

# RF Measurements

for CELLULAR PHONES and  
WIRELESS DATA SYSTEMS

*ALLAN W. SCOTT*

*REX FROBENIUS*

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# RF MEASUREMENTS FOR CELLULAR PHONES AND WIRELESS DATA SYSTEMS

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E2010000980

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Published by John Wiley & Sons, Inc., Hoboken, New Jersey  
Published simultaneously in Canada

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***Library of Congress Cataloging-in-Publication Data:***

Scott, Allan W.

RF measurements for cellular phones and wireless data systems/Allan W. Scott, Rex Frobenius.  
p. cm.

ISBN 978-0-470-12948-7 (cloth)

1. Radio frequency integrated circuits—Testing. 2. Wireless communication systems—Equipment and supplies—Design and construction. 3. Cellular telephones—Equipment and supplies—Design and construction. I. Frobenius, Rex. II. Title.

TK7874.S36 2008

621.3845'6—dc22

2008004929

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

# FOREWORD

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In the late 1960s as part of a technical seminar team, I traveled with HP's first-generation Automatic Network Analyzer (ANA), discussing and demonstrating new measurements and s-parameter design techniques. One of our stops was at a U.S. East Coast based defense organization, where a large group gathered to hear our talk. At the conclusion, a man with a skeptical expression on his face indicated that he had two questions. In a somewhat hostile manner he asked, "Are you telling me that with this new equipment I can reliably characterize active devices at microwave frequencies?" We assured him that for small-signal applications it was true. Then he went on, "If I turn off the equipment today, and repeat my measurement tomorrow, will I get the same data?" Again, we replied that after proper calibration, he will have the same results. Shaking his head in disbelief he said, "I cannot believe such b.s.," and stormed out of the lecture hall.

It is hard to understand such a reaction today. However, until the introduction of the network analyzer, obtaining reliable and repeatable y-parameter component characterization with its predecessor, the General Radio RF Bridge, was not possible. Without accurate data or component models, microwave circuit design was more of an art than science.

Even after the spectrum analyzer, network analyzer, and modern power meters became available, relatively simple gain, impedance, power, harmonic and two-tone intermodulation measurements represented a large percentage of microwave testing. This is in sharp contrast to what test engineers and technicians face today, working on products using a wide range of mixed-mode signal processing. In addition, they have to understand and measure parameters, Bit Error Rate (BER), constellation and eye diagrams, Adjacent Channel Power (ACP), just to mention a

few. They also have to be familiar with various digital modulation systems, including analog concepts. Last but not least, in the globally competitive marketplace, measurements must be performed rapidly and inexpensively.

The authors of this book based the contents on their extensive experience teaching continuing education courses to practicing professionals of the RF and microwave industries. Their course material is fine-tuned with the feedback provided by course participants and constantly updated to keep up with changes in technology. Measurements described in the book range from basic to advanced types, in addition to reviewing the necessary technical background of cellular and wireless communication systems. I am not aware of any other textbook having such a wealth of information, written in a simple, easily understandable style, without constant use of complex mathematics. Learning the techniques described in the book will elevate the value of anyone working in the field.

LES BESSER

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# ACKNOWLEDGMENTS

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We would like to thank all the organizations and people who helped make this book possible.

The idea began when the Test and Measurement Division of Hewlett-Packard offered Besser Associates the loan of a suite of RF test equipment for demonstration in their RF classes. Besser Associates is the worldwide leader in RF training, having trained over 40,000 engineers, technicians and managers in RF topics. We serve as instructors for Besser Associates. So beginning in 1998, we began a demonstration class on RF Measurements using the HP equipment.

When HP split off their Test and Measurement Equipment division to become Agilent Technologies, Agilent continued the loan of RF test equipment to Besser. As the cellular phone and wireless data industry grew and became more technically complicated, so did the test equipment. We are grateful to Susan Owen of Agilent for continuing to support this ongoing relationship, which always allowed us access to the latest models of their equipment. We would also like to thank Ben Zarlingo, who offered extensive support and insight into the operation of the Vector Signal Analyzer.

Many other companies, like Anritsu, Rhode and Schwartz, Aeroflex, and Keithley, to name a few, also make excellent test equipment. Often they demonstrated their test equipment in our course. Along these lines we enjoyed a great deal of support from David Vondran of Anritsu corporation, who provided detailed background on the Scorpion Network Analyzer and noise figure measurements. We did not try to make comparisons between test equipments, but continued to conduct a course using the Agilent equipment, because of their generosity in always loaning us the

latest and best they had. This kept us busy learning how to operate their continually evolving equipment, as the cell phone industry itself evolved.

The Besser RF Measurements course has continued to grow in popularity. Initially we taught the five-day course a few times a year, then several times a year. Last year (2007) we taught it 7 times. About a year ago, we decided to write this book, based on the RF Measurements course.

We would also like to thank everyone at Besser Associates, Founder Dr. Les Besser, President Jeff Lange, VP of Sales Annie Wong, and all the administrative staff and instructors who helped and encouraged us to write this book. We would also like to thank Allen Podell for providing numerous technical insights as well as practical tips on keeping our fragile lab components in good repair.

Finally, we would like to thank all the engineers, technicians, and managers who have taken our RF measurements course and made valuable suggestions on how to make it better.

We hope you will enjoy our book and find it useful. We hope that it will improve your understanding of RF measurements by at least 7 dB.

AL SCOTT  
REX FROBENIUS

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