Application Note for Bi-phase Voltage Variable Attenuator, VVA-MCM-1.9G-b

Introduction:

Merrimac's bi-phase voltage variable attenuator, VVA-MCM-1.9G-b is a continuously variable, electronically controlled two-stage attenuator, ideal for vector modulation control. A significant reduction in size is accomplished through the use of Merrimac's Pico products. Two quadrature hybrids (QHD-2Z-1.9G) are used in the configuration shown in Figure 1. This hybrid-based approach enables flat attenuation to be achieved with minimal phase shift variations. It also has the advantage of maintaining a good impedance match at the input and output independent of bias. The attenuation flatness is a direct function of, and hence limited to the passband characteristics of the quadrature hybrid.

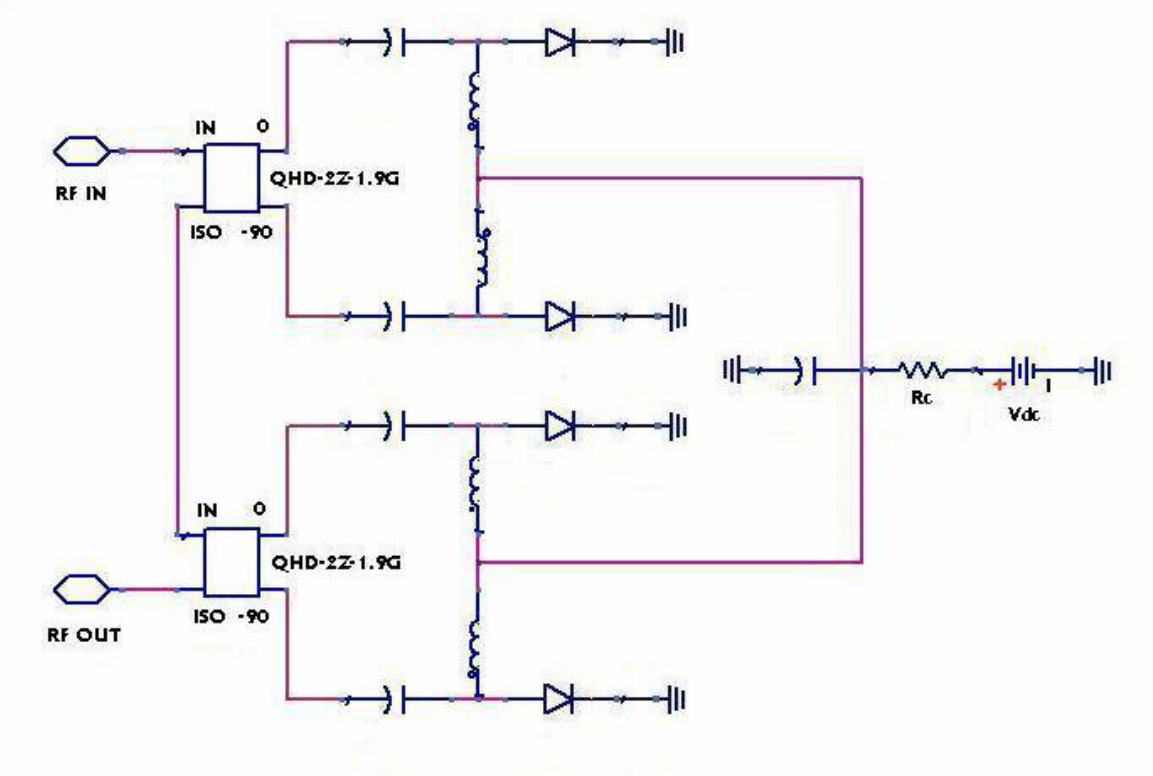


Figure 1: Schematic of the Circuit

Theory of Operation:

A detailed schematic of a single-stage attenuator is shown in Figure 2 for analysis. The diode resistance is shown as a lumped resistance R. The bi-phase characteristics are described by the following three cases.

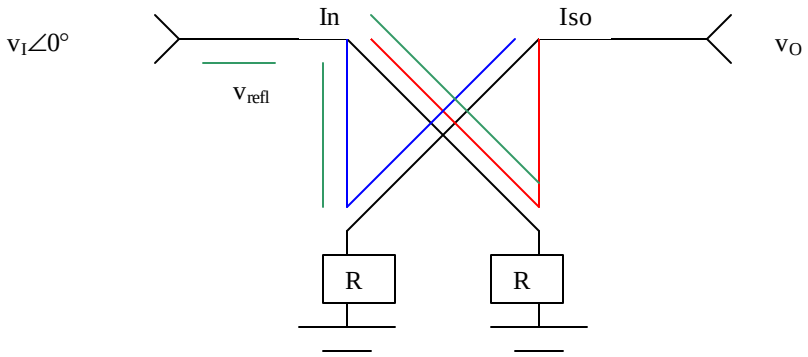


Figure 2: Simplified schematic for analysis

$$\Gamma = g\angle q \quad , \; g = \frac{|R-50|}{(R+50)}$$

Case 1:
R > 50 Ohms
Then $\Gamma = \mathbf{g}\angle 0°$

$$\mathbf{v_O} = (2 * \mathbf{v_I}(0.707 * \mathbf{g} * 0.707))\angle(-90°) = (\mathbf{v_I} * \mathbf{g})\angle(-90°)$$

$$\mathbf{v_{refl}} = (\mathbf{v_I} * (0.707 * \mathbf{g} * 0.707)) * (1\angle 0° + 1\angle 180°) = 0$$

Case 2:
R < 50 Ohms
Then $\Gamma = \mathbf{g}\angle 180°$

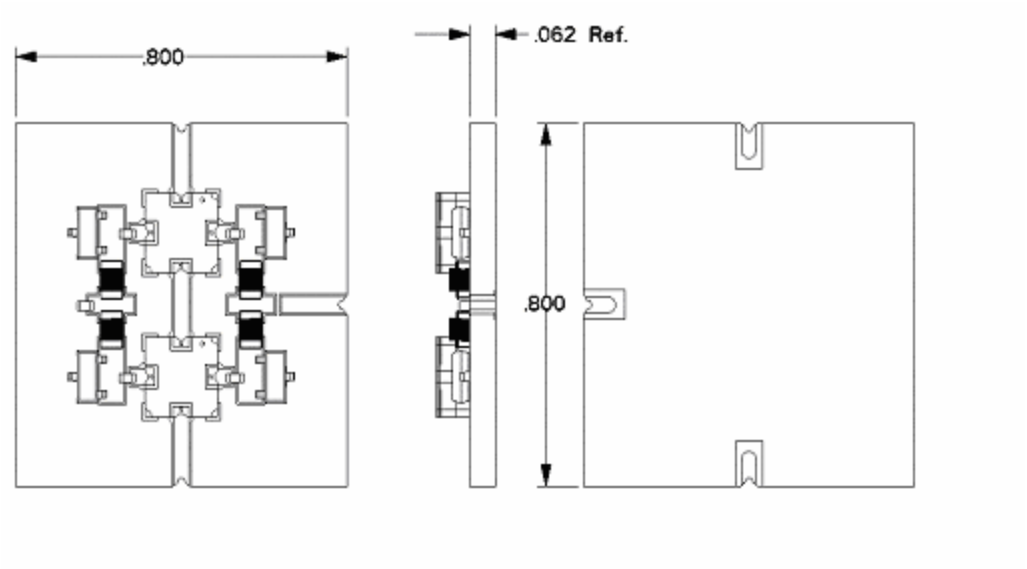
$$\mathbf{v_O} = (2 * (0.707 * \mathbf{g} * 0.707))\angle(90°) = (\mathbf{v_I} * \mathbf{g})\angle(90°)$$

$$\mathbf{v_{refl}} = (\mathbf{v_I} * (0.707 * \mathbf{g} * 0.707)) * (1\angle 180° + 1\angle 0°) = 0$$

Case 3:
R = 50 Ohms => $\Gamma = 0$ and $\mathbf{v_O} = 0$

Implementation:

The VVA-MCM-1.9G-b was assembled using coplanar lines on Rogers 4003 material, 0.060" thick. The overall board dimensions are (0.8 x 0.8) inches. An outline and photograph are shown in Figure 3. The module may be surface mounted or connectorized to suit one's requirements.



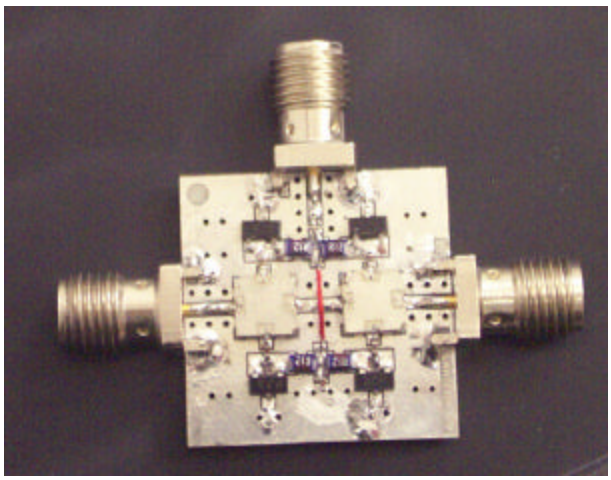
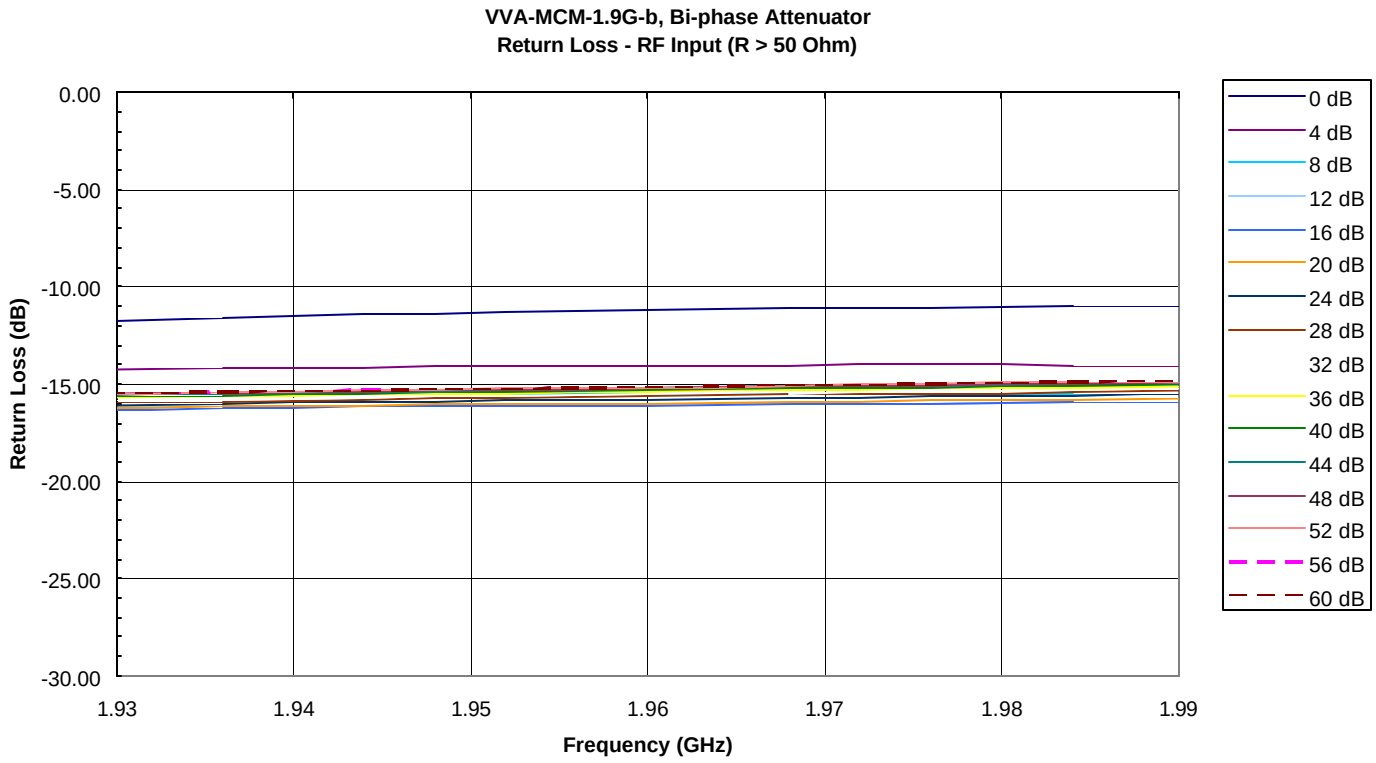
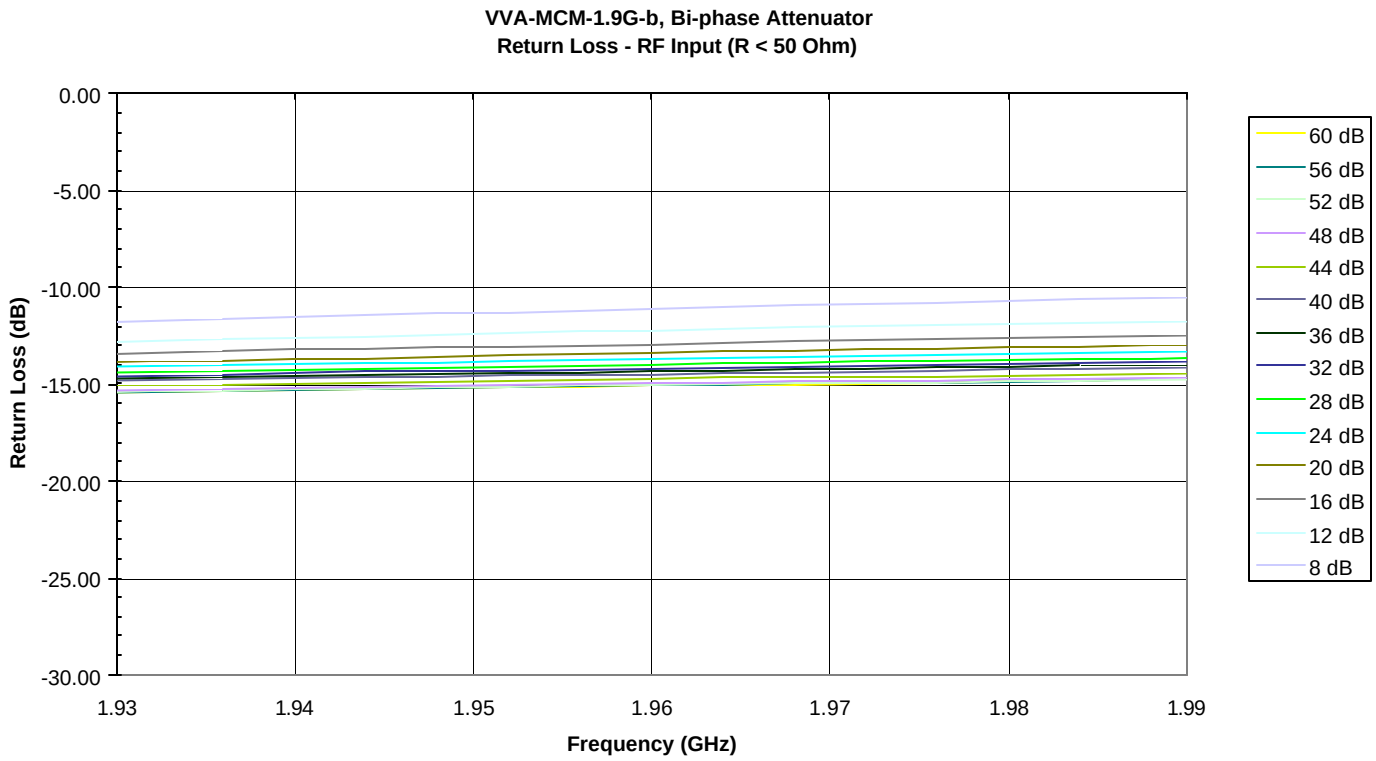


Figure 3: Outline drawing and photograph of the assembly

Results:

Frequency Range:	1.93 – 1.99 GHz
Attenuation Range:	0 – 60 dB min
Attenuation Flatness:	0.5 dB (0 - 40 dB attenuation)
Insertion Loss:	3 dB max.
VSWR:	1.9:1 max.
Impedance:	50 Ohms
Control Current:	0 to + 429 mA
Control Voltage (Rc=70Ω):	0 to + 30 V
Input 1-dB Compression Point:	+ 31 dBm
Input Intercept Point (2 Tone, 3rd Order):	+ 41 dBm
Switching Speed:	10 μs
Operating Temperature:	-55°C to 85°C


VVA-MCM-1.9G-b, Bi-phase Attenuator
Return Loss - RF Input (R > 50 Ohm)
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
Return Loss (dB)
1.93
1.94
1.95
1.96
1.97
1.98
1.99
Frequency (GHz)
0 dB
4 dB
8 dB
12 dB
16 dB
20 dB
24 dB
28 dB
32 dB
36 dB
40 dB
44 dB
48 dB
52 dB
56 dB
60 dB


VVA-MCM-1.9G-b, Bi-phase Attenuator
Return Loss - RF Input (R < 50 Ohm)
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
Return Loss (dB)
1.93
1.94
1.95
1.96
1.97
1.98
1.99
Frequency (GHz)
60 dB
56 dB
52 dB
48 dB
44 dB
40 dB
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32 dB
28 dB
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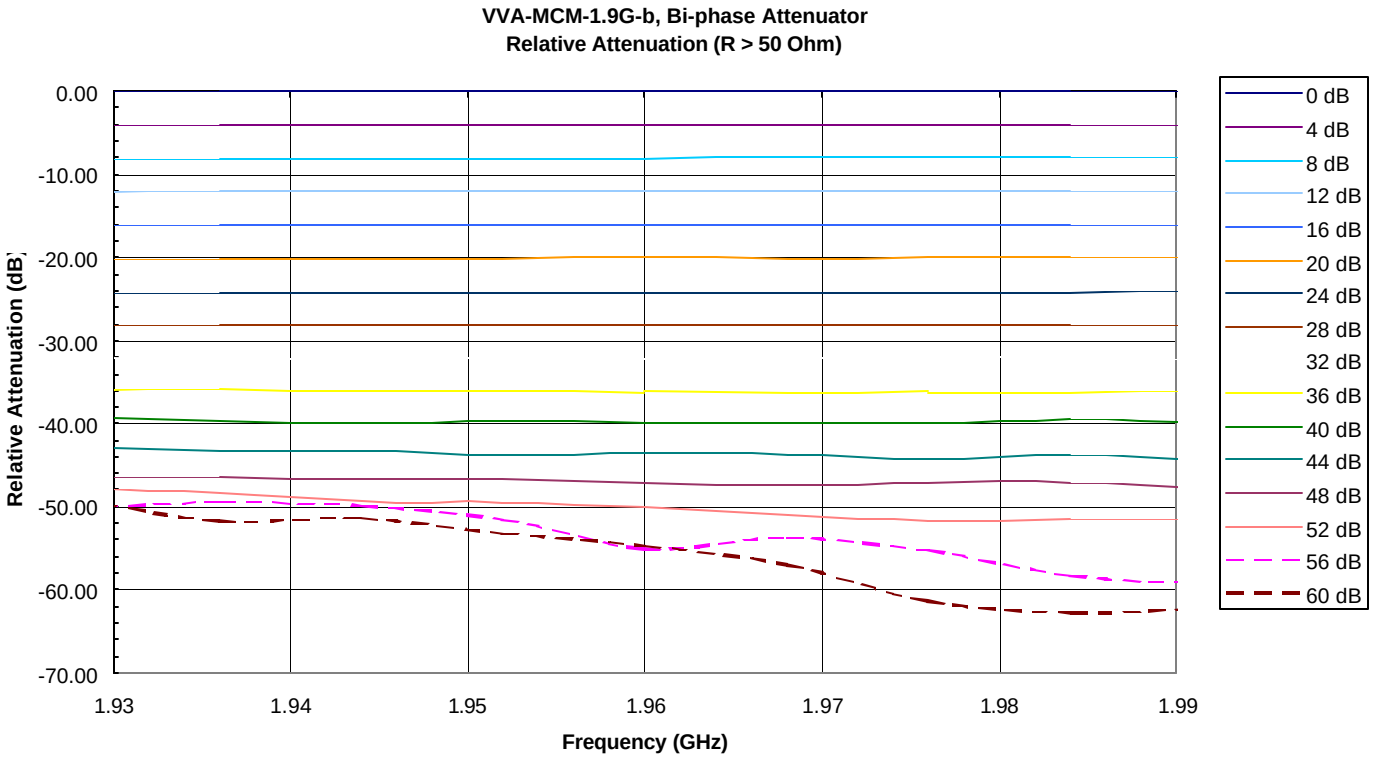
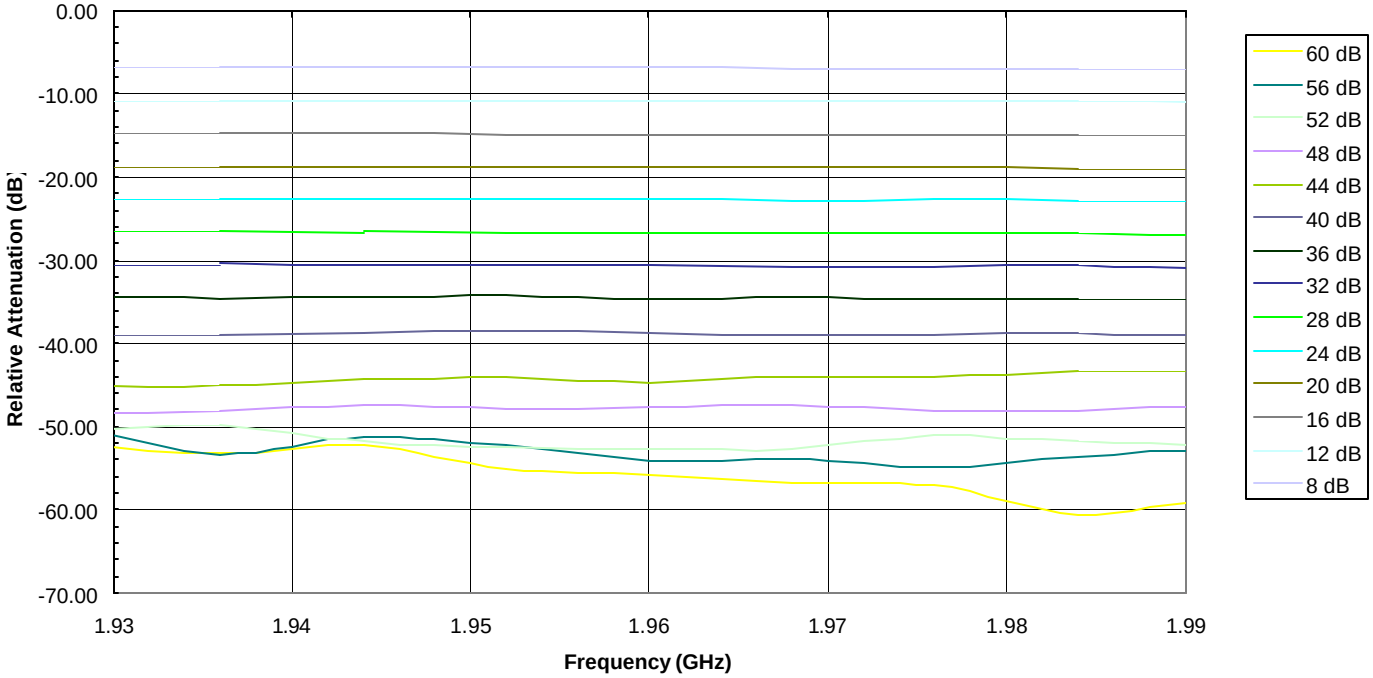
8 dB


VVA-MCM-1.9G-b, Bi-phase Attenuator
Relative Attenuation (R > 50 Ohm)
Relative Attenuation (dB)
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
1.93
1.94
1.95
1.96
1.97
1.98
1.99
Frequency (GHz)
0 dB
4 dB
8 dB
12 dB
16 dB
20 dB
24 dB
28 dB
32 dB
36 dB
40 dB
44 dB
48 dB
52 dB
56 dB
60 dB


VVA-MCM-1.9G-b, Bi-phase Attenuator
Relative Attenuation (R < 50 Ohm)
Relative Attenuation (dB)
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
1.93
1.94
1.95
1.96
1.97
1.98
1.99
Frequency (GHz)
60 dB
56 dB
52 dB
48 dB
44 dB
40 dB
36 dB
32 dB
28 dB
24 dB
20 dB
16 dB
12 dB
8 dB