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Dualband Shared-Aperture Microstrip Antenna for Reflectarray Feeding Structure of LEO Satellite System

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Abstract

This paper presents a new dualband shared-aperture microstrip antenna to operate in the S-Band of 2 GHz and X-Band of 8 GHz, for a Low Earth Orbit satellite antenna system. The proposed antenna incorporates two types of patches those are a rectangular loop-shaped for the S-Band and a square patch for the X-Band. Each patch are optimized for its respective operating band with minimal interference. The proposed antenna achieves a bandwidth of 16 MHz in the S-Band and 572 MHz in the X-Band. The highest gain is measured 7.14 dBi at 1.99 GHz and 7.95 dBi at 7.88 GHz. The proposed antenna exhibits half power beamwidths of 85 degree and 80 degree at 1.99 GHz and 7.88 GHz, respectively. The proposed dualband shared-aperture microstrip antenna may be a good candidate for as a feeding system of a dualband reflectarray antenna With its unidirectional radiation pattern from excellent agreement between simulation and measurement results.

Key words : Microstrip Antenna, Dualband, Shared Aperture, Reflectarray Feed, Low Earth Orbit Satellite

Ⅰ. INTRODUCTION

Reflectarray antenna is an interesting alternative to achieve high gain, particularly in long-distance communication applications such as satellite communications [1]-[2] due to its notable advantages, including high gain, light weight, and ease of fabrication [3]-[4].

This type of antenna consists of planar reflector and feeder antenna. Typically, an antenna with a unidirectional radiation pattern is chosen to illuminate the reflector area. Microstrip antennas offer a design flexibility feature that makes them easy to adjust to obtain the desired radiation pattern.

The implementation of dualband shared-aperture technology in microstrip antennas has been investigated in [5]-[6] to simplify the design, reducing both complexity and cost. Therefore, this research discuss about the design of a dualband shared-aperture microstrip antenna proposed as a feeder for a dualband reflectarray antenna.

Ⅱ. ANTENNA DESIGN AND ANALYSIS

Dualband microstrip array antenna designed to serve as a feeder antenna for a dualband reflectarray antenna as illustrated in Fig. 1. A rectangular loop-shaped patch antenna with dimension of length *(L)* × width (*W)* was chosen as the radiating element for S-Band. The slot has length of *S*-mm, proposed to secure a place for the X-Band patch with length of *P*-mm as

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illustrated in Fig. 2, while the port position illustrated in Fig. 3 with *px2* and *py2* as the S-Band port in x and y-axis respectively, *px8* and *py8* as the X-Band port in x and y-axis respectively.

The proposed antenna designed on a 1.575 mm-thick Rogers RT/duroid 5880 substrate, with ground plane size of 80 mm × 80 mm.

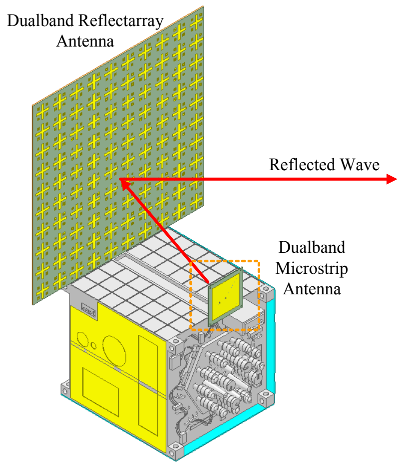


Fig. 1. Introduction of the proposed antenna purpose in the total satellite antenna system.

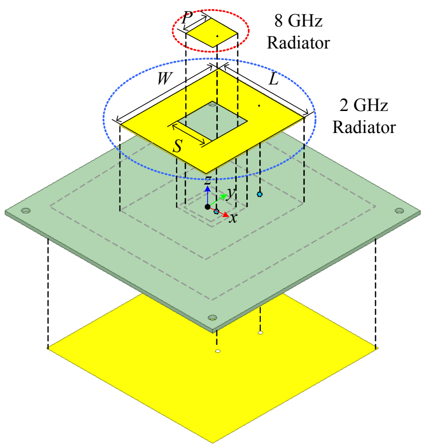


Fig. 2. Configuration of the proposed antenna.

There is a 10 mm extension on each side of the antenna intended as an assembly mechanism for the reflectarray antenna structure.

As depicted in Fig. 4, the length of *P* is responsible for the frequency operation of the X-band. A larger *P* value will lead to frequency shifting to a lower level. Meanwhile, the port position in x-axis (*px8*) related to the impedance matching of the antenna at 8 GHz.

Simulation results in Fig. 5 show that the length of *L* has a significant impact on the frequency operation of the S-Band antenna. The longer *L* will eventually shift the frequency to the lower level.

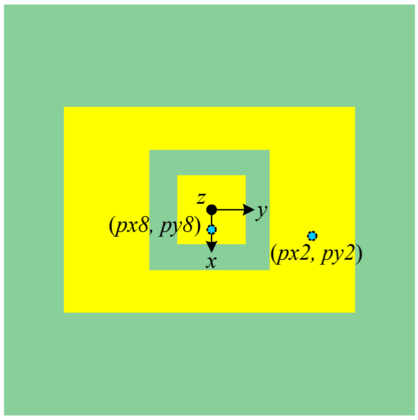


Fig. 3. Feeding position at 2 GHz and 8 GHz operation for the proposed antenna.

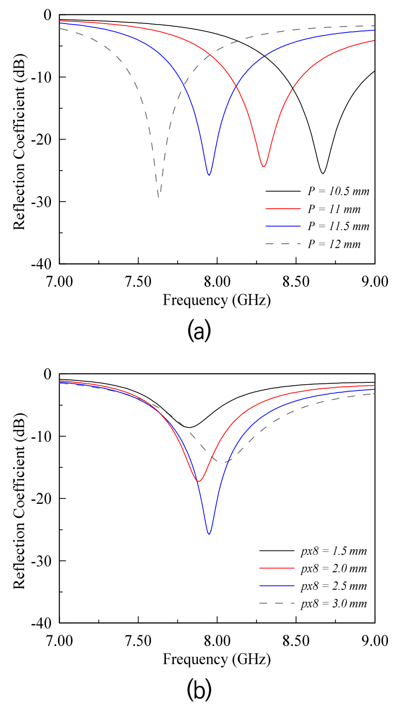
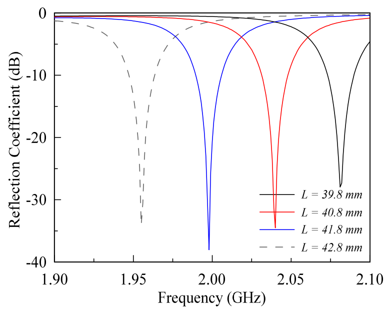
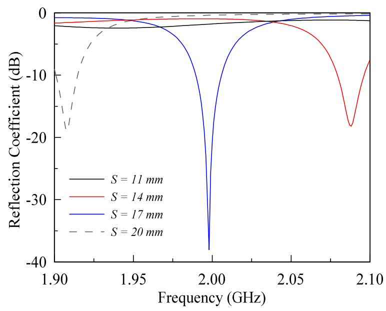


Fig. 4. Computed frequency responses in X-Band with varying the dimension of (a) *P* and (b) *px8*.

The slot gives a loading effect to the antenna. The operating frequency decreases proportionally with the increase in the *S* value. The final dimensions of the proposed antenna are listed in Table 1. Meanwhile, in Fig. 6, it can be seen that the electric-field mainly distributed on the dedicated patch and has a minimum impact on the nearby patch for each band.

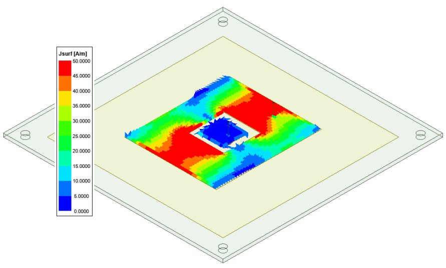


(a)

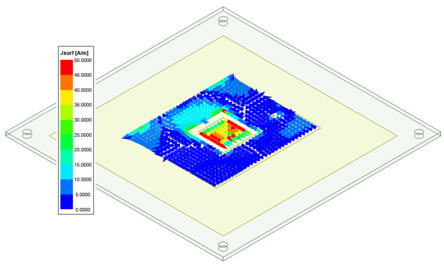


(b)

Fig. 5. Computed frequency responses in S-Band with varying the dimension of (a) *L* and (b) *S*.



(a)



(b)

Fig. 6. Simulated distributions of the electric field magnitudes in the surface of the shared-aperture radiator at (a) 2 GHz and (b) 8 GHz.

Table 1. Optimized dimension of the proposed antenna.

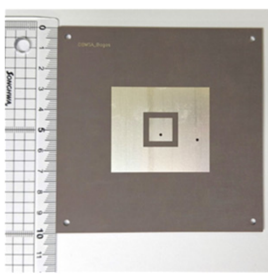
Design parameters	Description	Value (mm)
L	length of rectangular loop	41.8
W	Width of rectangular loop	48.0
S	slot length between square patch and rectangular loop	17.0
P	length of square patch	11.5
px2	2 GHz feed position in x-axis	5.0
py2	2 GHz port position in y-axis	18.0
px8	8 GHz feed position in x-axis	2.5
py8	8 GHz port position in y-axis	0.0

Ⅲ. MEASUREMENT

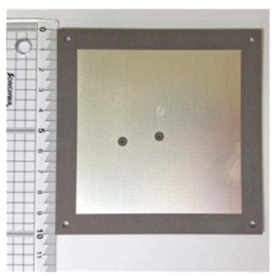
The proposed antenna was fabricated on a 1.575 mm-thick Rogers RT/duroid 5880 substrate, featuring a dielectric constant of 2.2 and a loss tangent of 0.0009, as illustrated in Fig. 7. The antenna has a total size of 100 mm × 100 mm, with a ground plane size of 80 mm × 80 mm.

Fig. 8 shows the antenna measurement for reflection coefficient using the Key-Sight E5071C vector network analyzer, which operates from 300 kHz up to 20 GHz and far-field radiation patterns in an anechoic chamber with the capability to measure antenna radiation patterns in the range of 800 MHz to 8 GHz.

As shown in Fig. 9, the measurement results show a minor difference from dielectric constant of the substrate. In the simulation, it is set to be 2.2, while the fabricated antenna has dielectric constant of 2.25 which leads to a slightly frequency shift to a lower level for both bands of



(a)



(b)

Fig. 7. Photos of the fabricated antenna. (a) Top radiator side and (b) bottom ground side.

operation. Overall, the fabricated antenna have good reflection coefficient performance shown by a 10-dB impedance bandwidth of 16 MHz, ranging from 1.98 GHz to 2.00 GHz in S-Band.

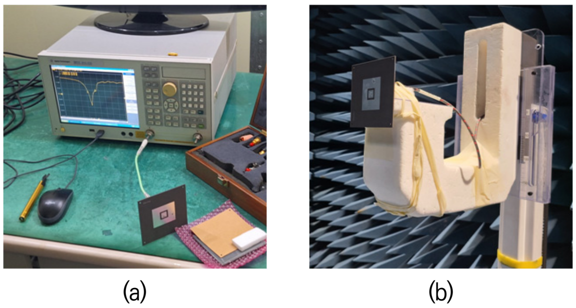


Fig. 8. Photos of measurement environments for (a) reflection coefficient and (b) far-field radiation pattern in an anechoic chamber.

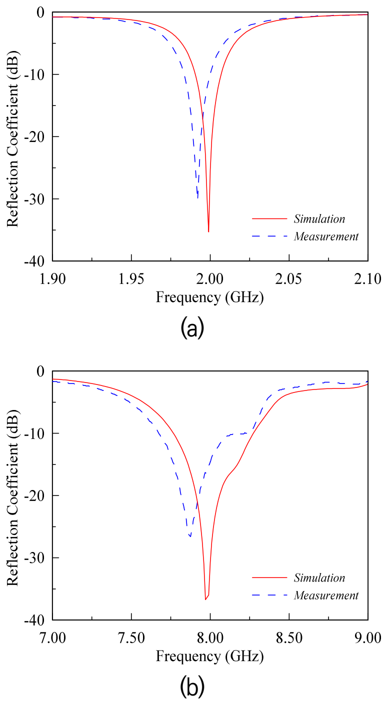


Fig. 9. Reflection coefficients of the proposed antenna in (a) S-Band and (b) X-Band.

Meanwhile, in X-Band, the antenna achieves a bandwidth of 572 MHz, spanning from 7.67 GHz to 8.24 GHz.

In Fig. 10, the gain is depicted. In the S-Band, the highest gain reaching 7.14 dBi at 1.993 GHz. Comparatively, simulation results show the highest gain of 7.28 dBi at 1.998 GHz. In the X-Band, the highest gain recorded at 7.876 GHz, reaching 7.95 dBi. The simulation also yielded the highest gain of 7.95 dBi, observed at 7.978 GHz.

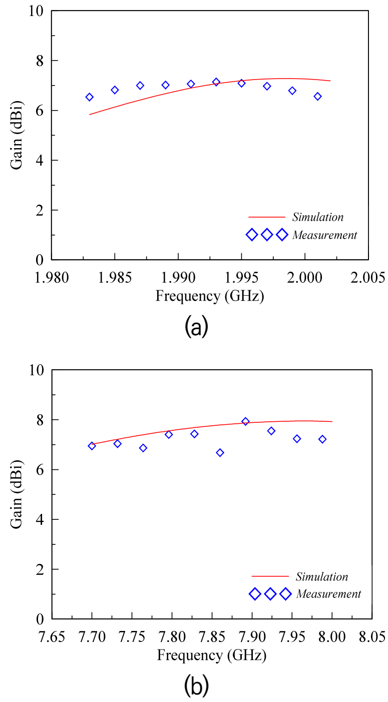


Fig. 10. Realized antenna gains of the proposed antenna with simulation and measurement results in (a) S-Band and (b) X-Band.

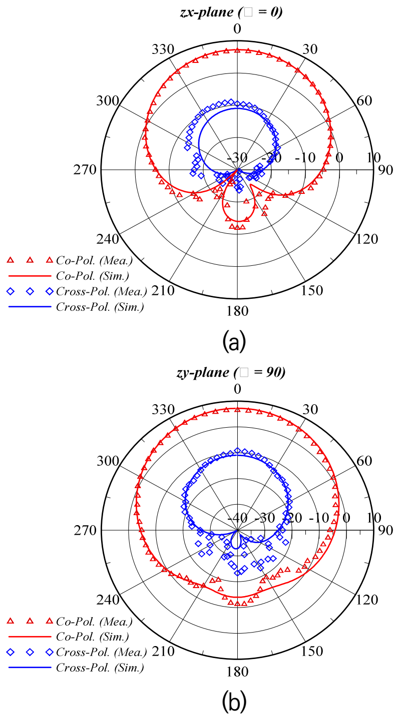


Fig. 11. Far-field radiation patterns of the proposed antenna in S-Band. (a) *zx*-plane and (b) *zy*-plane.

Fig. 11 exhibits the radiation pattern of the proposed antenna in S-Band, while Fig. 12 is in X-Band. The radiation patterns were measured at 1.993 GHz and 7.876 GHz, considering the frequencies where the highest gains were measured. It can be seen that there are gaps between the co-polarization and cross-polarization levels, which means the proposed antenna has good cross-polarization isolation, especially in the S-Band operation. The measured half-power beamwidth (HPBW) of the antenna at 1.993 GHz was around 85°.

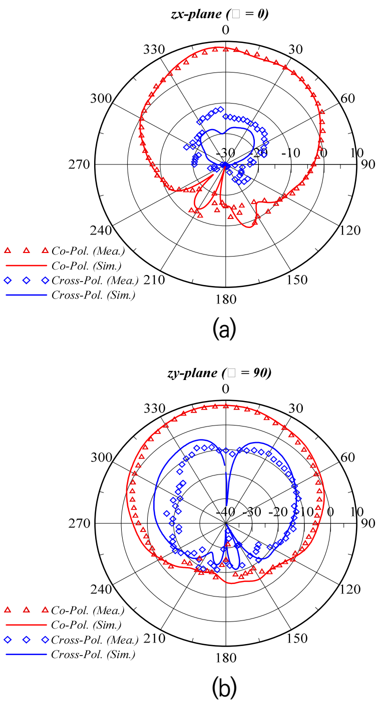


Fig. 12. Far-field radiation patterns of the proposed antenna in X-Band. (a) *zx*-plane and (b) *zy*-plane.

Meanwhile, about 80° of HPBW was measured at 7.876 GHz. It is also shown that the antenna has a unidirectional radiation pattern with the main beam directed to theta equal to zero in both operating bands.

Ⅳ. CONCLUSION

A new dualband shared-aperture microstrip antenna designed to operate in S-Band and X-Band was discussed and demonstrated. The fabricated antenna exhibits a good match with simulation results in terms of reflection coefficient, with only a slight shift to lower frequencies. Additionally, the proposed antenna demonstrates compatibility gain performance between measurement and simulation results. The antenna features a unidirectional radiation pattern, which suitable for reflectarray feeder.

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