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Investigation of Mutual Coupling Reduction of Slot-Coupled Planar Antenna

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1. Introduction

The next generation mobile communication systems, which will provide high-speed transmission, require base station antennas that have a broad operating frequency bandwidth and a diversity configuration to mitigate multipath fading. A polarization diversity configuration is effective in reducing the number of antennas at the base station establishment sites. The feeding scheme for aperture-coupled patch antennas (ACPAs), which were first proposed by Pozar [3], eliminates the soldering process required to secure a pin-connected feed circuit to the patch, which is necessary in fabricating the conventional probe-fed patch antenna. The feeding scheme can greatly reduce the complexity in constructing large patch arrays consisting of many elements. The ground plane, sandwiched between the feed circuitry and the radiating patch, can prevent radiation from the feed network interfering with the patch radiation pattern. This type of antenna is attractive due to its low cost, low profile, conformability, and ease of manufacturing. A dual-polarized antenna is achieved by cutting two offset orthogonal slots into the ground plane. The broad bandwidth can be achieved by modifying the aperture shape, which yields improved coupling for an ACPA [1].

On the other hand, to cut down the limitation of installation site of base station antennas, the Tx and Rx antennas are usually installed in same antenna radome. In this case, the mutual coupling between Tx antenna and Rx antenna should be reduced. For those systems that have a broad operating frequency bandwidth and frequency spectrum of up-link and down-link are juxtaposed to each other, the mutual coupling will negative effect the antenna's performance. As mutual coupling is inversely related to the distance between two antennas, this problem will be increased significantly as the distance between Tx antenna and Rx antenna decreased.

Our goal is to develop a broadband dual-polarized planar antenna which includes Tx antenna and Rx antenna in same dielectric radome. As the first step, we present a technique that can cut down the mutual coupling between Tx antenna and Rx antenna and without increase the outer size of antenna. To achieve the object, we propose an ACPA that comprised a crank shaped aperture on the ground plane. By comparing the S parameter between ACPA with proposed crank shaped aperture and without crank shaped aperture, we show that the proposed configuration yields reduce the mutual coupling between Tx antenna and Rx antenna. In this paper, the operating frequency band is defined as having a Voltage Standing Wave Ratio (VSWR) of less than 1.5.

2. ACPA with crank shaped aperture

Fig. 1 shows Tx antenna and Rx antenna that are set up at a distance d. d is approximately $0.5\lambda^c_{Tx}$. λ^c_{Tx} is the wavelength at center frequency of Tx spectrum. And in this paper, ratio between central frequency at Tx spectrum and Rx spectrum is $f^c_{Tx} : f^c_{Rx} = 1.3$. As shown in Fig. 1, the proposed crank shaped aperture is installed on the ground plane, which is located between the feed layer and radiation layer. The 3D electromagnetic field simulator software CST Microwave Studio Suit 2006 [2] is used for the simulation, and 4 layers of Berenger's PML absorbing boundary condition are employed in the simulation.

Fig. 2 shows the top-view of conventional ACPA without any filter structure and S parameter of conventional antenna. Because the target of this study is for base station antenna, the VSWR of less

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than 1.5 is required. The dimensions are given at Table 1 with respect to the notation in Fig. 2(a). We define the minimum frequency when Tx antenna's VSWR is 1.5 as f_0. Fig. 2(b) shows the S parameter of ACPA without crank aperture versus frequency normalized by f_0. The worst value of mutual coupling between Tx antenna and Rx antenna within the Tx spectrum when $S_{22} \leqq -14dB$ is observed. Figure shows that the worst mutual coupling is around -22dB.

Fig. 3(a) shows the top-view of ACPA with proposed crank aperture. The crank aperture is located on the ground plane, which is sandwiched by feed line and patch #1. The patch #1 and above parasitic element patch #2 are operated as radiation elements. Fig. 3(b) shows the S parameter of ACPA with crank aperture versus frequency normalized by f_0. The worst value of mutual coupling between Tx antenna and Rx antenna within the Tx spectrum is around -27dB. The mutual coupling characteristic is improved by using the proposed crank aperture. And the bandwidth of Rx antenna and Tx antenna when VSWR $\leqq$ 1.5 is around 10%. The crank aperture is installed between the feed layer and radiation layer. There are two patches that operated as radiation elements in front of the crank aperture. This structure can avoid the disturbance of the radiation pattern on Y-Z plane. Fig. 4 shows comparison of radiation patterns on Y-Z plane of conventional model and proposed model. The half power beam width of proposed model is around 57^o, which is equal to the case of without crank aperture. The proposed crank aperture doesn't affect the antenna's radiation pattern.

Fig. 5 shows the mutual coupling characteristics (S_{21}) due to the length of crank aperture. As shown in Fig. 5, the curve of mutual coupling between Tx antenna and Rx antenna changed when we increase the length of crank aperture. We can adjust the reject frequency spectrum by changing the crank aperture's length. The open-circuited stub usually needs a stub length of $\lambda_g/2$. λ_g is the wavelength in guidewave, which responses to the wavelength of the frequency that want to be rejected. The proposed crank aperture length is about 17% smaller the case of using open-circuited stub. A smaller crank aperture can increase the flexibility of aperture's location. This is a large advantage on building a polarization diversity configuration.

3. Conclusion

In this paper, we proposed a broadband ACPA that can reduce the mutual coupling between Tx antenna and Rx antenna. Using a crank aperture installed between the feed layer and radiation layer, the mutual coupling can be reduced without increase the antenna's outer size. And the proposed structure can maintain the radiation pattern. The length of crank aperture, which is smaller compare to the usual open-circuited stub, can adjust the reject spectrum to arbitrarily frequency.

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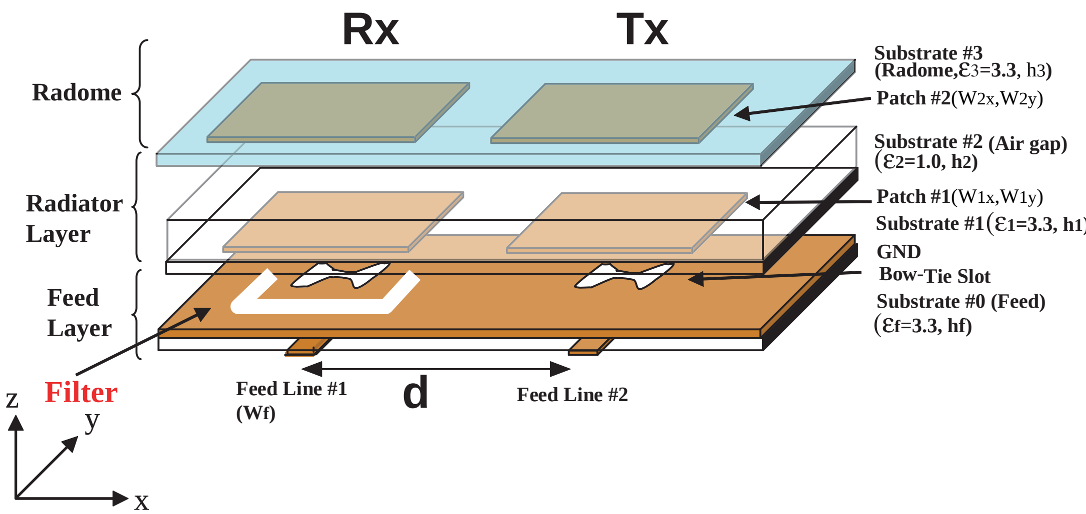


Figure 1: Aperture Coupled Planner Antenna with Filter Structure

Table 1: Fixed parameters of Rx antenna in the simulation

Feed line	$W_f = 0.04\lambda_{Rx}$
Substrate #0	$\epsilon_f = 3.3, h_f = 0.01\lambda_{Rx}$
Substrate #1	$\epsilon_1 = 3.3, h_1 = 0.03\lambda_{Rx}$
Patch #1	$W_{1x} = W_{1y} = 0.46\lambda_{Rx}$
Substrate #2	$\epsilon_2 = 1.0, h_2 = 0.10\lambda_{Rx}$
Patch #2	$W_{2x} = W_{2y} = 0.55\lambda_{Rx}$
Substrate #3	$\epsilon_3 = 3.3, h_3 = 0.03\lambda_{Rx}$
Bow-Tie Slot	$W_a = 0.15\lambda_{Rx}, L_a = 0.02\lambda_{Rx}, L_h = 0.05\lambda_{Rx}, L_s = 0.13\lambda_{Rx}$

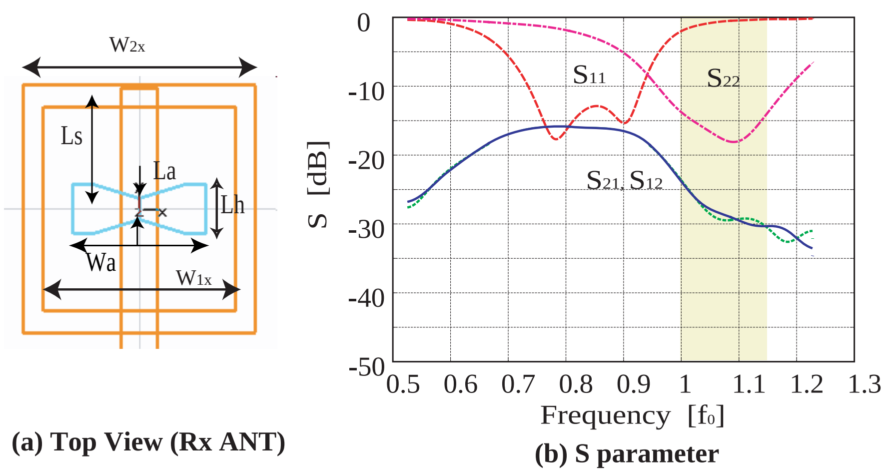
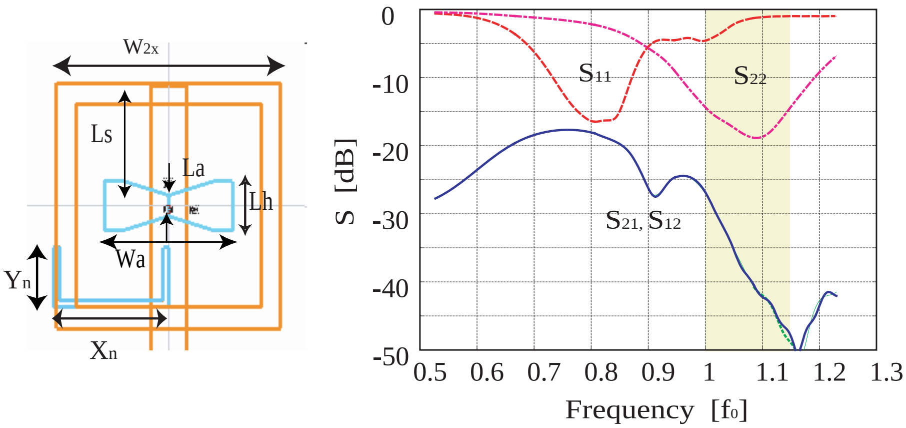


Figure 2: S parameter of Conventional Aperture Coupled Planner Antenna



(a) Top View (Rx ANT) **(b) S parameter**

Figure 3: S parameter of Proposed Aperture Coupled Planner Antenna with Filter Structure($X_n = 0.16\lambda_0$, $Y_n = 0.03\lambda_0$)

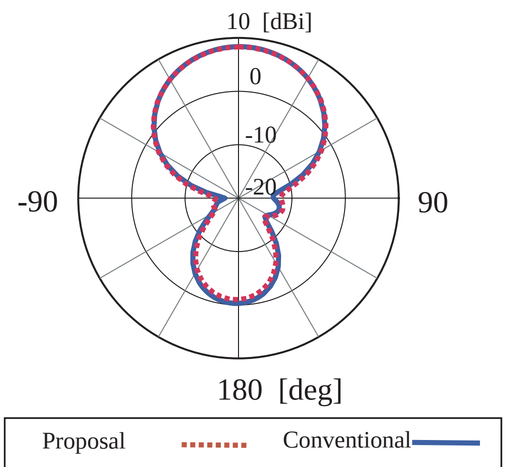


Figure 4: Radiation Pattern of Proposed Aperture Coupled Planner Antenna with Filter Structure (freq = f_{Rx}^{c})

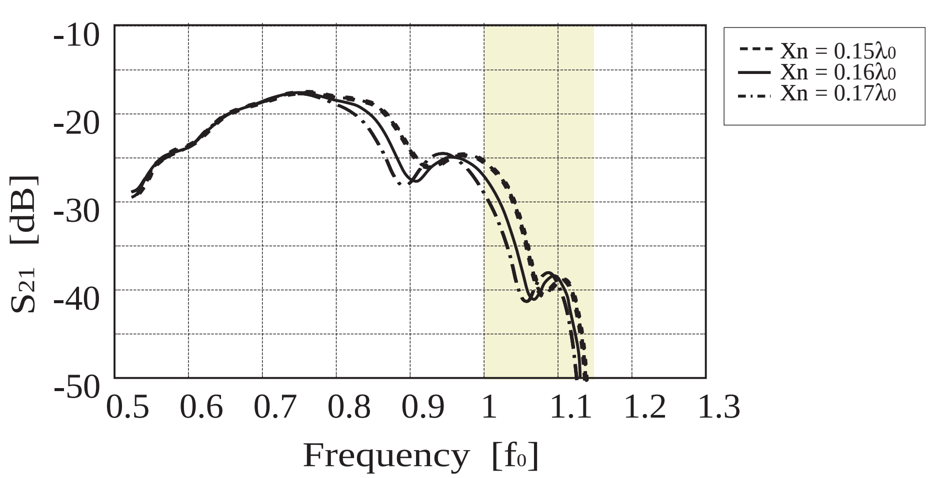


Figure 5: S_{21} characteristic due to length of Filter Structure ($Y_n = 0.05\lambda_0$)