VISSR ATMOSPHERIC SOUNDER

Monthly Progress Report No. 2
For the period 1 Oct. 1973 to 31 Oct. 1973

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Goddard Space Flight Center
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I. Introduction

During the past month and a half discussions with SBRC, GSFC, and NOAA have brought to light new opportunities and new problems which impact the basic VAS detector configuration and VAS operation. Important factors bearing on this situation are: (1) a general consensus exists that 3.7μ and 4.3μ channels provide significant improvements in sounding capability; (2) the 6 HgCdTe + 6 InSb detector array suggested by U.W. in September results in a complex dewar package which, according to SBRC, represents substantial risk to the program schedule; (3) previously assumed operational constraints which required imaging/sounding (non-interfering) as a primary mode appeared to be relaxed to the degree that dwell sounding operation could be considered as primary; and (4) greater emphasis was placed by NASA on minimizing multiplexer modifications as much as possible.

As a result of these and other considerations considerable effort during the past month was directed at evaluating possible alternative detector configurations and operating modes. Additional areas of investigation included registration problems and improvements in the large time interval model for the autocovariance function. The latter work is reported in the addendum.

II. Evaluation of Alternative Detector Configurations

Suggestions of alternate detector configurations were made with a number of objectives in mind, many of which are conflicting. Among the most important are the following:

(1) minimize the number of detectors to reduce dewar complexity and simplify MUX modifications (reduce total sampling rate required);

(2) increase the number of detectors to improve capability to sound without

interfering with imaging;

(3) increase detector size to obtain better radiometric accuracy and minimize detector registration problems;

(4) reduce detector size to improve cloud discrimination and imaging capabilities and reduce detector registration problems;

(5) increase total detector area to decrease sounding time; and

(6) decrease total detector area to minimize dissipation on the cold finger.

In all, seven different detector configurations have been considered in terms of these objectives. These are identified by numbers of detectors of different size and/or type as outlined in Figure 1, which also displays the geometrical arrangements for each possibility. Only the "6" configuration is absent from Figure 1. It is the original configuration specified in the April 1972 document "SMS Sounder Specification" and is the same as the "6 + 6" configuration of Figure 1 except that the InSb array of 6 detectors is omitted. Note that Figure 1 does not accurately portray the detailed east-west positioning of the detector elements which depends on lead runout requirements, sampling intervals, etc. One should also note that the numbers in the configuration I.D. also state the numbers of detectors which must be sampled in any given scan. For example, in the "4 + 2" configuration 4 HgCdTe detectors are sampled during scans which have a filter from any of bands 1-10, while 2 InSb detectors are sampled during other scans.

The configurations were analyzed in terms of a number of performance characteristics and compared in Table 1. Before evaluating these comparisons it is first necessary to explain each of the performance factors listed. These are discussed in the following.

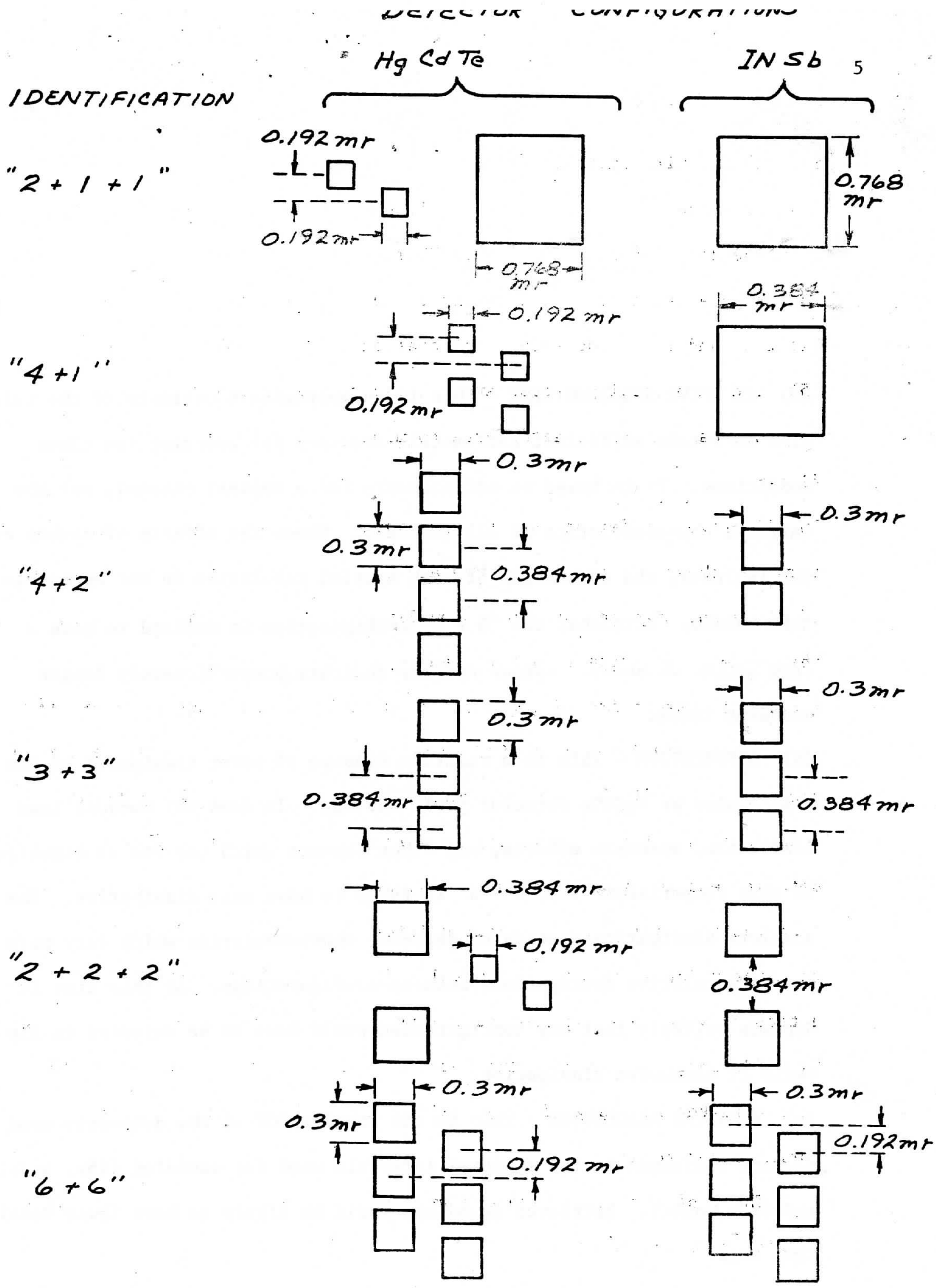


Figure 1 Alternative Detector Configurations and Identification
The milliradian dimensions are equivalent to subsatellite FOV's of 6.9 km for 0.192mr, 10.7 km for 0.3 mr, 13.7 km for 0.384mr, and 27.5 km for 0.768mr.

(a) RELATIVE SOUNDING TIME - This is an approximate estimate of the relative time to obtain sufficient radiometric accuracy for sounding for clear conditions. It is based on noise levels for a typical channel, not the weighted characteristics of all channels. Since the effects of clouds are not included, the advantages of high spatial resolution do not appear in this column. Note that the "6 + 6" configuration is defined to have a time factor of unity. Larger numbers indicate proportionately longer sounding times.

(b) DISSIPATION - This is a relative measure of power dissipated on the cold finger by HgCdTe detector joule heating. It does not include lead conduction, aperture effects, and other factors which are not as significant in this comparison. The "6 + 6" is taken to have unit dissipation. The absolute dissipation depends on detector characteristics which vary more than the relative dissipations between configurations. At this time it appears unlikely that any configuration would have to be rejected on the basis of excessive dissipation.

(c) SOUNDING RESOLUTION - This is the angular FOV of the detectors used to measure radiances in the spectral intervals used for sounding (15μ, 4.3μ, and 6.7μ bands). Retrieved soundings would be likely to have lower resolution than this.

(d) IMAGING RESOLUTION - This is the angular FOV of the detectors used to measure radiances in the 11.1μ window channel.

(e) SOUNDING SAMPLES/DWELL - This is the number of samples per dwell that could be obtained without changing the multiplexer bit rate. The dwell time used is one typical to the 15μ channels (or bands). The "W MOD" column indicates what could be achieved by changing the MUX format (and also omitting sync words); the "W/O MOD" column indicates what can be obtained within the present MUX format by switching from one detector to the next at the same rate as the present switching between primary and redundant detectors.

(f) NEED FOR LIGHT PIPE - Large detectors, which are more frequently observing cloud contamination, must produce accurate registration of spatial responses from channel to channel. However, non-uniformity of detector responsivity across the detector surface (± 10% for InSb and greater than ± 50% for HgCdTe) makes this impossible unless a light pipe is used to diffuse radiation from each image point over the entire detector surface. For small detectors, which have a greater tendency to observe either cloud or clear conditions, the responsivity variations do not represent such a great problem. However, no absolute requirement can be used to determine whether or not light pipes must be used since this varies with data processing procedures and depends on how accurately light pipes can be constructed. Consequently the estimates of need are just estimates at this time.

(g) POSSIBILITY OF LIGHT PIPE - This is an estimate by SBRC of the feasibility of constructing a light pipe of the required size with present fabrication techniques. It does not represent an accurate determination of whether the achievable precision meets the ultimate geometrical requirements (as yet uncertain).

(h) RISK FACTOR - These are very approximate estimates of the risk to the program schedule for each detector configuration. These are based on information provided by SBRC. A risk factor of 2 represents an intolerable risk (program delays are quite possible). A risk factor of 1 represents a marginal risk, while a risk factor of 0.25 represents very little risk.

(i) S/C MODIFICATION DIFFICULTY - In order to achieve sampling rates which are acceptable three levels of modification were considered. These are: 1. no MUX or A/D converter modifications, only low speed switching between detector arrays at line rates within the VISSR package; 2. high speed switching among more than two detectors at the same rate as presently done between two detectors, with switching done on the S/C and no basic changes in MUX format or A/D converters; 3. changes in MUX format, omission of some sync words, A/D modifications as required to increase total sampling rate.

Note that none of these modifications change the transmission bit rate. Nor do they affect the visible sampling and formatting.

(j) IMAGING/SOUNDING CAPABILITIES - This is the number of sounding channels that can achieve full spatial coverage in one pass in the imaging/sounding mode of operation. It is assumed that the 11.1μ window channel always requires full spatial coverage in this mode.

Any evaluation of these comparisons must face the difficulty of assigning appropriate weights to each of the factors considered. In many cases this is just a matter of opinion or general consensus rather than an objective logical process. In the present context of this program, however, significant conclusions can be drawn from these comparisons: (1) the "6 + 6" configuration involves an unacceptable risk in terms of dewar package fabrication; (2) the "4 + 1" configuration requires too much sounding time (4 x the minimum); (3) the "6" configuration does not have the proven cloud discriminating capabilities of a 3.7μ window channel; and (4) the "2 + 1 + 1" configuration has relatively high dissipation and risk as well as low sounding resolution. Of the remaining configurations which do not have serious disadvantages, or a combination of relatively serious disadvantages, the basic choice is between the "4 + 2" and the "2 + 2 + 2", the former providing somewhat better imaging/sounding capabilities, while the latter provides the lower dewar risk and the lowest impact on S/C modifications of all the configurations.

Table 1. Comparison of Alternative Detector Configurations

DETECTOR ARRAY	RELATIVE SOUNDING TIME	RELATIVE DISSIPATION	SOUNDING RESOLUTION	IMAGING RESOLUTION	SOUNDING SAMPLES/DWELL		LIGHT PIPE		RISK FACTOR	S/C MOD DIFFICULTY	IMAGING/ SOUNDING CAPABILITIES
					W MOD	W/O MOD	NEED	POSSIBLE			
"2 + 1 + 1"	0.9	1.23	0.768mr	0.192mr	--	18.4	yes	yes?	1.0	1	2
"4 + 1"	3.7	.27	0.192mr (1)	0.192mr	1.83	1.15	yes	yes?	1.0	3	3
"4 + 2"	1.5	.67	0.30mr	0.30mr	2.9	1.8	?	?	0.7	2-3	3
"3 + 3"	2.0	.50	0.30mr	0.30mr	3.6	2.4	?	?	1.0	2	2
"2 + 2 + 2"	1.8	.68	0.384mr	0.192mr	---	4.6	?	?	0.7	1	2
"6 + 6"	1	1.0	0.30mr	0.30mr	2.0	1.2	?	?	2.0	3	5
"6"	1 + Q (2)	1.0	0.30mr	0.30mr	2.0	1.2	?	?	0.3	3	5

NOTES: (1) The 0.192mr applies for 15 channels, 0.768mr at 4 .

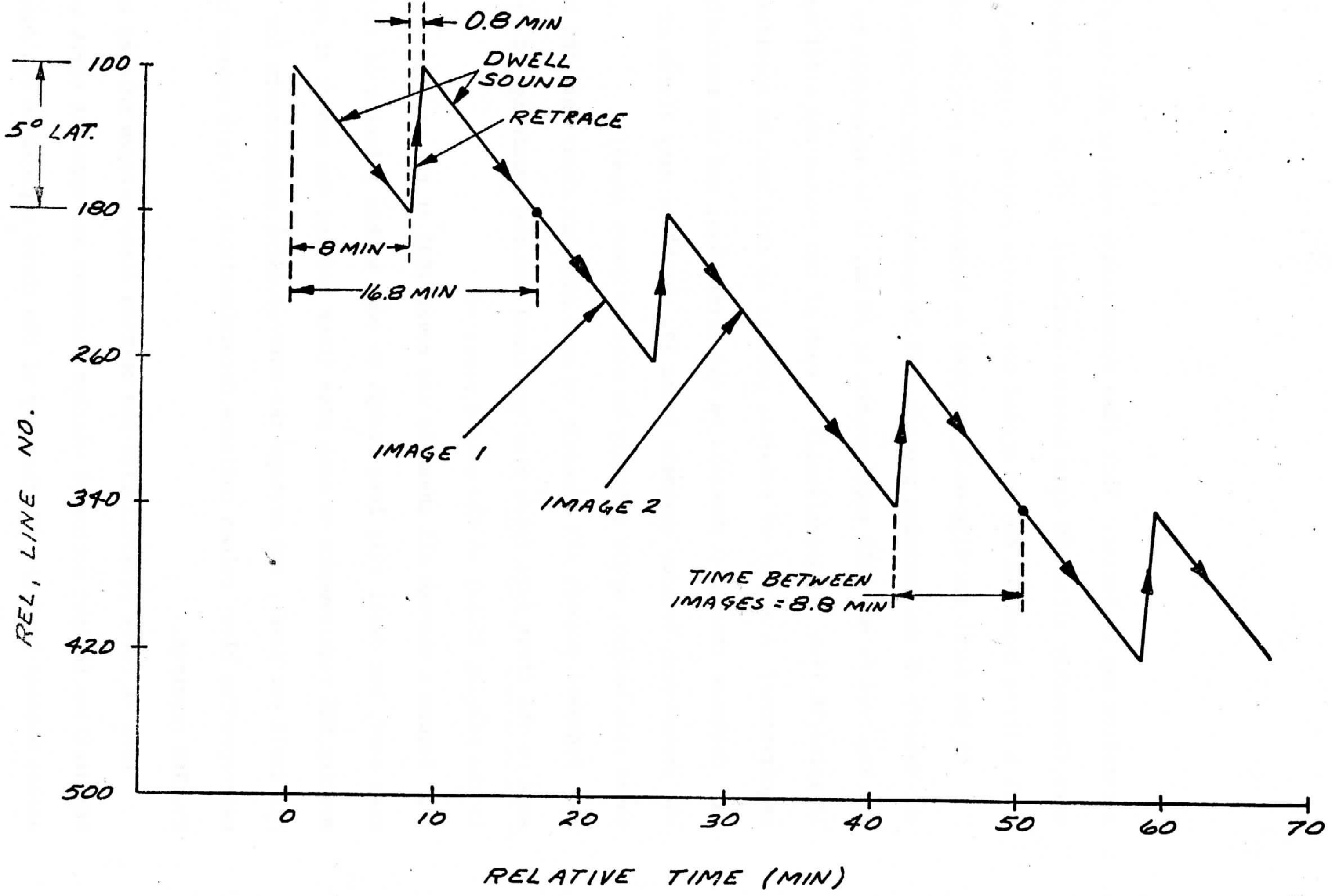
(2) Time allotted for Q bands would substantially increase the total time unless external data used.

On the whole, the "2 + 2 + 2" configuration provides dwell sounding capabilities (considering clear sounding time and cloud discrimination effectiveness) as good as any of the configurations, and also has the best chance of success (highest feasibility) of any of those configurations including InSb detectors.

III. Operating Modes - Dwell Sounding

During dwell sounding (with the "2 + 2 + 2" configuration, for example) it is possible to meet NEN requirements at a spatial resolution of 30 km while scanning one IR line per 20 spins (average). This amounts to about 20° of latitude (near the subsatellite point) per hour. Since the value of these soundings would be greatly augmented by simultaneous wind field information some modification of the dwell sounding mode should be considered. Instead of merely scanning down 30° of latitude to obtain sounding coverage it would be advantageous to break the 30° swath into smaller pieces (say 5° to 10° swaths) and scan each twice at twice the rate to obtain an image pair which could be used to derive cloud displacements ("winds"). Actually this process would produce 13 image pairs (12IR and 1 visible) which would provide a unique opportunity to determine the vertical structure of the wind field.

In simplified terms the proposed dwell sounding mode would operate as follows: (1) scan down from start line to end line at an average rate of 1 line every 10 spins; (2) retrace at 1 line per spin from end line to start line; (3) scan down again at 1 line per ten spins. At this point a new subframe could be initiated. An example of a dwell sounding sequence of 5° subframes is presented in Figure 2. The image time separation of 8.8 min. may not be optimum considering the geometrical precision of the VISSR scanner and the required wind accuracy. A 10° subframe with 17.4 min. image


0.8 MIN
DWELL
SOUND
RETRACE
5° LAT.
8 MIN
16.8 MIN
IMAGE 1
IMAGE 2
TIME BETWEEN
IMAGES = 8.8 MIN
REL, LINE NO.
100
180
260
340
420
500
0
10
20
30
40
50
60
70
RELATIVE TIME (MIN)

separation may be better. This time optimization problem will be addressed more thoroughly after SMS data becomes available. (It is also possible that a three image set may be needed for quality control purposes.)

If the dwell sounding mode operates as suggested, a problem arises as to the details of the scanning process. If 20 spins/IR line (80 spins/dwell) are required to meet NEN requirements at 30 km, is it acceptable to obtain 10 spins/IR line (40 spins/dwell) on each of two passes and still meet requirements? A number of possible ways to do this must be considered:

(a) Sequence through 6 channels on the first pass, and the remaining 6 on the second pass (window channels 8 and 12, which use very little of the total spin budget, would actually be used on every pass);

(b) Sequence through all channels on each pass but cover only 50% of the area on the first pass (with missing lines) and the remaining 50% (filling in the missing lines) on the second pass; or

(c) Sequence through all channels and cover 100% of the scanned area on each pass, but dwell only long enough to come within a factor of $\sqrt{2}$ of meeting NEN requirements on each pass (thus halving the number of spins per dwell per pass), and average the corresponding measurements (or corresponding clear column radiance determinations) on both passes to obtain the NEN required.

Each of these possibilities has certain disadvantages related to registration (slight motion of weather features and apparent earth motion occurs between passes). Whether any of the three approaches can duplicate the performance obtained in a single slow scan (20 spins/IR line average) is currently a matter of conjecture needing further study. If closer examination dictates, additional methods for obtaining image pairs will be considered.

IV. Registration Errors - Responsivity Variations

In processing cloud contaminated sounding channel data to obtain equivalent clear column radiances it is usually necessary to use paired (geometrically adjacent) fields of view and the 11.2μ window channel in the following formula

$$I_{c,\nu} = \frac{I_\nu^{(1)} - N^* I_\nu^{(2)}}{1 - N^*} \tag{1}$$

where

$$N^* = \frac{I_w^{(1)} - I_{c,w}}{I_w^{(2)} - I_{c,w}} \tag{2}$$

and we use the definitions

$I_{c,\nu}$ = clear column spectral radiance for spectral band ν

$I_{c,w}$ = clear column spectral radiance for a window channel

$I_\nu^{(j)}$ = observed radiance from FOV #j in band ν

$I_w^{(j)}$ = observed radiance from FOV #j in a window channel

In order to apply this formula it is necessary to know $I_{c,w}$ and to have the following conditions satisfied:

(1) $N^* \neq 1.0$

(2) clouds in FOV's 1 and 2 have grey emittance-transmittance properties

(3) the height of the clouds is the same in FOV's 1 and 2

It is the function of the 3.7μ window channel to provide a test for conditions (2) and (3). For example, if equation (2) is applied for both 3.7μ and 11μ windows and the two N* values determined do not agree then the assumed cloud conditions are not present. In order to make this check, however, it is essential that both 3.7μ and 11.2μ windows have identical FOV's, i.e. that they observe the same thing. Otherwise the check is meaningless.

Registration of 3.7μ and 11.2μ window channels is complicated by the fact that neither detector has uniform responsivity over the detector surface.

The HgCdTe detectors typically have (according to SBRC) 50% responsivity variations,while the InSb detectors (for the 3.7μ window) have 10% responsivity variations. Thus, if two detectors of the same size are considered, these variations of sensitivity in the projected FOV are so large as to make the paired FOV corrections hopeless. However, if small HgCdTe detectors (0.192mr FOV) are used in conjunction with large InSb detectors (0.384mr FOV); it is possible that, over the larger FOV, the assemblage of small HgCdTe FOV's may have an effective responsivity variation significantly smaller than that of each individual small FOV.

An indication of this improvement can be seen from simulation results from somewhat different test conditions. Four lines and six samples per line of 0.3mr FOV's were averaged to obtain radiances over a 30 km square. Each 0.3mr FOV was broken into 9 subsegments with individual weights simulating 50% responsivity variations. Sloped and Peaked (S and P) weight distributions were used with maxima at Bottom, Right, or Center (B, R or S) of the detector (hence the notation BS for bottom sloped). A variety of weights and a variety of seven cloud distributions were used in the test. Results were compared to the same average with flat field detectors. As indicated in Figure 3 resulting radiometric errors depend on cloud distribution, weight distribution, and the difference between cloud and clear radiances. For approximately 50% cloud cover the RMS overall error is approximately 2% of the difference. For many cases this means errors of the order of 1 erg/(sec-cm^2-ster-cm^{-1}), a quite unsatisfactory result. Unless better responsivity uniformity can be obtained larger averaging areas, smaller cloud amounts, or warmer clouds, or all three restrictions must be applied to obtain adequate radiometric registration.

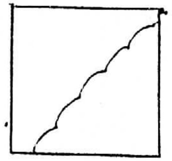
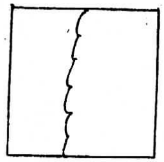
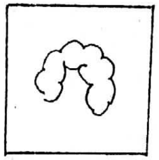
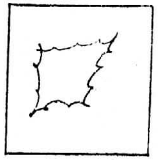
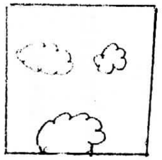
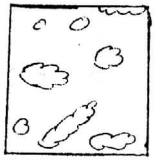
	SCENE:	(1) 	(2) 	(3) 	(4) 	(5) 	(6) 	(7) 		
	DETECTOR WEIGHTS									RMS %
1)	BS, RS, BP, CP	2.8%	0.9%	0.0%	0.5%	-0.9%	1.5%	-0.5%	→	1.3
2)	BS, RS, BS, RS	3.7%	1.9%	0.0%	0.9%	-1.5%	1.4%	-0.9%	→	1.8
3)	BP, CP, BP, CP	1.8%	0.0%	-1.7%	0.9%	0.7%	2.7%	0.7%	→	1.2
4)	BS, BS, BS, BS	3.2%	0.0%	4.2%	0.5%	0.0%	-0.5%	-0.2%	→	2.0
5)	RS, RS, RS, RS	3.4%	3.7%	0.0%	-0.5%	0.3%	-1.2%	0.3%	→	2.0
		↓	↓	↓	↓	↓	↓	↓		↓
	RMS %	3.1	1.9	2.0	0.7	0.9	1.6	0.6	→	$\boxed{1.8}$

Figure 3 RADIOMETRIC ERROR = $-\Delta$ x (tabulated value)

Δ = radiance difference beteeen clear and cloudy conditions

Example: Δ = 50 ergs/etc., Detector wts. 1), Scene (6)
Radiance error (compared to flat weights) $= 50 \times \frac{1.5}{100} = 0.75$ erg/etc.

It should be noted that there are many other sources of registration errors which have not been discussed, and which are being studied.

ADDENDUM TO MONTHLY PROGRESS REPORT NO. 2 (Oct.) on NAS5-21965

CALCULATION OF AUTOCOVARIANCE FUNCTIONS

Prepared by Subhash Dandage

[1] Previous work

Until now, the calculation of the autocovariance function,

$$\underline{C(\tau)} = \int_0^\infty T^2(f)P(f)\cos 2\pi f\tau df \qquad (1)$$

was based on the assumption of an ideal bandpass filter. In other words it was assumed that

$$T^2(f) = \begin{cases} 1 \text{ for } f\text{min} \leq f \leq f\text{max} \\ 0 \text{ for } f < f\text{min and } f < f\text{max} \end{cases}$$

also $P(f) = \left(1 + \frac{f_c}{f}\right) \cdot K$ where $K = \frac{\sigma^2}{\Delta f_N}$

In such a case $\frac{C(\tau)}{\sigma^2}$ is given by

$$\frac{C(\tau)}{\sigma^2} = \frac{1}{\Delta f_N} \int_{f\text{min}}^{f\text{max}} \left(1 + \frac{f_c}{f}\right)\cos(2\pi f\tau)df \qquad (2)$$

where $\Delta f_N = f\text{max} - f\text{min} + f_c \ln \frac{f\text{max}}{f\text{min}}$

Program "COVARM" written in Oct. 71 was used to compute $\frac{C(\tau)}{\sigma^2}$ for such a case. Use of math tables was done in computation of integrals.

$\frac{C(\tau)}{\sigma^2}$ was also modelled by an equation of the form:

$$\frac{C(\tau)}{\sigma^2} = a - b\ln\tau \qquad (3)$$

for the case under consideration, a and b can be computed with the help of the formulae: $b = \frac{f_c}{\Delta f_N}$; $a = b(-\ln 2\pi f\text{min} - \gamma)$, $\gamma = .577216$ (4)

Refer to the report on program "COVARM" dated 23 Oct. 71 for more details about this special case.

[2] Recent work

The ideal bandpass filter assumption is not realistic. The real filter transfer function should include:

1) the presampling filter and

2) Restore circuit noise transfer function.

The following parameters are known:

fmax = 17450 Hz

fmin = .026 Hz

f_c = 750 or 10 Hz

Presampling filter:

The pole locations for this filter (normalized so that -3 dB radian frequency = 1 rad/sec) are given as

$$p_1 = -0.70557 + j0$$
$$p_{2,3} = -0.67745 \pm j0.94007$$
$$p_{4,5} = -0.54117 \pm j1.82565$$

Program 'FILTER', listed in Appendix A, uses these pole locations to compute the normalized power transfer function for the presampling filter. This power transfer function is plotted in Figure 1.

D.C. Restore noise transfer function:

This transfer function is represented by the following relation

$$N(f) = \sqrt{1 - \frac{2\sin(2\pi fT_1)}{2\pi fT_1[1 + (2\pi fT_2)^2]^{1/2}} + \frac{1}{[1 + (2\pi fT_2)^2]}} \quad (5)$$

and is plotted in Figure 2.

In this work, it was assumed that $T_1 = T_2 = 0.3$ sec.

Figure 3 (a,b) show the combined effect of the presampling filter and D.C. Restore. It can be noticed that the oscillations in the D.C.R. noise transfer function cause a small bump in the total transfer function.

[3] Calculations without D.C.R.

The transfer function of the presampling filter was approximated by a sum of 25 transfer functions, each corresponding to an ideal bandpass filter and having a weighting factor of 0.4. This approximation is shown in Figure 1

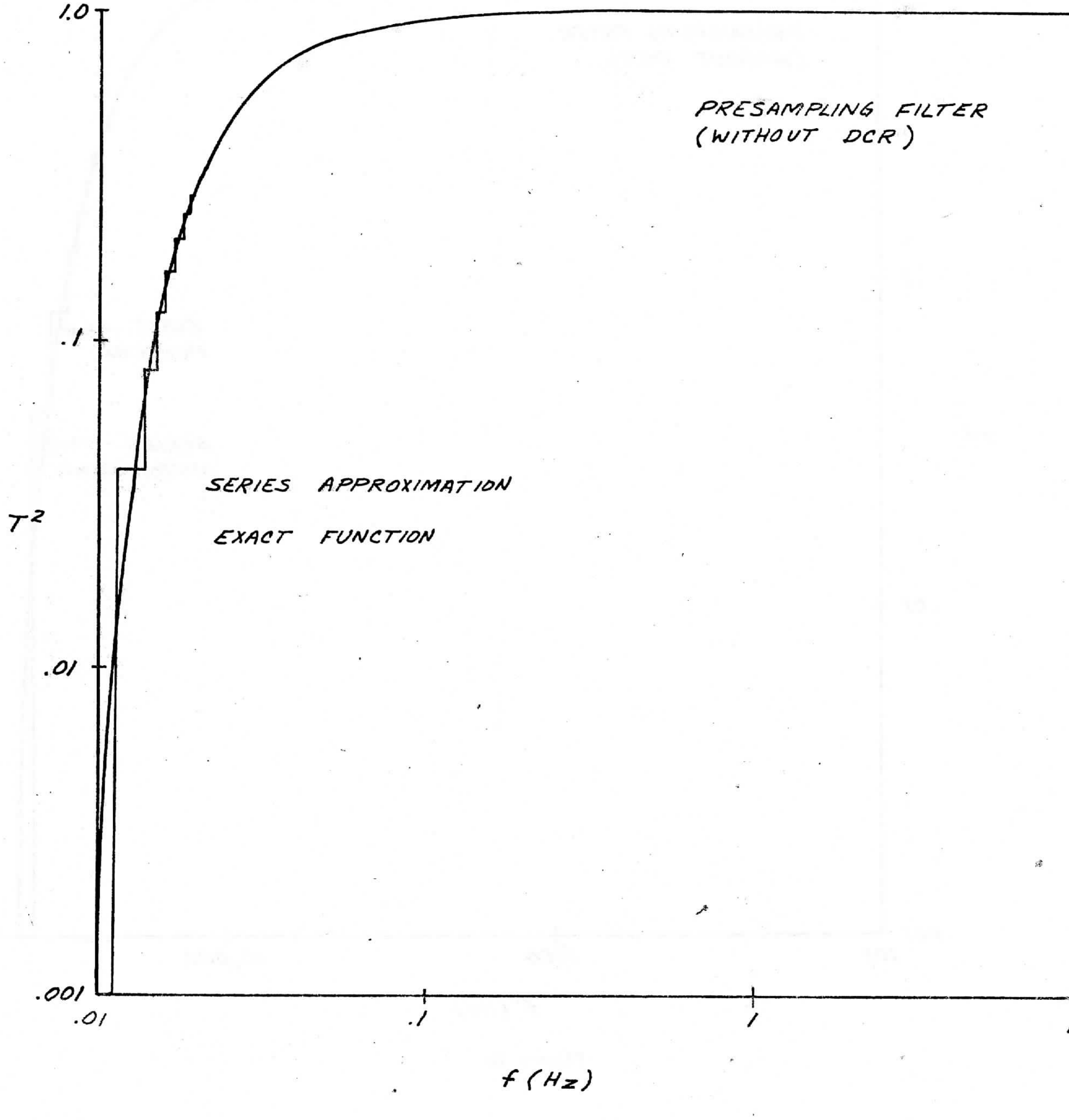

1.0
.1
.01
.001
T²
.01
.1
1
f (Hz)
PRESAMPLING FILTER
(WITHOUT DCR)
SERIES APPROXIMATION
EXACT FUNCTION

Figure 1a

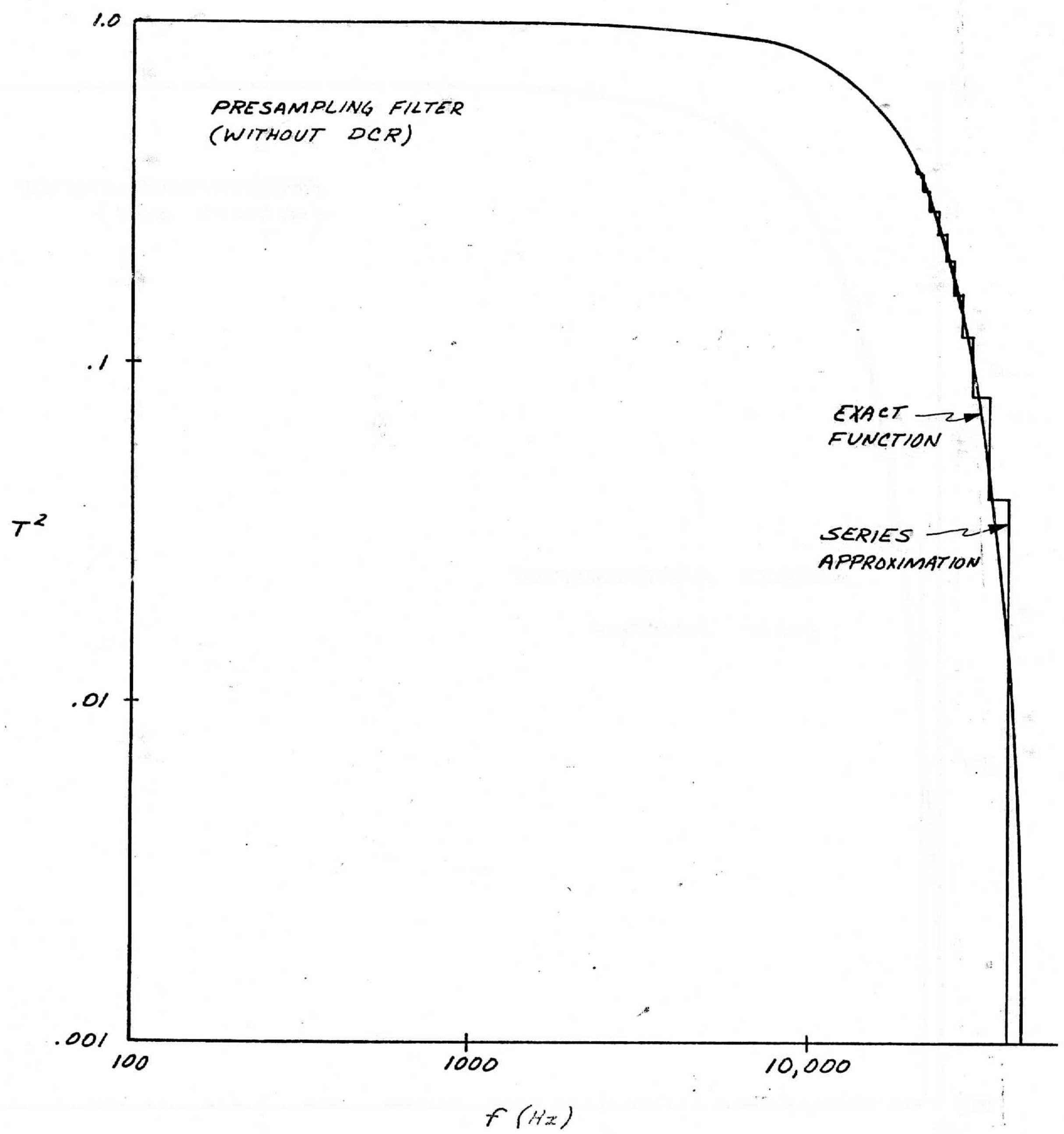

1.0
.1
.01
.001
T^2
PRESAMPLING FILTER
(WITHOUT DCR)
EXACT FUNCTION
SERIES APPROXIMATION
100
1000
10,000
f (Hz)

Figure 1b

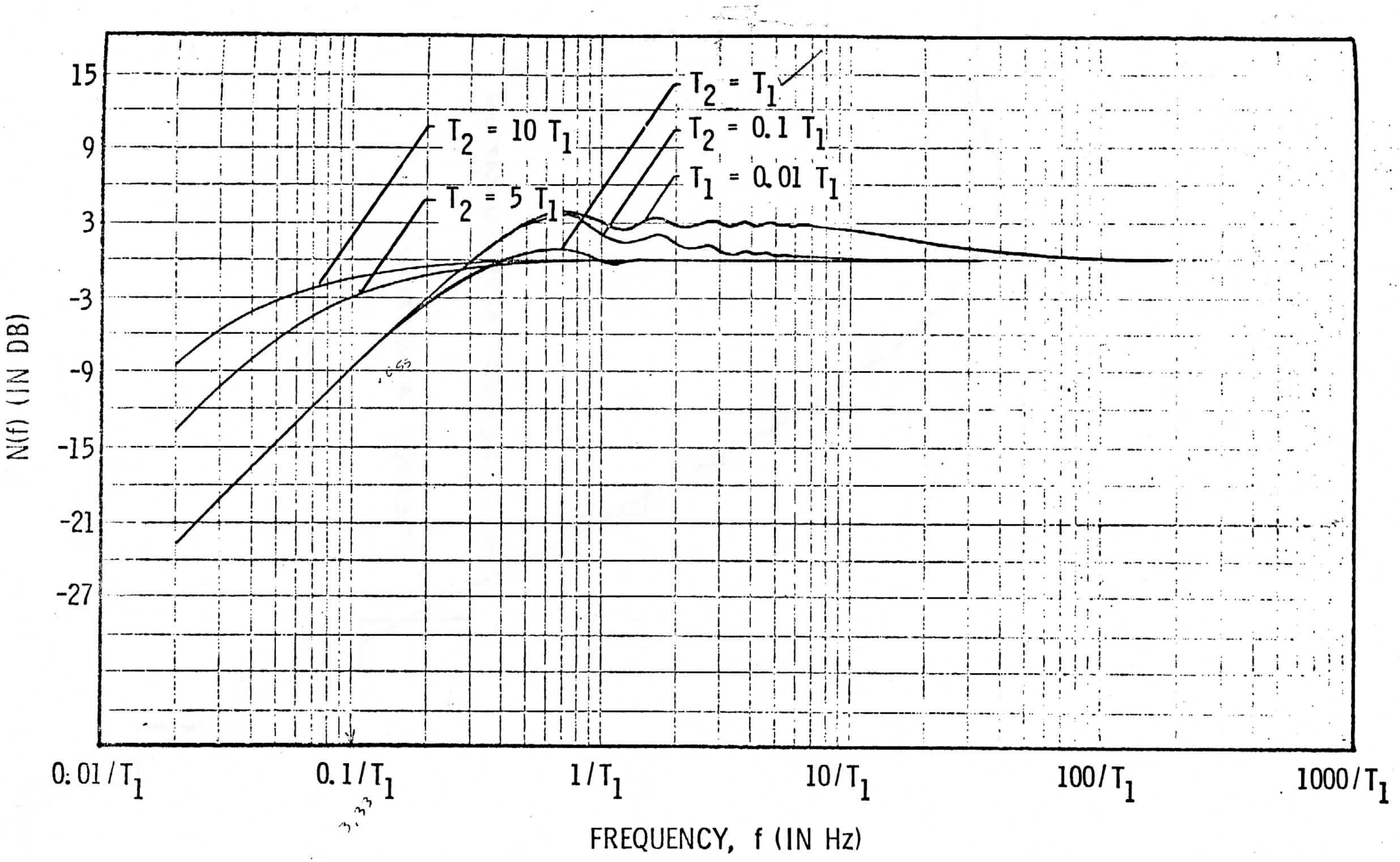


Figure 2

RESTORE CIRCUIT NOISE TRANSFER FUNCTION

Provided by Santa Barbara Research Corporation,
VISSR Sounder Program Initiation meeting at GSFC, 10 July 1973.

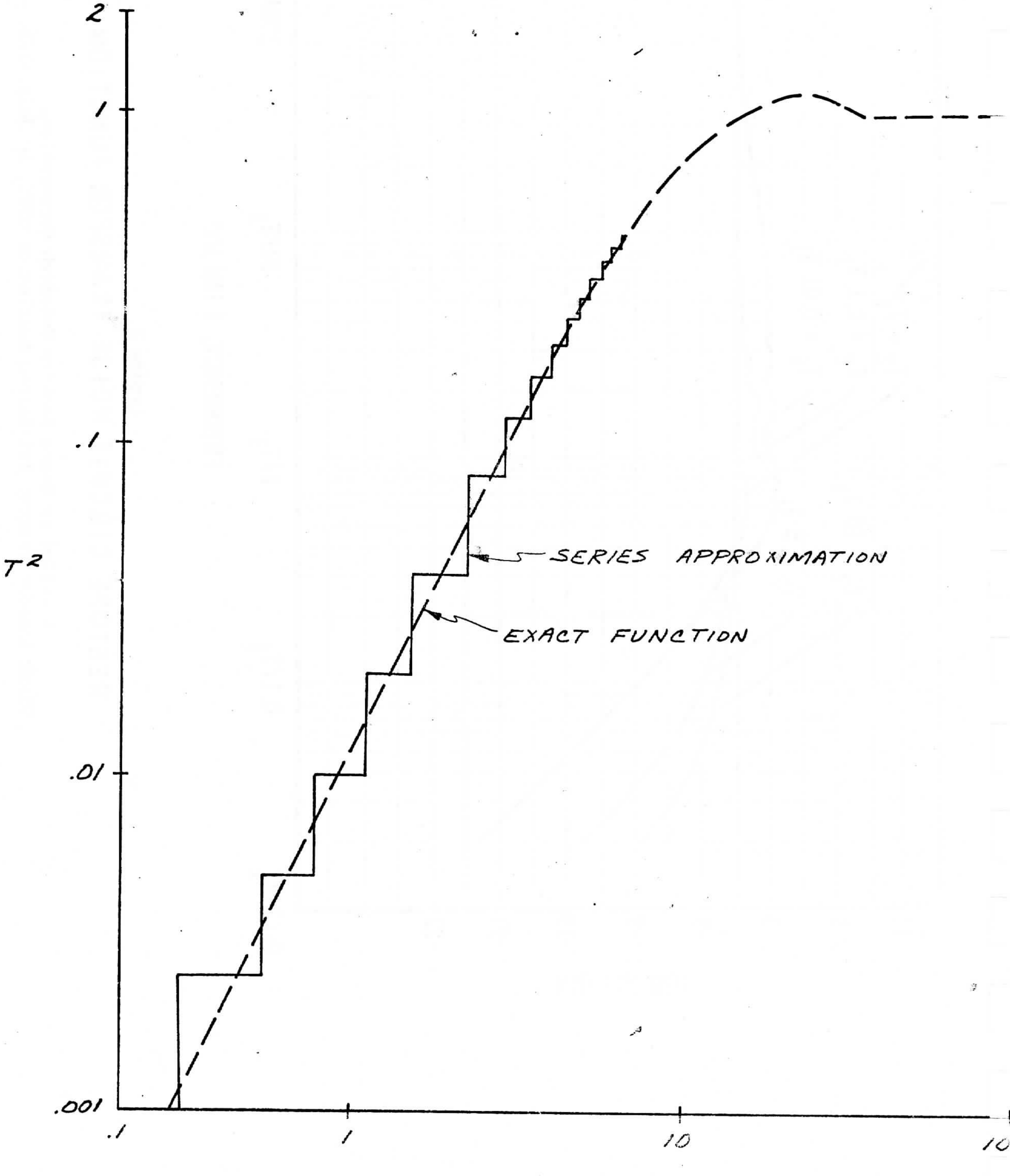

2
1
.1
.01
.001
T^2
SERIES APPROXIMATION
EXACT FUNCTION
.1
1
10
10
f (Hz)

Figure 3a

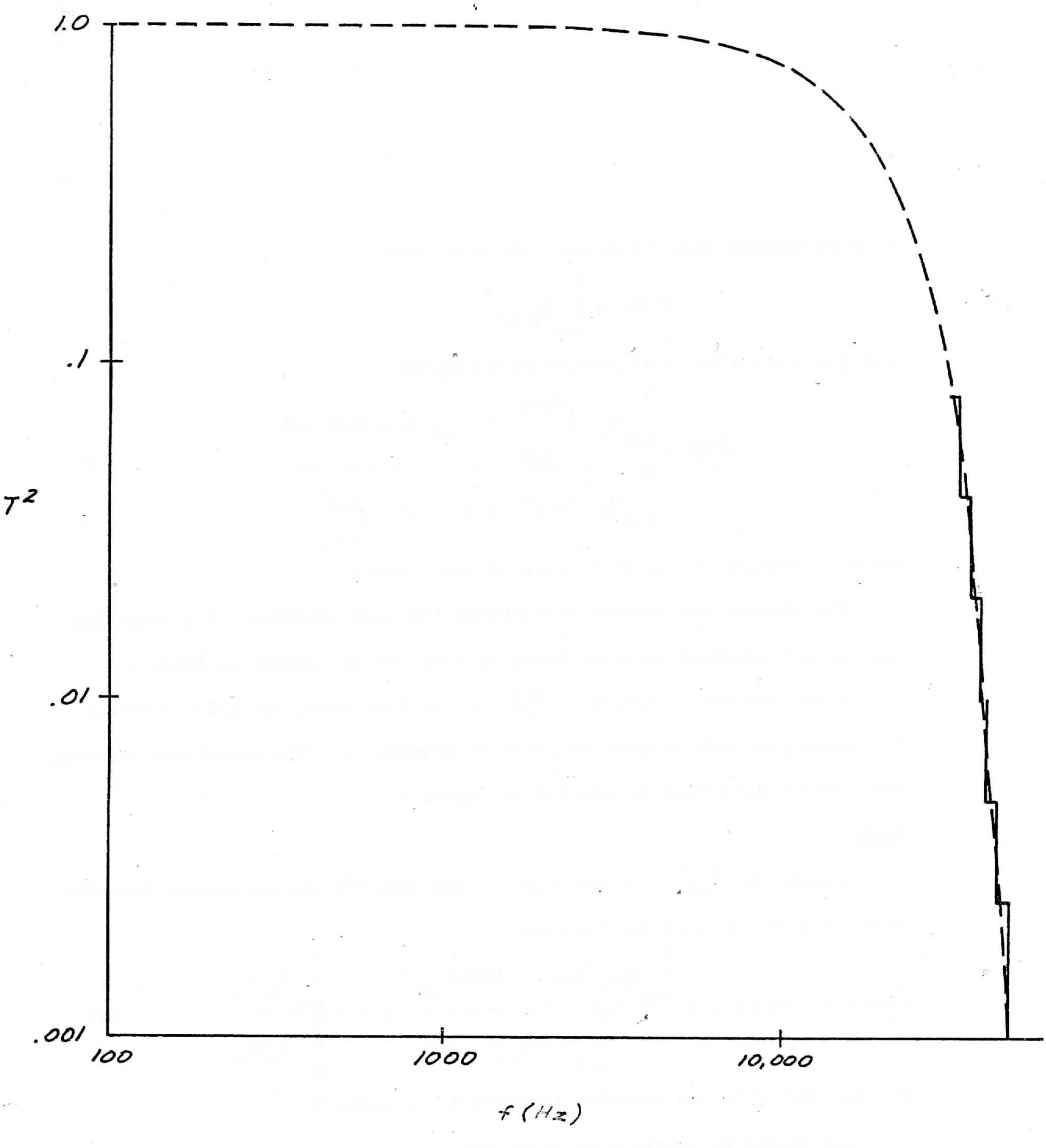


Figure 3b

by superimposed step functions. We then have:

$$T^2(f) = \sum_{k=1}^{N} W_k T_k^2(f)$$

and therefore after some manipulations we get

$$\frac{C(\tau)}{\sigma^2} = \frac{\sum_{k=1}^{N} W_k \int_{f_{1,k}}^{f_{2,k}} (1 + \frac{f_c}{f}) \cos(2\pi f\tau)df}{\sum_{k=1}^{N} W_k \left[f_{2,k} - f_{1,k} + f_c \ln \frac{f_{2,k}}{f_{1,k}} \right]} \qquad (6)$$

Refer to appendix B for derivation of the formula.

The minimum and maximum frequencies for each subfilter, its weighting factors and cumulative power transfer function are listed in Table 1.

A new program to calculate $\frac{C(\tau)}{\sigma^2}$ was written under the title "CONEW." The listing of this program is given in Appendix C. The covariance function obtained by the method is plotted in Figure 4.

*Model:

A model for $\frac{C(\tau)}{\sigma^2}$, of the form of equation (3) was calculated for this case, with the help of the formulae:

$$\frac{C(\tau)}{\sigma^2} = a - b\ln\tau; \; a = \frac{\sum_{k=1}^{N} W_k f_c \, [-\gamma - \ln 2\pi f_{2,k}]}{\sum_{k=1}^{N} W_k \Delta f_{N,k}} \; ; \; b = \frac{\sum_{k=1}^{N} W_k f_c}{\sum_{k=1}^{N} W_k \Delta f_N} \qquad (7)$$

The derivation of the formulae is given in Appendix B.

The following models were obtained:

$$\text{for } f_c = 750 \text{ Hz:} \quad \frac{C(\tau)}{\sigma^2} = 0.0287 - 0.0272\ln\tau$$

$$\text{for } f_c = 10 \text{ Hz:} \quad \frac{C(\tau)}{\sigma^2} = 0.0006 - 0.0006\ln\tau \qquad (8)$$

The straight lines superimposing the actual $\frac{C(\tau)}{\sigma^2}$ curves in Figure 4, represent these models. For large τ there seems to be a very good agreement between the models and the accurate calculations.

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*Program 'CTAU' which computes these models, is listed in Appendix D.

Table 1 Presampling Filter

k	$\text{fmin}_{,k}$	$\text{fmax}_{,k}$	W_k	T_k^2
1	.35	19,002	.04	1.00
2	.105	4,000	.04	.96
3	.079	5,900	.04	.92
4	.064	7,300	.04	.88
5	.0535	8,500	.04	.84
6	.0475	9,800	.04	.80
7	.043	11,000	.04	.76
8	.038	12,000	.04	.72
9	.034	13,200	.04	.68
10	.0316	14,200	.04	.64
11	.0296	15,400	.04	.60
12	.0278	16,500	.04	.56
13	.026	17,500	.04	.52
14	.0248	18,500	.04	.48
15	.0235	19,300	.04	.44
16	.0222	20,200	.04	.40
17	.021	21,500	.04	.36
18	.0202	22,500	.04	.32
19	.0192	23,750	.04	.28
20	.0182	25,000	.04	.24
21	.0169	26,500	.04	.20
22	.0158	28,000	.04	.16
23	.0149	30,300	.04	.12
24	.0137	33,900	.04	.08
25	.0113	38,500	.04	.04

Fmin = .026

Fmax = 17,450

F_c = 750 or 10 Hz

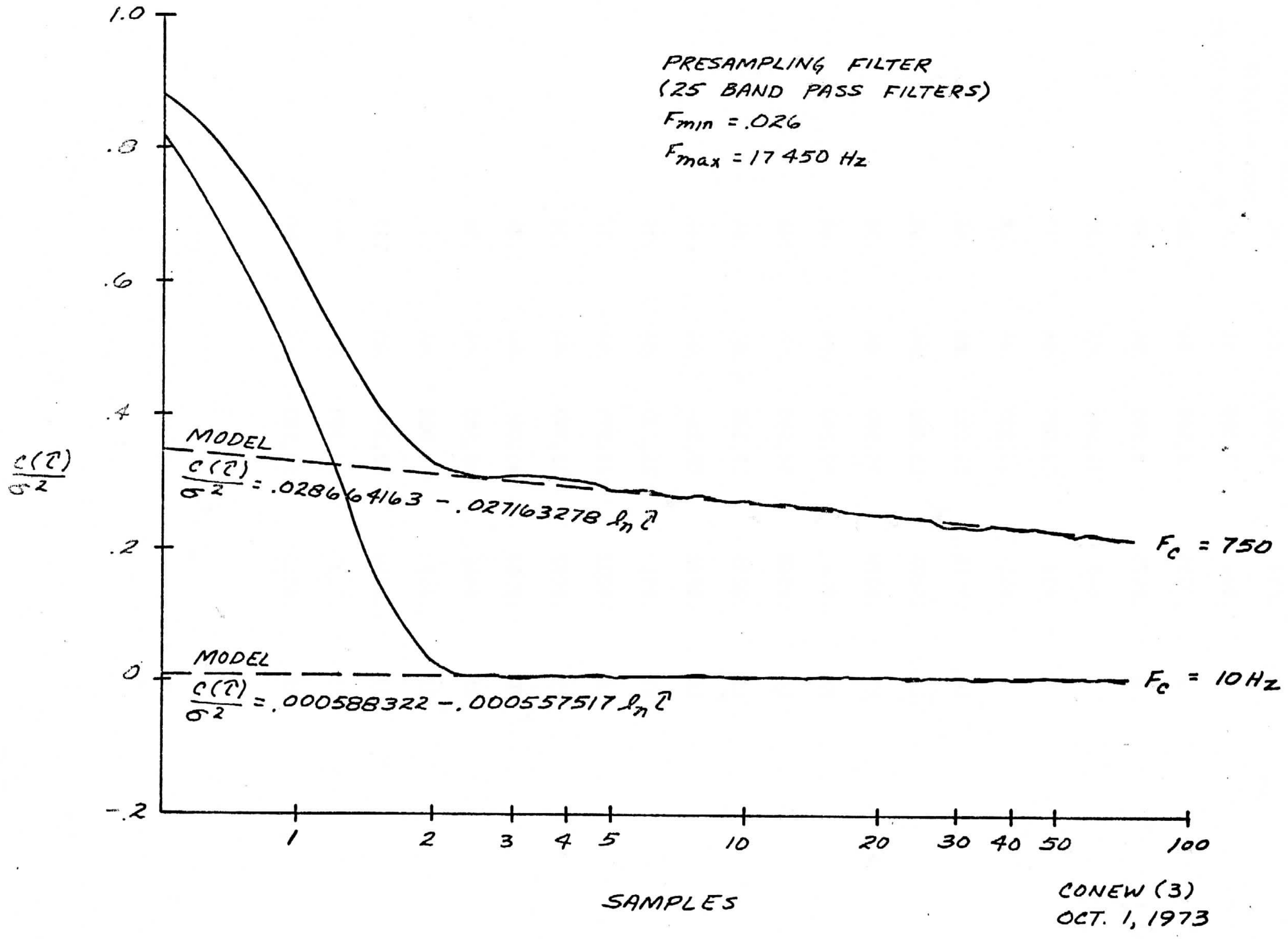
PRESAMPLING FILTER
(25 BAND PASS FILTERS)
F_{min} = .026
F_{max} = 17 450 Hz
MODEL
$\frac{c(\tau)}{\sigma^2} = .02864163 - .027163278 \ln \tau$
MODEL
$\frac{c(\tau)}{\sigma^2} = .000588322 - .000557517 \ln \tau$
F_c = 750
F_c = 10 Hz
$\frac{c(\tau)}{\sigma^2}$
1.0
.8
.6
.4
.2
0
-.2
1
2
3
4
5
10
20
30
40
50
100
SAMPLES
CONEW (3)
OCT. 1, 1973

Figure 4

Variance and standard deviation of $\frac{C(\tau)}{\sigma^2}$

Program 'RTSPAC' written by Ralph Dedecker calculates the variance and standard deviation of $\frac{C(\tau)}{\sigma^2}$, for a given $\frac{C(\tau)}{\sigma^2}$ array. The results obtained are given in Table 2.

To include the effect of D.C.R. in the variance calculations, the following values of 'DCR' were used

For f_c = 750 Hz DCR = 0.0908

f_c = 10 Hz DCR = 0.00189

[4] Calculations with D.C. Restore

The method for analysis of this case is the same as the one in [3]. As shown in Figure 3 (a,b), in this case 32 bandpass filters approximate the effective transfer function. Three of these filters (forming the bump) have very short bandwidths. The weighting factors for different filters are different in this case, as can be seen from Table 3.

Formula 6 (Program CONEW) is used to compute the covariance functions plotted in Figure 5. Also superimposed in the figure, are the following models obtained from program 'CTAU'.

For f_c = 750 Hz: $\frac{C(\tau)}{\sigma^2} = -.1544 - .0354\ln\tau$

For f_c = 10 Hz: $\frac{C(\tau)}{\sigma^2} = -.0027 - .00061\ln\tau$

The variance and standard deviation results for this case are given in Table 4.

The deviation between the model and the calculations in case of f_c = 750 Hz is found to be a result of the bump. As mentioned in Appendix B, the model is good for $2\pi f_{max}\tau > 1$. In case of the 3 filters forming the bump, this is not true. Therefore it was decided to repeat the calculations neglecting the bump.

Table 2

WITHOUT D. C. RESTORE

F_C = 750 Hz

DCR = 0.0908

MPLE NO	KM	VARIANCE OF MEAN
1	.53700000+01	.10000000+01
2	.10740000+02	.31641003+01
3	.16110000+02	.58524415+01
4	.21480000+02	.90091065+01
5	.26850000+02	.12631961+02
6	.32220000+02	.16688560+02
7	.37590000+02	.21174129+02
8	.42960000+02	.26072104+02
9	.48330000+02	.31381825+02
10	[illegible]	.37094228+02
11	.59070000+02	.43198096+02
12	.64440000+02	.49693185+02
13	.69809999+02	.56569643+02
14	.75179999+02	.63829382+02
15	.80549999+02	.71457460+02
16	.85920000+02	.79458282+02
17	.91290000+02	.87820411+02
18	.96660000+02	.96546459+02
19	.10203000+03	.10562528+03
20	.10740000+03	.11506239+03
21	.11277000+03	.12484785+03
22	.11814000+03	.13498357+03
23	.12351000+03	.14546313+03
24	.12888000+03	.15628614+03
25	.13425000+03	.16744803+03
26	.13962000+03	.17894458+03
27	.14499000+03	.19077849+03
28	.15036000+03	.20294269+03
29	.15573000+03	.21543603+03
30	.16110000+03	.22825502+03
31	.16647000+03	.24139782+03
32	.17184000+03	.25486302+03
33	.17721000+03	.26864648+03
34	.18258000+03	.28275138+03
35	.18795000+03	.29716931+03
36	.19332000+03	.31190559+03
37	.19869000+03	.32695605+03
38	.20406000+03	.34232262+03
39	.20943000+03	.35800462+03
40	.21480000+03	.37399792+03
41	.22017000+03	.39030497+03
42	.22554000+03	.40691892+03
43	.23091000+03	.42384353+03
44	.23628000+03	.44107407+03
45	.24165000+03	.45860802+03
46	.24702000+03	.47644397+03
47	.25239000+03	.49458153+03
48	.25776000+03	.51301531+03
49	.26313000+03	.53174882+03
50	.26850000+03	.55077829+03
51	.27387000+03	.57010579+03
52	.27924000+03	.58973232+03
53	.28461000+03	.60965230+03
54	.28998000+03	.62986642+03

```
55   .29535000+03          .65037558+03
56   .30072000+03          .67116869+03
57   .30609000+03          .69225254+03
58   .31146000+03          .71362164+03
59   .31683000+03          .73527635+03
60   .32220000+03          .75722037+03
61   .32757000+03          .77945550+03
62   .33294000+03          .80197333+03
63   .33831000+03          .82477165+03
64   .34368000+03          .84784839+03
65   .34905000+03          .87120355+03
66   .35442000+03          .89484123+03
67   .35979000+03          .91875958+03
68   .36516000+03          .94295110+03

LINES NO SAMS AREA(KMXKM) VARIANCE STD DEV


 1         2 10.74  10.74    .79103    .88940
 2         3 17.61  16.11    .32514    .57021
 3         5 24.49  26.85    .16843    .41040
 4         6 31.36  32.22    .11589    .34043
 5         7 38.23  37.59    .08643    .29398
 6         8 45.11  42.96    .06790    .26057
 7        10 51.98  53.70    .05299    .23020
 8        11 58.86  59.07    .04463    .21125
 9        12 65.73  64.44    .03834    .19581
10        14 72.60  75.18    .03257    .18046
11        15 79.48  80.55    .02887    .16992
12        16 86.35  85.92    .02587    .16083
13        17 93.22  91.29    .02338    .15289
14        19100.10102.03     .02090    .14457
15        20106.97107.40     .01918    .13848
16        21113.84112.77     .01769    .13302
17        22120.72118.14     .01641    .12808
18        24127.59128.88     .01507    .12278
19        25134.46134.25     .01410    .11875
20        26141.34139.62     .01324    .11505
21        28148.21150.36     .01233    .11102
22        29155.09155.73     .01164    .10791
23        30161.96161.10     .01103    .10501
24        31168.83166.47     .01047    .10231
25        33175.71177.21     .00987    .09934
26        34182.58182.58     .00941    .09699
27        35189.45187.95     .00898    .09479
28        37196.33198.69     .00853    .09236
29        38203.20204.06     .00817    .09041
30        39210.07209.43     .00785    .08858
31        40216.95214.80     .00754    .08683
32        42223.82225.54     .00721    .08490
33        43230.70230.91     .00695    .08334
34        44237.57236.28     .00670    .08186
35        46244.44247.02     .00643    .08021
36        47251.32252.39     .00622    .07886
37        48258.19257.76     .00602    .07758
38        49265.06263.13     .00583    .07634
39        51271.94273.87     .00562    .07497
```

```
40        52278.81279.24    .00545    .07384
41        53285.68284.61    .00529    .07276
42        54292.56289.98    .00514    .07171
43        56279.43300.72    .00498    .07055
44        57306.30306.09    .00484    .06939
45        58313.18311.45    .00471    .06855
46        60320.05322.20    .00457    .06762
47        61326.93327.57    .00446    .06676
48        62333.80332.94    .00435    .06593
49        63340.67338.31    .00424    .06512
50        65347.55349.05    .00412    .06422
XCB=      .00189
```

```
MPLE NO        KM           VARIANCE OF MEAN

   1     .53700000+01     .10000000+01
   2     .10740000+02     .28808247+01
   3     .16110000+02     .48142127+01
   4     .21480000+02     .67591441+01
   5     .26850000+02     .87366450+01
   6     .32220000+02     .10720590+02
   7     .37590000+02     .12719520+02
   8     .42960000+02     .14723384+02
   9     .48330000+02     .16741999+02
  10     .53700000+02     .18772583+02
  11     .59070000+02     .20808328+02
  12     .64440000+02     .22856739+02
  13     .69809999+02     .24911332+02
  14     .75179999+02     .26981318+02
  15     .80549999+02     .29052299+02
  16     .85920000+02     .31136083+02
  17     .91290000+02     .33222325+02
  18     .96660000+02     .35319666+02
  19     .10203000+03     .37417463+02
  20     .10740000+03     .39527701+02
  21     .11277000+03     .41641009+02
  22     .11814000+03     .43763936+02
  23     .12351000+03     .45891600+02
  24     .12888000+03     .48027113+02
  25     .13425000+03     .50167837+02
  26     .13962000+03     .52311296+02
  27     .14499000+03     .54464463+02
  28     .15036000+03     .56620806+02
  29     .15573000+03     .58781849+02
  30     .16110000+03     .60945718+02
  31     .16647000+03     .63112675+02
  32     .17184000+03     .65283478+02
  33     .17721000+03     .67454995+02
  34     .18258000+03     .69633939+02
  35     .18795000+03     .71811108+02
  36     .19332000+03     .73995925+02
  37     .19869000+03     .76184711+02
  38     .20406000+03     .78382043+02
  39     .20943000+03     .80589046+02
  40     .21480000+03     .82802028+02
  41     .22017000+03     .85026340+02
  42     .22554000+03     .87254579+02
  43     .23091000+03     .89493860+02
  44     .23628000+03     .91739651+02
  45     .24165000+03     .93990516+02
  46     .24702000+03     .96246378+02
  47     .25239000+03     .98508530+02
  48     .25776000+03     .10077140+03
  49     .26313000+03     .10304163+03
  50     .26850000+03     .10531535+03
  51     .27387000+03     .10759699+03
  52     .27924000+03     .10986948+03
  53     .28461000+03     .11218662+03
  54     .28998000+03     .11449390+03
```

WITHOUT D. C. RESTORE

F_C = 750 Hz

DCR = 0.00189

```
   55   .29535000+03             .11680606+03
   56   .30072000+03             .11911759+03
   57   .30609000+03             .12143670+03
   58   .31146000+03             .12375715+03
   59   .31683000+03             .12607972+03
   60   .32220000+03             .12841413+03
   61   .32757000+03             .13076072+03
   62   .33294000+03             .13311068+03
   63   .33831000+03             .13546265+03
   64   .34368000+03             .13781506+03
   65   .34905000+03             .14016927+03
   66   .35442000+03             .14253191+03
   67   .35979000+03             .14490176+03
   68   .36516000+03             .14726997+03

0 LINES NO SAMS AREA(KMXKM) VARIANCE STD DEV


    1          2 10.74  10.74    .72021     .84865
    2          3 17.61  16.11    .26746     .51716
    3          5 24.49  26.85    .11649     .34130
    4          6 31.36  32.22    .07445     .27285
    5          7 38.23  37.59    .05192     .22785
    6          8 45.11  42.96    .03834     .19581
    7         10 51.98  53.70    .02682     .16376
    8         11 58.86  59.07    .02150     .14662
    9         12 65.73  64.44    .01764     .13280
   10         14 72.60  75.18    .01377     .11733
   11         15 79.48  80.55    .01174     .10834
   12         16 86.35  85.92    .01014     .10067
   13         17 93.22  91.29    .00884     .09404
   14         19100.10102.03    .00740     .08604
   15         20106.97107.40    .00659     .08117
   16         21113.84112.77    .00590     .07682
   17         22120.72118.14    .00532     .07293
   18         24127.59128.88    .00463     .06806
   19         25134.46134.25    .00422     .06500
   20         26141.34139.62    .00387     .06220
   21         28148.21150.36    .00344     .05864
   22         29155.09155.73    .00318     .05637
   23         30161.96161.10    .00294     .05426
   24         31168.83166.47    .00274     .05231
   25         33175.71177.21    .00248     .04978
   26         34182.58182.58    .00232     .04813
   27         35189.45187.95    .00217     .04660
   28         37196.33198.69    .00199     .04458
   29         38203.20204.06    .00187     .04326
   30         39210.07209.43    .00177     .04203
   31         40216.95214.80    .00167     .04086
   32         42223.82225.54    .00155     .03932
   33         43230.70230.91    .00147     .03830
   34         44237.57236.28    .00139     .03733
   35         46244.44247.02    .00130     .03605
   36         47251.32252.39    .00124     .03520
   37         48258.19257.76    .00118     .03438
   38         49265.06263.13    .00113     .03361
   39         51271.94273.87    .00106     .03257
```

```
40        52278.81279.24     .00102     .03187
41        53285.68284.61     .00097     .03121
42        54292.56289.98     .00093     .03058
43        56299.43300.72     .00088     .02972
44        57306.30306.09     .00085     .02915
45        58313.18311.46     .00082     .02859
46        60320.05322.20     .00078     .02785
47        61326.93327.57     .00075     .02734
48        62333.80332.94     .00072     .02686
49        63340.67338.31     .00070     .02639
50        65347.55349.05     .00066     .02576
N
```

Table 3 Presampling Filter * D.C. Restore

k	fmin	fmax	W_k	T_k^2
1	.3	48,000	.0025	.025
2	.54	44,500	.0025	.05
3	.77	41,000	.005	.01
4	1.1	39,500	.01	.02
5	1.52	37,000	.02	.04
6	2.2	34,000	.04	.08
7	2.82	30,300	.04	.12
8	3.47	28,000	.04	.16
9	3.88	26,500	.04	.20
10	4.3	25,000	.04	.24
11	4.7	23,750	.04	.28
12	5.03	22,500	.04	.32
13	5.55	21,500	.04	.36
14	5.9	20,200	.04	.40
15	6.3	19,300	.04	.44
16	6.8	18,500	.04	.48
17	7.2	17,500	.04	.52
18	7.6	16,500	.04	.56
19	7.9	15,400	.04	.60
20	8.3	14,200	.04	.64
21	8.8	13,200	.04	.68
22	9.3	12,000	.04	.72
23	9.8	11,000	.04	.76
24	10.3	9,800	.04	.80
25	11.0	8,500	.04	.84
26	11.5	7,300	.04	.88
27	12.0	5,900	.04	.92
28	12.7	4,000	.04	.96
29	13.5	1,900	.04	1.0
30	14.8	32.5	.04	1.04
31	15.8	30.0	.04	1.08
32	18.0	27.0	.04	1.12

Fmin = .026

Fmax = 17,450 Hz

F_c = 750 Hz <u>or</u> 10 Hz

ΔT = .00000716197

Input to COVAR → F_c, Fmin_1, Fmax_1, ΔT Weights & punched output from COVAR → Input to averaging program

2 2

⋮ ⋮ 32 card sequence

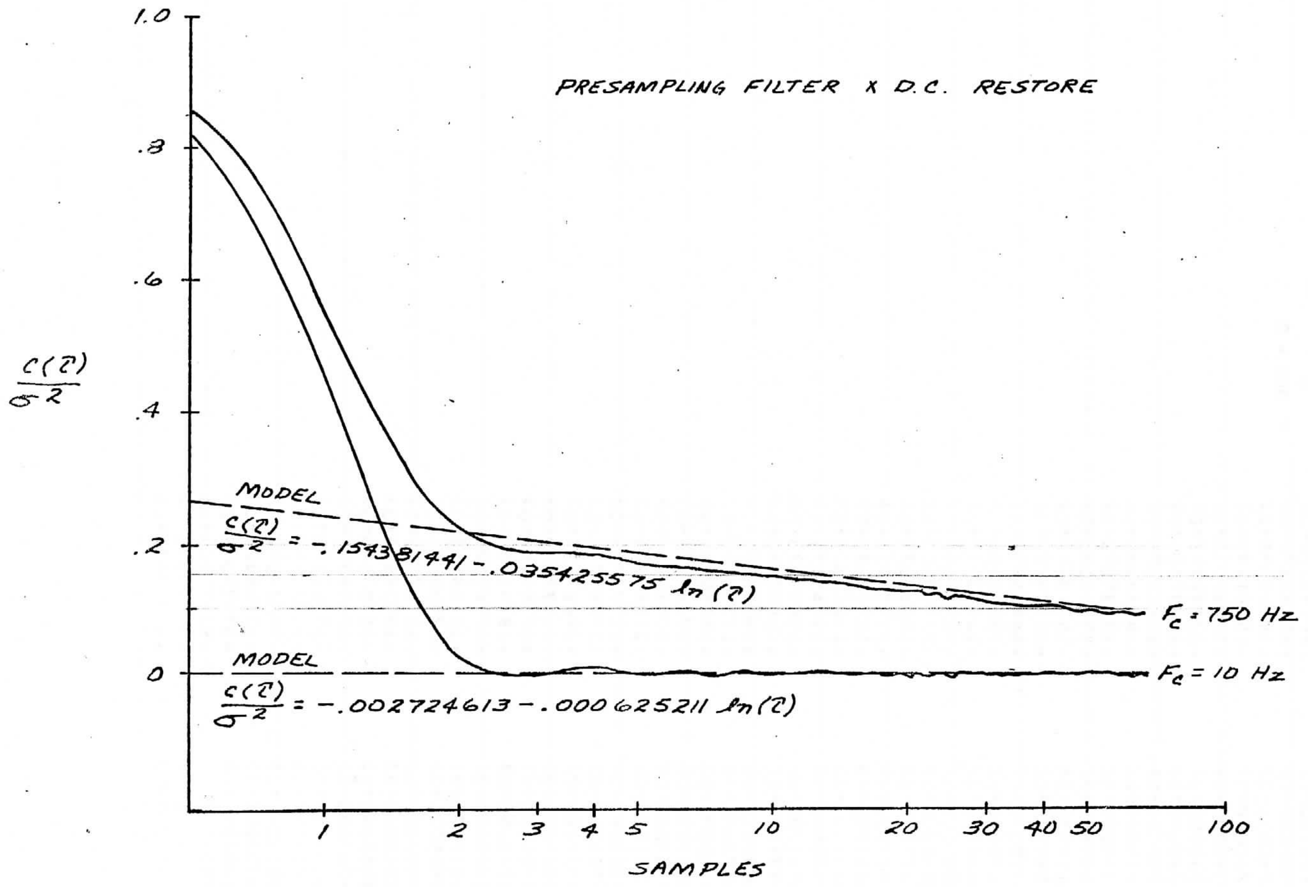
PRESAMPLING FILTER x D.C. RESTORE
$\frac{c(\tau)}{\sigma^2}$
1.0
.8
.6
.4
.2
0
MODEL
$\frac{c(\tau)}{\sigma^2} = -.15431441 - .035425575 \ln(\tau)$
$F_c = 750$ Hz
MODEL
$\frac{c(\tau)}{\sigma^2} = -.002724613 - .000625211 \ln(\tau)$
$F_c = 10$ Hz
1
2
3
4
5
10
20
30
40
50
100
SAMPLES

Figure 5

Table 4

MPLE NO	KM	VARIANCE OF MEAN
~~1~~	~~.53700000+01~~	~~.10000000+01~~
2	.10740000+02	.31098800+01
3	.16110000+02	.56543399+01
~~4~~	~~.21480000+02~~	~~.85762378+01~~
5	.26850000+02	.11868240+02
6	.32220000+02	.15501799+02
~~7~~	~~.37590000+02~~	~~.19467096+02~~
8	.42960000+02	.23749717+02
9	.48330000+02	.28347356+02
~~10~~	~~.53700000+02~~	~~.33250575+02~~
11	.59070000+02	[illegible]
12	.64440000+02	.43939045+02
~~13~~	~~.69809999+02~~	~~.49715301+02~~
14	.75179999+02	.55773634+02
15	.80549999+02	.62104767+02
~~16~~	~~.85920000+02~~	~~.68706697+02~~
17	.91290000+02	.75573785+02
18	.96660000+02	.82703712+02
~~19~~	~~.10203000+03~~	~~.90087658+02~~
20	.10740000+03	.97730503+02
21	.11277000+03	.10562071+03
~~22~~	~~.11814000+03~~	~~.11376293+03~~
23	.12351000+03	.12214678+03
24	.12888000+03	.13077605+03
~~25~~	~~.13425000+03~~	~~.13964115+03~~
26	.13962000+03	.14874273+03
27	.14499000+03	.15807858+03
~~28~~	~~.15036000+03~~	~~.16764573+03~~
29	.15573000+03	.17743936+03
30	.16110000+03	.18745831+03
~~31~~	~~.16647000+03~~	~~.19769915+03~~
32	.17184000+03	.20816083+03
33	.17721000+03	.21883964+03
~~34~~	~~.18258000+03~~	~~.22973735+03~~
35	.18795000+03	.24084715+03
36	.19332000+03	.25217247+03
~~37~~	~~.19869000+03~~	~~.26371090+03~~
38	.20406000+03	.27546268+03
39	.20943000+03	.28742855+03
~~40~~	~~.21480000+03~~	~~.29960339+03~~
41	.22017000+03	.31198958+03
42	.22554000+03	.32458105+03
~~43~~	~~.23091000+03~~	~~.33737994+03~~
44	.23628000+03	.35038329+03
45	.24165000+03	.36358655+03
~~46~~	~~.24702000+03~~	~~.37698979+03~~
47	.25239000+03	.39059138+03
48	.25776000+03	[illegible]
~~49~~	~~.26313000+03~~	~~.41837852+03~~
50	.26850000+03	.43256321+03
51	.27387000+03	.44694344+03
~~52~~	~~.27924000+03~~	~~.46151924+03~~
53	.28461000+03	.47623591+03
54	.28998000+03	[illegible]

WITH D. C. RESTORE

F_C = 750 Hz

DCR = 0

```
55   .29535000+03          .50639244+03
56   .30072000+03          .52172172+03
57   .30609000+03          .53723830+03
58   .31146000+03          .55293661+03
59   .31683000+03          .56881656+03
60   .32220000+03          .58498265+03
61   .32757000+03          .60113617+03
62   .33294000+03          .61756895+03
63   .33831000+03          .63417778+03
64   .34368000+03          .65095140+03
65   .34905000+03          .66791898+03
66   .35442000+03          .68505540+03
67   .35979000+03          .70235852+03
68   .36516000+03          .71985026+03

LINES NO SAMS AREA(KMXKM) VARIANCE STD DEV


  1        2 10.74 10.74   .77747   .88174
  2        3 17.61 16.11   .31413   .56047
  3        5 24.49 26.85   .15824   .39780
  4        6 31.36 32.22   .10765   .32810
  5        7 38.23 37.59   .07946   .28188
  6        8 45.11 42.96   .06185   .24869
  7       10 51.98 53.70   .04750   .21795
  8       11 58.86 59.07   .03972   .19930
  9       12 65.73 64.44   .03390   .18413
 10       14 72.60 75.18   .02846   .16869
 11.      15 79.48 80.55   .02509   .15841
 12       16 86.35 85.92   .02237   .14955
 13       17 93.22 91.29   .02012   .14183
 14       19100.10102.03   .01783   .13351
 15       20106.97107.40   .01629   .12763
 16       21113.84112.77   .01497   .12235
 17       22120.72118.14   .01383   .11759
 18       24127.59128.88   .01261   .11231
 19       25134.46134.25   .01176   .10844
 20       26141.34139.62   .01100   .10489
 21       28148.21150.36   .01018   .10091
 22       29155.09155.73   .00959   .09793
 23       30161.96161.10   .00906   .09516
 24       31168.83166.47   .00857   .09258
 25       33175.71177.21   .00804   .08966
 26       34182.58182.58   .00764   .08743
 27       35189.45187.95   .00728   .08533
 28       37196.33198.69   .00688   .08294
 29       38203.20204.06   .00658   .08111
 30       39210.07209.43   .00630   .07937
 31       40216.95214.80   .00604   .07772
 32       42223.82225.54   .00575   .07583
 33       43230.69230.91   .00553   .07436
 34       44237.57236.28   .00532   .07276
 35       46244.44247.02   .00509   .07135
 36       47251.32252.39   .00491   .07008
 37       48258.19257.76   .00474   .06887
 38       49265.06263.13   .00459   .06772
 39       51271.94273.87   .00441   .06638
```

```
 40        52278.31279.24    .00427    .06532
 41        53285.68284.61    .00414    .06431
 42        54292.56289.98    .00401    .06333
 43        56299.43300.72    .00387    .06220
 44        57306.30306.09    .00376    .06130
 45        58313.18311.46    .00365    .06044
 46        60320.05322.20    .00353    .05943
 47        61326.93327.57    .00344    .05863
 48        62333.80332.94    .00335    .05785
 49        63340.67338.31    .00326    .05710
 50        65347.55349.05    .00316    .05623
DCR=     .00000
```

1PLE NO	KM	VARIANCE OF MEAN
~~1~~	~~.53700000+01~~	~~.10000000+01~~
2	.10740000+02	.28748200+01
3	.16110000+02	.47994840+01
~~4~~	~~.21480000+02~~	~~.67356619+01~~
5	.26850000+02	.86977676+01
6	.32220000+02	.10667264+02
~~7~~	~~.37590000+02~~	~~.12646484+02~~
8	.42960000+02	.14629430+02
9	.48330000+02	.16623838+02
~~10~~	~~.53700000+02~~	~~.18627125+02~~
11	.59070000+02	.20634511+02
12	.64440000+02	.22648965+02
~~13~~	~~.69809999+02~~	~~.24670719+02~~
14	.75179999+02	.26700954+02
15	.80549999+02	.28733751+02
~~16~~	~~.85920000+02~~	~~.30772535+02~~
17	.91290000+02	.32814815+02
18	.96660000+02	.34862620+02
~~19~~	~~.10203000+03~~	~~.36909721+02~~
20	.10740000+03	.38966578+02
21	.11277000+03	.41022513+02
~~22~~	~~.11814000+03~~	~~.43087492+02~~
23	.12351000+03	.45151925+02
24	.12888000+03	.47224459+02
~~25~~	~~.13425000+03~~	~~.49296247+02~~
26	.13962000+03	.51371479+02
27	.14499000+03	.53450525+02
~~28~~	~~.15036000+03~~	~~.55532730+02~~
29	.15573000+03	.57614946+02
30	.16110000+03	.59698602+02
~~31~~	~~.16647000+03~~	~~.61782032+02~~
32	.17184000+03	.63866536+02
33	.17721000+03	.65949812+02
~~34~~	~~.18258000+03~~	~~.68036604+02~~
35	.18795000+03	.70120354+02
36	.19332000+03	.72207657+02
~~37~~	~~.19869000+03~~	~~.74297496+02~~
38	.20406000+03	.76392137+02
39	.20943000+03	.78494457+02
~~40~~	~~.21480000+03~~	~~.80599904+02~~
41	.22017000+03	.82713480+02
42	.22554000+03	.84829362+02
~~43~~	~~.23091000+03~~	~~.86952231+02~~
44	.23628000+03	.89080267+02
45	.24165000+03	.91209515+02
~~46~~	~~.24702000+03~~	~~.93341997+02~~
47	.25239000+03	.95477417+02
48	.25776000+03	.97511148+02
~~49~~	~~.26313000+03~~	~~.99749678+02~~
50	.26850000+03	.10188858+03
51	.27387000+03	.10403330+03
~~52~~	~~.27924000+03~~	~~.10619551+03~~
53	.28461000+03	.10834033+03
54	.28998000+03	.11050200+03

WITH D. C. RESTORE

F_C = 10 Hz

DCR = 0

```
 55   .29535000+03          .11266631+03
 56   .30072000+03          .11482709+03
 57   .30609000+03          .11699267+03
 58   .31146000+03          .11915728+03
 59   .31683000+03          .12132199+03
 60   .32220000+03          .12349394+03
 61   .32757000+03          .12567609+03
 62   .33294000+03          .12785451+03
 63   .33831000+03          .13004154+03
 64   .34368000+03          .13222202+03
 65   .34905000+03          .13440107+03
 66   .35442000+03          .13658616+03
 67   .35979000+03          .13877573+03
 68   .36516000+03          .14096074+03

0 LINES NO SAMS AREA(KMXKM) VARIANCE STD DEV


  1        2 10.74 10.74     .71870     .84776
  2        3 17.61 16.11     .26664     .51637
  3        5 24.49 26.85     .11597     .34054
  4        6 31.36 32.22     .07408     .27217
  5        7 38.23 37.59     .05162     .22720
  6        8 45.11 42.96     .03810     .19519
  7       10 51.98 53.70     .02661     .16313
  8       11 58.86 59.07     .02132     .14600
  9       12 65.73 64.44     .01748     .13220
 10       14 72.60 75.18     .01362     .11672
 11       15 79.48 80.55     .01161     .10775
 12       16 86.35 85.92     .01002     .10009
 13       17 93.22 91.29     .00873     .09346
 14       19100.10102.03     .00730     .08546
 15       20106.97107.40     .00649     .08059
 16       21113.84112.77     .00581     .07625
 17       22120.72118.14     .00524     .07236
 18       24127.59128.88     .00455     .06749
 19       25134.46134.25     .00415     .06443
 20       26141.34139.62     .00380     .06164
 21       28148.21150.36     .00337     .05808
 22       29155.09155.73     .00311     .05580
 23       30161.96161.10     .00288     .05370
 24       31168.83166.47     .00268     .05176
 25       33175.71177.21     .00242     .04922
 26       34182.58182.58     .00226     .04758
 27       35189.45187.95     .00212     .04604
 28       37196.33198.69     .00194     .04403
 29       38203.20204.06     .00182     .04271
 30       39210.07209.43     .00172     .04148
 31       40216.95214.80     .00162     .04031
 32       42223.82225.54     .00150     .03877
 33       43230.70230.91     .00143     .03775
 34       44237.57238.28     .00135     .03679
 35       46244.44247.02     .00126     .03550
 36       47251.32252.39     .00120     .03465
 37       48258.19257.76     .00115     .03384
 38       49265.05263.13     .00109     .03306
 39       51271.94273.87     .00103     .03202
```

```
40      52278.81279.24    .00098    .03133
41      53285.68284.61    .00094    .03067
42      54292.56289.98    .00090    .03004
43      56299.43300.72    .00085    .02918
44      57306.30306.09    .00082    .02861
45      58313.18311.46    .00079    .02806
46      60320.05322.20    .00075    .02731
47      61326.93327.57    .00072    .02681
48      62333.80332.94    .00069    .02632
49      63340.67338.31    .00067    .02586
50      65347.55349.05    .00064    .02522
```

[5] Calculations with DCR, without the bump

In this case we have only the first 29 bandpass filters from Table 3. The procedure remains the same. $\frac{C(\tau)}{\sigma^2}$ and the models are shown in Figure 6. The models are:

For f_c = 750 Hz: $\frac{C(\tau)}{\sigma^2} = -.1350 - .03171\ln\tau$

For f_c = 10 Hz: $\frac{C(\tau)}{\sigma^2} = -.0024 - .00061\ln\tau$

A good agreement between the models and accurate calculations is seen in this case.

Table 5 shows the variance and standard deviation results for this case.

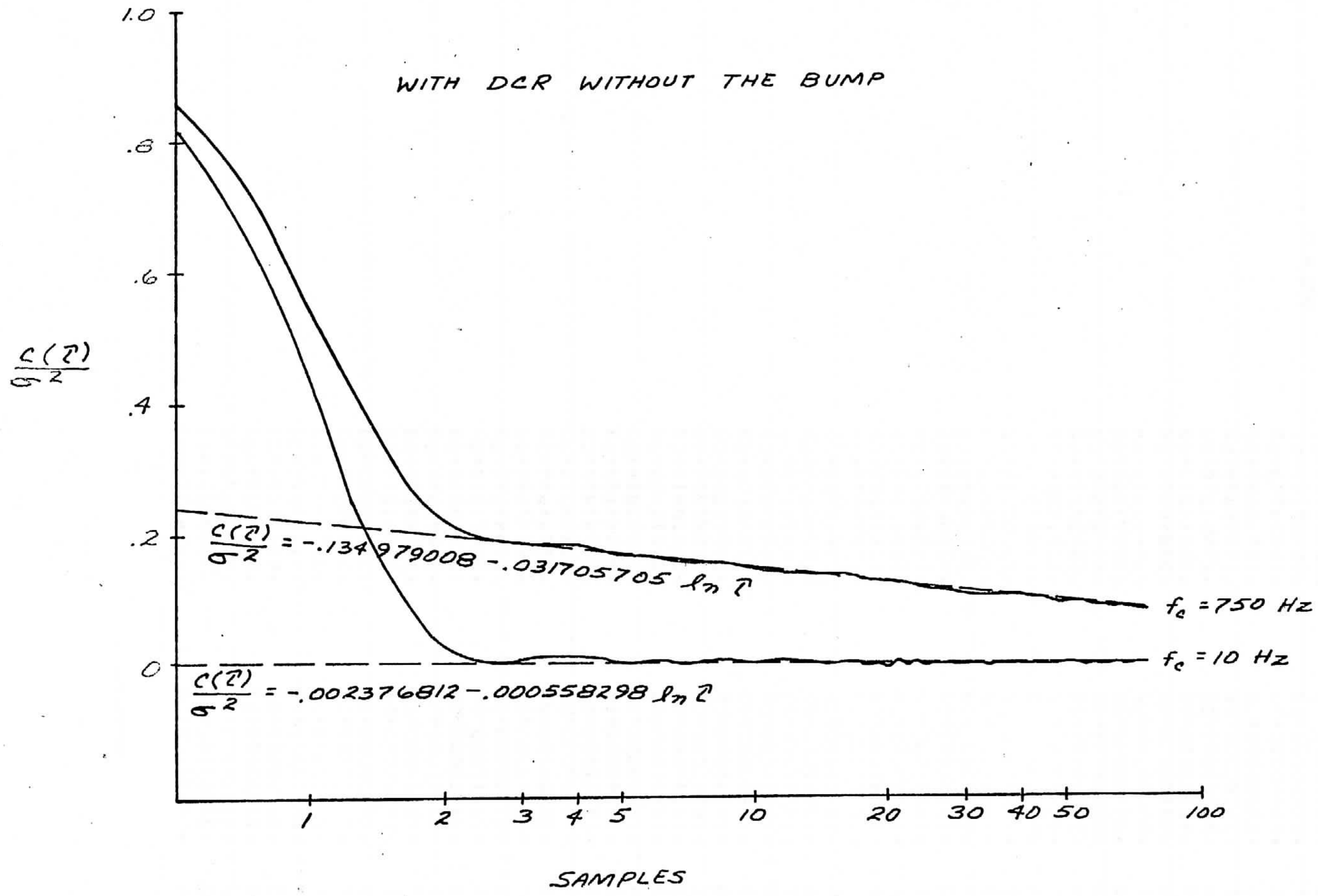
WITH DCR WITHOUT THE BUMP
$\frac{C(\tau)}{\sigma^2}$
1.0
.8
.6
.4
.2
0
$\frac{C(\tau)}{\sigma^2} = -.134979008 - .031705705 \ln \tau$
$\frac{C(\tau)}{\sigma^2} = -.002376812 - .000558298 \ln \tau$
$f_c = 750$ Hz
$f_c = 10$ Hz
1
2
3
4
5
10
20
30
40
50
100
SAMPLES

Figure 6

Table 5

MPLE NO	KM	VARIANCE OF MEAN
1	.53700000+01	.10000000+01
2	.10740000+02	.31077400+01
3	.16110000+02	.56462999+01
4	.21480000+02	.85584197+01
5	.26850000+02	.11836740+02
6	.32220000+02	.15452659+02
7	.37590000+02	.19396319+02
8	.42960000+02	.23653278+02
9	.48330000+02	.28221217+02
10	.53700000+02	.33090676+02
11	.59070000+02	.38251513+02
12	.64440000+02	.43699368+02
13	.69809999+02	.49429585+02
14	.75179999+02	.55437779+02
15	.80549999+02	.61714654+02
16	.85920000+02	.68269388+02
17	.91290000+02	.75062914+02
18	.96660000+02	.82125920+02
19	.10203000+03	.89438986+02
20	.10740000+03	.97006771+02
21	.11277000+03	.10481774+03
22	.11814000+03	.11287654+03
23	.12351000+03	.12117276+03
24	.12888000+03	.12971023+03
25	.13425000+03	.13847928+03
26	.13962000+03	.14748060+03
27	.14499000+03	.15671197+03
28	.15036000+03	.16617040+03
29	.15573000+03	.17585106+03
30	.16110000+03	.18575281+03
31	.16647000+03	.19587220+03
32	.17184000+03	.20620818+03
33	.17721000+03	.21675703+03
34	.18258000+03	.22752054+03
35	.18795000+03	.23849187+03
36	.19332000+03	.24967447+03
37	.19869000+03	.26106593+03
38	.20406000+03	.27266649+03
39	.20943000+03	.28447684+03
40	.21480000+03	.29649193+03
41	.22017000+03	.30871410+03
42	.22554000+03	.32113727+03
43	.23091000+03	.33376357+03
44	.23628000+03	.34659008+03
45	.24165000+03	.35961219+03
46	.24702000+03	.37283002+03
47	.25239000+03	.38624189+03
48	.25776000+03	.39984290+03
49	.26313000+03	.41363670+03
50	.26850000+03	.42761874+03
51	.27387000+03	.44179209+03
52	.27924000+03	.45615678+03
53	.28461000+03	.47070781+03
54	.28998000+03	.48544724+03

WITH D. C. RESTORE BUT WITHOUT THE BUMP

F_C = 750 Hz

DCR = 0

```
55    .29535000+03              .50037042+03
56    .30072000+03              .51547131+03
57    .30609000+03              .53075513+03
58    .31146000+03              .54621636+03
59    .31683000+03              .56185493+03
60    .32220000+03              .57767534+03
61    .32757000+03              .59367883+03
62    .33294000+03              .60985733+03
63    .33831000+03              .62620747+03
64    .34368000+03              .64272813+03
65    .34905000+03              .65941838+03
66    .35442000+03              .67628323+03
67    .35979000+03              .69332034+03
68    .36516000+03              .71052180+03

LINES NO SAMS AREA(KMXKM) VARIANCE STD DEV


 1        2  10.74  10.74    .77693    .88144
 2        3  17.61  16.11    .31368    .56007
 3        5  24.49  26.85    .15782    .39727
 4        6  31.36  32.22    .10731    .32758
 5        7  38.23  37.59    .07917    .28137
 6        8  45.11  42.96    .06160    .24819
 7       10  51.98  53.70    .04727    .21742
 8       11  58.86  59.07    .03952    .19879
 9       12  65.73  64.44    .03372    .18363
10       14  72.60  75.18    .02828    .16818
11       15  79.48  80.55    .02494    .15791
12       16  86.35  85.92    .02222    .14906
13       17  93.22  91.29    .01998    .14135
14       19100.10102.03      .01770    .13303
15       20106.97107.40      .01617    .12715
16       21113.84112.77      .01486    .12188
17       22120.72118.14      .01372    .11713
18       24127.59128.88      .01251    .11185
19       25134.46134.25      .01166    .10799
20       26141.34139.62      .01091    .10444
21       28148.21150.36      .01009    .10046
22       29155.09155.73      .00950    .09749
23       30161.96161.10      .00897    .09473
24       31168.83166.47      .00849    .09216
25       33175.71177.21      .00796    .08923
26       34182.58182.58      .00757    .08701
27       35189.45187.95      .00721    .08492
28       37196.33198.69      .00681    .08253
29       38203.20204.06      .00651    .08069
30       39210.07209.43      .00623    .07896
31       40216.95214.80      .00598    .07732
32       42223.82225.54      .00569    .07543
33       43230.70230.91      .00547    .07396
34       44237.57236.28      .00527    .07256
35       46244.44247.02      .00503    .07095
36       47251.32252.39      .00486    .06969
37       48258.19257.76      .00469    .06849
38       49265.06263.13      .00453    .06733
39       51271.94273.87      .00436    .06579
```

```
40          52278.81279.24     .00422      .06494
41          53285.68284.61     .00409      .06393
42          54292.56289.98     .00396      .06296
43          56299.43300.72     .00382      .06183
44          57306.30306.09     .00371      .06093
45          58313.18311.46     .00361      .06007
46          60320.05322.20     .00349      .05906
47          61326.93327.57     .00339      .05826
48          62333.80332.94     .00331      .05749
49          63340.67338.31     .00322      .05674
50          65347.55349.05     .00312      .05587
```

WITH D. C. RESTORE BUT WITHOUT
THE BUMP

F_C = 10 Hz

DCR = 0

```
PLE NO        KM        VARIANCE OF MEAN

  1    .53700000+01      .10000000+01
  2    .10740000+02      .28746600+01
  3    .16110000+02      .4779[illegible]59+01
  4    .21480000+02      .673[illegible]28+01
  5    .26850000+02      .86955656+01
  6    .32220000+02      .10663855+02
  7    .37590000+02      .12641606+02
  8    .42960000+02      .14622818+02
  9    .48330000+02      .16615229+02
 10    .53700000+02      .18616256+02
 11    .59070000+02      .20621118+02
 12    .64440000+02      .22632786+02
 13    .69809999+02      .24651489+02
 14    .75179999+02      .26678411+02
 15    .80549999+02      .28707630+02
 16    .85920000+02      .30742572+02
 17    .91290000+02      .32780748+02
 18    .96660000+02      .34824184+02
 19    .10203000+03      .36866651+02
 20    .10740000+03      .38918612+02
 21    .11277000+03      .40969385+02
 22    .11814000+03      .43028940+02
 23    .12351000+03      .45087685+02
 24    .12888000+03      .47154267+02
 25    .13425000+03      .49219838+02
 26    .13962000+03      .51288590+02
 27    .14499000+03      .53360893+02
 28    .15036000+03      .55436090+02
 29    .15573000+03      .57511036+02
 30    .16110000+03      .59587157+02
 31    .16647000+03      .61662788+02
 32    .17184000+03      .63739231+02
 33    .17721000+03      .65814179+02
 34    .18258000+03      .67892381+02
 35    .18795000+03      .69967277+02
 36    .19332000+03      .72045460+02
 37    .19869000+03      .74125916+02
 38    .20406000+03      .76210909+02
 39    .20943000+03      .78303321+02
 40    .21480000+03      .80398593+02
 41    .22017000+03      .82501733+02
 42    .22554000+03      .84606915+02
 43    .23091000+03      .86719822+02
 44    .23628000+03      .88835632+02
 45    .24165000+03      .90953391+02
 46    .24702000+03      .93074122+02
 47    .25239000+03      .95197529+02
 48    .25776000+03      .97319023+02
 49    .26313000+03      .99444973+02
 50    .26850000+03      .10157107+03
 51    .27387000+03      .10370273+03
 52    .27924000+03      .10584161+03
 53    .28461000+03      .10798284+03
 54    .28998000+03      .11013066+03
```

```
55     .29535000+03          .11228085+03
56     .30072000+03          .11442726+03
57     .30609000+03          .11657820+03
58     .31146000+03          .11872786+03
59     .31683000+03          .12087744+03
60     .32220000+03          .12303397+03
61     .32757000+03          .12520043+03
62     .33294000+03          .12736790+03
63     .33831000+03          .12953374+03
64     .34368000+03          .13169773+03
65     .34905000+03          .13386005+03
66     .35442000+03          .13602815+03
67     .35979000+03          .13820045+03
68     .36516000+03          .14036794+03

0 LINES NO SAMS AREA(KMXKM) VARIANCE STD DEV


  1       2 10.74 10.74   .71866   .84774
  2       3 17.61 16.11   .26661   .51634
  3       5 24.49 26.85   .11594   .34050
  4       6 31.36 32.22   .07405   .27213
  5       7 38.23 37.59   .05160   .22715
  6       8 45.11 42.96   .03808   .19514
  7      10 51.98 53.70   .02659   .16308
  8      11 58.86 59.07   .02130   .14595
  9      12 65.73 64.74   .01746   .13215
 10      14 72.60 75.18   .01361   .11667
 11      15 79.48 80.55   .01160   .10770
 12      16 86.35 85.92   .01001   .10004
 13      17 93.22 91.29   .00873   .09341
 14      19100.10102.03   .00729   .08541
 15      20106.97107.40   .00649   .08054
 16      21113.84112.77   .00581   .07620
 17      22120.72118.14   .00523   .07232
 18      24127.59128.88   .00455   .06744
 19      25134.46134.25   .00414   .06438
 20      26141.34139.62   .00379   .06159
 21      28148.21150.36   .00337   .05803
 22      29155.09155.73   .00311   .05575
 23      30161.96161.10   .00288   .05365
 24      31168.83166.47   .00267   .05171
 25      33175.71177.21   .00242   .04917
 26      34182.58182.58   .00226   .04753
 27      35189.45187.95   .00212   .04599
 28      37196.33198.69   .00193   .04397
 29      38203.20204.06   .00182   .04266
 30      39210.07209.43   .00172   .04143
 31      40216.95214.80   .00162   .04026
 32      42223.82225.54   .00150   .03871
 33      43230.70230.91   .00142   .03770
 34      44237.57236.28   .00135   .03674
 35      46244.44247.02   .00126   .03545
 36      47251.32252.39   .00120   .03460
 37      48258.19257.76   .00114   .03379
 38      49265.06263.13   .00109   .03301
 39      51271.94273.87   .00102   .03197
```

```
40        52278.81279.24     .00098     .03128
41        53285.68284.61     .00094     .03062
42        54292.56289.98     .00090     .02999
43        56299.43300.72     .00085     .02913
44        57306.30306.09     .00082     .02556
45        58313.18311.46     .00078     .02801
46        60320.05322.20     .00074     .02726
47        61326.93327.57     .00072     .02676
48        62333.80332.94     .00069     .02627
49        63340.67338.31     .00067     .02581
50        65347.55349.05     .00063     .02517
N
```

APPENDIX A

```
!RUN SSEC1900,6271,9000118597
'FOR,ISZ  FILTER
C  $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
C    SUBHASH DANDAGE, SEPTEMBER 1973
C    THIS PROGRAM COMPUTES THE TRANSFER FUNCTION FOR THE PRESAMPLING FILTER.
C    LIST OF VARIABLES
C       P1,P2,P3,P4,P5 ..POLES OF THE PRESAMPLING FILTER9 THESE  CORRESPOND TO TH
C                            E LOW PASS FILTER WHICH IS THEN CONVERTED TO A REQUIRED
C                            BAND PASS FILTER.
C       W1..MIN.FREQ.(OMEGA1) OF THE BANDPASS FILTER
C       W2..MAX.FREQ.(OMEGA2)
C       W0=CENTRAL FREQ.
C       WB..A BAND PASS FREQ.
C       WL..CORRESPONDING LOW PASS FILTER FREQ.
C       H..POWER TRANSFER FUNCTION
C
C   SUBROUTINES
C    LOPASS--COMPUTES THE VOLTAGE TRANSFER FUNCTION FOR AN INPUT LOW PASS FREQ.
C    NOISTF--COMPUTES THE NOISE TRANSFER FUNCTION(DCR) FOR AN INPUT BANDPASS FRE
C   $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
      IMPLICIT COMPLEX(P)
      READ 1,P1,P2,P3,P4,P5
    1 FORMAT( 2F10.5)
      PRINT 1,P1,P2,P3,P4,P5
      READ,W1,W2
      W0=SQRT(W1*W2)
      PRINT 3,W1,W2,W0
    3 FORMAT(1H / ' W1=',F10.4,'   ,W2=',F10.3, '   ,W0=',F10.4//)
      WOL=(W2-W1)/W0
      DO 10 I=1,80
      X=I*0.1
      WB=10.**X *0.001
      WL=WB/W0 - W0/WB
      WL=WL/WOL
      WL=ABS(WL)
      CALL LOPASS(P1,P2,P3,P4,P5,WL,C)
      T1=0.03
      T2=T1
      CALL NOISTF(WB,T1,T2,TNOISE)
      H=C*TNOISE
C   NORMALIZATION
      H=H*H/(.097073*0.8728)
      PRINT 2,WB,WL,C,TNOISE,H
    2 FORMAT(5F12.4)
   10 CONTINUE
      STOP
      END
'FOR,ISZ  LOPASS
      SUBROUTINE LOPASS(P1,P2,P3,P4,P5,W,C)
      IMPLICIT COMPLEX (S,P,C,T)
      S=CMPLX(0.,W)
      S1=S+P1
      S2=S+P2
      S3=S+P3
      S4=S+P4
      S5=S+P5
```

```
        D=S1*S2*S3*S4*S5
        T=1./D
        A=REAL(T)
        B=AIMAG(T)
        C=CABS(T)
        FI=ATAN(B/A) * 180./3.14159265
      2 FORMAT( 7F10.5)
        RETURN
        END
'FOR.ISZ  NOISTF
        SUBROUTINE NOISTF(F,T1,T2,TNOISE)
        TWOPI=2.*3.14159265
        A=TWOPI*F*T1
        B=TWOPI*F*T2
        C=1.+B*B
        D=1-2.*SIN(A)/(A*SQRT(C))+1./C
        TNOISE=SQRT(D)
        RETURN
        END
'XQT
0.70557
0.67745     -0.94007
0.67745      0.94007
0.54117     -1.82565
0.54117      1.82565
 0.026      17450.
'FIN
```

APPENDIX B

I. Calculation of the Autocovariance Function $C(\tau)$

$$C(\tau) = \int_0^\infty T(f)P(f)\cos 2\pi f\tau df$$

$P(f)$ = noise power spectral density in the detector

$T(f)$ = power transfer function of the electronics following the detector

Special case

$$P(f) = K(1 + \frac{f_c}{f})$$

$$T(f) = \begin{cases} 1 \text{ for } f_1 \le f \le f_2 \\ 0 \text{ for } f < f_1 \text{ or } f > f_2 \end{cases}$$

$$C(\tau) = \int_{f_1}^{f_2} P(f)\cos 2\pi f\tau df$$

$$C(0) = \sigma^2 = \int_{f_1}^{f_2} P(f)df = K(f_2 - f_1 + f_c \ln\frac{f_2}{f_1}) = K\Delta f_N$$

$$\Rightarrow K = \frac{\sigma^2}{\Delta f_N}$$

$$C(\tau) = \frac{\sigma^2}{\Delta f_N}\int_{f_1}^{f_2}(1 + \frac{f_c}{f})\cos 2\pi f\tau df$$

Model for special case

$$C(\tau) = \sigma^2\frac{f_c}{\Delta f_N}[-\gamma - \ln 2\pi f\text{min}\tau] \quad \text{for } 2\pi f\text{max}\tau > 1$$

where $\gamma = .577216$

For τ in seconds, f, in Hz we have

$$\frac{C(\tau)}{\sigma^2} = a - b\ln\tau,$$

where $a = b(-\ln 2\pi f\text{min} - \gamma)$, $b = \frac{f_c}{\Delta f_N}$, $\Delta f_N = f\text{max} - f\text{min} + f_c\ln\frac{f\text{max}}{f\text{min}}$

General Case solved by series

$$T(f) = \sum_{k=1}^{N} W_k T_k(f)$$

where $T_k(f) = \begin{cases} 1 & fmin_k \le f \le fmax_k \\ 0 & f \le fmin_k \text{ or } f > fmax_k \end{cases}$

can be used to approximate a bandpass filter with realistic rolloff or the combined effects of bandpass and DC restore filters.

For the series approximation we have

$$C(\tau) = \sum_{k=1}^{N} W_k \int_{f_{1,k}}^{f_{2,k}} P(f)\cos 2\pi f\tau df, \text{ and}$$

$$\sigma^2 = \sum_{k=1}^{N} W_k \int_{f_{1,k}}^{f_{2,k}} P(f)df = K \sum_{k=1}^{N} W_k[f_{2,k} - f_{1,k} + f_c \ln\frac{f_{2,k}}{f_{1,k}}]$$

Thus

$$\frac{C(\tau)}{\sigma^2} = \frac{\sum_{k=1}^{N} W_k \int_{f_{1,k}}^{f_{2,k}} (1 + \frac{f_c}{f})\cos 2\pi f\tau df}{\sum_{k=1}^{N} W_k [f_{2,k} - f_{1,k} + f_c \ln\frac{f_{2,k}}{f_{1,k}}]}$$

model

$$\int_{f_{1,k}}^{f_{2,k}} (1 + \frac{f_c}{f})\cos 2\pi f\tau df \simeq f_c([-\gamma - \ln 2\pi f_{1,k}] - \ln\tau)$$

where $\Delta f_{N,k} = f_{2,k} - f_{1,k} + f_c \ln\frac{f_{2,k}}{f_{1,k}}$

$$\frac{C(\tau)}{\sigma^2} \simeq \frac{\sum_{k=1}^{N} W_k f_c[-\gamma - \ln 2\pi f_{1,k} - \ln\tau]}{\sum_{k=1}^{N} W_k \Delta f_{N,k}}$$

$$\frac{C(\tau)}{\sigma^2} \approx \left[\frac{\sum_{k=1}^{N} W_k f_c[-\gamma - \ln 2\pi f_{1,k}]}{\sum_{k=1}^{N} W_k \Delta f_{N,k}}\right] - \left[\frac{\sum_{k=1}^{N} W_k f_c}{\sum_{k=1}^{N} W_k \Delta f_{N,k}}\right] \ln\tau$$

$$\approx \tilde{a} - \tilde{b}\ln\tau \text{ , where}$$

$$a = \frac{\sum_{k=1}^{N} W_k f_c[-\gamma - \ln 2\pi f\mathrm{min}_k]}{\sum_{k=1}^{N} W_k \Delta f_{N,k}} \quad \text{and} \quad b = \frac{\sum_{k=1}^{N} W_k f_c}{\sum_{k=1}^{N} W_k \Delta f_{N,k}}$$

Calculation of autocovariance function:

$$\frac{C(\tau)}{\sigma^2} = \tilde{a} - \tilde{b}\ln\tau, \text{ where}$$

$$\tilde{a} = \frac{\sum_{k=1}^{N} W_k f_c[-\gamma - \ln 2\pi f\mathrm{min}_k]}{\sum_{k=1}^{N} W_k \Delta f_{N,k}}$$

SUM3

$$\tilde{b} = \frac{\sum_{k=1}^{N} W_k f_c}{\sum_{k=1}^{N} W_k \Delta f_{N,k}}$$

$$\frac{\mathrm{SUM1}}{\mathrm{SUM2}}$$

GAMMA = .577216

```
     READ FC
     DO   10   I=1,.N
     READ101,FMIN,FMAX,W
101  FORMAT
     DELF = FMAX - FMIN + FC*ALOG(FMAX/FMIN)
     TOPIFM=2.*3.14159265*FMIN
     SUM1=SUM1+W*FC
     SUM2=SUM2+W*DELF
     SUM3=SUM3+W*FC*[-GAMA-ALOG(TOPIFM/
 10  CONTINUE
     A=SUM3/SUM2
     B=SUM1/SUM2
     PRINT102A,B
102  FORMAT('C(TAU)=,F10.5,'+',F10.5,'*ALOG(TAU)')
```

APPENDIX C

```
'RUN SSEC1900,4623,9000118597,2M,150/1000
'FOR,ZSI CONEW
                   40      120
      PARAMETER K=~~29~~,N=~~136~~
      DIMENSION A(K,N),COV(N),TAU(N),W(K)
      DIMENSION CIA(51),CI(151),CIB(81)
      DIMENSION CIC1(21),CIC2(21)     dimension glabel(6)/'6 C(TAU)/SIGMA**2$$'/
      COMMON/CC/CIA,CI,CIB,CIC1,CIC2
      COMMON/FF/FC,FMIN,FMAX,DELT
C $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $
C  SUBHASH DANDAGE,OCT 10, 1973
C  CONEW-- THIS PROGRAM  COMPUTES THE  AVERAGED C(TAU)/SIGMA**2 FOR A GIVEN
C  *SET OF SUB-FILTERS
C
C  INPUT VARIABLES
C   PARAMETER K=NO. OF SUB-FILTERS
C   PARAMETER N=NO. OF C(TAU) CALCULATIONS
C   CIA,CI,XIB,CIC1,CIC2--FROM MATH. TABLES, USED FOR INTEGRATION CALCULATIONS
C   FC=CUTOFF FREQ.
C   DELT=~~IFOV~~ SAMPLING INTERVAL
C   FMIN=MIN.FREC. OF THE SUE-FILTER
C   FMAX=MAX.FREQ. OF THE SUB-FILTER
C   W(K)=WEIGHTING FACTOR ASSOCIATED WITH K-TH SUB-FILTER
C
C  LIST OF VARIABLES
C   ~~TSAM=NO. OF SAMPLES PER IFOV~~
C   CONST=NOISE EFFECTIVE BANDWIDTH
C   COV=C(TAU)
C
C  SUBROUTINES
C   COVAR--COMPUTES C(TAU) FOR AN INDIVIDUAL SUB-FILTER
C   FCI--MATH.FUNCTIONS COMPUTING THE INTEGRALS
C $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $
      READ ~~101,CIA~~
      READ ~~101,CI~~
      READ ~~101,CIB~~
      READ ~~101,(CIC1(I),CIC2(I),I=1,21~~)
      PRINT 101,CIA
      PRINT 101,CI
      PRINT 101,CIB
      PRINT 101,(CIC1(I),CIC2(I),I=1,21)
  101 FORMAT(8F10.5)
    1 READ(-,-,END=33)FC,DELT        750, .000008
      SUMSI2=0.
      DO 10 I=1,K
      READ ~~70~~,FMIN,FMAX,W(I)
      PRINT 71,FC,FMIN,FMAX,DELT,W(I)
      ~~TSAM=1./(2.*DELT*FMAX)~~
      ~~PRINT 73,TSAM~~
~~73    FORMAT('0NO OF SAMPLES PER IFOV=',F8.2)~~
   ~~70 FORMAT(3F10.5~~)
   71 FORMAT(1H1,3HFC=,F12.5,5HFMIN=,F12.5,5HFMAX=,F12.5,'  DEL T=',E12.
     *6,'  ,WEIGHT=',F7.5)
      CONST=FMAX-FMIN+FC*ALOG(FMAX/FMIN)
      SUMSI2=SUMSI2+CONST*W(I)
   10 CALL COVAR(N,K,I,A,TAU)
      DO 110 I=1,N
```

```
        COV(I)=0.
        DO 100 L=1,K
 100    COV(I)=COV(I)+A(L,I)*W(L)
   110  COV(I)=COV(I)/SUMSI2
        ~~PRINT 2,DELT,W~~
~~2       FORMAT('1DELT=',F20.9/' WEIGHTS ',(10F10.6))~~
        PRINT 4
      4 FORMAT('0POSITION        TAU         COV')
        DO 102 I=1,N
 102    PRINT 3,I,TAU(I),COV(I)
 3      FORMAT(I6, 2F14.7)
        ~~PUNCH,((TAU(I),COV(I)),I=1,N)~~
        GO TO 1
 33     STOP
        END
```

call graph(100,TAU,COV,'W', GLABEL)
call graphp

```
'FOR,ISZ    COVAR,COVAR
        SUBROUTINE COVAR(N,K,I,COVAR,TAU)
        DIMENSION TAU(N),COVAR(K,N)
        COMMON/FF/FC,FMIN,FMAX,DELT
        TWOPI=2.*3.14159265
        DO 10 KK=1,N
        TAU(KK)=FLOAT(KK)*DELT
        TWOPIT= TWOPI*TAU(KK)
        X1=TWOPIT*FMAX
        X2=TWOPIT*FMIN
        CIX1=FCI(X1)
        CIX2=FCI(X2)
        ROMB=CIX1-CIX2
        ROMB=(SIN(TWOPIT*FMAX)-SIN(TWOPIT*FMIN))/TWOPIT+FC*ROMB
 C        COVAR ISCOVARIENCE FUNCTION C(TAU)/SIGMA**2
        COVAR(I,KK)=ROMB
     10 CONTINUE
        PRINT 72,(KK,TAU(KK),COVAR(I,KK),KK=1,N)
     72 FORMAT(1H ,2(' NO    K    TAU        C(TAU)/SIG**2')//
      1 (2( I9,F10.6,5X,E12.6)))
        RETURN
        END
'FOR,ISZ    FCI,FCI
        FUNCTION FCI(X)
        DIMENSION CIC1(21),CIC2(21)
        DIMENSION CIA(51),CI(151),CIB(81)
        COMMON/CC/CIA,CI,CIB,CIC1,CIC2
        GAMA=0.57722
         IF(X.GT.10.)GO TO 4
        IF(X.GE..50) GO TO 2
        IX=INT(X*100.)+1
        D=X-(IX-1)*0.01
        Y=CIA(IX)+D*(CIA(IX+1)-CIA(IX))
        FCI    =Y*X*X+GAMA+ALOG(X)
        RETURN
      2 IF(X.GT.2.00) GO TO 3
        IX=INT((X-.5)*100.)+1
        D=X-0.5-(IX-1)*0.01
        FCI=CI(IX)+D*(CI(IX+1)-CI(IX))
        RETURN
      3 IX=INT((X-2.0)*10.)+1
```

```
      D=X-2.-(IX-1)*0.1
      FCI=CIB(IX)+D*(CIB(IX+1)-CIB(IX))                                    C3
      RETURN
    4 X1=1./X
      IX=INT(X1*200.)+1
      D=X1-(IX-1)/200.
      XFX=CIC1(IX)+D*(CIC1(IX+1)-CIC1(IX))
      X2G=CIC2(IX)+D*(CIC2(IX+1)-CIC2(IX))
      FCI=XFX*SIN(X)/X-X2G*COS(X)/(X*X)
      RETURN
      END
'MAP,I
'XQT
  -.25000    -.25000    -.25000    -.24999    -.24998    -.24997    -.24996    -.24995
  -.24993    -.24992    -.24990    -.24987    -.24985    -.24982    -.24980    -.24977
 -.24973     -.24970    -.24966    -.24962    -.24958    -.24954    -.24950    -.24945
  -.24940    -.24935    -.24930    -.24924    -.24918    -.24913    -.24906    -.249000
  -.24893    -.24887    -.24880    -.24873    -.24865    -.24858    -.24850    -.24842
  -.24834    -.24826    -.24817    -.24808    -.24799    -.24790    -.24781    -.24771
  -.24761    -.24751    -.24741
  -.17778    -.16045    -.14355    -.12707    -.11099    -.09530    -.07999   -0.06504
  -.05044    -.03619    -.02227    -.00867     .00460     .1758     .03026     .04265
   .05476     .06659     .07816     .08946     .10051     .11131     .12187     .13220
   .14230     .15216     .16181     .17124     .18046     .18947     .19828     .20689
   .21530     .22353     .23157     .23942     .24710     .25460     .26192     .26908
   .27607    .28289     .28956     .29606     .30242     .30861     .31466     .32056
   .32632     .33193     .33740     .34274     .34794     .35300     .35793     .36274
   .36741     .37196     .37639     .38069     .33487     .38894     .39289     .39672
   .40044     .40405     .40754     .41093     .41421     .41739     .42046     .42343
   .42629     .42906     .43173     .43430     .43678     .43916     .44144     .44364
   .44574     .44775     .44968     .45151     .45326     .45493     .45651     .45800
   .45942     .46075     .46201     .46318     .46428     .46530     .46624     .46711
   .46790    .46862     .46927     .4685     .470356     .47079     .47116     .47146
   .47169     .47186     .47196     .47200     .47197     .47188     .47173     .47152
   .47125     .47091     .47052     .47007     .46956     .46900     .46838     .46770
   .46697     .46618     .46535     .46446     .46351     .46252     .46148     .46038
   .45924     .45805     .45681     .45553     .45419     .45282     .45139     .44992
   .44841     .44685     .44526     .44362     .44194     .44022     .43846     .43665
   .43481     .43293     .43102     .42906     .42707     .42504     .42298
   .42298     .40051     .37507     .34718     .31729     .28587     .25334     .22008
   .18649     .15290     .11963     .08699     .05526     .02468    -.00452    -.03213
  -.05797    -.08190    -.10378    -.12350   -.14098     -.15617    -.16901    -.17951
  -.18766    -.19349    -.19705    -.19839    -.19760    -.19478    -.19003    -.18348
  -.17525    -.16551    -.15439    -.14205    -.12867    -.11441    -.09944    -.08393
  -.06806    -.05198    -.03587    -.01989    -.00418     .01110     .02582     .03985
   .05308     .06539     .07670     .08691     .09596     .10379     .11036     .11563
   .11960     .12225     .12359     .12364     .12243     .12002     .11644     .11177
   .10607     .09943     .09193     .08368     .07476     .06528     .05535     .04507
   .03455     .02391     .01325     .00268    -.00770    -.01780    -.02752    -.03676
  -.04546
    1.00000    1.00000     .99995     .99985     .99980     .99940     .99955     .99866
     .99920     .99762     .99876     .99630     .99822     .99469     .99758     .99282
     .99686     .99069     .99604     .98831     .99514     .98568     .99415     .98383
     .99308     .97976     .99153     .97649     .99071     .97303     .98941     .96939
     .98804     .96557     .98660     .96160     .98510     .95748     .98353     .9532[illegible]
     .98191     .94885
```

```
 750.      0.00000716197
 10.            0.026        17450.
   0.3          48000.       0.0025
   0.54         44500.       0.0025
   0.77         41000.       0.005
   1.1          39500.       0.01
   1.52         37000.       0.02
   2.2          34000.       0.04
   2.82         30300.       0.04
   3.47         28000.       0.04
   3.98         26500.       0.04
    4.3         25000.       0.04
   4.7          23750.       0.04
   5.03         22500.       0.04
   5.55         21500.       0.04
   5.9          20200.       0.04
    6.3         19300.       0.04
   6.[illegible]   [illegible]   [illegible]
   7.2          17500.       0.04
   7.6          16500.       0.04
   7.9          15400.       0.04
   8.3          14200.       0.04
  8.8           13200.       0.04
   9.3          12000.       0.04
   9.8          11000.       0.04
   10.3          9800.       0.04
   11.0         8500.        0.04
   11.5         7300.        0.04
   12.0         5900.        0.04
   12.7         4000.        0.04
   13.5         1900.        0.04
  'FIN
```

APPENDIX D

```
@RUN SUBHASHSSEC,4623,9000118597
@FOR,ISZ    CTAU
      GAMA=0.577216
C $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $
C  SUBHASH DANDAGE, OCT.10, 1973
C  CTAU--THIS PROGRAMCOMPUTES THE MODEL FOR C(TAU)ON THE BASIS  OF THE FORMULAE
C  *DERIVED IN THE REPORT ON THE CALCULATION OF THE COVARIANCE FUNCTION.
C
C  INPUT VARIABLES
C   N=NO. OF SUB-FILTERS
C   FC=CUTOFF FREQ.
C   FMIN=MIN.FREQ. OF THE PRESAMPLING FILTER
C   FMAX=MAX FREQ. OF THE  PRESAMPLING FILTER
C  OTHER VARIABLES
C   DELF=NOISE FQ.BANDWIDTH
C  THE FORM OF THE MODEL IS  C(TAU)=A-ALOG(B)
C   A AND B ARE THE OUTPUT VARIABLES
C $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $
    1 READ(-,-,END=33)N
      READ 101,FC,FMIN,FMAX
      PRINT 102,FC,FMIN,FMAX
  101 FORMAT(3F10.5)
  102 FORMAT(' FC=',F10.4,' ,FMIN=',F10.5,' ,FMAX=',F10.3)
      SUM1=0.
      SUM2=0.
      SUM3=0.
      DO 10 I=1,N
C
C  INPUT VARIABLES
C   FMAX=MAX FREQ. OF THE SUB-FILTER
C   FMIN=MIN FREQ. OF THE SUB-FILTER
C   W=WEIGHTING FACTOR FOR THE SUB-FILTER
C
      READ 101,FMIN,FMAX,W
      DELF=FMAX-FMIN+FC*ALOG(FMAX/FMIN)
      TOPIFM=2.*3.14159265*FMIN
      SUM1=SUM1+W*FC
      SUM2=SUM2+W*DELF
      SUM3=SUM3+W*FC*(-GAMA-ALOG(TOPIFM))
   10 CONTINUE
      A=SUM3/SUM2
      B=SUM1/SUM2
      PRINT 103,A,B
  103 FORMAT(' C(TAU)=',F15.9,' - ',F15.9,' * ALOG(TAU)')
      M=136
      TFOV=0.00000716197
      DO 20 I=1,M
      TAU=I*TFOV
      CTAU=A-B*ALOG(TAU)
      PRINT,I,TAU,CTAU
20     CONTINUE
      GO TO 1
   33 STOP
      END
@XQT
29    /
```

```
  750.         0.026        17450.
   0.3         48000.       0.0025
   0.54        44500.       0.0025
   0.77        41000.       0.005
   1.1         39500.       0.01
   1.52        37000.       0.02
   2.2         34000.       0.04
   2.82        30300.       0.04
   3.47        28000.       0.04
   3.88        26500.       0.04
    4.3        25000.       0.04
   4.7         23750.       0.04
   5.03        22500.       0.04
   5.55        21500.       0.04
   5.9         20200.       0.04
    6.3        19300.       0.04
   6.8         18500.       0.04
   7.2         17500.       0.04
   7.6         16500.       0.04
   7.9         15400.       0.04
   8.3         14200.       0.04
  8.8          13200.       0.04
   9.3         12000.       0.04
   9.8         11000.       0.04
   10.3         9800.       0.04
   11.0        8500.        0.04
   11.5        7300.        0.04
   12.0        5900.        0.04
   12.7        4000.        0.04
   13.5        1900.        0.04
  29
  10.          0.026        17450.
   0.3         48000.       0.0025
   0.54        44500.       0.0025
   0.77        41000.       0.005
   1.1         39500.       0.01
   1.52        37000.       0.02
   2.2         34000.       0.04
   2.82        30300.       0.04
   3.47        28000.       0.04
   3.88        26500.       0.04
    4.3        25000.       0.04
   4.7         23750.       0.04
   5.03        22500.       0.04
   5.55        21500.       0.04
   5.9         20200.       0.04
    6.3        19300.       0.04
   6.8         18500.       0.04
   7.2         17500.       0.04
   7.6         16500.       0.04
   7.9         15400.       0.04
   8.3         14200.       0.04
  8.8          13200.       0.04
   9.3         12000.       0.04
   9.8         11000.       0.04
   10.3         9800.       0.04
```

```
 11.0        8500.      0.04
 11.5        7300.      0.04
 12.0        5900.      0.04
 12.7        4000.      0.04
 13.5        1900.      0.04
'FIN
```

APPENDIX E

```
'RUN SUBHASHSSEC,4623,9000118597,2M,100/1000
'FOR,ZSI RTSPAC
        DIMENSION COV(136),COVS(68),V(68),D(68)
        DIMENSION TAU(136)
100     READ(-,-,END=33)DCR
        PRINT 900,DCR
  900   FORMAT(1H1,'  DCR=',F10.5)
        READ(-,-)          ((TAU(I),COV(I)),I=1,136)
        COVS(1)=1.
        DO 300 I=2,68
        IJ=2*(I-1)
300     COVS(I)=(COV(IJ      )-DCR)/(1.-DCR)
        DO 400 I=1,68
        V(I)=0.
        DO 400 J=1,I
        DO 400 K=1,I
        IJ=1+IABS(J-K)
400     V(I)=V(I)+COVS(IJ)
        PRINT 2
2       FORMAT('1SAMPLE NO        KM       VARIANCE OF MEAN'//)
        DO 5 I=1,68
        D(I)=FLOAT(I)*2.9992
5       PRINT 1,I,D(I),V(I)
1       FORMAT(I6,F15.8,E20.8)
        PRINT 3
3       FORMAT('0NO LINES NO SAMS AREA(KMXKM) VARIANCE STD DEV'//)
        DO 6 NL=1,50
        SEE NOTE BELOW.
        NTOT=NL*NS
        VA=FLOAT(NL)*V(NS)/FLOAT(NTOT**2)
        DV=35.8*(.3+FLOAT(NL-1)*.192)
        STDV=SQRT(VA)
6       PRINT 4,NL,NS,DV,D(NS),VA,STDV
4       FORMAT(I6,I8,2F6.2,F9.5,F9.5)
        GO TO 100
33      STOP
        END
'MAP,IX
'XQT
0.0
       7.1620E-06      8.5572E-01      1.4324E-05      5.5387E-01      2.1486E-05
       3.1622E-01      2.8648E-05      2.1541E-01      3.5810E-05      1.9136E-01
       4.2972E-05      1.8678E-01      5.0134E-05      1.8541E-01      5.7296E-05
       1.8310E-01      6.4458E-05      1.7663E-01      7.1620E-05      1.6880E-01
       7.8782E-05      1.6504E-01      8.5944E-05      1.6387E-01      9.3106E-05
       1.6048E-01      1.0027E-04      1.5665E-01      1.0743E-04      1.5568E-01
       1.1459E-04      1.5549E-01      1.2175E-04      1.5391E-01      1.2892E-04
       1.5076E-01      1.3608E-04      1.4727E-01      1.4324E-04      1.4559E-01
       1.5040E-04      1.4521E-01      1.5756E-04      1.4371E-01      1.6473E-04
       1.4166E-01      1.7189E-04      1.4108E-01      1.7905E-04      1.4095E-01
       1.8621E-04      1.3899E-01      1.9337E-04      1.3584E-01      2.0054E-04
       1.3434E-01      2.0770E-04      1.3441E-01      2.1486E-04      1.3343E-01
       2.2202E-04      1.3136E-01      2.2918E-04      1.3040E-01      2.3635E-04
       1.3031E-01      2.4351E-04      1.2924E-01      2.5067E-04      1.2685E-01
       2.5783E-04      1.2503E-01      2.6499E-04      1.2597E-01      2.7215E-04
       1.2736E-01      2.7932E-04      1.2503E-01      2.8648E-04      1.2159E-01
```

NOTE: Use this with 0.192mr FOV - NS=INT((.192+FLOAT(NL-1)*.192)/.0838+.5)

Use this with 0.384mr FOV - NS=INT((.384+FLOAT(NL-1)*.384/.0838+.5)

```
                                                                                   E2
  2.9364E-04      1.2210E-01      3.0080E-04      1.2392E-01      3.0796E-04
  1.2201E-01      3.1513E-04      1.1871E-01      3.2229E-04      1.1871E-01
  3.2945E-04      1.2062E-01      3.3661E-04      1.1955E-01      3.4377E-04
  1.1581E-01      3.5094E-04      1.1445E-01      3.5810E-04      1.1613E-01
  3.6526E-04      1.1659E-01      3.7242E-04      1.1503E-01      3.7958E-04
  1.1402E-01      3.8675E-04      1.1353E-01      3.9391E-04      1.1226E-01
  4.0107E-04      1.1112E-01      4.0823E-04      1.1097E-01      4.1539E-04
  1.1054E-01      4.2256E-04      1.0933E-01      4.2972E-04      1.0882E-01
  4.3688E-04      1.0914E-01      4.4404E-04      1.0830E-01      4.5120E-04
  1.0657E-01      4.5837E-04      1.0643E-01      4.6553E-04      1.0755E-01
  4.7269E-04      1.0734E-01      4.7985E-04      1.0543E-01      4.8701E-04
  1.0391E-01      4.9418E-04      1.0427E-01      5.0134E-04      1.0563E-01
  5.0850E-04      1.0581E-01      5.1566E-04      1.0445E-01      5.2282E-04
  1.0356E-01      5.2999E-04      1.0457E-01      5.3715E-04      1.0589E-01
  5.4431E-04      1.0490E-01      5.5147E-04      1.0259E-01      5.5863E-04
  1.0237E-01      5.6580E-04      1.0384E-01      5.7296E-04      1.0354E-01
  5.8012E-04      1.0150E-01      5.8728E-04      1.0051E-01      5.9444E-04
  1.0102E-01      6.0161E-04      1.0157E-01      6.0877E-04      1.0124E-01
  6.1593E-04      1.0010E-01      6.2309E-04      9.8789E-02      6.3025E-04
  9.7802E-02      6.3742E-04      9.7419E-02      6.4458E-04      9.7858E-02
  6.5174E-04      9.8220E-02      6.5890E-04      9.7030E-02      6.6606E-04
  9.5019E-02      6.7323E-04      9.4570E-02      6.8039E-04      9.5861E-02
  6.8755E-04      9.6401E-02      6.9471E-04      9.5140E-02      7.0187E-04
  9.4127E-02      7.0904E-04      9.4740E-02      7.1620E-04      9.5642E-02
  7.2336E-04      9.5850E-02      7.3052E-04      9.5689E-02      7.3768E-04
  9.4765E-02      7.4484E-04      9.3172E-02      7.5201E-04      9.2819E-02
  7.5917E-04      9.4188E-02      7.6633E-04      9.4475E-02      7.7349E-04
  9.1890E-02      7.8065E-04      8.8975E-02      7.8782E-04      8.8865E-02
  7.9498E-04      9.0700E-02      8.0214E-04      9.1530E-02      8.0930E-04
  9.0473E-02      8.1646E-04      8.8715E-02      8.2363E-04      8.7866E-02
  8.3079E-04      8.8666E-02      8.3795E-04      9.0076E-02      8.4511E-04
  9.0921E-02      8.5227E-04      9.1470E-02      8.5944E-04      9.1559E-02
  8.6660E-04      9.0061E-02      8.7376E-04      8.7481E-02      8.8092E-04
  8.5862E-02      8.8808E-04      8.5854E-02      8.9525E-04      8.6035E-02
  9.0241E-04      8.5237E-02      9.0957E-04      8.4353E-02      9.1673E-04
  8.4816E-02      9.2389E-04      8.6239E-02      9.3106E-04      8.7278E-02
  9.3822E-04      8.7334E-02      9.4538E-04      8.6176E-02      9.5254E-04
  8.3992E-02      9.5970E-04      8.2156E-02      9.6687E-04      8.2029E-02
  9.7403E-04      8.3238E-02
).0
  7.1620E-06      8.1727E-01      1.4324E-05      4.3733E-01      2.1486E-05
  1.4294E-01      2.8648E-05      2.4793E-02      3.5810E-05      3.7037E-03
  4.2972E-05      5.6255E-03      5.0134E-05      1.0265E-02      5.7296E-05
  1.2833E-02      6.4458E-05      9.3368E-03      7.1620E-05      3.5635E-03
  7.8782E-05      2.6808E-03      8.5944E-05      4.7306E-03      9.3106E-05
  3.6297E-03      1.0027E-04      1.7307E-03      1.0743E-04      3.1885E-03
  1.1459E-04      5.5995E-03      1.2175E-04      6.0208E-03      1.2892E-04
  4.3086E-03      1.3608E-04      2.0232E-03      1.4324E-04      1.9172E-03
  1.5040E-04      3.4507E-03      1.5756E-04      3.4030E-03      1.6473E-04
  2.5326E-03      1.7189E-04      3.5182E-03      1.7905E-04      5.0217E-03
  1.8621E-04      4.1090E-03      1.9337E-04      1.6336E-03      2.0054E-04
  1.1486E-03      2.0770E-04      2.7105E-03      2.1486E-04      2.8621E-03
  2.2202E-04      1.5472E-03      2.2918E-04      1.6165E-03      2.3635E-04
  2.7742E-03      2.4351E-04      2.6316E-03      2.5067E-04      7.1106E-04
  2.5783E-04     -4.8425E-04      2.6499E-04      1.8583E-03      2.7215E-04
  4.7467E-03      2.7932E-04      2.8049E-03      2.8648E-04     -5.9341E-04
```

```
                                                                              E3
   2.9364E-04        1.0900E-03        3.0080E-04        4.3910E-03        3.0796E-04
   2.9075E-03        3.1513E-04       -4.0556E-04        3.2229E-04        5.3694E-04
   3.2945E-04        2.9196E-03        3.3661E-04        3.4443E-03        3.4377E-04
  -5.0551E-04        3.5094E-04       -1.4073E-03        3.5810E-04        1.5907E-03
   3.6526E-04        2.9922E-03        3.7242E-04        1.7753E-03        3.7958E-04
   1.2851E-03        3.8675E-04        1.4478E-03        3.9391E-04        5.7595E-04
   4.0107E-04       -1.2618E-04        4.0823E-04        4.1404E-04        4.1539E-04
   5.8824E-04        4.2256E-04       -2.8010E-04        4.2972E-04       -2.4527E-04
   4.3688E-04        8.3810E-04        4.4404E-04        4.0549E-04        4.5120E-04
  -1.1773E-03        4.5837E-04       -7.4392E-04        4.6553E-04        1.3022E-03
   4.7269E-04        1.6269E-03        4.7985E-04       -2.5533E-04        4.8701E-04
  -1.6530E-03        4.9618E-04       -6.2374E-04        5.0134E-04        1.6450E-03
   5.0850E-04        2.3850E-03        5.1566E-04        1.1367E-03        5.2282E-04
   4.8470E-04        5.2999E-04        2.2691E-03        5.3715E-04        4.4615E-03
   5.4431E-04        3.7095E-03        5.5147E-04        1.2223E-03        5.5863E-04
   1.4312E-03        5.6580E-04        3.8327E-03        5.7296E-04        3.9340E-03
   5.8012E-04        1.7948E-03        5.8728E-04        1.0214E-03        5.9444E-04
   2.1833E-03        6.0161E-04        3.3632E-03        6.0877E-04        3.4231E-03
   6.1593E-04        2.4512E-03        6.2309E-04        1.2574E-03        6.3025E-04
   4.7511E-04        6.3742E-04        4.5264E-04        6.4458E-04        1.4861E-03
   6.5174E-04        2.4137E-03        6.5890E-04        1.3374E-03        6.6606E-04
  -8.0899E-04        6.7323E-04       -9.5612E-04        6.8039E-04        1.1275E-03
   6.8755E-04        2.2285E-03        6.9471E-04        9.8995E-04        7.0187E-04
   7.2760E-05        7.0904E-04        1.2455E-03        7.1620E-04        2.7822E-03
   7.2336E-04        3.4266E-03        7.3052E-04        3.6132E-03        7.3768E-04
   2.8307E-03        7.4484E-04        1.1708E-03        7.5201E-04        1.1187E-03
   7.5917E-04        3.2969E-03        7.6633E-04        4.0915E-03        7.7349E-04
   1.1860E-03        7.8065E-04       -2.1523E-03        7.8782E-04       -1.8920E-03
   7.9498E-04        8.3565E-04        8.0214E-04        2.2671E-03        8.0930E-04
   1.2662E-03        8.1646E-04       -6.3993E-04        8.2363E-04       -1.3900E-03
   8.3079E-04       -3.7847E-05        8.3795E-04        2.0827E-03        8.4511E-04
   3.4696E-03        8.5227E-04        4.4976E-03        8.5944E-04        4.9711E-03
   8.6660E-04        3.4284E-03        8.7376E-04        5.0279E-04        8.8092E-04
  -1.1856E-03        8.8808E-04       -8.1250E-04        8.9525E-04       -2.1847E-04
   9.0241E-04       -9.1144E-04        9.0957E-04       -1.7374E-03        9.1673E-04
  -8.4661E-04        9.2389E-04        1.2692E-03        9.3106E-04        2.8919E-03
   9.3822E-04        3.2695E-03        9.4538E-04        2.1072E-03        9.5254E-04
  -3.6835E-04        9.5970E-04       -2.4096E-03        9.6687E-04       -2.2737E-03
   9.7403E-04       -4.4603E-04
'FIN
```