Design of Antipodal Vivaldi Antennas Using Kernel Regression Optimization

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***Abstract* – This paper proposes the design of antipodal Vivaldi antennas using the kernel regression method. The kernel regression is applied for training a cost function model to predict the next sample with improved cost values, and the information of the predicted sample is employed to re-train the model. This process is repeated until the cost value converges to our design goal. The shapes of the tapered slot line and the extended ground are determined by adjusting coefficients of multi-Gaussian functions. The optimized antenna has an overall dimensions of 88.1 × 120 mm^2 and shows an average reflection coefficient of −11.1 dB in the frequency band.**

***Index Terms* — Vivaldi antennas, antenna optimization, kernel regression.**

1. Introduction

Vivaldi antennas have gained popularity because of its broadband characteristics, end-fire radiation patterns, and low costs for fabrication [1]. Various approaches have been proposed to broaden matching bandwidths, while maintaining constant gain properties [2]. However, the transition structure between the feed and the slot line limits the upper bound of the impedance matching bandwidth. Although this bandwidth limitation can be resolved by adopting the antipodal structure, the matching and radiation characteristics still depend on the shape of the tapered slot line [3].

In this paper, we propose the design of antipodal Vivaldi antennas using the kernel regression method. The operating frequency band of the antenna is from 1 GHz to 6 GHz, and the shape of the tapered slot line and the extended ground are determined by adjusting coefficients of multi-Gaussian functions. The kernel regression is applied to train the cost function model by fitting the training data, and the trained model is used to predict the next sample with improved cost values. The information of the predicted sample is then employed to re-train the model, and this process is repeated until the cost value converges to our design goal. The optimized antenna has an overall dimensions of 88.1 × 120 mm^2 and shows an average reflection coefficient of about −11.1 dB in the frequency band.

2. Optimization of antipodal Vivaldi antennas

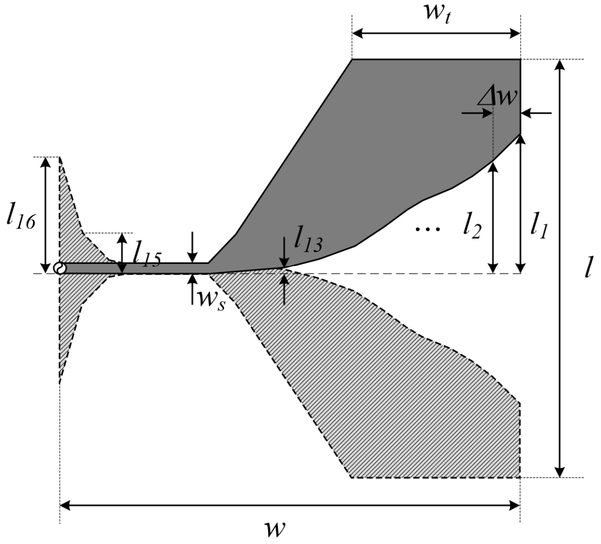

Fig. 1. Design parameters of a Vivaldi antenna.

Fig. 1 shows design parameters of the proposed antipodal Vivaldi antenna that is printed on an FR4 substrate (ε_r = 4.5, tanδ = 0.02) with a thickness of 1.6 mm. The shape of the tapered slot line is determined by 13 parameters (l_1, l_2, … , l_{13}), and that of the extended ground is designed by 3 parameters (l_{14}, l_{15}, l_{16}). These parameters are calculated by varying 11 coefficients (a_1, a_2, … , a_{11}) of multi-Gaussian functions that are defined by

$$function = a_1 e^{-\frac{(x-0\cdot\Delta x)^2}{\lambda}} + a_2 e^{-\frac{(x-1\cdot\Delta x)^2}{\lambda}} + \cdots + a_{11} e^{-\frac{(x-10\cdot\Delta x)^2}{\lambda}} \quad (1)$$

, where λ = 100 mm and $\Delta x = w/10$. w_s is varied from 0.5 mm to 2.5 mm, and w_t has a value between 0 mm and 25 mm.

Fig. 2 shows a flowchart of the proposed optimization process with the kernel regression method. In our approach, random antenna samples of size d (x_1, x_2, … , x_d) with different design parameters are generated to calculate initial cost values (y_1, y_2, … , y_d) using a commercial EM simulation tool [4]. These cost values are used to determine model coefficients (θ_1, θ_2, … , and θ_d) by applying the kernel regression, and the input data (x_1, x_2, … , x_n) are weighted and summed to fit the model. Then, the fitted model is exploited to predict the next sample (x_{n+1}), and the cost value of the predicted sample (y_{n+1}) is then employed to re-train the model. This process is repeated by updating the coefficients until the cost value converges to our design goal, which is the average reflection coefficient of less than 0.3.

Our optimization process was terminated at 200 iterations with the cost value of 0.28, and the optimized values of the

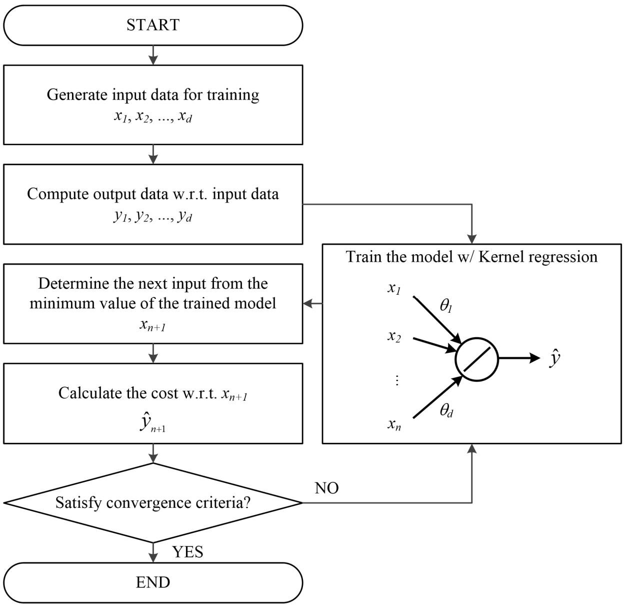

Fig. 2. Flowchart of kernel regression optimization.

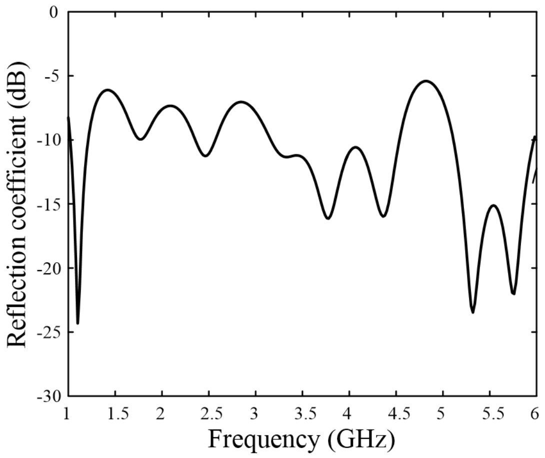

Fig. 3. Reflection coefficients of the optimized antenna.

design parameters are as follows: w = 120 mm, l = 88.1 mm, w_s = 2.4mm, w_t = 35 mm, Δw = 5 mm, l_1 = 41.2 mm, l_2 = 37.4 mm, l_3 = 31.4 mm, l_4 = 25.1 mm, l_5 = 19.7 mm, l_6 = 13.5 mm, l_7 = 7.3, l_8 = 3.3 mm, l_9 = 1.9 mm, l_{10} = 1.7 mm, l_{11} = 1.2 mm, l_{12} = 0.6 mm, l_{13} = 0.2 mm, l_{14} = 2.7 mm, l_{15} = 6 mm, l_{16} = 21.2 mm.

Fig. 3 shows the reflection coefficient of the optimized antenna. The antenna shows that the maximum reflection coefficient is −5.4 dB at 4.82 GHz, and the average value is −11.1 dB in the frequency band.

3. Conclusion

We proposed the design of antipodal Vivaldi antennas using the kernel regression method. The shapes of the tapered slot line and the extended ground were determined by adjusting coefficients of multi-Gaussian functions, and our optimization process was terminated at 200 iterations with the cost value of 0.28. The reflection coefficients of the optimized antenna are less than −5.4 dB, and their average value is −11.1 dB in the frequency band.

Acknowledgment

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References

[1] M. Moosazadeh, S. Kharkovsky, and J. T. Case, “Microwave and millimetre wave antipodal Vivaldi antenna with trapezoid-shaped dielectric lens for imaging of construction materials,” *IET Microw. Antennas Propag.*, vol. 10, no. 3, pp. 301-309, Feb. 2016.

[2] A. Z. Hood, T. Karacolak, and E. Topsakal, “A Small Antipodal Vivaldi Antenna for Ultrawide-Band Applications,” *IEEE Antennas Wirel. Propagat. Lett.*, vol. 7, pp. 656-660, Mar. 2008.

[3] S. Chamaani, S. A. Mirtaheri, and M. S. Abrishamian, “Improvement of Time and Frequency Domain Performance of Antipodal Vivaldi Antenna Using Multi-Objective Particle Swarm Optimization,” *IEEE Trans. Antennas Propag.*, vol. 59, no. 5, pp. 1738-1742, May 2011.

[4] FEKO Suite 7.0, EM Software and Systems, 2014 [Online]. Available: http://www.feko.info