More on Nonlinear Distortion Correction*

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Summary—Further consideration is given to basic amplitude limitations which may apply to the complementary distortion method of nonlinear distortion correction. It is found, in disagreement with others, that points at which the differential gain is zero or infinite do not limit the amplitude over which complete correction is possible but that relative maxima, minima, gain zeros, and infinite-gain points in the characteristic do set limitations when the usual simply connected tandem configuration is employed. When the characteristic to be corrected is multiple valued or passes through points of zero or infinite gain within a given amplitude range, a multiply connected correction circuit must be used for perfect correction of distortion over the amplitude range in question.

THERE has recently been a certain amount of controversy concerning amplitude limitations in the complementary distortion method of nonlinear distortion reduction. Two such limitations, which will be further discussed herein, were pointed out in the original paper[1] and Waldhauer[2] later suggested a specific configuration for complete distortion correction which is stated to be limited to the amplitude range over which $|de_1/de_0|>0$, where $e_0=A\cos\omega t$ is an input signal and $e_1\equiv f(e_0)$ is the output signal obtained when e_0 is applied to the input of a predistortion network which is to correct the distortion of a given black box whose input is e_1 and whose output, as shown in Fig. 1(a), is $e_2\equiv g(e_1)$. Perfect distortion correction only occurs when $e_2=Ke_0=g\{f(e_0)\}$, where K is the over-all amplification fac---. As pointed out by Pritchard,[3] perfect correction is only achieved in Waldhauer's configuration provided the two amplifiers he uses are assumed to have zero input and infinite output impedance respectively. These conditions, which cannot be met in practice over a nonzero amplitude range, can still be well approximated over a limited range. Within this range, the important advantage of Waldhauer's approach is that the same elements and circuit configuration appearing in the black box whose characteristic is to be corrected appear also in the pre- or postdistortion correcting network.

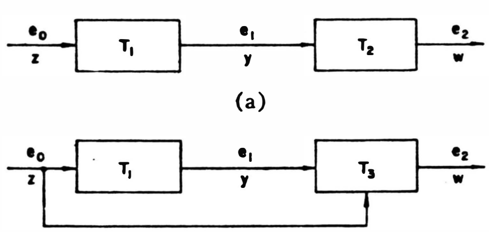

Fig. 1—(a) Usual configuration for correcting nonlinear distortion by complementary distortion. z, y, and w are normalized signal variables. (b) A multiply connected configuration for correcting nonlinear distortion generated in the left-hand circuit.

In the rest of this paper, we shall be concerned with amplitude restrictions for complete distortion correction. In the limit of complete correction, the distinction between pre- and postdistortion vanishes.[2,3] Therefore, we shall consider two nonlinear black boxes connected in tandem as shown in Fig. 1(a) and shall make no distinction between which represents the correcting circuit and which the circuit to be corrected. No significant generality will be lost if we take $K=1$, making the final output equal to the input when complete correction is achieved. In the simplest case, the transfer functions $e_1/e_0\equiv T_1=f(e_0)/e_0$ and $e_2/e_1\equiv T_2=g(e_1)/e_1$ may be considered as real, single-valued operators which operate on a single input to give a single output. Then, the condition

$$T_1T_2 = I \tag{1}$$

where I is the identity operator, leads to complete correction. In this case, the boxes may clearly be interchanged and $T_2T_1=I$ as well. Thus, the operators commute, a result which may also readily be established formally.

In the latter part of the Appendix of the author's paper,[1] a method of complete distortion correction was described which depends on the condition $T_1T_2=I$. This method was later generalized by Waldhauer[2] and has been recently mentioned again by Holbrook and Todosiev.[4] Further discussion of any amplitude restriction applying to this method is needed since the conclusions in the author's paper,[1] those of Waldhauer, and those of Holbrook and Todosiev are inconsistent with each other in some cases. Note that this method is more general than, and is distinct from, Waldhauer's approximate configuration for obtaining response inversion.

In order to discuss amplitude limitations, it will be convenient to consider various classes of transfer functions for the left black box and to ask over what input-signal amplitude range the nonlinearity introduced by

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[1] J. R. Macdonald, "Nonlinear distortion reduction by complementary distortion," IRE TRANS. ON AUDIO, vol. AU-7, pp. 128–133; September–October, 1959.

[2] F. D. Waldhauer, "Comments on 'nonlinear distortion reduction by complementary distortion,'" IRE TRANS. ON AUDIO (Correspondence), vol. AU-8, p. 103; May–June, 1960.

[3] J. R. Macdonald, "Reply to comments on 'nonlinear distortion reduction by complementary distortion,'" IRE TRANS. ON AUDIO (Correspondence), vol. AU-8, pp. 104–105; May–June, 1960.

[4] G. W. Holbrook and E. P. Todosiev, "Amplitude limitations in nonlinear distortion correction," IRE TRANS. ON AUDIO (Correspondence), vol. AU-8, p. 235; November–December, 1960.