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Ultra-Wideband Positioning Systems

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Abstract

Position estimation of wireless devices has many applications in short-range networks. Ultra-wideband (UWB) signals provide accurate positioning capabilities that can be harnessed in wireless systems to realize these applications. This text provides detailed coverage of UWB positioning systems, offering comprehensive treatment of signal and receiver design for ranging, range estimation techniques, theoretical performance bounds, ranging algorithms and protocols. Beginning with a discussion of the potential applications of wireless positioning, and investigating UWB signals for such applications, later chapters establish a signal processing framework for analyzing UWB positioning and ranging systems. The recent IEEE 802.15.4a standard related to UWB is also studied in detail. Each chapter contains examples, problems and Matlab scripts to help readers grasp key concepts. This is an ideal text for graduate students and researchers in electrical and computer engineering, and practitioners in the communications industry, particularly those in wireless communications. Further resources are available at www.cambridge.org/9780521873093.

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Ultra-wideband Positioning Systems

Theoretical Limits, Ranging Algorithms, and Protocols

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Contents

Preface

Ability to locate assets and people will be driving not only emerging location-based services, but also mobile advertising, and safety and security applications. Cellular subscribers are increasingly using their handsets already as mapping and navigation tools. Location-aware vehicle-to-vehicle communication networks are being researched widely to increase traffic safety and efficiency. Asset management in warehouses, and equipment and personnel localization/tracking in hospitals are among other location-based applications that address vast markets. It is a fact that application space for localization technologies is very diverse, and performance requirements of such applications vary to a great extent.

The Global Positioning System (GPS) requires communication with at least four GPS satellites, and offers location accuracy of several meters. It is used mainly for outdoor location-based applications, because its accuracy can degrade significantly in indoor scenarios. Wireless local area network (WLAN) technology has recently become a candidate technology for indoor localization, but the location accuracy it offers is poor, and also high power consumption of WLAN terminals is an issue for power-sensitive mobile applications. Ultra-wideband technologies (UWB) promise to overcome power consumption and accuracy limitations of both GPS and WLAN, and are more suitable for indoor location-based applications.

The Federal Communications Commission (FCC) and European Commission (EC) regulate certain frequency bands for UWB systems. These have prompted worldwide research and development efforts on UWB. Another consequence was development of international wireless communication standards that adopt UWB technology such as IEEE 802.15.4a WPAN and IEEE 802.15.3c WPAN.

The writing of this book was prompted by the fact that UWB is the most promising technology for indoor localization and tracking. As of today there is no book with particular focus on theoretical and practical evaluation of the capabilities of various UWB localization systems. The book is written for graduate-level students and practicing engineers. Prior knowledge in probability, linear algebra, digital signal processing, and signal detection and estimation is assumed.

The scope of the book is not limited to time-based UWB ranging systems, because in addition to signal design and time of arrival estimation, most location systems should adopt a ranging protocol and perform certain position estimation and tracking techniques. For completeness of the course, in depth coverage from signal design to position solving and tracking techniques is given. Each chapter includes examples and problems to accelerate readers' understanding. Programming exercises allow readers to simulate various techniques in UWB systems and help them see impacts of various design parameters.

Although the main focus of all chapters is on UWB systems, Chapters 1, 4, and 9 are not limited to UWB. Current trends for location-aware applications and taxonomy of localization systems are given in the first chapter. Position estimation and tracking techniques, which are applicable to any location system, are discussed in Chapter 4. Recent developments and future research directions form the main topic of Chapter 9.

UWB-specific treatment starts with Chapter 2, in which various UWB signal waveforms are studied, international regulations for UWB signal emissions are presented, and various UWB standards are discussed. UWB channel models arising from channel measurements conducted for 2–10 GHz, below 1 GHz and 57–66 GHz frequency band regions are overviewed in Chapter 3. Also, differences between narrowband and UWB channels are highlighted in this chapter. Treatment of time based ranging via UWB radios is given in Chapter 5. Its content includes discussion of potential error sources and quantification of fundamental performance limits via Cramer–Rao and Ziv–Zakai lower bounds. Chapter 6 is devoted to the discussion of various ranging protocols, and their pros and cons. The ranging aspect of the recently published IEEE 802.15.4a UWB WPAN standard is studied in detail, including preamble and start of frame delimiter design, timing counter management, and clock frequency offset mitigation. Narrowband and multiuser interference mitigation techniques, ranging privacy mechanisms and the state-of-the-art coded payload modulation technique are the special topics covered in Chapter 7. Practical considerations for UWB system design are given in Chapter 8, including signal design under practical constraints, link budget analysis, and specific hardware issues.

Solutions for the problems at the end of each chapter and Matlab simulation scripts can be found by visiting the website for this book, which is currently at www.cambridge.org/9780521873093. The most up-to-date errata sheet and references to additional material can also be found at the same site.

We would like to thank experts in the field, who have reviewed and commented on the draft of the manuscript. Their inputs greatly helped us improve the presentation. Special thanks to Andreas F. Molisch from Mitsubishi Electric Research Labs for his suggestions about the channel modeling chapter, Davide Dardari from University of Bologna for his thorough review of Chapter 5, Henk A. Wymeersch from Massachusetts Institute of Technology and Qin Wang from Harvard University for their inputs in general and for helping organize Chapter 6 in particular, Yihong Qi from AMD for her inputs on Chapters 4 and 7, Rainer Hach from Nanotron Inc. for his review of Chapter 6, Chia Chin Chong from NTT DoCoMo Labs and Fikret Altinkilic from Syracuse University for their suggestions on Chapter 3, Philip Orlik from Mitsubishi Electric Research Labs for reviewing and providing suggestions and comments on Chapters 2 and 4, and furthermore Fujio Watanabe from NTT DoCoMo Labs, Huseyin Arslan from University of South Florida and Volkan Efe from Motorola for providing comments on various chapters.

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DWM1000 Position Module Ultra-wideband Indoor UWB Positioning Module for Difference Positioning System Low Power Consumption. 5.0 (1 votes) Store: IOT EC Store. US $18.89.Â An accurate real-time positioning system (RTL) that uses a two-way ranging or time difference scheme in various markets. Location-aware wireless sensor network (WSN). DWM1000 module block diagram. 1.1 Denition of Ultra Wide-Band system. The Federal Communication Commission (FCC) [4] has dened UWB systems as those which have an absolute bandwidth larger than 500 MHZ and fc larger than 2.5 GHZ, or have a Bfrac larger than 0.2 for systems with fc lower than 2.5 GHZ. The fc is the frequency in which the system has the maximum power density (shown in Figure 1.1) and the frequencies fH and fL determine the location where the power spectral density is 10 db below the fc.Â [28] I. G. Zafer Sahinoglu, Sinan Gezici. Ultra-wideband Positioning Systems: Theoretical Limits, Ranging Algorithms, and Protocols. Cambridge University Press, October 6, 2008. [29] L. Zwirello, C. Ascher, G. F. Trommer, and T. Zwick. Although Ultra Wideband was once considered a potentially suitable technology for personal area networks and an early competitor to WiFi, UWB has since transitioned to become a highly accurate, affordable, and low-energy solution to indoor positioning. Although there is a multitude of technologies that are appropriate for use in indoor positioning applications, UWBâ€™s low-frequency and high-bandwidth mean that it can pass through both walls and other obstacles and that it can exist in harmony with other radio signals, such as those from cellular telephones. Taken together, this makes UWB ideal