METAMAGNETICS

Compact Magnet-Less Circulators and Isolators for K_A-Band Radar and other Instruments

NASA Program Managers: Parminder Ghuman and Robert Connerton

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Presenter: Mr. Douglas Linkhart (dlinkhart@mtmgx.com)
Principal Engineer, Metamagnetics, Inc.

PI: Dr. Anton Geiler (ageiler@mtmgx.com)
President, Metamagnetics, Inc.

ESTF2017
Earth Science Technology Forum 2017

NASA

Agenda

- Circulators!
- Motivation for Developing Smaller & Lighter Circulators
- Applications of Circulators
- Circulator Size Reduction
- Ferrite Material Properties & Improvements
- K_A-Band Circulator Performance Data

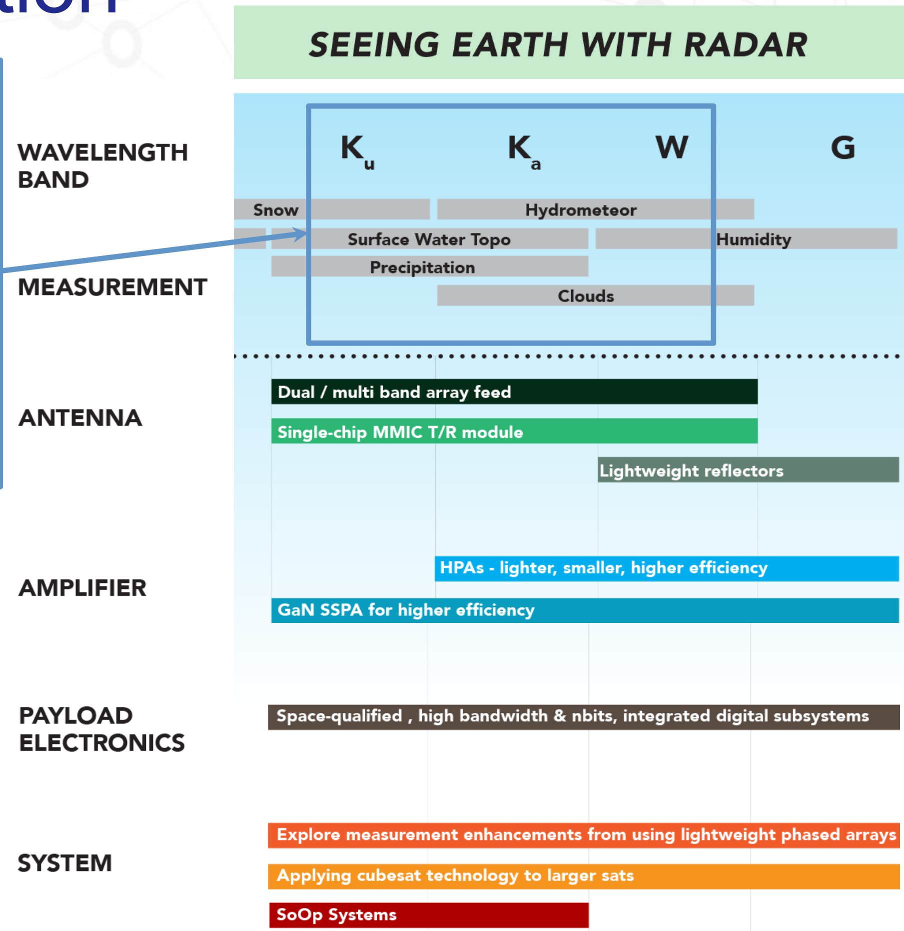
METAMAGNETICS

Background and Motivation

Earth Science Goals

"Multi-band radar with Doppler and imaging capability is crucial for improved understanding of the characteristics of clouds, precipitation, and their interaction" [1]

- Improved accuracy of Ice Water Path, Liquid Water Path, particle size, and particle phase estimates
- Characterize vertical air motion, convective up- and down-draft, particle size and classification, and latent heat transportation



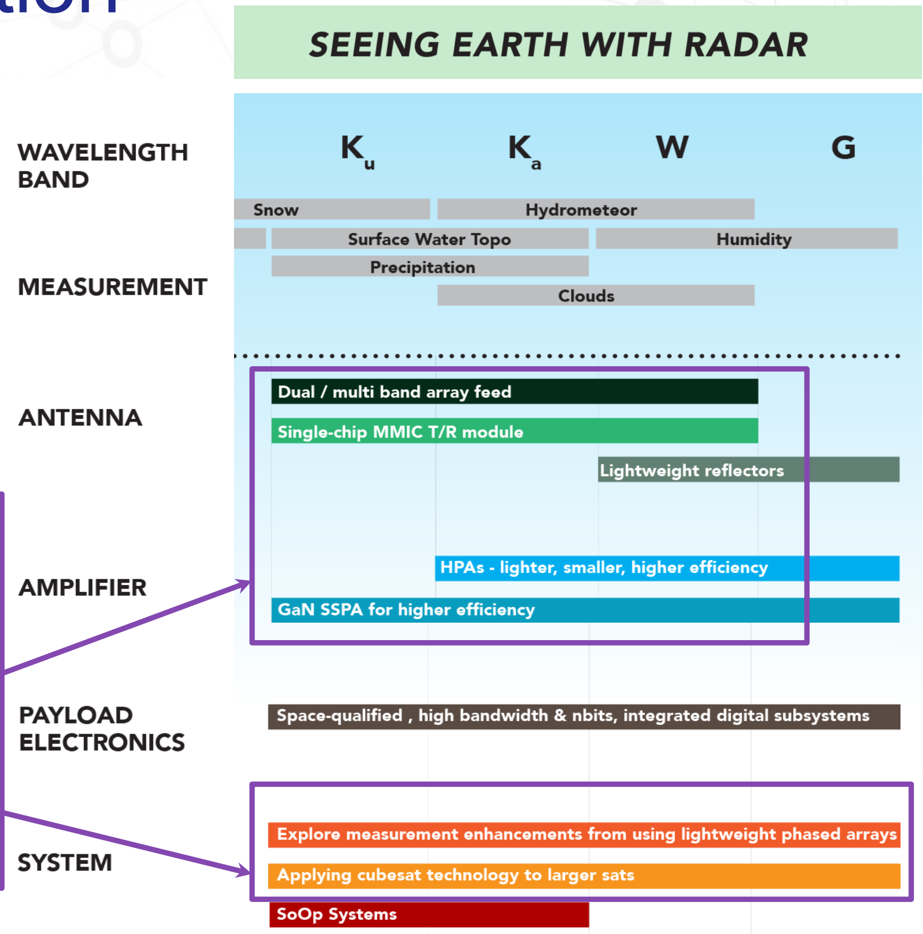
Adapted from NASA ESTO 2016 Microwave Technologies Review and Strategy [2]

Background and Motivation

Enabling Technology

Multi-Band Radar Demands:

- Dense array element spacing
- Efficiency
- Component miniaturization and integration
- Mass reduction
- High Tx/Rx isolation
- Wide array scanning angles



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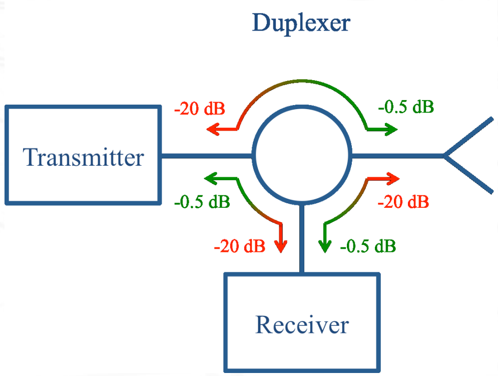
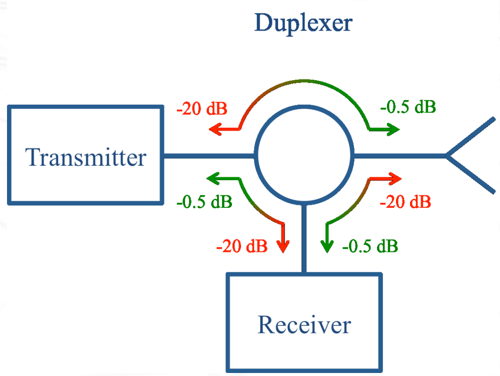
Circulators and Isolators in Phased Arrays



Circulator configured as duplexer to enable Tx and Rx through a shared aperture

Circulators and Isolators in Phased Arrays



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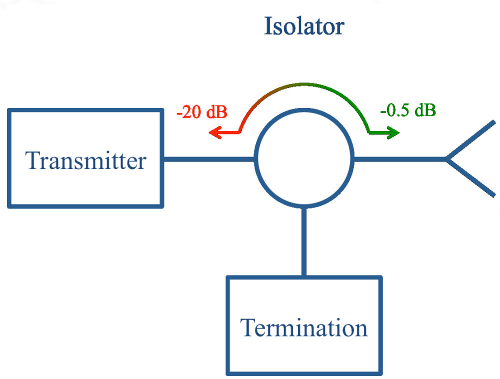


Circulator configured as isolator to isolate Tx from load impedance variation

Traditional Ferrite Circulators and Isolators

Source: www.dorado-intl.com

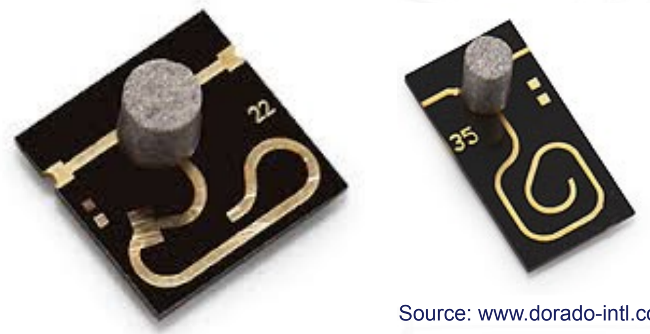
COTS microstrip isolators at Ku and Ka bands

- Size of magnet is proportional to operating frequency

$f_0 \propto H_{bias}$

- Magnet adds weight, height, and cost

Traditional Ferrite Circulators and Isolators



Source: www.dorado-intl.com

COTS microstrip isolators at Ku and Ka bands

- Size of magnet is proportional to operating frequency

$f_0 \propto H_{bias}$

- Magnet adds weight, height, and cost

- Array element spacing proportional to wavelength and decreases with increasing scan angle

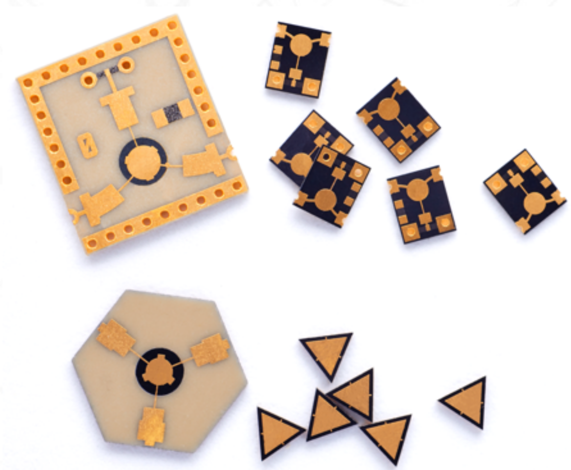
$d < \frac{\lambda}{1+\sin\theta}$

Traditional vs. Self-Biased Circulators

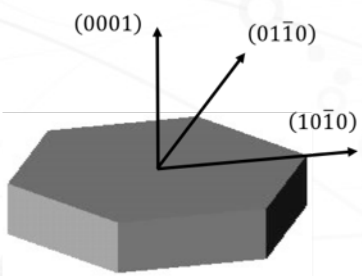
Both designs at 35 GHz

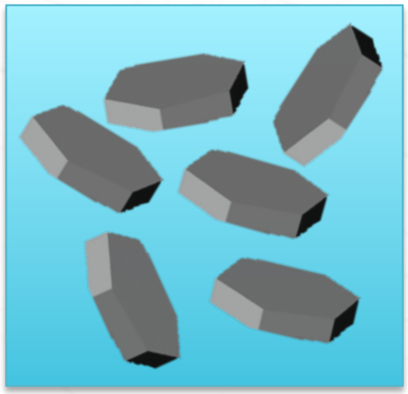
Self-Biased Circulator

- No external permanent magnet
- 95% lighter and 90% smaller
- Shock and vibration tolerant (up to 70,000 g)
- K_U- through W-band
- Earth science and satellite communications applications



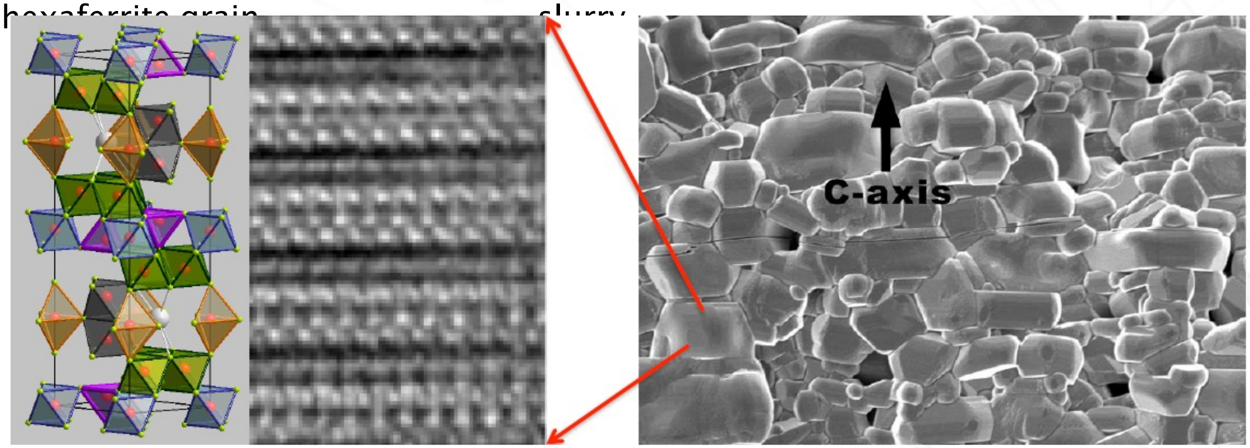
Self-Biased Ferrite Material Synthesis





Single magnetic domain M-type hexaferrite grain

Grains dispersed in slurry



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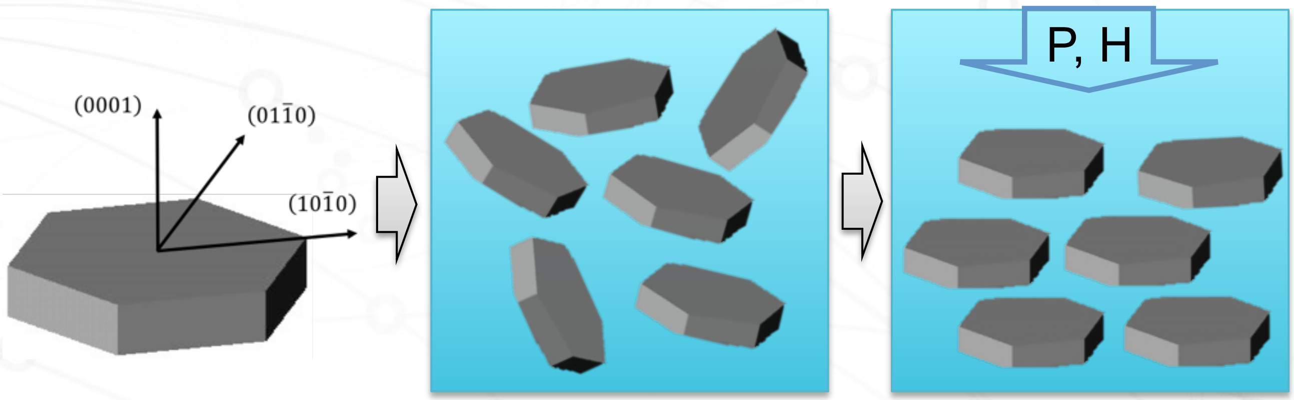
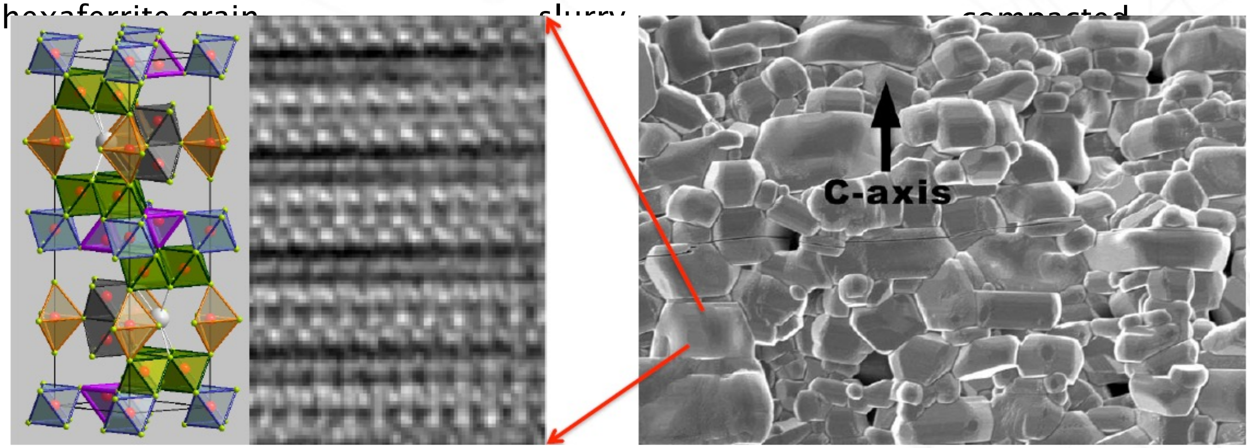


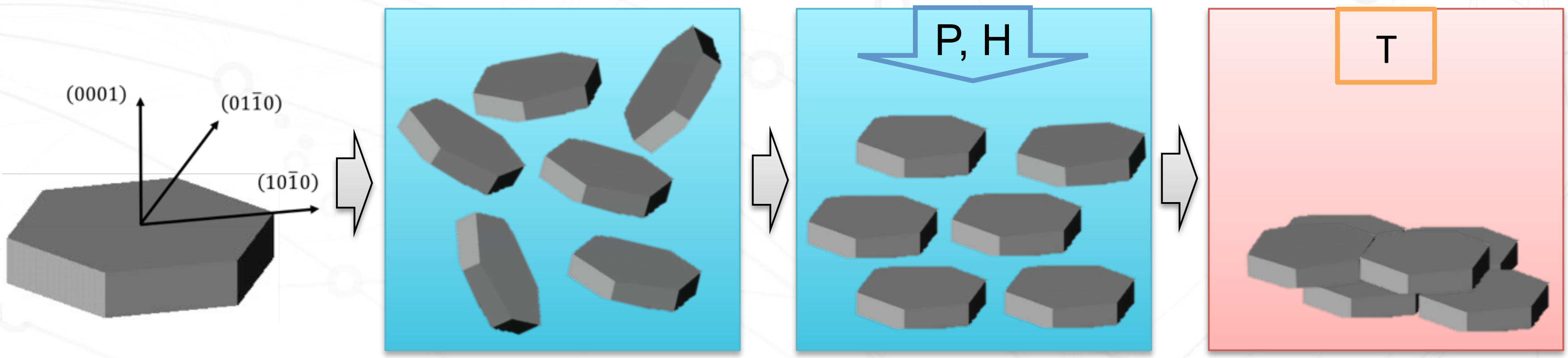
Single magnetic domain M-type

Grains dispersed in

Grains oriented in magnetic field and



Self-Biased Ferrite Material Synthesis

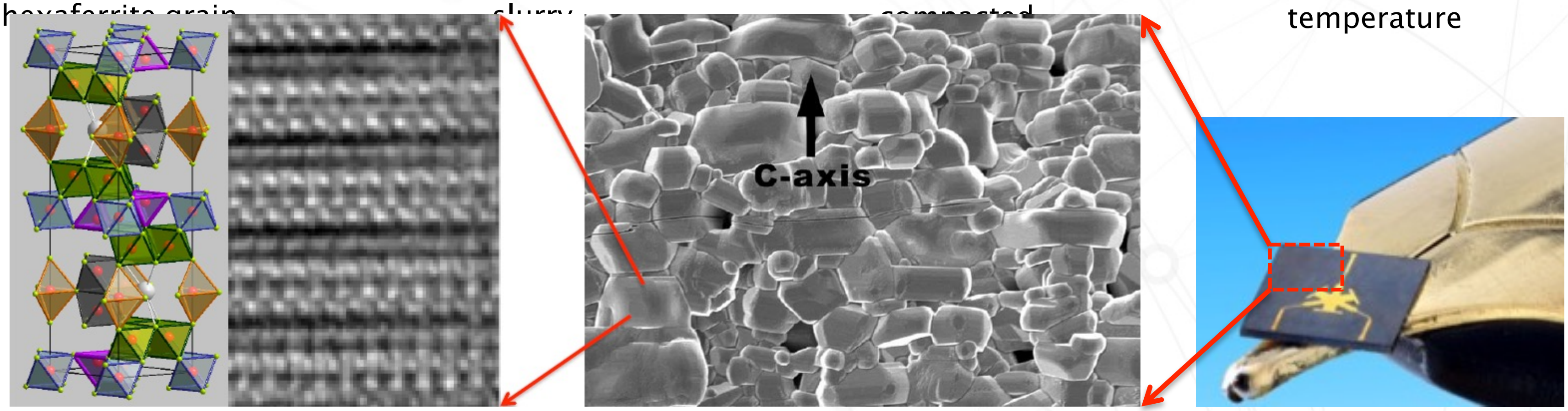


Single magnetic domain M-type hexaferrite grain

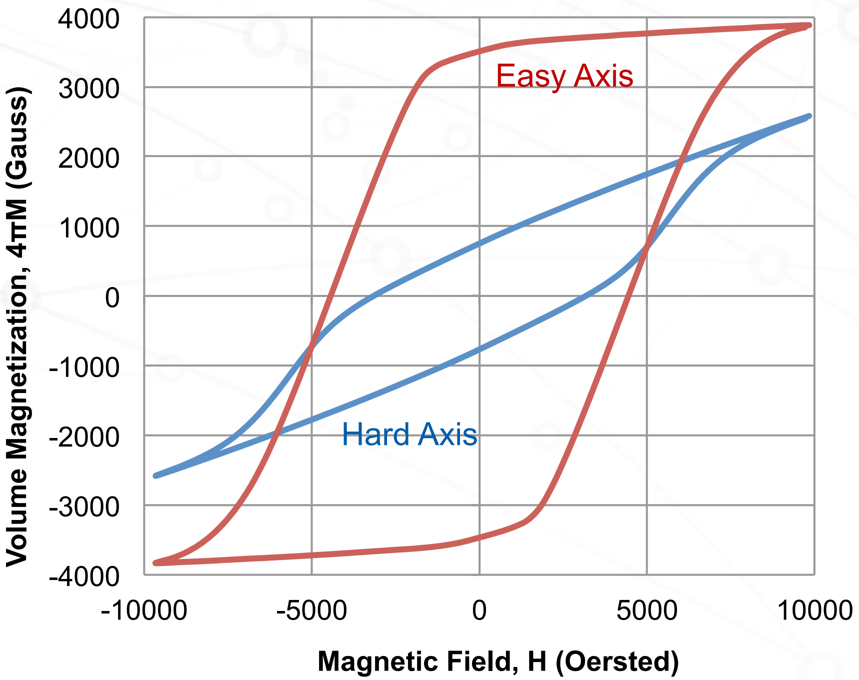
Grains dispersed in slurry

Grains oriented in magnetic field and compacted

Grains dehydrated and sintered at high temperature



Magnetic Properties of Self-Biased Ferrites



- Remanent magnetization > 90% of M_S optimal for self biasing
- Coercive field > 4,400 Oe for temperature stability

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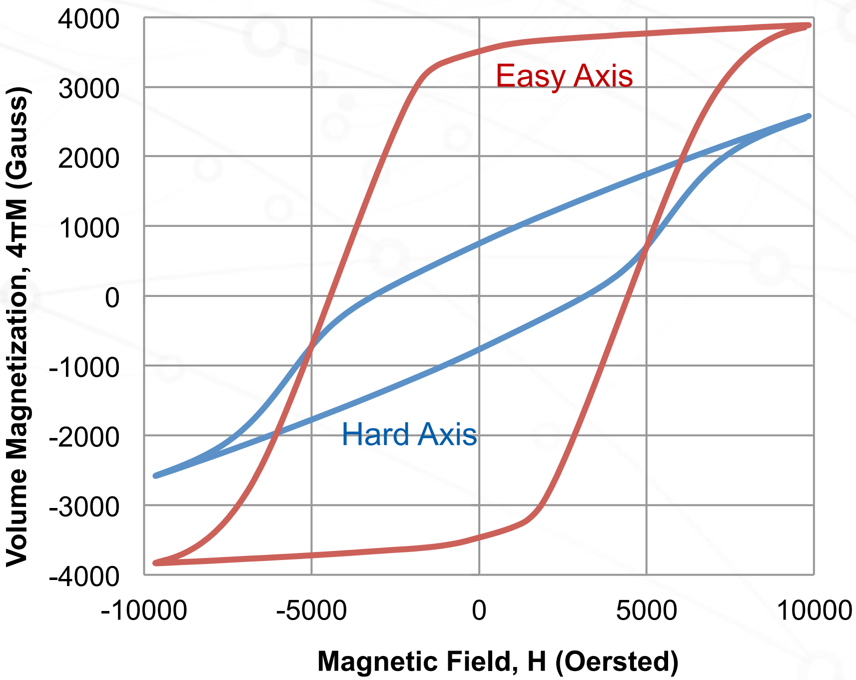
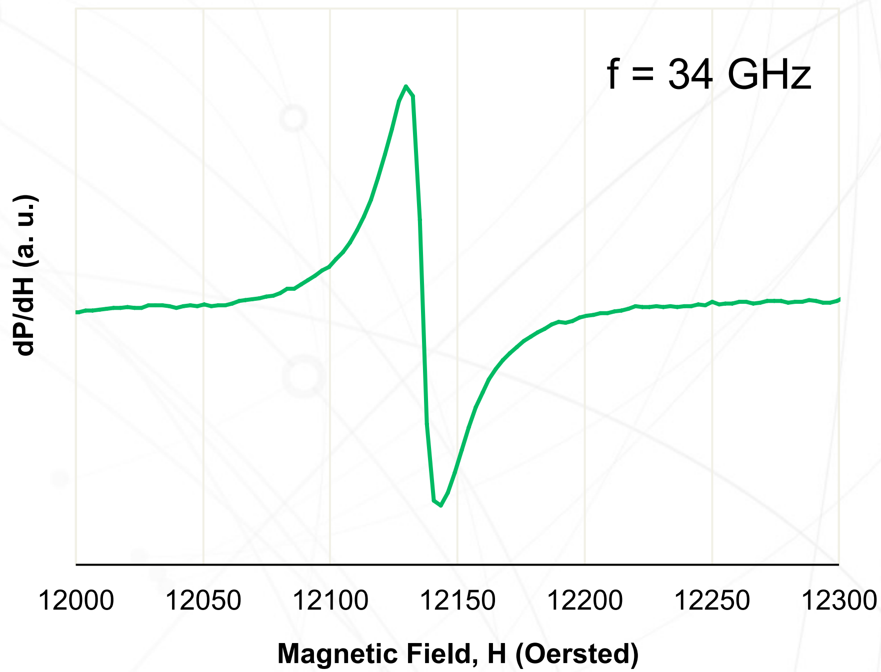
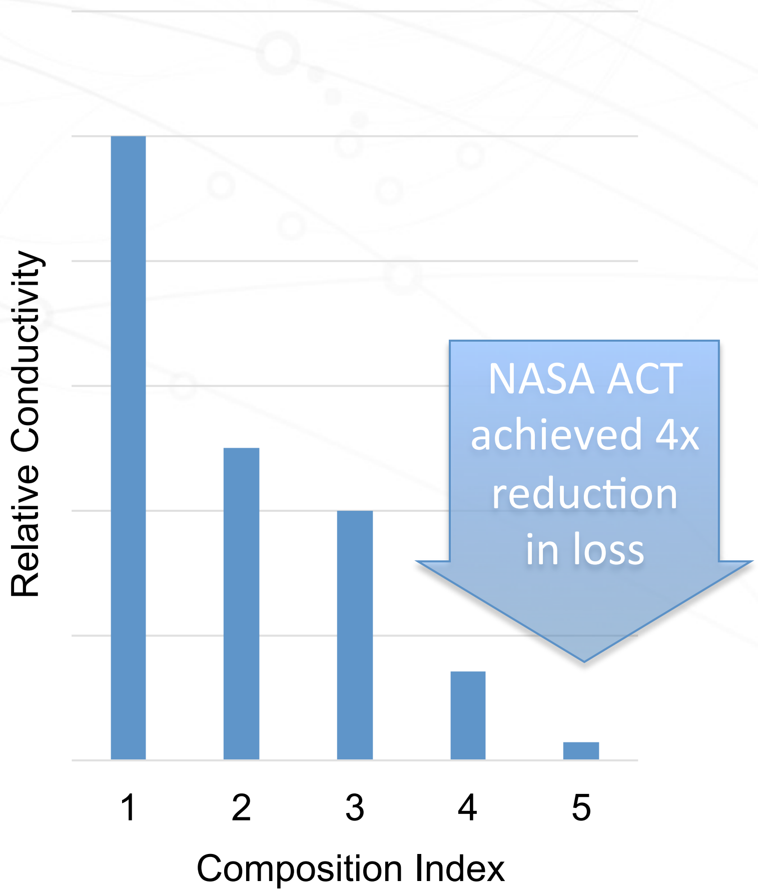




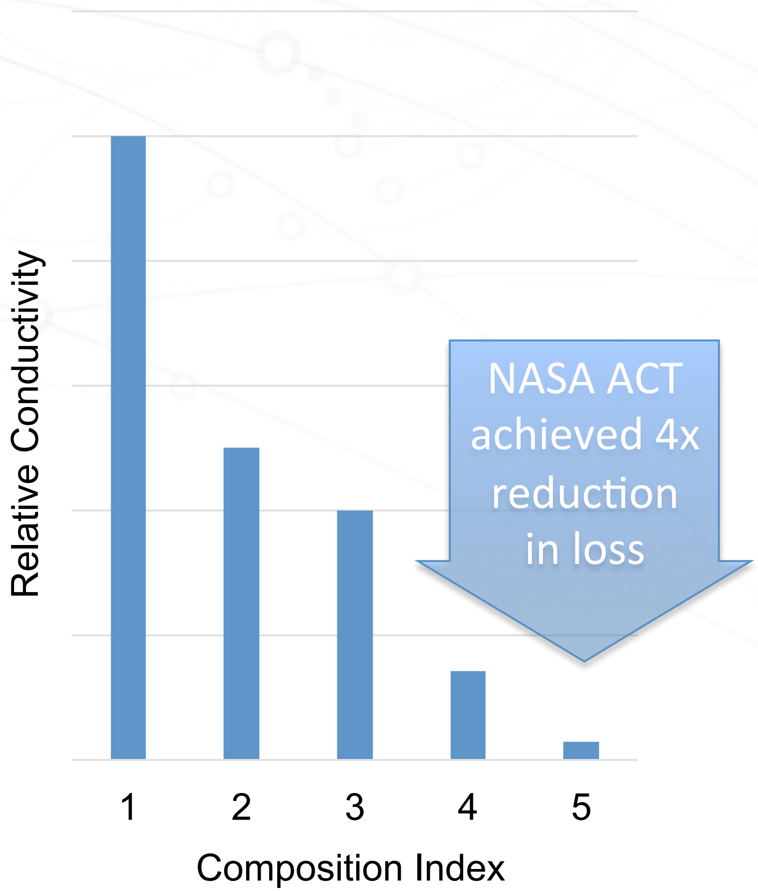
- Remanent magnetization > 90% of M_S optimal for self biasing
- Coercive field > 4,400 Oe for temperature stability

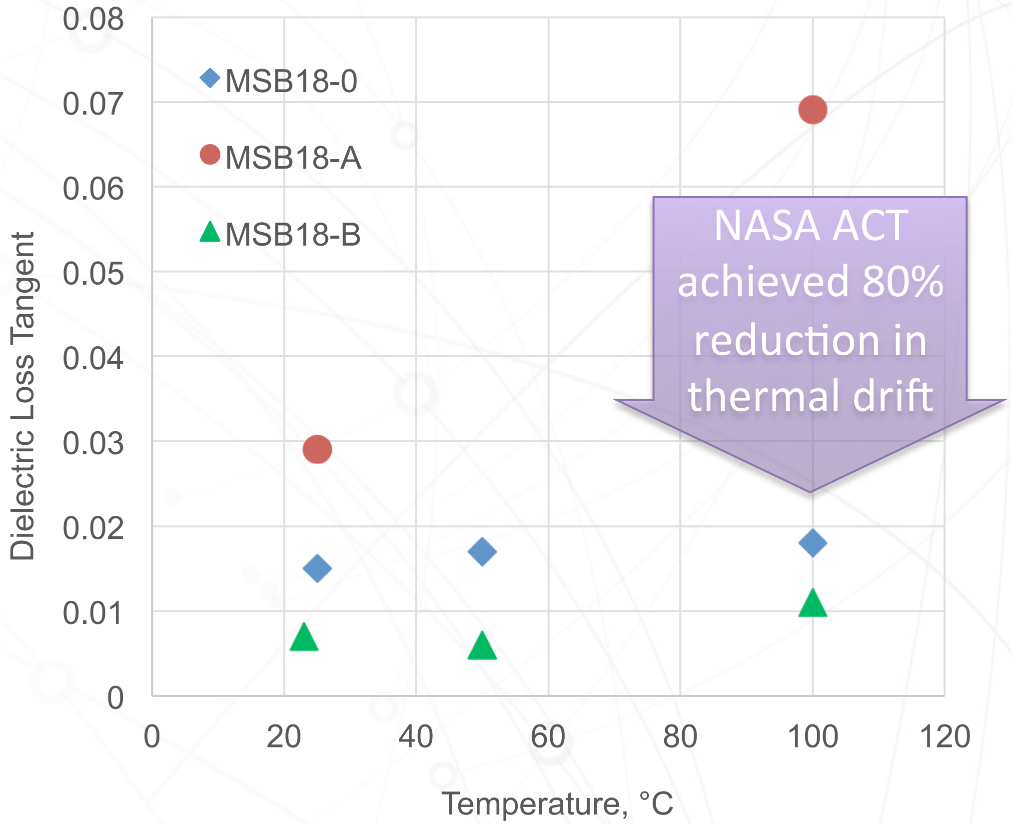
- Ferrimagnetic resonance -3 dB linewidth < 20 Oe
- Lowest value ever recorded for self-biased ferrite

Dielectric Loss Tangent Improvement

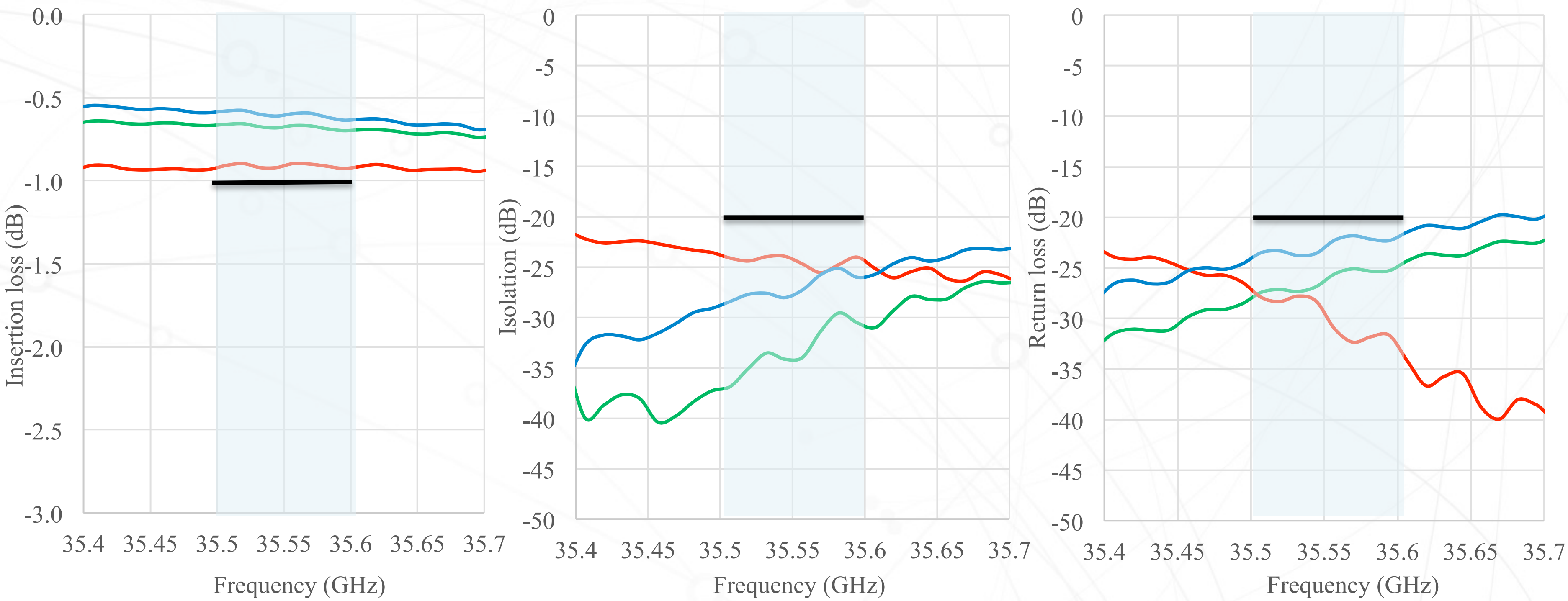


Dielectric Loss Tangent Improvement



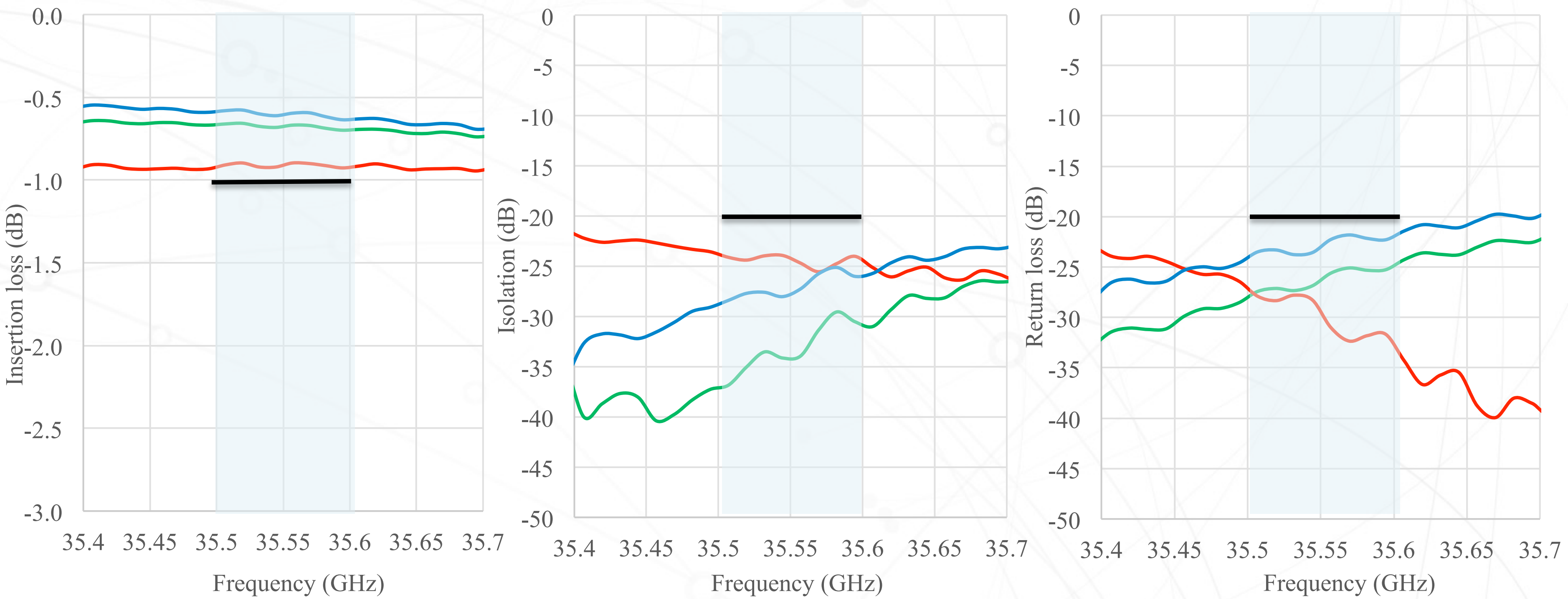


Electrical Test Data at Temperature Extremes for 3rd-Iteration Circulator



- -20°C
- +21°C INITIAL MEASUREMENT
- +75°C
- Goal

Electrical Test Data at Temperature Extremes for 3rd-Iteration Circulator



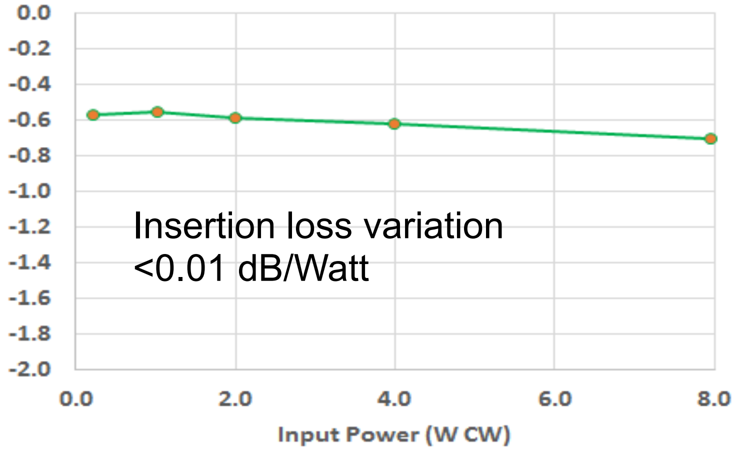
-20°C

+21°C INITIAL MEASUREMENT

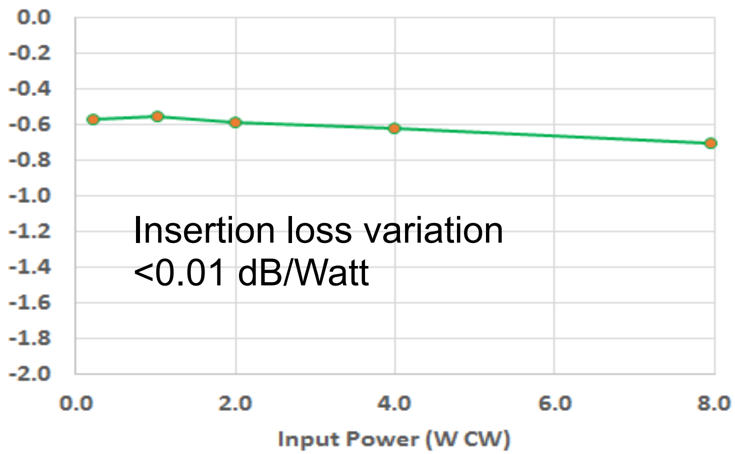
+75°C

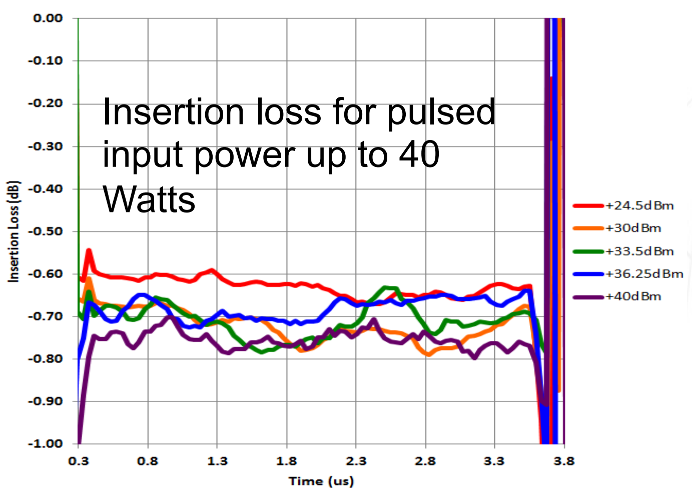
Goal

Power Handling Measurements



Power Handling Measurements



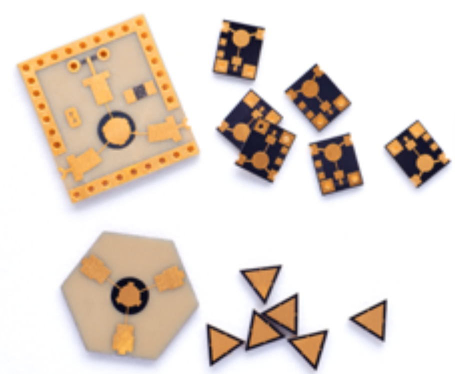


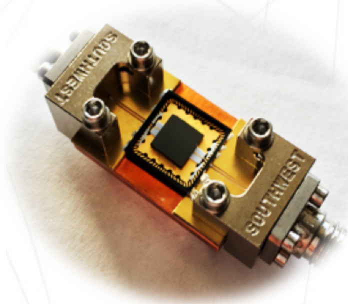
Company Overview

- ❖ Established in 2009 (C-Corp., DE)
- ❖ Veteran-owned small business (VOSB)
- ❖ Headquartered in Westborough, MA
- ❖ 9,200 sq. ft. facility housing materials synthesis, design and modeling, device fabrication, and office space

Key Competencies

- ❖ Advanced magnetic materials
- ❖ EM simulation and modeling
- ❖ Device design from HF to mm-wave
- ❖ Prototyping and low-rate production





Questions?

- Douglas Linkhart
  - Principal Engineer
  - E-mail: dlinkhart@mtmgx.com
  - Phone: (781) 562-9137

- Michael Hunnewell
  - Director of Business Development
  - E-mail: mhunnewell@mtmgx.com
  - Phone: (617) 833-2950

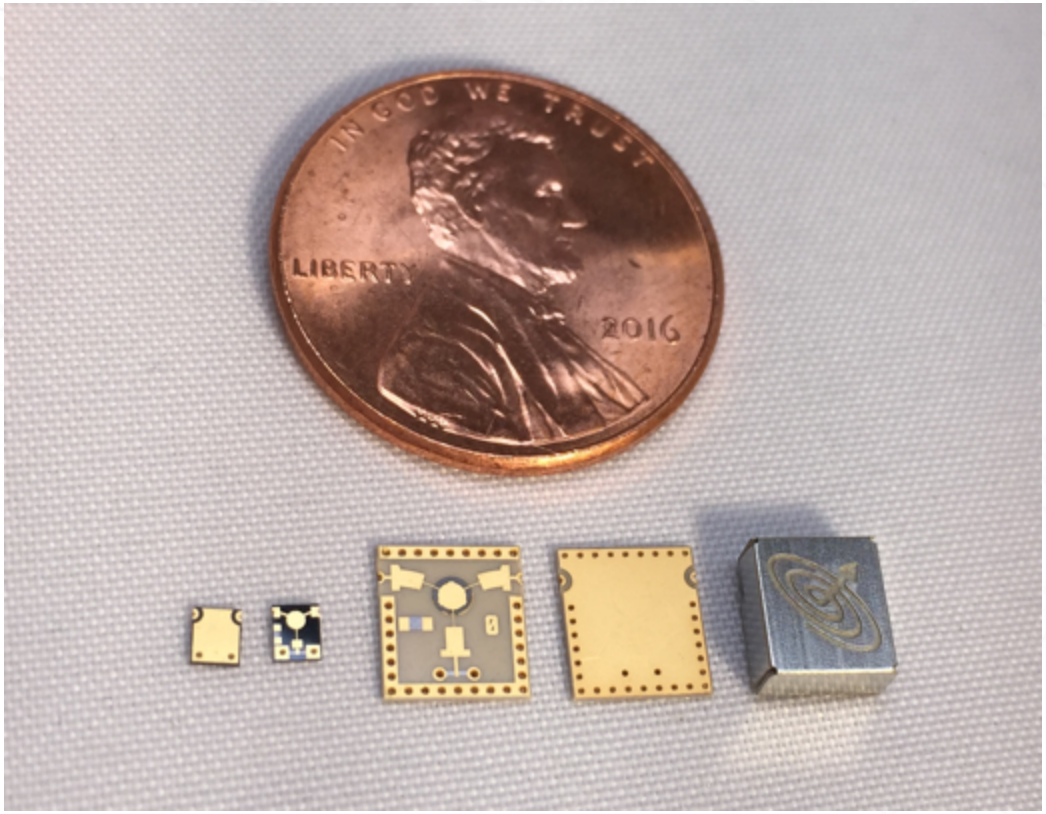
- Dr. Anton Geiler
  - President
  - E-mail: ageiler@mtmgx.com
  - Phone: (781) 562-0756 (x 101)

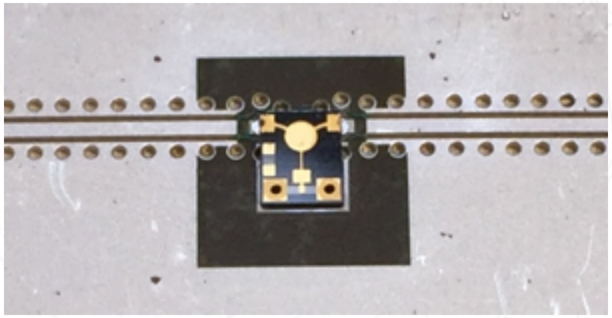
References & Backup Slides

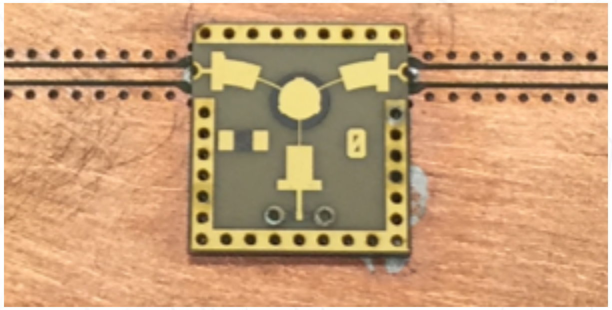
References:

1. Li, L., et al., “Technology Development for a Wide-swath Shared-aperture Cloud Radar (WiSCR),” ESTF 2016.
2. NASA ESTO 2016 Microwave Technologies Review and Strategy.
3. https://commons.wikimedia.org/wiki/File:Phased_array_radiation_pattern.gif
4. Rytting, D., “Network Analyzers: from Small Signal to Large Signal Measurements.”

K_A-Band Surface-Mount Self-Biased Isolators







K_A-Band Surface-Mount Self-Biased Isolator