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Theory of Megaphones and Receiving Horns

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NOTE ON THE THEORY OF THE OPTIMUM ANGLE OF A CONICAL HORN

G. W. STEWART

Hoersch[1] has given a theoretical explanation of the optimum angle of a conical horn experimentally found by the writer.[2] The optimum angle is the one giving the greatest amplification, the horn acting as a receiver. The theory of Hoersch states that the angle is an optimum when the dissipation at the vertex is equal to the dissipation at the open end. The value of this angle is expressed by the formula:

$$\Theta_m = 1/\sqrt{n}\ \sqrt{\rho\omega^3 y_2/2\pi^3 a} \qquad (1)$$

wherein n has the integer values 1, 2, 3, etc., these being used respectively for the fundamental and the overtones taken in order; ρ is the mean density of the air; ω is 2π times the frequency; y_2 is defined by the admittance, y_1+iy_2, this term being the ratio of the volume displacement and pressure; a is the velocity of sound.

It is the purpose of this note to compare the experimental results with Hoersch's theory. The experimental values that are unchanged are $\sigma=0.16$ cm², $a=34\times10^3$ cm/sec. The other values and the experimental and computed values of Θ_m are shown in the following table.

n	f	Θ_m	Θ_m Computed
1	256	0.10	0.12
1	512	0.13	0.16
2	256	0.072	0.08
2	512	0.10	0.12

The results of computation are consistently about 20% higher than in the experiment.

The conclusion is that the agreement between experiment and theory justified confidence in the explanation of the optimum angle as given by Hoersch.

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THEORY OF MEGAPHONES AND RECEIVING HORNS

G. W. STEWART AND G. R. BUTZ

In 1919, A. G. Webster[1] published a theory of the action of horns used as receivers. Recent development has given an in-

1 Hoersch, Phys. Rev.
2 Stewart, Phys. Rev. XVI, No. 4, Oct. 1920.
1 Proc. Nat'l Acad. of Sci. Vol. 5, p. 275, 1919.

creased interest in the megaphone. Webster's theory may be modified to cover the case of the megaphone, assuming the constancy of the acoustic point impedance of the horn at the source. The result obtained is that the emitted energies at different frequencies are related as are the values of

$$[(a\,d - b\,c)/(a - c\,z_2)]^2$$

wherein *a, b, c* and *d,* have the values specified in Webster's theory [1] and $z_2 = \varrho a^2 k^2 (ki/2\pi - 1/c_0)$, k being 2π divided by wave length, ρ the density, a the velocity of sound and c_0 the conductivity of the opening.

It is shown that this result is approximately correct even if the diameter is of the order of a wave length provided the rate of change of area along the axis is small.

By the use of the Helmholtz reciprocal theorem it is now shown that the amplification of a receiving horn, with the impedance at the receiving end large, is proportional to this same value. It is further shown that the theory is quite exact for long wave lengths and is a fair approximation for wave lengths of the order of the diameter of the opening, particularly at frequencies where z_2 does not enter importantly into the value of the computed result.

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RAINBOW AND OTHER ATMOSPHERIC PHENOMENA

F. MAY TUTTLE

Perfectly well behaved rainbows are usually supposed to appear opposite the sun, following a shower; but they sometimes change their minds and appear elsewhere.

During the past three years we have been jotting down a few notes and felt they might be of interest to other students of nature's wonderland.

The first occurrence was a perfect rainbow in the zenith, March 20, 1921, at 4 o'clock in the afternoon. It, of course, was reflected on a bank of dark gray clouds.

August 15, 1922, L. F. Tibbetts of this city, witnessed an unusual occurrence when his attention was attracted to a rainbow reflected on the side of a house next door to the one where he was staying in Waterloo, on Lafayette street, which runs approximately north and south. This was seen after a shower in the afternoon.

Mrs. Ethel Lovejoy Wilson of Osage told me of a rainbow she