This bridge design does not use a transformer with magnetic coupling. Instead it uses a current balun to pickup the bridge voltage. That makes it inherently very wideband. The balun impedance must be kept high over the frequency range of the bridge, since this impedance effectively appears in parallel with the unknown. A compensating impedance is used across the internal bridge reference termination to maintain balance at the frequency extremes of the bridge. This design is used in many commercial bridges.

With the beads placed close to the PCB, you need to measure the bridge directivity while you move the beads away from the PCB. First on one side, then you try the other side. One bead at a time, then two or three, until you find a spot that gives the highest directivity between 300 and 2000 MHz. It's best to use a network analyzer setup so that you can observe the frequency response in real time. To attach the bead, use anything that is non metallic, such as tie wraps, cords, glue. The RG174 cable lengths should be about the same, the exact length is not critical. Just use the length that is required as I did.

Recommended resistor tolerance: 0.2 % giving –64 dB atten. worst case.
-50 dB bridge attenuation worst case, -60 dB average with 1 % resistors
-70 dB bridge attenuation worst case, -80 dB average with 0.1 % resistors
50 ohm bridge resistors

50 ohm termination

Cu wire
Same diam as coax

TEST PORT

50 ohm bridge resistors

50 ohm Semi-rigid coax

50 ohm termination

OUTPUT

INPUT

RETURN LOSS BRIDGE MODEL 1 100KHz – 1000 MHz
RETURN LOSS BRIDGE MODEL 2  20KHz – 2000 MHz

- RG-174 wound on LF-HF large toroid FT150A-W. 6 turns
- VHF-UHF beads on RG-174 cable. 25 beads on each side, FT23-77
- Plexiglass disk (removed) 0.112 in. thick
- Plexiglass 0.112 in. thick at the bottom to space the two toroids from ground
- FT150A-W ferrite core dimensions:
  - OD : 1.5 in.
  - ID : 0.75 in.
  - Height : 0.5 in.
  - Permeability : 10 000
- Note that the beads have been attached with cords to secure them in place and optimize directivity.
- Same enclosure as bridge model 3
- Test port
- PCB as in model 3
- Felt pad gently holding the toroid in place with a screw. Two pads per toroid.

VE2AZX
RETURN LOSS BRIDGE MODEL 2  20KHz – 2000 MHz

Notice the coax connection to the BNC connector. Keep the center conductor short.
RETURN LOSS BRIDGE MODEL 2  performance tests
RETURN LOSS BRIDGE MODEL 3 1 MHz to 2500 MHz
Selected 100 ohm 1% 1206 size bridge resistors in parallel (0.1%)

Copper foil to interconnect PCB ground to N connector (Foil completely covers PCB underneath)

Bridge input RG-174 coax

Added 2 tapped holes and screw to secure PCB on N connector

N connector mounting holes

PCB gnd plane

RG-174 coax shield

Bridge output
RETURN LOSS BRIDGE MODEL 3   bridge mounted in its enclosure

INPUT

Tie-wrap

Silicone to hold the ferrites in place after adjustment by changing the ferrite position

Test Port

OUTPUT

Air bubble material to hold coax cables
PCB for return loss bridge models 2 and 3

See slide 5
RETURN LOSS BRIDGE MODEL 3
Short / Open Response
RETURN LOSS BRIDGE MODEL 3
Short - Open Response

CH1 S21/M log MAG 5 dB/ REF 0 dB 3: 1.9386 dB

SCALE
5 dB/div

1 MHz
100 MHz

0 dB

START 0.030 000 MHz STOP 3 000.000 000 MHz

1 MHz
100 MHz
RETURN LOSS BRIDGE MODEL 3
Directivity w/r to open
RETURN LOSS BRIDGE MODEL 3
Directivity w/r to short

1 MHz
100 MHz
RETURN LOSS BRIDGE MODEL 3
Return Loss at Input – 50 ohm at test port
RETURN LOSS BRIDGE MODEL 3

Stocklist

QTY
10 Amidon FB43-801 Ferrite beads (u=850)
on Fair-Rite 43 SHIELD BEAD: 2643000801
  u = 800 (43 material)
  0.094 in / 0.296 in. and 0.297 in. Long
  Use 5 per side.
4 Use Fair-Rite 31 SHIELD BEAD: 2631250202
  Amidon equivalent: FB-31-0202
  u = 1500 (31 material)
  0.125 in / 0.25 in. and 1.0 in. long
  Use two per side.
2 BNC Bulkhead Jacks, RG174 Digikey # A1813-ND
1 N type connector with flat back
1 Al Case Hammond Manufacturing # 1590B
6 Selected 100 ohm +/- 0.1 ohm 1206 SMT resistors
1 PCB
18 in. RG174 miniature coax.

Note that high freq performance critically depends on:
1- Using a small PCB, located behind the N test connector.
2- Using RG174 bulkhead BNC connectors.
3- Adjusting the location of the ferrite beads for best balance, preferably by looking at the
   S21 curve from 500 to 3000 MHz.
Fair-Rite 43 SHIELD BEAD: 2643000801

$u = 800$ (43 material)
0.094 in / 0.296 in. and 0.297 in. long
Very close to Amidon FB43-801
Use five per side

http://www.fair-rite.com/cgibin/catalog.pgm
Fair-Rite authorized distributors:
http://www.fair-rite.com/newfair/support.htm

**Electrical Specifications**

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Typical Impedance ($R$) (ohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 MHz</td>
<td>42</td>
</tr>
<tr>
<td>25 MHz</td>
<td>63</td>
</tr>
<tr>
<td>100 MHz</td>
<td>92</td>
</tr>
<tr>
<td>250 MHz</td>
<td>109</td>
</tr>
</tbody>
</table>

$Z \times 5$

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Total Impedance ($Z$) (ohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MHz</td>
<td>94</td>
</tr>
<tr>
<td>2 MHz</td>
<td>390</td>
</tr>
<tr>
<td>3 MHz</td>
<td>591</td>
</tr>
<tr>
<td>4 MHz</td>
<td>920</td>
</tr>
<tr>
<td>5 MHz</td>
<td>1025</td>
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</tbody>
</table>

Impedance, reactance, and resistance vs. frequency.
Fair-Rite 31 SHIELD BEAD: 2631250202

\( u = 1500 \) (31 material)

0.125 in / 0.25 in. and 1.0 in. long
Use two per side.

**Electrical Specifications**

<table>
<thead>
<tr>
<th>Typical Impedance (Ω)</th>
<th>( Z \times 2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MHz</td>
<td>54</td>
</tr>
<tr>
<td>5 MHz</td>
<td>140</td>
</tr>
<tr>
<td>10 MHz</td>
<td>180</td>
</tr>
<tr>
<td>25 MHz</td>
<td>276</td>
</tr>
<tr>
<td>100 MHz</td>
<td>460</td>
</tr>
<tr>
<td>250 MHz</td>
<td>480</td>
</tr>
</tbody>
</table>

http://www.fair-rite.com/cgibin/catalog.pgm

Impedance, reactance, and resistance vs. frequency.
RL Bridge Simulations
Effect of the ferrite resistance

Circuit used for simulations

INPUT from 50 ohm source

OUTPUT to 50 ohm det.

R1 = 50 ohm
R2 = 50 ohm

T1

P = 1

R4 = Zx

the DUT

R5 and R6 are the ferrite resistance

Simulation Results

<table>
<thead>
<tr>
<th>Ohms</th>
<th>Rferrite</th>
<th>Bridge Insertion Loss dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td>Open</td>
<td>Open - Short</td>
</tr>
<tr>
<td>10000</td>
<td>12.048</td>
<td>12.066</td>
</tr>
<tr>
<td>10000</td>
<td>12.058</td>
<td>12.113</td>
</tr>
<tr>
<td>5000</td>
<td>12.075</td>
<td>12.183</td>
</tr>
<tr>
<td>2000</td>
<td>12.123</td>
<td>12.390</td>
</tr>
<tr>
<td>1000</td>
<td>12.204</td>
<td>12.726</td>
</tr>
<tr>
<td>500</td>
<td>12.362</td>
<td>13.378</td>
</tr>
<tr>
<td>200</td>
<td>12.821</td>
<td>15.147</td>
</tr>
</tbody>
</table>

Notes:
- Simulations use 50 ohm source and detector.
- The ferrite impedance is assumed to be resistive.
- The resistance of the ferrites increases bridge losses above its 12.04 dB basic loss.
- Worst case RL measurement errors occur at impedance extremes: short and open. Errors are at minimum with Zx around 50 ohms.
- Ferrite resistance affect more the open.
- Higher Zx above 50 ohms will give more error in RL measurements.
- Open - short attenuation difference is directly related to the resistance of the ferrites.
- The ferrite should provide > 500 ohms resistance.
- At 500 ohms the difference open - short = 1 dB
- For best accuracy, refer the RL measurements to the average open and short.