BNC Adapters ~ *The Weight of the Evidence*

Whitham D. Reeve

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1. Introduction

When I started working professionally with electronics in the 1960s, RF connectors and adapters were relatively inexpensive. The name brands I used, mostly Amphenol, were invariably high quality, met military standards and were assigned a *UG*-series number. For example, the 90° BNC adapter was the UG-306/U or UG-306A/U. I do not recall ever having a bad connector or adapter in my professional work (connector installations on coaxial cables were a different matter). It was not until I started purchasing BNC connectors through eBay to save a buck and to use in my observatories that I started having problems: Weak springs, poor dimensional tolerances and fit, poor construction and intermittent operation when jiggled. I know I am not the only person who has encountered these kinds of contemporary problems.

I recently built another RF patch panel with bulkhead mount BNC-female connectors. Since the patch panel is mounted in a semi-portable rack enclosure with front and back covers, I used 90° adapters on each panel connector to prevent the enclosure covers from interfering with the interconnecting cables. After I deployed the enclosure to a remote site, I was running a series of tests when one of the adapters fell apart (figure 1). I examined the pieces and noted the male and female parts are press-fit but have poor mechanical tolerances. I checked another adapter of the same type and with surprisingly little effort I could pull it apart, although in that case I did use pliers for gripping. I thought it would be interesting to further investigate these adapters.

Figure 1 ~ Poor quality right-angle BNC adapters. The two pieces at lower-right are the male and female parts of the adapter that fell apart in my hand. The knurled press-fit barrel is visible in the lower-right foreground. More detailed images are shown later. The three pieces to the left are from another identical adapter that I easily pulled apart with pliers. The end-cap for the female barrel part was removed and is partially hidden behind the male body part. The two adapters in the back are intact but went to the garbage can. Image © 2019 W. Reeve

After returning home I looked through my BNC adapter stock and noted three basic types of construction used on the 90° adapters (figure 2). I will call these basic types Adapter 1, 2 and 3. Adapter 3 is noticeably heavier than the other two types (table 1) and its appearance is very similar to Amphenol part number 31-9 and 31-9-RFX. For convenience I will call the Amphenol units Adapter 4, and these are slightly heavier yet. I do not know the manufacturers of any of the other adapters but I do know the connector that fell apart, Adapter 1, was purchased through eBay from a Chinese vendor in a 25-pack. The remainder of this article discusses the mechanical and electrical characteristics of the 90° BNC adapters in my stock.

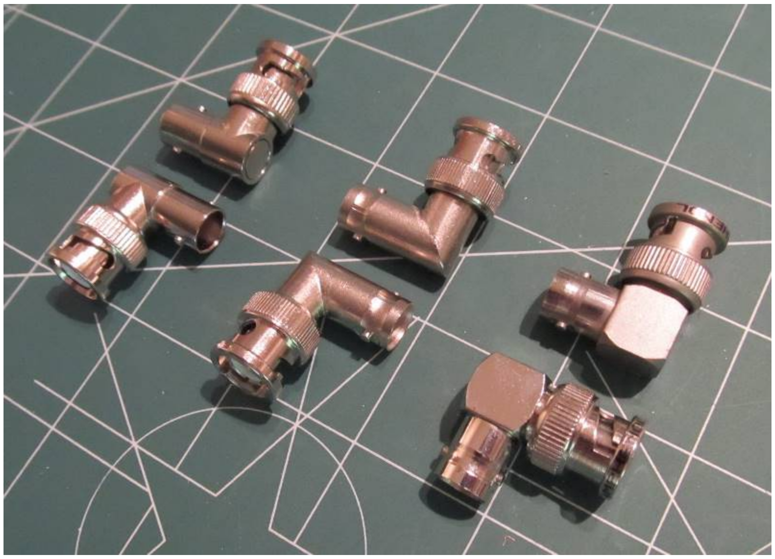

Figure 2 ~ Right-angle BNC adapters, left-to-right, Adapter 1, 2 and 3. The adapters on the right are noticeably heavier than the other two types. Not shown is Adapter 4, which is externally identical to Adapter 3 but slightly heavier. Image © 2019 W. Reeve

Table 1 ~ 90° BNC Adapter weights measured on a precision electronic scale for ammunition reloading

Adapter	Weight (g)	Remarks
1	10.57	Tubular press-fit construction
2	15.52	Tubular welded construction
3	18.65	Tubular press-fit, squared construction
4	19.35	Amphenol p/n 31-9; externally identical to adapter 3

2. Mechanical

Adapter 1, mechanically the worst of the three, consists of two main assemblies, one male and one female. Each assembly has its own center conductor in a cylindrical PTFE dielectric (PTFE is an abbreviation for PolyTetraFluoroEthylene, commonly known by the trademark and brand name *Teflon*). The center conductor contact on the female side (figure 3) has a tab that makes contact with the male side when the two parts are pressed together during assembly. This contact depends on the spring action of the tab and is not solid.

The male part is knurled for a press-fit with the female part but the thin material, poor tolerances or poor design allow it to easily come apart. The body material appears to be nickel-plated brass and, of the three adapters, the barrels are the thinnest, which accounts for the lighter weight. There is a gap in the dielectric at the center conductor connection point, but this is not unusual for right-angle adapters.

Adapter 2 uses a completely different assembly method. The body parts appear to be nickel-plated brass and use welded construction with a continuous center conductor that is bent (figure 4). PTFE dielectric cylinders holds the center conductor in the body parts at both ends. There is a dielectric gap at the 90° bend. In order to disassemble this adapter, I used a small motorized rotary tool with an abrasive cutting wheel to cut it apart.

Figure 3 ~ Adapter 1 male (left) and female (right) barrels. The knurled area on the male part is press-fitted to the female part from the left. The male center contact, in the dielectric but exposed at the end, makes a spring contact with the tab seen in the female part. The shadow line parallel to the tab is a ridge in the white PTFE dielectric. Image © 2019 W. Reeve

Figure 4 ~ Adapter 2 center contact is a continuous copper alloy. The female contact is toward the upper-right. PTFE dielectric cylinders hold the two ends in position in the connector body parts. Image © 2019 W. Reeve

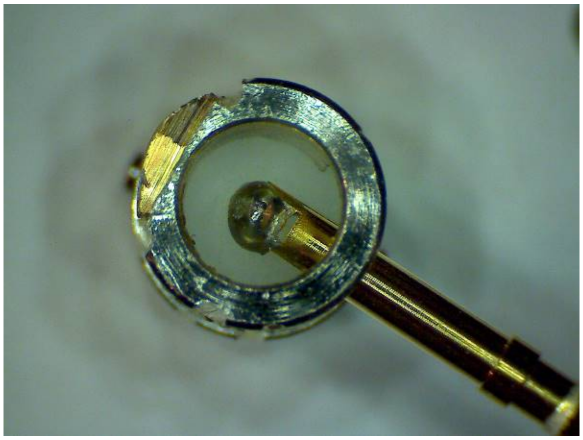

Figure 5 ~ End view of Adapter 3 female part with the end-cap removed. The soldered center contact can be seen in the middle of the barrel (it is slightly out of alignment from the cutting and disassembly operation). The male contact is in the lower-right of this image; it extends through a round hole into the female barrel. During assembly the two contacts are soldered before the end-cap is press-fitted. Image © 2019 W. Reeve

I could not pull Adapter 3 apart even if I held it in a vice, so I cut it open using the same tool as Adapter 2. It is made from substantially thicker nickel-plated brass parts and required much more cutting effort. Adapter 3 consists of male and female barrels that are press-fitted during assembly similar in concept to Adapter 1 but the fit is very tight and the thicker material grips much better than Adapter 1.

The center conductor in Adapter 3 also is constructed in two parts. However, unlike Adapter 1, the center contacts are soldered together at their junction (figure 5) through an open port in the female barrel after the two parts are assembled. The port is then sealed with a press-fit cap. This adapter has an almost continuous dielectric with a small gap where the contacts are soldered. I did not cut apart Adapter 4 but its exterior appearance is identical to Adapter 3, and I suspect its interior is the same as well.

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3. Electrical

Procedures: I tested the adapters with a Keysight FieldFox N9923A vector network analyzer (VNA). The frequency range of BNC connectors depends on the manufacturer but most name-brand datasheets show at least 4 GHz. Ideally, the instrument would be calibrated to the highest frequency with test cables that have BNC connectors and then directly connected to the 90° BNC adapters (the device under test, or DUT) for the measurements. However, this would require a set of BNC calibration standards suitable for the full frequency range, something I do not have. Therefore, I employed a compromise calibration to only 1 GHz as described below.

In this calibration, I used test cables with type N connectors and a type N calibration standards kit (HP model 85032B). After calibration I used a set of type N/BNC adapters for connecting the DUT (figure 6). This means that the measurements include any degradation caused by both the N/BNC adapters and 90° BNC adapters. I could easily measure the degradation caused by the N/BNC adapters and then use these measurements as a reference for comparison to the DUT.

Figure 6 ~ Type BNC-female to N-female (left) and BNC-male to N-female (right) adapters used during the measurements but not during calibration. These adapters introduced a 10 dB reduction in return loss when they were attached to the VNA test cables. The manufacturer and model is unknown. Note the flats for a wrench. A wrench normally is not used to tighten type N connectors; however, a wrench may be used to hold the adapter and prevent it from turning while the mating connector is tightened by hand. Image © 2019 W. Reeve

As part of the calibration process, I used the *Port Extension* feature of the VNA to move the calibration plane from the N connectors on the test cables to the BNC side of the N/BNC adapters. This feature applies a phase correction to compensate for the added lengths of the adapters. In the FieldFox VNA, the port extension feature only allows adjustment for phase delay and not power loss, but this is of no consequence for my purposes.

To use the Port Extension feature, I adjusted the delay on each VNA port to maximize the reflection coefficient with nothing connected to each of the N/BNC adapters (equivalent to an Open). The resulting delays were 88.5 ps for the N/BNC-female adapter on VNA port 1 and 102.0 ps for the N/BNC-male adapter on VNA port 2. Using the velocity factor for PTFE (0.7), these values are equivalent to 18.57 mm and 21.41 mm adapter lengths, respectively. It should be noted that it is possible the entire internal lengths of the N/BNC adapters do not have the PTFE dielectric, so these distances are nominal. Nevertheless, they are approximately the same as the device physical measurements. My port extension method does not employ an Open calibration standard at the new reference plane but is adequate for my purposes. In any case, using the Port Extension feature made no difference in the measurements presented here.

The steps involved in my calibration and measurement procedure are:

1) Calibrate the VNA from 2 MHz to 1 GHz with type N calibration kit and two 36 in LMR-400-UF test cables. The test cables have type N-male connectors at both ends. For reference after calibration, measurement markers were set at 10, 250, 500 and 750 MHz;
2) Connect the two test cables together with high a quality N-female/N-female coupler (UG-29A/U) and measure all S-parameters (S11, S21, S12, S22). Remove the coupler after measurement;
3) Connect an N-female/BNC-female adapter to the test cable on VNA port 1 and an N-female/BNC-male adapter to the test cable on VNA port 2. This arrangement allows an *insertable DUT* – the 90° BNC adapter – in later measurements;
4) Connect the two test cables together (no additional adapter is required) and measure all S-parameters;
5) Insert, in turn, Adapters 1, 2, 3 and 4 between the test cables and measure all S-parameters for each one;
6) Compare the changes in the S-parameters for the type N coupler (step 2 above), type N/BNC adapters (step 4 above) and the Adapters 1, 2, 3 and 4 (step 5 above). Two adapters of each type are measured – not enough for a meaningful statistical analysis but adequate for the comparison described here (besides, I only had two pieces each of Adapter 2 and Adapter 3).

<u>Measurements</u>: The measurement data is summarized to show S11 (forward reflection coefficient) and S21 (forward transmission) for the measurements at 750 MHz (table 2). The data for S22 (reverse reflection coefficient) and S12 (reverse transmission) were similar, as would be expected for a symmetric passive device, and are averaged with S11 and S21, respectively.

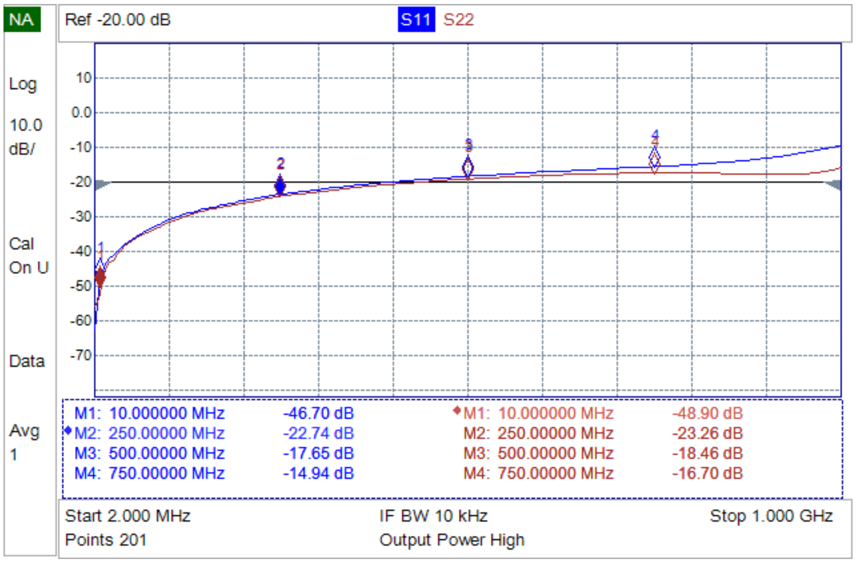
Table 2 ~ Measurements summary at 750 MHz. The columns labeled S11 are averages of S11 and S22 measurements and the columns labeled S21 are averages of S21 and S12 measurements. Degraded performance with respect to a direct connection of the N/BNC adapters is indicated by more negative Δ values.

Adapter	**S11 (dB)**	**ΔS11 (dB)**	**S21 (dB)**	**ΔS21 (dB)**	**Remarks**
Type N coupler (UG-29A/U)	34.3	N/A	0.007	N/A	N Ref.
Type N/BNC	24.2	–10.1	0.072	–0.065	Δ = N/BNC – N Ref.
1	16.6	–7.6	0.349	–0.277	Δ = 1 – N/BNC Ref.
2	17.9	–6.3	0.182	–0.110	Δ = 2 – N/BNC Ref.
3	21.7	–2.5	0.170	–0.099	Δ = 3 – N/BNC Ref.
4	20.6	–3.6	0.129	–0.057	Δ = 4 – N/BNC Ref.

Degradation in the RF performance of the adapters increases with frequency; for example, the differences between the various adapters are more obvious at 750 MHz than, say, 100 MHz. An example of a set of measurement plots is provided here (figure 7) and all plots are given in the **Appendix**. <u>Note</u>: The **Appendix** is available only in the online version of this article; see {Reeve}.

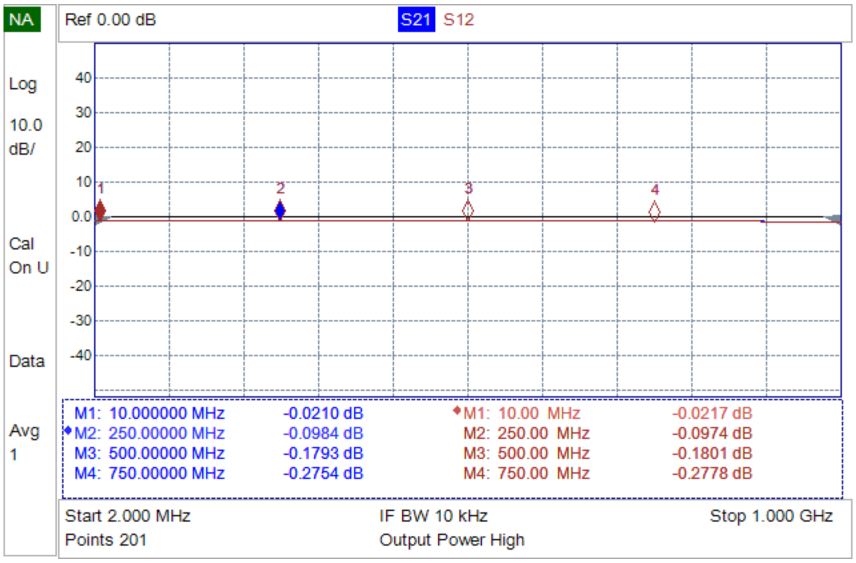
<u>Discussion</u>: Connecting the two test cables with the UG-29A/U type N coupler provided a reference reflection coefficient and transmission performance. For comparison, connecting the cables with the N/BNC adapters (no DUT) degraded the reflection coefficient by about 10 dB but had little effect on transmission performance.

Using the N/BNC adapters as the reference, the 90° adapters (DUT) further degraded the performance with Adapter 1 being the worse. For example, the reflection coefficient was made worse by almost 8 dB and transmission loss was made worse by almost 0.3 dB. Fractional dB changes in loss normally are not a problem in ordinary low frequency RF applications but, in this case, the loss was added by a device having a path length less than 50 mm, indicating that the connections and not the length contributed to the change.



```
M1: 10.000000 MHz   -46.70 dB      M1: 10.000000 MHz   -48.90 dB
M2: 250.00000 MHz   -22.74 dB      M2: 250.00000 MHz   -23.26 dB
M3: 500.00000 MHz   -17.65 dB      M3: 500.00000 MHz   -18.46 dB
M4: 750.00000 MHz   -14.94 dB      M4: 750.00000 MHz   -16.70 dB
Start 2.000 MHz          IF BW 10 kHz            Stop 1.000 GHz
Points 201               Output Power High
```

Figure 7.a ~ Reflection coefficients S11 and S22 plot for Adapter 1 measured from 2 to 1000 MHz. S11 (blue trace) is the reflection coefficient for the forward direction (port 1 to port 2 of the VNA), and S22 (magenta trace) is the reflection coefficient for the reverse direction. The reference level for both traces is –20 dB. Note the increased degradation and the divergence of the two traces between 750 and 1000 MHz. Also note the fairly rapid change in reflection coefficient between 2 and 250 MHz.



```
M1: 10.000000 MHz   -0.0210 dB     M1: 10.00  MHz   -0.0217 dB
M2: 250.00000 MHz   -0.0984 dB     M2: 250.00  MHz  -0.0974 dB
M3: 500.00000 MHz   -0.1793 dB     M3: 500.00  MHz  -0.1801 dB
M4: 750.00000 MHz   -0.2754 dB     M4: 750.00  MHz  -0.2778 dB
Start 2.000 MHz          IF BW 10 kHz            Stop 1.000 GHz
Points 201               Output Power High
```

Figure 7.b ~ Transmission coefficients S21 and S12 plot for Adapter 1 measured from 2 to 1000 MHz. S21 (blue trace) is the transmission coefficient for the forward direction and S12 (magenta trace) is the transmission coefficient for the reverse direction.

Adapters 3 and 4 gave the best relative performance, and Adapter 2 was in the middle. It is interesting that the Adapter 3 reflection coefficient is slightly better (1 dB) while the transmission performance is slightly worse (0.04 dB) than the name brand Adapter 4. However, as a practical matter, these differences probably are not important and may be due to normal variations in the connectors or my measurement method. It is possible that Adapter 3 is a high-quality name brand adapter or it might even be the same model as the Amphenol part, Adapter 4.

In terms of adapter mass, it is easily understood that saving a few grams of material translates into cost and material savings when a production runs consist of tens of thousands of units. On the other hand, removing too much material from the parts design, as in the case of adapter 1, translates into poor product quality. It is interesting that the mass of Adapter 1 is almost one-half that of Adapter 4. Also, the friction contact method used in Adapter 1 for the center conductor is inferior to the other adapters – the connection probably has poor vibration and thermal cycling performance.

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4. Conclusions

The first legal proceeding in which I participated as an expert witness was in early 1978 at a regulatory commission hearing for competing public telecommunications service proposals. The regulatory commission attorney held up the two service proposal documents, one in each hand. One of the proposals was more detailed, much thicker, and heavier than the other. He declared "Based on the weight of the evidence alone, this proposal (the heavier one) will result in better service than the other." While that is a dubious legal concept, the idea apparently applies also to BNC adapters. The weight of Adapters 3 and 4 are greater than the others, and they performed better than the others in all measurements. One may conclude that, in this case, the heavier the adapter the higher its quality and performance.

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5. References and Weblinks

[MILSTD348] MIL-STD-348B with Change 3, Radio Frequency Connector Interfaces, available at: https://landandmaritimeapps.dla.mil/Downloads/MilSpec/Docs/MIL-STD-348/std348not3.pdf

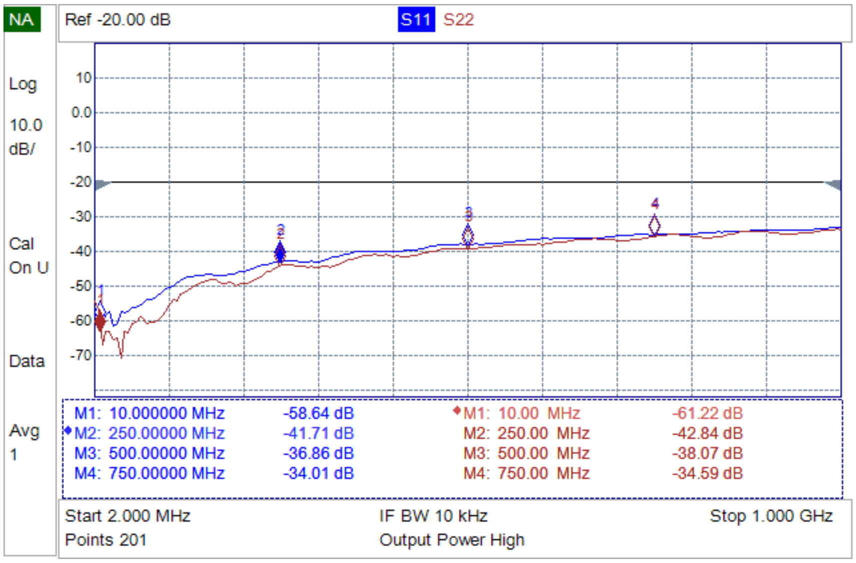
{Reeve} Reeve, W., BNC Adapters ~ The Weight of the Evidence, 2019, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_BNC-Conn.pdf

Author - Whitham Reeve is a contributing editor for the SARA journal, Radio Astronomy. He obtained B.S. and M.S. degrees in Electrical Engineering at University of Alaska Fairbanks, USA. He worked as a professional engineer and engineering firm owner/operator in the airline and telecommunications industries for more than 40 years and now manufactures electronic equipment used in radio astronomy. He has lived in Anchorage, Alaska his entire life. Email contact: whitreeve@gmail.com

Appendix ~ S-Parameter Plots

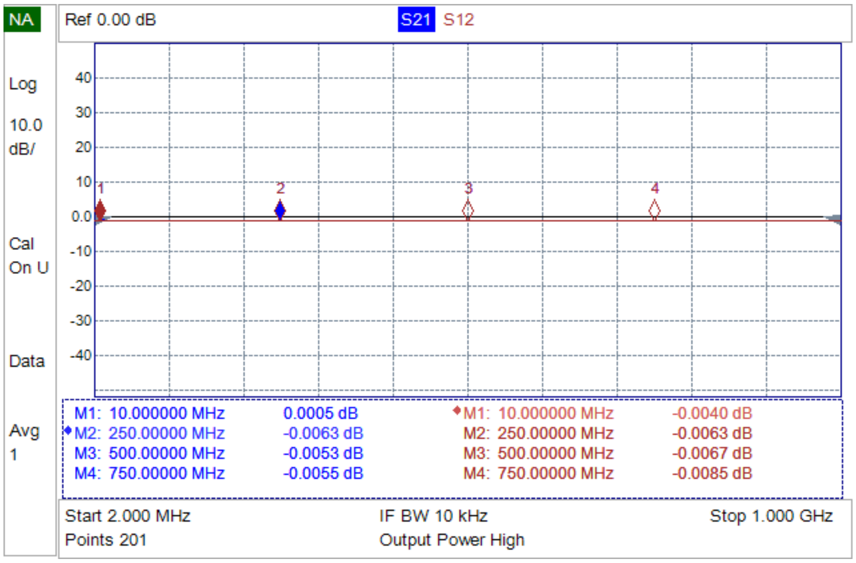
S11 and S22 are reflection coefficients and S21 and S12 are transmission coefficients. For convenience on all plots, the reflection coefficient reference is set to –20 dB and the transmission coefficient reference is set to 0.0 dB. One set of measurements are presented for the type N coupler (figure A.1) and another for the N/BNC adapters (figure A.2). Two complete sets of measurements are presented for each of two Adapters 1, 2, 3 and 4 (figures A.3, A.4, A.5 and A.6, respectively).

Type N Coupler (UG-29A/U), step 2)



```
Ref -20.00 dB
 M1: 10.000000 MHz    -58.64 dB     ♦M1: 10.00  MHz    -61.22 dB
♦M2: 250.00000 MHz    -41.71 dB      M2: 250.00  MHz   -42.84 dB
 M3: 500.00000 MHz    -36.86 dB      M3: 500.00  MHz   -38.07 dB
 M4: 750.00000 MHz    -34.01 dB      M4: 750.00  MHz   -34.59 dB
Start 2.000 MHz            IF BW 10 kHz              Stop 1.000 GHz
Points 201                 Output Power High
```

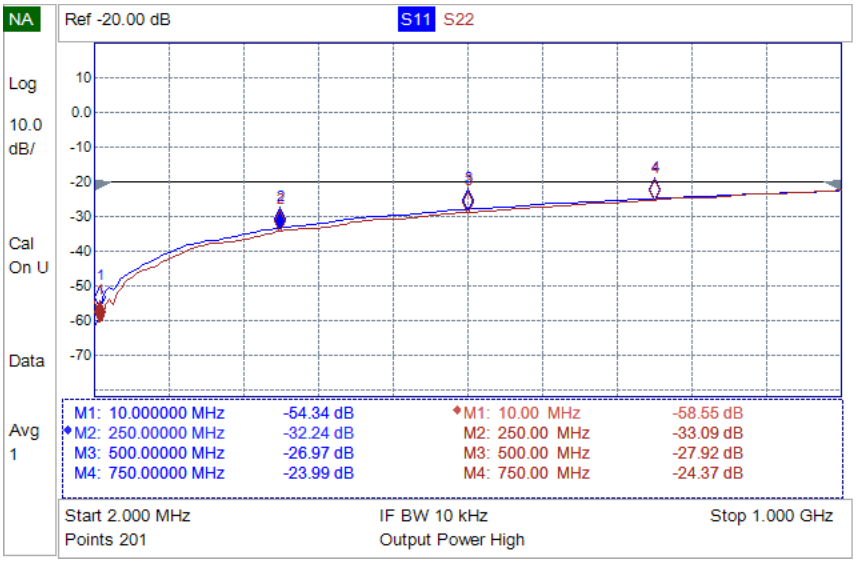
Figure A.1.a ~ Type N Coupler, S11 (blue trace) and S22 (magenta trace).



```
Ref 0.00 dB
 M1: 10.000000 MHz    0.0005 dB     ♦M1: 10.000000 MHz    -0.0040 dB
♦M2: 250.00000 MHz    -0.0063 dB     M2: 250.00000 MHz    -0.0063 dB
 M3: 500.00000 MHz    -0.0053 dB     M3: 500.00000 MHz    -0.0067 dB
 M4: 750.00000 MHz    -0.0055 dB     M4: 750.00000 MHz    -0.0085 dB
Start 2.000 MHz            IF BW 10 kHz              Stop 1.000 GHz
Points 201                 Output Power High
```

Figure A.1.b ~ Type N Coupler, S21 (blue trace) and S12 (magenta trace).

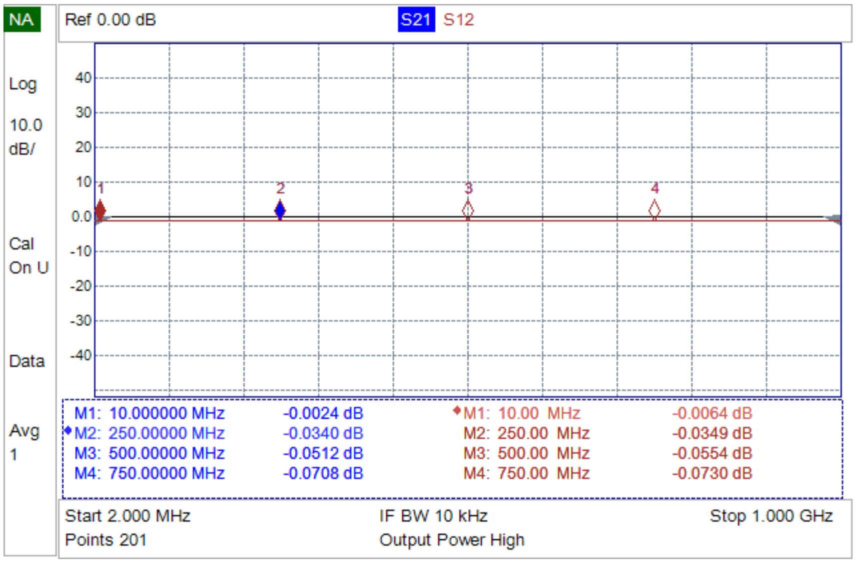
Type N/BNC Adapters, connected, step 4)



```
M1: 10.000000 MHz    -54.34 dB    ◆M1: 10.00  MHz    -58.55 dB
◆M2: 250.00000 MHz   -32.24 dB     M2: 250.00  MHz   -33.09 dB
M3: 500.00000 MHz    -26.97 dB     M3: 500.00  MHz   -27.92 dB
M4: 750.00000 MHz    -23.99 dB     M4: 750.00  MHz   -24.37 dB

Start 2.000 MHz            IF BW 10 kHz             Stop 1.000 GHz
Points 201                 Output Power High
```

Figure A.2.a ~ Type N/BNC Adapter, S11 (blue trace) and S22 (magenta trace).

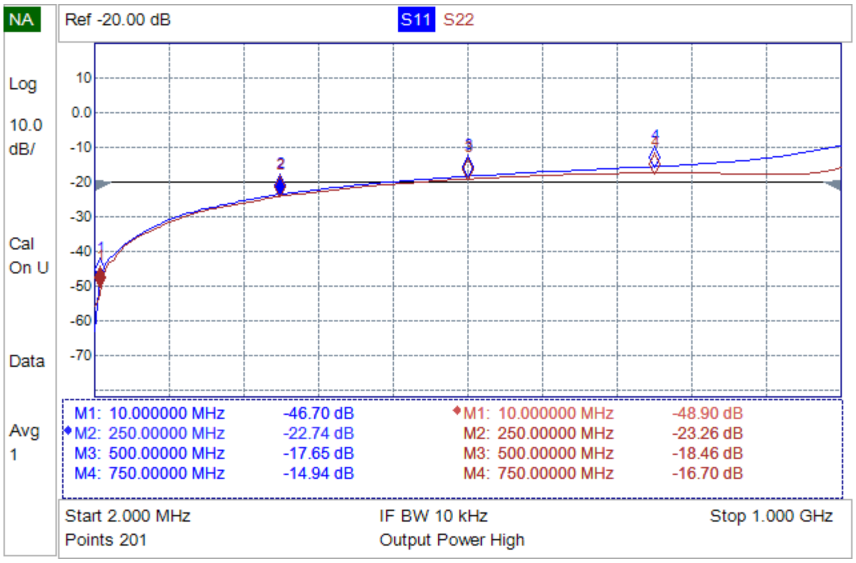


```
M1: 10.000000 MHz    -0.0024 dB    ◆M1: 10.00  MHz    -0.0064 dB
◆M2: 250.00000 MHz   -0.0340 dB     M2: 250.00  MHz   -0.0349 dB
M3: 500.00000 MHz    -0.0512 dB     M3: 500.00  MHz   -0.0554 dB
M4: 750.00000 MHz    -0.0708 dB     M4: 750.00  MHz   -0.0730 dB

Start 2.000 MHz            IF BW 10 kHz             Stop 1.000 GHz
Points 201                 Output Power High
```

Figure A.3.b ~ Type N/BNC Adapter, S21 (blue trace) and S12 (magenta trace).

Adapter 1, step 5)

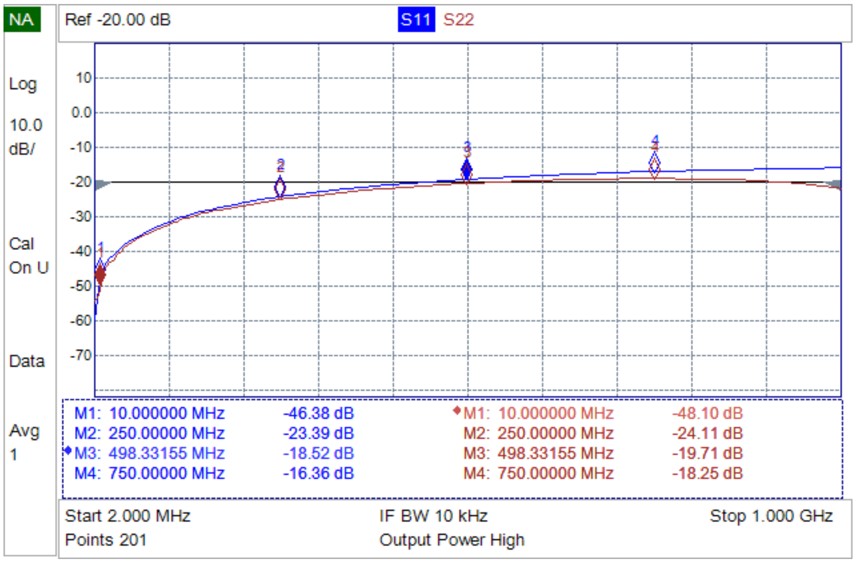


```
Ref -20.00 dB                S11  S22

M1: 10.000000 MHz    -46.70 dB    ◆M1: 10.000000 MHz    -48.90 dB
◆M2: 250.00000 MHz   -22.74 dB     M2: 250.00000 MHz    -23.26 dB
M3: 500.00000 MHz    -17.65 dB     M3: 500.00000 MHz    -18.46 dB
M4: 750.00000 MHz    -14.94 dB     M4: 750.00000 MHz    -16.70 dB

Start 2.000 MHz              IF BW 10 kHz              Stop 1.000 GHz
Points 201                   Output Power High
```

Figure A.3.a ~ Adapter 1, one of two, S11 (blue trace) and S22 (magenta trace).

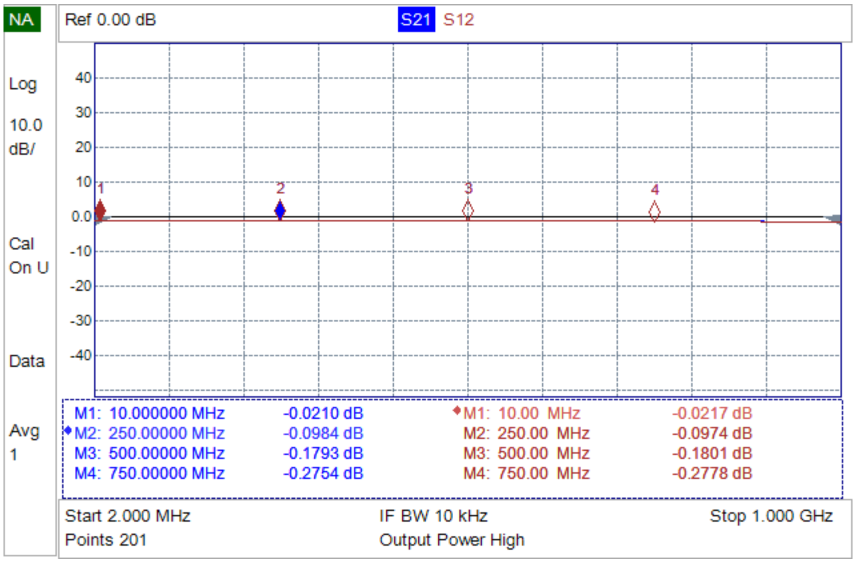


```
Ref -20.00 dB                S11  S22

M1: 10.000000 MHz    -46.38 dB    ◆M1: 10.000000 MHz    -48.10 dB
M2: 250.00000 MHz    -23.39 dB     M2: 250.00000 MHz    -24.11 dB
◆M3: 498.33155 MHz   -18.52 dB     M3: 498.33155 MHz    -19.71 dB
M4: 750.00000 MHz    -16.36 dB     M4: 750.00000 MHz    -18.25 dB

Start 2.000 MHz              IF BW 10 kHz              Stop 1.000 GHz
Points 201                   Output Power High
```

Figure A.3.b ~ Adapter 1, two of two, S11 (blue trace) and S22 (magenta trace).

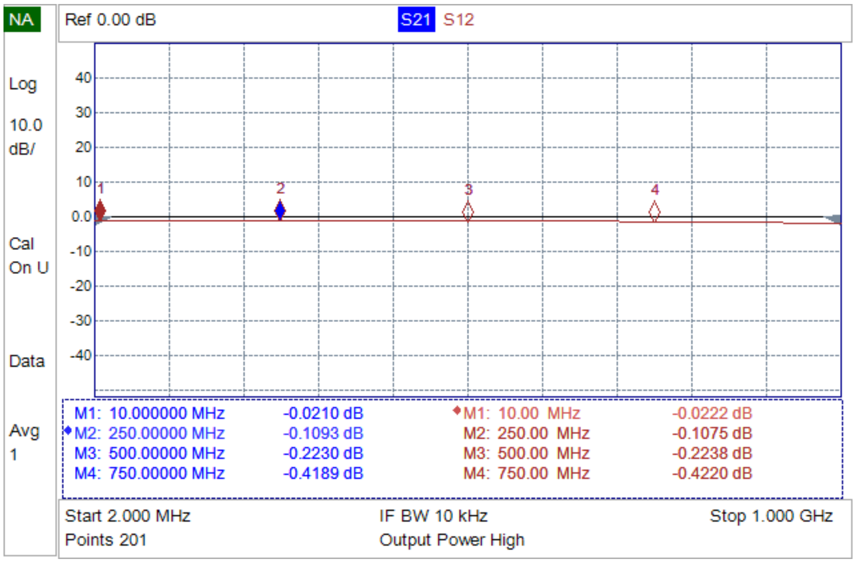


```
Ref 0.00 dB                  S21  S12

M1: 10.000000 MHz    -0.0210 dB   ◆M1: 10.00 MHz     -0.0217 dB
◆M2: 250.00000 MHz   -0.0984 dB    M2: 250.00 MHz    -0.0974 dB
M3: 500.00000 MHz    -0.1793 dB    M3: 500.00 MHz    -0.1801 dB
M4: 750.00000 MHz    -0.2754 dB    M4: 750.00 MHz    -0.2778 dB

Start 2.000 MHz              IF BW 10 kHz              Stop 1.000 GHz
Points 201                   Output Power High
```

Figure A.3.c ~ Adapter 1, one of two, S21 (blue trace) and S12 (magenta trace).

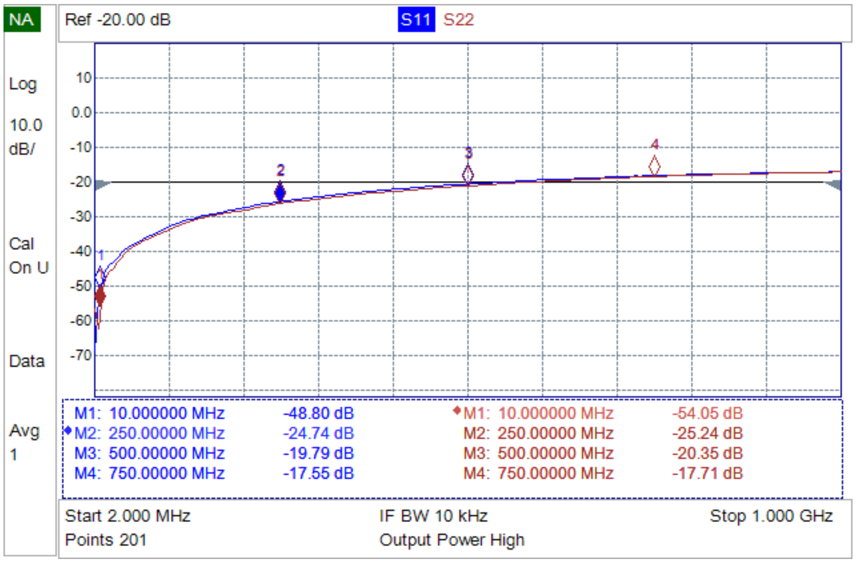


```
M1: 10.000000 MHz   -0.0210 dB    ◆M1: 10.00  MHz   -0.0222 dB
◆M2: 250.00000 MHz  -0.1093 dB     M2: 250.00  MHz  -0.1075 dB
M3: 500.00000 MHz   -0.2230 dB     M3: 500.00  MHz  -0.2238 dB
M4: 750.00000 MHz   -0.4189 dB     M4: 750.00  MHz  -0.4220 dB
```

```
Start 2.000 MHz          IF BW 10 kHz          Stop 1.000 GHz
Points 201               Output Power High
```

Figure A.3.d ~ Adapter 1, two of two, S21 (blue trace) and S12 (magenta trace).

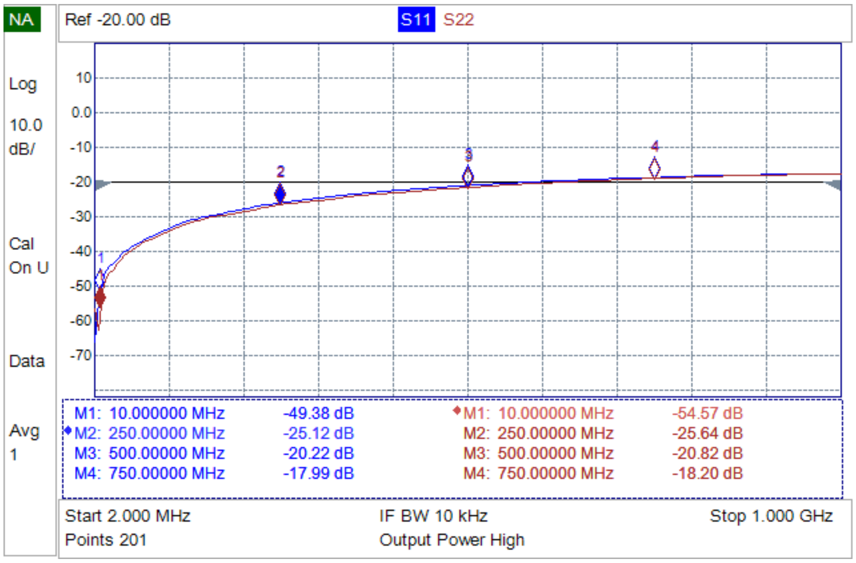
Adapter 2, step 5)



```
M1: 10.000000 MHz   -48.80 dB    ◆M1: 10.000000 MHz  -54.05 dB
◆M2: 250.00000 MHz  -24.74 dB     M2: 250.00000 MHz  -25.24 dB
M3: 500.00000 MHz   -19.79 dB     M3: 500.00000 MHz  -20.35 dB
M4: 750.00000 MHz   -17.55 dB     M4: 750.00000 MHz  -17.71 dB
```

```
Start 2.000 MHz          IF BW 10 kHz          Stop 1.000 GHz
Points 201               Output Power High
```

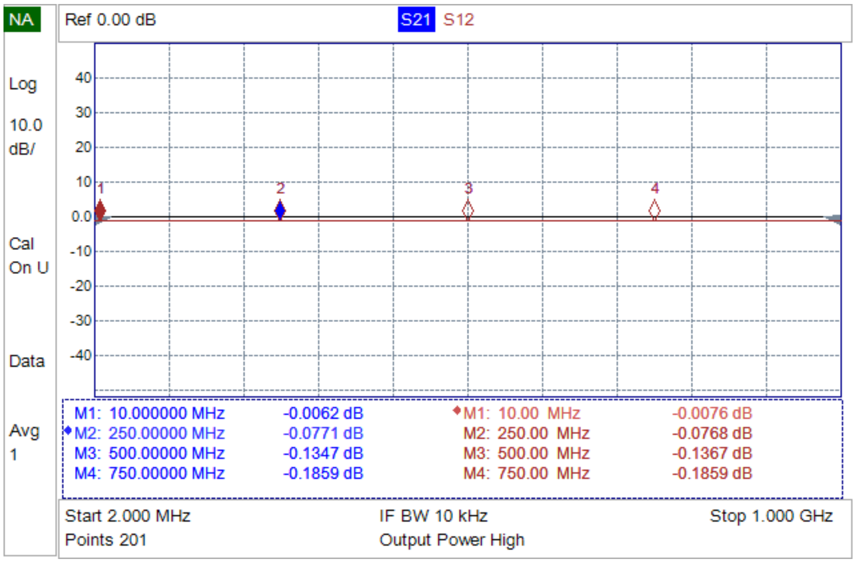
Figure A.4.a ~ Adapter 2, one of two, S11 (blue trace) and S22 (magenta trace).



```
M1: 10.000000 MHz   -49.38 dB    ◆M1: 10.000000 MHz  -54.57 dB
◆M2: 250.00000 MHz  -25.12 dB     M2: 250.00000 MHz  -25.64 dB
M3: 500.00000 MHz   -20.22 dB     M3: 500.00000 MHz  -20.82 dB
M4: 750.00000 MHz   -17.99 dB     M4: 750.00000 MHz  -18.20 dB
```

```
Start 2.000 MHz          IF BW 10 kHz          Stop 1.000 GHz
Points 201               Output Power High
```

Figure A.4.b ~ Adapter 2, two of two, S11 (blue trace) and S22 (magenta trace).

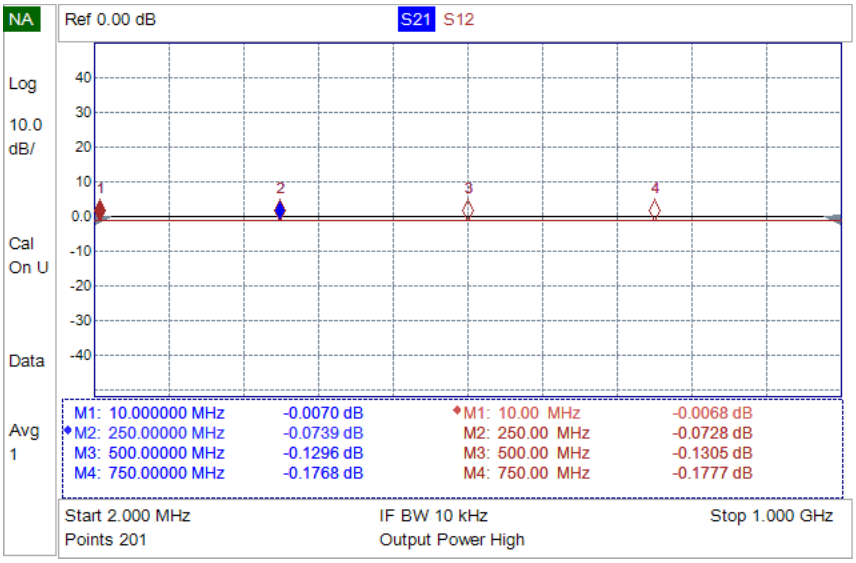


```
Ref 0.00 dB                    S21 S12

M1: 10.000000 MHz    -0.0062 dB    M1: 10.00  MHz    -0.0076 dB
M2: 250.00000 MHz    -0.0771 dB    M2: 250.00  MHz   -0.0768 dB
M3: 500.00000 MHz    -0.1347 dB    M3: 500.00  MHz   -0.1367 dB
M4: 750.00000 MHz    -0.1859 dB    M4: 750.00  MHz   -0.1859 dB

Start 2.000 MHz              IF BW 10 kHz              Stop 1.000 GHz
Points 201                   Output Power High
```

Figure A.4.c ~ Adapter 2, one of two, S21 (blue trace) and S12 (magenta trace).



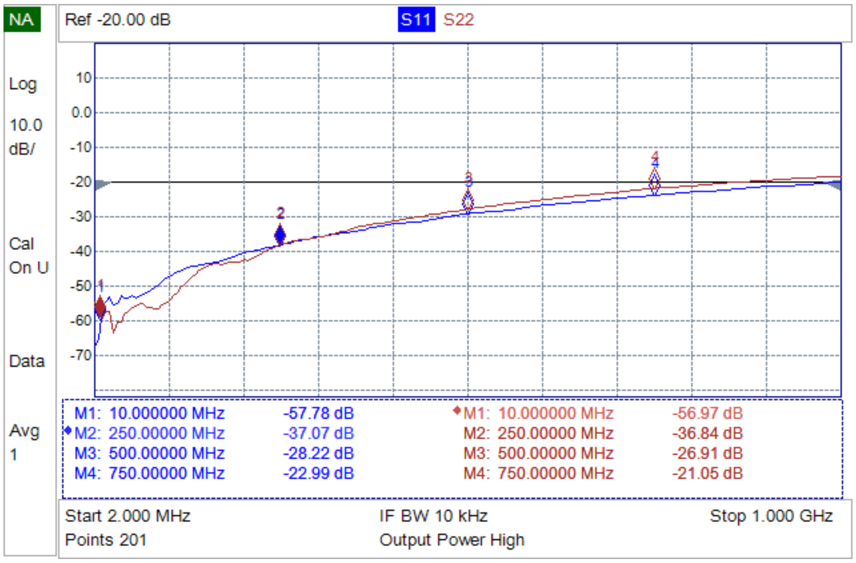
```
Ref 0.00 dB                    S21 S12

M1: 10.000000 MHz    -0.0070 dB    M1: 10.00  MHz    -0.0068 dB
M2: 250.00000 MHz    -0.0739 dB    M2: 250.00  MHz   -0.0728 dB
M3: 500.00000 MHz    -0.1296 dB    M3: 500.00  MHz   -0.1305 dB
M4: 750.00000 MHz    -0.1768 dB    M4: 750.00  MHz   -0.1777 dB

Start 2.000 MHz              IF BW 10 kHz              Stop 1.000 GHz
Points 201                   Output Power High
```

Figure A.4.d ~ Adapter 2, two of two, S21 (blue trace) and S12 (magenta trace).

Adapter 3, step 5)

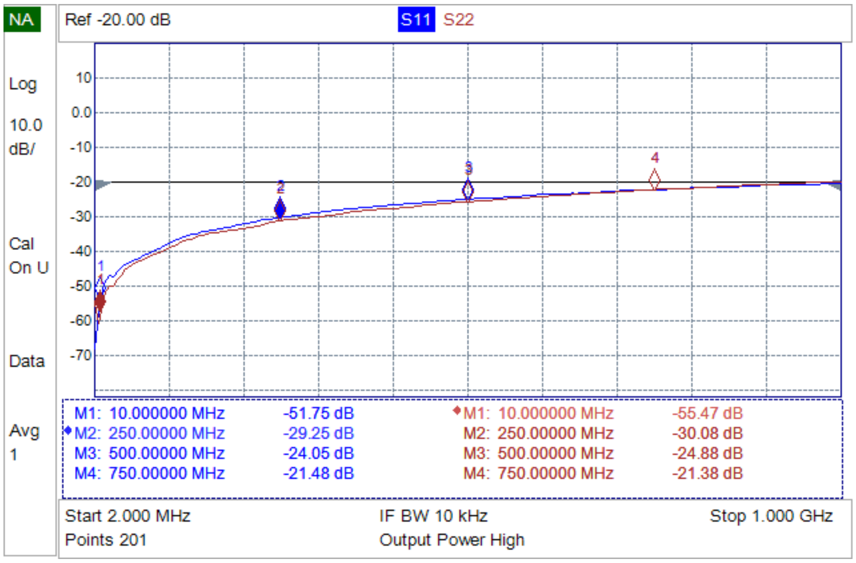


```
Ref -20.00 dB                S11  S22

M1:  10.000000 MHz   -57.78 dB    M1:  10.000000 MHz   -56.97 dB
M2:  250.00000 MHz   -37.07 dB    M2:  250.00000 MHz   -36.84 dB
M3:  500.00000 MHz   -28.22 dB    M3:  500.00000 MHz   -26.91 dB
M4:  750.00000 MHz   -22.99 dB    M4:  750.00000 MHz   -21.05 dB

Start 2.000 MHz            IF BW 10 kHz             Stop 1.000 GHz
Points 201                 Output Power High
```

Figure A.5.a ~ Adapter 3, one of two, S11 (blue trace) and S22 (magenta trace).

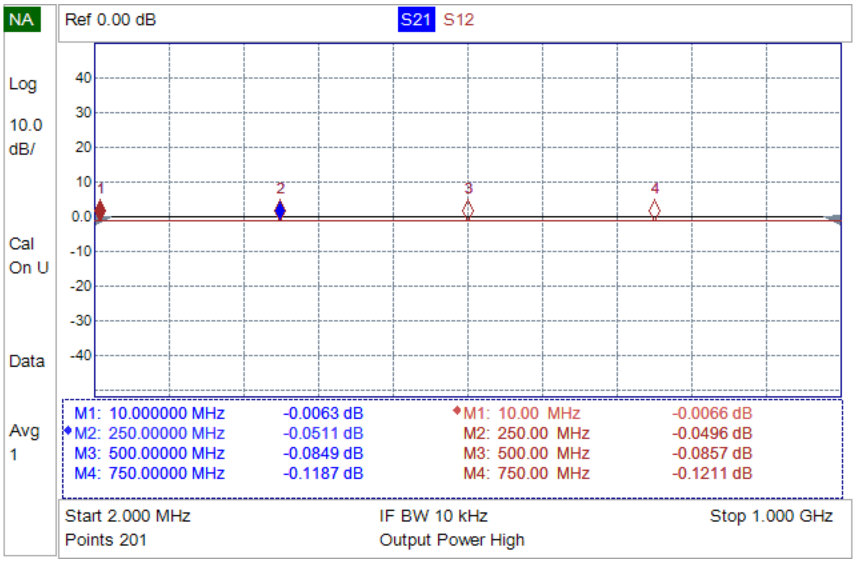


```
Ref -20.00 dB                S11  S22

M1:  10.000000 MHz   -51.75 dB    M1:  10.000000 MHz   -55.47 dB
M2:  250.00000 MHz   -29.25 dB    M2:  250.00000 MHz   -30.08 dB
M3:  500.00000 MHz   -24.05 dB    M3:  500.00000 MHz   -24.88 dB
M4:  750.00000 MHz   -21.48 dB    M4:  750.00000 MHz   -21.38 dB

Start 2.000 MHz            IF BW 10 kHz             Stop 1.000 GHz
Points 201                 Output Power High
```

Figure A.5.b ~ Adapter 3, two of two, S11 (blue trace) and S22 (magenta trace).

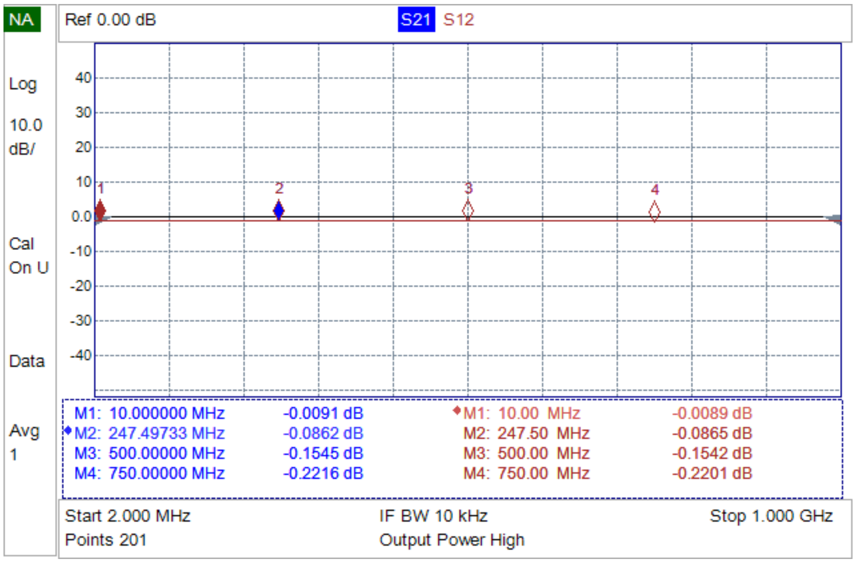


```
Ref 0.00 dB                  S21  S12

M1:  10.000000 MHz   -0.0063 dB   M1:  10.00  MHz   -0.0066 dB
M2:  250.00000 MHz   -0.0511 dB   M2:  250.00  MHz  -0.0496 dB
M3:  500.00000 MHz   -0.0849 dB   M3:  500.00  MHz  -0.0857 dB
M4:  750.00000 MHz   -0.1187 dB   M4:  750.00  MHz  -0.1211 dB

Start 2.000 MHz            IF BW 10 kHz             Stop 1.000 GHz
Points 201                 Output Power High
```

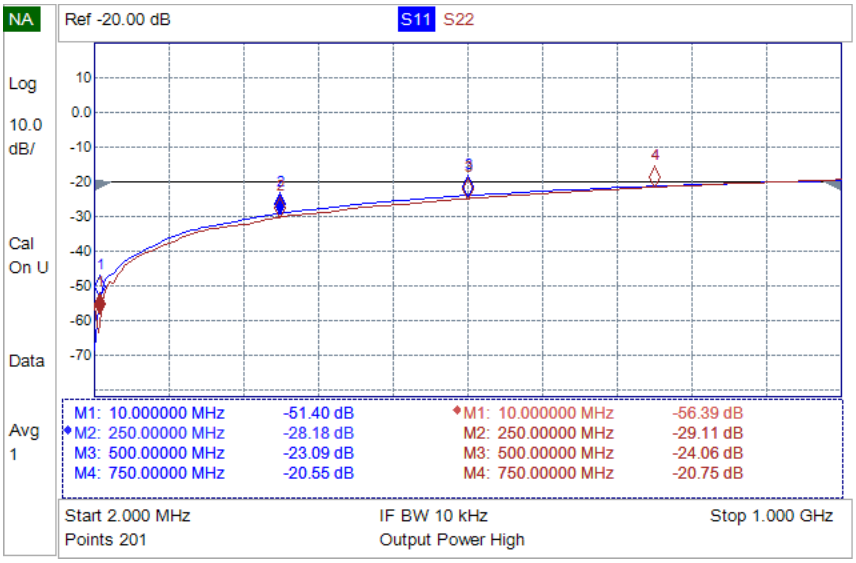
Figure A.5.c ~ Adapter 3, one of two, S21(blue trace) and S12 (magenta trace).



```
Ref 0.00 dB
M1: 10.000000 MHz   -0.0091 dB    M1: 10.00  MHz   -0.0089 dB
M2: 247.49733 MHz   -0.0862 dB    M2: 247.50  MHz  -0.0865 dB
M3: 500.00000 MHz   -0.1545 dB    M3: 500.00  MHz  -0.1542 dB
M4: 750.00000 MHz   -0.2216 dB    M4: 750.00  MHz  -0.2201 dB
Start 2.000 MHz          IF BW 10 kHz          Stop 1.000 GHz
Points 201               Output Power High
```

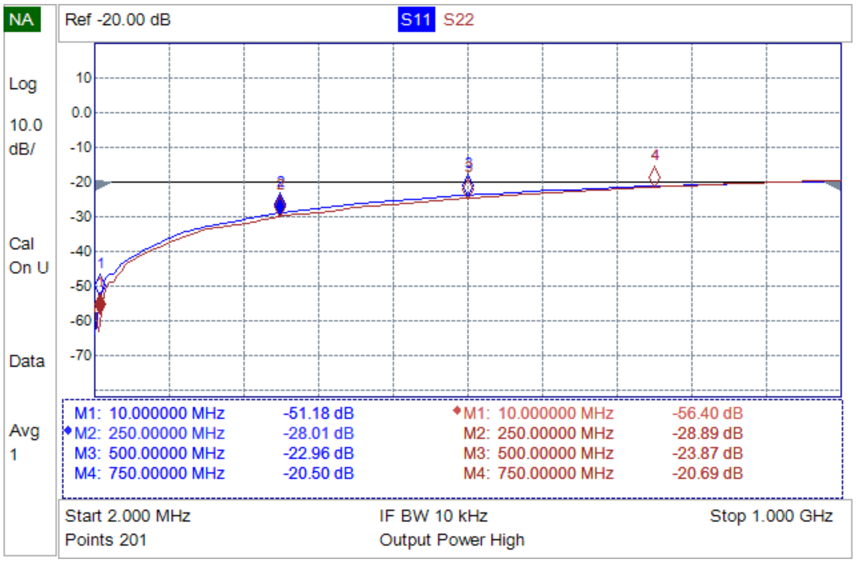
Figure A.5.d ~ Adapter 3, two of two, S21 (blue trace) and S12 (magenta trace).

Adapter 4, step 5)



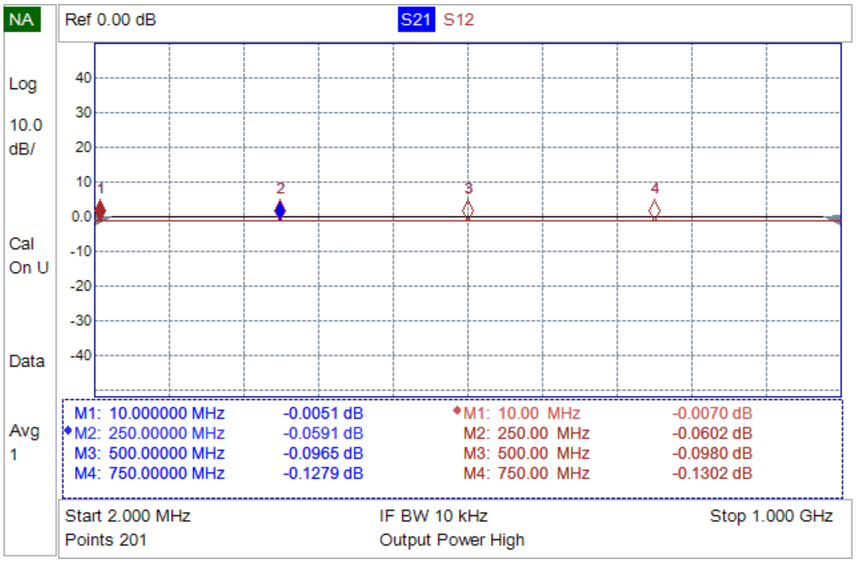
```
Ref -20.00 dB
M1: 10.000000 MHz   -51.40 dB    M1: 10.000000 MHz   -56.39 dB
M2: 250.00000 MHz   -28.18 dB    M2: 250.00000 MHz   -29.11 dB
M3: 500.00000 MHz   -23.09 dB    M3: 500.00000 MHz   -24.06 dB
M4: 750.00000 MHz   -20.55 dB    M4: 750.00000 MHz   -20.75 dB
Start 2.000 MHz          IF BW 10 kHz          Stop 1.000 GHz
Points 201               Output Power High
```

Figure A.6.a ~ Adapter 4, one of two, S11 (blue trace) and S22 (magenta trace).



```
Ref -20.00 dB
M1: 10.000000 MHz   -51.18 dB    M1: 10.000000 MHz   -56.40 dB
M2: 250.00000 MHz   -28.01 dB    M2: 250.00000 MHz   -28.89 dB
M3: 500.00000 MHz   -22.96 dB    M3: 500.00000 MHz   -23.87 dB
M4: 750.00000 MHz   -20.50 dB    M4: 750.00000 MHz   -20.69 dB
Start 2.000 MHz          IF BW 10 kHz          Stop 1.000 GHz
Points 201               Output Power High
```

Figure A.6.b ~ Adapter 4, two of two, S11 (blue trace) and S22 (magenta trace).

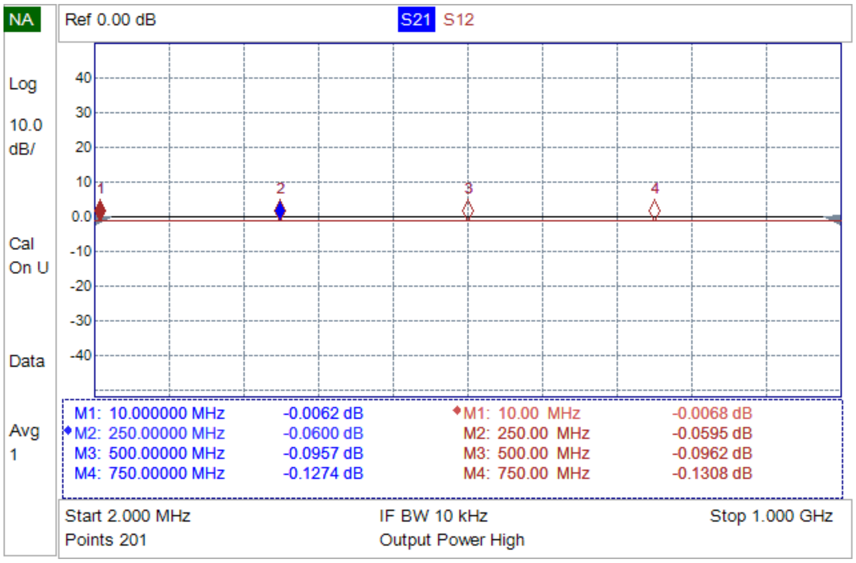


Ref 0.00 dB

```
M1: 10.000000 MHz    -0.0051 dB    M1: 10.00  MHz    -0.0070 dB
M2: 250.00000 MHz    -0.0591 dB    M2: 250.00  MHz   -0.0602 dB
M3: 500.00000 MHz    -0.0965 dB    M3: 500.00  MHz   -0.0980 dB
M4: 750.00000 MHz    -0.1279 dB    M4: 750.00  MHz   -0.1302 dB
```

Start 2.000 MHz
Points 201
IF BW 10 kHz
Output Power High
Stop 1.000 GHz

Figure A.6.c ~ Adapter 4, one of two, S21 (blue trace) and S12 (magenta trace).



Ref 0.00 dB

```
M1: 10.000000 MHz    -0.0062 dB    M1: 10.00  MHz    -0.0068 dB
M2: 250.00000 MHz    -0.0600 dB    M2: 250.00  MHz   -0.0595 dB
M3: 500.00000 MHz    -0.0957 dB    M3: 500.00  MHz   -0.0962 dB
M4: 750.00000 MHz    -0.1274 dB    M4: 750.00  MHz   -0.1308 dB
```

Start 2.000 MHz
Points 201
IF BW 10 kHz
Output Power High
Stop 1.000 GHz

Figure A.6.d ~ Adapter 4, two of two, S21 (blue trace) and S12 (magenta trace).

Document information

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