ARTEMIS:
An Enabling Technology for Long Range or High Data Rate Microspacecraft Communications

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Ground Stations Arrays for Improved Microspacecraft Communications

- Effective improvement without incurring dramatic price increases while allowing for large aperture areas - costs scale linearly for increasing effective aperture
- Can retrofit existing assets or develop low-cost new assets
- Enables higher data rate microsatellite LEO missions (1 Mbps or more) and interplanetary microspacecraft missions
- Most flexible array design: downconvert each antenna signal to baseband, transmit to a central site, and use time correlation to align the signals in phase and time (this method is used by the DSN)

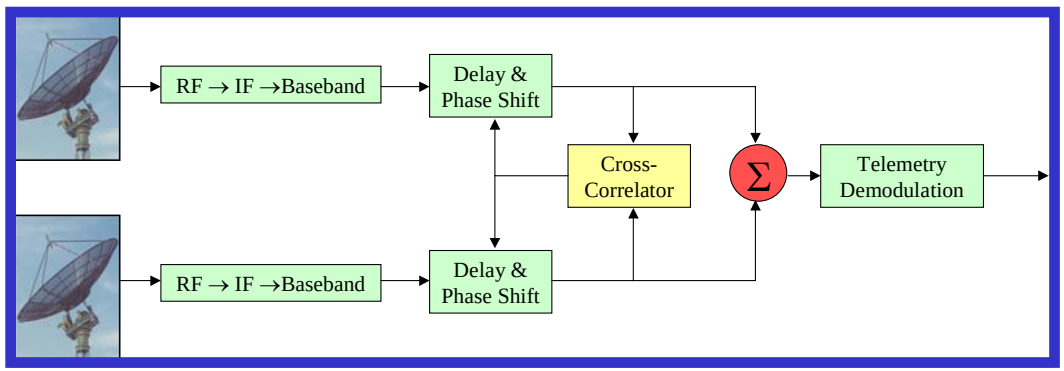
Frequency Offsets in Array

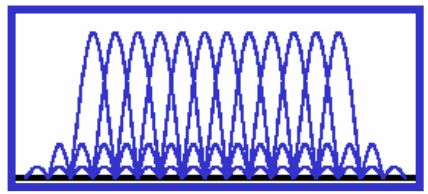
- Frequency offsets between the various local oscillators of each antenna in the array and the microspacecraft, as well as errors in Doppler shift correction must be dealt with
  - DSN uses hydrogen masers as frequency sources to give high frequency accuracy to avoid these error - expensive and difficult to obtain for general use

- SFL developed a software solution to the problem that can be used with any ground station equipment - frequency correlation

Low-Cost Alternative: ARTEMIS

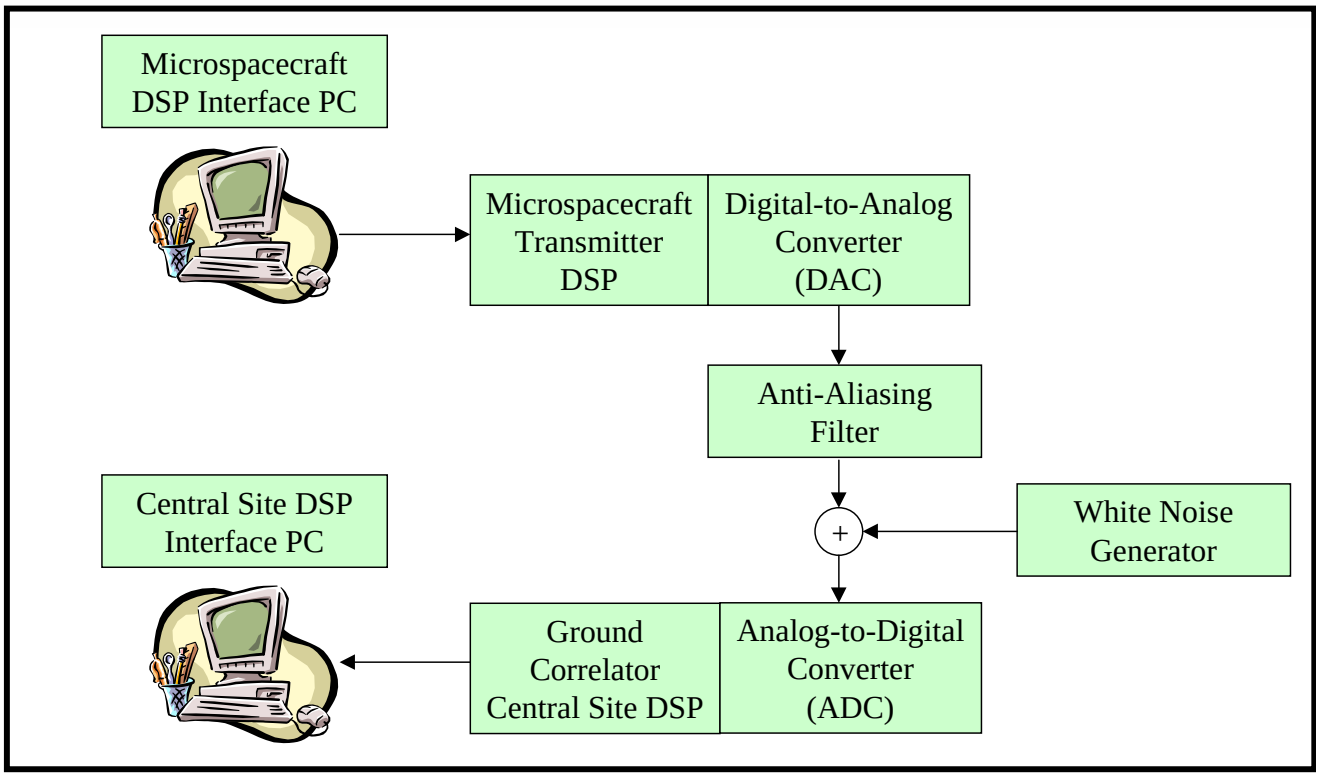
- ARraying Techniques for Enhanced Multiplexing of Interferometric Signals
- Uses both Time Domain and Frequency Domain Correlation to replace hardware requirements with software solutions





Low-Cost Ground Equipment + Time Correlation (DSN: Full Spectrum Combining) + Frequency Correlation (Orthogonal Frequency Division Multiplexing)

ARTEMIS Proof-of-Concept Hardware Apparatus



IF Wired Link Between Transmitter and Receiver/ Ground Correlator

(digital upconversion to IF of up to 38.4 kHz)

- Transmitter and Receiver / Ground Correlator are TI floating-point DSPs (optimized for I/FFT function)

ARTEMIS Frequency Correlation Experiments

- Example experiment:
  - No. OFDM channels vs. receiver SNR
    - Correlation will not function if digital signal SNR at any of the antennas in the array is too low (ie. the array will not function regardless of its size)
    - Adding more OFDM channels allows for frequency and time correlation to function for weaker signals.
  - Comparison to traditional "single-channel" transmission

Experimental Results

- Frequency correlation works down to -21 dB receiver SNR (at each antenna) with 4096 OFDM channels
  - Equivalent "single-channel" signal at best would work down to -15 to -18 dB, and data rate has to be further reduced to get an equivalent frequency offset detection resolution as the OFDM signal
- This means that ARTEMIS will allow for higher downlink data rates on smaller array antenna assets using low-cost ground station equipment

ARTEMIS Applications

Microspacecraft Missions to the Moon & Mars

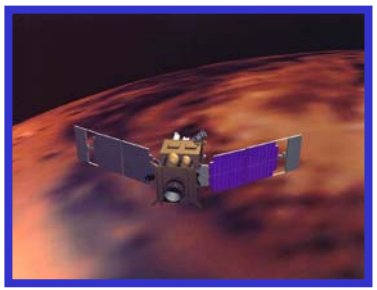
3 m Parabolic Antennas in Array

450 kbps data rate

6.1 m Parabolic Antennas in Array

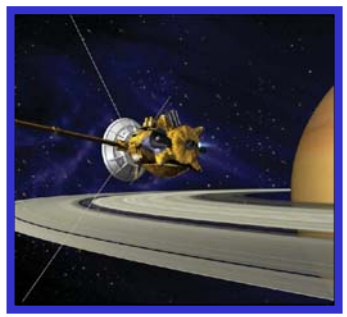
2 to 80 kbps data rate

Mars Global Surveyor



6.1 m Parabolic Antennas in Array

300 kbps data rate avg.
(DSN: 42 kbps avg.)



Cassini

6.1 m Parabolic Antennas in Array

60 kbps data rate avg.
(DSN: 16 kbps avg.)

Next Steps for ARTEMIS

- Additional memory for DSP to allow for more OFDM channels
- Addition of an RF link between the transmitter and multiple receivers, with the receivers connected to the central correlator via a wired digital data link
- LEO flight experiment on a future SFL mission
  - OFDM transceiver in orbit
  - ARTEMIS array with central correlator site on ground

Summary

- Deep Space Communications:
  ARTEMIS as a low-cost alternative to DSN
  - For new ground stations, can use low-cost RF equipment
  - Can create ad-hoc array with existing antenna infrastructure (large or small) using low-cost equipment.
- Microspace Applications of ARTEMIS
  - High data rate LEO missions
  - Greater range for Interplanetary Microsats
- LEO flight experiment on future SFL mission

Thank You

Partners

Sponsors

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Dr. Stephen Braham (UBC)

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