Wallops CubeSat-SmallSat Ground Stations and Frequency Standardization

Wallops UHF on left, S-Band on right

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Goddard Space Flight Center (GSFC) Wallops Flight Facility (WFF)

- GSFC is the largest combined organization of scientists and engineers in the United States dedicated to increasing knowledge of the Earth, the Solar System, and the Universe via observations from space
- Identify and aggressively pursue technology advancements that enable science breakthroughs

Wallops is a Part of Goddard

GSFC/Wallops Small Satellite Mission

Mission: GSFC/WFF enables new and exciting science, technology, and educational Small Satellite missions, by providing low-cost value- added services and technologies at the request of the Principal Investigator

GSFC/WFF Services and Facilities

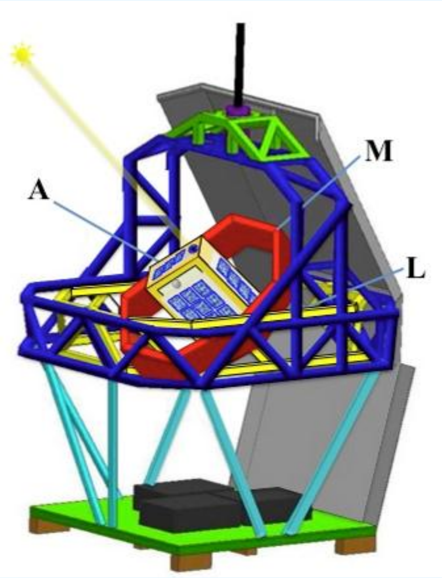
- Mission Planning
- Engineering
    - Mechanical
    - Thermal
    - Guidance, Navigation & Control
    - Command & Data Handling
    - Communication
    - Power
    - Systems
    - Propulsion
- Project Management
- Integration and Test
- Mission Operations
    - Frequency Policy
    - Communication Solutions
    - Groundstations
        - Range
        - Ground Network
- TRL Advancement on suborbital carriers
- Science Collaboration

GSFC/WFF Technologies

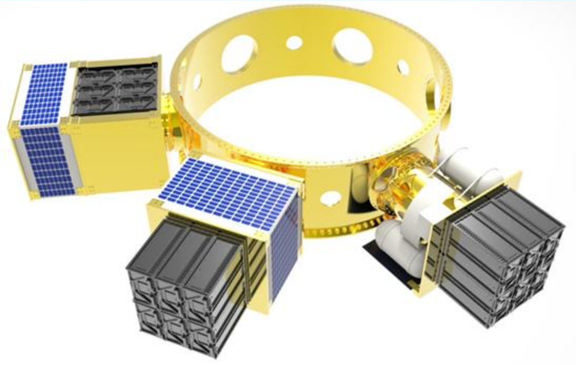
- Deployers
- Transporters
- Ground stations
- Tools/Processes
- Miniaturized Instruments
- Radios
- Attitude Determination and Control
- Antennas
- Propulsion
- Increased Reliability
- Command & Data Handling

Some Cool Technologies for Small Satellites

- Testing a CubeSat (A) on a balloon
  - Fraction of the cost of a satellite mission
  - Payload is recovered
  - Up to 120,000’ for hours/days
  - Wallops arc-second pointer (L) (WASP) successfully demonstrated pointing balloon-borne telescopes at inertial targets with arc-second accuracy
- Wallops Small Satellite Transporter
  - Mounts to an ESPA ring
  - Vehicle to transport small satellites, primarily CubeSats, to destinations currently not practical through means of standard delivery via ejection from launch vehicles
  - Removes propulsion burden from the small satellite and helps them retain the smaller form factor



6U CubeSat on a Balloon Gondola



Wallops Small Satellite Transporter Mounted to an ESPA Ring

Wallops /Morehead CubeSat Groundstation Network

- Wallops UHF Groundstation Specifications
  - Built 1959 by MIT Lincoln Labs
  - Valued at $20M
  - Beamwidth: 2.9 degrees
  - Frequency Range: 380 to 480 MHz
  - Frequency Band: UHF-Band
  - Secondary Frequency Band: X-Band available for future high data rate CubeSat communication
  - Antenna Main Beam Gain: 35 dBi
  - Diameter: 18.3 meters (60')
- Wallops UHF CubeSat Groundstation Use
  - Cutting-Edge CubeSat communication over a government-licensed UHF frequency allocation that enables high data rates (3.0 Mbit/Sec)
  - Currently communicating with DICE spacecraft
  - Slated for use for Firefly, MicroMAS, MiRaTA, CeREs and many proposed CubeSats
- Future Capability at Morehead State
  - NSF funding a backup UHF capability with around 37 dBi gain at UHF-band at Morehead State University using their 21 meter X, S-band dish.

Morehead State University 21 Meter antenna

Wallops UHF on left, S-Band on right

Wallops-Morehead Ground Network (NWMGN)

- Two large-aperture Earth Stations:
  - Wallops UHF Radar CubeSat Ground Station
  - Morehead State University 21-Meter Ground Station

- NWMGN can provide services to a wide variety of mission customers at multiple frequency bands through all phases of a mission's lifetime
  - Low-earth orbits (LEO)
  - Geosynchronous orbits (GEO)
  - Lagrange point orbits
  - Lunar
  - Inner solar system missions

- NWMGN services are contracted through the NASA Wallops Flight Facility

Morehead State University 21 Meter antenna

Wallops UHF on left, S-Band on right

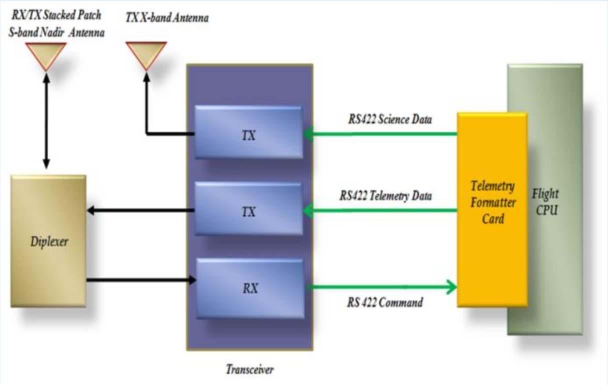
UHF for LunarCube Communication

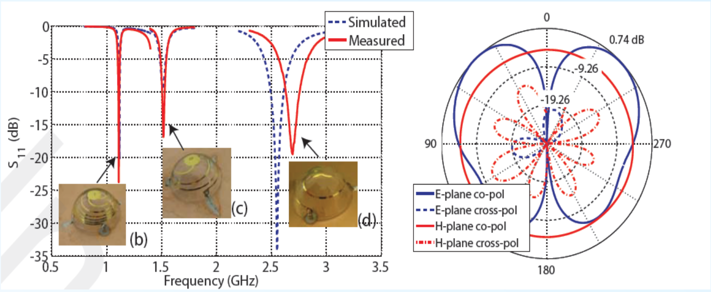
S/C Antenna	Data Rate Downlink-kbps
Low Gain Dipole(dBi)-Linear Polarization	1.5
Medium Gain(dBi)-Linear Polarization	6
High Gain Deployable(dBi)-Circular Polarization	50

- Uplink Data Rate is a function of the ground amplifier
  - 19.2 Kbits/sec Uplink with a 100W amplifier
- Downlink with a 2W satellite transmitter ranges from 1.5 to 50 Kbits/sec depending on the satellite antenna
- Calculation assumptions
  - Lunar Reconnaissance Orbiter (LRO) maximum slant range of 406,094 km
  - Wallops UHF CubeSat Groundstation G/T of 10.6 dB/K
  - L-3 Cadet UHF CubeSat Radio

Standardization of CubeSat Frequency Authorization and Recommendations

- Preparing a White Paper focused on establishment of a blanket authorization policy for allocating a band segment for Government CubeSats similar to that allocated to amateurs
- Precursor to advancing radios and antennas for CubeSats and small satellites
- Minimize the time required to obtain an authorization and to establish the availability of existing NASA ground resources for support of Government CubeSats
- Coordinating with NASA HQ SCaN Space Communications and Navigation (SCaN)
- X-band communication system is being considered to increase the data rate for CubeSats/small satellites
- In discussions with University of Colorado Laboratory for Atmospheric and Space Physics (LASP) regarding development of a X- band radio for CubeSats, small satellites, and sounding rockets
- Also in discussion with MSFC on a X-band radio can support up to 150 Mbps
- Working with University of Michigan and JEM engineering on CubeSat antennas





Transceiver Candidates

Board	TRL	Flight Heritage	Frequency Bands	Data Rate	Mass (g)	Output Power(watt)	Volume(cm^3)	Modulation/FEC
Tethers Unlimited	TRL5	No	S-band-2450MHz	400 kbps	380	1	10X10X3.5	BPSK/FEC can be added
MHX-2420	TRL9	RAX, DOVE	S-band	230 kbps Downlink/115 kbps Uplink	75	1	8.9X5.3X1.8	FSK/FSK
AstroDev Lithium Radio	TRL9	RAX, Firefly, CXBN, CSSWE, CINEMA	UHF S-band being developed	9.6 kbps, 38.4 kbps, 76.8 kbps	52	250 mW – 4 W	10X6.5X3.3	FSK/GMSK
L3 Cadet	TRL9	DICE, MicroMAS, MiRaTA, CeREs	UHF	24Mbps downlink/250 kbps uplink	215	2	6.9X6.9X1.3	OPSK/FSK,GMSK : TurboFEC/ConvolutionalCoding
	TRL4	No	S-band downlink/UHF uplink	24Mbps downlink/250 kbps uplink	215	2	6.9X6.9X1.3	OPSK/FSK,GMSK : TurboFEC/ConvolutionalCoding
Nimitz Radio	TRL3	No	S-band Downlink/UHF uplinlk	50 kbps/1Mbps	500	1	9X9.6X1.4	Uplink FSK, GFSK Downlink BPSK
MSFC	TRL 7	FASTSat2	S and X-band downlink/S-band Uplink	150 mbps/50kbps uplink	<1kg	2	10.8X10.8X7.6	BPSK/OQPSK - LDPC 7/8

NASA Ground Stations Options Exist in the Following Frequency Ranges and G/T performances

- X Band downlink via Ground Network and Poker Flat 8200-8500 MHz
  - G/T= 34.5 dB/K
- S Band via the ground network 2200-2400 MHz
  - Cost of using NASA's GN and "S" band may be prohibitive for low budget satellites
  - Wallops Range 2200-2400 MHz Downlink and 2025-2120 MHz uplink Range resources
  - G/T= 23 dB/K
- Upper S band 2700-2900MHz
  - Wallops SPANDAR S-band Radar dish
  - G/T= 29 dB/K
- UHF 380 to 480 MHz
  - Wallops UHF CubeSat groundstation
  - Morehead UHF, X, S – band CubeSat groundstation
  - Government Frequency licenses are secondary
  - G/T=10.6 dB/K

Interference Concern

- Prior to requesting a specific downlink frequency the spectrum must be monitored at that frequency at all the sites where that frequency is to be received to assure that no R.F. interference will exist within that bandwidth to be received and sufficient guard band exists from adjacent emissions

Additional Considerations and Recommendations

- Recommend avoiding the use of S band for SmallSat and CubeSat downlinks and instead designing to use the NASA Ground Network (GN) (X-band down, S-band up).
- NASA GN antennas provide S band command uplink and X band telemetry downlink support from the same antenna and provide existing world wide connectivity generally required for NASA missions
- NASA GN supports equatorial thru polar orbital inclinations
- Consideration should be given to development of a transponder for CubeSats capable of S band command reception and X band downlink telemetry at power levels needed to support anticipated link margins
- Recommended X band downlink modulation is OQPSK and uplink should be compatible with the NASA GN
- X band downlink use Low Density Parity Coding 7/8 and uplink should adapt standards compatible with NASA GN command modulation formats
- Standardized flight communications hardware should be developed and adapted to enable a one time NTIA Spectrum Certification for all Government funded CubeSat missions thereby eliminating the time required for the first step of the two-step process.
- The GN ground systems already have NTIA Spectrum Certification for the first step of the process.

Questions

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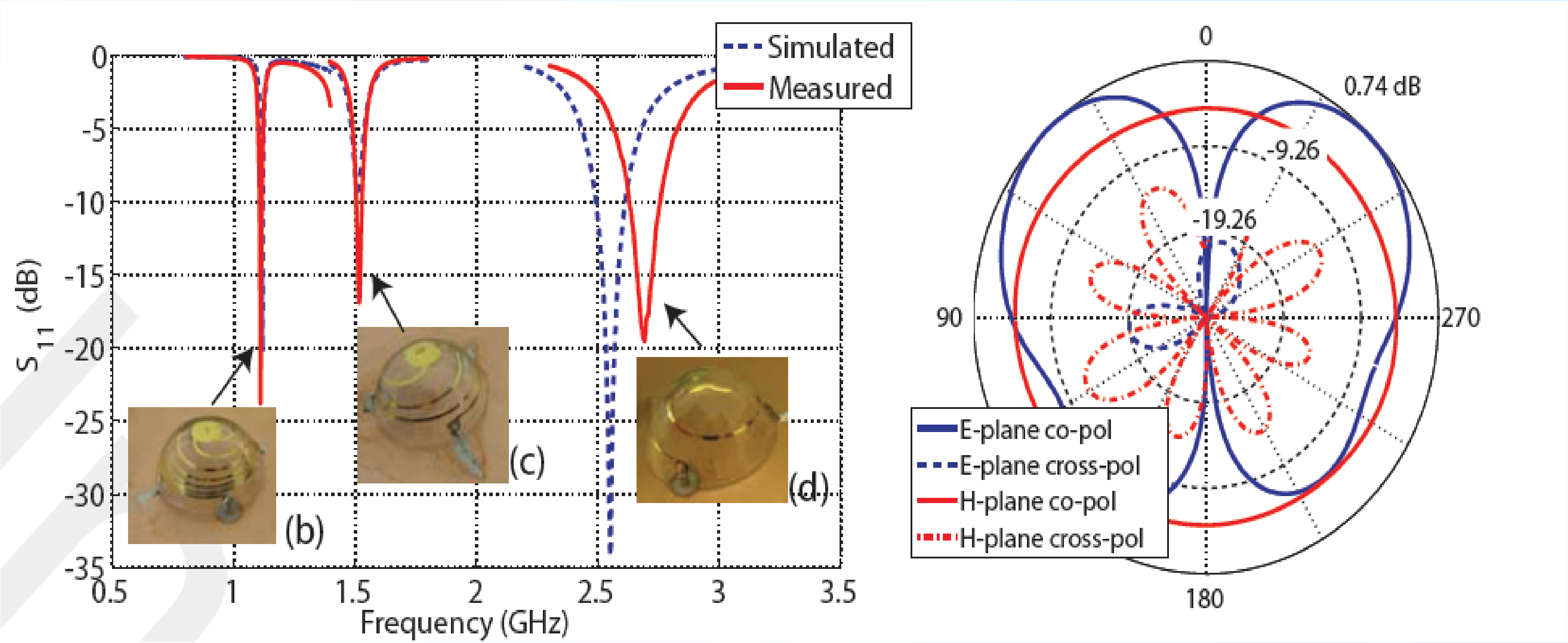
Backup

UHF-, S- and X-band Performance Comparison

- UHF – band : 10.6 dB/K
- S-Band: 23 dB/K
  - Delta : 12.4 dB/K versus UHF-band
- X-band: 34.5 dB/K-
  - Delta : 23.9 dB/K versus UHF, 11.5 dB/K versus S-band
- X-band antennas/communication systems are compact
- UHF-band has significant Interference
- Performance enhancement by utilizing higher gain compact X-band communication systems instead of UHF or S-band communication systems.
  - Using antennas gain delta 5-10 dB comparing UHF with X-band
- X-band systems can support 150 Mbps: FastSat2 and LCT2
- X-band communication system offers real science missions with Cube/Small Satellites
- However one should also consider increase in free space loss associated with higher frequencies

Collaborated with Univ. Of Mich. on on Electrically Small Printed Helical Antennas to compensate slant range differences



[1] C. Pfeiffer, A. Grbic, X. Xu, and S. R. Forrest, "New methods to analyze and fabricate electrically small antennas," in *Proc. IEEE Antennas Propag. Int. Symp., 2011, pp. 761–764.*