UNIVERSITÀ DEGLI STUDI DI L'AQUILA
DIPARTIMENTO DI INGEGNERIA ELETTRICA

Prot. N. 1811/H6 del 29.09.2004

PROEL SPA
Sant'Omero (TE)
ITALY

Comment on the Results

The measurements carried out in the Electrical and Electronic measurements Laboratory in the Engineering department of the 'Università degli Studi' University in Aquila, Italy have been done so under conditions worse than those usually used in similar tests. This has been done to reproduce the extreme conditions of use to which the cables are subjected. The connection of the cable to the measurement apparatus has been carried out using two connectors complementary to those applied by the constructor at the two ends of the cable. In doing so, the parameters measured also take account of the two connections which often constitute the most critical aspect in the connection of two audio systems.
The results obtained have consistently revealed reactions superior to what was expected, keeping in consideration the type of application. The transmitted frequency band measured during the laboratory testing have resulted as consistently above 2MHz, two orders superior to that of an audio signal (20kHz). This parameter guarantees a constant attenuation ratio for the entire signal band, a condition necessary to avoid alteration in the spectral components, guaranteeing a distortion free signal.
5 meter cables complete with connectors have shown a resistance of only one tenth of an Ohm, a value attainable exclusively with state of the art technology for the construction of the conductors and connectors. Regarding the inductivity and the capacity parasites, non significant values have been found which, insofar as not being normally present in cables, is found as a result of the constructive geometries of the conductors.
The diaphonic tests have shown reduced interference effects between the channels, often at the limits of resolution of the measurement apparatus.
It has been seen that the cables examined feature further positive aspects, such as the extreme flexibility which the manufacturer has achieved, even in the cables with a thicker diameter and an elevated quality of the connectors, almost all with 24k gold plated contacts.

In conclusion, the DIE HARD cables have demonstrated an excellent response to all of the measurements and tests and can therefore, for the construction characteristics and materials used, be classified as a connection system of elevated performance, applicable for professional applications.

L'Aquila, 28.09.2004

Prof. Giovanni Bucci

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TEST OF CABLES USED FOR INTERCONNECTING AUDIO SYSTEMS

1. Introduction

The transmission of an electrical analogical signal between two devices requires a suitable cable that should allow for transferring it with low distortion and losses. Ideally a cable does not introduce power-losses and the electrical signal applied at the input is transferred integrally to the output, without any modifications of its parameters. This behaviour is considered necessary for all the audio applications and specifically for high-fidelity (hi-fi) products.

Unfortunately, in real conditions there is always an alteration of the transmitted signal, because of reactive and resistive (parasite) parameters of the interconnection system constituted by the cable and the two end connectors. Greater is the frequency and more evident are the effects of the parasite parameters.

The general opinion of hi-fi end users is that the choice of audio interconnection systems has an audible effect upon the perceived sound. This is the reason of frequently experiments with various types of cables and the motivation to purchase expansive cables which are claimed to provide high level of subjective performance. In recent years the production of these devices has grown out, even if some manufacturers publicize special cable qualities without any established scientific basis. Even if, from a technical point of view, it is normal that the properties of a connection system may affect the transmitted signal, the perceived subjective differences between cables can have different explanations.

Most would agree that the ideal connecting system is one which brings us as close to the experience of the original musical event, hearing the music as it was recorded without adding or missing signal components (cable neutrality). This ideality can be obtained only with zero parasite inductance and capacitance**,** providing an unlimited transmittable bandwidth.

Some cable manufacturers adopt a different philosophy, using networks, filters and additional elements improving the audio signal by altering it, producing colorations that destroy the natural, musical reproduction. The result is artificial and contrived, rather than ideal and neutral, even if it can be appreciate by some people more than a neutral system.

According to the IEC standards, cable parameter measurement requires the adoption of complex procedures, also because some standards refer to cable for general purposes [1-7] and not for audio applications. To this aim a measurement procedure for the evaluation of the performance of high-quality cables for professional audio applications has been implemented. The main features of these high-performance cables are: attenuation lower than 0.25 dB in the frequency range of DC-50 kHz, resistance around to 0.1 ohm, and inductance in the range between 6-24 μH.

2. The measured parameters

The behaviour of a real interconnection system can be evaluated taking into consideration the set of electrical parameters related to the adopted modelling methodology. The traditional approach refers to the lumped elements: resistance (*R*), inductance (*L*) and capacity (*C*). The behaviour of a cable can be also described by means of the transfer function. Moreover it is

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important to analyze the electric and magnetic coupling between different lines of the interconnect system, because they can be a source of crosstalk noise, that can become critical with the increasing of the frequency.
The equivalent circuit model of an interconnection system is shown in Fig.1.

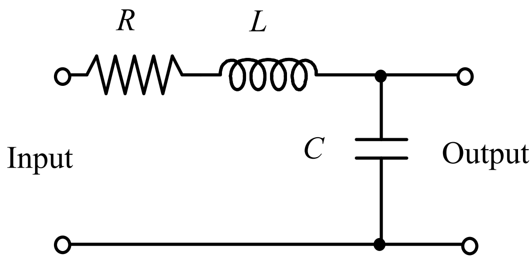

Fig.1 The adopted lumped parameter circuit to model a connection system

- The electrical *resistance* of the cable depends on the wiring nature (resistivity) and size of conductor, other than on the cable length. A good cable must have a low resistance, in order to guarantee a low power loss, that is low signal attenuation. Low resistance requirement is crucial in case of low amplitude signals, to ensure an adequately high signal-to-noise ratio (S/N).
- The cable must show a low *capacitance* between the conductors. The reason is that it not transfer the entire amount of signal energy, but a fraction of it is stored into the electrostatic field, in the way similar of a capacitor that store electrostatic energy. Dielectric material absorbs energy and releases it back into the conductor out of phase with the audio signal, cancelling part of the transmitted signal and/or inducing noise. The capacitance increases with the cable length and depends on the properties of dielectric material. Greater is the relative permittivity of dielectric and greater is the stored energy. The lower value for this parameter is obtained using the vacuum or the air, material hard to use in an audio cable. Lower is the capacitance and greater is the signal propagation velocity.
- The cable must have a low *inductance*. This quantity depends on the cable's geometry and manufacturing parameters, such as number of conductors (single or multiconductor), size, shape (circular or rectangular) and configuration (compact or stranded). The parasitic inductance stores part of the signal energy into the electromagnetic field and releases it back successively. Greater is the inductance and greater is the filtering effect on the signal (the pass band decreases).

The cable performance is governed by the LRC parameters. Within the audio signal band the capacitance remains fairly constant with frequency, while the inductance has a greater variation. Moreover, the resistance increases with the frequency because of the skin effect. These variations can produce different filtering effects and electrical resonances within the cable interface, also depending on the value of impedance connected at the input and output. A filtering effect variable with the frequency introduces an undesirable disuniform reduction in the harmonics amplitude and a consequently signal distortion.

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The inductance and capacitance are the parameters that mostly affect the signal transmission: the maximum frequency linearity can be achieved only with a low capacitance and a low inductance.
The main characteristics of a high-quality cable are:

- offer the minimal distortion over the whole audio frequency band, ensuring the flattest frequency response;
- ensure that potential inevitable distortions happen at non-critical frequencies, outside the audio band;
- present a good shield, in order to offer the best protection against external interferences, especially if the cable is connected at a high value impedance (tens or hundreds of chiloohm).

Hi-fi audio signal bandwidth spans the entire audible range of frequencies, from the 41 Hz (and below) of bass guitar and synthesizer to the 20 kHz harmonics of keyboards and cymbals. Professional applications demand a wide bandwidth interconnecting system to preserve the signal integrity. By considering the reduced frequency band of audio signals, the typical parasitic cable parameters and its limited length, its behaviour can be described using the simplified lumped model of Fig.2. Basically, this is a voltage divider circuit where the input signal V_{in} is transmitted at the output at the value V_{out}:

$$V_{out} = (\boldsymbol{Z_2} / \boldsymbol{Z_1}+\boldsymbol{Z_2})\ V_{in} \qquad (1)$$

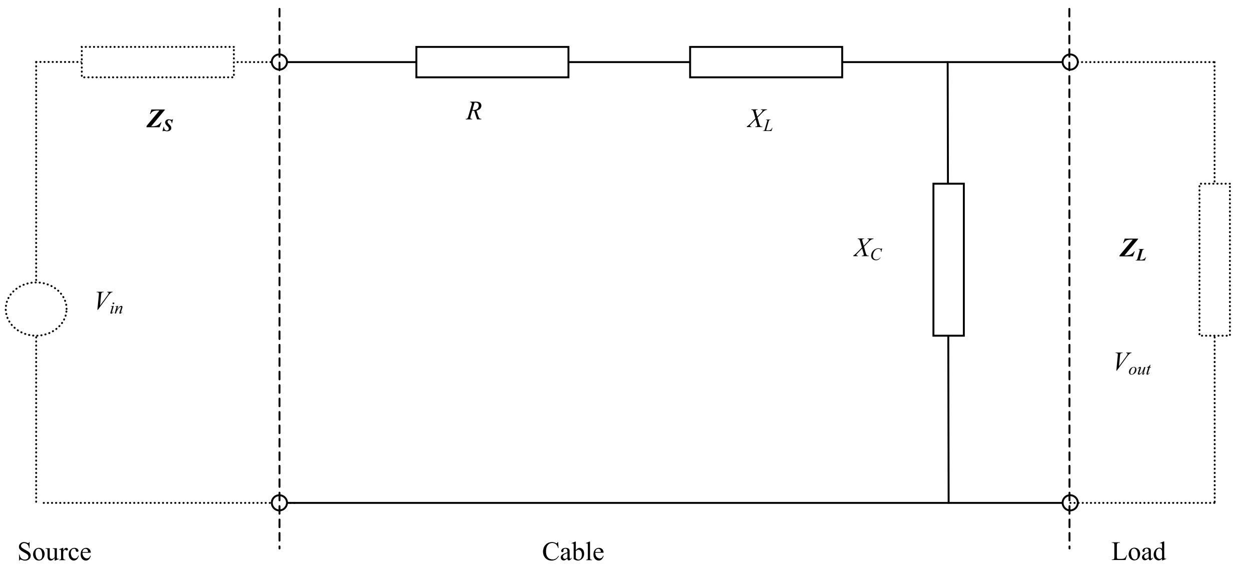

Fig.2 Electrical equivalent circuit for an audio interconnection system

where:

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$\boldsymbol{Z_1}$ includes: the output impedance of the signal source $\boldsymbol{Z_S}$, connected in series with the cable resistance R and inductive reactance $X_L = \omega L$

$$\boldsymbol{Z_1} = \boldsymbol{Z_S} + R + jX_L \qquad (2)$$

$\boldsymbol{Z_2}$ includes: the load impedance $\boldsymbol{Z_L}$, connected in parallel with the capacitive reactance of the cable $X_C = 1/\omega C$

$$\boldsymbol{Z_2} = \boldsymbol{Z_L} \,//\, (-jX_C) \qquad (3)$$

The electrical equivalent circuit behaviour is that of a second-order low-pass LC filter, which cutoff frequency is:

$$f_t = \frac{1}{2\pi\sqrt{LC}} \qquad (4)$$

From the (4) results that a reduction of L and C values corresponds to an increase in the bandwidth of the cable. For a flat response in the whole audio band, the cutoff frequency (frequency corresponding to the attenuation of -3 dB) must be over 100 kHz.
In the audio field, there are two main kinds of applications:

i) the interconnection between audio systems in which the output system $\boldsymbol{Z_L}$ has an high impedance (about 100 kΩ) and the input system $\boldsymbol{Z_S}$ a low impedance (in the range of 80-800 Ω); in these conditions the transmitted signal has low power (approximately some tens of milliwatt);

ii) the interconnection between amplifiers and acoustic diffusers in which the transmitted analogical signal transfers power to the diffusers, which have typical impedance values in the range of 4-16 Ω.

2. The main characteristics parameters of audio cables

Apart the R, L and C, other significant parameters are widely used to characterize the behaviour of an audio connection, such as the the frequency response (amplitude and phase) and crosstalk.
The *attenuation ratio* V_{out}/V_{in} is a parameter that represents the reduction of power during the transmission from the input to the output and is usually measured in decibel (dB):

$$A = 20 \log (V_{out} / V_{in}) \qquad (5)$$

Greater is its value and greater is the signal level at the output.

The electric and magnetic coupling between two adjacent signal lines of an interconnect assembly may originate interferences. The parameter usually measured is the *crosstalk ratio*. This is the ratio of the magnitude of the signal coupled (induced) into the quiet line to the magnitude of the signal in the driven line. A typical example is the mutual influence between two stereo channels. Lesser is the crosstalk ratio and greater is the separation between the channels.

2.1. Interconnection between audio systems

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With audio interconnects, the source impedance is reasonably high, usually in the range of 80-800 ohm. The cable's resistance and inductive reactance are so small in comparison to be neglected. The load impedance is even higher, with a typical value of 100 kiloohm.
The values of the source and load impedances make possible to disregard the resistance and inductive reactance for these cables, so if

$$\boldsymbol{Z_L} >> \boldsymbol{Z_S} >> X_L \text{ and } R \quad (6)$$

the cable acts as a RC first-order system, with a cutoff frequency of

$$f_t = \frac{1}{2\pi \boldsymbol{Z_S} C} \quad (7)$$

where $\boldsymbol{Z_S}$ is a resistive impedance.

The condition to have a cutoff frequency $f_t > 100\ kHz$, is that:

$$\boldsymbol{Z_S}\, C < 2\pi 10^{-5} \approx 10^{-6} \quad (8)$$

From the (1) the ratio V_{out} / V_{in} can be expressed as the ratio between the impedances:

$$V_{out} / V_{in} = |\boldsymbol{Z_2}| \,/\, (\, |\boldsymbol{Z_1} + \boldsymbol{Z_2}|\,) = |\boldsymbol{Z}| \quad (9)$$

from which the attenuation is:

$$A = 20 \log (\, |\boldsymbol{Z}|\,) \quad (10)$$

And the phase shift Φ is:

$$\Phi = (\, 360 / 2\pi\,) \tan^{-1} [\, Im(\boldsymbol{Z}) / Re(\boldsymbol{Z})\,] \quad (11)$$

2.2. Speaker cables

In the cables used to transmit power to speakers, the capacitive reactance can be neglected, because it is linked in parallel to the very low speaker's input impedance. In other words, the cable capacitance can be considered as a less significant factor in overall performance compared to the effect of speaker wire resistance.
For these applications $\boldsymbol{Z_L}$ and $\boldsymbol{Z_S}$ have values greater than R ($R \approx 0.1\ \Omega$) then the inductance is the only parameter that regulates the frequency response, corresponding to a LR first-order filter, with a cutoff frequency of:

$$f_t = Z_L / (\, 2\pi L\,) \quad (12)$$

from which, cutoff frequencies greater than 100 kHz can be obtained with maximum inductances of about

- 6 μH for a 4 Ω load,
- 12 μH for a 8 Ω load,
- 24 μH for a 16 Ω load.

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The typical values for these kinds of cables are in the range from 1 μH /m to 0.1 μH /m.

To correctly analyze the problem related to the cable's inductance and to its variation in the audio band, we must also consider that the speaker impedance is usually largely dependent on frequency. Real impedance of a nominal 8 ohm speaker, for example, can vary from 6 ohm to 10 ohm (variation can be much higher on some speakers). The nature of the speaker impedance can also change with the frequency from a purely resistive to inductive or capacitive. The problem of the cable parameter variation with the frequency becomes of secondary importance for most applications.

Referring to the voltage divider model, the output voltage becomes increasingly dependant on the magnitude of $\boldsymbol{Z_2}$ with a deviation d from linearity of

$$d = 20 \log \left[\boldsymbol{Z_{min}} (\boldsymbol{Z_1} + \boldsymbol{Z_{max}}) / \boldsymbol{Z_{max}} (\boldsymbol{Z_1} + \boldsymbol{Z_{min}}) \right] \qquad (13)$$

where $\boldsymbol{Z_{mix}}$ e $\boldsymbol{Z_{max}}$ are the minimum and maximum values of the speaker's input impedance. A deviation of 0.5 dB is acceptable, anything below 0.2 dB is excellent.

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3. Characterization tests

Some characterization tests have been carried out in order to measure the main cable's electrical parameters.
In an interconnection system it is important the cable's performance, but most important is the connector's performance, where one can suppose the signal degradation occurs especially in live concert applications, where the extremely dynamic cable movement produced by the artists can generate a connection mechanical instability. For this reason we linked the systems under test to the measurement instruments using the connectors complementary to those mounted by the manufacturer at the end of the cable, so the measured parameters refer to both the cable and the two connections. The obtained results will be pejorative, compared with those obtained testing only the cable, but they will reflect more realistic applications.
To characterize the interconnection systems, we measured their main parameters, such as the electrical R-L-C, the frequency response (magnitude and phase characteristics) and crosstalk, at different signal frequencies.

3.1. Measurement of R-L-C parameters

The R-L-C parameters have been measured with the Wayne Kerr 4265 impedance meter at a frequency up to 100 kHz, with the connections shown in Figs. 3 and 4. The resistance and inductance have been measured connecting the impedance meter from the input and the output of each conductor (Fig.3). The capacitance has been measured connecting the impedance meter between the two inputs of a couple of conductors, and opening the other end.

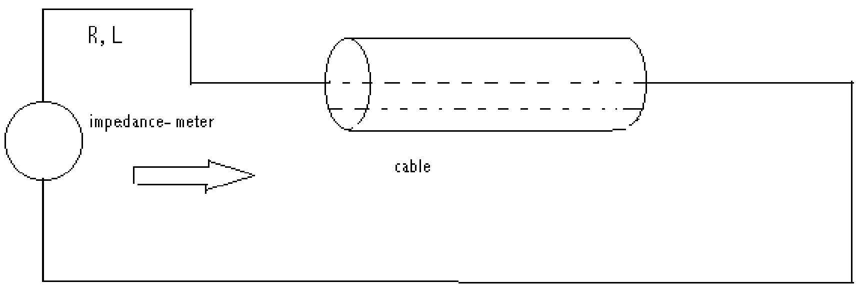

Fig.3 Resistance and inductance measurement

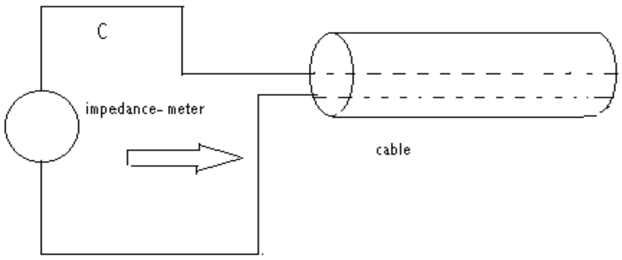

Fig.4 Capacitance measurement

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3.2. Measurement of the frequency response (amplitude and phase)

The frequency response has been measured by means of the Stanford DS345 function generator, the Keithley 2001 voltmeter, the HP 5335A counter and the LeCroy LC584AXL digital oscilloscope (Fig. 5). Sinusoidal signals at different frequencies (from 10 Hz to 100 kHz) have been applied at the cable input, terminated with the generator characteristic impedance (50 Ω). The V_1 and V_2 signal amplitudes and the phase differences have been measured by means of the voltmeter and counter, visualizing the signals on the oscilloscope.

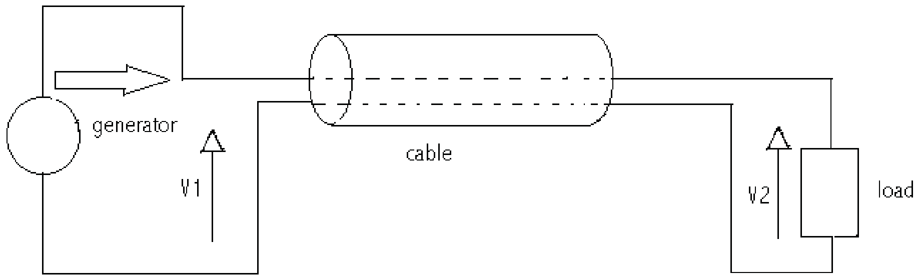

Fig.5 Frequency response measurement

3.3. Measurement of the crosstalk

The crosstalk has been measured according to CEI EN 60512-25-1, using a Stanford DS345 function generator and a Stanford SR770 FFT Signal Analyzer. A sinusoidal signal (V_g) with a frequency variable in the range from 10 Hz to 100 kHz is applied to the driven line, terminated with the generator characteristic impedance (50 Ω). The coupled signal, induced on the quiet line (V_i) is measured with the spectrum analyzer. The quiet line is terminated with the analyzer characteristic impedance (50 Ω for the single-ended input and 100 Ω for the differential input). Two parameters have been measured:

- the NEXT (Near End crosstalk raTio), the ratio of the signal amplitude measured at the line in proximity to the generator to the generated signal amplitude V_{i_n} / V_g (Fig.5);

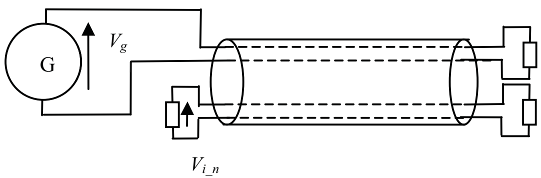

Fig. 5 Near End Crosstalk ratio measurement

- the FEXT (Far End crosstalk raTio), the ratio of the signal amplitude measured at the far end of the quiet line to the generated signal amplitude V_{i_f} / V_g (Fig.6).

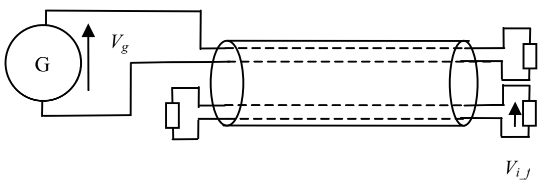

Fig. 6 Far End Crosstalk ratio measurement

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RESULTS OF THE LABORATORY TESTS

The following pages report the test results for each of the cables.

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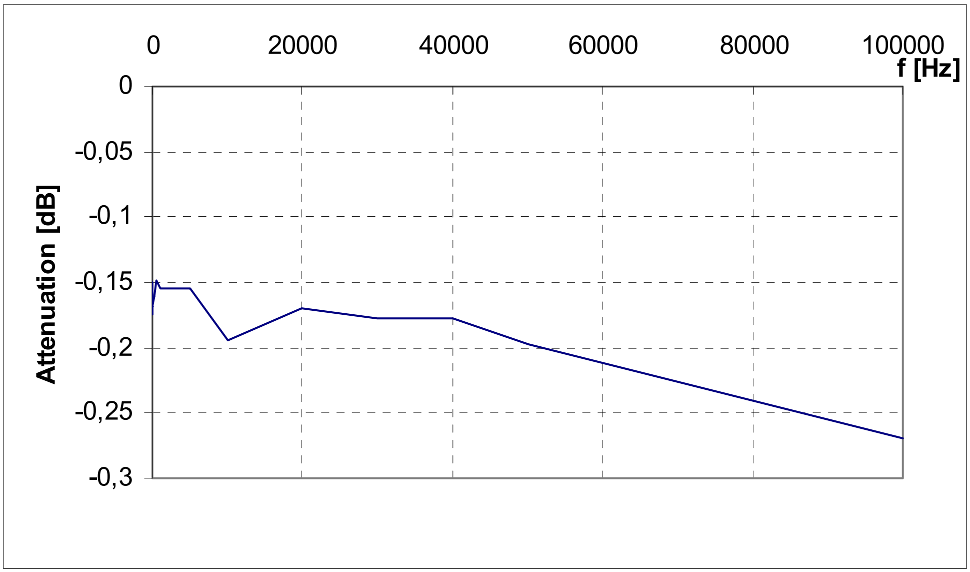
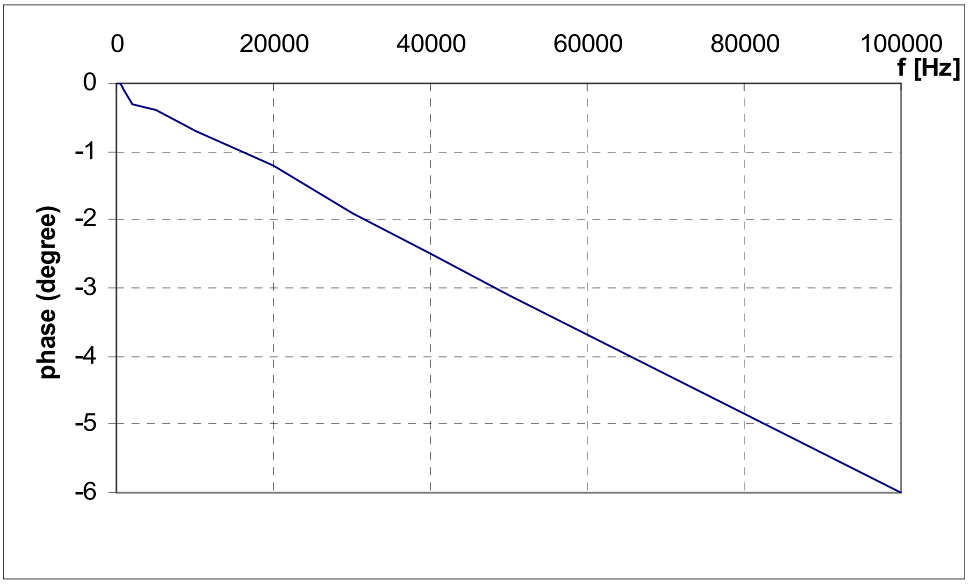
Cable under test	manufacturer	PROEL S.p.A.
	model	DIE-HARD **DH100LU5**
	length	5 m
	description	Instrument cable. Conductors: 6.5 mm overall diameter, red copper braid shield. Connectors: 6.3 mm mono jack - 6.3 mm mono jack. 24K gold plated contacts.





Frequency response: amplitude and phase characteristics (f_t=2.3 MHz)

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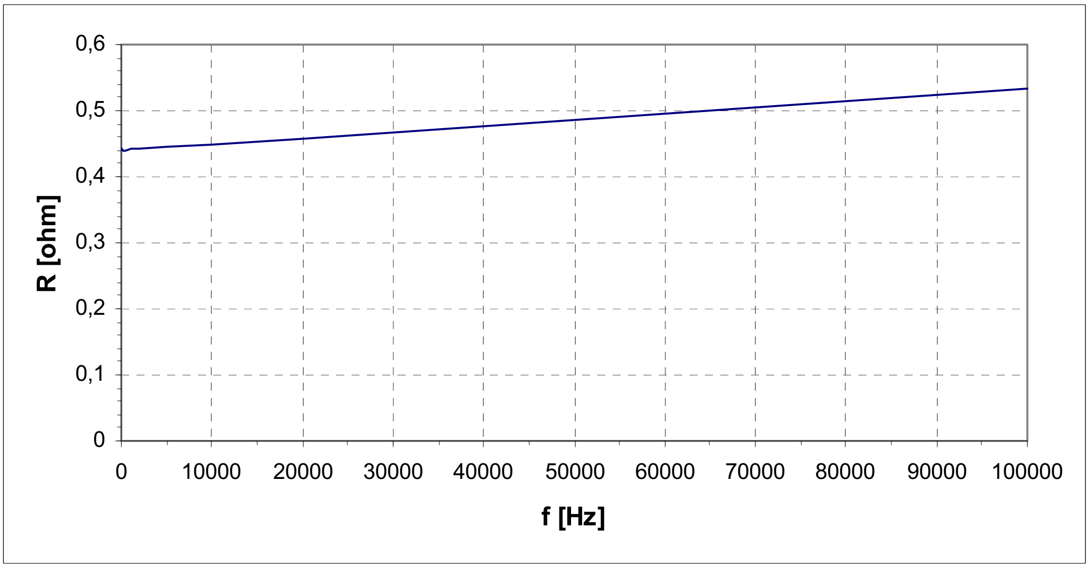
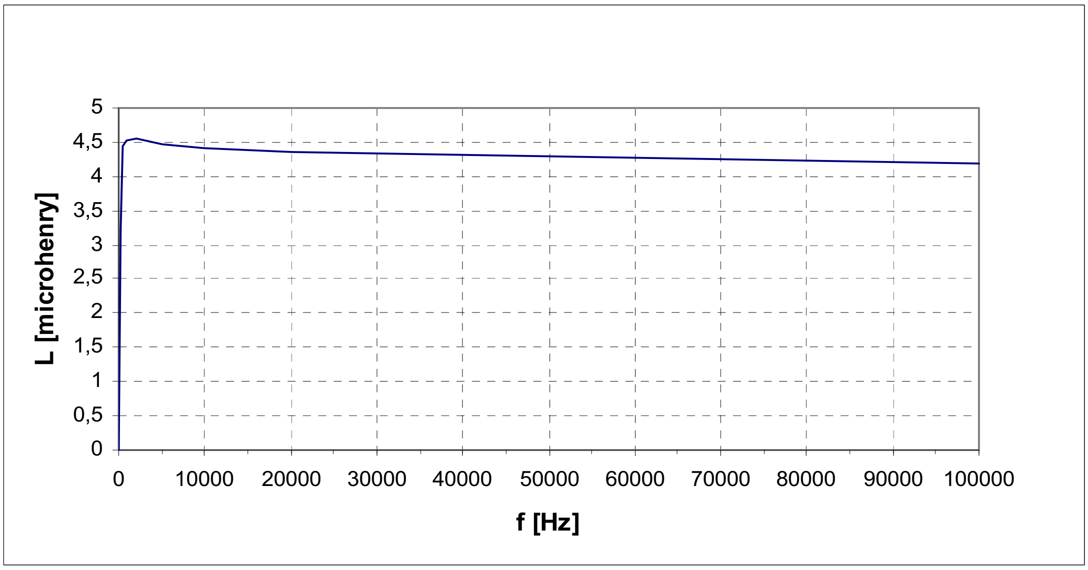


Resistance from the beginning to the end of the signal conductor



Inductance from the beginning to the end of the signal conductor

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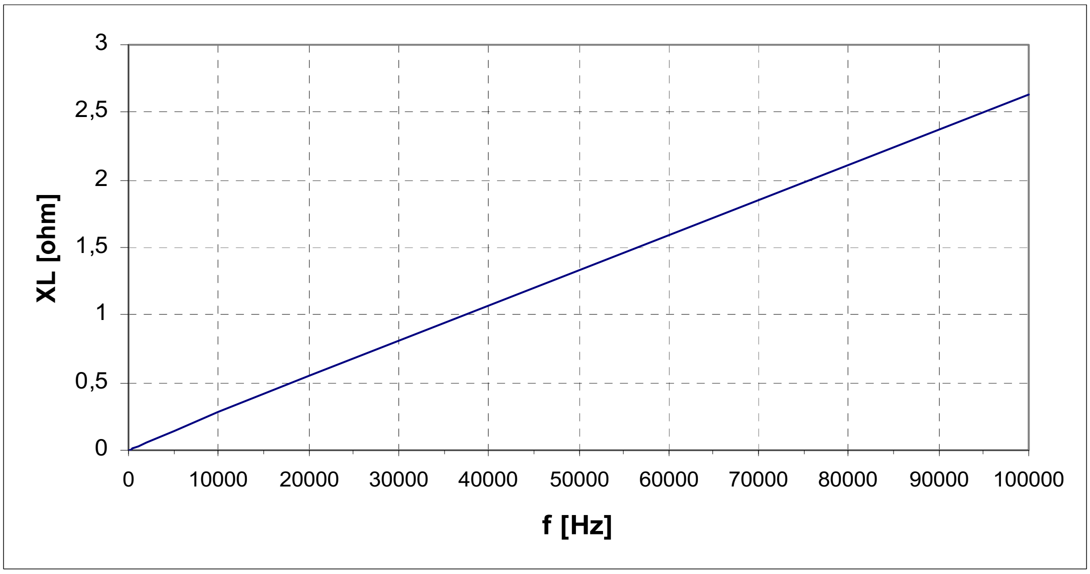
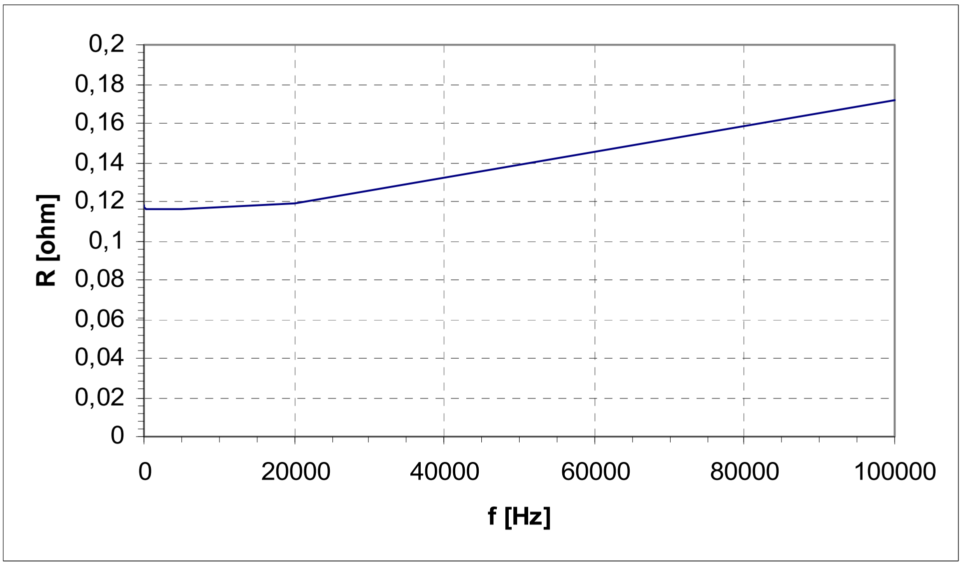


Inductive reactance from the beginning to the end of the signal conductor



Resistance from the beginning to the end of the ground conductor

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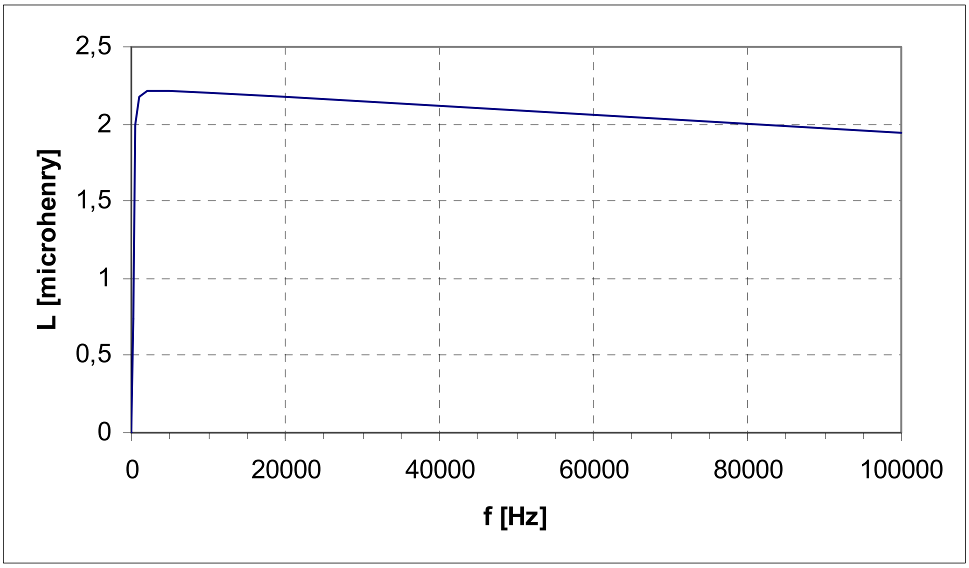
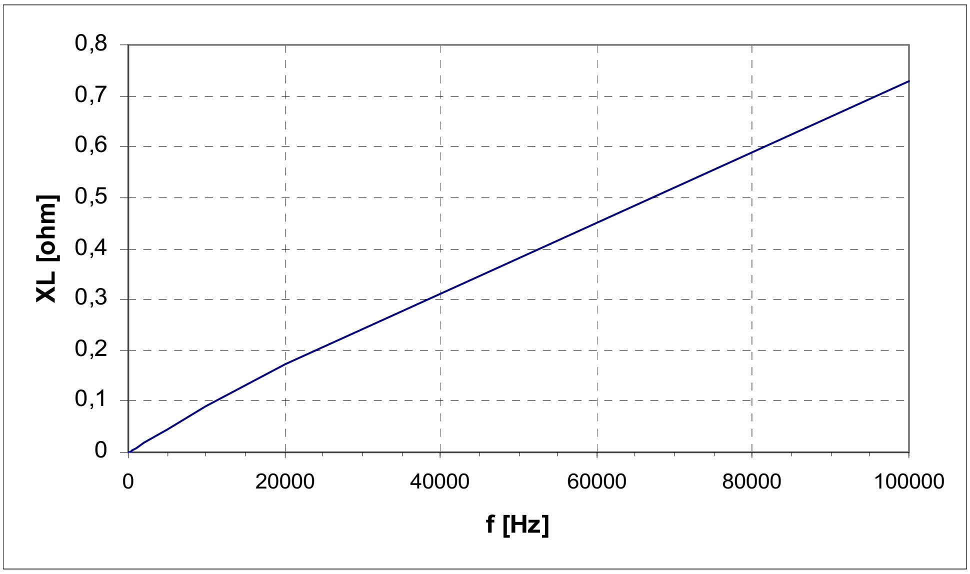


Inductance from the beginning to the end of the ground conductor



Inductive reactance from the beginning to the end of the ground conductor

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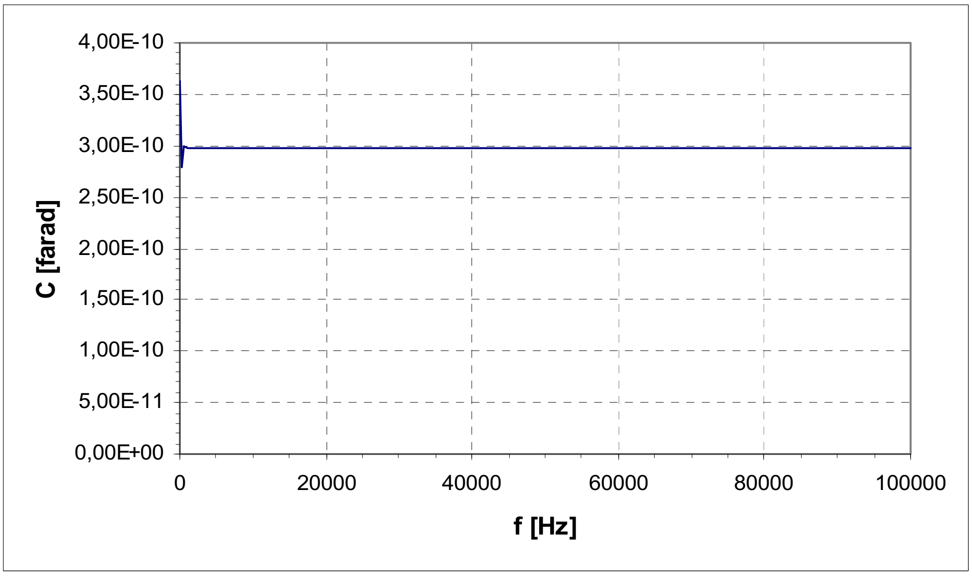

Capacitance between signal and ground conductors

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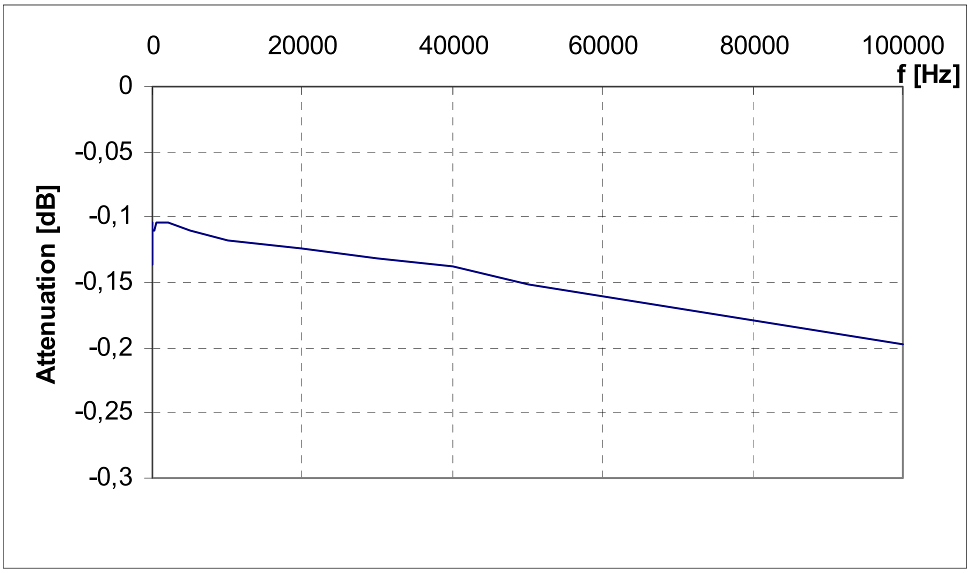

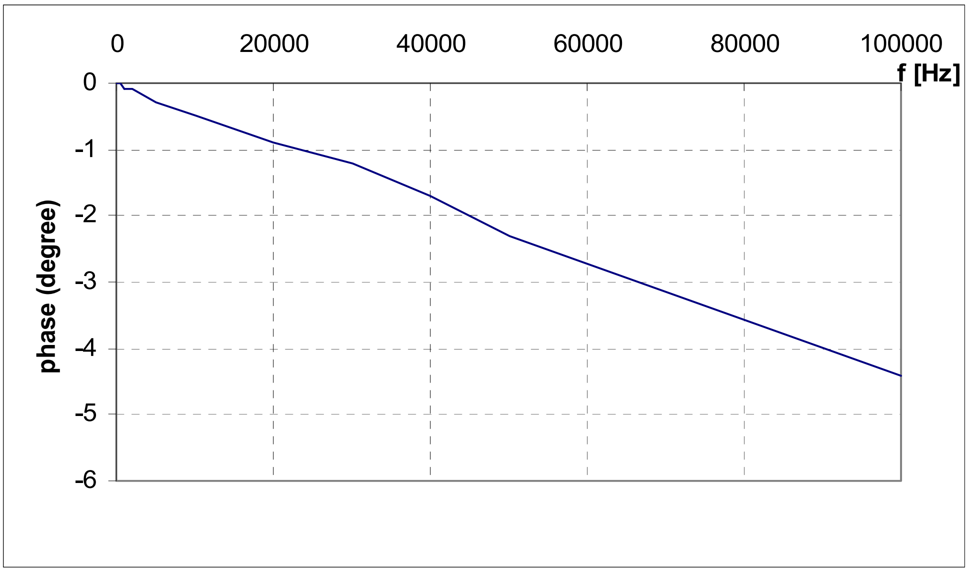

Frequency response: amplitude and phase characteristics measured from the conductor (+) and the ground (f_t=3 MHz)

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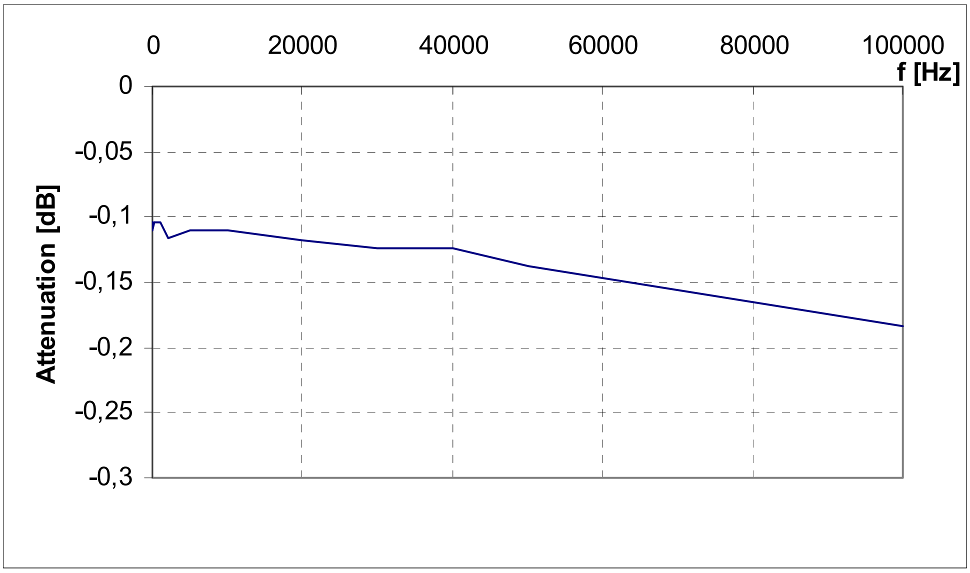

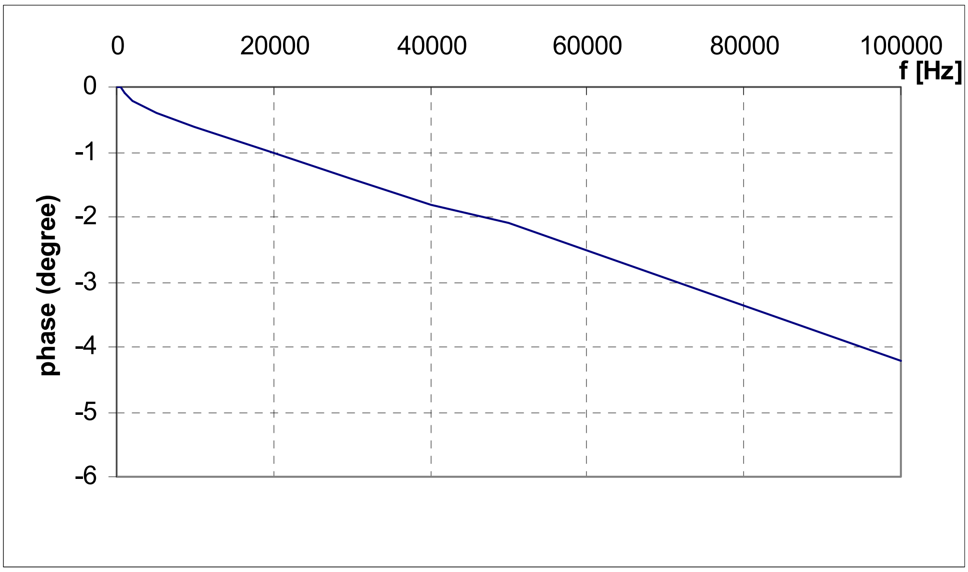

Frequency response: amplitude and phase characteristics measured from the conductor (-) and the ground (f_t=3 MHz)

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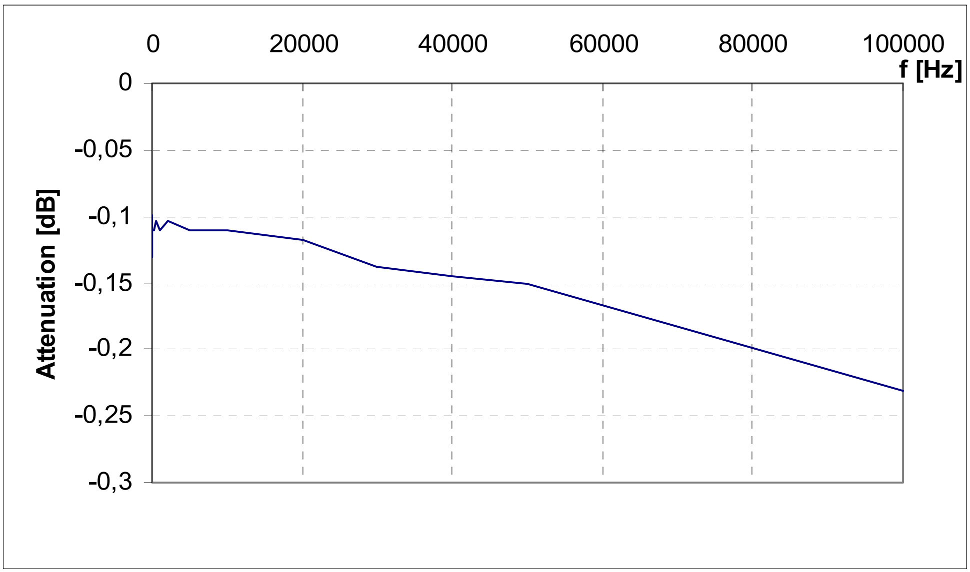
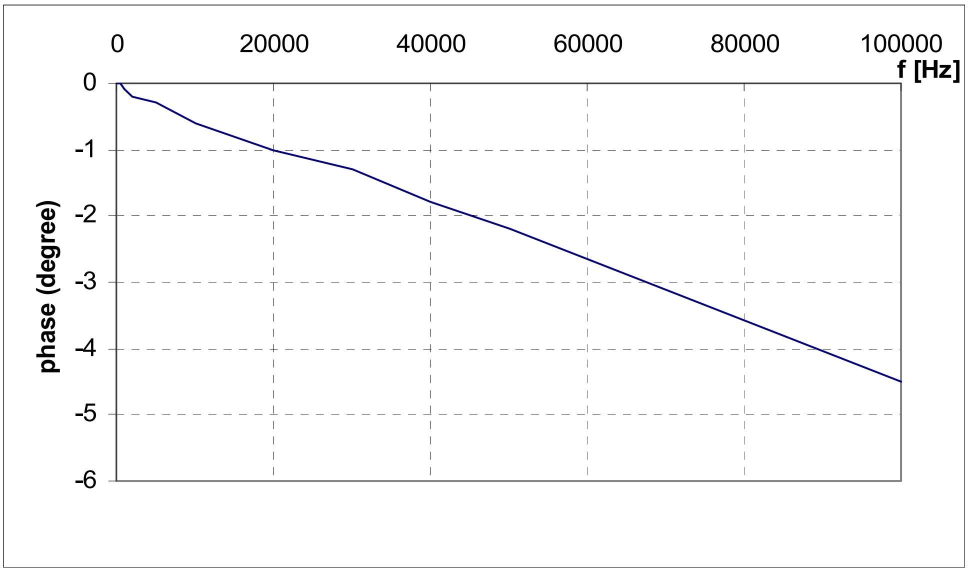
ph: (+39) 0862 434402 - fax (+39) 0862 434403 - email segdie@ing.univaq.it - Part. IVA n. 01021630668





Frequency response: amplitude and phase characteristics measured from the conductor (+) and the conductor (-) (f_t=3 MHz)

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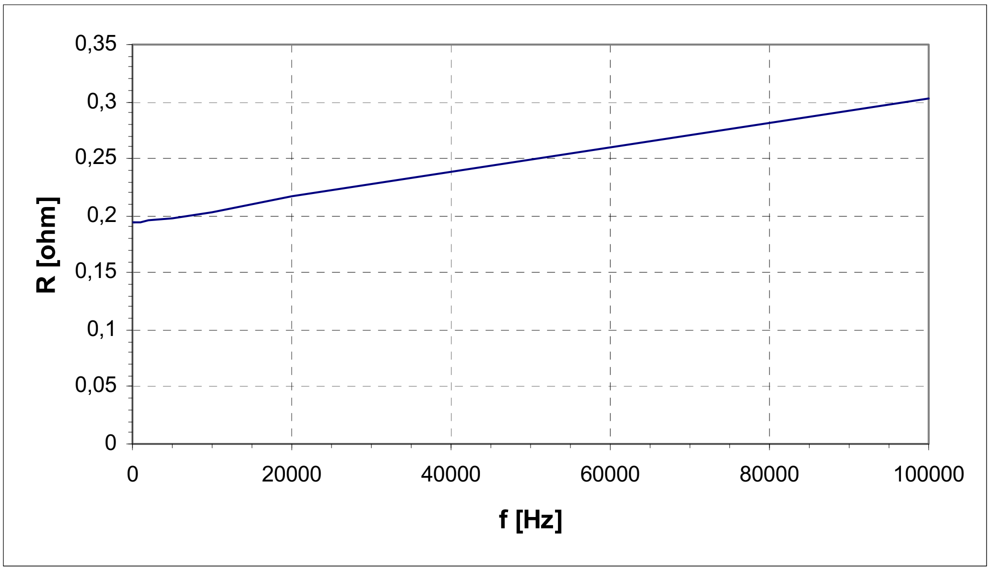
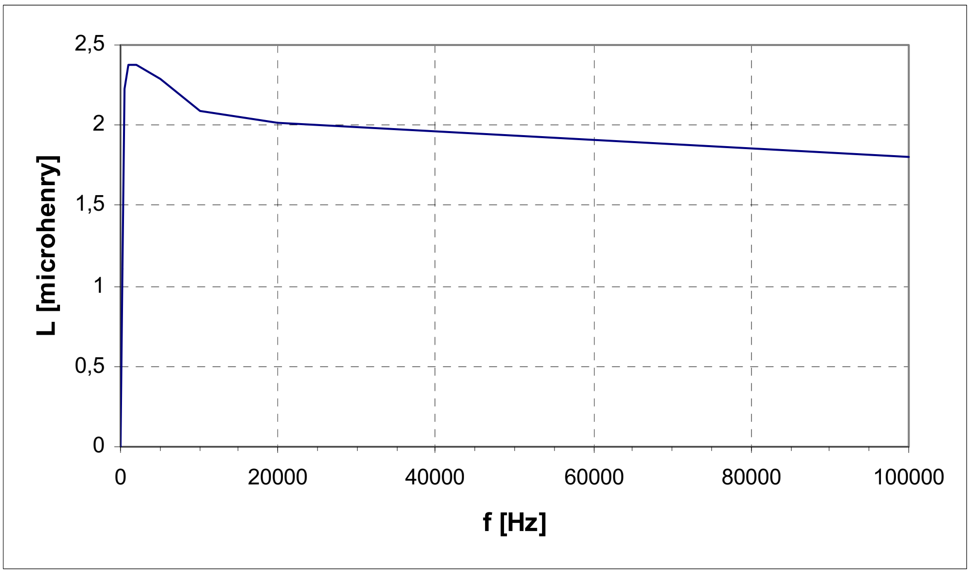


Resistance from the beginning to the end of the conductor (+)



Inductance from the beginning to the end of the conductor (+)

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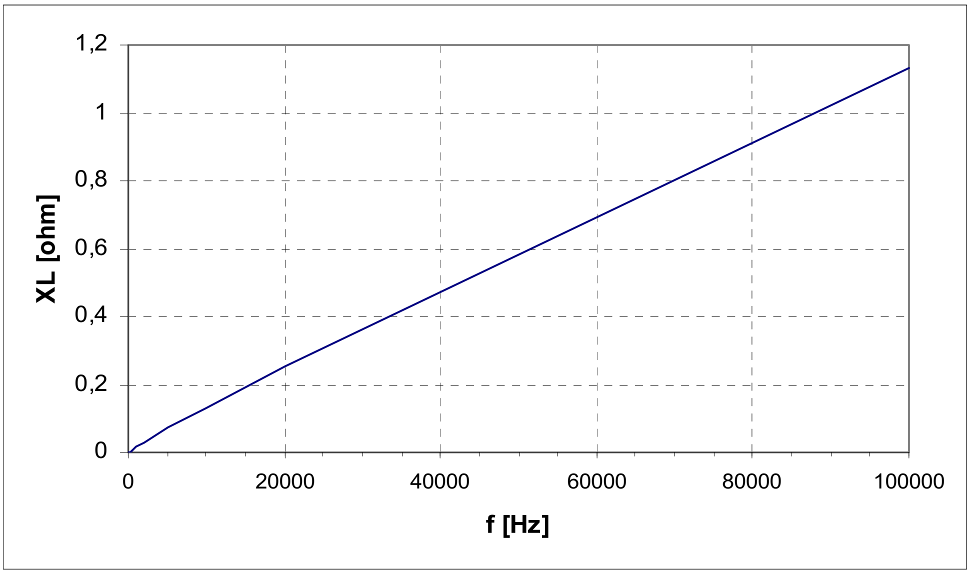
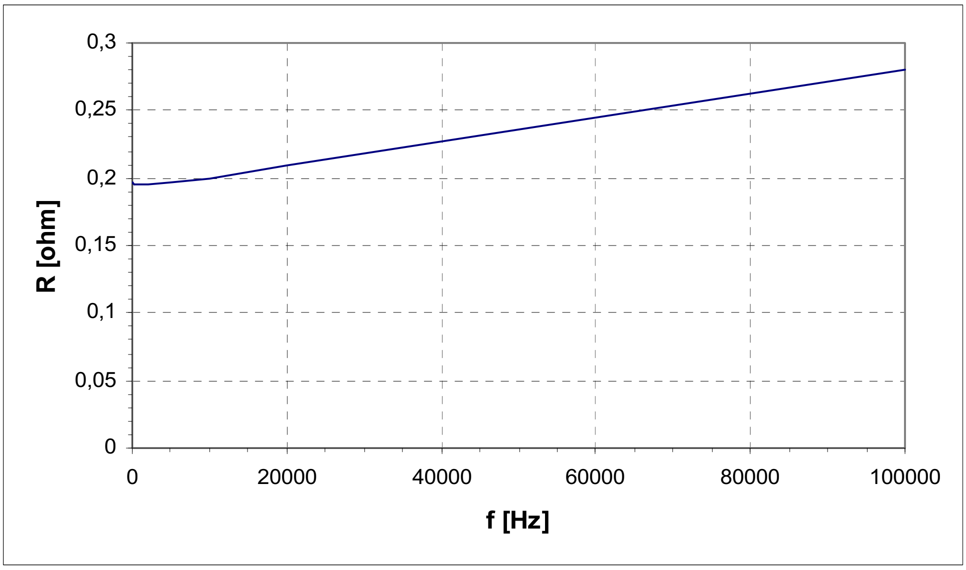


Inductive reactance from the beginning to the end of the conductor (+)



Resistance from the beginning to the end of the conductor (-)

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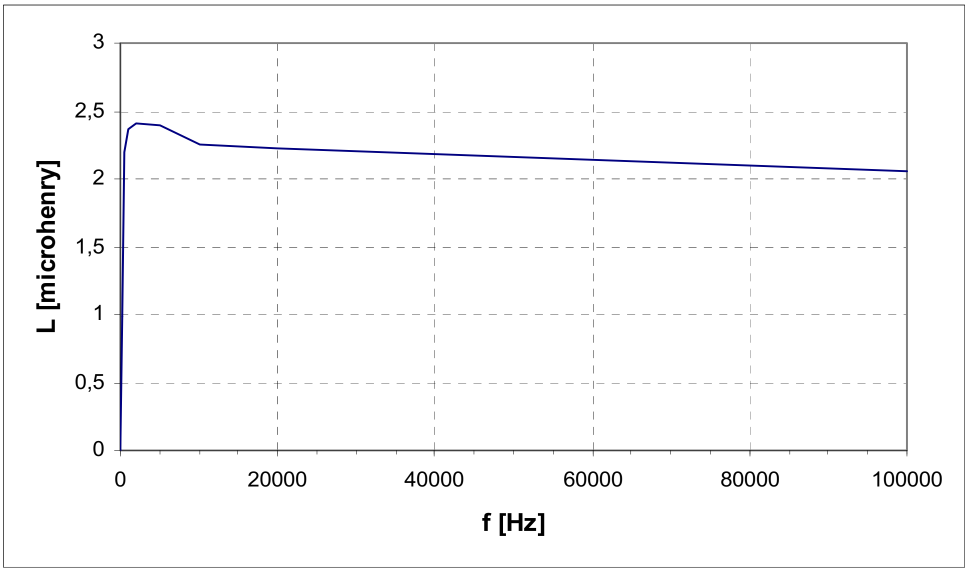
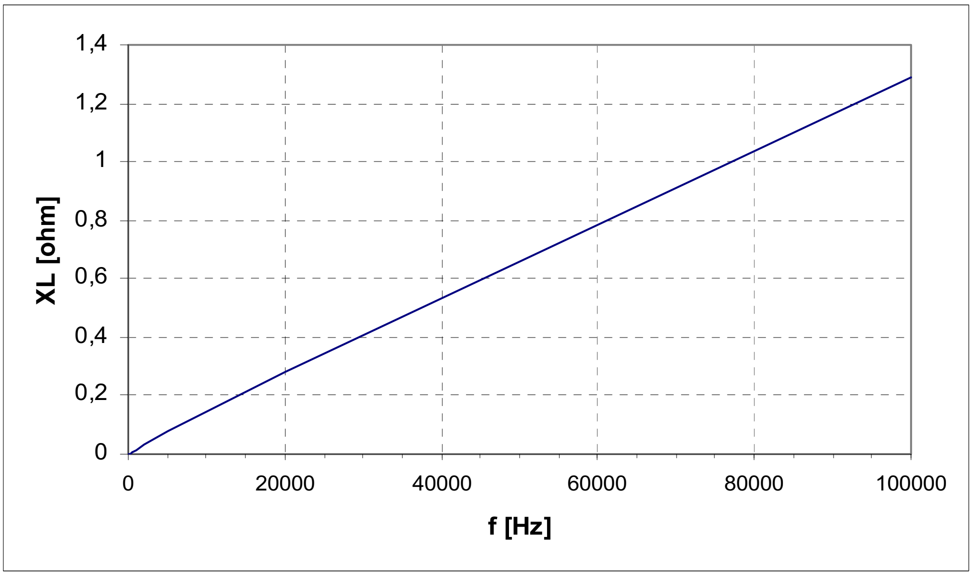


Inductance from the beginning to the end of the conductor (-)



Inductive reactance from the beginning to the end of the conductor (-)

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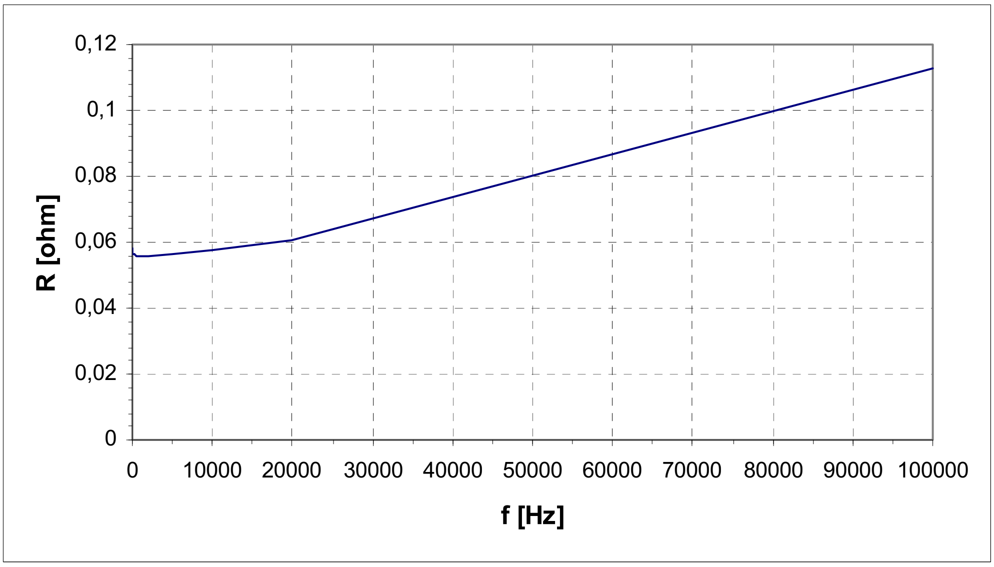
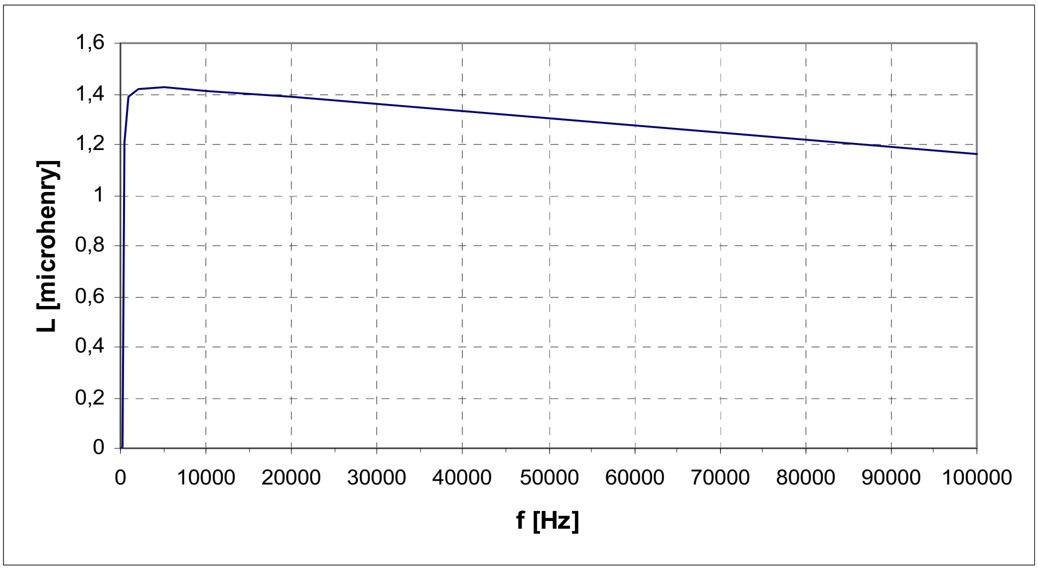


Resistance from the beginning to the end of the ground conductor



Inductance from the beginning to the end of the ground conductor

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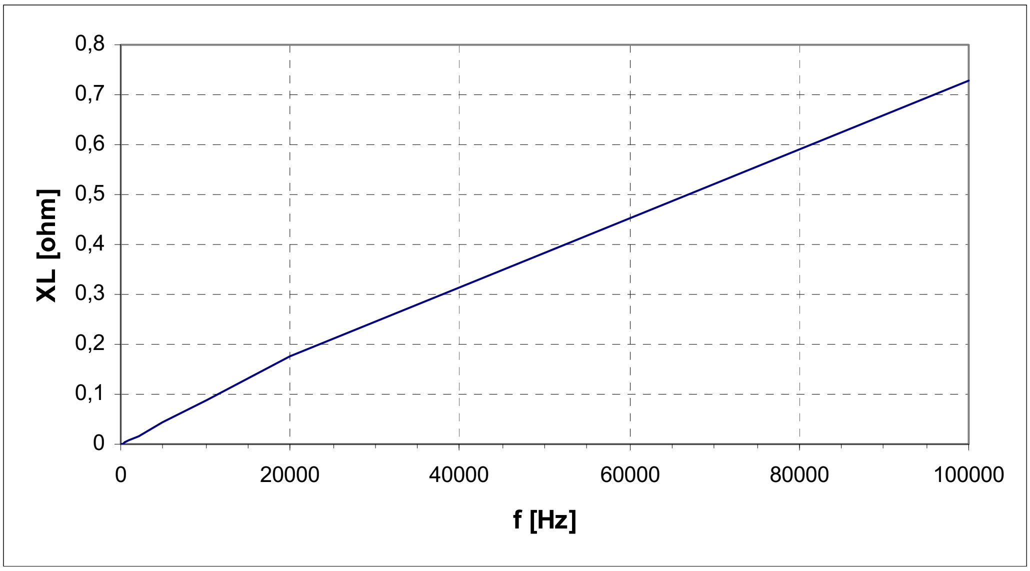
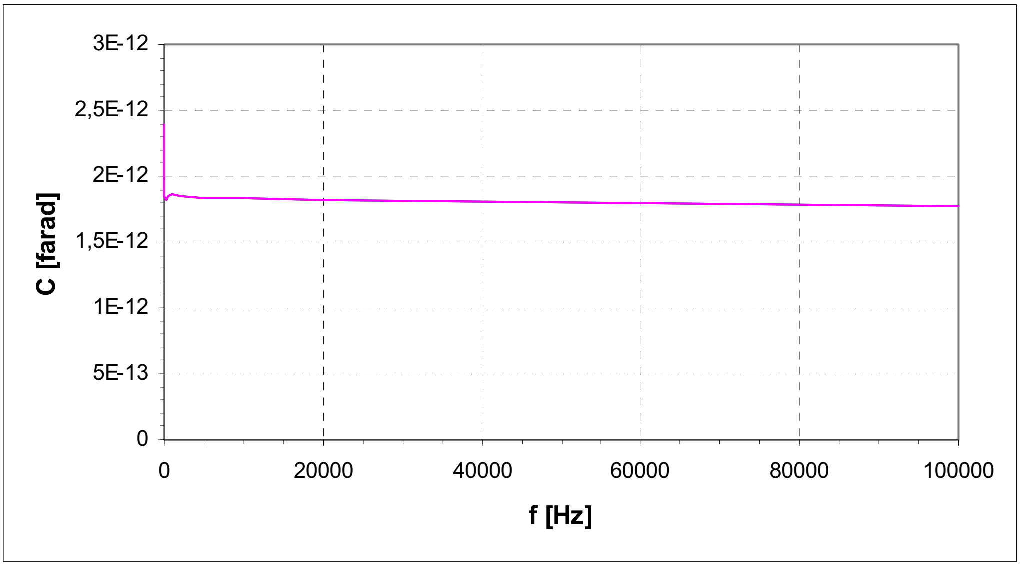


Inductive reactance from the beginning to the end of the ground conductor



Capacitance between signal (+) and ground conductors

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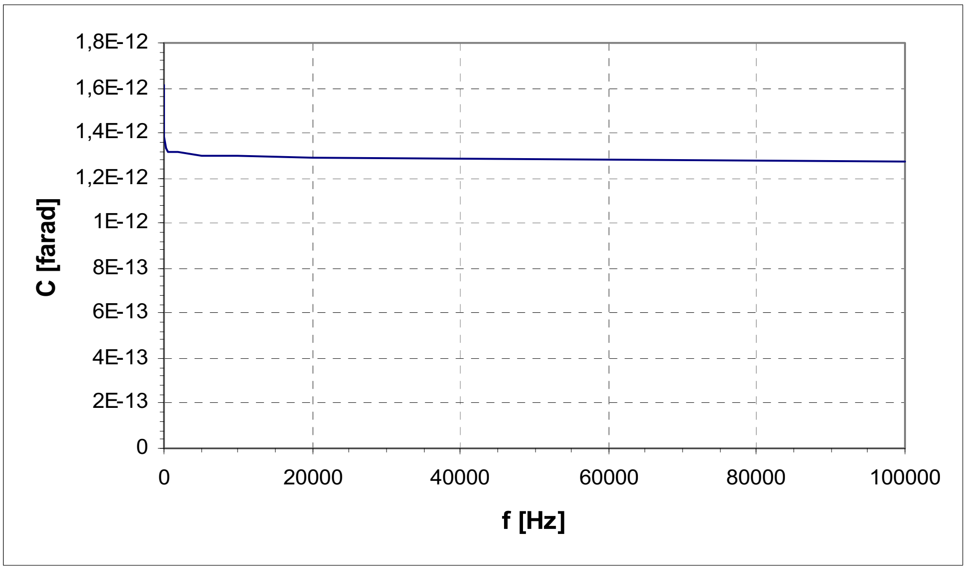
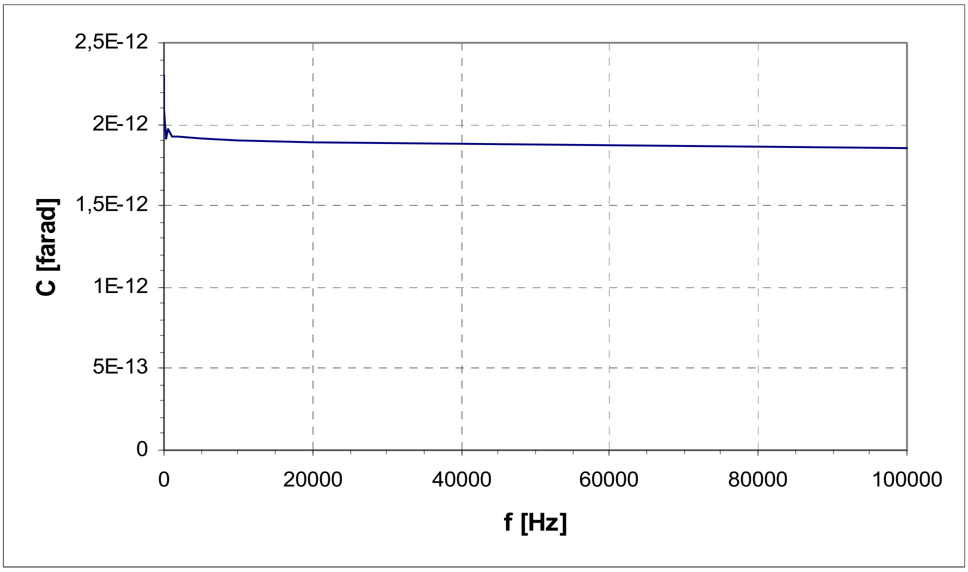


Capacitance between signal (-) and ground conductors



Capacitance between signal (+) and signal (-) conductors

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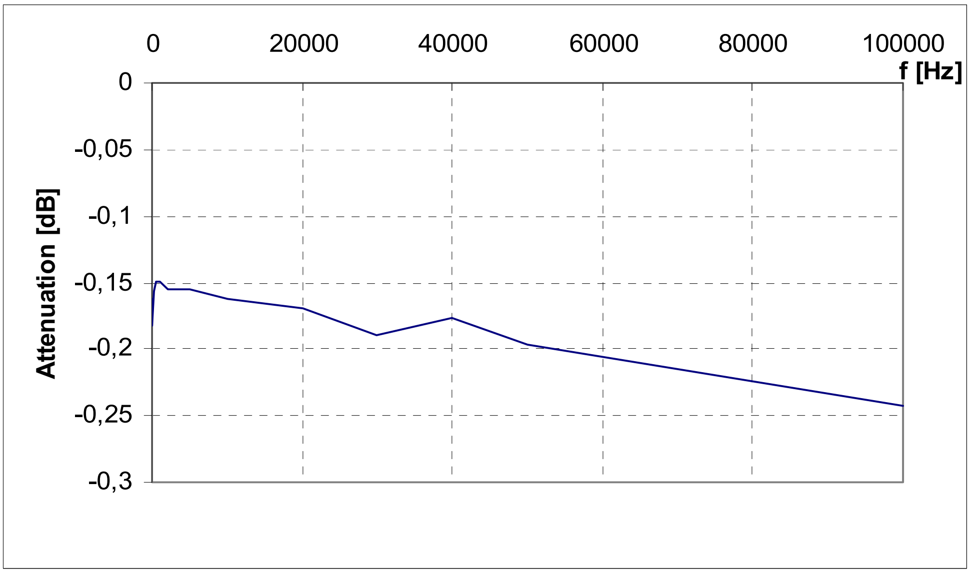
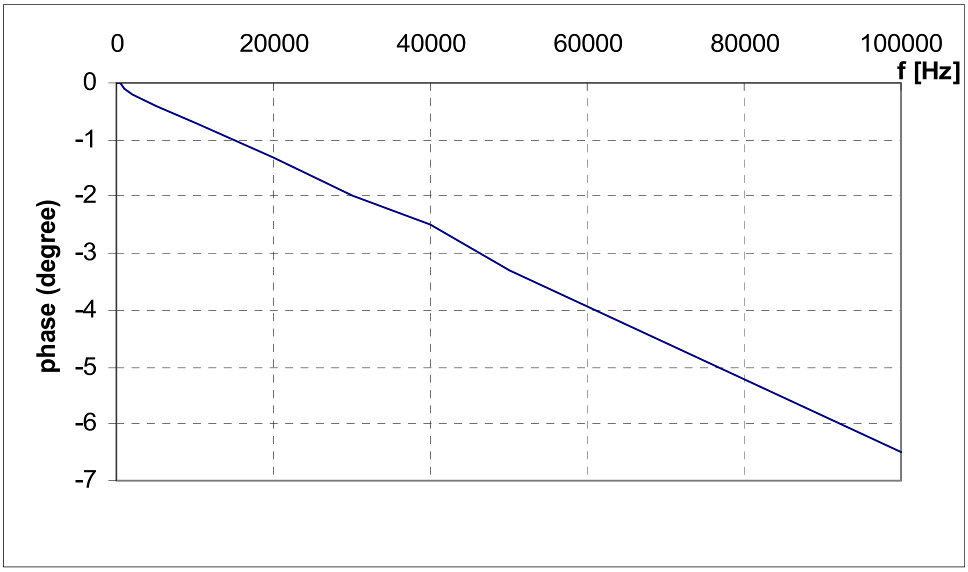
Cable under test	manufacturer	PROEL S.p.A.
	model	DIE-HARD **DH200LU5**
	length	5 m
	description	Microphone cable. Conductors: 6.5 overall diameter. Connectors: XLR connector with mechanically stabilised contact. Tinned copper braid shielded. 6.3mm mono jack - XLR Female. 24K gold plated contacts





Frequency response: amplitude and phase characteristics measured from signal and ground conductors (f_t=2.3 MHz)

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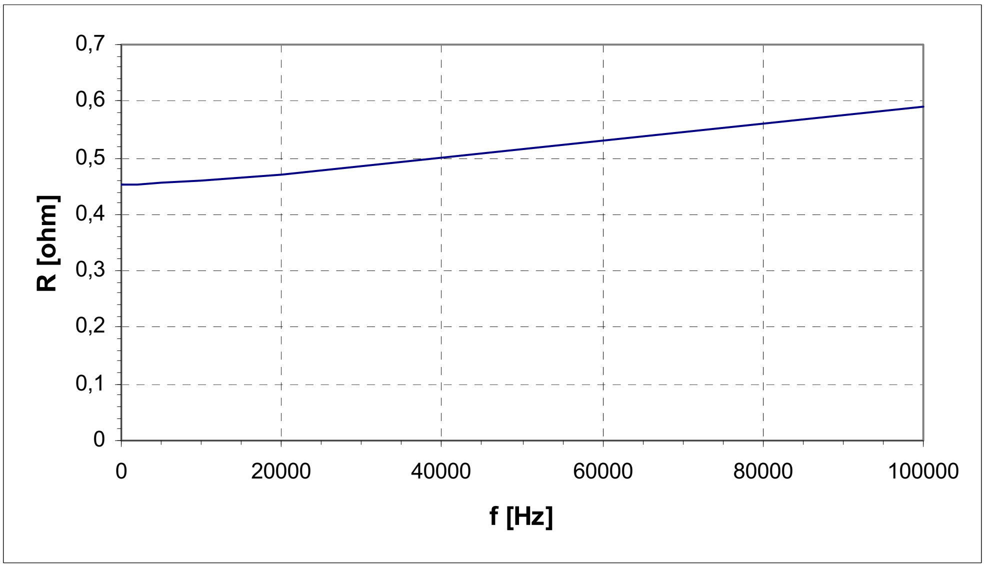
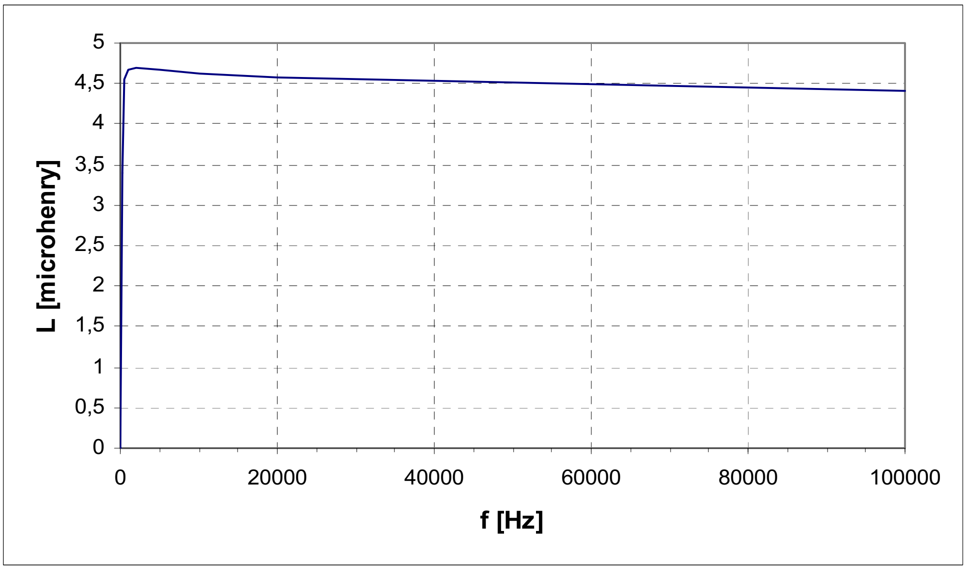


Resistance from the beginning to the end of the signal conductor



Inductance from the beginning to the end of the signal conductor

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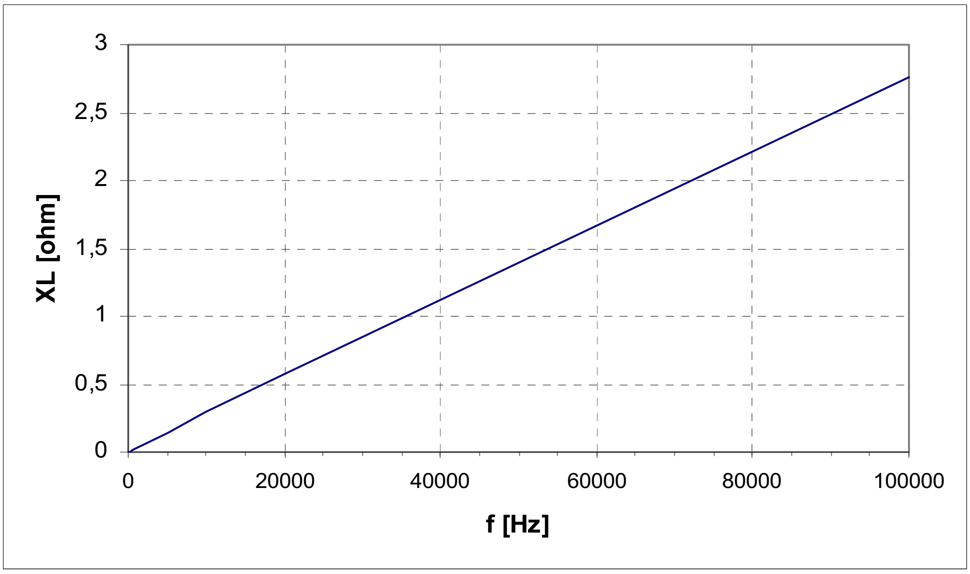
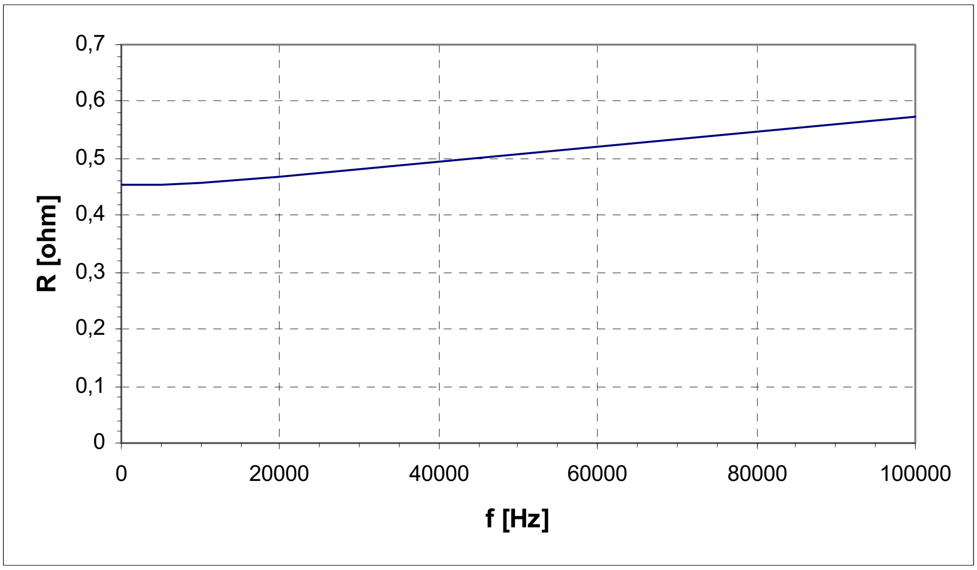


Inductive reactance from the beginning to the end of the signal conductor



Resistance from the beginning to the end of the ground conductor

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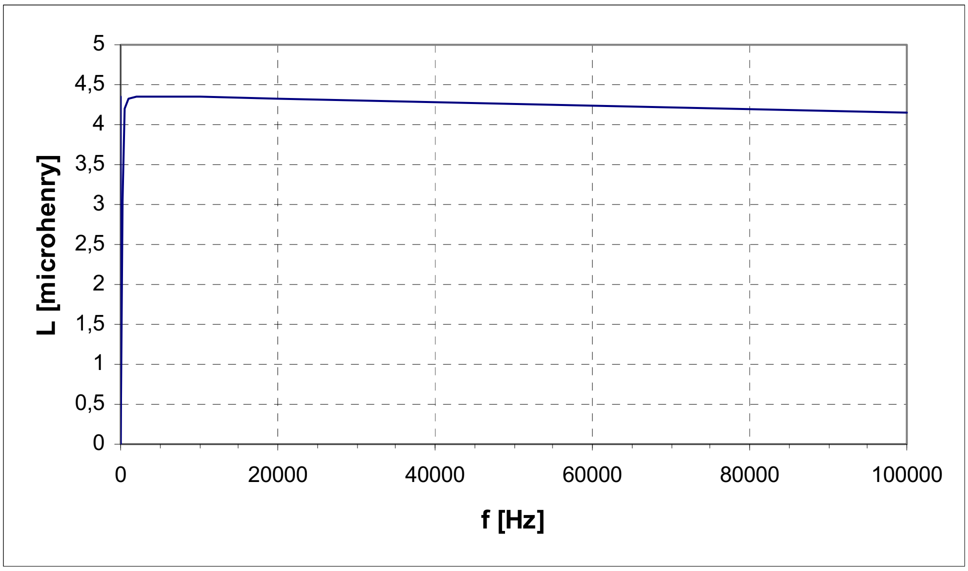
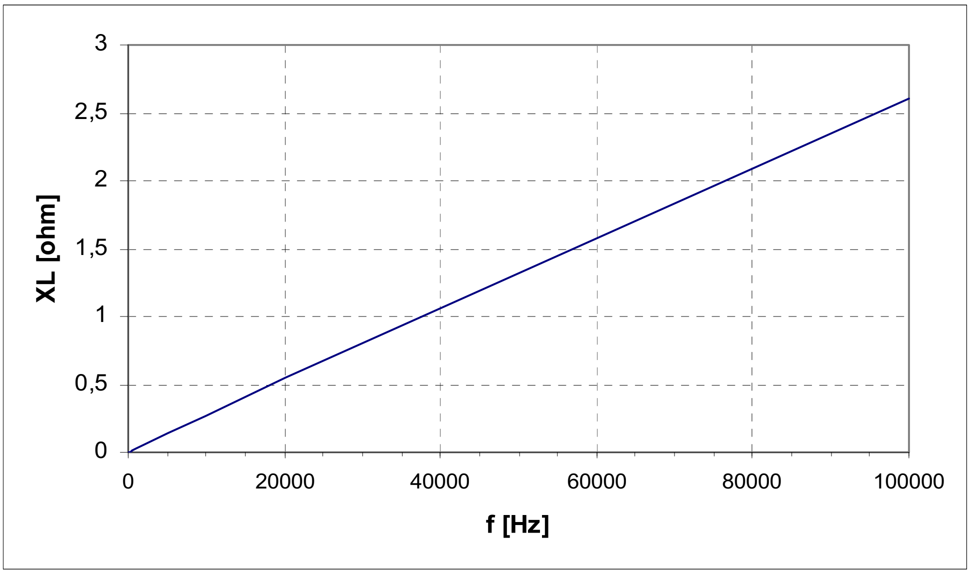


Inductance from the beginning to the end of the ground conductor



Inductive reactance from the beginning to the end of the ground conductor

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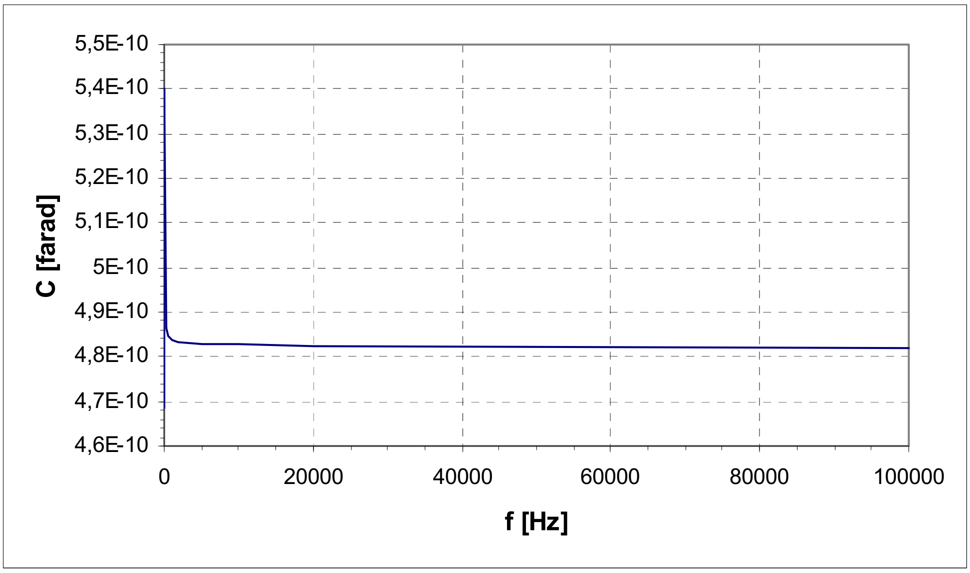

Capacitance between signal and ground conductors

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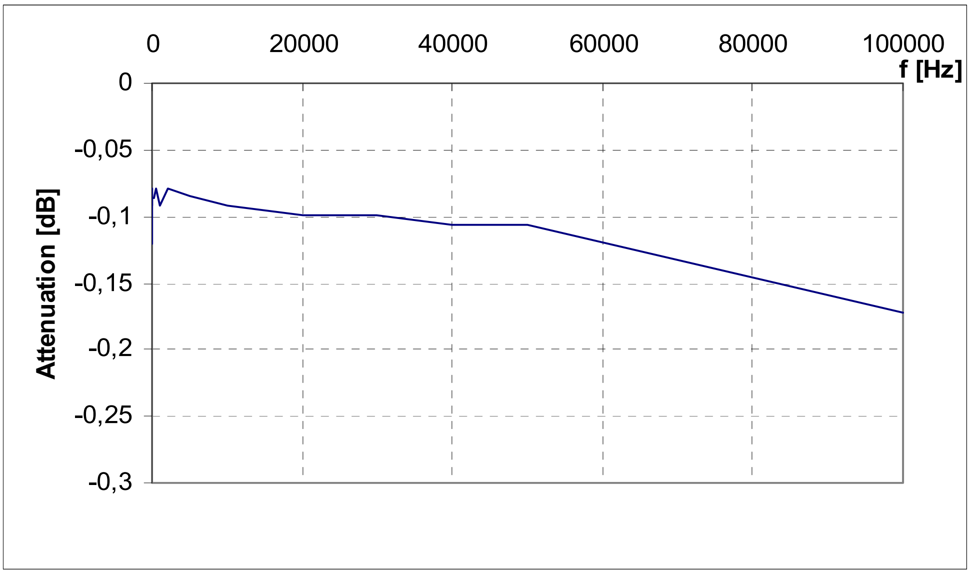
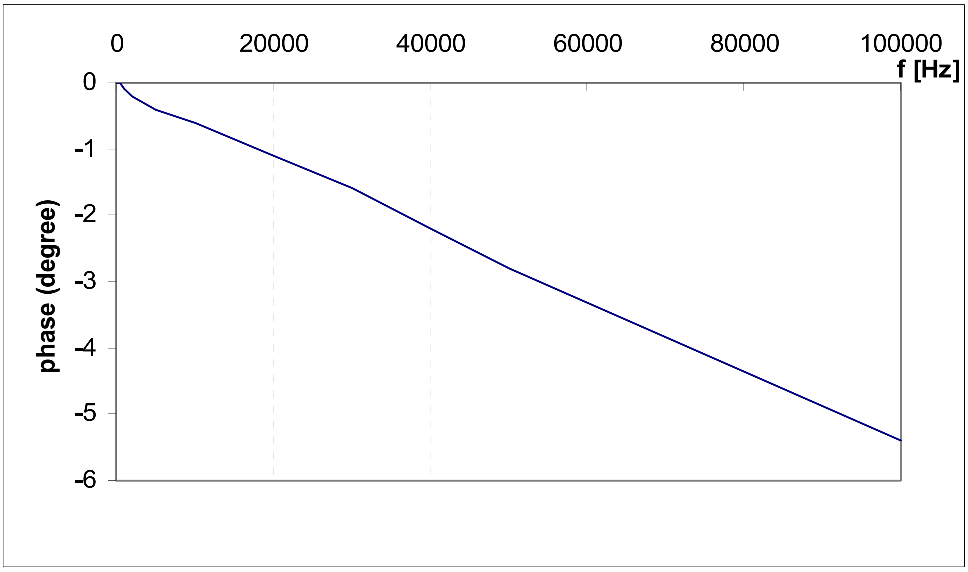
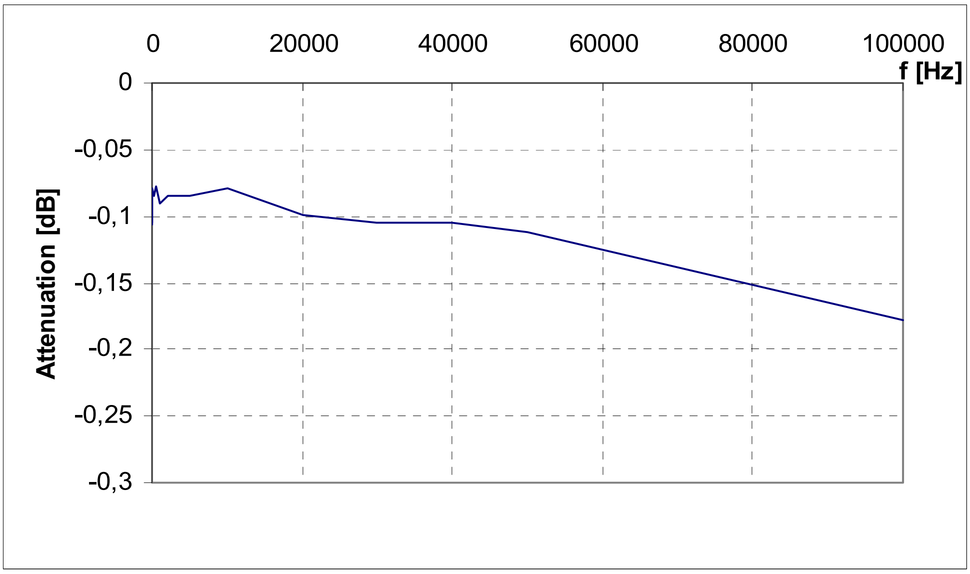
ph: (+39) 0862 434402 - fax (+39) 0862 434403 - email segdie@ing.univaq.it - Part. IVA n. 01021630668

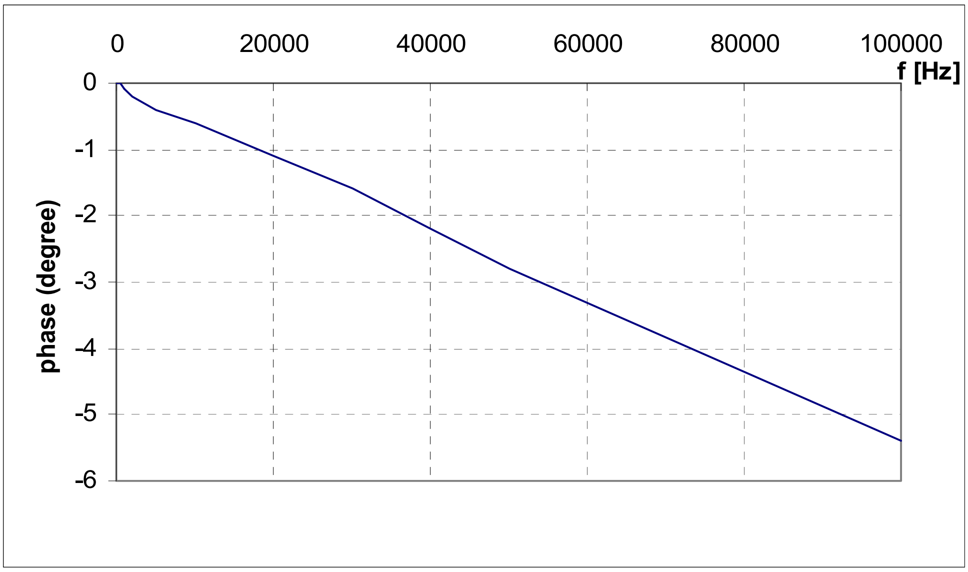
Cable under test	manufacturer	PROEL S.p.A.
	model	DIE-HARD **DH240LU5**
	length	5 m
	description	Microphone cable. Conductors: 6.5 overall diameter. Connectors: XLR connector with mechanically stabilised contact- 6.3mm stereo jack. Tinned copper braid shielded. Schermo a treccia in rame stagnato. XLR female - XLR male. 24K gold plated contacts.





Frequency response: amplitude and phase characteristics measured from the conductor (1) and the conductor (2) , (f_t=2.5 MHz)





Frequency response: amplitude and phase characteristics measured from the conductor (1) and the conductor (3), (f_t=2.7 kHz)

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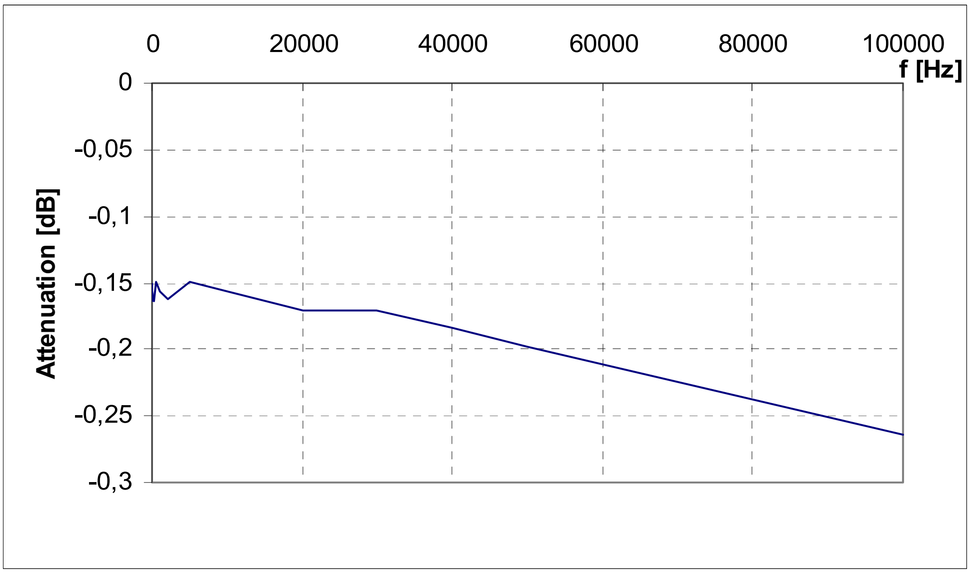

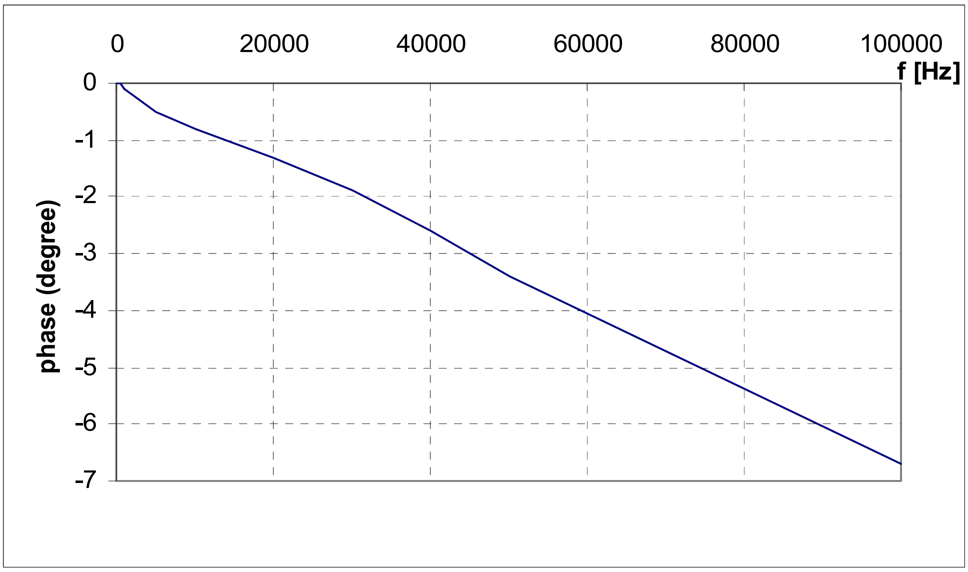

Frequency response: amplitude and phase characteristics measured from the conductor (2) and the conductor (3, (f_t=2.1 kHz)

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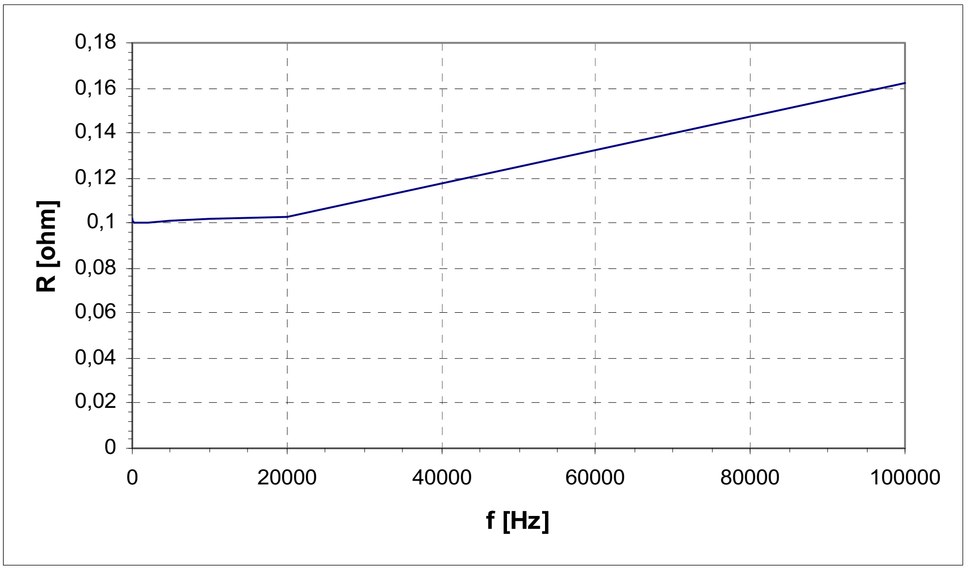
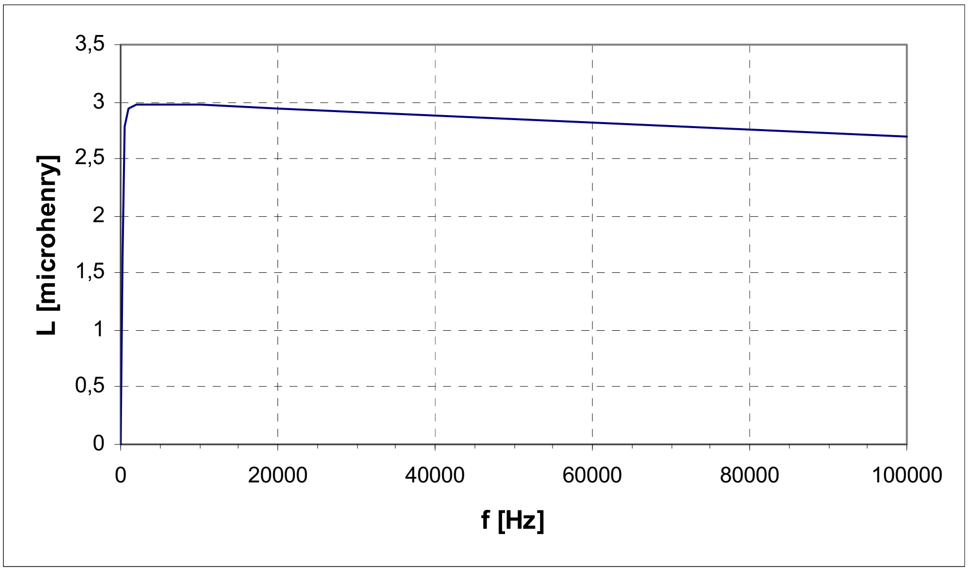


Resistance from the beginning to the end of the conductor (1)



Inductance from the beginning to the end of the conductor (1)

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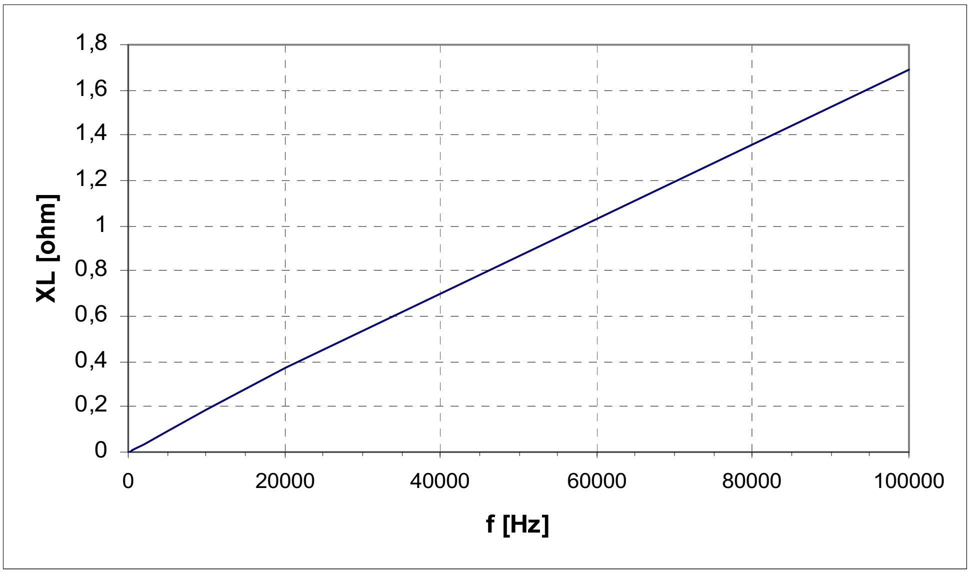
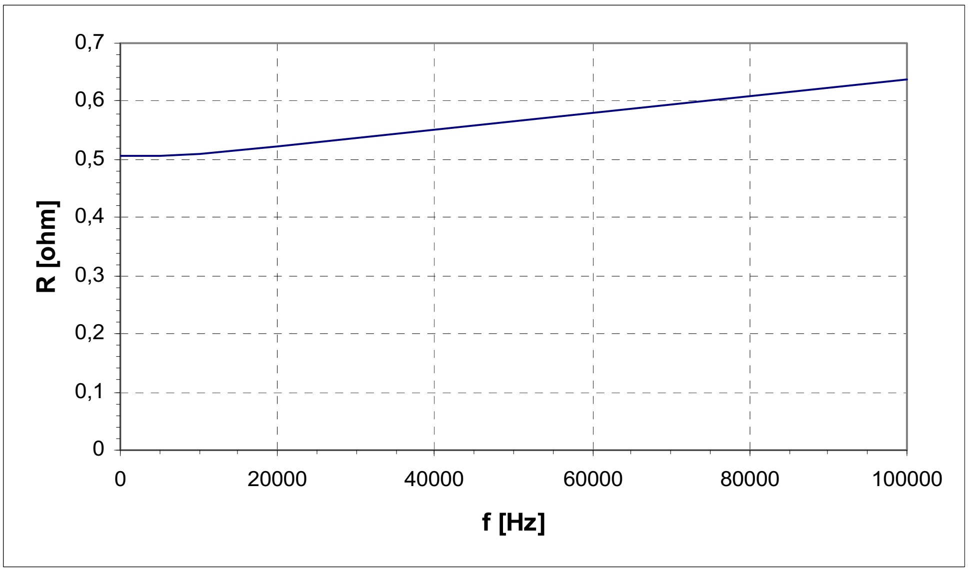


Inductive reactance from the beginning to the end of the conductor (1)



Resistance from the beginning to the end of the conductor (2)

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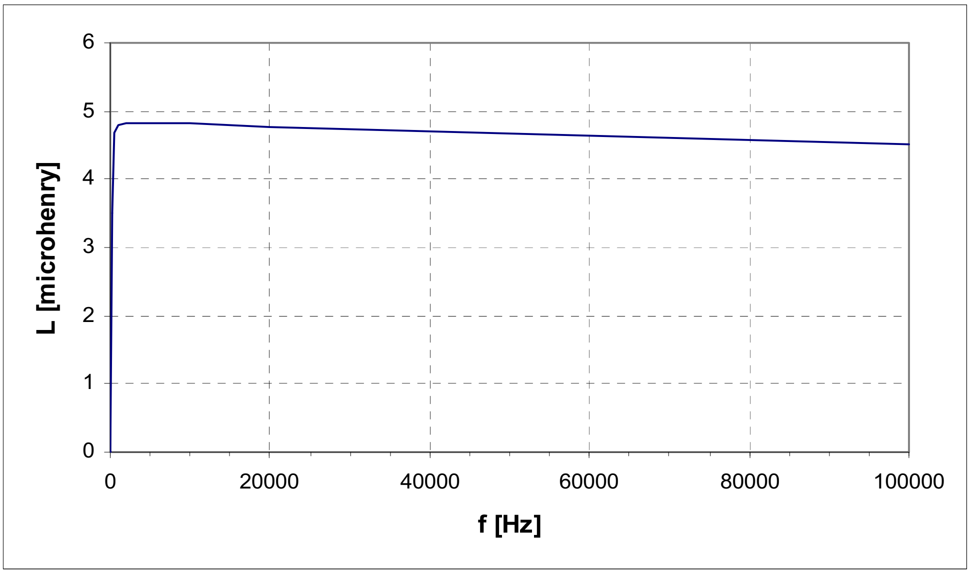
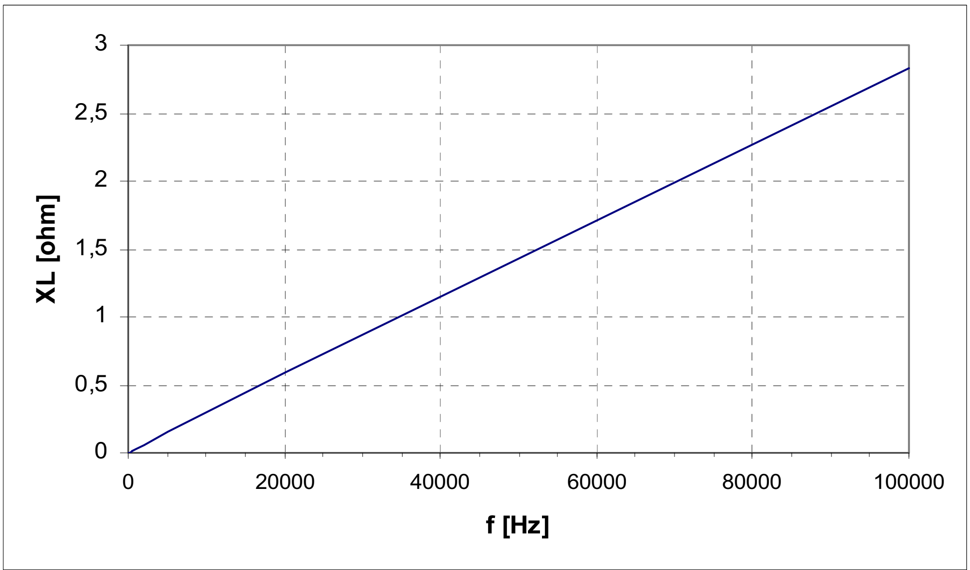


Inductance from the beginning to the end of the conductor (2)



Inductive reactance from the beginning to the end of the conductor (2)

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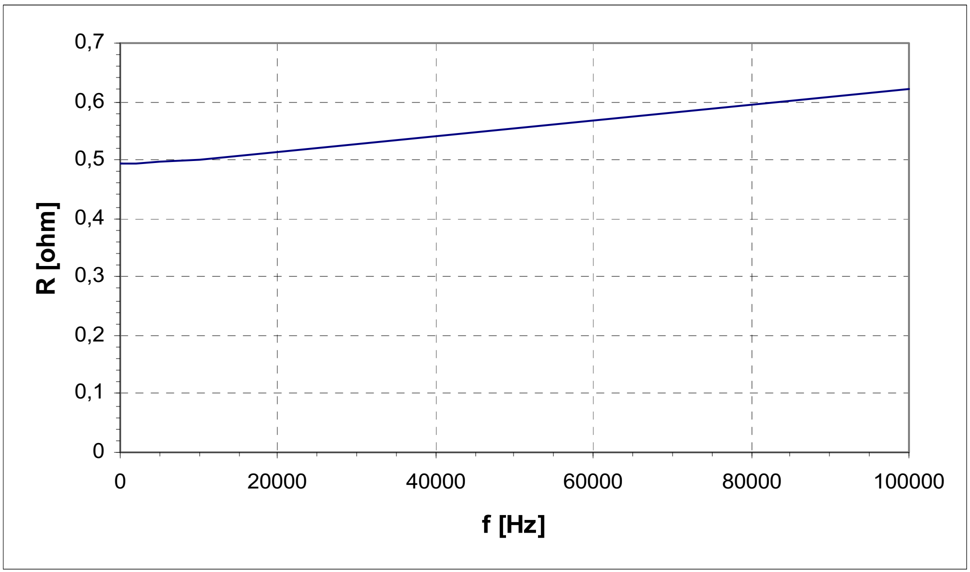
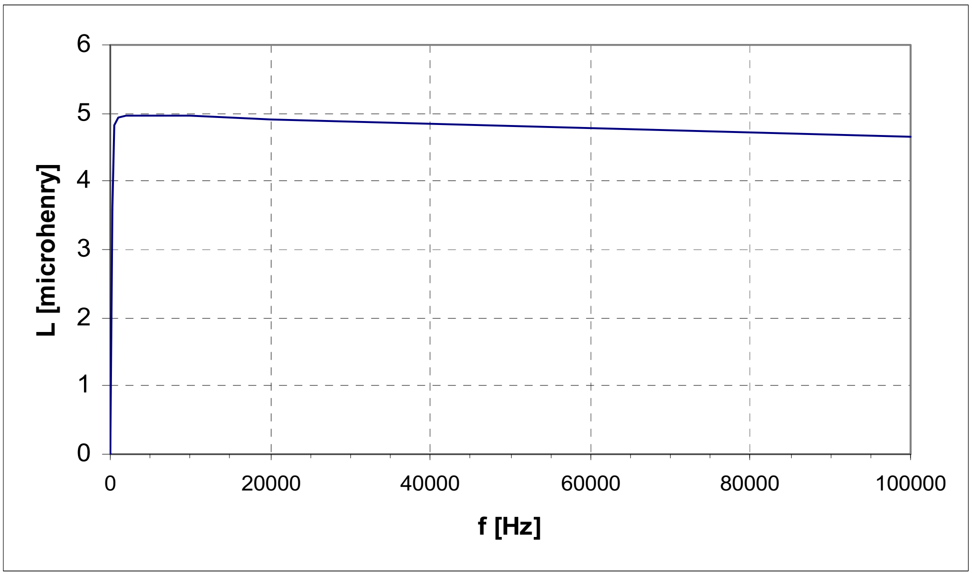


Resistance from the beginning to the end of the conductor (3)



Inductance from the beginning to the end of the conductor (3)

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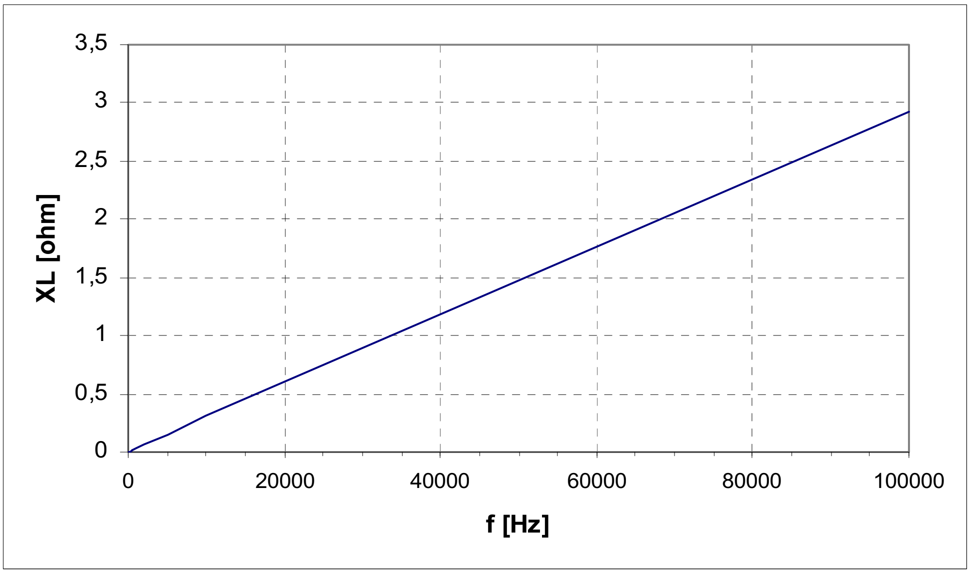
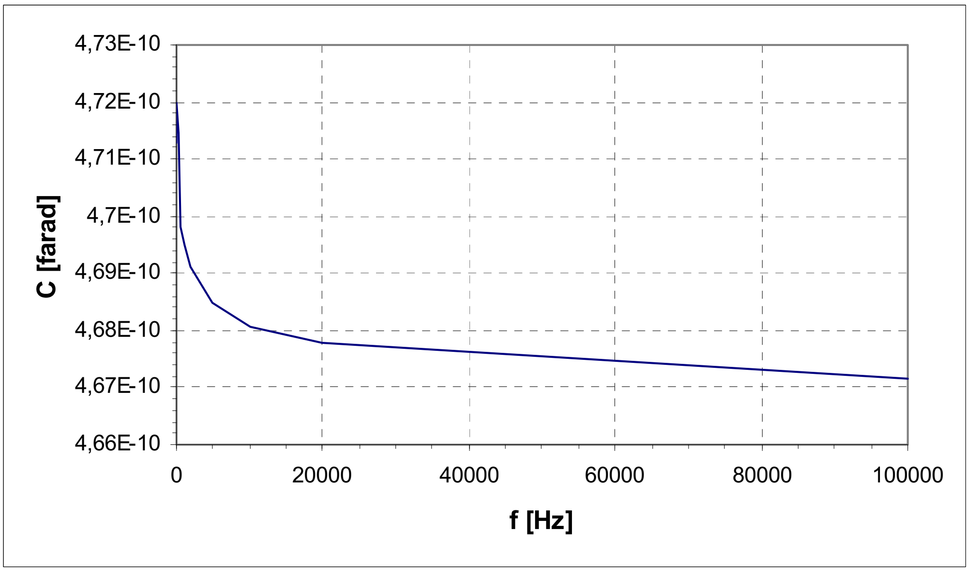


Inductive reactance from the beginning to the end of the conductor (3)



Capacitance between conductor (1) and conductor (2)

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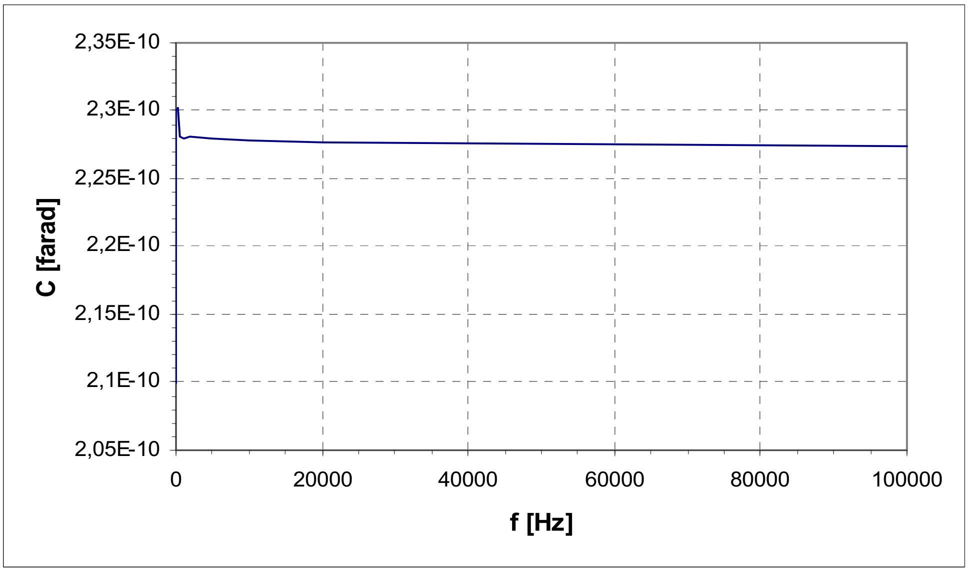
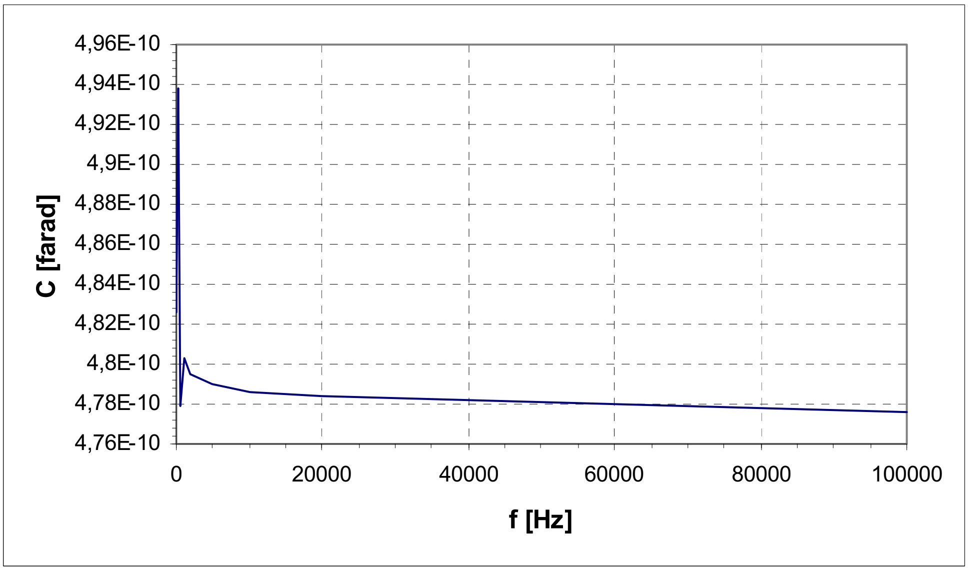


Capacitance between conductor (2) and conductor (3)



Capacitance between conductor (3) and conductor (1)

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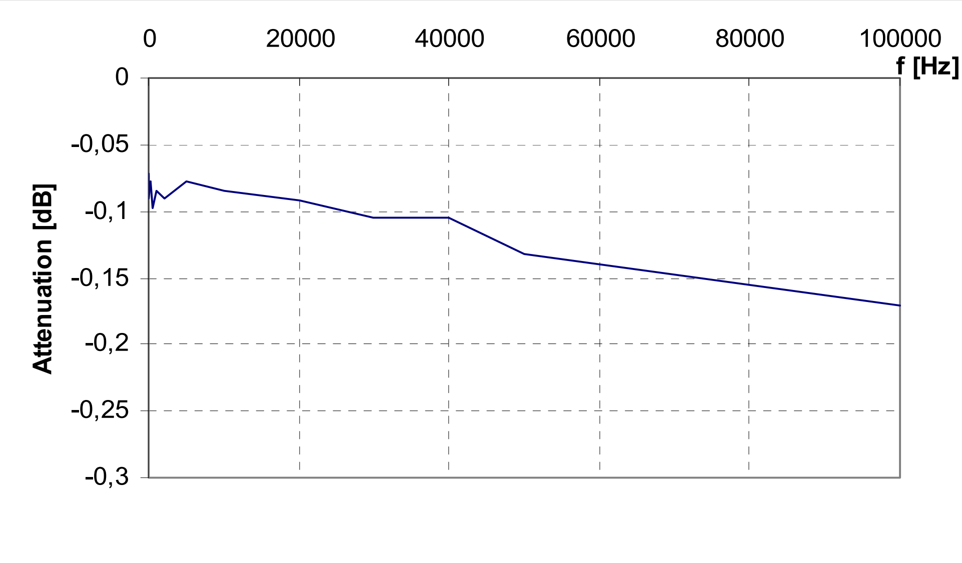
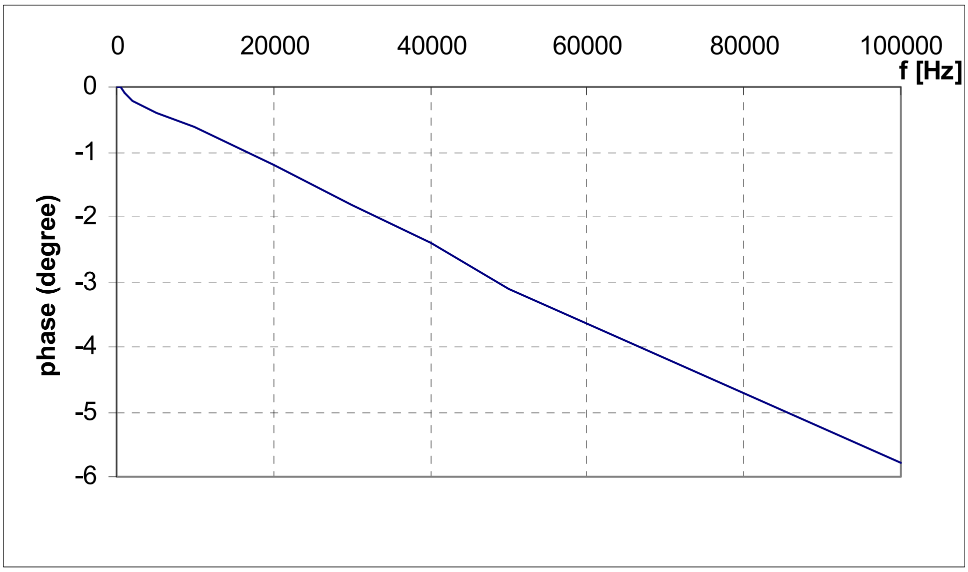
ph: (+39) 0862 434402 - fax (+39) 0862 434403 - email segdie@ing.univaq.it - Part. IVA n. 01021630668

Cable under test	manufacturer	PROEL S.p.A.
	model	DIE-HARD **DH300LU5**
	length	5 m
	description	Passive speaker cable. Conductors: 6 mm overall diameter. High flexibility. Connectors: 6.3 mm mono jack - 6.3 mm mono jack. 24K gold plated contacts





Frequency response: amplitude and phase characteristics measured from the signal and ground conductors, (f_t=2 MHz)

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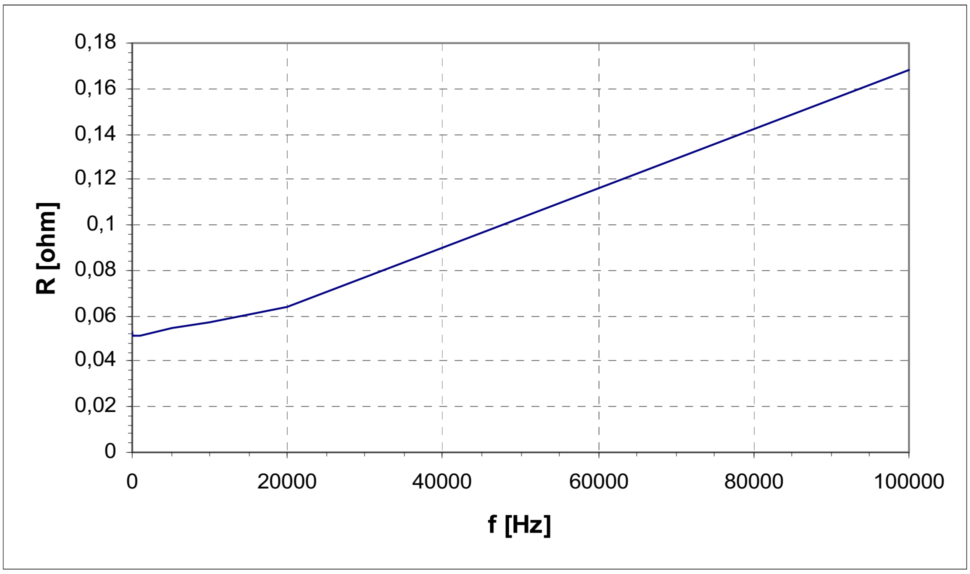
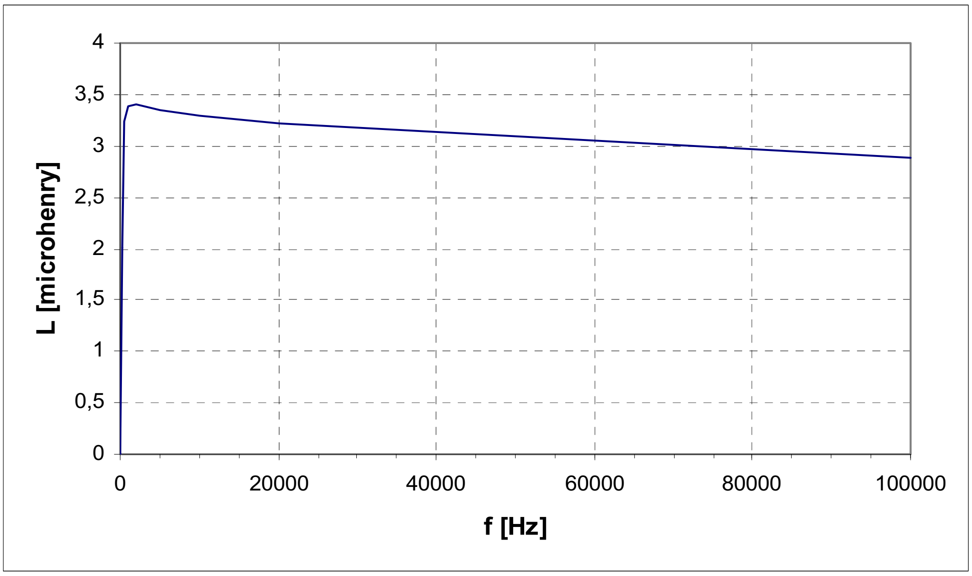
ph: (+39) 0862 434402 - fax (+39) 0862 434403 - email segdie@ing.univaq.it - Part. IVA n. 01021630668



Resistance from the beginning to the end of the signal conductor



Inductance from the beginning to the end of the conductor

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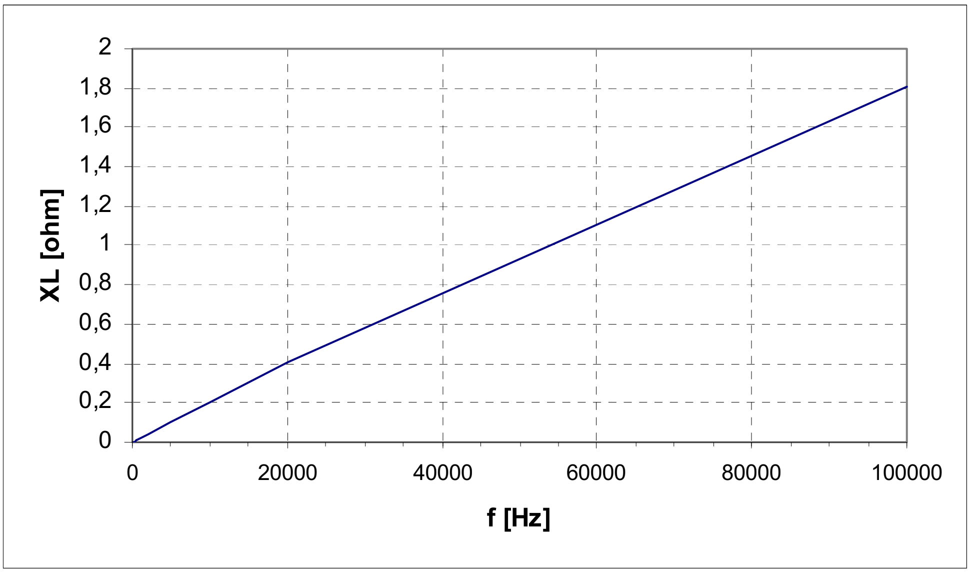
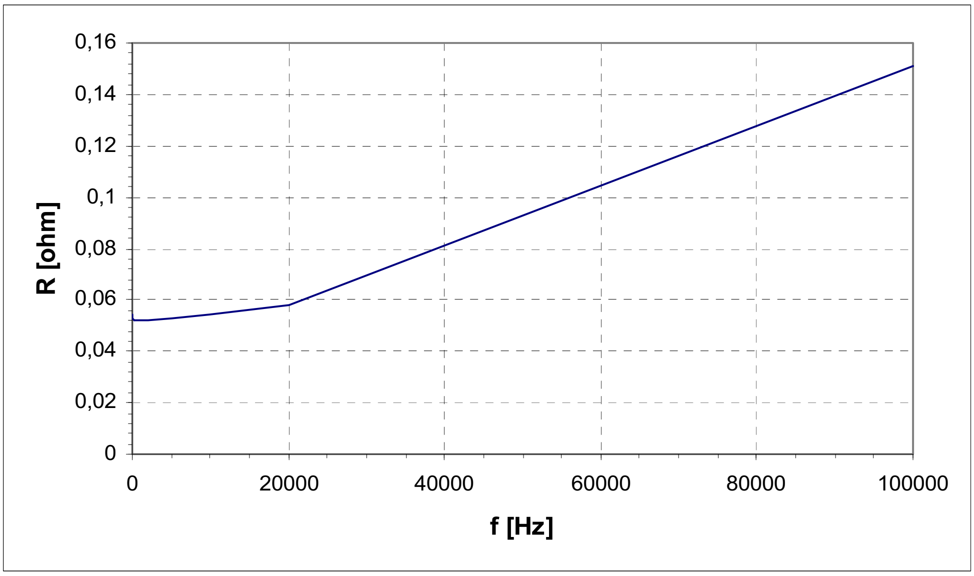


Inductive reactance from the beginning to the end of the signal conductor



Resistance from the beginning to the end of the ground conductor

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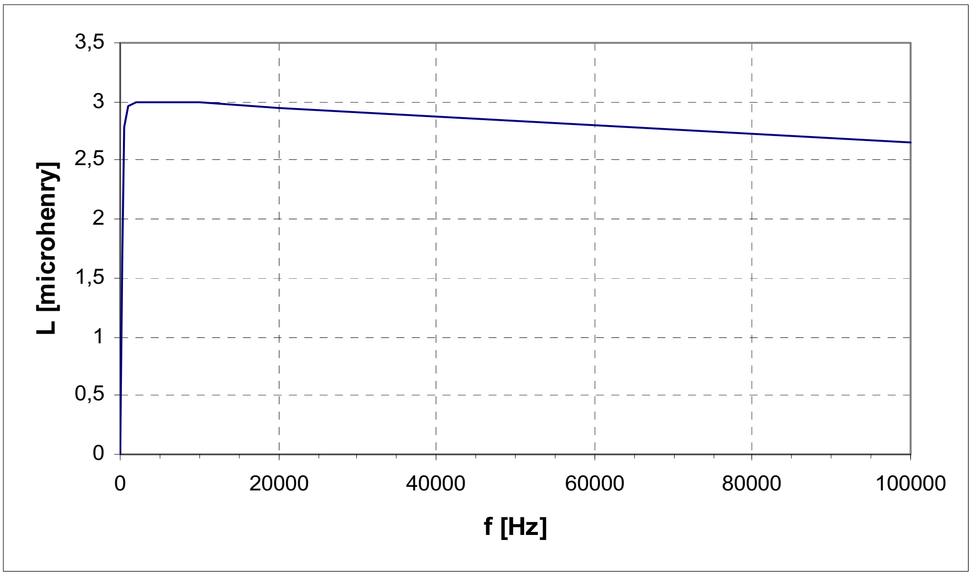
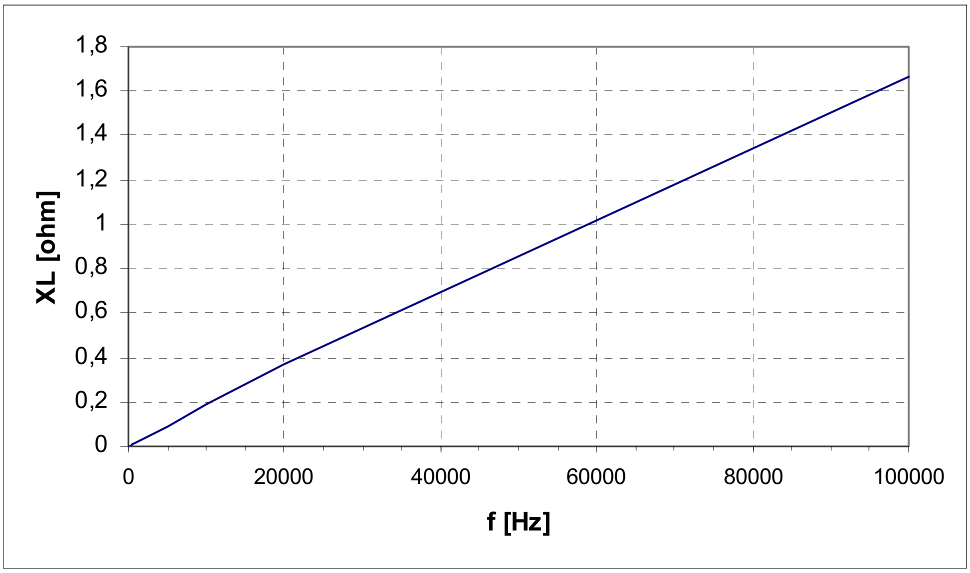


Inductance from the beginning to the end of the ground conductor



Inductive reactance from the beginning to the end of the ground conductor

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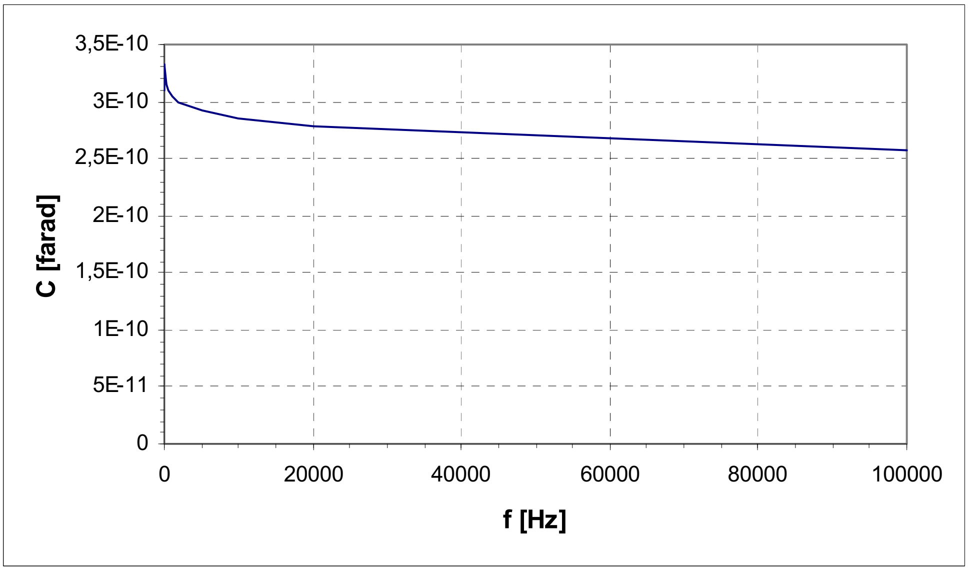

Capacitance between signal and ground conductors

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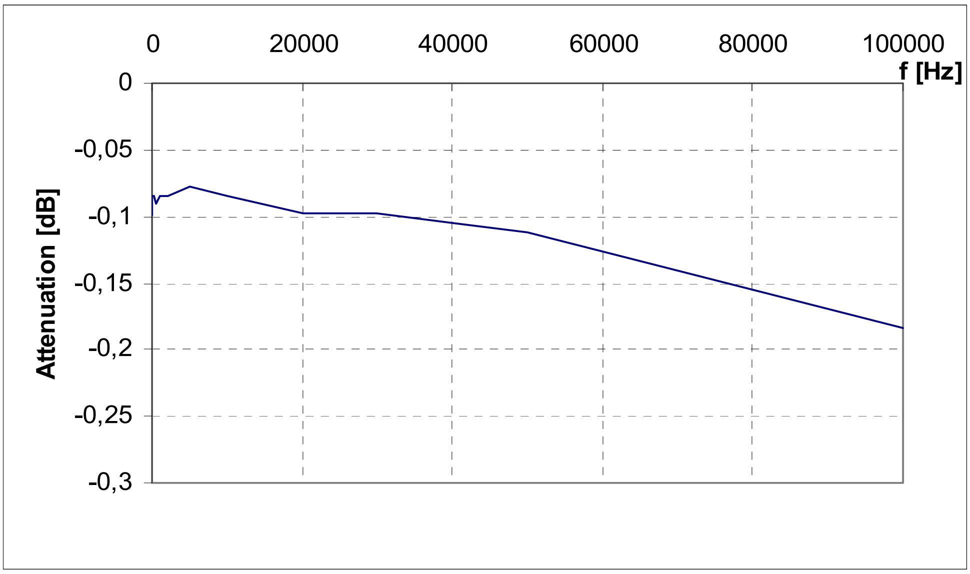
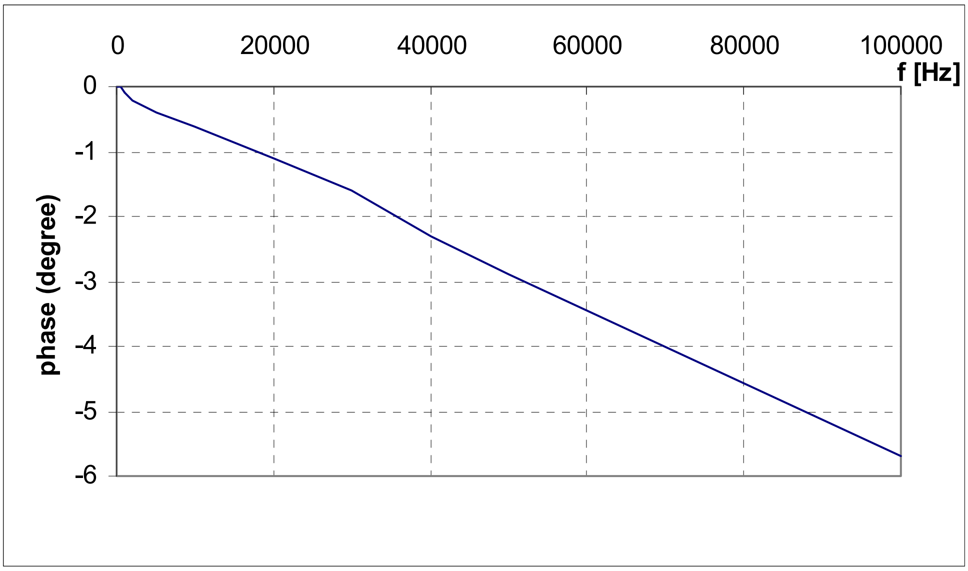
Cable under test	manufacturer	PROEL S.p.A.
	model	DIE-HARD **DH330LU5**
	length	5 m
	description	Passive speaker cable. Conductors: 11 mm overall diameter. High flexibility. Connectrors: Speakon 2 pole - Speakon 2 pole.





Frequency response: amplitude and phase characteristics measured from the conductor (+) and the conductor (1-), (f_t=2 MHz)

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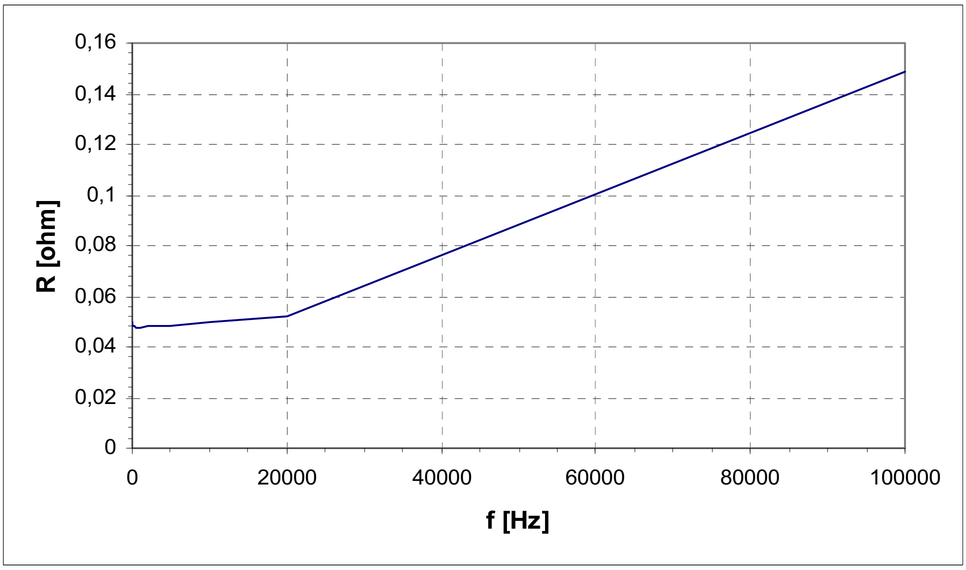
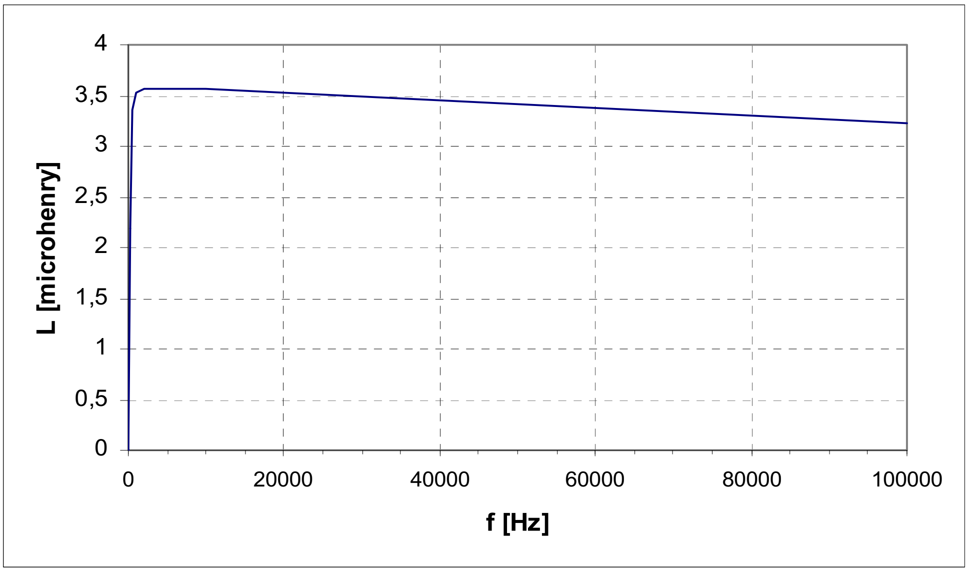


Resistance from the beginning to the end of the conductor (1+)



Inductance from the beginning to the end of the conductor (1+)

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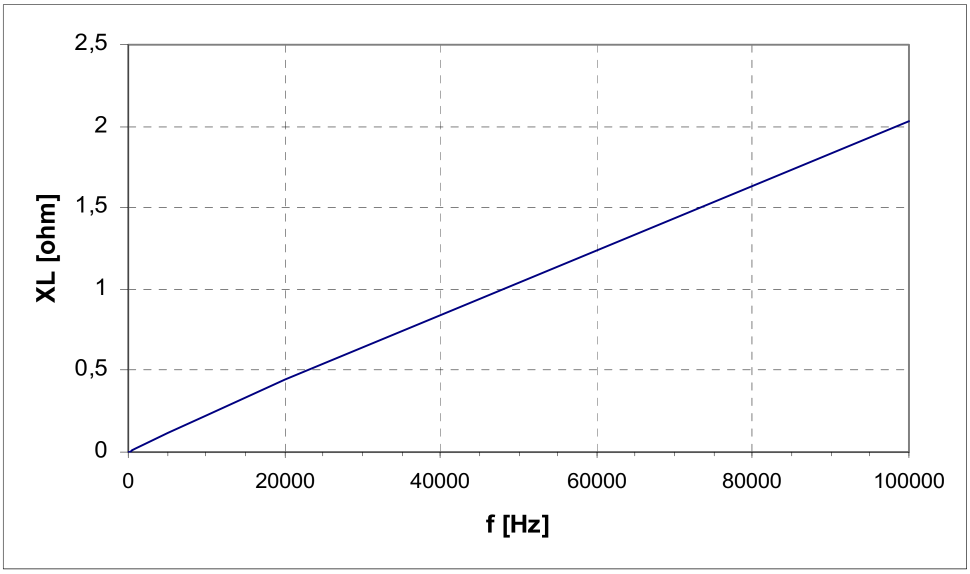
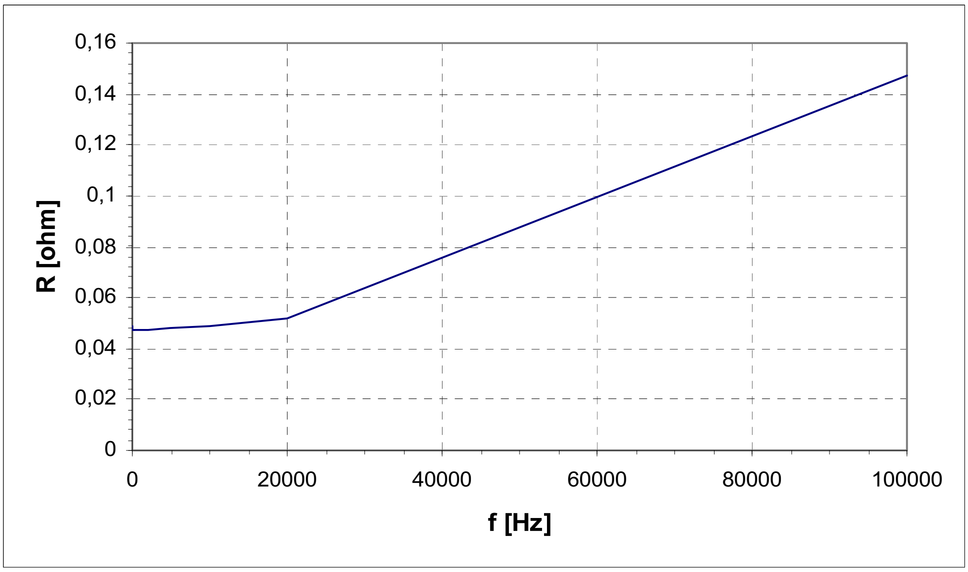


Inductive reactance from the beginning to the end of the conductor (1+)



Resistance from the beginning to the end of the conductor (1-)

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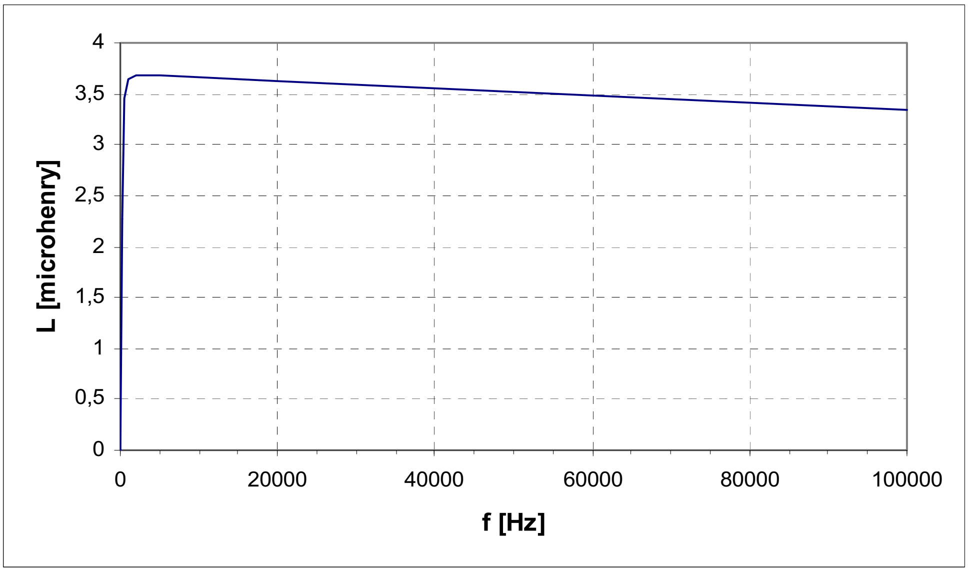
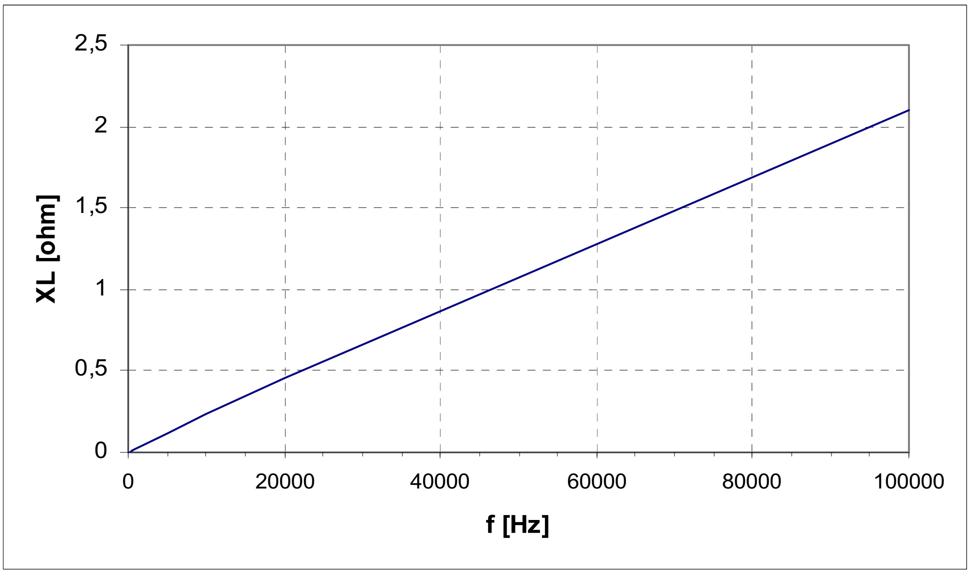


Inductance from the beginning to the end of the conductor (1-)



Inductive reactance from the beginning to the end of the conductor (1-)

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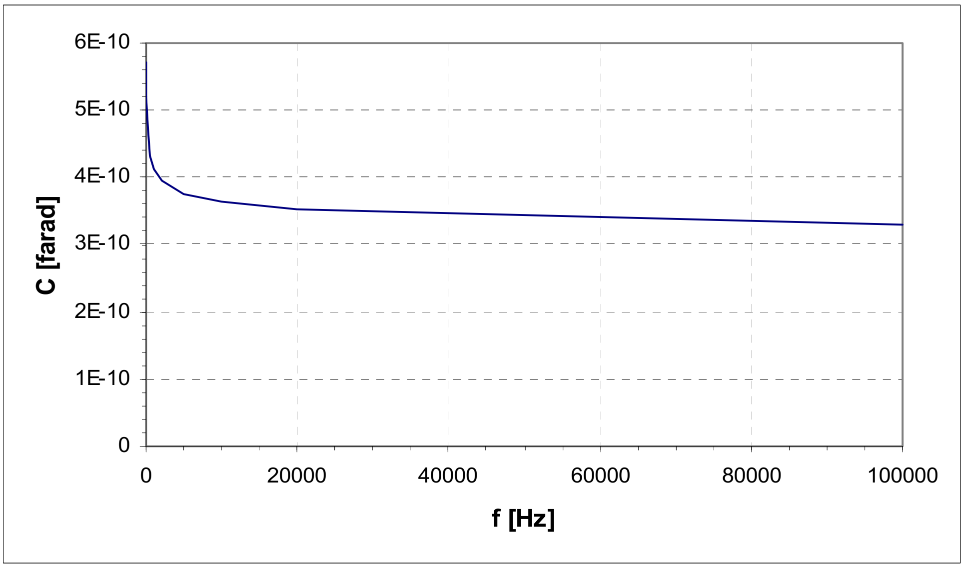

Capacitance between conductor (1+) and conductor (1-)

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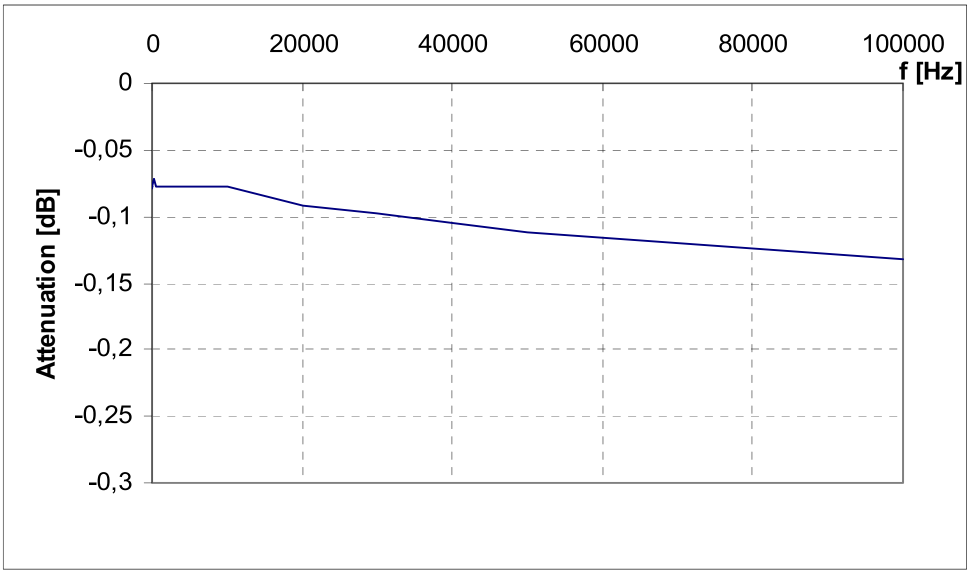
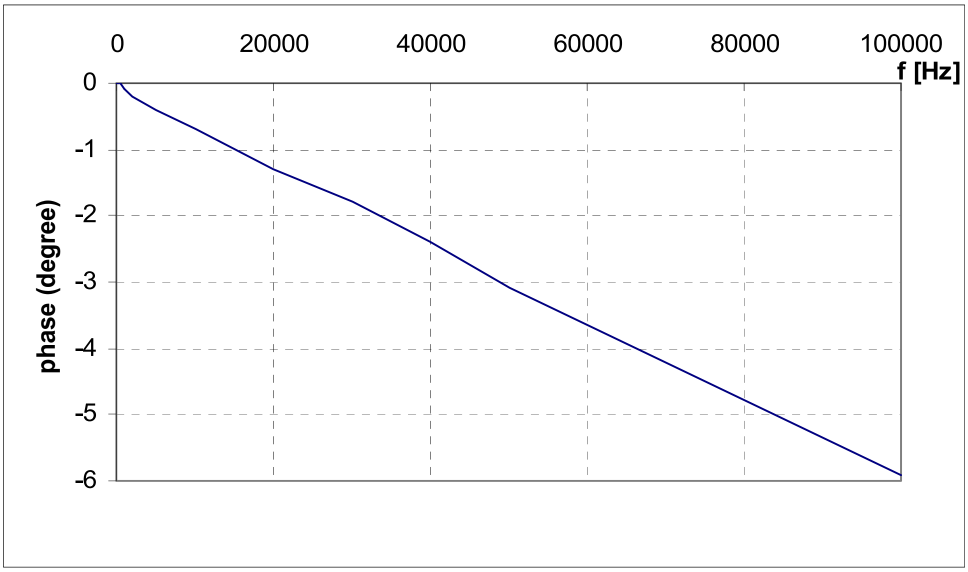
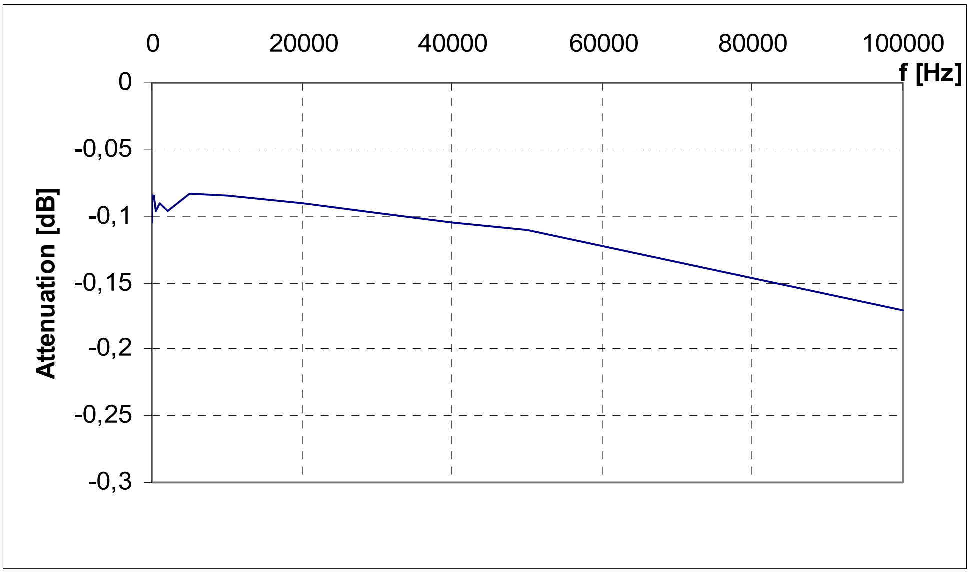
ph: (+39) 0862 434402 - fax (+39) 0862 434403 - email segdie@ing.univaq.it - Part. IVA n. 01021630668

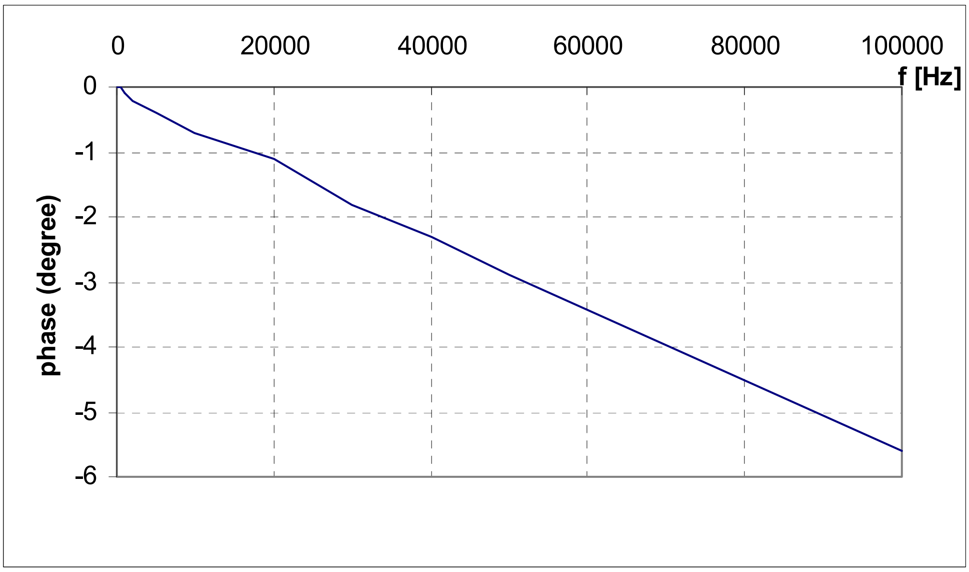
Cable under test	manufacturer	PROEL S.p.A.
	model	DIE-HARD **DH340LU5**
	length	5 m
	description	Passive speaker cable. Conductors: 12.5 mm overall diameter. High flexibility. Connectors: Speakon 4 pole - Speakon 4 pole.





Frequency response: amplitude and phase characteristics measured from the conductor (1+) and the conductor (1-), (f_t=2.1 MHz)





Frequency response: amplitude and phase characteristics measured from the conductor (2+) and the conductor (2-), (f_t=2 MHz)

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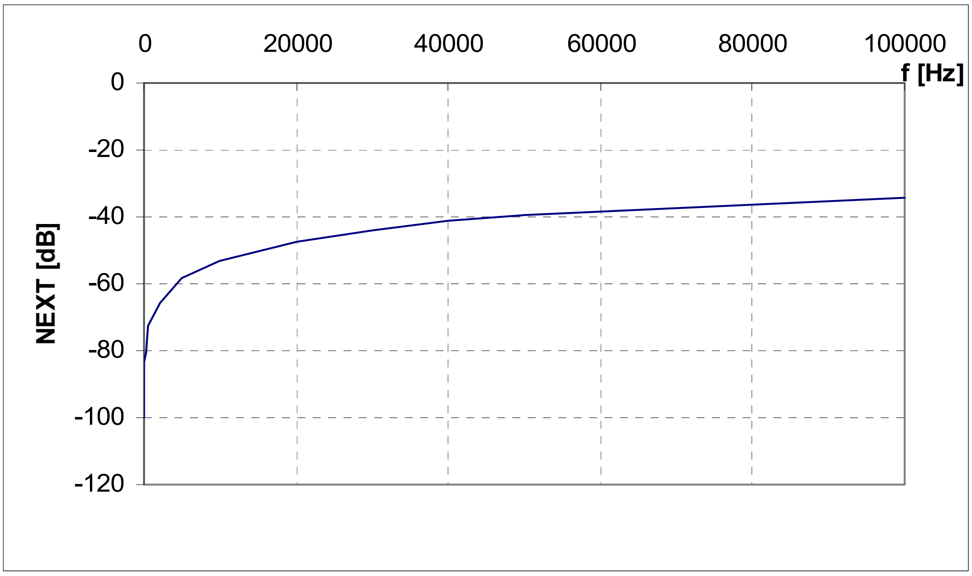
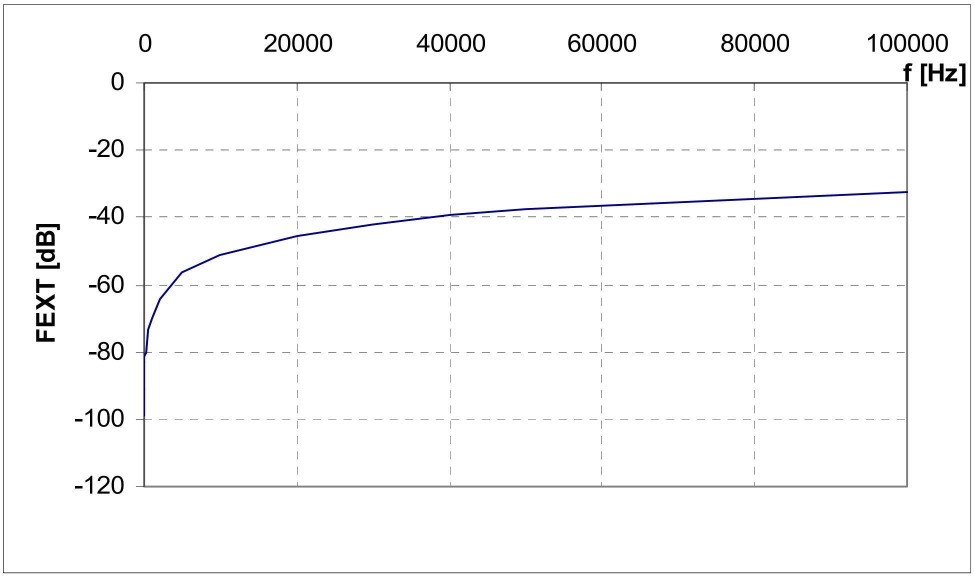


NEXT Crosstalk characteristic: stimulus circuit (1+) (1-), measure circuit (2+) (2-)



FEXT Crosstalk characteristic: stimulus circuit (1+) (1-), measure circuit (2+) (2-)

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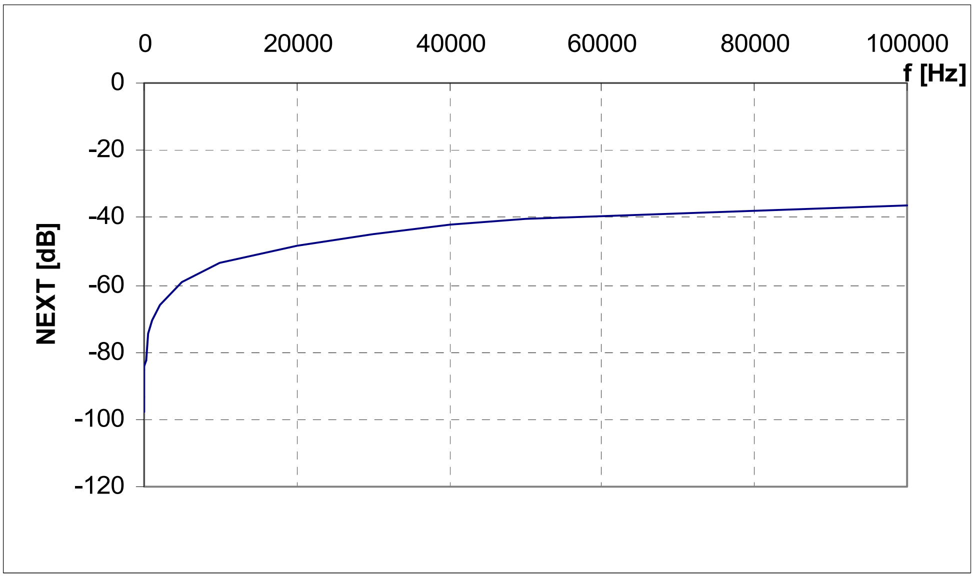
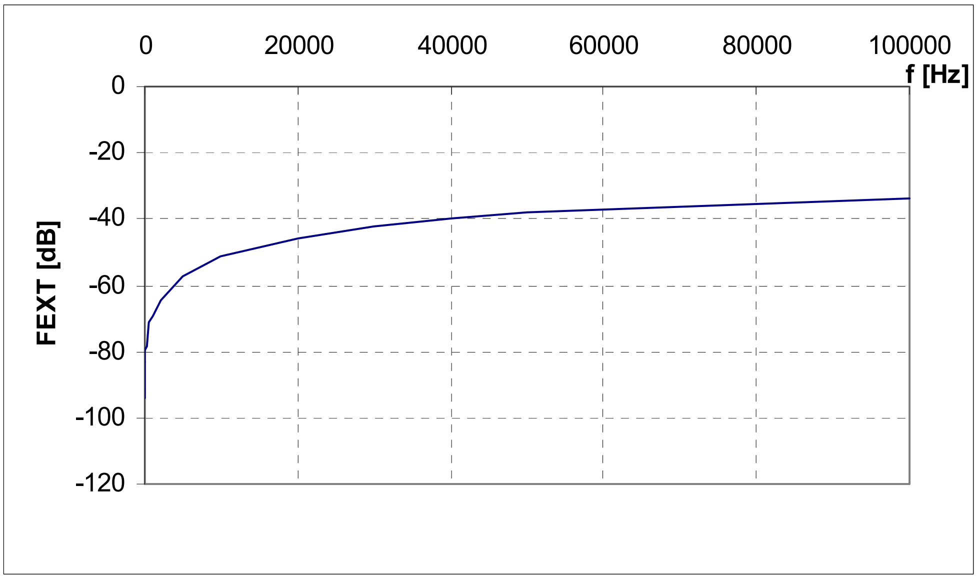


NEXT Crosstalk characteristic: stimulus circuit (2+) (2-), measure circuit (1+) (1-)



FEXT Crosstalk characteristic: stimulus circuit (2+) (2-), measure circuit (1+) (1-)

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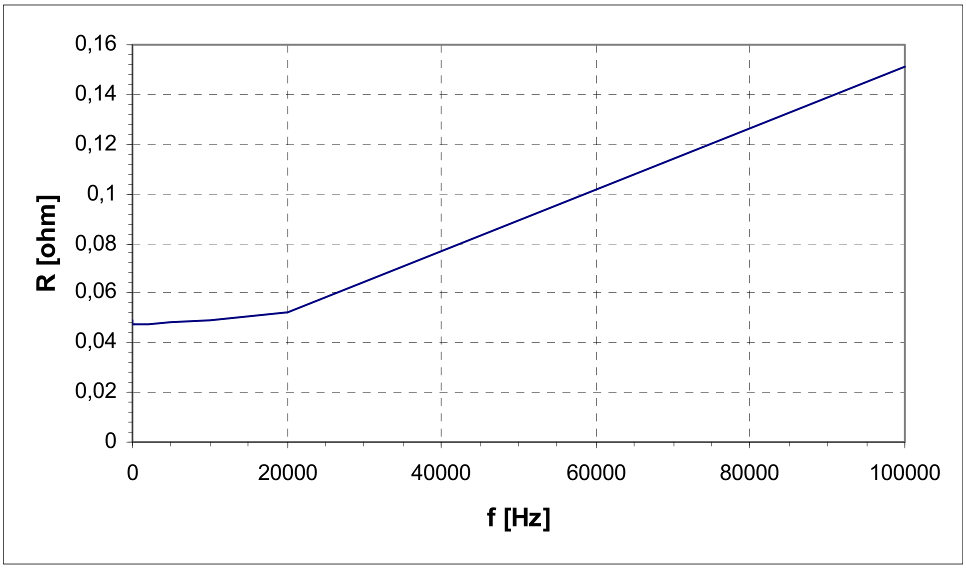
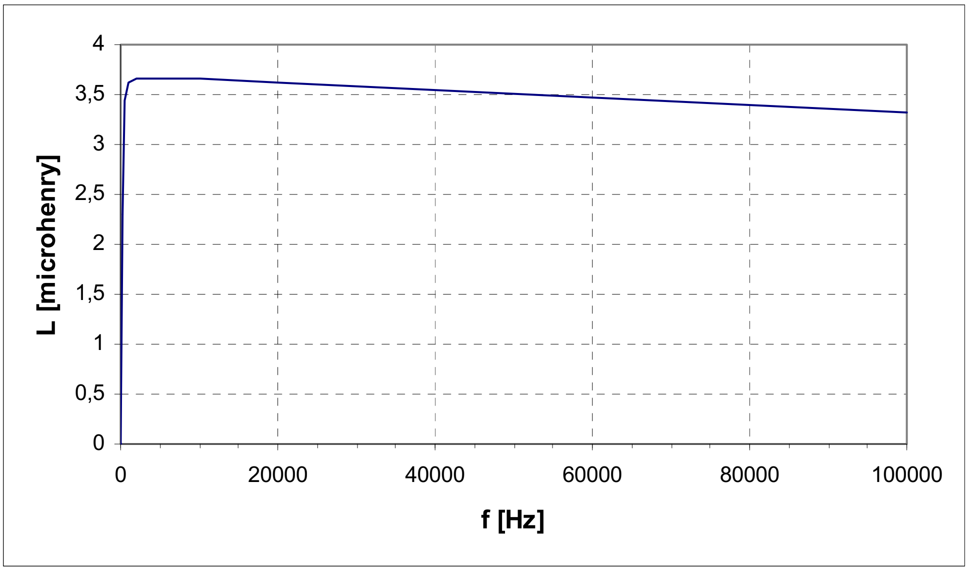


Resistance from the beginning to the end of the conductor (1+)



Inductance from the beginning to the end of the conductor (1+)

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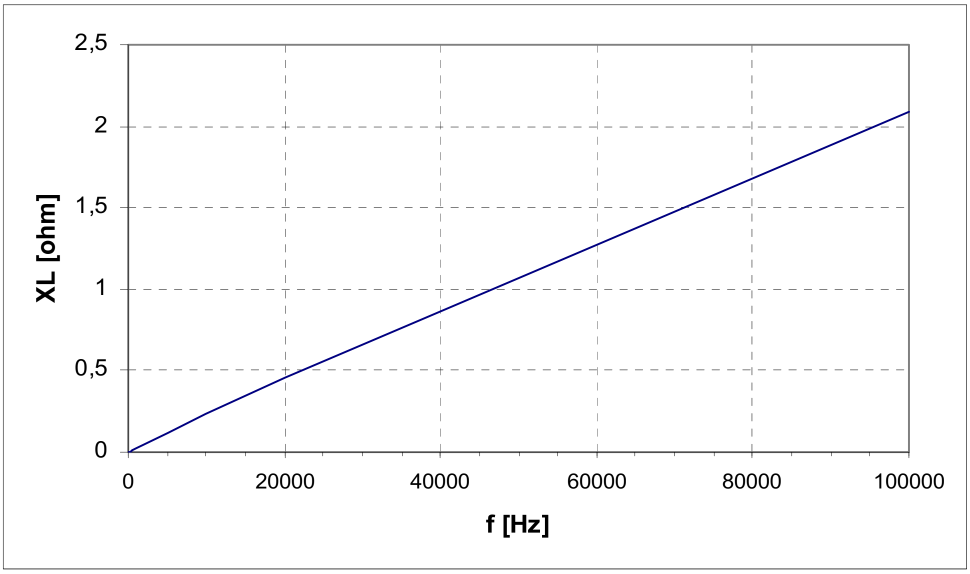
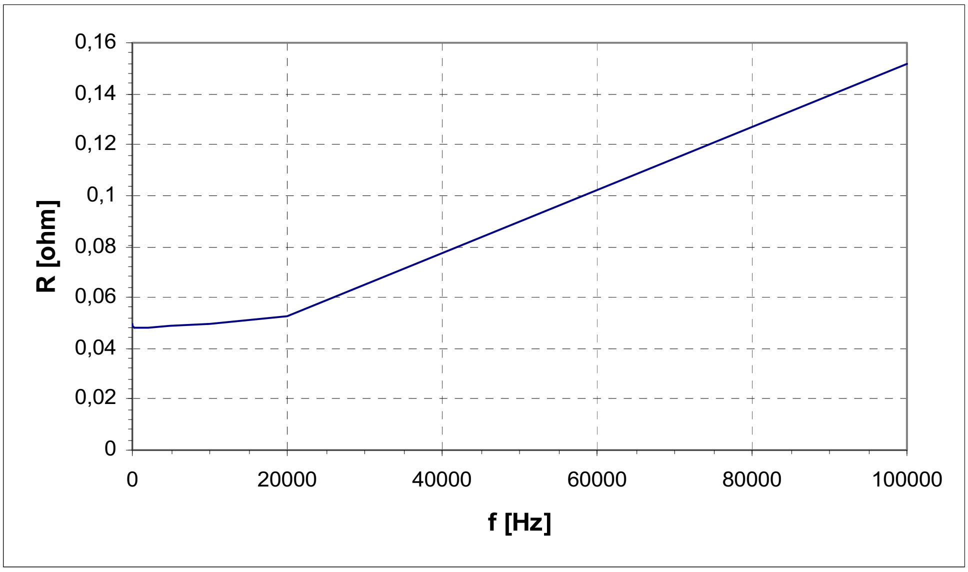


Inductive reactance from the beginning to the end of the conductor (1+)



Resistance from the beginning to the end of the conductor (1-)

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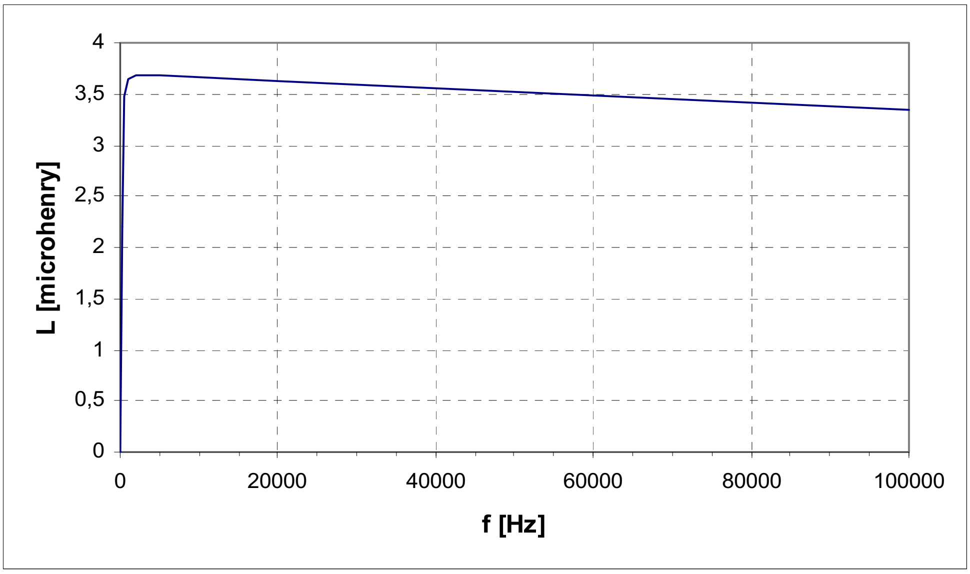
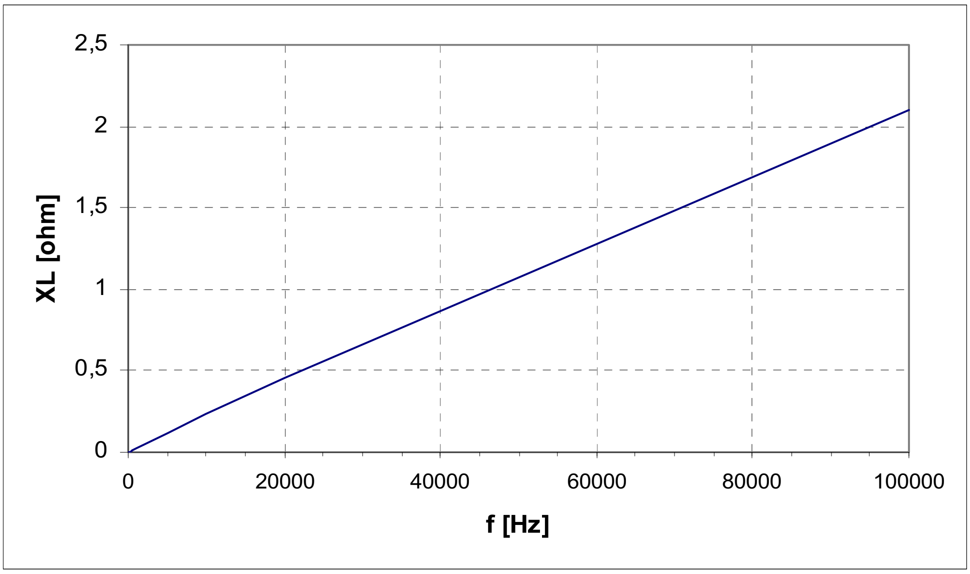


Inductance from the beginning to the end of the conductor (1-)



Inductive reactance from the beginning to the end of the conductor (1-)

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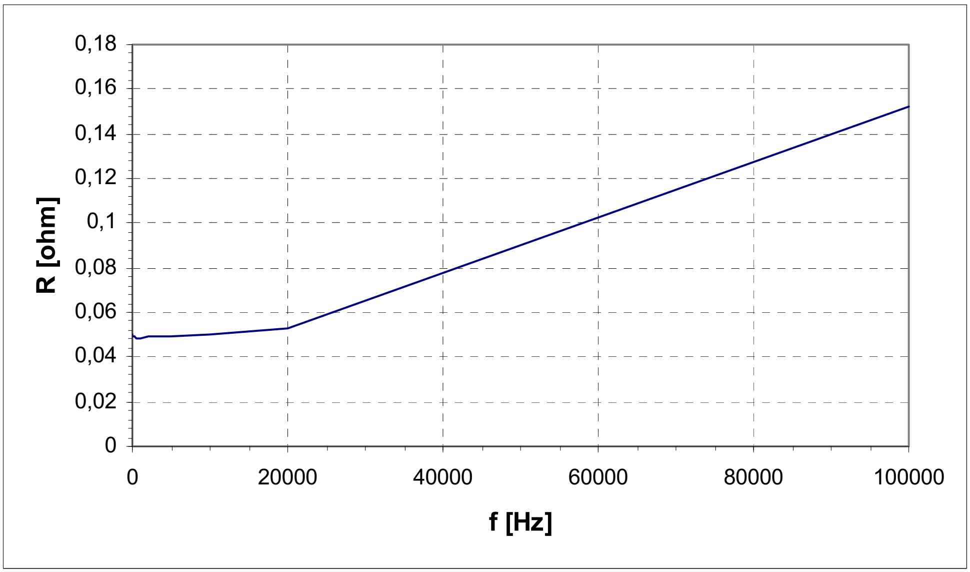
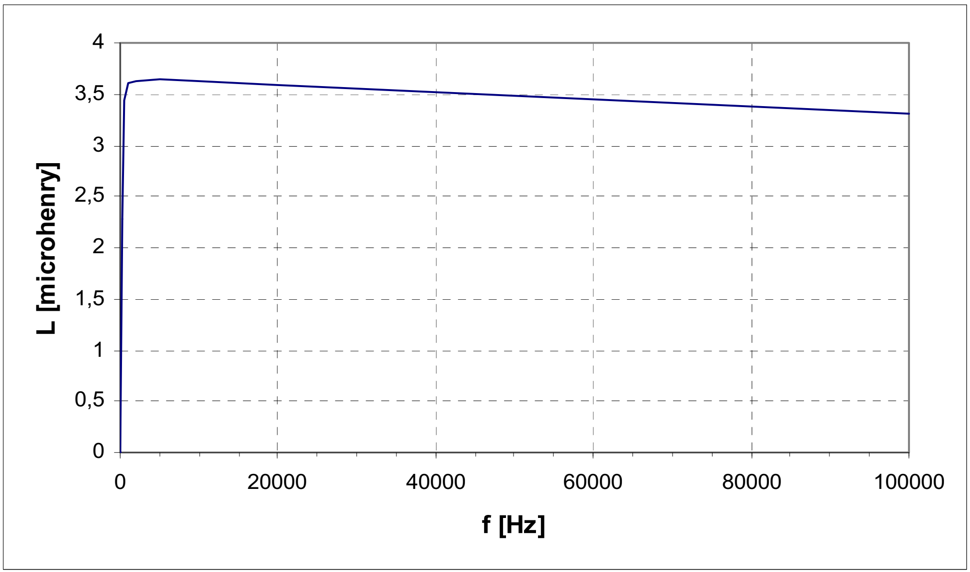


Resistance from the beginning to the end of the conductor (2+)



Inductance from the beginning to the end of the conductor (2+)

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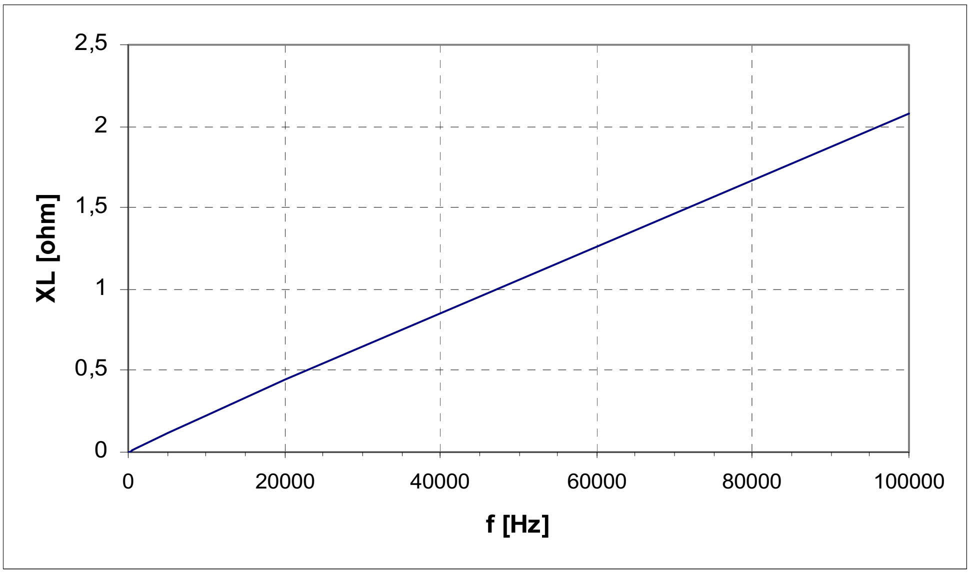
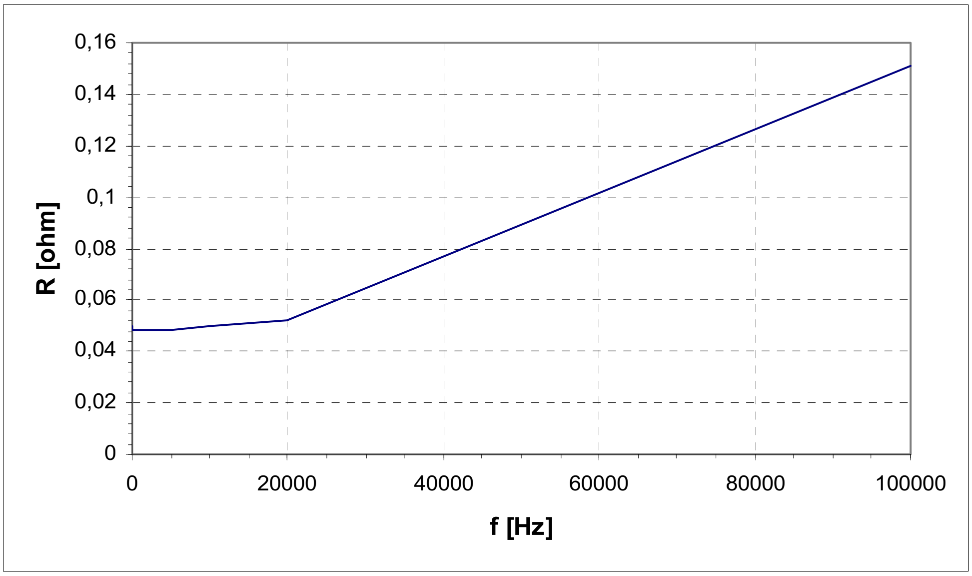


Inductive reactance from the beginning to the end of the conductor (2+)



Resistance from the beginning to the end of the conductor (2-)

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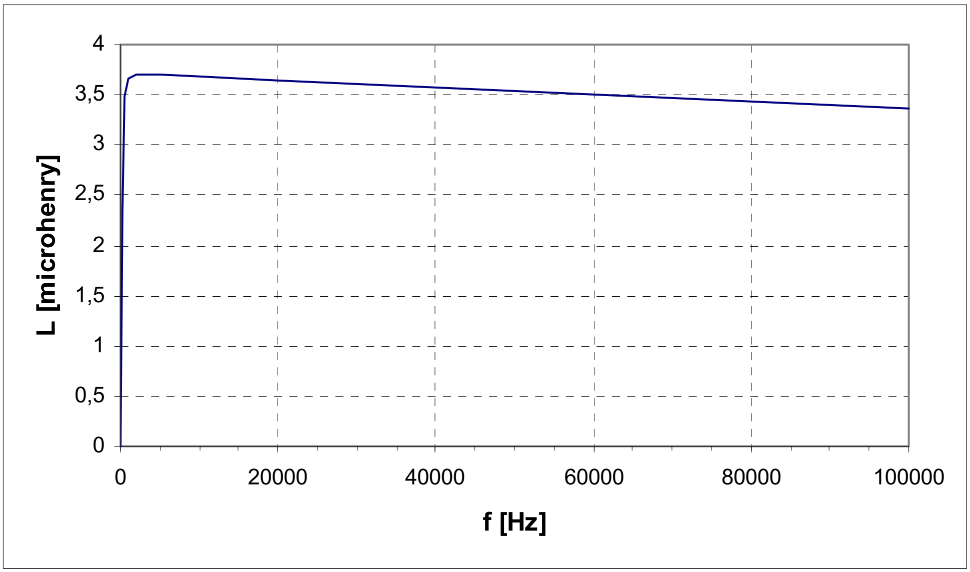
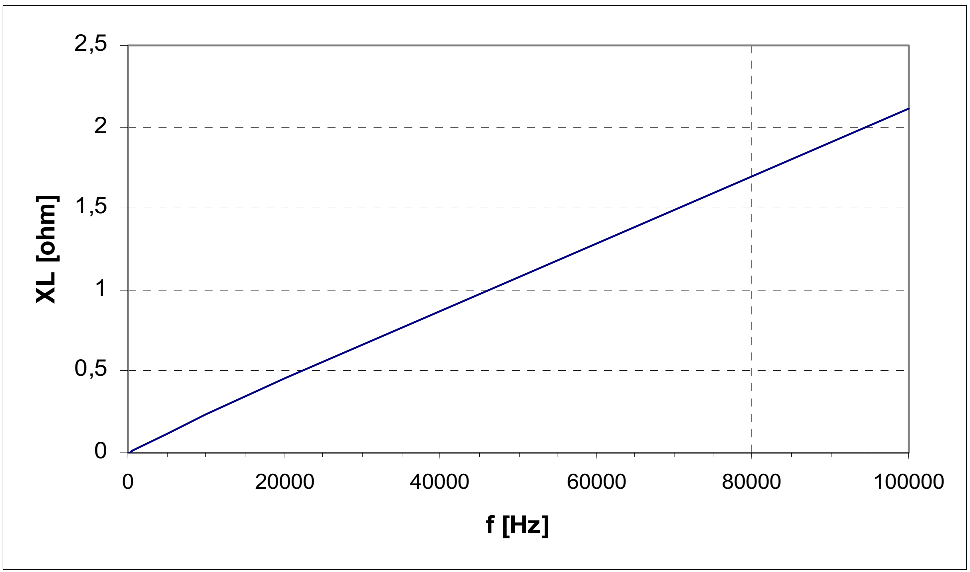


Inductance from the beginning to the end of the conductor (2-)



Inductive reactance from the beginning to the end of the conductor (2-)

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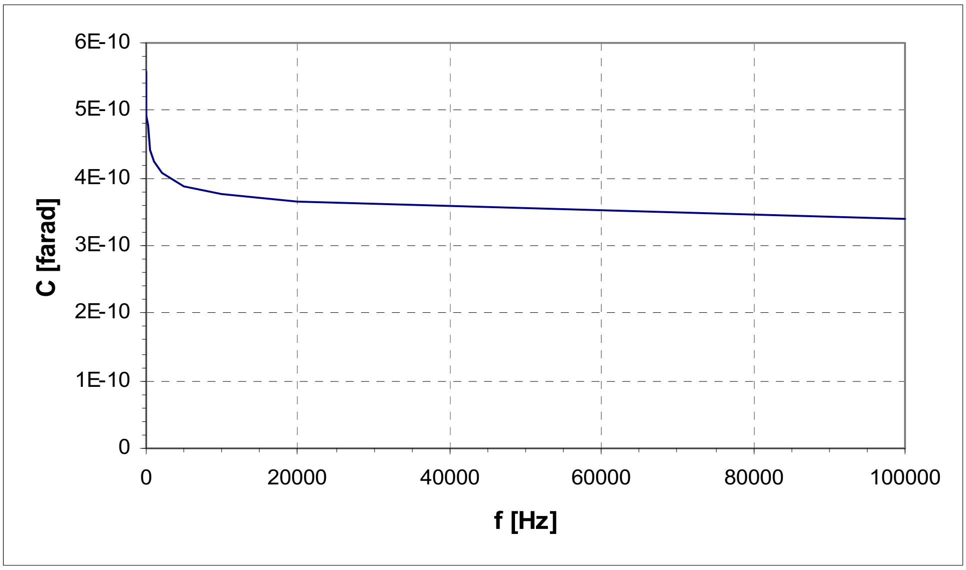
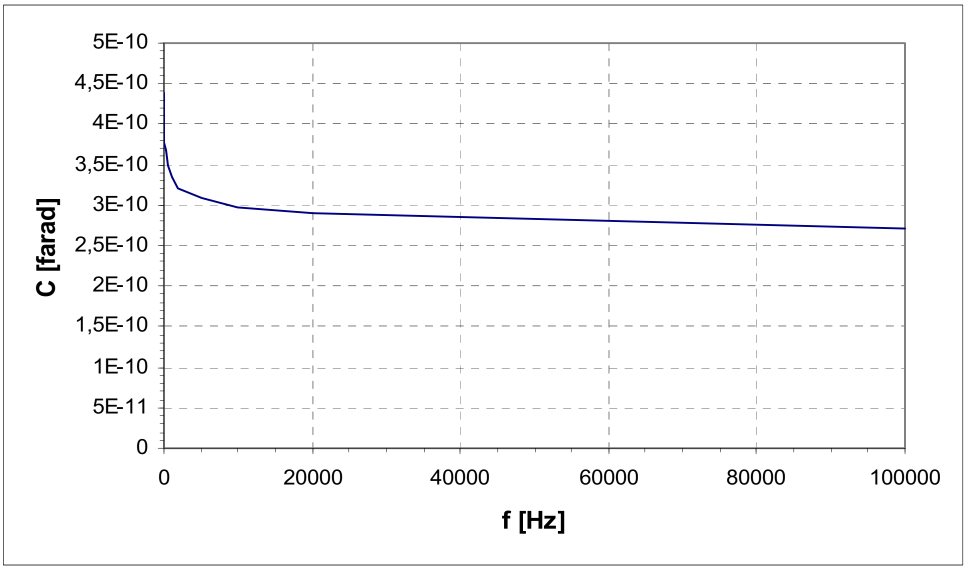


Capacitance between conductor (1+) and conductor (1-)



Capacitance between conductor (1+) and conductor (2+)

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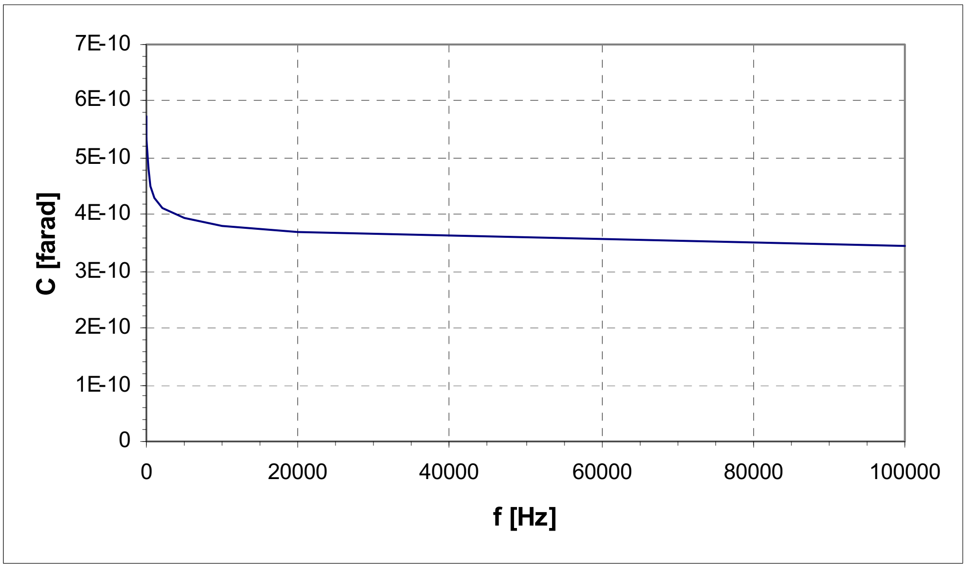
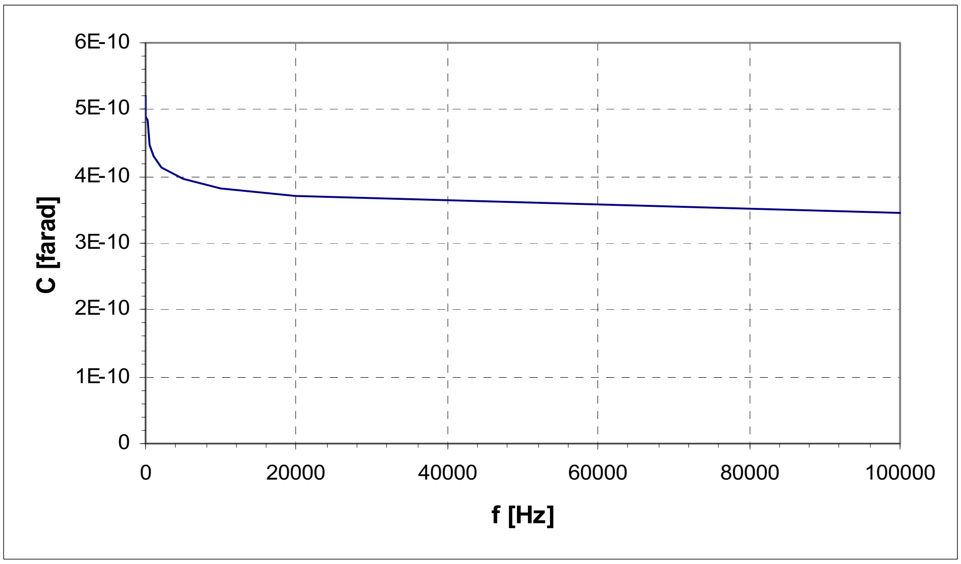


Capacitance between conductor (1+) and conductor (2-)



Capacitance between conductor (1-) and conductor (2+)

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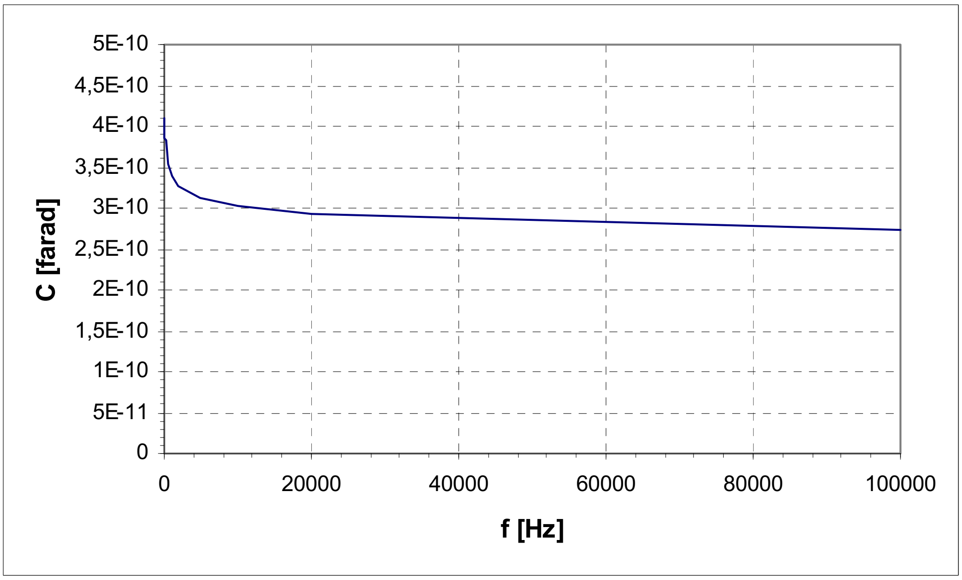
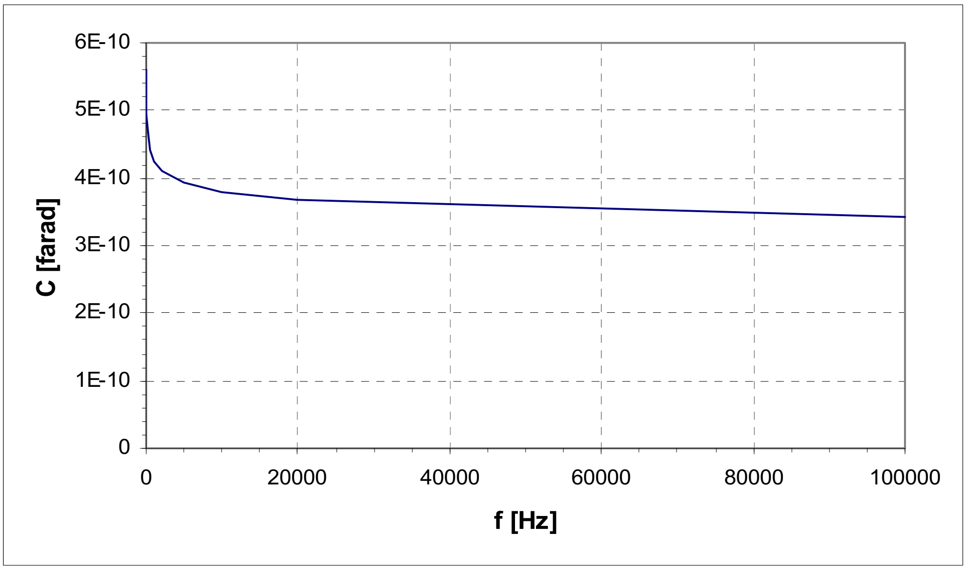


Capacitance between conductor (1-) and conductor (2-)



Capacitance between conductor (2+) and conductor (2-)

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SYNTHETIC ANALYSIS OF THE RESULTS

e been summarized in the two next tables, for an overall synthetic analysis. These tables show the *R* and *L* the *C* and f_t (for each couple of conductors). They also show the values of these parameters for unity of cable es of *R*, X_L and X_C measured at the maximum frequency of the audio band (20 kHz) with reference to each ne signal.

h reference to the standard *CEI EN 61938 "Audio, video and audiovisual systems. Interconnections and g values of analogues signals*" (1998.12). This standard defines some characteristics for the cables used to dio systems:

ductor resistance should be less than 1/100 Z_L;
luctive reactance at the maximum frequency of interest should not exceed 1/3 Z_L; this condition guarantees naximum working frequency;
veen audio systems
ductor resistance should be less than 1/10 Z_L;
nimum capacitive reactance for conductors carrying different audio signals should be greater than 1000 Z_L at terest; this ensure that the relative crosstalk level is approximately of -60 dB;
nimum capacitive reactance for conductors to screen should be greater than 3 Z_S (impedance of the signal ures less than 1 dB loss at the highest frequency of interest.

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audio systems

nductor	R Ω	R/l Ω/m	$R_{t,20kHz}$ Ω	L µH	L/l µH/m	$X_{L,20kHz}$ Ω	C F	C/l F/m	$X_{C,20kHz}$ Ω	f_t MHz	A_{20kHz} dB
+	0.53	0.11	0.58	4.5	0.90	0.82	3 µF	0.6 µF/m	-2.67E+4	2.3	-0.17
round	0.17	0.03		2.2	0.44						
+	0.30	0.15	0.26	2.4	1.2	0.43	1.8 pF	0.9 pF/m	-8.70E+6	3.0	-0.12
round	0.11	0.06		1.4	0.7						
-	0.28	0.14	0.27	2.4	1.2	0.45	1.4 pF	0.7 pF/m	-6.17E+6	3.0	-0.12
round	-	-		-	-						
+	-	-	-	-	-	-	2 pF	1 pF/m	-	3.0	-
-	-	-		-	-						
+	0.58	0.12	0.94	4.7	0.94	1.12	48.5 nF	9.7 nF/m	-1.65E+4	2.3	-0.17
round	0.57	0.11		4.4	0.88						
(GND)	0.16	0.03	0.63	3.0	0.60	-	47 nF	9.4 nF/m	-1.70E-4	2.5	-
2 (+)	0.63	0.13		4.8	0.96						
(GND)	-	-	0.61	-	-	-	49 nF	9.8 nF/m	-1.66E+4	2.7	-
3 (-)	0.62	0.12		4.9	0.98						
2 (+)	-		1.04	-		1.21	23 nF	4.6 nF/m	-2.67E+4	2.1	-0.17
3 (-)	-			-							

equency greater than 2 MHz, a value very greater than the bandwidth of audio signals.
m frequency is lower than that required by the standard (1 dB).
d connectors) is of 0.26 – 1.04 Ω; to have R<1/10 Z_L it is necessary to have Z_L>10 R=2.6-10.4 Ω.
$_{0kHz}$ > 1000 Z_L it is necessary that Z_L< $X_{C,20kHz}$ / 1000, for which Z_L<16.5 Ω for example for the cable

n capacitive reactance for conductor to screen at 20 kHz greater than 3 Z_S (impedance of the signal source),
33 1.66E+4=5478 Ω for example for the cable DH240LU5.

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	conductor	R Ω	R/l Ω/m	$R_{t,20kHz}$ Ω	L µH	L/l µH/m	$X_{L,20kHz}$ Ω	C F	C/l F/m	$X_{C,20kHz}$ Ω	f_t MHz	A_{20kHz} dB
n	+	0.17	0.03	0.12	3.4	0.68	0.77	30 nF	6.0 nF/m	-2.86E+4	2.0	-0.09
	ground	0.15	0.03		3.0	0.60						
n	1+	0.15	0.03	0.10	3.6	0.72	0.90	47 nF	9.4 nF/m	-2.25E+4	2.0	-0.10
	1-	0.15	0.03		3.6	0.72						
	1+	0.15	0.03	0.10	3.7	0.74	0.91	38 nF	7.6 nF/m	-2.18E+4	2.1	-0.09
	1-	0.15	0.03		3.7	0.74						
	2+	0.15	0.03	0.11	3.7	0.74	0.91	39 nF	7.8 nF/m	-2.16E+4	2.0	-0.09
	2-	0.15	0.03		3.7	0.74						
n	1+	-	-	-	-	-	-	33 nF	6.6 nF/m	-	-	-
	2+	-	-	-	-	-						
	1+	-	-	-	-	-	-	39 nF	7.8 nF/m	-	-	-
	2-	-	-	-	-	-						
	1-	-	-	-	-	-	-	39 nF	7.8 nF/m	-	-	-
	2+	-	-	-	-	-						
	1-	-	-	-	-	-	-	35 nF	7.0 nF/m	-	-	-
	2-	-	-	-	-	-						

equency greater than 2 MHz, a value very greater than the bandwidth of audio signals.
nd connectors) is of 0.15 – 0.17 Ω, with 0.03 Ω/m; to have R<1/100 Z_L it is necessary to have Z_L>100 R=15-

t parameter for this kind of cables, is always lower than 4 µH with around 0.7 µH/m. The condition
>3 $X_{L,20kHz}$ =2.3-2.7 Ω.
m frequency is lower than 1/10 of that required (1 dB).

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