Design of a Bandwidth Enhanced Dual-Band Dual-Polarized Array Antenna

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1. Introduction

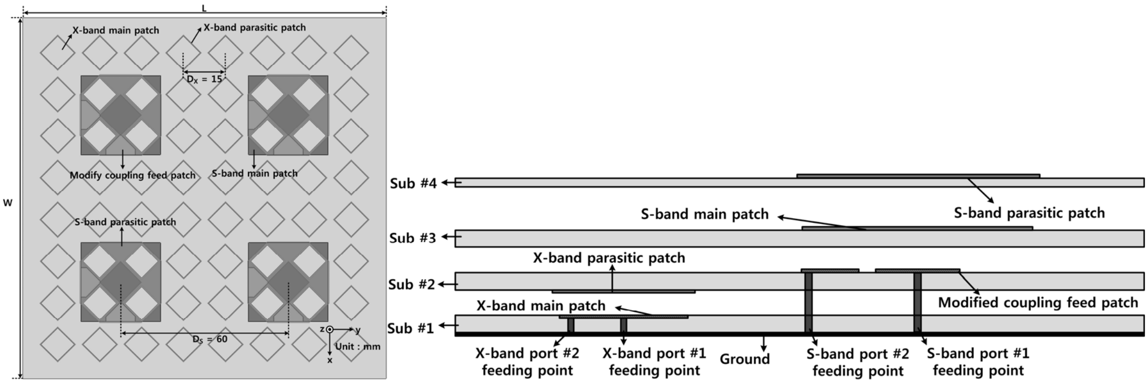
The role of the future navy continues to require higher levels of functionality, performance, and interoperability from shipboard systems. Embedded in the superstructure of future navy ships will be a variety of antenna arrays that will perform different functions such as radar. In an advanced multi-function RF concept (AMRFC), separated Tx and Rx arrays are required to provide the capability to perform a variety of functions [1]. To accommodate multiple functionalities, AMRFC radar systems require advanced antennas operating in multiband and with multi-polarization. In general, a dual-polarized operation can provide more information for radar systems, can increase the isolation between the transmitting and receiving signals of transceivers and transponders, and can double the capacity of communication systems by means of frequency reuses[2]-[3].

Recently dual-band dual polarized (DBDP) antenna arrays have been widely studied for satellite and wireless communication applications, particularly for synthetic aperture radar (SAR) applications [4]-[8]. In [4]-[6], DBDP array antennas were proposed, but those array antennas had narrow bandwidth at both bands. A DBDP array design consisting of four double dipole radiators for WLAN applications [7] was suggested to provide very low cross-polarization levels. However, this technique cannot be utilized for the AMRFC radar applications due to its complex structures. Although many DBDP antennas have been proposed, not all of them are good candidates for array design due to their complex structures, complex feeding-line networks, and narrow bandwidth. In addition, many of them are bulky and heavy.

In this paper, a dual-band dual-polarized (DBDP) array antenna with improved bandwidth for AMRFC radar applications is proposed. The proposed antenna operates at S- and X-bands with a frequency ratio of about 1:3. To improve the impedance bandwidth, perforated patches and modified coupling feed patches are used in S-band and diamond-shaped patches are used in X-band. The configuration of the DBDP antenna array is presented in the following sections and the parameters affecting the array characteristic are analyzed.

2. Antenna Design and Results

The configuration of the proposed DBDP array antenna is shown in Fig.1. The proposed antenna consists of a ground plane, X-band main patches, X-band parasitic patches, modified coupling feed patches, S-band main patches, S-band parasitic patches, and four Taconic TLC substrates (ε_r = 3.2) with different thicknesses. The ground plane is printed on the back side of Taconic TLC substrates (sub #1) with thickness of 0.762 mm. The X-band main patches are placed on the top side of sub #1. The X-band parasitic patches and modified coupling feed patches are printed on the bottom and top sides of a Taconic TLC substrate (sub #2) with a thickness of 0.762 mm. The S-band main patches, which are printed on the top of a 0.762 mm Taconic TLC substrate (sub #3), have a size of 28.5 mm × 28.5 mm with four perforations. The S-band parasitic patches are printed on the top side of a 0.508 mm Taconic TLC substrate (sub #4) with truncated edges and five perforations.

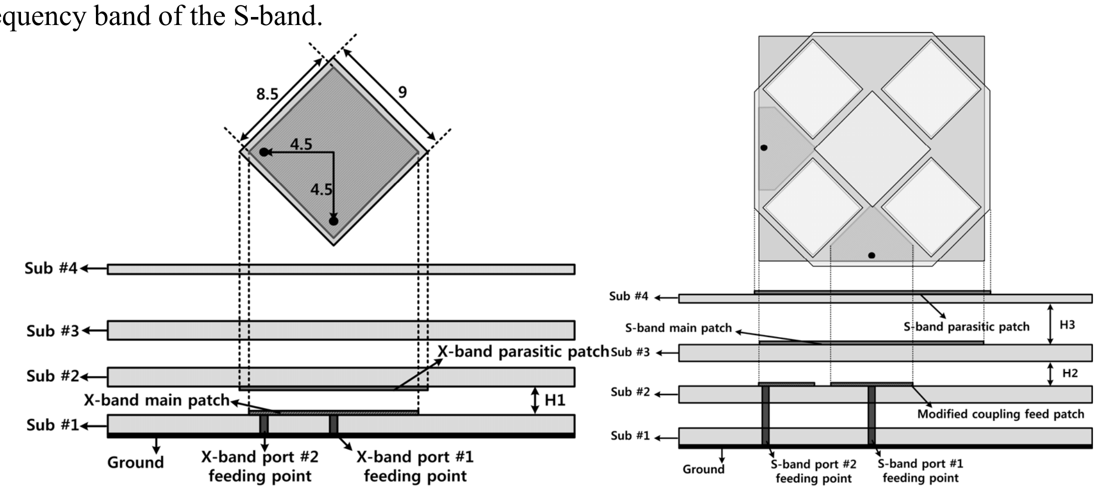


(a) Top view (b) Side view

Figure 1: Structure of proposed DBDP array antenna

Figure 2 shows the top and side views of the proposed dual polarized X-/ S-band main patch and parasitic patch. For the X-band array, stacked diamond-shaped patches were selected as its unit element. Each side of the X-band main patch has a length of 8.5 mm and that of the parasitic patch has a length of 9 mm. The required impedance bandwidth can be obtained by controlling the coupling between the X-band main patch and the parasitic patch. Thus, the height between the X-band main patch and parasitic patch should be adjusted very carefully both to widen the bandwidth and to improve the impedance mating characteristic.

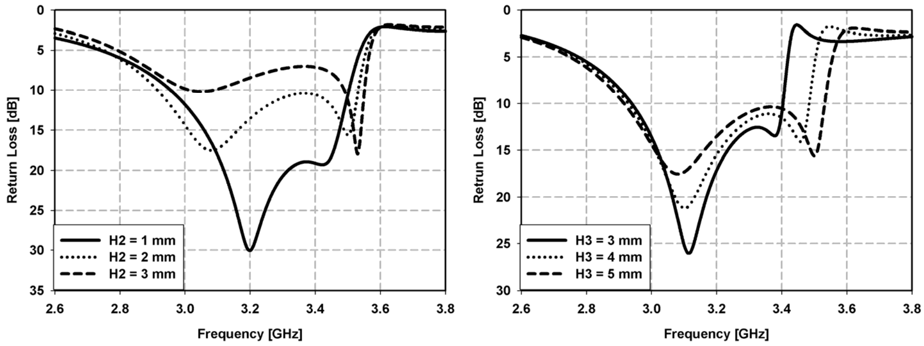
The S-band elements consist of a modified coupling patch, S-band main patch, and S-band parasitic patch as shown in Fig. 2(b). An important design consideration for multilayer dual band arrays is that the S-band elements should be nearly transparent to the X-band elements. Otherwise, the S-band elements may degrade the performance of the X-band antenna. Two perforated patches with different polarizations are used for the S-band. The required impedance bandwidth is obtained by the electromagnetic coupling between the modified coupling patch and both patches. The frequency band of the S-band antenna with only S-band main patch satisfies lower frequency band of the S-band while that of the S-band antenna with only S-band parasitic patch satisfies higher frequency band of the S-band.



(a) X-band (b) S-band

Figure 2: Top and Side views of the X- / S-band main patch and parasitic patch

Figure 3 shows the simulated return loss characteristics for various separations. When the separation (H2) between the modified coupling feed patch and S-band main patch is decreased, the impedance matching is improved over the whole S-band from 3 GHz to 3.5 GHz. When the separation (H3) between the S-band main and parasitic patch is increased, the second resonance frequency is shifted toward the higher frequency band. The required bandwidth can be obtained by adjusting the coupling among the S-band elements.

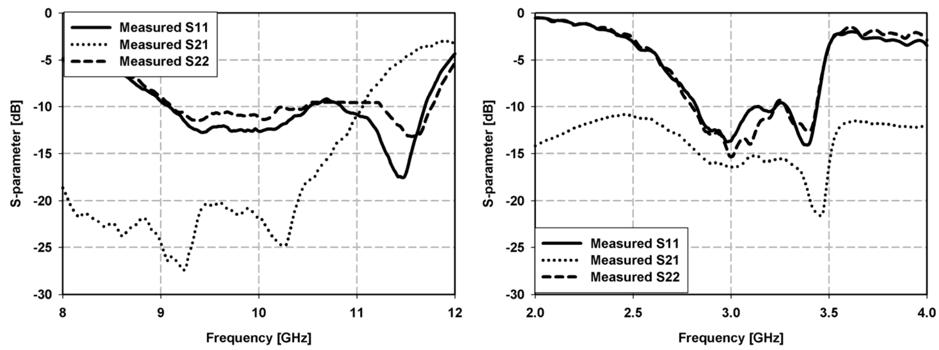


(a) Variation in H2 (b) Variation in H3

Figure 3: Simulated return loss characteristics for different design parameter values

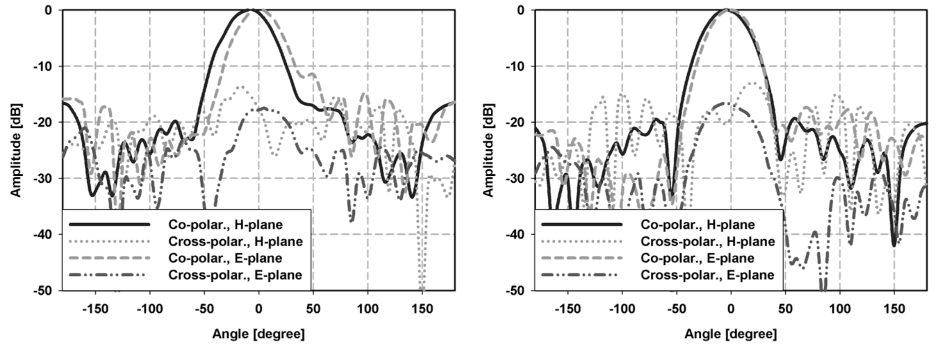
The measured S-parameter characteristics of the DBDP array antenna are shown in Fig. 4. The measured resonance frequencies of the S-band are shifted toward the lower frequency side comparing to the simulated ones. The measured bandwidth of VSWR ≤ 2 is 19.8 % from 2.82 GHz to 3.44 GHz. The isolation between the two orthogonal polarizations is higher than 15 dB within the operating band. For the X-band array, the measured bandwidth of VSWR ≤ 2 reaches 25.7 % from 9 GHz to 11.7 GHz. Since the X-band patch antenna is probe-fed, the measured isolation between port #1 and port #2 (S21=S12) is higher than 15 dB.

The measured co-polar and cross-polar radiation patterns of the S-band array are shown in Figs. 5 (a) and (b), respectively. The cross-polarization levels in both the E-plane and the H-plane are lower than -18 dB and the side lobe levels are lower than -17 dB. The maximum measured array gain is higher than 11 dBi over the whole band. For the X-band array, the measured co-polar and cross-polar radiation patterns of the horizontal and vertical polarizations are shown in Figs. 6(a) and (b), respectively. In both E-plane and H-plane, the cross-polarization levels are lower than -17.5 dB and the side lobe levels are below -10 dB. The peak gain of the X-band array is higher than 18.5 dBi.



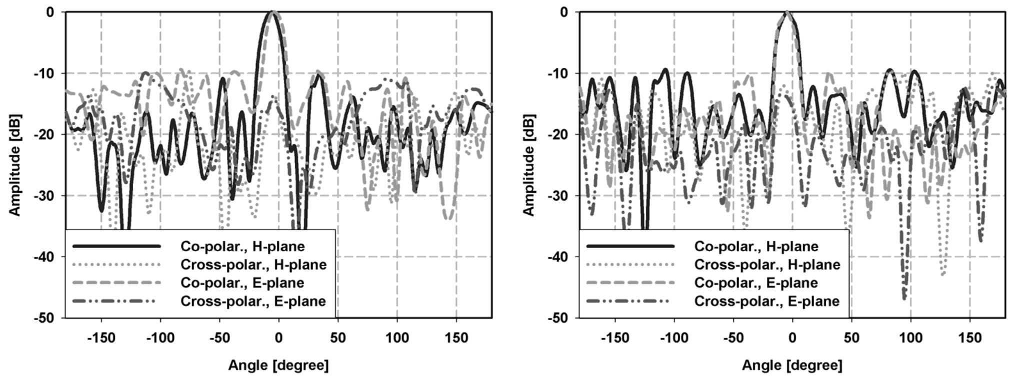
(a) X-band (b) S-band

Figure 4: Measured S-parameter characteristics of the DBDP array antenna



(a) Port #1 is excited (b) Port #2 is excited

Figure 5: Measured radiation patterns of the S-band 2 x 2 array antenna at 3.25 GHz.



(a) Port #1 is excited (b) Port #2 is excited

Figure 6: Measured radiation patterns of the X-band 8 x 8 array at 9.2 GHz

3. Conclusion

In this paper, a dual-band dual-polarized array antenna with improved bandwidth for AMRFC applications operating at S-and X-bands was proposed. The required impedance bandwidth of the X-band was obtained by adjusting the electromagnetic coupling between the main and parasitic patches. To increase the bandwidth of the S-band, the proposed antenna used the modified coupling feed patch and two perforated patches. The distance between S-band main and parasitic patches is the main parameter to control the bandwidth performance of the proposed S-band array antenna. The measured impedance bandwidth (VSWR≤2) of the prototype array reached 19.8 % and 25.7 % for the S- and X-bands, respectively, and the measured isolation between the two orthogonal polarizations for both bands was less than -15 dB. The measured cross-polarization level was less than -17 dB for S-band and less than -17.5 dB for X-band. From the experimental results, we are convinced that the proposed DBDP antenna can be a good candidate for AMRPC radar applications.

Acknowledgments

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References

[1] G. C. Tavik, C. L. Hilterbrick, J. B. Evins, J. J. Alter, J. G. Crnkovich, Jr., J. W. de Graaf, W. Habicht II, G. P. Hrin, S. A. Lessin, D. C. Wu, S. M. Hagewood, "The Advanced Multifuction RF Concept", IEEE Transaction on Microwave Theory and Techniques, vol. 53, no. 3, pp. 1009-1020, Mar. 2005.
[2] S. Gao and A. Sambell, "Dual-Polarized Broad-Band Microstrip Antennas Fed by Proximity Coupling", IEEE Transactions on Antennas and Propagation, vol. 53, no. 1, pp. 526-530, Jan. 2005.
[3] X. Qu, S. Zhong, Y. Zhang, and W. Wang, "Design of an S/X Dual-Band Dual-Polarised Microstrip Antenna Array for SAR Applications", IET Microwave, Antennas and Propagation, vol. 1, no. 2, pp. 513-517, Apr. 2007.
[4] Y. J. Ren, S. H. Hsu, M. Y. Li, and K. Chang, "A dual-frequency dual-polarized planar airborne array antenna", Antennas and Propagation Society International Symposium, pp. 1-4, Jul. 2008.
[5] G. Vetharatnam, V. C. Koo, "Compact L- & C-band SAR antenna", Progress in electromagnetics Research C, vol. 8, pp. 105-114, 2009
[6] Y. Ren, Y. Zhang, "Ultra-lightweight dual-polarized X-band array antenna for airborne weather radar applications", Microwave and Optical Technology Letters, vol. 51, pp. 1324-1326, May 2009.
[7] J. M. Steyn, J. W. Odendaal, and J. Joubert, "Dual-band dual-polarized array for WLAN applications", Progress in electromagnetics Research C, vol. 10, pp. 151-161, 2009.
[8] L. N. Zhang, S. S. Zhong, and X. L. Liang, "Dual-band dual-polarized hybrid antenna array", Progress in Electromagnetics Research Symposium, Mar. 2010.