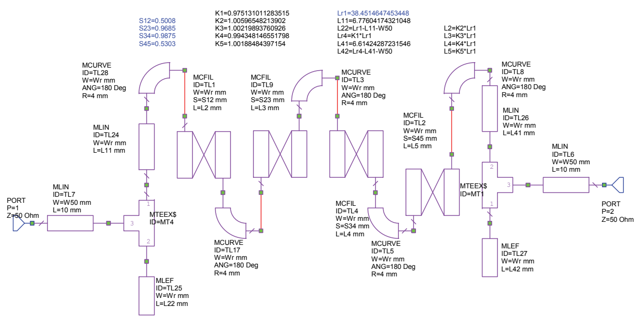
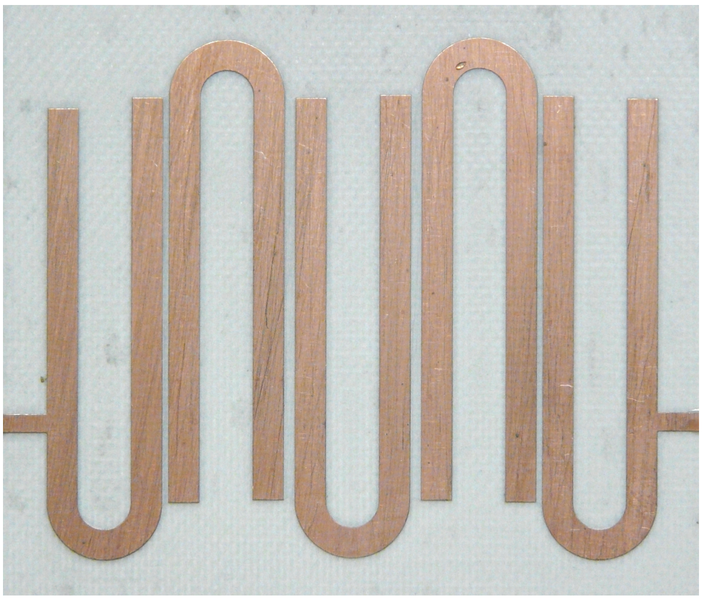
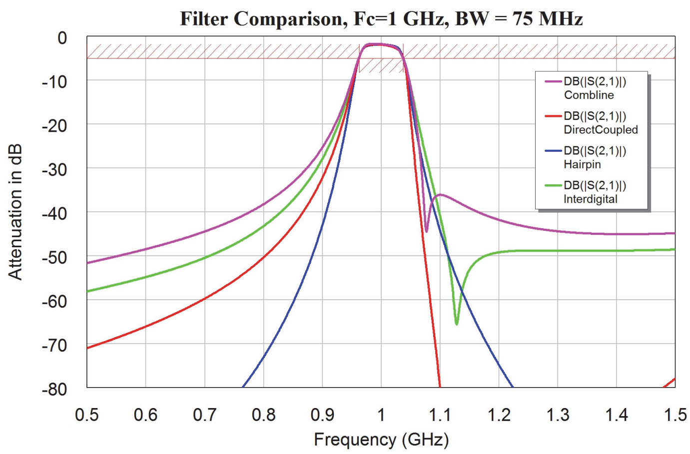
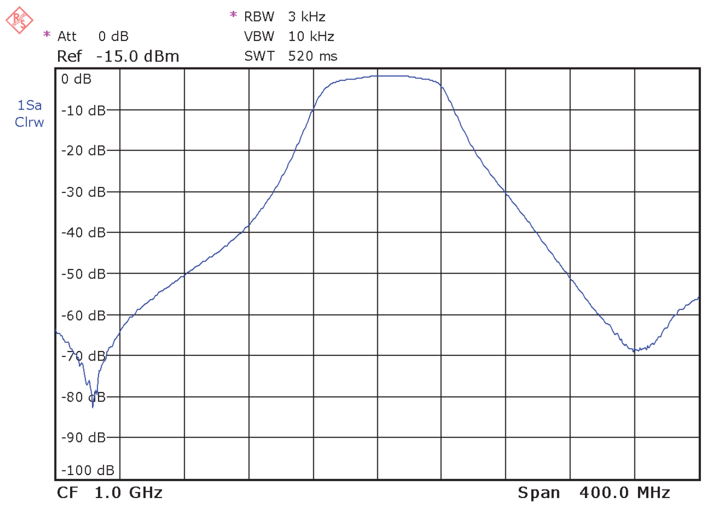
RF Electronics

Design and Simulation









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RF Electronics

Design and Simulation

Cornelis J. Kikkert

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Townsville, Queensland, Australia

Contents

Preface

The material presented in this book evolved from teaching analogue electronics courses at James Cook University over many years. When I started teaching electronics design, computer simulation tools were non-existent and most of the design optimisation was done by replacing components in hardware. It was a big step forward when EESOF became available in the mid 1980's. The computer simulation tools have progressed enormously since then. Early in my career, I was given the following advice for designing electronic circuits. "Get the circuit to work and then start taking components out. Put back the one that stops the circuit from working." This is a silly statement, since in a proper design removing any component will stop if from working, but it does illustrate the goal of any designer: *Design a circuit that will work first time, according to specification. It must do so reliably and at as low a cost as possible.* Since labour is expensive, the circuits also should not require any adjustments after manufacture in order that they meet the specifications.

Using the computer simulation used in this book, we can now design our analogue electronic circuits such that they satisfies all these conditions. We can change active device parameters in the simulation, to ensure that variations in performance during manufacturing do not cause the circuit to fail to meet the specifications. We can check that the circuit will meet specifications under any permitted temperature, power supply and input signal variations. For RF circuits, we can change microwave PCB substrates for lower cost FR4 type substrates and ensure that the circuit still performs correctly. For consumer or space critical applications, the computer simulation tools used in this book will allow Low Temperature Cofired Ceramic (LTCC) circuits to be designed. With those circuits one cannot open them up to change components. They must be correct right from the start.

During the last 20 years, much of the analogue electronics in radio and TV receivers has been replaced with digital electronics, causing a change in the operating frequency of analogue electronic designs. There has been a rapid growth in the number of radio transmitters and receivers used. Many developed countries now have more mobile phones than people and most smart-phones and computers use WLAN/WiFi to access the internet. WLAN/WiFi, Bluetooth, Wireless Gigabit, WiMax, Zigbee, W-CDMA and LTE are all relatively new communication systems using microwave (above 1 GHz) frequency bands. Because of this demand for radio spectrum, the operating frequencies are getting higher and the spectrum is becoming more crowded.

This explosion in microwave system applications, requires a matching RF and microwave electronic design capability from our engineers. More stringent filtering is required and less intermodulation distortion is permitted from amplifiers, to ensure systems do not interfere with each other. 20 years ago most electronic designs using microwave frequencies were for military, instrumentation or high-end communication applications, such as microwave radio links operated by Telcos. Now most microwave designs are for consumer applications. As a result the emphasis on reducing the cost of both the circuit and the design has become more important. RF and microwave circuit simulation play a significant part in this cost reduction.

It is important for Universities to realise however that computer simulation of an electronic design is not the end point, but only a step in the realisation of the production of hardware that operates as required. That is why in this book, firstly computer simulation has been used to enhance the understanding by students and designers of the properties and limitations of their designs, and secondly many photographs and measured performance of the hardware realisation of these designs presented have been included.

I hope that the material presented in this book will increase the RF and microwave design skills of many students and practicing designers.

This whole book is suitable for teaching RF and microwave electronic design in the final year of an undergraduate Bachelor Degree program or as a course in a postgraduate program. Chapter 2 can be used at earlier years of a Bachelor Degree program to teach the principles of computer simulation and design of analogue electronic circuits. These computer simulation techniques are not limited to RF and Microwave frequencies. For that reason, chapter 2 includes examples operating below 100 kHz. The modelling of mains (50/60 Hz) power distribution transformers, described in chapter 2, could not have been done without the optimisation capability of AWRDE.

Unless otherwise indicated, any of the hardware shown in photographs, have been designed by the author and produced by him with assistance from JCU technical staff. There are some photos of hardware from unknown manufacturers (UM). Those have been labelled with (UM).

Acknowledgment

I thank my wife Maxine for her patience and tolerance of my absences, as I tried to fulfil my desire to teach students the art of electronic design and for the time spent in writing this book.

I also thank my past and present colleagues at James Cook University, for their encouragement and feedback on the course that resulted in this book. I thank AWR for making their software available for teaching at James Cook University at a reasonable cost. Without that, this book could not have been written. I thank Dane Collins and Sherry Hess from AWRCorp, for the novel step that we took in distributing this book on their web site. That allows this book to be used by many more students. Finally I thank Mike Heimlich, who peer reviewed this book and made very many valuable comments, which resulted in this book being much better than the draft version.

About the Author

Cornelis Jan Kikkert obtained his BE and PhD from Adelaide University in 1968 and 1972 respectively. He is a Fellow of Engineers Australia and a Life Senior Member of IEEE. He was a lecturer at Adelaide University for 3 years and was at James Cook University in Townsville for 37 years, as a lecturer, senior lecturer, associate professor and head of Electrical and Computer Engineering. He "retired" in 2010 to have more time for research and is now an Adjunct Associate Professor at both James Cook University and The University of Adelaide.

He has more than 30-year experience in the design of electronics for communication equipment, broadcast transmitters, satellite beacon receivers, weather satellite receivers and many other applications, as well as the design of electronic instrumentation for measuring RF and microwave signals.

He is the author of more than 90 peer-reviewed papers, 3 book chapters and an inventor on 8 patents.

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