Proceedings of the Institute of Acoustics

A SPEECH ABSORBING MICROPHONE

Robin Cross, MIOA.

British Telecommunications plc, Acoustics Laboratory, Martlesham Heath, Ipswich, Suffolk, IP5 7RE.

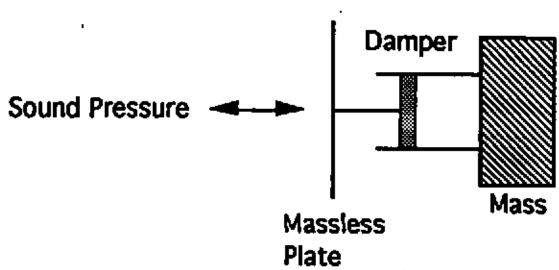
1. INTRODUCTION

In the nearfield of a point source the sound field is reactive. A theoretical study shows the possibility of a communications microphone whose input impedance is matched to the speech wavefront. Benefits include high sensitivity, good noise rejection and reduced external speech levels.

2. THE PRINCIPLE OF THE REACTIVE TERMINATION

Since the Specific Acoustic Impedance of a sound wave is only completely resistive when it's a plane wave, ie, infinite radius from the source. It follows that in an Anechoic Chamber of finite dimensions there will be a calculable reactive component to the wavefront. In order to completely terminate this wavefront such that the returned energy is zero, it's necessary to provide a termination strategy which has the same impedance / frequency characteristic as the wave.

In fact, it turns out [1] that if a point source is placed in the centre of a circular anechoic chamber then the boundary mass (reactance) required is exactly three times the mass of the enclosed air. The equivalent mechanical model is shown below in figure 1.



Equivalent mechanical model of a resistive / reactive termination.

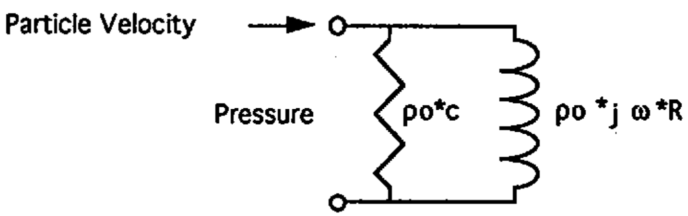
Figure 1.

In other words, the termination moves and doesn't absorb at low frequencies, and absorbs and doesn't move at high frequencies. The crossover point is at $kR = 1$, where k is the wave number and R is the radius (distance) of the reactive absorber from the point source.

In terms of deviation from the inverse square law, the low frequency cut off performance of the Anechoic Chamber at BT can be described almost entirely in terms of wavefront / termination mismatch. The chamber is constructed from conventional 1.5 metre open cell foam wedges.

3. ELECTRICAL ANALOGY

The complex impedance of the required (perfect) termination is equivalent to the Specific Acoustic Impedance of the spherical wavefront and can be equated to a parallel R / L circuit. Figure 2 below gives the form, where the component values are: $\rho o = 1.21$ kg/m^3, $c = 343$ m/sec, $\omega = 2.\pi.f$ rad/sec, R = the wavefront radius in metres.



Termination / source complex impedance equivalent circuit.

Figure 2.

It can be clearly seen from the above that the effect of the reactive component of the wavefront impedance is reduced as frequency and radius are increased.

4. APPLICATION OF THE REACTIVE TERMINATION TO A HANDSET MICROPHONE

The concept is introduced whereby it may be possible to design a large diameter microphone (50 mm) with a diaphragm which absorbed all of the speech energy radiating into the solid angle defined by its concave surface and the speech point source. This will reduce the amount of energy radiated into the roomspace, reducing spillage, and, if the available energy can be utilised efficiently, the sensitivity will be high. (5 mW illumination at 2 % efficiency yields ≈ –20 dB re 1V / Pa into 600Ω). Additionally, since both sides of the microphone diaphragm are "open" to the surrounding space the noise cancelling properties of the microphone will be enhanced.

In telephony, a handset microphone is operating in near point source conditions. The point source is considered to be 6 mm inside the lips, (measured using Long Term Active Speech Level). Together with the average speaking distance, the effective distance from the point source to the microphone diaphragm is around 50 mm.

A SPEECH ABSORBING MICROPHONE

The Active Speech Sound Pressure Level at the mouth reference point (25 mm on axis) can vary from - 15 dBPa to + 5 dBPa, and, since the distance has been doubled, the effective Speech Level is approximately -21 dBPa to -1 dBPa, (73 dB spl to 93 dB spl) These quantities are useful when calculating diaphragm displacement and sensitivity.

Tables 2a and 2b below give the specific acoustic impedance of the wavefront at various values for radius R (in Metres) and Frequency f. Also included is the return loss of the wavefront impedance relative to a resistive termination of ρo * c (415 MKS Ω). (The value of 3.2 metres for the value of R is used as it is an approximation to the radius of the BT Anechoic Chamber, where calculations have been made regarding the low frequency performance.)

R	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz
0.05	0.3+j12.0	1.4+j23.9	5.4+j46.9	21.0+j90.9	72.9+j157.9
0.1	1.4+j23.9	5.5+j47.3	21.0+j90.9	72.9+j157.9	191+j206.9
0.2	5.5+j47.3	21.0+j90.9	72.9+j157.9	191+j206.9	320.9+j173.8
0.4	21.0+j90.9	72.9+j157.9	191+j206.9	320.9+j173.8	386.7+j104.7
0.8	72.9+j157.9	191+j206.9	320.9+j173.8	386.7+j104.7	407.6+j55.2
1.6	191.0+j206.9	320.9+j173.8	386.7+j104.7	407.6+j55.2	413.1+j28.2
3.2	320.9+j173.8	386.7+j104.7	407.6+j55.2	413.1+j28.2	414.5+j14.1
6.4	386.7+j104.7	407.6+j55.2	413.1+j28.2	414.5+j14.1	414.9+j7.1
12.8	407.6+j55.2	413.1+j28.2	414.5+j14.1	414.9+j7.1	415.0+j3.5
25.6	413.1+j28.2	414.5+j14.1	414.9+j7.1	415.0+j3.5	415.0+j1.8
R	Ret loss	Ret loss	Ret loss	Ret loss	Ret loss
3.2	-11.70	-17.40	-23.30	-29.30	-35.40

Table 2a

R	1000 Hz	2000 Hz	4000 Hz	8000 Hz	16000 Hz
0.05	191+j206.9	320.9+j173.8	386.7+j104.7	407.6+j55.2	413.1+j28.2
0.1	320.9+j173.8	386.7+j104.7	407.6+j55.2	413.1+j28.2	414.5+j14.1
0.2	386.7+j104.7	407.6+j55.2	413.1+j28.2	414.5+j14.1	414.9+j7.1
0.4	407.6+j55.2	413.1+j28.2	414.5+j14.1	414.9+j7.1	415.0+j3.5
0.8	413.1+j28.2	414.5+j14.1	414.9+j7.1	415.0+j3.5	415.0+j1.8
1.6	414.5+j14.1	414.9+j7.1	415.0+j3.5	415.0+j1.8	415.0+j0.9
3.2	414.9+j7.1	415.0+j3.5	415.0+j1.8	415.0+j0.9	415.0+j0.4
6.4	415.0+j3.5	415.0+j1.8	415.0+j0.9	415.0+j0.4	415.0+j0.2
12.8	415.0+j1.8	415.0+j0.9	415.0+j0.4	415.0+j0.2	415.0+j0.1
25.6	415.0+j0.9	415.0+j0.4	415.0+j0.2	415.0+j0.1	415.0+j0.1
R	Ret loss	Ret loss	Ret loss	Ret loss	Ret loss
3.2	-41.40	-47.40	-53.40	-59.40	-65.50

Table 2b

5. CONSIDERATIONS

1: The damping mechanism must also act as the transduction mechanism, as this is where the real (sic) work is done to harness the available energy.

2: The reactive mass associated with a 50 mm diameter diaphragm microphone operating at a radius of 50 mm is approximately 143 milligrams. This has implications in terms of increased physical shock susceptibility of the device.

3: Breath puff is expected to be a problem with the device outlined due to large diaphragm displacements at low frequencies. However, once again this can be minimised with careful design.

4: Handsets produced with this type of microphone will look quite different to the "modern" style and will probably (presently) be more expensive to produce. It is therefore imperative that the performance is markedly superior to the High Acoustic Impedance Electret Pressure Microphones favoured at present. However the theoretical work shows that this may indeed be the case.

6. CONCLUSIONS

1: Theoretical work carried out elsewhere [1] with reference to complex wavefront terminations for Anechoic Chambers has been harnessed to provide insight into the development of a Speech Absorbing Microphone with enhanced performance in noisy conditions. The noise cancelling properties should extend over a wider frequency range than at present.

2: A passive microphone, if achievable, will exhibit a higher sensitivity than a conventional type due to the increased energy captured.

3: A working microphone is likely to have active elements to control the resistive component of the input impedance.

4: The topology and transduction strategy of the device is the key area of further research.

7. NOTE

Although the Author is employed by BT in the discipline of Acoustics, this contribution is not connected in any way with research directed by the company.

8. REFERENCE

[1] D. B. KEELE, Jr, 'Anechoic Chamber Walls: Should They Be Resistive or Reactive at Low Frequencies ?', Journal of the Audio Engineering Society, Volume 42, Number 6, June 1994, pp 454 - 466.