'Energy-sucking' Radio Antennas,

N. Tesla's Power Receiver

Here's something that has always bugged me: light waves are about 5000 Angstroms in wavelength, while atoms are more like 1 Angstrom across. Atoms are thousands of times smaller than light waves, yet atoms obviously interact very strongly with light. How can they do this? Perhaps they get around the problem by employing Quantum Mechanics (photon-physics rather than EM waves?) There must be some explanation. After all, when a metal dipole antenna is only one foot long, it certainly cannot absorb much 5000ft-wave radiation. I never encountered a good explanation for this during my physics education. I finally found a couple of physics papers that make things clear. And it's not QM that solves the problem. It turns out that the real explanation is both little-known and fascinating.

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PERPETUAL MOTION?!! Strangely, several people have made the mistaken assumption that this article is about a perpetual motion machine. Why leap to such a conclusion? Who knows. Perhaps I need to point out that in Fig. 2 and Fig. 3, the "10 megavolt supply" is a distant radio transmitter (an EM *energy source*, powered by the utility grid.)

This article is about the ability of an LC resonator to "funnel" incoming electromagnetic waves towards tiny antennas. These antennas behave as if they were much larger than their physical diameter, as if there was an "invisible lens" focusing more of the incoming EM energy upon the antenna. In conventional terms, it's about enhancing the EA (effective aperture) of small antennas.

- 1-dimensional model
- 1-dimensional model w/resonance

HOW DO ATOMS DO IT?

I stumbled across the answer to my questions in a paper about VLF/ELF loop antennas. Apparently Quantum Mechanics does **not** supply the answer. Instead the question of small antenna behavior is resolved by a little-known section of classical electromagnetism. It involves resonance, but more importantly, it involves the magnetic and electric fields which surround any antenna. (I guess I should have expected this. After all, much of physics works fine with classical concepts, with photons and EM waves both explaining the same phenomena.)

An "electrically small" antenna is one where the physical antenna size is far smaller than the EM wavelength being received. At first glance, electrically small antennas aren't all that strange. If we use them to *transmit* radio waves, they work just as you'd expect. In order to force a tiny antenna to send out a large amount of EM energy, we can simply give it a huge driving signal (high voltage on a tiny dipole, or high current on a tiny loop antenna.) If the EM fields are strong at a distance of 1-wavelength from the small antenna, then the total EM radiation sent out by the antenna will be significant. It's almost as if the EM fields themselves are acting as the antenna. Weak fields act "small," while intense fields behave as a "large" antenna. This explains how a tiny antenna can transmit lots of EM. But what about reception?

It turns out that a similar idea works for reception; for "input" as opposed to "output." By manipulating the EM fields, we can force an electrically-small receiving antenna to behave as if it was very, *VERY* large. The secret is to intentionally impress an artificial AC field upon the receiving antenna. We'll transmit in order to receive, as it were. Conventional half-wave antennas already do exactly this because their electrons can slosh back and forth, generating their own EM fields. For example, the thin wires of a half-wave antenna are far too thin to block any incoming radio waves and absorb them. However, the current in such an antenna, as well as the voltage between the two wires, these send out large, wide, volume-filling EM fields which have a constant phase relative to the incoming waves. Because of the constant phase, these fields interact very strongly with those incoming waves. They create the lobes of an interference pattern, and this pattern has an odd characteristic: some of the incoming energy has apparently vanished. The fields produced by the antenna have cancelled out some of the energy of the impinging EM waves.

TRANSMIT IN ORDER TO RECEIVE?!!!

Rather than relying upon the wiggling electrons in the wires of the large half-wave antenna to generate EM fields... what if we used use a power supply instead? If an antenna is 1/10,000 wavelength across, we should be able to force it to behave as if it's huge; perhaps 1/3 wavelength across. We simply have to drive it hard with an RF source. We must drive it at the *same* frequency as the incoming waves, then adjust the phase and amplitude of the power supply to a special value. At one particular value, our transmissions will cause the antenna to be best at absorbing the incoming waves.

Take a loop antenna as an example. If we want our little loop-antenna to receive far more radio energy than it normally would, then we need to produce a large AC current in the antenna coil, where the phase of this current is locked in synch with the waves we wish to receive, and is lagging by 90 degrees. The voltage across the antenna terminals stays about the same as when an undriven antenna receives those waves. However, since the current is much higher in the driven antenna, the energy received per second is much higher as well. This seems like engineering blasphemy, no? How can adding a larger current increase the RECEIVED power? And won't our receiving antenna start transmitting? Yet this actually does work. Power equals volts times amps. To increase the RF power received from distant sources, we increase the antenna's amperes intentionally.

This sounds really silly. How can we improve the reception of an electrically small antenna by using it to *transmit*? The secret involves the cancellation of magnetic or electric fields in the near-field region of the antenna. The physics of the nearfield region of antennas has a kind of nonlinearity because conductors are present. In the electromagnetic nearfield region, it's possible to change the "E" of a wave without changing the "M" (change the antenna's voltage without changing the current), and vice versa. Superposition of EM traveling waves does not quite apply here because the ruling equations for energy propagation near conductors depends upon V^2 or I^2 separately. In addition, V is almost independent of I in the near-field region. If a very small loop antenna (a coil) should happen to receive a radio wave as a very small signal, we can increase the received *energy* by artificially increasing the current. Or if we're using a tiny dipole antenna (a capacitor,) we can increase the short dipole's received energy by applying a large AC voltage across the antenna terminals.

NOT CRACKPOTTY AFTER ALL

Note that this does not violate any rules of conventional physics. If we add stronger EM fields, they sum with the incoming EM plane waves and cause these radio waves to bend towards the tiny antenna, and the antenna absorbs them. This increases the antenna's EA (effective area, or effective aperture.) We can use this process to alter the coupling between the antenna and the surrounding space, but the total energy still follows the conservation law. The altered fields only change the "virtual size" or EA of the antenna.

More importantly, the phenomenon is quite limited. We can only use it with electrically "small" antennas. We cannot increase the "virtual size" much beyond a quarter wavelength for the waves involved. If we already have a large 1/2-wave dipole, then no matter how large is our artificially-add AC voltage, we cannot make it absorb more incoming waves. However, if we have an extremely small antenna, say, a 10KHz loop antenna the size of a pie plate, we can make that antenna seem very, very large indeed. Think like this: how large is the diameter of the antenna's nearfield region at 10KHz? Around 10 kilometers? What if we could extract half of the incoming energy from that entire volume?!! In theory we can: half can be absorbed, and the other half scattered. In theory a tiny loop antenna sitting on your lab bench can intercept just as much energy as a longwire 1/2-wave antenna which is 10KM long. Bizarre, eh?

Here's a way to look at the process. If I can create a field which CANCELS OUT some of the energy in an extended region surrounding a tiny antenna, this violates the law of Conservation of Energy. Field energy cannot just vanish! That's correct: if we cancel out the energy in the nearfield of an antenna, this is actually an absorption process, and the energy winds up inside the antenna circuitry. By emitting an EM field, a receiving antenna sucks EM energy into itself. If we ACTIVELY DRIVE an antenna with an "anti-wave", we will force the antenna to produce stronger fields which cancel the incoming waves, and simultaneously the antenna absorbs more energy from the EM fields in the surrounding region of space than it ordinarily would. It also emits some waves of its own. But in antenna theory these waves are identical to the received signals, and they are considered to be reflected or "scattered" from the antenna. It's a general law that we cannot receive EM waves without scattering half of the energy away again.

Here's the interesting part. If we wish to receive power rather than signals, a critical issue arises.

Driving a tiny antenna with a large signal will create large currents and heat the antenna. Small antennas are inefficient when compared to half-wave dipoles. If we wish to maximize the virtual aperature of a really tiny antenna (e.g. make our 10KHz pie-plate coil act 10KM across,) we'll quickly be frustrated by wire heating. All the extra received energy will go into warming the copper. Possible solutions: use superconductor loops, or at low frequencies use the nearest equivalent to an AC-driven superconductor: a rotating permanent magnet or rotating capacitor plates.

BUT HOW DO ATOMS DO IT?

OK, if this supposedly explains how tiny atoms can receive long light waves, how can we increase the voltage signal to a SINGLE ATOM?! Actually it's not difficult. No angstrom-sized radio transmitter is needed. The key is to use EM energy stored as oscillating fields; i.e. resonance.

If an atom resonates electromagnetically at the same frequency as the incident light waves, then, from a Classical standpoint, that atom's internal resonator will store EM energy accumulated from the incoming waves. It will then behave as an oscillator, becoming surrounded by an increasingly strong AC electromagnetic field as time goes by. (Quantum Mechanics might say that the atom is surrounded by virtual photons at the resonant frequency.) If this alternating field is locked into the correct phase with the incoming light wave, then the atom's fields can interact with the light waves' fields and cancel out quite a bit of the light energy present in the nearfield region around the atom. The energy doesn't vanish, instead it ends up INSIDE the atom. Half of the energy goes into kicking an electron to a higher level, and the other half is re-emitted as "scattered" waves.

By resonantly creating an "anti-wave", which superposes with incoming waves and bends them towards the atom, the tiny atom has "sucked energy" out of the enormously long light waves as they go by. And since the atom has no conventional copper coils inside it wasting energy, it can build up some really strong fields which allow it to behave extremely "large" when compared to it's physical diameter.

Impossible? Please track down the C. Bohren paper in the references below. He analyzes the behavior of small metal particles and dielectric particles exposed to long-wave EM radiation, and rigorously shows with semi-Classical analysis that the presance of a resonator can cause dust motes to "act larger than they really are."

How can this stuff be true?! After all, electric and magnetic fields cannot BEND other fields. They cannot affect each other directly. They work by superposition. For the same reason, a light wave cannot deflect another light wave. Ah, but as I said before, the mathematics of the fields around a coil or a capacitor are not the same as the mathematics of freely-propagating EM waves. If we add the field of a bar magnet to the field of a radio wave, and if the bar magnet is in the right place (at a spot where the phase of the b-field of the radio wave is reversing polarity,) then the radio wave becomes distorted in such a way that it momentarily bends towards the bar magnet. And then, as the EM wave progresses, we must flip the magnet over and over in order to keep the field pattern from bending away again during the following half-cycle. The energy flow continues to "funnel in" towards the rotating magnet. Now replace the bar magnet with an AC coil, and vary the coil current so the fields stay locked to the traveling radio wave in the same way. In that case the wave energy will ALWAYS bend towards the coil and be absorbed. Superposition still applies, but this is a COHERENT superposition, so it acts like a static field pattern: as if a permanent magnet can bend a radio wave inwards and absorb its energy rather than simply having the fields sum together without interesting results.

Note that the coil will also emit its own EM ripple. This emission is well known: atoms ideally will scatter half the light they absorb, and dipole antennas behave similarly: they scatterer incoming EM waves as they absorb part of the energy. When all is said and done, our oscillating coil has absorbed half of the incoming EM energy and re-emitted (or "scattered") the rest. In a phase-locked system, we cannot tell the difference between reflection and transmission.

A "HOLE" IN PHYSICS

When viewed as a halfwave receiving antenna, a resonant atom acts as if it has expanded in size to fill its entire nearfield region. In terms of Quantum Mechanics, it does so by locally creating a large virtual-photon AC field which normally would not exist. Because of coherent superposition, in a sense this new field BECOMES THE ANTENNA. The significant part of this new field extends to (Pi*wavelength)/2 distance around the atom, and this distance can be thousands of times larger than the atom's radius. A 1-angstrom atom with a large AC field can behave as a 1/3-wave antenna at optical frequencies. Though tiny, the atom can absorb "longwave" radiation such as light. Our 1-angstrom atom becomes a black sphere 2000 angstroms across, and efficiently absorbs 6000-Angstrom light waves. Very strange, no? I've certainly never encountered such a thing during my physics training. Apparently the missing details of the absorption of light wave by atoms is a "hole" in physics education, and it has only been treated in a couple of contemporary physics papers in the 1980s. Here's another hole: when an atom absorbs waves, it has to scatter away half the energy. Does this mean that when an atom absorbs a photon, it must always interact with TWO photons, eating one and reflecting the other?!!!! I've never heard of such a requirement. It flys in the face of the usual description of atoms and photons. (Is it mentioned in Feynman's QED book?)

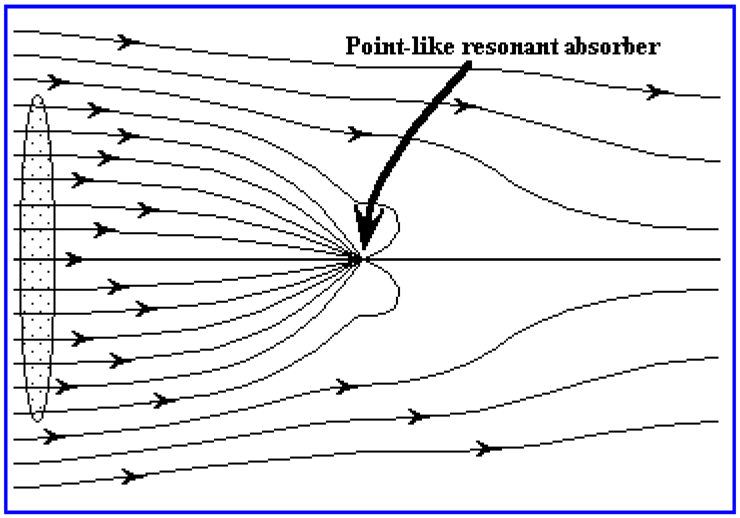

Fig 1. Energy flux lines for the nearfield region of a resonant absorber. The tiny absorber acts like a large disk.
[from ref#4]

This "energy suction" effect is not limited to atoms. We can easily build a device to demonstrate the phenomenon. Below is a simple physics analogy to show how tiny atoms can "suck energy" from long light waves. Suppose we transmit a VLF radio signal at 1KHZ frequency. Let's arbitrarily set the signal strength so it's about the same strength as the Earth's weak vertical e-field: 100 Volt/meter. If the transmitter's e-field is contained entirely below the conductive ionosphere, and if the bottom of the ionosphere is about 100Km high, then the Earth's entire vertical field is about 10 megavolts top to bottom. Our transmitter must produce such a field. These values aren't totally ridiculous. Large, well-designed Tesla coils commonly produce 10 megavolts. If such a coil was erected outdoors and connected to an insulated metal tower, it would fill the Earth's entire atmosphere with 1KHz radiation. The Earth's atmosphere would be like a microwave oven cavity. Such an AC voltage field would produce a feeble 100V/M field everywhere on the Earth's surface. This field would be detectable by instruments, but otherwise it would be too small for humans to notice, and we certainly would not expect to be able to get significant power out of it.

CAPACITIVE-PLATE ANTENNA

OK, we've got a feeble AC e-field in the outdoor environment. How will a simple antenna-plate perform as an energy receiver? See fig.2 below. If it's a large horizontal metal plate about one meter off the ground, it will give out a 100 volt signal at 1KHz, but this one hundred volt "power source" has an extremely large capacitive series impedance. Let's say that the plate/ground capacitance is 10pF. To draw energy with the maximum possible voltage, the load resistor should be approximately equal to the series impedance. This impedance is dominated by the 10pF capacitor value, so this gives 1/(2*PI*F*C) = 16 megohm load resistor, and it drags the antenna's voltage down from 100V to 70.7V. The received energy in the resistor is 300 microwatts, and the current in the resistor is in the microamp range. Just as we might expect, everything here is similar to a conventional radio antenna. The weak e-field from the incoming EM waves behaves only as a "signal", and it is not a source of significant power. It can't drive a motor or light an LED.

```
  __________    -->
 | 10 MVolt |_______
 | @ 1KHz   |       |
 |__________|       |
    |           ___|___     Capacitance from ionosphere to plate
   _|_                      ( very small, say 1/10,000 pF )
  ////          _______
                   |
                   |
                   |______________     <--- 70.7V @ 1KHz
     antenna       |              |
   (metal plate) ___|___          \
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                  10pF      /  16.7 Megohm
           _______          \
              |             /
              |_____________|
             _|_
            ////

FIGURE 2
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The fundamental problem with the above system is that the empty space around our metal plate is acting like a voltage divider. If the sky has 10 Megavolts compared to ground, and if the metal plate is a few feet above the surface of the ground, then the plate only has a relatively tiny voltage. Current is tiny, so wattage is also tiny. Maybe we could power an LED flasher with this antenna... but only if we set it to flash every few minutes. Maybe if we erected an enormous antenna tower we could do better by lifting the plate higher from the ground (but with such a huge antenna, we could easily steal more power by ignoring our 1KHz broadcast, because many high-power conventional AM radio stations exist: BBC shortwave, Voice of America, etc.)

RESONANT ANTENNA

Now lets add a tuned circuit to the above schematic and see what happens:

```
  __________   -->
 | 10 MVolt |_______
 | @ 1KHz   |       |
 |__________|       |
    |            ___|___     Capacitance from ionosphere to plate
   _|_                       ( very small, say 1/10,000 pF )
  ////           _______
                    |
                    |
                    |_____________       <---  10 Megavolts!
                    |             |
```

```
  antenna            |                 \_
 (metal plate)  ____|____              (_)
                          10pF         (_)  Coil
                ________               (_)
                     |                 (_)
                     |                 /
                     |_______________|
                     |
                    _|_        1KHz resonant, infinite Q
                   ////

     FIGURE 3
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At resonance, the 10pF capacitance of our metal plate effectively vanishes. At resonance, an ideal parallel-resonant circuit behaves like an infinite resistor. If the LC circuit is exactly at resonance, and neglecting the resistance of the wires involved, how high will the voltage on the metal plate rise? It rises to ten megavolts!!!! The resonant circuit will continuously accumulate EM energy until the voltage at the antenna-plate rises to the same value of voltage as the transmitter. Weird!

Keep in mind that this device is a relatively small affair sitting in your back yard. It's not a 1KHz quarter-wave dipole tower 25 miles tall. There's no huge antenna, so we would not expect to find any huge level of electric power appearing in the circuit. If we weren't aware of the mechanism behind this, all we'd see is a passive LC resonator which seems to burst into oscillation of its own accord, and the voltage grows higher and higher until the darned thing suffers a corona outbreak or something. Lightning bolts shoot out! The EM fields near the metal plate grow FAR STRONGER than the weak fields already present in the environment. The device in our back yard resembles an impossible "perpetual motion" machine, which might make physicists suspect a hoax. However, the real explanation is completely conventional, and the source of the energy is a feeble, unnoticed AC e-field field produced by the very distant 10-megavolt transmitter tower. Note: the above phenomenon can only occur for an *ideal* LC circuit, where the resistance of the coil is zero and where the Q of the circuit is infinite. If our antenna plate were connected to the resonant "secondary" of a superconductive Tesla coil, we might in fact see the output voltage grow to the megavolt range. However, in most real-world tuned circuits it wouldn't reach such heights.

But remember, voltage is not energy. What will be the realistic behavior of such a device? Perhaps the incoming power is still small (maybe like 300 microwatts we saw earlier), or perhaps it works well, yet it takes months to build up so much voltage across even a superconductor resonator Just what is the actual received energy flow? Let's put a resistor across the tuned circuit so we create a flow of real energy and drag the voltage down to, say, .707 of the unloaded voltage. The resistance should equal the impedance of the series capacitor: 10 ^ -16 Farads, giving 1600 giga-ohms. (A huge resistor. Clearly it makes sense to try instead to extract energy using a low-value resistor in series with the inductor coil, rather than using a huge parallel resistor across the tuned circuit. A 1.6 tera-ohm power-resistor might be hard to find in the surplus parts catalogs! That is, if you don't have the parts- catalog featured in THIS ISLAND EARTH, that old SF movie where the two engineers build an "Interociter" from parts sold by mail-order in a strange electronics catalog. Obviously the Interociter is Alien Tesla coil technology, aha!)

Ahem. :)

HUGE RECEIVED POWER

With our 1.6 giga-megohm resistor in place, the RF power intercepted by the small metal plate is now 30 watts. That's ONE HUNDRED THOUSAND TIMES HIGHER than the power from the simple non-resonant antenna plate. Our tiny antenna has essentially reached out and made a kind of "direct contact" with the distant transmitter. By changing its own impedance, it has converted the femtofarad "sky capacitor" into an efficient coupling device. It has sent out a cancelling wave and pulled in energy from an enormous volume encompassing the surrounding fields. It has become a "matching transformer" which steps down the 10MV sky voltage and steps up the "sky current." If we either increase the receiver plate's size, or lift it up high on an antenna tower, or connect it to a beam of x-rays which produce an ionized pathway extending vertically upwards, then the received power rises proportionally.

So, connect a high-Q resonator to a small antenna, and you'll drag in far more wave energy. Simple?

[The engineers on SCI.ELECTRONICS.DESIGN forum have pointed out that the 10MV voltage limit on the above resonator is wrong. In reality, it can grow much higher than the voltage on the transmitter. The system is actually series-resonant, so the output voltage is limited only by the Q of the system (by the resistance of the wires in the resonator coil) and is not limited by the 10MV drive voltage of the distant

transmitter.]

In our earlier antenna, (the nonresonant, resistor-only version,) a small amount of "real power" did take a path through the capacitance of the sky while on its way to the metal plate and to the load resistor. If the voltage across that resistor could be forced to oscillate hugely, and if it had the right phase compared to the tiny displacement current coming from the transmitter, then we'd obtain a major increase in energy flow. The tiny sky-current would remain about the same, but with the much larger voltage on the antenna, the value for V*I is increased and wattage is increased. Remember the unwanted capacitive-voltage-divider effect in figure 2? With a resonant system, that effect would no longer apply, and the output voltage would no longer be so low. Things would behave differently. The displacement-current going through the "sky capacitor" might still be microamps, but if the tuned circuit can alter the high voltage at our end of the transmission system, then it can drastically change the energy throughput. As with any power-transmission system, we can put more power through it by raising the line voltage while keeping the current the same.

CONCLUSION

To sum up: we see that by putting a big AC voltage on the tuned circuit and by adjusting its phase in relation to the tiny incoming current, we can "suck" the E x M wattage from the enormously broad wavefronts of the incoming waves. It also works this way inside a simple circuit using conventional voltage dividers: add a resonant circuit, and the series impedance of the power source behaves smaller. See this example circuit. It should still work this way even when a part of the antenna circuit contains a series capacitor whose dielectric is made up of many feet (or even tens of km) of empty space. It's very much like building a high-voltage power line: to transmit high wattage on a thin wire, we use high voltage at low current, and then we put a step-down transformer at the far end of the power line. However, in the "power line" shown in the above diagram, we then put a tiny capacitor in series with the high-voltage line. Then we increase the thickness of the capacitor's air-dielectric until dielectric is miles thick and the current in the system is mostly composed of displacement current in the empty space between the pair of widely-separated capacitor plates. To transmit significant power, step the voltage up to astronomical levels at one end, then step it back down at the other end. Rather than using only a step-down transformer in the receiver, instead we use a hi-Q resonator, and we allow the resonant voltage to rise to a huge value. As a result, EM energy will be "sucked" into the receiver.

THE TESLA CONNECTION

Note that all of this stuff comes directly from Nikola Tesla's "Wireless power" transmission scheme. If we can flood the atmosphere with VLF 2KHz standing waves, and if the ionosphere keeps most of this EM energy from escaping into space, then a small, high-Q resonator can grab significant wattage right out of the air. A small resonator can produce an extensive and intense AC field of its own, and can act as an "EM funnel" which grabs significant wattage right out of the ambient radiation field. It can do so even when the ambient field is quite feeble, and even when the transmitter is thousands of KM away. This is not "radio," where wavelength is the same size as the components. This is "circuitry", where wavelength is huge, and circuits are small, and the antenna operation more resembles "AC wiring" rather than "EM radiation." This is probably the concept that put that "Mona Lisa grin" on photographs of old Nikola. And that twinkle in his eye...

If we use a metal loop-antenna instead of a metal capacitor plate, then the current in the loop can perform a similar task as the voltage on the plate in figure 3: the oscillating current should grow huge and surround the coil with an intense, volume-filling AC magnetic. If the phase is correct, this b-field should "suck energy" from the transmitter (or from the local b-fields of the incoming electromagnetic waves.) Keep in mind that all this applies to SMALL ANTENNAS. If your wavelength is 150MHz and your antenna is 1 meter across, then "energy sucking antennas" cannot be used to improve reception. The idea applies to the longwave bands, to longwire antennas, and to VLF power transmission using the Earth-ionosphere Schumann resonant cavity.

These sorts of antennas obey circuit-physics, not the physics of EM waves in space. The region of space adjacent to ANY antenna obeys a combination of circuit-physics and wave-physics, (the near-field and far-field EM equations,) and I've never quite visualized exactly how this works. Now it looks like there are several interesting things hidden between the near-field and the far-field mathematics. For example, simple crystal radios have "energy suckers" instead of "tuners." And everyone owns invisible antennas a thousand meters across... generated by every AM portable radio! Cool.

The "energy grabbing" effect is very limited. It's a nearfield effect. It could only operate within about a 1/6- or 1/4-wavelength radius around a coil or capacitor antenna, or in the region between the peaks of a propagating EM wave. In other words, when we add a tuned circuit, we can increase the "effective size" of a tiny antenna until it resembles a half-wave dipole antenna. It usually would be easier to simply build a half-wave dipole in the first place. Normally we would do so.

At VHF or UHF frequencies, a hi-Q "energy sucking" resonator antenna would not gather any more energy than a normal antenna, since the hi-Q antenna would be electrically large. But whenever the conventional dipole antenna might end up being too large to construct (like at 1KHz frequency or even 550KHz), then a high-voltage capacitor plate antenna, (or perhaps a tuned-coil antenna, both with a very high Q-factor, with inductors wound from thick copper pipe?) ...these would behave like far larger antennas than anyone could possibly imagine.

NOT IN YOUR PHYSICS BOOKS?

In hindsight, the above stuff seems somewhat obvious, but why have I never heard of it before? RESONATING ANTENNAS BECOME ABNORMALLY EFFICIENT RECEIVERS?! And perhaps the reverse must also be true: high-field resonant antennas will leak radio waves, even if their size is very small compared to the wavelength. If resistive losses don't halt them, their AC fields will grow in intensity until the signal finally does escape. Do most radio designers realize that all small resonant antennas with huge EM fields act like long-wire antennas having fields of the usual strength? Do Ham radio operators currently use 80-meter transmission antennas having high-Q resonators and enormous magnetic or electrostatic fields? Do AM radio companies know that their antenna towers are really not necessary? Do science teachers realize that even the simplest "crystal radio" can only operate a pair of headphones when a tuned circuit present? (The tuned circuit in a crystal radio is not a bandpass filter: it is an energy-suction device!) Do physicists really grasp, at a gut level, just how those tiny atoms can absorb and radiate the huge wavelengths associated with light waves? And are physicists aware that two photons are needed for atomic interaction: one to be absorbed, and one to be scattered?

Portable AM radios already employ tuned resonant-loop antennas, and they've always been this way. We've been carrying around Nikola Tesla's power-receiver in our back pockets since the 1960s. Also, in bygone decades, those old "regenerative" receivers were not what they seemed. They were transmitting in order to receive, they were harnessing this bizarre "energy sucking" process. Regeneration isn't just a fancy way to amplify a small signal, instead it increases the incoming signal from a short antenna by using some weird physics. Do the designers of 90 years ago know something that modern scientists do not?

UPDATE 9/6/99

In thinking more on this (and while talking to people on the email lists) a couple of new thoughts have occurred to me. One: try to give your receiver's tank circuit as high a Q as possible, and then connect it to a load through a zener diode or other nonlinear device. This will allow the voltage/current of the tuned circuit to rise to a huge level and produce an intense AC field, but without the load interfering. Only after the AC field has reached the appropriate level will we extract any energy and deliver it to the load. [NO, NOT A ZENER! A zener would just act as a series RESISTANCE, dissipate heat, and throw away energy uselessly. Instead, just use a detector diode, and charge up a DC capacitor. 11/1/99]

Two: try using an FM detector circuit to force the receiver to "lock on" to the transmit frequency. If we do this, we could still use immensely high q-factors, but without making our frequency-match adjustments be so sensitive. We could even send out modulated signals (broadband, not narrowband), and still use them to power distant motors. I don't have a solid idea of how FM detectors work, so this might not be straighforward. Might need an active PLL driving a variable capacitor...

Three: once the receiver is oscillating and energy is being transferred, try suddenly changing the voltage of the transmitter. Since the entire system acts like a well-coupled transformer, I suspect that fast changes in transmitter voltage will appear as fast changes at the receiver. Maybe it only takes a single AC cycle for the change to appear. Weird thought: if the transmitter is modulated *faster* than the transmission frequency, would the fast modulation signal appear at the receiver?!!! That would be impossible, since it would violate Shannon and the rules of AM transmission theory. However, the coupled-resonator system more resembles a pair of atoms transferring photons, rather than resembling an RF transmit/receive system. If the device behaves like a quantum-mechanical coherent system, then perhaps we can modulate the transmitter at a faster rate than the carrier frequency! If it worked, that would REALLY be weird, no? Imagine transmitting at the 59Hz earth resonant overtone frequency, then amplitude-modulating the 59Hz carrier at 1 KHz, and having the signal appear at the receiver's resonator! We wouldn't really be transmitting radio energy. The signal would more resemble QM "wavefunction collapses" which propagate throughout the Earth's ionospheric resonant cavity.

Four: 11/1/99 This circuit mimics atomic absorption, and it also should mimic stimulated emission. Once the circuit is oscillating, it's absorbing the incoming waves because of its phase. The phase relationship causes it to couple to the transmitter. If the transmitter was suddenly turned off, then maybe the circuit would not be able to radiate, since without the waves from the transmitter it could not perform the "poynting-flux emission" process. The phenomenon is definitely not linear! So... what happens when the waves from a transmitter should suddenly encounter the fields of a short antenna? If the phase is right, the short antenna should change from an oscillator to an emitter, and begin emitting energy! This is the reverse of the "energy sucking effect," because while "energy suction" can only occur when the short antenna is surrounded by a powerful field, "energy emission" can only occur when the powerful fields around a short antenna are given a traveling-wave field to provide the "stimulation" for stimulated emission to occur. Absorption/emission requires both the trapped fields at the antenna, as well as the traveling fields from a distant transmitter. If my reasoning isn't faulty (it probably is,) this means that it should be possible to build a sort of radio-freq laser, where a distant transmitter causes a small loop-antenna resonator to add its energy to the transmitted wave.

Also, my crackpot side is starting to yammer at me. It's saying that this particular "hole in physics" might seriously damage contemporary Quantum Electrodynamics, and might even show that Einstein's original photoelectric experiment might be interpreted incorrectly. Hey, if Einstein was wrong, does that mean that the Nobel is withdrawn retroactively and awarded to whoever can show rigorously that "energy sucking antennas" are a better explanation for QM phenomena of all kinds? Or does it just mean that my "crackpot half" is just trying to make certain that no conventional scientist will dare to experiment with this stuff! :)

BEWARE: ODDBALL IMPLICATIONS

If EM resonance is extremely important, and if mainstream science doesn't recognize the effects, then god only knows how many unusual phenomena are awaiting exploration by amateurs. The professional explorers with their well-funded troops haven't yet arrived on this particular "new continent." There are still mysteries to be experienced, and it could be many years before the whole thing is paved over with well-traveled highways built through NSF funding.

Ears as antisound-emitters

Whenever any type of "small" receiver seems to be generating an AC field around itself spontaneously, perhaps we should suspect that the receiver is employing the above concepts; that it is actively generating an "anti-signal," and as a result is receiving more wave energy than it's physical size would suggest. THIS MIGHT APPLY TO ACOUSTIC SYSTEMS! If we illuminate a tiny resonant chamber with long-wave sound of the right frequency, standing waves will build up within the chamber, and it will become an emitter. If there is an acoustic analogy for the above antenna physics, the resonant chamber should "bend" the incoming sound towards itself. When the emitted sound superposes with the 3D incoming waves, the wavefronts of incoming sound will be distorted so they they impact on the resonator and thereby increase the area of its "virtual intake orifice". In EM physics this is well known, it's just the Effective Aperture concept.

Might biological evolution have "discovered" this energy-sucking resonator effect in regards to ears? A collection of *programmable resonators* might work far better than a broadband receiver, even an amplified one.

It turns out that human ears are known to generate their own signals. Much about this is still a mystery, and proposed theories do not match experimental findings. I note that at frequencies below a few KHz, the wavelength of sound is physically larger than the external ear. Perhaps our human hearing system increases its gain by emitting signals which are phase-locked with the incoming sound? This could be easily missed, since the emitted sound would greatly resemble the incoming sound, and could be mistaken as a reflection.

I've heard that human ears have an unexplained property: they can detect signals which are far below any logical noise level. Their detection capability supposedly even exceeds the QUANTUM MECHANICAL noise level. Perhaps ears increase their net received acoustic energy via an "anti-sound" feedback process resembling resonance? Might there be other situations where small acoustic resonators can receive abnormally large amounts of energy? Shades of Ernst Worrel Keely! Hey, maybe I finally have a clear explanation for that "Acoustic Black Hole" phenomenon with the soda straws. And... and... once again the infamous Dr. Thomas Gold is vindicated, and his detractors are shown to be a bit, shall we say, "deaf" to his words.

Side note: How might the inner ear generate sound? Maybe it does not. Maybe it rapidly modulates the stiffness of its parts and therefore uses nonlinear physics to take energy from other frequency bands and use it to power an oscillation at the frequency it wishes to emit. Sort of like using one crystal radio as a "battery" to power the audio amplifier of another crystal radio tuned to a different station. Or like striking a bell with slow blows, while the bell emits a fast oscillation.

Oooo, Very Weird Idea! If ears generate sound only when sound is being received, then perhaps we can detect this. Perhaps it's even under conscious control. When we listen intently to a particular frequency, obviously we're tuning the brain's internal signal processing algorithms. But what if our conscious action actually changes our inner ear mechanics, so that it "sucks energy" at that frequency? If so, then just flood the room with white noise, stick a tiny microphone near your ear, display a realtime spectrogram of the detected noise from the microphone, then try to concentrate on listening to the "high" tones in the noise, and later listen to the "low" tones. Will your ear change (will the spectrogram of the microphone's signal change?) Or, if you try to pick up a constant tone in the noise, will a small absorption band appear in the spectrum of energy near your ear? Easier test: subtract (null out) the noise-generator's signal from the microphone's signal and observe this difference signal. (an electronic delay line would probably be needed.) Now concentrate on listening to the highs or the lows. Will the observed difference-signal change? If so, build a circuit which detects this change and turns on a light bulb. Stick a microphone in your ear, decode the alterations in the sound spectrum, and run your appliances by "thinking" about a tone-sequence!!

If THAT works, then try this next one.

Set up the above system. Listen to the white noise, and imagine that you hear the word "yes". Do it many times. Now play back the recording of the difference signal (or even the raw signal from the microphone.) Can you hear the word "yes" being transmitted by your *EARS*? If so, then you now know how to speak through your ears. This only works when you are listening to white-noise. Imagine that you hear music in the noise, then see if it appears in the recording from the tiny microphone. Perhaps composers can "think music" right onto the tape recorder. "Think aloud" to yourself, and see if your "verbal thoughts" can be heard issuing from your ears as they... leak out of your head? Perhaps one form of telepathy is... acoustic? Can a blind person navigate via a sort of whitenoise-correlation "acoustic radar?"

OK, now hire a schitzophrenic who hears voices, and see if you can record the voices via whitenoise environment and ear-canal microphones. Ask the disconnected personality fragments some questions, see if they answer. Now go interview the "Voices" on the Tonight Show, with or without the cooperation of the victim.

Who'll be the first to explore this silly idea and find out if I'm full of balony?

BALL LIGHTNING

Ball lightning is not yet explained. One of the orthodox explanations is the Storm Maser theory: if thunderstorms emit microwave energy, and if something can somehow focus this energy, then a nitrogen electrical-plasma could feed off the intense microwave flux. The "Energy sucking" theory gives us a second option. Suppose thunderstorms emit weak ELF/VLF e-fields instead of supposedly emitting intense microwaves? If a plasma happened to be resonant with the coherent AC e-field being created by the storm, and if the Q of the resonant plasma system was high, then that plasma would develop an enormous high-frequency e-field around itself. It would suck energy from the fields of the storm and remain "alight." Do nitrogen/oxygen (or carbon?) plasmas have any high-Q resonances in the ELF/VLF spectrum? The plasmas in coronas in the storm clouds might emit the same frequency that a nitrogen plasma-ball would absorb. What about carbon-fiber networks composed of condensing soot? [CORUM & CORUM] Or rather than the plasma-balls extracting energy via pure resonances, do they have self-organization which can communicate with the self-organized lightning plasmas within the thunderstorm and "agree" between themselves to create a "Tesla Power System"? We'd mistake the Ball Lightning's energy source for feeble EM white-noise. The storm becomes the transmitter and the ball-lightning plasma-glob acts as the hi-Q "frequency hopping" receiver.

Do storms create any coherent VLF e-fields? VLF radios certainly don't detect such things, so we normally would assume that such signals don't exist. But hold on! There could be a nearfield effect, where there is no RF radiation, and where e-fields and b-fields aren't directly connected together via the impedance of free space. A loop-antenna in a radio receiver is used with the assumption that incoming EM waves have an E and an M component, and we should just as easily receive the M component as receiving the E. (And so a loop antenna would work just as well as a dipole antenna.) Maybe this is not true of environmental VLF e-fields. Suppose that a storm (or even the entire Earth) has a very strong vertical AC electrostatic field. The loop antennas on VLF radios would not detect it. Horizontal dipoles would not detect it. However, a resonant circuit connected to a suspended wire (and to ground) certainly would. With a high-Q resonant circuit, the antenna might even receive significant power. Call it the "artificial ball-lightning" analogy.

RF TRANSFORMERS: TIGHT COUPLING BETWEEN TWO DISTANT COILS

Iron-core transformers are examples of tight magnetic coupling, and significant power can be transferred between the coils of a 60Hz transformer. Capacitors are similar: they are examples of tight electrostatic coupling. Resonant circuits give us two new options for tightly-coupled power systems: pairs of high-amperage resonant loop-antennas, and pairs of high-voltage resonant dipole antennas. The spacing of each of these must be below 1/4 wavelength for the phenomenon to appear, and the e- or b-field strength must be very high. Now that I'm speaking of this, I know I've seen such things in common use. Air-core transformers in high-power VHF radio transmitters employ this effect. If both sides of an air-core transformer are tuned to the same frequency, then the b-field surrounding the transformer will build up to a very high level, and the throughput of energy will be very high, even though there's no closed iron-ring magnetic circuit, and coupling between the coils is *apparently* very loose.

MECHANICAL "ENERGY SUCTION"

Rick M. points out that mechanical forces might become significant in resonant EM systems. Normal transformers and capacitors certainly do display significant mechanical forces. If a transformer can be made into an induction motor, and if a capacitor can be made into an electrostatic motor, what kind of motor can be built from a loose/tight coupled high-frequency resonant EM device? I have no idea. Perhaps some strange and interesting hobbyist projects are lurking in these particular "undergrowths." Imagine a radio-frequency induction motor built without iron, whose (resonant) stator is at a great distance from the (resonant) rotor, yet the torque between them is still immense. Imagine a high-Q capacitor-based high voltage motor with huge torque, and with all of its parts embedded within plastic (to eliminate the corona problems associated with DC electrostatic motors.) Imagine a carefully-balanced supermagnet that's spinning at 60Hz in a vacuum chamber out in the woods, driven by the feeble environmental 60Hz magnetic field.

ELECTROMAGNETIC PRANKSTERS

An evil though: if we built a resonant antenna within a 1/4-wave distance of an AM radio tower, we might be able to "suck energy" at such a high rate that we could run motors and light lightbulbs! The resonant antenna might be very small, but it would have an intense e-field (or magnetic field if it was a loop antenna), and would reach out and touch the AM tower electrically. I've heard of people using "inductive coupling" to steal 60Hz AC electrical energy. Resonant energy-theft. The addition of a resonant circuit would vastly increase the ability of a pickup coil to suck in energy from any distant conductors as long as the frequency was fairly low. In physicist-speak, "If the world is already full of Sodium light, build some artificial Sodium atoms as absorbers."

Now I guess I need to go make a high-Q tuned circuit and set it to the same frequency as an AM radio station. Dunk the coil in liquid nitrogen. Maybe I can light up an LED! I know that longwire antennas can do this. I also know that an AM radio, if tuned to a weak station, can be affected when an adjacent unpowered AM radio is tuned to the same station. Untuned inductive pickup coils can receive "inductively coupled" energy if the b-field in the area is strong. Instead, with a small coil which resonates at 60Hz, maybe I can magnetically grab some AC power out of the wiring in my walls? It would be cool to have a wireless lightbulb connected to nothing but a high-value 60Hz inductor and capacitor. Maybe it would work a bit better if I wrap a couple of turns of "transmit loop" around my house and drive it with 10KHZ from my stereo. With thick wire and hi-Q resonance, it wouldn't take much to put many amperes into such a coil. Rats, now I wish I still lived next to a big AM transmitting tower like I did when I was a kid.

L.O.S., THE CREATIVITY DRUG

In conclusion, I must answer the obvious question: is Bill Beaty on drugs or WHAT?!!! No, instead I'm on deadline. I'm staying up all night for many nights in a row while beating my head on this interwoven industrial application interrupt-driven cludgy embedded set of C-code background tasks. Lack of sleep is itself a drug. Not LSD, use LOS! College students at exam time are well aware of this phenomenon. Stay up all night for a few too many nights, and you find that philosophy gains entirely new meaning, your wife starts looking at you funny, you are in danger of following Heinlein/Hubbard/Wilson and attempting to start your own religion... and the shades of Tesla and Feynman start subspace-idly coupling some 'Special Ideas' into your throbbing demented neuronal subprocessor networks.

So what do *YOU* do for fun?

;)

Bill b article: Light without photons (NEW 9/99)

MORE: some email discussions

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LINKS

- Realtime Schumann e-field spectrum, and photo of antenna
- Zenneck's EM surface wave
- EM wave applets
- MIT E&M: dipole radiation anim
- Tesla & surface waves
- Sutton's active antenna and "regeneration"

- For sale: resonant antennas from Terk and Select-a-tenna
- Resonate coil project
- Crossed-field Antenna
- Gieskieng Antenna (E-to-M 90deg phase shift output)
- BOOK: Causality, EM Induction and Gravitation (Dr. Oleg Jefimenko)
- JCE: creation/absorption of photons
- PHYSLETS: accelerated charge
- Dipole radiation movie
- H. G. Schantz papers (and antenna animations!)

http://amasci.com/tesla/tesceive.html
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