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Master's Degree Thesis

Optimization of AC-DC converter for Wireless Power Transmission of Energy Harvesting System

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TAE IL YUN

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에너지 하베스팅 시스템에서 무선 전력전송을 위한
AC-DC 컨버터의 최적화

February 25, 2015

Graduate School of Chosun University
Department of IT Fusion Technology
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Optimization of AC-DC Converter for Wireless Power Transmission of Energy Harvesting System

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This thesis is submitted to The Graduate School of Chosun University in partial fulfillment of the requirements for the Master's degree

October 2014

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November 2014

Graduate School of Chosun University

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Acronyms

AC	Alternating Current
ADS	Advanced Design System
BAN	Body Area Network
CMOS	Complementary Metal-Oxide Semiconductor
DC	Direct Current
DMM	Digital Multi Meter
HPD	High Power Design
LPD	Low Power Design
RF	Radio Frequency

요 약

에너지하베스팅 시스템에서 무선전력전송을 위한 교류-직류 변환기의 최적화

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Energy Harvesting에서는 일반적으로 -10 ~ 15dBm 범위의 전력이 수확된다. 수확되는 전력의 크기가 작기 때문에 소자에서 발생하는 손실이나 소비전력, 그리고 정합 특성 등이 시스템의 성능에 크게 영향을 미치게 된다. 기존의 관련 연구들에서는 -20 dBm 근방의 전력을 사용하는 시스템에 최적화된 AC-DC Converter를 제안되었지만, 전력이 더 커짐에 따라 효율이 급격하게 감소되고, 전력의 크기 변화에 따라 안정적인 효율을 제공하지 못하고 있다.

이 논문에서는 Energy Harvesting에서 발생된 에너지를 안정적으로 DC로 변환하는 고효율의 AC-DC 컨버터를 개발하였다. -10 ~ 15dBm 범위를 가진 수 십 MHz의 RF전력이 AC-DC 컨버터로 전송되고, 공진형 코일에서 수신되는 전력의 크기에 따라 matching network가 결정된다. 그리고 최대의 출력 전력을 얻기 위해서 부하 조건이 최적화 되었다. 일반적으로 Small Signal(약 -30dBm이하)에 사용되는 S-parameter를 이용한 정합 방식 대신 Large Signal(-20~20dBm)에서의 전력 값에 대한 정합 방식을 통해 변환효율을 향상시켰다. 이를 위해 주파수, 정합 소자, 부하 저항, 스테이지의 수 등의 다양한 조건들이 변환 효율에 미치는 영향을 분석 하였다.

AC-DC 컨버터로 인가되는 -10 ~ 15dBm 사이의 RF전력에서 변환 효율은 최소 50%에서 최대 87%를 나타낸다. 기존의 유사한 전력 및 주파수 범위를 사용하는 다른 컨버터들

과 비교하여, 20% ~ 40% 더 높은 최대 효율을 나타낼 뿐만 아니라 20 ~ 50% 더 높은 평균 효율을 보여준다. 따라서 일정한 전력의 공급이 불안정하여 입력전력의 크기가 바뀌는 상황에서도 안정적인 성능을 나타낼 수 있기 때문에 일정한 크기의 전력을 기대하기 힘든 Energy Harvesting을 전력원으로 이용하고 있는 Wearable 기기나 BAN 등에 응용될 수 있다.

I. Introduction

Wearable devices and body area networks (BANs) are fields in which the most recent wireless power transmission systems can be applied. Because wearable devices and BANs require portability and are used with human activity, the means by which power is provided is important.

For example, batteries and energy harvesting circuits can be used as power sources [1]-[2]. In wearable devices and BANs that are used with human activity, the ideal is to remove the constraints of time available by providing power with an energy harvesting circuit rather than a battery. Moreover, because the recent wireless power transmission systems using resonant coils [3]-[4] generally have high power requirements of more than 50 W, the optimization of such systems in the medium power range (-10 to 15 dBm) is needed for their application in the mentioned fields.

In the application of resonant coils on the human body, the coils must transmit power with a resonance frequency of 10-100 MHz because of physical constraints, such as coil diameter, length, etc. [5]. When the transmitted RF power is changed to DC power for use in applications, it is very important to fully convert the power with high efficiency because the amount of power generated by energy harvesting is too small.

The amount of power, the frequency, the arrangement of the matching component, the load resistor, and the number of stages of the voltage multiplier are considered for high-efficiency conversion of RF power transmitted to the AC-DC converter.

The proposed converter could greatly improve the conversion efficiency in 10-100 MHz band by using matching characteristics according to amount of received power and optimum load resistance.

In Section II, the previous method is shown in similar power range. In Section III, the matching network and system design are described in detail. In Section IV, the simulation and measured efficiency results designed using large signal analysis with ADS from Agilent Technologies will be compared in relation to the amount of power with small signal analysis and large signal analysis in the range from -10 to 15 dBm. Then, the performance of the proposed converter will be compared with that of other converters and analyzed in terms of the average and maximum efficiency [6]-[8]. In Section V, conclusions will be given.

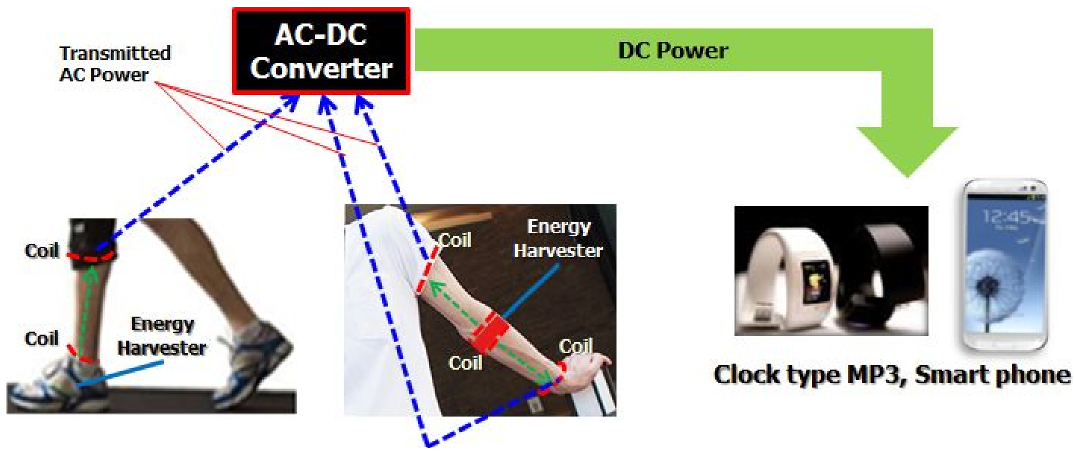


Figure 1.1. Application of wireless power transmission system with energy harvesting on the human body

Ⅱ. Previous Methods

Ⅱ-1. Hybrid Rectenna

Hybrid sensitive rectenna(rectifier + antenna) is a zero-bias microwave sensitive rectifier using commercial Schottky diodes that is optimized and validated.

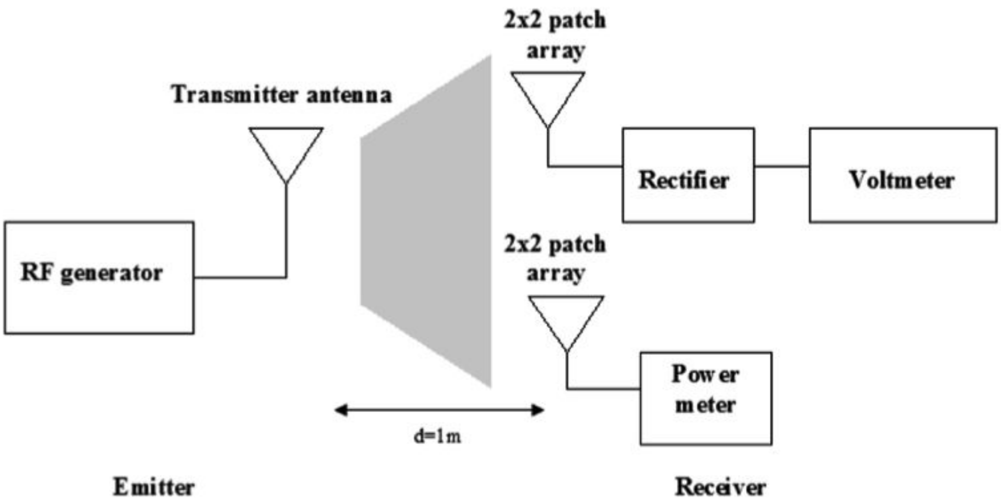


Figure 2.1. Hybrid rectenna system[7]

As shown in Figure, hybrid rectenna used 2 X 2 patch antenna array and commercial Schottky diode (HSMS2820) in order to validate the rectenna system. It has an maximum RF-DC conversion efficiency of 56%.

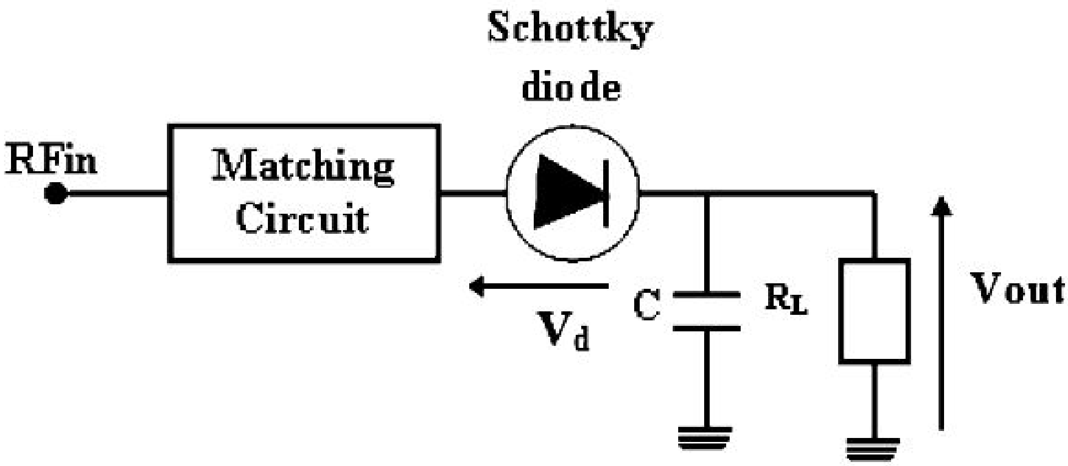


Figure 2.2. Series microwave rectifier configuration[7]

Figure 2.2. is conversion efficiency curve of hybrid rectenna system, it has high performance in input power range only over 0 dBm. However, It has bad performance in input power range under 0 dBm.

For that reason, even though hybrid rectenna system has comparatively high conversion efficiency, it might have low performance in energy harvesting system on the human body because energy harvesting system has unstable input power.

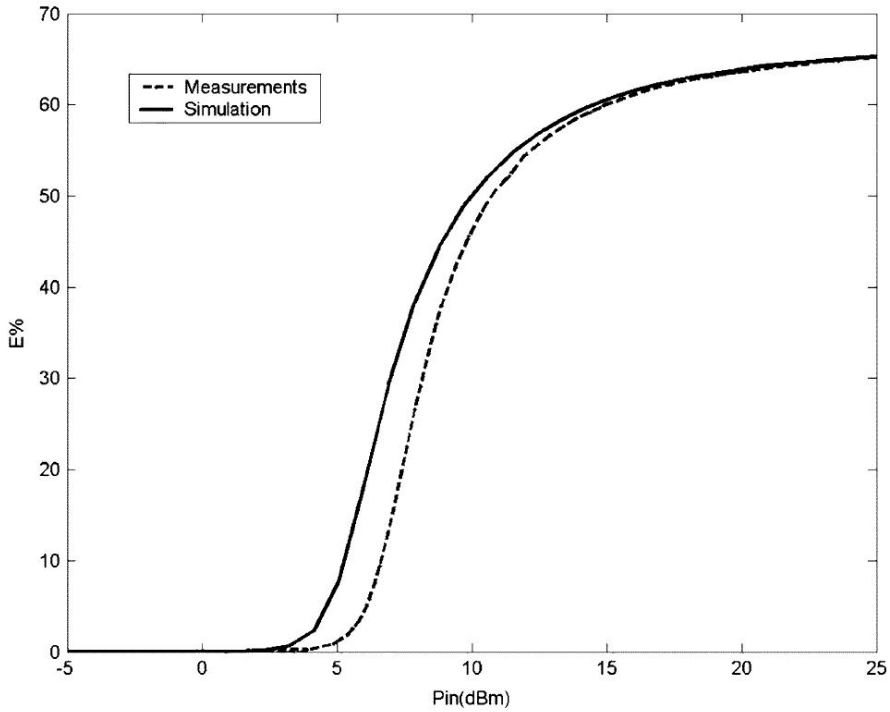


Figure 2.3. Simulated RF-DC conversion efficiency[7]

II-2. AC-DC Converter using CMOS

Figure 2.4. and 2.5. is dual band RF energy harvester using CMOS. Based on the circuit analysis, a design procedure is given for a narrow-band energy harvester. The antenna and harvester co-design methodology is discussed to improve RF to DC energy conversion efficiency. A dual-band CMOS energy harvester is designed and fabricated using an IBM 0.13μm process.

The simulated and measured results show over 9% conversion efficiency for two different bands (around 900 MHz and around 1900 MHz) at an input power as low as

-19.3 dBm. The DC output voltage of this system is over 1 V, which can be used to recharge the battery to form an inexhaustibly powered communication system.

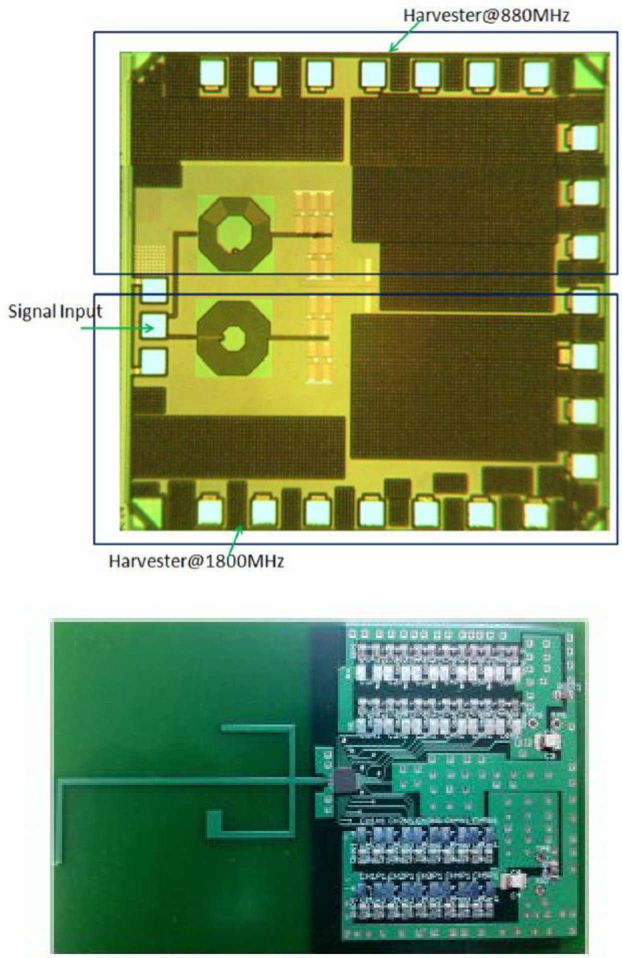


Figure 2.4. Photograph of the fabricated energy harvester with integrated antenna[9]

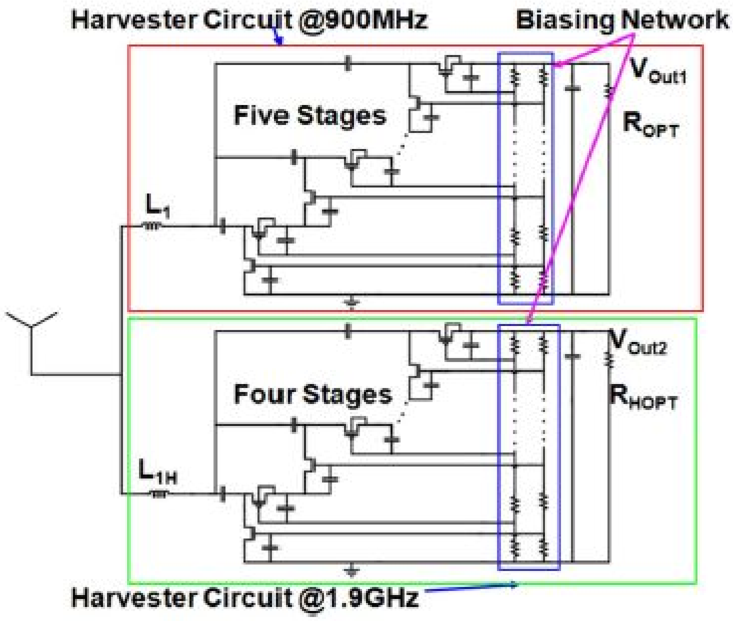


Figure 2.5. Circuit schematic of the designed dual-band energy harvester[9]

Rectifier using CMOS is one of frequently using methods at low environmental power levels. however, it has a comparatively lower conversion efficiency than Schottky diode from -20 to 20 dBm. Therefore, using Schottky diode is better than using CMOS in the energy harvesting system on the human body because power range of that field is near 0 dBm.

II-3. AC-DC Converter in RF Energy Harvesting Circuit

Figure 2.6. is RF energy harvester using Schottky diode. it has a dual-stage energy harvesting circuit composed of a seven-stage and ten-stage design, the former being more receptive in the low input power regions, while the latter is more suitable for higher power range.

Each stage here is a modified voltage multiplier, arranged in series and our design provides guidelines on component choice and precise selection of the crossover operational point for these two stages between the high (20 dBm) and low power (-20 dBm) extremities. And, it is compared with Mica2 sensor mote, with accompanying simulations on both ideal and non-ideal conditions for identifying the upper bound on achievable efficiency.

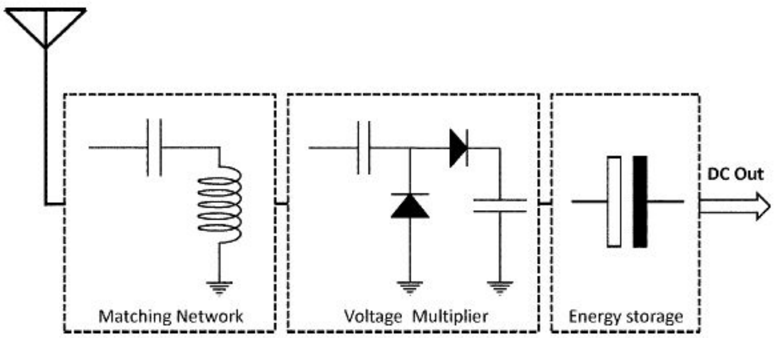


Figure 2.6. Ambient RF energy harvesting[6]

System of [6] has similar power range that is used in this thesis. But, when system of [6] is composed, it has some errors. So, curve of Figure 2.7. is patchy. In this thesis, some errors are modified and performance is improved compared to system of [6]. These errors are clarified in following sections.

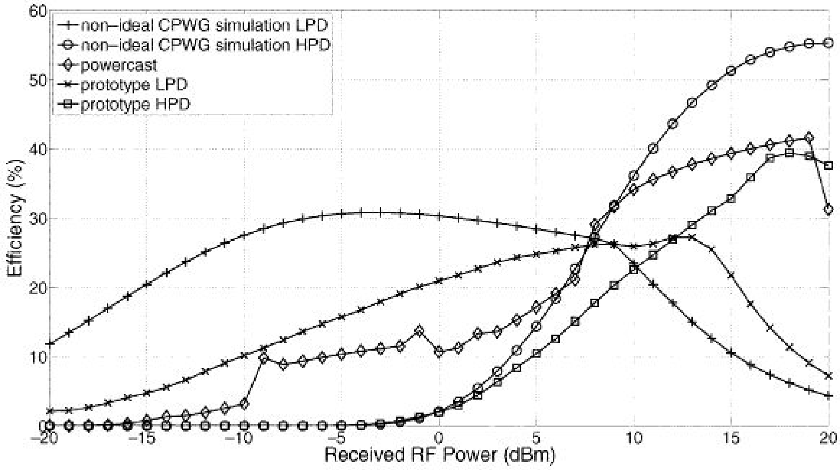


Figure 2.7. Efficiency comparison of simulation, prototype and powercast energy harvesting circuit[6]

Ⅲ. Design of System

Ⅲ-1. Purpose

If resonant coils are made for the human body like Figure 3.1., resonant frequency of the Tx and Rx coils is between 10 MHz and 100 MHz. In this frequency band, inductor for the matching network is limited.

Transmitted power range is from -10 to 15 dBm because this range is similar to input power range generated from the energy harvester. Output voltage should be at least 3.3 V for operating one chip which is used in the application. Therefore, AC-DC converter must have low power consumption because input power range is too small.

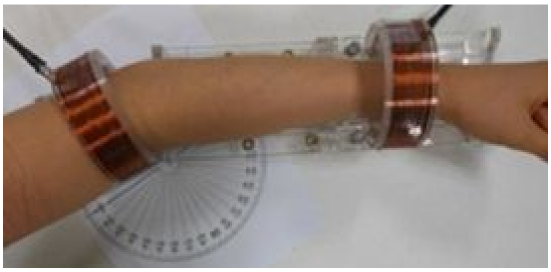


Figure 3.1. Coils for the human body[5]

III-2. Structure

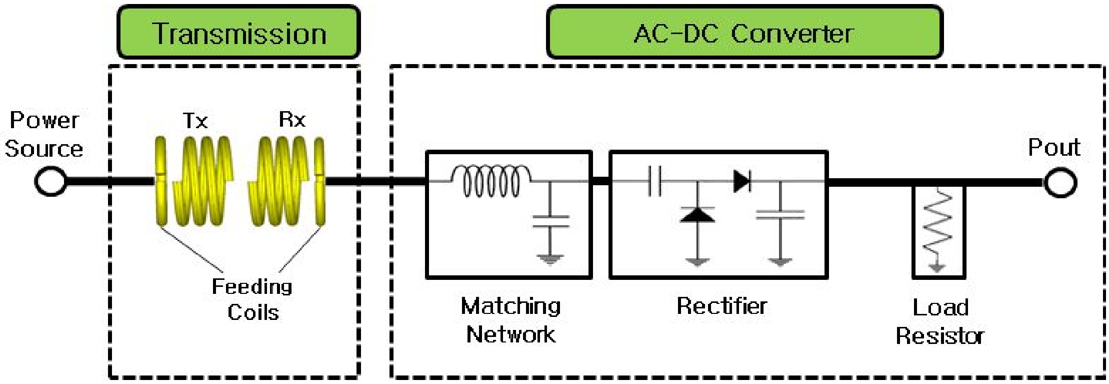


Figure 3.2. Structure of wireless power transmission system

Figure 3.2. shows the structure of wireless power transmission system on the human body. It is divided into three parts, source, wireless transmission, AC-DC converter.

RF power generated from power source is transmitted to AC-DC converter through resonant coils. Schottky diode is used for minimizing conversion loss because used power is low. it has turn on voltage of 0.34 V, breakdown voltage is 15 V and operating frequency is up to a few GHz. If voltage on both sides of diode is over 15 V, diode is broken. So, the input voltage of the diode should be use under 15 V.

And, in the matching network, RF inductor and chip capacitor is used. inductor must be carefully considered because effect of inductor on the reflection loss is very larger than capacitor in scores of MHz frequency range. inductor is used in the system shows the best characteristic among inductors for this experiment. it has a few μH scale inductance and operating frequency is up to 50 MHz.

Power source and resonant coils, resonant coils and AC-DC converter are matched 50 ohm.

III-3. Large Signal Analysis

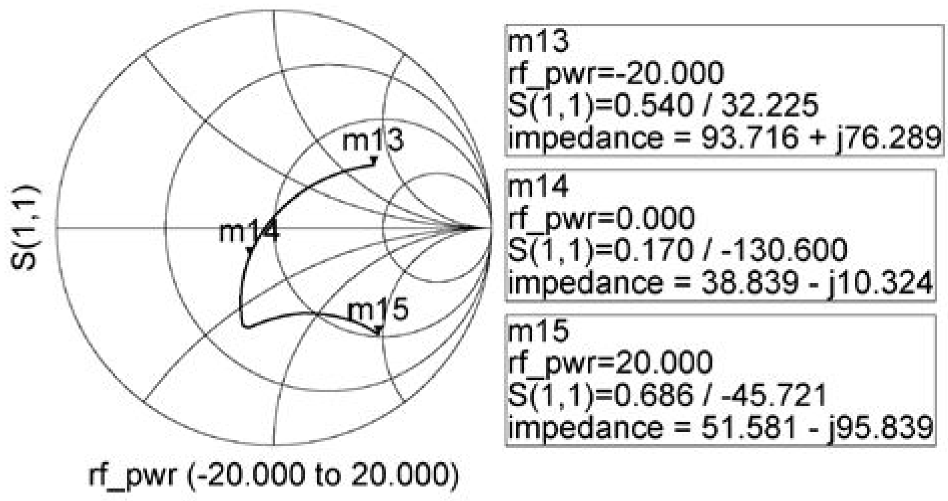


Figure 3.3. Variation of impedance according to power[6]

As shown in Figure 3.3., impedance of circuit is changed according to variation of power because used components in the circuit have non-linearity, so characteristics of the circuit is also changed.

Thus, matching network should be considered according to power to maximize conversion efficiency. Reflection power from AC-DC converter is minimized and input power to AC-DC converter is maximized in this way.

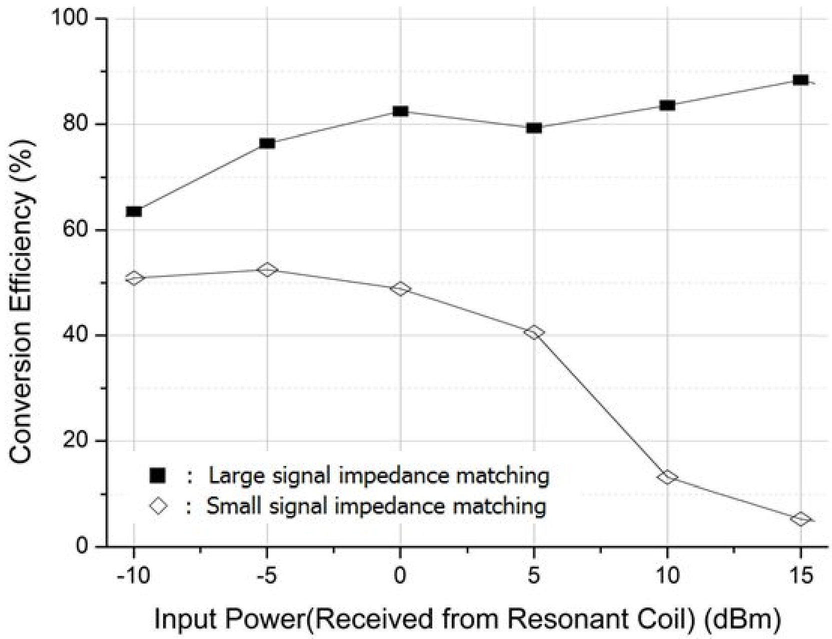


Figure 3.4. Conversion efficiency of large signal and small signal impedance matching

Figure 3.4. is the comparison of performance. In case of large signal impedance matching, efficiency curve is gradually increased because of matching in each power, but small signal impedance matching is not.

Large signal impedance matching was used in previous study[6]. reference[6] used similar power range to this thesis and also same diode, however, conversion efficiency is lower than this thesis.

Actually, reflection power is minimized in each power because the matching network was designed considering each input power. However, previous study was performed under the condition that the incident voltage is larger than the breakdown voltage of the diode used in the rectifier circuits.

III-4. Number of Stages

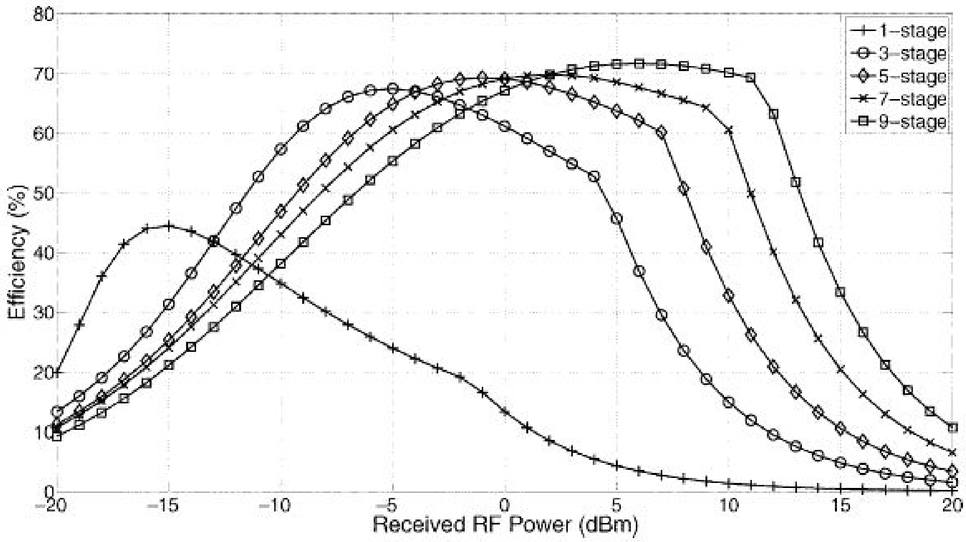


Figure 3.5. Effect of number of stages on the efficiency of energy harvesting circuit[6]

As shown in Figure 3.5., peak point seems to be changed according to number of stages. However, selection of diode is wrong in the previous study[6]. If measurement is performed under the proper condition, performances according to number of stages are not much different.

In this thesis, AC-DC converter in the system consists of the one stage in order that output voltage can be at least 3.3 V for operating one chip of application part.

III-5. Specification of the Diode

Table 3.1. Data sheet of (a) HSMS-285x and (b) HSMS-282x series

SOT-23/SOT-143 DC Electrical Specifications, (Temperature = +25℃, Single Diode)

Part Number HSMS-	Configuration	Maximum Foward Voltage V_F (mV)	Maximum Reverse Leakage I_R (μA)	Typical Capacitance $C_T(pF)$
2850	*Single*	*150 250*	*175*	*0.30*
2852	*Series pair*			
2855	*Unconnected pair*			
Test Conditions		I_F = *0.1* mA	V_R = *2* V	V_R = *-0.5* V *to -1.0* V f = *1 MHz*

(a) Specification of HSMS-285x [10]

Absolute Maximum Ratings (Temperature = 25 ℃)

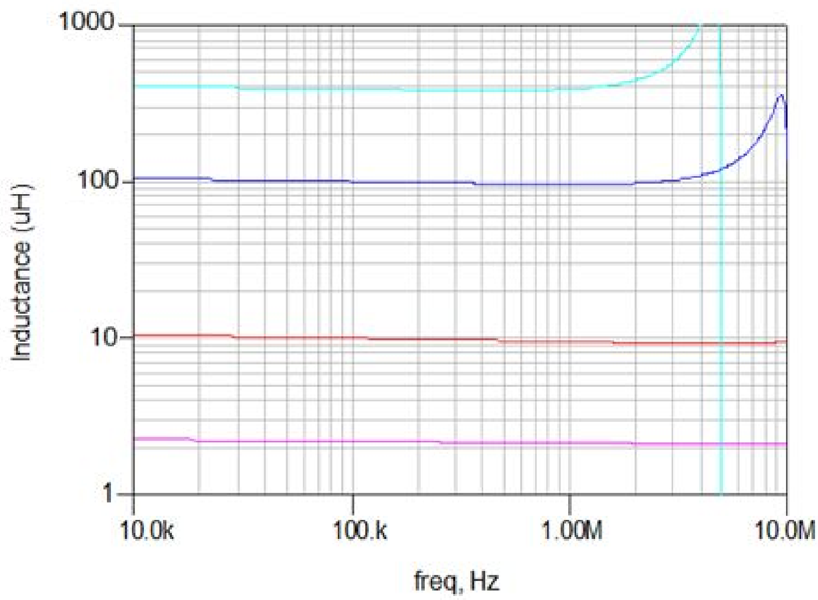
Parameter	Unit	SOT-23/SOT-143	SOT-323/SOT-363
Forward Current (1 μs Pulse)	*Amp*	*1*	*1*
Peak Inverse Voltage	V	*15*	*15*
Junction Temperature	℃	*150*	*150*
Storage Temperature	℃	*-65 to 150*	*-65 to 150*
Thermal Resistance	℃/W	*500*	*150*

(b) Specification of HSMS-282x [11]

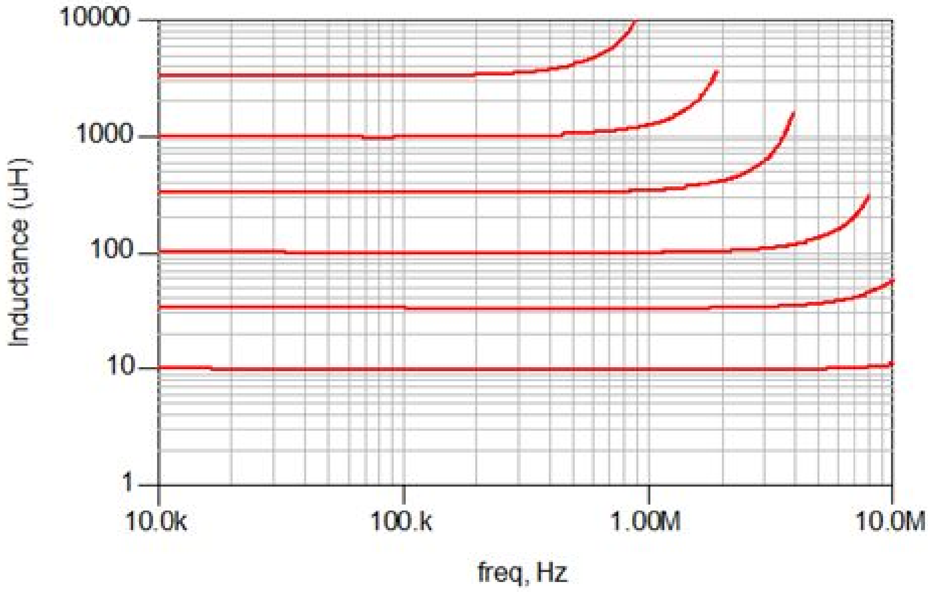
Figure 3.5. is data sheet of HSMS-2852 that is used in the AC-DC converter of [6]. Once you examine data sheet of HSMS-2852, Avago's HSMS-258x family of zero bias Schottky detector diodes has been designed and optimized for use in small signal (Pin < -20 dBm) applications at frequencies below 1.5 GHz, and for detector applications with input power levels greater than -20 dBm, Avago ecourages user to use the HSMS-282x series at frequencies below 4.0 GHz, and the HSMS-286x series at frequencies above 4.0 GHz. The HSMS-285x series is not recommended for these higher power level applications. Thus, performance data above -20 dBm in [6] has no credibility.

In this thesis, HSMS-2822 is used from -10 dBm to 15 dBm in AC-DC converter for the condition that is below the power limit of the diode.

III-6. Specification of the Inductor

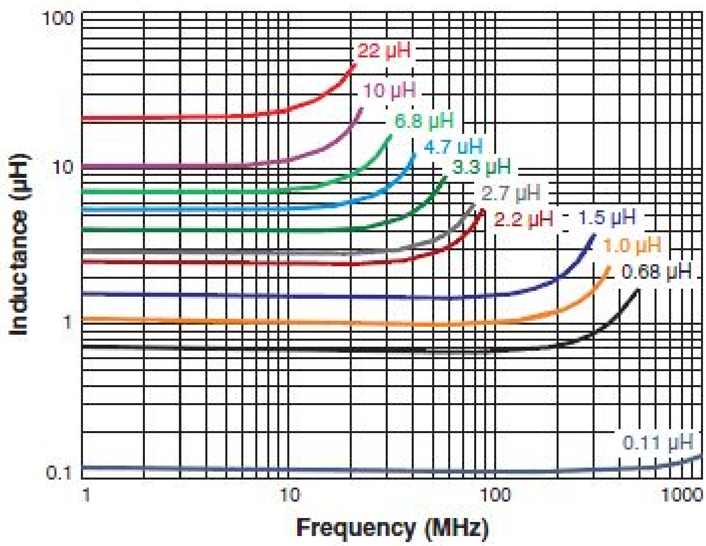


(a) MSS series [12]-[14]

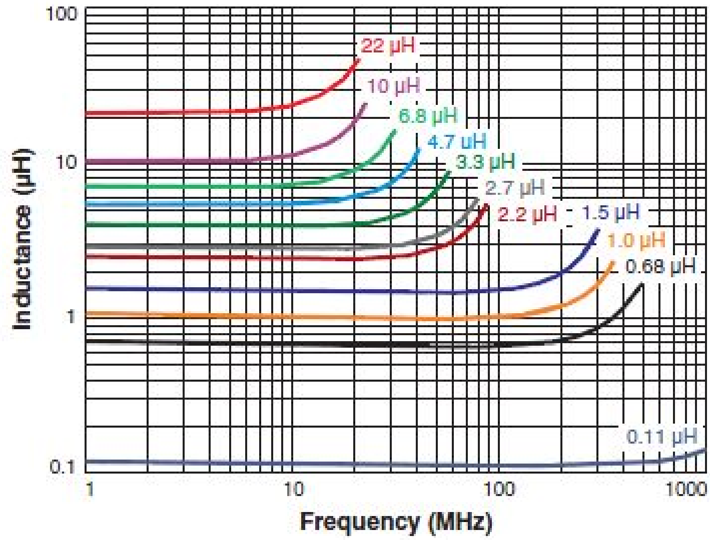


(b) LPS Series [15]-[16]

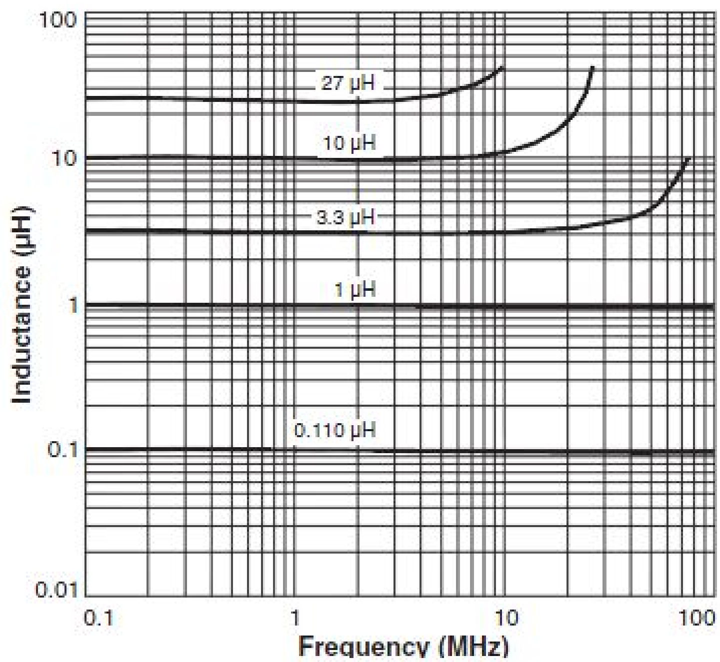
Figure 3.6. Effect of the power inductors[(a)MSS, (b)LPS series] on frequency



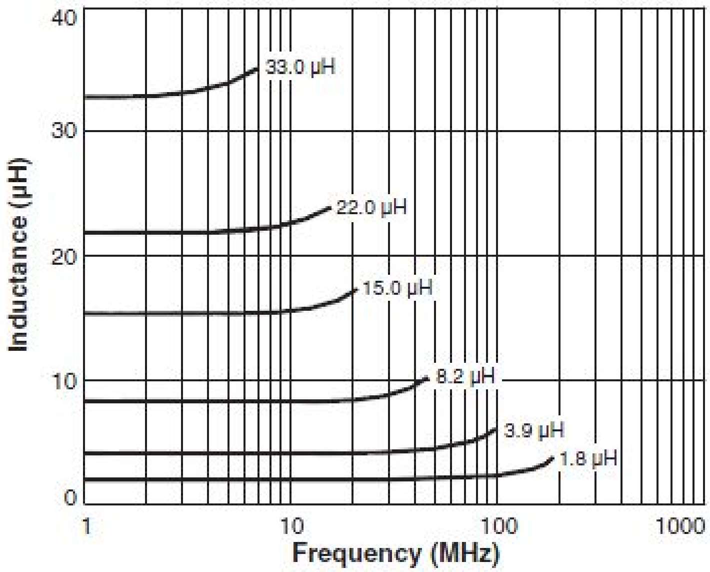
(a) 0608AF Series [17]



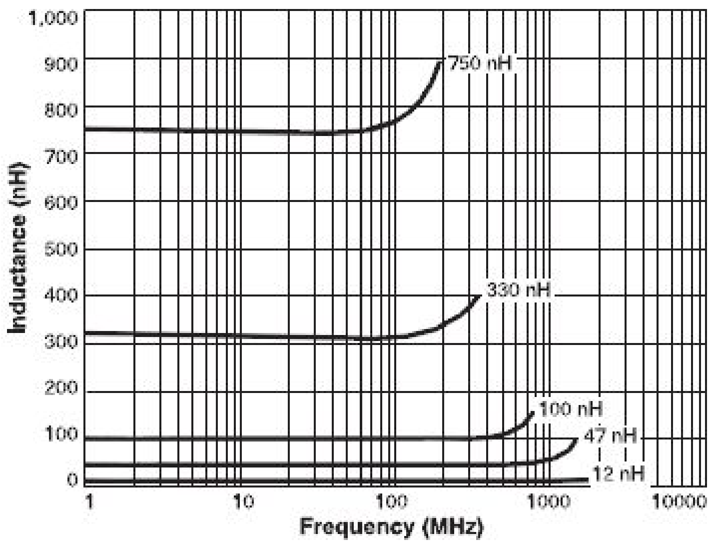
(b) 0805AF Series [18]



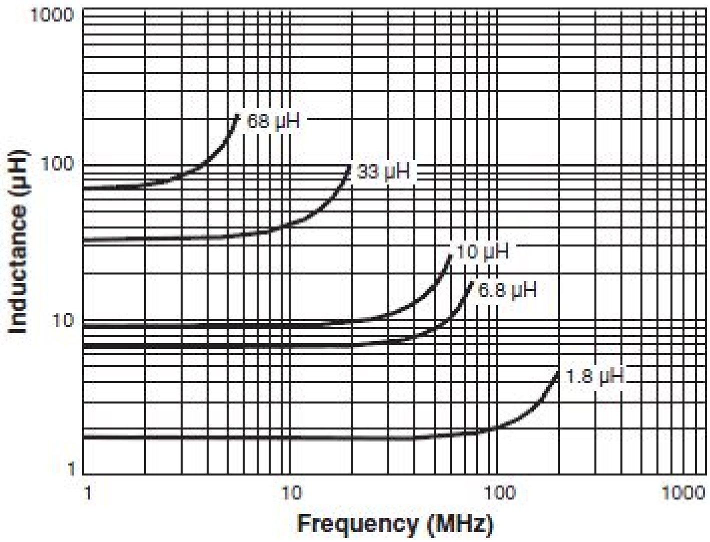
(c) 0805LS Series [19]



(d) 1812CS Series [20]



(e) 1008CS Series [21]



(f) 1008LS Series [22]

Figure 3.7. Effect of the RF inductors[(a)0608AF, (b)0805AF, (c)0805LS, (d) 1812CS, (e)1008CS, (f)1008LS series] on frequency

Figure 3.6. and Figure 3.7. are data sheet of power and RF inductors. Actually, power and RF inductors are not much different in 10 - 20 MHz, but RF inductors has more stable inductance according to the frequency than power inductors.

Selection standards of inductors in this study are frequency tolerance of inductance and resistance for minimum loss. Actually, inductors as shown in Fig. 3.6 and 3.7 have similar performance, but performance of them show great difference in measurement. therefore, inductor was selected experimentally.

Thus, in order that system has more stable performance at wide frequency band, RF inductors is used in this thesis.

Ⅳ. Simulation and Measurement

Ⅳ-1. Setup

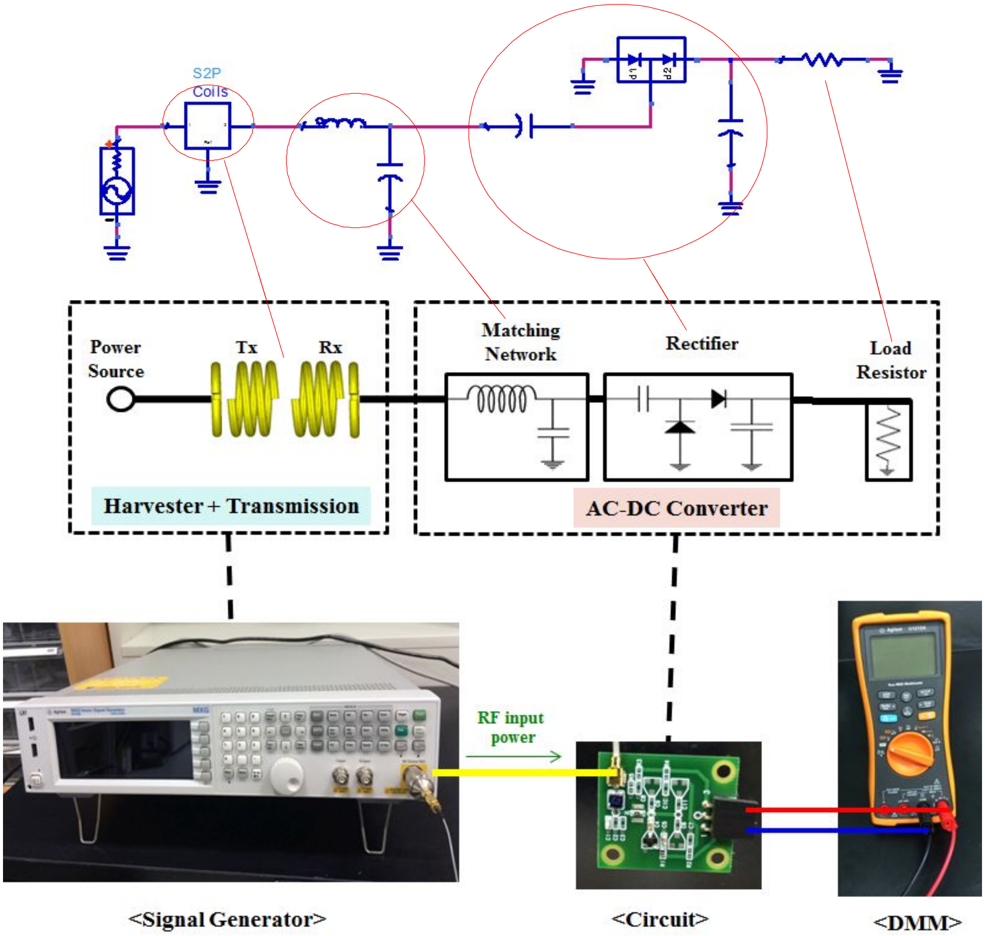


Figure 4.1. Simulation and Measurement setup

Figure 4.1 is simulation and experiment setup. For convenience of measurement, received power on the coils is substituted by signal generator. Then, AC power from the signal generator was converted DC power using the AC-DC converter. Output voltage on the load resistor is measured by DMM (Digital Multi Meter), and conversion efficiency is calculated from output voltage and load resistor.

Performance of AC-DC converter is changed according to various conditions such as matching network, frequency, input power, etc.. In following sections, effects of various conditions on performance of AC-DC converter will be clarified.

IV-2. Simulation and Measurement Results

Figure 4.2. shows the conversion efficiency results of the AC-DC converter optimized by power matching with Advanced Design System of Agilent. The proposed AC-DC converter shows efficiency of up to 87%, and a high average efficiency is shown owing to the gradual width of decrease even if the received power is decreased.

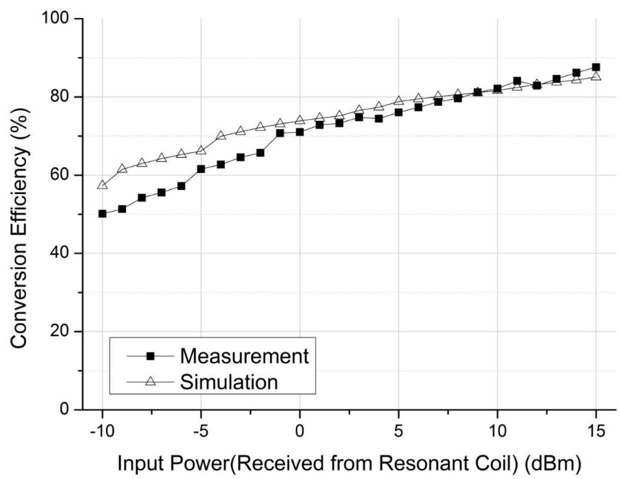


Figure 4.2. Conversion efficiency according input power

Ⅳ-3. Performance Comparison

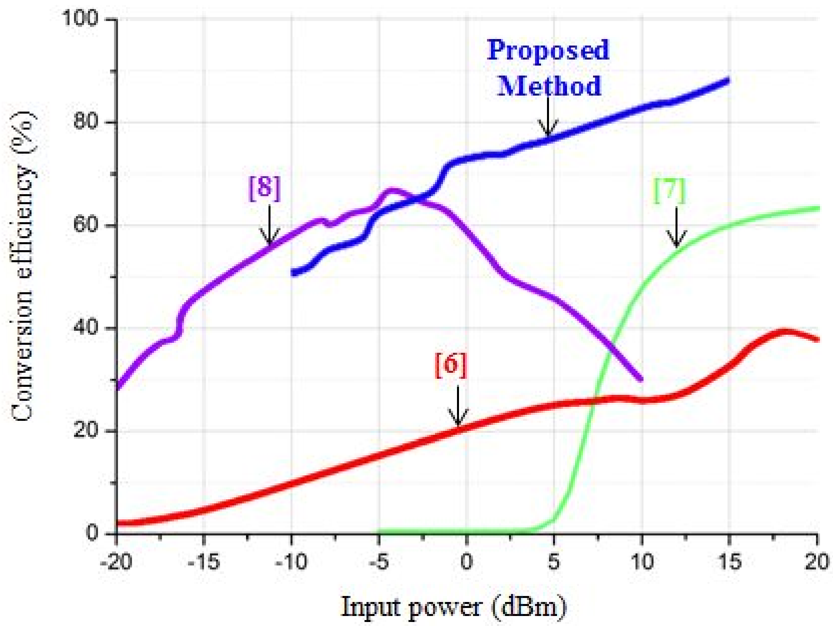


Figure 4.3. Performance Comparison with other studies

Table 4.1. Comparison of Peak efficiency and Average efficiency

Design	Proposed Method	[6] (900MHz)	[7] (2.45GHz)	[8] (953MHz)
Peak Efficiency	87%	38%	67%	65%
Average Efficiency (-10 to 15 dBm)	65%	34%	48%	12%

Figure 4.3. and Table 4.1. are comparison with other studies. The measured maximum conversion efficiency and average efficiency of other converters using

similar power ranges are shown in Table 4.1. and Figure4.3.. Even though frequency bands of previous studies are different from this study, efficiency curves that used proposed method in their frequency bands are not much different from this study in additional simulations and experiments. Compared with other converters, the maximum and average efficiency of the converter proposed in this thesis are superior to those of other AC-DC converters.

Although the AC-DC converter of this study uses the same method of [5], the simulation and measurement results show a tendency unlike the result of that. There are two reasons for this. First, the simulation and measurement data of the prior work lack credibility because the specification limit of the diode is exceeded in that power range. HSMS-2852 used in the low-power design of the prior study has less than -20 dBm available power when the load condition is like that. Similarly, HSMS-2822 used in the high-power design of the prior work has a breakdown voltage of 15 V.

Thus, the use of power in the -20 to 15 dBm range that does not exceed 15 V that comes into both ends of the diode is proper. Second, because the prior work uses seven to ten stages to obtain the peak efficiency at the intended power value, the influence of the parasitic effect increases. Further, the design in the prior work using only one stage showed decreased efficiency.

The AC-DC converter proposed in this thesis comprises only one stage, but it shows higher efficiency than that using one stage. Although a matching method like that used in the prior work is used in this study, the parasitic effect on the circuit could be decreased and efficiency could be greatly improved by a design that is suitable for the specifications of the diode component.

V. Conclusion

In this thesis, a highly efficient AC-DC converter was developed in which the matching network was optimized according to the input power in the range from -10 to 15 dBm. Compared to other converters, the implemented AC-DC converter shows the highest peak efficiency and average efficiency in the intended power range.

Unlike another converter using same method, because a gradual efficiency curve was seen in the simulation and measurement results, this indicates that the implemented AC-DC converter of this study achieves better optimization in the -10 to 15 dBm range. That means that the circuit achieves high performance and that it can be converted with high conversion efficiency even if the input power is changed by the surrounding environment.

Therefore, if the AC-DC converter of this study is applied when RF power generated from energy harvesting is transmitted to devices that may require power with wireless power transmission, the technique proposed in this thesis can be advantageous in situations in which the received power is unstable owing to movement of the human body.

References

[1] Mitcheson PD, Yeatman EM, Rao GK, Holmes AS, Green TC, "Energy harvesting from human and machine motion for wireless electronic devices," Proc IEEE, vol. 96, issue 9, pp. 1457-1486 , September 2008.

[2] J. Granstorm, J. Feenstra, H. A Sodano and K. Farinholt, "Energy harvesting from a backpack instrumented with piezoelectric shoulder straps," Smart materials and Structures, Vol. 16, No. 5, pp. 1810-1820, September 2007.

[3] S.M. Kim, I. K. Cho, J. I. Moon, J. H. Yoon, W. J. Byun, J. I. Choi, "1.9MHz Wireless Power Transmission system using Coupled Magnetic Resonance," Microwaves, Radar and Wireless Communications, pp. 519-522, May 2012.

[4] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, M. Soljacic, " IEEE Wireless power transfer via strongly coupled magnetic resonances," Science, vol. 317, pp. 83-86, July 2007.

[5] M. J. Jeong, K. H. Park, J. M. Kim, J. H. Hwang, C. H. Hyoung and Y. T. Kim, "Feasibility study on application of power transmission using magnetic coupling to body area network," IEEE Electronics letters, vol. 48, no. 16, pp. 1013-1015 , August 2012.

[6] P. Nintanavongsa, U. Muncuk, D. R. Lewis, K. R. Chowdhury, "Design Optimization and Implementation for RF Energy Harvesting Circuits," IEEE Journal on emerging and selected topics in circuits and systems, vol. 2, no. 1, pp. 24-33, March 2012.

[7] U. Olgun, C. Chi-Chih, "Investigation of rectenna array configurations for enhanced RF power harvesting," IEEE Antennas Wireless Propag. Lett., vol. 10, pp. 262-265, April 2011. , Daejeon, South Korea, Electromagnetic Compatibility Symposium - Perth (EMCSA), pp. 1-4, 9-11 November. 2011.

[8] J. Zbitou, M. Latrach, and S. Toutain, "Hybrid rectenna and monolithic integrated zero-bias microwave rectifier," IEEE Trans. Microw. Theory Tech., vol. 54, no. 1, pp. 147-152, January 2006.

[9] Bo Li, Xi Sho, Negin Shahshahan, Neil Goldsman, Thomas Salter, and George M. Metze, "An Antenna Co-Design Dual Band RF Energy Harvest," IEEE Transactions

on Circuit and Systems Vol. 60, No. 12, pp. 3256-2366, December 2013.
[10] Avago Technologies HSMS-2852, http://www.avagotech.com/
[11] Avago Technologies HSMS-2822, http://www.avagotech.com/
[12] Coilcraft inductor Spice Model - MSS-5131, http://www.coilcraft.com/
[13] Coilcraft inductor Spice Model - MSS-1260, http://www.coilcraft.com/
[14] Coilcraft inductor MSS-1246T Data sheet, http://www.coilcraft.com/
[15] Coilcraft inductor LPS-4414 Data sheet, http://www.coilcraft.com/
[16] Coilcraft inductor LPS-5030 Data sheet, http://www.coilcraft.com/
[17] Coilcraft inductor 0603-AF Data sheet, http://www.coilcraft.com/
[18] Coilcraft inductor 0805-AF Data sheet, http://www.coilcraft.com/
[19] Coilcraft inductor 0805-LS Data sheet, http://www.coilcraft.com/
[20] Coilcraft inductor 1812-CS Data sheet, http://www.coilcraft.com/
[21] Coilcraft inductor 1008-CS Data sheet, http://www.coilcraft.com/
[22] Coilcraft inductor 1008-LS Data sheet, http://www.coilcraft.com/

List of Publications

Tae-il Yun, Jang Hyun Lee, Jong Jin Baek, and Youn Tae Kim, "AC-DC converter for Wireless Power Transmission of Energy Harvesting System", *IEEE International Symposium Consumer Electronics, June 22-25.*

Min Joo Jeong, **Tae-il Yun**, Kun Ho Park and Y. T. Kim, "Wireless Power Transmission Using Wearable Coils for Ubiquitous Healthcare," *International BioMedical Engineering Conference, Nov., 2014*

Abstract

Optimization of AC-DC Converter for Wireless Power Transmission Of Energy Harvesting System

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In this thesis, a high-efficiency AC-DC converter is developed for a wireless power transmission system that transmits power generated from energy harvesting.

RF power is transmitted in the frequency of 10-100 MHz, and power of -10 to 15 dBm is received by the AC-DC converter. A matching network is designed according to the received power from resonant coils, and the load resistor is optimized to obtain maximum output power.

As a result, conversion efficiency ranging from 50% to a maximum of 87% is

achieved in an RF power range of −10 to 15 dBm that has 10−100 MHz frequency.

Compared to other converters, the implemented AC-DC converter shows not only 20%-40% higher peak efficiency, but also 20%-50% higher average efficiency. It is suitable for application in wearable devices or body area networks.

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TAE IL YUN