Masking theory in pure tone audiometry
– Systematic lectures – Part 3

Part 3 Lecture 6: Application for the Rainville method
Lecture 7: Factors that determine difficulty levels of masking

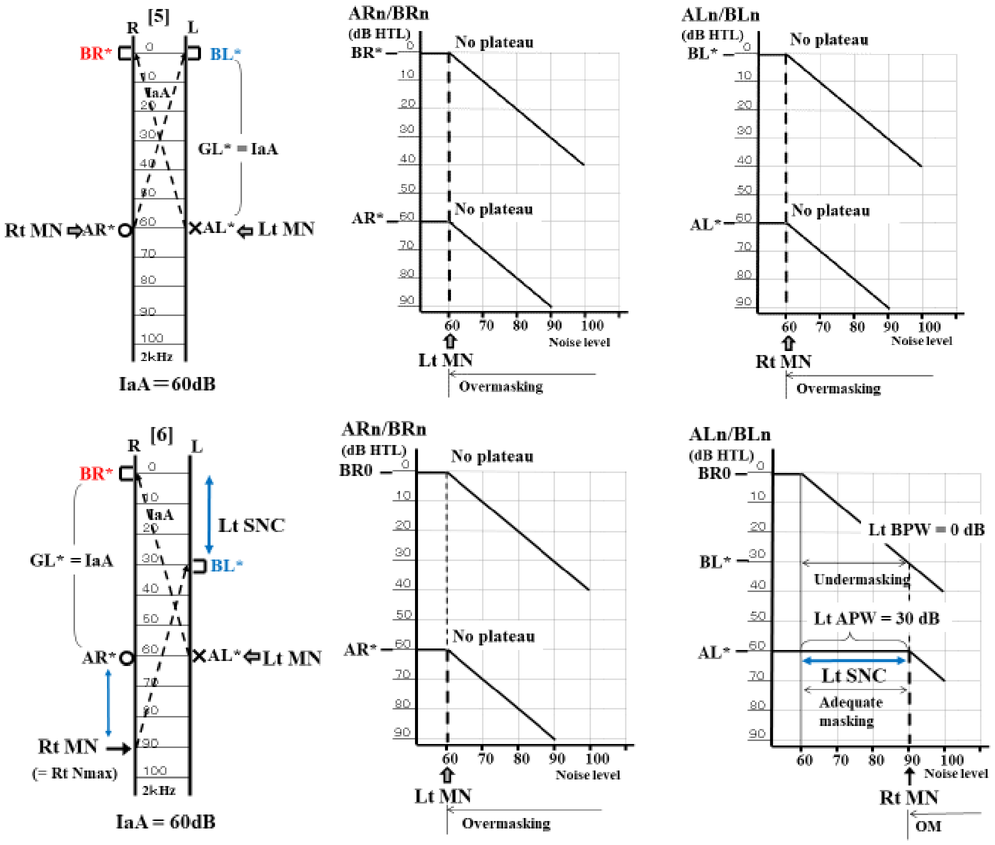
Lecture 6: Focal point

The audiometric configurations in which the apparent AC thresholds do not differ (AA gap = 0 dB) are classified into five patterns: [5], [5’], [6], [6’], and [7].

In pattern [5] (both the true AB gaps are equal to IaA and BR* = BL*), the noises higher than 60 dB HL always cause OM in both ears. Therefore, the AC and BC thresholds measured in both ears are OM thresholds (a masking dilemma).

In pattern [6] (the right ear’s true AB gap is equal to IaA and BR < BL* = 30 dB HTL), only the AC plateau width of the left ear presents (Lt APW = 30 dB). Therefore, AL* of 60 dB HTL and Rt MN of 90 dB HL are decided. At this point, Both BR0 of 0 dB HTL and AR0 of 60 dB HTL are proved to be the true thresholds automatically. BL* can be obtained using the OM method:

BL* = BR* + (Rt MN − Lt MN) = 0 (dB HTL) + {90 (dB HL) − 60 (dB HL)}
= 30 dB HTL.



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Lecture 7: Focal point

When the right and left apparent AC thresholds differ significantly (Rt AA gap = AL0 − AR0 ≥ 15 dB), Rt δ (= IaA − GR0) can be represented using Rt AA gap and Lt δ (= IaA − GL0):

Patterns [1]–[4]: Rt δ = IaA − GR0 = Rt AA gap,

Patterns [1’]–[3’]: Rt δ = IaA − GR0 = Rt AA gap + Lt δ.

When the right and left apparent AC thresholds do not differ significantly (Rt AA gap = AL0 − AR0 < 15 dB), Rt δ can be represented using Rt AA gap and Lt δ:

Patterns [5], [6], [7-0]: Rt δ = IaA − GR0 = Rt AA gap,

Patterns [5’], [6’]: Rt δ = IaA − GR0 = Rt AA gap + Lt δ.

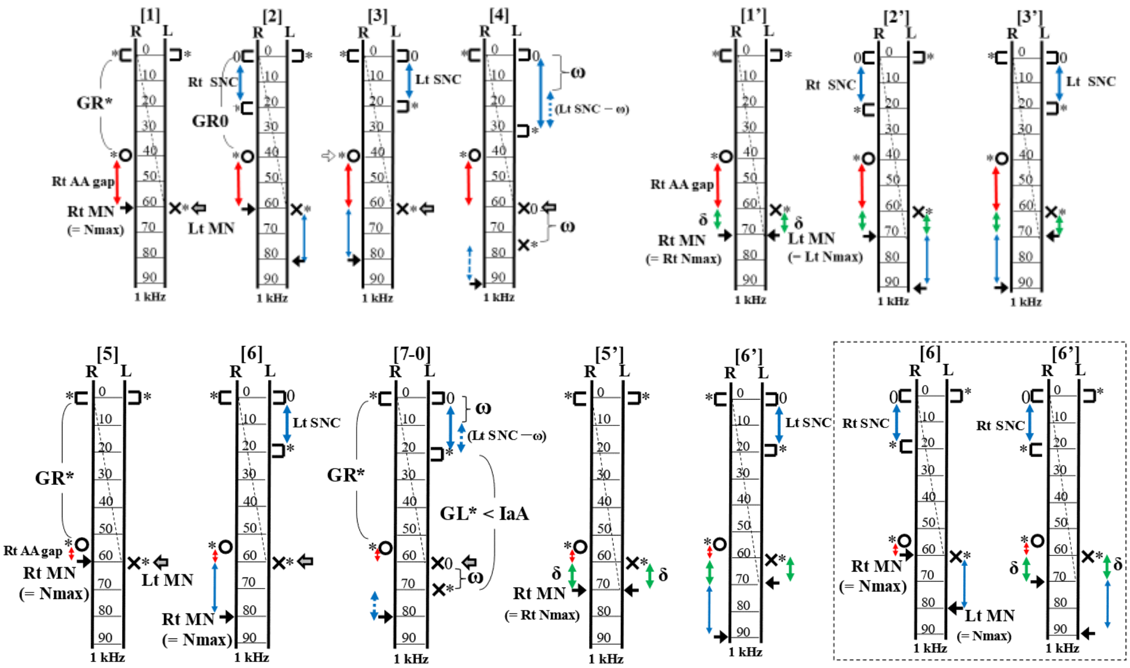
Therefore, the PWs may be reduced to formulas including the AA gap. Here, in patterns [1’], [2’], [3’], [5’], and [6’], Lt δ is simply shown as δ.

Although the PWs cannot be established before the four elements (δ, Rt SNCs, Lt SNC, and ω) have been determined, we can easily find the Rt AA and Lt AOB gaps on the audiogram without masking. With the aid of the two factors, we may estimate the difficulty level of masking to some extent before masking.

Plateau widths using Rt AA gaps

Patterns		Rt APW	Rt BPW	Lt APW	Lt BPW
[1], [5]:	δ = 0 dB	(−)	(−)	Rt AA gap	Rt AA gap
[2], [6]:	δ = 0 dB	**Rt SNC**	0 dB	Rt AA gap	Rt AA gap
[3], [6]:	δ = 0 dB	(−)	(−)	Rt AA gap + **Lt SNC**	Rt AA gap
[4], [7]:	δ = 0 dB	(−)	(−)	Rt AA gap + **Lt SNC** − ω	Rt AA gap
[1’], [5’]:	δ ≥ 5 dB	δ	δ	Rt AA gap + δ	Rt AA gap + δ
[2’], [6’]:	δ ≥ 5 dB	δ + **Rt SNC**	δ	Rt AA gap + δ	Rt AA gap + δ
[3’], [6’]:	δ ≥ 5 dB	δ	δ	Rt AA gap + δ + **Lt SNC**	Rt AA gap + δ

1) Rt AA gap = AL0 − AR0 ≥ 0 dB (AR0 ≤ AL0),
2) δ = Lt δ = IaA − GL0 = IaA − Lt AOB gap ≥ 0 dB,
3) Rt SNC = BR* − BL* ≥ 0 dB,
4) Lt SNC = BL* − BR* ≥ 0 dB,
5) ω = AL* − AL0 ≥ 0 dB.



Lecture 6: Application for Rainville's method

In this lecture, we will reveal that when the apparent AB gap of the non-test ear is equal to IaA, masking for BC also becomes impossible. In such a case, however, if a plateau for AC is present, we may estimate the true BC threshold in the test ear indirectly by applying Rainville's method.

Additionally, in this lecture series, we distinguish theory from practice, and the clinical consideration will be done in Lecture 8. However, the theoretical consideration is too far from the practice to lose the significance of the theory itself. As Lecture 6 tends to discuss a theory for the sake of theory, we would discuss issues of masking with the clinical significances as needed.

6.1 Masking for BC in cases where the apparent AB gap of the non-test ear is equal to IaA

When the apparent AB gap of the non-test ear is the maximum value (e.g., GR0 = IaA), the true BC threshold in the test ear cannot be determined as below.

(1) Cases where the apparent AC and BC thresholds in the non-test ear are both the true thresholds

As shown in **Fig. 6-1**, the apparent AC and BC thresholds in the right (non-test) ear are the true thresholds. That is, the apparent AB gap of the non-test ear (GR0) is equal to the true AB gap (GR*) and IaA (GR0 = GR* = IaA). When masking with Nn (> AR*) in the right ear, the singular level occurs in the left (test) ear (cf. 5.7), and masking for BC becomes impossible. Therefore, the true BC threshold in the test ear cannot be determined.

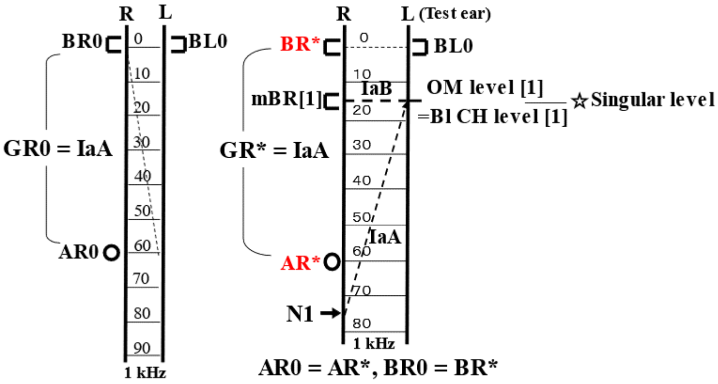


Figure 6-1 Singular level

(2) Cases where the apparent BC threshold in the non-test ear is the SH thresholds

There are two cases below.

a) The apparent AC threshold in the non-test ear is the true threshold (AR0 = AR*), (GR0 = IaA > GR*) (**Fig. 6-2 [a]**).

b) The apparent AC thresholds in the non-test ear is the SH threshold (AR0 < AR*), (GR0 = IaA ≥ GR*) (**Fig. 6-2 [b]**).

In these cases, what HTL in dB is the true BC threshold in the left (test) ear (BL*)?

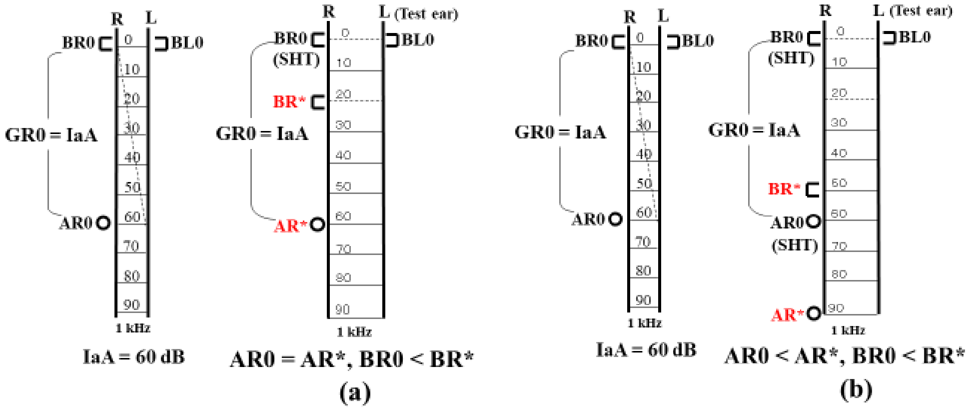


Figure 6-2 Cases where BR0 is the SH threshold

**** Further note ****

*) The main abbreviations are listed. AC: Air conduction, BC: Bone conduction,
SH: Shadow hearing, CH: Cross hearing, OM: Overmasking, STH: Shadow hearing threshold,
GR*: True air-bone (AB) gap in the right ear, GR0: Apparent AB gap in the right ear,
IaA: Interaural attenuation for AC signals, IaB: Interaural attenuation for BC signals,
AL-CH level [0]: CH level for AC in the left ear without masking.
AL-CH level [1]: CH level for AC in the left ear with masking of N1

*) The apparent threshold is measured without masking.

*) In **Fig. 6-2**, there are no cases where AR0 is the SH threshold and BR0 is the true threshold.

*) In the operation of levels and quantities (amounts), each term of equality and inequality is represented as a numerical value (cf. 2.4 **[1]**).

Since the apparent BC thresholds in both ears (BR0, BL0) cannot the SH thresholds at the same time, the apparent BC threshold in the left ear (BL0) is always the true threshold (BL0 = BL*) (**Fig. 6-3 [a]**, **[b]**). Therefore, the noises higher than 60 dB HL always cause OM, and the BC plateaus are not present (**Fig. 6-3 [c]**). Although the singular levels do not occur in these cases, the true BC threshold in the test ear cannot be obtained.

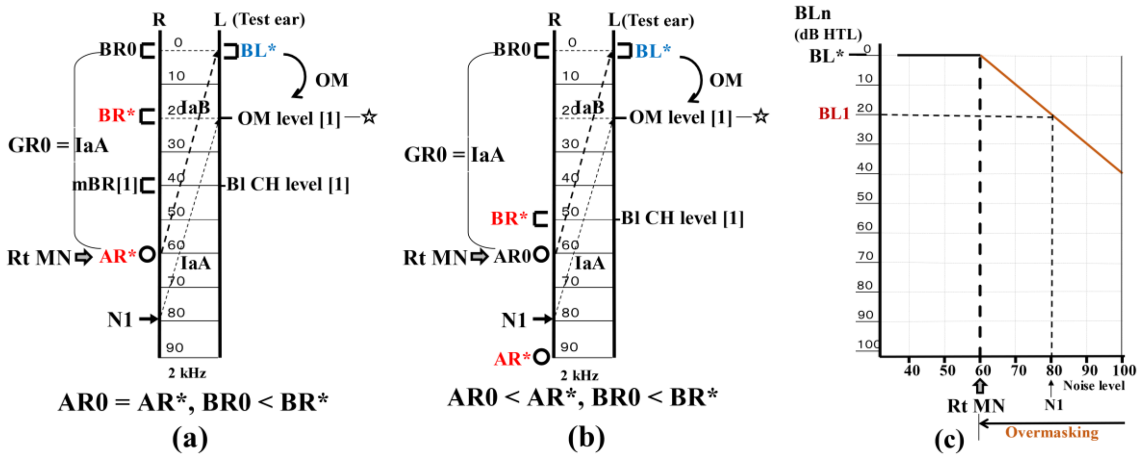


Figure 6-3 BR0 < BR*, BL0 = BL*

> In summary, when the apparent AB gaps of the non-test ear are equal to IaA (cf. **Fig. 6-1** and **Fig. 6-3 [a]**, **[b]**), masking for BC becomes impossible. The true BC thresholds in the test ear cannot be determined.

The basic audiogram **[C-1]** in **Fig. 6-4** shows both the apparent AC thresholds (AR0, AL0) and the apparent BC threshold in the right ear (BR0). The apparent BC threshold in the left ear (BL0) can be assumed to be almost the same level as BR0. Before masking, we can estimate that masking for BC in both ears will be difficult because the apparent AB gaps of both ears (GR0, GL0) at each frequency are as large as the IaA values at that frequency. Consequently, even if the true AC and BC thresholds in the non-test ear are unknown, we can predict the difficulty level of masking.

Additionally, when the true AC and BC thresholds in both ears cannot be determined, it is a masking dilemma, which is described later (cf. **6.4-2**). The apparent AB gap of the non-test ear is one of the factors that determine the difficulty level of masking. This will be addressed in Lecture 7.

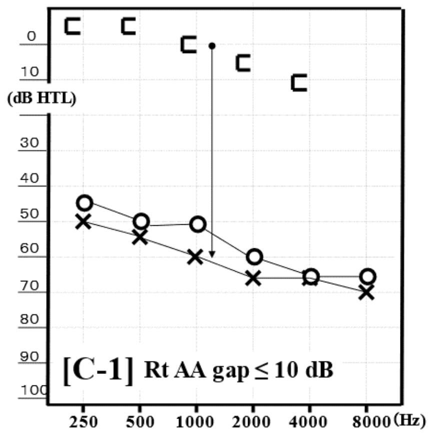


Figure 6-4 Basic audiogram [C-1]

**** Further note ****

*) In **Fig. 6-3(b)**, the masking noise of 80 dB HL (N < AR*) is ineffective in the non-test ear. However, it causes OM in test ear.

*) OMT: Overmasked hearing threshold

6.2 Rainville's method

(1) Masking for BC in patterns [1], [2], [1'], and [2']

As already discussed (cf. **5.8 [2]**), in patterns [1], [2], [1'], and [2'], the true BC threshold in the right, better ear by AC (BR*) needs to be obtained with masking in the left, poorer ear by AC (**Fig. 6-5**).

In patterns [1] and [2], in which the true AB gaps of the left ear are equal to IaA (GL* = IaA), the true BC thresholds in the right ear (BR*) cannot be determined using BC test signals (cf. **5.7**).

In patterns [1'] and [2'], when the true AB gaps of the left ear are large, that is, the difference between IaA and GL* is only a little (IaA − GL* ≤ 10 dB), masking for the right BC is difficult with regard of measurement errors.

Rainville's method is well indicated for these cases (Rainville, 1955).

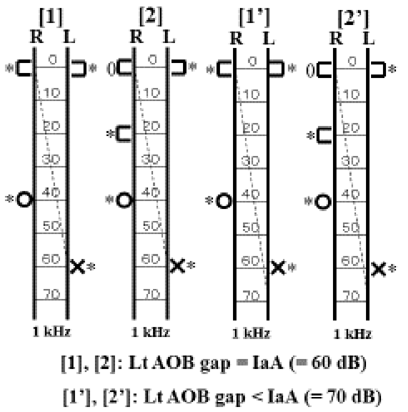


Figure 6-5 Patters in which BC masking is difficult

(2) The principle of Rainville's method

A precondition for achieving Rainville's method is that the true AC threshold in the test ear has been established. Its principle is an approach to calculate the true BC threshold in the test ear indirectly through the use of OM by BC noises. When the BC noises are calibrated in terms of the effective masking level (cf. **2.2-1**), as shown in **Fig. 6-6**, the maximum level of BC noise at which OM does not occur in the right ear (Rt BMN of 20 dB HL) will be obtained. The BC noises of the level higher than Rt BMN elevate the AC threshold in the test ear. Therefore, according to the boundary conditions, BR* is equal to the cochlear level of Rt BMN (cf. **2.2-2**, **2.3-2**):

BR* = Rt BMN − 0 (dB) = 20 dB HTL.

If the AC noise is used in place of the BC noise, the principle is the same (**Fig. 6-7**). Namely, the cochlear level of Lt MN (OM level [MN] = Lt MN − IaA) is equal to BR* (c.f. **2.3-3 [2]**):

BR* = Lt MN − IaA.

Here, we only know that the IaA value is larger than or equal to the Lt AOB gap (IaA ≥ Lt AOB gap = GL* = 55 dB) and thus we cannot calculate BR* with only this equation. Then, let us consider the approach shown on the next page.

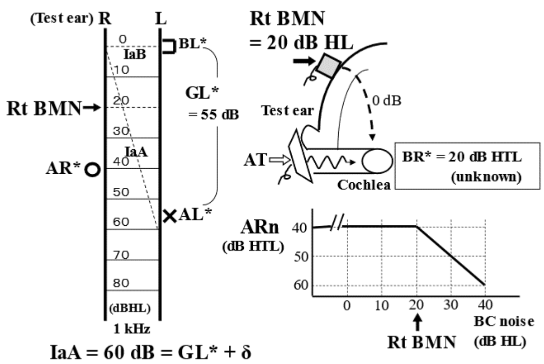


Figure 6-6 Principle of the Rainville method

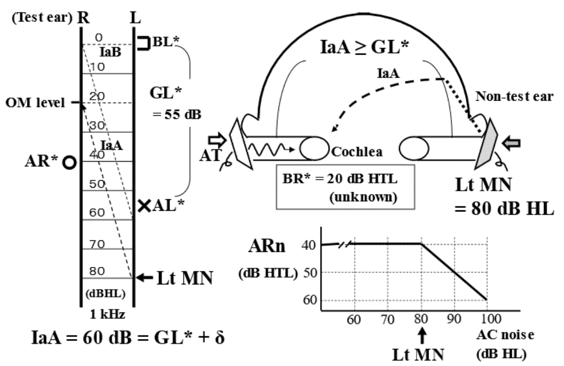


Figure 6-7 Overmasking

**** Further note ****

*) "Masking for the right BC" means that the masking noise is presented to the left ear to obtain the true BC threshold in the right ear (cf. **2.4 [4]**).

*) MN is the maximum level of masking noise at which OM does not occur.

*) When the BC threshold in the test ear is elevated with masking, OM occurs (cf.**2.3-1**).

*) In patterns [1'] and [2'], in which the AOB gaps are small (< 40 dB = min IaA), N1 in the left ear is as follows: Lt N1 = Lt Nx = (BR0 + 40) dB HL. Masking for BC is easy (cf. **5.5 [2]**).

6.3 Masking in cases where the apparent AC thresholds differ significantly

6.3-1 An overmasking method

Fig. 6-8 shows the audiometric configurations with the Rt AA gap (= AL0 − AR0) of 20 dB. Let the difference between IaA and an apparent AB gap be δ (delta):

Rt δ = IaA − GR0, Lt δ = IaA − GL0.

In pattern [1], since the true BC thresholds in both ears are the same level (BR* = BL*), both MNs are also the same level:

Rt MN = 60 dB HL, Lt MN = 60 dB HL.

By contrast, in pattern [2], since BR* is 20 dB higher than BL*, Lt MN is 20 dB higher than Rt MN:

Rt MN = 60 dB HL, Lt MN = 80 dB HL.

Therefore, the difference between BR* and BL* (BR* − BL* ≥ 0 dB) is equal to the difference between Lt MN and Rt MN (Lt MN − Rt MN ≥ 0 dB):

BR* − BL* = Lt MN − Rt MN,

∴ **BR* = BL* + (Lt MN − Rt MN)**.

Since BL* is already known (BL* = BL0), BR* can be calculated by measuring each MN. This approach is called an overmasking method (OM method). For example, in pattern [2], BR* can be calculated:

BR* = BL* + (Lt MN − Rt MN) = 0 (dB HTL) + {80 (dB HL) − 60 (dB HL)}
= 20 dB HTL.

In pattern [1’] and [2’], when there is a small difference between IaA and GL0 (IaA − GL0 = Lt δ; 0 dB < Lt δ ≤ 10 dB), masking for the right BC becomes difficult or impossible. These patterns are also applicable to the OM method.

In this lecture series, the difference between BR* and BL* is termed a relative amount of sensorineural component of the right ear compared to the left ear (Rt SNC):

Rt SNC = BR* − BL* = Lt MN − Rt MN (≥ 0 dB).

In the case in which the test ear is on the left, Lt SNC is as follows:

Lt SNC = BL* − BR* = Rt MN − Lt MN (≥ 0 dB).

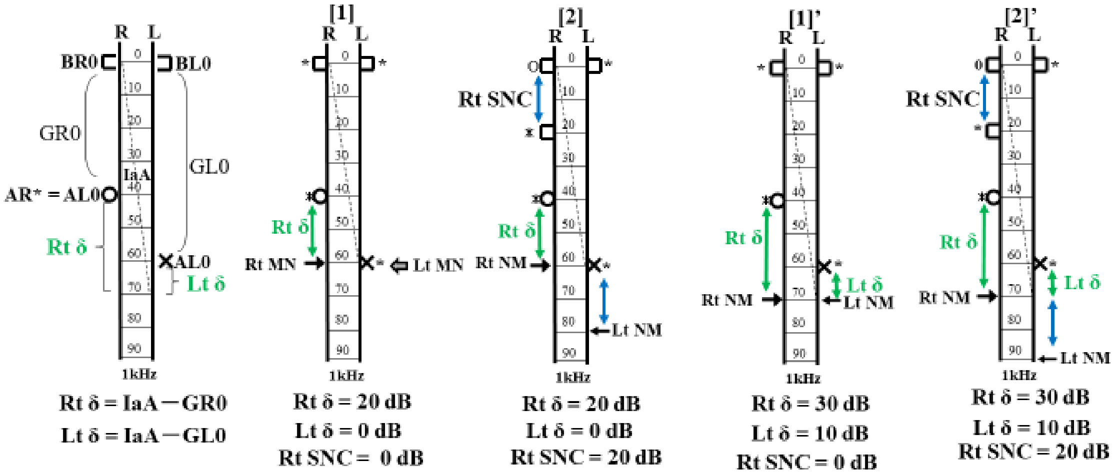


Figure 6-8 Difference between the right and left ear’s true BC thresholds and MN

A precondition for using the OM method is that the true AC threshold in the test ear has been established. If the true AC threshold is not obtained, the method is not applicable. Since the apparent AC thresholds in the right, better ear by AC, (AR0s) in the patterns above are always the true thresholds (cf. **4.2 [4]**), these patterns meet the precondition. Furthermore, since AR0 is the true threshold, if the noise levels in the left ear are raised and the AC thresholds measured in the right ear are elevated, then we can estimate that the noises cause OM.

Additionally, Lt SNC (= BL* − BR* ≥ 0 dB) is defined when BL* ≥ BR*. Thus, when BL*< BR*, Lt SNC is assumed to be 0 dB.

6.3-2 Estimation for the true BC threshold in the better ear by AC

In patterns [1], [2], [1'], and [2'], the plateau widths for AC and BC (APW, BPW) in both ears are shown in **Table 6.1** (cf. **7.2-1**).

Table 6-1 Plateau widths

	Rt APW (= Rt SNC +Lt δ)	Rt BPW (= Lt δ)	Lt APW (= Rt δ)	Lt BPW (= Rt δ)
Pattern [1]	not present	not present	20 dB	20 dB
Pattern [1']	10 dB	10 dB	30 dB	30 dB
Pattern [2]	20 dB	0 dB	20 dB	20 dB
Pattern [2']	30 dB	10 dB	30 dB	30 dB

Rt SNC = BR* − BL* = Lt Nmax − Rt Nmax ≥ 0 dB. Lt δ = IaA – GL0, Rt δ = IaA – GR0.
Rt SNC: Relative amounts of sensorineural component in the right ear compared to the left ear

In these patterns, with masking in the right, better ear by AC, the true BC thresholds in the left ear prove to be the same level as the apparent BC thresholds in the left ear (BL* = BL0). In turn, with masking in the left, poorer ear by AC, the true BC threshold in the right ear (BR*) must be obtained.

In pattern [1], there is no plateau width for BC in the right ear (Rt BPW) (**Fig. 6-9**). In pattern [2], Rt BPW of 0 dB cannot be identified (**Fig. 6-11**). In patterns [1'] and [2'], in which the difference between IaA and GL0 (= GL*) is only 10 dB (Lt δ = IaA − GL* = 10 dB), Rt BPW of 10 dB does present (**Fig. 6-10**, **6-12**). However, clinically, since the plateau width of 10 dB is not significant, BR* cannot be determined.

Therefore, in these circumstances, let us search the plateau width for AC in the right ear (Rt APW) with masking in the left ear. If Lt MN can be obtained, then the OM method is applicable.

(1) Pattern [1] (**Fig. 6-9**)

No APW in the right ear presents with masking in the left ear. Since AR0 is the true AC threshold (AR0 = AR*), evidently the noises cause OM. Then, Lt MN of 60 dB HL is obtained. Since Rt MN is also 60 dB HL, Rt MN = Lt MN. This means that the true BC thresholds in each ear are the same level. According to the OM method,

BR* = BL* + (Lt MN − Rt MN) = BL* + 0 (dB) = BL*
= 0 dB HTL.

(2) Pattern [1'] (**Fig. 6-10**)

With masking in the left ear, Rt APW can be obtained as 10 dB, which is not significant clinically. If the noise levels are higher than 70 dB HL, the AC thresholds measured in the right ear are elevated, i.e., OM occurs. Therefore, Lt MN is determined to be 70 dB HL. Since Rt MN is also 70 dB HL (Rt MN = Lt MN), we can estimate that BL* = BR* = 0 dB HTL.

(3) Pattern [2] (**Fig. 6-11**)

With masking in the left ear, Rt APW can be obtained as 20 dB, which is significant clinically; Rt MN is 60 dB HL. Since the noises of the levels from 60 dB HL to 80 dB HL do not cause OM (adequate masking), Lt MN is 80 dB HL. As we cannot distinguish this case from pattern [2'], the OM method is used.

BR* = BL* + (Lt MN − Rt MN) = 0 (dB HTL) + {80 (dB HL) − 60 (dB HL)}
= 20 dB HTL.

(4) Pattern [2'] (**Fig. 6-12**)

Rt APW of 30 dB and Lt MN of 90 dB HL can be obtained with masking in the left ear.

BR* = BL* + (Lt MN − Rt MN) = 0 (dB HTL) + {90 (dB HL) − 70 (dB HL)}
= 20 dB HTL.

The main limitation of this approach is the low measurement accuracy. However, and most importantly, this concept is applicable for individuals in whom apparent AC thresholds are equal bilaterally.

Now, the theoretical consideration for masking procedure was completed in the configurations where the apparent AC thresholds differ significantly.

**** Further note ****

*) Lt δ = IaA − GL0 = IaA − (AL0 − BL0) = IaA − (AL0− BR0) = IaA− Lt AOB gap, IaB = 0 dB.

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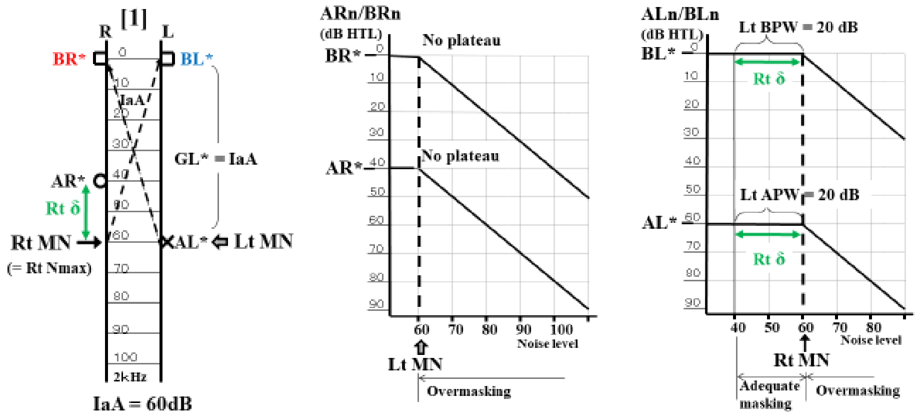

Figure 6-9 Pattern [1]

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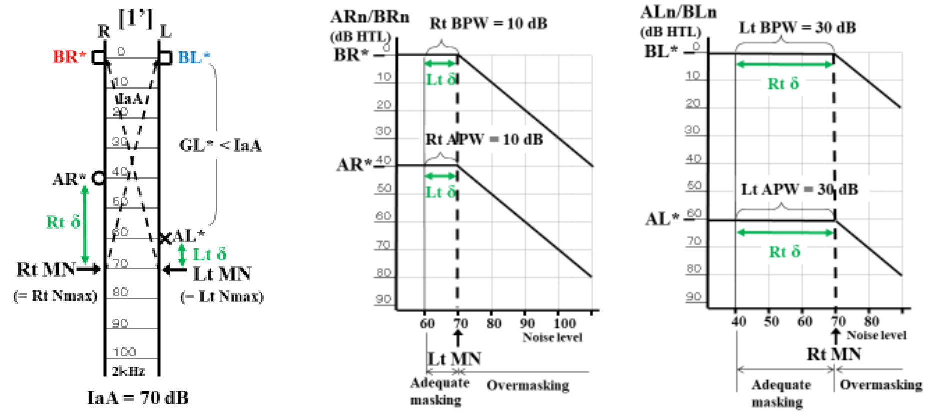

Figure 6-10 Pattern [1']

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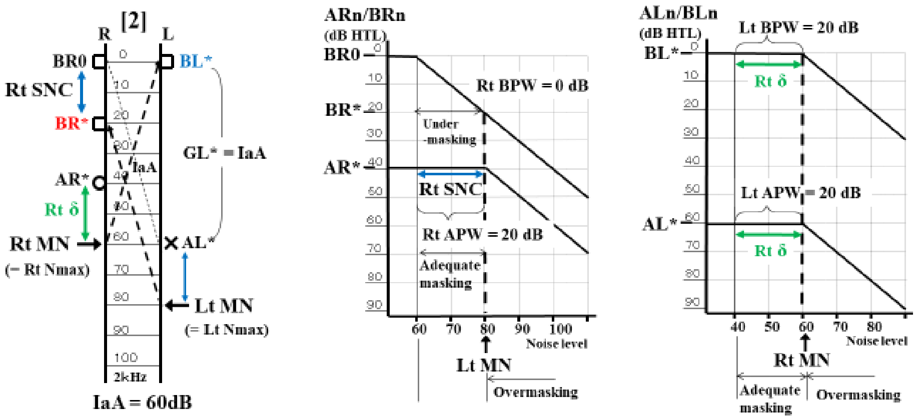

Figure 6-11 Pattern [2]

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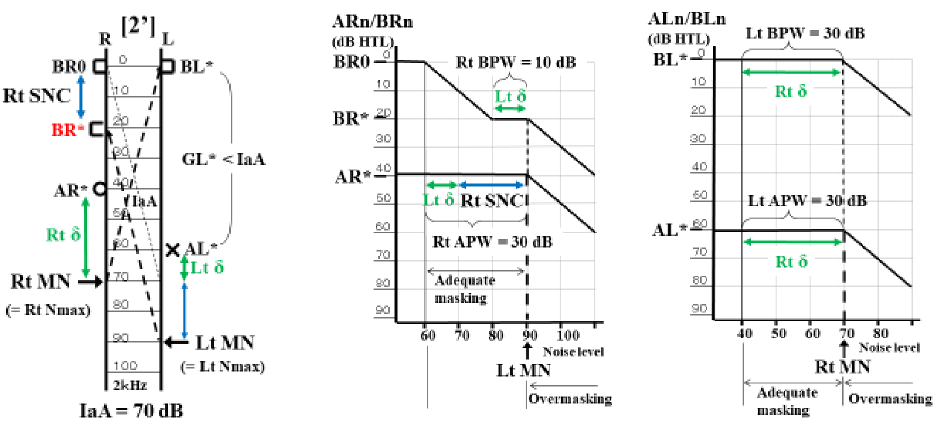

Figure 6-12 Pattern [2']

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

Insignificant AA gaps are smaller than or equal to 10 dB (0, 5, or 10 dB). To simplify the discussion, let us consider the cases with an AA gap of 0 dB (AR0 = AL0).

6.4-1 Five audiometric patterns

At a given frequency, the audiometric configurations in which the apparent AC thresholds do not differ (AA gap = 0 dB) are classified into five patterns (**Fig. 6-13**). The apparent AC and BC thresholds in at least one ear are always the true thresholds.

(1) Pattern [7]

Only in pattern [7] can the apparent AC threshold in one ear (AL0) be the SH threshold, in which case the apparent BC threshold in the same ear (BL0) is also the SH threshold. This pattern is subdivided into three patterns (**Fig. 6-14**, cf. **Fig. 5-28**). Supposing that AL0 is the SH threshold, the true AB gap of the left ear (GL*) is as follows:

Pattern [7-0]: GR* = IaA, GL* < IaA,
Pattern [7-1]: GR* = IaA, GL* = IaA,
Pattern [7-2]: GR* = IaA, the left ear is a complete hearing loss.

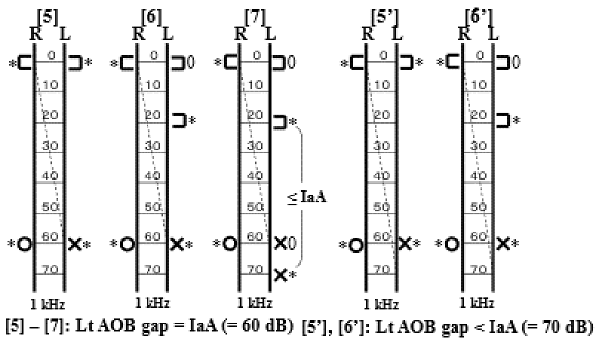

Figure 6-13 Audiometric patterns (AR0 = AL0)

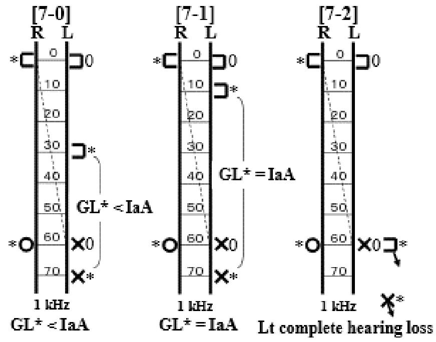

Figure 6-14 Subdivided patterns [7]

(2) Patterns needed only for BC masking

In pattern [5'] and [6'], in which Lt AOB gaps are small (< 40 dB = min IaA), only masking for BC is needed (**Fig. 6-15**). The initial masking noise (N1) is set to Nx as follows (cf. **5.5 [2]**):

Rt N1 = Rt Nx = (BL0 + 40) dB HL,
Lt N1 = Lt Nx = (BR0 + 40) dB HL.

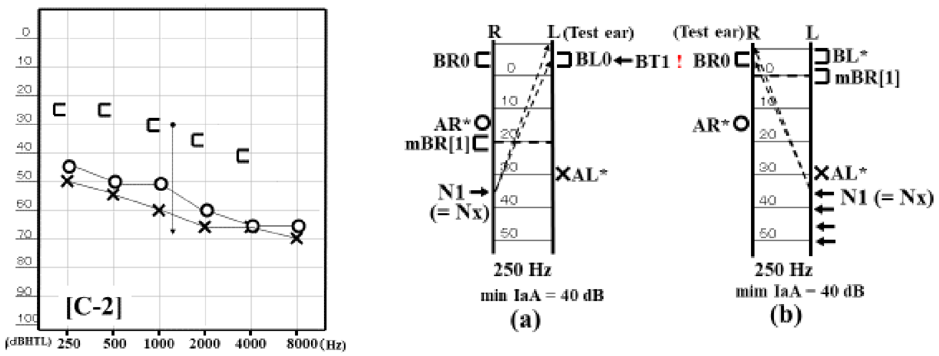

Figure 6-15 Masking for BC in cases where Lt AOB gap < 40 dB

(3) Patterns needed for AC masking

When Lt AOB gaps are ≥ 40 dB, masking for AC is needed. In the patterns shown in **Fig. 6-13**, we cannot in advance estimate the efficient masking noise as was described in Lecture 5. Then, the plateau method should be used. If bilateral APWs cannot be identified, we cannot determine the true BC as well as true AC thresholds. It is a masking dilemma described next.

**** Further note ****

*) Nx is the maximum level of masking noise at which OM does not occur in any case, assuming the minimum IaA value of 40 dB

6.4-2 The masking dilemma

(1) Three audiometric configurations of the masking dilemma

The masking dilemma (Naunton, 1960) preciously means that both the true AC and BC thresholds cannot be determined with masking noises of any level. Theoretically, the following three audiometric configurations are the cases:

(a) Pattern [5]: bilateral true AB gaps are equal to IaA and BR* = BL* (**Fig. 6-16 [a]**).

(b) Pattern [7-1]: bilateral true AB gaps are equal to IaA and BR* < BL* (**Fig. 6-16 [b]**).

(c) Pattern [7-2]: the true AB gap in one ear is equal to IaA and the other ear has a complete hearing loss (**Fig. 6-16 [c]**).

In each pattern above, no plateau is present or even if it is present, PW of 0 dB cannot be detected.

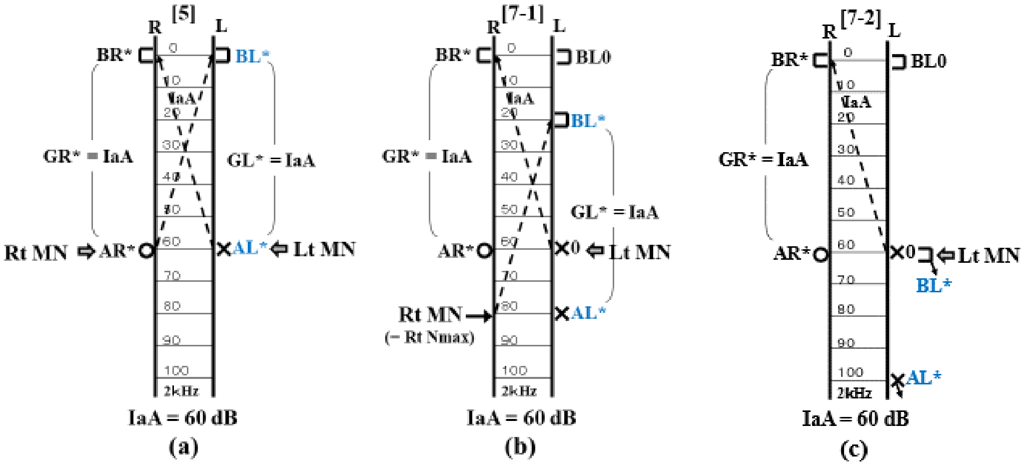

Figure 6-16 Masking dilemma

(a) Pattern [5]: bilateral true AB gaps are equal to IaA and BR* = BL*

With masking in the right ear (**Fig. 6-17**), the noises higher than 60 dB HL always cause OM and the AC and BC thresholds measured in the left ear are OM thresholds. Since the adequate masking noise levels are not present, the plateaus for both AC and BC are also not present (cf. **3.5 [2]**).

With masking in the left ear, the AC and BC thresholds measured in the right ear are also OM thresholds. Therefore, bilateral plateaus are not present and all the true thresholds cannot be determined.

This is the case where the noises cause OM in both ears and no plateaus are present:

Rt MN = [AR*] = 60 dB HL,

Lt MN = [AL*] = 60 dB HL.

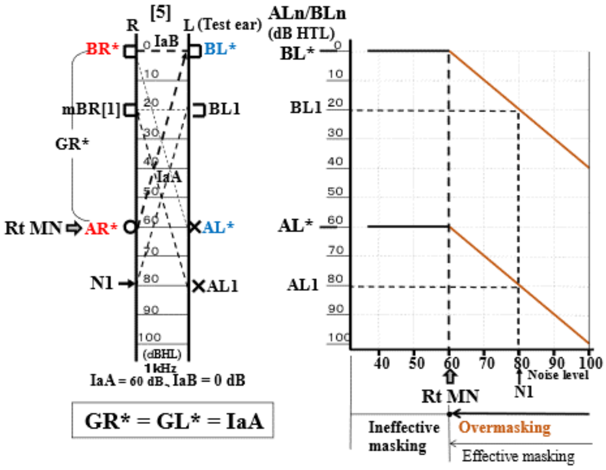

Figure 6-17 Masking dilemma (a)

**** Further note ****

*) In **Fig. 6-17**, adequate masking cannot be performed with masking in the right ear, and the true AC and BC thresholds in the left ear cannot be determined. In this lecture series, this is termed "adequate masking in the right ear is impossible," or "masking for the left AC and BC is impossible."

(b) Pattern [7-1]: bilateral true AB gaps are equal to IaA and BR* < BL*.

For AC, with masking in the right ear (**Fig. 6-18**), the noises lower than 80 dB HL cause undermasking. Then, the AC thresholds measured in the left ear are SH thresholds. The noises higher than 80 dB HL cause OM and the AC thresholds measured in the left ear are OM thresholds. In particular, when N1 is 80 dB HL, the initial AC test signal (AT1) of 80 dB HL is barely heard by both the inner ears (mBR[1] and BL*). The hearing of AT1 is true and the left ear's AC threshold measured with N1 (AL1) is the true AC threshold (AL1 = AL*). N1 is the minimum and maximum adequate masking levels for AC (cf. 3.1-2 **[4]**):

Rt N1 = Rt ANmin = Rt Nmax (= Rt MN).

Thus, Lt APW = 0 dB. The plateau of 0 dB does exist; however, it cannot be identified. Therefore, the true AC threshold in the left ear cannot be determined. If the significant plateau width is not present, **we** walk past the true threshold without sighting it.

For BC, if IaB is supposed to be 0 dB,

Rt N1 = Rt BNmin = Rt Nmax (= Rt MN).

Thus, Lt BPW = 0 dB. Therefore, the true BC threshold cannot be obtained, by using BC test signals.

In the left ear, for AC and BC, the minimum and maximum adequate masking noise levels are equal.
Rt ANmin = Rt Nmax = 80 dB HL
Rt BNmin = Rt Nmax = 80 dB HL

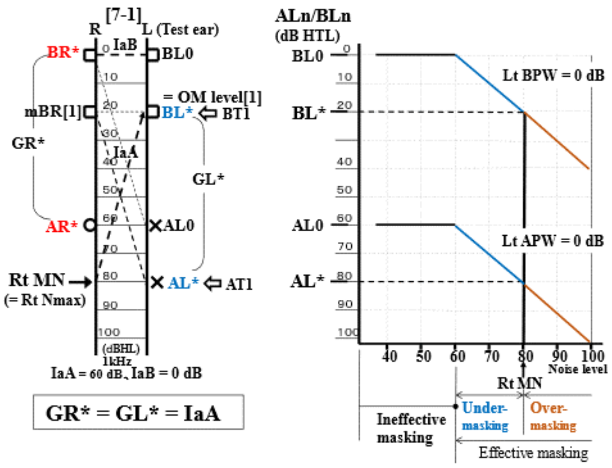

Figure 6-18 Masking dilemma (b)-1

Next, with masking in the left ear (**Fig. 6-19**), the noises higher than 60 dB HL always cause OM (cf. **Fig. 6-17**); hence, the adequate masking noise levels are not present. Rt. APW and BPW are not present and the true AC and BC thresholds in the right ear cannot be obtained.

In the right ear, masking noises (> 60 dB HL) always cause OM.

Lt MN = [AL0] = 60 dB HL.

Note that the apparent AB gap of the left ear is equal to IaA (GL0 = AL0 − BL0 = IaA) (cf. **6.1 [2]**). Both AL0 and BL0 are the SH thresholds.

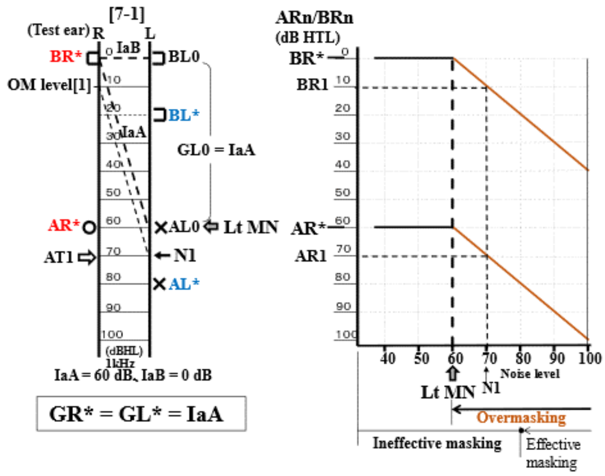

Figure 6-19 Masking dilemma (b)-2

**** Further note ****

*) A typical example of masking dilemma is the configuration in **Fig. 6-18**. If noise levels are increased in order to avoid undermasking, OM occurs. If noise levels are decreased in order to eliminate OM, undermasking occurs. It is a dilemma, which means that the true thresholds cannot be determined.

(c) Patterns [7-2]: the true AB gap of one ear = IaA, and the other is a complete hearing loss.

With masking in the right ear (**Fig. 6-20**), the noises higher than 60 dB HL cause undermasking. Then, the AC and BC thresholds measured in the left ear are SH thresholds. Since adequate masking noises are not present, the plateaus for AC and BC are also not present. With masking in the left ear, the AC and BC thresholds measured in the right ear are OM thresholds (cf. **Fig. 6-19**). Therefore, bilateral plateaus are not present and the true thresholds cannot be determined.

In the left ear, undermasking occurs: No MN, ANmin, and BNmin in the left ear are present.

In the right ear, OM occurs:

Lt MN = [AL0] = 60 dB HL.

Although the true AB gap of the left ear is unknown, note that the apparent AB gap of the left ear is equal to IaA (GL0 = AL0 − BL0 = IaA) (cf. **6.1 [2]**). Both AL0 and BL0 are the SH thresholds.

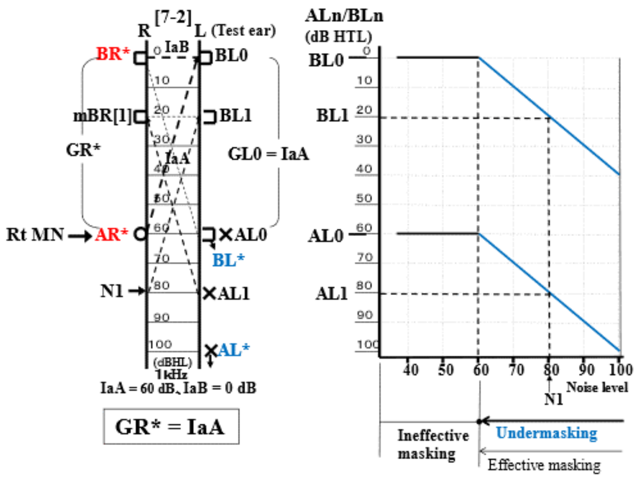

Figure 6-20 Masking dilemma (c)

(2) The plateau graph with no significant plateaus: GR0 = GL0 = IaA.

When bilateral apparent AB gaps are equal to IaA (GR0 = GL0 = IaA), no plateaus are present or plateau widths of 0 dB cannot be identified (**Fig. 6-21**). Therefore, the true AC and BC thresholds cannot be determined, which is an undecidable case for masking in theory. Clinically, when PW = 5 dB or 10 dB, the true thresholds cannot be decided.

The plateau graphs in **Fig. 6-17** to **6-20** are the same for the examiners, hence they cannot identify the actual configuration (**Fig. 6-21**).

We only know that the apparent AC and BC thresholds in at least one ear are true thresholds and the other ear is a complete hearing loss or its true AB gap is equal to IaA.

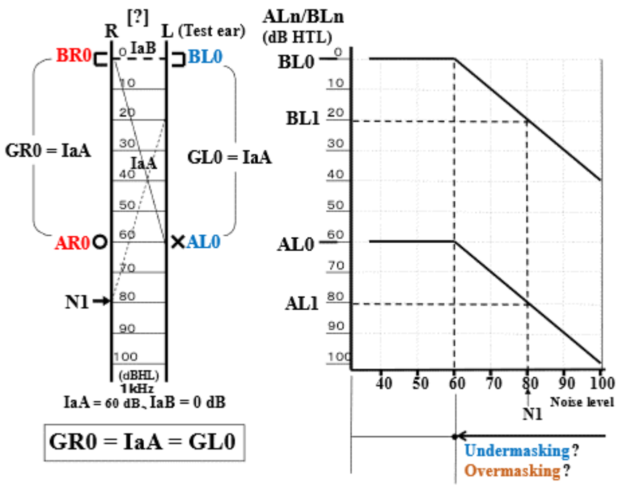

Figure 6-21 Plateau graphs with no plateaus

If no plateaus are present, and it is impossible or difficult to identify them (PW = 0, 5, or 10 dB), then true thresholds cannot be determined. It is the masking dilemma. If you correctly acknowledge the cases where the true thresholds cannot be determined, you will preclude a lot of wasted effort. Although the dilemma is not dissolved, such a dilemma in mental meaning as to make an effort to dissolve it will go away.

"There is no royal road to learning." However, wasting your efforts, you should not walk beggar's road, if any (T.S.).

6.4-3 Estimation for the true BC threshold: the OM method

When no BPW can be detected, the OM method should be used. Its precondition is that the true AC thresholds in the test ear have been determined. If they are not obtained, the method is not applicable. Therefore, at first, we should examine whether the true AC threshold can be obtained or not. Let us consider each pattern below.

(1) Pattern [5] (**Fig. 6-22**)

Since the noises of effective masking (N > 60 dB HL) always cause OM in both ears, bilateral APWs are not present (cf. **3.5** **[2]**). Moreover, bilateral BPWs are also not present. Therefore, this is an undecidable case for masking. The clinical configuration in pattern [5] is such a rare case as congenital atresia of the external meatus in each ear.

The APW and BPW in each pattern are shown in **Table 6-2** (cf. **Fig. 7-8**).

Table 6-2 APWs and BPWs

	Rt APW (= Lt δ)	Rt BPW (= Lt δ)	Lt APW (=Lt SNC + Rt δ)	Lt BPW (= Rt δ)
Pattern [5]	not present	not present	not present	not present
Pattern [5’]	10 dB	10 dB	10 dB	10 dB
Pattern [6]	not present	not present	30 dB	0 dB
Pattern [6’]	10 dB	10 dB	40 dB	10 dB

Lt SNC = BL* − BR* = Rt Nmax − Lt Nmax ≥ 0 dB. Lt δ = IaA – GL0, Rt δ = IaA – GR0.
Lt SNC: Relative amounts of sensorineural component in the left ear compared to the right one

(2) Pattern [5’] (**Fig. 6-23**)

In this example, Lt δ = 10 dB, Rt δ = 10 dB. Since bilateral APWs of 10 dB are clinically insignificant (cf. **3.3**), the true AC thresholds cannot be confirmed. We cannot distinguish this pattern from another pattern [5].

(3) Pattern [6] (**Fig. 6-24**)

With masking in the left ear (the poorer ear by BC), no Rt APW is presented. At this time, the examiner cannot know whether the cause is due to undermasking or OM. (cf. **3.5** **[2]**). Subsequently, with masking in the right ear (the better ear by BC), Lt APW of 30 dB presents and is clinically significant. Therefore, AL* of 60 dB HTL and Rt MN of 90 dB HL are decided. At this point, the examiner knows that the true BC threshold in the left ear is higher than that in the right ear (BR* < BL*). Both BR0 of 0 dB HTL and AR0 of 60 dB HTL prove to be the true thresholds automatically. Furthermore, he or she knows that masking in the left ear has caused OM: Lt MN = 60 dB HL. Here, with masking in the right ear (GR* = IaA), Lt BPW of 0 dB is present; however, cannot be detected. The OM method is used:

BL* = BR* + (Rt MN − Lt MN) = 0 (dB HTL) + {90 (dB HL) − 60 (dB HL)}
= 30 dB HTL.

Even when the apparent AB gap of one ear is equal to IaA (e.g., GR0 = IaA), so fa as the true BC threshold in the opposite ear (BL*) is relatively higher to some extent (BR* < BL*), the true AC threshold in the opposite ear (AL*) can be established. Consequently, the OM method is applicable.

(4) Pattern [6’] (**Fig. 6-25**)

In this example, Lt δ = 10 dB, Rt δ = 10 dB. The masking procedure is similar to that of the pattern [6]. With masking in the left ear, Rt APW of 10 dB is not significant. With masking in the right ear, Lt APW of 40 dB is significant: Rt MN = 100 dB HL. Then, AL* is determined as 60 dB HTL. At this time, BR0 and AR0 turn out to be true thresholds. Furthermore, masking in the left ear is detected as OM: Lt MN = 70 dB HL. Here, even with masking in the right ear, Lt BPW is only 10 dB. The OM method is used:

BL* = BR* + (Rt MN − Lt MN) = 0 (dB HTL) + {100 (dB HL) − 70 (dB HL)}
= 30 dB HTL.

Additionally, the true AC threshold cannot be determined in pattern [6’] when there is only a little difference between IaA and the apparent AB gap of the non-test ear (IaA − GR0 = Rt δ) and the relative difference between the true BC thresholds (Lt SNC) is small. At this time, Lt APW is also small or narrow: Lt APW = Rt δ + Lt SNC ≤ 10 dB (**Fig. 6-25**). This is a clinical masking dilemma.

*

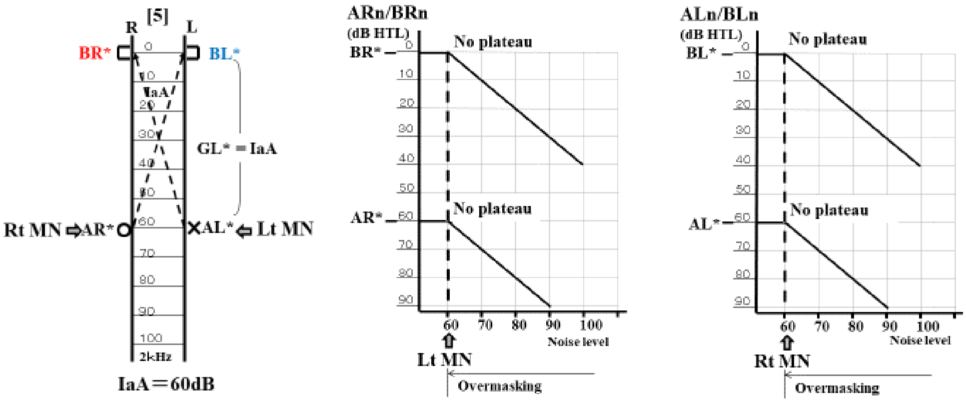

Figure 6-22 Pattern [5]

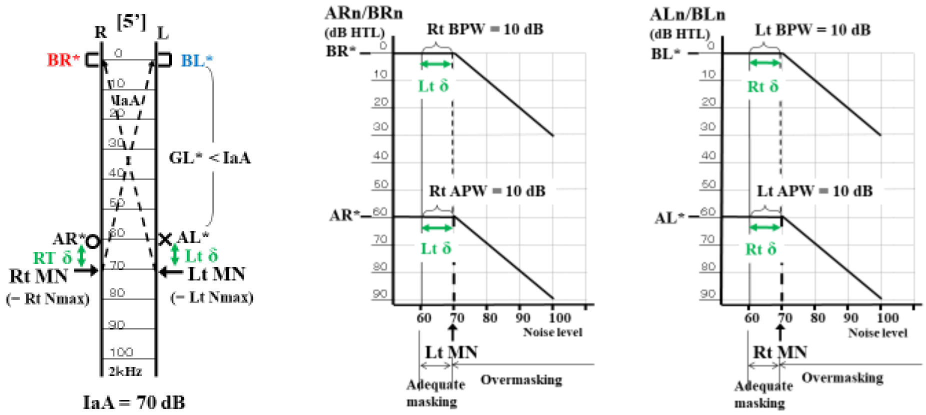

Figure 6-23 Pattern [5']

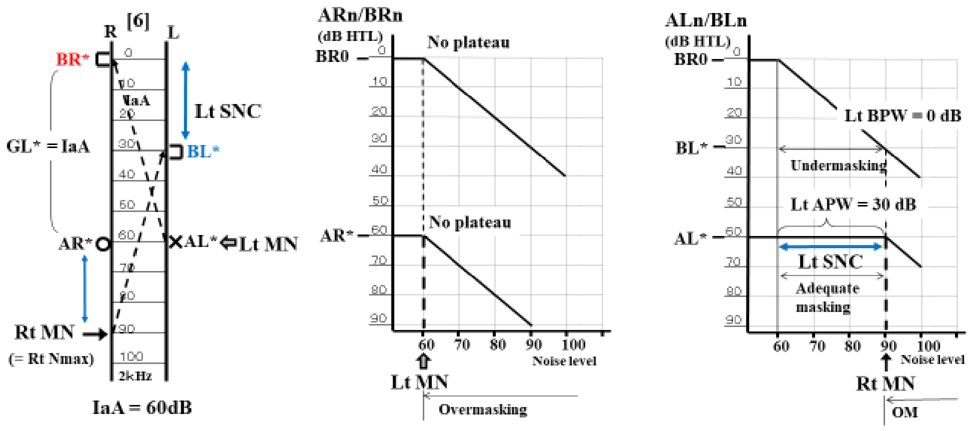

Figure 6-24 Pattern [6]

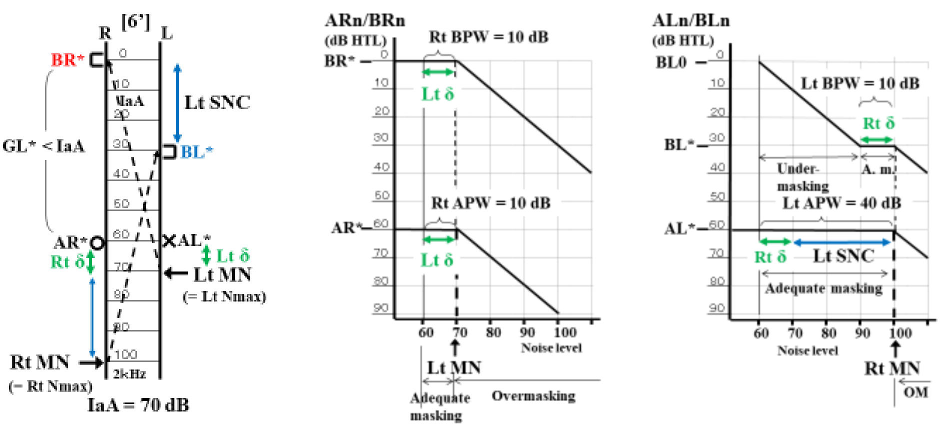

Figure 6-25 Pattern [6']

(5) Pattern [7-0]

Patten [7-0] is the configuration where the true AB gap of the poorer ear by AC is smaller than IaA and that ear is not a complete hearing loss (cf. **Fig. 6-14**). As shown in **Fig. 6-26 [a]**, the following configuration is discussed:

The right ear: AR* = 60 dB HTL, BR* = 0 dB HTL, GR* = 60 dB = IaA,
The left ear: AL* = 80 dB HTL, BR* = 40 dB HTL, GL* = 40 dB < IaA.

First, when the masking noises higher than 60 dB HL are delivered to the left ear, Rt APW is not present (**Fig. 6-26 [b]**). At this time, the examiner cannot distinguish whether the threshold elevation is due to undermasking or OM. He/she cannot know Lt MN.

Next, when masking noises from 80 dB HL to 100 dB HL are introduced to the right ear, Lt APW is obtained as 20 dB (**Fig. 6-26 [c]**). Thus, the true AC threshold in the left ear (AL*) of 80 dB HTL and Rt MN of 100 dB HL are determined. At this point, the examiner knows that this configuration is a pattern [7-0]. The following facts are established:

1) AL0 (= 60 dB HTL) and BL0 (= 0 dB HTL) are the SH thresholds.
2) AR0 (= 60 dB HTL) and BR0 (= 0 dB HTL) are the true thresholds.
3) IaA can be calculated (IaA = AL0 − BR* = 60 dB).

On the time, the examiner realizes that masking in the left ear has caused OM (**Fig. 6-26 [b]**):

∴ **Lt MN = 60 dB HL**.

Here, the true BC threshold in the left ear (BL*) cannot be identified using BC test signals because the right ear's true AB gap = IaA. The OM method is used.

BL* = BR* + (Rt MN − Lt MN) = 0 (dB HL) + {100 (dB HL) − 60 (dB HL)}
= 40 dB HTL.

Lt APW of 20 dB, in this case, is clinically significant. However, if Lt APW is only 5 dB, the examiner cannot judge such a narrow plateau to be significant (cf. **3.3**). For accuracy, the masking noise level should be increased in 5-dB steps.

Additionally, in cases where MN exceeds the maximum output level of the masking noise (NN), NN is used in place of MN. If the IaA value is 60 dB and NN is 100 dB HL, the measurement limit of BC thresholds is 40 dB HTL.

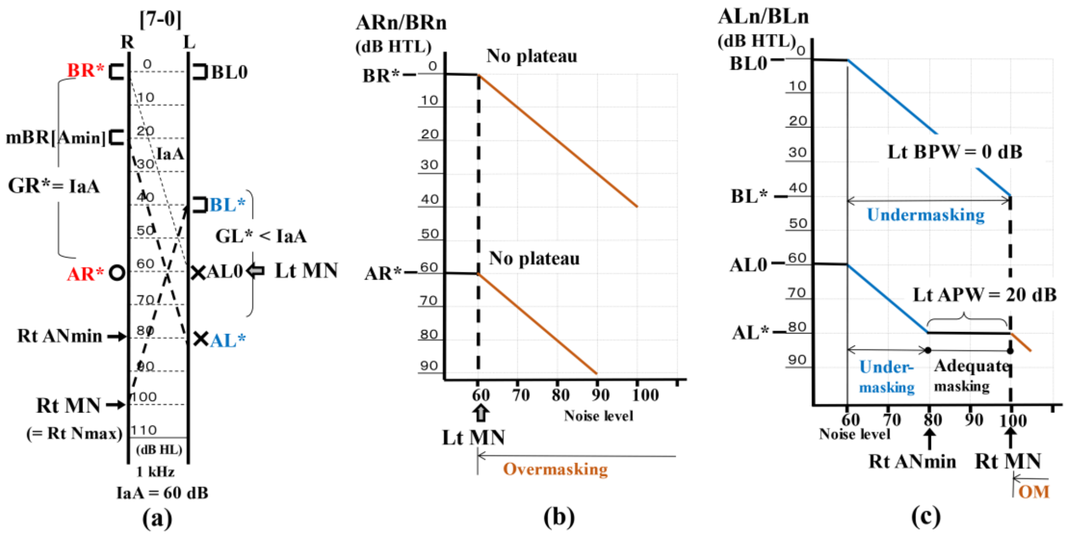

Figure 6-26 Masking in pattern [7-0]

Now, the theoretical considerations for the masking procedure in all patterns were completed. Clinical discussions will be addressed in Lecture 8.

**** Further note ****

) The apparent AB gap in one ear is the difference between the AC and BC threshold measured in that ear without masking. There are three cases: GL0 = AL − BL*, GL0 = AL* − BL0, GL0 = AL0 − BL0 (cf. **6.1**).

*) NN is an abbreviation used in the ABC method.

6.4-4 Masking procedure

As shown in **Fig. 6-27**, in the basic audiogram **[C-0]**, the apparent AC thresholds do not differ significantly (Rt AA gap = AL0 − AR0 ≤ 10 dB), then we should measure the BC thresholds in the better ear by AC without masking. Since AR0 ≤ AL0, let us measure the BC threshold in the right ear (BR0).

In **[C-2]**, since Lt AOB gap = AL0 − BR0 < 40 dB, masking for AC is not needed.

In **[C-1]**, since Lt AOB gap = AL0 − BR0 ≥ 40 dB, masking for AC is needed.

Theoretically or under ideal conditions, the AC thresholds in the better ear (AR0s) are the true ones. However, considering the measurement errors, AR0s might be the SH thresholds.

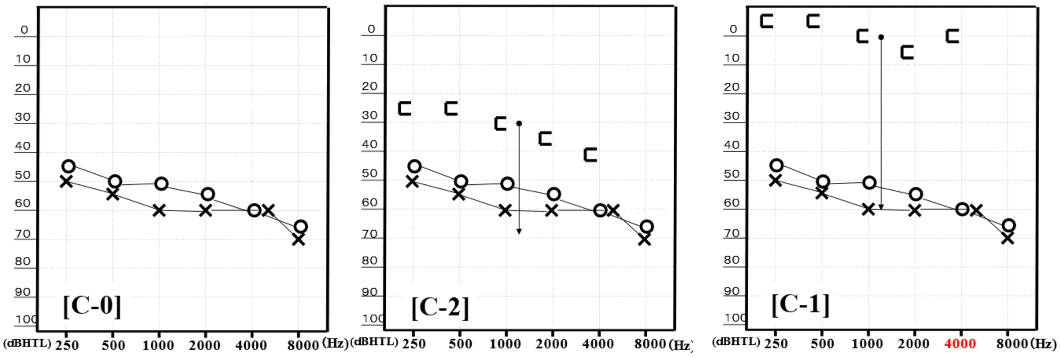

Figure 6-27 Basic audiograms (AA gap ≤ 10 dB)

Let us consider the configuration at 4000 Hz in **[C-1]**. Considering the patterns below (**Fig. 6-28**). the right ear is masked and the AC threshold in the left ear is measured using the plateau method (Rt N1 = [AR0] + 5, in 5-dB steps). If the significant Lt APW (≥ 15 dB) may be obtained, the true AC threshold in the left ear is established and simultaneously, both AR0 and BR0 are automatically determined to be the true thresholds. Subsequently, the left ear's true BC threshold should be estimated using the OM method.

When the significant Lt APW is not obtained, in turn, the left ear is masked. If the significant Rt APW cannot be obtained, it is an undecidable case for masking: patterns [5], [7-1], or [7-2].

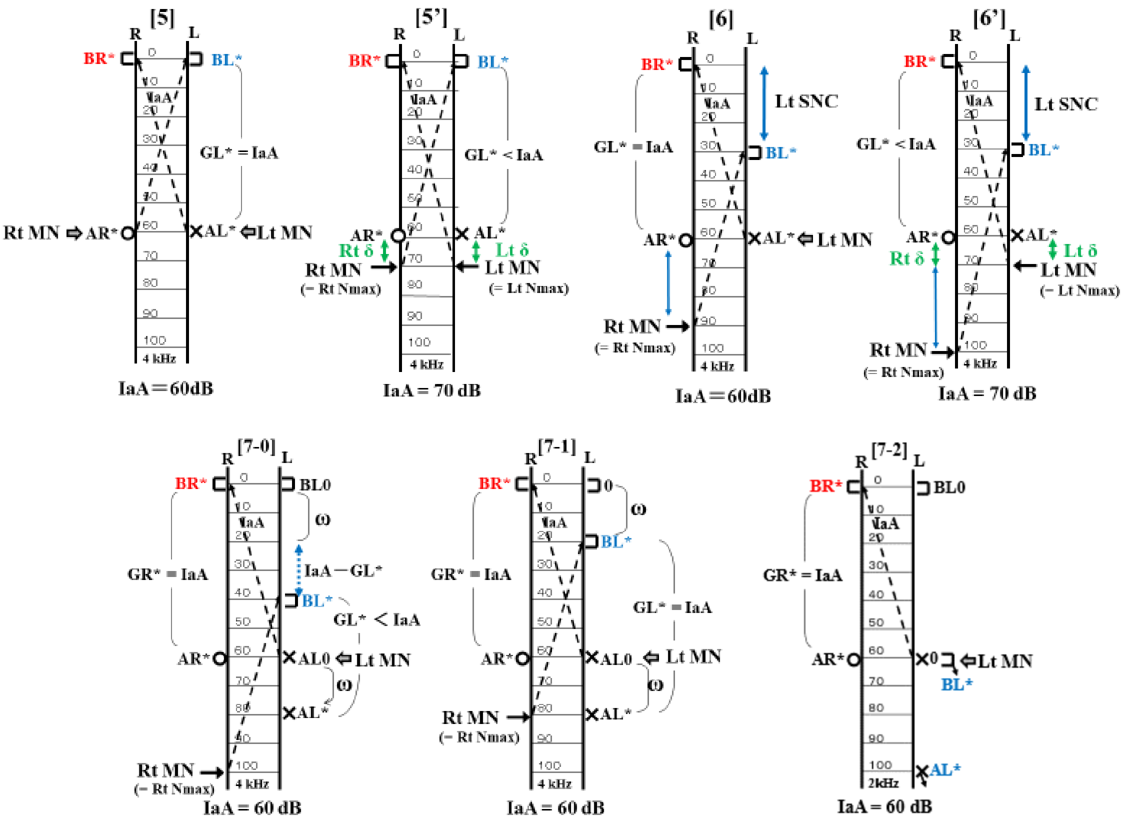

Figure 6-28 Audiometric patterns (AA gap ≤ 10 dB)

6.5 Summary of Lecture 6

1. The audiometric configurations where the apparent AB gap of the non-test ear is equal to IaA (e.g., GR0 = IaA) are following three patterns.

a) Cases where the apparent AB gap is equal to the true AB gap:

AR0 = AR*, BR0 = BR*; GR0 = IaA = GR*.

b) Cases where the apparent AC threshold is the true one (AR0 = AR*), and the apparent BC threshold is the SH threshold (BR0 < BL*):

AR0 = AR*, BR0 < BL*; GR0 = IaA = AR* − BR0 > GR*.

c) Cases where both the apparent AC and BC thresholds are the SH thresholds:

AR0 < AR*, BR0 < BR*; GR0 = IaA = AR0 − BR0 ≥ GR*.

Theoretically, masking for BC is impossible when the apparent AB gap of the non-test ear is equal to IaA (GR0 = AR0 − BR0 = IaA) and IaB is 0 dB. Namely, the true BC threshold cannot be determined using BC test signals.

Clinically, even when there is a little difference between IaA and GR0 (IaA − GR0 = 5 dB or 10 dB), masking for BC might become impossible.

2. The principle of the Rainville's method is an approach to calculate the true BC threshold in the test ear indirectly through the use of OM by BC noises. If the AC noise is used in place of the BC noise, the principle is the same. The precondition for using this method is that the true AC threshold in the test ear has been determined.

3. The difference between bilateral true BC thresholds (e.g., BR* − BL* ≥ 0 dB) is equal to the difference between Lt Nmax and Rt Nmax (Lt Nmax − Rt Nmax ≥ 0 dB). Therefore, BR* can be calculated as follows:

BR* = BL* + (Lt-Nmax − Rt-Nmax).

This approach is called an overmasking method (OM method). The precondition for using the OM method is that the true AC threshold in the test ear has been determined. When the true BC threshold cannot be determined using BC test signals (i.e., IaA − GR0 ≤ 10 dB), the OM method is applicable. In this method, the IaA value is not needed.

4. In patterns [1] and [2], since the true AB gap of the left, poorer ear by AC is equal to IaA (GL* = IaA), masking for the right BC is impossible. In patterns [1'] and [2'], when the difference between IaA and GL* is only a little (i.e., IaA − GL* ≤ 10 dB), masking for the right BC is difficult with regard of measurement errors. The OM method is applicable for these patterns.

5. The masking dilemma means that both the true AC and BC thresholds cannot be determined with masking noises of any level. Theoretically, the following three configurations are the cases:

a) Pattern [5]: bilateral true AB gaps are equal to IaA and BR* = BL*.
b) Pattern [7-1]: bilateral true AB gaps are equal to IaA and BR* < BL*.
c) Pattern [7-2]: the true AB gap of one ear is equal to IaA and the other ear is completely deaf.

In each pattern above, no plateau is present or even if it is present, PW of 0 dB cannot be found.

A clinical masking dilemma is the case in which both APWs are ≤10 dB (insignificant). For example, in pattern [6'], in which there is only a little difference between IaA and the apparent AB gap (Rt δ = IaA − GR0 or Lt δ = IaA − GL0), and the relative difference between the true BC thresholds (Rt SNC or Lt SNC) is small:

Lt APW = Rt δ + Lt SNC ≤ 10 dB, or

Rt APW = Lt δ + Rt SNC ≤ 10 dB.

Then, the true BC thresholds cannot be determined.

6. In patterns [5]', [6], and [6]', when the APW in only one ear is significant, the OM method is applicable. In pattern [7], in which the apparent AC threshold in one ear is the SH threshold and the APW in that ear is clinically significant (≥ 15 dB); i.e., in pattern [7-0], the true BC threshold in the same ear can be estimated by using the OM method.

7. The OM method requires further clinical validation.

Lecture 7. Factors that determine difficulty levels of masking

All told, plateau widths (PWs) determine the difficulty level of masking. As described in Lecture 3, assuming that the left is the poorer ear by AC, PWs for AC and BC of the left ear (Lt APW and BPW) in pattern [4] may be written as follows:

$$\text{Lt APW} = (\text{IaA} - \text{GR*}) + (\text{IaA} - \text{GL*}),$$
$$\text{Lt BPW} = (\text{IaA} - \text{GR*}) + \text{IaB},$$

where GR* and GL* are the true AB gaps of the right and left ear, respectively. In this lecture, general expressions of the PWs are derived and the difficulty level of masking is discussed. When the apparent AC thresholds in both ears differ (e.g., AR0 ≤ AL0), the Lt APW and Lt BPW may be written as

$$\text{Lt APW} = (\text{IaA} - \text{GR0}) + (\text{BL*} - \text{BR*}) - (\text{AL*} - \text{AL0})$$
$$= \text{Rt }\delta + \text{Lt SNC} - \omega,$$
$$\text{Lt BPW} = (\text{IaA} - \text{GR0}) + \text{IaB}$$
$$= \text{Rt }\delta + \text{IaB},$$

where GR0 is the apparent AB gap of the right ear.

As the derivation of the PWs is somewhat complicated, it is recommended to make a forecast for a full picture, looking over the summary of Lecture 7.

7.1 General expressions of the plateau widths

(1) Audiometric configurations with typical plateaus: Pattern [4]
(2) Audiometric configurations with an atypical plateau: Pattern [3’]
(3) Theoretical plateau widths

7.2 Schemes of the plateau widths

7.2-1 Plateau widths in a case with significant AA gaps

7.2-2 Plateau widths in a case with no significant AA gaps

7.3 Factors that determine the difficulty level of masking

7.3-1 General expression of plateau widths

7.3-2 Factors that determine the difficulty level of masking for AC and BC

(1) Difficulty levels of masking for AC
(2) Difficulty levels of masking for BC

7.4 Expression of the plateau widths using AA gap

(1) Cases with significant Rt AA gaps (Rt AA gaps ≥ 15 dB, AL0 > AR0)
(2) Cases with insignificant Rt AA gaps (Rt AA gaps ≤ 10dB)
(3) Representation of the term “masking”

7.5 Findings of an audiogram without masking

(1) Audiogram without masking and audiometric configurations at a given frequency
(2) Estimation of difficulty levels of masking: AA and AOB gaps

7.6 Masking windows of the present method

(1) Masking windows for AC
(2) Difficulty levels of masking for AC
(3) Masking windows for BC
(4) Difficulty levels of masking for BC
(5) Efficiency of masking

7.7 Series of the audiometric patterns and their utmost limit

(1) Pattern [1] series
(2) Pattern [2] series
(3) Pattern [3] series
(4) Pattern [4] series

7.8 Summary of Lecture 7

7.1 General expression of the plateau widths

(1) Audiometric configurations with typical plateaus: Pattern [4]

In adequate masking, the difference between the maximum adequate masking noise level (Nmax) and the minimum adequate masking noise level (Nmin) in the test ear is defined as the plateau width (PW). In other words, the PW is the range of the noise levels required for adequate masking (cf. **3.1-2 [5]**):

Lt APW = Rt Nmax − Rt ANmin,
Lt BPW = Rt Nmax − Rt BNmin.

The audiometric configuration in **Fig. 7-1 (a)** shows the pattern [4-0] with typical plateaus for both AC and BC. When the right, better ear by AC is masked, adequate masking for AC is detected in the noise range where 60 dB HL ≤ N ≤ 95 dB HL (**Fig. 7-1 [b]**). Here, Rt Nmax is equal to the maximum level of masking noise at which OM does not occur in the right ear (Rt MN). The APW of the left, poorer ear by AC (Lt APW) is described below (cf. **3.4**):

Lt APW = (IaA − GR*) + (IaA − GL*)
= 20 (dB) + 15 (dB) = 35 dB.

This formula is true only when typical plateaus are obtained. Then, with attention to the fact that GR* = GR0, and IaA = AL0 – BR*, let the formula change into the more general form below, or simply the form can be intuitively derived from the configuration in **Fig. 7-1 (c)**:

Lt APW = (IaA − GR*) + (IaA − GL*)
= (IaA − GR0) + {(AL0 − BR*) − (AL* − BL*)}
= (IaA − GR0) + (BL* − BR*) − (AL* − AL0).

∴ Lt APW = Rt δ + Lt SNC − ω,

where Rt δ (= IaA − GR0) is the difference between IaA and the apparent AB gap of the non-test ear, Lt SNC (= BL* − BR*) is the relative sensorineural component of the left ear, and ω (= AL* − AL0) is the amount of AC threshold elevation in the test ear.

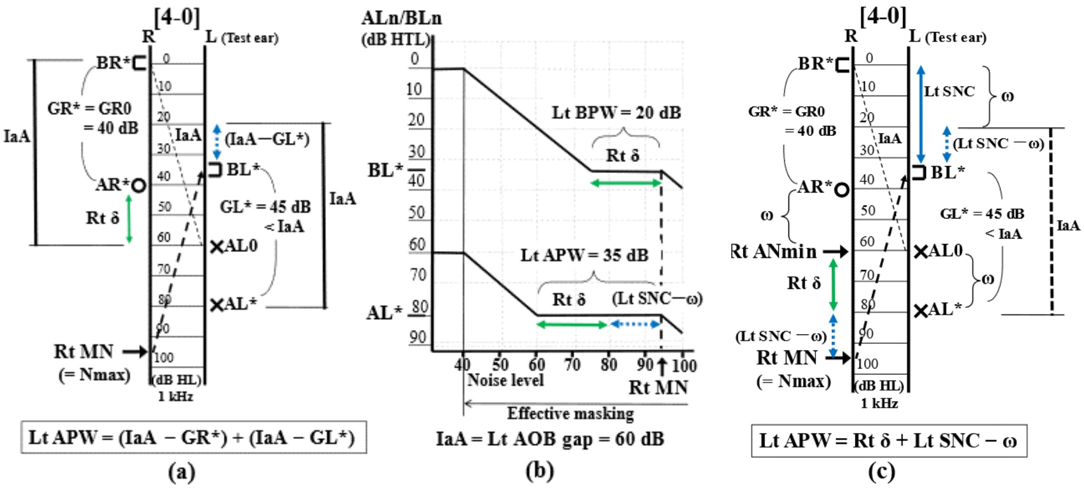

Figure 7-1 Typical plateaus for AC and BC in pattern [4]

Adequate masking for BC is detected in the noise range where 75 dB HL ≤ N ≤ 95 dB HL (**Fig. 7-1[b]**). The BPW of the left ear (Lt BPW) is written as (cf. **3.4**)

Lt BPW = (IaA − GR*) + IaB = 20 (dB) + 0 (dB) = 20 dB.

Let the formula change into the more general form below, assuming that IaB is 0 dB.

Lt BPW = (IaA − GR*) + IaB
= (IaA − GR0) + 0 (dB).

∴ Lt BPW = Rt δ.

**** Further note ****

*) The main abbreviations are listed. AC: Air conduction, BC: Bone conduction,
SH: Shadow hearing, CH: Cross hearing, OM: Overmasking,
GR*: True air-bone (AB) gap in the right ear, GR0: Apparent AB gap in the right ear,
IaA: Interaural attenuation for AC signals, IaB: Interaural attenuation for BC signals,

*) In the operation of levels and quantities (amounts), each term of equality and inequality is represented as a numerical value (cf. **2.4 [1]**).

(2) Audiometric configurations with an atypical plateau: Pattern [3’]

To take the case of pattern [3’], **Fig. 7-2** shows an atypical APW, which has no noise of undermasking. When 45 dB HL < Rt N ≤ 90 dB HL (**Fig. 7-2 [b]**), these noises provide adequate masking for AC, thus, the Rt Nmax is 90 dB HL. However, a 45 dB HL noise causes ineffective masking, and Rt ANmin is not present or cannot be defined. Therefore, instead of Rt ANmin, the N0 of a level equal to the true AC threshold level in the non-test ear should be used: Rt N0 = [AR*] dB HL (cf. **3.5 [1]**). The range of the adequate masking noise levels for AC; i.e., Lt APW can be represented as follows:

Lt APW = Rt Nmax − Rt N0
= (BL* + IaA) − [AR*]
= 90 (dB) − 45 (dB) = 45 dB.

Let the formula change into the more general form below, or alternatively the form can be intuitively derived from the configuration in **Fig. 7-2(c)**:

Lt APW = (BL* + IaA) − [AR*]
= IaA − (AR* − BL*)
= IaA − {(AR* − BR*) − (BL* − BR*)}
= IaA − (GR* − Lt SNC)
= (IaA − GR0) + Lt SNC,

∴ Lt APW = Rt δ + Lt SNC.

Adequate masking for BC is detected in the range where 65 dB HL ≤ Rt N ≤ 95 dB HL (**Fig. 7-2 [b]**). Lt BPW is written as

Lt BPW = (IaA − GR*) + IaB
= (IaA − GR0),

∴ Lt BPW = Rt δ,

where the IaB value is assumed to be 0 dB.

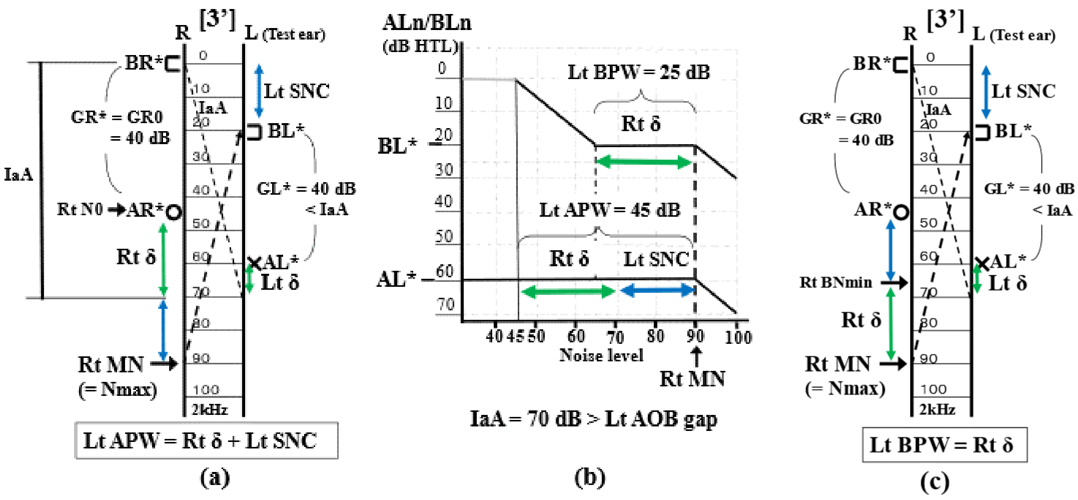

Figure 7-2 Atypical plateau for AC in pattern [3’]

(3) Theoretical plateau widths

If the true BC thresholds in the test ear are high (i.e., profound sensorineural hearing impairment), the Nmax might exceed the limit of the noise levels; then, the PWs become smaller or narrower than those of the above equations. To simplify the discussion, theoretical PWs in disregard of the noise limit are discussed in this lecture. Actual PWs, with consideration of the limit, are addressed in Lecture 8 (cf. **8.2-1 [2]**).

Additionally, Lt SNC (= BL* − BR* ≥ 0 dB) is true only when BL* ≥ BR*. Thus, when BL*< BR*, Lt SNC is assumed to be 0 dB.

**** Further note ****

*) Apparent AB gaps are measured without masking.

7.2 Schemes of the plateau widths

7.2-1 Plateau widths in cases with significant AA gaps

When the Rt AA gap = AL0 − AR0 ≥ 15 dB (AR0 < AL0), the PWs in both ears consist of five elements below:

1) Rt δ = IaA − GR0. 2) Lt δ = IaA − GL0.
3) Rt SNC = BR* − BL*. 4) Lt SNC = BL* − BR*.
5) ω = AL* − AL0 (> 0 dB; only in pattern [4]).

Here, the case with no plateau is indicated using the symbol (−).

Table 7-1 Plateau widths (Rt AA gap ≥ 15 dB)

Patterns	Rt APW	Rt BPW	Lt APW	Lt BPW
[1] Lt δ = 0 dB	(−)	(−)	Rt δ	Rt δ
[2] Lt δ = 0 dB	Rt SNC	0 dB	Rt δ	Rt δ
[3] Lt δ = 0 dB	(−)	(−)	Rt δ + Lt SNC	Rt δ
[4] Lt δ = 0 dB	(−)	(−)	Rt δ + Lt SNC − ω	Rt δ
[1'] Lt δ ≥ 5 dB	Lt δ	Lt δ	Rt δ	Rt δ
[2'] Lt δ ≥ 5 dB	Lt δ + Rt SNC	Lt δ	Rt δ	Rt δ
[3'] Lt δ ≥ 5 dB	Lt δ	Lt δ	Rt δ + Lt SNC	Rt δ

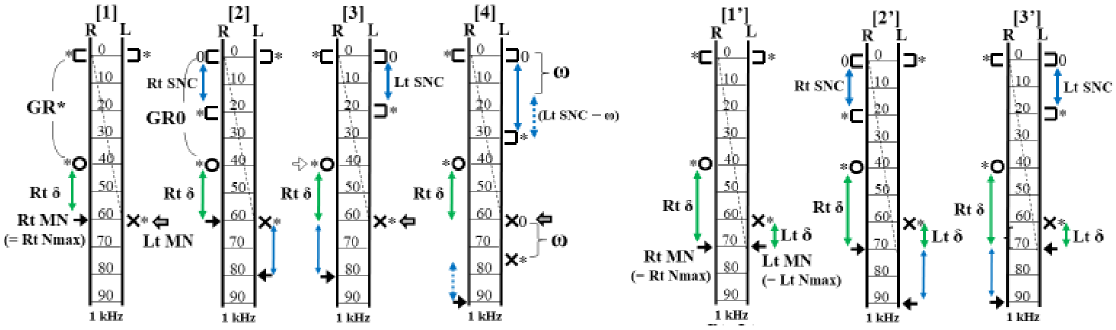

Figure 7-3 Audiometric configurations (Rt AA gap = 20 dB ≥ 15 dB)

a) The PWs of the left, poorer ear by AC (Lt APW, Lt BPW)

When the true BC threshold in the left ear is equal to the apparent BC threshold (BL* = BL0: patterns [1], [2], [1'], and [2']), Lt APW is as follows:

Patterns [1], [2], [1'], [2']: **Lt APW = (IaA − GR0) = Rt δ**.

This formula is referred to as the basic form of Lt APW (**Table 7-1**, **Fig. 7-3**, **7-4**).

When BL* is higher than BL0 (BL* > BL0: patterns [3], [3'], and [4]), Lt APW is the basic form added to Lt SNC:

Patterns [3], [3']: **Lt APW = Rt δ + Lt SNC**.

However, in pattern [4] Lt APW is reduced as ω (= AL* − AL0 > 0 dB):

Pattern [4]: **Lt APW = Rt δ + Lt SNC – ω**.

Lt BPWs in all patterns are written as

Lt BPW = (IaA − GR0) = Rt δ.

This formula is referred to as the basic form of Lt BPW.

b) The PWs of the right, better ear by AC (Rt APW, Rt BPW)

Table. 7-1 shows Rt APW and BPW. In patterns [1], [3], and [4], as the masking noises higher than 60 dB HL in the left ear (Lt N > 60 dB HL) always cause OM, Rt APW and BPW are not existent (cf. **5.7**).

Rt APW and BPW in patterns [1'] and [3'] are as follows:

Rt APW = (IaA − GL0) = Lt δ,

Rt BPW = (IaA − GL0) = Lt δ.

These are also referred to as the basic forms of Rt APW and BPW.

Rt APW and BPW in patterns [2] and [2'] are as follows:

Rt APW = (IaA − GL0) = Lt δ + Rt SNC,

Rt BPW = (IaA − GL0) = Lt δ,

where Lt δ is 0 dB in pattern [2].

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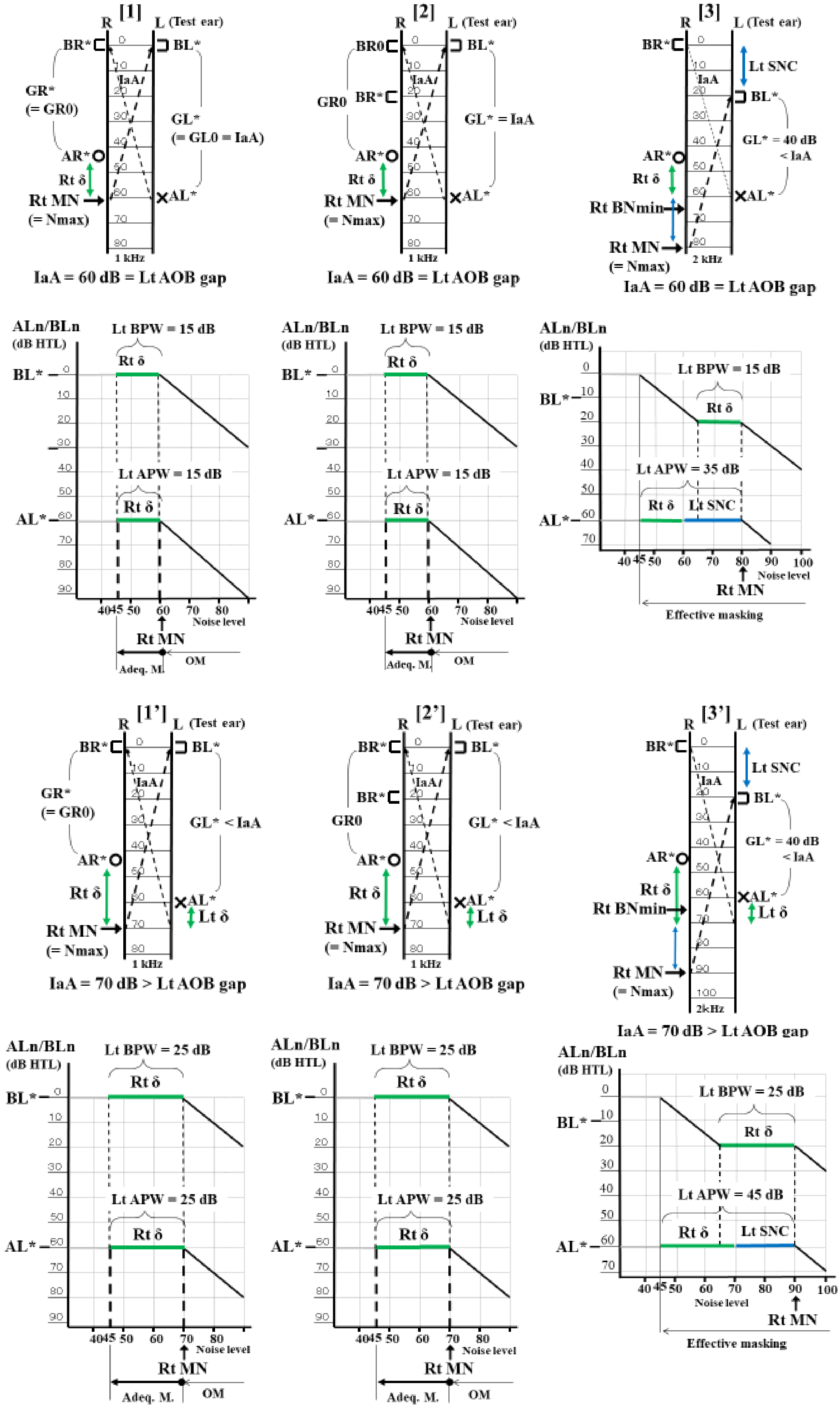

Figure 7-4 Plateau graphs (Rt AA gap ≥ 15 dB)

7.2-2 Plateau widths in cases with no significant AA gaps

When the Rt AA gap = AL0 − AR0 ≤ 10 dB, the PWs in both ears consist of the five elements below (**Table 7-2**). For simplicity, the Rt AA gap is supposed to be 0 dB.

1) Rt δ = IaA − GR0. 2) Lt δ = IaA − GL0.
3) Rt SNC = BR* − BL*. 4) Lt SNC = BL* − BR*.
5) ω = AL* − AL0 (> 0 dB; only in pattern [7]).

Here, the case with no plateau is indicated using the symbol (−).

Table 7-2 Plateau widths (Rt AA gap ≤ 10 dB)

Patterns	Rt APW	Rt BPW	Lt APW	Lt BPW
[5] Rt δ = Lt δ = 0 dB	(−)	(−)	(−)	(−)
[6] Rt δ = Lt δ = 0 dB	(−)	(−)	Lt SNC	Rt δ (= 0 dB)
[7] Rt δ = Lt δ = 0 dB	(−)	(−)	Lt SNC − ω	Rt δ (= 0 dB)
[5'] Rt δ = Lt δ > 0 dB	Lt δ	Lt δ	Rt δ	Rt δ
[6'] Rt δ = Lt δ > 0 dB	Lt δ	Lt δ	Rt δ + Lt SNC	Rt δ

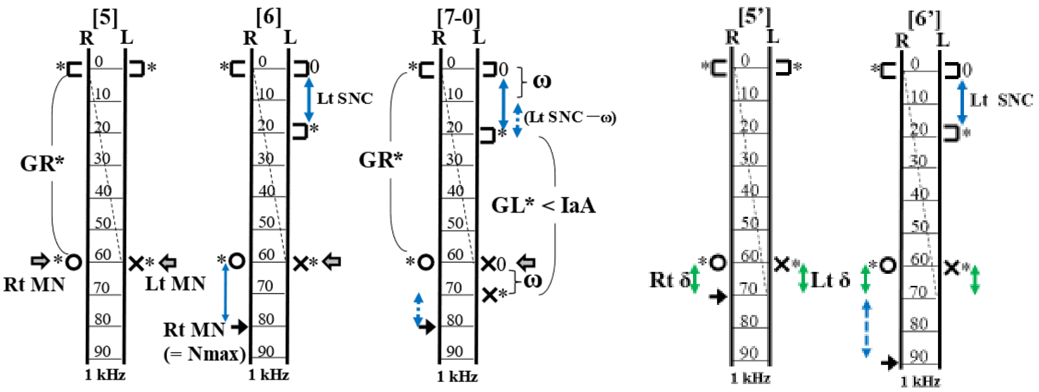

Figure 7-5 Audiometric configurations (Rt AA gap = 0 dB ≤ 10 dB)

a) Cases where BR* = BL* (patterns [5] and [5'])

In pattern [5], since GR* = GL* = IaA, the APW and BPW of both ears are not present (cf. **6.4-3**).

In pattern [5'] the APWs and BPWs are as follows:

Pattern [5']: **Rt APW = Rt BPW = (IaA − GL0) = Lt δ**,

Pattern [5']: **Lt APW = Lt BPW = (IaA − GR0) = Rt δ**.

These are the basic forms of PWs as has been noted (**Fig. 7-5**, **7-6**).

b) Cases where BR* < BL* (patterns [6], [6'], and [7])

In **Fig.7-5**, the left ear is the poorer ear by BC. Lt APW is the basic form (Rt δ) added to Lt SNC. Here, Rt δ = 0 dB in patterns [6] and [7].

Pattern [6]: **Lt APW = Lt SNC**,

Pattern [6']: **Lt APW = Rt δ + Lt SNC**.

However, in pattern [7], Lt APW is reduced as ω (= AL* − AL0 > 0 dB).

Pattern [7]: **Lt APW = Lt SNC – ω**.

Lt BPW is the basic form (Rt δ). In patterns [6] and [7], Rt δ = 0 dB.

Pattern [6]: **Lt BPW = Rt δ** (= 0 dB),

Pattern [6']: **Lt BPW = Rt δ** (> 0 dB),

Pattern [7]: **Lt APW = Rt δ** (= 0 dB).

For the right ear, the better ear by BC, Rt APW and BPW in patterns [6] and [7] are not existent, while those in patterns [5'] and [6'] are the basic form:

Patterns [5'], [6']: **Rt APW = Rt BPW = (IaA − GL0) = Lt δ.**

**** Further note ****

*) If there are a few differences between AR0 and AL0 (Rt AA gap = 5 dB or 10 dB), Lt δ is not equal to Rt δ, in which cases will be discussed in Lecture 8.

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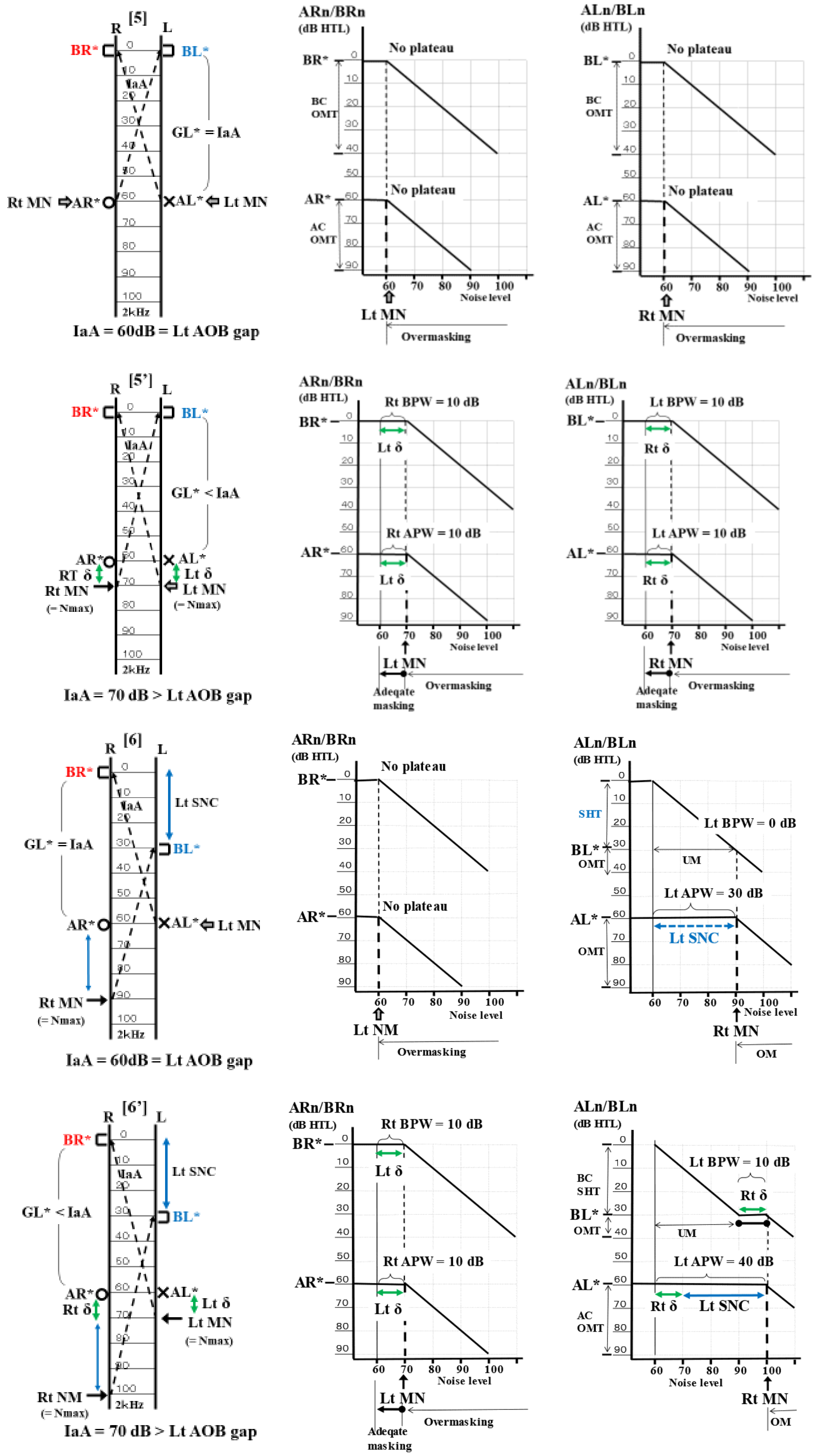

Figure 7-6 Plateau widths in Pattern [5]-[6’]

7.3 Factors that determine the difficulty level of masking

7.3-1 General expression of plateau widths

The PWs in the twelve patterns of the audiometric configurations are shown in **Table 7-3**, **Fig. 7-7**, and **Fig. 7-8**. The PWs in both ears consist of the following five elements:

1) Rt δ = IaA − GR0. 2) Lt δ = IaA − GL0.

3) Rt SNC = BR* − BL*. 4) Lt SNC = BL* − BR*.

5) ω = AL* − AL0 (> 0 dB; only in patterns [4] and [7]).

Here, the case with no plateau is indicated using the symbol (−).

Table 7-3 Plateau widths in all patterns

Patterns	The right ear: the better ear by AC		The left ear: poorer ear by AC	
	Rt APW	Rt BPW	Lt APW	Lt BPW
[1] Lt δ = 0 dB	(−)	(−)	Rt δ	Rt δ
[2] Lt δ = 0 dB	Rt SNC	0 dB	Rt δ	Rt δ
[3] Lt δ = 0 dB	(−)	(−)	○Rt δ + Lt SNC	Rt δ
[4] Lt δ = 0 dB	(−)	(−)	●Rt δ + Lt SNC − ω	Rt δ
[1'] Lt δ ≥ 5 dB	Lt δ	Lt δ	Rt δ	Rt δ
[2'] Lt δ ≥ 5 dB	△Lt δ + Rt SNC	Lt δ	Rt δ	Rt δ
[3'] Lt δ ≥ 5 dB	Lt δ	Lt δ	○Rt δ + Lt SNC	Rt δ
Patterns	The right ear		The left ear	
	Rt APW	Rt BPW	Lt APW	Lt BPW
[5] Rt δ = Lt δ = 0 dB	(−)	(−)	(−)	(−)
[6] Rt δ = Lt δ = 0 dB	(−)	(−)	Lt SNC	Rt δ (= 0 dB)
[7] Rt δ = Lt δ = 0 dB	(−)	(−)	⦿Lt SNC − ω	Rt δ (= 0 dB)
[5'] Rt δ = Lt δ > 0 dB	Lt δ	Lt δ	Rt δ	Rt δ
[6'] Rt δ = Lt δ > 0 dB	Lt δ	Lt δ	○Rt δ + Lt SNC	Rt δ

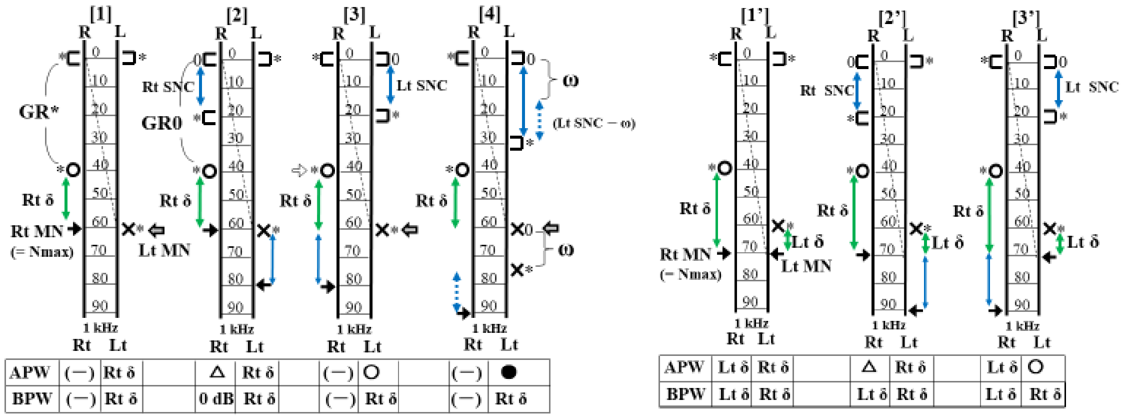

Figure 7-7 Patterns where both the apparent AC thresholds differ (Rt AA gap = 20 dB)

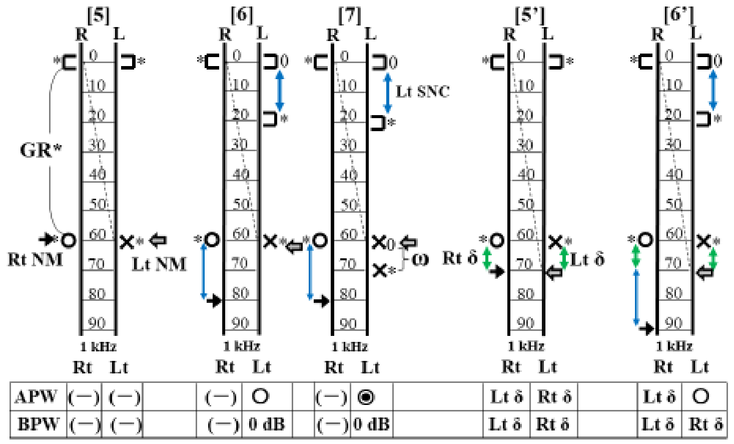

Figure 7-8 Patterns where both the apparent AC thresholds do not differ (Rt AA gap = 0 dB)

The general expression of Lt APW is as follows:

Lt APW = Rt δ + Lt SNC − ω

= (IaA − GR0) + (BL* − BR*) − (AL* − AL0)

From this formula, Lt APW in each pattern is derived.
When **ω > 0 dB (AL* > AL0)**, the configurations are patterns [4] and [7].
When Rt δ > 0 dB (pattern [4]), **Lt APW = Rt δ + Lt SNC − ω**.
When Rt δ = 0 dB (pattern [7]), **Lt APW = Lt SNC – ω**.
When **ω = 0 dB (AL* = AL0)**, the configurations are patterns, except for patterns [4] and [7].
When Rt δ > 0 dB and Lt SNC > 0 dB (patterns [3], [3'], [6']), **Lt APW = Rt δ + Lt SNC**.
When Rt δ = 0 dB and Lt SNC > 0 dB (patterns [6]), **Lt APW = Lt SNC**.
When Rt δ > 0 dB and Lt SNC = 0 dB (patterns [1], [1'], [2], [2'], [5']), **Lt APW = Rt δ**.
When Rt δ = 0 dB and Lt SNC = 0 dB (pattern [5]), **Lt APW is not present**.

The basic forms of Lt APW and BPW are as follows:

Lt APW = Rt δ, **Lt BPW = Rt δ**.

7.3-2 Factors that determine the difficulty level of masking for AC and BC

If the PWs are wide (or large), masking becomes easy. In contrast, if they are narrow (or small), masking becomes difficult. When PWs are 0 dB or not present, masking is impossible. The IaA value is assumed to be a constant of 60 dB.

(1) Difficulty level of masking for AC: Lt APW = (IaA − GR0) + Lt SNC − ω.
F1 F2 F3

Three factors determine the difficulty level of masking for AC.
The first is the apparent AB gap of the right (non-test) ear (GR0).
The second is the relative amount of sensorineural component in the left (test) ear (Lt SNC).
The third is the difference between the SH threshold for AC and true AC threshold in the test ear in patterns [4] and [7] (ω = AL* − AL0 > 0 dB).

Even if GR0 is equal to IaA, Lt APW is wide so long as Lt SNC is large, and masking for AC becomes easy. As ω is larger in patterns [4] and [7], Lt APW becomes narrower due to offsetting Lt SNC.

In patterns [4] and [7], the second and third factors can be replaced with IaA and the true AB gap of the non-test ear (GL*), as follows:

Lt SNC − ω = (BL* − BR*) − (AL* − AL0) = (AL0 − BR*) − (AL* − BL*) = IaA − GL*,

∴ Lt SNC − ω = IaA − GL*.

(2) Difficulty level of masking for BC: Lt BPW = (IaA − GR0) + IaB.
F1 F2

Two factors determine the difficulty level of masking for BC.
The first is the apparent AB gap of the right (non-test) ear (GR0).
The second is the IaB value.

When GR0 is larger, Lt BPW becomes narrower and masking for BC becomes difficult. Furthermore, if GR0 is equal to IaB, and IaB is 0 dB, then Lt BPW is either equal to 0 dB or not present. Consequently, masking for BC becomes impossible. Since the apparent AB gaps are identified without masking, the difficulty level of masking for BC can be predicted before masking (cf. **7.4 [3]**).

In this lecture series, for simplicity, the IaB value has been assumed to be 0 dB. However, when the BC vibrator is placed at the mastoid, the IaB value cannot be clinically neglected. The BPW of the ear in which the apparent BC threshold is the SH threshold is as follows:

Patterns [2] and [2']: Rt BPW = (IaA − GR*) + IaB,
Patterns [3], [3'], [4] [6], [6'], and [7]: Lt BPW = (IaA − GR*) + IaB.

Therefore, when IaB > 0 dB, the BPWs are wider by the IaB value (cf. **3.2 [2]**, **Supplement 6**).

7.4 Expression of the plateau widths using AA gaps

Rt δ (= IaA − GR0) and Lt δ (= IaA − GL0) cannot be determined before the IaA value has been obtained. Then, an AA gap is transformed into the PWs as a parameter.

(1) Cases with significant Rt AA gaps (Rt AA gaps ≥ 15 dB, AL0 > AR0)

When the right and left apparent AC thresholds differ significantly (e.g., Rt AA gap = AL0 − AR0 ≥ 15 dB), Rt δ can be represented using Rt AA gap and Lt δ (**Fig. 7-9**):

Patterns [1]–[4]: Rt δ = IaA − GR0 = Rt AA gap,

Patterns [1’]–[3’]: Rt δ = IaA − GR0 = Rt AA gap + Lt δ.

Here, Lt δ is simply shown as δ in patterns [1’], [2’], and [3’]. Therefore, as shown in **Table. 7-4**, the PWs may be reduced to formulas including the AA gap. In **Fig. 7-10** on the next page, the plateau graphs of the poorer ear by AC (the left ear in **Fig. 7-9**) are shown.

Lt AOB gap = IaA.

Lt δ = IaA − Lt AOB gap
= 0 dB.

∴ Rt δ = Rt AA gap.

Lt AOB gap < IaA.

Lt δ = IaA − Lt AOB gap
= 10 dB (= δ).

∴ Rt δ = Rt AA gap + δ

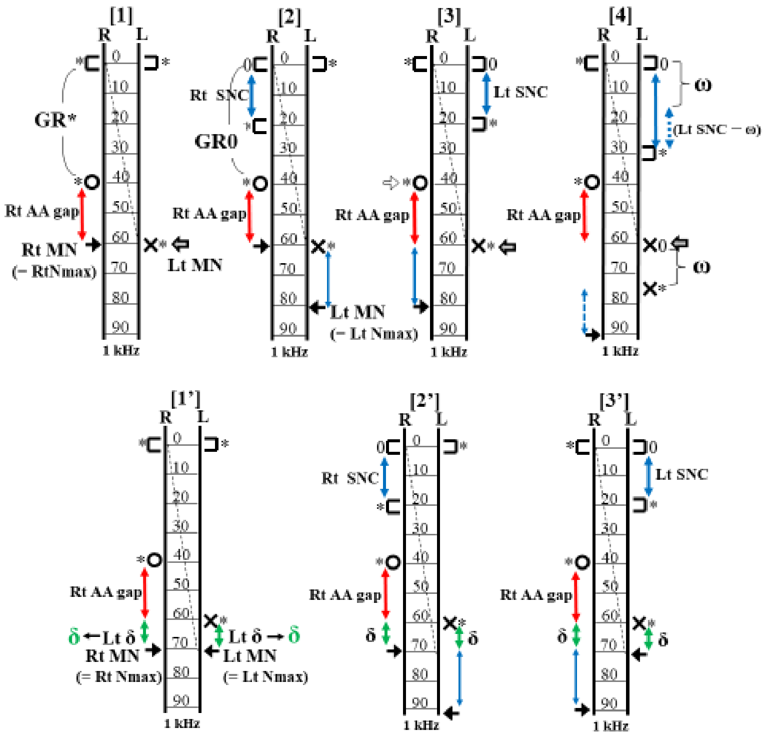

Figure 7-9 Expression of the plateau widths using AA gaps (Rt AA gap = 20 dB)

Table 7-4 Plateau widths (Rt AA gaps ≥ 15 dB)

Patterns	Rt APW	Rt BPW	Lt APW	Lt BPW
[1] Lt δ = 0 dB	(−)	(−)	Rt AA gap	Rt AA gap
[2] Lt δ = 0 dB	Rt SNC	0 dB	Rt AA gap	Rt AA gap
[3] Lt δ = 0 dB	(−)	(−)	Rt AA gap + Lt SNC	Rt AA gap
[4] Lt δ = 0 dB	(−)	(−)	Rt AA gap + Lt SNC − ω	Rt AA gap
[1’] Lt δ ≥ 5 dB	δ	δ	Rt AA gap + δ	Rt AA gap + δ
[2’] Lt δ ≥ 5 dB	δ + Rt SNC	δ	Rt AA gap + δ	Rt AA gap + δ
[3’] Lt δ ≥ 5 dB	δ	δ	Rt AA gap + δ + Lt SNC	Rt AA gap + δ

1) Rt AA gap = AL0 − AR0 2) δ = Lt δ = IaA − GL0 = IaA − Lt AOB gap
3) Rt SNC = BR* − BL* 4) Lt SNC = BL* − BR*
5) ω = AL* − AL0 (> 0 dB; only in pattern [4]).
Here, the case with no plateau is indicated using the symbol (−).

Among the five elements of PWs, only AA gaps can be determined without masking. The other elements (δ, Rt SNCs, Lt SNC and ω) are unknown. However, as the Lt AOB gap is larger, δ becomes smaller and the plateau width becomes narrower. The reverse is also true. Namely, the Lt AOB gap, which can be determined without masking, may be an indicator for estimating the difficulty level of masking.

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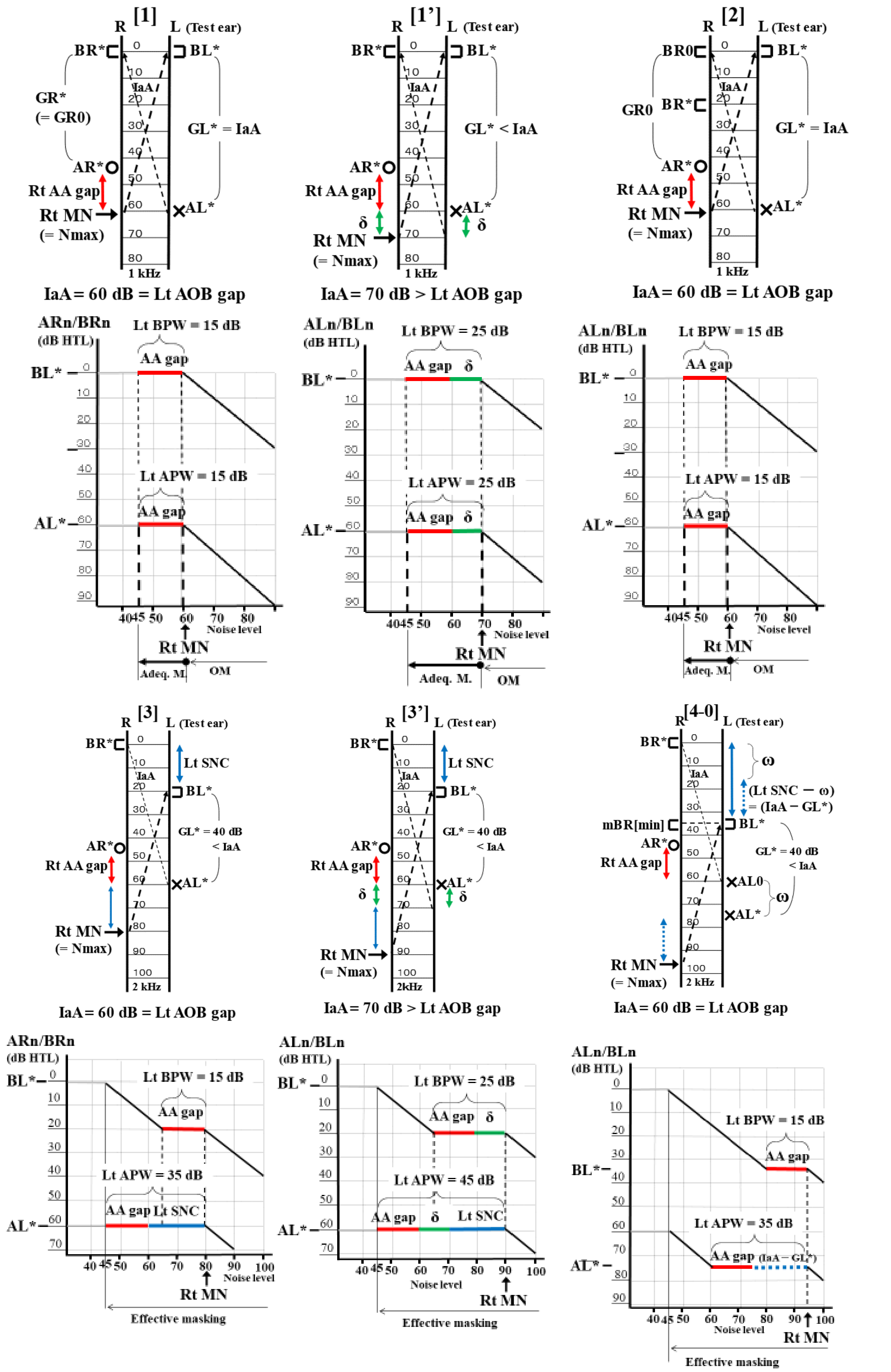

Figure 7-10 APW and BPW of the poorer ear by AC in Patterns [1]-[4] (Rt AA gap = 15 dB)

**** Further note ****

*) Lt PWs in pattern [2’] are equal to those in pattern [1’].

(2) Cases with insignificant Rt AA gaps (Rt AA gaps ≤ 10 dB)

The patterns with an Rt AA gap of 5 dB and their PWs are shown in **Fig. 7-11** and **Table 7-5**, respectively. **Fig. 7-13** on the next page shows the plateau graphs in each pattern.

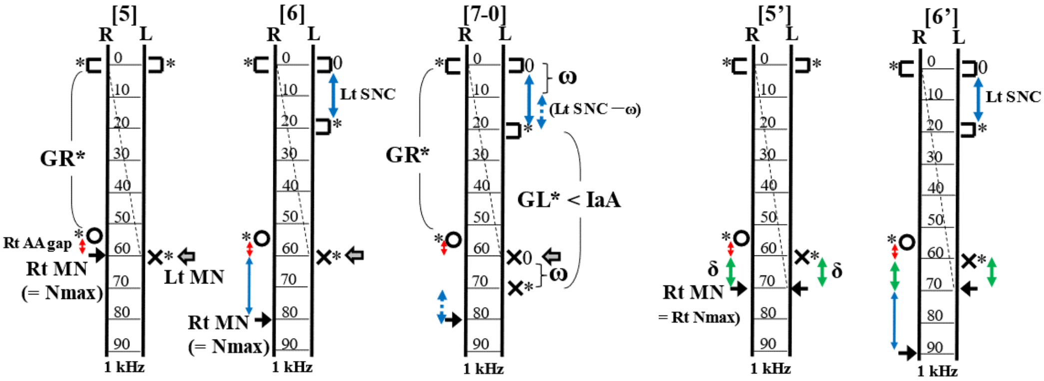

Figure 7-11 Audiometric configurations (Rt AA gap = 5 dB)

Table 7-5 Plateau widths (Rt AA gap ≤ 10 dB)

Patterns	Rt APW	Rt BPW	Lt APW	Lt BPW
[5] δ = 0 dB	(−)	(−)	Rt AA gap	Rt AA gap
[6] δ = 0 dB	(−)	(−)	Rt AA gap + Lt SNC	Rt AA gap
[7] δ = 0 dB	(−)	(−)	Rt AA gap + Lt SNC − ω	Rt AA gap
[5'] δ ≥ 5 dB	δ	δ	Rt AA gap + δ	Rt AA gap + δ
[6'] δ ≥ 5 dB	δ	δ	Rt AA gap + δ + Lt SNC	Rt AA gap + δ
[2] [6] δ = 0 dB	Rt SNC	0 dB	Rt AA gap	Rt AA gap
[2] [6'] δ ≥ 5 dB	δ + Rt SNC	δ	Rt AA gap + δ	Rt AA gap + δ

1) Rt AA gap = AL0 − AR0 2) δ = Lt δ = IaA − GL0 = IaA − Lt AOB gap
3) Rt SNC = BR* − BL* 4) Lt SNC = BL* − BR*
5) ω = AL* − AL0 (> 0 dB; only in patterns [7]).
the case with no plateau is indicated using the symbol of (−).

In **Fig. 7-11**, the poorer ear by BC is set to the left ear in patterns [6] and [6'] (BR* < BL*). However, since there is no significant difference between the true AC thresholds, the poorer ear by BC may be either ear. As shown in **Fig. 7-12**, when the poorer ear by BC is the right ear, their plateau widths are the same as those in patterns [2] and [2'] (**Table 7-5**).

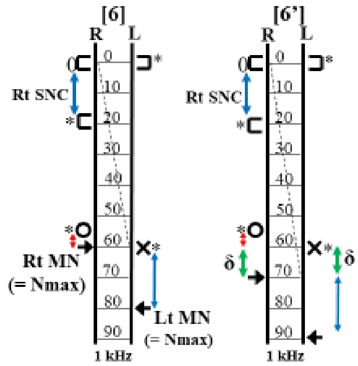

Figure 7-12 Patterns [6] and [6']

(3) Representation of the term "masking"

"Masking in the right ear" means that masking noises are presented to the right ear or the right ear is masked by masking noises (cf. **2.4 [4]**). "Masking for AC" means that masking noises are presented to the non-test ear and we attempt to obtain the true AC threshold in the test ear. In this lecture series, "masking in the right ear to obtain the left ear's true AC threshold" is simply represented as "masking for the left AC." "Masking for the left AC is easy" means that when the masking noise is presented to the right ear, the left ear's true AC threshold can be obtained easily." Note that it is the right ear to be masked.

**** Further note ****

*) "Masking for the left AC is needed" means that it is necessary to mask the right ear to obtain the left ear's true AC threshold.

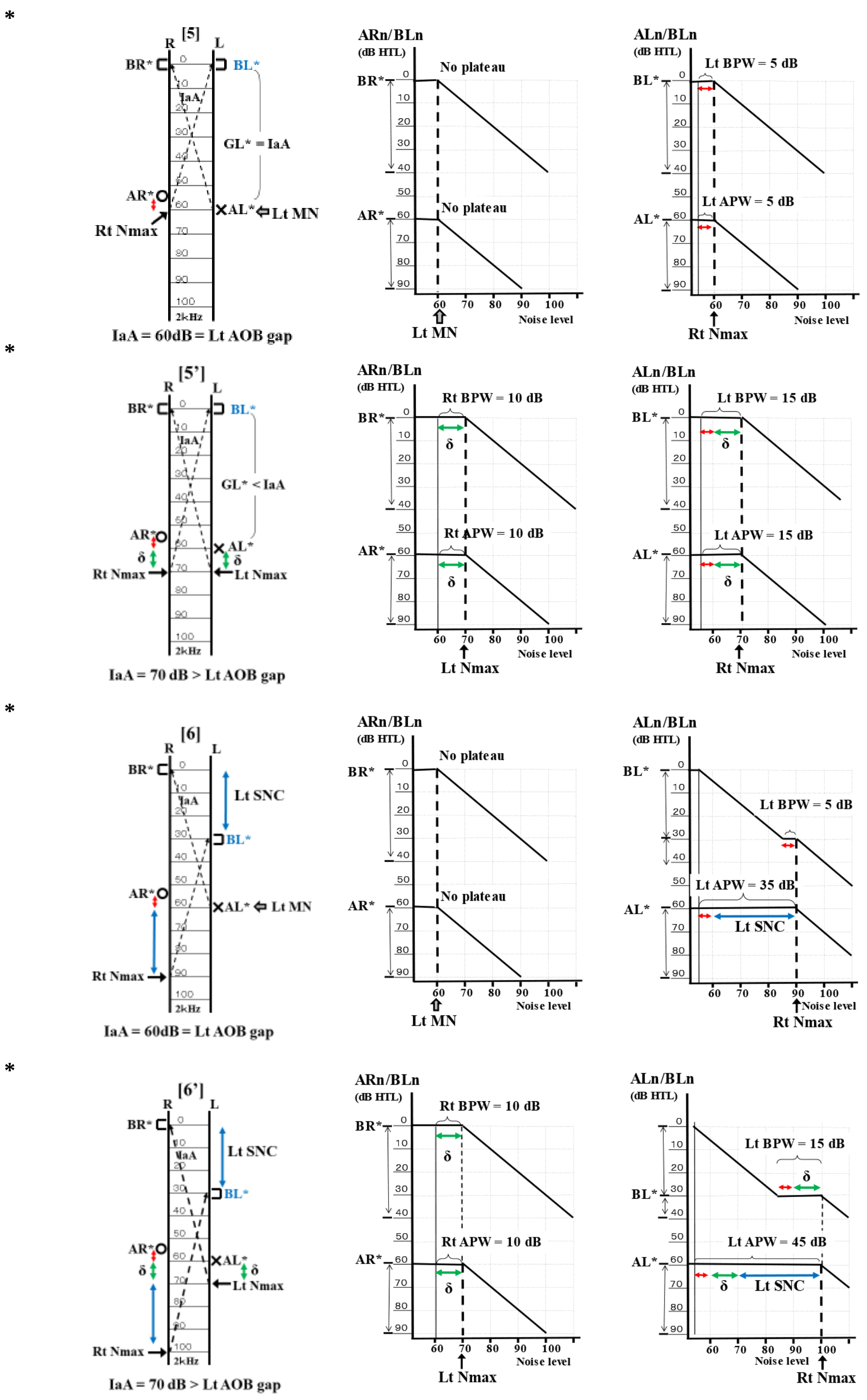

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Figure 7-13 Plateau graphs (Rt AA gap = 5 dB)

**** Further note ****

*) Nmax is the maximum adequate masking level. MN is the maximum level of masking noise at which OM does not occur.

7.5 Findings of an audiogram without masking

(1) Audiograms without masking and audiometric configurations at a given frequency

The basic audiograms **[A-1]** and **[B-1]** (**Fig. 7-14**), in which the Rt AA gaps are significant (Rt AA gap ≥ 15 dB), correspond to the configurations in **Fig. 7-15**. In contrast, the basic audiograms **[C-1]**, in which the Rt AA gaps are insignificant (Rt AA gap ≤ 10 dB), correspond to those in **Fig. 7-16**.

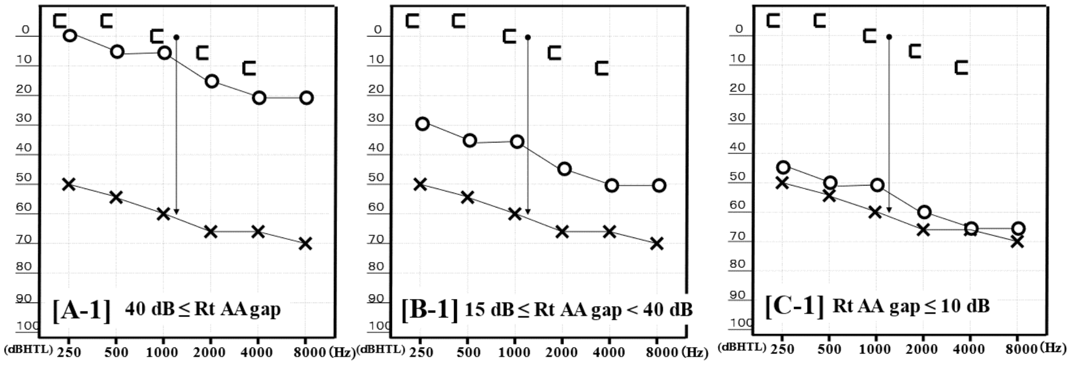


Figure 7-14 Basic audiograms without masking

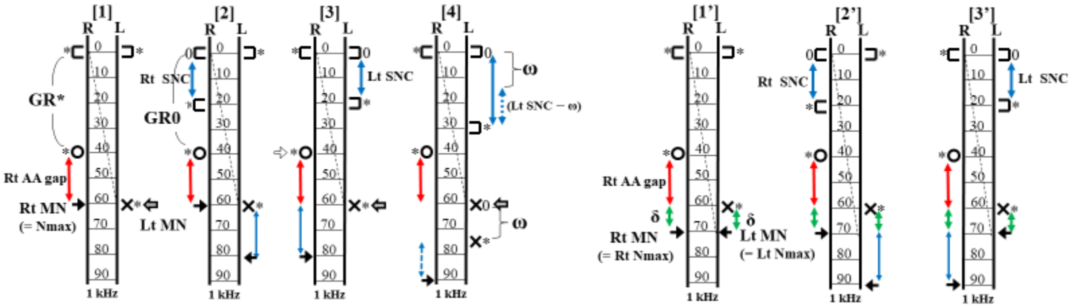


Figure 7-15 Audiometric configurations with Rt AA gap of 20 dB (≥ 15 dB)

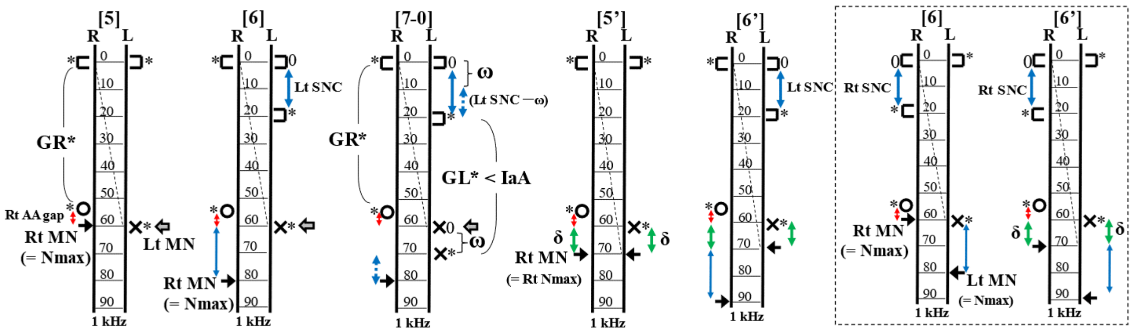


Figure 7-16 Audiometric configurations with Rt AA gap of 5 dB (≤ 10 dB)

Table 7-6 Plateau widths using Rt AA gaps

Patterns	Rt APW	Rt BPW	Lt APW	Lt BPW
[1], [5]: δ = 0 dB	(−)	(−)	Rt AA gap	Rt AA gap
[2], [6]: δ = 0 dB	Rt SNC	0 dB	Rt AA gap	Rt AA gap
[3], [6]: δ = 0 dB	(−)	(−)	Rt AA gap + Lt SNC	Rt AA gap
[4], [7]: δ = 0 dB	(−)	(−)	Rt AA gap + Lt SNC − ω	Rt AA gap
[1'], [5']: δ ≥ 5 dB	δ	δ	Rt AA gap + δ	Rt AA gap + δ
[2'], [6']: δ ≥ 5 dB	δ + Rt SNC	δ	Rt AA gap + δ	Rt AA gap + δ
[3'], [6']: δ ≥ 5 dB	δ	δ	Rt AA gap + δ + Lt SNC	Rt AA gap + δ

1) Rt AA gap = AL0 − AR0 ≥ 0 dB (AR0 ≤ AL0),
2) δ = Lt δ = IaA − GL0 = IaA − Lt AOB gap ≥ 0 dB,
3) Rt SNC = BR* − BL* ≥ 0 dB,
4) Lt SNC = BL* − BR* ≥ 0 dB,
5) ω = AL* − AL0 ≥ 0 dB.

(2) Estimation of the difficulty level of masking: AA and AOB gaps

Although the PWs cannot be established before the four elements (δ, Rt SNCs, Lt SNC and ω) have been determined, we can easily receive the Rt AA and Lt AOB gaps on the audiogram without masking. With the aid of the two factors, we may estimate the difficulty level of masking to some extent before masking.

a) For BC, Lt BPW is represented as follows:

Lt BPW = Rt AA gap + δ = Rt AA gap + (IaA − Lt AOB gap).

If the Rt AA gap is large and Lt AOB gap is small (i.e., δ is large), the Lt BPW is wide. Therefore, masking for the left BC is easy. By contrast, as shown in **Fig. 7-17 (a)**, if the Rt AA gap is small and the Lt AOB gap is large (i.e., δ is small), the Lt BPW becomes narrow and masking for the left BC may be difficult or impossible.

Even if the Lt AOB gap is large as in **Fig. 7-17 [b]**, the Lt BPW is guaranteed to be significant so long as the Rt AA gap is significant (≥ 15 dB):

Lt BPW ≥ Rt AA gap ≥ 15 dB.

Furthermore, as in **Fig. 7-17 (c)**, even when the Rt AA gap is small (≤ 10 dB), masking for the left BC will be easy so far as the Lt AOB gap is small (i.e., δ is large).

b) For AC, Lt APW is larger than or equal to Lt BPW. Thus, if Rt AA gap is significant, Lt APW is also significant:

Lt APW ≥ Lt BPW ≥ Rt AA gap ≥ 15 dB.

Even when masking for BC might be difficult, masking for AC will be easy so long as the SNC of the test ear is large. However, the value of SNC cannot be predicted.

For practical purposes, AA gaps serve as a clear indicator to predict the difficulty level of masking.

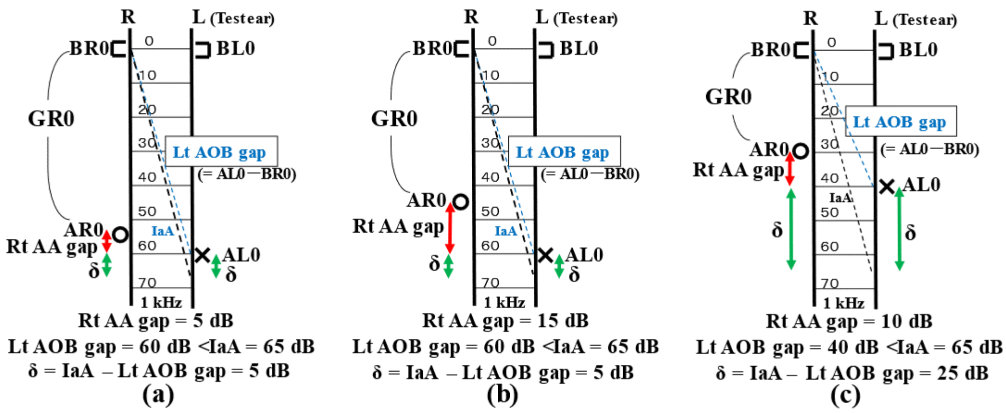


Figure 7-17 Lt BPW ≥ Rt AA gap

Next, let us consider examples below. At 1000 Hz in **[A-1]**, **[B-1] [C-1]** (cf. **Fig. 7-14**), masking for the left AC is needed because the Lt AOB gap ≥ 40 dB,

[A-1]: The Rt AA gap at 1000 Hz is 55 dB. The wide PWs for both AC and BC may be obtained (Lt APW ≥ Lt BPW ≥ 55 dB), thus, we can expect that masking for the left AC and BC is easy.

[B-1]: The Rt AA gap at 1000 Hz is 25 dB. Although the PWs are smaller than those in **[A-1]**, the sufficient PWs of the left ear can be expected (Lt APW ≥ Lt BPW ≥ 25 dB).
In patterns [1], [2], [1'], and [2'], masking for the right BC is needed (cf. **5.8 [2]**). Then, since the apparent AB gap of the left ear (GL0) is large, we can predict that masking for the right BC may be difficult (cf. **Table 7-6**).

[C-1]: The Rt AA gap at 1000 Hz is 10 dB (< 15 dB). Since Lt AOB gaps are large (≥ 40 dB), the Lt BPW may be narrow. The same holds for Rt BPW. Therefore, we can expect that masking for BC in both ears may be difficult or impossible (cf. **6-2 [1]**). Masking for AC might also be difficult. However, if either the Rt SNC or Lt SNC is large, the APW can be detected in one ear.

If the examiner could previously predict the result of the test, pure tone audiometry will be performed more efficiently and becomes less of a burden on the participants being tested.

7.6 Masking windows of the present method

The AC and BC thresholds measured in the test ear exist within a certain range when masking in the non-test ear. The range of the measured thresholds possible is termed a masking window (MW). The difficulty level of masking is discussed by means of the MWs with the initial masking noise of this method.

(1) Masking windows for AC: the range of the measured AC thresholds

Consider the configuration at 500 Hz in **Fig. 7-18**.

a) Pattern [4] (**Fig. 7-19 [a]**): when N1 of 60 dB HL (= AL0) is presented to the right ear, the AC threshold measured in the left ear with N1 (AL1) exists within the range below:

AL0 (= 60 dB HTL) < AL1 ≤ AL-CH level [1] (= 80 dB HTL).

b) Other patterns except for pattern [4] (e.g., pattern [2]) (**Fig. 7-19 [b]**): with N1 of 60 dB HL in the right ear, AL1 of 60 dB HTL (= AL0) is obtained. Therefore, the range of AL1 possible, i.e., the masking window for AC in the left ear with N1 (AL-MW [1]) is as follows:

AL-MW [1]: AL0 ≤ AL1 ≤ AL-CH level [1].
(= 60 dB HTL) (= 80 dB HTL)

Noted that the AL-MW [1] (20 dB) is equal to Rt AA gap of 20 dB at 500 Hz.

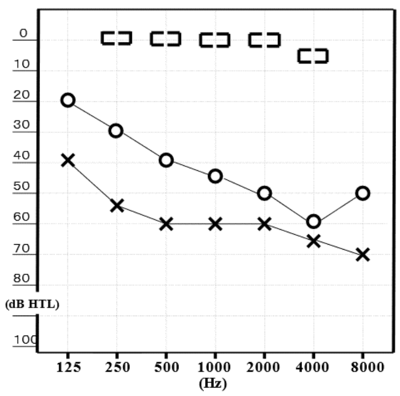


Figure 7-18 Audiogram without masking

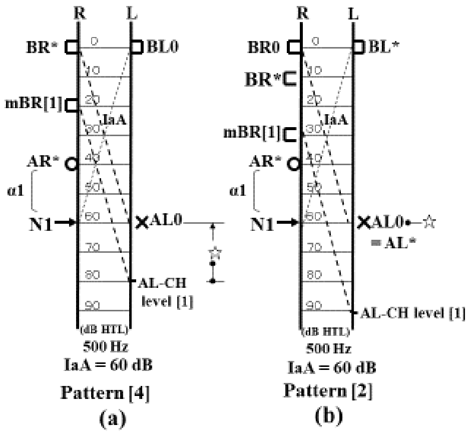


Figure 7-19 AL-MWs

(2) Difficulty level of masking for AC

At each frequency in **Fig. 7-20**, when N1 for AC (= [AL0] dB HL) is presented to the right, better ear by AC, the AL-MW [1] is equal to Rt AA gap at the test frequency. As the Rt AA gap is larger, the AL-MW [1] becomes wider and masking for the left AC becomes easy. Namely, the true AC threshold in the left ear is easy to obtain. By contrast, as the Rt AA gap is smaller, masking for the left AC might become difficult. Therefore, in the actual examination, it is recommended that masking should be started at frequencies with wide AA gaps. AA gaps are easy-to-grasp index to understand the difficulty level of masking.

	Rt AA gap
125 Hz:	20 dB
250 Hz:	25 dB
500 Hz:	20 dB
1000 Hz:	15 dB
2000 Hz:	10 dB
4000 Hz:	5 dB
8000 Hz:	20 dB

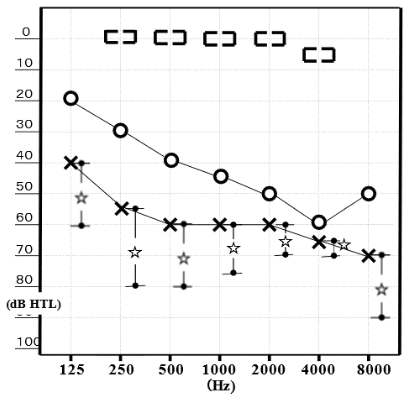


Figure 7-20 Rt AA gap and Lt AC MW

(3) Masking windows for BC: the range of the measured BC thresholds

The masking window for BC in the left ear with N1 (BL-MW [1]) is as follows:

a) Pattern [4]: at 1000 Hz in **Fig. 7-21**, AL0 is an SH threshold. When masking with N1 of 75 dB HL (= AL* > AL0) in the right ear (**Fig. 7-22 [a]**), the BC threshold measured in the left ear with N1 (BL1) exists between the OM level [1] and BL-CH level [1].

BL-MW [1]: OM level [1] ≤ BL1 ≤ BL-CH level [1].
(= 15 dB HTL) (= 30 dB HTL)

Note that the BL-MW [1] (15 dB) is equal to the Rt AA gap of 15 dB at 1000 Hz.

b) The patterns, except for pattern [4] (e.g., pattern [3']): at 500 Hz in **Fig. 7-21**, AL0 is a true threshold. When masking with N1 of 60 dB HL in the right ear (**Fig. 7-22 [b]**), the range of BL1 possible is between the BL0 and BL-CH level [1].

BL-MW [1]: BL0 ≤ BL1 ≤ BL-CH level [1].
(= 0 dB HTL) (= 20 dB HTL)

The BL-MW [1] (20 dB) is equal to the Rt AA gap of 20 dB at 500 Hz.

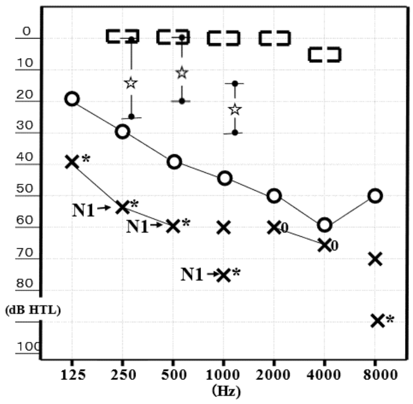


Figure 7-21 Audiogram with AC masking completed

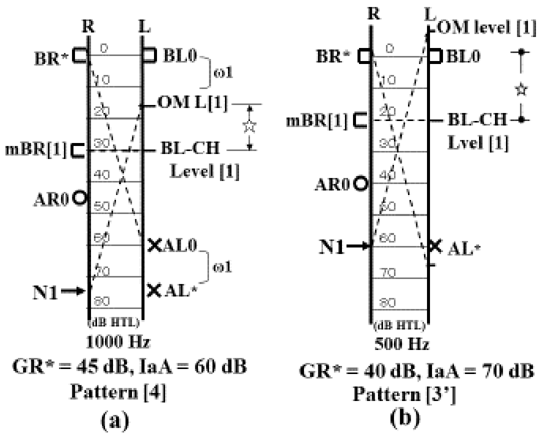


Figure 7-22 BL-MWs

(4) Difficulty level of masking for BC

When masking with N1 for BC (= [AL*] dB HL) in the right ear, the BL-MW [1] is equal to the Rt AA gap at the test frequency (**Fig. 7-21**). Therefore, masking for BC should be also started at frequencies with wide AA gaps.

(5) Efficiency of masking

At 500 Hz in **Fig. 7-18** on the preceding page, when a noise lower than N1 (e.g., N1' = 50 dB HL < N1 = 60 dB HL) is presented to the right ear, the AL-MW [1'] (10 dB) is smaller than the 20 dB of the Rt AA gap (cf. **Fig. 7-19 [a]**) and the efficiency of masking for AC is reduced.

By contrast, if the noise levels are higher than N1, OM may occur, although the AL-MW might be wider. To complicate matters, we are forced to consider whether the measured thresholds are the true, SH, or OM thresholds. Therefore, the noises of this method are the most efficient in masking for AC. It holds true for BC.

When AA gaps are large enough (> 40 dB), MWs are wide and masking for AC and BC is easy. In these cases, we should avoid an excessive load of the noise on the non-test ear. It is discussed in Lecture 8.

**** Further note ****

*) Even if the AA gap is small, masking for AC is not always difficult. When the true BC threshold in the test ear is elevated to some extent, the APW is easy to identify.

*) The singular level means that the MW for BC has closed completely (cf. **5.7**).

7.7 Series of the audiometric patterns and their utmost limits

All patterns of audiometric configurations at some frequency are grouped into four series.

(1) Pattern [1] series (Fig. 7-23)

In pattern [1'], Lt PWs = Rt AA gap + δ = 25 dB. When δ = 0 dB, Lt PWs = Rt AA gap; i.e., pattern [1]. The two patterns are termed pattern [1] series. Furthermore, if the Rt AA gap becomes smaller and insignificant (Rt AA gap ≤ 10 dB), the patterns shift to patterns [5'] and [5] (i.e., pattern [5] series). The utmost limit of the pattern [1] series is the pattern [5] series.

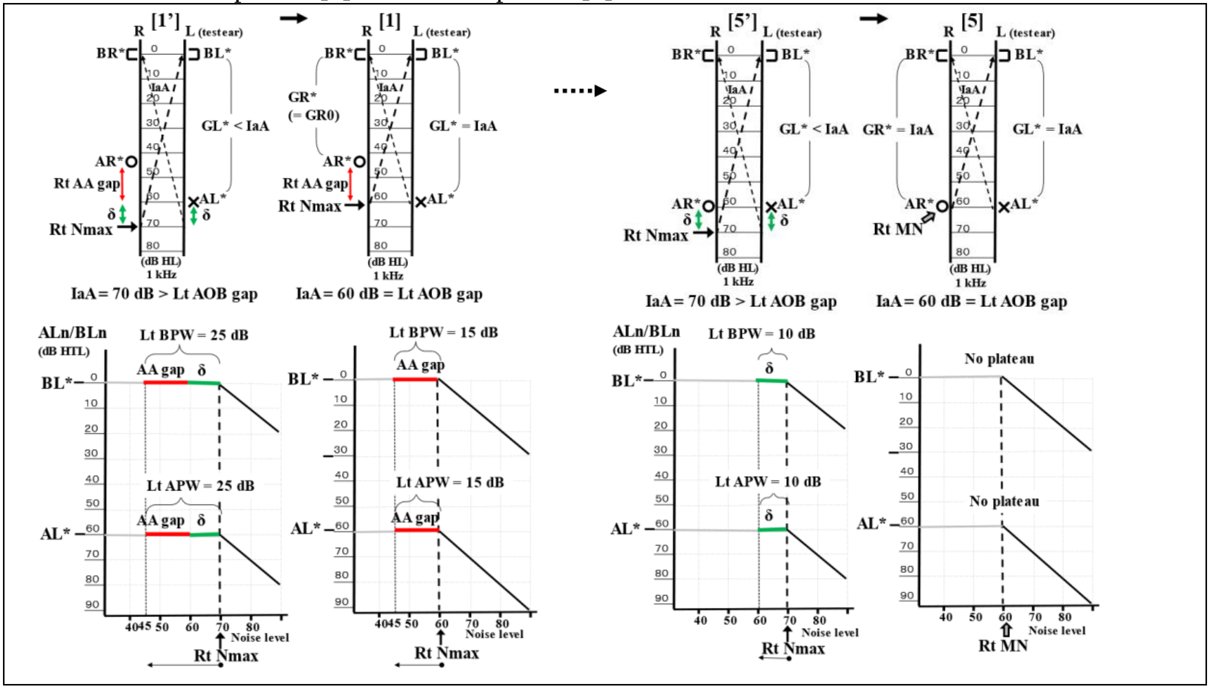


Figure 7-23 Pattern [1] series and its utmost limit

(2) Pattern [2] series (Fig. 7-24)

Pattern [2] series consists of pattern [2'] (IaA = Lt AOB gap + δ) and pattern [2] (IaA = Lt AOB gap). The utmost limit of the pattern [2] series is the pattern [6] series (pattern [6] and [6']). The Lt PWs of the pattern [2] series are the same as those of the pattern [1] series. Additionally, in the pattern [6] series, since the difference between the true AC thresholds in both ears are insignificant, the poorer ear by BC may be either the right or left (cf. Fig. 7-12).

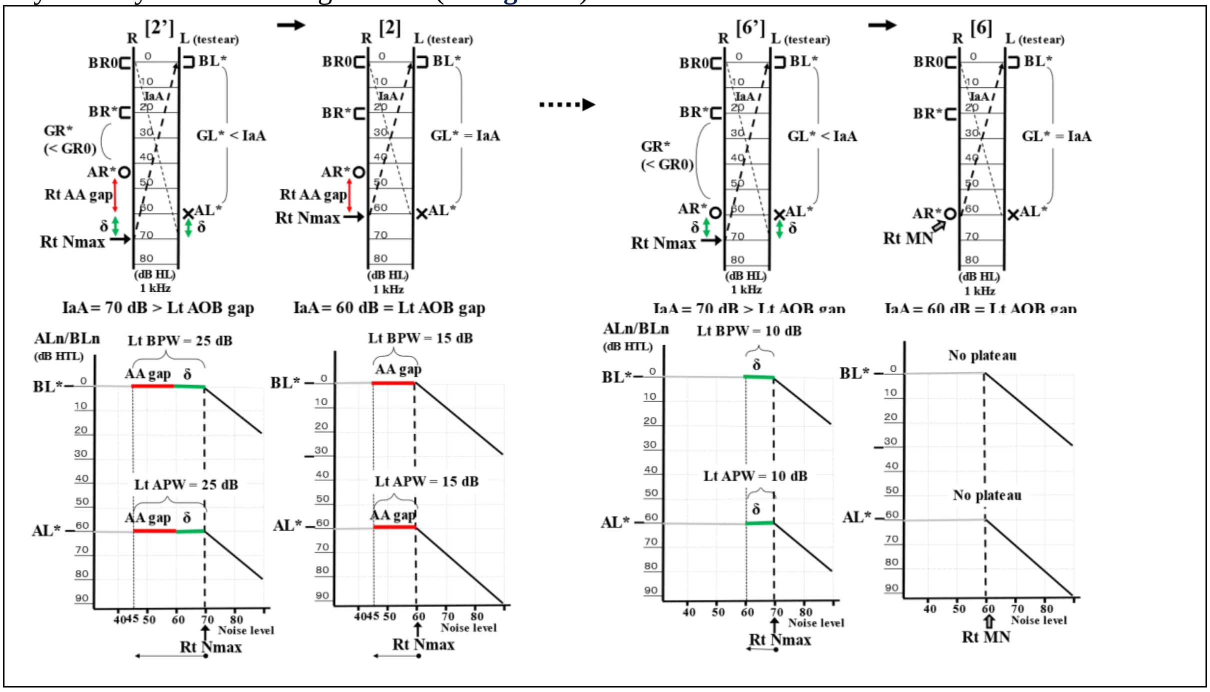


Figure 7-24 Pattern [2] series and its utmost limit

(3) Pattern [3] series (Fig. 7-25)

Pattern [3] series consists of pattern [3'] (IaA = Lt AOB gap + δ) and pattern [3] (IaA = Lt AOB gap). The utmost limit of the pattern [3] series is the pattern [6] series.

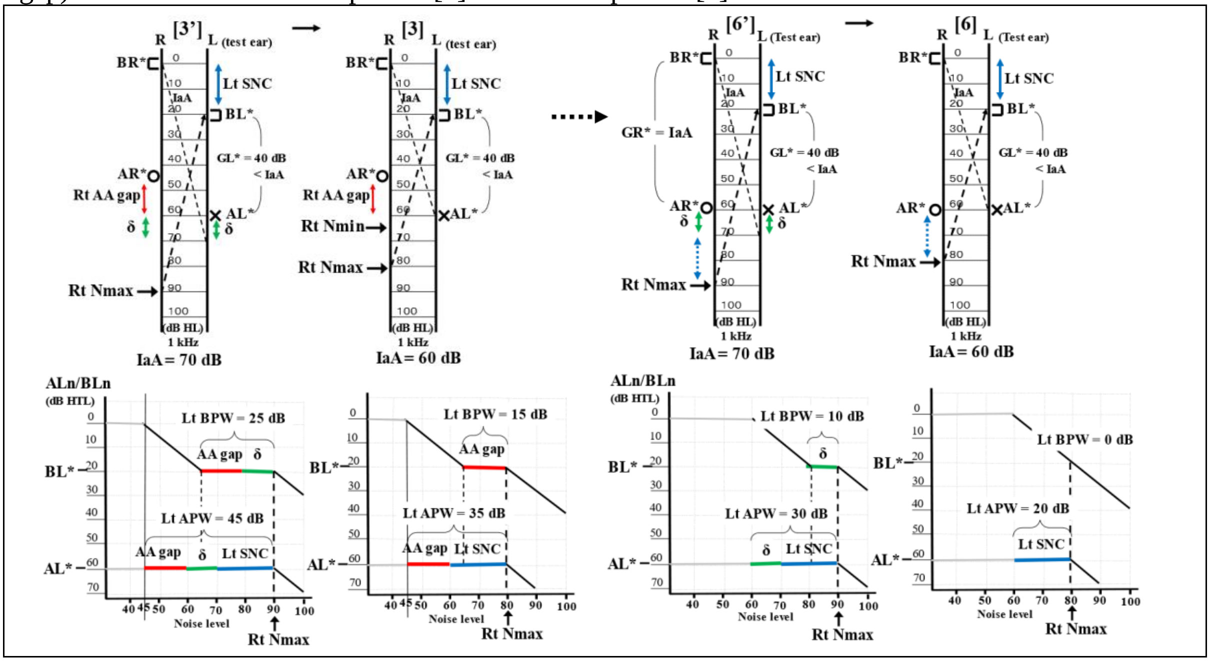


Figure 7-25 Pattern [3] series and its utmost limit

(4) Pattern [4] series (Fig. 7-26)

In pattern [4-0], the true AB gap of the left, poorer ear by AC is smaller than IaA (GL* < IaA). In pattern [4-1], GL* = IaA. In pattern [4-2], the left ear has a complete hearing loss. Furthermore, if the Rt AA gap becomes smaller and insignificant (Rt AA gap ≤ 10 dB), each pattern [4] series shifts to patterns [7-0], [7-1], and [7-2] (cf. **5.8 [3]**). The utmost limit of the pattern [4] series is the pattern [7] series.

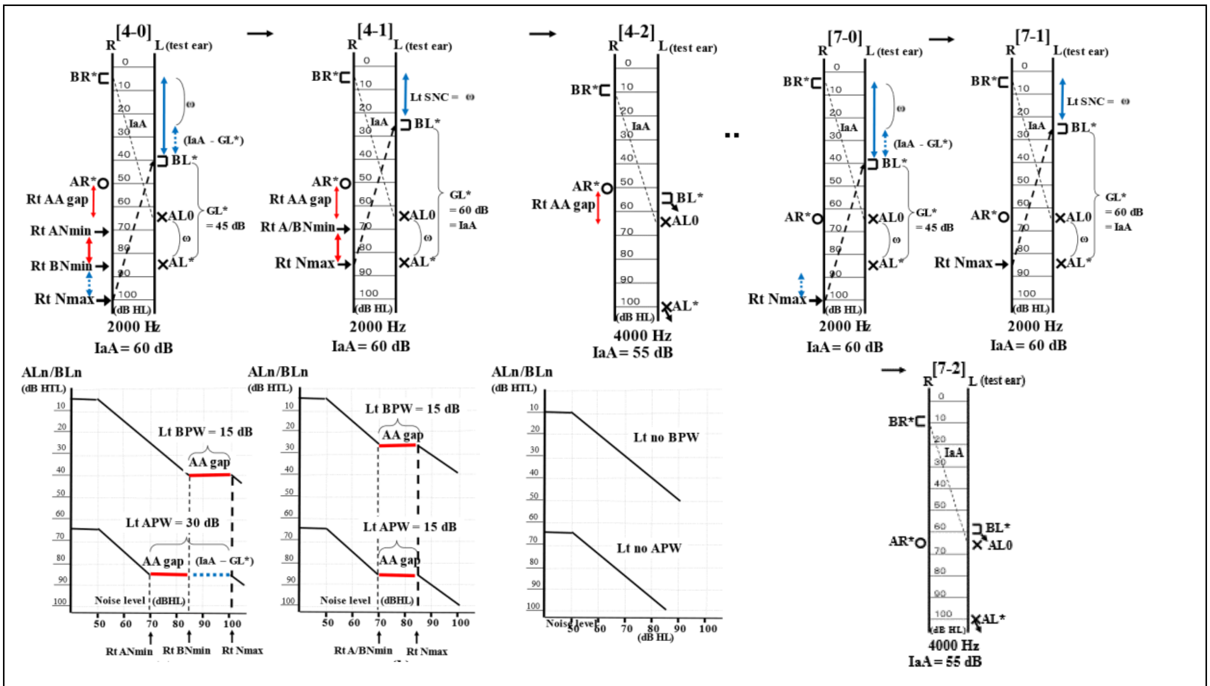


Figure 7-26 Pattern [4] series and its utmost limit

**** Further note ****

*) Let Rt AA gaps be smaller in 5-dB steps: 20 dB, 15 dB, 10 dB, 5 dB. The utmost limit is Rt AA gap of 0 dB. The focal point of Lecture 7 is an AA gap.

7.8 Summary of Lecture 7

1. The plateau widths of audiometric configurations at a given frequency consist of five elements below:

1) Rt δ = IaA − GR0 ≥ 0 dB 2) Lt δ = IaA − GL0 ≥ 0 dB
3) Rt SNC = BR* − BL* ≥ 0 dB 4) Lt SNC = BL* − BR* ≥ 0 dB
5) ω = AL* − AL0 (> 0 dB; only in patterns [4] and [7]).

Here, the case with no plateau is indicated using the symbol (−).

	The right ear: the better ear by AC		The left ear: poorer ear by AC	
Patterns	Rt APW	Rt BPW	Lt APW	Lt BPW
[1] Lt δ = 0 dB	(−)	(−)	Rt δ	Rt δ
[2] Lt δ = 0 dB	Rt SNC	0 dB	Rt δ	Rt δ
[3] Lt δ = 0 dB	(−)	(−)	Rt δ + Lt SNC	Rt δ
[4] Lt δ = 0 dB	(−)	(−)	Rt δ + Lt SNC − ω	Rt δ
[1’] Lt δ ≥ 5 dB	Lt δ	Lt δ	Rt δ	Rt δ
[2’] Lt δ ≥ 5 dB	Lt δ + Rt SNC	Lt δ	Rt δ	Rt δ
[3’] Lt δ ≥ 5 dB	Lt δ	Lt δ	Rt δ + Lt SNC	Rt δ

	The right ear		The left ear	
Patterns	Rt APW	Rt BPW	Lt APW	Lt BPW
[5] Rt δ = Lt δ = 0 dB	(−)	(−)	(−)	(−)
[6] Rt δ = Lt δ = 0 dB	(−)	(−)	Lt SNC	Rt δ (= 0 dB)
[7] Rt δ = Lt δ = 0 dB	(−)	(−)	Lt SNC − ω	Rt δ (= 0 dB)
[5’] Rt δ = Lt δ > 0 dB	Lt δ	Lt δ	Rt δ	Rt δ
[6’] Rt δ = Lt δ > 0 dB	Lt δ	Lt δ	Rt δ + Lt SNC	Rt δ

The general expression of Lt APW is as follows:

Lt APW = Rt δ + Lt SNC − ω
= (IaA − GR0) + (BL* − BR*) − (AL* − AL0).

From this formula, Lt APW in each pattern is derived.
When ω > 0 dB (AL* > AL0), the configurations are patterns [4] and [7].
When Rt δ > 0 dB, pattern [4]: **Lt APW = Rt δ + Lt SNC − ω**.
When Rt δ = 0 dB, pattern [7]: **Lt APW = Lt SNC − ω**.
When ω = 0 dB (AL* = AL0), the configurations are patterns except for patterns [4] and [7].
When Rt δ > 0 dB and Lt SNC > 0 dB (patterns [3], [3’], [6’]), **Lt APW = Rt δ + Lt SNC**.
When Rt δ = 0 dB and Lt SNC > 0 dB (patterns [6]), **Lt APW = Lt SNC**.
When Rt δ > 0 dB and Lt SNC = 0 dB (patterns [1], [1’], [2], [2’], [5’]), **Lt APW = Rt δ**.
When Rt δ = 0 dB and Lt SNC = 0 dB (pattern [5]), **Lt APW is not present**.

The basic formulas of Lt APW and Lt BPW are as follows:

Lt APW = Rt δ, **Lt BPW = Rt δ.**

2. Three factors determine the difficulty level of masking for AC.
The first is the apparent AB gap of the right, non-test ear (GR0).
The second is the relative amount of sensorineural component in the left (test) ear (Lt SNC).
The third is the difference between the SH threshold for AC and the true AC threshold in the test ear in patterns [4] and [7] (ω = AL* − AL0 > 0 dB).

Even if GR0 is equal to IaA, Lt APW is wide so long as Lt SNC is large, and masking for AC becomes easy.

3. Two factors determine the difficulty level of masking for BC.
The first is the apparent AB gap of the right (non-test) ear (GR0).
The second is the IaB value.

When GR0 is larger, Lt BPW becomes narrower and masking for BC becomes difficult. If GR0 is equal to IaA, and IaB is 0 dB, then Lt BPW is either equal to 0 dB or not present. Masking for BC becomes impossible.

4. When Rt AA gap = AL0 − AR0 ≥ 0 dB, the plateau widths may be reduced to formulas including the Rt AA gap. AA gaps serve as a clear indicator to predict the difficulty level of masking.

Patterns [1] - [4]: Rt δ = IaA − GR0 = Rt AA gap,

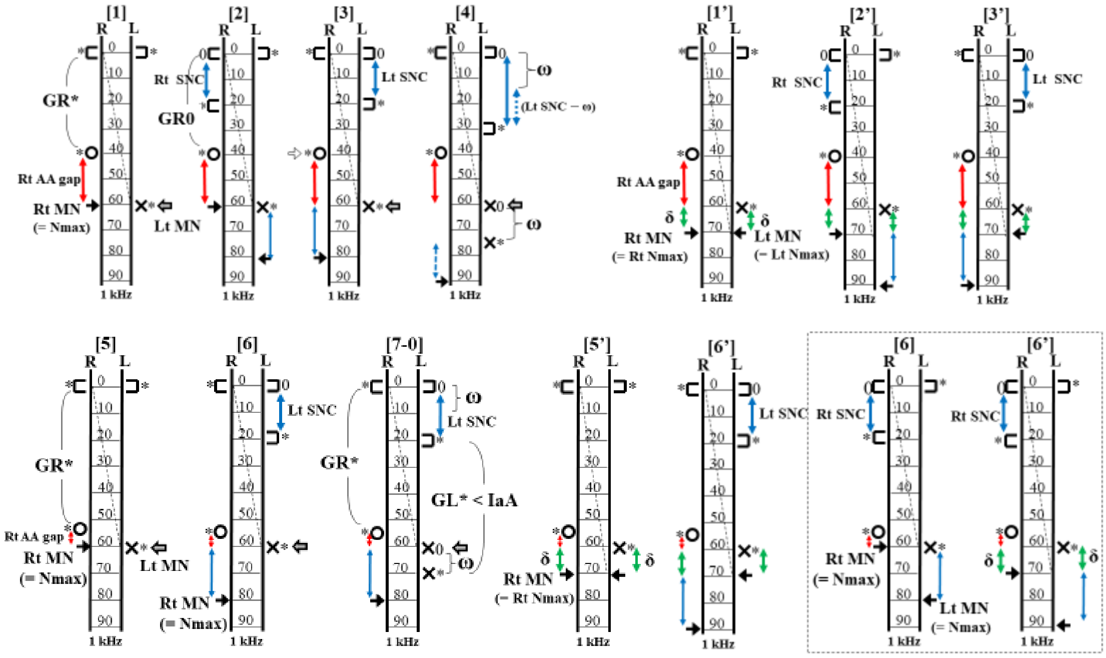
Patterns [1’] - [3’]: Rt δ = IaA − GR0 = Rt AA gap + Lt δ = Rt AA gap + δ,

where Lt δ is simply shown as δ.

When Rt AA gap ≥ 15 dB, the configurations are either patterns [1], [2], [3], [4], [1’], [2’], or [3’].
When Rt AA gap ≤ 10 dB, those are either patterns [5], [6], [7], [5’], or [6’].

1) Rt δ = IaA − GR0 = Rt AA gap ≥ 0 dB 2) Lt δ = IaA − GL0 = δ ≥ 0 dB
3) Rt SNC = BR* − BL* ≥ 0 dB 4) Lt SNC = BL* − BR* ≥ 0 dB
5) ω = AL* − AL0 (> 0 dB; only in patterns [4] and [7]).

Patterns	Rt APW	Rt BPW	Lt APW	Lt BPW
[1], [5]: δ = 0 dB	(−)	(−)	Rt AA gap	Rt AA gap
[2], [6]: δ = 0 dB	**Rt SNC**	0 dB	Rt AA gap	Rt AA gap
[3], [6]: δ = 0 dB	(−)	(−)	Rt AA gap + **Lt SNC**	Rt AA gap
[4], [7]: δ = 0 dB	(−)	(−)	Rt AA gap + **Lt SNC** − ω	Rt AA gap
[1’], [5’]: δ ≥ 5 dB	δ	δ	Rt AA gap + δ	Rt AA gap + δ
[2’], [6’]: δ ≥ 5 dB	δ + **Rt SNC**	δ	Rt AA gap + δ	Rt AA gap + δ
[3’], [6’]: δ ≥ 5 dB	δ	δ	Rt AA gap + δ + **Lt SNC**	Rt AA gap + δ

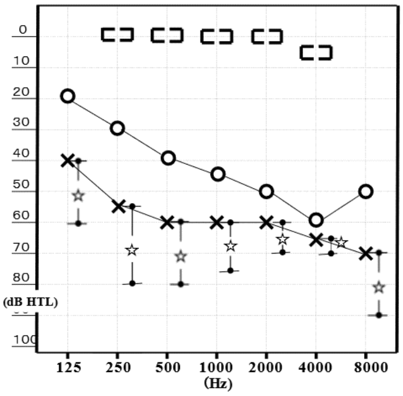


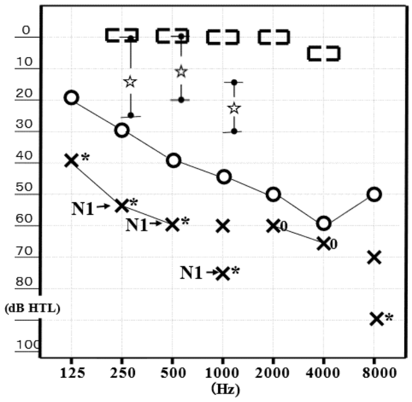
5. We may estimate the difficulty level of masking to some extent before masking although the PWs cannot be established before the four elements (δ, Rt SNC, Lt SNC, and ω) have been determined,

1) When Rt AA gap = AL0 − AR0 ≥ 15 dB, since the minimum plateau width is equal to the Rt AA gap (Rt AA gap ≤ Lt BPW ≤ Lt APW), Lt BPW and Lt APW are guaranteed to be significant (≥ 15 dB). We know masking for the left AC and BC is easy.

2) When Rt AA gap = AL0 − AR0 ≤ 10 dB, the plateau method should be used. When both AOB gaps are large (≥ 40 dB), we can expect that masking for both the BC may be difficult or impossible. Masking for AC might also be difficult. However, if either Rt SNC or Lt SNC is large, the APW can be detected in one ear. As a result, the OM method is applicable.

6. When Rt AA gap is larger, masking for the left AC becomes easy. Therefore, it is recommended that masking for AC should be started at frequencies with wide AA gaps. The same holds for BC.





7. All patterns of audiometric configurations at a given frequency are grouped into four series.