VII. MULTIPATH TRANSMISSION

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A. CASCADED BANDPASS LIMITERS

The effect of a stage of ideal bandpass-limiting upon the disturbances arising from multipath and cochannel interference has been shown to result in a substantial reduction in the minimum necessary bandwidth requirements (for interference rejection) in the discriminator FM-to-AM characteristic. It has also been demonstrated that the same effect will be experienced with additional stages of bandpass limiters, and, thus, that cascading a sufficient number of such limiters will successively reduce the minimum requirement in discriminator bandwidth to that of the intermediate frequency. Since this effect may be looked upon as a reduction in the effective peak strength of the weaker signal relative to the stronger one, we find that a chain of cascaded bandpass limiters will also, successively, (a) increase the maximum permissible values of the time constants in the discriminator and limiter circuits; (b) decrease the effectiveness of the audible harmonic content of the detected instantaneous frequency spike trains when the difference frequency between the two paths (hence, the frequency of recurrence of the detected spikes) is audible; (c) decrease the minimum required bandwidth in the ideal filters following the succeeding ideal limiters (perhaps a matter of secondary importance, in practice).

In view of these disturbance-reducing qualities, such a chain of bandpass limiters appears indispensable in any real attempt to combat cochannel and multipath disturbances. In fact, we suspect that the use of such a chain (seven limiters in all) might well have been a major contributor (in addition to the careful design of the receivers) to the success achieved in the laboratory type of transatlantic FM receivers — success previously attributed to the use of "wideband" limiters (which in the light of the plots of Figs. IX-1 and IX-4 in the Quarterly Progress Report of Oct. 15, 1954, can still be classed as "bandpass") and discriminators.

1. Time-Constant Requirements

Assuming a grid-circuit limiter of the form shown in Fig. VII-1 (which is more or less the standard type of limiter with a time constant) and assuming the usual type of operation, we find that the maximum permissible time constant varies (under two-path conditions) in accordance with the curves plotted in Fig. VII-2. In this figure, $\tau_n = W_{IF}CR$, where W_{IF} is the i-f bandwidth in cycles per second, has been used as a convenient dimensionless parameter. The requirements at the grid circuit of the first limiter, following the intermediate frequency, have an upper bound defined by τ_{no}. In the grid circuit of the second limiter, the upper bound is defined by τ_{n1} when the first
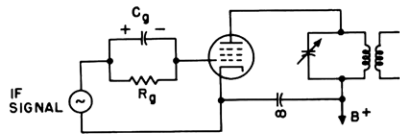
Fig. VII-1
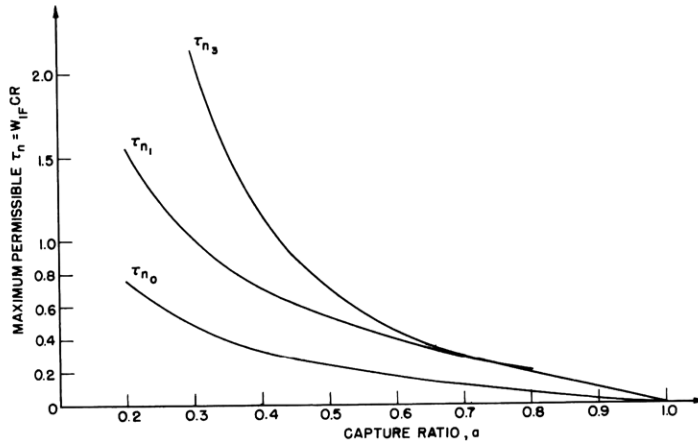
Grid-circuit limiter for
time-constant computation.

Fig. VII-2

Variation of the maximum permissible values
of the grid-circuit time constant with the ratio
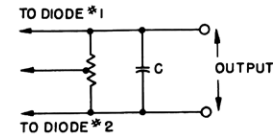of weaker to stronger signal, a.

Fig. VII-3

Discriminator output circuit
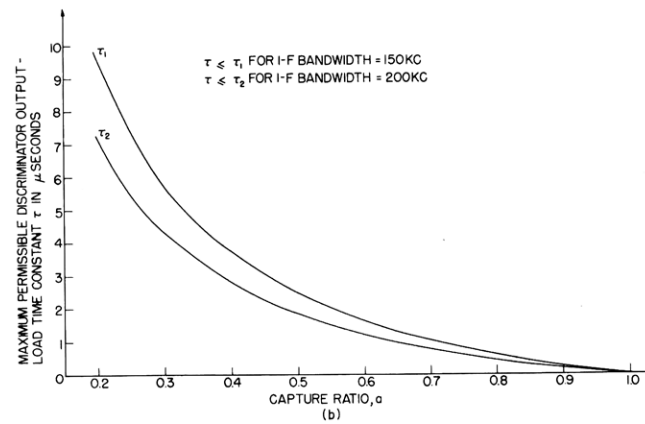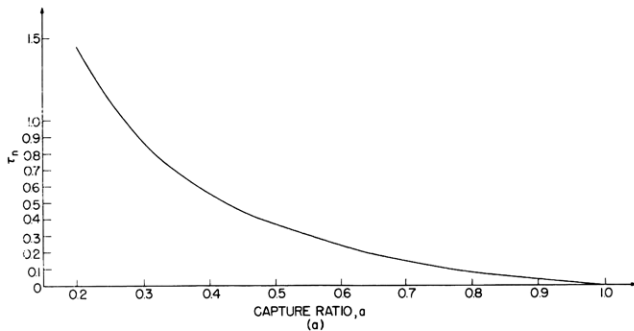for time-constant computation.

Fig. VII-4

Variation of the maximum permissible values of the discriminator output-circuit
time constant with the ratio of weaker to stronger signal, a.

ideal limiter bandwidth equals W_{IF}; τ_{n3}, when the first limiter bandwidth equals $3W_{IF}$.

In the discriminator circuit, the output circuit across which the voltage level (varying with the instantaneous-frequency variations of the signal impressed upon the discriminator) is taken, may be reduced to the form shown in Fig. VII-3. Clearly, if the average value of this voltage level is to correspond to the value dictated by the frequency of the stronger signal, the RC combination must be able to follow the voltage variations dictated by the instantaneous frequency spike train. Straightforward analysis reveals the curve for the maximum permissible $\tau_n = W_{IF}RC$ values shown in Fig. VII-4(a). Here, as in Fig. VII-2, W_{IF} is the i-f bandwidth in cycles per second. Figure VII-4(b) shows the discriminator output-circuit maximum permissible time constants, in microseconds, for two common values of i-f bandwidth. Numerical computation to determine the effect of preceding the amplitude-insensitive discriminator with one stage of narrow-band limiting is being completed.

2. Problem of Audible Spike Repetition Rates

In general, after the instantaneous-frequency variations are properly translated into instantaneous voltage variations (about the direct-voltage level dictated by the frequency of the stronger signal), those voltage variations are modified by the action of the de-emphasis and audio filters fed by the discriminator output. If the difference frequency between the two paths lies beyond the audible range (as it will do much of the time) the Fourier components of the recurrent spike train will all be filtered out by the lowpass filters, effectively marking the end of the disturbance caused by the presence of the weaker signal. However, when the difference frequency between the two paths is audible, the component of the fundamental frequency, plus a number of harmonics depending upon the position of this frequency in the audible spectrum, will pass through the lowpass filters and will be heard in the output signal.

Note that two factors play more or less obvious roles in minimizing the importance of the disturbance that leaks through: the action of the two lowpass filters in rejecting most of the harmonic components, and the fact that the magnitude of each interference spike (and hence the amplitude of each constituent Fourier component of the detected spike train) is directly proportional to the value of the difference frequency. Consequently, even though more undesired harmonics of the difference frequency are likely to get through the lowpass filters as this difference frequency assumes lower and lower values in the audio range, the amplitudes of the passed components will also be lower and lower.

A third important factor in minimizing the effect of the disturbance when the difference frequency is audible, is the effect of narrow-band limiting upon the shape and amplitude of the spike trains. Both the relative values of the harmonics and the values of
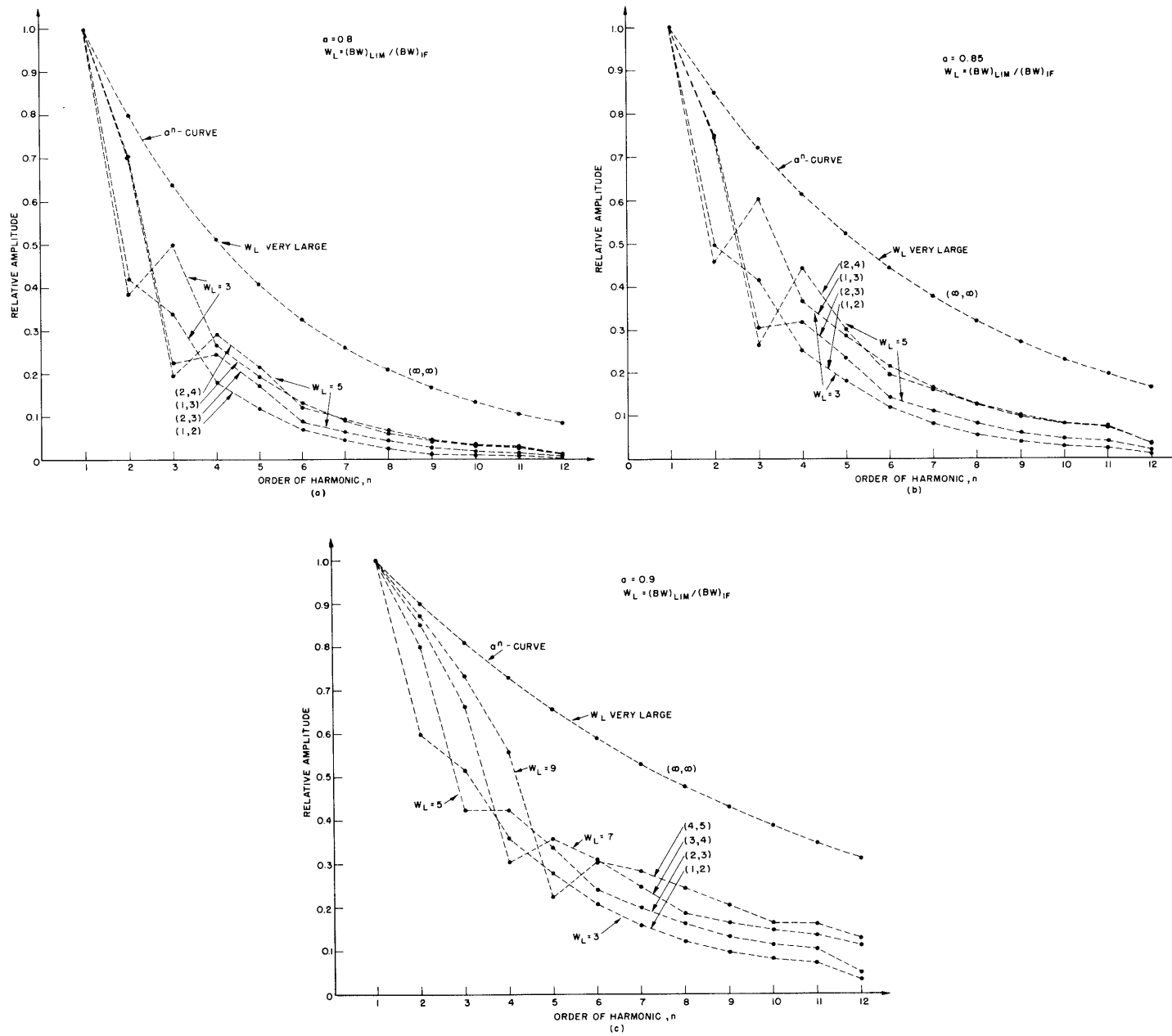
Fig. VII-5

Plots of the relative harmonic amplitudes in the structure of the detected instantaneous frequency spike train.

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the individual amplitudes are reduced by the action of the limiter filter. Curves illustrating the harmonic amplitude reduction caused by limiter filter action are shown in Fig. VII-5(a, b, c). In this figure, the numbers in parenthesis associated with each curve and arranged in the order (M, N) are M = number of lower sideband components passed by the first limiter ideal filter, and N = number of upper sideband components passed. (The weaker signal is assumed to have a slightly higher frequency than that of the stronger signal.) Also, the parameter W_L denotes the limiter bandwidth used in units of one i-f bandwidth.

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