Tactically Extensible and Modular Communications – X-Band

TEMCOM-X

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Abstract

- This paper will discuss a CubeSat size (3U) telemetry system concept being developed at Marshall Space Flight Center (MSFC) in cooperation with the U.S. Department of the Army and Dynetics Corporation.

- This telemetry system incorporates efficient, high-bandwidth communications by developing flight-ready, low-cost, Proto-flight software defined radio (SDR) and Electronically Steerable Patch Array (ESPA) antenna subsystems for use on platforms as small as CubeSats and unmanned aircraft systems (UASs).

- Higher bandwidth capacity will enable high-volume, low error-rate data transfer to and from tactical forces or sensors operating in austere locations (e.g., direct imagery download, unattended ground sensor data exfiltration, interlink communications).
Introduction

- This paper provides information on the Marshall Space Flight Center (MSFC) SDR Low-Cost Transponder as well as the Army/Dynetics Electronically Steerable Phased Array - X-Band (ESPA-X)

- The SDR, called PULSAR – Programmable Ultra Lightweight System Adaptable Radio – as well as the ESPA-X can be incorporated into orbital and suborbital platforms.

- In doing so, Tactically Extensible and Modular Communications - X-Band (TEMCOM-X) will allow project/programs to perform remote commanding capabilities, as well as real-time payload(s) and science instruments telemetry.

- The leap ahead technology is the low-cost space / high-altitude qualified reconfigurable SDR transponder for simultaneous X-band transmit and receive communications at a minimum of 110 Mbps with very low bit error rates.
Technical approach

- The proposed TEMCOM-X Project leverages the lessons learned during the PULSAR telemetry system (First Generation) development, which used NASA funds from FY2012-13.

- The PULSAR base design has three to four selectable decks – power deck, processor deck, X-Band receiver deck, and X-Band telemetry transmitter deck. The application determines the configuration, thus the number of decks used.

- Exemplifying flexibility, PULSAR will transmit using Low Density Parity Check (LDPC, rate 7/8), Reed-Solomon (223/255), or convolutional (Rate ½) Forward Error Correction (FEC) based on mission requirements.

- The antenna array (front-end) will incorporate a planar design consisting of multiple board layers with integrated array circuitry to reduce the array depth.
The system contains sufficient RF link capacity to achieve the desired performance while maintaining the goal Bit Error Probability (BEP) assuming that the design goal gain (19.76dBi) can be met.

<table>
<thead>
<tr>
<th></th>
<th>Uplink</th>
<th>Downlink</th>
</tr>
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<tbody>
<tr>
<td>Frequency</td>
<td>8.2GHz</td>
<td>8.2GHz</td>
</tr>
<tr>
<td>$P_T$</td>
<td>50W</td>
<td>1W</td>
</tr>
<tr>
<td>$L_{C(T)}$</td>
<td>1dB</td>
<td>1dB</td>
</tr>
<tr>
<td>$G_T$</td>
<td>43.9dBi$^1$</td>
<td>19.76dBi$^2$</td>
</tr>
<tr>
<td>$L_P$</td>
<td>2448km$^3$</td>
<td>2448km$^3$</td>
</tr>
<tr>
<td>$L_M$</td>
<td>0dB</td>
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</tr>
<tr>
<td>$L_{Pol}$</td>
<td>0.25dB</td>
<td>0.25dB</td>
</tr>
<tr>
<td>$L_A$</td>
<td>1.0dB</td>
<td>1.0dB</td>
</tr>
<tr>
<td>$G/T$</td>
<td>-4.91dB/K$^4$</td>
<td>22.5dB/K$^1$</td>
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<tr>
<td>Data Rate</td>
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<tr>
<td>kB</td>
<td>-116.84dB</td>
<td>-116.84</td>
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<tr>
<td>SNR</td>
<td>22.08dB</td>
<td>8.35dB</td>
</tr>
<tr>
<td>Threshold</td>
<td>No FEC</td>
<td>FEC</td>
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<tr>
<td>Margin</td>
<td>+10.08dB</td>
<td>+3.35dB</td>
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</tbody>
</table>
Alignment

- NASA is called, at the direction of the President and Congress, to maintain an enterprise of technology that aligns with missions and contributes to the Nation’s innovative economy.

- NASA has been and should be at the forefront of scientific and technological innovation.

- In response to these calls, NASA generated a plan (NASA Strategic Space Technology Investment Plan) to advance technologies and nurture new innovation that will feed into future missions.

- PULSAR aligns primarily with the Technology Area (TA) 5 – Communication & Navigation – but has connections to other TAs in which lightweight structures, power efficiency, and communication reliability and throughput are the focus.
The current notional design of the espa-x includes a radiating element that is a circularly polarized patch antenna with +8dbi gain with a maximum 11 db return loss (1.78 vswr) in the band of interest.

The t/r module will transmit in horizontal polarization and receive in vertical.

The transmit chain is quite simple, with a phase shifter (nominal 7 db loss), an amplifier, and a harmonic reject filter (nominal 1.5 db loss).

The receive chain gain distribution assumes a 0.4 db loss through the patch antenna and a 1.2 db loss through the front-end bandpass filter.

The Ina’s noise figure of 0.6 db is sufficient to insure that the overall transmit chain’s noise figure will remain below the required 2.5 db.
Operational Scenario

- The operational scenario in the graphic shown in the Introduction depicts U.S. and partner nation (PN) small-unit forces operating beyond line-of-sight communications with their command center, and in close proximity to hostile forces.
Operational Scenario

- Encrypted voice between the small units and the command center;
- Relay of imagery, full-motion video (FMV), and other near-real-time data from airborne and orbital sensor platforms to the small units and the command center.
- Multiple beam-forming to provide simultaneous access to multiple locations;
- Provides high rate bandwidth for satellite interlink communications;
- Full duplex transmit and receive for maximizing communication opportunities.
Conclusion

- The TEMCOM X Project is currently in the late formulation stages and has been proposed for planned full implementation to develop and test a protoflight unit of the integrated PULSAR-X and ESPA-X technologies.

- TEMCOM-X leverages existing Marshall Space Flight Center SDR designs and commercially enhanced capabilities.

- Also, TEMCOM-X increases flexibility to implement multiple transponder types by utilizing the same hardware with altered logic – no hardware change required – all of which will eventually be accomplished in orbit.

- TEMCOM-X offers high capability, low cost, transponders to programs of all sizes. The final project outcome will be the introduction of a low-cost CubeSat to SmallSat telemetry system.

- The proposed TEMCOM-X Roadmap includes adaptation into options such as C-Band and Ka-Band. These technologies are planned for continued development.