Preface to the Second Edition (Student Edition)

Since this book was first published in 1985 the topic of Surface Acoustic Wave Devices has continued to develop, confirming its niche as the major technology for passive filters in the 50 to 2000 MHz region. In addition to widespread development of commercial products, continuing research and development efforts have yielded further advances. For example, a variety of new techniques for low-loss filtering make front-end filtering feasible, thus opening up the possibility of substantial new markets. Stabilities obtainable from SAW oscillators have improved markedly, and fabrication techniques can now give 0.5 micron linewidths in production, increasing the SAW frequencies obtainable.

While maintaining its original function as a reference work, it is hoped that this soft-covered second Edition will also be useful for students on university courses and others new to the field. I am delighted that, with some support from colleagues, the publishers have decided to issue this edition. The subject continues to fascinate its practitioners, with its seemingly endless variety of devices, the wide range of technical topics, and the challenge of meeting exacting practical requirements – more exacting as time goes on. I hope that new readers will find the book both illuminating and enjoyable.

Some minor mathematical errors have been corrected in the new edition.

DAVID MORGAN

Preface

Devices using acoustic waves have been employed in electronic systems for many years, notable examples being the quartz crystal oscillator and the acoustic delay line, both of which use acoustic wave propagation in the bulk of a material. In contrast, the use of *surface* acoustic waves, in which the wave motion is bound to a plane surface of a solid, has developed quite recently, though the existence of the wave itself was established by Lord Rayleigh in the 19th Century. The use of surface waves introduces several attractions, notably a considerable degree of versatility due to the accessibility of the wave in two dimensions, and the prior existence of a variety of suitable fabrication techniques. These attractions were first recognised in the 1960's, and since then there have been substantial developments in understanding the wave behaviour and a wide variety of electronic devices has emerged. Today, surface-wave devices are used in many practical systems, particularly in communications, radar and broadcasting.

In this book I have chosen to concentrate on the devices most commonly found in electronic systems, and the principles underlying them. Most of these devices perform signal processing operations – for example, a bandpass filter is used to select some required frequency band, while chirp filters and PSK filters perform correlation of complex waveforms. To appreciate the function of the devices some knowledge of signal processing is necessary, and this is included in the appropriate parts of the book.

Chapter 1 gives a descriptive survey, intended to introduce the subject to those unfamiliar with it, and Chapters 2 to 5 give the theoretical background needed to appreciate the operation of the devices considered later. The devices here use surface waves in piezoelectric materials, which enable the waves to be generated or detected by means of metal electrodes on the surface. Chapter 2 considers basic properties of acoustic waves and emphasises surface waves in piezoelectric materials, though some other relevant cases are also included. Chapter 3 covers electrical excitation of surface waves, introducing the effective permittivity and the Green's function, and these concepts are applied to the analysis of interdigital transducers in Chapter 4 and to multi-strip couplers in Chapter 5. Interdigital transducers are used in all of the devices considered in this book, and in many devices the response is determined mainly by the

transducer behaviour, which is therefore treated in detail. The analysis for transducers and multi-strip couplers makes use of the quasi-state approximation, described in Section 4.3. This simplifies the results considerably since it neglects electrode interactions, which are not very significant in most practical devices; however, interaction effects are considered in Appendices D and E. Generation of bulk waves in surface-wave devices is another complication ignored in Chapters 4 and 5, but this is considered in Appendix F.

Chapter 6 describes several surface-wave propagation effects, particularly diffraction, and gives a comparative assessment of materials commonly used for practical devices. The remaining chapters are mainly concerned with the design and performance of devices. Chapter 7 describes delay lines, including some practical aspects of transducer performance, while bandpass filters are covered in Chapter 8. Chapter 9 describes chirp filters, commonly used in pulse-compression radar systems, including interdigital devices and reflective array compressors. This chapter also includes the characteristics and design of chirp waveforms. Finally, Chapter 10 is mainly concerned with devices for spread-spectrum communication systems, including the PSK filter and the non-linear convolver which are used to correlate phase-shift-keyed waveforms. The surface-wave oscillator and resonator are also considered briefly.

It should be noted that the coverage here is quite selective. The literature includes substantial material on topics hardly mentioned, for example interaction with light and with semiconductors, and the behaviour of surface-wave waveguides. There is also a very considerable variety of devices in addition to those mentioned above, and these are omitted apart from some brief comments.

The book is intended to appeal mainly to engineers developing surface-wave devices and to those developing systems using the devices, though it should also be helpful in connection with university course or research work. The reader will not need a prior knowledge of acoustics, as the concepts required are included in Chapter 2. However, an undergraduate-level knowledge of network analysis, and of some basic concepts of crystallography, are assumed. The extensive use of Fourier transforms arises quite naturally, since the time- and frequency-domain representations of a device response both correspond to common laboratory measurements, and both domains occur in device specifications. In addition, Fourier transforms are used in the analysis of transducers and other structures. The relationships needed are summarised in Appendix A, which also gives some basic relationships for analysis of linear filters. However, the reader unfamiliar with these topics will probably find that further reading, from the references quoted in Appendix A for example, will be helpful.

The material in this book arises from experience in several laboratories, and has benefited substantially from cooperation and discussion with many colleagues. It is a pleasure to acknowledge the past involvement with colleagues in University College London, the Central Research Laboratories of the Nippon Electric Company Ltd. (Kawasaki), and the University of Edinburgh. I am especially indebted to the surface-wave group in Plessey Research (Caswell) Ltd. Many of the ideas in the book arose from the work of this group, and most of the experimental results shown refer

to devices developed by the group. In particular, I wish to mention R. W. Allen, R. Almar, R. Arnold, R. E. Chapman, R. K. Chapman, J. M. Deacon, R. M. Gibbs (who fabricated most of the devices), W. Gibson, J. Heighway, J. A. Jenkins, P. M. Jordan, B. Lewis, J. G. Metcalfe (who also computed some theoretical figures for the book), R. F. Milsom, J. J. Purcell, D. Selriah and D. H. Warne. Many helpful discussions were contributed by E. G. S. Paige and M. F. Lewis. During the writing of the book the initial drafts were reviewed by E. G. S. Paige, B. Lewis and, in part, by J. J. Purcell, and I am greatly indebted to these gentlemen for their thorough and painstaking efforts; their comments have been of immense value throughout the writing process. Much of the work reported was supported by the Procurement Executive of the U.K. Ministry of Defence, sponsored by DCVD, and this applies in particular to the development of reflective array compressors and convolvers.

Thanks are also due to the management of Plessey Research (Caswell) Ltd. for some of the time involved and for funding the typesetting, and in particular to the Director, Dr. J. C. Bass, for his encouragement and for kindly contributing the Foreword. I am also grateful to the staff of The Alden Press (London and Northampton) Ltd. for their fine work in typesetting the script and preparing the figures.

DAVID MORGAN
Caswell, 1985