technical note

Philips Magnetic Products

3S3 a new Soft Ferrite for EMI-suppression

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Philips Components

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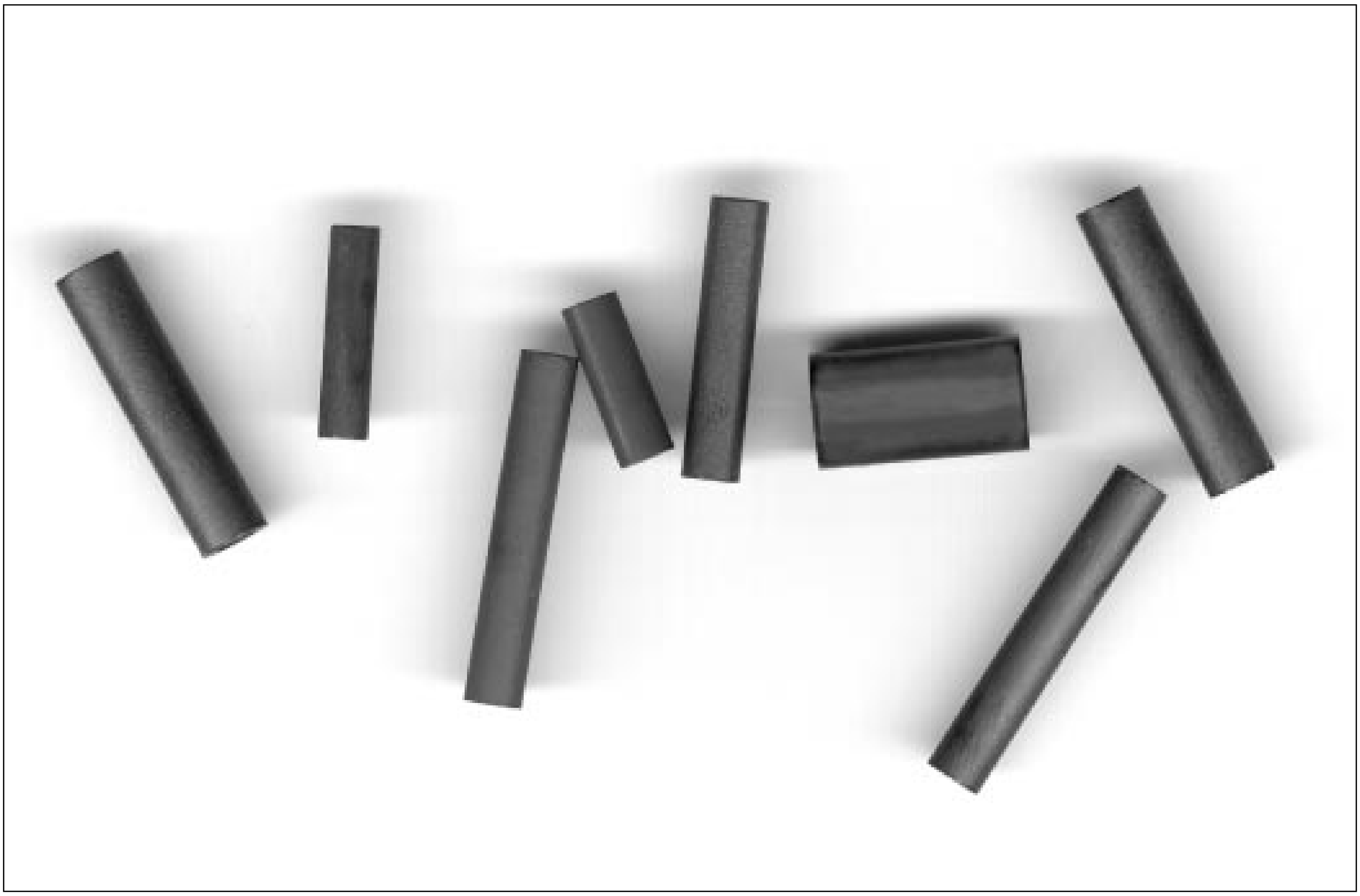
3S3
a new Soft Ferrite for EMI-Suppression

Contents



Our range of rods in 3S3 material

3S3 - a new Soft Ferrite for EMI-Suppression under bias conditions

Philips Components introduces a new manganese-zinc (MnZn) soft ferrite. It suppresses RF interference up to frequencies of 1 GHz, even under bias conditions, thereby matching the performance of nickel-zinc ferrite (NiZn) .
Up to now, the extremely high resistivity ($10^5 \Omega$m), which avoids the induction of eddy currents, made NiZn ferrites the only option for suppression at very high frequencies.

However the presence of nickel, cadmium and cobalt (even in a chemically non-active form) in NiZn soft ferrites is a disadvantage. These heavy metals are a potential hazard to the environment, their use is often discouraged for environmental reasons.

MnZn ferrites are the usual alternative, mainly because they present no hazard to the environment, and their high permeability (up to 10000) gives them excellent low-frequency characteristics. Until now, however, low resistivity (1 to 10 Ωm) has limited their frequency of operation to a maximum of 30 MHz.

This has now changed with the introduction of PHILIPS' new 3S3 MnZn ferrite material.

According to EACEM, 3S3 is:

- Cadmium free
- Nickel free
- Cobalt free

and has a very low Zn content.

Precise control of material composition has resulted in an increase in resistivity to a value of around $10^4 \Omega$m, very close to the standard NiZn grades and thus rivalling the performance of NiZn in RFI-suppression up to 1 GHz.

Moreover, 3S3 has a high Curie temperature and high saturation, which together with the high resistivity make this grade an ideal replacement for NiZn ferrites in suppression applications under high DC bias field conditions.

Material specification of 3S3

The following table shows the properties of the new grade together with those of 4B1 material. It is clear from these data that 3S3 can compete with the NiZn grades over the whole frequency range up to 1 GHz.

3S3 has been specially developed for applications under high DC bias or high temperature conditions, such as rods for noise suppression chokes which are used in many industrial areas, e.g.:

- Automotive component industry
- Home appliances
- Electric tools

				MATERIAL	
PROPERTY	SYMBOL	UNIT	CONDITIONS	3S3	4B1
Initial permeability	μ_i		25°C; ≤10kHz; 0.1mT	≈ 350	≈ 250
Flux density	B	mT	25°C; 10kHz;250A/m	≈ 300	≈ 300
			100°C; 10kHz;250A/m	≈ 250	≈ 260
Typical impedance	$\|Z\|$ (1)	Ω	25°C; 30MHz	≈ 40	≈ 45
			25°C; 100MHz	≈ 75	≈ 80
			25°C; 300MHz	≈ 115	≈ 90
Resistivity	ρ	Ωm	DC; 25°C	≈ 10^4	≈ 10^5
Curie temperature	Tc	°C		≥ 110	≥ 250
Density		kg/m^3		≈ 4800	≈ 4600

Characteristics refer to:

- A standard , non-finished, ring core of dimensions 25/15/10 mm for all properties except impedance.
- A bead of dimensions 5/2/10 mm on a short wire for impedance values.

Properties of other products made from this material grade may be different, depending on shape, size or finishing.

Typical material curves

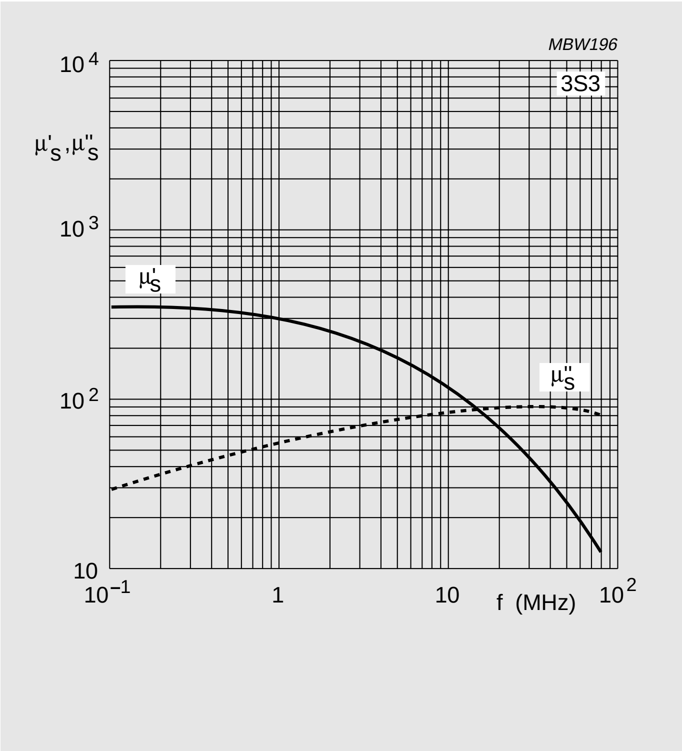


Fig.1 Complex permeability as a function of frequency

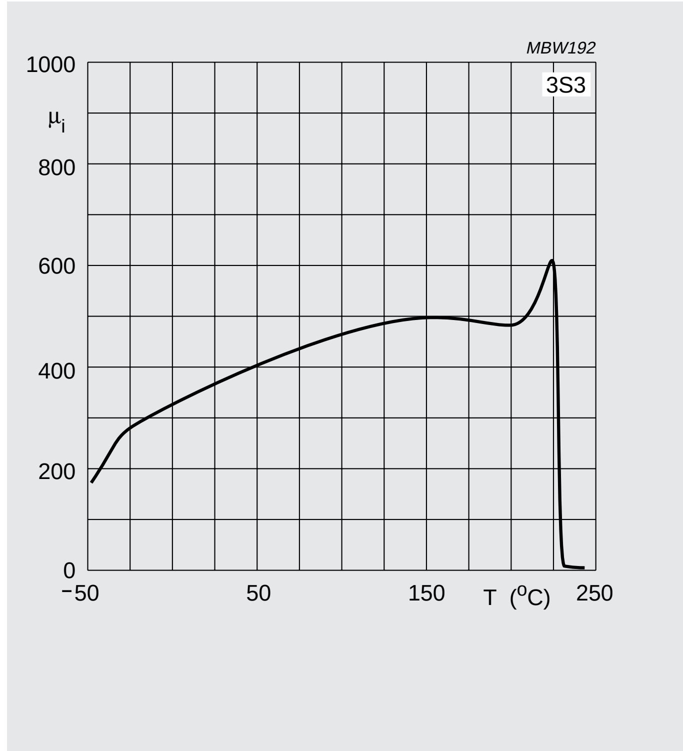


Fig.2 Initial permeability as a function of temperature

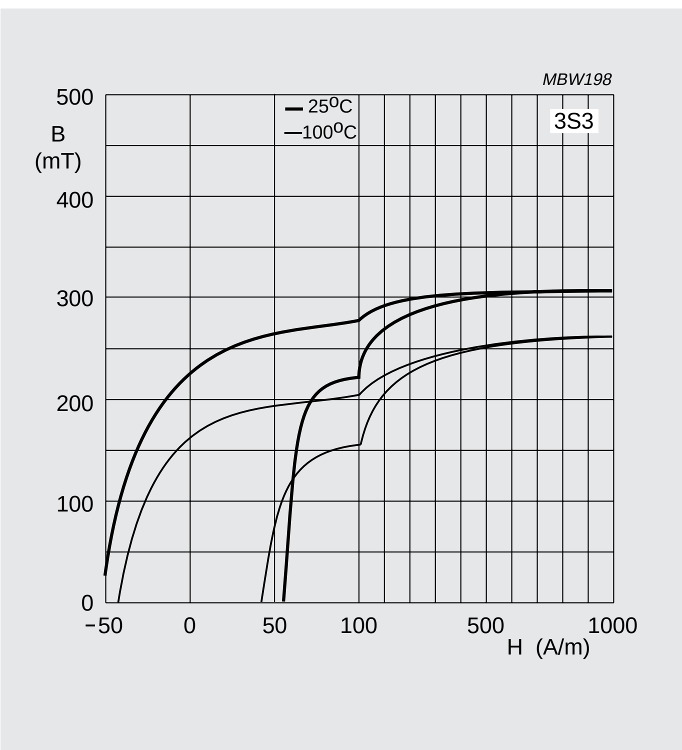


Fig.3 Typical B-H loops

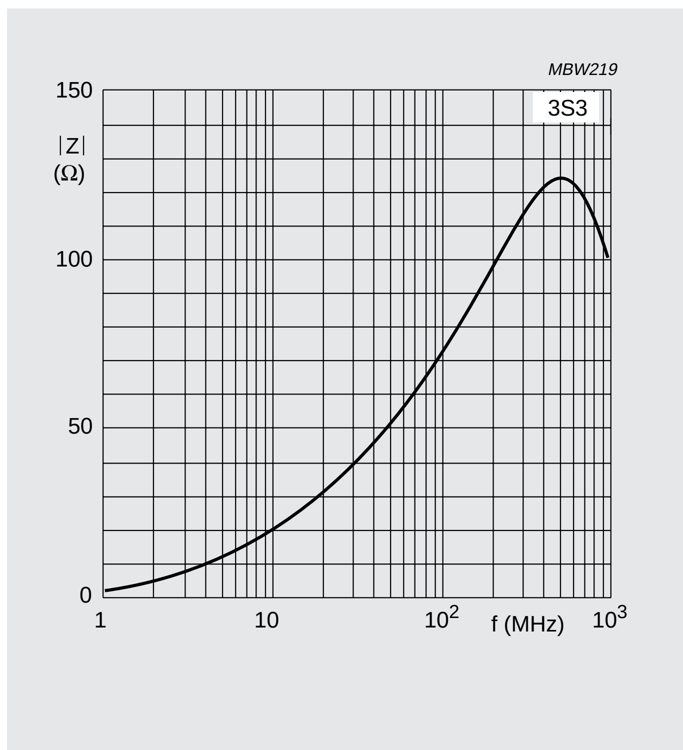


Fig.4 Impedance as a function of frequency

Application Notes

In the car industry, first FM radios (86-108 MHz) and later electronic control and management were introduced, and thus EMI suppression became a critical issue.
DC commutator motors, like starter motors, window screen wiper motors, cooling fans or electric windows, can cause HF interference. The most important characteristic of these motors is the high current they need (up to a few tens of amperes!).

Due to these high currents, ferrite beads and wideband chokes would certainly saturate. Current compensated chokes or iron powder ring cores require expensive winding operations. A good solution is a ferrite rod with a solenoid winding directly on the core. The open magnetic circuit of a rod has a low effective permeability with high current carrying capability, while the lower inductance is not a problem since the frequency is very high.

To create a high impedance, the rod is wound over the full length. The maximum number of turns follows from the minimum wire diameter, given by the current rating.

The material must have a high Curie temperature (operating temperatures will exceed 100^{o}C) and high saturation. These two parameters, together with the high resistivity, indispensable to avoid short-circuits when the winding is directly on a non-coated rod, make 3S3 specially suited for these automotive applications and also for suppressing EMI in electric power tools.

An extra advantage of 3S3 rods is that they have a higher mechanical strength, which considerably reduces the risk of breakage of the core during winding and automatic insertion.

Remark: Philips Components only supplies the ferrite core, not the winding.

Test and measurement

The relevant parameters for EMI suppression differ completely from those in an antenna rod application. Inductance and Q-factor are not of interest, but impedance (Z) or attenuation (insertion loss IL) at the EMI frequencies are. Therefore, measurements are carried out with an impedance analyser (Z) or a network analyser (IL). If the test requires the application of a high bias current, a power supply is needed, and also a special LC filter with 2 functions:

- To protect the measurement equipment from the DC current.
- To eliminate the influence of the power supply impedance on the HF measurement.

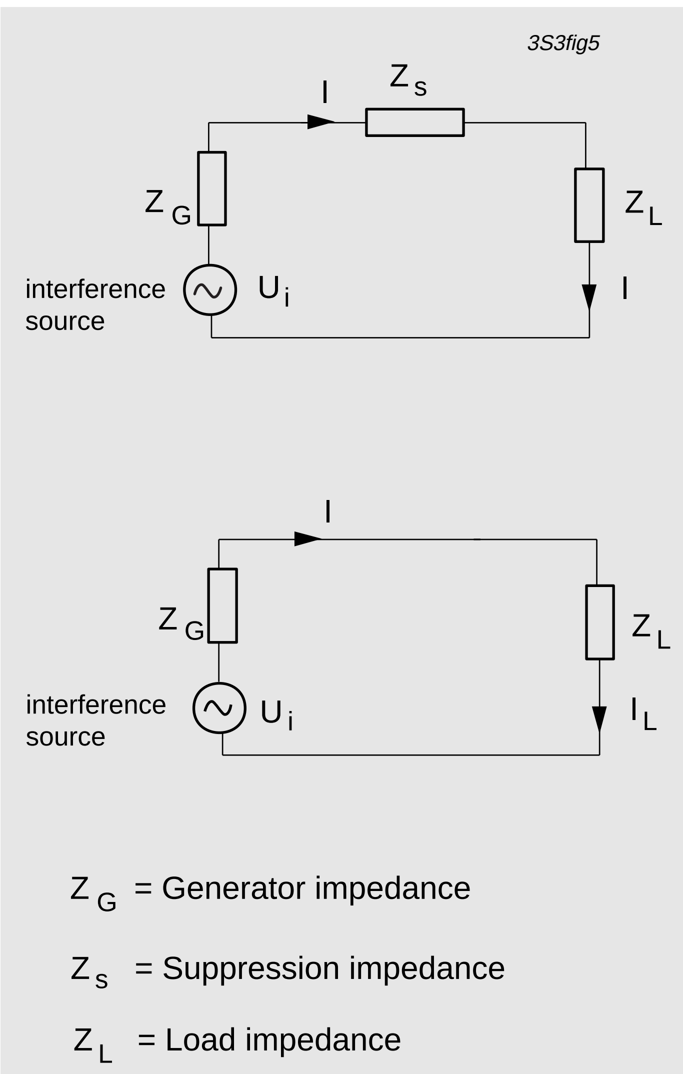


Fig 5 Principles of EMI-suppression

The filter used for these tests is constructed according to VDE 0565 (Part 2/9.78) and DIN 57 565 (Part 2).

At RF frequencies, a ferrite choke shows a high impedance which suppresses unwanted interference current. The resulting voltage over the load impedance will be lower than without suppression component, the ratio of the two is called Insertion Loss. See figure 5:

The insertion loss is expressed as:

$$IL = 20 \cdot \log (E_0/E)$$
$$IL = 20 \cdot \log |Z_G + Z_L + Z_S| \,/\, |Z_G + Z_L|$$

For a 50Ω/ 50Ω system:

$$IL = 20 \cdot \log(1 + Z/100)\ \text{dB}$$

E = load voltage with inductor
Eo = load voltage without inductor

To express insertion loss in dB seems very practical because interference levels are usually expressed in decibels as well. But be aware! Insertion loss depends on source and load impedance, so it is not a pure product parameter like impedance. In the application source and load are seldom 50W fixed resistors. They might be reactive, frequency dependent and quite different from 50W.

Conclusion:
Insertion loss is a standardized parameter for comparison, but it will not predict directly the attenuation in the actual application.

Example of an Insertion Loss specification

	$I_{DC} = 0$		$I_{DC} = 26$ A
CONDITIONS	IL	CONDITIONS	IL
50MHz, 25°C	≈ 20 dB	50MHz, 140°C	≈ 18 dB
100MHz, 25°C	≈ 28 dB	100MHz, 140°C	≥ 22.5 dB
200MHz, 25°C	≈ 29 dB	200MHz, 140°C	≈ 30 dB

Measured on ROD6.5/25-3S3 with 14 turns of diam. 1.6mm copper wire

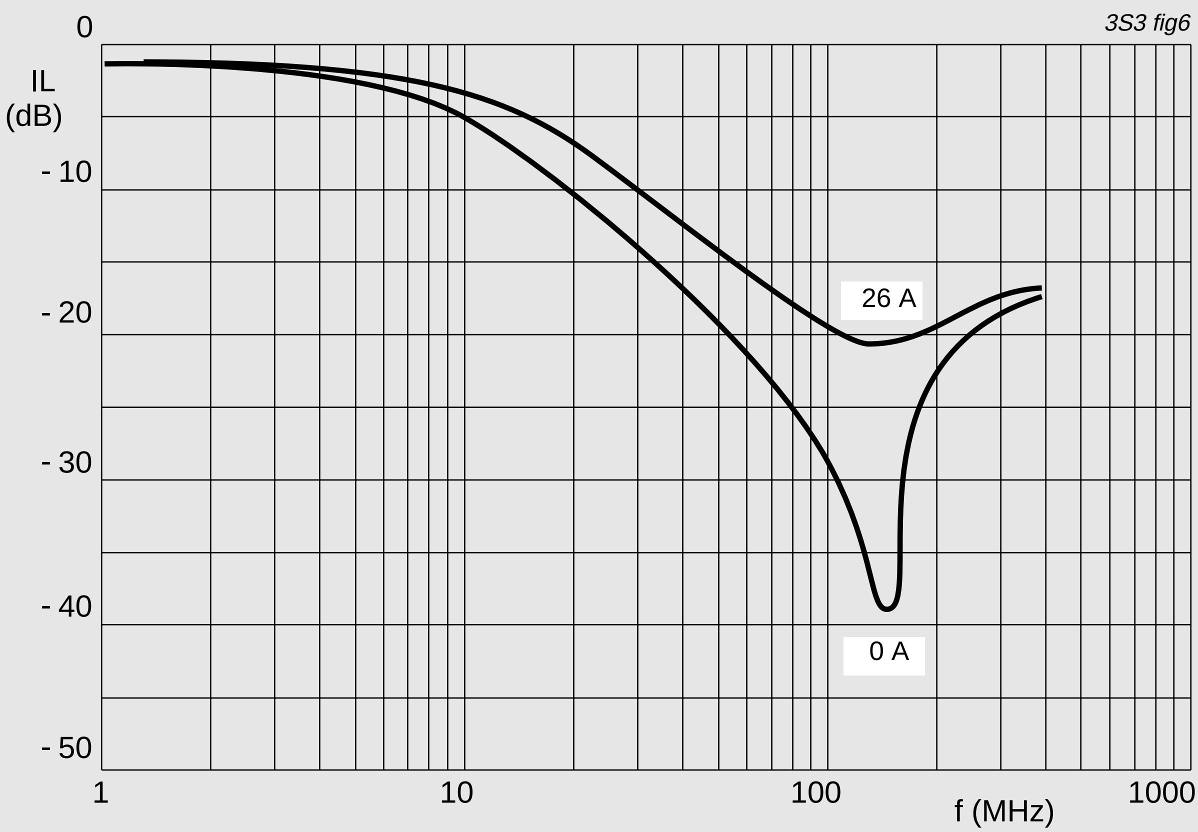


Fig. 6 Insertion loss of a choke consisting of a ferrite rod type ROD6.5/25-3S3 and 14 turns of ª 1.6mm copper wire under various conditions, measured in a 50W /50W system

Saturation and temperature

Choke design (ferrite rod and coil) should be such that for the rated DC current the two major negative effects on its attenuation are kept within limits. These effects are:

- Saturation
- Heating

The cross-section (effective area) of the ferrite core is inversely proportional to saturation current and directly proportional to attenuation. And the larger the volume of the rod, the longer it takes to heat it.

If the coil consists of thin wire and many turns, saturation limits the performance. In this case current is not very high and heating is not the real problem. Once the bias is on, the change in Z or IL characteristics with respect to the non-magnetized state (0A) remains stable, This means, it does not matter how long the current is applied, since temperature rise will be small and does not affect the behaviour of the choke.

In the case of thicker wire and fewer turns, temperature is the limitation. DC currents are higher and dissipation due to the resistance of the copper winding will heat up the ferrite. This will decrease the saturation level and the impedance characteristics of the material. Z and IL curves will start changing until an equilibrium temperature is reached.

These factors must be taken into account during the design of a choke. The application itself will determine the final performance, because not in every case the DC current is applied for a long time.

For example, the motors of an electric window or sun roof are only working for a few seconds, so there is no time for a serious temperature rise. But fuel pumps or some ventilators are continuously on, so temperatures can become very high and stabilize at these levels.

The graphs on next pages show different impedance and insertion loss characteristics for two choke designs, measured in a 50Ω/50Ω system.

Impedance and insertion loss versus frequency for a choke consisting of a ferrite rod ROD3/17-3S3 and 17 turns of ∅ 0.85mm copper wire under various conditions.

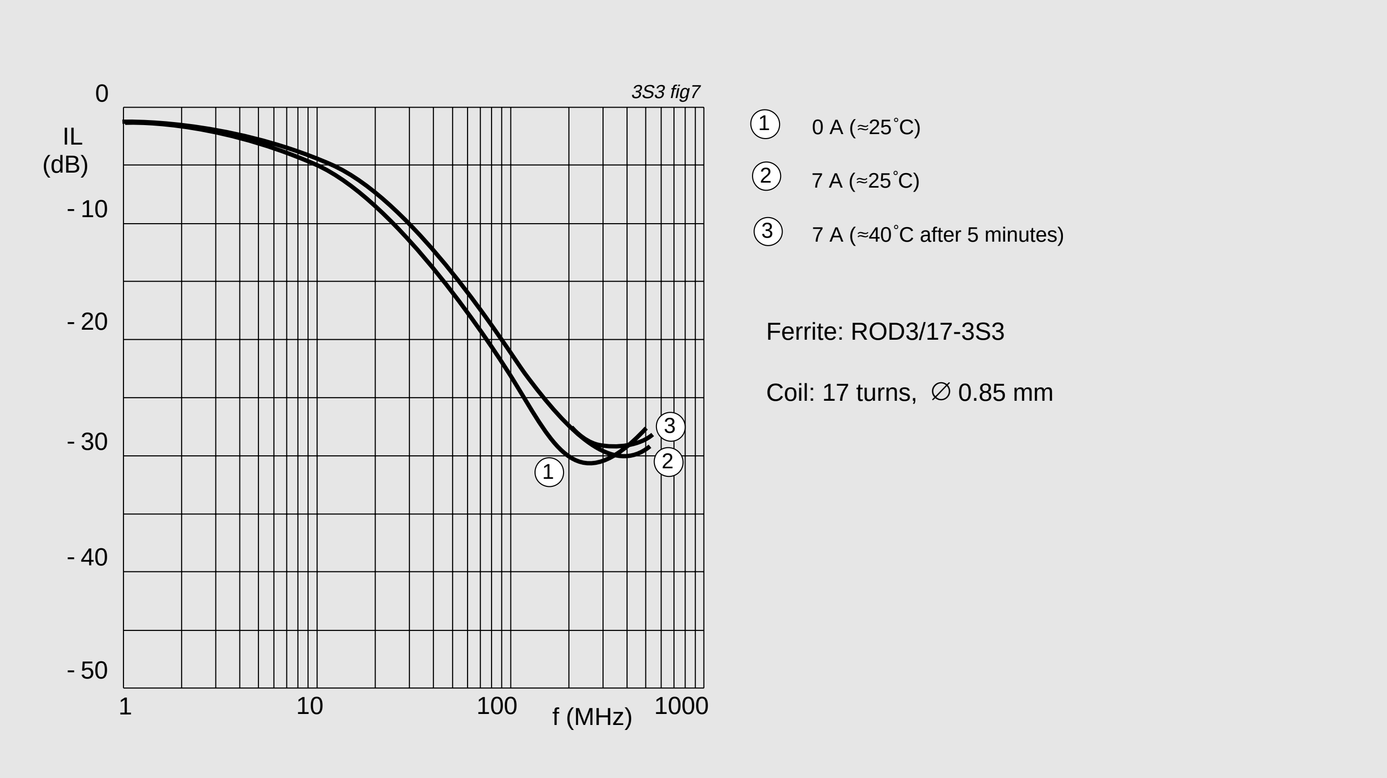


Fig.7 Insertion loss as a function of frequency

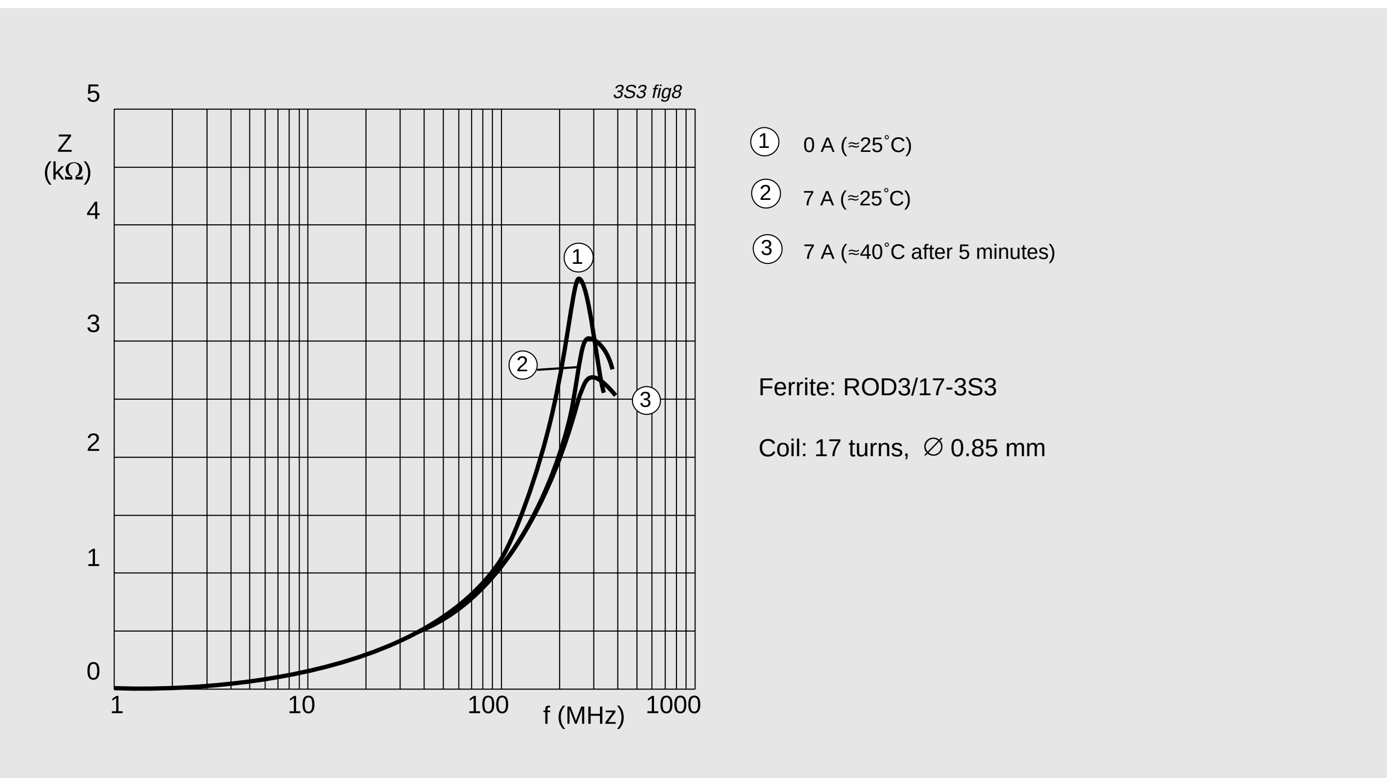


Fig.8 Impedance as a function of frequency

Impedance and insertion loss versus frequency for a choke consisting of a ferrite rod ROD6.5/25-3S3 and 14 turns of ∅ 1.6mm copper wire under various conditions.

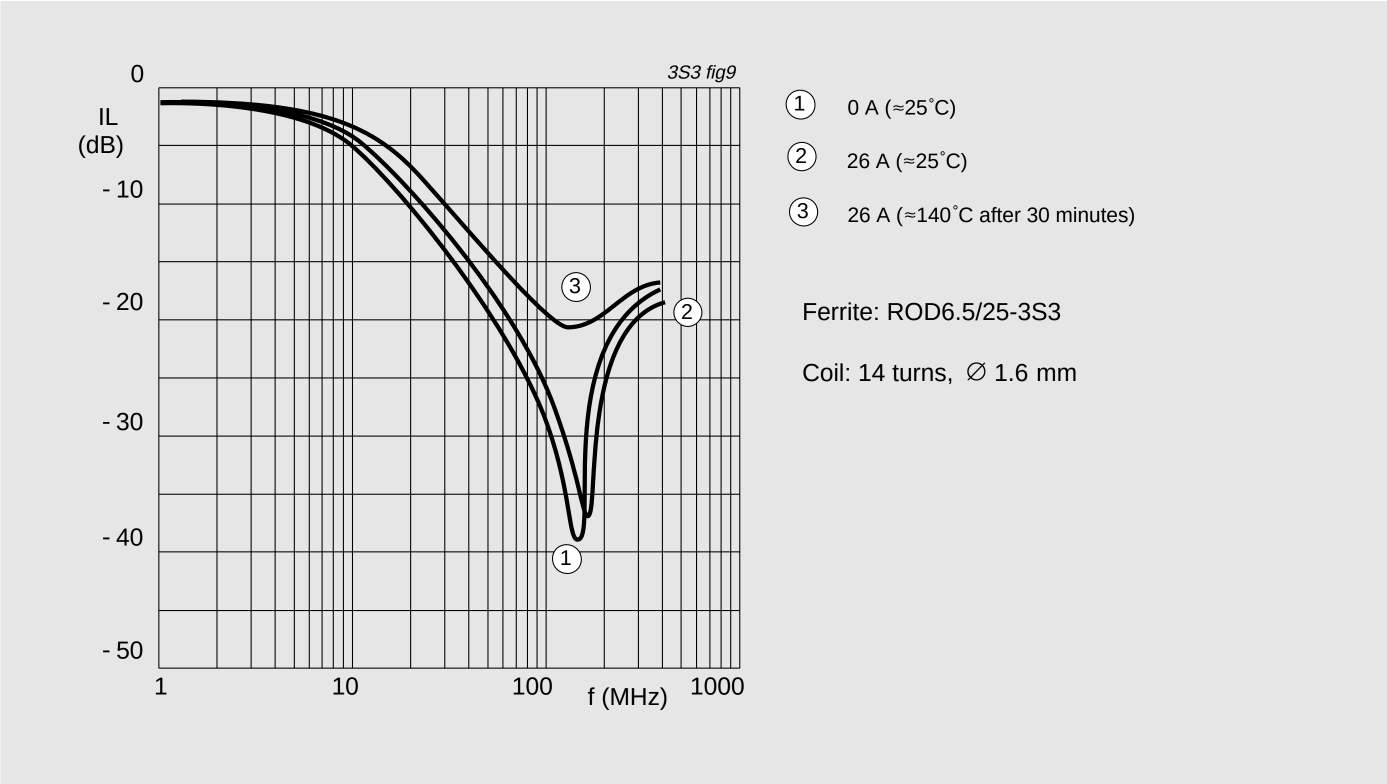


Fig.9 Insertion loss as a function of frequency

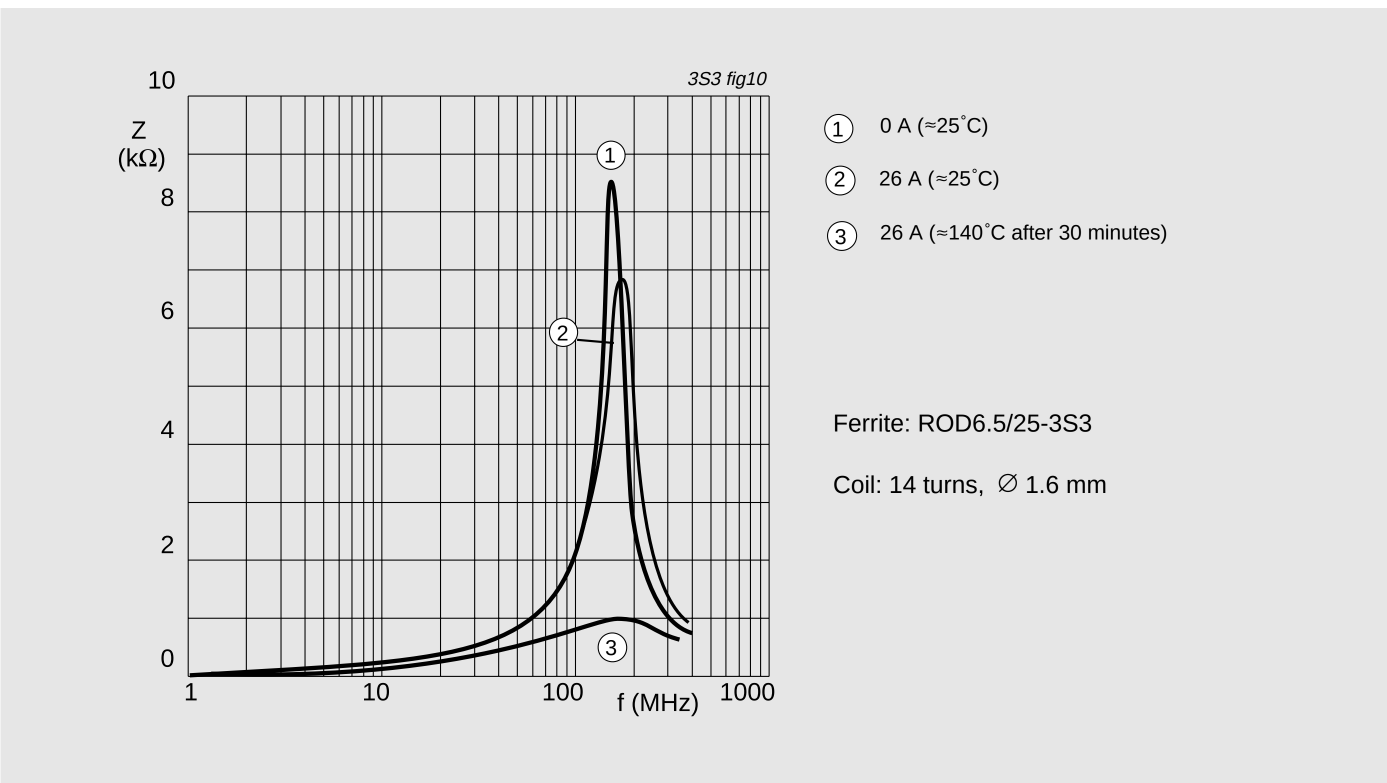


Fig.10 Impedance as a function of frequency

Impedance and insertion loss versus frequency for a choke consisting of a ferrite rod ROD3/17-3S3 and 17 turns of Ø 0.85mm copper wire under various conditions.

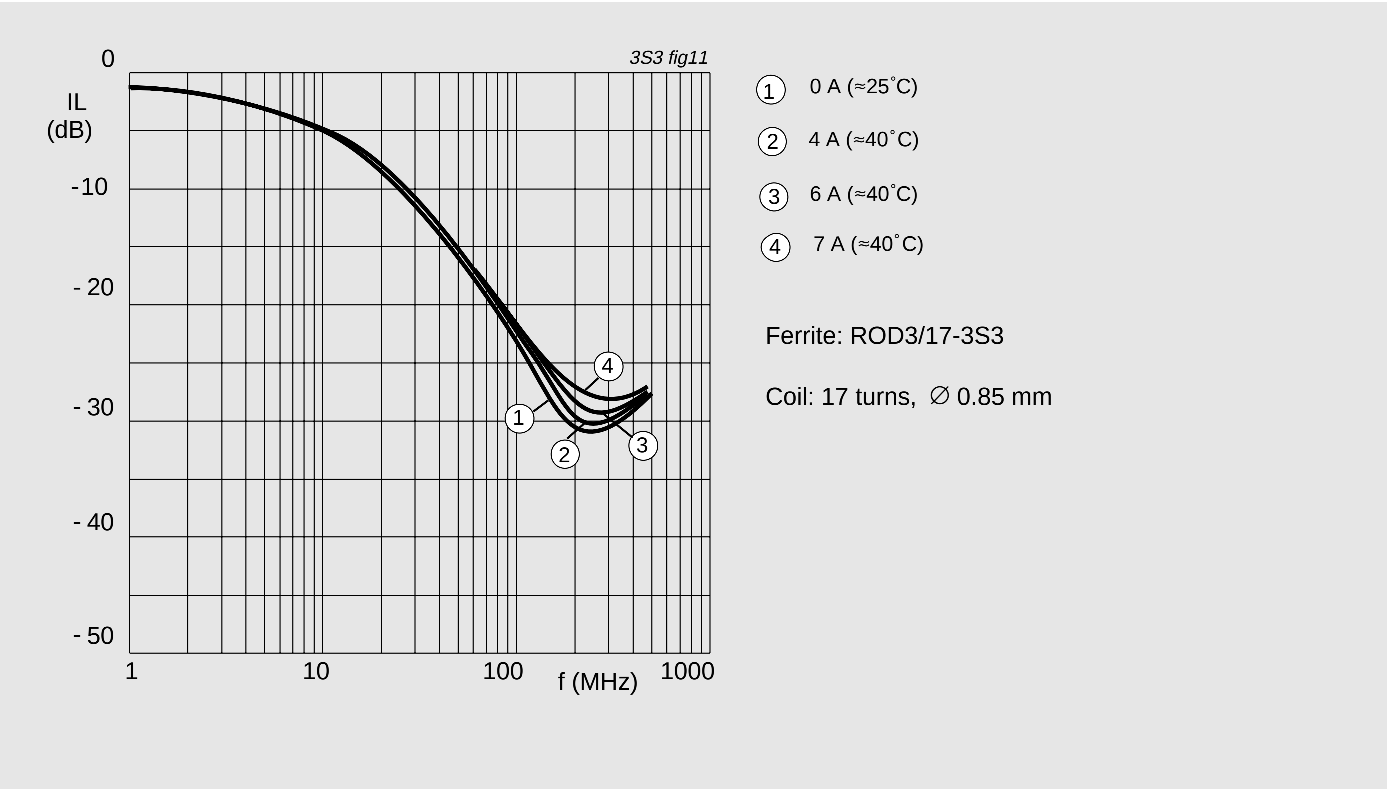


Fig.11 Insertion loss as a function of frequency

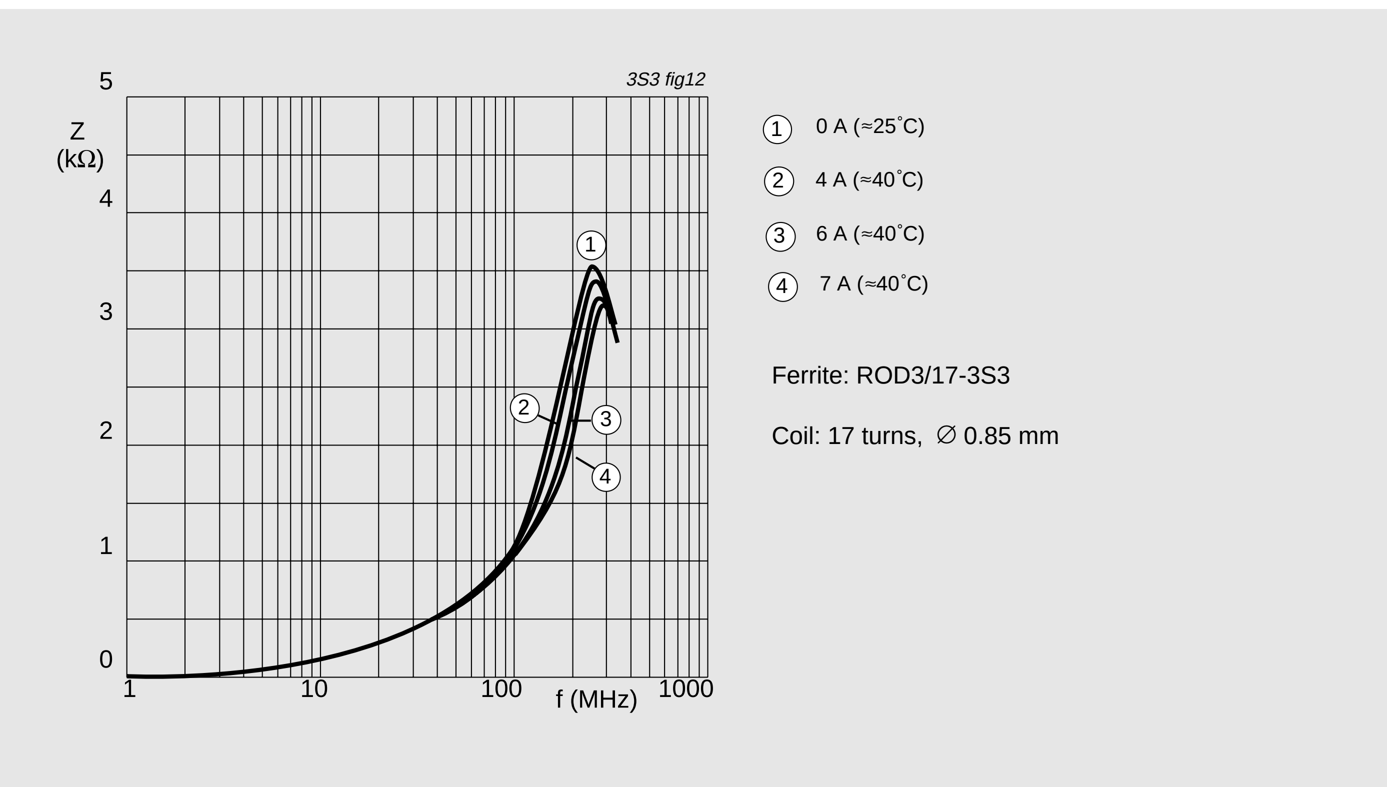


Fig.12 Impedance as a function of frequency

Impedance and insertion loss versus frequency for a choke consisting of a ferrite rod ROD6.5/25-3S3 and 14 turns of Ø 1.6mm copper wire under various conditions.

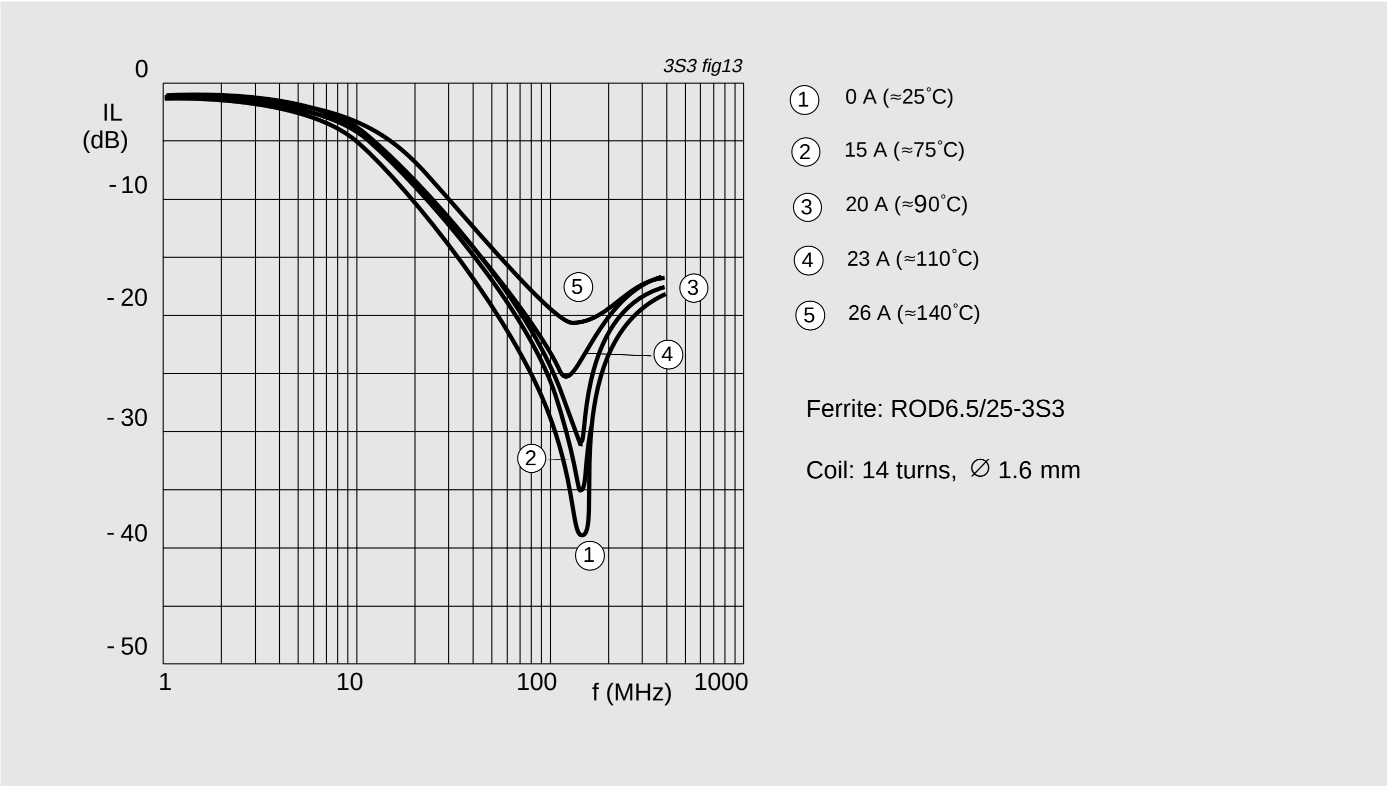


Fig.13 Insertion loss as a function of frequency

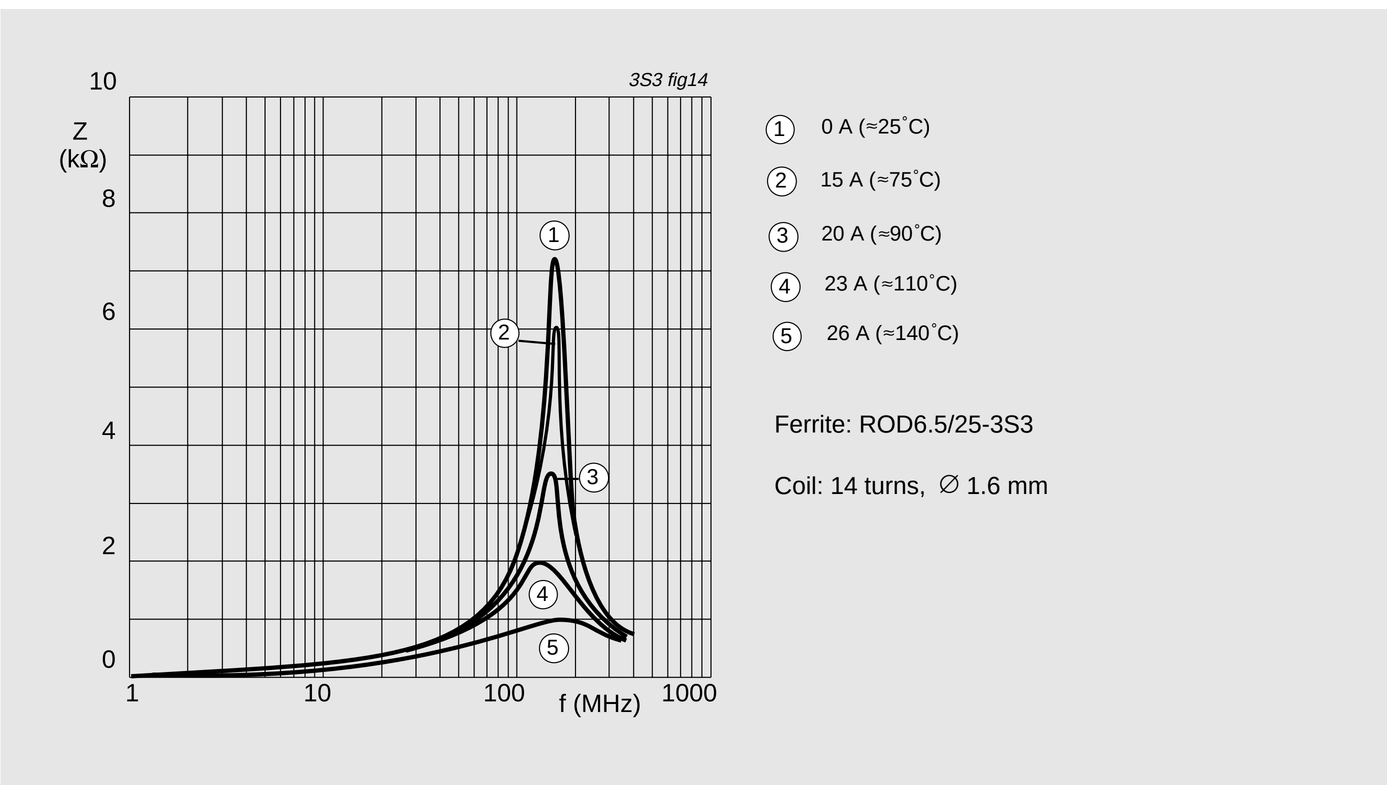


Fig.14 Impedance as a function of frequency

Choke design

The function of these chokes is to suppress Electro Magnetic Interference (EMI) at certain frequencies in DC commutator motors. The most common frequency range is 50 to 200 MHz. For this purpose, it is necessary to achieve the maximum impedance or attenuation within that range.

The best solution is a rod with a single layer winding over its full length. Additionally, a large DC current causes an increase of temperature and/or a high premagnetization of the rod .

Selecting the choke
From the application point of view, the thicker the rod, the better it would be: the more cross section (effective area), the less saturation and the more attenuation, and moreover, the larger current it stands without heating up. But some other considerations, as a limited space or low cost, make the rod and coil selection a critical issue.

Impedance and attenuation depend on the mechanical dimensions of the rod, but hardly on the material permeability at lower frequencies. Other material parameters, like Curie temperature, resistivity and saturation, are of importance.

At higher frequencies the winding plays a major role. The performance is limited by the parallel capacitance of the winding and not by the ferrite properties.

The DC current is given by the application. Starting from this current and the duration of its application, a suitable wire type should be chosen.

The maximum number of turns follows from the rod length and wire diameter. Impedance (or attenuation) level is proportional to the square of the number of turns.

Conclusions
In a suppression choke made from a ferrite rod and operating under bias conditions the performance is defined by a combination of all following parameters:

- Rod size
- Material characteristics
- Wire diameter
- Number of turns
- DC current level
- Duration of the DC current
- Operating conditions (temperature)
- .....

The main effects of DC current on the choke are saturation and heating. Performance of the choke may change because of these effects.

Product Range

The following standard rods will be available in the new grade 3S3.
Additional, customized, sizes can be manufactured upon request.

Type Number	Diameter (mm)	Length (mm)
ROD2.2/16-3S3	2.2 - 0.2	16 ± 0.4
ROD2.5/20-3S3	2.45 - 0.2	20 - 0.8
RODR3/17-3S3-DL	3 - 0.05	17 ± 0.3
ROD3/20-3S3	3 - 0.3	20 ± 0.4
ROD3.3/17-3S3	3.3 ± 0.1	17 ± 0.3
ROD3.3/20-3S3	3.3 ± 0.1	20 + 0.4/ - 0.6
ROD4/20-3S3	4 - 0.3	20 ± 0.5
ROD5/14-3S3	5 - 0.3	14 - 0.8
ROD5/18-3S3-DL	5 - 0.05	18 ± 0.3
ROD5/20-3S3	5 - 0.3	20 ± 0.5
ROD5/25-3S3	5 - 0.3	25 - 1
ROD5/30-3S3	5 - 0.3	30 - 1.2
ROD5.3/18-3S3	5.25 - 0.3	18 ± 0.3
ROD5.3/35-3S3	5.3 - 0.3	35 ± 0.6
ROD6/25-3S3	6 - 0.3	25 ± 0.6
ROD6/30-3S3	6 - 0.3	30 ± 0.9
ROD6.5/25-3S3	6.5 - 0.3	25 ± 0.6

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