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WITRICITY REVIEW THROUGH MAGNETIC RESONANCE COUPLING

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ABSTRACT

A moment without electricity makes your thinking go dry. The major source of conventional form of electricity is through wires. The continuous research and development has brought forward a major breakthrough, which provides electricity without the medium of wires. This wonder baby is called WiTricity.If we are particularly organized and good with tie wrap then also a few dusty power cord tangles around our home. We have even had to follow one particular cord through the seemingly impossible snarl to the outlet hoping that the plug pull will be the right one. This is one of the downfalls of electricity. While it can make people's lives easier, it can add a lot of clutter in the process. For these reasons, scientists have tried to develop methods of wireless power transmission that could cut the clutter or lead to clean sources of electricity. Wireless power transmission is not a new idea. Many researchers developed several methods for wireless power transmission. But WiTricity is a new technology used for wireless power transmission. By the use of this technology transmission of electrical energy to remote objects without wires can be possible. The inventors of WiTricity are the researchers from Massachusetts Institute of Technology (MIT). They developed a new technology for wireless electricity transmission and this is based upon the coupled resonant objects. In this resonant magnetic fields are used. So the wastage of power is reduced. The system consists of WiTricity transmitters and receivers. The transmitters and receivers contain magnetic loop antennas made of copper coils and they are tuned to the same frequency.

KEYWORDS: Magnetic Loop Antenna, Wireless Power Transmission WiTricity

INTRODUCTION

Electricity is today a necessity of modern life. It is difficult to imagine passing a day without electricity. The conventional use of electricity is made possible through the use of wires. However researchers in MIT have devised a means of providing electricity without any wires WiTricity, a portmanteau for wireless electricity, is a term coined initially by Dave Gerding in 2005 and used by an MIT research team led by Prof. Marin in 2007.

Wireless power transmission is not a new idea; Nikola Tesla demonstrated a "transmission of electrical energy without wires" that depends upon electrical conductivity as early as 1891 The receiver works on the same principle as radio receivers where the device has to be in the range of the transmitter. It is with the help of resonant magnetic fields that witrecity produces electricity, while reducing the wastage of power. This is unlike the principle adopted by Nikola Tesla in the later part of the 19th century; where conduction based systems were used. The present project on WiTricity aims at power transmissions in the range of 100 watts. May be the products using WiTricity in future might be called Witric or Witric's So far the Recently, MIT proposed a new scheme based on strongly coupled magnetic resonances, thus presenting a potential breakthrough for a mid-range wireless energy transfer. The fundamental principle is that resonant objects exchange energy efficiently, while non-resonant objects do not. Figure 1 shows the basic coil system composed of four coils: drive, transmit resonance, receive resonance, and load coils. The transmit resonance coil is coupled to the drive coil which is linked to a power amplifier that supplies energy to the system. The receive resonance coil is coupled with the load coil to provide the power to an external load. The scheme is carried with a power transfer of 60 W and has RF-to-RF coupling efficiency of 40% for a distance of 2 m, which is more than three times the coil diameter. We expect that coupled magnetic resonances will make possible the commercialization of a mid- range wireless power transfer.Magnetic resonance coupling is a new concept in wireless energy transmission[2].

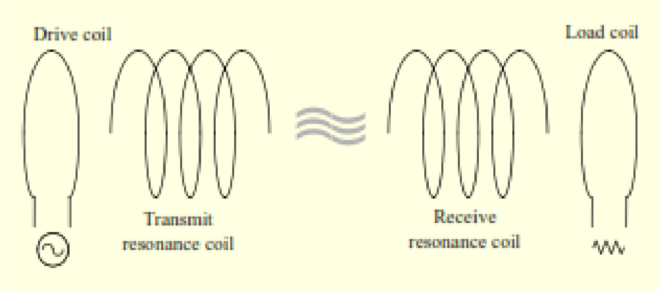

Figure 1: Schematic of Wireless Energy-Transfer System Using Coupled Magnetic Resonances

In recent years, there has been an increasing interest in wireless power transfer technology. In particular, significant progress has been charted for inductively coupled systems .Inductively coupled power transfer systems have been developed for a wide range of applications, including vehicle battery charging systems, and a very high end-to-end system efficiency of up to 80% has been documented . However, most studies have been restricted to close range, that is, typically shorter than 30% of the coil diameter. The transmission distance is generally close to 1 cm, and 15 cm is considered a fairly large distance . Results at the mid- range (that is, more than twice the coil diameter) have not been reported.

HISTORY OF WIRELESS ENERGY TRANSFER [4]

- 1820: André-Marie Ampère develops Ampere's law showing that electric current produces a magnetic field.
- 1831: Michael Faraday develops Faraday's law of induction, an important basic law of electromagnetism
- 1864: James Clerk Maxwell synthesizes the previous observations, experiments and equations of electricity, magnetism and optics into a consistent theory and mathematically models the behavior of electromagnetic radiation.
- 1891: Nikola Tesla improves Hertz-wave transmitter RF power supply in his patent No. 454,622 "System of Electric Lighting."
- 1893: Tesla demonstrates the wireless illumination of phosphorescent lamps of his design at the World's Columbian Exposition in Chicago
- 1894: Tesla wirelessly lights up single-terminal incandescent lamps at the 35 South Fifth Avenue laboratory, and later at the 46 E. Houston Street laboratory in New York City by means of "electrodynamic induction," i.e., wireless resonant inductive coupling.
- 1896: Tesla transmits signals over a distance of about 48 kilometers (30 mi)
- 1897: Guglielmo Marconi uses a radio transmitter to transmit Morse code signals over a distance of about km.
- 1897: Tesla files the first of his patent applications dealing with wireless transmission.
- 1917: Tesla's Wardenclyffe tower is demolished.
- 1926: Shintaro Uda and Hidetsugu Yagi publish their first paper on Uda's "tuned high-gain directional array"better known as the Yagi antenna.
- 1961: William C. Brown publishes an article exploring possibilities of microwave power transmission.

- 1968: Peter Glaser proposes wirelessly transferring solar energy captured in space using "Powerbeaming"technology. This is usually recognized as the first description of a solar power satellite.
- 2007: A physics research group, led by Prof.Marin Soljačić, at MIT confirm the earlier (1980's) work of Prof. Boys by wireless powering of a 60W light bulb with 40% efficiency at a 2 metres (6.6 ft) distance using two 60 cm- diameter coils.
- 2009: A Consortium of interested companies called the Wireless Power Consortium announced they were nearing completion for a new industry standard for low-power Inductive charging
- 2009: Texas Instruments releases the first device.
- 2010-11: Haier Group debuts the world's first completely wireless LCD television at CES 2010 based on Prof. Marin Soljacic's follow-up research on wireless energy transfer and Wireless Home Digital Interface (WHDI).

SOME TERMS RELATE WITH WITRICITY

WiTricity Technology

The Basics Understanding What WiTricity technology is transferring electric energy or power over distance without wires is quite simple. Understanding how it works is a bit more involved. We'll start with the basics of electricity and magnetism, and work our way up to the WiTricity technology.

Electricity

The physical phenomena arising from the behavior of electrons and protons that is aused by the attraction of particles with opposite charges and the repulsion of particles with the same charge.

Magnetism

A fundamental force of nature, which causes certain types of materials to attract or repel each other. Permanent magnets, like the one on your refrigerator and the earth's magnetic field, are examples of objects having constant magnetic fields. Oscillating magnetic fields vary with time, and can be generated by alternating current (AC) flowing on a wire. The strength, direction, and extent of magnetic fields are often represented and visualized by drawings of the magnetic field lines[4].

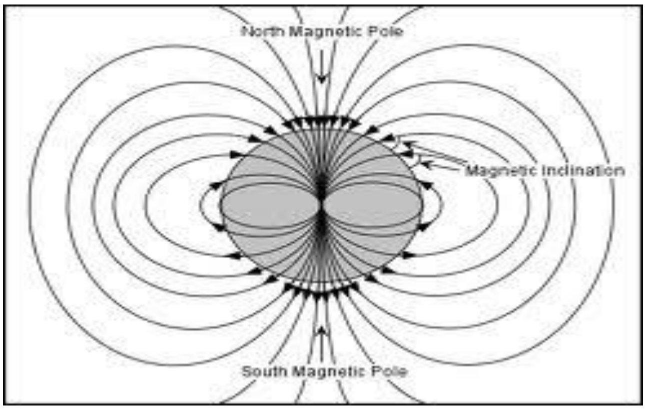

Figure 2: Illustration Representing the Earth's Magnetic Field

Electromagnetism

A term for the interdependence of time-varying electric and magnetic fields. For example, it turns out that an oscillating magnetic field produces an electric field and an oscillating electric field produces a magnetic field.

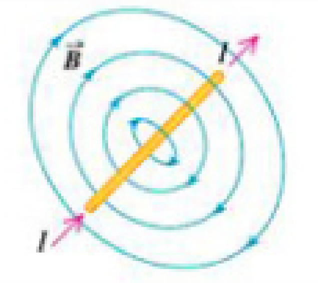

Figure 3: Illustration Representing the Electro Magnetic Field

As electric current, I, flows in a wire, it gives rise to a magnetic field, B, which wraps around the wire.When the current in reverses direction, the magnetic field also reverses its direction.

Magnetic Induction

The amount of magnetic flux in a unit area perpendicular to the direction of magnetic flow.Some common examples of devices based on magnetic induction are electric transformers & electric generator.

Energy/Power Coupling

Energy coupling the transfer of electrical energy from one circuit segment to another. One simple example is a locomotive pulling a train car the mechanical coupling between the two enables the locomotive to pull the train, and overcome the forces of friction and inertia that keep the train still and, the train moves. Magnetic coupling occurs when the magnetic field of one object interacts with a second object and induces an electric current in or on that object. In this way, electric energy can be transferred from a power source to a powered device. In contrast to the example of mechanical coupling given for the train, magnetic coupling does not require any physical contact between the object generating the energy and the object receiving or capturing that energy.

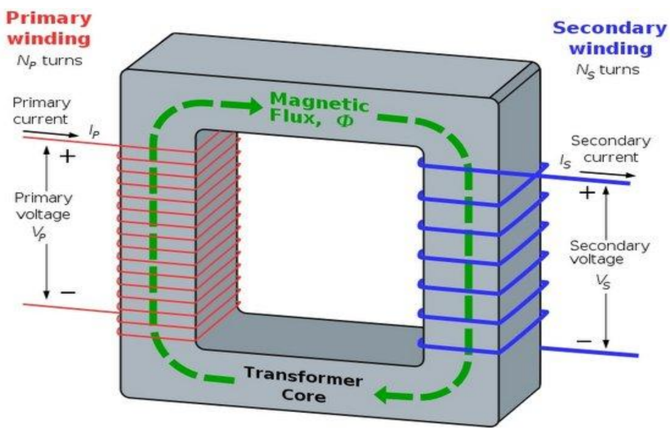

Figure 4: Schematic Energy / Power Coupling

An electric transformer is a device that uses magnetic induction to transfer energy from its primary winding to its secondary winding, without the windings being connected to each other. It is used to “transform” AC current at one voltage to AC current at a different voltage.

Resonant Magnetic Coupling

Magnetic coupling occurs when two objects exchange energy through their varying or oscillating magnetic fields. Resonant coupling occurs when the natural frequencies of the two objects are approximately the same.

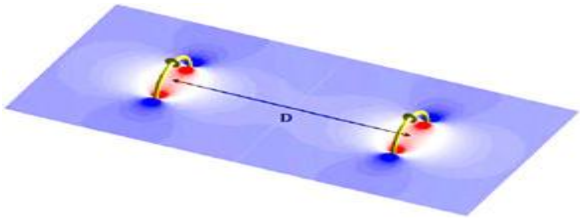

Figure 5: Two Idealized Resonant Magnetic Coils

Two idealized resonant magnetic coils, shown in yellow. The blue and red color bands illustrate their magnetic fields. The coupling of their respective magnetic fields is indicated by the connection of the color bands[4] .

WiTricity Technology

WiTricity power sources and capture devices are specially designed magnetic resonators that efficiently transfer power over large distances via the magnetic near-field. These proprietary source and device designs and the electronic systems that control them support efficient energy transfer over distances that are many times the size of the sources/devices themselves.

The WiTricity power source, left, is connected to AC power. The blue lines represent the magnetic near field induced by the power source. The yellow lines represent the flow of energy from the source to the WiTricity capture coil, which is shown powering a light bulb. Note that this diagram also shows how the magnetic field (blue lines) can wrap around a conductive obstacle between the power source and the capture device.

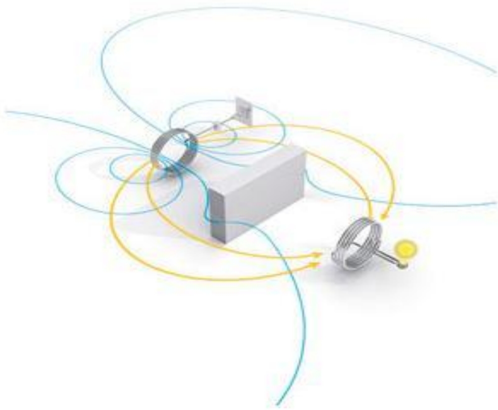

Figure 6: WiTricity Technolgy

The Possibility of Energy Transfer via Coupled Magnetic Resonances

The general principle is that if a given amount of energy is placed into a primary coil which is capacitively loaded, the coil will 'ring', and form an oscillating magnetic field. The energy will transfer back and forth between the magnetic field in the inductor and the electric field across the capacitor at the resonant frequency. This oscillation will die away at a rate determined by the Q factor, mainly due to resistive and radiative losses. However, provided the secondary coil cuts enough of the field that it absorbs more energy than is lost in each cycle of the primary, then most of the energy can still be transferred.

The primary coil forms a series RLC circuit, and the Q factor for such a coil is:

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Because the *Q* factor can be very high, (experimentally around a thousand has been demonstrated with air cored coils) only a small percentage of the field has to be coupled from one coil to the other to achieve high efficiency, even though the field dies quickly with distance from a coil, they can be several diameters apart.

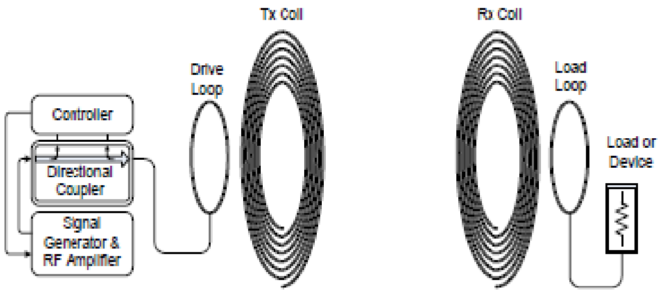

Figure 7: Sketch of the Magnetically Coupled Resonance Wireless Power System

We present a model of magnetically coupled resonators in terms of passive circuit elements and derive system optimization parameters. Additionally, a method for automatically tuning the wireless power system is demonstrated, so that the maximum possible transfer efficiency is obtained for nearly any distance and/or orientation as long as the receiver is within the working range of the transmitter. This is important from a practical standpoint because in many applications, such as laptop recharging, the range and orientation of the receive device with respect to the transmit device varies with user behaviour[4].

NEED OF WITRICITY

WiTricity is nothing but wireless electricity. Transmission of electrical energy from one object to another without the use of wires is called as WiTricity. WiTricity will ensure that the cell phones, laptops, iPods and other power hungry devices get charged on their own, eliminating the need of plugging them in. Even better, because of WiTricity some of the devices won't require batteries to operate.

Imagine a future in which wireless power transfer is feasible: cell phones, household robots, mp3 players, laptop computers, and other portable electronics capable of charging themselves without ever being plugged in, freeing us from that final, ubiquitous power wire. Some of these devices might not even need their bulky batteries to operate.

SYSTEM OVERVIEW

Energy Transfer System via Coupled Magnetic Resonance

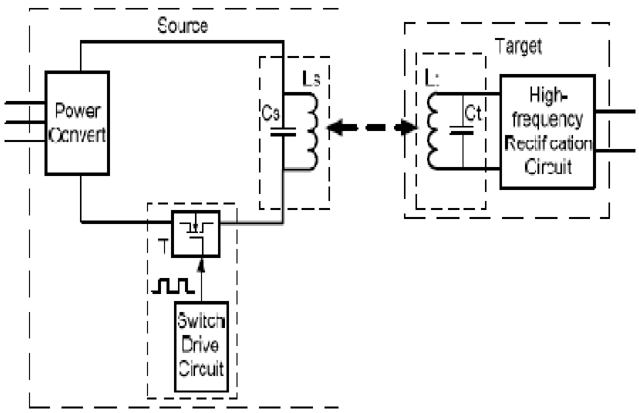

Figure 8: Block Diagram of Energy Transfer System via Coupled Magnetic Resonance

As shown in figure, a simple structure of energy transfer system via coupled magnetic resonance is proposed. The energy supply of source is provided by power convert module, inductor L_s and capacitor C_s constitute a resonance source circuit to generate an alternative non-radiative magnetic field. The resonance frequency of LC circuit is f_s . The control signal for power switch tube T is generated by switch drive circuit, and its frequency is f_k . In theory, when f_t is close or equal to f_s , the oscillation of source resonance circuit is strongest, the value of resonance current is highest, and the magnetic field intensity is also strongest. Inductor L_t and capacitor C_t constitute the receiving resonance circuit to produce resonance with the magnetic field which generated by source resonance circuit to receive energy. The frequency of receiving resonance circuit is f_t, the parameters of L_t and C_t needn't be in full accord with the source resonance circuit. What the receiving resonance circuit must need is to ensure $f_s = f_t$, that is the necessary condition for energy transfer[2].

Circuit Representation of a Resonant Coupled System with a Single Load

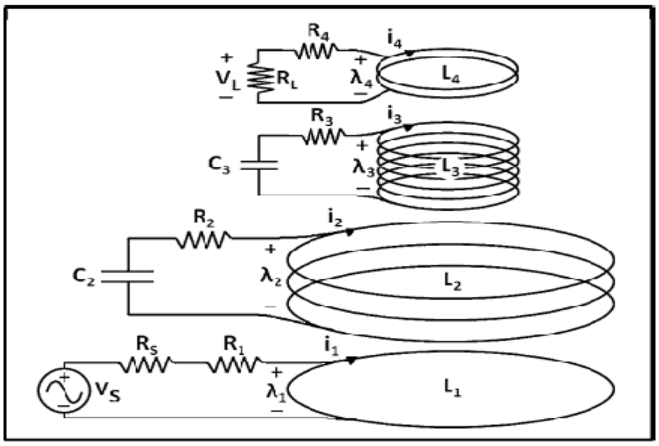

Figure 9: A Schematic Circuit Drawing of a Source Coil Pair and a Signal-Receiving Coil Pair. Each Load in Multiple Receiver System Involves a Receiving Coil Pair

Fig. 8 shows a schematic circuit representation of a system like the experimental system shown in above figure, but with only a single load coil pair. We use this system to develop an understanding of the resonant coupling mechanism and to serve as a basis for extending it to multiple receivers. In the single receiver system of Fig. 8, the source drives a large single-turn coil, labelled L_1 that is inductively coupled to a large multi turn resonant coil L_2 of the same diameter. The small resonant coil L_3 is inductively coupled to a small coil of the same diameter, labelled L_4, that is terminated by a load element. Lumped capacitors C_2 and C_3 respectively terminate the resonant coils L_2 and L_3. The resistances R_1, R_2, R_3, and R_4 are the small resistances of the coils themselves, while Rs is the internal resistance of the source, and R_L is the load resistance.

The two identical open-circuited "self-resonant" coils, with a resonant frequency based upon the distributed inductance and distributed capacitance of each coil. Here, with completely different source and receiver coils, the lumped capacitances are chosen so as to yield identical resonant frequencies,

$$\omega_0 = \frac{1}{\sqrt{L_2 C_2}} = \frac{1}{\sqrt{L_3 C_3}}$$

This alteration provides a simple means to achieve resonant coupling between a large source coil and one or several small receiving coils [3].

SYSTEM ANALYSIS

Circuit Analysis

A circuit model for the experimental setup with only one receiving coil pair driving a single load, as represented in Fig.7 is based upon the application of Kirchhoff's voltage law around each of the four loops. The voltage at the terminals of each coil is described as the time rate of change offlux linkage. Λ_1 through Λ_4 and i_1 through i_4 represent complex amplitudes of flux linkages and currents in each of the four coils; V_S represents the complex amplitude of the ideal voltage source. With resistances R_1 through R_4, R_S, and R_L, and capacitances C_2 and C_3, the circuit constraints at frequency ω are

$$V_S = (R_S + R_1) + i_1 + j\omega\Lambda_1 \quad \dots\dots\dots\dots\dots (1)$$

$$0 = R_2 i_2 + \frac{i_2}{j\omega C_2} + j\omega\Lambda_2 \quad \dots\dots\dots\dots\dots (2)$$

$$0 = R_3 i_3 + \frac{i_3}{j\omega C_3} + j\omega\Lambda_3 \quad \dots\dots\dots\dots\dots (3)$$

$$0 = (R_4 + R_L) i_4 + j\omega\Lambda_4 \quad \dots\dots\dots\dots\dots (4)$$

Since each of the four coils is inductively coupled to the other three, the flux linkages are related to the currents by a symmetric 4 × 4 inductance matrix:

$$\begin{bmatrix} \Lambda_1 \\ \Lambda_2 \\ \Lambda_3 \\ \Lambda_4 \end{bmatrix} = \begin{bmatrix} L_{11} & M_{12} & M_{13} & M_{14} \\ M_{12} & L_{22} & M_{23} & M_{24} \\ M_{13} & M_{23} & L_{33} & M_{34} \\ M_{14} & M_{24} & M_{34} & L_{44} \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{bmatrix} \quad \dots\dots\dots\dots..(5)$$

For a known ideal source voltage V_S and known resistances, capacitances, and self inductances and mutual inductances, (1) to (4), with (5) substituted for the flux linkages, comprise four simultaneous equations that determine the currents i_1 through i_4, and thus the complex amplitude of the load voltage $V_L = -R_L\ i_4$. Since the system is linear, this analysis determines the transfer function based upon the source frequency, $|(V_L/V_S)(\omega)|$.

Extension of the circuit model to multiple loads, as for the experimental two-load system straightforward, with six equations replacing four. More generally, extension to an arbitrary number of loads. The use of a circuit model here is appropriate because, as described in, the interaction involves magneto quasistatic field structures.

Equivalently, we can compare radiated electromagnetic power with power dissipated in the resistances of the circuit model. The radiation resistance Rr of a coil with N turns and radius a, at source frequency f and corresponding free space wavelength $\lambda = c/f$ where c = 3.00 × 108 m/s is

$$R_r = \left(\frac{2\pi}{\lambda}\right)^4 (\pi a^2 N)^2$$

Coil 2, then has the largest radiation resistance, with value R_{r2} = 8.7 × 10−4 Ω which is far too small in comparison with the ohmic resistance R_2 to be significant. Unintended magnetic coupling with nearby objects is of far less significance than it would be at higher frequencies, with wavelengths on the scale of the transmitting coil. [3]

Comparative Study of Different Energy or Power Transfer System [1]

	Electromagnetic Induction	Radio Reception	Resonance
Output power	Several W to hundred KW	several dozen mW	max power of several KW
Effective Distance	Probably 1cm or less	range of several meters	range of several meters
Control Level	Simple to make and control	Hard to make but under control	Hard to make but under control
Safety Level	**Depends on the Conditions and Technical Approach**		
Convenience	Acceptable Level	Highest	Fairly

CONCLUSIONS

While scientists have built working prototypes of aircraft that run on wireless power, larger-scale applications, like power stations on the moon, are still theoretical. As the Earth's population continues to grow, however, the demand for electricity could outpace the ability to produce it and move it around. Eventually, wireless power may become a necessity rather than just an interesting idea.

This paper disclosed that WiTricity power application not much operate at full efficiency. The potential applications of WiTricity are expected to materialize in the new future, of say a few years' time, after the necessary modifications are to them. These WiTricity applications are expected to work on the gadgets that are in close proximity to a source of wireless power where in the gadget charges automatically without necessarily having to get plugged in. There are no limitations in WiTricity power application where anything and everything that used to run with batteries or electrical connections can be used using WiTricity. Just imagine, the future WiTricity power application permit you to use wireless energy, without having to replace or recharge batteries either or of remembering to recharge batteries periodically. In addition to this, with WiTricity, there is no need of plugging in any wires and plugs and thus face a mess of wires.

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