

## APPLICATION NOTE - 016

### Testing RFI Line Filters – Frequency Response Analysis

#### Testing RFI line filters

Radio frequency interference (RFI) is unwanted electromagnetic noise within a radio communications frequency range that can interfere with the correct operation of electronic equipment.

To ensure the reliable operation of electronic products and compliance with international standards, designers and manufacturers must ensure that their products incorporate satisfactory RFI filtering.

#### Modes of RFI

There are two modes of interference that must be considered; ‘conducted interference’ i.e. RFI on signal or power conductors and ‘radiated interference’, i.e. electromagnetic waves in free space.

Conducted RFI is usually tested over a frequency range of 10kHz to 30MHz with direct measurement of signal attenuation provided by the RFI line filter, while radiated RFI relates to frequencies from 30MHz to 1GHz tested against absolute radiated limits for a complete product.

In this document, we look at performance testing of RFI line filters used to attenuate conducted interference on AC power lines.

#### Operating principle

The attenuation of RFI noise is achieved using a network of passive components arranged to allow power currents at 50-60Hz to pass through the filter with little or no attenuation while frequency components in the RFI frequency range are attenuated. The following schematic illustrates a typical RFI line filter circuit:

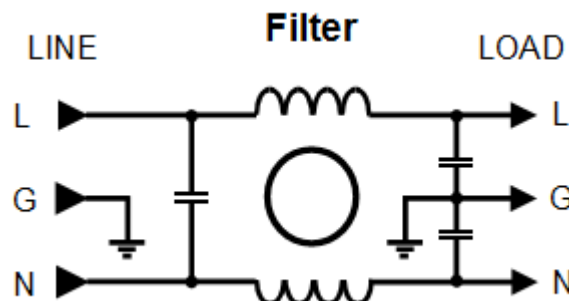


Fig 1.

Testing RFI Line Filters – Frequency Response Analysis	525-016	Issue 1
Newtons4th Ltd 30 Loughborough Rd Mountsorrel Loughborough LE12 7AT UK Tel: +44 (0)116 2301066		

The circuit is a dual low-pass design providing filtering of both differential and common mode signals, so it is important to ensure that both filtering modes meet required limits.

The apparent simplicity of this design leads many people to assume that with similar component values, any RFI line filters will provide comparable performance but in practice, this is not true.

Small differences in component structure and the layout of components within the filter may have little effect at low frequencies but can result in significantly different levels of attenuation as the frequency increases. It is therefore important to ensure that any filter selected for use in a product has been tested over the full frequency range for which it is specified.

### **Confirming filter performance**

In order to confirm the correct operation of an RFI line filter it is necessary to test the transfer function of the filter over the specified operating frequency range. The transfer function is a definition of the attenuation from filter input to filter output over a range of frequencies and in this application, the term 'Insertion Loss' is used to define the signal attenuation that results from inserting the filter into a circuit.

### **Insertion Loss**

Insertion loss is defined as the ratio of the voltage at the load without a filter compared to the voltage at the load when the filter is inserted. The ratio is expressed in dB and since the voltage at the load without a filter is equal to the input to the filter (line), insertion loss is calculated as follows:

$$\text{dB} = 20 \log_{10}(V_{\text{out}} / V_{\text{in}})$$

Testing RFI Line Filters – Frequency Response Analysis	525-016	Issue 1
Newtons4th Ltd 30 Loughborough Rd Mountsorrel Loughborough LE12 7AT UK Tel: +44 (0)116 2301066		

**Test circuit**

The level of signal attenuation from any filter is dependent upon the load impedance of the circuit to which it is connected so when testing insertion loss, it is necessary to maintain defined circuit impedance. In the case of RFI line filters, it is common practice to use a circuit impedance of 50Ω so the test circuit should be as follows:

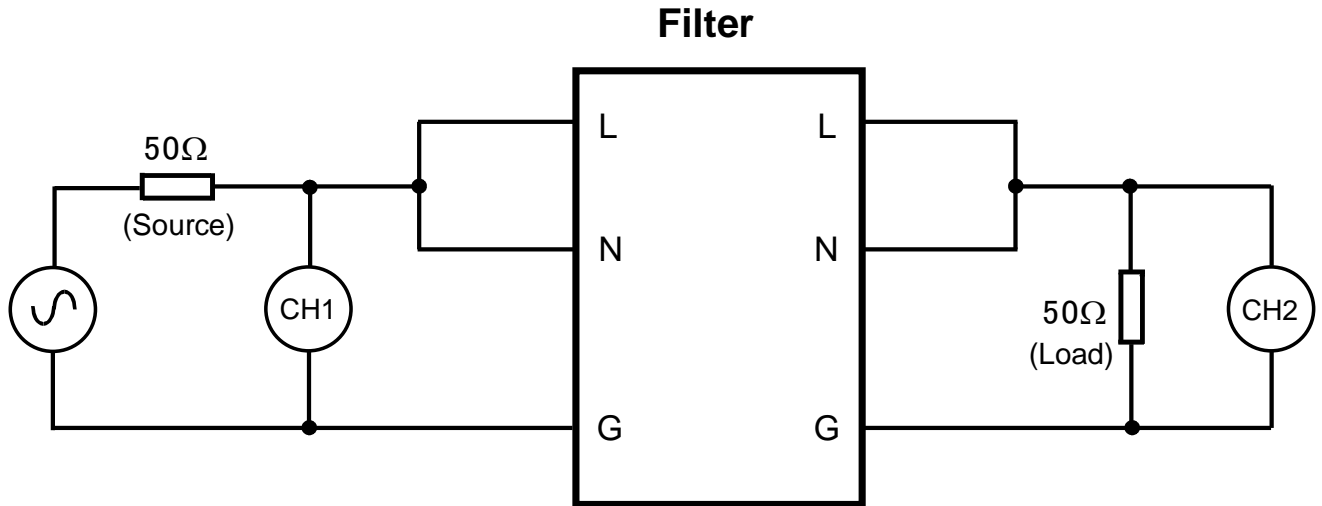


Fig 2.

**Differential and Common Mode testing**

The test circuit shown in Fig 2 applies a common signal to both Line and Neutral terminals relative to ground and will therefore provide a measure of Common Mode (CM) Insertion Loss.

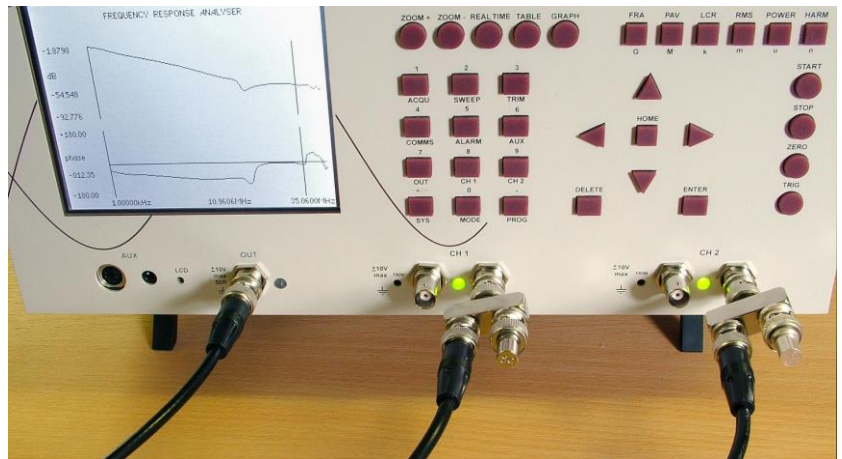
By removing connections to the Neutral terminals, Live to Ground Differential Mode (DM) Insertion Loss will be obtained or by removing connections to the Line terminals, Neutral to Ground DM Insertion Loss is obtained.

Testing RFI Line Filters – Frequency Response Analysis	525-016	Issue 1
Newtons4th Ltd 30 Loughborough Rd Mountsorrel Loughborough LE12 7AT UK Tel: +44 (0)116 2301066		

## Making measurements

With signal generator, two independent measurement channels and 35MHz frequency range, the PSM1735 permits direct testing RFI line filters.

By using BNC 'T' piece adaptors fitted with a 50Ω terminator on each measurement channel, BNC to crocodile leads can be used to connect directly to the RFI Line Filter being tested.



PSM1735 with connection leads and 50Ω terminators for RFI line filter testing

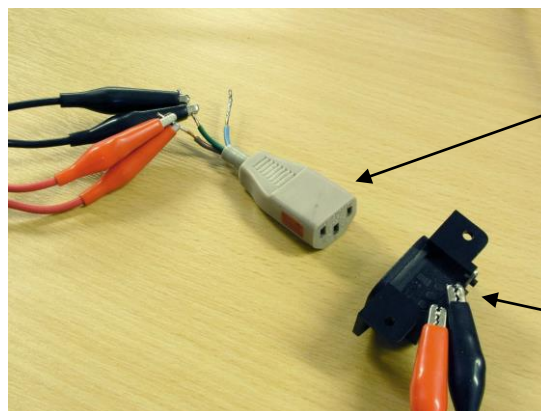
## Notes:

1. The PSM signal generator has 50Ω source impedance, so it is not necessary to fit an additional source resistor.
2. The 50Ω terminator fitted to the T piece adaptor on CH2 provides the load impedance required for insertion loss measurements and correct termination impedance for the BNC cable.
3. The 50Ω terminator fitted to the T piece adaptor on CH1 provides correct termination impedance of the BNC cable that is required for accurate high frequency measurements. Provided that load termination is 50Ω, the reduced source impedance of the test circuit resulting from this additional resistance has negligible effect on insertion loss measurements.

## Test connections

BNC to crocodile leads from Generator and CH1

(Connections made between Live and Ground ready for



BNC to crocodile lead from CH2

IEC connector with stripped conductors for easy crocodile clip connection. Lead length on the IEC connector should be as short as possible to minimise the inductive impedance of the test circuit.

IEC socket to allow the Insertion Loss of the test circuit to be checked with no filter fitted.

Testing RFI Line Filters – Frequency Response Analysis	525-016	Issue 1
Newtons4th Ltd 30 Loughborough Rd Mountsorrel Loughborough LE12 7AT UK Tel: +44 (0)116 2301066		

**Test sequence**

**1. Check insertion loss of the test circuit**

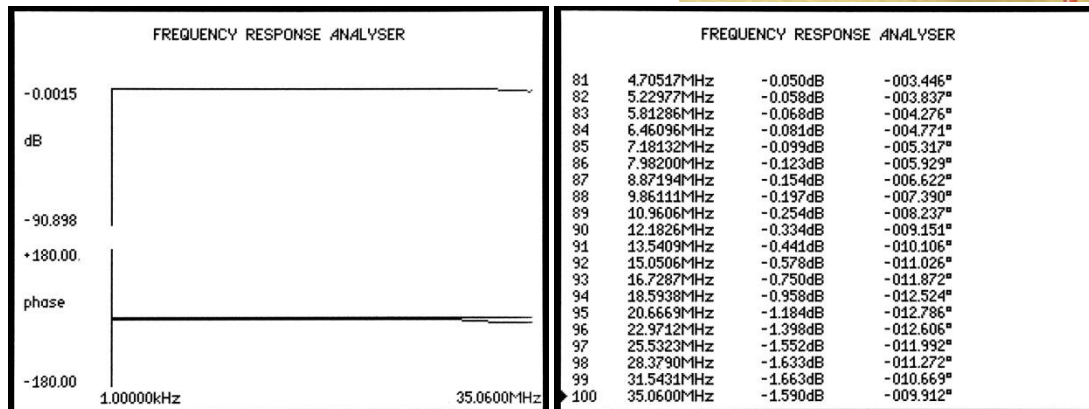
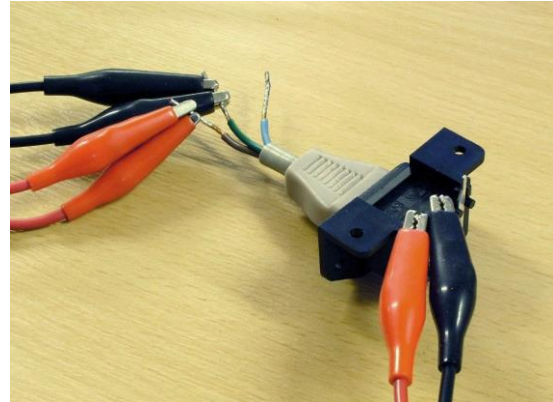
With the IEC connector pushed into the IEC socket, run an FRA sweep with the following settings:

Output ON - 2V pk

Channel 1 / 2 - 'main' input – 'ac' coupled

Sweep start - 1kHz

Sweep stop - 35MHz

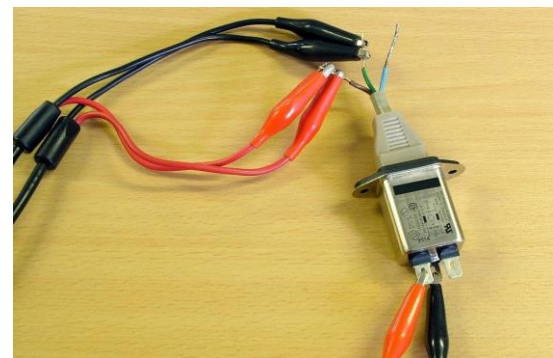


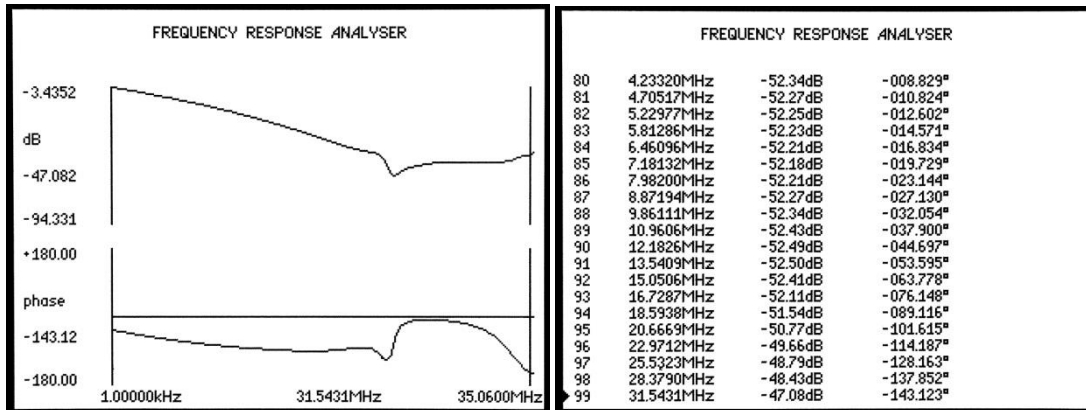
Here it can be seen that throughout the complete frequency range, the insertion loss results are less than 1.7dB which is therefore the maximum error associated with the test circuit.

**2. Test Differential Mode Insertion Loss**

With the IEC connector pushed into a sample RFI filter and CH2 crocodile clips connected to L and G load terminals (black to G), press 'START'.

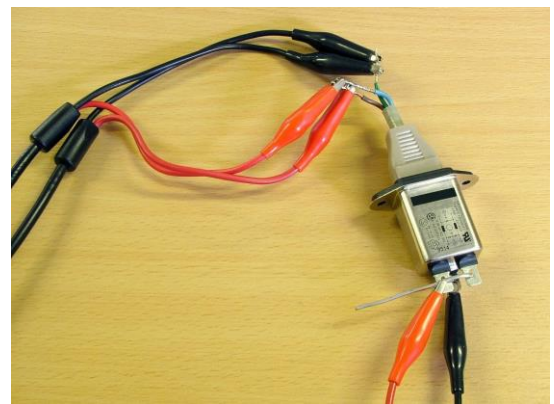
The results obtained represent the Live to Ground DM Insertion Loss.



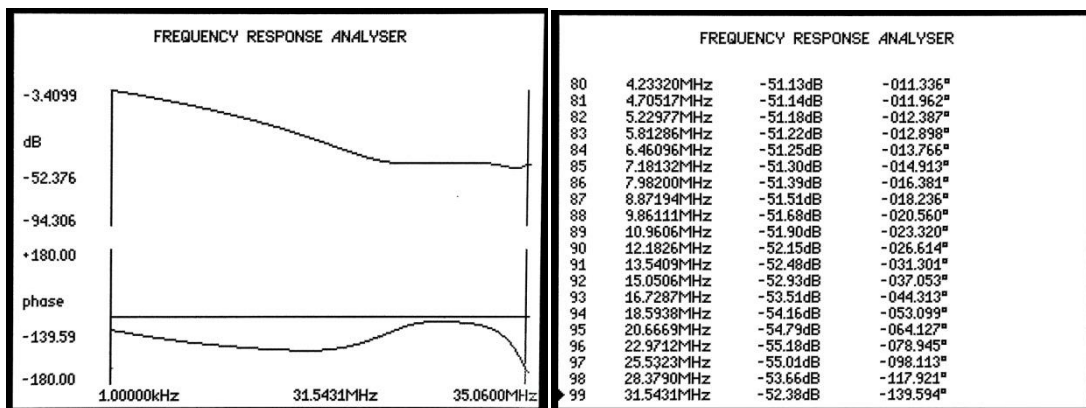


### 3. Test Common Mode Insertion Loss

Now change connections to the Line and Load sides of the filter with the black crocodile clips to Ground and the red crocodile clips connected to both Live and Neutral points. Note: to link Live and Neutral points at the load terminals of the filter, it may be necessary to use a shorting link as shown here.



Press 'START' and measurements will be presented in the same way as before but the results now represent CM Insertion Loss.



## Summary

To establish the correct performance of an RFI Line Filter, it is necessary to test the value of Insertion Loss over the complete frequency range for which the filter is designed to operate.

It is normal for Insertion Loss results obtained in differential or common mode configurations to differ and therefore testing of both modes will be required unless one specific mode is defined.

Using the techniques described above, the PSM1735 provides a complete test solution for conducted RFI testing of RFI Line Filters to ensure compliance with defined specifications.

Testing RFI Line Filters – Frequency Response Analysis	525-016	Issue 1
Newtons4th Ltd 30 Loughborough Rd Mountsorrel Loughborough LE12 7AT UK Tel: +44 (0)116 2301066		