Self-Steering Antenna Arrays for Distributed Picosatellite Networks

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Motivation

Distributed Small-Satellite Networks
- Flexible, reconfigurable, and adaptive to changing missions
- Less susceptible to single-point failures or attack
- Replacements are more economical
Omnidirectional Crosslinks

Spy

Satellite 1

Satellite 2

Satellite 3
**Self-Steering Crosslinks**

**Proposed Solution:**

*Self-steering antennas* that maintain a secure crosslink as satellites move about in the network.

Secure link can be maintained without any a priori knowledge of interrogator and transponder location.
Simple Retrodirective Arrays

**Corner Reflector**
- Simplest form of retrodirective array
- Signal is passively reflected
- No modulation possible

**Van Atta Array**
- Element connections passively flip the phase of the incoming signal to achieve retrodirectivity
Signal is received at individual antennas at different phases depending upon the incoming beam direction.

Received signal is phase conjugated at each element and re-transmitted.

This produces a beam in the direction of the incoming signal.

Modulation possible through LO signal.

Ideal for secure satellite crosslinks.

\[ V_{RF} = V_{RF} \cos(\omega_{RF}t + \theta_n) \times V_{LO} \cos(\omega_{LO}t) \]

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

\[ \omega_{LO} = 2\omega_{RF} \]

**Phase-Conjugating Array**

- Ideal for secure satellite crosslinks
Mission: To investigate the applicability of retrodirective antenna array technology for satellite-to-satellite communication within a distributed small-satellite network

Method: Compare the performance of a retrodirective antenna array to a conventional fixed-beam antenna array
1-D Array Prototype

- Frequency: 10.5GHz
- 1x4 array
- Components:
  - 1x4 circularly polarized array
  - Passive mixer
  - Power divider optimized for 21GHz
  - LO – Frequency generator (external)

Local Oscillator: \( f_{LO} = 2f_{RF} \)
Bistatic RCS Results

Source

Retro Bi-static at 0 Degrees

Retro Bi-static at -20 Degrees

Retro Bi-static at +20 Degrees

Receiver

Source

Retrodirective Array

\[ \theta = 0^\circ \]

\[ \theta = -60^\circ \]

\[ \theta = +60^\circ \]
Conclusions and Future Work

• Proposed retrodirective antenna arrays for self-steering, secure crosslinks for distributed picosatellite applications
• Demonstrated a 1-D prototype
• Future work: demonstrate 2-D prototype