# Beam Switched Antenna by Phase Difference Feed

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## 1. Introduction

The securing of indoor communication quality is needed as cellular communications spreads. When the base-station antenna is set up indoors, the desired radiation pattern is different according to the installation location. In general, it is suitable to have monopole radiation pattern on the ceiling and uni-directional pattern on the wall side installation [1]. It is also required that the antenna is low profile and space-saving for the actual system requirements. There are many ways to implement beam switched antennas. In [2]; an array of parasitic elements and a reflector around the antenna are used. Whereas in [3]; two or more antennas with different directivity are combined and the excitation ports are switched. As the beam tilt dipole antenna in [2], it switches two or more parasitic elements around the excitation element. Polarization diversity antenna in [3] introduces beam switching by combining notch antenna and planar inverted-F antenna. Using parasitic elements in [2] and combining different shape antennas in [3] provides various switching patterns, however, the occupied space of antenna is expanded and may be complex in structure.

In this paper, the antenna with two radiation patterns is proposed by switching the phase of excitation ports for the closely-located two planar F-shaped antennas. Resonance frequency is 2.7 GHz ($\lambda$ = 111.1 mm), and the antenna size is 25 mm × 25 mm × 5 mm (0.225 $\lambda$ × 0.225 $\lambda$ × 0.045 $\lambda$). In section 2, the proposed antenna geometry and operation are explained, and the switch of the radiation pattern by the phase difference feed is also demonstrated. The section 3, we show the method to decrease the mutual coupling by using a neutralization technique for the closely placed elements. In section 4, we confirm the beam switching characteristics by the prototype antenna.

## 2. Beam Switched Antenna

In this section, we propose beam switched antenna using two planar inverted-F antennas (PIFA). Changing the phase difference between feed ports of the proposed antenna, it shows that the antenna has monopole and uni-directional radiation patterns by the out of phase (for monopole) and in phase (for uni-direction) excitation, respectively. The proposed antenna consists of two PIFAs arrayed in the point symmetry as shown in Fig. 1. For the out of phase excitation, the radiation from each PIFA in the point symmetry is synthesized in phase along z-axis, and it provides uni-directional radiation pattern in Fig. 2. On the other hand, for the in phase excitation, the radiation is cancelled in the z-axis, and it shows the monopole radiation pattern as shown in Fig. 3.

Mutual coupling between the PIFAs is caused by closely-located antenna elements with spacing g. The S21 is reduced for large g as shown in Fig. 2, and then a trade-off between decoupling and spacing g should be optimized. For example, if we require S21 less than -10 dB, the g should be more than 28 mm (0.252 $\lambda$). However, to downsize antenna in this paper g = 14 mm (half of the distance of g = 28 mm) is adopted to have S21 less than -10 dB, not to get the radiation pattern distortions.

In the next section, to decrease mutual coupling between the PIFAs, we introduce the method of decoupling using a neutralization technique.

## 3. Decoupling

By inserting a suspended line (SL) between antenna elements, the currents at each port are cancelled and the neutralization effect is achieved [4]. The proposed antenna geometry with SL is shown in Fig. 5. Hereafter, the proposed antenna uses the geometry of Fig. 5. The SL connects each excitation point of PIFA. The S-parameters with SL is shown in Fig. 6, which shows that S21 decreases from -5.5 dB to -15.4 dB.

Next, we present the principle of decoupling. The current distribution on the top surface is shown in Fig. 7, where the right PIFA is excited. In Fig. 7 (a), the parasitic element (left PIFA) has large coupled currents for the antennas without SL, while in Fig. 7 (b), the SL decrease the coupled current on the parasitic element. The S11 characteristic of right PIFA is also shown in Fig. 8. When SL is not inserted, it has two resonates around 2.7 GHz. The SL eliminates the resonance of parasitic element and decreases the mutual coupling.

## 4. Experiment

In this section, we demonstrate the beam switching by measuring the prototype antenna. For a convenience of fabrication, fabricated antenna size is double of the proposed antenna size and the resonance frequency is 1.35 GHz. In this scaling up, the antenna geometry is not correctly double due to the thickness of the plate and wire, then we adjust the SL shape to optimize the neutralization effect. We also make a 180 degree hybrid circuit as the feed circuit and combine with the fabricated antenna in the measurement. The S-parameter characteristics comparing with or without SL are shown in Fig. 9. Similar to S-parameters in Fig. 5, S21 is less than -10 dB, and we confirm the effect of neutralization. The measurement of radiation patterns of scale-model antenna are shown in Figs. 10 and 11. We obtain a uni-directional radiation pattern for the out of phase excitation and a monopole radiation pattern for the in phase excitation. The reason why null direction tilt from zenith in the yz-plane is the effect of coaxial cable for the excitation.

## 5. Conclusion

In this paper, we proposed beam switched antenna to switch monopole and uni-directional radiation pattern by the use of phase difference feed. This antenna consisted of two PIFAs arrayed in the point symmetry. We obtained beam switching by the out of and in phase excitation. To decrease the mutual coupling between antenna elements, we introduced a neutralization technique by a suspended line and mutual coupling is decreased from -5.5 dB to -15.4 dB. In addition, the beam switched antenna pattern is verified by experiment. The future challenges are to rationalize a neutralization technique and apply to other antennas.

## References

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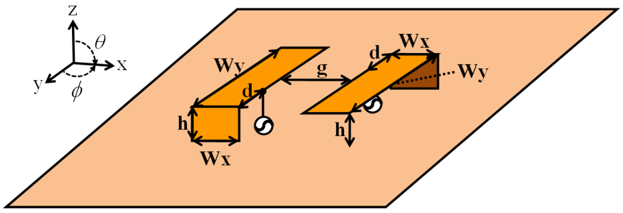


Figure 1: Proposed antenna geometry.
Wx=5.5, Wy=25, d=4.5, h=5, g=14 [mm]
GND: 50×50 [mm$^2$]

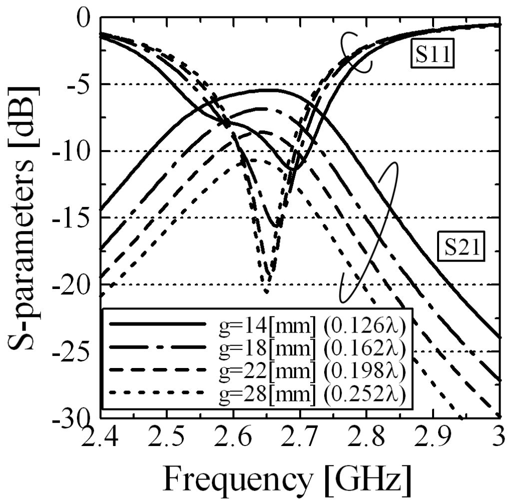


Figure 4: S-parameters for different g.

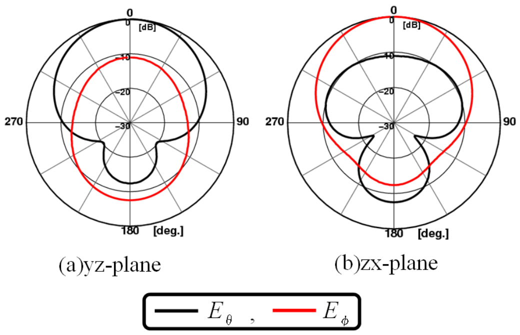


Figure 2: Out of phase radiation pattern.

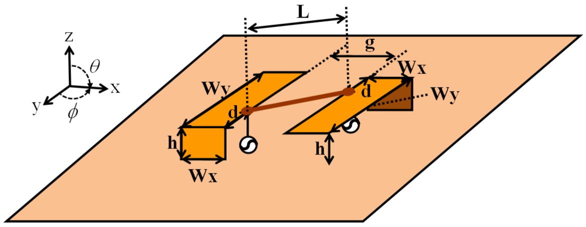


Figure 5: Proposed antenna geometry (w/ SL).
Wx=5.5, Wy=25, d=4.5, h=5, g=14, L=21.3 [mm]
GND: 50×50 [mm$^2$]

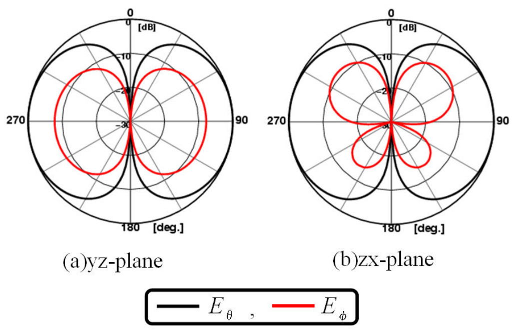


Figure3: In phase radiation pattern.

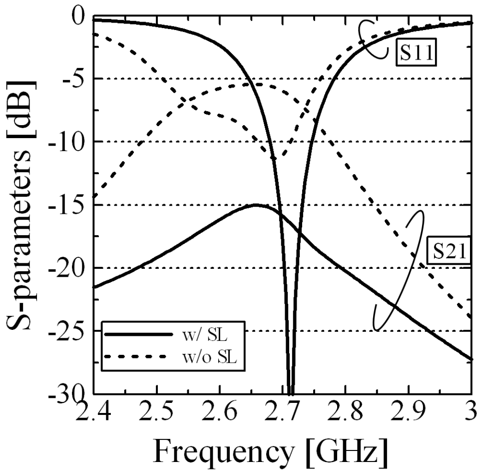


Figure 6: S-parameters for inserted SL.

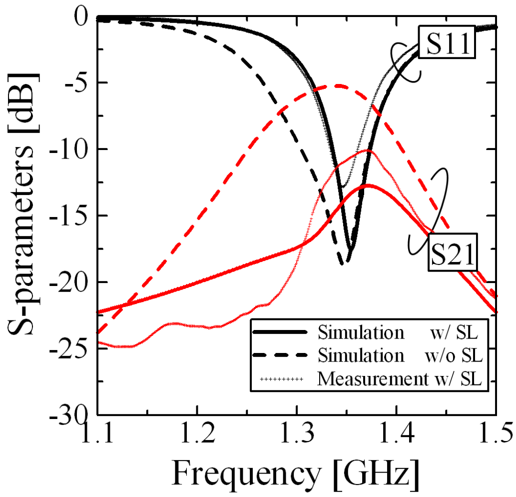


Figure 9: S21 characteristic for inserted SL.

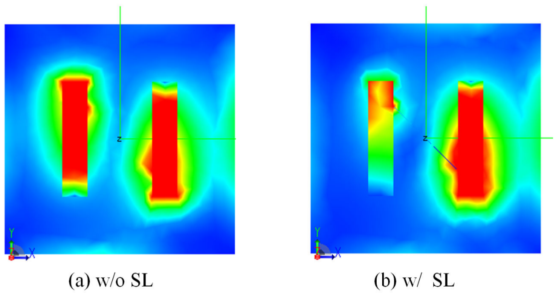


Figure 7: Current distribution of PIFAs.

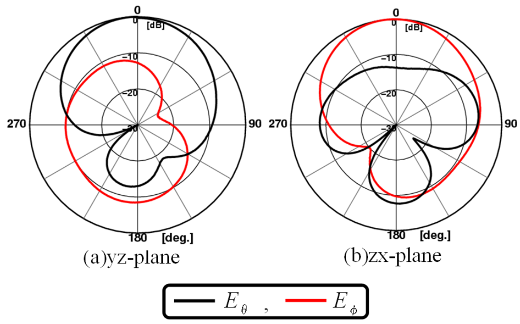


Figure 10: Radiation pattern of fabricated antenna (out of phase)

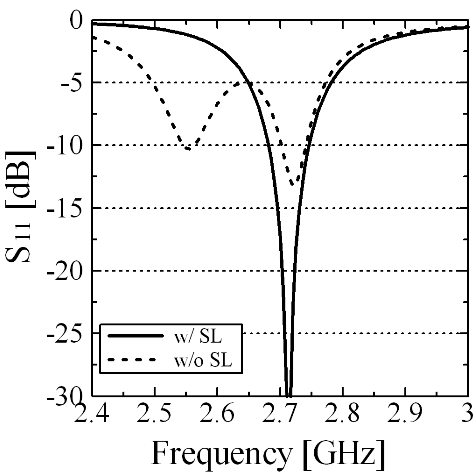


Figure 8: S11 at right PIFA excitation.

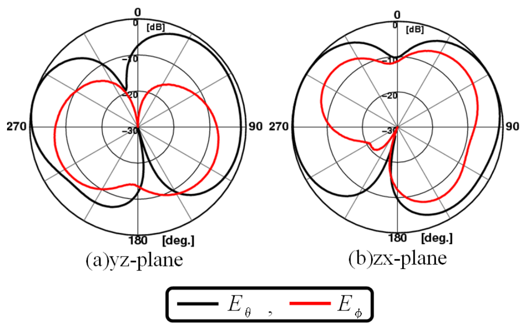


Figure 11: Radiation pattern of fabricated antenna (in phase)