Prof. E. J. Baghdady   Prof. J. B. Wiesner   F. I. Sheftman
K. P. Luke

A. AN OSCILLATING LIMITER FOR THE SUPPRESSION OF INTERFERENCE IN FM RECEIVERS

A study has been made of the locking and interference suppression characteristics of an oscillating limiter (1, 2, 3). A summary of the results follows.

It has been shown that interaction between two signals, $E_s \cos pt$ and $aE_s \cos(p+r)t$, causes a frequency disturbance in the form of frequency spikes, whose amplitudes are a function of the interference ratio a and the frequency difference r between the two signals. When positive bandlimited feedback is applied around the limiter, the interference ratio a and, consequently, the amplitudes of the frequency spikes are reduced, as predicted by Baghdady (1, 2, 3) and shown in Fig. X-1.

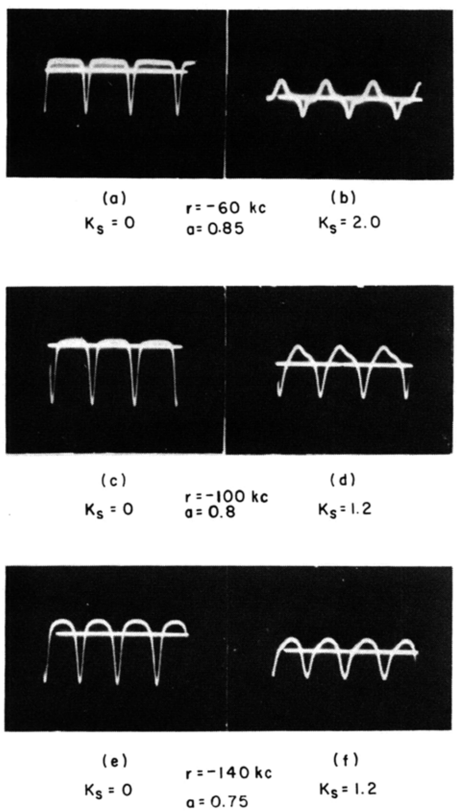

Fig. X-1. Effect of positive feedback around the limiter on the frequency spikes that result from interaction between the two signals, $E_s \cos pt$ and $aE_s \cos(p+r)t$. K_s is the feedback factor.

It was also predicted (1, 2, 3) that positive bandlimited feedback decreased the limiting threshold of a practical limiter through an increase in the effective signal amplitude seen by this limiter. Figure X-2 shows typical cases in which the effective signal amplitude seen by the limiter is increased by positive feedback, and Fig. X-3 shows a corresponding improvement of the output waveforms. Figure X-4 shows the famous "noise-squelching" effect of an oscillating limiter in the absence of an input signal.

Interference generally has a detrimental effect on the locking range and locking threshold of an oscillating limiter. Figures X-5 and X-6 show plots of the locking range and locking threshold of an oscillating limiter as a function of the interference ratio a. For simplicity, and to illustrate the most unfavorable condition of interference, an unmodulated

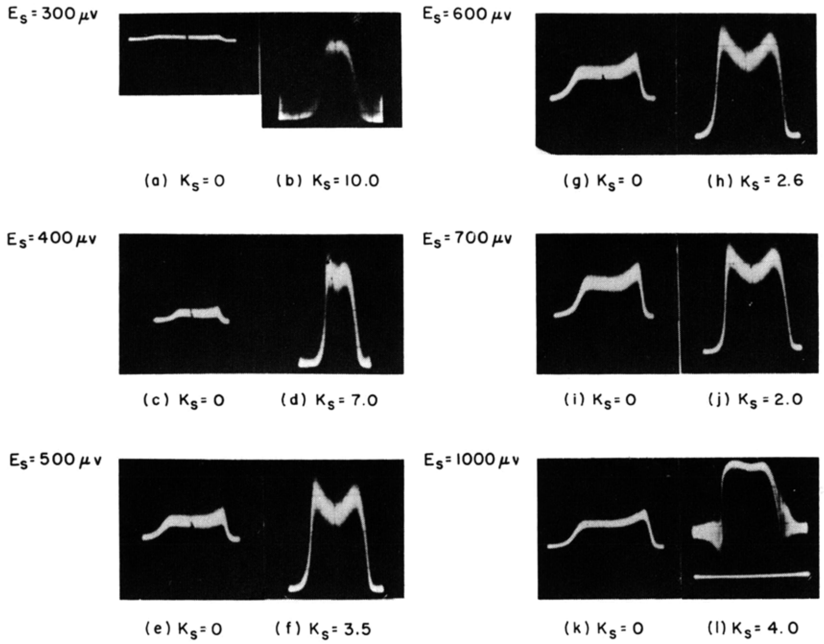

Fig. X-2. Effect of positive feedback around the limiter on the input-signal levels to the limiter for different input-signal levels to the i-f amplifier.

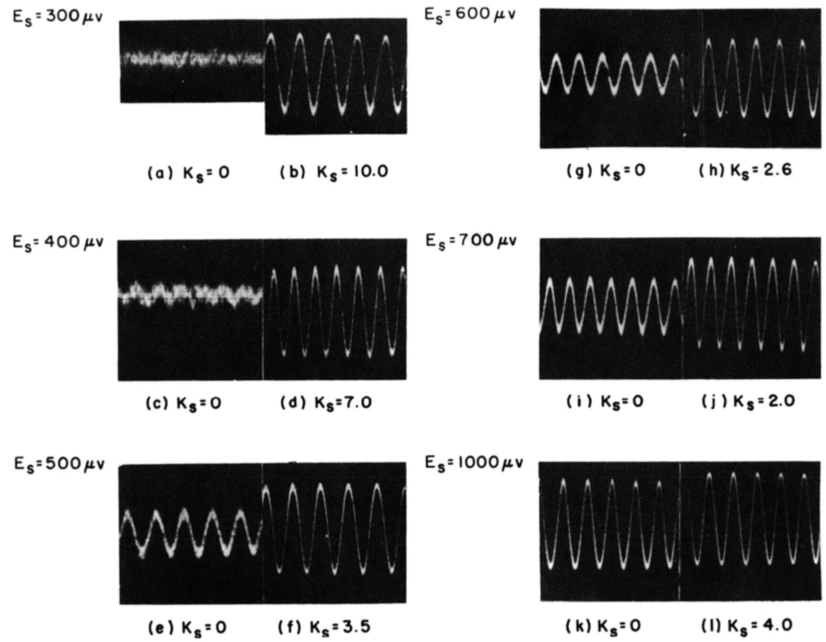

Fig. X-3. Effect of positive feedback around the limiter on the quality of the output signals for different input-signal levels to the i-f amplifier. $\Delta f = \pm 20$ kc.

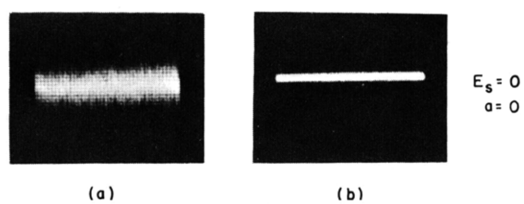

Fig. X-4. Noise-squelching effect of an oscillating limiter in the absence of an input signal: (a) without feedback; (b) with feedback.

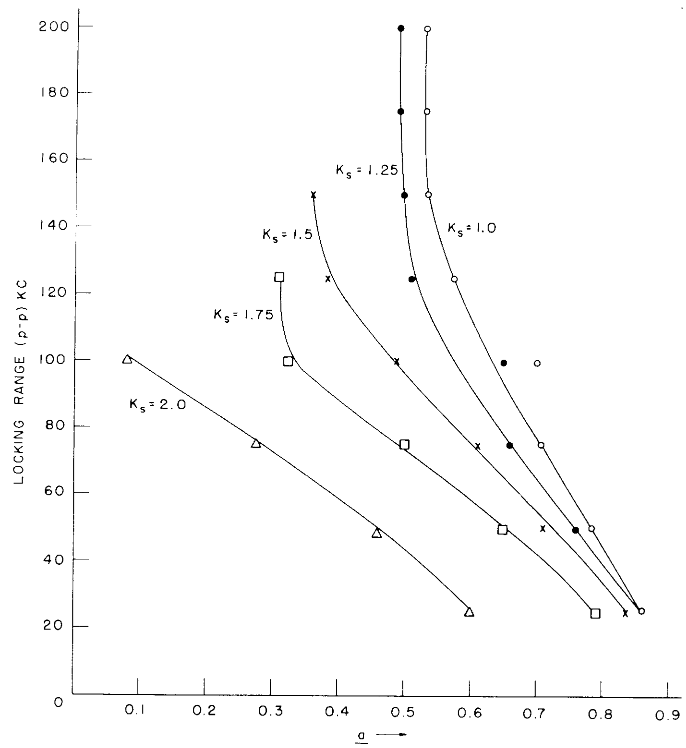

Fig. X-5. Locking range versus a characteristics for an oscillating limiter.

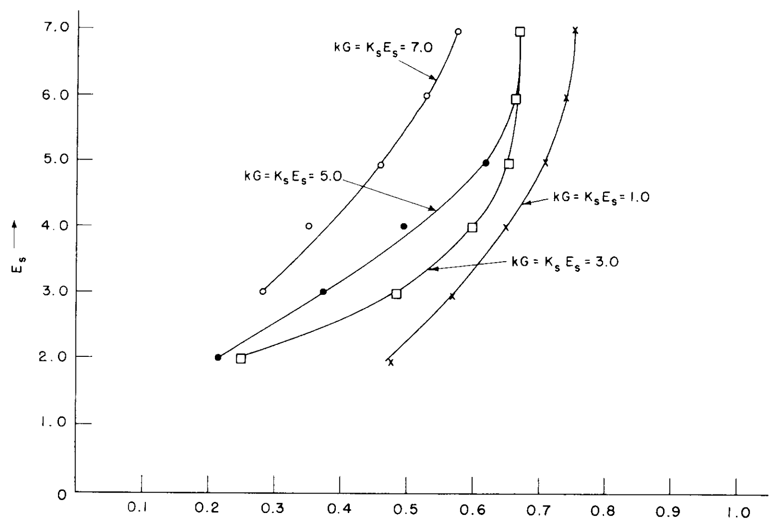

Fig. X-6. Locking threshold versus a characteristics for an oscillating limiter. Locking range, 120 kc p-p.

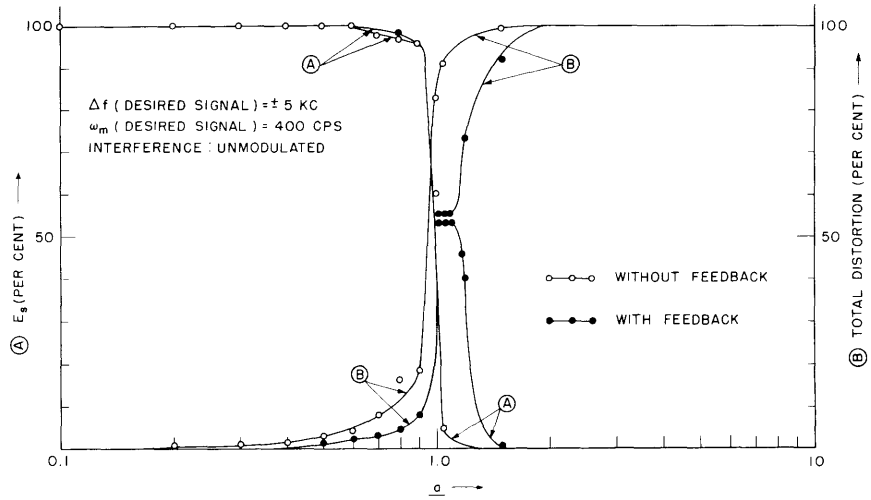

Fig. X-7. Capture characteristics of receiver.

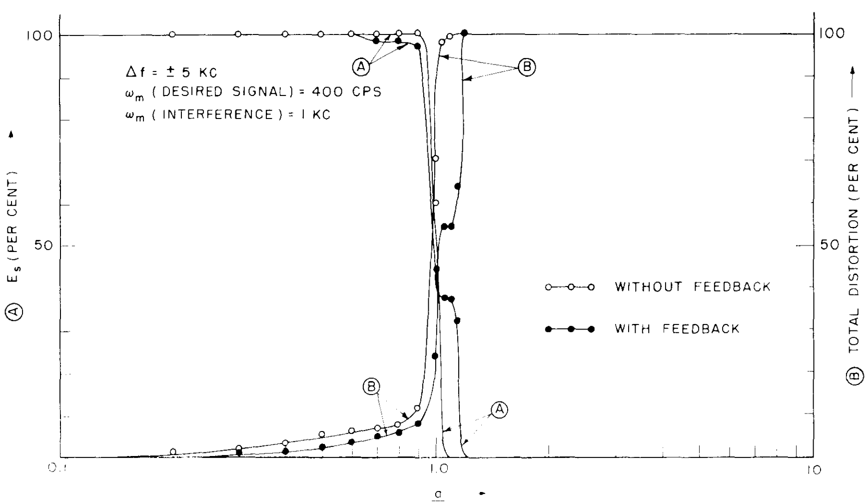

Fig. X-8. Capture characteristics of receiver.

signal at the center of the i-f passband was chosen for the interference.

The capture characteristics of the receiver are plotted in Figs. X-7 and X-8. The remarkable features of these capture curves when feedback is applied are: (a) the reduction in total distortion, and (b) the significant increase in the desired signal output and decrease in total distortion for the values of a that are near unity. In the measurements that led to the capture curves of Figs. X-7 and X-8, the two signals are at the center of the i-f passband. In Fig. X-7 the desired signal is modulated with a deviation of ±5 kc, and the interference is unmodulated; in Fig. X-8 each signal is modulated with a deviation of ±5 kc. The modulation frequencies are 1 kc for the weaker signal, and 400 cps for the stronger signal.

K. P. Luke

References

1. E. J. Baghdady, Theory of feedback around the limiter, IRE National Convention Record, Part 8, 1957, pp. 176-202.
2. E. J. Baghdady, Interference rejection in FM receivers, Sc.D. Thesis, Department of Electrical Engineering, M.I.T., May 1956.
3. K. P. Luke, The locking and interference suppression characteristics of an oscillating limiter, S.M. Thesis, Department of Electrical Engineering, M.I.T., Sept. 1958.

B. CAPTURE OF THE WEAKER SIGNAL

A receiver capable of capturing the weaker of two cochannel FM signals has been constructed and tested in the laboratory. It utilizes standard frequency-conversion techniques and a fixed trap to suppress the stronger signal without materially distorting the weaker signal (1).

In the experimental model the weaker signal can be received satisfactorily in the presence of an interfering signal that is more than twenty times as strong. For voice modulation, the output is perfectly intelligible and is useful for many applications, although some noise and cross talk are present. Decreasing the relative strength of the interfering signal improves the quality of the output but does not quite render it

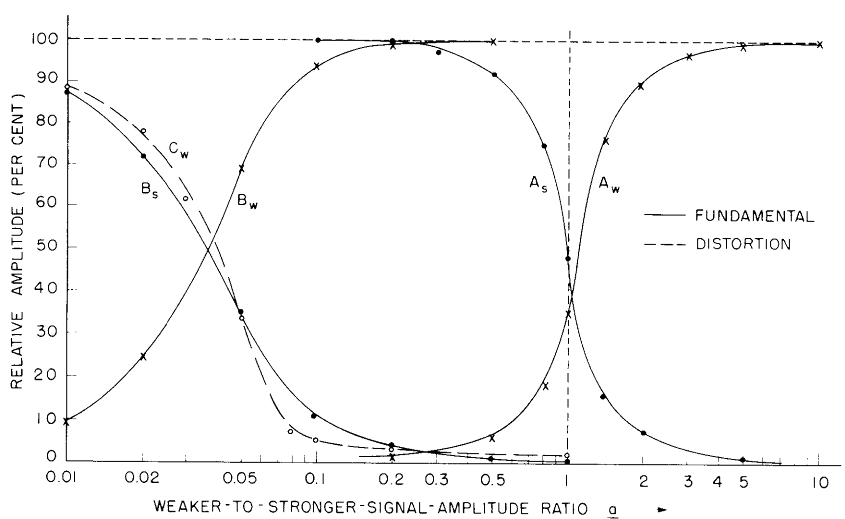

Fig. X-9. Capture characteristics of conventional and fixed-trap receivers. All curves are for cochannel signals for a deviation of ±75 kc. Subscripts refer to strong and weak signals.

suitable for high-fidelity applications.

A quantitative measure of the receiver performance can be obtained by use of single tones, instead of voice or music, to modulate each signal. A plot of the fundamental and of the distortion of each tone versus the input interference ratio a (weaker-to-stronger-signal-amplitude ratio) gives the complete capture characteristic of the system. Curves A_w and A_s of Fig. X-9 show the capture characteristics of a conventional FM receiver when both signals are centered in the middle of the passband. The deviation is ±75 kc for each signal, and the modulating tones are 400 cps and 1 kc for the strong and weak signals, respectively. Curves B_s and B_w represent the output of the weak-signal receiver for the same input. It will be observed that the capture-transition region is now centered at a ≈ 0.04 instead of at a = 1, as in the conventional receiver. The quality of the weak signal is indicated by the total distortion of the fundamental (curve C_w), which shows a good output for a ≈ 0.1.

The best performance of the present experimental receiver is obtained when the stronger signal is unmodulated or when its modulating frequency is low and the deviation is small. Curve D_w of Fig. X-10 gives the fundamental of the weak signal in the presence of an unmodulated stronger signal. The distortion curve E_w shows that the output is quite good for a ≈ 0.01.

Curves F_w and F_s indicate the performance for a deviation of ±35 kc for each

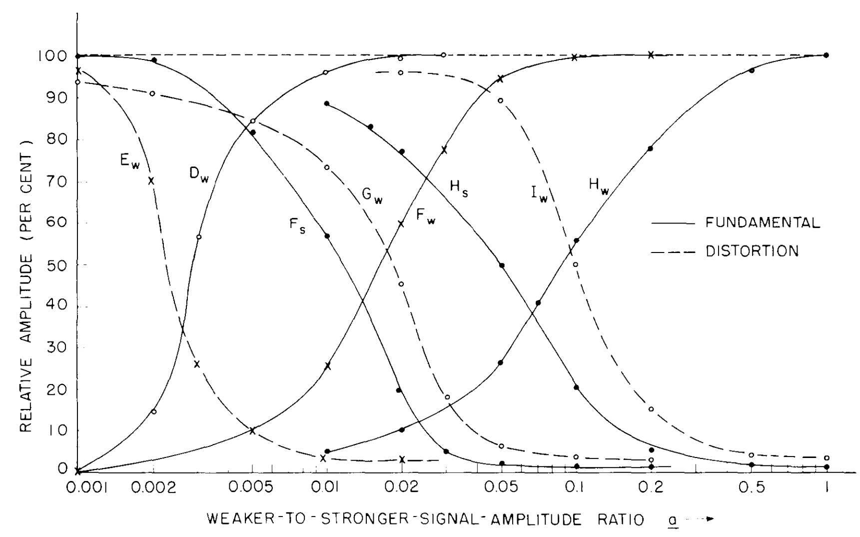

Fig. X-10. Limitations on capture performance of the receiver. Curves D_w, E_w, H_w, I_w, H_s represent a deviation of ±75 kc; curves F_s, F_w, and G_w, a deviation of ±35 kc. All modulating frequencies are the same except for curves H_s, H_w, and I_w, in which they are interchanged.

carrier, with the same choice of modulating tones as before. Curve G_w shows the quality of the output, which is quite good for a ≈ 0.03. The most serious limitation of the present system is demonstrated by curves H_s and H_w which result from interchanging the modulating tones. The strong signal is now modulated by the 1-kc tone; and curve I_w clearly shows that the output is rather distorted for all a up to approximately 0.5.

All of the foregoing data were taken for the maximum attainable trap attenuation (approximately 0.001) and for a constant trap bandwidth of approximately 10 kc between the frequencies at which transmission is 0.3 per cent of the maximum. Since ordinary music and voice waveforms have an average value that is less than 50 per cent of the peak value, curves F_w, F_s, and G_w describe the output of the system under typical broadcast operating conditions.

F. I. Sheftman

References

1. F. I. Sheftman, A fixed-trap system for capturing the weaker of two co-channel FM signals, S. M. Thesis, Department of Electrical Engineering, M. I. T., Sept. 1958.