

ADVANCED TOPICS IN SCIENCE AND TECHNOLOGY IN CHINA

国家科学技术学术著作出版基金资助出版

Qihu Li

Digital Sonar Design in Underwater Acoustics

Principles and Applications



ZHEJIANG UNIVERSITY PRESS

浙江大学出版社



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**ADVANCED TOPICS
IN SCIENCE AND TECHNOLOGY IN CHINA**

ADVANCED TOPICS IN SCIENCE AND TECHNOLOGY IN CHINA

Zhejiang University is one of the leading universities in China. In Advanced Topics in Science and Technology in China, Zhejiang University Press and Springer jointly publish monographs by Chinese scholars and professors, as well as invited authors and editors from abroad who are outstanding experts and scholars in their fields. This series will be of interest to researchers, lecturers, and graduate students alike.

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*To my wife Xiaoping,
my children Hai and Ye,
my grandson Mike*

Preface

Sound wave is the only physical medium which can propagate over a long distance in the ocean. Other physical media, such as electromagnetic, optical or laser beams will quickly dissipate in the ocean because sea water is a good electrical conductor.

Sound navigation and ranging (Sonar) is a technique which is based on sound propagation to navigate, to communicate with or to detect other vessels. It is used extensively in ocean development and military applications.

Digital sonar is a sonar system that uses digital signal processing theory and techniques and that realizes system integration in a digital manner. Compared with the analogue processing of signal, digital processing has many advantages, as digital data are easy to store, transmit, and process.

With the rapid development of the semiconductor industry, digital chips have become more and more powerful and can now complete very complicated algorithms which were impossible to perform in the past. As a result, the performance of digital sonar has improved greatly.

The design of a modern digital sonar depends not only on the theory of underwater acoustic signal processing but also on our knowledge of the ocean environment, including ambient noise, the acoustic channel, the characteristics of the sea surface and sea floor, etc.

This book aims to describe the basic design principles of digital sonar and its applications. We have tried to focus our description on the basic theory and design techniques of modern digital sonar by stripping away all unimportant details.

Most theoretical results are illustrated with a practical example so that the reader should understand the application background of the basic theory.

I would like to emphasize that the best way of learning the theory of digital sonar design is to design a modern digital sonar for a particular application area. Experiments in lake or sea water are essential. I believe that experiments at sea provide some of the most important lessons for aspiring sonar designers.

The theoretical and experimental results described in this book include a wide

variety of contributions from my colleagues and graduate students at the Institute of Acoustics, Chinese Academy of Sciences. I would like to express my sincerely thanks to Dr. C.H. Zhang, J.B. Liu, B.X. Xie, B.L. Tu, X.P. Chen, T. Xu, C.Y. Sun, S.Q. Li, L. Yin, H.N. Huang, J.S. Tang, J.Y. Liu, J.D. Luan, G.Q. Sun, X.T. Yang, M. Li, H.B. Yu, G. Liu, L. Wang, X.H. Chen, C.H. Wei and L.P. Dong.

Any comments or criticisms about this book are most welcome.

Qihu Li
June, 2011

Abbreviations

A

A-RCI: Acoustic rapid COTS insertion
ABF: Adaptive beamforming
ADCAP: Advanced capability
ADS: Advanced Deployable System
ADSL: Asynchronous digital subscriber line
AEGIS: Air early guard integration system
AERONET: Aerosol Robotic Network
AGC: Automatic gain control
AIP: Air Independent Propulsion
AMFP: Adaptive matched field processing
ALE: Adaptive line enhancer
ANC: Adaptive noise canceling
ASDIC: Anti-submarine division-ics
ASK: Amplitude Shift Keying
ATM: Asynchronous transfer mode
ATOC: Acoustic thermometry of ocean climate
AUTEC: Atlantic undersea test and evaluation center

B

BATS: Bermuda Atlantic Time Series

C

C2: Command and control
C3: Command, control and communication
C4ISR: Command, control, communication and computer,
information, surveillance and recognition
CBF: Conventional beamforming
CDMA: Code division multiple access
CGS: Centimeter Gram Second
CORDIC: Coordinate rotation digital computer
COTS: Commercial off the shelf

CSDM: Cross spectral density matrix

D

DARPA: Defense advanced research project agency

DCT: Discrete Cosine Transform

DDS: Diver detection sonar

DEOS: Dynamics of Earth and Ocean System

DELTIC: Delay Line Time Compressor

DEMON: Demodulation on noise

DFT: Discrete Fourier transforms

DICANNE: Digital Interference Canceling Adaptive Network Nulling Equipment

DICASS: Directional command-activated sonobuoy system

DIFAR: Directional frequency analysis and ranging

DIMUS: Digital multi-beam system

DOA: Direction of arrival

DoD: Department of defense

DOFIX: Doppler fixing

DRAM: Dynamic random access memory

DWDM: Dense Wave Division Multiplexing

DS: Direct sequence

DSP: Digital signal processing, Digital Signal processor

DWDM: Dense wave division multiplexing

E

E3: Effective, Engagement, Envelope

ENIAC: Electronic Numerical Integrator and Calculator

ESONET: European sea floor observatory network

ESPRIT: Estimation of signal parameters via rotational invariant techniques

EVM: Evaluation module

F

FDDI: Fiber distributed data interface

FDS: Fixed Distributed System

FFT: Fast Fourier Transform

FH: Frequency hopper

FIR: Finite Impulse Response

FM: Frequency modulation

FOM: Figure of Merit

FRONT: Front resolving observatory network with telemetry

FSK: Frequency shift keying

FSS: Fixed Surveillance System

G

GOOS: Global ocean observatory system

GPS: Global positioning system

GSC: Grey scale conversion
GSS: Generic sonar simulator

H

H2O: Hawaii-2 observatory
HCI: Human computer interface
HMS: Hull mounted sonar

I

IBF: Inverse beamforming
IDFT: Inverse discrete Fourier transform
IDS: Intrude detection sonar
IFS: Iterated Function System
IIR: Infinite Impulse Response
IP: Internet protocol
ISDN: Integrated service digital network
IT-21: Information technology for the 21th century Initiative
IUSS: Integrated Undersea Surveillance System

J

JAMSTEC: Japan marine science & technology center
JPEG: Joint Photographic Experts Group
JV 2010: Joint vision 2010

L

LAN: Local area network
LOFAR: Low frequency analysis record
LOFIX: LOFAR Fixing

M

MAP: Maximum a posterior probability
MARS: Monterey accelerated research system
MBP: Model based processing
MDW: Mass destruction weapon
MFLOPS: Million Floating-Point Operations Per Second
MFP: Matched field processing
MIPS: Mega Instruction Per Second
MIUW: Mobile in-shore undersea warfare
MOPS: Mega Operation Per Second
MPEG: Moving Pictures Experts Group
MQPSK: Modified quadric-phase shift keying
MSE: Minimum mean square error
MTBCF: Mean Time Between Critical Failure
MTBF: Mean Time Between Failures
MTTF: Mean Time to Failure

MTTR: Mean Time to Repair
MUSIC: Multiple signal classification

N

NEPTUNE: North east Pacific time series undersea network experiments
NATO: North Atlantic Treaty Organization
NCOIC: Network Center Operation Industry Consortium
NCSL: Naval Coastal System Laboratory
NCW: Network Centric Warfare
NOPP: National oceanographic partnership program
NUWC: Navy underwater warfare center
NURC: NATO Undersea Research Center

O

ODN: Own Doppler null
OFDM: Orthogonal frequency division multiplexing
ONR: Office of naval research
ORBIS: Object-oriental rule based interactive system
OTA: Order truncate average

P

PCI: Personal Computer Interface
PDM: Pulse duration modulation
PFA: Passive Fixed Array
PLL: Phase lock loop
PRS: Passive ranging sonar
PSK: Phase Shift Keying
PVDF: Polyvinylidene fluoride

Q

QoS: Quality of service
QPSK: Quadrature phase shift keying

R

ROC: Receiver operating curve

S

SABSOON: South Atlantic Bight Synoptic offshore observatory
SAS: Synthetic Aperture Sonar
SDS: Swimmer detection sonar
FRONT: Front-Resolving Observational Network with Telemetry
SHARC: Super Harvard architecture
SNR: Signal-to-noise ratio
SOFAR: Sound frequency and ranging channel
Sonar: Sound navigation and ranging

SONET: Synchronous optical network
 SOSS: Soviet Ocean Surveillance System
 SOSUS: Sound Surveillance Sonar
 SPAWAR: Space and naval warfare systems center
 SRAM: Static random access memory
 SSBN: Nuclear ballistic missile submarine
 SSN: Nuclear attack submarine
 SSP: Sound speed profile
 STDV: System technology demonstration vehicle
 STFT: Short Time Fourier Transform
 SURTASS: Surveillance Towed Array Sensor System
 SVP: Sound velocity profile
 SWATH: Small water area twin hull

T

TAGOS: Tactical Auxiliary General Ocean Surveillance
 TALON: Tactical acoustic littoral ocean network
 TCP/IP: Transmission control protocol/Internet protocol
 TDMA: Time division multiple access
 TMA: Target moving analysis
 TOGA: Tropical ocean and the global atmosphere
 TRM: Time reversal mirror
 TVG: Time Varying Gain

U

UDT: Underwater defense technology
 UUV: Unmanned undersea vehicle
 UUVI: Unmanned undersea vehicle initiative

V

VDS: Variable depth sonar
 VENUS: Victoria experimental network under the sea
 VIM: Vibration isolate module
 Virtual Collaboration
 VME: Versa Module Europe
 VTC: Video teleconference

W

WAA: Wide Aperture Array
 WHOI: Woods hole oceanographic institute
 WOCE: World ocean circulation experiment
 WTD: Wehrternisshe Dienststelle

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