A VARIABLE SINGLE BAND ACOUSTIC WAVE FILTER

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Abstract

Single band acoustic filter; simple method of varying the width of the transmitted band.—An extension of the earlier theory indicates that if the size of the orifice leading into the side tube is altered, the upper limiting frequency should change while the lower limiting frequency remains constant, thus changing the width of the band. The orifice is readily changed by introducing a cylinder of paper with punched holes of the proper size and position. Experimental results confirm the prediction as to the lower limit and give for three different orifices upper limiting frequencies of 455, 390 and 340 per sec., in fair agreement with the corresponding theoretical values 510, 440 and 385, respectively.

THE acoustic wave filter to be described is presented to illustrate the possibility of varying the width of the transmission band with but a slight alteration in the filter itself. It is not to be regarded as highly developed in form, for as yet little effort in that direction has been made.

Theory

For the sake of brevity reference will be made to a former paper[1] on the general theory, for equations and for the meaning of *impedance*, *inertance* and *capacitance*. The filter and its transmission curve are shown in Fig. 1 which is the same as Fig. 8 of that paper. The filter is drawn to scale, the length over all being 10 cm. In the previous article it was found that formula K gave the best agreement with experimental values. We will therefore make the assumptions involved in K', viz., that the orifice into the surrounding chamber has the inertance M_2', the conduit between two adjacent branches the inertance M_1, the chamber the capacitance C_2 and the branch tube leading to the outside, the inertance M_2. In addition, however, we will use a variable orifice at the opening from the conduit to the side tube and note the resulting change made in the transmission curve. The inertance of this orifice will be designated by M_2''.

According to Eq. (27)[1] the impedance of the side branch with the orifice represented by M_2'' omitted, is

$$(Z_2)_A = i\frac{M_2\omega(M_2C_2\omega^2-1)}{M_2C_2\omega^2+M_2'C_2\omega^2-1} \tag{1}$$

[1] Stewart, Phys. Rev. **20**, 528, 1922

If we now introduce the orifice M_2'' in series, we have, since its impedance is $i\omega M_2''$,

$$(Z_2)_B = i\,M_2''\,\omega + i\frac{M_2\omega(M_2'C_2\omega^2-1)}{M_2C_2\omega^2+M_2'C_2\omega^2-1}$$

$$= i\frac{M_2''\omega(M_2C_2\omega^2+M_2'C_2\omega^2-1)+M_2\omega(M_2'C_2\omega^2-1)}{M_2C_2\,\omega^2+M_2'C_2\omega^2-1} \qquad (2)$$

If the conduit has an inertance between the branch openings of M_1, its impedance Z_1 is $iM_1\,\omega$. The limiting frequencies of no attenuation can

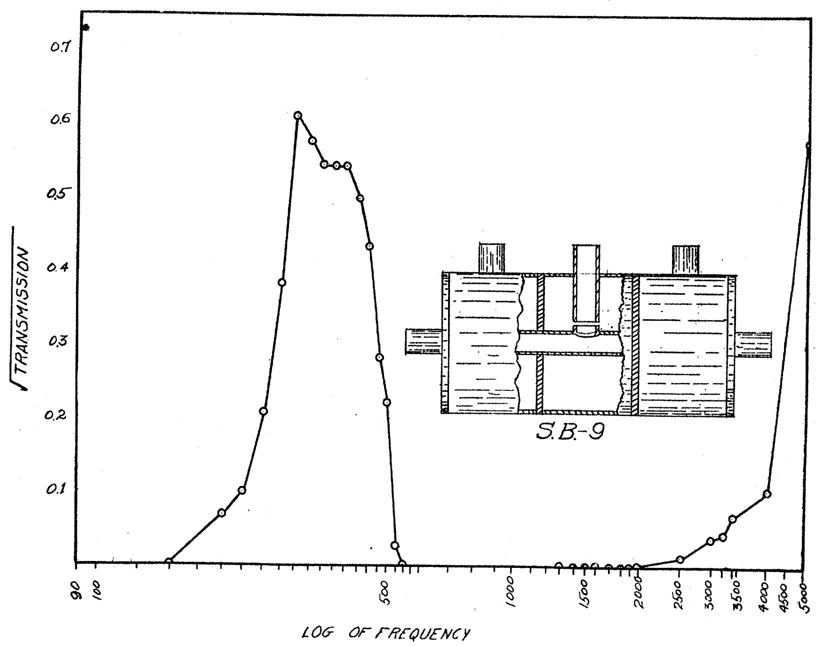

Fig. 1

now be ascertained by using $Z_1/Z_2=0$ and $Z_1/Z_2=-4$. If this is done, we find for the frequency $\omega/2\pi$ the following values:

$$f_1=\frac{1}{2\pi}\sqrt{\frac{1}{C_2(M_2+M_2')}} \qquad (3)$$

and

$$f_2=\frac{1}{2\pi}\sqrt{\frac{M_1+4\,(M_2+M_2'')}{C_2\,[4M_2(M_2'+M_2'')+M_2'(M_1+4M_2'')\,M_1M_2]}} \qquad (4)$$

Eqs. (3) and (4) show the interesting fact that the lower limiting frequency f_1 is independent of M_2'', whereas the upper limiting frequency f_2 is dependent upon M_2''. Thus, if the theory be substantially correct, the width of the band may be changed by altering the size of the orifice represented by M_2''. In applying (3) and (4) the following measurements of the filter are substituted:

$$M_1=\rho l_1/S_1,\ M_2=\rho l_2/S_2,\ M_2'=\rho/c',\ M_2''=\rho/c'' \text{ and } C_2=V_2/\rho a^2.$$

In these, l and S refer to the length and area respectively, the subscripts having the same significance as already adopted; ρ is the density of the fluid, a is the velocity of sound, c' is the conductivity of the orifice into the volume M_2 computed approximately as an elliptical channel, and c'' is the conductivity of the circular orifice into M_2, numerically equal to twice the radius. The value of M_2' was $\rho/.455$.

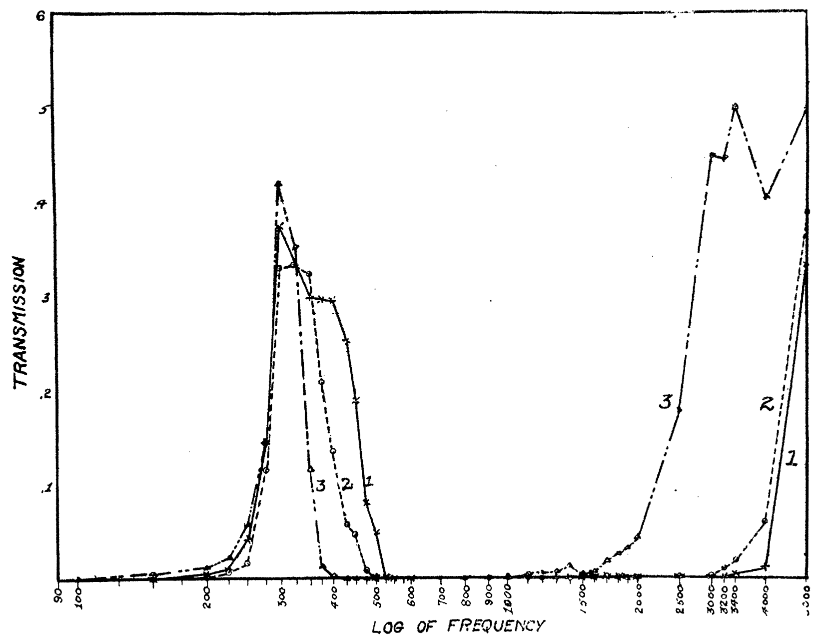

Fig. 2

Experiment

In order to introduce and to modify the orifice, a tightly fitting roll of heavy writing paper with holes of selected sizes was introduced into the conduit, the holes being centered in the branch tubes.

The transmission curves are shown in Fig. 2. Curve 1 is with the orifice 0.486 cm in diameter, the curve being the same as in Fig. 1. This orifice is really the end of the tube M_2, and is considered as part of it. Hence it does not give any value to M_2'' and $M_2''=0$. Curves 2 and 3 are for orifices with diameters of 0.3 cm and of 0.1 cm, respectively. As is clearly shown, the lower limiting frequency, taken as the frequency for one-half of the maximum transmission, remains unchanged, as indicated by the theory. For the upper limiting frequency, we have the following experimental and corresponding theoretical values. The latter were obtained by Eq. (4) and are placed in parentheses. Curve 1, 455 (510); curve 2, 390 (440); and curve 3, 350 (385).

Discussion

The agreement between experiment and theory is satisfactory since it covers both points, viz., the constancy of the lower limiting frequency and the decrease of the upper limiting frequency with decrease in the size of the orifice.

The fact that the transmission increases appreciably at 3,200 per sec. in curve 1, and at lower frequencies in curves 2 and 3, is not anticipated in the present theory, which gives attenuation for all frequencies higher than those of the band. The extension of the theory which explains this increase of transmission has been made and will be presented in a later paper. As will be shown in later contributions, there are at least two ways in which this transmission at higher frequencies may be practically eliminated.

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