Advanced Metric Wave Radar

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Preface

It was metric wave radar that became my research topic when I started my work more than 20 years ago. The idea to write this book relates to the International Radar Conferences that I attended. The International Conferences on Radar were held in China, America, Britain, France, and Australia in turn. The 2013 International Conference on Radar was held in Adelaide, Australia. About 300 radar experts and scholars from more than 20 countries and regions attended this conference. In the a.m. of the opening ceremony day, I and Professor Griffiths, a famous British radar expert, were arranged to give plenary meeting reports. The title of my report was "Some Issues in the Development of Metric Surveillance Radar". In the report, I introduced my technological research efforts and some experimental results achieved in advanced metric wave radar. And, the communions were also conducted with the conference representatives. The report aroused strong responses. Australian Defense Magazine (ADM) issued a special report titled as "Radar smarts on show in Adelaide", with emphasis on what I reported. The 2014 International Conference on Radar was held in France, and the theme of conference was "Catch invisible". On invitation of the honorary president of this International Conference on Radar, Francois Le Chevalier, I gave a plenary report titled as "Research on Improvements of VHF-band Radar Performance". The report described metric wave radar how to overcome multipath effects and improve height finding performance in complex environment, as well as the novel methods to make metric wave radar have a certain target recognition capability under narrowband condition. My report also aroused great responses. During the conference, some famous radar experts, including the honorary president, Francois Le Chevalier, made deep discussions with me on some relevant problems about metric wave radar. They all showed great interests.

Attended the International Conference on Radar two times, I realized that the international radar community is interested in anti-stealth technologies, and the development and advancement of advanced metric wave radar. In future, this field will become one of the research hotspots of the international radar community. By looking up the sci-tech books at home and abroad, no book concerning this aspect

has been found. Therefore, an idea burgeoned in my mind to write a book about advanced metric wave radar for readers.

"Advanced metric wave radar", different from traditional metric wave radar, is a new type of metric wave radar, where the major problems of traditional metric wave radar have been solved by using the novel theory, idea of system design and by combining the applications of new methods, such as modern array signal processing, etc. In the past, metric wave radar was considered to be simple and backward because it not only failed to measure height owing to its poor measurement accuracy but also had large low-elevation blind zone and discontinuous coverage resulting from its beam cocking-up and beam splitting due to ground reflection. At one time, the radar experts widely considered that high frequency band radar would be the direction of radar development. Even more, the Western countries have gotten rid of the development of metric wave radar on one occasion. The need to counter stealth aircraft brings a new chance of developing metric wave radar. Metric wave radar has advantages in both countering stealth in frequency band and large power-aperture product at relatively low cost. With the superposition effect of the two factors, metric wave radar can achieve a gain of 40dB above in detecting stealth aircraft under the condition of equivalent cost in comparison with microwave frequency band radars, for example, S-band radar. If the main problems of metric wave radar mentioned above are overcome, metric wave radar can become the backbone anti-stealth equipment. That is to say, an economic and effective anti-stealth technological path can be found.

However, the problems of traditional metric wave radar lasted over a long period of time and the relative recognitions were also deepseated. Taking the height finding of metric wave radar as an example, the previous viewpoints of many experts were that metric wave radar could not realize accurate height finding due to its severe beam deformation resulting from ground reflections. And, the super-resolution techniques are not used successfully in radar for a long term because the radar community generally considers that the super-resolution algorithms require such a high signal-to-noise ratio that radar cannot meet the requirement. Also, the traditional thinking believes that metric wave radar certainly has poor low-elevation performance due to its beam cocking-up, so that it can be used only as middle and high-altitude detection radar. To solve the problems of metric wave radar, first, we should dare to break the bondage of traditional thinking and seek breakthrough by innovation. I started to bend myself to the research on metric wave radar anti-stealth technologies at the beginning of 1990s. On the basis of my investigations and experimental results, I have concluded that the most root cause resulting in the above problems of traditional metric wave radar is that the serious ground or water multipath interference existing in metric wave band cannot be well solved. During the research of more than 20 years, I and my team have gradually explored and formed our theory and method. I call them "Multiple phase centers" theory and "Multi-freedom terrain matching" theory. The former means that multiple sufficiently separated independent phase centers are used to complement and smooth multipath interference fringes, which supports and produces a multi-phase-center radar system. It is a new system, and I call it "Synthetic impulse

and aperture radar". For details, please read the monograph *Synthetic Impulse and Aperture Radar (SIAR)–A Novel Multi-Frequency MIMO Radar*, which has been written cooperatively by me and Professor Chen Baixiao. The latter means that the flexibility brought by multiple independent transmit/receive channels of array antenna, namely multi-freedom, is utilized to realize good terrain matching, which can improve the multipath interference fringes. Along this direction, we have explored the partitioned reshaping beam design methods to solve the problems about low-elevation blind zone and airspace coverage discontinuity. By keeping experiments and modifications, these methods can adapt well to various terrain environments so as to make metric wave radar glow with new vigorous vital force. The book summarizes our scientific research practices and gives emphasis to the novel methods and designs aiming at increasing the height finding accuracy and improving the coverage performance of metric wave radar. The experiment results are given.

To break the limit set by the narrow absolute bandwidth of metric wave radar and further bring the potential of metric wave radar into play, the book arranges a chapter to devote the narrowband target recognition methods suitable for metric wave radar, along with relevant experiment results. Aiming at the particular interference environment faced by metric wave radar, a special topic is established in this book to study the anti-interference methods for metric wave radar. The book gives a special discussion on the cooperative detection of metric wave radar network. Furthermore, the book also gives detailed descriptions of antenna mechanical structure design, antenna techniques, and transmit/receive techniques of metric wave radar. The theories, methods, and technologies introduced in this book are also applicable to UHF radar.

The author thanks Professor Chen Baixiao, Researcher Hu Kunjiao, Doctor Yang Xueya, Doctor Zhu Wei, Doctor Tian Xilan, Researcher Hu Yuankui, Researcher Sun Shaoguo, Researcher Wang Bing, Senior Engineer Wang Mei, Researcher Zhu Qingming, and Doctor Liu Guanghong for their help in writing this book. The author would also like to thank Academicians Wang Xiaomo and Lu Jun for their comments on the manuscript.

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A Brief Introduction to This Book

The advanced metric wave radar presented in this book is a novel metric wave radar, which is different from traditional metric wave radar. The advanced metric wave radar is based on active electronic scanning array (AESA) or digital array (DA) radar technology. With new theory, method, and system design idea, as well as modern array signal processing technique, the advanced metric wave radar can solve the major problems of traditional radar and achieve a leap in the performance of metric wave radar.

In this book, the author gives a systemic description of the advanced metric radar in combination with engineering practical application. A comprehensive introduction to the advanced metric wave radar techniques is also given from the theory and method to solve the major problems of metric wave radar to system design, antenna/feed, transmitting/receiving subsystem, and mechanical structure design. As the emphasis, the methods to solve large blind zone and discontinuity in detection coverage and the height finding method of metric wave radar are studied. Moreover, this book gives detailed accounts of how to use the super-resolution technique for solving the low-angle height finding problem in metric wave radar. In addition, as for the unique jamming environment faced by metric wave radar, the anti-jamming method is introduced. In order to cope with the limitation of narrow absolute bandwidth in metric wave radar and further exploit the potential of metric wave radar, a special introduction to narrowband target recognition method is given. About the metric wave radar netting, the cooperative detection is covered in this book. Finally, the main experimental results are shown. The theories, methods, and technologies researched in this book are also applicable to UHF radar.

This book is intended for the professional engineers as well as the graduate students who engage in radar system engineering, electronic engineering, and signal processing.

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