METAMAGNETICS

ADVANCED FERRITE-BASED SOLUTIONS

METAMAGNETICS COMPANY OVERVIEW

U.S. based and veteran owned, Metamagnetics develops and markets advanced ferrite-based solutions to enhance the performance and effectiveness of mission-critical security, surveillance and communication systems. Our unparalleled knowledge of electromagnetism and materials science empowers break-through technologies that can bring significant value to defense and commercial projects. Efficient and agile, our team can help you rapidly design and deploy innovative solutions for current and next-generation radar, sensing and related systems.

Capabilities

- Low loss inductor and transformer cores for high performance power electronics
- Low profile, high power handling microstrip ferrite phase shifters for cost effective phased arrays
- Low profile, high power handling, tunable microstrip ferrite filters for systems operating in dense electromagnetic environments
- Ferrite junction circulators and isolators that do not require biasing magnets (self-biased)
- Advanced ferrite materials for nonlinear transmission lines and high power microwave generation
- Low profile, compact, broadband, metamaterial-based antennas

Our Partnerships Include

Lockheed Martin Corporation

NAVSEA

Northup Grumman

Office of Naval Research

Raytheon

Army PEO Missiles and Space

Contact

Michael Hunnewell
Director, Business Development
617-833-2950
mhunnewell@mtmgx.com

ITAR Registered" and DCAA Compliant

ABOUT METAMAGNETICS

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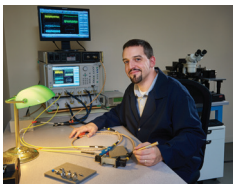
TEST, MEASUREMENT, AND FABRICATION SERVICES

Metamagnetics has a wide range of test, prototyping and measurement equipment, enabling us to offer fabrication, testing, and characterization services of structural, magnetic and high frequency properties of materials and devices.



Material characterization capabilities include:

- Vibrating sample magnetometry
- Ferromagnetic resonance spectrometry
- Complex permeability and permittivity spectroscopy (0.1 to 50 GHz)
- Power core loss characterization (0.1 to 10 MHz)
- Optical particle size analysis (100 to 1000 nm)
- Scanning electron microscopy
- X-ray diffractometry

Device characterization facilities include:

- Vector network analysis (0.1 to 50 GHz)
- Impedance analysis (10 kHz to 100 MHz)
- Spectrum analysis (100 Hz to 22 GHz)
- Pulsed and continuous wave power analysis (S and X band)
- Probe station and microstrip/ stripline test fixtures

Materials and device fabrication facilities include:

- Compaction presses with and without application of magnetic fields
- Vacuum and gas flow furnaces
- Machining and polishing
- Powder processing
- Photolithography
- Wire bonding

These services can be provided with or without expert analysis of data at competitive rates.

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CONSULTING AND DESIGN SERVICES

Consulting Services

Metamagnetics' knowledge and expertise in leveraging ferrite materials technology in current and next-generation systems is unmatched. A spin-out from the Northeastern University Center for Microwave Magnetic Materials and Integrated Circuits (CM3IC)—a world recognized leader in microwave and mm-wave ferrite materials, metamaterials and multiferroics—Metamagnetics offers expert consulting services.

Our mission is to optimize existing systems and components or enable entirely new ones by replacing out-of-date or inefficient ferrite devices and materials with new state-of-the-art concepts and compositions. Metamagnetics has demonstrated that utilizing the correct materials within a microwave system can directly increase performance, due to increased efficiency, reduced size and weight or reduced cost.

Metamagnetics' team has extensive industry experience working with the armed forces, DARPA, and major US defense prime contractors.

Design Services

Metamagnetics' expert design staff is comprised of Ph.D. scientists, engineers and consultants who collectively have more than 75 years of experience in the design, prototyping, and manufacturing of current and next-generation microwave devices. Metamagnetics leverages the core competencies of the company's staff and consultants for custom design and prototyping services, focused on the optimization of microwave devices such as antennas, circulators, phase shifters and filters.

We take great pride in working collaboratively with our customers and providing responsive, flexible services to ensure each device design meets or exceeds all customer specifications. Metamagnetics is an ITAR registered company.

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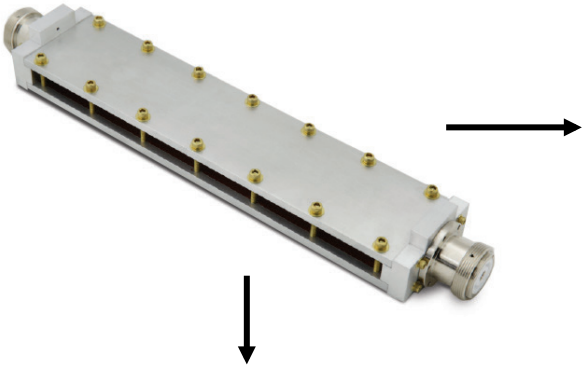
HIGH POWER RADIO FREQUENCY PULSED SOURCE



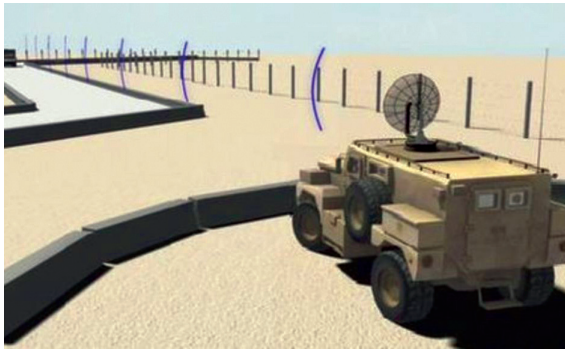


Photo courtesy of the U.S. Navy

- Ferrimagnetic non-linear transmission line (NLTL)
- Planar design
- Compact footprint
- All solid-state solution

- Ground penetrating radar technology for the detection of IEDs
- Disrupt/destroy electronic triggers
- Initiate premature detonation
- Inhibit radio-controlled detonation

The US Military relies on directed energy weapons to disrupt, damage or destroy adversary electronic equipment at a distance while minimizing collateral damage. Directed energy weapons of interest include high-energy lasers and high-power microwave/radio frequency (HPM/HPRF) sources.

Metamagnetics' ferrimagnetic Nonlinear Transmission Line (NLTL) offer an effective alternative solution to large and expensive traditional vacuum-based HPRF sources. Unlike traditional HPRF systems, Metamagnetics' ferrimagnetic NLTLs are drastically smaller and light weight; enabling employment of practical HPRF systems on ground vehicles and aircraft – increasing mobility. Metamagnetics' NLTL provide the added benefit of frequency tunability which reduces costs compared to large and expensive traditional HPRF systems.

Mounting

The HPRF system is composed of three major sections; HV source which generates the power; RF source (NLTL) which converts the power to microwaves; and antenna which radiates those microwaves out at the target. Metamagnetics' NLTLs can be coupled to directly to a variety of high voltage sources (spark gap, solid state) and antennas using high voltage connectors. Please contact us to discuss your interfaces.

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Features

- Frequency agility: Frequency radiated from the NLTL can be altered in real time enabling one system to be used for a broad range of targets and operational scenarios on the battlefield.

- Solid-state technology: Solid-state components allows for improved reliability and longevity of the NLTLs.

- Mobility: Metamagnetics' use of cost-effective solid state componentry increases reliability and eliminates expensive and bulky vacuum components utilized in legacy HPRF systems. As such, Metamagnetics systems are compact, lightweight, reliable and suitable for incorporation on ground vehicles as well as aircraft – increasing mobility.

- Dynamic tuning, innovative waveforms: Signals can be tailored to more effectively disrupt targets enabling dynamic adaption and higher success rate per system.

- Reduced heat generation and electrical energy consumption: To improve the power efficiency and further reduce the weight and size of the system, Metamagnetics' planar NLTL features permanent magnetic biasing system instead of current-driven solenoids.

- Capable of levels of 10 MW power, at a minimum, and rep-rates on the order of kHz in the frequency range of VHF to S band.

Options

- Coaxial Ferrimagnetic NLTL:

    - Higher range of frequency tuning
    - Custom sizes available

- Planar Ferrimagnetic NLTL:

    - Smaller footprint
    - Higher peak power
    - Custom sizes available

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ADVANCED FERRITE-BASED SOLUTIONS

RADIO FREQUENCY PROTECTION AND CLEANUP AUTO-TUNE FILTERS (ATFS)

Military operations rely on Electronic Warfare (EW) systems to deceive, deny, and/or destroy an adversary's signals, which range across the entire electromagnetic spectrum (EMS). These unwanted signals can easily render complex and expensive systems inoperable or even physically damage the circuitry itself. In some cases, the user's own electronics can interfere with each others preventing the user from running applications simultaneously. One case of this conflict is when your own jamming system ends up jamming your own electronics, forcing you to turn off your jamming system just to establish a line of communication. Jamming, co-site interference, signal fratricide, antenna mismatch, and overloading are all major EMS issues being played out on the battlefield today and will become increasingly larger issues for years to come.

One current method to combating these problems requires complex active systems that search for incoming harmful signals and reduce those signals while allowing desired friendly signals to pass through. Unfortunately these solutions tend to be large, complex, and expensive. Also since it is an active system, there is a lag from when the attack hits to when the countermeasure is implemented. During this reaction time, the EW attack can reach the electronics being safeguarded, causing irreparable damage. Another method to fighting these attacks is to just muffle all incoming signals altogether. The disadvantage to this is not only are the dangerous adversary signals muffled, but friendly desired signals are muffled as well. Therefore, a second workflow needs to be implemented to amplify the quieted desired signals again.

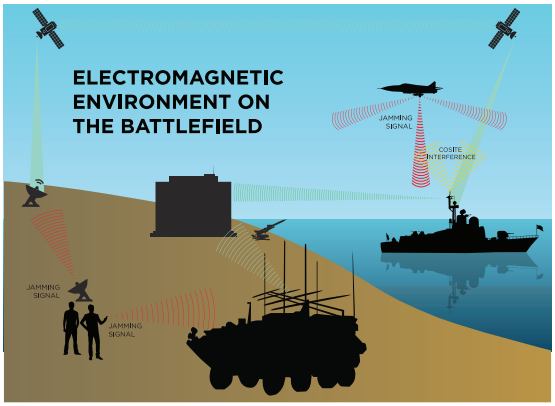

Fig. 1. Left are some examples of the electromagnetic environment on the battlefield. Secure communications are crucial to maintain communications from land, to sea, to air, to even space. At any moment these systems could be under attack including small handheld systems by insurgents, advanced widespread systems like jet carried jamming systems, and even interference from one's own electronic systems. As the battle for bandwidth continues to grow the need to protect one's own system will become even more dire.

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Metamagnetics has proposed a simpler, more effective and more economical answer to this problem through our auto-tune filters (AtFs). These devices work by setting a power threshold level which no one signal can exceed. If a signal exceeds this threshold, the AtF automatically limits it by attenuating the dangerous signal. In the meantime, all safe and desired radio frequency (RF) signals operating below the power threshold pass through the system largely unaltered. Hazardous signals are taken care of without any adverse effects to your wanted signals. This wide band component can be applied and easily designed into almost any application where your antenna system could be receiving a possible EW threat and/or unwanted RF interference. Whether it is topside on a sea system, in the sky for an aerial division, or on the ground for troop communication and land based satellite uplink stations, any RF receiving device can be easily benefit from this component.

NOTABLE FEATURES OF METAMAGNETICS' ATFS

- Automatically adapts to filter interferes above a preset power level without attenuating other signals
- Fast response time and excellent selectivity
- Multi octave bandwidths with high linearity
- Completely passive and suitable for phased array application
- Adaptable across multiple platforms for land, sea, or air solutions

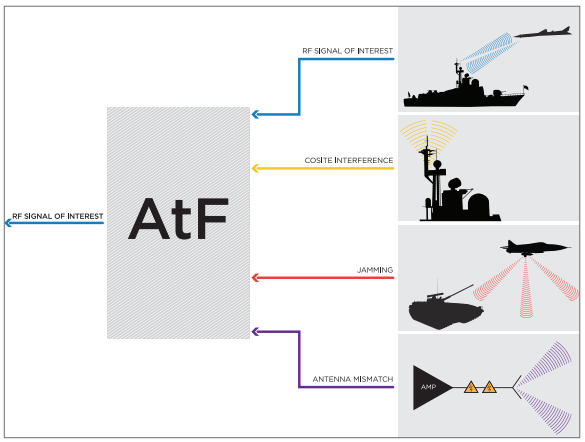

Fig. 2. Interference with your receiver can come from a variety of sources (as seen above) and sometimes more than one of these problems can arise simultaneously. Metamagnetic's AtF can limit and reduce all of these harmful signals at the same time without compromising your RF signal of interest. This allows all in one solution, whereas alternative methods force the user to build out multiple systems to counter each individual EMS problem like in the case of multiple jamming signals. Where two notch filters would be used to mitigate two jamming signals, the AtF can handle both signals with one unit.

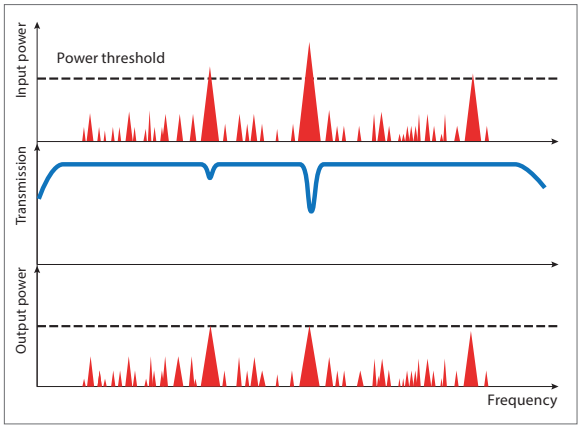

Fig. 3. The AtF provides automatic selective attenuation (aka signal limiting) of above-threshold power signals while all other signals propagate unaltered. This capability allows for the mitigation of EMS threats and interference with improved performance at a fraction of the cost of current solutions.

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AUTO-TUNE FILTER SPECIFICATIONS

Metamagnetics has created a completely new solution to mitigate the RF interference problem. Don't call it a notch filter or a limiter. Metamagnetics' auto-tune filters provide a broadband, fast response, simple solution compared to active limiting.

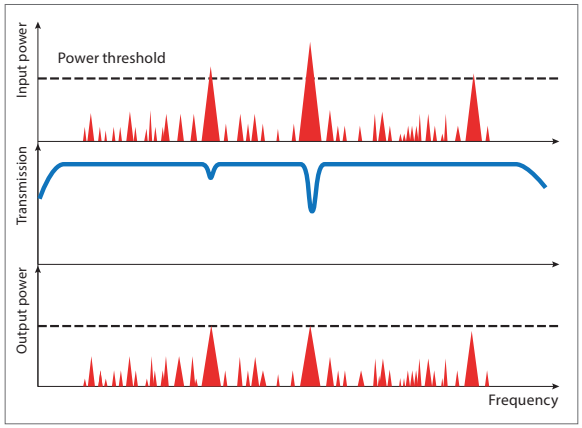

Fig. 1. The AtF provides automatic selective attenuation (aka signal limiting) of above-threshold power signals while all other signals propagate unaltered. This capability allows for the mitigation of EMS threats and interference with improved performance at a fraction of the cost of current solutions.

Frequency	Power Threshold (dBm)	Attenuation (dB)	Insertion Loss (dB)	Response Time (ns)
2 GHz	-3 to +3	20	1.5	50
2-4 Ghz	0 to +6	20	1.5	50
4-8 GHz	+3 to +9	30	1.5	50
8-12 GHz	+6 to +12	30	2	50
12-18 GHz	+9 to +15	30	3	50

Mounting

These Auto-tune Filters can be mounted to a housing or printed circuit board using conductive epoxy or solder. Please let us know your process temperature profiles so that we can ensure magnetic stability of the devices.

Electrical interconnects can be implemented using wire bonds or ribbons. Surface mount designs are available. Please contact us to discuss your interfaces.

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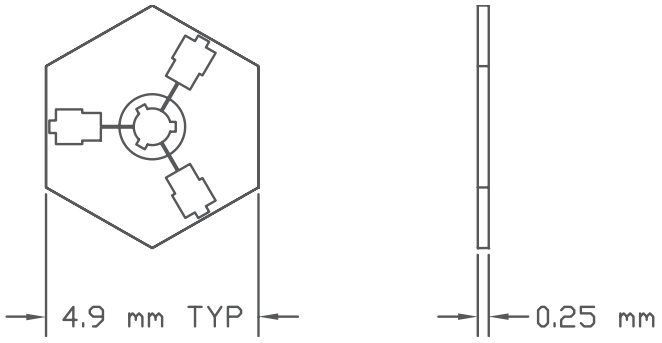
K_A-BAND SELF-BIASED CIRCULATORS AND ISOLATORS

Frequency GHz	Bandwidth GHz	Isolation dB (min)	Insertion Loss dB (max)	VSWR (max)	Power Handling W CW	Operating Temp, °C
28 - 32	(full)	14	1.3	1.45:1	8	0 to +50
29 – 31	(full)	19	1.2	1.25:1	10	0 to +50
29.5 – 30.5	(full)	20	1.0	1.20:1	10	0 to +50
29.6 – 30.6	(full)	20	1.0	1.20:1	10	0 to +50
34.5 – 35.5	(full)	20	1.0	1.20:1	10	0 to +50
26 – 40	1	20	1.0	1.20:1	8	0 to +50
26 - 39	2	18	1.3	1.30:1	8	0 to +50
26 - 38	4	13	1.4	1.50:1	8	0 to +50

Typical Circulator Dimensions



Options

- Lower center frequencies with slightly reduced performance
- Rectangular footprints with Y or T port configurations
- Isolators: termination options include small integrated termination or high-power dc-isolated meander-line terminations
- Ground vias for coplanar waveguide launches
- Surface-mount versions

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Mounting

These self-biased circulators and isolators can be mounted to a housing or printed circuit board using conductive epoxy or solder. Please let us know your process temperature profiles so that we can ensure magnetic stability of the devices.

Electrical interconnects can be implemented using wire bonds or ribbons. Please contact us to discuss your interfaces. We can design your circulator or isolator to absorb some or all of your bond wire or ribbon inductance!

Features

- Smaller: at Ka-band, the biasing magnet of traditional circulators and isolators can be up to 90% of the component size, and this problem is augmented as you move up in frequency and the magnet becomes an even larger portion of the device.
- Lighter: UAVs, missiles and space systems are weight-sensitive to the gram. By eliminating the biasing magnet required by traditional devices, Metamagenetics has achieved a 95% reduction in component weight.
- Resistant to Shock and Vibration: to avoid interference with the circuitry, a traditional circulator has its magnet attached by a weak epoxy. This creates a significant problem in any application with high shock or vibration. Metamagnetics self-biased circulators have been tested to survive over 50,000 Gs enabling new communication platforms for small caliber projectiles.
- End to Rare-Earth Magnet Dependency: the composition of the biasing magnet found in traditional circulators is typically of rare earths- NdFeB (Neodymium Iron Boron) or SmCo (Samarium Cobalt). Metamagnetics self-biased design doesn't require a rare earth magnet.
- Economical: a re-engineered product design has enabled Metamagnetics to remove many of the costly steps in the manufacturing process. This creates a circulator with enhanced performance and functionality while boasting a highly competitive price point.

Contact us today to learn more about our self-biased circulators and isolators. Our team of experts can help you find the best fit with a pre-existing component or a custom designed solution to meet the most rigorous specifications of both DOD and commercial customers.

Please direct all sales and informational inquiries to (617) 833-2950

METAMAGNETICS

ADVANCED FERRITE-BASED SOLUTIONS

FERRITE PHASE SHIFTERS

Metamagnetics' ferrite phase shifters are expertly designed with low insertion loss and high power handling capability to satisfy the requirements of current and next-generation phased array systems. Available in surface mount or connectorized packages, components are manufactured to fit array spacing and the most demanding performance requirements.

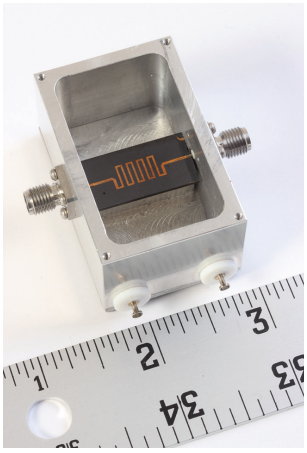

Fig. 1. Ferrite phase shifters manufactured to fit array spacing and the most demanding performance requirements.

Phase shifters can be deployed in surface, shipboard, airborne or space platforms at low cost because they do not require hermetic packaging as they are naturally radiation hardened. Metamagnetics' phase shifters are inherently analog devices, so high bit resolution can be achieved without a linear scale up of losses, a disadvantage of digital semiconductor devices.

Metamagnetics also develops and manufactures high efficiency, low power driver circuitry. The drivers can be designed to address the most stringent tuning accuracy, response time and jitter specifications. Continuously driven or latched operation can be realized to meet the power consumption requirements of a wide range of platforms. The result is a broadband, low loss, low cost and high power handling component.

The combination of high peak and average power handling capability with low insertion loss and low power consumption makes Metamagnetics' phase shifters well suited for both passive and corporate feed phased arrays and other radars. Metamagnetics has the manufacturing capacity in place to fill both small and large orders, and our team works diligently to ensure your product is expertly designed to meet all specifications.

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METAMAGNETICS
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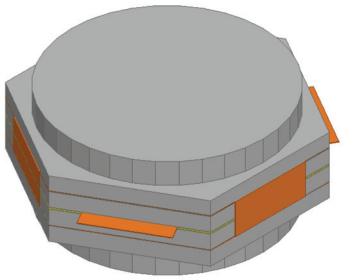
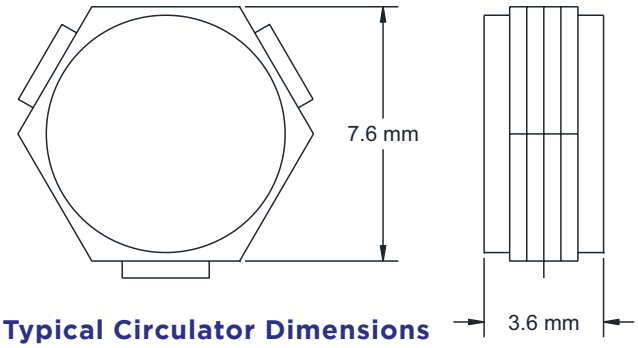
LUMPED ELEMENT CIRCULATOR





Typical Circulator Dimensions

Frequency GHz	Bandwidth %	Isolation dB (min)	Insertion Loss dB (max)	VSWR (max)	Power Handling W CW	Operating Temp, °C
0.8 - 2.4	10	20	0.5	1.25:1	10	0 to +70

Tuning

- Circulator can be tuned for any center frequency in the range of 0.8 – 2.4 GHz using external customer-furnished capacitors and inductors. A typical tuning network consists of one shunt capacitor, one series capacitor, and one series inductor. Approximate element values furnished on request.
- Wider bandwidths can be achieved using more complex tuning networks.

Mounting

- These circulators can be mounted to a housing or printed circuit board using conductive epoxy or solder. Please let us know your process temperature profiles so that we can ensure magnetic stability of the devices.
- Alternatively, circulators can be supplied with mounting flanges for screw attachment.
- Electrical interconnects can be implemented by soldering the circulator tabs to a printed circuit board.

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