Integrated Wireless Propagation Models
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(A listing of abbreviations and acronyms is available at www.mhprofessional
.com/iwpm.)
Preface

Ever since I created the macrocell prediction model in 1977 at Bell Labs, many people wanted to know the details of the model. AT&T had held it as proprietary and did not disclose it. Afterward, I created the microcell model in 1988. Both models are briefly described in my previous books, but the whole models were not fully disclosed at that time because of Pactel’s proprietary interest. In 1991, David Lee worked for me at Pactel (the company was renamed AirTouch in 1994), making many field measurements in the different countries of Pactel’s markets for deploying the desired cellular systems. In the meantime, the merit of these two models as a tool in deploying the systems in those countries has been shown. Starting in 1995, the two of us had worked on the in-building (picocell) model, which used mostly empirical data. In 2008, David asked me if I wanted to write a book on the Lee model. He would do all the preparation work for the book. From his hard work collecting all the necessary material, this book resulted.

Chapter 1 introduces all the terms and describes the natural phenomena in the mobile communications environment. Chapter 2 introduces the macrocell models that have been created by others. They are the most popular area-to-area models used in the industry. Chapter 3 introduces the point-to-point prediction models in the macrocell models. There are two models. The Lee model is for short distances (<10 miles), and the Longly–Rice model is for long distances (>10 miles). Chapter 4 introduces the microcell models. The Lee microcell model is introduced in the first part of the chapter. The near-in distance used in microcell prediction is clearly defined based on the equations derived in my earlier published books. A lot of empirical data collected from different areas, in both domestic and foreign markets, were used to verify the Lee model.

Chapter 5 introduces the Lee in-building model for both picocell and femtocell. The newly defined close-in distance for the indoor environment is derived. Many earlier papers regarding the Lee in-building model published by David and me have been modified in this book, such as in the case of “same floor” and especially in the case of “interfloor,” shown in Sec. 5.5.3. In Chap. 6, the integration of the three Lee models is described. David has made a software tool to plot a prediction signal strength chart covering the three different Lee models.

In this book, many other prediction models are included with their merits for readers to understand besides the Lee models. Also, the integration of the three Lee models—macrocell, microcell, and in-building (picocell and femtocell)—is displayed and used for future planning of an overall cellular system in a specific area. Users should understand that a good prediction model can be accepted if its standard
deviation of prediction error is within ±8 dB. In small cells, the prediction error should be ±5 dB.

Measuring signal strengths in a large area is costly. Therefore, we may depend on many prediction charts on a specified coverage generated roughly by area-to-area models. Each chart represents a specified environment. Then the Lee model derives a point-to-point model using a terrain map and the antenna effective height to fine-tune the signal strength. The point-to-point prediction model is useful when cell size is large. When cells become small, measuring signal strength in a small area is considerably easier and less expensive; we can collect more empirical data in a particular confined area. Thus, the prediction model becomes more accurate based on the empirical data.

How was the Lee model created? In 1976, engineers at Bell Labs were discussing the deployment of a cellular system in an area without doing a massive measurement in that area. Then I wrote an internal memorandum about my point-to-point prediction based on Okumura et al.’s legendary paper in 1968, which was the first paper to provide the ground work for an area-to-area model. At that time, I had to prove to Bell Labs engineers that the tool was working. Initially, in 1976, I had requested engineers from the Tri-State Telephone Team (which consisted of New York Bell, New Jersey Bell, and Connecticut Bell) to assist me because they could provide me with the measured data that I wanted in their territory. Also, they had the manpower to generate the coarse terrain charts I wanted. First, I had used the commercial 50,000:1 scale topographical maps printed by the U.S. Defense Mapping Agency. Each map was roughly 5 by 8 miles (8 by 13 km). The contour lines were in 20-ft increments. To make plotting a terrain contour along a mobile path on a map easier, we generated grid maps. Each grid was about one-half of a square kilometer. Each map had 18 by 24 grids. The Tri-State engineers used an eyeball average of the terrain altitudes in each grid. Each grid had one value. Each map had 432 (18 by 24) values, and one in each grid. It was a tedious job. After the grid maps were generated, we started to pick the routes in the Tri-State territory for getting the measured data. Every planned route on a particular map was drawn, crossing the grids where the route laid to make the signal strength measurements on that route. The altitudes along the route were plotted according to the eyeball average altitudes. Once the transmitter antenna was set up with its known location, height, power, and gain, as well as the height and gain of the mobile unit, the Tri-State engineers passed information on to me. I was the one to use hand calculations according to the eyeball values in the corresponding grids on the terrain contour map to plot the predicted signal strength curve along the mobile path and gave that to the Tri-State engineers before the measurement. The next day, the Tri-State engineers took the measured data on the particular planned route and compared these with my predicted values. I never went out and participated in taking measurements. Therefore, it was a totally independent process between the measurement and prediction.

The process went on for more than a year, and the predicted values were very good compared with the measured data in general. Not only was my prediction tool good, but the eyeball average of altitudes also turned out to be a good method. After more than a year of doing hand calculations to predict signal strengths in many different Tri-State areas, I was like a computer. At that time, I was young and had a lot of energy, and I was not afraid of my colleagues teasing me.

Finally, Bell Labs decided to use my tool in 1978. The eyeball average proved that the coarse grid contour maps were adequate. Then the 1° by 1° tape scaling 250,000:1 was purchased from the Defense Mapping Agency Topographic Center (DMATC).
A software tool was created using the 1° by 1° tape for inputting the terrain data and my prediction tool for system planning. It was called ACE, later renamed ADMS. The planning engineers at AT&T and later the Baby Bells were trained to use the tool in their cellular markets starting in 1983. On October 30, 1979, Mr. C. S. Phelan, patent attorney of Bell Labs, wrote me a letter (printed on page 20 of Lee’s Essentials of Wireless Communications [McGraw-Hill, 2001]) and acknowledged my contribution from a Bell Labs internal memorandum, “A New Mobile Radio Propagation Model,” Case 39445-7, March 30, 1979, written by me. The use of the terrain contour data maps with the effective antenna height gain to predict the signal strength at any known location was the invention of my point-to-point prediction model. Bell Labs did not want to patent this model but rather wanted to keep it for internal use.

In 1980, Hata wrote a paper on his area-to-area model and I was one of the reviewers. Also, I was the associate editor of IEEE Transactions on Vehicular Technology to accept his paper. Later, the Hata model was adopted by CCIR. I am very glad that it became an internationally well-known model. Readers may not know that I have been working in this field for 50 years. If you are interested in the past, I have many stories to tell and most of them are good ones.

This is my fourth book that has been published by McGraw-Hill. I hope this book will provide readers with clear guidelines to further implement the propagation models in future 4G or 5G systems.

William C. Y. Lee, Ph.D.
In preparing this book, we have drawn on many models that are related to the Lee model. We should apologize for not including all the models in our book because of page limitations. We are thankful for the kind advice of many scholars—Prof. Bingli Jiao of Beijing University, China; Prof. Lajos Hanzo of the University of Southampton, UK; Prof. Ping-Zhi Fan of Southwest Jiaotong University, China; Prof. Yi-Bing Lin of National Chiao Tung University, ROC; Dr. Joseph Shapira of Netvision Inc., Israel; and Prof. J. R. Cruz of the University of Oklahoma—during the preparation of this book.

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Bill’s two grandchildren, Alex and Sophia
David’s son, Richard

to follow our steps in their future careers.

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