DIVERSITY ANTENNA LOADED WITH REACTANCE CONTROL CIRCUITS CONFIGURED WITH VARIABLE CAPACITORS FOR EFFECTIVE COMBINING

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Abstract

Diversity antenna loaded with the reactance control circuits configured with variable capacitors was proposed. Advantages of this proposed configuration are that signals are detected only by one receiver and that the hardware architecture is simple. However, effective combining has not been achieved due to a mismatch between the combiner and the receiver. In order to improve this problem, we considered the resistance of the output load. Finally, we show that the performance of the proposed system is close to selection combining.

1 Introduction

High quality transmission techniques are desired for applications such as indoor wireless LAN and mobile systems. However, mobile systems are often used under NLOS multipath environments. Using the mobile systems in such environments degrade the transmission quality through fading. Diversity reception is an important technique to reduce the fading and there are combining techniques for it. Maximal ratio combining (MRC) and equal gain combining (EGC) allow high diversity gain. However, combining in the baseband needs the same number of A/D converters as branches and combining in the RF process needs some phase shifters and thus MRC and EGC have some problems on power consumption, cost and size.

On the other hand, a new combining technique which uses variable capacitors has been proposed (Fig. 1)[1]. The phases of the signals are controlled by the reactance control circuits configured with variable capacitors and the signals are combined. Advantages of this structure are that signals are detected only by one receiver and that the hardware architecture is simple. However, effective combining has not been achieved due to a impedance mismatch between the combiner output and the receiver input.

First, This paper addresses the controllable range of phase by a simulation and the comparison between the performance of the proposed system and conventional combining techniques (selection combining and MRC). Moreover, we consider some resistance values of the receiver in order to reduce the mismatch, and evaluate their performances. Finally, we show that the performance of the proposed system is close to the selection combining (SC) process.

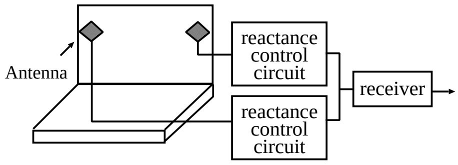

Figure 1: Diversity antenna loaded with the reactance control circuits configured with variable capacitors

2 Proposed system

We evaluate the performance of the two branch diversity antenna that consists of half-wave dipole antennas (Fig. 2) under NLOS multipath environment. In this paper, we configure the reactance control circuit with one variable capacitor and one inductor. Figure 3 illustrates the equivalent circuit of Fig. 2's configuration. In Fig. 3, the parts enclosed with dashed lines, the parts enclosed with dotted lines and the resistance r indicate the equivalent circuit of the antenna, the reactance control circuit and the input impedance of the receiver, respectively. In this model, we assumed a large distance between the antennas so that mutual coupling between each antenna can be ignored. Theoretically, if the phase of the incident voltage can be controlled more than $\pm$ 90 degrees, the system can obtain a higher performance than SC. However, it has been reported that in this circuit, the mismatch occurs between the combiner output and the receiver input, therefore, there was no effective combining made[1]. This is because the change of reactance implies the change of the input impedance seen looking into each branch. In order to reduce the mismatch, we perform simulations and evaluate cases when the value of the resistance r is changed.

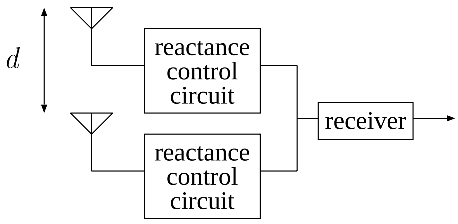

Figure 2: Considered model

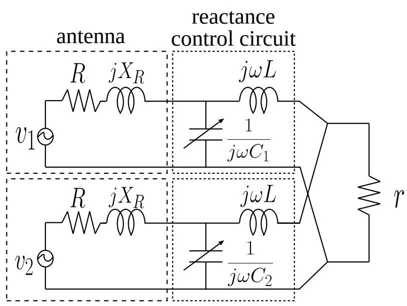

Figure 3: Equivalent circuit of the considered model

3 Diversity antenna gain (DAG)

When signals are combined in the RF process, it is necessary to consider some specific factors of degradation of the performance, for example, the impedance mismatch which is a specific problem of RF signal processing. We use diversity antenna gain (DAG)[2], which can evaluate the total performance of the system including an antenna system and propagation environment such as layout of antennas, incoming wave distribution and so on. If the fading is slow, the outage probability is a good criteria to measure the link quality. DAG–OP is defined as the gain of SNR at a specific outage probability with respect to a reference antenna under the same propagation environment. The DAG–OP (outage probability) is represented as

$$F = \frac{\Gamma_{\rm div}}{\Gamma_{\rm ref}}, \tag{1}$$

where $\Gamma_{\rm div}$ is the SNR at a specific outage probability for the diversity reception case and $\Gamma_{\rm ref}$ is the SNR at the same outage for the reference antenna, which is a half-wave dipole antenna in this case.

4 Simulation condition

We assumed an indoor environment, where the incident waves were modeled to be arriving from arbitrary 3D directions with constant probability. Therefore, the distribution functions $P_\theta(\Omega)$ and $P_\phi(\Omega)$ of θ– and ϕ– polarization components of the incident plane waves, respectively, were expressed as

$$P_\theta(\Omega) = P_\phi(\Omega) = \frac{1}{4\pi}. \tag{2}$$

In Fig. 3, $R + {\rm j}X_R$ is the complex impedance of the half-wave dipole antenna and is 73.1+j42.5 Ω. Moreover, we set the inductor L on the reactance control circuit as 1nH to achieve the wide controllable range and the good matching. The simulation is performed when the load r at the output is set as $0.3R$, $0.5R$ and $0.7R$. The operating frequency is 5GHz. In the monte-carlo simulation, incident waves are modeled by six rays with random angles of arrival, constant amplitude and random phase values. The distance between each antenna is one wavelength. The reactances of the variable capacitors are varied in order to achieve the maximum output power at the load r. The simulation is repeated 100,000 times. The control range of the variable capacitors is from 0.7pF to 6.0pF corresponding to the TOSHIBA 1SV287 varactor diode. In order to determine the optimum reactance values, firstly, the controllable values of the reactances divided into twenty points. Moreover, the best one, which give the maximum output power, is chosen from all combinations of the reactances.

With conditions as identified above, we evaluate the controllable range of phase. Moreover, in order to evaluate the performance of the proposed system, we compared them to the SC and MRC techniques[3][4].

5 Simulation results

In general, the output voltage v can be expressed as $v = {\rm A}v_1 + {\rm B}v_2$ in Fig. 3. Therefore, the phase difference between A and B corresponds to the equivalent phase rotation of the combiner. Figure 4 shows the phase rotation of the combiner for the proposed configuration. It is indicated that the range is ± 143 degrees.

Figure 5 illustrates the reflection coefficient of the antennas and the reactance control circuits as seen from the output r for the proposed system when $r = 0.3R$, $r = 0.5R$ and $r = 0.7R$. It can be seen that a small value of r can improve the mismatch.

Figure 6 illustrates the cumulative probabilities for the SC, MRC and the proposed system with conditions as identified above. The DAG–OPs which satisfy outage probability of 5 percent are 8.4dB for MRC and 6.9dB for SC. Moreover, it can also be seen that the values are 6.9 dB, 6.2 dB and 5.7 dB for the proposed system when $r = 0.3R$, $r = 0.5R$ and $r = 0.7R$, respectively. The result indicates that the system with smaller r configuration gives higher performance than the large r, moreover, the performance of the proposed system by using $r = 0.3R$ is close to the selection combining process.

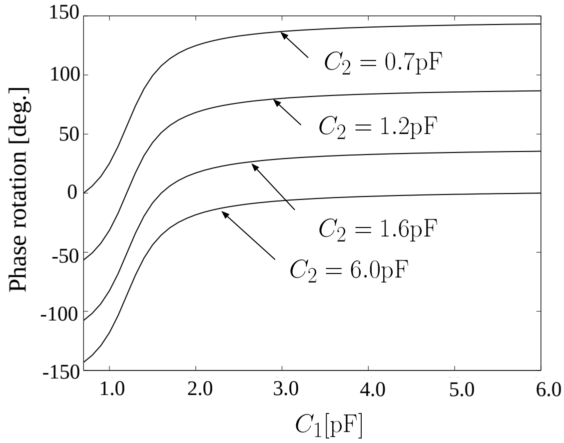

Figure 4: Controllable range of phase in the parallel-capacitors configuration

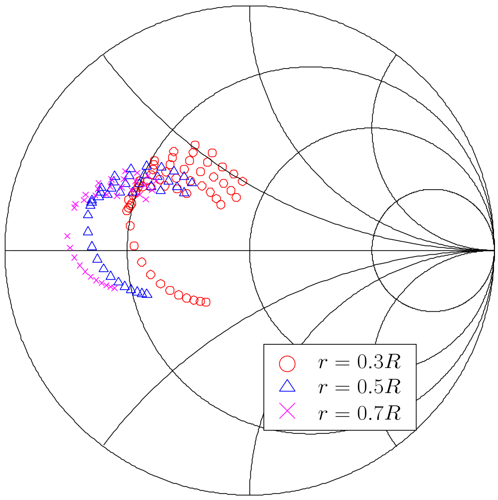

Figure 5: Reflection coefficient

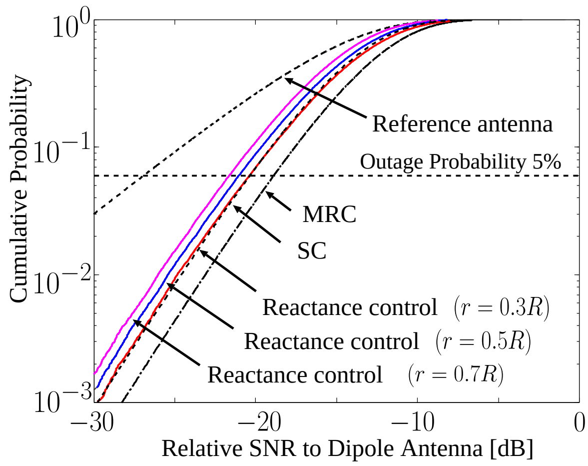

Figure 6: Cumulative probability

6 Discussion and conclusion

The diversity antenna loaded with the variable capacitors can realize a wide range of phase control against the incident voltage on the antenna. Although the proposed system makes it possible to control over ± 90 degrees, a better performance was not achieved. This is because there is an impedance mismatch between each branch and the output load. However, we have shown that the small input impedance of the receiver can reduce the mismatch and the performance is close to SC. If it is difficult to change the input impedance of the receiver, it is expected that the change of the input impedance of the antenna will bring equivalent effects. Moreover, it is expected that appropriate parameters will be able to give a higher performance.

For future work, it is necessary to take into account several issues like the increasing number of branches, optimization of the parameters for the reactance control circuit and the equivalent circuit of the antenna, and cases which include interference. In addition, the calculation time grows exponentially when the number of variable capacitors increase, and thus it is also necessary to consider the method of finding the optimum variable capacitances with a reasonable time for the calculation.

Acknowledgement

This research was supported by the National Institute of Information and Communications Technology of Japan.

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