메타표면 벽을 이용한 2중편파 1차원 광대역(2.83:1) 다이폴 위상배열안테나

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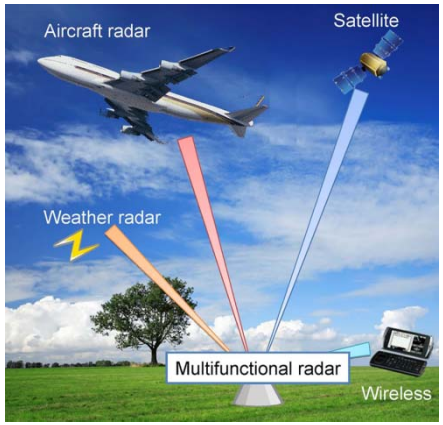
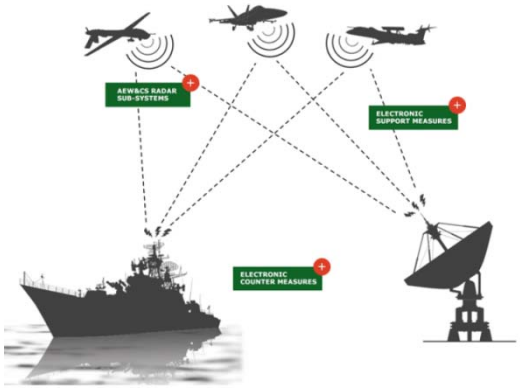
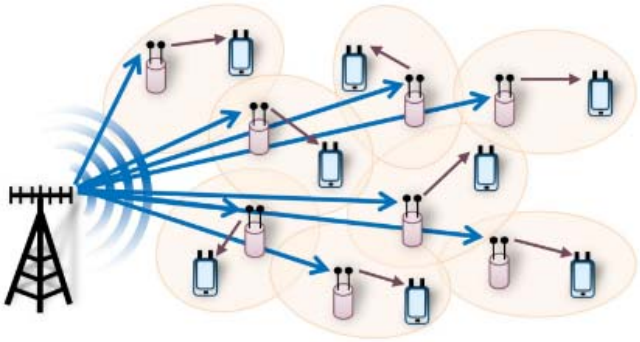
- Introduction
- Design of a Low-profile TCA Antenna
- Prototype of the Proposed TCA and Measured Results
- Design of an one-dimensional TCDA and Measured Results
- Conclusion

Introduction

- **Ultra-Wideband Arrays**







- **Multi-functional radar**
- **Electronic Warfare**
- **Communications**

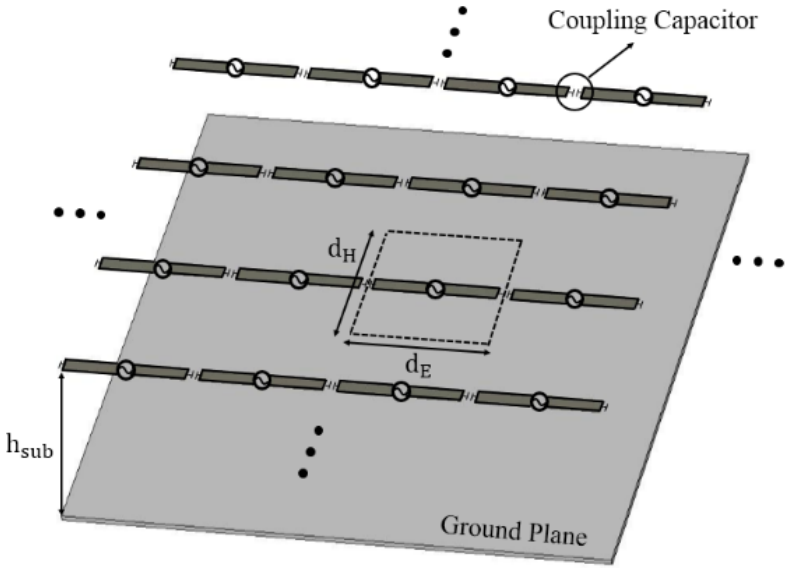
Issues

- **Wide bandwidth**
- **Large scan angle**
- **Low profile**
- **Low cost**

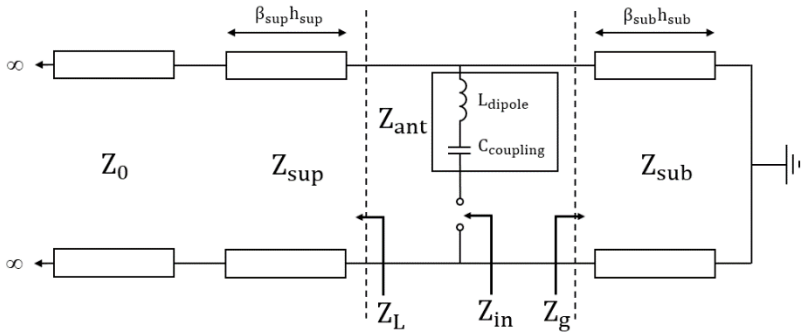
Design of a Low-profile TCA Antenna

- **TCDA concept (low profile) and equivalent circuit**

  - **TCDA schematic**



  - **TCDA equivalent circuit**



$$Z_g = jZ_{sub}\tan\beta_{sub}h_{sub}$$

$$Z_L = Z_{sub}\frac{Z_0 + jZ_{sup}\tan\beta_{sup}h_{sup}}{Z_{sup} + jZ_0\tan\beta_{sup}h_{sup}}$$

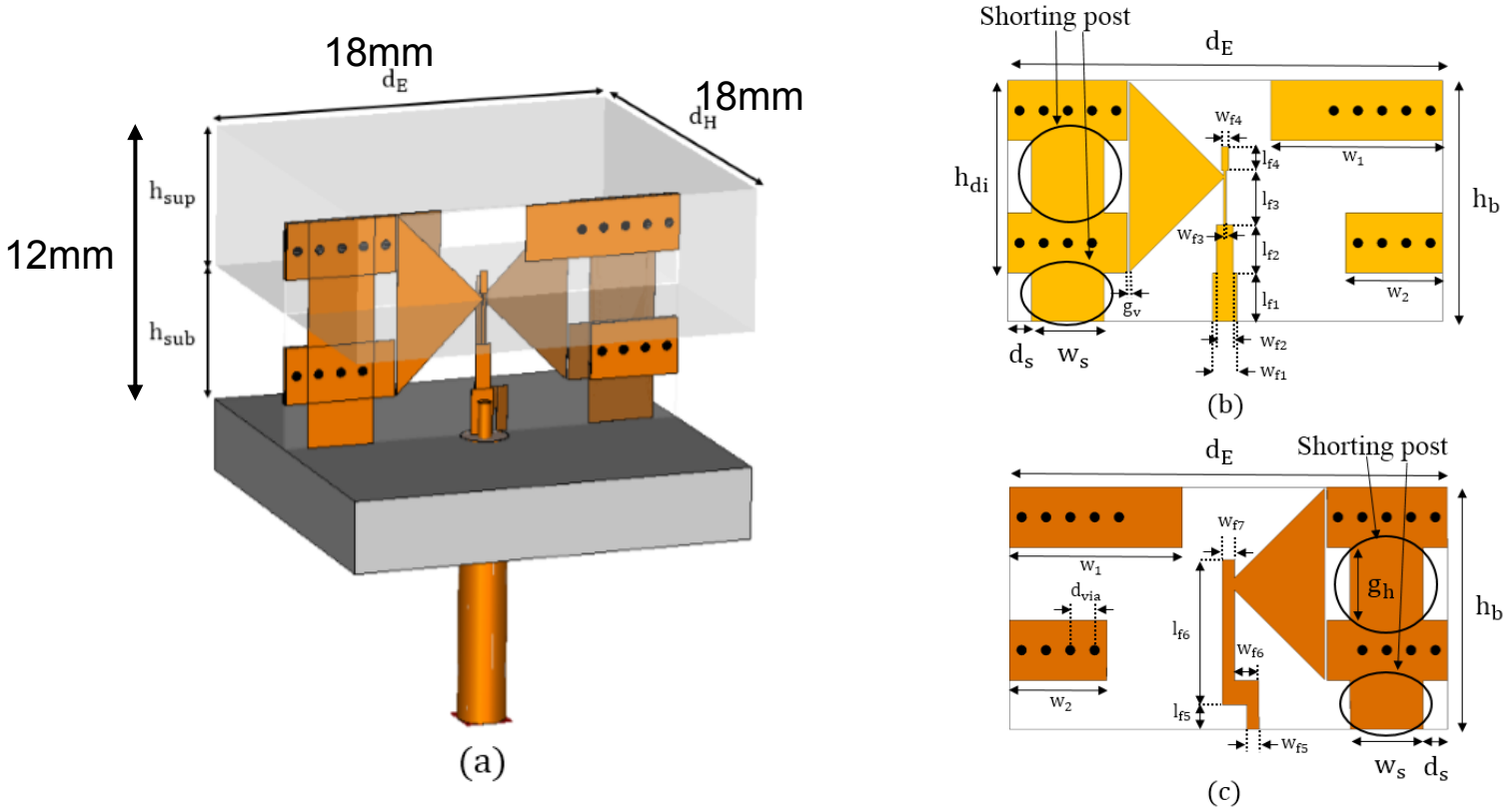
$$Z_{ant} = j\omega L + 1/\ j\omega C$$

$$Z_{in} = Z_g\ //\ Z_L + Z_{ant}$$

- The coupling capacitance compensates the inductance of ground plane at low frequency

Antenna Impedance Controlled TCA with Unbalanced Feeding

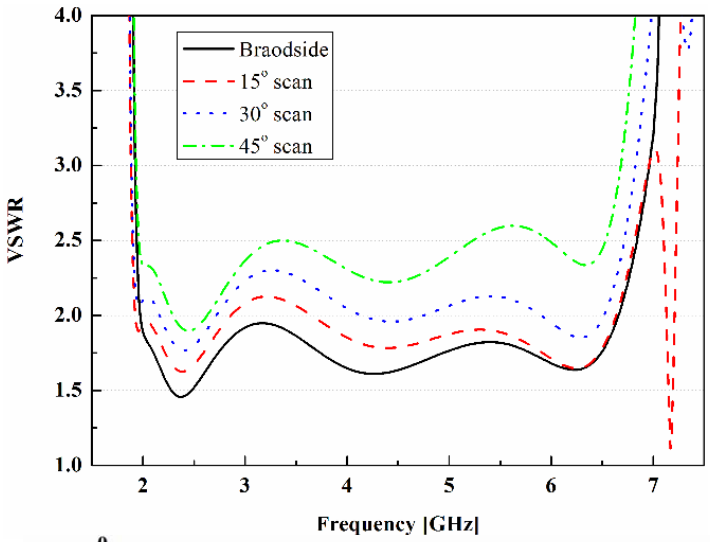
- **Proposed TCA antenna unit cell for 2 to 6 GHz low profile array antenna**

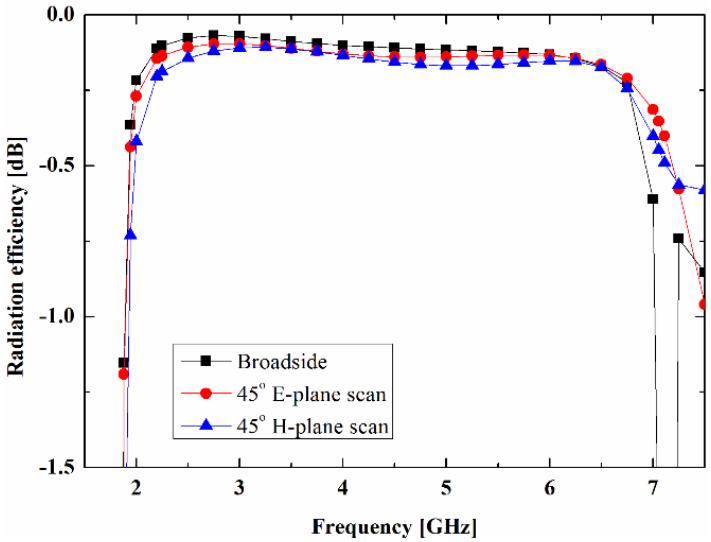


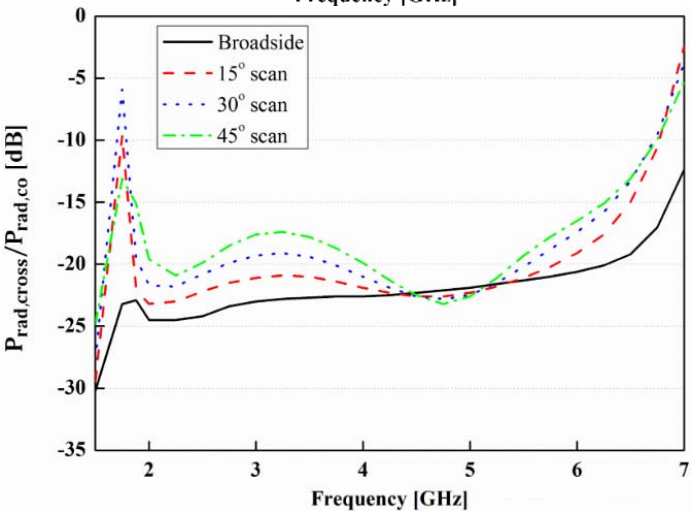
- Unbalanced feeding line is designed as a stepped-impedance line
- Shorting posts control the common mode resonance frequency, and via holes remove the unwanted resonance

Antenna Impedance Controlled TCA with Unbalanced Feeding

- **Proposed TCA with shorting posts and via holes**







When scans 45˚ for both planes

- VSWR ≤ 2.6
- Radiation loss ≤ 0.4dB
- Polarization purity ≥ 18dB

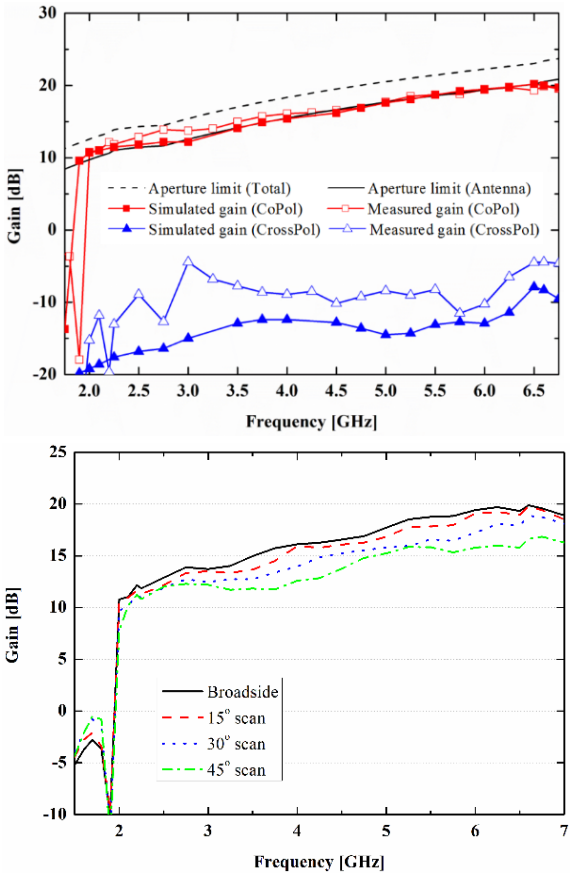
Prototype of the Proposed TCA and Measurement Results

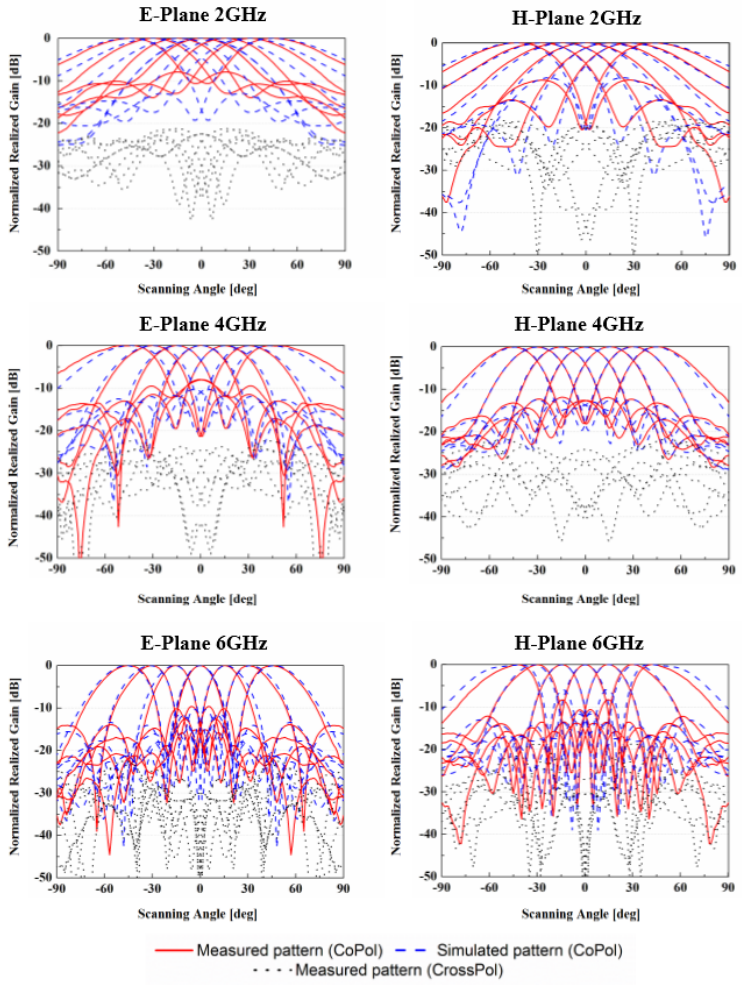
- **Fabrication**

- An 8 X 8 proposed array prototype is fabricated.
- The measured process is based on the unit excitation active element pattern method.
- According to the method, total pattern can be synthesized through post-processing by all element patterns.

Prototype of the Proposed TCA and Measurement Results

Measurement results





- Measured results are good agree with simulation.
- Beam steering is possible with small gain loss for both planes.

Prototype of the Proposed TCA and Measurement Results

- **Comparison with other works**

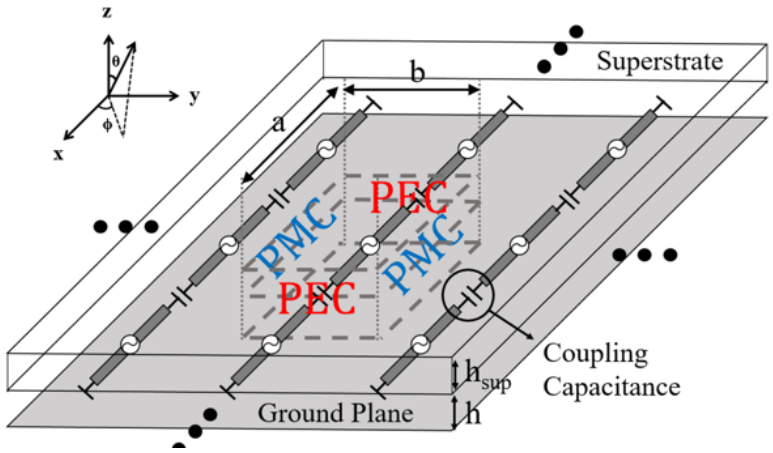
	This work	[1]	[2]	[3]	[4]	[5]
Operating Band (GHz)	1.97 ~ 6.66	7 ~ 21	0.71 ~ 4.9	0.29 ~ 4.03	0.6 ~ 3.6	0.29 ~ 3.9
Bandwidth Ratio	3.38 : 1	3 : 1	6.9 : 1	13.9 : 1	6 : 1	13.1 : 1
Total Height (λ_{low})	1 / 12.6	1 / 5.27	1 / 6.65	1 / 8.92	1 / 5.81	1 / 8.48
Designed Balun	X	X	O	O	O	O
Resistive FSS	X	X	X	O	X	O
Layer	Single	Multi	Multi	Multi	Multi	Multi

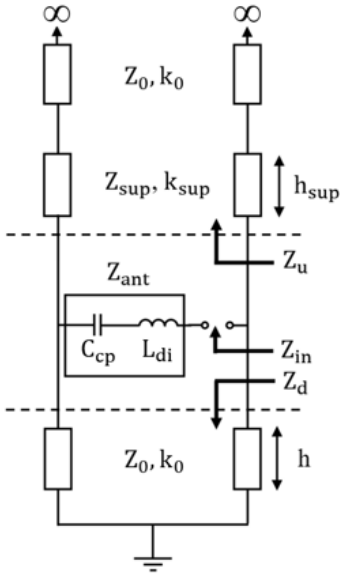
- Although the proposed array has a smaller bandwidth than some previous works, it has a notable low profile and is realized by a single-layer PCB without a designed balun and resistive FSS

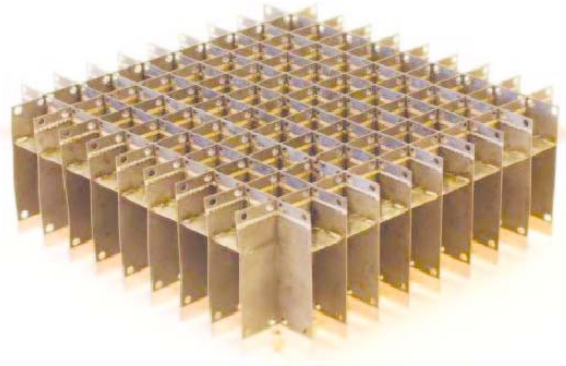
1차원 이중 편파 강한 결합 배열안테나 연구 개요

- 강한 결합 배열안테나 (Tightly Coupled Array Antenna)는 낮은 높이의 광대역 배열안테나를 설계하는 방법 중 하나로, 개별 소자 간격을 줄여 형성된 소자간 커플링을 저주파 대역 매칭 특성 향상에 이용

- 수직 편파, 수평 편파 안테나를 십자가 형태로 배치하여 이중 편파 특성을 얻고 이러한 단일 엘리먼트를 2차원 형태로 배치하여 이용되어 왔음



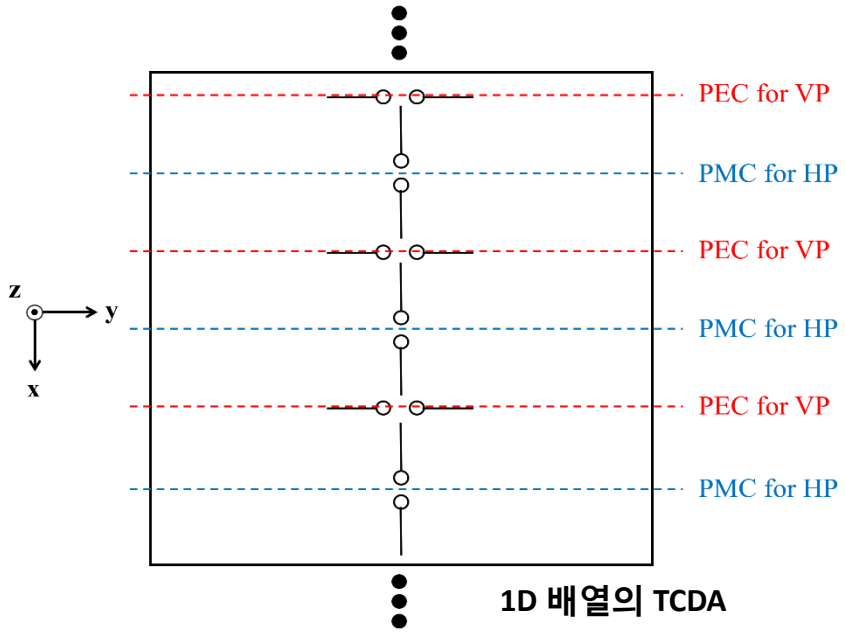




연구 목표

- 2차원 배열이 아닌 1차원 배열만으로 TCDA 이중 편파 특성을 획득할 수 있도록 하는 것이 연구의 목표

- 1차원 배열만으로도 2차원 배열과 같은 단일 안테나 경계조건을 갖도록 인공적인 Impedance Surface 를 배치하여 이중 편파 특성을 획득



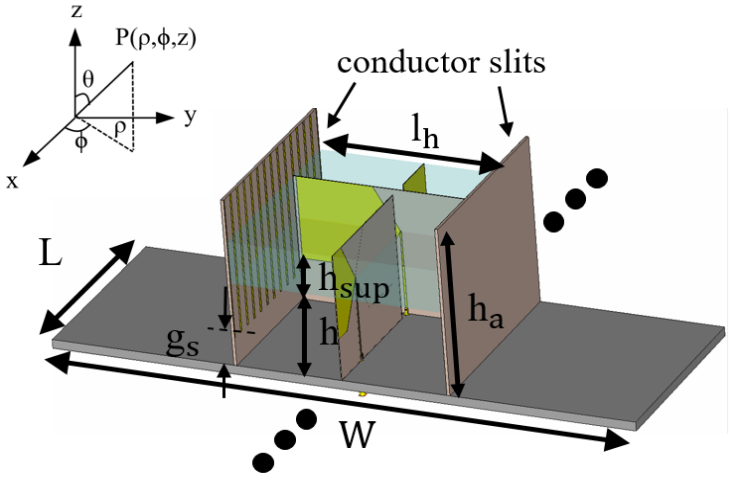
1D 배열의 TCDA

- HP 소자를 위한
  PEC 경계조건 필요 (양 옆)
- VP 소자를 위한
  PMC 경계조건 필요 (양 옆)

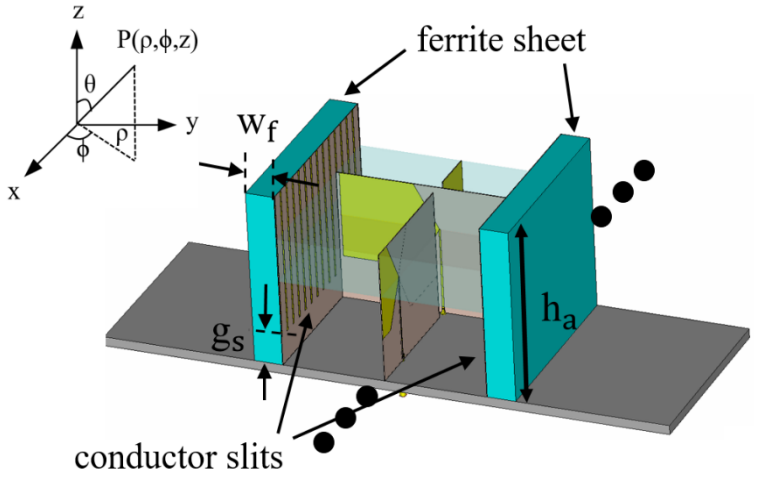
제안한 아이디어

- 양 옆의 경계조건을 만족하기 위한 Impedance Surface 를 배치하여 1D 배열에서의 이중 편파 특성을 검증

- HP 소자를 위한 conductor slit 구성, VP 소자를 위한 ferrite sheet 를 배치 후 각각의 편파 성분에 의한 동작 특성을 확인함

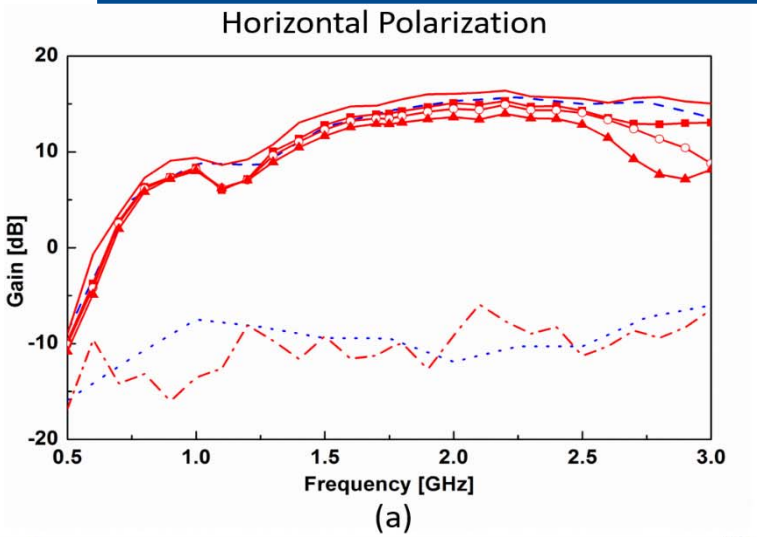


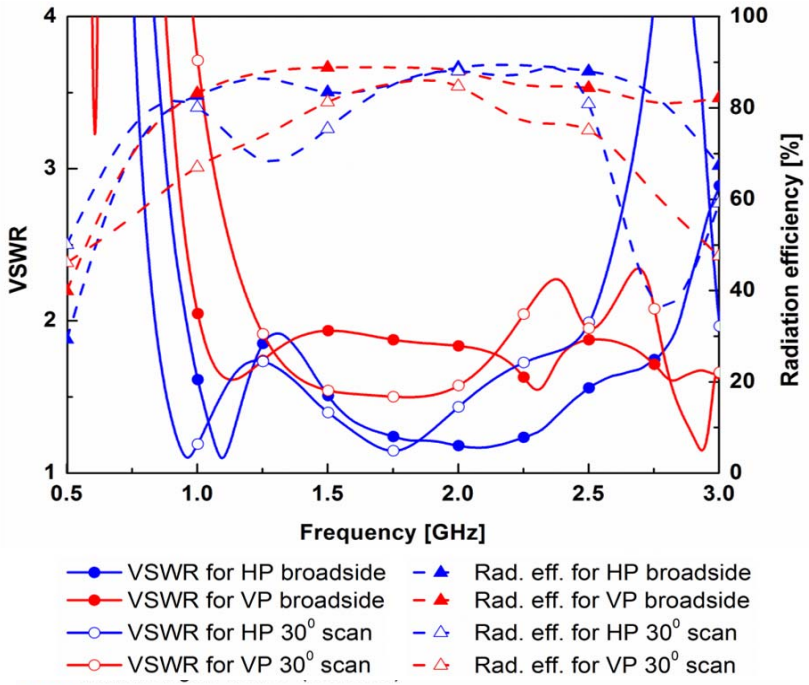
HP 소자를 위한 conductor slit 배치 (양 옆)

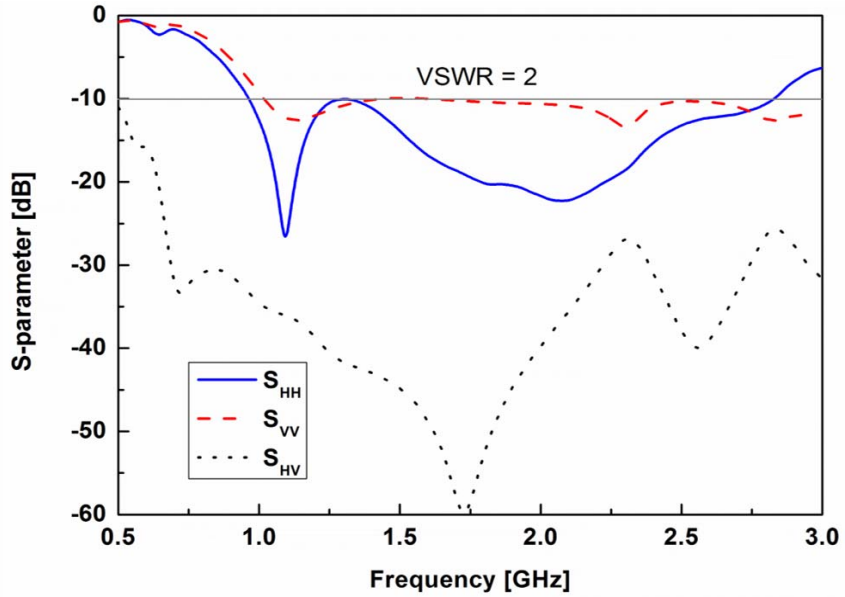


VP 소자를 위한 ferrite sheet를 추가로 배치 (양 옆)

안테나 성능 측정 결과

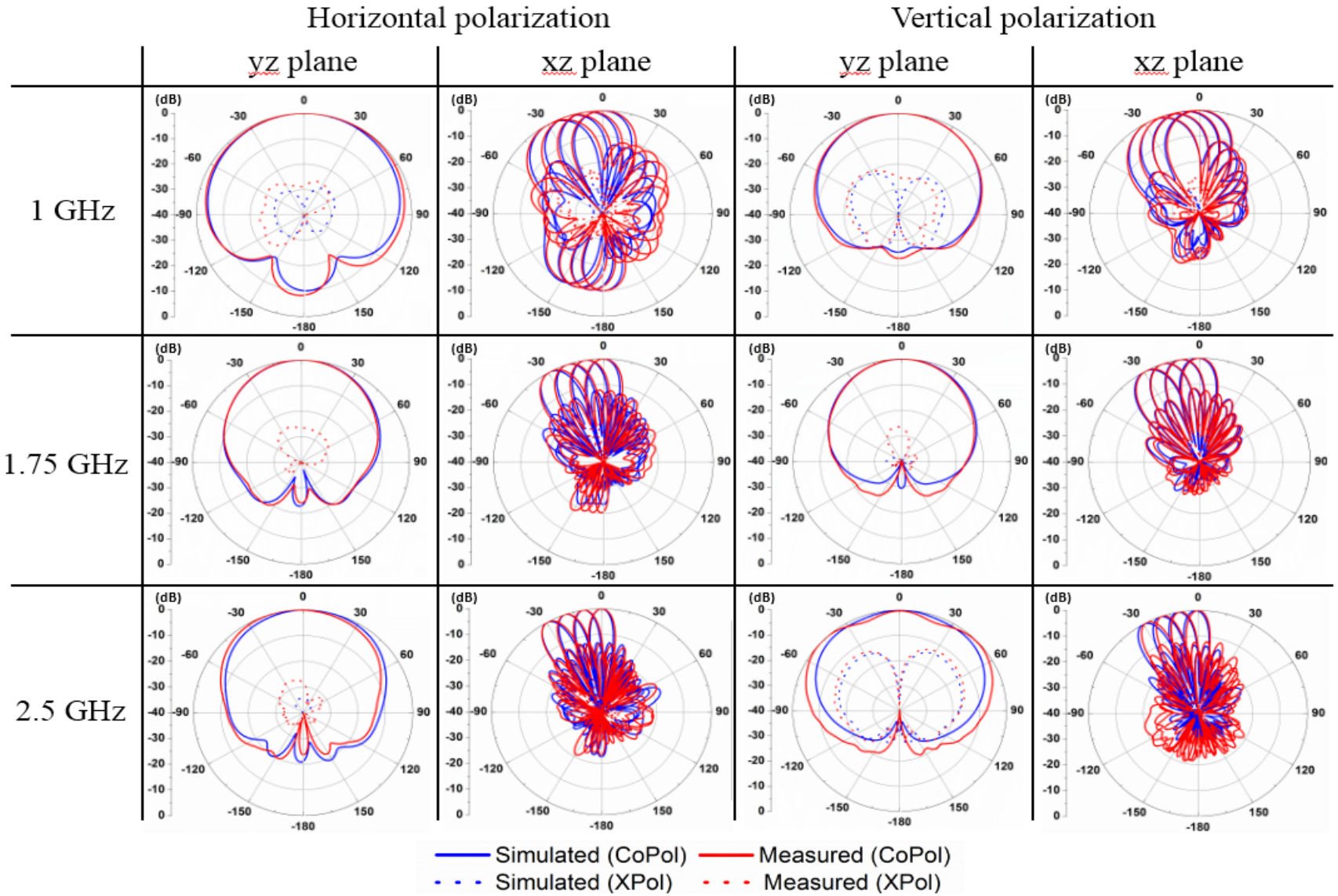






- 1 x 8 VP dipole array, 1 x 9 HP dipole array 강한 결합 배열안테나의 성능 특성
- VSWR < 2 기준으로 1 – 2.83 GHz 대역 확보
- 30° 조향시 1.16 – 2.57 GHz 대역 확보
- Broadside radiation 효율 > 81 %
- 30° 조향시 효율 > 70 % 유지

안테나 방사패턴


Horizontal polarization
Vertical polarization
yz plane
xz plane
yz plane
xz plane
1 GHz
1.75 GHz
2.5 GHz
(dB)
Simulated (CoPol)
Measured (CoPol)
Simulated (XPol)
Measured (XPol)

Conclusion

- We proposed low-profile array antenna with the wide bandwidth and scan angle.
- One-dimensional TCDA can be implemented using meta-surface wall with ferrite sheet.

Goal

- ✓ BW 3.37 : 1 > 3 : 1
- ✓ Low profile (Total height) $1/12.6\lambda_{low} < 1/10\lambda_{low}$
- ✓ Scan angle ≤ ±45°
- ✓ Single layer PCB process

	Dimension (mm)	Bandwidth	Height (λ_{low})	Isolation (dB)	HPBW in yz plane (°)	Gain (dBi)	Array(scan angle)
This work	600 × 200	1 ~ 2.83 GHz (95.6%)	1 / 5	> 25	> 61	> 8.6	9-HP, 8-VP(30°)

Q & A

Reference

[1] S. S. Holland, D. H. Schaubert, and M. N. Vouvakis, “A 7-21 GHz dualpolarized planar ultraiwdeband modular antenna (PUMA) array,” *IEEE Trans. Antennas Propag.*, vol. 60, no. 10, pp. 4589–4660, Oct. 2012.

[2] J. P. Doane, K. Sertel, and J. L. Volakis, “A wideband, wide scanning tightly coupled dipole array with integrated balun (TCDA-IB),” *IEEE Trans. Antennas Propag.*, vol. 61, no. 11, pp. 4538–4548, Nov. 2013.

[3] W. F. Moulder, K. Sertel, and J. L. Volakis, “Ultrawideband superstrate-enhanced substrate-loaded array with integrated feed,” *IEEE Trans. Antennas Propag.*, vol. 61, no. 11, pp. 5802–5807, Nov. 2013.

[4] M. Novak and J. L. Volakis, “Ultrawideband antennas for multiband satellite communications at UHF–Ku frequencies,” *IEEE Trans. Antennas Propag.*, vol. 63, no. 4, pp. 1334–1341, Apr. 2015.

[5] D. K. Papantonis and J. L. Volakis, “Dual-Polarized Tightly Coupled Array With Substrate Loading,” *IEEE Antennas Wireless Propag. Lett.,* vol. 15, pp. 325–328, 2016.