Diversity antenna loaded with variable capacitors for effective combining

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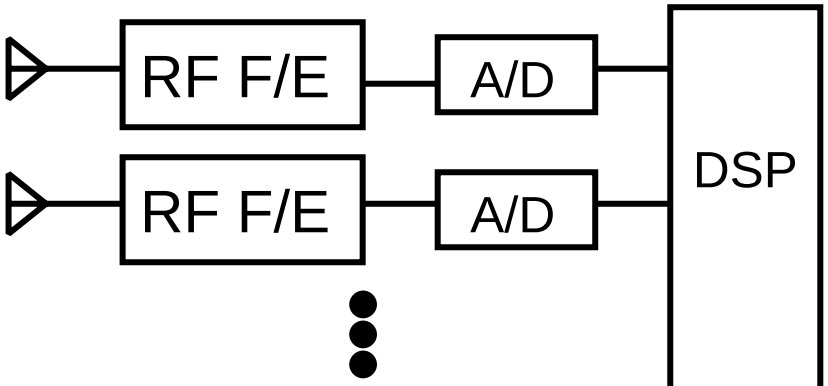
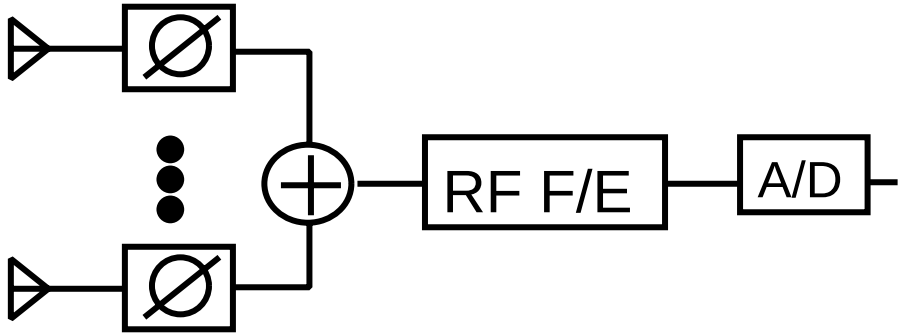
Introduction

- High quality transmission is desired for indoor wireless LAN and mobile systems.
- Mobile systems is often used under NLOS multipath environment, which degrade the transmission quality through fading and interference from other equipments.
- Adaptive array antenna (AAA) is useful technique to reduce those deteriorate factors. However, they need same number of A/D converters or phase shifters as branches.
- Therefore, there are some problems for power consumption, size and cost.



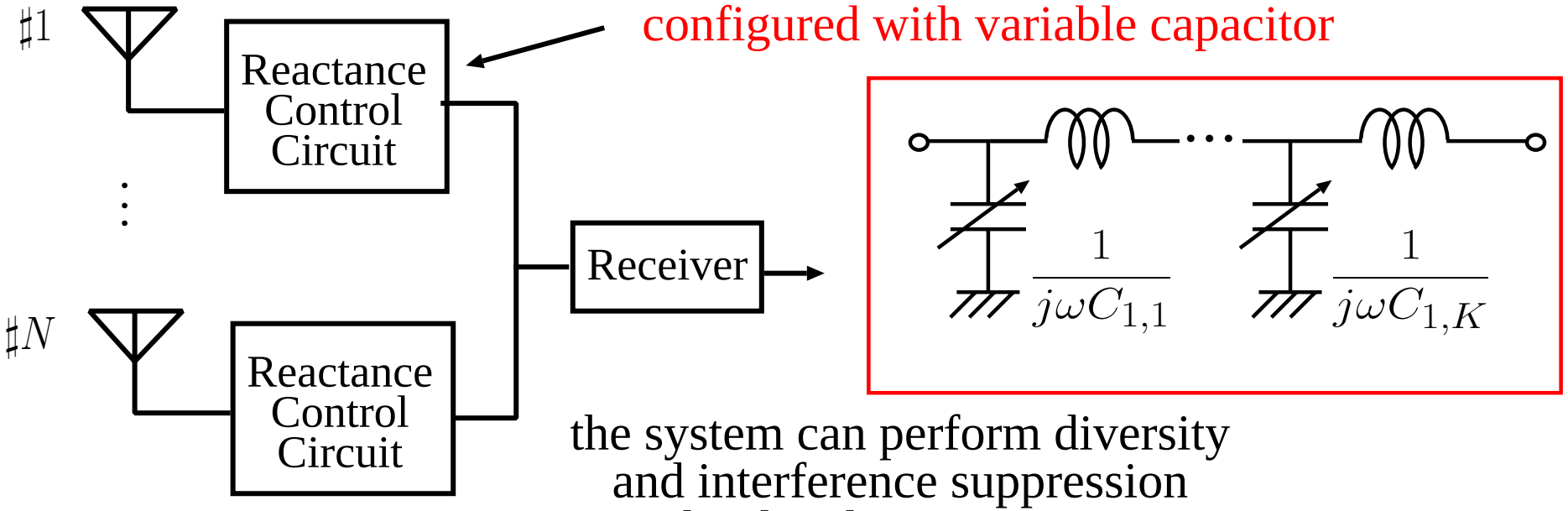
digital process



baseband process

Proposed system

We propose adaptive array antenna configured with variable capacitors.
Signal processing is performed in RF process.



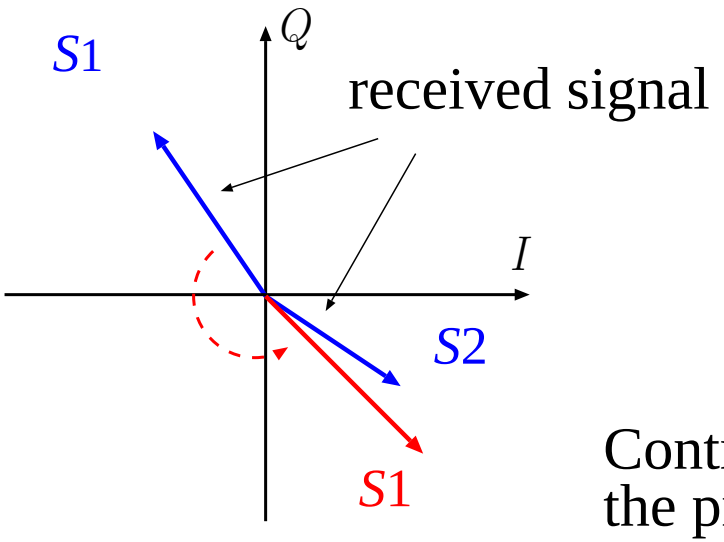
the system can perform diversity
and interference suppression
by the phase rotation.

Advantage

- The signals are combined by only one receiver
- Hardware architecture is simple

Function of the proposed system (The case for 2 diversity reception)

First, for feasibility study, we focus on diversity effects brought by the proposed system.



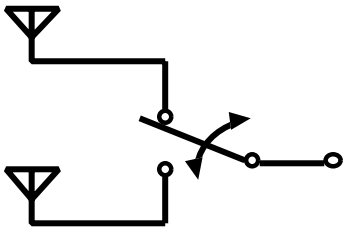
If nothing is done, signals are canceled.

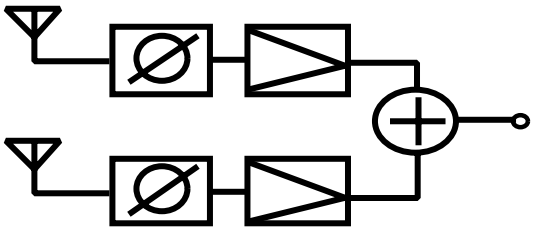
the phase of the signals are controlled by the variable capacitors

The received signals are combined in phase as much as possible.

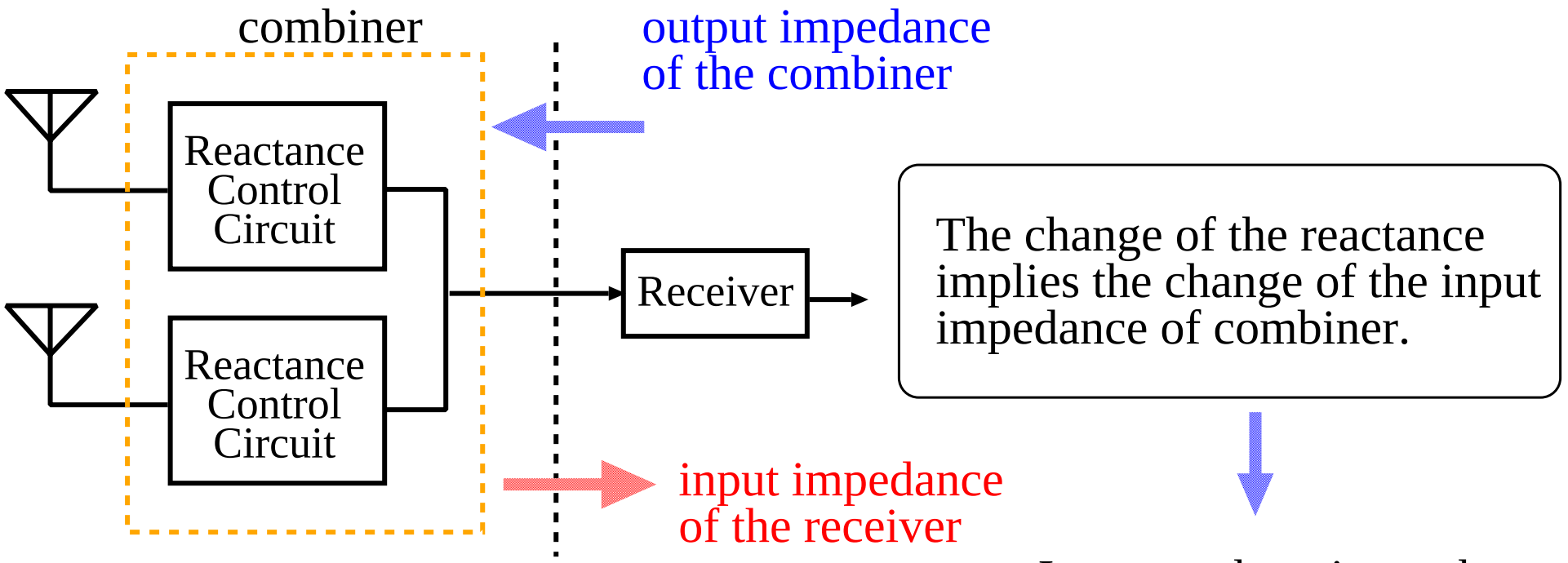
Controllable range of the phase rotation, realized by the proposed system, is important factor to consider.

- Conventional combining techniques
  - Selection combining (SC)
  - Maximal ratio combining (MRC)





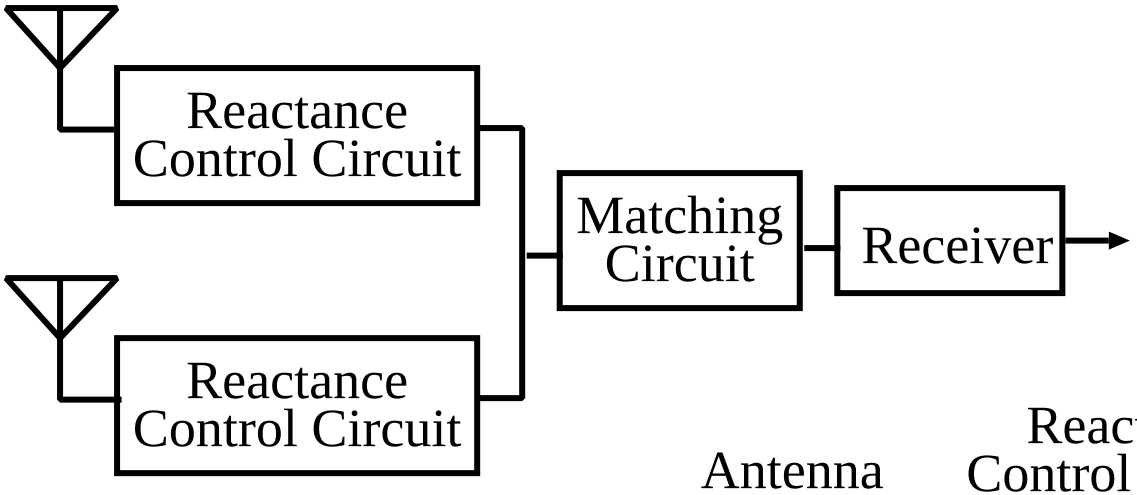
How to reduce the mismatch



In order to reduce the mismatch,

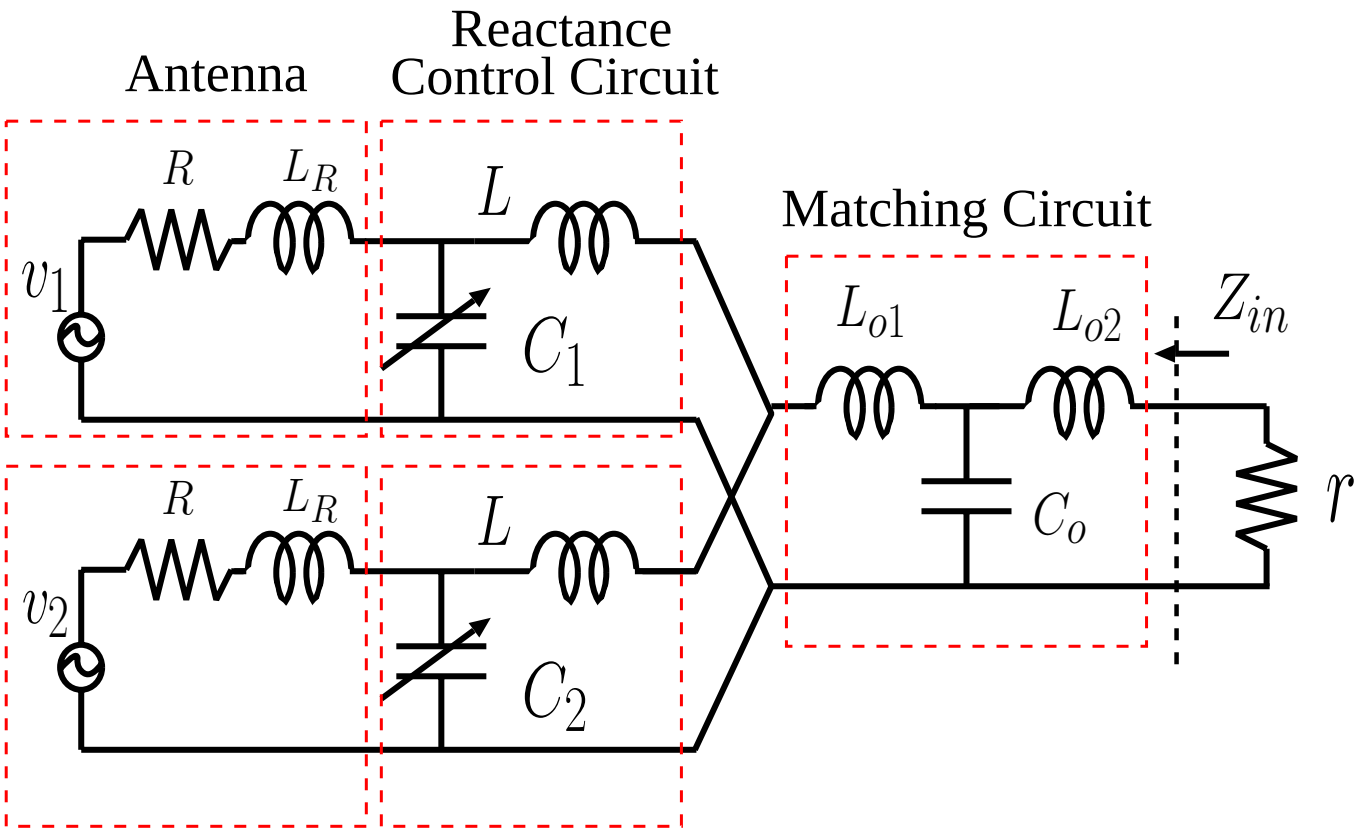
- One way is the changing the input impedance of receiver.
- Another way is the implementation of the matching circuit

Equivalent circuit of the proposed system



- Antenna distance is large.
- Correlation coefficient is zero.

Equivalent circuit

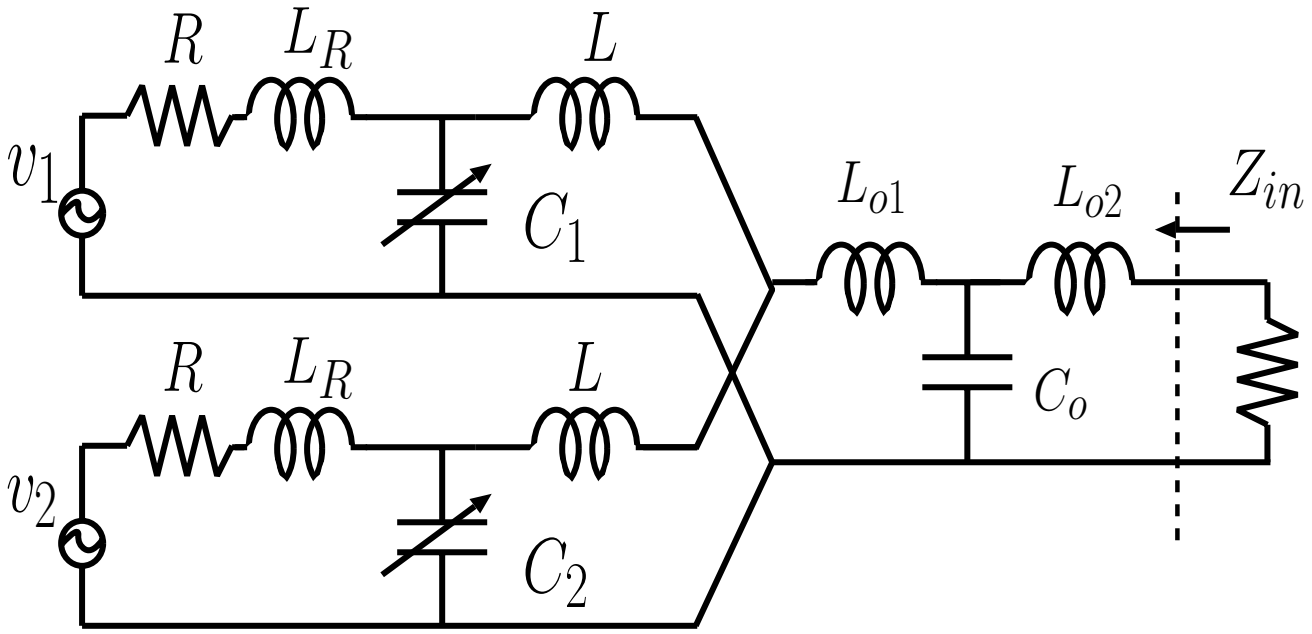


How to determine the circuit parameter.

In order to achieve good performance, we need

- wide controllable range for the received signal of each branch.
- good matching between combiner output and receiver input.

Controllable range of the phase depends on the antenna and reactance control circuit. First, we determine those parameters. Second, we tune the matching circuit to get the good matching.



$R = 73.1\Omega$

$L_R = 3.4\text{nH} \quad (X_{LR} = 106\Omega)$

$L = 0.8\text{nH}$

$C_o = 1.1\text{pF}$

$L_{o1} = 1.1\text{nH}$

$L_{o2} = 5.18\text{nH}$

$r = 50\Omega$

Diversity antenna gain

- Diversity Antenna Gain (DAG)

It can evaluate the total performance of the system
which includes antennas and propagation environment

If the fading is slow, the outage probability is
a good criterion to measure the link quality.

$$F = \frac{\Gamma_{\mathrm{div}}}{\Gamma_{\mathrm{ref}}}$$

Γ_{div} : The SNR at a specific outage probability
for the diversity reception case

Γ_{ref} : The SNR at a same outage for a reference antenna

Simulation condition and propagation environment

Simulation condition

Frequency	5GHz
Distance between each antenna	1λ
Number of operations	100,000
Tuning range of the variable capacitor (TOSHIBA 1SV287)	0.7~6.0pF

Propagation environment

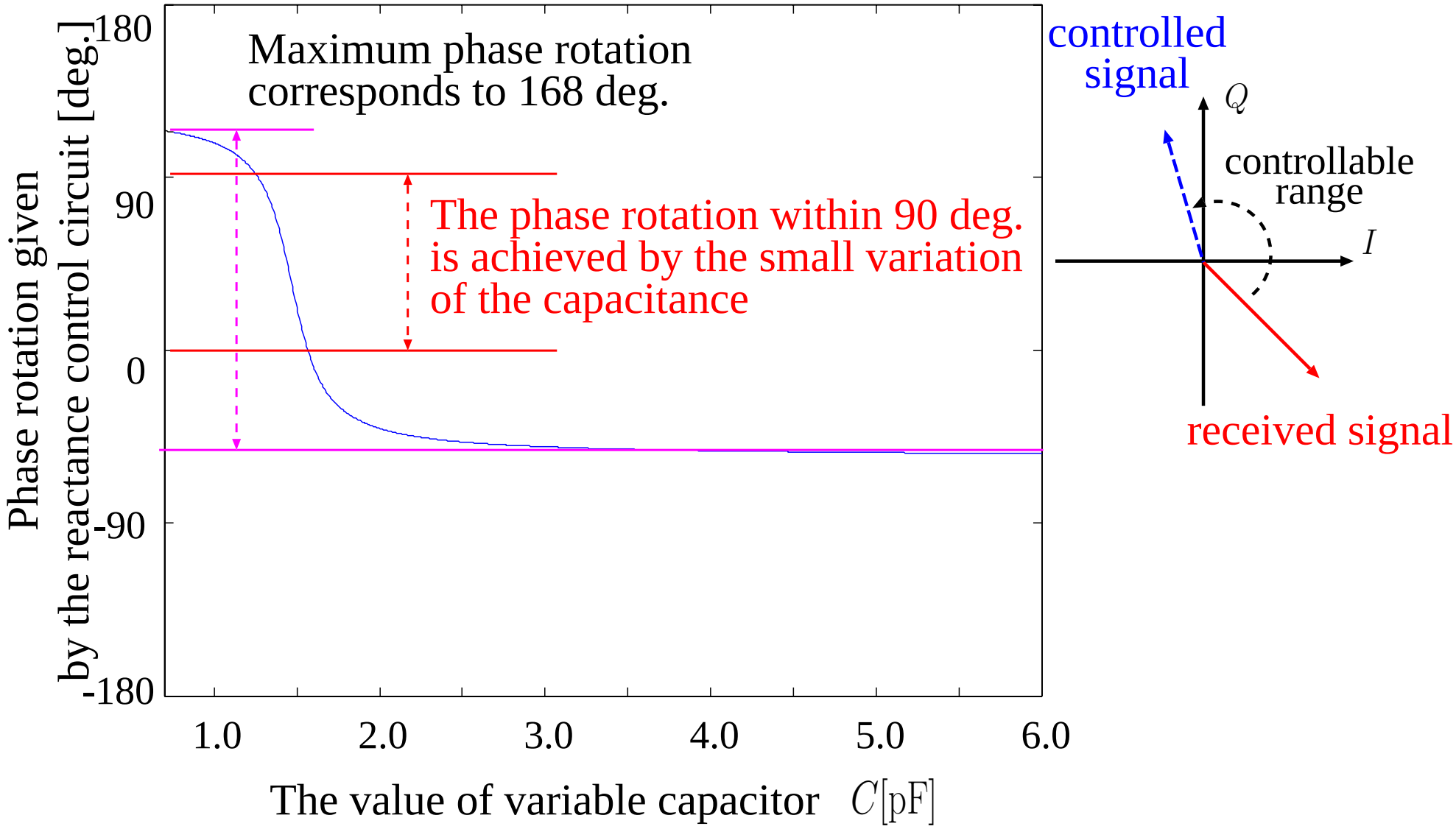
- Incoming wave from arbitrary 3D directions with constant probability.

  Amp. is Rayleigh distribution and phase is random.

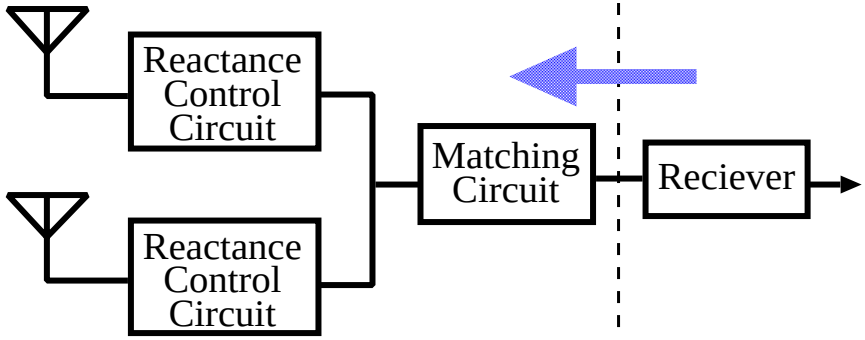
- There is no interference.
- Correlation coefficient is zero.

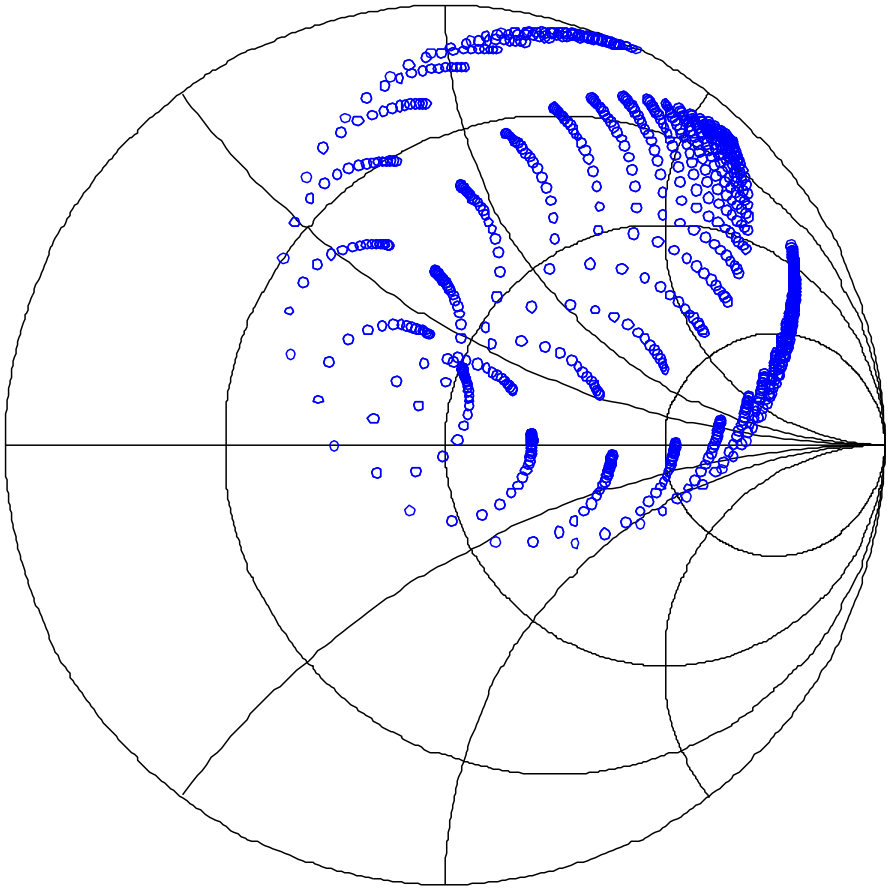
In simulation, we use the steepest descent method for optimization algorithm.

Controllable range for the received signal

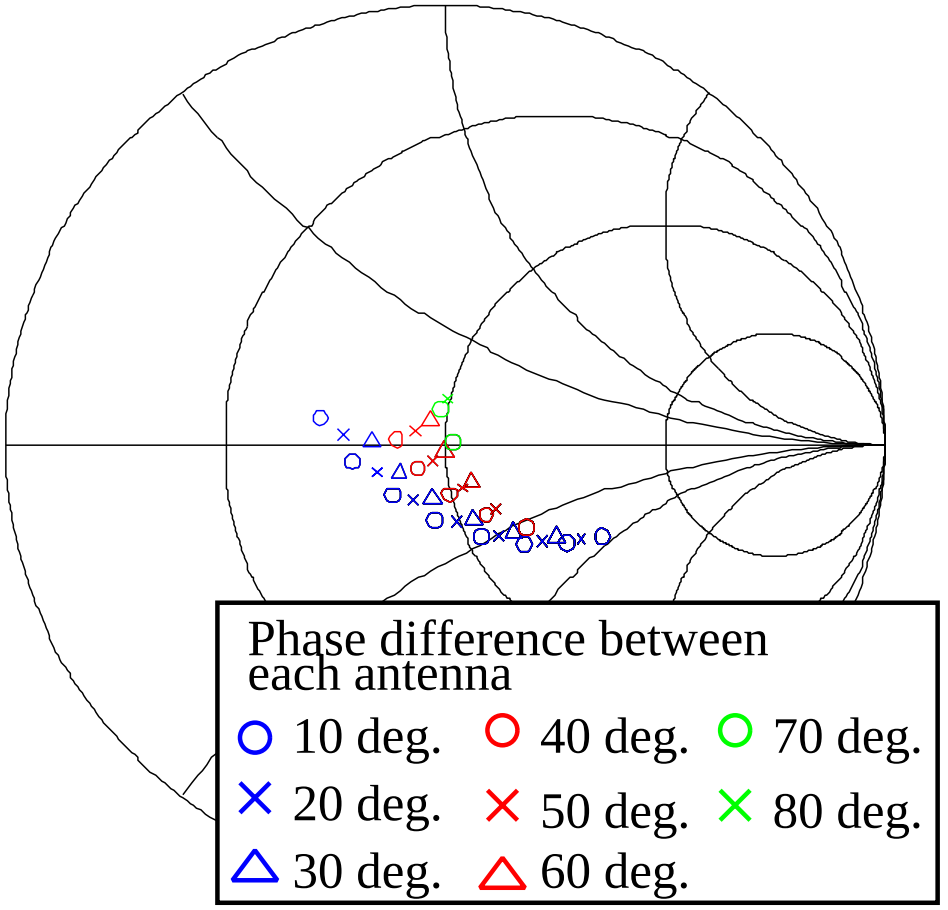


Output impedance of the matching circuit





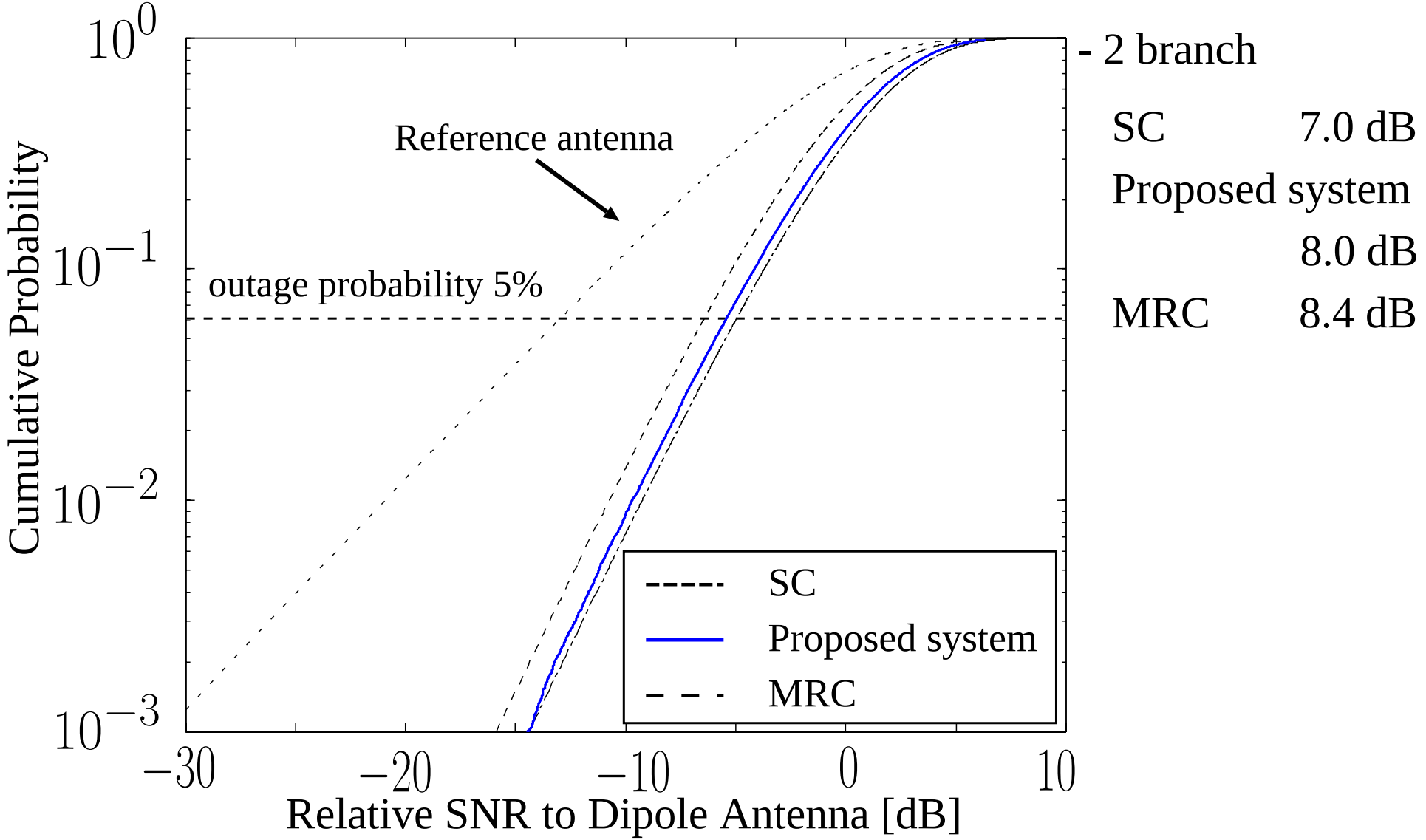
The case when the variable capacitors are changed for all range (from 0.7 to 6.0 pF).



The case when the variable capacitors are changed for sensitive phase rotation area (from 1.3 to 1.6 pF).

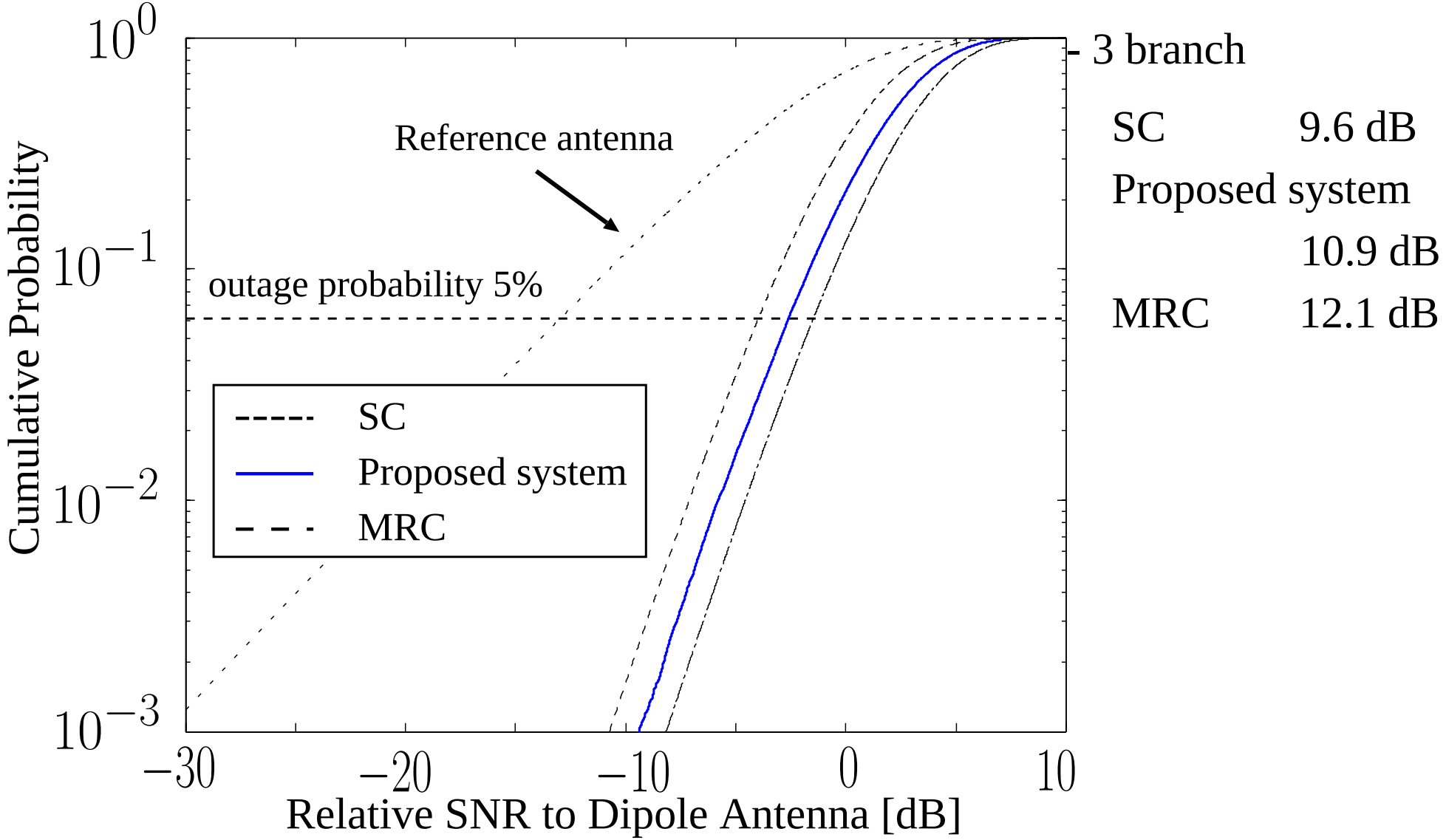
The performance of proposed system (1)

Cumulative probability (the case for 2 branch case)



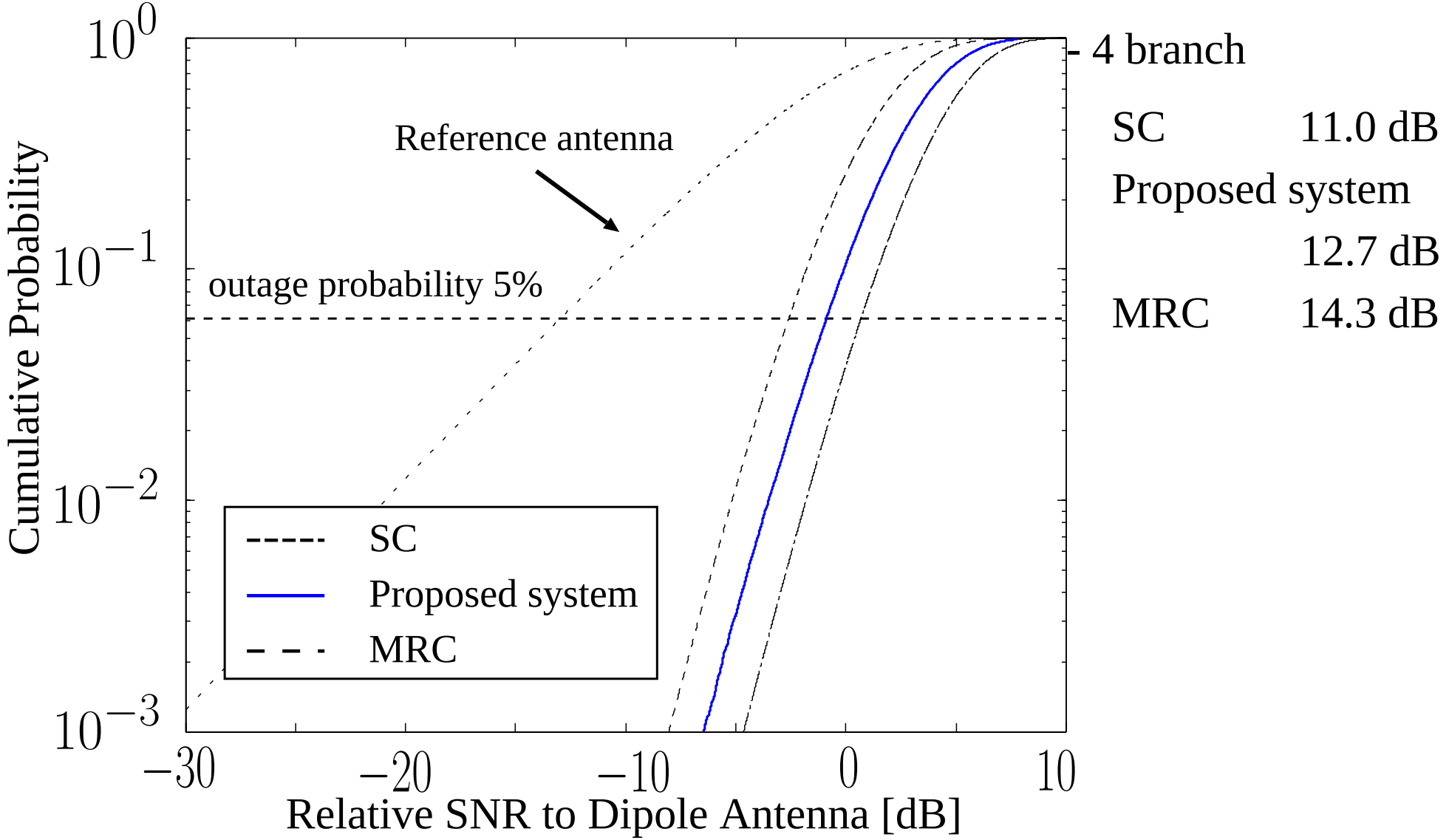
The performance of proposed system (2)

Cumulative probability (the case for 3 branch)



The performance of proposed system (3)

Cumulative probability (the case for 4 branch)



The comparison between the proposed system and conventional combining technique

	SC	Proposed system	MRC
2 branch	7.0 dB	8.0 dB	8.4 dB
3 branch	9.6 dB	10.9 dB	12.1 dB
4 branch	11.0 dB	12.7 dB	14.3 dB

Conclusion

- We proposed RF adaptive array antenna configured with variable capacitors and show the wide phase controllable range.

- We showed that the proposed system provides higher performance than the selection combining.

Future works

- Consideration for the case including the circuit’s loss.
- Consideration for the case including interference