A 60-GHz 4th Subharmonic Phase-Conjugated Retrodirective Array

Ji-Yong Park and Tatsuo Itoh

Electrical Engineering Department
University of California, Los Angeles

University of California, Los Angeles

Outline

- **Motivation**

- **Introduction**

- **4th Subharmonic Phase Conjugation Mixer**

- **Planar Active Retrodirective Array at 60 GHz**

- **Results**

- **Conclusions**

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Motivation

- **Millimeter-wave bands**
  - Lower microwave bands saturation
  - Multimedia digital data rates requirement

- **Advantages**
  - Compact and light weight circuit implementation
  - Larger spectrum availability and broad-band capability

- **Higher frequency**
  - Low loss and high power-efficiency necessary
  - Careful device model and CAD needed

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Introduction

- **Retrodirective Array**

  - Able to automatically retransmit incoming signal

  - Automatic target tracking
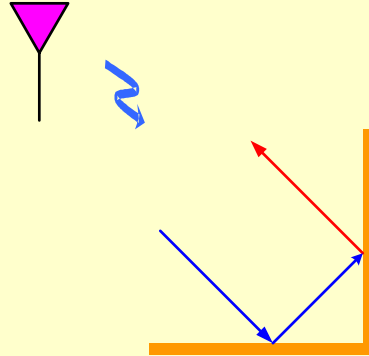
  - Accomplished using purely analog processing

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Retrodirective Phenomena
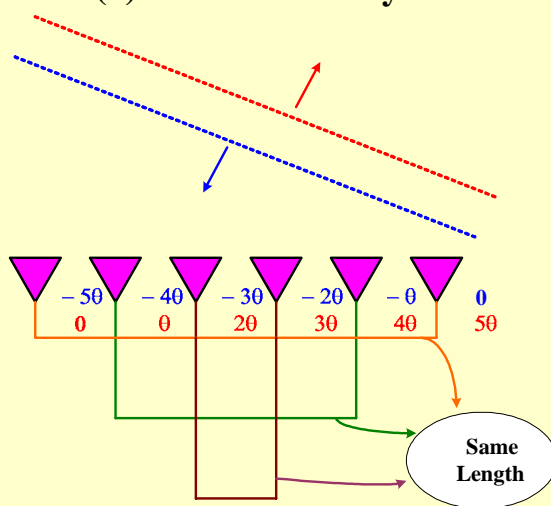
(1) Corner Reflector

Source

Reflector

Retrodirective Phenomena

(2) Van Atta Array

-5θ -4θ -3θ -2θ $-\theta$ 0

0 θ 2θ 3θ 4θ 5θ

Same Length

Phase Conjugation

Tx Array

$e^{+jnkdcos\theta_0}$

θ_0

Rx Array

$e^{-jnkdcos\theta_0}$

1

1

Retrodirective Phenomena

(3) Phase Conjugation Mixer

ω_{RF}, θ_{RF}

ω_{IF}

$\omega_{LO} = 2\omega_{RF}$

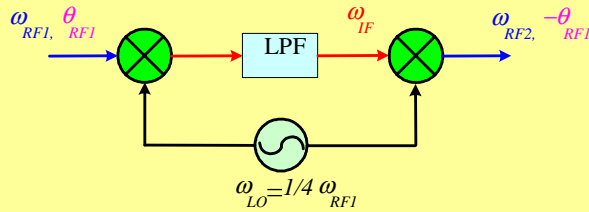$$V_{IF} = V_{RF}\cos(\omega_{RF}t + \theta_{RF}) \times V_{LO}\cos(\omega_{LO}t)$$

$$= \frac{1}{2}V_{RF}V_{LO}\left[\cos((\omega_{LO} - \omega_{RF})t \boxed{-\theta_{RF}}) + \cos((\omega_{LO} + \omega_{RF})t + \theta_{RF})\right]$$

Phase Conjugation

4th Subharmonic Phase Conjugation

$$\omega_{RF1,}\; \theta_{RF1} \qquad \omega_{IF} \qquad \omega_{RF2,}\; -\theta_{RF1}$$

LPF

$$\omega_{LO} = 1/4\; \omega_{RF1}$$

$$V_{IF} = V_{RF1}\cos(\omega_{RF1}t + \theta_{RF1}) \times V_{LO}\cos(\omega_{LO}t)$$

$$= \frac{1}{2}V_{RF1}V_{LO}\left[\cos((\omega_{LO} - \omega_{RF1})t - \theta_{RF1}) + \cos((\omega_{LO} + \omega_{RF1})t + \theta_{RF1})\right]$$

$$V_{RF2} = \frac{1}{2}V_{RF1}V_{LO}(\cos((\omega_{LO} - \omega_{RF1})t - \theta_{RF1})) \times V_{LO}\cos(\omega_{LO}t)$$
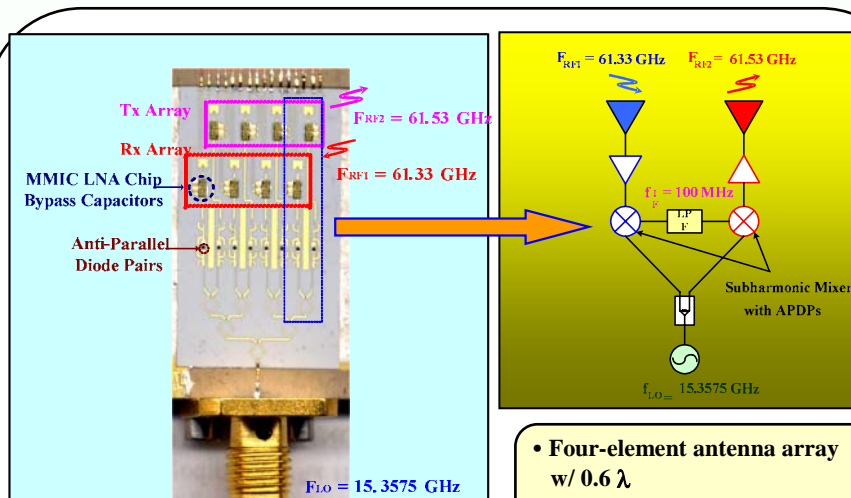
$$= \frac{1}{4}V_{RF1}{V_{LO}}^2\left[\cos((\omega_{LO} + \omega_{IF})t - \theta_{RF1}) + \cos((\omega_{RF1})t - \theta_{RF1})\right]$$

Phase Conjugation

4th Suuharmonic Phase-Conjugated RetrodirectiveArray

Tx Array

Rx Array

F_{RF2} = 61.53 GHz

F_{RF1} = 61.33 GHz

MMIC LNA Chip
Bypass Capacitors

Anti-Parallel
Diode Pairs

F_{LO} = 15. 3575 GHz

• Circuit size : $15 \times 25\; mm^2$

F_{RF1} = 61.33 GHz F_{RF2} = 61.53 GHz

f_1 = 100 MHz

LPF

Subharmonic Mixers
with APDPs

$f_{LO=}$ 15.3575 GHz

• Four-element antenna array
   w/ 0.6 λ
• Subharmonic mixer w/ APDP
• Substrate : ε_r = 9.8, h = 5 mils

4th Suuharmonic Phase-Conjugated RetrodirectiveArray

Bias Circuits

RCS Measurements
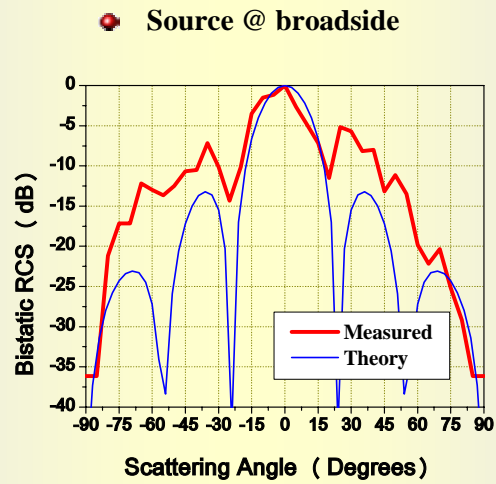

▪ **Monostatic**   ▪ **Bistatic**

Monostatic RCS

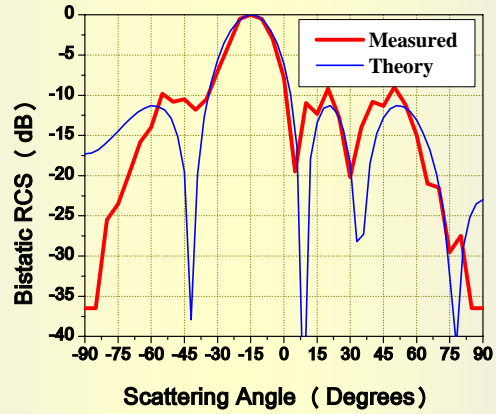University of California, Los Angeles

Bistatic RCS

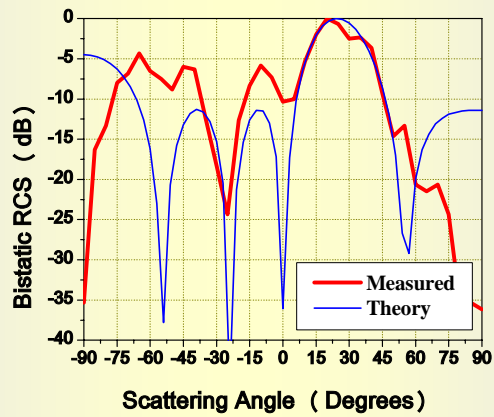
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7

Bistatic RCS

Source @ $\theta = -15°$

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Bistatic RCS

Source @ $\theta = 25°$

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8

Conclusions

- **A planar retrodirective array with 4th subharmonic phase conjugation mixer**

- **Useful not to use expensive millimeter-wave LO**

- **Monostatic and bistatic RCS measured**

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