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SERIES P: TELEPHONE TRANSMISSION QUALITY,  
TELEPHONE INSTALLATIONS, LOCAL LINE  
NETWORKS

Communications involving vehicles

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### In-car communication audio specification

Recommendation ITU-T P.1150

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*For further details, please refer to the list of ITU-T Recommendations.*

# Recommendation ITU-T P.1150

## In-car communication audio specification

### Summary

Recommendation ITU-T P.1150 describes communication requirements for an in-car communication (ICC) system that utilizes integrated microphones and speakers in the motor vehicle cabin to amplify conversation and which is aimed at providing an improved communication between all occupants in a motor vehicle.

This Recommendation sets base levels of function and quality to ensure that the ICC operates to a quality such that the motor vehicle driver does not feel it necessary to turn their head to amplify their voice when talking to other passengers. This can, for example, aid in preventing driver distraction.

To meet these requirements, the use of audio zones within a motor vehicle cabin for speech communications between audio zones, and tests to ensure good speech intelligibility and quality between those zones are defined. This Recommendation covers requirements and test methods for:

- 1) system stability;
- 2) speech intelligibility;
- 3) speech quality;
- 4) talker localization accuracy.

The use of wearable headphones (audiophones) by the driver or passengers is outside the scope of this Recommendation.

### History

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### Keywords

Communication, hands-free, motor vehicle, QoS, quality of service.

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Electronic attachment: Concatenated test signals.

# Recommendation ITU-T P.1150

## In-car communication audio specification

### 1 Scope

This Recommendation<sup>1</sup> describes communication requirements for an in-car communication (ICC) system that utilizes integrated microphones and speakers in the motor vehicle cabin to amplify conversation and which is aimed at providing an improved communication between all occupants in a motor vehicle.

This Recommendation sets base levels of function and quality to ensure that the ICC operates to a quality such that the motor vehicle driver does not feel it necessary to turn their head to amplify their voice when talking to other passengers. This can, for example, aid in preventing driver distraction.

To meet these requirements, the use of audio zones within a motor vehicle cabin for speech communications between audio zones, and tests to ensure good speech intelligibility and quality between those zones are defined. This Recommendation covers requirements and test methods for:

- 1) system stability;
- 2) speech intelligibility;
- 3) speech quality;
- 4) talker localization accuracy.

The use of wearable headphones (audiophones) by driver or passengers is outside the scope of this Recommendation.

### 2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

|               |                                                                                                                                |
|---------------|--------------------------------------------------------------------------------------------------------------------------------|
| [ITU-T G.160] | Recommendation ITU-T G.160 (2012), <i>Voice enhancement devices</i> .                                                          |
| [ITU-T P.10]  | Recommendation ITU-T P.10 (2017), <i>Vocabulary for performance, quality of service and quality of experience</i> .            |
| [ITU-T P.56]  | Recommendation ITU-T P.56 (2011), <i>Objective measurement of active speech level</i> .                                        |
| [ITU-T P.57]  | Recommendation ITU-T P.57 (2011), <i>Artificial ears</i> .                                                                     |
| [ITU-T P.58]  | Recommendation ITU-T P.58 (2013), <i>Head and torso simulator for telephonometry</i> .                                         |
| [ITU-T P.340] | Recommendation ITU-T P.340 (2000), <i>Transmission characteristics and speech quality parameters of hands-free terminals</i> . |

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<sup>1</sup> This Recommendation includes an electronic attachment containing the concatenated test signals specified in clause 8.4.2.

|                   |                                                                                                                                                                                       |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [ITU-T P.501]     | Recommendation ITU-T P.501 (2017), <i>Test signals for use in telephonometry.</i>                                                                                                     |
| [ITU-T P.581]     | Recommendation ITU-T P.581 (2014), <i>Use of head and torso simulator for hands-free and handset terminal testing.</i>                                                                |
| [ITU-T P.1100]    | Recommendation ITU-T P.1100 (2019), <i>Narrowband hands-free communication in motor vehicles.</i>                                                                                     |
| [ITU-T P.1110]    | Recommendation ITU-T P.1110 (2019), <i>Wideband hands-free communication in motor vehicles.</i>                                                                                       |
| [ETSI TS 103 224] | ETSI TS 103 224 V1.3.1 (2017), <i>Speech and multimedia Transmission Quality (STQ); A sound field reproduction method for terminal testing including a background noise database.</i> |
| [ETSI TS 103 558] | ETSI TS 103 558 V.1.1.1 (2019), <i>Speech and multimedia Transmission Quality (STQ); Methods for objective assessment of listening effort.</i>                                        |
| [IEC 61260-1]     | IEC 61260-1:2014, <i>Electroacoustics – Octave-band and fractional-octave-band filters – Part 1: Specifications.</i>                                                                  |
| [IEC 61672-1]     | IEC 61672-1:2013, <i>Electroacoustics – Sound Level Meters– Part 1: Specifications.</i>                                                                                               |

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

**3.1.1 fullband signal:** [ITU-T P.10].

**3.1.2 motor vehicle:** [ITU-T P.1100].

**3.1.3 narrowband signal:** [ITU-T P.10].

**3.1.4 super-wideband signal:** [ITU-T P.10].

**3.1.5 wideband signal:** [ITU-T P.10].

#### 3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

**3.2.1 direct voice delay:** The time between the transmission of voice from the talker's mouth and reception by the listener's ear, where talker and listener are physically close enough to converse.

**3.2.2 reinforcement:** An increase in speech level, normally done in the presence of noise.

**3.2.3 reinforced noise:** Vehicle interior noise processed through an active in-car communication (ICC) system.

**3.2.4 reinforced speech:** Speech signal originated from talker zone processed through an active in-car communication (ICC) system.

**3.2.5 reinforcement voice delay:** The time between the transmission of voice from the talker's mouth through the motor vehicle sound system and received by the listener's ear in the motor vehicle cabin.

**3.2.6 speech in receive zone:** Speech signal produced by the head and torso simulator (HATS) in the receive zone.

**3.2.7 speech in transmit zone:** Speech signal produced by the head and torso simulator (HATS) in the transmit zone.

**3.2.8 talker localization:** The listener's ability to identify the direction and distance of the detected talker.

**3.2.9 vehicle interior noise:** Actual noise originated from the vehicle inside the cabin, with no in-car communication (ICC) interaction.

**3.2.10 zone:** An acoustic space inside a motor vehicle, normally at a single seat position.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

|                   |                                                                            |
|-------------------|----------------------------------------------------------------------------|
| ASL               | Active Speech Level                                                        |
| dBPa              | Sound pressure level relative to 1 pascal (Pa), expressed in decibels (dB) |
| DT                | Double-Talk                                                                |
| HATS              | Head and Torso Simulator                                                   |
| HFRP              | Hands-Free Reference Point                                                 |
| HVAC              | Heating Ventilation and Air Conditioning                                   |
| ICC               | In-Car Communication                                                       |
| MOS <sub>LE</sub> | Mean Listening Effort Opinion Score                                        |
| MRP               | Mouth Reference Point                                                      |
| Rx                | Receive direction                                                          |
| SNR               | Signal-to-Noise Ratio                                                      |
| SPL               | Sound Pressure Level                                                       |
| ST                | Single-Talk                                                                |
| Tx                | Transmit direction                                                         |
| VIN               | Vehicle Interior Noise                                                     |

## 5 Conventions

None.

## 6 How to use this Recommendation

### 6.1 Determining compliance with this Recommendation

To claim compliance with this Recommendation, the following must be true:

- 1) the test arrangement shall follow clause 7;
- 2) the test signals in clause 8 shall be used as specified in the specific tests in clause 9;
- 3) the standard set of usage scenarios in Annex A shall be followed;
- 4) the requirements for every specific test in clause 9 where both requirements and test method(s) are defined, shall be fulfilled.

## 7 Test arrangement

This clause discusses the physical environment and equipment configuration for testing ICC.

### 7.1 Zones and measurement paths

Figures 7-1 and 7-2 show a typical motor vehicle seating configuration for a three-row passenger vehicle for left-hand and right-hand drive vehicles. Each seating position is a designated zone for a talker or listener to engage with an ICC system.

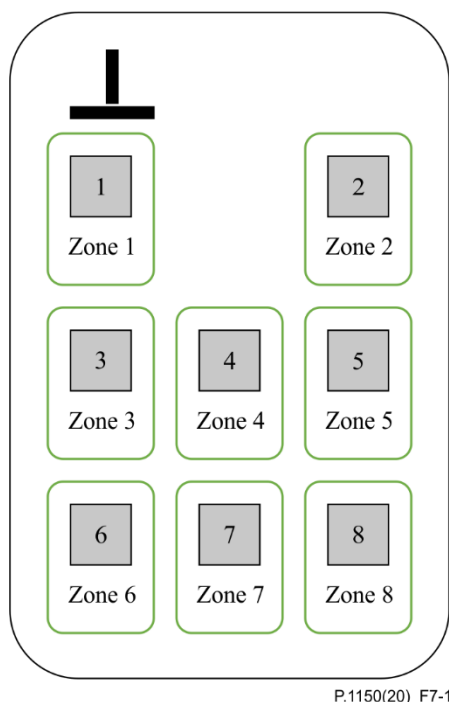


**Figure 7-1 – Left-hand drive common passenger motor vehicle seating positions**

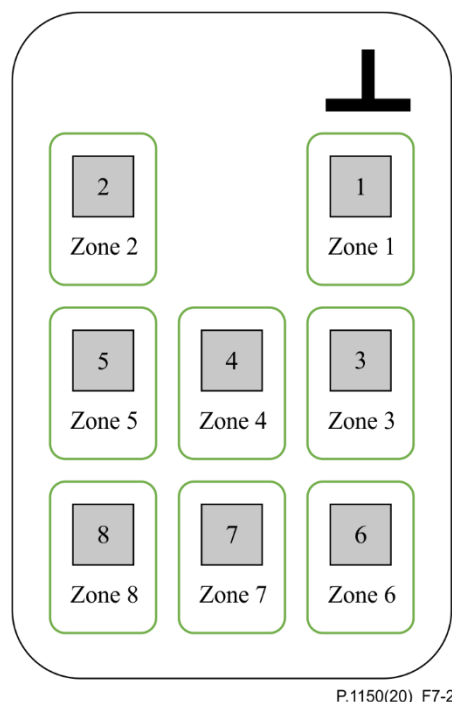


**Figure 7-2 – Right-hand drive common passenger motor vehicle seating positions**

In reference to Figures 7-1 and 7-2, Table 7-1 shows the ICC paths that may be enabled providing the vehicle is configured with the seating positions. Inter-zone communication between immediately adjacent seats in 3-seat rows are ignored.

**Table 7-1 – Zone to Zone communications paths**

| <b>Zone Interaction</b>                                                                                                                                                                                                               | <b>1 Rx</b> | <b>2 Rx</b> | <b>3 Rx</b> | <b>4 Rx</b> | <b>5 Rx</b> | <b>6 Rx</b> | <b>7 Rx</b> | <b>8 Rx</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 1 Tx                                                                                                                                                                                                                                  | NA          | ✓           | ✓           | ✓           | ✓           | ✓           | ✓           | ✓           |
| 2 Tx                                                                                                                                                                                                                                  | ✓           | NA          | ✓           | ✓           | ✓           | ✓           | ✓           | ✓           |
| 3 Tx                                                                                                                                                                                                                                  | ✓           | ✓           | NA          | AJ          | ✓           | ✓           | ✓           | ✓           |
| 4 Tx                                                                                                                                                                                                                                  | ✓           | ✓           | AJ          | NA          | AJ          | ✓           | ✓           | ✓           |
| 5 Tx                                                                                                                                                                                                                                  | ✓           | ✓           | ✓           | AJ          | NA          | ✓           | ✓           | ✓           |
| 6 Tx                                                                                                                                                                                                                                  | ✓           | ✓           | ✓           | ✓           | ✓           | NA          | AJ          | ✓           |
| 7 Tx                                                                                                                                                                                                                                  | ✓           | ✓           | ✓           | ✓           | ✓           | AJ          | NA          | AJ          |
| 8 Tx                                                                                                                                                                                                                                  | ✓           | ✓           | ✓           | ✓           | ✓           | ✓           | AJ          | NA          |
| <p>AJ – adjacent zones<br/> ✓ – ICC operates for this zone pair in the direction indicated<br/> ✓ – mandatory inter-zone testing configurations<br/> NA – not applicable<br/> Rx – receive direction<br/> Tx – transmit direction</p> |             |             |             |             |             |             |             |             |

The above descriptions are a model for test configurations. The manufacturer shall make sure that the system works for all zones and combinations the system is intended to work in. A typical test set-up may be a subset; specifically, it may depend from the vehicle type (e.g., sedan, convertible, van) and symmetries may be exploited. Any seat is considered as a separate zone.

Mandatory tests and arrangement required are defined in clauses 7.2 through 7.6 of this Recommendation.

## **7.2 Talker-listener combinations under test**

### **7.2.1 Adjacent zone testing**

Testing between adjacent zones indicated in Table 7-1 is optional.

### **7.2.2 Testing driver and all zones**

Inter zone testing of 1-3, 1-5, 1-6, and 1-8 (if applicable) is mandatory. Testing between the driver zone (zone 1) and the co-driver zone (zone 2) is mandatory for convertibles.

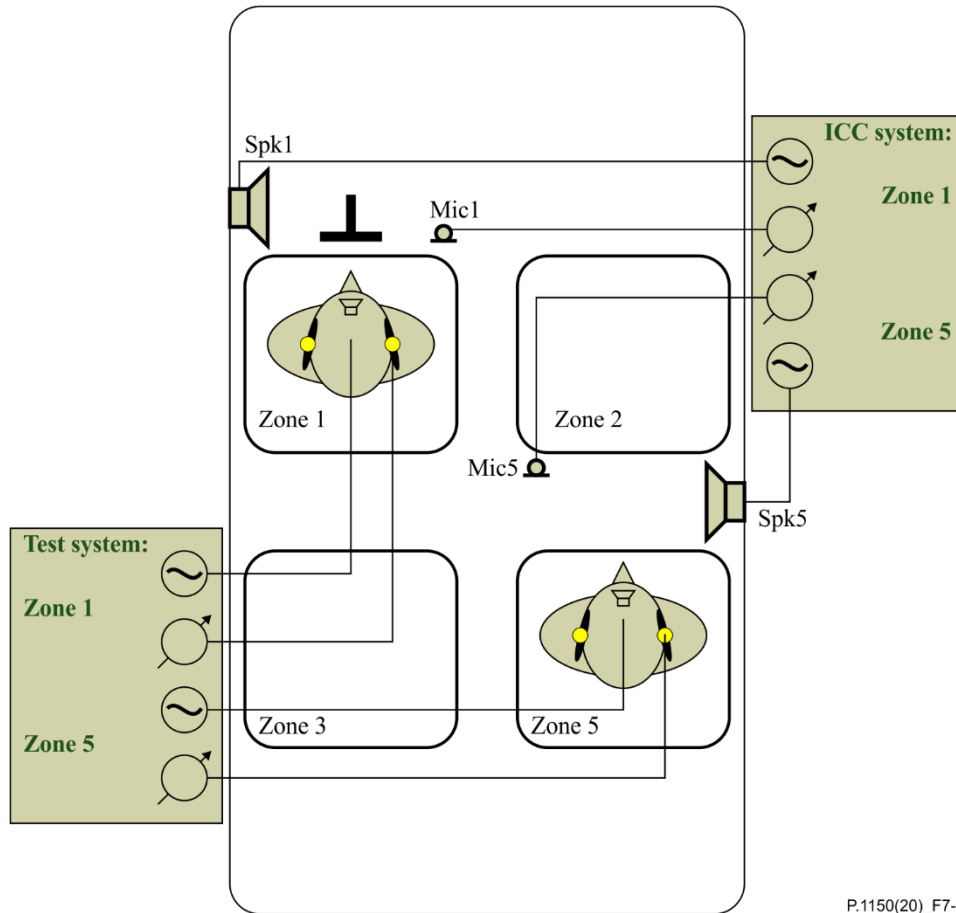
## **7.3 Test arrangement in a car**

### **7.3.1 Introduction**

The acoustical interface for all tests is realized by using two artificial head and torso simulators (HATS) – according to [ITU-T P.58]. The properties of the artificial heads shall conform to [ITU-T P.58] for send as well as for receive acoustical signals.

All HATS are connected to a test equipment conforming to the required standard with an audio interface possible to handle calibration and equalization.

An example for a test arrangement is shown in Figure 7-3.



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**Figure 7-3 – Example of test equipment placement in a car cabin with zones**

### 7.3.2 Artificial mouth

The artificial mouth of the artificial head shall conform to [ITU-T P.58]. The artificial mouth is equalized at the mouth reference point (MRP) according to [ITU-T P.340].

With sound pressure level relative to 1 pascal, expressed in decibels (dBPa), the sound pressure level (SPL) is calibrated at the HATS hands-free reference point (HATS-HFRP) to a level of 25.7 dBPa. The SPL at the MRP has to be corrected correspondingly. The detailed description for equalization at the MRP and level correction at the HATS-HFRP can be found in [ITU-T P.581].

### 7.3.3 Artificial ears

The HATS is equipped with artificial ears of type 3.3 or 3.4 according to [ITU-T P.57]. If not specified otherwise, the ear signals of both ears of the artificial head are used with diffuse-field equalization. More detailed information can be found in [ITU-T P.581].

## 7.4 ON/OFF control

For testing purposes an ICC ON/OFF control shall be made available.

An end user-accessible ICC ON/OFF control is recommended.

## 7.5 ICC setting

ICC implementations may allow the users to change the ICC behaviour according to their preferences. For the testing, the ICC system shall be set to a predefined default setting. For test regarding stability, the test shall be done also with the setting which applies the highest gain to the signal.

## 7.6 Side information

ICC systems may use side information such as vehicle speed to control the ICC system. The ICC vendor shall inform the test house whether it requires use of side information. The method of providing this side information is outside the scope of this recommendation and is solely the responsibility of the ICC vendors and test houses. If such information is provided it shall be used for the relevant tests and its accuracy agreed between the ICC system vendor and the test laboratory.

## 8 Test signal and signal levels

### 8.1 Speech signals

#### 8.1.1 Speech material

If not specified otherwise, the British English fullband speech samples according to Annex C of [ITU-T P.501] shall be used as a concatenated sequence. Each sentence shall be centred in a time window of 4.0 s, leading to an overall signal of 32.0 s duration.

Table 8-1 provides a detailed description of the exact crop and merge positions in order to compose the test sequence, which is depicted in Figure 8-1.

**Table 8-1 – Composition of test sequences**

| [ITU-T P.501] Annex C filename | Crop Start [s] | Duration [s] | Merge Position [s] |
|--------------------------------|----------------|--------------|--------------------|
| P501_C_english_m1_FB_48k.wav   | 0.58           | 2.15         | 0.93               |
| P501_C_english_m1_FB_48k.wav   | 3.73           | 2.22         | 4.89               |
| P501_C_english_m2_FB_48k.wav   | 0.54           | 2.55         | 8.73               |
| P501_C_english_m2_FB_48k.wav   | 4.19           | 2.63         | 12.69              |
| P501_C_english_f1_FB_48k.wav   | 0.52           | 2.73         | 16.64              |
| P501_C_english_f1_FB_48k.wav   | 4.13           | 3.13         | 20.44              |
| P501_C_english_f2_FB_48k.wav   | 0.50           | 2.64         | 24.68              |
| P501_C_english_f2_FB_48k.wav   | 4.07           | 2.46         | 28.77              |

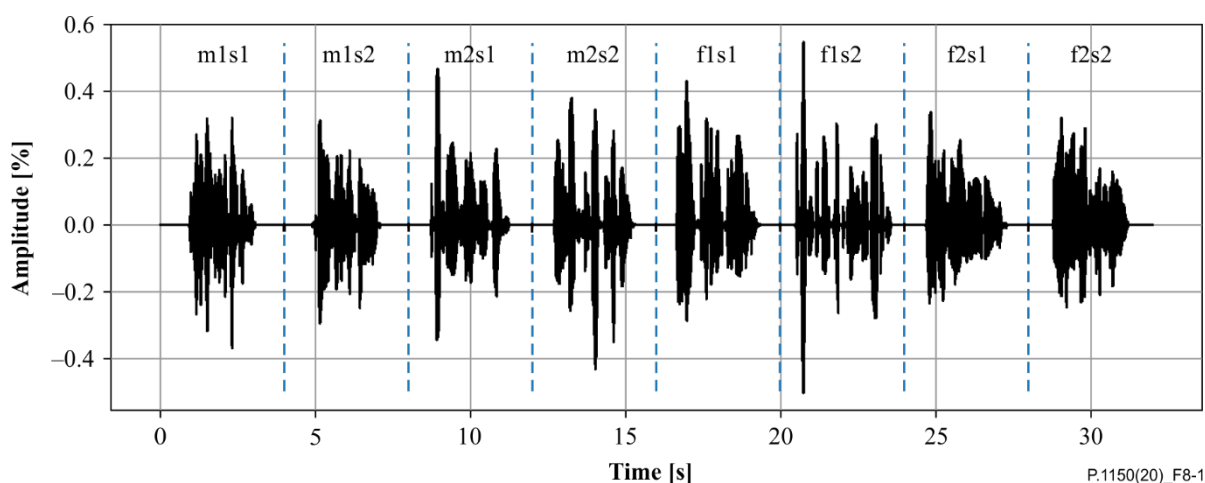


**Figure 8-1 – Composed test sequence**

The sequence is calibrated to an active speech level (ASL) according to [ITU-T P.56] of  $-1.7$  dBPa at the MRP, which corresponds to  $-25.7$  dBPa at the HFRP.

If not specified otherwise, the Lombard gains as specified in the following clauses (for ICC ON/OFF) shall be applied on the test signal.

NOTE – In general, the widely used speech level of  $-4.7$  dBPa is increased by  $+3$  dB according to [ITU-T P.340]. This gain typically is observed in communication scenarios, where test subjects are forced to talk via hands-free microphone/system. Similar results were found in situations, where the talker is aware that the listener is located further away (e.g., talking from front to back seat), see Appendix I.

### 8.1.2 Lombard effect with activated ICC

When testing with vehicle noise, the output level of the mouth is increased to account for the "Lombard effect." The Lombard effect refers to the change in speaking behaviour caused by acoustic noise. To be consistent with the intent that an effective ICC system should significantly reduce the requirement for the talker to raise their voice in the presence of noise, the simulated Lombard effect for ICC is calculated as half the Lombard effect observed when ICC is not present. The level is increased by  $1.5$  dB for every  $10$  dB that the long-term A-weighted noise level exceeds  $50$  dB(A), see Appendix I for more information. This relationship is shown in the following formula:

$$I(N) = \begin{cases} 0 & \text{for } N < 50 \\ 0.15 (N - 50) & \text{for } N \geq 50 \end{cases}$$

where:

- $I$  = The increase in dB of the mouth output level due to noise level
- $N$  = The long-term A-weighted noise level measured close to the talker's head position

As an example, if the vehicle noise measures  $70$  dB(A), then the output of the mouth would be increased by  $3$  dB. No gain is applied for noise levels below  $50$  dB(A). The Lombard level increase shall be limited to  $8$  dB. Vehicle noise levels are measured using HATS microphones of the talker. The average level between left and right ear signals is used for the Lombard level calculation formula.

### 8.1.3 Lombard effect with deactivated ICC

Several studies indicated that the Lombard effect is more pronounced in environments without speech reinforcement (see Appendix I) or in noisy hands-free communication scenarios [ITU-T P.1100].

In cases when measurements with deactivated ICC system are conducted and if not specified otherwise, the Lombard level increase shall be twice the amount of the value as specified in clause 8.1.2. The Lombard level increase shall be limited to  $8$  dB. The average level between left and right ear signals is used for the Lombard level calculation formula.

As an example, if the vehicle noise measures  $70$  dB(A), then the output of the mouth would be increased by  $3$  dB with activated ICC and  $6$  dB without activated ICC.

### 8.1.4 Convergence sequence

In order to allow the ICC system to adapt its signal processing to the current measurement scenario (speech and background noise level), an appropriate convergence sequence is used in some tests. For this purpose, the British English short conditioning sequence according to clause 7.3.7.1 of [ITU-T P.501] shall be used. The male and female conditioning sequences are added, leading to a condition sequence of  $10$  s duration.

Unless stated otherwise, the ASL according to [ITU-T P.56] shall be calibrated to the level described in the test, where this sequence is used. Figure 8-2 illustrates the composition of the convergence sequence.