Wideband Dual-Polarized Low-Profile Filtering Microstrip Patch Antenna

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***Abstract*—A wideband low-profile dual-polarized filtering antenna is designed and simulated. It is realized using second-order bandpass filters with an air-cavity backed microstrip patch antenna functioning as the radiating resonator element. The single-layer planar design allows for realistic implementation in high throughput and wideband mobile handsets/base-station systems and agile radar transceivers. The dual-polarized antenna has fractional bandwidth 13.5%, peak broadside realized gain of 5.36dBi at operation frequency $f_0 = 4.8$GHz, and provides at least 25dB of out-of-band gain suppression up to $2f_0$. The isolation between the two ports is at least 12dB in the passband region, with cross-pol discrimination greater than 16.5dB.**

I. Introduction

The demand for wideband, high throughput, highly efficient yet compact antenna solutions is ever increasing due to rapidly advancing mobile/base-station communications and radar systems. One solution is the dual-polarized antenna, known for its ability to increase the channel capacity through polarization diversity and robustness to multipath fading. Yet, recent implementations [1], [2] are narrowband or impractical for realistic installment due to their physical construction.

Filtering antennas (FAs) offer natural integration between the antenna and filter, eliminating the 50Ω interface and merging two traditionally separate fields to enhance each other's characteristics. Recent FAs [3], [4] demonstrate ease of integration and low cost prototypes with desirable filtering characteristics. However, most solutions are limited either in their performance (e.g. narrow bandwidth or insufficient out-of-band suppression), utilize surface mount components, or are practically unrealizable due to their physical construction.

We present a planar single-layer dual-polarized FA that preserves the desired filter characteristics and offers wideband input matching, flat passband gain, isolation among the two ports, and highly efficient radiation patterns with good cross-pol discrimination. Section II presents the theory and design of the dual-polarized FA. Section III discusses the simulation results and highlights the performance of the proposed FA.

II. Antenna Theory and Design

The design of the proposed FA begins with the bandpass filter network. The order and type of filter is determined by the target bandwidth requirements and the passband and stopband characteristics; for this paper we consider a two-pole Butterworth filter with center frequency $f_0 = 5$GHz, bandwidth spanning 20% and a transmission zero at approximately $2f_0$. Once the bandpass response is synthesized with $\lambda_g/4$ short-circuited shunt-stub resonators (λ_g is the guided wavelength at f_0), one of the shunt-stub resonators is replaced by a radiating resonator element, an air-cavity backed dual-polarized microstrip patch antenna. The patch antenna, or equivalently resonator, must have similar amplitude and phase responses to that of the substituted shunt-stub resonator, as this allows the filter to preserve its characteristics as a FA. The standalone air-cavity backed patch antenna has stable gain over frequency and wideband input matching, which further maintains the bandpass filter characteristics. The resulting FA equivalent circuit in Fig. 1 consists of two parallel branches (one branch represents one polarization) and a coupling scheme represented by a transformer with coupling coefficient, k, which should be kept as low as possible to improve the port isolation.

The critical enabling factor for dual-polarization operation is the patch resonator's two orthogonal and degenerate (TM_{100} and TM_{010}) modes formed within the cavity. Furthermore, the patch resonator and its cavity backing must be square to realize identical modes at the same frequency in both polarizations. Finally, the patch cannot have any feeding insets as they cause further coupling between the orthogonal modes within the cavity, decreasing the isolation between orthogonal polarizations. The parasitic coupling between the two orthogonal shunt-stubs within the filtering network is minimized as the dielectric is very thin, preventing substrate mode cross-talk.

The construction of the dual-polarized FA is shown in Fig. 2 (a). The filtering network and the antenna are fabricated on the same side of the PCB. The short-circuited shunt-stub is split into two parallel short-circuited shunt-stubs to achieve the desired resonator admittance. The metal/dielectric stackup is shown in Fig. 2. The FA consists of a thin single-layer PCB with 0.5oz copper (Cu) and a 0.254mm layer of Rogers 4350 (ϵ_r = 3.86 and $\tan\delta$ = 4.0×10^{-3}) dielectric placed on top of a 3mm tall Cu block such that the air-cavity and microstrip patch antenna are aligned. The Cu block serves as the PCB ground plane. The air cavity is carved 2.47mm deep within the Cu block, denoted by the white space surrounded by black dashed lines. Due to this simple construction, the

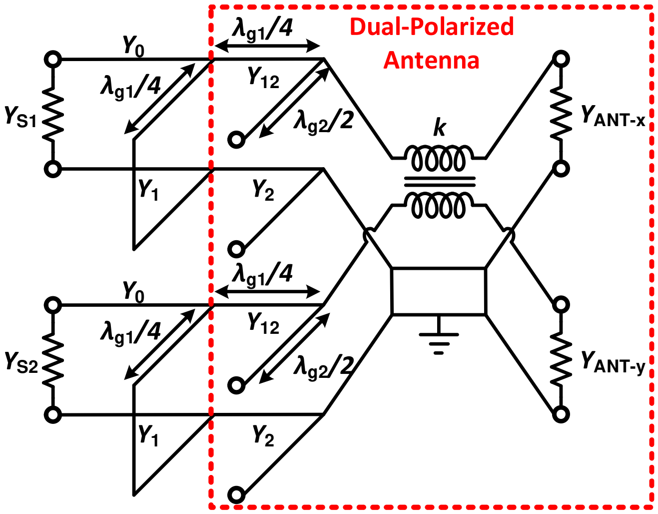

Fig. 1. The equivalent circuit of the dual-polarized FA. Y_{S1} and Y_{S2} are source admittances at Port 1 and Port 2, respectively. A transmission line with characteristic admittance, Y_0, is inserted in series. The shunt-stub resonators have admittances Y_1 and Y_2 and are $\lambda_{g1}/4$ and $\lambda_{g2}/2$ long, respectively, where λ_{g1} and λ_{g2} are the guided wavelengths in only the dielectric substrate and in the air-cavity/dielectric substrate combination, respectively. The shunt-stub resonators are separated by a $\lambda_{g1}/4$ transmission line with admittance Y_{12}. The aperture admittances are denoted by $Y_{\text{ANT-x}}$ and $Y_{\text{ANT-y}}$ for Port 1 and Port 2, respectively. The circuit in the red dashed block represents the dual-polarized patch resonator radiator.

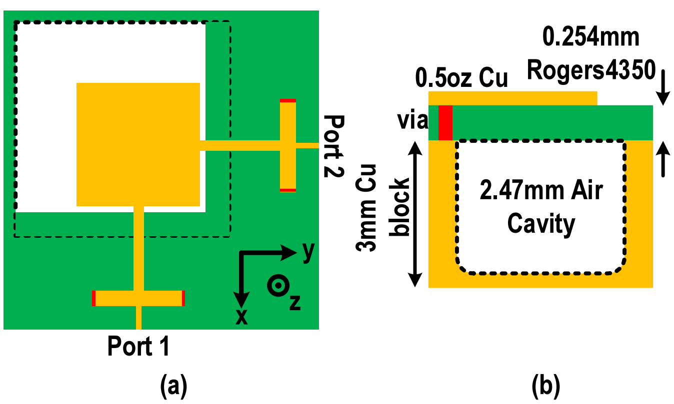

Fig. 2. (a) Dual-polarized FA top-view layout. (b) Metal/dielectric stackup cross-sectional view, where the single-layer PCB is placed on the Cu block, above the air-cavity carved within the Cu block denoted by the black dashed lines. The red rectangles represent vias to the Cu block.

patch antenna effectively sees only an air-cavity as it is much thicker than the dielectric ($< \lambda_0/200$, where λ_0 is the free space wavelength at f_0). The cavity is further laterally carved underneath the PCB to preserve the radiating fields of the patch antenna, denoted by the extended black dotted outline underneath the dielectric.

III. Simulation Results

The resulting dual-polarized FA is designed and simulated using ANSYS HFSS. The S-parameter response is shown in Fig. 3 (a). It has 10-dB return-loss bandwidth of 13.5%, from 4.48GHz to 5.13GHz, with center frequency f_0 = 4.8GHz. It has better than 12-dB isolation between orthogonal orientations in the passband. The peak realized broadside gain is 5.36dBi in both polarizations with a 1-dB variation between 4.35GHz and 5.35GHz. The realized broadside gain is suppressed by at least 25dB till approximately $2f_0$, demonstrating the two-pole Butterworth filter characteristics. Radiation patterns for both polarizations are shown in Fig. 3 (b), exhibiting at least 16.5-dB cross-pol discrimination and 89.6% simulated radiation efficiency in both planes.

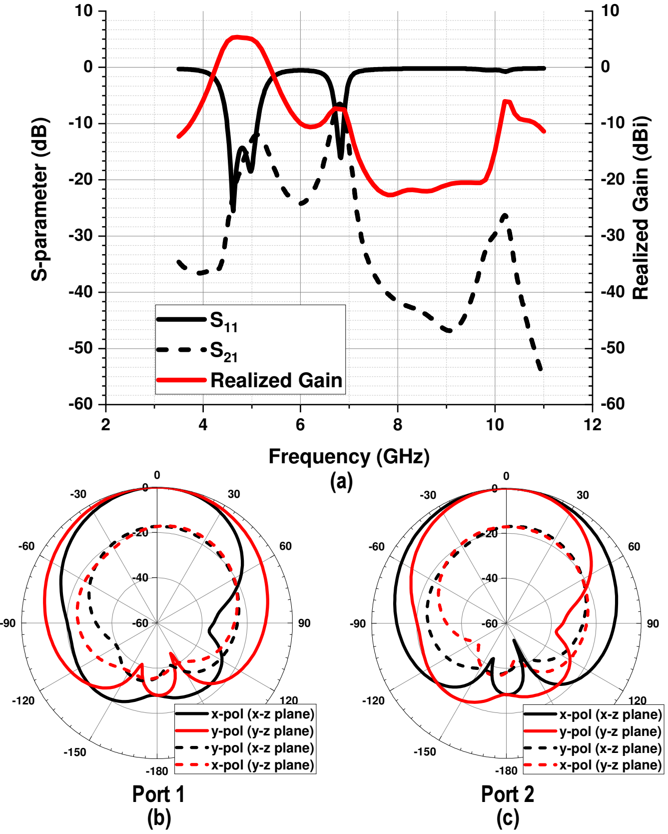

Fig. 3. (a) S-parameter and co-pol realized broadside gain responses. (b) The radiation patterns when fed at (b) Port 1 and (c) Port 2.

References

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