# Gain Enhancement of a Dual Feed Microstrip Array Antenna Using Parasitic Elements

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***Abstract*—In this paper, an in-phase/anti-phase dual feed microstrip array antenna with parasitic elements is proposed to improve the antenna's gain and it is experimentally evaluated. The proposed antenna provides various kinds of functionality such as direction-of-arrival estimation, beam steering and polarization switching with a simple structure. Better than 2-dB gain enhancement is expected by using the parasitic elements. The separation and height of the parasitic elements are also discussed. The separation of 0.8λ₀ with height of 0.5λ₀ provides the highest gain for both the in-phase and anti-phase feeds.**

***Keywords*—in-phase/anti-phase dual feed microstrip array antenna; magic-T; parasitic element.**

## I. Introduction

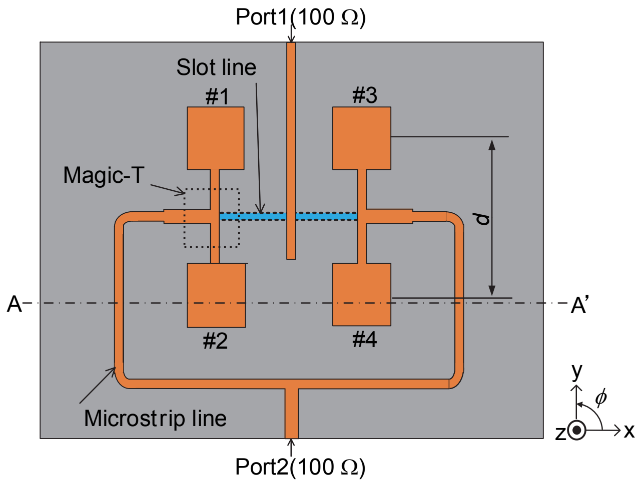
Wireless communication systems such as cell phone and wireless LAN are widely used in our lives. Everything will be connected to the Internet in the near future. In this case, wireless will be the promising solution of the connections. Advanced antennas [1-2] which have functionality with a simple structure are required to achieve future wireless systems. There are many approaches to provide such kind of advanced antennas [3]. We have also proposed several advanced antennas such as a direction-of-arrival (DOA) estimation antenna [4-5], beam steering antenna [6] and polarization control antenna [7-15] by integrating planar antennas and microwave functional circuits. In these antennas, an in-phase/anti-phase dual feed microstrip array antenna employing magic-T circuits is an essential element. In this paper, a new high gain in-phase/anti-phase dual feed microstrip array antenna is proposed and its performance is numerically evaluated using an electromagnetic simulation.

This paper is organized as follows. In Section II, the structure and features of the proposed antenna are described. The results of the numerical analysis are demonstrated in Section III. Finally, Section IV concludes the paper.

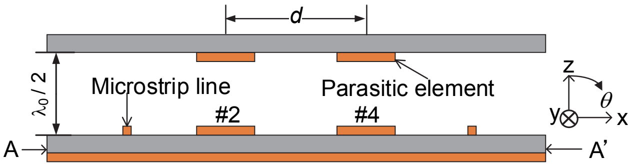
## II. Structure and Features of the Proposed Antenna

### A. Structure

Fig. 1 shows the structure of the proposed microstrip array antenna. Four microstrip antenna elements are placed on a base substrate. Each antenna element is connected to magic-Ts constructed with a microstrip line T junction and a slot-to-microstrip line T branch. The slot line is connected to Port 1 via a microstrip-to-slot line branch located at the center of the array antenna. The microstrip line of the magic-T is connected to Port 2. Four parasitic elements are placed on the bottom of the upper substrate at the height $h$ above the base substrate. The size of the parasitic elements is same as that of the microstrip antenna elements.




(a) Top view of the base substrate




(b) Cross sectional view

Fig. 1. Structure of the proposed in-phase/anti-phase dual feed microstrip array antenna.

### B. Features

The magic-T is constructed with a combination of a microstrip-line T junction and a slot-to-microstrip line T branch. As the microstrip-line T junction is a parallel branch, it provides in-phase power division. On the other hand, as the slot -to-microstrip line T branch is a series branch, it provides anti-phase power division. Isolation between the microstrip line and slot line is also achieved due to the difference of their propagation modes. The feed points of the two antenna

This work was supported in part by JSPS KAKENHI Grant Number 15K06070 and the Cooperative Project Program of the Research Institute of Electronics, Shizuoka University.

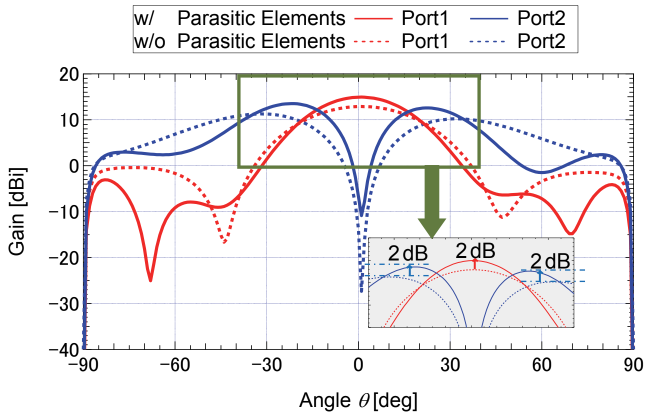



Fig. 2. E-plane radiation pattern ($f$ = 5.8 GHz, $h$=$\lambda_0$/2).

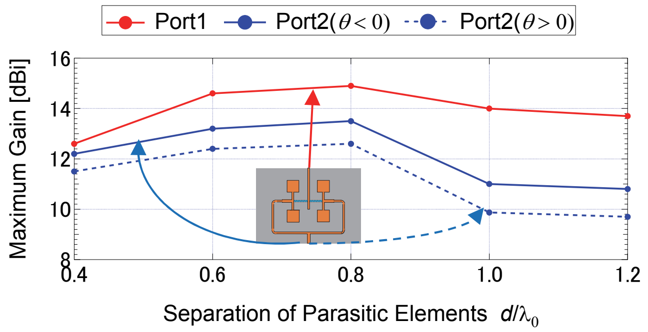



Fig. 3. Variation of the maximum gain ($f$ = 5.8 GHz, $h$=$\lambda_0$/2).

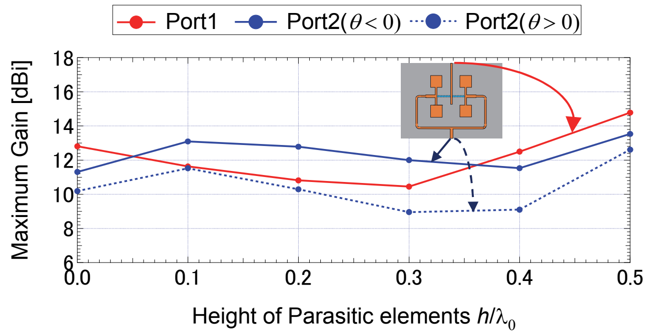



Fig. 4. Variation of the maximum gain ($f$ = 5.8 GHz).

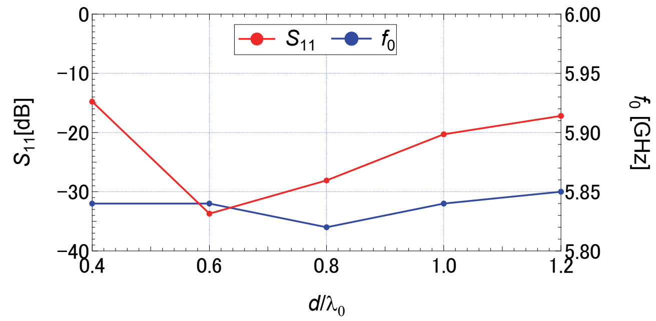



Fig.5. Simulated $S_{11}$ and frequency $f_0$ at the minimum return loss with respect to $d$.

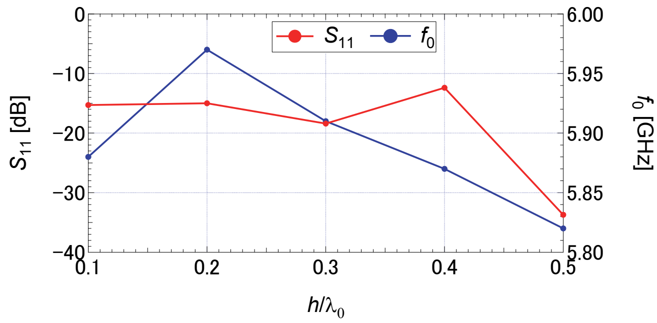



Fig.6. Simulated $S_{11}$ and frequency $f_0$ at the minimum return loss with respect to $h$.

elements connected to the magic-T are the opposite side of the patches. Hence, signals fed from Port 1 and Port 2 excite the two antenna elements in the same phase and anti-phase, respectively.

The features of this antenna structure provide advanced functionality to a planar microstrip array antenna. For example, when the radio wave is received by antenna element #1 and #2 shown in Fig. 1, the sum and difference of the signals are obtained separately from Port 1 and 2, respectively. The use of the sum and difference of the received signals easily realizes a DOA estimation antenna based on the mono-pulse mechanism. As the DOA estimation antenna is constructed with only passive circuits, a beam steering antenna is also easily realized when it is used as a transmission antenna. The feed circuit employing the magic-T can be also used as a bias circuit because the slot line does not feed DC. By using this feature, a polarization control antenna whose antenna elements incorporate switching diodes for polarization switching can be realized in a simple structure.

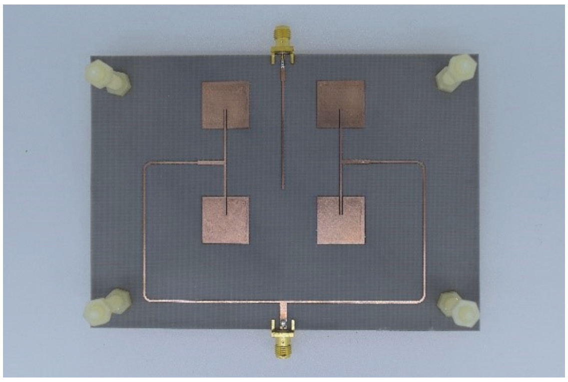
## III. Performance Evaluation

Fig. 2 shows a calculated E-plane radiation pattern of the proposed microstrip array antenna. The radiation patterns of the proposed antenna are shown in solid lines. The radiation patterns of a microstrip array antenna without parasitic elements are also shown in dotted lines as a reference. Red lines show the radiation pattern of the signal fed from Port 1 and blue lines show the one of the signal from Port 2. Here, the separation $d$ of the parasitic elements is 0.8$\lambda_0$ which is same as that of microstrip antenna elements. The center frequency is designed 5.8 GHz, and the impedance at each port is 100 Ω.

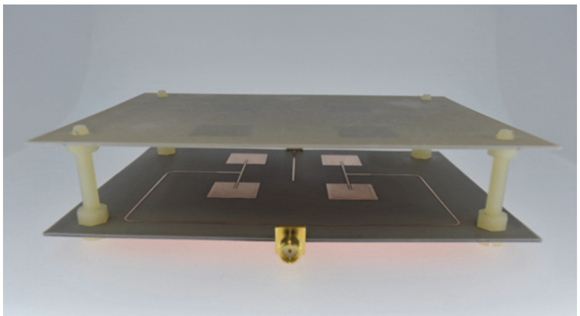
The maximum gains of the proposed microstrip array antenna with parasitic elements are 14.9 dBi for the signal fed from Port 1 and 13.5 dBi (θ < 0) and 12.6 dBi (θ > 0) for the signal fed from Port 2. On the other hand, the maximum gains of the microstrip array antenna without parasitic elements are 12.9, 11.3 and 10.2 dBi, respectively. About 2-dB enhancement is achieved by using the parasitic elements.

Fig. 3 shows the maximum gain variations of the proposed antenna when only the separation of parasitic elements $d$ are changed. Here, the separation between microstrip elements is fixed to 0.8$\lambda_0$. The separation $d$ of 0.8$\lambda_0$ provides the highest gain.

Fig. 4 shows the maximum gain variations of the proposed antenna when only the height of parasitic elements $h$ are changed. Here, the separation between parasitic elements is fixed to 0.8$\lambda_0$. The center frequency is also designed 5.8 GHz,



(a) Top view of the base substrate



(b) Side view of the base substrate with parasitic elements

Fig.7. Photograph of the fabricated in-phase/anti-phase dual feed microstrip array antenna with parasitic elements.

and the impedance at each port is 50 Ω, because of comparing simulation data and experiment result.

Fig. 5 shows simulated $S_{11}$ and $f_0$ at the minimum return loss of the proposed microstrip array antenna with respect to $d$ by $\lambda_0$. The separation $d$ does not also affect the matching frequency. Here, the height $h$ is fixed to $\lambda_0/2$.

Fig. 6 shows simulated $S_{11}$ and $f_0$ at the minimum return loss of the proposed microstrip array antenna with respect to $h$ by $\lambda_0$. The matching frequency changes from 5.82 GHz to 5.88 GHz. Here, the separation $d$ is fixed to $0.8\lambda_0$.

Fig. 7 shows photographs of the fabricated in-phase/anti-phase dual feed microstrip array antenna with parasitic elements. It is fabricated on a Teflon fiber substrate($\varepsilon_r$=2.15, thickness=0.8mm). The size of dual feed microstrip array antenna is 10 x 14 cm.

Fig. 8 shows the maximum gain variations of the proposed antenna. An electromagnetic simulation is shown by the circle marker. The result of the experiment is shown by the square marker. There is the difference of maximum gain between simulation and experiment. There are about 5dB differences between simulated and experimental results. However, similar trends are obtained.

In these calculations, Keysight Technologies' Momentum is used.

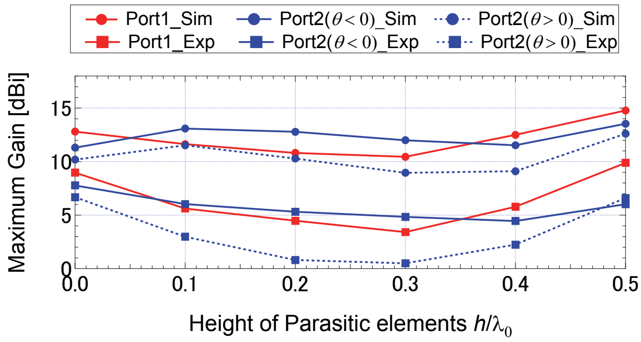



Fig.8. Variation of the maximum gain using an electromagnetic simulation and the result of maximum gain by experiment.

## IV. Conclusion

Gain enhancement of an in-phase/anti-phase dual feed microstrip array antenna using parasitic elements is evaluated. By employing the parasitic elements, better than 2-dB of gain enhancement is obtained. The effect of the separation of the parasitic elements is also examined. The maximum enhancement was obtained at the separation $d$ = $0.8\lambda_0$ and the height $h$=$0.5\lambda_0$.

## Acknowledgment


The authors would like to thank Dr. Takayuki Tanaka, Saga University for his fruitful discussions.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