Microstrip Antennae with Various Substrate Thicknesses

by

Mehmet Kara

*Dipl.-Ing. (M.Sc.Eng) (Konstanz, West Germany)*

*Dipl.-Ing. (M.Sc.Eng) (West Berlin, West Germany)*

A thesis submitted in fulfilment of the requirement for the degree of

Doctor of Philosophy

The University of Adelaide
Department of Electrical and Electronic Engineering
Faculty of Engineering

May, 1996
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Abstract

Microstrip antennae have been in the spotlight ever since their introduction in early sixties. A strong demand has arisen in many areas for small, lightweight and low profile antennae, for example in mobile communications, satellite communication terminals, covert communications, phased array, electronic warfare, missile seekers, missile telemetry, altimeters, biological telemetry, navigation, radar, surveillance, radiometers, and low probability of intercept - systems.

The effective design, analysis and application of microstrip antennae presupposes a quantitative knowledge of their properties as both elements and arrays on substrates of various sizes, thicknesses and permittivities. The significant advantages of printed circuits are somewhat offset by the electromagnetic complexity of the structure, because inherent inhomogeneity makes accurate analysis and performance prediction rather difficult. In particular, antennae with thick substrates require a detailed analysis of both radiated and surface waves. Many models have been proposed for microstrip antenna analysis, from simple static and quasistatic approximations to full-wave integral formulations solved by sophisticated computer techniques. None of these methods can be used to calculate all the physical and electrical properties of a microstrip antenna. This means that approximations and modifications may be needed when using the methods and this is inevitable when thick antenna element design is considered.

The research presented in this thesis principally addresses probe fed classical rectangular microstrip antenna elements and arrays, that are fabricated on substrate materials with various thicknesses and relative permittivities. A fundamental requirement for the design and analysis of microstrip antennae is the development of accurate and versatile analytical tools. Formulae have been developed for calculating the patch dimensions, the resonant input resistance, the resonant frequency, the bandwidth and the radiation patterns of elements, as well as the mutual coupling coefficients of arrays. The research has to some extent been driven by identifying methods capable of delivering fast and reliable numerical results, and which can be modified for calculating physical and electrical properties of thick antennae. To demonstrate the capability of the methods developed in this thesis, antenna elements and arrays with various substrate sizes, thicknesses and
permittivities were constructed and tested. The experimental results agree well with those calculated by the developed methods.

Increasingly stringent system requirements have led to a shift in focus to the design of novel miniaturised rectangular and ring broad-band and dual-band antenna elements. The size reduction and cost effective implementation of such antennae for microwave operation requires extensive experimental and numerical research. Novel configurations of patch antennae have been presented in this thesis, which provide dual-band and broad-band operations. Progress and achievement on unproved characteristics and miniaturisation is ultimately judged by its overall size reduction, cost effectiveness and reliability, as well as the specified microwave performance requirements. This thesis achieves several successes in further miniaturising of microstrip antennae, and in doing so has shown the potential for a new generation of antenna systems.

Useful information has been obtained which reveals the influence of the physical and effective dimensions of the patch, thickness, size and permittivity of the substrate, surface wave, radiation, dielectric and conductor losses, and feed point location on the antenna characteristics. The information is of sufficient detail to enable an engineering design that exploits these effects to optimise performance. The principles and results of the research presented in this thesis are in a form which is intended to be easily understood by all who wish to use it, irrespective of their level of mathematical skill. Numerical results, pertaining to the analysis of microstrip antenna elements satisfactorily indicate the accuracy and utility of the developed techniques for designing microstrip antennae and calculating mutual coupling coefficients between two rectangular antenna elements.