Dual-Linearly-Polarized Printed Dual-Dipole Antenna Array for Polarimetric Radar Application

Ian Huang, Chin-Lung Liao, and Shih-Yuan Chen
Graduate Institute of Communication Engineering, National Taiwan University, Taipei 106, Taiwan
Emails: f06942135@ntu.edu.tw, r05942145@ntu.edu.tw, shihyuan@ntu.edu.tw

***Abstract*— This paper presents a dual-linearly-polarized printed dual-dipole antenna array and its polarimetric radar system application. A 5x5 antenna array with a 3-D feeding circuit for S-band is designed, fabricated, and tested. For the array, the half-power beamwidth is around 20 degrees with a gain of 16.1±0.8 dBi and 15.75±0.75 dBi for the x- and y-polarized sub-arrays, respectively, from 3.1 GHz to 3.5 GHz. The efficiency is larger than 60% and 69% for the x- and y-polarized sub-arrays, respectively.**

Keywords—antenna array, polarimetric, dual-polarization, 3-D power distribution network

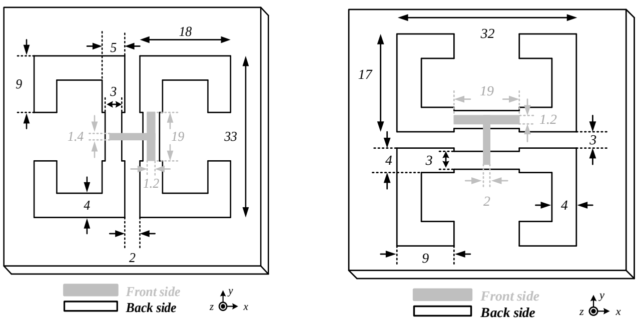
I. Introduction

Target identification has been a popular research topic for military applications for a while. One way of identifying targets is to use a polarimetric radar system, which can both detect the target location as well as obtain information of what the target is. This system detects not only the scattering characteristics of the target through sending and receiving two orthogonally polarized electromagnetic (EM) waves, but it can also detect the interaction between the two polarized EM waves. In this paper, the design, fabrication and testing of a 5×5 dual-linearly-polarized dual-dipole antenna array prototype with a 3-D feeding circuit will be presented.

II. Antenna Array Design Considerations

A. Printed Dual-Dipole Antenna Unit

In this work, the structure of the antenna unit is based on the structure proposed in [2]-[3], as shown in Fig 1. The unit is composed of two parallel center-fed folded-dipoles that are connected in parallel by coplanar strip (CPS) sections on the back of the dielectric substrate and is fed by a T-shaped coupling structure on the front of the substrate. The CPS sections with a stepped width provides impedance matching, while the T-shaped coupling structure with the two open-ended symmetrical lateral arms serves as a balun. This cancels out any unwanted radiation due to its structural symmetry, which significantly lowers the cross-polarization level. To achieve a dual-linearly-polarized array, two antenna orientations with an angle difference of 90° are used to generate orthogonally-radiated signals.



(a) (b)

Fig. 1. Configuration and dimensions of the printed dual-dipole (a) x-polarized and (b) y-polarized antenna. (Units: mm)

B. 5×5 Dual-Polarization Antenna Array

For the polarimetric radar application, a 5×5 dual-polarization radar array prototype is proposed, as shown in Fig. 2. In the figure, the x- and y-polarized antenna units are in black and grey, respectively. The center-to-center spacing between adjacent antenna units was chosen to be 40 mm to avoid the presence of grating lobes.

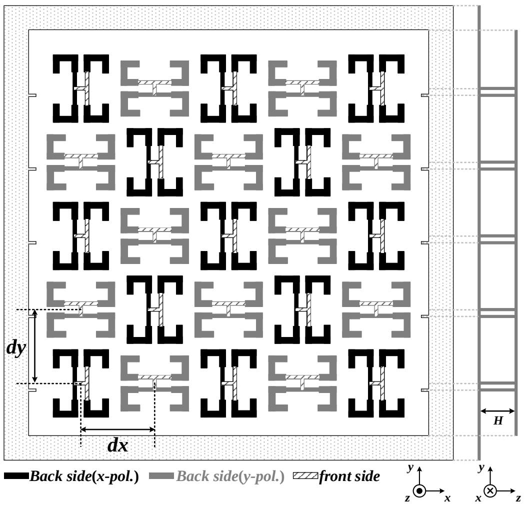


Fig. 2. Configuration of the 5×5 dual-polarization antenna array.

C. 3-D Feeding Circuit Design for the 5×5 Array

The 3-D feeding circuit for this radar is composed of vertical and horizontal feeding sub-circuits. The ground plane of the horizontal feeding sub-circuit can also act as a reflector of the array. A mortise design is used in the antenna array and the one horizontal feeding sub-circuit substrate, while a tenon design is used for the ten vertical feeding sub-circuit substrates. Fig. 3 shows the feeding network of the y-polarized antenna.

The 20 mm height of the vertical feeding subcircuit was designed to be close to a quarter wavelength. The 5×5 array can be divided into five 5×1 linear subarrays, each consisting of three x-polarized antenna units and two y-polarized units, or vice versa. For each linear sub-array, there will be two pieces of vertical feeding subcircuits, one connecting the two or three x-polarized units to the left feeding port, while the other vertical feeding subcircuit connecting the three or two y-polarized antenna units to the right feeding port.

For the vertical subcircuits connecting to the 5×1 linear sub-array, a three-way power divider is used when feeding three units on one piece of the vertical sub-circuit, while a two-way power divider is used when feeding the other two units from the other piece of the vertical sub-circuit. The three-way power divider uses a quarter wave transformer for each branch with a 120 mm signal trace, while the two-way power divider uses a $\sqrt{2}Z_0$ quarter wave transformer for each branch with a 80 mm signal trace.

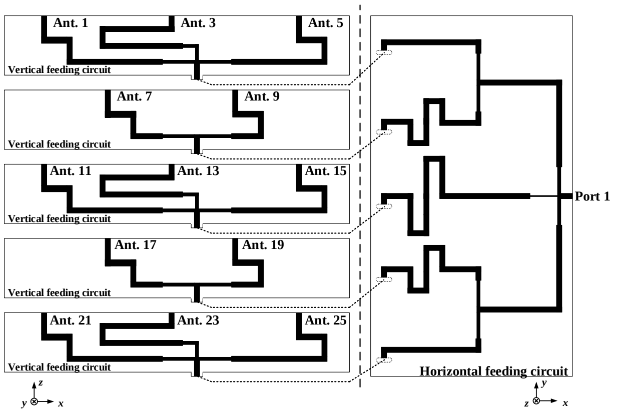
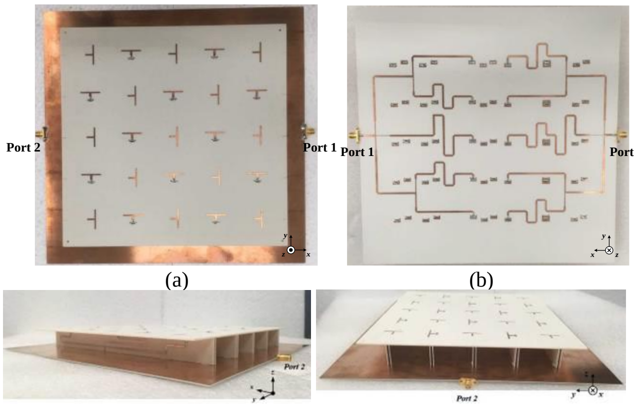


Fig. 3. Configuration of half the total 3-D feeding circuit for the 5×5 dual-polarization antenna array.



(a) (b) (c) (d)

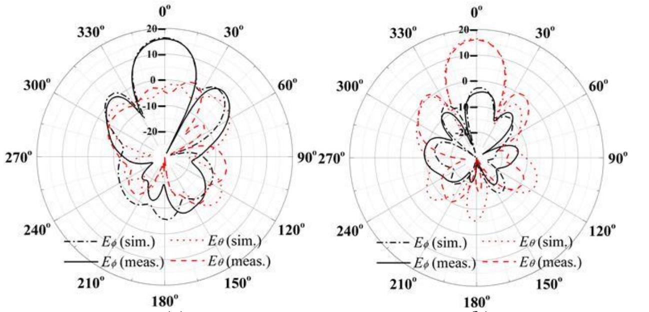
Fig. 4. (a) Top, (b) bottom, (c) and (d) side views of the prototype antenna.

For the x-polarization horizontal subcircuit, a five-way power divider is used. Three output branches are initially formed, with the first and third branch then splitting into two more sub-branches to create five branches. The first and third branches use $\sqrt{13/3}Z_0$ and $\sqrt{13/5}Z_0$ quarter wave transformers, and then use $\sqrt{5/3}Z_0$ and $\sqrt{5/2}\,Z_0$ quarter wave transformers when divided again. The middle branch uses a $\sqrt{6}Z_0$ quarter wave transformer. A 40-mm delay line was added to the second and fourth branches while an 80-mm delay line was added to the third branch to make all the paths equal. Using the same design concept, the y-polarization horizontal subcircuit was also designed to ensure that equal amplitude and phase signals are fed to each antenna unit.

III. Simulation and Measurement Results

Rogers RO4003C is used as the substrate for the antenna array as well as for the vertical and horizontal feeding sub-circuits. For both ports 1 and 2, the design specifications are for an operating bandwidth of 3.1 GHz to 3.5 GHz, a reflection coefficient lower than –10 dB, and an isolation better than 25 dB. Figs. 6(a) and 6(b) show the x-z and y-z plane radiation patterns of the y-polarized antenna sub-array at 3.3 GHz. The half-power beamwidth for the radiation patterns are about 20° with less than -10 dB side lobe levels.

Fig. 8 shows the gain and efficiency of the y-polarized sub-array. When estimating the total efficiency, both the standalone array and the feeding circuit efficiencies need to be accounted for. For both sub-arrays, the simulated



(a) (b)

Fig. 6. Simulated and measured radiation patterns of y-polarized dipole excitation at 3.3 GHz (unit: dBi). (a) x-z plane and (b) y-z plane patterns.

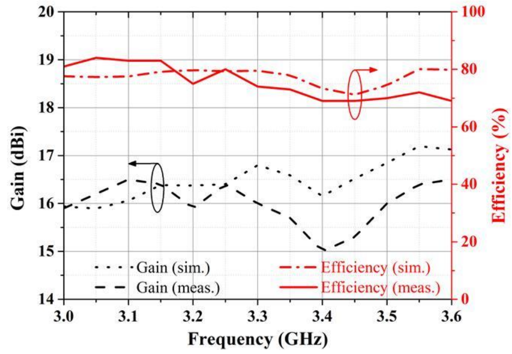


Fig. 8. Simulated and measured antenna gain and radiation efficiency of the prototype antenna when y-polarized antenna excitation only.

standalone array efficiency is around 87% while the feeding circuit has about an 80% efficiency, which lets the total simulated efficiency to be about 70%. From Fig. 8, the y-polarized sub-array has an efficiency larger than 69% in the desired bands. There is also a gain of 16.1±0.8 dB for the x-polarized sub-array and a gain of 15.75±0.75 dB for the y-polarized sub-array throughout the desired operating band. The peak gain can be increased by extending the proposed design concept to a larger array.

From the measured x-polarization results, the x-z plane and y-z plane radiation patterns, antenna gain, and radiation efficiency also are similar to the simulation results.

IV. Conclusion

This work proposes a dual-linearly-polarized printed dual-dipole antenna array with a 3-D feeding circuit for polarimetric radar system applications. X-polarization and y-polarization signals are fed into individual five-way power dividers, to then send the signals to the folded-dipole antenna units through vertical sub-circuits. A 5×5 dual-polarization antenna array has been realized with its x-polarized sub-array having a gain of 16.1±0.8 dB and over 60% efficiency; and the y-polarized sub-array having a gain of 15.75±0.75 dB, with over 69% efficiency for the entire operating band.

References

[1] R. Bari, T. Brown, S. Gao, M. Notter, D. Hall, and C. Underwood, "Dual-polarized printed S-band radar array antenna for spacecraft applications," *IEEE AWPL*, vol. 10, pp. 987-990, 2011.

[2] Y. Cui, R. Li, and P. Wang, "A novel broadband planar antenna for 2G/3G/LTE base stations," *IEEE Trans. Antennas Propag.*, vol. 61, no. 5, pp. 2767–2774, May 2013.

[3] C. Liao and S. Chen, "Compact Printed Dual-Dipole Antenna with a New T-Shaped Feeding Structure for Dual Broadband Operation," 2019 APMC, Singapore, Singapore, 2019, pp. 506-508