Chapter 1

Introduction

This document concerns the development of a new impedance matching algorithm. The problem will be placed in context and the motivation for developing a new impedance matching algorithm will be given in this chapter.

Section 1.1 will consider the reasons for the development of a new impedance matching algorithm in light of the current state of the art. Section 1.2 will then present the objectives for the algorithm developed during this dissertation.

1.1 Motivation

A large volume of work has been published on the problem of impedance matching and there has to be some doubt concerning whether yet another technique is really necessary. The motivation for developing a new impedance matching algorithm will be presented in this section with special attention being paid to the limitations of current techniques.

Impedance matching is a very important part of high frequency circuit design. Vendelin *et al.* [1] even go so far as to state "The most important design tool in amplifier and oscillator design is the concept of impedance matching." The importance of impedance matching arises because the gain available at high frequencies is limited, so it is important to ensure that the power loss due to impedance mismatches is kept to a minimum. The impedance presented to an active device also determines the noise, gain, output power, and stability of the device [2, 3].

The current state of the art in impedance matching is embodied in the real-frequency techniques developed by Carlin, Yarman and their co-workers [4–9]. These techniques optimise the transfer function of an impedance matching network and then extract components from the optimised transfer function. The main advantage of the real-frequency techniques is that they use the real measured impedances of the system, rather than an approximation to the system impedances like the earlier analytic techniques. The most important real-frequency techniques were published in 1977 by Carlin [4], 1982 by Yarman and Carlin [6, 7], and in 1983 by Carlin and Yarman [8]. In 1990, Yarman and Fettweis [9] published a simplified version of the algorithm developed by Carlin and Yarman [8]. The most recent real-frequency technique was published by Carlin and Civalleri [10] in 1992 and is an extension to Carlin's original work [4]. The fact that no papers concerning developments to the real-frequency techniques have been published in the last decade seems to indicate that these algorithms are mature and very little further development is possible. The main disadvantage of the real-frequency techniques is that the use of a transfer function means that a constant, corresponding to an ideal transformer, is usually present. Another disadvantage is that component ranges cannot be specified, leading to implementation difficulties because the component ranges that are available at high frequencies are limited by parasitics [2].

Recently, Abrie [2] published an impedance matching algorithm that uses the transformation-Q factor (also known as the node Q) that is applied to narrowband matching [2, 3]. The values of the transformation-Q factors are adjusted by an optimisation algorithm to obtain broadband networks. The main advantages of this technique are that ideal transformers are not required, resonant sections are possible, component ranges can be controlled, and distributed elements can be used.

While these techniques are extremely powerful, they do still have some limitations, limitations that this work seeks to address. These limitations are inadequate consideration of transmission lines, difficulties in handling more complex components like microstrip lines and discontinuities, and limitations in mixed-circuit synthesis.

The real-frequency techniques are limited to problems where commensurate lines (lines with the same fixed length) are used, and the published version of the transformation-Q algorithm does not allow the length and impedance of transmission lines to be varied simultaneously. This is a drawback because only half the available parameters are used, potentially ignoring good solutions.

Microstrip lines are a type of transmission line, but they do not operate in a perfect Transverse Electromagnetic (TEM) mode [11], leading to dispersion. This means that microstrip lines can only be approximated by perfect transmission lines at low frequencies. Additionally, the junctions between microstrip lines form discontinuities that have a significant effect on the network's transfer function. Most impedance matching algorithms assume that these effects are negligible and simply ignore them. Abrie's algorithm does compensate for discontinuities in the sense that attempts are made to limit their effects.

Mixed circuits use both lumped and distributed components. A major problem with this type of circuit is determining which circuit elements should be lumped and which should be distributed. This difficulty means that only a very limited class of mixed problems has been considered in the literature.

The algorithm developed during the course of this research overcomes all of these difficulties. Component ranges can be specified for lumped and distributed components. Transmission line networks can be synthesised by the algorithm, with both the length and impedance of the transmission lines being varied. The parasitic effects of microstrip lines and discontinuities are considered by the algorithm – the only limitation is the accuracy of the models used. Mixed circuits are considered in a completely general way and all combinations of lumped and distributed components are possible within the ladder structure considered.

The new algorithm developed during this dissertation is able to achieve all of these objectives by using a modified genetic algorithm. Many of the modifications used in this dissertation are unique and lead to greatly improved performance of the algorithm.

1.2 Objectives

The objectives for this dissertation are presented below and arise directly from the limitations of current impedance matching algorithms.

The major objective of this dissertation is to develop an impedance matching algorithm that can produce results comparable to the best current algorithms.

The second objective of this dissertation is to eliminate the problems associated with other algorithms. These problems include an inability to specify component ranges, restricted facilities for dealing with transmission lines, inadequate consideration of microstrip elements and discontinuities, and limited mixed-circuit capabilities.

These objectives will be achieved by using a modified genetic algorithm to design impedance matching networks. The main advantage of genetic algorithms is that they can be applied to any problem and should thus be able to overcome the limitations of other approaches.

A known limitation of genetic algorithms is that they converge very slowly, meaning that a large amount of computer time and processing power is required to produce a good result. Every effort will be made to ensure the algorithm is as efficient as possible to limit this problem. However, the quality of the final result will be considered more important than the time required to obtain that result, so this is a secondary objective.

1.3 Summary

The motivation for, and objectives of this dissertation were outlined in this chapter. The overriding objective was to develop an impedance matching network design algorithm that overcomes the limitations of current algorithms.