NEW GENERATION OF COMMUNICATION AND RADAR TRANSCEIVERS FOR CUBESATS

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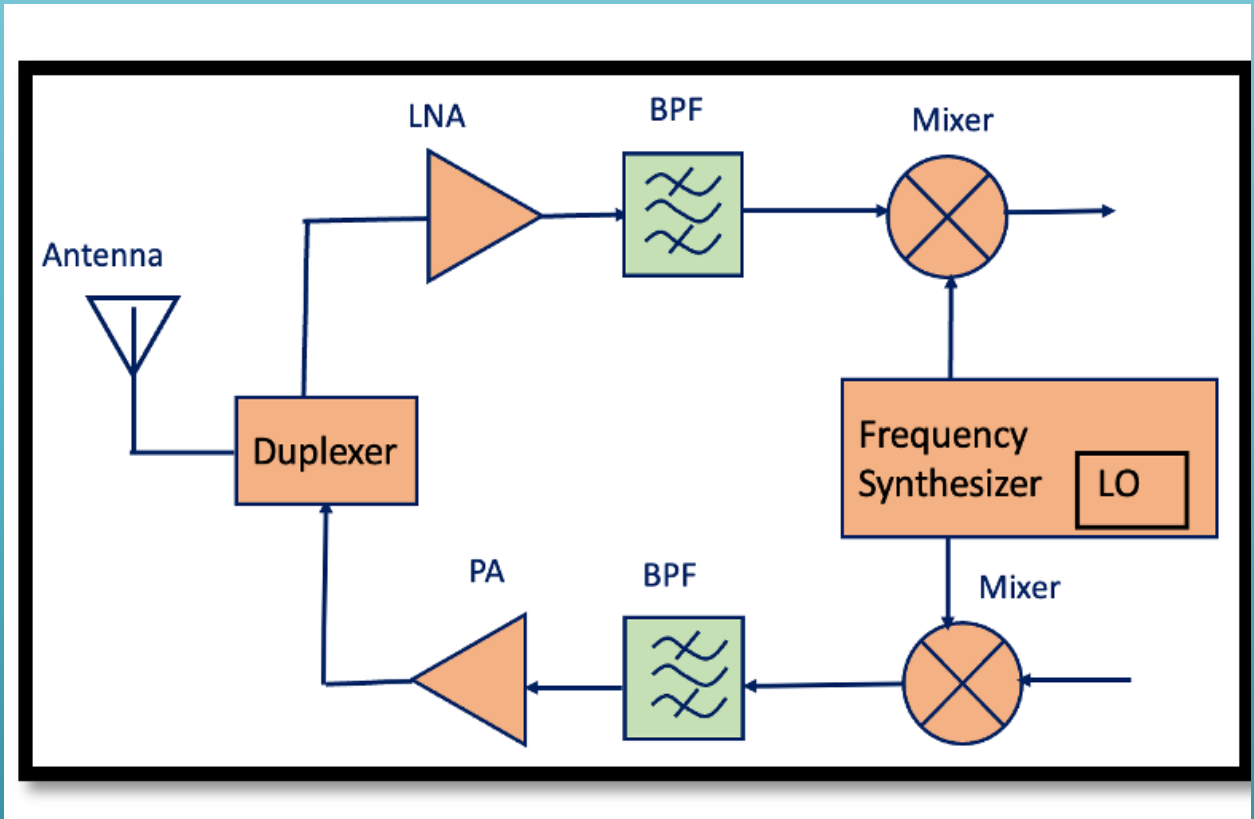
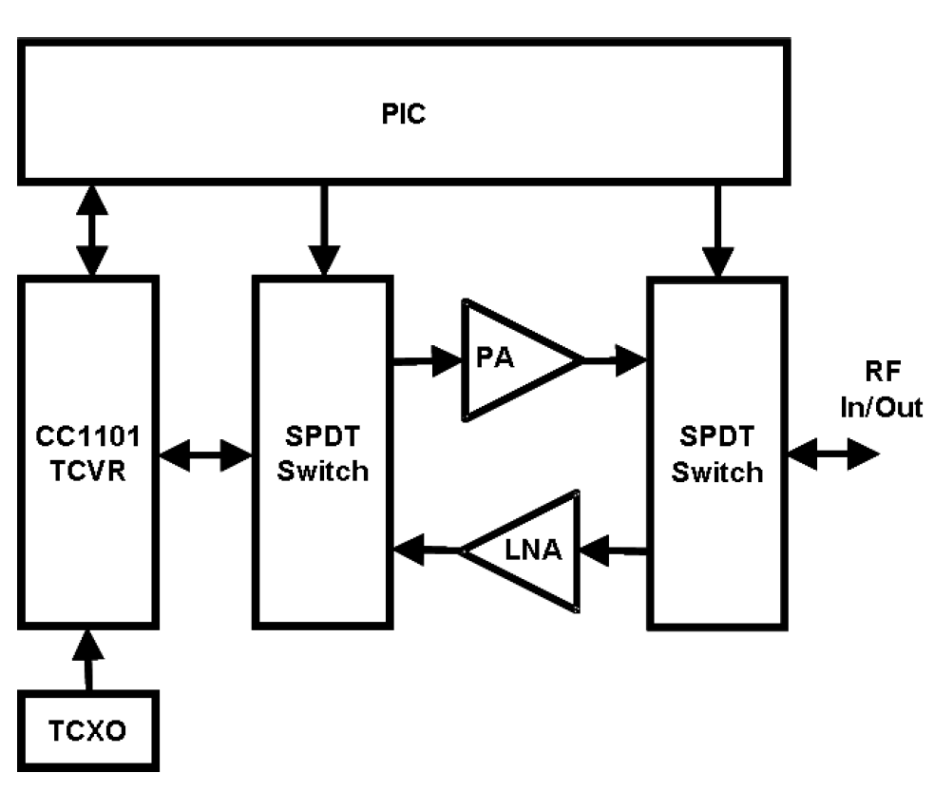
Presentation Overview

- Introduction and Motivation for Developing New Generation of Transceivers for CubeSats
- Prerequisites and Critical Requirements for CubeSat-based Transceivers
- Technologies and Electromagnetic Spectral Bands for Transceivers
- State-of-the Art and Commercially Available Products
- Advances- Recent and Future Projection
- Examples and Tradeoffs
- Conclusion

Transceiver Architectures





Introduction and Motivation for Developing A New Generation of Transceivers for CubeSats

- Higher Data Rate, Bandwidth Than Currently Available from Commercial Communication Links/Radios
- Reduced SWaP-C (Size, Weight, Power Consumption and Cost)
- Utilize Software Defined Radios where possible
- Performance (Linearity, Power Use, Efficiency, Reliability, ….)
- Commercial Availability as COTS Products

Prerequisites and Critical Requirements for CubeSat-based Transceivers

Low SWaP-C (Size, Weight, Power Consumption- and Cost)

- **Small and compact to fit CubeSat dimensions/form-factor**
- **Lightweight (< 0.5 kg for most applications)**
- **Highly efficient (>30% Power-Added Efficiency), Low Power Consumption**
- **Affordable as COTS items**

Performance and Operational Requirements

- **Availability for frequency bands from 8 to above 76 GHz**
- **Scalable transmitter power output levels (1 to 25^{+} Watts) and Data Rates**
- **Broadband and highly linear (handle very high data rates)**
- **Highly reliable in Space environment**

Design and Availability

- **Modular design with "standardized" modules,**
- **Mass-producible to meet market demands.**

Electromagnetic Spectral Bands For Space to Earth, Intersatellite Links and Radars/Sensors

Applications of CubeSat Transmitters

Communications
Data Transport
Inter-Satellite Links (ISL)
Sensor/Radar
Other emerging uses

Radar And Sensor Bands

S band (3.2 GHz)
L band (1.25 GHz)
X band (8-8.5 GHz)
Ka band (35-36 GHz)
V band (65-71 GHz)
W band (93-95 GHz)

Communication and Data Transport Bands

RF

- **VHF/UHF (30-1000 MHz)**

Microwave

- **S (2-2.5 GHz)**
- **X (7.1-8.5 GHz)**
- **Ku (12-16 GHz)**

Millimeter waves and Terahertz

- **K (17.2-21.2 GHz)**
- **Ka (25.5-27.5 GHz, 31-33 GHz), 35.5 GHz**
- **Q (37.5-42.5 GHz)**
- **E/V/W (71-76, 81-86 GHz)**
- **Terahertz (Between 100 and 1000^{+} GHz)**

Advances and Innovations In Technologies for CubeSat-based Transceivers

- Power Amplifiers- Gallium Nitride-based Power Amplifier Devices
- Additive Manufacturing Methods
- Surface-Mountable Components
- Thermal Management Methods and Implements
- Availability of COTS Components for Space Use
- “New Space” Design and Qualification Philosophy
- Growth in Supplier Base
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Gallium Nitride (GaN) Technology-based Power Amplifiers -Challenging Tube-based Amplifiers (TWTA)

Offer exceptional transmitter power and efficiency compared to other device technologies, thus reducing the size, mass and power consumption with reduced heat removal requirement.

Can reliably operate at higher device junction temperature >175 C

Typical devices can offer transmit power from a few Watts to more than 50 Watts, with Power-Added Efficiency from 20% to 50%

Advanced thermal design using innovative cooling techniques and materials

Unique products and/or methods have emerged with direct applicability to transceivers for CubeSats.

-Oscillating/Pulsating Heat Pipes,

-Synthetic Graphite, Carbon Nanofiber (Thermal Interface Materials)

-Novel Thermal Design of Printed Circuit Boards

These facilitate very efficient heat removal from power amplifiers within the transmitters and other active components in the Transceiver- resulting in significantly increased efficiency, output power and lifetime.

Advantages of Novel Thermal Management Technologies-

- Reduced Junction/Channel Temperature > Much Higher Performance and Longer Lifetime of Transmitters
- Light Weight and Smaller Size Compared to Traditional Cooling Methods
- Carriers and Substrates* with Excellent Match of Coefficient of Thermal Expansion AND Good Conductivity
- Printed Circuit Boards with Higher Circuit Density

Examples: Oscillating Heat Pipes, Heat Spreaders, Synthetic Graphite in PCBs, Fiber thermal Interface, Carbon nanotubes-based Thermal Interface Material, etc.

* **Mo12 to Mo52; Aluminum-diamond; Aluminum Silicon Carbide, Cu-diamond, Strain balanced structure-diamond; Silver-diamond; Cu-Moly**

Surface-Mountable Devices (SMD) for Printed Circuit Board-based Implementation

Recent Availability of High-Frequency Devices in SMD Package for Use in PC boards Leads to Compact, Low-Cost, Large-Scale Production of Transceivers Even at Higher Frequencies.

Multi-function SMD Packages Available for Microwave and Millimeter-wave Frequencies

Active Electronically Scanned Arrays (AESA) Realizable Using T/R Modules- Provide New Possibilities

Advances in Silicon RF Technologies, e.g., Germanium (SiGe), CMOS have the potential to revolutionize the CubeSat Transceiver designs and reduce their cost drastically

Additive Manufacturing (AM; 3-D Printing Technology) for Manufacturing Transmitter Structures

AM offers potential for producing RF modules for CubeSats at very low cost and high production rates with performance comparable to conventional structures

Structural Components and Heat Pipes are produced Using AM Methods

Many functions and structures already implemented using Additive Manufacturing

Examples- Antennas, Filters, Waveguide Structures, Power Combiners

Use of Commercial Off-The-Shelf (COTS) Components

Recent trends in extensive use of COTS parts for Space equipment has potential for dramatic reduction in cost and manufacturing time without appreciable impact on reliability or performance. COTS-based Subassemblies and Modules Now Available and Utilized in Transceivers

“New Space” Design and Implementation Philosophy Promotes the Use of Qualified COTS Parts where Appropriate for Application and Usage

Standardization and Modularity

The designers and manufacturers of these transceivers use formats that fully conform to established standards for CubeSats, thus permitting perfect integration with the satellite payload

Transmit/Receive (T/R) Modules Are Available for Realizing Beamforming and Steering Using AESA and Phased Array Configurations

Many Vendors and Commercial Suppliers Offer COTS Modules and Products for CubeSats with Competitive Prices and Rapid Delivery Worldwide

New Space's Qualification and Testing Philosophy

This approach eliminates formal qualification and detailed testing of custom transceivers by CubeSat integrators or users since the manufacturer carries this out

Derating Guidelines and Qualification Protocols have been formalized by Space Agencies and Other Space Standards Organizations

Conclusions

Thank you for your attention!

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