NEWNES GUIDE TO

Radio and Communications Technology

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Preface

Radio technology is a fascinating subject that encompasses an enormous number of topics. In recent years its importance has risen tremendously. Originally its uses were restricted and normally licences were required. Now it is regulated less and with the widespread use of cellular telephones, wireless local area networks and much more, it is used in a far wider range of applications.

The aim of this book is first to provide a grounding in the principles that underpin radio, and then to provide understandable introductions to various radio applications from broadcasting to satellites and cellular telecommunications to wireless local area networks.

Many of the basic principles have been long established, but the new technologies are advancing at a tremendous rate. Possibly the fastest changing area is that of cellular telecommunications. The first main systems started to appear in the 1980s. During the 1980s their use was restricted mainly to businesses as the costs of owning and using these phones was high. However, this has all changed and they are widely used across sectors of business and society. It is the aim of this book to look at today's latest technologies so that the reader is able to gain a good appreciation of what is actually being used now.

In preparing this book it has been necessary to seek the advice and assistance of several other people. I am indebted to many that have helped by discussing technologies, providing reference material, reviewing the work and supplying images. The support, assistance and encouragement of all has been very much appreciated, and has been invaluable in the preparation of the book.

Ian Poole
January 2003

1 An introduction to radio

Radio technology is an integral part of our everyday lives. Since it was first invented, its importance has steadily increased and today we have come to accept all that radio technology offers and we take it for granted. By providing a means of sending information without wires it offers the flexibility that is becoming increasingly important in today's highly mobile world.

Radio performs many functions today. One of the most established uses is domestic broadcasting. Most homes have a variety of radio sets, ranging from the relatively simple and cheap portable radios, through the more sophisticated car radios to the high fidelity systems. All of these sets offer a high degree of performance that has resulted from many years of use and development. Even so the performance of radio sets is being improved all the time and new facilities are being introduced. The introduction of wideband FM represented a major improvement when it was first introduced. Stereo facilities are now taken for granted and other enhancements like RDS (Radio Data System) are available in many countries today. Beyond this digital radio or digital audio broadcasting has started. This brings true CD quality to radio broadcasts as well as allowing data to be broadcast at the same time.

Cellular telecommunications is another technology that has been made possible by the development of radio. By the use of radio technology, telecommunications has been given considerably greater flexibility as previously only landlines were available. The flexibility offered by cellular phones has given rise to a phenomenal growth in this area. In

Figure 1.1 *A digital radio tuner (courtesy Arcam)*

Figure 1.2 *An example of a mobile phone handset (courtesy Nokia)*

many countries in the world around 60 to 70 per cent of the population own one of these phones. The enormous usage has enabled a considerable amount of development to be undertaken. The first phones that were used were very large. Now phones can be slipped into a shirt pocket, and all the time the level of functionality they offer is increasing. The first generation systems used analogue technology. The second generation systems use digital technology, and now the third generation systems (3G) are offering high data rate capabilities that will enable them to provide far more facilities and flexibility.

Radio is being used increasingly in many short range 'wireless' applications. Not only are many items such as remote very low power short-range devices including door bells, thermostats and the like being widely used these days, but standards like Bluetooth, HomeRF and 802.11 are being developed and equipment introduced for interconnecting computer devices, mobile phones, and many devices around the home. This is likely to fuel an enormous growth in the short-range radio market as it will mean that offices and the home will use radio instead of wires.

Radio is also used for long-range communications. Satellite technology has enabled radio communications to reliably span the world. Once the short wave bands were used, but even though there are many uses for these frequencies most of the communications we use today are routed via satellites to give communications worldwide. Satellites are used for many purposes. Obviously they enable long-distance communications to be made, but they are also used in applications that include weather monitoring, navigation, search and rescue, direct broadcasting and much more.

Naturally there are many other areas where radio is used today, from point to point communications to other forms of radio links, and it is not possible to mention them all.

There has been a vast amount of investment needed to achieve the high standards of communication needed today. Satellites, microwave links, cellular phone base stations, sophisticated radio data links are but a few that are needed to support today's requirements. To achieve this a number of different types of technology are needed: antennas, transmitters, and receivers as well as several other items are all needed to make up the complete system. This provides a great amount of variety for anyone looking to take radio up as a career or hobby.

Before looking at the emerging technologies and where radio technology is moving, it is always worth having a look at how radio technology arrived at where it is today. In this way it is possible to understand some of the reasons why it is structured and organized in the way it is. The story of the development is fascinating and the very earliest discoveries of major importance can be traced back thousands of years.

The story of radio

The very first discoveries of interest in this story can be traced back to the ancient Greeks and Chinese who investigated the properties of lodestone, a magnetic oxide of iron. In fact the Chinese are often credited with the invention of the magnetic compass. Knowledge of this discovery spread over the known globe and eventually it reached Europe. Here the Greeks with their well-developed society paid most attention to it.

Another early discovery of major importance was that when amber was rubbed against another material, it attracted other objects towards it. This phenomenon possibly added value to the stone when it was traded.

These were only basic discoveries and very little was understood about them. It took many hundreds of years before people started to make any progress.

One of the first people to make anything of these phenomena was William Gilbert, the physician to Queen Elizabeth I of England. He performed a vast number of experiments on magnetism and electrostatics, discovering electrostatic repulsion and the fact that the earth acts as a giant magnet. He published his findings in 1600 in a large volume entitled *De magnete* written in Latin.

After this many other researchers added their own contributions to the newly developing science associated with electricity. Volta, for example, discovered that electricity could be produced by using two dissimilar metals separated by a suitable solution. Ampère made significant advances in linking electricity and magnetism by describing the magnetic forces that exist around a current carrying conductor. Georg Ohm is also well known, especially for determining how current flow was governed in a conductor. This culminated in the famous Ohm's law.

Many other famous names like Faraday, Oersted and Henry made very significant contributions, laying the foundations for developments in radio that were made in the years to follow.

Electricity soon started to find some uses, and became more than just a phenomenon to be demonstrated in the laboratory. The need to communicate swiftly over large distances had long been recognized. The French had set up a system of semaphore towers primarily for military purposes. However, electrical systems were soon introduced. Some early versions were very ambitious. Together Cooke and Wheatsone developed a system of pointers that indicated the required letter. In 1837 the first experimental link was opened between Euston and Camden stations. Although the experiment was a technical success the directors of the company were not impressed and the system was dismantled. Two years later the Great Western Railway Company agreed that a system could be installed between Paddington and West Drayton (not far from where Heathrow Airport stands to the west of London). Two years later this was extended to Slough, allowing communication between the stations. The initial systems required five wires, and as wire production was very expensive it meant that very few systems were installed.

It took a few more years for a system to be developed that would gain widespread acceptance. The inventor was an American artist named Samuel Morse. He had always taken an interest in the new and developing science associated with electricity and while returning by ship from Europe shortly after the discovery of the electromagnet he developed some ideas for an electrical signalling system. On his return to the USA his work commitments took priority and development was particularly slow. Eventually he enlisted assistance from others and the development started to move forwards. After many setbacks he eventually convinced the American Congress to provide funding for a trial line and on 24 May 1844 Morse sent his first message along the line between Baltimore and Washington which read 'What hath God wrought!'. The system quickly gained acceptance because it only used one wire and was easy and reliable to use. Not only did its use spread very rapidly in the USA, but it was used worldwide, linking countries and continents, enabling messages to be sent across the world in a few minutes or hours where they would have taken weeks before.

The Morse system only enabled text messages to be sent. The next major development entailed the sending of sounds over wires. The invention of the telephone is often credited to a Scot named Alexander Graham Bell. He had followed his father in working to enable deaf people to speak and in 1870 the Bell family moved to Canada. Bell was very successful and soon found himself appointed as Professor of Vocal Physiology at Boston University in the USA. His researches involved looking at sound vibrations, and this led him to wonder whether these vibrations could be transmitted along wires in the form of electrical variations. His initial attempts at realizing his idea gave sounds that were unintelligible. Then in 1876 he set up a new system, and the first message that was successfully transmitted over wires was Bell saying 'Mr Watson, come here I want you.' Bell had spilt some acid from a battery over himself and he wanted his assistant Watson to help. In this way the first telephone message was an emergency call!

These were many of the essential foundations that were required before discoveries in radio could begin. Here the first major stone was set in place by a brilliant mathematician and researcher named Maxwell. Born in 1831 he entered Edinburgh University when he was only 16. After graduating, he spent time at a number of universities, but it was when he was at King's College in London that he undertook most of the work into electromagnetic theory for which he is famous. He published three main papers between 1855 and 1864, and finally summarized his work in a book entitled *Treatise on Electricity and Magnetism*. His work proved the existence of an electromagnetic wave. However, much of Maxwell's work was theoretical and he was never able to demonstrate the presence of electromagnetic waves in practice. Sadly, Maxwell died at the early age of 48, and the work he started was left to others to continue.

The quest for the electromagnetic wave took many years. A number of people including Edison and Henry came close to discovering it. However, it was a German named Heinrich Hertz to whom the honour fell.

Hertz performed a wide variety of experiments to prove the existence of these new waves. He also gave a number of demonstrations and lectures. In one of these he used an induction coil connected to a loop of wire in which two large spheres were placed slightly apart. The induction coil generated a large voltage in the circuit causing a spark to jump across the gap. In turn this caused a spark to jump across the gap of a similar coil with two spheres placed within a few metres of the transmitter.

Using other equipment Hertz managed to prove many of the basic properties of these waves. He showed that they had the same velocity as light, and they were refracted and reflected in the same way. As Hertz had discovered the waves, they soon became known as Hertzian waves.

With the existence of the electromagnetic wave firmly established it did not take long before people started to think of using them for communicating. However, to be able to achieve this it was necessary to be able to have a much better way of detecting them. This came in the form of the coherer. A Frenchman named Edouard Branly initially designed it in 1890. He discovered that the resistance of a glass tube filled with metal filings fell from a very high resistance to a few hundred ohms when the filings cohered or clung together when an electrical discharge took place nearby. A small tap on the glass could reset it quite easily.

After its initial discovery the coherer was greatly improved and popularized by an English scientist named Sir Oliver Lodge. Such were his improvements that in 1894 he was able to detect signals from a transmitter a few hundred yards away.

It was around this time that a young Italian named Marconi started to experiment with Hertzian waves. His drive, intuition and business sense enabled this new science to progress much faster than it would otherwise have done.

Marconi was born in Bologna in northern Italy in 1874, receiving a private education during his early years. Despite his parents' expectations he failed to gain a place at Bologna University. Fortunately he had a growing interest in science and a family friend who was a lecturer at the university encouraged him. Marconi was allowed to sit through his lectures and through this he discovered about the new Hertzian waves.

Marconi quickly became interested and soon started to perform many experiments in the attic of his parents' house. Early in the summer of 1895 he managed to transmit a signal a distance of a few yards. By the end of the summer he had succeeded in receiving a signal over 2 km away from the transmitter.

Even at this early stage Marconi was able to see the commercial possibilities. Accordingly he approached the Italian Ministry of Posts with his ideas for wire-less communications, but his proposal was turned down. It was this rejection which caused Marconi to come to England in 1896.

On his arrival he soon set to work and filed a patent for a system of wireless telegraphy using Hertzian waves which was granted on 2 June 1896. In England there was considerably more interest for Marconi's work. Soon he was introduced to a man named William Preece who was the chief engineer of the Post Office.

Marconi gave some preliminary demonstrations of his equipment in the laboratory and then he set up a transmitter and receiver on the roofs of some buildings in London a few hundred yards apart. The success of this demonstration promoted a further demonstration on Salisbury Plain in September 1896 when representatives of the Post Office together with others from the War Office and the Navy were present.

The Navy saw the possibilities of using wireless equipment for communication at sea and they showed considerable interest. However, Marconi also started to sell his equipment to other maritime users. Initially the take-up was slow, but soon other organizations like Lloyd's endorsed its use as a method of sending distress signals and very quickly more vessels were fitted with Marconi's equipment.

Not satisfied with supplying equipment for maritime use, Marconi also started to investigate its use for providing a long-distance communications link. Initial experiments sending a message across the English Channel proved the possibilities and gave valuable propaganda. But the main goal was to be able to send a message across the Atlantic. This was not an easy task. Many difficulties needed to be overcome, but with the help of his team consisting of Vyvyan, Professor Fleming of University College London, Paget, and Kemp, stations at Poldhu in Cornwall and Cape Cod were soon established. Unfortunately the aerials were destroyed in storms and it was decided that their design should be changed. At the same time the site at Cape Cod was abandoned in favour of one at St Johns in Newfoundland. Finally on 12 December 1901 the first transmission was received when the letter 'S' was detected in the receiver and Marconi became a legend in his own time.

This was a major success, and it ably proved the value of wireless as a means of providing long-distance communications. However, it also

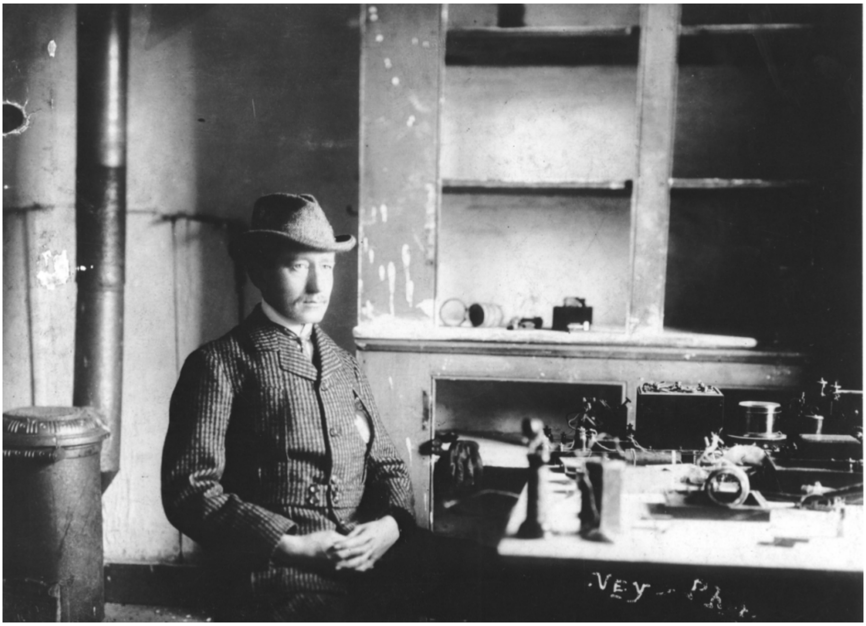

Figure 1.3 *Marconi after his transmission (courtesy Marconi plc)*