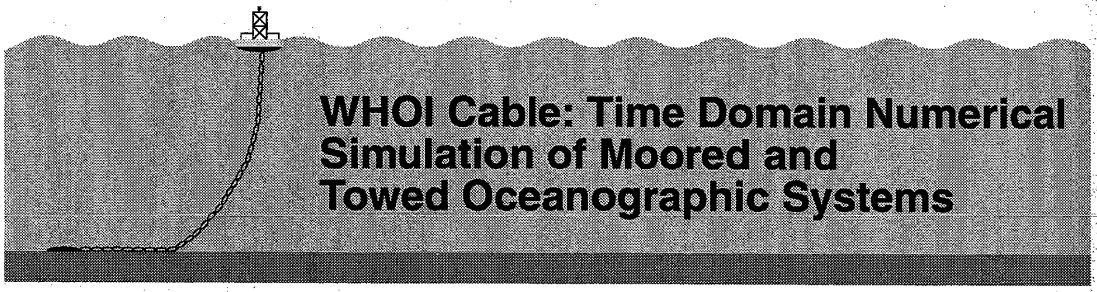
WHOI-97-15

Copy 2

# Woods Hole Oceanographic Institution



# WHOI Cable: Time Domain Numerical Simulation of Moored and Towed Oceanographic Systems

by

Jason I. Gobat, Mark A. Grosenbaugh, and Michael S. Triantafyllou

November, 1997

## Technical Report

Funding was provided by the Office of Naval Research under
Contract Nos. N00014-92-J-1269 and N00014-95-1-0106

Copyright ©1997 by Woods Hole Oceanographic Institution. All rights reserved.

DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

WHOI-97-15

# WHOI Cable: Time Domain Numerical Simulation of Moored and Towed Oceanographic Systems

by

Jason I. Gobat, Mark A. Grosenbaugh, and Michael S. Triantafyllou

Woods Hole Oceanographic Institution
Woods Hole, MA 02543

November, 1997

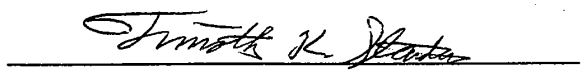
## Technical Report

Funding was provided by the Office of Naval Research through grants N00014-92-J-1269 and N00014-95-1-0106 and an Office of Naval Research Graduate Fellowship.

Reproduction in whole or in part is permitted for any purpose of the United States Government. This report should be cited as: Woods Hole Oceanographic Institution Technical Report WHOI-97-15.

Copyright ©1997 by Woods Hole Oceanographic Institution. All rights reserved.

**Approved for Distribution:**



**Timothy K. Stanton, Chairman**
Department of Applied Ocean Physics
and Engineering

DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

# Contents

**Foreword** **9**

About this Manual . . . . . 9

Acknowledgements . . . . . 9

Typographical Conventions . . . . . 10

**1 Introduction** **11**

1.1 Overview of problem types . . . . . 11

1.2 *WHOI Cable* mathematical features . . . . . 12

1.3 *WHOI Cable* implementation features . . . . . 12

**2 Mathematical and Numerical Theory** **13**

2.1 General numerical approach . . . . . 13

2.2 Numerical details of static problems . . . . . 15

2.2.1 Boundary conditions . . . . . 15

2.2.2 Initialization . . . . . 17

2.2.3 Coordinate integration . . . . . 18

2.2.4 Bottom interaction . . . . . 18

2.3 Numerical details of dynamic problems . . . . . 18

2.3.1 Wave forcing . . . . . 19

2.3.1.1 Wave followers . . . . . 19

2.3.1.2 Morison's equation . . . . . 19

2.3.1.3 Froude-Krylov forcing model . . . . . 20



DOCKET ALARM Find authenticated court documents without watermarks at docketalarm.com.

2.3.2 Coordinate integration . . . . . 20
2.3.3 Bottom interaction . . . . . 21
2.3.4 Dynamic pay-in and pay-out of cable . . . . . 21
2.4 Equations of motion . . . . . 22
2.4.1 Two-dimensional problems . . . . . 22
2.4.1.1 Static equations . . . . . 22
2.4.1.2 Dynamic equations . . . . . 23
2.4.2 Three-dimensional problems . . . . . 23
2.4.2.1 Static equations . . . . . 23
2.4.2.2 Dynamic equations . . . . . 24
2.5 Coordinate transformations . . . . . 26
2.5.1 Two-dimensional . . . . . 26
2.5.2 Three-dimensional . . . . . 27

**3 Structure of a *cable* Problem** **29**
3.1 Notation and coordinate systems . . . . . 29
3.2 Basic language features . . . . . 29
3.2.1 Expressions . . . . . 30
3.2.1.1 Continuous functions . . . . . 30
3.2.1.2 Discrete functions . . . . . 31
3.2.2 Units . . . . . 31
3.3 Components of an input file . . . . . 31
3.3.1 Problem description . . . . . 32
3.3.2 Analysis parameters . . . . . 32
3.3.3 Environmental parameters . . . . . 35
3.3.4 Cable, chain and rope materials . . . . . 37
3.3.5 Connectors . . . . . 38
3.3.6 Buoys . . . . . 39
3.3.7 Anchors . . . . . 40



DOCKET ALARM Find authenticated court documents without watermarks at docketalarm.com.

DOCKET ALARM

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

**LAW FIRMS**
Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

**FINANCIAL INSTITUTIONS**
Litigation and bankruptcy checks for companies and debtors.

**E-DISCOVERY AND LEGAL VENDORS**
Sync your system to PACER to automate legal marketing.