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THE OBJECTIVE MEASUREMENT OF HUMAN SIDETONE IN SMALL ENCLOSURES.

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1: INTRODUCTION.

Everybody has audible experience of the effect a small enclosure such as a telephone hood or small room has on their own voice. This effect can be pleasant, unpleasant or just annoying. Recent work at the British Telecom Sound and Vibration Laboratories required the characteristics of this effect to be objectively measurable to enable diagnosis and design.

A Head and Torso Simulator, together with a Fourier Signal Analyser can be used to separate the reflected signal from the direct sidetone path, enabling problem frequencies to be determined and controlled. Furthermore, by unwrapping the associated phase characteristic and calculating the delay it is possible to pinpoint the re-radiating surfaces .

This new measurement has proved to be a useful extra tool in the quest to provide objective descriptors for enclosures and rooms and to further improve our everyday acoustical environment.

2: BACKGROUND.

A recent research project has involved the application of passive absorption treatment to internal telephone housings (telephone hoods). The requirement was to reduce the amount of sound energy which exists in the vicinity of the telephone user. The energy arrives mainly from two sources, notably externally generated sound and from the telephone user herself or himself. The sound attenuation of the hood is relatively easily measured and a method exists in the form of a CCITT recommendation [1]. What has not been objectively quantified to date is the level of sound energy present at the telephone users ear due to his own voice. This quantity is termed local human acoustic sidetone to distinguish it from local electrical sidetone received by way of the telephone circuit.

If the local human acoustic sidetone path can be objectively quantified and linked to the telephone users ideal requirements then we have an additional useful tool to describe the performance of a telephone kiosk or hood. Indeed the metric could be used in the design and purchase specification. Figure 1 below depicts the Head and Torso Simulator with the local acoustic sidetone path shown.

HEAD AND TORSO SIMULATOR SHOWING THE LOCAL ACOUSTIC SIDETONE PATH.

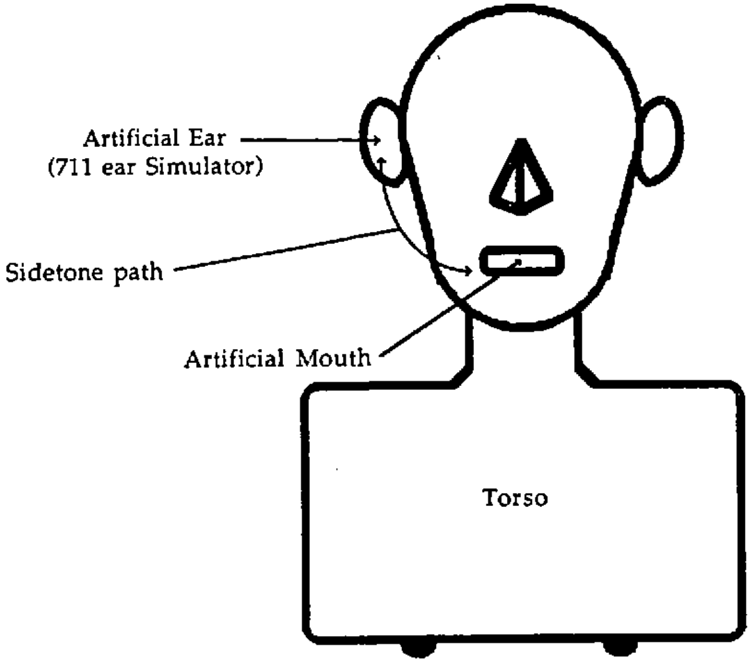


Figure 1.

3: EQUIPMENT.

The measurement of local human acoustic sidetone is based upon the use of the Head and Torso Simulator manufactured by Brüel and Kjær of Denmark. The Head and Torso Simulator consists of an average human sized head equipped with two artificial ear simulators and an artificial voice. Additionally, a Torso simulates the average obstacle effect of a real person. The ear simulators sport soft pinnae manufactured from silicone rubber. Under free field conditions these pinnae give the ear simulators the appropriate polar response required for this measurement. Similarly the artificial voice also has the appropriate point source and polar characteristics.

In order to determine local human acoustic sidetone two separate measurements have to be made. These are most easily handled by a Fourier Signal Analyser which has disc storage and file manipulation capabilities. In this case a Hewlett Packard 3562A Dynamic Signal Analyser was used.

4: PROCEDURE.

Figure 2 below shows a stylised representation of the complex transfer function between the artificial voice and ear of the Head and Torso Simulator. The transfer function f(a) is measured in anechoic conditions between points A and B using pink noise as the stimulus. This result is stored on disk.

COMPLEX TRANSFER FUNCTION BETWEEN POINTS A AND B IN ANECHOIC CONDITIONS.

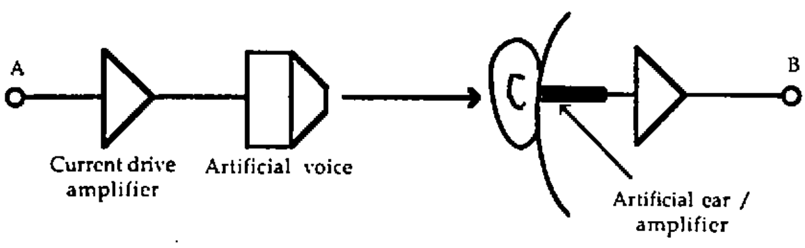


Figure 2.

Figure 3 shows the complex transfer function when the Head and Torso Simulator is introduced into the environment to be quantified. This transfer function is f(a+e). It can be seen that f(a+e) includes the direct path f(a) and that of the local acoustical environment f(e). In order to extract the quantity f(e) which represents the reflected energy only, the transfer functions are subtracted. Dividing by f(a) normalises the result.

Hence;

$$f(e) = \frac{f(a+e) - f(a)}{f(a)}$$

COMPLEX TRANSFER FUNCTION BETWEEN POINTS A AND B IN REFLECTIVE CONDITIONS.

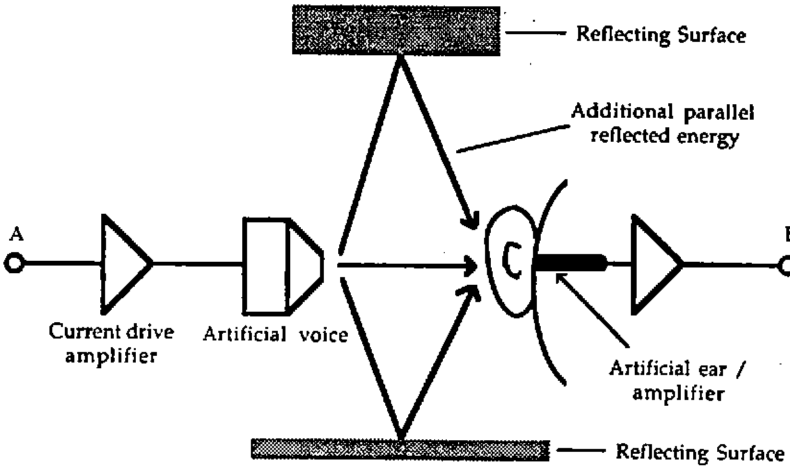


Figure 3.

When the reflecting surfaces are small, ie as f(a+e) approaches f(a) the equation will tend to zero. For this reason it is important that the two measurements are performed one after the other as small variations in local conditions could produce changes in the transfer functions. The major contributor to this effect has been found to be heating of the artificial voice loudspeaker winding which increases its resistance and reduces the current. This sensitivity change can be reduced by an order of magnitude by feeding the artificial voice from a current drive rather than the more usual voltage drive amplifier.

5: INTERPRETATION OF RESULTS.

The resultant quantity f(e) represents the reflected energy contributions of all the surfaces which are relevant. Interestingly, although the Modulus component of f(e) describes the reflected energy as a function of frequency, the Phase information is even more revealing. After differentiating the unwrapped phase characteristic into a delay characteristic, the delay information now reveals the distance away from the Head and Torso Simulator of the reflecting surface, as a function of frequency.

In many cases this surface will be obvious, however, if this is not the case the delay characteristic can be used as a diagnostic tool as it always reveals the effective distance away of the major contributor, ie the surface to be treated which will make the most significant initial improvement. Once this surface is treated or removed a new delay measurement will reveal the next surface for treatment. Figures 4 and 5 below show the results from a typical internal acoustic telephone housing. Note how the phase characteristic has two distinct slopes representing different delays.

MODULUS AND PHASE COMPONENTS OF THE ACOUSTIC SIDETONE FOR A TELEPHONE ACOUSTIC HOOD.

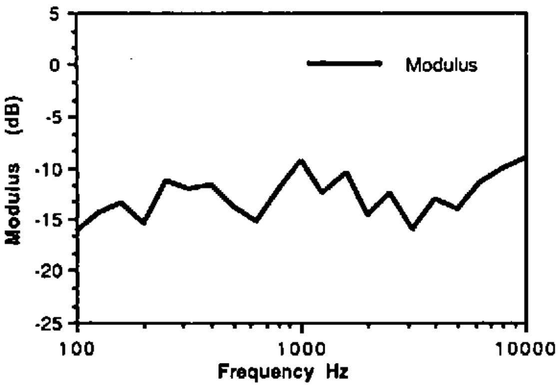
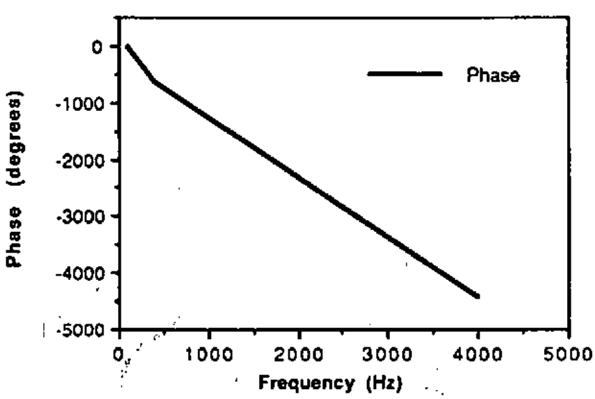


Figure 4 above : Figure 5 below.



The sensitivity of the measurement technique is sufficient to accurately detect and locate a 200 millimetre square metal plate at a distance of 3 metres.

6: FURTHER CONSIDERATIONS.

In telephony, much effort is expended to ensure that the speech level sent to line from the telephone is within a controlled range. When a subject is using a telephone in a reflective environment two extra mechanisms occur. Firstly, the subjects own local acoustic sidetone is raised by f(a+e)/f(a) dB. This local feedback has the effect of reducing the subjects speech level by a similar amount. Secondly, the speech signal received by the telephone microphone is also raised by a small amount. These effects will conspire to compensate one with another as far as the speech signal is concerned but, significantly, will operate in concert with each other to reduce the effective speech to room/environmental noise sent to line. This will worsen the conversational opinion score for the far end telephone user.

7: CONCLUSION.

A measurement method has been established which enables small enclosures to be objectively quantified in terms of the amount of the telephone users acoustic speech energy returned to his/her hearing system. Furthermore the technique is useful as a diagnostic tool to identify problem surfaces and to ensure that acoustic treatment is applied where it will be most effective.

Work still has to be done to determine suitable values of local acoustic sidetone above which internal housings would be deemed to be unsuitable for use by the public. Schroeder [2] suggests that the first 13 to 15 dB of room reverberation time determines the subjective response to the room. It is felt that a similar value may very well apply to the Human local sidetone measurement.

8: REFERENCES.

[1]. Evaluation of the efficiency of telephone booths and acoustic hoods.
CCITT Recommendation P.32 Volume V. P Series. (Blue Book)

[2]. B.S. Atal, M.R. Schroeder, G.M. Sessler,"Subjective Reverberation Time and its Relation to Sound Decay" 5th International Congress on Acoustics, Liege (1965) Paper G.32.