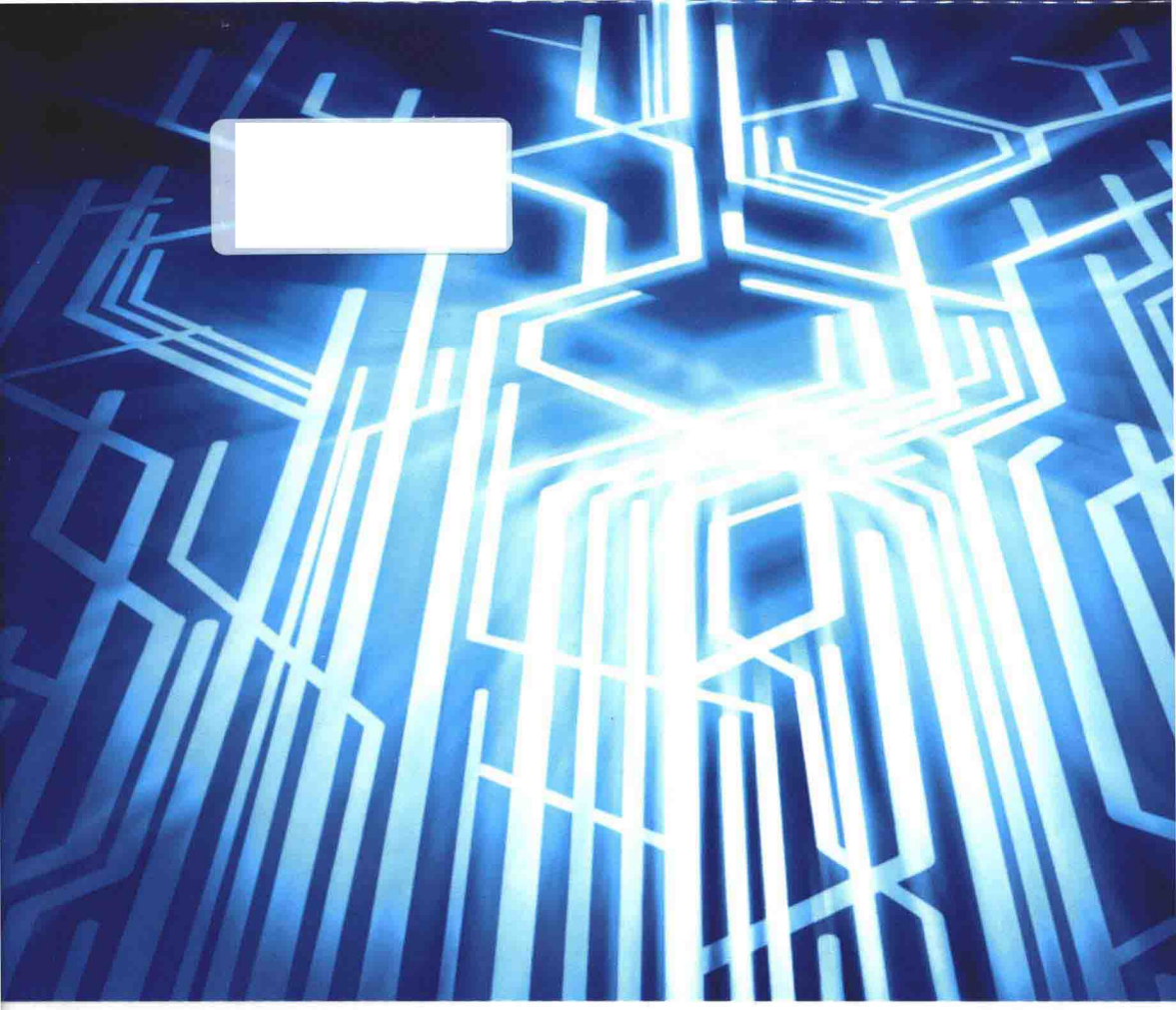

Passive & Active RF-Microwave Circuits

Pierre Jarry and Jacques N. Beneat

Course and Exercises with Solutions

iSTE PRESS

ELSEVIER

Series Editor
Pierre-Noël Favennec

Passive and Active RF-Microwave Circuits

Course and Exercises with Solutions

Pierre Jarry
Jacques N. Beneat

ISTE PRESS
ELSEVIER

First published 2015 in Great Britain and the United States by ISTE Press Ltd and Elsevier Ltd

ISTE Press Ltd
27-37 St George's Road
London SW19 4EU
UK

www.iste.co.uk

Elsevier Ltd
The Boulevard, Langford Lane
Kidlington, Oxford, OX5 1GB
UK

www.elsevier.com

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

British Library Cataloguing in Publication Data
A CIP record for this book is available from the British Library
Library of Congress Cataloging in Publication Data
A catalog record for this book is available from the Library of Congress
ISBN 978-1-78548-006-5

Printed and bound in the UK and US

Passive and Active RF-Microwave Circuits

Acknowledgments

These courses were given at the universities of Limoges, Brest and Bordeaux (all in France), but also in USA, UK and Brazil.

Pierre Jarry gave also these courses in engineers schools such as Evry (INT), Brest (ENSTBr), Rennes (INSA) and Bordeaux (ENSEIRB).

Pierre Jarry wishes to thank his colleagues at the University of Bordeaux and in particular Professor Eric Kerherve, specialist in microwave amplifiers.

He would like to express his deep appreciation to his wife and his son for their tolerance and support.

Jacques Beneat is very grateful to Norwich University in USA, a place conducive to trying and succeeding in new endeavors.

Finally, we would like to express our sincere appreciation to all the staff at ISTE involved in this project for their professionalism and outstanding efforts.

Preface

Microwave and Radio Frequency (RF) circuits play an important role in communication systems, and due to the proliferation of radar, satellite and mobile wireless systems, there is a need for design methods that can satisfy the ever-increasing demand for accuracy, reliability and fast development times. This book provides basic design techniques for passive and active circuits in the microwave and RF range. It has grown out of the authors' own teaching and as such has a unity of methodology and style, essential for a smooth reading.

The book is intended for microwave engineers and advanced graduate students.

Each of the 16 chapters provides a complete analysis and modeling of the microwave structure used for emission or reception technology. We hope that this will provide students with a set of approaches that they could use for current and future RF and microwave circuit designs. We also emphasize the practical nature of the subject by summarizing the design steps and giving numerous examples of realizations and measured responses so that RF and microwave students can have an appreciation of each circuit. This approach, we believe, has produced a coherent, practical and real-life treatment of the subject. The book is therefore not only theoretical but also experimental with over 16 microwave circuit realizations (couplers,

filters, amplifier and oscillators). Problems and exercises constitute about 30% of the book.

Then if we consider, for example, the diagram of an earth station in the C band (Figure P.1), we see that we have at the reception and the emission several microwave elements which can be active or passive:

– active as the amplifiers and the oscillators;

– passive as the different filters and the couplers (couplers are elements that allow us to take a part of the signal in the oscillators).

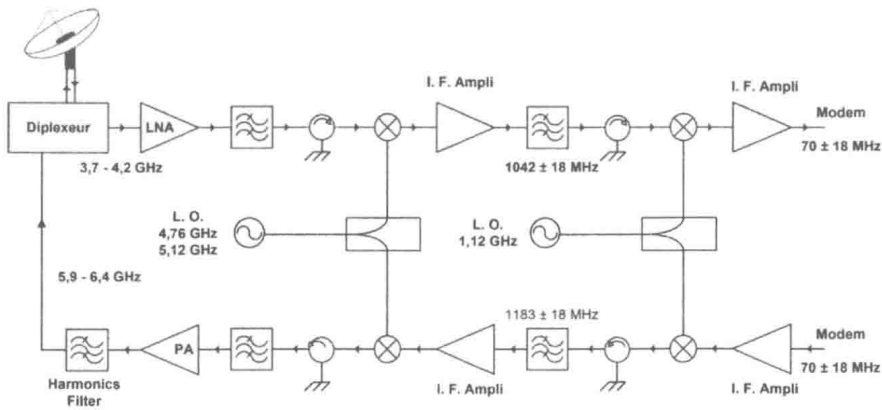

Figure P.1. *Diagram of an earth station in the C band*

We decided to successively study the principal elements that allow the reception and emission of a signal in the cases of earth stations, satellites and RF (mobile phones):

– couplers;

– filters;

– amplifiers;

– oscillators.

For all these four elements (two are passive and two are active), we give their principal properties in three chapters and add one chapter of exercises and problems.

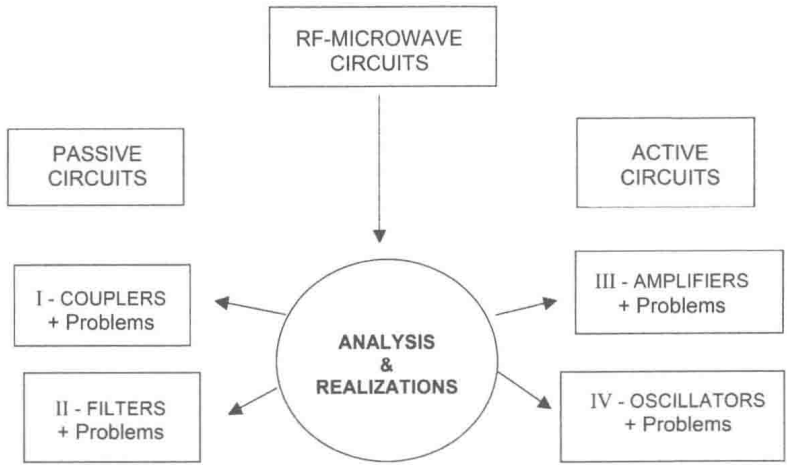

Figure P.2. *Organization of the book*

The book is divided into four parts and 16 chapters.

Part 1 is devoted entirely to the theory and realizations of couplers.

In Chapter 1, we recall the fundamental knowledge about microwave coupled lines and define in particular the even and odd modes.

Chapter 2 gives the analysis of a strip coupler while computing reflection and transmission in the even and odd cases. We define the coupling coefficients, the energy and enlargement of the bandwidth.

Chapter 3 presents the hybrid and magic T and their applications. We consider the cases of the perfect and non-perfect magic T.

In Chapter 4, we present three problems with their solutions. The first problem is devoted to the determination of the elements of a coupler while with the second we compute a two-stage coupler and then we consider (third problem) what happens for a perfect directive coupler. For all three problems, we provide detailed solutions.

In Part 2, we consider how to compute and realize microwave and RF filters.

The goal of Chapter 5 is to design a filter made up of only one resonator (a cavity) and two irises, and we give the response of this very simple filter (out of the resonance and near the resonance).

Chapter 6 deals with the electromagnetic of the iris while considering propagating and evanescent modes.

In Chapter 7, we describe the different methods of synthesis (Tchebycheff and Butterworth) and the possible realizations of the iris. After simulations of the cavities and the iris, we present a method of realizing the entire filter.

The last chapter of the second part (Chapter 8) is devoted to four exercises. The first problem is theoretical because we consider a network composed of 2 two–ports separated by a guide. The second problem is classical and gives the synthesis of a filter made up of a guide with direct couplings. The third and fourth problems give, respectively, the solutions of Cohn and Matthaei.

In Part 3, we consider how to realize microwave and RF amplifiers.

In this case, we give the different flow graphs (Chapter 9) and define, using Masson's rules, the different gains of an amplifier made up of a field effect transistor (FET).

Chapter 10 is devoted to the problems of stability, i.e. the limits of stability and the conditional and unconditional stabilities.

The problem of noise is also very important and it will be given in Chapter 11. In this chapter, we define the sources of noise and also the noise factor and the circles of noise necessary for realizing an amplifier.

In Chapter 12, we present four problems with their solutions. The first problem is devoted to a symmetric of the gain of a non-unilateral amplifier. In the second exercise, we determine the stability conditions of a broadband transistor from 300 to 900 MHz. In the third and fourth exercises, we give the input and output matching circuits for a

narrowband amplifier around 500 MHz and for a low noise amplifier around 2.5 GHz.

In the last part (Part 4), we give how to compute and realize microwave and RF oscillators.

First, we have to give (Chapter 13) the quasi-static analysis and the overvoltage coefficients and show that it is possible to extend these definitions to nonlinear circuits as the oscillators.

In Chapter 14, we discuss synchronization and the variation of the frequency with the variation of the load (pulling). We give also the specter of the oscillator.

Chapter 15 is devoted to the realization(s) of oscillators with a very stable element: the dielectric resonator (DR). We consider the coupling of a DR with a microstrip line and the different uses of the active element (FET in our case).

The last chapter (Chapter 16) presents five exercises with their solutions. With the first two exercises, we show how to compute the scattering parameters of a transistor alone and what happens when there are also oscillation conditions. With the third and fourth exercises, we talk of synchronization and pulling. With the last exercise (exercise 5), we give and compute the equivalent circuit of a DR coupled with a line.

These courses and the corresponding problems are given during the fifth year of university and at specialist engineering schools.

Pierre JARRY
France

Jacques N. BENEAT
USA
January 2014

Contents