Full Duplex Retrodirective Array using Mutually Exclusive Uplink and Downlink Modulation Schemes

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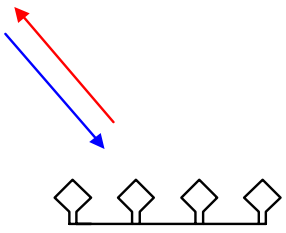
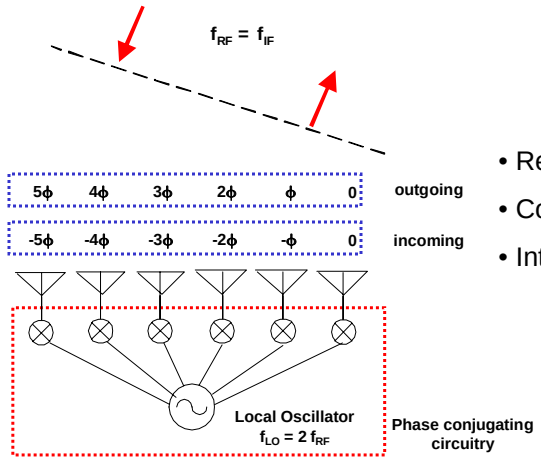
Retrodirective Arrays



- Able to automatically transmit a signal response to the interrogation direction without any previous knowledge of the source direction
- Automatic target tracking
- Accomplished using purely analog processing

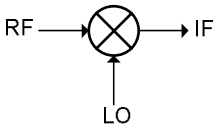
Retrodirective Array Using Phase Conjugation Technique



$$f_{LO} = 2 f_{RF}$$

- Recovered Wavefront
- Conformal Array Possible
- Integration of Other Functions

Phase Conjugating Operation



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

LSB

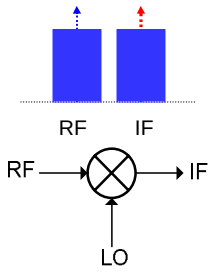
$$\omega_{LO} = 2\omega_{RF}$$

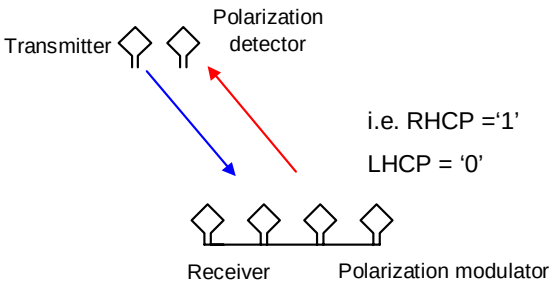
$$\cos(\omega_{RF}t - \theta_{RF})$$

Phase conjugation

Full Duplex Communication using Time and Polarization Modulation

- Received information contained in time domain (AM, BPSK, etc.)
- Retrodirected information contained in polarization
- Limited for line of sight use due to scattering effect on polarization

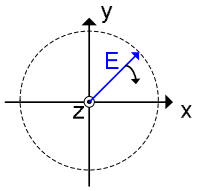




Circular Polarization

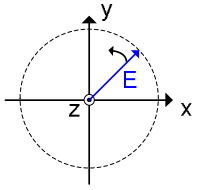
Right-hand CP: $\tilde{E}(z) = \frac{E_o}{\sqrt{2}}(\hat{x} + \hat{y}e^{j90^\circ})e^{+jkz}$

(-z traveling wave)

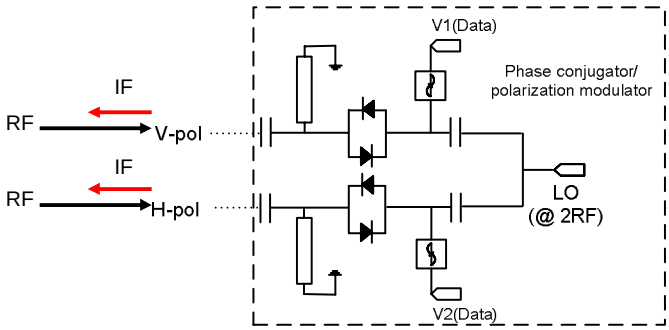


Left-hand CP: $\tilde{E}(z) = \frac{E_o}{\sqrt{2}}(\hat{x} + \hat{y}e^{-j90^\circ})e^{+jkz}$

(-z traveling wave)



Phase conjugation and polarization modulation mixer

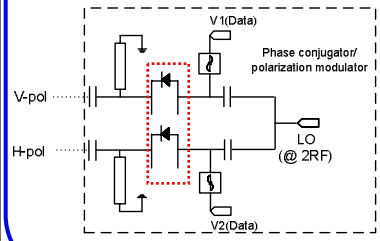


- **Shared RF/IF port**
- **LO=2RF, phase conjugation**
- **Mixer is connected to two ports of dual feed patch antenna**
- **Phase shift between V-pol and H-pol output controlled by V1 V2 pair**

Modulation States

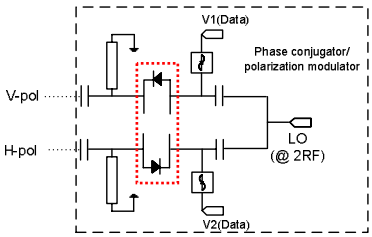
Case 1: V1=V2

(Co-directional Diode Current)



Case 2: V1=-V2

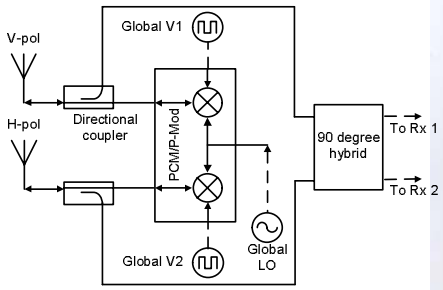
(Anti-directional Diode Current)



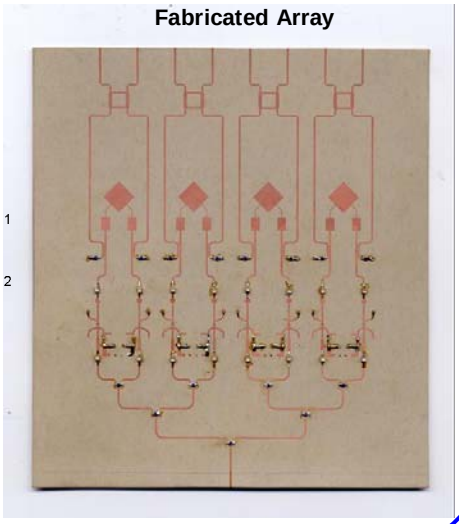
H_{in}	V_{in}	Pol-Sense$_{in}$	V(data)	H_{out}	V_{out}	Pol-Sense$_{out}$
0°	-90°	LHCP (-z prop)	V1=V2	0°	-(90)=+90°	LHCP (+z prop)
0°	-90°	LHCP (-z prop)	V1=-V2	0°	-(-90)-180=-90°	RHCP (+z prop)

Retrodirective Transceiver Array

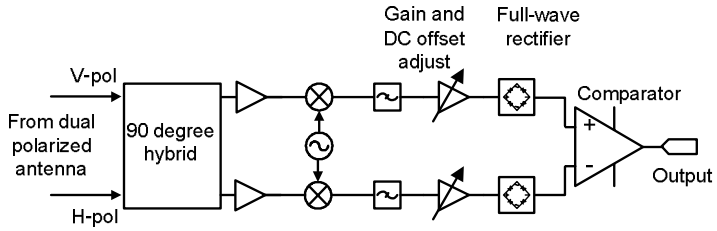
Schematic of single element of array



Fabricated Array

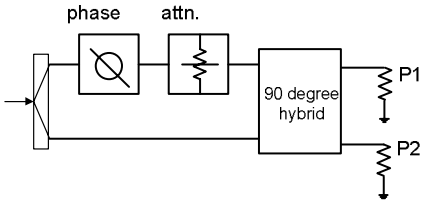


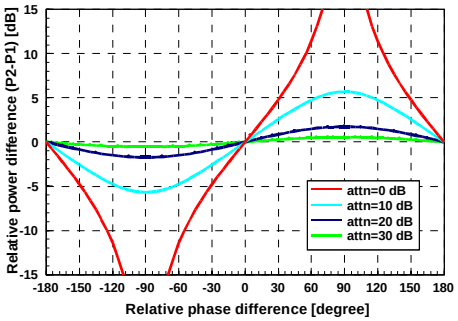
Polarization Detector



- **Polarization sense by comparing the power of the two branches of hybrid coupler**
- **E.g. $P_{branch1} > P_{branch2}$ ⇒ LHCP '0' $P_{branch1} < P_{branch2}$ ⇒ RHCP '1'**
- **Sensitive to circuit imbalance and DC offsets**

Polarization Detector Tolerance

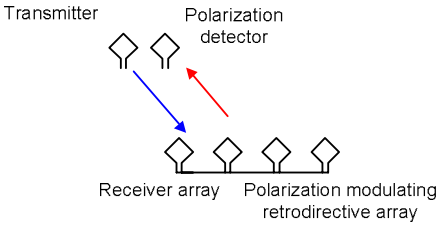




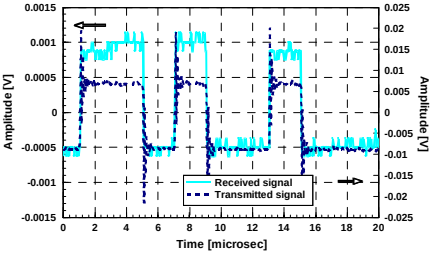
- **Relative amplitude and phase used to determine tilt, sense, axial ratio**
- **Detector functions even with elliptical polarization**
- **Polarization sense detector!**

CP: Phase =+/- 90 °, atten.= 0 dB

Measurement of Full Duplex Link

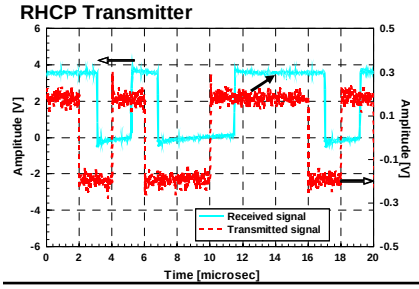


Received signal at receiver array (transmitted by transmitter-time domain)

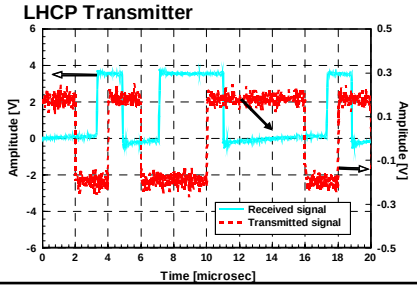


Recovered polarization modulation data

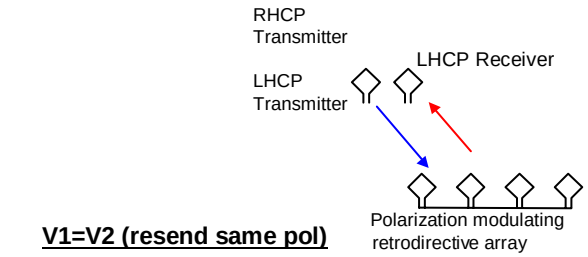
RHCP Transmitter



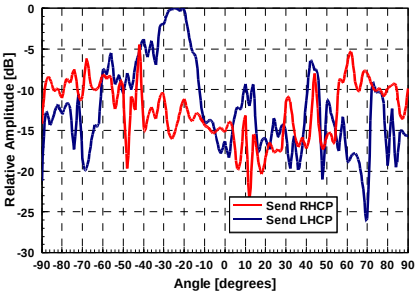
LHCP Transmitter



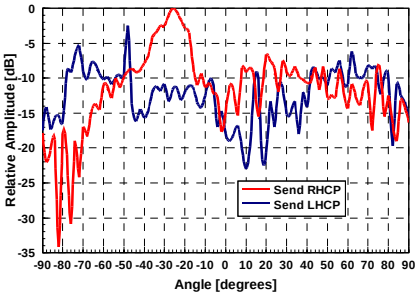
Bi-Static RCS Measurement



V1=V2 (resend same pol)



V1=-V2 (resend opp. pol)



Conclusions

- Downlink data time domain encoded
- Uplink data encoded in polarization of retrodirected return signal
- Phase conjugator/Polarization modulator presented
- Full duplex operation demonstrated