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PART III



UNSTEADY LOW-SPEED WINDTUNNEL TEST
OF A STRAKED DELTA WING, OSCILLATING IN PITCH

PART III: PLOTS OF THE ZEROth AND FIRST HARMONIC UNSTEADY
PRESSURE DISTRIBUTIONS (CONCLUDED) AND PLOTS OF
STEADY AND FIRST HARMONIC UNSTEADY OVERALL LOADS

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NATIONAL AEROSPACE LABORATORY (NLR)
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Results of a wind tunnel test of an oscillating straked wing. The report provides unsteady airloads and pressure distributions for a range of incidences (-8 to 50 deg.) and amplitudes (1 to 16 deg.). The wind speed was 80 meters/second, which provided reduced frequencies up to 0.50 based on root chord. The zeroth and first harmonic as well as the continuous time history of the pressure and overall loads were measured. Flow visualization was performed for flow of 30 meters/second using a pulsating laser light sheet. In this part III appendix A presents the remainder of the unsteady zeroth and first order harmonic components of the unsteady pressure distribution plots for which the preceding runs were given in appendix B of part II. In appendix B, plots of the steady and the zeroth and first order harmonic components of the unsteady overall loads are presented. These results are presented as functions of angle of attack, frequency and amplitude in various forms for all measured components.					
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(CONCLUDED) AND PLOTS OF STEADY AND ZEROth AND ZEROth AND FIRST HARMONIC
UNSTEADY OVERALL LOADS

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Zwaan, R.J., " " " " "

FOREWORD

This report summarizes the results of the windtunnel test of an oscillating straked wing conducted under a cooperative program of research between General Dynamics Fort Worth Division, Fort Worth, Texas, and the National Aerospace Laboratory (NLR), The Netherlands. The model and support system was designed and fabricated at NLR under a separate program with General Dynamics and NLR funding. The test preparation, wind-tunnel test and reporting were performed at NLR under Air Force Contract F33615-85-C-3013, for the Flight Dynamics Laboratory of the Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio. The work was administered by Mr. D.W. Kinsey of the Aeromechanics Division (AFWAL/FIM). Additional technical monitoring support was provided by Mr. T. Cord of the Flight Control Division (AFWAL/FIG).

The program manager and principal investigator was Dr. A.M. Cunningham Jr. at General Dynamics and Mr. R.G. den Boer was the principal investigator at NLR. Mr. den Boer was assisted by the following NLR specialists: C.S.G. Dogger, E.G.M. Geurts, A.J. Persoon, A.P. Retèl and R.J. Zwaan.

This report consists of six parts. Part I presents a general description of the model and test program and a discussion of the results. Part II contains the steady pressure distribution plots and the major part of the zeroth and first order harmonic unsteady pressure distribution plots. Part III contains the remainder of the unsteady pressure distribution plots and plots of the steady and the zeroth and first order harmonic unsteady overall loads. Part IV contains time history plots of the unsteady pressures and overall loads. Part V contains power spectral density plots of the overall loads at harmonic oscillation and time history plots of overall loads for (1-cos) model motions. Part VI contains results of the flow visualization program.

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LIST OF SYMBOLS

ALPHA, α	wing incidence	(deg)
b	local wing span	(m)
bw	wing span (bw = 0.8000)	(m)
BETA, β	sideslip angle	(deg)
c	local chord	(m)
Cl	wing rolling moment coefficient	
(Cl)m	mean wing rolling moment coefficient (Cl)m = $1/(Q*S*bw)$	
(Cl)i	unsteady wing rolling moment coefficient (Cl)i = $1/(Q*S*bw*d\alpha)$ (Cl)i = Re(Cl) + i Im(Cl)	
Cm	wing pitching moment coefficient	
(Cm)m	mean wing pitching moment coefficient (Cm)m = $m/(Q*S*cr)$ ref. axis x/cr = 73.27 %	
(Cm)i	unsteady wing pitching moment coefficient (Cm)i = $m/(Q*S*cr*d\alpha)$ ref. axis x/cr = 73.27 % (Cm)i = Re(Cm) + i Im(Cm)	
Cn	wing yawing moment coefficient	
(Cn)m	mean wing yawing moment coefficient (Cn)m = $n/(Q*S*bw)$	
(Cn)i	unsteady wing yawing moment coefficient (Cn)i = $n/(Q*S*bw*d\alpha)$ (Cn)i = Re(Cn) + i Im(Cn)	
CN	wing normal force coefficient	
(CN)m	mean wing normal force coefficient (CN)m = $N/(Q*S)$	
(CN)i	unsteady wing normal force coefficient (CN)i = $N/(Q*S*d\alpha)$ (CN)i = Re(CN) + i Im(CN)	
Cp	pressure coefficient	
(Cp)m	mean pressure coefficient	
(Cp)i	unsteady pressure coefficient (Cp)i = $p_i/(Q*d\alpha)$ (Cp)i = Re(Cp) + i Im(Cp)	
cr	root chord (cr = 0.7855)	(m)
CT	wing tangential force coefficient	
(CT)m	mean wing tangential force coefficient (CT)m = $T/(Q*S)$	
(CT)i	unsteady wing tangential force coefficient (CT)i = $T/(Q*S*d\alpha)$ (CT)i = Re(CT) + i Im(CT)	
CY	wing side force coefficient	



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LIST OF SYMBOLS (Cont'd)

(CY) _m	mean wing side force coefficient (CY) _m = Y/(Q*S)	
(CY) _i	unsteady wing side force coefficient (CY) _i = Y/(Q*S*dα) (CY) _i = Re(CY) + i Im(CY)	
DALPHA, dα	harmonic oscillation: amplitude of unsteady wing incidence	(deg, rad)
f, FREQ	frequency	(Hz)
HARM	harmonic component (HARM = 0: mean) (HARM = 1: first harmonic)	
i	SQRT(-1)	
l	wing rolling moment (figure 1, part I)	(Nm)
m	wing pitching moment (figure 1, part I) ref. axis x/cr = 73.27 %	(Nm)
MACH	freestream Mach number	
n	wing yawing moment (figure 1, part I)	(Nm)
N	wing normal force (figure 1, part I)	(Nm)
NO	number of pressure transducer	
p	pressure at model surface	(Pa)
ps	static pressure	(Pa)
pt	total pressure	(Pa)
Q	dynamic pressure	(Pa)
REDFR	reduced frequency, REDFR = pi * f * cr/V	
RUN	run number	
S	wing area (S = 0.2640)	(m**2)
T	wing tangential force (figure 1, part I)	(N)
T	stagnation temperature in settling chamber	(deg C)
V	freestream velocity	(ms**-1)
x	chordwise coordinate in wing reference plane apex: x=0 (figures 1, 5, part I)	(m)
Y	wing side force (figure 1, part I)	(N)
y	spanwise coordinate in wing reference plane (figures 1, 5, part I)	(m)
Y	wing side force (figure 1, part I)	(N)

LIST OF SYMBOLS (Cont'd)

GREEK

α ,ALPHA	wing incidence	(deg)
$d\alpha$,DALPHA	harmonic oscillation: amplitude of unsteady wing incidence	(deg,rad)
β ,BETA	sideslip angle	(deg)

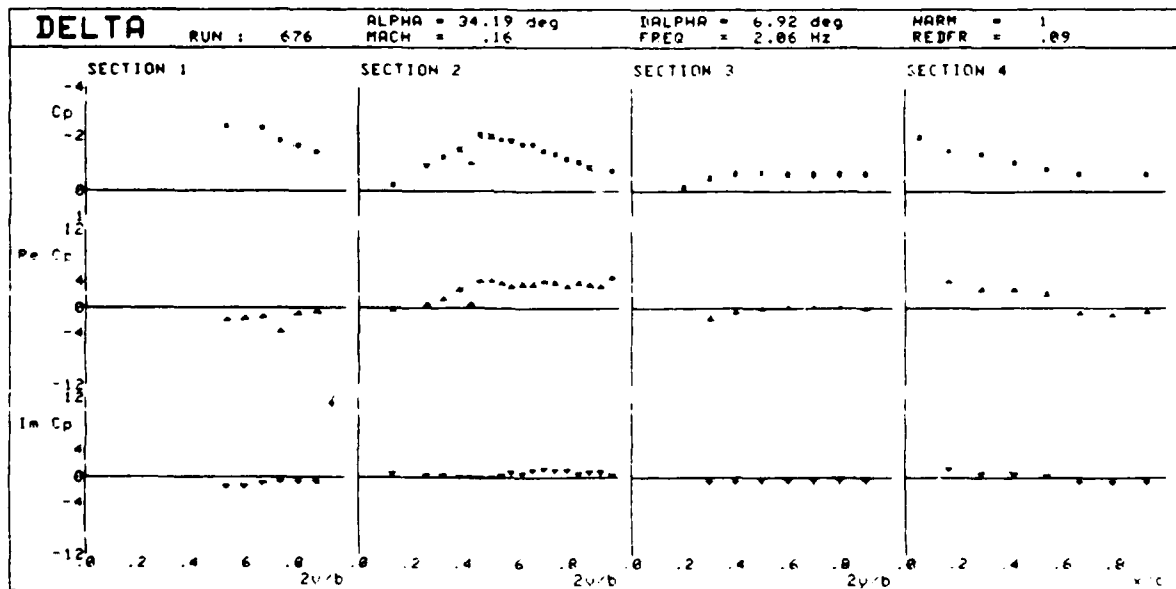
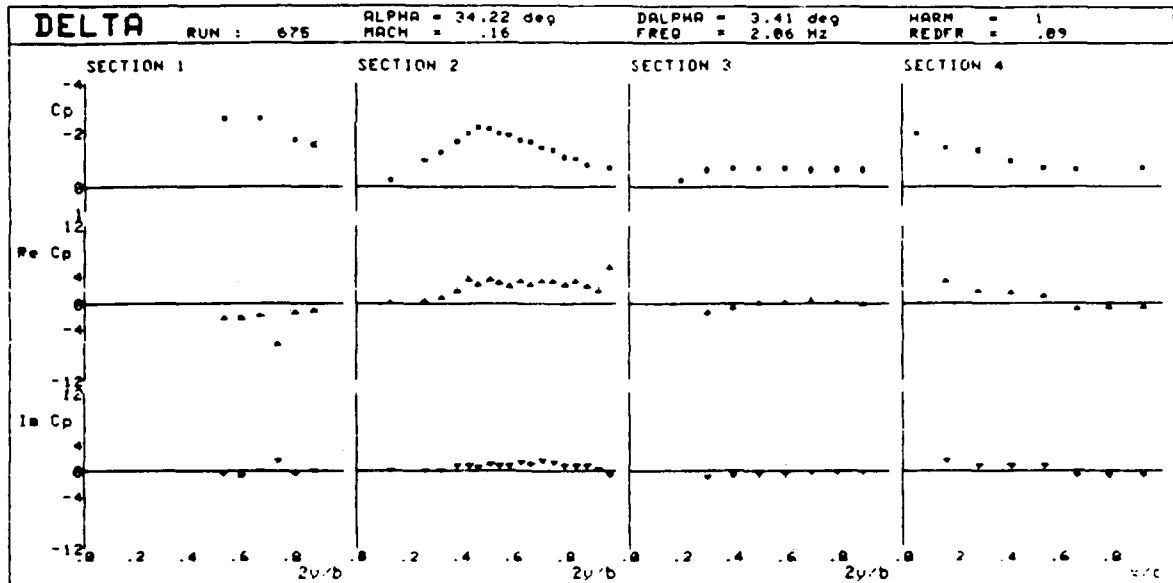
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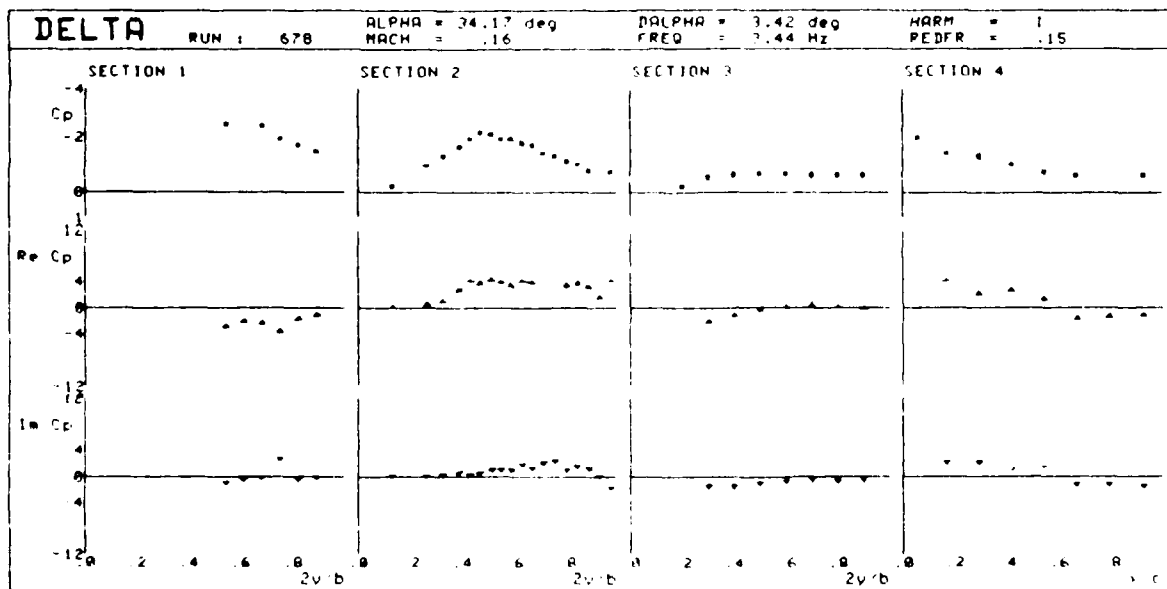
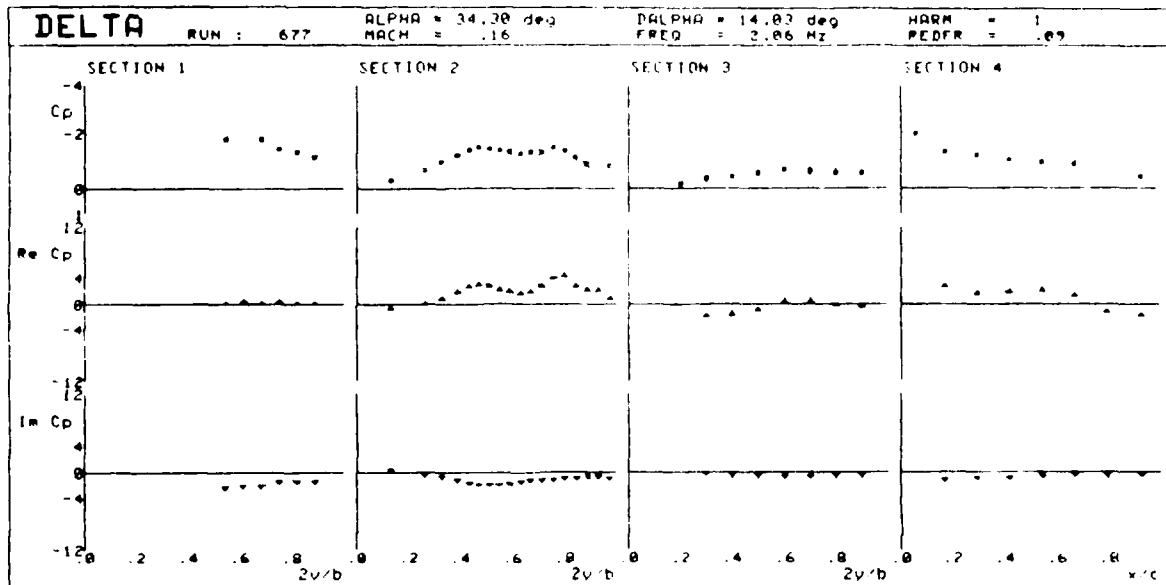
m	mean
i	unsteady

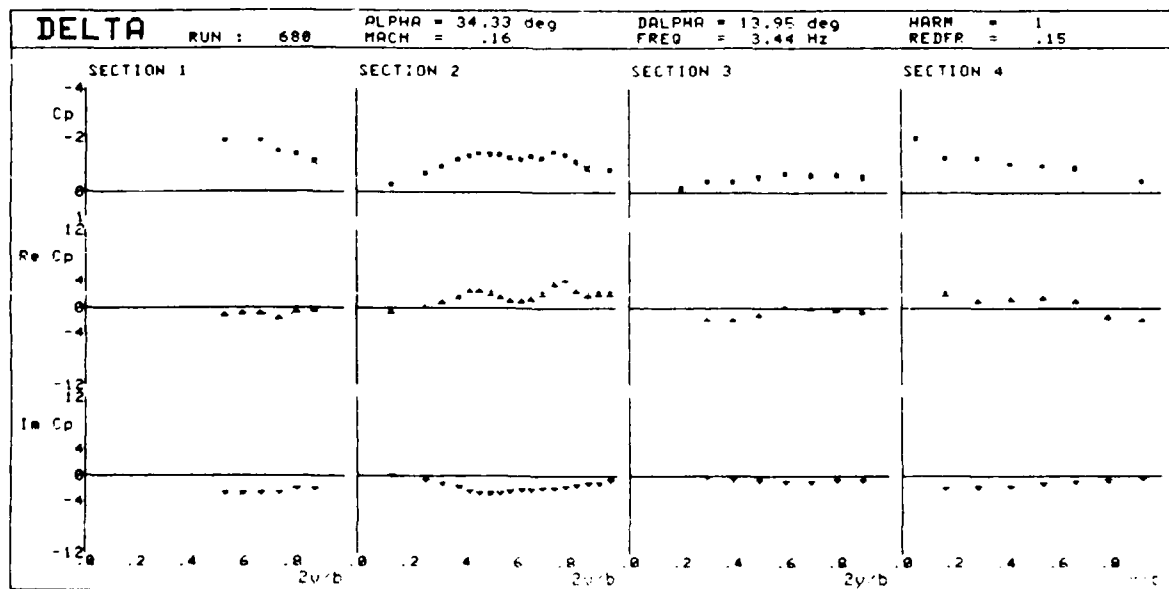
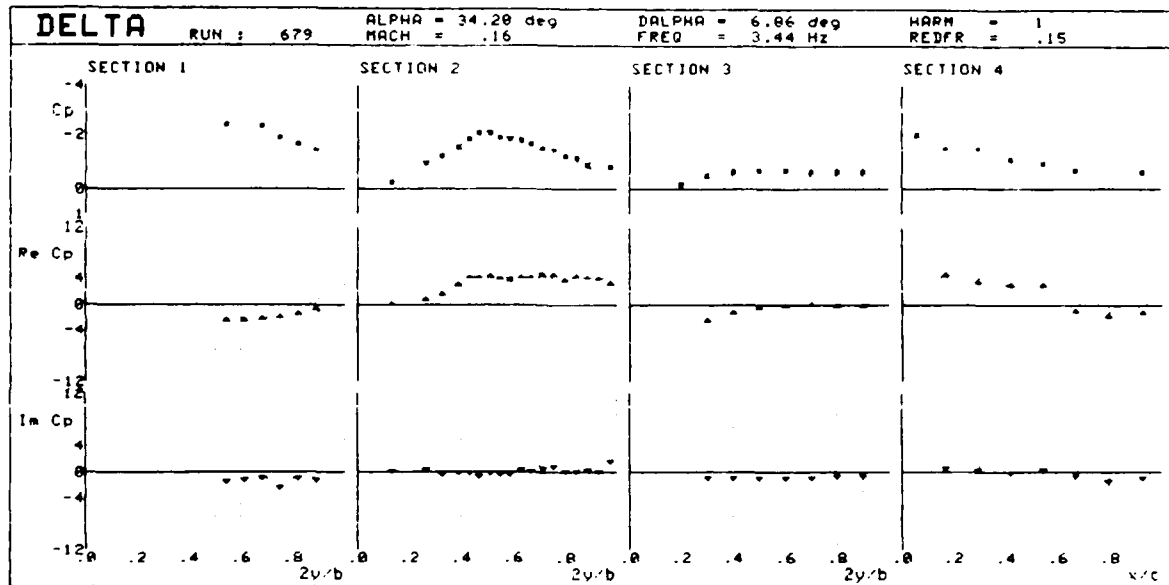
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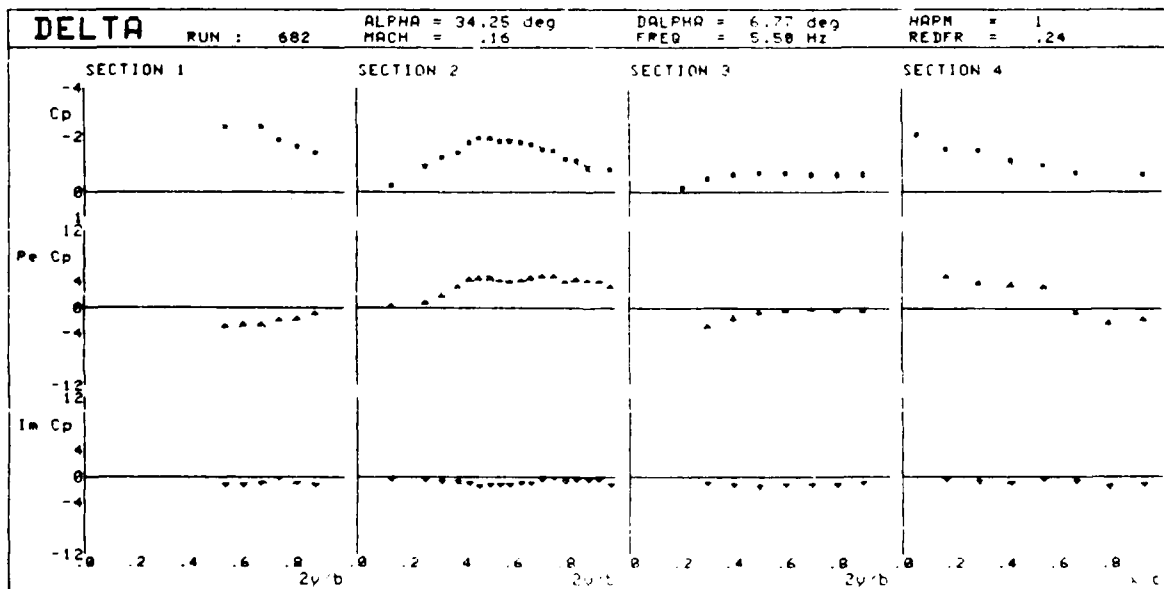
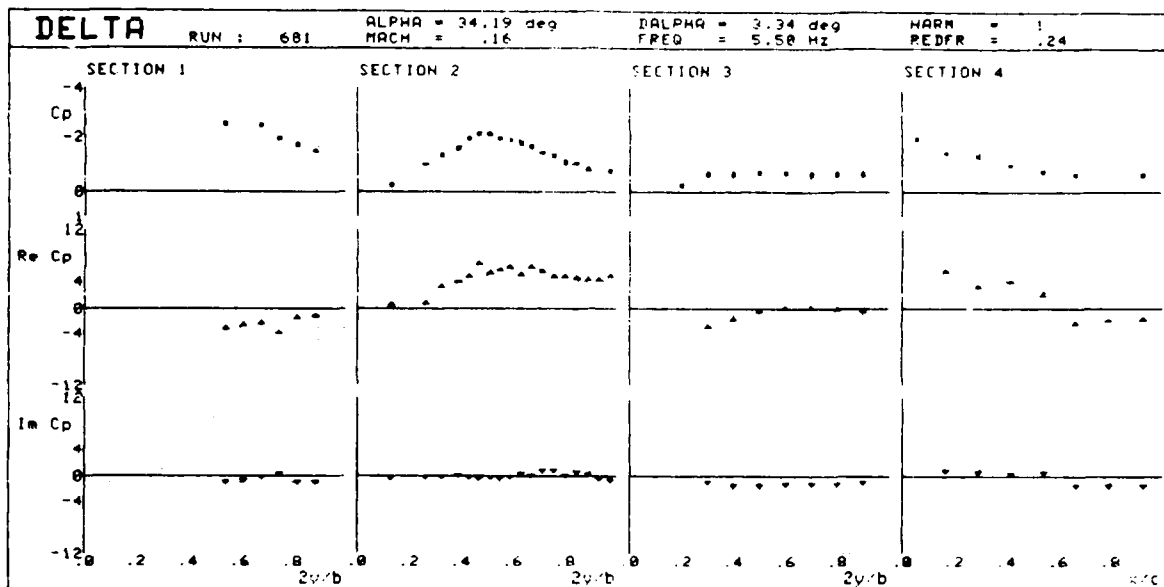
APPENDIX A

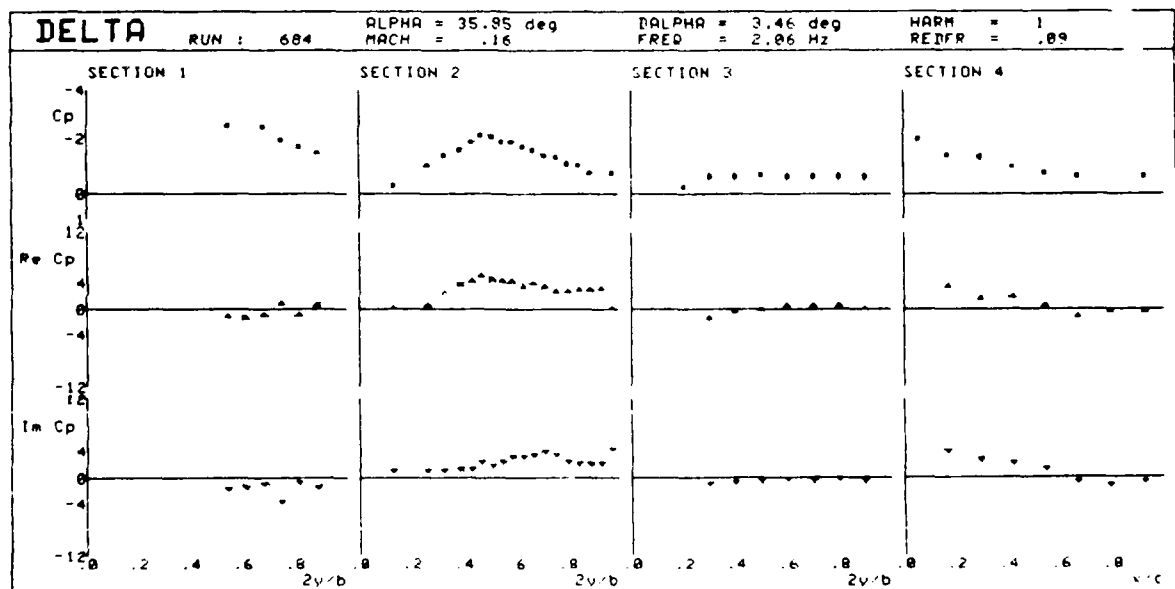
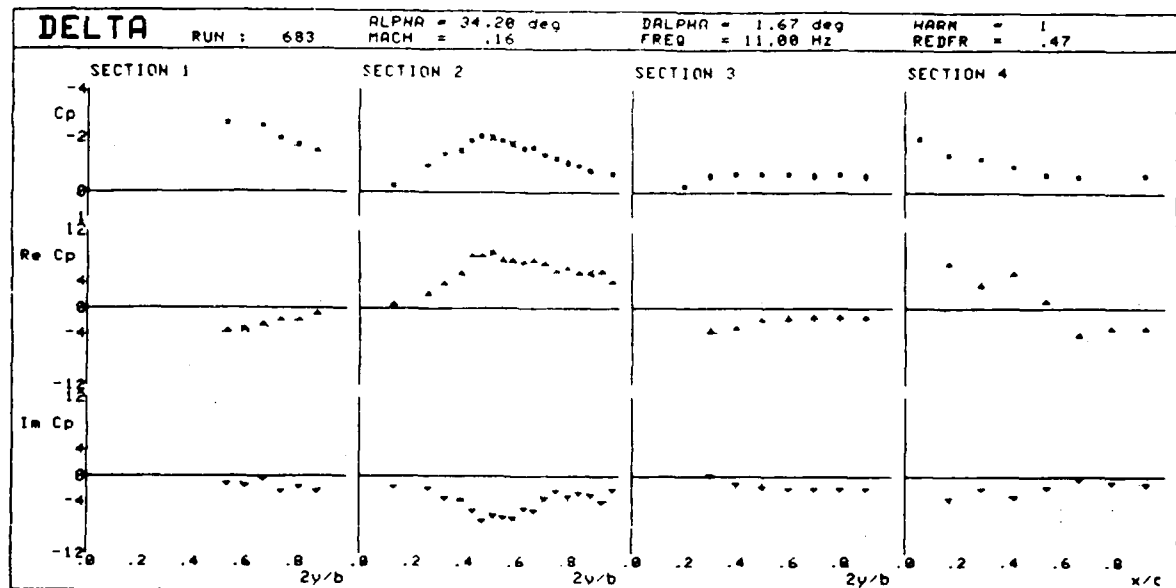
PLOTS OF THE ZEROth AND FIRST ORDER HARMONIC
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(runs 675 to 1059, concluded)

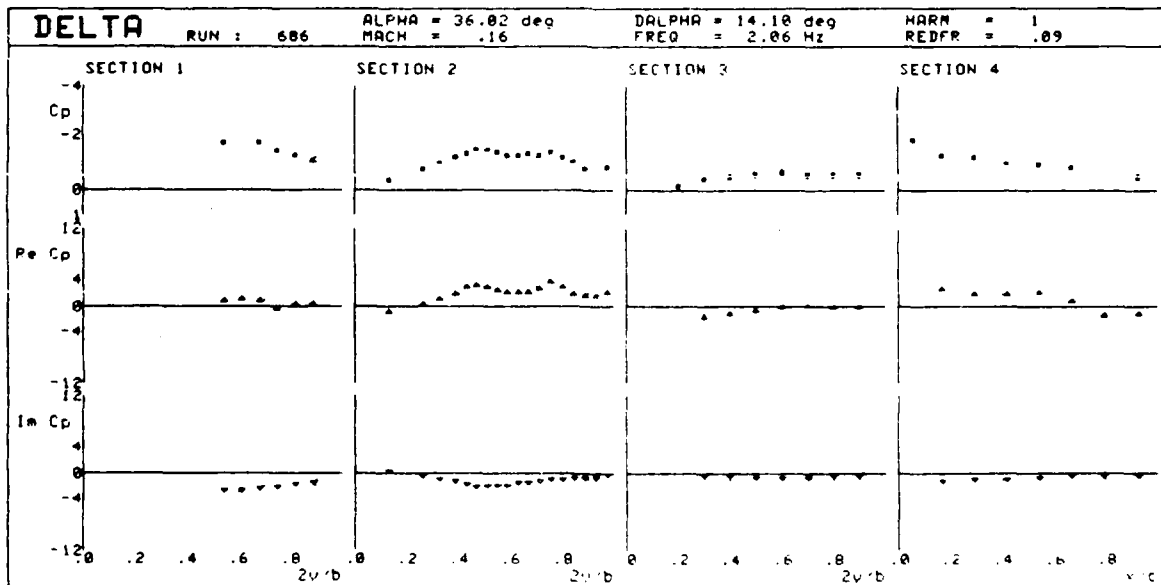
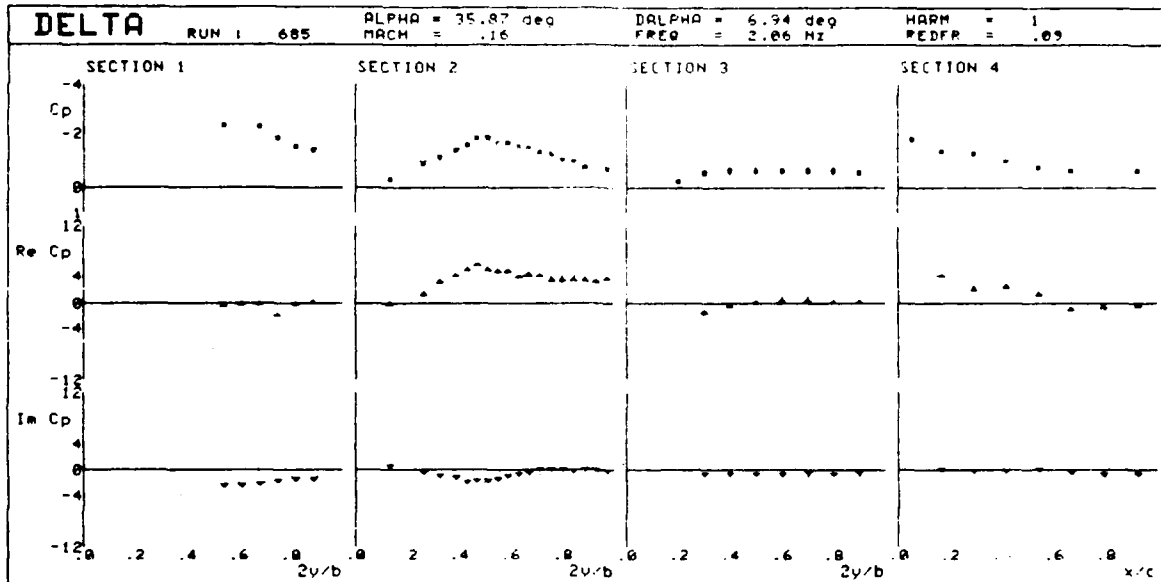


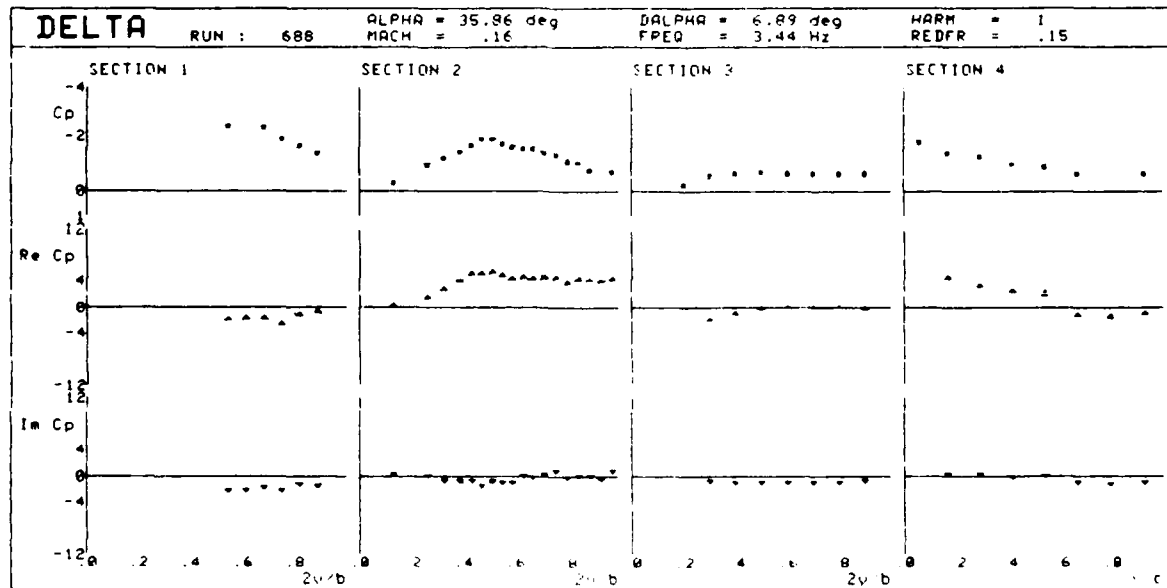
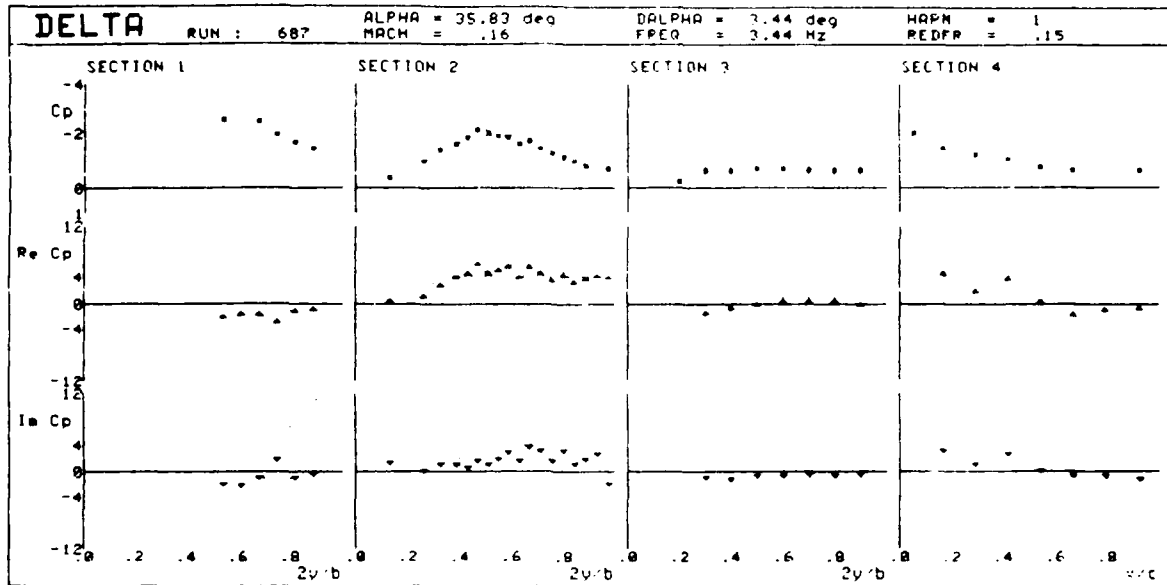


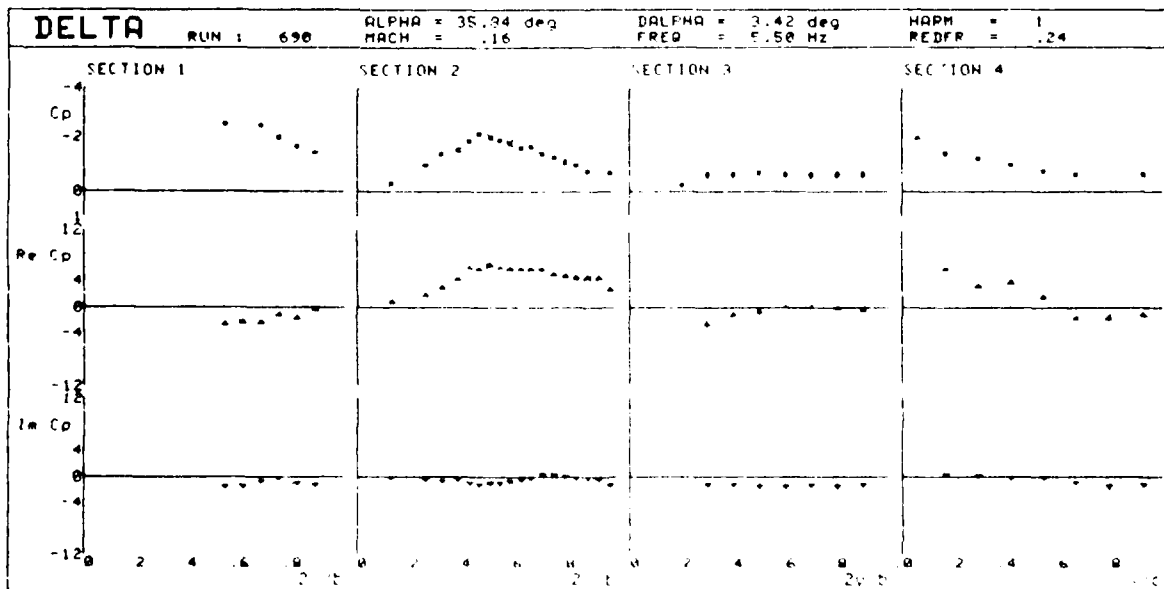
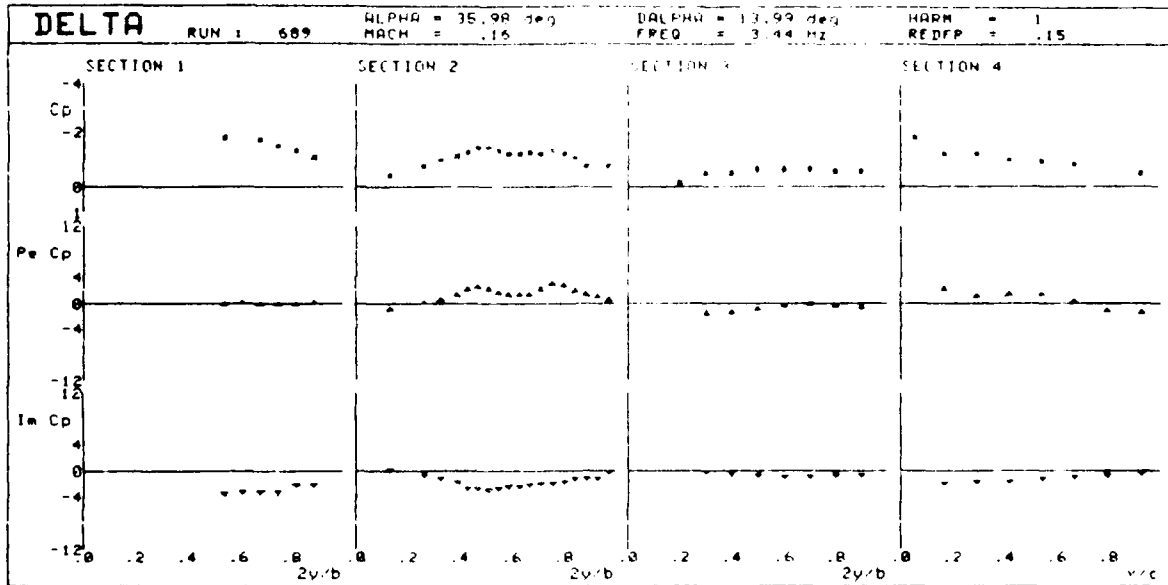


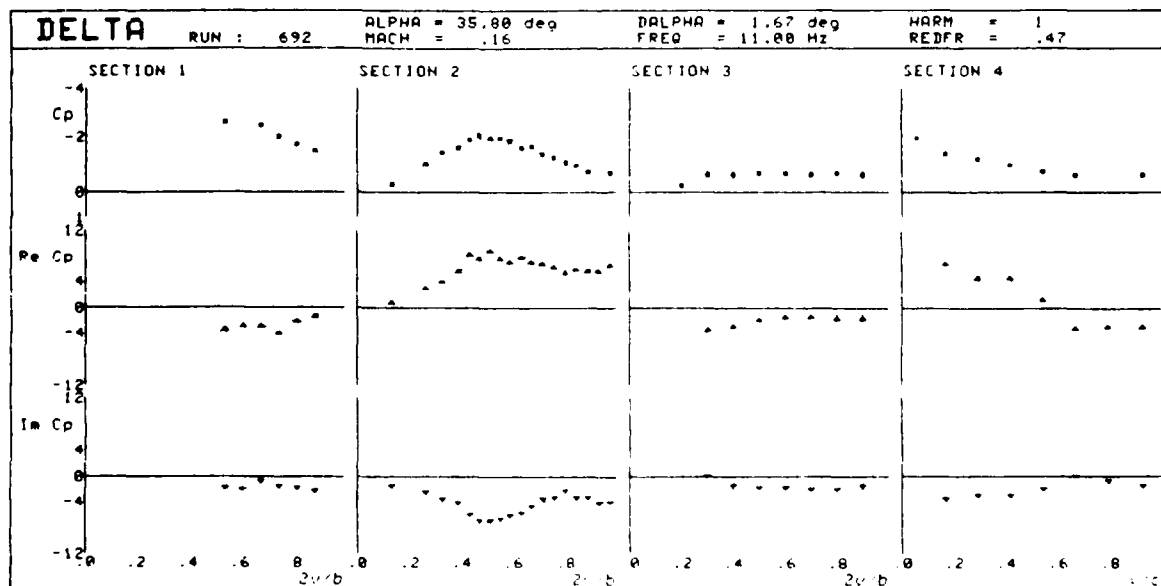
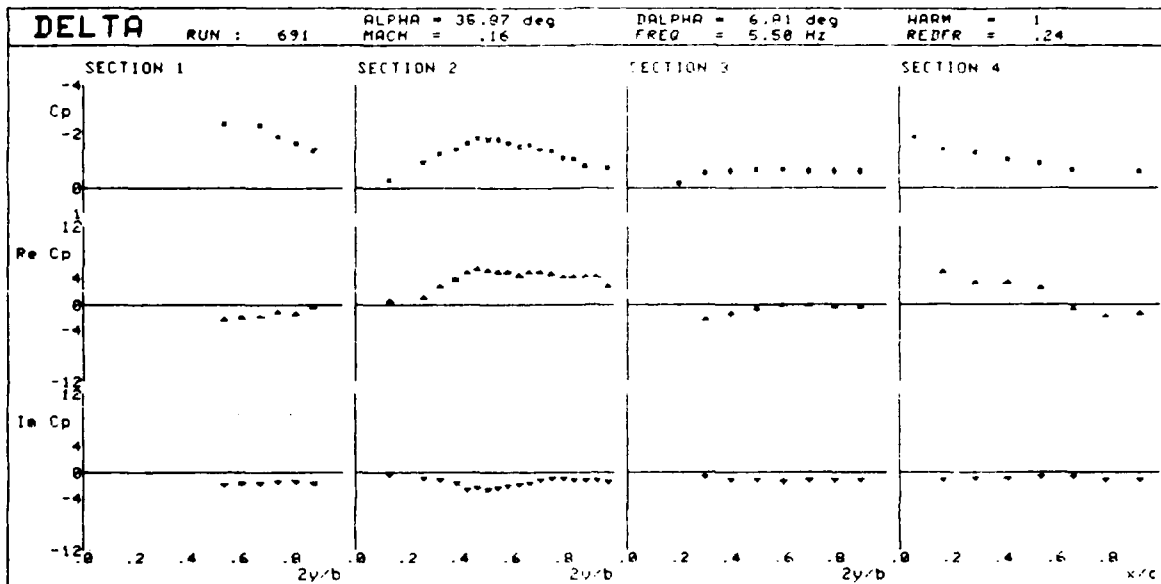


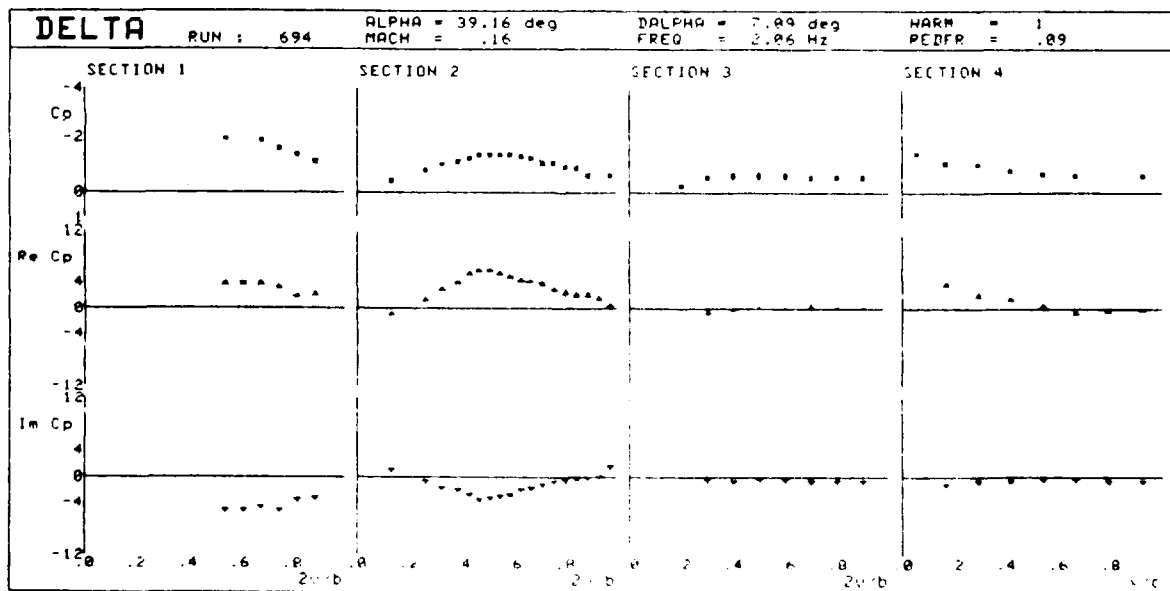
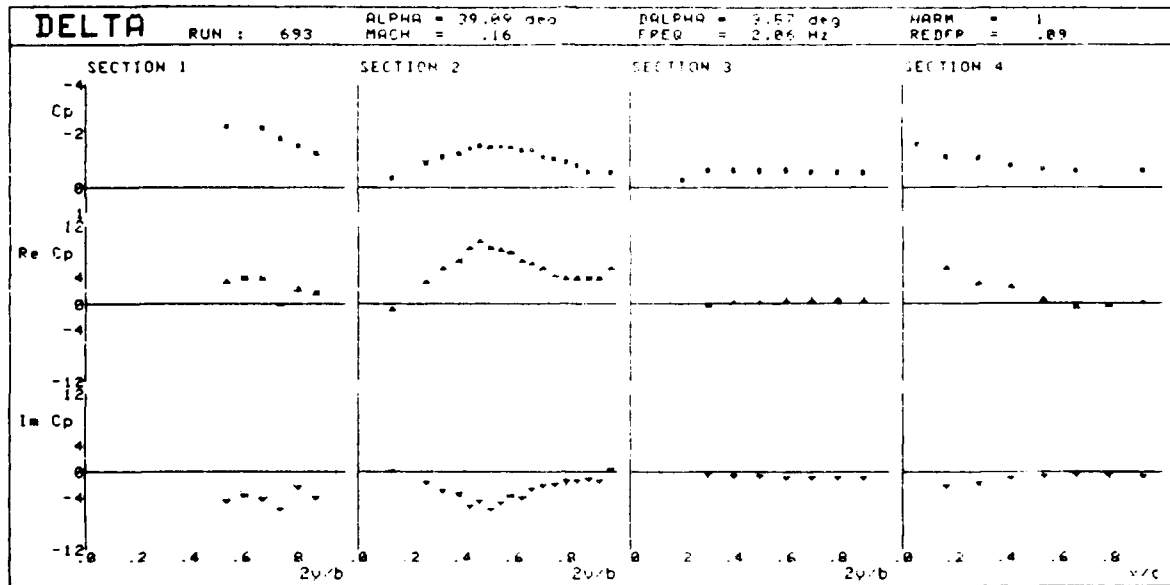


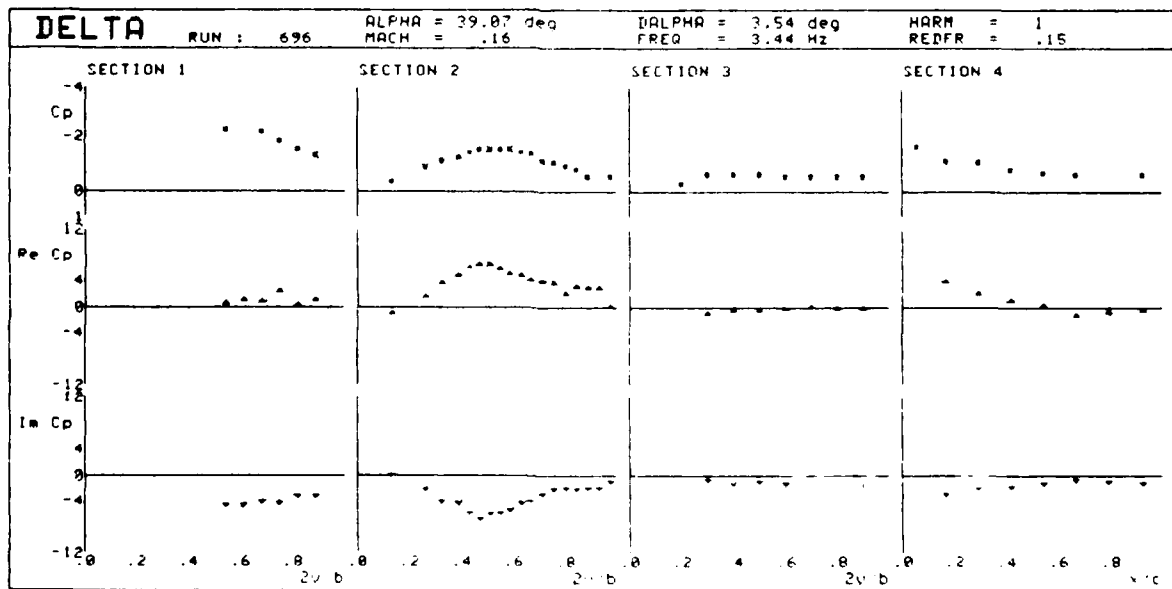
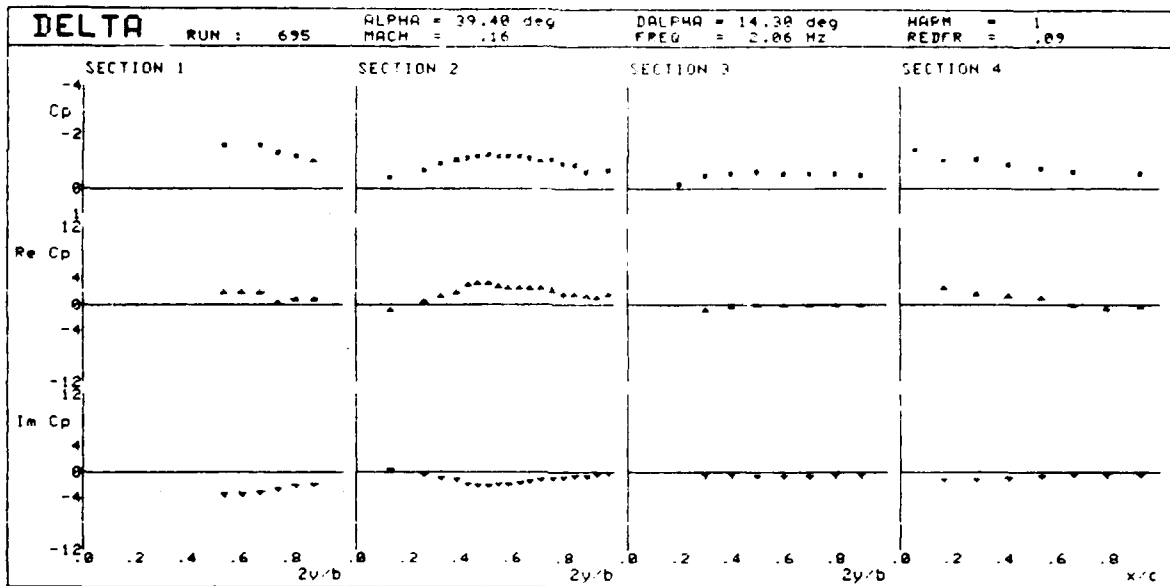


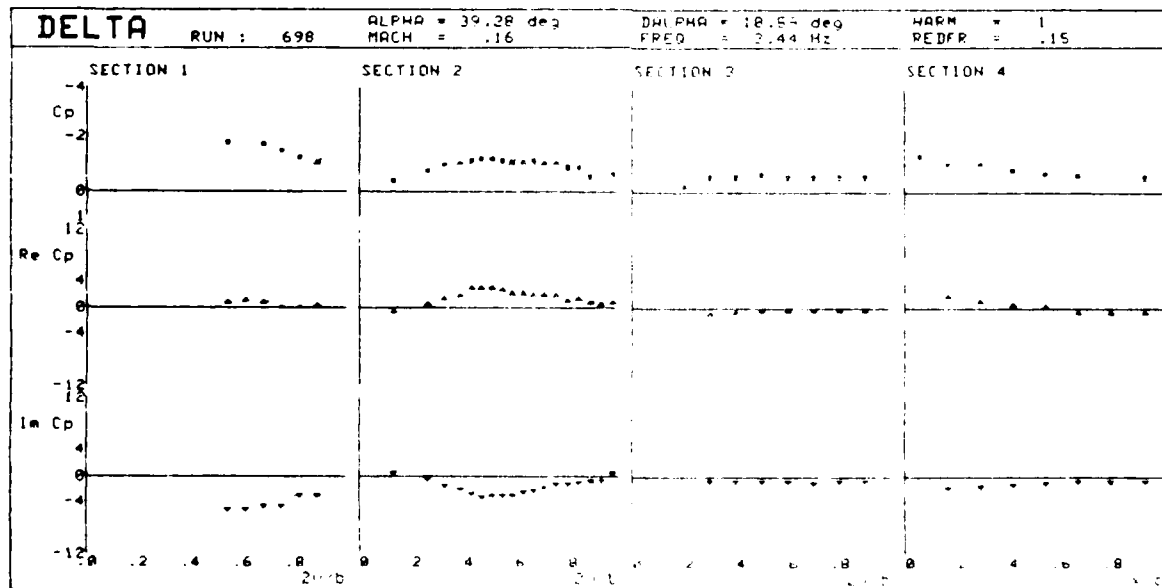
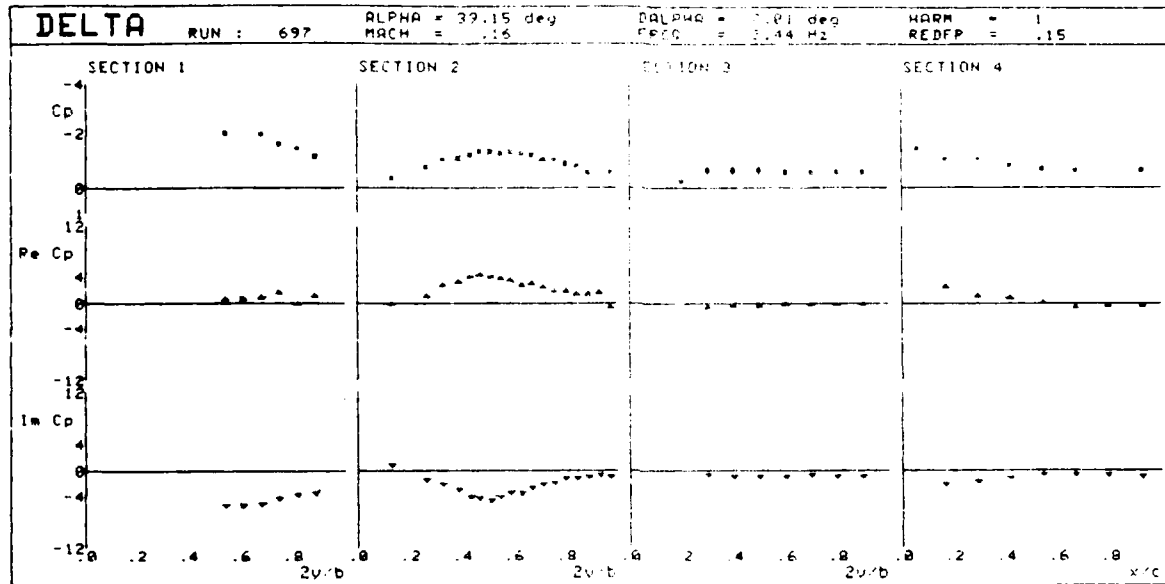


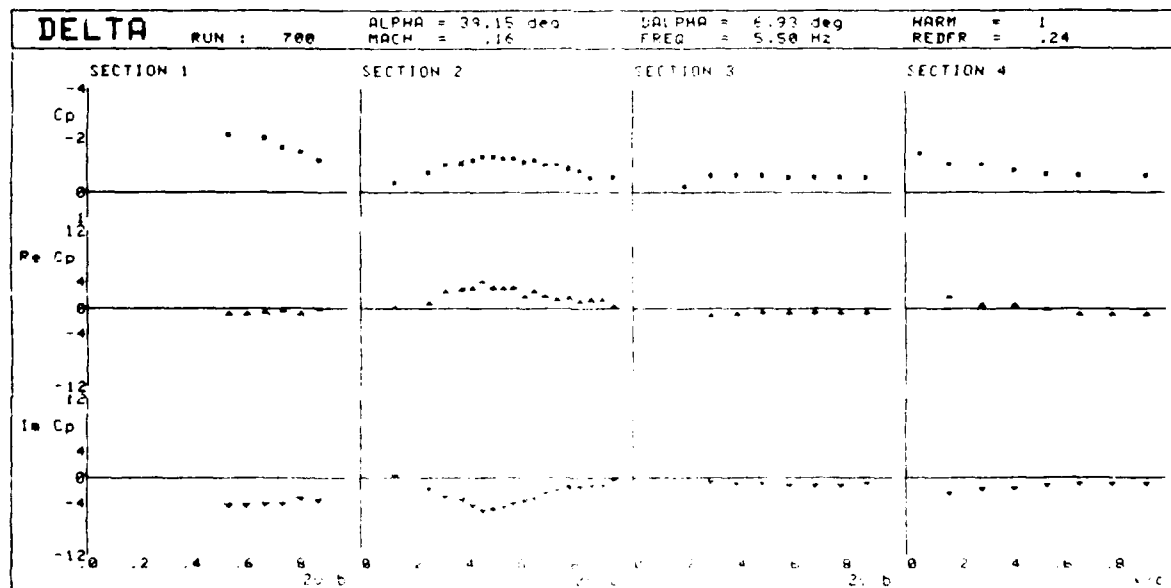
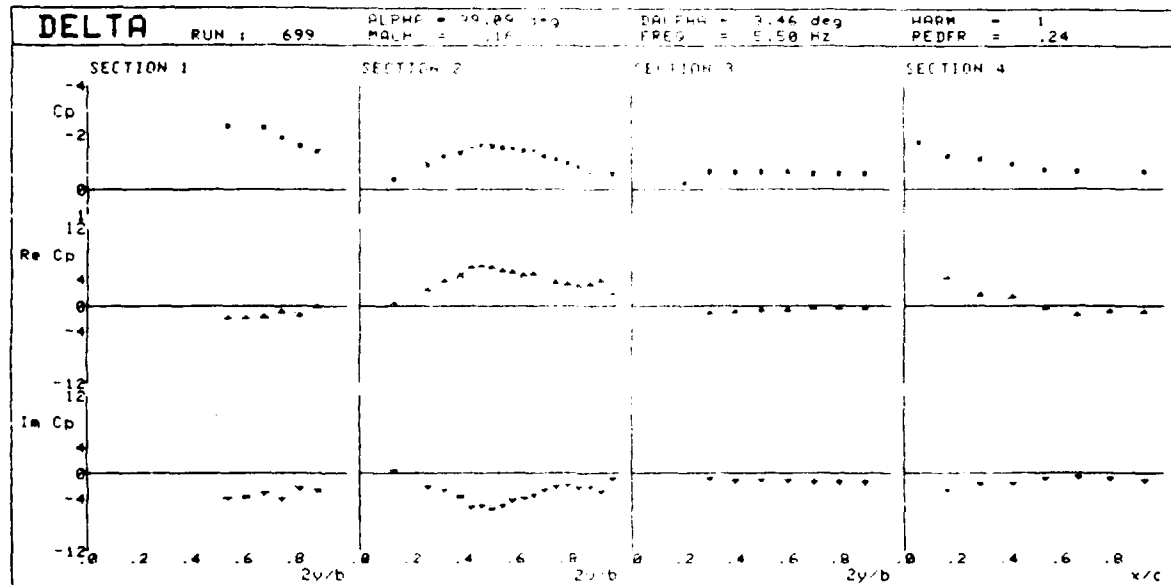


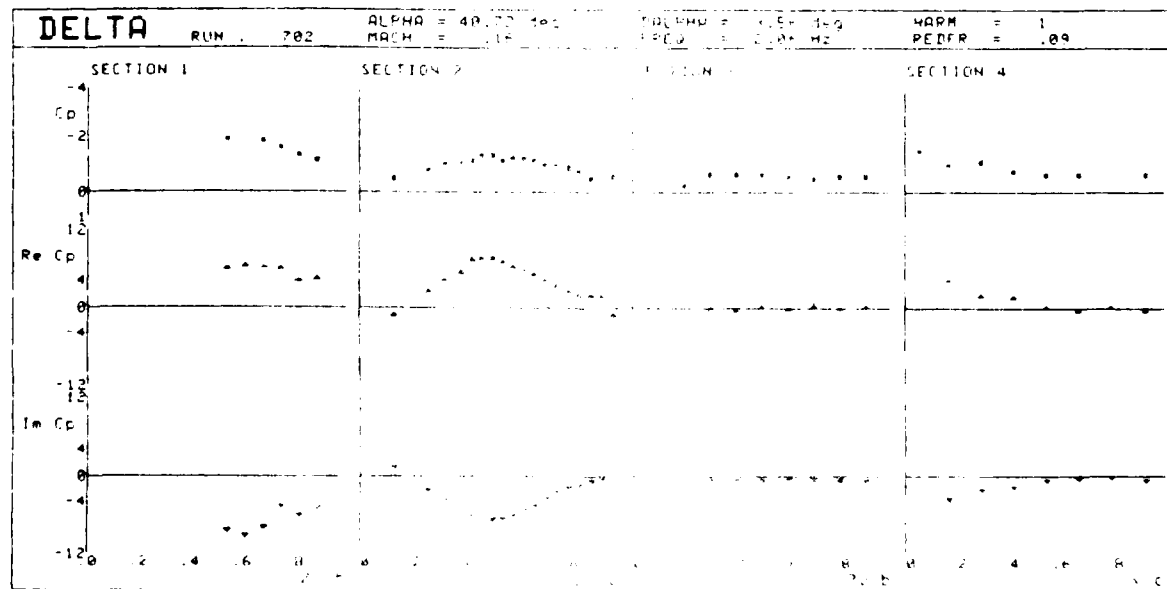
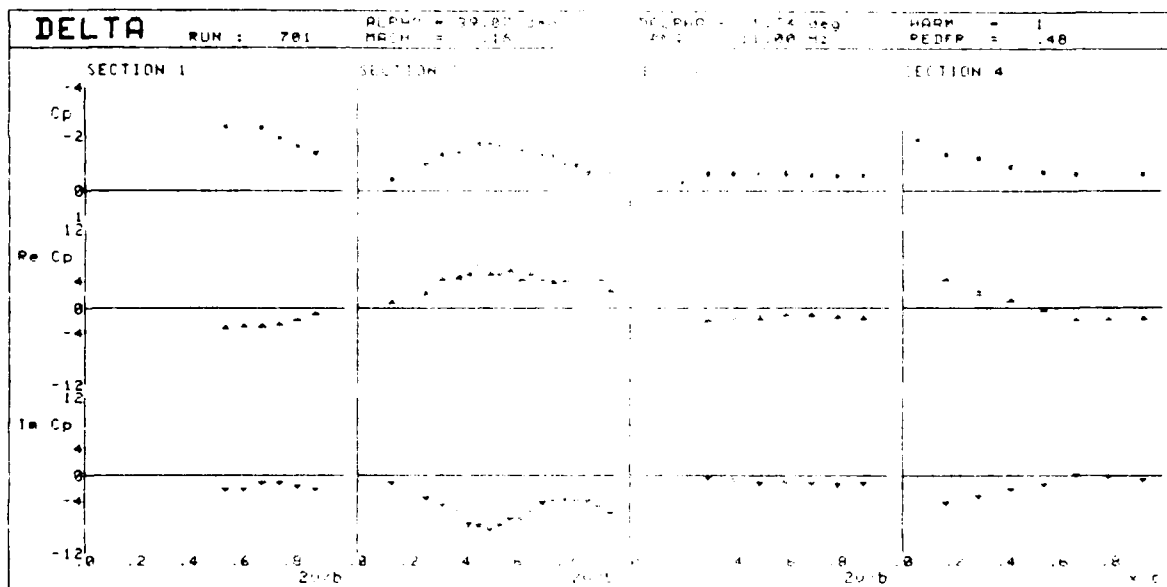


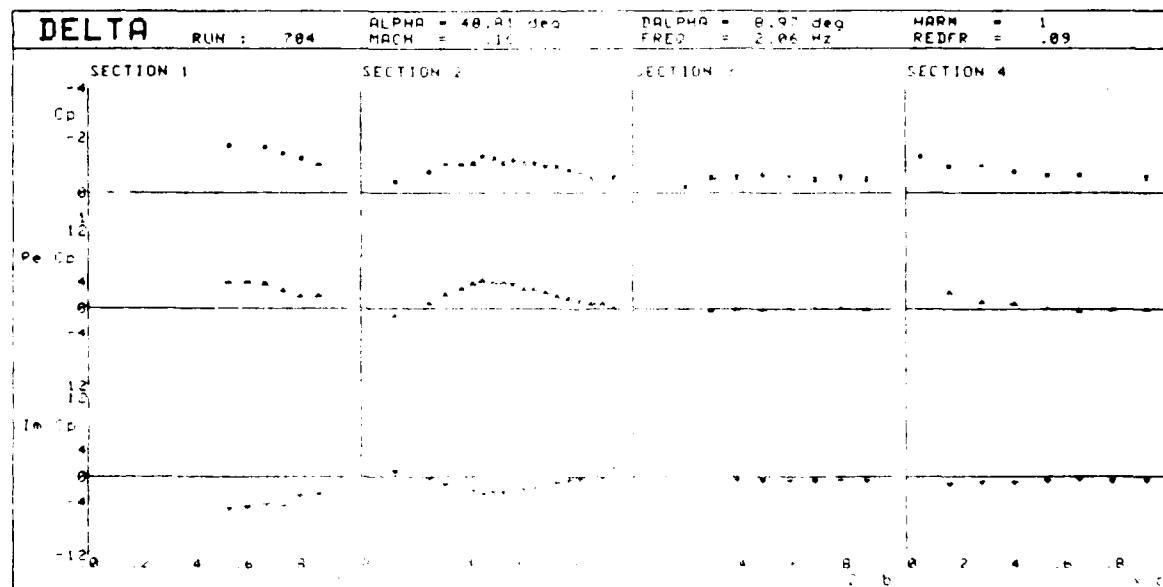
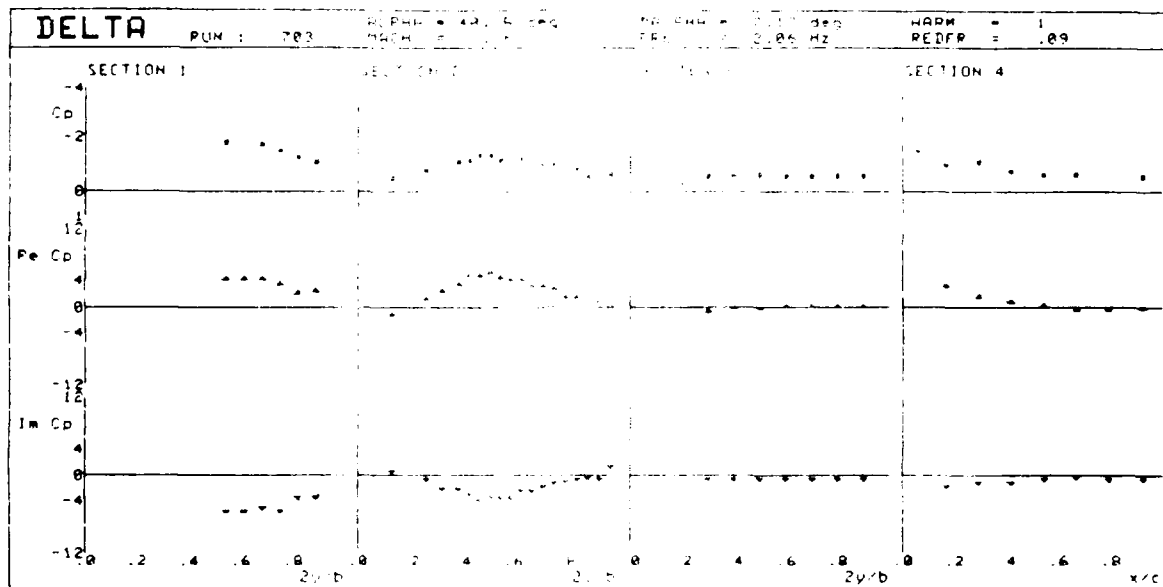


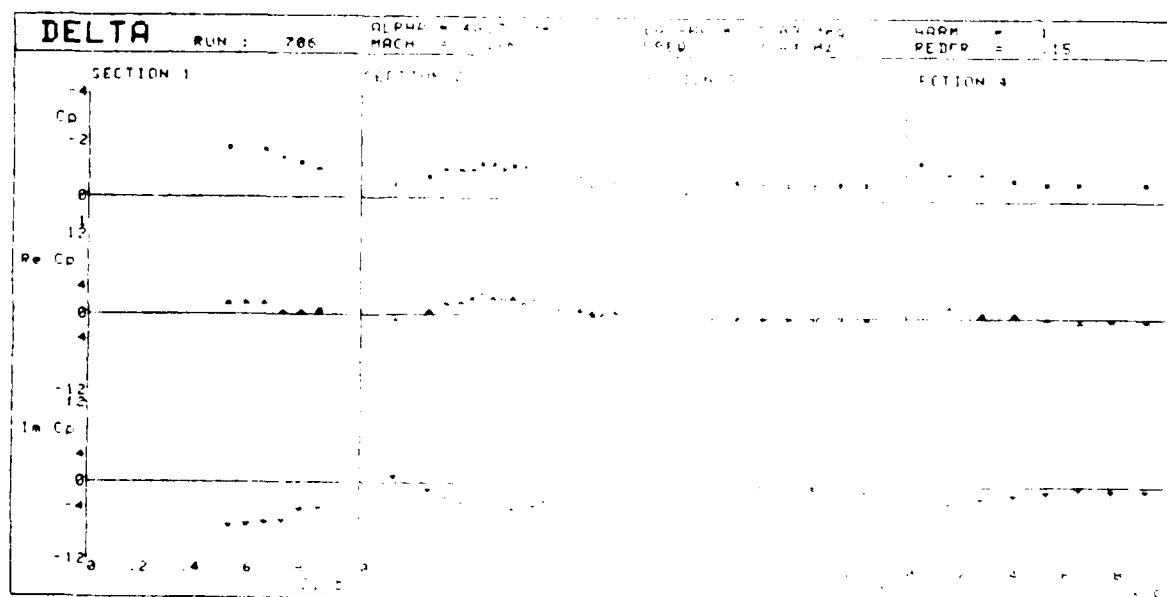
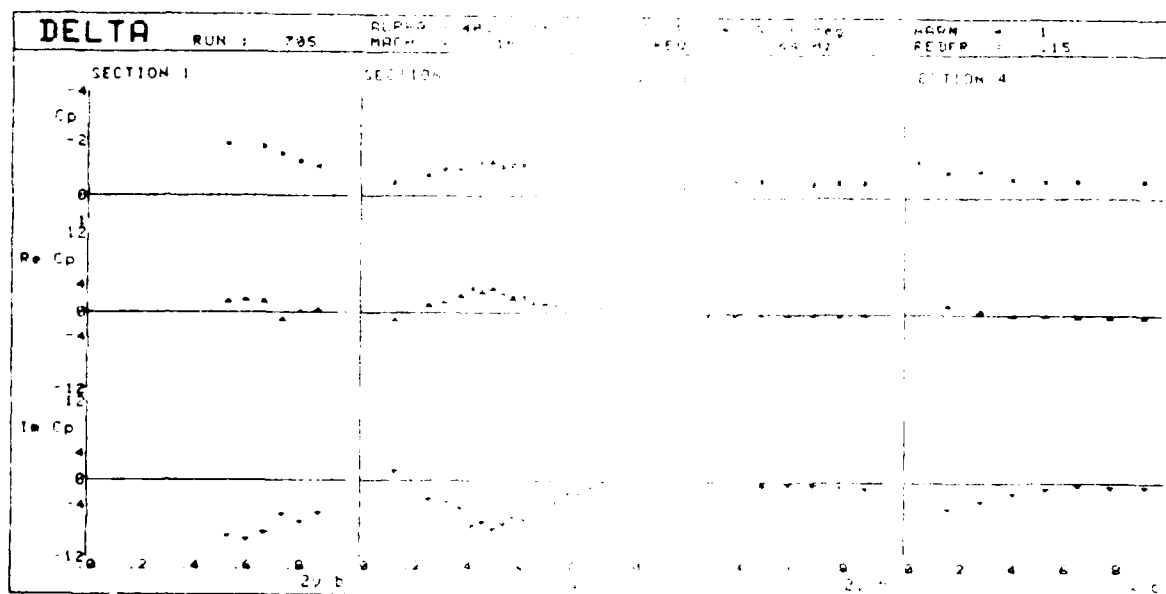


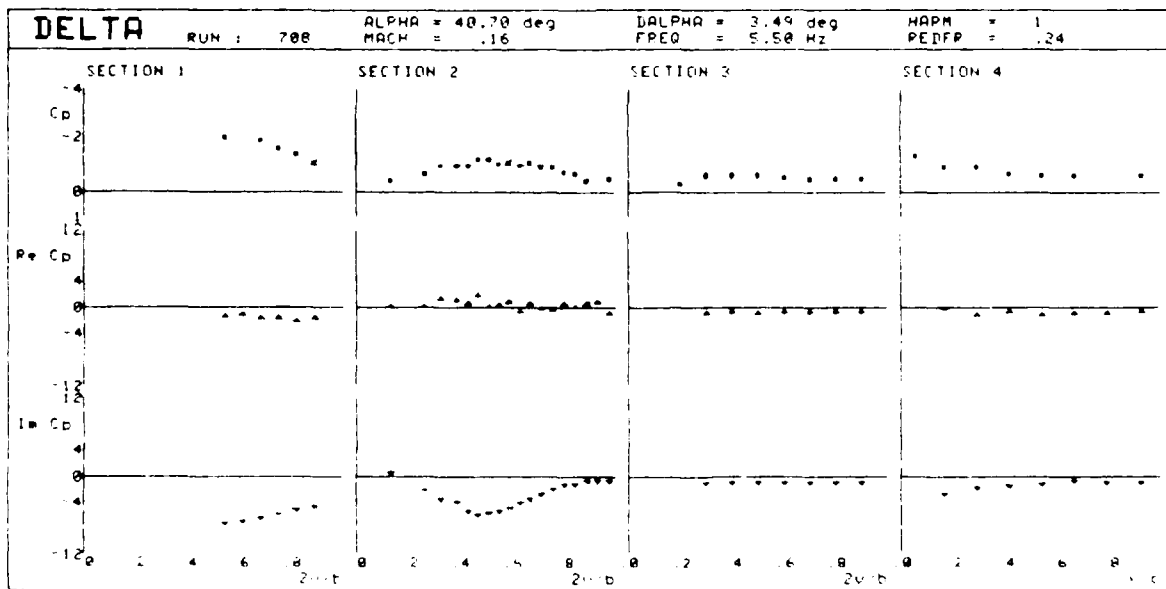
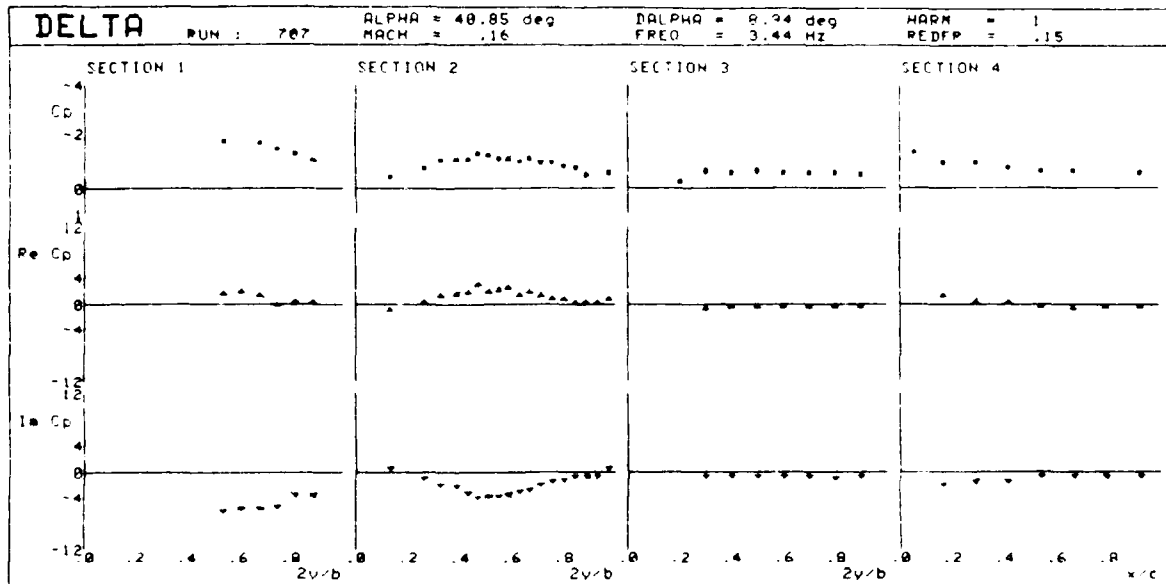


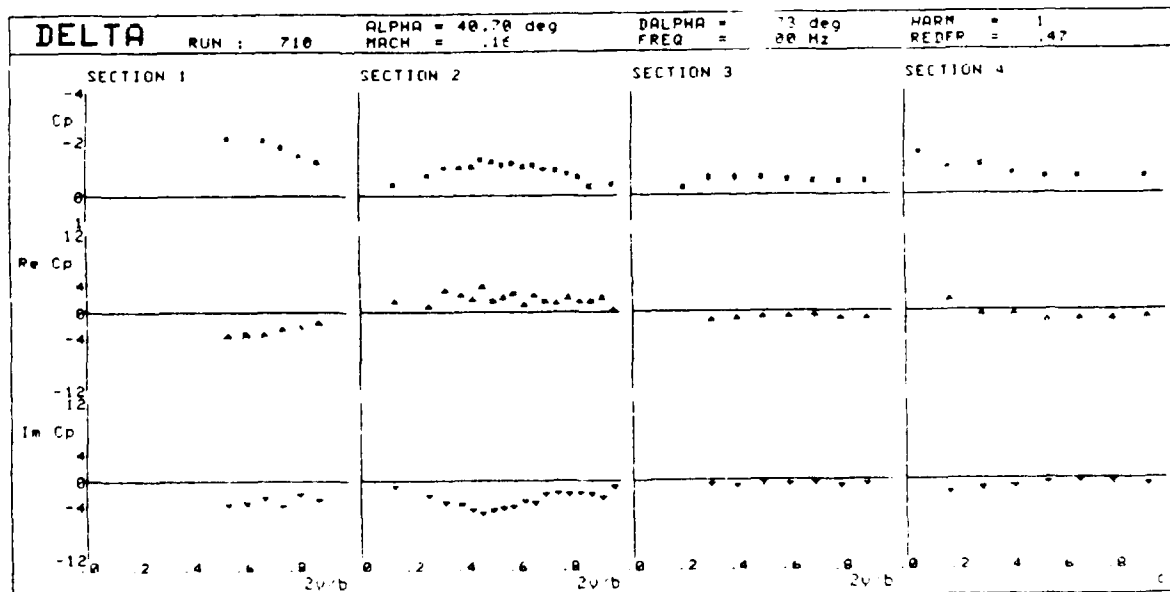
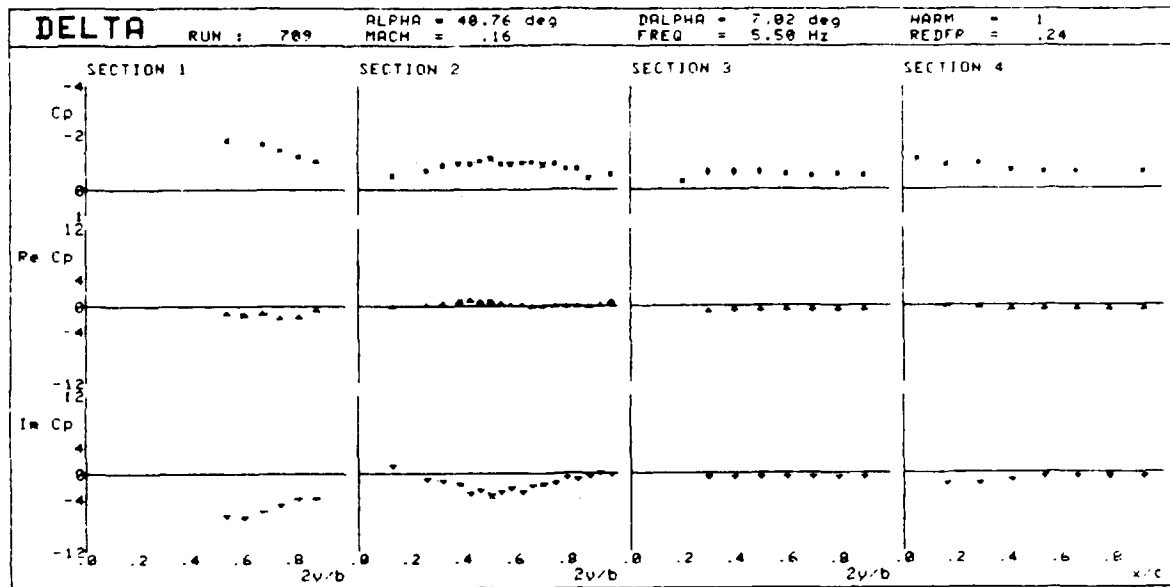


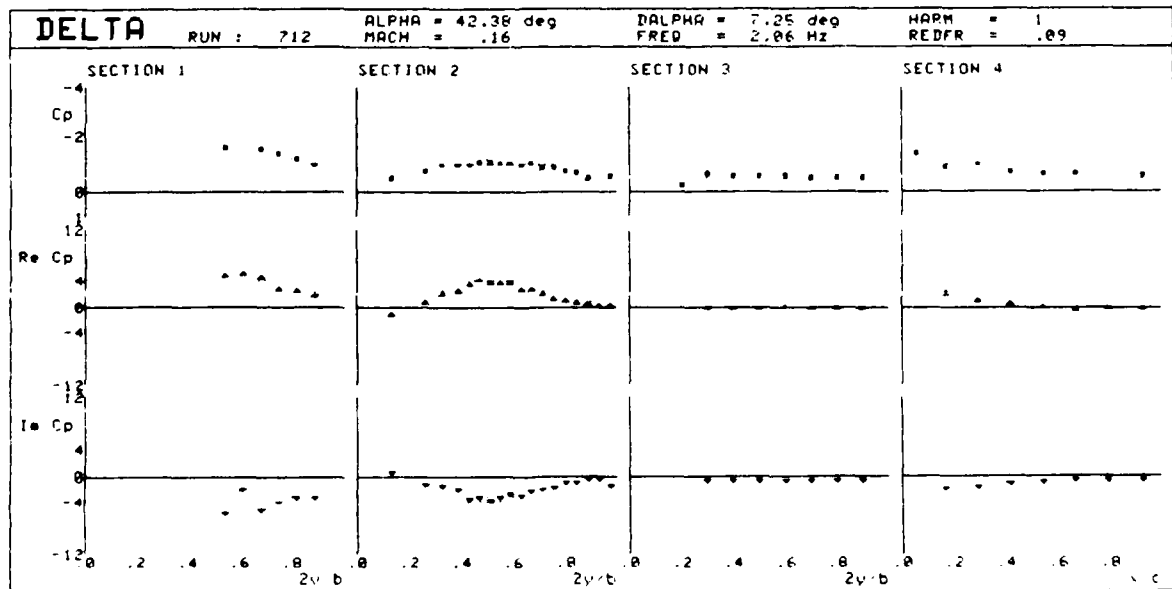
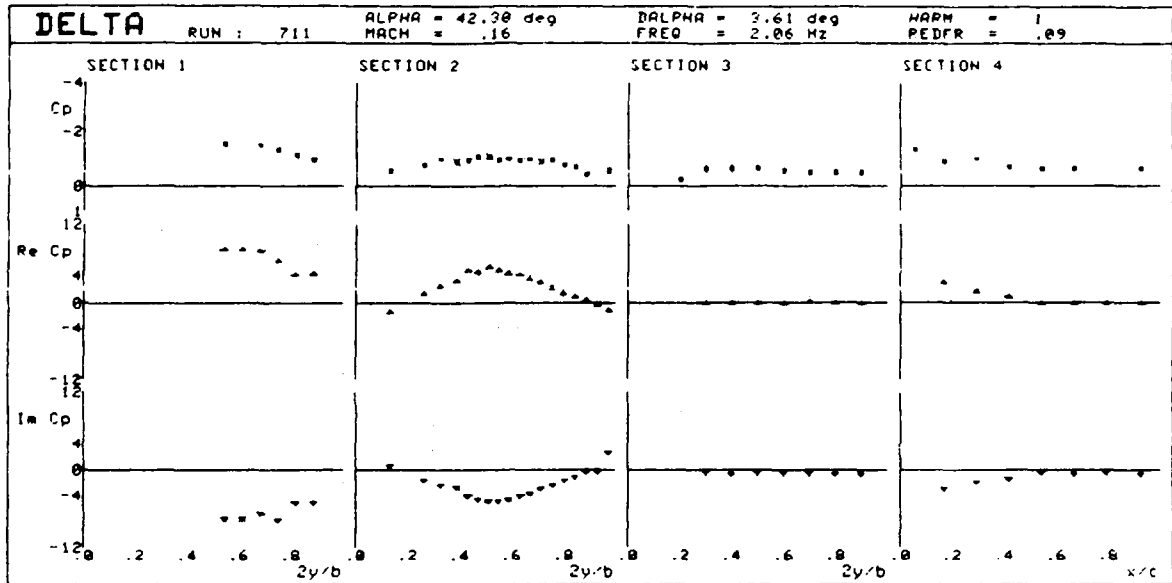


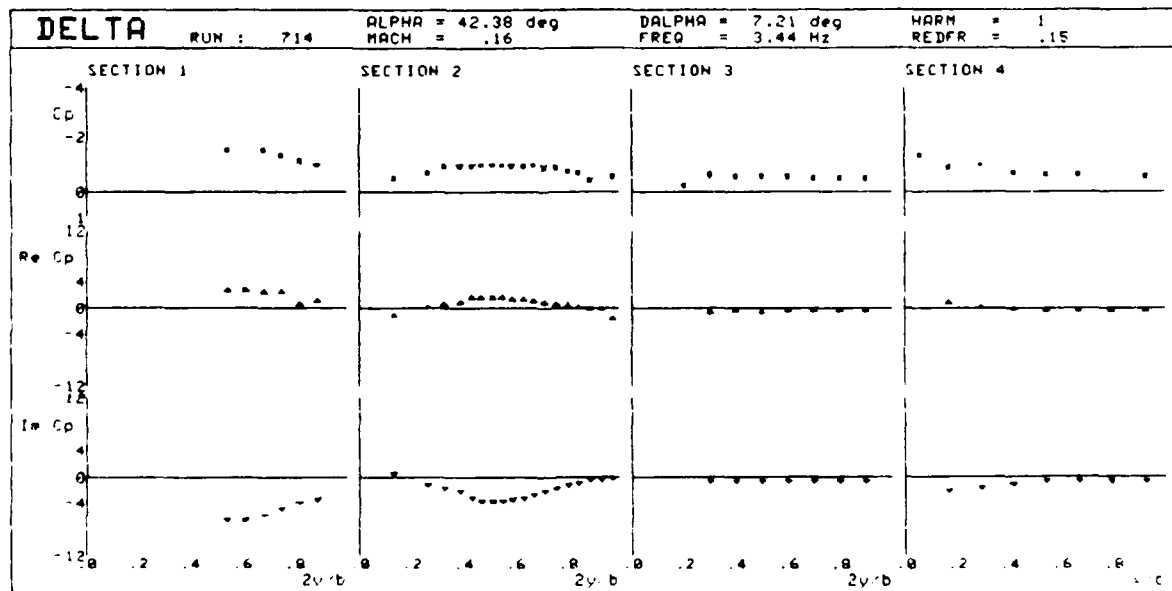
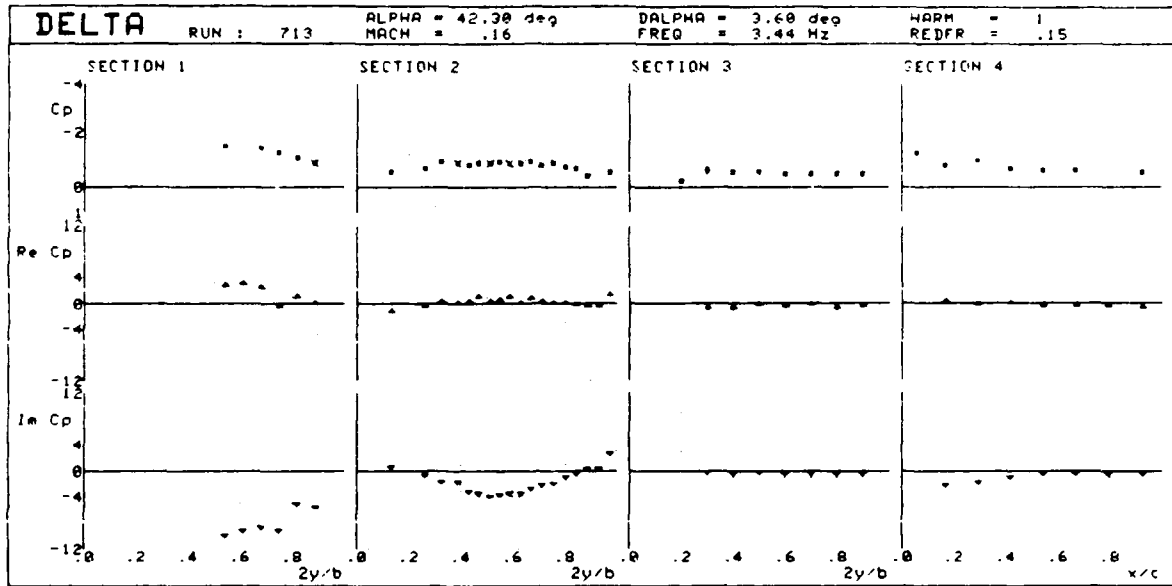


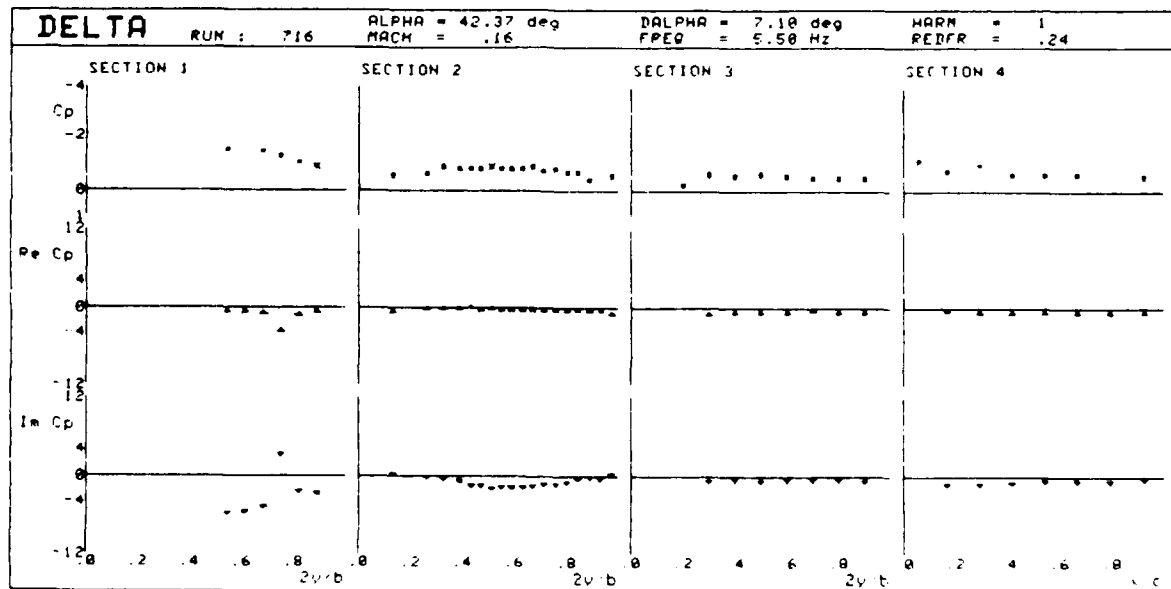
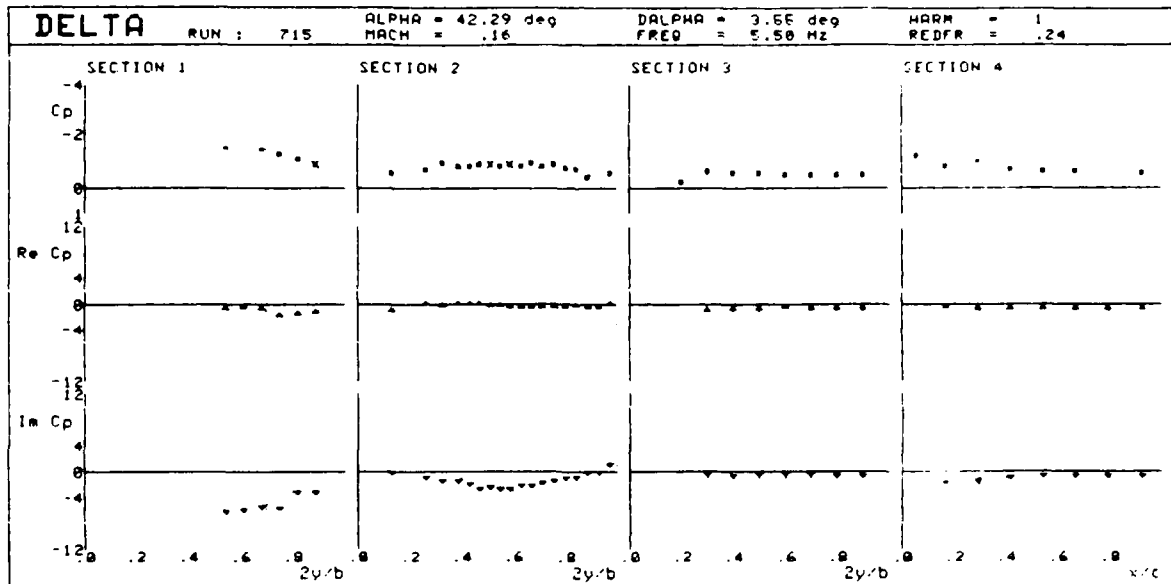


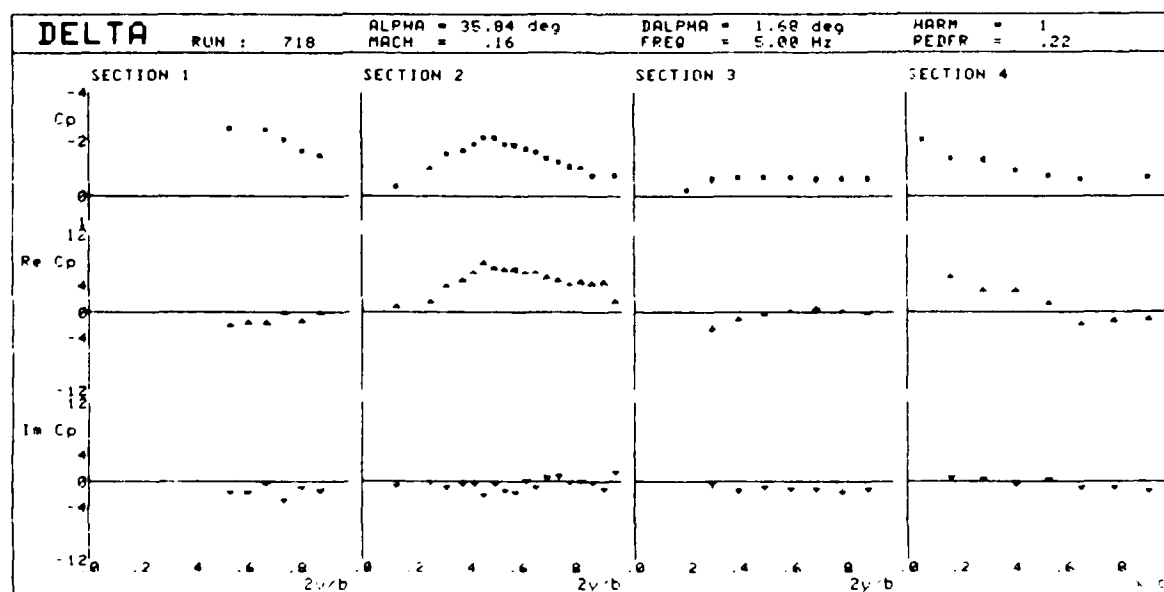
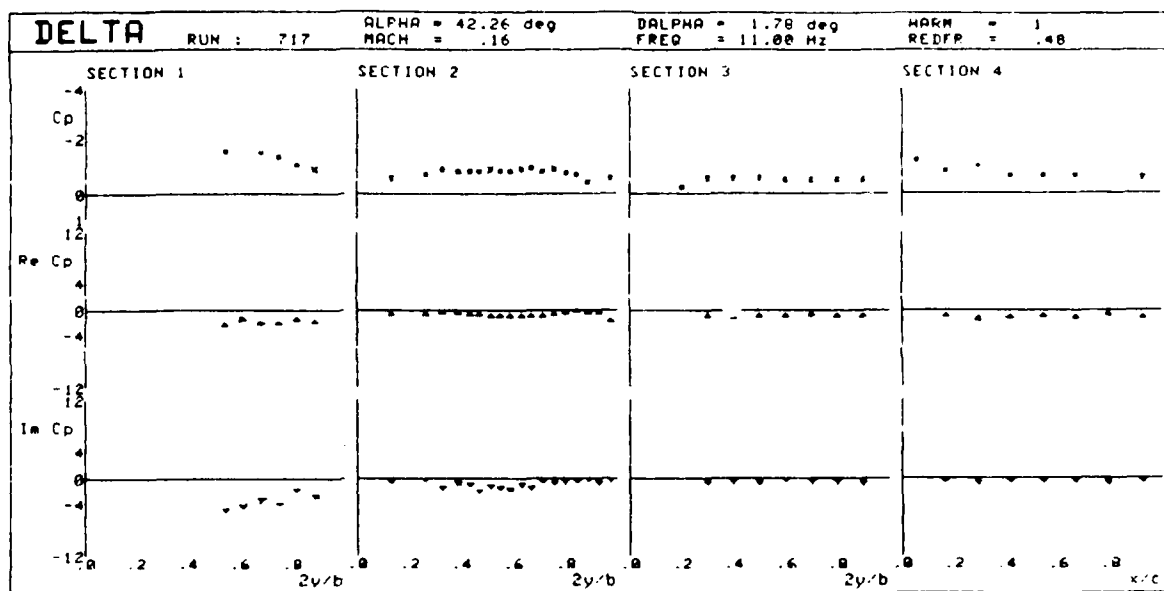


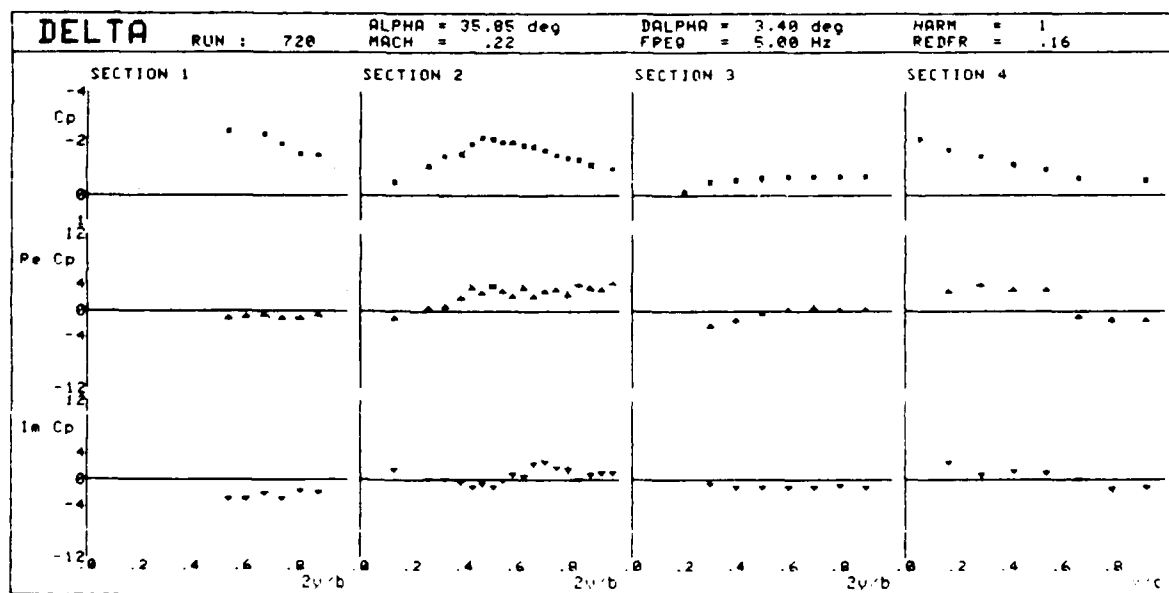
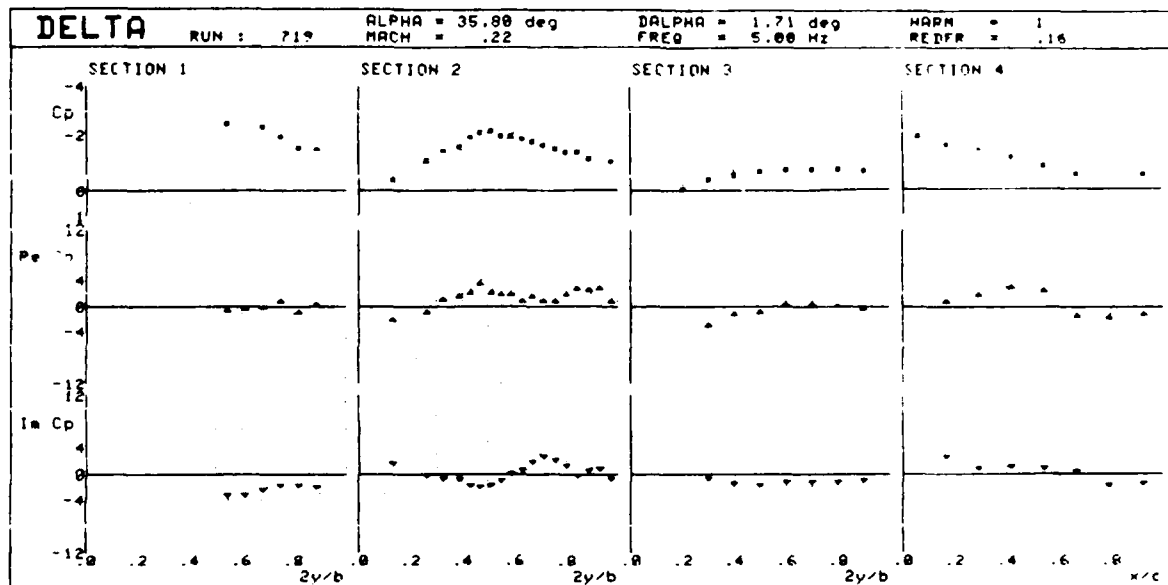


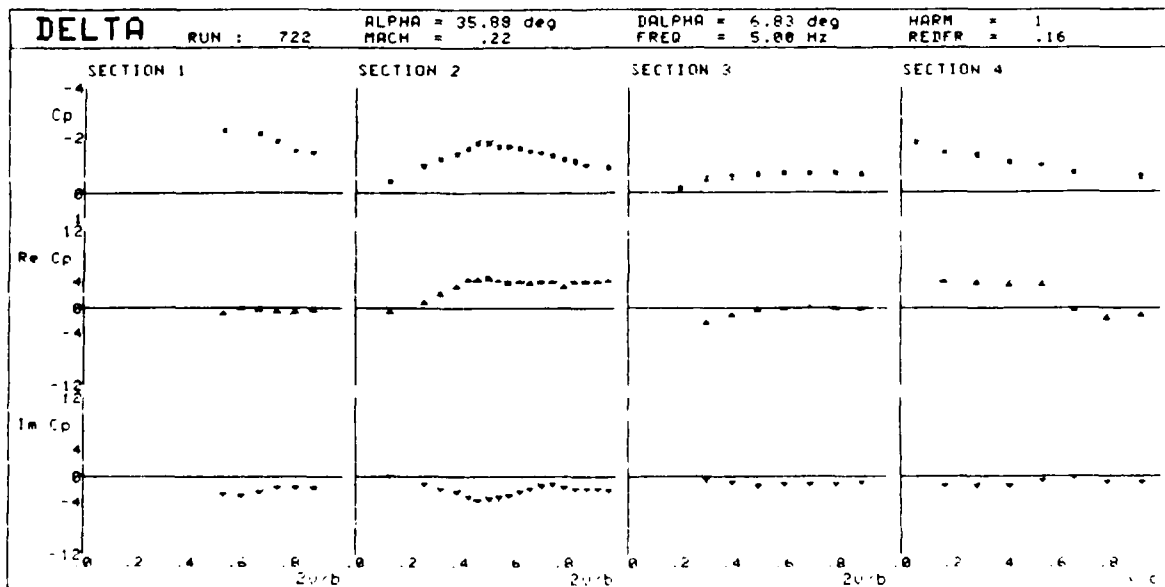
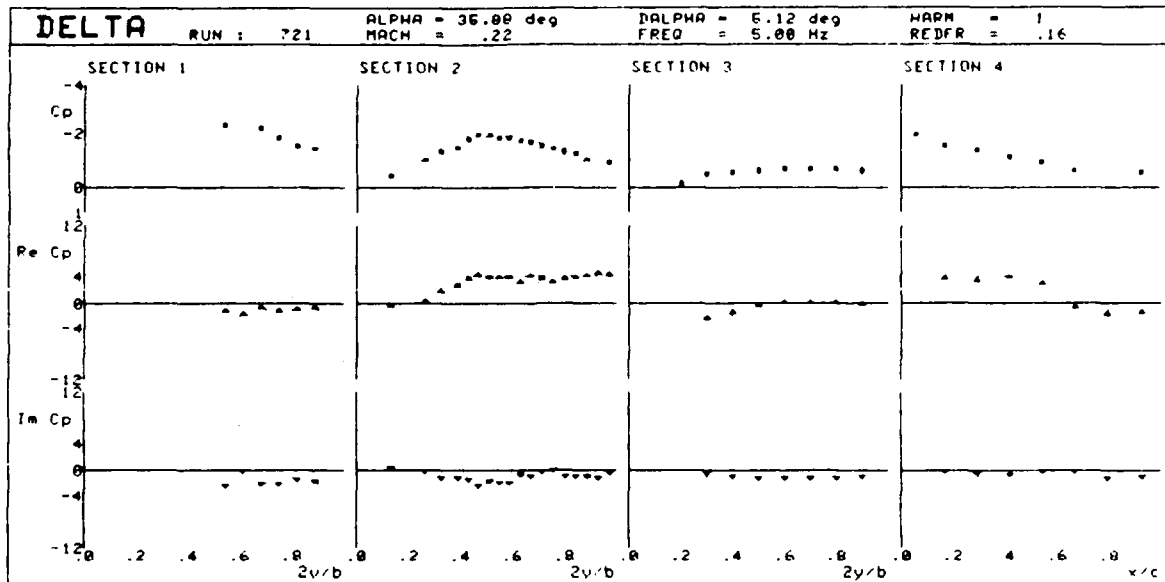


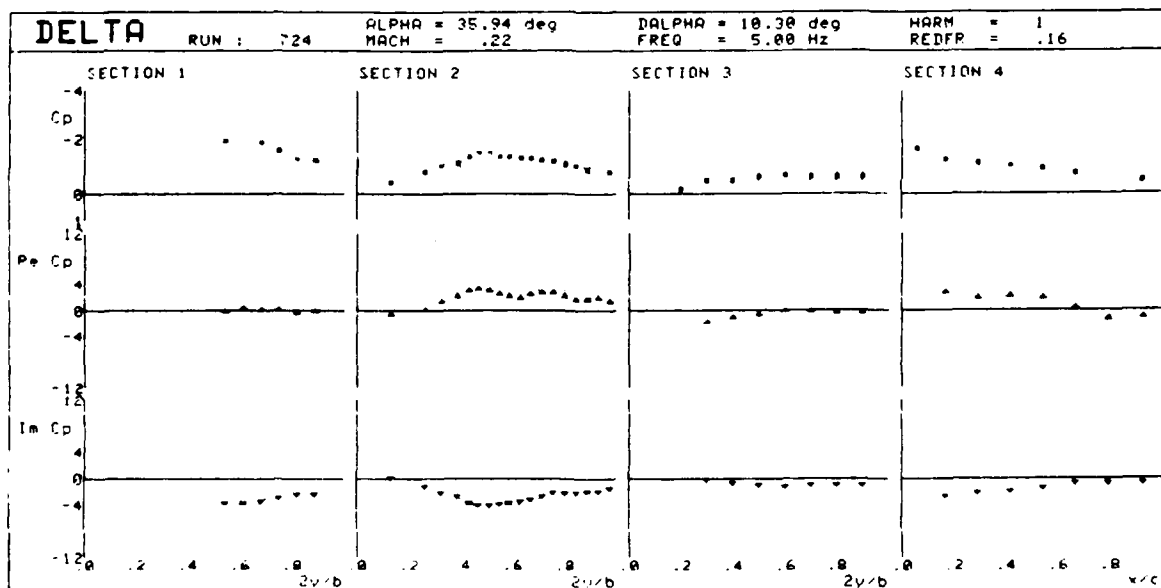
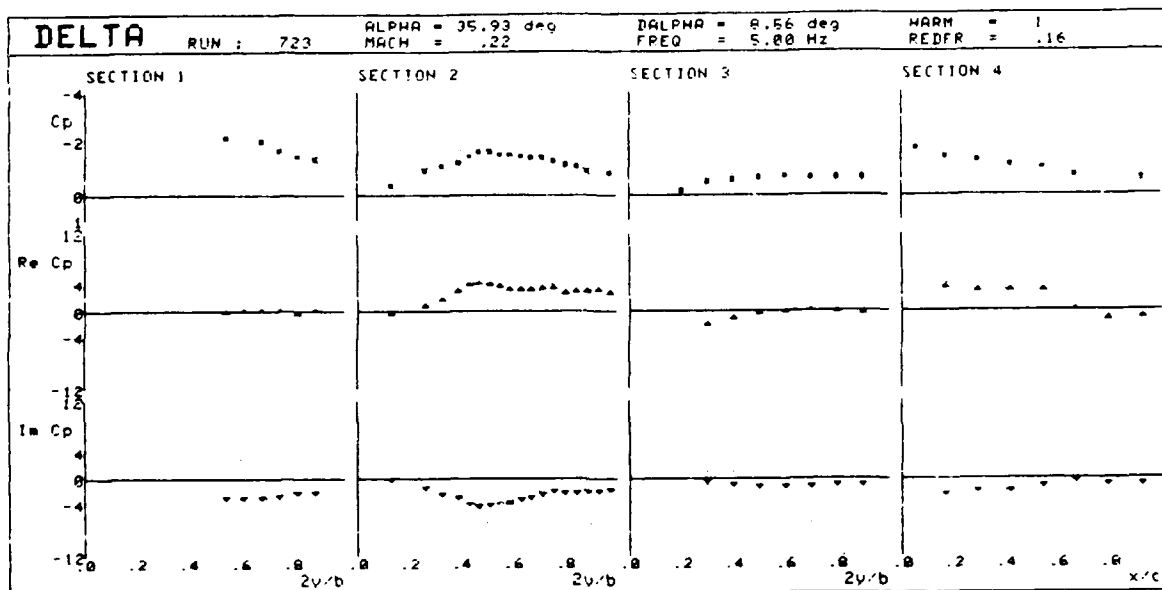


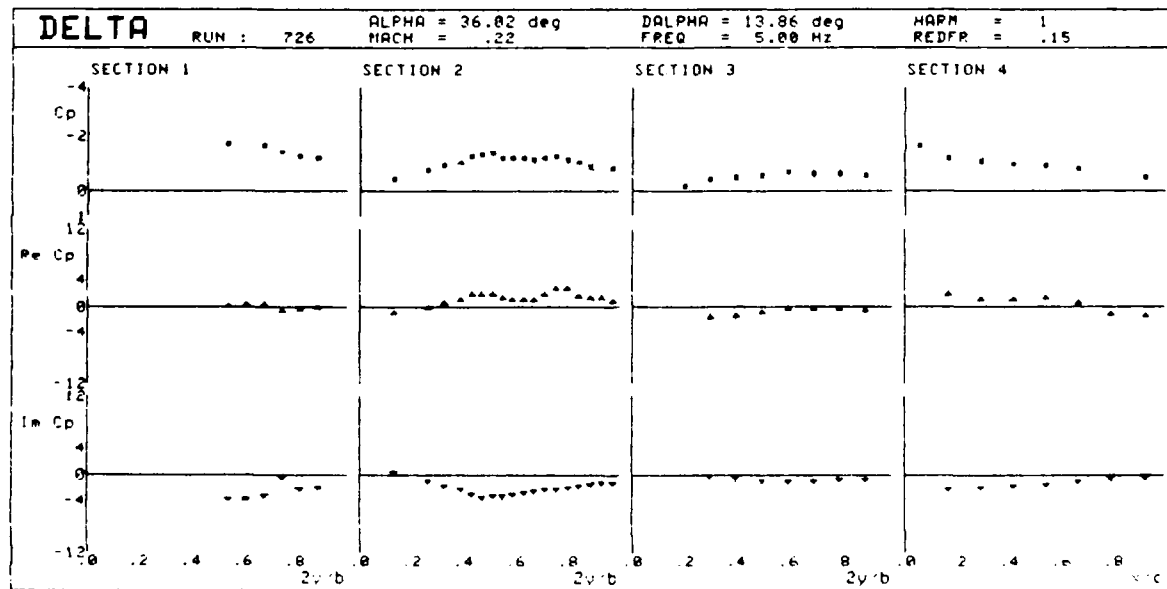
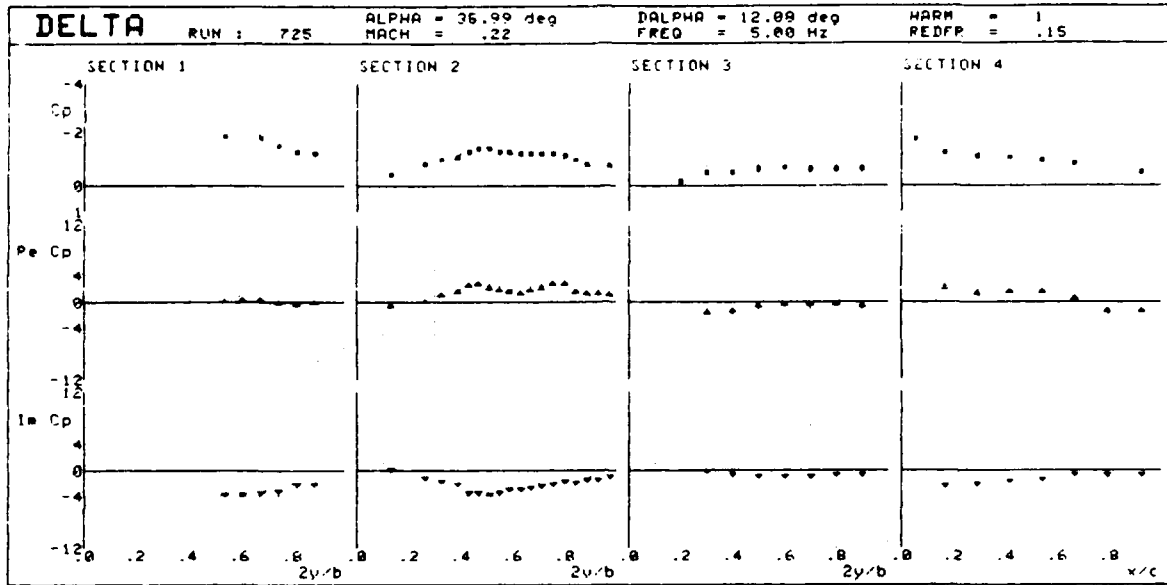


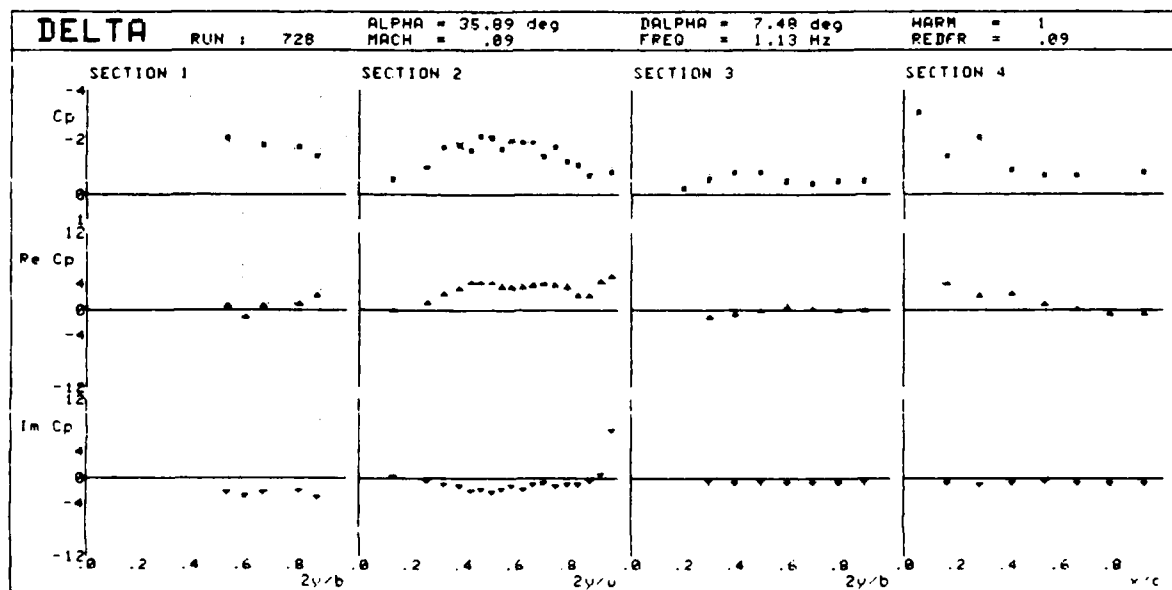
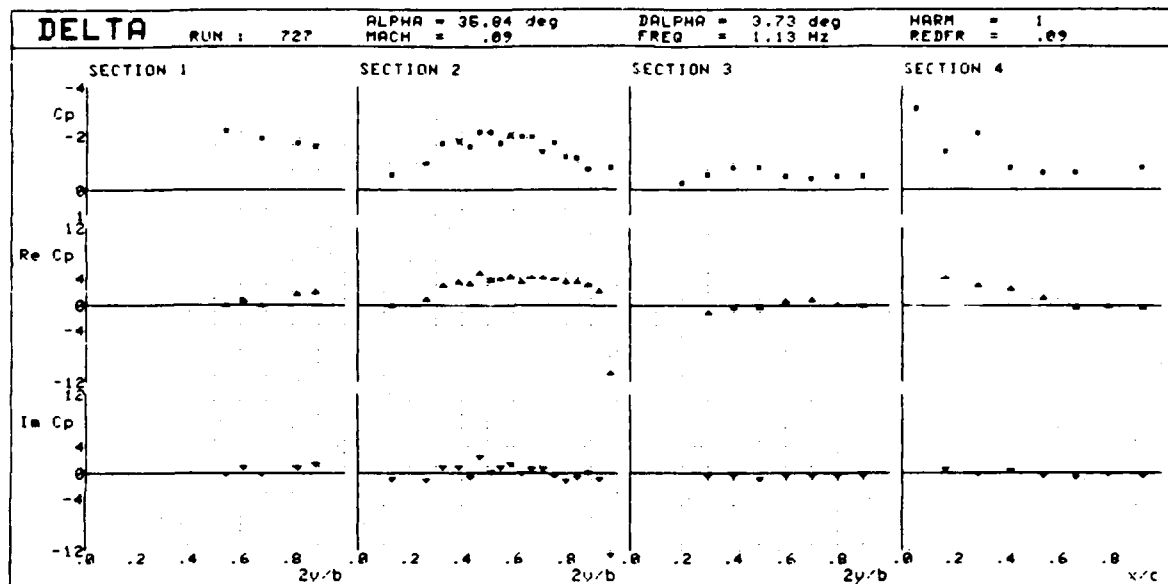


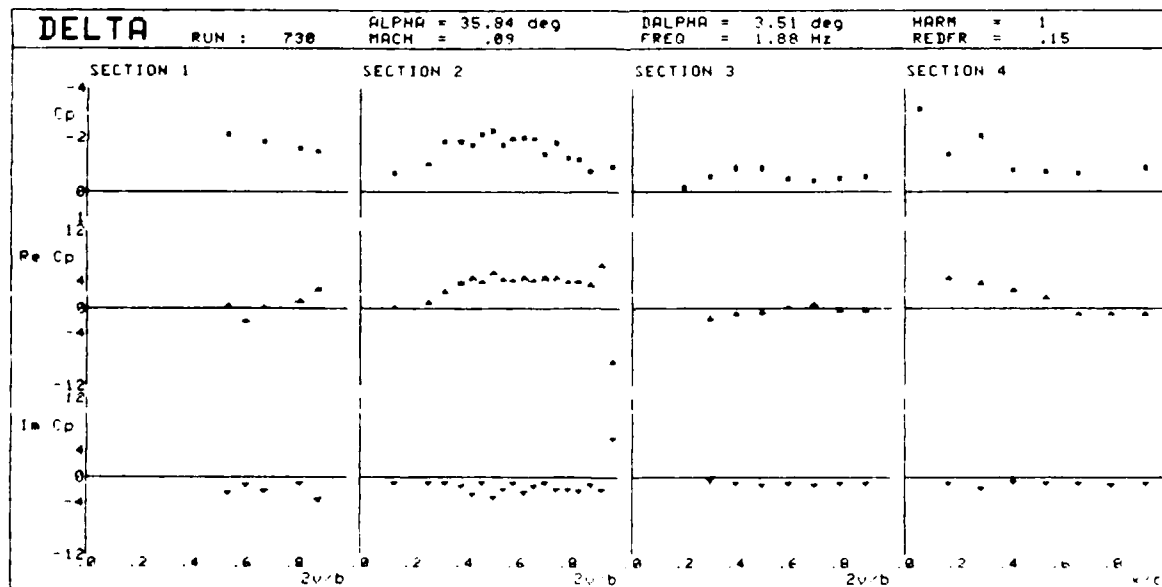
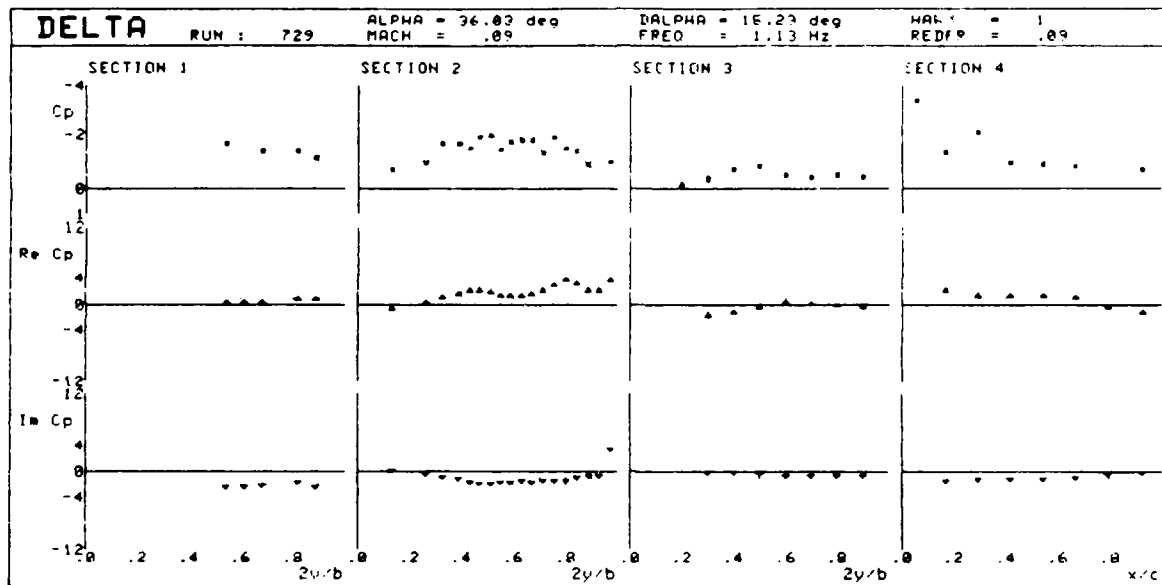


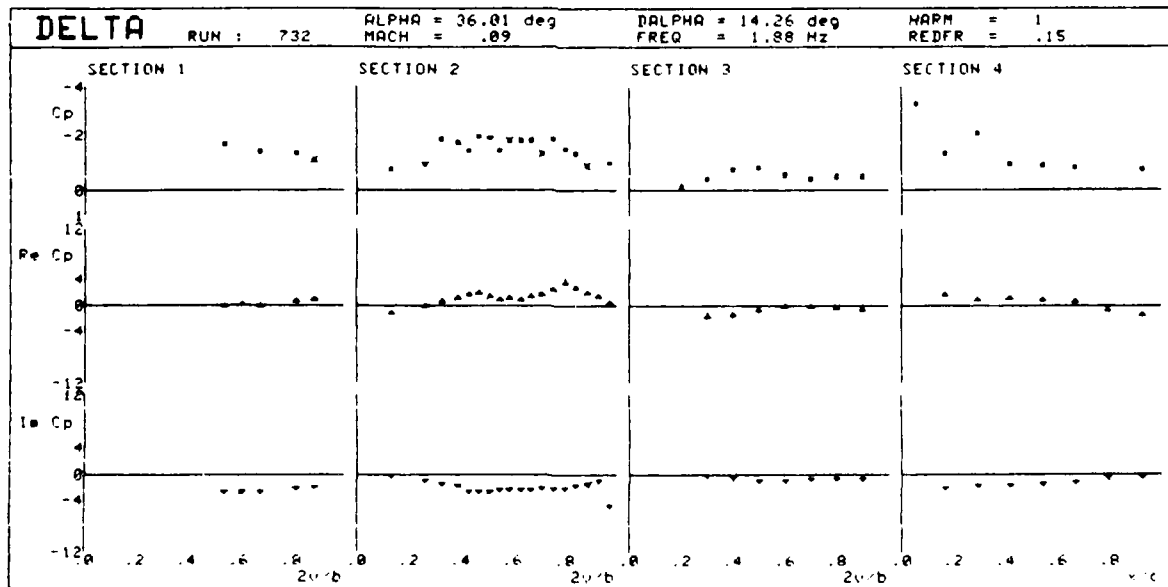
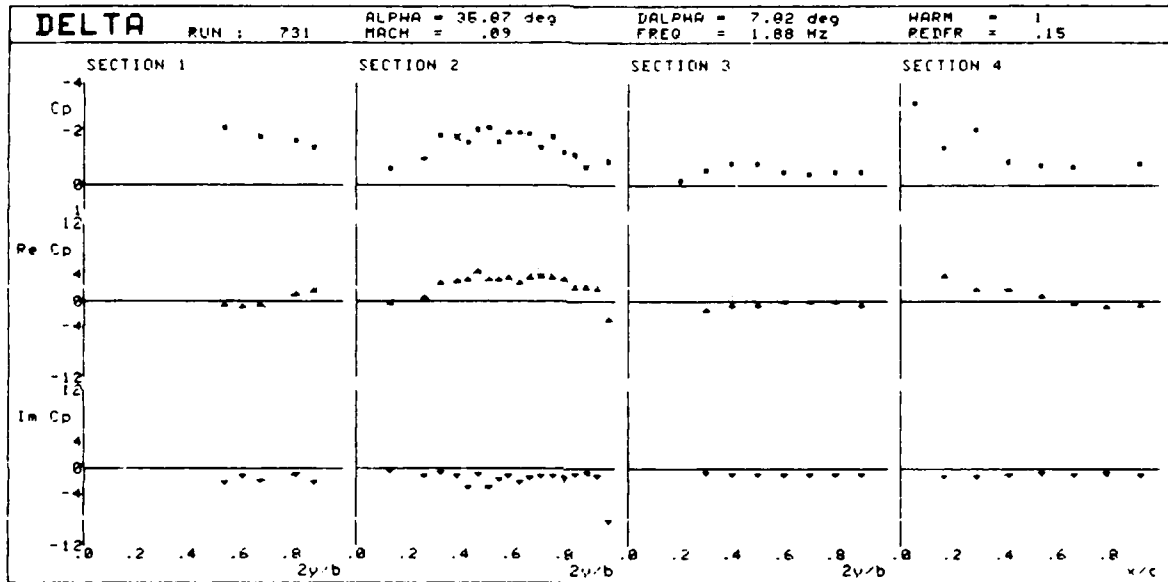


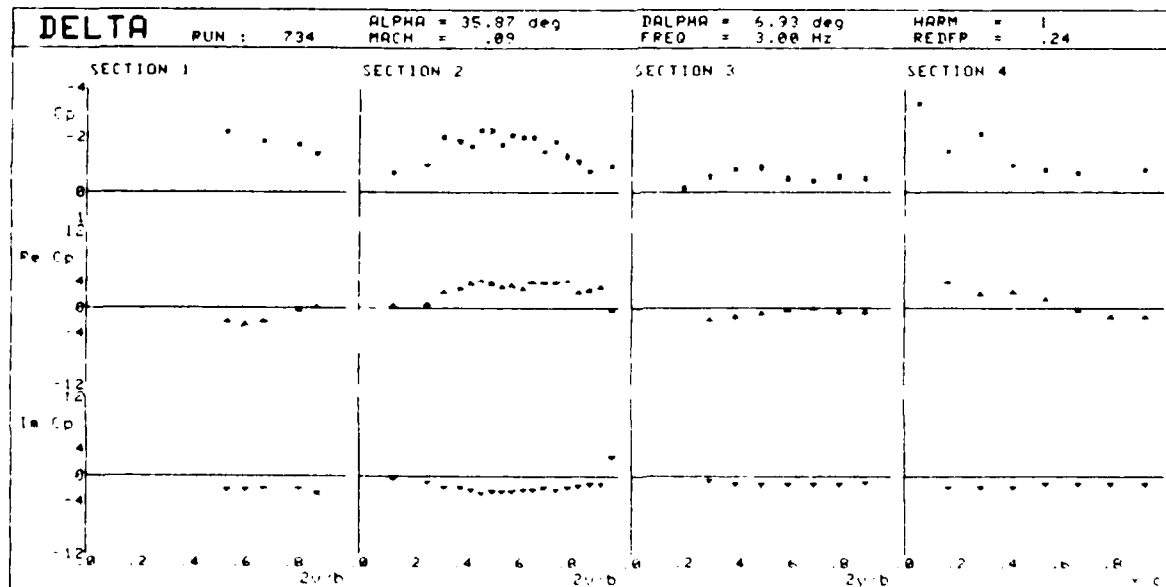
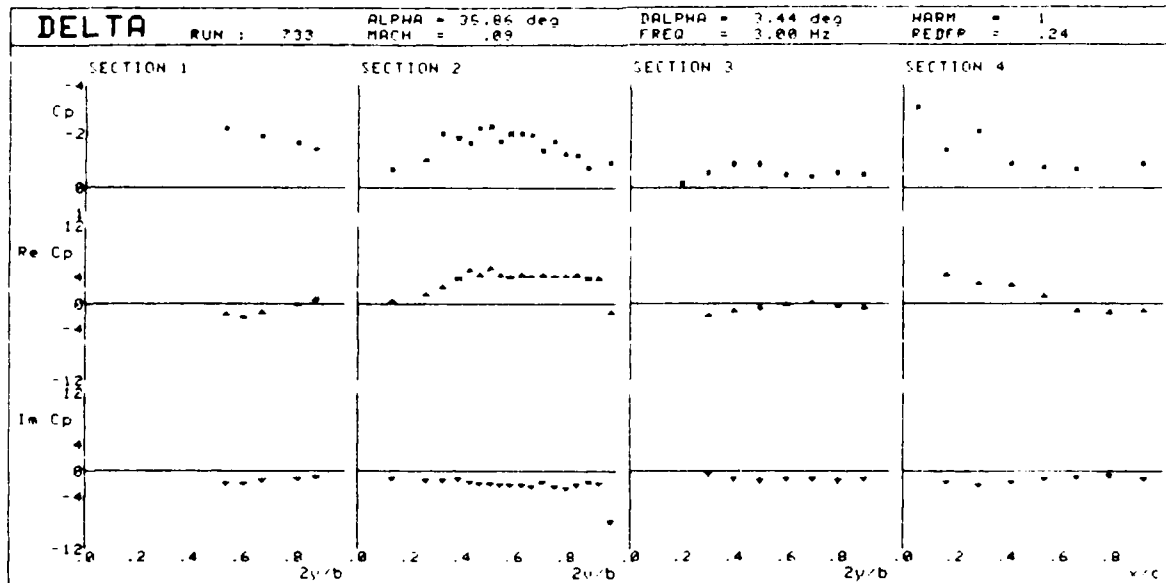


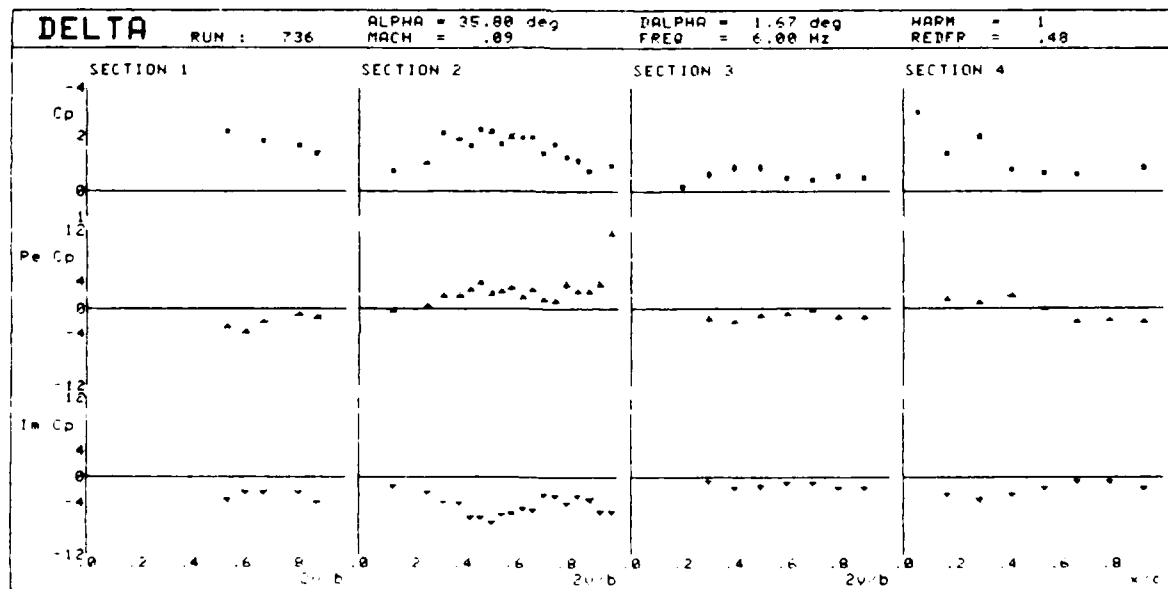
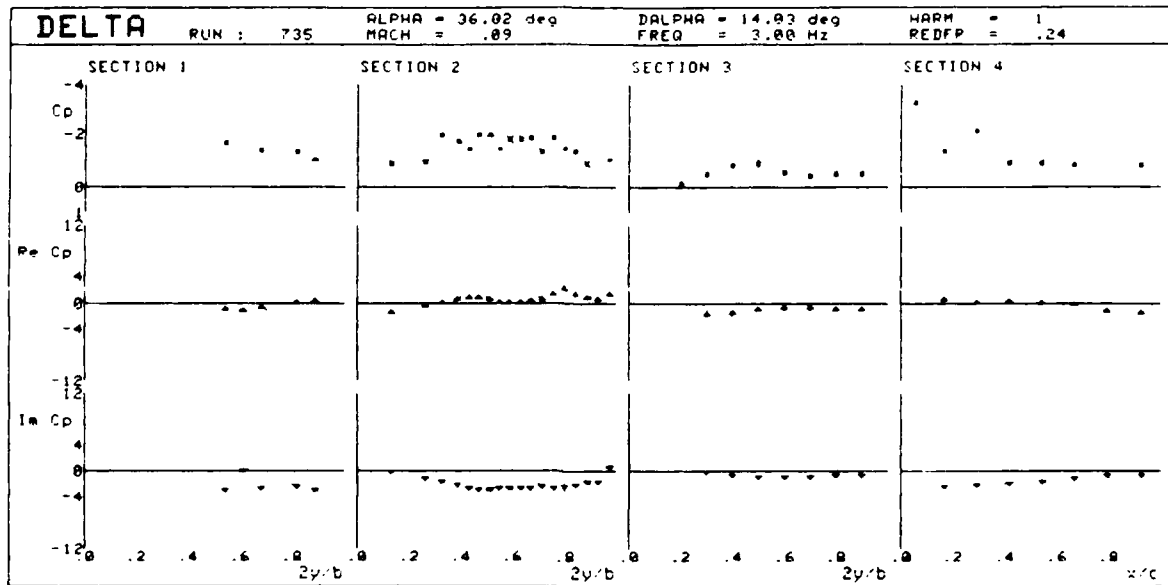


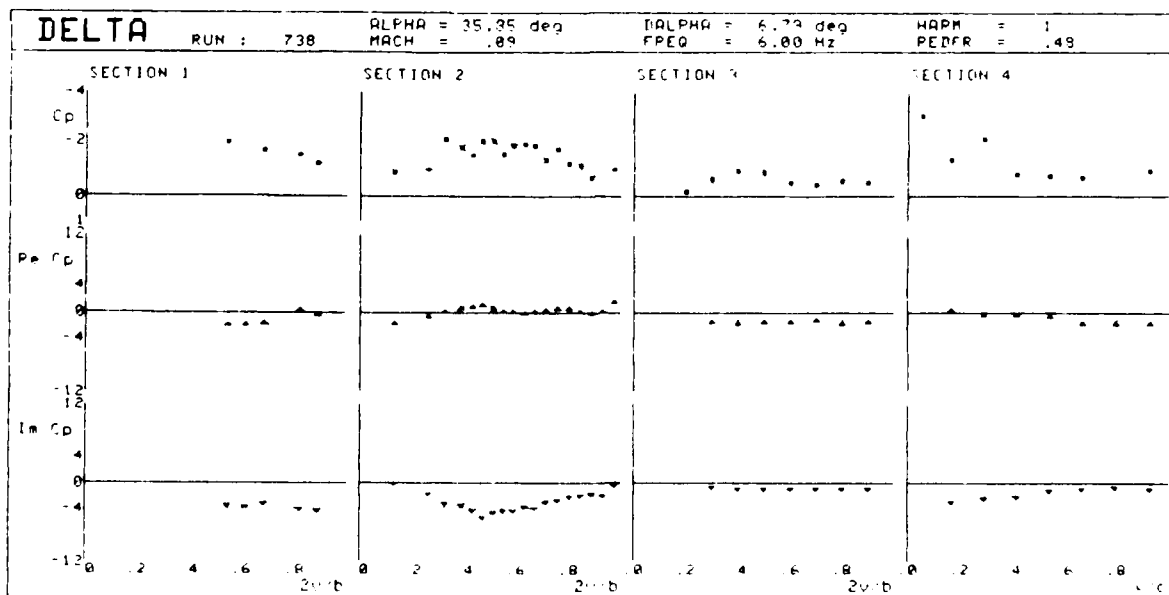
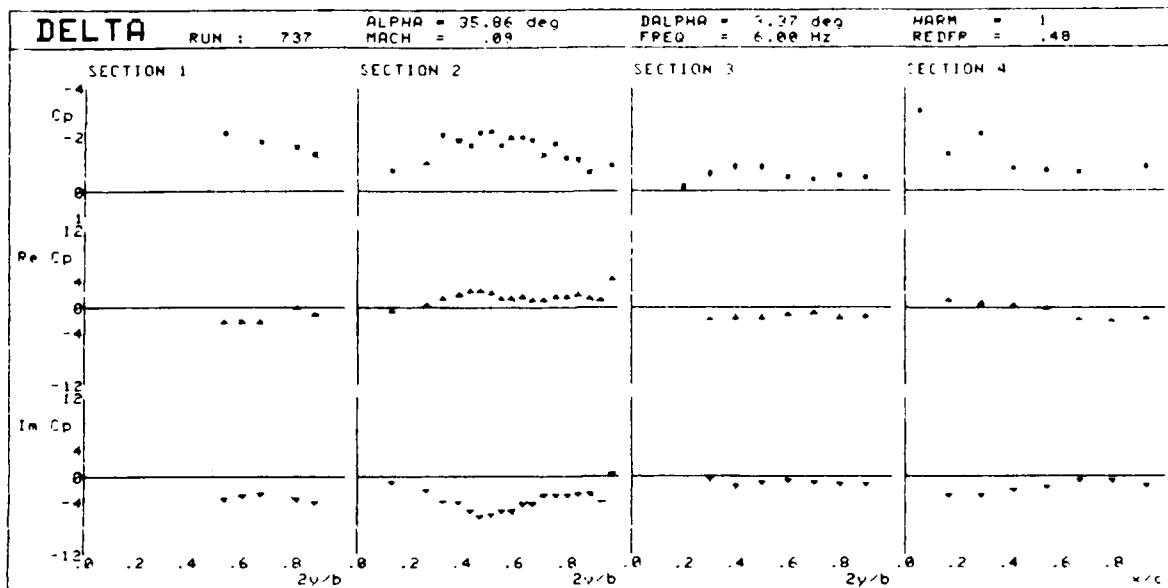


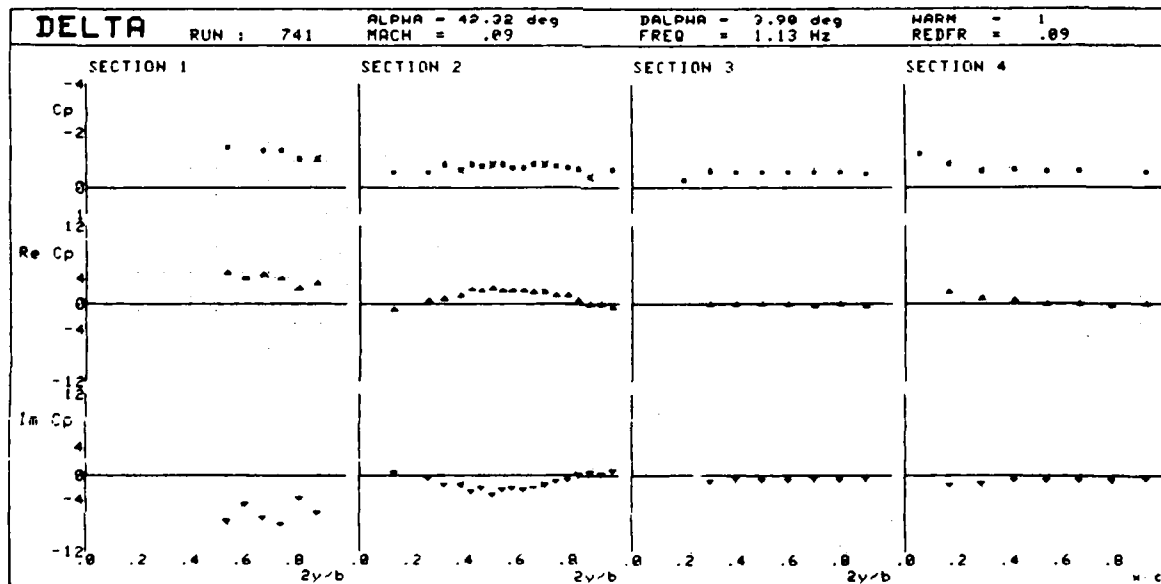
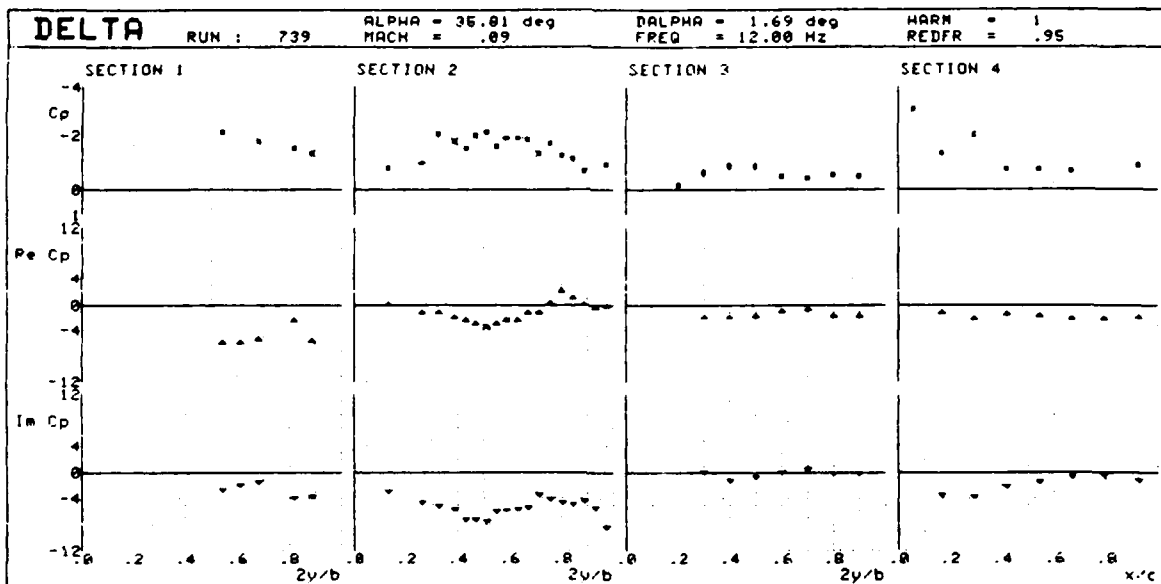


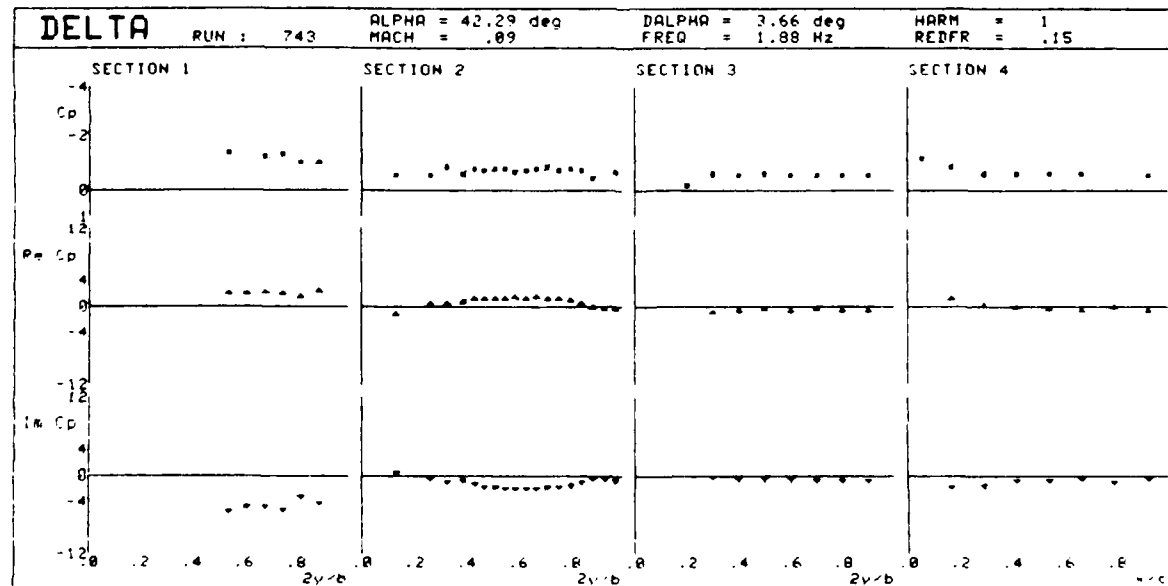
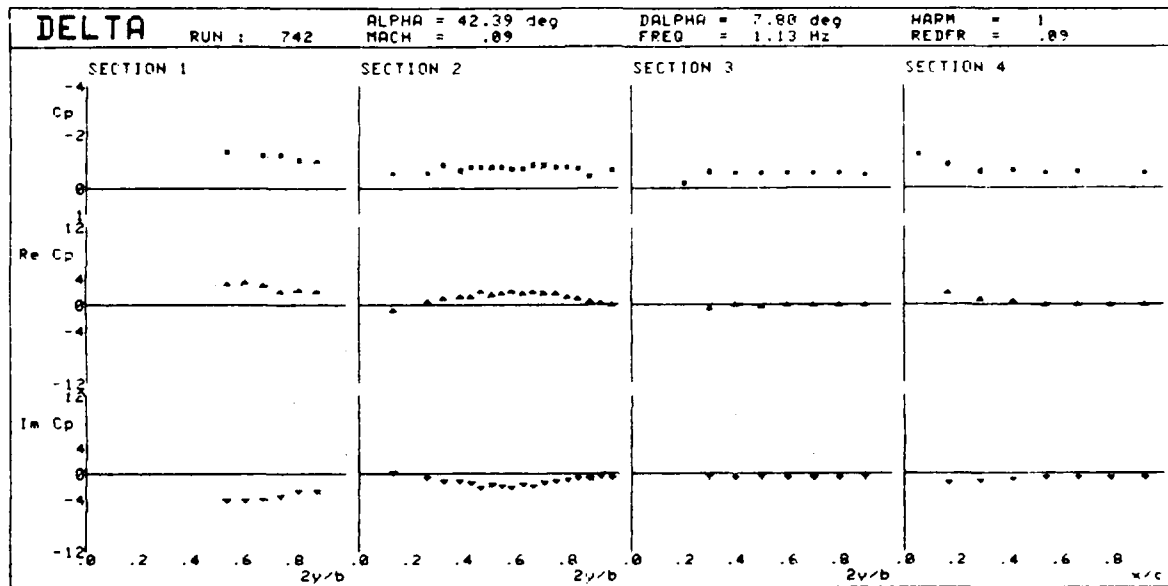


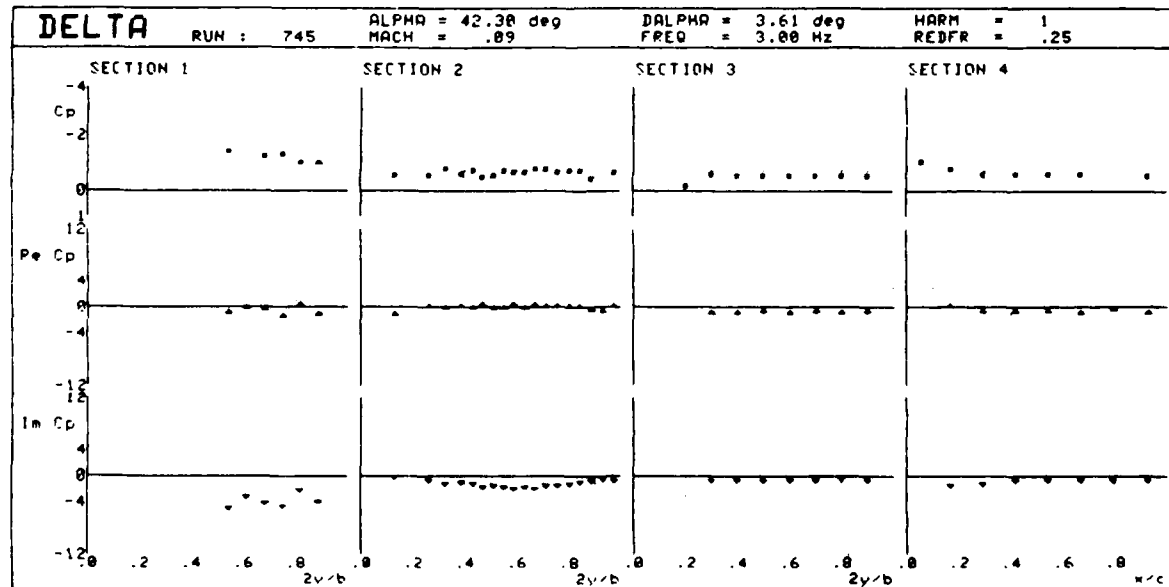
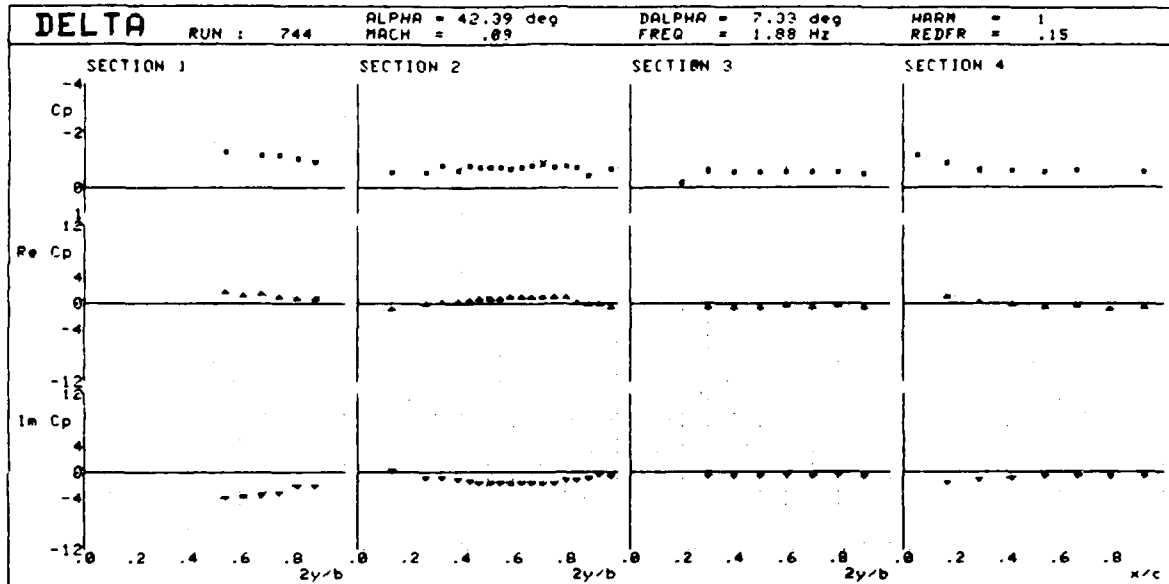


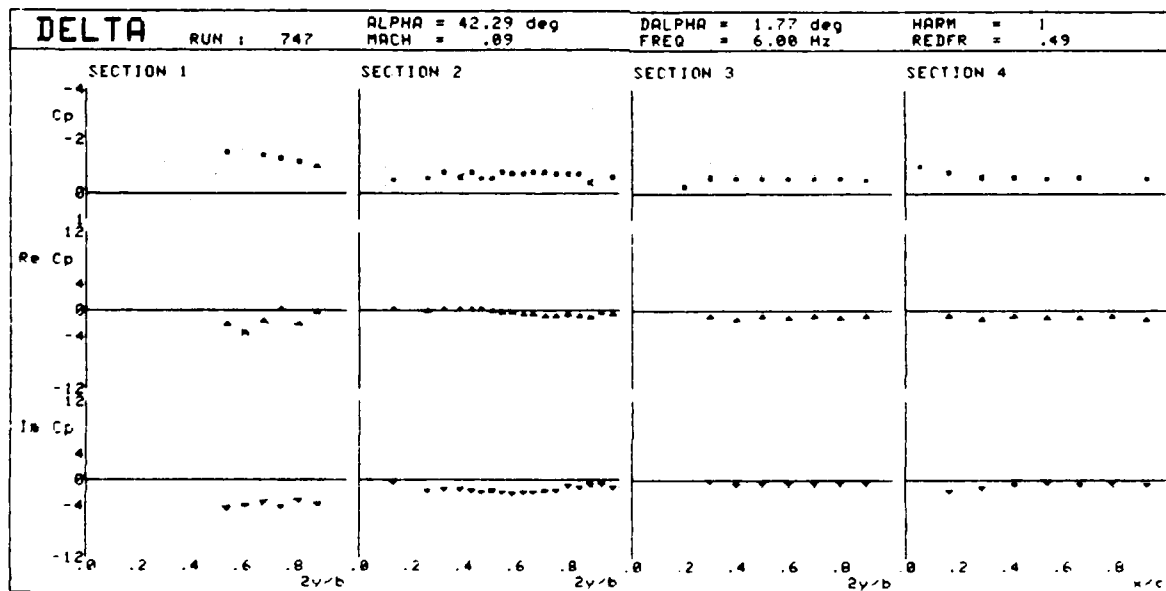
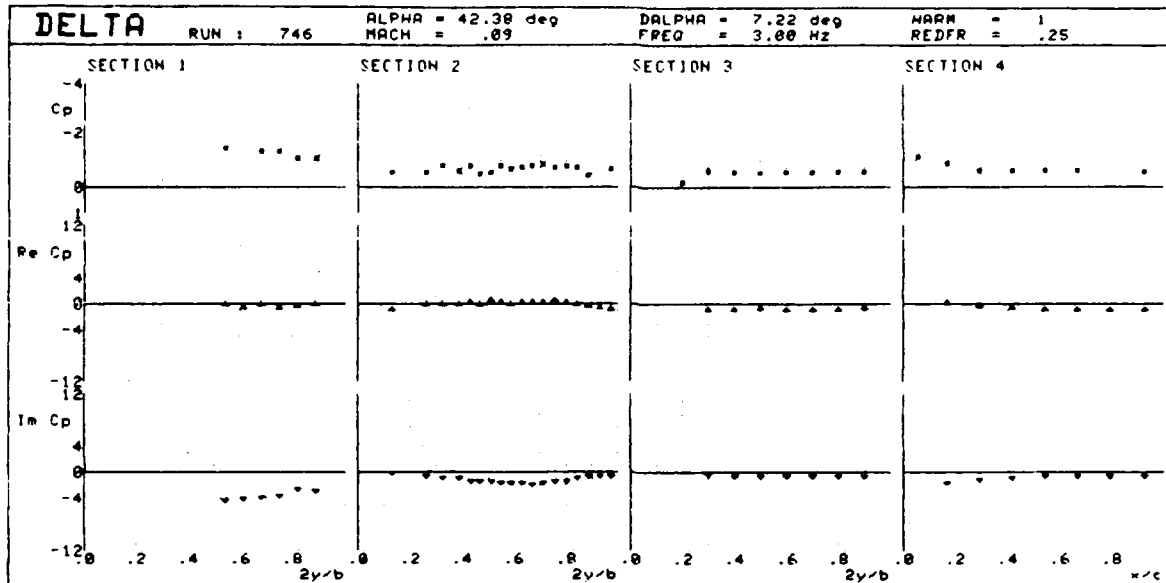


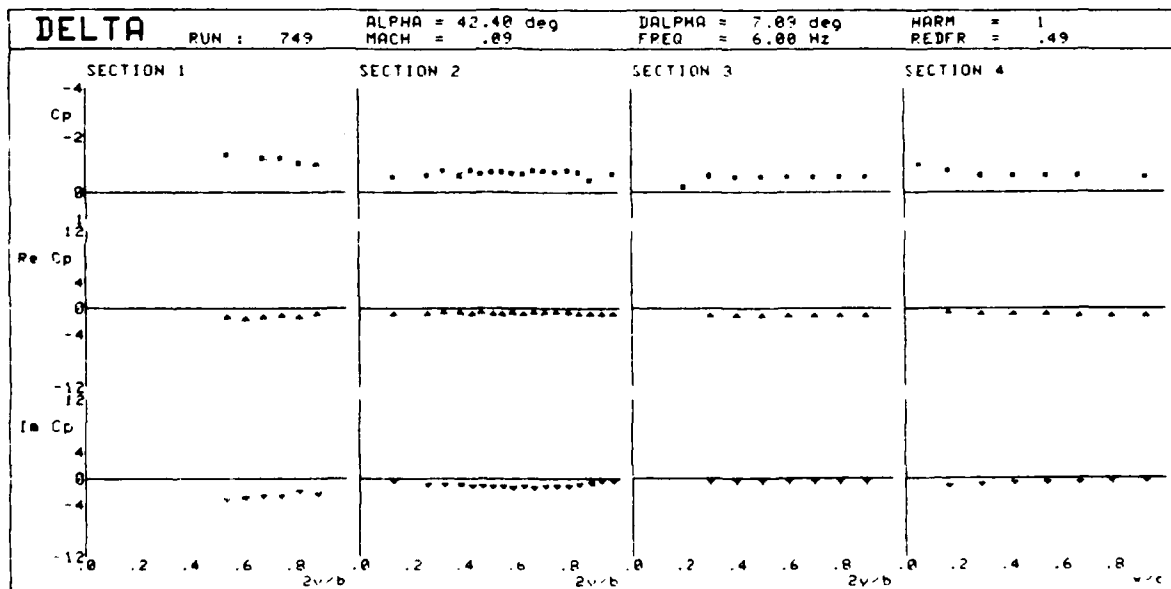
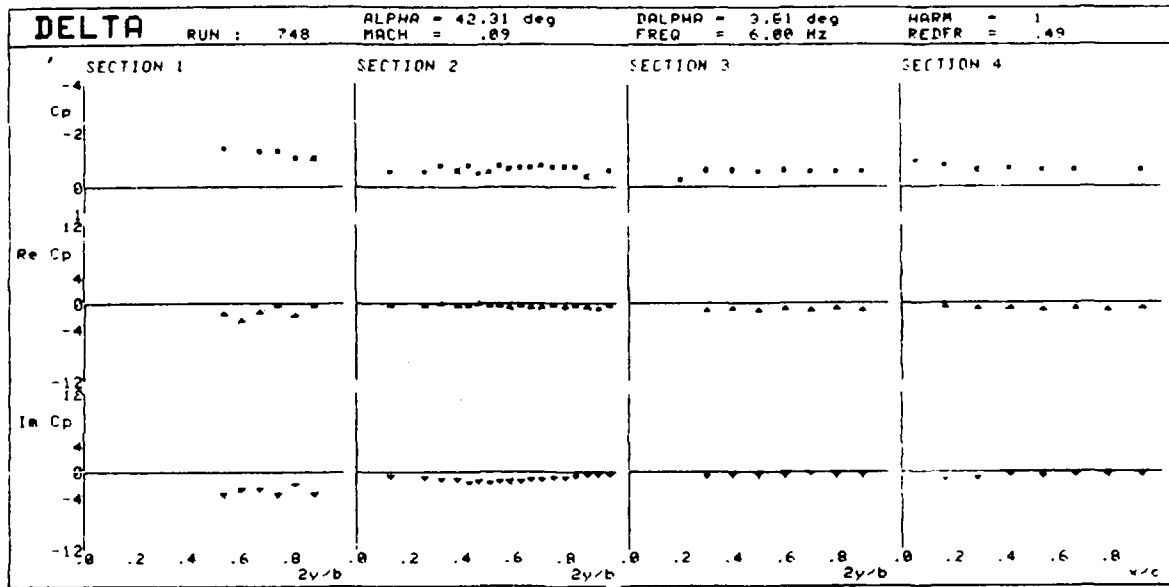


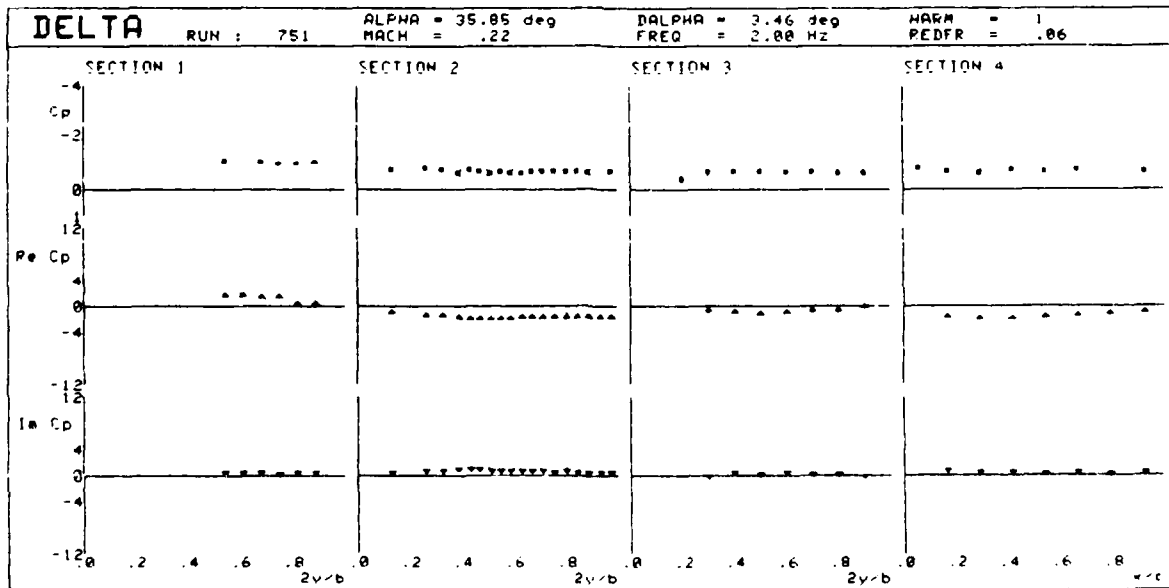
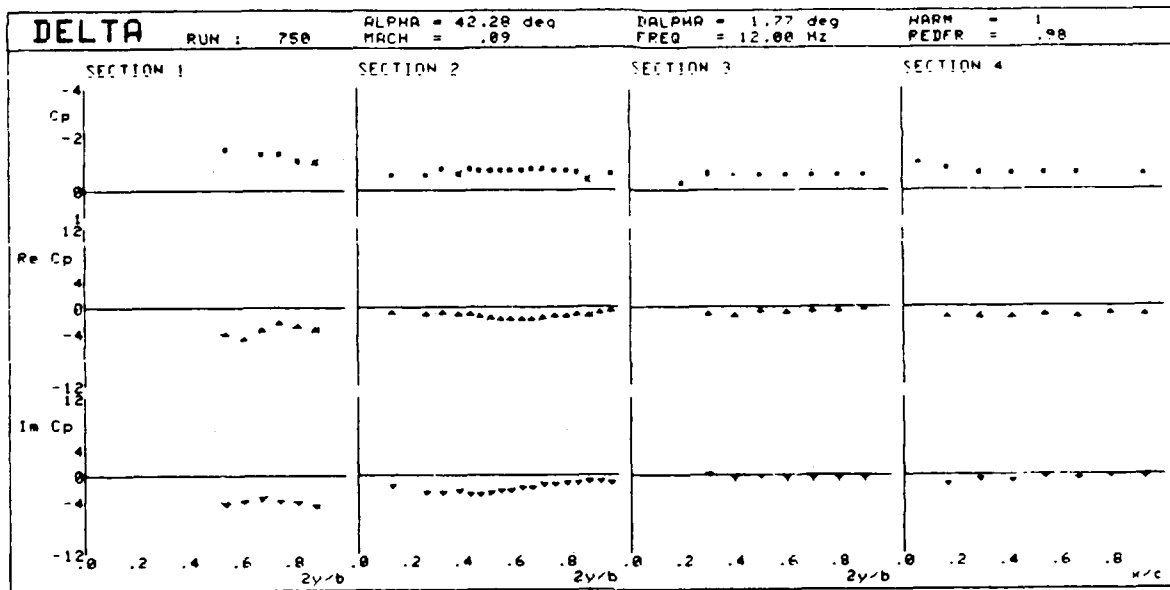


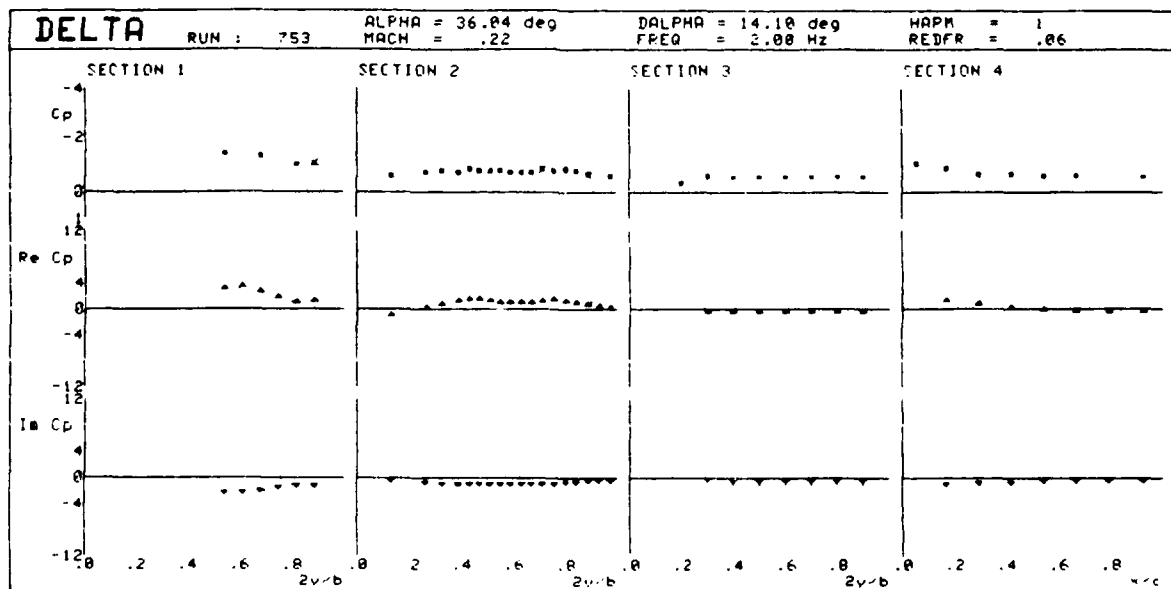
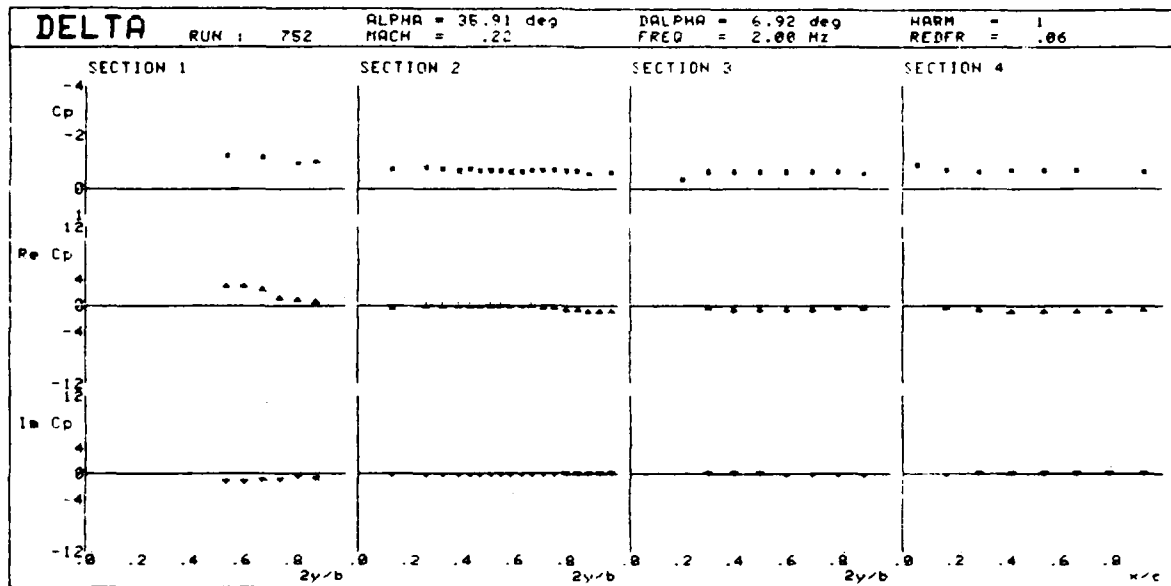


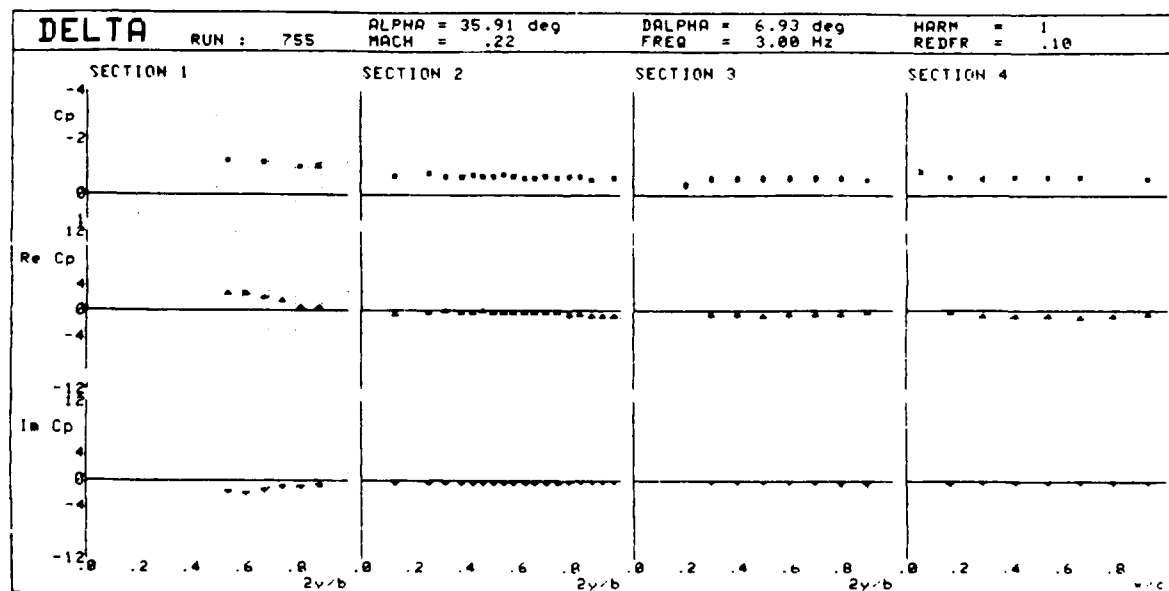
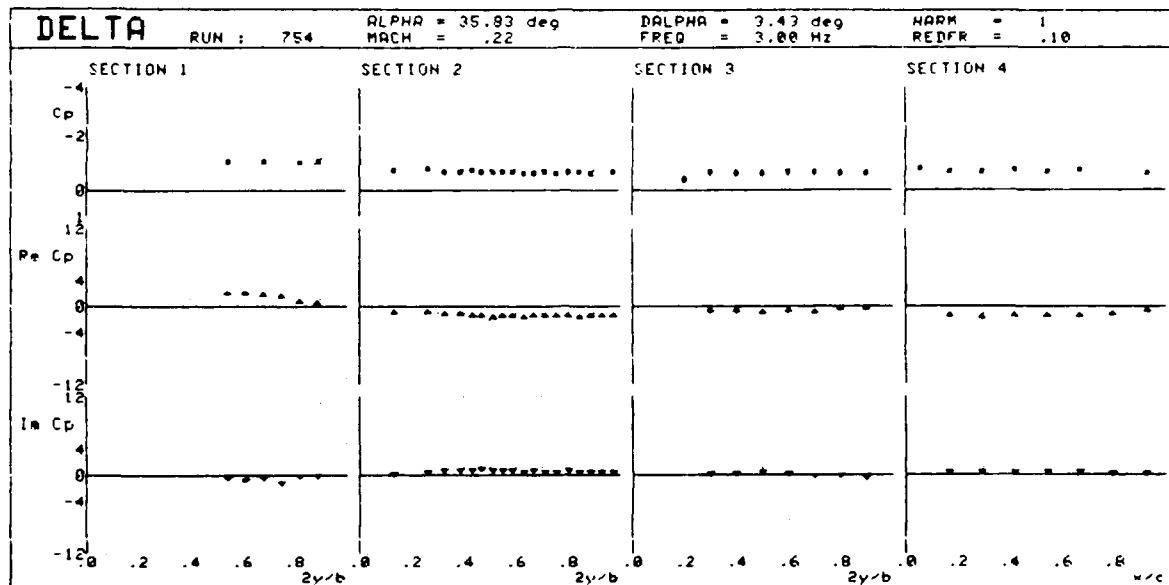


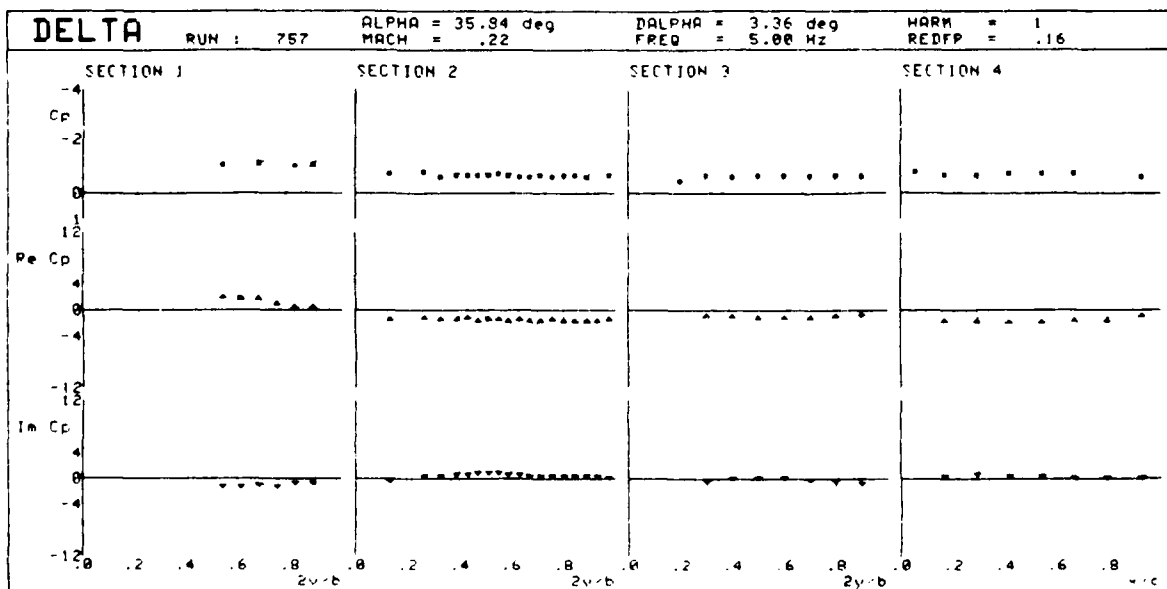
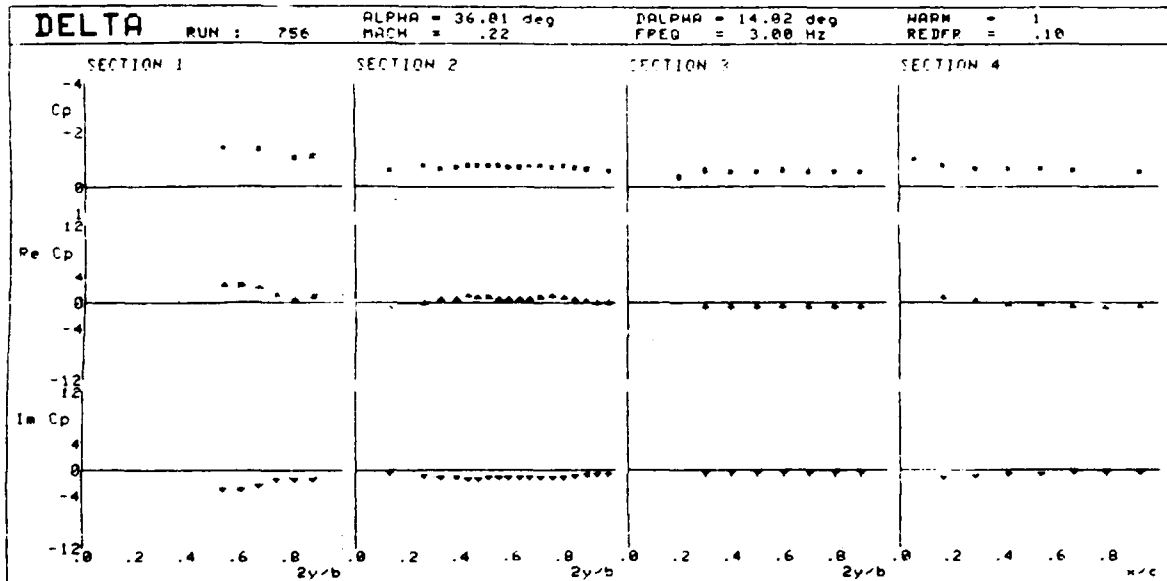


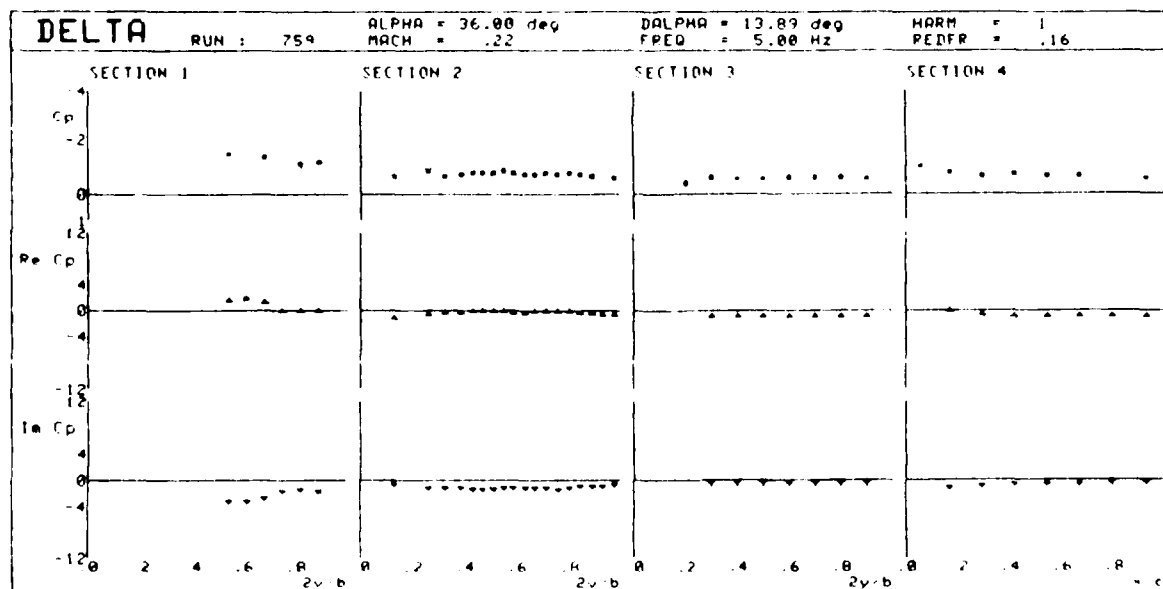
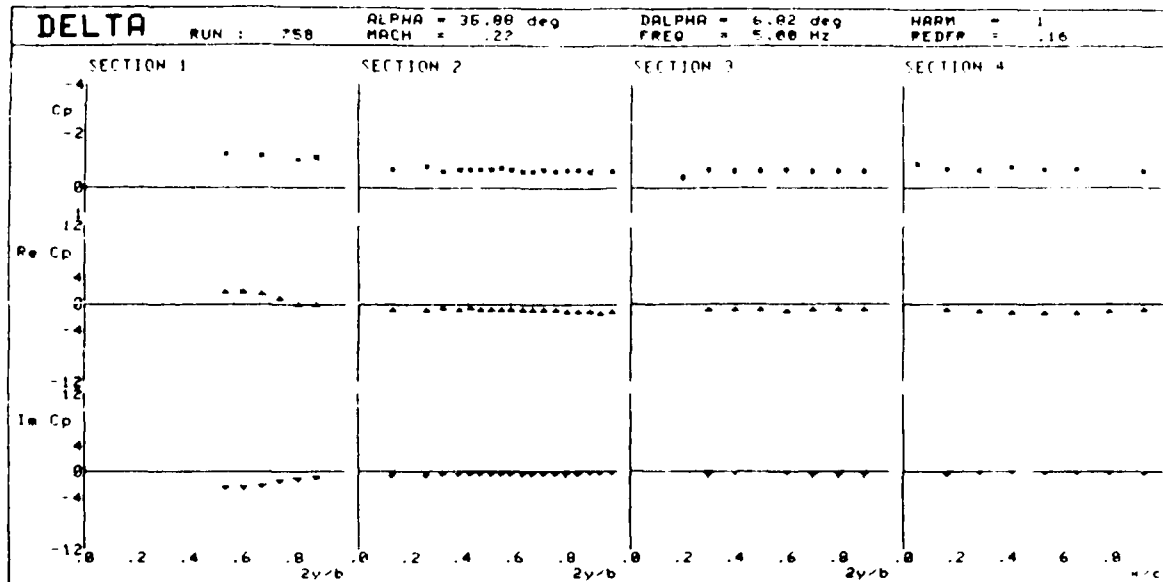


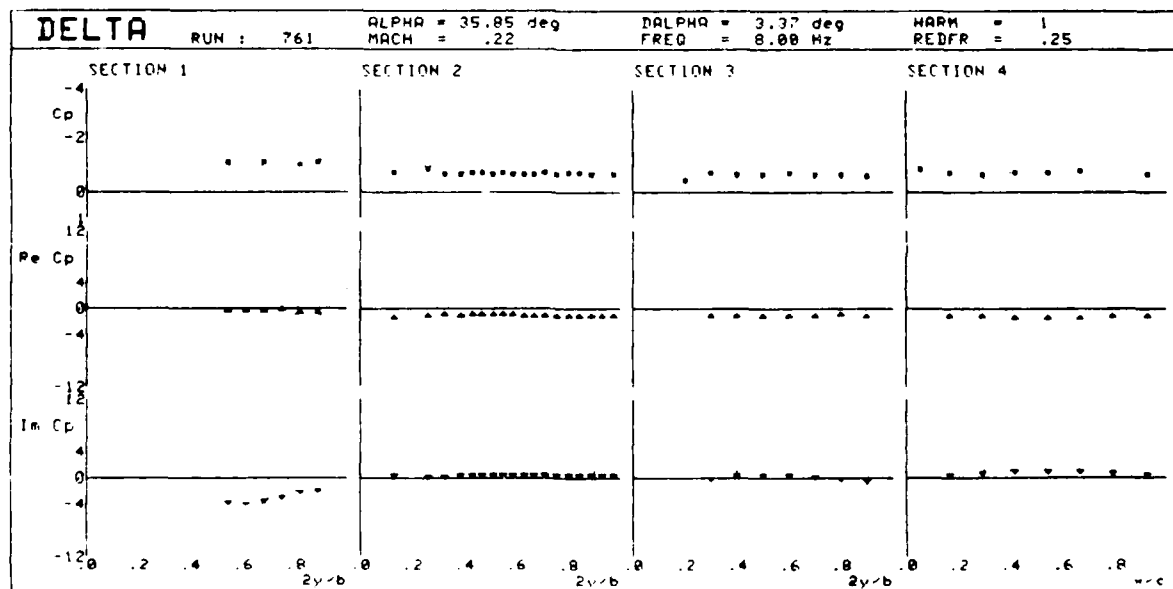
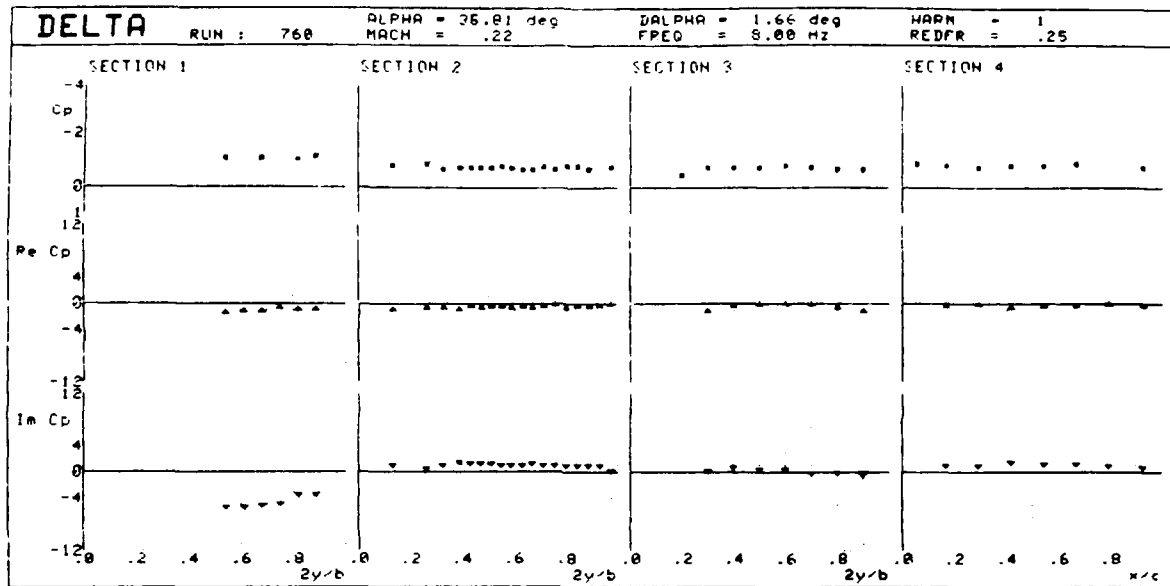


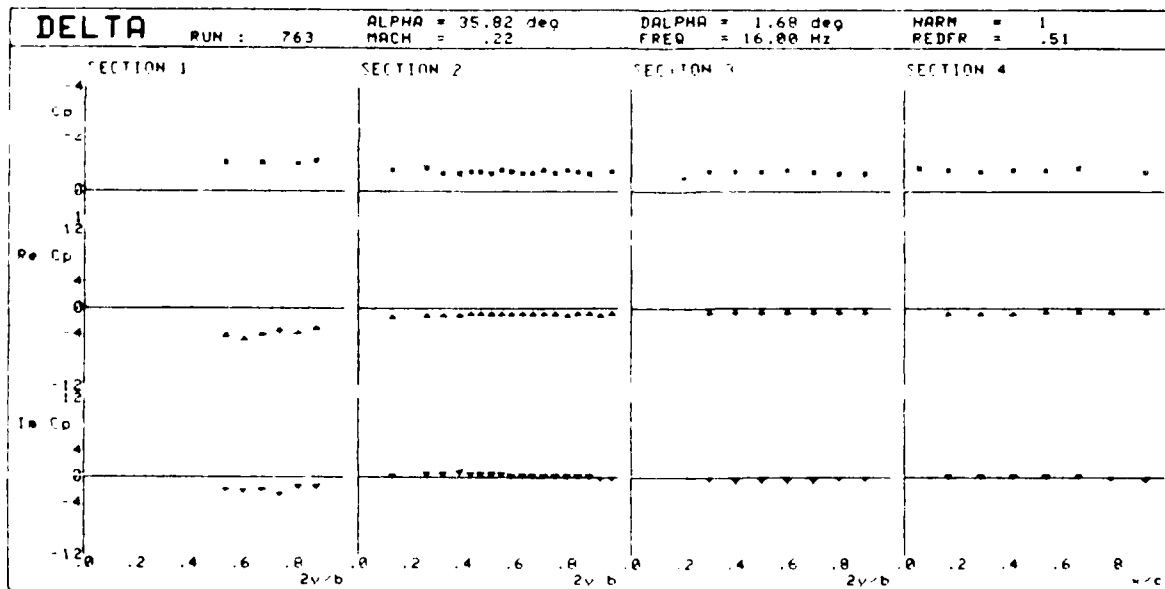
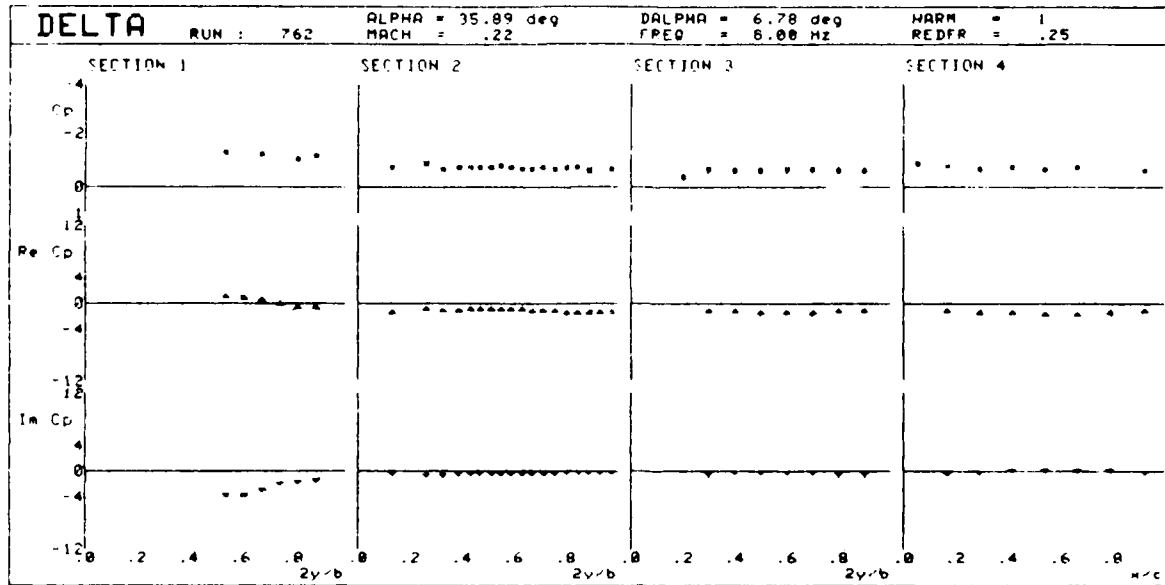


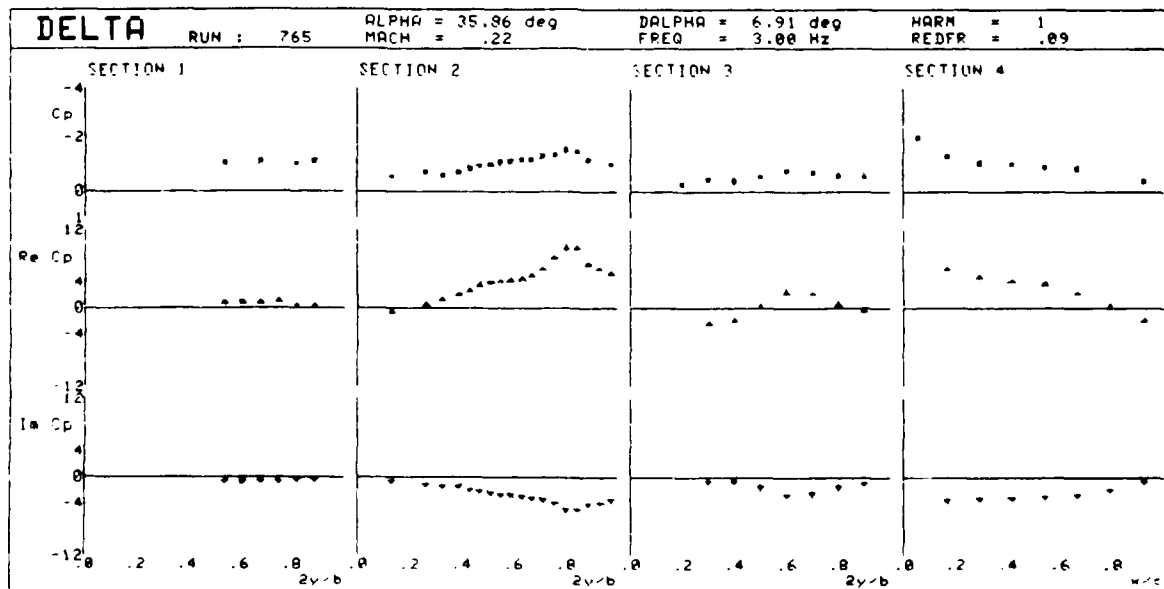
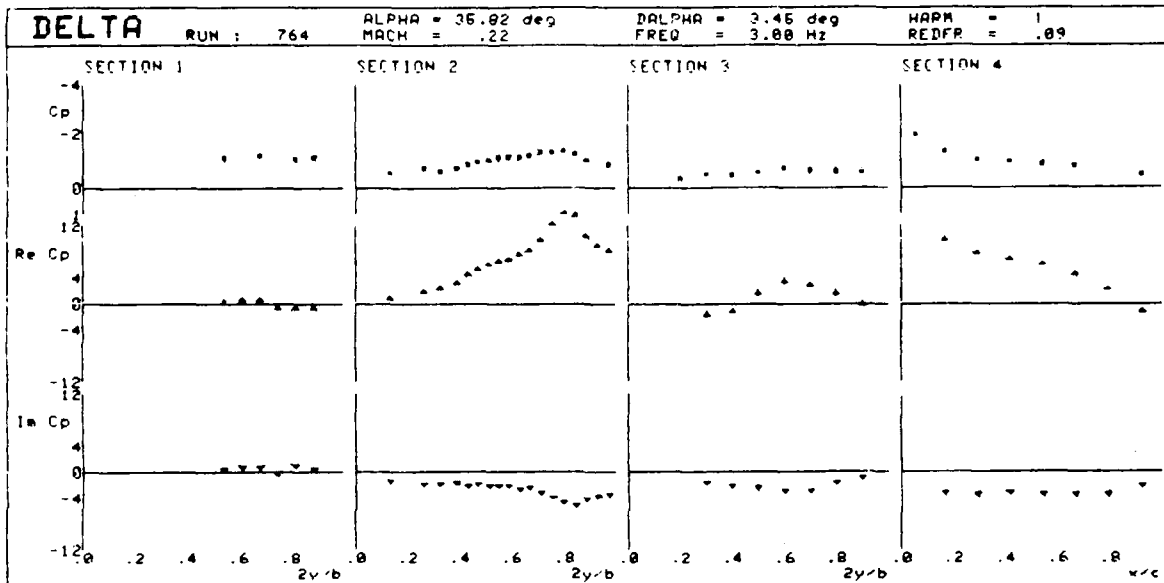


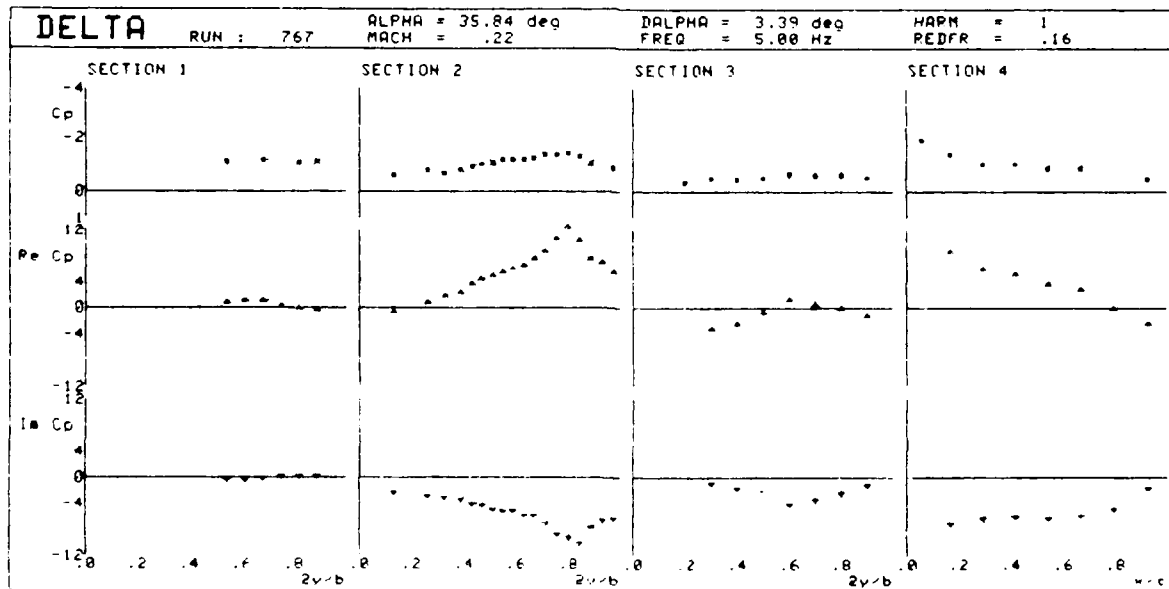
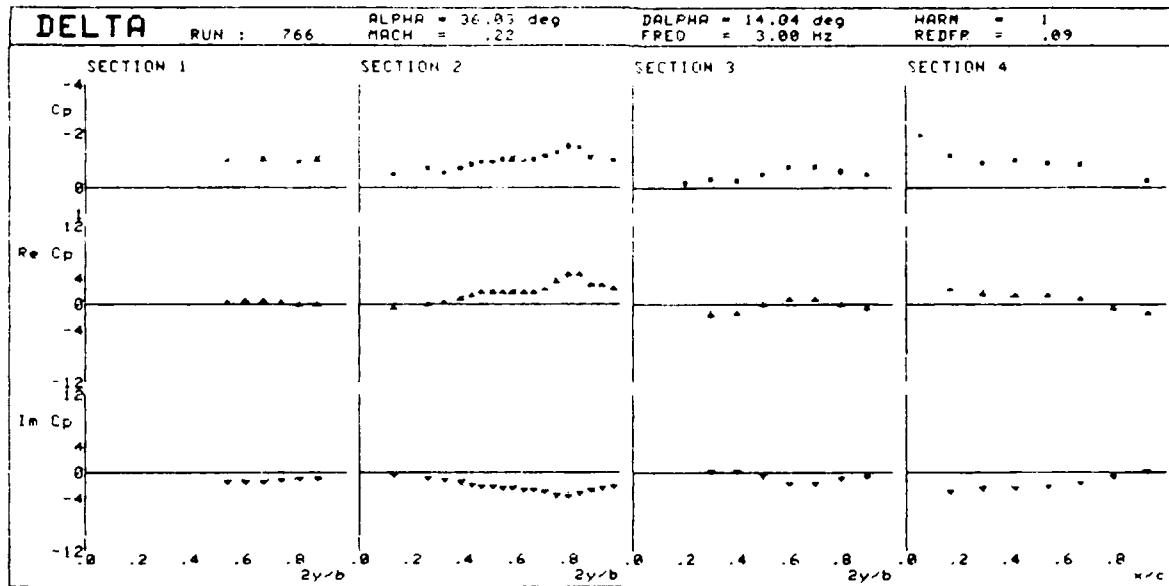


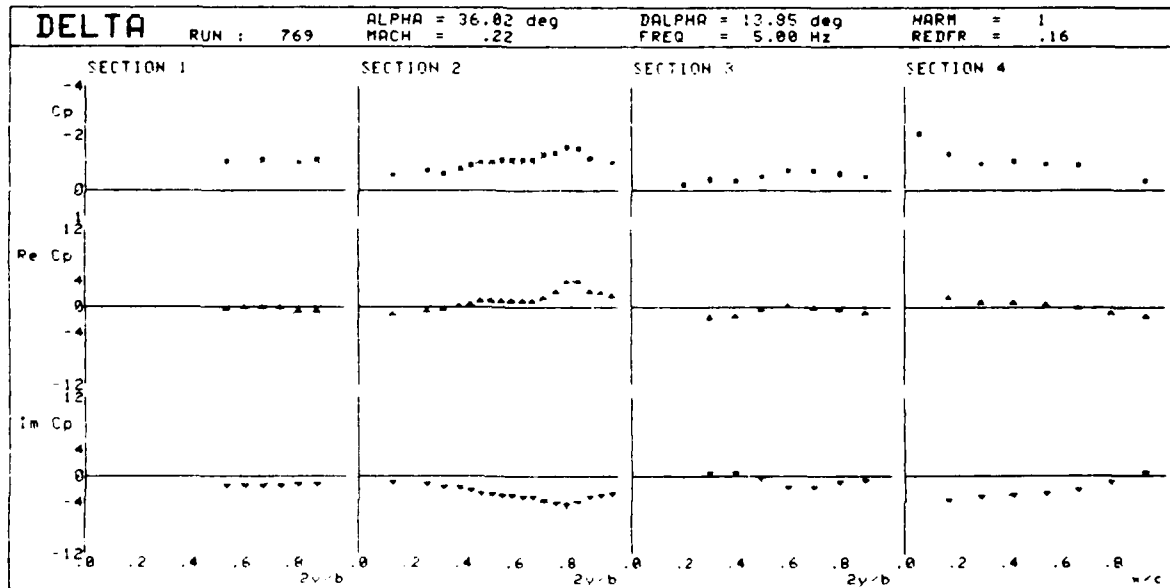
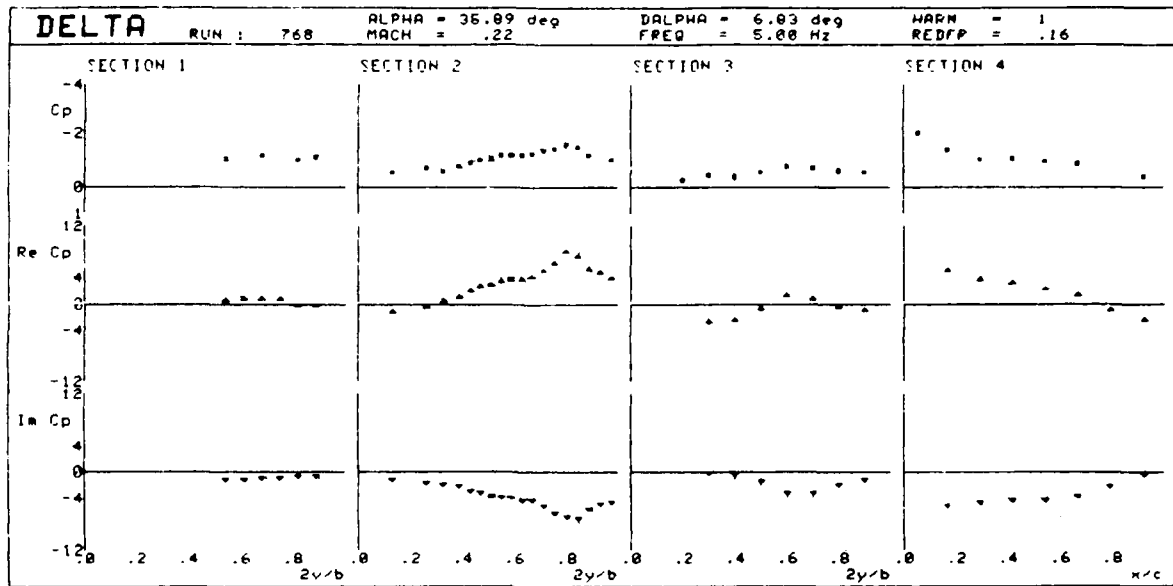


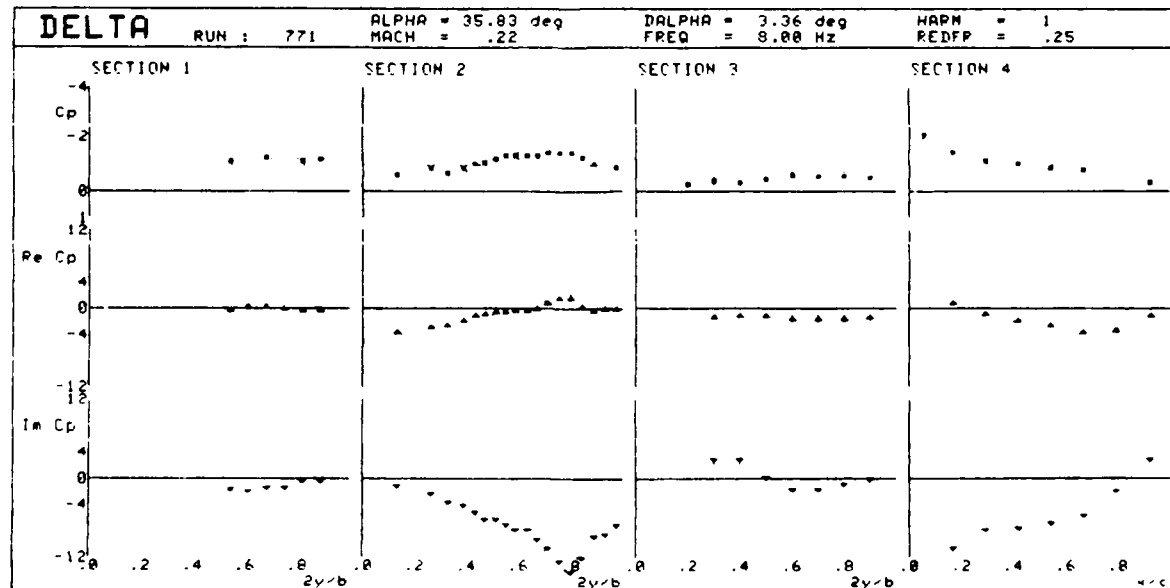
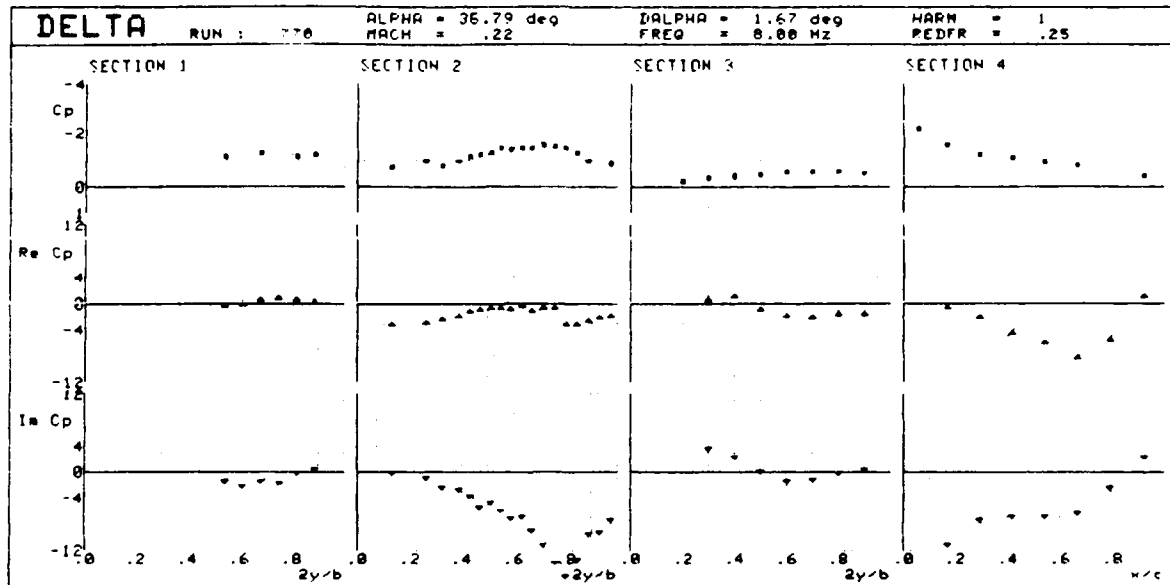


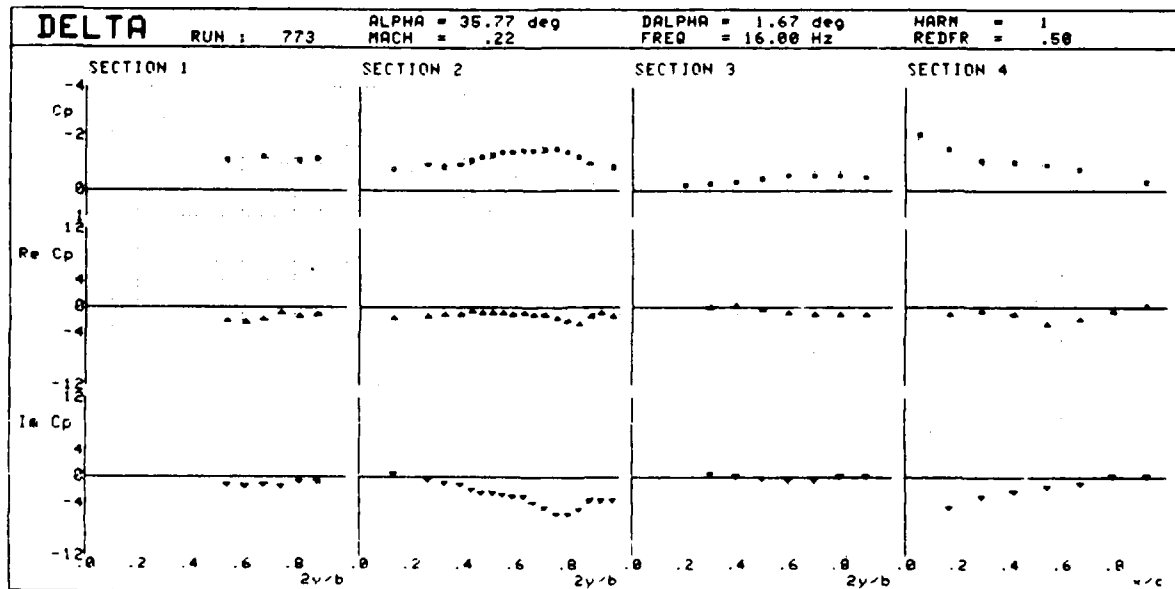
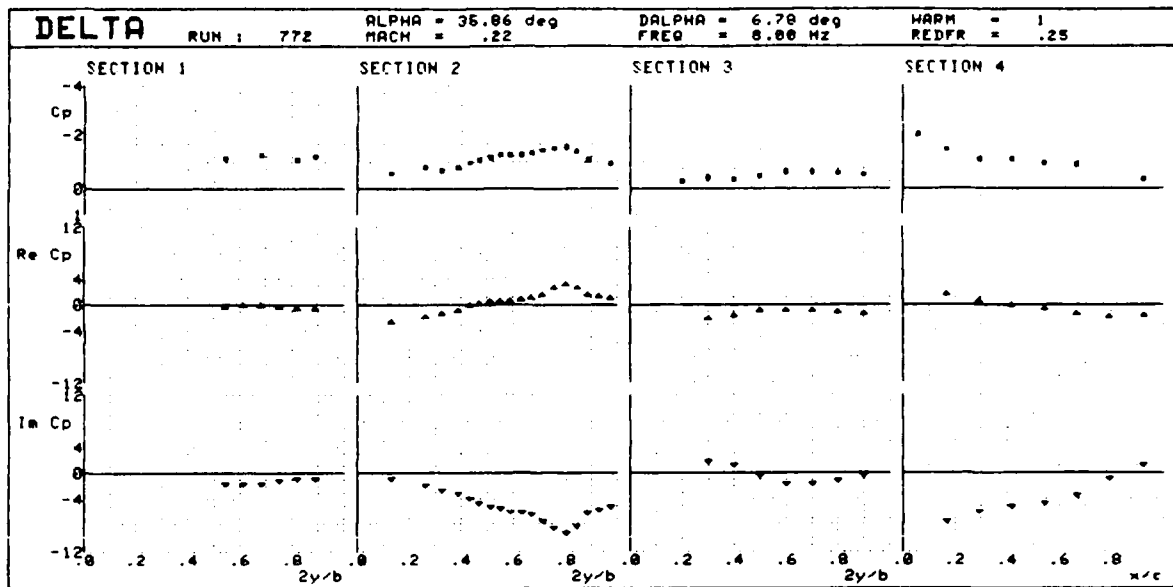


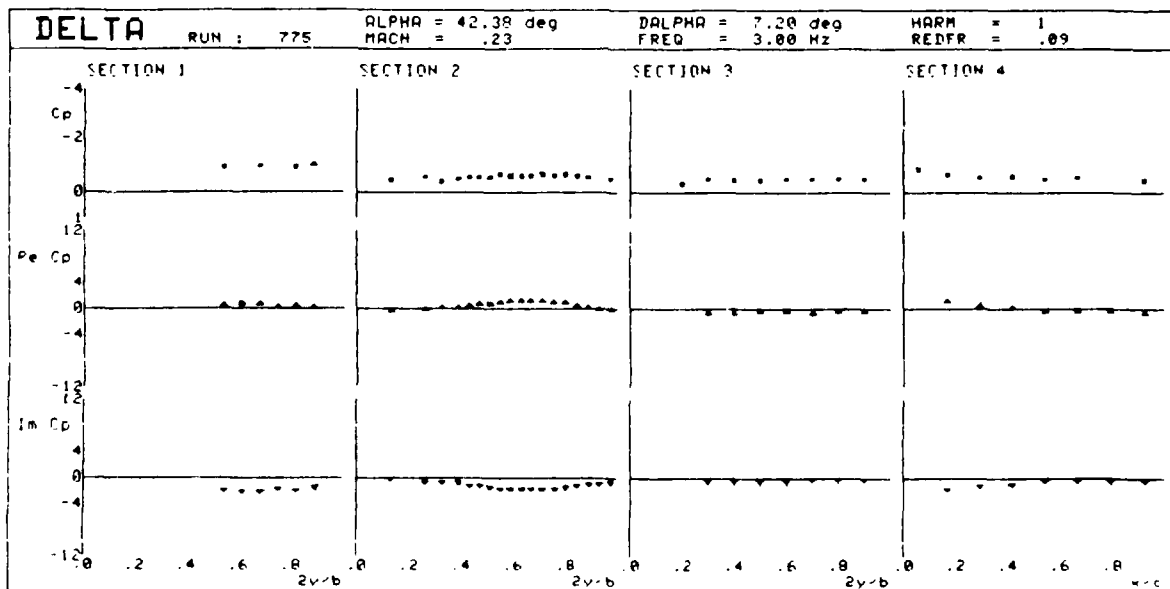
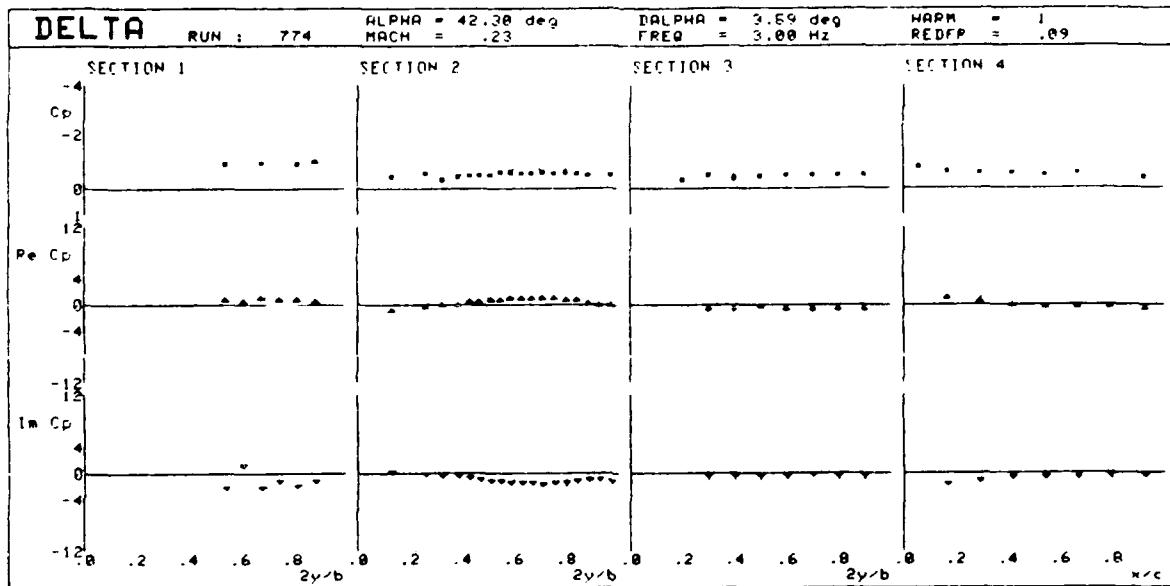


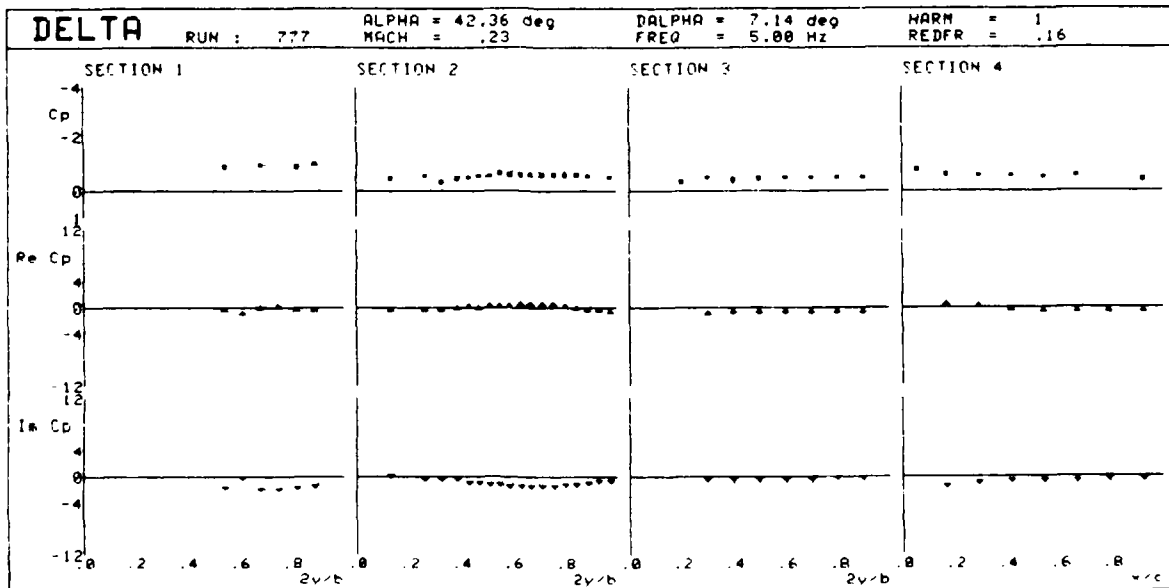
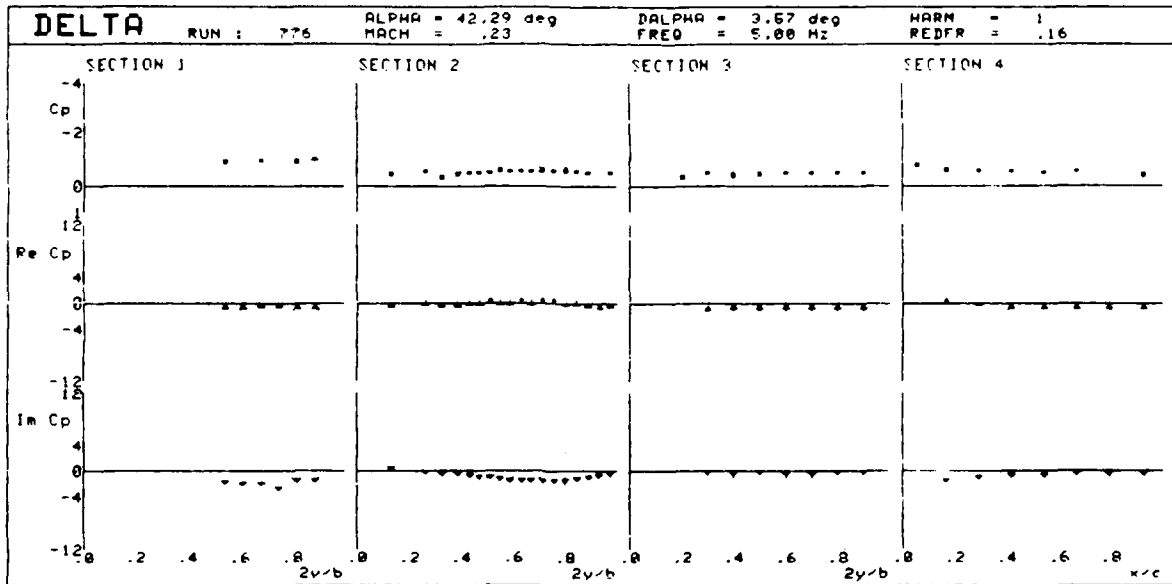


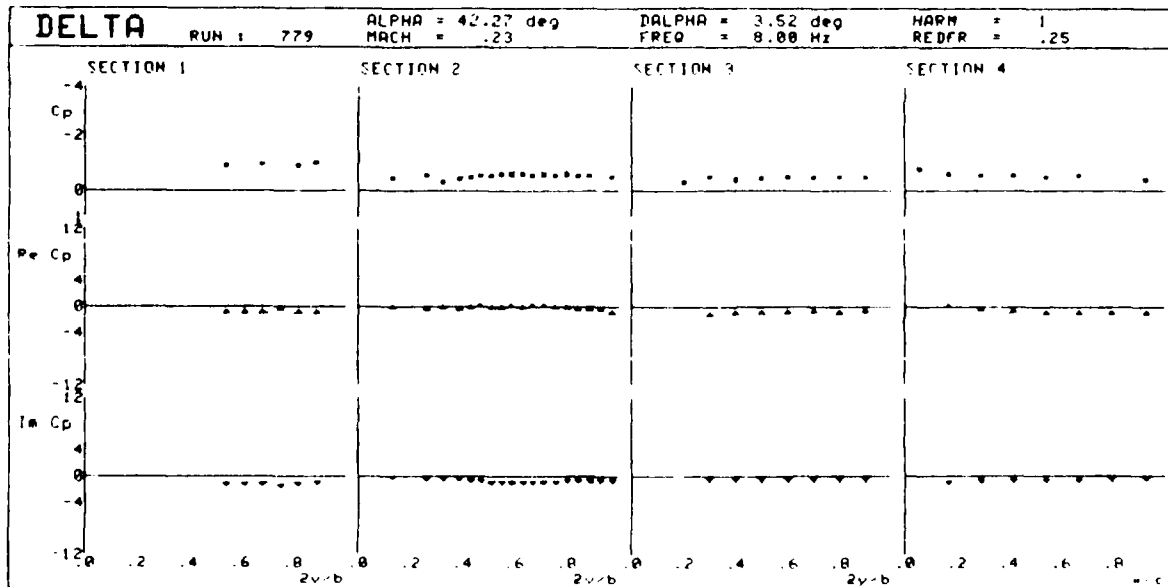
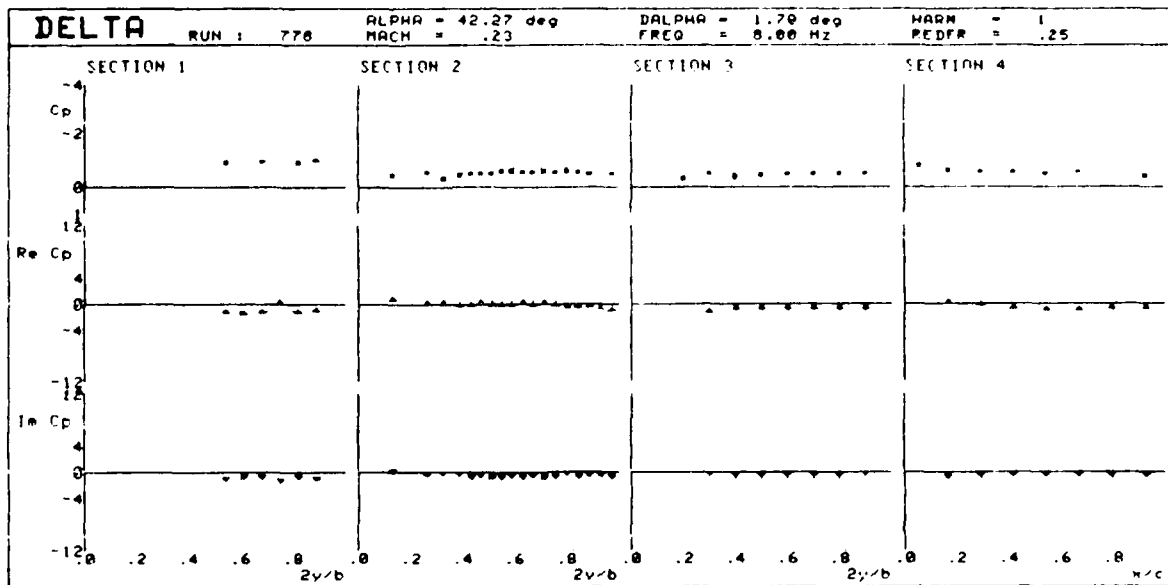


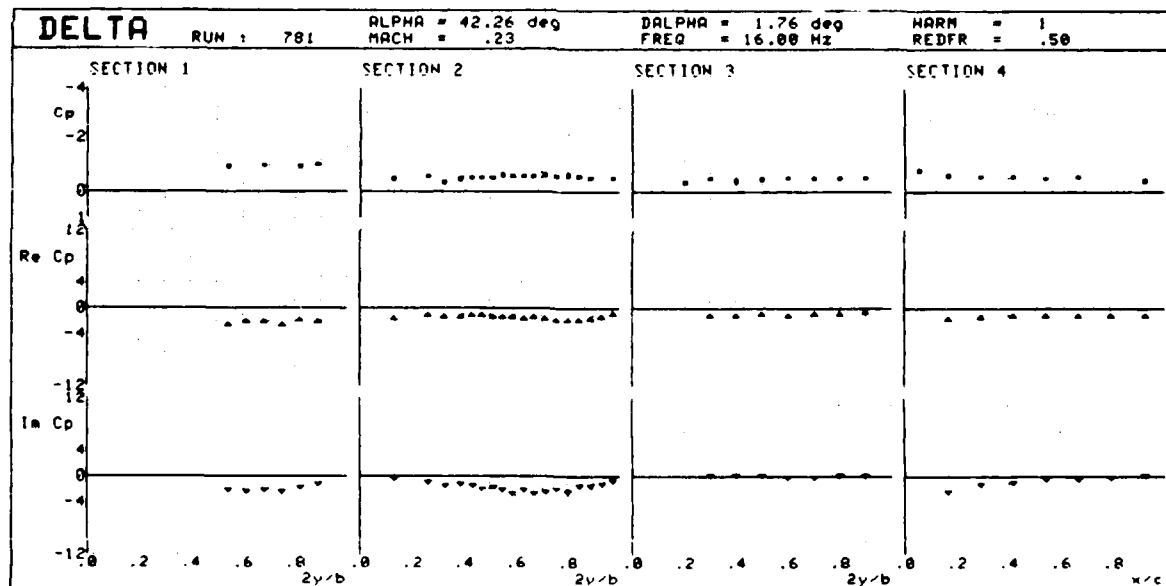
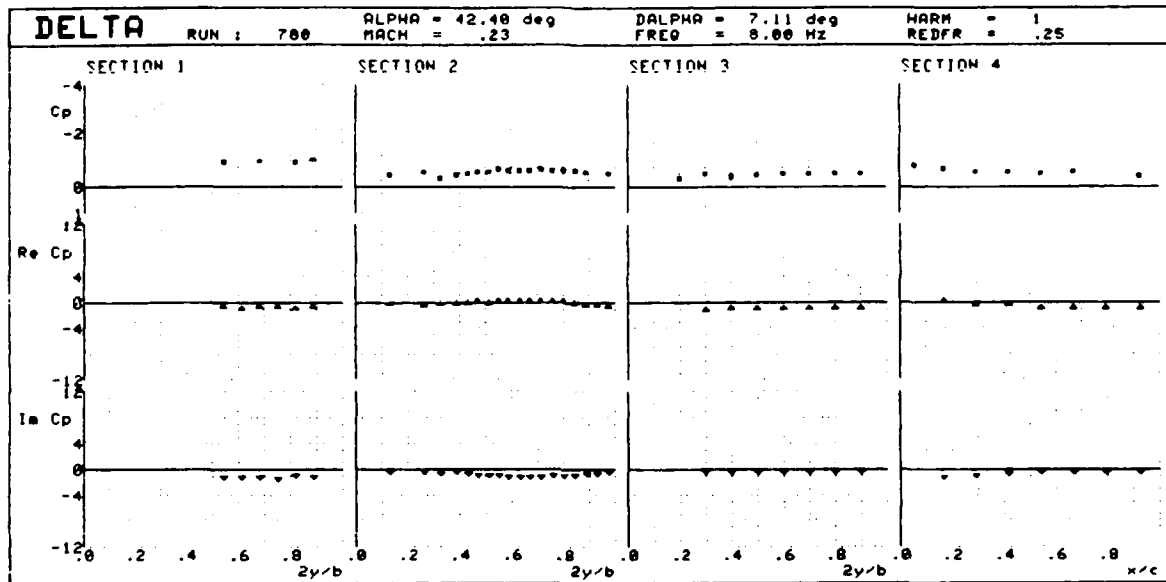


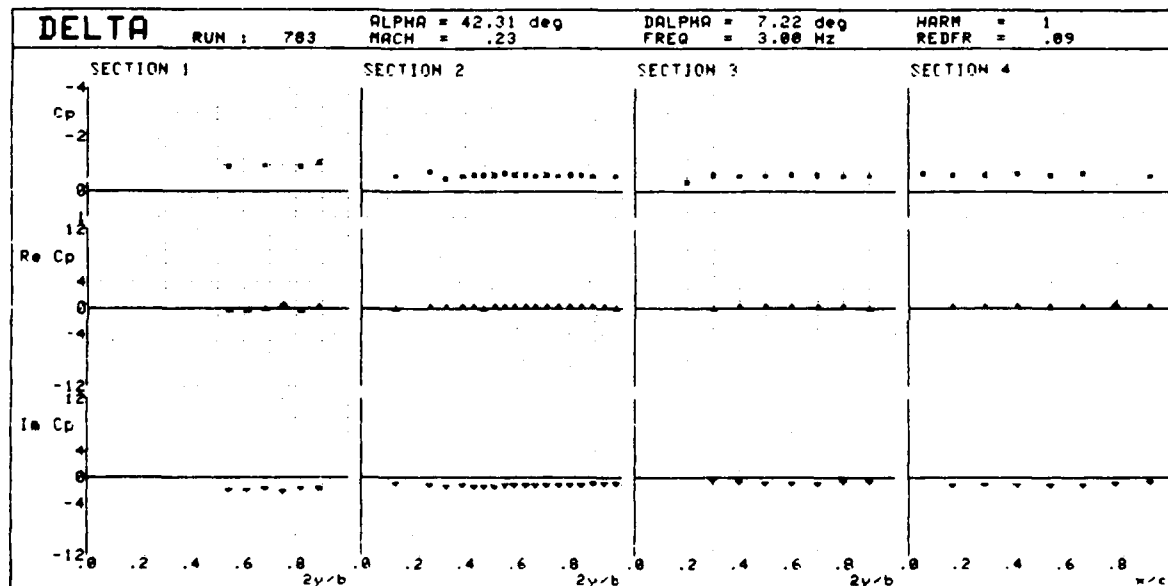
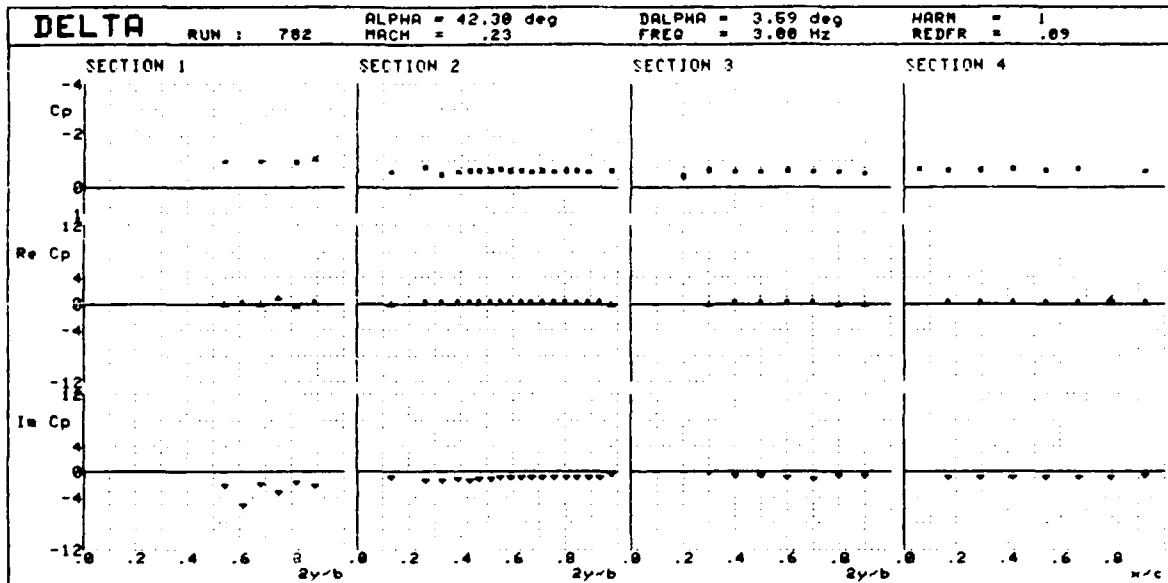


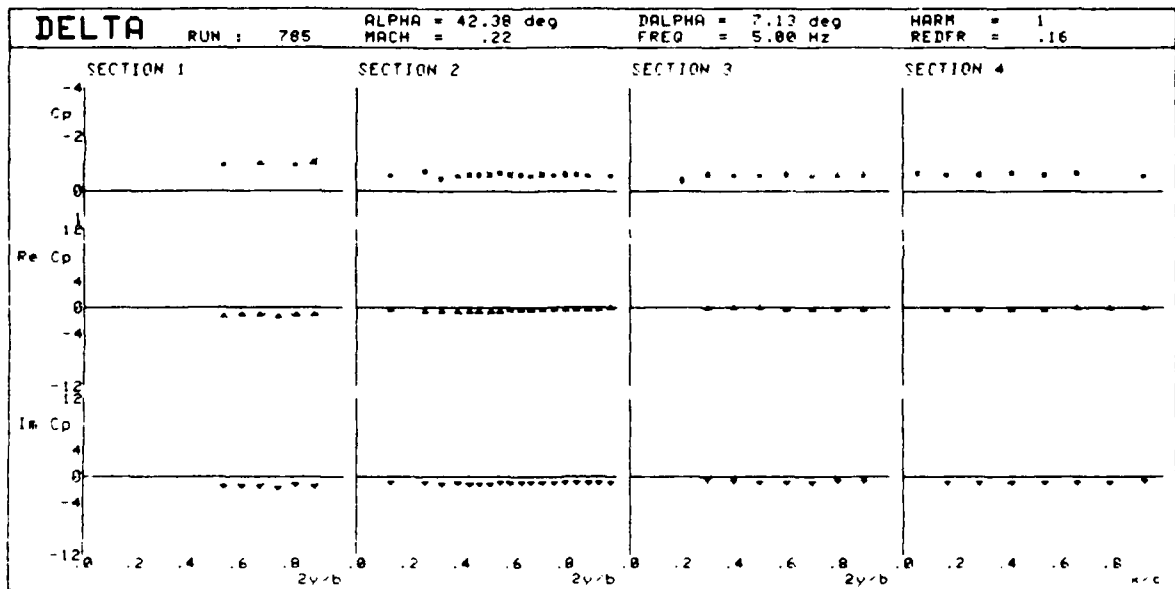
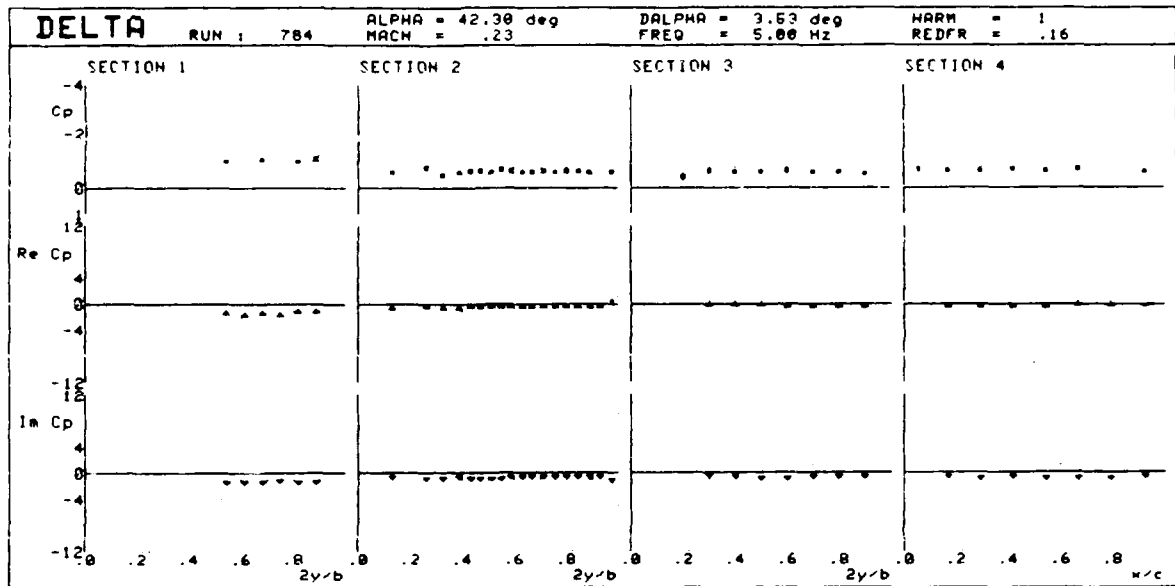


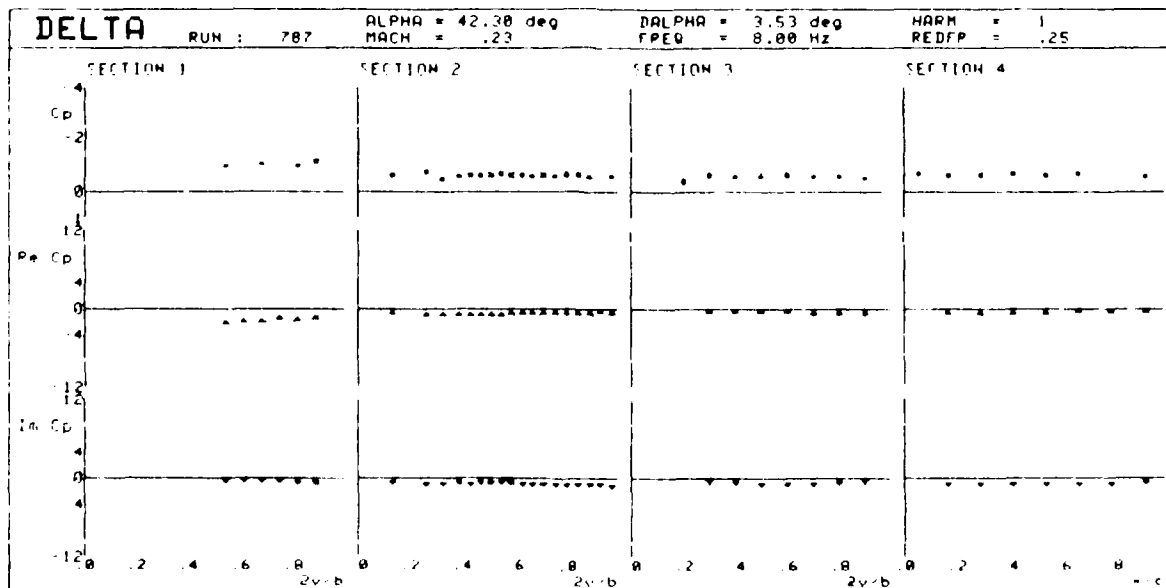
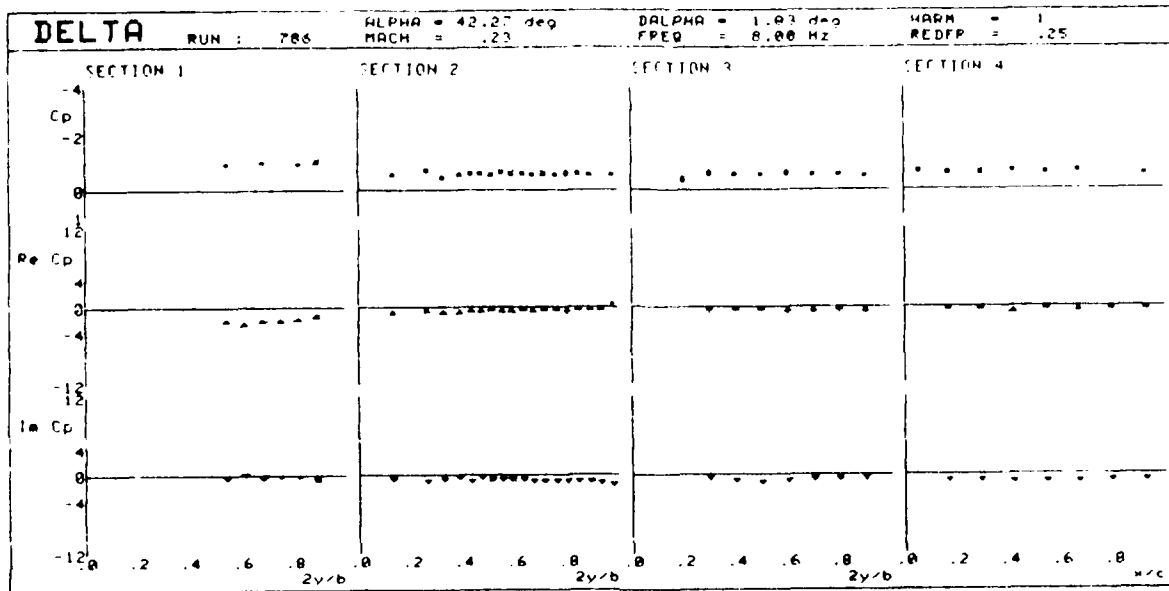


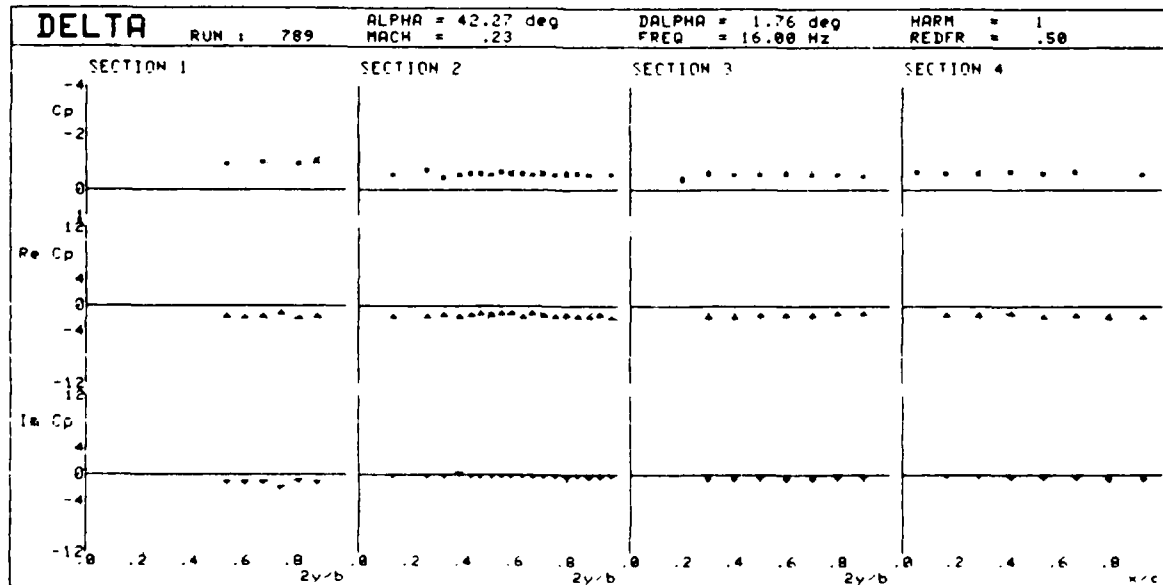
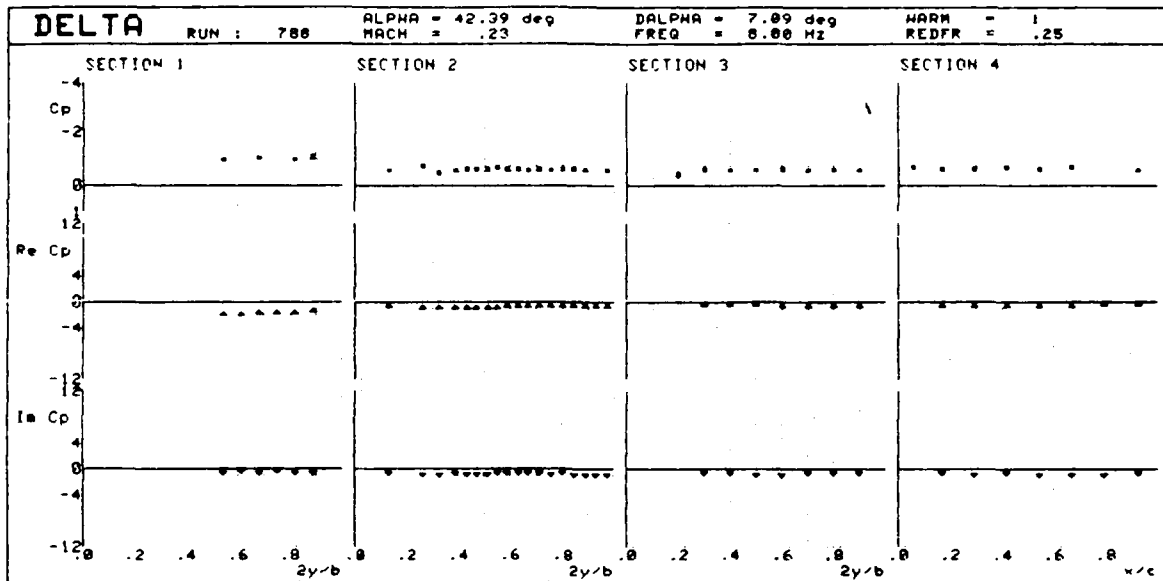


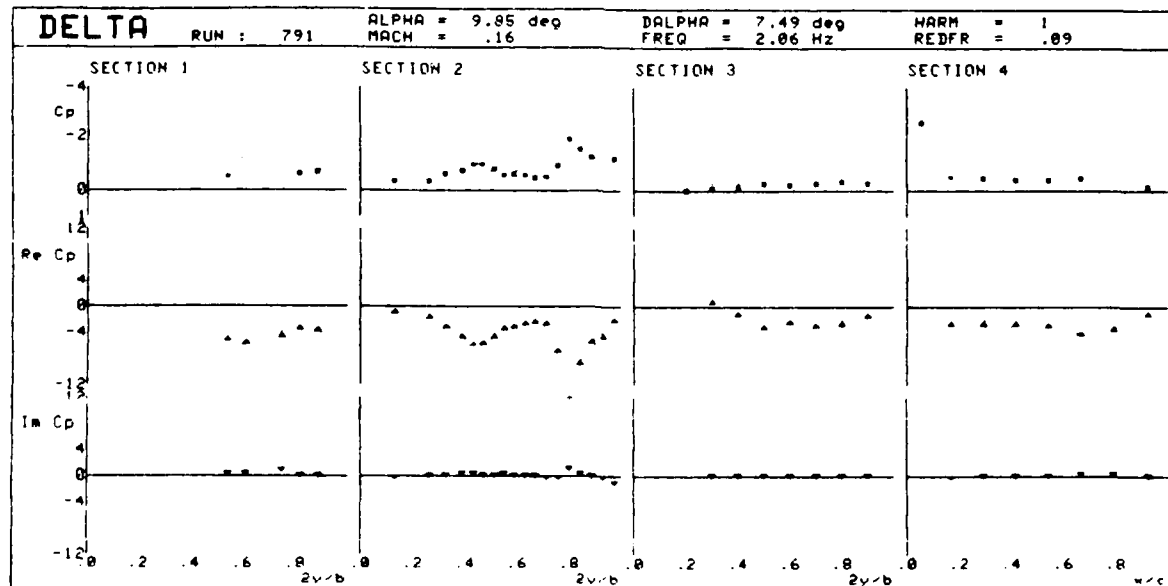
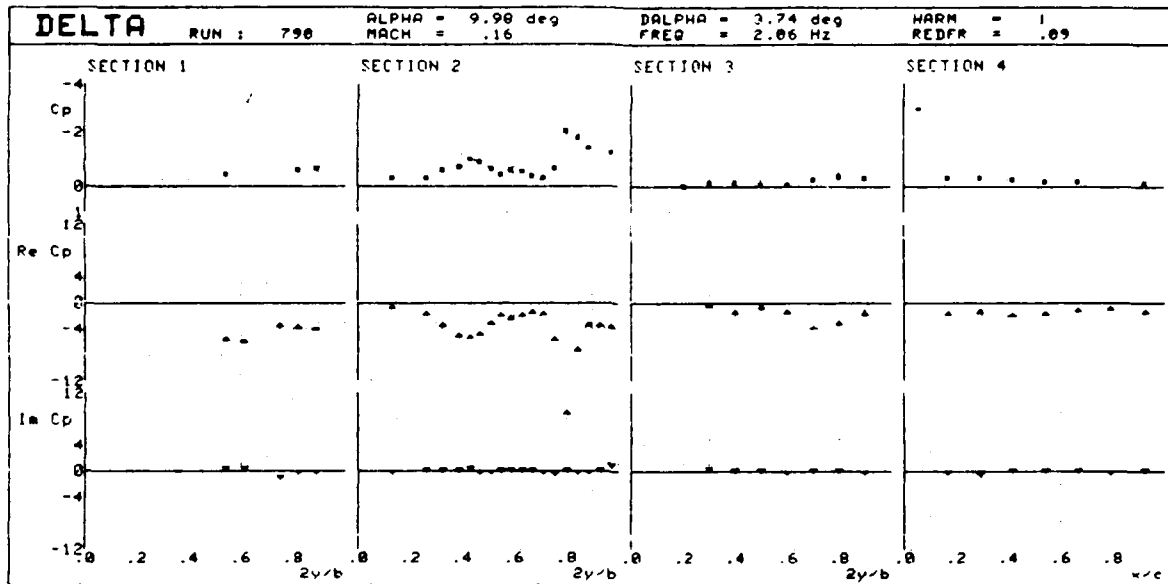


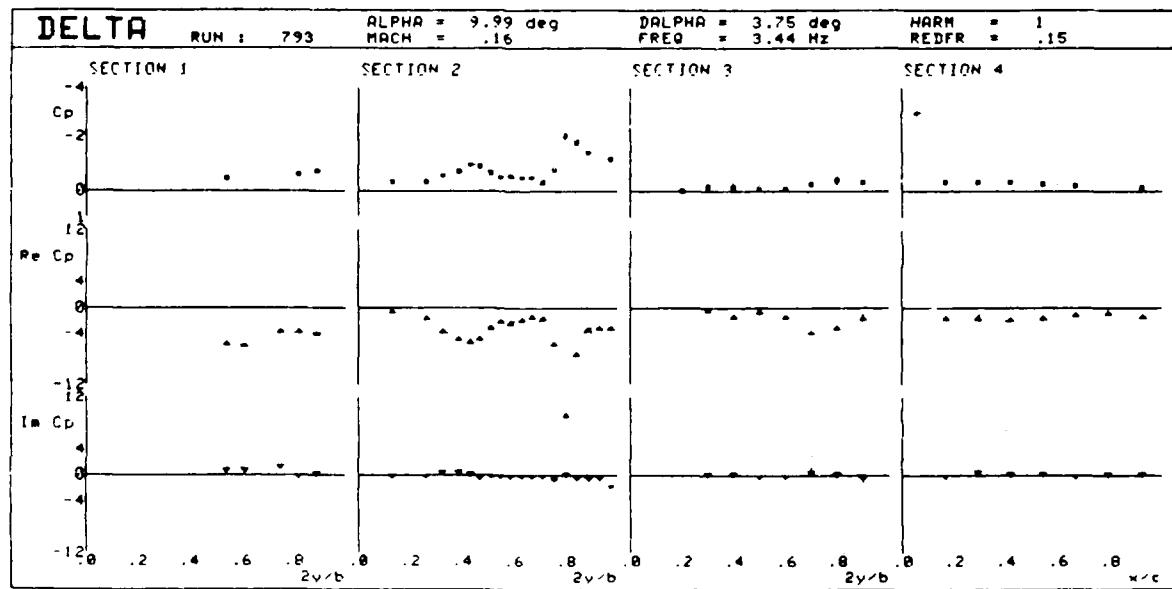
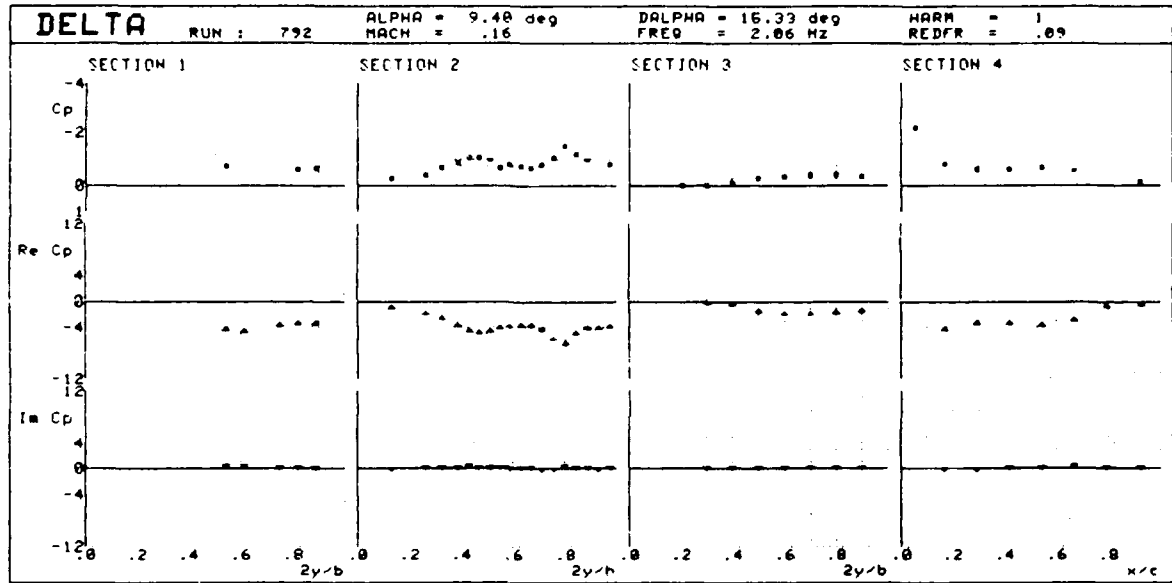


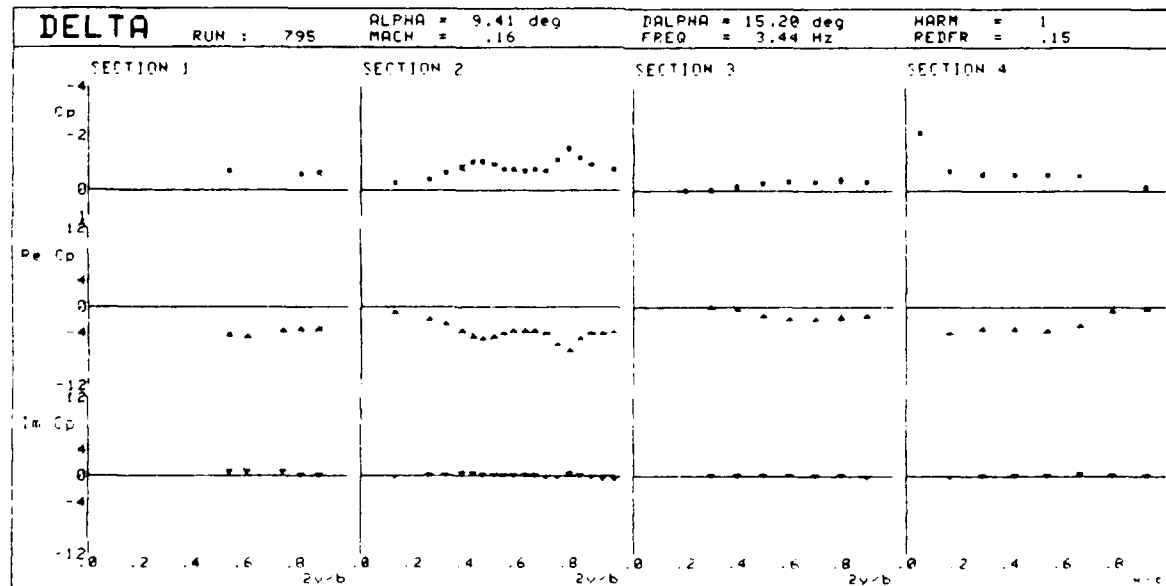
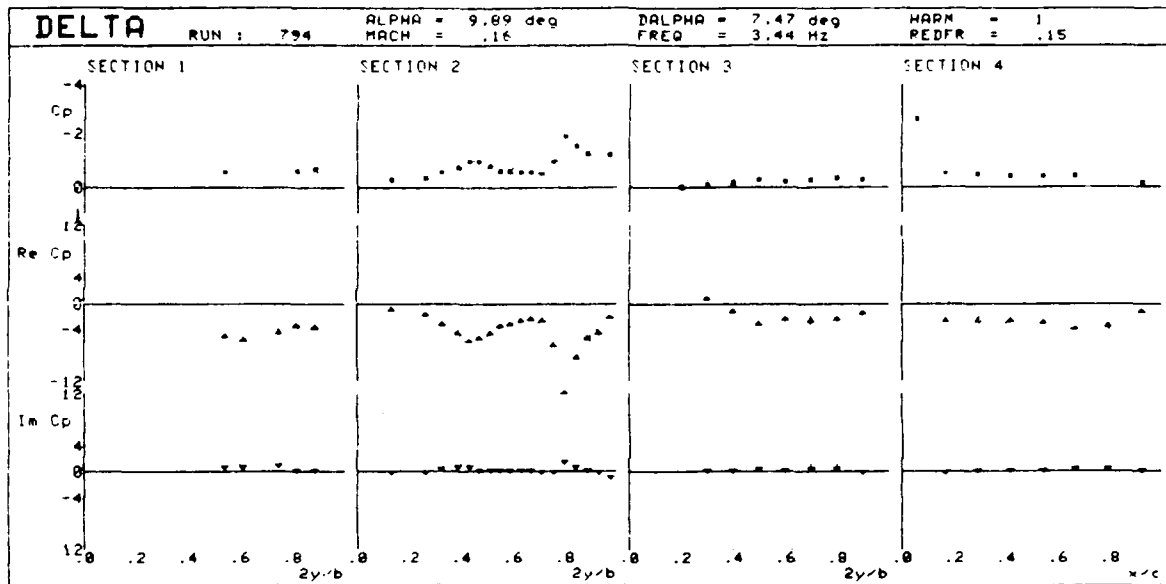


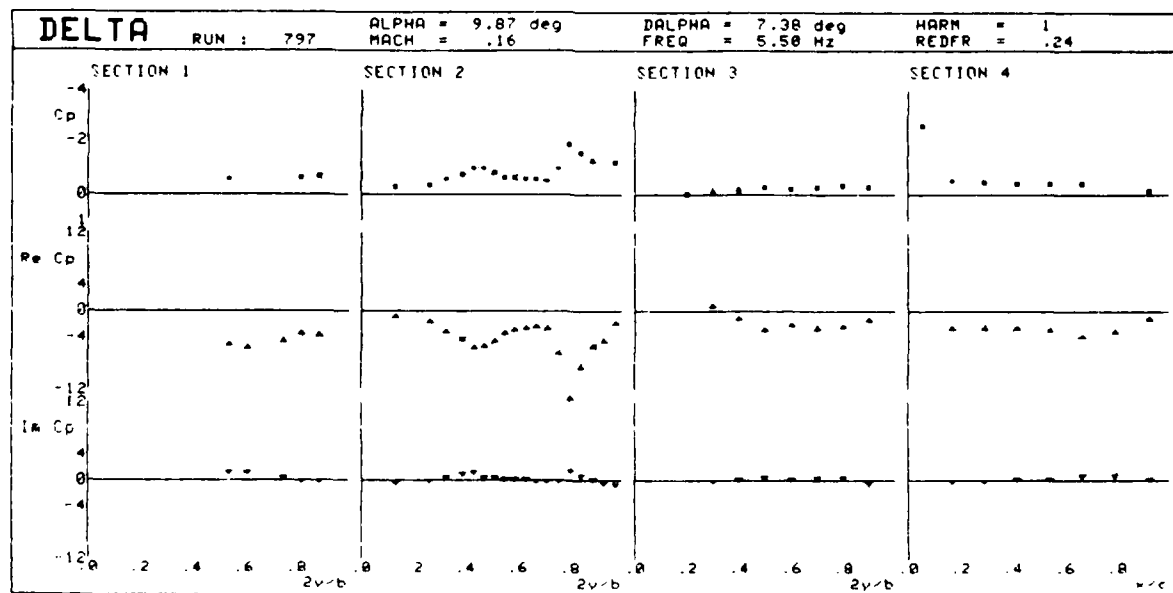
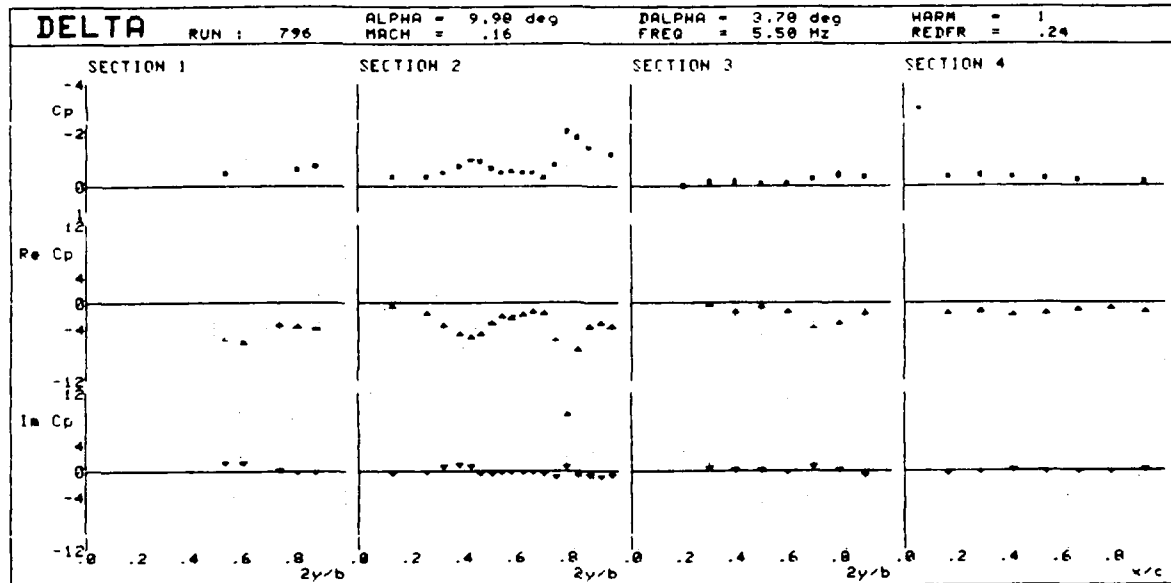


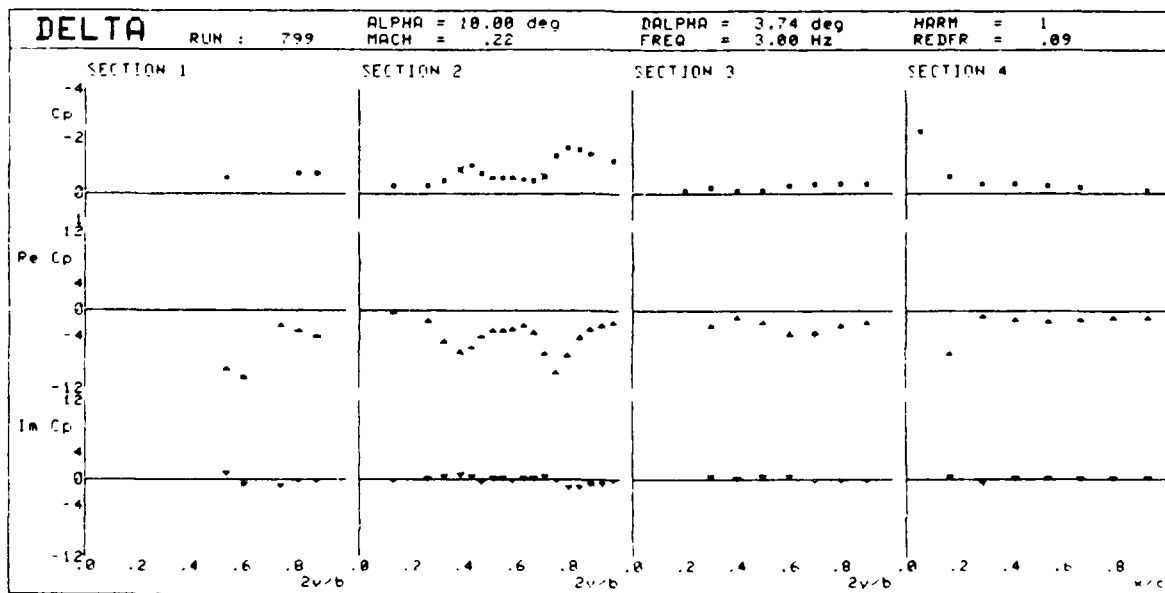
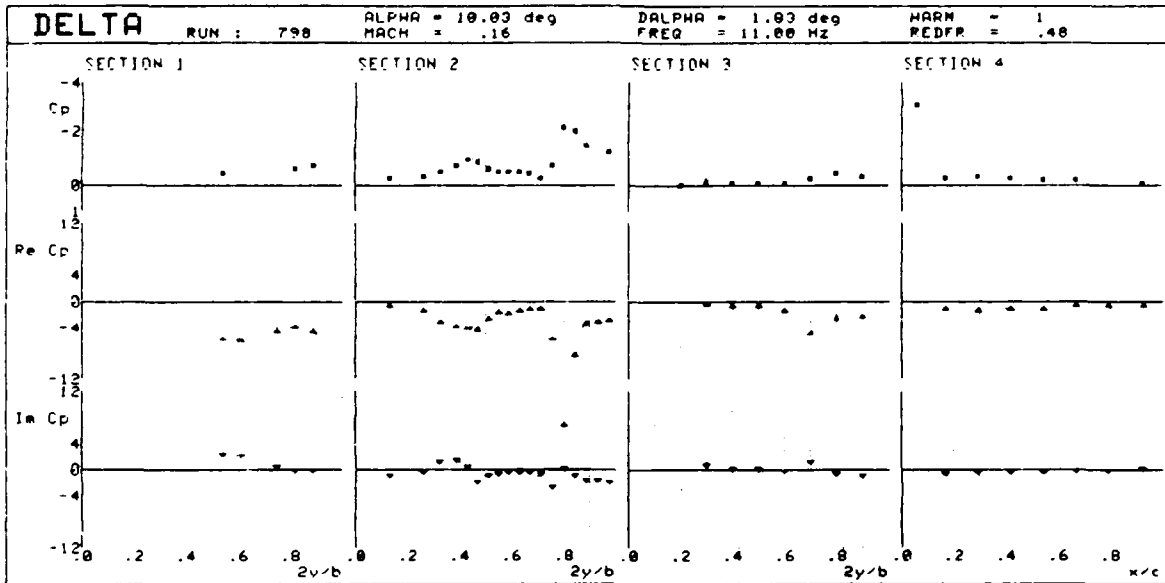


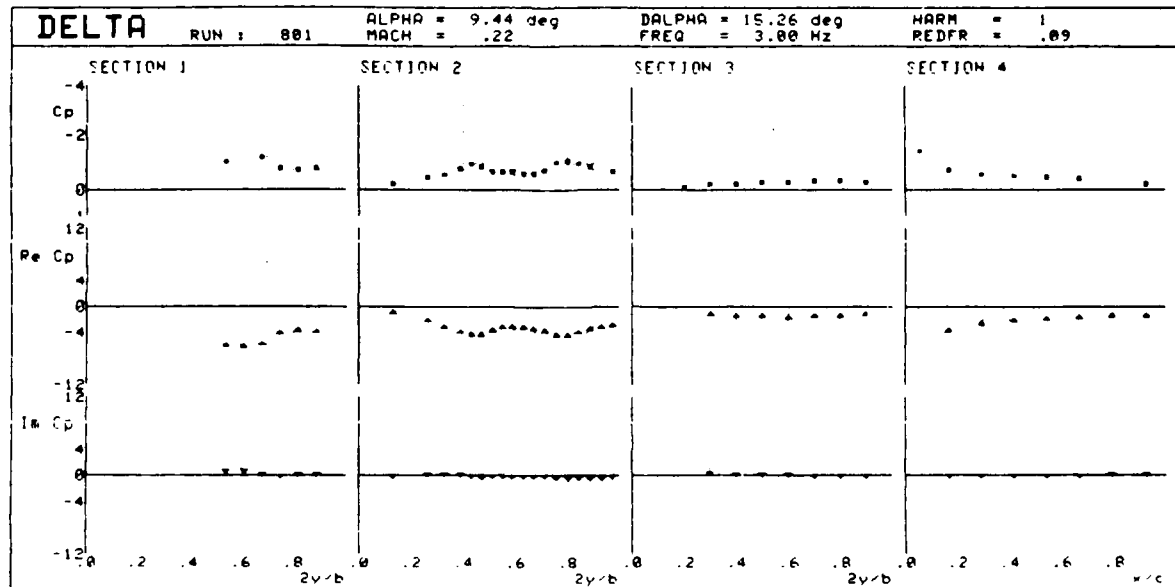
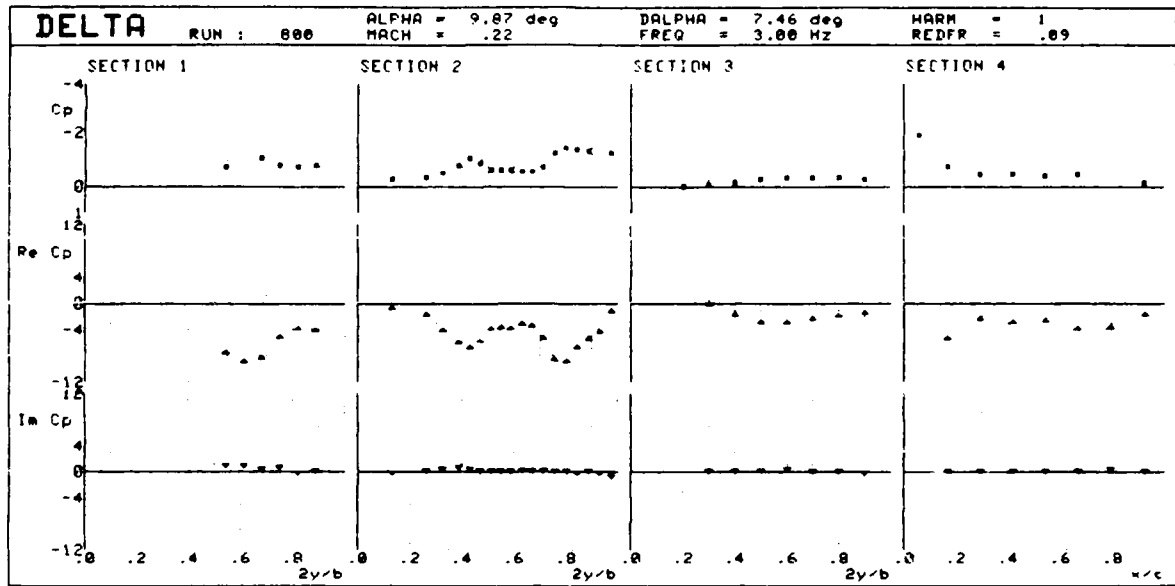


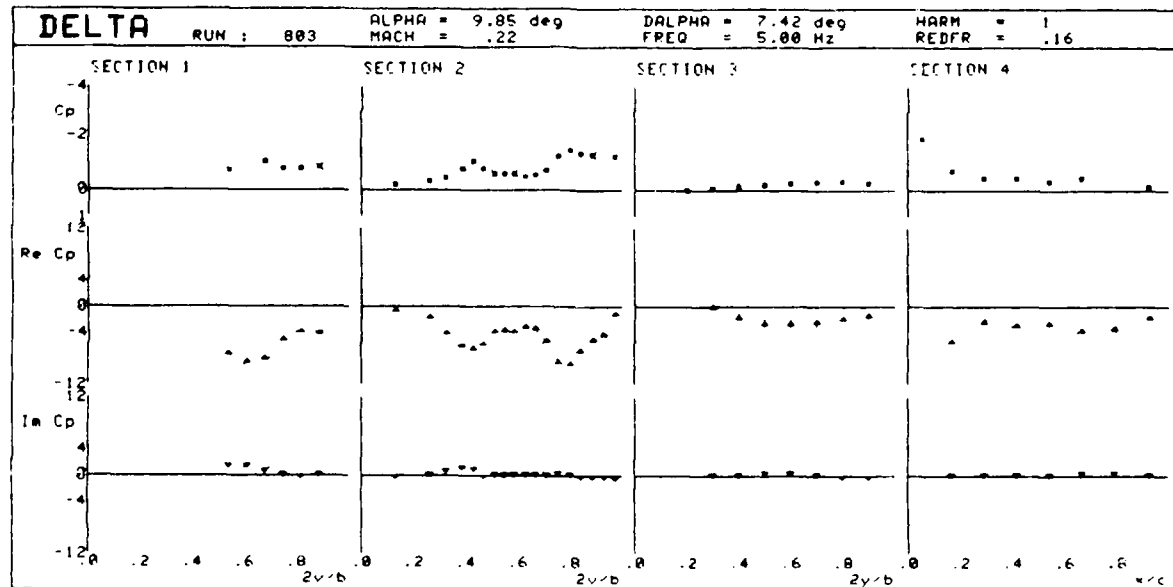
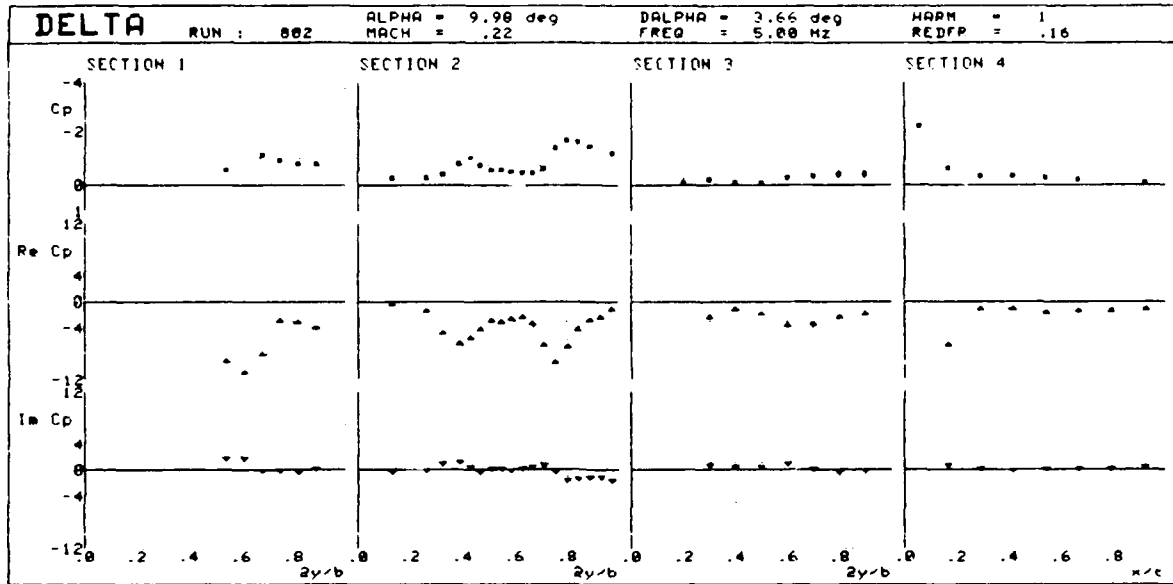


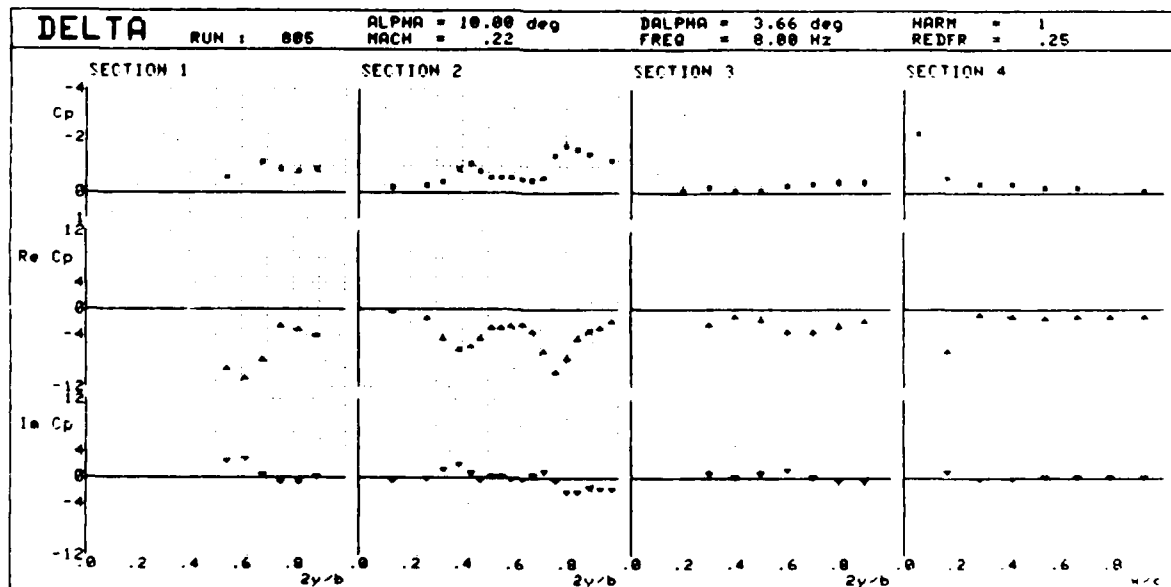
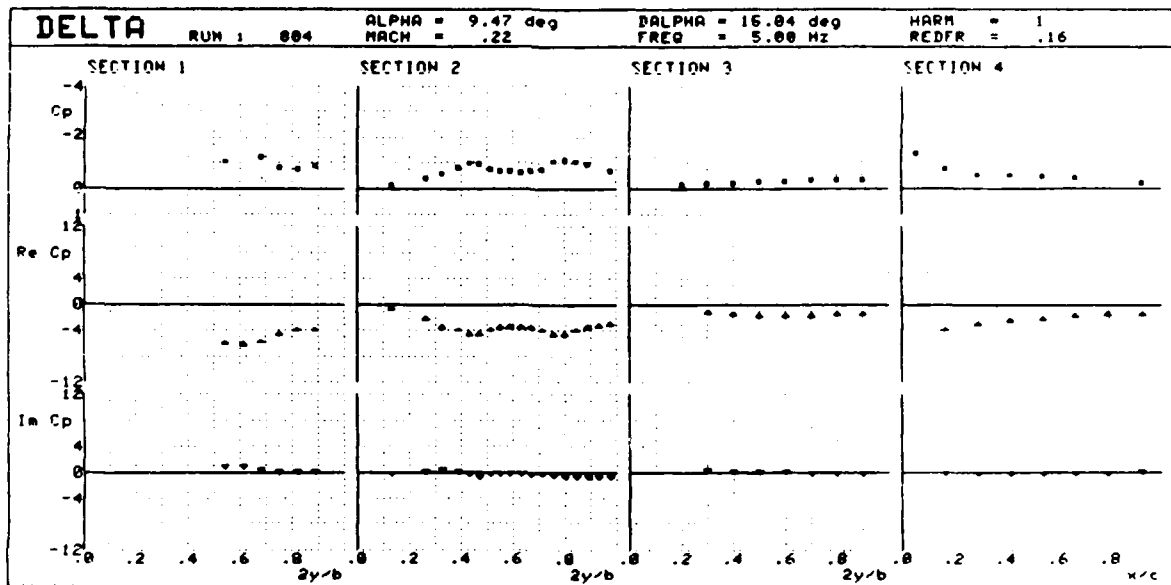


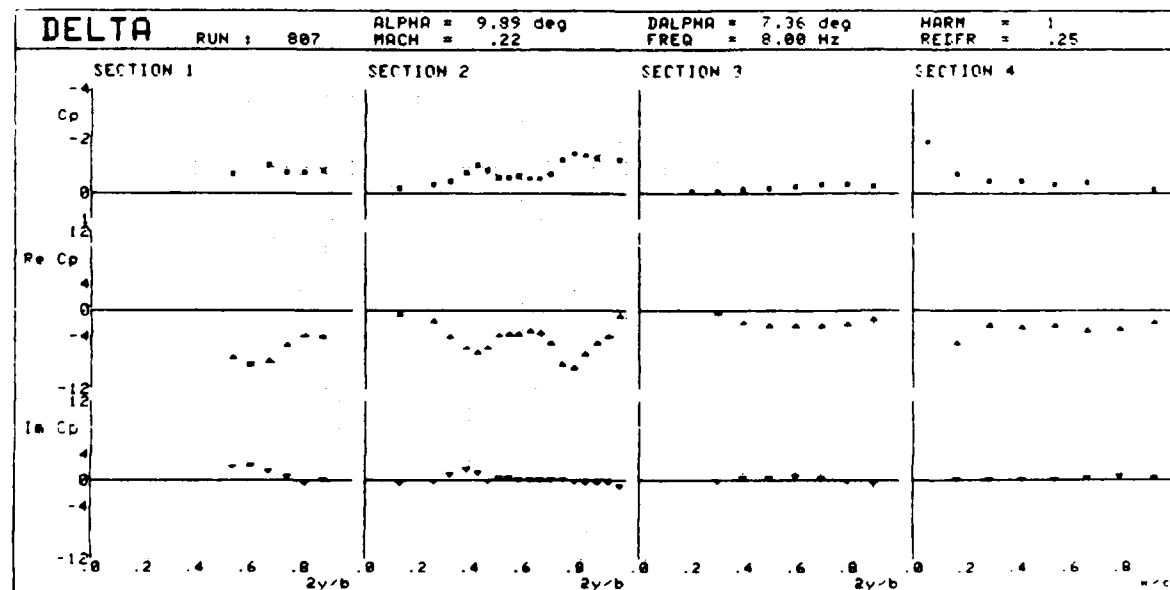
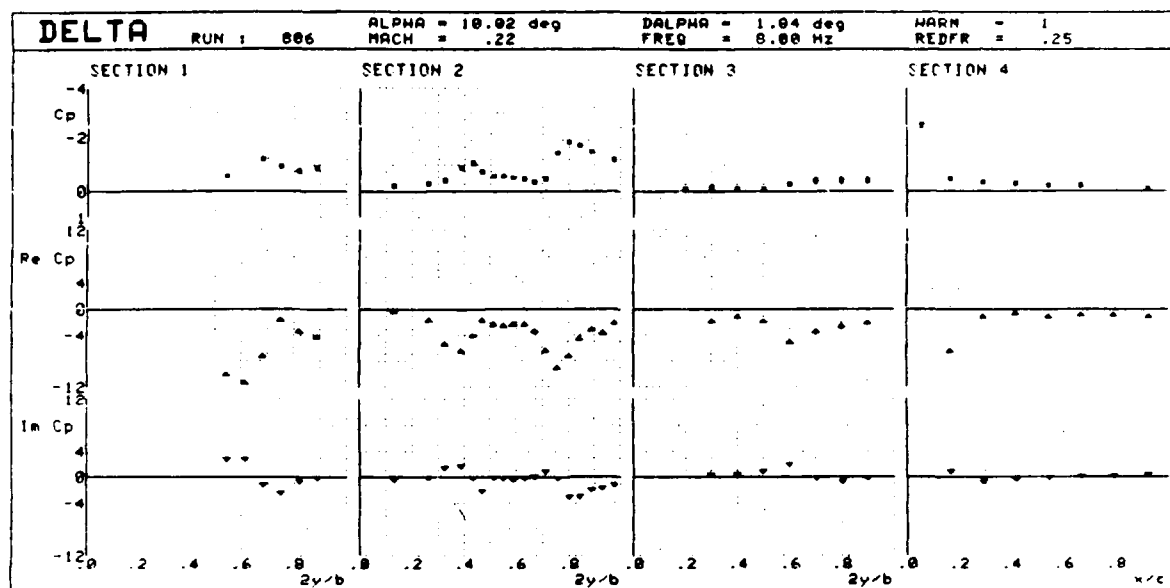


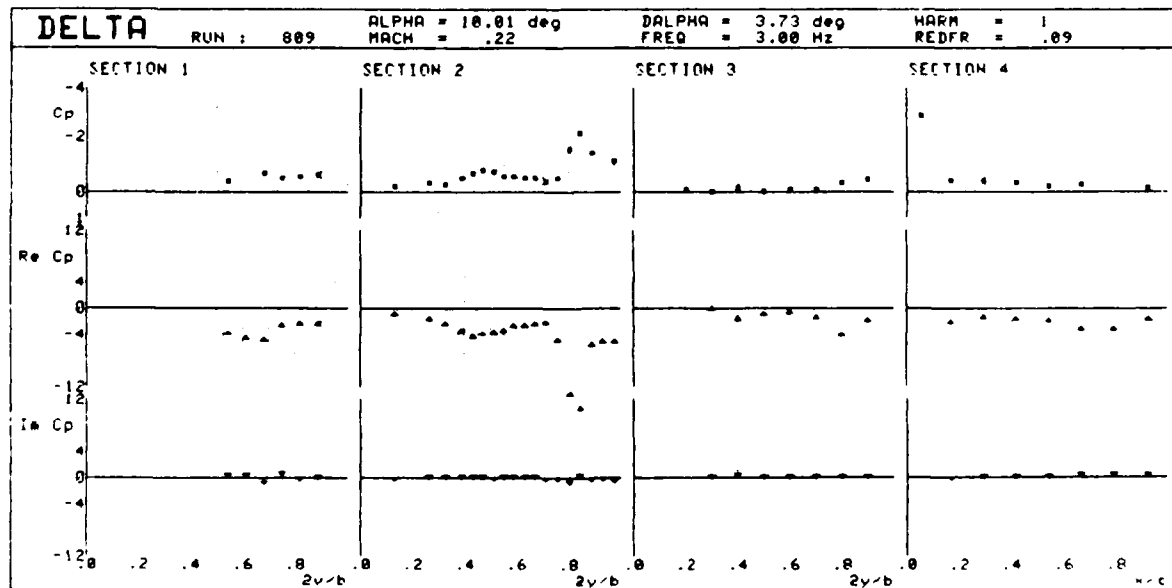
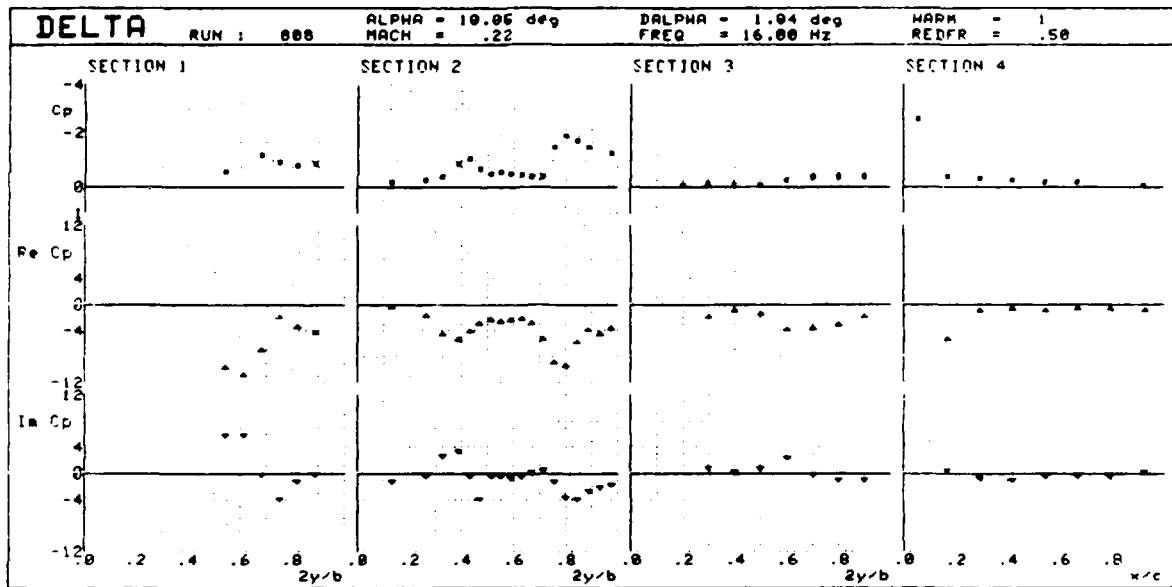


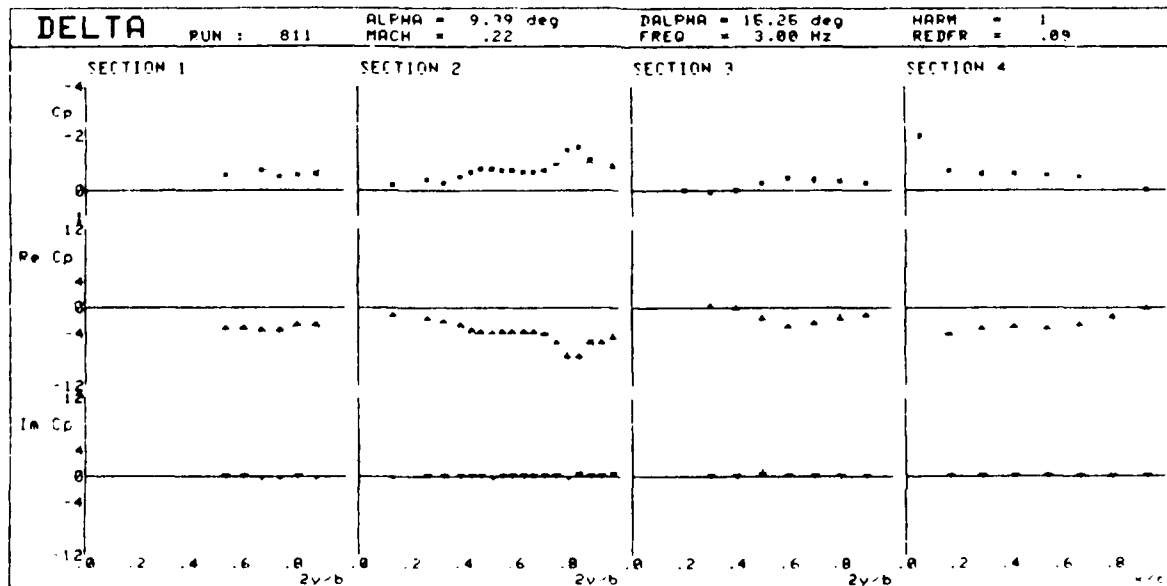
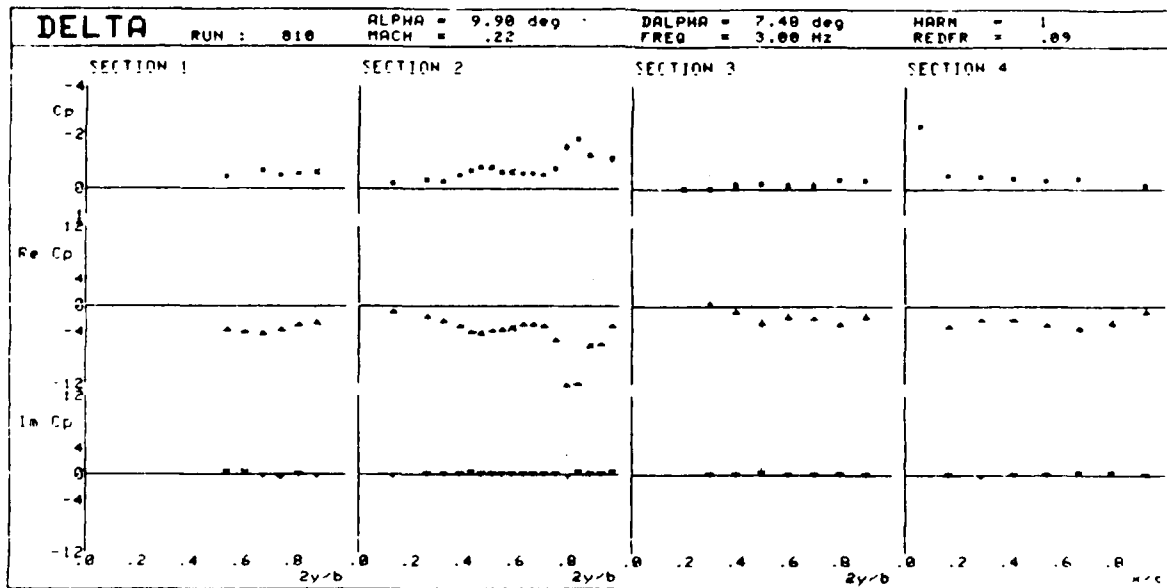


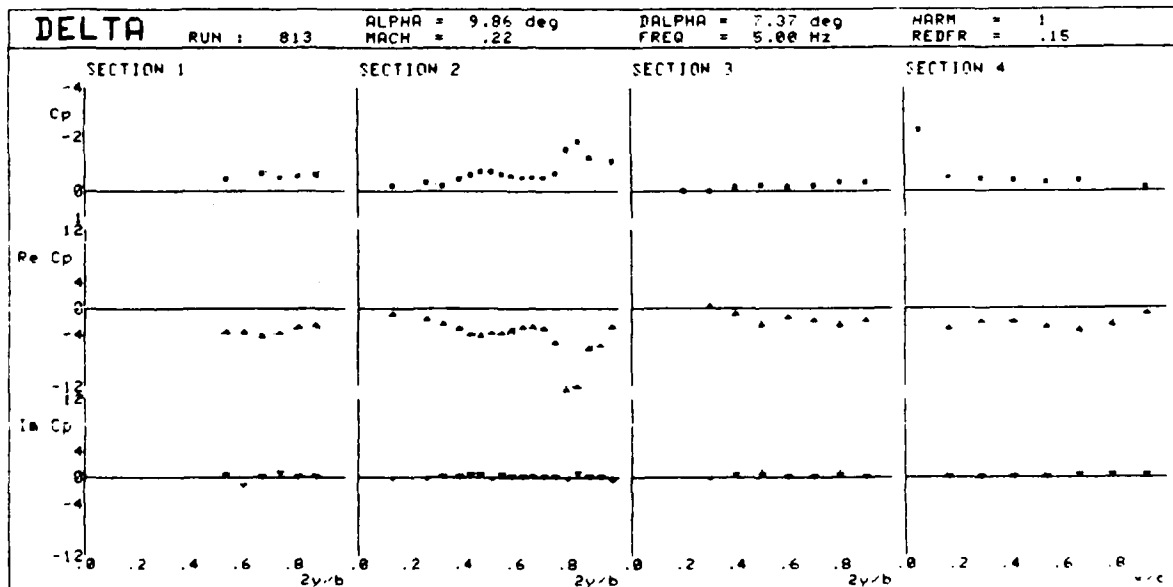
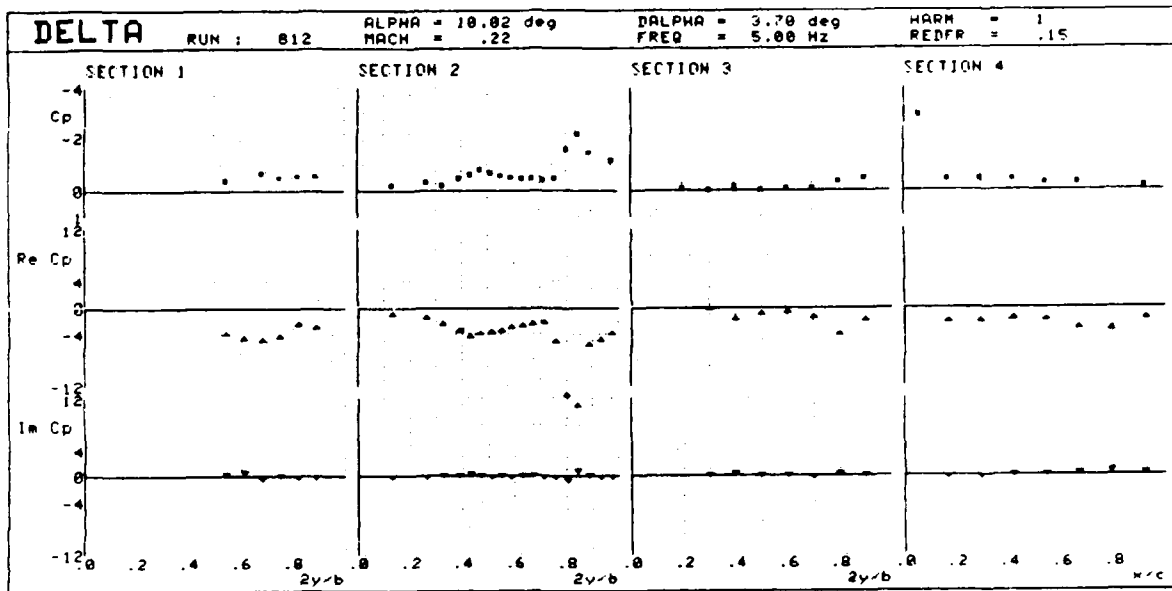


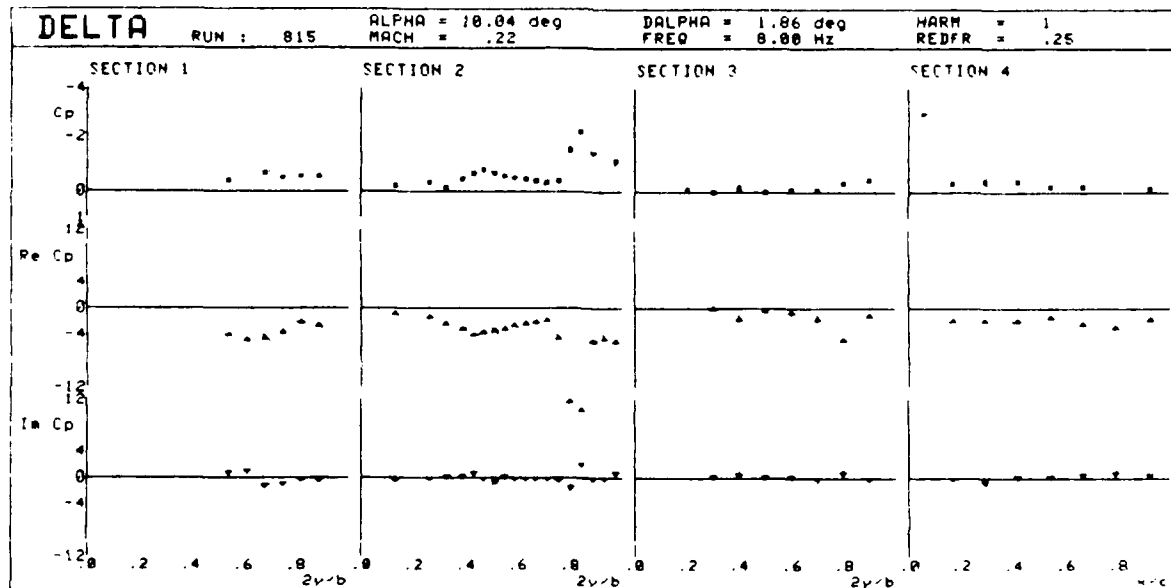
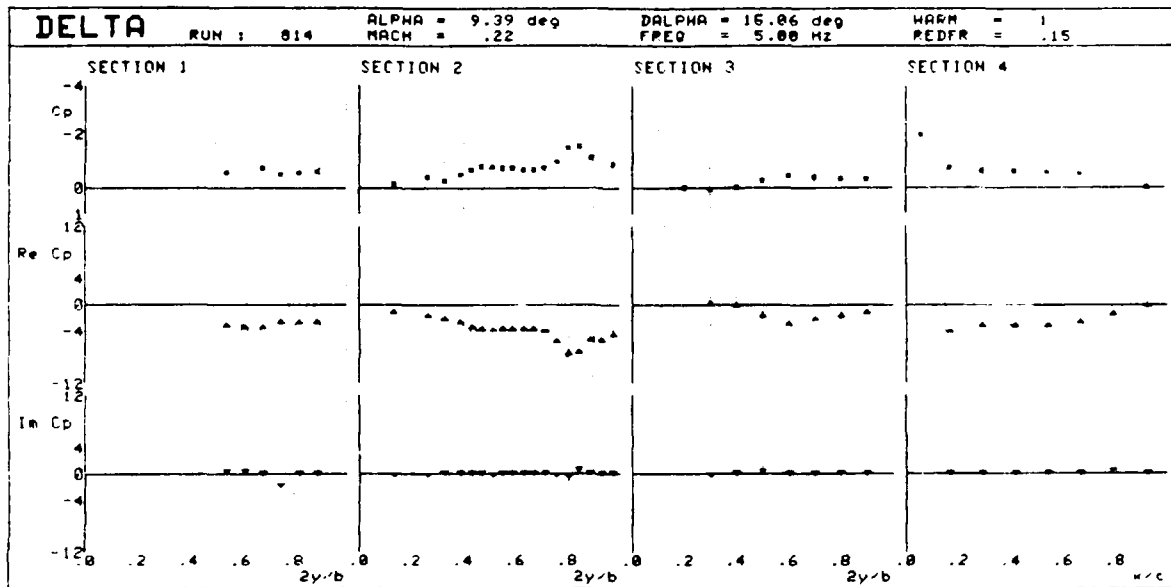


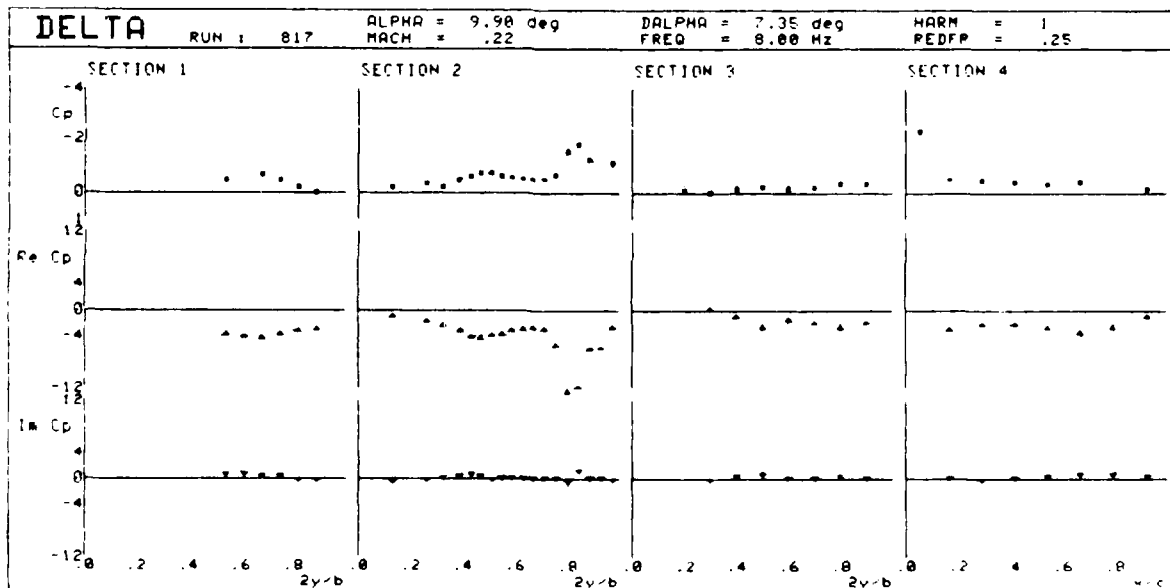
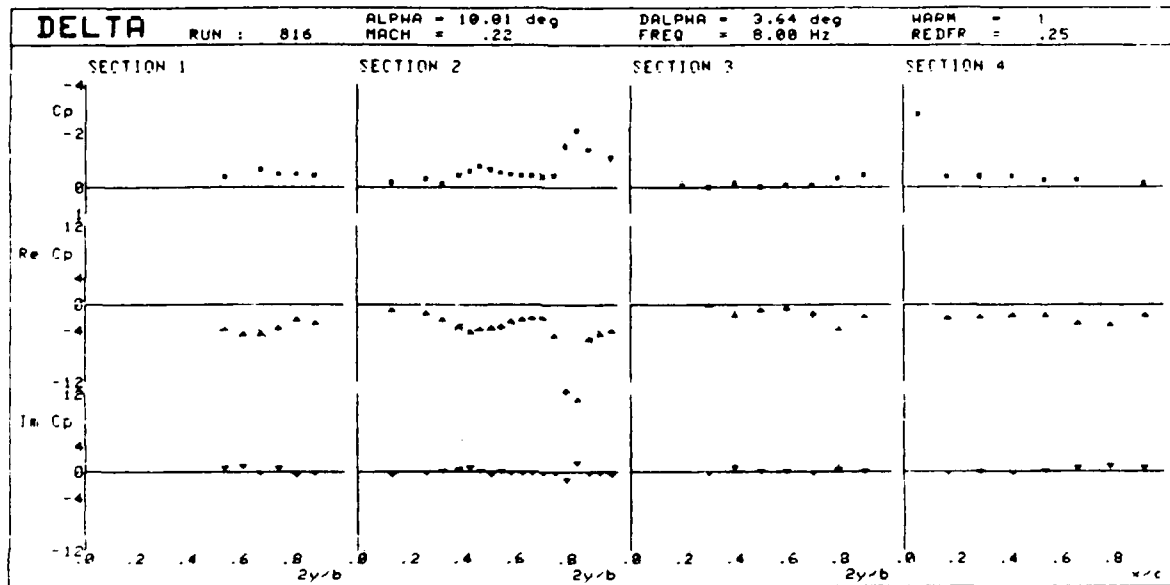


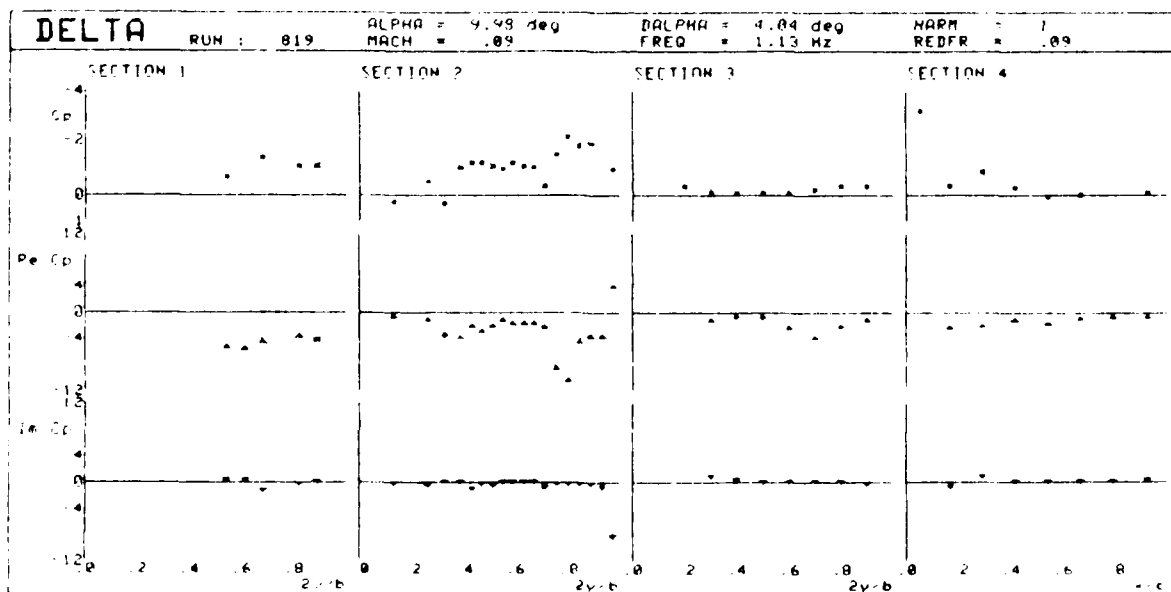
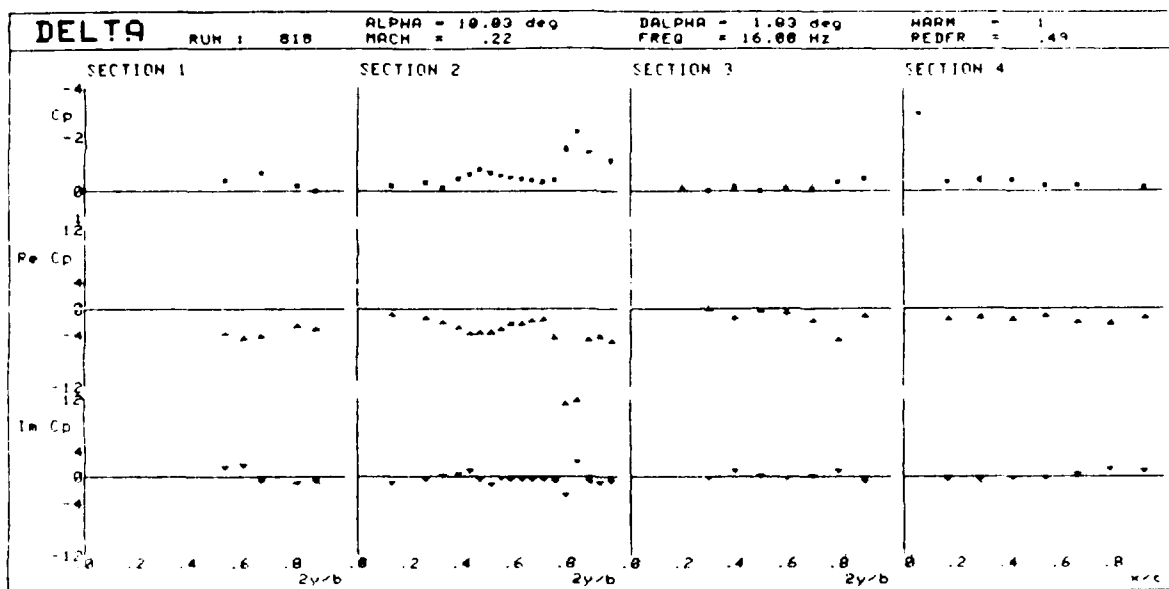


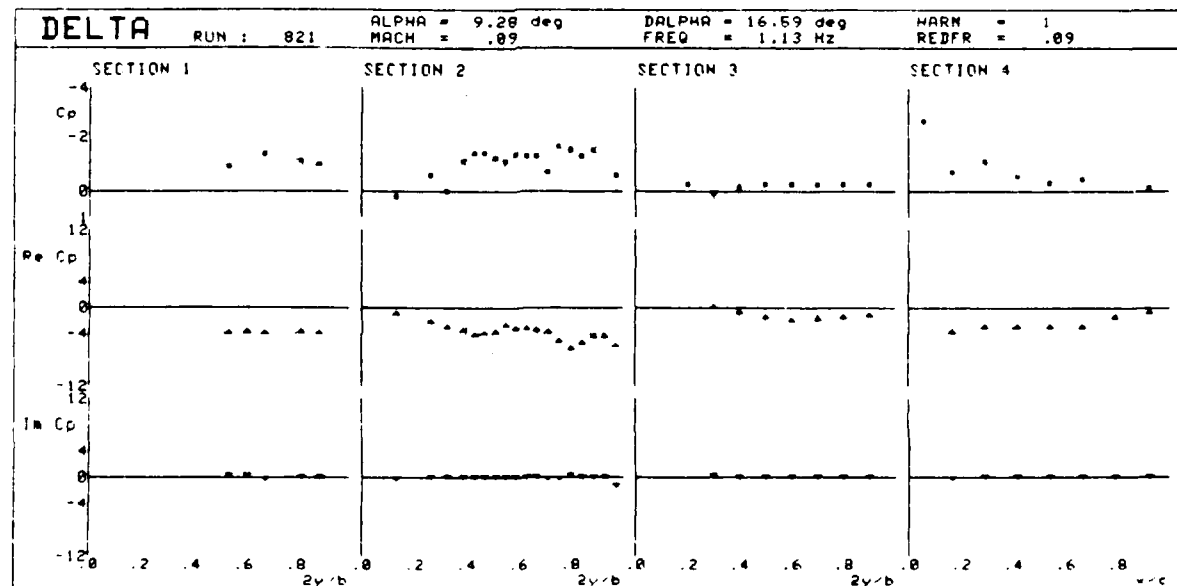
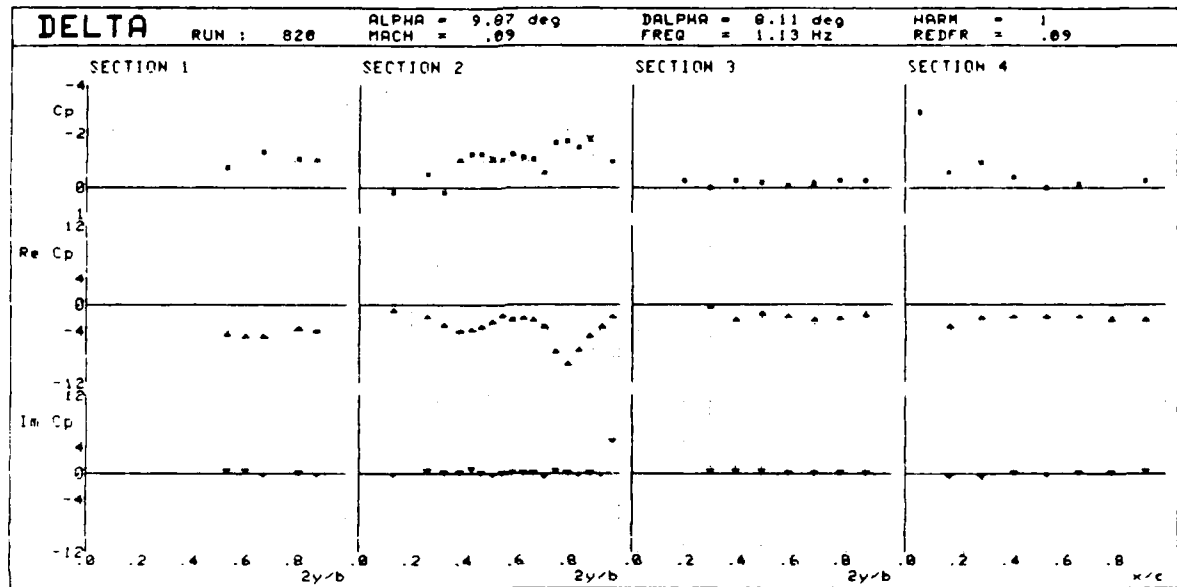


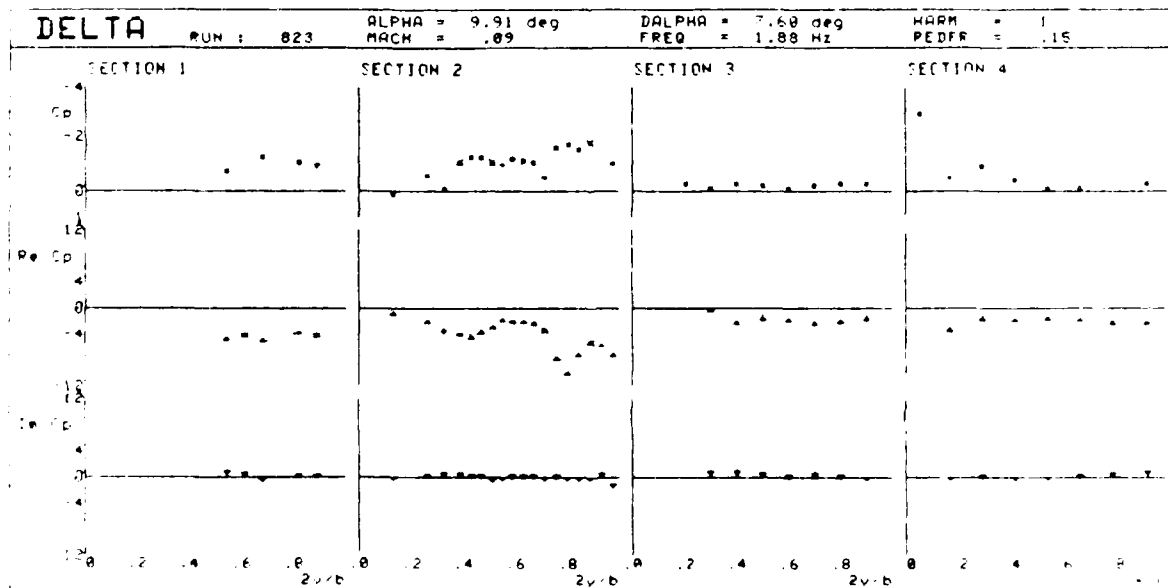
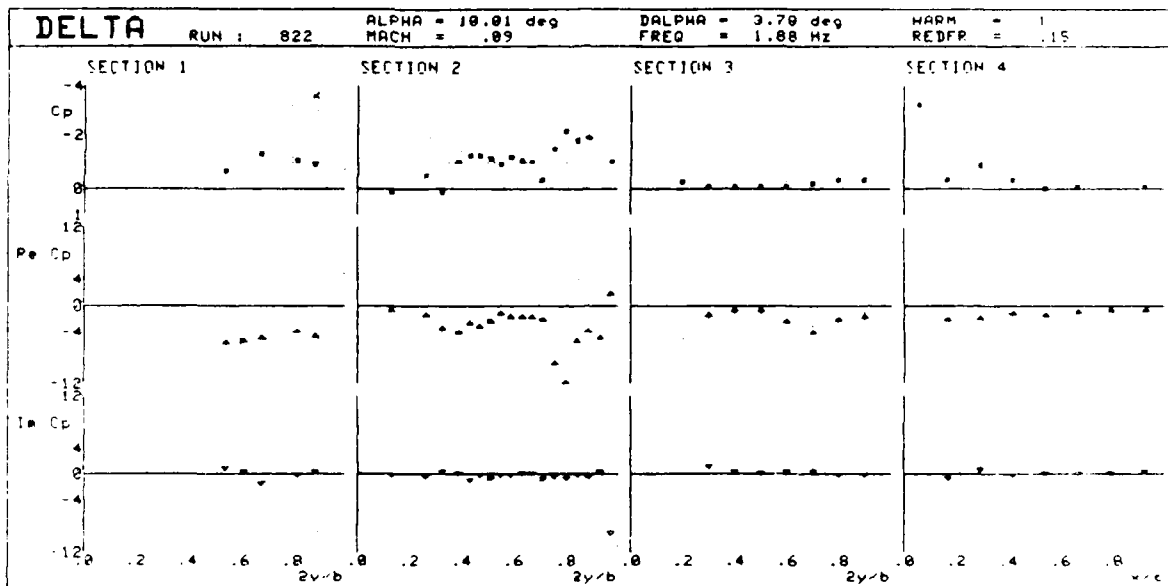


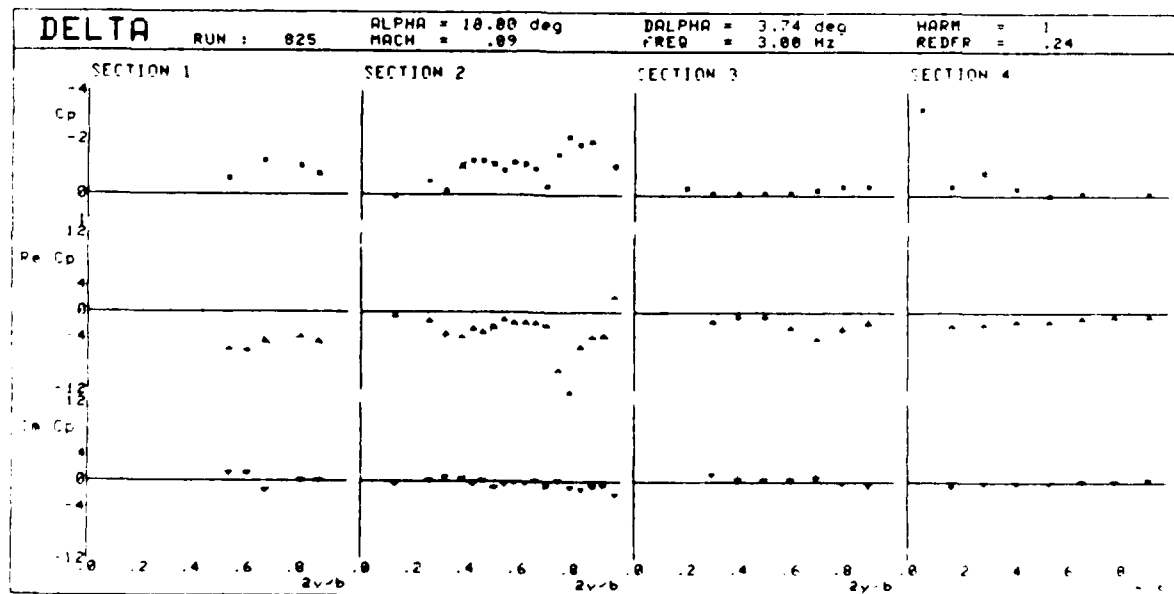
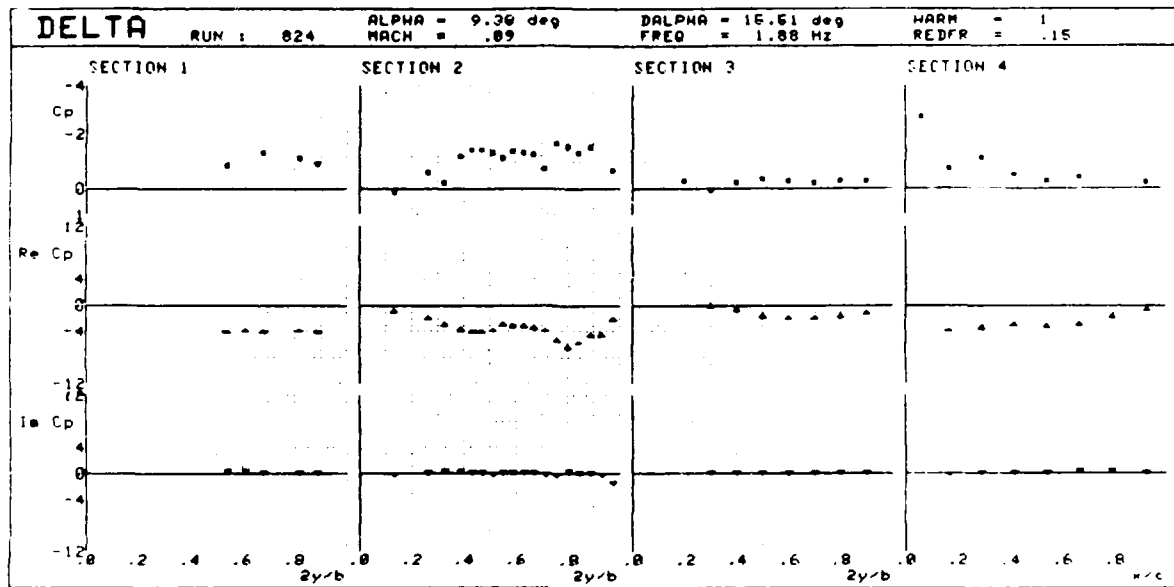


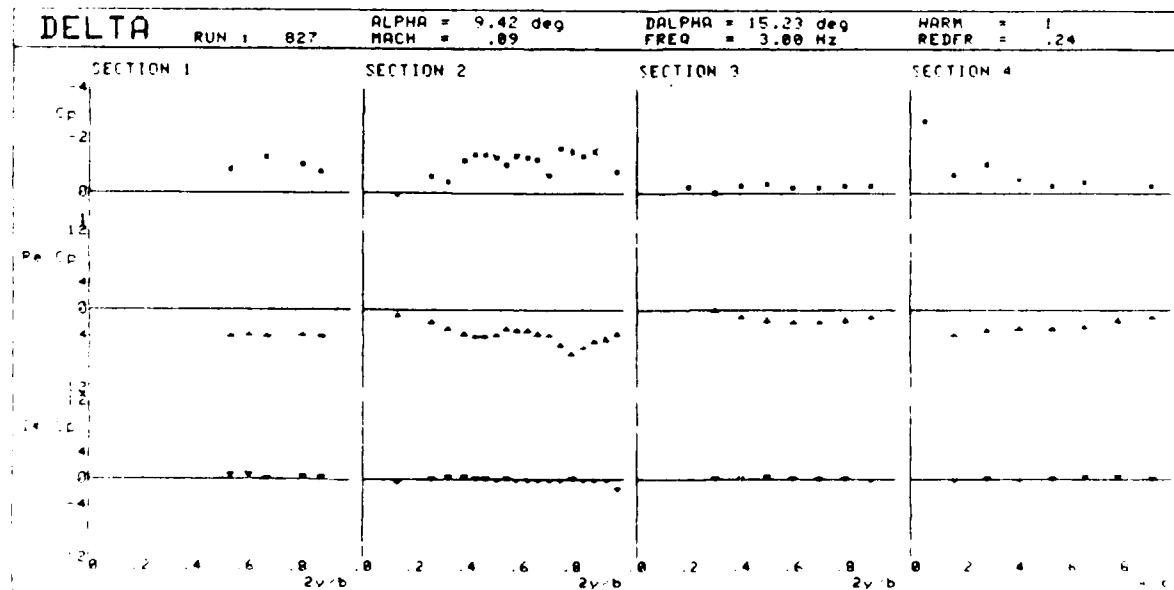
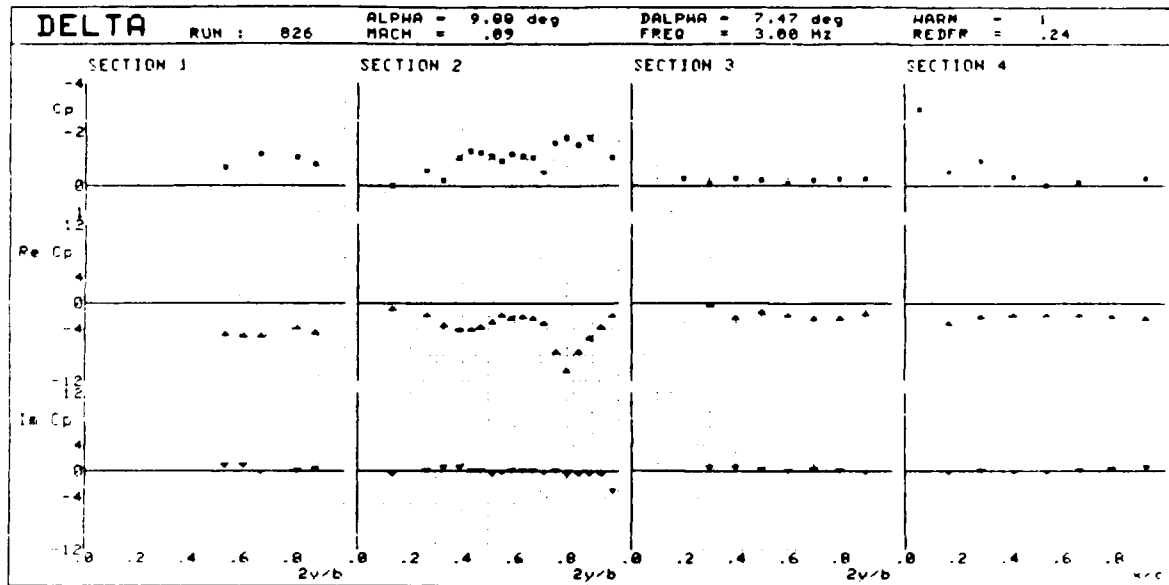


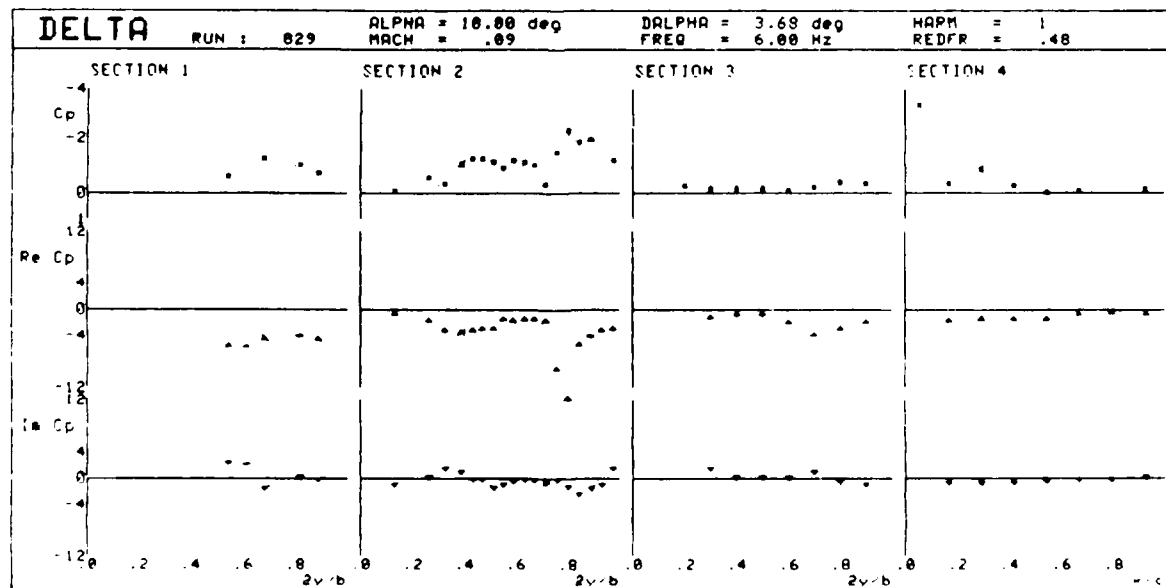
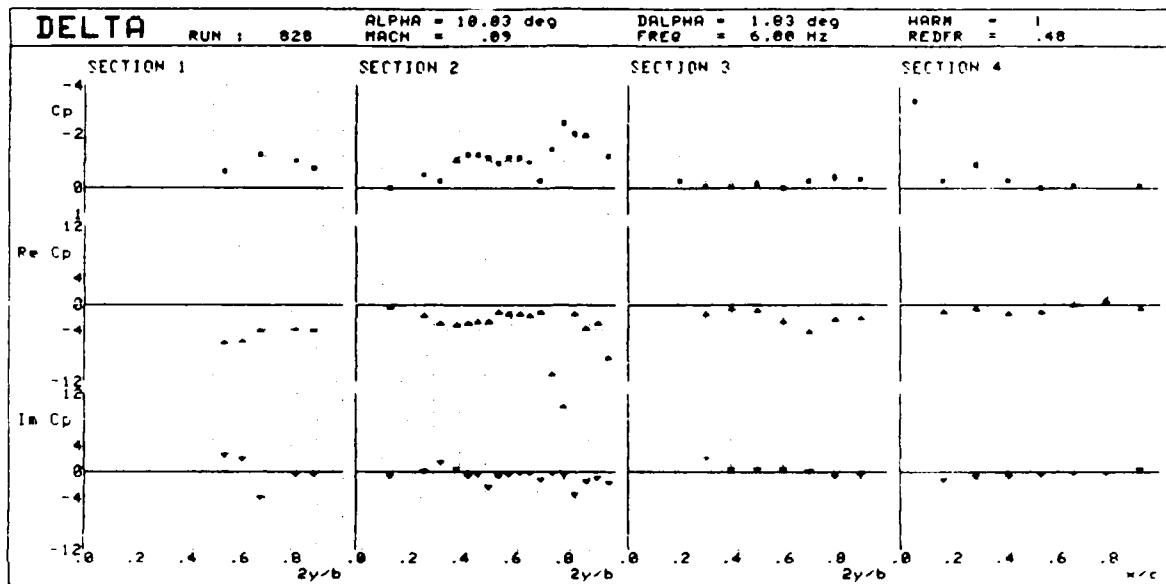


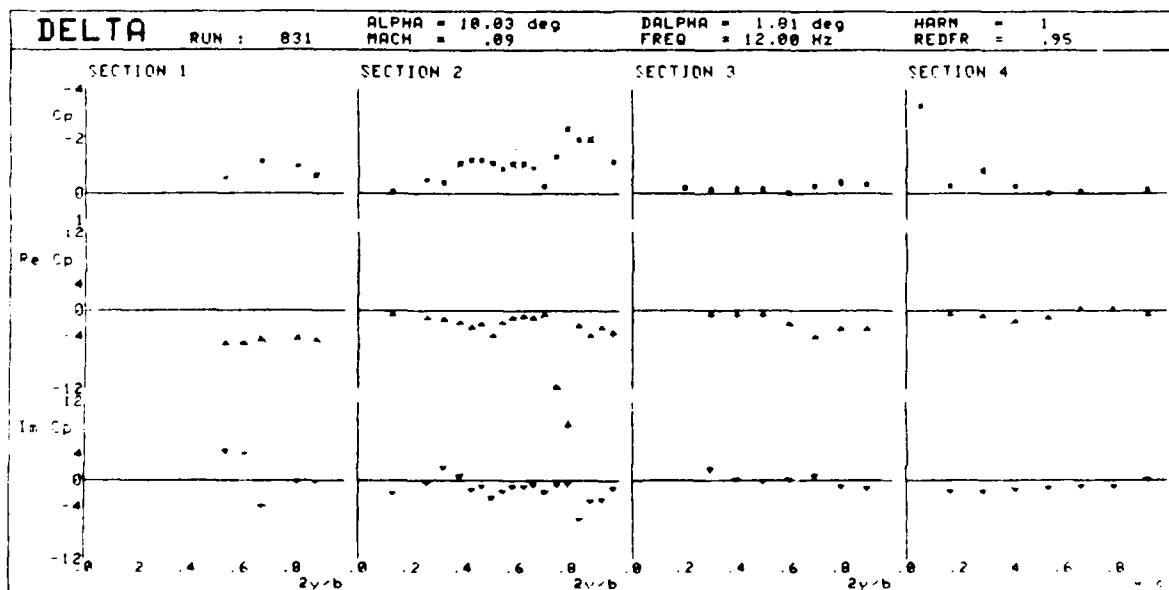
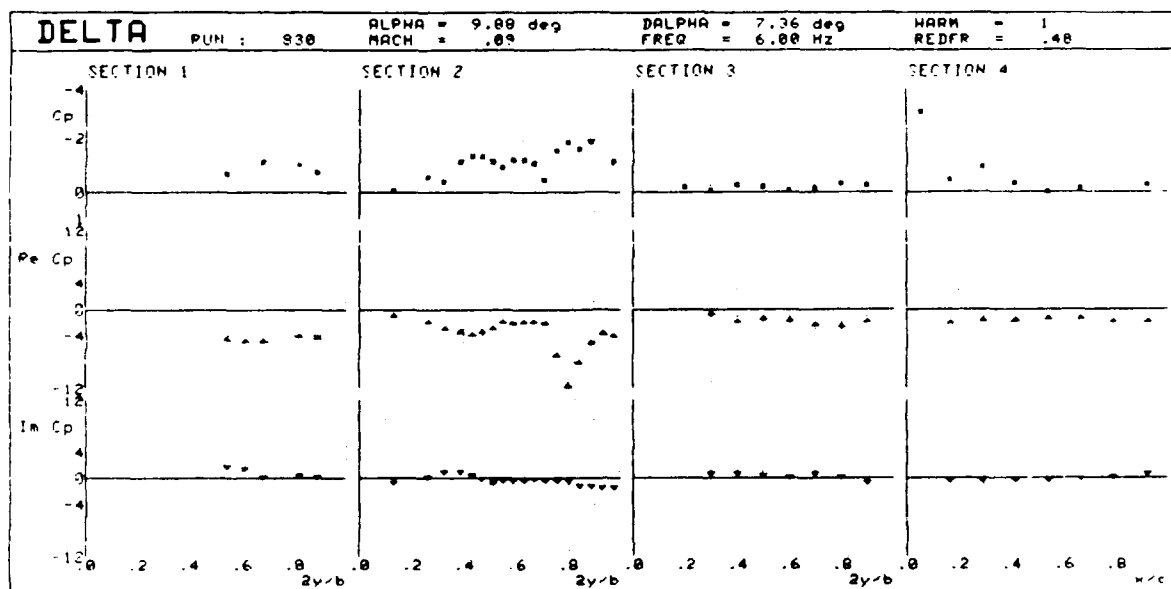


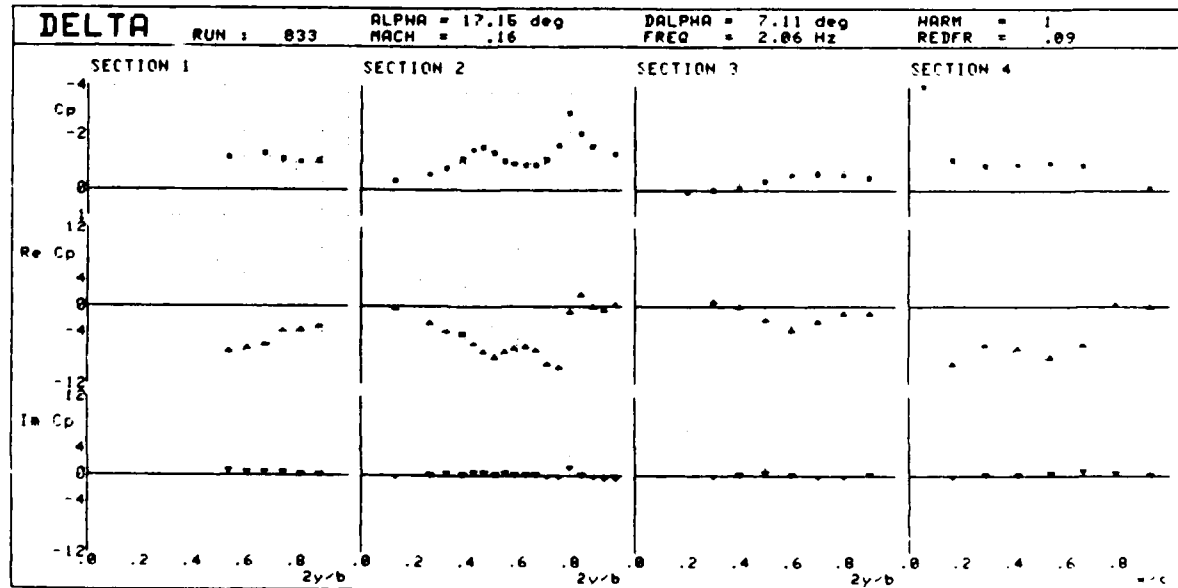
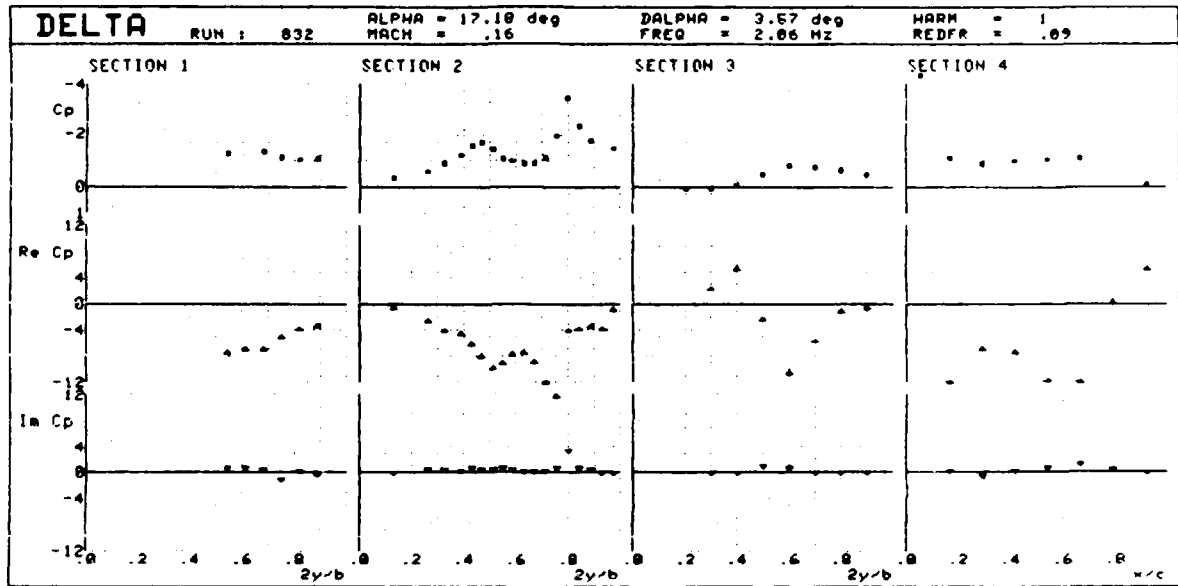


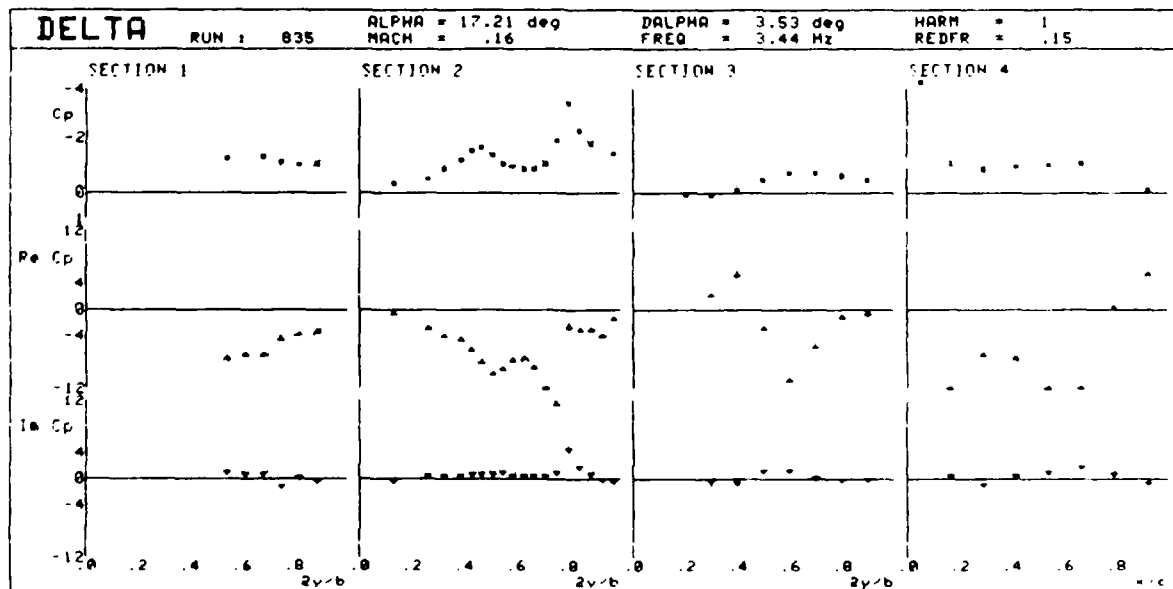
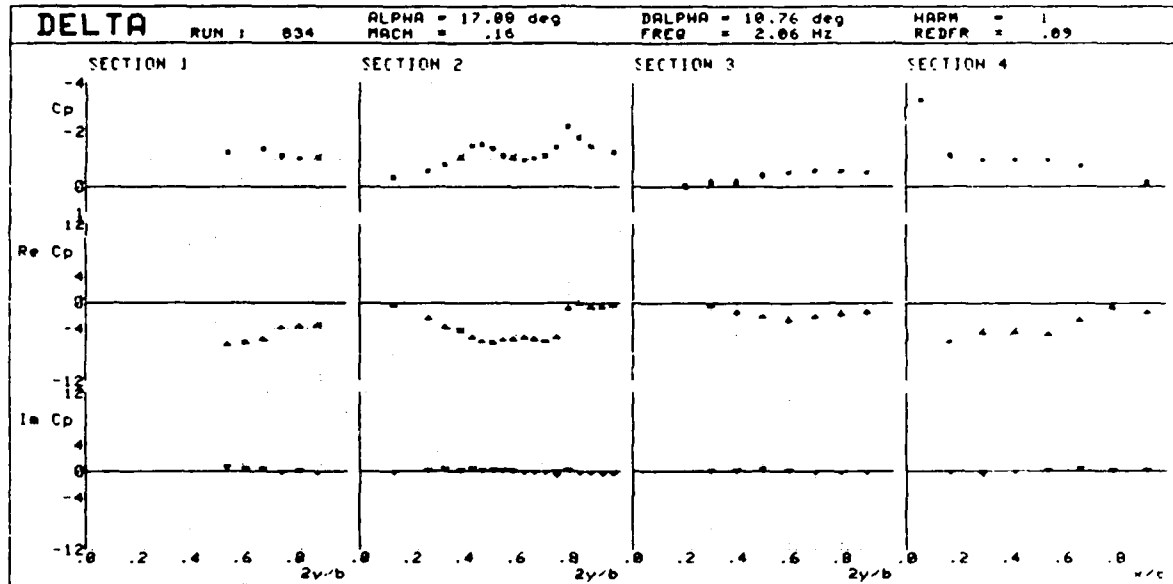


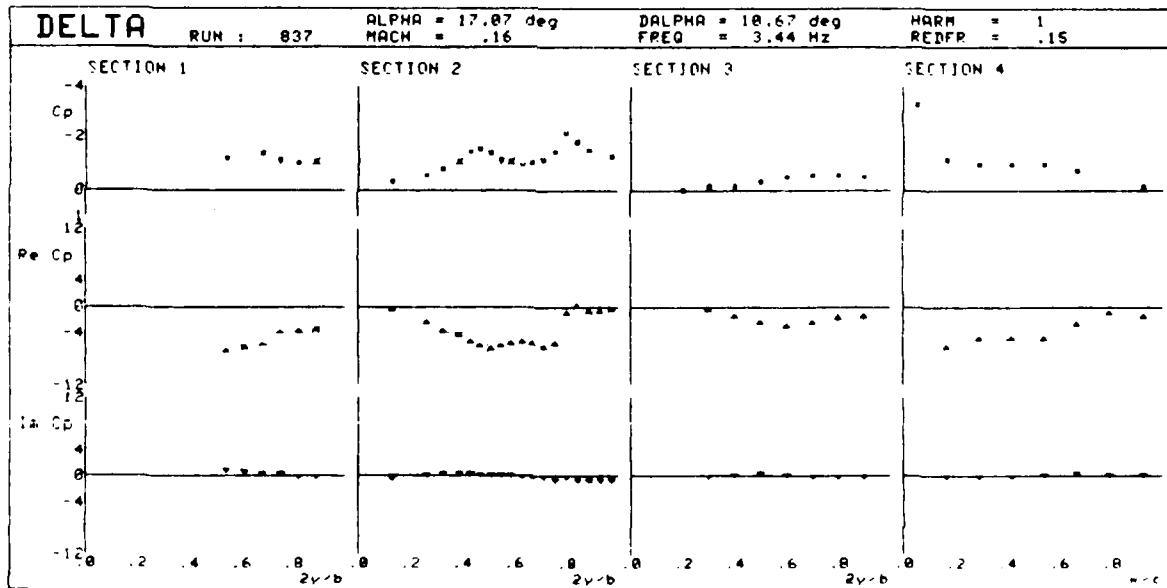
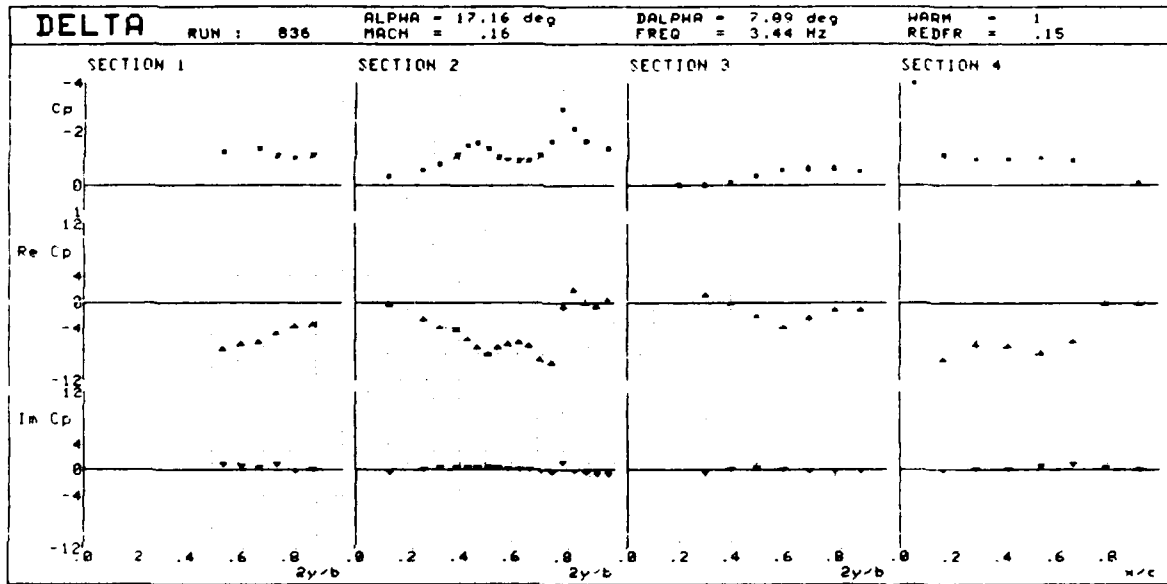


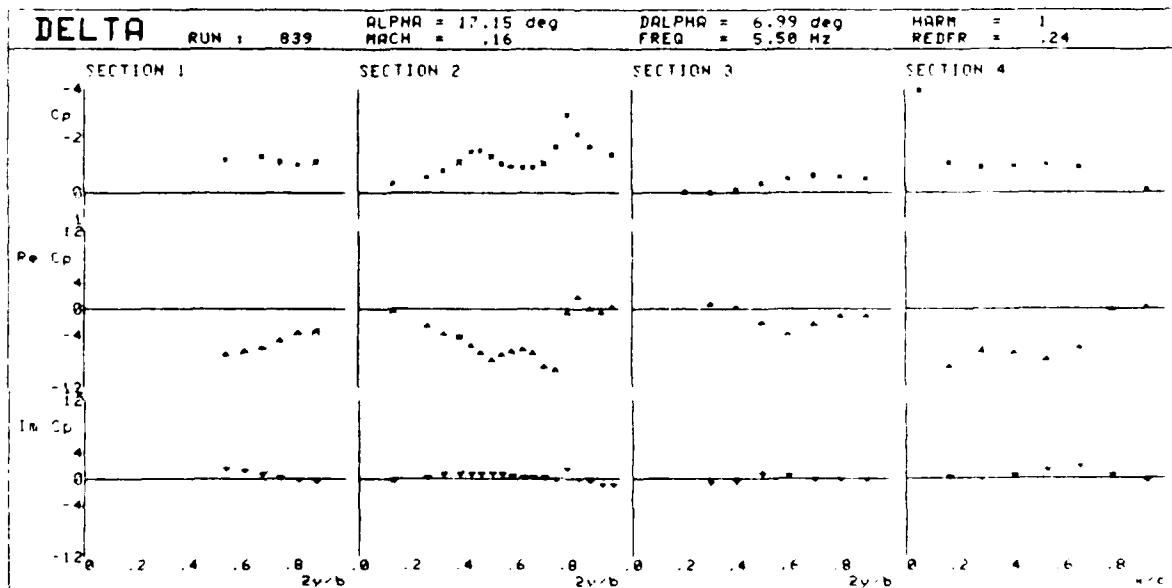
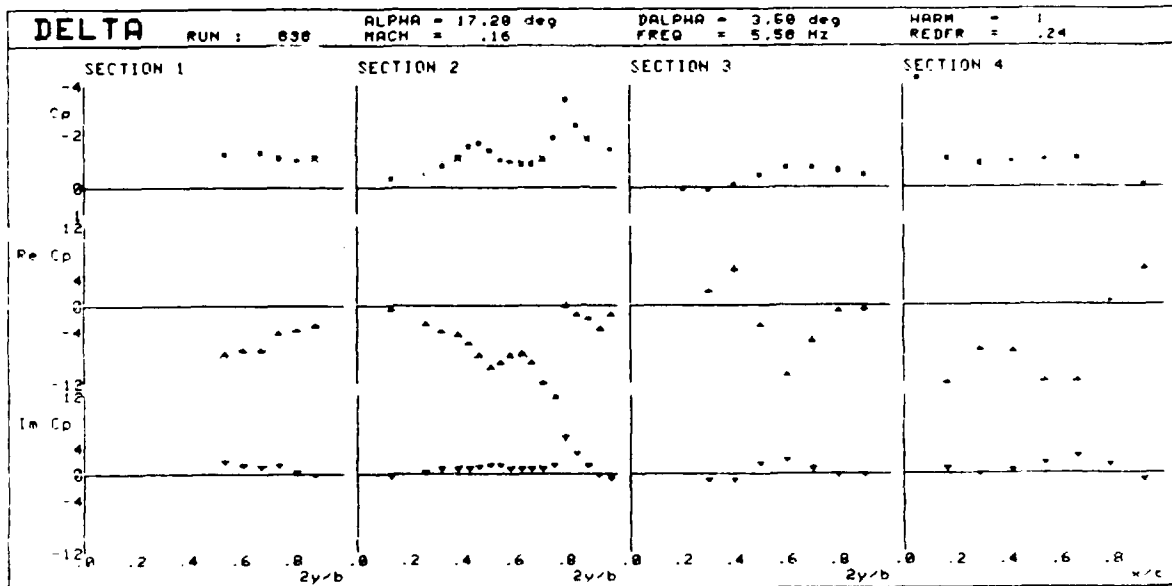


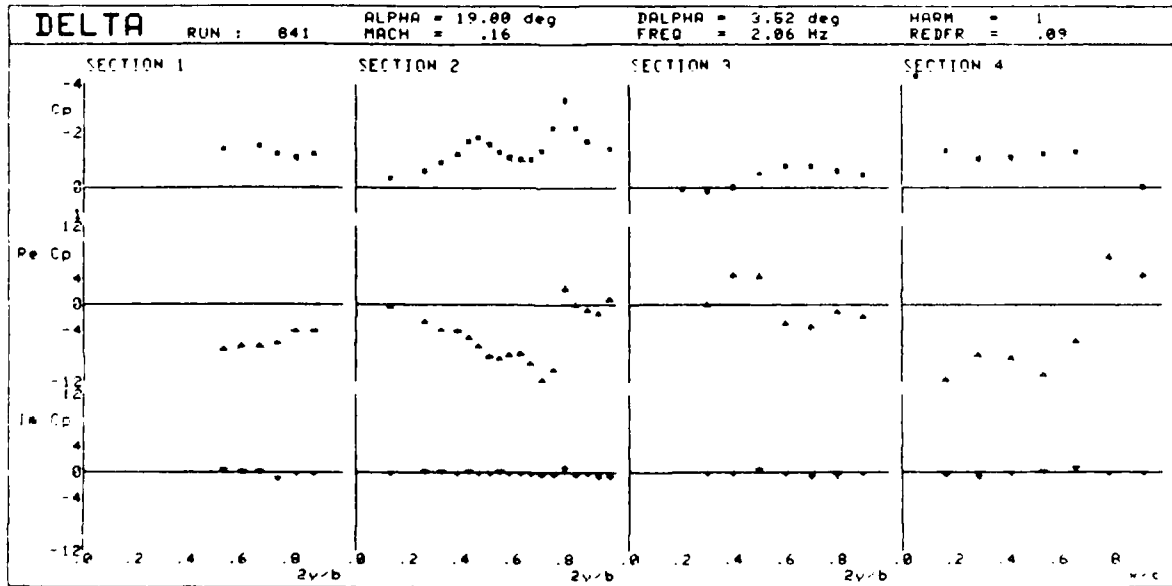
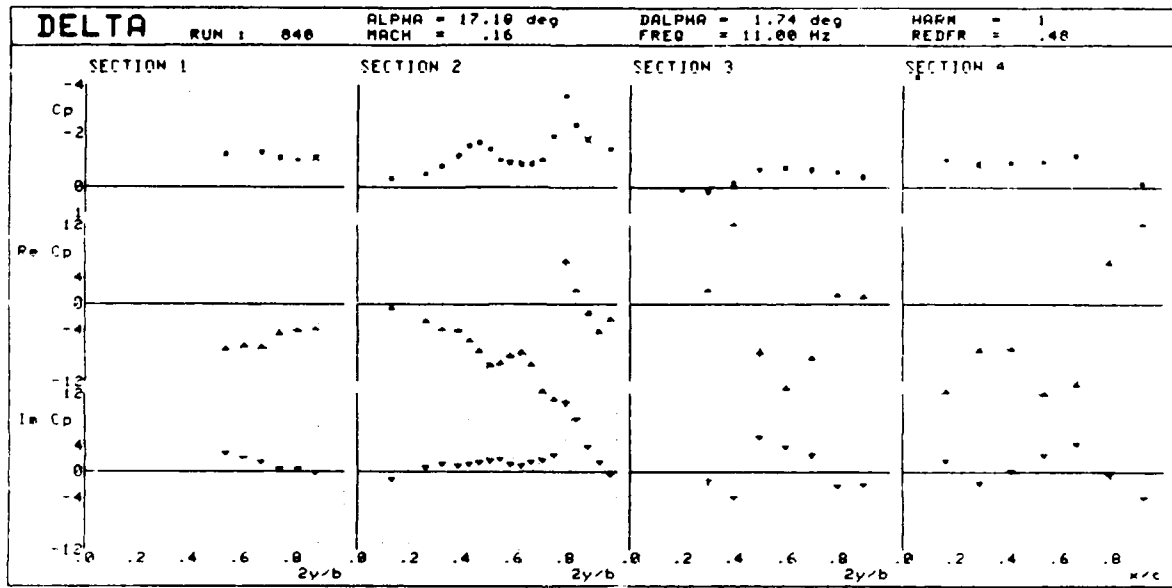


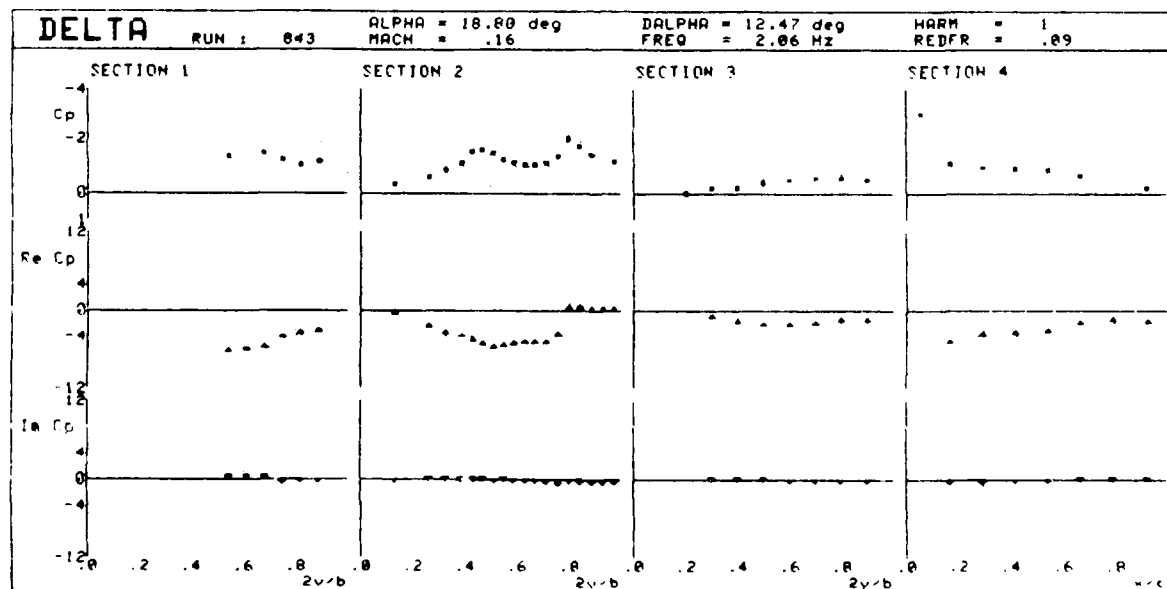
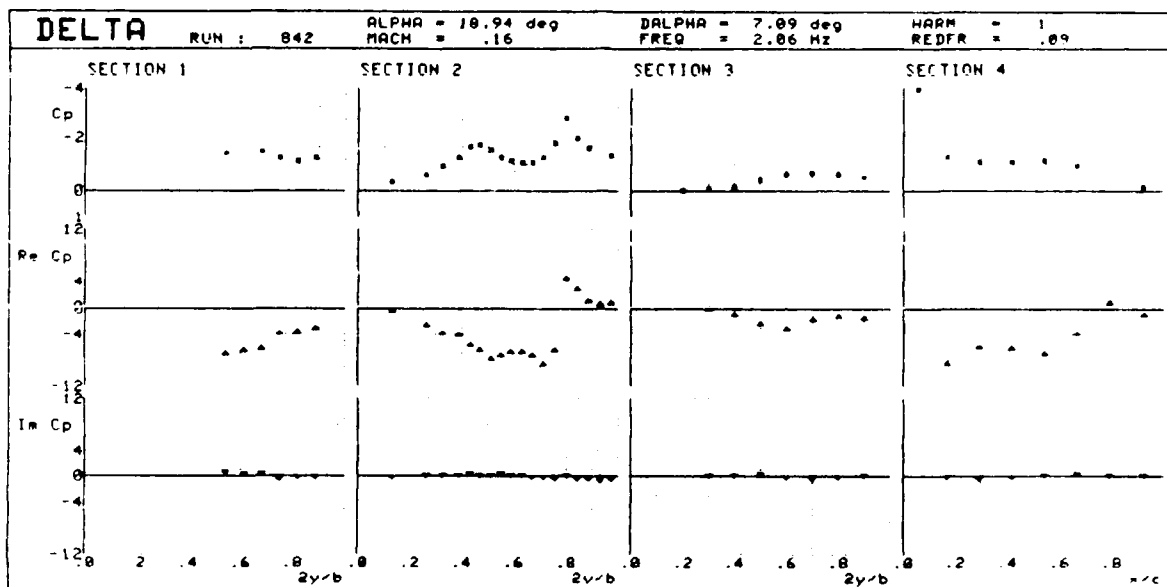


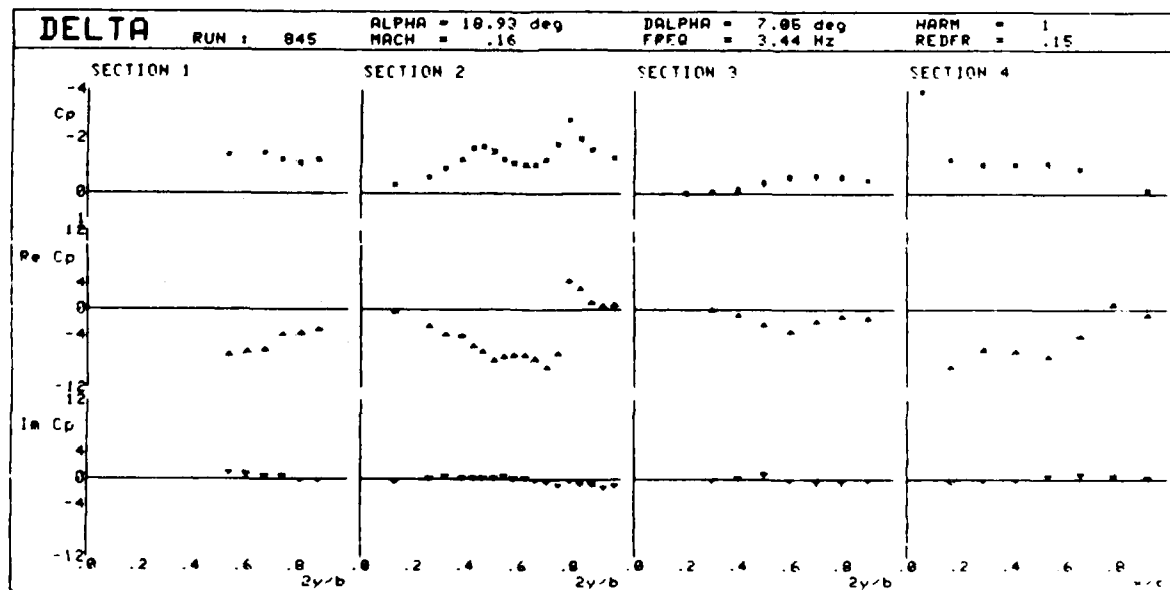
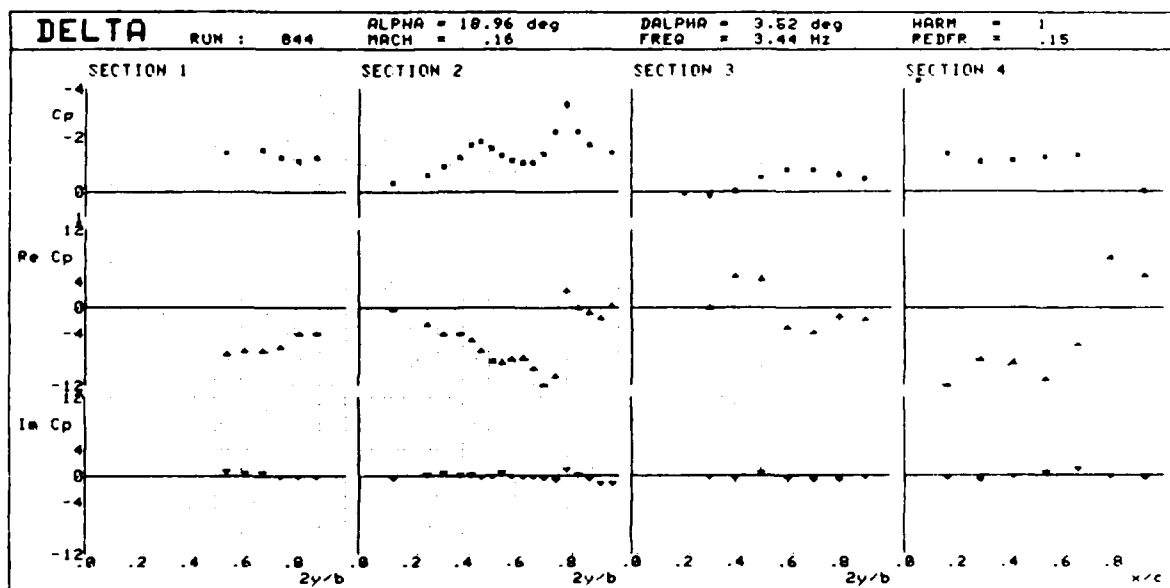


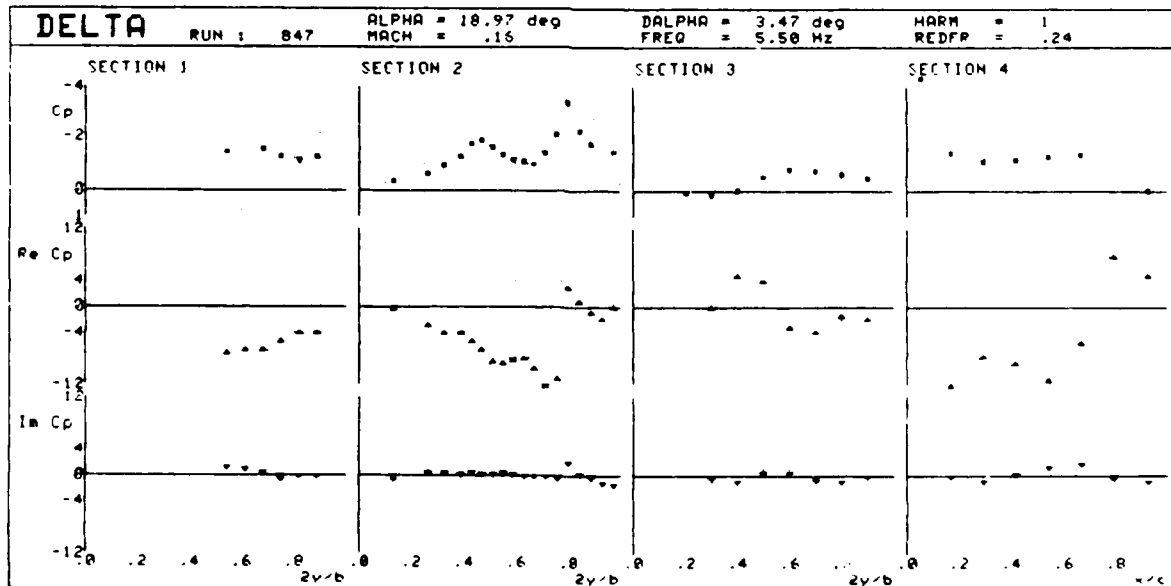
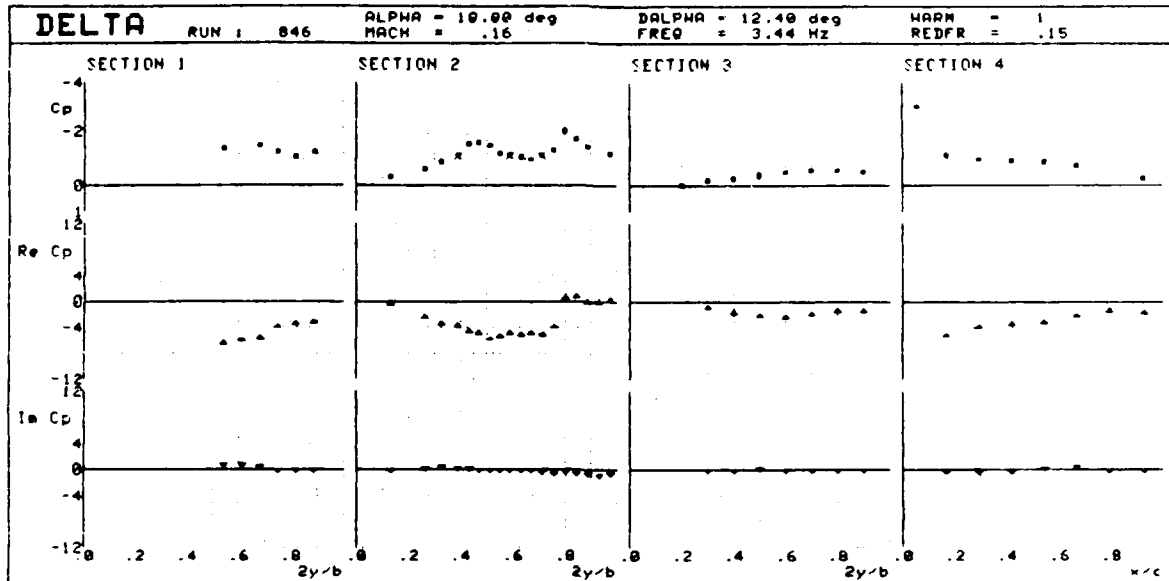


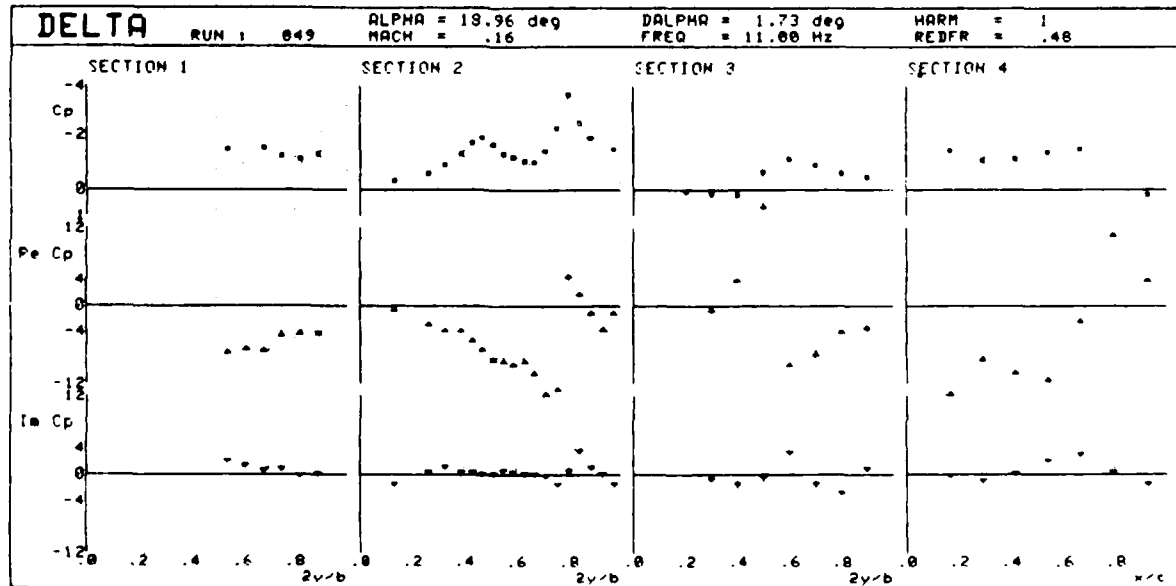
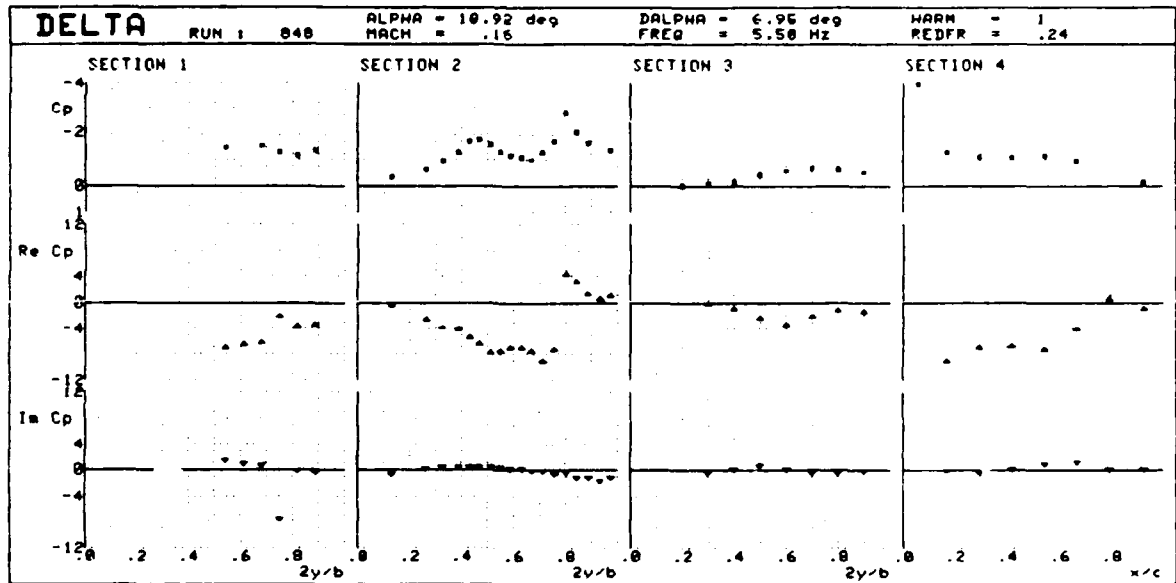


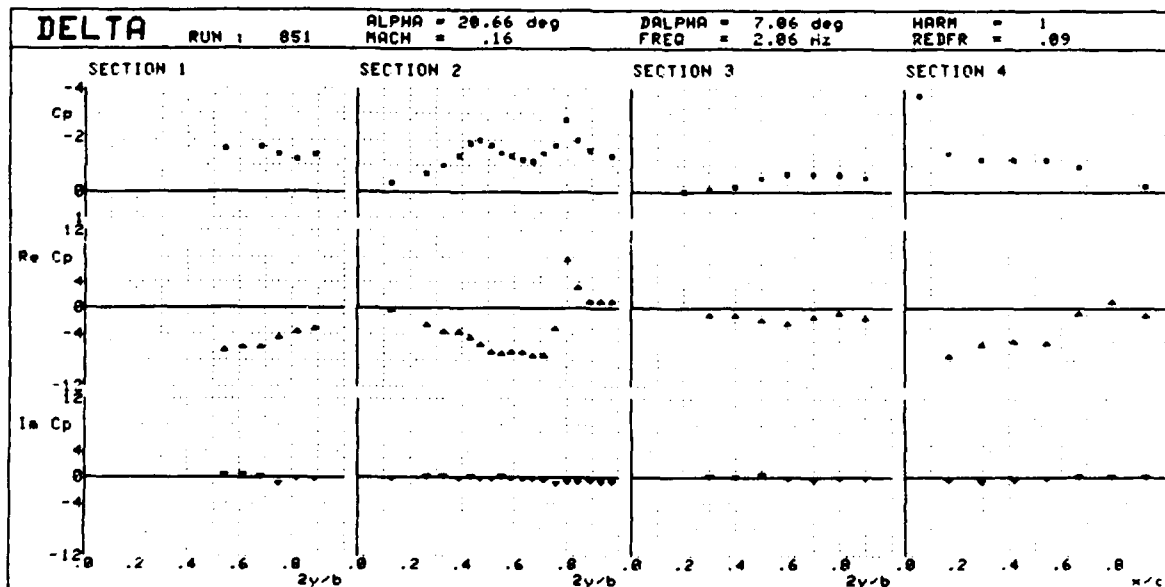
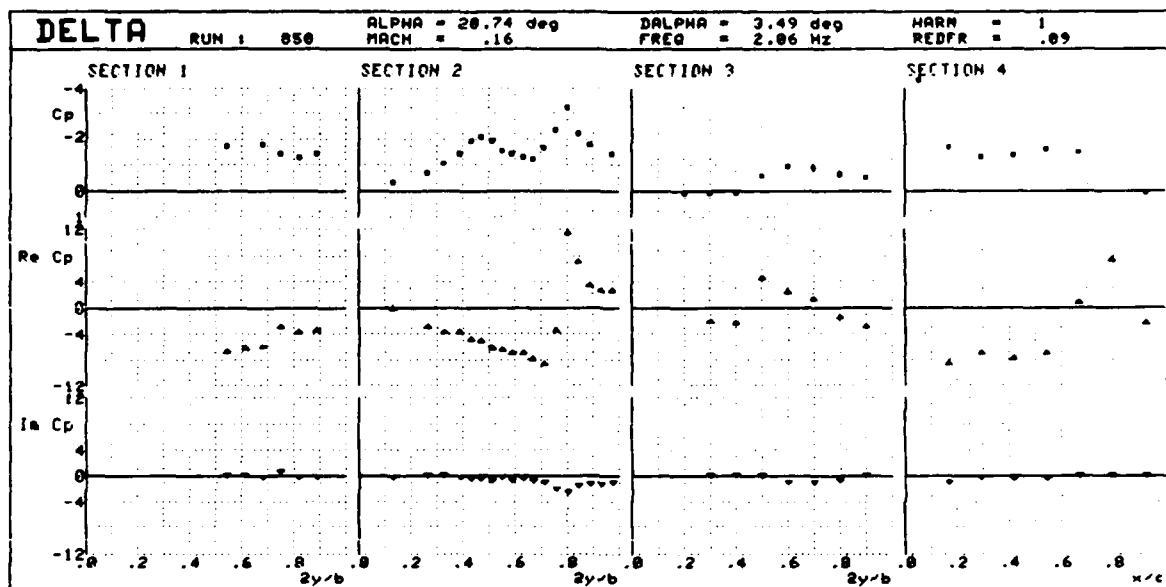


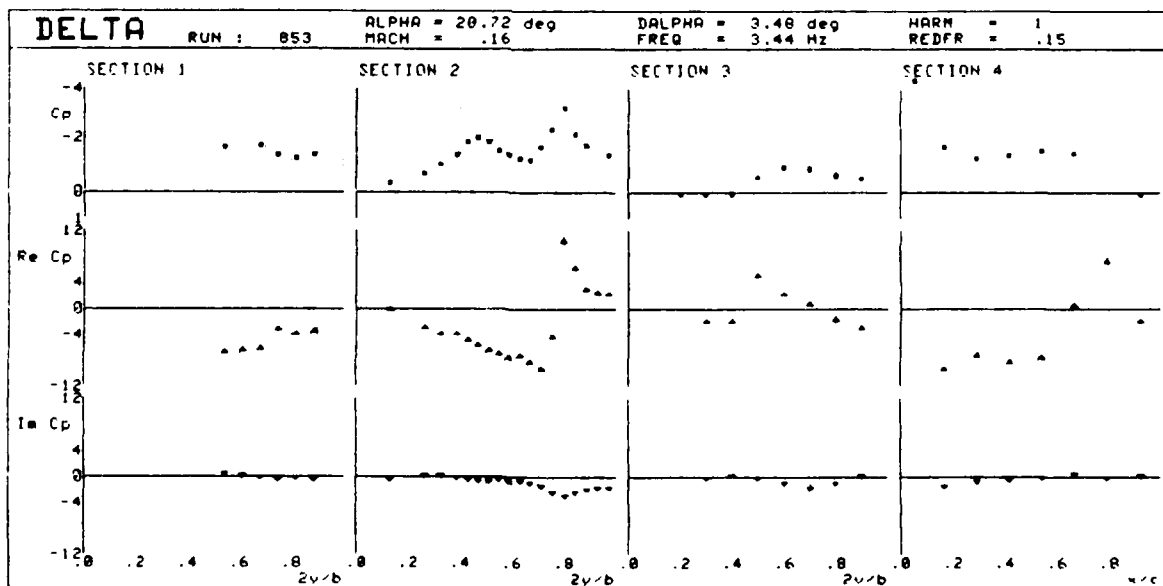
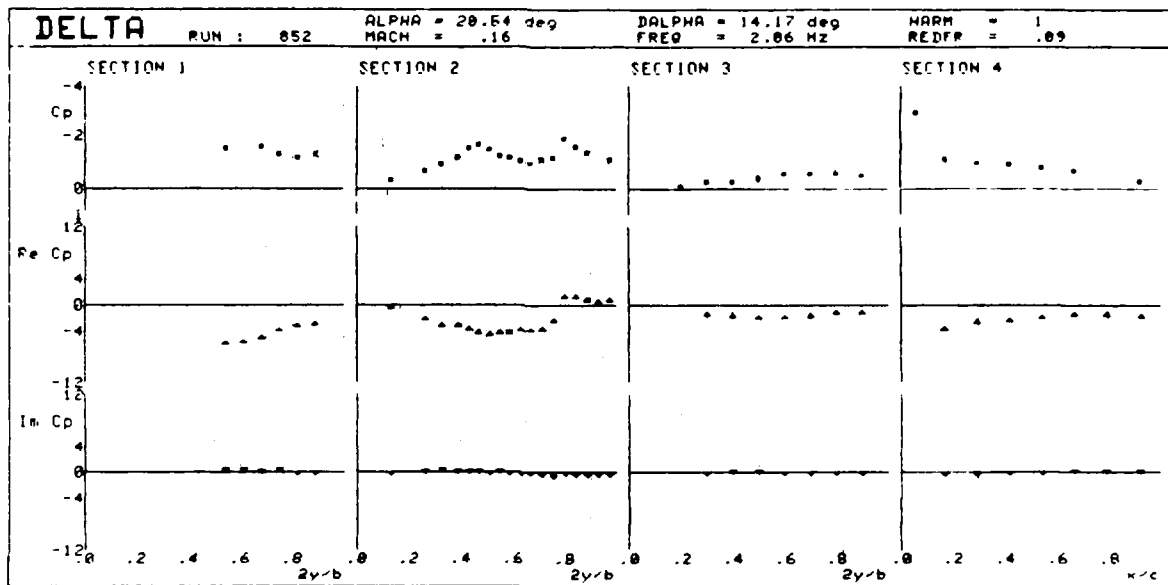


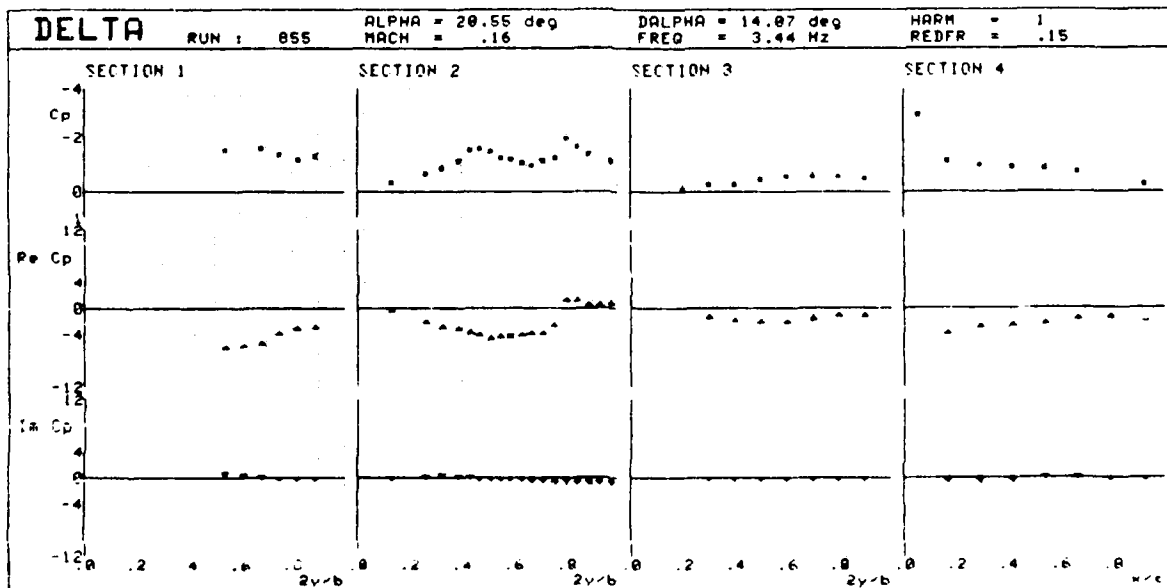
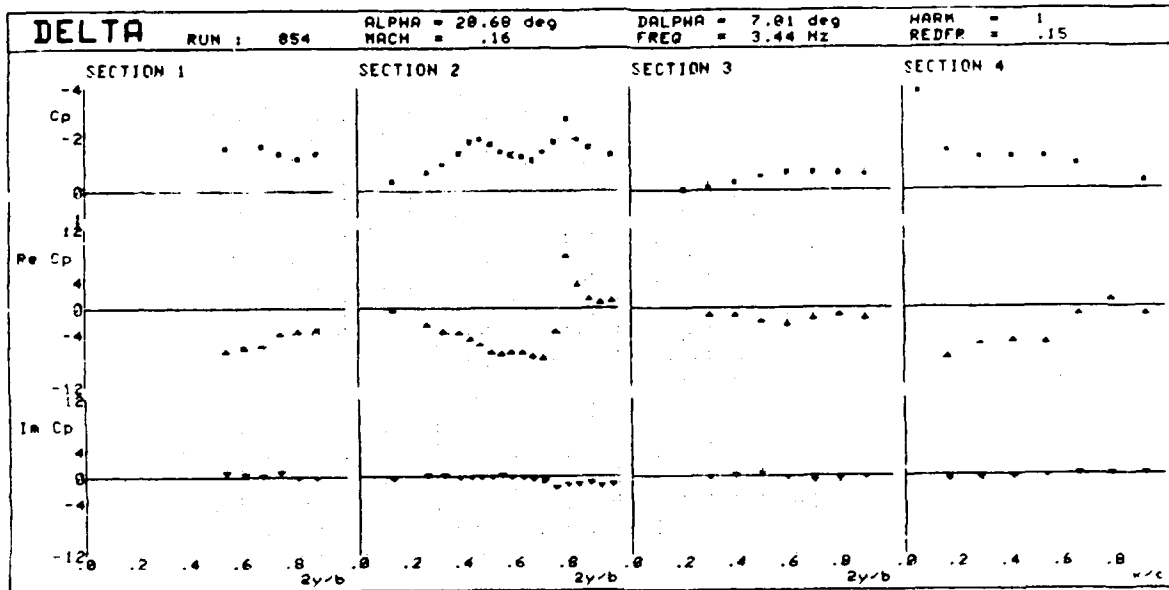


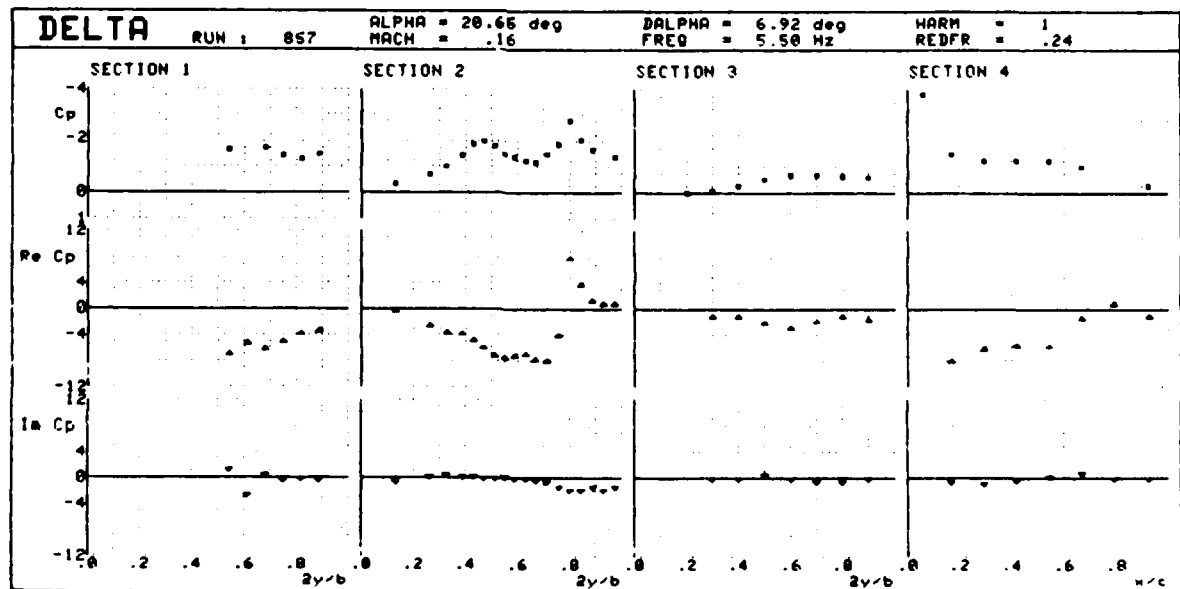
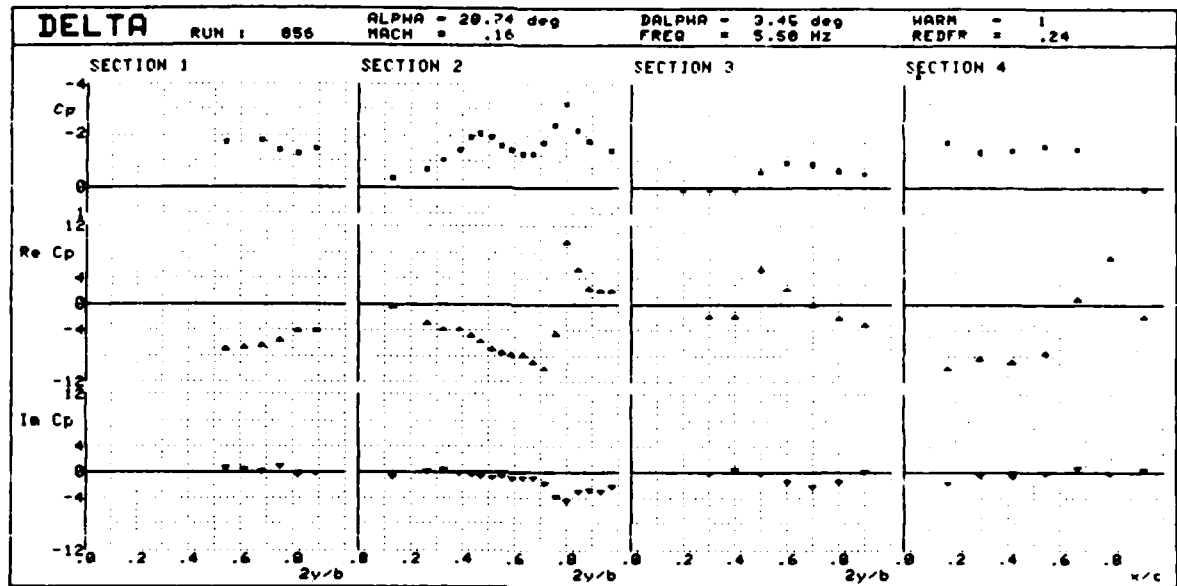


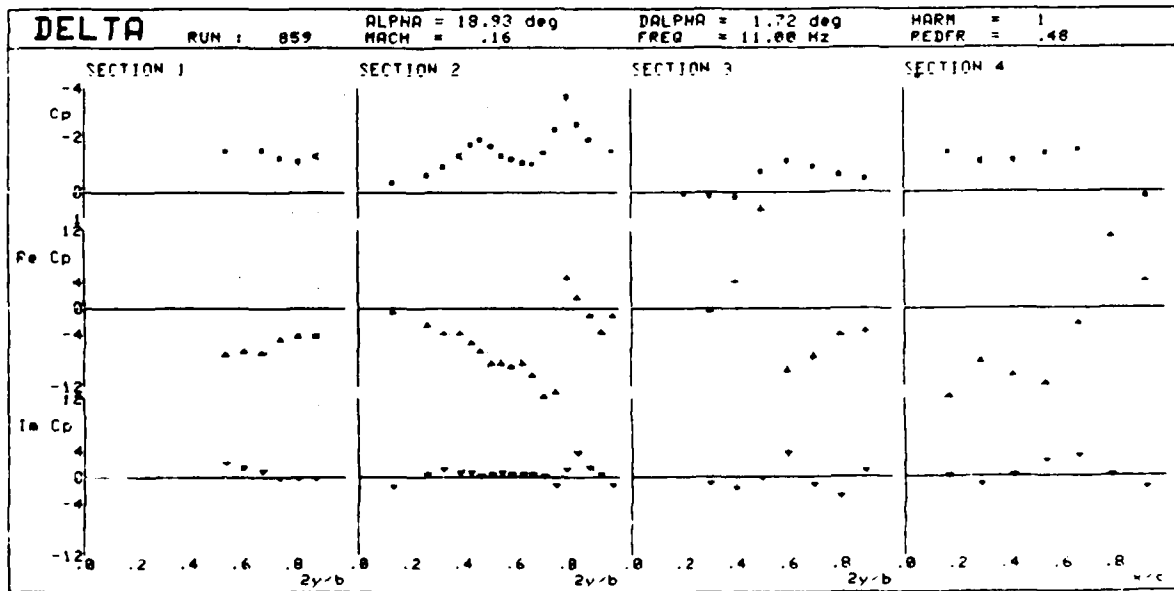
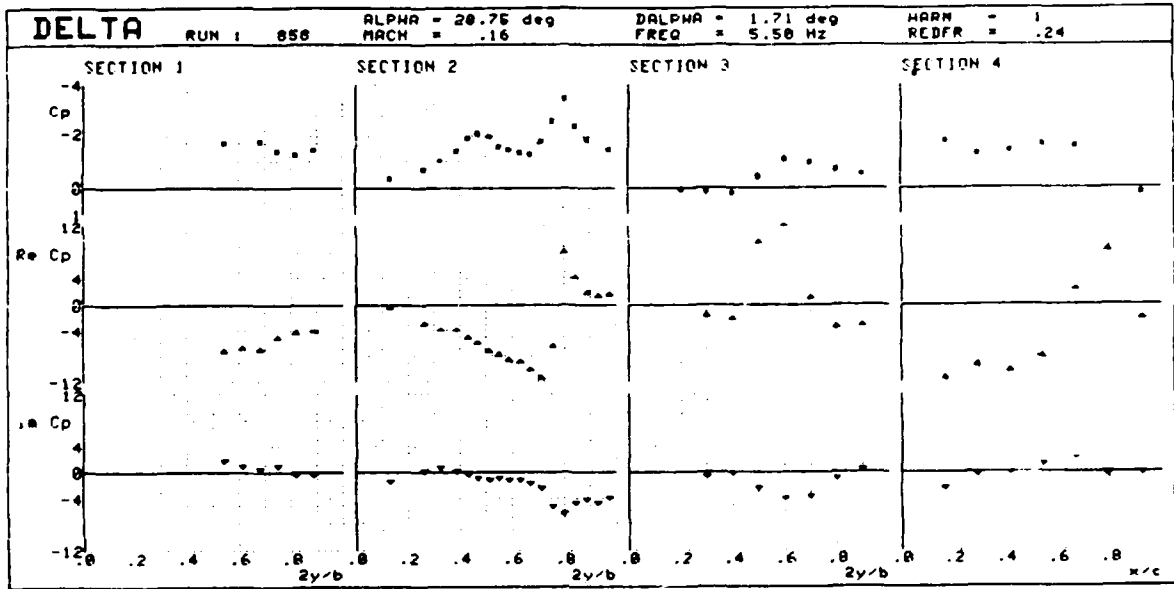


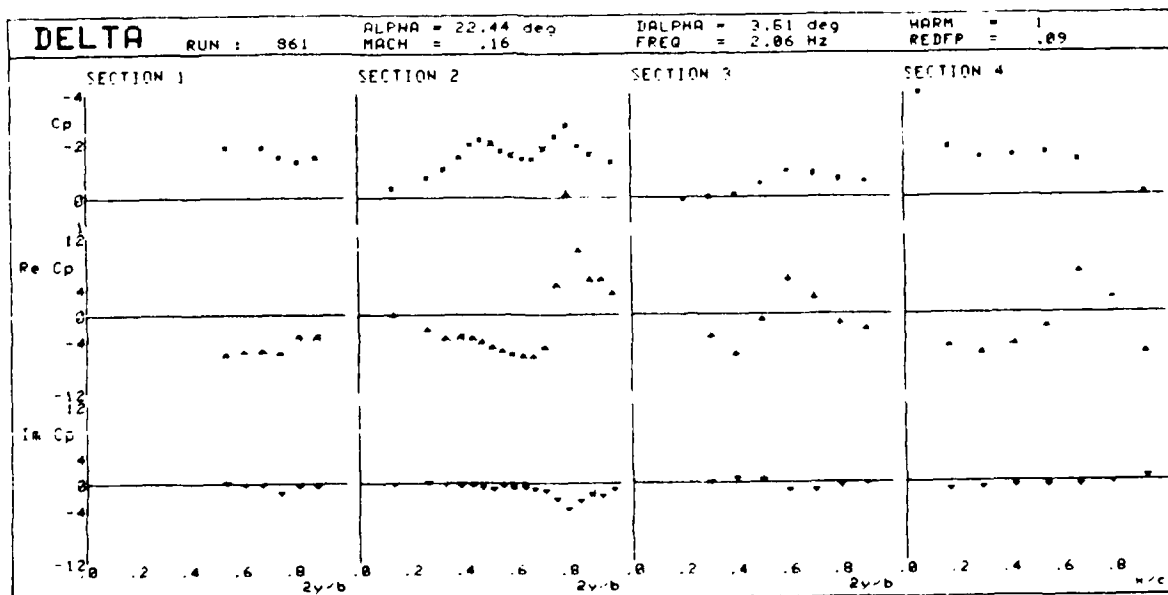
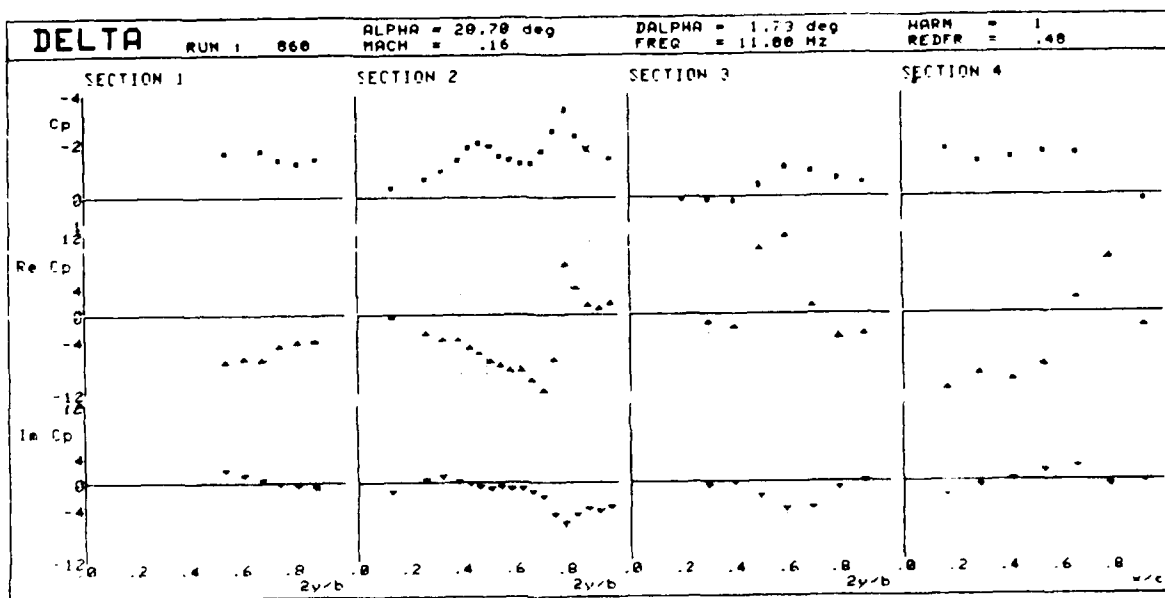


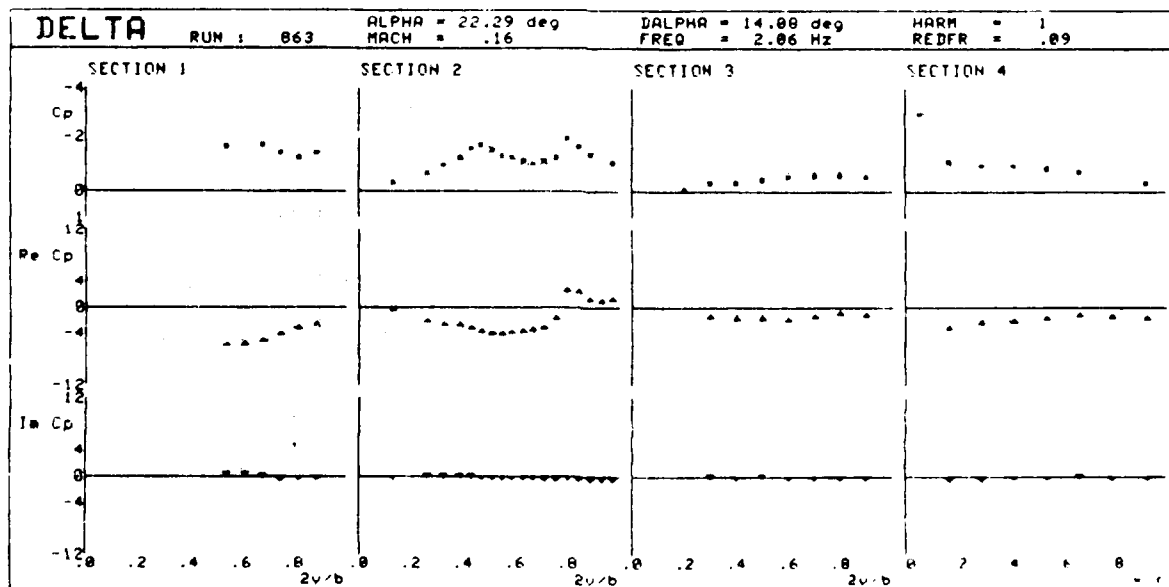
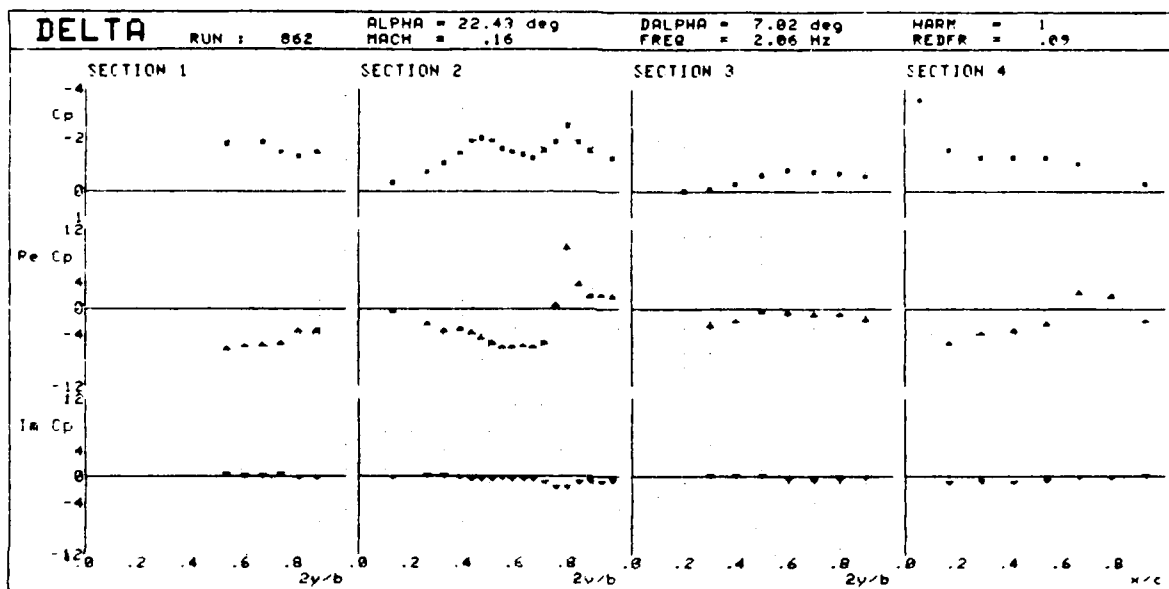


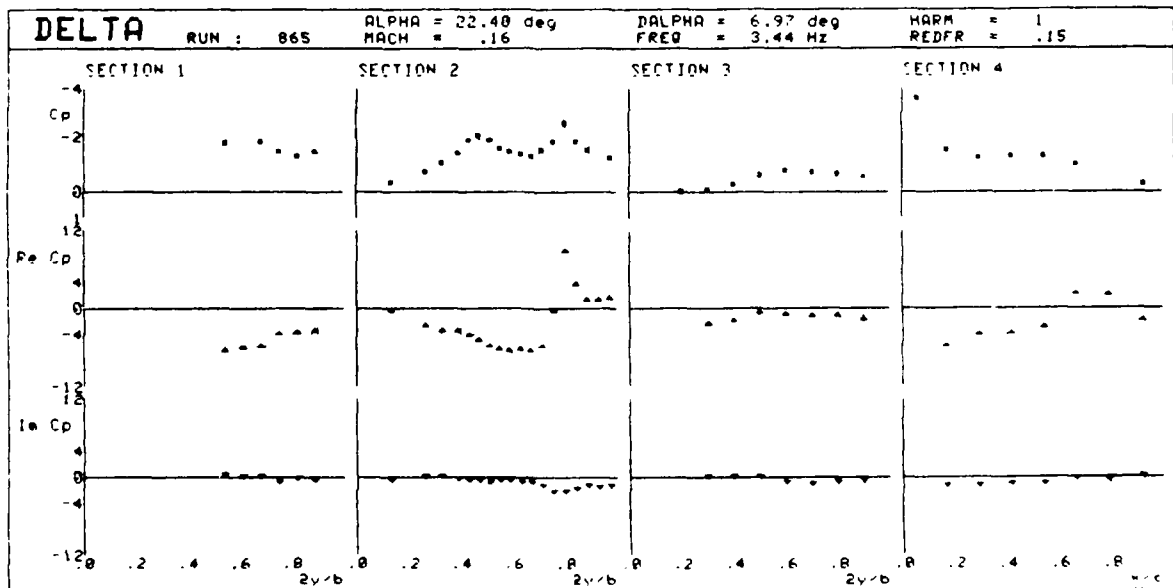
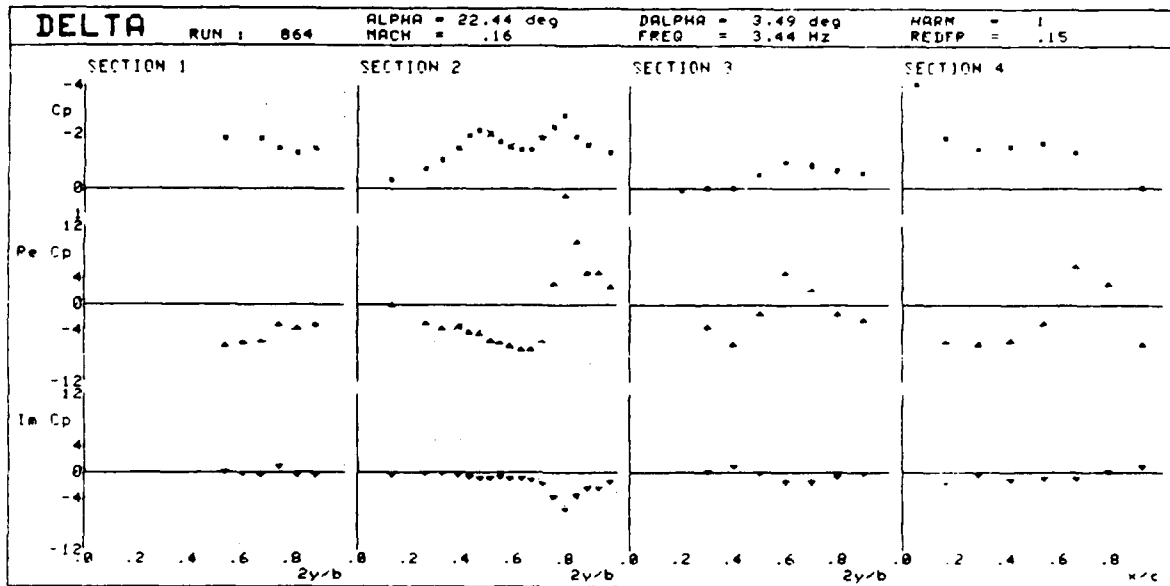


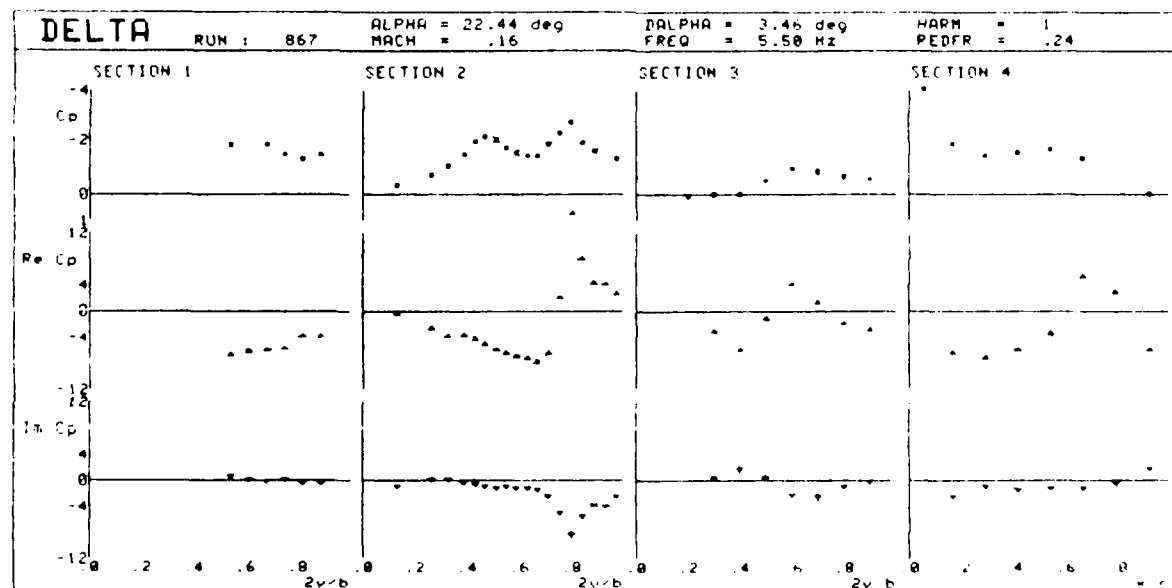
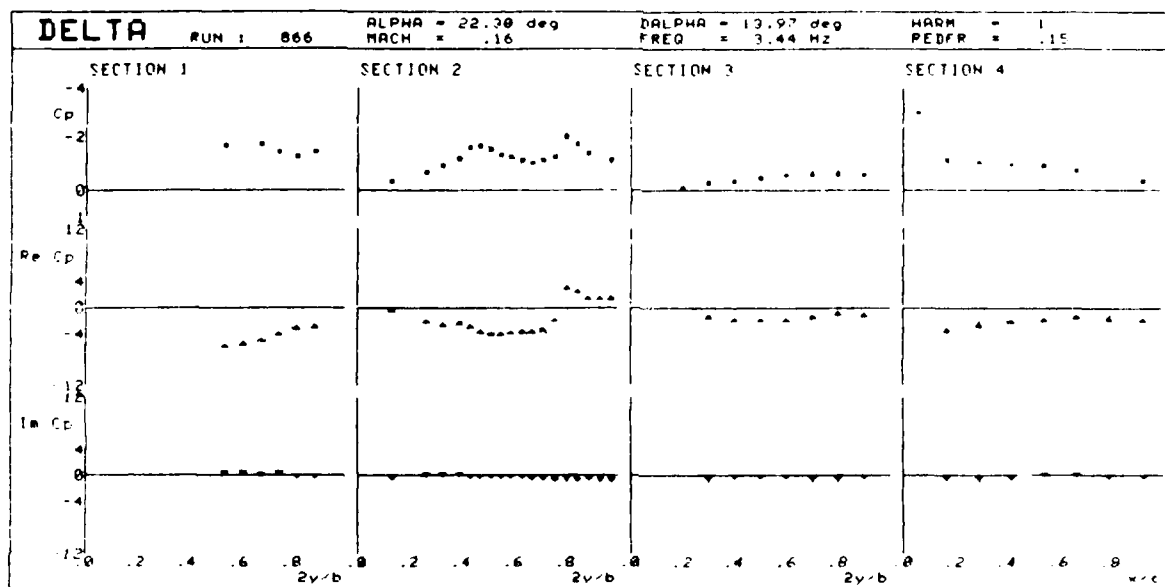


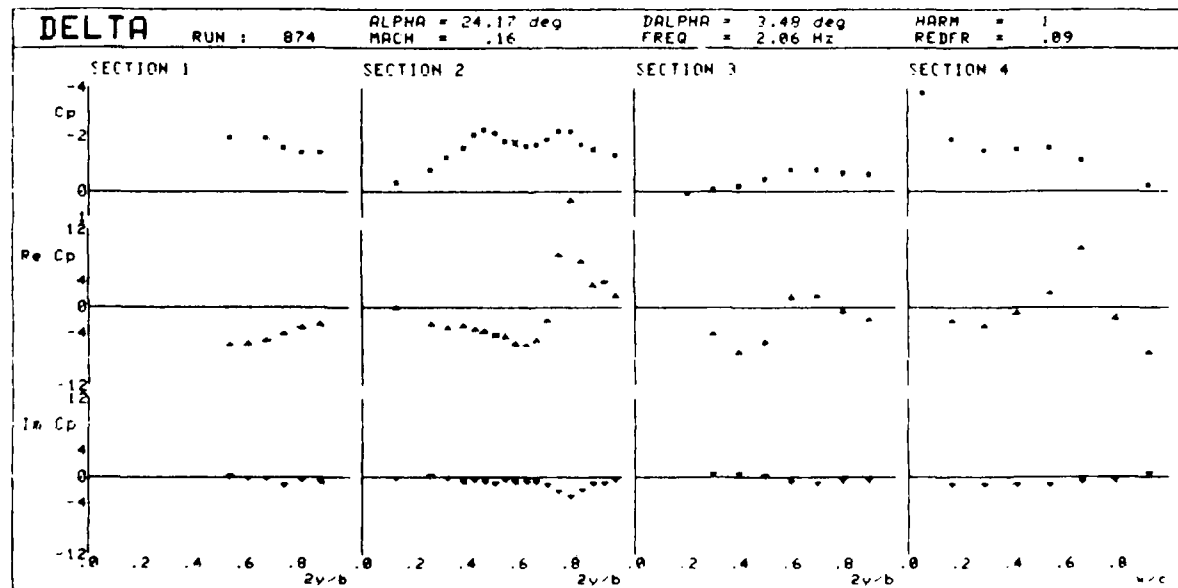
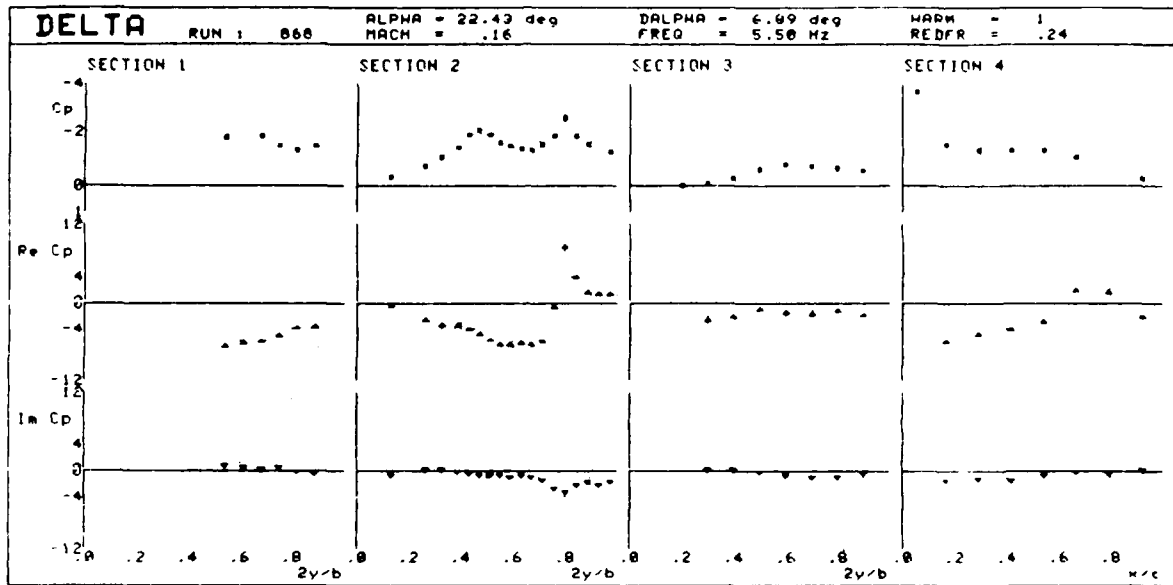


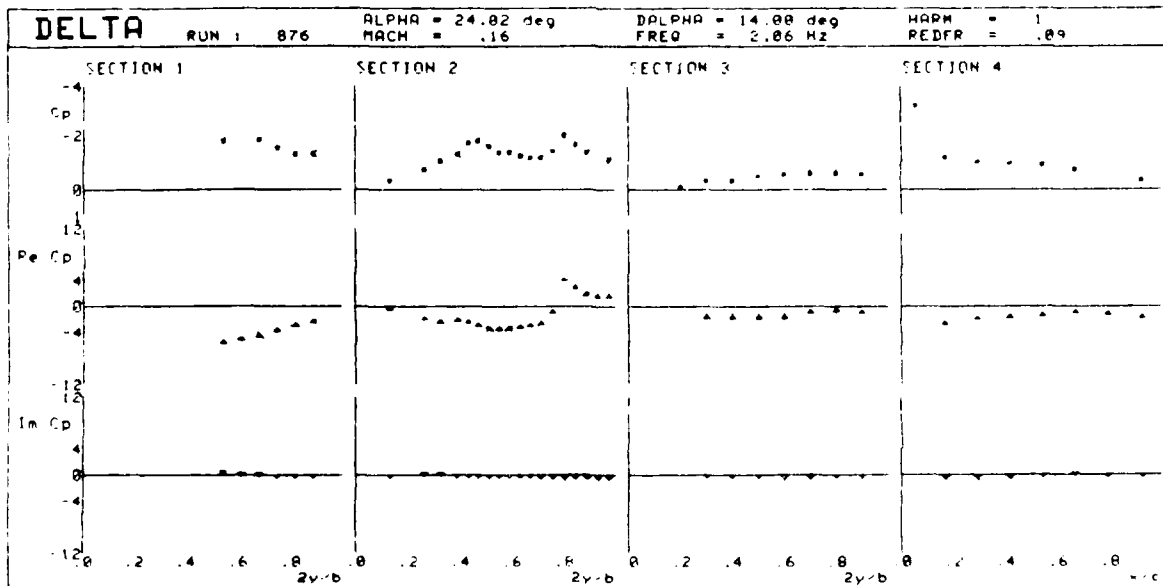
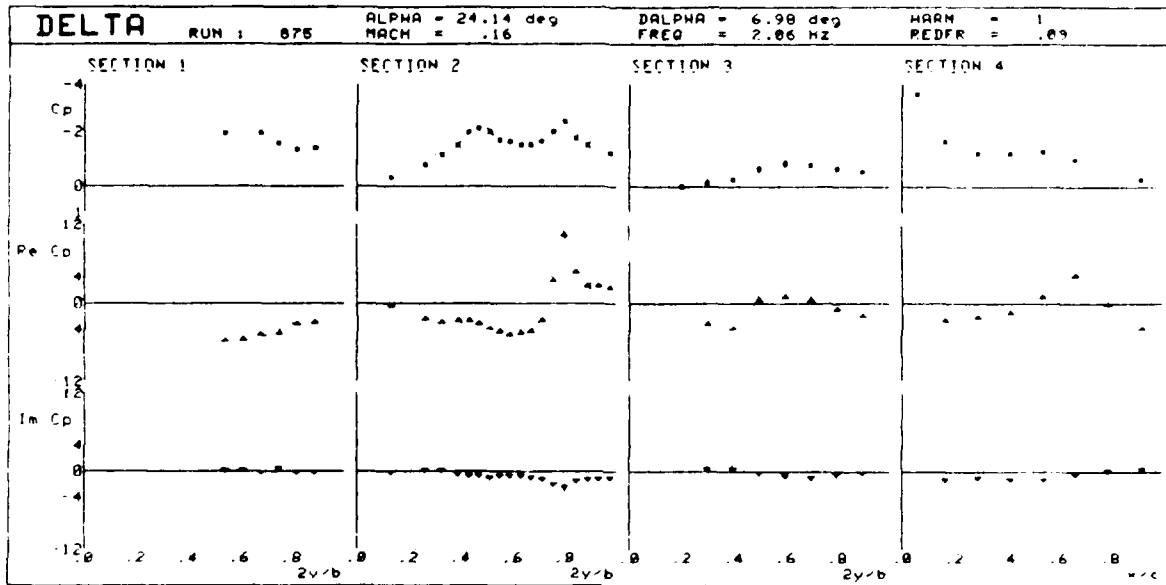


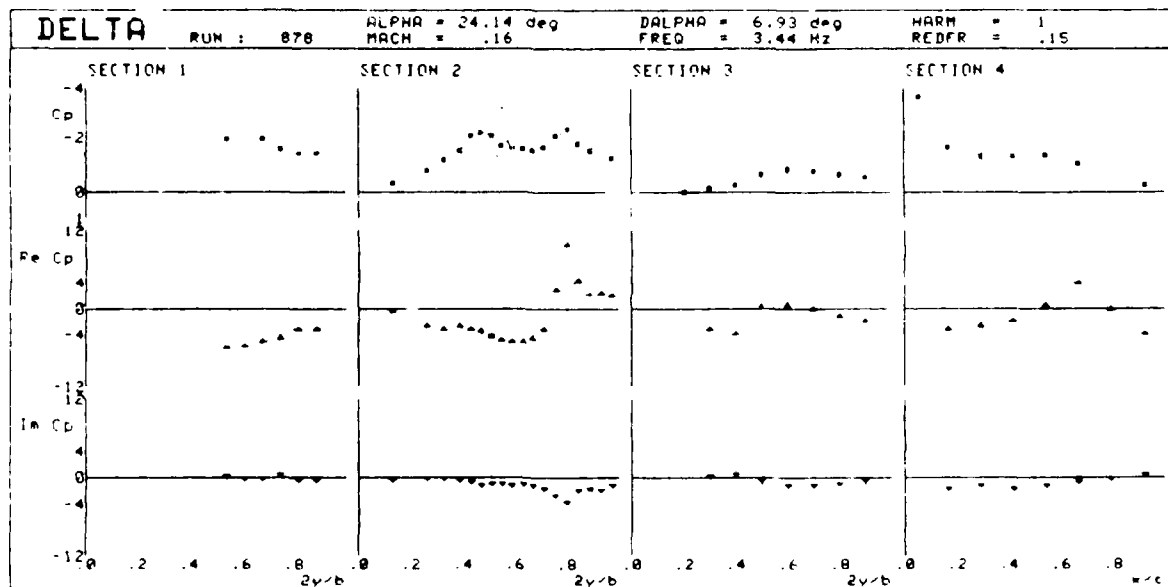
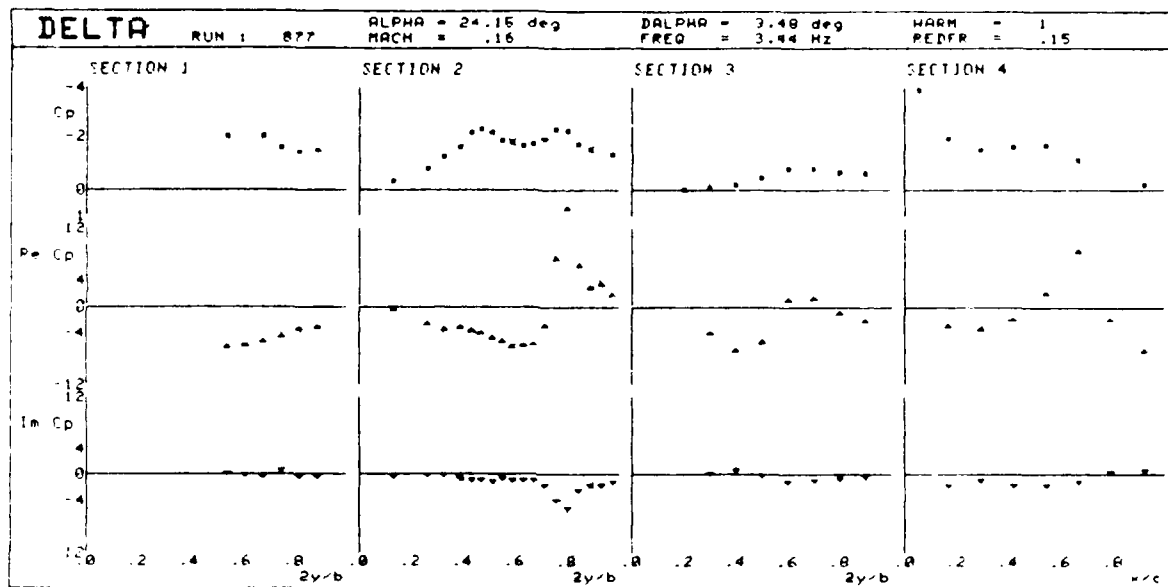


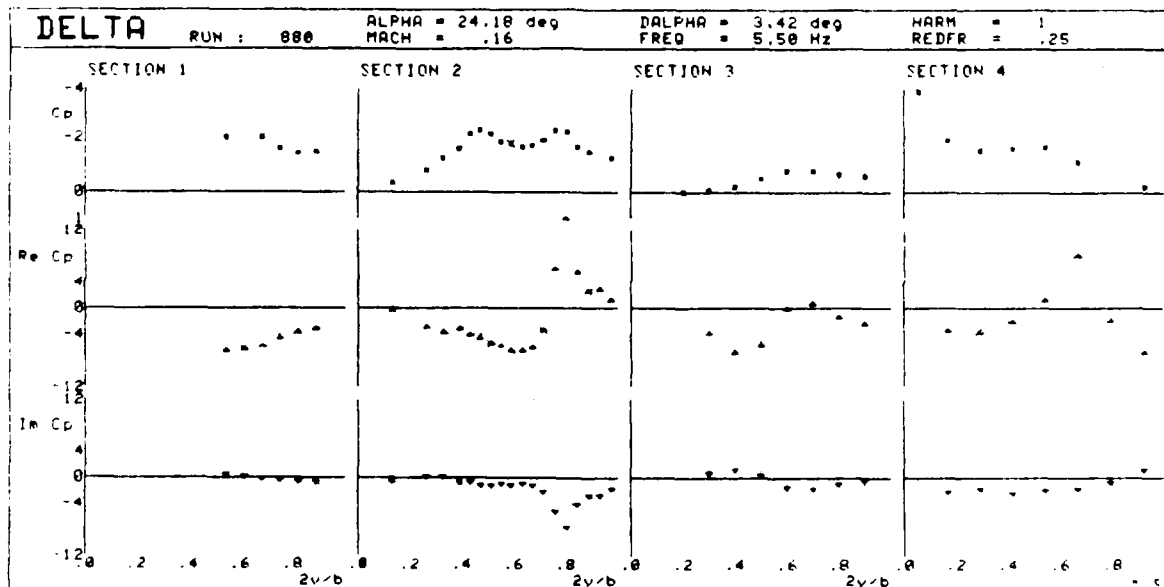
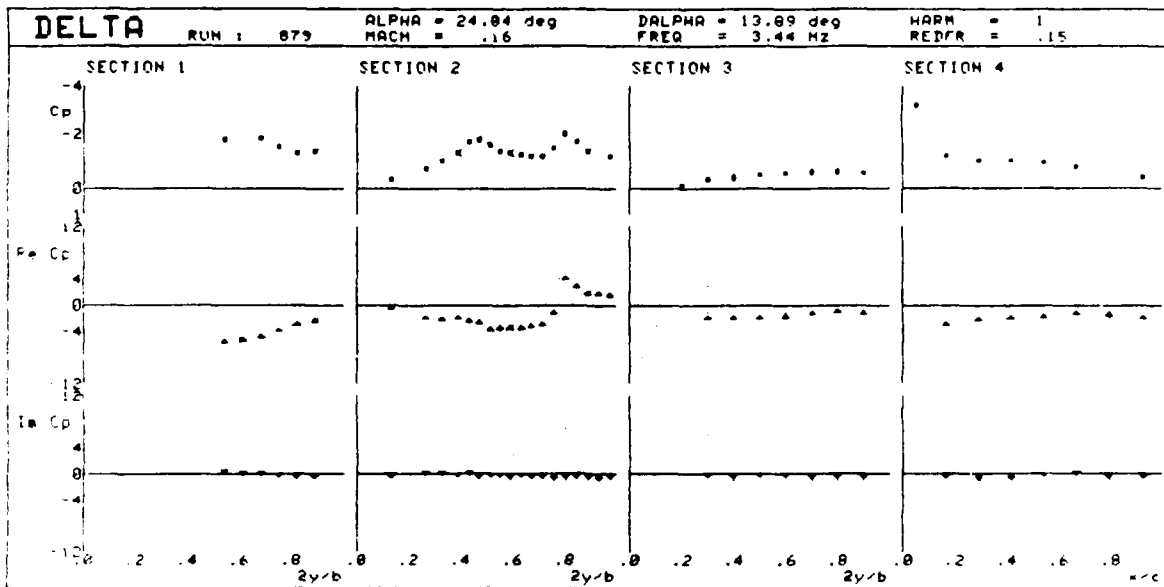


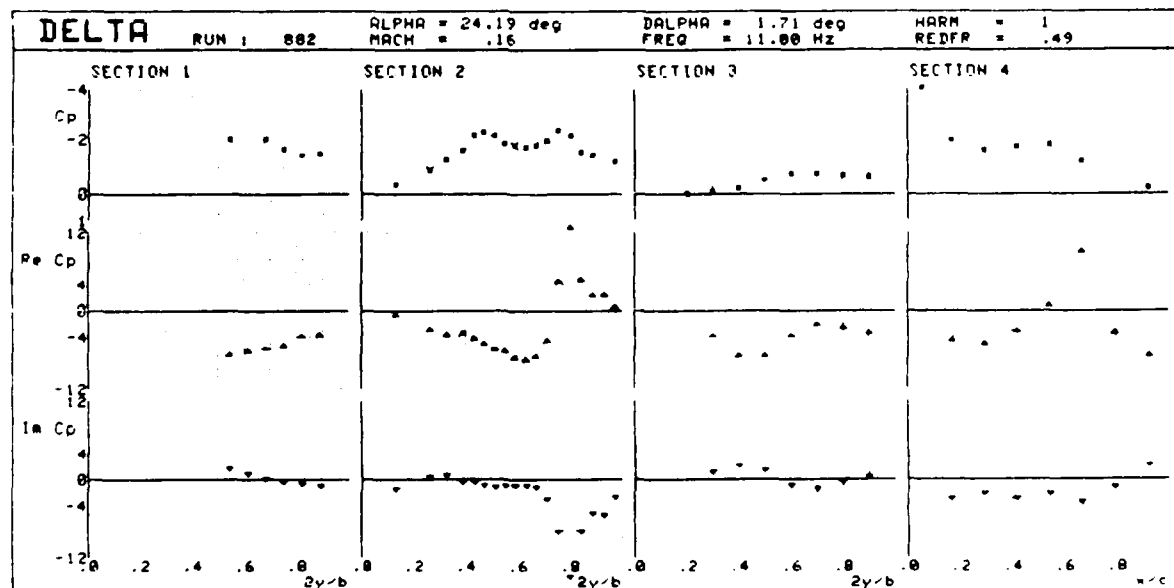
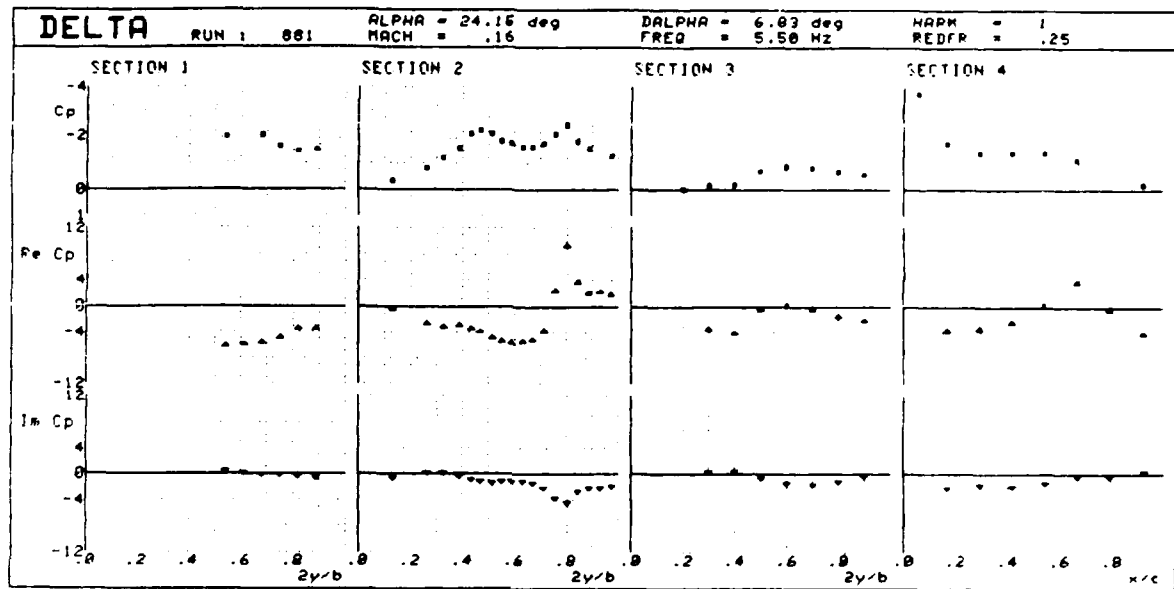


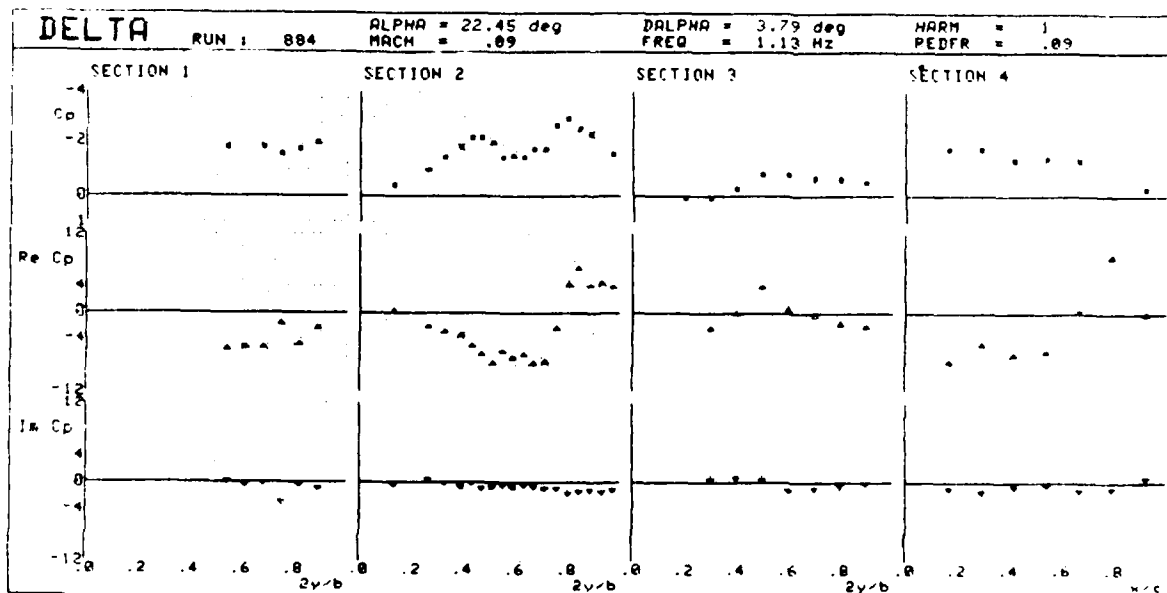
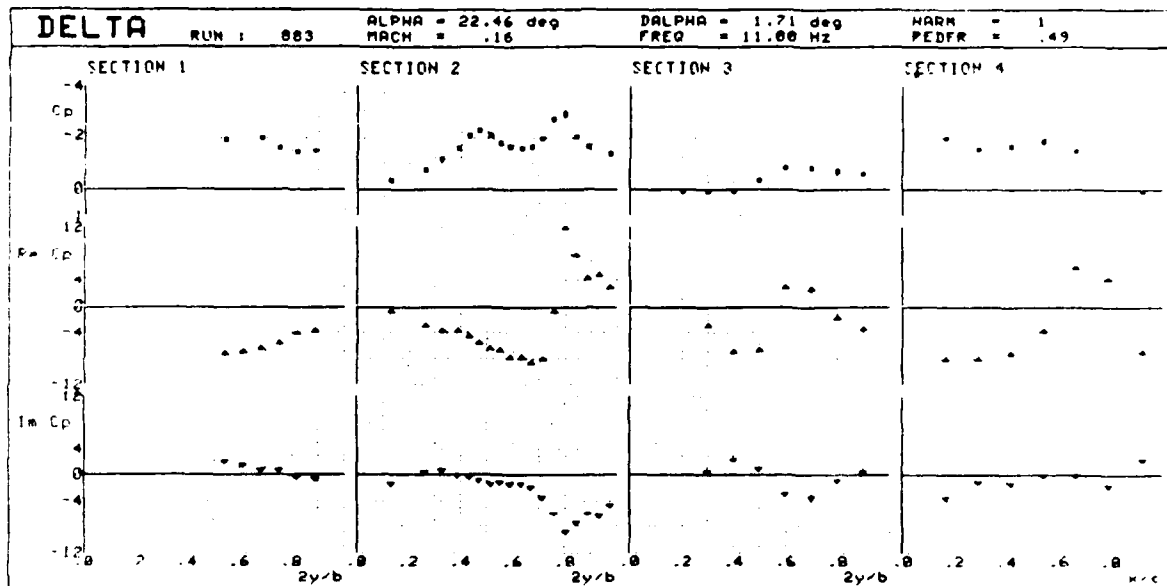


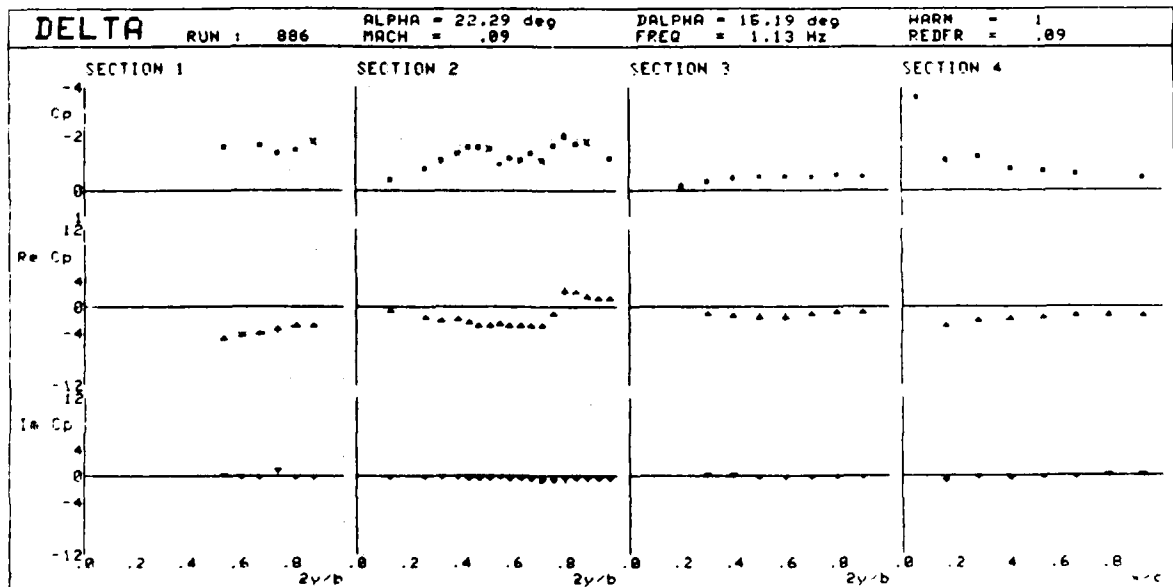
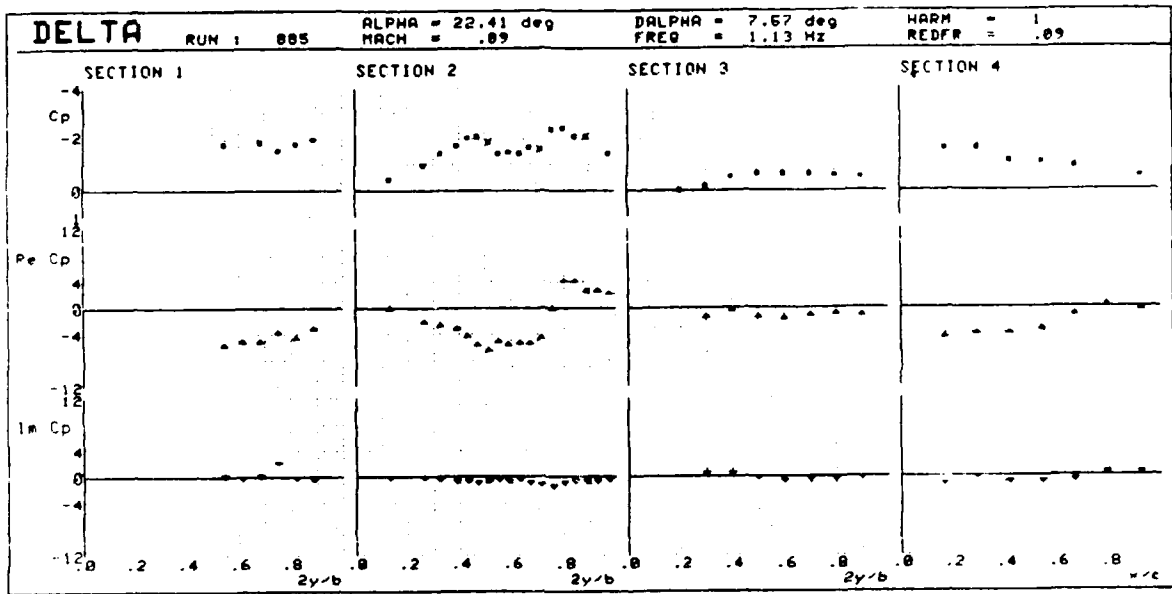


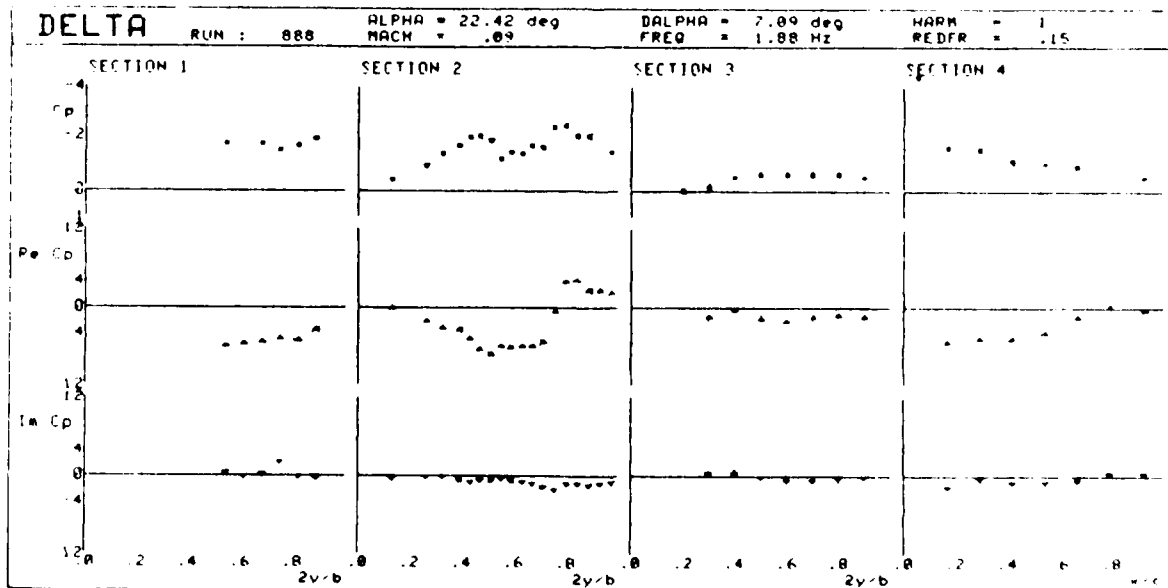
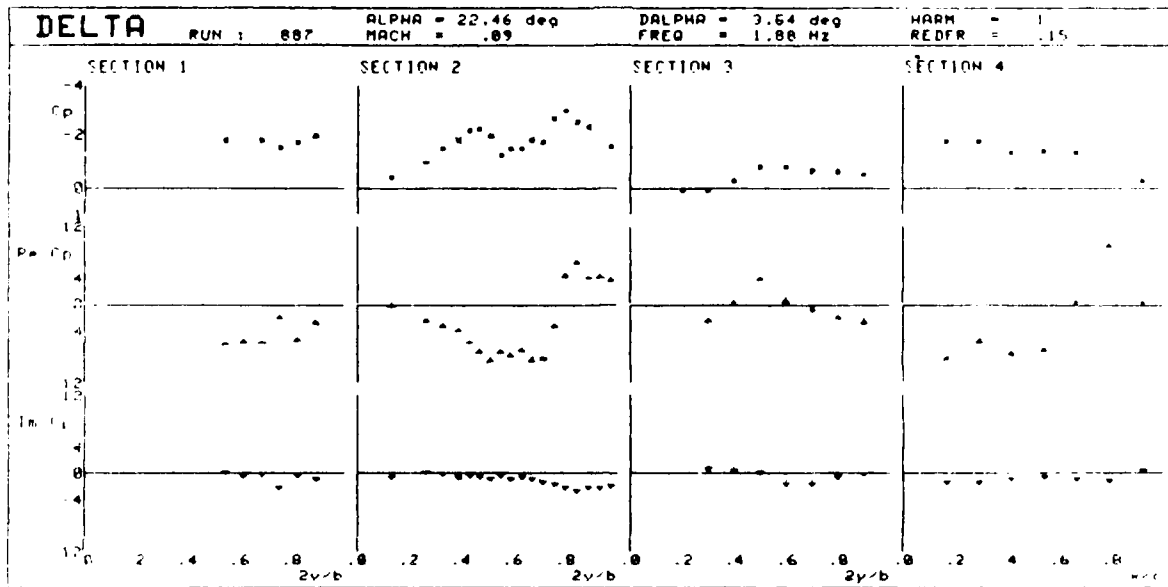


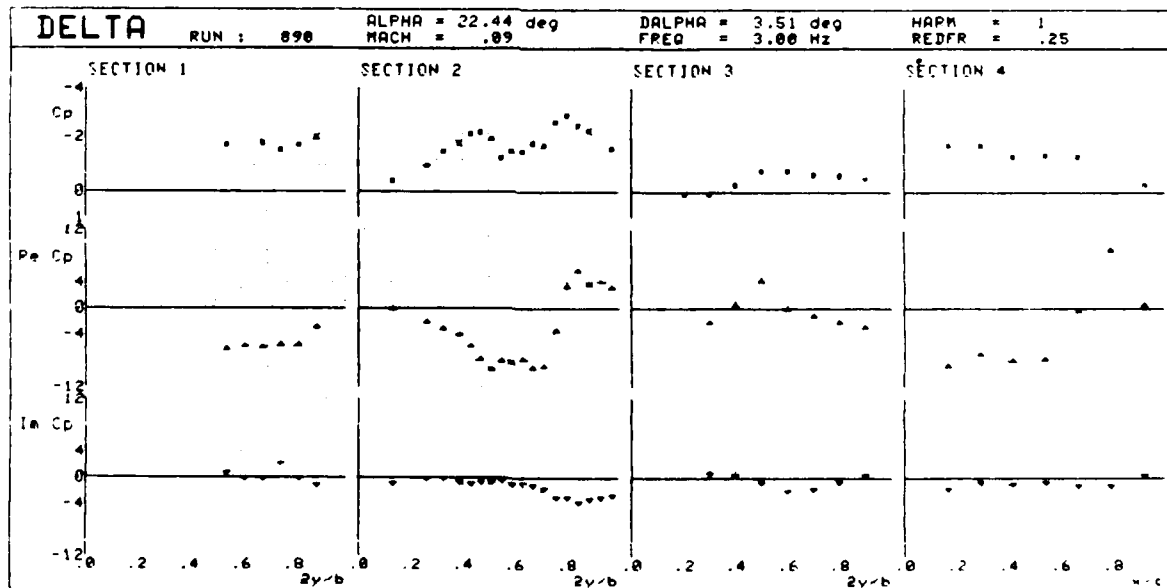
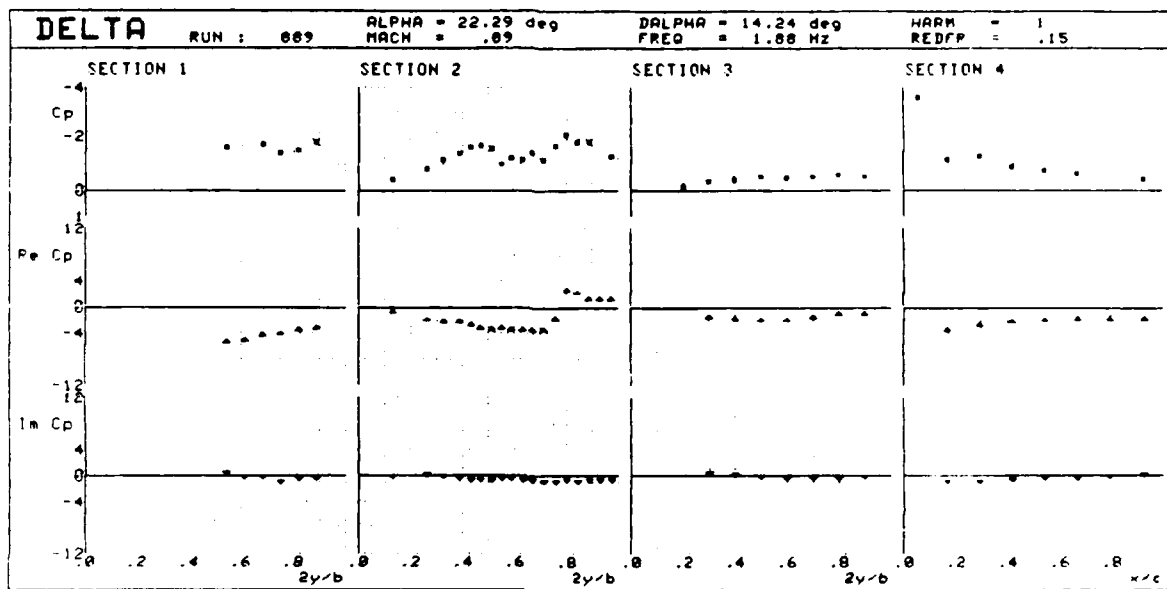


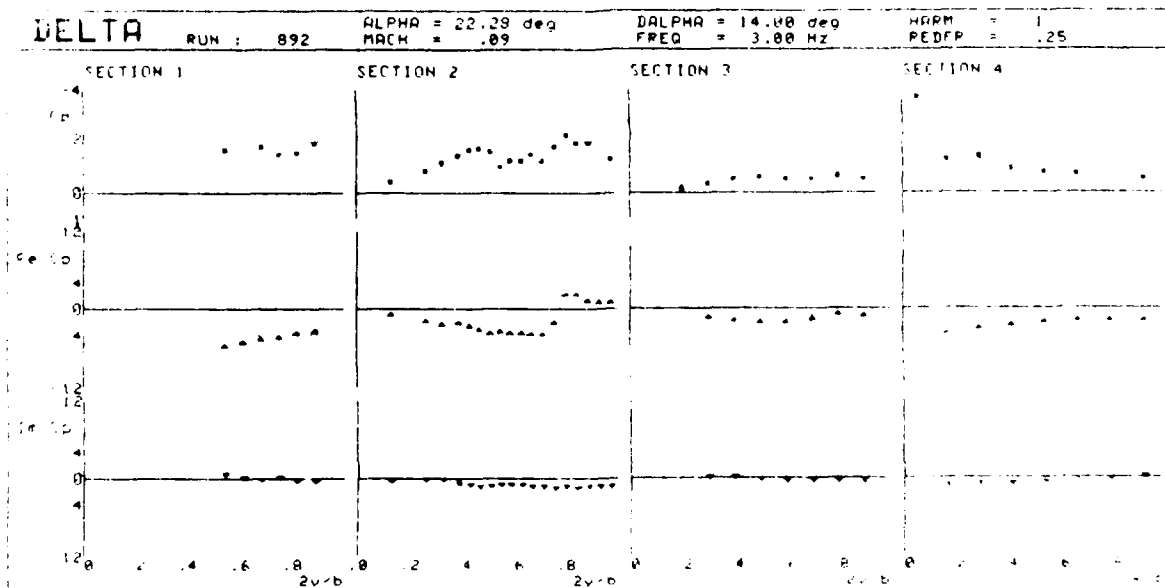
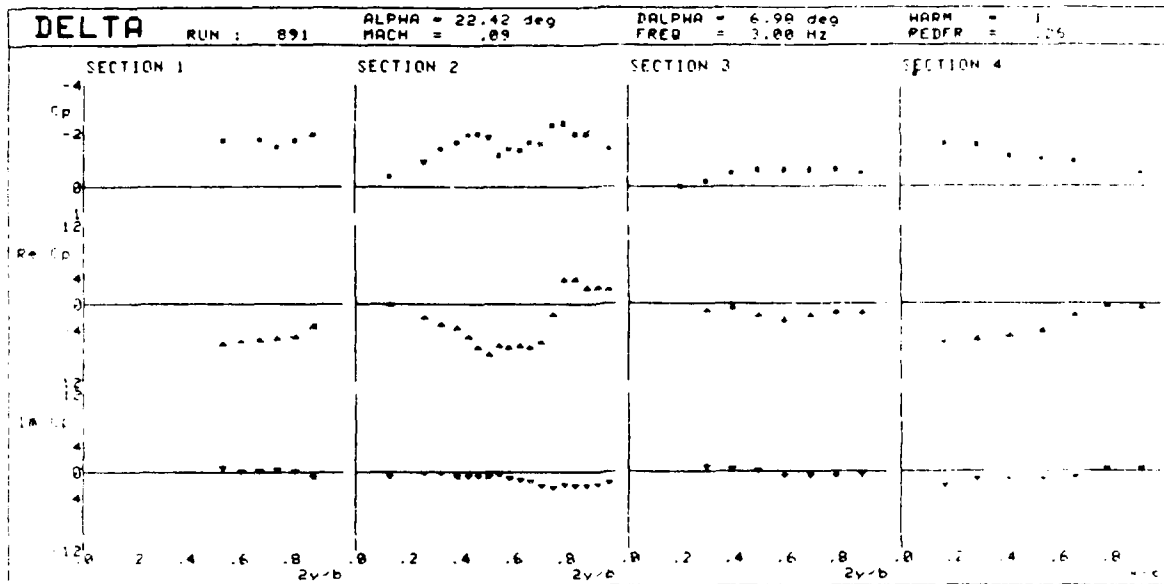


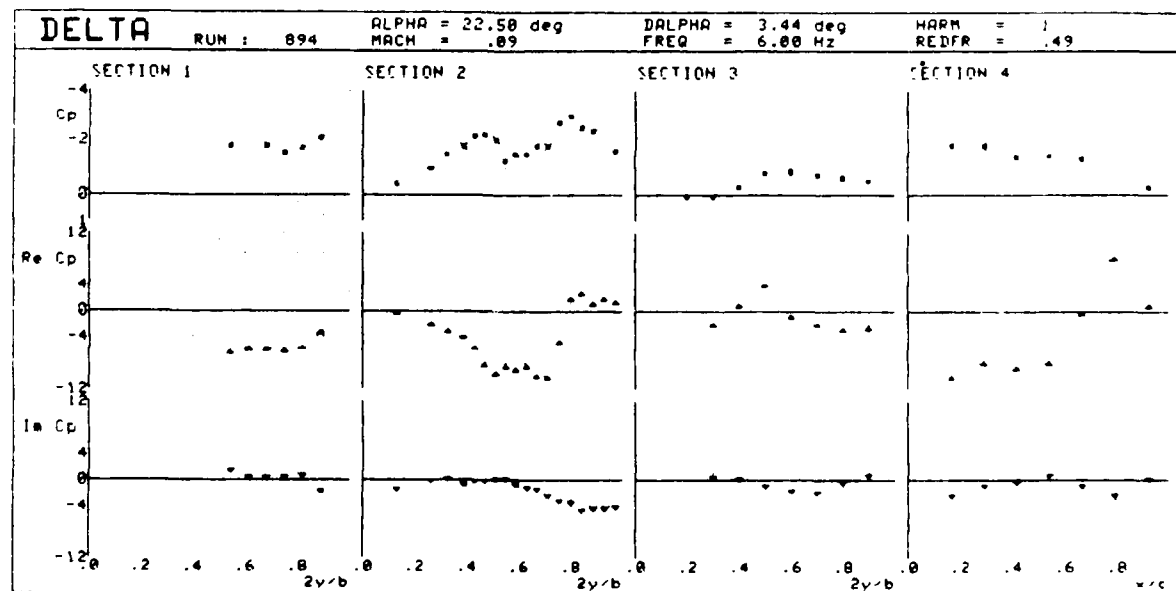
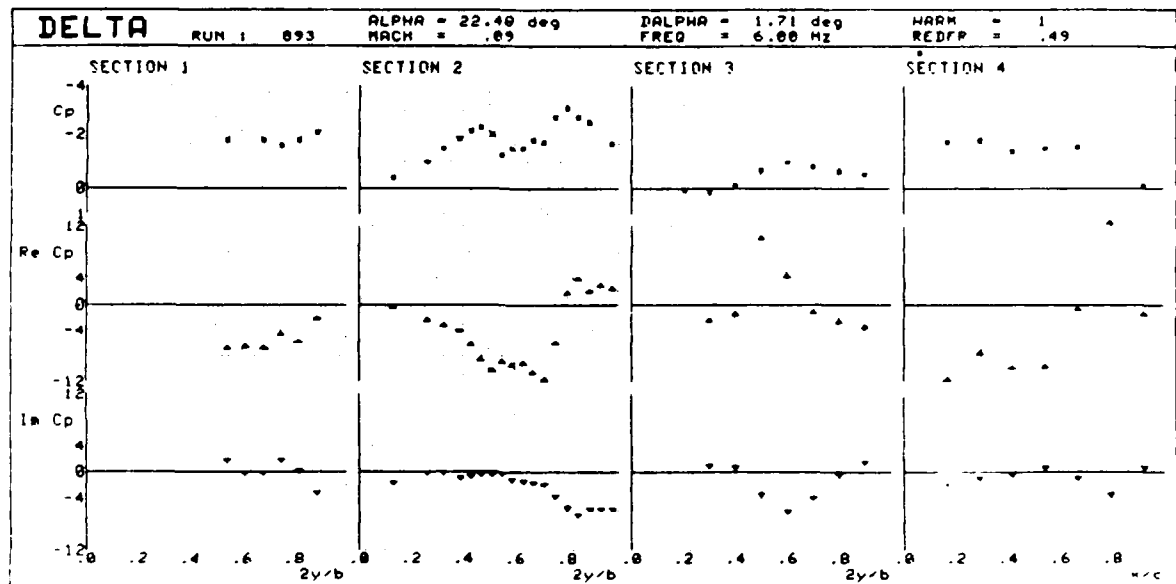


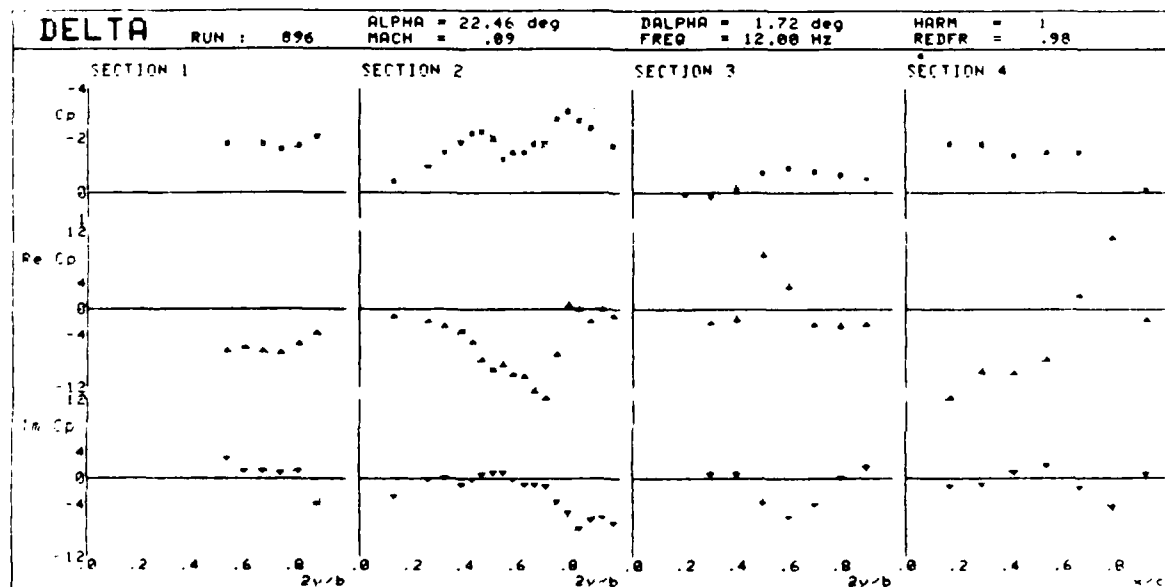
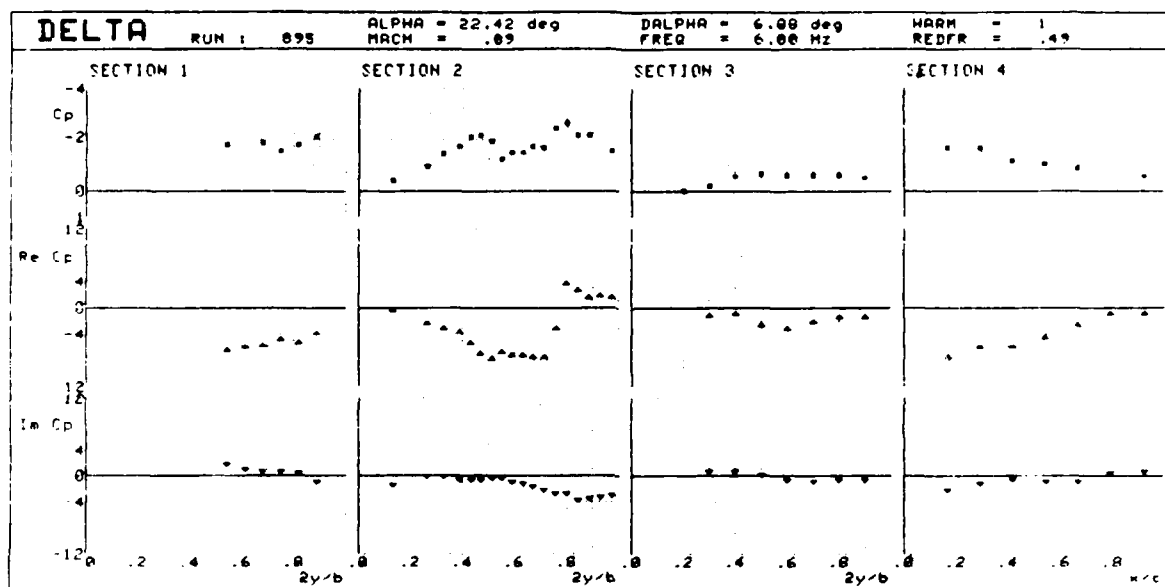


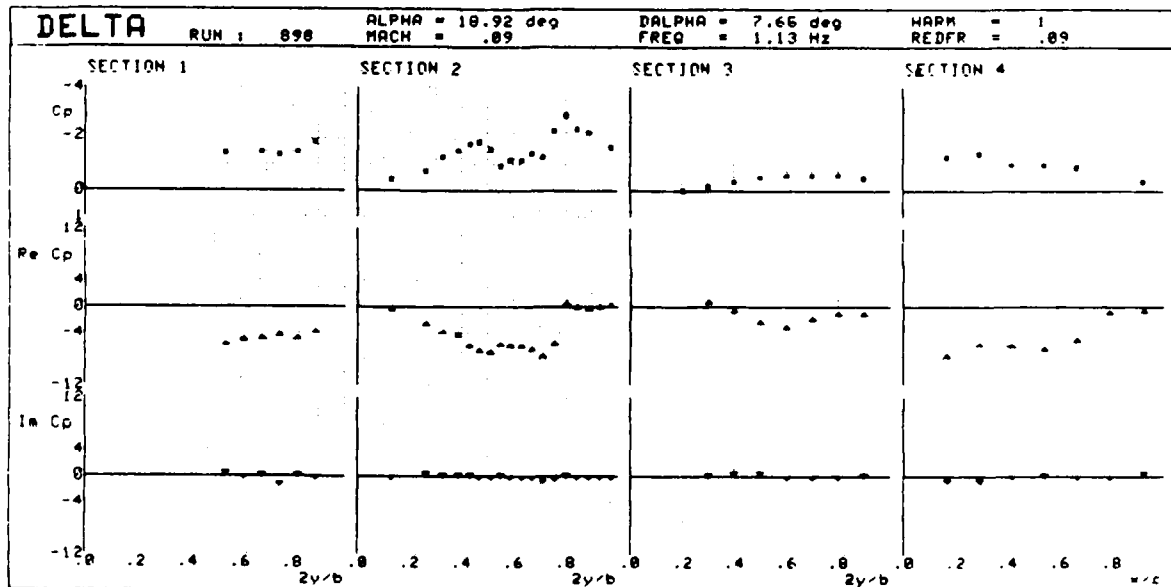
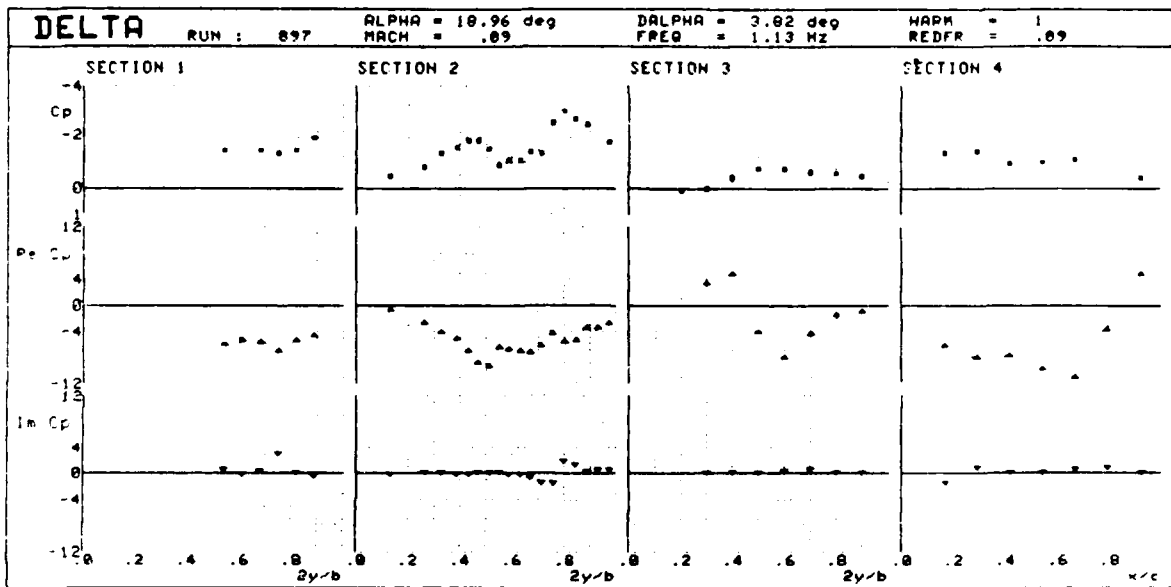


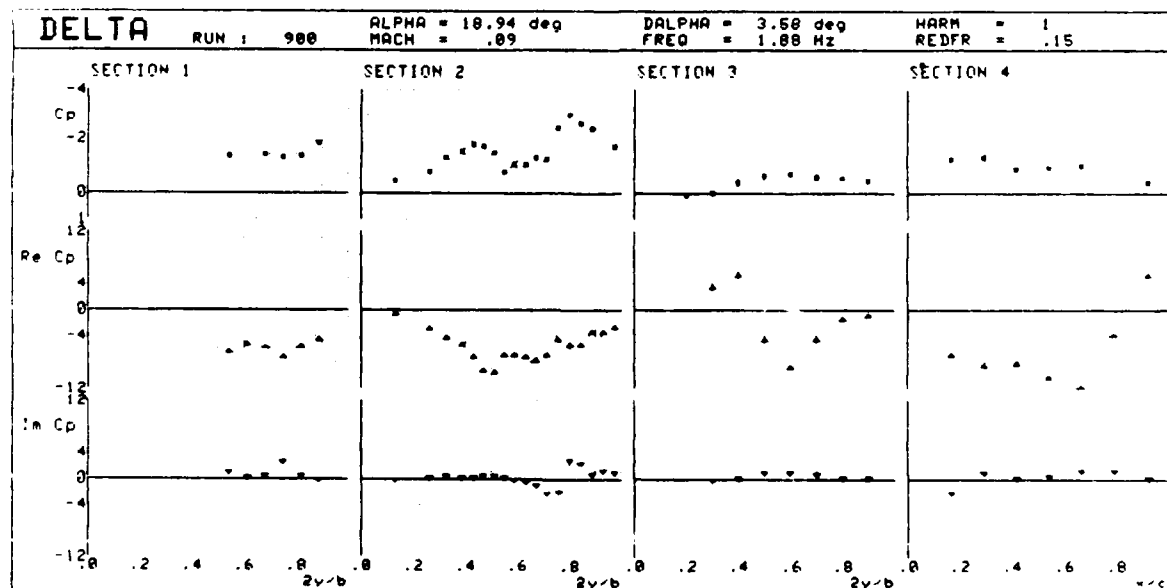
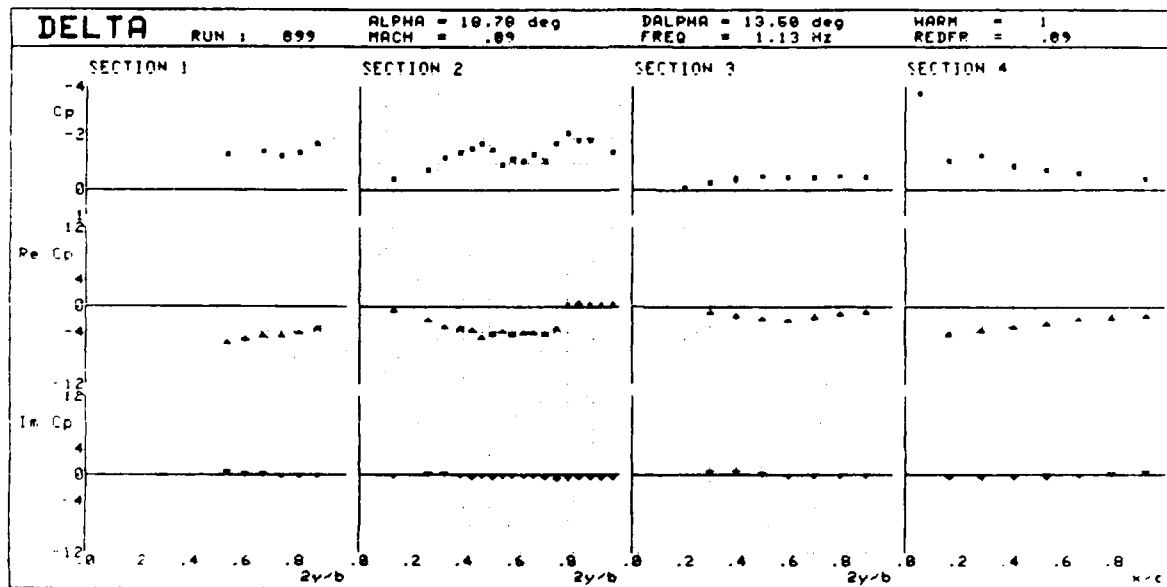


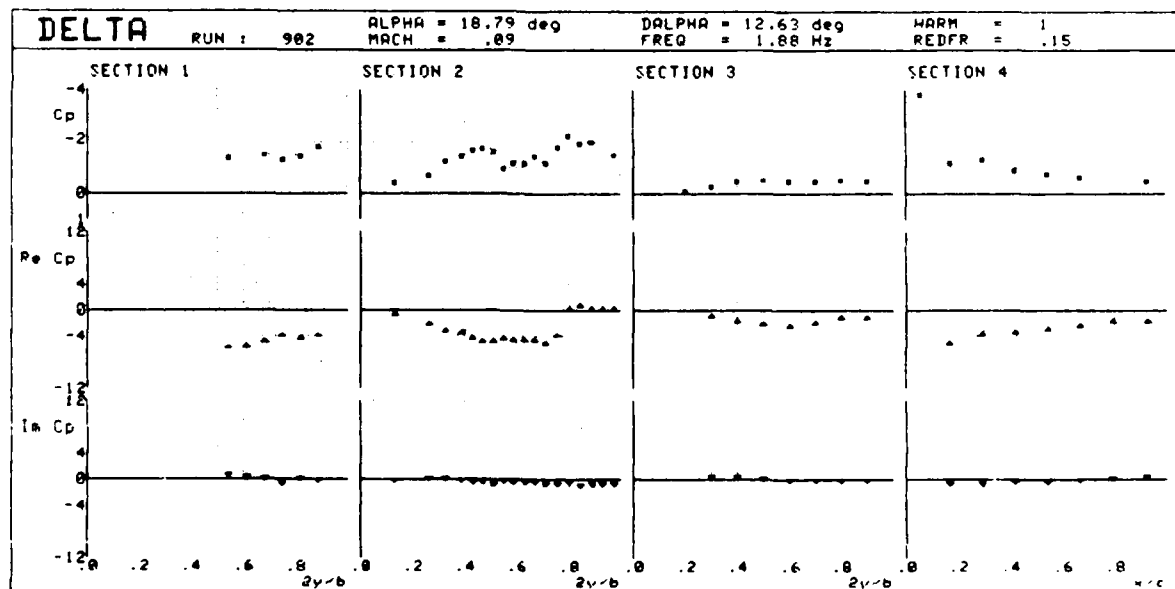
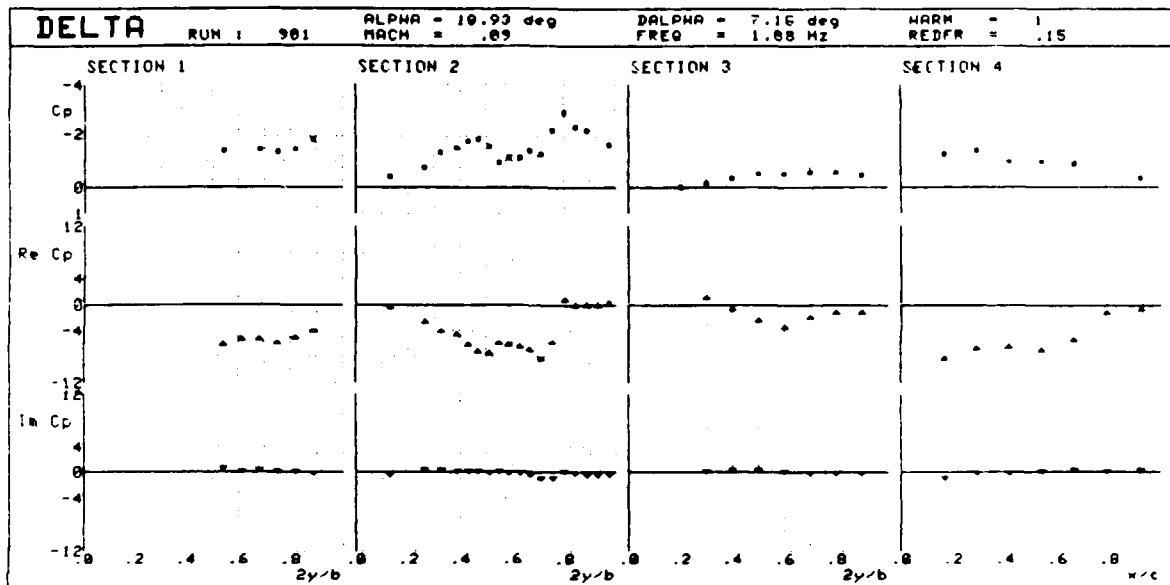


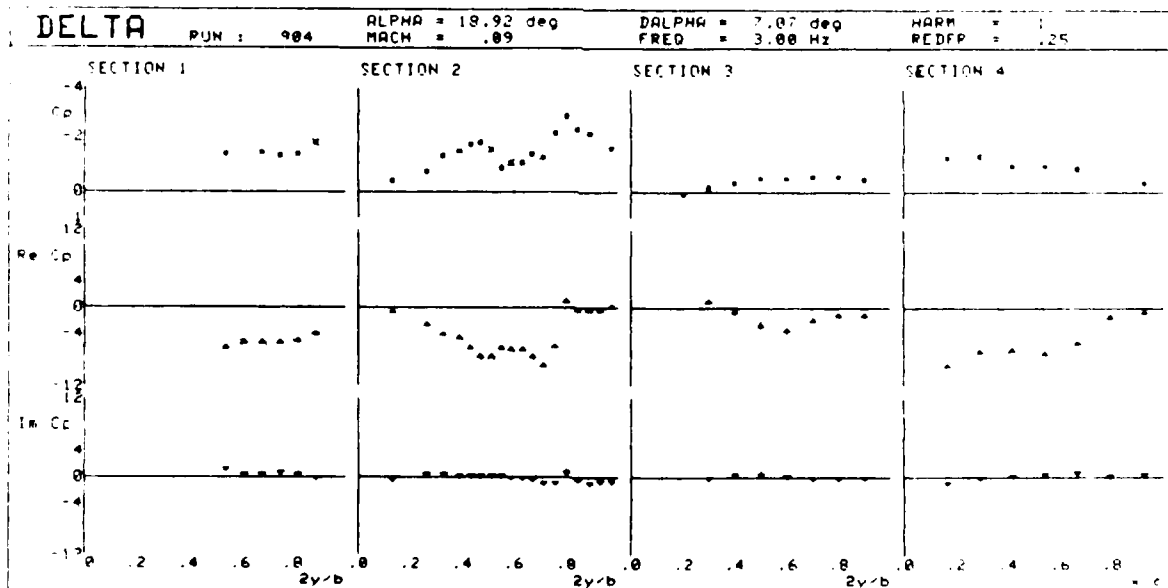
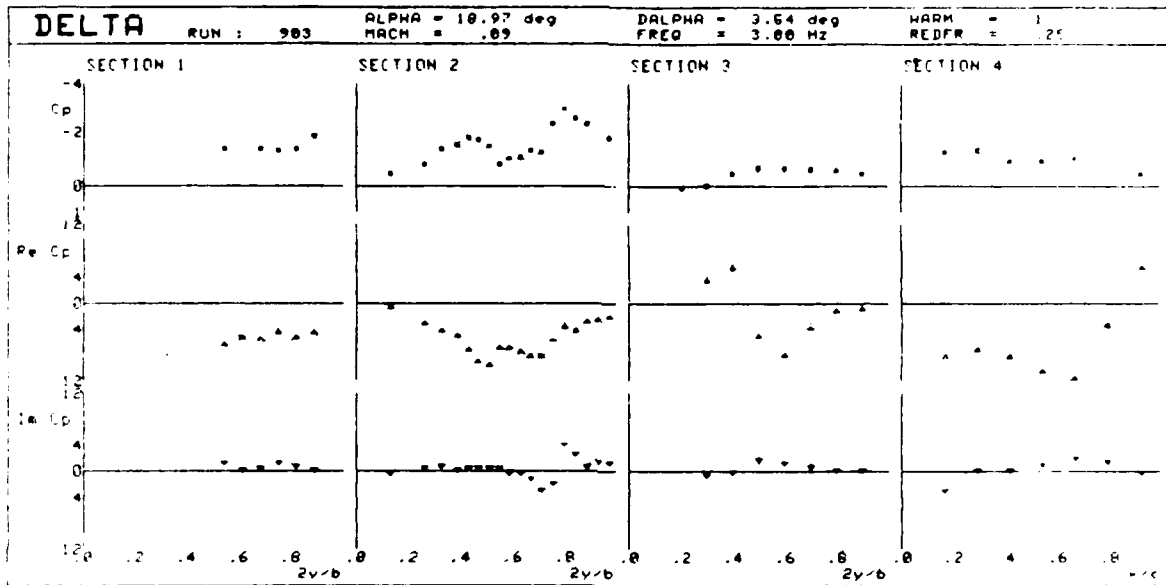


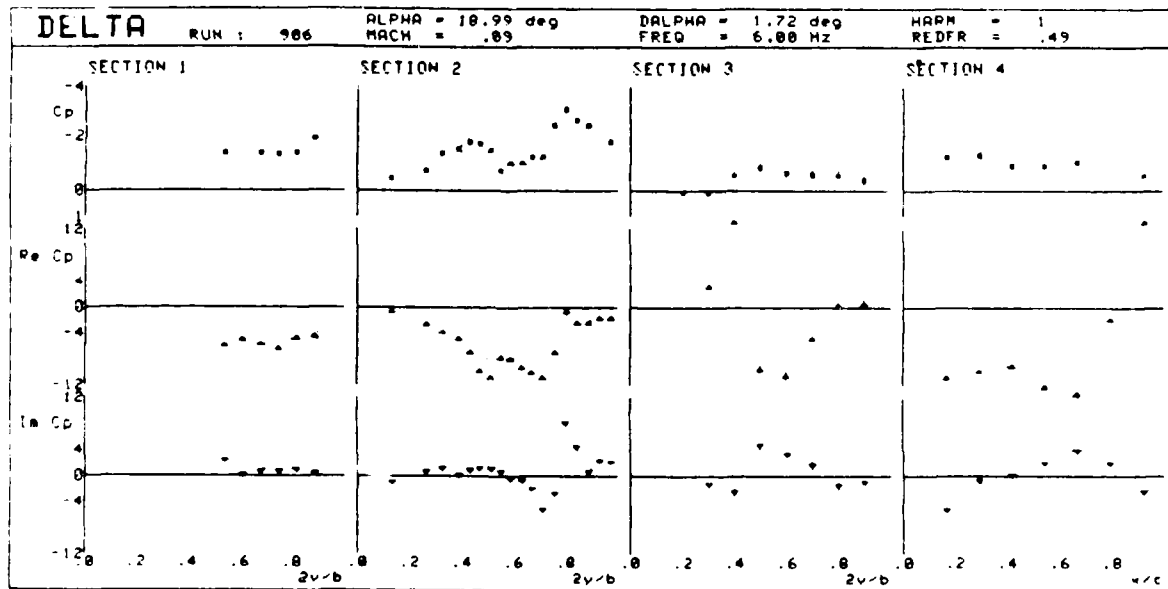
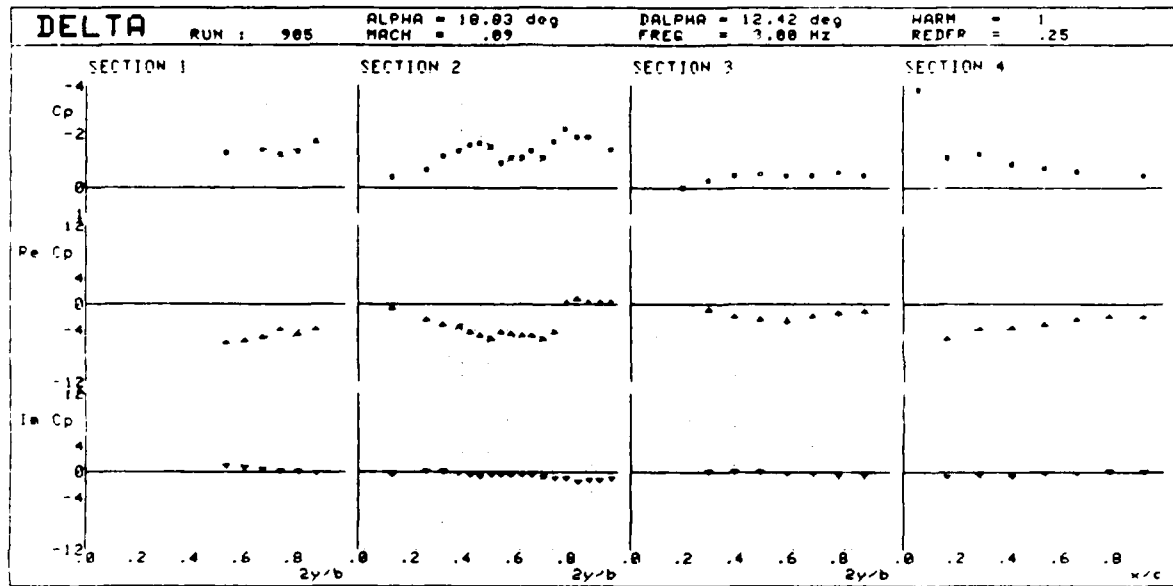


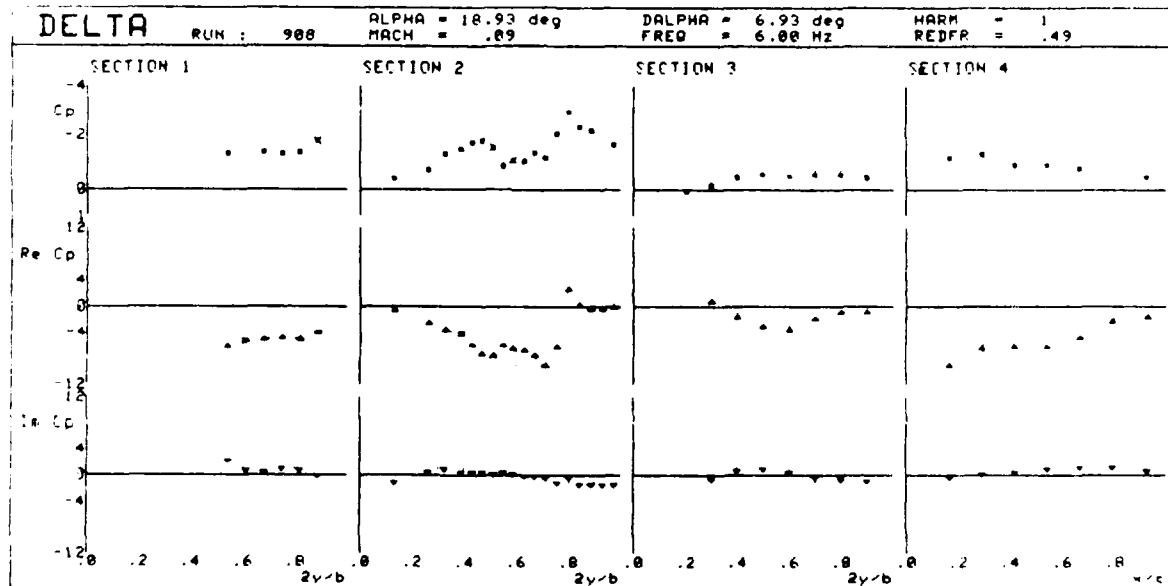
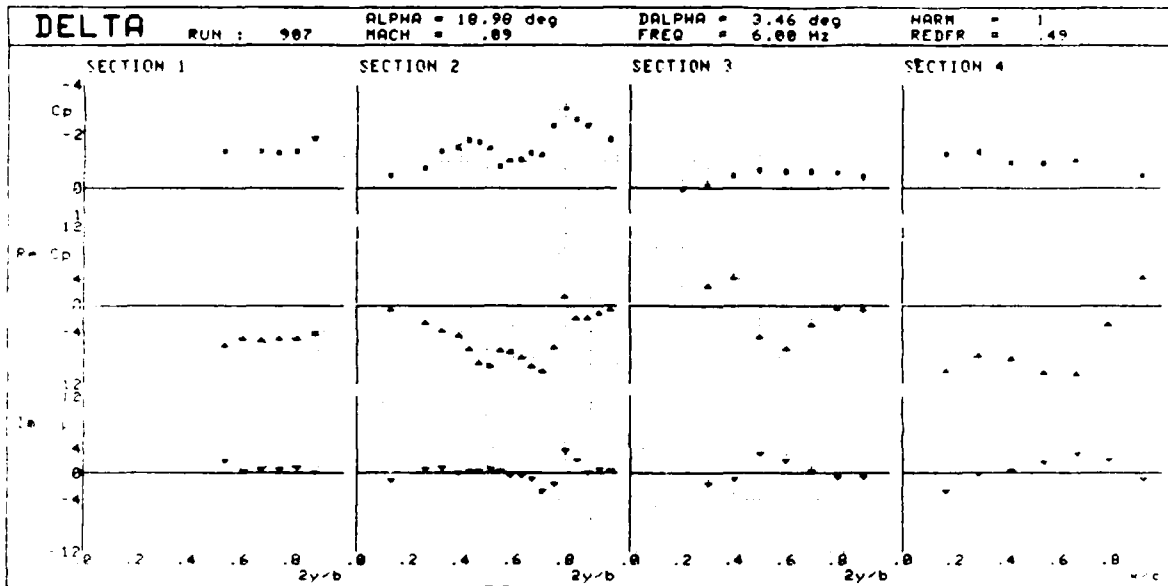


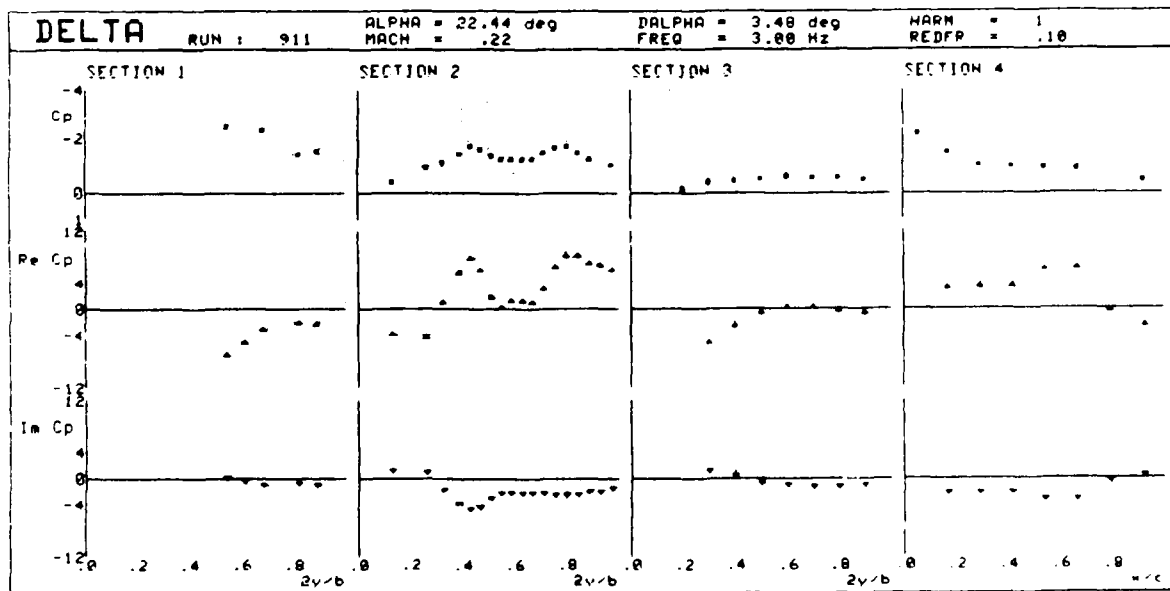
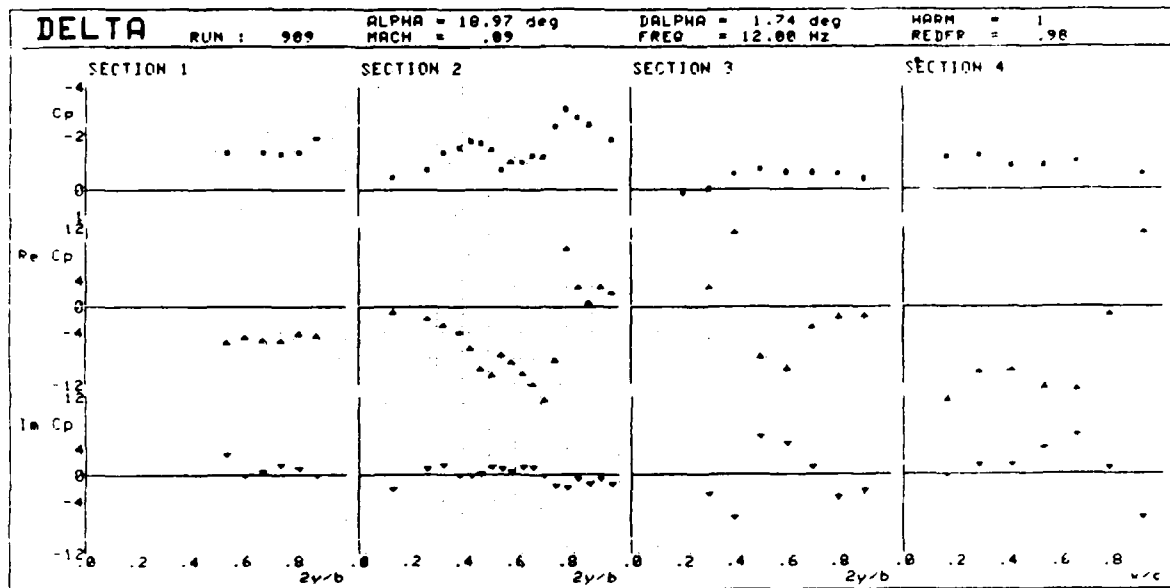


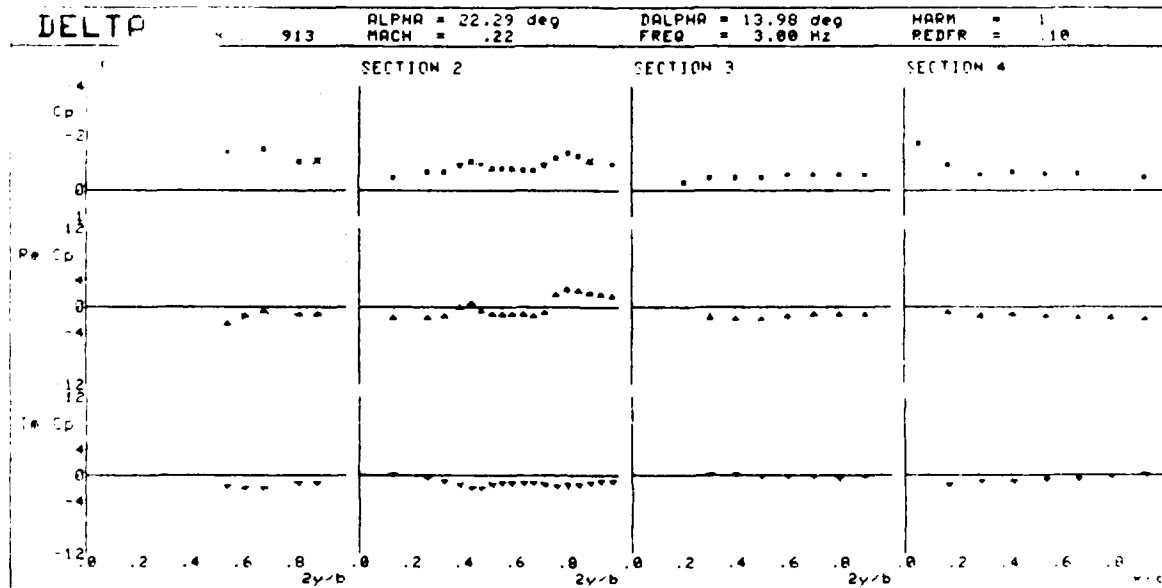
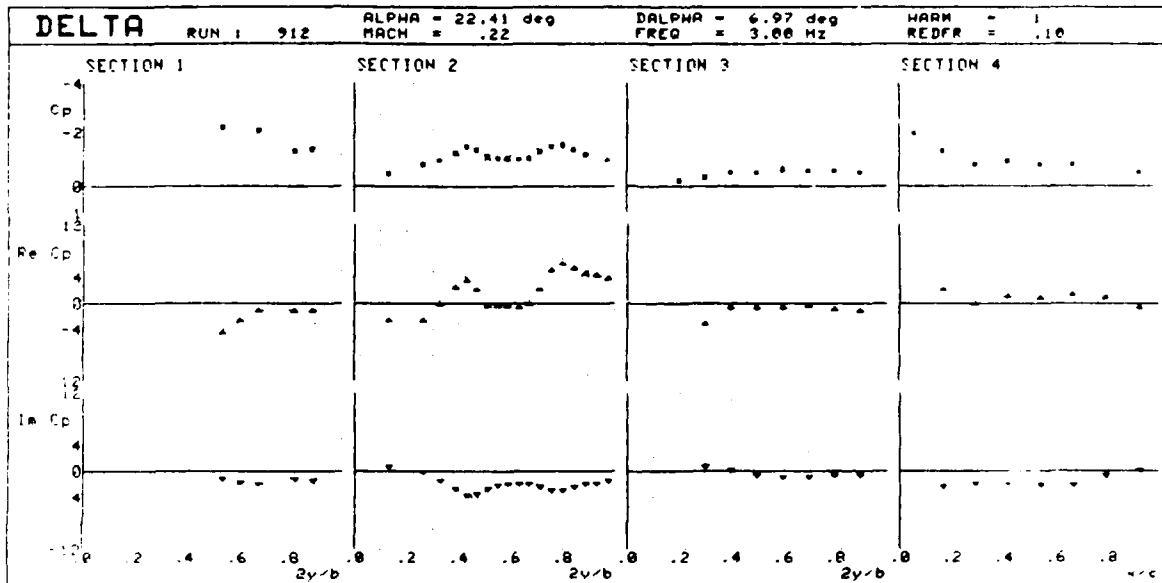


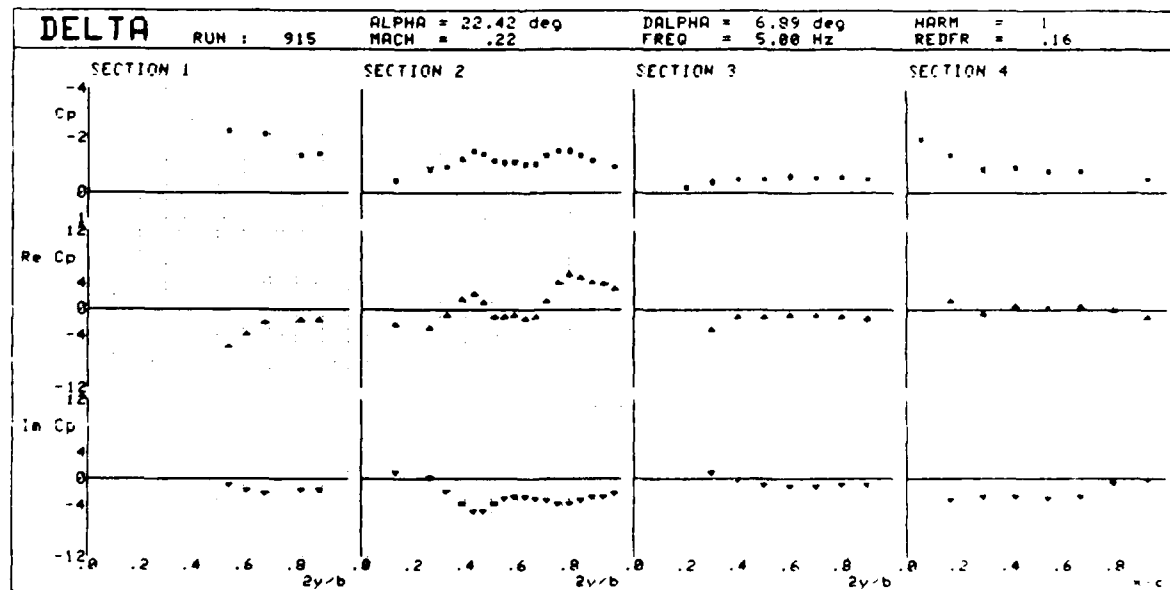
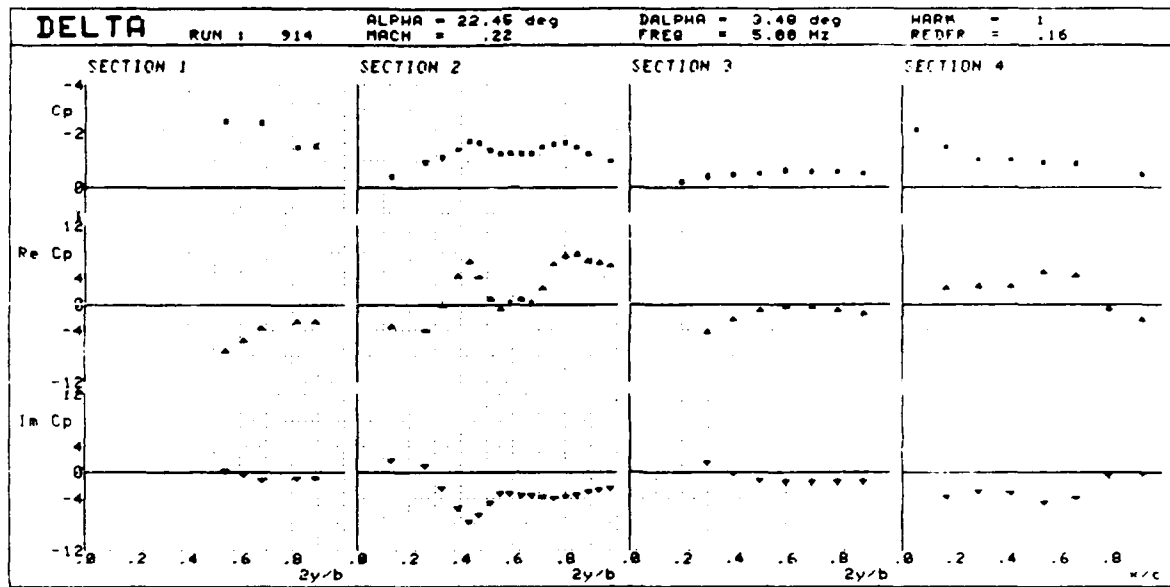


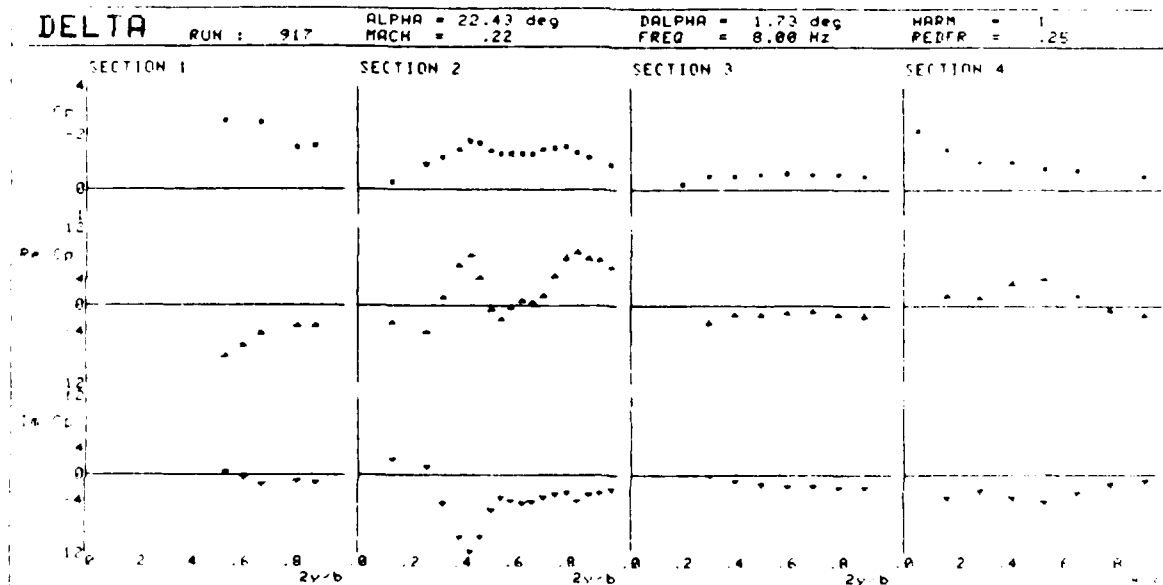
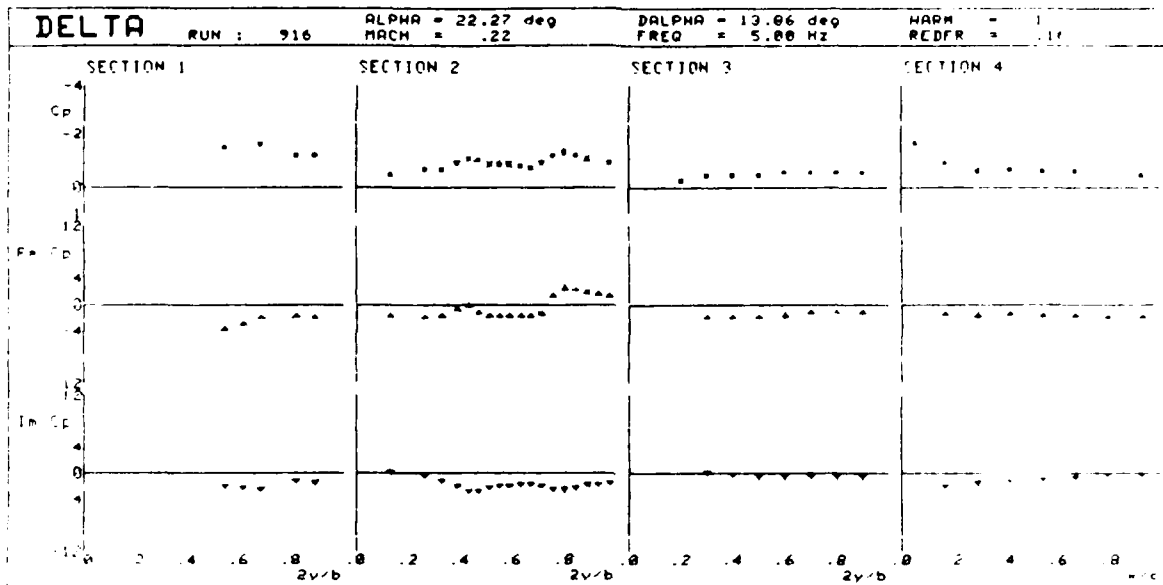


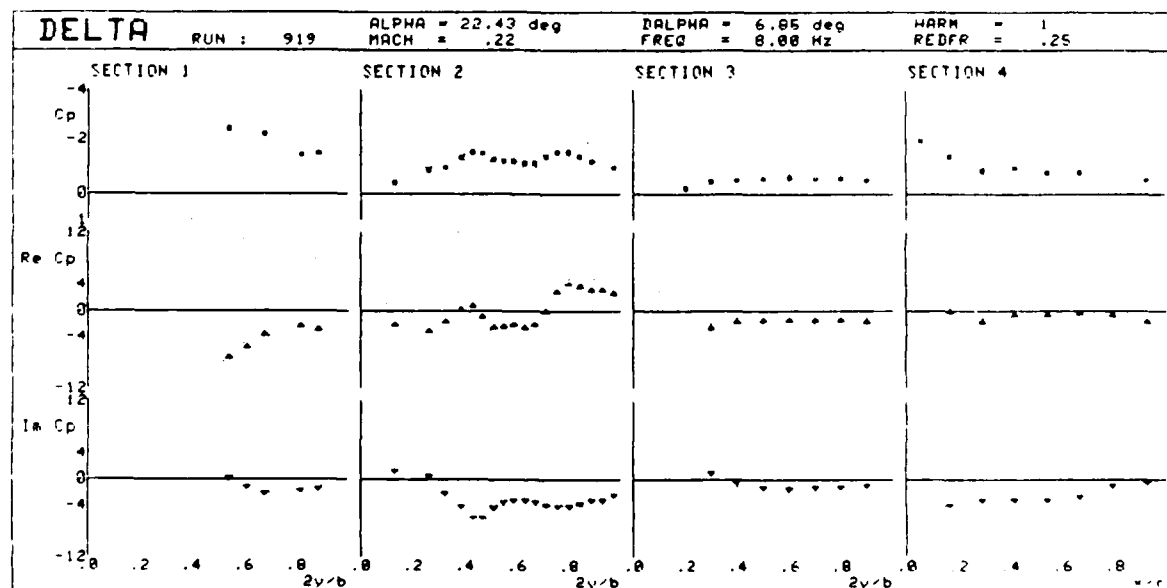
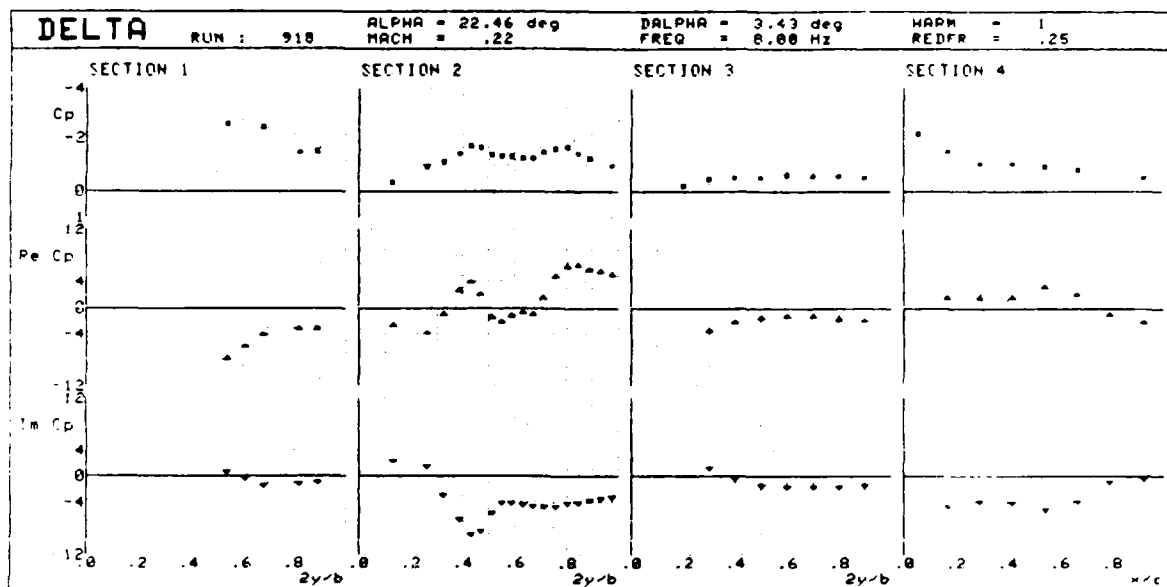


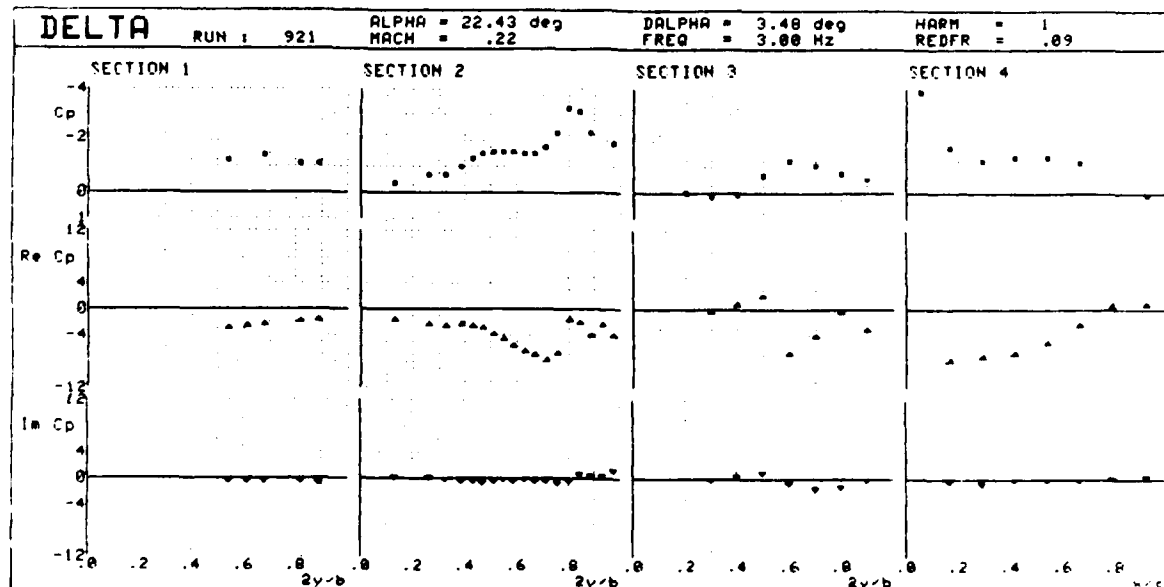
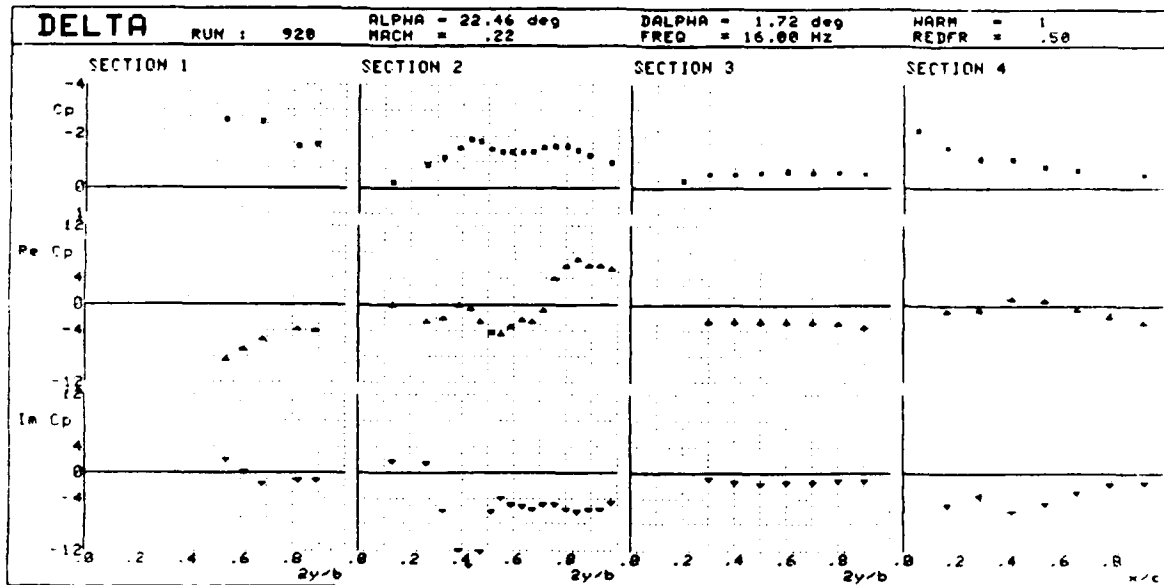


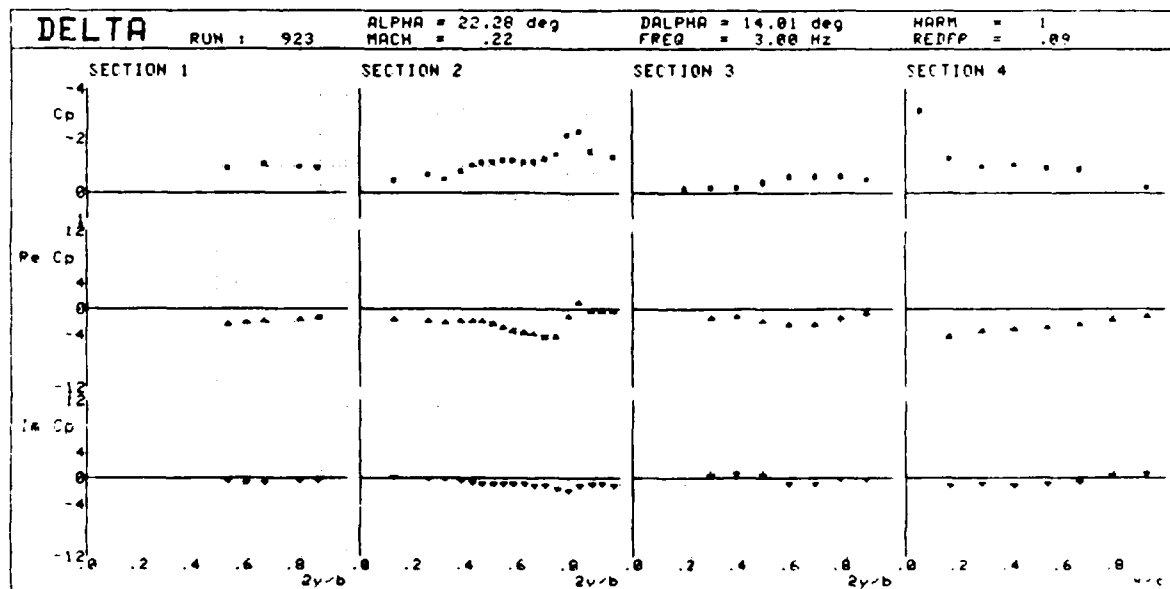
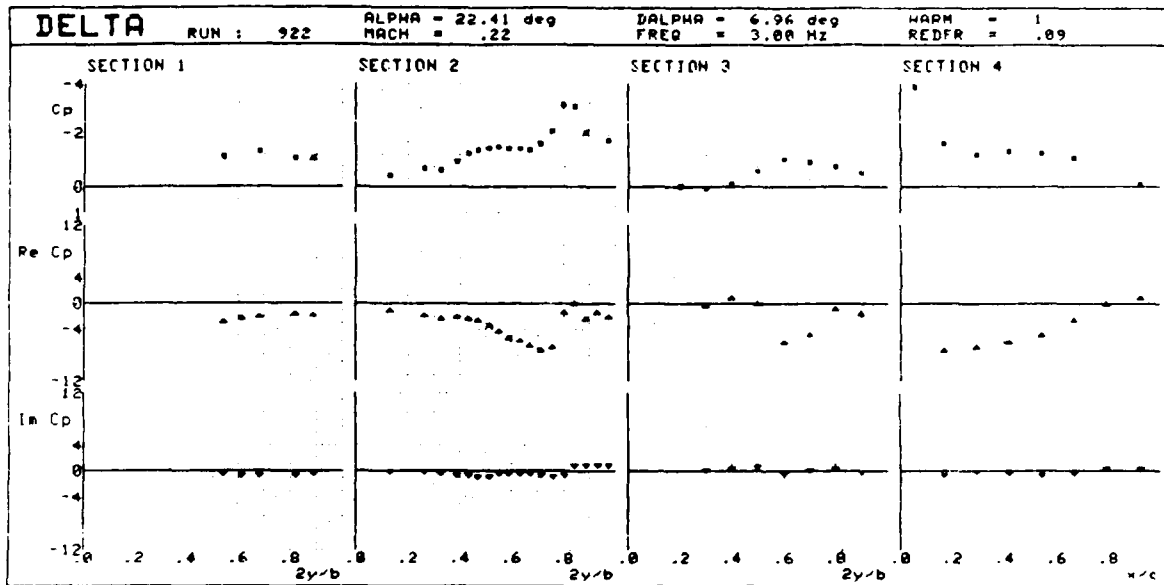


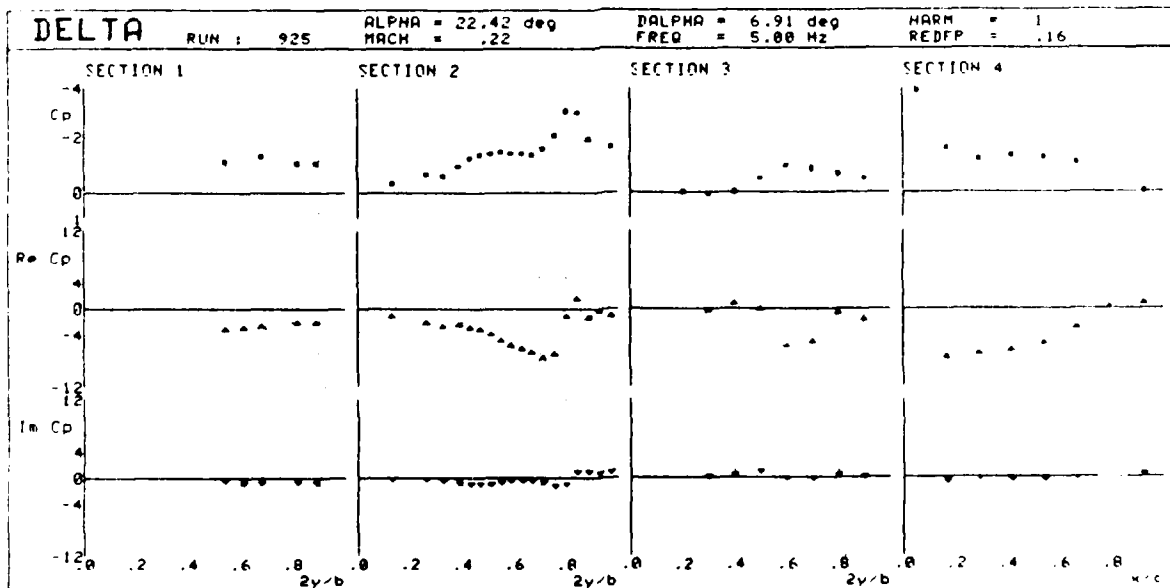
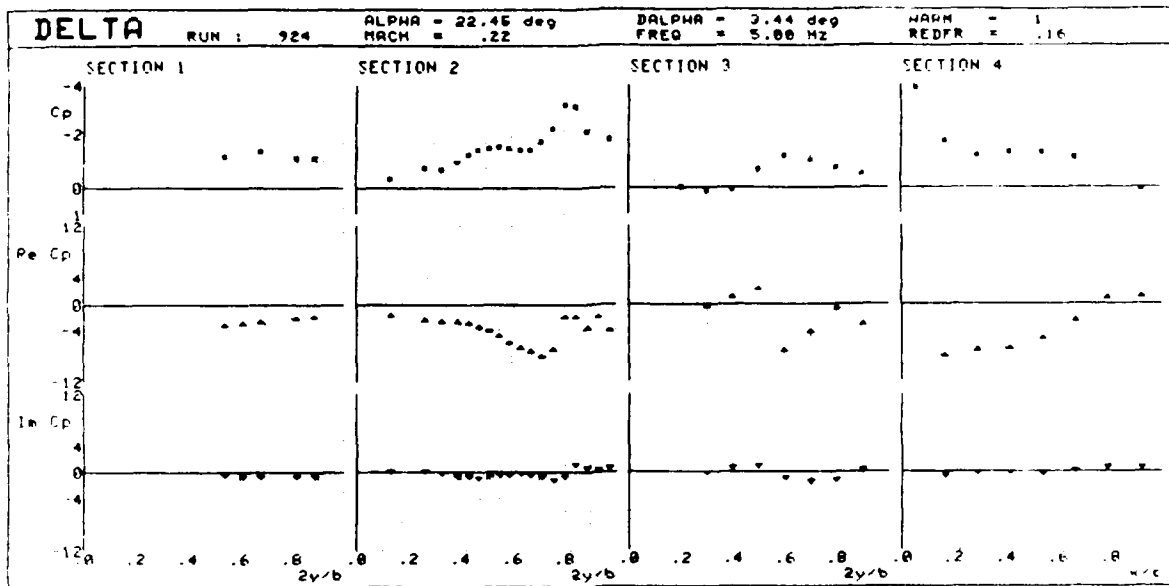


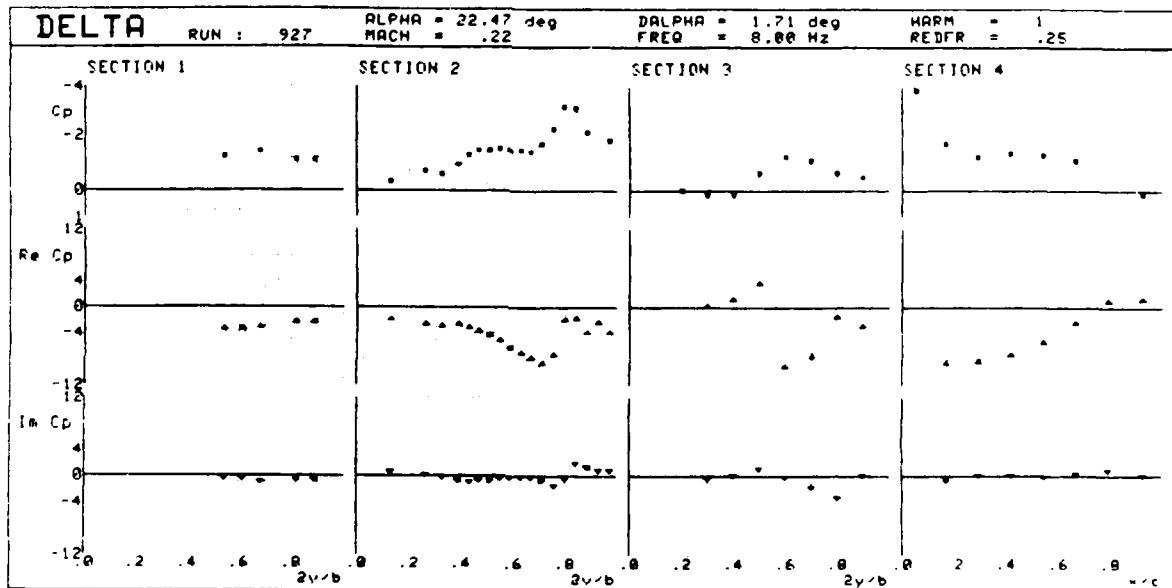
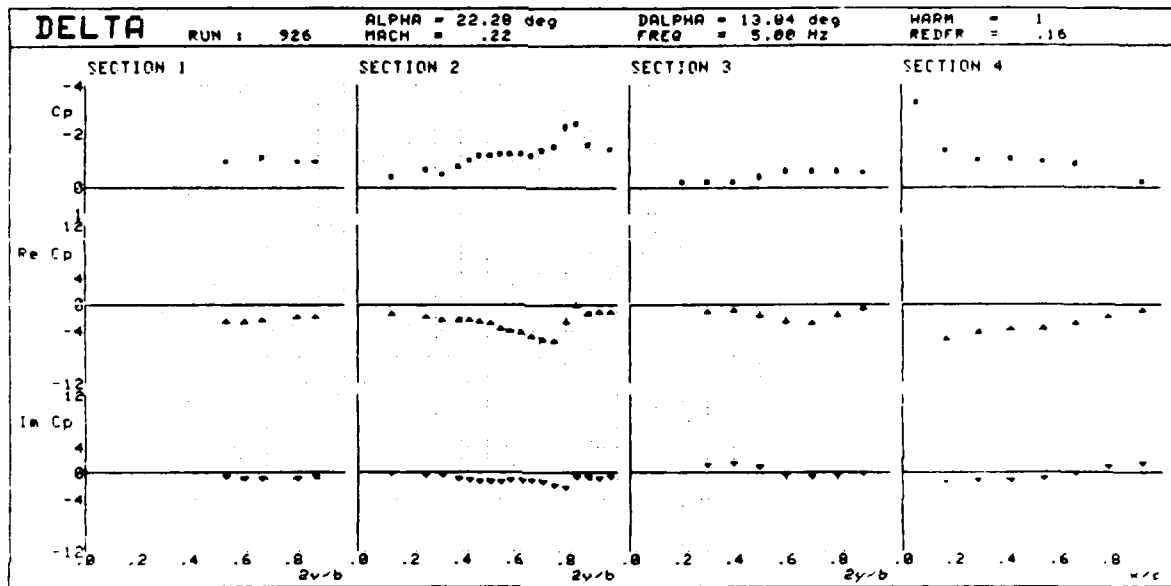


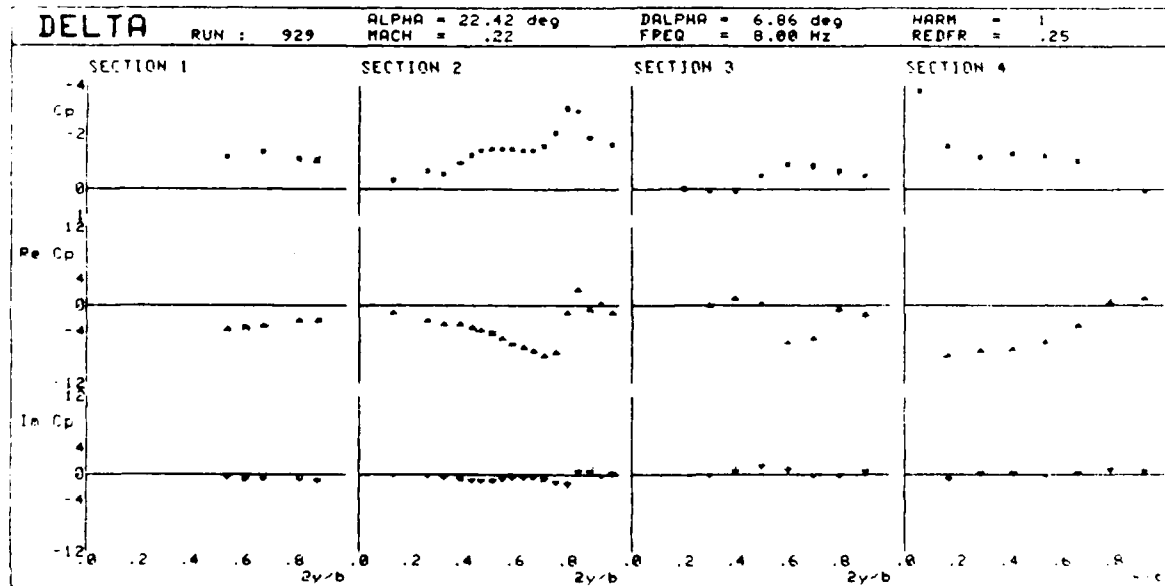
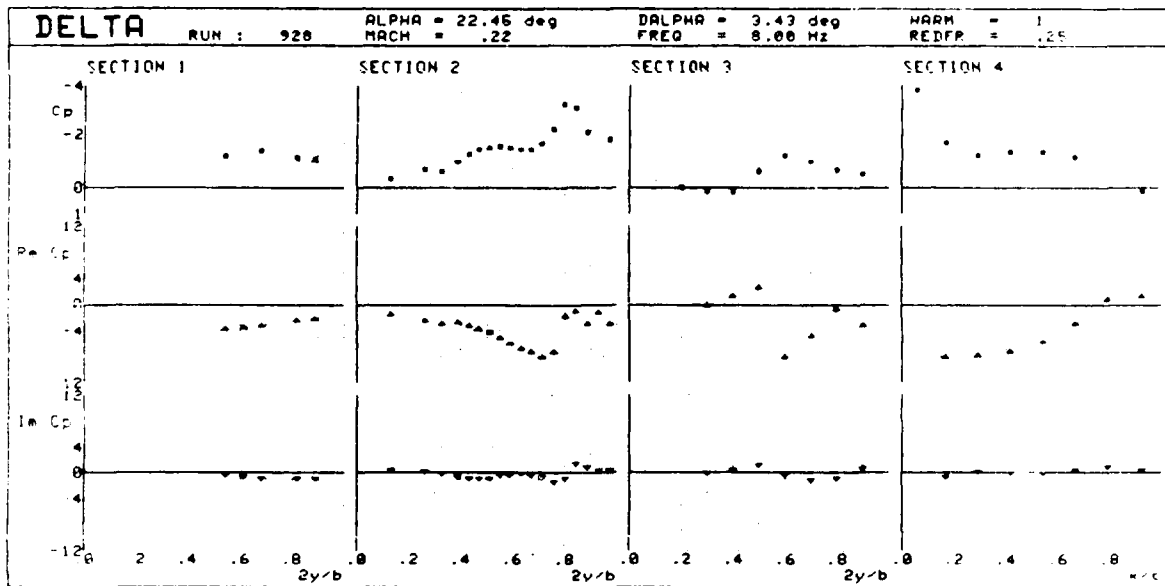


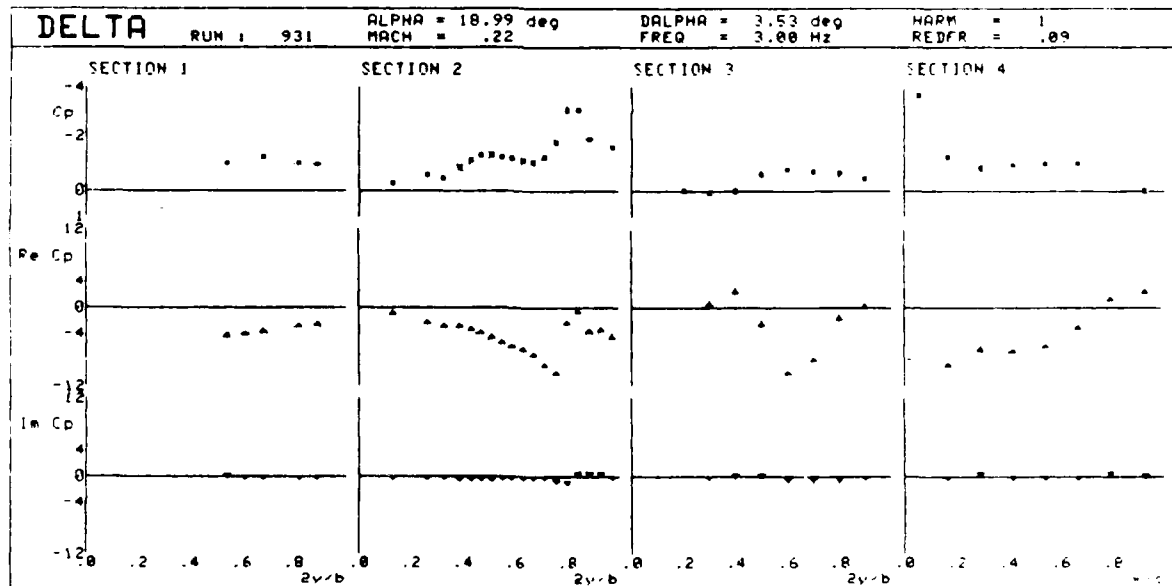
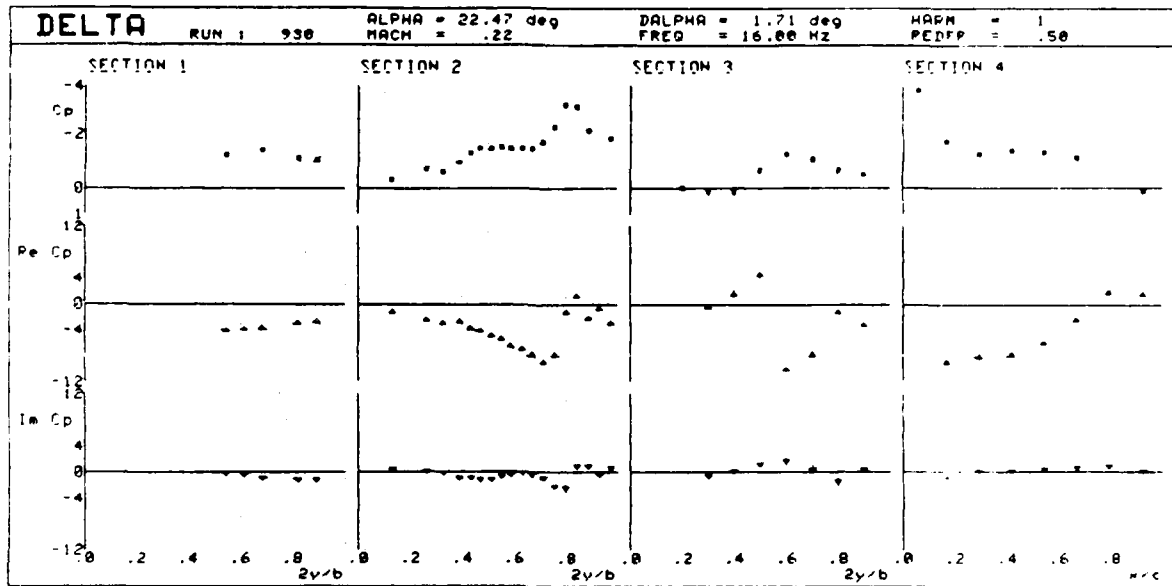


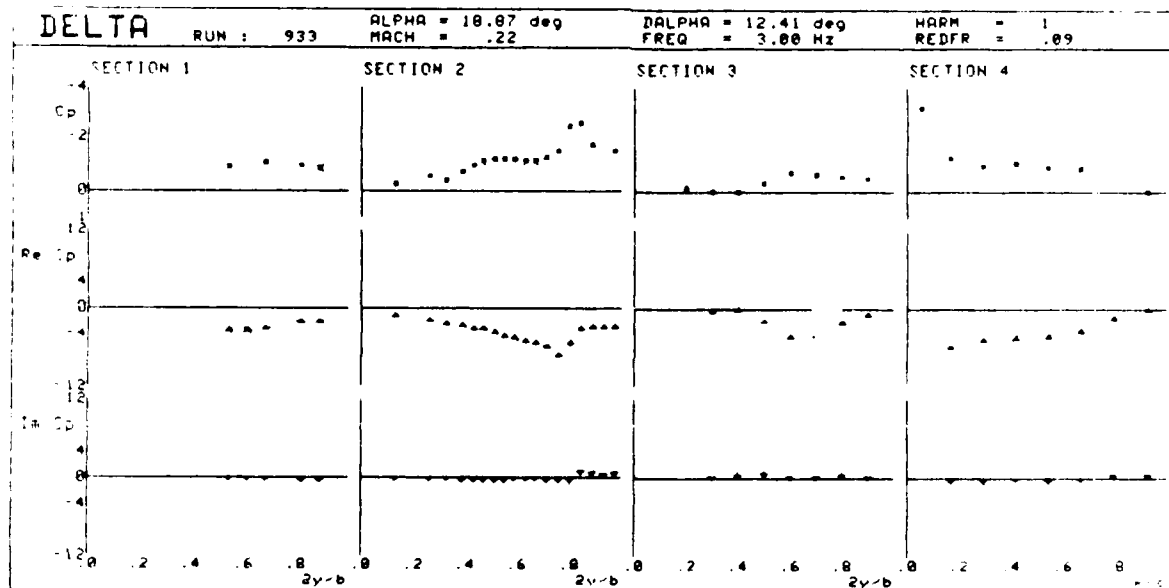
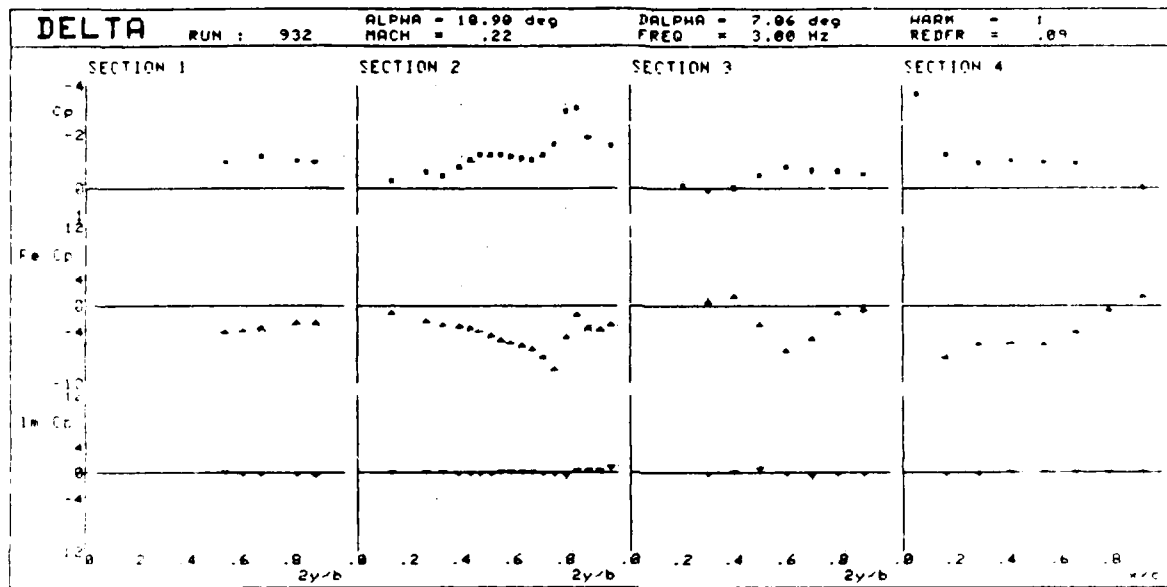


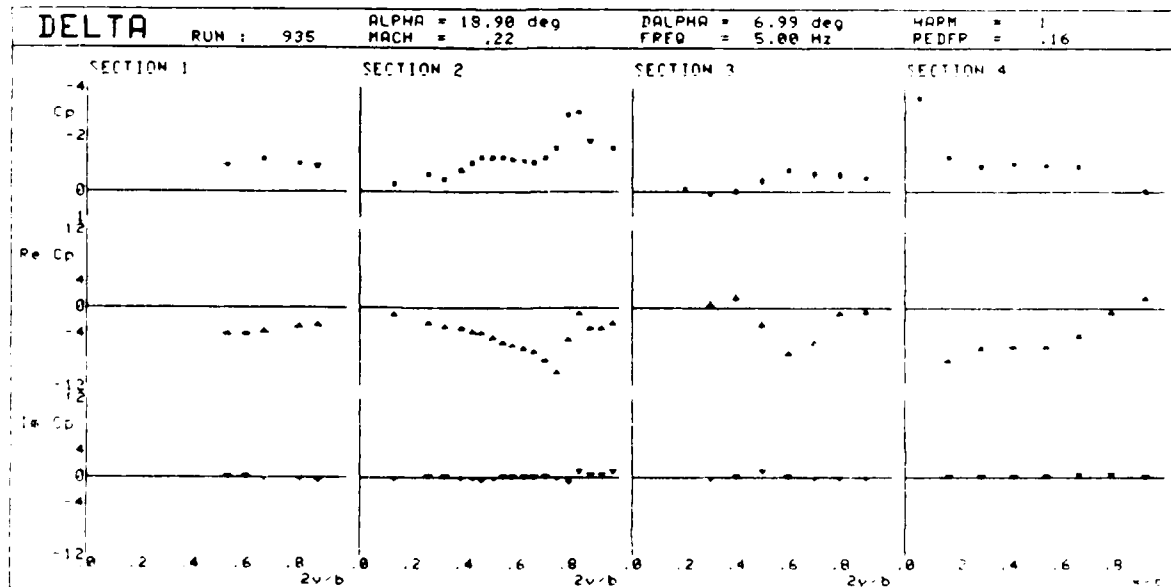
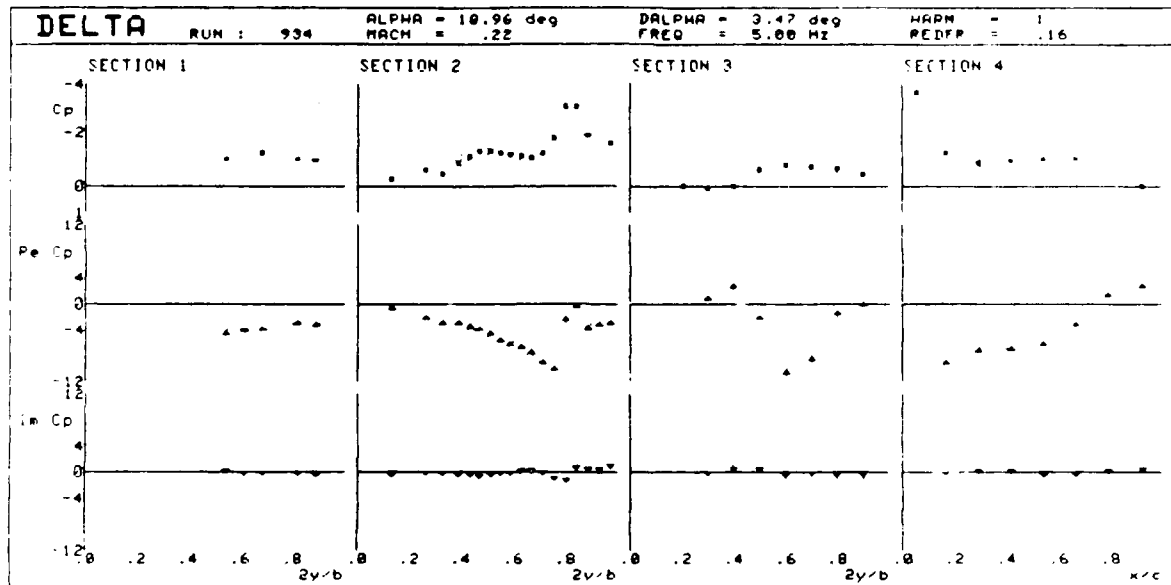


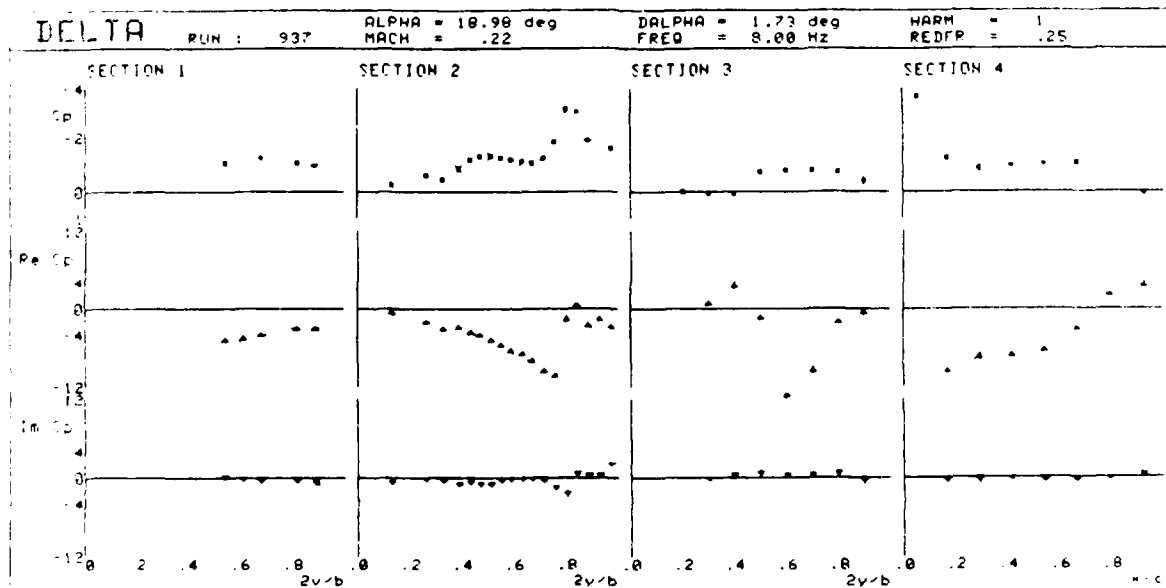
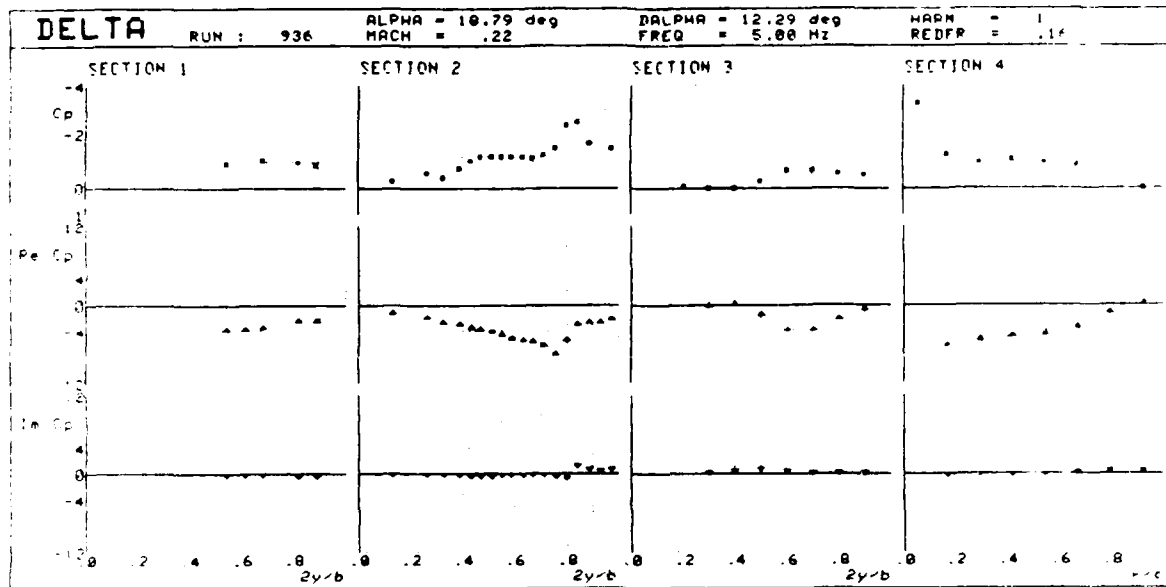


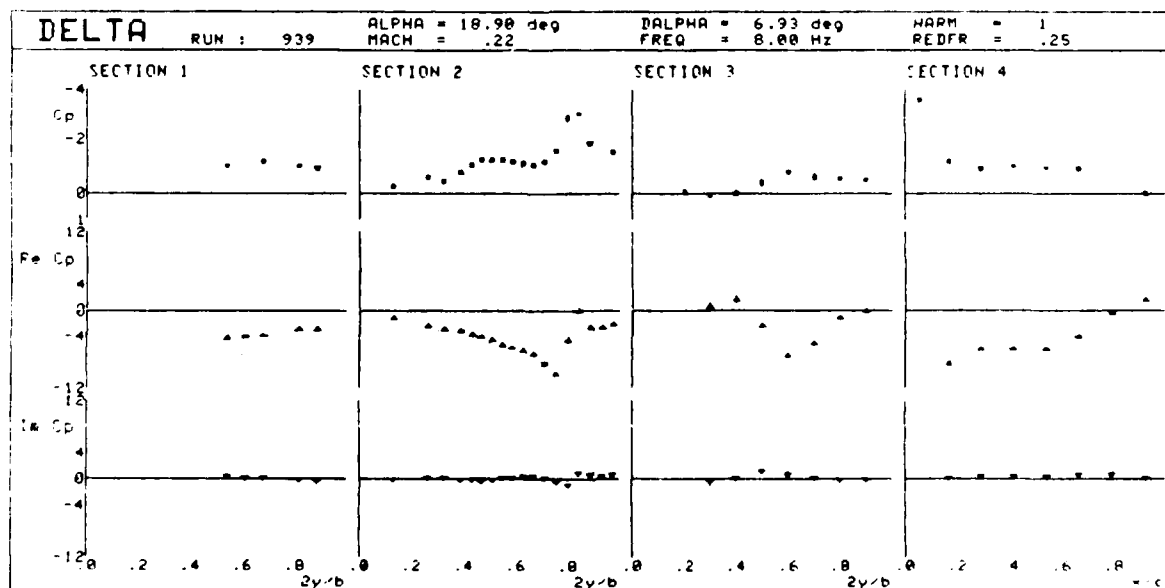
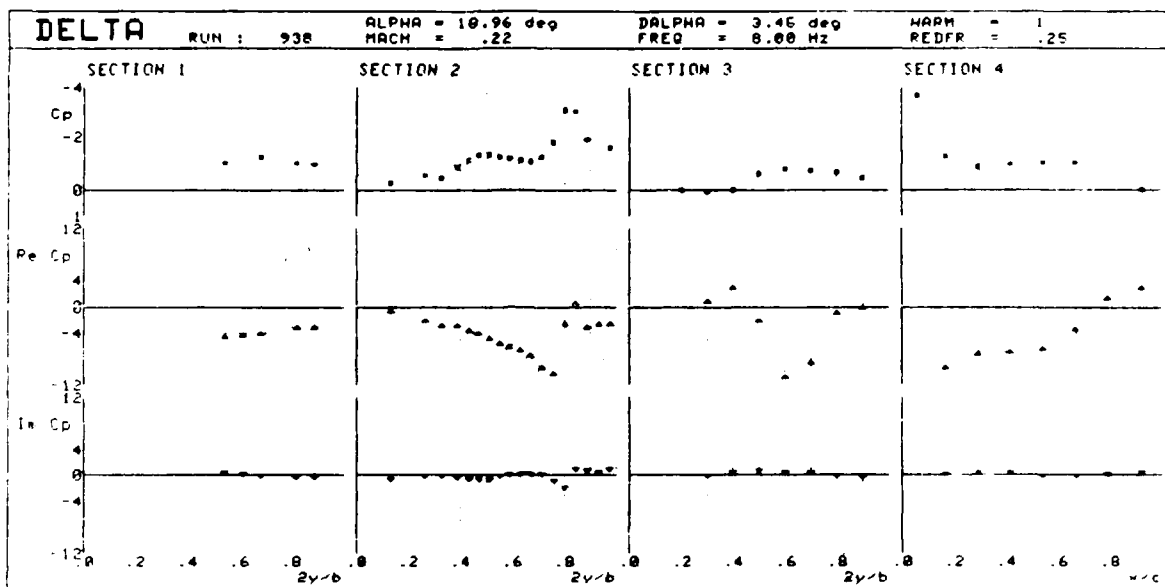


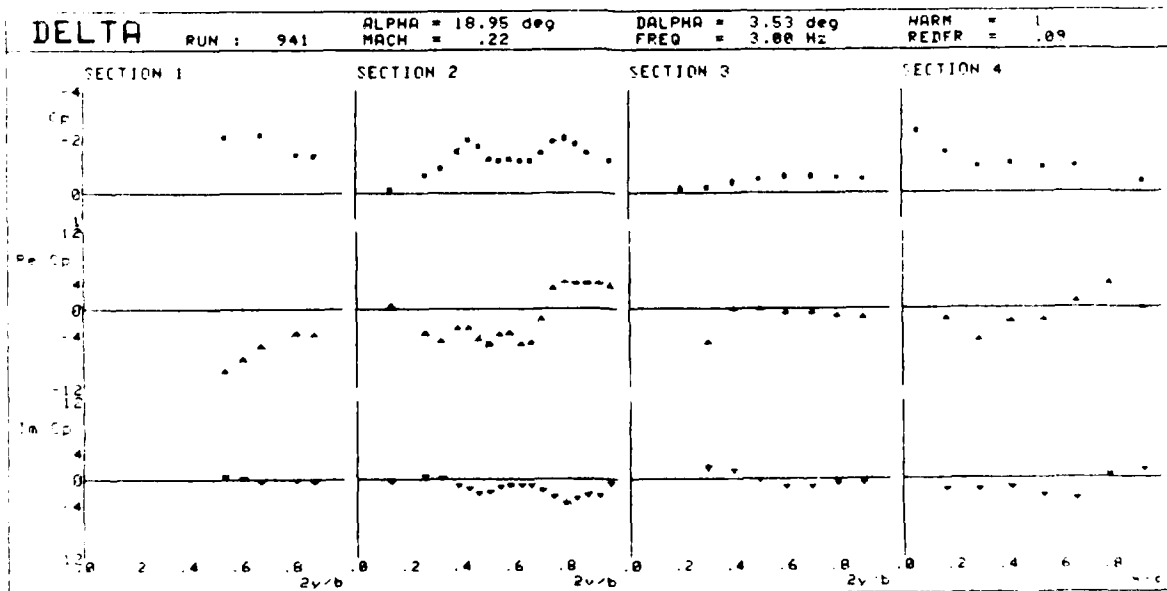
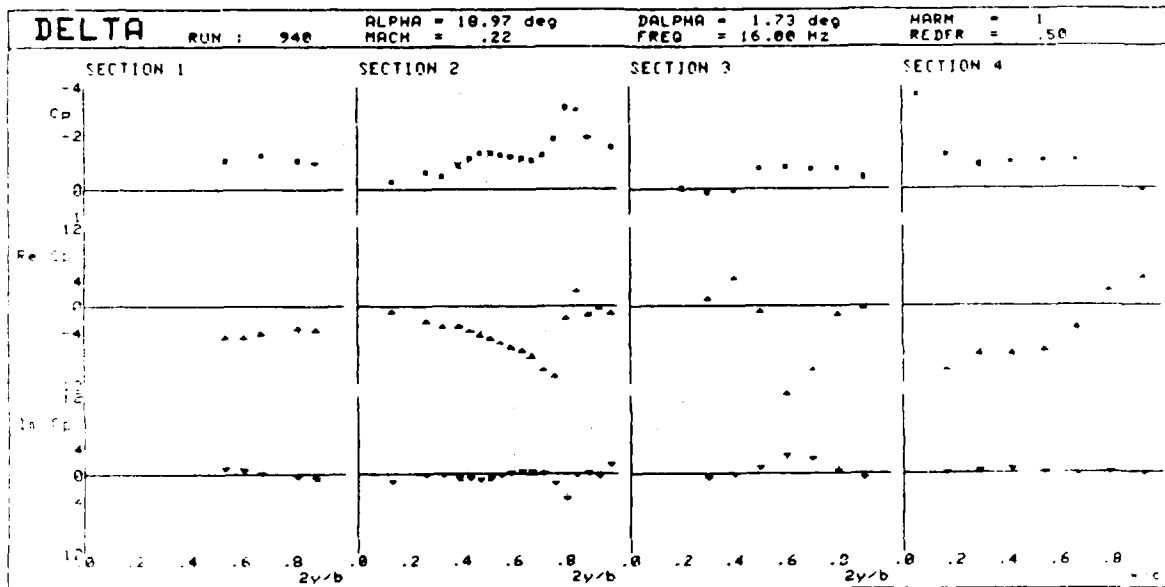


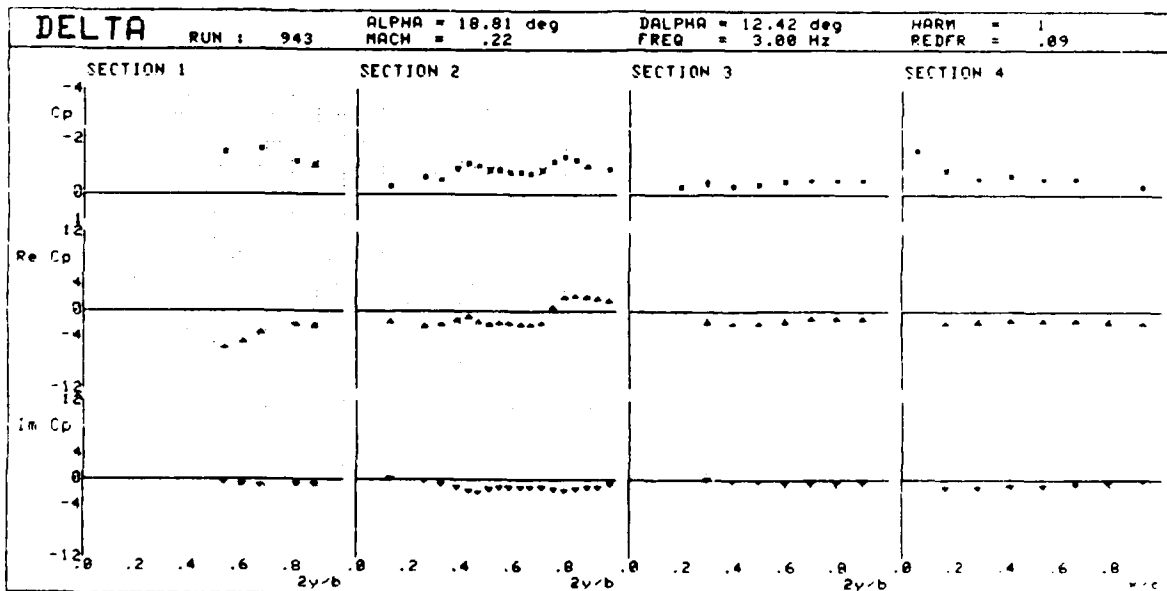
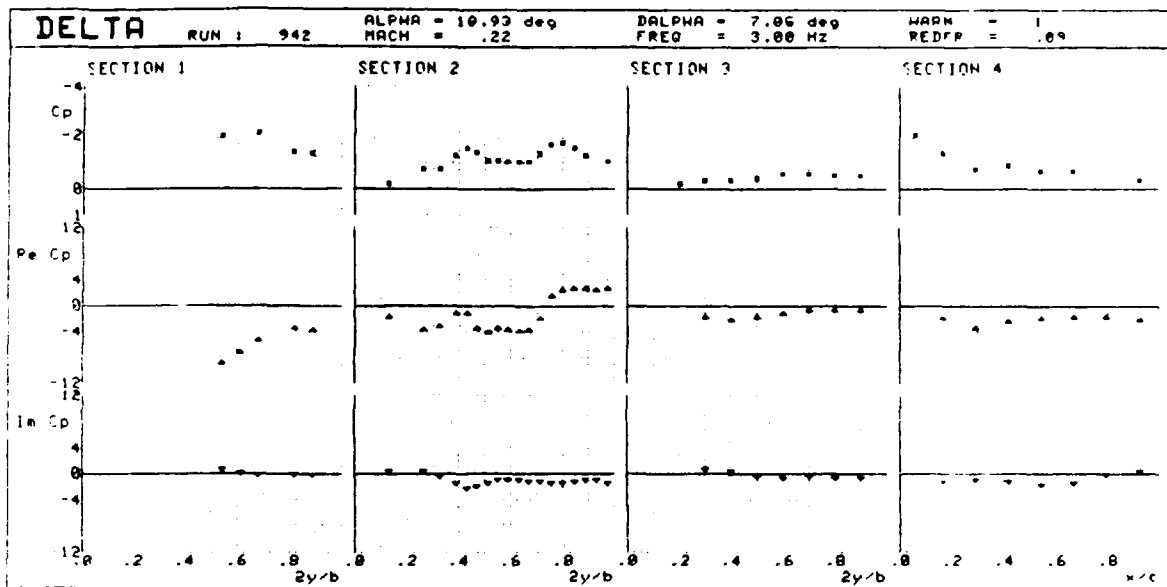


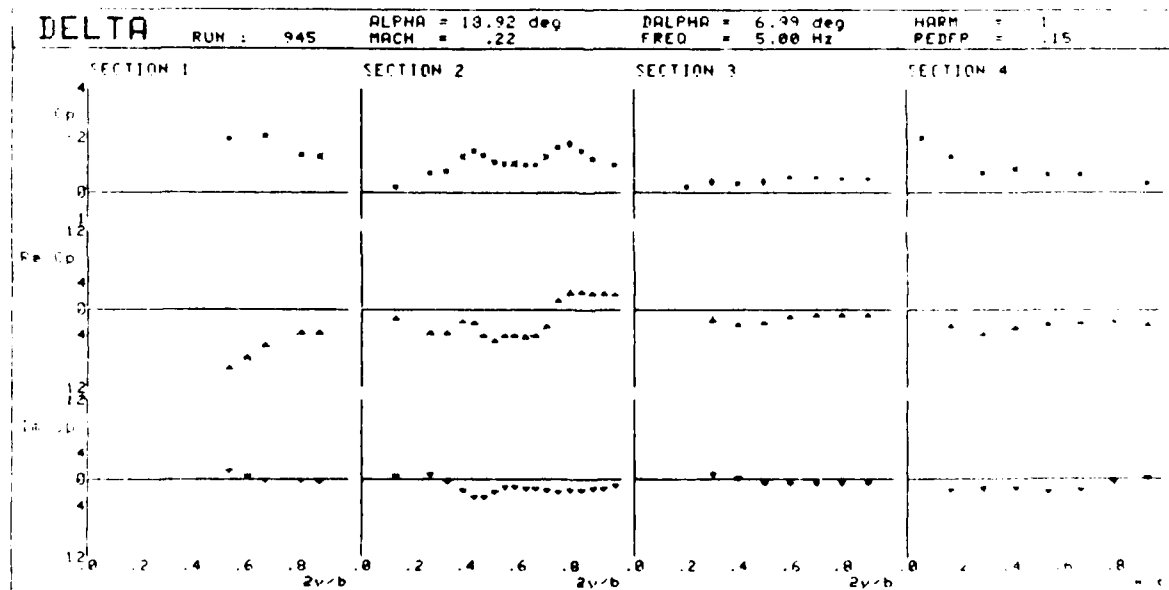
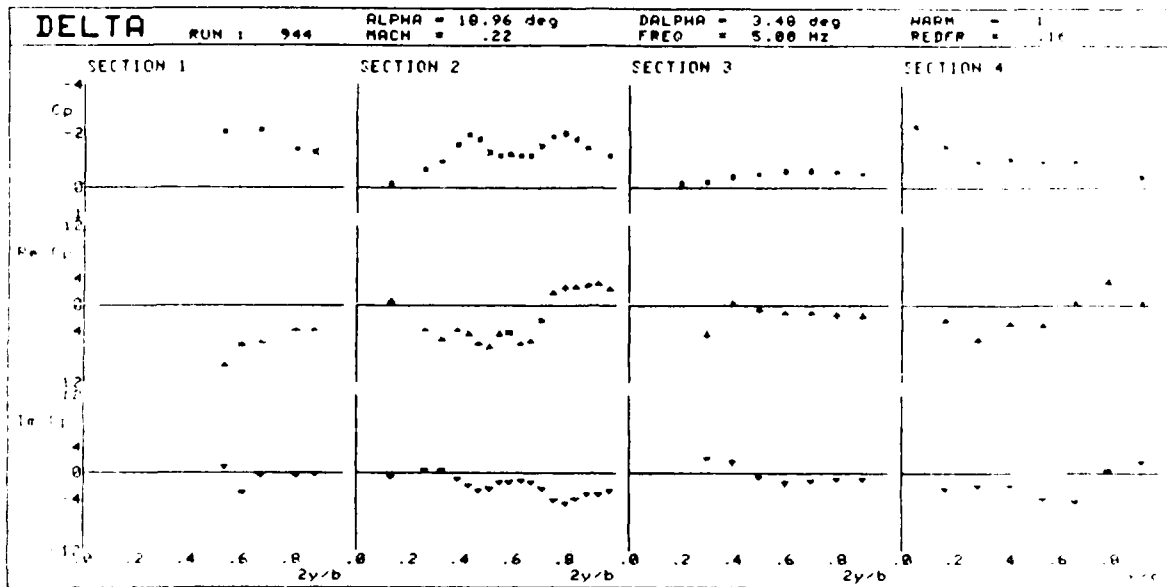


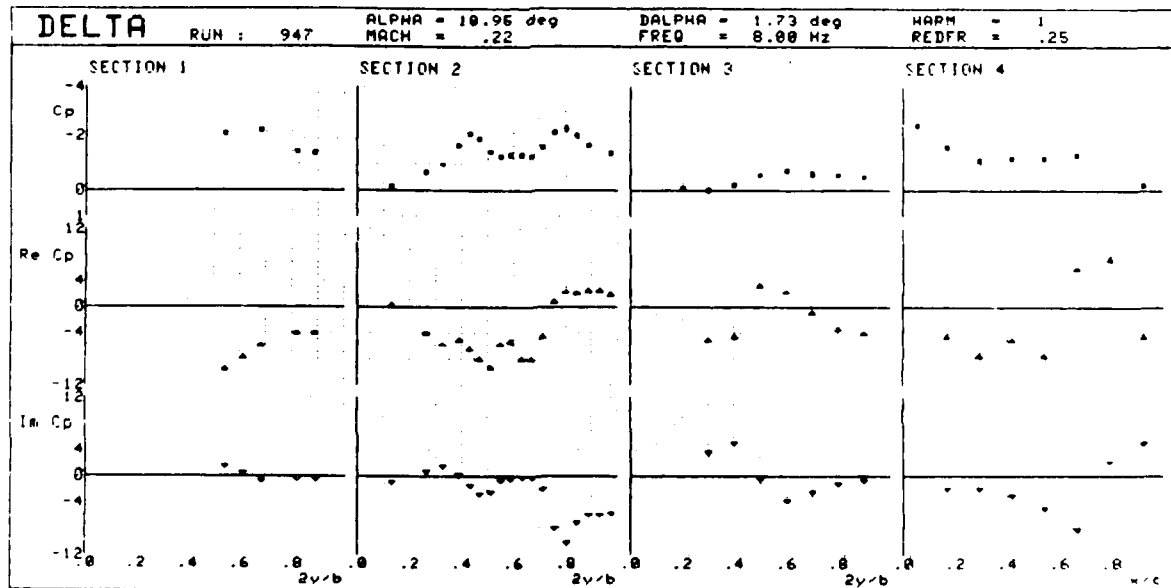
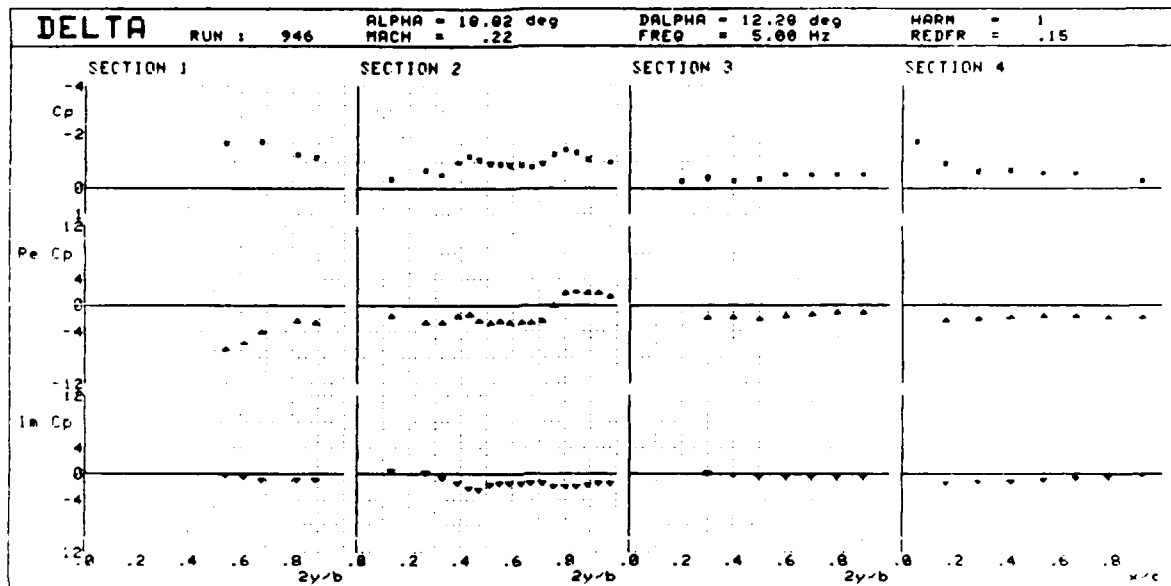


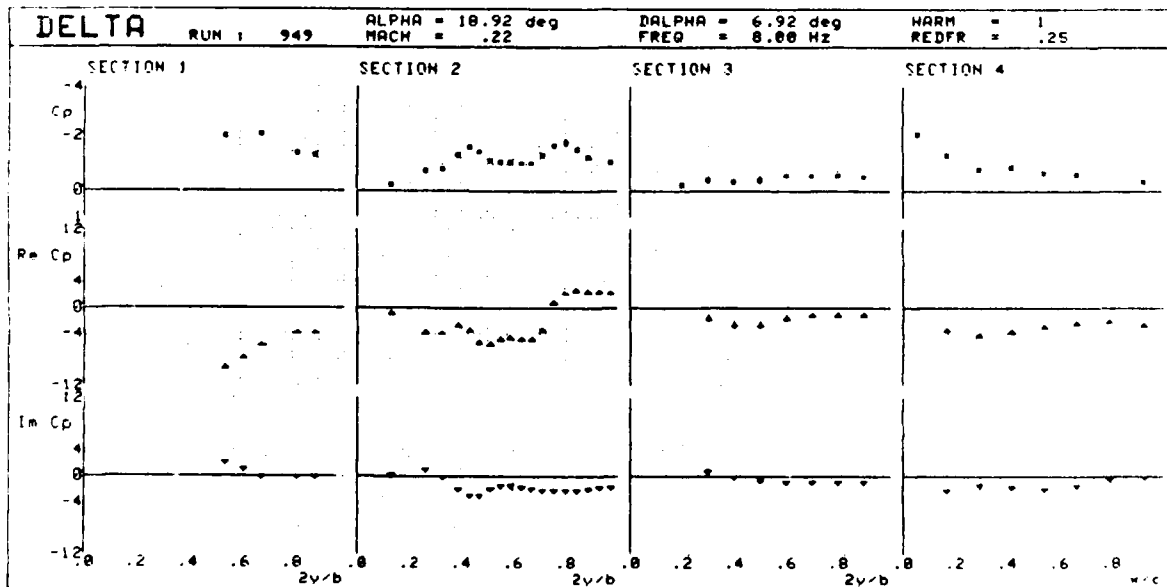
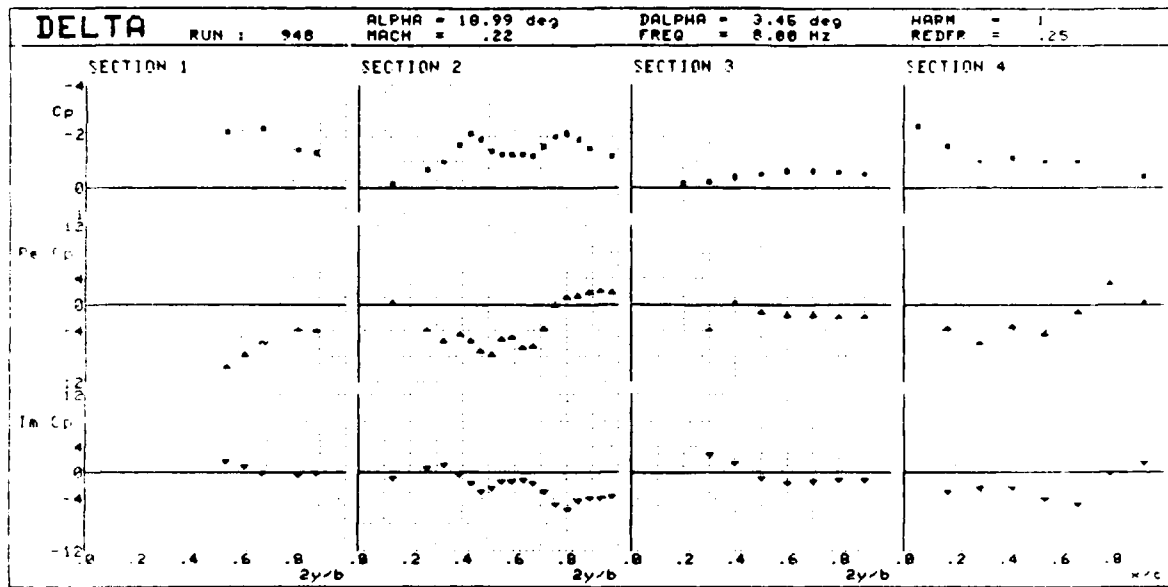


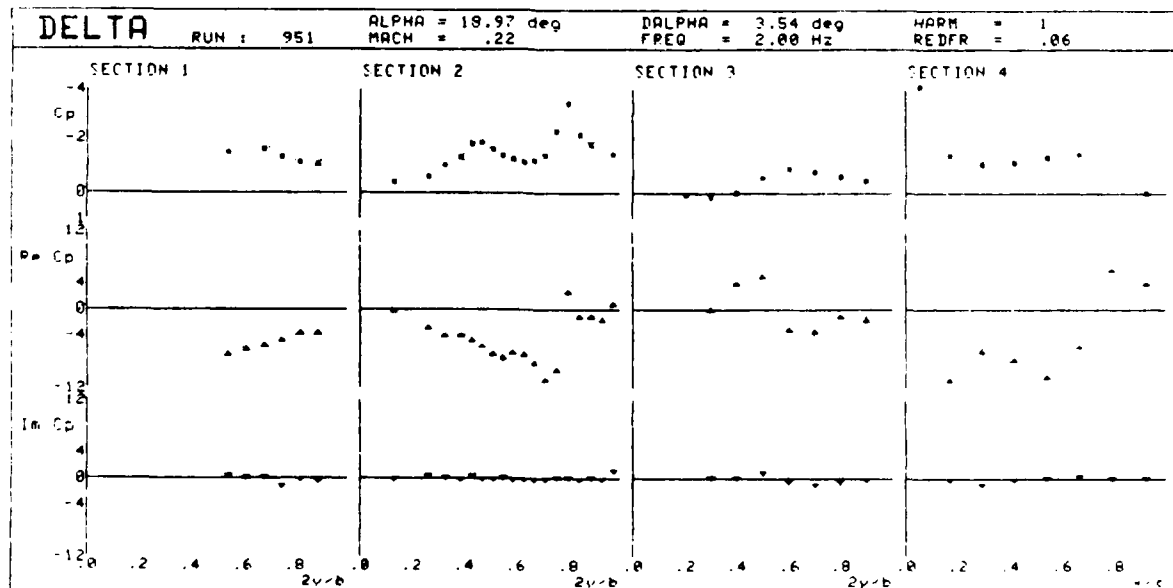
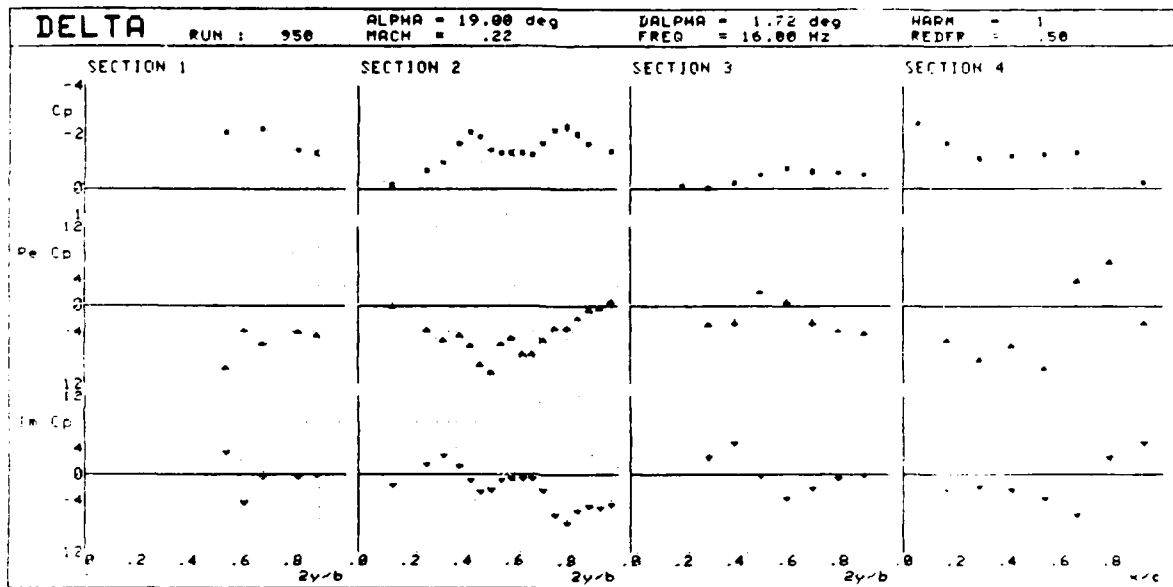


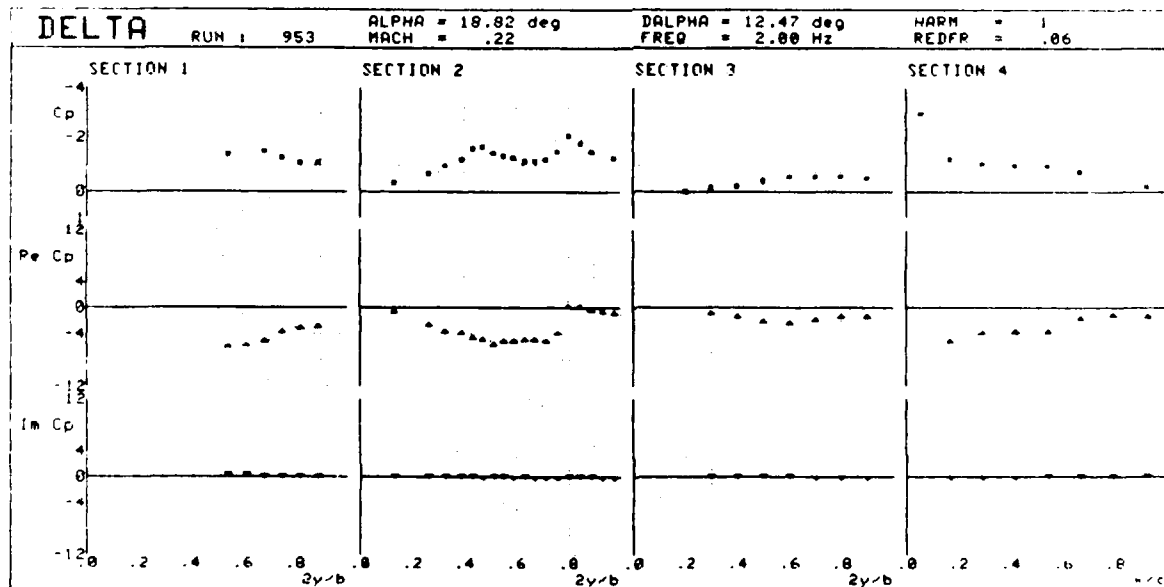
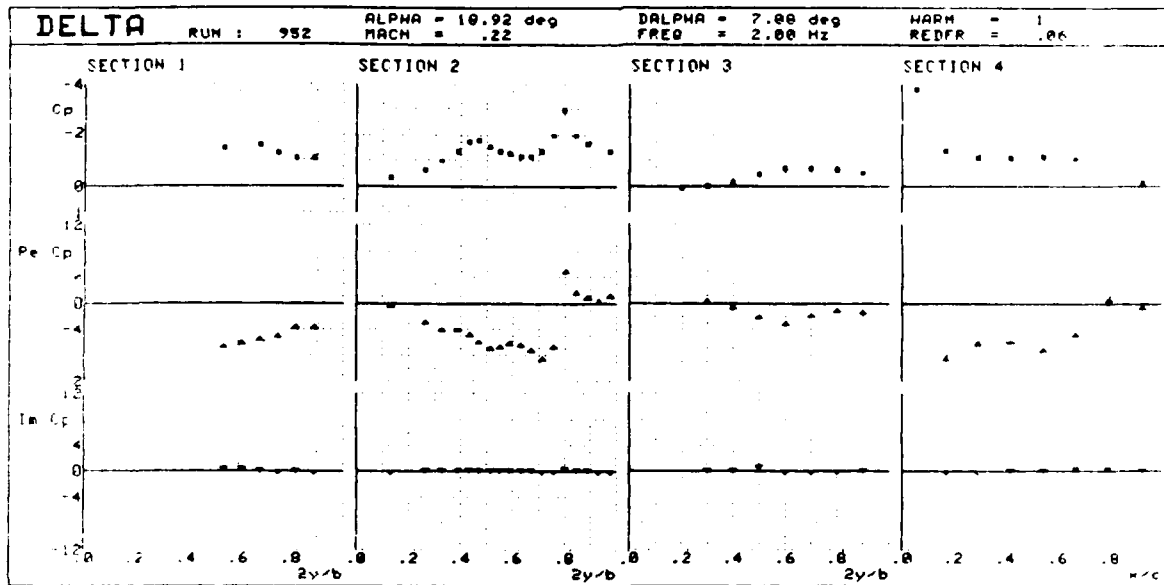


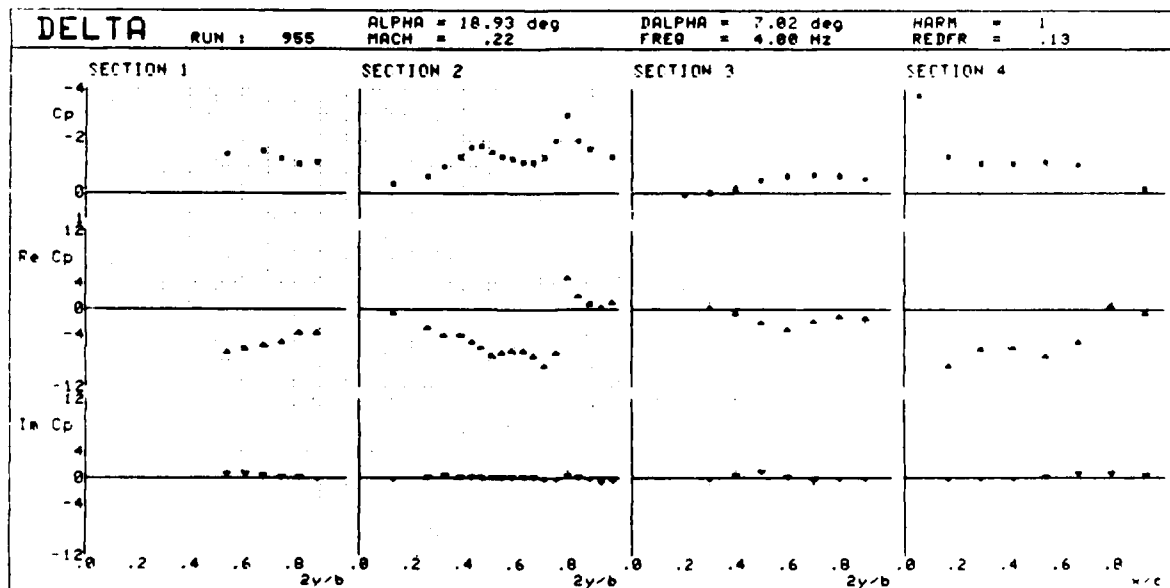
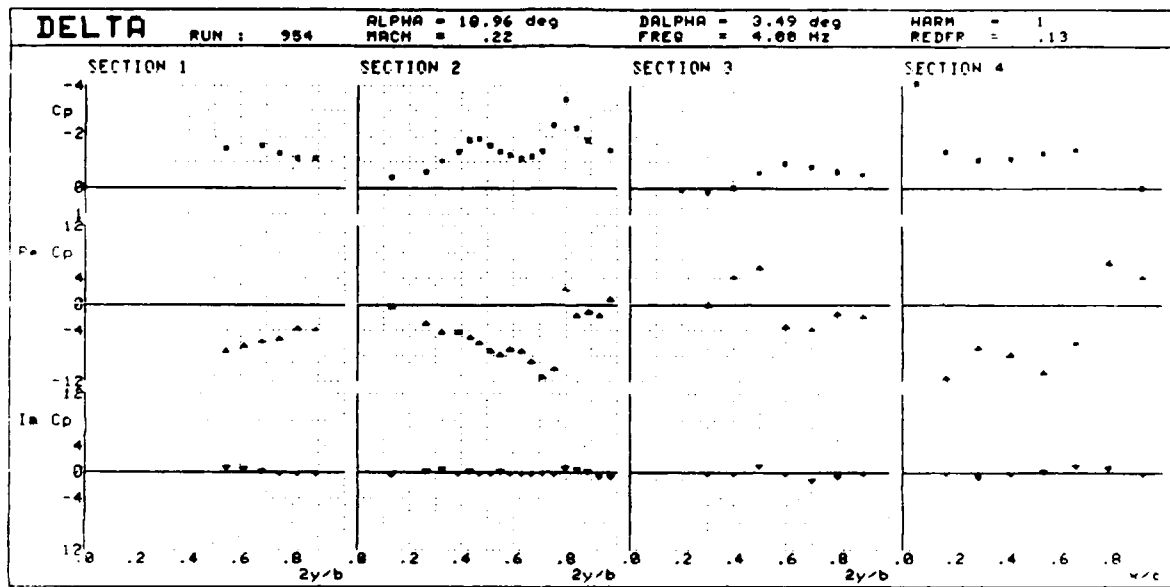


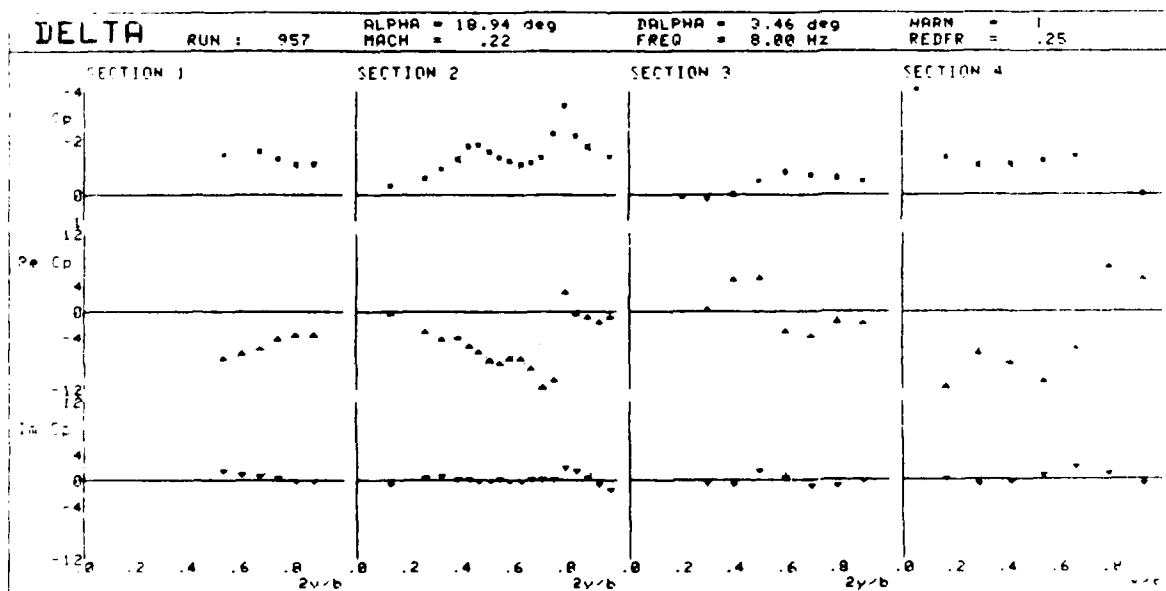
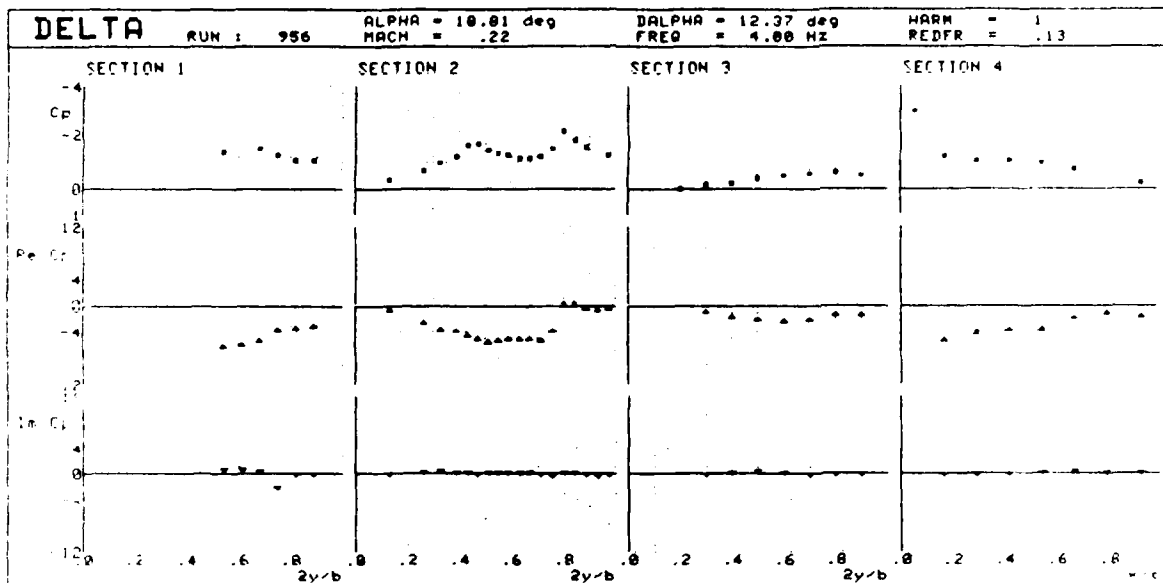


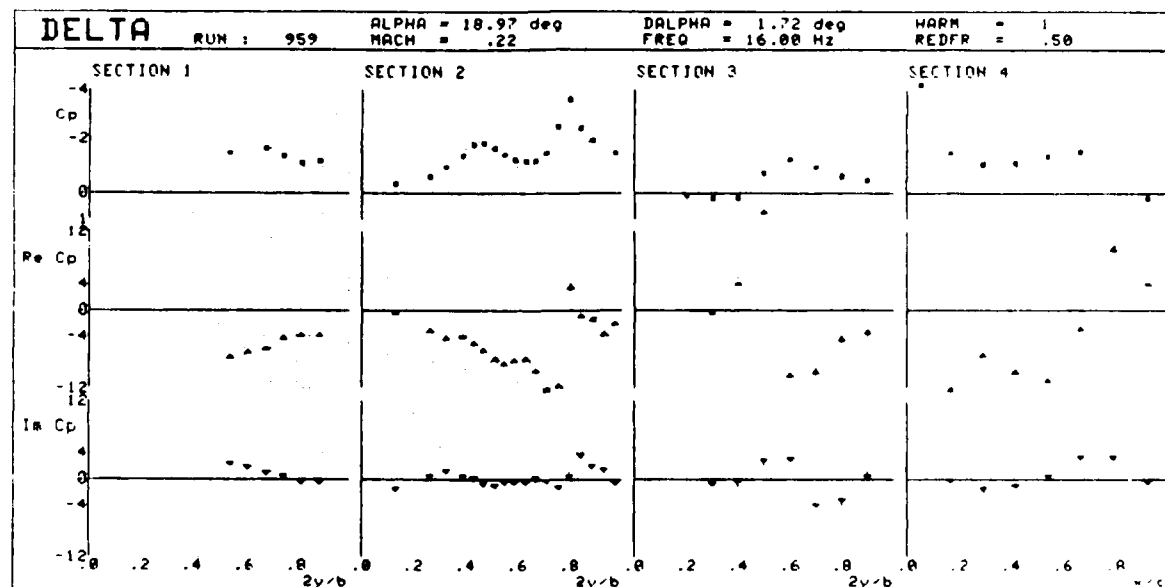
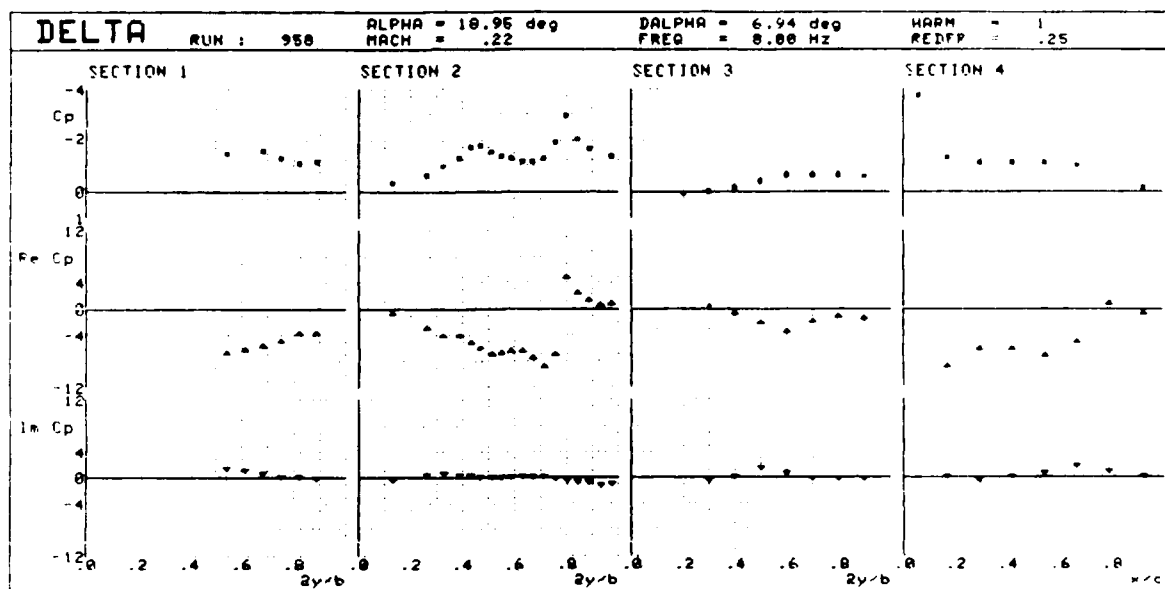


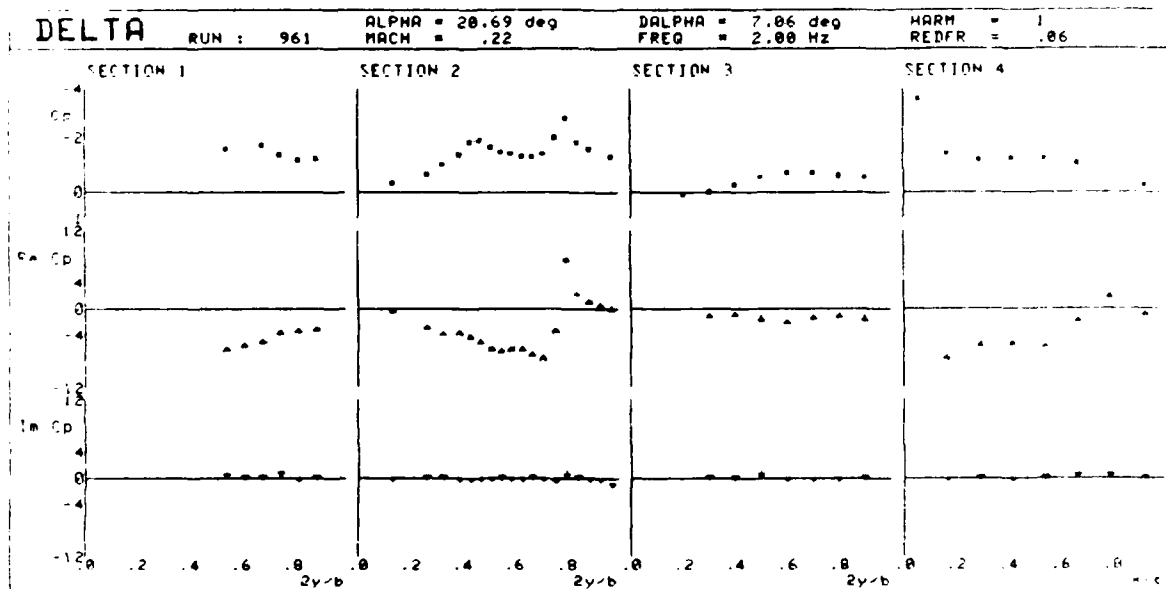
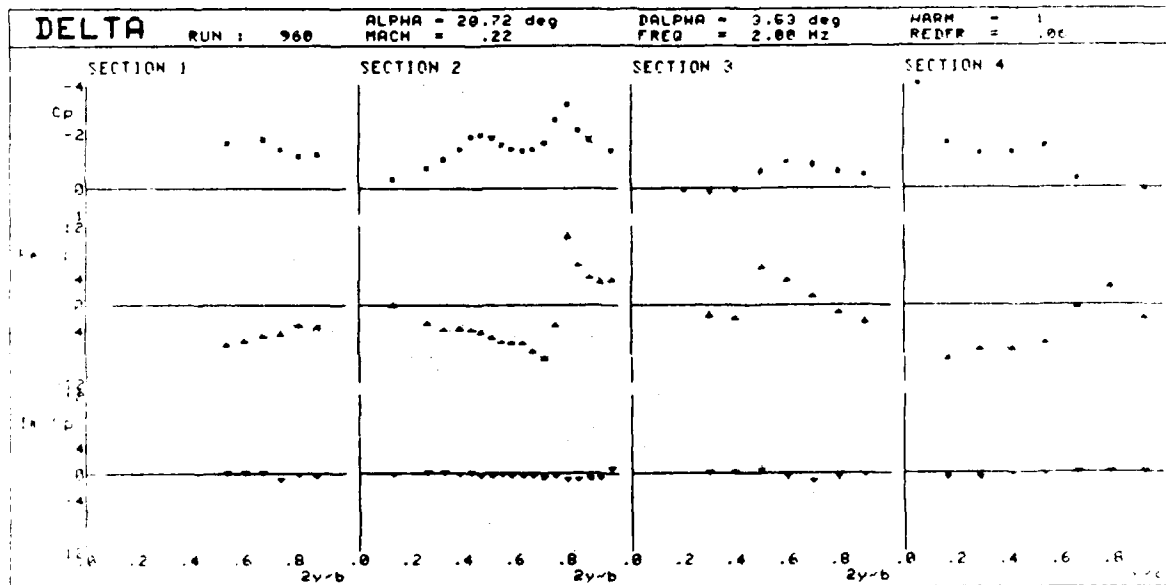


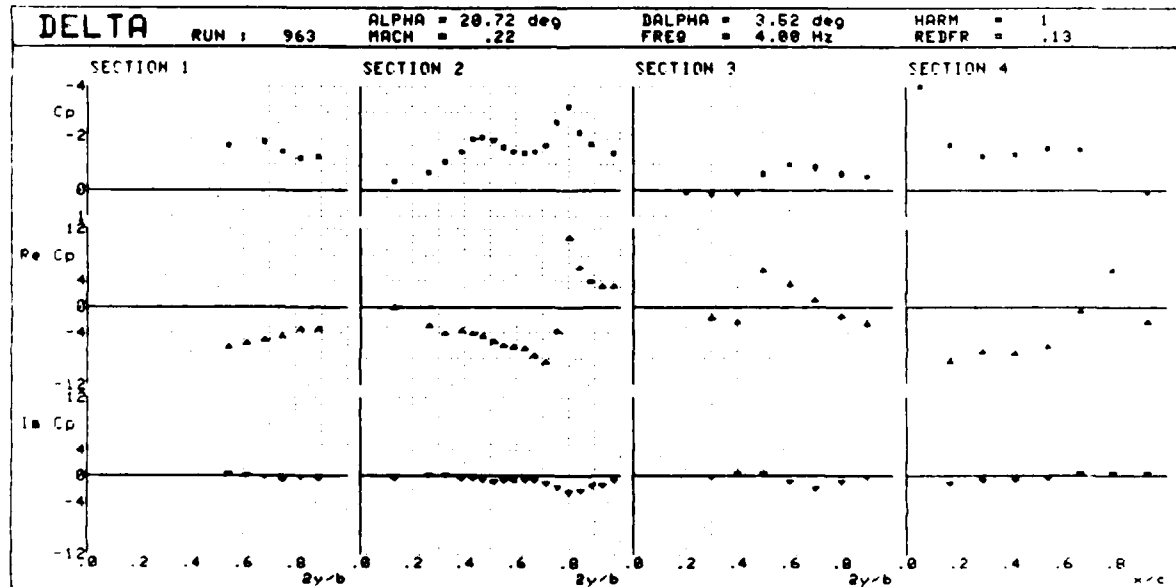
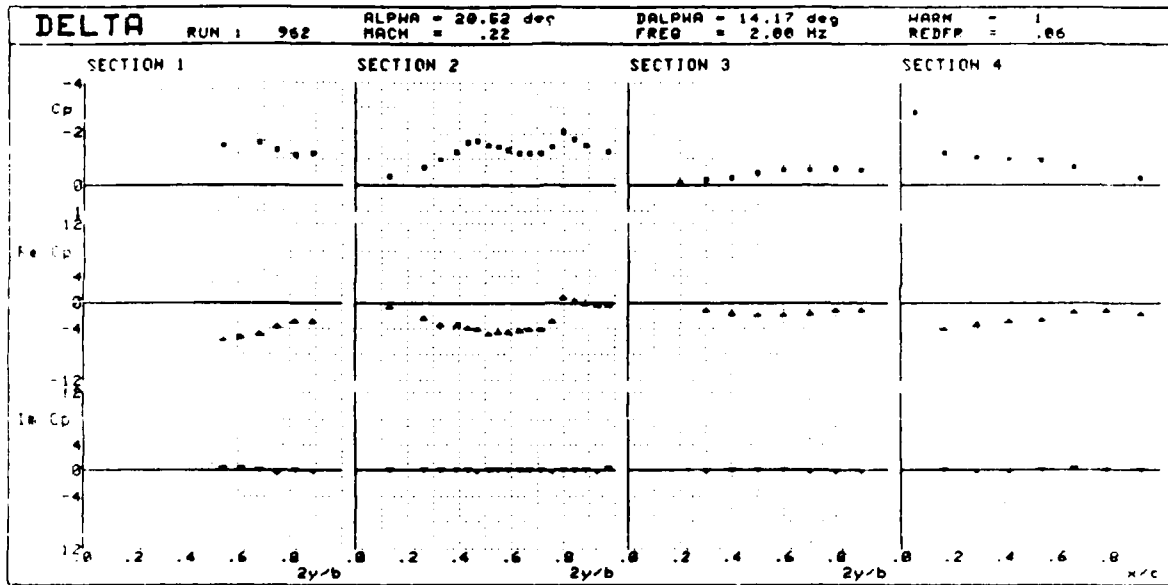


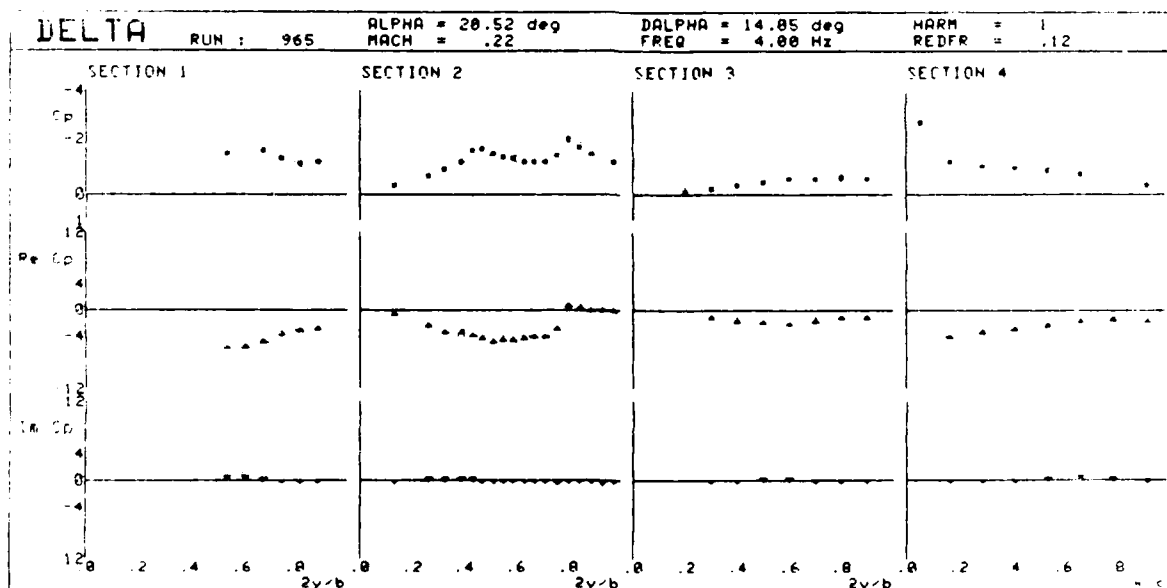
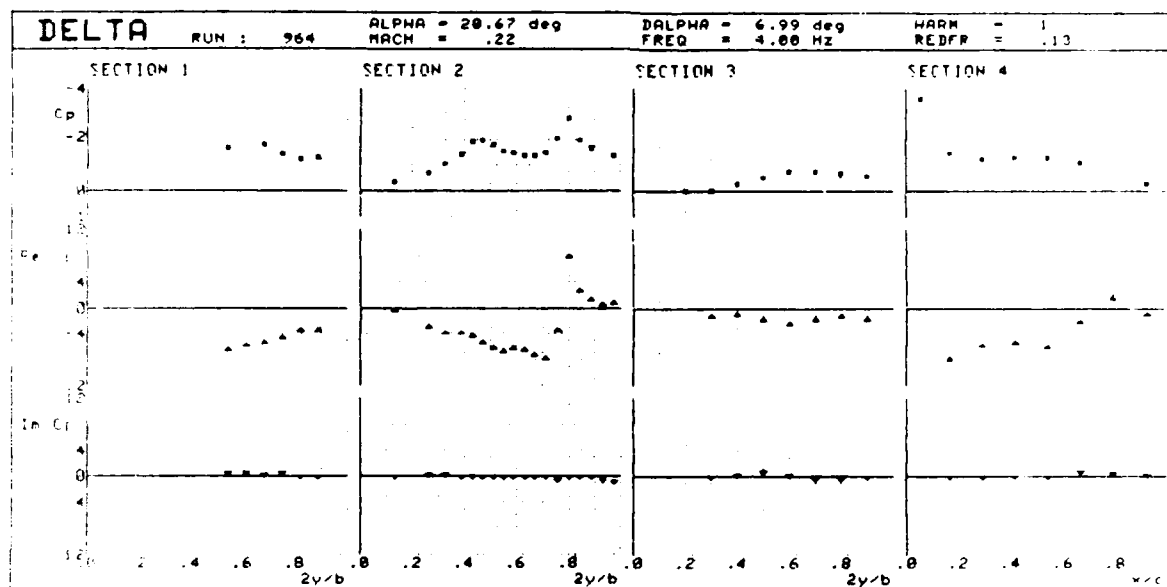


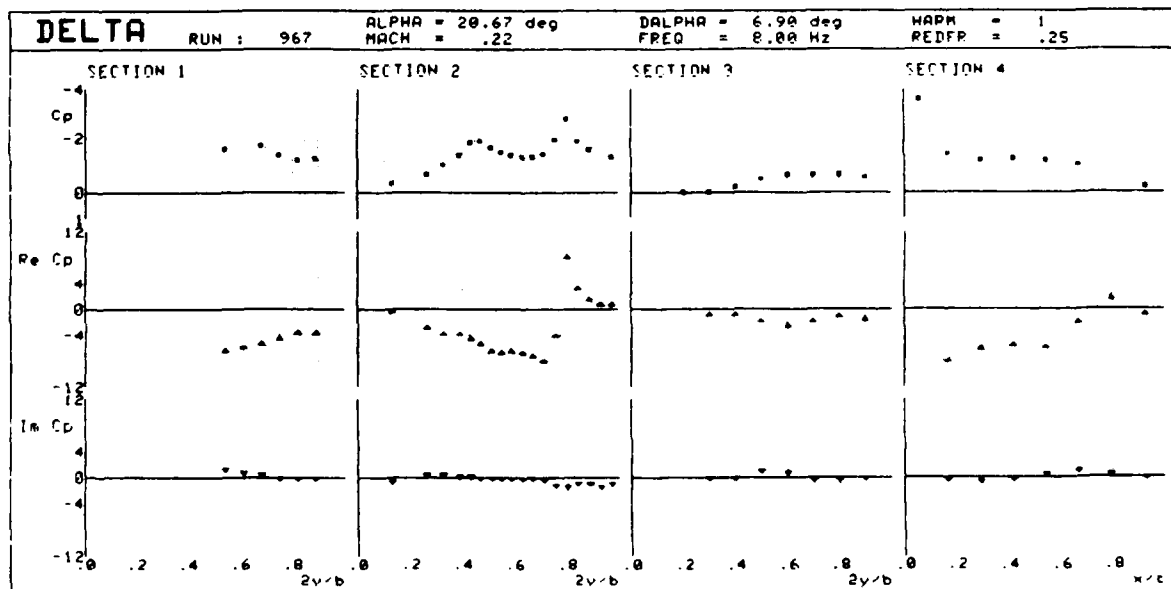
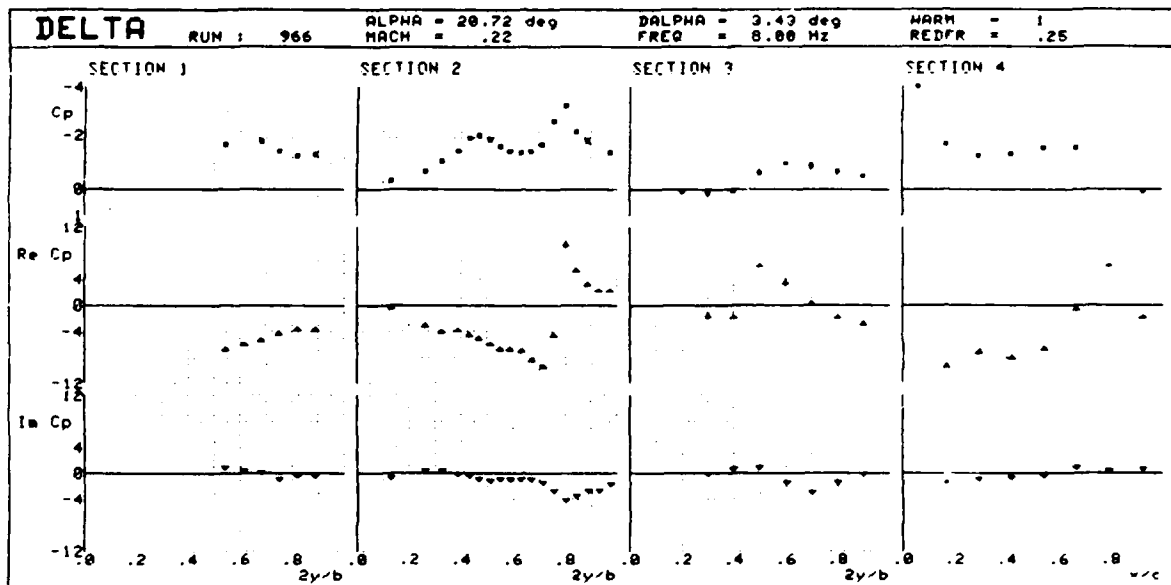


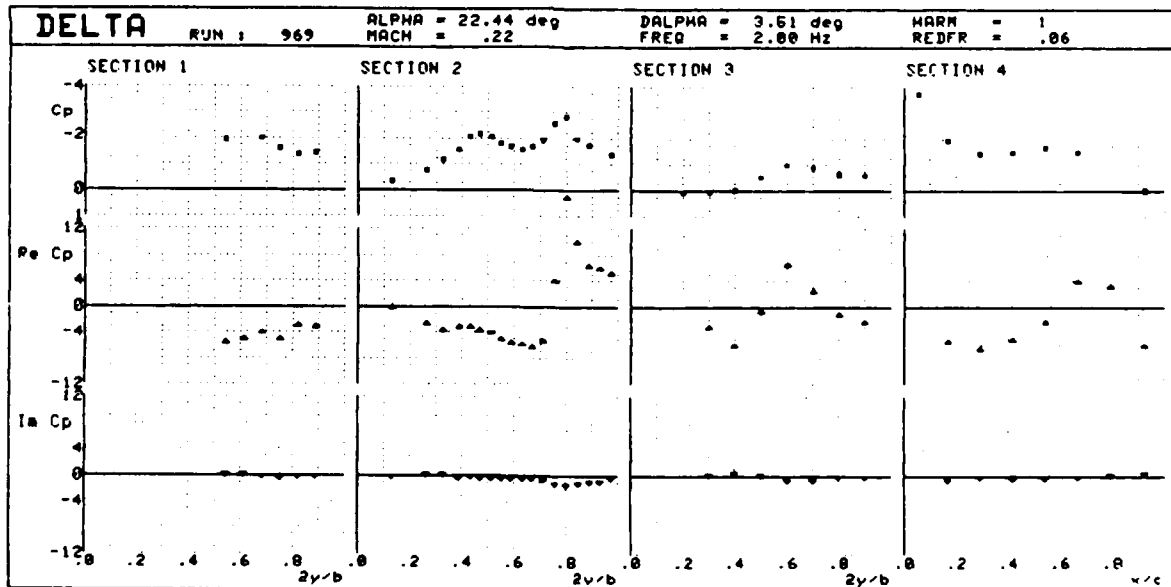
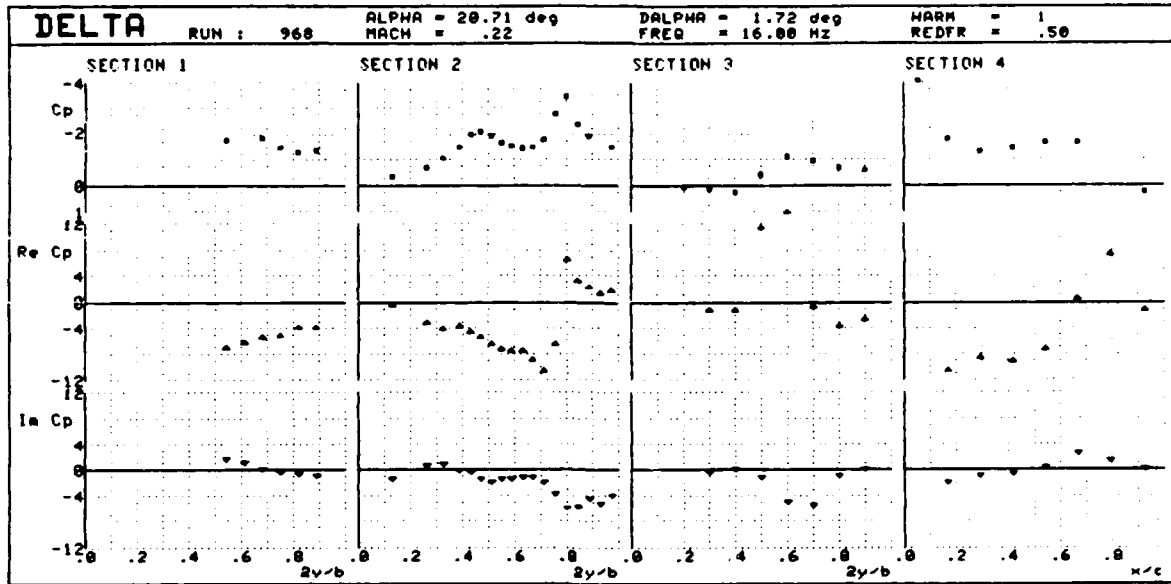


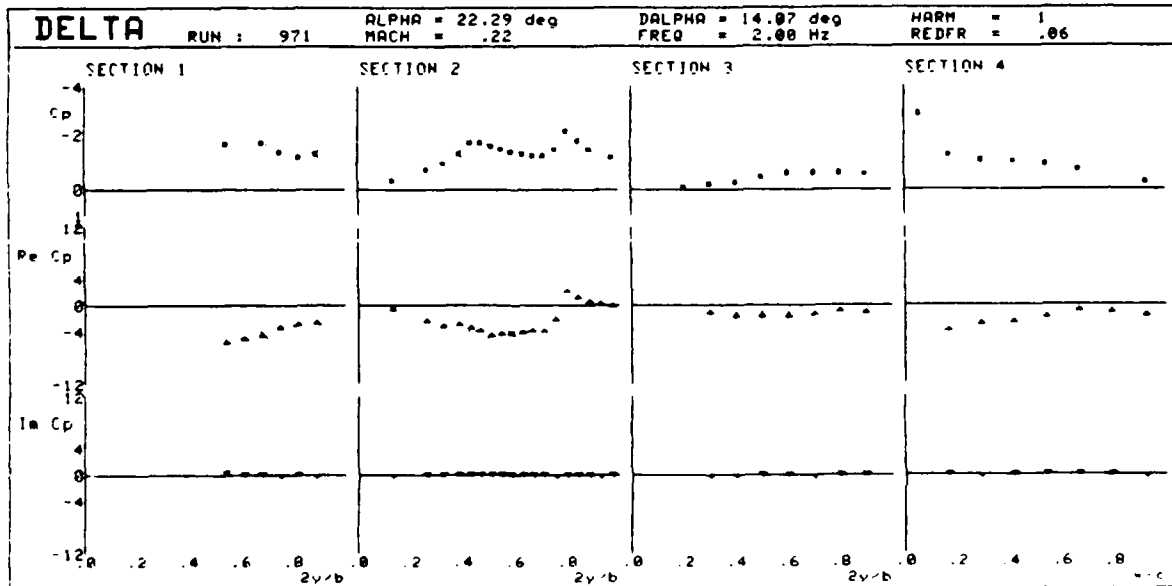
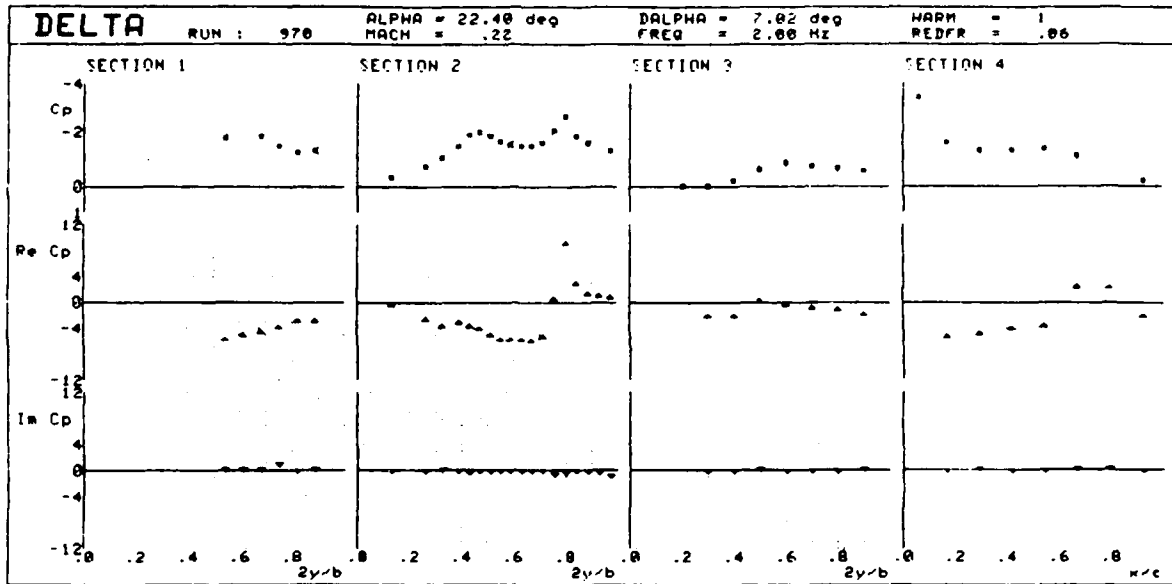


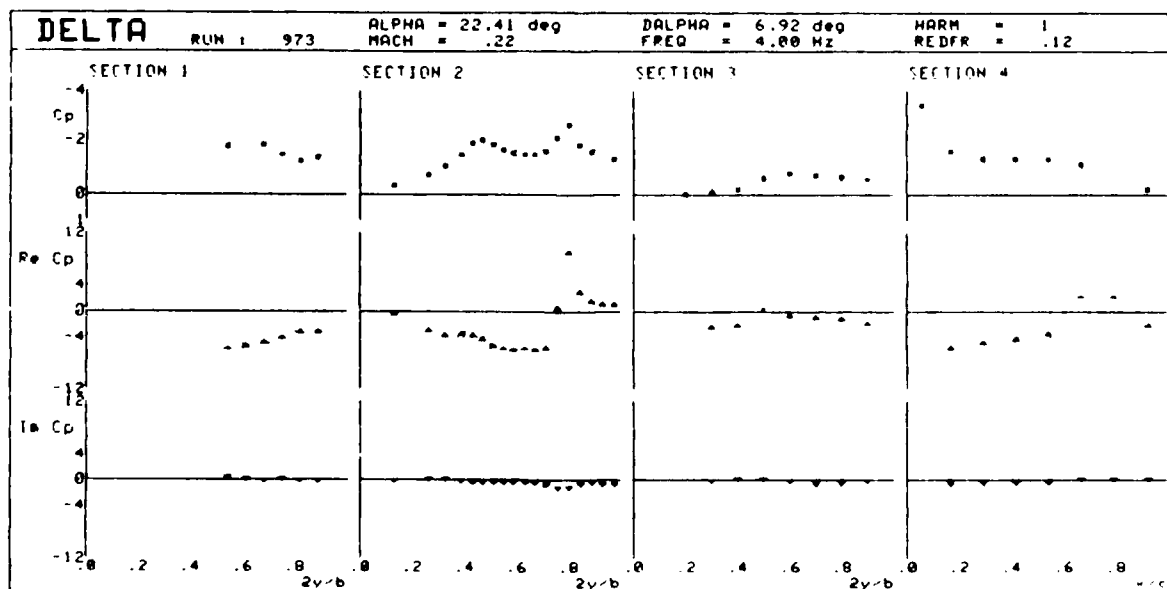
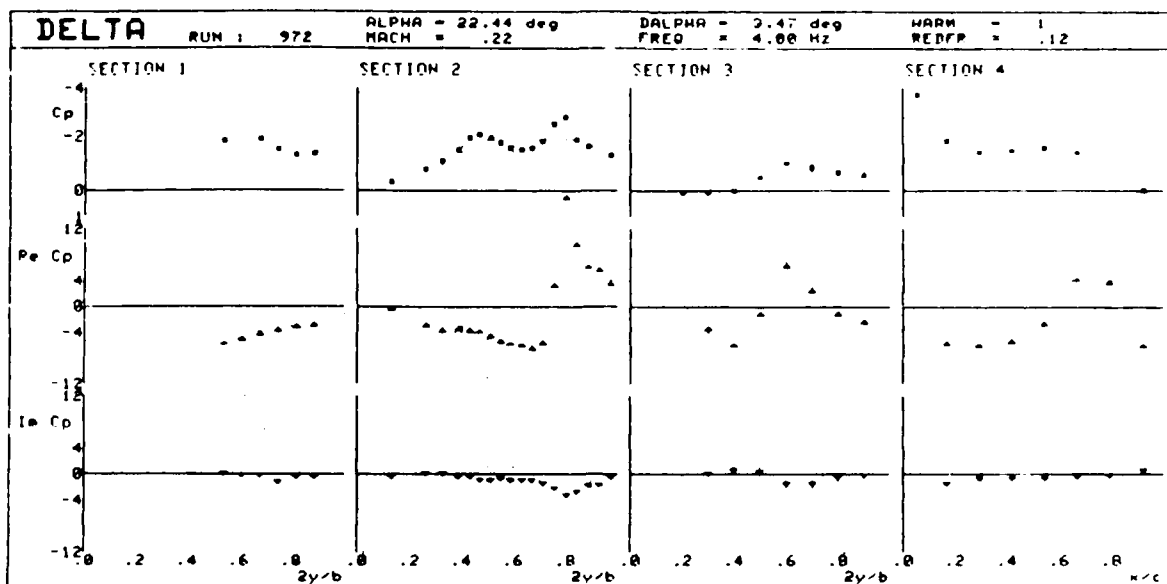


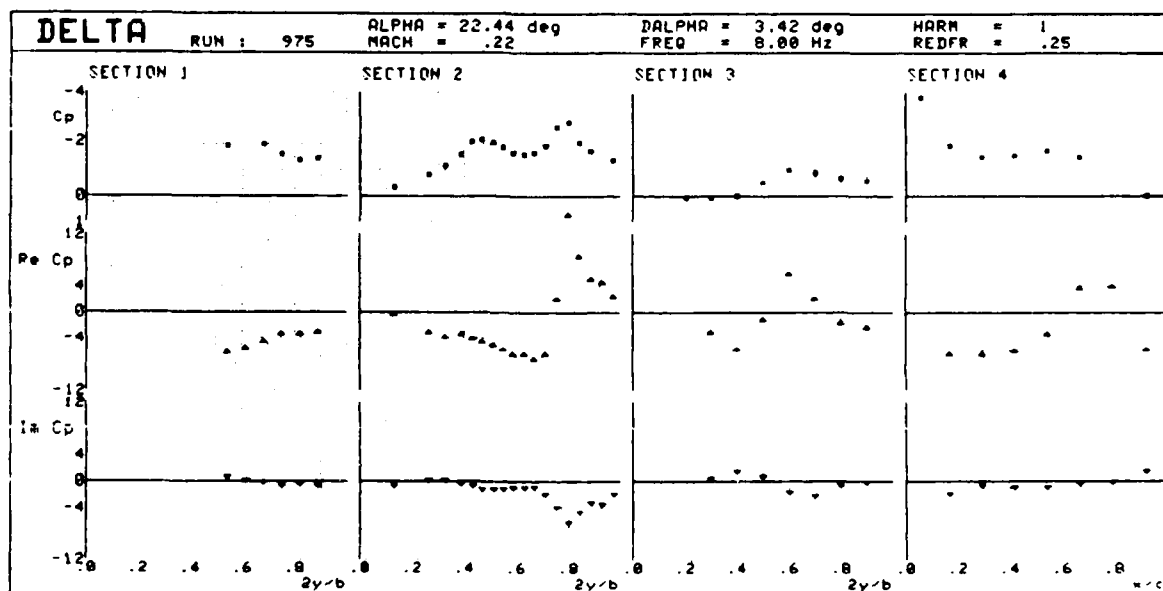
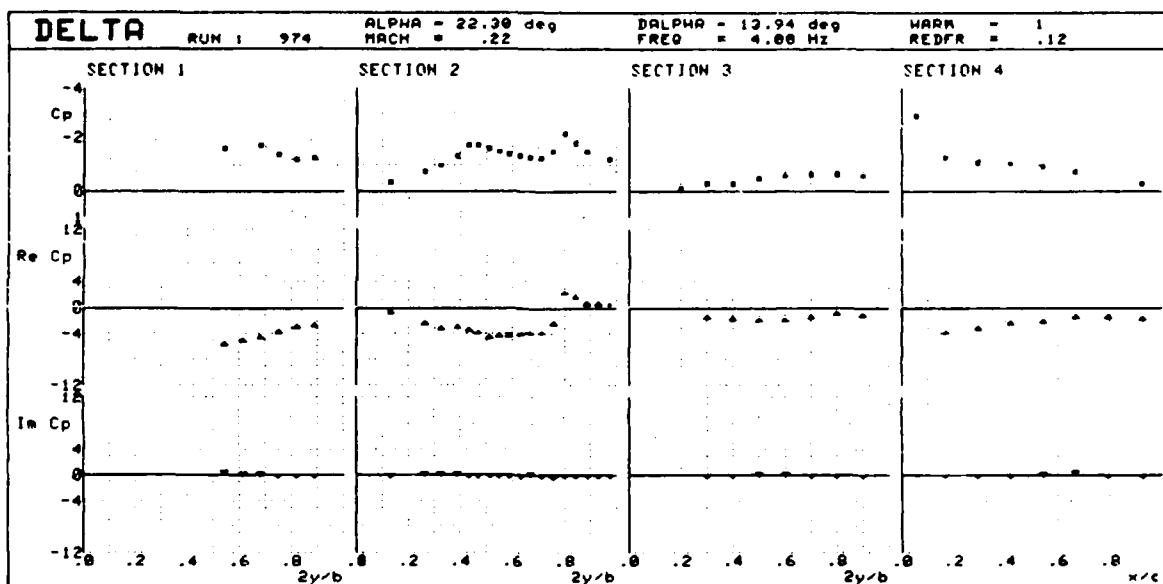


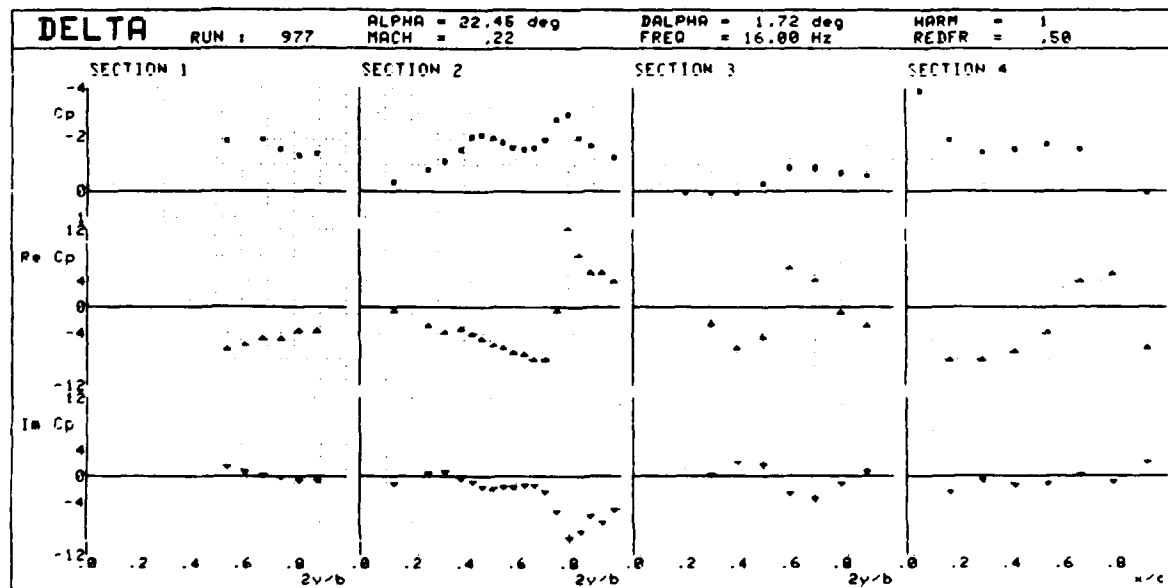
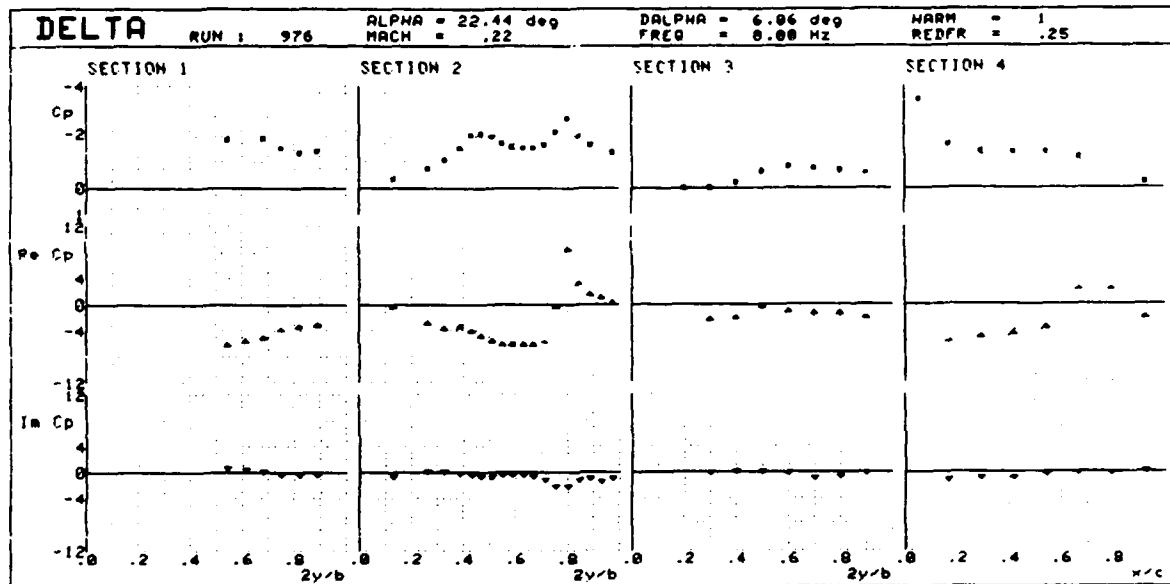


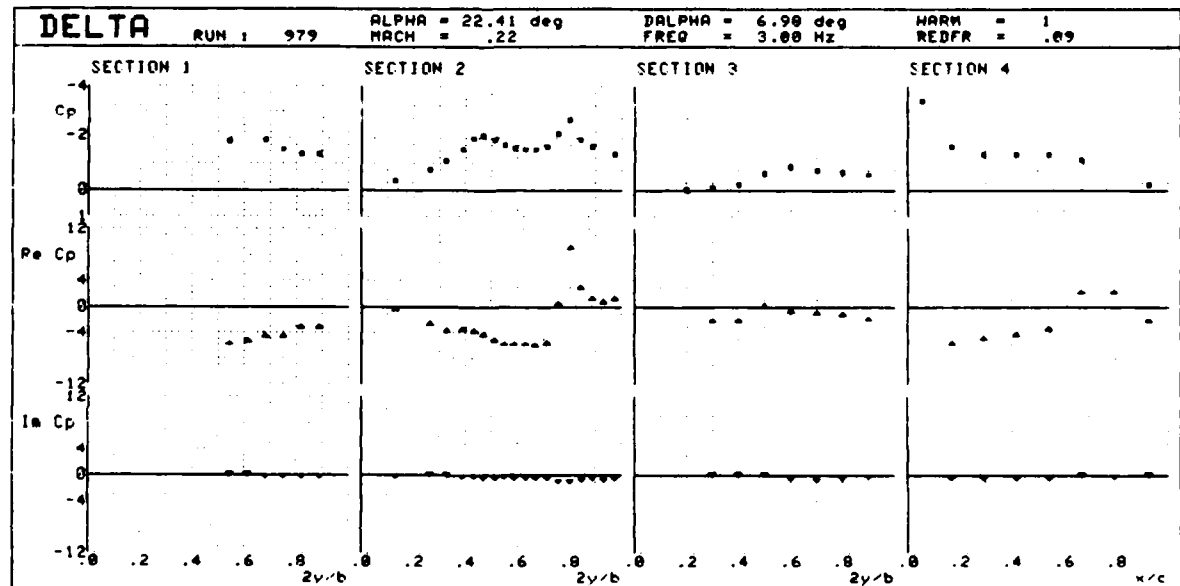
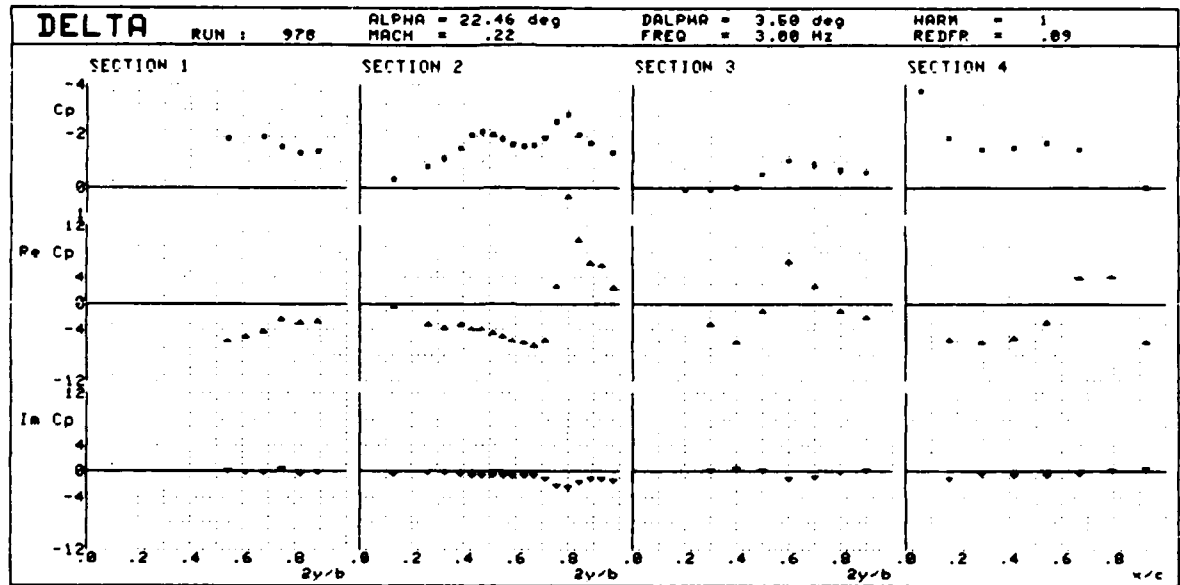


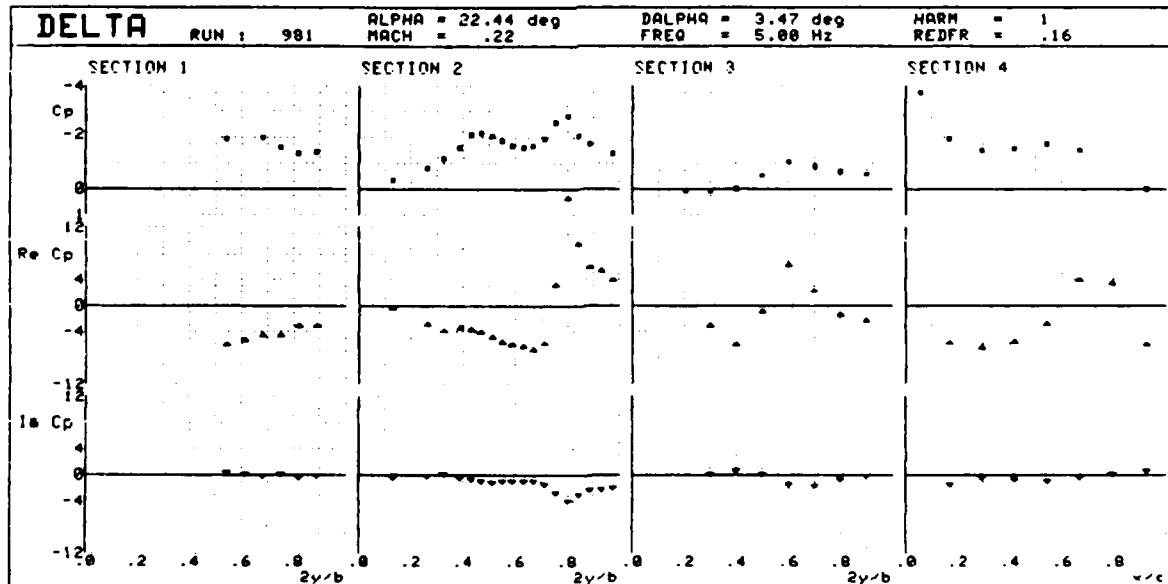
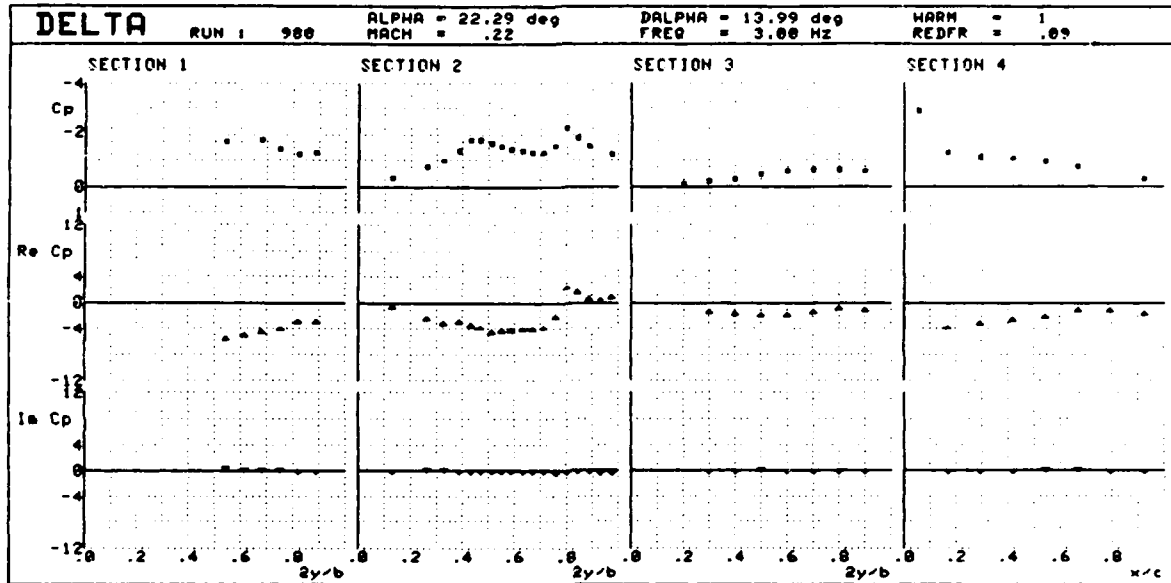


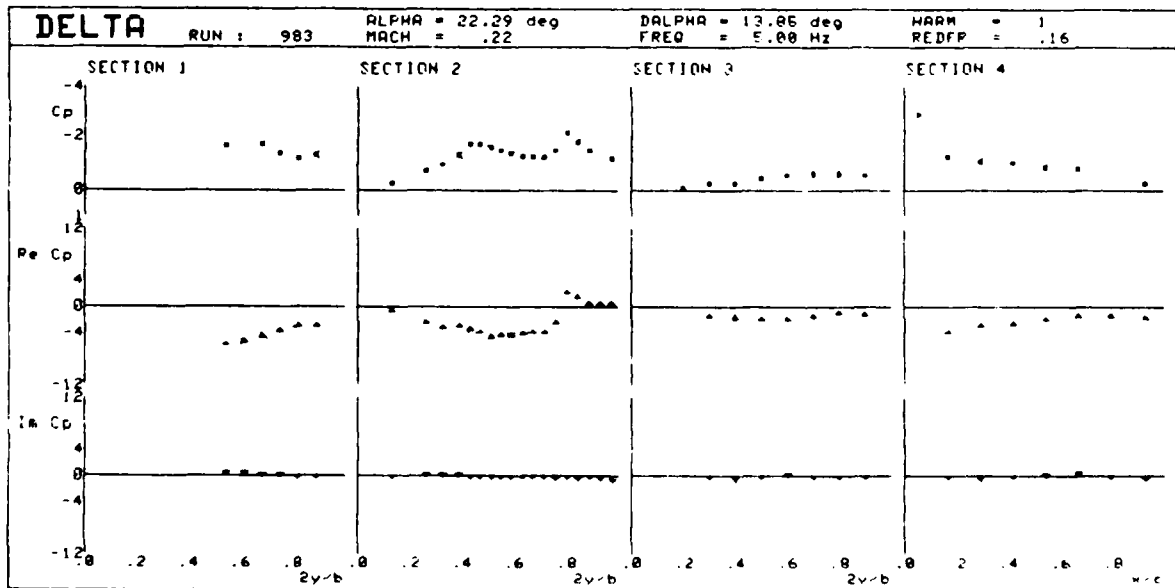
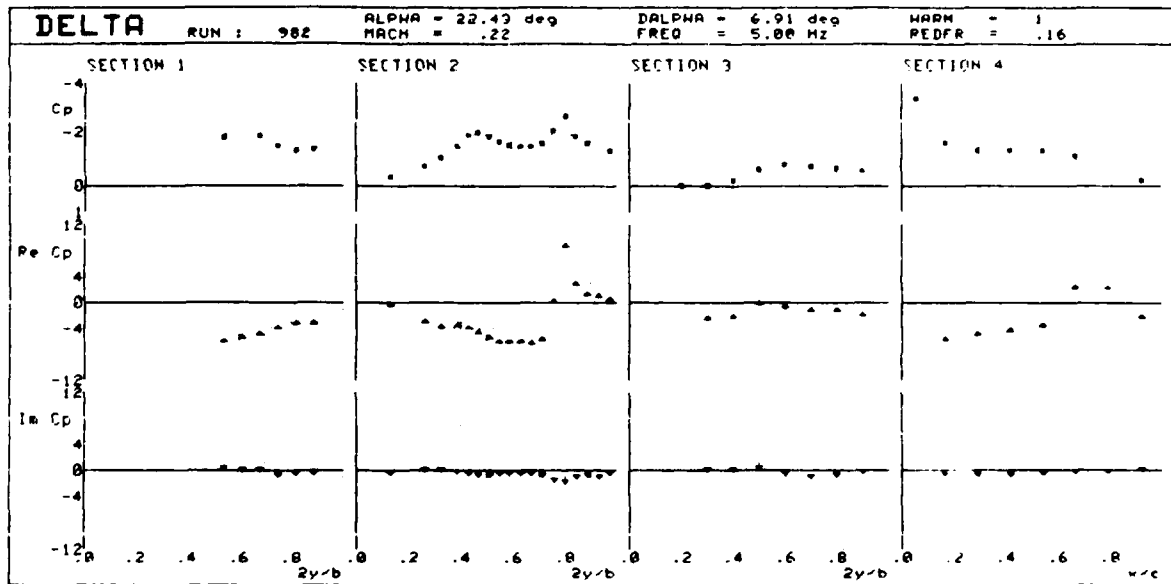


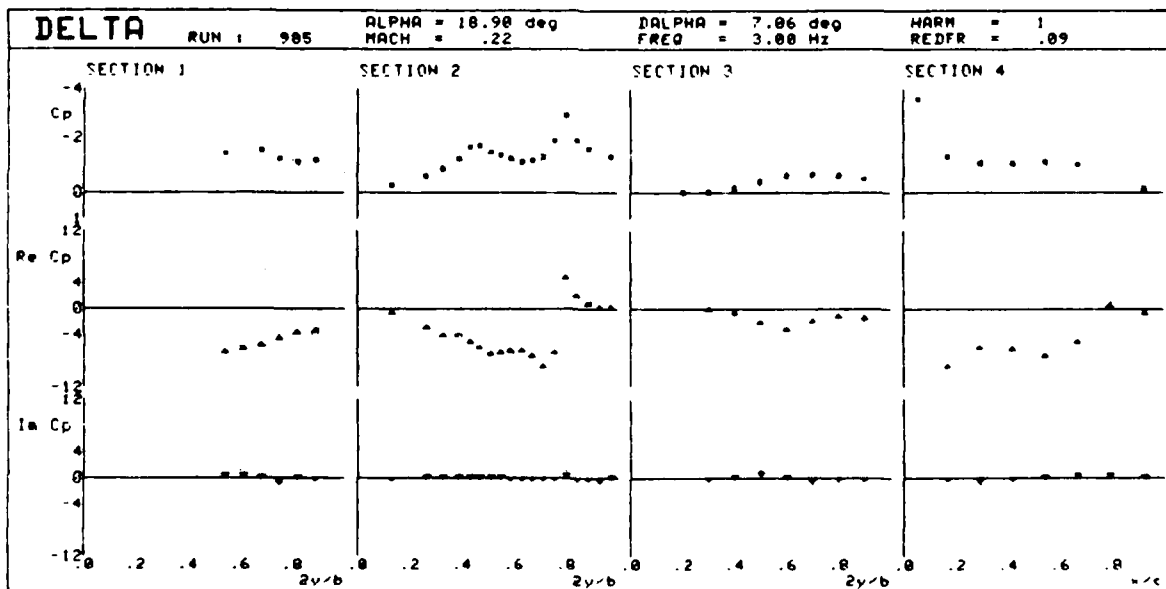
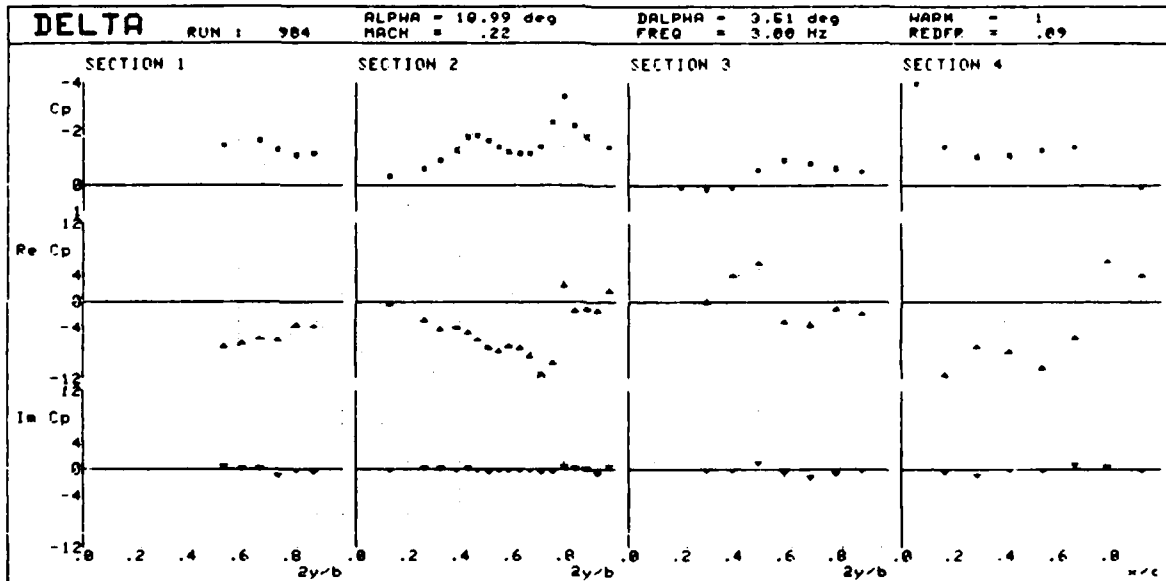


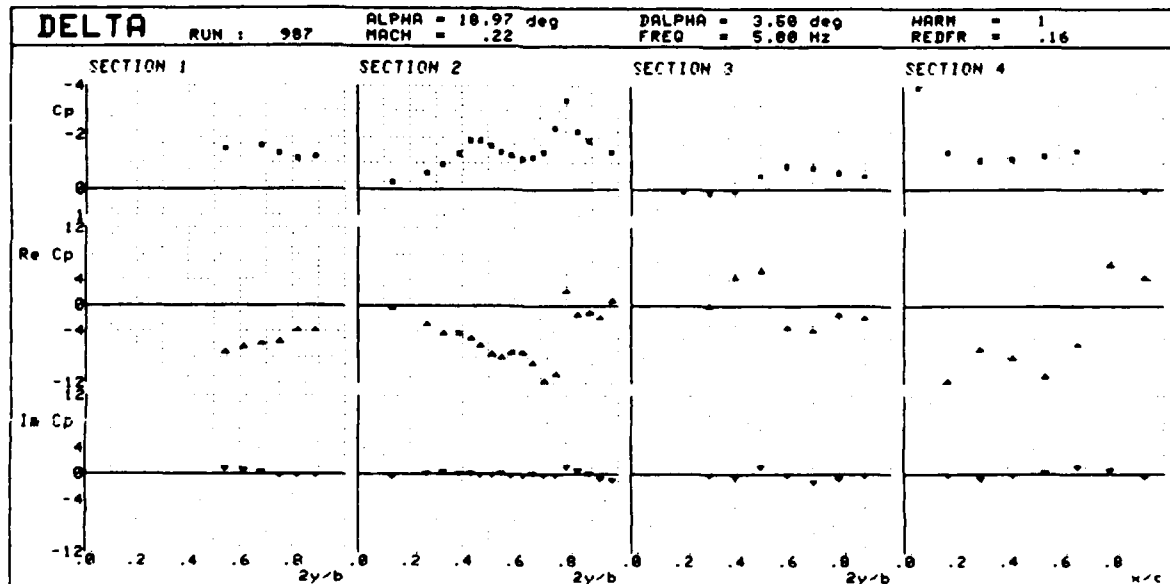
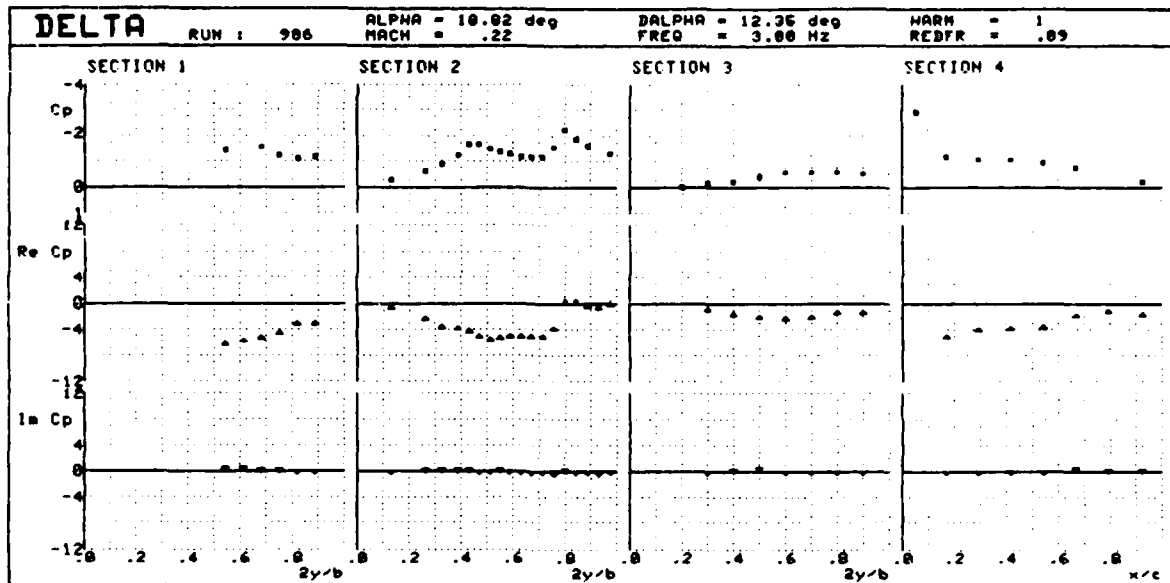


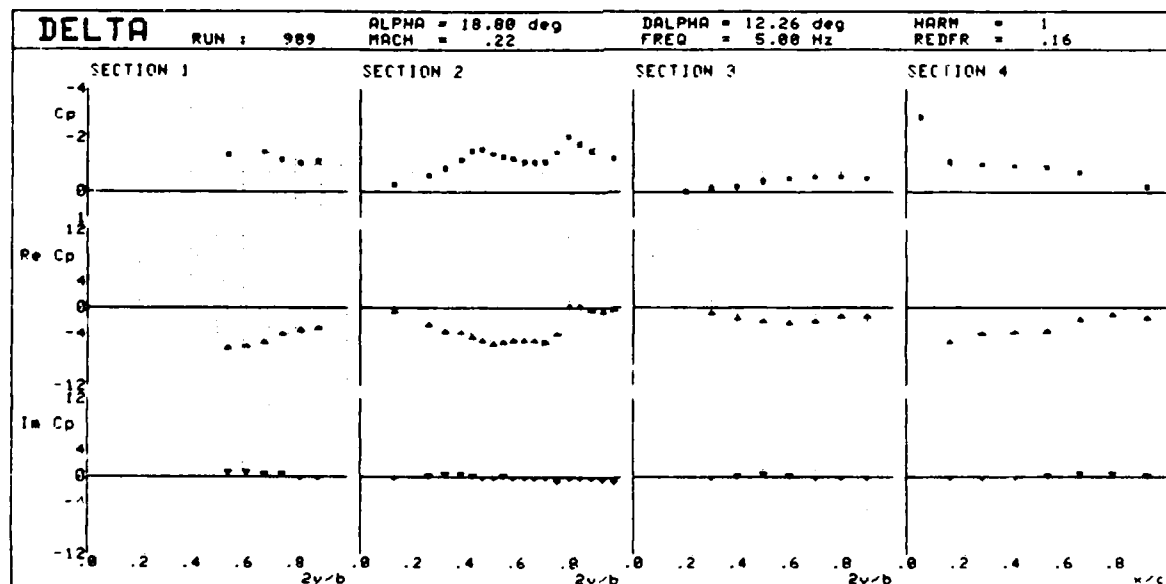
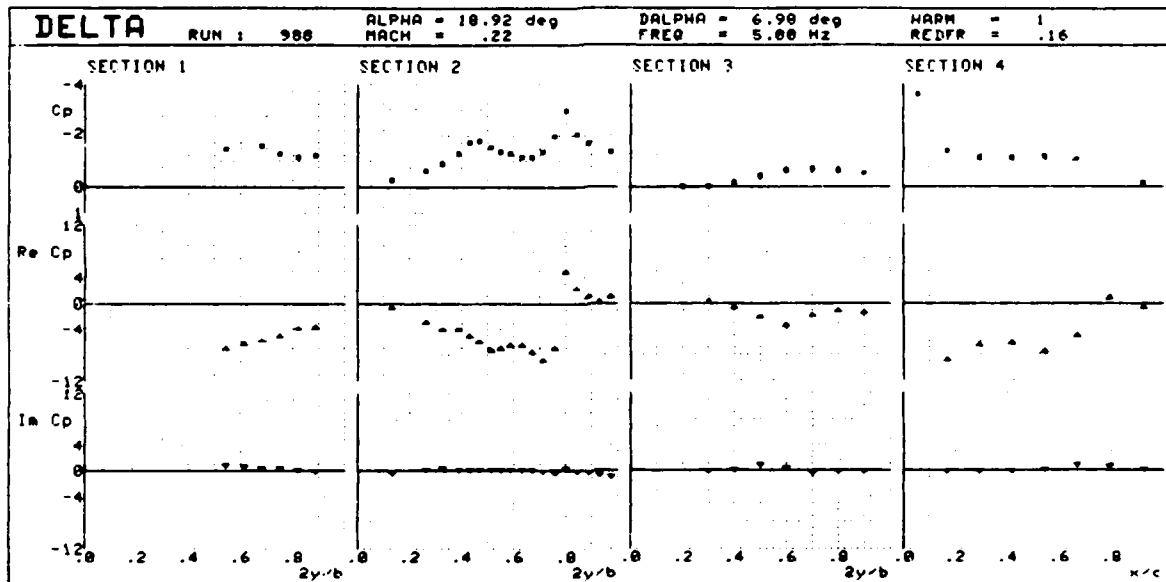


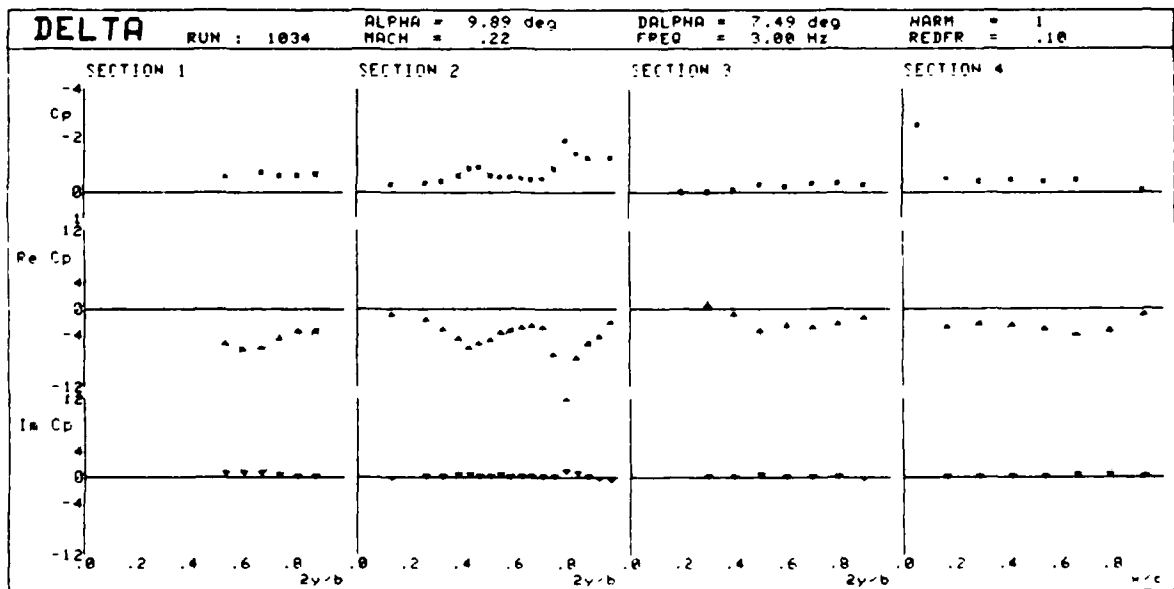
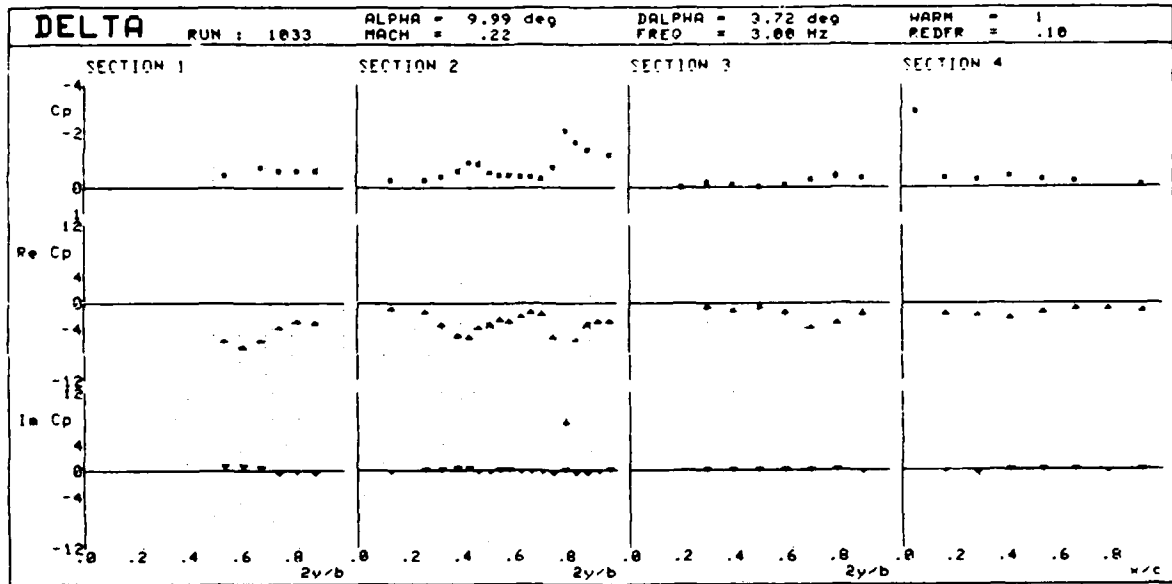


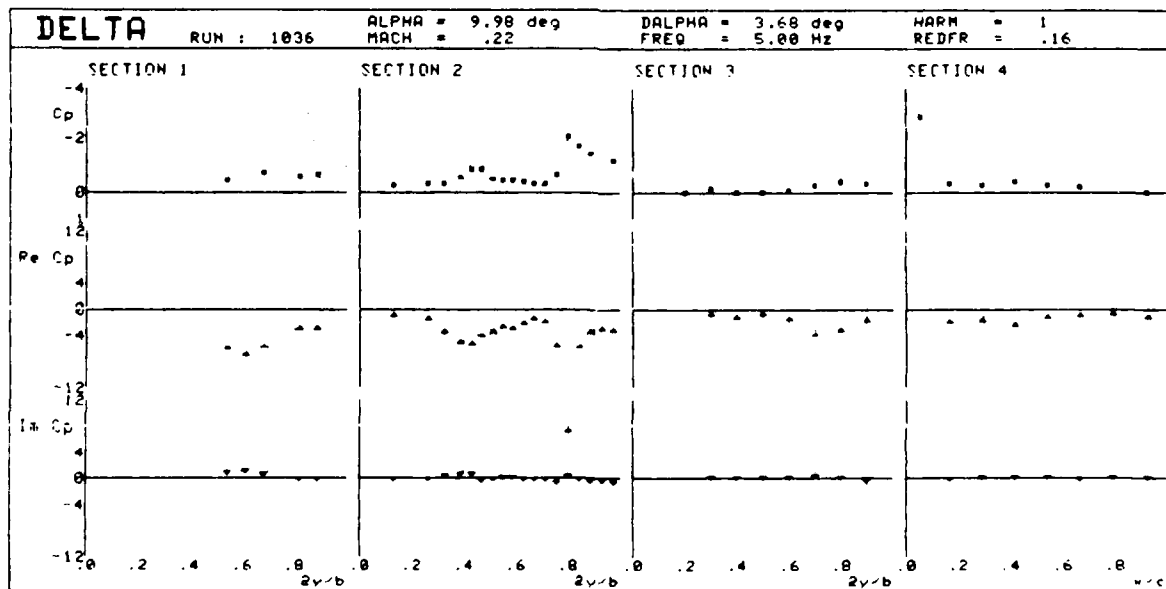
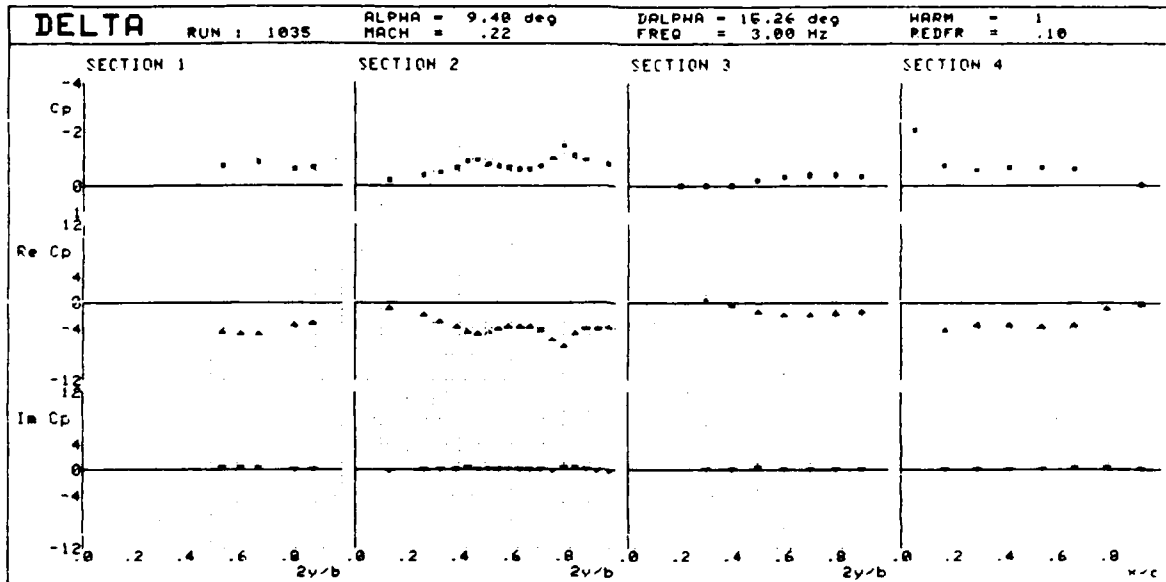


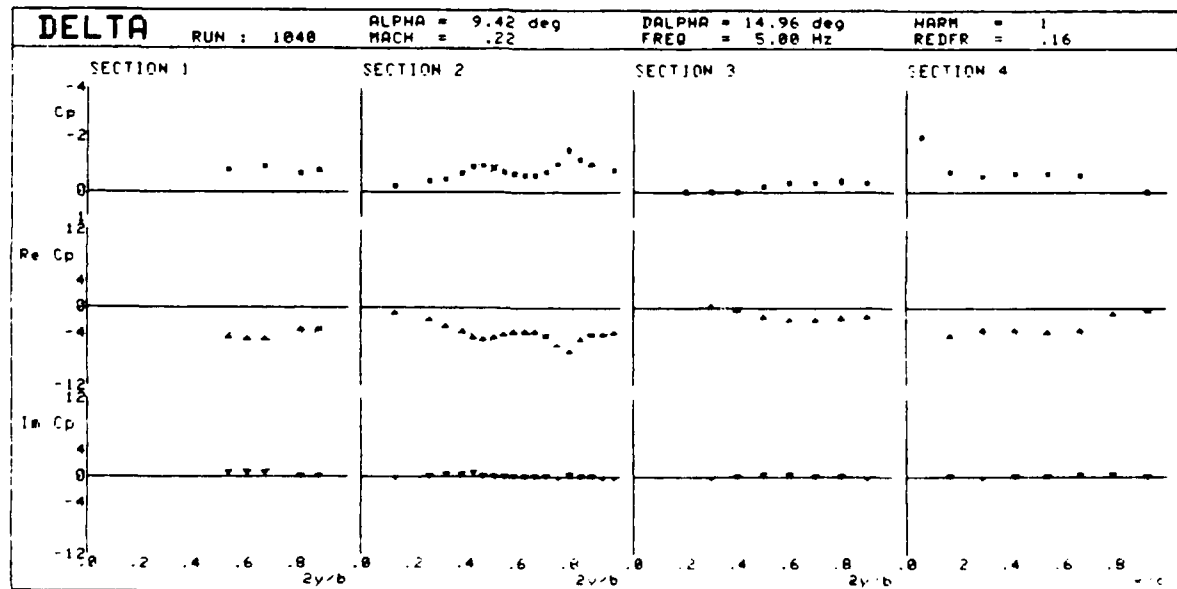
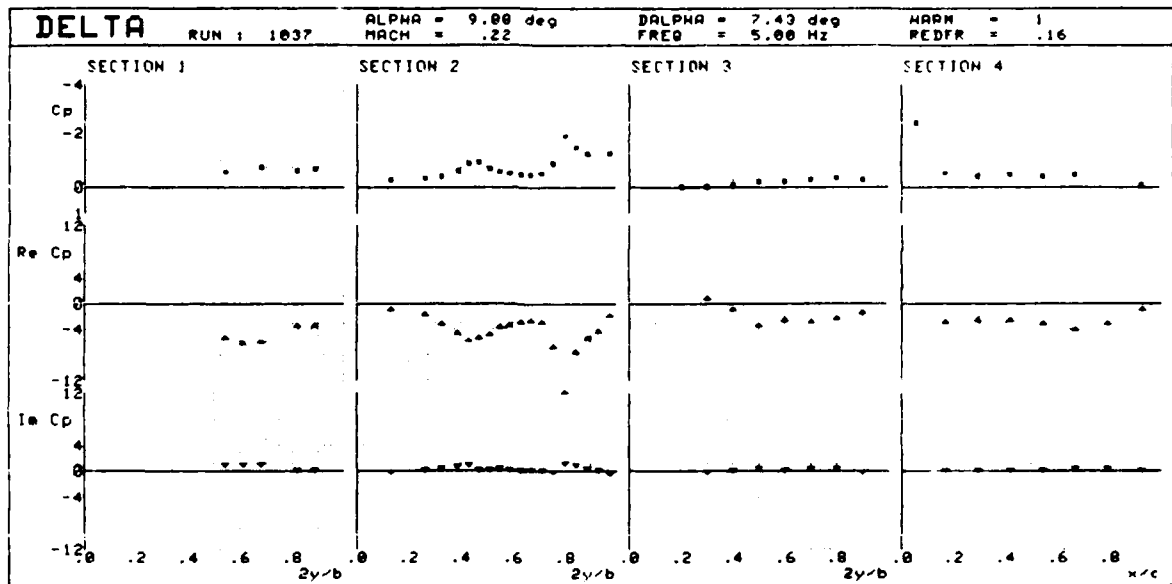


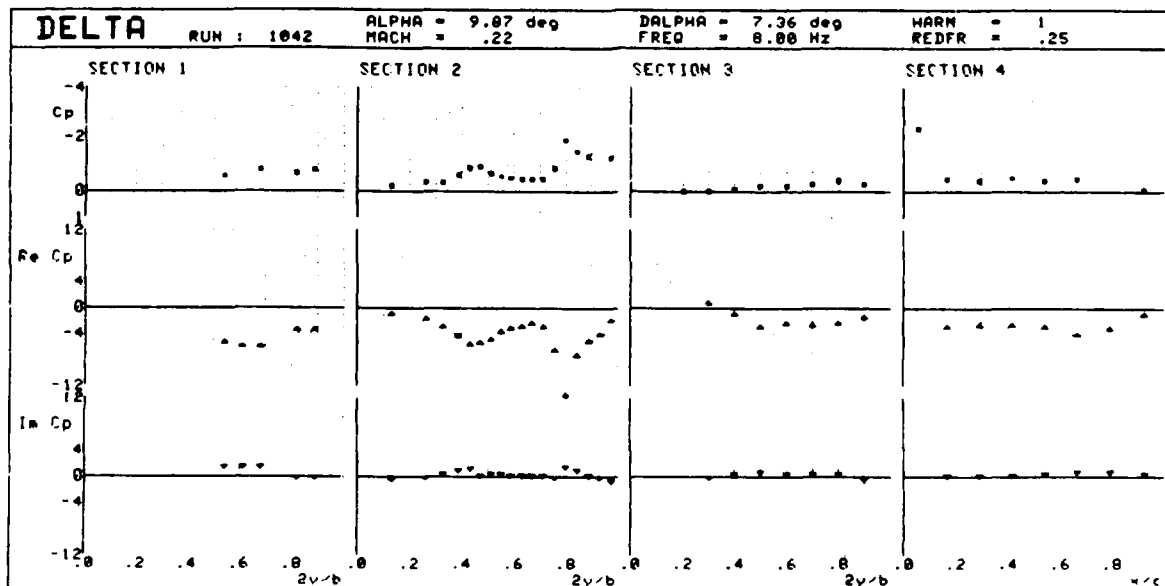
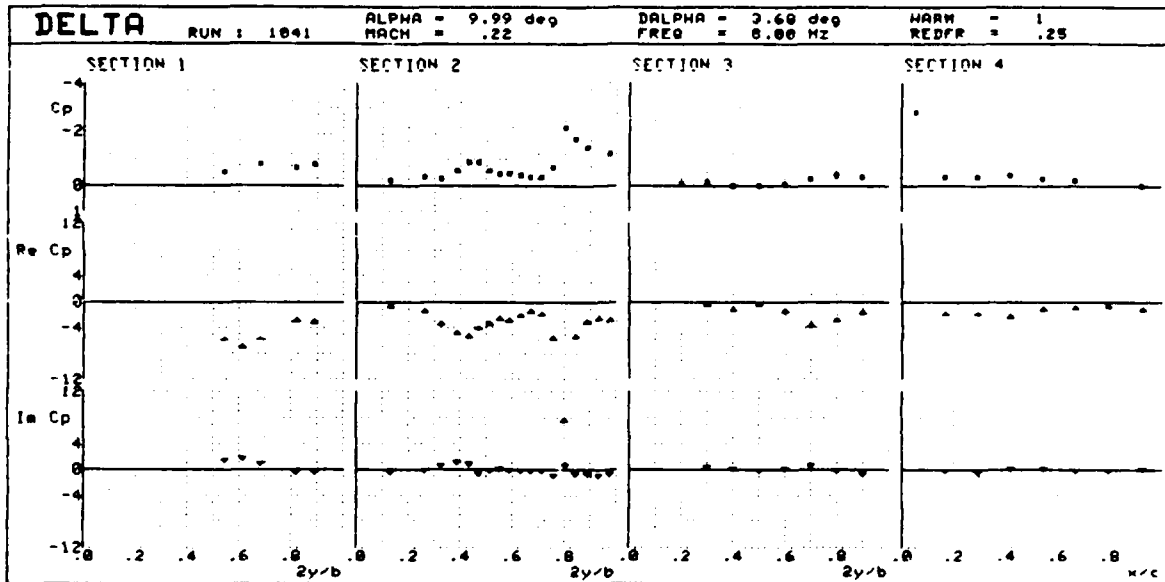


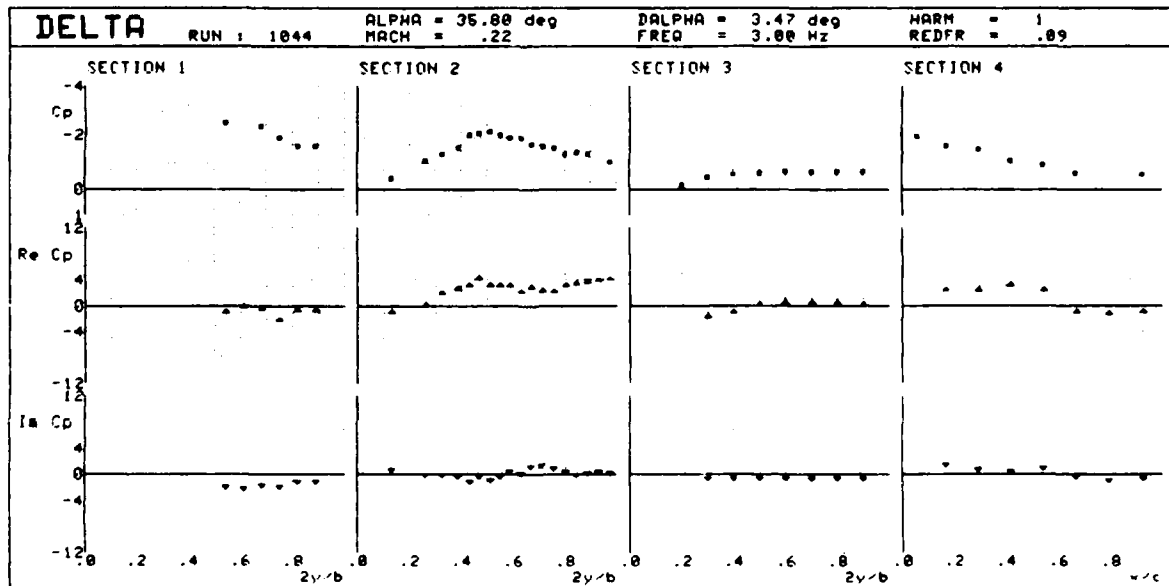
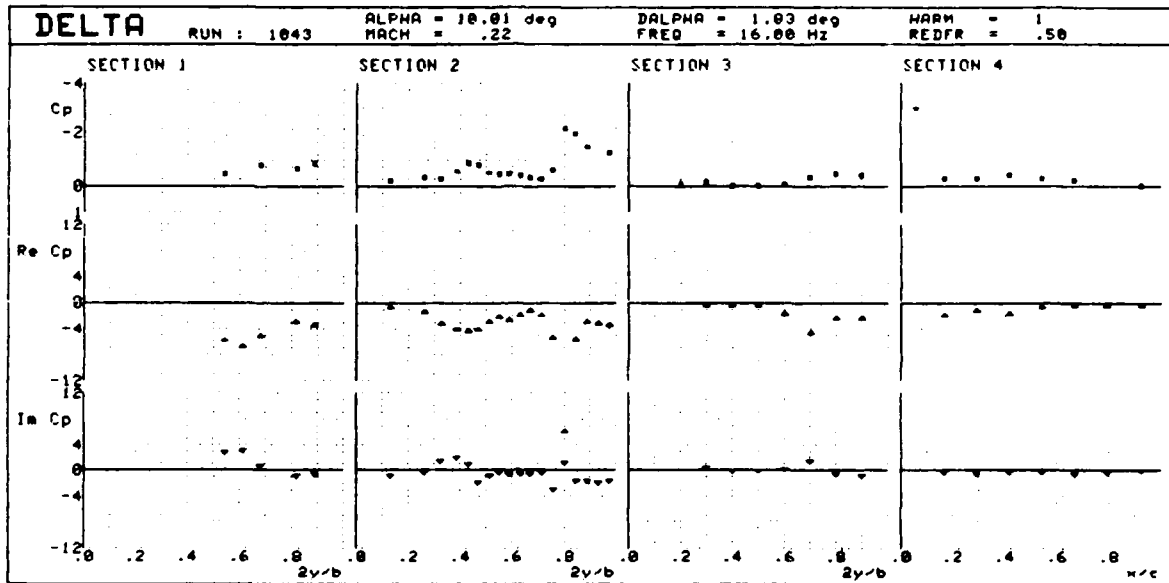


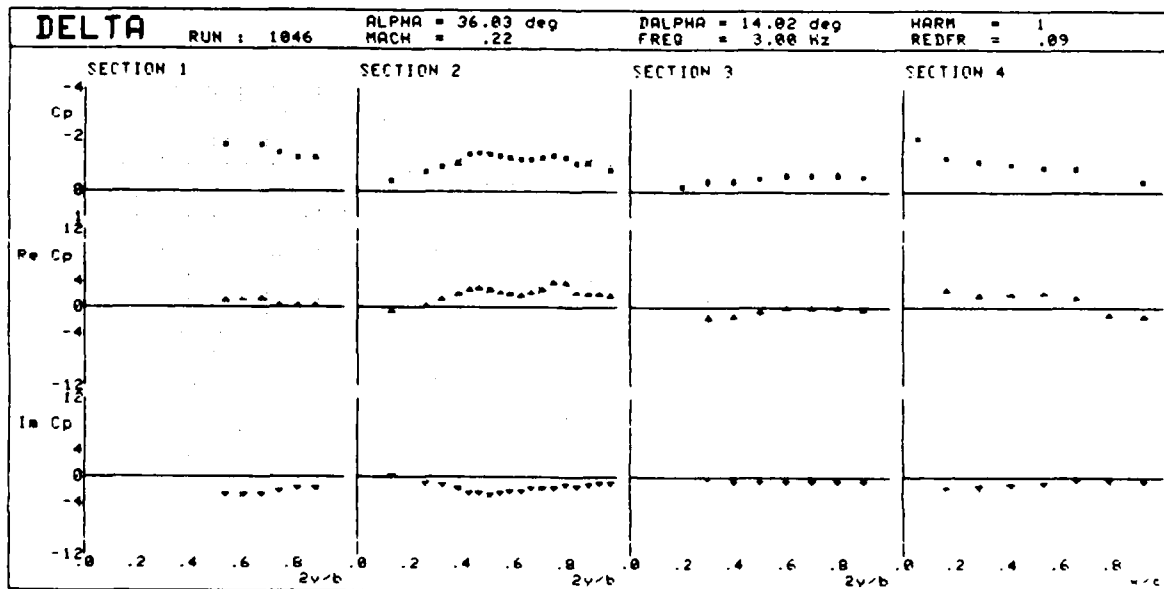
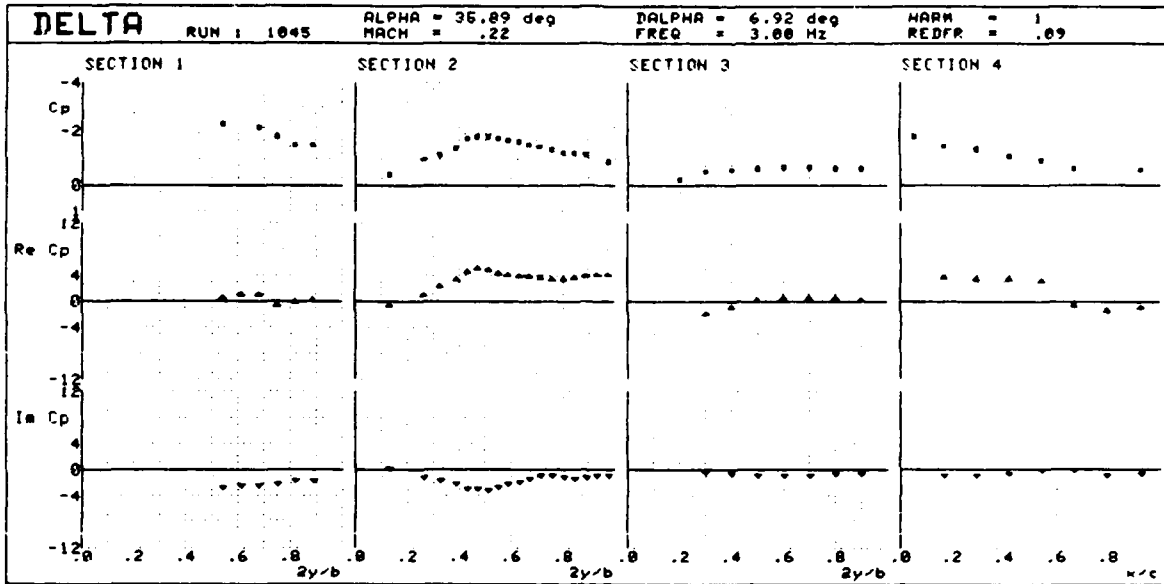


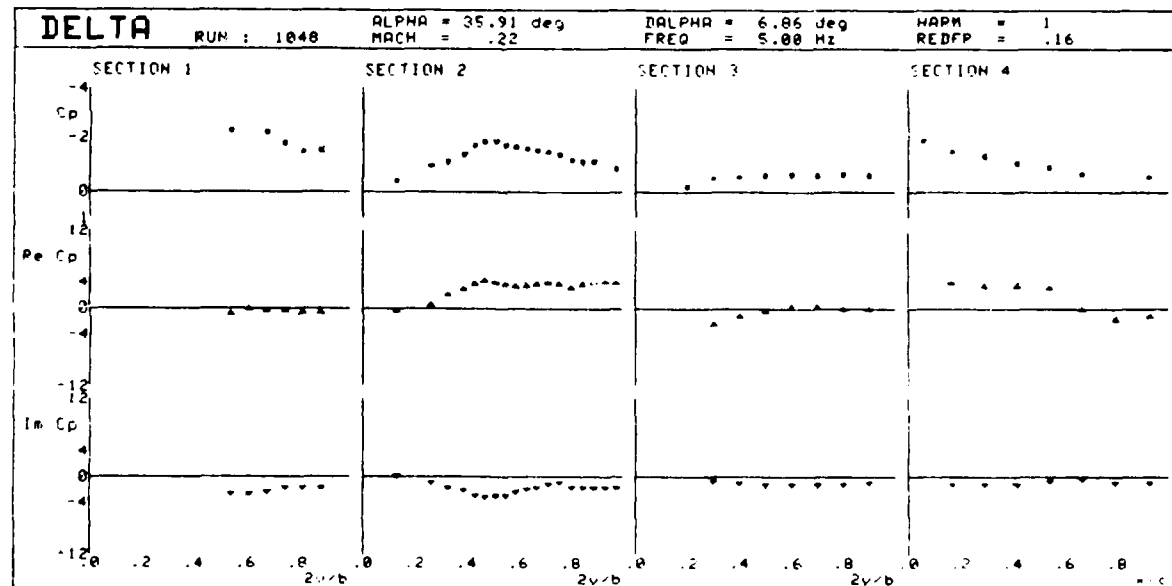
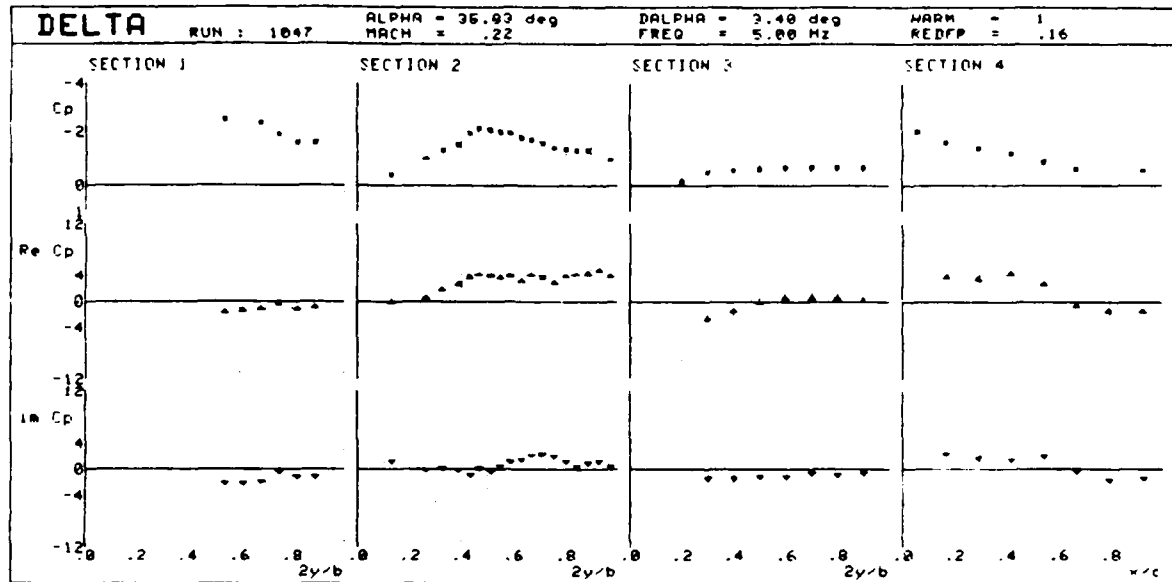


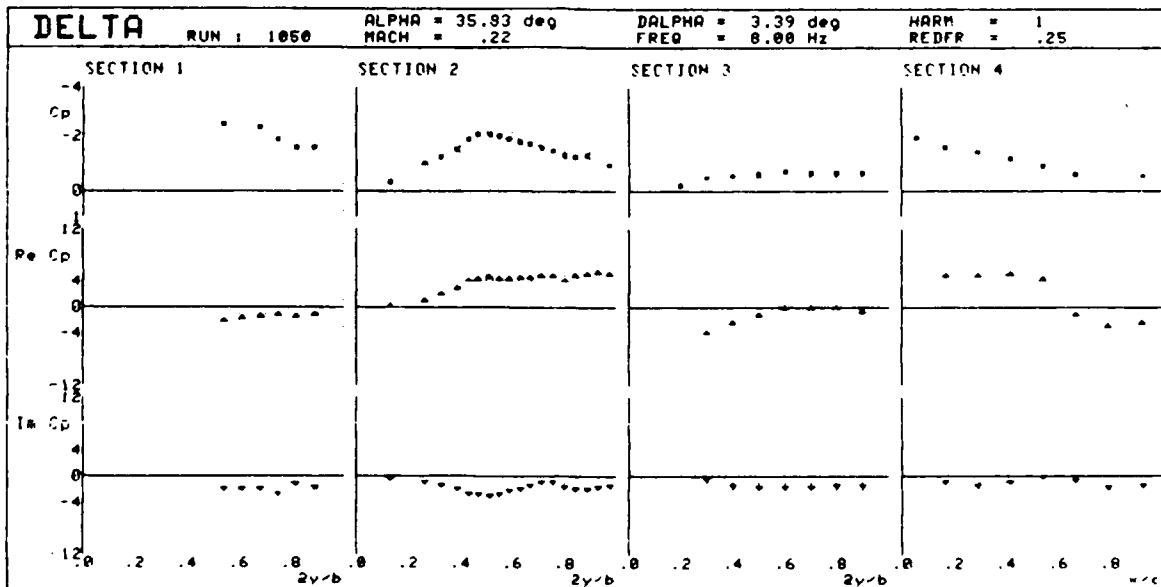
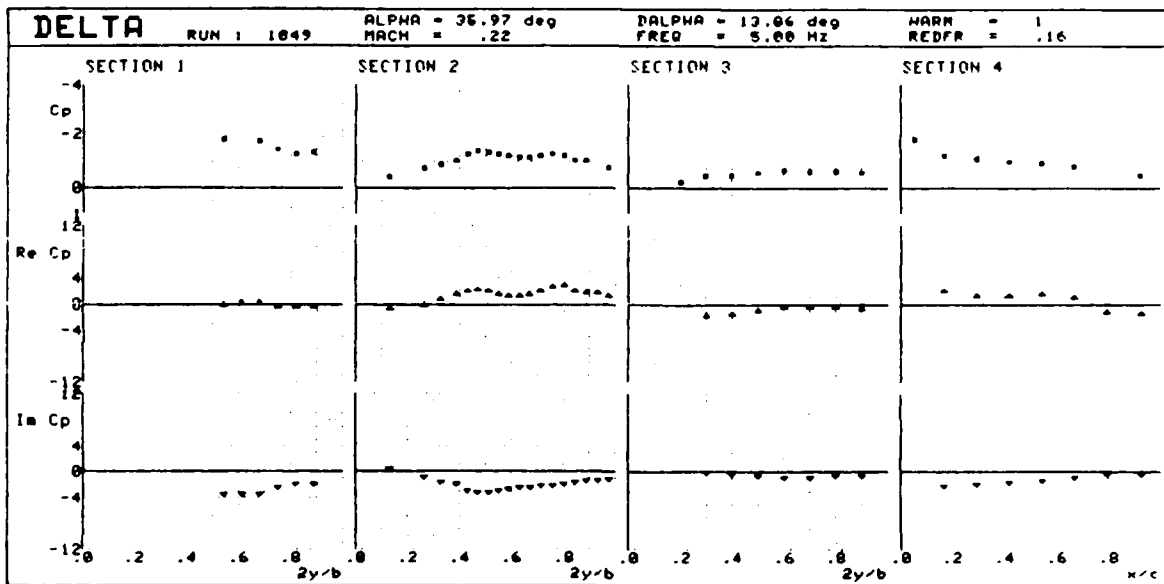


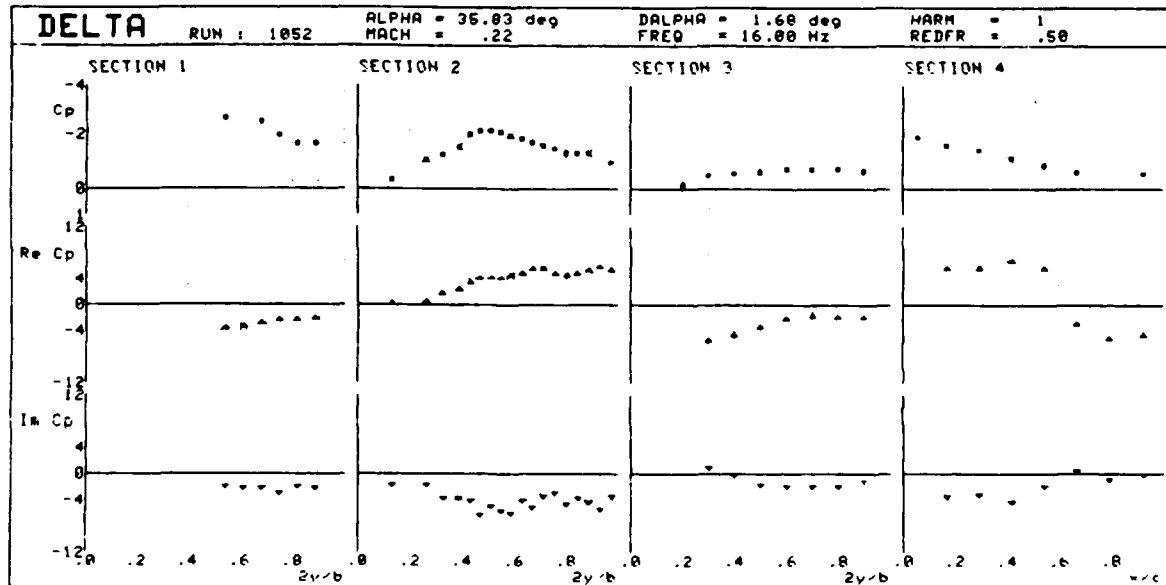
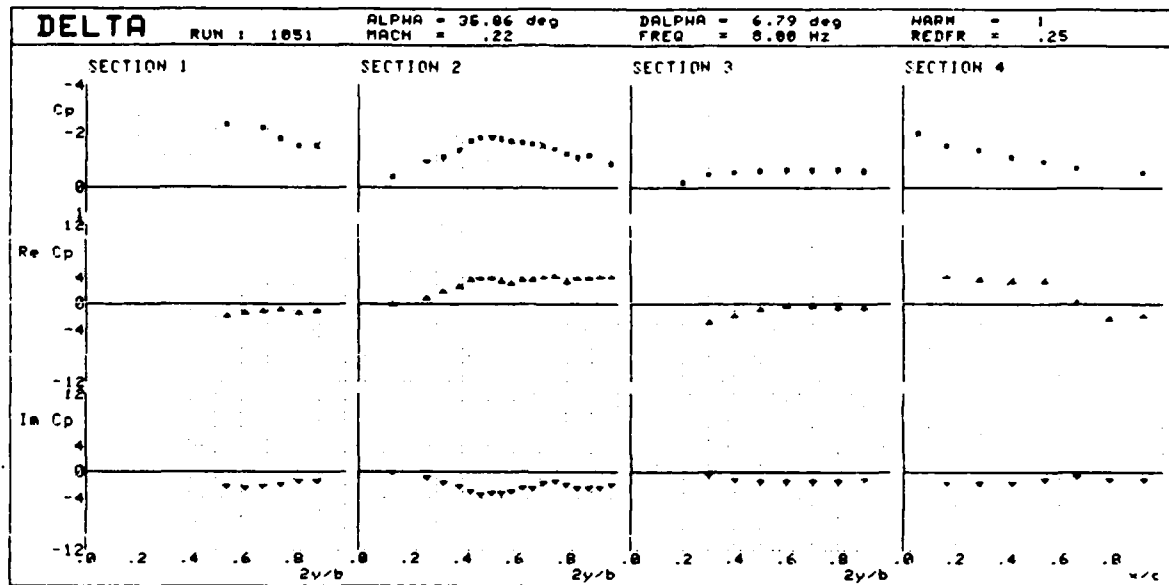


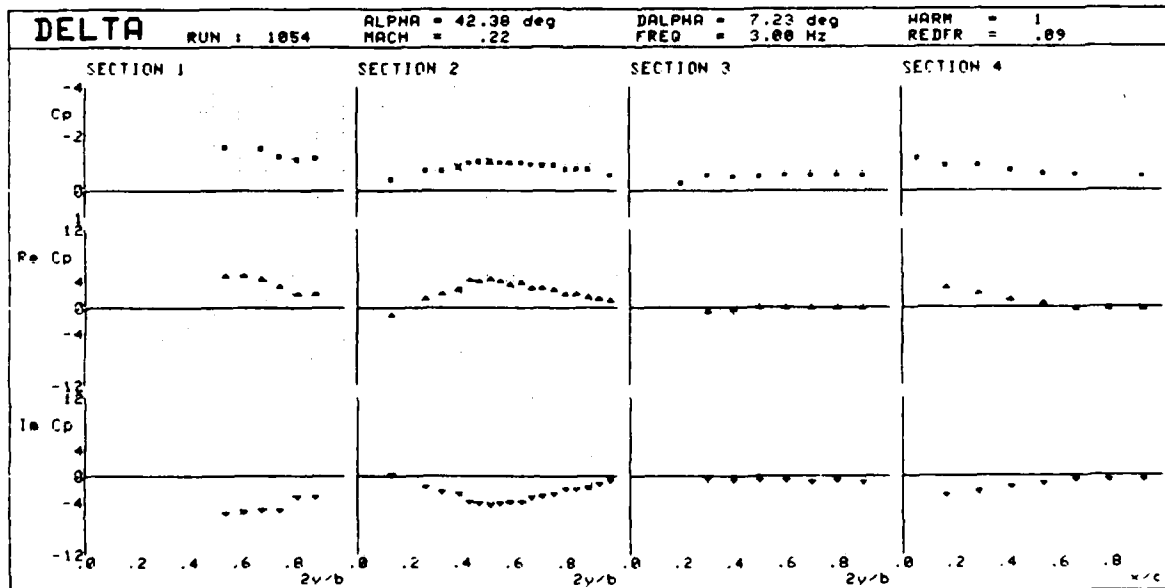
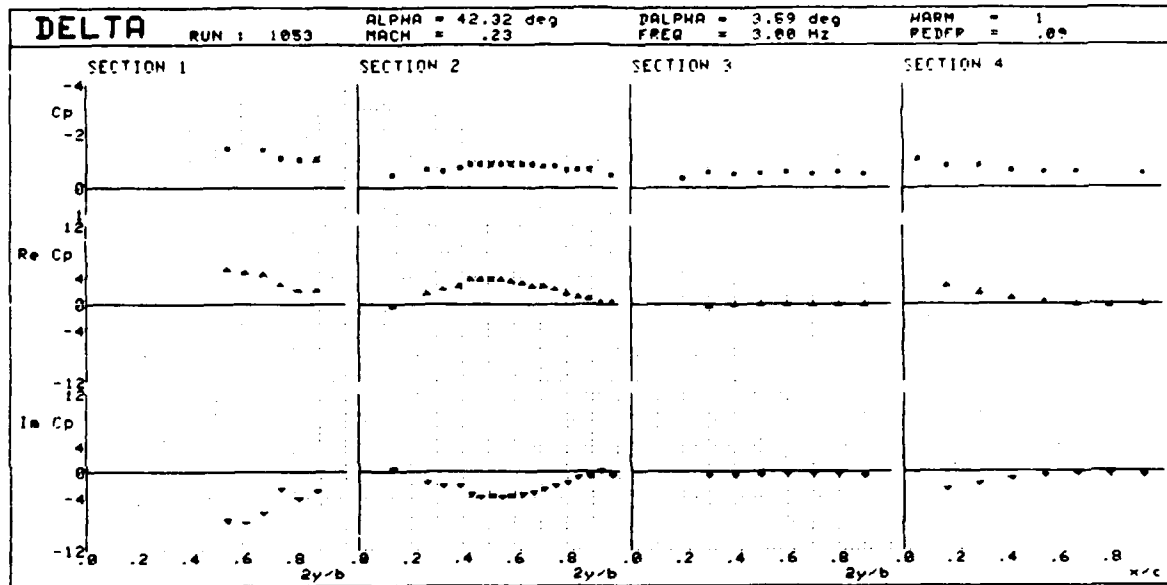


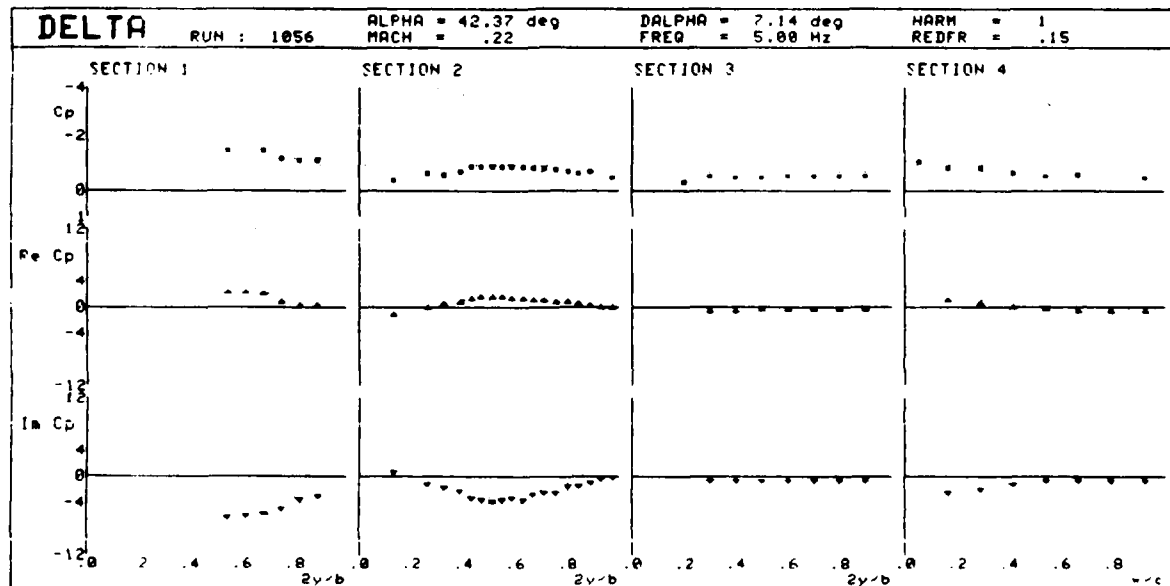
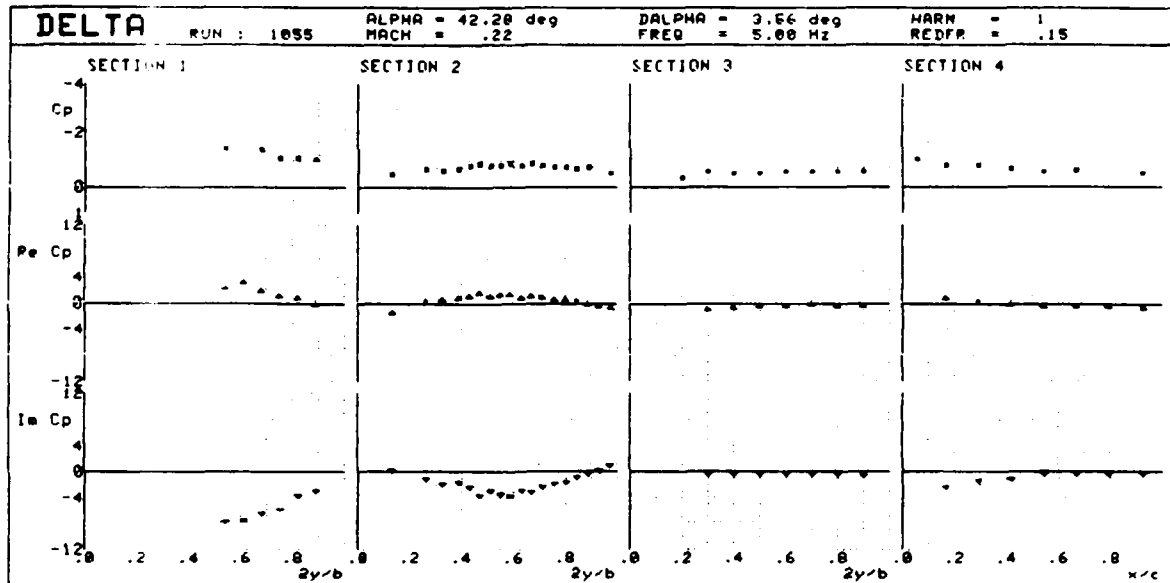


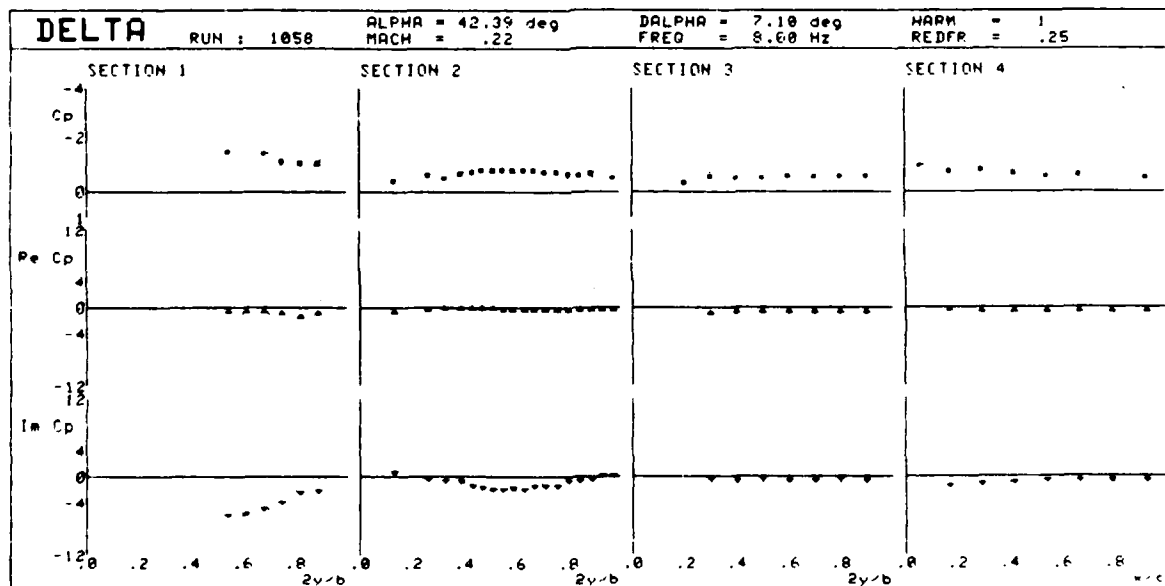
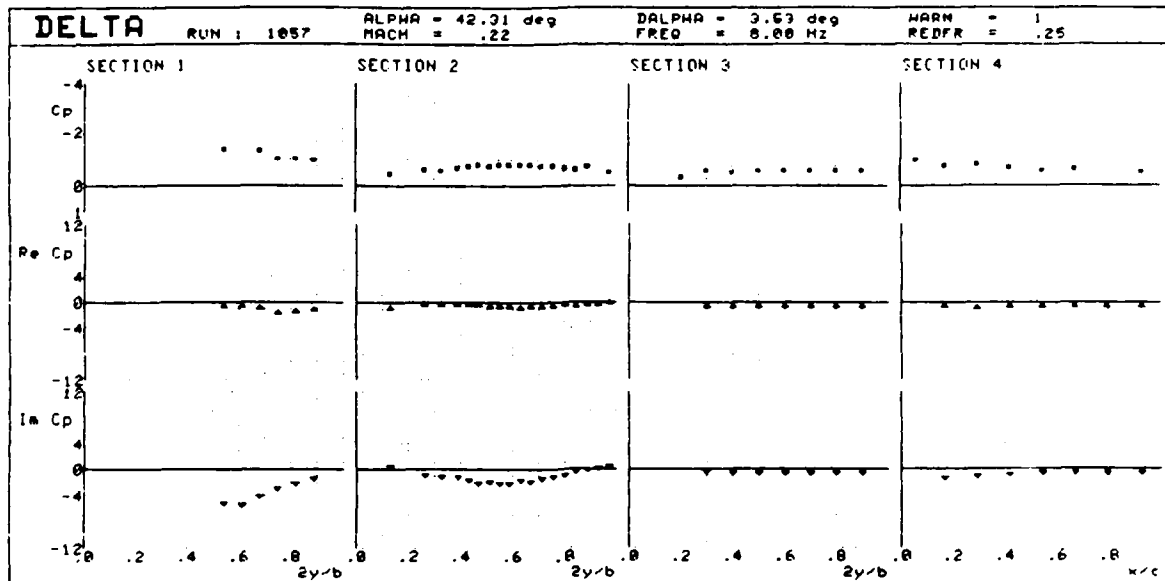


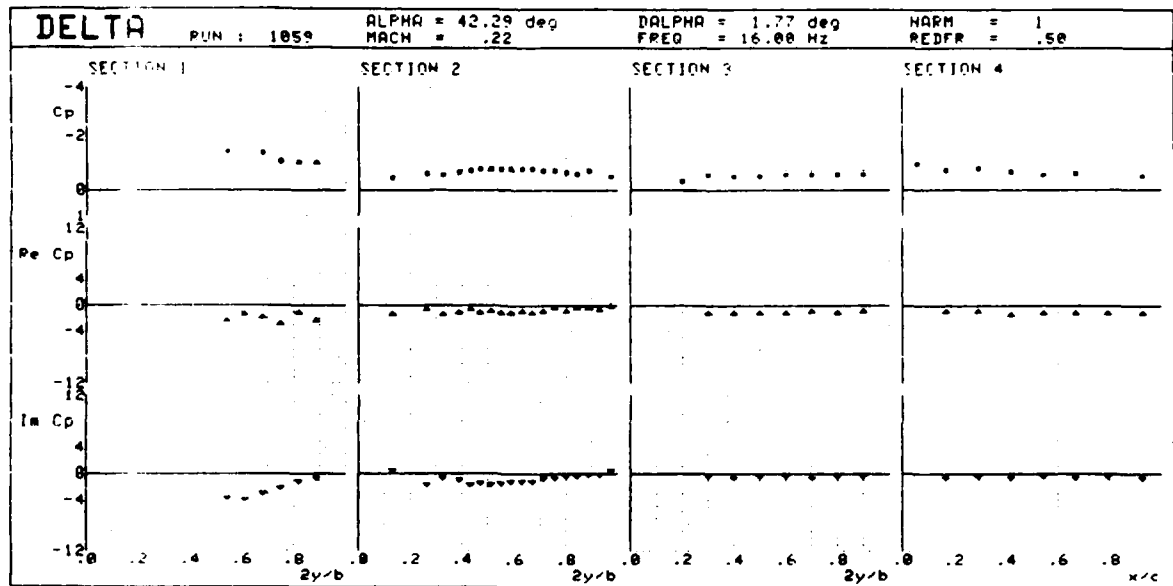












APPENDIX B
PLOTS OF THE STEADY AND ZEROth AND FIRST ORDER HARMONIC
COMPONENTS OF THE UNSTEADY OVERALL LOADS

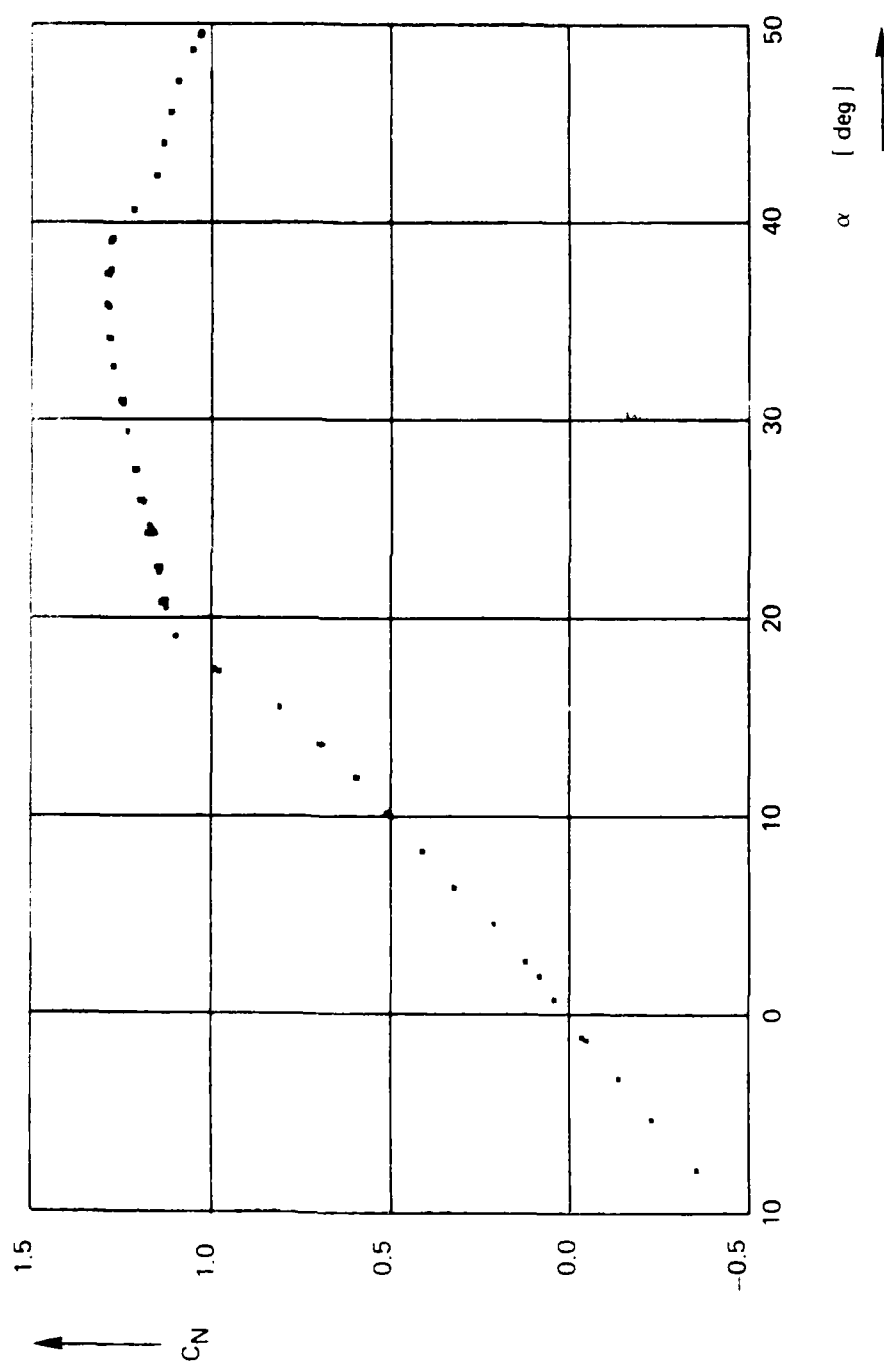


Fig. B1 Steady normal force coefficient vs. incidence
($\beta = 0$ deg, $V \approx 80$ m/s)

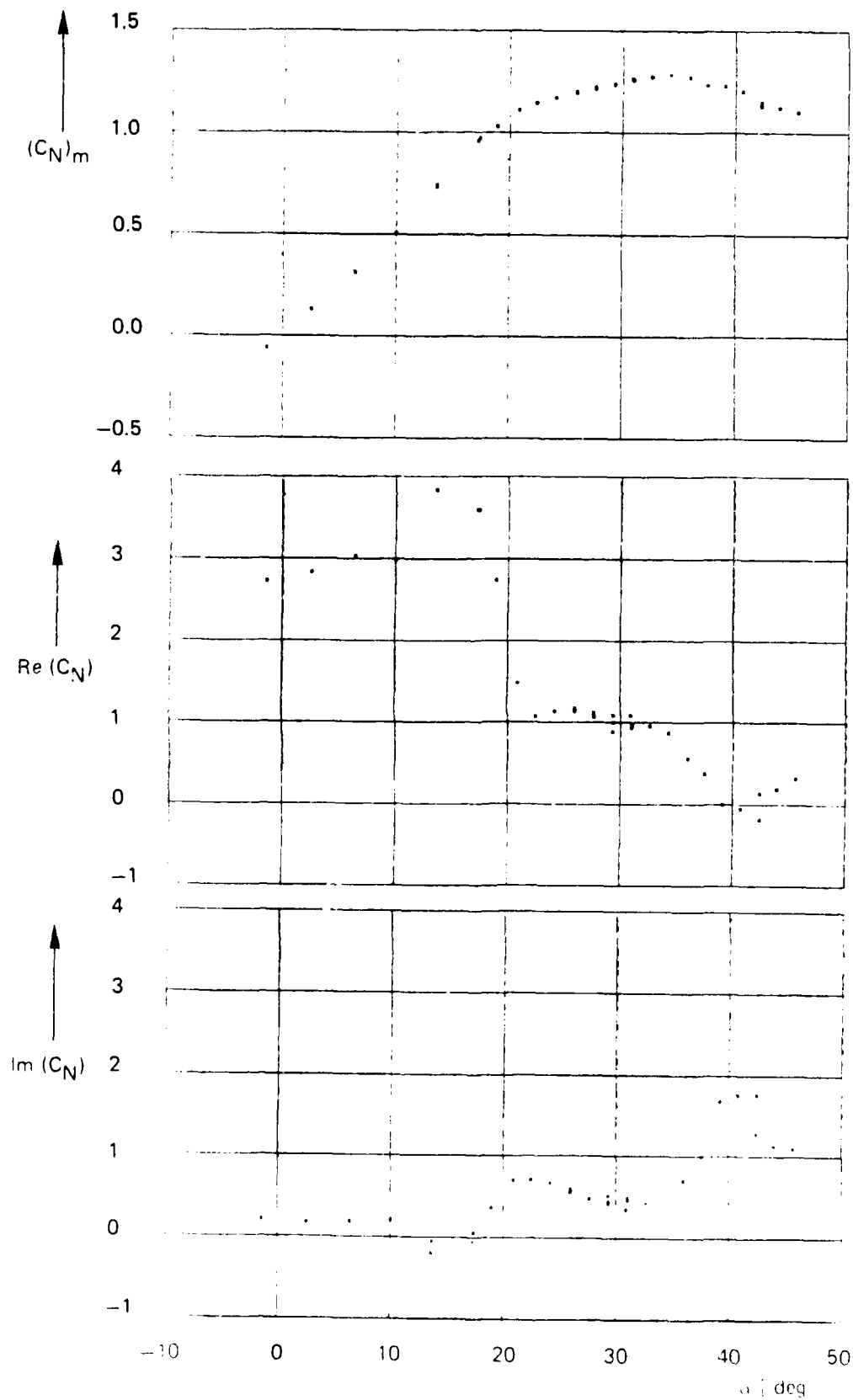


Fig B2 Zeroth and first order harmonic components of unsteady normal force coefficient ($\delta \approx 3.5$ deg, $f = 3$ Hz, $\gamma = 0$ deg, $V \approx 80$ m/s)

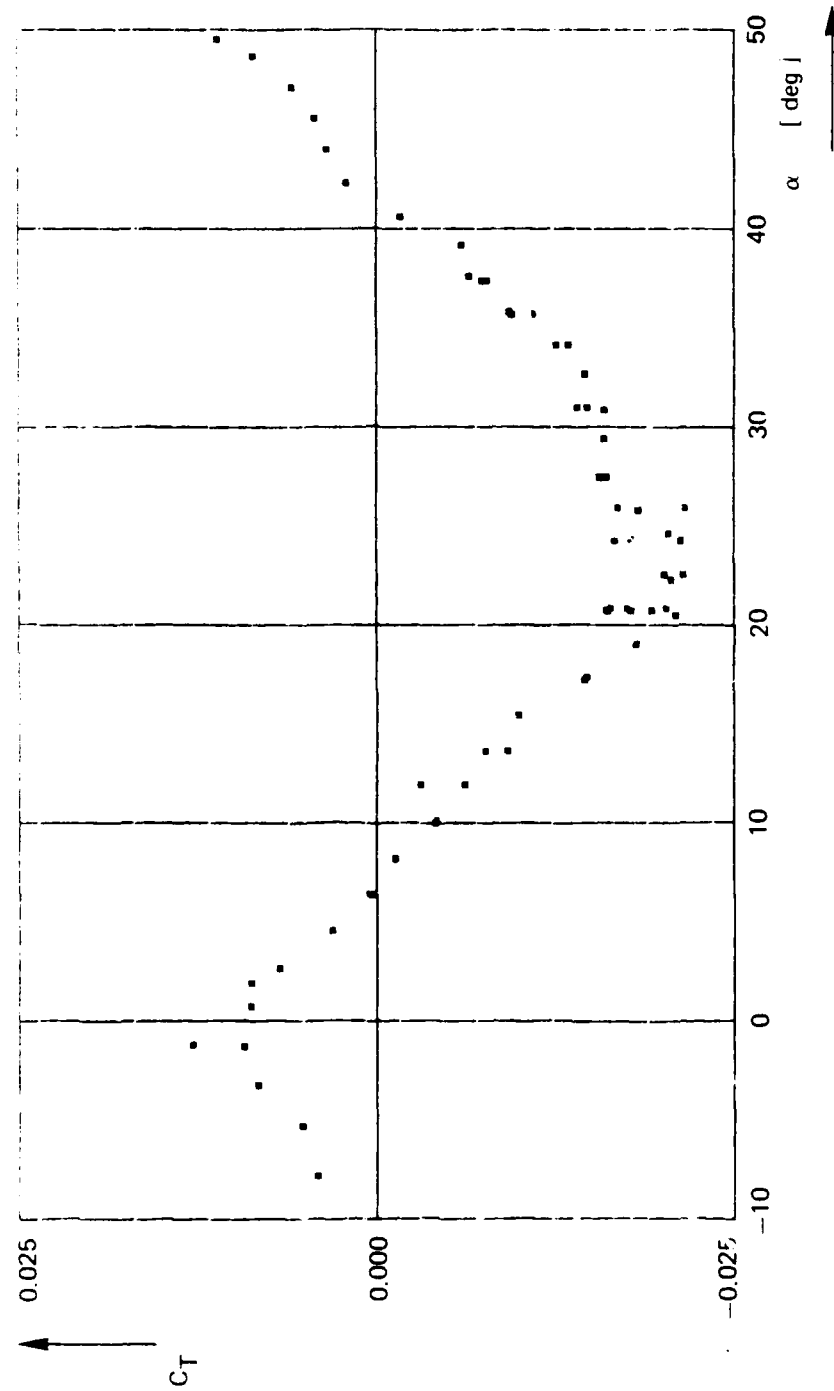


Fig. B3 Steady tangential force coefficient vs. incidence
($\beta = 0$ deg, $V \approx 80$ m/s)

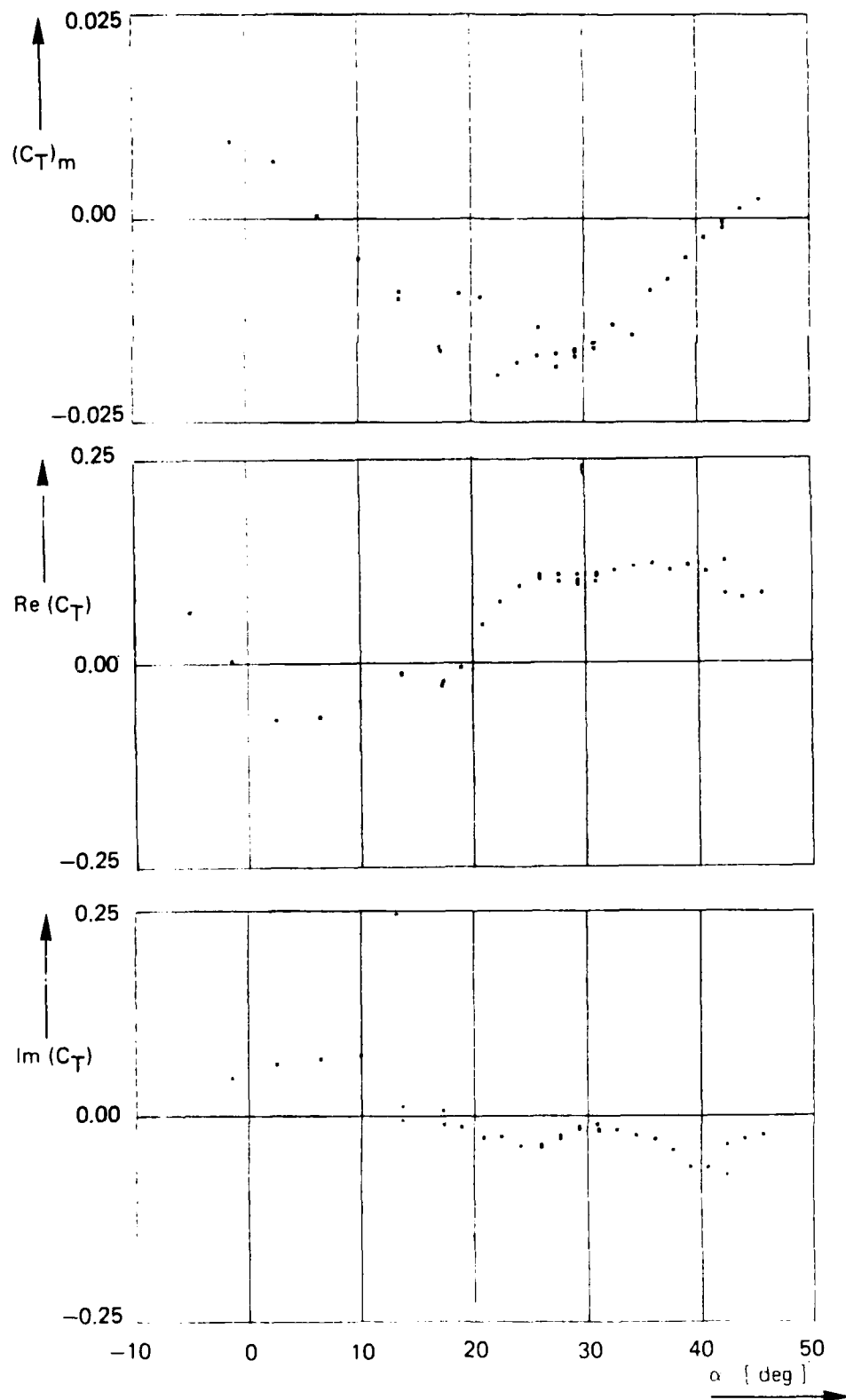


Fig. B4 Zeroth and first order harmonic components of unsteady tangential force coefficient ($dx \approx 3.5$ deg, $f = 3$ Hz, $\beta = 0$ deg, $V \approx 80$ m/s)

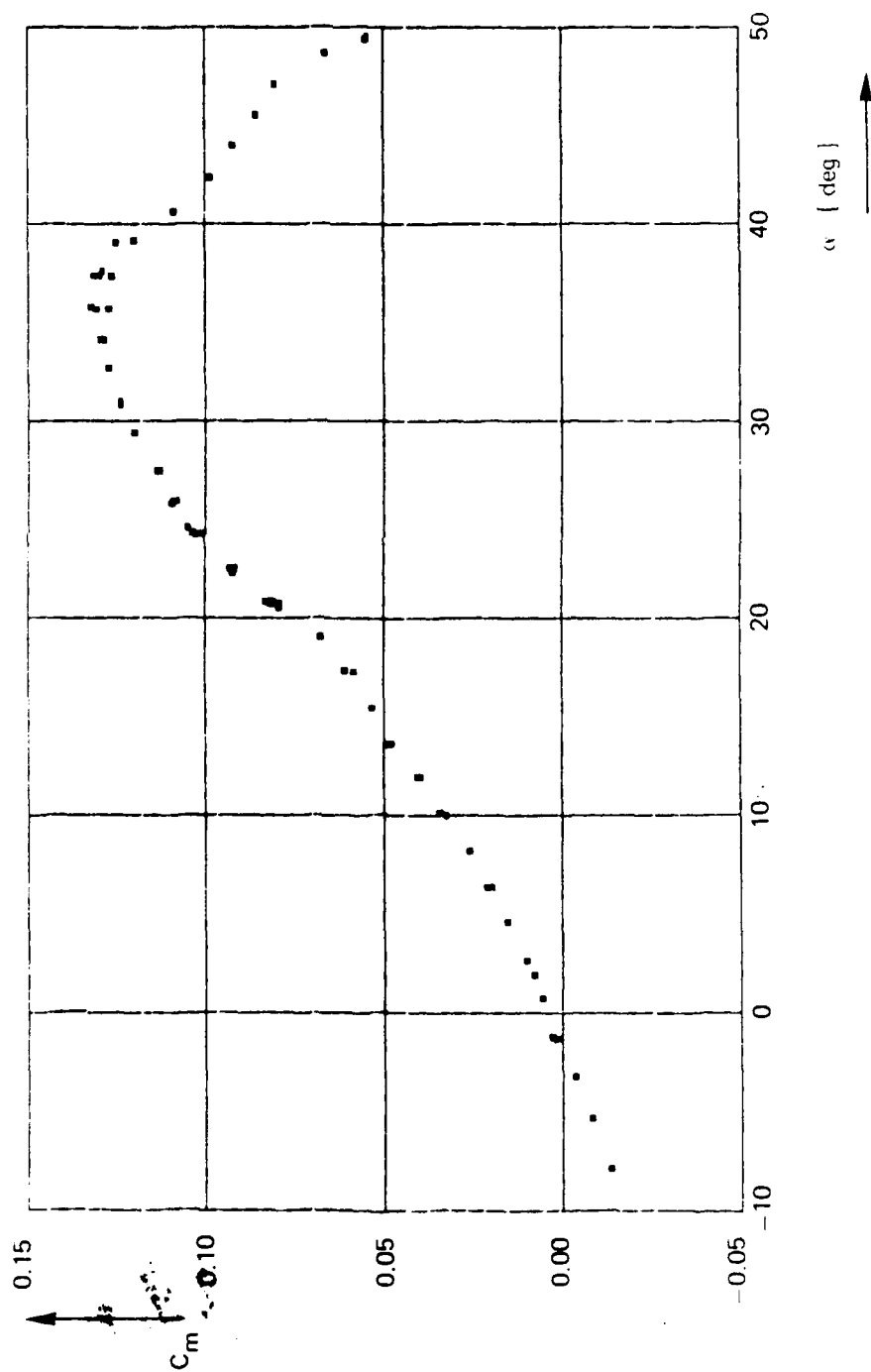


Fig. B5 Steady pitching moment coefficient vs. incidence
($\beta = 0$ deg, $V \approx 80$ m/s)

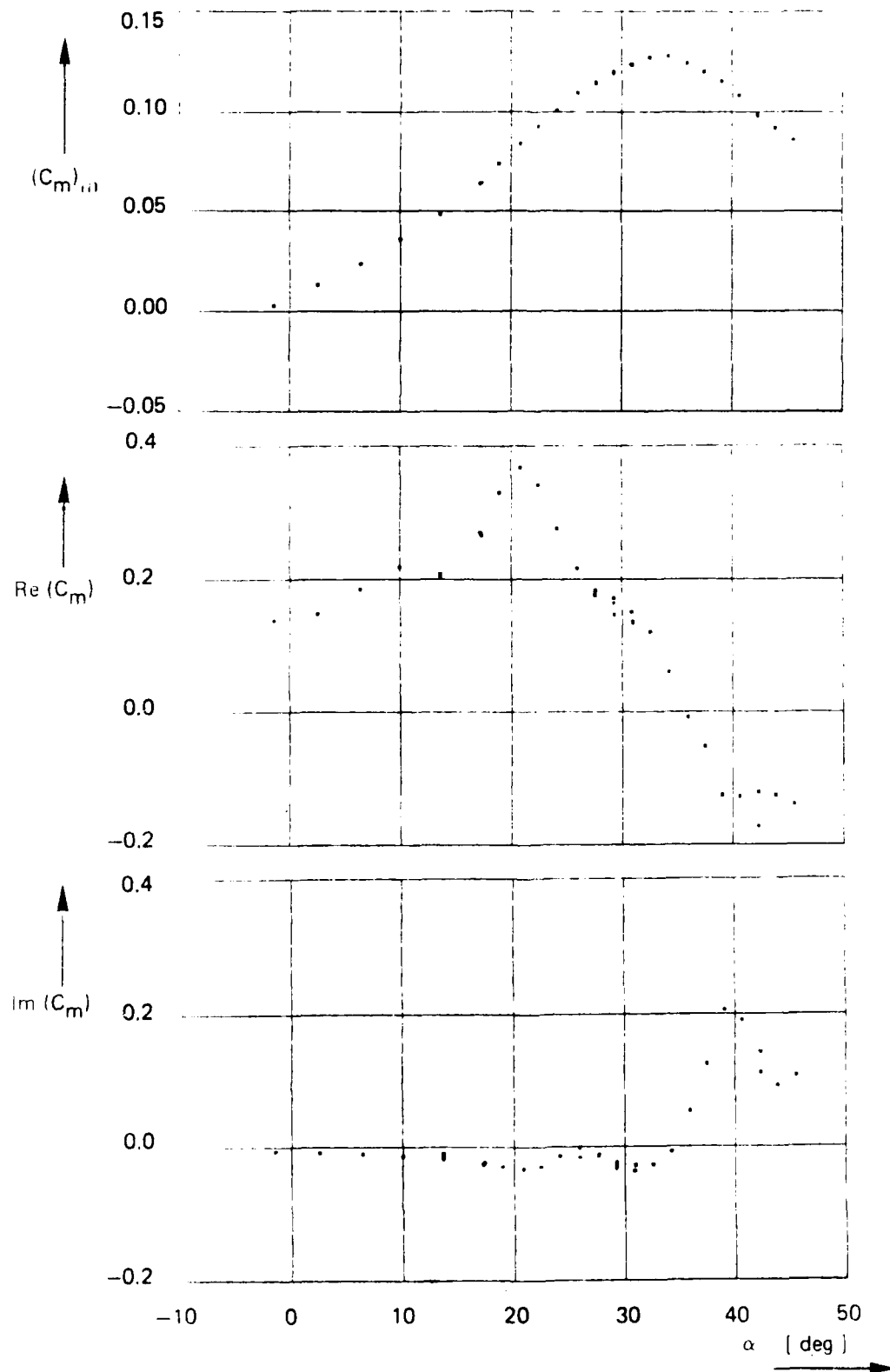


Fig. B6 Zeroth and first order harmonic components of unsteady pitching moment coefficient ($d\alpha \approx 3.5$ deg, $f = 3$ Hz, $\beta = 0$ deg, $V \approx 80$ m/s)

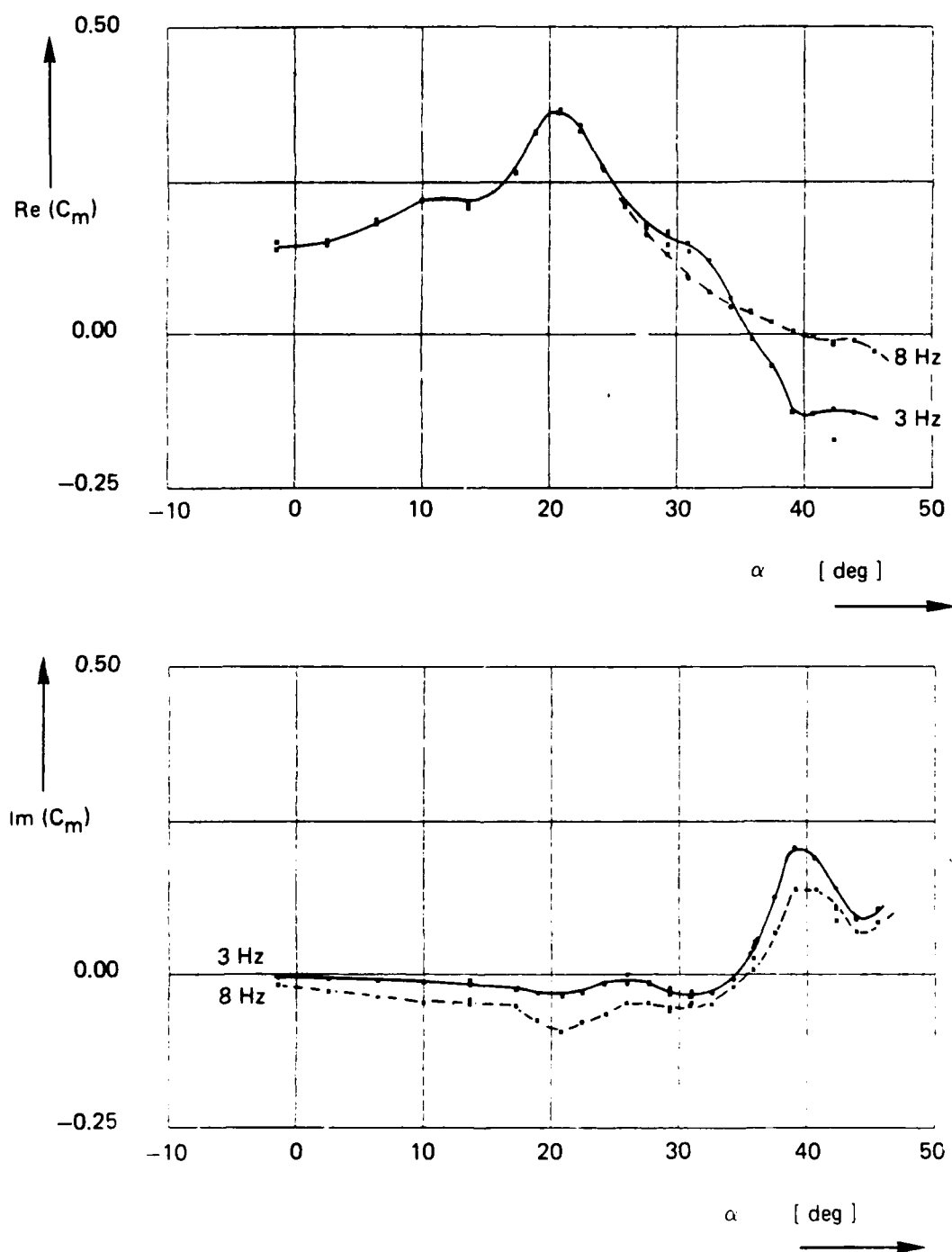


Fig. B7 First order harmonic components of unsteady pitching moment coefficients at 3 and 8 Hz ($d\alpha \approx 3.5$ deg, $\delta = 0$ deg, $V \approx 80$ m/s)

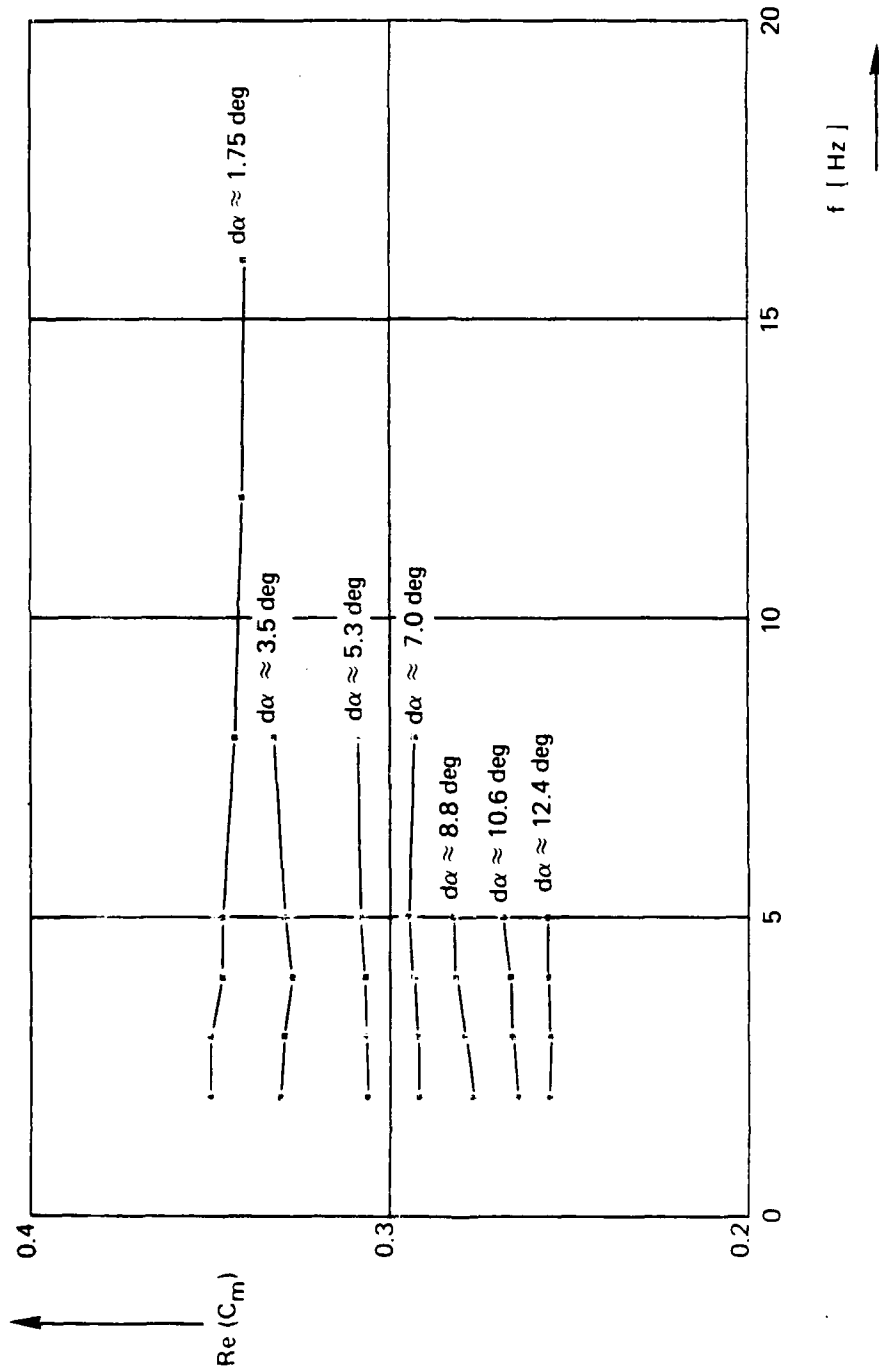


Fig. B8 Real part of first order harmonic component of unsteady pitching moment coefficient vs. frequency ($\alpha \approx 18.9$ deg, $\beta = 0$ deg, $V = 80$ m/s)

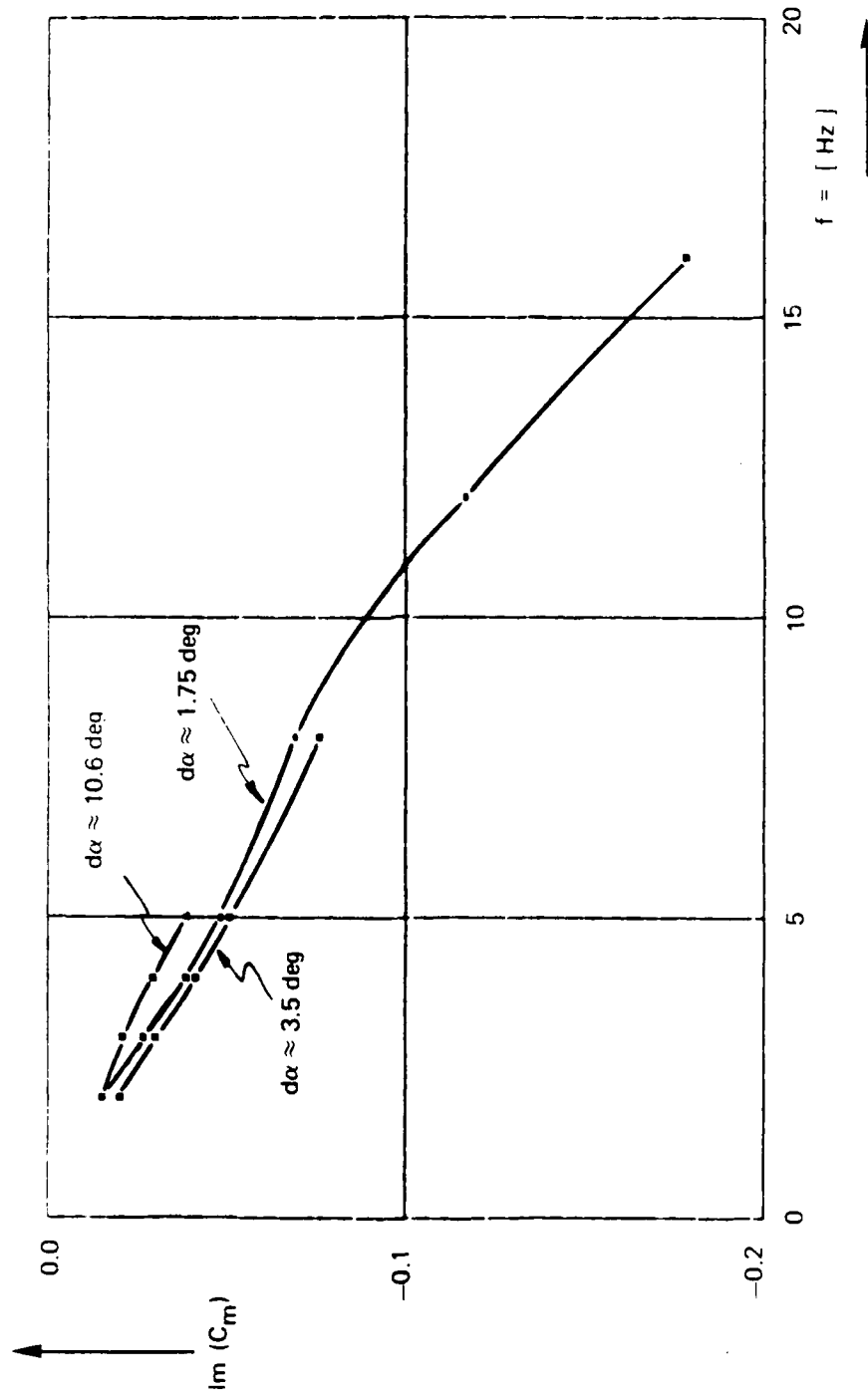


Fig. B9 Imaginary part of first order harmonic components of the unsteady pitching moment coefficient vs. frequency ($\alpha \approx 18.9 \text{ deg}$, $\beta = 0 \text{ deg}$, $V \approx 80 \text{ m/s}$)

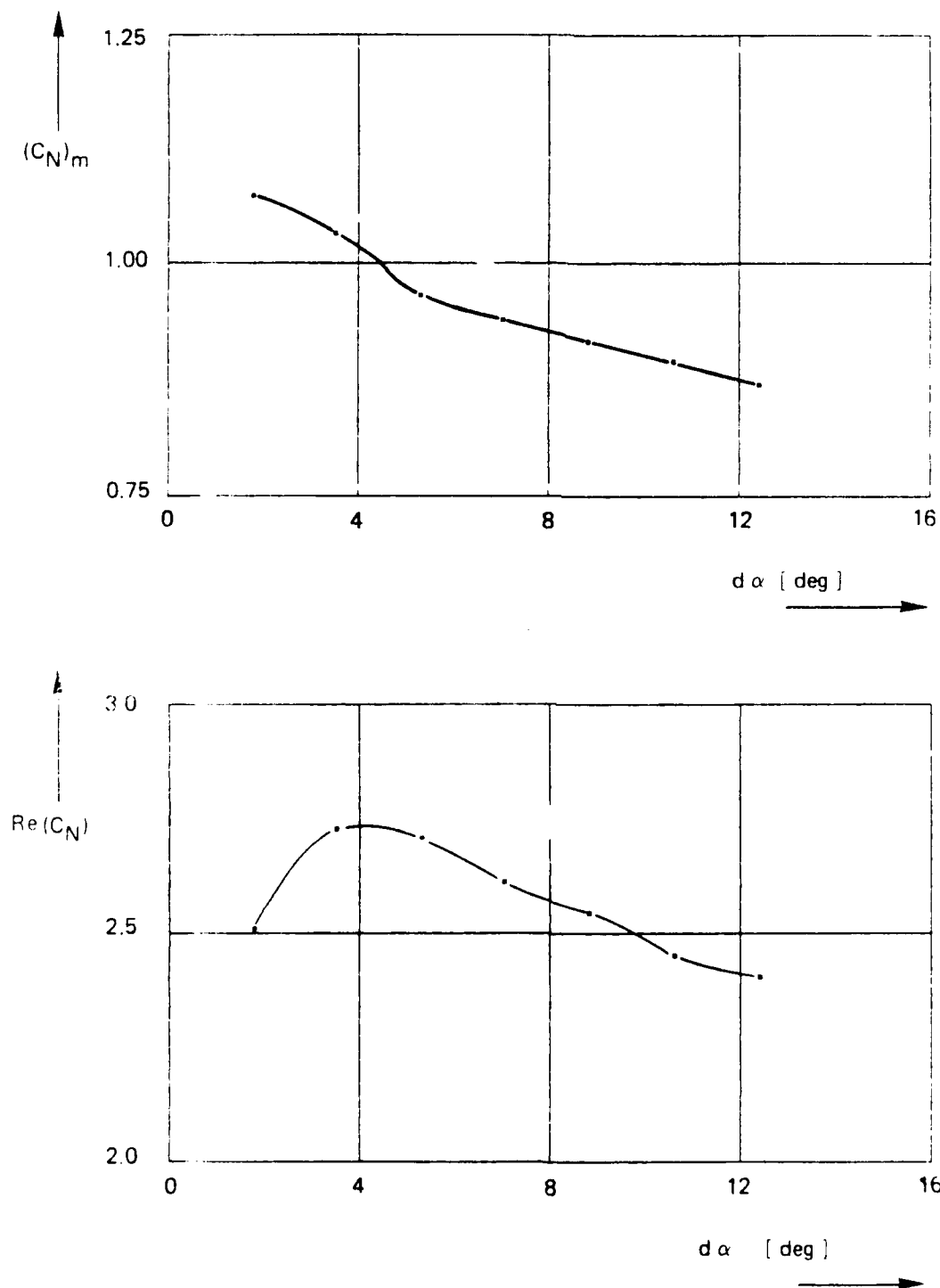


Fig. B10 Zeroth order harmonic component and real part of first order harmonic component of unsteady normal force coefficient vs. amplitude ($\alpha \approx 18.9$ deg, $f = 3$ Hz, $\beta = 0$ deg, $V \approx 80$ m/s)

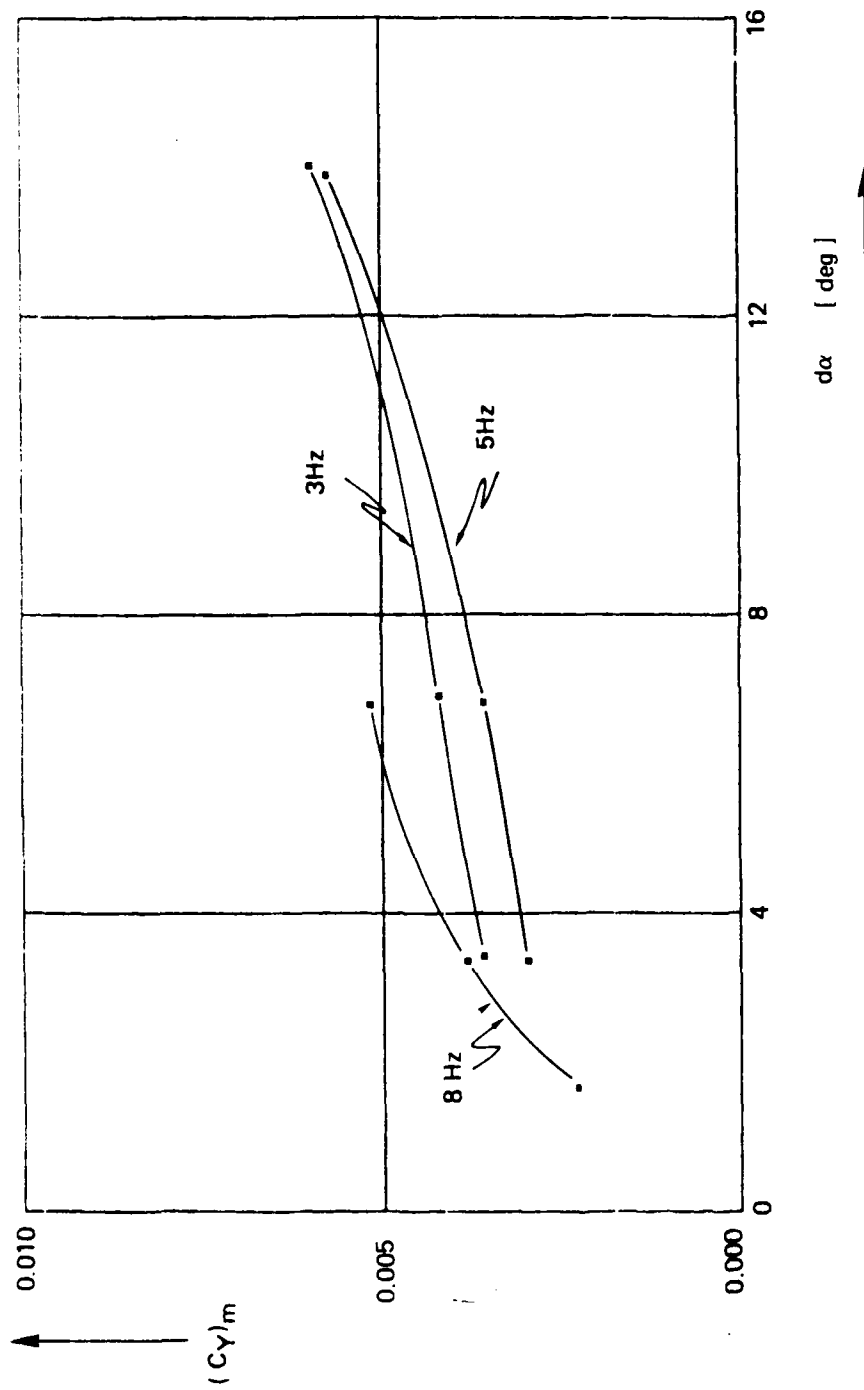


Fig. B11 Zeroth order harmonic component of unsteady side force coefficient vs. amplitude ($\alpha \approx 35.9$ deg, $\beta = 5$ deg, $V \approx 80$ m/s)

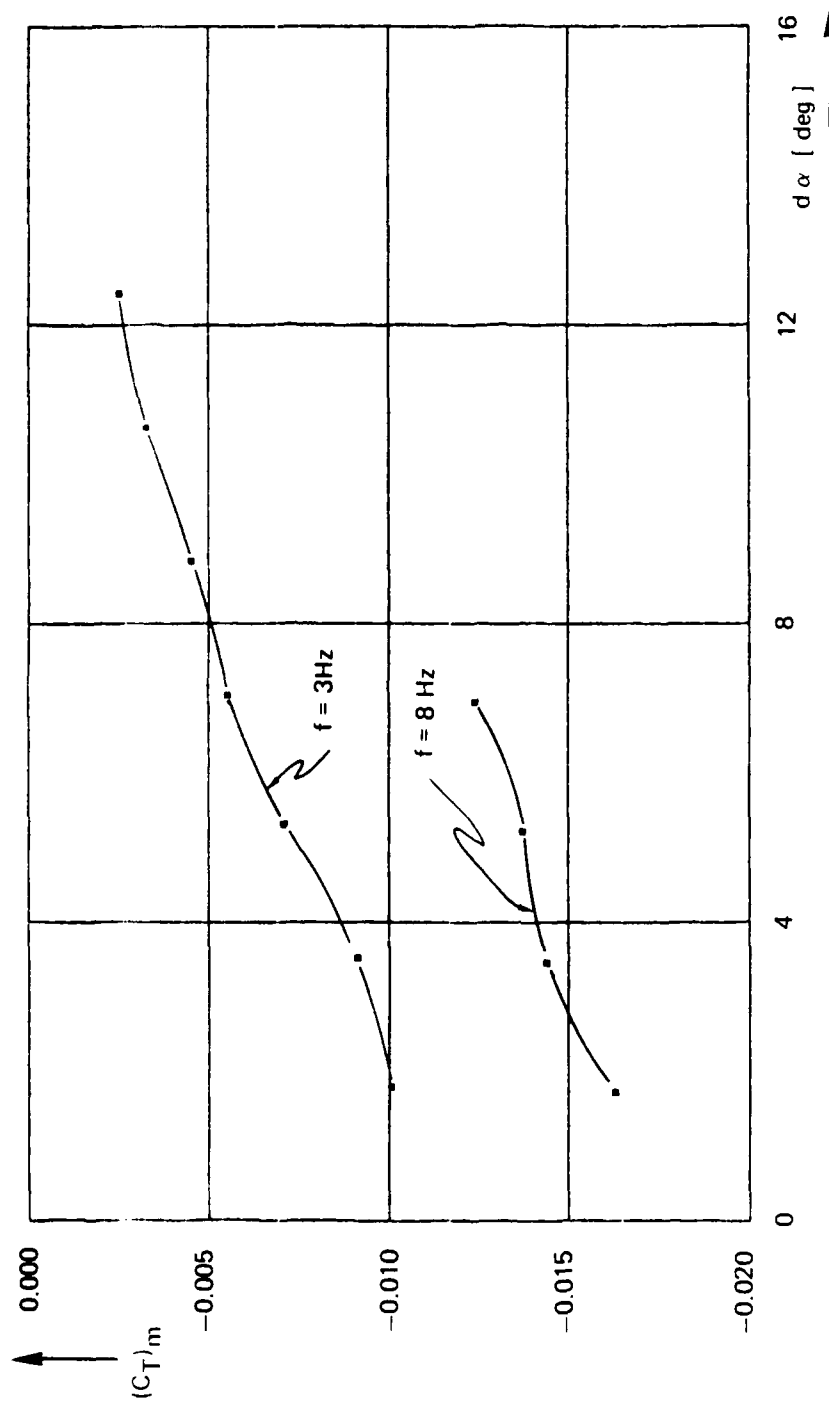


Fig. B12 Zeroth order harmonic component of unsteady tangential force coefficient vs. amplitude ($\alpha \approx 18.9$ deg, $\beta = 0$ deg, $V \approx 80$ m/s)

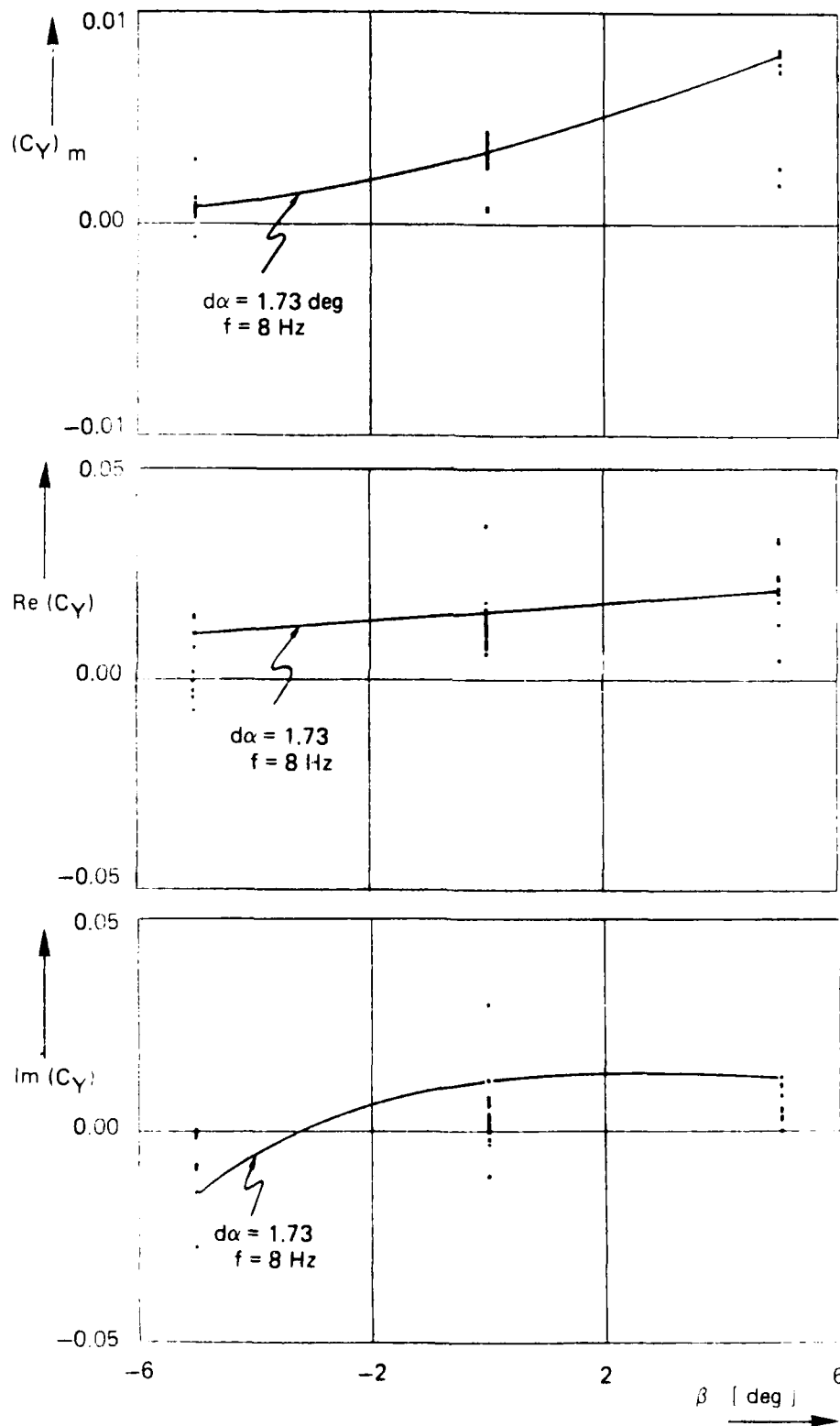


Fig. B13 The effect of sideslip on the zeroth and first order harmonic components of the unsteady side force coefficient at various frequency amplitude combinations ($\alpha \approx 18.9$ deg, $V \approx 80$ m/s)

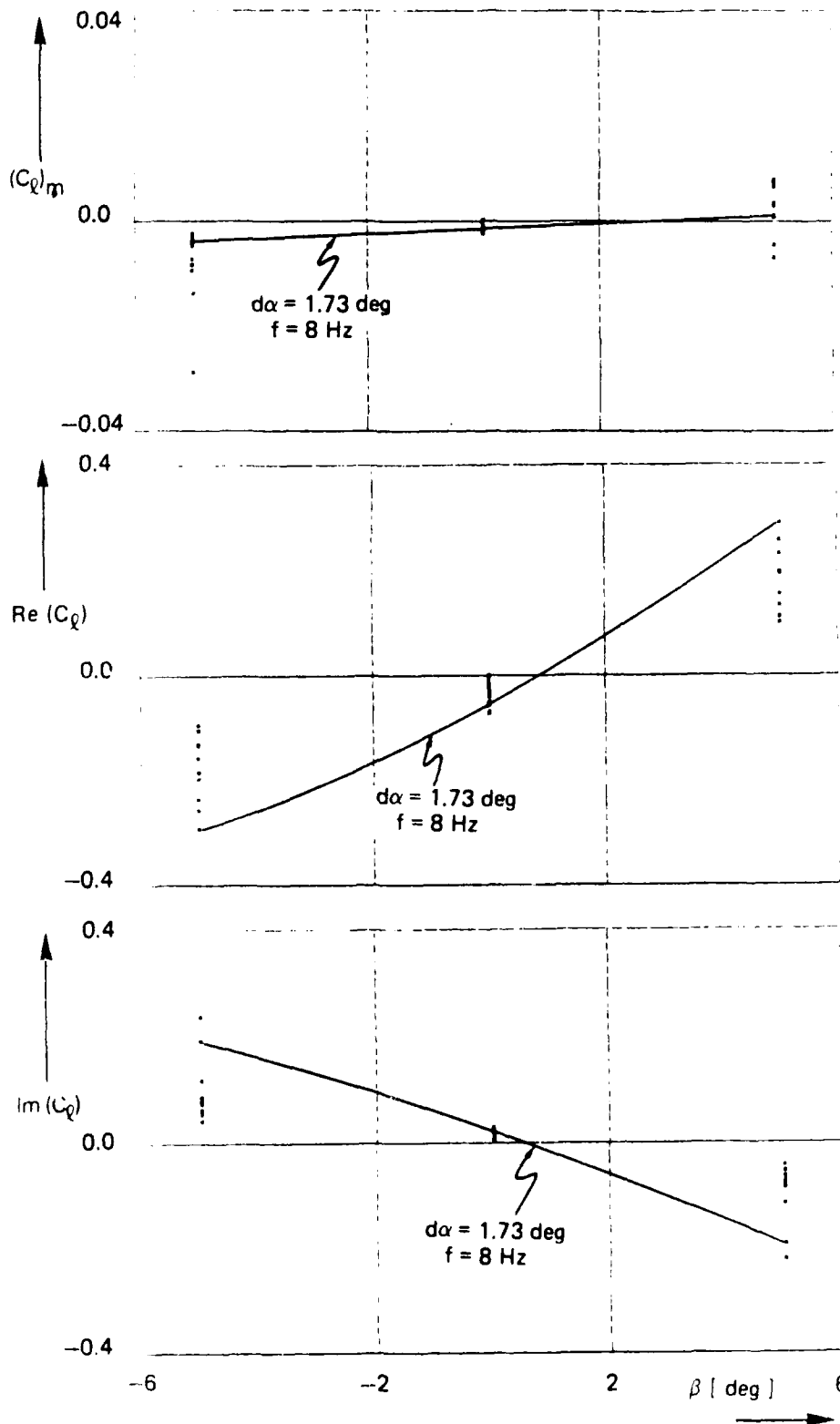


Fig. B14 The effect of sideslip on the zeroth and first order harmonic components of the unsteady rolling moment coefficient at various frequency amplitude combinations ($\alpha \approx 18.9 \text{ deg}$, $V \approx 80 \text{ m/s}$)

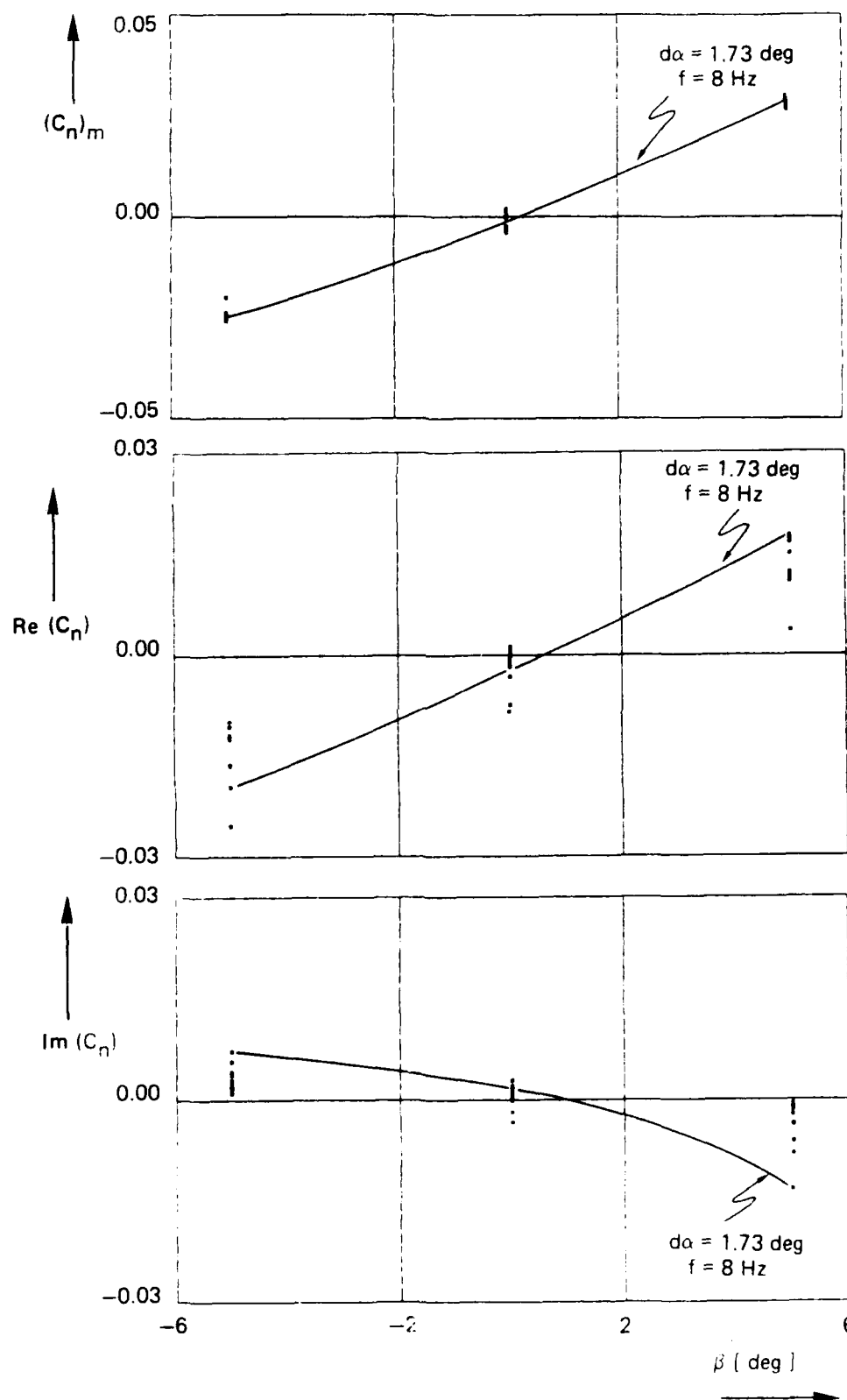


Fig. B15 The effect of sideslip on the zeroth and first order harmonic components the unsteady yawing moment coefficient at various frequency amplitude combinations ($\alpha \approx 18.9 \text{ deg}$, $V \approx 80 \text{ m/s}$)

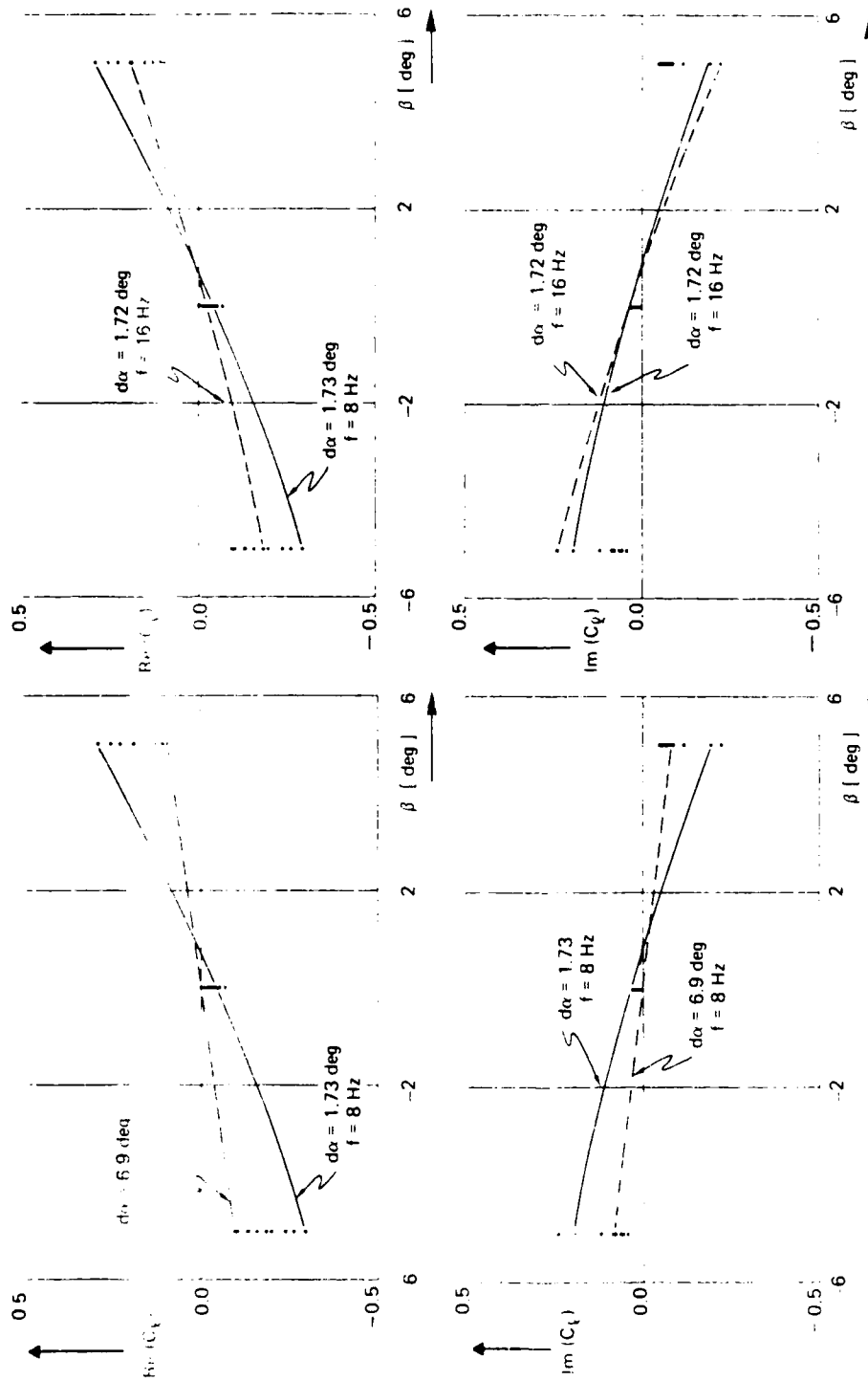


Fig. B16 The effect of sideslip on the first order harmonic component of the unsteady rolling moment coefficient ($\alpha \approx 18.9$ deg, $V \approx 80$ m/s)
Left side of figure : amplitude effect
Right side of figure: frequency effect