to the second time-derivative of the proper energy density, and the proper energy density will be the rest-mass of the lattice ions plus their potential energy due to lattice stresses produced by the action of the **E** field. With a sinusoidal applied **E** field, after initial transients have settled out, there will be some fixed total energy added to the ions that will periodically shift between the kinetic and potential states. The peak kinetic energy for each ion will just be the ion's mass times the square of its peak **v**. The instantaneous ion potential energy will then be that peak kinetic energy minus the instantaneous value of the kinetic energy, or:

$$PE = \frac{1}{2} m \left(\frac{\mathbf{E}_0 q}{\omega m} \right)^2 \left[1 - \cos^2(\omega t)\right] = \frac{1}{2k} (\mathbf{E}_0 q)^2 \left[1 - \cos^2(\omega t)\right], \tag{7}$$

where $\mathbf{E}_0$ is the amplitude of the applied **E** field, q the ion charge, m its mass, and k the "spring" constant of the lattice forces. (Since simple harmonic motion is assumed here, we may use the fact that $\omega = (k/m)^{1/2}$ to simplify the expression for the *PE* as above.) Applying trigonometric identities we find that:

$$PE = \frac{1}{4k} (\mathbf{E}_0 q)^2 \left[1 - \cos(2\omega t)\right]. \tag{8}$$

Since we are only interested in the phase of the Mach effect mass fluctuations with respect to the velocity of the ions in the lattice, and since ρ_0 is just the quiescent proper matter density plus the *PE*s of all of the lattice ions, it follows that:

$$\delta m \propto \frac{\partial^2 \rho_0}{\partial t^2} \propto \frac{\partial^2}{\partial t^2}[1 - \cos(2\omega t)]. \tag{9}$$

Taking the indicated derivatives we arrive at:

$$\delta m \propto 4\omega^2 \cos(2\omega t). \tag{10}$$

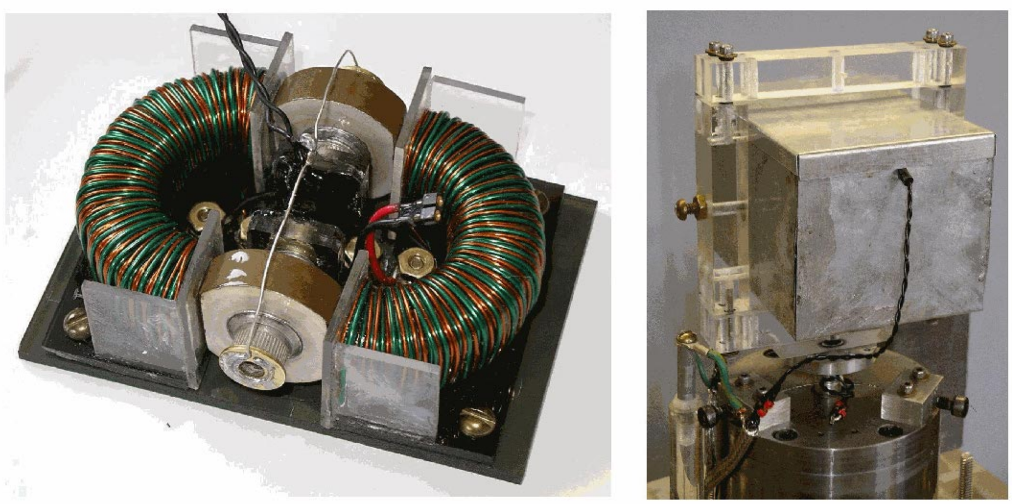
Or, writing K_1 for the constant of proportionality in Equation (10) [the coefficient of the trigonometric term in Equation (8)] and absorbing the 4 into that constant,

$$\delta m = K_1 \omega^2 \cos(2\omega t). \tag{11}$$

We thus see that the Mach effect mass fluctuations do indeed occur when the (absolute) velocities of the ions in the lattice of the core material are at a maximum. As a result, we may reasonably expect that the application of the B field described above will act to produce a force on the lattice ions when the Mach effect produces a fluctuation in their proper masses. And consequently, we may expect to see stationary thrusts in auspiciously engineered Mach-Slepian devices. A quantitative treatment of thrust production in these devices is provided below.

AN EXPERIMENTAL TEST

While Brito's Mach-Slepian device, shown schematically in Figure 2 above, is elegant in its simplicity, toroidal capacitors with cores of high dielectric constant are not easy to come by. (Brito had his specially fabricated.)



(a) A Hybrid Mach-Slepian Device with High Voltage Capacitors Mounted Between High Flux Inductors.

(b) The Faraday Cage on the Force Sensor.

FIGURE 3. Mach 3 and Its Mounting Arrangement on the Force Sensor.

Nonetheless, hybrid devices that can be operated at significantly higher power can be assembled from common, off-the-shelf components that are both cheap and readily available. High voltage capacitors made with materials with dielectric constants in the range of 8000 to 9000 (roughly twice the dielectric constant of Brito's capacitors) can be had for a dollar or two a piece. And powdered iron inductor cores in a toroidal shape likewise can be had in a variety of sizes and shapes at a cost of several dollars. Indeed, when it became clear that the Mach-Slepian approach was that to be explored, I fabricated the device shown in Figure 3a – labeled Mach 3 as the third iteration of the basic design – from a pair of Cera-Mite capacitors (top and bottom center of Figure 3a) and an Amidon inductor core (0.05 m OD, material #26, with several hundred turns of bifilar windings) in the spare parts supply of my laboratory.

The inductor halves are wired in series and driven by a circuit separate from that for the capacitors. Together with the high permeability core (μ = 75), when driven with an alternating current with an amplitude of typically four amperes, **B** fluxes in the gaps where the capacitors are located on the order of several hundredths of a Tesla can be achieved. The modified Cera-Mite high voltage capacitors each have a capacitance of 5.5 nanofarads. Like the inductor, they are driven by a high power (2 kW) amplifier through a toroidal step-up transformer. The secondary circuits of the two step-up transformers have sense resistors so that the currents and voltages in each can be monitored, and the current and voltage in each multiplied to give the instantaneous power waves in the circuits. The phase-locked, phase-adjustable waveforms that drive the high power amplifiers are produced by a simple sine wave generator fitted with a phase shifter, suitable filters, and automatic gain control circuits to stabilize the two outputs of the generator. The device is mounted in a Faraday cage with bolts into the outer studs of the capacitors through a plastic frame that is attached to the force/weigh sensor, as shown in Figure 3b.

The trust/weight detection apparatus used in this experiment was that developed in earlier work. It is described in some detail in Woodward, 2003a, so I shall only briefly mention the main parts of it here. The thrust/weigh sensor is a Unimeasure U-80 position sensor fitted with a stainless steel diaphragm spring that converts it into a force sensor. It is based on two magneto-resistive Hall probes mounted on a shaft that move with the shaft in a fixed magnetic field that determines the resistance of the probes. This device is wired as one leg of an adjustable Wheatstone bridge. The bridge voltage is amplified so that high sensitivity differential weight/thrust measurements can be made. Data is acquired from this sensor at the 600 ADC counts per gram (or, roughly, 1000 dynes) level. So, with signal averaging, weight changes/thrusts at the level of a milligram/dyne or better can be resolved. The upper part of the one cm thick steel case that shields the U-80 is visible in Figure 3b.

The U-80 with Mach 3 mounted thereon in the Faraday cage shown in Figure 3b is mounted in a transparent plastic vacuum vessel which was evacuated to the range of 15 to 30 milliTorr during normal operation. The Faraday cage insures that leakage fields from the device in operation are trapped and do not couple either to other fixed parts of the apparatus, or electrically to the thrust/weight sensor circuitry. If one assumes the validity of the conservation of momentum, the Faraday cage also eliminates all purely electromagnetic schemes such as Brito's, Corum's, and others' as candidate explanations for any thrusts seen since all electromagnetic fields and effects are isolated inside the cage. Running in a vacuum eliminates spurious effects that might arise from corona and wind effects that might be driven by the high field strengths present in immediate proximity to the device.

The thrust/weight of the devices was sampled at a rate of 100 Hz and stored in the memory of a PC using a Canetics ADC board. In addition to the thrust/weight signal, the powers present in the capacitor and inductor circuits were also sampled and recorded. 50 Hz anti-aliasing filters were used on all ADC channels. The power signals were switched with the two DAC channels on the Canetics board. Data were acquired in 7 second cycles, the leading and trailing parts of each cycle being quiescent conditions. The two power signals were not switched together. Rather, one signal was switched on, and then a fraction of a second later the other signal was switched on. Switch-off was done in reverse order. This way the effect of the individual signals, as well as the combined effect of the two signals, could be ascertained. Since the noise in the system was larger than the signals sought, signal averaging of typically 100 or more data cycles was done to suppress the noise and bring out the signals.

RESULTS

Since the effect sought was expected to be small – on the order of a few tens of dynes [one dyne is 10^{-5} n.] at best – the apparatus was adjusted to maximize the frequency and power in the circuits because the effect scales with these quantities. 50 kHz was found to be about the optimum running frequency, so, aside from a frequency scaling test mentioned below, this was the frequency used in the work reported here. The other chief quantity that the predicted thrust depends upon is the relative phase of the voltage in the capacitor circuit (and thus the **E** field in the dielectric cores) and the current in the inductor circuit (and thus the **B** flux in both the inductor and capacitor cores). As sketched above, to generate a thrust the **B** flux must peak when the ion velocities in the dielectric, under the action of the **E** field, peak. In terms of the voltage and current, this translates into the requirement that the voltage in the capacitor circuit and the current in the inductor circuit must have a relative phase of either 90 or 270 degrees for a thrust to be produced. At 0 and 180 degrees of relative phase, no effect is expected for the mass fluctuations occur when the **B** field does not act on the ions in the dielectric. The conditions just stipulated are, of course, ideal. In real circumstances we might expect, for example, transient thrusts when the power to the circuits are switched since at switching the ideal phase relationships will not perfectly obtain. But once the signals have stabilized, such switching transients should die out.

The chief results obtained with this system are displayed in the four panels of Figure 4. The thrust/weight signals are noisy and colored red. They are scaled on the left hand side of the panels. The capacitor power signals are presented in green with their corresponding scale on the right hand side of the panels. They are all roughly 2.2 kWatt. The inductor power signals are shown in blue, unscaled. They are all roughly 33 Watts, corresponding to a current with an amplitude of four amperes delivered to the inductor windings. About 250 data cycles were averaged for each panel in Figure 4.

Ignoring the residual fuzz in the thrust/weight traces, inspection of Figure 4 reveals that, aside from a switching transient when the capacitors are switched on, there is little or no thrust present in either the 0 or 180 degree data – as expected. Secular evolution of the thrust trace, especially in the 180 degree data, is present (likely due to heating of the power feeds). But a prompt shift in the thrust trace, particularly at capacitor power switch-off, that is the signature of the presence of a real thrust is, at most, a few dynes in the 0 and 180 degree data. This is not true for the 90 and 270 degree data. A thrust of 20 to 30 milligrams/dynes is present in both cases, especially at capacitor power switch-off. And the direction of the thrust changes between 90 and 270 degrees of phase – exactly as one would expect of a Mach effect thrust. Moreover, the observed thrust lies in the expected range of a few tens of dynes (assuming that Brito saw a real Mach effect in his experiments).

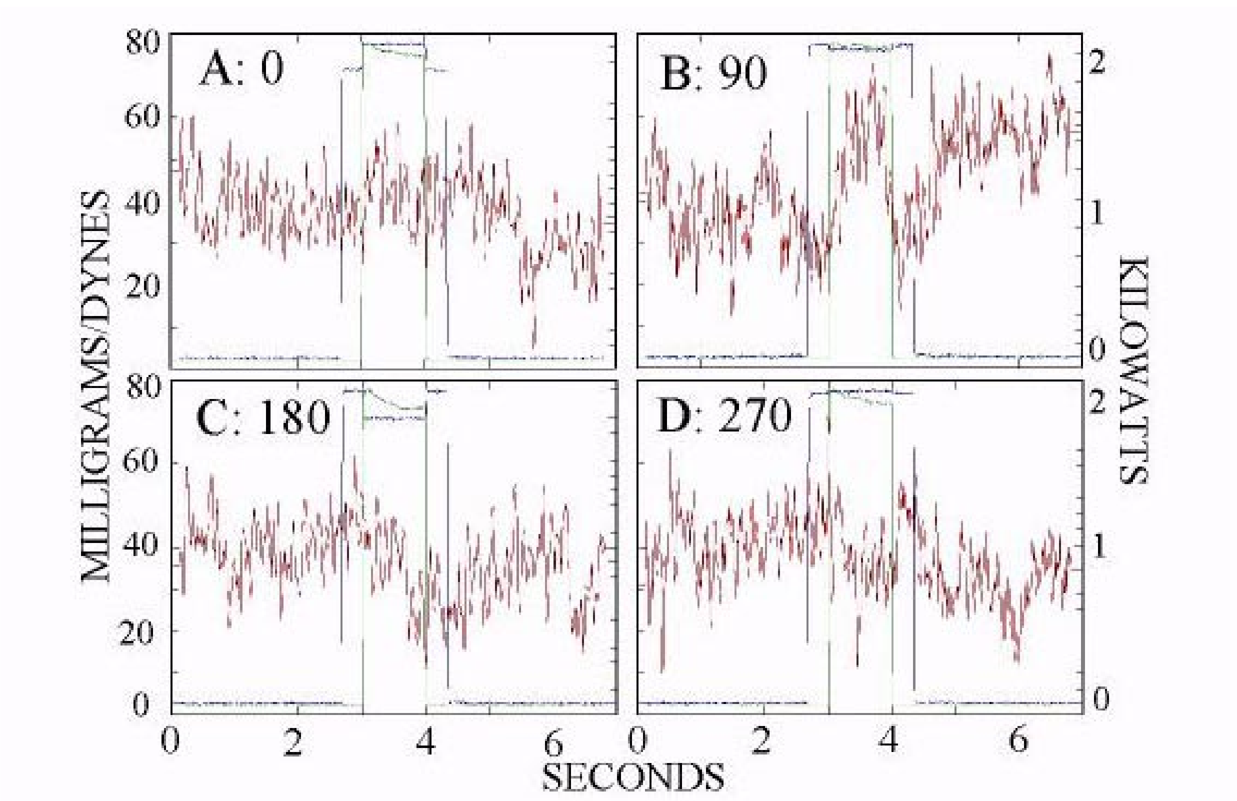


FIGURE 4. The Thrusts Measured with Mach 3 at the Indicated Relative Phases for the Voltage in the Capacitors and the Current in the Inductors.

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The obvious question here is: Aside from all of the precautions taken to avoid spurious signals, is there any reason to take the data in Figure 4 as evidence for a real thrust generated by the predicted Mach effect mass fluctuation? Perhaps the thrusts that appear in panels B and D of Figure 4 are simply a consequence of switching on the capacitors. The fact that this didn't happen at 0 and 180 degrees speaks against this possibility. But another test would be reassuring. What about the chance that the effect might be due to leakage fields not fully trapped by the

Faraday cage? And what about the possibility that the recorded thrust might be due to a purely electromagnetic effect of the sort advanced by Brito and others (notwithstanding that momentum conservation is violated by such schemes)?

FREQUENCY SCALING

We tackle the last question first by inquiring into the frequency scaling of the thrust seen. From Equation (6) we see that Brito's effect scales linearly with the frequency, the inductor current, and the capacitor voltage. Equation (11) shows that the Mach effect mass fluctuations scale with the square of the frequency of the exciting **E** field – all other things remaining the same. But when one takes power scaling into account, the frequency scaling changes (because the power is a function of frequency too). For comparison (and practical) purposes, a joint frequency and power scaling relationship is more helpful than Equation (11). As mentioned above, the first time-derivative of the proper energy density in Equation (2) is just the instantaneous power density, and integrated over the volume of the capacitors, this is the total instantaneous power delivered to the capacitors. So in this case, writing the proper power as P_0 [$= P\sin(2\omega t)$], Equation (2) can be rewritten as:

$$\delta m_0(t) \approx \frac{\phi}{4\pi G \rho_0 c^4} \frac{\partial P_0}{\partial t}. \tag{12}$$

Taking the time-derivative of P_0 [$= P\sin(2\omega t)$] yields that the mass fluctuation scales linearly with the product of the power amplitude and the frequency. So, if we reduce the frequency by one half, keeping the voltage and current amplitudes as nearly the same as possible, Brito's predicted thrust drops to a half of its original value. The Mach effect in the Cera-Mite capacitors used, however, because the power in the capacitors scales with the current in their own circuit, rather than that in the inductor circuit, in fact drops to one twelfth of its initial value. (The power drops to one sixth of its 50 kHz value and the frequency is halved.) Accordingly, the thrust should drop by at least this much.

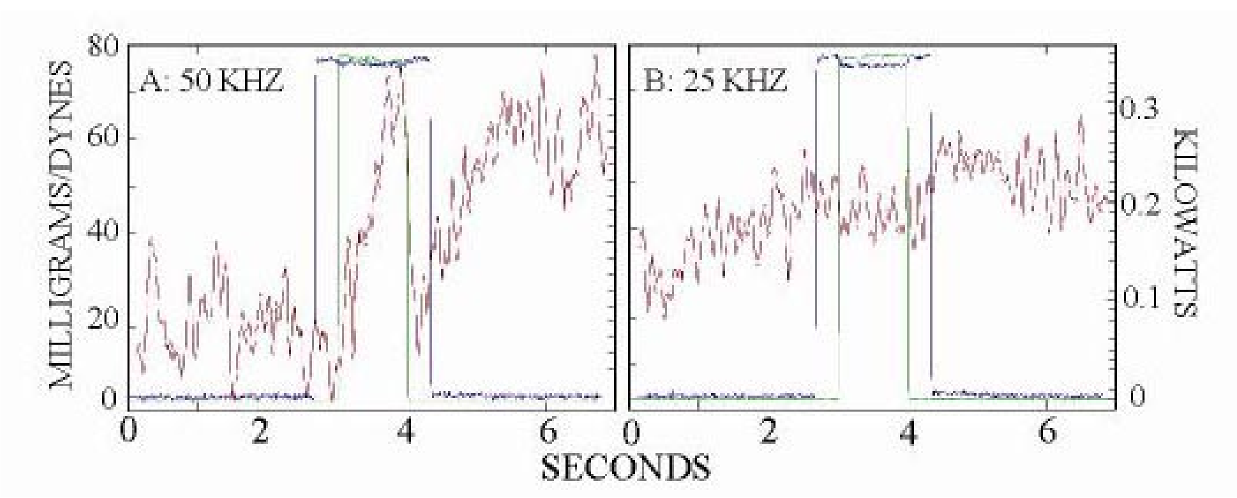

FIGURE 5. The Thrust Responses at 50 and 25 kHz. (The 25 kHz Data are Consistent with the Mach-Slepian Scheme. They are not Consistent with the Purely Electromagnetic Scheme.)

When this test was actually carried out, halving the frequency to 25 kHz, it turned out that the amplitude of the voltage signal in the capacitors could only be maintained at 80 to 90% of its 50 kHz value, and the amplitude of the current in the inductors could only be maintained at 80% of its 50 kHz value without clipping the output signals of the power amplifiers. So the prediction of Brito's purely electromagnetic effect drops from one half to one third of the 50kHz effect. The Mach effect in this case drops, because the power decreases to one sixth of its 50 kHz value at 25 kHz, to one twelfth. And since the amplitude of the **E** field is smaller, **v** is also smaller; since the current amplitude is smaller, **B** decreases. So the expected Mach-Slepian thrust is less than 5% of the 50 kHz value. Figure 5 shows the 90 degree responses at 50 and 25 kHz. (About 120 data cycles were averaged in each case and the fuzz in the raw data was busted by performing a 60 millisecond running average on the thrust/weight traces.) Evidently, the roughly 10 milligram/dyne response *expected* on the basis of Brito's theoretical conjecture at 25 kHz is not realized. Indeed, the only obvious behavior in the 25 kHz data is a secular downward drift, presumably of thermal origins; and the data are consistent with the Mach-Slepian prediction of an effect on the order of two dynes or less. This result should not be too surprising since the thrust generated by Mach 3 occurs in a Faraday cage where any purely electromagnetic thrust would be trapped (and thus nullified) in any event (if momentum is conserved).

THE PREDICTED MACH EFFECT MAGNITUDE

We next address the question: Does the observed effect correspond to that expected on the basis of Mach effect mass fluctuations? The predicted mass fluctuation can be computed using Equation (12) above which, after differentiation of P_0 and taking account of the fact that $\phi = c^2$, reads:

$$\delta m_0(t) \approx \frac{\omega P_0}{2\pi G \rho_0 c^2} \cos(2\omega t). \tag{13}$$

The amplitude of the mass fluctuation, the coefficient of the cosine function on the RHS, from knowledge of the operating frequency (50 kHz), power amplitude (2.3 kWatts), density of the material (roughly 5.6 gm/cm^3), and the standard values of G and c. That turns out to be about 3.5 gm (3.5 X 10^{-3} kg), a non-negligible fraction of the total mass of the active dielectric in the capacitors. The total mass of the dielectric is 43 gm (0.043 kg), but only about two thirds of that material (29 gm) lies in the region of intense **B** field.

To compute the thrust produced by the action of the **B** field on the dielectric in the capacitors we note that the vertical component of the force on the thrust sensor is:

$$F_v = (m_0 + \delta m_0)\mathbf{a}_v, \tag{14}$$

where $\mathbf{a}_v$ is the vertical component of the acceleration exerted on the sensor. Since we are only interested in the net time-averaged thrust due to the action of the **B** field on the parts with fluctuating mass, that is, the capacitor dielectric, we ignore the action of local gravity and the various mechanical and electromagnetic forces that act on other parts of the apparatus that time-average to zero. Accordingly, we note that the peak force $\boldsymbol{F}_B$ on the displacement current i in the dielectric is just:

$$F_B = \mathbf{B}_v iL, \tag{15}$$

where L is the sum of the thicknesses of the capacitors (1.65 cm), $\mathbf{B}_v$ has the computed (on the basis of Ampere's Law) value 0.025 Tesla, and i in the capacitor circuit is a little more than four amperes. This yields that $\boldsymbol{F}_B$ is about 165 dynes (0.00165 n). Since the part of $\mathbf{a}_v$ due to $\boldsymbol{F}_B$ is just $\boldsymbol{F}_B$ divided by m_0, and the first term on the RHS of Equation (14) time-averages to zero for periodic $\mathbf{a}_v$, we find that:

$$\langle F_v \rangle = \frac{\delta m_0}{m_0} F_B. \tag{16}$$

Substitution of the values for the quantities on the RHS of Equation (16) gives that thrust attributable to Mach effect mass fluctuation in this case should be about 20 dynes (0.00020 n). Evidently, the predicted value of the Mach effect thrust matches that observed in the experiment described here. A word of caution regarding this match, however, seems in order. Given the several computed values that go into the prediction and the uncertainties in the measures of the input values, the prediction is probably only valid up to a factor of two or three notwithstanding the careful measurement of the various parameters involved.

OTHER TESTS OF THE RESULTS

Having disposed of “stress-tensor” types of explanations of the effects seen, we turn to more mundane types of spurious signal sources. Absent any other information, it might be that the effects present in Figures 4 B and D and Figure 5 A are simply a consequence of turning on the capacitors. That these effects evidently depend on the relative phase of the inductor current speaks against this possibility. But a simple way to check this is to reverse the switching order to see if the effect is only present when both the capacitor and inductor circuits are energized. Accordingly, data of this sort was collected. It is displayed in Figure 6 below.

Another potential source of spurious signals is electromagnetic coupling of the power circuits, the Faraday cage notwithstanding, to the fixed parts of the apparatus like the plastic vacuum case. Again, the absence of any effects when only one of the two power circuits is activated speaks against such signals (especially since the power feeds entered the cage at opposite ends). This was first checked by taking data with the lid of the steel box removed, exposing Mach 3 to the upper part of the vacuum case. These data, to suppress noise, were 60 millisecond running time-averaged as only 60 cycles were taken. That average is displayed as panel A of Figure 6. The result, allowing for the reversed switching order, does not differ dramatically from panel D of Figure 4. A 15 to 20 dyne prompt effect at the switch-off of the, in this case, inductor power is clearly present.

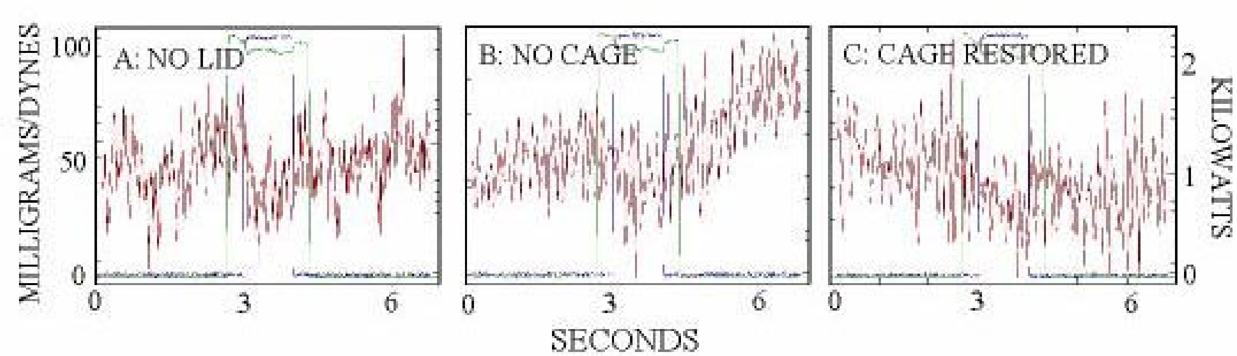

FIGURE 6. A. The Response for Mach 3 for Several Configurations of the Faraday Cage.

A more extreme test of this sort is possible: complete removal of the Faraday cage. Since the mass of the cage is a significant fraction of the total loading mass on the thrust/weight sensor, removal of the cage changes the mechanical response of the sensor noticeably. But if electromagnetic coupling of the device and its power circuits to their surroundings is really important, a dramatic change in the signals can be expected. Otherwise we should still see an effect like that in Figures 4 D and 6 A. Data taken without the cage are presented in Figure 6 B. And effect, as expected, is still present. But it is a bit smaller than that in panel A. In part this difference may be due to the changed mechanical response of the thrust sensor owing to the significant change in its’ loading with the cage removed.

As a final check to see if the smaller response in panel B (with the cage removed) might be due to a systematic change (ageing of parts or some such thing) the cage was restored and a sequence of data taken. This data is displayed in panel C of Figure 6. 40 of the 110 cycles averaged in this panel were taken with the power feed for the capacitors exterior to the cage lengthened by about 30 percent to see if the feed length affected the behavior of the system. It didn’t. The 15 to 20 dyne prompt effect at inductor power switch-off is still present. So the switching order reversal and all of the manipulations of the Faraday cage and power feeds are consistent with the effects shown in Figures 4 through 6 being of Machian origins. Further tests of this sort will be carried out after the rather small vacuum chamber is replaced with a larger one.

CONCLUSION

What are we to make of the experimental results presented here? Although much more work remains to be done, they seem to be a fairly straight-forward, reasonably complete case for the reality of Mach effect mass fluctuations and their use in Mach-Slepian systems to produce thrust without the ejection of propellant. Further work will certainly show whether that is true. Since the Mach effect scales linearly with the frequency of the exciting signals when the power is held constant, the two kW input power in Mach 3 activating a device operating at, say, 50 MHz (with a comparable inductor current amplitude) should produce 30,000 dynes (30 grams) of thrust. That is enough to do ISS reboost with a single device. Assuming, of course, that no unexpected problems arise when scaling the operating frequency by three orders of magnitude. (Complications at higher frequencies and powers can be expected because the second transient term in Equation (1) will likely be excited.) Higher frequencies and powers, and larger shuttling magnetic fields hold out more promise yet. So it would seem that Mach-Slepian systems may be the long-sought answer to the problems of access to space. And our future out there in spacetime may prove interesting.

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