Chapter 1

Introduction

1.1 Background

The use of microstrip antennas has become increasingly popular. They have the advantages that they are compact in size, light in weight, low in cost and easy to fabricate [1]. Furthermore, these antennas can easily be integrated with microwave circuits and used for implementation in conformal arrays [2]. Despite these advantages they exhibit an inherently narrow bandwidth. A number of techniques to overcome this problem have been presented and work very effectively [1]. Some of the bandwidth enhancement techniques are thicker substrate, lower dielectric constant for the substrate or reactively loaded and multiple-resonator antennas.

The use of thicker, lower permittivity substrate, discussed in [3], results in a very effective increase in impedance bandwidth for the microstrip patch antenna. The problem associated with this technique, however, is the inductive component of the probe-feed. The series inductance is added to the RLC-equivalent impedance behaviour of the microstrip patch antenna [4], and if not compensated for in the design will lead to a substantial mismatch. The radiation pattern of the antennas is also affected by the thicker substrate, with higher cross-polarisation levels encountered, particularly in the H-plane. A remarkable increase in beam squint as a result of the probe is also sometimes introduced. A number of techniques for compensation of this problem have been discussed in the literature. One of these techniques is probe compensation through capacitive feeding. The problem encountered with the input impedance is effectively solved with the capacitive feed, but the probe's influence on the radiation pattern remains [5-9]. Another feed structure mentioned in the literature is aperture coupling [10,11]. Aperture coupling has proven to work very effectively, lowering the cross-polarisation levels in the H-plane to negligible values. One drawback with this type of feed is that the aperture in the ground plane results in an increase in back lobe radiation.

Multiple resonators and reactive loading of the antenna are used to create more than one resonant frequency. A major design focus for this type of structure is dual-band antennas that will operate at two discrete frequencies [12 - 14]. By choosing the two resonant frequencies close to each other, it is possible to create a wider bandwidth due to the two overlapping resonant frequencies. The overall structure of this antenna is much more complex than a single patch antenna, thus leading to more intensive design procedures and less ideal radiation patterns [15].

The implementation of an impedance matching circuit to enhance the bandwidth of microstrip patch antennas was first introduced by Pues et al. [1]. Subsequent research led to the creation of the Simplified Real Frequency Technique (SRFT) [2,4]. This technique was used on passive antennas, and a bandwidth improvement factor in the range of 100% of the original impedance bandwidth was obtained. The SRFT was also implemented on active antennas, designing a matching circuit between the amplifier and the antenna [16]. This is named the dual-matching case, where both the load and system impedance consist of real and imaginary values.

The inclusion of the matching network in the feed has no effect on the radiation properties of the patch antenna itself. For a probe-fed microstrip patch antenna, the feed line with the matching network is hidden behind the ground plane of the antenna and there can be no physical coupling between the reactive circuit and the radiating element. The radiation pattern remains fairly constant for a frequency range often wider than the Voltage Standing Wave Ratio (VSWR) bandwidth of the patch antenna [1]. However, a remarkable loss in gain is encountered over the bandwidth considered. Although part of the loss is due to the fact that one moves away from the resonant frequency, drop in gain can also be attributed to mismatch losses encountered at the feed point. The aim is to reduce these losses at the feed point by using a wideband feed network.

Recently, coupled transmission lines as a means to increase the bandwidth of patch antennas have been discussed [17, 18]. Coupled lines as matching networks for implementation in patch arrays are discussed in [17]. The resonant nature of the feed line results in an improvement of the 2:1 VSWR bandwidth of the array of about 110%. The structure proposed in [17] consists of two coupled quarterwave sections. The transmission line required to feed the antenna would then be more than half a wavelength long. In view of this relatively large size the coupled line matching technique is recommended mainly for antenna arrays where the antenna itself is already larger in size. A second coupled line structure presented in [18] implements a resonant feed on the same side of the substrate as the antenna. There is no physical connection between the antenna and the feed line, effectively resulting in two quarterwave coupling sections as well. The technique does, however, occupy less space than the structure presented in [17]. The bandwidth improvement factor given for this technique is considered to be three times the original bandwidth. The fact that the feed network is on the same side as the radiating element limits the usability of this technique, since the antenna cannot be placed on thicker substrate with lower relative dielectric constant than the microstrip feed network allows.

1.2 Contribution of this dissertation

Impedance matching of microstrip antennas proved to be a viable solution to the bandwidth limitation problem encountered with microstrip patch antennas. The SRFT is a matching technique for microstrip patch antennas that presented promising results, but the numerical optimisation and calculation of the matching circuit is a tedious process [17]. The coupled quarterwave matching circuit provided a simple solution to the wideband matching problem. Space occupancy proved a major drawback for this technique, as well as limitations on the choice of possible dielectric substrates.

In this dissertation a relatively simple matching circuit, consisting of a parallel capacitor-inductor combination and a phase transformator, is proposed. The design of the matching circuit is called the Single LC-Resonator Matching Technique. The Single LC-Resonator Matching Technique is able to increase the VSWR bandwidth of probe-fed patch antennas to almost double the original bandwidth. The matching circuit can be designed to provide an increase in VSWR bandwidth for any predefined VSWR specification.

An improved version of the proposed matching technique, named the Optimum Bandwidth Single LC-Resonator Matching Technique (SRMT), is also presented [19, 20]. This technique includes impedance transformation, and the design procedure of the originally obtained Single LC-Resonator Matching Technique is revised. Results comparable to the SRFT and the coupled quarterwave matching lines are obtained, with the VSWR bandwidth improved to more than double the original bandwidth.

The SRMT is compact and does not occupy much space. It is easy to design and implement in microstrip line.

1.3 Organisation of this dissertation

In Chapter 2 a general overview of previous impedance matching techniques is presented. The SRFT is described with specific attention paid to the components used and the circuit lay-out in microstrip line. The resonant feed with coupled lines [17, 18] is also considered, as well as two additional example antenna configurations that implement the feed network as the main contributor for an enhanced VSWR bandwidth.

Chapter 3 discusses the whole design procedure of the proposed matching circuit. The discussion is undertaken with the aid of a patch antenna example. The SRMT is explained on a step-by-step basis, with a brief explanation given with each new step.

The example published for the SRFT is considered in Chapter 4. The results obtained using respectively the SRFT and the SRMT are directly compared on the patch antenna implemented as test case for the SRFT in [2, 4]. Results for other standard matching techniques are also included, namely the quarterwave stub, single stub, double stub and triangular matching network.

Chapter 5 includes full-wave simulations as well as actual measurements for a number of different types of microstrip patch antennas. A summary of the results obtained for the SRMT is presented at the end of Chapter 5.

Chapter 6 concludes the dissertation, and provides a brief summary of the results shown in the dissertation. Some ideas for future work and expanding the basic matching circuit are also included.