A Test for the Existence of Mach Effects With a Rotary Device

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Abstract: Owing to the variation in the results of several experiments designed to produce thrust with devices employing Mach effects, it was decided to design an experiment with the simple purpose of determining whether or not Mach effects actually exist. Mach effects – transient changes in the masses of objects when they are accelerated – are predicted when internal energy changes in the objects accompany the accelerations. The question arises, can Mach effects be produced when the required accelerations and internal energy changes are separately supplied? In the experiment arrays of eight 500 pf high voltage capacitors are mounted on the end of a rotor and spun to and from speeds of about 60 Hz (3600 rpm) to produce the acceleration, while they are excited with a 40 KHz voltage signal with amplitudes up to 6 KV to produce the internal energy variation. The capacitors are sandwiched between two accelerometers and any Mach effect mass fluctuation is detected as a "weight" fluctuation that produces signals in the two accelerometers that are antiphase. Those two signals are subtracted with a differential instrumentation amplifier. Other signals of whatever origins that affect the accelerometer signals equally are suppressed as common mode noise. The distinctive feature of Mach effect signals is that they depend on the rotation speed, whereas electromechanical [piezoelectric and electrostrictive] effects in the capacitors do not. Signals with the Mach effect properties sought have been found and recorded with video equipment. They suggest that Mach effects are real, and that the accelerations and internal energy changes that produce them can in fact be separately supplied.

Introduction:

After carrying out a variety of experiments designed to exploit the presumed existence of Mach effects to produce small thrusts that yielded varying results, the decision was taken to carry out an experiment to test for the existence of such effects in the simplest of all possible circumstances. The aim was to settle the question of the existence the effects. Underlying physics suggests that these effects should exist; but in some experiments the effects expected were either not present, or much smaller than predicted. Without experimental evidence that the predicted Mach effects in fact do exist, situations in which they are small or not present may be taken as evidence that Mach effects do not exist. But if the effects are known independently to exist, then unexpected results can be ascribed to other causes than the putative non-existence of the effects. With convincing experimental evidence of the existence of Mach effects, when things do not work as expected, the issue one faces becomes one of engineering, rather than one of science. If

Mach effects do not exist, then attempts to generate thrust using them is a waste of time and resources. A simple existence experiment, thus, has considerable value.

The underlying physics of Mach effects consists of the observation that in general relativity, when "critical" cosmic matter density is present (as in fact it is), inertial reaction forces arise from the gravitational action of chiefly cosmic matter on local accelerated objects. The action is communicated via a field. The local sources of the field that causes inertial reaction forces can be obtained by taking the divergence of the field. When changes in the internal energies of accelerating bodies are allowed, time-varying source terms that correspond to fluctuations in the masses of these bodies are recovered in this calculation. They trace their origin to the derivative with respect to proper time of the four-momentum of the accelerated object, in particular, the time-derivative of the time-like part of the four-momentum, *mc*. (This follows from the fact that the inertial reaction force field strength is equal to the inertial reaction force per unit mass, and that depends on the derivative with respect to proper time of the four-momentum of the accelerating object.) If the internal energy of the accelerated object is changing during the acceleration, then the time-derivative of *m* does not vanish. Terms arising from the non-vanishing derivative of *m* end up contributing to the local sources of the field that causes inertial reaction forces – that is, the gravitational field. Note that the internal energy changes take place in the fields in the space between the constituent particles that make up the body. As the *fields* are changing, this is *not* a vacuum effect, and quantum mechanics is not required to explain what is going on, at least as far as Mach effects are concerned.

An important feature of the calculation just mentioned is that it depends on "bulk" acceleration of a body in which internal energy changes take place. Simply changing the internal energy of an object without subjecting is simultaneously to an acceleration does not lead to the prediction of mass fluctuations. So the design of an experiment to test the prediction of mass fluctuations must provide for both the acceleration of a body as well as internal energy changes if mass fluctuations are to be produced. The formal derivation of the Mach effects sought presupposes that the acceleration and internal energy changes both arise from the application of an accelerating force. However, there is nothing in the mathematics that demands that this be the case. So, it may well be that the acceleration and the internal energy changes can be separately supplied. This too is tested in the rotary device used in this experiment.

The apparatus:

The chief element of the apparatus is a ring of eight 500 pf high voltage capacitors (for a total of 4.15 nf) glued and wired into a ring potted with Bondo. (See Photos 1 and 2 at the end of this document.) The capacitor ring is clamped between two accelerometers made with thin PZT disks glued to steel washers (1.5 inches OD) on a (1/4 – 28) bolt with a lock nut. (See Photo 2.) The bolt on which these parts are mounted is one of the two rotor arms in the assembly. The transformer that matches the capacitor array to the Carvin audio power amplifier is mounted with the same type of washers on a second bolt that counter balances the bolt with the capacitor ring. The two bolts are screwed into an aluminum hub on the shaft of the device. (See Photo 3.) One end of the shaft is devoted to the drive motor and power circuit slip rings. Special Fabricast brushes [80% Ag, 19% C, 1% MoS_2] are used here to handle the currents of several amps. At the other end of the shaft a special Northrop-Grumman [PolyScientific] instrumentation slip ring assembly carries the signals from the two accelerometers and a resistive voltage divider that monitors the voltage across the capacitors to buffer amplifiers and the rest of the signal processing circuitry. (See Photo 4.) Owing to large currents in the ground return parts of the circuits, it was found necessary to separately buffer both the "high" and "ground" leads from the signal sense circuits as instrument ground was often different from the local ground of the signal sense circuit.

The capacitors, whose internal energies are made to vary by the application of an alternating voltage (with amplitude up to 6 KV at a frequency of 40 KHz), are given a "bulk" acceleration by spinning the rotor. If a mass fluctuation results from the acceleration accompanied by the voltage fluctuation, it is recorded by the "weight" variation of the capacitors sensed by the accelerometers at twice the frequency of the voltage signal applied to the capacitors (80 KHz). Note that the signals that the two accelerometers record if a "weight" fluctuation occurs are antiphase, so their signals are processed by making them the inputs (after buffering as mentioned above) of a differential instrumentation amplifier. The differencing procedure for antiphase weight signals doubles the amplitude of the signal of each accelerometer. But, in principle, this differential technique should suppress all conventional sources of signals as they should be present in equal magnitude in the two accelerometer sensor circuits and cancelled as common mode noise by the differential amplifier.

In practice, complete conventional signal cancellation at the frequency of interest doesn't happen. The problem is not electromagnetic pickup and the like. Those noise/signal sources are suppressed by careful design and shielding. Indeed, the only signals of significance recorded by the accelerometers are the electromechanical signals they were designed to detect. The dominant signal for both accelerometers is a 40 KHz signal produced by the expansion/contraction of the capacitors due to their piezoelectric properties (at 6 KV applied capacitor voltage, the accelerometer signals have an amplitude of a bit more than 100 mV). [For crude scaling purposes, a 1 kg mass removed promptly from one of the accelerometers produces a voltage step of a couple of volts.] However, the responses of the two accelerometers are not exactly the same. The amplitudes of the two signals depend on the particular responses of the PZT disks used, so provision for trimming both accelerometer signal amplitudes was made so that the amplitudes could be adjusted to be equal in circumstances where there is no reason to expect any difference in the amplitudes – that is, at 0 Hz rotation frequency.

When the amplitudes of the accelerometer signals are adjusted to minimize the differential signal as just mentioned, the net output signal of the differential amplifier becomes a small fraction of either of the accelerometer signals, but it does not vanish into the noise in the system. The reason is that the relative phase of the two signals is not exactly zero, as one would expect it to be in an ideal system. In order to compensate for this state of affairs, matched phase shifting circuits were inserted into the accelerometer signal paths between the buffer amplifiers and the differential amplifier. With careful successive adjustments of the phase and amplitude of the accelerometer signals it was possible to drive the net signal to levels approaching the apparent noise in the system, especially after the net signal was processed through a bandpass filter with a broad pass band (10 KHz to 150 KHz in fact so that the second and third harmonics of the 40 KHz operating frequency were not suppressed). The amplitude and phase adjustments of the two accelerometer signals were facilitated by their display as the two channels of a digital oscilloscope (which made trace discrimination simple as cute colors – yellow and blue – distinguished them).

The signals resulting from the processing described so far were displayed in real time during operation of the system on an analog oscilloscope and fed into a Picoscope (12 bit resolution) run in FFT power spectrum mode so that the magnitudes of the components of the net signal could be discriminated. Since the Mach effect of interest is expected at the second harmonic of the frequency of the voltage signal applied to the capacitors, in order to view it in real time it must be filtered from the other parts of the net signal. This was done with a narrow pass band filter consisting of high and low pass parts rolled off at 72 KHz and 90 KHz respectively. The output of this filter was displayed on an analog oscilloscope. Should there be changes in the amplitude and phase of the second harmonic part of the signal – as the presence of a Mach effect that depends on the rotation frequency of the rotor suggests should be the case – they should be manifest in this signal (as well as in the power spectrum recorded by the Picoscope).

Runs with Mach Effects:

If the application of an AC voltage to the spinning capacitor array does in fact produce a Mach effect mass fluctuation, then the two accelerometer signals will be 180 degrees out of phase (as the capacitor array will be accelerated toward the outer accelerometer and away from the inner accelerometer), and the difference of these signals will not be zero. So, if the 0 Hz rotation frequency signal is minimized by adjustments of the amplitude and phase of the accelerometer signals, then any Mach effect signal – presumably 0 at 0 Hz rotation frequency as the capacitors have no bulk acceleration – will progressively modify the 0 Hz residual signal as the rotation speed is increased. How in detail that takes place will depend on the particulars of the Mach effect supposed to be present, and the fact that the residual electromechanical signal itself may be affected by the increasing rotation speed, as already discussed. Before turning to the interplay of electromechanical and Mach effects, we examine issues relating to Mach effects alone.

Of these issues, the trickiest is how Mach effects should depend on rotation frequency in this experiment. When the acceleration in question is also so source of the mass-energy fluctuation in the Mach effect calculation, things are simple. If one starts at the predicted mass fluctuation in the impulse term and backtracks through the calculation of the effect, one finds that the acceleration of the body that causes the effect is implicit in the dP/dt factor. Indeed, it is the source of P itself as P follows from the $dm/dt = (1/c^2)dE/dt =$

$(1/c^2)P$ in the time-like part of the four-momentum. The time-derivative of P in the impulse term comes from the time-like part of the four-divergence.

This, however, is not the case in the rotary device experiment. The P in the capacitors is produced completely independently of the acceleration that arises from the rotation and is not causally linked to any bulk acceleration of the dielectric. That is supplied separately by the rotation. Now, it may be that in these circumstances no Mach effects appear – and should they not appear, that would not be a demonstration of their non-existence. But should any effects appear, it would seem that the magnitude of such effects ought to be linked to magnitude of the acceleration produced by the rotation. The simplest way to proceed seems to be to write:

$$\delta m(a) = k \delta m \bullet a ,$$

where k is a constant with dimension of inverse acceleration to be determined from experiment. Other assumptions are possible, but they are all more complicated and seem significantly less likely. Now, since the forces on the accelerometers will be proportional to $\delta m.a$, the forces recorded by the accelerometers should be:

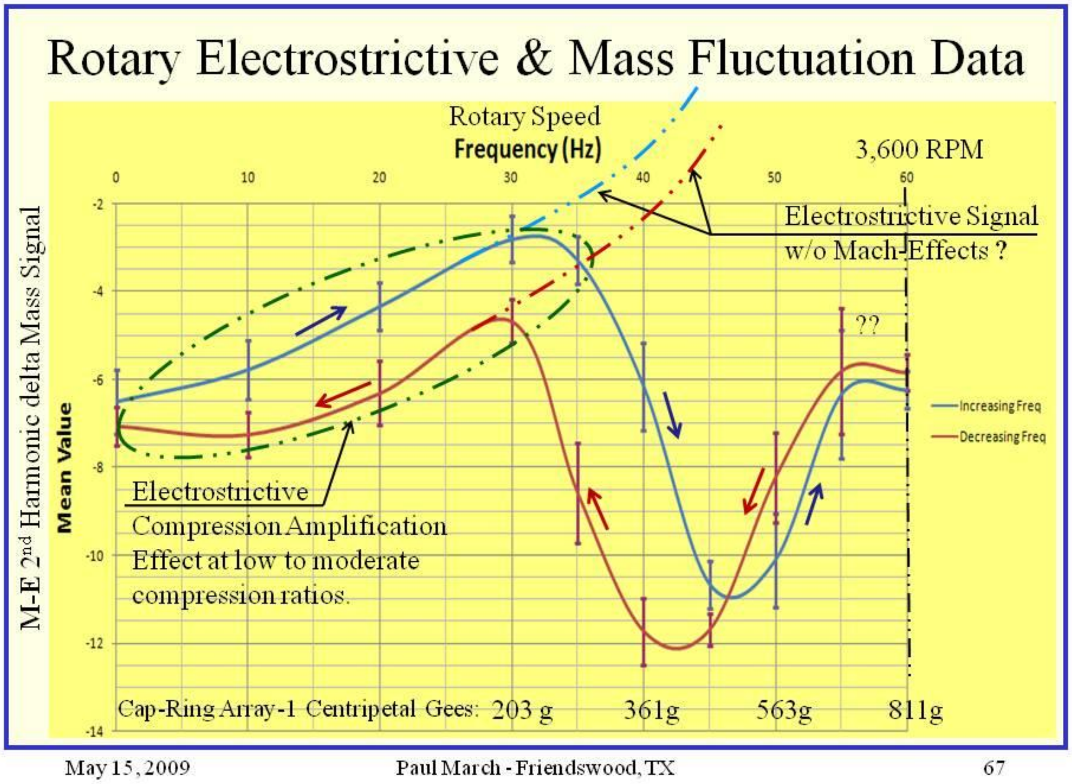
$$F(a) = k\, \delta m \bullet a^2$$

and since $a = \omega^2 R$,

$$F(a) = k\, \delta m \bullet \omega^4\, R^2 .$$

Evidently, where the dependence on rotation frequency of electromechanical effects is either non-existent or weak, the dependence of Mach effects (with the simplest assumption regarding acceleration) is quite strong if they are present.

The other scalings worth mentioning are capacitor voltage frequency and capacitor voltage amplitude. We ignore capacitor voltage frequency as this has not yet been explored. As far as capacitor voltage amplitude scaling is concerned, the dependence is on the power (actually, the time-derivative of the power), and that is equal to the product of the voltage and current in the capacitors. Since the current is proportional to the voltage, the dependence turns out to be the square of the voltage.



The videos:

The videos related to this experiment that have been uploaded to zshare are listed here below. Description of the videos and important things to note in the videos are included in brief comments accompanying each listing.

THE DEVICE IN OPERATION: http://www.zshare.net/video/59506760a6754bd2/

This video comes in two parts. The first part shows a typical run of the actual physical apparatus. The second part shows the responses of the instrumentation to a typical run.

Part 1: starts with a zoom in to the stationary rotor with the capacitor array and accelerometers on the left and the matching transformer on the right. As the rotor begins to spin, the picture is widened to include the entire device. In the foreground are the power slip rings and brushes, and to their right is the cable from the power amplifier. The Northrop-Grumman instrumentation slip ring module is at the other end of the shaft; and just to the left of the module is the cast aluminum box housing the accelerometer buffer amplifiers (easily identified by the red "Big Flasher" on its left hand side. Note the smooth operation of the device as it is spun up to 60 Hz and then back down.

Part 2: the run displayed on the instruments in this part of the video was done with two noteworthy conditions. First, no power filter was used to suppress any second (or higher) harmonic component of the driving voltage applied to the capacitor array. Second, the device had relaxed for more than a month after the securing nut on the rotor arm was torqued to provide a preload on the accelerometers and capacitor array.

The instruments are:

Center bottom: a frequency counter that records the spin frequency of the rotor.
Right: the display of the Picoscope functioning in power spectrum mode.
Left: Three oscilloscopes that display various versions of the capacitor voltage and accelerometer signals. The top digital oscilloscope displays the two buffered, amplitude and phase adjusted accelerometer signals (yellow and blue) and their difference (red). [8 bit resolution] The bottom analog oscilloscope displays the capacitor voltage signal – the smooth sinusoid used as a phase reference – and the net accelerometer trace after it has been filtered by a broad bandpass filter and amplified. This trace is the processed version of the red difference trace on the top digital oscilloscope. The center analog oscilloscope displays, again, the capacitor voltage trace, and the second harmonic component of the net accelerometer signal so that its amplitude and phase can be viewed uncomplicated by the presence of signals at other frequencies.

The run:

The Picoscope spectrum display is not helpful as it is running in "normal" mode – without averaging to suppress noise – and the signals of interest are hard to pick out from the noise.

The rotation frequency can be read off of the frequency counter. An antique, it was programmed to show each count in progress (at roughly one second intervals) and the result of the count is only very briefly displayed before the next count commences.

Both of the digital (top) oscilloscope channels are set to 200 mV/div. During the course of the run, while there is some quasi DC jitter in the traces (that likely come from brush noise), there is no easily detectable change in either of the accelerometer traces or their difference. This means that any signal present is small and reassures one that the apparatus is performing as it was intended to. In particular, there are no large mechanical signals and pickup is likely not present.

The net accelerometer trace displayed on the bottom analog oscilloscope reveals that the amplitude and phase compensation for the 0 Hz rotation frequency signal have worked quite well. While there is some periodic structure to the trace, it does not display pronounced variations at either 40 or 80 KHz. As the rotation speed is increased, this changes in the range of 35 to 45 Hz, and the signal that emerges in this rotation frequency range increases in prominence as the rotation frequency rises to 60 Hz. As the rotor is spun down, the signal decreases in prominence, though not exactly in reverse order from spinup. This means that secular thermal effects are present.

The accelerometer signal displayed on the center oscilloscope where the 80 KHz second harmonic is isolated and amplified is not in the noise at 0 Hz rotation frequency. As the rotor is spun up, this signal remains mostly unchanged until 35 Hz is reached. At 35 Hz the signal first decreases, and then begins to increase in the 40 to 45 Hz region. This amplitude change is accompanied by fluctuations in the relative phase of the 80 KHz signal. The amplitude continues to rise as spinup continues to 60 Hz. The accelerometer signal changes are the approximate reverse of the spinup changes during spindown, but the hysteresis noted above is also present.

It is clear that a net accelerometer signal of the sort expected from the predicted Mach effect is present in the data from this run. It is complicated by the presence of two electromechanical signals: electrostriction and piezoelectric responses. Nonetheless, since electromechanical signals are not expected to have appreciable dependence on the rotation speed, and the main signal present clearly does have strong dependence, it seems reasonable to infer that the signal seen is due to the Mach effect sought.

CAPACITOR VOLTAGE SCALING: http://www.zshare.net/video/6093935653908fa9/

This video shows three runs of the device taken in succession with the capacitor voltage set first at 6 KV (as can be ascertained from the phase reference trace of the capacitor voltage knowing that the scale is 2 KV/div). The second and third runs are at 4 KV and 2 KV respectively. When the accelerometer trace amplitudes are compared, one finds that the 4 KV amplitude is a bit smaller than half of the 6 KV amplitude; and the 2 KV accelerometer amplitude is about a tenth of the 6 KV amplitude. V^2 scaling expected on the basis of Mach effects predicts that the 4 and 2 KV accelerometer amplitudes be factors of 0.44 and 0.11 of the 6 KV amplitude. Evidently, the predicted scaling is present. Unfortunately, the predicted Mach effect capacitor voltage scaling is not unique. One may reasonably expect that an electromechanical effect – electrostriction – will have the same scaling as it scales with the square of the capacitor voltage power. The voltage scaling test, however, does eliminate pickup and some electromechanical effects as candidate explanations for the accelerometer responses as they should scale linearly with voltages present.

SOME PHOTOS:

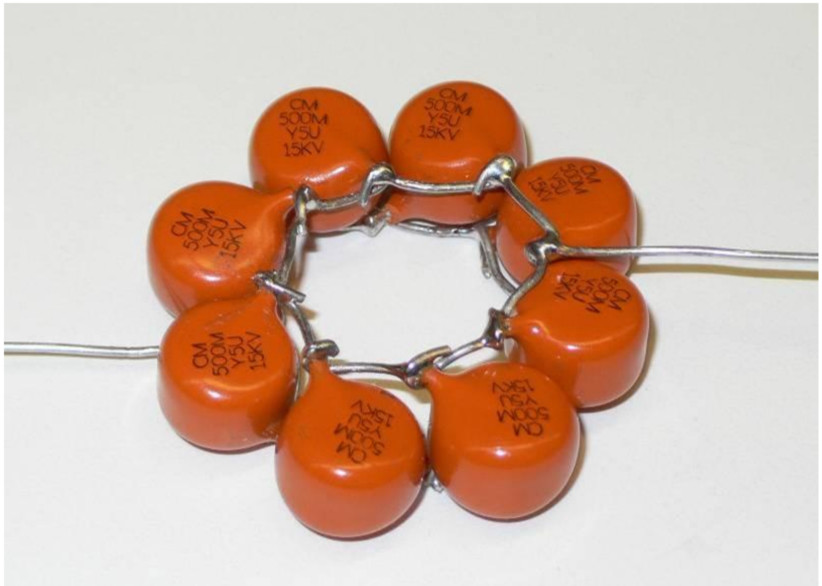


Photo 1: The capacitor array used in this experiment when under construction. Eight high voltage disk capacitors are wired together as compactly as possible. Bondo is added to make the array stronger and provide better mechanical contact with the accelerometers that hold the array.

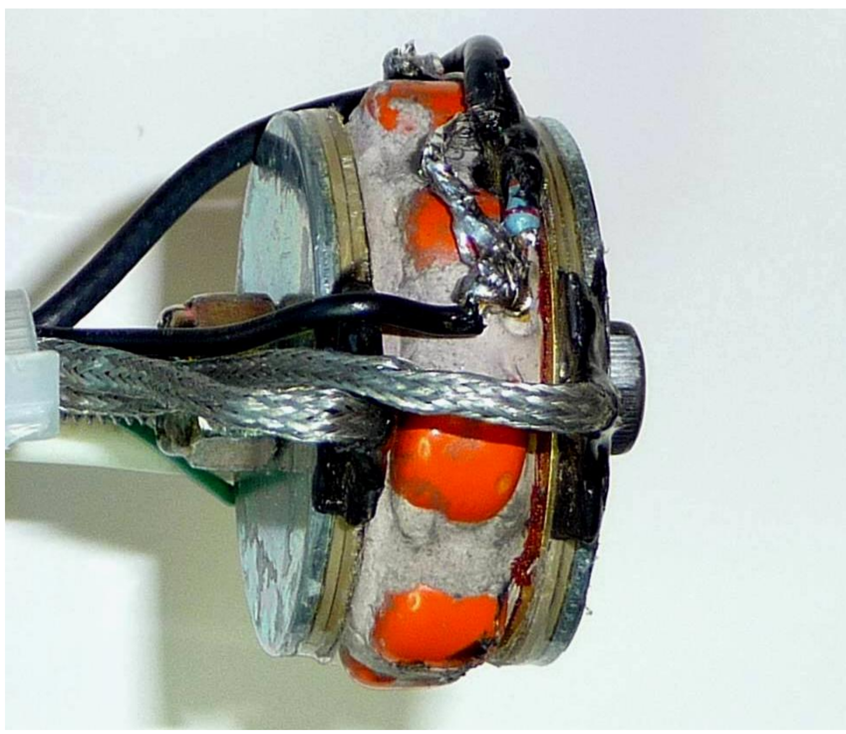


Photo 2: Closeup of the accelerometer/capacitor array assembly. The accelerometers are made with thin PZT disks (tan) on either side of the Bondoed capacitor array. The accelerometer leads are double braid shield.

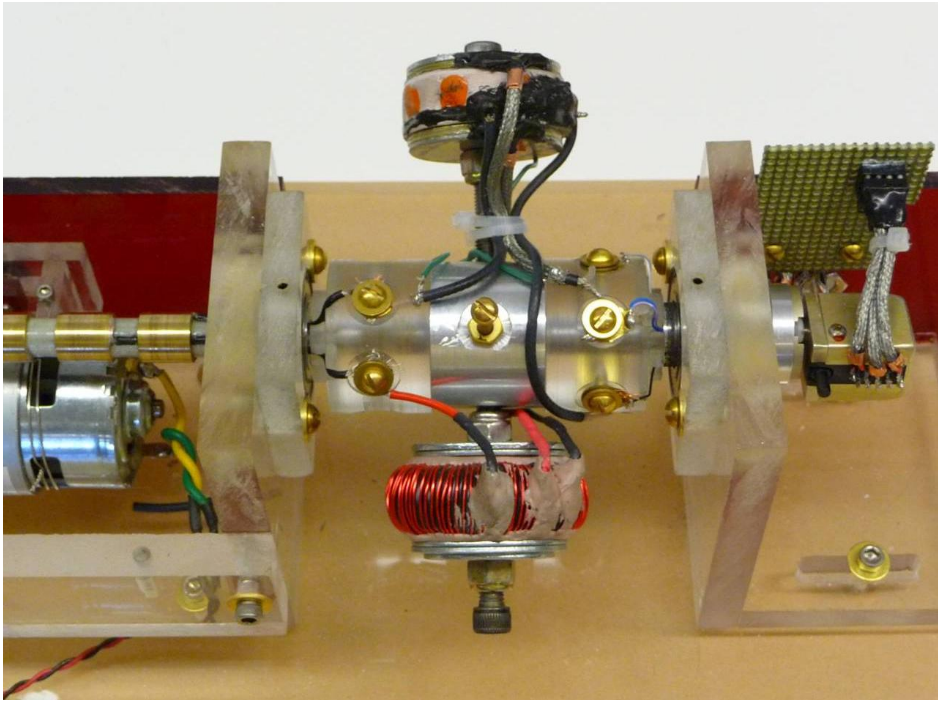


Photo 3: The assembled rotor with the capacitor array at the top and the matching transformer at the bottom. The Northrop-Grumman instrumentation slip ring module is at the right, and some of the power feed slip rings can be seen at the left. The Fabricast silver/carbon/MoS_2 brushes used in the power circuit have been removed exposing part of the drive motor below the shaft.

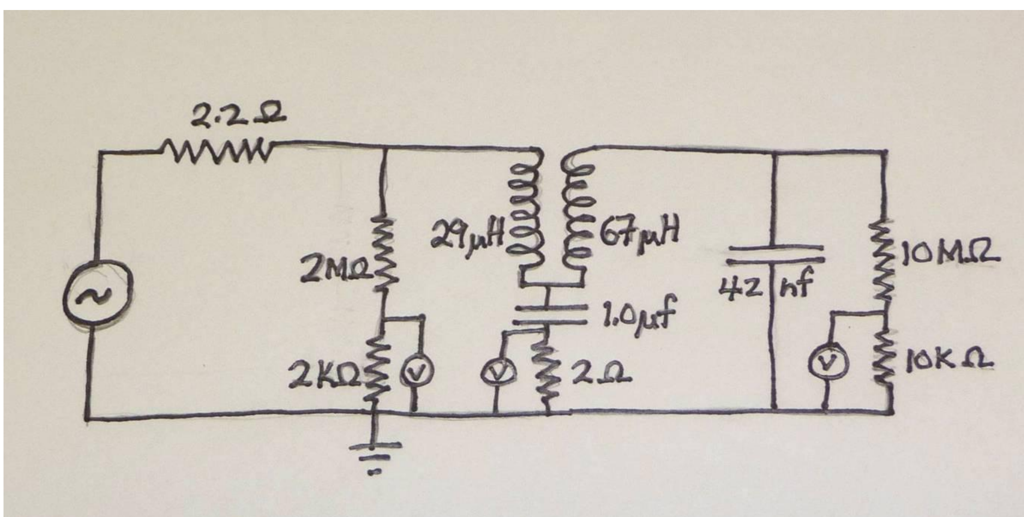


Photo 4: The diagram of the power circuit. Note that the decimal between the 4 and 2 of the capacitor array capacitance is not inked. The value is 4.2 nf. The capacitor array voltage is read off the resistor divider at the right.

Photo 5: The static clamp test. As the load is increased by tightening the clamps, the amplitude of the accelerometer signal increases when the capacitor array is activated.