NuWaves Engineering RF Solutions for Unmanned Systems

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About NuWaves

- Veteran-owned small business
- Established Sept 2000
- 70 employees
- AS9100 & ISO 9001 Certified
- Located in Middletown, OH (north of Cincinnati)
- Core Competencies
  - Miniaturized RF/microwave design
  - Quick-Tempo Design Services Concept to Production
  - System Sustainment and Modernization

What We Do

- **RF / MW Design Services**
  - Complete RF / MW system, subsystem module design, production, test and qualification
  - Contract Manufacturing
  - Reverse Engineering
- **System Sustainment**
  - Life Cycle Support & Management
  - Depot Level Maintenance
  - Obsolescence Mitigation
- **COTS Products Solutions**
  - RF Power & Bidirectional Amplifiers
  - Low Noise Amplifiers
  - Frequency Converters
  - RF Filters
  - Transceivers
  - RF Front Ends
  - Cybersecurity HW

Markets & Applications

- Military Communications
- System Sustainment & Modernization
- Electronic Warfare
- Airborne / UAVs
- Ground and Shipboard
- Medical

RF & Microwave Power Amplifiers

NuPower™ family of solid-state power amplifiers combine broadband operation and power efficiency in the industry's smallest form factors. NuPower's attractive size, weight, and power (SWaP) profile makes it ideal for Group 2 - 5 UAS.

- Unidirectional and Bidirectional (Xtender™)
- 200 MHz to 5.85 GHz
- 5 to 100 Watts of RF output power
- DC power efficiencies 30-50%
- Ruggedized enclosures as small as 1.7 in.^{3}

Product Solutions

RF Upconverters
- Programmable IF & RF
- 2 to 70 MHz IF input
- 2 MHz to 3 GHz RF output

RF Downconverters
- Programmable from 200 MHz to 2.5 GHz
- 70 MHz IF output
- User-selectable IF bandwidths

Power Amplifiers
- 100 MHz to 5.85 GHz
- 5 W to 100 W
- Miniature size – as small as 1.6 in^3

Bi-directional Amplifiers
- 1.0 GHz to 5.875 GHz
- 5 W to 18 W
- Linear models for OFDM, etc.

Low Noise Amplifiers
- 2 MHz to 10 GHz
- 20 to 50 dB of gain
- Ruggedized & lab models

RF Filters
- Cavity Filters, UHF to Ku Band Miniature, connectorized filters
- 300 MHz to 2.4 GHz
- 1-40% 3 dB bandwidth

Pre-selectors & Tuners
- Fully programmable
- 200 MHz to 2.5 GHz
- 4-8% 3 dB bandwidth

Unmanned Systems

Platform OEMs

TEXTRON

AeroVironment™

INSITU

KRAUS HAMDANI AEROSPACE

MAG AEROSPACE

Radio OEMs

PERSISTENT SYSTEMS

TrellisWare® TECHNOLOGIES

SILVUS TECHNOLOGIES

DOODLE labs

Both

Collins Aerospace

KRATOS

CUBIC Global. Innovative. Trusted.

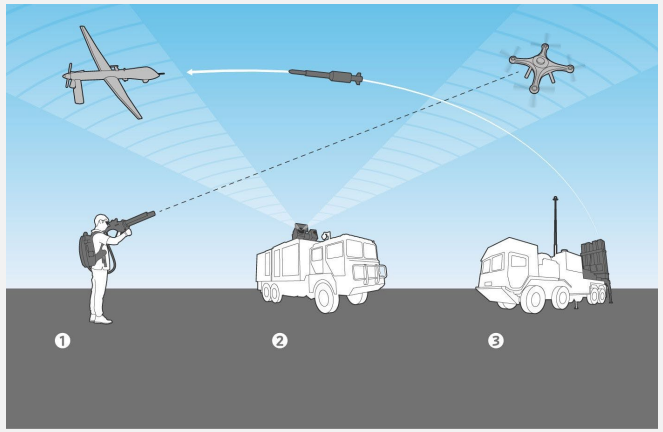
L3HARRIS™

Raytheon

NASA

Counter-UAS

"For every sword there is a shield"



WHITEFOX

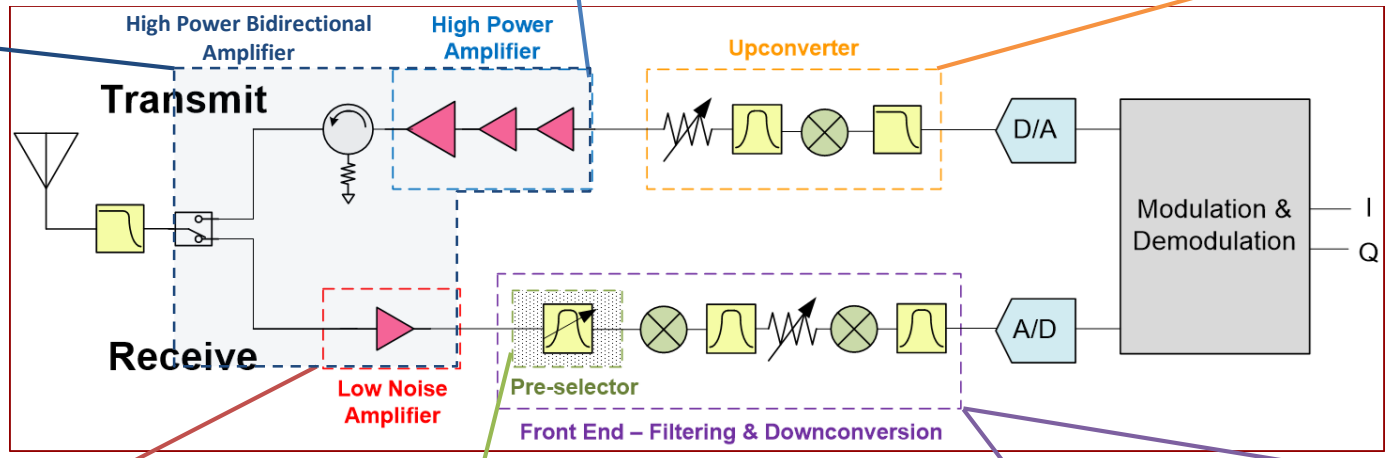
Another industry-leading C-UAS OEM who preferred anonymity

Products - Where We Fit in the RF Chain

NuPower Xtender™ Series

NuPower™ Series

MORF™ Series



ConvertaWave™ Series

HILNA™ Series

HiPerTuner™ Series

NuFilter™ Series/µFilter™ Series/Custom Filter Programs

Benefits of NuWaves Products for Unmanned Systems

Range extension

- We can provide up to 10x in link distance improvement
  - Can be even greater depending on power
- High Throughput Data Streams
  - Adding minimal distortion
- Increased power savings allows for longer time of operation

Better performance

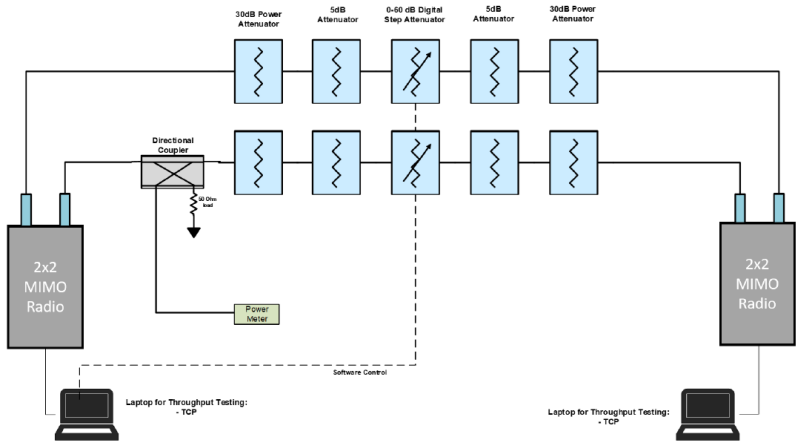
- Optimized RF links via proper filtering techniques and power amplifier design

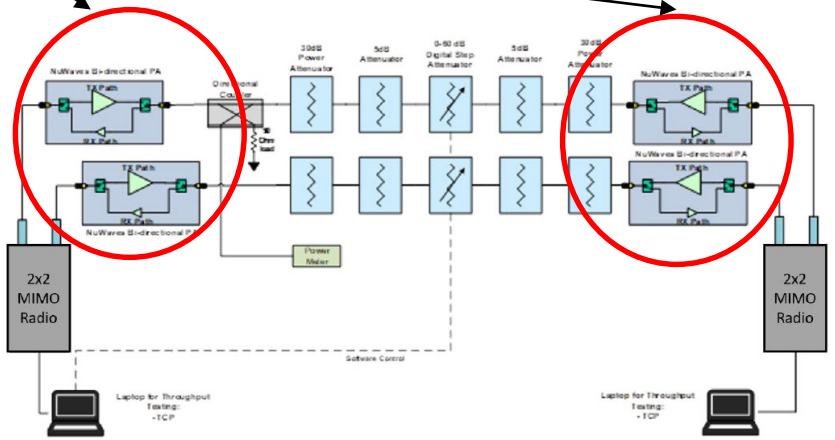
SWaP

- We are 1/2 to 1/3 size and weight reduction compared to industry
- GaN – for higher power density, more power from a smaller package
- RF SoC - Provides versatility and fast customization turnaround times

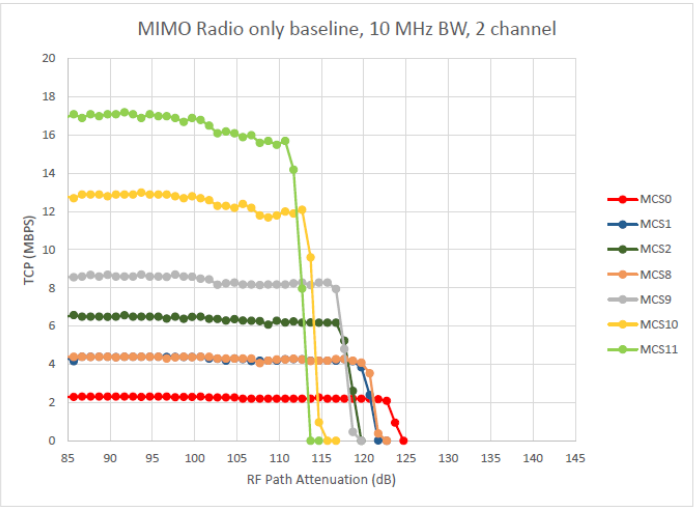
PA Linearity and Range Extension

NuWaves BDAs

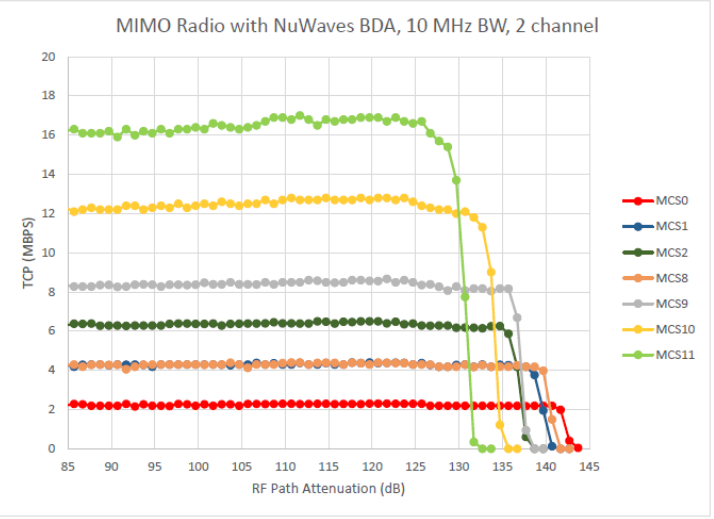




Radio Settings: 10 MHz BW, Radio only baseline. MCS mode comparison



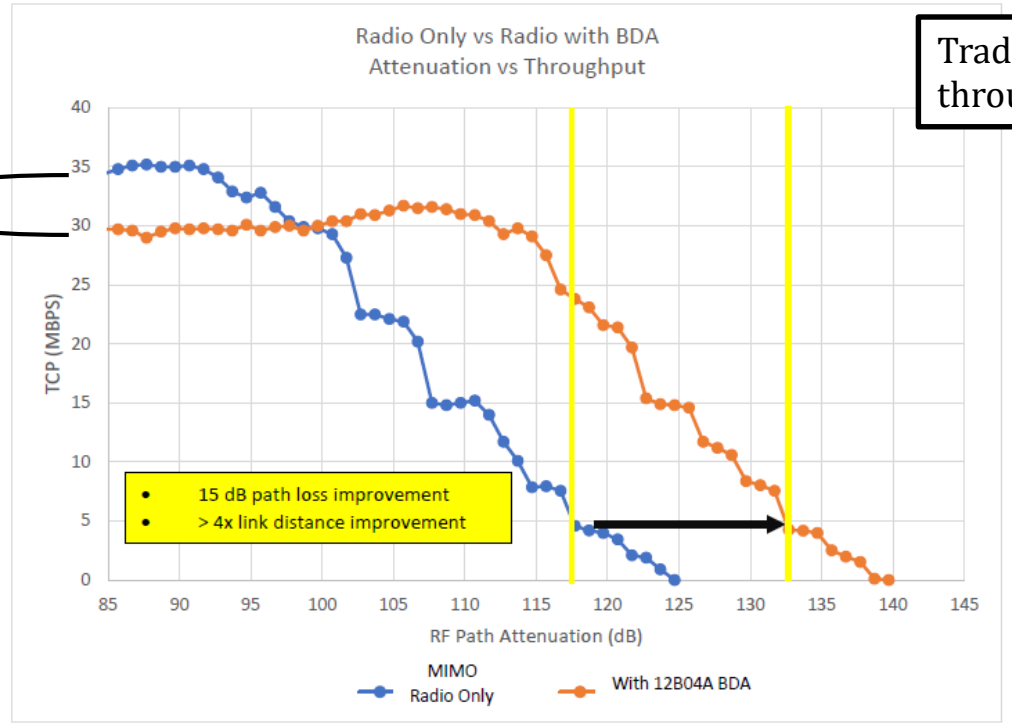
Radio Settings: 10 MHz BW, Radio with BDA, MCS mode comparison, (15dB PA gain, +33dBm max PA power in GUI)



PA Linearity and Range Extension

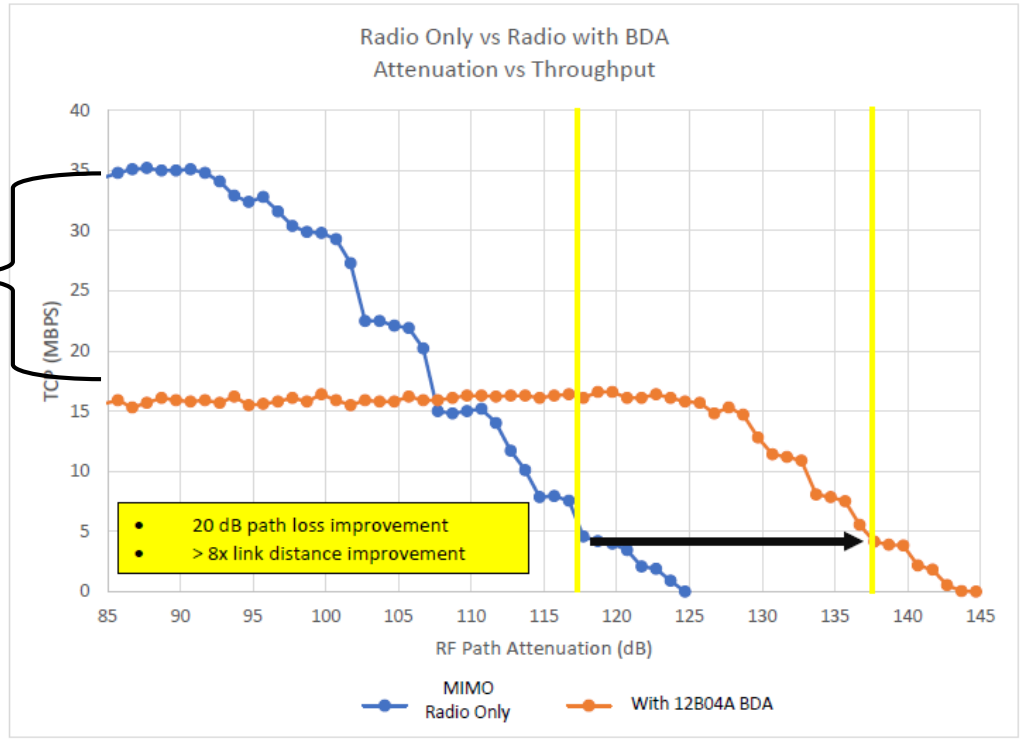
Radio Settings: 10 MHz BW, MCS255 mode, Dual Streams, (15dB PA gain, +27dBm max PA power in GUI)

Trade-off in throughput



Radio Settings: 10 MHz BW, MCS255 mode, Dual Streams, (15dB PA gain, +33dBm max PA power in GUI)

Trade-off in throughput

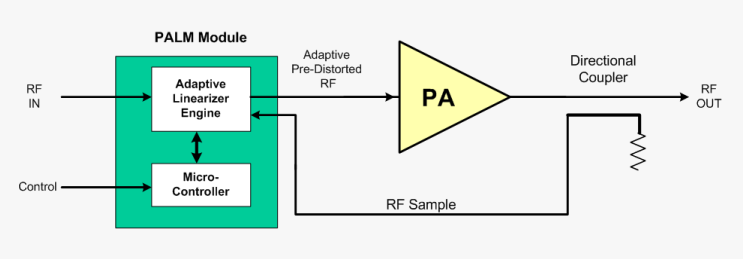


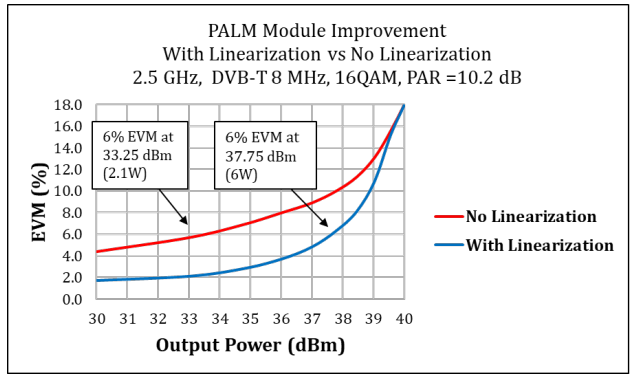
- Trade-space for range extension is cannot meet highest throughput of radio due to non-linearities of power amplification (e.g., Psat and PAPR)
- Could achieve higher throughput w/ a larger amplifier or linearization

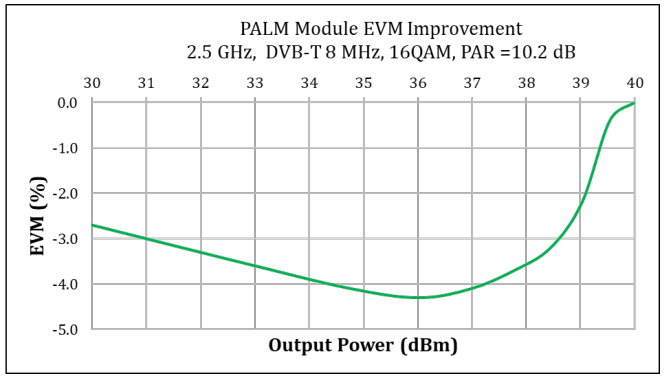
PA Linearity and Range Extension

Linear PAs: Power Amplifier Linearizer Module (PALM)

- More data throughput at significantly higher output power levels (high bandwidth signals such as video)
- Range extension
- 3.5-5 watts of added power consumption







Click to add text

4.5 dB output power improvement for operating at 6% EVM. A 2.8x output power capability improvement 2.1W to 5.95W → **1.65x increase in range**

Methods of Linearization:

- Pre-distortion
  - Analog
  - Digital
- Feed forward

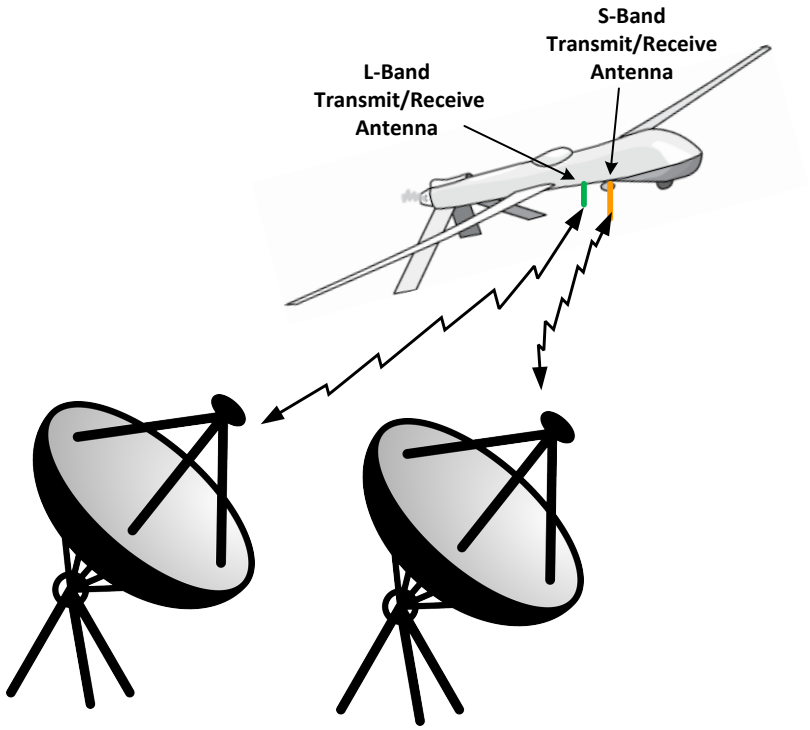
Pros of Linearization:

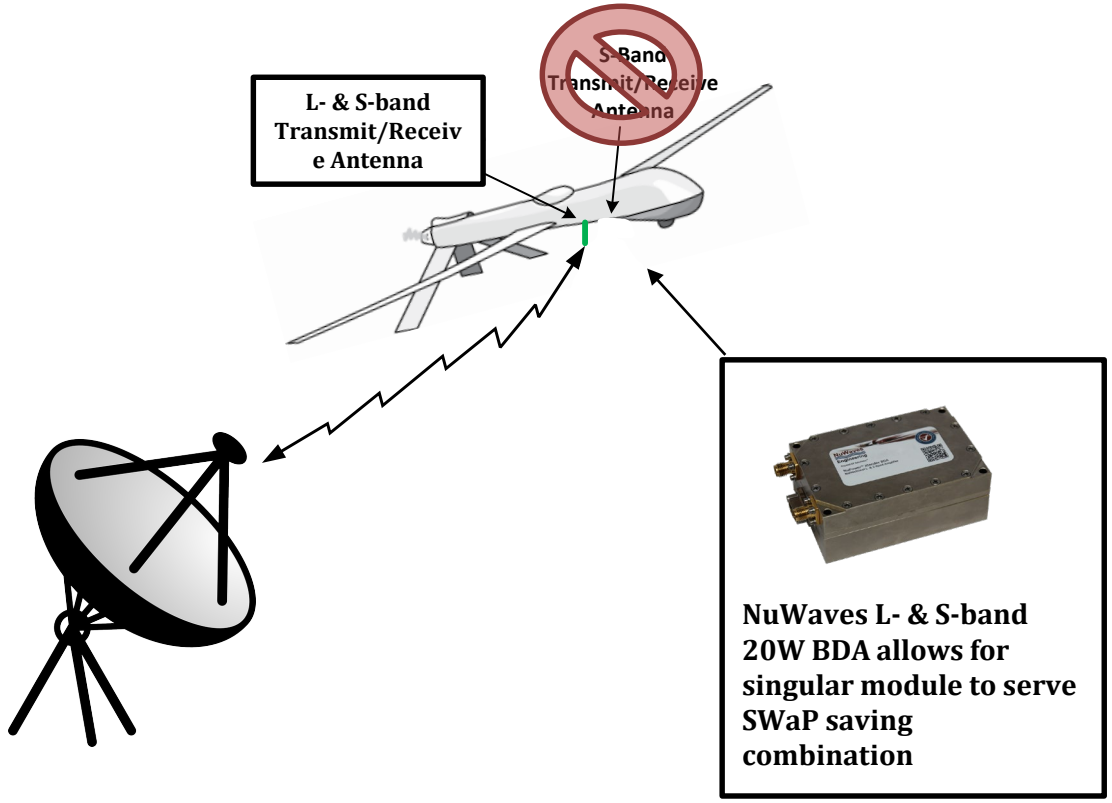
- Increased range due to improved output capability
- Additional waveforms accessible with small change to existing system

Cons of Linearization:

- Increased SWaP
- Increased cost

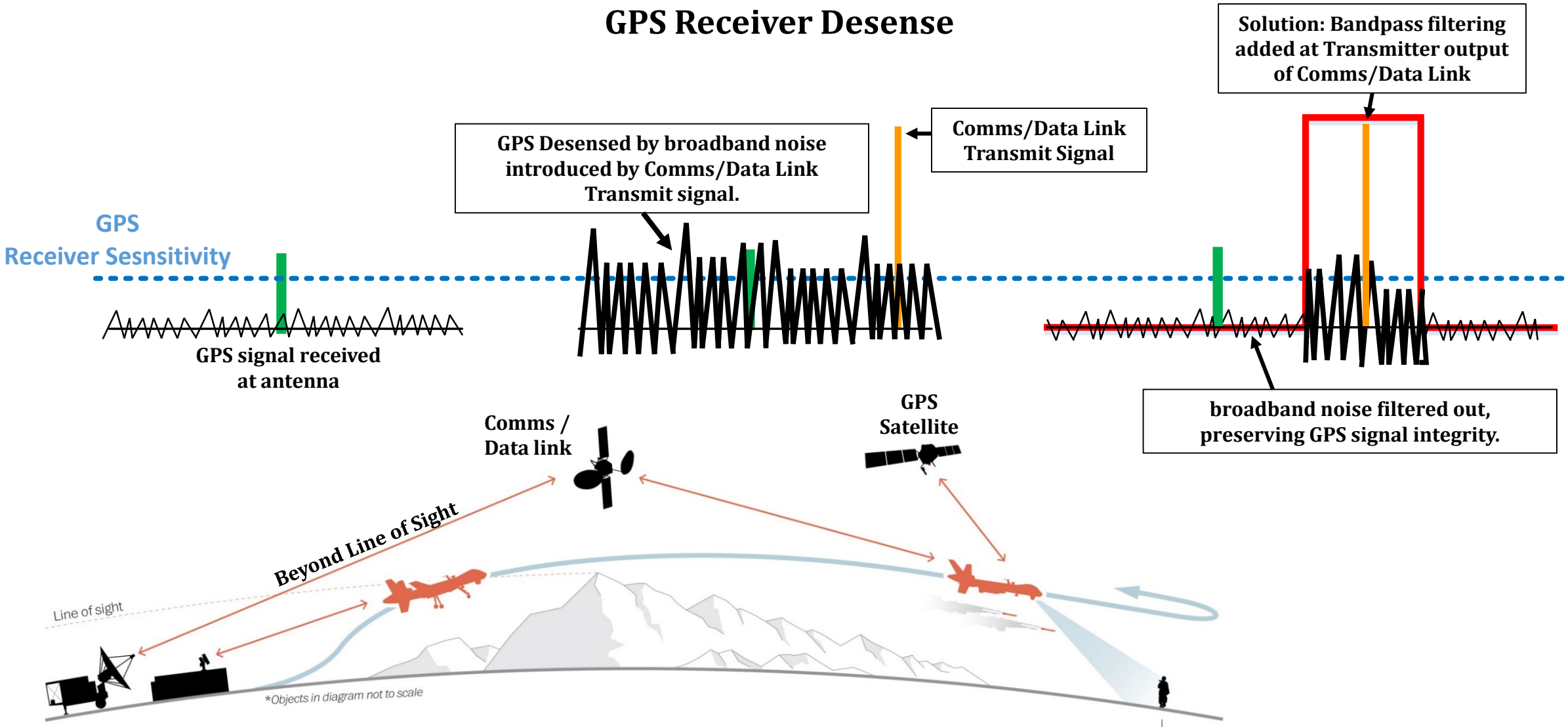
Combining Datalinks for SWaP Reduction





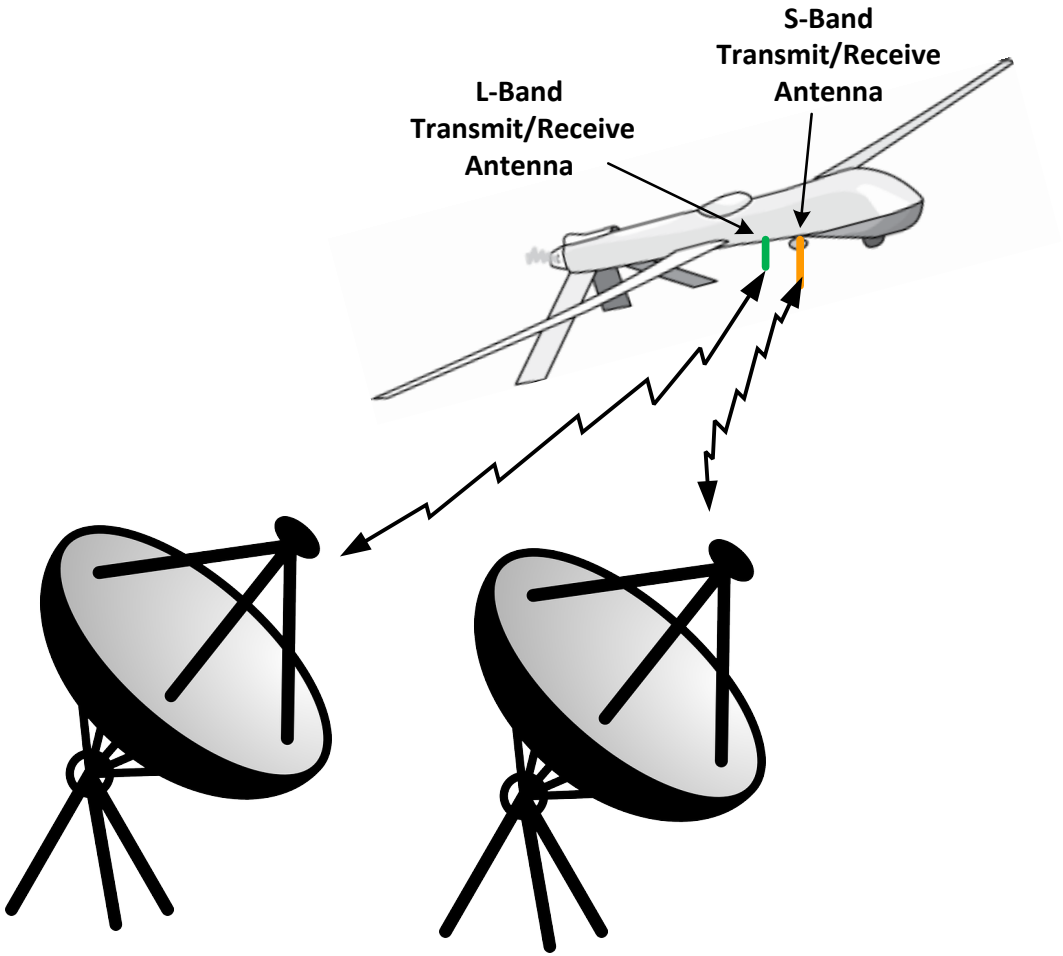
- Date types (such as C2, telemetry, video, etc) can be combined onto into single datalink with technological advances in radios
- Combining datalinks streamlines hardware needed improving overall SWaP and range

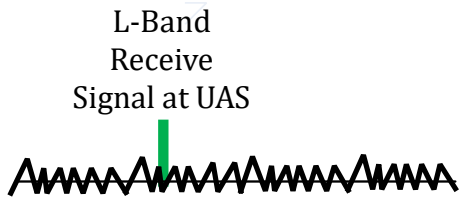
UAS System Degradation Causes

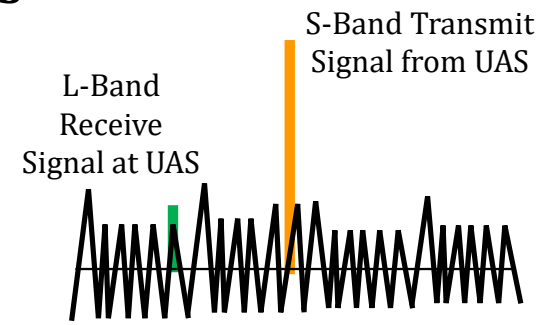


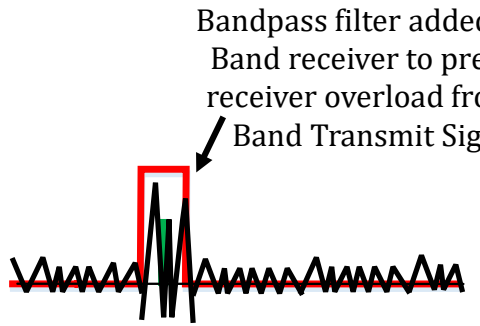
System Degradation Causes

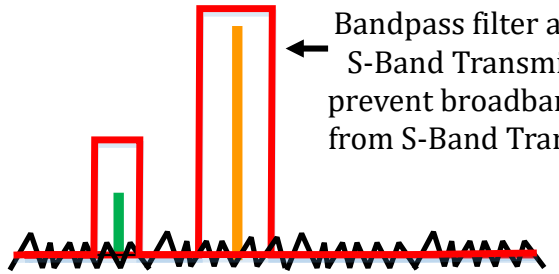
Poor Isolation and Co-located Transmitters



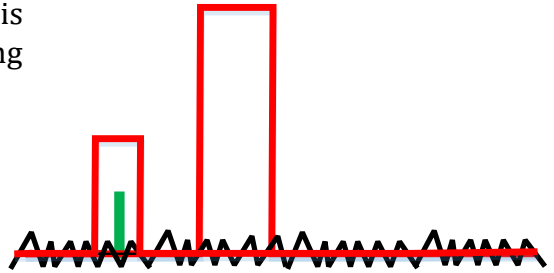








L-Band Receive Signal is now received, providing maximum range!!!



New Product Developments

New Product	Benefits to Unmanned Systems
SCISR-20	• Improve CDL data link range
CNPC	• Power Amplifier to improve the UAS link range • Based on NASA SBIR Phase II effort and need
Vegas / Vampire	• Cybersecurity for 1553 data diode / data logger
GPS RF Front End	• 20 Watt TR module with integrated GPS filtering • Integrated Diplexer
12B04A-D27/D30	• Developed for MIMO, MANET and MUOS radios
2-20 GHz PA	• Signal jamming for Electronic Warfare and Counter UAS • Can be used to reduce the amount of hardware required to operate multiple frequencies with the same platform and footprint
Updated MORF	• Frequency converter extended to 6 GHz capability • It achieves a frequency capability which is not provided by the native radio

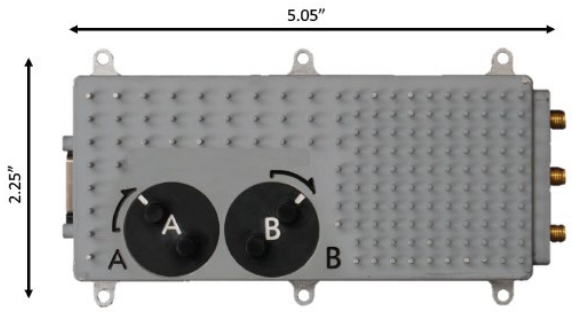
Secure CDL Intelligence, Surveillance, and Reconnaissance (SCISR) Radio

- **Extremely small SWaP**
- **Tri-band (L, S and C) full duplex**
- **Type-1 encryption US and NATO versions**
- High data rates (up to 45 Mbps)
- Non-proprietary control and interface
- 2W transmit power with adjustable power
- control
- **BE-CDL Rev. B and Rev. A waveforms**
- TBS waveforms
  - Vortex Native Waveform (VNW)
  - Tactical "Predator" Waveform
  - 466 Extended Range (466ER)
- Spreading waveform enhancement in progress
- Non-proprietary control and interface
- **Interoperable with current and legacy terminals**
  - **Rover**
  - **Video Scout**
  - **MMT**
  - **Vortex**
  - **Bandit**

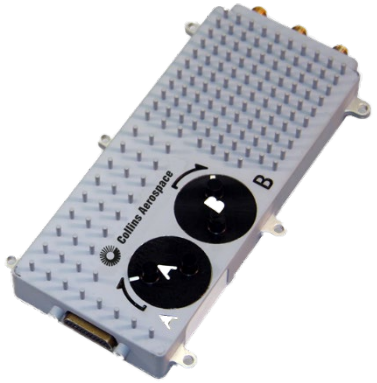
Government-funded development to eliminate proprietary waveforms of legacy radios to increase vendor competition

<u>Takeaway</u>: This radio and variants of it will be used on many platforms currently using radios soon to be phased out

Current SCISR Vendors

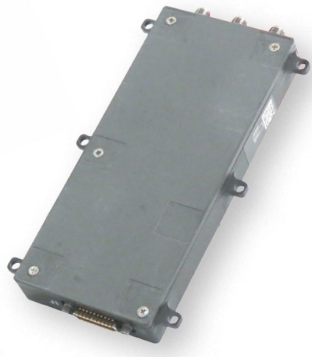


SCISR Baseline Radio



Collins Aerospace

RT-2071(C) Secure CDL ISR (SCISR) Radio



Cubic

Nano Multiband Transceiver (nMT)

L3Harris

Bandit 2x Miniature Tri-Band Transceiver

Kratos (RT Logic)

Jaeger Family Radios for C2/ISR

All radios compatible with baseline radio. Each vendor product is its own "flavor" with additional features, etc.

NuPower Xtender™ SCISR-20

In-Band and Cross-Band Operation

Each channel operates independent of one another. Here are a few examples of how the SCISR-20 could be operated:

- Receiving on S-band while transmitting on S-band (half-duplex)
- Receiving on S-band while transmitting on C-band (full-duplex)
- Receiving on S-band while transmitting on L- and C-band (full-duplex)
- Receiving on L-, S-, and C-band simultaneously
- Transmitting on L-, S-, and C-band simultaneously

What is it?

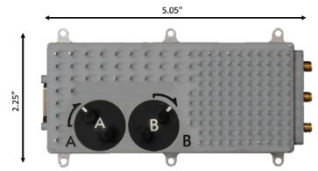
- Multi-Channel, Tri-Band Bidirectional Amplifier
- Layman's Terms: A 3-in-1 BDA!
- TX output power → 20 W
- RX receive gain → 15 dB

What does it do?

- Increases link margin in both transmit AND receive
- In-band (half-duplex) and cross-band (full-duplex) communication

Why did we make it?

- Designed to support secure CDL ISR (SCISR) radios in a compact form factor
  - *Collins Aerospace RT-2071*
  - *Cubic nMT*
  - *Kratos JaegerTR*
  - *L3Harris Bandit 2*



- Easy-to-integrate solution for airborne or ground terminals

Who can use it?

- ***Anyone!*** This is **NOT** just for SCISR radio users, **but anyone who needs bidirectional amplification in L-, S-, and C-band**

CNPC Datalink and NuWaves

Command Non-Payload Control (CNPC)

- 9-year NASA project co-funded by Collins Aerospace
- Unique waveform intended to allow UAS to operate safely within NAS
- Expected completion date of Sept. 2020 pushed due to Covid-19
- Upon completion, **new frequency band opening up for UAS command & control (C2) datalinks: 5030-5091 MHz**

2013-2019

2020

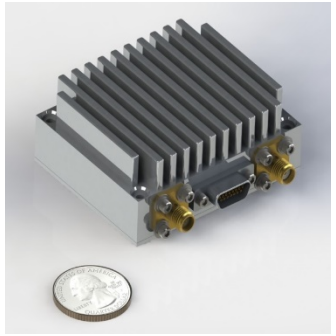
Collins Aerospace

NASA

NuWaves engineering

NuWaves Involvement

- NuWaves developed C-band PA for CNPC-5000 through Phase II SBIR with Collins/NASA
- NuWaves planning new CNPC products in future to support 5030-5091 MHz



NuPower Xtender C10RX03
4400-5100 MHz, 10W BDA

NuPower C30R01
5030-5091 MHz, 30W PA

Future Technology Highlights

Capability	Benefits
RFSoC	• Flexible Firmware Development that can be handled at the Hardware Level • Frequency adjustments through firmware • Digital pre-distortion improvements • Provides versatility and fast customization turnaround times
Chip and Wire	• Allows for higher frequency designs (e.g. up to 36 GHz) • Improved power levels due to increased control of thermal design to achieve higher efficiency and RF output power • More control at design level vs. Manufacturing to implement more bond wires for resistance reduction and improved performance • Impedance matching at die level vs board level to improve size
Up to 36 GHz capability	• Tri-band frequency converter from X-Band, K-Band, Ka-Band

Contact Us Today!

A Few of Our Customers

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www.nuwaves.com

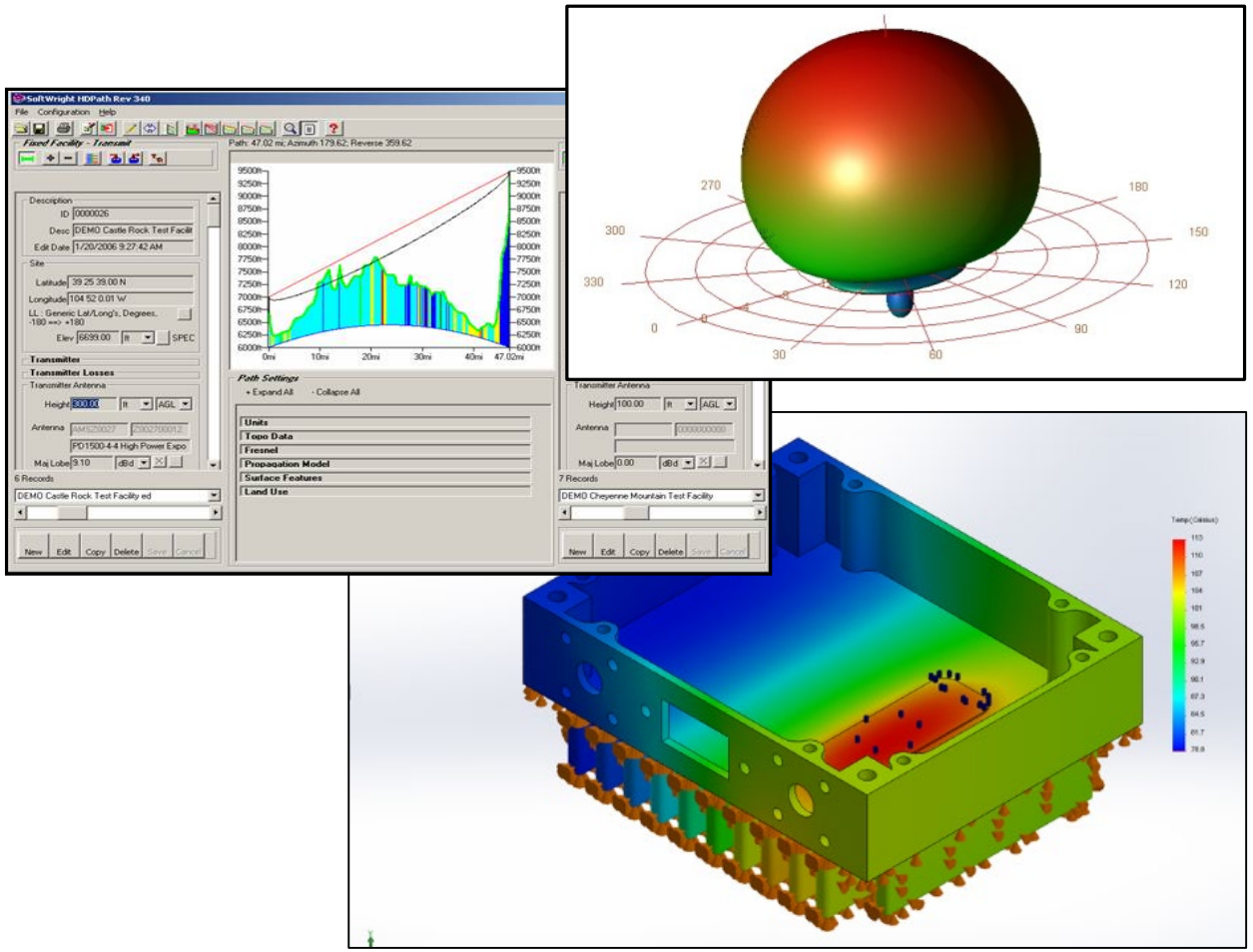
132 Edison Dr. Middletown, OH 45044

A Few of Our Customers

Backup Slides

- Other Services and Capabilities that NuWaves Provides
  - Contract Manufacturing
  - Production
  - Testing
  - Rapid Prototyping
  - RF Design Services

Capabilities Overview



- Linear, non-linear, and electro-magnetic simulation
- Antenna Modeling & Prototyping
- Complementary digital logic design
- Schematic capture
- Printed circuit board (PCB) layout
- Mechanical design and thermal analysis
- Rapid prototyping
- Design Verification Testing
- Acceptance Testing
- Qualification Testing
- Manufacturing & Production
- Installation & Training Support
- RF Propagation Analysis & Site Surveys

Contract Manufacturing

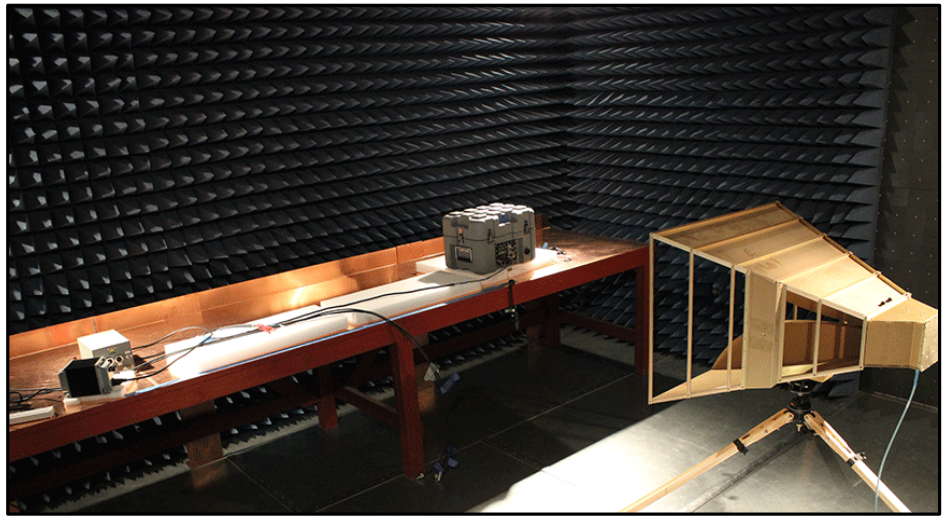
- **Aerospace Electronics Manufacturing**
  - In-House Engineering Staff
  - Circuit Card Assembly
  - Machine Shop
  - X-Ray and Rework Machine
  - Reflow Oven
  - Aqueous Batch Cleaning
  - Conformal Coating
  - Certifications:
    - ***NuWaves' Quality Management System***
      - *ISO 9001:2015/AS9100:2016 Rev D*
    - *IPC-A-610*
    - *IPC/WHMA-A-620*
    - *J-STD-001*
    - *IPC-7711/IPC-7721 Rework & Repair*
- **PCB Assembly**
- **Environmental Testing**
  - Design Verification, Acceptance, and Qualification Testing
  - Temperature and Humidity
  - Shock and Vibration
  - EMI/EMC
- **Automated Testing & Maintenance Hardware**
- **Rapid Prototyping**

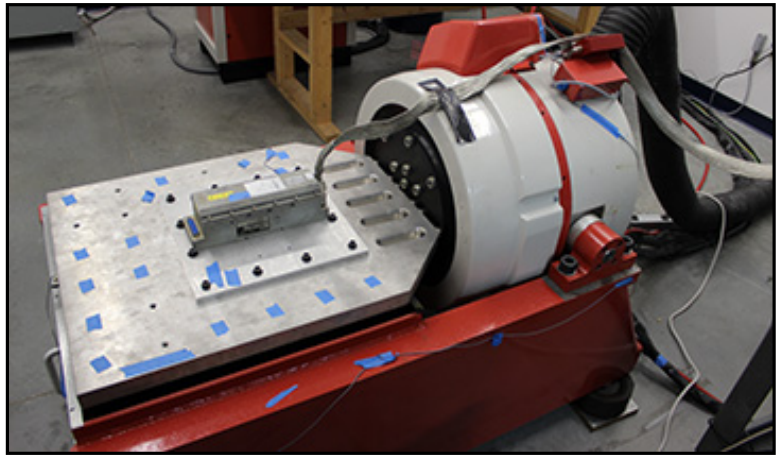
Production

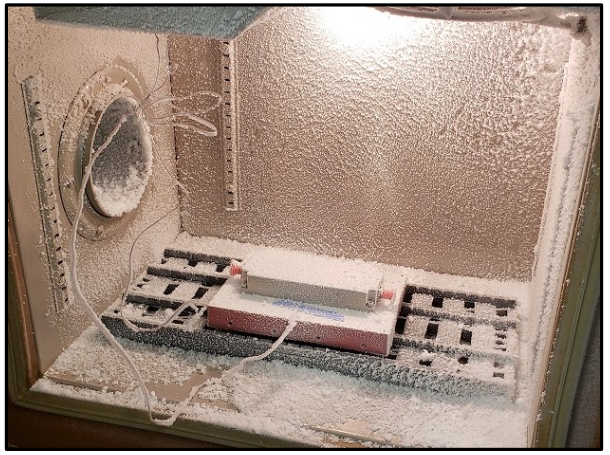
- 10k ft^2 facility
- Automated SMT assembly
- IPC-J-STD-001E and IPC-A-610E, Class 2/3

Testing

- Design Verification, Acceptance, and Qualification Testing
- Temperature and Humidity
- Shock and Vibration
- EMI/EMC

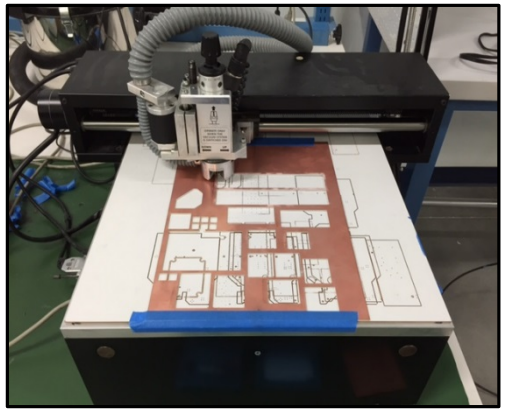


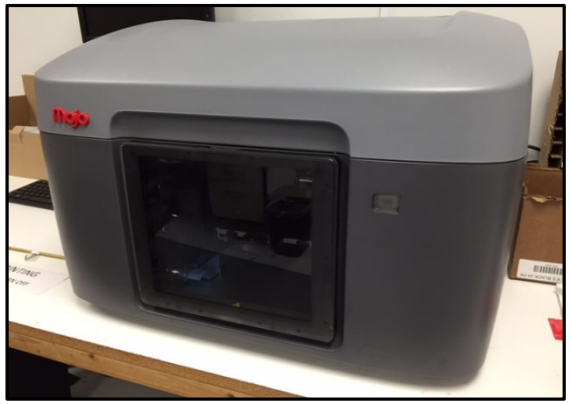


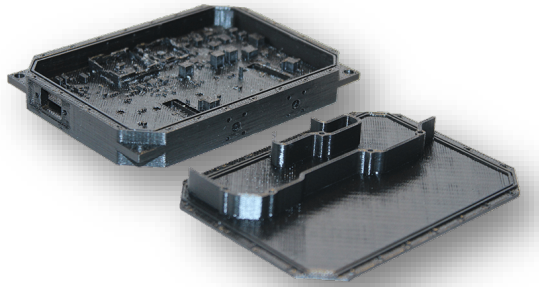


Rapid Prototyping

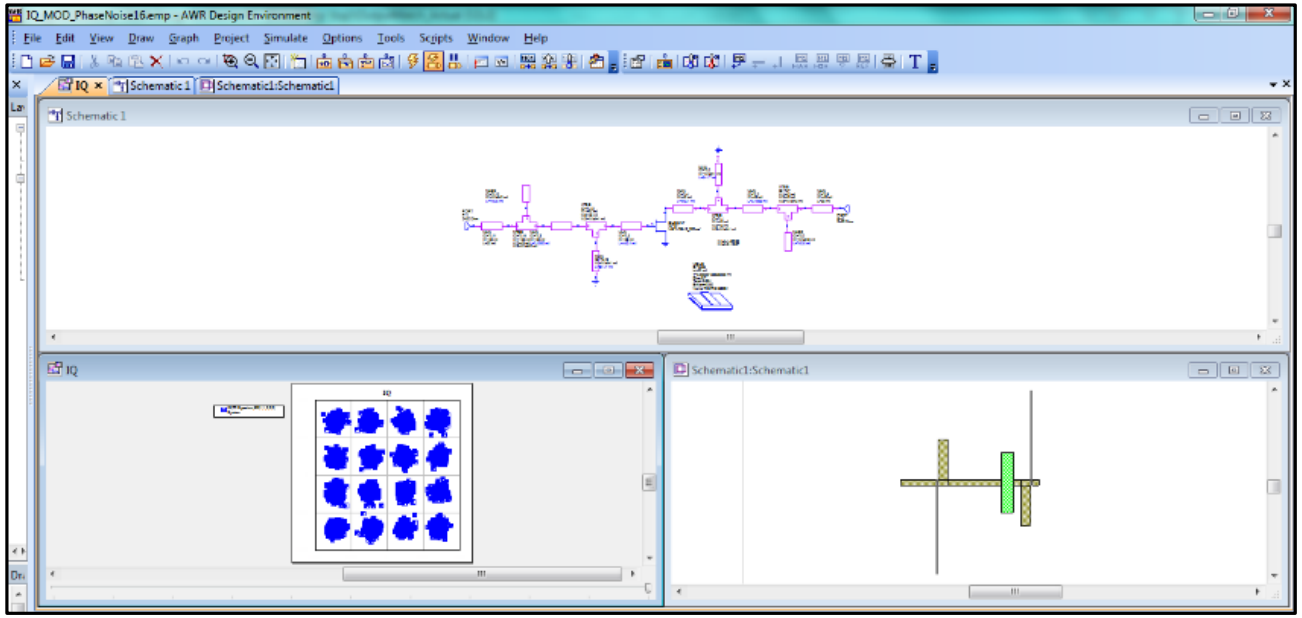
- PCB prototyping and quick-turn SMT assembly
- 3D printing
- Machining
  - CNC, lathe, drill press
  - Full production machining







RF Design Services



- High-performance, one-of-a-kind solutions
- System, subsystem, and module designs
- HF to Ka-band
- Miniaturization