Short Range Wireless Charging System for Smart Phone through New Energy Harvesting Circuit

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ABSTRACT
Present handheld devices like Smart phones, can be charged wirelessly using new energy harvesting circuit technique through using the traditional wireless technologies. In this case, Bluetooth with a charging circuit enables a short-range wireless charging of a mobile handheld. This paper present the overview of new process of charging and structure of power charging based on Scotty diode with a real commercial film-type antenna on mobile terminal. So that it may called smart charging, this new circuit improves the efficiency in charging upto 160%, known to be 0.45 mA, relatively, 5 mA for smart phones.

Keywords- Bluetooth, Three-stage Villard voltage multiplier, smart phones

1. INTRODUCTION
Handheld devices like smart-phone can be seen as a everywhere computing platform as well as a hybrid of mobile phones and personal digital assistant (PDA). In addition, a smart-phone supports a lot of application and various services, such as digital multimedia broadcasting, Wi-Fi and Bluetooth etc. Consequently the battery consumption on mobile terminal dramatically increases.

To work out the limitation of battery life and as well as universal wireless battery charger for portable mobile device can use ambient radio frequency or electromagnetic signals as renewable energy resource, emitted by different source for communication. Thus, if battery charger is applied in smart-phone, it can catch various energy resources wirelessly because of having, four or five antennas. But, many sources are DMB, Wi-Fi, this are severely affected by noise especially for a long-distance power charging except Bluetooth. A short-distance charging technology, such as using Bluetooth, is more resilient against noise. Therefore short distance charging is better. In addition, Bluetooth has a point designed for the low-energy systems because of low-power consumption and allows two devices to connect automatically regardless of device vender. According to Maxwell's equations, in my results cannot simply get enough power into most devices without a large induction coil. This approach deliver an optimal rate of 0.45 mA, so 1000 times more to charge for a current smart-phone in the buyer market, Although here describe more advanced circuit for energy-harvesting system, and it will be more benefit in distant future.

2. PROPOSAL AND MOTIVATION
In this paper, an energy-charging and harvesting circuits in Bluetooth environment for smart-phones.

1. First, here express the smart-phone issue, wireless-charging method by using ambient RF signals and why does Bluetooth adopt for wireless charging.
2. Then it explains motivation and trend.
3. And introduces features of Bluetooth and film-type antenna that is adopted in my research.
4. Later the proposed architecture of energy-charging system and three-stage schottky diode based on Villard voltage-doubler circuit.
5. Finally the advantage of architecture with compared data and trade-off.

The issue of energy wireless charging is the effectiveness of electromagnetic field to person and interference by noises.

First, effectiveness of electromagnetic field do not directly influence on person. However, mixed signal from ambient RF sources which are added electromagnetic field and electric field might increase the probability of influence to people. Recently, new wireless-charging research that is proposed by Marin Soljacic comes into the spotlight because this technique do not influence to person as well as able to transfer energy between host and terminal at long distance by coil.

Therefore this research is adopted the energy-charging method by using resonance way. Second, many researchers try to improve the energy-harvesting technology called as power harvesting and free energy. Since amount of energy charging is very small. It should be noted that difficult to design an accurate charging circuit because of considering many factors. For example, solar inference, vibration, electromagnetic, temperature gradient, thermoelectric, heel strike, push buttons, RF, acoustic etc. Thus, this research focuses short-distance charging methods as Bluetooth. Though, we understand that it is difficult to charge fully smart-phone battery by using Bluetooth .Because the amount of power consumption when Bluetooth turns on charging circuit is higher than energy charging from other sources. However, the system confirms that change trade-off near future.

3. BLUETOOTH AND ANTENNA
3.1 Bluetooth Features

1. The first version of Bluetooth is classified into three classes based on range and power consumption. In most cases class 2 is used: 10 m, 1 Mbps and 2.5 MW, the other classes: 1–100 m, 1 Mbp and 1–100 MW.
2. The second version (v2. ×) supports backward compatibility with the first version (v1.2) and improves the data rate. To satisfy the demand for high speed, the Bluetooth SIG adopted Bluetooth v3.0. In this version, the Bluetooth link is used for negotiation and establishment and the Wi-Fi link for

the high data rate traffic.

3. Bluetooth SIG announced the Bluetooth v4.0, which increases the communication range while keeping the power consumption low. This version transmits very short data at 1 Mbps.

Table 1: Specifications of Bluetooth

Version	Range in m	Speed in Mbps	Power consumption, In mW
1.2	10 (1–100)	1	2.5 (1–100)
2.1	10 (1–100)	2–3	2.5 (1–100)
3.0	10 (1–100)	24	15–20
4.0	61	1	1.5–20

3.2 Film-Type Antenna Features

Film-type antenna and the chip antennas have been used in smart-phone for making small mobile handheld and protecting antenna by external shocks between them. The chip antennas are generally adopt for Bluetooth throughout the world. However, the film-type antenna is mainly used in current generation of smart-phones made. Fig.1 shows the antenna attached on smart-phone used in this paper.

Fig. 1 Film-typed antennas on smart-phone

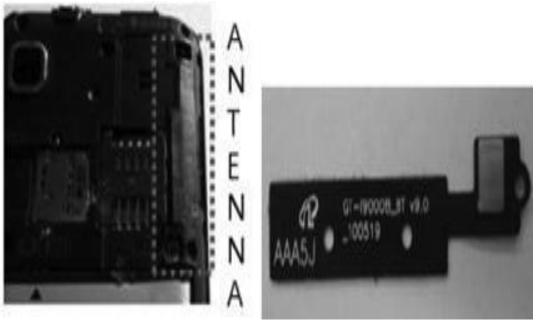

Table 2 specification of film-typed antenna

Frequency(2400 MHz case)		
azimuth (Avg)		− 5.18dBi
elevation-1 (Avg)		− 5.24dBi
elevation-2 (Avg)		− 3.74dBi
VSWR	BAR	2.58
	JIG SPEC	1.60 (±0.30)
Input impedance		50 Ω

4. PROPOSED CHARGING SYSTEM IN SMART PHONE

4.1 Architecture of Energy Harvesting System

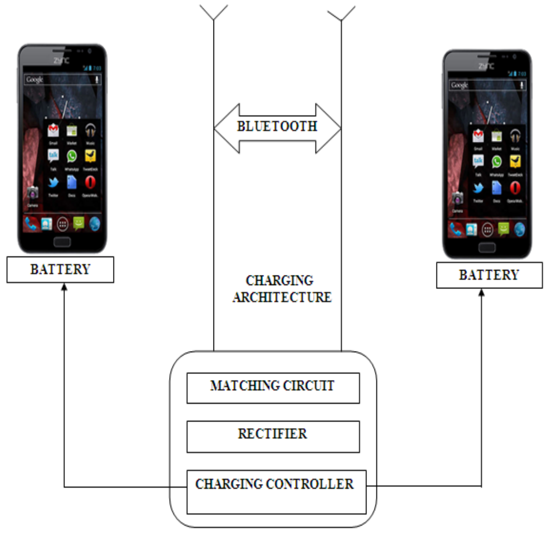

Fig. 2 Architecture of energy harvesting system design

Fig.2 shows the block diagram of proposed charging system on a smart-phone, where Bluetooth signal are captured by antenna. To convert RF signal to DC signal. The receiver circuits on the mobile terminal consist of matching circuit, rectifier, charging controller and battery as shown in Fig.3.After the matching circuit the rectifier circuit converts RF signal to DC signal finally, the charging controller operates similar to a switch.

4.2 Experimental Performance of a Three-Stage Schottky diode-based Villard voltage-doubler circuit

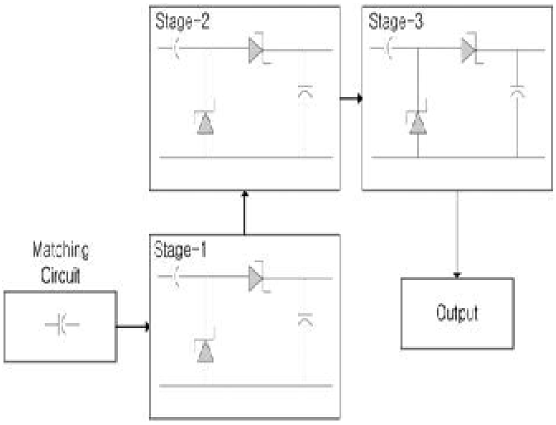

Fig.3 Conventional three-stage Villard voltage multiplier circuit

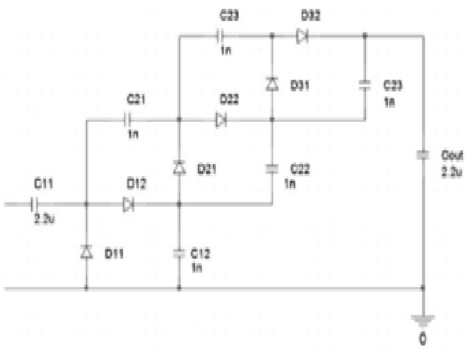

Fig: 4 case1: A three stage Villard voltage multiplier

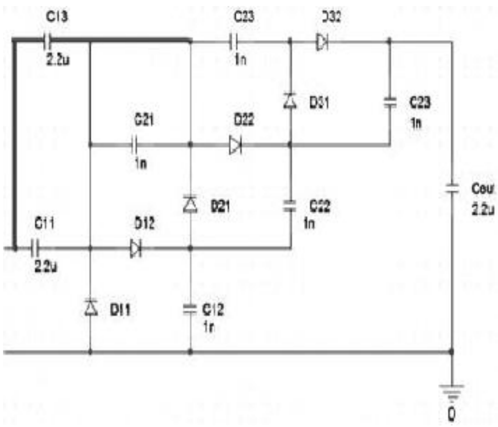

Fig: 5 case2: A three staged Villard voltage multiplier

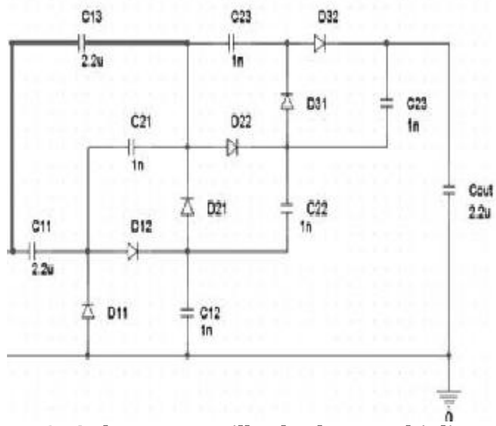

Fig: 6 case3: A three-stage Villard voltage multiplier

The voltage-doubler as a prior art is an electrical circuit that converts AC electrical power from a lower voltage to roughly twice the peak DC voltage by means of capacitors and diodes combined into a network. Among voltage-doubler methods, for example Villard, Greinacher and Bridge circuit. Here we experiment with three-stage Villard voltage-doubler in this paper.

A conventional three-stage Villard voltage-doubler based on capacitors and schottky diodes. Moreover, it is not expensive to manufacture the proposed circuit.

In this paper, develop a new design with four-cases based on three-stage. Villard voltage multiplier circuit in Figs.4-7 to obtain higher voltage than Hamid Jabber's work. Each three-stage Villard voltage multiplier in Figs 4-7 is constructed with each stage using two schottky diodes (HSMS-2802-TR1G) and capacitors with specific parameters in Table 3. Also, Table 3 shows a test specification for measuring gain by using Cadence's Or CAD. The experiment condition of each case is that input signal voltage is 300 mV, value of C_{11} and C_{out} on all cases is adjusted 0.23–0.72 µF for finding higher gain and C_{11} and C_{out} are used same value for supporting a stable ripple voltage.

In case of Case 1 in Fig.4, when C_{11} and C_{out} is 0.72 µF, output voltage is 835 mV that is biggest gain value among six capacitor value condition. Also, in case of Case 2, Case 3 and Case 4 in Fig.5, Fig.6 and Fig.7, when C_{11} and C_{out} is 0.72 µF, the maximum output voltage is, respectively, 970, 1078 and 1359 mV in Table 4. Especially, Case 4 whose efficiency is 353% is superior to other Cases.

Efficiency equation = ((output−input) /input)

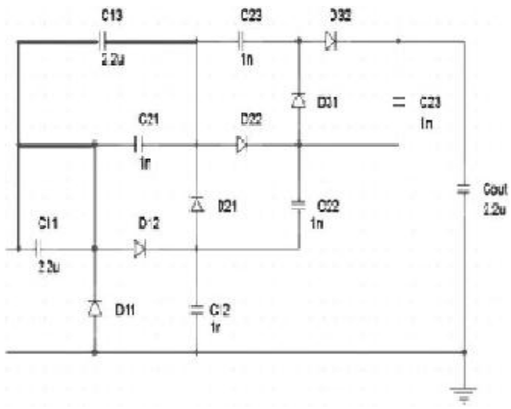

Fig: 7 case4: A three staged Villard voltage multiplier

Table 3 Comparison of conventional three-stage Villard voltage multiplier (Case 1)

Node	Capacitor value in µF	Input mv	Output mv	Efficiency
C11, Cout	0.23 0.25 0.27 0.32 0.52 0.72	300mv	830 832 833 833 834 835	178%

Table 4 Comparison of conventional three-stage Villard voltage multiplier (from Case 1 to Case 4)

Node	Case	Capacitor value, µF	Input, mV	Output mV	Efficiency, %
C11, Cout	Case 1 Case 2 Case 3 Case 4	0.72	300	835 970 1078 1359	178 223 259 353

5. PROTO-TYPE DESIGN

5.1 Proposed three-stage Villard voltage multiplier with antenna

Fig:8 shows the proposed three-stage Villard voltage multiplier proto-type based on Case 4, which is better efficiency of 353% for checking the amount of charging energy. However, charging energy of the proposed three-stage Villard voltage multiplier proto-type is very small, approximately 0.45 mA, so 1000 times more to charge for a real product.

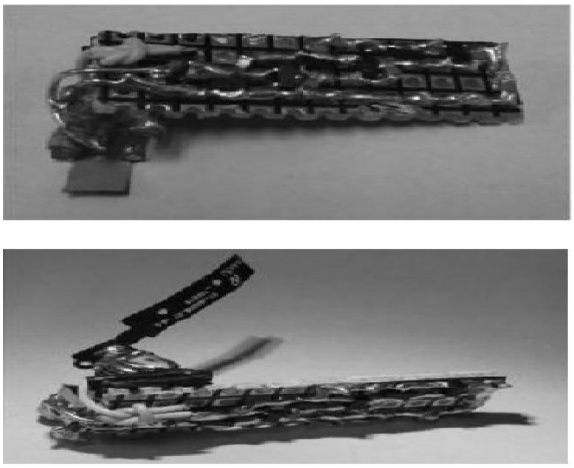

Fig: 8 Based on case 4, the proposed three-stage Villard voltage multiplier with film-typed antenna

5.2 CMOS transistor based voltage multiplier circuit

In general, schottky diodes are designed by using transistors and LC matching circuits. Villard voltage multiplier proto-type is very small, approximately 0.45 mA, so 1000 times more to charge for a real product.

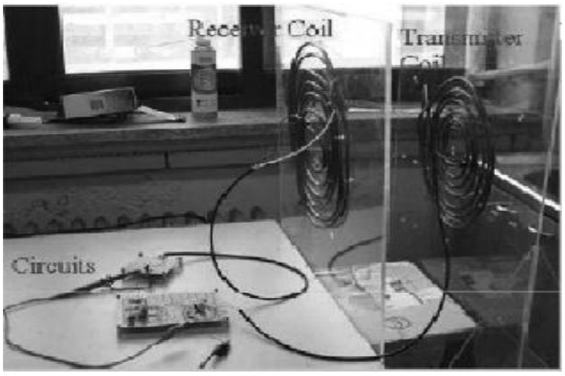

Fig: 9 Experiment set-up with resonant coils

Therefore the paper has used large resonance coil based on the proposed theory in Fig: 9 previous result outcomes is shown in the Fig: 10.

With input impedance 50 Ω, a film-typed antenna has −5.24 dBi, 2.58 VSWR, for 2.400 GHz channel and −5.76 dBi, 1.9 VSWR for 2.485 GHz channel, respectively. Fig 10 shows an average gain (Azimuth) of two different channels (2.4 and 2.485 GHz) for the proposed three-stage Villard voltage multiplier with film-typed antenna. However, the most circuit of recently released mobile device is designed by using CMOS transistor. Therefore Cockroftwalton multiplier is introduced for getting same performance of traditional schottky diodes. It should be noted that the performance of Cockroftwalton multiplier is relatively lower than schottky diodes based on transistor because threshold voltage and input signal is different than CMOS and Bipolar transistor. As a traditional design, one of the designs from Cockroftwalton multiplier consists of connecting gate and drain and linking body and ground shown in Fig.11.

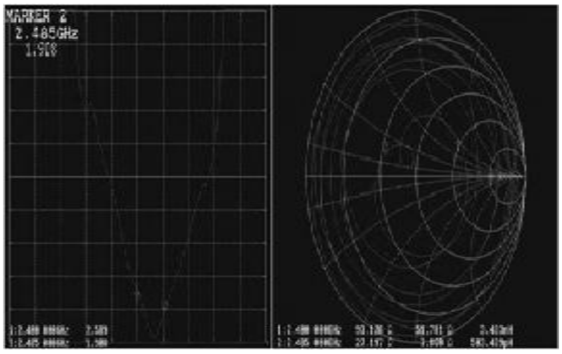

Fig. 10 Electrical specification of antenna

Rather than a conventional voltage multiplier in Fig.11. The system proposes a new circuit with a change, which include schottky diodes with a new LC matching circuit. Fig 12 shows Hamid's Villard voltage multiplier circuit. The features of this new circuit is that the implementation of a matching network resistant to parasitic losses, through a form of self-biasing to reduce the threshold voltage inherent in diode connected CMOS transistor and by floating the body of a PMOS to reduce body effect losses for improving efficiency approximately 22.97%. Also, it will discuss the strategy of new LC tank adopted for the newest results in a subsequent paper submission and reporting the development of advanced methods by the team.

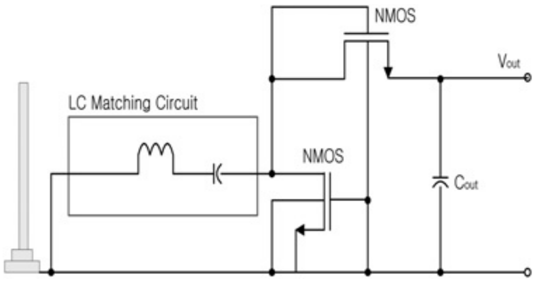

Fig: 11 Conventional Villard voltage multiplier circuit

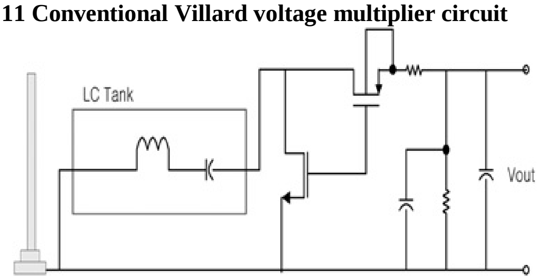

Fig. 12 Hamid' Villard voltage multiplier circuit

TABLE 5: Efficiency comparison of conventional Proposed Villard voltage multiplier circuit

Power μW	Output Power in μW		Efficiency %	Output Power in μW		Efficiency %
	Conventional work # 1	Proposed work		Conventional work # 2	Proposed work	
316	8.43	12.39	46.96	12.39	19.23	55.21
562	45.12	94.19	108.75	94.19	202.35	114.83
1000	133.85	347.03	159.27	347.03	824.31	137.53
1778	282.58	495.75	75.44	495.75	903.22	82.19
3162	495.75	743.63	50.00	743.63	1124.35	51.20

6. COMPARISON OF RESULTS

This paper shows two Villard voltage multiplier circuit based on CMOS transistor to compare the efficiency. Two Villard voltage multiplier circuits are designed by Cadence' Virtuoso and show a peak DC voltage. Also, this research uses the TSMC 0.25 µm CMOS technology because of satisfying low threshold voltage. Table 5 shows the output voltage comparison of traditional and proposed Villard voltage multiplier circuit.

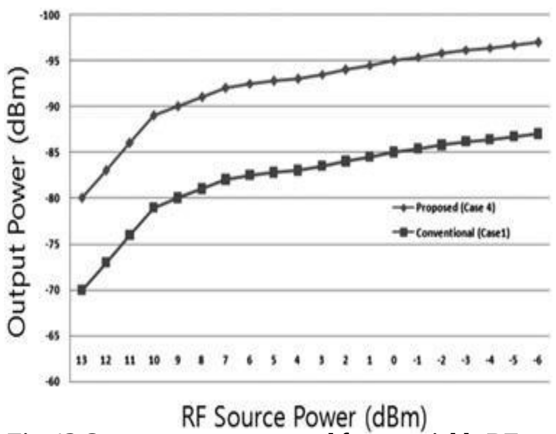

Fig. 13 Output power generated from variable RF source power

The percentage increase in power using circuit in Fig.12 over the traditional circuit of Fig.11 is shown in middle column of Table 5. Moreover, the efficiency of proposed circuit increases power more than the traditional circuit. In particular, when the input voltage is 1000 µW, the efficiency is getting bigger. In count, the research plan to discuss about a measurement of distance between the charging devices, and propose a new design of a LC tank circuit along with better performance to satisfy a fast-phase charging system. Fig, 13 shows the comparison result when RF source power is a variable and each circuit was tuned and tested separately. In this case, distance between circuit and source antennas is 2 cm, more or less.

7. CONCLUSION

This paper show that charge energy by using Bluetooth technology. Although the amount of charging energy is not enough to use ambient charging technology now, proposed circuit based on Bluetooth can improve to capture higher charging energy. It can useful for all handheld devices like Tablet PC, PDA. Here the proposed system put forward a new charging circuit based on schottky diode with a real commercial film-type antenna on mobile terminal. New power-charging structures have a charging efficiency approximately by 160%, that is, 0.45 mA rather than 5 mA for a current Smartphone in the consumer market.

8. REFERENCES

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