

VII. FREQUENCY MODULATION

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A. SUPPRESSION OF TWO INTERFERING SIGNALS

With more than one extraneous signal present at the input of the limiter the mathematical analysis of the spectrum of the amplitude-limited resultant signal becomes intractable. But some general and useful statements can be made. The simplest, most general form in which we can express the sum of three sinusoids is

$$e(t) = E_s \cos pt + aE_s \cos (p+r)t + bE_s \cos [(p+q)t + \psi]$$

where ψ is some relative phase angle that can take on any value between 0 and 2π with equal probability. In the absence of zero crossings in the envelope of $e(t)$, the amplitude-limited resultant signal can be expressed in the form

$$e_l(t) = k \cos [pt + \theta(t)]$$

$$= k \sum_{m, n=-\infty}^{\infty} B_{m, n}(a, b, \psi) \cos (p-nr-mq)t$$

This expression shows that the spectrum at the limiter output will contain components at $p \pm nr \pm mq$ rad/sec, with $m, n = 0, 1, 2, \dots$. Thus, in addition to the components at the strongest-signal frequency p and at frequencies $p \pm nr$ and $p \pm mq$, there will, in general, be components at frequencies in between. The amplitudes of the various spectral lines will depend upon the relative signal amplitudes, as well as upon the initial phase ψ .

Figure VII-1 illustrates the effect of successive narrow-band limiting of the resultant of three sinusoids of different amplitudes and different frequencies (1). The strongest signal is visibly enhanced in all of these oscillograms, even when the sum of the two weaker signals, properly phased, exceeds the amplitude of the strongest signal.

A system that will make it possible to select the desired signal out of any three sinusoids under conditions of abutting- or adjacent-channel interference is shown in Fig. VII-2. Each feedforward system can be adjusted so that one of the three incoming signals is suppressed. The method, evidently, can be extended to separate more than three signals. Trapping techniques can also be utilized under suitable conditions to suppress one or more undesired signals.

In a recent investigation, R. G. Griffin (1) constructed an experimental system according to the block diagram of Fig. VII-2. The performance of this system is illustrated (1) in Fig. VII-3. The isolation of each of the three input sinusoids requires

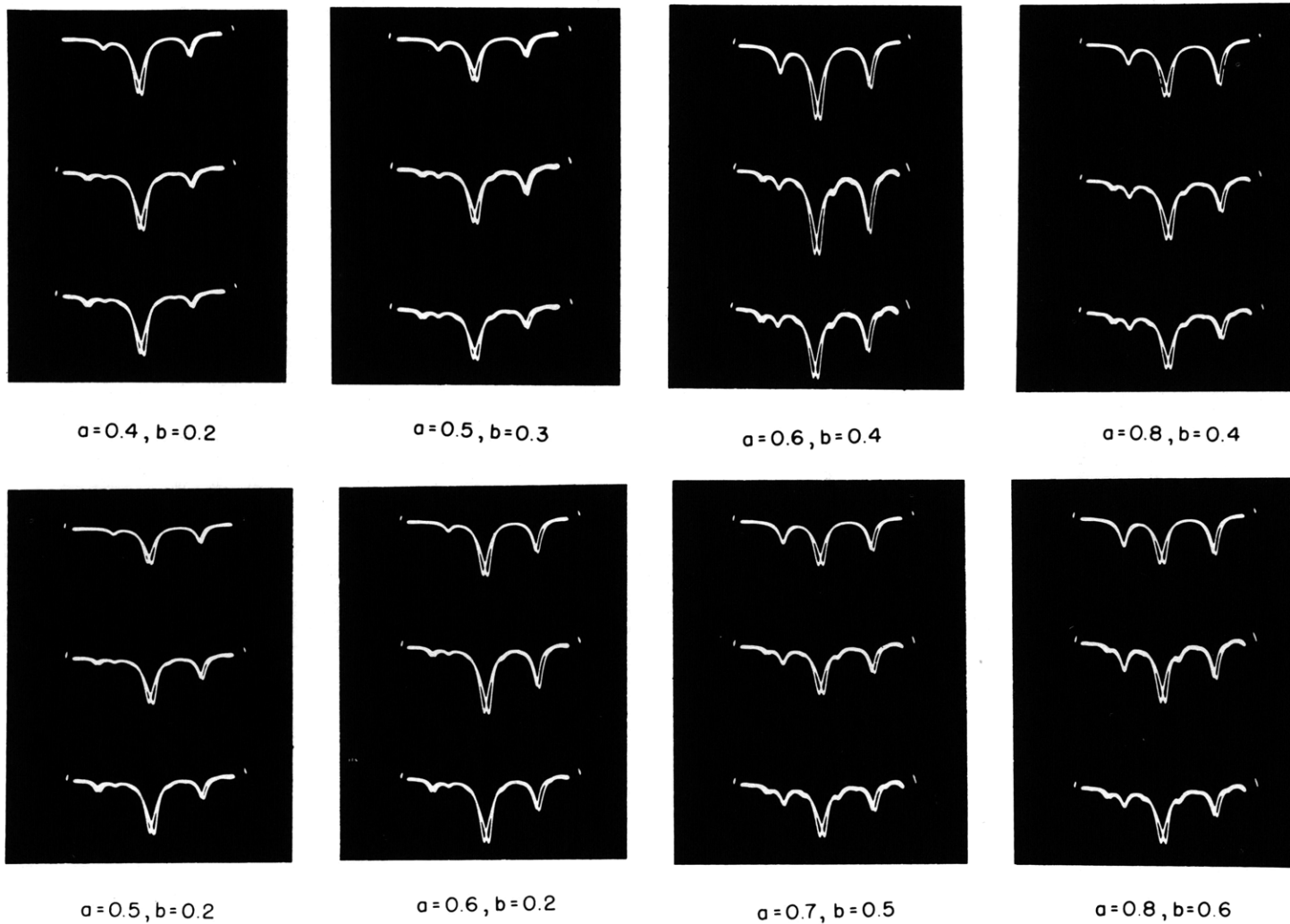


Fig. VII-1. Effect of two successive narrow-band limiting operations upon the sum of three input sinusoids of different amplitudes and different frequencies. Top trace: input spectrum. Middle trace: spectrum at output of first narrow-band limiter. Bottom trace: spectrum at output of second narrow-band limiter.

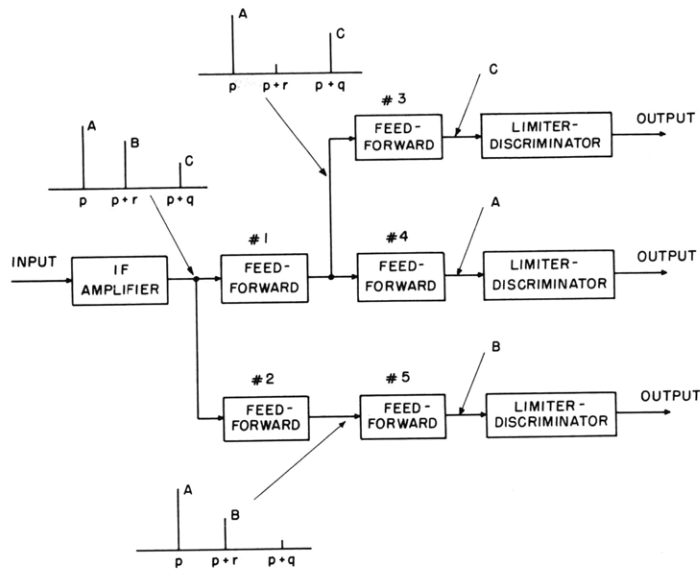


Fig. VII-2. A system that enables the selection of a desired signal from three sinusoids of different amplitudes and different frequencies.

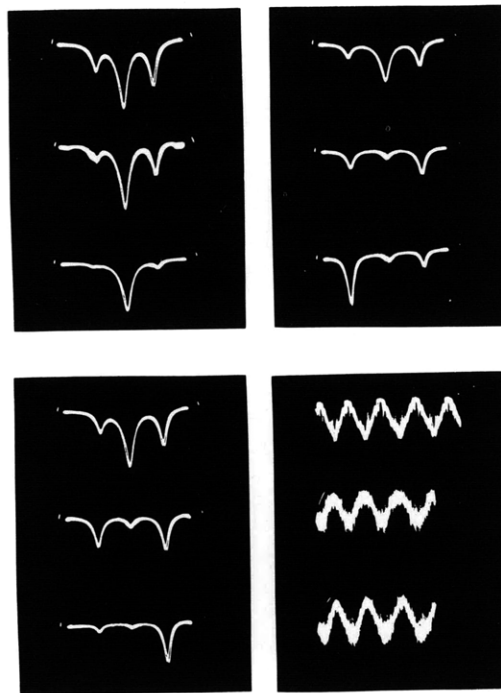


Fig. VII-3. Performance of an experimental realization of the system of Fig. VII-2. In the first, second, and third quadrants: Top trace shows input spectrum; middle trace shows spectrum after one feedforward operation; bottom trace shows spectrum after two feedforward operations. In the fourth quadrant: Retrieved tone from each of three sinusoidally modulated FM signals.

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two successive feedforward operations. When the three sinusoids are frequency-modulated so that their instantaneous frequencies sweep three separate, but contiguous, frequency channels of the same width, the three limiter-discriminator combinations shown in Fig. VII-2 deliver the waveforms shown in the fourth quadrant of Fig. VII-3. Three modulation frequencies, 100 cps, 400 cps, and 1 kc, were used; in order to stabilize the trace more easily, the 100-cps tone was always applied to the signal that was to be observed at the output. Most of the noise shown can be reduced by circuit design (mainly in the limiter-discriminator sections) that will contend with the reductions in signal level caused by the successive signal cancellations.

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References

1. R. G. Griffin, A multi-carrier, single-channel FM multiplex system, S.M. Thesis, Department of Electrical Engineering, M.I.T., August 1959.