

Methods of

Measurement of the suppression characteristics of passive radio interference filters and suppression components

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This British Standard, having been prepared under the direction of the General Electrotechnical Engineering Standards Committee, was published under the authority of the Board of BSI and comes into effect on 29 October 1982

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National foreword

This British Standard has been prepared under the direction of the General Electrotechnical Engineering Standards Committee. It is identical with CISPR Publication 17 “Methods of measurement of the suppression characteristics of passive radio interference filters and suppression components” published in 1981 by the International Electrotechnical Commission (IEC) on behalf of its Special Committee on Radio Interference (CISPR).

Terminology and conventions. The text of the CISPR Publication has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is drawn especially to the following.

In clause **2** the reference to “C.I.S.P.R. publication” should be read as “British Standard”.

Cross-references. The technical committee has reviewed the provisions of CISPR Publication 12, to which reference is made in the text and has decided that they are acceptable for use in conjunction with this standard. The related British Standard is BS 833 “*Radio interference limits and measurements for the electrical ignition systems of internal combustion engines*”.

In **B.2.2** reference is made to CISPR Report No. 53 for information only. This report has been published in CISPR Publication 8D.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 24, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Introduction

As a general rule, suppression characteristics of radio suppression components, that is to say capacitors, inductors and filters, depend on the impedances between which they work (these being of decisive importance for energy reflection on the input of the filter), on operating current and voltage levels and also on other factors, for example ambient temperature.

In order to make it possible to compare the results of measurements of these characteristics performed in various laboratories, or reported by various manufacturers, standard test methods must be used.

2 Scope

This C.I.S.P.R. publication prescribes methods of measurement of insertion loss of passive radio-frequency suppression filters, which may consist of single elements, such as capacitors, inductors or resistors, or combinations of inductors, capacitors and resistors of either the lumped or distributed types. The methods include those for use in a laboratory or on a production line, utilizing fixed impedance terminations or “worst case” terminations, those to be used *in situ* or in model installations, and provide for voltage and current loading.

3 Definitions

3.1

insertion loss

at a given frequency, the insertion loss of a filter connected into a given transmission system is defined as the ratio of voltages appearing across the line immediately beyond the point of insertion, before and after insertion of the filter under test

3.2

load current

d.c. or a.c. mains (power) frequency current flowing through the current conductor(s) of the filter under test

3.3

load voltage

d.c. or a.c. mains (power) frequency voltage applied between specified parts of the filter under test

3.4

impedance of the test circuit

impedance across the terminals of the test circuit without the filter connected

3.5

asymmetrical test circuit

a test circuit in which the filter under test is connected with a coaxial cable of which the outer conductor constitutes a return path for high-frequency current

3.6

symmetrical test circuit

a test circuit in which the filter under test is connected with screened conductor pairs in which asymmetrical voltage is small enough to be neglected

3.7

symmetry coefficient of symmetrical test circuit

the ratio of symmetrical and asymmetrical voltages which appear at the points of connection of the filter under test (expressed in decibels)

4 Test methods

Where filters are intended to be used with non-sinusoidal current (for example switched mode power supplies), it is essential to test the filters with a load current equal to the peak value of the non-sinusoidal waveform to be suppressed.

Methods may be divided as follows:

4.1 Standard method

The measurement of suppression characteristics of the filter is made with its input and output terminated in equal and fixed resistances, normally $50\ \Omega$ to $75\ \Omega$. Two variants are in use:

- filter without load;
- filter under full d.c. or a.c. load (current and/or voltage).

The characteristics obtained may differ from those observed in practice because the terminating impedances during the measurement differ from those existing during use in an actual device.

At present this method is used in various countries for investigation of filters:

- without load over the frequency range of 10 kHz to 1 GHz;
- or under current load up to 100 A over the frequency range of 10 kHz to 100 MHz;
- or under voltage load (ceramic filters) up to several kilovolts over the frequency range of 10 MHz to 300 MHz;

Measurements using the standard method shall be made in accordance with the procedure described in Appendix A.

4.2 Worst-case methods

4.2.1 Introduction

It is possible for filters containing only reactive elements to have an insertion gain *in situ* at frequencies within or outside the passband, especially where the connecting circuits have equivalent circuits dominated by reactive elements.

4.2.2 Methods of measurement

Two classes of measurement method are described. In the first, the objective is to obtain values of the true worst case. In the second, a simpler approximate method is used.

4.2.2.1 Worst-case methods

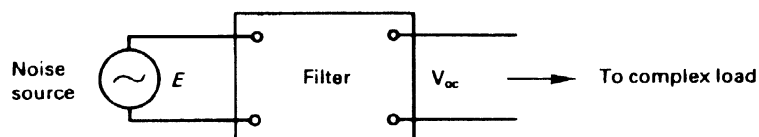
Two variants are described. In the first, measurements are made in which the load impedance is varied over a complete range of values of effective series resistance and reactance until the minimum attenuation is obtained. In the second, a quasi-analytic method is used.

4.2.2.1 a) Impedance variation method (to be developed)

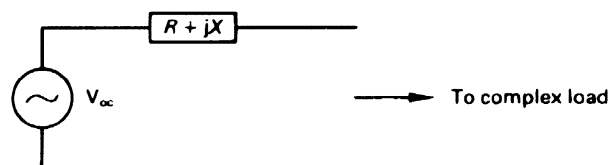
4.2.2.1 b) Quasi-analytic method

A. Theory of the method

Consider the circuit shown below:



The Thevenin equivalent circuit is:



The minimum voltage attenuation is obtained at each frequency over the desired range by two measurements of the filter:

- 1) the Thevenin impedance, that is the impedance of the filter at the load terminals with the input short-circuited, and
- 2) the transfer impedance, that is the ratio of voltage sent to current received in a short circuit at the load terminals.

From these two measurements, the minimum voltage attenuation ($\alpha V_{\min}$) (that is to say, the ratio of input to output voltage) is given by:

$$\alpha V_{\min} = 20 \log_{10} (Z_0 \times g_0) \text{ dB}$$

where Z_0 is the transfer impedance in ohms, and

$$g_0 = \frac{R}{(R^2 + X^2)} \text{ siemens}$$

where $(R + jX)$ is the Thevenin impedance.

B. Methods of measurement

A method of measuring the transfer impedance is shown schematically in Figure 1a, page 5. A signal generator, preferably of low output impedance, is connected to the input terminals of the filter network and monitored with a valve voltmeter. The output terminals of the network are short-circuited and a current probe (that is to say a radio-frequency current transformer) is used to measure the current in the short circuit which is needed for the calculation of transfer impedance.

To measure the Thevenin impedance of the network, the circuit shown schematically in Figure 1b, page 5, is adopted. This uses the same apparatus with the addition of a radio-frequency impedance bridge. In this case, the signal generator becomes the source of energy for the bridge and the measuring set its detector.

C. Sources of error

Transfer impedance

In this measurement, the input voltage is known to within (say) $\pm 3\%$ and the received current to within $\pm 15\%$. The total error, therefore, expressed in decibels, will be not greater than 1.5 dB.

A greater source of error will be the inability to construct a short circuit for the network at higher frequencies, as it has to be long enough to permit the inclusion of the current probe. Also, the current probe will reflect some impedance into the "short circuit" and, unless care is taken, this can be appreciable.

Fortunately, neither of these errors is serious for the following reasons: at frequencies approaching the cut-off for typical filters (that is to say, $f_c = 50$ kHz), the short circuit has little impedance and the measurement contains only the 1.5 dB error. At frequencies well above cut-off, the impedance of the short circuit will increase; let it be assumed that it is as great as 20Ω at 10 MHz for the typical circuit shown in Figure 2, page 5. The reactance of the inductor will be about $2\,000 \Omega$ at this frequency and the error introduced will be less than 10 dB. However, the frequencies at which this occurs are many times cut-off and, with the circuit shown in Figure 2, the minimum attenuation, theoretically, is of the order of 100 dB. In any event, the inductance added by insertion of the current probe is not large compared with typical wiring inductance.

In practice, the measured performance of a filter at frequencies well above cut-off is determined by the inability to detect the received current.

Thevenin impedance

The accuracy of the bridge is (say) $\pm 3\%$ and the only other possible source of error is the short circuit applied to the sending end terminals, P. However, unlike the measurement of transfer impedance, the short circuit can be kept short in length as there is no current probe and the filter can be made to see a genuine short circuit.

Leakage fields

As has been stated, the received current is determined by measuring the voltage induced in a current probe. This voltage, at frequencies as low as a few megahertz, is of the order of a few micro-volts and such a signal is just as likely to be induced by stray magnetic field as that created by the current in the short circuit.

A method which reduces the effects of stray fields and which has been proved to be satisfactory up to tens of megahertz is shown in Figure 3, page 6. The filter is mounted in a copper box such that its output end is only just entering it. The short circuit is contained within the box with the current probe fixed coaxially with it. In this manner, the effect of radio-frequency currents, which find their way to the outer surface of the filter screen, is considerably reduced. It is also necessary to provide additional screening from the copper box to surround the filter under test. If all the apparatus is then set out on a ground plane, no stray fields of any significance exist near the current probe.

D. Limitation of method

The limitations of the method are mostly concerned with frequency and, in particular, with the measurement of the transfer impedance.

Due to the manner in which the valve voltmeter must be connected to the input of the attenuator, there is a limiting frequency at which the distance between them cannot be made negligibly small. Consequently, in part of the VHF band and above, the voltage measured will not be that applied to the suppressor because of standing waves.

This method must therefore be regarded as satisfactory up to say 100 MHz. To measure the minimum attenuation of a filter at higher frequencies, another method has been developed, which will be the subject of a separate document.

Indeed, long before 100 MHz is reached, it becomes impossible, with many filters, to measure the received current, as the signal is well below the electrical noise in the measuring set.

4.2.2.2 Approximate method for power line filters*A. Introduction*

In this method, which applies to power line filters, instead of measuring the insertion loss in a $50\ \Omega/50\ \Omega$ system (75/75), the filter shall be measured in a $0.1\ \Omega/100\ \Omega$ (and its reverse) system. In the frequency range of 1 kHz to 300 kHz, two wideband transformers are required (1.4 : 1 and 22 : 1 for a $50\ \Omega$ system).