A Classical Physics Assessment of Tesla's Wireless Energy Transmission

(an array of Tesla's concepts fall into this)

by

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OVERVIEW

The presentation is based on what we understand as classical, mainstream physics

Its aim is to steer clear from convoluted concepts which, after all have hurt rather than helped N. Tesla's scientific contributions and reputation

On the basis of the fundamental laws that describe (or as best as we think we understand them) electromagnetic, resonance and other physical phenomena this presentation is an attempt to qualify questions as such:

Are certain far-reaching Tesla's assertions/experimental observations within the fundamental laws or do they violate them?

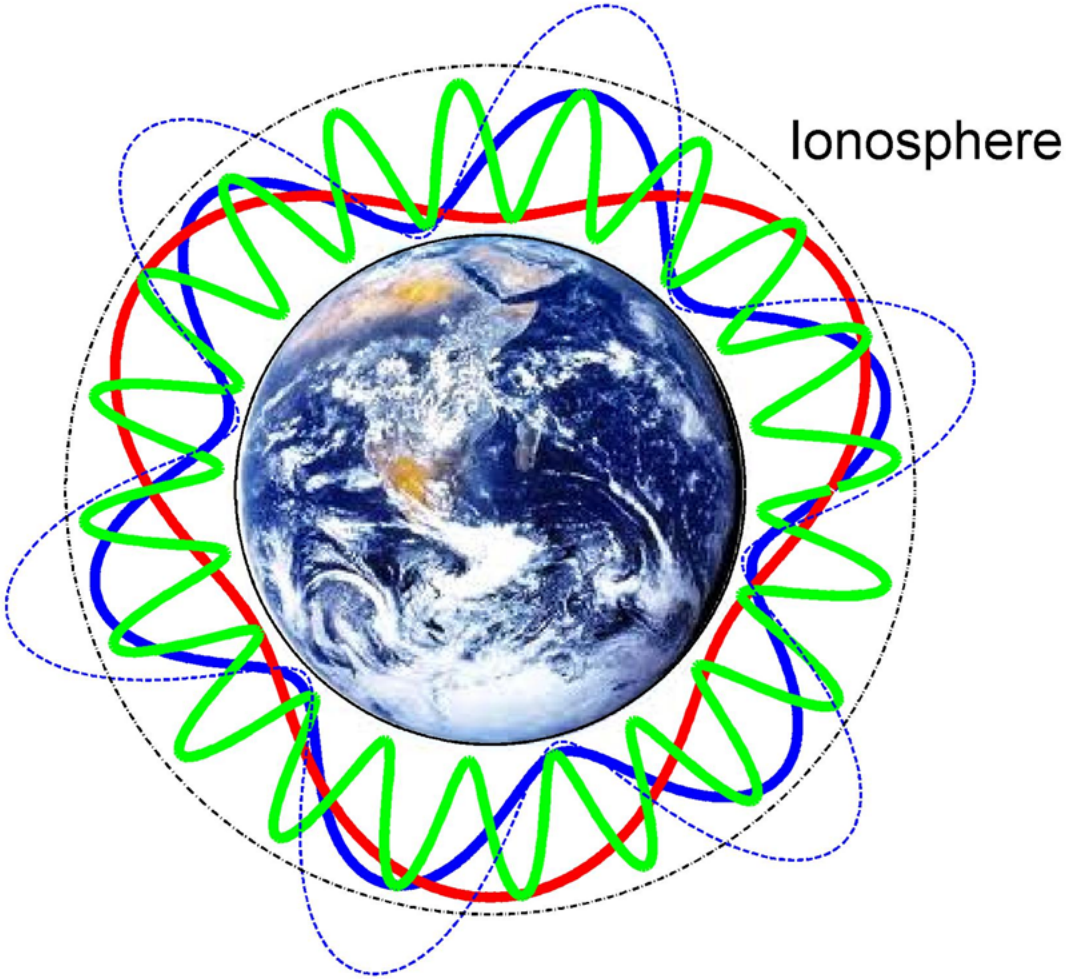
Is there an explanation of the observations, based on classical physics, and how our scrutiny of the "accepted" governing laws may have helped reveal hidden connections to his claims?

Are we finally connecting the dots between his thoughts and the great potential they may carry so as a society benefit as a whole?

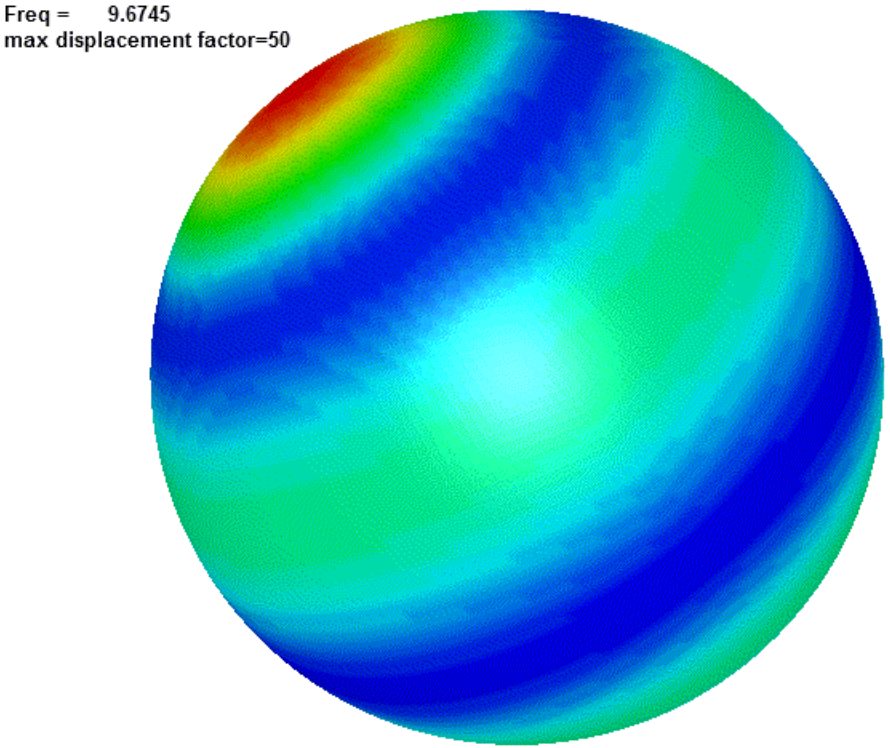
Schumann Resonance ➔ Earth-Ionosphere Cavity

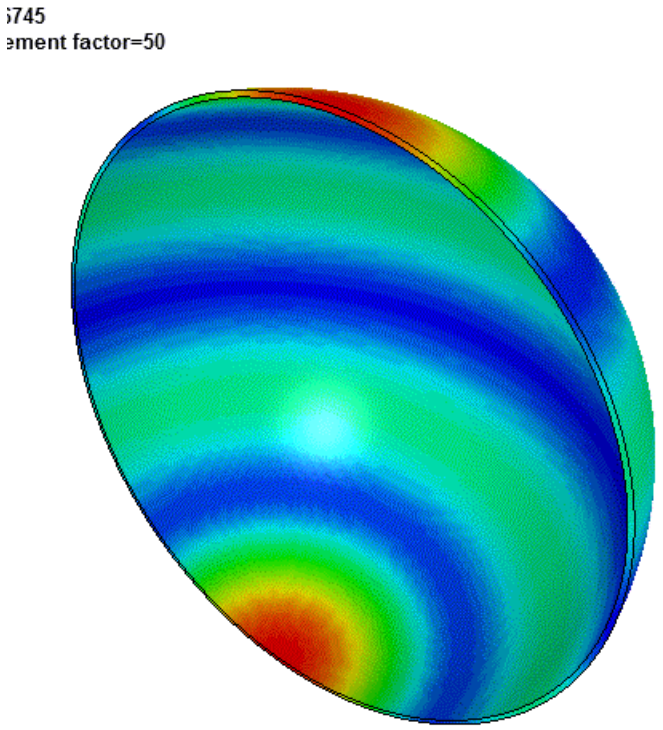
pivotal !!!!

Schumann Resonances – “Earth Breathing”



Let’s look at some “mechanical” analogies of the cavity resonances or standing waves





“mechanical” analogies of the cavity resonances or standing waves

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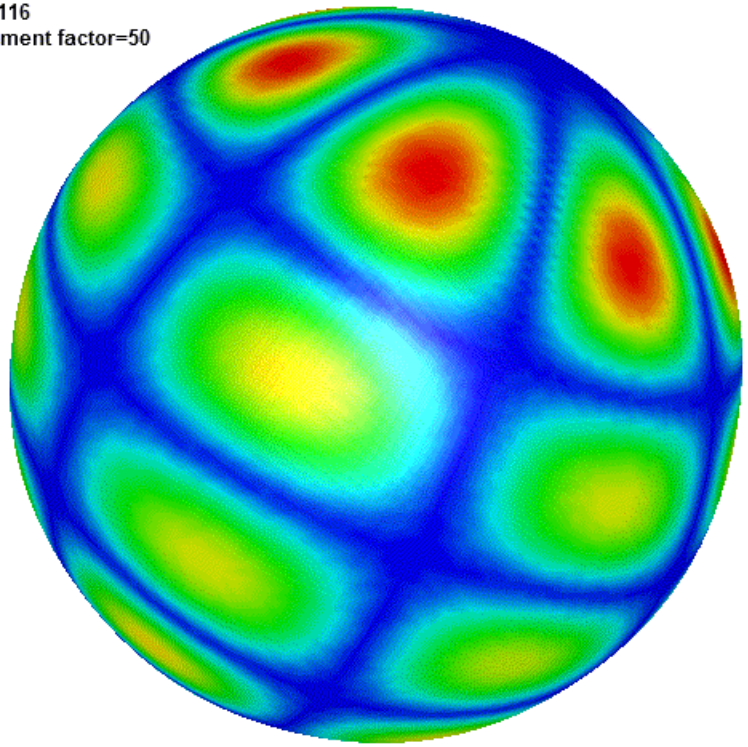
max displacement factor=50



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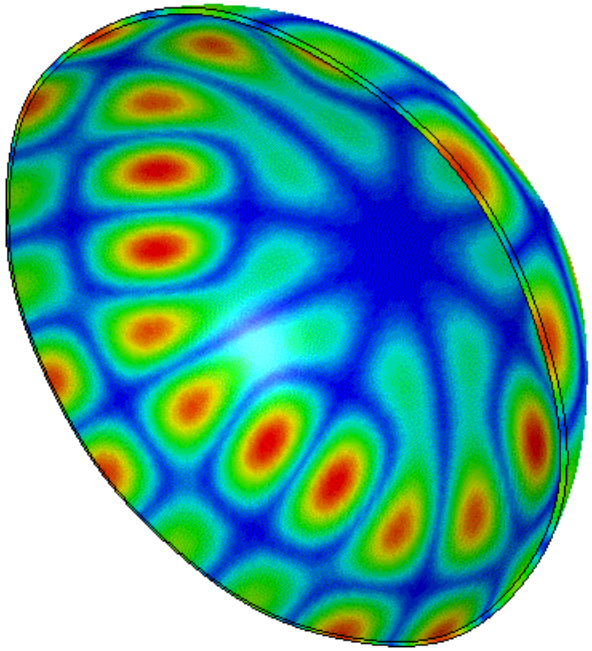

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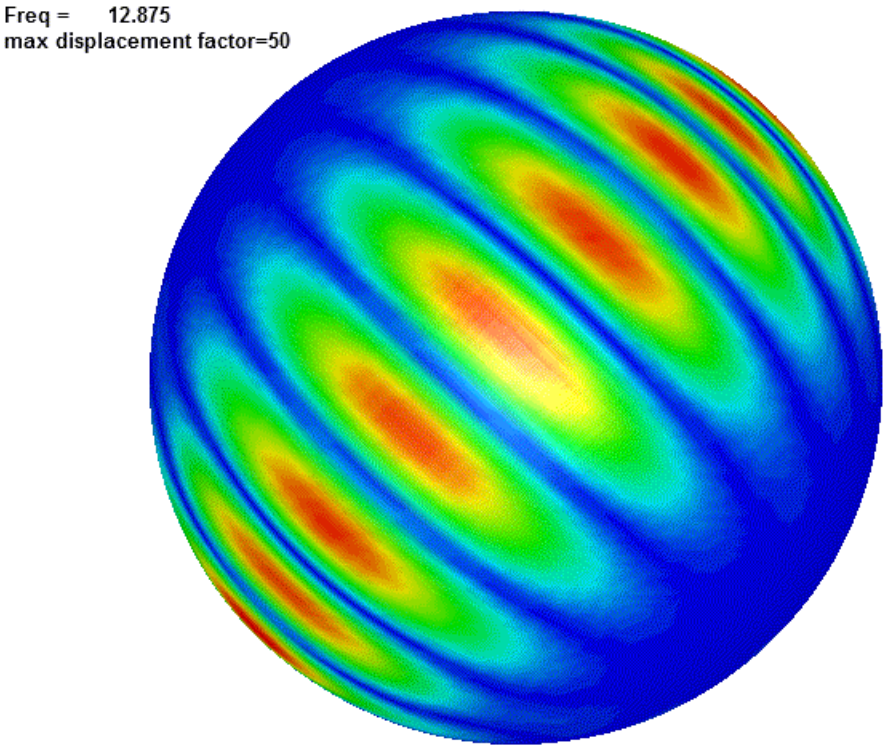
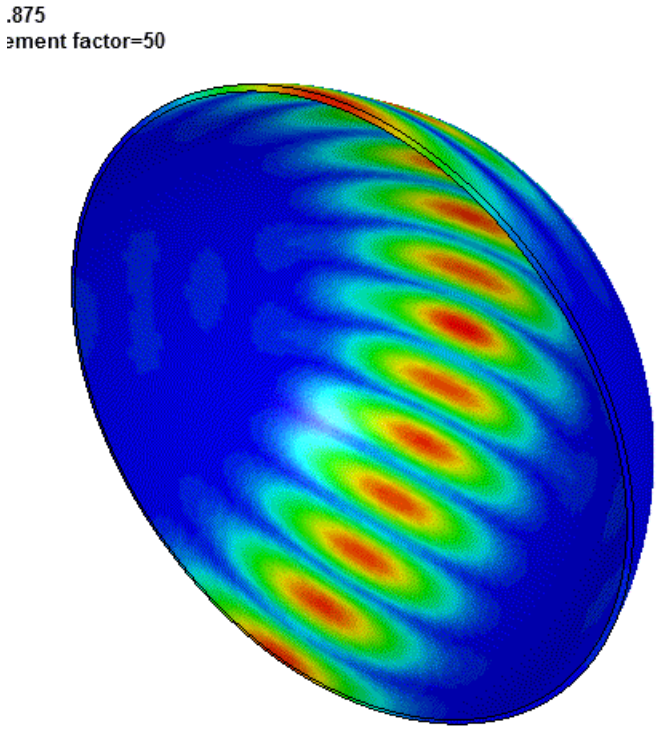




Ionosphere ➔ electrically positively charged (also utilized to transmit radio waves by bouncing off this layer)

Earth's surface ➔ negative charge

Hence a **spherical CAVITY** between the two conductive surfaces with the almost non-conductive air in between

STANDING waves (modes-like) are formed in the cavity which functions like a wave guide
Wavelength ~ circumference ➔ electromagnetic wave of 7.83 Hz

Lightning discharges EXCITE these modes and especially those considered Extremely Low Frequency (ELF) – including the 7.83 Hz mode

Prof. O. Schumman around 1952 mathematically estimated the 7.83 Hz mode that was soon after (1954) confirmed with measurements

Quote:
Physicist Nikola Tesla back in 1890's was FIRST to experiment with the CAVITY, powerful discharges emulating lightning and exciting ELF waves based on which he "discovered" the resonance frequency of the earth at 8 Hz.

....

"***Unfortunately Tesla was before his time and his discoveries were not taken seriously***"

According to Wikipedia:

The first documented observations of global electromagnetic resonance were made by Nikola Tesla at his Colorado Springs laboratory in **1899**. The observations led to certain conclusions about the electrical properties of the Earth, and which made the basis for his idea of wireless energy transmission.

Tesla researched ways to transfer power wirelessly over long distances (via transverse and longitudinal waves) transmitting ELF through the earth and as well as between the Earth's surface and the Kennelly-Heaviside layer (standing waves).

Making calculations based on the experiments, Tesla discovered that the resonant frequency of the Earth was ~8 Hz. In the 1950's researchers confirmed that the resonant frequency of the Earth's ionospheric cavity was in that range (later named the Schumann resonance)

Finally, N. Tesla in the company of pioneers and immortal scientists

Figure 1.1: The pioneers of electromagnetic theory. From left to right: André Marie Ampère (1775–1836), French physicist. Michael Faraday (1791–1867), English chemist and physicist. James Clerk Maxwell (1831–1879), Sc[illegible] mathematician.

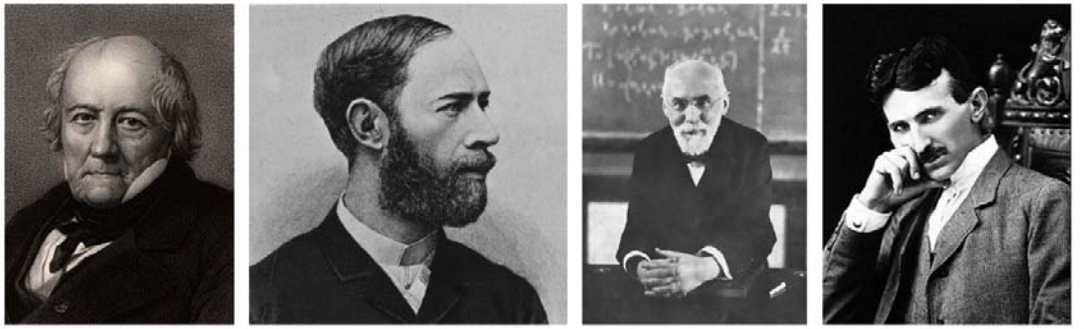


Figure 1.2: Immortal scientists of electromagnetic theory. From left to right: Jean-Baptiste Biot (1774–1862), French physicist, astronomer, and mathematician. Heinrich Rudolf Hertz (1857–1894), German physicist. Hendrik Antoon Lorentz (1853–1928), Dutch physicist. Nikola Tesla (1856–1943), Serbian inventor, mechanical engineer, and electrical engineer.

How significant are these observations and what do they reveal about N. Tesla?

Tesla & Colorado Springs

"**Singularities**" in discharges ➔ dipole-like

ELF waves and their excitation

Modes and standing waves

energy transferring with first modes
"white noise" excitation ➔ all modes

Singularities ➔ separation of wave fields (wave zone, longitudinal and transverse waves)

Tesla understood the cavity effect ➔ figured out the resonance !!!!

- ➔ understood/predicted that ionosphere is conducting (plasma state)
- ➔ ringing of a bell at the right time or interval (in this case at 8 Hz)!!
- ➔ understood the waveguide effect and its potential (we use it extensively today)

Resonance ..... and N.TESLA

Heraclitus: "τα παντα ρει ... everything is in motion"

and **Tesla** understood that "everything oscillates"

earth and its eigenmodes
fields
systems

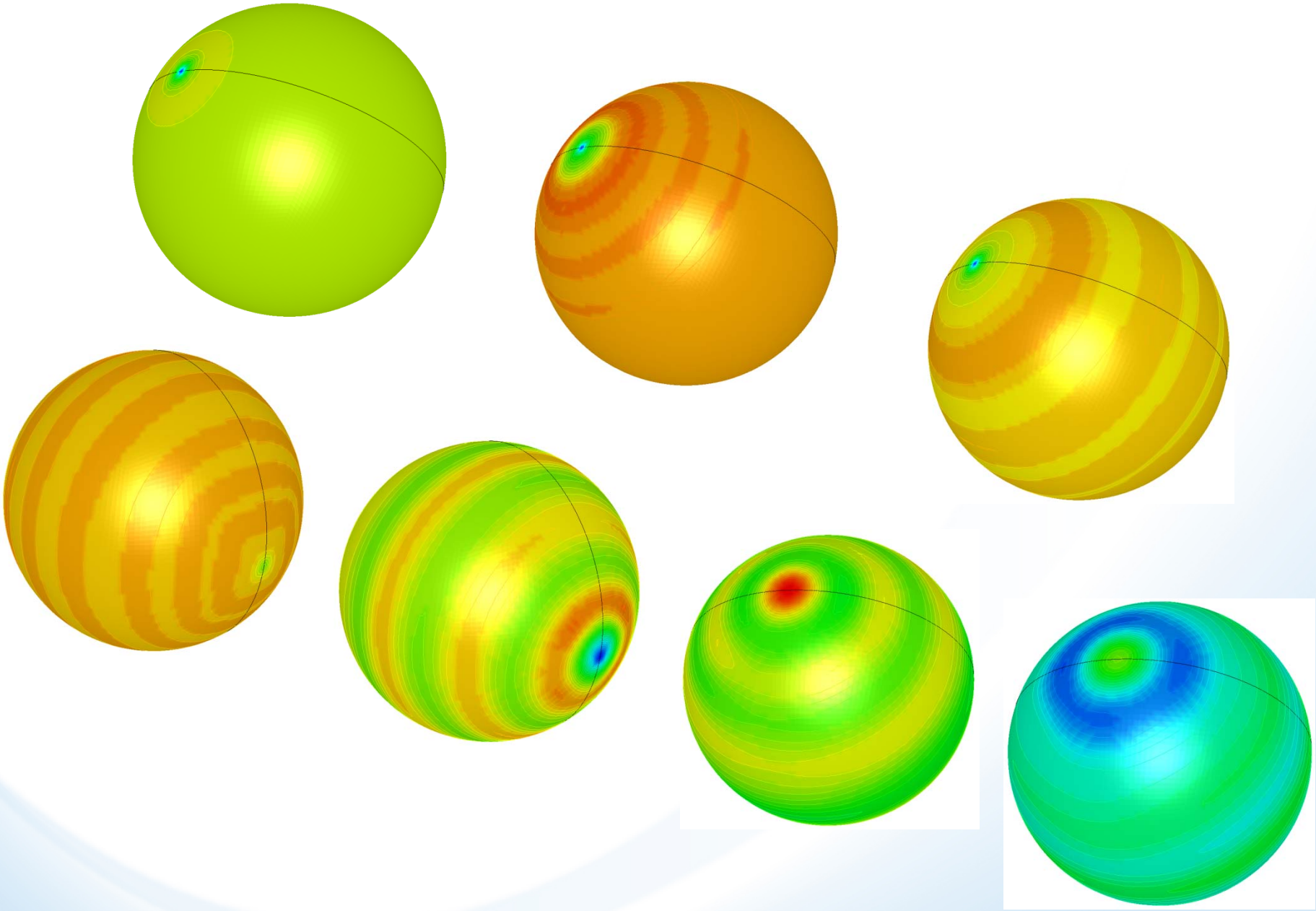
Energy transmission using earth resonance principles

The beauty of STANDING waves

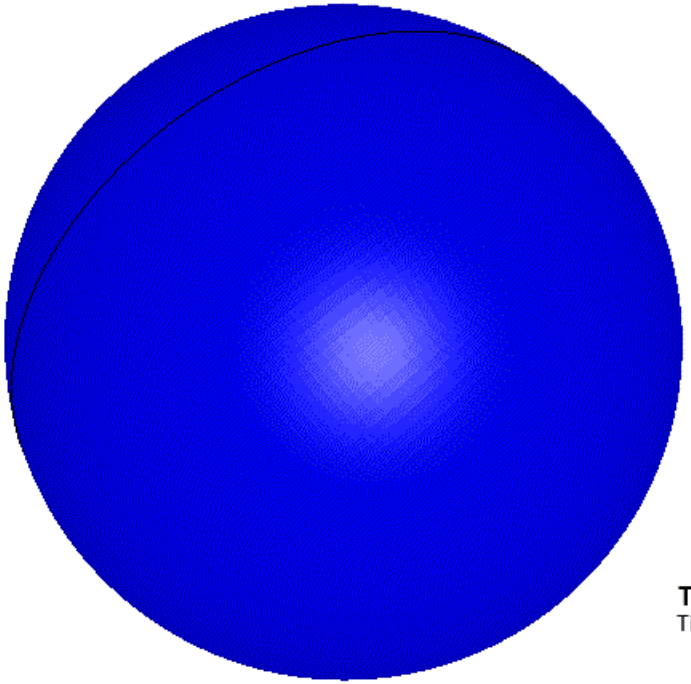
Power would be transmitted by creating "standing waves" in the earth by **charging the earth with a giant electrical oscillator** that would make the earth vibrate electrically in the same way a bell vibrates mechanically when it is struck with a hammer. . . ."

Well, here is the mechanical similarity in the principle ...

Tesla's Earth Crust Standing Waves Concept



Tesla's Earth Crust Standing Waves Concept
Time = 0



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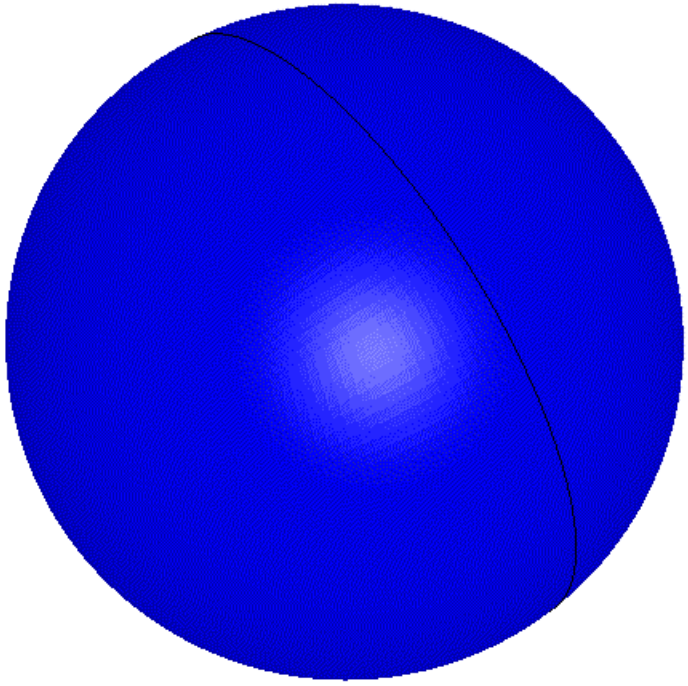
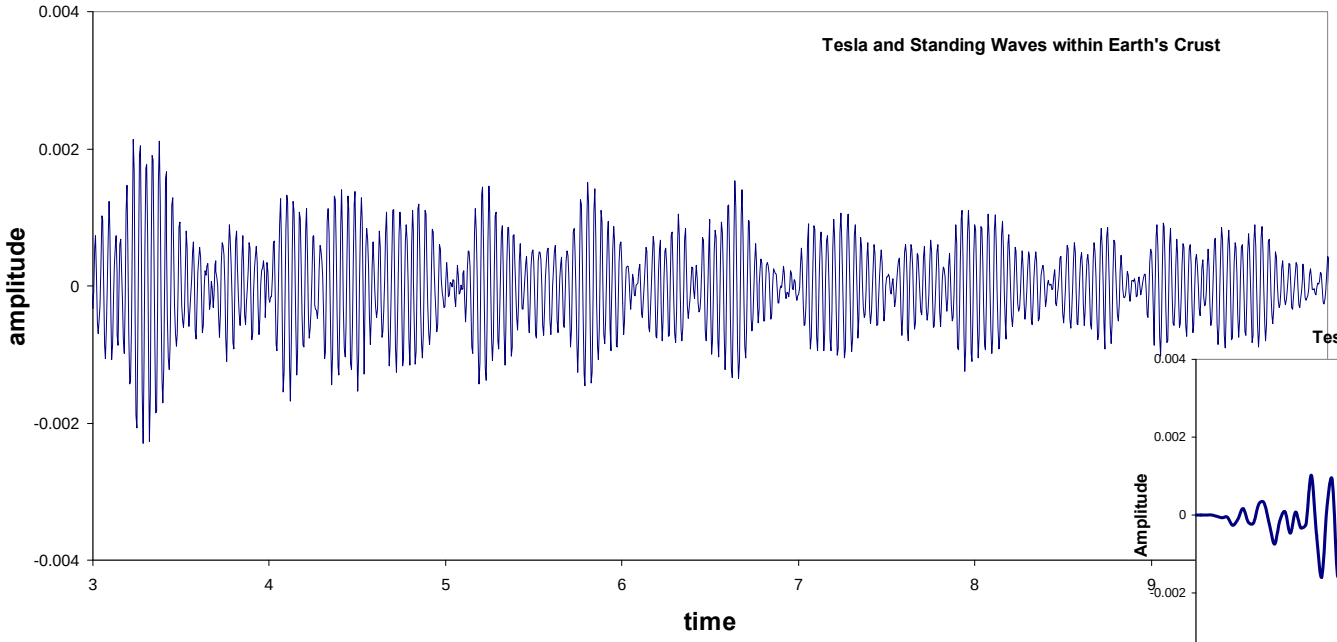
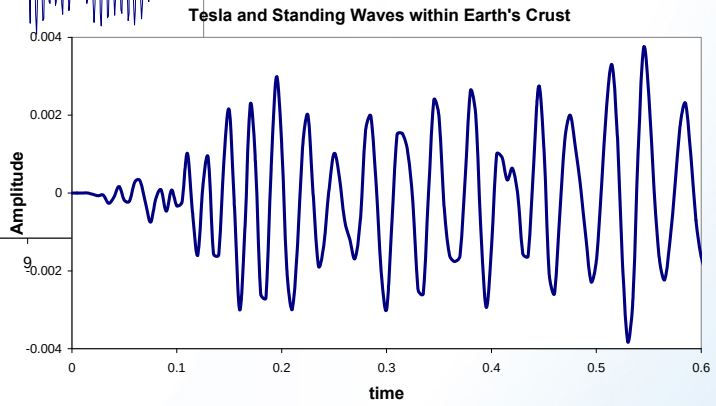
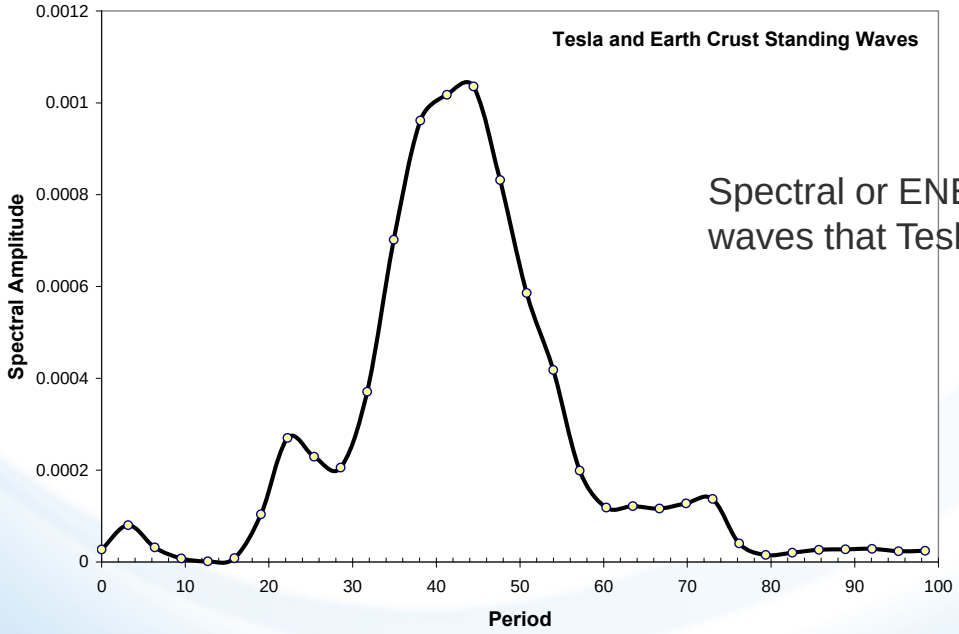








Spectral or ENERGY significance of standing waves that Tesla wanted to capitalize on

Constructive interference between source outgoing and antipode reflecting waveforms

Maxwell Equations ..... and TESLA

It is a well established fact that inconsistencies (both mathematical and physical) MAY EXIST in the Maxwell Equations

Singularities or DISCONTINUITIES in the fields and the physical meaning of singular solutions to these equations

Maxwell's Eqns written in terms of the electric field E and magnetic field B

$$\nabla \times E = -\mu \frac{\partial B}{\partial t} (Faraday's - Law)$$

$$\nabla \times B = J + \varepsilon \frac{\partial E}{\partial t} (Ampere - Law)$$

$$\nabla \bullet E = \frac{\rho_v}{\varepsilon} (Gauss - Law)$$

$$\nabla \bullet B = 0 (Gauss - Law - magnetism)$$

ρ_v is volume electric charge density, J is the electric current density (A/m^2), ε is the permittivity and μ is the permeability)

Classical Maxwell equations are supposed to be satisfied point-wise at any instant of time.

Their solutions are assumed to be smooth enough to allow differential calculus

Therefore, discontinuous or singular solutions are not allowed

Absence of point-wise concentrated charges and

avoidance of singular solutions

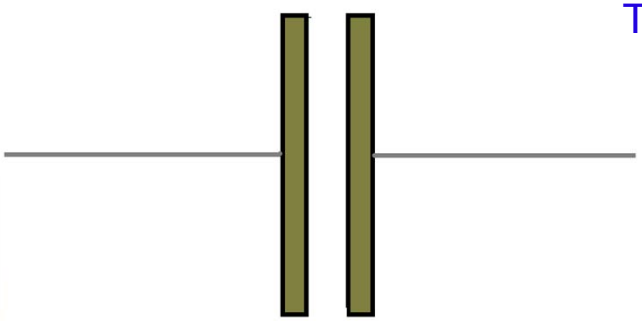
Maxwell Equations ..... and TESLA

Tesla, in his “wireless transmission” conceived of

Earth modes
Standing Waves
Longitudinal Electromagnetic Waves
Field Disturbance Singularities
Electrostatic Induction or electric displacement fields

How do these concepts measure up to our understanding of the laws of electromagnetism according to the unified **Maxwell Equations?**

The funny thing is that we have been accustomed to wireless energy transmission and it is an accepted notion ➔ **CAPACITOR !!!**



Tesla thought of a capacitor function in a grand scale!!
(note wavelength transmission limitations)

Resonant frequency ..... from the earthquake machine to wireless transmission of energy

While at Colorado Springs: **DID Tesla Excite Longitudinal Waves????**

Experimented with large discharges and observed that the pulse returned almost undiminished in strength ➔ **electric field with a singularity-like load**

Via **resonant inductive coupling** managed to transfer electric charges at long distances (longitudinal waves, standing waves ???)

in his words:

"This mode of conveying electrical energy to a distance is not 'wireless' in the popular sense, but a transmission through a conductor, and one which is incomparably more perfect than any artificial one.

All impediments of conduction arise from confinement of the electric and magnetic fluxes to narrow channels. The globe is free of such cramping and impediments.....”

Electromagnetic Longitudinal (➔vortex rings) and Transverse Waves (Hertzian)

Any vector field (finite, uniform, continuous and doubly integrable) can split into longitudinal and transverse fields

$$F = F_{\perp} + F_{\parallel}$$

$$\nabla \times F_{\parallel} = 0$$
$$\nabla \bullet F_{\perp} = 0$$

Maxwell equation for the long. part of electric displacement field

$$\nabla \bullet D_{\parallel} = \rho(r,t)$$

$D_{\parallel}$ = longitudinal electric excitation
$E_{\parallel}$ = longitudinal electric field

Which leads to:

$$D_{\parallel}(r,t) = \frac{1}{4\pi}\int \rho(r',t)\frac{r-r'}{|r-r'|^3}d^3r'$$

$$E_{\parallel}(r,t) = \frac{1}{4\pi\varepsilon}\int \rho(r',t)\frac{r-r'}{|r-r'|^3}d^3r'$$

$D_{\parallel}$ and $E_{\parallel}$ respond instantly to changes in charge density ρ

(Source: J. Nitsch, et al, Equivalent Circuit Method)

An interesting finding which says that the long. electric displacement $D_{\parallel}$ and electric strength $E_{\parallel}$ are determined from the instantaneous Coulomb charge !!!

In other words, change at a single point (singularity in the form of discharge) is tied to modes of field !!
(analogy in statics where the effect is not waves in traditional sense by the excitation of modes)

Ongoing Debate on Longitudinal Waves and Maxwell Equations

Can Longitudinal Electromagnetic Waves Exist?
By G. W. BRUHN

They don't exist !!!

We consider a homogeneous medium of **constant dielectricity and constant permeability** that is **free of electric sources and currents**

Then all electromagnetic processes are governed by the homogeneous Maxwell equations

That may be (not entirely) true in free space !!!
where only transverse (Hertzian) exist/propagate

important statement

How can the problem be treated when these sources exist?

or

How has the field been generated in the first place?

Source charge, source dipole moment?

$$\nabla \times F_{\parallel} = 0$$

$$D_{\parallel}(r,t) = \frac{1}{4\pi}\int \rho(r',t)\frac{r-r'}{|r-r'|^3}d^3r'$$

$$E_{\parallel}(r,t) = \frac{1}{4\pi\varepsilon}\int \rho(r',t)\frac{r-r'}{|r-r'|^3}d^3r'$$

as we saw earlier the field responds instantly to the change at the source
Hence, not waves in the conventional sense BUT mode-like behavior

Arrived at this by solving the Boundary Value Problem (J. Nitsch, et al, Equivalent Circuit Method)

Ongoing Debate on Longitudinal Waves and Maxwell Equations

electrostatic or magneto-hydrodynamic plasma wave model

Singularities of the Electromagnetic field

Electrostatic Waves (*K. T. McDonald, An Electrostatic Wave*)

Assertion: Longitudinal waves in plasma; purely longitudinal electric waves are limiting cases of more general waves; longitudinal electric waves can coexist with background electrostatic and magneto-static fields of the usual type

Electric field with no time dependence derives from scalar potential V ➔ $E = -\nabla V$

$$E = E_x \hat{x} e^{i(kx-\omega t)}$$

$$E = -\nabla V$$

$$V = i\frac{E_x}{k} e^{i(kx-\omega t)}$$

$$\rho = -\nabla P$$

$$\nabla \times E = 0; \frac{\partial B}{\partial t} = 0; \frac{\partial E}{\partial t} = 0$$

$$\nabla \bullet E = 4\pi\rho$$

$$P = -\frac{E}{4\pi}$$

$$Condition: D = E + 4\pi P = 0$$

These show that a LONGITUDINAL electric wave E can exist with background electrostatic and magnetostatic fields of the usual type

Wireless power transmission and the IONOSPHERE

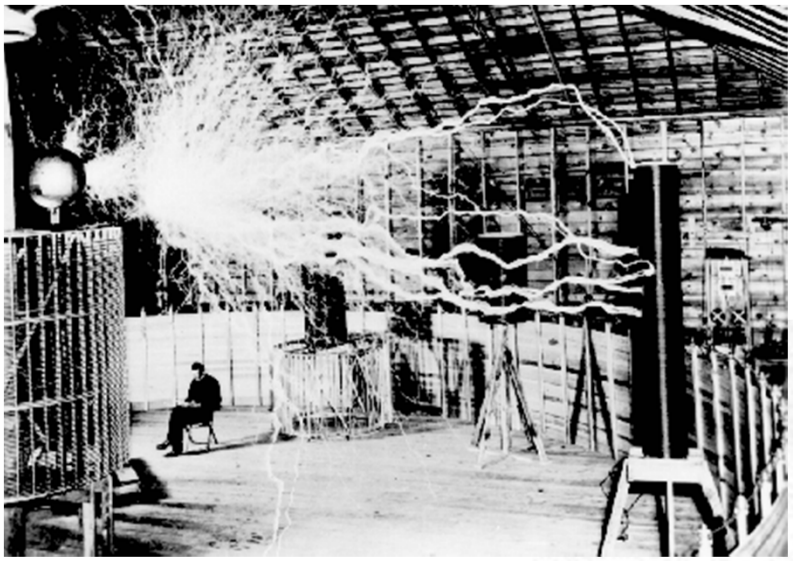
Shoreham Connection

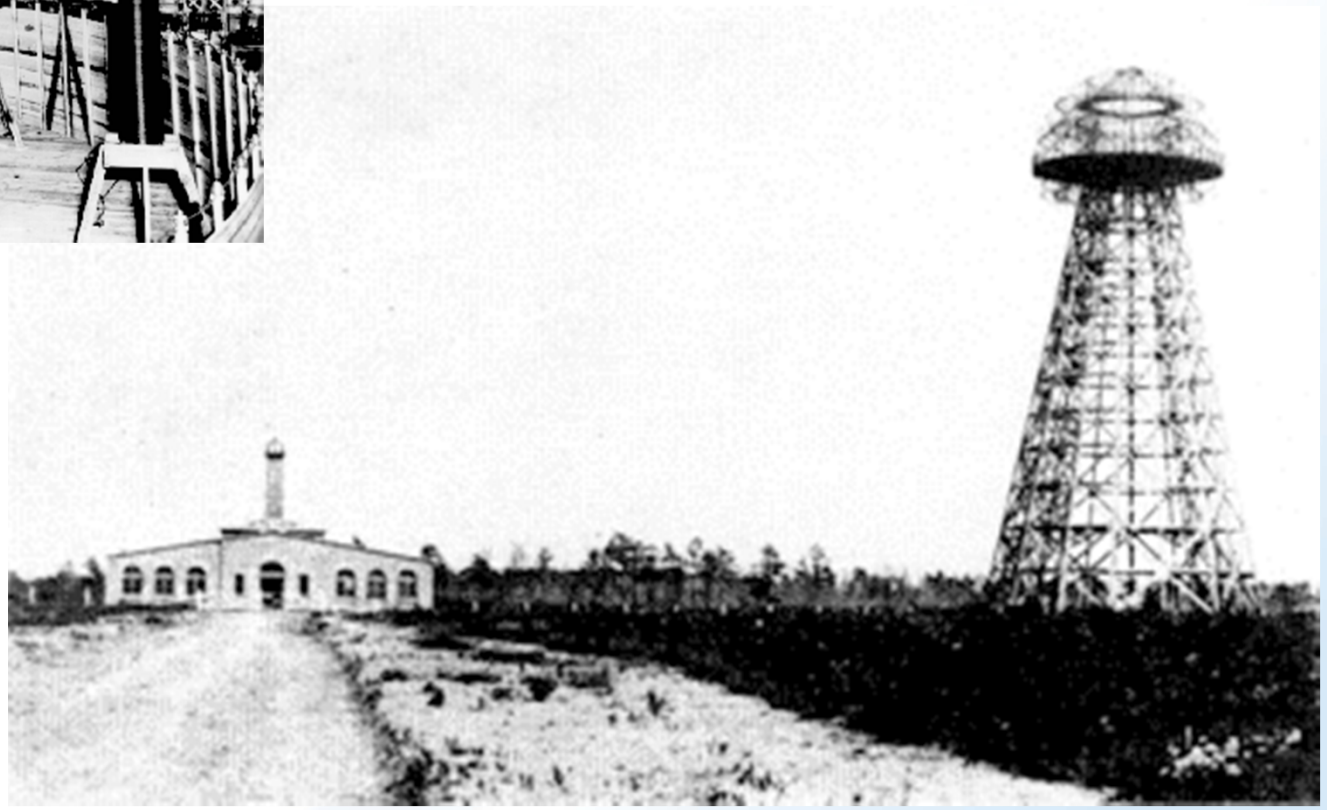
Tesla aimed to utilize the strata 60-kilometers above the earth known as **the ionosphere**

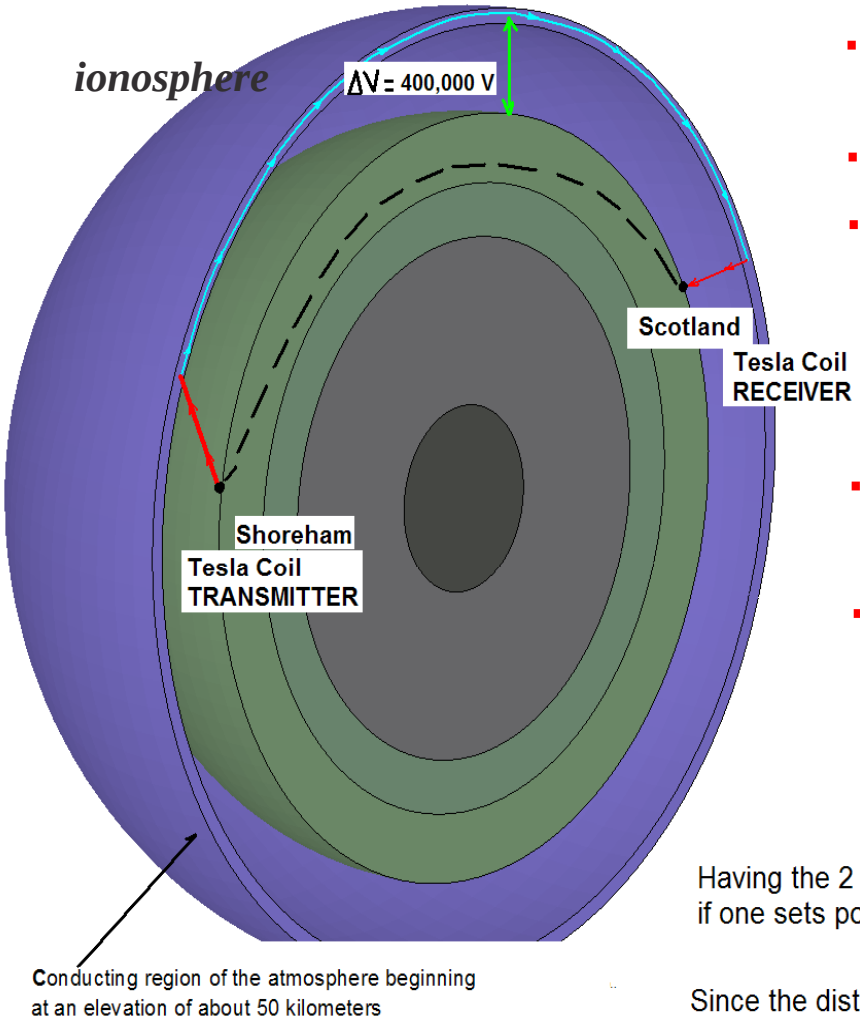
He **speculated** and confirmed its existence in Colorado Springs that his region of the atmosphere would be highly conductive

What he needed was the technical means to send electrical power to such a high altitude

and so comes the **FIRST Ionized Beam !!!!**







- Electrical Current flowing through earth between two Tesla coils (transmitter & receiver)
- Atmospheric Conduction (current passes thru earth & atmosphere)
- Electric current through the earth BALANCED by equivalent electrical displacement of opposite sign above
  - Electrical displacement achieved by conduction

- ~15 million V needed on both terminals to break down insulating air around and above coils (plants)
- Ionization of atmosphere facilitated by ultraviolet radiation (ionizing beam) - Plasma high-voltage transmission line

(para-phrased) Tesla Assertion:

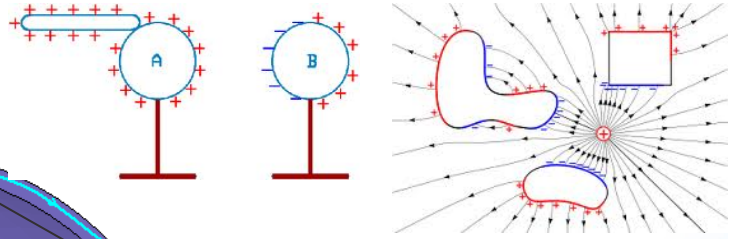
Having the 2 conductors in place (earth and ionosphere) separated by an little insulating stratum, if one sets potential differences at a point that will result in potential fluctuations in the "circuit"

Since the distance from earth to the conducting atmosphere is much smaller than the distance between the two stations through the earth, the energy will prefer the ionosphere path, transform into conduction currents and travel like it travels over a wire

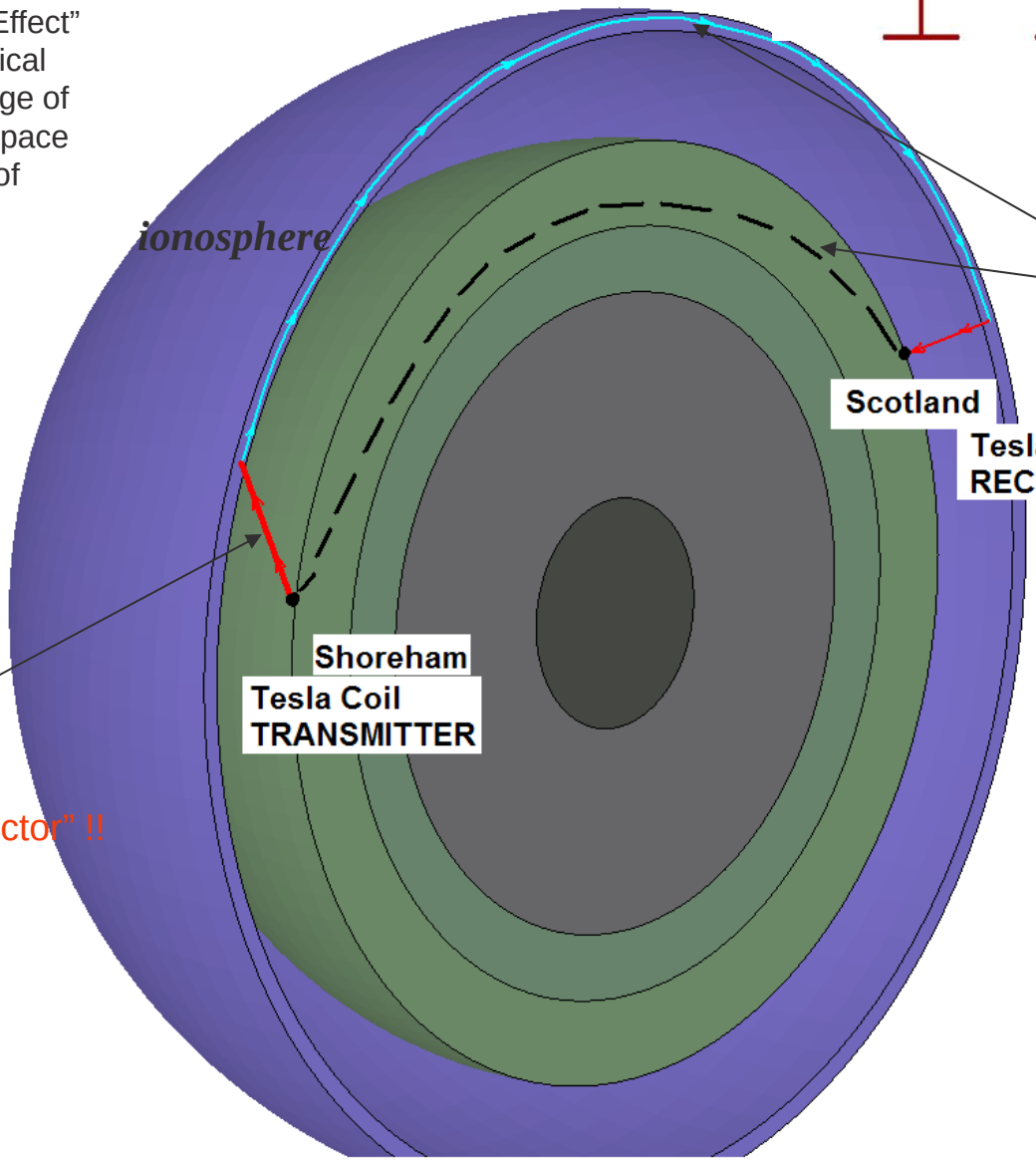
(pretty neat !!)

Electrostatic Induction (capacitive coupling)

High-field Gradient or differential capacitance



Also known as the “Tesla Effect” can be described as electrical displacement or the passage of electrical energy through space other than the application of voltage potential



ENERGY SUCKING ANTENNAS and TESLA

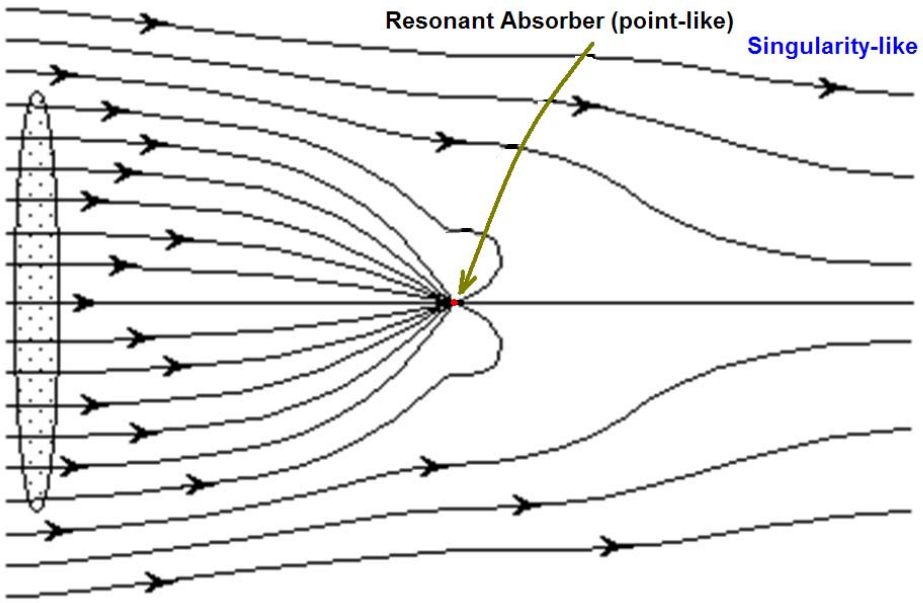
Parallelism with ATOMS (1 Am) strongly interacting with LIGHT (5000 Am wavelength)

Flood the atmosphere with standing waves (ionosphere keeps most of this EM energy from escaping into space) then a small resonator can grab significant wattage right out of the air (effective disk in figure)

So, what happens at the receiving end .....?

How do you collect energy from these currents flowing over the vast ionosphere .... ?

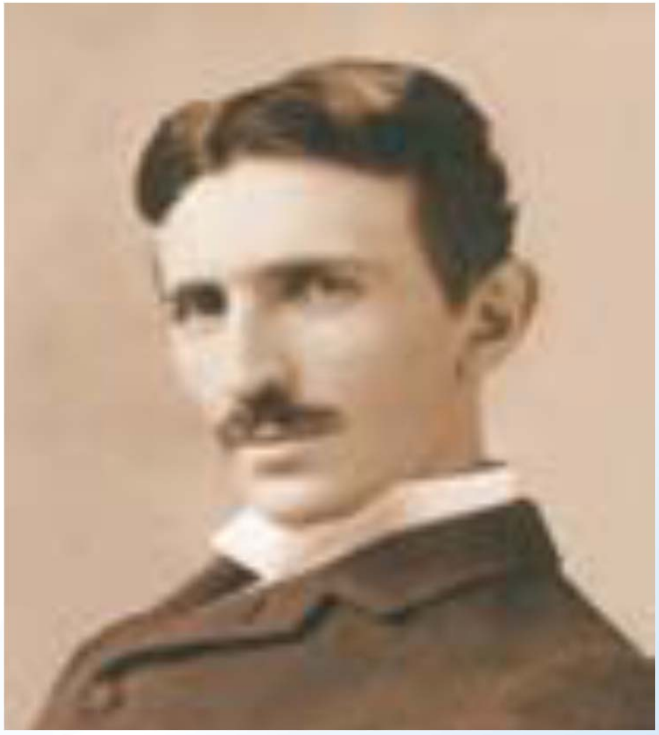
A **small resonator** can produce an extensive and intense AC field of its own, and can act as an "**EM funnel**" (simple desktop experiments demonstrated it !!!)



http://amasci.com/tesla/tescv2.html

This is "circuitry", where wavelength is huge, and circuits are small

As one said: *"This is probably the concept that put that "Mona Lisa grin" on photographs of old Nikola. And that twinkle in his eye..."*



Tesla and "Electrostatic induction“

In Tesla’s model the two distant elevated terminals are electrically coupled together in a manner similar to the transfer of electrical energy between two closely spaced capacitor plates in a typical AC circuit, **but at distances greatly exceeding 1/6 - 1/2 wavelength**

Tesla used the term electrostatic induction to describe the behavior of capacitors, or more generally, the electrical coupling of two or more conducting surfaces that are separated by one form or another of dielectric.

This model considered to be inconsistent with a basic tenet of mainstream physics (related to the scalar derivatives of the electromagnetic potentials)

So we thought, BUT “**Witricity**” is proving to be otherwise

➔ MIT tests and Resonant Inductive Coupling (distances > ¼ wavelength, maybe not the distances Tesla envisioned BUT much greater than what was thought as the threshold of a capacitor)

N. Tesla and X-rays

Discovery of X-rays credited to Röntgen

Wilhelm Conrad Röntgen – Cathode ray studies 1895
This radiograph 1896 (hand of Anna Röntgen)
Röntgen won the First Nobel prize in Physics 1901

Tesla Radiograph in 1896

Hrabak M et al. Radiographics 2008;28:1189-1192

Investigations by Tesla starting 1892 on vacuum tubes included observations of
- 'Visible light,
- black light and a
- very special radiation"

Very special radiation turned out to be X-rays

RadioGraphics

SPECIAL EXHIBIT 1189

Scenes from the Past

Nikola Tesla and the Discovery of X-rays[1]

Maja Hrabak, MD • Ranka Stern Padovan, MD, PhD • Marko Kralik, MD • David Ozretic, MD • Kristina Potocki, MD, PhD

Introduction

Every radiologist is aware of Nikola Tesla's research in the field of electromagnetism. The International System (SI) unit of magnetic flux density, the Teslacon magnetic resonance imager (Technicare, Solon, Ohio), and Teslascan manganese contrast agent (GE Healthcare, Waukesha, Wis) were all named after him. Without his other inventions like the alternating current supply, Tesla-Knott generator, and fluorescent lights in view boxes, it is impossible to even imagine a workday in a contemporary radiology department (1). But if the discovery of x-rays is mentioned, only a few radiologists associate it with Tesla's name.

Early Days

Nikola Tesla (Fig 1) was born in 1856 in the small village of Smiljan, Croatia. After finishing high school in Croatia, he continued his education in engineering in Graz, Austria, until 1878. Four years later he moved to Paris, France, and started working for the Continental Edison Company. In 1884 he emigrated to the United States, where he first began to work with Thomas

Figure 1. Nikola Tesla (1856–1943) at the age of 36 years. (Courtesy of the Tesla Museum, Belgrade, Serbia; document no. MNT,VI/V, 10.)

Tesla's RADIANT Radiation of the *invisible* kind

In **April 1887** Tesla began investigating X-rays using high voltages and tubes (own design)

Based on his technical publications he developed a special single-electrode X-ray tube which differed from X-ray tubes having no target electrode

Principle behind Tesla's device is the **Bremsstrahlung Process**
(*high-energy secondary X-ray production given off by the electrons as they are scattered by the strong electric field near the high-Z nuclei*).

Several experiments by 1892 BUT did not categorize them as X-rays

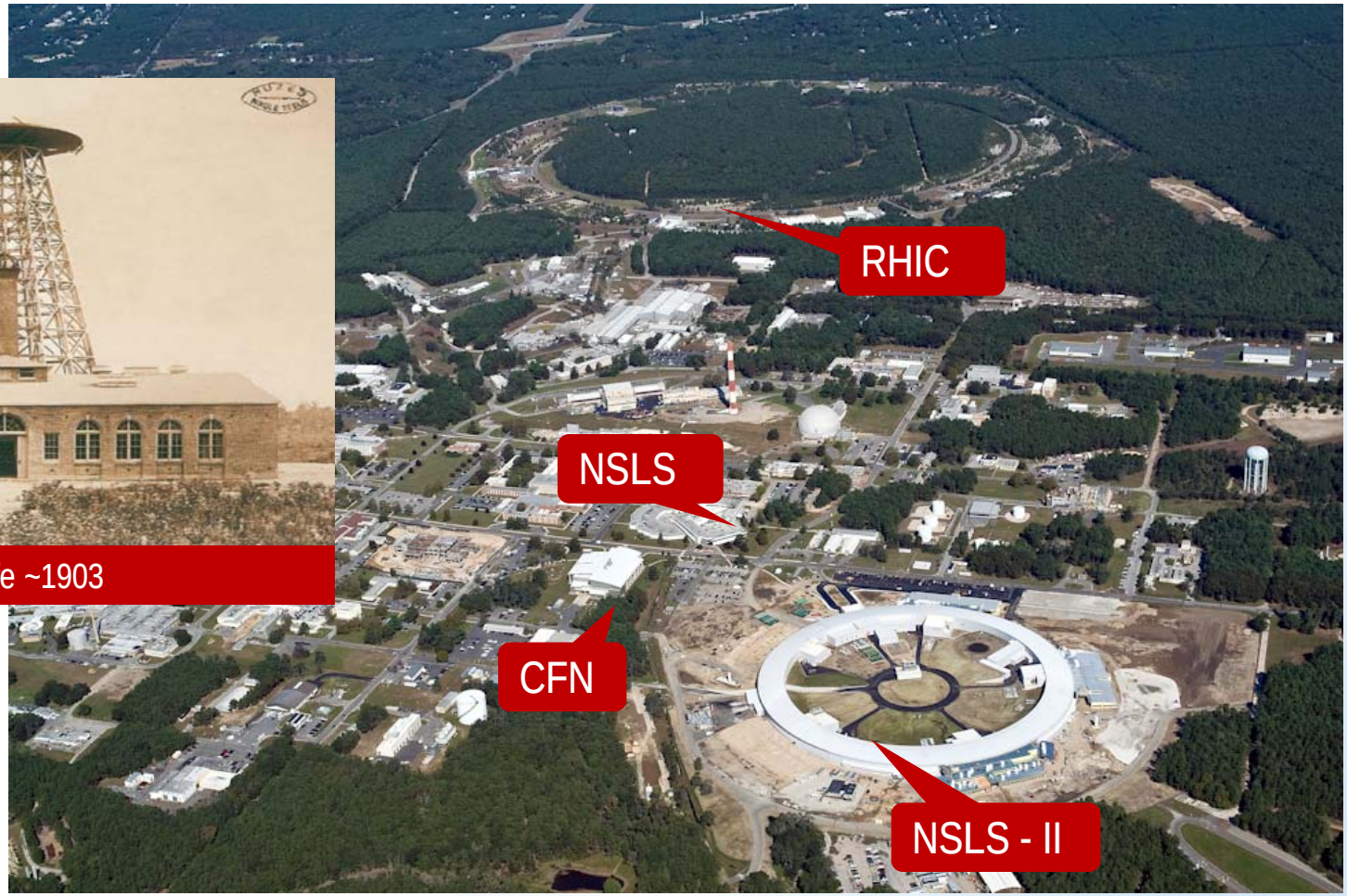
Generalized them as RADIANT radiation of "invisible" kinds (1897 X-ray lecture before NY Academy of Science)

ALERTED the scientific community to the biological hazards associated with X-ray exposure

So, from Tesla's vacuum tubes to .....

Brookhaven National Laboratory

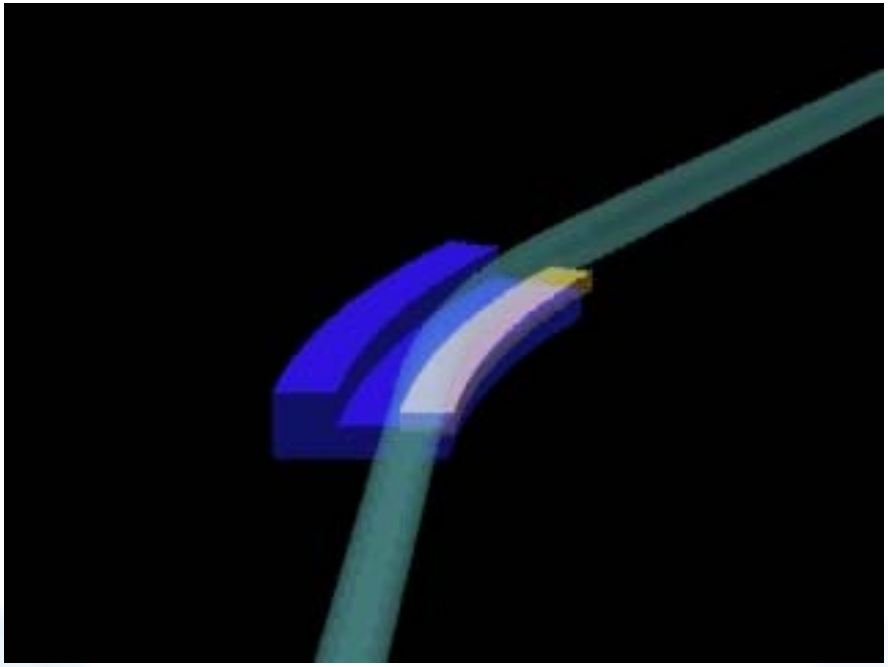
Wardenclyffe ~1903

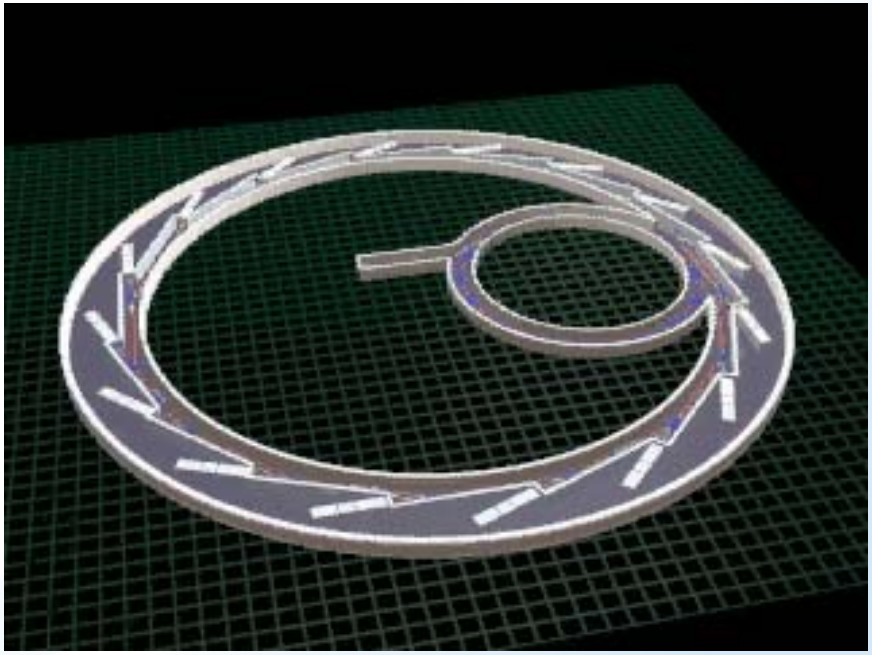


What is a synchrotron?

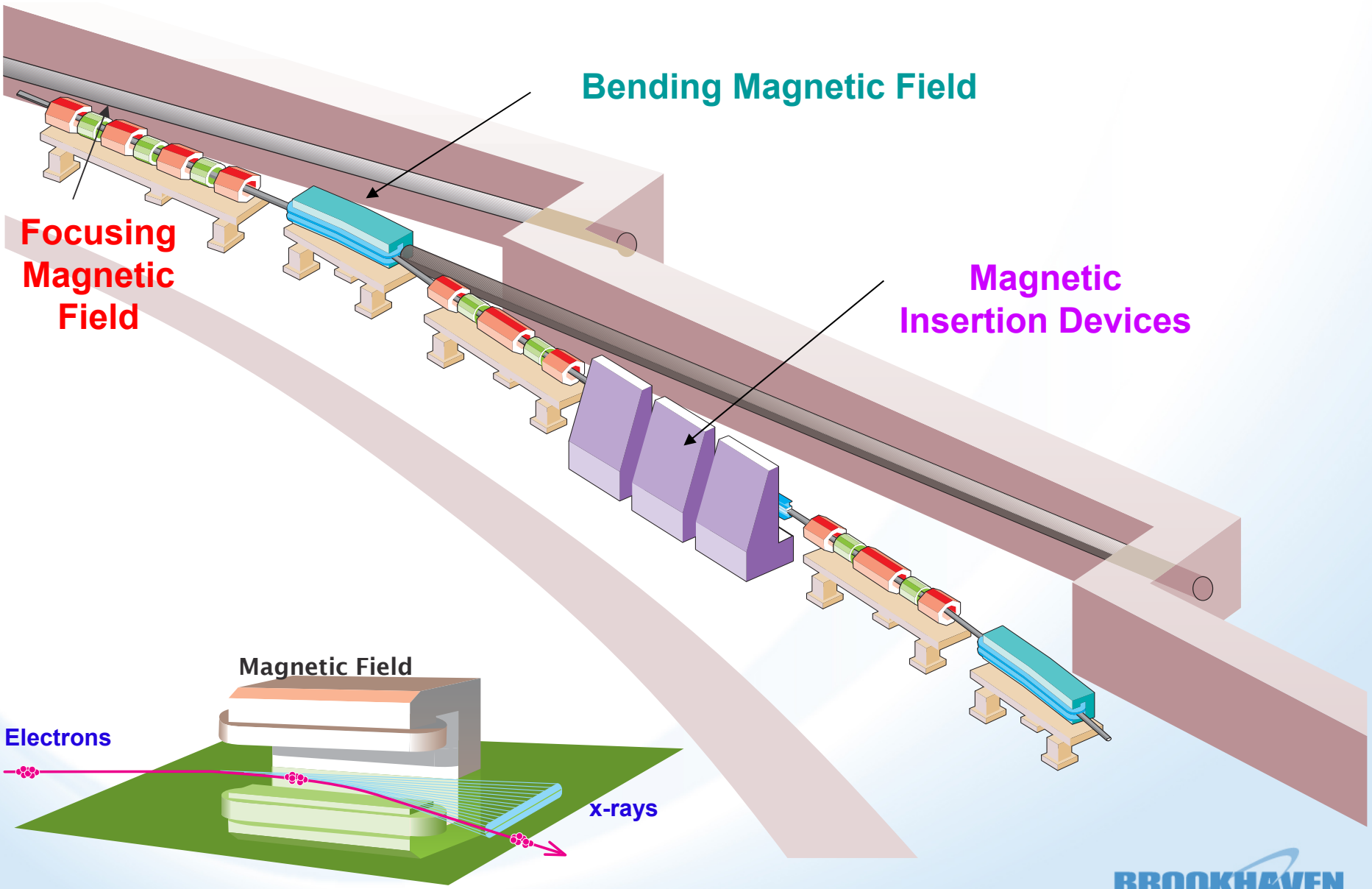
A synchrotron is a huge accelerator that produces very bright light of many different wavelengths (from Infra-Red to UV-visible light to x-rays).

A synchrotron can be thought of as a giant microscope. It allows matter to be observed at the atomic scale





Storage Ring



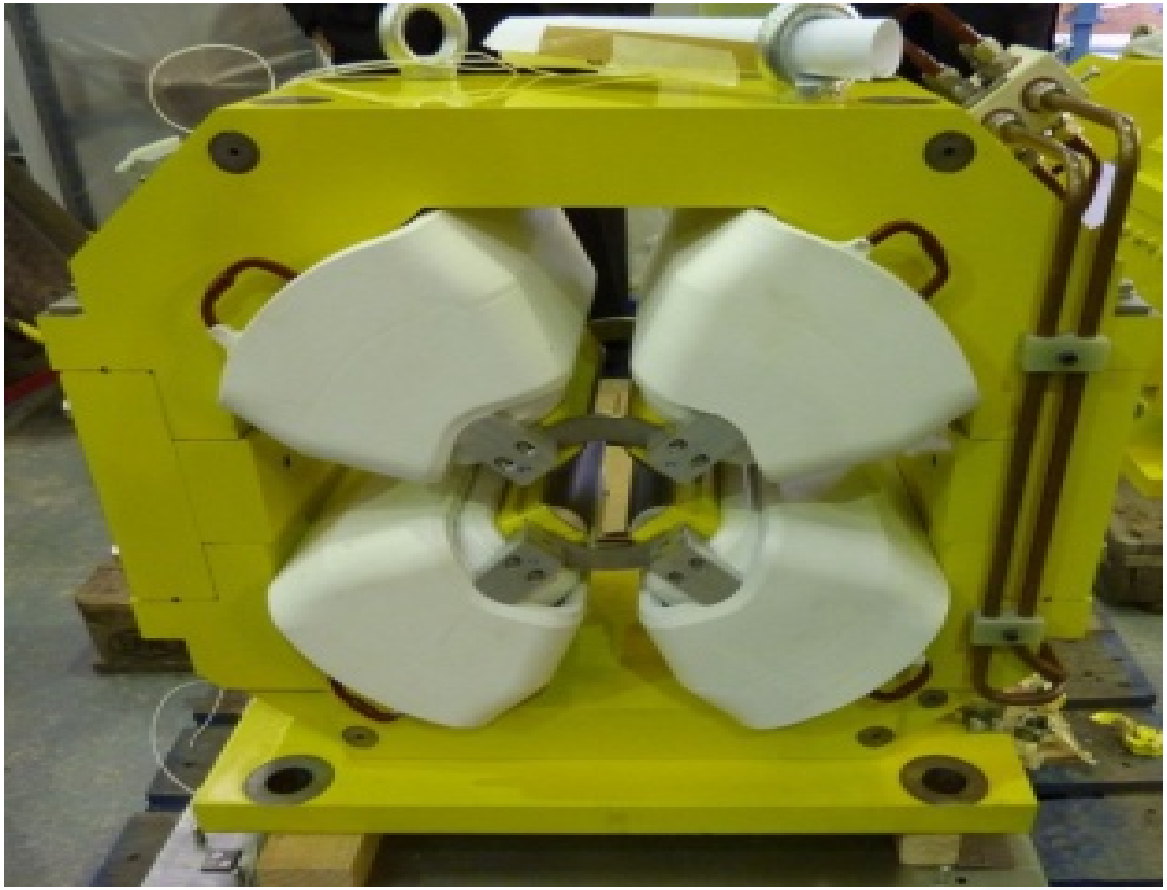
A LARGE Scale Microscope

World's finest capabilities for x-ray imaging and high-resolution energy analysis, ~10 times better than any other synchrotron now operating or under construction

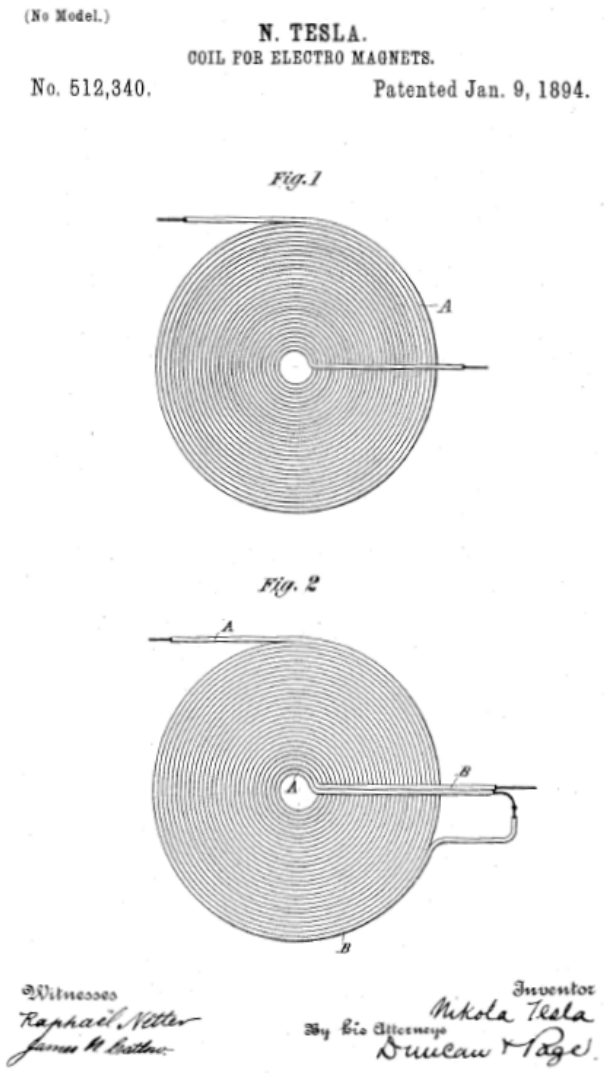
So what is the connection .....??

Tesla Technology

Nikola Tesla Patent on method for winding a magnet coil (1894)



NSLS-II Quadrupole Magnet (2011)



(No Model.)

N. TESLA.

COIL FOR ELECTRO MAGNETS.

No. 512,340. Patented Jan. 9, 1894.

Fig. 1

Fig. 2

Witnesses

Raphael Netter

James M. Chittenden

Inventor

Nikola Tesla

By his Attorneys

Duncan & Page

In his own words .....

Let the future tell the truth, and evaluate each one according to his work and accomplishments.

The present is theirs; the future, for which I have really worked, is mine.

Nikola Tesla

It is possible then that our future already lies in our past

..... All we need to do is continue connecting the dots

Acknowledgments

Drs. E. Johnson and E. Dooryhee, Photon Sciences Directorate, BNL

Links and Resources

www.bnl.gov/ps – BNL Photon Sciences

www.teslasciencecenter.org – TESLA Science Center at Wardenclyffe

www.teslasociety.org – Tesla Society of USA and Canada

http://radiographics.rsna.org/content/28/4/1189 –

Nikola Tesla and the Discovery of X-rays, Hrabak, Stern-Padovan, Kralik, Ozretic and Potocki, RadioGraphics 2008;28:1189-119

J. Nitsch, F. Gronwald, G. Wollenberg, “Equivalent Circuit Method”, Wiley

Back-Up SLIDES

Electromagnetic Longitudinal (rings of a vortex) and Transverse Waves

These solutions of ME associated with the longitudinal component of the electromagnetic field are tied to and determined by the instantaneous electric charge density *ρ(r', t)*

Note that *r'* is the charge location while *r* is the observation point

Hence, longitudinal components do not have own Degrees of Freedom but tied to those of the electric charge density (could think of the electric charge density field having modes)

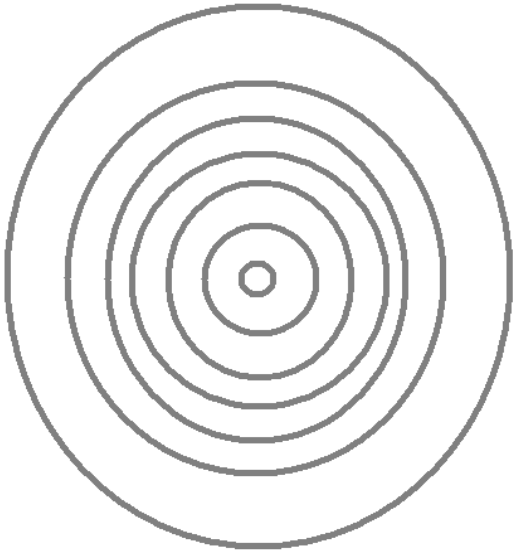
BUT Tesla had been seeking and experimenting with RIDING these modes

..... Exciting field modes by resonating with characteristic frequencies of this field

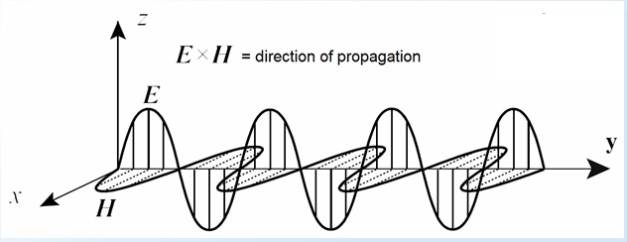
..... Exciting field modes with singular discharges

..... Exciting terrestrial modes

$$E_{\|}(r,t) = \frac{1}{4\pi\varepsilon}\int \rho(r',t)\frac{r-r'}{|r-r'|^3}d^3r'$$



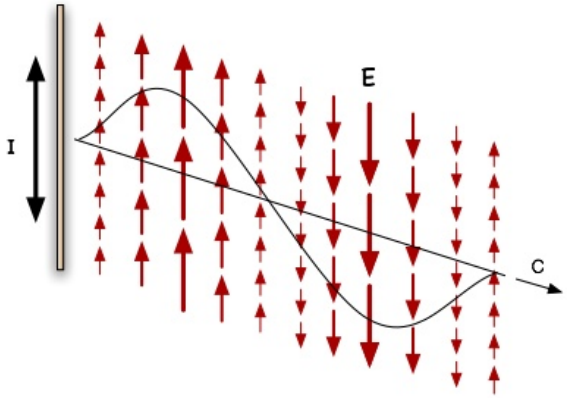
Instead of

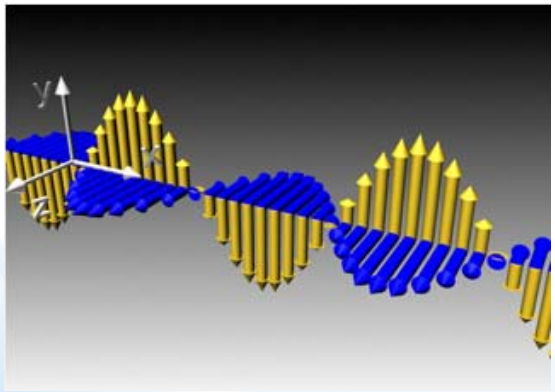


Ongoing Debate on Longitudinal Waves and Maxwell Equations

Transverse waves (**Hertz type**) are undulations with orientation of fluctuation perpendicular to the direction of travel.

An antenna given a high frequency electrical signal will radiate **transverse electromagnetic waves** as shown





Longitudinal waves fluctuate in the direction of propagation like sound waves, which consist of an alternating series of ***displacements*** in air where the displacement points in the direction that sound travels.

For longitudinal EM waves, the vector potential fluctuates in the direction of travel, not perpendicular to it.
They show ***no vorticity*** and thus no magnetic field
➔"curl-free vector potential"

Seemingly in direct violation of the **Maxwell equations** that state **there must be an induced magnetic field for every change in the electric field**

The controversy can be reconciled if one accepts that the notion that there is either electric or magnetic field with longitudinal waves, not both.

Then ➔longitudinal waves do not violate Maxwell's equations; rather they are what Maxwell termed ***displacement* current**

Current = flow of charges. Across a **capacitor** consisting of two conductors separated by an insulator that allows no charge to pass, oscillating energy can still transfer

Photoelectric effect illuminated

Planck ➔quantized electromagnetic field ➔ most physicists immediately agreed that Planck's "light quanta" were unavoidable flaws in his model.

A more complete derivation of black body radiation would produce a fully continuous, fully wave-like electromagnetic field with no quantization.

However, in 1905 Albert Einstein took Planck's black body model in itself and saw a wonderful solution to another outstanding problem of the day:

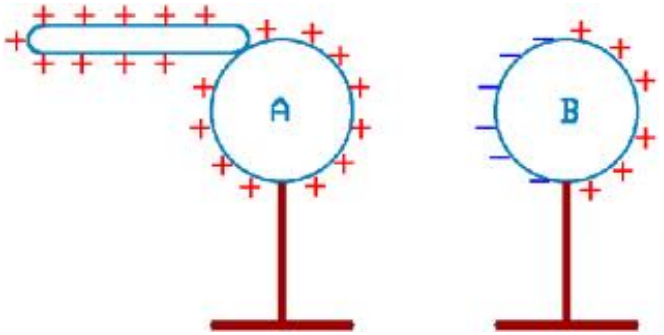
the photoelectric effect

Nikola Tesla discovered in 1901 that when a metal was illuminated by high-freq light (e.g., ultraviolet light), electrons were ejected from the metal at high energy

This work was based on the previous knowledge that light incident upon metals produces a current, but Tesla was the first to describe it as a particle phenomenon.

Electrostatic Induction (capacitive coupling)

High-field Gradient or differential capacitance



Also known as the “Tesla Effect” can be described as electrical displacement or the passage of electrical energy through space other than the application of voltage potential