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A COMPARISON OF THREE PEDESTAL REMOVAL TECHNIQUES FOR AN OPTICAL TIME-INTEGRATING CORRELATOR

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N. Brousseau and J.W.A. Salt

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 94-16

Canada

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ABSTRACT

The correlation peak produced by an optical time-integrating correlator appears on a pedestal. It is advantageous to remove this pedestal to allow detection of the peak by a simple thresholding operation. This technical note presents two new techniques developed and tested at DREO to remove the pedestal. The new methods are compared for speed and accuracy with the conventional method. Experimental results are presented.

RESUME

Le pic de corrélation produit par un corrélateur optique à intégration temporelle est formé sur un piedestal. Enlever ce piedestal permet la détection du pic par un simple ébasage. Cette note technique présente deux nouvelles techniques, conçues et testées au CRDO, pour enlever le piedestal. La vitesse et la précision des nouvelles méthodes sont comparées aux résultats de la méthode conventionelle et des résultats expérimentaux sont présentés.

EXECUTIVE SUMMARY

The correlation peak produced by an optical time-integrating correlator appears on a pedestal. It is advantageous to remove this pedestal to allow detection of the peak by a simple thresholding operation. This technical note contains a description of the operation of a time-integrating correlator, the format of the output of the correlator and comparison of three pedestal removal techniques. The conventional technique, where a 180° phase shift is applied to one of the input signals is described and two new techniques developed and tested at DREO are presented. These new techniques do not require phase shift but use previously acquired pedestals to enhance the correlation peak. The three methods are compared for speed and accuracy. The experimental results are presented and show that while the accuracy is similar, the speed is superior using the new techniques.

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LIST OF ABBREVIATIONS

RF: Radio frequency

TIC: Time-Integrating Correlator

SNR: Signal to noise ratio

1.0 INTRODUCTION

Time-integrating correlators (TICs) are analog optical computers designed to correlate two data streams of long duration. The two input RF signals to be processed are introduced into the optical system via acousto-optic interaction in Bragg cells. The correlation is produced when the images of the two light distributions in the Bragg cells are coherently added and time-integrated by a linear detector array.

The typical electrical output of the detector array of a TIC is characterized by the presence of a pedestal. When the input signals are identical, a correlation peak appears on the pedestal. In order to confirm the presence of a correlation peak by a simple thresholding operation, it is convenient to remove the pedestal.

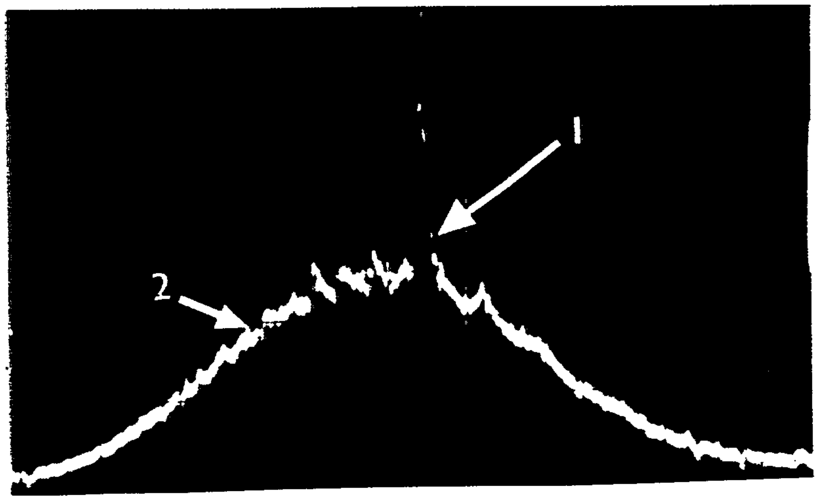
Figure 1A illustrates a pedestal and a correlation peak. In this particular case, the peak is not modulated by a fringe system because the two diffracted beams of the TIC configuration illustrated in Figure 2 are adjusted to propagate in the same direction. Figure 1B illustrates a correlation peak modulated by a fringe system. In this case the two diffracted signals are adjusted to propagate in different directions and the period of the fringes depends on the angle between the directions of propagation. One can also notice the Gaussian shape of the pedestal; it is an expanded version of the Gaussian profile of the illuminating laser beam.

Only one method of pedestal removal has previously been described in the literature [1-2]. The characteristics of that method, including some of its shortcomings, will be reviewed in this Technical Note. Two new methods will also be proposed to alleviate these shortcomings. Experimental results from the three methods will be presented and their speed and accuracy will be compared. This report describes the pedestal removal techniques for a TIC based on the tandem architecture [3] illustrated in Figure 2.

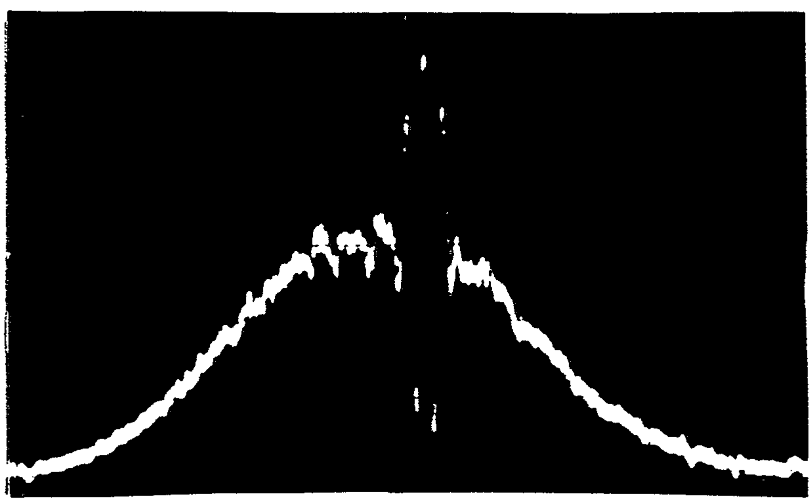
2.0 DESCRIPTION OF A TIME-INTEGRATING CORRELATOR

The techniques used to construct optical time-integrating correlators are well documented in the literature [1-5]. The correlation between two signals a(t) and b(t) is mathematically described by

$$f(t) = \int_{0}^{U} a(u)\, b(t-u)\, du$$



A. CORRELATION PEAK WITHOUT FRINGE



B. CORRELATION PEAK WITH FRINGE

FIGURE 1: PEDESTAL AND CORRELATION PEAKS PRODUCED BY A TIC

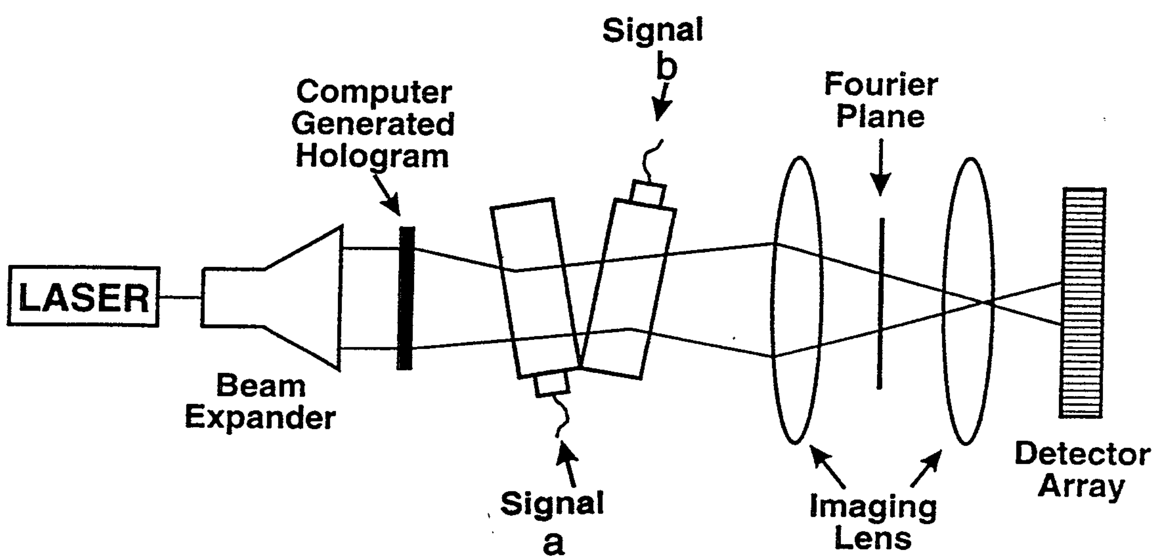


FIGURE 2: TIME-INTEGRATING CORRELATOR: TANDEM ARCHITECTURE

In an optical TIC, the two RF signals a(t) and b(t) are first applied to separate Bragg cells. The Bragg cells are oriented in opposite directions (see Figure 2). The signals are thus propagating in opposite directions, a condition needed for correlation. A computer generated hologram divides the laser beam into two beams propagating at an angle such that each beam interacts with only one of the Bragg cells. The information contained in each RF signal is simultaneously transferred to the optical beams illuminating the Bragg cells. The optical signals diffracted by the Bragg cells now contain the information of the two RF signals. If the variable z is the distance along the Bragg cells and their images, and if the origin z=0 is defined to be at the centre of the Bragg cells and, correspondingly at the centre of their images on the detector array, the optical signals diffracted by the Bragg cells are a(t+z/v) and b(t-z/v) where v is the velocity of propagation of the signal in the Bragg cells. These light distributions are imaged onto a linear array of photodetectors by a series of lenses and spatial filters. The detected electrical signal, s(t,z), is proportional to the square of the light distribution

$$s(t,z) = |a(t+z/v) + b(t-z/v)|^2 \qquad (1)$$

$$= a^2(t+z/v) + b^2(t-z/v) + a(t+z/v)b*(t-z/v) \qquad (2)$$

This electrical signal is then time-integrated and the resulting signal S(T,z) is

$$S(T,z) = \int_0^T [a^2(t+z/v) + b^2(t-z/v) + a(t+z/v)\, b^*(t-z/v)]\, dt \qquad (3)$$

The first two terms produce the undesired pedestal and the third term is the desired correlation after an appropriate change of variable. If the input signals are identical, the correlation peak is formed at the point where the signals meet on the detector array. [Note that each pixel of the detection array basically corresponds to a difference in the time of arrival of the input signals.] A typical electrical signal S(T,z) produced by the detector array of a TIC and displayed on an oscilloscope is shown in Figure 1. A close-up of such a signal is shown in Figure 3 where the outputs from the individual elements of the detector array are resolved.

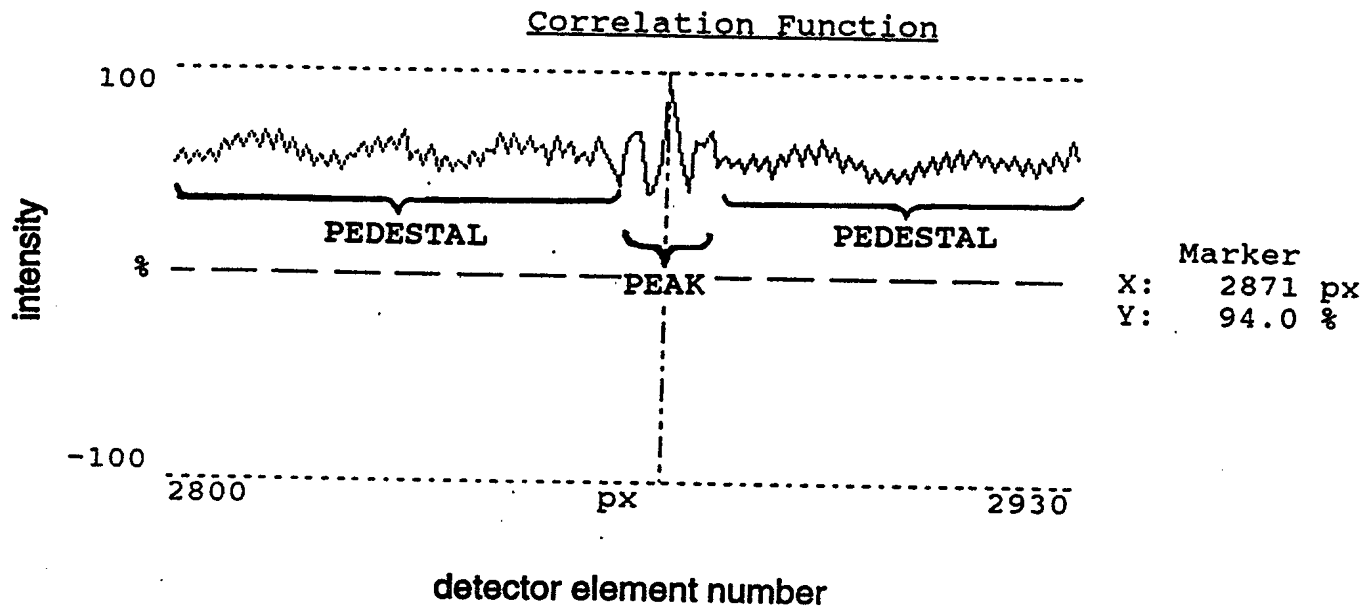


FIGURE 3: PEDESTAL WITH A PEAK

The response of all the individual elements of the detector array is called a correlogram. The peak indicates that the two input signals a and b are identical, conversely the absence of a correlation peak indicates that the two inputs are different.

The light distribution produced by the TIC can be described [6] using the three following elements:

a. a fringe pattern with a variable frequency;

b. a triangular envelope of variable width and location that defines the peaks; and

c. a uniform pedestal.

An idealized representation of the TIC output is obtained by multiplying the fringe pattern with the triangular envelope and adding the product to the uniform pedestal.

Let us consider the origin and the factors affecting the shape of the triangular envelope. The input signal is assumed to be a binary phase-shift keyed (BPSK) signal. The triangular envelope is formed by the auto-correlation of the rectangular chips modulating the input signals. Its width at the base is equal to the length of the chips and is, therefore, equal to the velocity v of the acoustic signal in the Bragg cell divided by the chip rate B used to build the sequence. The apex of the triangular envelope is located at the meeting point of the two input signals and can be found anywhere within the time window of the TIC according to the time of arrival difference of the signals. The other element contributing to the TIC output is the fringe system. In the absence of aberrations or misalignment of the optical system, the period of the fringe system is inversely proportional to the angle between the two output beams.

The third factor contributing to the output of a TIC is the pedestal that is added to the product of the fringe pattern with the triangular envelope. The pedestals illustrated in Figure 1 display the characteristic Gaussian shape of the laser beam illuminating the correlator. However, a uniform illumination is desirable to obtain a correlation peak that has the same height over the TIC's whole window of operation. Techniques to obtain such a distribution have been developed and are discussed in another publication [7].

The three pedestal removal techniques presented here are based on digital post-processing of the correlation signal collected by the detector. All three methods have in common that a subtraction is made between correlograms that were formed at different times, by different segments of the input data.

3.0 PHASE SHIFT PEDESTAL REMOVAL TECHNIQUE

The first method for pedestal removal considered here is described in [1-2]. It relies on the subtraction of two correlograms for which the polarity of their respective correlation peaks are made opposite in sign. This polarity change is accomplished by phase shifting one of the input RF signals by 180 degrees for one of the correlogram recordings. Figures 4a and 4b illustrate the correlation peak and part of the correlogram before and after the 180° phase shift respectively. Subtracting the signals in Figure 4a and 4b removes the pedestal and doubles the height of the peak as can be seen in Figure 4c. The whole 5000-element correlogram is presented in Figure 5.

In a typical situation, where the Bragg cells contain 50 μs of RF signal, a waiting period of 50 μs after a phase shift is needed to allow the phase shifted signal to propagate through and fill the Bragg cells before starting the integration.

In order to ensure complete pedestal removal and maximum enhancement of the peak height, it is important to have the Bragg cell filled with signal before starting the integration with the detector array. This allows the accumulation of energy in the peak to start at the beginning of the integration time, whatever the location of the peak. Therefore, precision timing of the input signals, the phase shifting and the data collection is required for proper operation of this technique.

If an integration time of 250 μs is used, the formation of a correlogram goes through the following cycle:

1. 180° phase shift
2. 50 μs waiting time to fill the Bragg cells
3. integration over 250 μs takes place
4. collection and storage of the first correlogram
5. 180° phase shift
6. 50 μs waiting time to fill the Bragg cells
7. integration over 250 μs takes place
8. collection and storage of the second correlogram
9. subtraction of the two correlograms

In this example there is a 100 μs delay while waiting for new signals to propagate through the Bragg cells; so, it takes 600 μs to obtain a useful integration time of 500 μs. Thus 17% of the time is spent waiting. With shorter integration times, the loss associated with the filling time of the Bragg cells becomes more important. A substantial improvement in the processing speed would result if it was possible to perform pedestal removal without interrupting the flow of data with phase shifts.

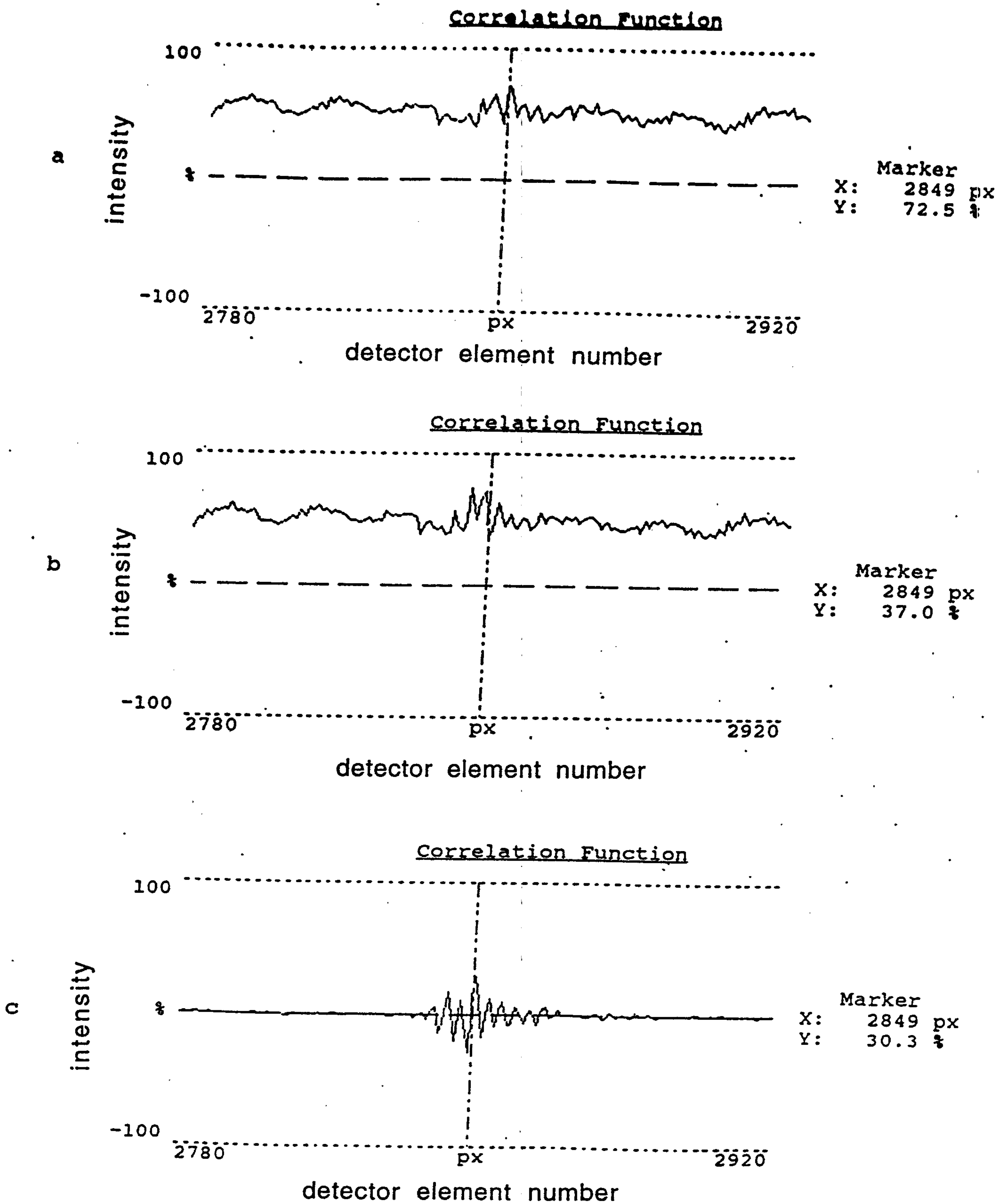


FIGURE 4: STEPS OF THE PHASE SHIFT PEDESTAL REMOVAL

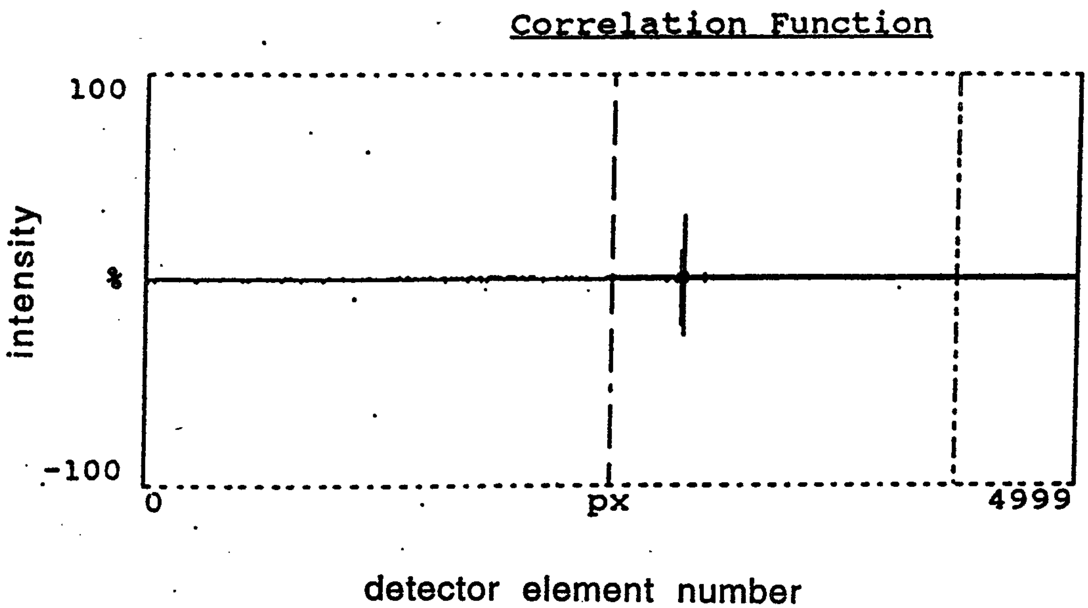


FIGURE 5: CORRELATION PEAK PRODUCED BY THE PHASE SHIFT TECHNIQUE

Another limitation of the phase shift pedestal removal technique becomes important when short integration times are required. The detector array has a minimum integration time T_{min} because of the way the read-out circuitry operates. In the phase shift pedestal removal method, the correlation peak is built up from two integration periods. The resulting minimum integration time for the phase shift pedestal removal technique is thus $2T_{min}$. This can be a serious drawback when integration times less than $2T_{MIN}$ are required. Larger than required integration times then have to be used and a substantial reduction in processing speed results.

4.0 GENERATED PEDESTAL REMOVAL TECHNIQUE

A second pedestal removal method was proposed [8] and implemented at DREO. It consists of subtracting from the last collected correlogram, a peakless reference correlogram stored in the processor. The pedestal is thus removed, leaving the peak intact (see Figure 6). The reference is updated after a set time. This method leads to substantial time savings in the operation of the TIC because it is not necessary to wait for the signals to propagate in the Bragg cells after every phase shift. Also, because the production of a peak with the generated pedestal removal technique involves the collection of a single correlogram, the minimum integration time associated with this technique, is the minimum integration time of the detector array, T_{min}.

5.0 AVERAGED PEDESTAL REMOVAL TECHNIQUE

A third method was proposed [8] and implemented at DREO to perform pedestal removal (see Figure 7). As for the generated pedestal method, a reference pedestal is subtracted from the last acquired correlogram. However, this time the reference pedestal is formed by adding a certain percentage (say 10%) of the last acquired correlogram, if it does not contain a peak, to the complementary percentage (say 90%) of the old pedestal. The decision on the presence of a peak is taken by checking if any value of the last correlogram is larger than a threshold set by the user. The size of the contribution of the last correlogram to the new pedestal is set by the user. The process of building the reference pedestal can be described by the following equations:

$$P_i = X\ P_{i-1} + Y\ C_i$$

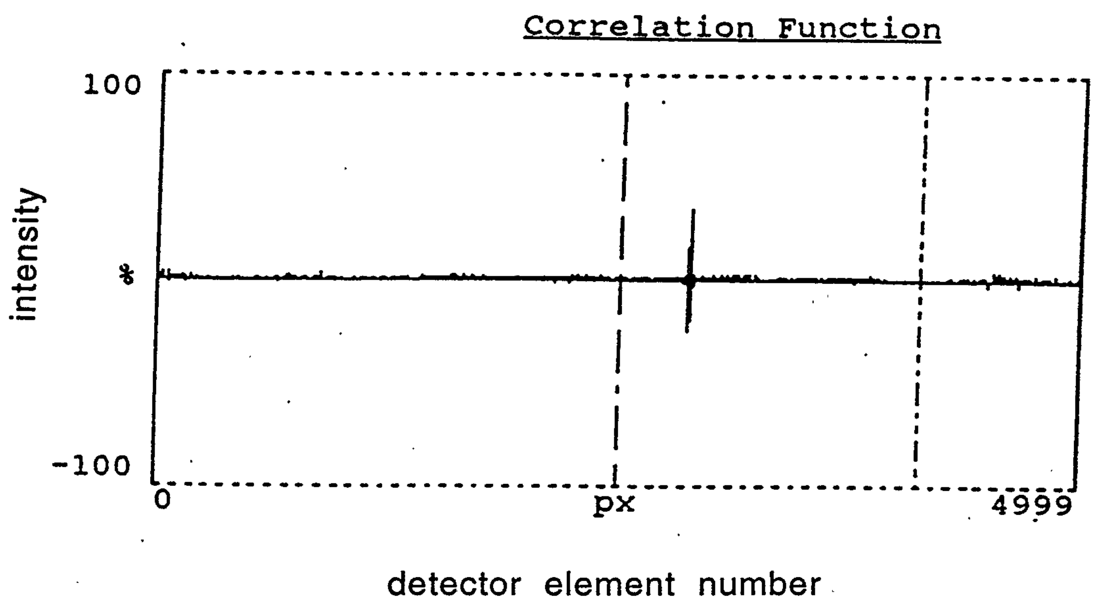


FIGURE 6: CORRELATION PEAK PRODUCED BY THE GENERATED PEDESTAL TECHNIQUE

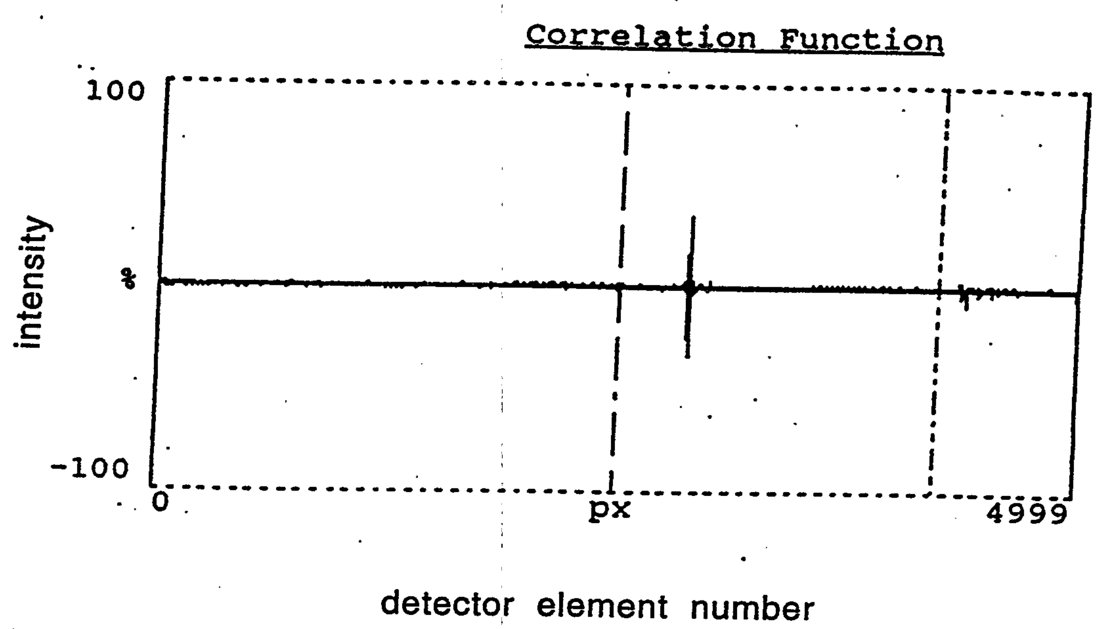


FIGURE 7: CORRELATION PEAK PRODUCED BY THE AVERAGED PEDESTAL TECHNIQUE

where

P_i = i^{th} reference pedestal
C_i = i^{th} peakless correlogram
X,Y = weighting factors such that X+Y = 1.

Similar to the second method, the third method does not involve any waiting time for the RF signal to fill the Bragg cell. The speed of the TIC is the same as for the generated pedestal method and the minimum integration time is also T_{min}.

6.0 COMPARISON OF THE THREE TECHNIQUES

Theoretically, all three methods produce a peak with the same signal to noise ratio (SNR). When the total integration time involved in the pedestal removal process is the same, the height of the correlation peaks is the same.

In practice, the results of the three methods may differ if the output of the optical correlator is not stable. Mechanical vibrations or laser power fluctuations may cause this to happen. The residual pedestals left after subtraction reflect the changes that occurred in the pedestal during the collection of the reference pedestal up to the last acquired correlogram.

The averaged pedestal removal technique is the only one having the capability to track variations of the pedestal level. Good results are produced if these variations are slow relative to the time involved in forming the reference pedestal. The phase shift and the generated pedestal removal techniques use periodic upgrades of the pedestal where a completely new pedestal is acquired. The phase shift technique works well if the variations between adjacent pedestals are small. The generated pedestal removal technique requires a good stability of the pedestal between the updates.

6.1 Comparison of the Speeds

In the first method, the integration time is built up from two integration times of duration T_{int}. As it is necessary to wait for the signals to propagate through the Bragg cells after every phase shift, the duration of one cycle of operation is $2T_{int}+2\tau$, where τ is the propagation time in the Bragg cell. In the averaged and generated pedestal methods, the cycle duration is equal the integration time and is T_{int}. If the minimum integration time of the detector array is T_{min}, the minimum integration times of the phase shift, the generated and the averaged pedestal removal techniques are respectively, $2T_{min}$, T_{min} and T_{min}. Thus the generated and averaged pedestal removal techniques have the advantage of allowing shorter integration times than the phase shift pedestal removal technique. This contributes to more flexibility in the setting of the parameters of operation of the TIC. Table 1 presents a summary of the characteristics of the three pedestal removal techniques.

TABLE 1: COMPARISON OF THE PARAMETERS FOR THE PHASE SHIFT, THE AVERAGED AND THE GENERATED PEDESTAL REMOVAL TECHNIQUES WHERE T_{int} IS THE INTEGRATION TIME USED TO COLLECT ONE CORRELOGRAM AND WHERE T_{MIN} IS THE MINIMUM INTEGRATION TIME PRODUCED BY THE DETECTOR ARRAY

parameter	phase shift method	generated pedestal method	averaged pedestal method
waiting time	2τ	zero	zero
min. integration time	$2T_{int}$	T_{int}	T_{int}
length of one cycle	$2T_{int}+2\tau$	T_{int}	T_{int}
speed in number of pedestal removal per section	$1/(2T_{int}+2\tau)$	$1/T_{int}$	$1/T_{int}$

A few examples of the processing speed associated with the three pedestal removal techniques have been calculated and are presented in Table 2. It can be concluded from Table 2 that the generated and averaged pedestal removal techniques lead to substantially faster processing than the phase shift method.

TABLE 2: EXAMPLES OF THE SPEED, IN NUMBER OF PEDESTAL REMOVAL PER SECOND, OF THE THREE PEDESTAL REMOVAL TECHNIQUES FOR τ = 50 μs, T_{MIN} = 250 μs, T_{INT} = 500 μs AND T_{INT} = 1000 μs.

integration time for one correlogram	speed phase shift method	speed generated method	speed averaged method	% improvement
T_{min} = 250 μs	1667	4000	4000	240%
T_{int} = 500 μs	909	2000	2000	220%
T_{int} = 1000 μs	476	1000	1000	210%

6.2 Comparison of Accuracy

The accuracy of the autocorrelations produced experimentally by the three pedestal removal techniques (see Figure 4, 5 and 6) have been compared by calculating the mean, the variance and the standard deviation on two 1001-pixel long segments not containing a peak for each autocorrelation. These pixels are the detector array elements number 1000 to 2000 and 3000 to 4000. The total integration time was 1020 μs for each of the three techniques and was set to be an even multiple of the duration of the m-sequence used for the experiment. This procedure prevents adding partial correlation noise to the results [9] and allows evaluation the noise produced by the three pedestal removal techniques. Ideally the mean, variance and standard deviation should be zero on segments of correlograms that do not contain a peak. The results are illustrated in Table 3. The values of the parameters are given as numbers that can vary between -100 and 100 and as percentage of the peak height (in parenthesis).

TABLE 3: COMPARISON OF EXPERIMENTAL RESULTS FOR THE THREE PEDESTAL REMOVAL TECHNIQUES

Segment	Parameters	Phase Shift	Generated	Averaged
pixels 1000 to 2000	peak height	30.6	34.2	35.7
	mean	-.02(.06%)	.3(.9%)	.6(1.7%)
	variance	.09(.3%)	.1(.3%)	.2(.5%)
	standard deviation	.3(1%)	.3(.9%)	.4(1.2%)
	SNR of the peak	31.8 dB	20.6 dB	17.7 dB
pixels 3000 to 4000	peak height	30.6	34.2	35.7
	mean	-.4(1.3%)	.3(.9%)	.7(2.0%)
	variance	.04(.1%)	.1(.3%)	.2(.5%)
	standard deviation	.2(.6%)	.3(.9%)	.4(1.2%)
	SNR of the peak	18.8 dB	20.6 dB	15.5 dB

The three methods performed very well, the maximum values of the mean, the variance and the standard deviation being respectively 2%, .5% and 1.2%. It is to be noted that the mean of the noise is very small for the phase shift method on the segment from 1000 to 2000 pixels. The SNR of the peak for that segment is thus better. No explanation is available for this anomaly. The average pedestal removal method seems to be slightly less accurate because it produces peaks with a lesser SNR.

7.0 CONCLUSION

This technical note contains the comparison of three methods of pedestal removal. They were compared for speed and accuracy and experimental results were presented. The conventional technique, where 180° phase shifts are applied to one of the input signals, is described and is demonstrated to be the slowest. The two new techniques developed and tested at DREO are presented. These new techniques do not require phase shifts and are more than twice as fast as the phase shift method. The three methods show comparable results in terms of accuracy. The most accurate is the generated pedestal technique and the least accurate is the averaged technique. The SNR of the output peak of the generated method is 5.1 db better than the averaged method.

8.0 REFERENCES

[1] M.W. Casseday, N.J. Berg, I.J. Abramovitz and J.N. Lee, "Wide-Band Signal Processing Using the Two-Beam Surface Acoustic Wave Acoustooptic Time Integrating Correlator", IEEE Transactions on Sonics and Ultrasonics, vol. SU-28, no. 3, May 1981, p. 205-212.

[2] N.J. Berg and J.N. Lee, "Acousto-Optic Signal Processing: Theory and Implementation", Marcel Dekker Inc., New York and Bassel, 1983, Chap.10.

[3] N. Brousseau and J.W.A. Salt, "Two Compacts Tandem Architectures for the Implementation of Time-Integrating Correlators", DREO TN 91-8.

[4] P. Kelman, "Time Integrating Optical Signal Processing", Ph.D. Dissertation, Dept. of Electrical Engineering, Stanford University, June 1979.

[5] D.A.B. Fogg, "A Compact Bulk Acousto-Optic Time-Integrating Correlator", Tech. Rep. ERL-0323-TR Department of Defence of Australia, Salisbury, Australia, 1984.

[6] N. Brousseau and J.W.A Salt, "Analysis and Optimization of the Data Collection Process of Time-Integrating Correlators", DREO TN to be published.

[7] N. Brousseau and J.W.A. Salt, "Illumination System for a Time-Integrating Correlator" (U), DREO TN (to be published).

[8] "Acousto-Optic Post-Processor Time-Integrating Correlator Update: Final Report", Report for Contract W7714-0-9886, Calian Communications Systems Ltd., 28 March 1991.

[9] R.C. Dixon, "Spread Spectrum Systems", p.76, John Wiley & Sons Inc., 1984.

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TIME-INTEGRATING CORRELATOR
DATA PROCESSING OF TIME-INTEGRATING CORRELATOR
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