Radar System Analysis and Modeling

David K. Barton
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During the past four or five years we have been told by the media, particularly through television channels, that military technology is declining; we should not waste our money in developing new weapon systems, and that the former threats posed by unforeseen major international conflicts have passed away. It is far beyond the competence of this reviewer (or the review itself) to figure out if such argumentation is really valid, but regardless, we have seen that at least radar issues are still a topic of continuously increasing scientific and tactical discussion. Naturally, this is at least partly due to the obvious challenges and possibilities created by the anti-terrorist actions but also the civilian applications of radar systems and devices are all the time increasing. As more affordable components and modules have appeared on the commercial market and higher carrier frequencies become feasible, previously rejected radar-like projects (for example in the process industry or in robotic automation) have been scooped up from the files. As our readers may have observed, the interest in radar has been reflected in the publication sector, too. 2003 and 2004 saw more than twenty international items relevant to this topical area and the trend seems to continue, so a reviewer has plenty to choose from. However, when rumors about a soon-to-come upgraded version of David Barton's ***Radar System Analysis*** reached this reviewer's ears sometime during last summer, certain re-arrangements of personal reading schedules became mandatory and slight excitement was in the air. It was already a moment of certain embarrassment when, in 2004, a friendly letter – triggered by one not-too-accurate book review – signed by M.I. Skolnik arrived. *What was now to come from one of the remaining founders of our current radar knowledge How can one review a book based on such long and wide experience?*

Here I have it in my hands, just from the publishers' rotary press, ***Radar System Analysis and Modeling,*** authored by David K. Barton and published by Artech House officially in 2005 (although it is December 2004 at the moment of writing). The book has 545 pages plus a CD-ROM. After the *Preface,* there are nine main chapters, a list of index items containing about 1000 words for searching, a *List of Symbols,* and a *List of Acronyms.* Every chapter has its own list of references, the total number of which in the entire book is about 168. The engineering-type approach favors graphs and illustrations (total number approximately 260) but there are also 569 equations that do not require complicated mathematical processing from the reader's side. Actually, most of the key expressions are available as ready-to-use code on the CD, which has about 100 solution tools for various radar evaluation tasks. Classroom use is supported by 95 problems, roughly 10 in each individual chapter.

Chapter 1 discusses the fundamental radar range equation in different environments and for various applications, particularly for search radar and if intentional jamming or clutter are to be regarded as the main limiting factors. Next, Chapter 2 is about target detection. Here, we read typical factors related to the processing of pulse trains, fluctuating targets, and get a basic treatment of constant false alarm rate or CFAR. Chapter 3 is entitled: *"Targets and Interference."* It contains a treatment of radar cross section in general, that of expected targets, and, finally, clutter. A very brief section of jamming issues is included as well. About fifty pages are devoted to radar antennas in Chapter 4. The main topics are radar antenna basics, arrays, ultra-low-sidelobe antennas, and multiple-beam constructions. Radar signal processing has been given another fifty pages in Chapter 5. There are three main areas of interest, namely, pulse compression, moving target indicator (MTI), and pulse Doppler. Chapter 6 is a condensed treatment of radar wave propagation and focuses on attenuation, diffraction, and refraction. Chapters 7, 8 and 9 are very much system-oriented. Radar surveillance is discussed in Chapter 7, with an emphasis on 2-D and 3-D processes and various physical realizations suitable for such tasks either in ground-based or maritime equipment. Some jamming-related material has been added here as well. Radar-based tracking and measurement is the field of Chapter 8, which naturally implies such items as angular and distance errors, speed measurement, and tracking challenges during hostile jamming. The final chapter gives a systematic way to handle the radar loss budget, logically assembled from the individual elements involved. Some typical examples of pre-computer losses are given, too. The associated CD contains radar system analysis tools in Mathcad® II environment. The total number of such files is about 100 and for users of other computation engines HTML-versions are given as well. The tools cover

detectability computation, RCS and clutter, MTI and Doppler, coverage and power computation for surveillance radars, tracking errors, and loss budget estimation.

Very many, if not almost all of our readers have long ago come to know the author, David K. Barton, as a respected specialist in the field of radar systems. His scientific journal articles and particularly the books such as: ***Radar System Analysis*** (1964), ***Radar Technology Encyclopedia*** (1999), ***Handbook of Radar Measurement*** (1969 and 1984), ***Radars*** (several volumes, 1978), ***Modern Radar System Analysis*** (1988) and ***Modern Radar Systems Analysis Software*** (1993) are frequently used by our radar community as authoritative references and sources of essential fundamentals. At present, Barton is a radar system consultant in New Hampshire, USA. He was born in Greenwich, Connecticut in 1927 and studied at Harvard from 1944 to 1949, but worked for two years in the US Army White Sands Test Range in-between. After completing his studies in physics, Mr. Barton returned to White Sands and moved from there to Fort Monmouth in 1953 to trigger the development of the first true monopulse measuring radar for the Signal Corps. In US military jargon, the device was given the code AN/FPS-16. As we understand it, Mr. Barton moved already in 1955 to RCA where he continued this development and participated in the field trials as well. A couple of years later he was given the first David Sarnoff Medal for Outstanding Achievement in Engineering based on this particular project. In 1960, Barton and his team fielded the design as the AN/FPS-49, which was a key component in the Ballistic Missile Early Warning System for 40 years – both in Alaska and in Great Britain. After this task was successfully completed, he joined Raytheon, where his role in the design of the US Air Force radar landing system, called AN/TPS-19 was vital. Besides this, he was involved during those twenty years in a number of other radar and guided missile studies. From 1984 to 2004, he worked at ANRO Engineering in the field of radar systems.

Mr. Barton is an IEEE Fellow since 1972 and was elected to the National Academy of Engineering in 1997. He was given the IEEE Dennis Picard Medal for Radar Technologies and Applications in 2002. We can easily guess his impact in such bodies and institutions as the scientific advisory board of the US Air Force, the US Defense Intelligence Agency, and the Army Research Laboratories. Artech House, the publisher of his books, has also already in 1975 selected Mr. Barton as their Radar Library Editor. That series of valuable books today contains about 140 titles.

After going through the contents and author data, we now proceed to the more difficult analytical part of this review. It might have been possible to perform some comparison between this book and its earlier versions or forefathers, dating back to 1964. I made a conscious decision not to do this. Instead, let's look at the entity as it is now. Very apparently, the author has at least partly wanted to create an educational tool, because every chapter contains a number of problems to be solved by students (there are even answers and solutions available). The second target audience must be somewhere among radar system engineers, as there is so much in-depth material about various challenges in real-life radar work and detailed examples of completed practical radar projects. Very different items are included, covering wave propagation, digital signal processing, target and platform kinematics, and so on. Indeed, we can speak about a true system-level book.

When trying to take a newcomer's attitude (which is not difficult at all – Barton was designing radars well before I was born), I feel happy with the book's easy approach.

- First, we seldom see experienced engineering authors who *want* and *can* select their writing style in this friendly way. Even if I had never before heard about MTI or clutter, reading through Mr. Barton's chapters readily gives efficient ways to proceed.

- Second, the problems have clearly been thought through before printing, because solutions exist. As our readers may have found out, it is not so rare in many other academic textbooks to have unsolvable student problems creating despair and amusement in the classroom. Rookies may find the detailed List of Symbols very attractive, because it also has a cross-referencing feature whereby readers can find the place in the book where that mysterious letter or subscript first pops up.

Changing my student cap to the warmer and more conservative project manager's clothing, my point-of-view must be adjusted accordingly. If I have been working for some time in the radar business (as is the case), much of the individual topics look pretty familiar (as they should) – there is not that much new available. However, the entire compilation makes sense, because a working radar engineer can search for many professional refreshing items from this one book, instead of having half a dozen volumes on his desk. Besides, a professional can readily use the provided pieces of software on the system level. The entire treatment, that is – the written book and the software examples – is strong in the areas of detection and signal processing, and in the evaluation of surveillance and tracking concepts.

Although I might now be pushed down from the cliff, I want to say some words of criticism as well. A minor detail is the fact that a number of illustrations are simply smudged photocopies from earlier publications. The reason to this is hard to accept, because, at times, readability is really marginal. The majority of graphics though is crisp and clear and gives true additional value to the text. Knowing the author's very long experience in the field of radar and the fact that many basic aspects stay as they once were, it is understandable that a considerable amount of the references in ***Radar System Analysis and Modeling*** dates back to 1970s, 1960s and even 1950s. A rapid counting action indicates that more than 90 out of the 164 references have first appeared before 1980. On the

other hand, as the number of international conferences close to radar topics and the number of journal articles discussing radar has been high throughout the decades, one might assume that some new details have come up. The reader may expect that a distinguished author has included such knowledge in the text, but it is not readily visible in the list of *References*. In some cases, a relatively fresh-looking reference might be misleading as well. For example, in Chapter 3 about targets and interference, the author has listed Shirman's book ***Computer Simulation of Aerial Target Scattering, Recognition, Detection and Tracking*** published by Artech House in 2002 as a reference. Having that book on my desk, I made a random check which suggests that most of the data in Shirman's fine book has initially been available in Russian in the 1960-1970 era. Especially those areas of radar design where the advance in semiconductor technology may or may not have had substantial effect should be considered carefully. For example, when the author uses a graph from 1982 as typical oscillator noise sideband data in Chapter 5, a cautious reader might wonder if more recent oscillator concepts show different performance characteristics. A digital receiver beam-forming block example from 1978 or a T/R module from 1977 could also cause discussion, despite the fact that procedures may have been quite stable since those days.

Another difficulty has been caused by the very wide scope the author covered in his book. First, the book's title suggests a thorough treatment of all radar concepts – an impossibility in itself. In reality, the book's focus is in pulse Doppler radars for the surveillance and tracking of airborne targets, preferably hundreds of miles away. Other users, such as maritime or battlefield units, are briefly explained but without much enthusiasm. Already in the initial definitions in Table 1.3 of this book only military use of radar is expected. That might not be so severe unless due to this millimeter frequencies (the main band for collision avoidance radars in cars and for industrial robotics) have practically been excluded from the remaining discussions. The same unbalanced nature is found on the lower levels of hierarchy. Chapter 4 does not contain so much engineering information about reflector antennas, as one might assume, and even in the References, there is, in fact, only one related book for further reading. Antenna arrays are very much emphasized and therefore a first-time reader might get a biased view.

It looks as if somehow the story has been inadvertently cut just when the author should have started describing, for instance, reflector feed structures and achievable illuminations. This is later a drawback when monopulse feeds are discussed in Chapter 8. Although the author mentions in Chapter 6 that propagation-related material is readily available, the entire treatment in this book is relatively weak. Here, the focus seems to have been in ground-to-air applications (on land or sea) only. Radar hardware, especially transmitter and receiver modules appear only in very coarse block diagrams and one might discuss the general importance of some older constructions. For example, issues related to frequency stability in Doppler processing are very well documented, but practically nothing is said about how such things are approached in real hardware. Finally, electronic warfare aspects (ECM and ECCM) of this book are broadly advertised by the publisher, but the content is more a good basic course treatment of mostly well-known subjects. Of course, it could be nothing else from a patriotic author, otherwise it would no more be ECM or ECCM!

Some things are naturally a simple matter of taste. When I first found the Blake pulse radar range worksheet in section 1.2.8 as a pasted photocopy image, I was a bit upset indeed, but after some thinking, I can understand how and why the author has come to this approach. There is obviously no point in inventing the wheel over and over again. However, I see the Blake worksheet more as a technician-level practical list – not as a real tool for the design of new radar systems or as a motivating element toward creative thinking. For academic education, I would use the more analytical parts of that chapter. Another example of things suitable for the coffee hour discussions is the author's choice of the computation engine. Barton is quite right when he points out the open and straightforward self-documenting feature of Mathcad. Unfortunately, many radar performance tools and tasks currently run in the more complicated, and, apparently, awkward matrix-format once heavily pushed through by the Matlab community. That might have been an alternative for mature project engineers and scientists. Of course, a classroom start-up with Mathcad is faster; but, *What if . . . ?*

As a summary, I feel a bit desperate now. With such an immense professional background and remarkable career, Mr. Barton certainly deserves our full respect and appreciation. His publication record is long and comprehensive and based on true practical and outstanding radar implementations. ***Radar System Analysis and Modeling*** in its third or fourth generation is a nice book, its facts are correct and it covers many topics. However, contrary to the publisher's claims, it is not really a thorough update of the entire field – more a collection of detection and signal processing methods and a compilation of design procedures and Mathcad routines for pulse Doppler radar, based on comprehensive expertise from the past 50 years or so. The book is suitable for educational purposes. Individuals interested in the evolution of radar knowledge or needing a cross-referencing handbook and not possessing any of the previous versions certainly find it worth purchasing as well.

Reviewed by Pekka Eskelinen