ON THE CAPILLARY METHOD OF IMPEDANCE MEASUREMENT — A BRIEF NOTE

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Dear Mr. Lurton:

After much delay I sit down to give a brief response to your letter about the capillary method of impedance measurement.

To begin, you will find a more recent paper by John Backus dealing more explicitly with the behavior of his annular capillary. As a practical matter, the capillary that Jansson and I used gives quite smooth (measured) response, being down some 3 dB around 2000 Hz. Backus' original paper presents a completely inadequate view of the mechanism. His second paper, with a much more detailed analysis (in response to comments by me!) shows the problem is much less than he thought before. In practice the problem is less yet.

Here is an excellent way to test (or calibrate) any capillary you may wish to use: The input impedance of a cylindrical tube of length L and characteristic impedance $R_0 = \rho c/\pi a^2$ varies with frequency according to

$$Z_{in} = R_0 \left[\frac{1 + jQ_0 \tan kL}{Q_0 + j\tan kL} \right]$$

where Q_0 is a measure of the down-and-back attenuation due to wall losses and the terminating reflection loss. If the returned wave has an amplitude F for unit wave sent into the system

$$Q_0 = \frac{1+F}{1-F} = \left\{ \frac{(R_0/R_t) + \tanh \alpha L}{1 + (R_0/R_t)\tanh \alpha L} \right\} \quad 3$$

Notice that when kL is an even or odd multiple of $\pi/2$ that $Z_{in} = R_0 Q_0^{\pm 1}$. This is the key to the procedure.

If you excite the pipe with a (capillary) source of strength $S_0(\omega)$ (which you hope is a constant) and measure the pressure P_i at the input end,

$$P_i = S_0 Z_{in}$$

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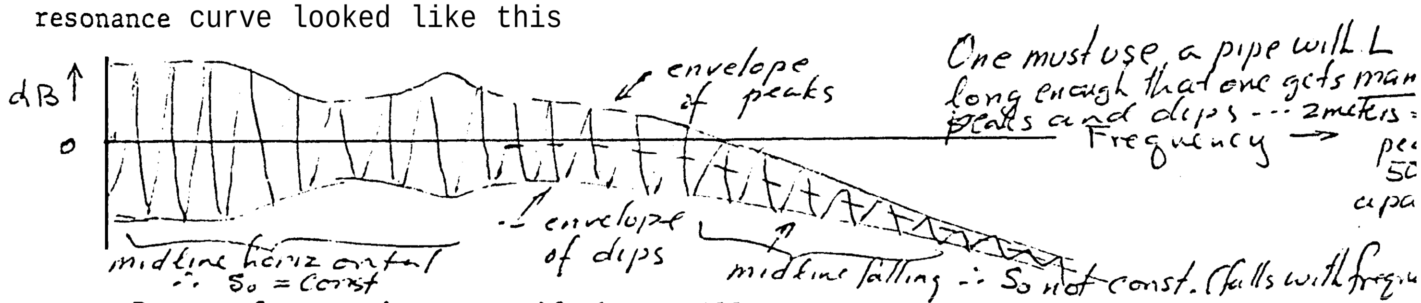
Plotting this on dB graph paper gives a curve whose peaks and dips are above and below the midline S_oR_o by an amount ±20 logQ_o. As long as Q_o is slowly varying, you can draw the envelope of the peaks, and of the dips. The midline drawn between these is now an estimate of S_oR_o. If this is a constant, you have established that S is constant. Deviations from constancy give a direct measure of noncons?ancy of S_o and thence of the properties of the capillary.

It is to be emphasized that as long as the entryway of the test pipe is cylindrical, any sort of (complex) termination is permissible, even a trumpet bell, or tuft of wool inserted a few cm from the open end. 1 have enjoyed using the technique even in extreme cases in which the resonance curve looked like this



Do not forget that even if the capillary is not frequency-independent, its behavior is smooth enough that a simple RC equalizing circuit can usually be designed for use in either the excitation feedback loop *or in* the pressure microphone channel to get an effectively constant system.

You will find it helpful to discuss these matters with René Caussé at IRCAM in Paris. He has set up equipment of this sort, and its relatives. He and I have worked together both here and in Paris.

Yours sincerely,

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