論文 / 著書情報
Article / Book Information

題目(和文)	バッテリレスセンサネットワークを実現するマルチポイント型ワイヤレス給電の研究
Title(English)	Multi-point Wireless Energy Transmission to Realize Battery-less Sensor Networks
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10150号, 授与年月日:2016年3月26日, 学位の種別:課程博士, 審査員:阪口 啓,安藤 真,高田 潤一,西方 敦博,廣川 二郎,篠原 真毅
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10150号, Conferred date:2016/3/26, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	電気電子工学	専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（ 工学 ）
学生氏名： Student's Name	前原 大樹		指導教員（主）： Academic Advisor(main)		阪口 啓
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Power supplying for sensor nodes has been a critical issue in WSNs (Wireless Sensor Networks) which are expected to perform many kinds of applications, i.e. energy management, medical, military, agriculture, and so on. Because WSNs deploy numerous sensor nodes arbitrarily distributed in the target field, sensor nodes with wired cables and batteries are suffered from the cost of the initial wired connection and the battery replacement respectively. In recent years, sensor nodes can be activated via ambient energy such as light, vibration and so on. However, the ambient energy can be easily influenced by its surrounding environments. Therefore, this thesis proposes to supply sensor nodes with energy by using microwave.
So far, the wireless energy transmission using microwave is employed by passive RFID (Radio Frequency IDentification) systems. In the RFID systems, R/Ws (Reader/Writers) transmit microwave and receive the information from the ID tags activated by the energy of the microwave. Since many RFID systems use single transmitter, the coverage of the readability is limited by its transmit power restricted by the radio regulation. In multiple transmitters systems, interference between multiple transmitters occurs in case a common frequency is used by all the transmitters. To avoid the interference, time division transmit systems can be used for RFID systems. However, these systems increase the complexity and reduce the time efficiency of the supply power.
To deal with the problem, this thesis proposes wireless grid which aims to supply energy to all the sensor nodes distributed in indoor environments. In the wireless grid, multiple transmitters, supplying microwave continuously, are employed to enhance the energy supply field and carrier shift diversity, in which multiple frequencies slightly different from each other are allocated to multiple transmitters, is used to avoid the interference among multiple transmitters. In this thesis, the proposed wireless energy transmission system is validated by both theoretical and experimental analyses in terms of propagation characteristics, activation of real battery-less sensor nodes, and implementation of the wireless grid in a real indoor environment.
In the analysis of the propagation characteristics, this thesis conducts indoor experiments in which we compare the power distribution and the coverage performance of different energy transmission schemes including single-point, simple multi-point and our proposed multi-point scheme. To easily observe the effect of the standing-wave caused by multipath and interference between multiple wave sources, 2 energy transmitters are employed and the received power is measured between 2 transmitters in both horizontal and vertical planes. The results together with those of numerical simulations that assumes a similar antenna setting show that the coverage of single-point and multi-point wireless energy transmission without carrier shift diversity are limited by path-loss, standing-wave created by multipath and interference between multiple wave sources. On the other hand, the proposed scheme can overcome power attenuation due to the path-loss as well as the effect of standing-wave created by multipath and interference between multiple wave sources.
In the analysis of the activation of real battery-less sensor nodes, this thesis develops low-energy battery-less sensor nodes whose consumed power and required received power for activation are about 140 μW and 400 μW respectively. In addition, we conduct indoor experiments in which both the received power and the activation of battery-less sensor nodes along the straight line between 2 transmitters are simultaneously observed by using the developed battery-less sensor node. The results show that the coverage of single-point and simple multi-point schemes are, respectively, 84.4% and 83.7%, while the coverage of the proposed scheme is 100%. Therefore, this analysis validates the effectiveness of the proposed scheme in terms of the activation of real battery-less sensor nodes.
By extending these fundamental analyses, in the implementation of the wireless grid, the multiple transmitters are deployed on the ceiling and embedded in the LED ceiling lights in order to supply energy to all the sensor nodes in an indoor environment and easily introduce the system in a real office

environment. In addition, the antenna directivity and polarization are designed to achieve the seamless coverage of 2-D space. Furthermore, a data communication network is designed to collect the information from the low-energy sensor nodes. To verify the system, this thesis develops wireless energy transmitter, battery-less sensor node and access point of WSN, and conducts indoor experiments. By the developments of the components, this thesis implements light control system using human detection sensors for energy saving in an office room. In the experiments, 4 energy transmitters which is minimum configuration of the wireless grid, are employed and the activation possibility of the sensor node is measured at the height of desks in 2-D plane among those transmitters. The experimental results show that the coverage of the developed system achieves full coverage to activate sensor nodes.
In conclusion, this thesis demonstrates the feasibility of battery-less sensor networks by the proposed system.