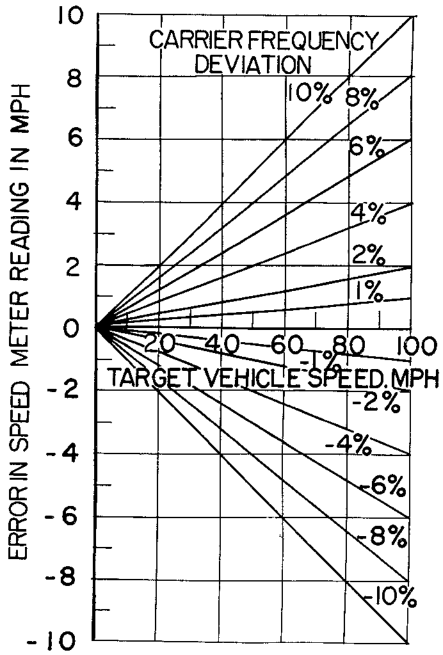

Fig. 1. Error in speed meter reading of a Doppler radar due to carrier frequency deviation.

This means that if the carrier frequency is deviated ($\Delta f_0/f_0$) per cent then the error in the speed meter reading ($\Delta\nu_m/\nu_m$) per cent is equal to ($\Delta f_0/f_0$) per cent.

Equation (8) shows that the magnitude of the error is proportional to the product of both the target vehicle speed and the carrier frequency deviation. It should be noted that the error becomes greater for a high speeding target vehicle. The error of speed meter $\Delta\nu_m$ is plotted against the target speed ν for various carrier frequency deviation $\Delta f_0/f_0$ in Fig. 1. This figure is useful for any carrier frequency. The results shown in Fig. 1 and (10) suggest that if the carrier frequency deviation is less than one per cent which is normally the case (FCC Rules and Regulations Section 89.115), the error in the speed reading is less than one per cent. The previously stated analysis may have been carried out individually on private basis before[7] but to the author's knowledge the analysis shown in this correspondence has never been published as yet in a professional publication as a public document. Considerable effort was devoted to a search for such a document. There were many articles about Doppler radars for military and navigation applications but none of these were about police radar. Those found did not deal with the error analysis due to the long-time frequency deviation of the carrier. For example, Kelly's analysis[8] was about the pulsed Doppler radar error due principally to the signal to noise ratio and his theoretical equations are not directly applicable to this case. Goetz and Albright[9] discussed frequency stability of airborne Doppler radar but the accuracy was that of range accuracy and not of speed accuracy. The previously mentioned articles were for pulsed radar and not for the CW radar which is used by the police. Craig, Fishbein, and Rittenbach[10] discussed the error of a continuous wave Doppler radar. This error analysis was not due to the carrier frequency deviation but was rather a comparative study of a proposed new method of speed determination compared to other conventional methods. Doppler radar was analyzed for air navigations by Mayer[11] and Feurstein, Safran, and James.[12] Airborne Doppler radar was discussed in these articles, but error was not due to the long term deviation of carrier frequency. These articles are *not* directly related to the police's continuous wave Doppler radar. This is the reason why this writer presented the error analysis of the police's continuous wave Doppler radar for traffic speed determination due to the long-time deviation of the carrier frequency.

As microwave engineers it is important for us to know the foregoing fact and to inform the public.

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[7] An unidentified person who reviewed this author's unpublished note stated that he had tried similar analysis independently with this author before, and the unidentified person claimed that similar results were obtained.

[8] Kelley, E. J., The radar measurements of range, velocity and acceleration, *IRE Trans. on Military Electronics*, vol MIL-5, Apr 1961, pp 51–47.

[9] Goetz, L. P., and J. D. Albridgt, Airborne pulse-Doppler radar, *IRE Trans. on Military Electronics*, vol MIL-5, Apr 1961, pp 116–126.

[10] Graig, S. E., W. Fishbein, and O. E. Rittenbach, Continuous-wave radar with high range resolution and unambiguous velocity determination, *IRE Trans. on Military Electronics*, vol MIL-6, Apr 1962, pp 153–161.

[11] Mayer, R. H., Doppler navigation for commercial aircraft in the domestic environment, *IEEE Trans. on Aerospace and Navigational Electronics*, vol ANE-11 Mar 1964, pp 8–15.

[12] Feurstein, E., H. Safran, and P. N. James, Inaccuracies in Doppler radar navigation systems due to terrain directivity effects, nonzero beamwidths and eclipsing, *IEEE Trans. on Aerospace and Navigational Electronics*, vol ANE-11, Jun 1964, pp 101–111.

Optimum Transducer Coupling Coefficient of a Multiple Reflection Pulsed Microwave Delay Line

Delay lines have been made which propagate pulses of sonic waves at microwave frequencies,[1] and transducers are required to convert electromagnetic waves to sonic waves.

With a finite length of line, a long delay time can be obtained by multiple reflections. The coefficient of coupling of the transducers in a multiple-reflection microwave delay line cannot have any arbitrary value; the limit of zero coupling is trivial, and the other

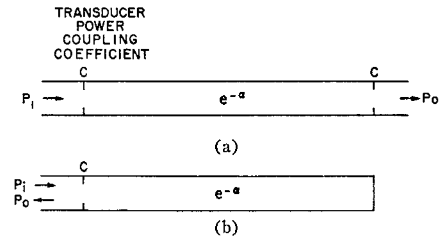

Fig. 1. Multiple reflection delay lines. (a) Two-transducer delay line. (b) One-transducer delay line.

limit of total coupling will not produce a reflection.

The purpose of this correspondence is to present a short analysis on the optimum coupling coefficient for any desired number of reflections. The results differ depending on whether the delay line has either one or two transducers. A schematic representation of multiple-reflection delay lines is shown in Fig. 1. The two-transducer delay line may be referred to as a transmission-type delay line. The one-transducer delay line requires a ferrite circulator to prevent the outgoing delayed signal from appearing at the generator.

In this analysis it is assumed that a) the transducers are lossless, and b) the pulse length is short compared to the one-way sonic delay time in the medium.

Symmetrical Two-Transducer Delay Line

By referring to Fig. 1(a), the output power P_0 after n transits (n odd) within the symmetrical two-transudcer delay line is given by:

$$P_0 = P_i C^2 (e^{-\alpha})^n (1 - C)^{n-1}$$

where

P_i = input power

C = power coupling (or transmission) coefficient, equal value for input and output transducers

$e^{-\alpha}$ = single-transit sonic attenuation in delay medium.

If the derivative of P_0/P_i with respect to C is equated to zero, the following nontrivial solution is obtained:

$$C = \frac{2}{n+1}.$$

For example, if the signal is to be reflected 100 times, i.e., $n = 100$, then the optimum C is 0.02 or -17 dB; the VSWR of this transducer is about 200.

One-Transducer Delay Line

By referring to Fig. 1(b), the output power P_0 of a one-transducer delay line after n transits (n even), is given by:

$$P_0 = P_i C^2 (e^{-\alpha})^n (1 - C)^{(n/2)-1}.$$

If the derivative of P_0/P_i with respect to C is equated to zero, the following nontrivial solution is obtained:

$$C = \frac{4}{n+2}$$

For example, if the signal is reflected 100 times, i.e., $n = 100$, then the optimum transducer coupling is -14 dB.

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[1] Tehon, S. W., and S. Wanuga, Microwave acoustics, *Proc. IEEE*, vol 52, Oct 1964, pp 1113–1127.