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Development of Wireless Charger using Dynamo and Transformer Principles

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Abstract: This study presents development of wireless charger by exploiting energy conversion principles. An oscillator has the role of generator from developed dynamo. However, the rectenna is a receptor of the waves obtained from induction to harvest the energy. The oscillator is an electric circuit formed basically by emitter coil. Moreover, the rectifier is a specific coil with capacitor and Diode Bridge then the energy is directed to accumulator required for machine operating. The performances of charging depend on many parameters such as frequency, number of coil turns and distance between emitter and receiver. Thereon, the goal of this study is to analyze the influence of significant parameters. We give simulation and system conception. Then, the validation is done by measurements and tests of machine working, especially for mobile phone battery.

INTRODUCTION

The radio wave energy is a challenge among various challenges of looking for newest sources of energies. The old resources of energy[1, 2] are not suitable for recent devices of smart technology. Inspiring from the radio station's that transmits the signal anywhere thanks to the power of electromagnetic waves, we propose here innovation of ordinal concept. The broadcast part puts out energy that radiates outward the receiver one carrying by the waves[3, 4]. The energy for a given area relied to the source is varying according to the propagation lines and medium losses. The amount passing through a medium drops to one-quarter the original strength when you double the distance from the source. The kinds of energy and probable changes[5] have deep impact when we are looking for energy conversion and transmission. Referred to the Federal Communications Commission and some references[6, 7], the theoretical maximum electric field 1 km away from a 50,000-watt transmitter is only 394 mV m^{-1} due to perturbations effects that absorb energy and cause attenuations. The metals parts in an antenna turn radio signals into electricity. Generally, the longer antenna ensures more signal to receive. Portable radio devices are using relatively short antennas and pick up weak energy. Often, the amplifier in the radio is required to boost the signal however the antennas improve the directivity towards suitable area. To harvest energy, the coil is needed as an insulated wire at least 20 feet long like the principle in the transformer. Many studies are basing on how to exploit the waves as spring of energy as we can inspire from these literatures[8-10]. Above, the same technique is observed in satellite signal where a concentrator of signals and receiver are required to ensure communications. Thereon, some metals are adequate to use aluminum larger than other metal that might block the signal that we want to receive. The principle in this work is to make wireless bridge to transmit the energy from

antenna to another and benefit from dynamo and transformer principles. The oscillations describe the waves and the measurement of voltage indicates the electrical energy, we get from vibrations due the mouvement. We can confirm reception of energy by connecting the antenna to the oscilloscope's input probe and set the vertical input range to 1 volt per division. The oscilloscope display noise pattern indicating radio energy from many different sources. To config our receiver device and let it to be more sensitive, we can choose small sensitivity such as 200 mV per division or less to show obviously the pattern. Each electronic component has special role for example diode to redress and smooth the signal, coil for induction and capacitor to store the energy. Before exploiting the energy of the wave we start from another source of energy[11]. In fact, the electricity, we obtain from radio waves is a high-frequency alternating current. Thereby, we should make accurate amplification and tuning to get specific frequency for suitable results. To harvest the electricity from radio waves, we yield it indirectly. Firstly, the conversion is required from the AC signal to direct current with a diode bridge. Indeed, the radio waves yield very small amounts of power. As result, we use capacitors as accumulators to get enough power and investigate electricity, especially after amplification circuit to get reach significant efficiency. Placing neighbors sources of electricity will affect precision of measurement due interferences of signals. To prevent this for sample we don't do experiments during thunderstorms cause it can induce a large voltage in a long wire so the risk to harm ourselves and any connected equipment. As applications the small amount of current we get during normal conditions unfortunately limits practical uses for electricity obtained from radio waves. Therefore, we wait for a specific time to store the energy. The current intensity and the voltage are insufficient for device operating, so, we implement capacitors to deliver suitable values, especially to get >3.7V and 100 mA that are required for mobile phone battery charging. In this work, we generate the energy from dynamo part and transmit it by transformer part like coils antennas communications. So, over a period of several rotor turns, the battery may accumulate enough energy to power phone battery. For the range of frequency we are looking to exploit wireless principle, so, the adequate range is included in 900-2400 MHz. However, the wavelength is significant for low frequency of this band which is 900 MHz from that we simulate around it as resonance and operation frequency. Along this work, we change emitter coil number turns and the distance between emitter and receiver to comparisons of performances as alternative technique for mobile phone battery charger. Moreover, this work is among methods on how to harvest the energy and use it with minimum of losses for mobile and smart devices.

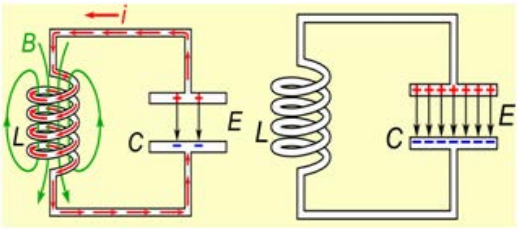

Fig. 1: LC oscillator concept

Experimental dispositif: The principle is to exploit oscillators' circuits to transmit the energy from antenna to another as we can inspire from given references[12-16]. Indeed, either the coil or capacitor has appropriate behaviors. For example, we store the energy under electric current in the coil, however, under voltage form in the capacitor. Referred to the theory a circuit of LC is an oscillator where the exchanging of energy is realized. Moreover, electromagnetic waves are based on electric field E and magnetic field B. The first one is created by charges in the capacitor and the second one is generated by the coil. Thereon, the emitter part has the coil as circuit core for emission and the receiver part is constructed by rectenna coil and capacitor. We illustrate the schematic of ideal circuit by Fig. 1.

Before studying conception of generator as transmitter and the receiver parts we explain the composition of each circuit. Generally, three parts are required to obtain wireless charger. The circuit plays dynamo role as power generator. The transmitter as career of energy using electromagnetic waves. However, the last part is a receiver where the rectenna is integrated and Diode Bridge for conversion to store harvest energy in a capacitor or battery. Moreover, the statics study can be done referring to others researches[17, 18]. The following figures describe both generator-emitter circuit and receiver circuit (Fig. 2 and 3).

Thereon, the developed device contains circuits for both emitter and receiver of electromagnetic waves. Above we implement Diode Bridge for stabilization by redressing the obtained signal to be available for storage. The antennas as coils are connected by induction effect to ensure suitable connection and improve directivity of emitted waves. The acquisition is verified either by digital oscilloscope or ampermeter and voltmeter instruments. Thus, each diode has a specific knee voltage, so, we take these properties in the choice of diodes to construct the suitable bridge. By integrating Arduino board and display screen LCD, we can program it to measure the tension voltage for the receiver circuit. Whatever that the power of all the electromagnetic signals is weak but the principle is that we base here on accumulation due to many turns of dynamo circuit. The experiment is very interesting wireless technology where devices do not require more

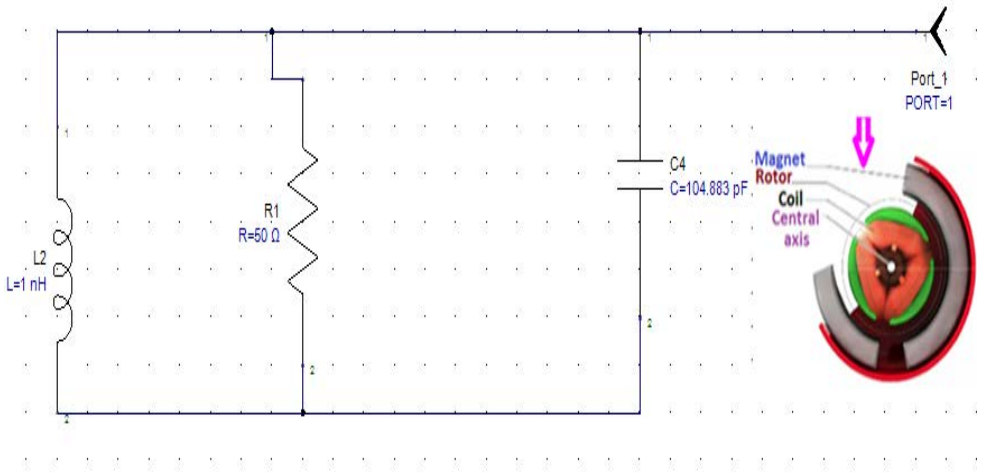

Fig. 2: Generator-emitter circuit schematic

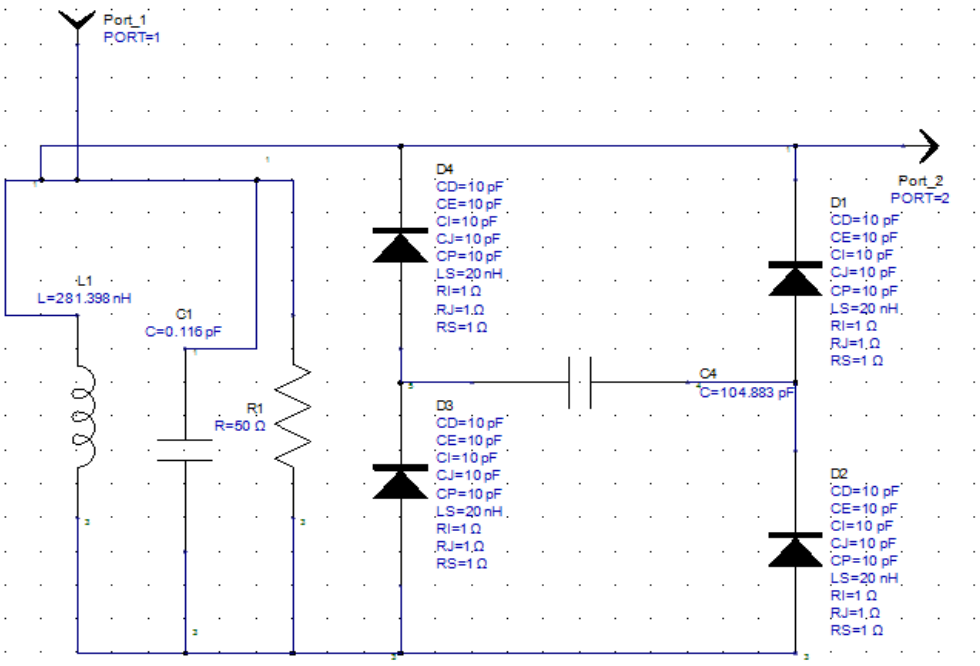

Fig. 3: Receiver circuit schematic

power as an alternative of how to harvest the auto-energy. Like the principle of crystal radio which is a simple AM receiver powered by the energy of the electromagnetic waves captured by its antenna this work consists to adopt this concept to harvest the energy when the rotor is in function and transmit it with a wireless concept. After capturing the wave by rectenna we should take in consideration that all diodes like leds have the knee voltage included between 0.3 and 0.7 V, so, we can deduct result voltage easily. Since, those weak signals that can be received, so, we propose auxiliary components like capacitors to obtain enough power. Also, the types of antenna and frequency bands are very significant. To sum up, the power generation is defiance for many researches so our build circuits are among techniques of using electromagnetic waves to harvest and store the electromagnetic wave energy. The circuit includes many components that, we should optimize such as size of antenna and rectenna as emitter and receiver coils to exploit in a good manner the electromagnetic waves. A rectifying circuit is used to stabilize the voltage and current. Then the storage circuit stores an output power obtained from the rectifying circuit for driving a load or charging desired battery. We give here fabrication of both generator-emitter and receiver circuit in Fig. 4 and 5.

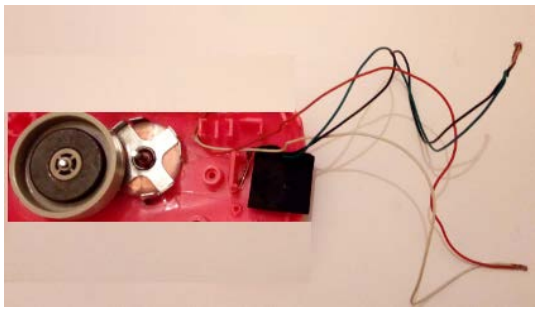

Fig. 4: Generator-emitter fabrication

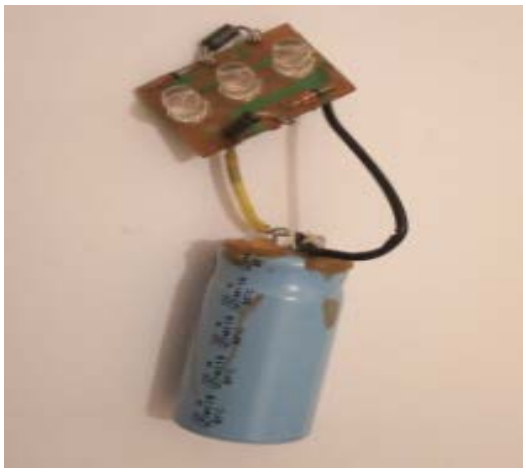

Fig. 5: Receiver conception

The type of the used antenna is a circular like coils in transformer principle. Its form is considered as patch antenna to minimize losses. Moreover, it has high gain and more efficient, so, we optimize the performances of our emitter and receiver.

RESULTS AND DISCUSSION

To establish a wireless transmission the developed system contains the rectenna or receiving antenna which is keeping in a special distance to obtain suitable induction and minimize losses. According to the radio range of frequencies that are near to wireless ranges we adjust dimensions and sizes to decrease losses and improve the gain. The simulation using Genesys and ADS are illustrating the pass band included in 850-2400 MHz for a good performances especially transmission and reflection coefficients that are describing antenna and rectenna like coils in the transformer principle. We notice that this circuit is more significant talking about deliver voltage and current to ensure charging of mobile phone battery. Thereon, we adopt it as emitter antenna and receiver rectenna to harvest the electromagnetic energy. The simulations can be done using Genesys and ADS software's. We give illustration of the circuit that constitutes antenna and rectenna parts that are separated with moderate distance as shown in the following simulations (Fig. 6 and 7).

The system is significant thanks to its suitable transmission coefficient which is maximal since lower frequency 900MHz of studied band. Indeed, this point is justified by analyzing of reflection coefficient that is very low especially when we have tendency into 1035 MHz (Fig. 8).

We remark that our system presents a good gain that increases to become maximal at 880 MHz. Even that it decreases, however, still satisfied for 900 MHz. Therefore, the system constitutes a good emitter and receiver as justified according to these simulations. The global system realization is shown in the following figure. Where the emitter and receiver are built together as wireless charger (Fig. 9).

For a good stabilization, we make minimization of fluctuations. We simulate the receiver part of our system using PsPice as given in the following figure schematic (Fig. 10 and 11).

The system presents a challenge on how to exploit electromagnetic waves to harvest the energy using special antenna and rectenna. Adequate capacitor and Diode Bridge are being adopted to smooth the signal. Further, the goal is to get enough electric current intensity from electromagnetic waves and confirm battery charge. The rotor which is in rotation like dynamo constitutes the source of power generation circuit by result the energy of electromagnetic wave is transmitting by the first coil antenna and then received by the second antenna with appropriate frequency as rectenna. The second coil is playing the role of rectenna that is able to rectify electromagnetic wave to harvest the energy in a good way. The capacitor is considered as booster component for output storing. After a given time the accumulation of voltage is enough, especially when the voltage becomes >3.7 V and the current intensity is around 100 mA, so, the switching circuit is used for machine load operation or mobile phone battery. Many parameters are having impact on the performances such as range of electromagnetic waves frequency. We make adaptation to ensure good connecting between two antennas. No doubt that size of antenna, especially number of turns coils affects the rate of receiving power. Above, the distance between two antennas is very important because electromagnetic waves in our case have high frequencies so the wavelength is smaller than other bands. We resume measurements in the tables depicted below. As comparison if the voltage is >3.7 V and the current intensity is above 100 mA the battery is charging. However, if no tendency to these values, we can confirm that the battery is not charging. According to dimensions of antenna and rectenna as coils,

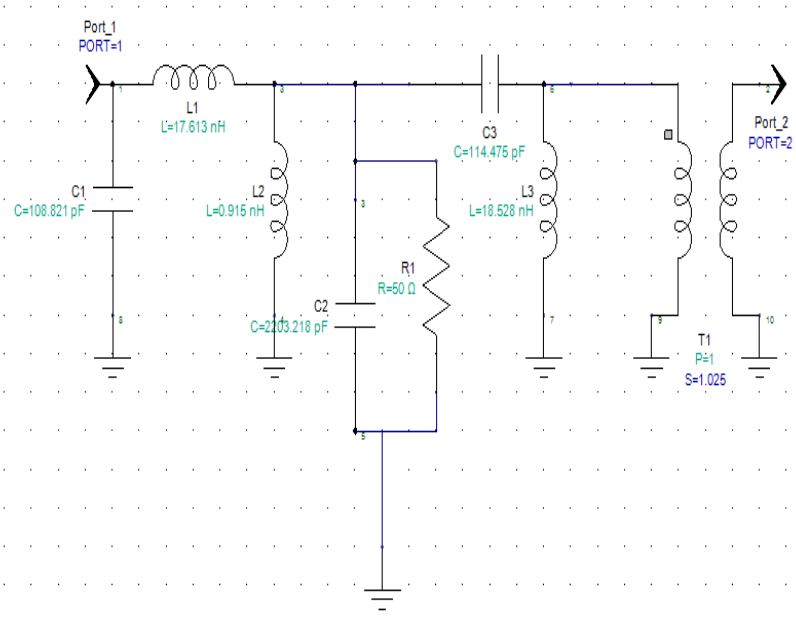

Fig. 6: Global schematic of the system

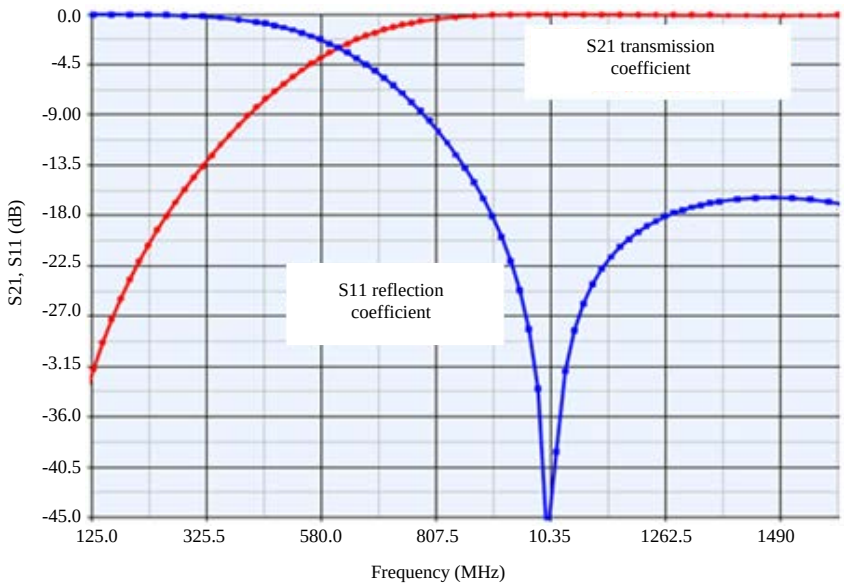

Fig. 7: Simulations of reflection and transmission coefficients

the rotor turns is varying in parallel, we calculate the gap due to the voltage and intensity and determine the state of the battery. We note by N number of emitter coil turns and d the distance between the emitter coil and receiver coil (Table 1-3).

Moreover, the present work provides a power generation circuit, transmission using electromagnetic waves and harvests the energy after emission by including the adequate antenna as rectenna circuit. The first antenna boosted by rotor and coil as oscillator has a great impact on the propagation of waves. However, the second antenna as a coil for receiving an electromagnetic wave play the role of rectifier circuit formed on diodes and capacitor for suitable smoothing. For a good rectifying of signal a booster parts are needed. In fact, without boosting the output it seems no susceptibility for storage. The optimal booster circuit permits a switching between accumulation of voltage in the capacitor for accurate time and load operating. The choice of capacitors and coils values is very significant. Indeed, the second antenna or

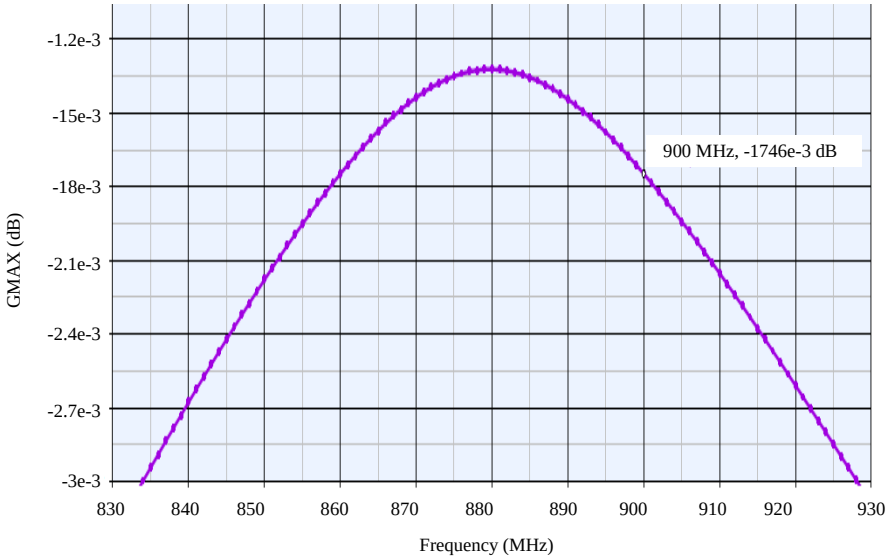

Fig. 8: Maximum gain measurement

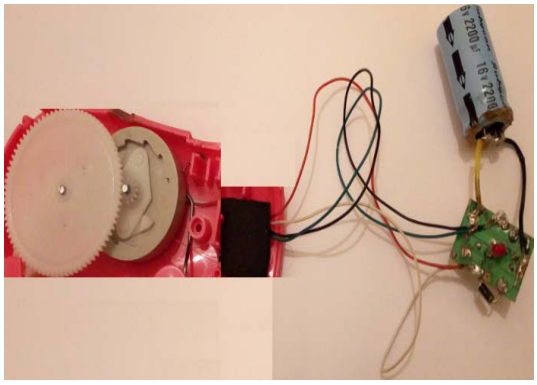

Fig. 9: Built circuit of global system

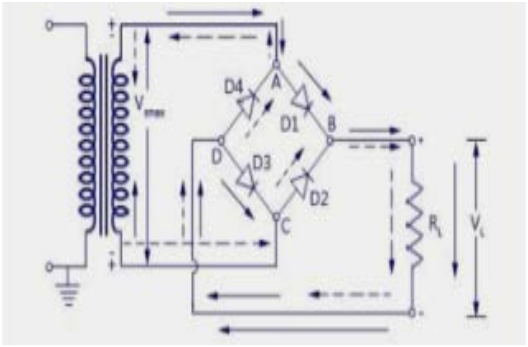

Fig. 10: Rectifying output signal

a second coil for receiving an electromagnetic wave having a different frequency than the frequency of the electromagnetic wave emitted by the first antenna, so, we adjust to get reception with high precision. The circuit

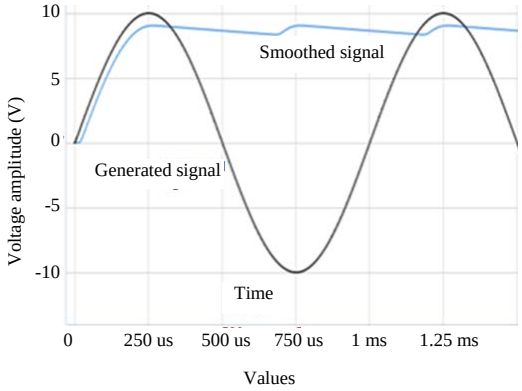

Fig. 11: Smoothing output voltage

Table 1: Measurements for N = 600 and d = 0.5 cm

No. of rotor turns	Intensity I(mA)	Voltage U(V)	State of battery
300	13	0.46	Not charging
500	22	0.94	Not charging
900	37	1.31	Not charging
1200	52	1.63	Not charging
1500	71	2.38	Not charging
1800	96	2.98	Not charging
2100	107	3.61	Not charging
2400	117	4.11	Charging

Table 2: Measurements for N = 500 and d = 0.8 cm

No. of rotor turns	Intensity I(mA)	Voltage U(V)	State of battery
300	16	0.46	Not charging
500	31	1.14	Not charging
900	62	1.51	Not charging
1200	84	1.93	Not charging
1500	103	2.63	Not charging
1800	126	3.88	Charging
2100	152	4.06	Charging
2400	178	4.51	Charging

Table 3: Measurement's for N = 400 and d = 1 cm

No. of rotor turns	Intensity I(mA)	Voltage U(V)	State of battery
300	6	0.46	Not charging
500	12	0.94	Not charging
900	38	1.31	Not charging
1200	54	1.63	Not charging
1500	72	2.38	Not charging
1800	86	2.68	Not charging
2100	97	2.84	Not charging
2400	108	3.81	Charging

generator-emitter has objective of mono-stable multi-vibrator to generate input signal. The first circuit ensures the power generation and the energy transmission thank to electromagnetic waves. The energy is stored pending accumulation due to the rotor turns of dynamo then, we switch the circuit for a defined period of time to feed our device as load. When power generation is performed by the second rectifier circuit after receiving an electromagnetic wave, we take measurements to determine performances of built system. The antenna reinforces the directivity of received signal and the gain to obtain the voltage required for analysis. Above all results are around the resonance frequency that is at order of 900 MHz. The system is working at range of 850 MHz until 2400 MHz with moderate performances. For N = 600 and d = 0.5 cm the generated voltage is increasing with number of turns of the rotor. In parallel, we measure the gap between required values for normal charging state that are 3.7 V and 100 mA and we conclude state of the battery. We note that for 2100 turns, we have tendency into suitable voltage however the current is not sufficient until 2400 turns where the intensity is equal to 117 mA and the battery is starting to charge. When we change the parameters to N = 500 and d = 0.8 cm, we remark that in this case, we increase the distance between coils and decrease number of emitter coil turns otherwise from 1500 turns the current intensity is significant with 103 mA but we should wait until 1800 rotor turns to get enough voltage and the battery is charging. For N = 400 and d = 1 cm the number of coil turns is less than previous case's the distance becomes important the performances are not good. Indeed, increasing the distance between coils has negative impact on wireless charger quality. According to measurements we get charging state after 2400 rotor turns with 108 mA as current intensity and 3.81 volts. Above that, both conditions of experiment and instruments have incertitude to prevent as possible. The attenuation of gap depends on antenna size and the distance of transmissiov towards the rectenna. From comparison of measured voltage, we optimize the wireless charger. Moreover, the present method has been made to solve the envisaged problem of mobile devices energy. The power can be generated by rotation due movement using electromagnetic generator and this technique provides our portable load by the required power. The generation circuit is able to be integrated in small and portable devices. Then the rectenna part that can be fixed in the phone is receiving energy from electromagnetic wave which propagates by wireless method. According to the present work, the power generation circuit using energy of electromagnetic wave includes an antenna and coil for receiving an electromagnetic wave. The last part is responsible for rectifying electromagnetic waves into a signal or voltage which is ready to store in adequate battery. Further, the power generation circuit is connected between an output of the storing circuit and a load which can be controlled to perform and ensure the enhancement of our device. To sum up by adjusting coils turns number and the distance between emitter and receiver, we can build a wireless charger with accepted performances.

CONCLUSION

The qualities of both antenna and rectenna parts improve performances to harvest the energy from electromagnetic waves. Their implementations are very significant to get suitable directivity and stability of received signal. Indeed, newest smart technology devices are very promising with condition of responding and providing easily by required energy. The portable devices are characterized by their challenge but also the problem is how to get enough power for operation. During this work we give a process of how to yield the energy by emission and receiving of electromagnetic waves. The concepts of antenna and rectenna are very fruitful to be adopted as solution of how to rectify and stabilize the feed energy. The system is working around 900 MHz which is the operation frequency to get high performances. Whenever, we move away this frequency the voltage generated is not sufficient, so, we should remain in a specific range of adequate wireless transmission. Many parameters have influence on the performances, especially antennas sizes and the distance that separates the antenna and rectenna. The analysis of rectified voltage confirms that both the number of rotor turns and coil turns number should be adjusted to improve and accelerate the manner of battery charging. When the distance becomes bigger the delay of charging is increase due losses of the medium. However, the cadence of rotor turns is very significant to reduce the time of required accumulation to reach charged state. Furthermore, the detection circuit of voltage to be stored and the part of load connection are both performed by utilizing the energy of the electromagnetic waves. The system is like a mono-stable multi-vibrator circuit when the detecting circuit detects that the voltage of the storage circuit is equal to or greater than a defined voltage, we connect the goal battery or load as mobile phone or another portable device of smart technology to make it in the function.

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