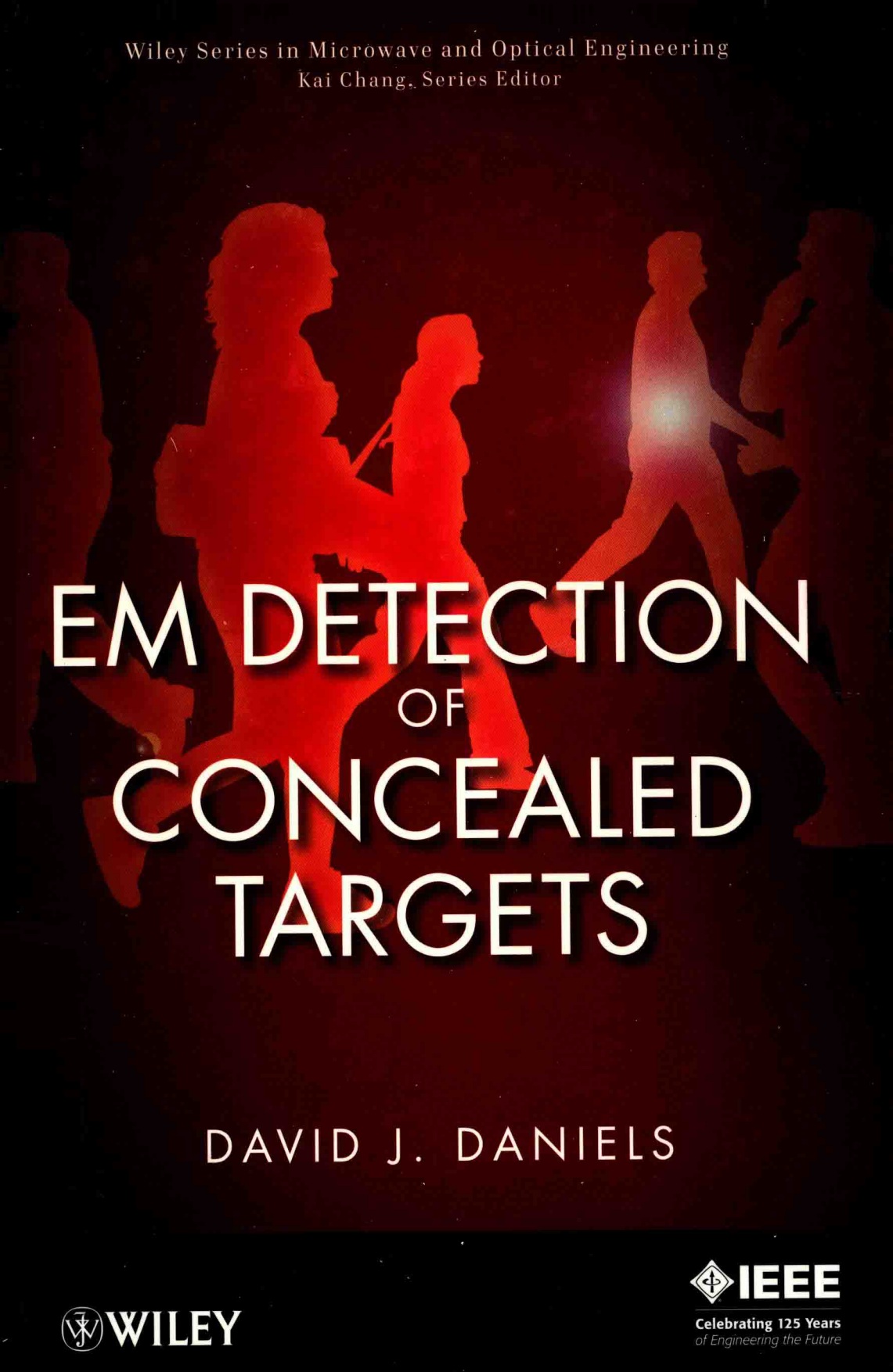


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The background of the cover features red silhouettes of several people walking from left to right. The silhouettes are semi-transparent, allowing the text to be visible through them. The overall color scheme is dark red and black.

EM DETECTION OF CONCEALED TARGETS

DAVID J. DANIELS

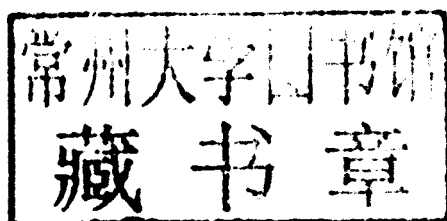
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EM Detection of Concealed Targets

DAVID J. DANIELS



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EM Detection of Concealed Targets

Preface

The subject matter of this book is the radio-frequency (RF), millimetre-wave, microwave, and terahertz detection of concealed targets. It is intended for those interested in the development and application of such techniques and equipment. The application is of significant importance in view of the threat posed by suicide bombers and criminals in relation to weapons, explosives, and narcotics as well as human trafficking. In addition, the detection of targets buried in the ground is relevant, and the applications can range from the detection of buried land mines and improvised explosive devices to humans buried in avalanches or earthquakes to hostiles behind walls. The main aim of this book is to bring together in one volume the core information on a variety of electromagnetic techniques that are useful in detecting such concealed targets. While much of the information is available in a range of different publications, it is dispersed and therefore less accessible by virtue of the disparate nature of many of the sources. Baum [1] treated the topic with an emphasis on the identification of targets by means of the analysis of target resonances and scattering behavior with an emphasis on the lower RF frequencies. The author describes the detection of buried objects using ground-penetrating techniques in Daniels [2] and is grateful to the Institute of Engineering and Technology (IET) for permission to use material from this reference to describe both the physics of propagation in soils as well as antenna designs in this volume. Astanin and Kostylev [3] consider the subject from the view of ultra-wideband radar; however, their treatment is more applicable to operation at frequencies up to a few tens of gigahertz.

The targets of interest may be targets buried in the ground, concealed in building structures, hidden under clothing or within luggage, or may be stowaways in vehicles, as well as victims of avalanches or earthquakes. A variety of techniques may be used to examine potential targets or target areas. Well-established techniques such as ionizing radiation (X rays), vapor

detection, optical techniques, and thermal imaging are readily available and in day-to-day use in airports and for maintaining security. However, they all have limitations such as range, penetration, specificity; so there is a role for RF and microwave/millimeter, and submillimeter-wave electromagnetic techniques for the detection of concealed targets can offer performance in the areas where conventional techniques struggle. Conversely, electromagnetic (EM) techniques have limitations that, for example, preclude their use for detecting objects concealed in metallic containers, submerged in saltwater, or in highly cluttered situations. The emphasis of the book is in developing an understanding of the factors that influence system performance and has been written from the perspective of the equipment designer to aid in understanding where such techniques can be applied successfully.

This book covers the following topics; radar systems and, in particular, ultra-wideband radar, ground-penetrating radar, millimeter, submillimeter, and terahertz imaging, and nonimaging systems, Doppler radar systems as well as radiometric systems, and nuclear quadrupole resonance systems. The key elements of the subject of electromagnetic techniques for the detection of concealed targets are considered, and in general terms the interrelationship between those topics in electromagnetism, system design, and signal processing that define system performance.

A further aim of this book is to provide an introduction for the newcomer to the field, as well as a useful source of further reading, information, and references for the current practitioner. By necessity, this book provides a snapshot of the field, and it is to be expected that further developments in hardware and signal-processing techniques will incrementally improve the performance and extent of applications. Note that the symbols i and j are both used for the complex operator.

The author has been involved with the design and application of the techniques associated with the detection of concealed targets and has developed equipment to meet many of the applications. Successful development and application is achieved from a sound understanding of the basic physics coupled with a realistic assessment of the technology. Satisfactory performance of the latter is achieved by close attention to the details of system design and engineering. The significant advances in device performance at microwave and millimeter wavelengths that have been achieved in the last decade has enormously benefited the development of sensors, and the designer has a wealth of choice in terms of component technology. This can only help to enable the end user to detect targets that were once invisible.

Acknowledgments

I am extremely grateful to many colleagues who provided much useful information, advice, and especially to those who assisted with reviewing the material in the preparatory stages. Professor John Smith from King's College, London, provided invaluable assistance with the chapter on nuclear quadrupole resonance, and my thanks are due to Dr. Tim Rayner from Rapiscan as well as Nigel Hunt from ERA Technology who kindly reviewed the material in that chapter. My thanks also go to Professor Steve Nightingale from ERA Technology who reviewed the material in the chapter on millimeter-wave systems and techniques and to Dr. Mike Phillipakis from ERA Technology who kindly reviewed the material on the chapter on antennas. My thanks also to Professor Hugh Griffiths of University College, London, who kindly reviewed the manuscript and whose suggestions greatly aided the readability of the book.

I would also like to pay tribute to the scientific and engineering expertise and support of my colleagues at ERA Technology who have enabled many of the sensors and designs to be built and tested over the last decade. My special thanks to Nigel Hunt who designed and developed many of the NQR and radar subsystems, to Paul Curtis for the development of the MINEHOUND™ time-domain radar system for land-mine detection, to Dr. Jon Dittmer for his input on signal-processing techniques on GPR systems, and to Blair Graham for his contribution to trials in some very interesting parts of the world.

I am also most grateful to Lisa Reading of the IET for permission to use material previously published in my earlier book on ground-penetrating radar. This material has been revised and updated for the current book.

My thanks to Lucy Hitz at John Wiley for her patience while the manuscript was being written.

This book is dedicated to all the inventive engineers and scientists whose efforts make the concealed visible and help develop techniques and equipment

to rescue the trapped or expose the threats that terrorists would conceal from our vigilance.

Finally, I would thank my wife Jenny for her patience and support while the manuscript was being written. Domestic life can get back to normal now this project is completed.

List of Frequently used Acronyms

ADC	analog-to-digital converter
AM	amplitude modulation
AN	ammonium nitrate
ANSI	American National Standards Institute
ASIC	application-specific integrated circuits
AT	Anti-Tank
AUT	antenna under test
BRCS	bistatic radar cross section
BW	beamwidth
DAC	digital-to-analog converter
DARPA	Defense Advanced Research Projects Agency
dc	direct current
DDS	direct digital synthesis
DGPS	differential Global Positioning System
DMA	dynamic memory allocation
DSP	digital signal processor
EFG	electric field gradient
ELF	extremely low frequency
EM	electromagnetic
EMC	electromagnetic compatibility
EMF	electromagnetic fields

ETSI	European Telecommunications Standards Institute
EU	European Union
FAR	false alarm rate
FCC	Federal Communications Commission
FFT	fast Fourier transform
FID	free induction decay
FMCW	frequency-modulated continuous wave
FN	false negative
FP	false positive
FPGA	field-programmable gate array
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GTD	geometric theory of diffraction
HMX	tetrahexamine tetranitramine
HPA	Health Protection Agency
HPBW	half-power beam width
HTS	high-temperature superconductor
ICNRP	International Commission on Non-Ionizing Radiation Protection
IED	Improvised explosive device
IEE	Institution of Electrical Engineers
IEEE	Institute of Electrical and Electronic Engineers
IET	Institute of Engineering and Technology
IF	intermediate frequency
ILDC	incremental length diffraction coefficient
INS	inertial navigation system
IR	infrared
IRA	impulse radiating antenna
ITU	International Telecommunication Union
LBRTM	Line-by-Line Radiative Transfer Model
LHCP	left-hand circular polarization
LIDAR	light detection and ranging
LNA	low-noise amplifier
LO	local oscillator

MoM	method of moments
MTI	moving target indication
NIR	non-ionizing radiation
NM	noise modulation
NMR	nuclear magnetic resonance
NQR	nuclear quadrupole resonance
NRPB	National Radiological Protection Board
NTIA	National Telecommunications and Information Administration
OSHA	Occupational Safety and Health Administration
PAPS	phase-alternated multiple-pulse sequence
PD	probability of detection
PETN	Pentaerythritol tetranitrate
PFA	probability of false alarm
PLL	phase lock loop
PPI	Plan position indicator
PRC	pseudo-random coded
PSL	pulsed spin locking
PTD	physical theory of diffraction
RAM	radar-absorbing material
RCS	radar cross section
RDX	cyclotrimethylenetrinitramine
RF	radio frequency
RFI	radio-frequency interference
RHCP	right-hand circular polarization
ROC	receiver operating characteristic
RPD	Radiation Protection Division
SAR	Specific Absorption Rate
SFCW	stepped frequency continuous wave
SLSE	spin-locked spin echo
SNR	signal-to-noise ratio
TD	time domain
TEM	transverse electromagnetic
TN	true negative

TNT	trinitrotoluene
TP	true positive
TPR	total power radiometer
TR	transmit–receive
UV	ultraviolet
UWB	ultra-wideband
VCO	voltage-controlled oscillator
VSWR	voltage standing-wave ratio
WKB	Wentzel–Kramers–Brillouin

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