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

Guidelines for placement of microphones and loudspeakers in telephone conference rooms [1] and for Group Audio Terminals (GATs)

ITU-T P-series Recommendations
Supplement 16

(Previously CCITT Recommendations)

ITU-T P-SERIES RECOMMENDATIONS

TELEPHONE TRANSMISSION QUALITY, TELEPHONE INSTALLATIONS, LOCAL LINE NETWORKS

For further details, please refer to ITU-T List of Recommendations.

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As of the date of approval of this Recommendation, the ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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Supplement 16[1] to P-series Recommendations

GUIDELINES FOR PLACEMENT OF MICROPHONES AND LOUDSPEAKERS IN TELEPHONE CONFERENCE ROOMS [1] AND FOR GROUP AUDIO TERMINALS (GATs)

(Malaga-Torremolinos, 1984; amended Melbourne, 1988)

(Quoted in Recommendations G.172 and P.30)

1 General

The following guidelines provide basic rules for assessing the acoustics of telephone conference rooms and for installing group audio terminals consistent with maximum speech intelligibility and easy talker recognition.

2 Conference room acoustics – General requirements

The design and installation of a telephone conferencing system or group audio terminals which meet reasonable cost and performance specifications involve numerous judgements and trade-offs. These guidelines will enable the planner and installation engineer to assess the acoustics of a room, to make the necessary choices and decisions, to install the appropriate equipment properly and thereby provide satisfactory service.

The audio portion of a group audio terminal consists of terminal equipment with microphones and loudspeakers installed in conference rooms and interconnected by an audio transmission facility. This transmission facility may be either public switched telephone connections or private line facilities.

In both public and private systems, transmission is frequently interconnected via a multipoint conference bridge so that each room can communicate simultaneously with any of the other locations. When this is done, it is most important that the bridge be located at the electrical loss center of the network in order to minimize level contrast between the speech originating in the different rooms.

Unlike telephony between handsets, the acoustic properties of the conference room and the placement of microphones in the room critically determine the level, the speech signal-to-ambient-noise ratio and the reverberant quality (rain-barrel effect) of the transmitted speech. Particularly in multipoint conferences, these three factors are easily judged and critically commented upon by users.

In general, the larger, noisier and more reverberant a room is, the less suitable it will be for group communication. The presence of noise and/or reverberation in the transmitted speech results in a system whose performance is unsatisfactory. In extreme cases, experience has demonstrated that excess noise in one room, e.g. from overflying aircraft, can temporarily block transmission between all rooms of a multipoint system. Excess reverberation results in such hollowness to the received speech that talkers become difficult to recognize and understand, causing users to fatigue easily and refuse to use the system.

In principle, any room is suitable for group communication if these guidelines are followed. However, the guidelines will dictate that in a noisy or reverberant room, talkers must speak so close to microphones that they might as well use handsets. The user requesting the installation must then choose one or more of the following options:

1) select another conference room;
2) acoustically treat the room; or
3) accept the close microphone/talker distances dictated by the guidelines.

Several very important criteria must be fulfilled simultaneously to assure satisfactory audio performance of a telephone conference system. The balance of this section describes the determination of these criteria. Briefly, these criteria are:

1) A room suitable for a normal face-to-face conference must be selected.
2) A noise dependent microphone/talker distance must be determined.

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1 Formerly supplement No. 25 to Fascicle III.1 *(Red Book)*.

3) A reverberation dependent microphone/talker distance must be determined.

4) The microphones and loudspeakers must be positioned in accordance with both these distances.

3 Ambient noise level considerations

The ambient noise level requirements for conference rooms of increasing size and number of conferences are given in Table 1. As the room size and number of conferences increase, the participants will sit further apart. Consequently, for comfortable talking and listening, the ambient noise level in the room must decrease as the group size increases.

Table 1 – Ambient noise level limits for conference rooms

Room description	Maximum sound level meter reading	Acoustic environment
Conference room for 50 people	35	Very quiet, suitable for large conferences at tables 6-9 m in length
Conference room for 20 people	40	Quiet, satisfactory for conferences at tables 4.5 m in length
Conference room for 10 people	45	Satisfactory for conferences at tables 1.5-2.5 m in length
Conference room for 6 people	50	Satisfactory for conferences at tables 1.0-1.5 m in length

Noise measurements as stipulated in Table 1 should be performed at the conference table with the room in normal operation but unoccupied. These noise measurements should be performed at least 0.6 m away from any surface.

Noise measurements in dBA can be made with a sound level meter employing A-weighting, a reference pressure level of 20 µ Pascal and otherwise conforming to Recommendation P.54. A-weighting is used in these guidelines since it approximates the annoyance level of noise to the human ear.

The maximum microphone/talker distance is limited by ambient noise. Figure 1 shows the maximum distance between a talker and a microphone which ensures a marginally acceptable signal-to-noise ratio of 20 dB in the transmitted speech. No attempt should be made to ignore or increase this distance beyond that determined in Figure 1. As an example, with an ambient noise level of 50 dBA, Figure 1 shows that the *maximum* distance (D_{max}) from talker to microphone for *marginal* acceptability is 0.5 m. Figure 1 applies to omnidirectional microphones. When directional microphones, e.g. cardioid or bidirectional are used, the D_{max} value determined in Figure 1 can be increased by 50 percent.

If more than one microphone is used to cover more than two or three talkers, and all microphones are active at the same time, then the amount of room noise picked up by the microphones and transmitted on the circuit will increase. How much it will increase is not completely predictable but a useful approximation is that the apparent noise level will rise 3 dB each time the number of microphones is doubled. This apparent rise in the effective noise level can be taken into account by adding it to the measured noise level before using Figure 1 to determine D_{max}.

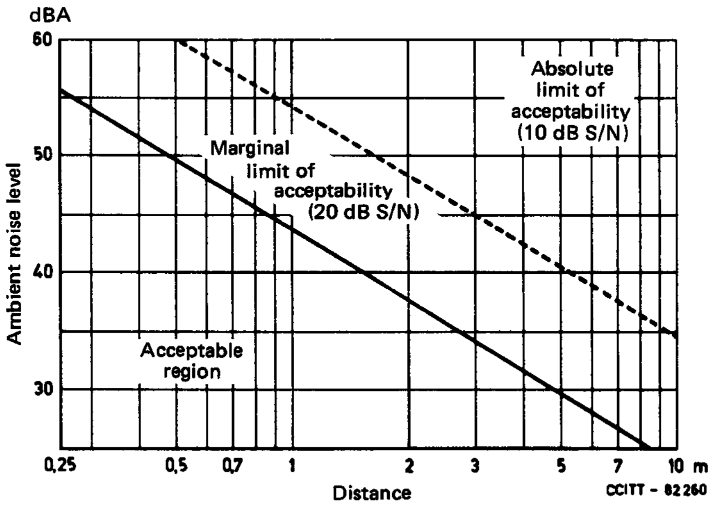

FIGURE 1

Maximum distance from talker to microphone

4 Reverberation considerations

Most rooms for telephone conferencing have acoustical characteristics which cannot be altered, thus the quality of sound transmitted from the room can only be controlled by microphone placement. When the microphone is close to the talker, the greatest percentage of sound picked up comes directly from the talker, reverberation in the room would exert relatively little influence. As the distance between the microphone and the talker increases, the direct sound level reaching the microphone decreases 6 dB for each doubling of the distance, whereas the average level of the reverberant sound remains more nearly constant.

The critical distance (D_c) of a room is a useful concept to describe a room. It is the distance from a sound source (talker, loudspeaker) at which the direct sound energy from the source equals the reverberant energy reflected off all room surfaces (walls, ceiling, furnishings, floor). Critical distances in conference rooms are typically in the range of 0.2 to 1.5 meters.

The critical distance can be expressed as:

$$D_c = 0.056 \sqrt{\frac{V}{T_R}} \text{ meters} \quad \text{(see ISO 35u)}$$

where

V is the volume of the room in cubic meters,

T_R is the reverberation time of room in seconds.

As the ratio of direct-to-reverberant sound energy decreases with increasing microphone/talker separation, reproduced speech becomes less intelligible, of poorer quality, difficult to recognize and fatiguing to listen to. It acquires a hollowness which sounds as if the person were speaking from the bottom of a rain-barrel. For good performance, microphones should be placed at no more than half the critical distance (0.5 D_c) from talkers. This usually requires installing multiple microphones on the conference table or lavaliere microphones[2] on conferees, and definitely rules out placing microphones in the ceiling. Many installations for group communication have failed because microphones were installed in ceilings without regard to the above acoustic requirements.

2 Microphones with an attached, adjustable strap which can be hung around the neck of the user.

When directional (cardioid or bidirectional) microphones are used, the distance between microphones and talkers may be increased by 50 percent, to three-quarters of the critical distance (0.75 D_c). For best results, talkers must sit in front of cardioid (heart shape) microphones; they may sit on either side of a vertically mounted bidirectional microphone with a cosine (figure-eight shape) sensitivity pattern. Table 2 gives typical microphone/talker separation distances for small (60-300 m^2 of wall, ceiling and floor surface area) and large (300-1000 m^2) rectangular conference rooms, together with the estimated critical distance (D_c). Areas in square meters are used in these guidelines, since they are much more relevant to conference room acoustics than are the often quoted room volumes.

Table 2 – Typical microphone/talker separation (meters)

Conference room	Omnidirectional microphone	Directional microphone	Critical distance
Small room (60-300 m^2)			
moderate room treatment [a)]	0.3	0.5	0.6
Large room (300-1000 m^2)			
some room treatment [a)]	0.6	0.9	1.2
considerable room treatment [a)]	0.9	1.4	1.8

a) In this context, a room with moderate treatment might have an accoustic ceiling and a carpet on the floor; one with some treatment might have either an accoustic ceiling or a carpet; while a room with considerable treatment might have heavy, lined drapes covering half the wall area in addition to a high-quality suspended acoustic ceiling and a thick carpet with underfelt.

5 Microphone type and placement

As stated earlier, when omnidirectional microphones are used the microphone/talker distance must be less than the maximum distance (D_{max}) determined from Figure 1 to ensure adequate signal-to-noise ratio. When directional microphones are used, the microphone/talker distance can be increased but must be less than 1.5 D_{max}.

Also stated earlier, when using omnidirectional microphones, the microphone/talker separation must be less than half the critical distance to ensure highly-intelligible, easily-recognizable, nonreverberant speech. When directional microphones are used, the microphone/talker distance can be increased but must be less than 0.75 D_c.

Microphones must be placed to satisfy *both* the above rules; in other words the microphone/talker distance must not exceed the smaller distance.

So that all talkers can satisfy the above microphone/talker criteria, more than one microphone is usually required. Typically one microphone for every 3 talkers is necessary. For each doubling of the number of microphones, the effective noise level in the room will increase by 3 dB. Thus, in the example of § 3 if four microphones were used, the reading of 50 dBA would be raised to an effective value of 56 dBA. The noise determined, D_{max} from Figure 1 would thus be reduced to 25 cm. Clearly, lavaliere microphones would provide a practical solution to keeping talkers within 25 centimeters of a microphone.

6 Loudspeaker placement

The requirements for placing loudspeakers in a conference room are much less critical than those for microphones. It is generally considered good practice to limit the distance from any listener in the room to the nearest loudspeaker to not more than twice the critical distance.

Loudspeakers should be distributed in the ceiling, on the walls, or on the conference table to ensure a minimum sound pressure level of 65 dBA at listener positions. If there is significant noise, the sound pressure level should be at least 20 dB above the ambient noise level. More "presence" and less "voice-on-high" effect is achieved when the loudspeakers are placed on or in the edge of the conference table.

Ceiling mounted loudspeakers are usually simpler to install and less conspicuous. Generally, loudspeakers installed in a visible grid, suspended, acoustic panel ceiling should be placed approximately 0.6 meters outside the edge of the conference table. Best results are obtained when the loudspeakers are *not* installed symetrically but somewhat randomly. This prevents exciting pronounced room modes of vibration.

Reference

[1] *Teleconference center construction guidelines*, Bell System Technical Reference, PUB 42903, May 1980, American Telephone and Telegraph Co.

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