DSP Analysis of Digital Vector Slope Gauge Data Produced by Ocean Wave Simulation

EECS 803 - Introduction to Research

Prof. Earl Schweppe, Instructor

Evan L. Bryson 618093

Overview

- Ocean Wave Behavior
- The Vector Slope Gauge (VSG)
  - VSG History
  - VSG Function
- Ocean Wave Data Simulation
- Off-line Processing
- Future Work

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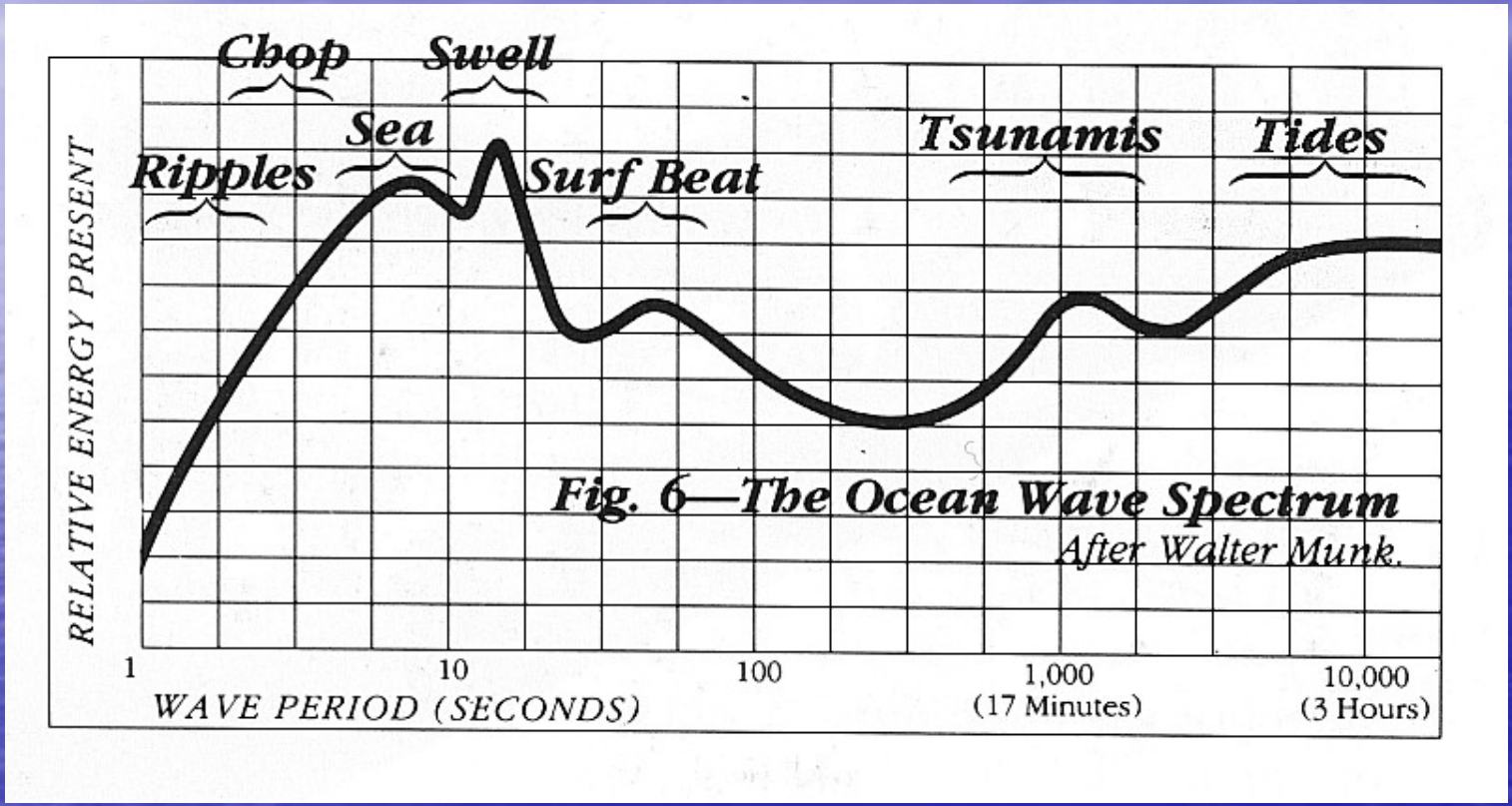
Ocean Wave Behavior

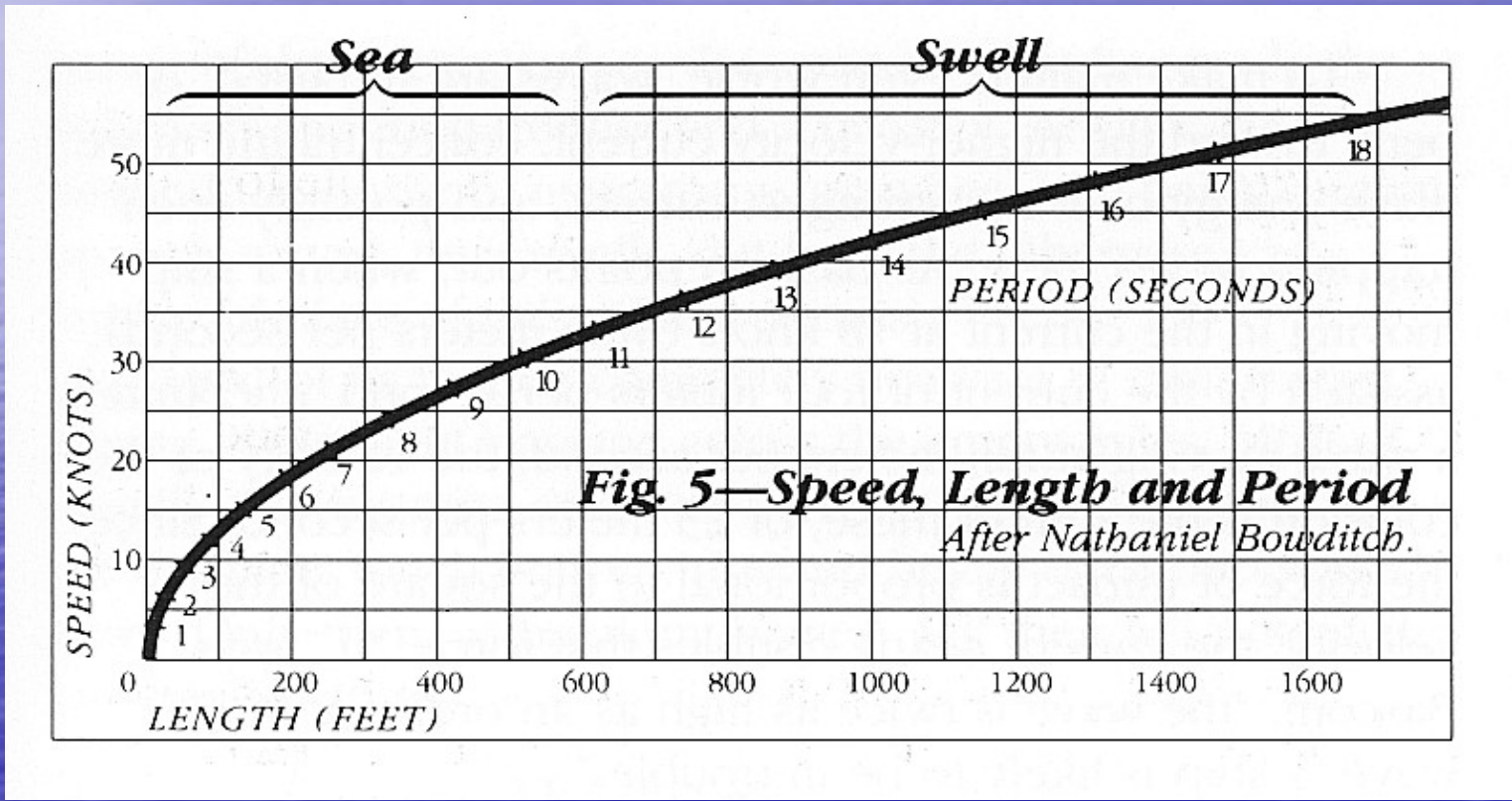
- Spectrum
- Wavelength, period, and velocity
- Deep water vs. shallow water waves
- Sea = linear sum of waves
- Orbital velocity

Ocean Wave Spectrum



(From Kampion, 1997)

Wave Velocity vs. Wavelength and Period



(From Kampion, 1997)

Simple Wavefront Description

Height of ocean wave at time t and position (x,y):

$$h(x, y, t) = A\cos(\Omega t + \kappa x\cos\alpha + \kappa y\sin\alpha + \phi)$$

where $\Omega = \dfrac{2\pi}{T}$ = angular frequency (rad/sec)

$\kappa = \dfrac{2\pi}{L}$ = wave number (rad/m)

L = wavelength (m)

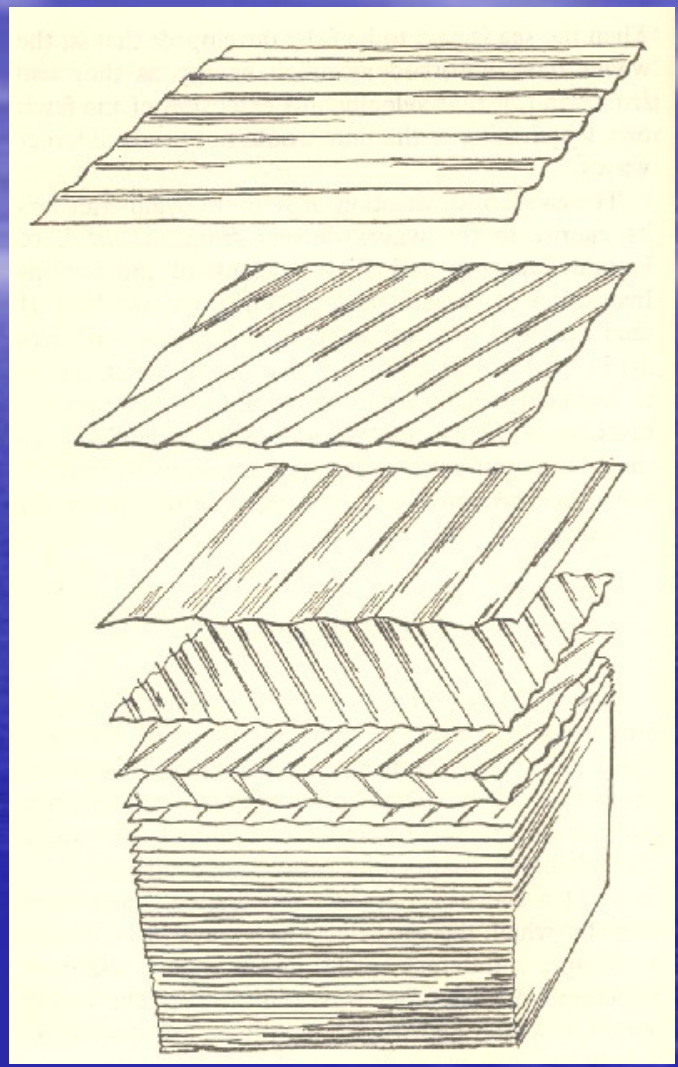
T = wave period (sec)

α = wave approach direction

ϕ = phase

Superposition of Waves

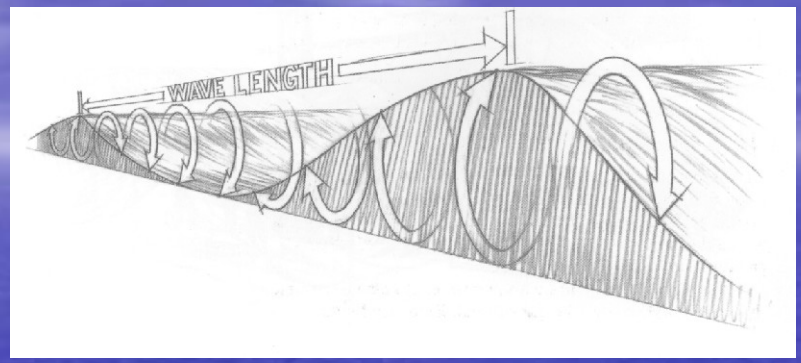
- Complex Sea = Superposition of many wavefronts
- Individual wavefronts are approximately sinusoidal in deep ocean
- Wavefronts change shape near shore as water depth decreases
- Single wavefront is rare in nature
- Wavefronts are initiated by winds over the ocean at other locations



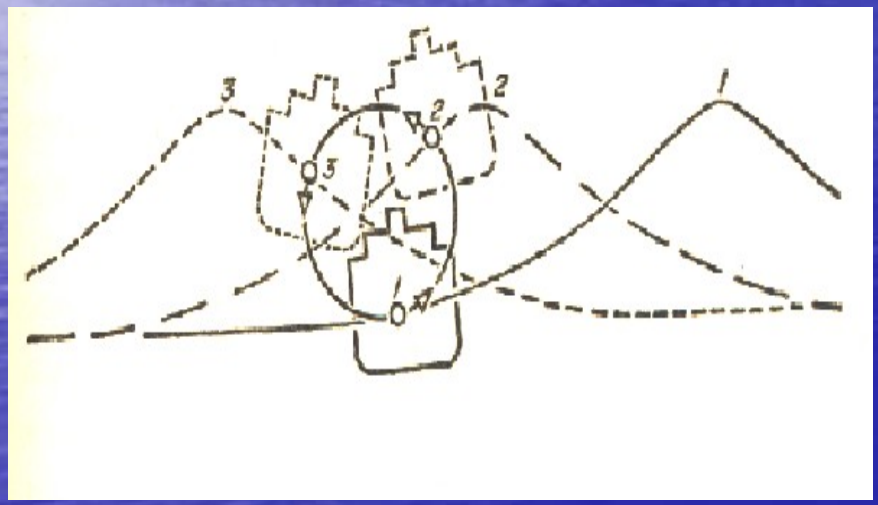
(From Bascom, 1964)

(From Kampion, 1997)

Orbital Velocity



(From Kampion, 1997)



(From Bascom, 1964)

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- **The Vector Slope Gauge (VSG)**
  - **VSG History**
  - **VSG Function**
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- Off-line Processing
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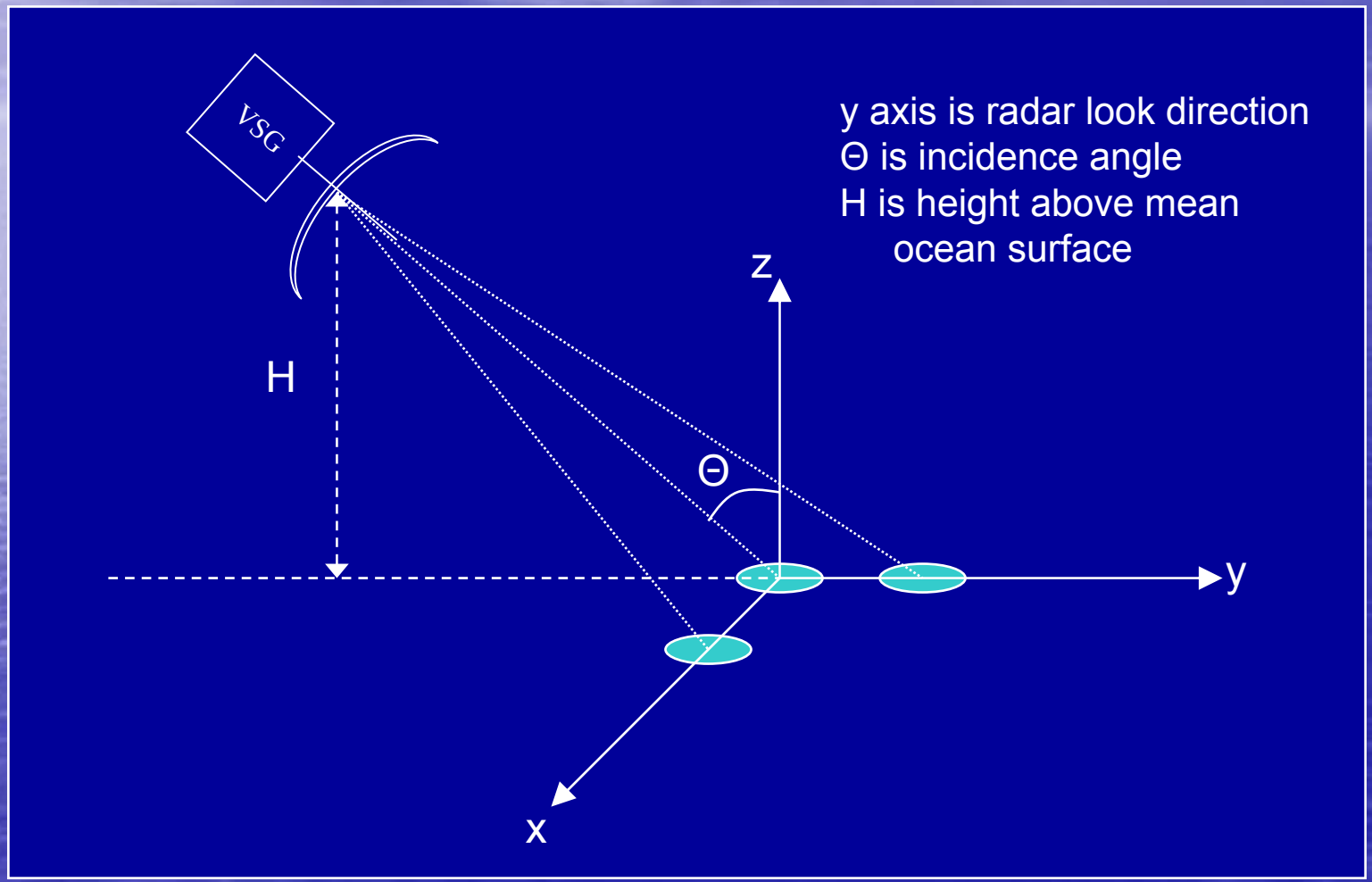
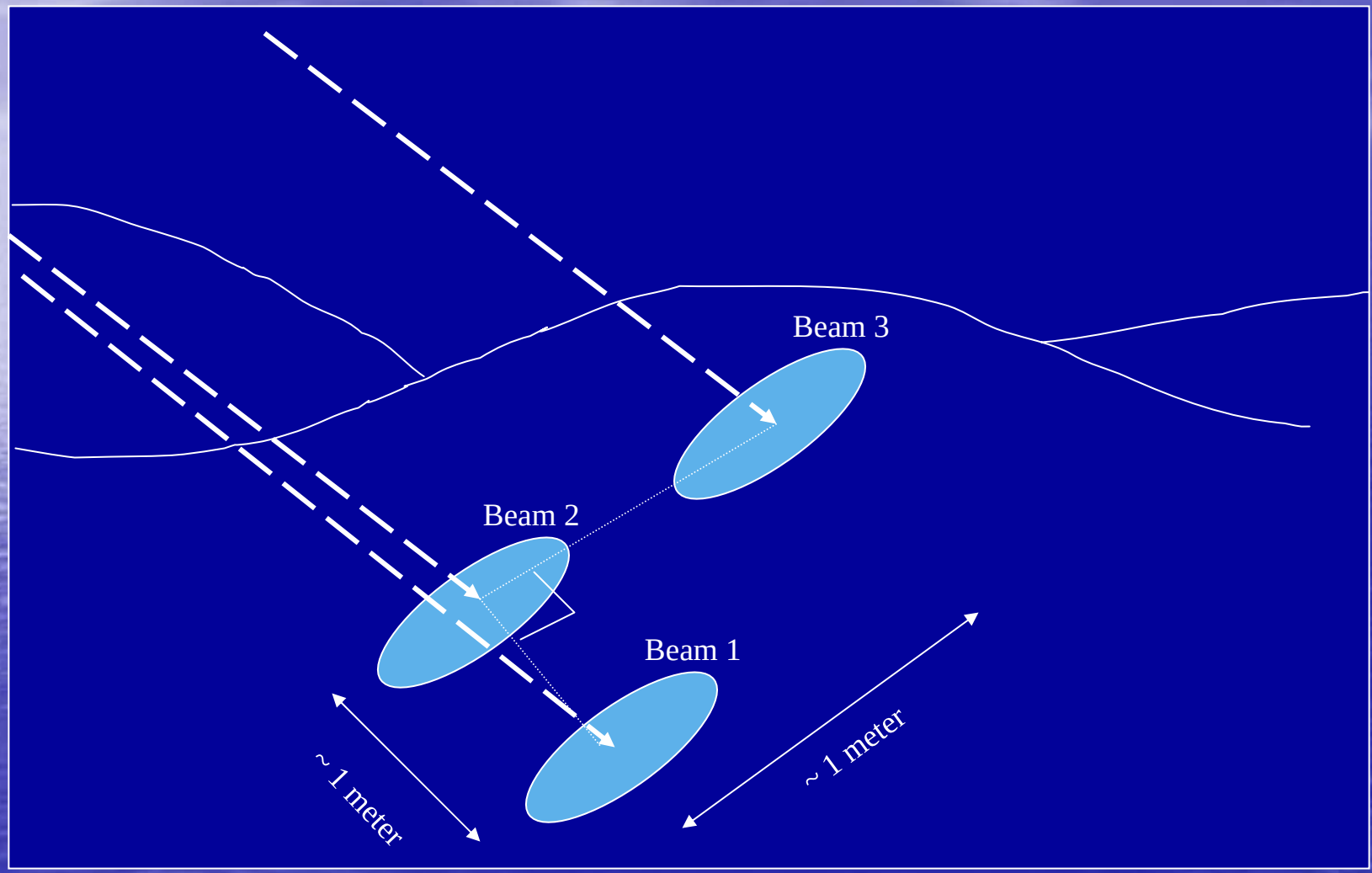
VSG History

- Version 1 – Analog VSG
  - Tested in the North Sea in 1990
- Version 2 – Improvement of Version 1
  - Tested at Duck Pier in 1995
- Version 3 – Digital VSG
  - No ocean surface data available

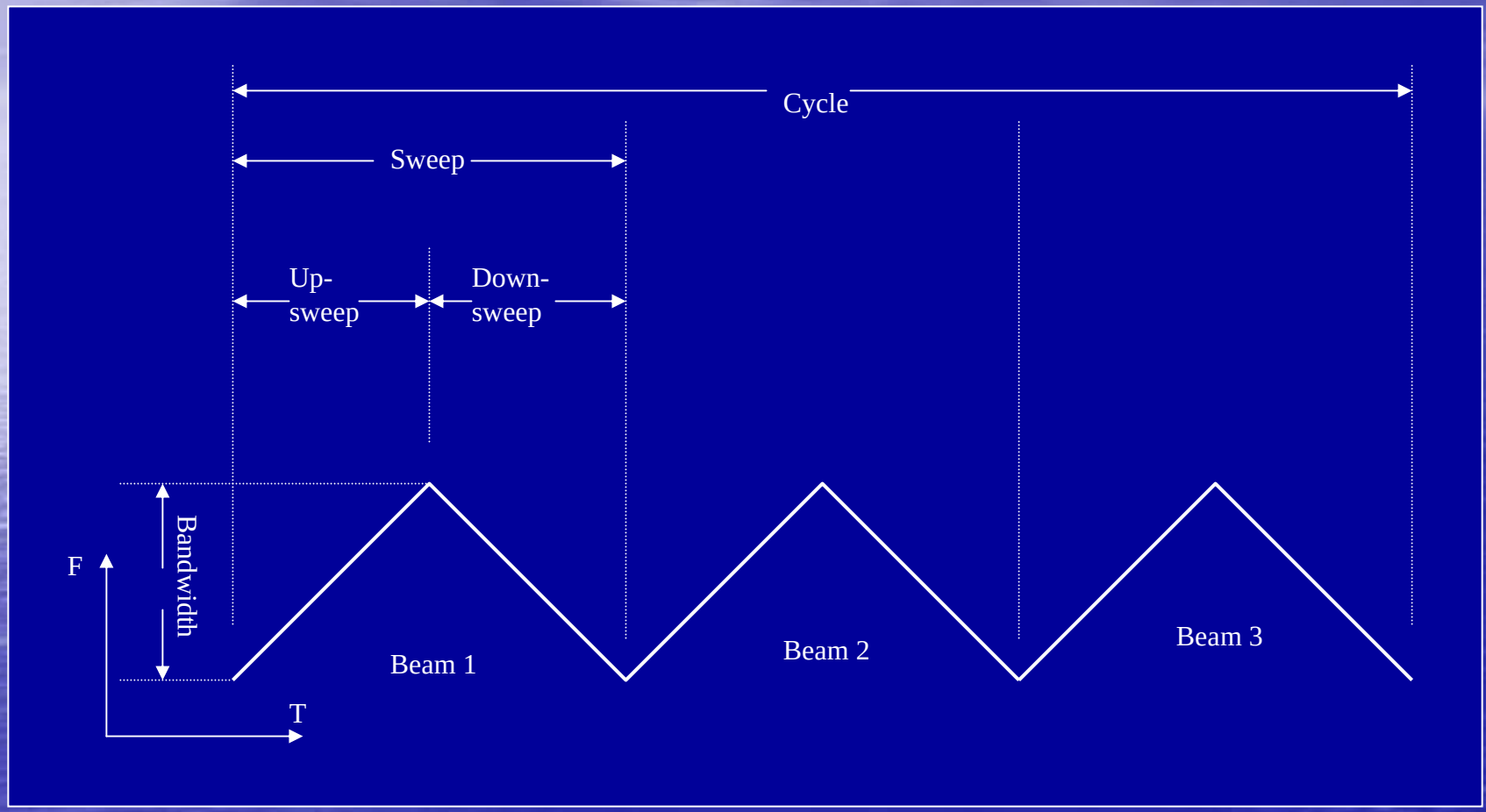
VSG Function



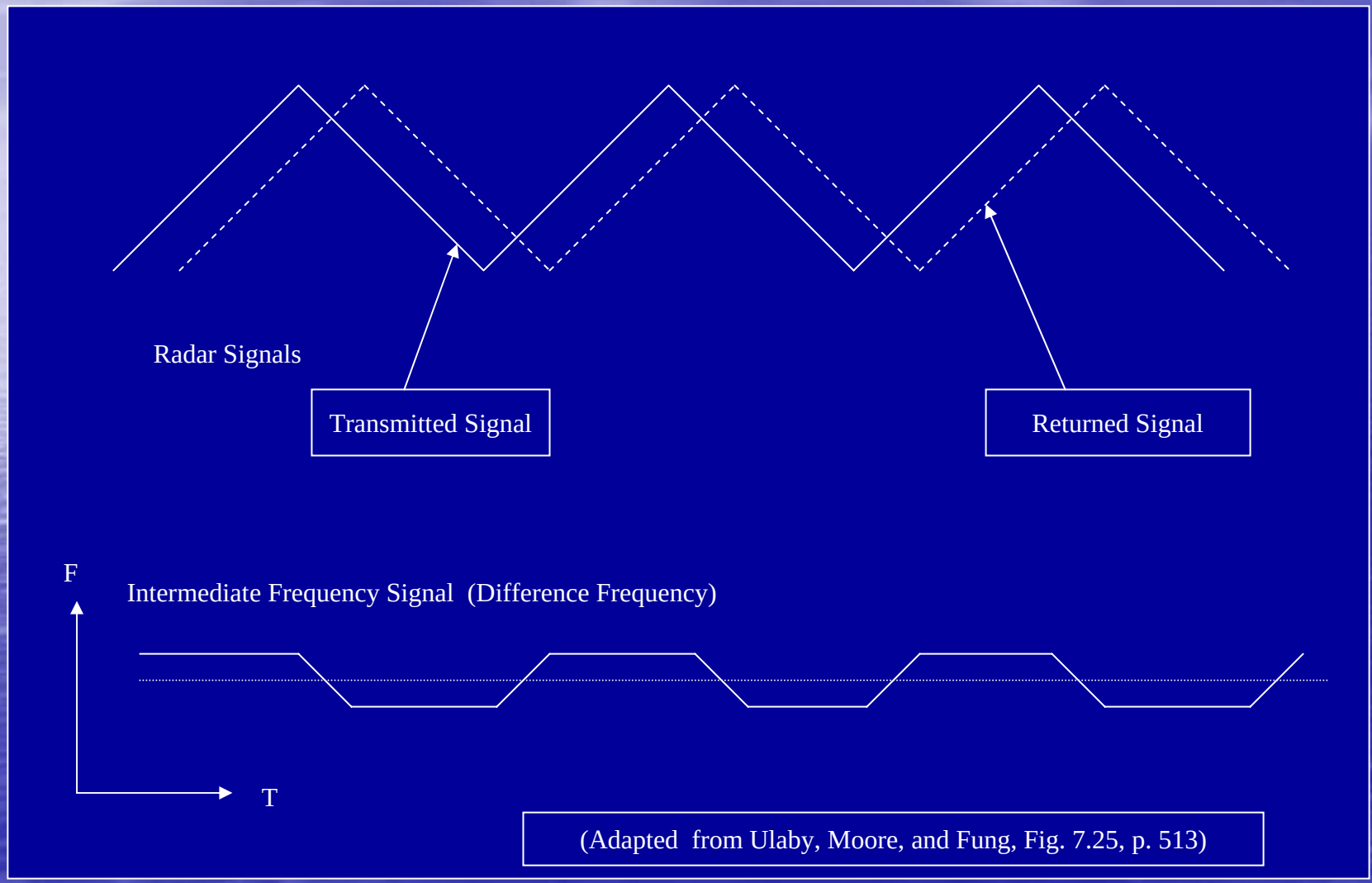
Typical VSG Beam Pattern on Ocean Surface



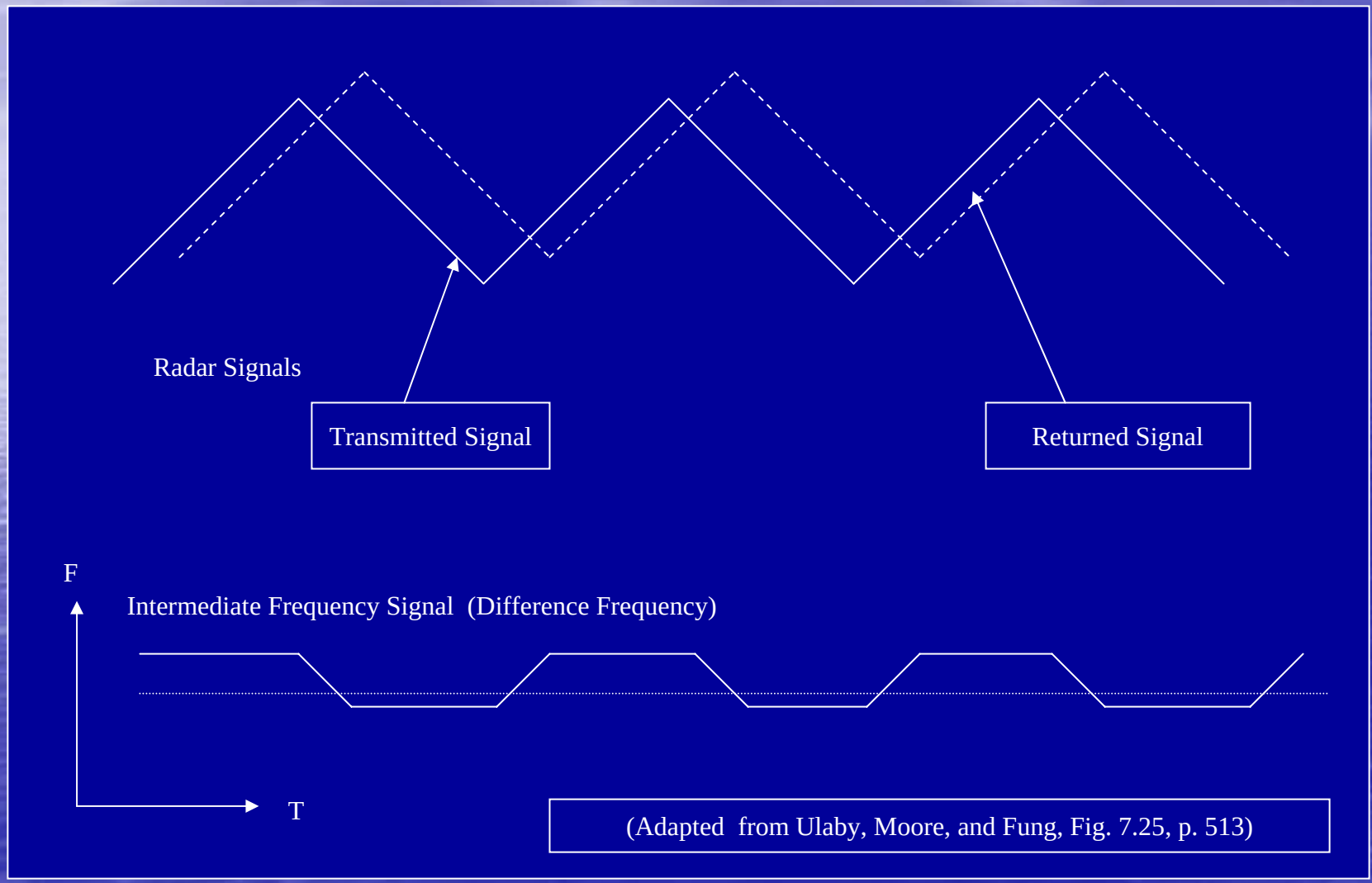
Frequency Format of VSG Radar Signal



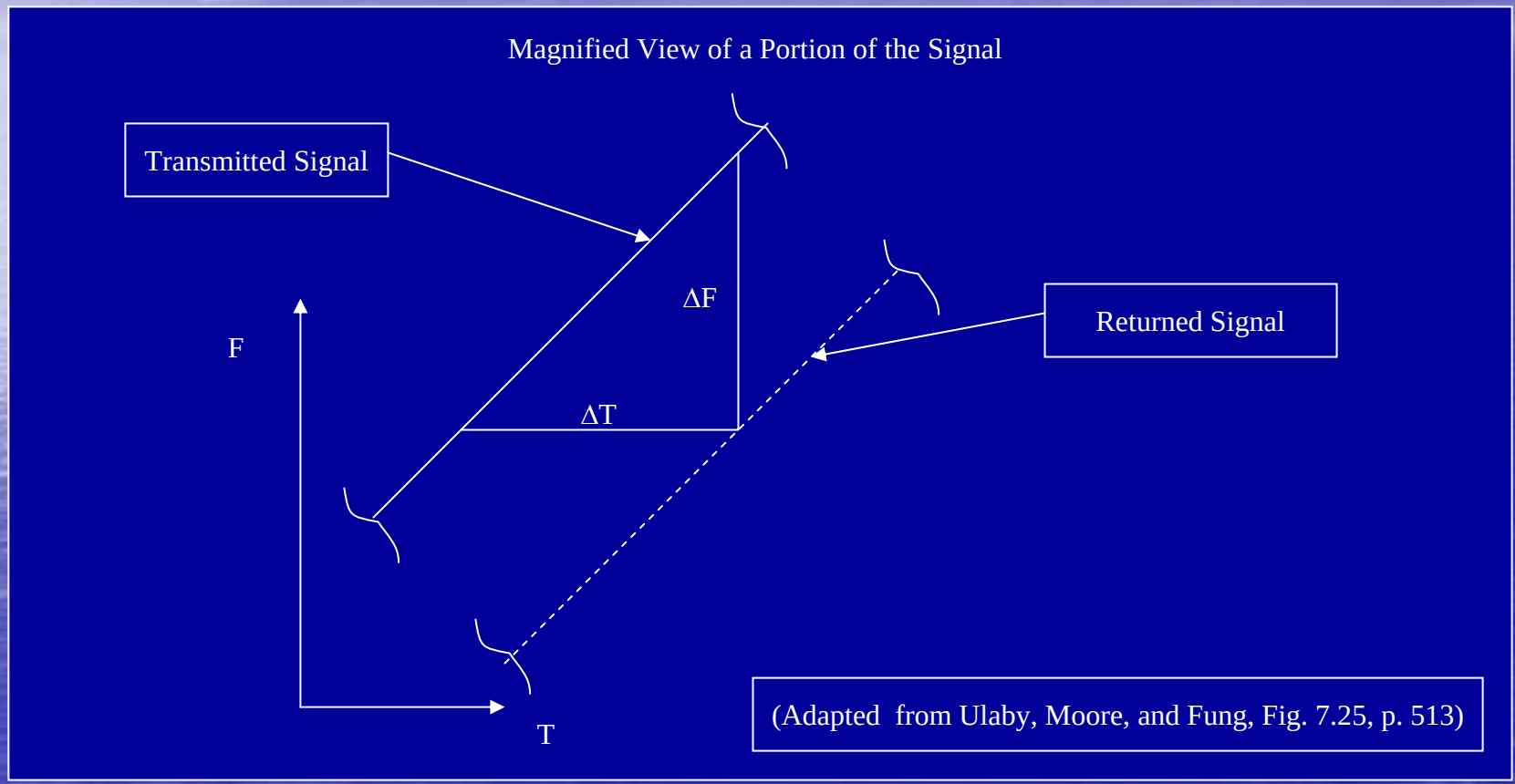
Instantaneous IF Output and Return for Range Measurement



Instantaneous IF Output and Return for Range and Doppler Measurement



Instantaneous Frequencies for Point Target



VSG Parameters

- Range
- Sweep repetition frequency
- Single (Up or Down) sweep time
- Sweep rate
- Minimum DSP sample rate

$$R = \frac{h_{VSG}}{\cos\theta} = \frac{10}{\cos(45)} = 14.14\ \text{m}$$

$$f_B = \frac{c \cdot f_{IF}}{4B \cdot R} = \frac{(3 \cdot 10^8)45 10^3}{4(600 10^6)14.14} \cong 4000\ \text{Hz}$$

$$T_{sweep} = \frac{1}{2f_B} \cong 126\ \mu\text{s}$$

$$\frac{\Delta f}{\Delta t} = \frac{B}{T_{sweep}} = \frac{600}{126} = 4.76\ \text{Mhz}/\mu\text{sec}$$

$$f_{s\min} = 2 \cdot f_{IF} \cdot 1.1 = 1.0\text{MHz}$$

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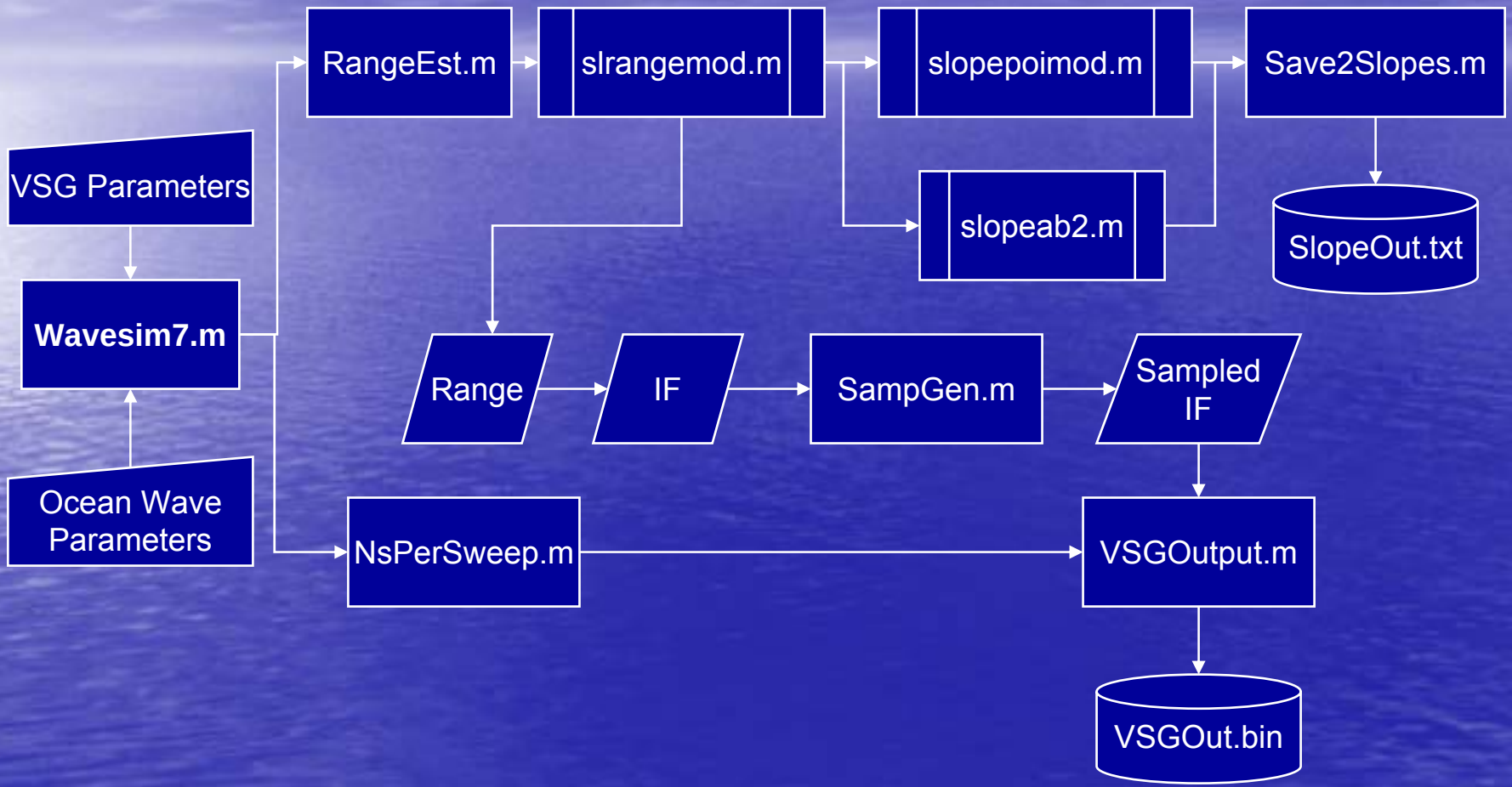
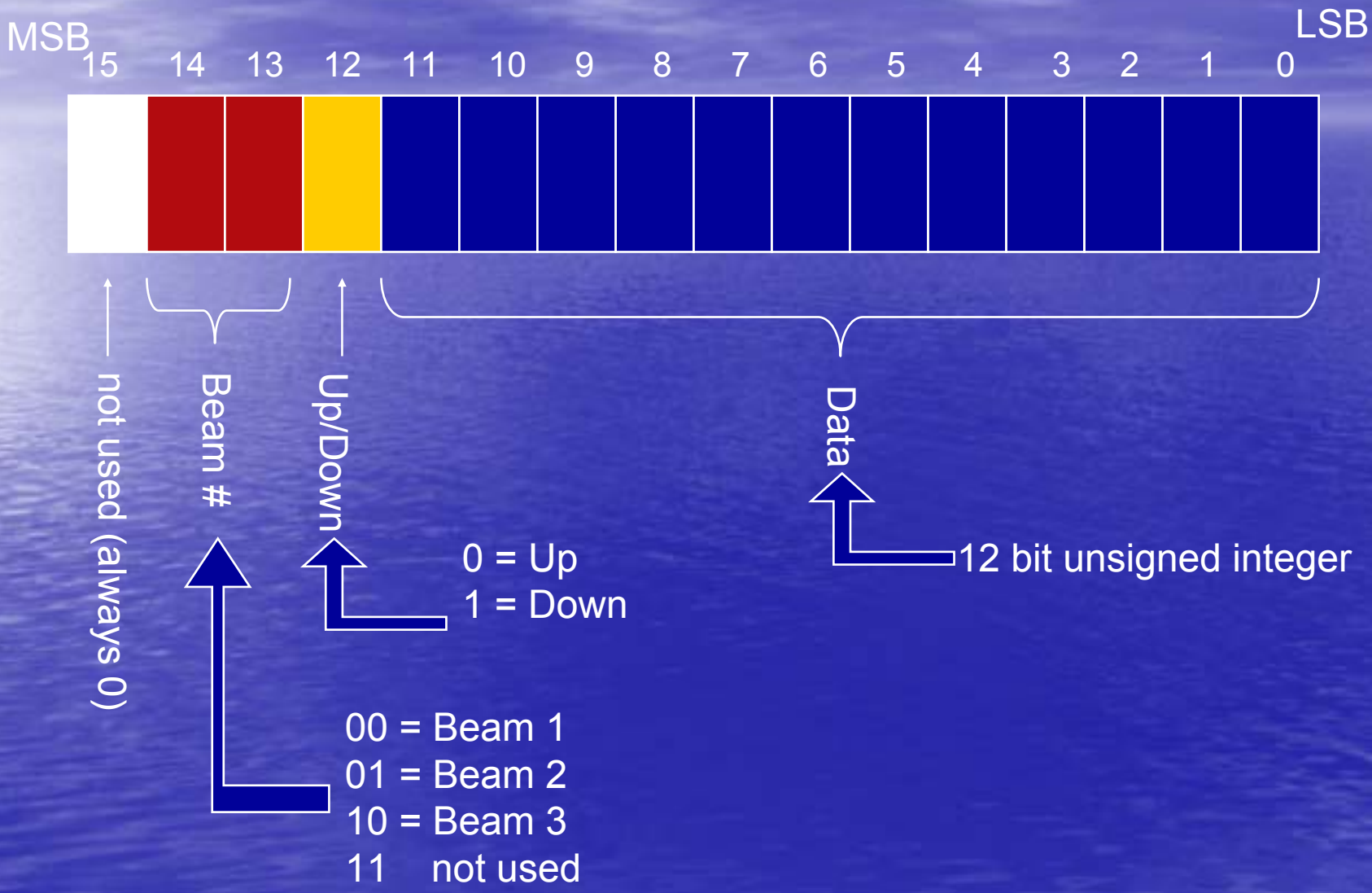
Ocean Wave Data Simulation for Digital VSG

- Characterize simple ocean surfaces
  - Flat surface (calm sea)
  - Single wavefront
  - Multiple wave fronts
- Add Doppler shift to surfaces
- Convert ranges + Doppler to frequencies
- Digital sampling of frequencies
- Scale and shift
- Convert to 12-bit unsigned integers
- Create data files in digital VSG format

Ocean Wave Data Simulation
WaveSim7.m



Digital VSG Data Format



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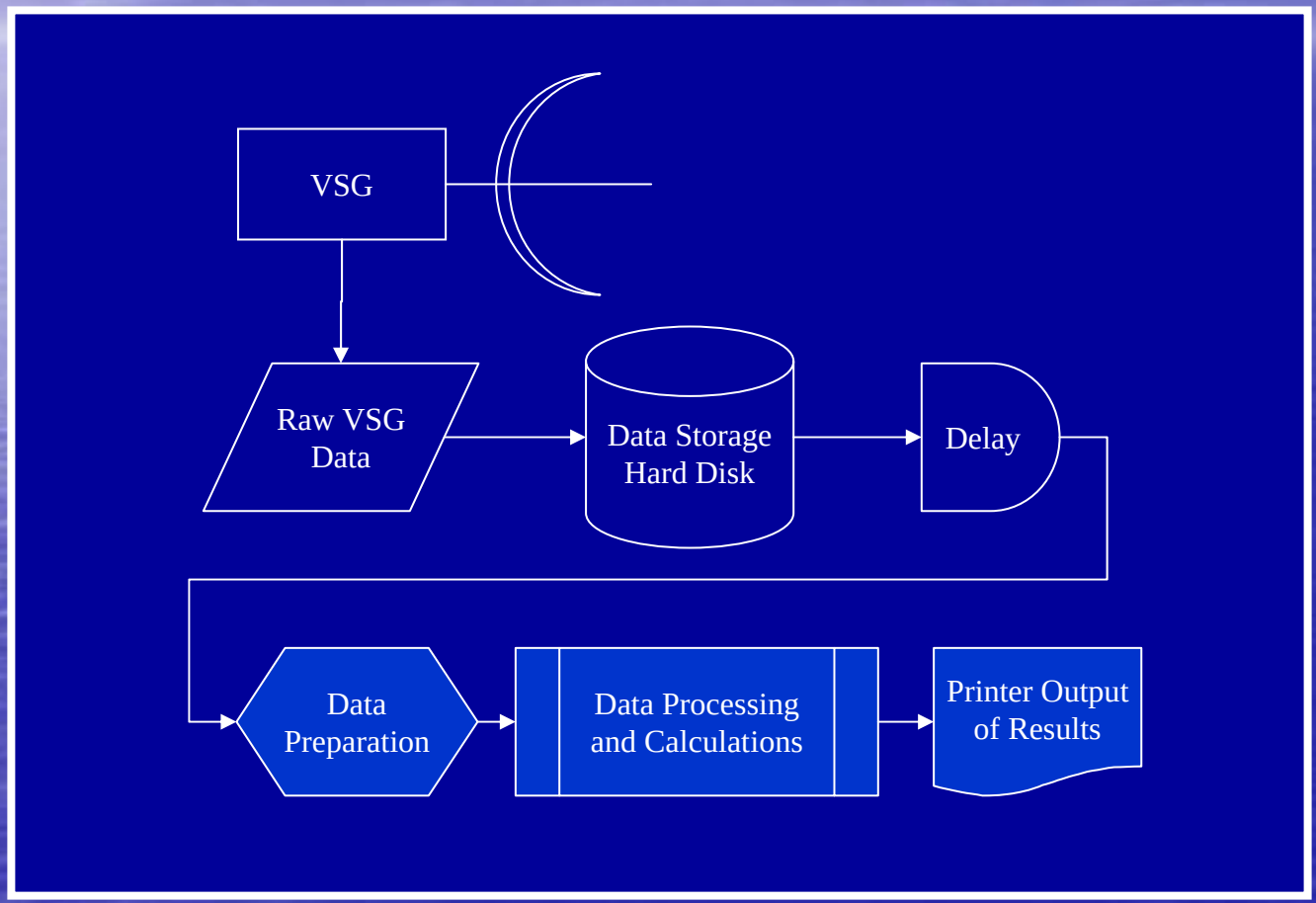
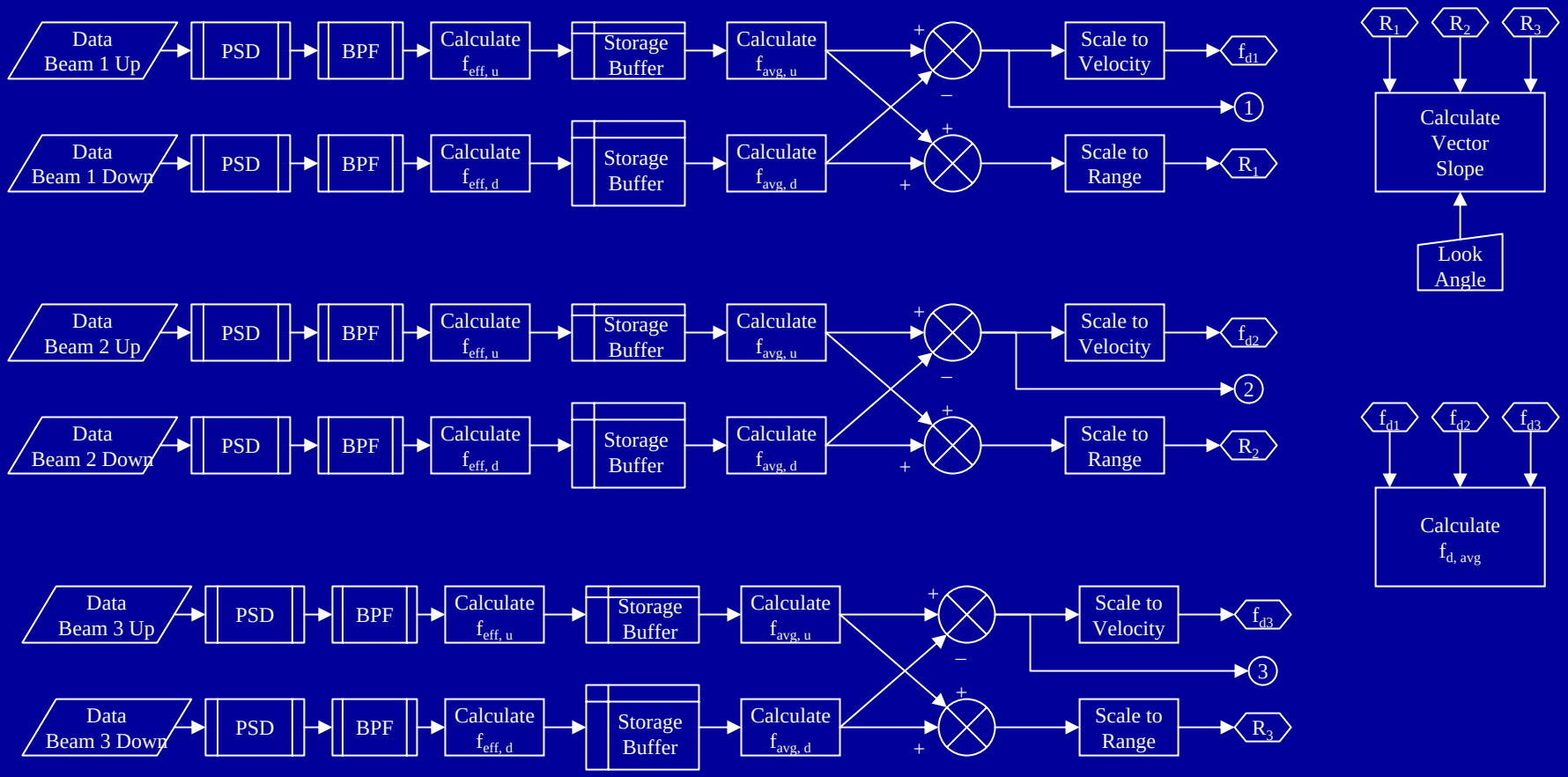
Off-line Processing

Current Vector Slope Gauge Concept

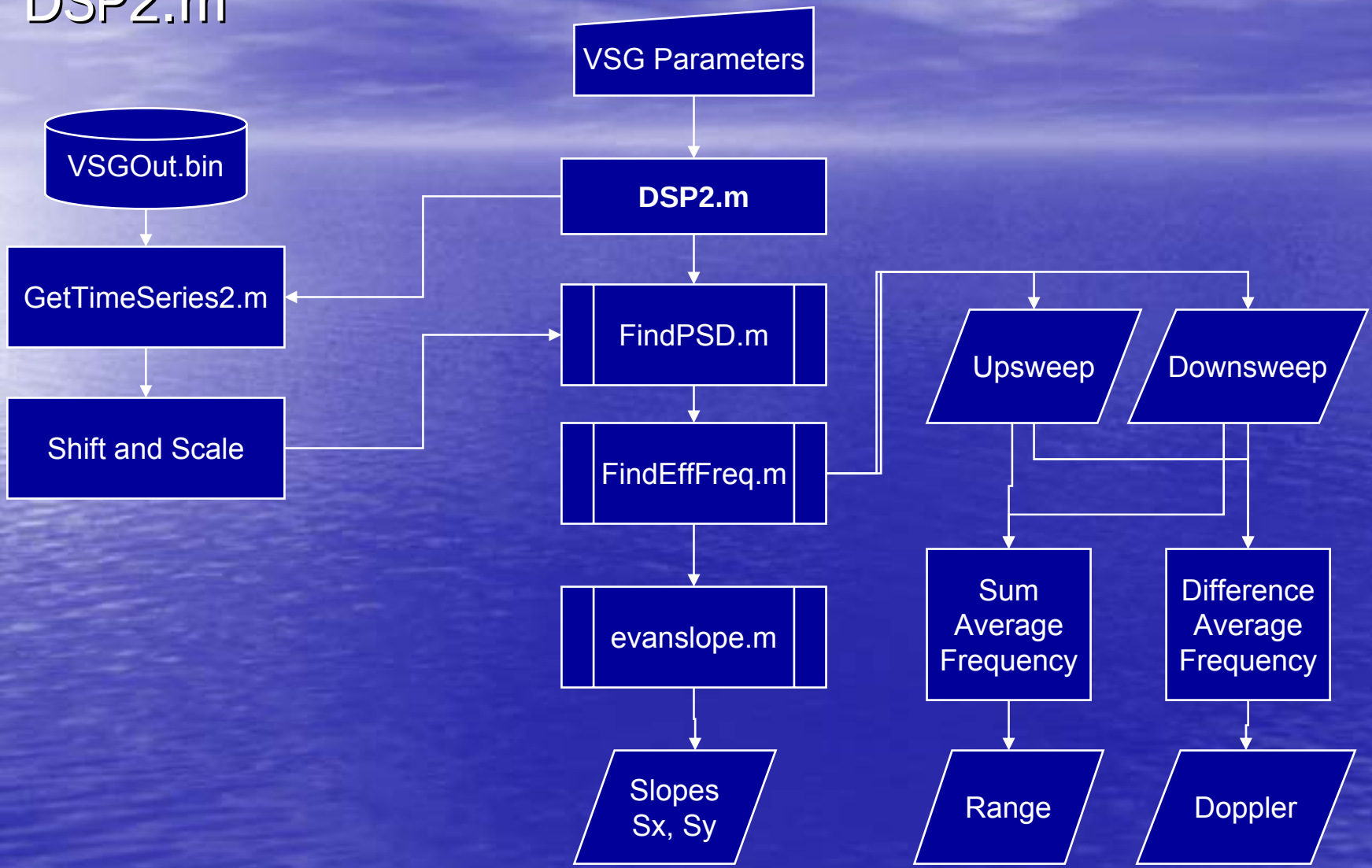


DSP Algorithm – Ocean Project



Adapted from DSP Algorithm for Ocean Radar Project, Gary W. Hamilton II

DSP of Stored Ocean Wave Data
DSP2.m



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Future Work

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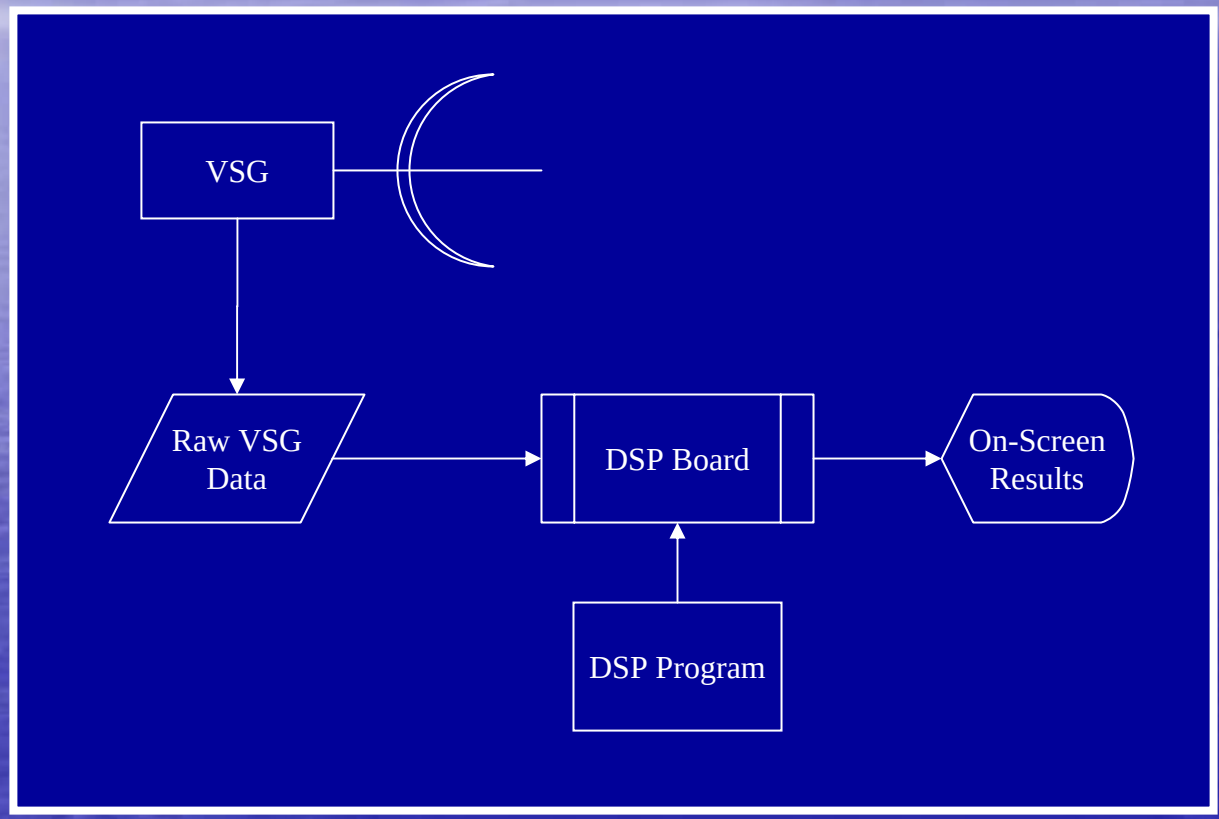
- Comparison to Duck Pier results
- Orbital velocity measurement
- Real-time DSP
- Adaptation to shipboard environment

Real-Time Vector Slope Gauge Concept



(Kampion, 1997)