Rapid Design of tunable metasurface using Deep Neural Networks for Field Localized Wireless power transfer

저자 (Authors)	Bui Huu Nguyen, Ngoc Hung Phi, Seneke Chamith Chandrarathna, Jong-Wook Lee
출처 (Source)	한국통신학회 학술대회논문집 , 2021.2, 383-384 (2 pages) Proceedings of Symposium of the Korean Institute of communications and Information Sciences , 2021.2, 383-384 (2 pages)
발행처 (Publisher)	한국통신학회 Korea Institute Of Communication Sciences
URL	http://www.dbpia.co.kr/journal/articleDetail?nodeId=NODE10547569
APA Style	Bui Huu Nguyen, Ngoc Hung Phi, Seneke Chamith Chandrarathna, Jong-Wook Lee (2021). Rapid Design of tunable metasurface using Deep Neural Networks for Field Localized Wireless power transfer. 한국통신학회 학술대회논문집, 383-384.
이용정보 (Accessed)	경희대학교 국제캠퍼스 163.***.117.92 2021/05/13 20:22 (KST)

Rapid Design of tunable metasurface using Deep Neural Networks for Field Localized Wireless power transfer

Bui Huu Nguyen*, Ngoc Hung Phi, Seneke Chamith Chandrarathna and Jong-Wook Lee*
Department of Electronics and Information Convergence Engineering, Kyung Hee University

요 약

Wireless power transfer (WPT) is a convenient method of delivering energy to multiple devices without connecting wires. To further enhance WPT efficiency, unique characteristic metamaterials, such as electromagnetic field focusing, have been successfully utilized. Normally, metamaterial characteristics depend on multiple parameters. Several metamaterial designs require a significant amount of time to complete numerical simulation. In this work, we propose a rapid design metamaterial method using a deep neural network (DNN). When DNN is used, the results show an accuracy of 98.1% and an accumulated mean square error (MSE) less than 0.3×10^{-3}. For synthesizing the design parameters, the MSE is less than 8×10^{-3}. Besides, the computation time of the 1000 samples can be reduced 85×10^{3} times compared to the HFSS simulation.

Ⅰ. Introduction

The wireless power transfer (WPT) is a convenient method of delivering energy to multiple devices without connecting wires. However, the previous approaches have an issue that the field generated by the antenna is much leakage to the unload because the receiver coil is small or not close to the source coil [1]. That is the reason why wireless power transfer efficiency is reduced.

Recently, cavity-metamaterials are useful in WPT for enhanced efficiency. Aruna et al. investigate the 2D metamaterial, which improves WPT efficiency by using cavities unit cell as the power hotspots [2]. The cavity unit cell metamaterial is created by tuning the characteristics, which depend on multiple parameters. Thus, the metamaterial design process takes a long time of simulation or complex computation. For numerous designs, the traditional method is unpreferred.

The DNN has recently been improved high accuracy and computing rate beyond the human level. These advantages of the DNN endow the designed metamaterial with high accuracy was approached [3]. The result shows that the DNN has been successfully used for predicting the transmittance coefficient of the dielectric metasurface.

In this work, we propose a rapid design metamaterial parameters method using a DNN. Using 2118 (18%) testing data of 11766 random samples, we investigate that the DNN can rapidly successfully predict the reflection coefficient (S_{11}) of the metamaterial.

Ⅱ. Design

Fig. 1(a) shows a schematic of the WPT charging table using the cavity-metamaterial assembled by the hexagonal unit cells. The unit cell characteristic is decided by six parameters: the width W, the spacing S, the metal thickness t_m, the dielectric thickness t_d, cell size a, and the capacitor C_S. Same as our previous work, there are 3.4×10^{11} designs when considering all the combinations of the parameters [4]. Fig. 1(b) shows the reflection coefficient of the hexagonal unit cell depending on C_S.

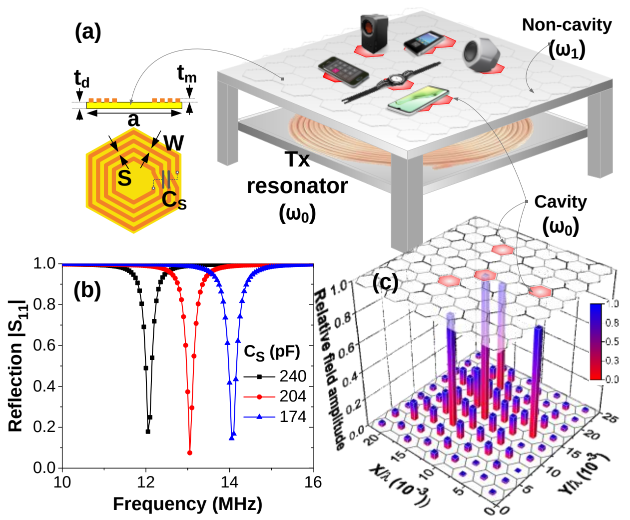

Fig.1. (a) Concept of WPT charging table using cavity metasurface. (b) Reflection of unitcell (S_{11}) depending on C_S. (c) Relative field amplitude distributes on metasurface.

Fig. 1(c) shows the measured relative field amplitude by scanning over the metasurface. Here, all the unit cells resonate at ω_1 = $0.86\omega_0$ except for the unit cells forming the cavity, which resonate at ω_0 =14 MHz. The result shows that the relative field amplitude in the cavity region is higher than in the surrounding region.

Fig. 2 shows the block diagram of the overall neural network. For synthesizing the design parameters, we use two fully-connected networks (FCNs), which are the design parameter to S-parameter (DPSP) and the S-parameter to design parameter (SPDP) networks. Both FCNs have nine layers with 1024 nodes.

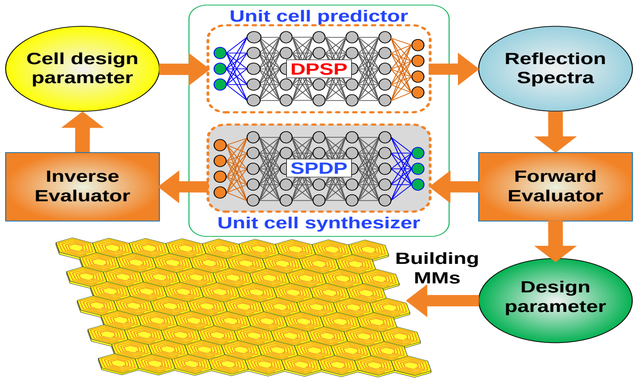

Fig.2. Two FCNs are used for predicting the frequency spectra and generating the design parameters of the hexagonal unitcell.

Fig. 3 shows the examples of test data for the DPSP network after 2500 epoch. For each sub-figure, the MSE is also shown. When we accumulate the MSE of the 2118 test set, 98.1% of them have MSE < 0.8×10^{-3}. The results show that the proposed approach using DNN faithfully reconstructs the reflection spectra.

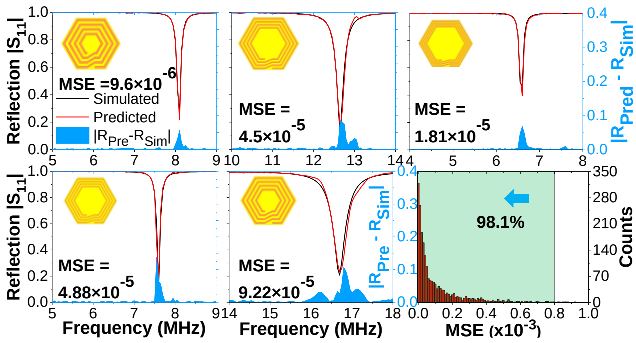

Fig.3. Examples of test data obtained using the DPSP network.

Fig. 4 shows the examples of test data for the SPDP network after 2500 epoch. When we accumulate the MSE of the 2118 test set, 97.7% of them have MSE < 8×10^{-3}. The results show that the DNN can be efficiently used for synthesizing the dimension of the hexagonal metamaterial unitcell.

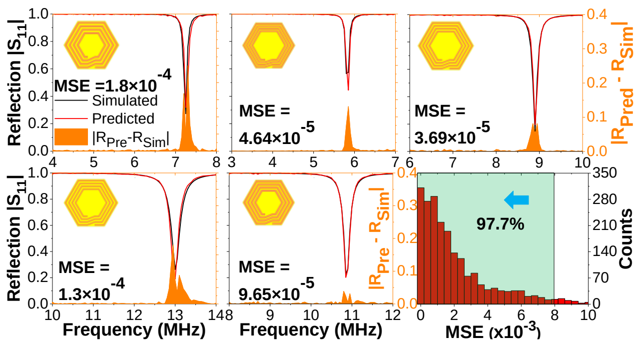

Fig.4. Examples of test data obtained using the SPDP network.

We use Ansys HFSS version 2019 for the EM solver and Tensorflow version 2.0 for DNN. To compare the computation time, both HFSS and DNN are run on the HP Z640 workstation having a 64 GB memory, a GTX1080 GPU, and a Xeon E5-1650v3 processor. When 1000 samples are calculated, the HFSS simulator takes 188057 sec (52.24 hours) while DNN takes 2.2 sec. The result shows that the DNN approach significantly reduces the computation time.

Ⅲ. Conclusion

In this work, we investigated the DNN can successfully predict the reflection spectra and synthesize the design parameters. Using DNN for 1000 metamaterial designs, the computation time of the process was reduced around 85×10^{3} times compared to the HFSS simulation.

ACKNOWLEDGMENT

This work was supported by the Basic Science Research Program (No. 2015R1A2A2A03004160) and BK21 FOUR (Fostering Outstanding Universities for Research) through NRF.

REFERENCES

[1] S. Kim, "Wireless power transfer to miniature implants: Transmitter optimization," *IEEE Trans. Antennas Propag.*, vol. 60, pp. 4838-4845, July 2012.

[2] A. L. A. K. Ranaweera, "An active metasurface for field-localizing wireless power transfer using dynamically reconfigurable cavities," *Sci. Rep.*, vol. 9, pp. 1-12, Aug. 2019.

[3] C. C. Nadell, "Deep learning for accelerated all-dielectric metasurface design," *Opt. Express*, vol. 27, pp. 27523-27535, Sep. 2019..

[4] H. N. Bui, "Design of Tunable Metasurface Using Deep Neural Networks for Field Localized Wireless Power Transfer," *IEEE Access*, vol. 8, pp. 194868-194878, Oct. 2020.