메타재질을 활용한 빔포밍 안테나 : GPS 안테나 사례

Metamaterial-Based Beamforming Antennas ‘GPS Array Antennas’

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Agenda

1. Background
2. Introduction
3. Design & Realization
4. Conclusion

An array antenna can steer the beam!

Arrays can keep up with reflector antennas w.r.t. high directive beam?
Background

- Many parts of local and global infrastructures are indebted to GPS.
- Security, safety, traffic, etc are heavily relying on GPS.
- GPS disruptions have occurred lately, and the air-traffic control affected by the Jamming was panicking.
Background

- Anti-Jamming devices and systems have been set up.

- Would-be victims should be protected by the anti-jammer or agile enough to avoid the attack.
Background

- How to enable the GPS antenna to be adaptive on the changing environment.

- Instead of the multiple antennas which are not aimed at far-field pattern creation, what about providing the beamforming scheme for agility?

기존의 GPS 다중 안테나
배열 안테나가 아니므로, 교란신호 피할 수 없다

배열 안테나화 : 교란신호 회피
빔을 형성하고 음직임

안테나 송수신부
Introduction

GPS Anti-Jamming System requires

Beam-forming and control unit:
- Detecting and recognizing Jamming (Power level surge, Signal degradation)
- Calculating the angle of arrival
- Beamforming with an array antenna
  - Pointing
  - Nulling

범형성하면 교란신호 회피하는 방안 : (1) 주 빔을 다른 방향으로 --- Pointing!
(2) 교란신호 입력가에 Null로 대응
Introduction

What will be shared today is

The scope of the present work: Array function provided for the GPS (Finding the possible scenarios for Agility in GPS)

- Design of the element GPS
  - Return loss at L1-band, Broadside pattern
- Beamforming
  - Trying the 1D- and 2D-arrays
- Incorporating Metamterial schemes into the array
  - Reducing the loss such as power dissipation in the feed network
Array factor which will be multiplied by the far-field pattern of the element

\[ AF = \sum_{n=1}^{N} I_{1n} \left[ \sum_{m=1}^{M} I_{m1} e^{j(m-1)(kd_x \sin \phi \cos \beta_x)} \right] e^{j(n-1)(kd_y \sin \theta \sin \phi + \beta_x)} \]
Intro: Theoretical illustration

Elements to an array

\[ AF = S_{xm} S_{yn} \]

\[ S_{xm} = \sum_{m=1}^{M} I_{m1} e^{j(m-1)(kd_x \sin \phi \cos + \beta_x)} \]

\[ S_{yn} = \sum_{n=1}^{N} I_{1n} e^{j(n-1)(kd_y \sin \phi \sin + \beta_x)} \]

- It is indicates that the pattern of a rectangular array is the product of the array factors of the array in the x- and y- directions.

- If the amplitude excitation coefficients of the elements of the array in the y-direction are proportional to those along the x, the amplitude of the \((m,n)\)th element can be written as

\[ I_{mn} = I_{m1} I_{n1} \]

- If \( I_{mn} = I_0 \)

\[ AF = I_0 \sum_{m=1}^{M} e^{j(m-1)(kd_x \sin \phi \cos + \beta_x)} \sum_{n=1}^{N} e^{j(n-1)(kd_y \sin \phi \sin + \beta_x)} : AF2D \]
Design(Basis) : Continued

Structure & functionalities

요소(동축 급전 패치)들을 2차원으로 배열한 형태

(1,1)  (1,2)  (1,3)  (1,4)
(2,1)  (2,2)  (2,3)  (2,4)
(3,1)  (3,2)  (3,3)  (3,4)
(4,1)  (4,2)  (4,3)  (4,4)
Design (Basis) : Continued

**Structure & functionalities**

(1,1) (1,2) (1,3) (1,4)
(2,1) (2,2) (2,3) (2,4)
(3,1) (3,2) (3,3) (3,4)
(4,1) (4,2) (4,3) (4,4)

- Progressive phasing
- De-activated

**Return loss**

**Axial ratio**

**Far-field pattern**

(peak gain : 8.26dBi)

배열을 1D 위상차 두기 : case 1

**Progressive phasing**

**De-activated**
Design(Basis) : Continued

Structure & functionalities

Progressive phasing

De-activated

배열을 1D 위상차 두기 : case 2

Return loss

Axial ratio

Far-field pattern
(Peak gain : 8.26dBi)
Design(Basis) : Continued

**Structure & functionalities**

Elements all in phase

Progressive Phasing 0, 즉 동위상

Return loss

Axial ratio

Far-field pattern

(Peak gain : 13.20dBi)
Design(Basis) : Continued

**Structure & functionalities**

- Progressive phasing
- Progressive Phasing after 1 period

**Graphs and Data**

- Return loss
- Axial ratio
- Far-field pattern
  - Peak gain: 13.20dBi

Reference:
- XYZ-coordinates (Global view)
- Main-beam (Local view)
Realization

Gain 14 dBi
Tot. effic : 50.2%(FR4 사용)
Realization: Metamaterial phase-shifter

CRLH 전송선로 모델

Schematic of a CRLH Phase-shifter

Example phases by the CRLH Phase-shifter

Patches are excited by the phase-shifted feed
Realization: Metamaterial phase-shifter

Gain 12.5 dBi
Tot. effic: 58.7%
Conclusion

• Looking back on the aftermath of GPS Jamming and the current technical trend to take steps on it

• The expected roles of the GPS antenna are described to avoid the Jamming.

• The scenarios and technical implementation of beamforming to dodge the jamming have been made.
Conclusion (continued)

• When the array meets good phase-shifters (small and low-insertion loss) as in the metamaterial CRLH components, the overall antenna system will be definitely enhanced over the conventional or expensive array antennas!
THANK YOU