Abstract

Background/Objective: Heat dissipation due to long runs and ageing has been a major challenge for any power associated system. To combat this issue, implementation of chill mat is necessary in every electric sink to flush out the thermal heat, thereby increasing the efficiency of the system. This paper emphasizes the sophisticated solution by implementing the Chill-Mat using Enhanced Cable-less power transfer technology. Method Analysis: The chill-mat is energized using Resonant Power Transmission (RPT) by magnetic coupling and this is achieved effectively by accomplishing the perfect impedance matching design for source, repeator and device resonator to attain Maximum Power Transmission (MPT). An intermediate repeater circuitry is implemented between the source and device resonator is to enhance the flux linkage between the spirals. Results/Findings: The efficiency of the enhanced cable-less power transmission system is enhanced to 87% and the distance of power transmission is increased. This is achieved with lesser number of components in circuit design and it is superior from the existing work which shows only 70% efficiency even for a lesser distance of propagation between the spirals. Conclusion/Applications: The use of chill mat is the best solution to purge away the thermal dissipation and thus the working efficiency of the power related system is improved using Enhanced Cable-less Power Transfer technology.

Keywords: Enhanced Cable-less Power Transfer, Inductive Coupling, Impedance Matching, Maximum Power Transmission, Resonant Power Transmission

1. Introduction

Enhanced Cable-less Power Transfer (ECPT) refines the classical way of wired power transfer to the modern sophisticated way of powering the sink without the use of physical wires. The concept of wireless power transfer got its breath in the late 19th century, when Nicolai Tesla theorized the concept of cable less power transmission, which emphasizes the power transfer from source to the sink through magnetic flux linkage which is not harm to any living organism. The source terminal and the load have the spiral wound of coil which act as a transmitter and the receiver of magnetic flux lines. Those loop structures are coupled by magnetic induction. For the target of achieving the maximum power transmission, the event of resonance has to occur. Both the capacitive and inductive reactance have to be perfectly matched i.e. Impedance Matching for Resonant Power Transfer. The primary phase of the paper emphasis on introduction of cable-less power transfer. The secondary phase of the paper deals with the need, identification of the problem and practical solution to combat that issue is addressed. The tertiary phase of the paper deals with the proposed scheme which comprises of the functional block diagram, operating principle and this is followed by the project outcome, conclusion and the citation of references.

1.1 Cable-less Power Transmission

The theoretical concept of Cable-less power transmission dates back to a couple of centuries ago where Nicolai Tesla made a remarkable footprint for all present upcoming inventions using this concept. This paved the way for modern revolution which made this concept as a practical outcome to solve many problems which needs frequent charging, need for inbuilt battery and thus the size of the
sink can be reduced, because the battery occupies nearly 40% of the total system size. The basic schematic for achieving cable-less power transmission is as portrayed in Figure 1.

![Figure 1. Schematic diagram for cable-less power transmission.](image)

In the transmitter part if we use D.C power supply as a source, we have to use oscillator as an intermediate circuitry which generates continuous sinusoidal waveform to produce the time variant change in flux to energize the transmitter loop else if we use an A.C supply it is sufficient to use an amplifier as an intermediate circuitry to energize the transmitter loop. In the receiver part, we are using a rectifying element to convert the pulsating trapped A.C voltage by the receiver to D.C voltage for biasing the load terminals. The task of impedance matching and resonance has to be achieved for event of utmost power transmission to be achieved.

## 2. Existing Work

Cable-less power transfer is so-far used for energizing low power application like a smart phone wireless charging applications as cited in many journals, though the concept also holds good for heavy electronic power consuming gadgets with far field technology, but still it is not emerged in a full-fledged manner to give a solution to solve many practical issues to quench the need of this sophisticated world.

### 2.1 Literature Survey

There are many methods to implement cable-less power transfer by inductive and capacitive-coupling, here we are reviewing some of the existing works of Cable-less Power Transmission technology.

6 have implemented this technology with less distance of propagation for achieving cable-less power transmission, which is not feasible for many practical applications which requires long distance power transmission to be achieved. 7 have implemented this technique with more coil windings for energizing low power sink like LED which is less efficient and it fails to power the motor which requires the medium consumption of electric potential. 8 have implemented this concept of inductive power transfer with number of coil windings in transmitter and receiver part for achieving cable-less power transmission. 9 have utilized this technique without the usage of intermediate repeater as a booster circuit and thus, his methodology fails for medium power consuming gadgets and it suitable only for charging low power sink and it exhibits 75% efficiency only for lesser distance of cable-less power transmission which fails to be efficient when the distance between the transmitter and the receiver coil is increased.

## 3. Proposed System

This paper emphasis a concept which is a step ahead of the existing system for powering a Chill-mat which has a motor to rotate a fan, which is energized with the help of inductive power transfer by implementing a repeater circuit in-between the source and load resonator and it has the advantage of being used for multipurpose applications like laptop cooler pad, router cooler pad and many more sophisticated applications.

### 3.1 Identification of Problem

Most of the electronic and electric gadgets produce the copious quantity of heat which is a preventative factor to its effective functionality. To battle this issue we put through the wired cooling pad to flush out thermal dissipation. Those wires are clumsy when we have the bulkier systems like the main router room which has an enormous amount of interconnecting wires and again the wired connections for cooler pads or hot flushes won’t be an intelligent solution to overcome this clumsy problem.

### 3.2 Need for Cable-less Power Transfer

The impulse of modern society to be active from the wired era to the new booming wireless era is increasing day by day and this problem with clumsy wired connection for hot flusher’s in an electric sink is ruled over by sophisticated Cables less power transmission technology which energizes the cooler pad efficiently.
3.3 Working Principle of Cable-less Power Transfer Technology

The principle behind the inductive power transfer is made on two laws Lenz law and Faraday's law.

i. Lenz law: A time varying current in a conducting coil produces the time varying magnetic field in the master spiral

ii. Faraday’s law: The secondary coil which is located in the line of sight with the primary coil will capture the magnetic flux, i.e. flux linkage, and it will create an induced emf in that roll.

In order to achieve the maximum power transfer via inductive coupling, impedance matching condition i.e. Inductive Reactance (\(X_L\)) = Capacitive Reactance (\(X_C\)), have to be satisfied to fetch the maximum gain at the output sink. In-order to increase the gain we can introduce a repeater (booster) as an intermediate circuitry and this gives a hike in flux linkage thereby increasing the distance of propagation effectively as depicted in Figure 2. The change of electromagnetic flux in transmitter coil induces an alternating current in repeater and now transmitter and repeater resonates at the same resonant frequency of the transmitter, this in turn induces the load resonator to resonate in such a way that the transmitter, repeater, receiver coils beats together in accordance with the resonant frequency\(^{10,11}\). Now the scheme is said to be synchronized.

![Figure 2. Implementation of an intermediate Repeater between the transmitter and the receiver to enhance the flux linkage between source and load.](image)

The basic functional block of Cable-less power transmission is emphasized as shown in Figure 3. A biasing D.C. voltage is given to an oscillator circuit and hence sinusoidal A.C voltage is obtained and this is applied to impedance circuit and then fed into the transmitting loop which emits its equivalent electromagnetic wave in air propagation. This is captured by receiver loop if its resonant frequency matches with that of transmitter resonant frequency and its equivalent sinusoidal A.C. Voltage is rectified by passing it to a rectifier circuit to the load. The flux linkage between the source resonator and the load resonator is enhanced by the diligence of a booster circuit in-between source and the load resonators. The resonant frequency of the repeater or promoter should be same as of both the terminal resonators for the procedure of achieving maximum power transmission from the source to the load.

![Figure 3. Block diagram for achieving enhanced cable-less power transmission.](image)

Transmit coil is magnetically coupled with the receiver coil. We use Hartley oscillator in transmitter coil to produce the alternating voltage because its gain is high when compared with other oscillators. The frequency of oscillation is determined by the passive components in the oscillator circuit. Coil winding with a capacitor 4.7nf constitutes the tank circuit of the Hartley Oscillator\(^{12}\). The transistor plays the major role in creating sinusoidal waveform i.e. alternating current and thus the flux intensity increases and decreases in the inductor coil and this change in flux beats periodically in accordance with the resonant frequency of the oscillator.

As depicted in Figure 4, Inductor (L1) is connected to the base and Inductor (L2) is connected to the collector terminal of the transistor and both the inductors are connected to the common point ‘O’ as depicted in the transmitter circuitry. The sinusoidal voltage produced in the inductor L1 and L2 are out of phase by 180° referable to the center-tap action of the transformer. The voltage across L1 is fed to the base terminal of the transistor and it will be the amplified and inverted by in the collector terminal and this is fed to L2 of the loop structure, thus the resultant voltage prevailing in the inductor L2 is of the same phase. The total phase shift around the loop is 360° or 2\(\pi\) i.e. by the transistor and transformer action.
and total loop gain of the schematic is achieved to be unity thus the Barkhausen’s criterion for sustained oscillation is satisfied. Receiver circuitry was constructed as shown in Figure 5, with the same impedance matching capacitor 4.7nF the flux linkage happen and receiver coil resonates with the same frequency with respect to transmit coil, thus cable-less power transfer is achieved. In case of long distance power transmission, Repeaters are used in between the transmitter and the receiver coil.

![Transmitter coil](image1)

**Figure 4.** Transmitter coil.

![Receiver coil](image2)

**Figure 5.** Receiver coil.

The repeater is built with loop dimensions which are exactly same as the transmitter and receiver antenna along with an impedance matching capacitor, thus the total amount of flux linkage between the transmitter and the receiver loop is enhanced which paves the way for the event of maximum resonance to happen. Repeater is implemented in-between the transmit and receive circuitry.

### 3.4 Mathematical Equation for Impedance Matching and Resonant Power Transfer

Circuit specification for both the transmitter and receiver coil is as depicted in Table 1.

| Parameter | Dimension |
|-----------|-----------|
| Diameter of the coil (D) | 17 cm | 17 cm |
| Radius of the coil (a- Transmitter, b- Receiver) | 8.5 cm (a) | 8.5 cm (b) |
| No of turns (N) | 1 | 1 |
| Length of coil (l) | 35 cm |
| Thickness of the coil | 3 mm |

**Table 1.** Circuit specification

Inductance (L) for the circular coil

\[
L = \frac{\mu_0 \pi a^2}{l} - \frac{\mu_0 \pi b^2}{l} = 8.149 \mu H
\]  

Resonant Frequency \(F_0\) = \(\frac{1}{2\pi\sqrt{LC}}\) = 813.24 KHz

Mutual inductance (M) between two circular coils is found by evaluating the elliptical integral, where, K (m) and E (m) are first and second kind of elliptical integral and m takes the value between 0 and 1.

\[m = \sqrt{\frac{4ab}{(a+b)^2 + d^2}} = 0.9881\]  

\[K(m) = \frac{\pi}{2} + \frac{\pi}{8} \times \frac{m^2}{1 - m^2} = 17.7823\]  

\[E(m) = \frac{\pi}{2} - \frac{\pi}{8} \times m^2 = 1.1873\]

\[M = \frac{2\mu\sqrt{ab}}{m} \times \left[1 - \frac{m^2}{2}\right] \times K(m) - E(m) = 171.1025 \mu H\]  

As there is an intermediate repeater, the mutual inductance is equally divided along both the sides as 85.5512 \(\mu H\).

Condition for effective Resonant Power Transfer i.e.

Inductive Reactance \(X_L\) = Capacitive Reactance \(X_C\)

\[X_L = 2\pi F_0 L = 2\pi \times 813.24 \times 10^3 \times 8.149 = 41 \Omega\]  

\[X_C = \frac{1}{2\pi F_0 C} = \frac{1}{2\pi \times 813.24 \times 10^3 \times 4.7 \times 10^{-7}} = 41 \Omega\]  

Thus, Inductive Reactance \(X_L\) = Capacitive Reactance \(X_C\) is satisfied for perfect impedance matching. The effective resistance offered by the source and load coils are same and hence maximum power is transferred from the source to the load i.e. inductive reactance and capacitive reactance matches with each other and impedance matching is achieved.
4. Results and Discussion

The biasing D.C. voltage given to the system is 9 V and it is amplified and changed into a sinusoidal voltage by drawing it to the oscillator circuitry. This project outcome emphasis that cable-less power transmission can also be achieved with lesser number of windings and with reduced components as shown in the Figures 6a and 6b. The Figure 6a shows the output when the switch in the receiver circuitry is open and load draws no current from the transmitter and meanwhile the shunt capacitor in receive circuitry starts charging exponentially towards maximum captured voltage to supply the initial voltage to the load for the next iteration when the switch is closed. When the switch is closed, the sudden discharge of the shunt capacitor makes the motor to rotate. The Figure 6b shows the output when the switch is closed in the receiver circuitry.

![Figure 6a](image1.png)

Figure 6a. Output Snapshot when the switch is opened in the receiver circuitry.

![Figure 6b](image2.png)

Figure 6b. Output Snapshot when the switch is closed in the receiver circuitry.

The Hartley oscillator thus used produces the constant voltages over a frequency range in the form of sinusoidal voltage as shown in Figure 7. When the transmitter and receiver loop are in-phase with resonance and without the intermediate repeater the received voltage is depicted in Figure 8.

![Oscillator output](image3.png)

Figure 7. Oscillator output.

![Received voltage without repeater](image4.png)

Figure 8. Received voltage without repeater.

The implementation of an intermediate repeater, boost the flux linkage between the transmitter and the receiver loop and thus the received voltage is enhanced as depicted in the Figure 9. Maximum voltage is trapped by the receiver loop when the process of resonance is in-phase between the transmitters, repeater and load resonator. The results with comparisons of the output responses different cases are as portrayed in Table 2.

\[
\text{Efficiency}(\eta') = \frac{V_0'}{V_{in}} = \frac{8.4}{12.2} = 68.85\% \quad (8)
\]

\[
\text{Efficiency}(\eta) = \frac{V_0}{V_{in}} = \frac{10.6}{12.2} = 86.88\% \quad (9)
\]
The efficiency ($\eta'$) of the system, without the implementation of the intermediate repeater is obtained as 69\% and the efficiency ($\eta''$) of the system, with the implementation of the intermediate repeater is obtained as 87\%. Thus, efficiency ($\eta''$) of the system is enhanced by the implementation of the intermediate repeater between the transmitter and the load spirals.

5. Conclusion and Future Work

This paper presents the design specification and implementation of the Enhanced Cable-less Power Transmission system as a practical solution to overcome the clumsy wired connection to cool every thermal sink and thus the efficiency of the system is improved in terms of enhancing its performance by purging away the thermal dissipation which is achieved with lesser number of components, lesser coil windings in both the transmitter and receiver loop and thus efficiency of the system is enhanced with the help of an intermediate repeater which boost the flux linkage between the two terminal loops. This project will be extended in the future by placing a sensor in thermal flushers to have the control of speed over rotating-fan based on the amount of thermal dissipation from the sink with the integration of controllers.

6. References

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