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IMPROVED BANDWIDTH AND PERFORMANCE FOR A DIGITAL MTI SIGNAL PRO--ETC(U)
AUG 78 R C HOUTS DAAG29-76-G-0212
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The important results are summarized in this report. The basic problem studied was the effect of using various algorithms for specifying the digital filter coefficients for a moving target indicator (MTI) radar signal processor in terms of improving the usable percentage of the pulse repetition frequency (PRF) while retaining an acceptable level of clutter attenuation. This study concentrated on the design of multiband filters for suppression of both ground and weather clutter using a linear-phase filter algorithm. Furthermore, the substitution of minimum-phase filters for the aforementioned design examples plus high-pass filters (HPF)

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20. ABSTRACT CONTINUED

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FINAL REPORT

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I. STATEMENT OF PROBLEM

The basic problem studied was the effect of using various algorithms for specifying the digital filter coefficients for a moving target indicator (MTI) radar signal processor in terms of improving the usable percentage of the pulse repetition frequency (PRF) while retaining an acceptable level of clutter attenuation. This study concentrated on the design of multiband filters for suppression of both ground and weather clutter using a linear-phase filter algorithm. Furthermore, the substitution of minimum-phase filters for the aforementioned design examples plus high-pass filters (HPF) for ground clutter suppression was investigated. Finally, the role of MTI filter in frequency response was studied when the PRF was staggered, either on a pulse-to-pulse or block-to-block basis.

II. SUMMARY OF IMPORTANT RESULTS

The MTI linear-phase filters were designed to suppress clutter while still retaining acceptable target detection probabilities over a large portion of the PRF. The clutter was assumed to have a Gaussian power-density spectrum with narrow bandwidth (ground) or centered at 10-15% of PRF with much wider bandwidth (weather or chaff). The tradeoff was maximized by allowing some combination of passband edges to vary until the maximum deviation (error) was reduced to acceptable levels in both the pass and stop bands. Although some work had been published previously on the ground clutter vs. usable bandwidth tradeoff for a HPF, nothing existed prior to our work on such tradeoffs for band-stop filters (BSF) or multi-band filters (MBF) designed to suppress both ground and weather (bimodal) clutter. Although our early work on HPF (Ref. 1) had shown the advantage of odd length filters (N odd), the MBF studies showed that N even was quite acceptable, even preferable when the ground clutter was quite narrowband. Finally, for such cases a new design called bimodal filter (BMF) was proposed, which in reality is an N even BSF. Several hypothetical examples were simulated to demonstrate the feasibility of designing BSF, MBF and BMF. A BSF was designed to provide 20 dB weather clutter attenuation when the clutter standard deviation (σ) was 0.02, i.e. 2% of the PRF. The attenuation was achieved with a 25-tap BSF at the cost of 29% lost bandwidth. A second example for bimodal clutter with the same weather clutter plus 50 dB attenuation of ground clutter ($\sigma = 0.002$) was achieved using a 26-tap MBF at the cost of 39% lost bandwidth. Finally a BMF design was investigated which was capable of 35 dB attenuation of weather clutter ($\sigma = 0.01$) plus 35 dB attenuation of ground clutter ($\sigma = 0.0002$). A 20 tap BMF achieved the desired goals at a cost of 40% lost bandwidth. This final example demonstrated the sensitivity of the solution-feasibility to the initial estimates of passband edges and choice of edge combinations which are varied. The details of the various design procedures are found in Refs. 1, 3, 5 and 6.

Recent work has focused on the design of length N minimum-phase MTI filters, i.e. the linear-phase requirement is removed. The technique involves design of a length 2N-1 linear-phase prototype followed by removal of the zeros outside the z-plane unit circle and one-half of the double zeros found on the unit circle; i.e. in the stop band. Since the prototype can be scaled to provide frequency response (after factoring) equivalent to a length N linear-phase design, it is reasonable to assume the minimum-phase filter has less transition band between stop and pass bands, i.e. less lost bandwidth. Studies of 9 and 10-tap minimum-phase designs for a variety of passband ripples indicate a considerable improvement in the lost bandwidth when compared to linear-phase designs. The improvement for 10-tap designs ranged from 45 to 50%, while a smaller improvement (15-22%) was obtained for 9-tap designs. However, the actual lost bandwidth for 10-tap minimum-phase designs was smaller than for 9-tap designs, whereas all even values of N for linear-phase designs yielded considerably more lost bandwidth than their N-odd counterparts. The amount of improvement was most significant for short filters ranging from 64;76% for N=5;6 to 20;46% for N=13;14. As the length of the prototype filter increases numerical errors in computer algorithms start to become significant. This has made it difficult to compare results with the 20 to 26 tap linear-phase BSF, MBF and BMF designs discussed earlier. However, a technique for manually removing the error generated during the root-finding procedure appears promising and work continues on this task. It is likely that results will be available for presentation at one of the IEEE-sponsored Spring conferences, e.g. Refs. 5 & 6.

The typical MTI radar transmits pulses uniformly spaced every 1/PRF seconds. Unfortunately, the sampled-data nature of the system generates velocity blinds, i.e. zero response at multiples of the PRF. Consequently, several schemes have been proposed for moving the blind away from the region of probable target velocities by use of staggered interpulse periods. The interactive nature of the MTI filter response and the effect of pulse staggering has been ignored by most authors. A computer program was developed to simulate a phase-incoherent digital MTI radar processor (Ref. 2). The user can specify the interpulse spacings, filter-tap values, number of pulse returns, transmit frequency, and possible transmitter frequency-shift (agility). The simulation indicates the velocity response of the processor, the amount of clutter rejection for various ground clutter bandwidths, and a histogram of user-selected velocity responses. Several filter designs and/or stagger techniques were compared in a paper presented at RADAR-77 (Ref. 4).

It was shown that block (vs. pulse) stagger provided excessive clutter rejection at the cost of degraded passband velocity response. Furthermore, filter designs which emphasized maximum clutter attenuation for prespecified pulse-stagger sets sacrificed passband response when compared to filter designs which emphasized a constrained clutter attenuation phiosophy, even when stagger was not a design factor. Overall, it appears that the choice of stagger configuration was considerably more important than the choice of filter coefficients. More recently, the stagger simulation program has been used to compare realistic MTI filters with published results which assumed an ideal HPF of sufficient bandwidth to eliminate the primary clutter spectrum located at dc and multiples of the PRF. It was determined for a system using M unique stagger intervals that the displaced clutter spectra located at (m/M) PRF where m = 1,2,...,M-1 typically yield less clutter power collectively than the residual clutter spectrum at dc after MTI filtering; consequently, their effect can be reasonably ignored in most simulations. Moreover, the theoretical work assumed the clutter attenuation to be a function only of the product of rms stagger deviation and clutter standard deviation, whereas results actually depend on which of these is assigned a specific value. It was also shown that a theoretical prediction on the first-null depth at the PRF served as a useful lower bound on the true value for a realistic MTI filter, provided the average stagger deviation is zero. However, it was also demonstrated that worst-null depth is often not the same as first-null depth. These results have been accepted for publication (Ref. 7).

III. LIST OF PUBLICATIONS AND TECHNICAL REPORTS

1. R. C. Houts & D. W. Burlage, "Maximizing the Usable Bandwidth of MTI Signal Processors", IEEE Trans. Aerospace & Elect. Sys., Vol. AES-13, No. 1, Jan. 1977, pp. 48-54.

2. R. C. Houts, "PPABLK - A Computer Simulation of the Velocity Response of Moving-Target Indicator Radars Using Pulse or Block Stagger", U.S. Army Missile Research and Development Command Technical Report TE-77-1, 1 Feb. 1977, 37 pp.

3. R. C. Houts & B. P. Holt, "Design of Bandstop Digital Filters for Rejecting Weather or Chaff Clutter in MTI Radars", IEEE SOUTHEASTCON '77, Apr. 1977, pp. 136-139.

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7. R. C. Houts & S. B. Crabtree, "The Effect of MTI Filter and Number of Unique Staggers on First-Null Depth and Clutter Attenuation", *IEEE Trans. Aerospace & Elect. Sys.* (Accepted for Publication).

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