

Contiguous Filtering for HF Radar Acceleration and Velocity Signal Processing

[Unclassified Title]

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October 18, 1966



DECLASSIFIED: By authority of
DPNAVINST 5510.14, 29 APR 88
Cite Authority Date
C. ROBERTS 122.1
Entered by NRL Code

NAVAL RESEARCH LABORATORY
Washington, D.C.

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ABSTRACT

A contiguous filter was earlier proposed for use with the spectral compression technique of processing acceleration signals. This technique is implemented by the Acceleration Gate System located with the HF radar at the Chesapeake Bay Division (CBD) of NRL. The filter will permit the acceleration and velocity processing system to accommodate a wide dynamic range of input signals by, first, limiting large-amplitude interference or desired signals (without generating harmonics) so that they will not be spread in acceleration or velocity on the display and, in fact, are eliminated if they do not match an acceleration profile, and, second, minimizing the "capture" effect of large undesired signals over smaller desired signals without sacrificing minimum detectable signal level. At the same time, linear signal response is provided for azimuth determination and other measurements. A discussion is given of the operational requirements of such a composite filter, followed by detailed design and performance characteristics of a model designed and constructed to verify its operation with the system at CBD. A series of photographs illustrates the improvement in the displayed signals that results from the use of the contiguous filter.

PROBLEM STATUS

This is an interim report on the problem and covers work performed on the design and evaluation of the contiguous filter. Work on other phases of the problem is continuing.

AUTHORIZATION

NRL Problem R02-23
Project No. RF 001-02-41-4007,
MIPR (30-602)-63-2928,
MIPR (30-602)-63-2929,
MIPR (30-602)-63-2995,
MIPR ES-6-918

Manuscript submitted August 25, 1966.

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AND VELOCITY SIGNAL PROCESSING
[Unclassified Title]

INTRODUCTION

One problem that besets a velocity analyzing radar that utilizes coherent integration over a multisecond storage time and provides good doppler resolution occurs as a result of target acceleration with respect to the radar site. In the accelerating target case, the return signal, stored for the integration period, has its energy distributed over a range of doppler frequencies, with a consequential reduction in signal energy at any single frequency or any fractional frequency band. A degradation of minimum detectable signal and of doppler resolution is thereby produced. Attempts to minimize the acceleration effects normally result in a reduction of doppler resolution and the ability to detect low-level signals.

In previous NRL reports (1-7) a system (the Acceleration Gate System) for spectrally compressing the acceleration-spread doppler frequency spectrum has been proposed, developed, and shown to operate as originally predicted. This system is capable of detecting returns from accelerating targets, as well as constant-velocity targets, without loss of velocity resolution or signal-to-noise ratio (accrued from multisecond coherent integration), and it also adds the acceleration of the target as a system parameter. However, the same frequency modulation that is employed to compress the spread spectrum of the return signal from an accelerating target can produce frequency spreading of the signal energy from a constant-velocity target in the same manner that the signal return from an accelerating target is spectrally spread in the absence of spectral compression techniques. In either case, a large-amplitude signal return will be detected and displayed (spread) over a wide band of doppler frequencies, with nearly equal amplitudes, so that an accurate doppler or velocity reading is not possible. Also, other signals of interest may be of less amplitude and occur within the region of doppler spreading of the larger signal. These signals will then be masked by the larger spread signal.

Since the energy at any frequency in the spread spectrum is proportional to the total signal energy, and approximately inversely proportional to the frequency spreading (beyond a velocity resolution bandwidth), it follows that if the total signal amplitude is limited, a limit is likewise imposed upon the bandwidth over which the signal may be spread and yet still exceed the detectable level. This principle is used to eliminate the undesired spreading, at the display, of large amplitude, unmatched signals and is instrumented by means of a set of contiguous filters and associated limiters located between the signal store and the acceleration and velocity analyzer. In the application of the contiguous filter to the Acceleration Gate System, low-level signals from accelerating targets may be spectrally compressed and detected without a loss of the signal-to-noise ratio obtained with integration. Large- or small-amplitude signals or interference which do not match an acceleration profile or modulation function may be eliminated from the display.

The contiguous filter provides the second feature of separating the doppler frequency span into a number of frequency bands before limiting. Without this separation into frequency bands, a very large signal could "capture" small signals, existing anywhere in the whole doppler band, by the limiting process. But in the contiguous filter the capture effect occurs, within a 60-db system limit, in no more than one channel (only one-tenth of

the doppler band) even for a cw interfering signal. In that single channel the large-amplitude signal will be reduced to the limiting level, and undesirable display effects will be eliminated. Signals in the remaining nine-tenths of the doppler band will be unaffected and may be processed normally.

For those instances where a linear response without limiting is desired, such as for amplitude comparisons in monopulse applications, means will be provided for bypassing the contiguous filter. Implementation of this bypass may be accomplished by a gate circuit which will bypass the contiguous filter only during the interval of the gating pulse. Thus, the filter may be bypassed for specific selected signals, or selected time intervals, without interfering with the normal operation on all other signals.

A further advantage may be gained by (a) permitting a single velocity and acceleration analyzer to be used with a contiguous filter for all acceleration analyses greater than zero and (b) operating with a linear input response for all zero-acceleration analyses.

THEORY

One particular contiguous filter is composed of ten separate channels, as indicated by the block diagram of Fig. 1. The single input is distributed to all channels, each consisting of a driver amplifier, a bandpass filter (BPF), a video amplifier, an amplitude limiter, a second BPF identical to the first, and an output (driver) amplifier. The outputs of all channels are combined in an adder stage. Each channel is provided with a video amplifier gain control and an output amplifier gain control. One input level control and one output level control are provided for the entire set of channels.

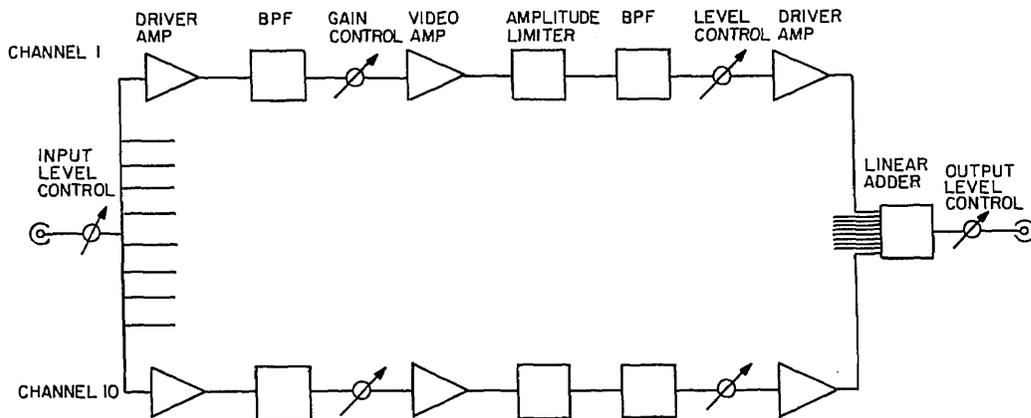


Fig. 1 - Block diagram of a ten-channel contiguous filter. Each channel is made up of the indicated component parts.

Basically, the input BPF's of all channels are of equal bandwidths, with their passbands positioned immediately adjacent to one another in frequency and designed for a passband such that the composite total covers the entire input signal bandwidth. This bandwidth is determined by the product of the unambiguous doppler extent and the processing time-compression-ratio of the signal storage system. The minimum detectable doppler frequency is limited to the cutoff frequency of the backscatter rejection filter,

and the maximum unambiguous doppler frequency is limited to one-half of the pulse repetition frequency (PRF). In the present Madre radar, operation at a PRF of 180 cps, with a storage time of 20 sec, in conjunction with a backscatter comb filter that has a cutoff frequency of 9 cps will produce an input signal range of 0.7452 to 7.452 Mc/s to the contiguous filter. If the contiguous filter is made up of ten channels, individual channel coverage will be as follows:

Channel	Input Signal Range (Mc/s)	Channel	Input Signal Range (Mc/s)
1	0.75-1.42	6	4.10-4.77
2	1.42-2.09	7	4.77-5.44
3	2.09-2.76	8	5.44-6.11
4	2.76-3.43	9	6.11-6.78
5	3.43-4.10	10	6.78-7.45

The input signal will always be accompanied by wideband noise plus any other interference. The wideband noise portion may be assumed to be distributed uniformly over the signal bandwidth so that the relative noise power level in each channel is equal to the total noise power divided by the number of contiguous filter channels. Thus, a 10-db reduction in total noise is obtained in a single channel when ten equal bandwidth channels are used. An input signal from a constant-velocity target will exist in only one of the channels and, prior to limiting, will not be reduced in amplitude; thus, the signal-to-noise (S/N) ratio in that channel is improved by 10 db over that at the input. Signals that exceed the noise peaks by a large amount may be limited in amplitude to a value just slightly in excess of most of the noise peaks. Since noise peak-to-peak voltage (white gaussian noise) will exceed 7.8 times the noise rms value only 0.01 percent of the time, insignificant degradation will result in the S/N ratio of the minimum detectable signal (MDS) if the peak-to-peak voltage limiting level is adjusted to at least 7.8 times the noise rms voltage.

A 13-db S/N ratio is required at the displays (or threshold detector) to provide a combined probability of detection of 98 percent, with a probability of false alarm of no more than 0.01 percent. The corresponding S/N ratio that would exist at the input of the frequency analyzer may be determined by subtracting the processing gain of the analyzer. If the analyzer processing gain is 20 db, as it sometimes will be, the S/N ratio at the analyzer input is -7 db and may be found from the rms voltage values shown in Fig. 2. Total processing SNR gain includes the 10 db due to bandwidth reduction across the storage and equals 30 db. The rms voltages of signals and noise are also shown for several other points within the contiguous filter; at the limiter input the S/N corresponding to the above is +3 db. If the peak-to-peak limiting level is adjusted to 7.8 times the rms noise voltage (or the peak adjusted to 3.9 times rms), the input signal may be raised approximately 6 db above the MDS before limiting occurs. This is the limiting level shown in Fig. 2.

The frequency analyzer output amplitude for any input signal will be reduced whenever the input signal energy is spectrally spread in excess of the analyzer predetection filter bandwidth. For a constant-amplitude input signal, the analyzer output will be reduced by about 3 db each time the analyzer input signal spectral bandwidth is doubled (beyond the predetection filter bandwidth). A similar effect may also be caused by the acceleration modulation of the analyzer conversion oscillator, which can spectrally spread the energy of a signal of different acceleration (possibly zero). If the maximum

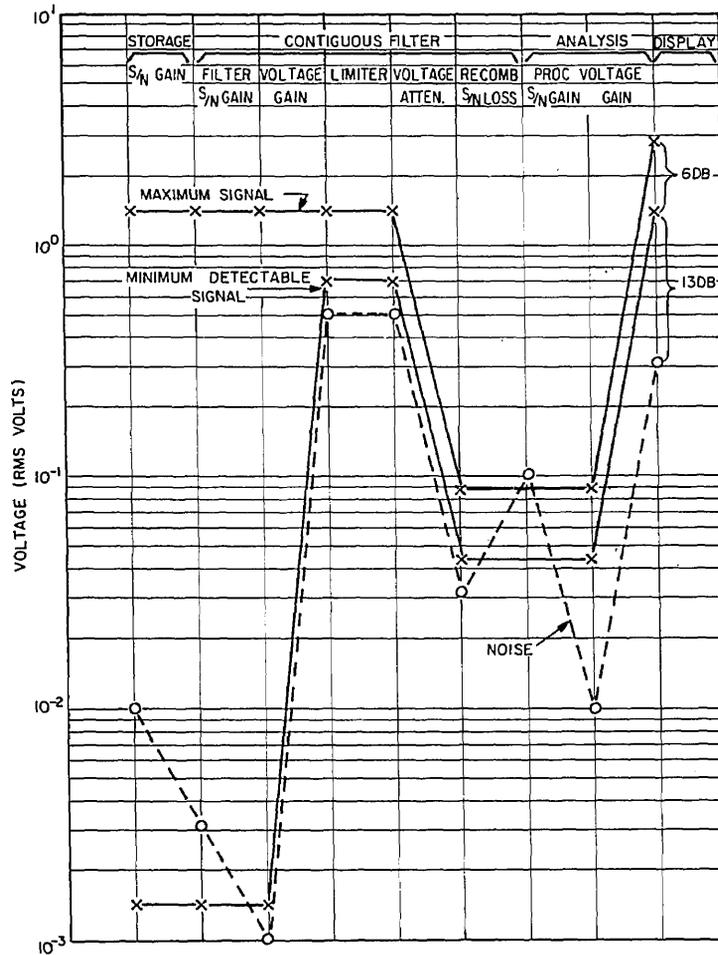


Fig. 2 - Signal and noise rms voltages which exist in the indicated component parts of the Madre Acceleration Gate System

analyzer level is limited in input to only 6 db above the minimum detectable level, the spread signal will be detectable for no more than four (plus-minus one and a half either side of the center bandwidth) velocity resolution bandwidths. Thus, the spreading effect or large signals is minimized to practical values.

The use of ten channels in the contiguous filter permits the limiting level to be set 10 db closer to the minimum detectable signal than would otherwise be possible, thus resulting in a signal dynamic range that need not be greater than 6 db at the input of the frequency analyzer. It also permits the passband of all channels to cover less than a 2:1 frequency range so that any harmonics of individual channel input frequencies, introduced by the limiting action within a channel, will be attenuated by the channel output filter of the same channel before recombination of the ten channels.

DESIGN OF TEST MODEL

A five-channel contiguous filter was designed and constructed in order to evaluate its operation with the Acceleration Gate System. A schematic of one of the five channels is shown in Fig. 3. The input video signal is coupled to an input level control potentiometer, which is common to all five channels and serves also as the 100-ohm termination of the coaxial input. Stage V1 is a linear amplifier which isolates the separate bandpass filter loads from the common bus. The amplifier must be linear over the full range of input signals; otherwise it could generate harmonics which would be passed without attenuation by a channel other than the one intended for the fundamental frequency. Amplifier V1 also supplies adequate drive to the input BPF, whose impedance was made a low value to insure that a good filter characteristic could be obtained for the higher frequency units even if the five-channel contiguous filter were later extended to a full ten-channel filter and filter responses to 7.5 Mc/s were required. Individual channel frequency coverages for the five-channel filter are as follows:

Channel	Input Signal Range (Mc/s)	Channel	Input Signal Range (Mc/s)
1	0 -0.750	4	2.250-3.000
2	0.750-1.500	5	3.000-3.750
3	1.500-2.250		

The filter is terminated by a 100-ohm potentiometer, which allows adjustment of the input level to the following two-stage amplifier and which, in turn, is followed by a peak-to-peak diode limiter. The potentiometer is intended to equalize the input levels at which limiting begins for all five channels. Another peak-to-peak limiter is located between amplifier stages V2 and V3 and consists of (a) positive limiting, by the input grid, to cathode-diode action of V3 and (b) negative limiting by the semiconductor diodes connected from grid to ground. It will limit only signals of very high input levels and is intended only to improve the overall limiting action for very large inputs. Amplifier V2, whose plate load is a simple resistor for channel 1, includes series peaking for channel 2 and utilizes very broadly tuned parallel-resonant circuits for channels 3, 4, and 5. The gain in any channel is more than adequate to limit noise peaks when a 0.25-v peak-to-peak amplitude white noise is applied to the input of V1.

The peak-to-peak limiter following V3 is a two-stage device having an excellent limiting characteristic over more than the required frequency range. The type 1N916 diode possesses a very fast recovery time and is well suited for this application.

Cathode follower V4 drives the output filter. Since limiting precedes this stage, the maximum input is the limited value. A level control potentiometer allows the output of the individual channels to be balanced at recombination in the plate of the linear adder V5. A separate triode section is used for each channel, and the plates are connected together to a common load resistor that is also the output level control. Output follower V6 is capable of driving the 100-ohm terminated output coaxial cable. A 2.5-mh choke across the output minimizes any power line frequency hum that is sometimes produced in cathode-follower stages.

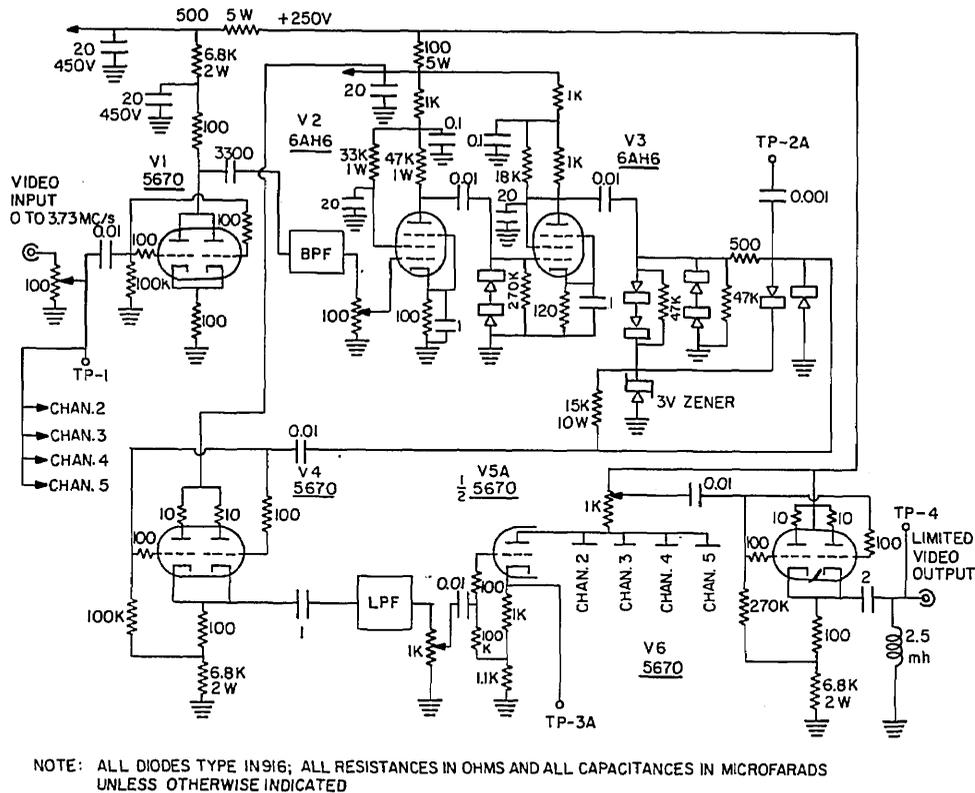


Fig. 3 - Schematic diagram of one channel of the five-channel contiguous filter

Several performance characteristics for components in this chassis are of interest. The input bandpass filter response curve is plotted in Fig. 4 for each of the five channels. The passband responses are to within 3 db, and attenuation reaches a value in excess of 40 db at frequencies approximately 80 percent of the lower passband edge and 125 percent of the upper passband edge. Attenuation beyond these frequencies is generally in excess of 40 db. The filter for channel 1 is actually a low-pass filter (LPF) and requires fewer components. However, an extra section was added to this LPF and an improved attenuation resulted. The schematic diagrams of these input filters are shown in Fig. 5. The output filters are low-pass, constant-k sections with half m-sections at input and output. The cutoff frequency has been designed at 125 percent of the channel upper band edge, and corresponds to a value of m of 0.6. Figure 6 shows the response of the output filters, and a typical schematic is shown in Fig. 7.

Channel phase characteristics are important for two reasons. First, the recombination voltages of signals near channel band edges are the vector sum of the voltage-phase outputs of adjacent channels. The sum of two equal-amplitude signals could be any value between zero and twice amplitude if the phase relationships between adjacent channels were allowed to be any value, including multiples of π . Thus, the effect of amplitude limiting would be reduced. Second, an overall linear dependence of phase on input frequency is desired. Figure 8 is a plot showing the overall linear dependence. Although this relationship is not entirely linear within a single channel bandwidth, the characteristic does remain close to an overall linear response over the five-channel bandwidth

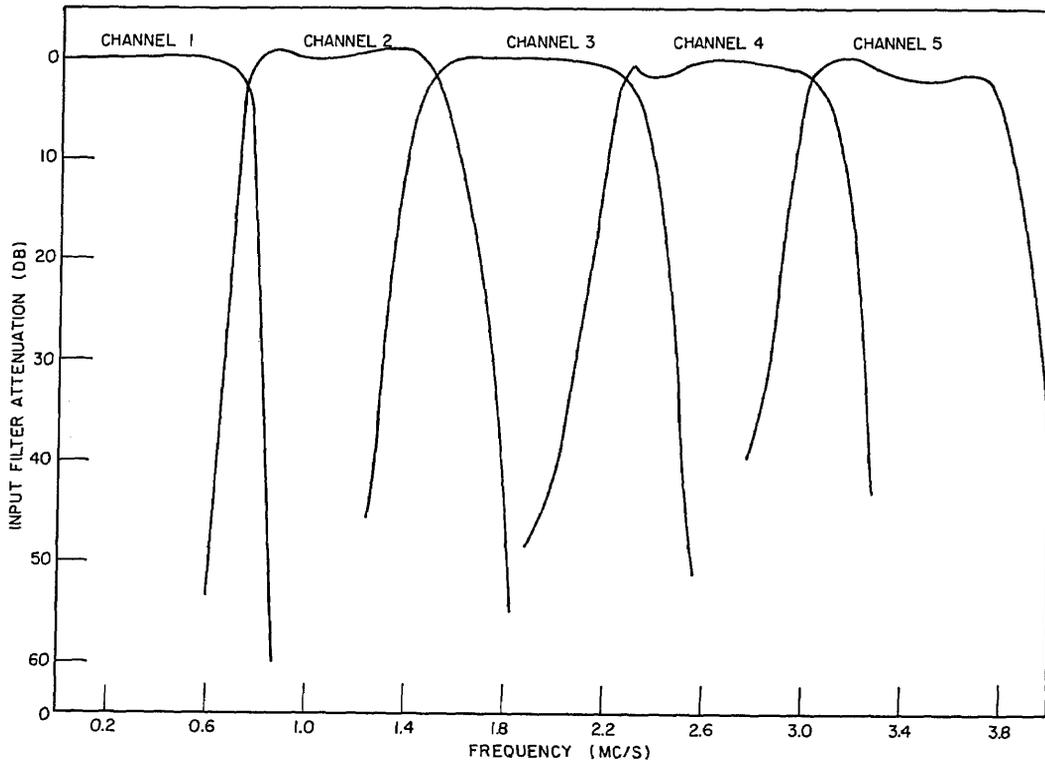
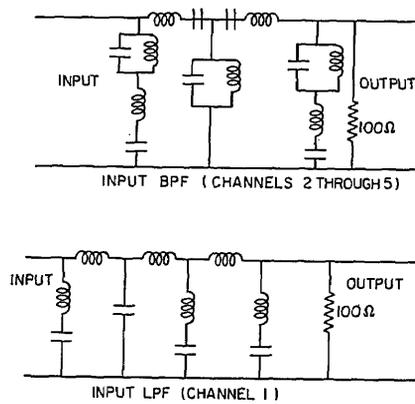


Fig. 4 - Input bandpass filter characteristics for each channel of the five-channel contiguous filter

Fig. 5 - Schematic diagrams of the input bandpass filters and the input low-pass filter used in the five-channel contiguous filter



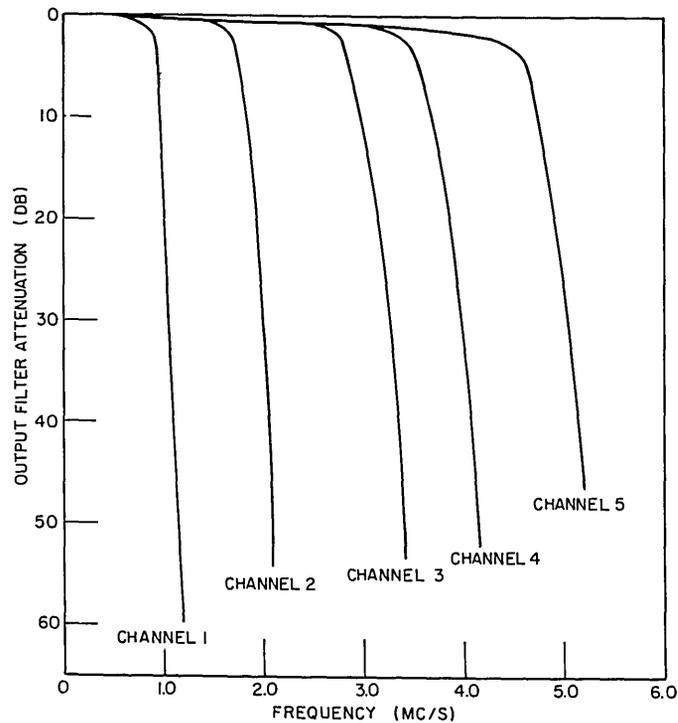


Fig. 6 - Output low-pass filter characteristics for each channel of the five-channel contiguous filter

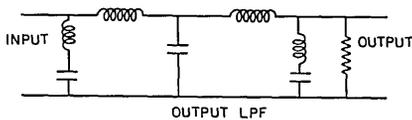


Fig. 7 - Schematic diagram of the output low-pass filters used in the five-channel contiguous filter

and is fully adequate for the intended application. Since the contiguous filter channels are in parallel the phase shift is not cumulative from one channel to the next as frequency is increased, but plotting in the manner used in Fig. 8 permits comparison to an overall straight line.

The overall output-input amplitude ratio vs input frequency is shown in Fig. 9 for three different levels — one below limiting, another near limiting, and a third heavily limiting. The fluctuation in amplitude is greater with overdrive (0.3 v (rms)), as may be expected.

An amplitude response was measured at an input frequency of 2 Mc/s to determine the degree of limiting. The output was measured by oscilloscope peak-to-peak volts at the channel 3 limiter output TP-2c (similar to TP-2a on Fig. 3) and the result is shown on Fig. 10. Hard limiting occurred between the input of 0.08 and 0.10 v rms, and no further change in output level could be discerned for inputs up to 2.0 v rms.

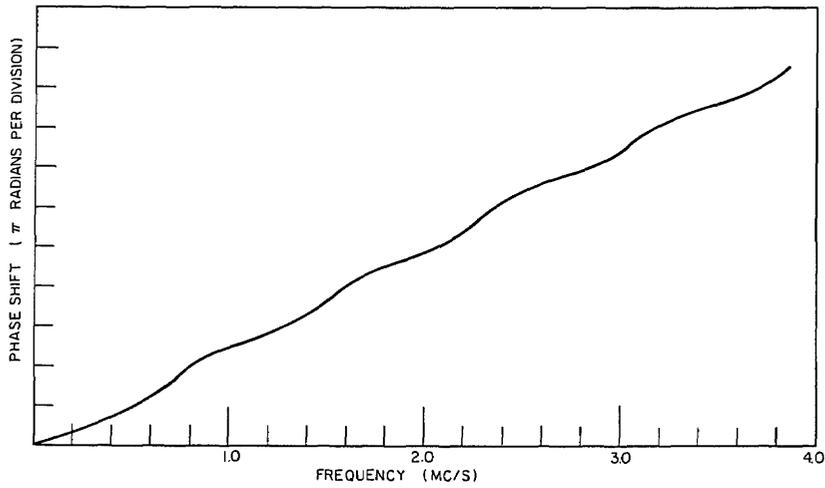


Fig. 8 - Phase vs input frequency for the five-channel contiguous filter. An overall linear relationship is shown to exist.

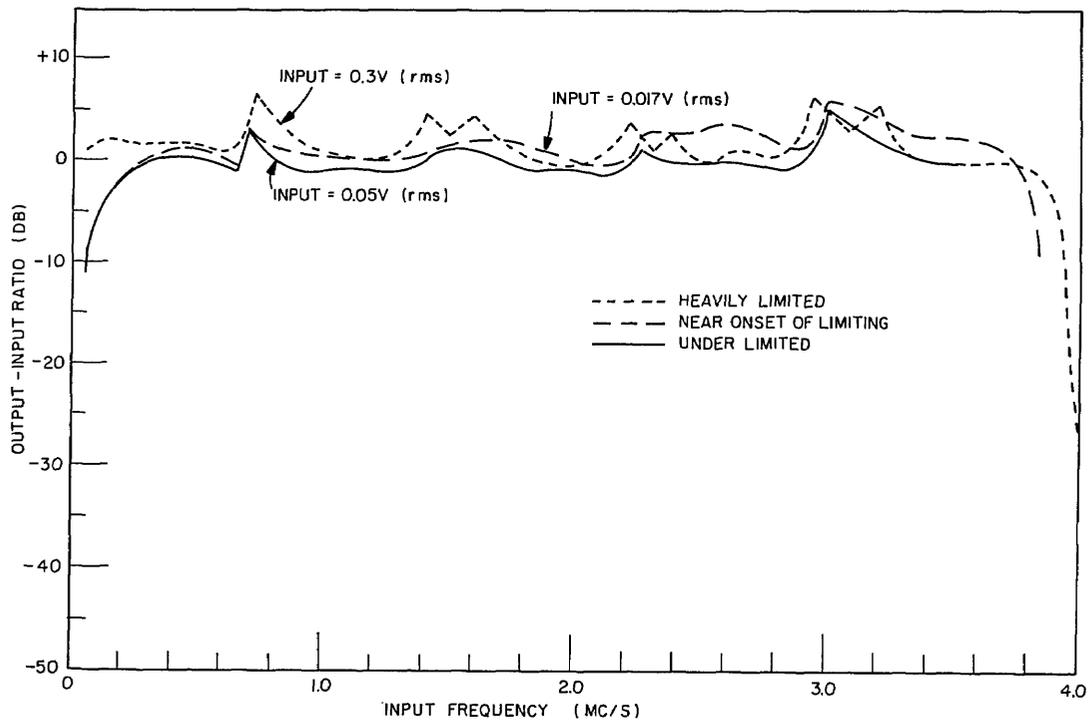


Fig. 9 - Output-input amplitude ratio vs input frequency for the five-channel contiguous filter. Three conditions showing the effect of the degree of limiting are illustrated.

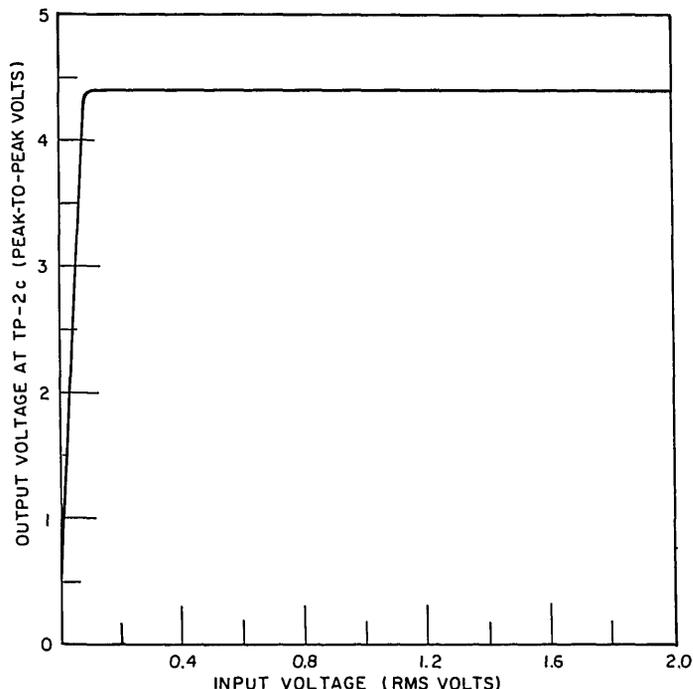


Fig. 10 - Output voltage vs input voltage at an input frequency of 2 Mc/s. The degree of limiting at the channel 3 limiter output (terminal TP-2c) is determined by this curve.

APPLICATION

The contribution of the acceleration gate processing to the high-frequency coherent pulse doppler radar is clearly illustrated by the series of photographs of Figs. 11 and 12. These figures also show that the contiguous filter, which successfully limits the dynamic range of input signals to the acceleration and velocity analyzer, does not simultaneously degrade the spectral compression capability of the Acceleration Gate System. Figures 13 through 15 show the system improvement achieved by control of the input signal dynamic range by the contiguous filter.

Figures 11 and 12 are photographs of oscillograph displays of the acceleration and velocity analyzer output amplitude (vertical deflection) vs a linear time sweep. Since the velocity analysis is performed linearly with time, the horizontal deflection may be calibrated either in target radial velocity or in terms of its equivalent magnetic-storage-drum output frequency. This frequency is equal to the product of the doppler frequency and the drum time compression ratio of 82,800. The input to the analyzer is a simulated signal of characteristics that would normally be obtained from the output of the magnetic storage drum, and this signal may be positioned in range, velocity, and acceleration. Since the five-channel contiguous filter is limited to a maximum passband frequency of 3.75 Mc/s (equivalent to a maximum doppler frequency of about 45 cps), the simulated signals are restricted to frequencies below this maximum limit. The simulated signal is fed to the analyzer either directly or via the contiguous filter, and a separate photograph of each is contained on the figures for comparison.

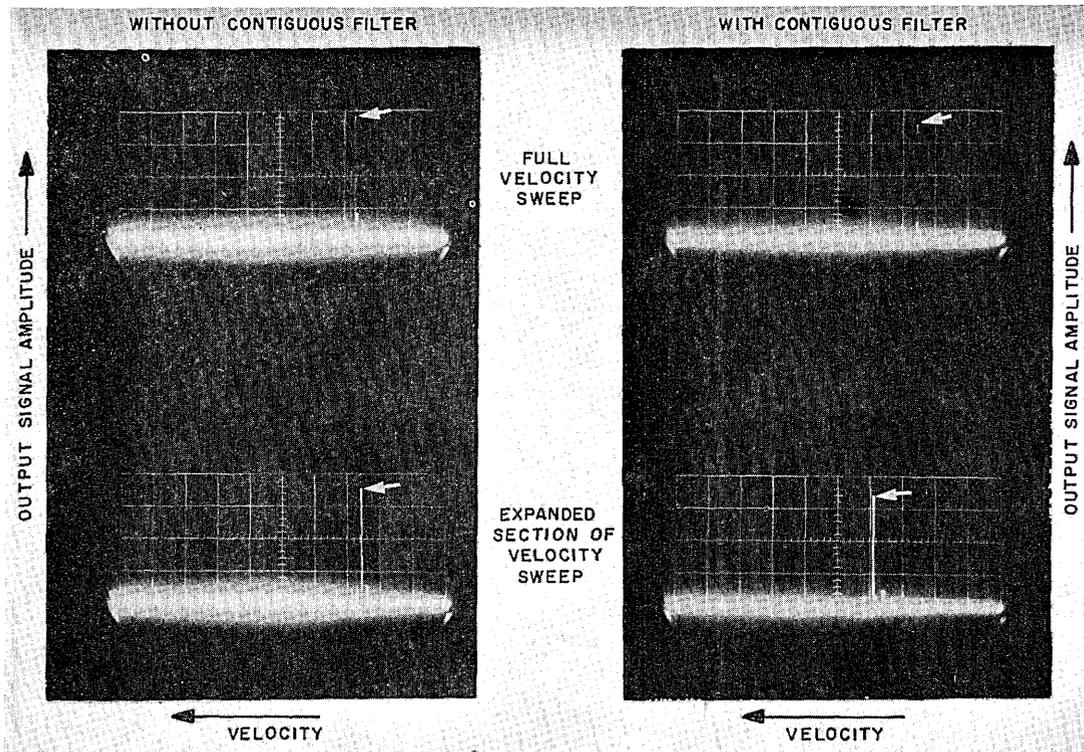


Fig. 11 - Comparison of analyzer output of a simulated input signal processed with and without the use of a contiguous filter. The input signal was set for a constant velocity equivalent to 1.0 Mc/s (storage drum output frequency) and zero acceleration.

In Fig. 11 both photographs show the acceleration and velocity analyzer output for a simulated input signal that was set for a velocity of 1.0 Mc/s and zero acceleration. (A doppler frequency of 12 cps produces a drum output frequency of 1 Mc/s.) The only difference between the upper and lower traces of each photograph is the horizontal time scale. In the upper trace of each photo, the horizontal sweep displays the velocity analysis range up to 3.75 Mc/s in a time of about 1.7 sec. The intensity of the signal is low because its pulse width is very narrow with regard to the sweep time, so a white arrow has been added to indicate its peak. In the lower trace the horizontal sweep is expanded about the signal and its total sweep time is a small fraction of the time shown above. This allows the trace to be brightened so that the signal is easily photographed, and it also shows the output level at the adjacent velocity bins. This expanded trace does not show a true signal frequency spectrum since many spectral lines are summed in each displayed output line, but it is indicative of the spread frequency extent and the relative amplitudes of the sideband frequencies. There is no significance in the horizontal positioning of the signal in the lower trace as this is merely a function of a delay setting and of an uncalibrated, expanded sweep width. Consecutive vertical lines that resemble spectral lines are spaced by the range scan period of 5555 μ sec. No significant change in analyzer output signal frequency content or readout capability is observed with the addition of the contiguous filter.

Figure 12 shows the effects when various accelerations are applied to the simulated signal. In each of the six photos contained in Figs. 12(a) to (c) the top trace shows the analyzer output signal that has been enhanced by the acceleration gate spectral compression, the center trace represents the same signal but with the scope sweep expanded for the reasons enumerated above, and the bottom trace shows the analyzer output amplitude and frequency dispersion in the absence of spectral compression. It should be observed in the bottom traces that as the acceleration is increased, the frequency dispersion increases, and the amplitude of the output signal correspondingly decreases. It should also be noted that a constant-amplitude input signal was maintained in all cases.

For the same input signal accelerations, the spectral compression technique has successfully confined most of the signal energy within a single velocity analysis bandwidth, as represented by one velocity bin output approaching a full amplitude pulse while the energy in adjacent velocity bins is quite low. A direct comparison may be made between the output amplitudes and velocity resolutions with spectral compression and without spectral compression, as shown in the top and bottom traces, respectively, each with the same horizontal velocity scale and vertical amplitude scale. With spectral compression one output signal predominates, with the velocity resolution maintained at one velocity bin, while without spectral compression many very low level signals, all of about

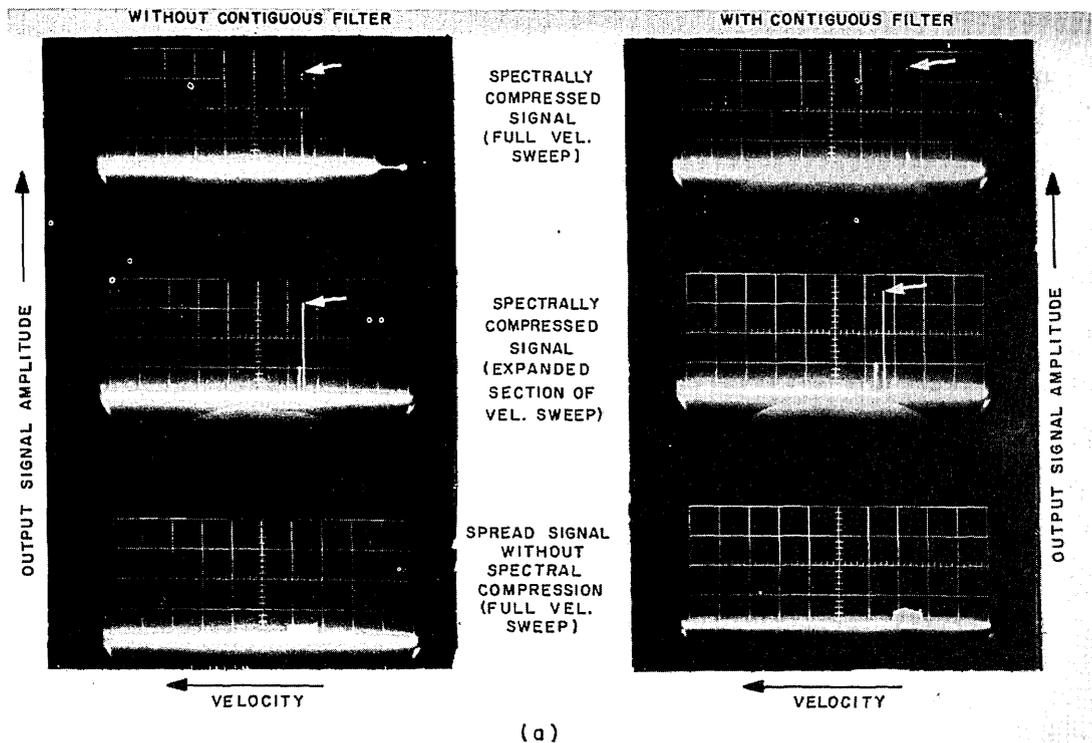


Fig. 12 - Comparison of analyzer output of a simulated input signal processed with and without the use of a contiguous filter. The input signal was set for a constant velocity equivalent to 1.0 Mc/s (storage drum output frequency) and an acceleration equivalent to (a) 1.0 Mc/s, (b) 2.0 Mc/s, and (c) 3.0 Mc/s.

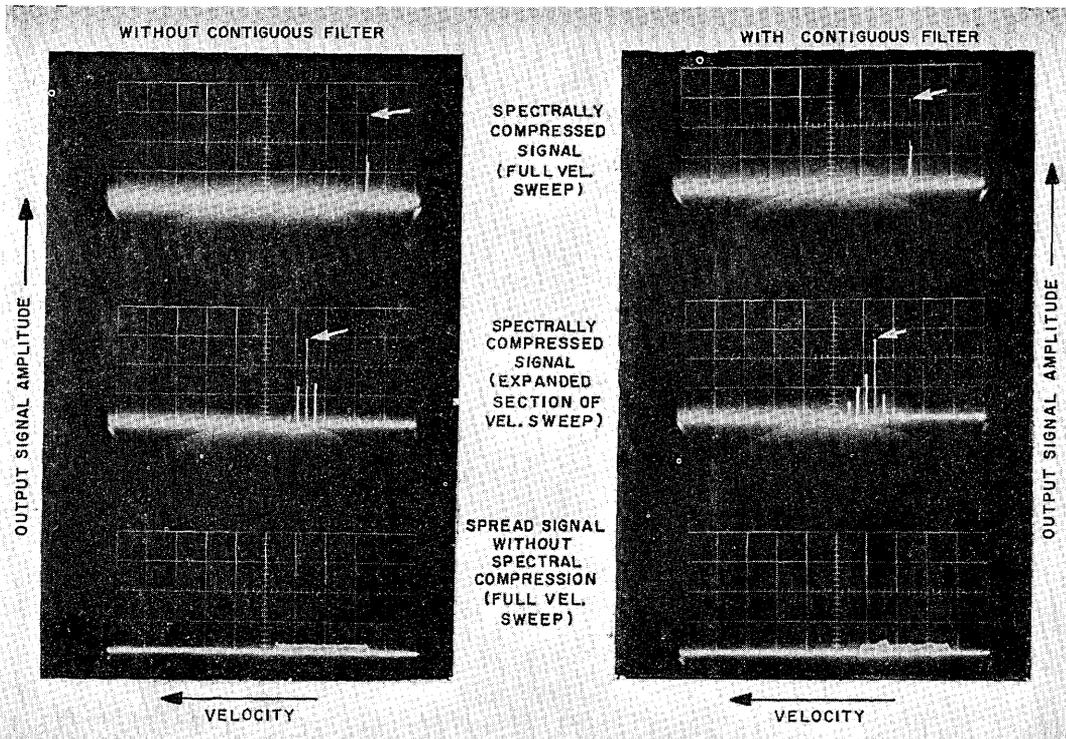
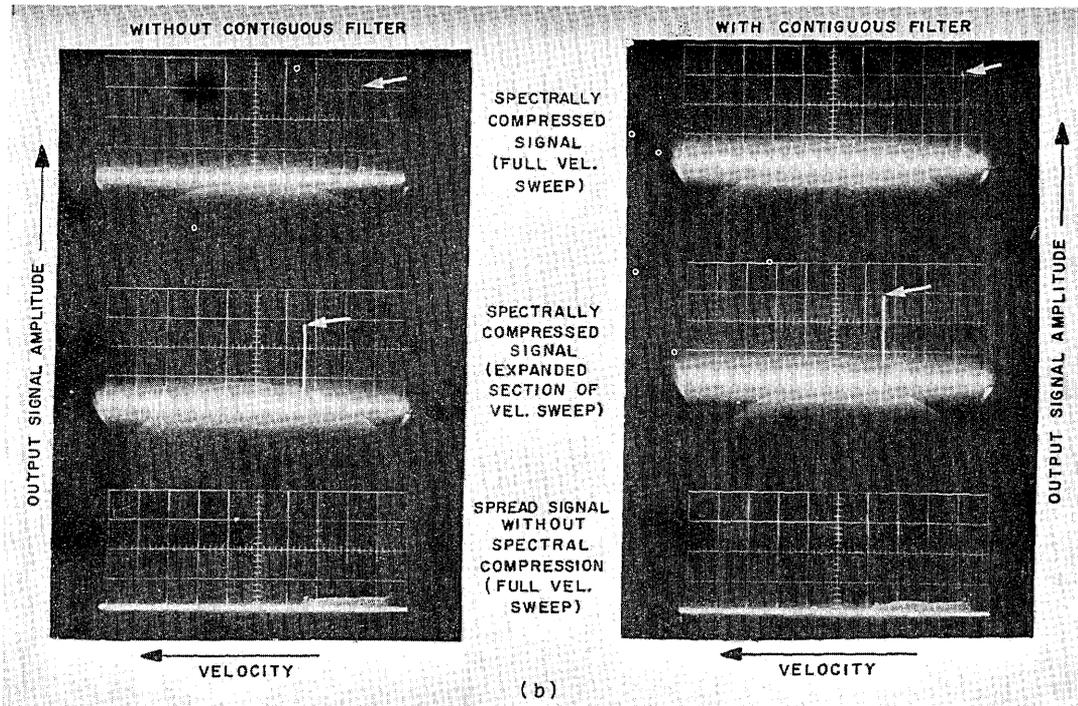


Fig. 12 (cont'd) - Comparison of analyzer output of a simulated input signal processed with and without the use of a contiguous filter. The input signal was set for a constant velocity equivalent to 1.0 Mc/s (storage drum output frequency) and an acceleration equivalent to (a) 1.0 Mc/s, (b) 2.0 Mc/s, and (c) 3.0 Mc/s.

equal amplitude, are observed to be spread over the full range of the acceleration input. (At lower levels of input the acceleration-caused loss of amplitude will greatly reduce the probability of detection.) A second comparison may be made between the spectral compression improvements in signal amplitude and in velocity resolution obtained without the contiguous filter and with the contiguous filter, and it may be seen that the signal readout is not degraded by the addition of the contiguous filter for accelerations up to 2 Mc/s. A slight spectral spreading is observed for the case of a 3-Mc/s (Fig. 12(c)) acceleration, but even in this case the change is minimal and the cause is attributed to an imperfect match of the acceleration-modulation waveform (which can be corrected) rather than to effects of the contiguous filter.

A test setup was devised to evaluate the improvement in displays made possible by the use of the contiguous filter. A standard oscilloscope was used as the display. A simulated signal was fed to the acceleration and velocity analyzer either directly or via the contiguous filter, as chosen, and the analyzer output signal was applied to the oscilloscope in the form of intensity modulation. The horizontal sweep (velocity) was a linear sawtooth with a period equal to the full velocity analyzing time; this sweep can be calibrated in terms of velocity as well as time. The vertical deflection (acceleration) was a single-sweep linear ramp generated at a very slow rate by a motor-driven potentiometer. The same motor drive was used to program an acceleration readout such that the acceleration began at zero at the low limit of vertical deflection and increased uniformly as the sweep progressed vertically upward. The acceleration calibration of the vertical sweep was 1 Mc/s per major division. Each full velocity analysis, represented by one horizontal sweep, was made for a different acceleration bin and required about 1.7 sec. Approximately 30 separate acceleration bins were required to complete the display, and this was accomplished in a time period of about 52 sec. This slow readout allows one acceleration gate channel to supply a full acceleration readout, but its use is restricted to nonreal time and, hence, is not intended as a system display but only for the purpose of this test to illustrate a full acceleration velocity display.

Figure 13(a) shows the effect of signal amplitude upon the display when the contiguous filter is not used. The simulated input signal was adjusted for an equivalent velocity of 1.8 Mc/s and an equivalent acceleration of 1.0 Mc/s. When the display intensity is suitably set for a 0.5-v peak-to-peak input signal (-6 db), as shown in the center trace, the signal disappears when the amplitude is further reduced 6 db (lower trace), and it is spread over about one-third of the total acceleration range, and also over velocity, when it is increased by 10 db (top trace) from the original level. By contrast, Fig. 13(b) shows that when the contiguous filter is used, the same general variation in input signal level may be accommodated without spreading or loss of signal. The signal is presented at essentially constant amplitude, as displayed at the extremes of -10 db and +7 db. The same result may be realized over a 60-db range.

The same acceleration vs velocity display that was described above is used to show another desirable feature of the contiguous filter when used in conjunction with the acceleration and velocity analyzer. This feature is the system's ability to separate and display multiple signal inputs that might otherwise interact and prevent separate identification. In this case two signals are simultaneously applied to the input of the contiguous filter, one simulated for a constant-velocity target, the other simulated for an accelerating target at the same range. Figures 14(a) through (d) show the displayed velocity and acceleration signals for various combinations of amplitudes of each and for the constant-velocity signal positioned either within the same contiguous filter channel in which the accelerating signal appeared or positioned in a channel whose passband is beyond the extent of the accelerating signal. It is to be expected that whenever a very large signal exists in a particular contiguous filter, that channel will hard limit and capture any small

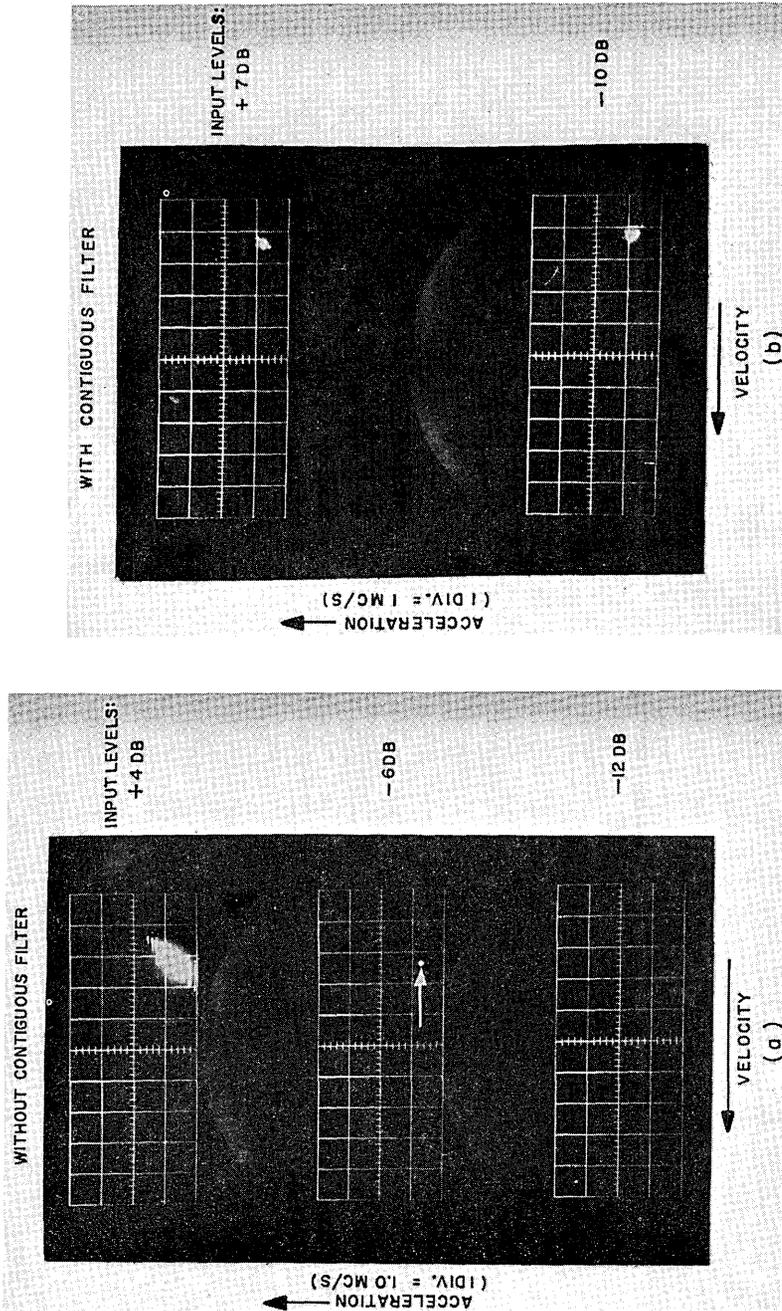
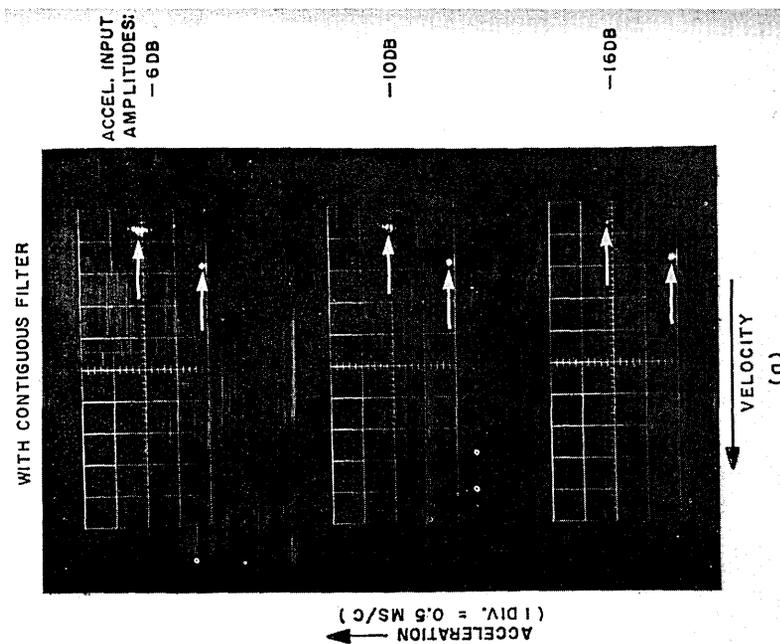
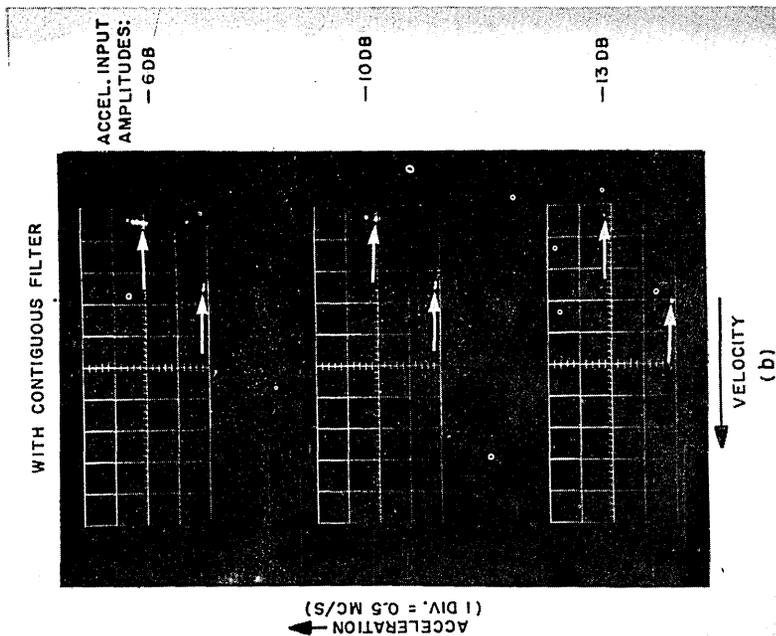


Fig. 13 - Comparison of acceleration and velocity analyzer output of a simulated input signal processed (a) without and (b) with the use of a contiguous filter. The input signal was set for a velocity equivalent to 1.8 Mc/s (storage drum output frequency) and an acceleration equivalent to 1.0 Mc/s. The input signal zero db level was set for 1 v peak to peak.



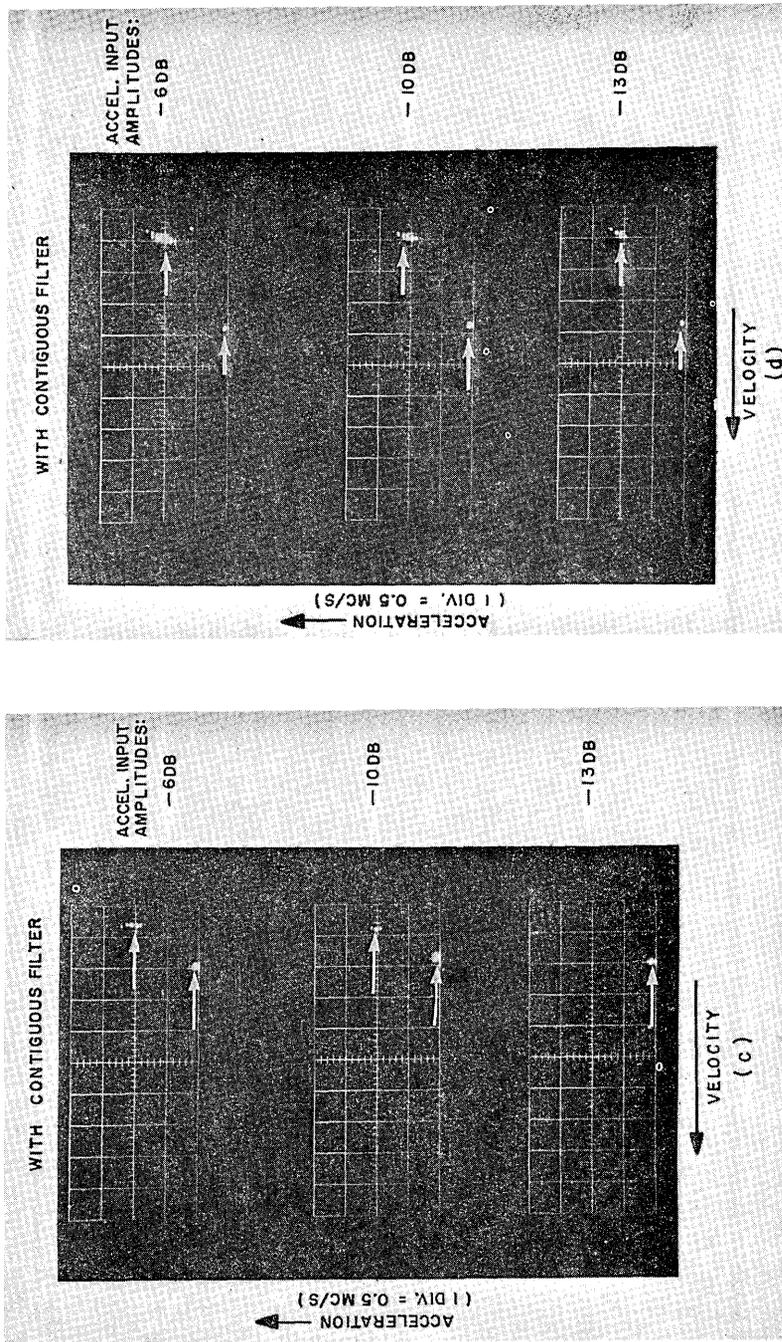


Fig. 14 - These oscilloscope traces show that signals received simultaneously from both constant-velocity and accelerating targets at the same range are distinctly separated by the acceleration and velocity analyzer. The lower arrow in each trace points to the (simulated) constant-velocity target; the upper arrow points to the (simulated) accelerating target. Detailed information for each of the figures is as follows: (a) lower arrows: constant velocity equivalent to 1.75 Mc/s, velocity input amplitude -6 db (0.5 v peak to peak), signal positioned in channel 3; upper arrows: velocity equivalent to 1.1 Mc/s, acceleration equivalent to 1.0 Mc/s, acceleration input varied as indicated; (b) lower arrows: constant velocity equivalent to 2.50 Mc/s, velocity input amplitude -6 db, signal positioned in channel 4; upper arrows: velocity equivalent to 1.1 Mc/s, acceleration equivalent to 1.0 Mc/s, acceleration input varied as indicated; (c) lower arrows: constant velocity equivalent to 1.75 Mc/s, velocity input amplitude +4 db, signal positioned in channel 3; upper arrows: velocity equivalent to 1.1 Mc/s, acceleration equivalent to 1.0 Mc/s, acceleration input amplitude varied as indicated, and (d) lower arrows: constant velocity equivalent to 3.50 Mc/s, velocity input amplitude +4 db, signal positioned in channel 4; upper arrows: velocity equivalent to 1.1 Mc/s, acceleration input varied as indicated.

signals that may also be present in the same channel. However, it will not capture the remainder of the doppler band. For Fig. 14(a) the accelerating signal was spread across parts of contiguous filter channels 2 and 3, while the fixed velocity signal of nearly sufficient amplitude for limiting, but insufficient for complete capture, was positioned in channel 3. Since a portion of the accelerating signal was also present in channel 2, it was unaffected by the other signal confined to channel 3, and sufficient signal remained to be displayed. The three traces were taken for the indicated inputs of the accelerating signal. Limiting occurs just above the -6 db input, while the -10 db level was below limiting level. The same signal was just visible at the -16 db input level. The constant-velocity signal is properly displayed in all three traces. It should be noted here that the same two input signals would not be separately displayed on a velocity vs range display in the absence of spectral compression processing because the position of the fixed velocity signal will fall within the spread frequency indication of the acceleration signal and thus be obscured. However, both signals may be discretely displayed on a velocity vs range display when spectral compression acceleration processing is utilized.

Figure 14(b) presents the photographed oscilloscope display for inputs similar to those of Fig. 14(a), except that the constant-velocity signal has been positioned in contiguous filter channel 4 whose frequency passband is entirely beyond the frequency extent of the accelerating input signal. In this example there should be no effect of either input signal upon the other since the contiguous filter will maintain amplitudes at the limiting level or below in each channel. The recombined signals will each be as effectively displayed as if the other signal were not present.

In the case of Fig. 14(c) the simulated acceleration signal energy is spread over frequencies of 1.1 to 2.1 Mc/s so that approximately 40 percent of its energy falls within channel 2 and 60 percent within channel 3. The constant-velocity signal of 1.75 Mc/s, which is positioned in channel 3, is increased 10 db in amplitude over a similar example, shown in Fig. 14(a), to a new level of +4 db. Both signals are visible in Fig. 14(c) even though the constant-velocity signal is sufficiently large to capture channel 3. The acceleration signal is visible in the two upper photographs because 40 percent of its energy in channel 2 remains for normal processing. However, it does drop below the minimum detection level sooner, as the lower section of Fig. 14(c) indicates.

Figure 14(d) shows that when the larger amplitude signal was positioned in a separate channel from the accelerating signal, both signals were again detectable. In this case the acceleration signal was visible for a few decibels lower in level, as would be expected with an increase of 40 to 100 percent in signal energy. The point is, however, that the acceleration signal is detectable through a large nonmatching signal, as demonstrated above.

CONCLUSION

A contiguous filter, which was previously proposed for use with the Acceleration Gate System, has been developed and a test model has been designed and constructed for use with the present partial signal-processing system located at the Chesapeake Bay Division of NRL. Tests of this model have shown its operation to be essentially as anticipated. It is concluded that its future use with the spectral compression technique of processing acceleration signals is highly desirable. Experience gained with the operation of the test model has enabled the writing of more accurate specifications for the procurement of a contiguous filter for the full Acceleration Gate System.

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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)		2 a. REPORT SECURITY CLASSIFICATION	
U.S. Naval Research Laboratory Washington, D.C. 20390			
		2 b. GROUP	
3. REPORT TITLE			
CONTIGUOUS FILTERING FOR HF RADAR ACCELERATION AND VELOCITY SIGNAL PROCESSING [Unclassified Title]			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
An interim report on one phase of the problem.			
5. AUTHOR(S) (Last name, first name, initial)			
McGeogh, J.E., Jensen, G.K., and Veeder, J.H.			
6. REPORT DATE		7 a. TOTAL NO. OF PAGES	7 b. NO. OF REFS
October 18, 1966		24	7
8 a. CONTRACT OR GRANT NO.		9 a. ORIGINATOR'S REPORT NUMBER(S)	
NRL Problem R02-23		NRL Report 6479	
b. PROJECT NO. RF 001-02-41-4007			
c. MIPR (30-602)-63-2928, MIPR (30-602)-63-2995, MIPR ES-6-918, and		9 b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d. MIPR (30-602)-63-2929		None	
10. AVAILABILITY/LIMITATION NOTICES			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY	
None		Dept. of Navy (Office of Naval Research) and U.S. Air Force	
13. ABSTRACT			
<p>A contiguous filter was earlier proposed for use with the spectral compression technique of processing acceleration signals. This technique is implemented by the Acceleration Gate System located with the HF radar at the Chesapeake Bay Division (CBD) of NRL. The filter will permit the acceleration and velocity processing system to accommodate a wide dynamic range of input signals by, first, limiting large-amplitude interference or desired signals (without generating harmonics) so that they will not be spread in acceleration or velocity on the display and, in fact, are eliminated if they do not match an acceleration profile, and, second, minimizing the "capture" effect of large undesired signals over smaller desired signals without sacrificing minimum detectable signal level. At the same time, linear signal response is provided for azimuth determination and other measurements. A discussion is given of the operational requirements of such a composite filter, followed by detailed design and performance characteristics of a model designed and constructed to verify its operation with the system at CBD. A series of photographs illustrates the improvement in the displayed signals that results from the use of the contiguous filter.</p>			

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radar signals Radar equipment Processing Performance Guided missile detection Madre Filters (electromagnetic waves)						

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