EXPERIMENTS, LONGITUDINAL MAGNETO DIELECTRIC, TRANSFERENCE, WIRELESS TRANSMISSION

Transference of Electric Power – Part 1

11TH NOVEMBER 2019

In this first part we will look at both video experiments and measurements to investigate and demonstrate the transference of electric power via the transmission medium of a single wire, and combined with and without multiple loads. The experiments are undertaken using the flat coils designed, measured, and tested in detail here. Part 1 of this topic is intended to experimentally introduce the transference of electric power, and the various properties, phenomena, and effects that can be measured within such an electrical system when excited using the vacuum tube generator as a feedback oscillator, details here.

A more detailed introduction to the principles of transference of electric power can be found here. The experimental work in this part is intended to investigate and demonstrate aspects of the following:

1. Tuning measurements using a vector network analyser to measure Z_{11}, the small signal ac input impedance for the experimental system, from the perspective of the generator.

2. Tuning the transmitter and receiver to different points to demonstrate different transference phenomena.

3. Single wire transmission and the longitudinal magneto-dielectric (LMD) mode.

4. Tuning to power a load within the single wire transmission line.

5. Tuning to power a load at the output of the receiver.

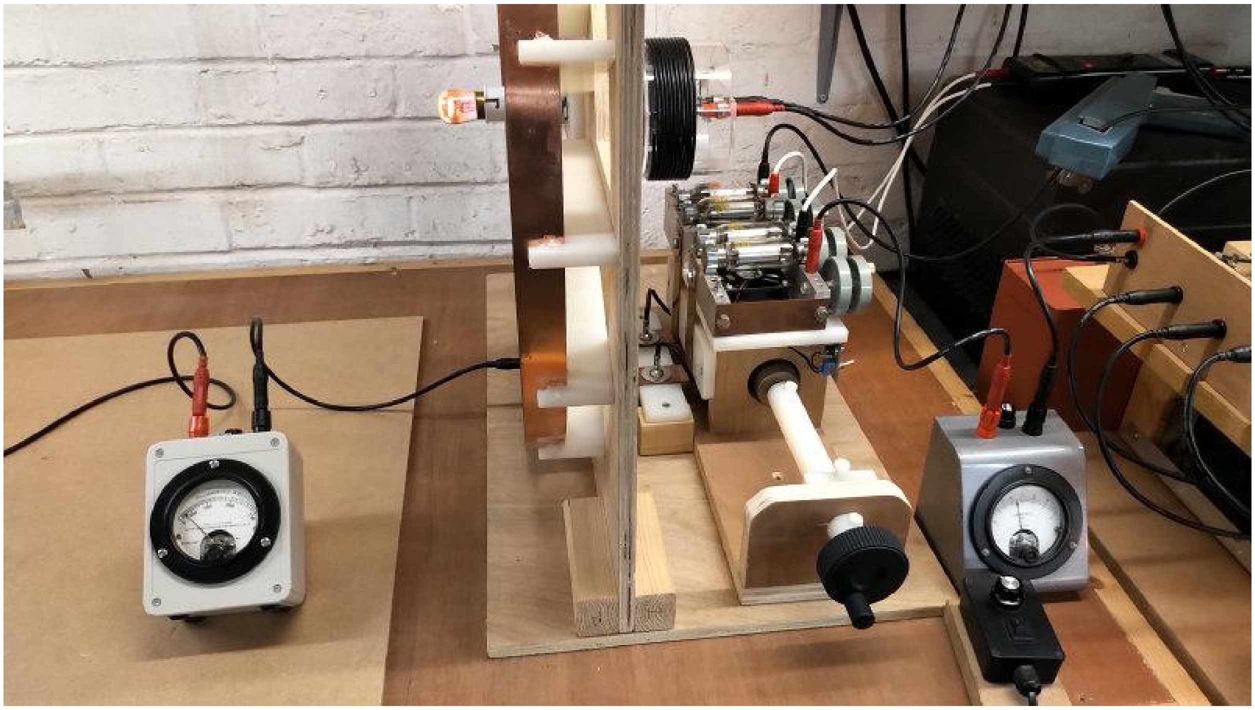
6. Tuning to establish the LMD mode of transmission between the transmitter and the receiver.

7. Tuning to establish the null point of the LMD mode within the single wire load.

8. Tesla's wireless transmission of electric power in the near field, using a pair of tuned Tesla magnifying transformers (TMT).

9. Transference of electric power between the transmitter and receiver in the near field.

Figures 1 below show an overview of the experimental arrangement which consists of two flat coils used as transmitter and receiver and joined via the base of the secondary coils by a single wire transmission line with an inline 100W four incandescent lamp load, (4 x 25W 240V pygmy lamps). The transmitter primary is connected to the 811A vacuum tube generator via a matching unit which in this case consists of only a 1200pF vacuum variable capacitor in parallel with the 2 turn copper strap primary. The receiver primary is tuned by another parallel connected 1000pF vacuum variable capacitor which in turn is connected to another 100W four incandescent lamp load. The outer end terminal of the receiver primary is connected directly to RF ground via a low inductance ground strap. The secondary coils of the transmitter and receiver are positioned facing each other on axis 1.5m apart, and are counter-wound to each other in order to produce a balanced and reciprocal cavity arrangement.

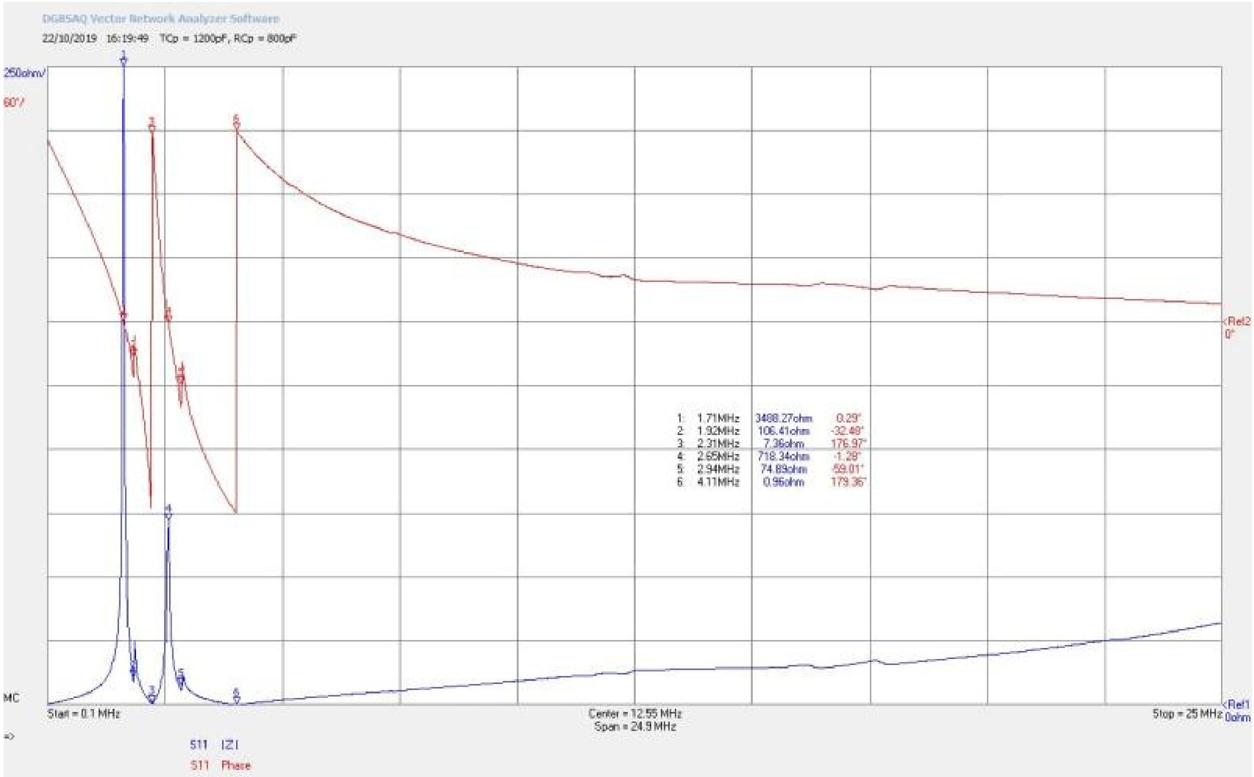


The 811A vacuum tube generator is used in this experiment as a tuned plate class-C Armstrong oscillator which derives automatic feedback from a pick-up coil placed close to the secondary coil of the transmitter, and can be clearly seen on the back of the transmitter in figures 1.4-1.6. The advantage of using a self-tuned oscillator as the generator for this experiment is that complete tuning of the system can be easily accomplished simply by adjusting C_{PT}, the primary capacitance of the transmitter, (and for fine tuning C_{PR} the primary capacitance of the receiver). As C_{PT} is adjusted over its range the generator tracks the tuning changes in the overall system allowing very precise and optimum frequency tracking through the various resonant bands of the system.

The dis-advantage of self-tuning the generator in this way, is in the regions where there is very little coupling between the primary and secondary of the transmitter coil, (far from the resonant regions), there is insufficient feedback to the vacuum tubes and oscillation can be unstable or non-existent. To explore these low coupling regions a fixed frequency excited linear amplifier would be the preferred choice, which will be covered in another part. For this part in exploring the transference of electric power via transmission between a transmitter and receiver coil via a single wire transmission line, we are most interested in the resonant regions of the system where the self-tuned oscillator allows for convenient and accurate tracking within these bands.

The first video introduces the experimental setup, instrumentation, and readings, and then looks in detail at the Z_{11} small signal impedance characteristics for a range of different tuning conditions for both the transmitter and receiver coils, combined with a single wire transmission medium, and both with and without multiple incandescent lamp loads.

Figures 2 below show the detailed Z_{11} impedance measurements that were presented in the first video, and will be referred to in the consideration of the experimental results after the second video.



The second video demonstrates interesting phenomena and effects relating to the transference of electric power from the vacuum tube generator to the transmitter, and then via the single wire transmission medium through to the receiver coil, and to finally the load at the output of the receiver. Various different modes of transmission are considered which are established by different tuning points of the experiment.

There have been a range of different interpretations as to the nature of wireless transmission of power from a resonant transmitter to a resonant receiver, through the surrounding medium, proposed as early as the late nineteen century by Maxwell[1], Tesla[2,3], Steinmetz[4] and much later by others such as Dollard et al.[5,6,7], Tucker et al. [8], and Leyh et al.[9]. Different sources have suggested different mechanisms for the transfer of power between transmitter and receiver, including the Longitudinal Magento-Dielectric mode, Multiple order magnetic field coupling, and Electric field coupling.

In my research into the transference of electric power so far, I have found most validity in both conceptual and experimental terms from wireless transmission at distances greater than that which can be attributed through near-field induction, (the conventional transformer effect), through the principle of the Longitudinal Magneto-Dielectric (LMD) mode. In my consideration of the results of the experiments presented in this post, I find the LMD principle to most closely account for the observed phenomena and properties surrounding the transfer of electric power through a near-field TMT arrangement.

I consider the experiments presented in this post to be transmission in the near-field, rather than what might ordinarily be considered by conventional antenna theory the mid-range, where the distance between the transmitter and receiver is more than 2-3 times the diameter of the coils, (antenna aperture). In this case the central tuned resonance of the TMT system is ~2Mc/s, which corresponds to a free-space wavelength of ~150m. Since the coils are connected by a single wire transmission line, and are spaced 1.5m apart, I very much consider this scenario to be near-field transmission since the receiver coil is very much less than a wavelength from the source.

The transfer of electric power in this scenario is as a result of the specific modes formed by the electric and magnetic fields of induction, and hence the transfer of power is “inducted” or “extended”, rather than propagated as would be the case for a transmitting antenna. In subsequent posts I will be presenting experiments on the telluric transfer of electric power where the wireless transmission distances are in the far-field, and are very much greater than the wavelength of the fundamental resonant frequency of the TMT system. Despite the near-field arrangement the transfer of electric power in this system is not via the conventional magnetic coupling of the “transformer effect”.

This was confirmed by removing the single wire transmission and simply terminating both bottom-ends of the secondary coils with a short wire extension, in order to lower the impedance at this end and ensure λ/4 resonation. In this condition, and when tuned over the full available frequency range, no transmission of power took place between the transmitter and receiver coils, even when both were tuned to the same resonant frequency at either the upper or lower frequency. If the conventional transformer effect occurred in the near-field then some detectable power would have been transferred between the generator and receiver load. This clearly shows that transference of electric power in this TMT experimental arrangement requires the transmission of the electric and magnetic fields of induction via a lower impedance path through the transmission medium, (in this case the single wire connection). When both of the short secondary extension wires were then subsequently connected to earth, (either independent dedicated rf grounds, or earth points from the utility supply), power was again transferred between the source and load at the correct tuning.

It is conjectured here that transference of electric power, at the correct point of tuning in this experiment, occurs through establishing the LMD mode of transmission as a standing wave between the transmitter and receiver coils, where a cavity is formed between the top-loads of the two secondary coils. In successive cycles of the generator oscillations electrical energy is coupled from the generator into the cavity. The pressure of the wavefront in the longitudinal mode moves backwards and forwards as it traverses the cavity from the transmitter to the receiver, reflected from the top load of the receiver and back again towards the transmitter where it is amplified or suppressed by coupling from subsequent cycles from the generator. Whether the longitudinal wavefront is amplified or suppressed depends on the tuning of the experiment and hence the longitudinal wavelength in the cavity.

At the correct point of tuning the amplitude of the wavefront is reinforced by successive cycles from the generator. The magnitude of this longitudinal wavefront reaches an equilibrium in the cavity based on the impedance characteristics of the cavity medium, its tuning, and dissipation of the stored power to both the transmission medium, and to the surrounding environment. The longitudinal wavelength within the medium is longer than that of the generator excitations, which represents a lower frequency of oscillation for the longitudinal mode. This puts the electric and magnetic fields of induction at different phase relationships throughout the length of the cavity, a property of the longitudinal mode that can measured in the cavity region, and is presented in the consideration of the experimental results below.

At the correct point of tuning the di-electric and magnetic fields of induction in the LMD mode form a standing wave in the cavity which results from the longitudinal wavelength, where the boundaries of the cavity are defined by the high impedance, high potential, points at the top-loads of the coils, and one or more null points form inside the cavity. At the fundamental frequency of the LMD mode, (not the same frequency as the fundamental resonance of the secondary coils or the generator oscillations), only a single null will exist in the centre of the cavity, and when the coils are closely spaced in the near-field. At higher order harmonics, and dependent on spacing between the coils multiple null points can form.

Each of the key experimental parts is now considered in more detail, and where appropriate based on the conjecture made above regarding the LMD mode of transmission:

Single wire transmission and the LMD mode

A key feature of the presented experiments in the transference of electric power between the transmitter and receiver is that power is transferred via a single wire which in itself is an unsusual method of transfer within standard electric circuit theory and experiment.

In a standard closed electric circuit current is continuous throughout the circuit with the voltage potential around the circuit dependent on the impedance of the elements and/or transmission lines that make up the circuit topology. The underlying premise is that a circuit has a forward and return path where the impedance is sufficiently low to allow for a “flow” of current from the source around the circuit, and returning to the source. Power is dissipated in the various impedances that make up the circuit according to their characteristics and the voltage and current phase relationship of the overall impedance of the circuit.

Ordinarily introducing a very high impedance, (in principle an infinite open-circuit), will reduce the current in the circuit to such a low-level, and in principle to zero, so that no current can flow around the circuit from and returning to the source, and hence no power is dissipated in that circuit. Even in an rf transmission line the normal transverse mode of transmission assumes a voltage and current distribution long the transmission line based on its distributed impedance, and its matching to the source and load terminations, where the transmission line is based on a closed circuit formed between the source and load in two or more conductive mediums between the source and load.

As can be seen in the videos the four incandescent load can be fully lit where no obvious closed circuit exists. The load is not connected between the outputs of the secondary (topload and base of the secondary), but is rather only connected via the base of a secondary. The other side of the load is left as open-circuit with a short trailing wire. Once again a cavity is formed between the top-load of the transmitter secondary and the open-circuit of the trailing wire, which would enable the LMD mode to establish. The electric and magnetic fields of induction are both present around the boundaries of the single wire, and a longitudinal wavefront is established at the longitudinal frequency in the cavity. At the upper and lower resonant frequency of the secondary energy is coupled from the generator into the cavity, and the longitudinal mode is established along the length of the cavity.

A higher impedance load placed within the electrical cavity at resonance will dissipate power in a transverse mode from the established wavefront when the electric and magnetic fields of induction local to the load are in phase. That is, the induced voltage across the load, and the induced current in the load, are predominantly in phase in the region of the load. In this case energy can then be transferred (induced) from the longitudinal wavefront to the transverse mode, and power will be dissipated in the lamp as both light and heat with a warm yellow colour temperature, as can be seen in the video. Placing the load right at the end of the wire will not light the incandescent lamp at the termination of the cavity, where the voltage and currents induced in the wire are 90° out of phase at the open-circuit termination.

Figures 3 below shows the phase relationship between the voltage and current oscillations of the generator in the primary, and the phase relationship between the voltage and the current at three different points in the single wire section of the cavity. It is conjectured that the changing phase relationship between the induced voltage and currents along the single wire is characteristic of the longitudinal mode established in the cavity, and results in unusual electrical phenomena and characteristics that are measured in TMT experimental systems.

In each figure the traces are as follows:,

Yellow – The voltage across the transmitter primary.

Green – The current through the transmitter primary, calibrated 1A/div.

Cyan – The voltage measured at centre of the single wire transmission line.

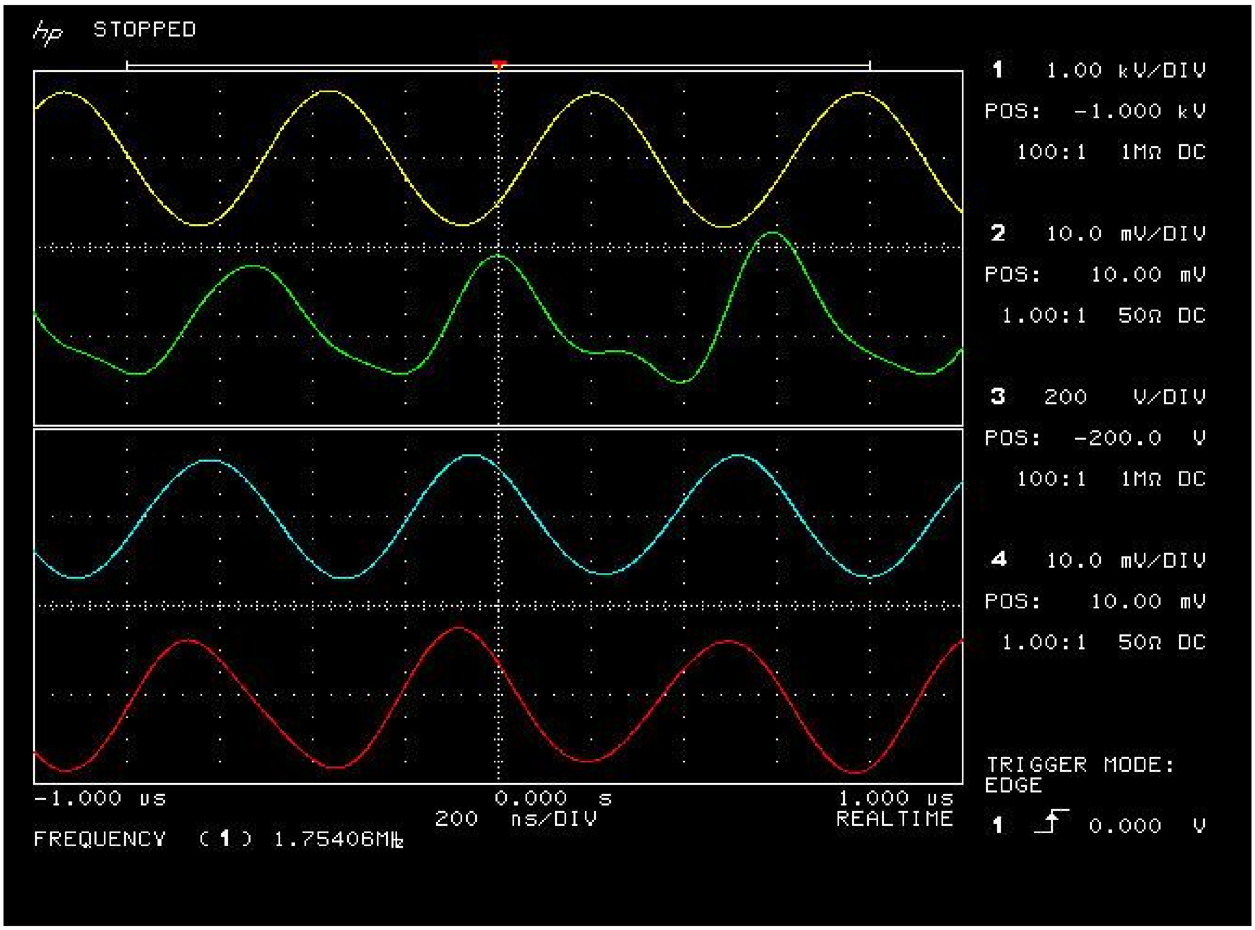
Red – The current measured through the single wire transmission line, calibrated 1A/div.

Each frequency 1.75, 1.94, and 3.32 Mc/s are measured at three different points in the single wire section of the cavity:

SWC1 – At the bottom-end of the transmitter secondary.

SWC2 – In the middle of the single wire.

SWC3 – At the bottom-end of the receiver secondary.



It is important to note from these measurements the varying change in phase relationship between the voltage and current at the transmitter, centre, and receiver ends of the single wire, (cyan and red trace), for tuned power in the receiver load, figures 3.4, 3.5, and 3.6. It is conjectured that this varying phase change across the single wire length between the voltage and the current, (~1.94Mc/s), which is hardly present when not correctly tuned for the transference of electric power (~1.75Mc/s and 3.32Mc/s), is indicative of a standing wave resonance of the LMD mode in the cavity, a cavity which has been formed by two coils that are matched at resonance in the TEM mode, and joined by a transmission medium. It is the combination of matched resonance in the TEM mode at the coils, and a tuned standing wave of the LMD mode that leads to the transference of electric power with very low loss between the generator and the final receiver load.

<u>Tuning to power a load within the single wire transmission line</u>

This experimental point is shown in figures 1.1 and figures 2.4, 2.7-2.9. Interestingly this condition is little different to the open-circuit terminated single wire case discussed above. However, now both transmitter and receiver are connected together via the single wire transmission line which also contains an incandescent lamp load. The single wire lamps could be tuned to light fully at either the lower or upper resonant frequencies of the combined secondary coils, with no or very little power dissipated in the final load at the receiver primary.

Once again a cavity is formed between the two top-loads of the transmitter and receiver secondaries, and through the single wire transmission line, the LMD mode is present, and there is a varying phase relationship between the voltage and current measured in the single wire. The mis-match in tuning between the transmitter and receiver means that, whilst the LMD mode is always present, it is not tuned to form a standing wave in the cavity. There are no detectable null points along the single wire and the neon lamp at the top-load of the receiver is not lit, showing that there is no high-potential at the top-end of the receiver coil. In this case the TMT transmission system is not tuned between the transmitter and receiver and so no power is being coupled through the receiver coil to its load. The system appears almost identical to the open-circuit single wire case above.

Energy is being coupled at the secondary resonant frequency from the generator into the transmitter secondary in the transverse mode, and the mis-match in tuning between the high-Q transmitter and receiver means that energy is not reaching the receiver coil but rather being consumed in the load in the single wire. This is further demonstrated in the video when the receiver secondary is unplugged from the single wire the lamps of the load in the single wire stay lit, they do change intensity slightly as the tuning changes, but can be returned back to full brightness by slight adjustment at the transmitter primary capacitor.

In summary, the transference of electric power from the generator to the single wire load occurs at the lower or upper resonant frequency of the transmitter coil, and is largely independent of the mis-matched termination at the other end of the single wire, whether that be a simple open-circuit, or short-circuit to ground, or another mis-matched resonant circuit such as a TMT receiver.

<u>Tuning to power a load at the output of the receiver</u>

This experimental point is shown in figures 1.2 and figures 2.5, and 2.6. With careful tuning there is a very narrow band, as seen on the video, where the high-Q TMT transmitter and receiver are tuned very accurately to one another, and power can be transferred directly between the transmitter and receiver via the single wire transmission, and with very little power dissipated in the single wire or its load. In this experimental setup the tuned frequency at the generator is between ~1.92 – 2.05 Mc/s to demonstrate the transference of electric power between generator and final load.

In this scenario the LMD mode is tuned in the cavity to form a standing wave, a null point is present at the centre of the path length of the cavity, which in this experiment where the single wire load was placed. Both top-loads are at maximum potential indicating that the cavity is in the fundamental resonant frequency of the LMD mode, that is $n\lambda_{LMD}/2$, where n=1 and there is a high potential point at the transmitter top-load, a zero potential null point in the single wire, (at the single wire load), and a high potential point at the receiver top-load.

Overall this is now the special condition where firstly, the transverse electromagnetic mode (TEM) is matched independently for both the transmitter and receiver coils, so they are both able to couple maximum energy, the transmitter from the generator, and the receiver to its load, at the same resonant frequency. This is secondly combined with the LMD mode formed in the secondary coil of the transmitter TMT, and tuned within the cavity of the single wire transmission medium to form a standing wave, where in its fundamental mode a single null point exists in the centre of the single wire transmission medium. The combination of the TEM and LMD modes both correctly tuned, leads to an inter-dependent balanced condition within the electrical system, where transference of electric power between the generator and load can occur with minimal loss.

In principle, transmission in this mode could cover great distances where an LMD standing wave is established in a transmission cavity where there are many null points along the single medium of the conductor, whether that be a wire, the earth, or other lower impedance or resonant medium. Again in principle with the correct setup of the TEM and LMD modes in the complete system very little power need be lost in the transmission medium, which can be tuned correctly by detecting the null points in the medium, and the varying phase relationship of the measured voltages and currents in the medium, which appears at this stage to be an indication of the LMD mode.

Summary of the results and conclusions so far:

1. In consideration of the experimental results presented and phenomena observed, it is conjectured that the LMD mode is established in a resonating coil when a cavity is formed between the top-load of the coil, in this case an open-circuit with a neon indicator bulb, and the outer boundary point of the circuit connected to the bottom-end of the coil. The LMD mode enables transmission of the electric and magnetic fields of induction together around the boundary of the single transmission medium, in this case around the outside of the single wire. The magnetic and di-electric fields of the LMD mode are in the same plane of travel and hence constitute a longitudinal pressure wavefront that traverses the cavity reflecting from the high impedance boundaries at each end and establishing an LMD wave with wavelength distinct from the transverse resonant wavelength of the transmitter and receiver secondary coils.

2. When the LMD mode is not established as a standing wave within the cavity of the single transmission medium the energy coupled from the generator into the transmitter coil by transverse induction is consumed by a higher impedance load in the single transmission medium, or with inadequate load in the transmission medium will be discharged to the surrounding environment through streamers at the high potential top-load.

3. When an LMD standing wave is established in the cavity, and the high-Q transmitter and receiver coils are both resonating in equilibrium with each other in the very narrow matched band (~1.92Mc/s – 2.05Mc/s) power is transferred directly from the generator to the final load at the receiver, with very little energy consumed in the single transmission medium

4. An LMD standing wave can be established in a cavity that is geometrically and electrically reciprocal at each end, e.g. with an identical TMT transmitter and receiver designed to resonate at the same transverse frequency, which causes the longitudinal pressure wave to be reflected from each end of the cavity.

5. Where the wavelength of the LMD mode is a whole number of half-wavelengths $n\lambda_{LMD}/2$, amplification of the LMD mode will occur in the transmitter until a dynamic equilibrium is established within the electrical system and with the surrounding medium. In this case the null point/s of the standing wave can be measured in the single transmission medium, and tuned carefully either side of this point will show the null point to move towards either end of the single transmission medium, before collapse of the standing wave at the coil boundaries.

6. The LMD standing wave mode could be indicated by a varying phase change between the voltage and current waveforms measured along the length of the transmission medium. It is conjectured that this phase change is preliminary evidence of the amplified longitudinal mode established in the cavity.

7. The combination of the TEM and LMD modes both correctly tuned, leads to an inter-dependent balanced condition within the electrical system, where transference of electric power between the generator and load can occur with minimal loss.

The preliminary results for the transference of electric power in the near-field indicate that considerable more study is required on the various transmission modes present in the TMT system, and particularly a more detailed measurement and study of the phase relationships of the electric and magnetic fields of induction in the transmission medium, and the difference in the resonant wavelengths of the transverse and the longitudinal modes. These two modes appear to interact constructively and in an inter-dependent way when tuned for the optimal transference of electric power between the generator and the receiver load.

Click here to continue to part 2 on the transference of electric power, where the experiment is powered by a spark gap generator, and the differences explored and contrasted to the results obtained here with a single frequency feedback oscillator.

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EXPERIMENTS, LONGITUDINAL MAGNETO DIELECTRIC, TESLA, TRANSFERENCE, WIRELESS TRANSMISSION

Transference of Electric Power – Part 2

6TH JANUARY 2020

In this second part on the transference of electric power we take a look at the differences that arise when a spark gap generator (SGG) is used as the power source for the experiment rather than a single frequency oscillator as used in part 1. It is recommended to study part 1 before this second part, in order to gain an underlying understanding of the overall experiment, phenomena, results, and suggested interpretation of the experimental results, that are characteristic to the practical investigations in the transference of electric power.

Unlike a single frequency oscillator or linear amplifier generator, a spark gap generator produces a very broad range of frequencies which result from the abrupt and impulse-like discharge that occurs at the spark gap. Frequencies generated by such a spark gap discharge, range from the very low in the 10s of Hz, all the way up to 100s of MHz, and beyond into GHz frequencies. With such a wide frequency band the stored energy available in the tank capacitors, which are charged at each half-cycle of the HV supply, is distributed across this wide band leading to two significant factors. Firstly that considerably less energy is available from the source at the resonant frequency of the transmitter coil, and secondly, tuning of the TMT transmission system has considerably less effect on the transference of electric power between the generator source and the receiver load.

The experimental work in this part is intended to investigate and demonstrate aspects of the following:

1. Tuning measurements using a vector network analyser to measure Z_{11}, the small signal ac input impedance for the experimental system, from the perspective of the spark gap generator.

2. Tuning indifference when powering a load either in the single wire transmission line or at the output of the receiver.

3. Reduced power available in the single wire transmission line.

4. Reduced power available in the receiver load.

5. Tesla radiant energy and matter phenomena.

6. Transference of electric power between the transmitter and receiver in the near field.

Figures 1 below show an overview of the experimental arrangement which consists of two flat coils used as transmitter and receiver and joined via the base of the secondary coils by a single wire transmission line with an inline 60W four incandescent lamp load, (4 x 15W 240V pygmy lamps). The transmitter primary is connected to the Spark Gap Generator via a matching unit which consists of two compound series tank capacitors, shunted 4 x 1B22 hydrogen-argon spark gap modulator tubes, and a 1200pF vacuum variable capacitor in parallel with the 2 turn copper strap primary.

The receiver primary is tuned by another parallel connected 1000pF vacuum variable capacitor which in turn is connected to a 50W two incandescent lamp load. The outer end terminal of the receiver primary is connected directly to RF ground via a low inductance ground strap. As in part 1 the secondary coils of the transmitter and receiver are positioned facing each other on axis 1.5m apart, and are counter-wound to each other in order to produce a balanced and reciprocal cavity arrangement.

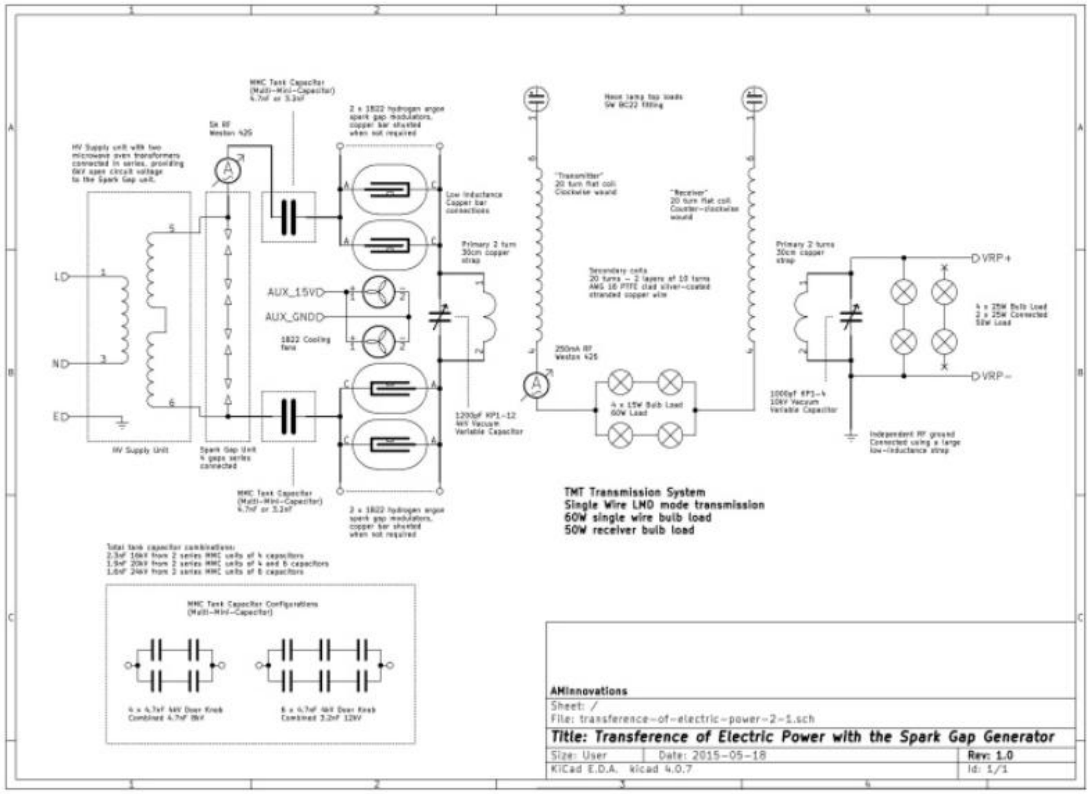


Figure 2 below show the schematic for the transference of electric power experiment powered by the SGG. The high-resolution version can be viewed by clicking here.

The principle of operation and matching requirements are somewhat different between the vacuum tube generator (VTG) and the SGG. In the VTG maximum power transfer between the generator and primary is accomplished when the impedance of the primary resonant circuit is equal to the combined vacuum tube internal impedance, when oscillating at the designed and configured operating point, (class C amplifier), for the tuned primary frequency, and run in CW (continuous wave) mode. In this case the primary circuit is not arranged to resonate at the same frequency as the secondary, where oscillating primary currents would be far too large and lead to destruction of the vacuum tubes. Rather the correct impedance match between the primary and tube oscillator facilitates maximum transfer of power from the non-resonant tube tank circuit to the tuned primary circuit, whilst keeping vacuum tube power dissipation under the maximum combined rating for the tubes.

In the SGG case it is in principle optimal to arrange the resonant frequencies of the primary tank circuit, and the secondary coil to be the same. In this case bursts of very large and maximal oscillating currents are generated in the primary tank circuit, which in turn result in strong magnetic coupling to the secondary circuit, and hence maximum power transfer between the resonant primary tank, and the secondary resonant coil. In practice matched primary tank and secondary coil resonant frequencies cause considerable operating issues when running, as the very high oscillating currents, in the high-Q low impedance primary, result in a very aggressive, unstable, and erratic spark discharge. The de-tuning of the circuit, by deliberate mis-match of the primary tank circuit resonant frequency and the secondary resonant frequency, reduces the Q considerably of the primary, reduces slightly the coupling between the primary and the secondary, whilst considerably stabilising the spark gap discharge to be suitable for experiments in the transference of electric power through a high-Q TMT transmission system.

In the case where a Tesla coil is being used for maximum streamer discharge, it is accepted as best practice to match the primary tank resonant frequency as close as possible to the secondary coil resonant frequency. Here maximum energy is coupled into the secondary and dissipated through the top-load accumulator. In this case the primary frequency is usually de-tuned slightly below the secondary frequency to maximise power transfer during streamer discharge, which leads to very white-hot powerful discharges. For example for a coil arranged to resonate with suitable top-load at 1.7Mc/s the primary resonant tank circuit would be tuned to resonate between ~ 1.5-1.6Mc/s, (~10% lower to compensate for secondary frequency drop on discharge). This case requires a very powerful and robust spark gap that will operate very aggressively, unstably, and producing large amounts of heat, light and noise.

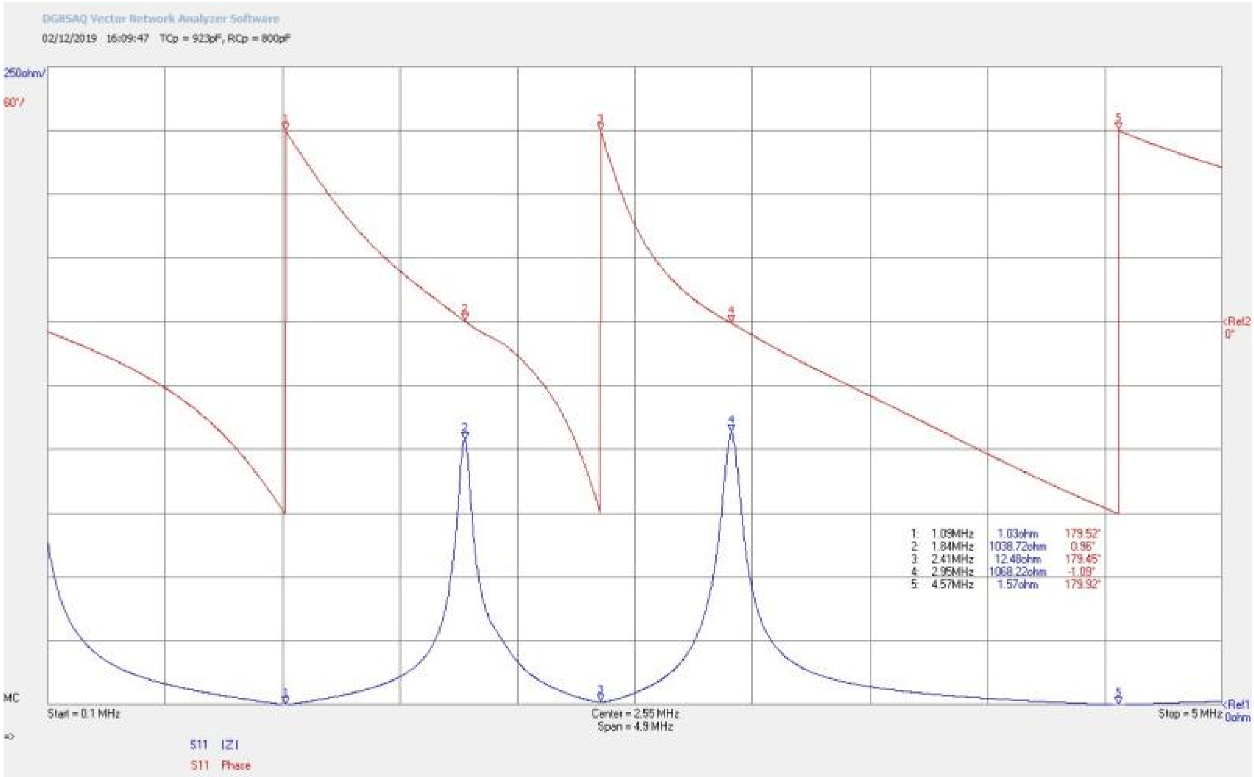
In the case for a TMT transmission system using two or more Tesla coils matched and tuned together in a high-Q narrow bandwidth arrangement, and connected with a single wire and operated in a balanced LMD transmission mode, the primary resonant tank frequency is optimally arranged to be lower in frequency than the secondary resonant coil frequency. In this case there is only a small measured difference in total power being transferred from the generator to the final receiver load as a result of the deliberate primary resonant tank and secondary coil resonant frequency mis-match. For example for a coil arranged to free resonate into a single wire transmission line at 1.7Mc/s the primary resonant tank circuit would be tuned to resonate between ~ 1.0-1.3Mc/s.

The 1B22 hydrogen-argon spark gap tubes were shunted out of the circuit for experiments in the transference of electric power to the receiver load, as their higher internal resistance reduces the primary currents, causing a reduction in the total transmitted power. The shunts are made from copper sheet which remove the tubes from the circuit without increasing the inductance of the primary tank circuit. In experiments relating to Tesla's radiant energy and matter it is possible to obtain improved results, (amplified phenomena), when the 1B22 tubes are included in the circuit. It is conjectured that the slight dioding action[1,2] as a result of the ionizing radioactive (Radium Ra-226) trigger element, and the improved pulse response of the primary tank circuit, improves the uni-directional energy supply from the tank circuit to the TMT system. This improved uni-directional energy supply increases the intensity of the LMD mode wavefront in the single wire cavity, amplifying radiant energy and matter phenomena.

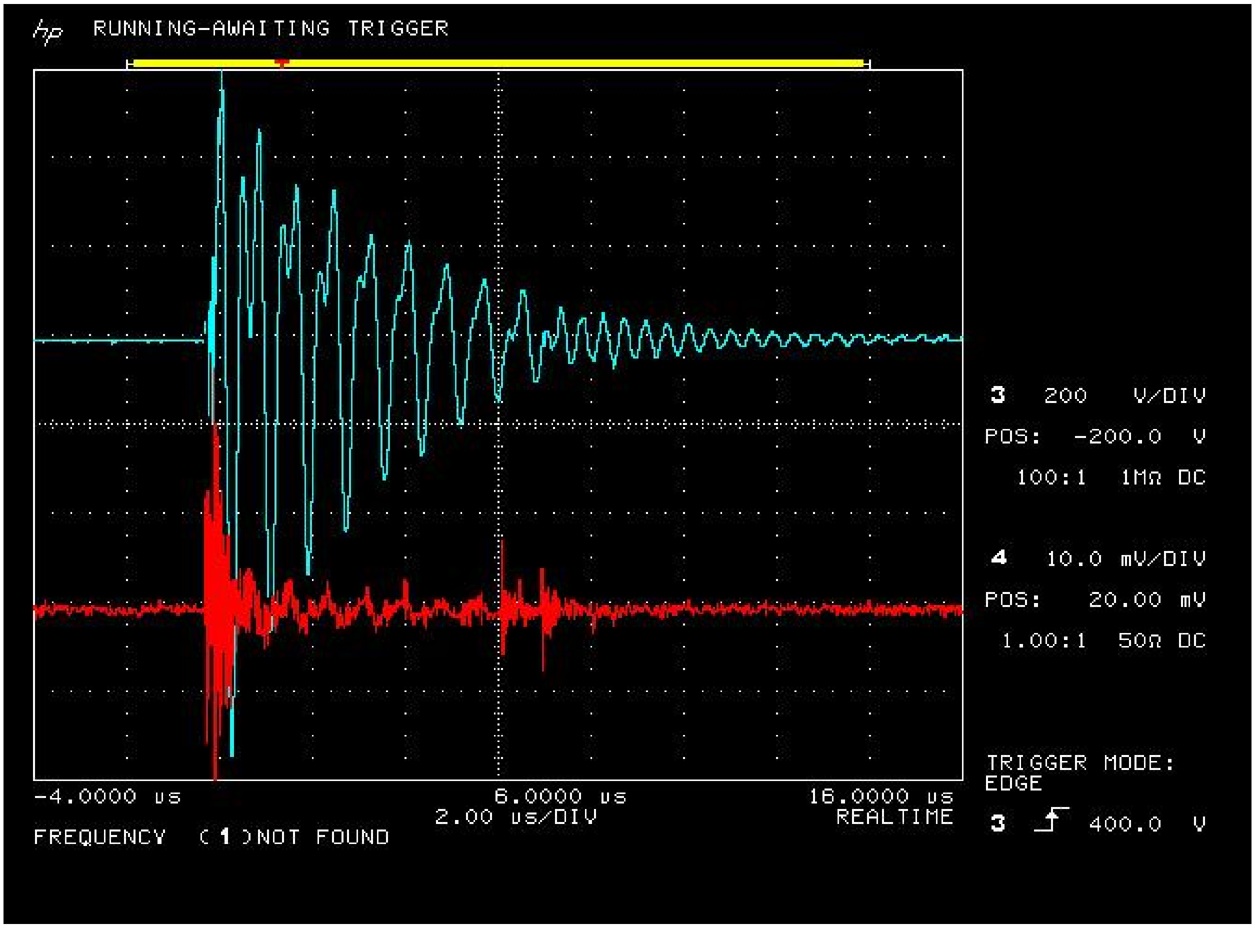
A correctly triggered and functioning 1B22 will emit a dark purple spark discharge within the aluminium can of the cathode terminal, which is quickly quenched by the rarefied hydrogen-argon gas mix. A defective 1B22 with a leak to air will still work as a spark gap but will generate a brighter green-yellow discharge as aluminium is combusted from the cathode surface. The discharge sustains for longer causing considerable burning of the electrodes, and rapid over-heating causes distortion of the glass tube, with finally destruction of the electrodes.

The following video introduces the experimental setup, instrumentation, and readings, and looks in detail at Z_{11} the small signal impedance characteristics of the experiment from the perspective of the spark gap generator. It concludes with a range of experiments in the transference of electric power using a spark gap generator, combined with a preliminary introduction to Tesla's radiant energy and matter experiments.

Figures 3 below show the detailed Z_{11} impedance measurements that were presented in the video, and will be referred to in the consideration of the experimental results.



Figures 4 below show the oscillating voltages and currents in the primary transmitter tank circuit, and also those measured at the single wire load. In both the green and red traces the current amplifier is calibrated at 50A/div, showing the large oscillating currents that occur in the primary, and those transferred to the burst in the secondary.



The principle of operation of the transmitter coil primary tank circuit is explained in detail in the post Spark Gap Generator – Part 2. In fig. 4.2 the current (red) in the single wire medium has become far more impulse-like in nature, rather than the oscillating sinusoidal established in the primary coil ring-down as the tank capacitors discharge in the series resonant tank circuit. It is conjectured that these impulse-like currents may be indicative of the burst wavefront constituting the LMD mode, within the cavity formed between the transmitter and receiver coil top-loads. It may also indicate more clearly why it is possible to observe radiant energy and matter phenomena more easily in a SGG driven TMT system, compared to a VTG or linear amplifier driven TMT system. That is, the nature of the burst currents generated in the primary resonant tank circuit by the SGG generator lend themselves more readily, when induced into the secondary cavity, to the LMD mode in the form of impulse-like, uni-directional bursts. These more uni-directional bursts in turn lead to an intensified wavefront in the cavity and the clearer observation of Tesla's radiant energy and matter phenomena. This experimental area will be explored in much more detail in subsequent posts, but for now serves as an empirical introduction to these fascinating phenomena.

Fig. 4.1. shows the oscillating voltage and currents generated by the SGG in the primary resonant tank circuit. The oscillating currents (green) are a product of the stored energy in the tank capacitors repeatedly transferred backwards and forwards between the tank capacitors and the inductance of the primary coil. As the stored energy is consumed by transfer to the secondary circuit, and by dissipation as heat, light, and noise in the spark gap, and the series resistances of the primary tank circuit, the envelope of the primary current decays until all stored energy in the current cycle is expended. The oscillating nature of the current when transferred from the primary to the secondary tends to cause "dragging" or "smearing" of the LMD wavefront in the secondary cavity reducing the potency and impact of the pressurised wavefront.

In the most ideal case the wavefront would constitute a single pulse of very large amplitude and with very short pulse width, resembling as closely as possible a true impulse function. This pulse wavefront would traverse the cavity in a uni-directional manner with no reflections or dispersion leading to a singular and positive acting pressure wave with both the di-electric and magnetic fields of induction coherently in phase. In this ideal case the transfer of electric power could be 100% between transmitter and receiver, or if radiant energy phenomena are so arranged by a suitable load or emitter in the single wire transmission medium of the cavity, 100% wireless transfer of electric power could be arranged between many points. The intense radiant energy burst from the strong wavefront may also generate a wide range of unusual and hitherto unexplored electrical and matter phenomena, which may in turn also assist in the experimental exploration of the displacement of electric power, the hidden underlying coherent guiding principle of the undifferentiated electric and magnetic fields of induction.

This most ideal case requires that in the primary tank circuit all the energy stored in the tank capacitor per cycle is transferred to the secondary within the first half-cycle of the ring-down. This would create a single pulse from each cycle where all energy available in the tank circuit is transferred to the secondary, in effect driving the primary with a pulse generator. In order to do this it would be necessary to quench the spark gap after the first half-cycle of the discharge, and also ensure that the impedance of the primary circuit was sufficiently low that all the stored energy in the tank could be discharged in this first half-cycle. Both of these requirements present very challenging practical implementations, and will be explored in more detail in subsequent posts.

Tank circuit capacitance optimisation

In the current primary circuit the tank capacitance was adjusted in three different configurations in order to find the optimum operating point for the experiments in the transference of electric power powered by the SGG. The circuit diagram in figure 2 shows the arrangement of the tank capacitor in these three configurations:

1. 2.3nF 16kV from two series MMC units of four capacitors each. This is the tank capacity used in the video experiment and is very stable with only a very small reduction in the amount of power transferred to the receiver load. From figs. 3.3 and 3.4 the resonant frequency of the series primary tank at M_1 is 1.09Mc/s. Good stable operation could be established up to ~800W.

2. 1.9nF 20kV from two series MMC units of four and six capacitors respectively. This tank capacity increased slightly the amount of power transferred to the receiver load over configuration 1, but the unbalanced capacity either side of the primary coil, (4 cap. unit one side, 6 cap. unit the other side), was found to lead to more instability in the spark discharge including “popping” and material ejection at the electrodes at powers only up to 500W. The resonant frequency of the tank circuit in this configuration is ~ 1.2Mc/s

3. 1.6nF 24kV from two series MMC units of six capacitors each. This was found to be the lowest practical tank capacity when running at powers up to 1kW. Lower than this the spark gap became too aggressive and erratic for good accurate measurements and stability in the transference of electric power. The resonant frequency of the tank circuit in this configuration is ~ 1.3Mc/s

Overall, configuration 1 was selected for most experiments in the transference of electric power, providing the best balance between longer-term stable and reliable operation of the spark gap, and with acceptable energy transfer to the transmitter secondary coil.

The other feature of the tank circuit was to minimise the inductance of the connections and components. The optimum condition is for all the current in the tank circuit to contribute to generating a magnetic field only within the primary coil itself, which maximizes the magnetic field coupling to the secondary coil. In practise magnetic fields are also created around the inductance of the tank circuit connections and components, storing some of the available tank circuit energy, and reducing the magnetic field generated within the primary coil. The inductance of the tank circuit components is kept minimum by keeping connection wires short and made from large many stranded conductors, by using copper busbars, and solid aluminium or copper mounting blocks for larger components. In the circuit diagram of fig. 2 the low inductance parts of the tank circuit extend from the spark gap to the primary coil and are indicated by thicker connecting wires.

Tuning indifference when powering a load

One of the most notable differences between the experiments in part 1 and 2, is that power dissipated in the both the single wire load and the receiver load varies only slightly with large changes to the transmitter and receiver primary tuning capacitor. The transmitter tuning capacitor was varied over the range 20-1200pF which in figs. 3.1 and 3.2 shows very large changes to the frequency spectrum of the TMT system. However when powered from a properly adjusted spark gap generator the bulbs in the single wire transmission medium remain well-lit over much of the tuning range. This is in stark contrast to part 1 where power dissipated or transferred in the various loads were very dependent on the tuning condition of the transmitter and receiver, and to the matching conditions of the VTG to the primary of the transmitter.

In fig. 4.2 we see that currents in the single wire transmission medium are much more impulse-like and consist of many narrow pulse excitations and rapid bursts. The spectral content of this time-domain signal will be very wide with energy distributed over a very broad-bandwidth, and consistent with the properties of the spark gap stimulus in the primary circuit. With such a wide bandwidth of frequencies present at the single wire load we would expect the bulbs to be illuminated irrespective of the tuning in the transmitter primary. Many frequencies are being transferred from the primary to the secondary circuit which is characteristic and typical of the properties of this experiment when driven from a spark gap based generator.

Given the above as a broad comparison with the experiment in part 1, tuning around the upper and lower resonant frequencies of the flat coil transmitter causes a slight increase in brightness for the single wire load, showing that more energy is selectively coupled at these frequencies from the generator as would also be expected from part 1, and from the frequency characteristics measured in figs. 3.1-3.4.

Reduced power in the single wire load and receiver load

The spread of energy over a very wide bandwidth results in less energy being dissipated in both the single wire load and also in the receiver load, as compared the single frequency oscillator experiment in part 1.

1. In the case of the single wire load, the bulbs can still be lit to almost full brightness since all the power from all transferred frequencies is being dissipated in this load. The bulb brightness showing the average power dissipation over many bursts coming from the spark gap generator. At an input power of 300W to the HV supply it was possible to illuminate the single wire load to around two-thirds of its maximum rating, so ~45W. At 500W the load could be illuminated fully to ~60W.

2. In the case of the receiver load, much less power could be coupled into this load even when tuned correctly as a complete TMT system, as shown in figs. 3.3 and 3.4. The single wire load had to be first removed to prevent power dissipation at this load, and then the receiver load could be illuminated to maximum ~0.5 of its total power e.g. about 25W. From the wide-band of frequencies available in the single wire transmission medium only a very narrow range at the resonant frequency of the receiver flat coil are transferred from the single wire to the receiver load. It should however be noted that the receiver bulb loads where illuminated dimly over the entire tuning range of the transmitter primary and the receiver primary. This again shows that a little of that wide bandwidth of energy is coupled to the receiver irrespective of the tuning, again tuning indifference based on the spectral content of the source energy.

In this case the spark gap generator is far from optimal for the transference of electric power, where for the same input power as in part 1, less energy is transferred to the single wire load, and very much less energy can be transferred to the receiver load. This proves to be the case even when the TMT system is optimally tuned as shown in figs. 3.3 and 3.4, and by further comparison with the optimal tuning results in part 1 of this experiment.

Tesla radiant energy and matter phenomena

These phenomena form some of the most interesting and unusual aspects of this TMT experiment using a spark gap generator. Whilst these effects can also be observed in the same experiment using a single frequency oscillator, linear amplifier, or other oscillating source they are much reduced in intensity when compared with a spark gap generator, burst oscillator, pulse generator, or properly designed and operated impulse or displacement generator. The exploration of these phenomena in this experiment is only as an introduction to these effects, and properly requires a much more detailed experimentation and consideration, which will be presented in a subsequent post along with very much magnified phenomena results.

The preliminary phenomena observed in this experiment include:

1. Attracting metals to the surface of an incandescent bulb in the single wire cavity, where the bulb acts as an emitter of radiant energy.

2. Amplification or intensification of a radiant energy event by interaction with a living organism, (human hand).

3. Charging a capacitor with radiant energy by bringing it close to the emitting bulb.

4. Radiant matter pressure waves emanating from the emitting bulb and impacting on a living organism, (human hand).

It should be noted here that improving the uni-directional pulse nature of the generator system by, for example, including components such as 1B22 spark gap modulator tubes in the tank circuit, early magnetic quenching of the spark discharge, or other impulse/pulse/burst generation methods, considerably magnifies the observed phenomena. It is also important to note that these types of phenomena are best observed when a cavity has been established using a resonant transformer, such as a Tesla coil, and where a longitudinal pressure wavefront is established within the cavity, preferably in an LMD type mode, or ideally with direct displacement.

Summary of the results and conclusions so far:

The transference of electric power experiment using the tuned TMT flat coil system has produced considerably different results when powered using a spark gap generator, as compared with the single frequency feedback oscillator in part 1. The key differences and results include the following:

1. Tuning indifference occurs due to the wide spectral bandwidth of the energy transferred from the generator to the final receiver load, and impacting on all parts of the TMT transmission system between these points.

2. Considerably reduced levels of transferred electric power both to the single wire transmission medium load, and the receiver load, for the same nominal input power to the HV supply of 300W. Again this is attributed to the diffuse spectral energy content when a wide bandwidth generator is connected to a narrow bandwidth high-Q TMT transmission system.

3. Tank circuit tuning configurations have shown that a de-tuned primary and secondary resonant frequency in the transmitter primary leads to the best balance between transferred electric power, and stable, consistent, and long-term reliable operating conditions.

4. Radiant energy and matter phenomena have been observed in the experiment, and indicate components and optimizations, including different generator configurations, that will intensify and maximise these unusual observations.

5. Generator configurations and types that improve the impulse/pulse/burst nature of the transferred energy may intensify radiant energy phenomena by generating a more uni-directional pressure wavefront in longitudinal system, which may also provide additional insight into the preliminary investigations into the displacement of electric power.

The results for the transference of electric power in the near-field using a spark gap generator indicate that this form of generator is not well suited for energy transmission in the narrow bandwidth high-Q TMT system. A very large and robust spark gap generator would be required to transfer adequate power from generator to load, with considerable losses at the spark gap, huge electromagnetic interference to the surrounding medium, and invasive and unstable operating conditions. However this form of generator does appear to lend itself to phenomena that arise from the longitudinal pressure wavefront generated in the cavity of a resonant transformer, such as a Tesla coil. As such it is conjectured that this form of generator may be useful in the exploration of displacement, the hidden underlying coherent guiding principle of the undifferentiated electric and magnetic fields of induction.

Click here to continue to the next part, looking at High-Efficiency Transference of Electric Power.

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1. Dollard, E. & Lindemann, P. & Brown, T., *Tesla's Longitudinal Electricity*, Borderland Sciences Video, 1987.

2. Dollard, E. and Energetic Forum Members, Energetic Forum, 2008 onwards.

DISPLACEMENT, EXPERIMENTS, LONGITUDINAL MAGNETO DIELECTRIC, RADIANT ENERGY, SINGLE WIRE CURRENTS, TESLA

Tesla's Radiant Energy and Matter

31ST MARCH 2020

Some of the most fascinating areas of research into the inner workings of electricity, are those that display unusual and interesting phenomena, and especially those not easily understood and explained by mainstream science and electromagnetism. The field surrounding Tesla's radiant energy and matter, the apparatus, experiments, and wealth of unusual electrical, and even non-electrical related phenomena, is a particular case to note. This first post in a sequence serves as a practical and experimental introduction to this area, along with consideration and discussion of the observed phenomena, and possible interpretations as to their origin and cause.

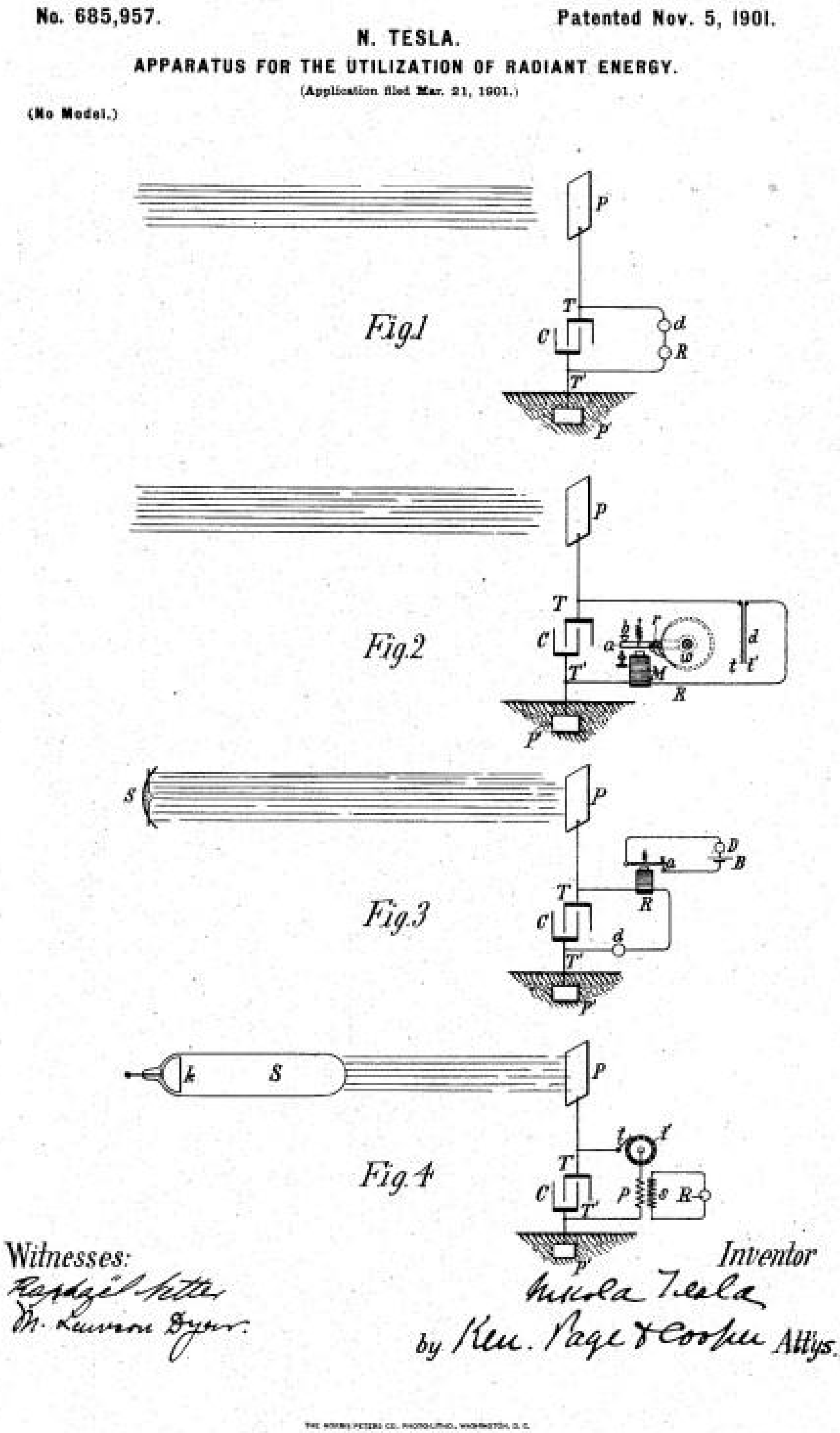
It is through working to understand these types of phenomena, often generated in high tension, unipolar, and non-linear electrical systems such as the Tesla coil and TMT transmission system, that the inner workings of electricity can be revealed little by little. That is to say, the outer workings of electromagnetism that account for almost all of those measurable electrical properties that constitute the transference of energy, and hence electric power, between source, load, and the intervening transmission medium, can be peeled back to show a more fundamental, coherent, and guiding mechanism.

This second inner level of electricity's mechanism and working I consider to be based on the principle of displacement, a coherent and dynamic state extending throughout the common medium, and where the electric and magnetic fields of induction are defined but as yet undifferentiated in their nature. These two undifferentiated facets we can only suppose originate from a yet deeper and hitherto unexplored level of inner workings, where the pressure applied by the one and only force of intent leads to the manifested universe, and all that is both known and unknown.

The differentiation of the electric and magnetic fields of induction lead to the outer manifestation of electricity as we commonly know it, transference, and all the electromagnetic properties and scientific measurements that accompany it, including, for example, the speed of light ***c*** in the vacuum, which only currently has a fixed and defined value based on the level it is measured and perceived at. At this outer level of transference, ***c*** is measured as a specific value based directly on the inter-action (propagation) of the differentiated electric and magnetic fields of induction. I conjecture that at the next inner level where these fields of induction are defined but not differentiated, that ***c*** has not only different measurable quantities, but also comes with qualities and properties that make it a multi-faceted vibration, rather than the simple linear measure of a fixed value.

It should be clear to the reader that in my interpretation of this field of research I see it as not enough to construct experiments, observe phenomena, measure quantities, and then try to fit this to a linear and physical way of thinking about the world, as is the case in mainstream science, and often even in the alternative approaches. I consider progress in this field of research to be a co-operation or union between high-quality science, and a more philosophical or esoteric understanding of the principles and processes of life. Only through new practical knowledge gained through this inclusive approach to life will it be possible to fully reveal, perceive, and utilise the inner workings of progressively deeper levels of electricity.

Such are my conjectures about the inner workings of electricity even at only the next inner level, that as of yet is an unknown mystery to both mainstream science, and the alternative electricity researcher alike. It is for this reason that I find experiments surrounding Tesla’s radiant energy and matter, and associated phenomena, so fascinating, exciting, and awe-inspiring, as they provide an opportunity to progressively take a look “under the hood” at the world of displacement, a hidden world yet to be discovered. A world much more vast in its import and effect than that which we currently observe, understand, and utilise.



In Tesla's[1] original patent of 1901, No. [685957](), he describes his understanding of radiant energy gained from experimentation and observation, and suitable apparatus for utilising this radiant energy:

"My own experiments and observations, however, lead me to conclusions more in accord with the theory heretofore advanced by me that sources of such radiant energy throw off with great velocity minute particles of

matter which are strongly electrified, and therefore capable of charging an electrical conductor, or, even if not so, may at any rate discharge an electrified conductor either by carrying off bodily its charge or otherwise."

"When rays or radiations of the above kind are permitted to fall upon an insulated conducting body connected to one of the terminals of a condenser, while the other terminal of the same is made by independent means to receive or to carry away electricity, a current flows into the condenser so long as the insulated body is exposed to the rays, and under the conditions hereinafter specified an indefinite accumulation of electrical energy in the condenser takes place. This energy after a suitable time interval, during which the rays are allowed to act, may manifest itself in a powerful discharge, which may be utilized for the operation or control of mechanical or electrical devices or rendered useful in many other ways."

It is clear from Tesla's own description that he saw radiant energy as a ray or beam-like emanation, that is capable of transferring energy between the emanating source, and a suitably arranged receiver. Under these conditions an electric current could be established when the radiant energy is accumulated in a capacitor and connected to an electric load.

Tesla also states that a suitable time interval is required to allow the rays to generate an action upon the receiver. Tesla conjectures that radiant energy causes minute particle to be thrown of at great velocity, both making a link between radiant energy and matter, and implying that a force can be exerted not only electrically but also physically on a distant body.

In my own experiments into radiant energy I have observed similar phenomena to those described by Tesla including, charging of capacitors from longitudinal wavefronts generated in the single wire cavity of a TMT system, electrical and physical forces exerted on conductors, insulators, and biological specimens placed in proximity to a source of radiant energy emanations, and electric currents and discharges when load circuits are connected to a condenser charged by radiant energy.

The following video introduces the apparatus, experiments, and phenomena that are most often attributed to Tesla's radiant energy and matter, and which have been successfully demonstrated in the prior art by researchers such as Dollard et al.[2]. The apparatus used in my video can be readily constructed by a competent electrical engineer, showing that experimenting and researching this fascinating area is accessible to any open-minded individual with the fortitude to undertake an experimental path of discovery regarding the inner workings of electricity. The video demonstrates and includes aspects of the following:

1. The difference in powering a load with a conventional closed-circuit from the primary coil of a spark gap generator, and a single wire from the Tesla coil secondary.

2. The change in properties observed in the load in a single wire with load position, generator matching, and changes in the single wire cavity length.

3. The force exerted on different materials as a result of radiant energy/matter emanating from an incandescent lamp emitter in the single wire load.

4. The different responses of materials to radiant energy emanating from the lamp emitter.

5. The radiant matter pressure wave emanating from the lamp emitter, as experienced by the human hand.

6. Discharge "plasma-like" emanations directly from the lamp emitter to the surrounding medium.

7. Vibration and physical movement stimulated in the lamp filaments when radiant energy interacts with another object in the surrounding medium.

8. Cool lamp glass temperature when emanating considerable light from the lamp emitter, a so-called “cold” electricity phenomenon.

9. Radiant energy charging of a capacitor, accompanied by subsequent discharge in a neon lamp load, showing a “cool” white-bluish discharge, and a violent snapping sound.

10. An initial consideration of the inter-relationship between the longitudinal and transverse modes of electricity in the single wire load.

11. The transformation of energy from the longitudinal mode to the transverse, and the dissipation of this energy as power in the single wire load.

Figure 2 below shows the schematic for the generator and experimental apparatus used in the video. The high-resolution version can be viewed by clicking here.

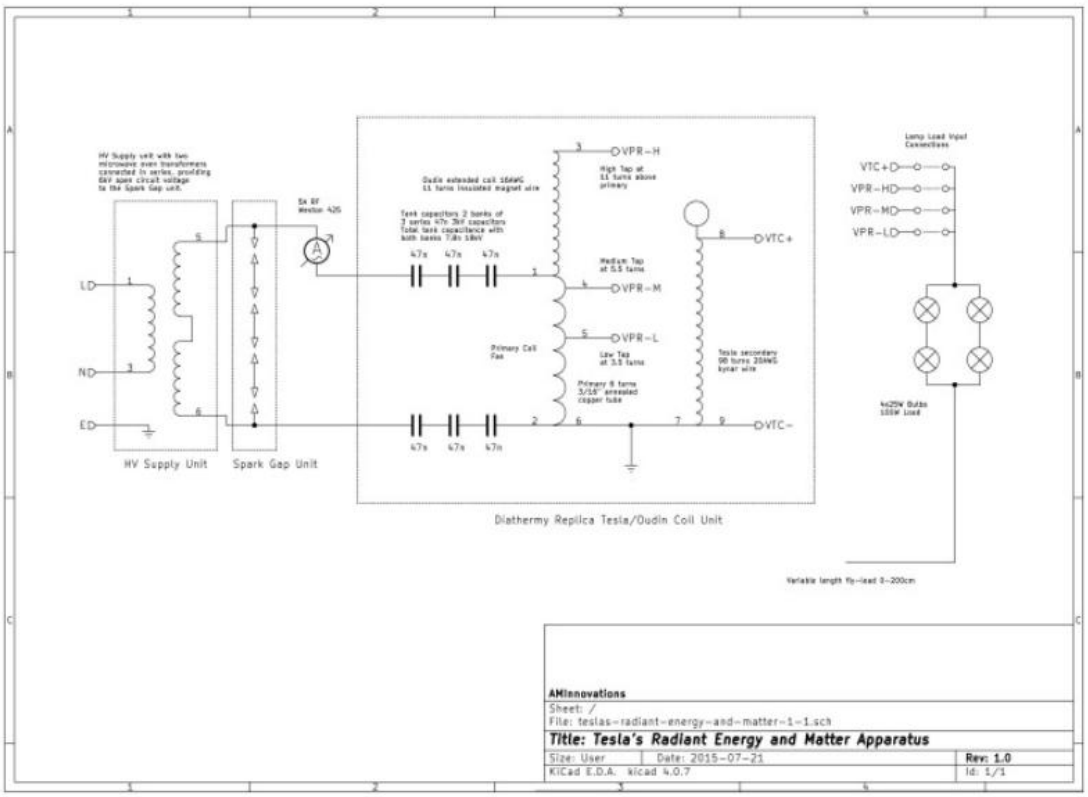
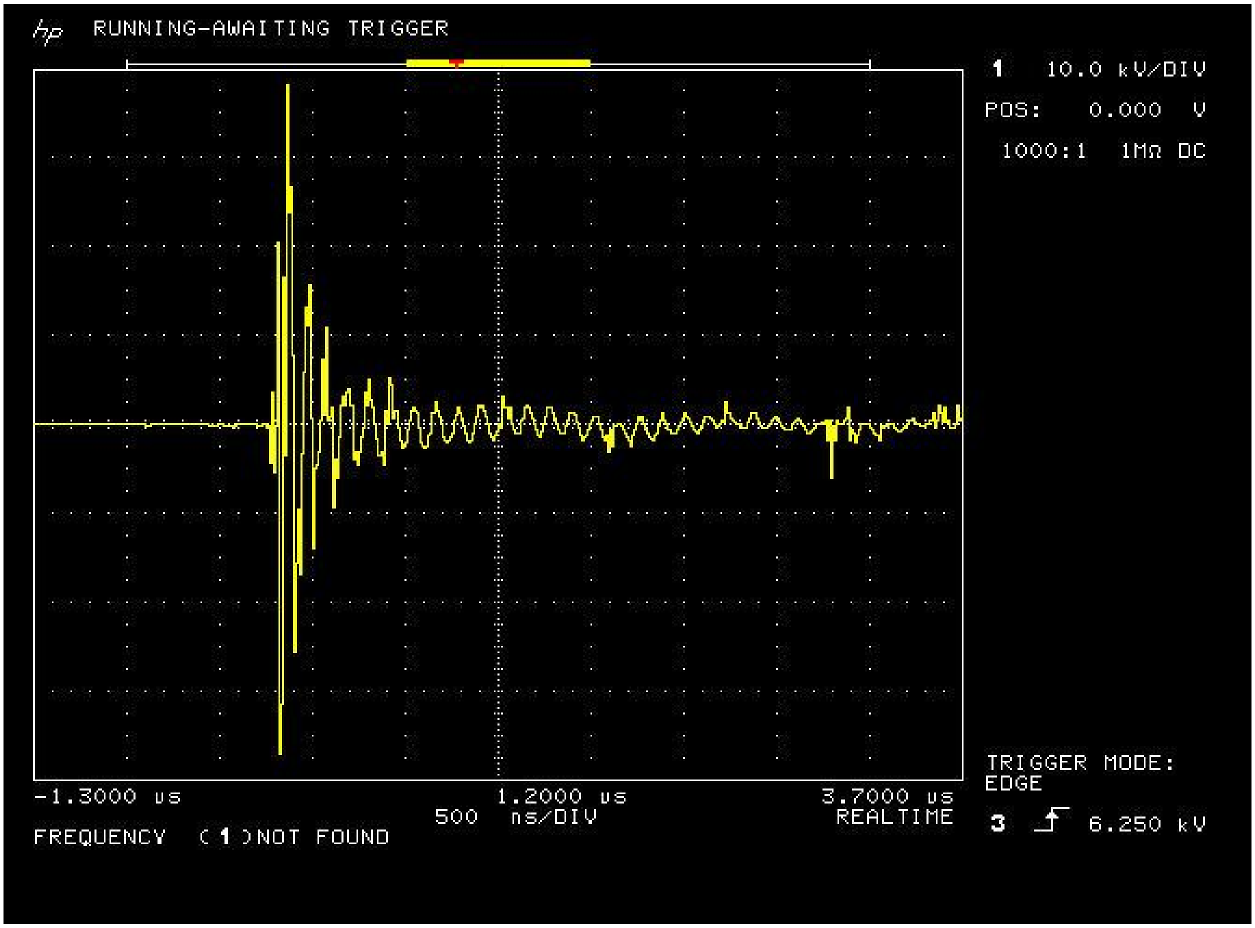


Figure 3 below shows the secondary pulse burst at the single wire load measured using a 40kV high voltage probe whose input terminal is placed closed to the load via a short fly-lead. The fly-lead was initially connected directly to the load but caused some interference and erratic operation to the measurement equipment, as shown in the video. This erratic operation results from transient current spikes induced directly through the probe connections to internal circuitry, and cross-coupled amongst the various earth connections in the equipment line-supply. Individual ferrite chokes can be used on the measurement instrument line supply cables to prevent this undesirable cross-coupling. In this case the fly-lead of the probe was simply disconnected from the load but left in close proximity to the measurement region, which had no detectable impact on the measured results, but sufficiently reduced the unwanted interference to allow for correct instrument operation.



It can be seen from the secondary pulse burst that transients in the single wire during the initial spark discharge are large in amplitude, (up to 40kV in voltage magnitude, and 100s of amps in current magnitude), and resemble impulse-like spikes with very short life-times, densely packed in time, and with very short duty cycles. These transient impulses give rise to both sinusoidal oscillations in the resonant circuit of the secondary, and as expected for a Tesla coil or TMT apparatus, stimulate generation of the characteristic longitudinal wavefronts in the cavity of the secondary circuit. As considered in previous posts, the longitudinal wavefronts themselves could result from the coherent spatial inter-action between the electric and magnetic fields of induction in the LMD mode, and where the coherent aspect is the direct consequence of underlying displacement events.

It is conjectured, and explored here, that high-energy transient impulses, that are ideally unidirectional in nature, and characterised by very large amplitudes and very short life-times, stimulate through non-linear processes electrical events or an imbalance in the system that needs to be, and can only be, rebalanced by the underlying coherent process of displacement. The product of this momentary exposure to displacement, (or an inner-working of electricity), is emission of the rays or beam-like emanations Tesla referred to as radiant energy, which in-turn give rise directly to the unusual electrical phenomena observed in the experiment. It is to be conjectured that the observed radiant energy emanations are directly the consequence of a displacement event taking place in the non-linear dynamics of the local electrical system.

With this conjecture stated the various experimental observations shown in the video will now be considered with the objective of determining their possible source or cause, and in order to get a better qualitative understanding of the underlying principles and processes involved. It should be noted that real experimental results, observations, and perceptions are being conjectured here into a possible underlying explanation, which will need considerable further consideration and experimentation to test, verify, and draw reliable and robust conclusions as to the validity of the considered conjecture.

Transference of electric power in closed and open-circuit systems

The dissipation of power in an “open-circuit” or single wire load is a very characteristic phenomena which can be readily observed and measured in almost any Tesla coil geometry and configuration. A suitable resistive load such as an incandescent lamp can be made to illuminate brightly when connected by a single terminal to either end of the Tesla coil, and the other terminal of the lamp has a small wire extension or fly-lead added. Without this fly-lead the lamp is at the very termination of the single wire and it will not illuminate or dissipate power.

This single wire power dissipation can be observed irrespective of how the Tesla coil primary is energised, whether it be from a sinusoidal linear amplifier or oscillator, a burst discharge from a spark gap, or a pulse generator. In other words, provided the primary and secondary coils are arranged to couple sufficient energy between them it does not matter whether this energy is from a single frequency linear sinusoid, a burst discharge envelope, or a set of non-linear transients, pulses, or impulses, it is possible to dissipate this coupled power within a resistive load placed in the single wire extension of the secondary coil.

It can be seen in the video that the lamp load could not be made to illuminate when connected to output taps on the primary side of the Tesla coil, even on the “HI” Oudin extension terminal. The tension on these primary side terminals is high, about 1kV on the LO, 2-4kV on the MID, and up to almost 10kV on the HI terminal. There is also a wide range of frequencies in the pulse burst due to the spark discharge in the primary circuit, so the output of these primary terminals is certainly a high tension RF burst discharge. This RF burst looks very similar in envelope shape and structure to that measured in the secondary, with the major exception that the oscillation within the burst envelope is dominated by the primary circuit characteristics, whereas in the single wire it is dominated by the secondary coil circuit characteristics.

Given all of this the lamp load will not illuminate and dissipate power when connected by a single wire extension to the primary side terminals, and yet will readily illuminate when connected by a single wire extension to the secondary coil. The only way found to illuminate the load when connected to the primary side terminals is to complete the circuit by connecting the single-wire extension back to the primary ground terminal, making a normal closed-circuit system.

A very similar example to this would be powering an incandescent lamp when placed across the output terminals of an oscillator, or even better in the coaxial transmission line between the output of an amateur radio transmitter tuned to transmit say in the 160m HF band (~2 Mc), and a half-wave dipole antenna at the far end of the coax. When the coax is connected on both terminals (circuit-closed) the lamp will light and dissipate some of the power from the transmitter dependent on the impedance it presents within the circuit, with the remaining power being radiated from the antenna and consumed by the coax. When either terminal of the coax is removed (open-circuit) the lamp will not light and no power is dissipated in either the lamp, or delivered to the antenna.

This most simple, and yet profound difference, between powering a load from the primary and secondary circuits of a Tesla coil, where both coil outputs are high tension and contain considerable RF energy, suggests a fundamentally different mechanism of electrical transmission and/or dissipation of power in the two cases. In the primary the system behaves exactly as one would expect for a conventional electrical circuit, and can be measured and calculated precisely in the case where a linear sinusoid is applied to the circuit. If we reduce all electric circuit characteristics to the inter-dependent relationship of the electric (or dielectric) field of induction (**Ψ**), and the magnetic field of induction (**Φ**), and their inter-action with material type, form, and structure, then it should be clear that there is a fundamental difference in the relationship, or mode of inter-action, between these two induction fields within primary circuit and the secondary circuit.

In the closed-circuit case the configuration of **Ψ** and **Φ** lead to voltages and currents distributed in time around the circuit that are transverse in nature and where the phase relationship between them is distinctly defined by the impedance elements, (boundary conditions), distributed in the overall system. In this case or mode **Ψ** and **Φ** are fully differentiated, non-coherent, not in-phase either spatially or temporally, and only becoming temporally in-phase in the transverse electro-magnetic (TEM) mode for far-field propagation.

In the open-circuit or single wire case and to dissipate power in a load it is necessary for the configuration of **Ψ** and **Φ** which are still fully differentiated, to be coherent, that is in-phase spatially and temporally. This can be accomplished through the longitudinal mode, or the LMD mode as it is known, where both **Ψ** and **Φ** are locked in phase alignment with each other, and form a combined traversing wavefront within the cavity, generating an electrical pressure wave ahead of the combined wavefront.

In this case local changes of impedance on the single wire, such as the filament of a lamp, lead to power dissipation at the pressure wave through local generation of instantaneous voltages and currents within the impedance change, and hence power dissipation, light, and heat. It can be seen that rms current decays in magnitude along the length of an open-circuit terminated single wire longitudinal cavity, rather than stay constant as would be expected for a transverse mode circuit. With the lamp as the termination of the single wire cavity it will not light as the local current in the wire end has reduced to zero, and no power can be dissipated in the load in the transverse mode.

In summary for now, the most basic Tesla coil presents a fundamentally different power transmission mode at the secondary coil, that is irrespective of how it is energised in the primary circuit, and is most likely longitudinal in nature, and results in the phenomena of single wire transmission of power.

Attractive and repulsive forces

The video shows a range of different materials mounted in a pendulum-like arrangement, that when brought in to close proximity to the single wire lamp load emitter, experience an attractive and in the case of certain materials, an additional repulsive force. The attraction of a material can be almost instantaneous on application of the emitter power, or in some cases can take a period of “charging” time to reach a sufficient level to pull the material towards the surface of the emitter. In most material cases the sample is retained on the surface of the lamp for a period of “discharging” time before being released from the surface after the emitter power is turned off. The responses of the different materials to radiant energy and matter emanations from the lamp are as follows:

Aluminium – attracted towards the emitter over a distance of up to 20mm with an electrical power level at the lamp of ~40W, (power present at the emitter lamp is estimated based on its relative brightness when illuminated at 100% of its nominal rating of 25W). 10mm at ~20W was demonstrated on the video, and this material is readily retained on the emitter surface after power off. No repulsion events were observed with this material.

Copper – both attracted and repulsed from the surface of the lamp at a distance of ~8mm at ~20W. This material is more gently attracted to the emitter but is more unlikely to be retained on the surface. The most observed phenomenon is that the copper in coming into contact with the lamp glass is then repulsed quite strongly from the surface rather than being retained on the surface. The repulsion has a defined force rather than a simple falling-away or bouncing off of the glass surface. The attraction and repulsion at the correct distance from the emitter leads to a sustaining mechanical oscillation of the pendulum.

Acetate (cellulose) – not attracted towards the emitter even at distances <1mm at up to 50W of emitter power. However at much high powers >100W with a different lamp, very small movements have been possible in the region of ~1mm from the lamp surface. Slow to attract over the distance, and very quick to release, implying very low pull force, and very low charging effect.

Biomatter (fresh and dried) – in this case both a fresh and dried leaf sample were strongly attracted to the lamp over a distance up to 20mm at ~20W. This material gives the most instantaneous response to emitter turn-on with very rapid movement to the lamp surface. This material is also barely retained on the lamp glass after emitter turn-off, being almost as quickly released as it is attracted to the surface. No repulsion events were observed with this material.

Cardboard – in this case the cardboard is very old originating from the original inner box of a Weston 425 meter, and showed good attraction up to 5-10mm at ~20W. This material is not retained on the lamp glass after emitter turn-off, and no repulsion events were observed with this material.

Clearly from this experiment it can be seen the emanations from the lamp emitter result in a physical force exerted on the material. This physical force is attractive for all of the materials, including the acetate, but varies very widely in scale based on the material type. Surprisingly the biomatter exhibits the strongest attraction, followed by the metals, all the way down to the insulator with only very small attraction at much higher powers. Only the copper shows a sustained repulsive force but only after an attractive event has first pulled the material to the surface of the glass of the lamp, almost as though an inversion occurs at the surface contact and the material is then repelled away. There is no situation where a material has been repelled away from the lamp at turn-on without first being attracted to the surface.

By studying the nature of the experiment it does at first appear like a “charging” effect. Emanations or wavefronts emitted from the lamp emitter cause negative charge accumulation at the surface of the material, where the degree of surface charging depends on the material type, its “impedance” to the emanations, and the material conductance. If this where the case it would be similar to an electrostatic force where two or more materials are attracted or repelled by the difference in their surface state charge.

It has been suggested[3] that the attractive force is magnetic in nature stemming from eddy currents generated in the material by the incident emanations. I have not so far been able to demonstrate this since the introduction of a strong bar magnet into the experiment makes no difference either attractive or repulsive to the material under test. The material still behaves as indicated above, and at the same power levels and distances, irrespective of the magnets influence on the experiment. However, this is not to say that the magnetic field of induction **Φ** is not involved in this process. This can also be partly supported by the observed sustained current through a neon lamp load in the capacitor charging part of the experiment, which could suggest that both **Ψ** and **Φ** are present within the nature of the radiant energy emanation.

At an empirical level this would appear to make sense, if the radiant energy is an emanation resulting from a displacement event at the emitter, and the displacement event involves the undifferentiated **Ψ** and **Φ** acting in temporal and spatial coherence, it would correspond that the emanation from this event is in phase, longitudinal in nature, and forms a forward moving unidirectional wavefront of “electrical pressure”. In this way this emanation conveying both **Ψ** and **Φ** when incident on materials within the transmission medium could stimulate an electric, magnetic, or a combination response from the material. This stimulated response may involve energy accumulation and storage, and also dissipation of energy through exertion a physical force, electromagnetic emission or absorption (light and dark), thermodynamic changes (temperature or pressure changes), or even perceptual changes of the surrounding medium.

As a coherent pressure wave its transmission over distance may be very large, transferring energy from the pressure wave to incident materials in the surrounding medium, or even becoming self-sustaining with distance through amplification from suitably arranged material forms and apparatus. The velocity of the pressure wave needs to be considered and suitable apparatus for its measurement arranged, however in the coherent state as an emanation from a displacement event it is considered possible that energy is displaced between source and load at velocities exceeding ***c*** the transverse electromagnetic speed of light in the vacuum.

In summary, radiant energy like emanations very similar to Tesla’s original observation in his patent, can be observed from a suitable load, (impedance change), placed in the cavity of a single wire transmission medium.

These emanations are conjectured to be the product of coherent underlying processes which stimulate a range of different responses from incident materials. The emanations are conjectured and discussed to be directly the product of displacement events generated by longitudinal electrical pressure imbalance at the single wire load.

Low temperature light emission and "cold" electricity

In Lindemann[4] the term "cold electricity" was used to describe experiments and observations by Gray (via Valentine)[5], based on light emitted by incandescent lamp loads, which was not accompanied by the normal rise in temperature expected from this type of resistive load, but rather the lamp had a cool glass surface when emitting "full power" illumination. Gray further demonstrated this by illuminating to full power an incandescent lamp submerged in cold water, which would ordinarily lead to fracture of the lamp glass. In the case of illumination by "cold electricity" no such fracture damaged was observed over sustained illumination periods.

In my experiment with incandescent lamps in the single wire load it was observed that the temperature of the lamp was quite low, and could comfortably be touched or held by the human hand after sustained illumination, equivalent to illumination at a full input power of 25W. This was compared to a control lamp, (same 25W pygmy make and style), powered from the normal line supply. After the same period of illumination where both lamps appeared the same brightness, the lamp in the single wire could be easily touched and held, whereas the control lamp was too hot to touch without causing a burn to the skin.

It appears likely from this experiment that the light being observed in the single wire lamp is, at least in part, emitted by a different process than the control lamp. Continuing the consideration from the previous section, and looking at the response of different materials to radiant energy emanations, it is possible to imagine that the filament of the bulb as a material that radiant energy is impinging upon, has its own unique and specific response to the coherent pressure wave emanation. In this case the response of the material to the radiant energy is to emit electromagnetic radiation in the form of light, which was not entirely generated by the resistive heating of the filament from the electrical current flowing in the single wire.

In a normal transverse and closed electric circuit case an incandescent lamp will generate light as emission from a resistive heated filament, where the colour temperature of the light is based on the filament material and temperature. Heat from radiation and conduction through the gas in the lamp heats the outer lamp glass to a temperature more than sufficient to cause sustained burns to biomatter. In the single wire lamp load light appears to be emitted through the filament response to the coherent longitudinal wavefront, which does not result entirely from resistive heating of the filament. Since the lamp does warm a little there is most likely a combination of processes going on, so some light emanation from radiant energy coherent processes, and some transverse current resistive heating in the filament.

This implies that there is a combination of the longitudinal and transverse electrical transmission modes within the single wire. It follows that improvement of the experimental system and boundary conditions could lead to a reduced transverse component, and a more pure longitudinal pressure wave in the single wire cavity reducing the heat emitted from the load to a level comparable to that observed by Gray in his experiments. In this case we would expect the temperature of the single wire lamp load to reduce from slightly warm to very cool, or even to cold in optimal experimental conditions and apparatus. Optimal conditions here means firstly reducing the transverse components within the single wire, which implies establishing the stable balance of **Ψ** and **Φ** boundary conditions in the complete system across the generator, primary, secondary, and cavity. And secondly it requires an increase to the uni-directional impulse like nature of the stimulus, where the increased non-linear inter-action between **Ψ** and **Φ** results in more displacement events and hence stronger emanations from the emitter.

In summary, it is considered that radiant energy emanations on the filament result in emission of light which is in part not as a result of resistive heating of the filament, which shows a similar result to that reported by Gray and considered by Lindemann. Improvements to the experimental apparatus and operating conditions should result in an increase in this phenomena, and will also help to confirm the validity of the conjectures made regarding displacement and radiant energy. It should be noted here that whilst I understand the label of “cold electricity” given to this phenomena, I find that the process conjectured here as being responsible for this phenomena is definitely not a “cold” principle. “Cold” in these terms implies the absence of something or something separated, in this case the energy to elevate the temperature through transverse dissipation, whereas I consider the emission of radiant energy, and the filament material response to that emission, to be an inclusive process which involves the coherent inter-action of both **Ψ** and **Φ**. Thus phenomena and emanations resulting from displacement are inclusive in nature, involve all parts of the system and medium in dynamic balance, and imply a sense of warmth, wholeness, and completeness.

Radiant energy accumulation and charge storage

In this experiment a capacitor is electrically charged by radiant energy emanations, showing energy transferred from the single wire emitter, accumulated in the capacitor, and then discharged through a neon bulb in the form of a spark discharge. In many ways this a similar consideration to the section on attractive and repulsive force, only additional accumulation can occur due to the capacity and storage of energy on the capacitor, which persists for much longer time intervals after the radiant energy emitter has been turned off.

An interesting observation to note from this experiment is that during the “charging” of the capacitor a smaller single wire circuit, or tributary from the main cavity, is created in the form of the capacitor in close proximity to but not touching the lamp, a wire connected to the other terminal of the capacitor, and a neon lamp load connected to the end of this wire. The active region of the neon lamp appears in the cavity tributary where there is also a short lead out of the neon lamp acting as the short fly-lead at the end of the single wire cavity, and ensuring there is a small but non-zero single wire current in neon load. During the charging stage the neon bulb lights continuously showing a single current flow down the tributary, and the transient like nature of the accumulating tension on the capacitor.

When the capacitor is adequately charged the main single wire load emitter can be turned off, and the charged capacitor and tributary circuit removed from the vicinity of the main experiment. The charge of the capacitor is retained over considerable time without any part of the circuit being closed with the neon bulb. When the circuit is closed the stored energy discharges rapidly through the neon bulb, with a characteristic snapping sound, and a bright bluish white discharge light in the neon bulb. The nature of this spark discharge shows that there is considerable tension on the capacitor, in fact it can be measured using a high voltage probe to be up to ~10kV, and considerably more than the maximum rating of the capacitor, (in this case 4kV). Unusually the capacitor appears unaffected by application of this overall tension across its terminals, and can provide a rapid and high-current discharge through the neon bulb.

In summary, energy can be stored in a tributary single wire circuit incorporating a capacitor as an accumulator, when a radiant energy pressure wave is incident on one terminal of the capacitor. The experimental arrangement used with the load attached by single wire to the other terminal of the capacitor, and kept open-circuit during charging demonstrates the possibility of the formation of single wire tributary cavities, which extend off the main cavity. In some ways this is similar in analogy to the “fern” discharge effect demonstrated by Dollard[6], when exploring extra-coil discharge phenomena with a pair of cylindrical phase-locked TMTs.

Radiant matter pressure on biomatter and reaction forces

In this experiment I placed my fingers close to and around the single wire lamp emitter but not touching, and not close enough for a high tension discharge to occur between the filament and my fingers. It was clear to experience a vibrating pressure exerted on my fingers in similar accordance to Tesla’s observation that *“… sources of such radiant energy throw off with great velocity minute particles of matter …”*, Tesla[1]. This radiant matter appeared to exert pressure on my fingers, or at least the experience of pressure waves as if being struck by waves of minute particles.

In addition to this I observed, and can be seen on the video, a reactionary force exerted on the filaments of the lamp emitter so that they would move permanently into another position, or else oscillated around a median position until filament breakage or becoming stuck to the inside surface of the lamp glass. Either way the movement of my fingers around the glass of the lamp resulted in both the experience of an exerted physical force on them, and simultaneously a reactionary force exerted on the filaments.

Although Tesla was clear about the nature of these “great velocity minute particles of matter”, I am not convinced of this explanation in this experiment, but rather that the experience is similar to that observed in the section on attractive and repulsive forces, where both **Ψ** and **Φ** are coherently inter-acting to form an emanation where again the stimulated response may involve energy accumulation and storage, and also dissipation of energy through exertion of a physical force, electromagnetic emission or absorption (light and dark), thermodynamic changes (temperature or pressure changes), or even perceptual changes of the surrounding medium.

Longitudinal and transverse mode coupling, or transformation, in a single wire cavity

This is a complex topic but one that needs to be initially considered here if we are to move toward a proper understanding as to the principles of transmission that take place in a single wire conductor, its relationship to the transverse and longitudinal mode, and ultimately the underlying stimuli and inner workings of electricity, displacement, and radiant energy.

In experiments and discussions thus far the Tesla coil or TMT system has been considered to form a cavity in the secondary circuit, where single wire transmission medium phenomena can be easily observed and measured. It has been suggested by others[2,3] and conjectured by myself that the single wire open-circuit nature of these phenomena, is a result of the longitudinal mode of transmission in the cavity created within the TMT system, where both **Ψ** and **Φ** are coherently locked in phase, creating an electrical pressure wavefront that traverses the cavity between boundaries, being reinforced by successive oscillations from the primary, and either transferring the power to a distant load in the primary of a receiver, or dissipating the energy in the wavefront within a load of different impedance within the single wire cavity.

The frequency of this longitudinal mode is expected to be different from the transverse resonant frequency of the Tesla coil secondaries for both the transmitter and receiver coil in a matched and tuned TMT transmission system. Whilst impedance measurements on a TMT with a vector network analyser, reveal in minute detail the transverse mode inter-action of the various resonant circuits making up the overall system, it appears to show nothing of the properties of the longitudinal mode which lay outside of its measurement paradigm. The concept of a longitudinal wavefront where both **Ψ** and **Φ** are temporally and spatially in phase does not currently exist in modern electromagnetism, and there is not an instrument currently available for probing this mode and condition.

Still the question stands of how it is possible to dissipate power in a single wire load in a longitudinal cavity. To start to address this we must consider the coupling between modes in the local impedance change of the load. Whilst the longitudinal mode of transmission dominates in the single wire cavity, energy and hence power can be transferred to distant loads, with in principle very low loss. To dissipate as power in the single wire load, rather than transfer the energy in the longitudinal mode, a coupling or transformation to the transverse mode must occur, generating local voltage potential difference and local currents in the load, which in turn are consumed as power in the resistive load, such as the filament of an incandescent lamp. I conjecture that it is this transformation process between modes that is characteristics of a single wire transmission medium, and allows for loads to be powered in an open-circuit condition, something that would not be possible in classical electric circuit theory or practice.

Radiant energy as emission from a displacement event

Further to this transformation between the longitudinal and transverse modes in the open-circuit single wire conduction model, it is conjectured and to be explored as a central concern in this research that as the TMT system becomes more non-linear, and when properly arranged to be stimulated with high-power impulse transients, displacement events required to rebalance the local **Ψ** and **Φ** dynamics of the system give rise to radiant energy emanations. These emanations result in many of the observed phenomena presented in this post, and when properly arranged in timing, amplitude, and duration lead to a very wide range of perceptual phenomena that are both electrical and non-electrical in nature, and yet to be explored.

So it is maintained and to be explored that the ideal TMT system is one that is carefully balanced, matched, and tuned between the "transmitter" and "receiver" coils both for the longitudinal and transverse modes, such that the single wire transmission medium forms a low impedance, reciprocal, and high Q cavity, where **Ψ** and **Φ** are dynamically balanced and in equilibrium for the linear case. This ideal TMT system when subsequently powered by a highly non-linear, uni-directional, transient impulse generator of very high tension, will cause such large discontinuities in the local balance of **Ψ** and **Φ** that displacement, as an underlying guiding mechanism in the inner workings of electricity, will be called-forth to re-balance the local dynamics of the electrical system.

These displacement events generate emanations, or electrically based shock waves, that are themselves longitudinal in nature, where both **Ψ** and **Φ** are coherently locked in phase, creating an electrical pressure wavefront that emanates outwards from the primary event. the stimulated response of materials and forms which encounter the incident wavefronts may involve energy accumulation and storage, but also dissipation of energy through exertion of a physical forces, electromagnetic emission or absorption (light and dark), thermodynamic changes (temperature or pressure changes), or even perceptual changes of the surrounding medium.

The creation of such an experimental system to test these assertions on displacement and transference, transformation of the longitudinal and transverse modes, and transmission of electric power to distant loads with very low loss, represents a challenge equivalent to surmounting a mountain higher than the highest yet ascended.

Summary of the results and conclusions so far

In this post we have experimentally observed a wide range of phenomena that are usually attributed to those related to Tesla's radiant energy and matter, and which have also been demonstrated and observed by other significant research efforts, including Dollard et al.[2]. It is clear from the experiments and observations that improvements to the TMT experimental system will facilitate a far more detailed and clear exploration of the underlying principles involved.

In considering the unusual observations of the experiment, and the accumulated understanding of the prior art through both my own collective work presented so far, and that of significant others[1-8], I have formulated a line of conjecture which combines both a philosophical and scientific approach towards the origin or source of these phenomena, and how that source could give rise, through fundamental principles and processes, to the materially observed effects of said experiments.

The formulated line of conjecture has the following key points:

1. The underlying origin or source of these phenomena resides in the inner workings of nature that, at the deepest conceivable level, is the result of the pressure of life's intent, which in turn gives rise to the need for the natural and living world to evolve.

2. The inner workings of electricity, as a part of the inner natural world, includes the undifferentiated fields of electric and magnetic induction **Ψ** and **Φ**, which act as one together in a fully inclusive manner, and which I

refer to as displacement **Q**. Dollard[8] refers to a similar principle **Q** as the Plank, or total electrification, which for me reflects the same inner workings of electricity.

3. A displacement event is not normally observable in the differentiated dynamics of **Ψ** and **Φ**. This differentiation between **Ψ** and **Φ**, and all the implications of their temporal and spatial inter-action results in what science currently understands as the field of electromagnetism, and gives rise to all the phenomena that I refer to as transference.

4. A severe imbalance created between **Ψ** and **Φ** in a circuit system where the "need" or purpose of the circuit is clearly stated, and where equilibrium cannot be re-established through the process of transference, will call-forth the underlying guiding principle of displacement. The act of displacement coherently puts the differentiated **Ψ** and **Φ** into their proper temporal and spatial alignment, upon where transference can resume as the external and observable dynamics of electricity.

5. The result of a displacement event is to generate an emanation or shock-wave, which Tesla called radiant energy, that permeates the medium surrounding the displacement event, and extending out until all emanation energy is stored or dissipated by external transference of electric power.

6. The radiant energy emanation is a direct consequence and extension of the displacement principle, and equivalent to bursts of energy or electrification injected into the surrounding medium. Suitable collection or reception of this emanation, when introduced to a load suitable to balance the overall system, will make it possible to harvest this additional electrical energy for suitable means, provided the overall balance of the complete system and medium is not violated. This is similar to what Tesla[7] referred to *"… it is a mere question of time when men will succeed in attaching their machinery to the very wheelwork of nature"*.

7. The radiant energy emanation where both **Ψ** and **Φ** are coherently inter-acting leads to stimulated responses from material and forms in the surrounding medium, where the stimulated response may involve energy accumulation and storage, and also dissipation of energy through exertion of a physical force, electromagnetic emission or absorption (light and dark), thermodynamic changes (temperature or pressure changes), or even perceptual changes of the surrounding medium.

8. The extension of radiant energy into the surrounding medium, and when incident on another open single wire circuit with established purpose, will constitute a tributary event, and transferring the same electrical event properties to the tributary, where the quantity of transferred energy is equivalent to the load or need of the tributary circuit.

9. The overall balance and natural order of the electrical system will be maintained through the inner workings of electricity and the principle of displacement, and can be observed and experimented with. Ultimately the energy generated through displacement can be utilised where the natural order and balance is preserved by the utilisation. This is equivalent to where the load represents a need that is inclusive to the system, then the system becomes regenerative, and can self-sustain with energy being supplied to all loads in balance.

This post has opened and exposed many further questions surrounding all of the observed phenomena, the need for much more measurement detail, further design of a more optimal experimental system, and most importantly the verification, or otherwise, of each and every one of the conjectures made to explain and understand what might be the source and mechanism behind Tesla's radiant energy and matter.

In the next post in this series I will be take a look at improvements to the TMT experimental apparatus that may lead to more detailed and clearly defined measurements to support aspects of the formulated line of conjecture.

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EXPERIMENTS, LONGITUDINAL MAGNETO DIELECTRIC, SINGLE WIRE CURRENTS, TESLA, TRANSFERENCE, WIRELESS TRANSMISSION

High-Efficiency Transference of Electric Power

13TH NOVEMBER 2020

In this post we take a preliminary experimental look at the transference of electric power using a cylindrical coil TC and TMT, energised using a linear amplifier generator, and also the high power transfer efficiency that can be achieved in a properly matched system. The setup, tuning, and matching of the linear amplifier is covered in detail in the video experiment where a 500W incandescent lamp can be fully illuminated at power transfer efficiencies over 99% in the close mid-field region. The power is shown to be transferred to the receiver through a single wire between the transmitter and receiver coil through the longitudinal magneto-dielectric mode, and not through transverse electromagnetic radiation or through direct transformer induction. This high-efficiency, very low-loss transference of electric power is possible as the dielectric and magnetic fields of induction are contained around the single wire.

It is also demonstrated that more than 500W of power can be transferred through a single wire no thicker than a human hair, a 40AWG (0.08mm or 80 microns) nickel plated copper wire, where the power transfer efficiency could be measured up to 100% according to the limits of experimental accuracy of the measurement equipment. Power transfer of this order through such a thin wire is again possible as the dielectric and magnetic fields of induction are contained or guided around the single wire. Removal of the single wire from the receiver end prevents any power transfer to the receiver, which shows that when driven by a linear sinusoidal generator, a lower impedance transmission medium, (in this case the single wire), is needed to guide the induction fields between the transmitter and receiver coils. The experiment presented in this post is the preliminary starting point for a more detailed and extensive study of power transfer efficiency over greater distances in the mid-field region with much longer single wires, and in the far-field with a Telluric transmission medium.

The video experiment demonstrates and includes aspects of the following:

1. Linear amplifier generator setup, matching, tuning, and operation to drive a cylindrical TC and TMT system.

2. Measurement and confirmation of the series and parallel modes of resonance for a balanced TC, against the Z_{11} impedance results, using the generator exciter and an oscilloscope.

3. Transference of electric power from the generator exciter unit, to a single wire transmission medium incandescent lamp load up to 120W.

4. Transference of electric power from the linear amplifier generator to a 500W incandescent lamp load at the TMT receiver output, and subsequently to two parallel 500W lamp loads.

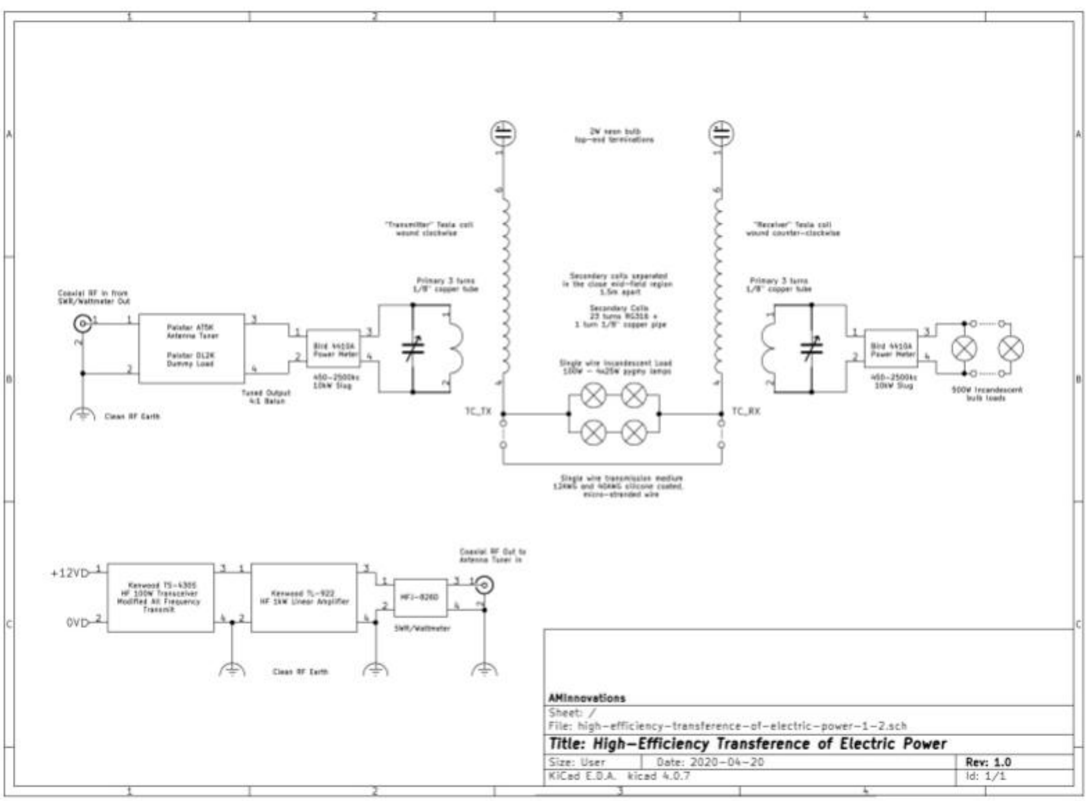
5. Longitudinal magneto-dielectric (LMD) mode measurement through central null with a fluorescent lamp, and mode interference patterns with an ultraviolet lamp.

6. Transference of electric power efficiency measurements up to 99% using an AWG12 single wire between the TX and RX coils.

7. Efficiency measurements up to 100% using an AWG40, 80 micron (0.08mm), 60cm long, single wire between the TX and RX coils.

Video Notes: The maximum calculated power transfer efficiency when using the 12AWG single wire in the video was 99%, and not 99.6% as stated in the video. During the introduction the small signal input impedance characteristics Z_{11}, are displayed for a short period in preparation for the subsequent presented linear amplifier setup. These characteristics can also be viewed in Fig. 3.1 below.

Figure 2 below shows the experimental system circuit diagram, followed by an overview of the linear amplifier generator components. Click here to view the high-resolution version.



1. The exciter is a Kenwood Trio TS-430S 100W HF amateur radio transceiver. This era of transceiver has digital frequency synthesis, a semiconductor power amplifier, AM and FM modulation, and is easily modified to extend its capabilities. In this case it has been modified to transmit on all frequencies across its tunable range, which makes it into a high-power, up to 120W, bench-top signal generator with modulation capabilities. The transceiver system is not connected to any elevated radiating antennas, and hence will not cause out-of-band interference.

2. The exciter is connected directly to a Kenwood TL-922 1kW linear amplifier which is a vacuum tube based, (dual Eimac 3-500Z), HF power amplifier. This linear amplifier has π-network matching circuits on both input and output. Slightly out of band operation prevents running this linear amplifier at the full 1kW when in the fully matched condition. The output of the linear amplifier is connected through an MFJ-804D digital power and SWR meter to monitor the match at the output of the linear amplifier.

3. The output of the SWR meter is connected to a Palstar AT5K 5kW antenna tuner which handles the impedance transformation from the 50Ω output of the linear amplifier to the ~ 7.5Ω input resistance R_S. The AT5K is a T-network matching unit, with input and output continuous variable capacitors, and a continuous variable roller inductor. In balanced output mode a internal 4:1 balun is present at the output of the unit, which further extends the range of possible impedance matching. This unit is capable of tuning a very wide impedance to the 50Ω system impedance, and is required for safe and optimum performance of the linear amplifier when driving TC and TMT systems.

4. The output of the AT5K can be switched to bypass which connects to a Palstar DL2K 2kW 50Ω dummy load which is used to initially tune the output of the linear amplifier for maximum power output at the exciter frequency. When this is completed the AT5K is switched back to balanced tuned output connected to the primary circuit of the transmitter cylindrical coil. Between the output of the AT5K and primary coil is a Bird 4410A Thruline power meter with a 450kc – 2500kc 10kW slug, for measuring the real power actually supplied to the transmitter primary. Between the output of the receiver primary circuit and the 500W incandescent lamp is a second Bird 4410A Thruline power meter with the same rated slug.

In measurements for high-efficiency where the final result is a ratio of the output power to input power, calibration of the key measurement instruments becomes critically important to ensure the highest levels of accuracy and confidence in the measured results. In this case the Bird Thruline power meters at the input and output primary coils were calibrated simultaneously inline with each other, with the actual slugs to be used during the experiment, and on the range that was to be used to make the efficiency measurements. The calibration procedure was as follows:

1. 500W of output power was provided from the linear amplifier generator simultaneously through the two Bird watt meters in series and terminated at the Palstar dummy load. Interconnections were kept to short BNC cables.

2. Both watt meters were first zeroed and then set to scale 10, which for the 10kW 450-2500Kc slug with element factor 100, results in a meter full scale reading of 1000W.

3. With 500W of power provided from the generator to the dummy load both watt meters were adjusted to read the same needle position on the meter scale at 500W. The operation was repeated multiple times with the power being turned-off and reapplied to confirm.

4. The series connection of the meters was then reversed to average out any insertion losses, and step 3 repeated to confirm agreement of the readings, with very slight adjustment to the calibration of each meter for optimal agreement in both steps 3 and 4.

In this way the meters were both calibrated for 500W input power direct comparison on a single range, and with a limit of experimental error of <0.5%. Due to the analogue nature of the meters, readings during the experiment needs to be done carefully and repeatedly in order to minimise errors due to estimation of the needle position when in-between minor graticule marks. It was determined overall that power efficiency measurements can be made by this method within an error limit of ±1%.

Figures 3 below show the key Z_{11} impedance measurements that relate to different configurations of the experimental apparatus that were used in the video experiment, along with a consideration of their analysis and characteristics relating to the most important phenomena.

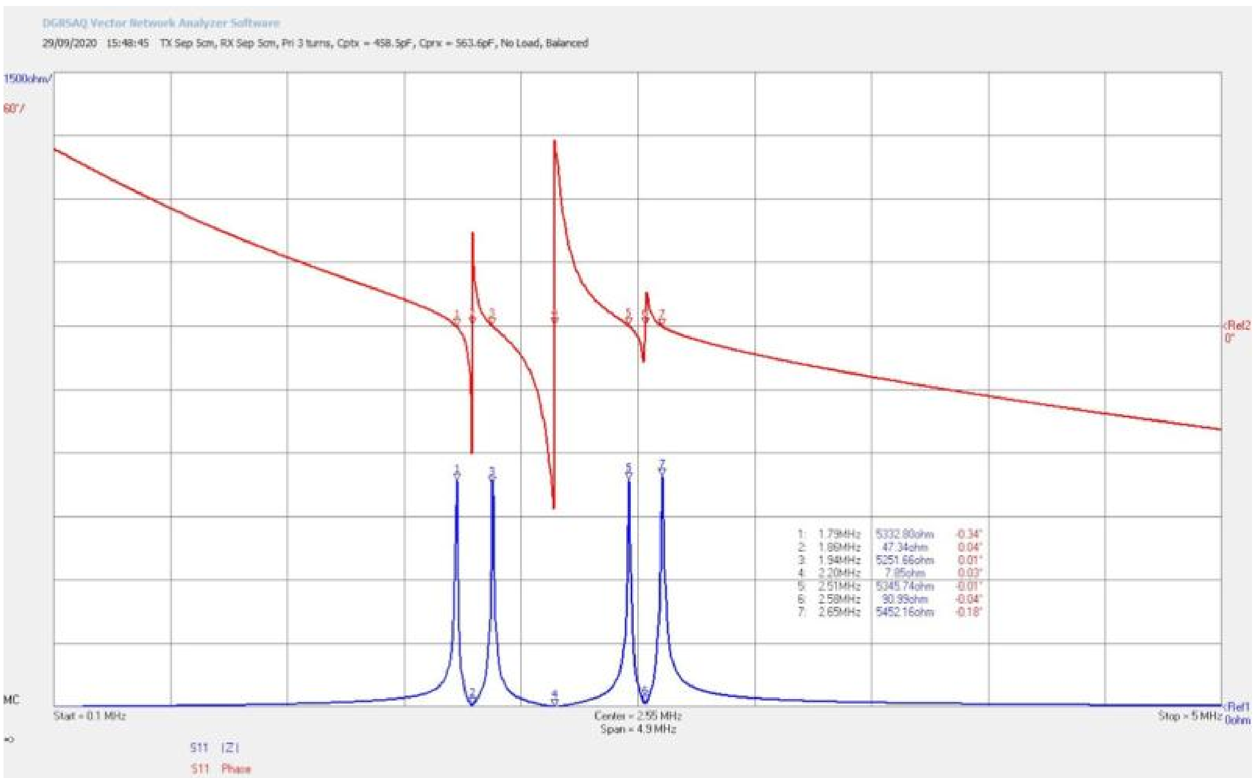


Fig 3.1. Shows the small signal input impedance Z_{11} for the starting point of the experiment, (also shown on the video), for the transmit cylindrical coil only with a single wire extension that includes a 100W incandescent load. The impedance characteristics consist of the three key points, as explained in detail in the post Cylindrical Coil Input Impedance – TC and TMT Z_{11}. In this experiment the linear amplifier generator was initially tuned to marker M_2 the series mode resonance at 2.19Mc. After confirming the Z_{11} measurements, using an oscilloscope to maximise the voltage output of the secondary, the generator was set at 2.20Mc for the start of the practical experiments. Markers M_1 and M_3 are the parallel mode resonant points for the transmit Tesla coil, at 1.89Mc and 2.68Mc respectively. In this case the parallel modes have been balanced between the primary and the secondary, in order to maximise coupling through the series mode to the parallel modes, and hence from the generator to the LMD mode in the cavity formed in the secondary coil and single wire extension. The series resonant mode at M_2 is suitable for driving the coil using a linear amplifier as the input impedance is minimum, 12.5Ω @ 2.19Mc, which can easily be matched to the power amplifier output impedance of 50Ω, via the Palstar antenna tuner with a 4:1 output balun.

It is interesting to note from the video experiment that the oscilloscope confirmation and measurement of the resonant modes of the Tesla coil is strongly dependent on the matching network used between the generator and the primary of the coil. In the simple case where the exciter was connected to the primary through direct bypass of the antenna tuner, (direct drive), the fundamental series resonant mode could be measured very clearly at 2.14Mc, but the parallel modes could not be identified at all in the measurement. This method is commonly used to measure the Tesla coil series resonant frequency, but completely masks the parallel modes from measurement, leading to an incomplete and ultimately inaccurate characterisation of the properties of a Tesla coil. It should also be noted that the measured maximum voltage peak on the oscilloscope at 2.14Mc does not completely correspond to that measured in the Z_{11} characteristics of 2.19Mc. In this case where no consideration of input impedance matching has been taken into account the basic oscilloscope measurement yields incomplete and inaccurate measurement results, and whilst gives a close estimate of the best frequency point to drive the Tesla coil, does no yield the optimum frequency and conditions for maximum transference of electric power.

When the same measurement is repeated but with a tuned matching network between the exciter and primary coil, (in this case the balanced and tuned T-network in the Palstar), the oscilloscope measurement closely matches the Z_{11} characteristics. Both parallel modes and the series mode can be measured accurately at the correct frequencies, and the initial starting point was again set to 2.20Mc. The difference in the two measurements is a clear example of why it is important to carefully match the output impedance of the generator to the input impedance of the Tesla coil, and this is even before we consider the optimum and maximum transfer of electric power. To maximise power transfer and obtain the highest efficiencies it is crucial to minimise power reflected from the primary circuit to the generator.

Fig 3.2. Here the transmitter and receiver coils are coupled together with a single-wire transmission medium to form a TMT system. No load is placed in the single wire, and no load is attached to the output of the receiver primary. This represents the highest quality factor, unloaded, characteristics of the system, and combines four parallel modes (M_1, M_3, M_5, and M_7), and three series modes (M_2, M_4, M_6) together. The TMT system has been carefully balanced using the primary tuning capacitor in the both the transmitter and receiver to match the impedance of the parallel modes across the system. Balancing of the parallel modes in this way appears to contribute significantly to maximising the LMD mode in the cavity through coupling maximum power between the TEM and LMD modes between the primary and secondary coils in both the transmitter and receiver. A more detailed analysis of this TMT system has already been presented in post Cylindrical Coil Input Impedance – TC and TMT Z_{11} – Fig. 2.1.

It should be noted that the fundamental series resonant mode at M_4 has remained constant at 2.20Mc, and for the type of linear amplifier generator being using in this experiment, is the best frequency point to drive the TMT system. At M_4 the input impedance is at its minimum and is purely resistive at 7.85Ω, and is well within the matching range of the Palstar antenna tuner with a 4:1 balun at the output. Tuning to drive at M_4 is also the most stable part of the Z_{11} characteristics, which is most determined by the the reciprocal wire lengths of the secondary coils. It is possible to also drive the TMT system using this generator at series mode points M_2 and M_6. Whilst this will preferentially couple energy into different aspects of the parallel longitudinal modes, the characteristics of these points in impedance are highly dependent on the primary tuning of both coils, and the loading conditions in any part of the TMT system, in the single-wire, at the output of the receiver primary, or even in proximity to other lower impedance structures. Driving the system at unstable positions M_2 and M_6 would require a lot of continuous tuning adjustments, and inevitably having to run at a higher SWR during experimental operation. For experiments across the characteristics of the parallel modes it is recommended to use a series feedback oscillator which is covered in detail in the second section of post Cylindrical Coil Input Impedance – TC and TMT Z_{11}.

Fig 3.3. Here the TMT system of the previous figure has had a 100W incandescent lamp load added in the single-wire cavity between the transmitter and receiver. The characteristics remain essentially very similar, although the Q of the system is reduced significantly by the resistive component in the cavity. The fundamental series resonant mode at M_4 has only shifted down in frequency by ~10kc to 2.19Mc, however the input impedance of the system has now increased to 19.1Ω based on the transformed down additional resistance of the 100W load in the secondary cavity. The tuning of the primary capacitors has been adjusted to maintain a balanced condition between the parallel modes. The biggest impact of adding a load in the cavity is to damp-down the parallel modes, and hence reduce the purity of the LMD mode formed in the cavity of the TMT system.

For clarity, the cavity extends between the top-end of the transmitter secondary, through the single wire transmission medium and load, and up to the top-end of the receiver cavity. Power is transferred from the generator through the primary circuit, and to the secondary primarily in the series TEM mode, which is further coupled to the parallel modes in the both the primary and secondary coils, and hence into the LMD mode across the cavity. Power is coupled out at the receiver through the reverse process from the LMD mode to the receiver parallel modes, and into the series TEM mode in the primary circuit. It is a condition of an LMD coupled TMT system that the frequency of the LMD mode < TEM mode. The LMD mode can be maximised by maximising the parallel modes in the coils which includes:

1. Specific and careful arrangement of the coil geometry (e.g. a balanced cylindrical coil), windings number, ratio and spacing, and coil materials.

2. Tuning of the parallel modes to balance the characteristics between the primary and secondary coils in both the transmitter and receiver.

3. Impedance transformations, characteristics, and loading within the single-wire transmission medium.

Coil geometry and their characteristics for Tesla coils and TMT systems are covered in detail in post Tesla Coil Geometry and Cylindrical Coil Design.

Fig 3.4. Shows the effect of moving the 100W lamp load from the single-wire to the output of the primary circuit of the receiver. The Q of the system remains reduced, and the parallel modes of the receiver coil have been almost completely damped-down (suppressed), so that they merge into the parallel modes of the transmitter, and appearing as only two parallel modes at M_1 and M_3. With slight transmitter primary capacitor tuning the merged parallel modes of the receiver can be revealed as slight distortions to the peak shapes at M_1 and M_3. The fundamental series resonant mode at M_2 remains constant at 2.20Mc as the wire length in the secondary coils of the TMT system cavity has not changed, but the input resistance has risen significantly to 59.8Ω, as the resistive load of the incandescent lamps is transformed across the TMT system from receiver back to transmitter input. In this case the 59.8Ω input resistance at M_2 is closer to the system impedance of 50Ω of the linear amplifier generator.

It should be noted that this represents another way to match the system impedance of the generator to the input of the TMT system, by arranging a suitable resistance load at the output of the receiver. The impedance transformation across the complex transmission line of the TMT apparatus, ensures a good TEM match at the input to the primary. The disadvantage of tuning in this way is that the resistive load reduces the Q of the system, and damps-down the parallel modes of the coils, which ultimately reduces the efficiency of the TMT system for the transference of electric power.

Fig 3.5. Shows the dramatic effect of connecting a 500W incandescent lamp at the output of the receiver, which has significantly unbalanced the TMT cavity, and suppressed the free-resonant characteristics of the receiver, through the low resistance and inductive impedance of the 500W lamp. The large collapse of the receiver characteristics has shifted the transmitter parallel modes M_1 and M_5 closer together, the lower parallel mode of the receiver at M_3 is still present but very small, and the upper parallel mode of the receiver (from the receiver primary coil) is no-longer present. The fundamental series resonant modes are shifted as well, with the transmitter moving down to 2.02Mc, and the receiver moving up to 2.30Mc. The best driving point for the generator is now at M_2 at 2.02Mc and with a input resistance of 24.7Ω, which is easily transformed and matched by adjustment of the antenna tuner. M_4 the series mode for the receiver could also be used as the driven point, although it is likely that less power will be coupled through the parallel modes at this point and hence into the LMD mode, due to the collapse of these modes from the high loading on the receiver coil.

It should be noted here that despite the imbalance of the impedance characteristics, very high-efficiency power transfer between the generator and the load can still be accomplished through the coupling between TEM and LMD modes in the secondary coils, and through the strong LMD mode maintained in the low impedance cavity of the single-wire transmission medium. In this arrangement with a large, low impedance load at the receiver transference of electric power efficiencies have been measured > 99.9% in hair-line thickness (0.08mm) single-wire cavities.

Figures 4 below show highlights from the video experiment, and also greater clarity on some of the key power measurements taken during the experiment, including high-efficiency power transfer results at > 99%.

The experiments show the seemingly amazing result of transferring stably 500W of power at very high-efficiency, (peak 800W measured in the experiment, but with lower efficiency), via a single wire 60cm long and 0.08mm thick (40AWG), and comparable to the thickness of a human hair. In a standard electric circuit we would expect to transfer this magnitude of power between the generator and the load using a suitably rated twin-wire arrangement. In the TEM mode the dielectric and magnetic fields of induction establish an alternating potential across the load and an alternating current flowing through the load. As the impedance of the incandescent load is dominated by the resistive part, almost all of the power is dissipated in the lamp element as heat and light, and with resistive and inductive losses in the circuit cabling and connections.

This is in fact what occurs in the receiver primary circuit which is a conventional twin-wire circuit. The receiver Tesla coil acts a step-down transformer and energy is coupled from the secondary coil resonant modes, (both series and parallel), to the primary coil. The dielectric and magnetic fields of induction coupled through to the primary establish in a TEM mode and hence setup alternating potential across the load and an alternating current flowing through the load. The power in the primary receiver circuit can be measured accurately using a standard RF power meter, (such as the Bird 4410A used here), in a standard twin-wire circuit.

There is an equivalent and reciprocal process in the generator primary circuit. The linear amplifier supplies RF power through a standard power meter into the twin-wire primary circuit at the transmitter. The dielectric and magnetic fields of induction established by the generator in the TEM mode, setup an alternating potential across the primary coil and an alternating current flowing through the primary coil. Power is coupled to the secondary coil through the series and parallel resonant modes of the transmitter Tesla coil. Power efficiency can be measured accurately in this system because the transmitter and receiver power measurements both take place in standard twin-wire circuits that are equivalent in impedance using standard twin-wire RF power meters. The primary circuits of both the transmitter and receiver are suitably arranged to minimise resistive and parasitic inductive losses, using good RF connections and cables.

In the cavity established between the transmitter and receiver secondary coils and through the single-wire transmission medium it is conjectured that very high-efficiency transference of electric power through a 60cm 40AWG 0.08mm single wire is possible due to the LMD mode being established across the cavity, where the dielectric and magnetic fields of induction form a longitudinal wavefront that traverses the cavity establishing a standing wave with central null point, and a varying (travelling) voltage and current phase relationship along the cavity. This varying voltage and current relationship in the single-wire cavity can be visualised using the ultraviolet lamp used in the experiment where a travelling interference pattern is setup in the lamp. This interference pattern results from the longitudinal wavefront traversing backwards and forwards between the two secondary top-loads guided by the single wire in-between. In this way the longitudinal cavity extends from the top-load of the transmitter secondary through to the base, into the single-wire, and into the base of the receiver secondary up to the top-load.

When the tuning of the cavity is adjusted through the parallel modes the interference pattern can be made stationary as demonstrated in the video, and represents the optimal tuning position for the LMD mode in the cavity, it is also the point where power transfer efficiency is highest, and most power can be transferred through the cavity between the transmitter and receiver. This is also the point where a diffuse fluorescent lamp will show a null point in the electrical centre point of the cavity. Either side of this tuning the interference pattern will be seen to move towards the receiver and transmitter eventually starting to collapse towards either end of the single wire medium as the LMD mode collapses in the cavity. Coupling to the LMD mode in the secondary coil is dependent on the parallel modes in the coil and these can be adjusted very accurately using the primary tuning capacitors in the transmitter and receiver primary circuits. The LMD mode appears optimised and maximum when the primary and secondary parallel modes are balanced using the primary tuning capacitors, as shown in figures 3.

In summary, it is conjectured here that very high-efficiency transference of electric power is directly possible because of the LMD mode established in a single wire cavity, where the dielectric and magnetic fields of induction are guided around the low impedance single-wire conductor. The single-wire acts in this case like it were a monopole waveguide which would only be possible where the LM and LD modes are spatially in phase, but temporally out of phase, the condition that I conjecture is necessary for the LMD mode to form in the cavity. Real power can be transferred and dissipated at the receiver load via the single-wire transmission medium, because both the dielectric and magnetic fields of induction are guided across the cavity, and where both of these induction fields are necessary to transfer power over the cavity distance. It does not appear possible that transference of electric power can occur here through dielectric field induction alone between the transmitter and receiver coil, but rather that both the magnetic and dielectric induction fields extend across the system by virtue of LMD wavefront in the cavity, and indeed if the single-wire is disconnected from either end (guiding cavity terminated), then no power can be transferred from source to load.

All this said, it now makes sense and can be understood how 500W of power can be transferred from source to load in a TMT system where part of the cavity is a single-wire conductor the thickness of a human air. This ultra-thin section is still only a part of the guiding conductor in the cavity, and appears as yet an even more effective guide to the dielectric and magnetic fields of induction in the configuration of the LMD mode. It is conjectured here from the experiments and measurements so far, that the efficiency of transference of electric power in an LMD transmission system appears to increase as the single-wire transmission medium is reduced in conductor volume per unit length, to the boundary condition limit of the skin depth for the material, in this case ~ 0.046mm (46μm) in copper at 2Mc, where the efficiency would reach a maximum before falling-off again.

Fig. 4.6. shows the comparison of the transmitter and receiver power measured during sustained transference of 500W of power between the source and load, where the wattmeter gauges have been combined from Figs. 4.4 and 4.5 into a single image. The transmitter meter on the left shows 520W of power, and the receiver on the right 515W of power. The calculated transference of electric power efficiency in this case is 99% ±1%, and could be measured consistently during the period of operation. Other measurements of power transfer efficiency were taken at various positions and states of tune in the video experiment and consistently in the range 95% – 100%. 100% power efficiency was measured initially when using the 0.08mm single-wire conductor but dropped to a constant 99% after further tuning adjustments.

Summary of the results and conclusions so far

In this post we have experimentally observed high-efficiency transference of electric power sustained at 99%, and maximum 100%, with a estimated error of ±1%. The experiments were conducted in the close mid-field region in a TMT system driven with a linear amplifier generator, and using high power incandescent lamp loads in the receiver primary circuit. From the experimental results and measurements presented the following observations, considerations and conjectures are made:

1. The high-efficiency transference of electric power across a 0.08mm single-wire transmission medium is possible because of the Longitudinal magneto-dielectric (LMD) mode established in the cavity between the transmitter and receiver secondary coils.

2. The transfer of power in the LMD mode across the cavity results in the dielectric and magnetic induction fields being guided around the single-wire like a monopole waveguide. Power does not appear to be coupled from transmitter to receiver by dielectric induction alone.

3. The LM and LD modes are spatially coherent (in-phase) and temporally out-of-phase, combining to form the LMD mode that belongs to longitudinal transference phenomena.

4. The LMD mode shows voltages and currents that can be measured along the wire with changing phase relationship, and is considered in more detail in Transferece of Electric Power – Part 1.

5. The LMD mode forms as a standing wave in the cavity with a null point at the centre of the reciprocal cavity which can be observed using a fluorescent lamp.

6. The LMD mode can be observed through the interference pattern generated in a ultraviolet lamp placed close to the single wire cavity, from the longitudinal wavefront traversing backward and forward across the cavity. Tuning of the cavity using the parallel resonant modes in the transmitter and receiver varies the direction of interference, and is stationary at the optimum point.

7. The efficiency of transference of electric power in an LMD transmission system appears to increase as the single-wire transmission medium is reduced in conductor volume per unit length, to the boundary condition limit of the skin depth for the material.

8. The optimal efficiency transference of electric power requires optimal matching of the generator to the transmitter coil at the fundamental series resonant mode in order to transfer as much power as possible into the secondary cavity, correct tuning of the LMD mode through coil geometry and parallel mode tuning, and optimal matching between the receiver coil and the load to extract the maximum power.

This post has explored aspects of the TEM and LMD modes in the high-efficiency transference of electric power, including generator matching, tuning, and observation and measurement of various phenomena associated with TMT operation using a linear amplifier generator. The experiments conducted here are in the close mid-field region and form an encouraging starting point to extend the distance between the transmitter and receiver. Further work in progress, and to be subsequently reported, includes transference of electric power using longer single-wires where the transmitter and receiver are placed in different rooms, and buildings, and comparison over the same distance with ground connected transmission, and full Telluric transmission for far-field experiments.

Click here to continue to the next part, looking at High-Efficiency Transference of Electric Power – 11m Single Wire.

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1. A & P Electronic Media, *AMInnovations by Adrian Marsh*, 2019, EMediaPress

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EXPERIMENTS, LONGITUDINAL MAGNETO DIELECTRIC, SINGLE WIRE CURRENTS, TESLA, TRANSFERENCE, WIRELESS TRANSMISSION

High-Efficiency Transference of Electric Power – 11m Single Wire

10TH JANUARY 2021

In this second part on high efficiency transference of electric power, we take a look at the characteristics and power efficiency of a cylindrical coil TMT system where the transmitter and receiver coils are spaced further apart in the mid-field region. In this experiment a single wire transmission medium 11m long is used to separate the coils into different rooms at the laboratory, and a remote camera is used to observe the power at the receiver load measured by an RF wattmeter. Transference of electric power over 11m, and the characteristics of a TMT system coupled by the LMD mode at this distance, is shown to be remarkably different from the close mid-field region, and requires a very different setup and configuration of the experimental apparatus in order to optimise the efficiency of power transfer up to 96%.

In the close mid-field region with a 2m single-wire in the previous experiment on High-Efficiency Transference of Electric Power, the maximum transfer efficiency was achieved when the TMT system was configured, tuned, and operated at the point where the parallel modes were balanced, and the generator was optimally impedance matched to the system. It was conjectured that this balance contributes to maximising the power transferred from the generator to the twin-wire primary circuit TEM mode, to the single-wire LMD mode within the cavity formed between the transmitter and receiver secondary coils, and back to the twin-wire primary circuit TEM mode to the load.

In the mid-field region with an 11m single-wire we will see that this balanced mode setup leads to a maximum efficiency of ~40%. It is demonstrated that it is necessary to significantly mismatch the balance between the transmitter and receiver coils in order to get the LMD mode to extend across the single-wire transmission medium and restore transfer efficiency to over 90%. Transmitter and receiver primary circuit mismatch is mainly used to restore the transfer efficiency, along with fine adjustment through generator to TMT system TEM mismatch, measured at a range of Standing Wave Ratio (SWR) of 1, $\pi/2$, φ (the golden ratio), and 2.

The video experiment demonstrates and includes aspects of the following:

1. Small signal ac input impedance Z_{11} for a cylindrical coil TMT system in the mid-field region, and connected via an 11m 12AWG single wire transmission medium.

2. Z_{11} balanced parallel mode impedance measurements, for a reciprocal TMT configuration with 3 primary turns and matched primary capacitor tuning.

3. Z_{11} unbalanced parallel mode impedance measurements, for a non-reciprocal TMT configuration with 4 transmitter primary turns, 2 receiver primary turns, and mismatched capacitor tuning.

4. Transference of electric power from the linear amplifier generator to a 500W incandescent lamp load at the TMT receiver output via the reciprocal TMT configuration, and with a measured efficiency around 40%.

5. Transference of electric power to a 500W incandescent lamp load at the TMT receiver output via the non-reciprocal TMT configuration, and with a measured efficiency of up to 96%.

6. Demonstration of the high tension and associated discharge that can be drawn from the high-end of the receiver secondary coil, via the 11m single wire.

7. Transference of electric power efficiency measurements up to 96% (90% average) at 400W dissipated load power (peak 500W), in the 160m amateur radio band at 2.01Mc, and via an AWG12 single wire 11m long between the TX and RX coils.

Video Notes: The receiver power meter reading is shown on the inset video in the top right corner. For clear viewing and reading of the inset meter readings, and the VNWA software measurements, “720p” or “1080p” video quality is recommended, and may need to be selected manually from the settings icon once playback has started.

The experimental system circuit diagram, followed by an overview of the linear amplifier generator components is available here.

Figures 1 below show the key small signal input impedance characteristics Z_{11} presented in the video experiment, along with a more detailed analysis as to their impact on the observed and measured experimental results.

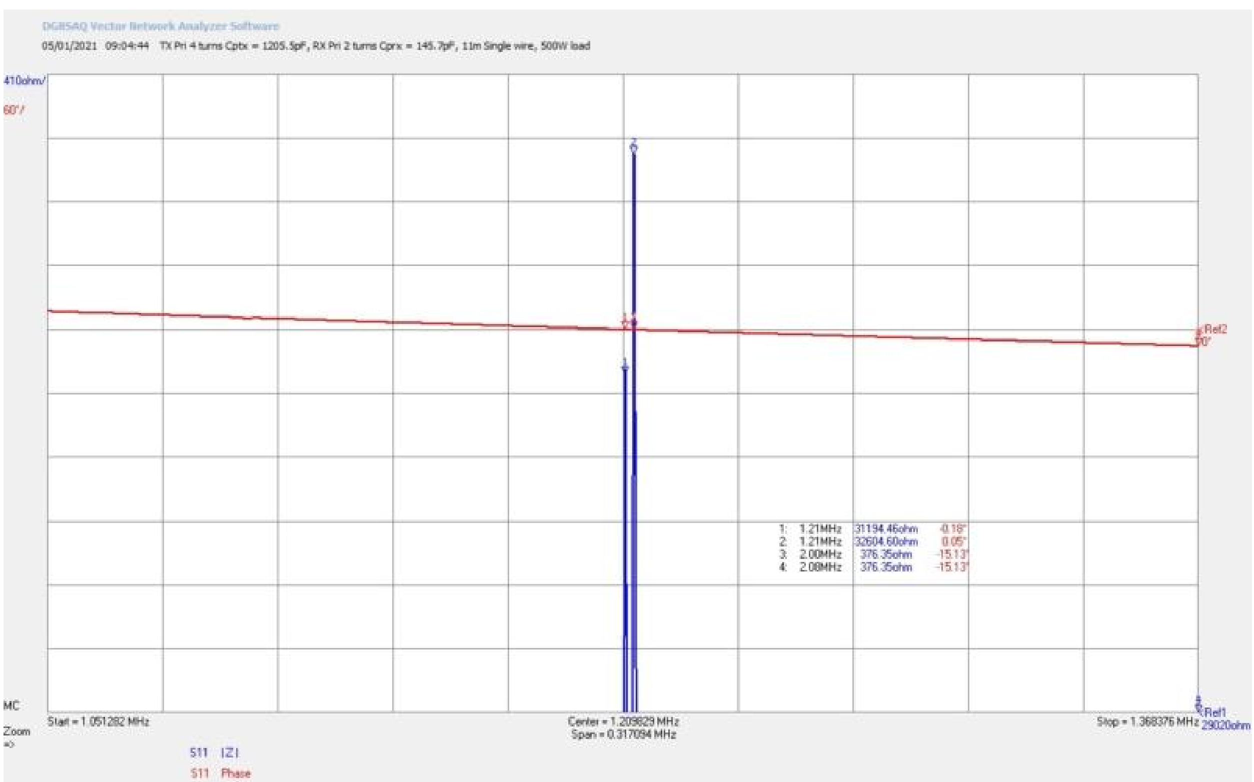

Fig 1.1. Shows the balanced and reciprocal input impedance for the cylindrical TMT system with 11m single wire transmission medium. The parallel modes, at markers M_1, M_2, M_4, and M_5, are balanced in the normal way by adjusting the primary tuning capacitors at both the transmitter and the receiver. The fundamental series resonant frequency M_3 @ 2.02Mc has a series resistance R_S = 11.3Ω, and is the primary drive point for the linear amplifier generator used in the experiment, with fine tuning around this point established at 2.01Mc as the optimum point. The parallel modes, one from the primary and one from the secondary, for both the transmitter and receiver coils are balanced, and show the frequency splitting that occurs when resonant modes of a very similar frequency are coupled together.

This form of impedance characteristic has been very well covered before in many posts on the website, and is discussed in detail in Cylindrical Coil Input Impedance – TC and TMT Z11. Previously these characteristics have been studied in the close mid-field region, typically with a single wire in the region of 1.5-2m long, or at least 2-3 times the diameter of the secondary coil, (0.5m in the case of the cylindrical TC). In this region the coupling between the transmitter and receiver coils, via the single wire transmission medium has been shown to be significant and the parallel modes split up to 200kc apart in frequency, as can be seen here. Within the split parallel regions there is a well defined and distinctive phase change from the extended series mode. The extended series modes, both upper and lower, can also be used as drive points for a linear amplifier generator, although the series resistance at these points is higher than the fundamental series mode, and ultimately will couple less total power from the generator through the TMT system.

With the single wire now extended to 11m in the mid-field region it can be clearly seen in this impedance scan that the coupling between the parallel modes of the transmitter and receiver has reduced, the frequency split is less at 30kc, and the extended series mode phase change is only just defined between markers M_1-M_2 and M_4-M_5. The fundamental series mode remains dominant at M_3 and is the optimum drive point for linear amplifier generator. Overall the transmitter and receiver coils are coupled together by the single wire transmission medium in the TEM mode, but the coupling is reduced from the close mid-field region, and the additional impedance of the longer single wire is transformed back through into the transmitter primary and reflected in the increased series mode resistance at M_3, R_S = 11.3Ω.

Fig 1.2. Shows the effect of adding a 500W incandescent lamp load at the receiver primary coil output. The transmitter primary tuning capacitor C_{PTX} has been adjusted from 663pF to 711pF in order to balance the transmitter parallel modes. The receiver primary tuning capacitor C_{PRX} remains the same at 793pF. The resistive and inductive loading presented by the high-power incandescent lamp at the receiver has significantly changed the operating characteristics of the TMT system from a well balanced cavity, to a strongly unbalanced cavity, at least in terms of the TEM input impedance Z_{11}.

The parallel modes of the receiver coil have been almost entirely suppressed with only a very slight presence at M_3, and the overall resonant circuit properties of the receiver distorted and skewed away from the reciprocal coil characteristics of the unloaded receiver TC, to the characteristic shown at M_3. It is important to note that this huge imbalance in the receiver end of the cavity in both the TEM mode, and I would conjecture the LMD mode due to the definite and distinctive change in the parallel modes, leads to a setup in this experiment where the transmitter end also needs to be unbalanced in order to reestablish the maximum efficiency in the transference of electric power. It is conjectured and discussed later that the setup change to the transmitter establishes a balance again in the LMD mode in the cavity when the total effect of the receiver and the longer single wire are taken into account together.

The fundamental series resonant mode has shifted down very slightly to 2.01Mc, R_S = 13Ω, which was found to be the optimum drive point for the linear amplifier generator during the tuning and setup part of the experiment prior to the video experiment itself. The balanced reciprocal setup shown in figures 1.1 on this page, and 2.1 here , which was so effective in the close mid-field region, is shown to yield a maximum power transfer efficiency of now more than 35-45%. It is clear that the coupling introduced by the single-wire transmission medium and the impedance that this presents to both the TEM and LMD mode is critically important in both the setup and operation of a TMT system over distance.

Fig 1.3. Here the setup of the transmitter and receiver has been changed from that of the balanced reciprocal cavity condition, which yields power transfer efficiencies no higher than 35-45%, to the seemingly mismatched characteristic that yields measured transfer efficiencies up to 96% in the experiment. This setup requires the transmitter primary turns to be increased from 3 to 4, and a significant increase in the primary tuning capacitor C_{PTX} = 1206pF. In correspondence, the setup of the receiver primary turns is also decreased from 3 to 2, and the primary tuning capacitor is significantly reduced to C_{PRX} = 146pF. In this setup the input impedance Z_{11} for the TEM mode appears highly imbalanced, however for the LMD mode it is conjectured that a strong coupling and balance is re-established.

The fundamental series resonance at M_3 has again only shifted very slightly in frequency to 2.0Mc, as the wire length of the experiment, the biggest contributor to this mode, remains constant, and with an increased series resistance R_S = 22.8Ω. This still represents the best generator drive point for this experiment, with the lowest series resistance, and maximum coupling to the both the series and parallel modes that are active in this configuration. Transmitter parallel modes at M_1, M_2, and heavily suppressed around M_3 and M_4, are shifted quite considerably by the primary tuning capacitor mismatch. The dominant parallel modes, and hence conjectured to contribute most strongly to the LMD mode in the cavity, are now at M_1 and M_2 and involve both the transmitter and receiver, which will become apparent in the next figure. It should be noted that this figure is on a vertical magnitude of impedance scale of 4kΩ, whereas the previous figures where set to 1.5kΩ. This emphasises the very strong lower parallel modes and suggests that the transmitter pump action, from the generator to the LMD mode in the cavity, has been preferentially increased at this lower frequency of 1.2Mc.

The reduction in the primary setup at the receiver appears to have loosened the coupling between the primary and secondary coils of the receiver, which in turn has increased the Q of the free resonance in the secondary coil, increasing the phase change at M_3, and emphasising the receiver characteristics transformed across the single wire cavity back to the transmitter. In short it appears like the LMD pump action into the cavity has been increased, whilst the Q of the receiver has also been increased. It is conjectured here that this combination of effects re-establish a balanced condition for the LMD mode, and hence a low impedance path for this mode across the cavity. With the LMD mode established across the cavity the efficiency of power transfer is pushed right back up to 95+%. Losses in the TEM mode are clearly increased with the longer single wire, but it is conjectured this is not the case for the LMD mode which is coherent spatially but not temporally over the entire cavity.

The split in frequency between the fundamental series mode at M_3 and the upper extended series mode at M_4 is now only 80kc, which is a very different condition than that which occurs in the balanced non-loaded mode. This close correspondence between these series two modes at the transmitter and receiver suggests part of the mechanism that allows very high-efficiency transference of electric power, where power is coupled from the primary to the secondary and hence into series modes to parallel modes, and then back through parallel modes to series modes at the receiver, a transformation across the TMT system from TEM to LMD and back to TEM mode in the load. Ultimately real power is passed from the generator through to the load which requires the TEM mode in both primary circuits, and the LMD mode as a result of the combined LM and LD modes across the cavity of the TMT.

Fig 1.4. Here we see a zoom of the peak of the dominant parallel mode from the previous figure at M_1 and M_2. Very interestingly we see that this peak is actually split into two peaks, suggesting two parallel modes that are dominant in both the transmitter and receiver but very weakly coupled. This now sets up the condition that we have two parallel modes separated by only ~ 1kc, and two series modes separated by only 80kc, from both the transmitter and receiver. I conjecture that it is this combination of series and parallel modes at each end of the TMT that makes it possible to yield very high-efficiency transference of electric power in this TMT system with a longer single-wire.

So what appears to be a loaded and unbalanced setup actually yields a TMT system that is balanced and matched for both the TEM **and** LMD modes combined. From a TEM perspective of the input impedance Z_{11} this appears to be heavily loaded and biased towards the transmitter, but on closer inspection and analysis suggests a configuration that balances the system between transmitter and receiver for maximum efficiency, minimum impedance for power transfer, and optimal conditions for the 500W incandescent load used in the experiment. Fine tuning of this configuration was further demonstrated by introducing a non-zero reflection coefficient from the transmitter primary circuit to the generator. This was accomplished by progressive adjustment of the antenna tuner away from the optimum SWR of 1.0, increasing up to 2.0. A standing wave ratio of $\pi/2$ to φ (the golden ratio) were found to increase the efficiency slightly making the difference between a stable 90% efficiency up to a maximum in this experiment of 96%.

It is suggested here that the TEM mismatch at the transmitter primary circuit is a method of fine tuning the balance of the circuit for the TEM and LMD modes combined. The balance between these two modes, and hence the energy coupled into and between these modes, and across the complete TMT system and cavity, appears to have the most impact on the power transfer efficiency.

Summary of the results and conclusions so far

In this post we have experimentally observed high-efficiency transference of electric power sustained at 90%, and with fine tuning and adjustment up to a maximum of 96% with an estimated error of ±1%. The power was transferred using a cylindrical coil based TMT system, where the transmitter and receiver are coupled by an 11m single wire transmission medium. 400W of power could be stably passed from the linear amplifier generator to the incandescent load at maximum transfer efficiency (90-96%), and up to 500W was tested at a reduced efficiency ~85%. From the experimental results and measurements presented the following observations, considerations and conjectures are made:

1. The “ideal” balanced reciprocal cavity setup, optimal in the close mid-field region, is not efficient for optimum power transfer in the more distant mid-field region, and most specifically when driving a heavy load at the receiver output.

2. An unbalanced TEM setup at the transmitter and receiver coil appears to restore the overall combined balance of the TEM and LMD modes across the entire TMT system restoring the high-efficiency power transfer characteristics in the mid-field region.

3. The unbalanced TEM setup appears to increase the LMD pump action into the cavity, whilst the Q of the receiver has also been increased by loosening the primary receiver coupling. It is conjectured here that this combination of effects re-establish a balanced condition for the LMD mode, and hence a low impedance path for this mode across the cavity.

4. The Z_{11} impedance characteristics in the unbalanced setup and when loaded at the receiver with a 500W incandescent lamp show a fine split between the series modes and the dominant lower parallel modes, which appears to show the transmitter and receiver coupled together in both the TEM and LMD modes

5. This close correspondence between these modes at the transmitter and receiver suggests part of the mechanism that allows very high-efficiency transference of electric power, where power is coupled from the primary to the secondary and hence into series modes to parallel modes, and then back through parallel modes to series modes at the receiver, a transformation across the TMT system from TEM to LMD and back to TEM mode at the load.

6. The maximum transfer efficiency could be fine tuned by mismatching the generator to the primary transmitter circuit and hence creating a reflection coefficient in the transmitter part of the system. SWRs in the region 1 to 2 were tested, with the best results around $\pi/2$ to φ (the golden ratio).

7. It is suggested, but needs considerable further work to develop, that the impedance presented by the single-wire transmission medium to the LMD mode is not the same as that presented to the TEM mode, and where a narrow single wire to the limit of the skin depth would appear as a high impedance at the driving

frequency to the TEM modes, this is not the case for the LMD modes. For the LMD modes (LM and LD) the single-wire appears as a low impedance monopole waveguide which is spatially coherent over the extent of the cavity.

This experiment has opened up a range of interesting questions that need further consideration and considerable investigation to answer and progress, and most particularly from conclusion 7; to understand and establish in more detail the impedance presented by a single-wire transmission medium to the LMD mode generated in the cavity. It would also be interesting to compare the single-wire to a Telluric transmission medium, which will be the focus of the next experiment in this series. This experiment will look at transference of electric power over a 40m single-wire where the transmitter and receiver are in separate buildings of the lab, and also to compare the measured performance to a Telluric connection between the two via a basic ground system at each end.

Click here to continue to the next part, looking at Transference of Electric Power – Single Wire vs Telluric.

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1. Tesla, N., *Colorado Springs Notes 1899-1900*, Nikola Tesla Museum Beograd, 1978.

2. A & P Electronic Media, *AMInnovations by Adrian Marsh*, 2019, EMediaPress

3. Dollard, E. and Energetic Forum Members, Energetic Forum, 2008 onwards.