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## Determining the acoustical characteristics of windscreens using the concept of “constant divergence of sound pressure level.”

Dr. Valentin Buzduga<sup>a</sup>  
Scantek Inc.  
7060 Oakland Mills Road, Suite L  
Columbia, MD 21046

### ABSTRACT

This paper deals with the insertion loss characterization of the microphone windscreens. The accuracy of this parameter is important especially for acoustical measurements in outdoor environments. The paper presents the insertion loss characteristics obtained for various windscreens by using the new method based on the “constant divergence of the sound pressure level” (CDP) and compares the results with those obtained by the method in the ANSI S1.17-2004. Discussed are insertion loss characteristics measured in free field conditions at different angles of sound incidence and for different positions of the windscreens on the measuring microphone. The paper also presents the phase shift introduced by windscreens, a parameter of interest for real time measurements. The conclusions point out the usefulness of the CDP method for accurate characterization of the windscreens.

### 1 INTRODUCTION

Windscreens on microphones are primarily intended for attenuating the wind effects in acoustical measurements but also used for protecting the microphones from dust, water, and mechanical damage. It is widely accepted that microphone windscreens should be characterized for their insertion loss (IL) and the efficiency in reducing the noise generated by wind. Following these goals, the Accredited Standards Committee S1 on Acoustics developed the ANSI S1.17-2004/Part 1 standard on measuring the windscreen IL in still or slightly moving air [1]. The importance of the windscreen characterization is pointed out in the IEC 61672-2 standard on sound level meters [2] which requires the nominal influence of a windscreen to be given in the instruction manual of the equipment. Obviously, the windscreens, intended to sound level meters of class 1, should be characterized to at least 16 kHz as required in [2]. Based on round-robin test results, standard [1] gives a guide for the uncertainty of the windscreen IL measured in reverberation rooms in the frequency domain up to 10 kHz, and shows that the uncertainty of the measurements in anechoic space has not been widely studied. Thus, the confidence interval of the IL measurements on large windscreens in reverberation rooms may vary from 0.3 dB to 0.8 dB in the individual lab tests, and from 0.8 dB to 4 dB for tests in group of laboratories. Preliminary results from round-robin tests on the windscreen IL measured in anechoic or semi-anechoic conditions in several laboratories are presented in [3]. Though the measurements were performed under controlled conditions, the diagrams given in [3] show important measurement uncertainties, up to a few dB, mostly at frequencies below 80 Hz.

This paper presents a promising solution for reducing the uncertainty of the results of IL measurements on windscreens. By using a test method based on the difference of the sound pressure level (SPL) at two locations in the field of the sound source, the IL measurements become more accurate, repeatable and immune to the environmental noise. The paper presents in brief the concept of the constant divergence of the sound pressure level (CDP), the specific

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<sup>a</sup> Email address: [buzdugav@yahoo.com](mailto:buzdugav@yahoo.com)

method for measuring the windscreen IL and experimental results obtained in anechoic or semi-anechoic space with this method on different windscreens. The uncertainty of the results obtained with the CDP test method is compared with the uncertainty of the results obtained when using the method recommended in [1]. A new parameter of interest is investigated with CDP method, the phase shift introduced by windscreens on the sound path from source to microphone.

This paper relies on the IL definition given in [1]: *the insertion loss of the windscreen is the arithmetic difference, in the same frequency band, of the time averaged sound pressure level with and without the windscreen on the microphone, under identical orientation and location and acoustical conditions as seen by the microphone.* The windscreen IL is calculated from the SPL measured without windscreen on microphone,  $L_{p, \text{bare}}$  and the SPL measured with windscreen on microphone,  $L_{p, \text{wscr}}$ , by using the equation:

$$IL = L_{p, \text{bare}} - L_{p, \text{wscr}} \quad [\text{dB}] \quad (1)$$

Thus, a windscreen which attenuates the sound is characterized by a positive IL value.

## 2 THE CONCEPT OF THE CONSTANT DIVERGENCE OF THE SOUND PRESSURE LEVEL

The concept of the constant divergence of the sound pressure level with respect to the power of the acoustical source was presented in [4] along with the CDP test methods for measuring acoustical parameters like the windscreen IL, the frequency response of microphones and the acoustical effect of the microphone grids.

In the acoustical field of any source, the difference of the SPL in dB at two locations, A1 and A2, does not depend on the power of the acoustical source. For example, a real loudspeaker can be modeled as a directional source. The SPL at the A1 and A2 locations in the field of the loudspeaker,  $L_{p1}$  respectively  $L_{p2}$ , can be expressed as follow [5], [6]:

$$L_{p1} = L_w + DI_{01} - 20 \log r_1 - 11, \quad L_{p2} = L_w + DI_{02} - 20 \log r_2 - 11, \quad (2)$$

where  $L_w$  is the sound power level of the directional source,  $r_1$  and  $r_2$  are distances and  $DI_{01}$ , and  $DI_{02}$  are directivity indexes corresponding to locations A1 and A2.

From (2) we get by subtraction:

$$L_{p2} - L_{p1} = DI_{02} - DI_{01} - 20 \log(r_2/r_1) = k_{12}, \quad (3)$$

where  $k_{12}$  is a constant at given positions of A1 and A2 in respect to the loudspeaker.

The constancy of the difference  $L_{p2} - L_{p1}$  with respect to the power level of the sound source can be easily checked for each type of acoustical source modeled in literature: point source, directional source, line source, finite plane source, etc. Equation (3) is used in test methods based on the constant divergence of the sound pressure level.

## 3 MEASURING THE WINDSCREEN INSERTION LOSS WITH CDP METHOD

### 3.1 The Test Arrangement

Figure 1 shows a test arrangement for measuring the windscreen IL with the CDP method. The measuring microphones are placed at the A1 and A2 locations in the acoustical field of the loudspeaker, and connected to the Ch1, respectively Ch2 channels of a real time analyzer (RTA). It is convenient, but not necessary, to arrange the two microphones symmetrically in respect to the main axis of the sound source, at the same distance from source. The distance between the measuring microphones can be between 15 cm and 20 cm, and the distance from microphones to the sound source about 70 cm. As recommended in [1], the SPL produced by loudspeaker should be at least 15 dB above the background noise level during the acoustical measurements. For measuring its IL, the windscreen will be placed successively on Mic1 and Mic2.

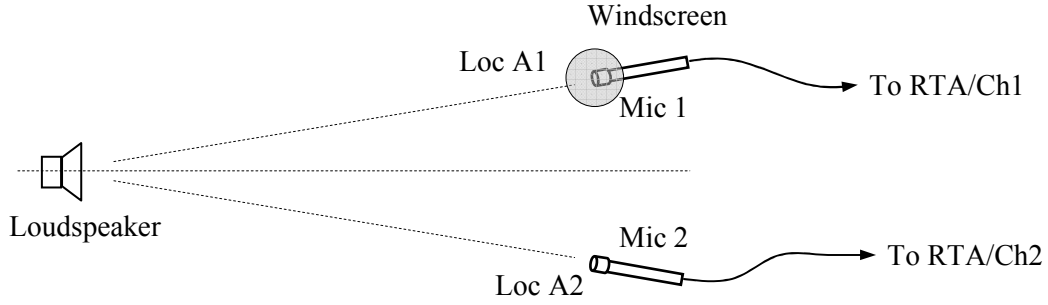


Figure 1: Test arrangement for windscreen IL measurements with CDP method

### 3.2 CDP Method for Measuring the Windscreen IL

The windscreen IL results from calculations with the data from two measurements.

In the first measurement step the windscreen is placed on Mic1. In this case, the two channels of the RTA will provide the following readings:

$$\text{Ch1} = L_{s1} + L_{mg1} + L_{p1, wscr} = L_{s1} + L_{mg1} + L_{p1, bare} - IL, \quad (4)$$

$$\text{Ch2} = L_{s2} + L_{mg2} + L_{p2, bare}, \quad (5)$$

where:

$L_{s1}$  and  $L_{s2}$  are the free field sensitivity levels of Mic1, and Mic2;

$L_{mg1}$  and  $L_{mg2}$  are the gains of the measuring channels.

$L_{p1, wscr} = L_{p1, bare} - IL$ , as results from equation (1).

From (4) and (5) we obtain by subtraction:

$$\Delta = \text{Ch2} - \text{Ch1} = (L_{s2} - L_{s1}) + (L_{mg2} - L_{mg1}) + L_{p2, bare} - L_{p1, bare} + IL \quad (6)$$

In the second step the windscreen is placed on Mic2. Similar calculations produce in this case the following expression of the channel difference,  $\Delta^*$ :

$$\Delta^* = \text{Ch2}^* - \text{Ch1}^* = (L_{s2} - L_{s1}) + (L_{mg2} - L_{mg1}) + L_{p2, bare}^* - L_{p1, bare}^* - IL \quad (7)$$

In (7) we assumed that the microphone sensitivities and the channel gains are the same in the two measurement steps, but the SPL at the diaphragms of the bare microphones may differ, for example, as a result of the fluctuations of the acoustical power level.

The channel reading differences  $\Delta$  and  $\Delta^*$  are recorded as SPL averaged values over the measurement time in the two steps. Taking into account equation (3), which shows that the difference  $L_{p2, bare} - L_{p1, bare}$  is constant in the two measuring steps, we subtract (7) from (6) and get the windscreen IL:

$$IL = (\Delta - \Delta^*)/2 \quad (8)$$

As shown in [4], the windscreen IL may also be calculated with alternative CDP methods. Figure 1 shows the test arrangement for measuring the windscreen IL at normal incidence of the sound on the microphone diaphragm. For measuring the windscreen IL at a different incidence angle, the two microphones should see the sound source at that angle.

## 4 MEASURING THE PHASE SHIFT INTRODUCED BY WINDSCREENS

The speed of the sound in the windscreen may differ from the speed of the sound in air and therefore it is expected to get a phase shift on the sound received by the microphone when using

windscreens. This parameter may be of interest for real time measurements and it can be evaluated by comparison. In the test arrangement shown in Figure 1, the outputs of the measuring microphones are monitored on the channels Ch1 and Ch2 of an oscilloscope.

The measurements are made at each (discrete) frequency with sinusoidal signals in two steps:

- In the first step is measured the phase shift  $\Delta\Phi$  between Ch2 and Ch1 when the windscreen is placed on Mic1;
- In the second step is measured the phase shift  $\Delta\Phi^*$  between Ch2 and Ch1 when the windscreen is placed on Mic2.

Equations similar to (4) ... (8), written for the phase of the signals, lead to the following expression of the phase shift introduced by the windscreen:

$$\Phi_{\text{wscr}} = (\Delta\Phi - \Delta\Phi^*)/2 \quad (9)$$

The phase shift measurements revealed delays of the sound through windscreens at each measuring frequency up to 20 kHz. These delays show lower speeds of the sound in the body of the windscreens than in air. In a first approximation, the speed of the sound in the body of a spherical windscreen enclosing the microphone at its center can be calculated with equation (10):

$$v_{\text{wscr}} = \frac{v_{\text{air}}}{1 + v_{\text{air}} \cdot \Phi_{\text{wscr}} / (\pi \cdot f \cdot D)}, \quad (10)$$

where:

- $v_{\text{air}}$  = the speed of the sound in air, in m/s;
- $\Phi_{\text{wscr}}$  = the phase delay introduced by windscreen at the frequency  $f$ , positive value in radians;
- $f$  = the test frequency, in Hz;
- $D$  = the diameter of the windscreen, in meters.

## 5 EXPERIMENTAL RESULTS

The measurements with CDP methods on windscreens were performed with a real time analyzer (Norsonic N-840), with the microphones placed in controlled conditions (an anechoic box). Some of the measurements were repeated in a standard anechoic room. The diagrams and table below show the following aspects from measurements:

- The influence of the windscreen position on the windscreen IL;
- The confidence interval at repeated measurements in the anechoic box;
- The comparison of results for IL measurements in anechoic box and standard anechoic room;
- The windscreen IL at different incidence angles of the sound on the microphone;
- The influence of a plastic wrap on the windscreen IL;
- The phase shift on the measured sound due to the windscreen.

### 5.1 The Influence of the Windscreen Position on the Windscreen IL

The IL of a windscreen depends on the position of the measuring microphone in the windscreen. Figure 2 presents the IL of a windscreen of 6 cm diameter at normal incidence of the sound on the microphone diaphragm, at three positions of the microphone in windscreen:

Curve 1 - the microphone is introduced 3 cm in the windscreen (completely introduced);

Curve 2 - the microphone is introduced 1.5 cm in the windscreen;

Curve 3 - the microphone is introduced 3 mm in the windscreen.

The IL of this windscreen may change at 20 kHz from 1.2 dB in the standard position to about 4.5 dB at improper arrangement on the measuring microphone.

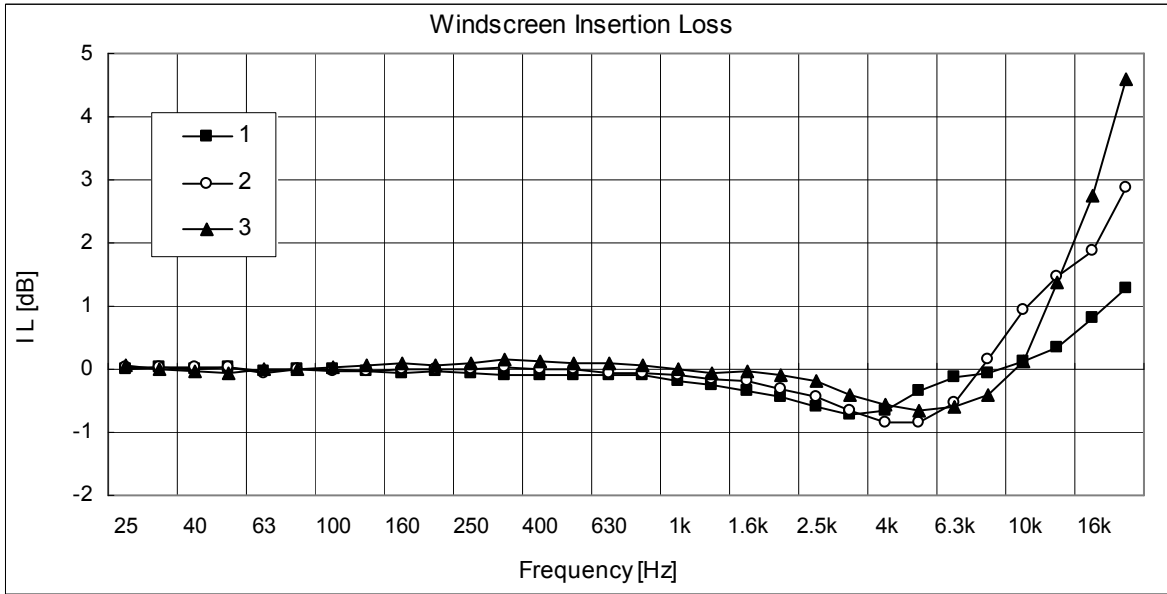


Figure 2: IL diagrams at different positions of the microphone in windscreen

### 5.2 The Confidence Interval at Repeated Measurements in the Anechoic Box

The IL of the windscreen characterized in Figure 2 was repeatedly measured at normal incidence of the sound on the microphone diaphragm and regular position of the windscreen on the microphone. The measurements were performed in the anechoic box at intervals of about one month. Figure 3 presents the confidence interval margins for 8 sets of measurements with the CDP method in the frequency domain 25 Hz to 20 kHz. For comparison, Figure 3 also presents the confidence interval margins for the IL measurements performed on the same windscreen in the same anechoic box with the method recommended in [1] for the tests in free field conditions.

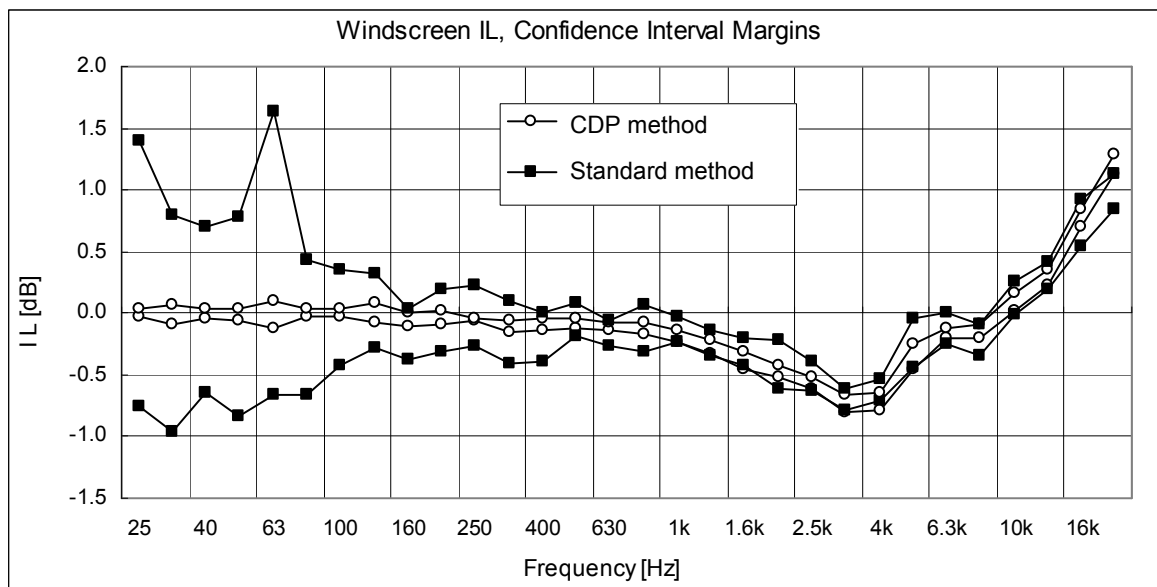


Figure 3: The confidence interval margins at repeated measurements in the anechoic box

### 5.3 Compared Results for IL Measurements in Anechoic Box and Standard Anechoic Room

The windscreen discussed above was measured with the CDP method (5 measurement sets) in the standard anechoic room of an acoustical research center. The confidence interval for the results of the CDP measurements in the standard anechoic room was within the limits shown in Figure 3 for the CDP tests in the anechoic box. Table 1 presents the deviation between the IL (average values) measured with CDP method in the acoustical box and in the standard anechoic room in the frequency domain 25 Hz to 20 kHz.

Table 1: The windscreen IL deviation for measurements in anechoic box and standard anechoic room.

f [Hz]	25	31.5	40	50	63	80	100	125	160	200
IL deviation [dB]	0.03	0.02	-0.01	0.00	-0.11	0.02	-0.03	-0.04	0.03	-0.01
f [Hz]	250	315	400	500	630	800	1 k	1.25 k	1.6 k	2 k
IL deviation [dB]	0.02	0.04	0.02	0.01	0.01	0.00	0.02	0.03	0.05	0.05
f [Hz]	2.5 k	3.15 k	4 k	5 k	6.3 k	8 k	10 k	12.5 k	16 k	20 k
IL deviation [dB]	-0.01	0.00	0.08	0.03	0.03	0.04	0.04	-0.02	0.00	-0.01

The low differences between the IL values measured in two different laboratories give hope for good repeatability of these measurements in a group of laboratories.

### 5.4 The Windscreen IL at Different Incidence Angles of the Sound

The IL of the windscreen of 6 cm diameter was measured at different incidence angles of the sound on the diaphragm of the measuring microphone. Figure 4 shows certain variation of the IL, depending upon the incidence angle. The asymmetries or the non-homogeneity of the windscreen body may lead to important IL variations with the incidence angle of the sound.

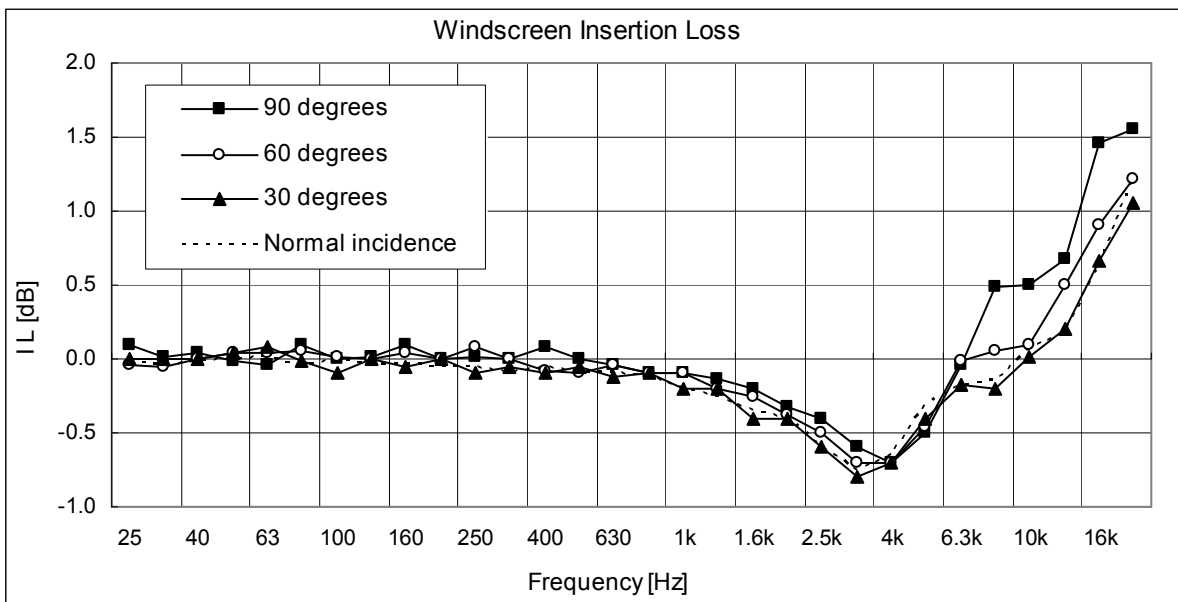


Figure 4: Windscreen IL at different incidence angles of the sound on the microphone diaphragm

### 5.5 The Influence of a Plastic Wrap on the Windscreen IL

An acoustical operator may be tempted to “protect” the windscreen against rain with a plastic foil. This solution may introduce additional IL up to 10 dB in the test arrangement. For the windscreen discussed above, a plastic wrap increases the IL from 1.3 dB to about 12 dB at 20 kHz. Figure 5 presents the IL of a windscreen formed of a spherical foam which surrounds a cylindrical one, between the two foam pieces being mounted a plastic wrap. The measurements reveal important IL values, with non-repetitive results.

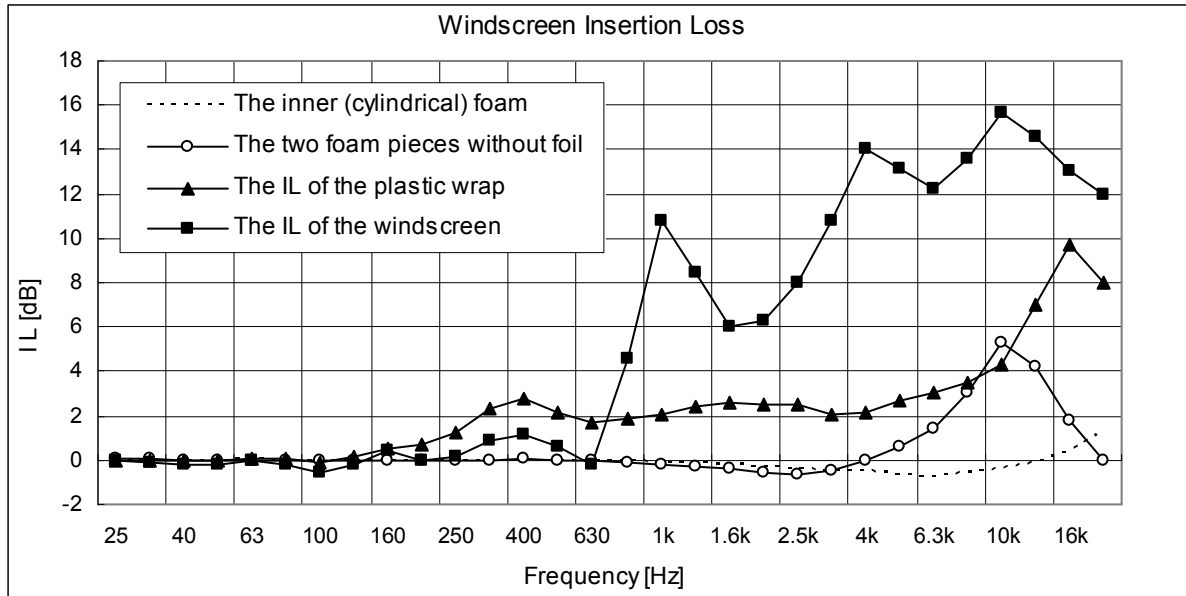


Figure 5: The IL of a two-section windscreen with plastic wrap

### 5.6 The Phase Shift on the Measured Sound due to Windscreens

Figure 6 presents the phase shift introduced by two windscreens made out of the same material (small cells, dense foam). For frequencies above 2 kHz, the phase delays correspond to the ratio of the windscreen diameters. Calculations based on equation (10) give the approximate value of 311 m/s for the speed of the sound in the material of these windscreens.

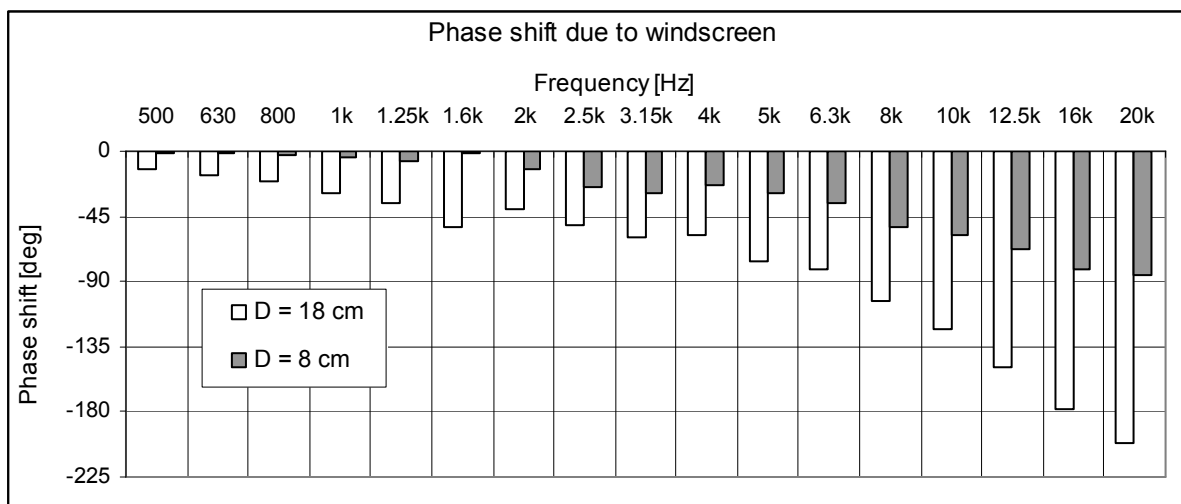


Figure 6: The phase shift on the measured sound due to windscreens

## 6 CONCLUSIONS

The CDP methods and the experimental results presented in this paper allow pointing out the following conclusions:

- The microphone windscreens characterization is still a challenging problem.
- The accurate modeling of the windscreen effects requires research on sound propagation in the body of the windscreen.
- The IL of a given windscreen depends on its position on the microphone.
- In the absence of accurate windscreen IL measurements or with wrong positioning of windscreen on the measuring microphone, a windscreen may easily change the class of a sound level meter from class 1 to class 2.
- The test methods based on the constant divergence of the sound pressure level in the field of the sound source provide accurate, repeatable results in acoustical measurements.

## 7 ACKNOWLEDGEMENT

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## 8 REFERENCES

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