TWEAKING FLUX CAPACITORS

James F. Woodward

Departments of History and Physics, California State University, Fullerton, CA  92834
714-278-3596;  jwoodward@fullerton.edu

Abstract. Mass fluctuations that arise from Mach effects when objects that can store internal energy are accelerated and their application to the production of propellantless thrusts are discussed. A follow-on experiment to that reported at STAIF 2004 is described. An effect of the sort expected continues to be observed. And it displays scaling behavior distinctive to Mach effects.

MACH'S PRINCIPLE AND THE ORIGIN OF INERTIA

Named by Einstein about the time he invented GRT, Mach’s principle is the assertion that the manifestations of inertia cannot be entirely innate and inherent, or simply imbued in material objects by virtue of their existence in absolute space. Rather, the manifestations of inertia in matter must arise from the presence in the universe of the rest of its material contents. This means that \( ma \) in Newton’s second law must arise as a consequence of accelerations with respect to the bulk of the matter in the universe as a consequence of the action of that matter on the accelerating object. Mach’s principle has a tortuous history, chiefly because both Newton and Mach couched much of their discussion of absolute space and inertia in terms of rotational motion (Newton’s famous bucket and its contents). The result has been some deeply confused and misguided arguments relating to the issue of the origin of inertia.

We ignore rotation, for all of that follows as long as the relativistic version of Newton’s three laws of mechanics obtain. In the context of the three laws, Mach’s principle can be stated very simply: The inertial reaction forces that agents acting on objects experience when they exert accelerating forces on those objects are the consequence of the gravitational action of the rest of the matter in the universe on the objects. Matter here is to be understood as any substance that exerts a gravitational action on other matter, as in GRT, not simply as electrons, neutrons, and protons. It turns out that this is true when the inertial masses of things are just equal to their total gravitational potential energies divided by the square of the speed of light.

Is Mach’s principle consistent with GRT? That is a matter of continuing contention. Derek Raine (Raine, 1975) showed that inertial reaction forces are caused by the gravitational action of cosmic matter if that matter is distributed isotropically. That is, the addition of the “boundary condition” of isotropically distributed matter at cosmological scale to GRT allows one to incorporate Mach’s principle in GRT. But his analysis did not take account of the energy supposed to be associated with gravity waves; so it is not considered compelling by some. Nonetheless, the equivalence of inertial and passive gravitational mass (the “weak” Equivalence Principle), and the implausibility of the proposition that inertia is a completely innate property of matter, suggests that Mach’s principle is correct. If so, does this open up possibilities for the solution of the propulsion challenges? That is, can means be found to accelerate objects without the expulsion of material propellants? And more radically, can “exotic” matter be induced in sufficient quantities to make traversable wormholes? If the results of the continuing investigation reported here are valid, it seems that the answers to these propulsion questions may be “yes”.

MACH EFFECTS

Treating inertia as a gravitational phenomenon makes the sources of local gravitational phenomena – now including
inertial reaction effects – dramatically larger than is customarily thought to be the case. Moreover, since inertial reaction forces only occur in situations where things are accelerated, it follows – if only from the electrodynamical analogy – that inertial effects involve radiative behavior. Indeed, inertial reaction forces can be viewed as the reaction to the radiative action of cosmic matter on accelerating objects. As is known from the case of electrodynamics, radiation reaction includes third, as well as second, time-derivatives in the equation of motion and consequently several peculiar phenomena not encountered in normal mechanics (for example, “pre-acceleration”).

In electrodynamics, electric charge is a “Lorentz invariant” quantity; that is, all observers, irrespective of their states of motion, agree on the numerical value of the quantity of any given charge. Mass-energy, the charge of both gravity and inertia, is not a Lorentz invariant quantity (though rest mass is). This raises the question: What happens to the mass-energy of some object when it is accelerated by some external force and the gravitational (or inertial as you choose) field of cosmic matter acts on the object radiatively to resist the acceleration? The way to “reverse engineer” the answer to this question is to write down the inertial reaction force in the form of a field that acts on the object, take the “divergence” of the field strength, and set it equal to the source of the field. When this is done four-dimensionally (correct from the relativistic point of view) and Mach’s principle is used to simplify the resulting equations, one finds that the resulting expression for the local source of the inertial (or gravitational) field has time-dependent terms that can be engineered to be surprisingly large. And one of the terms is always negative, though normally exceedingly small. These “Mach effects” can be generated in simple electrical circuits using high dielectric constant materials operated at high frequencies. They hold out the possibility of solving both of the propulsion challenges.

Do such effects actually occur?

THE MATH OF MACH EFFECTS

The Mach effect that holds out promise for propellantless propulsion follows from a differential field equation constructed by considering the inertial reaction force on an object accelerated by an external force and asking what the local sources of the “gravinertial” field are. With the help of Mach’s principle, one finds:

\[ \nabla^2 \phi - \frac{1}{c^2} \frac{\partial^2 \phi}{\partial t^2} = 4\pi G \rho_o + \frac{\phi}{\rho_o c^4} \frac{\partial^2 E_o}{\partial t^2} - \left( \frac{\phi}{\rho_o c^4} \right)^2 \left( \frac{\partial E_o}{\partial t} \right)^2 - \frac{1}{c^4} \left( \frac{\partial \phi}{\partial t} \right)^2 , \]

(1)

where \( \phi \) is the gravitational potential, \( c \) the speed of light, \( G \) Newton’s constant of universal gravitation, \( \rho_o \) the local proper matter density, and \( E_o \) the local proper energy density. It is the transient source terms on the RHS of Equation (1) that are of interest. They can be written:

\[ \delta \rho_0 (t) \approx \frac{1}{4\pi G} \left[ \frac{1}{\rho_o c^2} \frac{\partial^2 E_o}{\partial t^2} - \left( \frac{1}{\rho_o c^2} \right)^2 \left( \frac{\partial E_o}{\partial t} \right)^2 \right] , \]

(2)

where, as follows from Mach’s principle, \( \phi/c^2 = 1 \) has been used and the last term in Equation (1) has been dropped as it is always minuscule

The obvious way to test for the presence of proper matter density fluctuations of the sort predicted in Equation (2) is to subject capacitors to large, rapid voltage fluctuations. Since capacitors store energy in dielectric core lattice stresses as they are polarized, the condition that \( E_o \) vary in time is met as the ions in the lattice are accelerated by the changing external electric field. If the amplitude of the proper energy density variation and its first and second time derivatives are large enough, a detectable mass fluctuation should ensue. That mass fluctuation, \( \delta m_c \), is just the integral of \( \delta \rho_0 (t) \) over the volume of the capacitor, and the corresponding integral of the time derivatives of \( E_o \), since \( \partial E_0/\partial t \) is the power density, will be:
\[
\delta m_0 = \frac{1}{4\pi G} \left[ \frac{1}{\rho_0 c^2} \frac{\partial P}{\partial t} - \left( \frac{1}{\rho_0 c^2} \right)^2 \frac{P^2}{V} \right],
\]

where \( P \) is the instantaneous power delivered to the capacitor and \( V \) its volume. The predicted mass fluctuation can be computed using Equation (3) above which, after differentiation of \( P = P_0 \sin(2\omega t) \) and ignoring the second term on the RHS, reads:

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

As explained, for example, in Woodward (2004A, 2004B), such Mach effect mass fluctuations can be converted into sustained thrust by acting on capacitors in which mass fluctuations are driven with a magnetic field of the same frequency as the applied electric field. The device of this sort used to obtain the results reported below is shown in Figure 1. In it an array of high voltage capacitors are mounted between the poles of two “E” inductor cores on

\[\text{FIGURE 1.}\] The device tested comprised of “E” inductor cores wound with coils (clamped in a plastic jig) disposed so that the magnetic field between the poles threads four 2005 pf high voltage capacitors.

which four coils are wound. The electric field, in addition to producing the mass fluctuations, drives an alternating displacement current, \( i_d \), in the capacitors. The action of the magnetic \( B \) flux on the displacement current \( i_d \) follows from the Lorentz force law:

\[
F_B = i_d \times B \times L,
\]

where \( L \) is the length of the displacement current. Since \( i_d \) and \( B \) are orthogonal by construction and have the same frequency, we may write:

\[
F_B = B i_d L \cos \varphi,
\]

where \( \varphi \) is now the relative phase of \( B \) and \( i_d \). The device is mounted with two nylon screws in a plastic frame that is in turn bolted to the stage of a very sensitive force sensor.

The total force on the mechanical supports of the device (the plastic frame in which it is mounted in Figure 1), and thus the force that it exerts on the thrust/weigh sensor (in the steel shielding case in Figure 1), will be the inertial...
reaction forces to magnetic and the induced lattice restoring forces acting on the dielectric core material in the flux capacitors, or:

\[ F_{\text{tot}} = -(F_B + F_{\text{lat}}). \]  

(7)

In the absence of Mach effect mass fluctuations, this will time-average to zero as \( F_B \) and \( F_{\text{lat}} \) act in opposite directions, each for half a cycle, with equal strength once stationary operating conditions have been established. When Mach effect mass fluctuations are added to this behavior, the time-average of \( F_{\text{tot}} \) no longer vanishes in stationary circumstances if the phase relationship between \( F_B \) and \( i_d \) and \( \delta m_0 \) is such that \( F_B \) acts in phase with the mass fluctuation. The fractional part of the total proper mass due to the fluctuation will produce an inertial reaction force on the supports during the half-cycle that it acts that is not compensated during the other half cycle when the lattice forces act, for during that half-cycle the oppositely directed lattice force acts on a total proper mass that has a fractional component of the opposite sign due to the mass fluctuation. Since the signs of the force direction and mass fluctuation change together, that part of the inertial reaction force (relative to the force in the absence of mass fluctuations) will have the same sign as the fractional part of the force during the other half-cycle. This means that we can write for the time-averaged inertial reaction force on the device supports:

\[ \langle F_{\text{tot}} \rangle \approx -\frac{\delta m_0}{m_0} F_B \sin \varphi, \]  

(8)

where the phase angle \( \varphi \) is that between the voltage applied to the capacitors and the current in the inductors.

**EXPERIMENT**

The device in Figure 1 was constructed as a follow-on to the device described in Woodward (2004A, B). In the course of initial tests it was run as a series inductive-capacitive (LC) circuit to explore its resonance properties. In such a circuit, the L current and C voltage are always in quadrature. It thus came as a bit of a surprise that the relative phase of these quantities when displayed on an oscilloscope did not display this behavior – see Figure 2.

![FIGURE 2](image_url)

FIGURE 2. The inductor current and capacitor voltage signals recorded when the device in Figure 1 was run as a series LC circuit.

The apparent relative phase registered, using resistive current and voltage sensors, is shifted about 45 degrees from the simple quadrature relationship expected. Since the sense circuits worked fine at 50 kHz with an earlier device, it was determined that the 45 degree phase shift must have been due to hysteresis in the ferrite “E” cores (with a permeability of 2000 versus 75 for the inductor cores of the earlier devices). Checking to see if this shift was also displayed in the predicted Mach effect thrust data led to the restoration of separate circuits for the capacitors and inductors so that their relative phase could be adjusted (and so that larger currents in the inductors than those of the series LC circuit could be driven). Instead of the usual protocol of differencing results for 0 and 180 degrees, and 90 and 270 degrees to get the net effect for each phase reverse pair of operating conditions, data were taken for three
phase reversed pairs: 45 and 225 degrees, 90 and 270 degrees, and 135 and 315 degrees. If the traces in Figure 2 correctly track the L current and C voltage, then one should expect little or no thrust signal for the 45 – 225 degree results, and nearly the peak thrust signal for the 135-315 degree results.

The results (for typically 250 cycles of averaged data) are displayed in Figure 3 where the thrust, capacitor power, and inductor power signals are displayed. As in earlier work, staggered switching of the L and C circuits was use to insure that any thrust signal was only present when both the L and C signals were applied, for a signal present with

![Figure 3](image.png)

**FIGURE 3.** The differential thrusts for the differences of the voltage/current relative phases indicated in the upper left hand corner of each panel (noisy traces); along with the capacitor power (switched on at 3 s) in kilowatts and the inductor power (switched on at 2.7 s) which is not scaled.

only the capacitor or inductor energized clearly could not be of Mach effect origins. Inspection of Figure 3 reveals that the apparent phase shift of roughly 45 degrees between the L and C traces in Figure 2 – presumably due to the detection circuitry – is carried through to the Mach effect thrust generation. Although the initial response at capacitor switch-on in the 315-135 degree panel is sluggish, there can be no mistake about the prompt thrust shift when the inductors are shut off at 4 seconds – a shift of roughly 15 dynes. A smaller thrust shift, as one would expect, is present in the 270-90 degree panel, perhaps 5 dynes or so. And in the 225-45 degree panel there is no detectable thrust shift present at all; again, as one would expect from a Mach effect thrust given the relative L current versus C voltage phase in Figure 2.

Notwithstanding that many of the parameters of operation for the E-core device were different from those of the earlier devices, the recorded thrust – 7 or 8 dynes – is very nearly the same as that obtained with the earlier devices – about 12 to 15 dynes. Investigation of the details of operation revealed that this behavior was to be expected. More interesting than the measured magnitude of the effect is whether it is genuine or not. Earlier work showed that the sorts of stray electromagnetic fields present in the vicinity of one of these devices had no effect on the measured thrusts, so no attempt was made to run the device in a Faraday cage. The more compact structure of the E-core device, however, made regions of fairly strong field gradients that were not as pronounced with the earlier devices. Indeed, it was clear that ionization and coronal discharge effects were produced with the device, especially if it was operated before the limiting vacuum of the pump (about 20 milliTorr) was approached.

![Figure 4](image.png)

**FIGURE 4.** The results for 315 minus 135 degrees of relative phase (150 cycles averaged) when the E-core device was operated at atmospheric pressure.
Faced with the possibility that the observed thrusts might arise from modulated coronal discharge, the obvious test to check for this was carried out. That test is operation at atmospheric pressure where corona is essentially completely suppressed. Or, at any rate, given an ambient pressure that is orders of magnitude different, one might reasonably expect very different behavior from that at 20 milliTorr. A Mach effect thrust, however, should be the same regardless of the ambient pressure. When the device was operated at atmospheric pressure, the results shown in Figure 4 were obtained. They are somewhat noisier than those in Figure 3, for only 154 cycles of data were averaged in this case. But the presence of the effect at about the same level as in the vacuum results is unmistakable. It would appear that the expected Mach effect thrust in this flux capacitor device is indeed present.

**CAPACITOR VOLTAGE SCALING**

Another way to check for the genuineness of the thrust effect seen is to examine the scaling of the effect with the voltage amplitude of the signal applied to the capacitors in the device. Since the Mach effect scales linearly with the applied power, this will contribute a scaling with the square of the voltage. But in addition to this scaling, the observed thrust scales with the magnitude of the displacement current in the capacitor cores, and that scales linearly with the voltage applied to the capacitors – assuming linear behavior of the core material. When this is combined with the scaling of the Mach effect, the complete voltage scaling goes as the cube of the voltage applied to the capacitors, as long as all other parameters are held fixed.

This voltage scaling test is especially important, for others have also predicted thrusts in devices of the sort discussed here. For example, Brito and Elaskar (2005) claim that a purely electromagnetic effect can give rise to thrusts like those reported here. Their predicted thrust, being strictly electromagnetic, however, violates momentum conservation and scales linearly with the voltage applied to the capacitors. [See Woodward (2003) for a detailed exposition of this argument.]

Their predicted thrust for flux capacitor systems is:

$\langle F \rangle = \frac{\varepsilon_r \omega_0 l V d}{2 c_0^2} \sin \phi$  \hspace{1cm} (9)

where $\varepsilon_r$ is the relative dielectric constant of the capacitive elements with thickness $d$ in the circuit(s), $\omega$ the angular frequency of the applied capacitor voltage $V$ and inductor current $I$ with relative phase $\phi$, and $c_0$ is the vacuum speed of light.

To carry out this test, the voltage applied to the capacitor – a signal with a 1.0 kV amplitude – was reduced to 800 V amplitude. If linear scaling with voltage obtains, as in Brito’s analysis, the thrust observed should decrease to 80% of that present in the data presented above. A Mach effect thrust, on the other hand, should decrease to about 51% of the thrust produced with the voltage amplitude of 1 kV because of the $V^3$ scaling in that case. Since the Brito-Elaskar effect can be regarded as a stand-in for electromagnetic effects generally, this test was conducted with some care. First, the vacuum and air results taken at the 1 kV operating voltage were averaged together, giving a result that averaged 406 cycles of data. This is displayed in the left hand panel of Figure 5. Next, roughly equal numbers (229 and 231 cycles) of air and vacuum data were recorded at the 800 volt level and averaged together. This result is shown in the right hand panel of Figure 5. (Fuzz bustling of the thrust traces, by performing a running average of several data points along the traces, done in Figures 3 and 4 to reduce the extraneous high frequency noise in the traces, was not done for the data displayed in Figure 5.)

The same general behavior is present in both panels, though secular systematic effects are more prominent in the 800 volt result owing, at least in part, to the smaller prompt effect plainly present when the power to the inductors is shut off at 4.0 s. into the data. **But it is the prompt effect at inductor shut-down that is the signature of the thrust effect – whatever its cause – that we want to investigate.** So we do not trouble ourselves further about extraneous secular effects. Inspection of Figure 5 suggests that the 800 volt promptly switched thrust is indeed about half of that for the 1 kV result – as expected on the basis of the Mach effect explanation. **Indeed, when the data for the thrust traces are averaged over the 0.25 s preceding and following inductor power shut-down at 4.0 s and these averages are differenced to get the “step size” in the thrust traces one gets 17.93 dynes for the 1 kV results and 9.37...**

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dynes for the 800 V results. That is, the 800 V result is 52% of the 1 kV result – and the Mach effect prediction is confirmed. Other averaging intervals, for example, 0.20 and 0.30 s, yield varying results; but they are less than the

![Figure 5](image-url)

**FIGURE 5.** The air and vacuum results averaged together for high power operation, the capacitor voltage signal at 1.0 kV in the left hand panel; and at lower power, the capacitor voltage signal at 800 V in the right hand panel.

52% returned for the 0.25 s interval. The reason for this can be discerned by inspecting the thrust traces in the two panels of Figure 5. The prompt change in the thrust traces (noisy red) when the inductor circuit power is shut off at 4.0 s is about twice as large for the 1.0 kV results as that for the 800 V results – as expected if the Mach effect mass fluctuation is the source of the thrust that is switched off.

The 80% effect predicted by Brito and Elaskar seems not to be tenable. The obvious question, though, is how significant is the difference between observation and their prediction? This may be evaluated using a “deleted data” protocol to get an estimate of the spread of results for data with part of the total data set removed in blocks. The removed blocks of data ranged between 28 and 42 cycles, the typical deletion block being 35 cycles. The cycles in any particular deletion block were only removed once. This yielded 11 partial data groups for the 1 kV data, and 14 partial data groups for the 800 V data. After the 0.25 s averaging step at inductor power switch-off calculation was performed on each of the partial data groups, the standard deviations for the 1 kV and 800 V thrust steps were computed, yielding: 17.93 ± 1.27 dynes and 9.37 ± 0.63 dynes. A simple “T” test for the significance of these two means could be performed; but instead each of the partial data results for the 800 V group was used to calculate 11 ratios with the 11 partial data results for the 1 kV group. This yields 154 such ratios, the mean and standard deviation of which can then be computed. The result of these calculations is 0.524 ± 0.048; or 52% ± 5% -- where the predicted ratio is 51%. The Brito-Elaskar prediction of 80% lies more than five standard deviations away from the measured value. The likelihood, therefore, that the Brito-Elaskar prediction is correct is vanishingly small. The Mach effect prediction, however, stands fully confirmed.

**CONCLUSION**

Inasmuch as three flux capacitor devices of two different designs all display the presence of Mach effect thrusts, and careful tests for spurious effects that might masquerade as the Mach effect all suggest the effect is genuine, it would seem that further exploration of this technique of propellantless thrust generation is warranted. This is especially the case as the scaling dependence of the effect indicates that at higher frequencies, and especially at higher operating voltages, much larger effects should be attainable. Indeed, practical levels of thrust should be achievable.

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REFERENCES


NOMENCLATURE

\[ G \] = Newtonian constant of universal gravitation, Nm\(^2\)/kg\(^2\)
\[ \phi \] = scalar gravitational potential, m\(^2\)/s\(^2\)
\[ c \] = vacuum speed of light, m/s
\[ \rho_0 \] = proper mass density, kg/m\(^3\)
\[ E_0 \] = proper energy density, J/m\(^3\)
\[ P \] = power, W
\[ V \] = voltage, V; or volume, m\(^3\)
\[ \omega \] = angular frequency, rad/s
\[ m_0 \] = proper mass, kg
\[ \delta m_0 \] = mass fluctuation amplitude, kg
\[ \phi \] = relative phase, degrees
\[ \mathbf{B}, B \] = magnetic induction, T
\[ i_d, i_d \] = electric displacement current, A
\[ L \] = length, m
\[ F_{\text{tot}} \] = total force, N
\[ F_B \] = magnetic part of the Lorentz force, N
\[ F_{\text{lat}} \] = lattice restoring force, N
\[ <F> \] = time-averaged force, N
\[ \varepsilon_r \] = relative permittivity
\[ n \] = number of turns
\[ I \] = Brito’s inductor current, A