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# SELF ADAPTIVE BANDPASS FILTERS WITH APPLICATIONS TO 'FREQUENCY SET-ON' OSCILLATORS

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## Abstract

There are many potential applications particularly at microwave frequencies, for filters whose characteristics vary according to the signal applied to the device. Self adaptive bandpass filters are one class which produce a bandpass characteristic around the carrier frequency of a signal. One application is in multimode oscillators where any mode will then be stable when excited by a sample of an r.f. pulse.

## Summary

Self adaptive filters are devices whose transfer characteristics vary as a function of the applied signal. Bandpass devices should produce a characteristic which passes the carrier frequency but suppresses any modulation, noise or other signals away from the carrier.

Initial consideration was given to filters containing resonant elements plus varactors and Schottky diodes. Resistive impedances of the diodes can vary as a function of power and the resulting change of d.c. voltages could change the r.f. capacitance of the varactors. However, assume that a simple bandpass characteristic can be produced in this manner such that the centre frequency occurs at the instantaneous frequency of the applied signal. Then such a device will track the instantaneous frequency and allow any frequency modulated signal to pass through the filter. Thus, a self-adaptive bandpass filter has not been constructed.

To understand the concept of self-adaptive filters, it is important to consider the instantaneous frequency of a signal. If a signal is limited in amplitude and then in bandwidth, the instantaneous frequency is well defined. The instantaneous frequency will then possess a constant value (carrier frequency) plus a time varying component. To extract the constant value we must therefore produce a process which effectively lowpass filters the instantaneous frequency. Such networks may provide an output instantaneous frequency $\omega_o(t)$ which is related to an input instantaneous frequency $\omega_i(t)$ by:

$$W_o(p) = F(p) \cdot W_1(p) \qquad (1)$$

where $W_o(p)$ and $W_1(p)$ are Laplace transforms of the instantaneous frequencies and $F(p)$ is the transfer function of the linear frequency network. For a self adaptive bandpass filter $|F(j\Omega)|^2$ has to be lowpass in $\Omega$.

In the case of a signal frequency modulated by a sinusoidal baseband signal, the output of this network provides a signal at the carrier frequency. In terms of spectral components of the real signal, the modulated signal need not possess a component at the carrier frequency and since the output contains only this component, the linear frequency network must perform a non-linear action on the real signal.

Some of the components which may form a linear frequency network with their associated transfer functions are:

1. Delay Line

$$\omega_o(t) = \omega_i(t-\tau)$$
$$F(p) = z = e^{-p\tau} \qquad (2)$$



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2. <u>Frequency Multiplier + Bandpass Filter</u>

$$\omega_0(t) = K\omega_i(t) \;, \quad F(p) = K$$
$$K > 1 \quad \text{(normally an integer)} \tag{3}$$

3. <u>Frequency Divider + Filter</u>

$$\omega_0(t) = K\omega_i(t) \;, \quad F(p) = K$$
$$1/K > 1 \quad \text{(normally an integer)} \tag{4}$$

4. <u>Lower Sideband Mixer + Filter</u>

$$\omega_0(t) = \omega_1(t) - \omega_2(t) \tag{5}$$

where $\omega_1(t)$ and $\omega_2(t)$ are the input frequencies.

5. <u>Upper Sideband Mixer + Filter</u>

$$\omega_0(t) = \omega_1(t) + \omega_2(t) \tag{6}$$

The last two components allow the basic elements of a linear frequency network to be interconnected.

If all of the delays in the network are commensurate, i.e. integer values of $\tau$ then for any network

$$F(p) = H(z) \tag{7}$$

where $z = e^{-p\tau}$ and $H(z)$ is a rational function in z and may be expressed as the ratio of two polynomials.

Obviously $H(z)$ is a periodic function of $p = j\omega$ and therefore true lowpass characteristics cannot be achieved. However, if the bandwidth of the spectral components of the instantaneous frequency are limited, then quasi-lowpass characteristics will suffice.

<u>Lowpass Linear Frequency Network</u>

One possible transfer characteristic is

$$|H(z)|^2_{p=j\omega} = \frac{1}{2^{2n}} \left[\frac{\sin(2^{n-1}\Omega\tau)}{\sin(\Omega\tau/2)}\right]^2 \tag{8}$$

which is similar to the sinc function

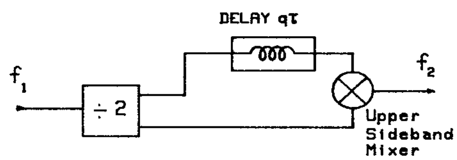
Recovering the bounded real transfer function we have

$$H(z) = \frac{1}{2^n}\left[\frac{1-z^{2n}}{1-z}\right]$$
$$= \frac{1}{2^n} \sum_{i=0}^{2^{n-1}} z^i$$
$$= \frac{1}{2^n} \prod_{i=1}^{n} (1 + z^q) \qquad q = 2^{i-1} \tag{9}$$

which represents a cascade of n sections each with a transfer function

$$\frac{(1 + z^q)}{2} \qquad q = 2^{i-1} \tag{10}$$

This section is then realised by a divide by 2 frequency divider which feeds into two paths, one direct and one with a delay $q\tau$ . to an upper sideband mixer which feeds the output as shown in Fig. 1.




<u>FIG. 1</u>

<u>Three Stage Filter</u>

A three stage filter operating over the band 400 - 600 MHz has been constructed. An ECL divide by two circuit was used with dual output to feed the two paths through the filter. The delay over the 200 - 300 MHz band was achieved by a cascade of lumped element all-pass sections as shown in Fig 2 where each stage contained 3, 6 and 12 sections respectively providing 6, 12 and 24 ns delay. Both arms were then fed into lumped element lowpass filters with a cut-off frequency at 300 MHz and greater than 50 dB attenuation from 400 to 600 MHz. The combining mixer was a double balanced diode mixer which was then followed by a lumped element 400 - 600 MHz bandpass filter providing greater than 50 dB attenuation below 300 MHz. The three stages were then cascaded to provide the complete filter.

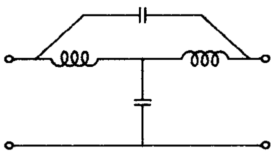


FIG. 2
All-Pass Section

To test the device, broadband noise was introduced into the input together with a higher power level single frequency signal which could then be sept over the band. A typical response, as measured on a spectrum analyser, is shown in Fig 3 indicating the sinc(x) function response around the carrier frequency.

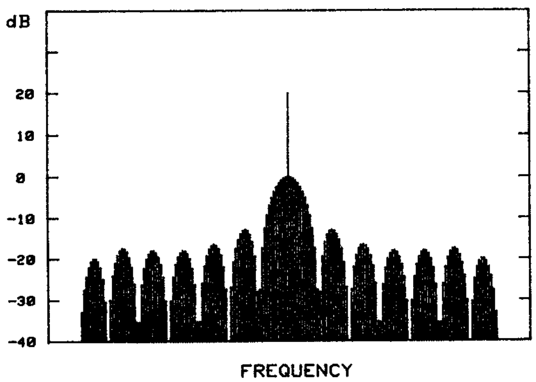



FIG. 3 Response of 3 stage self adaptive bandpass filter

## Frequency Set-On Oscillator

A multimode oscillator may readily be constructed using an amplifier and a delay line. If a self adaptive bandpass filter is now inserted, then if the oscillator is triggered into one mode of oscillation by an r.f. pulse, then the filter will prevent the build up of energy in the other modes resulting in a stable mode of oscillation.

A 'Frequency Set-On' Oscillator was formed by connecting the output of the third stage of the self adaptive bandpass filter back to the input. Due to the threshold requirement on the input comparators of the ECL divider no spurious oscillations occured. A signal was now injected into the system in the band 400 - 600 MHz. Upon removal of the signal the 'Frequency Set-On' oscillator remained in a stable mode of oscillation closest to the applied signal.

## Conclusions

A three stage self adaptive bandpass filter has been built and tested successfully. The self adaptive bandpass filter may be used in several ways. For example in an ESM system to counter the ECCM capability of frequency agility, the output from the filter may be used to mix with the input signal to produce an instantaneous baseband signal independent of carrier frequency.

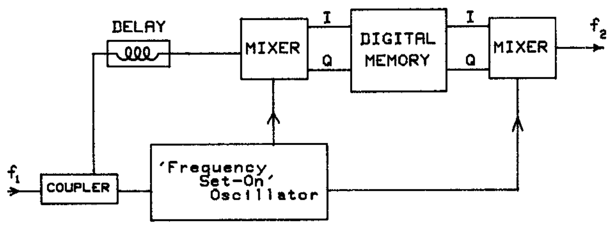



FIG. 4 Digital RF Memory

The use of the filter to form a frequency set on oscillator may be applied in an ECM system. A digital r.f. memory is considerably simplified if the input signal can be rapidly mixed to baseband for sampling purposes. Such a frequency set-on oscillator readily achieves this objective. A typical system as shown in Fig. 4 will accurately produce delayed and modified versions of pulse doppler or C.W. signals as well as reacting to coherent frequency hopping signals. To select the correct signal, a switched multiplexer would normally preceed the DRFM.