Infrared Design Examples

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SERIES INTRODUCTION

The Tutorial Texts series was begun in response to requests for copies of SPIE short course notes by those who were not able to attend a course. By policy the notes are the property of the instructors and are not available for sale. Since short course notes are intended only to guide the discussion, supplement the presentation, and relieve the lecturer of generating complicated graphics on the spot, they cannot substitute for a text. As one who has evaluated many sets of course notes for possible use in this series, I have found that material unsupported by the lecture is not very useful. The notes provide more frustration than illumination.

What the Tutorial Texts series does is to fill in the gaps, establish the continuity, and clarify the arguments that can only be glimpsed in the notes. When topics are evaluated for this series, the paramount concern in determining whether to proceed with the project is whether it effectively addresses the basic concepts of the topic. Each manuscript is reviewed at the initial state when the material is in the form of notes and then later at the final draft. Always, the text is evaluated to ensure that it presents sufficient theory to build a basic understanding and then uses this understanding to give the reader a practical working knowledge of the topic. References are included as an essential part of each text for the reader requiring more in-depth study.

One advantage of the Tutorial Texts series is our ability to cover new fields as they are developing. In fields such as sensor fusion, morphological image processing, and digital compression techniques, the textbooks on these topics were limited or unavailable. Since 1989 the Tutorial Texts have provided an introduction to those seeking to understand these and other equally exciting technologies. We have expanded the series beyond topics covered by the short course program to encompass contributions from experts in their field who can write with authority and clarity at an introductory level. The emphasis is always on the tutorial nature of the text. It is my hope that over the next few years there will be as many additional titles with the quality and breadth of the first ten years.

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PREFACE

This text is an extension of my earlier book, *Introduction to Infrared System Design*,[1] in which materials, detectors, optics, scanners, and sensitivity calculations were introduced. This text builds on the principles and information presented in the earlier work and addresses several problems in detail. Most of the problems are real, or closely resemble actual problems.

The MX Shell Game was proposed to me some years ago when the people who were considering housing the Peacekeeper wanted to know if the position of the vehicle could be detected by the "Red Team." I have altered it slightly to illustrate the principles of designing a demanding strip mapper. The final sections of Chapter 2 discuss less-demanding applications, some of which have been implemented. The Space Campout is a whimsical design of an instrument that detects ICBMs in midcourse. It illustrates principles that I have applied in addressing many varied design problems over the years.

The third problem, the night driving system, I first tackled at Honeywell for tanks, and most recently at General Motors for civilian cars. I never really looked at the BOSS, but my imagination was piqued by Tom Clancy's book,[2] and I considered the design of an infrared detection system that could track surface vessels on the oceans of the world in place of Clancy's radar surveillance device, the RORSAT. Again, similar problems exist in the scientific and corporate milieus. The collision avoidance system for airplanes was considered in the 80s for civilian applications, and it exists in the military as tail-warning systems that protect the aircraft from behind from a variety of missiles and aircraft attacks. The helicopter pilot system (described briefly in Chapter 5) was carried out for McDonnell Douglas in Mesa. The design presented here is mine, not necessarily the one chosen by them or the Army. It is a nice example of how vision and display considerations can, and should, determine many aspects of the design.

The applications are military, industrial, aeronautical, space, medical, and even piscatorial. Almost every military application has a civilian counterpart and *vice versa*. The applications are driven by different requirements, including high probability of detection, speed, cost, and size. They employ photon and thermal detectors, starers and scanners, pushbrooms and whiskbrooms, the midwave and longwave spectral bands, automobiles, satellites, airplanes, and ears.

I have not dealt with spectrometers, LIDARS, other active systems, or pollution monitoring. Maybe next time.

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[1]W. L. Wolfe, *Introduction to Infrared System Design,* SPIE Press (1996).

[2]T. Clancy, *Red Storm Rising*, Putnam and Sons (1986).

I wrote this text in a personal way, because I dealt with these problems personally. I chose a range of problems that illustrate most of the design issues encountered in the field of infrared technology.

Each problem is discussed in almost a stream-of-consciousness genre, and that is intentional. I have tried to solve each problem as an engineer would. The classical techniques of many texts, in which an inexorable and direct approach to the proper solution is described, has not been used here. I don't think I have ever made all the right decisions at every step of the way in any design—or most other aspects of my life!

The design process outlined in Chapter 2 works in almost all cases. However, infrared design is something of an art based on experience. Just as a cheetah goes for the jugular, the experienced infrared-system designer must recognize at the outset the critical aspects of the design. This means that, although I have outlined a rational sequential procedure, there are times when one must jump around. The plodder will get there, but maybe only after a good deal of unnecessary effort. It is better to be smart and lazy. And it is even better to be lucky!

Every one of these systems involves electronics and mechanics. Details of these and other required, related disciplines have not been included so that the time and space could be used for the infrared aspects of the problems.

I chose an unorthodox approach in the presentation of the equations; they are Mathcad printouts. Many of the figures have a combination of these equations and plots of the data for some domain of an independent variable. For those who are not conversant with Mathcad, I have described the equations line by line, and repeated them in the body of the text. To minimize repetition, I assumed that the reader will become familiar with the presentation and I became much briefer. For those who are not conversant, I recommend starting with the MX shell game; it has the most detailed explanations of the Mathcad formalism.

To set a value for a variable, say, for example, the speed of light, the format is $c:=2.9975x10^{10}$. The colon followed by the equals sign indicates a setting. The same is true for an equation f:=m*a. The asterisk signifies multiplication. When only an equals sign is used, then a value has been calculated: v=7.4. The domain of an independent variable is set with the first value, a comma, the next value, a semicolon, and the last value: t:=1,2;50. Dependent variables must have their associated independent variables in parentheses: v(t):=s/t. Both the independent and the dependent variables are included on the axes of graphs. Experienced users will recognize that there are many features of Mathcad that I have not employed for the sake of simplicity. One of these is the incorporation of units with the variables as something of a sanity check.

I would like to again acknowledge the editorial acumen of Don O'Shea, who provided many useful comments, as he did on my earlier Tutorial Texts. Bjorn Andresen carefully read and made many worthwhile and perspicacious corrections. A debt is owed to an anonymous reviewer, Bob Fischer, who also contributed

valuable comments. My wife suffered me and wondered about the time I spent in front of the computer—but now she has one too. I may try another text. I hope these examples and the style in which they are presented are useful to the reader.

I dedicate this text to those who went before me and affected my career—Stan Ballard, Luc Biberman—mentors both; Kiyo Tomiyasu, Lloyd Mundie, Gwynn Suits, George Zissis, Mike Holter, Bob Rynearson, Aden Meinel, Peter Franken, Bob Shannon, and Dick Powell—bosses all. And all are—or were—friends.

William L. Wolfe
July 1999