Masking theory in pure tone audiometry
– Systematic lectures – Part 4

Part 4 Lecture 8: Clinical masking procedures
Lecture 9: Supplements
Lecture10: The occlusion effect

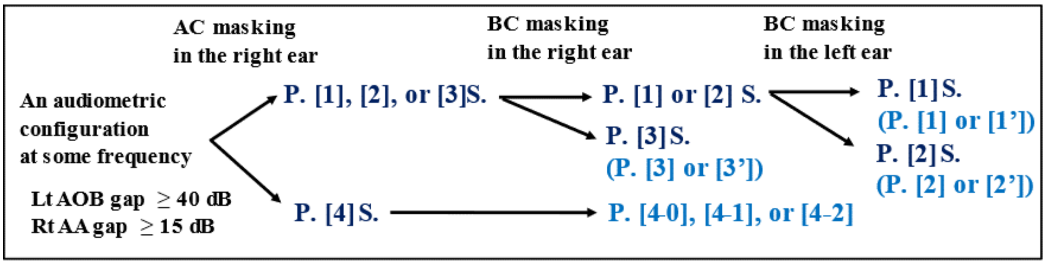
Lecture 8: Focal point

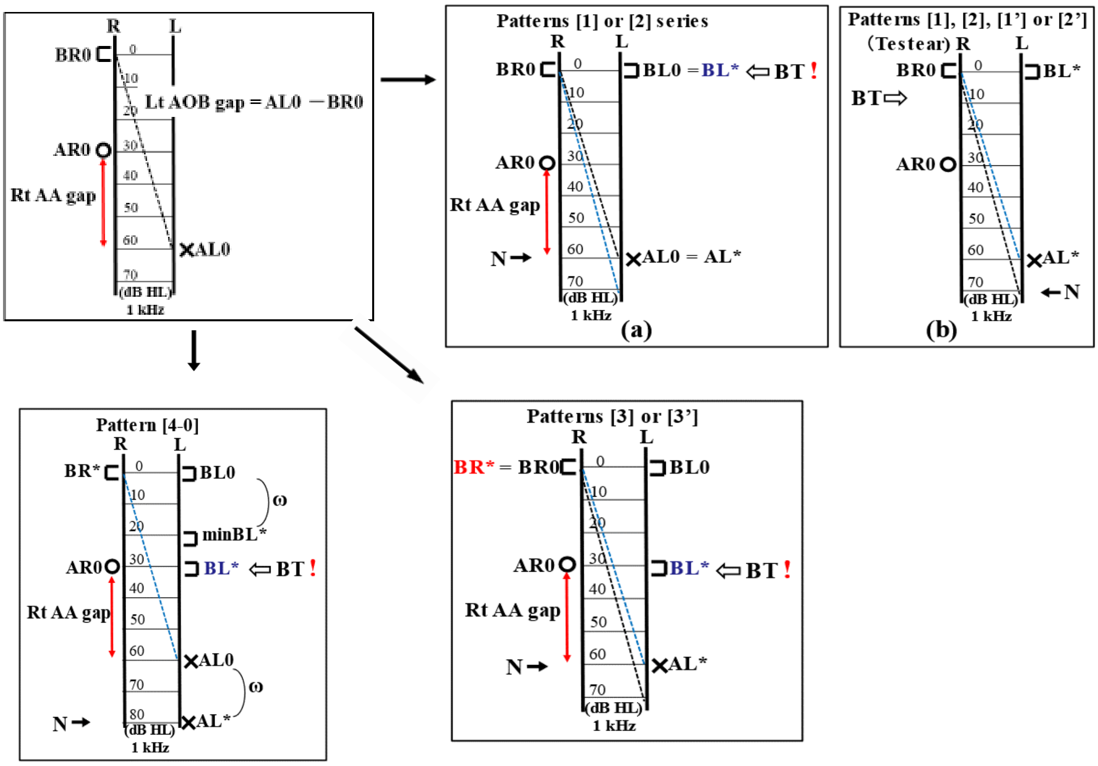
A general description of the masking procedure is described in the audiometric configuration where the apparent AC thresholds differ significantly (Rt AA gap = 30 dB ≥ 15 dB, AR0 < AL0). The AC plateau width in the left ear (Lt APW) is as follows:

Lt APW = (Rt AA gap + δ) + Lt SNC − ω,

where δ = IaA − Lt AOB gap, Lt SNC = BL* − BR*, and ω = AL* − AL0.

When the true AC thresholds are determined, the configurations are divided into two series: patterns [1], [2], and [3] series and pattern [4] series.





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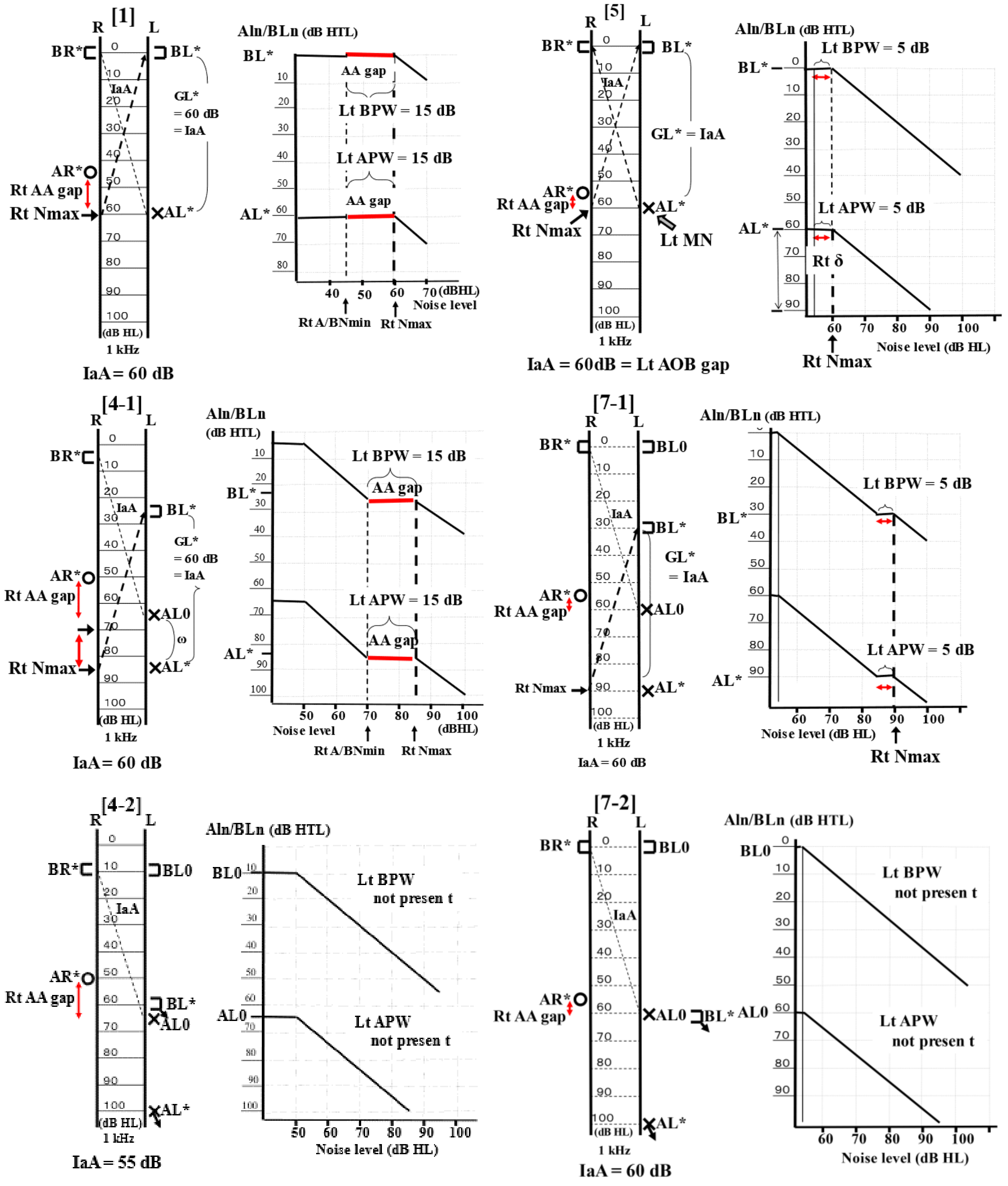
Patterns [5], [7-1], and [7-2], where Rt AA gaps are small (≤ 10 dB), are the clinical masking dilemma. Although patterns [1] and [4-1] have Rt AA gaps of 15 dB, the significant plateaus for AC and BC cannot be obtained if clinical plateau contraction occurs. Patterns [4-2] and [7-2] have no PWs in both ears. The clinical masking dilemma depend on measurement accuracy.

If the apparent AC threshold levels in the non-test ear are too high to ensure sufficient masking amounts, the configurations are also the clinical masking dilemma.



Lecture 8: Clinical masking procedure

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8.1 Introduction

(1) Theory and practice

From a theoretical perspective, efficiency is required first when masking in pure tone audiometry, indicating that true thresholds should be determined with fewer noise steps in the shortest amount of examination time. However, from a clinical point of view, the accuracy or reliability of the measured thresholds is more important than efficiency. Therefore, within the limited 10- to 15-minutes examination time, obtaining the results at certain frequencies with high reliability is desirable, even if the thresholds at all frequencies cannot be obtained.

Even when the thresholds measured with only one level of masking noise are theoretically considered the true thresholds, the results should be re-examined using other levels of noise. If the two measured results are at the same level, reliability is improved. In this lecture series, this approach is referred to as a principle of measurement.

The purpose of this lecture is to familiarize the readers with the fundamental structure of masking. Then, they will be able to set the optimum masking noise levels in accordance with the need of each case, and make a judgment whether the measured thresholds are true or false.

(2) Basic audiograms and plateau widths

The basic audiograms **[A-1]** and **[B-1]** (Rt AA gap ≥ 15 dB) have seven audiometric configurations patterns (**Fig. 8-1**, **8-2**), while **[C-1]** (Rt AA gap ≤ 10 dB) has five patterns at a certain frequency (**Fig. 8-1**, **8-3**). Masking for the left AC and BC is necessary because all Lt AOB gaps in these audiograms are larger than or equal to 40 dB (**Table 8-1**).

Lt APWs in theory are as follows:

Patterns [1], [2], [5]:	Lt APW = Rt AA gap.	(Rt AA gap = AL0 − AR0)
Patterns [1'], [2'], [5']:	Lt APW = Rt AA gap + **δ**.	(**δ** = IaA − GL0)
Patterns [3], [6]:	Lt APW = Rt AA gap + **Lt SNC**.	= IaA − Lt AOB gap)
Patterns [3'], [6']:	Lt APW = Rt AA gap + **δ** + **Lt SNC**.	(Lt SNC = BL* − BR*)
Patterns [4-0], [7-0]:	Lt APW = Rt AA gap + **Lt SNC** − ω.	(ω = AL* − AL0)
	= Rt AA gap + (IaA − GL*).	(IaA > GL*)
Patterns[4-1], [7-1]:	Lt APW = Rt AA gap.	(IaA = GL*)

Lt BPWs in theory are as follows:

Patterns [1], [2], [3], [4], [5], [6], [7]: Lt BPW = Rt AA gap.
Patterns [1'], [2'], [3'], [5'], [6']: Lt BPW = Rt AA gap + **δ**.
The IaA value is assumed to be 0 dB.

(3) Difficulty level of masking

The plateau widths define the difficulty level of masking, as discussed in Lecture 7. In the audiometric configurations on **[A-1]**, since Rt AA gaps are ≥ 40 dB, the Lt APWs and BPWs (≥ Rt AA gaps) are large (wide). Therefore, it can be predicted that masking for the left AC and BC is easy. In **[B-1]**, when the configurations with Rt AA gaps are > 20 dB, the plateaus are also wide. However, in **[B-1]** and **[C-1]**, where the Rt AA gaps are small (≤ 20 dB), Lt BPWs are also small (narrow) and masking for the left BC becomes difficult or impossible. Dealing with configurations like these is a focal point of Lecture 8.

Even if the true BC thresholds cannot be determined, they can be estimated to some extent using the OM method, provided that the true AC thresholds are obtainable. However, if the true AC threshold is unobtainable, the true BC thresholds in both ears are inevitably indeterminable. Whether the true AC threshold can be obtained or not is the ultimate deciding factor as to whether masking is possible or not.

Additionally, the limiting levels of the test signal and masking noise also define the plateau widths. In this lecture series, it is assumed that at all frequencies, the maximum output levels of the AC test signal and the masking noise are 100 dB HL, and that of the BC test signal is 60 dB HL.

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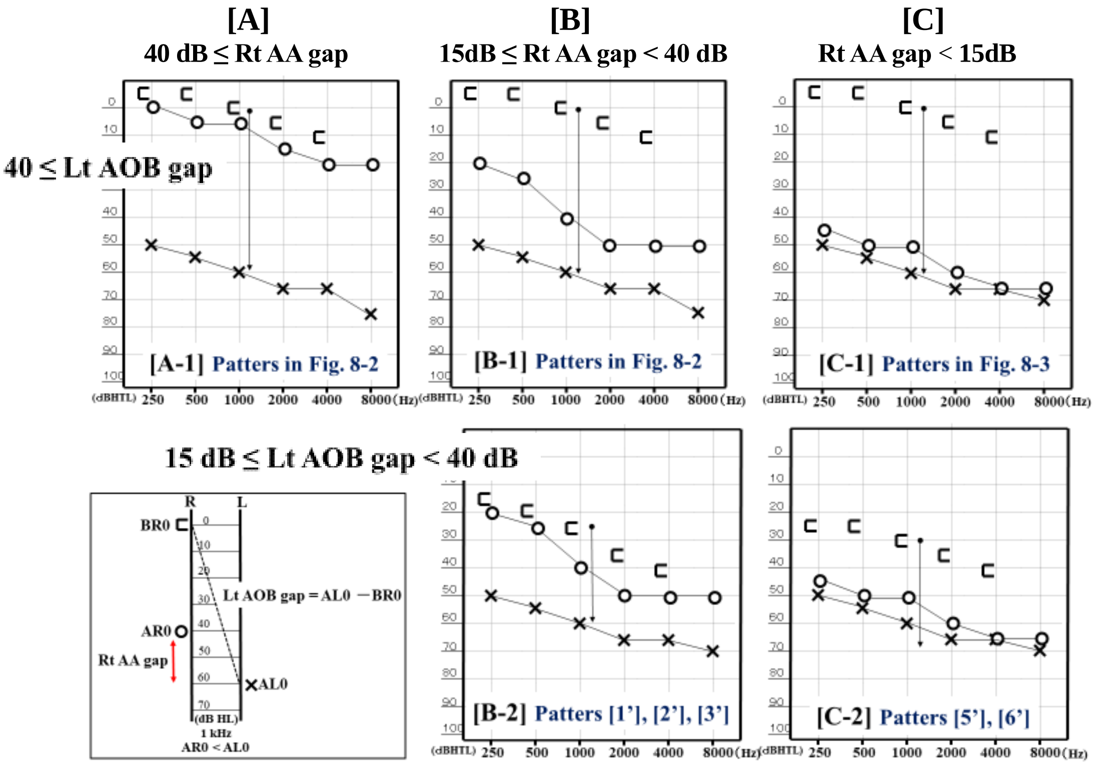


Figure 8-1 Basic audiograms

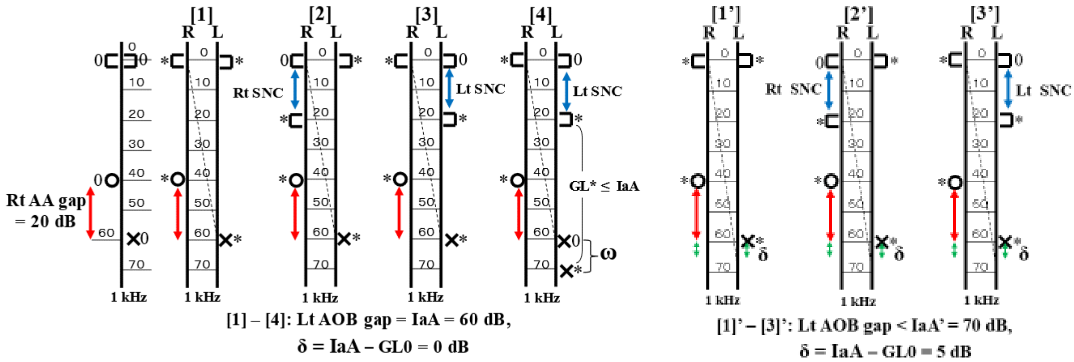


Figure 8-2 Audiometric patterns with significant AA gaps (Rt AA gap ≥ 15 dB)

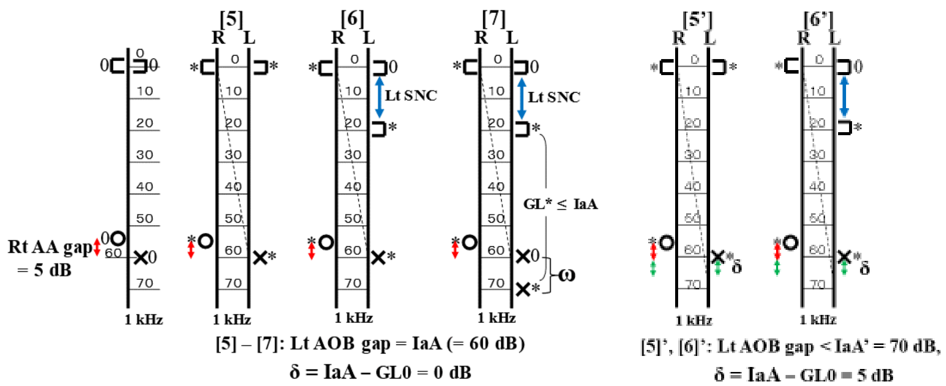


Figure 8-3 Audiometric patterns with insignificant AA gaps (Rt AA gap ≤ 10 dB)

Table 8-1 Criteria for masking

	Basic audiograms	AC masking	BC masking
1. 40 dB ≤ Lt AOB gap	[A-1], [B-1], [C-1]	Needed	Needed
2. 15 dB ≤ Lt AOB gap < 40 dB	[B-2], [C-2]	Not needed	Needed

8.2 Plateau widths

8.2-1 Classification of the plateau widths

(1) Theoretical plateau widths

The plateau widths, regardless the measurement errors and the maximum noise level, are termed the theoretical PWs (cf. **7.1 [3]**). When the apparent AC thresholds differ significantly (Rt AA gap = AL0 − AR0 ≥ 15 dB, AR0 < AL0), the elements of the theoretical PWs are as follows:

Elements of Lt theoretical APWs:

1) Rt AA gap = AL0 − AR0, 2) δ = IaA − Lt AOB gap, 3) Lt SNC = BL* − BR*,
4) ω = AL* − AL0: only patterns [4] and [7].

Elements of Lt theoretical BPWs:

1) Rt AA gap = AL0 − AR0, 2) δ = IaA − Lt AOB gap.

Here, IaB at the mastoid is assumed to be 0 dB in principle.
We only know the Rt AA and Lt AOB gaps before masking.

a) Pattern [1] series (**Fig. 8-4**): AL0 and BL0 are both true thresholds (GL0 = GL*).
IaA is ≥ 60 dB (= Lt AOB gap) and δ (= IaA − Lt AOB gap) is ≥ 0 dB.

Pattern [1']: Lt APW = Rt AA gap + δ.	Pattern [1]: Lt APW = Rt AA gap.
Pattern [1']: Lt BPW = Rt AA gap + δ.	Pattern [1]: Lt BPW = Rt AA gap.

The utmost limit of the pattern [1] series is the pattern [5] series. (Rt AA gap = 0 dB).

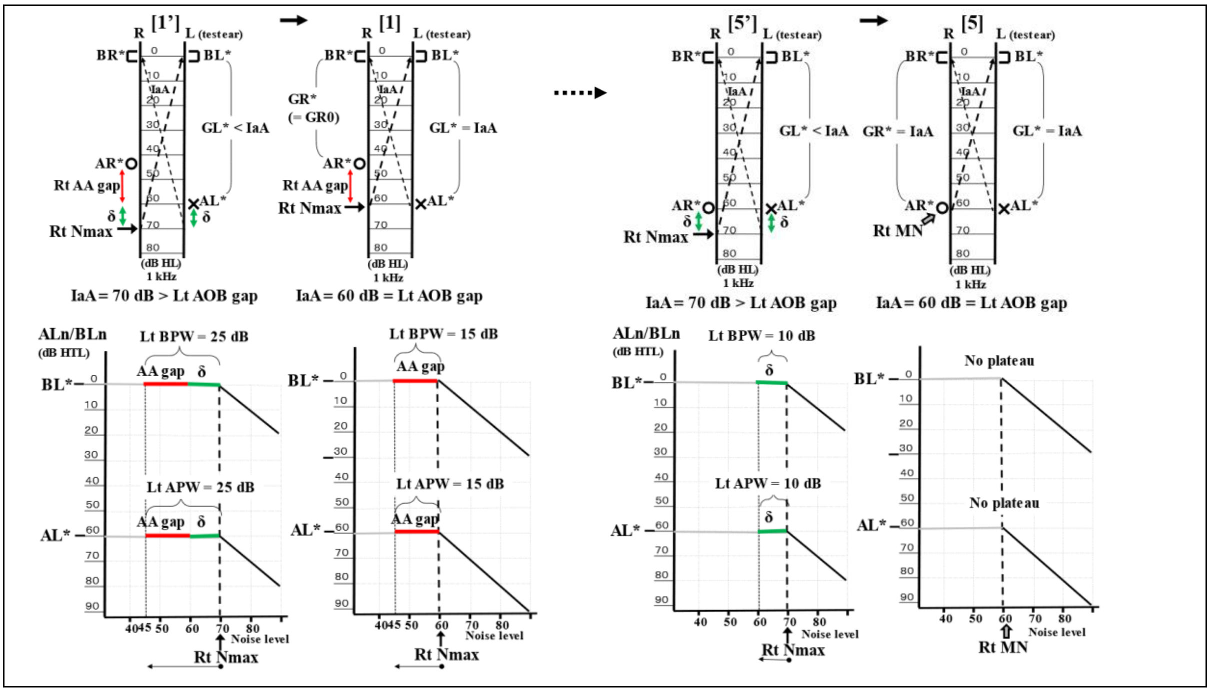


Figure 8-4 Pattern [1] series and its utmost limit

b) Pattern [2] series: GL0 = GL*.
IaA is ≥ 60 dB (= Lt AOB gap) and δ (= IaA − Lt AOB gap) is ≥ 0 dB.

Pattern [2']: Lt APW = Rt AA gap + δ.	Pattern [2]: Lt APW = Rt AA gap.
Pattern [2']: Lt BPW = Rt AA gap + δ.	Pattern [2]: Lt BPW = Rt AA gap.

Both Lt APWs and BPWs in pattern [2] series are the same as those in the pattern [1] series.
The utmost limit of the pattern [2] series is the pattern [6] series. (Rt AA gap = 0 dB) (cf. **Fig. 7-24**).

**** Further note ****

*) Lt SNC is the relative amount of sensorineural component in the left ear compared to the right ear
*) Since Lt δ (= IaA − Lt AOB gap) is equal to Rt δ (= IaA − GR0 − AA gap), Lt δ represents simply δ.
*) In patterns [3], [3'], [4-0], [6], [6'], and [7-0], the apparent BC threshold in the left ear is the SH threshold.
Lt BPW can be represented as follows (**Supplement 5, 6**):
Lt BPW = AA gap + Lt δ + IaB = (IaA − GR*) + IaB.

c) Pattern [3] series (Fig. 8-5): BL0 is an SH threshold and AL0 is a true threshold.

IaA is ≥ 60 dB (= Lt AOB gap) and δ (= IaA − Lt AOB gap) is ≥ 0 dB.

Pattern [3']: Lt APW = Rt AA gap + δ + Lt SNC.	Pattern [3]: Lt APW = Rt AA gap + Lt SNC.
Pattern [3']: Lt BPW = Rt AA gap + δ.	Pattern [3]: Lt BPW = Rt AA gap.

The utmost limit of the pattern [3] series is the pattern [6] series (Rt AA gap = 0 dB).

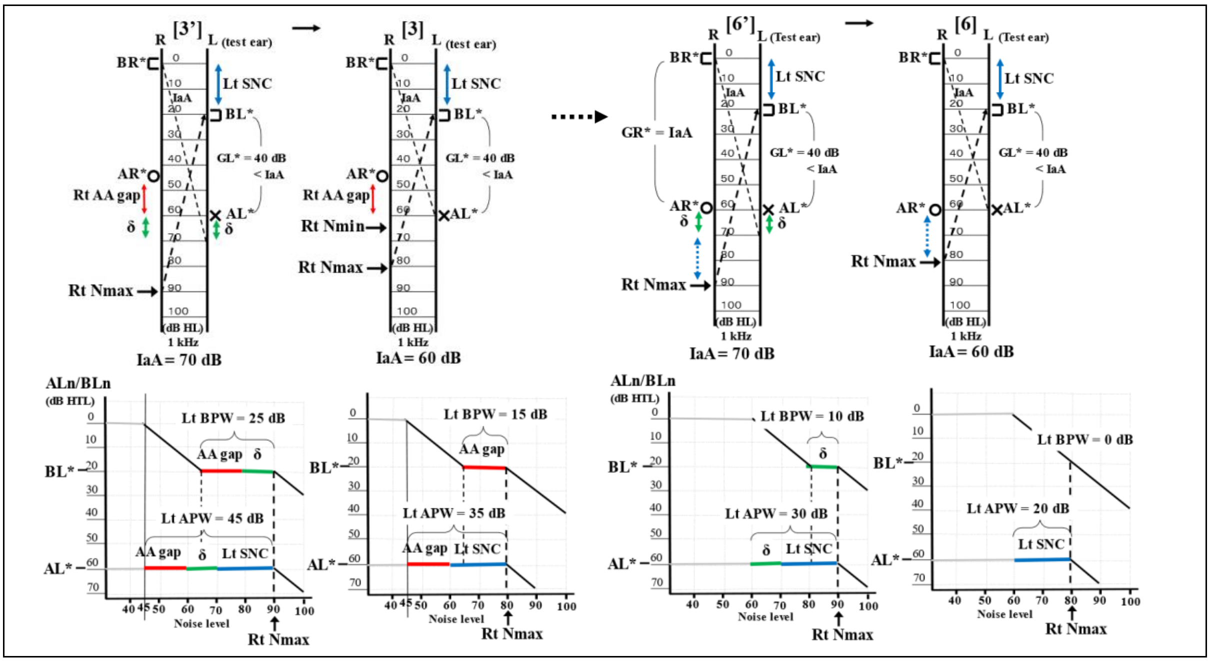


Figure 8-5 Pattern [3] series and its utmost limit

d) Pattern [4] series (Fig. 8-6): AL0 and BL0 are both SH thresholds.

IaA is 60 dB (= Lt AOB gap) and δ (= IaA − Lt AOB gap) is 0 dB.

Pattern [4-0]: Lt APW = Rt AA gap + (Lt SNC − ω)	Pattern [4-1]: Lt APW = Rt AA gap.
= Rt AA gap + (IaA − GL*)	Pattern [4-1]: Lt BPW = Rt AA gap.
= (IaA − GR*) + (IaA − GL*).	Pattern [4-2]: no plateaus present.
Pattern [4-0]: Lt BPW = Rt AA gap.	Pattern [7-2]: no plateaus present.

The utmost limit of the pattern [4] series is the pattern [7] series.

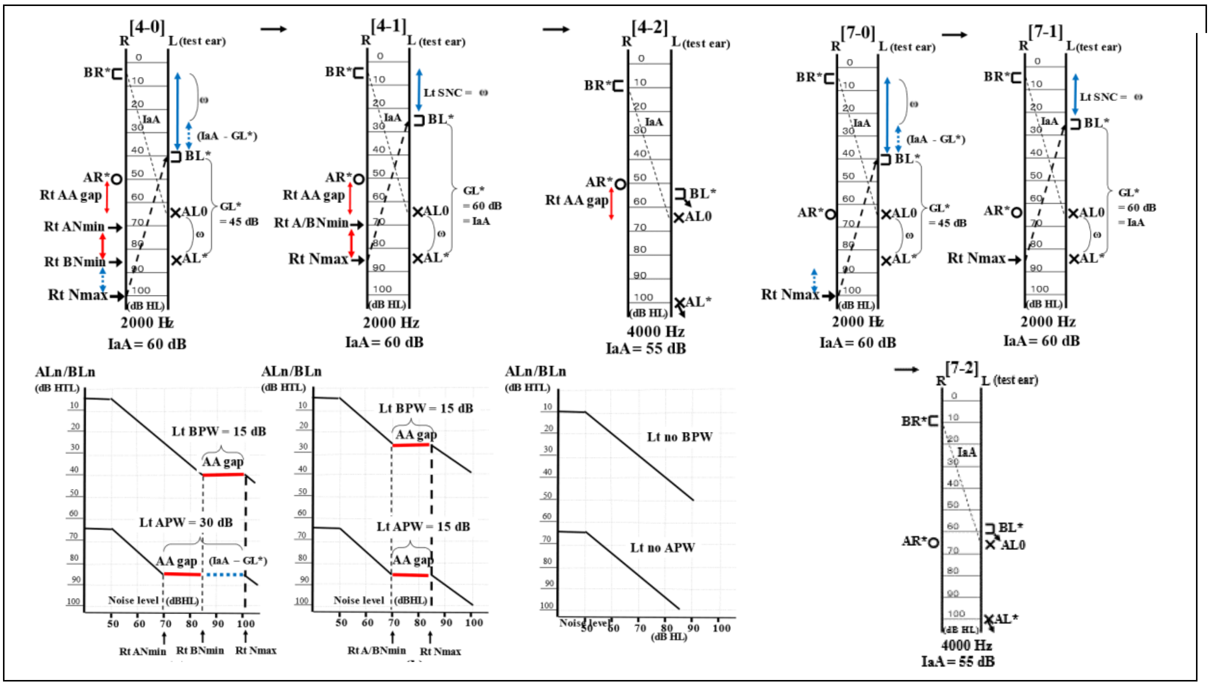


Figure 8-6 Pattern [4] series and its utmost limit

(2) Actual plateau widths

Up to this point, the theoretical PWs have been discussed without considering the noise limit (NN = 100 dB HL). However, when the true BC threshold levels in the test ear are high (i.e., profound sensorineural hearing impairment), Nmax might exceed NN. As shown in **Fig. 8-7 (a)**, **(b)**, the PWs for AC and BC are narrower than the theoretical PWs due to the difference between Nmax and NN. These PWs are termed actual PWs. For example, in **Fig. 8-7 (a)**, Lt theoretical BPW is 15 dB (= Rt AA gap), and Lt actual BPW is 5 dB. Furthermore, in **Fig. 8-7 (c)**, since the BL-CH level which corresponds to NN is 45 dB HL, the measurement limit of the BC threshold in the right ear is 45 dB HTL.

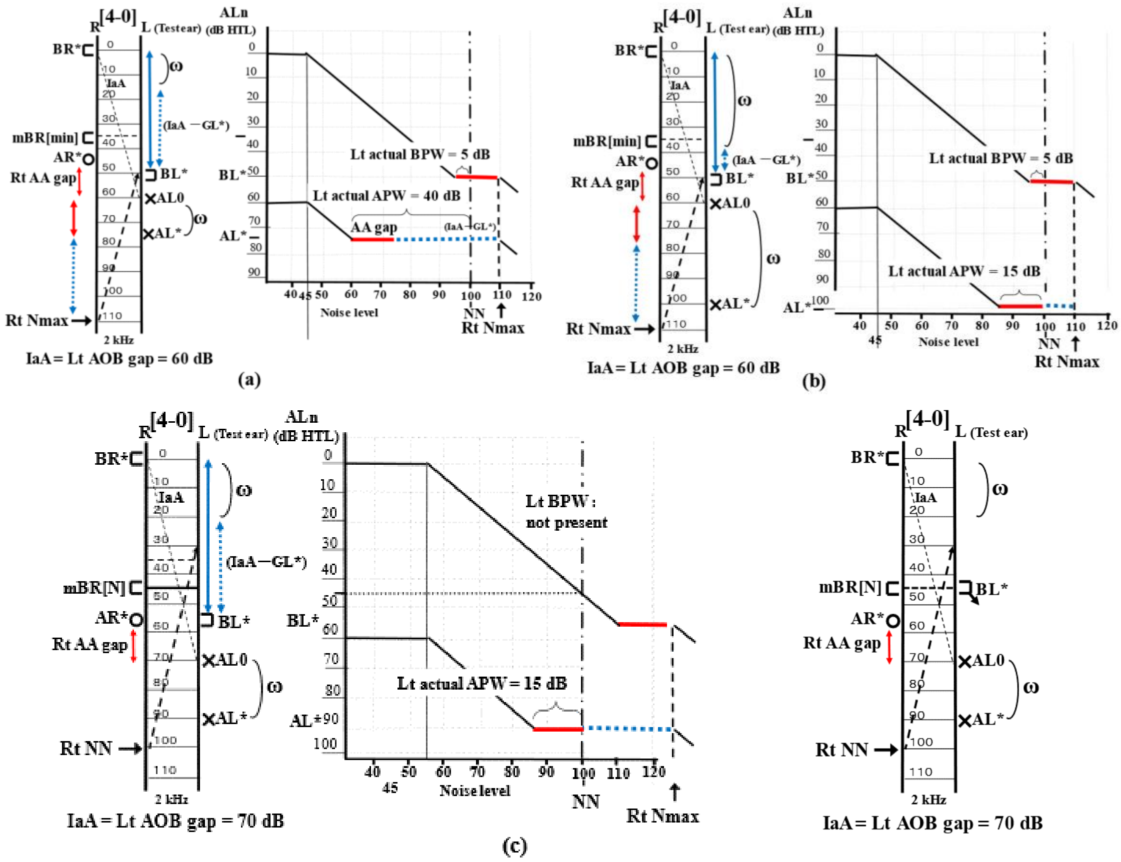


Figure 8-7 Actual PWs in pattern [4-0]: Nmax > NN

(3) Actual measurement plateau widths

Although the Lt APW in **Fig. 8-8 (a)** is 30 dB, the whole plateau width is, in fact, not always measured. In this case, the plateau has been reached at N2, N3 and N4:

AL0 < AL1 < AL2 = AL3 = AL4.

Thus, the width of 20 dB from N2 to N4 has been measured from the whole width of 30 dB. This width is termed the actual measurement plateau width (MPW). The MPWs for AC and BC are represented as aMPW and bMPW, respectively. Both the aMPW and bMPW of ≥ 15 dB are assumed to be significant.

At the case of the atypical APW in **Fig. 8-8 (b)**, its aMPW is 30 dB between the true AC threshold level of the test ear [AR*] (20 dB HL) and N3 (50 dB HL) (cf. **Fig. 8-29 [a]**).

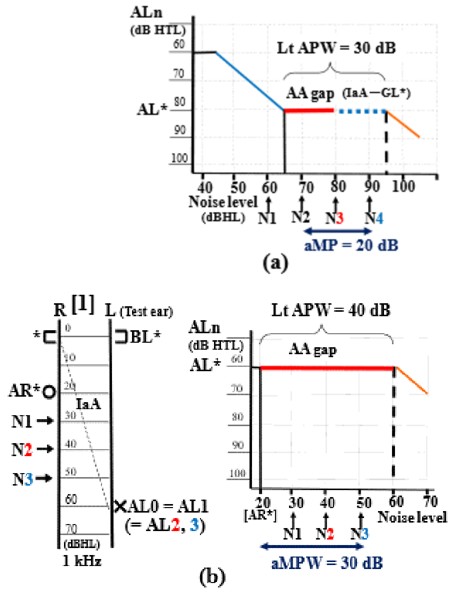


Figure 8-8 Actual measurement plateau widths

(4) Clinically significant plateau widths

In this lecture series, the PWs of ≥ 15 dB for both AC and BC are assumed to be clinically significant to ensure a wide safety margin. When a significant PW is obtained, it is stipulated that "a clinically significant plateau can be identified" (cf. **3.3**).

Conversely, cases in which "a clinically significant plateau cannot be identified" include the following (cf. **3.5** **[2]**):

1) Cases in which the plateaus are not present (cf. **6.4-2** **[1]**)
2) Cases in which, even if a 0 dB plateau is present (PW = 0 dB), it cannot be identified (cf. **6.4-2** **[1]**)
3) Cases in which, even if plateaus are present (PW = 5 dB or 10 dB), they are clinically difficult to identified

1) The noises higher than 60 dB HL (i.e., N > [AR0] dB HL, effective masking) always cause OM (pattern [5]) or undermasking (pattern [7-2]) (**Fig. 8-9**). Therefore, the AC and BC plateaus are not present.

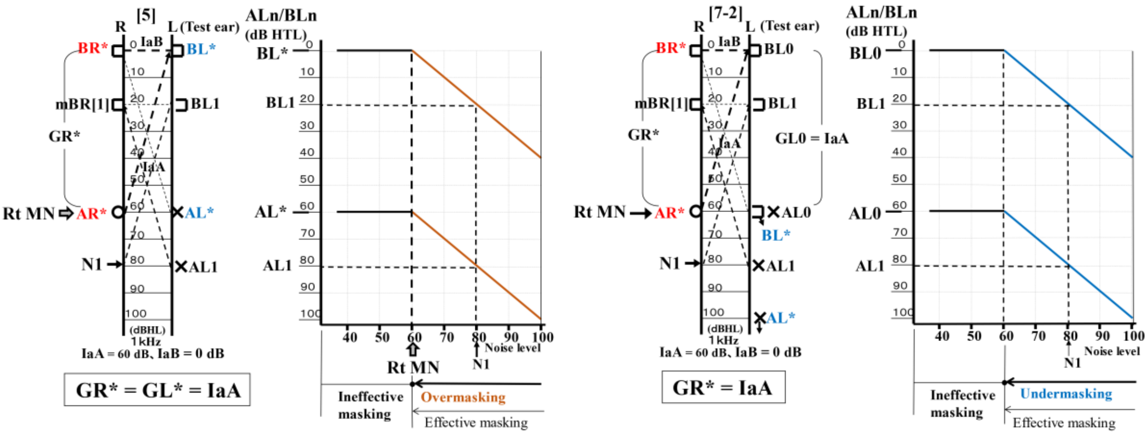
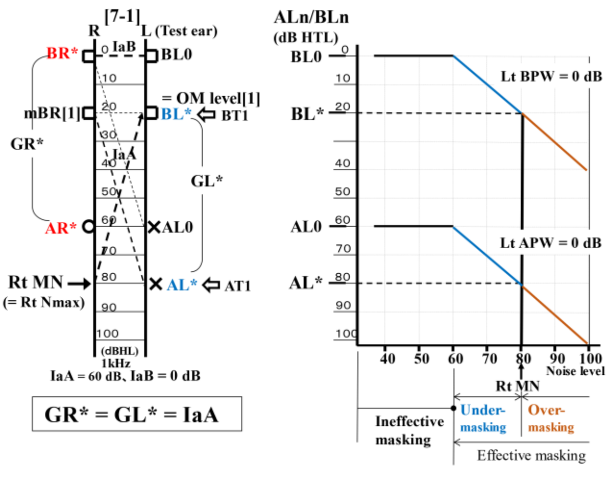


Figure 8-9 No plateau cases: overmasking and undermasking

2) In pattern [7-1], since the AC and BC plateau widths are 0 dB, they cannot be identified (**Fig. 8-10**) .

3) When the plateau widths are 5 dB or 10 dB, they are not clinically significant. However, PWs of 10 dB may be significant if they can be obtained with high measurement accuracy.



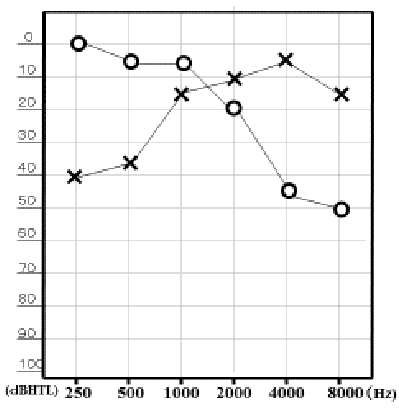


Figure 8-10 Lt APW = Lt BPW = 0 dB

Figure 8-11 Actual audiogram

Actual audiometric configurations

Basic audiograms are simplified audiometric configurations. In practice, the need for masking must be determined at every frequency. For example, on an audiogram without masking in **Fig. 8-11**, the apparent AC threshold in the left ear at 250 Hz (AL0 = 40 dB HTL) may be an SH threshold. Thus, the AC threshold needs to be re-established with masking in the right ear. At 4000 and 8000 Hz, the apparent AC thresholds in the right ear need to be retested with masking in the left ear.

8.2-2 Plateau contraction due to clinical factors

(1) Clinical factors that might make measurement errors

The four clinically important factors are:

a) Central overmasking effect: **ΔCOM** = 5 dB.

The amounts of threshold elevation due to central overmasking are approximately 5−15 dB (cf. **5.9** **[2]**). In this lecture series, the threshold shift is assumed to be 5 dB.

b) Cases where the boundary condition for OM is not true: **ΔBC** = 5 dB.

If the OM level is equal to the true BC threshold level in the test ear, and the boundary condition for OM is not true, then the AC and BC thresholds measured in the test ear are elevated by 5 dB (cf. **2.3**). The threshold elevations of ΔCOM and ΔBC occur when masking.

c) Response error for the AC and BC test signals: **Δa**, **Δb**

Here, an error associated with the participant's response is termed response error, a major measurement error (cf. **0.2**). On measurement, participants respond to the test signal that can be barely heard by pressing the switch. At this time, they require concentration and good judgement. If they hesitate to respond to the test signal, they will respond to a level higher than the true threshold level by +5 or +10 dB and an error occurs. Furthermore, the examiner's skill may also contribute to a certain error.

d) All factors except for the three abovementioned factors: **ΔOF**

The factors involve systemic errors (an error of the audiometer itself) and so on.

Thus, the AC and BC measurement errors of the left ear (ΔAL, ΔBL) may be written as

ΔAL = ΔaL + ΔCOM + ΔBC + ΔOF,

ΔBL = ΔbL + ΔCOM + ΔBC + ΔOF.

(2) Ideal conditions with no error

The initial masking noise of the present method (N1 = AL0) is the highest level that has no possibility of OM (MNnpo). It is based on the ideal conditions described below:

a) Central overmasking effect is nonexistent: ΔCOM = 0 dB.
b) Boundary condition for OM is always true: ΔBC = 0 dB.
c) No response errors exist in both AC and BC: Δa = 0 dB, Δb = 0 dB.
d) The other factors have no errors: ΔOF = 0 dB.

Clinically, N1 might cause OM if some of these clinical factors have significant errors. In the audiometric configurations shown in **Fig. 8-12**, OM is most likely to occur in patterns [1] and [2]. In these patterns the test ear has the maximum conductive disorder (GL* = IaA), which is called the maximum AB gap ear. When the test ear has the max. AB gap, MNnpo might be equal to MN (the maximum level of masking noise at which OM does not occur). When masking with MN, the clinical factors have the greatest effect on PWs.

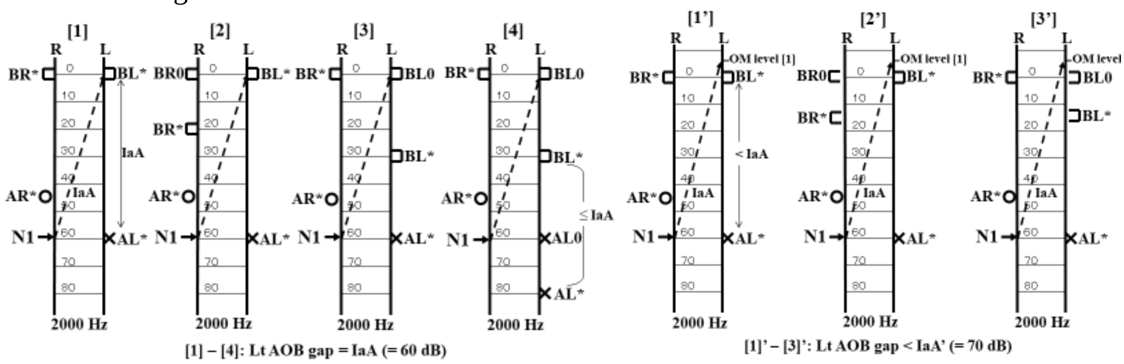


Figure 8-12 MNnpo

**** Further note ****

*) The sign of measurement errors is positive (+) in many cases. If the BC vibrator is touching an auricula even slightly, the measured threshold is better than the true one; i.e., the sign is negative.

*) The maximum AB gap ear is a substantially rare pathological condition such as atresia of the external auditory canal or ossicular discontinuity.

*) To be strict, no measurement error is not equal to an error of 0 dB. In the discussion here, they are assumed to be equal.

*) Consideration under the ideal condition is scientific method as far back as Galileo Galilei.

(3) Plateau graphs and clinical factors

When masking with Nn (n = 1, 2, 3, …), the AC measurement error of the left (test) ear with Nn (ΔALn) is described as follows:

ΔALn = ΔaLn + ΔBCn + ΔCOMn + ΔOFn,

where n of 0 means no masking. First, the influence of the AC response errors on the AC plateau width is considered, assuming that ΔBCn + ΔCOMn + ΔOFn = 0 dB.

a) In **Fig. 8-13 (a)** (pattern [1]), on the assumption that the AC response errors with Nn are all 0 dB (ΔaLn = 0 dB), the theoretical APW of the left ear is 15 dB (**Fig. 8-14 [a]**):

Lt theoretical APW = 15 dB.

Subsequently, since the response errors cannot always be 0 dB clinically, clinical plateaus in which those errors are randomly determined are considered. It is assumed that the response error is either 0 or +5 dB.

b) N1 = 50 dB HL (= AR* + 5), OM level [1] < BL*, ΔaL1 = 0 dB (**Fig. 8-13 [b]**).
N1 does not cause OM. The AC threshold measured with N1in the left ear (AL1) of 60 dB HTL (= AL*) is obtained. When N2 = 55 dB HL (ΔaL2 = 0 dB), AL2 is also 60 dB HTL.

c) N3 = 60 dB HL (= AR* + 15), OM level [3] = BL*, ΔaL3 = +5 dB (**Fig. 8-13 [c]**).
N3 is the maximum level of masking noise at which OM does not occur in the right ear (Rt MN). AL3 of 65 dB HTL (> AL*) is obtained.

d) N4 = 65 dB HL (= AR* + 20), OM level [4] > BL*, ΔaL4 = 0 dB (**Fig. 8-13 [d]**).
N4 causes OM. AL4 of 65 dB HTL is obtained. Therefore, the Lt clinical APW is 5 dB smaller than the theoretical value (**Fig. 8-14 [b]**):

Lt clinical APW = 10 dB.

It is called the plateau contraction due to clinical factors in this lecture series. Since the clinical factors, except for the response errors, also affect plateau widths, the maximum contraction is supposed to be 10 dB (**Fig. 8-14 [c]**). Therefore, even if the AC plateau width is theoretically estimated to be 15 dB, it might be decreased to 5 dB clinically. The same is true for BPWs.

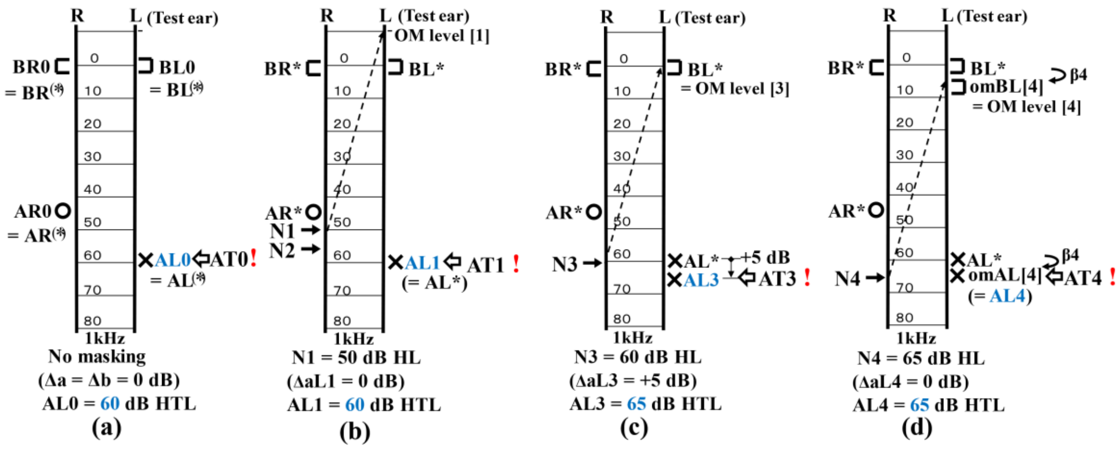


Figure 8-13 Measured thresholds and measurement errors

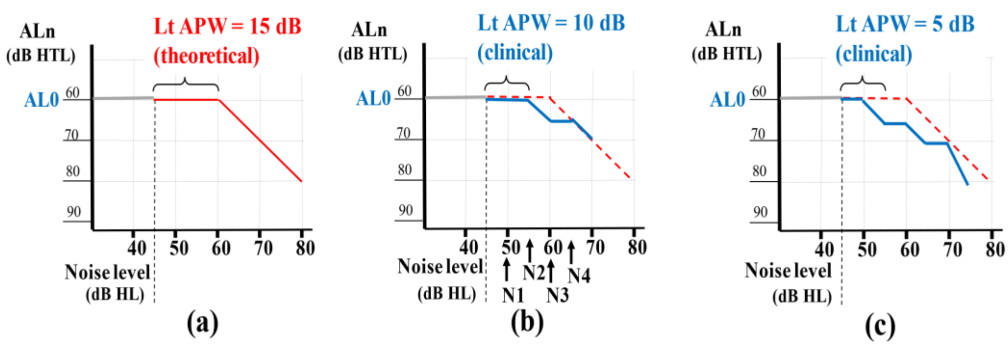


Figure 8-14 Plateau graphs regarding as clinical factors

**** Further note ****

*) The two factors (ΔCOMn and ΔBCn) cause the threshold shifts to occur when masking in the non-test ear. Without masking (n = 0), ΔCOM0 and ΔBC0 are 0 dB. ΔAL0 =ΔaL0 + ΔOF0.

8.3 Application for the present method and theoretical masking procedure

(1) Criteria for masking

a) Criterion for masking through AC testing

In the basic audiograms **[A-1]** and **[B-1]** shown in **Fig. 8-15**, the apparent AC thresholds in the right, better ear (AR0s) are always the true thresholds according to the requirements for SH thresholds (cf. **4.2 [4]**). Subsequently, whether the apparent AC thresholds in the left, poorer ear, (AL0s) are the SH thresholds or not should be considered. Assuming the minimum IaA values of 40 dB (min. IaA = 40 dB) at all frequencies, the criterion for masking through AC testing (cf. **4.4-1**) is as follows:

Lt AOB gap = AL0 − BR0 ≥ 40 dB (= min IaA).

Therefore, in **[A-1]** and **[B-1]**, AL0s may be the SH thresholds. Consequently, masking for the left AC is needed. In **[B-2]**, AL0s are always the true thresholds because Lt AOB gap < 40 dB.

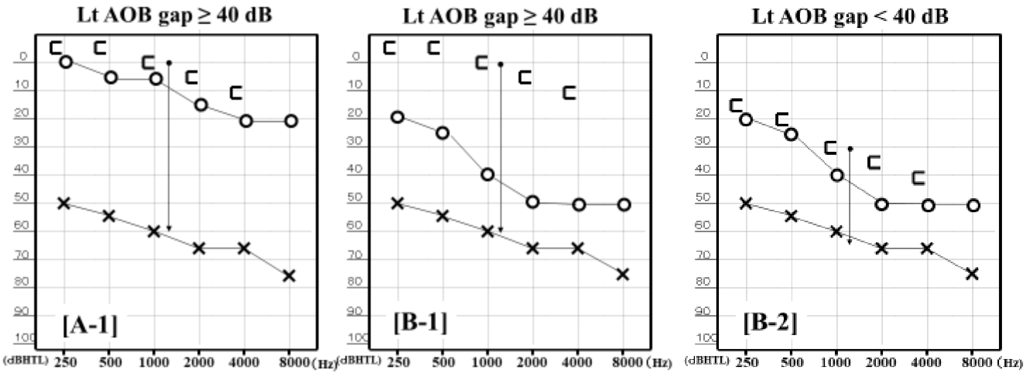


Figure 8-15 Basic audiograms with Rt AA gap of ≥ 15 dB

To consider AL0 might be the SH threshold is to assume that its audiometric configuration might be the pattern [4] (cf. **4.5**). If the AL0 is the SH threshold (AL* < AL0), 1) BR0 is the true threshold (BR0 = BR*): the first cause of SH, 2) BL0 is also the SH threshold (BL* < BL0): AB gap ≤ IaA, 3) IaA = Lt AOB gap = (AL0 − BR*) dB.

b) Criteria for masking through BC testing

The clinical criteria for BC masking-1 are as follows (cf. **4.4-2**):

Lt apparent AB gap = GL0 = AL0 − BL0 ≥ 15 dB (**Fig.8-16 [a], [b], [c], [d]**), and, or

Rt apparent AB gap = GR0 = AR0 − BR0 ≥ 15 dB (**Fig.8-16 [d], [e]**).

In the case where only BR0 is measured (**Fig. 8-16 [e]**), the criterion is as follows:

Lt AOB gap = AL0 − BR0 ≥ 15 dB.

When Rt AA gaps ≥ 15 dB as shown in **Fig. 8-16**, since Lt AOB gaps are always ≥ 15 dB, the BC thresholds in the left, poorer ear by AC should be retested with masking in the right ear.

Furthermore, as shown in **Fig. 8-16 (d)**, **(e)**, masking for the right BC might be needed (cf. **8.4-4**).

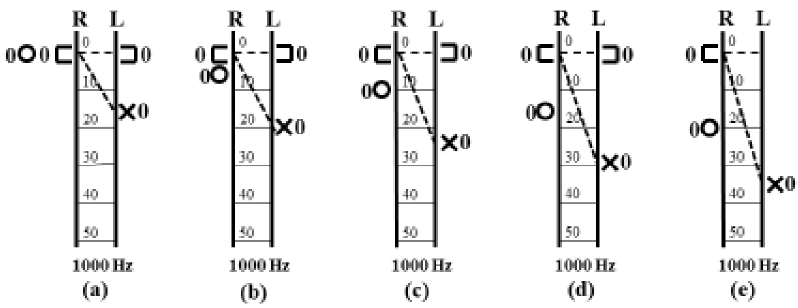


Figure 8-16 Audiometric patterns with Rt AA gap of ≥ 15 dB

**** Further note ****

*) In **Fig. 8-18** on the next page, the black star indicates the range within which the true BC thresholds exist.

*) The maximum output level of the BC test signal is 60 dB HL.

(2) Masking procedure for AC audiometry in the present method

The present method applies to **[A-1]** and **[B-1]** (Rt AA gap ≥ 15 dB, Lt AOB gap ≥ 40 dB). When the initial masking noise (N1 = [AL0]) is presented to the right ear, the AC threshold measured in the left ear with N1 (AL1) is as follows (**Fig. 8-17**):

When AL1 = AL0, AL0 is the true threshold (AL*): patterns [1]-[3], [1']-[3'].

When AL1 > AL0, AL0 is the SH threshold: pattern [4].

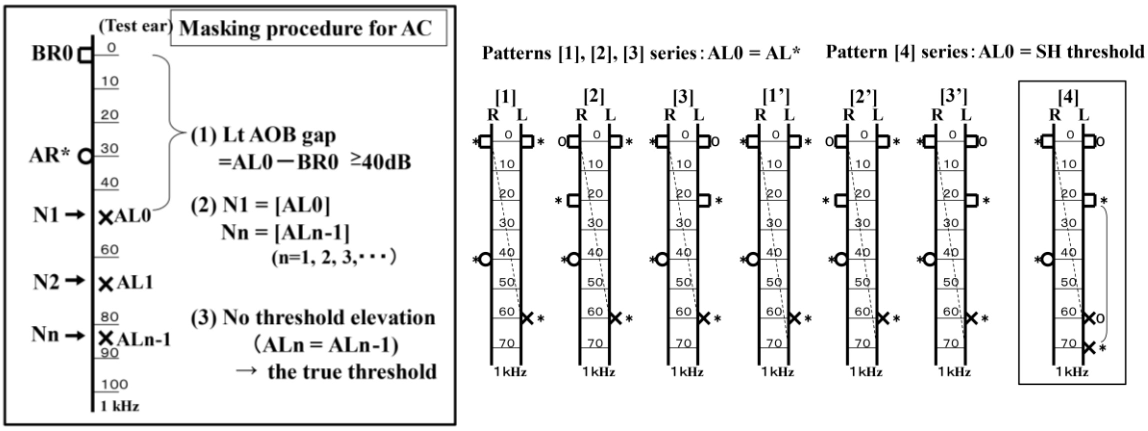


Figure 8-17 Masking procedure for AC (AR0 < AL0) and audiometric patterns

At the point where masking for AC has been completed, the audiometric configurations are divided into two series: patterns [1], [2], and [3] series and pattern [4] series (cf. **8.2-1**).

(3) Masking procedure for BC in the present method

a) Patterns [1], [2], and [3] series (**Fig. 8-18 [a]**): the apparent AC threshold in the left, poorer ear by AC (AL0) is the true threshold (AL0 = AL*). IaA is ≥ 60 dB and δ is ≥ 0 dB.

b) Pattern [4] series (**Fig. 8-18 [b]**): AL0 is the SH threshold (AL0 < AL*). IaA is 60 dB and δ is 0 dB.

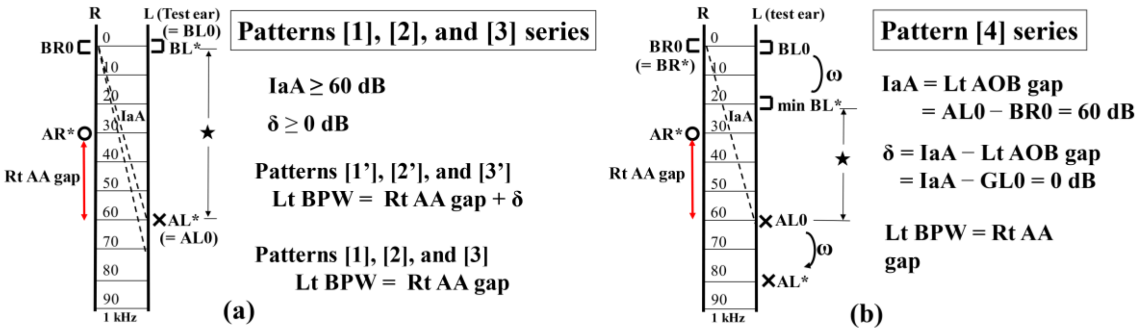


Figure 8-18 Pattern [4] and the other series ([1], [2], [3])

The basic procedure for BC is the same as that for AC (**Fig. 8-19**). The classical technique involves raising the noise levels by the amount of BC threshold elevation.

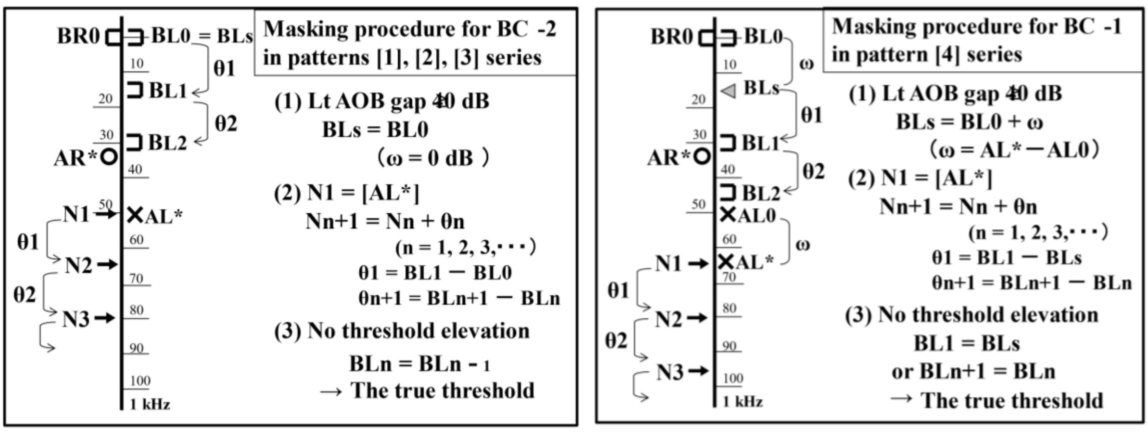


Figure 8-19 Masking procedure for BC (AR0 < AL0)

(4) General description of the masking procedure

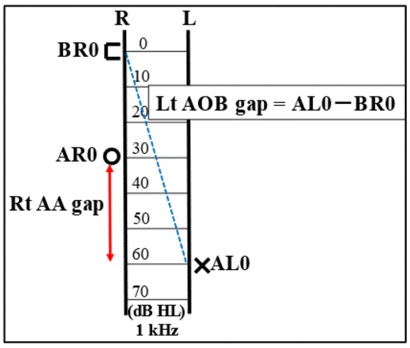


Figure 8-20 Rt AA gap = 30 dB

A general description of the masking procedure is described below to provide greater insight. **Fig. 8-20** shows the audiometric configuration where the apparent AC thresholds differ significantly.

Rt AA gap = AL0 − AR0 = 30 dB (≥ 15 dB).

AR0 < AL0

Lt APW = (Rt AA gap + δ) + Lt SNC − ω.

δ = IaA − Lt AOB gap,

Lt SNC = BL* − BR*, and

ω = AL* − AL0.

The following are considered before masking:

< What is already known before masking >

1) The IaA value at 1000 Hz is larger than or equal to 60 dB.

IaA ≥ Lt AOB gap = AL0 − BR0 = 60 dB.

2) The apparent AC threshold in the better ear (AR0) is the true threshold (AR0 = AR*).

3) Since the Rt AA gap is 30 dB, Lt APW and BPW are ≥ 30 dB.

Lt APW ≥ Lt BPW ≥ Rt AA gap = 30 dB.

< Unknown elements >

1) BR0 and AL0 are not determined as either the SH or true thresholds.

BL0 is not measured. Since IaB = 0 dB, BL0 = 0 dB HTL = BR0.

2) The three elements of Lt APW (δ, Lt SNC, ω) are unknown.

Primarily, the true AC threshold in the left, poorer ear by AC (AL*) needs to be established with masking in the right ear.

<Predictable things with adequate masking for AC >

a) When AL0 is determined to be the true threshold (**AL0 = AL***),

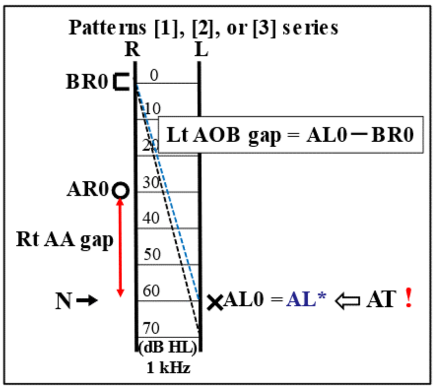


Figure 8-21 AL0 = AL*

the configuration is either a pattern [1], [2], or [3] series (**Fig. 8-21**).

1) The IaA value is ≥ 60 dB,
2) BR0 is undetermined,
3) Lt SNC and δ are also unknown.

b) When AL0 is determined to be the SH threshold (**AL0 < AL***),

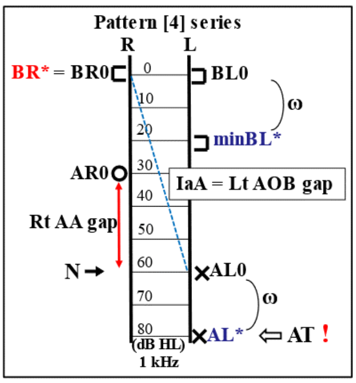


Figure 8-22 AL0 < AL*

the configuration is a pattern [4] series (**Fig. 8-22**).

1) BR0 is the true threshold (BR0 = BR*).
2) BL0 is the SH threshold (BL0 < BL*).

ω = AL* − AL0 = 20 dB.

min BL* = BR0 + ω = BR0 + (AL* − AL0)
= 20 dB HTL.

3) The IaA value is determined.

IaA = Lt AOB gap = AL0 − BR* = 60 dB.

4) δ = IaA − Lt AOB gap = 0 dB.
5) Lt SNC is unknown.

When the true AC thresholds are determined, the configurations are divided into two series: patterns [1], [2], and [3] series (AL0 < AL*) and pattern [4] series (AL0 = AL*) (**Fig. 8-23**).

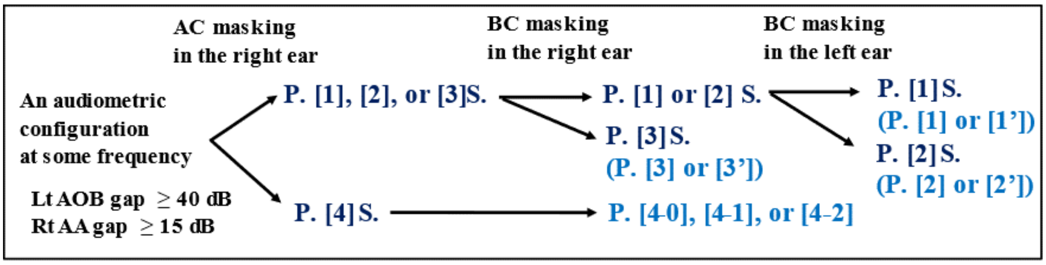


Figure 8-23 General description of the masking procedure

< Predictable things with adequate masking for BC >

a) In patterns [1], [2], and [3] series, BL* is measured with masking in the right ear.

When **BL0 = BL***, the configuration is either a pattern [1] or [2] series (**Fig. 8-24 [a]**). Subsequently, as BR0 is unknown, the true BC threshold in the right ear (BR*) needs to be obtained with masking in the left ear (**Fig. 8-24 [b]**).

When **BL0 < BL***, it is a pattern [3] series (**Fig. 8-25**). Then, BR0 is automatically determined to be the true threshold (**BR0 = BR***), and the test is completed. It is not decided whether the configuration is a pattern [3] (IaA = Lt AOB gap) or [3'] (IaA > Lt AOB gap).

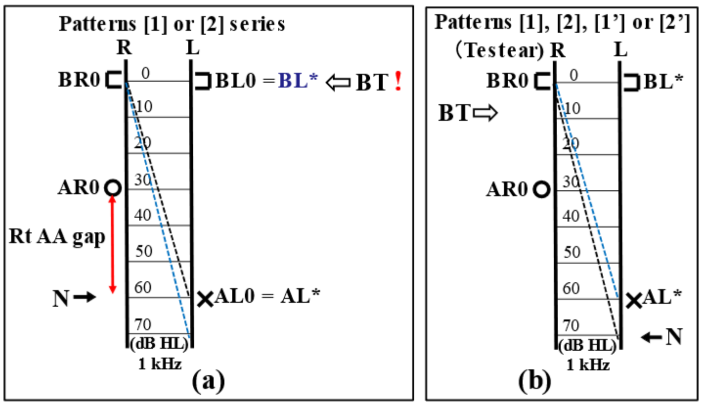


Figure 8-24 AL0 = AL*, BL0 = BL*

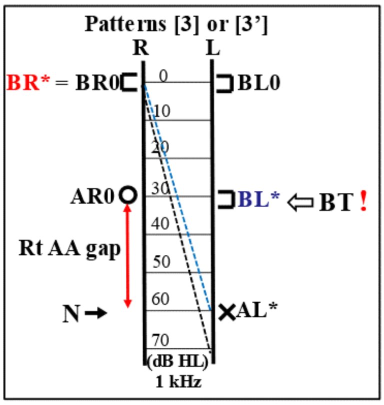


Figure 8-25 BL0 < BL*

b) In pattern [4] series, when masking in the right ear, the true BC thresholds in the left ear (BL*) are determined. Then, the test is completed (**Fig. 8-26**).

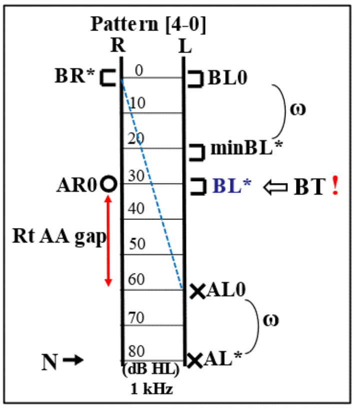


Figure 8-26 AL0 < AL*, BL0 < BL*

In this example, the configuration is determined to be a pattern [4-0] (min BL* < BL*, GL* < IaA).

If it is a pattern [4-1] (GL* = IaA), BL* is equal to min BL*.

Next, concreate masking procedures are discussed.

**** Further note ****

*) In this lecture series, it is assumed that at all frequencies, the maximum output levels of the AC test signal and the masking noise are 100 dB HL, and that of the BC test signal is 60 dB HL.

8.4 Masking procedure in cases where the apparent AC thresholds differ significantly

8.4-1 Masking in [A-1]: Rt AA gap ≥ 40 dB, Lt AOB gap ≥ 40 dB

(1) Masking procedure for AC in [A-1]

Fig. 8-27 shows the basic audiogram **[A-1]**. The apparent AC threshold in the left ear (AL0) might be the SH threshold because Lt AOB gap ≥ 40 dB. Thus, masking for the left AC is needed. Since Rt AA gaps are large (> 40 dB), the APWs in theory (≥ Rt AA gap) are wide. It can be predicted that masking for the left BC is easy. The true AC thresholds in the left ear (AL*) are shown in **[A-1']**.

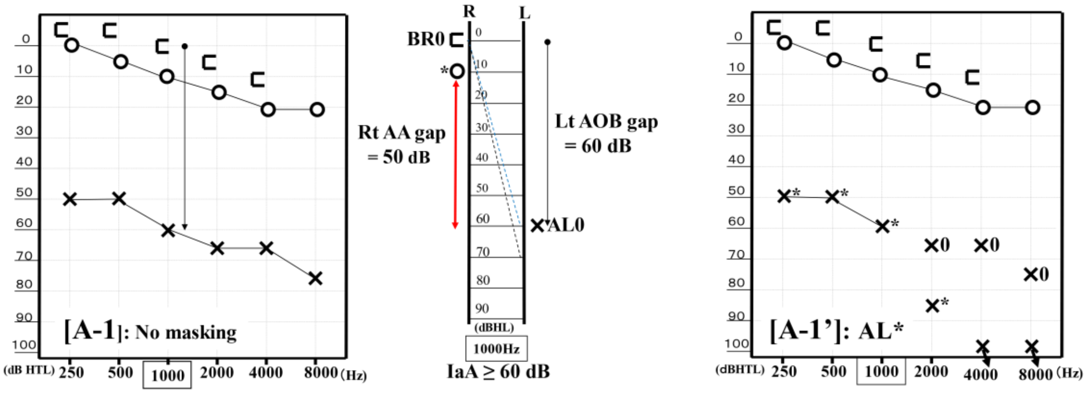


Figure 8-27 Basic audiograms [A-1] and [A-1']

< Clinical masking procedure in [A-1] >

Clinically, an excessive load of noises on the non-test ear should be avoided. The initial masking noise level 20 dB above the AC threshold level in the non-test ear (AR0) should be used.

N1 = ([AR0] + 20) dB HL, α1 is 20 dB.

At **1000 Hz** (Rt AA gap = 50 dB) (**Fig 8-28 [a]**): when masking with N1 of 30 dB HL, the left ear's AC threshold measured with N1 (AL1) of 60 dB HTL is obtained. Since the measured threshold remains stable (AL1 = AL0), AL0 is considered the true threshold. Furthermore, increasing the noise level by 10 dB (N2 = N1 + 10 = 40 dB HL), the measured threshold remains stable (AL2 = AL1 = AL0) and we can conclude that the AL0 is the true threshold. At this point, the audiometric configuration is found to be any one of the patterns [1], [2], and [3] series.

At **2000 Hz** (Rt AA gap = 50 dB) (**Fig. 8-28 [b]**): when N1 is 35 dB HL, AL1 of 85 dB HTL is obtained (AL0 < AL1). The amount of the measured AC threshold elevation (ω1) of 20 dB is considered an effect of SH. The noise level is elevated by 20 dB (N2 = N1 + ω1 = 55 dB HL) and AL2 is 85 dB HTL (AL2 = AL1): AL1 is considered the true threshold. Next, the AC threshold should be retested with N3 (= N2 + 10 = 65 dB HL). It should be ensured that there are no threshold elevations (AL3 = AL2 = AL1 = AL*). Thus, the configuration is found to be either a pattern [4-0] or [4-1].

At **4000 Hz** (Rt AA gap = 45 dB) (**Fig. 8-28 [c]**): when N1 is 40 dB HL, AL1 is 85 dB HTL (ω1 = 20 dB). When N2 = N1 +ω1 = 60 dB HL, AL2 is scaled out. The AC threshold must be retested with N3 (= N2 + 10) and it should be ensured that AL3 = AL2 = S.O. The configuration can be estimated to be a pattern [4-2], and so too with the case at **8000 Hz** (Rt AA gap = 55 dB) (**Fig. 8-28 [d]**).

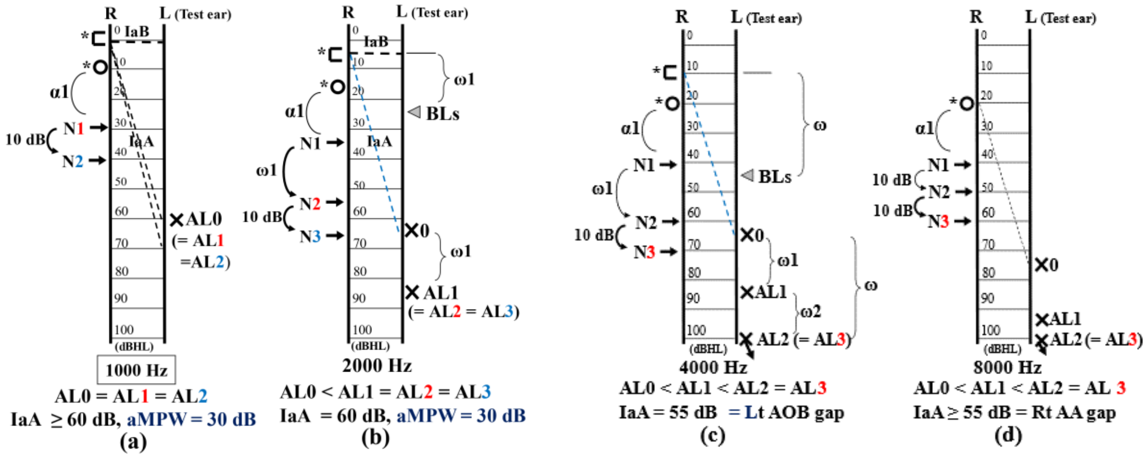


Figure 8-28 Masking for AC in [A-1] (Rt AA gap ≥ 40 dB): the clinical procedure

When the true AC threshold in the left ear has been determined, the audiometric configurations are divided into two series: patterns [1], [2], and [3] series and pattern [4] series.

a) AL0 is the true threshold (AL0 = AL*): patterns [1], [2], and [3] series	250, 500, 1000 Hz.
b) AL0 is the SH threshold (AL0 < AL*): pattern [4] series	2000, 4000, 8000 Hz.

a) The configuration at **1000 Hz** (AL0 = AL*) is any one of the patterns [1], [2], and [3] series. The pattern cannot be identified until the true BC threshold in the left ear (BL*) is determined.

Fig. 8-29 (a) shows a case of **pattern [3']** (BL* = 30 dB HTL > BL0, IaA = 70 dB > Lt AOB gap). Since the measured AC thresholds are not elevated within the noise levels from 10 dB HL (= [AR*]) to 40 dB HL (= N2), the actual measurement plateau width for AC (aMPW) is 30 dB(cf. **Fig. 8-8 [b]**).

b) The configuration at **2000 Hz** (AL0 < AL*) is a pattern [4] series. The IaA value = Lt AOB gap.

Fig. 8-29 (b) shows a case of **pattern [4-0]** (BL* = 40 dB HTL, GL* = 30 dB < IaA = 60 dB). The measured AC thresholds remain stable within the noise levels from 35 dB HL (= N1) to 65 dB HL (= N3): the aMPW is 30 dB.

The configuration at **4000 Hz** is a case of **pattern [4-2]** (both the AC and BC thresholds are S.O.). The plateaus cannot be identified (**Fig. 8-29 [c]**). Since the noises do not cause OM evidently, we may conclude that the true AC threshold is the scaled-out level, and so too with the case at 8000 Hz (**Fig. 8-28 [d]**). However, when Rt AA gaps are small, the judgement decision becomes difficult (cf. **8.6 [3]**).

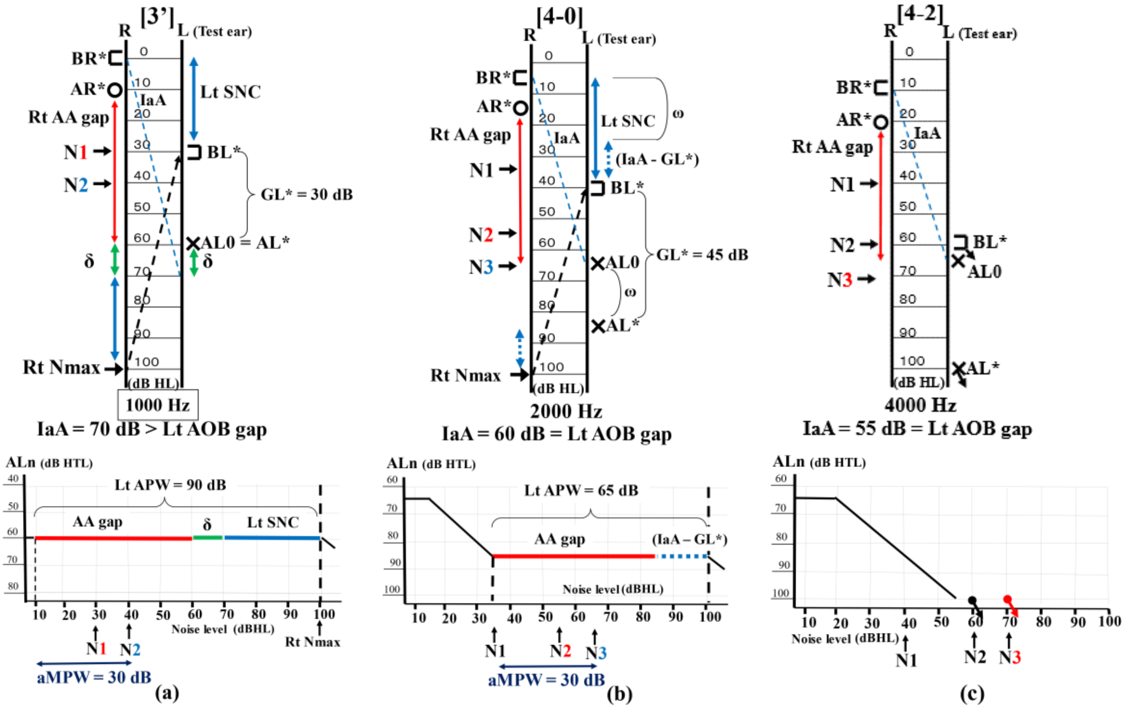


Figure 8-29 Plateau graphs of patterns in [A-1] and actual measurement PWs

The essential points in clinical masking procedure are as follows:

1. A needlessly excessive load of noises should be avoided on the non-test ear
2. Masking noises that do not cause OM in principle should be used.
   *We may need only to consider whether the measured thresholds are either the true or SH thresholds. If OM occurs, judgement becomes difficult.
   *OM does not occur due to the noises of the levels that are lower than the AC threshold level measured in the test ear with N n-1 (ALn-1); i.e., **Nn < ALn-1**.
3. The plateau should be reached.
   *Even if the measured thresholds are considered the true thresholds theoretically, clinically, we should ensure that the thresholds remain stable in increasing or decreasing the noise levels. The actual measurement PW should be larger than or equal to 15 dB.

**** Further note ****

*) If the AC threshold is elevated only by 5 dB (AL1 = AL0 + 5), the AL0 should be considered the true threshold, considering the central overmasking effect.

*) If the true AC threshold is out of the limit as in **Fig. 8-29 (c)**, the plateau cannot be identified.

(2) Masking procedure for BC in [A-1']

Fig. 8-30 shows the basic audiogram **[A-1']** wherein the true AC thresholds in the left ear (AL*) have been established. Let us consider masking for BC in the following two cases:

a) AL0 = AL*: Patterns [1], [2], or [3] series 250, 500, 1000 Hz.
b) AL0 < AL*: Pattern [4] series 2000, 4000 Hz.

Since Rt AA gaps are large, it can be predicted that masking for the left BC is easy. The true BC thresholds in the left ear (BL*) are shown in **[A-1"]**. These configurations are basic cases.

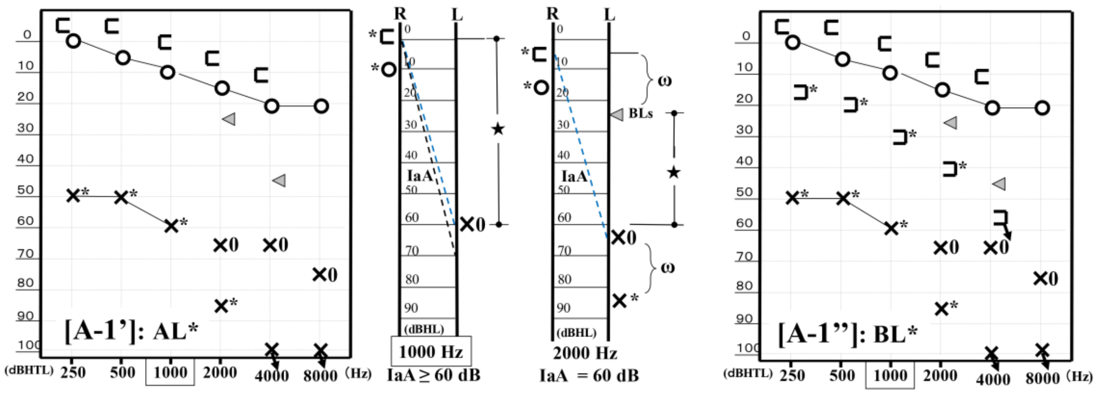


Figure 8-30 Basic audiograms [A-1'] and [A-1"]

a) AL0 = AL*

The configuration at **1000 Hz** (Rt AA gap = 50 dB) is either a pattern [1], [2], or [3] series. The basic case is set to the **pattern [3']** (BL* = 30 dB HTL, IaA = 70 dB > Lt AOB gap) (**Fig. 8-31 [a]**). The range of the left ear's true BC threshold possible is 0 dB HTL ≤ BL* ≤ 60 dB HTL.

When the initial masking noise level (**N1 = 30 dB HL** = [AR0] + 20, α1 = 20 dB) is used (**Fig. 8-31 [b]**), the left ear's BC threshold measured with N1 (BL1) is 20 dB HTL (BL0 < BL1). Then, the noise level is increased by the amount of the measured BC threshold elevation (θ1 = BL1 − BL0 = 20 dB).

When **N2 = 50 dB HL** (= N1 + θ1) (**Fig. 8-31 [b']**), BL2 is 30 dB HTL (BL1 < BL2, θ2 = 10 dB). The noise level is increased by 10 dB (= θ2).

When **N3 = 60 dB HL** (= N2 + θ2) (**Fig. 8-31 [b"]**), BL3 is 30 dB HTL (= BL2). Since the measured threshold remains stable, BL2 is considered the true threshold. Clinically, the BC threshold should be retested as the noise level is increased by 10 dB (N4 = 70 dB HL). It should be ensured that there are no threshold elevations (BL4 = BL3 = BL2): the bMPW is 20 dB. We can conclude that the BL2 is the true threshold. At this point, the configuration is found to be the patterns [3] series.

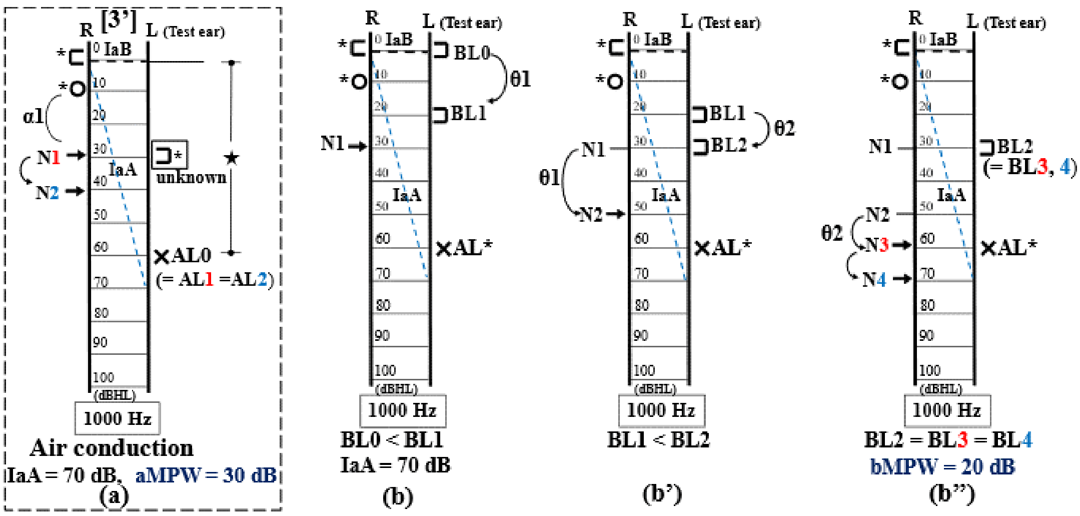


Figure 8-31 Masking for BC in [A-1']: the clinical procedure in the pattern [3']

**** Further note ****

*) The initial effective amount of masking (α1) may be set to 30 dB.

*) The configuration cannot be determined whether it is pattern [3] or [3'].

At 1000 Hz, the basic case is a pattern [3’] , the 2nd case is a pattern [3], the 3rd case is a pattern [1’], and the 4th case is a pattern [1]. As shown in **Fig. 8-32 (a)**, **(b)**, if the configuration at 1000 Hz is either a pattern [3’] (δ = 10 dB) or [3] (δ = 0 dB), a wide plateau width (Lt BPW ≥ 50 dB) can be obtained. Furthermore, in pattern [1] series, Lt BPWs are also wide (**Fig. 8-32 [c]**, **[d]**). Lt BPWs in patterns [2] and [2’] are the same as those in patterns [1] and [1’].

Therefore, masking for AC and BC is easy to perform because Rt AA gaps are large in [A-1].

Patterns [3] and **[1] series (AL0 = AL*, Rt AA gap ≥ 40 dB)**

IaA and δ values cannot be determined: IaA ≥ Lt AOB gap, δ = IaA − Lt AOB gap ≥ 0 dB.

Pattern [3’]: Lt APW = Rt AA gap + δ + Lt SNC. **Pattern [3]**: Lt APW = Rt AA gap + Lt SNC.

Pattern [1’], **[2’]**: Lt APW = Rt AA gap + δ. **Pattern [1]**, **[2]**: Lt APW = Rt AA gap.

Pattern [1’], **[2’], [3’]**: Lt BPW = Rt AA gap + δ. **Pattern [1]**, **[2]**, **[3]**: Lt BPW = Rt AA gap.

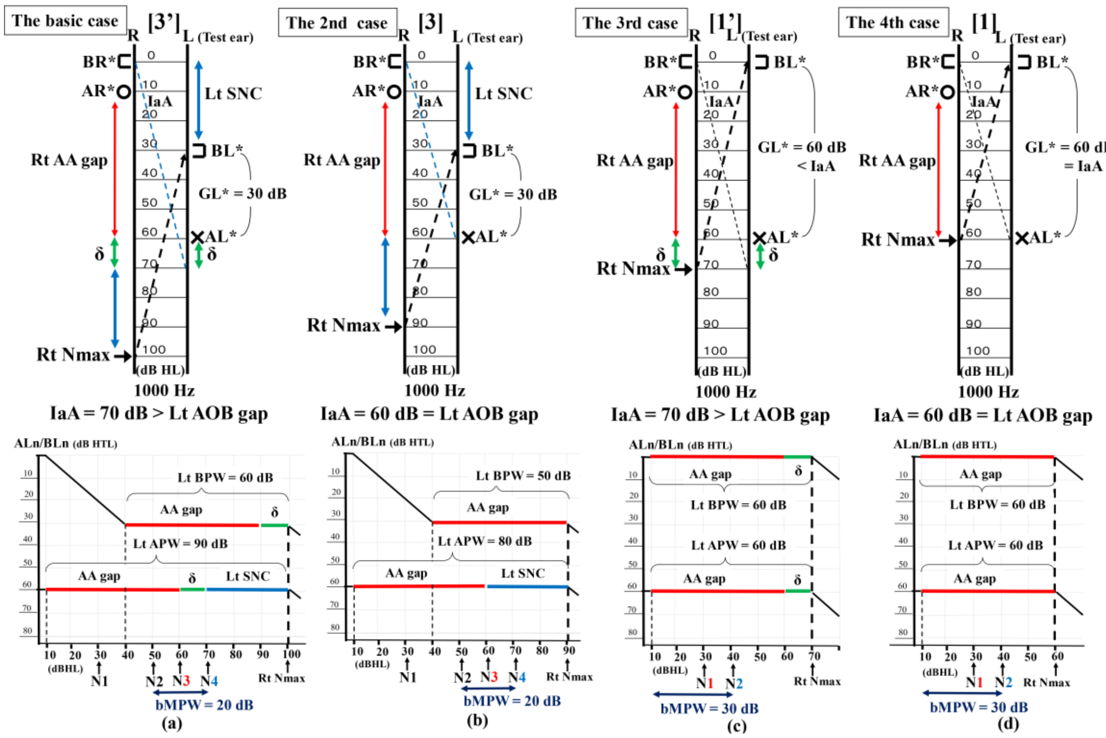


Figure 8-32 Plateau graphs of patterns [3] and [1] series (Rt AA gap = 50 dB)

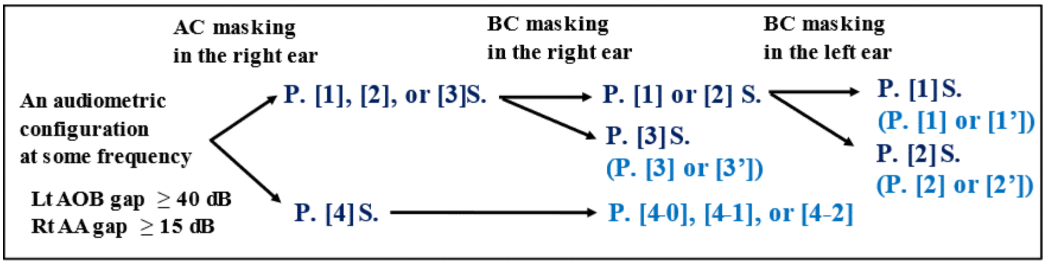


Figure 8-33 General description of the masking procedure

In patterns [1] and [2] series, when the apparent AB gaps are larger than or equal to 15 dB in the better ear by AC (GR0 ≥ 15 dB), the true BC thresholds in that ear need to be obtained (cf. **8.4-4**).

**** Further note ****

*) Compare **Fig. 8-32** with **Fig. 8-43** (Rt AA gap of 20 dB).

) If this configuration is the pattern [3’] (δ = 10 dB) and the left (test) ear has profound sensorineural deafness (BL = 50 dB THL), Rt Nmax (= 120 dB HL) exceeds the maximum output level of the noise (NN = 100 dB HL). Therefore, the actual BPW (40 dB) is smaller (narrower) by 20 dB than the theoretical BPW of 60 dB.

b) AL0 < AL*

The configuration at **2000 Hz** (Rt AA gap = 50 dB) is a pattern [4] series (AL0 < AL*). The basic case is set to the **pattern [4-0]** (BL* = 40 dB HTL, GL* = 45 dB < IaA) (**Fig. 8-34 [a]**). BR0 is the true threshold, IaA is 60 dB (= Lt AOB gap), and the minimum level of the left ear's true BC thresholds possible (BLs) is 25 dB HTL: 25 dB HTL ≤ BL* ≤ 60 dB HTL.

If the present method is used (**Fig. 8-34 [b]**), theoretically, the left ear's true BC threshold can be determined with N2 of 100 dB HL, which will give an excessive noise load on the non-test ear. Clinically, as shown in **Fig. 8-34 (c)**, N1 is set to 65 dB HL (= [AL0]) and BL1 of 40 dB HTL is obtained. The alternative standard of BC threshold is BL0 (θn = BLn − BLn-1, n = 1, 2, …). When the noise level is increased by the amount of the BC threshold elevation (θ1 = 35 dB), N2 of 100 dB HL has a large load on the non-test ear. Therefore, as the noise level is increased in 10-dB steps, it should be ensured that there are no threshold elevations (BL3 = BL2 = BL1 = BL*) (**Fig. 8-34 [c']**). Since GL* = 45dB < IaA, the configuration is found to be the pattern [4-0].

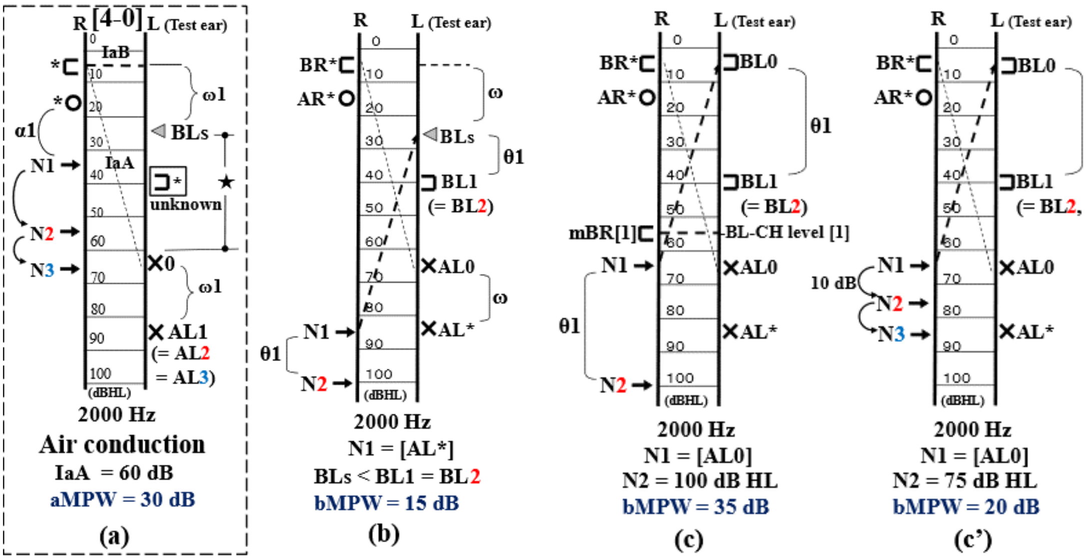


Figure 8-34 Masking for BC in [A-1']: the procedure in the pattern [4-0] at 2000 Hz

The configuration at **4000 Hz** (Rt AA gap = 45 dB) is also the pattern [4] series. The basic case is set to the **pattern [4-2]** (both the AC and BC thresholds are S.O.) (**Fig. 8-35 [a]**). BR0 = BR*, IaA = 55 dB, and BLs = 45 dB HTL (45 dB HTL ≤ BL* ≤ 60 dB HTL). The N1 of the present method is 100 dB HL, which will also give an excessive noise load on the non-test ear (**Fig. 8-35 [b]**). Thus, clinically, N1 is set to 65 dB HL (= [AL0]) and BL1 of 55 dB HTL is obtained (**Fig. 8-35 [c]**). Then the noise level is increased in 10-dB steps and the measured BC thresholds are scaled-out (BL3 = BL2 = S.O.) (**Fig. 8-35 [c']**). If the true BC threshold is beyond the limit, the BC plateau cannot be determined. Thus, the configuration is found to be the pattern [4-2] (cf. **Fig. 8-36 [c]**).

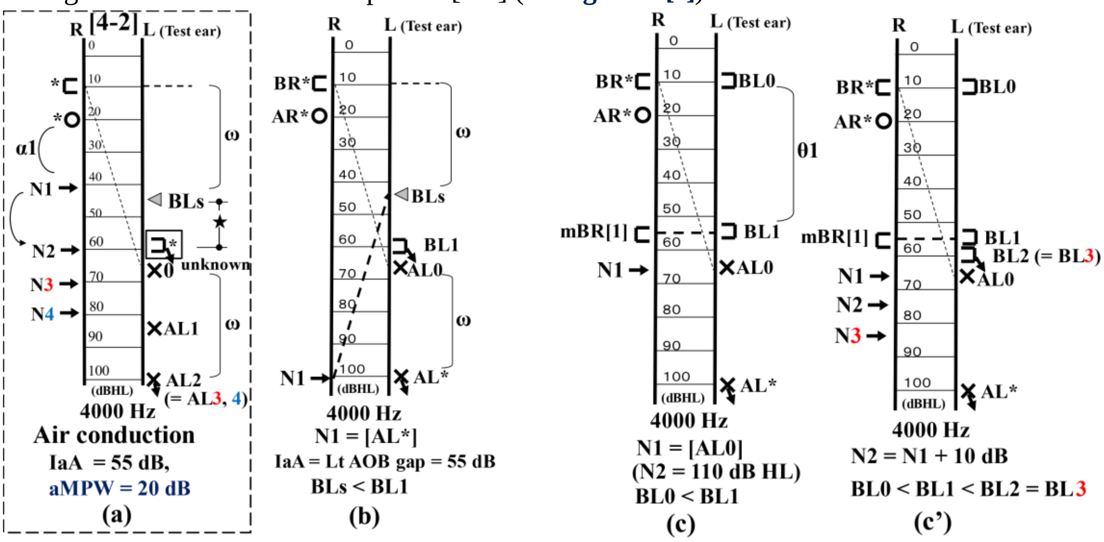


Figure 8-35 Masking for BC in [A-1']: the procedure in the pattern [4-2] at 4000 Hz

At **2000 Hz**, the basic case is a pattern [4-0] (GL* < IaA), and the 2nd case is a pattern [4-1] (GL* = IaA) ((**Fig. 8-36 [a]**, **[b]**). If the true AC and BC thresholds are within the measurement limits, sufficient plateau widths will be obtained. Theoretically Lt BPW = 50 dB = Rt AA gap.

The basic case at **4000 Hz** is a pattern [4-2] (**Fig. 8-36 [c]**), wherein the true AC and BC thresholds are beyond the measurement limits, hence, the plateaus cannot be determined. When the measured threshold levels are elevated with direct proportion to the noise levels and turn out to be the scaled-out levels, the possibility of OM should be watched out for. For the present case, since the Rt AA gap is large (= 45 dB), masking can be done using the noises that do not cause OM evidently. Therefore, we can conclude that both the true AC and BC thresholds are scaled-out levels (i.e., complete hearing impairment). Cases with small AA gaps (< 15 dB) will be discussed later.

Pattern [4] (AL0 < AL*, AA gap ≥ 40 dB)

Since the IaA value is 60 dB (i.e., IaA = Lt AOB gap), δ = (IaA − Lt AOB gap) = 0 dB.

Pattern [4-0]: Lt APW = Rt AA gap + (Lt SNC − ω).
= Rt AA gap + (IaA − GL*).
= (IaA − GR*) + (IaA − GL*).

Pattern [4-0]: Lt BPW = Rt AA gap.

Pattern [4-1]: Lt APW = Rt AA gap.

Pattern [4-1]: Lt BPW = Rt AA gap.

Pattern [4-2]: Lt PWs are not present.

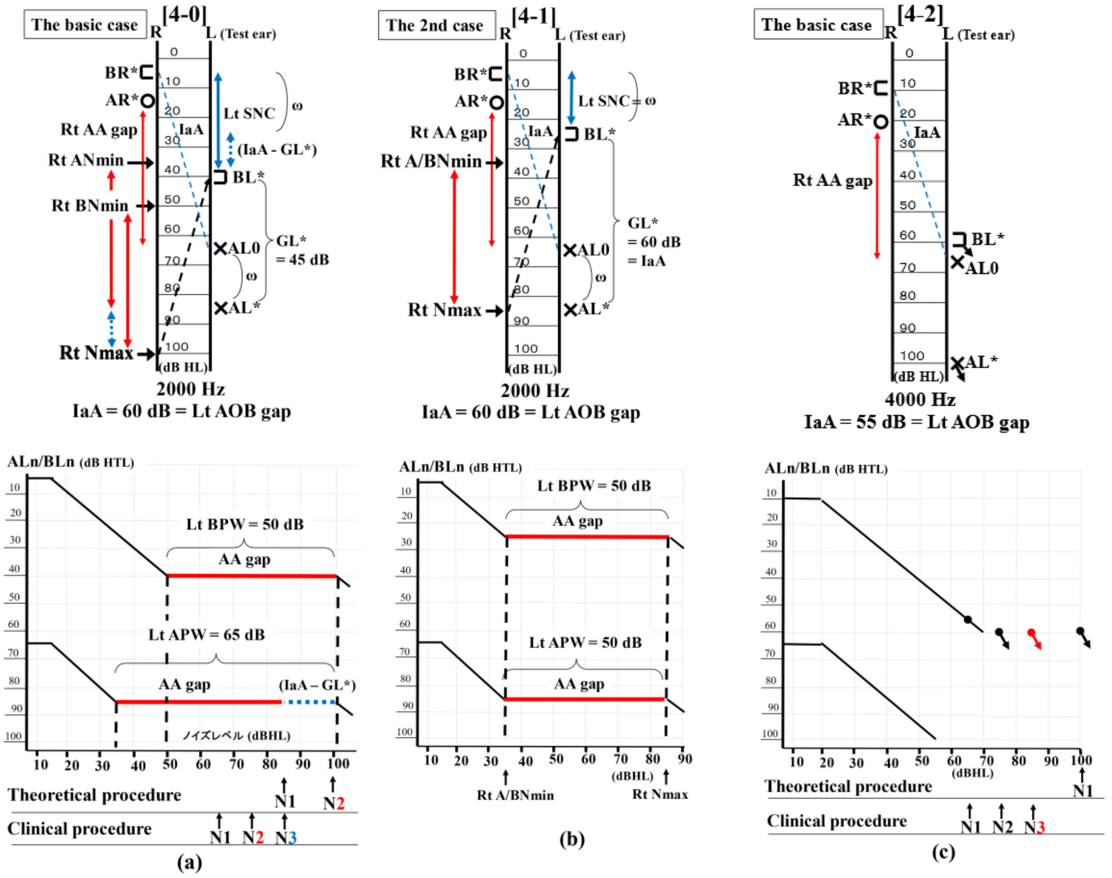


Figure 8-36 Plateau graphs of the pattern [4] series (Rt AA gap ≥ 45 dB)

**** Further note ****

) It is automatically determined that BR0 is equal to BR in the pattern [4] series.

*) It can be determined whether the measured thresholds are the SH thresholds or not by calculating the masked BC threshold in the non-test ear and the BL-CH level. However, it is more practical that we ensure there is no threshold elevation or achieving the plateau with the noise levels changed.

*) If the error of BLs is large, that of θ1 is also large. N2 will have many errors. When N1 of [AL0] is used, the calculation of BLs can be excluded. The alternative standard of BC threshold is BL0.

) When AL is S.O. and BL* is 50 dB HTL, its configuration is a pattern [4]. In addition, when AL* is SO., since ω > 35 dB, exactly BLs > 45 dB HTL.

8.4-2 Masking in [B-1]: 15 dB ≤ Rt AA gap < 40 dB, Lt AOB gap ≥ 40 dB

(1) Masking procedure for AC in [B-1]

Fig. 8-37 shows the basic audiogram **[B-1]**. The apparent AC threshold in the left ear (AL0) might be the SH threshold because Lt AOB gap ≥ 40 dB. Thus, Masking for the left AC is needed. If the Rt AA gaps are small, it can be predicted that masking for the left AC might be difficult. The true AC thresholds in the left ear are shown in **[B-1']**.

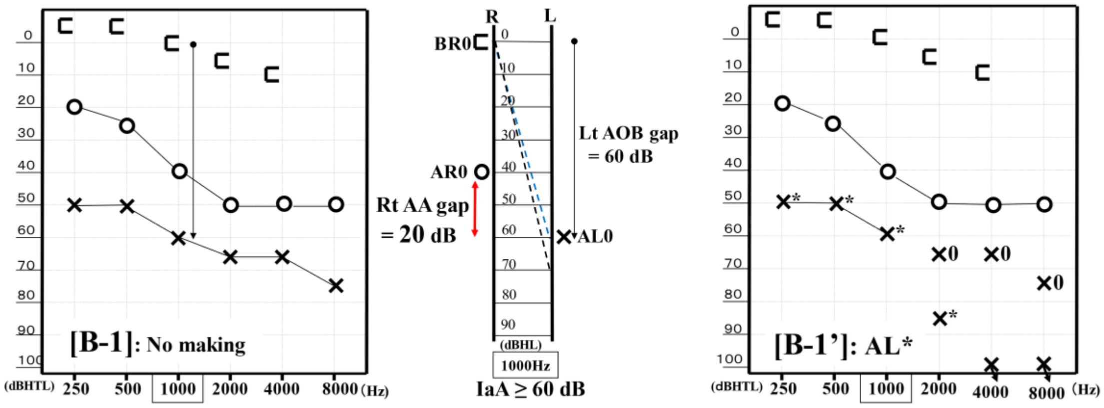


Figure 8-37 Basic audiograms in [B-1] and [B-1']

< Clinical masking procedure in [B-1] >

The basic procedure is the same as that of **[A-1]**. N1 is set to the level 10 dB above the non-test ear's AC threshold (**N1 = ([AR0] + 10) dB HL**, **α1 = 10 dB**), and is increased in 10-dB steps. When AA gaps are small (≤ 20 dB), the noise step for confirmation is 5 dB.

At **1000 Hz** (Rt AA gap = 20 dB) (**Fig. 8-38 [a]**): when N1 is 50 dB HL (= [AR*] +10), AL1 of 60 dB HTL is obtained (AL1 = AL0). AL0 is considered the true threshold. Furthermore, increasing the noise level by 5 dB (N2 = 55 dB HL), the measured threshold remains stable (AL2 = AL1 = AL0). We can conclude that AL0 is the true threshold. This configuration is found to be any one of the patterns [1], [2], and [3] series.

At **2000 Hz** (Rt AA gap = 15 dB) (**Fig. 8-38 [b]**): when N1 is 60 dB HL, AL1 is 75 dB HTL (AL0 < AL1). The noise level is elevated by the amount of the AC threshold elevation (ω1 = 10 dB): when N2 = 70 dB HL, AL2 is 85 dB HTL (AL1 < AL2, ω2 = 10 dB). Next, when N3 is 80 dB HL (N2 + ω2), the measured threshold remains stable (AL3 = 85 dB HTL = AL2). Furthermore, the noise level is elevated by 5 dB (N4 = 85 dB HL) and it should be ensured that there are no threshold elevations (AL4 = AL3 = AL2 = AL*). This configuration is found to be a pattern [4-0] or [4-1].

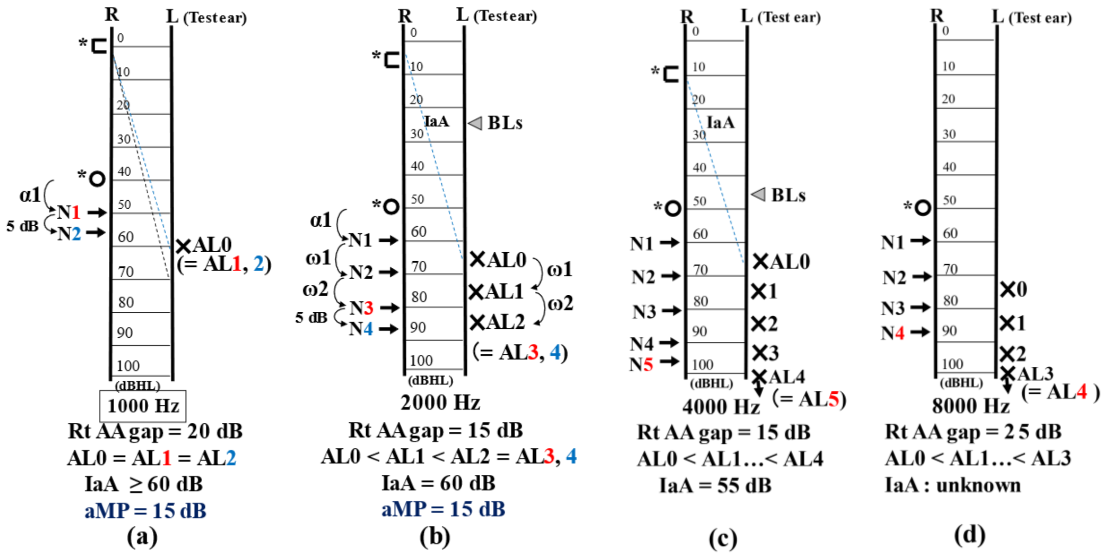


Figure 8-38 Masking for AC in [B-1] (15 dB ≤ Rt AA gaps < 40 dB): the clinical procedure

At **4000 Hz** (Rt AA gap = 15 dB) (**Fig. 8-38 [c]**), since the measured AC threshold levels are elevated with direct proportion to the noise levels, the configuration may be estimated to be a pattern [4-2].

Here, if it is a pattern [1] (**Fig. 8-39**), N1 of 60 dB HL is presented to the right ear, and its overmasking level in the left ear is as flows:

OM level [1] = 5 dB HL < BL* = 10 dB HTL.

Theoretically, N1 does not occur overmasking. However clinically, OM might occur due to the clinical conditions. Then, the measured AC thresholds are the OM thresholds and the APW is not present.

Therefore, when AA gaps are small (≤ 20 dB) and significant PWs (≥ 15 dB) cannot be identified, we must consider carefully whether the result is derived from SH (pattern [4-2]) or OM (pattern [1]). We should reserve judgement that the true AC threshold is scaled out (cf. **8.6 [2]**).

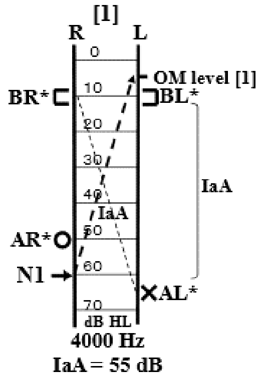


Figure 8-39 Pattern [1]

At **8000 Hz** (Rt AA gap = 25 dB) (**Fig. 8-38 [d]**), since the Rt AA gap is larger than that at 4000 Hz, even if the configuration is the pattern [1], OM might not be occurred. When the measured AC thresholds are scaled-out levels using a 5-dB step method, it may be considered that the configuration denotes a complete hearing impairment (cf. **8.6 [2]**).

When the true AC thresholds are determined, the configurations are divided into two series.

a) AL0 = AL*: Patterns [1], [2], [3] series **b) AL0 < AL***: Pattern [4] series.

a) The configuration at **1000 Hz** (Rt AA gap = 20 dB) is either a pattern [1], [2], or [3] series. **Fig. 8-40 (a)** shows a case of **pattern [3]** (BL* = 30 dB HTL, > BL0, IaA = 60 dB = Lt AOB gap). The measured AC thresholds remain stable within the noise levels from 40 dB HL (= [AR*]) to 55 dB HL (= N2): the aMPW is 15 dB. If it is a **pattern [1]** (BL* = 0 dB HTL, GL* = 60 dB = IaA), the aMPW of 15 dB is obtained since the measured AC thresholds are not elevated up to N2 of 55 dB HL (**Fig. 8-40 [b]**). Here, increasing the noise levels, although in the pattern [3] these AC thresholds are not elevated up to the noise level of 90 dB HL (= Rt Nmax), in the pattern [1] they continue to be elevated when N1 > 60 dB (= Rt Nmax) HL. From the difference of the Rt Nmax in each pattern, the true AC threshold in the test ear may be estimated to some extent before masking for BC. It should be noted that even if the Rt AA gaps are small, Lt APWs are wide as long as the Lt SNC is large.

b) The configuration at **2000 Hz** (Rt AA gap = 15 dB) is a pattern [4] series. **Fig. 8-40 (c)** shows a case of **pattern [4-0]** (BL* = 40 dB HTL, GL* = 45 dB < IaA = 60 dB). The measured AC thresholds remain stable within the noise levels from 70 dB HL (= N2) to 85 dB HL (= N4): the aMPW is 15 dB.

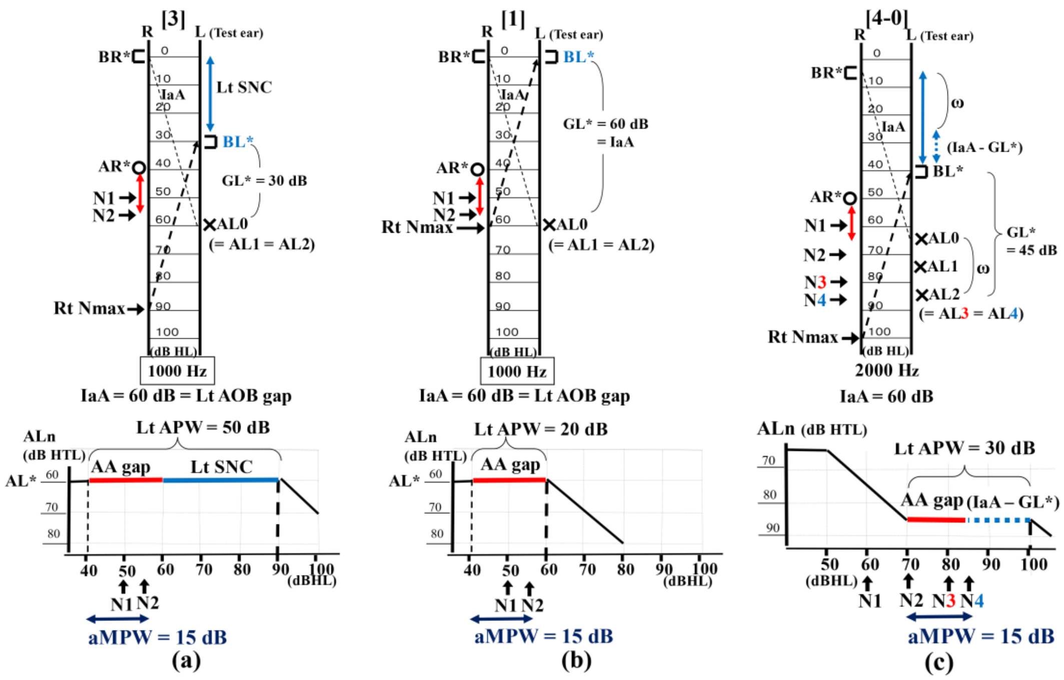


Figure 8-40 Patterns [3] and [1] series (Rt AA gap = 20 dB)

(2) Masking procedure for BC in [B-1']

Fig. 8-41 shows the basic audiogram **[B-1']** where the true AC thresholds in the left ear have been established. Let us consider masking for BC in the following two cases:

a) AL0 = AL*: patterns [1], [2], and [3] series 250, 500, 000 Hz

b) AL0 < AL*: pattern [4] series 2000, 4000, 8000 Hz

Since the Rt AA gaps at 2000 and 4000 Hz are only 15 dB (Lt BPW ≥ 15 dB), it can be predicted that masking for the left BC will be difficult. The left ear's true BC thresholds (BL*) are shown in **[B-1"]**.

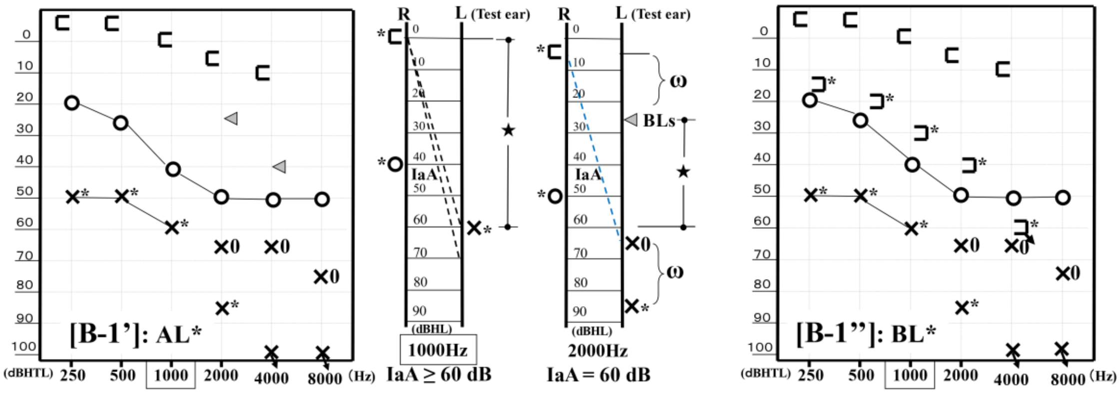


Figure 8-41 Basic audiograms in [B-1'] and [B-1"]

a) AL0 = AL*

The configuration at **1000 Hz** (Rt AA gap = 20 dB) is either a pattern [1], [2], or [3] series. The basic case is set to the **pattern [3']** (BL* = 30 dB HTL, IaA = 70 dB > Lt AOB gap) (**Fig. 8-42 [a]**). The range of the left ear's true BC threshold possible is 0 dB HTL ≤ BL* ≤ 60 dB HTL. As shown in **Fig. 8-42 (b)**, the initial masking noise level (N1 = [AR*] + 10 = 50 dB HL, α1 = 10 dB) is used, and the noise level is increased in 10-dB steps. When N2 is 60 dB HL, BL2 is 20 dB HTL. When N3 is 70 dB HL, BL3 of 30 dB HTL is obtained, and the plateau has been reached with N4 and N5 (BL3 = BL4 = BL5 = BL*). Thus, the configuration is found to be a pattern [3] series.

In **Fig. 8-42 (c)**, N1 is set to the level 15 dB above AR* (α1 = 15 dB), in which masking efficiency is improved a little. **Fig. 8-42 (d)** shows the present method (N1 = [A+*], α1 = 20 dB) (cf. **Fig. 8-43 [a]**). Among the three procedures, the one in 10-dB steps has the advantage of lesser load on the non-test ear, although it entails many noise steps (**Fig. 8-42 [b]**).

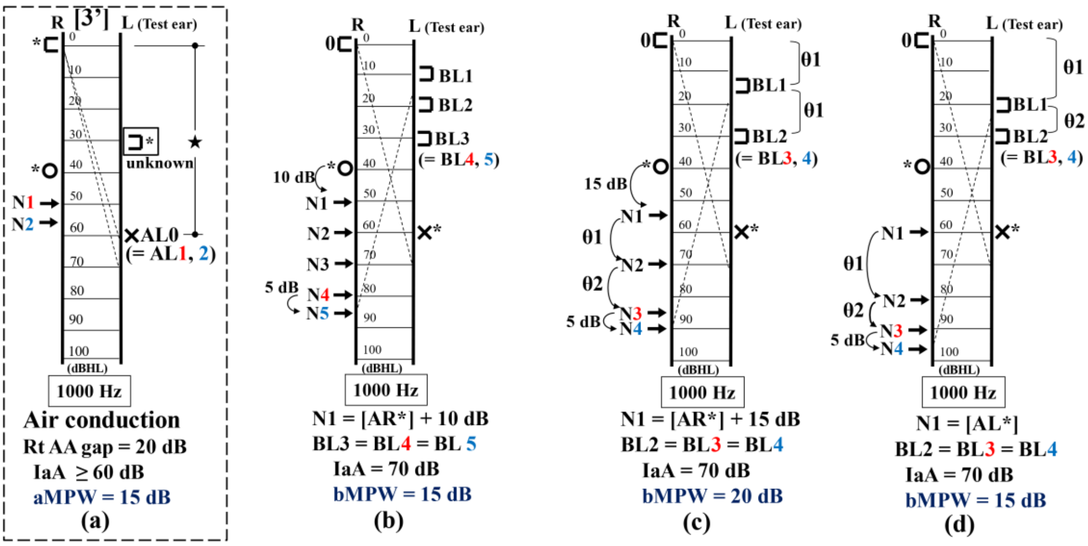


Figure 8-42 Masking for BC in [B-1']: the clinical procedure in the pattern [3']

**** Further note ****

*) the configuration cannot be determined whether it is the pattern [3] or [3'].

*) It is recommended that masking should be done at frequencies with wide AA gaps (cf. **7.6**).

At 1000 Hz, the basic case is a pattern [3’] , the 2nd case is a pattern [3], the 3rd case is a pattern [1’], and the 4th case is a pattern [1] (**Fig. 8-43**).

For pattern [3] series, even if the true BC thresholds in the test ear are difficult to identify due to narrow BPWs, they may be estimated using the OM method, as long as the true AC thresholds in the test ear are determined (**Fig. 8-43 [a]**, **[b]**).

However, for pattern [1] series, since Lt APW is equal to Lt BPW, as the Rt AA gap and δ get smaller, Lt APW becomes narrower and is difficult to identify (**Fig. 8-43 [c]**, **[d]**). Consequently, the true BC threshold is also difficult to determine. This will be addressed in **8.6**.

For pattern [2] series, the PWs for AC and BC in the poorer ear by AC are equal to those of pattern [1] series.

Pattern [3], **[1] series** (AL0 = AL*, 15 dB ≤ Rt AA gap ≤ 40 dB)
IaA ≥ Lt AOB gap, δ = IaA − Lt AOB gap ≥ 0 dB.
The configuration at 1000 Hz in [B-1’’] is either a pattern [3] or [3’], since BR* < BL*.
When BR* = BL*, its configuration is any one of the patterns [1], [1’], [2] and [2].

Pattern [3’]: Lt APW = Rt AA gap + δ + Lt SNC. **Pattern [3]**: Lt APW = Rt AA gap + Lt SNC.
Pattern [1’], **[2’]**: Lt APW = Rt AA gap + δ. **Pattern [1]**, **[2]**: Lt APW = Rt AA gap.
Pattern [1’], **[2’]**, **[3’]**: Lt BPW = Rt AA gap + δ. **Pattern [1]**, **[2]**, **[3]**: Lt BPW = Rt AA gap.

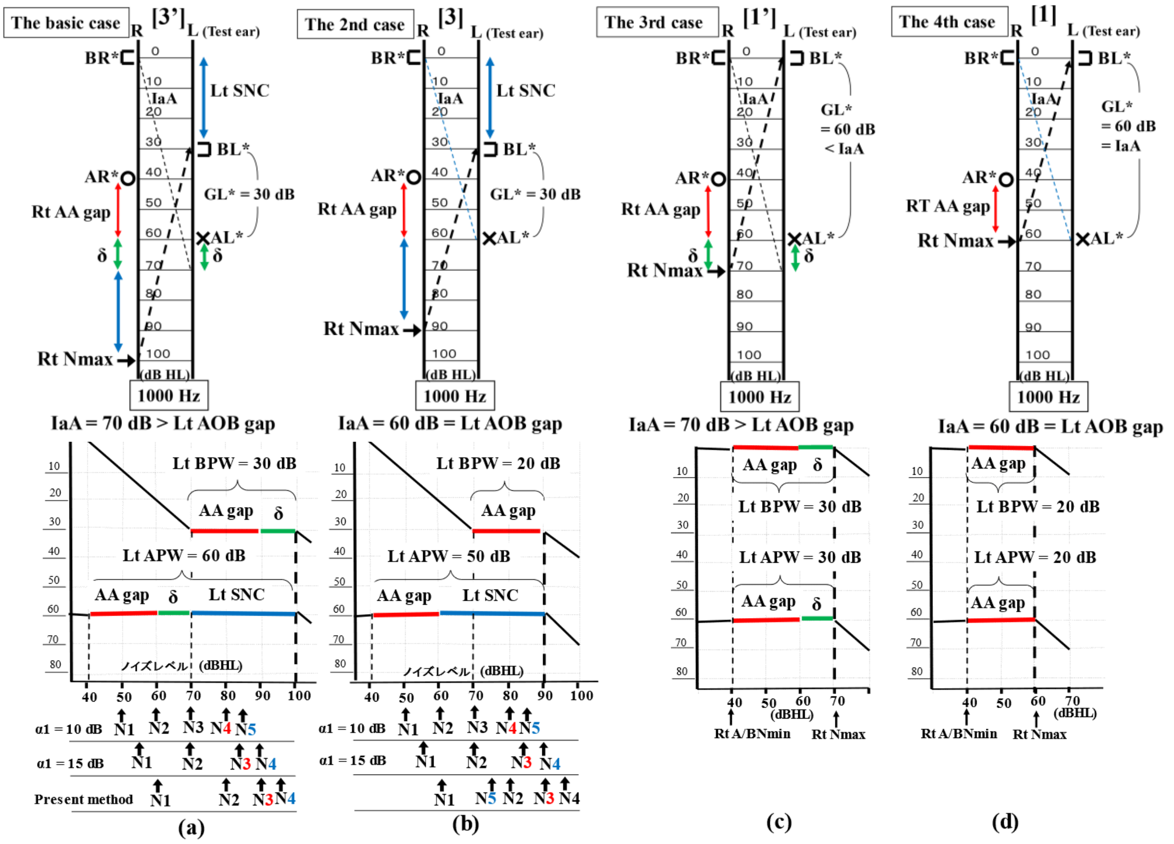


Figure 8-43 Plateau graphs of patterns [3] and [1] series (Rt AA gap = 20 dB)

** Further note **

*) Compare **Fig. 8-43** with **Fig. 8-32** (Rt AA gap = 25 dB). The configurations with small AA gaps in [B-1] and [C-1] are reviewed in **8.6**.

*) In **Fig. 8-43 (b)**, according to the present method, overmasking occurs when N4 of 95 dB HL is presented to the right ear for confirmation. Therefore, N5 of 75 dB HL should be used.

b) AL0 < AL*

The configuration at **2000 Hz** (Rt AA gap = 15 dB) is a pattern [4] series. The basic case is set to the **pattern [4-0]** (BL* = 40 dB HTL, GL* = 45 dB < IaA) (**Fig. 8-44 [a]**). BR0 = BL*, IaA = 60 dB (= Lt AOB gap), and BLs = 25 dB HTL (25 dB HTL ≤ BL* ≤ 60 dB HTL). Since Rt AA gap is only 15 dB, masking for BC can be predicted to be difficult (**Fig. 8-44 [c]**).

If the present method is used (**Fig. 8-44 [b]**), when N1 is 85 dB HL (= [AL*]), BL1 is obtained as 40 dB HTL (θ1 = BLs − BL1 = 15 dB), and when N2 is 100 dB HL (= N1 + θ1), BL2 is equal to BL1. Theoretically, the true BC threshold in the test ear can be identified. However, in fact, the BLs (= BR0 + AL* − AL0) may not be accurately determined due to the measurement errors of the AC and BC thresholds. Therefore, the theory is not always consistent with practice.

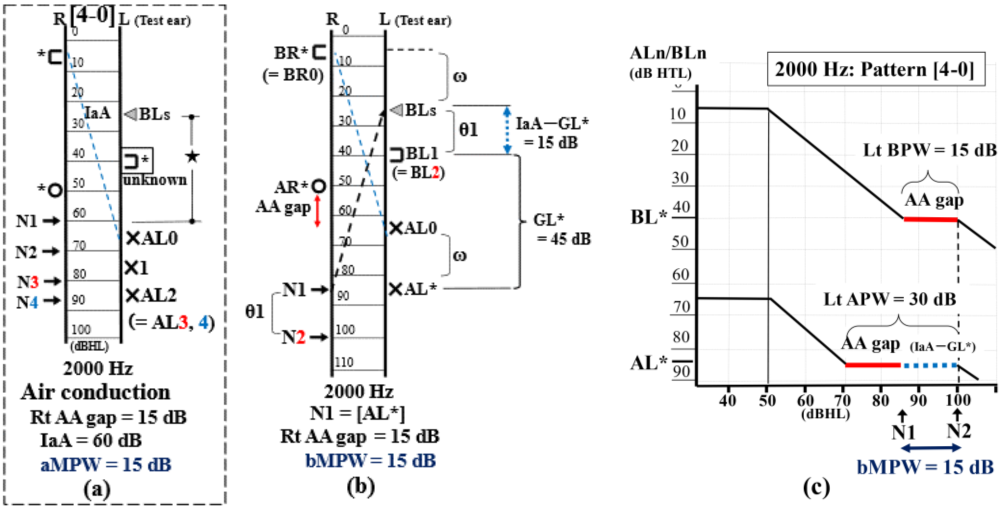


Figure 8-44 Masking for BC in [B-1']: the present method in pattern [4-0]

Thus, clinically, as is the case with **[A-1']** (cf. **Fig. 8-34 [c]**, **[c']**), N1 of 65 dB HL (= [AL0]) should be used (**Fig. 8-45 [a]**). The calculation of BLs can be excluded. The alternative standard of BC threshold is BL0 (θn = BLn − BLn-1, n = 1, 2, …). When N2 is 80 dB HL (= N1 + θ1), BL2 is 35 dB HTL (θ2 = 15 dB). As the noise level is increased, the plateau has been reached with N3 of 95 dB HL and N4 of 100 dB HL (BL3 = BL4 = 40 dB HTL): the bMPW = 5 dB.

In order to confirm the significant PW, the BC threshold should be retested by increasing or decreasing the noise level in 5-dB steps (**Fig. 8-45 [a']**, **[b]**). Since N5 of 105 dB HL is out of the limit (NN = 100 dB HL), the BC thresholds are measured with N6 of 90 dB HL and N7 of 85 dB HL. The bMPW proves to be 15 dB. The configuration is found to be the pattern [4-0]. If the significant BPW cannot be identified due to the clinical plateau contraction, the OM method should be used (cf. **Fig. 8-46 [a]**).

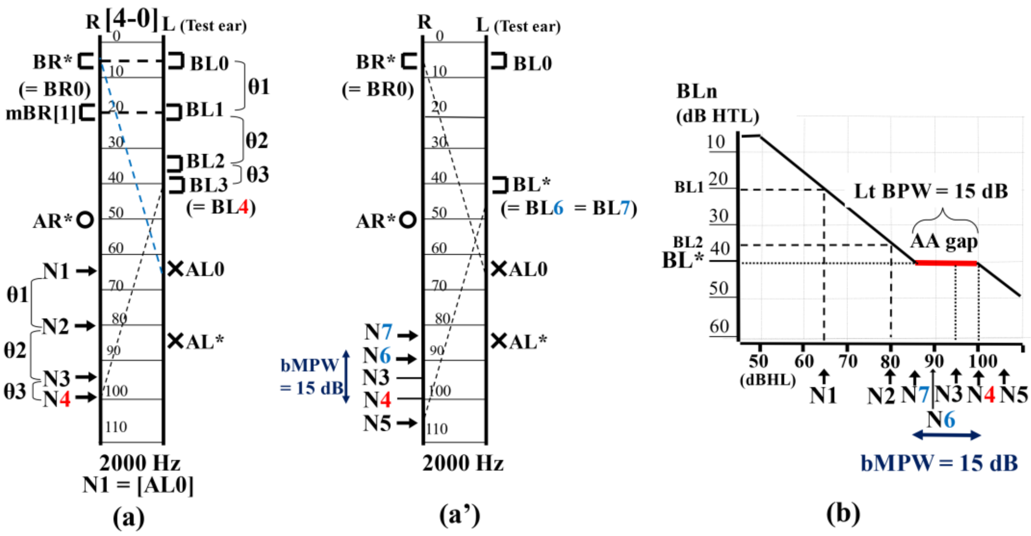


Figure 8-45 Masking for BC in [B-1']: the clinical procedure in the pattern [4-0]

At **2000 Hz**, the basic case is a pattern [4-0] (GL* = 45 dB < IaA), and the 2nd case is a pattern [4-1] (GL* = 60 dB = IaA) (**Fig. 8-46 [a]**, **[b]**). In theory, Lt BPW = Rt AA gap = 15 dB.

At **4000 Hz** (Rt AA gap = 15 dB), the basic case is a pattern [4-2] (GL* = 60 dB = IaA), where the measured thresholds in the left ear continue to be elevated directly proportional to the noise levels and prove to be scaled out levels for both AC and BC (**Fig. 8-46 [c]**). The noises occur undermasking and the measured thresholds are the SH thresholds.

When AA gaps are small (**[B-1]**: Rt AA gap = 15 dB) (**Fig. 8-46 [c]**), this pattern must be differentiated from the pattern [4-1] in **Fig. 8-46 (b)**, because the clinical plateau contraction makes their district difficult. Configurations in which masking is clinically difficult or impossible are addressed in **8-6**. However, when AA gaps are large (**[A-1]**: Rt AA gap = 45 dB, pattern [4-2]) (cf. **Fig. 8-29 [c]**, **8-36 [c]**), the results are reliable because the masking noises at which OM evidently never occurs can be used.

Pattern [4] (AL0 < AL*, 15 dB ≤ Rt AA gap ≤ 40 dB)

IaA = Lt AOB gap, δ = IaA − Lt AOB gap = 0 dB

Pattern [4-0]: Lt APW = Rt AA gap + (Lt SNC − ω)
= Rt AA gap + (IaA − GL*)
= (IaA − GR*) + (IaA − GL*).

Pattern [4-0]: Lt BPW = Rt AA gap.

Pattern [4-1]: Lt APW = Lt BPW = Rt AA gap.

Pattern [4-2]: no plateau presents.

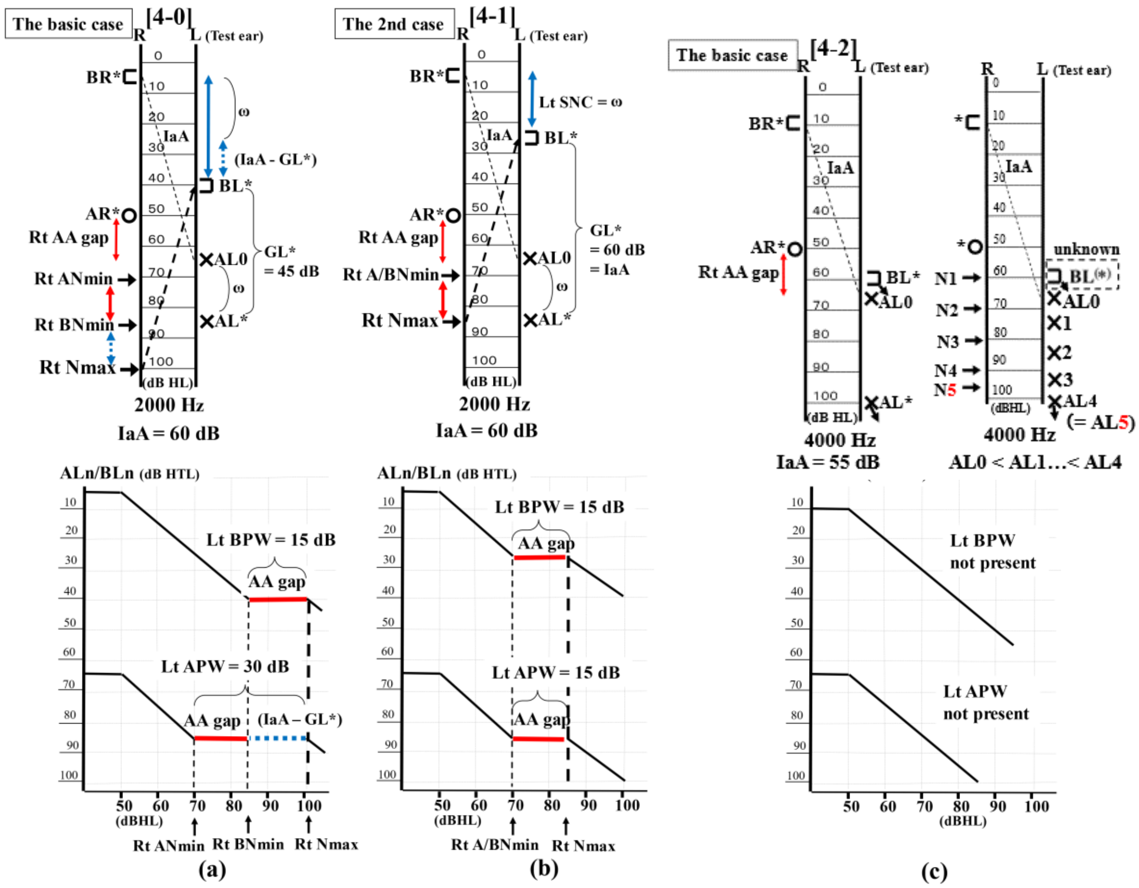


Figure 8-46 Plateau graphs of pattern [4] series (Rt AA gap = 15 dB)

**** Further note ****

*) Compare **Fig. 8-46** with **Fig. 8-36** (Rt AA gap ≥ 45 dB).

8.4-3 Masking in [B-2]: 15 dB ≤ Rt AA gap, 15 dB ≤ Lt AOB gap < 40 dB

(1) Criteria for masking

The audiometric patterns, in which Lt AOB gaps are < 40 dB, are three, and the apparent BC threshold in at least one ear is the true threshold (**Fig. 8-47**). AL0 cannot possibly be the SH threshold. Thus, masking for the left AC is not needed. Since Lt AOB gaps are ≥ 15 dB, masking for the left BC is needed.

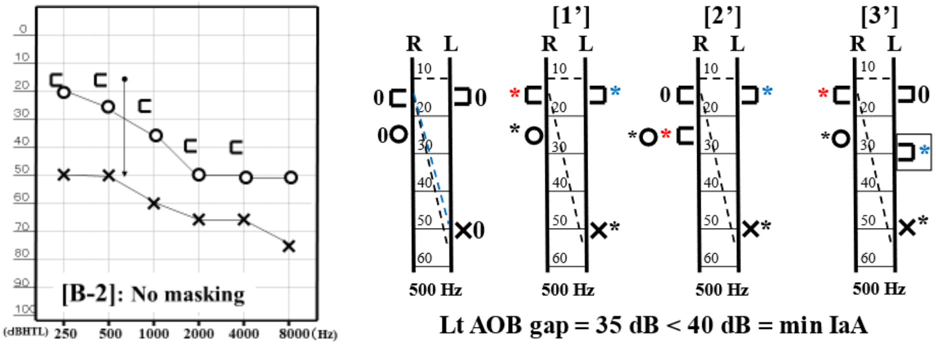


Figure 8-47 Basic audiogram [B-2] and audiometric configurations (Lt AOB gap < 40 dB)

(2) Masking procedure for BC in [B-2]

To take the case of the pattern [3'] in **Fig. 8-47** (BL* = 30 dB HTL), the right ear will be masked. Since Lt AOB gap at 500 Hz = 35 dB < 40 dB, N1 is set to Nx (the maximum level of masking noise at which OM does not occur in any case, assuming the minimum IaA value of 40 dB) (cf. **5.5 [2]**):

N1 = Nx = BL0 + min IaA = 15 (dB HTL) + 40 (dB)
= 55 dB HL.

When N1 is presented to the right ear (**Fig. 8-48 [a]**), BL1 of 30 dB HTL is obtained (θ1 = BL1 − BL0 = 15 dB). When N2 is 70 dB HL (= N1 + θ1), BL2 is equal to BL1 (**Fig. 8-48 [b]**). If IaA is 40 dB, noises above N2 cause OM. Thus, the BC threshold should be retested with N3 (= 65 dB HL = N2 − 5) (**Fig. 8-48 [c]**). However, IaA of 40 dB is in fact extremely rare. As shown in **Fig. 8-48 (d)**, N3 of 75 dB HL may be used.

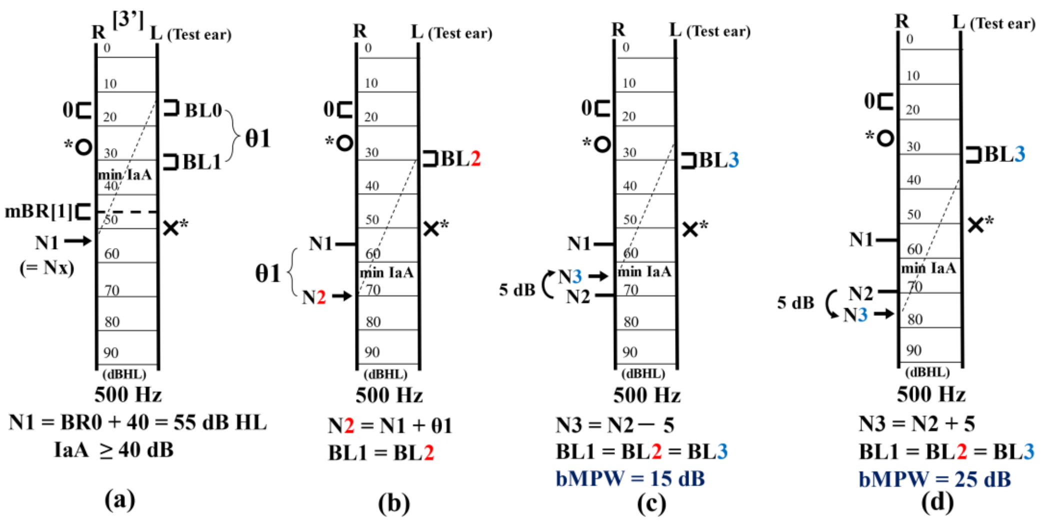


Figure 8-48 Masking procedure for BC in [B-2]

In **Fig. 8-48**, since the apparent AB gap of the right ear is 10 dB (GR0 = 10 dB), the apparent BC threshold in the right ear (BR0) is determined to be the true threshold. Masking for the right BC is not needed.

**** Further note ****

*) At low frequencies, when the conductive disorders are small (CL < 20 dB), the occlusion effect may occur (cf. **L 10**).

*) It should be reconsidered whether the minimum value of IaA is 40 dB.

*) If IaB = 0 dB, it can be estimated that BL0 is equal to BR0 without measuring BL0.

8.4-4 Cases needed to obtain the true BC threshold in the better ear by AC

It is assumed that the right ear is the better ear by AC and that there are no measurement errors (the ideal conditions, cf. **0.1**). In patterns [4] and [3] series (BL0 < BL*), the apparent BC thresholds in the right ear are always the true thresholds (BR0 = BR*) (**Fig. 8-49 [a]**, **[b]**). By contrast, in patterns [1] and [2] series (BL0 = BL*), BR0 is the true or SH threshold (**Fig. 8-49 [c]**, **[d]**). Therefore, masking for the right BC is needed.

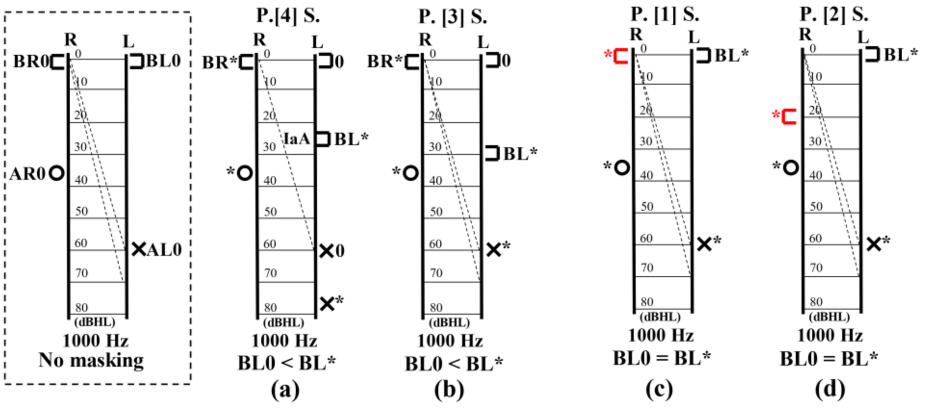


Figure 8-49 True BC thresholds in the better ear by AC

The clinical criteria for BC masking-2

Let us reconsider the clinical criteria for BC masking under actual conditions with measurement errors. Here, it is supposed that IaB is 0 dB and the errors for the BC threshold are ±5 dB (ΔB = −5, 0 or +5 dB). When the apparent AB gaps of both ears are larger than or equal to 15 dB, clinically, a simplified formula may be used as follows (cf. **4.4-2**).

In cases where the apparent AB gaps of both ears ≥ 15 dB (**Fig. 8-50 [a]**),
after the true BC threshold in the left ear (BL*) has been determined, compare BL* with BR0.
a) When the difference between BL* and BR0 is smaller than or equal to 10 dB
(BL* − BR0 ≤ 10 dB), BR0 may be the SH threshold (**Fig. 8-50 [b]**).
Therefore, masking for the right BC is needed.
b) When the difference between BL* and BR0 is larger than or equal to 15 dB
(BL* − BR0 ≥ 15 dB), BR0 can be considered the true threshold (**Fig. 8-50 [c]**).
Therefore, masking for the right BC is not needed.

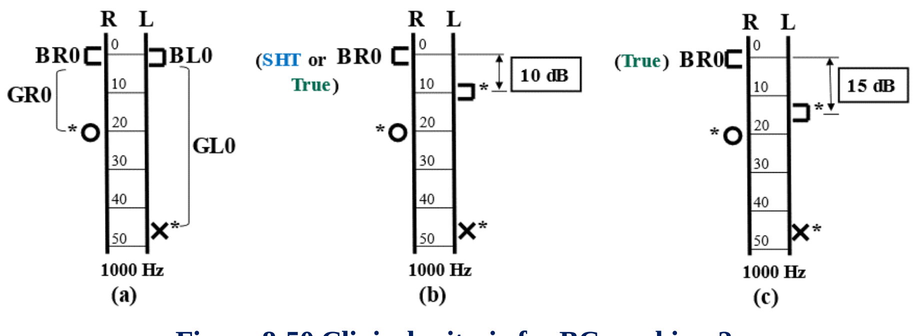


Figure 8-50 Clinical criteria for BC masking-2

For **[B-2]**, N1 of Nx may be used. However, for **[A-1']** and **[B-1']**, since the AB gaps of the left, poorer ear by AC are large (GL* ≥ 40 dB), it can be predicted that masking for the right BC may be difficult.

**** Further note ****

) When BL−BR0 ≥ 15 dB, BR0 can not be the SH threshold, assuming that the measurement errors of BR0 and BL* as −5 dB and +5 dB, respectively.

*) The above criteria vary depending on the estimate for the measurement errors of BC thresholds.

8.4-5 Efficient masking procedure for AC

The present method requires only the AC thresholds measured in the test ear to set up the masking noise levels. Hence, the BC thresholds do not need to be measured to perform masking for AC.

In **[A-0]** (**Fig. 8-51**), since Lt AOB gap ≥ 40 dB, the apparent AC thresholds in the left ear (AL0s) may be the SH thresholds. Regardless of measuring the right ear's BC thresholds, masking for AC is needed. By contrast, in **[B-0]**, unless the right ear's BC thresholds are determined, we cannot determine whether AL0s are the SH thresholds or not. However, we might suspect that AL0s are the SH thresholds based on some information. In both audiograms, after measuring the apparent AC thresholds (AR0s, AL0s), masking in the right ear may be initiated with the initial noise of the present method (N1 = [AL0]) or noises lower than N1, leaving a supra-aural earphone as it is. Note that these noises do not cause OM regardless of whether the test ear's true BC thresholds have been identified.

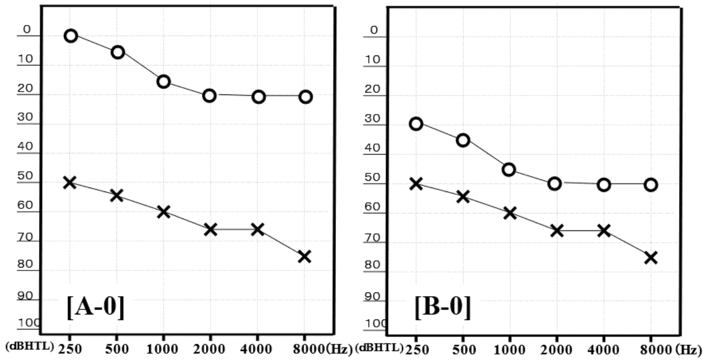


Figure 8-51 Basic audiograms [A-0] and [B-0] without masking

This technique has several advantages. **Fig. 8-52** shows the basic audiograms **[A-0']** and **[B-0']** in which the true AC thresholds in the left ear are determined with adequate masking. For example, at 2000 Hz in **[B-0']**, since the apparent AC threshold in the left ear (AL0) is the SH threshold (**Fig. 8-52 [b]**), the apparent BC threshold in the opposite, right ear (BR0) is anticipated to be the true one before measuring the right ear's BC threshold (**Fig. 8-52 [b']**).

Furthermore, we can predict the minimum level of the true BC threshold possible in the left ear (min BL* = BL0 + ω, ω = AL* − AL0) (cf. **4.1 [3]**). Specifically, we can estimate the result before measuring the BC thresholds. Moreover, the attachment and removal of the earphone can be cut through one time. Resultantly, time for measurement can be reduced. We might estimate the true BC thresholds in the test ear, bearing in mind the AC plateaus in **Fig. 8-53** on the next page.

When the SH thresholds for AC are obtained, it is recommended to write down these thresholds on the audiogram (a proposal of Isogai). Then, we can decide whether the masking procedure is right or wrong.

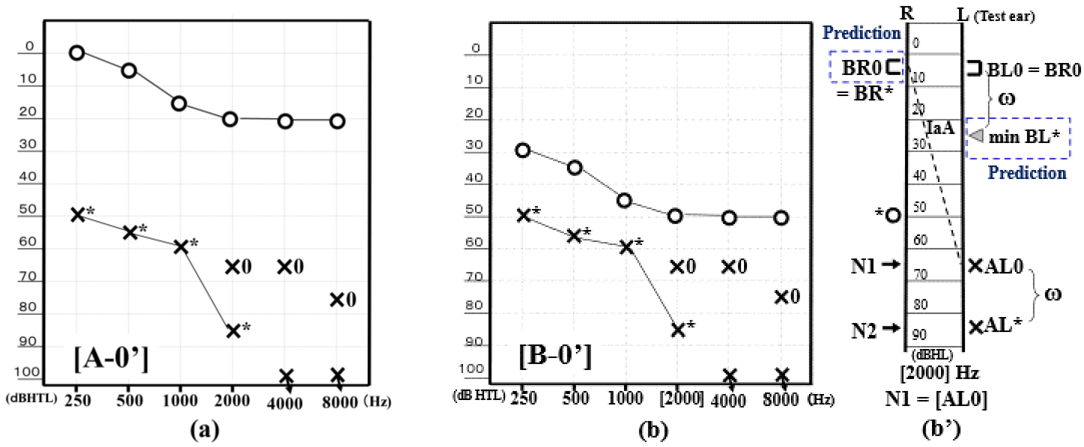


Figure 8-52 Basic audiograms [A-0'] and [B-0'] after masking for the left AC

**** Further note ****

*) Some information: for example, the case where an individual complaints of acute profound hearing impairment in the left ear with chronic otitis media in the right ear.

When the apparent AC thresholds differ significantly, typical AC plateaus will be obtained in patterns [4-0] and [4-1] (**Fig. 8-53**). The IaA values can be determined (IaA = Lt AOB gap).

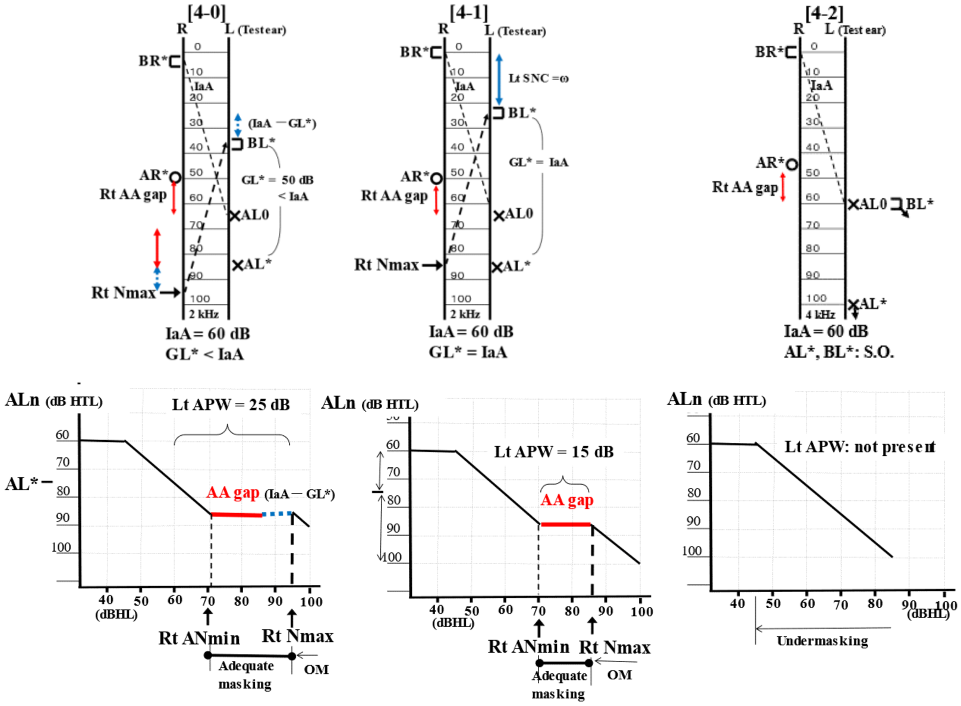


Figure 8-53 Typical AC plateaus

In patterns [3] and [1] series, atypical AC plateaus are obtained (**Fig. 8-54**). we only know that IaA ≥ Lt AOB gap. At 250, 500, and 1000 Hz in **[A-0']** and **[B-0']**, the configurations are patterns [3], [1], or [2] series. We might estimate the true BC thresholds in the test ear (BL*) by the level of the Nmax in each pattern.

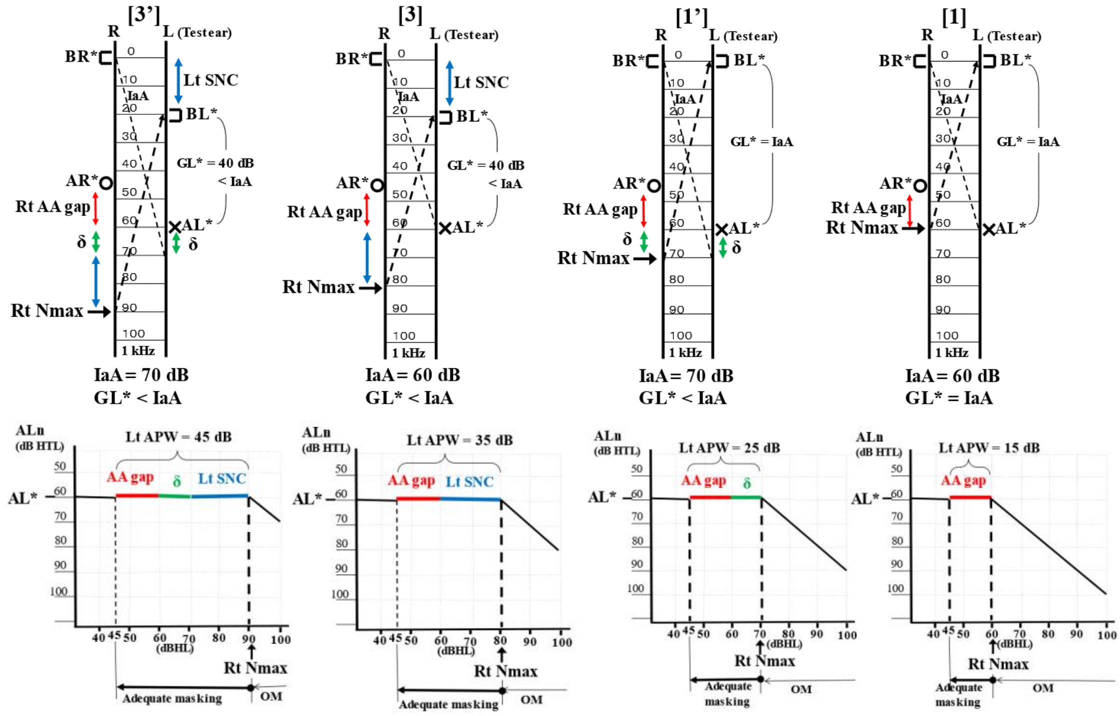


Figure 8-54 Atypical AC plateaus

**** Further note ****

*) Both Lt APWs and BPWs in pattern [2] series are the same as those in the pattern [1] series.

*) The measurement errors of BC thresholds have no effect on masking for AC.

8.5 Masking procedure in cases where the apparent AC thresholds do not differ significantly

Let us consider cases where the apparent AC thresholds do not differ significantly (**Fig. 8-55**):

Rt AA gap = AL0 − AR0 ≤ 10 dB, (AR0 ≤ AL0) or

Lt AA gap = AR0 − AL0 ≤ 10 dB, (AR0 ≥ AL0).

The theoretical method has been described in Lecture 6.

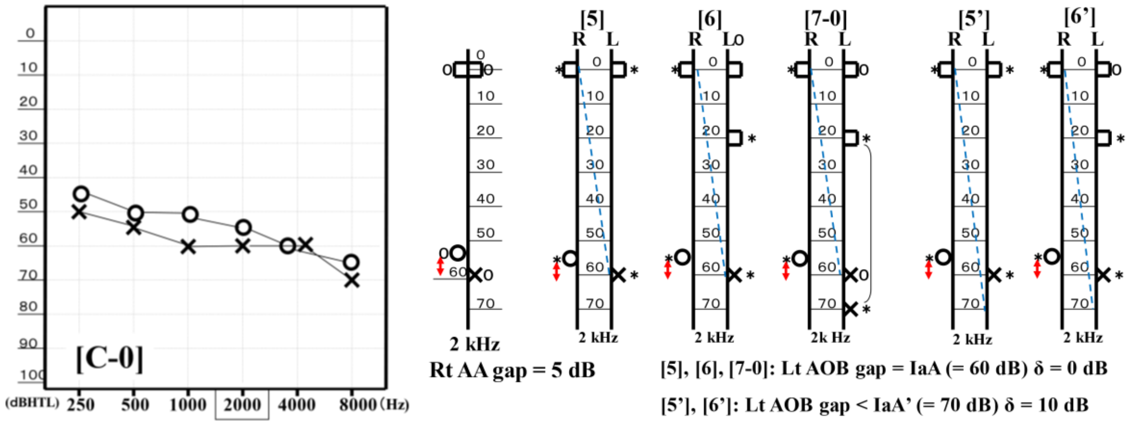


Figure 8-55 Basic audiogram [C-0] and audiometric configurations (Rt AA gaps = 5 dB)

8.5-1 Criteria for masking

The apparent AC threshold (AR0 or AL0) in at least one ear is the true threshold. Note that the configuration, in which the apparent AC threshold in one ear is the SH threshold, is only the pattern [7] series . If there is a little difference between AR0 and AL0 (e.g., Rt AA gap = 5, 10 dB), the BC threshold should be measured in the better ear by AC (i.e., the right ear) without masking. For example, in the basic audiogram **[C-0]**, the right ear's BC thresholds (BR0s) are measured (**[C-1]** in **Fig. 8-56**).

a) Criterion for masking through AC testing is as follows:

Lt and/or Rt AOB gap ≥ 40 dB (= min. IaA).

b) Criteria for BC masking-1 are as follows:

Lt and/ or Rt apparent AB gap ≥ 15 dB, or Lt and/ or Rt AOB gap ≥ 15 dB.

(1) [C-1]: Lt AOB gap ≥ 40 dB

Fig. 8-56 shows the basic audiogram **[C-1]** and the configuration at 1000 Hz with Rt AA gap of 10 dB and Lt AOB gap of 60 dB. It is either a pattern [5], [5'], [6], [6'], or pattern [7] series. Then, in pattern [7] series, the apparent AC threshold in one ear is possible to be the SH threshold. Therefore, masking for AC is needed.

Since the apparent AB gaps (GR0, GL0) are large (≥ 40 dB), masking for BC may be predicably difficult. For AC, if the SNC in one ear is sufficiently large, the APW of the same ear is also wide.

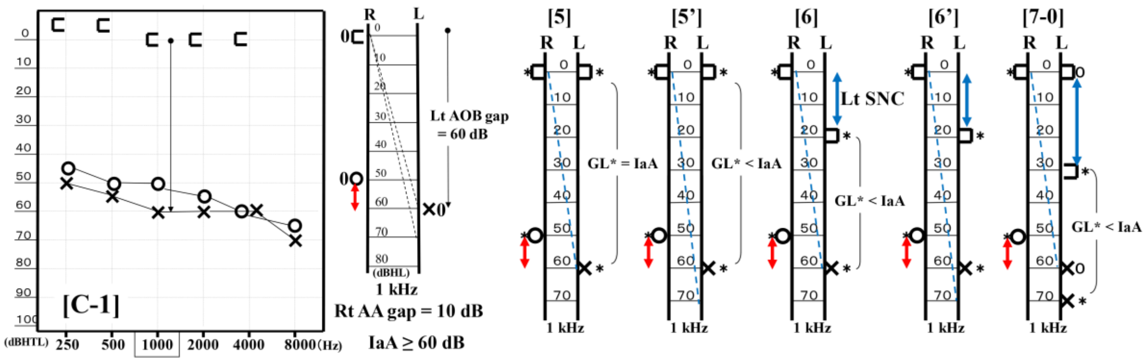


Figure 8-56 Basic audiogram [C-1] (Rt AA gap ≤ 10 dB and Lt AOB gap ≥ 40 dB)

**** Further note ****

*) In patterns [6] and [6'], the poorer ear by BC may be either the right or left because the difference between the true AC thresholds in both ears are insignificant.

*) In pattern [7] in **Fig. 8-56**, AL0 is the SH threshold. If Rt AA gap is 0 or 5 dB, AR0 might be the SH threshold.

In **[C-1]**, the apparent AC and BC thresholds in at least one ear are the true thresholds. It should be kept in mind that true thresholds cannot be determined (the masking dilemma), when the true AB gap of one ear is equal to IaA and the other ear has the same maximum degree of conductive impairment (patterns [5] and [7-1] in **Fig. 8-57**) or has the complete hearing loss (pattern [7-2] in **Fig. 8-57**).

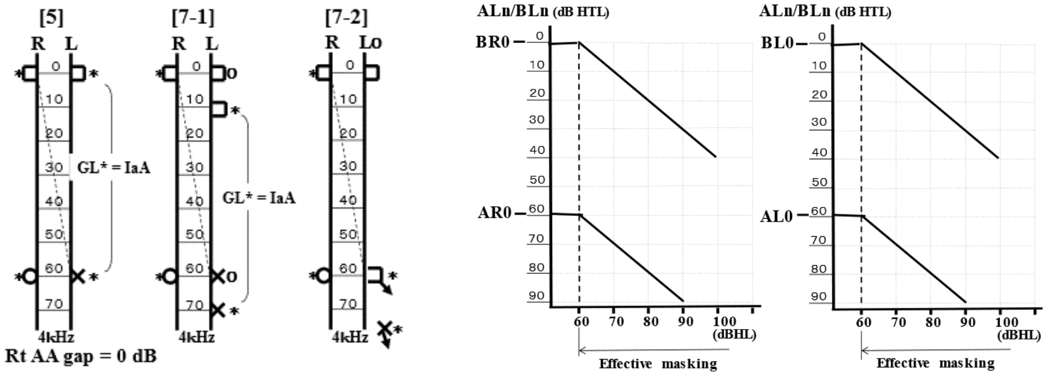


Figure 8-57 Three patterns of the masking dilemma

(2) [C-2]: 15 dB ≤ Lt AOB gap < 40 dB

Fig. 8-58 shows the basic audiogram **[C-2]** and the configurations at 1000 Hz with Lt AOB gap of 35 dB (< 40 dB = min IaA). Then, the apparent AC thresholds in both ears cannot be the SH, but the true thresholds. Thus, masking for AC is not needed. Only masking for BC is needed. This configuration is limited to either a pattern [5'] or [6']. The masking procedure is basically the same as that for BC in **[B-2]** (cf. **8.4 [3]**). Nx is used as the initial masking noise:

N1 = Nx = [BL0] + min IaA = ([BL0] + 40) dB HL.

Additionally, in the pattern [6'], the poorer ear by BC may be either the right or left because the difference between the true AC thresholds in both ears are insignificant (cf. **Fig. 7-12**).

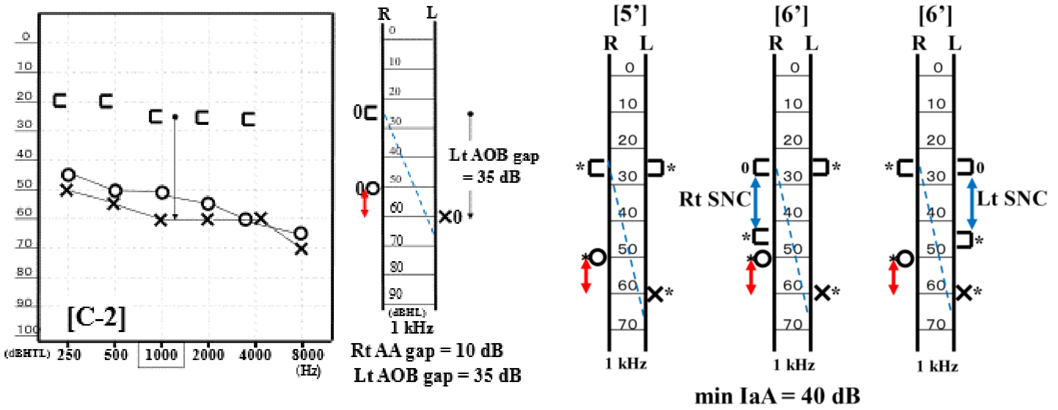


Figure 8-58 Basic audiogram [C-2] (Rt AA gap ≤ 10 dB and 15 dB ≤ Lt AOB gap < 40 dB)

(3) [C-3]: Lt AOB gap ≤ 10 dB (Fig. 8-59)

The apparent AC thresholds in both ears are the true thresholds.

Is the accurate identification of an AB gap of 10 dB clinically meaningful? In such cases, we might estimate whether it is a conductive or sensorineural disorder by the tympanic findings or tympanometry. Thus, masking for BC will not be needed.

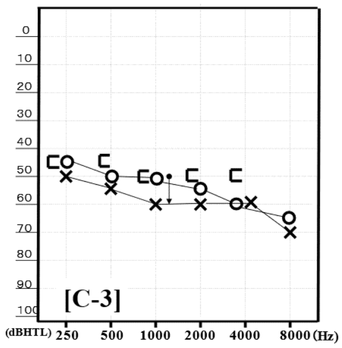


Figure 8-59 Basic audiogram [C-3]

**** Further note ****

*) True thresholds in the clinical situation are the thresholds measured including measurement errors (cf. **0.2**).

8.5-2 Masking procedure for AC and BC in [C-1]

(1) Plateau graphs of [C-1]: Rt AA gap ≤ 10 dB and Lt AOB gap ≥ 40 dB.

Fig. 8-60 shows the cases where the difference between apparent AC thresholds (Rt AA gap) is 5 dB. The 5 dB difference is not significant. The plateau graphs are shown in **Fig. 8-61** on the next page.

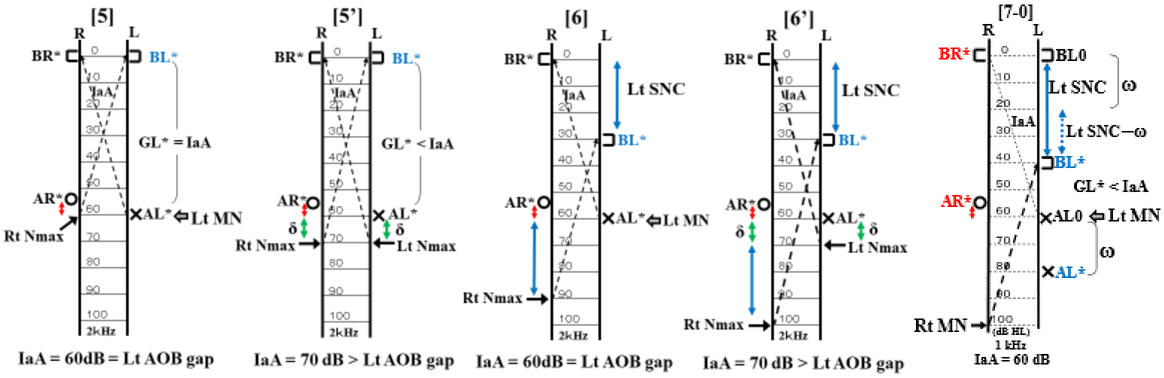


Figure 8-60 Audiometric patterns in [C-1] (Rt AA gap = 5 dB)

The plateau widths in each pattern are as follows:

Pattern	Rt APW	Rt BPW	Lt APW	Lt BPW
[5]	(−)	(−)	Rt AA gap	Rt AA gap
[5']	δ	δ	Rt AA gap + δ	Rt AA gap + δ
[6]	(−)	(−)	Rt AA gap + **Lt SNC**	Rt AA gap
[6']	δ	δ	Rt AA gap + δ + **Lt SNC**	Rt AA gap + δ
[7-0]	(−)	(−)	Rt AA gap + (**Lt SNC** – ω)	Rt AA gap

δ = IaA – Lt AOB gap, Rt SNC = BR* − BL*, Lt SNC = BL* − BR*,
ω = AL* − AL0, (–): No plateau is present. Rt AA gap = 5 dB

(2) Masking procedure in [C-1]

a) Masking procedure for AC (cf. **Fig. 8-61**)

In a case where there is a little difference between AR0 and AL0 (AA gap = 5 dB or 10 dB), the better ear by AC is masked with the noise 10 dB above the apparent AC threshold in that ear. If there is no difference (AR0 = AL0), it doesn't matter whether the first masked ear is the right or left.

1) When the significant APW (≥ 15 dB) in one ear exists, the configuration is either a pattern [5'], [6], [6'] (AL0 = AL*) or [7-0] (AL0 < AL*). Then, the apparent AC threshold in the opposite ear is automatically determined as the true threshold (cf. **6.4-3**).

2) When the significant APW in one ear does not exist and that in the opposite ear is obtained, it is a pattern [5'], [6], [6'] or [7-0].

3) When both the significant APWs cannot be obtained, the AC thresholds should be re-examined with masking noise levels increased in 5-dB steps. Nevertheless, if we cannot observe significant APWs, then it is a clinical masking dilemma (pattern [5], [7-1], or [7-2]; cf. **Fig. 8-57**). In pattern [5'], if the clinical plateau contraction occurs, the APW is difficult to identify.

b) Masking procedure for BC (cf. **Fig. 8-61**)

1) In patterns [5'] and [6'], since Lt BPW (= Rt AA gap + δ) is equal to or more than 15 dB, the true BC thresholds might be determined.

2) In patterns [5], [6], and [7-0], the BPW in one ear is not present and that in the opposite ear is insignificant (≤ 10dB). Therefore, it is difficult to determine the true BC thresholds. However, in patterns [6], [6'], and [7-0], the significant APW in one ear exists. Thus, the true BC threshold might be estimated using the OM method (cf. **6.4-3**): BL* = BR* + (Rt MN − Lt MN), (Rt MN ≥ Lt MN).

In a clinical setting, the MNs in both ears are sometimes difficult to determine with accuracy. Hence, the estimation of the true BC threshold depends on the accurate measurement of the AC thresholds.

**** Further note ****

*) For patterns [6] and [6'] in **Fig. 8-61**, the true AC threshold in the left ear can be determined easily because Lt SNC is large (30 dB). However, as Lt SNC gets smaller, masking for left AC becomes difficult.

*) In pattern [7-0], if Rt AA gap is 0 or 5 dB, AR0 might be the SH threshold.

***

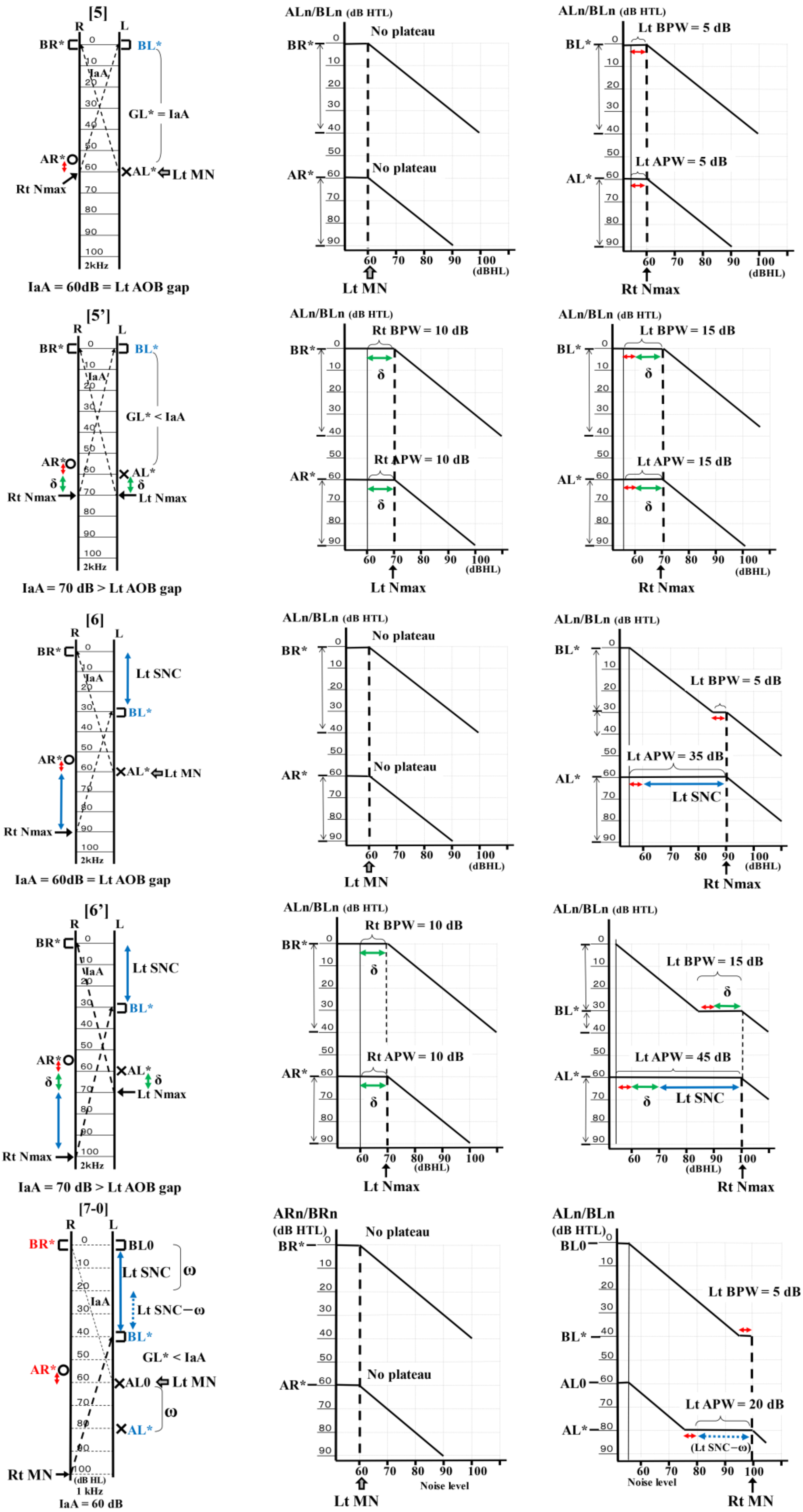


Figure 8-61 Plateau graphs of patterns in [C-1] (Rt AA gap = 5 dB)

8.6 Audiometric configurations in which masking is difficult to perform

(1) AA gaps and plateau widths

Let us compare the two basic audiograms, **[A-1]** (Rt AA gap = 50 dB) and **[B-1]** (Rt AA gap = 20 dB). If the Rt AA gaps are small, the plateau widths are narrow: it can be predicted that masking might be difficult.

a) Patterns [3] and [1] series (AL0 = AL*) (**Fig. 8-62**, **8-63**)

IaA ≥ Lt AOB gap, δ = IaA − Lt AOB gap ≥ 0 dB.

Pattern [3']: Lt APW = Rt AA gap + δ + Lt SNC. **Pattern [3]**: Lt APW = Rt AA gap + Lt SNC.

Pattern [1'], [2']: Lt APW = Rt AA gap + δ. **Pattern [1], [2]**: Lt APW = Rt AA gap.

Pattern [1'], [2'], [3']: Lt BPW = Rt AA gap + δ. **Pattern [1], [2], [3]**: Lt BPW = Rt AA gap.

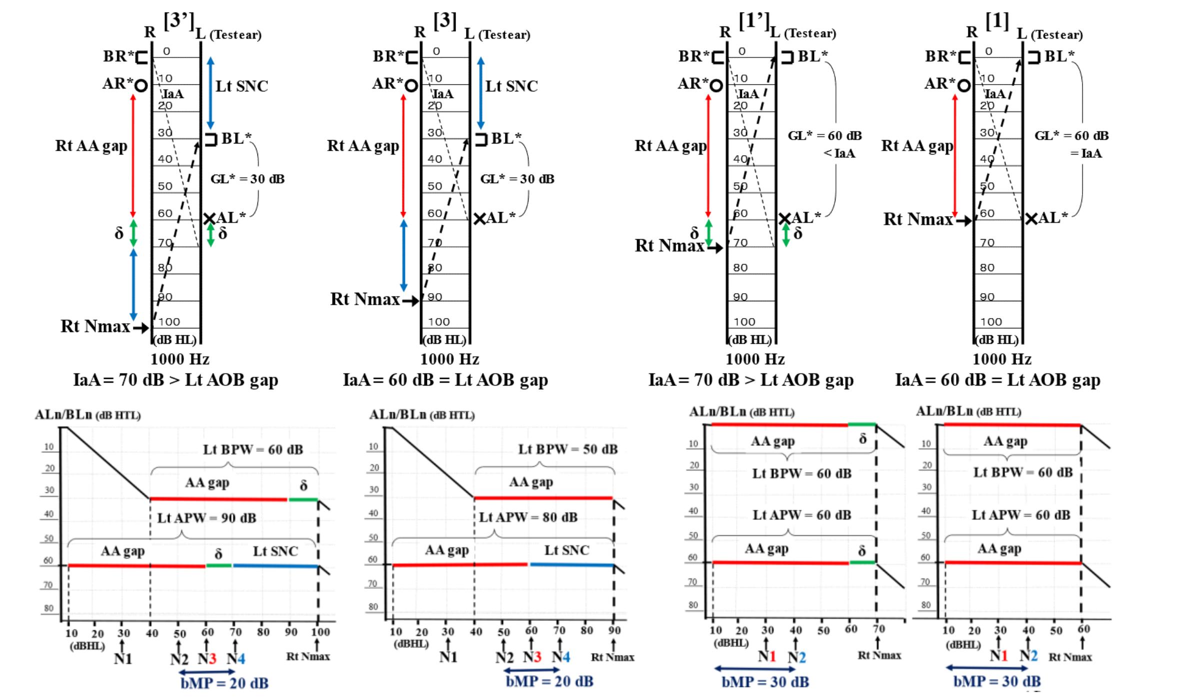


Figure 8-62 Plateau widths of patterns in [A-1]: Rt AA gap = 50 dB (the same as Fig. 8-32)

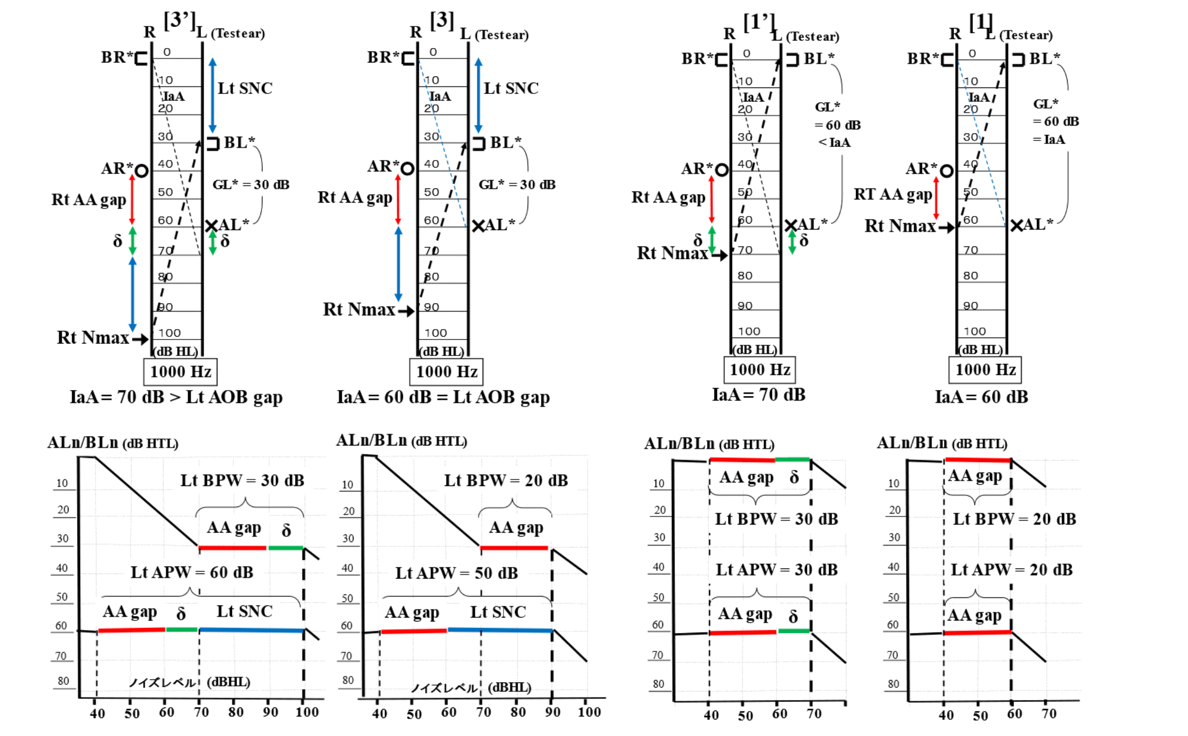


Figure 8-63 Plateau widths of patterns in [B-1]: Rt AA gap = 20 dB (the same as Fig. 8-43)

b) Patterns [4] series (AL0 < AL*) (**Fig. 8-64**, **8-65**)

IaA = Lt AOB gap = 60 dB, δ = (IaA − Lt AOB gap) = 0 dB

Pattern [4-0]: Lt APW = Rt AA gap + (Lt SNC − ω).
= Rt AA gap + (IaA − GL*).
= (IaA − GR*) + (IaA − GL*).

Pattern [4-1]: Lt APW = Rt AA gap.

Pattern [4-0], **[4-1]**: Lt BPW = Rt AA gap.

Pattern [4-2]: Lt plateaus are not present.

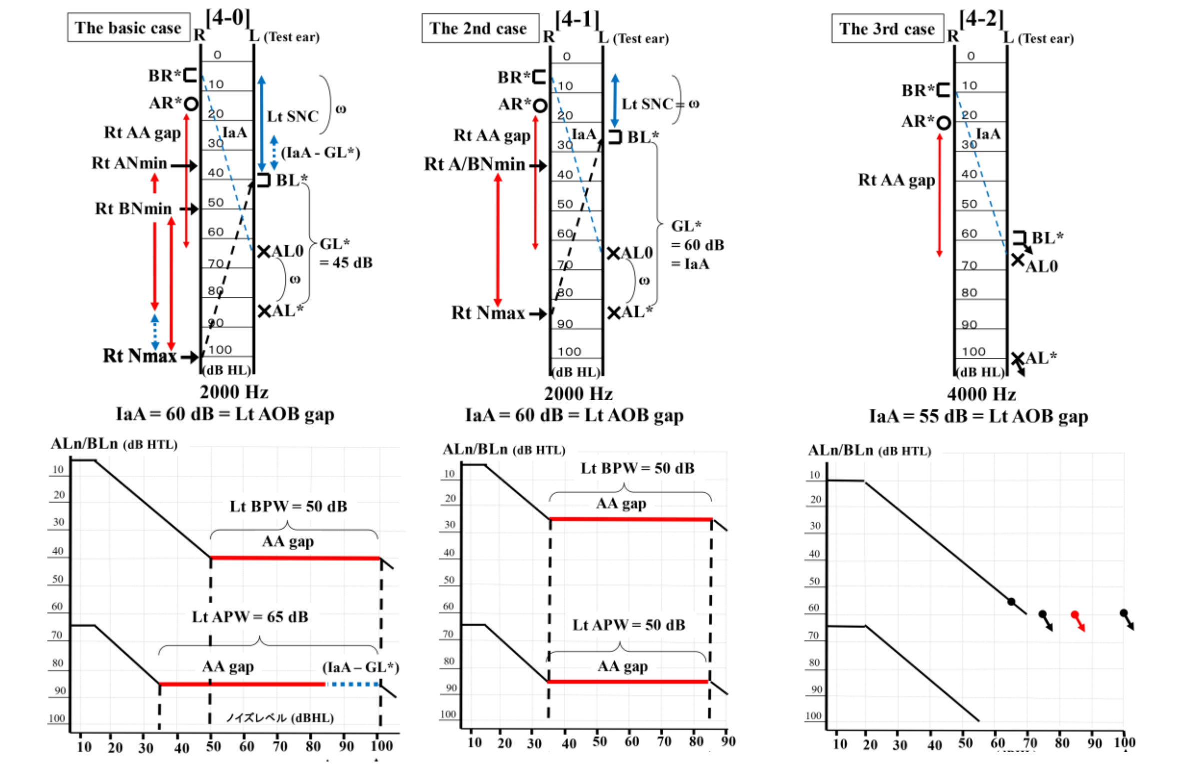


Figure 8-64 Plateau widths of patterns in [A-1]: Rt AA gap ≥ 45 dB (the same as Fig. 8-36)

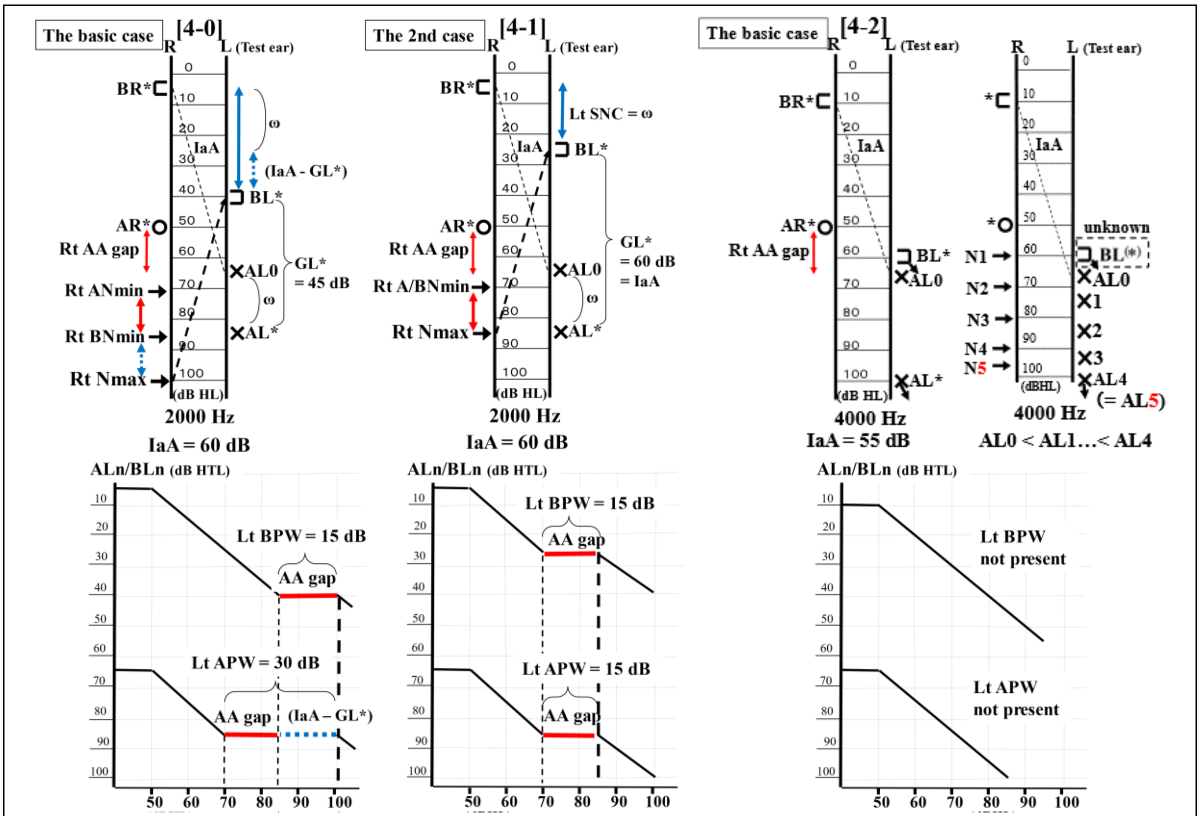


Figure 8-65 Plateau widths of patterns in [B-1]: Rt AA gap = 15 dB (the same as Fig. 8-46)

(2) Review of the masking procedures for AC in [B-1]

In **Fig. 8-66**, Rt AA gaps at 2000 and 4000 Hz are only 15 dB (Lt APW ≥ Rt AA gap). Thus, it can be estimated that masking for AC may be difficult. When the measured AC thresholds are scaled-out levels, such as those at 4000 and 8000 Hz (**Fig. 8-67 [c]**, **[d]**), we must take a specific consideration, as described below (cf. **8.4-2**).

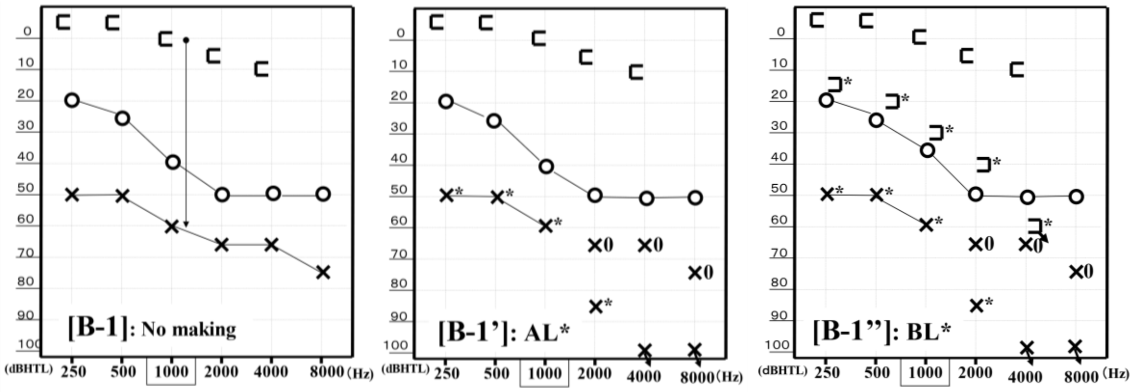


Figure 8-66 Basic audiograms [B-1], [B-1'] and [B-1"] (the same as Fig. 8-37, 8-41)

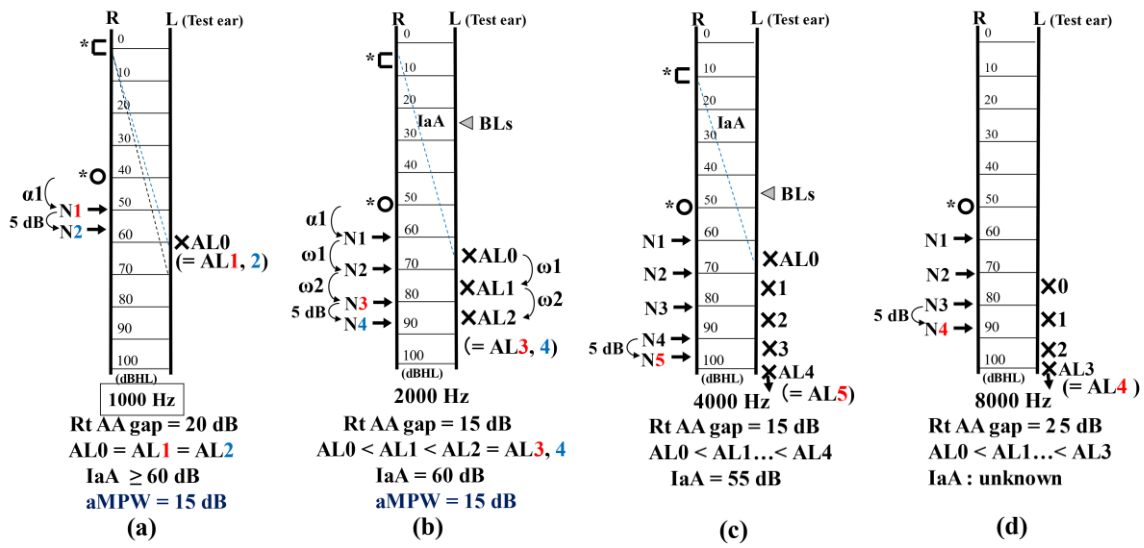


Figure 8-67 Masking for AC in [B-1] (the same as Fig. 8-38)

a) The configuration at 2000 Hz (Rt AA gap = 15 dB)

The configurations in **Fig. 8-68** are pattern [4] series. For example, as shown in **Fig. 8-68 (a)**, if it is a pattern [4-0] (BL* is 40 dB HTL, GL* = 40 dB < IaA), Lt APW in theory is 30 dB, "Wide APW". In this case, even if the clinical plateau contraction may occur, the true AC threshold can be determined. However, if it is a pattern [4-1] (BL* is 25 dB HTL, GL* = 60 dB = IaA) (**Fig. 8-68 [b]**), Lt APW in theory is 15 dB, "Narrow APW". Therefore, it may be difficult to determine the true AC threshold if the contraction occurs.

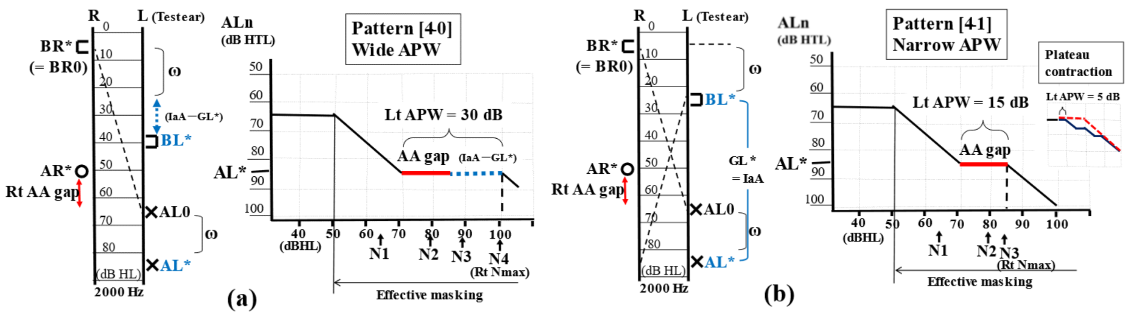


Figure 8-68 Lt APWs and clinical plateau contraction

b) The configuration at 4000 Hz (Rt AA gap = 15 dB)

The cases in which APWs cannot be identified are the most problematic clinically. For the configuration at 4000 Hz in **Fig. 8-67 (c)** on the preceding page, significant PWs for both AC and BC cannot be obtained. In the pattern [4-2] (**Fig. 8-69**), the noises of effective masking always cause undermasking and the AC thresholds measured in the left ear are all the SH thresholds. Therefore, Lt APW is not present. This pattern must be distinguished from two patterns below.

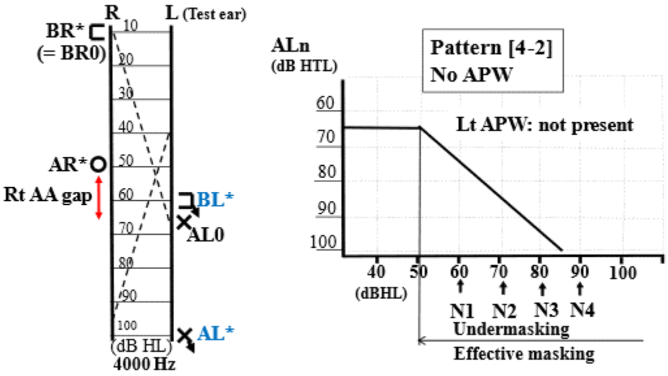


Figure 8-69 Pattern [4-2]

In patterns [1] and [4-1], Lt APWs in theory are 15 dB (Narrow APWs) (**Fig. 8-70 [a]**, **[b]**). If the clinical plateau contraction occurs, the Lt APWs become difficult to identify.

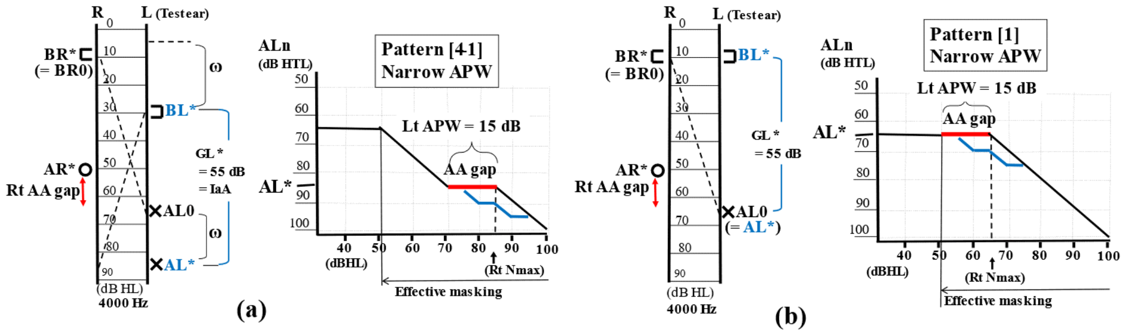


Figure 8-70 Configurations needed to be differentiated from the deaf ear

The cases in which the APWs cannot be determined are as follows:

Pattern [4-2]: APWs are not present.

Patterns [4-1] and [1]: APWs are insignificant due to the clinical plateau contraction.

Since we cannot distinguish between three patterns, the true AC thresholds cannot be determined. Consequently, in a clinical setting, when AA gaps are small (≤ 20 dB) and APWs cannot be obtained, AC thresholds should be retested with the initial noise level 5 dB above the non-test ear's AC threshold level (N1 = [AR*] + 5) in 5-dB steps (5-dB step method). Nevertheless, if a significant plateau cannot be obtained, differentiating them is impossible.

The abovementioned factor is a consideration for 4000 Hz only. From the standpoint of the whole audiometric configurations (cf. **Fig. 8-66**), BC hearing acuity cannot be normal at 4000 Hz only because the left ear has sensorineural hearing disturbance. Furthermore, it is unnatural that only the AB gap at 4000 Hz is equal to IaA. Therefore, the configuration at 4000 Hz in **Fig. 8-67 (c)** is assumed to denote a complete hearing impairment; i.e., the pattern [4-2].

c) The configuration at 8000 Hz (Rt AA gap = 25 dB)

In **Fig. 8-67 (d)**, Rt AA gap at 8000 Hz is 25 dB and Lt APW in theory is 25 dB. Even if the clinical plateau contraction of 10 dB occurs, Lt APW of 15 dB in actual measurement becomes significant. Hence, in cases where AA gaps are ≥ 25 dB, when the measured AC thresholds are determined to be scaled-out using a 5-dB step method (i.e., significant plateaus are not present), it may be considered that OM has not occurred, and that the configuration denotes a complete hearing impairment.

**** Further note ****

*) At 4000 Hz in **[A-1]**, the APW cannot be determined. However, the results are reliable because the masking noises at which OM evidently never occurs can be used (cf. **Fig. 8-29 [c]**).

(3) Summary of the audiometric patterns where masking is difficult or impossible

Patterns [5] and [7-1] in **[C-1]**, where Rt AA gaps are small (≤ 10 dB), are the clinical masking dilemma (**Fig. 8-71**). Although patterns [1] and [4-1] in **[B-1]** have Rt AA gaps of 15 dB, the significant plateaus for AC and BC cannot be obtained if clinical plateau contraction occurs. Patterns [4-2] and [7-2] have no PWs in both ears.

In this lecture series, the significant PWs and AA gaps are set at ≥ 15 dB, which is not an absolute standard. If measured thresholds have high accuracy (e.g., ΔA/B = 0 dB or 5 dB), PWs of only 10 dB may be considered significant. The clinical masking dilemma depend on measurement accuracy.

Additionally, if the apparent AC threshold levels in non-test ear are too high to ensure sufficient masking amounts, the configurations are also a clinical masking dilemma.

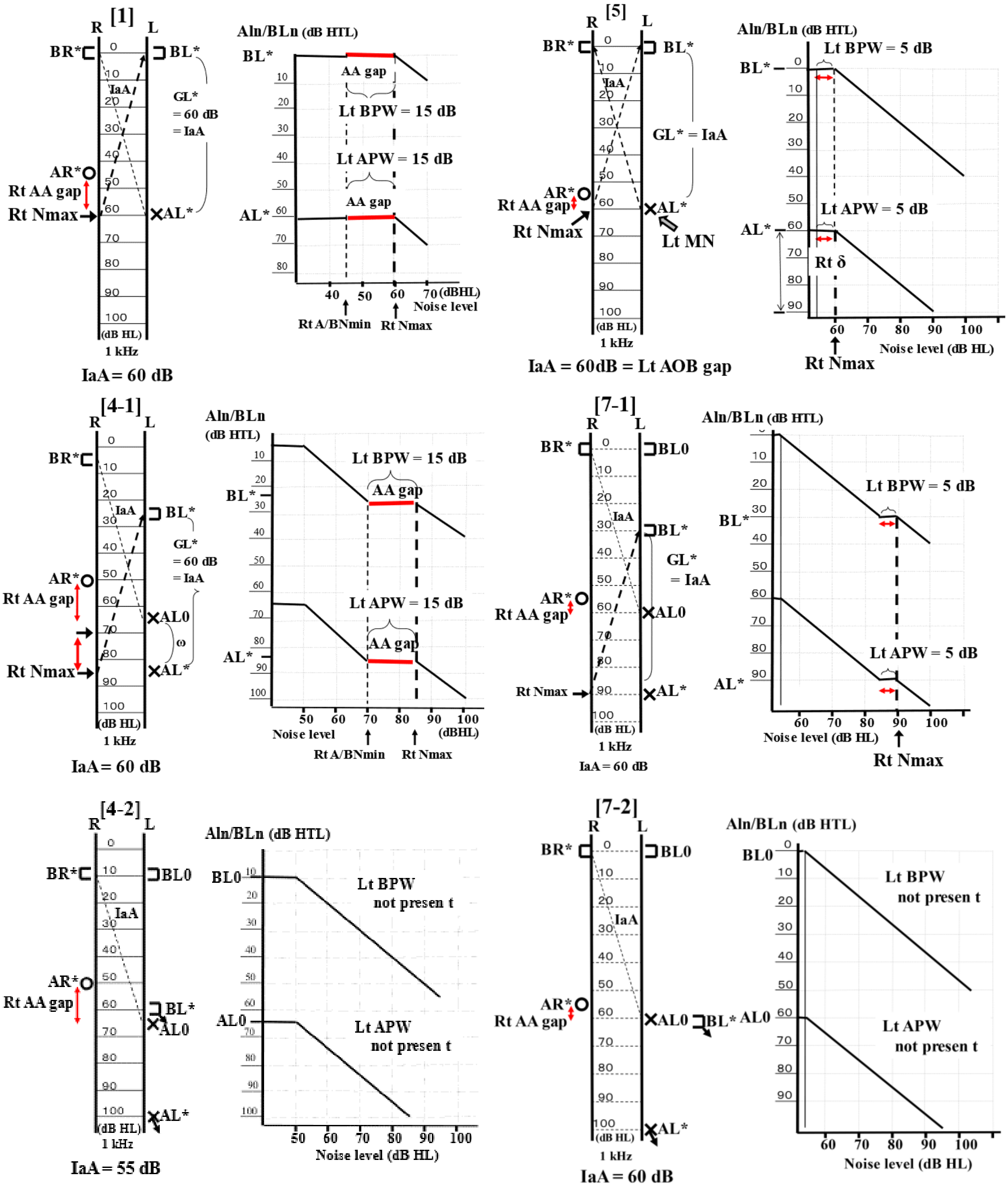


Figure 8-71 Audiometric patterns where masking is difficult or impossible

**** Further note ****

*) The utmost limit of the pattern [1] series is the pattern [5] series. The utmost limit of the pattern [4] series is the pattern [7] series.

8.7 Summary of Lecture 8

1. General description of the masking procedure

When the true AC thresholds are determined, the configurations are divided into two series: patterns [1], [2] and [3] series (AL0 = AL*) and pattern [4] series (AL0 < AL*) (**Fig. 8-72**).

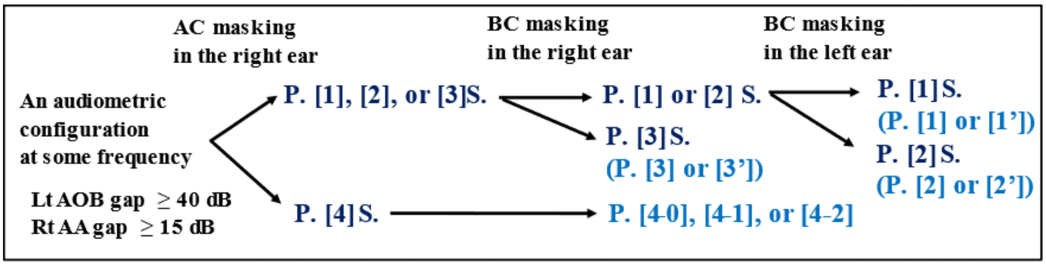


Figure 8-72 General description of the masking procedure

a) **AL0 = AL***: patterns [1], [2], [3] series.
b) **AL0 < AL***: pattern [4] series.

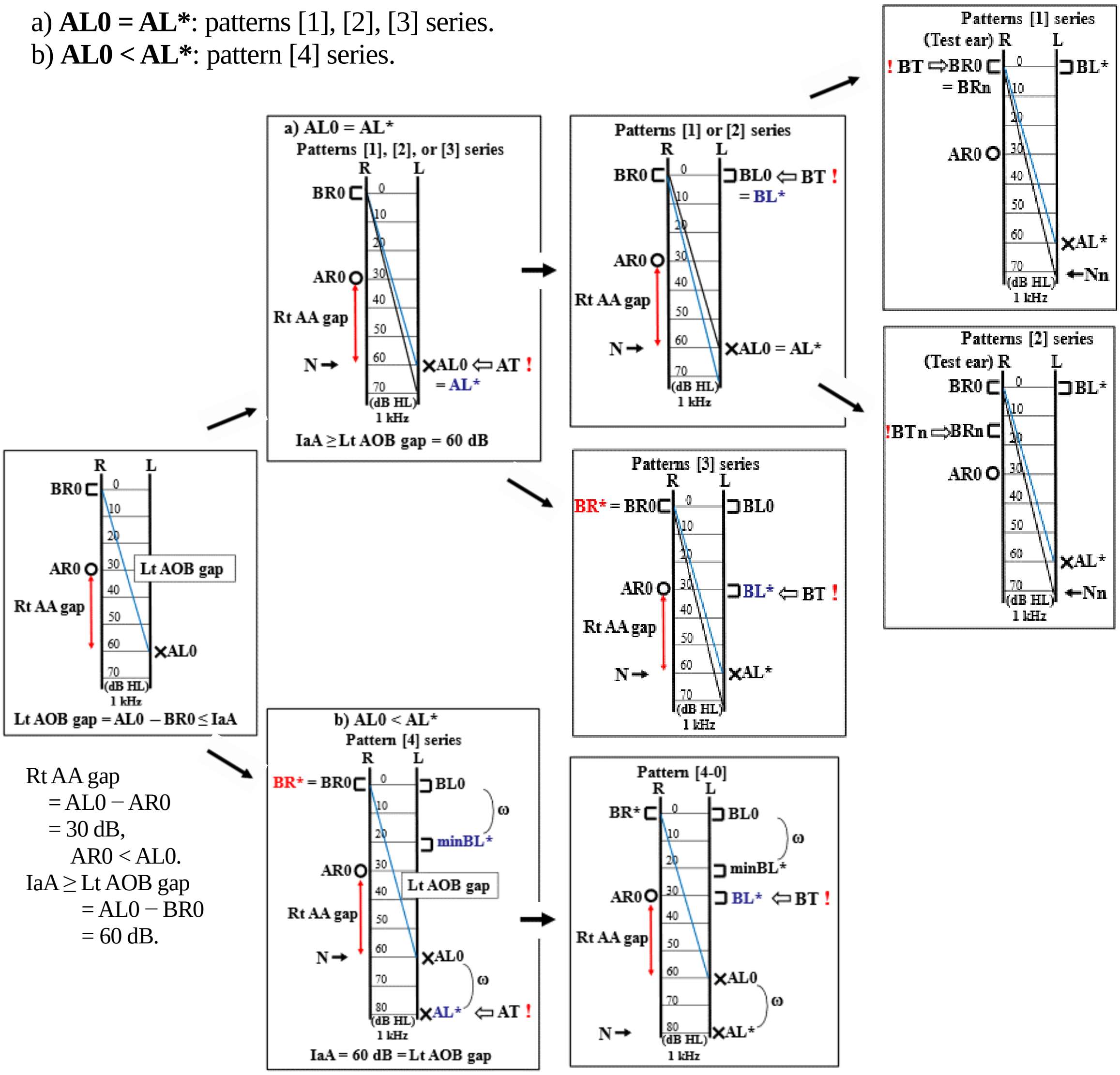


Figure 8-73 Two audiometric pattern series

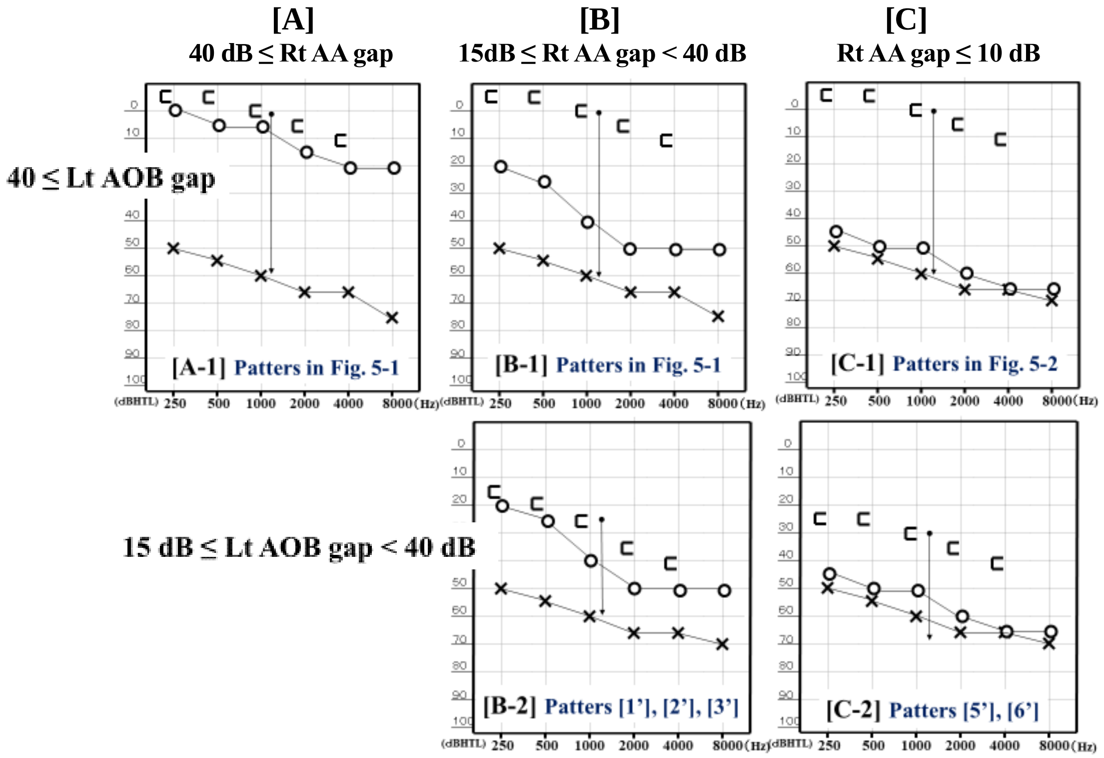
In patterns [1], [2], and [3] series, the BC threshold in the left ear is measured (**Fig. 8-73**). When **BL0 = BL***, the configuration is either a pattern [1] or [2] series. Since BR0 is unknown, the true BC threshold in the right ear (BR*) needs to be obtained with masking in the left ear.
When **BL0 < BL***, it is a pattern [3] series. BR0 is automatically determined to be the true threshold (**BR0 = BR***), and the test is completed.

In pattern [4] series, if the true BC thresholds in the left ear are determined with adequate masking for BC, the test is completed.

2. Basic audiograms

(1) Significant AA and AOB gaps

Fig. 8-74 shows the basic audiograms in which the AC and BC thresholds are all measured without masking. The AA gaps in **[A]** and **[B]** are significant (Rt AA gap = AL0 − AR0 ≥ 15 dB), and the AA gaps in **[C]** are not significant (Rt AA gap ≤ 10 dB).



	Basic audiograms	AC masking	BC masking
1.	[A-1], [B-1], [C-1]	Needed	Needed
2.	[B-2], [C-2]	Not needed	Needed
3.	[C-3]	Not needed	Not needed

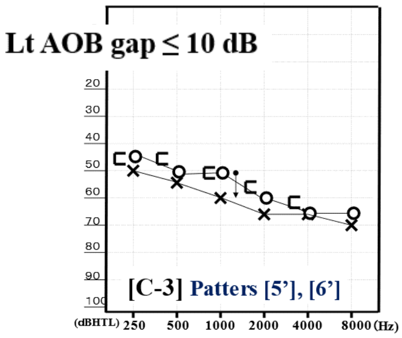


Figure 8-74 Basic audiograms

(2) Criteria for masking AC and BC

1) [A-1], **[B-1]**, and **[C-1]**

For AC, in **[A-1]** and **[B-1]**, since Lt AOB gap ≥ 40 dB, the AC thresholds in the poorer ear (AL0) may be the SH thresholds and the AC thresholds in the better ear (AR0) are always the true thresholds .Thus, masking for the left AC is needed. In **[C-1]**, since bilateral AOB gaps are ≥ 40 dB, one of the AC thresholds can be the SH threshold. Therefore, masking for AC in at least one ear is needed.

For BC, in **[A-1]**, **[B-1]**, and **[C-1]**, since Lt AOB gap ≥ 15 dB, masking for the left BC is needed. Furthermore, in **[B-1]** and **[C-1]**, masking for the right BC is needed at sometimes.

2) [B-2] and **[C-2]**,

Since 15 dB ≤ Lt AOB gap < 40 dB, only masking for BC is needed.

3) [C-3]

Since Lt AOB gap ≤ 10 dB, masking for both AC and BC is not needed.

(3) Basic audiograms and plateau widths

The basic audiograms **[A-1]** and **[B-1]** have seven audiometric configurations patterns (**Fig. 8-75**), while **[C-1]** has five patterns at a certain frequency (**Fig. 8-76**).

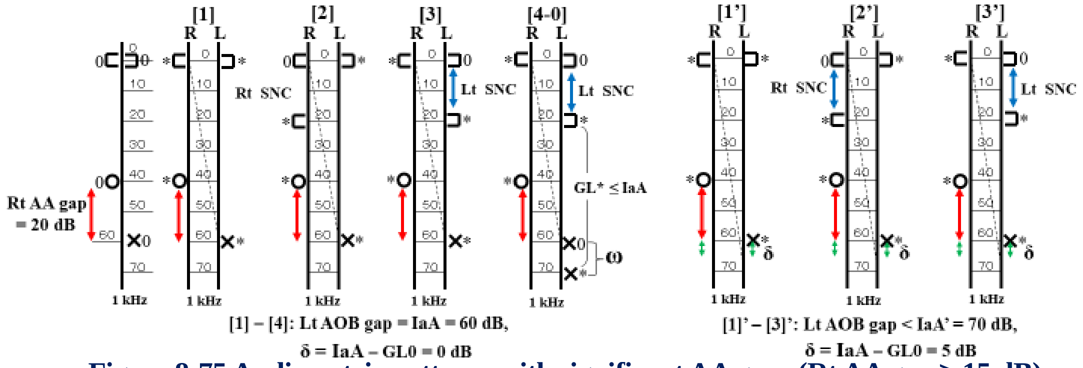


Figure 8-75 Audiometric patterns with significant AA gaps (Rt AA gap ≥ 15 dB)

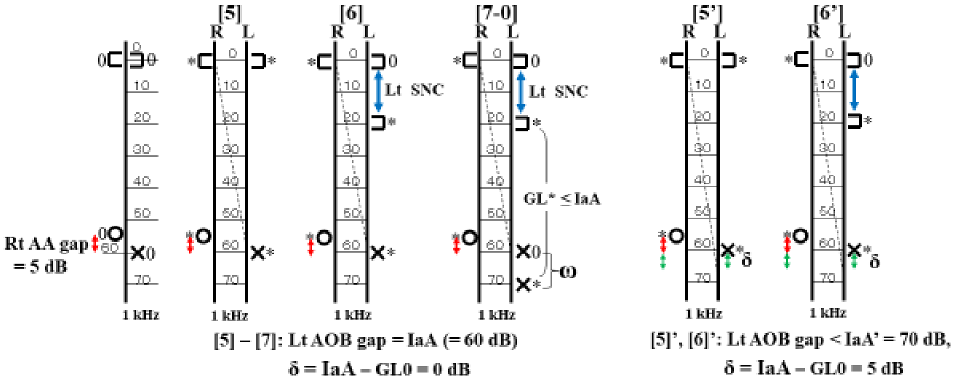


Figure 8-76 Audiometric patterns with insignificant AA gaps (Rt AA gap ≤ 10 dB)

Lt APWs in theory are as follows:

Patterns [1], [2], [5]: Lt APW = Rt AA gap. (Rt AA gap = AL0 – AR0)
Patterns [1'], [2'], [5']: Lt APW = Rt AA gap + δ. (δ = IaA – GL0)
Patterns [3], [6]: Lt APW = Rt AA gap + **Lt SNC**. = IaA – Lt AOB gap)
Patterns [3'], [6']: Lt APW = Rt AA gap + δ + **Lt SNC**. (Lt SNC = BL* – BR*)
Patterns [4-0], [7-0]: Lt APW = Rt AA gap + **Lt SNC** – ω. (ω = AL* – AL0)
= Rt AA gap + (IaA – GL*). (IaA > GL*)
Patterns[4-1], [7-1]: Lt APW = Rt AA gap. (IaA = GL*)

Lt BPWs in theory are as follows:

Patterns [1], [2], [3], [4], [5], [6], [7]: Lt BPW = Rt AA gap.
Patterns [1'], [2'], [3'], [5'], [6']: Lt BPW = Rt AA gap + δ.
The IaA value is assumed to be 0 dB.

Elements of Lt PWs are following four:

1) Rt AA gap = AL0 – AR0, 2) δ = IaA – Lt AOB gap,
3) Lt SNC = BL* – BR*, 4) ω = AL* – AL0: only patterns [4] and [7].

We only know Rt AA gap and Lt AOB gap before masking.

(4) Difficulty level of masking

The plateau widths define the difficulty level of masking.

[A-1]: Since Rt AA gaps are large (> 40 dB), masking for AC and BC in the left ear is easy.

[B-1]: Rt AA gaps are smaller than those of [A-1]. The plateau widths may become narrower than the theoretical plateau widths due to the clinical plateau contraction. In particular, when the test ear is the maximum AB gap ear, masking is occasionally difficult or impossible.

[C-1]: Rt AA gaps are small (≤ 10 dB) and both the ear's AOB gap are large. In general, the plateau widths are narrow.

3. Masking procedure: Rt AA gaps ≥ 15 dB, AA gaps are significant

When the apparent AC thresholds differ significantly (**Fig. 8-77**), the true AC and BC thresholds in the poorer ear by AC are measured. An excessive load of noises on the non-test ear should be avoided.

(1) Masking procedure for AC audiometry

Criterion: Lt AOB gap ≥ 40 dB, **[A1]**, **[B1]**.

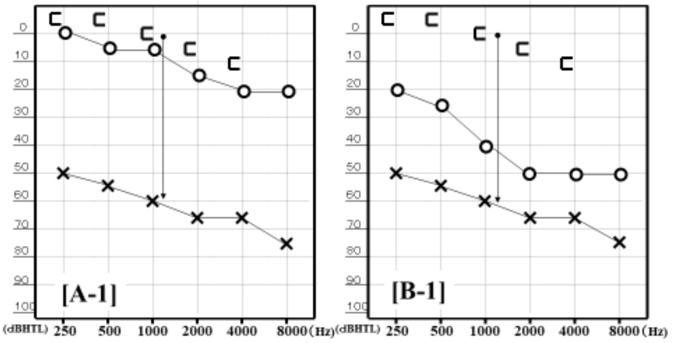


Figure 8-77 Basic audiograms with no masking

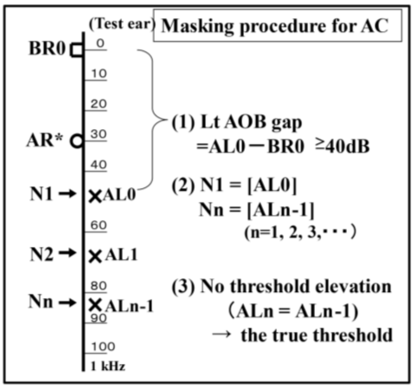


Figure 8-78 Theoretical procedure for AC

< Theoretical procedures > (**Fig. 8-78**)

When N1 (= [AL0]) is presented to the right ear, the AC threshold measured with N1 in the left ear (AL1) is obtained. Central overmasking effect is estimated as 5 dB.

a) If **AL1 ≤ (AL0 + 5)**, AL0 is the true threshold (AL*): patterns [1], [2] and [3] series .

BR0, BL0, and IaA (≥ AL* − BR0) are undetermined.

b) If **AL1 > (AL0 + 10)**, AL0 is the SH threshold: pattern [4] series.

BR0 = BR*, BL0 < BL*, and IaA = AL0 − BR*.

< Clinical procedures > (**Fig. 8-81**)

[A-1] (**Fig. 8-79[a]**, **[a']**): The initial masking noise level 20 dB above the AC threshold level in the non-test ear (AR0) should be used: **N1 = ([AR0] + 20) dB HL, α1 is 20 dB**. Subsequently, the noise level is elevated by the amount of the measured AC threshold elevation (ω). The noise step for confirmation is 10 dB.

[B-1] (**Fig. 8-79 [b]**, **[b']**): N1 is set to the level 10 dB above the AR0 (**N1 = [AR0] + 10, α1 is 10 dB**), and the noise level is increased in 10-dB steps. The noise step for confirmation is 5 dB.

When significant actual measurement PWs for AC (aMPWs ≥ 15 dB) are obtained, the true AC thresholds are determined. If Rt AA gaps are small (≤ 20 dB) and significant aMPWs cannot be identified, the AC thresholds should be retested in 5-dB steps. Nevertheless, if the significant aMPW is not obtained, it is a clinical masking dilemma. When the measured AC thresholds are scaled-out, let us consider the configuration where masking is difficult or impossible (cf. **8.6**).

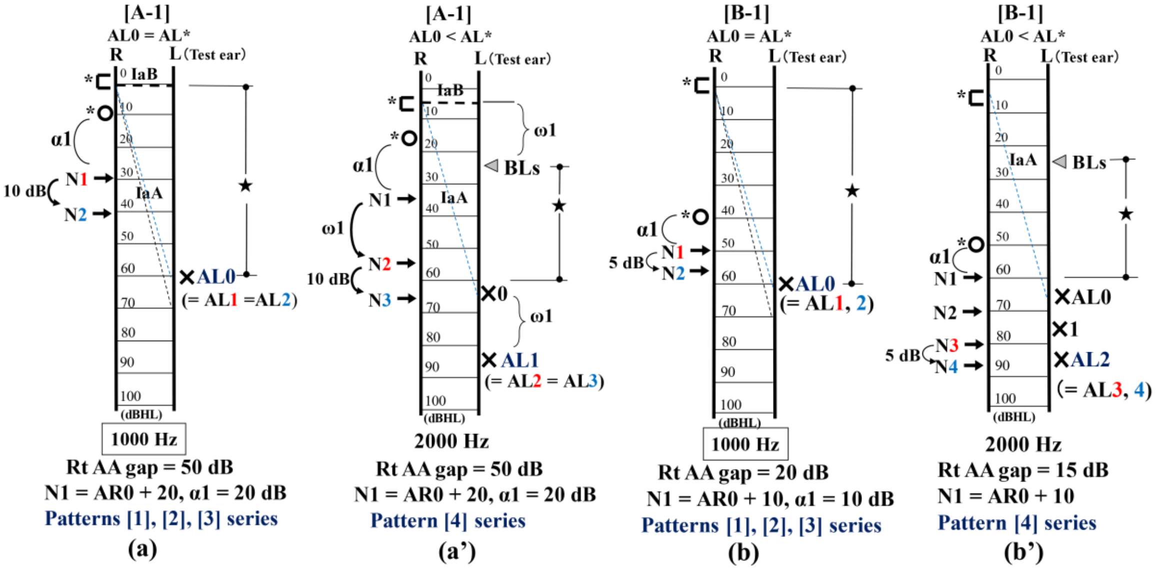


Figure 8-79 Clinical masking procedures for AC

(2) Masking procedure for BC audiometry

At the point where masking for AC has been completed, the audiometric configurations are divided into two series: patterns [1], [2] and [3] series, and pattern [4] series. Since the Rt AA gaps are large in **[A-1']**, masking for the left BC is easy. It may be difficult in **[B-1']** (**Fig. 8-80**).

Criterion: Lt AOB gap ≥ 15 dB, **[A-1'], [B-1'], [B-2]**.

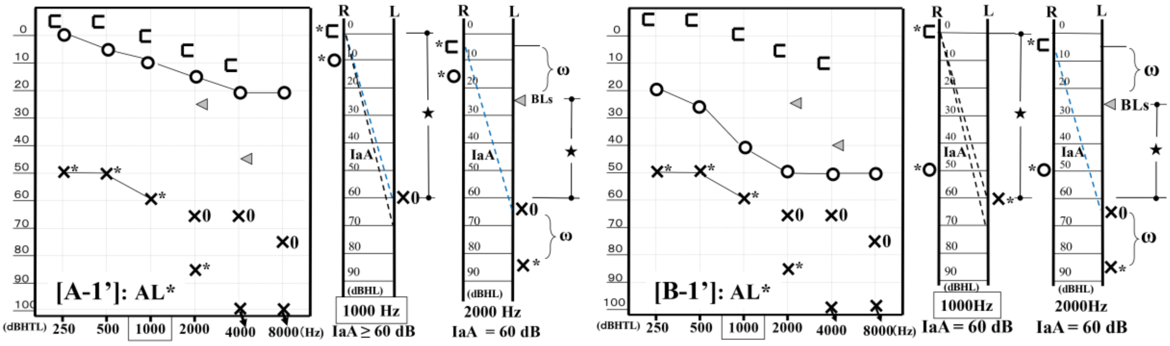


Figure 8-80 Basic audiograms with the true AC thresholds established

< Theoretical procedure >

[A-1'], [B-1']: Lt AOB gap ≥ 40 dB. N1 = [AL*] dB HL.

[B2]: 15 dB ≤ Lt AOB gap < 40 dB. N1 = Nx = BL0 + min IaA = (BL0 + 40) dB HL.

< Clinical procedure >

[A-1']: In patterns [1], [2], and [3] series (**Fig. 8-81 [a]**), according to the procedure for AC, N1 is set to the level 20 dB above the non-test ear's AC threshold (N1 = [AR0] + 20, α1 = 20 dB). Subsequently, the noise level is elevated by the amount of the measured BC threshold elevation (θ). In pattern [4] series (**Fig. 8-81 [a']**), N1 (= [AL0]) is used, and the noise level is increased in 10-dB steps. The noise step for confirmation is 10 dB.

[B-1']: In patterns [1], [2] and [3] series (**Fig. 8-81 [b]**), N1 is set to the level 10 dB above the non-test ear's AC threshold (N1 = [AR0] + 20, α1 = 10 dB). In pattern [4] series (**Fig. 8-81 [b']**), N1 (= [AL0]) is employed. For both series, the noise level is increased in 10-dB steps. The noise step for confirmation is 5 dB.

When significant bMPWs (≥ 15 dB) are obtained, the true BC thresholds are determined. If the significant bMPW cannot be identified, the BC threshold should be retested in 5-dB steps. Nevertheless, if the bMPW cannot be obtained, it is a clinical masking dilemma for BC. Let us consider using the OM method.

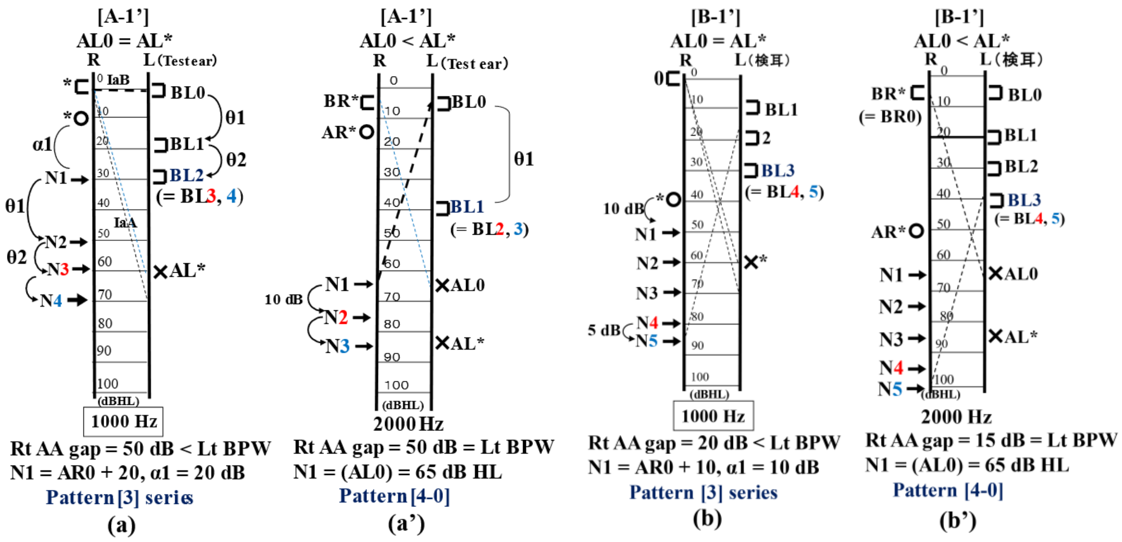


Figure 8-81 Clinical masking procedures for AC

4. Masking procedure: AA gaps ≤ 10 dB, AA gaps are not significant.

The apparent AC thresholds do not differ significantly (**Fig. 8-82**).

(1) Masking procedure for AC audiometry

Criterion: Lt AOB gap ≥ 40 dB, **[C-1]** (cf. **6.4-3**).

If there is a little difference between AR0 and AL0 (e.g., AR0 < AL0, Rt AA gap = 5 dB or 10 dB), the better (right) ear by AC is masked with the noise 10 dB above the apparent AC threshold (AR0), and the noise level is increased in 10-dB steps.

a) When the significant APW (≥ 15 dB) in one ear exists, the configuration is either a pattern [5'], [6], [6'] (AL0 = AL*) or [7-0] (AL0 < AL*). Then, the apparent AC threshold in the opposite ear is automatically determined as the true threshold (cf. **6.4-3**).

b) When both the significant APWs cannot be obtained, the AC thresholds should be re-examined by using a 5-dB step method. Nevertheless, if we cannot observe significant APWs, then it is a clinical masking dilemma (pattern [5], [7-1], or [7-2]; cf. **Fig. 8-83**).

(2) Masking procedure for BC audiometry

Criterion: Lt AOB gap ≥ 15 dB, **[C-1]**, **[C-2]**.

a) [C-1]: Lt AOB gap ≥ 40 dB

In patterns [6], [7-0], even if the significant APW is present in one ear, the true BC threshold in the same ear cannot be determined. Then, the OM method is used.

b) [C-2]: 15 dB ≤ Lt AOB gap < 40 dB.

N1 = Nx = [BL0] + min IaA = ([BL0] + 40) dB HL

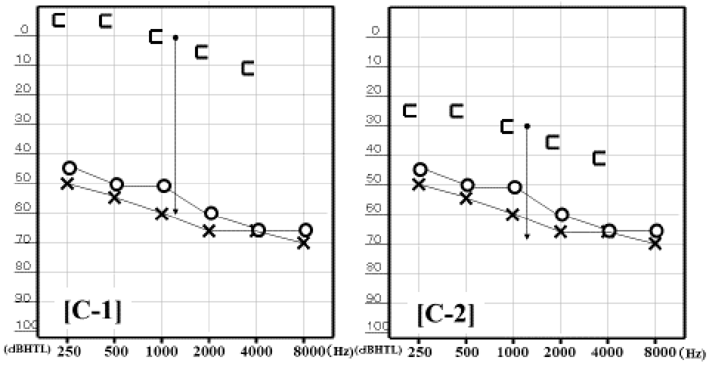


Figure 8-82 Basic audiograms: Rt AA gaps ≤ 10 dB

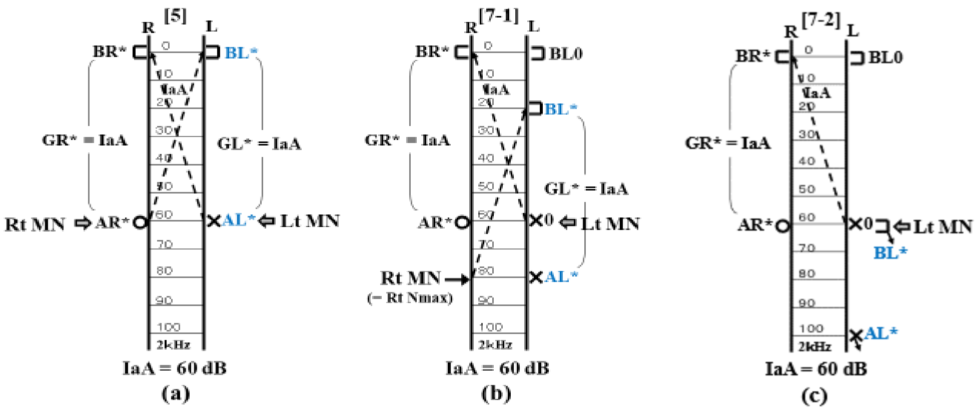


Figure 8-83 Theoretical masking dilemma

5. Clinical significance of the IaB value

In this lecture series, the IaB value is assumed to be 0 dB in principle. However, the value at the mastoid can be larger than 0 dB. The IaB value might have some meanings at a critical setting (cf. **Supplement 6**).

Lecture 9: Supplements

Supplement 1: Definition of interaural attenuation (Lecture 1)

If the three values in PTA (IaA, IaB, and CL) can be defined as relative attenuation values, we will be able to explain masking with a simple schematic model in which signals are relatively attenuated by a certain amount (rY: IaA, IaB, or CL) and reach the cochlea in one ear via the transmission pathways (**Fig. 9-1**). Then, the various phenomena can be expressed visually using the masking diagram. We must define the three values accurately, because ambiguous definitions for the basic terms prevent masking from being understood correctly.

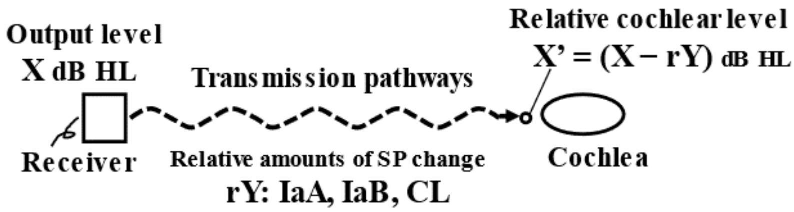


Figure 9-1 Relative attenuation in transmission pathways

(1) Definition of IaB

Why is the interaural attenuation for BC signals at the forehead always 0 dB? This is resolved by the concept of relative sound pressure change (**Fig. 9-2**). The traditional commentaries do not explain that IaB is a relative attenuation. IaB is not a physical and absolute attenuation (**Fig. 9-3**).

In this lecture series, measurement errors are supposed to be 0 dB in order to define the interaural attenuation theoretically. Actually, the measurement errors for BC thresholds must be expected to range from 10 to 15 dB. Therefore, the accuracy of IaB values is terribly low. Nevertheless, IaB should be defined because we can treat IaA, IaB, and CL equally. The basis of the masking theory is the simple response that the signals are “heard” or “not heard”.

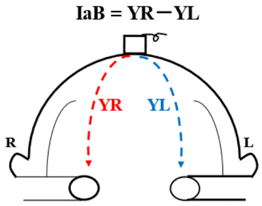


Figure 9-2 IaB at the forehead

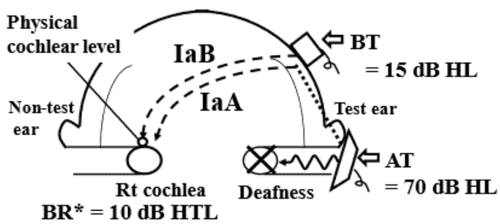


Figure 9-3 Physical IaB and IaA

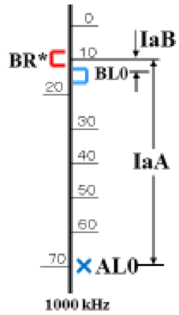


Fig. 9-4 Ia values

(2) Definition of IaA

When the AC signal is introduced into one ear by supra-aural earphones, the earphone generates a BC signal corresponding to the output level of the AC signal, and the BC signal reaches the opposite cochlea via the cross-converted BC pathway. Thus, the interaural attenuation for the AC signals (IaA) is defined as the difference between the output level of the AC signal and its cochlear level in the opposite ear (**Fig. 9-3**):

IaA (dB) = Cochlear level [AT] in the opposite ear (dB HL) − AT (dB HL).

However, the physical IaA value cannot be obtained clinically (cf. **1.1-4**).

The value of IaA is obtained in the configuration where one ear is normal and the other has complete hearing impairment (**Fig. 9-4**, cf. **1.2-3**). The calculation is expressed as follows:

IaA = AL0 − BR*.

where AL0 is the SH threshold for AC in the left ear and BR* is the true BC threshold in the right ear. Note that this is how IaA is calculated, rather than a definition of IaA. The meaning of the expression is the definition. Next, let us consider IaA in a clinical sense.

Further note

*) In **Fig. 9-4**, the precondition for the calculated expressions for the IaA and IaB values is that the occlusion effect does not occur in the right ear.

As described in Lecture 2, if the proposition that the AC signals are reduced to the BC signal is true, IaA can be defined as relative attenuation, similarly to IaB. However, it is in fact not true, as discussed below. Additionally, in Lecture 1, under this assumption, BC signals generated by supra-aural earphones have been termed converted BC signals. Hereafter, they are called "accessory BC signals."

In the early days, it had been considered that the cross hearing of AC signals occurred via air conduction, that is, the AC signal escaped from the earphones, and was attenuated in the air before reaching the opposite cochlea. If this is so, as shown in **Fig. 9-5**, when the AC signal of 70 dB HL is presented to the left ear, the escaped AC signal is attenuated by 60 dB in the air, and reaches the right cochlea as an AC signal of 10 dB HL. Certainly, in this case, since the AC signal is attenuated, the IaA value is 60 dB.

However, cross hearing in fact occurs via bone conduction. The supra-aural earphones produce not only the AC output but also BC output. The example in **Fig. 9-6** shows that the true BC threshold in the right ear (BR*) is 10 dB HTL and the left ear has complete hearing impairment. First, when the BC test signal of 10 dB HL is presented to the right ear, it is barely heard by the right cochlea. Subsequently, when the AC signal of 70 dB HL is presented to the left ear, it is barely heard. At this time, the participant hears not the AC signal but the accessory BC signal. Therefore, it can be said that corresponding to an input for the supra-aural earphone, the AC output for the left cochlea is 70 dB HL, and the BC output for the right cochlea is 10 dB HL. In other words, the vibrational energy of the earphone, which produces the AC output of 70 dB HL, also generates the BC output of 10 dB HL for the right cochlea.

As an example, consider the conversion of 100 Yen to dollars: the result is 1 dollar, but that does not mean 100 Yen are reduced to 1 dollar; both quantities are equivalent. Similarly, the vibrational energy of the earphone, which produces the AC output of 70 dB HL, can be converted to the BC output of 10 dB HL. In particular, the AC signals are never reduced to the BC signals. Consequently, IaA might be worthy of being called the "conversion quantity."

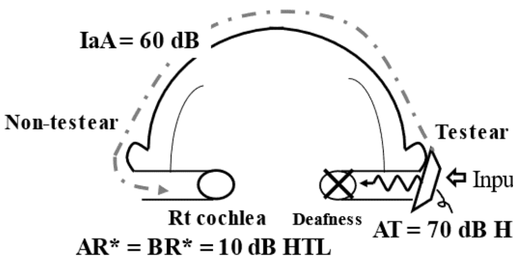


Figure 9-5 IaA value of 60 dB

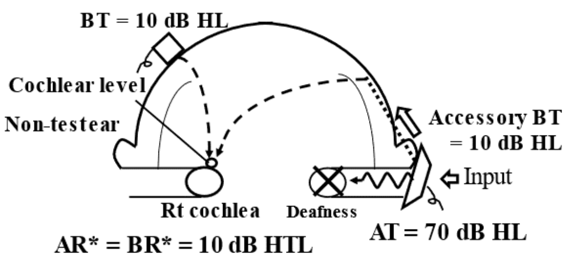


Figure 9-6 Two outputs of the earphone

Fig. 9-6 is represented as **Fig. 9-7 (a)** using the masking diagram. For the sake of visual clarity, it is conveniently assumed that the AC signals, which are reduced in the cross-converted BC pathway, are converted to BC signals, and reach the opposite cochlea. As a result, the signal transmission becomes a simple composition as **Fig. 9-7 (b)**. Clinically, it is convenient for visual understanding.

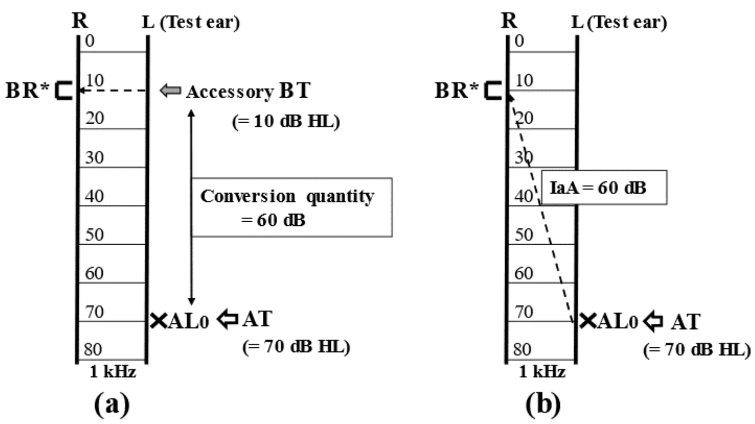


Figure 9-7 IaA on the diagram

Supplement 2: Another perspective on the boundary conditions (Lecture 2)

The boundary condition for effective masking is a proposition: when the noises are being heard, how many decibels in HL is the test signal that is barely heard by the test ear? (cf. **2.2-2**). For simplicity, the right ear is selected as the masked ear and the BC test signal is used.

Without masking, whether the BC test signal is "heard" or "not heard" by the right inner ear is determined by the relationship between the cochlear level of the test signal (Cochlear level [BT]) in the direct BC pathway and the true BC threshold level in the right ear (BR*) (cf. **1.2-4**):

Cochlear level [BT] < BR* ----- the test signal is "not heard."
Cochlear level [BT] = BR* ----- the test signal is "barely heard."
Cochlear level [BT] > BR* ----- the test signal is "heard."

With masking, when the cochlear level of the noise in the AC pathway is higher than BR* (Cochlear level [N] > BR*), the noise is heard by the right inner ear. Then, whether the test signal is "heard" or "not heard" by the right inner ear is determined by the relationship between the cochlear level of the test signal and that of the noise (**Fig. 9-8 [a]**).

Cochlear level [BT] < Cochlear level [N] ----- the test signal is "not heard."
Cochlear level [BT] > Cochlear level [N] ----- the test signal is "heard."

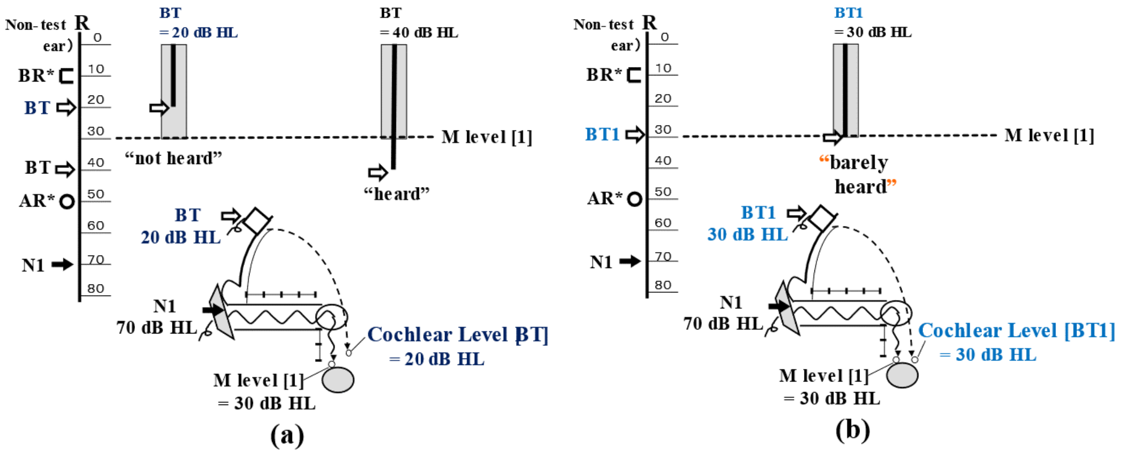


Figure 9-8 Boundary condition for effective masking

The question is whether the test signal is heard when both levels are equal. According to ANSI (2004), if the masking noise level is equal to the true AC threshold level in the right, non-test ear (N = [AR*] dB HL), the BC threshold in the right ear is not elevated. That is, when the cochlear level [N] is equal to the true BC threshold level in the right ear (BR*), the BC test signal of the level equal to BR* (BT = [BR*] dB HL) is barely heard by the right inner ear. Consequently, when the cochlear levels of the test signal and noise are equal, the test signal is barely heard (**Fig. 9-8 [b]**).

Cochlear level [BT] = Cochlear level [N] ----- the test signal is "barely heard".

When masking with N (= AR* + α, α > 0 dB) in the right ear,

Cochlear level [N] = N − AB gap* = (AR* + α) − (AR* − BR*)
= BR* + α.

Here, if the BC test signal (BT = [BR* + α] dB HL) is presented to the right ear, the cochlear level [BT] is equal to the cochlear level [N], and the test signal is barely heard. Consequently, the BC threshold in the right ear is elevated by α (dB) under the masking condition. The right ear's BC threshold masked by Nn is represented as follows:

mBR[n] = (BR* + α) dB HTL.

Supplement 3: Paradox of IaA (Lecture 3)

Let us consider the following audiometric configuration at 1000 Hz in **Fig. 9-9**: the right ear has complete hearing loss, and the left ear has chronic otitis media, in which the true BC threshold is within normal range (BL* = 10 dB HTL) and the conductive loss is 50 dB. Without masking, the AC and BC thresholds in the left ear (AL0 of 60 dB HTL and BL0 of 10 dB HTL) are obtained. The true AB gap of the left ear (GL*) is 50 dB. Subsequently, the AC threshold in the right ear is measured. If the IaA value at 1000 Hz is 40 dB, an AT0 of 50 dB HL is attenuated by 40 dB via the cross-converted BC pathway, and the BC stimuli of 10 dB HL reaches the left cochlea (BL* = 10 dB HTL). Thus, the signal is barely heard. The AC threshold in the right ear (AR0) of 50 dB HTL is obtained, and is the SH threshold (SHT).

Here, an AT of 50 dB HL cannot be heard by the left ear, because AL* is 60 dB HTL. However, when an AT of 50 dB HL is presented to the right ear, it is heard by the left inner ear, which is strange. Let us consider this paradox.

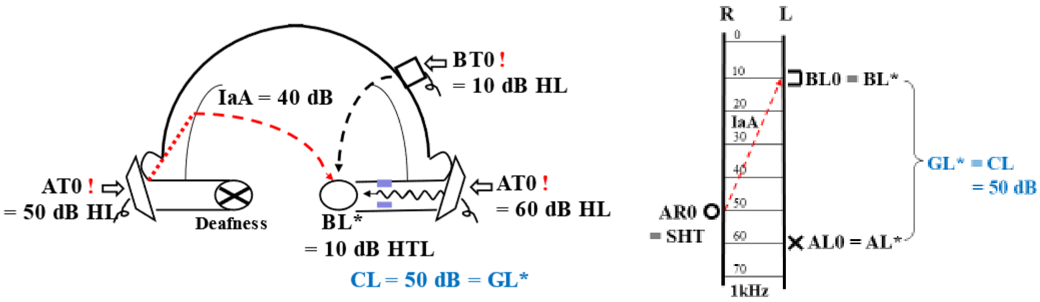


Figure 9-9 Audiometric configuration at 1000 Hz

As discussed in Lecture 3, the typical plateau widths of the left ear are as follows:

Lt APW = (IaA − GR*) + (IaA − GL*),

Lt BPW = (IaA − GR*) + IaB,

where GR* and GL* are the true AB gap of the right and left ear, respectively. Since the plateau widths cannot be negative, an AB gap is never larger than IaA. If an AB gap was larger than IaA, the plateau widths would be negative, and the unusual situation above would occur.

In the traditional description, the relationship between the AB gap and IaA has not been considered, causing an impossible configuration, in which an AB gap is larger than IaA, to be assumed. Even now, incorrect explanations for masking have not been modified. As a result, clinical masking becomes incomprehensible.

< Mechanism of the paradox>

When an AT0 of 50 dB HL is presented to the left ear, the converted BC signal reaches the left cochlea via the direct-converted BC pathway (**Fig. 9-10**). At this time, the BC stimuli of 10 dB HL reaches the cochlea, and is barely heard. The AC threshold in the left ear is obtained as 50 dB HTL. As the IaA value is 40 dB, the true AB gap is never larger than 40 dB (cf. **4.4-1 [3]**).

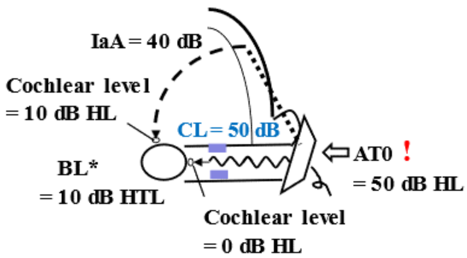


Figure 9-10 Direct-converted BC pathway

We may doubt whether the hearing of the converted BC signals can be assumed to be the true hearing. In the near future, when the relationship (AB gap ≤ IaA) has been widely recognized, the issue will become a focus of discussion. Isogai, the founder of the ABCI method, has insisted that it is a second shadow-hearing. How many Japanese people have understood this statement?

Supplement 4: Another perspective on MNnpo (Lecture 5)

The initial masking noise level of the present method is equal to the test ear's AC threshold level measured without masking (N1 = [AL0] dB HL). Theoretically, this is the maximum level of masking noise that has no possibility of overmasking (MNnpo). From another perspective, MNnpo can be considered as the following.

It is supposed that the attenuation value of the converted signals (the AC test signal and AC masking noise) in the direct-converted BC pathways is equal to the IaA value. Then, if the output levels of the AC test signal and AC noise are equal, the cochlear levels of both signals are always equal in the test inner ear (**Fig. 9-11 [c']**).

a) Cases where AL0 is the SH threshold (**Fig. 9-11 [a]**)

When an AT0 of 60 dB HL is presented to the left (test) ear, it is heard only by the right (non-test) ear. Notably, **the signal of 60 dB HL is not heard by the left ear**. Therefore, if the noise N1 of the level equal to the AT0 is presented to the right ear, it is not heard by the left ear. Since N1 is not heard by the test ear, overmasking (OM) does not occur.

Colloquially, "When the signal that is not heard by the test ear is presented to the non-test ear, it is not heard by the test ear."

b) Cases where AL0 is the true threshold: common cases (**Fig. 9-11 [b]**)

An AT0 of 60 dB HL reaches the left cochlea via the AC pathway, and is barely heard. However, it is not heard via the direct-converted BC pathway. Instead, **the signal of 60 dB HL is heard only via the AC pathway**. Therefore, if the noise N1 of the level equal to AT0 is presented to the right ear, it reaches the left cochlea via the cross-converted BC pathway, and is not heard. Since N1 is not heard by the test ear, OM does not occur.

Colloquially, "Since only the signal via the AC pathway of the test ear can be barely heard by the test ear, noise of the same level delivered to the non-test ear is not heard by the test ear, because it goes through the BC pathway."

c) Cases where AL0 is the true threshold: rare cases (**Fig. 9-11 [c]**)

For atresia of the external canal, an AT0 of 60 dB HL reaches the left cochlea via the direct-converted BC pathway, and is barely heard. However, the signal via the AC pathway is not heard. Instead, **the signal of 60 dB HL is heard only via the BC pathway**. Therefore, if the noise N1 of the level equal to the AT0 is presented to the right ear, it reaches the left cochlea via the cross-converted BC pathway, and is barely heard.

Colloquially, "Since only the signal via the BC pathway can be barely heard by the test ear, noise of the same level delivered to the non-test ear is barely heard by the test ear via the BC pathway."

If the test signal and noise are barely heard at the same time by the test ear, according to the boundary condition for OM, the hearing threshold level for the test signal is not elevated: OM does not occur. If the boundary condition is not true, OM occurs.

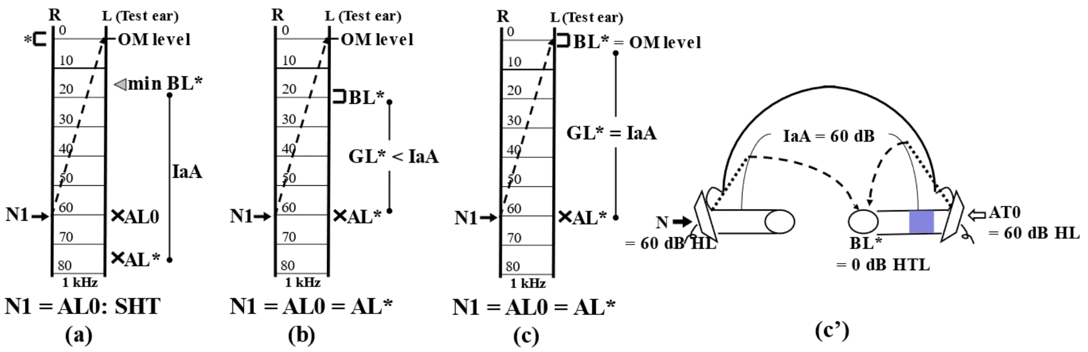


Figure 9-11 Another perspective of MNnpo

****Further note****

*) There may be a case where the AC test signal via the AC pathway and the converted BC test signal via the direct BC pathway reach the test inner ear at the same time and are barely heard.

Supplement 5: Obtaining the plateaus (Lecture 7)

The plateau widths of the test ear can be represented using the true AB gaps (GR*, GL*) and the true BC thresholds (BR*, BL*) (**Fig. 9-12**, **9-13**).

When the left ear is set to the test ear,

Lt APW = (IaA − GR*) + (IaA − GL*), ----- (A1)
Lt APW = (IaA − GR*)＋(BL* − BR*), ----- (A2)
Lt BPW = (IaA − GR*)＋(BL* − BR*), ----- (B1)
Lt BPW = (IaA − GR*) + IaB, ----- (B2)
Lt BPW = (IaA − GR*). ----- (B3)

When the right ear is set to the test ear,

Rt APW = (IaA − GL*)＋(BR* − BL*), ----- (A2’)
Rt BPW = (IaA − GL*)＋(BR* − BL*), ----- (B1’)
Rt BPW = (IaA − GL*) + IaB, ----- (B2’)
Rt BPW = (IaA − GL*). ----- (B3’)

(—): no plateau
Pattern [2]: Rt BPW = (IaA − GL*) + IaB = 0 dB + IaB = IaB.
Pattern [6], [7-0]: Lt BPW = (IaA − GR*) + IaB = 0 dB + IaB = IaB.

The plateau widths given above are so called exact solutions. As described in Lecture 7, assuming that the IaB values at all frequencies are 0 dB, the plateau widths using the apparent AB gaps (GR0, GL0) are represented as the simple forms, which are general solutions (cf. **7.3-1**).

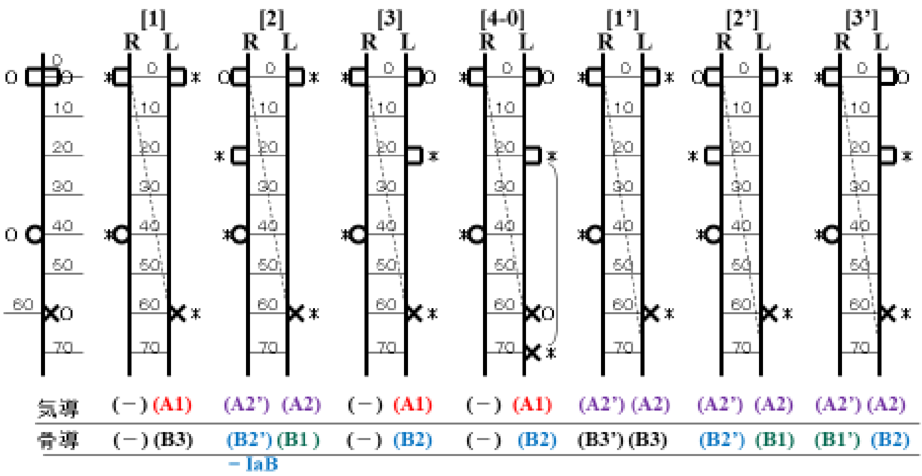


Figure. 9-12 Patterns in which apparent AC thresholds differ

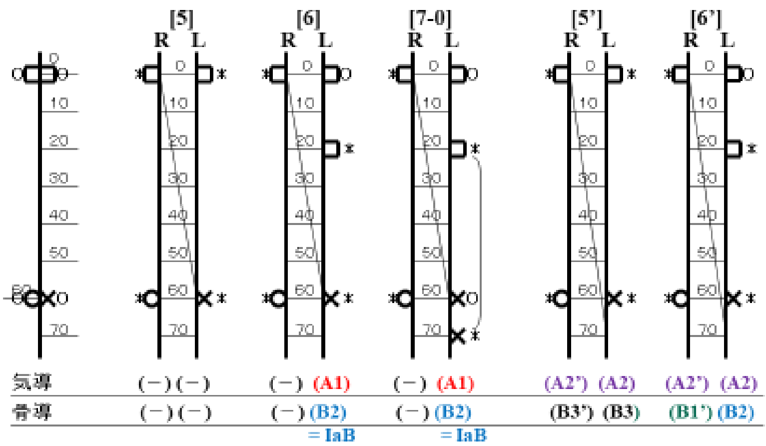


Figure. 9-13 Patterns in which apparent AC thresholds do not differ

Supplement 6: Clinical significance of the IaB value

In the cases in which the apparent BC threshold in the left, poorer ear by AC (BL0) is the SH threshold, Lt BPWs are as follows:

Patterns [2] and [2']: Rt BPW = (IaA − GR*) + IaB,

Patterns [3], [3'], [4] [6], [6'], and [7]: Lt BPW = (IaA − GR*) + IaB.

Although the IaB value has been supposed to be 0 dB, this is not always true. As shown in **Fig. 9-14**, the Rt AA gap at 1000 Hz is 10 dB. If IaB is 0 dB, the Lt BPW of only 10 dB is clinically difficult to identify. However, if IaB is 5 dB (**Fig. 9-15**), Lt BPW of 15 dB is clinically significant.

Actually, the IaB value is not easy to obtain with high accuracy. Clinically, we have no option to search the plateaus for BC.

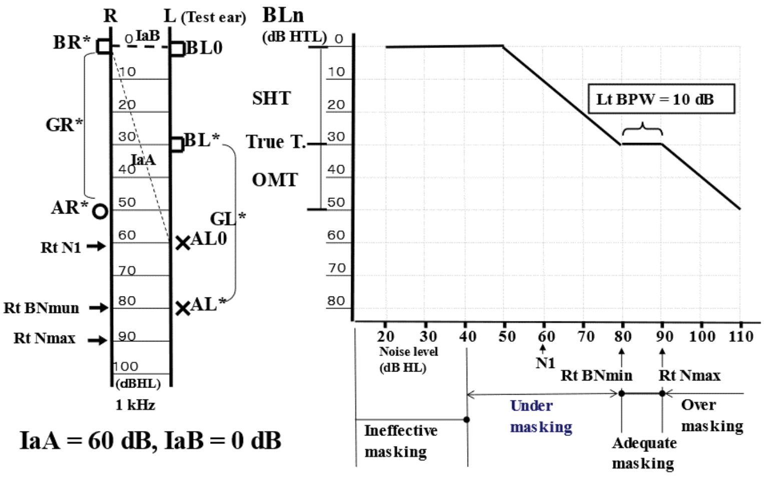


Figure 9-14 Lt BPW = (IaA − GR*): IaB = 0 dB

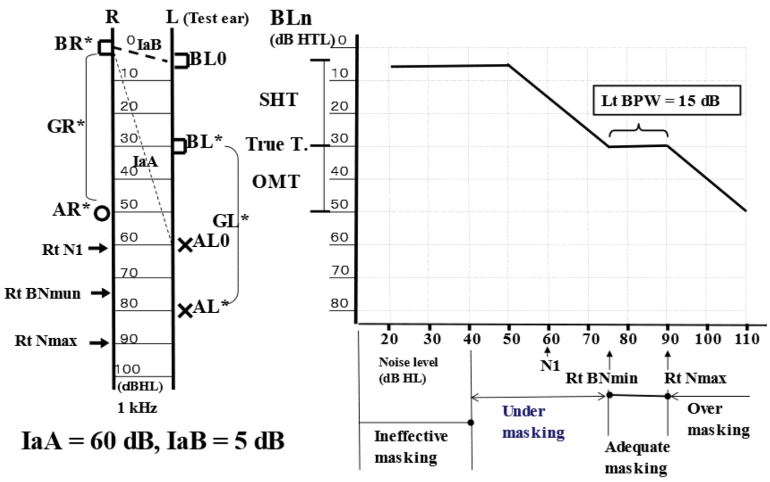


Figure 9-15 Lt BPW = (IaA − GR*) + IaB: IaB = 5 dB

Lecture 10 The Occlusion effect

10.1 The basic points

(1) The occlusion effect: OE

When the external auditory canal is covered by a supra-aural earphone, the external canal component of the bone-conducted (BC) sounds for the low frequencies (250, 500, and 1000 Hz) are transmitted to the cochlea via the conductive system. If there is no conductive disorder (i.e., normal hearing and sensorineural hearing loss), the intensity of the BC sounds reaching the cochlea is increased and the BC thresholds at low frequencies are decreased, that is, the BC hearing acuity is improved. This is an occlusion effect (OE). However, in the ears with conductive disorder, the OE is decreased **or** disappeared. In addition, when the air-conducted (AC) test signals or noises are conducted to the cochlea via the AC pathway, the OE is not created. The OE values by the standard supra-aural earphone are as follows:

Frequency (Hz)	250	500	1000	2000	4000	
OE value (dB)	20	20	5	0	0	(Audiology Japan 1990)

(2) An assumption of the occlusion effect

It is assumed that the maximum occlusion effect value is 20 dB and the occlusion effect is cancelled out by the extent of the true AB gap. For example, at 250 Hz,

If the true AB gap is 0 dB, the OE value is 20 dB.
If the true AB gap is 10 dB, the OE value is 10 dB.
If the true AB gap is 20 dB, the OE is not created.

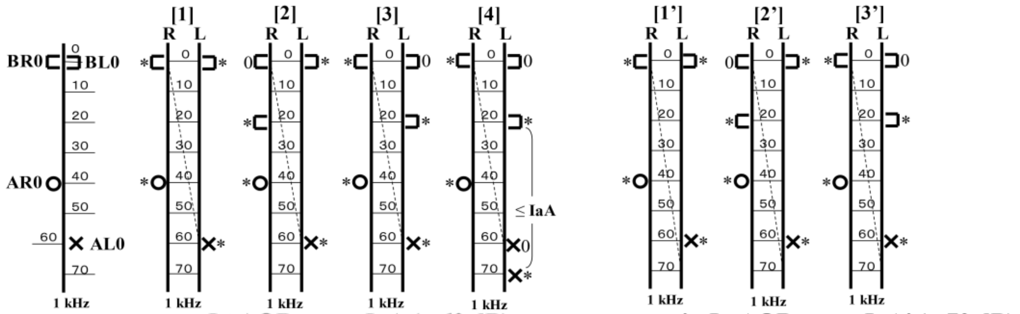
(3) The clinical significance of the occlusion effect

If the occlusion effect is created in the non-test ear, the masking effect is decreased by the OE value. Therefore, the initial masking noise level must be increased by the OE value. Especially if the effect is created in the cases where masking is difficult to perform, the possibility of overmasking occurs and masking becomes more difficult, which is a traditional concept. However, this lecture shows that the OE is not the factor which makes masking more difficult.

(4) The bone-conducted output of the supra-aural earphone

When the converted BC sounds (test tone or noise), which are the BC output of the supra-aural earphone, reach the opposite cochlea via the cross BC pathway, the sound pressures might be boosted, like the BC test signal. That is, the converted sounds can also create the occlusion effect (cf. **Fig. 10-20 [c]**).

Patterns of audiometric configurations at a given frequency



[1] – [4]: Lt AOB gap = IaA (= 60 dB) **[1'] – [3']: Lt AOB gap < IaA' (= 70 dB)**

Patterns where bilateral AC thresholds measured without masking (apparent AC thresholds) differ significantly (AR0 < AL0: AL0 − AR0 ≥ 15 dB)

The right ear is the better ear by AC. The left ear is the poorer ear by AC
Patterns [1], [1']: the apparent AC and BC thresholds are all the true thresholds.
Patterns [2], [2']: the apparent BC thresholds in the right ear (BR0) is the SH threshold.
Patterns [3], [3']: the apparent BC thresholds in the left ear (BL0) is the SH threshold.

(5) The BC threshold including the occlusion effect in the non-test ear

Take the audiometric configuration where the right ear is normal (AR* = BR* = 0 dB HTL) and the left is completely deafness at 500 Hz. When the right AC threshold is measured with both the ears covered by the supra-aural earphones, the AC test signal is reached to the right cochlea via the AC route and no occlusion effect is created (**Fig. 10-1 [a]**): the apparent AC threshold in the right ear (AR0 = 0 dB HTL) is the true one (AR0 = AR*).

The BC threshold is measured with the external canal open (**Fig. 10-1 [b]**): the apparent BC threshold in the right ear (BR0 = 0 dB HTL) is the true one (BR0 = BR*) , the apparent BC threshold in the left ear (BL0 = 0 dB HTL) is the shadow hearing threshold (SHT).

Next, the right BC threshold is measured with the right ear occluded (**Fig. 10-1 [c]**). Then, the BC test signal (BT) is reached to the right cochlea via the direct BC route and the sound pressure is boosted due to the occlusion effect. Since the right true AB gap is 0 dB, the OE value is 20 dB. When BT0 of −20 dB HL is introduced to the right ear, it is barely heard by the right cochlea. Thus, the measured BC threshold including the OE in the right ear (BR0’) is −20 dB HTL. Therefore, without masking, the right ear’s BC threshold including the OE (OE-BR0) is as follows:

OE-BR0 = BR* − OE = 0 dB HTL − 20 dB = −20 dB HTL.

The OE value can be obtained as following equation:

OE = BR0 − BR0’ = 0 dB HTL − (−20 dB HTL) = 20 dB.

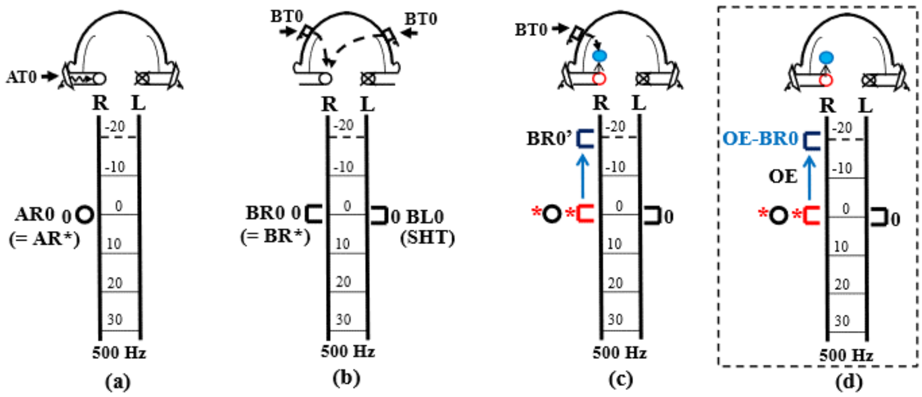


Figure 10-1 OE-BR0

(6) The BC threshold masked with masking noise including the occlusion effect

When N1 of 40 dB HL (α1 = 40 dB) is introduced in the right ear with the supra-aural earphone, and if the OE is not created, the BC threshold masked with N1 in the right ear (i.e., mBR[1]) is as follows (cf. **2.2-1**):

mBR[1] = BR* + α1 = 0 dB HTL + 40 dB

= 40 dB HTL.

By contrast, if the OE is created (**Fig. 10-2**), the BC threshold masked with N1 including the occlusion effect in the right ear (i.e., OE-mBR[1]) is as follows:

OE-mBR[1] = OE-BR[0] + α1 = −20 dB HTL + 40 dB

= 20 dB HTL.

Here, when BT1 of 20 dB HL is presented to the right ear, the test signal is barely heard by the right cochlea, that is, the masking effect is decreased by 20 dB of the OE value. Therefore, in order to avoid undermasking, the noise level must be higher by the OE value, which is described in the established textbooks on masking procedure.

However, the occlusion effect should be considered depending on the audiometric configurations.

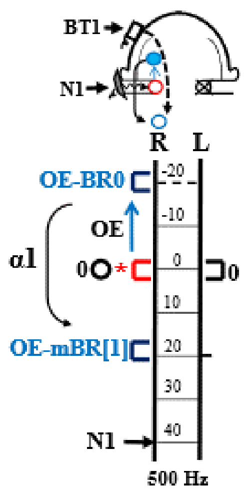


Figure 10-2 OE-mBR[1]

(7) The interaural attenuation for AC and the occlusion effect

Let us consider the case where the right ear is normal (AR* = BR* = 0 dB HTL) and the left is completely deafness at all frequencies. **Fig. 10-3** shows an audiogram in which the AC thresholds are measured with the supra-aural earphones and the BC thresholds are measured with the external canal open. The apparent AC and BC thresholds in the left ear (AL0, BL0) are the SH thresholds. At 2000 Hz (**Fig. 10-4 [b]**), the AC test signal (AT0 = 60 dBHL) delivered to the left ear is reached the right cochlea (BR* = 0 dB HTL = BR0) via the BC cross pathway and is barely heard. AL0 of 60 dB HTL is the SH threshold. Then, IaA is equal to Lt AOB gap:

IaA = AL0 − BR0 = Lt AOB gap = 60 dB. ∴ **IaA = Lt AOB gap**.

At 500 Hz (**Fig. 10-4 [a]**), the OE (20 dB) is created in the right ear. AT0 of 40 dBHL introduced to the left ear is barely heard by the right cochlea (OE-BR0 = −20 dB HTL). AL0 of 40 dB HTL is the SH threshold. Then, IaA is equal to Lt OE-AOB gap that is the air and opposite bone gap including the OE:

IaA = AL0 − OE-BR0 = Lt OE-AOB gap = 60 dB. ∴ **IaA = Lt OE − AOB gap**.

Assuming that the standard value of IaA is 60, when Lt AOB gap and Lt OE-AOB gap are equal to 60 dB (= IaA) respectively, AL0 might be the SH threshold and masking for AC is needed. However, in actual, since OE-BR0 is not measured, Lt OE-AOB gap is unknown.

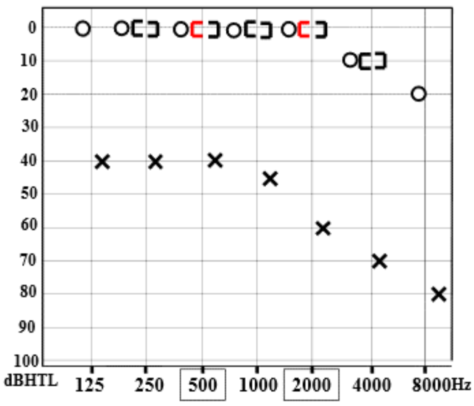


Figure 10-3 Audiogram with no masking

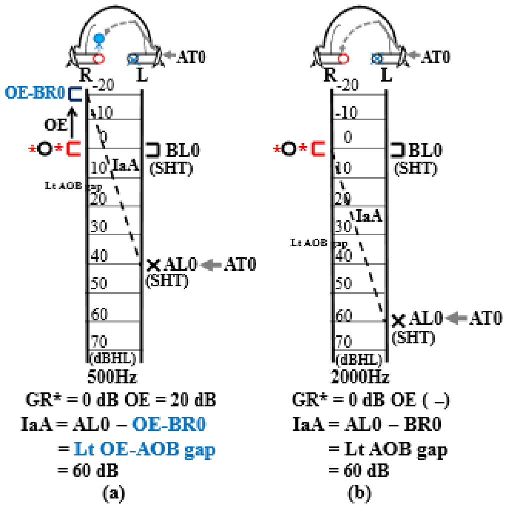


Figure 10-4 Lt OE-AOB gap and Lt AOB gap

Let us reconsider the criterion for masking through AC testing when the OE is created at the low frequencies. If the OE is created, Lt OE-AOB gap is larger by the OE value than Lt AOB gap:

Lt OE-AOB gap = Lt AOB gap + OE.

When Lt AOB gap is 40 dB, assuming that the maximum value of the OE (20 dB) is created, we could estimate that Lt OE-AOB gap is 60 dB (= IaA). The same goes for Lt AOB gap of 50 dB, assuming the OE value of 10 dB.

In conclusion, when Lt AOB gap is larger than or equal to 40 dB at low frequencies, masking for AC is needed.

Assuming that the value of IaA is decreased by the OE value (20 dB) due to the sound pressure amplification of the OE, IaA is equal to Lt AOB gap (= 40 dB) (**Fig.10-5**). At the same time, the value of IaB becomes amplification (20 dB) (cf. **1.3**). This assumption makes the discussion described later troublesome. Therefore, it is not adopted in this lecture series.

In addition, although the minimum value of IaA has been regarded as 40 dB at all frequencies, it should be re-examined.

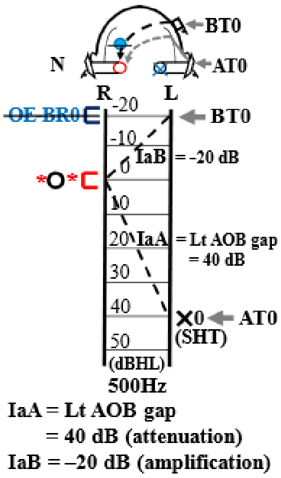


Figure 10-5 Ia

10.2 The bone conduction audiometry and the occlusion effect

When **15 dB ≤ Lt AOB gap < 40 dB = min IaA**, only masking for BC is needed because the apparent AC thresholds (AR0, AL0) are not the SH thresholds but true ones. The apparent AB gap in the right, non-test ear is GR0 (= AR0 − BR0).

(1) GR0 = 0 dB

GR0 is equal to GR* (AR* = BR* = 0 dB HTL) and the apparent AC thresholds differ significantly (AL0 − AR0 = 35 dB). The audiometric configuration is either a pattern [1’] (BL0 = BL*) or pattern [3’] (BL0 < BL*) (**Fig. 10-6**).

With the supra-aural earphone for masking noise in the right ear, since the true AB gap in the right ear (GR*) is 0 dB, the OE of 20 dB is created (**Fig. 10-7**). Without masking, the right ear’s BC threshold including the OE (OE-BR0) is as follows:

OE-BR0 = BR* − OE = −20 dB HTL.

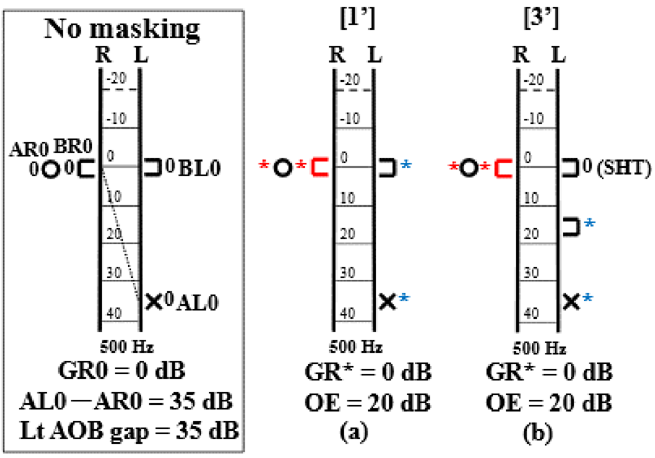


Figure 10-6 GR0 = 0 dB: GR* = 0 dB

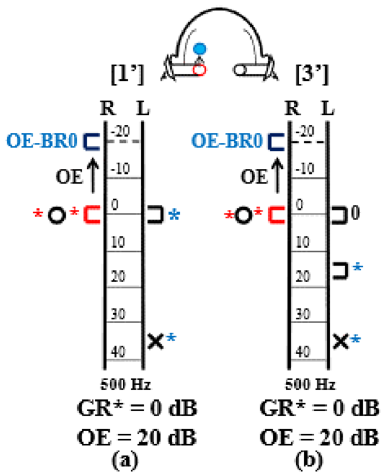


Figure 10-7 OE-BR0

The initial masking noise, N1 of 20 dB HL (α1 = 20 dB), is delivered into the non-test ear (**Fig. 10-8**), OE-mBR[1] is as follows:

OE-mBR[1] = OE-BR[0] + α1 = −20 dB HTL + 20 dB

= 0 dB HTL (= BR*).

Since the effective amount of masking (α1 of 20 dB) is cancelled by the OE value of 20 dB, the non-test ear’s true BC threshold is not elevated. Thus, the masking with N1 is ineffective. BT1 is the BC test signals that is barely heard with masking noise of N1. IaB is 0 dB.

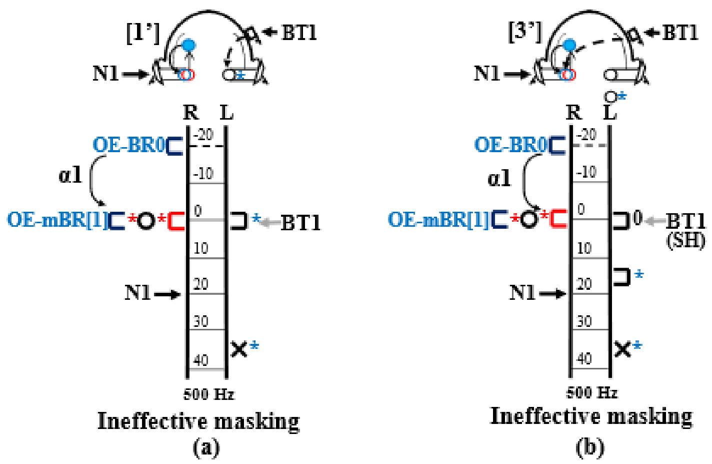


Figure 10-8 N1= 20dB (α1=20dB)

For effective masking, the masking noise levels need to be higher than 20 dB HL:

N > [AR*] + OE =20 dB HL.

Here, Nx, which never occurs overmasking, is used (**Fig. 10-9 [a], 10-10 [a]**) (ref. **6.1-1**) :

Nx = BL0 + min IaA = 0 dB HTL + 40 dB

= 40 dB HL (αx = 40 dB),

OE-mBR[x] = OE-BR0 + αx = −20 dB HTL + 40 dB

= 20 dB HTL (> BR* = 0 dB HTL).

Since the non-test ear's true BC threshold is elevated, the masking with Nx is effective. In both the patterns, the true thresholds can be determined with the noise levels raised, as follows.

a) The plateau graph in pattern [1'] with the OE (Fig. 10-9)

When N ≤ 20 dBHL, the masking is ineffective. When 20 dB HL < N ≤ 60 dB HL, the masking is adequate. The BC plateau width including the OE (Lt OE-BPW) is 40 dB. BTx is the BC test signals that is barely heard with masking noise of Nx.

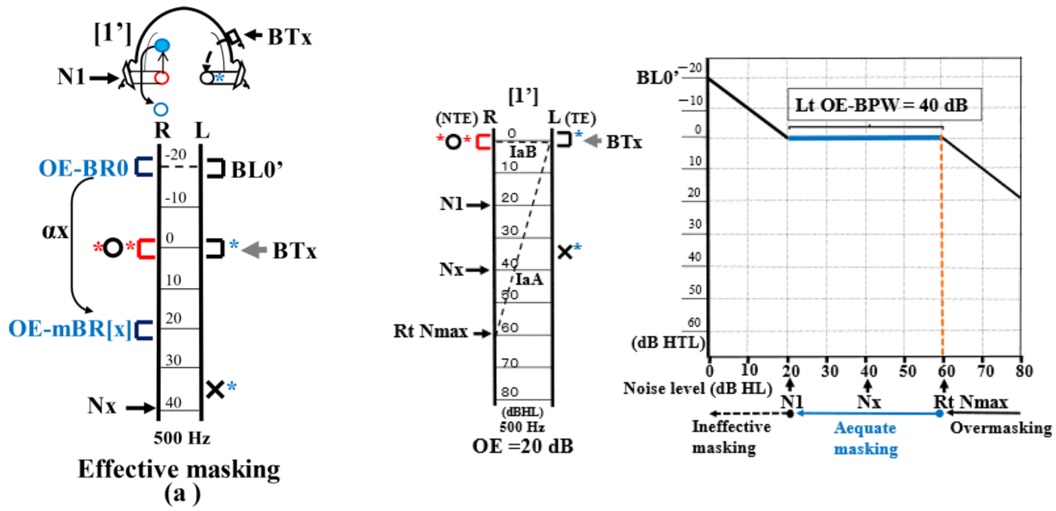


Figure 10-9 Lt OE-BPW in pattern [1']

b) The plateau graph in pattern [3'] with the OE (Fig. 10-10)

When 35 dB HL ≤ N ≤ 60 dB HL, the masking is adequate. Lt OE-BPW is 40 dB.

Rt OE-BNmin (= 35 dB HL) is the minimum adequate BC masking noise level including the OE.

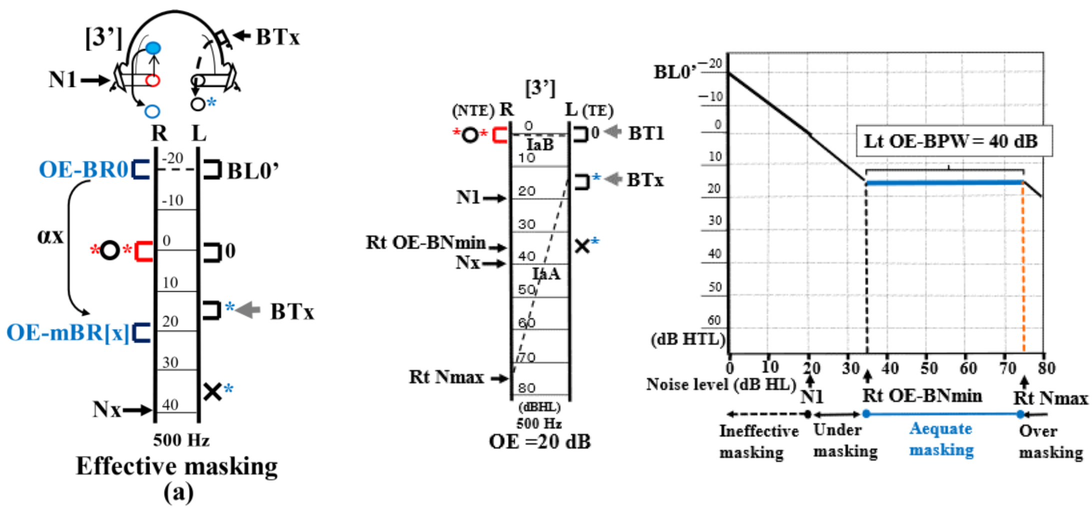


Figure 10-10 Lt OE-BPW in pattern [3']

Notably, in both the patterns, Lt OE-BPW is more shortened by 20 dB than Lt BPW without the OE. However, the significant plateau widths could be ensured.

(2) GR0 = 20 dB

The apparent AC thresholds differ significantly (AL0 − AR0 = 15 dB). The audiometric configuration is either a pattern [1’], [3’], or [2’].

When GR* = 20 dB: Patterns [1] and [3], the OE is not created (**Fig. 10-11 [a], [b]**).

When GR* = 10 dB: Pattern [2’]-1, the OE of 10 dB is created (**Fig. 10-11 [c]**).

When GR* = 0 dB: Pattern [2’]-2, the OE of 20 dB is created (**Fig. 10-11 [d]**).

It should be noted that the apparent BC threshold (BL0) is the true threshold in patterns [1’] , [2’]-1, and [2’]-2. BL0 is the SH threshold (SHT) in pattern [3’].

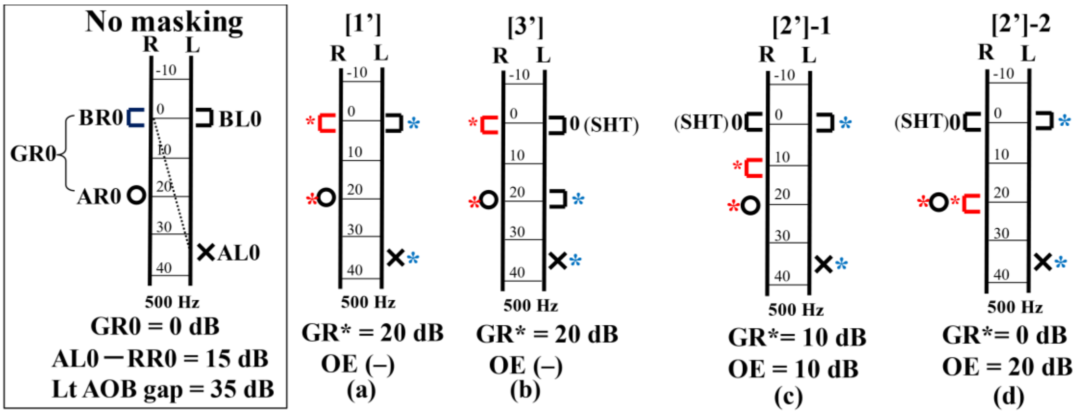


Figure 10-11 GR0 = 20 dB

If Nx = 40 dB HL (αx = 20 dB) is used, the masking with Nx is effective in patterns [1’], [3’], and [2’]-1 (**Fig. 10-12 [a], [b], [c]**).

By contrast, In pattern [2’]-2, when Nx is used (**Fig. 10-12 [d]**), OE-mBR[x] is as follows:

OE-mBR[x] = OE-BR0 + αx = 0 dB HTL + 20 dB

= 20 dB HTL (= BR*).

Since the non-test ear’s true BC threshold is not elevated, the masking with Nx is ineffective. However, the BC threshold measured with Nx in the left ear (BLx = 0 dB HTL) is the true one.

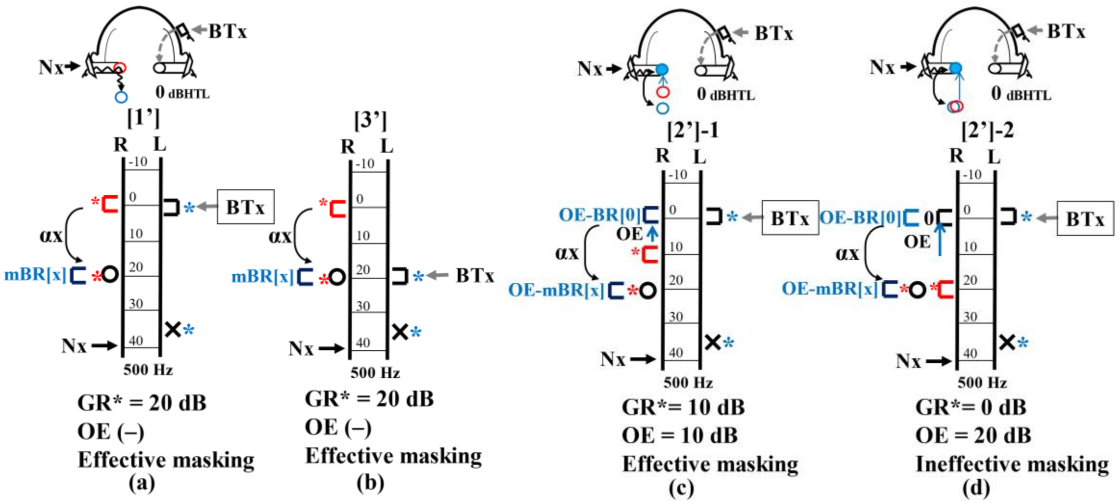
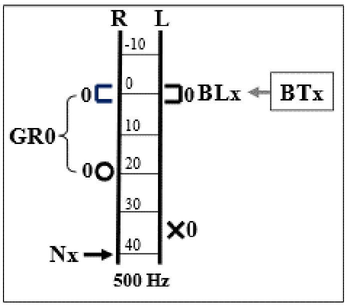


Figure 10-12 Nx = BL0 + minIaA

When the BC threshold measured with Nx in the test ear (BLx) is equal to BL0 (BLx = BL0), BLx is the true threshold (BLx = BL0 = BL*), regardless of whether the masking with Nx is effective (patterns [1’], [2’]-1) or ineffective (pattern [2’]-2). That is, at this time, the OE has no influence on measurement results.

When BLx > BL0, the configuration is a pattern [3’].



Next, let us compare the pattern [1’] without the OE and pattern [2’]-2 with the OE.

a) The plateau graph in pattern [1’] without the OE (Fig. 10-13)

When 20 dB HL < N ≤ 60 dB HL, the masking is adequate. The BC plateau width in the left ear (Lt BPW) is 40 dB.

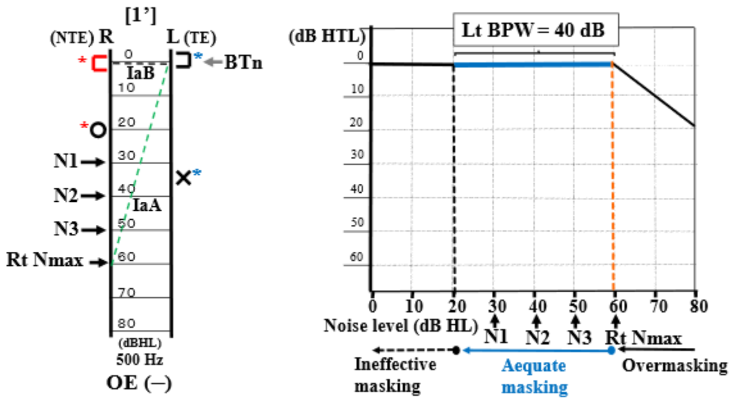


Figure 10-13 Lt BPW

b) The plateau graph in pattern [2’]-2 with the OE (Fig. 10-14)

When 40 dB HL < N ≤ 60 dB HL, the masking is adequate. Then the BC plateau width including the OE in the left ear (Lt OE-BPW) is 20 dB.

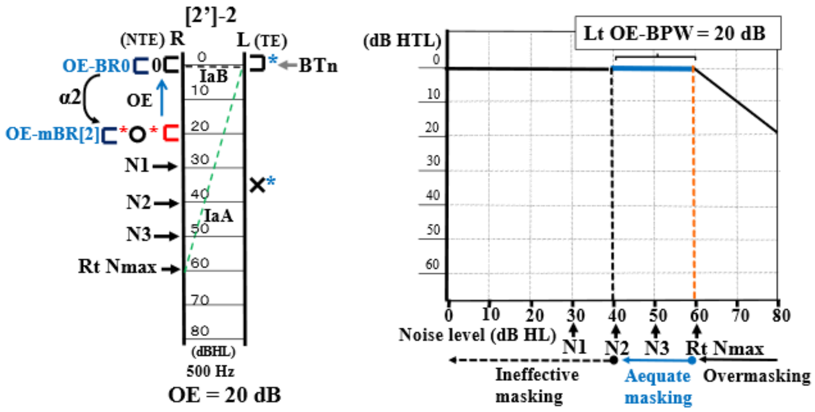
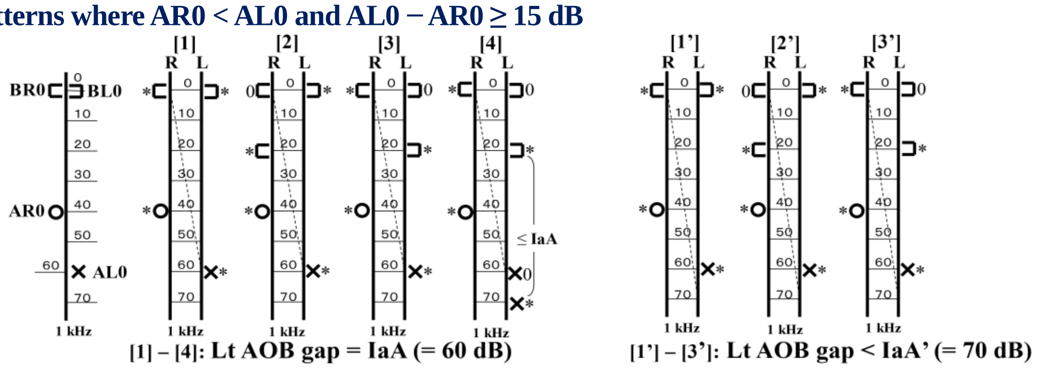


Figure 10-14 Lt OE-BPW

Although in pattern [2’] the BC plateau wide is shortened by the OE, the plateau graph’s form is the same as that without the OE in pattern [1’], which means that the OE has no influence on measurement results when the apparent AB gap is 20 dB.

Therefore, the OE need not to be taken into account when the apparent AB gap is 20 dB.

Patterns where AR0 < AL0 and AL0 − AR0 ≥ 15 dB



[1] – [4]: Lt AOB gap = IaA (= 60 dB)   [1’] – [3’]: Lt AOB gap < IaA’ (= 70 dB)

The right ear is the better ear by AC. The left ear is the poorer ear by AC

Patterns [1], [1’]: the apparent AC and BC thresholds in both ears are all the true thresholds.

Patterns [2], [2’]: the apparent BC thresholds in the right ear (BR0) is the SH threshold.

Patterns [3], [3’]: the apparent BC thresholds in the left ear (BL0) is the SH threshold.

(3) GR0 = 30 dB

The apparent AC thresholds do not differ significantly (AL0 − AR0 = 5 dB < 10 dB). The audiometric configuration is either a pattern [5’] or [6’].

When GR* = 30 dB: Pattern [5’] and [6’]L, the OE is not created (**Fig. 10-15 [a], [b]**).

When GR* = 20 dB: Pattern [6’]R-1, the OE is not created (**Fig. 10-15 [c]**).

When GR* = 10 dB: Pattern [6’]R-2, the OE value is 10 dB (**Fig. 10-15 [d]**).

When GR* = 0 dB: Pattern [6’]R-3, the OE value is 20 dB (**Fig. 10-15 [e]**).

Patterns [6’]R: the SH threshold is the right ear, patterns [6’]L: the SH threshold is the left ear.

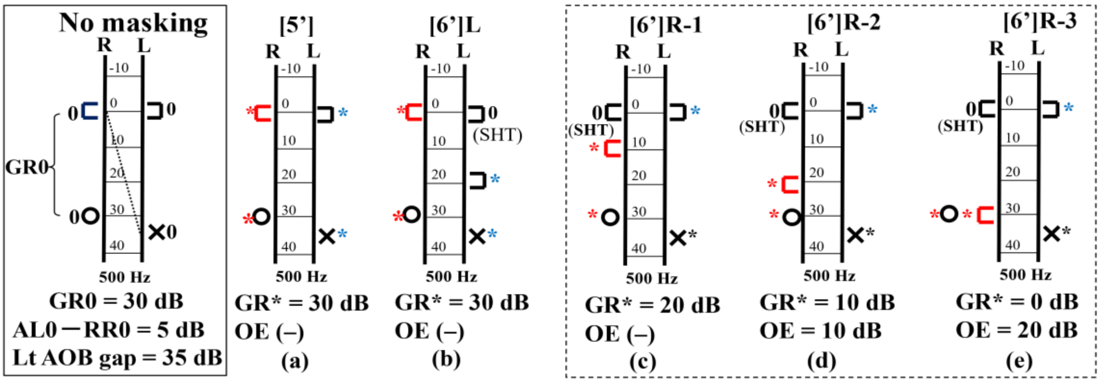


Figure 10-15 GR0 = 30 dB

In patterns [5’], [6’]L, and [6’]R-1(**Fig.10-16**), the masking with Nx of 40 dBHL (αx = 10 dB) is effective since the occlusion effect is not created.

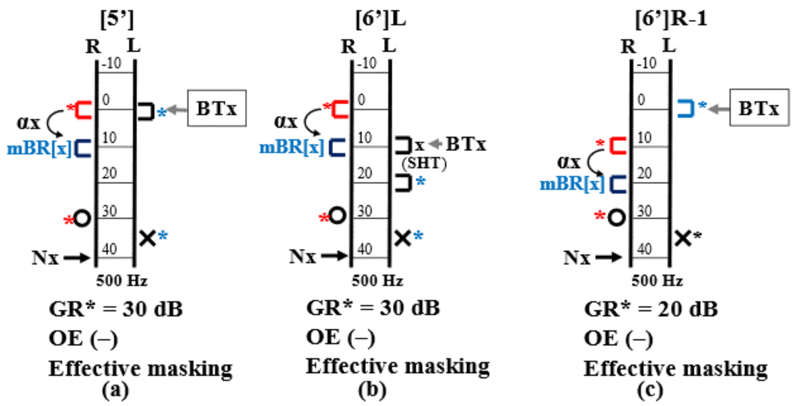


Figure 10-16 Nx = BL0 + minIaA

In patterns [6’]R-2, and [6’]R-3 (**Fig.10-17**), the masking with Nx of 40 dBHL is ineffective (OE-mBR[x] ≤ BR*). However, the measured BC threshold (BLx) is a true one.

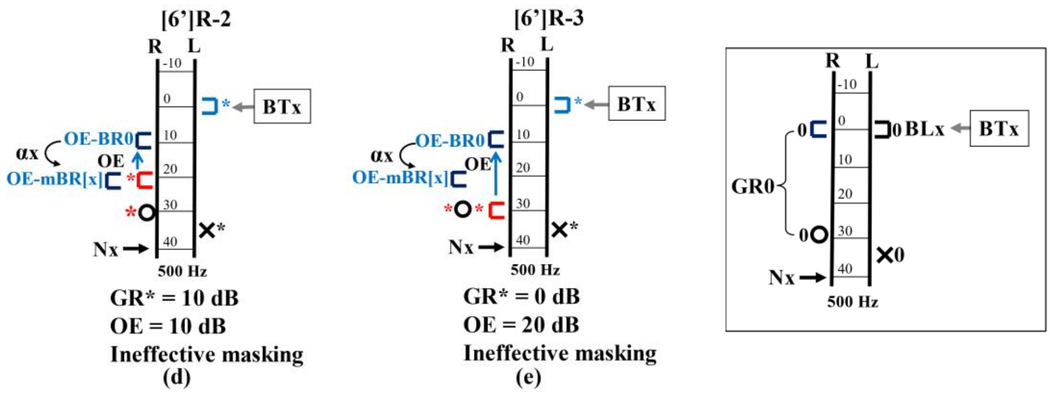


Figure 10-17 Nx = BL0 + minIaA

When the BC threshold measured with Nx in the test ear (BLx) is equal to BL0 (BLx = BL0 = 0 dB HTL), BLx is the true threshold (BLx = BL0 = BL*), regardless of whether the masking of Nx is effective (patterns [5’], [6’]L-1) or ineffective (patterns [6’]L-2, [6’]L-3). The OE has no influence on measurement results

Let us compare the plateau graphs in two patterns with and without the OE.

a) The plateau graph in pattern [5’] without the OE (Fig. 10-18)

When 30 dB HL < N ≤ 60 dB HL, the masking is adequate. Then, Lt BPW is 30 dB.

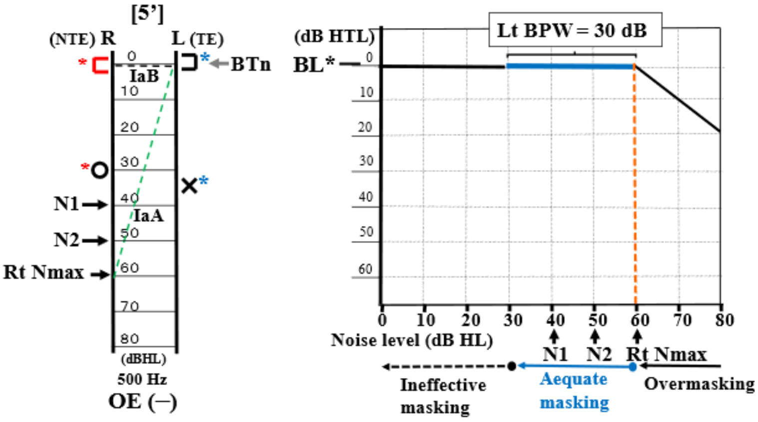


Figure 10-18 Lt BPW

a) The plateau graph in pattern [6’]-3 with the OE (Fig. 10-19)

When 50 dB HL < N ≤ 60 dB HL, the masking is adequate. Then Lt OE-BPW is 10 dB.

When the apparent AB gap is 30 dB, the plateau graph’s form with the OE is the same as that without the OE. Therefore, the occlusion effect need not to be taken into consideration.

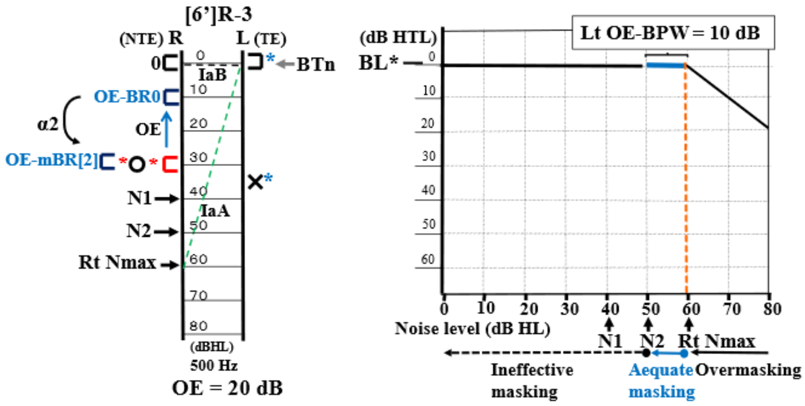


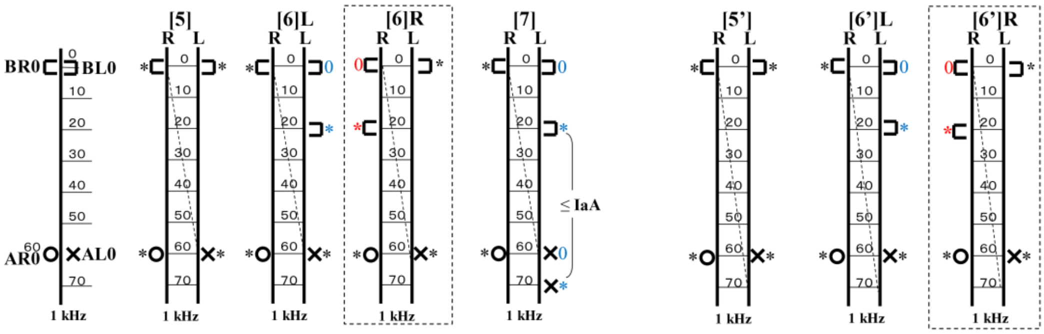
Figure 10-19 Lt OE-BPW

<< BC masking procedure in cases where Lt-AOB gap < 40 dB = min IaA>>

a) When the apparent AB gap in the non-test ear (GR0) is smaller than 20 dB (GR0 < OE = 20 dB), the true AB gap is also small and the occlusion effect is created. Therefore, we should mask the non-test ear, considering the decrease of masking effect.

b) When GR0 is larger than or equal to 20 dB (GR0 ≥ OE =20 dB), the occlusion effect has no influence on the measurement results. Then, we need not to take it into consideration.

Patterns where AR0 = AL0 or AL0 − AR0 < 10 dB



[5] – [7]: Lt AOB gap = IaA (= 60 dB) **[5’], [6’]: Lt AOB gap < IaA’ (= 70 dB)**

Patterns [6], [6’]: the apparent measured BC thresholds in one ear is the SH threshold and AOB gap is smaller than IaA (Rt AOB gap or Lt AOB gap < IaA).

10.3 The air and bone conduction audiometry and the occlusion effect

When **Lt AOB gap ≥ 40 dB = min IaA**, the apparent AC threshold in the left ear (AL0) might be the SH threshold: masking for AC is needed and masking for AC is also needed.

(1) GR0 = 0 dB (= GR*: AR* = BR* = 0 dB HTL) , Lt AOB gap = 40 dB

The apparent AC thresholds differ significantly (AL0 − AR0 = 40 dB). The audiometric configuration is either a pattern [1'], [3'], or [4] (**Fig.10-20 [a], [b], [c]**). Among these patterns, it is only the pattern [4] that AL0 is the SH threshold.

In pattern [4], IaA is 60 dB (> Lt-AOB gap = 40 dB). The assumption that the value of IaA is decreased by the OE is not adopted. As shown in **Fig.10-20 (d)**, although the masking with N1 (α1 = 20 dB) is ineffective (OE-mBR[1] = BR*), the true AC threshold can be determined increasing the noise levels (cf. **Fig 10-22**). The same goes for patterns [1'] and [3']. The true BC thresholds also can be determined (cf. **Fig 10-23**).

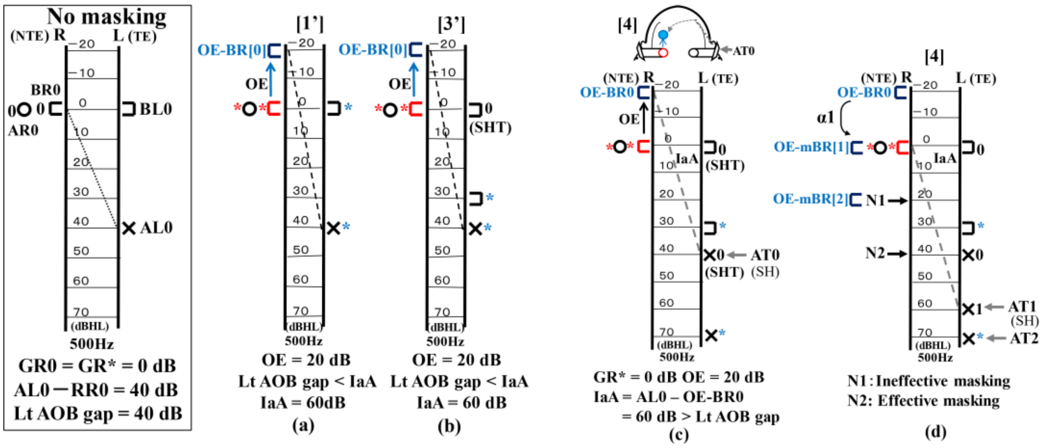


Figure 10-20 GR0 = 0 dB, Lt-AOB gap ≥ 40 dB

In the audiometric configuration shown in **Fig.10-21**, it is assumed that the occlusion effect is not created. Then IaA is equal to Lt-AOB gap (= 60 dB). The apparent AC threshold in the left, test ear (AL0) of 60 dB HTL and the apparent BC threshold in that ear (BL0) of 0 dB HTL are the SH thresholds.

The AC and BC plateau widths in the left ear (Lt-APW, Lt-BPW) are as follows:

Lt APW = Rt Nmax – Rt ANmin = 90 dB − 10 dB = 80 dB.

Lt BPW = Rt Nmax – Rt BNmin = 90 dB − 30 dB = 60 dB.

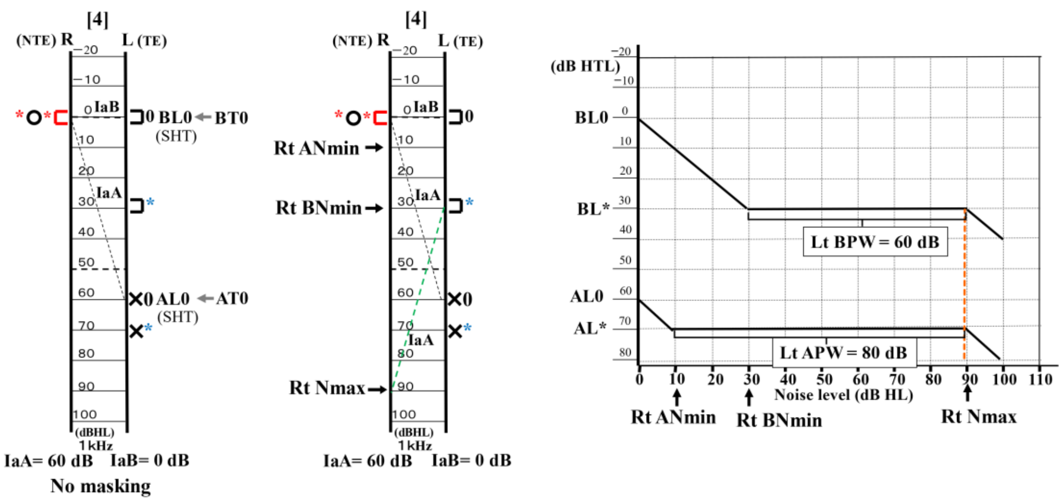


Figure 10-21 The AC and BC plateau widths not including the occlusion effect

By contrast, when the occlusion effect is created, the BC threshold in the non-test ear is decreased by 20 dB (OE-BR0 = −20 dB HTL). At this time, the apparent AC threshold in the test ear (AL0') of 40 dB HTL and the apparent BC threshold in that ear (BL0') of −20 dB HTL are the SH thresholds. The minimum adequate masking noise levels including the OE in the right ear (Rt OE-ANmin, Rt OE-BNmin) are higher by 20 dB than those not including the OE.

The occlusion effect is not created in the test ear because the true AB gap of the test ear is 40 dB: the maximum adequate masking noise level (Rt Nmax = BL* + IaA) is not changed. The plateau widths including the OE in the left ear (Lt OE-APW, Lt OE-BPW) are as follows:

Lt OE-APW = Rt Nmax – Rt OE-ANmin = Rt Nmax − (Rt ANmin + OE)
= (Rt Nmax – Rt ANmin) − OE
= Lt APW − OE = 80 dB − 20 dB = 60 dB.

Lt OE-BPW = Rt Nmax – Rt OE-BNmin = Rt Nmax − (Rt BNmin + OE)
= (Rt Nmax – Rt BNmin) − OE
= Lt BPW − OE = 60 dB − 20 dB = 40 dB.

If the apparent AB gap in the non-test ear is small (< 20 dB), the plateau width in the test ear is shortened by the occlusion effect. However, a significant plateau width can be ensured.

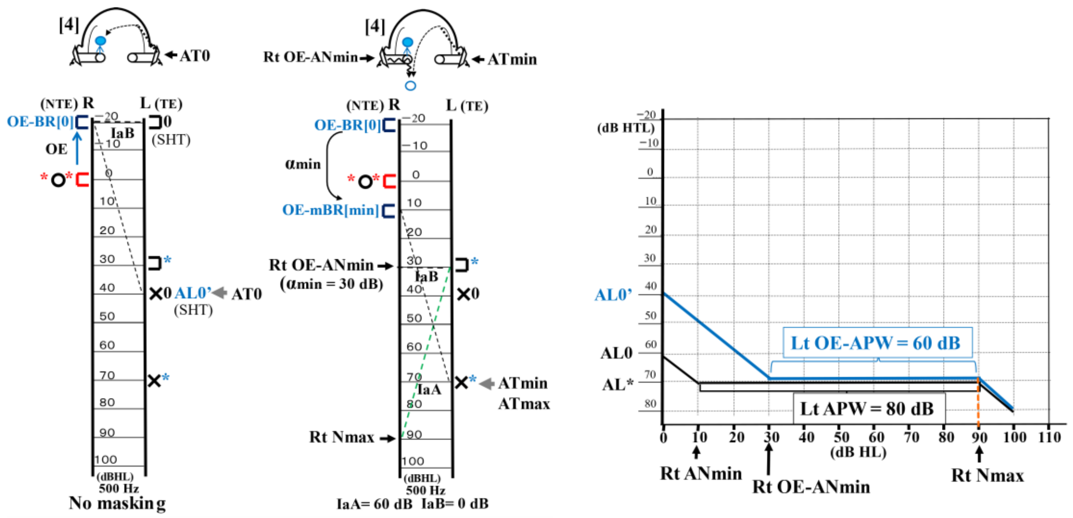


Figure 10-22 The APW contraction caused by the occlusion effect

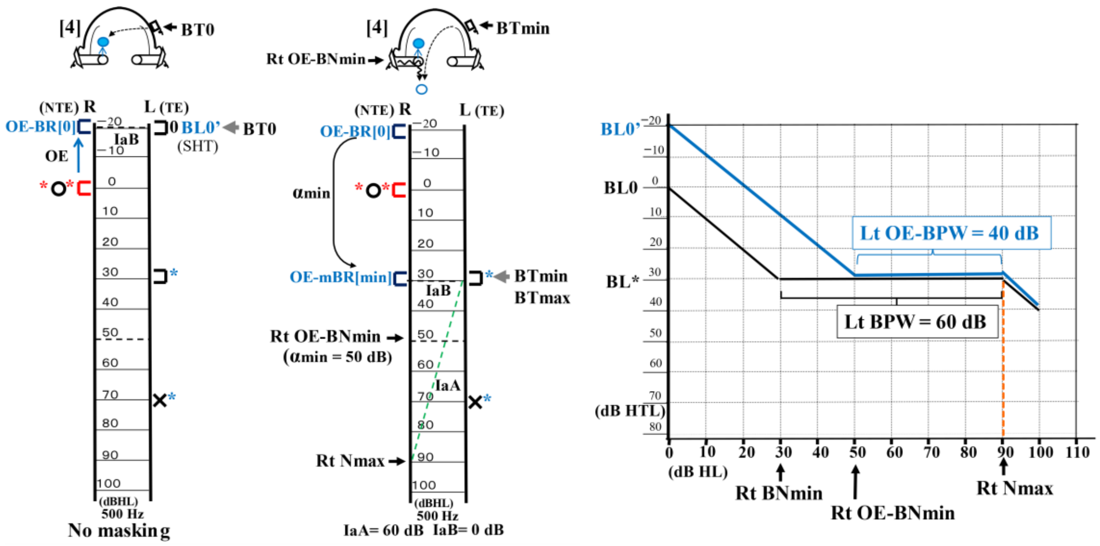


Figure 10-23 The BPW contraction caused by the occlusion effect

Although the PW is shortened by the OE, Nmin never exceeds Nmax. There is no audiometric configurations in which the PW is negative (i.e., PW = Nmax − Nmin < 0 dB, Nmax < Nmin).

(2) GR0 = 20 dB, Lt AOB gap = 60 dB (≤ IaA)

The apparent AC thresholds differ significantly (AL0 − AR0 = 40 dB).
When **GR0 = GR* = 20 dB**, the audiometric configuration is any one of the patterns [1], [3], [4], [1’], and [3’]. Among them, it is only the pattern [4] that the apparent AC threshold in the test, left ear (AL0) is the SH threshold (**Fig.10-24 [a]**). In pattern [4], the occlusion effect is not created in the non-test ear. Thus, the masking with N1 of 40 dB HL (α1 = 20 dB) is effective (**Fig.10-24 [b]**).

When **GR0 > GR* = 0 dB**, it is a pattern [2] or [2’]. the apparent AC and BC thresholds in the test ear are the true threshold (AL0 = AL*, BL0 = BL*). For example, in pattern [2] (**Fig.10-24 [c], [d]**) , the masking with N1 of 40 dB HL (α1 = 20 dB) is ineffective since the occlusion effect is created. The true AC threshold can be determined increasing noise levels. The same goes for the masking for BC. (cf. **8.4-4 [1]**).

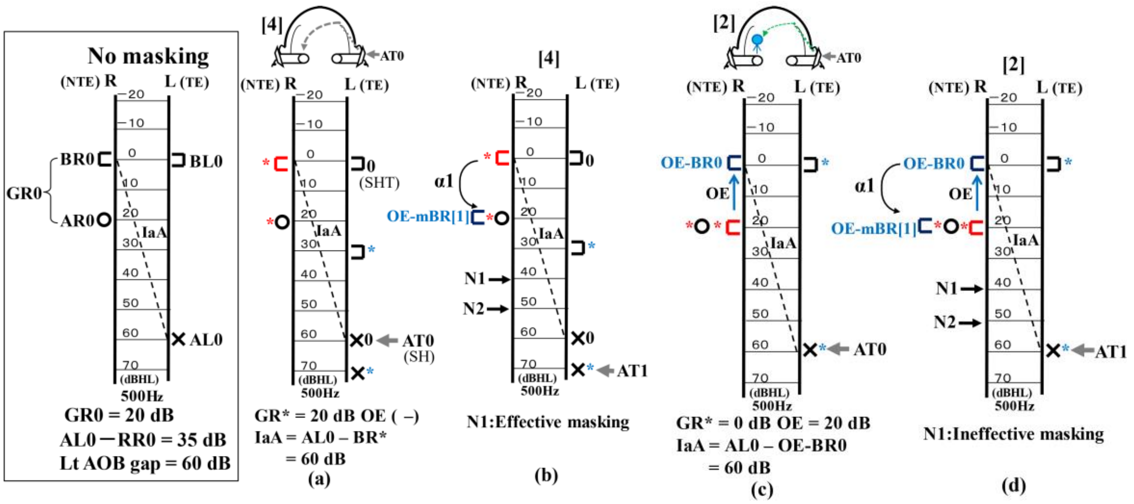
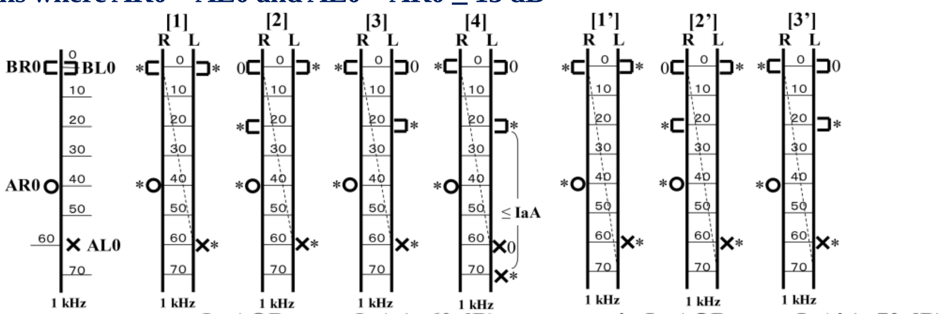


Figure 10-24 GR0 = 20 dB

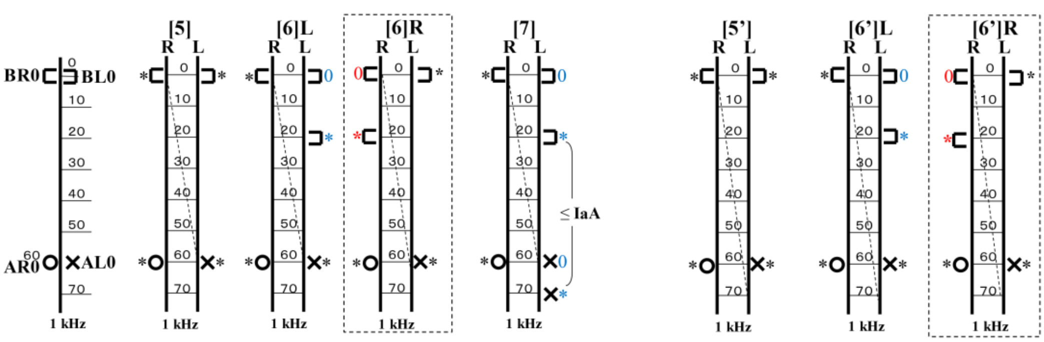
Patterns where AR0 < AL0 and AL0 − AR0 ≥ 15 dB



[1] – [4]: Lt AOB gap = IaA (= 60 dB) [1’] – [3’]: Lt AOB gap < IaA’ (= 70 dB)

Pattern [4]: the apparent AC and BC thresholds in the left, poorer ear by AC (AL0, BL0) are the SH thresholds.

Patterns where AR0 = AL0 or AL0 − AR0 < 10 dB



[5] – [7]: Lt AOB gap = IaA (= 60 dB) [5’], [6’]: Lt AOB gap < IaA’ (= 70 dB)

Patterns [6], [6’]: the apparent measured BC thresholds in one ear is the SH threshold.
Pattern [7]: the apparent AC and BC thresholds in one ear (AL0, BL0) are the SH thresholds.

(3) GR0 = 60 dB (≤ IaA), Lt AOB gap = 60 dB (≤ IaA)

The apparent AC thresholds do not differ significantly (AL0 − AR0 = 0 dB).

When **GR0 = GR* = 60 dB ≤ IaA**, the audiometric configuration is any one of the patterns [5], [6], [7], [5’], and [6’]. Among them, it is only the pattern [7] that the apparent AC threshold in the test, left ear (AL0) is the SH threshold. In pattern [7] (**Fig.10-25 [a]**), the occlusion effect is not created.

When **GR0 > GR* = 0 dB** (AR* = BR*), it is either a pattern [6] or [6’] : the measured BC threshold in one ear is the SH threshold. For example, in pattern [6] as shown in **Fig.10-25 (b)**, the OE (20 dB) is created in the non-test ear. Then, the noises which are higher than 60 dBHL directly cause overmasking (**Fig.10-25 [c]**): masking is impossible with no involvement from the OE. In pattern [6’], masking becomes difficult as the plateau widths are narrow. The OE is uninvolved in the process (cf. **6.1**).

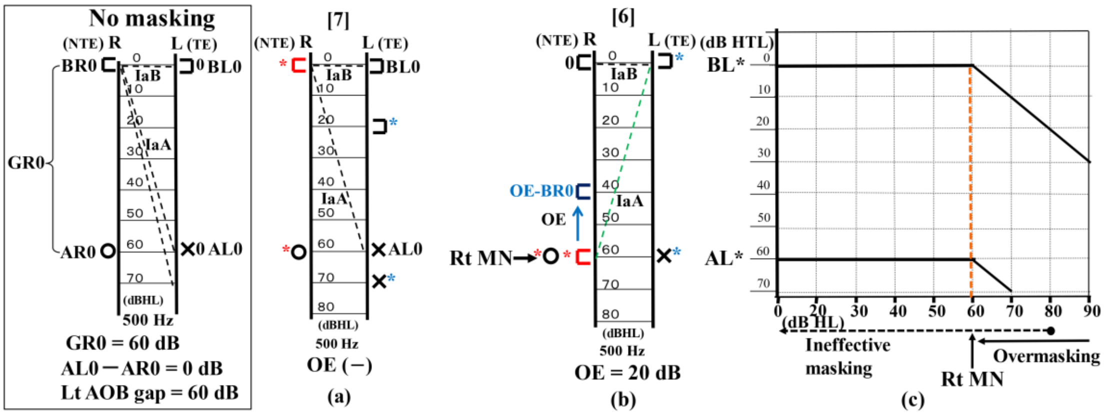


Figure 10-25 The plateau graph in pattern [6]

< Conclusion >

The prime factor that determines the difficulty of masking is the apparent AB gap of the non-test ear (ex., the right ear; GR0). When it is small, masking is easy to perform. As the GR0 becomes larger, masking becomes difficult, and until at last when GR0 = IaA, adequate masking might be impossible (cf. **6.1**).

The occlusion effect can be dealt as follows:

1) When GR0 is small (< 20 dB),
the true AB gap is also small (< 20 dB), as a result, the occlusion effect is created and the AC and BC plateau widths are shortened. However, the adequate masking is possible.

2) When GR0 is large (≥ 20 dB) and the true AB gap (GR*) is small (< 20 dB),
the occlusion effect is created. Then, the audiometric configuration is confined to either a pattern [2], [2’], [6] or [6’]: the apparent AC and BC thresholds in the test ear are the true thresholds. Therefore, the occlusion effect has no influence on the measurement results. Clinically, the occlusion effect need not to be taken into account when GR0 ≥ 30 dB, considering the measurement errors of BC thresholds.

3) When GR0 is large (≥ 20 dB) and the true AB gap (GR*) is large (≥ 20 dB),
the occlusion effect is not created. In the audiometric configurations in which adequate masking is impossible, masking dilemma (cf. **6.4-2**), the OE is not created.

In conclusion, the occlusion effect is not the factor which makes masking more difficult.

It is not recommended that we make a judgement whether the measured threshold is the true or false one (SHT) using only one masking noise level. According to the principle of measurement, we should ensure that the measured thresholds stay the same with the noise levels raised or decreased in 5- or 10-dB steps, which means the plateau has been reached.

Postscript

In 1963, König reported that an AB gap is never larger than IaA (AB gap ≤ IaA). However, there seems to have been no attempt to make use of this relationship for masking theory. Isogai rediscovered the relationship at the end of fall in 1985. He improved on Tacheuchi's ABC masking method and accomplished a masking procedure known as the ABCI method (Isogai, 1986). Almost simultaneously, the present author also discovered this independently, and invented the masking procedure with MNnpo as discussed in Lecture 5 (Urabe et al, 1986). We confirmed that the relationship was indispensable for theorizing about masking methods. Although Isogai had emphasized its significance at the meeting of the audiology association in Japan with great patience throughout approximately three decades, he was misunderstood in Japan.

In 2004, Turner's articles were published in the Journal of the American Academy of Audiology (Turner, 2004). His method also uses the maximum level of masking noise that has no possibility of overmasking. It differs in detail (MN' = MN − 5 dB, cf. **2.3-4**). However, the basic idea is the same among three formulations. Specifically, anyone who can derive meaning from the relathionship will reach the same conclusion. I believed that the significance would be recognized in English-speaking countries at long last. However, his method received a limited assesment; in particular, that it is more efficient than the plateau method. The more important issues regarding the fundamental principle were not received.

In these circumstances, the only person who understand is Dr. H. Hattori (Professor emeritus of Kobe University). He is a great scholar in audiology, and has worked to promote a correct masking procedure. In 2012, he said the following to me in a telephone conversation: "Currently, your assertions will not be acknowledged in Japan. If this goes on, the masking theory created in our country might be imported from abroad. It is a nihon no haji (Japan's shame or disgrace). You should translate your Japanese-language articles to English, and transmit them to the world." I felt hesitant for a moment, and started writing with determination. In 2013, a journal gave me permission for secondary publication; however, the submitted manuscript was rejected. Then, having modified the theoretical framework in many ways, I submitted them to three journals sequentially with similar results.

To understand masking, we do not require great knowledge and experience. The important things are to describe the basic issues correctly, and to show how to think about them. If materials and tools are provided, we can think through the concepts by ourselves. Depending on logic, anyone will reach the same conclusion. Therefore, to provide an explanation from basic principles, I decided to adopt the manner of a lecture for students and post the theory on a web site without peer review in 2016.

As mentioned at the beginning, the typical plateaus are so called particular solutions, and do not hold true in a general way. I had always attempted to obtain general solutions. However, this was unsuccessful (cf. **Supplement 5**). Having considered the occlusion effect, I realized that the apparent AB gaps of the non-test ear occupied a key role in forming plateau widths. Using them, I was finally able to derive the general solutions for plateau widths. The plateau width formulation may not be identified in the literature because its derivation needs the universal clarification of audiometric configurations, which requires the relationship.

Physicists believe that the gravitational constant (g) in Newtonian dynamics, Plank's constant (h) in quantum theory, and the velocity of light (c) in relativity theory appear in physical equations and calculations because they (g, h, c) are deeply implicated in all appearances. Similarly, the relationship must be implicated deeply in masking. Although the relationship is simple, it has a profound meaning, and is highly universal because it is simple. This lecture series just seeks the meanings of the relationship.

I have attempted to describe these concepts and issues in the clearest and most easily understood way. Nevertheless, the discussion may be difficult to follow. I would like you to read the lecture series over again. Then, you will know the whole picture of clinical masking, and will be able to perform pure tone audiometry with confidence.

Acknowledgements

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