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

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Outline

- **Motivation**
- **Introduction**
- **4th Subharmonic Phase Conjugation Mixer**
- **Planar Active Retrodirective Array at 60 GHz**
- **Results**
- **Conclusions**

Motivation

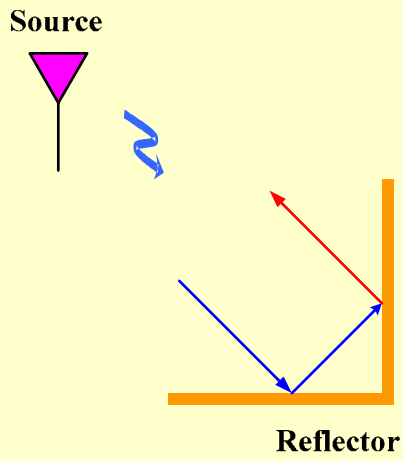
- **Millimeter-wave bands**
  - Lower microwave bands saturation
  - Multimedia digital data rates requirement
- **Advantages**
  - Compact and light weight circuit implementation
  - Larger spectrum availability and broad-band capability
- **Higher frequency**
  - Low loss and high power-efficiency necessary
  - Careful device model and CAD needed

Introduction

- **Retrodirective Array**
  - Able to automatically retransmit incoming signal
  - Automatic target tracking
  - Accomplished using purely analog processing

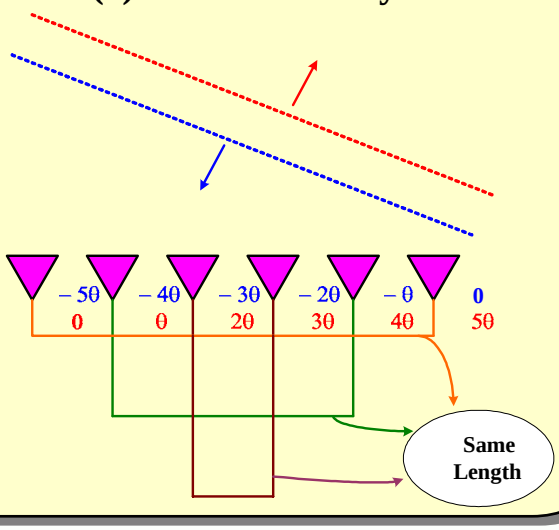
Retrodirective Phenomena

(1) Corner Reflector

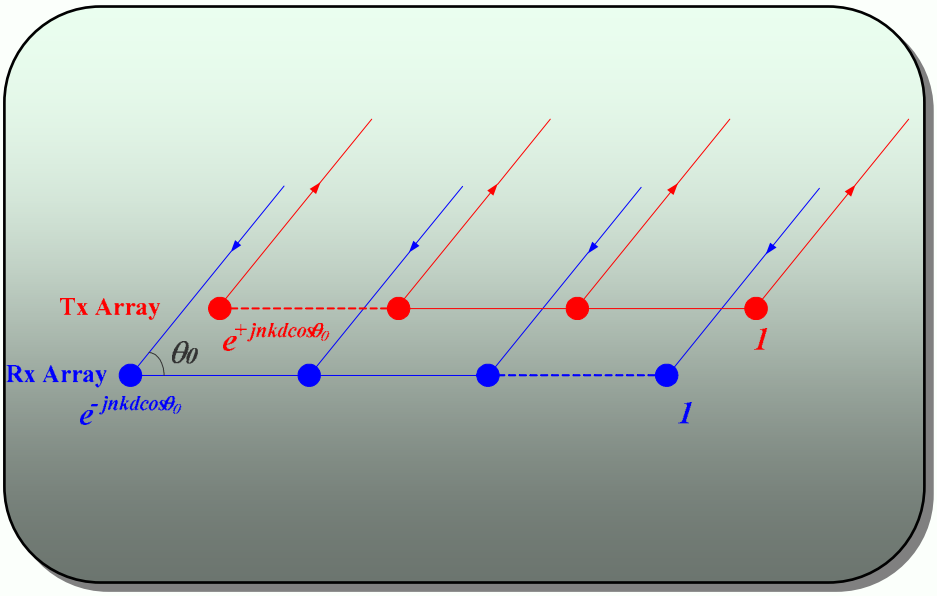


Retrodirective Phenomena

(2) Van Atta Array

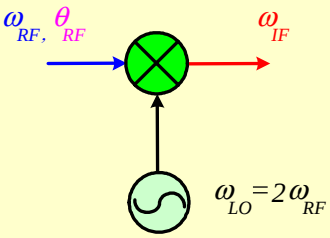


Phase Conjugation



Retrodirective Phenomena

(3) Phase Conjugation Mixer

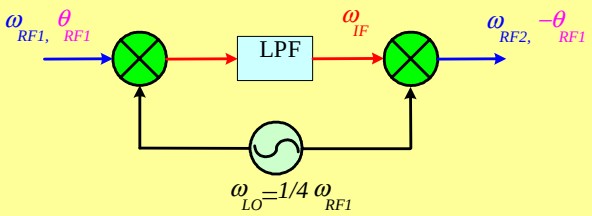


$$V_{IF} = V_{RF}\cos(\omega_{RF}t + \theta_{RF}) \times V_{LO}\cos(\omega_{LO}t)$$

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

Phase Conjugation

4th Subharmonic Phase Conjugation



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

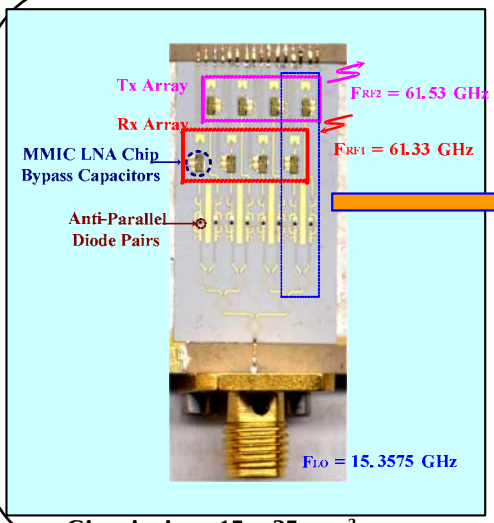
$$= \frac{1}{2}V_{RF1}V_{LO}\left[\cos((\omega_{LO} - \omega_{RF1})t - \theta_{RF1}) + \cos((\omega_{LO} + \omega_{RF1})t + \theta_{RF1})\right]$$

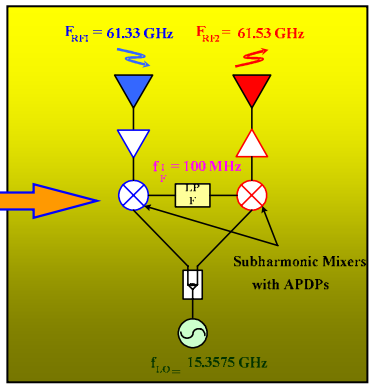
$$V_{RF2} = \frac{1}{2}V_{RF1}V_{LO}(\cos((\omega_{LO} - \omega_{RF1})t - \theta_{RF1})) \times V_{LO}\cos(\omega_{LO}t)$$

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

Phase Conjugation

4th Suuharmonic Phase-Conjugated RetrodirectiveArray

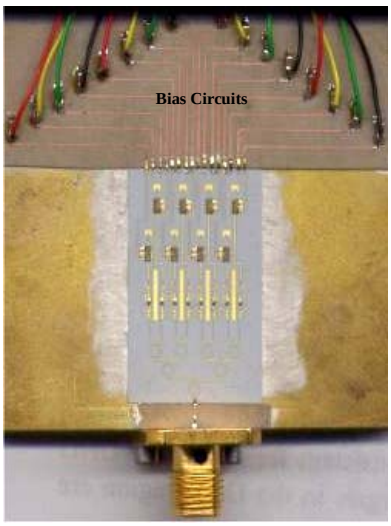




- **Four-element antenna array w/ 0.6 λ**
- **Subharmonic mixer w/ APDP**
- **Substrate : ε_r = 9.8, h = 5 mils**

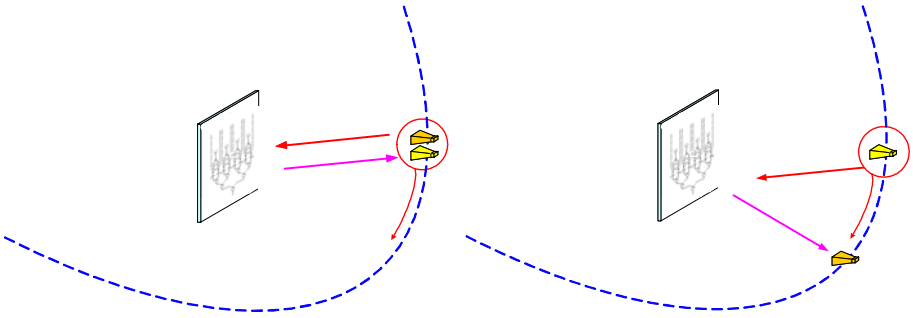
- **Circuit size : 15 × 25 *mm*^{2}**

4th Suuharmonic Phase-Conjugated RetrodirectiveArray

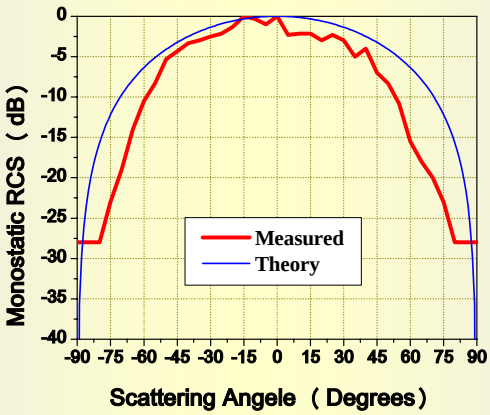


RCS Measurements

- **Monostatic**
- **Bistatic**

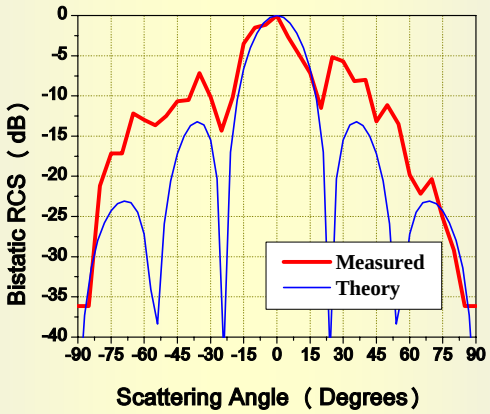


Monostatic RCS



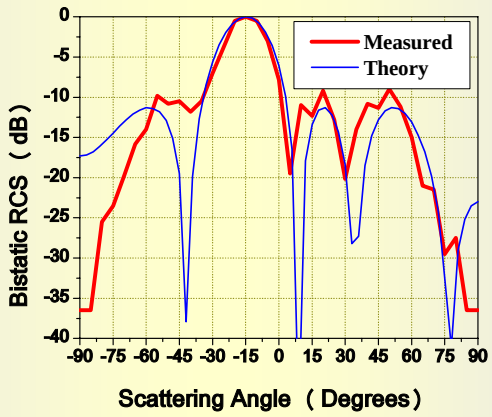
Bistatic RCS

- Source @ broadside



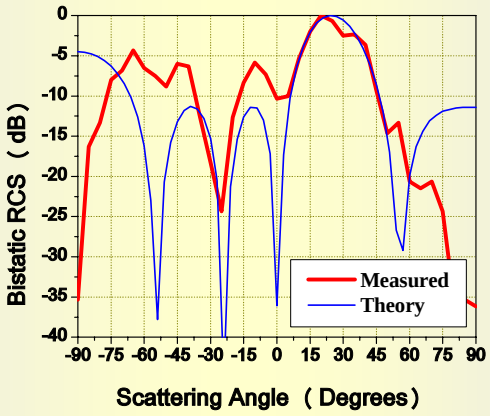
Bistatic RCS

- Source @ $\theta = -15°$



Bistatic RCS

- Source @ $\theta = 25°$



Conclusions

- **A planar retrodirective array with 4th subharmonic phase conjugation mixer**
- **Useful not to use expensive millimeter-wave LO**
- **Monostatic and bistatic RCS measured**