MicroHarmonics

Isolators & Circulators 25-400 GHz

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Contents

Introduction

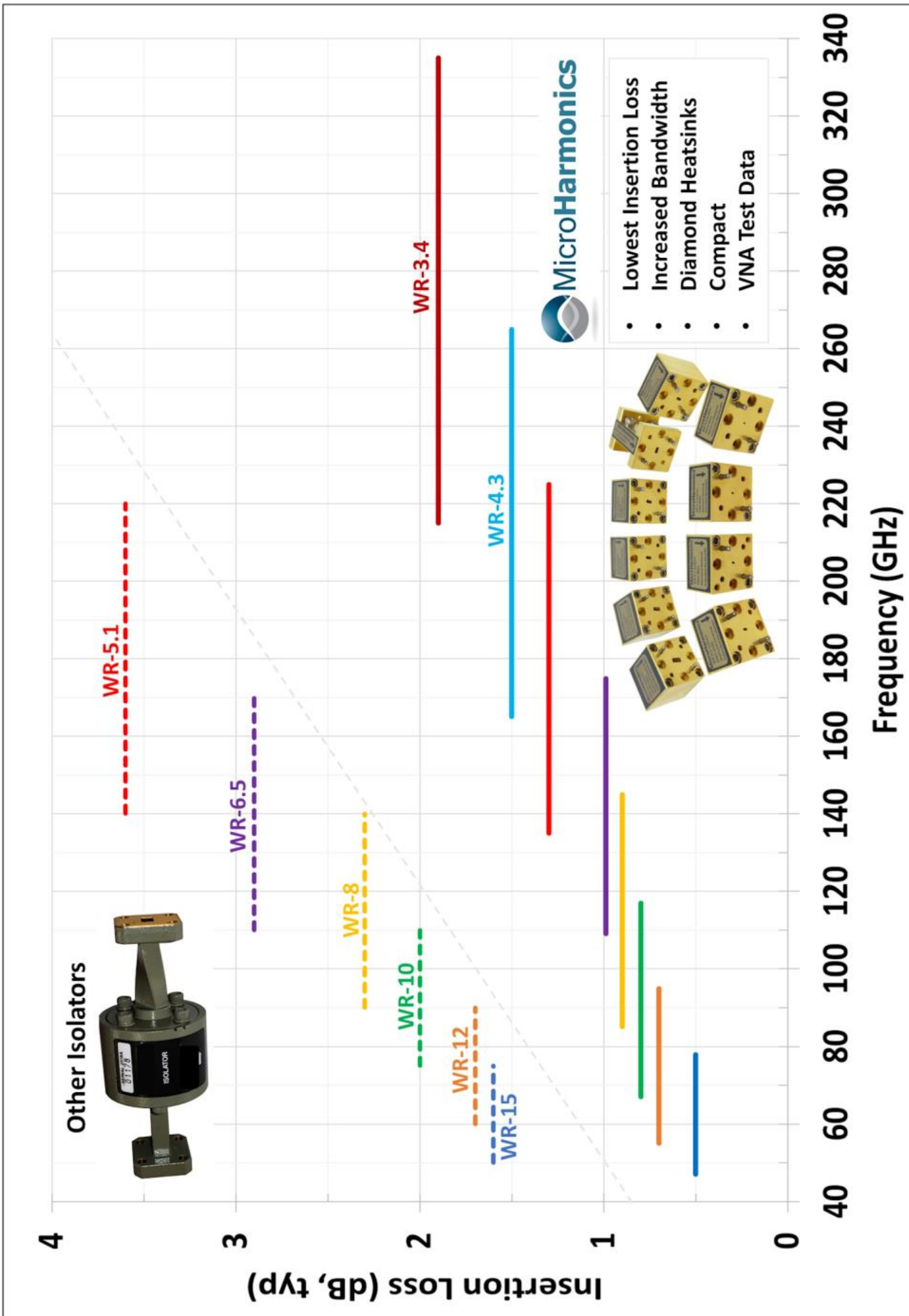
Micro Harmonics is a high-tech company located in Fincastle, Virginia. We specialize in advanced ferrite components including Faraday rotation isolators and circulators. We offer a complete line of Faraday rotation isolators covering 50-330 GHz in every standard waveguide band from WR-15 through WR-3.4. We plan to extend this line lower to WR-28 (26-40 GHz) and higher to the WR-2.8 (260-400 GHz) and WR-2.2 (330-500 GHz) bands. We are currently developing a line of isolators designed for optimal performance at cryogenic temperatures. In March of 2019 we introduced our first cryogenic isolator in WR-10. Cryogenic models at bands from WR-15 through WR-3.4 will follow.

We design and manufacture all of our products in the United States. Our components were developed under SBIR grants through NASA JPL. Because of language in the congressional SBIR authorization, our products can be sole sourced for government acquisitions.

Why Choose Micro Harmonics Products?

Our products are the most advanced on the market today. They exhibit state-of-the-art performance in terms of low-insertion loss, broad-bandwidth, low port reflections, and the highest frequency coverage in the industry. The graph on page 3 gives a good illustration of how our insertion loss and bandwidth compare to the competition. Our isolators employ a unique diamond heatsink for improved power handling and reliability. Every component is tested over the full band on a vector network analyzer to ensure compliance. All parts are thoroughly examined for dimensional tolerance. We do reliability testing (Belcore) and cryogenic cycling tests. We use nylon thread lockers to ensure that our components stay assembled in the field. All of our products are fully warranted. Yet with all of these advantages, our components remain competitively priced.

Many companies are engineering our isolators into their systems. They are seeing real tangible improvements in system performance. Their systems are getting smaller and better. Don’t get left behind by the competition.

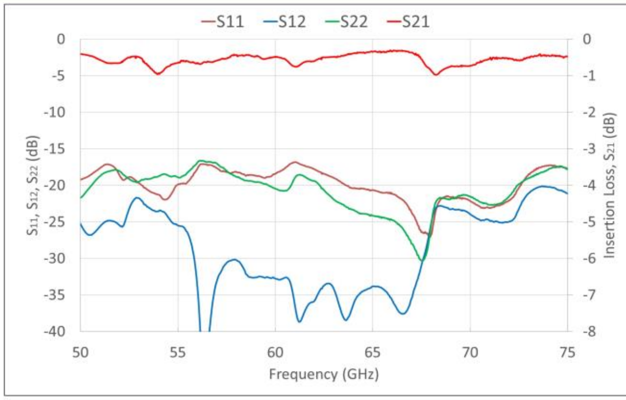

Other Isolators
ISOLATOR
WR-5.1
WR-6.5
WR-8
WR-10
WR-12
WR-15
WR-3.4
WR-4.3
MicroHarmonics
• Lowest Insertion Loss
• Increased Bandwidth
• Diamond Heatsinks
• Compact
• VNA Test Data
Insertion Loss (dB, typ)
4
3
2
1
0
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
Frequency (GHz)

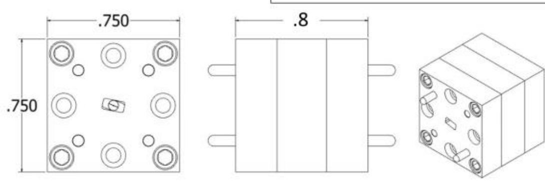
WR-15 Isolators (50-75 GHz)

Model: FR148

Specifications	
Flange	WR-15
Frequency (GHz)	50-75
Insertion Loss (dB, typ)	0.7
Insertion Loss (dB, max)	1.8
Isolation (dB, typ)	25
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.4:1
Maximum Power (W)	1.7
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.





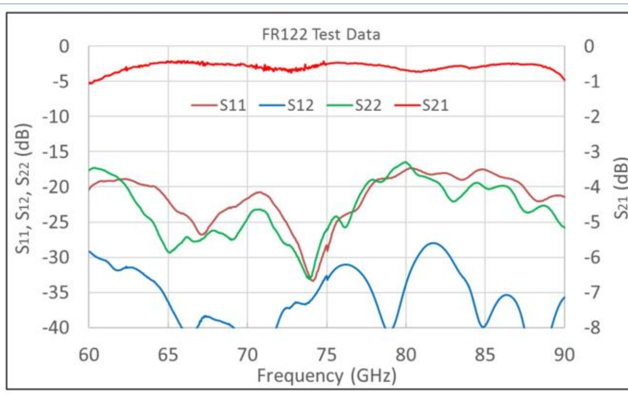
April 1, 2020

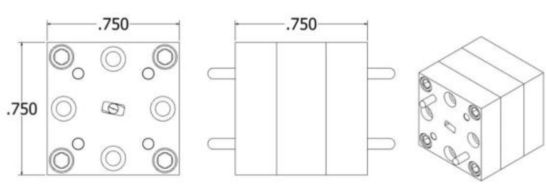
WR-12 Isolators (60-90 GHz)

Model: FR122

Specifications	
Flange	WR-12
Frequency (GHz)	60-90
Insertion Loss (dB, typ)	0.8
Insertion Loss (dB, max)	2.2
Isolation (dB, typ)	25
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	22
VSWR (max)	1.4:1
Maximum Power (W)	1.5
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.





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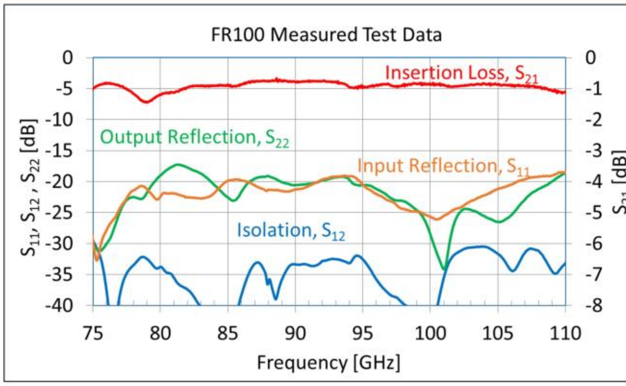
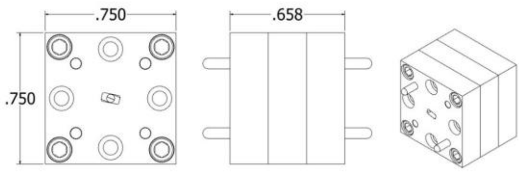
WR-10 Isolators (75-110 GHz)

Model: FR100

Specifications	
Flange	WR-10
Frequency (GHz)	75-110
Insertion Loss (dB, typ)	0.8
Insertion Loss (dB, max)	1.8
Isolation (dB, typ)	30
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	22
VSWR (max)	1.4:1
Maximum Power (W)	1.3
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.





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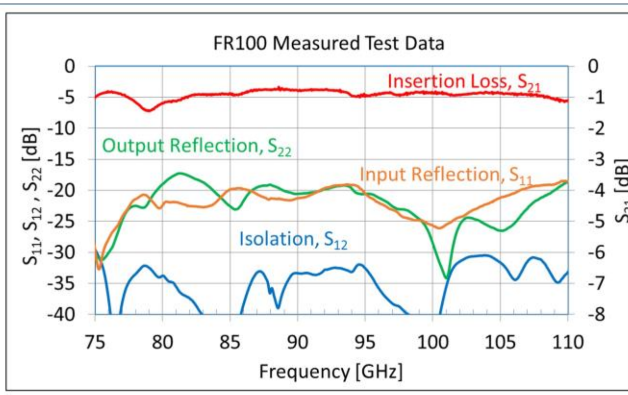
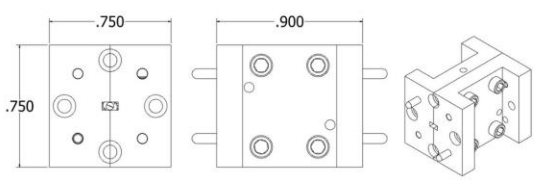
Model: FR100D*

Specifications	
Flange	WR-10
Frequency (GHz)	75-110
Insertion Loss (dB, typ)	1.4
Insertion Loss (dB, max)	2.4
Isolation (dB, typ)	30
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.4:1
Maximum Power (W)	1.3
Diamond Heatsink	Yes

*See article on drop-in isolators in this catalog for more information.





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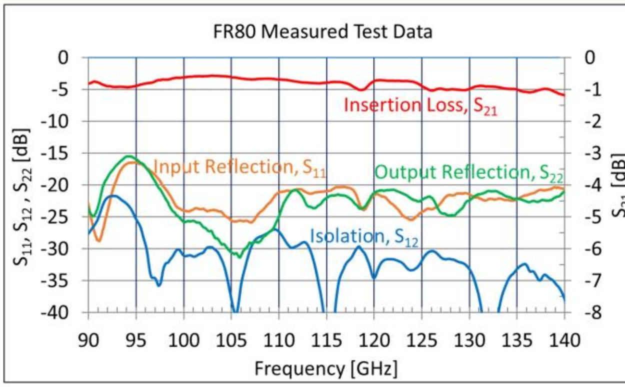
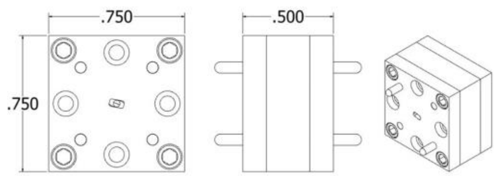
WR-8 Isolators (90-140 GHz)

Model: FR80

Specifications	
Flange	WR-8
Frequency (GHz)	90-140
Insertion Loss (dB, typ)	0.9
Insertion Loss (dB, max)	2.2
Isolation (dB, typ)	30
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.4:1
Maximum Power (W)	1.1
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.





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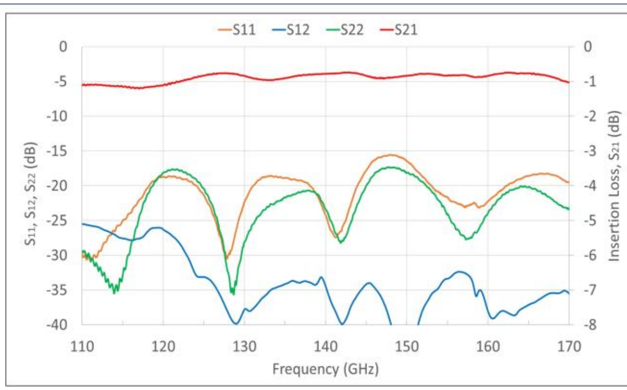
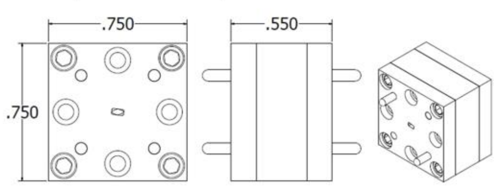
WR-6.5 Isolators (110-170 GHz)

Model: FR65

Specifications	
Flange	WR-6.5
Frequency (GHz)	110-170
Insertion Loss (dB, typ)	1.0
Insertion Loss (dB, max)	1.8
Isolation (dB, typ)	24
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.4:1
Maximum Power (W)	0.9
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.





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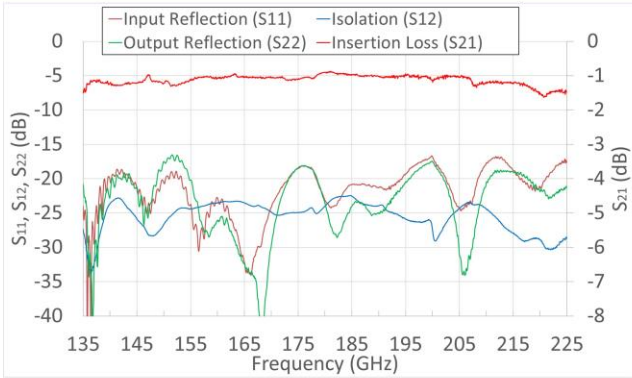
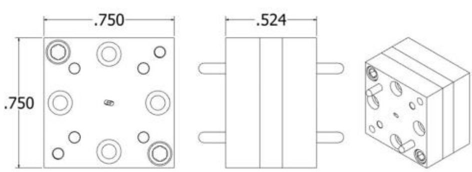
WR-5.1 Isolators (140-220 GHz)

Model: FR51

Specifications	
Flange	WR-5.1
Frequency (GHz)	140-220
Insertion Loss (dB, typ)	1.4
Insertion Loss (dB, max)	2.5
Isolation (dB, typ)	25
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.4:1
Maximum Power (W)	0.75
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.





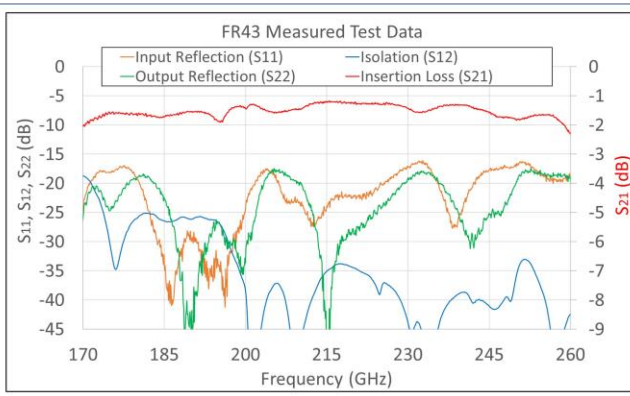
April 1, 2020

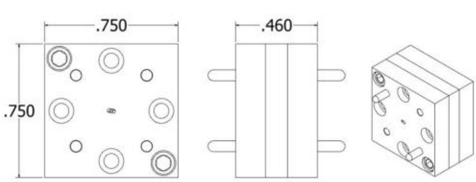
WR-4.3 Isolators (170-260 GHz)

Model: FR43

Specifications	
Flange	WR-4.3
Frequency (GHz)	170-260
Insertion Loss (dB, typ)	1.5
Insertion Loss (dB, max)	3.2
Isolation (dB, typ)	20
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.5:1
Maximum Power (W)	0.6
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.





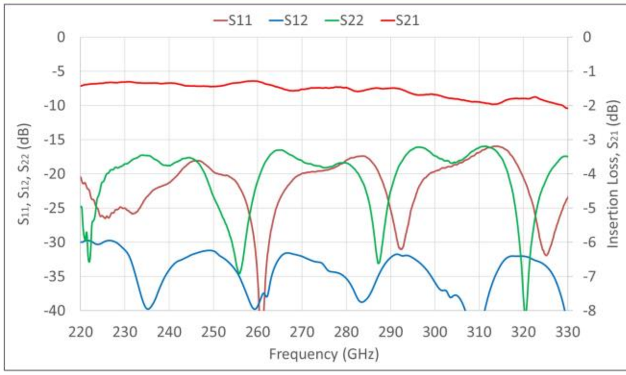
October 15, 2019

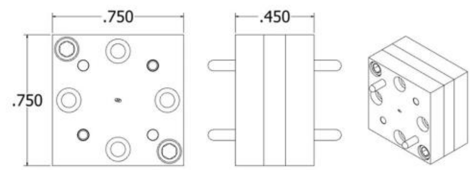
WR-3.4 Isolators (220-330 GHz)

Model: FR34

Specifications	
Flange	WR-3.4
Frequency (GHz)	220-325
Insertion Loss (dB, typ)	2
Insertion Loss (dB, max)	3.5
Isolation (dB, typ)	25
Isolation (dB, min)	18
Input Return Loss (dB, typ)	19
Output Return Loss (dB, typ)	19
VSWR (max)	1.5:1
Maximum Power (W)	0.4
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.





March 19, 2019

WR-2.8 & WR-2.2 Isolators

We are currently developing an isolator to cover the WR-2.8 band (260-400 GHz). Once that development is complete we will extend the work to the WR-2.2 band (330-500 GHz). The primary challenge is not EM design but rather fabrication and alignment of the constituent parts. Please visit our website for updates on our progress.

Cryogenic Isolators

We are currently developing a line of cryogenic isolators through an SBIR grant with NASA JPL. There are numerous material issues that must be addressed to ensure that the isolators are able to withstand the rigors of thermal cycling. Also, the ferrite saturation magnetization is temperature dependent. An isolator designed for room temperature operation will perform poorly when cooled. The degradation results from a roughly 20% increase in the magnetization which gives rise to a 9° over-rotation of the EM field. The end result is a slight rise in the insertion loss and a significant drop in isolation. This can be compensated by changing the ferrite length and retuning the transitions.

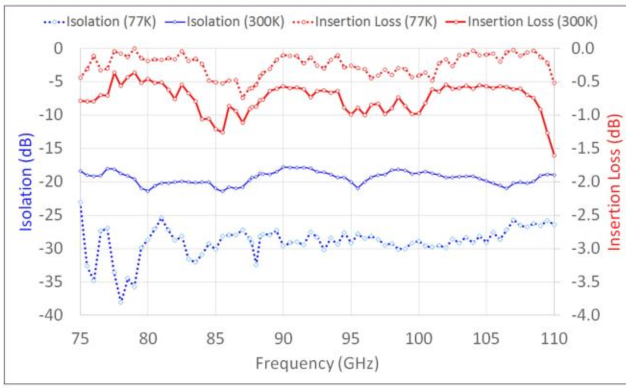
The initial development effort has been completed in WR-10 (75-110 GHz). These units have been fully characterized at both room temperature and 77 K. We plan to extend this line to every band from WR-15 through WR-3.4.

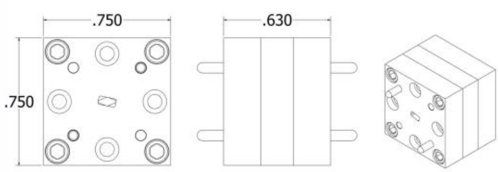
WR-10 Cryogenic Isolators (75-110 GHz)

Model: FR100C

Specifications	
Flange	WR-10
Frequency (GHz)	75-110
Insertion Loss (dB, typ, 300K)	0.9
Insertion Loss (dB, typ, 77 K)	0.4
Isolation (dB, typ, 300 K)	19
Isolation (dB, typ, 77 K)	26
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.4:1
Maximum Power (W)	1.0
Diamond Heatsink	No

Every isolator is tested on a vector network analyzer to ensure conformity.





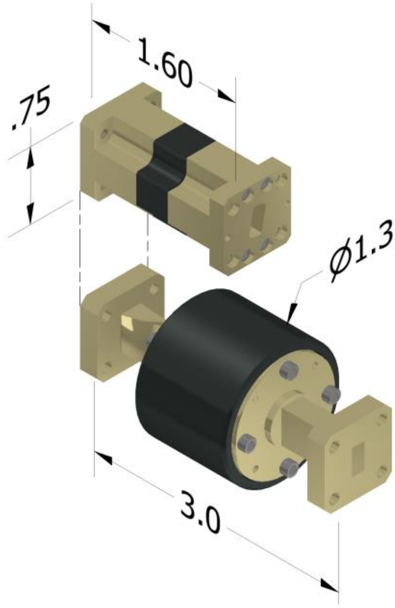
March 19, 2019

Warranty

All Micro Harmonics products are fully warranted for one year from the time of purchase. Please visit our website for more information.

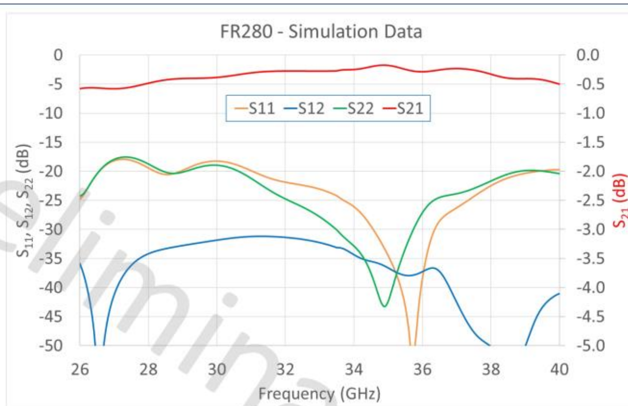
WR-28 Isolators

We are developing an isolator for the WR-28 band (26-40 GHz). The goal is to provide improved RF performance in a more compact size. A sketch of the new isolator is shown to the right alongside a typical WR-28 isolator offered by other vendors. Our isolator is 1.6 inches long with a cross section that does not exceed 0.75 inches square. The flange screws are accessible from the reverse side of the flange. Our WR-28 isolator will employ a diamond heatsink for improved power handling. The data in the graph below are from our HFSS simulation models. A cryogenic version will follow.

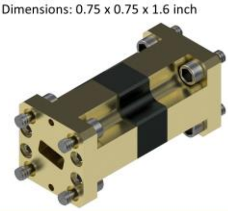


Model: FR280

Specifications	
Flange	WR-28
Frequency (GHz)	26-40
Insertion Loss (dB, typ)	0.5
Insertion Loss (dB, max)	1
Isolation (dB, typ)	30
Isolation (dB, min)	23
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.4:1
Maximum Power (W)	4
Diamond Heatsink	Yes



Dimensions: 0.75 x 0.75 x 1.6 inch

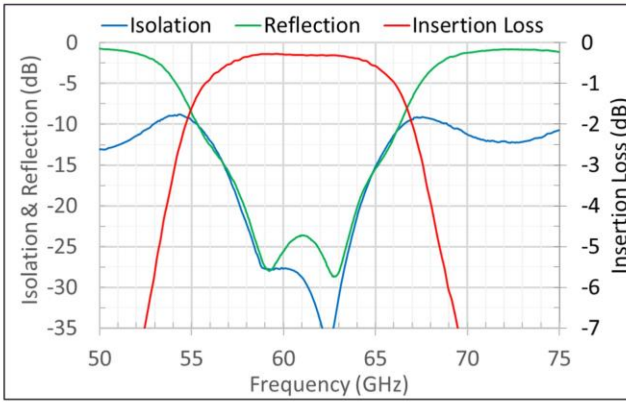


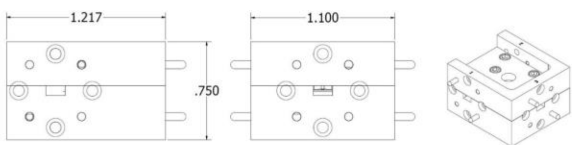
April 4, 2020

WR-15 Circulators

Model: YC148-61

Specifications	
Flange	WR-15
Frequency (GHz)	58-64
Insertion Loss (dB, typ)	0.4
Insertion Loss (dB, max)	0.6
Isolation (dB, min)	20
VSWR (max)	1.3:1



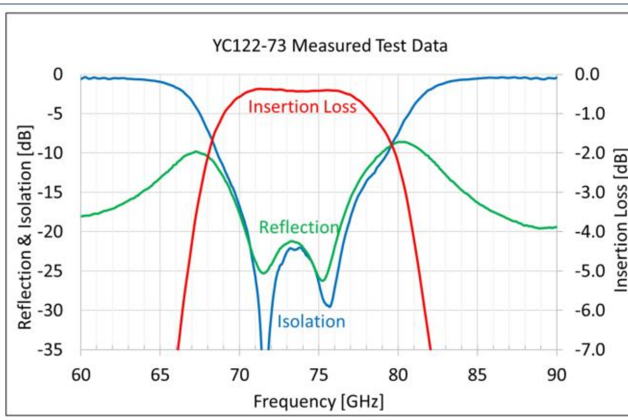


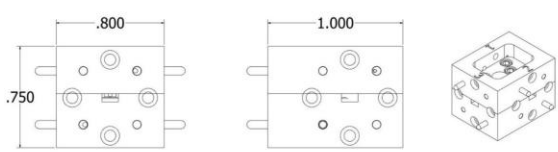
March 25, 2019

WR-12 Circulators

Model: YC122-73

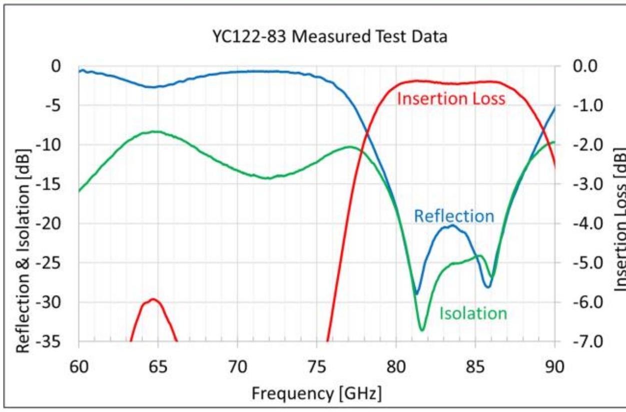
Specifications	
Flange	WR-12
Frequency (GHz)	71-76
Insertion Loss (dB, typ)	0.4
Insertion Loss (dB, max)	0.6
Isolation (dB, min)	20
VSWR (max)	1.3:1

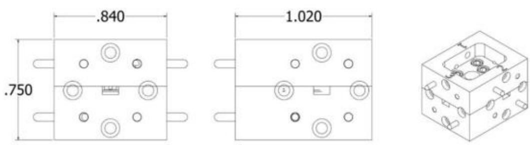




Model: YC122-83

Specifications	
Flange	WR-12
Frequency (GHz)	81-86
Insertion Loss (dB, typ)	0.5
Insertion Loss (dB, max)	0.7
Isolation (dB, min)	20
VSWR (max)	1.3:1

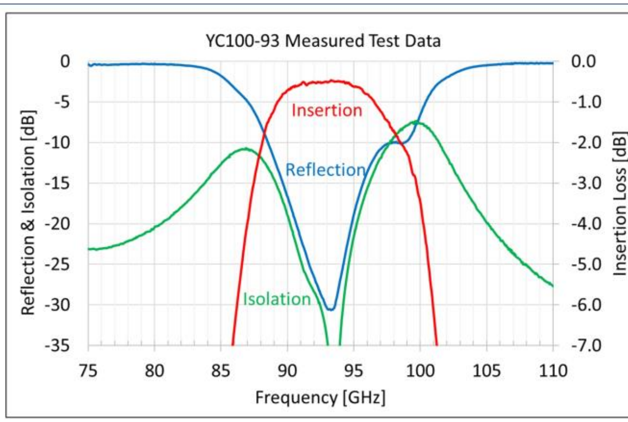


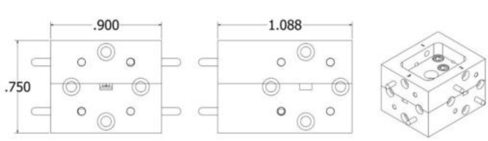


WR-10 Circulators

Model: YC100-93

Specifications	
Flange	WR-10
Frequency (GHz)	90-95
Insertion Loss (dB, typ)	0.6
Insertion Loss (dB, max)	0.8
Isolation (dB, min)	20
VSWR (max)	1.4:1

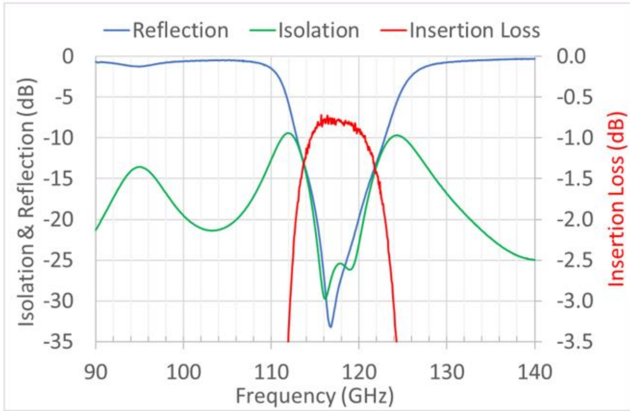


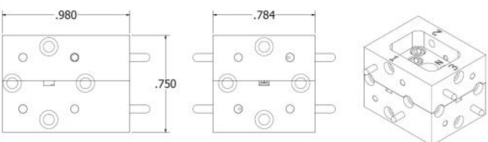


WR-8 Circulators

Model: YC80-118

Specifications	
Flange	WR-8
Frequency (GHz)	115-120
Insertion Loss (dB, typ)	0.9
Insertion Loss (dB, max)	1.1
Isolation (dB, min)	18
VSWR (max)	1.4:1

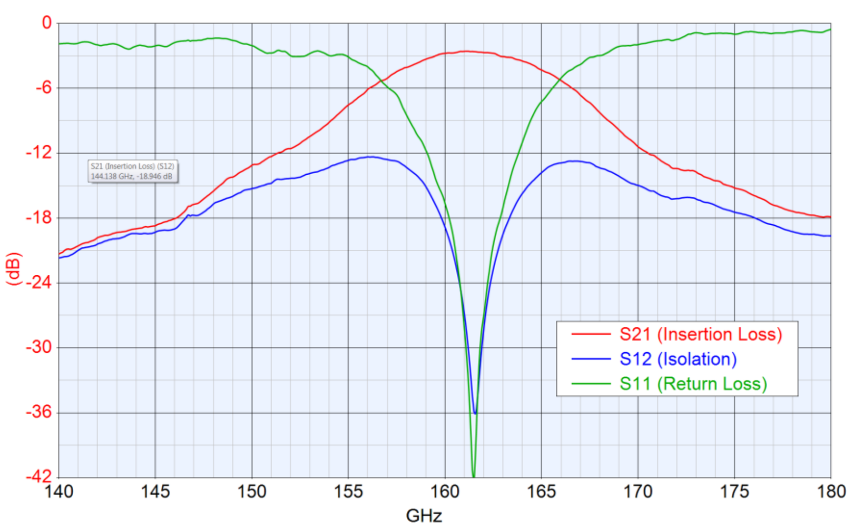




May 7, 2019

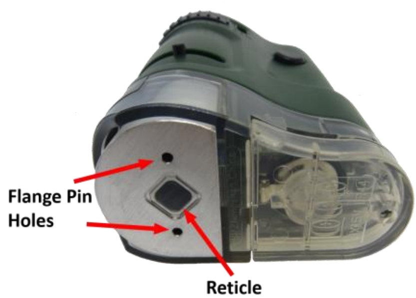
WR-5.1 Circulator Prototype

The graph below shows measured results from our WR-5.1 prototype. Please visit our website for more information on our circulator development.

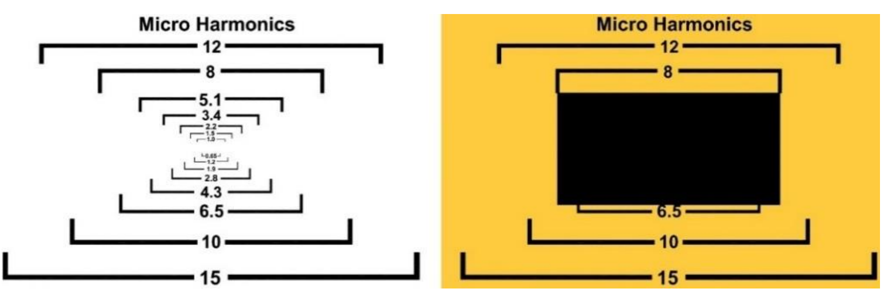


MMW Flange Identifier Tool

This tool is designed as a low-cost way to identify waveguide flanges from WR-15 to WR-0.65 (50 GHz to 1.7 THz). It comprises a microscope with adjustable zoom (20-40 X), adjustable focus, LED illumination and a reticle. The reticle has features to identify the waveguide flange. A pair of waveguide flange alignment pin holes are located at the bottom of the microscope. Slide the alignment pins of the flange you wish to identify into the holes at the base of the microscope. The reticle is slightly recessed so that it will come into close proximity but not touch the flange.



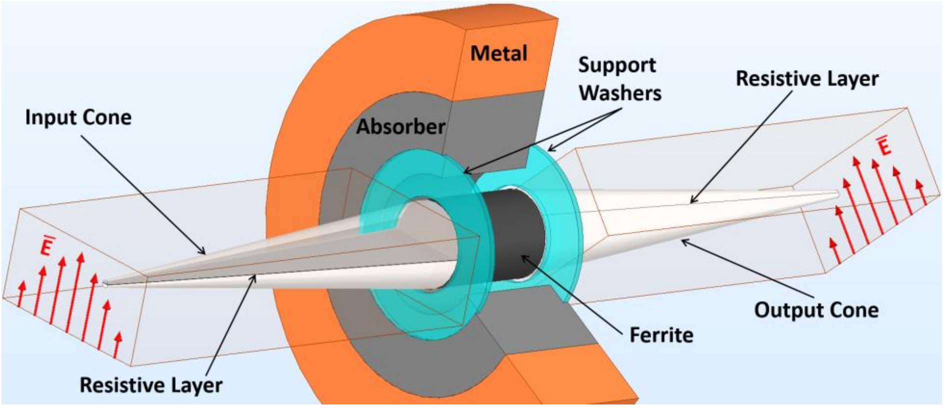
When the microscope is held to a lighted background (no waveguide flange attached), all features on the reticle are visible as shown in the left side of the graphic below. Before attaching to a waveguide flange, adjust the focus and magnification. When the microscope is attached to a waveguide flange, the area on the interior of the waveguide will go dark since there is no reflecting surface. For example, the graphic on the right shows the illuminated reticle with the microscope attached to a WR-8 waveguide flange. Although the markings for the 15, 12, 10 and 6.5 are still visible, only the "8" marker spans the exact length of the broad-wall of the waveguide thus identifying the flange as WR-8.



Diamond Heatsink Technology

Our isolators employ a modern design yielding much lower insertion loss than other commercial products. They also work over much broader bandwidths in excess of standard waveguide bands. But there is another important difference that sets them apart from the competition. Our isolators employ a diamond support disc that channels heat from the resistive layer in the cone to the metal waveguide block and thus they can handle greater reverse power levels. To our knowledge no other commercial isolators offer this advantage.

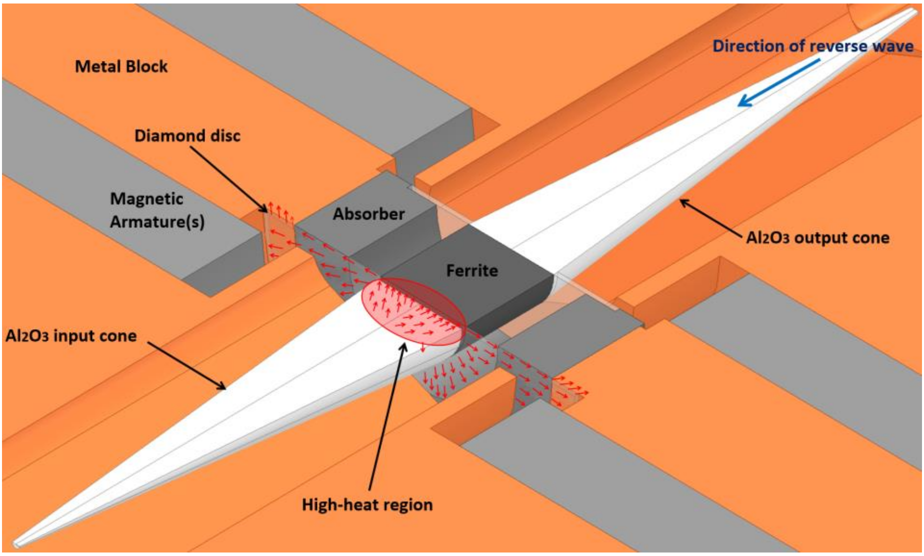
At the heart of a Faraday rotation isolator is a pair of alumina cones and a cylindrical ferrite core. The cones are used to couple EM fields from the waveguides to the ferrite. The cones are bisected by a resistive layer along their central axis. In most commercial Faraday rotation isolators, the ferrite and cones are suspended by a pair of washer-shaped supports as shown in the sketch below.



The cone & ferrite assembly is inserted through the inner support holes and then attached with a non-conductive epoxy. The support material is typically BOPET, Styrene, a resin or some other material with a low dielectric constant and low loss at millimeter-wave frequencies. Materials with these characteristics are generally in the class of thermal insulators and thus the cones and ferrite are thermally isolated from the metal block.

Power entering the output port of the isolator is absorbed in the resistive layer bisecting the input alumina cone. The absorbed power is converted to heat energy. Very little of this heat energy can be channeled away by thermal conduction through the washer-shaped supports, rather it must be dissipated through a radiative process or by means of convection through the surrounding air. The resistive layers are thus subject to high heat levels and even damage if too much reverse power is incident on the device. Historically this was not an issue as there was very little power available at these frequencies. But as higher power sources are becoming available there is a renewed interest in the power ratings of these devices.

At Micro Harmonics we have replaced the input support washer with a uniform high-grade optical CVD diamond disc. The diamond disc does not have a hole at the center. Diamond is the ultimate thermal conductor approaching 2200 W/mK, more than five times higher than copper. The graphic below shows a split-view of the isolator to give a better view of the constituent parts.



The diamond disc is sandwiched between the base of the input cone and the ferrite. The diamond disc is in intimate contact over the entire area of the cone base. This is the optimal location for the diamond disc since it is the region subject to the highest heat levels. The diamond disc is attached to the metal waveguide block over its entire periphery and thus provides an excellent conduit to channel heat away from the resistive layer. The red arrows indicate the path of heat flow. This topology is clearly superior for thermal conduction and thus our isolators will operate at lower temperatures.

Isolators Designed for Low-Insertion Loss

Commercial Faraday rotation isolators have been around since the 1960's. Traditional builds have good isolation throughout the microwave and millimeter-wave bands. The insertion loss is low in the microwave bands, but steadily increases with frequency. At mm-wave frequencies the insertion loss becomes problematic. For instance, in the WR-10 band (75-110 GHz) the insertion loss can exceed 3 dB. In the WR-5.1 band (140-220 GHz) the insertion loss can be more than 5 dB. Isolators in the WR-4.3 band (170-260 GHz) are difficult to find and have insertion loss exceeding 5 dB. At these frequencies the constituent parts are very small, and they are difficult to fabricate and align. And with the high insertion loss, there hasn't been much demand.

At Micro Harmonics we design isolators that are optimized for low-insertion loss. The typical insertion loss is about 0.7 dB for our WR-10 isolators and less than 2 dB for our WR-3.4 isolators (220-330 GHz). These numbers are game changers and mm-wave system developers are now reconsidering their use. So how do we do it? There are many factors to consider, but here we focus primarily on;

1) Minimizing Ferrite Loss
2) Minimizing Waveguide Loss
3) Precision Fabrication and Alignment

1) Minimizing Ferrite Loss - A good starting point is to consider the equation for EM field rotation in a Faraday rotation isolator.

$$\theta = \frac{4\pi M_Z \Upsilon l \sqrt{\varepsilon}}{2c}$$

Where,

$4\pi M_Z$ is the axial magnetization

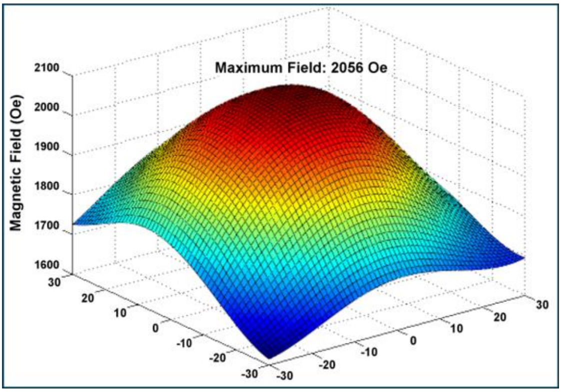
Υ is the gyromagnetic ratio (8.795×10^6xg rad/s/Oe)

l is the ferrite length

c is the speed of light

ε is the ferrite dielectric constant

This equation shows that the field rotation is directly proportional to the ferrite length and the axial magnetization. Minimum insertion loss and maximum isolation occur when the EM field is rotated by 45° as it passes through the ferrite. Ferrites are lossy at millimeter-wave frequencies, so it is essential that the length be reduced as much as possible. The traditional method used to tune Faraday rotation isolators is to use ferrites that are substantially longer than the minimum required length and then tune the magnetic bias field to achieve optimal performance. At Micro Harmonics we use a saturating magnetic bias field and the minimum possible ferrite length.



We measure our magnetic bias fields to insure the ferrites are saturated. We use magnetic armatures to achieve a focused, uniform bias field in the ferrite. The graph shows the measured magnetic bias field near the surface of the ferrite core. The peak measured value of 2000 Oe is substantially more than what is required for saturation. The measurements extend well outside of the area of the ferrite.

2) Minimizing Waveguide Loss – Since the EM field is rotated by 45° as it passes through the ferrite, it is necessary to realign the flanges. In traditional builds this is accomplished by twisting extruded waveguide (see photo). The twist must be implemented over a sufficiently long distance to avoid damaging the extruded guide. In the WR-10 through WR-3.4 bands the total length of extruded waveguide is about 2.3 inches in traditional builds, with some variations from band-to-band and between manufacturers.

At Micro Harmonics we use machined twist steps which are substantially shorter than the extruded waveguide twists. They yield good broadband performance and reduced waveguide loss. The total flange-to-flange length of a Micro Harmonics WR-3.4 isolator is 0.45 inch (see photo to the right). In WR-10 the waveguide loss is reduced by 0.2 dB, but at WR-3.4 the waveguide loss is reduced by 1 dB.

3) Precision Fabrication and Alignment – There are substantial challenges in fabricating and assembling the isolators at the higher bands. The parts become increasingly smaller and some of the materials are very difficult to machine (see photo on next page). Aside from the myriad fabrication complications there are considerable alignment difficulties that must be overcome.

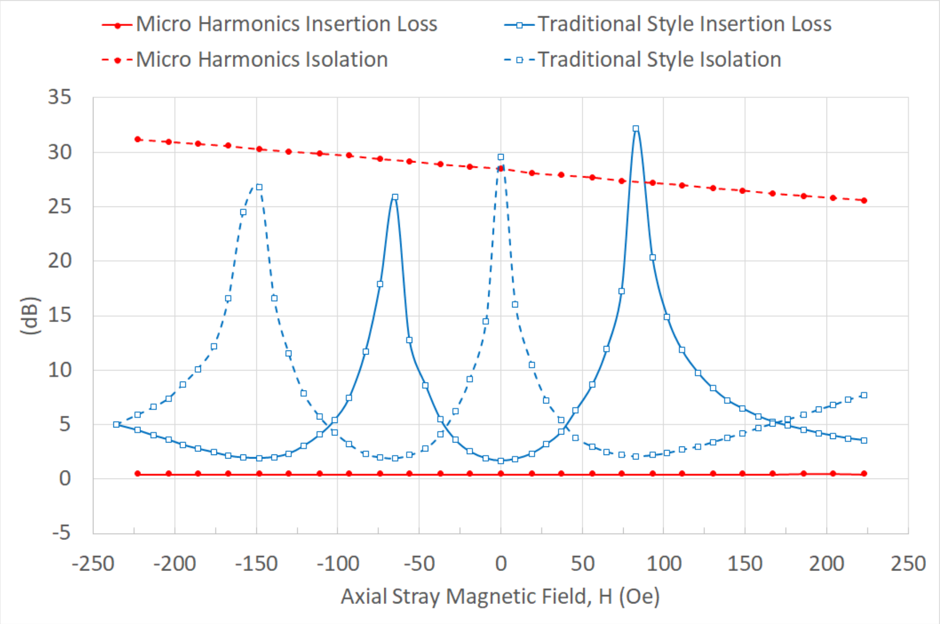
Small misalignment of the cones and ferrite by a few degrees can result in significant degradation of the isolator performance. The area near the ferrite can support more than thirty modes. Misalignment can cause significant coupling to the higher order modes resulting in unwanted structure in the response, increased insertion loss and port reflections as well as decreased isolation. Misalignment can alter the orientation of the resistive layers so that a component of the E-field of the forward travelling wave is in the plane of the resistive layer, resulting in higher insertion loss and lower isolation.

The assembly process is an art form. No two isolators have exactly the same signature. At Micro Harmonics we continually improve our techniques and the uniformity of assemblies. We also comprehensively test every isolator on a calibrated vector network analyzer to ensure it meets our specifications. Some competitors spot-check their components at a few frequencies using less sophisticated systems. This can lead to erroneous test data and missed signatures in the response. We also periodically perform thermal stress testing to verify the mechanical reliability of our devices.

The photograph shows two isolator core assemblies. The cores comprise a cylindrical ferrite (black) and a pair of alumina cones as well as a diamond disc. The two cores are used in the WR-12 isolator (larger) and the WR-3.4 isolator (smaller). The resistive layers bisecting the cones are visible in the larger core.

Stray Magnetic Fields

Stray magnetic fields can alter the magnitude and orientation of the magnetic bias field in the ferrite and cause under- or over-rotation of the signal as it passes through the ferrite. The result is higher insertion loss and reduced isolation. Our isolators employ ferrite rods with the shortest possible length and a highly saturated magnetic bias field. Only stray magnetic fields with a strong axial component opposing the magnetic bias field can bring the ferrite out of saturation. Traditional style isolators offered by other vendors use a much longer ferrite rod and a weaker magnetic bias field such that the magnetization ($4\pi M_Z$) is much less than saturation ($4\pi M_S$). This arrangement is more sensitive to stray magnetic fields since even small perturbations of the net magnetic bias field can cause over- or under-rotation of the signal. For this reason, the traditional style isolators employ a hollow cylindrical magnetic sheath to channel stray fields away from the ferrite. So which approach is more effective against stray fields? We recently put this to the test in W-band and here are the results. The data is taken at 92 GHz. The traditional style isolator fluctuates wildly. Another reason to use Micro Harmonics isolators!



Rectangular Waveguide Chart

MicroHarmonics **Rectangular Waveguide**

EIA WR-(##)	Band	Internal Dimension (mil)	Standard Frequency (GHz)	fc TE10 (GHz)	fc TE20 (GHz)	
42	K	420 x 170	17.5 - 26.5	14.1	28.2	
34		340 x 170	22.0 - 33.0	17.4	34.8	
28	Ka	280 x 140	26.5 - 40.0	21.1	42.2	UG-599/U
22	Q	224 x 112	33.0 - 50.5	26.3	52.6	UG-383/U
19	U	188 x 94	40.0 - 60.0	31.4	62.8	UG-383/UM
15	V	148 x 74	50.5 - 75.0	39.9	79.8	UG-385/U
12	E	122 x 61	60 - 90	48.4	96.8	UG-387/U
10	W	100 x 50	75 - 110	59	118	UG-387/UM
8	F	80 x 40	90 - 140	73.8	147.6	UG-387/UM
6.5	D	65 x 32.5	110 - 170	90.8	181.6	UG-387/UM
5.1	G	51 x 25.5	140 - 220	116	232	UG-387/UM
4.3		43 x 21.5	170 - 260	137	274	UG-387/UM
3.4		34 x 17	220 - 330	174	348	UG-387/UM
2.8		28 x 14	260 - 400	211	422	UG-387/UM
2.2	Y	22 x 11	325 - 500	268	536	UG-387/UM
1.9		19 x 9.5	400 - 600	311	622	UG-387/UM
1.5		15 x 7.5	500 - 750	393	786	UG-387/UM
1.2		12 x 6	600 - 900	492	984	UG-387/UM
1		10 x 5	750 - 1100	590	1180	n/a
0.8		8 x 4	900 - 1400	738	1476	n/a
0.65		6.5 x 3.25	1100 - 1700	908	1816	n/a
0.51		5.1 x 2.55	1400 - 2200	1157	2314	n/a

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The Micro Harmonics Advantage

At Micro Harmonics we are advancing the state-of-the-art in mm-wave isolators and circulators. The significantly reduced insertion loss of our isolators makes them suitable for use in mm-wave systems where signal power is at a premium. For example, our WR-3.4 isolator (220-330 GHz) has an insertion loss of less than 2 dB! Our advanced ferrite products offer:

- **Compact size**
- **Low insertion loss**
- **25 GHz to 400 GHz**
- **Cryogenic options**
- **Comprehensive test data**
- **High isolation**
- **Extended bandwidth**
- **Diamond heatsinks**
- **Competitive prices**
- **Resists Stray Magnetic Fields**

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