Agilent AN 346-2

Balanced Circuit Measurement with an Impedance Analyzer/LCR Meter/Network Analyzer

Application Note

Introduction

How a balanced circuit differs from an unbalanced circuit

A balanced circuit has its electrical midpoint grounded. An unbalanced circuit, however, has one side grounded. A balanced circuit is typically used in communications equipment because a balanced circuit has the advantage of better spurious noise suppression.

Figure 1 shows a balanced cable which is an example of a balanced circuit. The voltages of the cable's two conductors are at every point equal in amplitude and opposite in phase. Figure 2 shows an unbalanced cable which is an example of an unbalanced circuit. Most measurement circuits in Agilent Technologies' impedance analyzers and LCR meters are unbalanced.

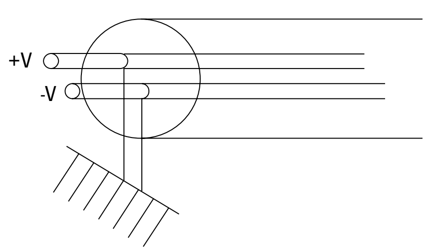

Figure 1. Balanced cable

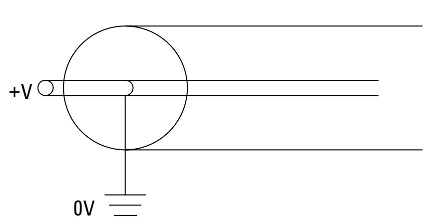

Figure 2. Unbalanced cable

Measuring a balanced circuit with an unbalanced measurement instrument

A balanced circuit cannot be directly measured with an unbalanced measurement instrument because of the difference in their configuration.

When measuring balanced circuits, the unbalanced measuring instrument requires a balun (balanced to unbalanced) transformer. A balun is a type of impedance-matching RF transformer.

Figure 3 shows the configuration for measuring a balanced circuit with an unbalanced instrument.

Note: In balanced cable measurements, residual current in the balun or the measuring instrument can cause measurement errors. To reduce the degree of error, perform open/short and load compensation at the measurement terminals of the balun.

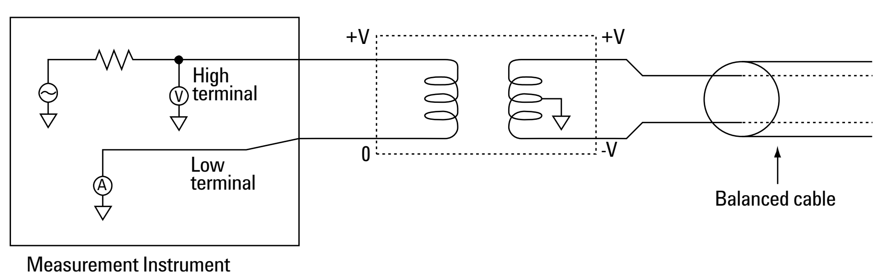

Figure 3. Balanced cable measurement configuration

Selecting a Balun

There are several types and brands of balun transformers. When selecting a balun, ensure that frequency is compatible with your measurement requirements. When you measure the impedance parameters of a balanced circuit, you don't have to use the balun which has the same impedance with the circuit under test. However, when you measure the transmission or reflection of it, you have to use a balun which has the same impedance with the circuit under test to keep impedance matching. Table 1 shows recommended balun transformers.

Measurement Configuration with a Balun and Compensation

Impedance measurement configuration with Agilent 4294A impedance analyzer
Figure 4 shows impedance measurement configuration (1)/(2) with the 4294A.

To calibrate/compensate for (1):
1. Perform open, short, and load compensation at the balanced terminals of the 16314-60011. Use the furnished compensation standards of the 16314-60011.

Standards	0 Ω	PN 04191-85300
	0S	PN 04191-85302
	50 Ω	PN 04191-85301

To calibrate/compensate for (2):
1. Assemble a female BNC connector as shown in Figure 5.

2. Perform open, short, and load calibration at the BNC connector using the following BNC Calibration standards:

Short standard	PN 1250-0929
50 Ω load standard	PN 11593A

3. Remove the connector and connect the DUT. Measure the DUT.

Impedance measurement configuration with the Agilent 4395A(#010)
Figure 6 shows impedance measurement configuration (2) with the 4395A.

To calibrate/compensate:
Refer to "To calibrate/compensate for (2)" of impedance measurement configuration with 4294A impedance analyzer.

Transmission measurement configuration with a network analyzer
Figure 7 shows transmission measurement configuration (3) with a network analyzer.

To calibrate/compensate:
Short the terminals closest to the DUT to the signal out and to the test port, then perform response/thru calibration.

Table 1. Recommended balun transformers

Unb/Bal. (W)	Bandwidth	Type No.	Suppliers
50:50	100 Hz to 10 MHz	16315-60011	Agilent Technologies
50:100	100 Hz to 10 MHz	16316A	Agilent Technologies
50:600	100 Hz to 3 MHz	16317A	Agilent Technologies
50:50	0.1–125 MHz	0001BB	North Hills Signal Processing
50:75	0.1–125 MHz	0101BB	North Hills Signal Processing
50:100	0.1–125 MHz	0300BB	North Hills Signal Processing
50:600	0.1–65 MHz	0700BB	North Hills Signal Processing
75:50	0.1–100 MHz	1000BB	North Hills Signal Processing
75:75	0.1–100 MHz	1100BB	North Hills Signal Processing
75:100	0.1–100 MHz	1300BB	North Hills Signal Processing
75:600	0.1–60 MHz	1700BB	North Hills Signal Processing

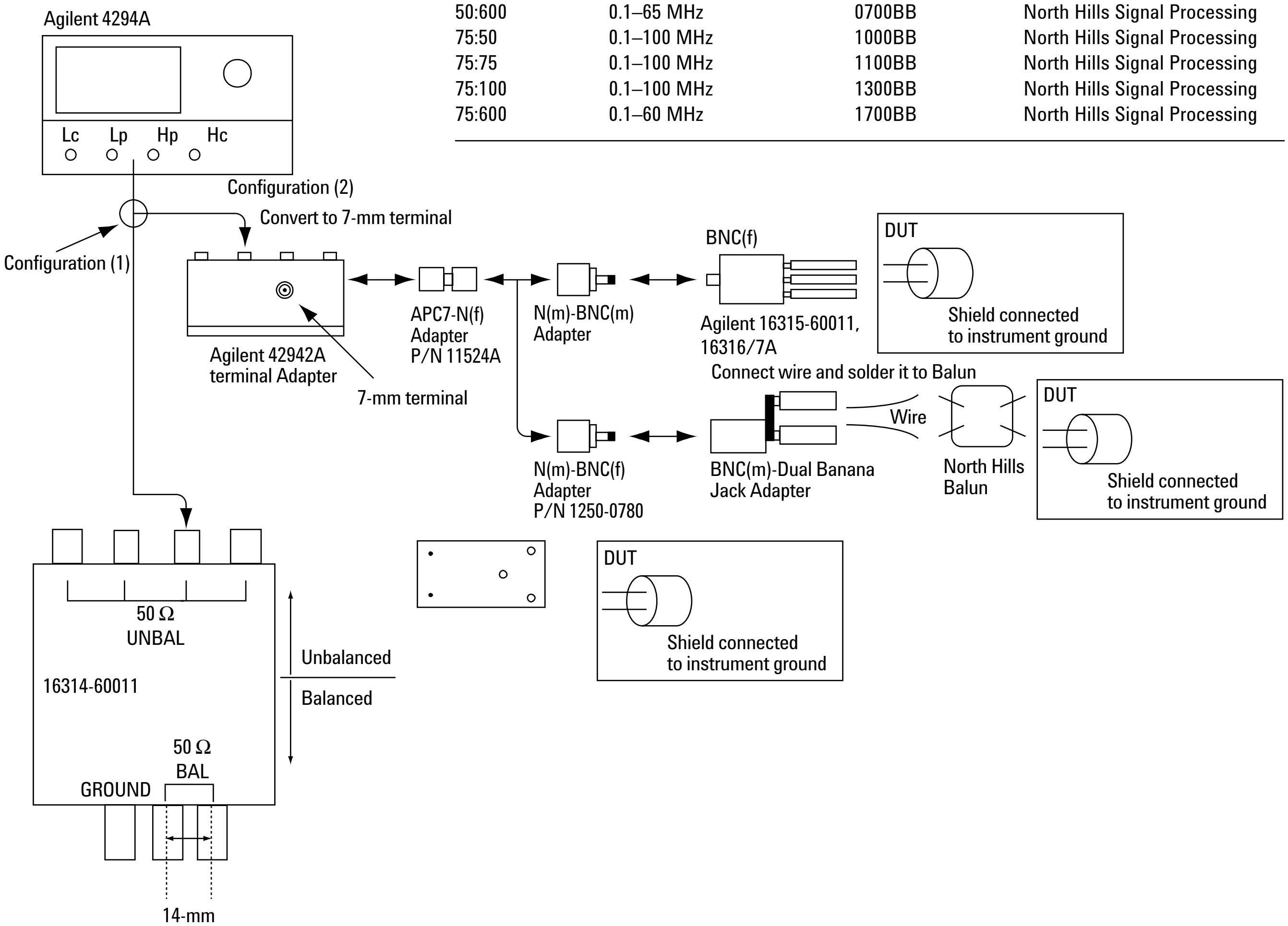

Figure 4. Measurement configurations with 4294A

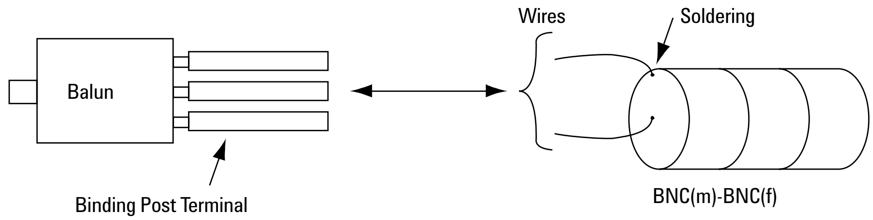

Figure 5. Assembling BNC connector

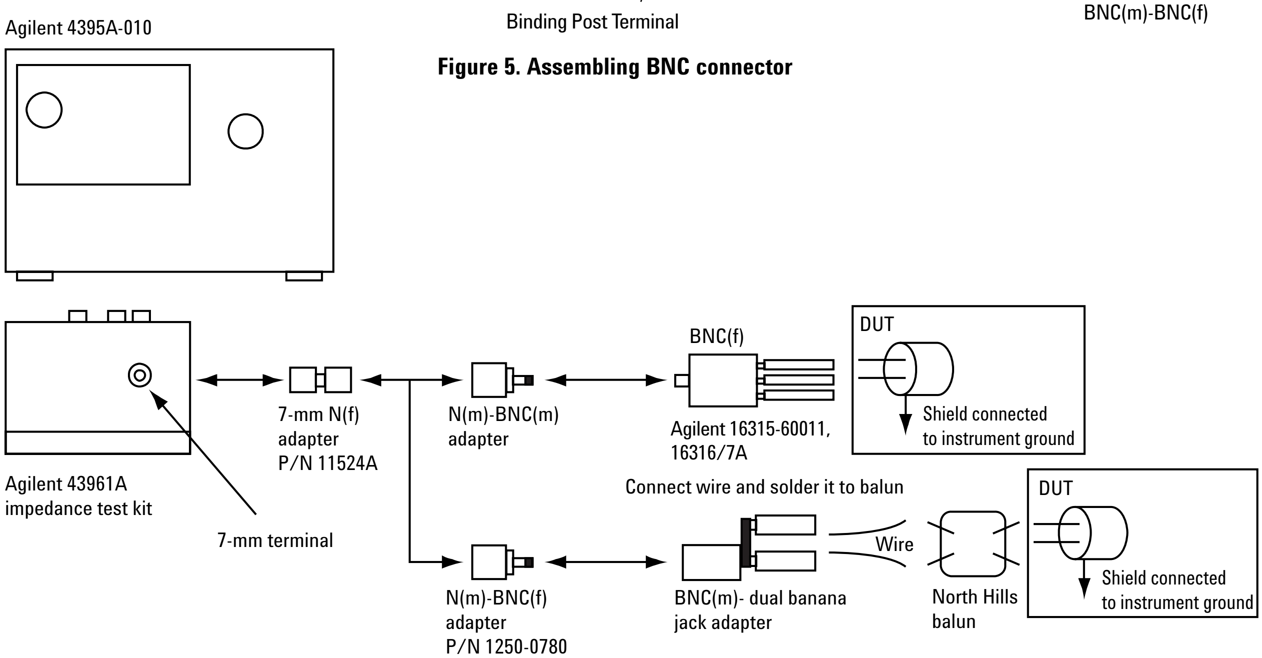

Figure 6. Measurement configuration (2)

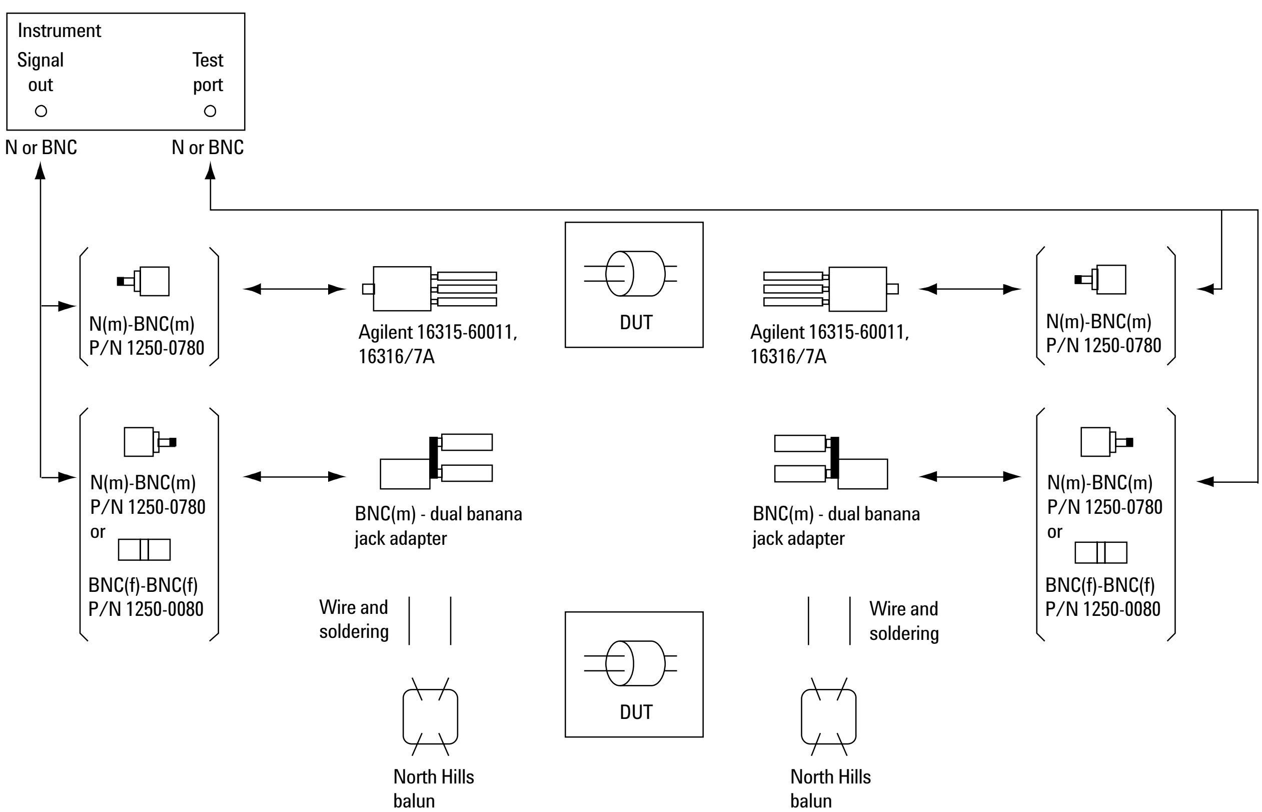

Figure 7. Measurement configuration (3)

Appendix: Agilent Balun Transformer Information

The Agilent balun transformers are excellent interfaces for measuring balanced components or circuits. They can be used with unbalanced system measurement instruments such as impedance analyzers, LCR meters, and/or network analyzers (that are unbalanced system measurement instruments). Agilent offers the following balun transformers.

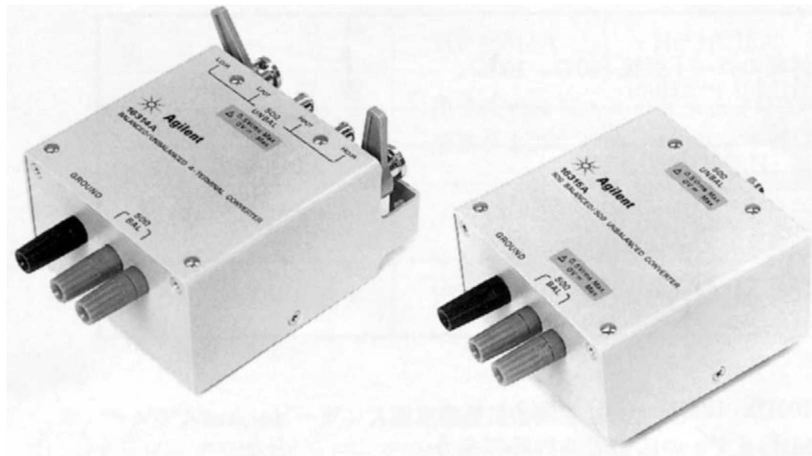

Figure 8. Agilent 16314-60011 and 16315-60011

Agilent 16314-60011

The 16314-60011 can be directly connected to a 4-terminal-pair impedance analyzer or an LCR meter. High-accuracy impedance measurements of balanced devices can be made by using the OPEN/SHORT/LOAD characteristic. This unique feature of the Agilent impedance analyzer and LCR meters is performed at the binding posts by using the furnished shorting plate and a 50 Ω load resistor.

- Wide frequency range (100 Hz to 10 MHz) is covered.
- Recommended instruments:
  - 4294A precision impedance analyzer
  - 4284A precision LCR meter
  - 4285A precision LCR meter
  - E4980A precision LCR meter

Agilent 16315-60011, 16316A, 16317A

- Reflection and transmission measurements of balanced devices and circuits can be measured with a network analyzer.
- With the furnished load resistor (50 Ω, 100 Ω, 600 Ω) and short plate, calibration can be performed for high-accuracy measurements.
- Depending on the impedance of the device, balanced impedance of 50 Ω, 100 Ω, or 600 Ω can be selected.
- Wide frequency range (100 Hz to 10 MHz (Agilent 16317A covers up to 3 MHz))
- Recommended instruments:
  - 4395A 500 MHz network/spectrum/impedance analyzer
  - 4396B 1.8 GHz network/spectrum/impedance analyzer
  - 4294A precision impedance analyzer

Specifications

Specifications describe the instrument's warranted performance over the temperature range of 0 to 50 °C (except where noted) and after 30-minute warm-up time.

Table 2. Agilent balun transformers specifications

<table>
<tr><td colspan="2">Item</td><td>16314-60011</td><td>16315-60011</td><td>16316A</td><td>16317A</td></tr>
<tr><td rowspan="4">Terminal configuration & nominal characteristic impedance</td><td rowspan="2">Balanced port</td><td colspan="4">Binding posts
2 signal terminals and 1 ground terminal (signal terminal spacing: 14.0 mm)</td></tr>
<tr><td>50 Ω</td><td>50 Ω</td><td>100 Ω</td><td>600 Ω</td></tr>
<tr><td rowspan="2">Unbalanced port</td><td>4 BNC connectors</td><td colspan="3">1 BNC connector</td></tr>
<tr><td colspan="4">50 Ω</td></tr>
<tr><td colspan="2">Size (mm)</td><td>89(W) x 56(H) x 133 (D)</td><td colspan="3">89(W) x 55(H) x 121 (D)</td></tr>
<tr><td colspan="2">Weight (g)</td><td>400</td><td colspan="3">350</td></tr>
<tr><td colspan="2">Operating temperature</td><td colspan="4">0 to 55 °C</td></tr>
<tr><td colspan="2">Operating humidity</td><td colspan="4">≤ 95% RH (@ 40 °C)</td></tr>
<tr><td colspan="2">Non-operation temperature</td><td colspan="4">-40 to +70 °C</td></tr>
<tr><td colspan="2">Non-operating humidity</td><td colspan="4">≤ 90% RH (@ 65 °C)</td></tr>
<tr><td colspan="2">Furnished accessories</td><td>50 Ω load resistor
Shorting plate
Manual</td><td>50 Ω load resistor
Shorting plate
Manual</td><td>100 Ω load resistor
Shorting plate
Manual</td><td>600 Ω load resistor
Shorting plate
Manual</td></tr>
</table>

Supplemental Characteristics

Supplemental characteristics are intended to provide information useful in applying the instrument by giving non-warranted performance parameters.

Table 3. Agilent Balun transformers supplemental characteristics (at 23 ± 5 °C)

<table>
<tr><td>Item</td><td>16314-60011</td><td>16315-60011</td><td>16316A</td><td>16317A</td></tr>
<tr><td>Operating frequency</td><td colspan="3">100 Hz to 10 MHz</td><td>100 Hz to 3 MHz</td></tr>
<tr><td>Insertion loss</td><td colspan="4">≤ 1.0 dB (@100 kHz)</td></tr>
<tr><td>Freq. response</td><td colspan="3">≤ 1.0 dB (relative to the insertion loss at 100 kHz)</td><td>≤ ±1.5 dB (relative to the insertion loss at 100 kHz)</td></tr>
<tr><td>Return loss</td><td colspan="3">≥ 10 dB (100 Hz ≤ Freq. < 300 Hz)
≥ 20 dB (300 Hz ≤ Freq. < 7 MHz)
≥ 17 dB (7 MHz ≤ Freq. < 10 MHz)</td><td>≥ 10 dB (100 Hz ≤ Freq. < 300 MHz)
≥ 20 dB (300 MHz ≤ Freq. ≤ 1 MHz)
≥ 15 dB (1 MHz < Freq. ≤ 3MHz)</td></tr>
<tr><td>Common mode loss</td><td colspan="3">≥ 50 dB (100 Hz ≤ Freq. < 3 MHz)
≥ 45 dB (3 MHz ≤ Freq. < 5 MHz)
≥ 40 dB (5 MHz ≤ Freq. < 10 MHz)</td><td>≥ 50 dB (100 Hz ≤ Freq. < 1 MHz)
≥ 45 dB (1 MHz ≤ Freq. < 3 MHz)</td></tr>
</table>

Web Resource

www.agilent.com/find/impedance
www.agilent.com/find/lcrmeters

References

Impedance Measurement Handbook,
Publication Number 5950-3000

For information on balun, contact the manufacturers:
North Hills Signal Processing
A Porta Systems Company
575 Underhill Blvd.
Syosset, NY 11791
Tel: (516) 682 7740
Fax: (516) 682 7704

www.northhills-sp.com/contact.html

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