8.2: FREQUENCY-SELECTIVE LIMITING

K. L. KOTZEBUE

Watkins-Johnson Company, Palo Alto, California

In the usual microwave limiter the presence of a large signal above a certain threshold power level produces a change in gain or attenuation of the device so that the output power level of this signal remains approximately constant as the input level is varied. This characteristic is desirable in many applications to provide crystal burnout protection in a receiver, act as a power leveler, etc. When more than one signal is present, however, such a limiter will have the undesirable property of increasing the attenuation of a small signal which is also within the passband of the limiter. Thus, while a receiver may be protected from permanent damage by such a limiter, it would be rendered inoperative whenever a strong signal is present.

While considerable work has been done on the properties of passive limiters utilizing some form of ferrite, there has been little or no work done on the behavior of these devices in the presence of multiple signals to ascertain whether suppression of small signals does indeed occur. It is therefore felt to be of interest to report on some recent investigations of limiting in low-power, coincidence mode ferrite limiters. Such limiters use low-loss single crystal ferrimagnetic material operated at ferrimagnetic resonance, as first described by DeGrasse[1]. For certain frequency ranges determined by the characteristics of the material used, these limiters exhibit rather low threshold powers[2-4].

The investigations which have been conducted on the limiting properties of such low-power limiters have been at C band using lithium ferrite and at S band using yttrium iron garnet. In the presence of multiple signals both limiters behaved in a similar fashion: when more than one signal was within the passband of the limiter, but separated one from another in frequency by about one megacycle or so, independent limiting of each signal was observed. Thus if two signals were present and below limiting, increasing one signal above limiting did not affect the second signal.

One experiment which was performed at S band was to apply a C-W signal at a power level above limiting, and a square-wave modulated signal below limiting. The amplitude of the modulated signal was then observed as the frequency of the large signal was varied. The bandwidth of the filter was about 9 Mc/s and the insertion loss was about 1.5 db.

Figure 1 shows the frequency separation required between the two signals in this experiment in order to suppress the small signal by 3 db. As the large signal power is increased, greater separation is required to avoid suppression of the small signal. Figure 2 shows how a small signa

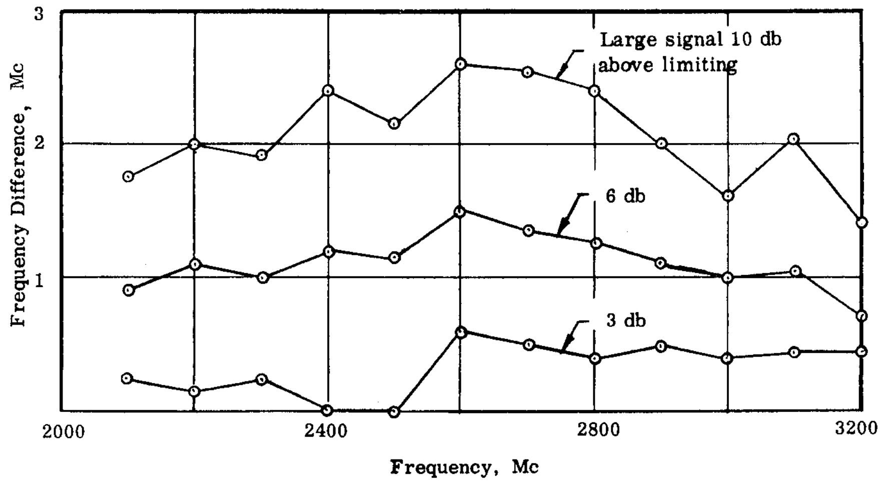

Fig. 1. Frequency difference required to produce 3 db suppression of a signal below limiting level of filter.

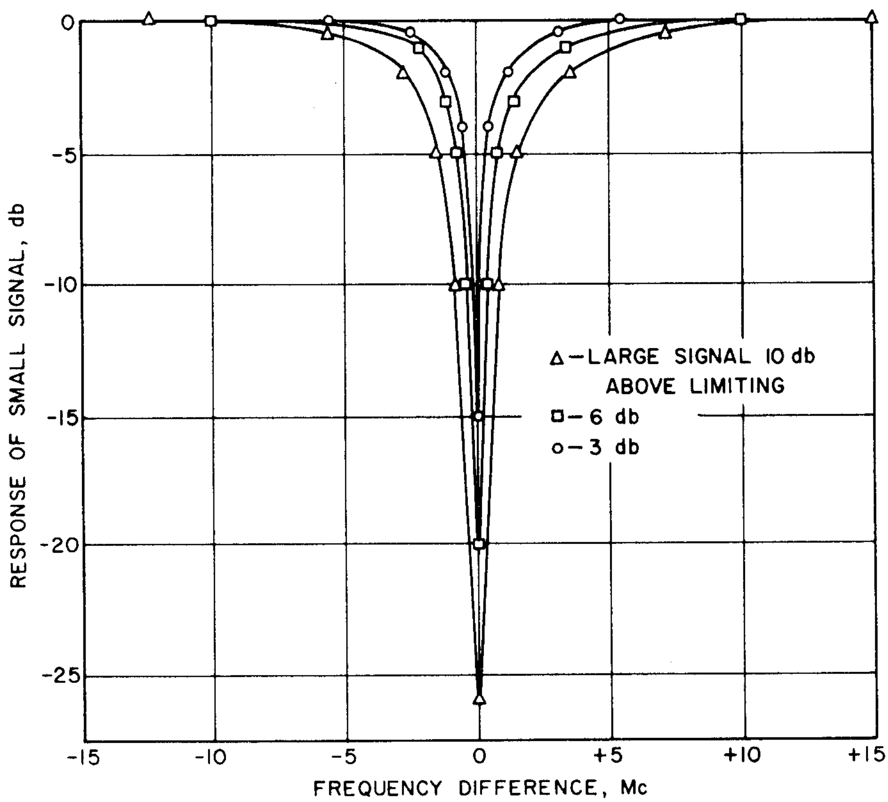

Fig. 2. Small signal suppression at 2700 Mc/s as a function of frequency difference.

at 2700 Mc/s is suppressed as the frequency and power of the large signal is varied. Quite high suppression occurs when the two signals coincide.

Measurements were also made with two unmodulated signals detected with a power meter to verify the observed characteristics described above. With two signals spaced several megacycles apart, the total output power from the limiter with both input signals above threshold was twice that with only one signal present. When the two signals were brought into frequency coincidence, the total output power declined to become very close to that obtained with only one signal present.

We can obtain a qualitative explanation of this frequency-selective limiting characteristic by noting that the mode of limiting involved is closely analogous, to a degenerate passive parametric limiter in which pump power supplied to a degenerate parametric oscillator is transferred to an oscillation at half pump frequency when a certain threshold has been exceeded[5,6].

Using the parametric limiter as a model, we may ask what will happen when two pump signals are simultaneously applied to this limiter. If these signals are of frequencies such that their respective half frequencies both fall within the bandwidth of the sub-harmonic oscillator, it would then be expected that both would contribute to a sub-harmonic oscillation and both would be limited in some complex manner. However, if one of the pump signals were outside of the pass-band and the sub-harmonic oscillator, it would not be limited. If we now take a second sub-harmonic parametric oscillator and also couple it to the pump circuit, it would be possible to independently limit two signals which are separated in frequency by at least the bandwidth of the oscillators. By increasing the number of oscillators, we can independently limit a large number of signals, and thus approximate a device which limits on a frequency-by-frequency basis.

A ferrite resonator is a good approximation to this model, for it possesses a large number of closely-spaced high-Q spin-wave modes. Such a limiter is therefore a possible frequency-selective limiter.

This frequency-selective mode of limiting appears to be potentially useful in both research and in application. In research it can be a useful tool to investigate spin-wave phenomena in a manner not previously possible; in practical application it can be useful in the construction of filters which protect sensitive receivers from saturation by high-level interferring signals while allowing the passage of the desired small signal without suppression. In the latter case it should be possible to build relatively broadband fixed-tuned limiters which possess this frequency characteristic; preliminary measurements have shown no significant change in this characteristic as the instantaneous bandwidth of the device is increased.

1. R. W. DeGrasse, "Low-loss Gyromagnetic Coupling Through Single Crystal Garnets," J. Appl. Phys., Suppl. to 30, 155S-156S (1959).

2. E. G. Spencer, R. C. LeCraw and C.S. Porter, "Ferromagnetic Resonance in Yttrium Iron Garnet at Low Frequencies," Appl. Phys. 29, 429-430 (1958).

3. F. V. Sansalone and E. G. Spencer, "Low-Temperature Microwave Power Limiter," Trans. IRE MTT-9, 272-273 (1961).

4. F. C. Rossol, "Power Limiting in the 4-kMc to 7-kMc Frequency Range using Lithium Ferrite," Proc. IRE 49, 1574 (1961).

5. A. E. Siegman, "Phase-Distortionless Limiting by a Parametric Method," Proc. IRE 47, 447-448 (1959).

6. A. A. Wolf and J. E. Pippin, "A Passive Parametric Limiter," Digest of Technical Papers, 1960 International Solid-State Circuits Conference, 90-91 (1960).