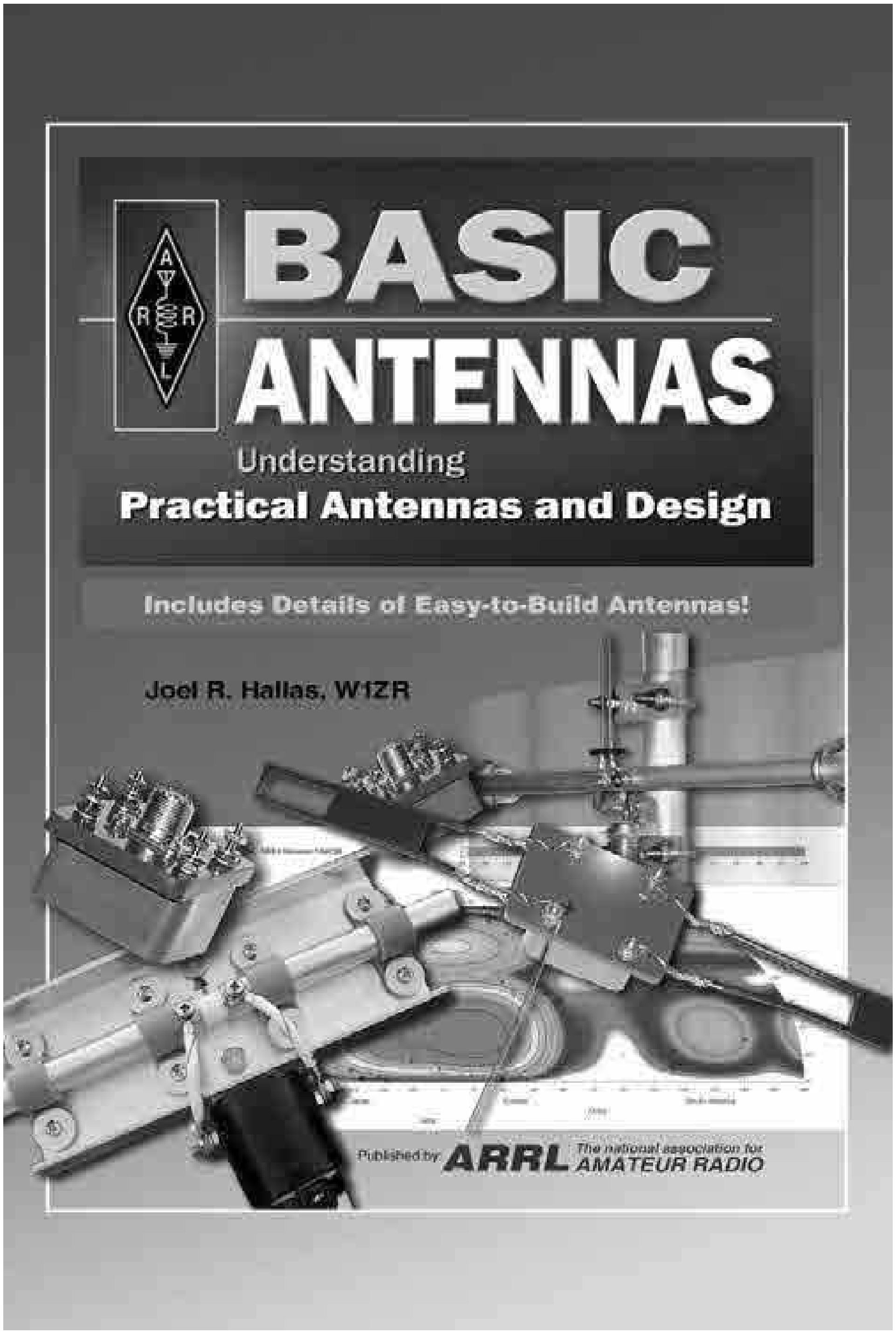

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Foreword

Antennas are one of the most critical elements of a radio system, yet perhaps one of the least understood. Most people involved in the radio arts enter from a background in the circuitry required to define radio equipment and many have difficulty making the transition to the electromagnetic side of radio.

This book is intended to assist those with a basic knowledge of radio technology in making that important leap from the circuit domain to the antenna domain. The technology is developed using the minimum of mathematical concepts to allow introduction of basic principles in an easy to read manner. This book assumes that you have been through and understand the concepts presented in *Understanding Basic Electronics* or a similar course of study in basic electronics principles. It also is assumed that you understand electronics as applied to basic radio systems as was presented in *Basic Radio — Understanding the Key Building Blocks*.

Upon completion of this book, readers should have enough understanding of the basic principles of antenna systems to be able to easily make decisions about selection of antennas for their applications or proper use of more advanced materials on the topic, such as are found in *The ARRL Antenna Book*.[1] There you will find the detailed numerical and mathematical data required to successfully construct and deploy many of the antenna types described here.

As with all ARRL books, be sure to check to see if there are any last minute changes that didn't get into the book before it went to the printer. Updates and errata, if any, can be found at **www.arrl.org/notes/**.

David Sumner, K1ZZ
Executive Vice President
Newington, Connecticut
October 2008

[1] R. D. Straw, Editor, *The ARRL Antenna Book,* 20th Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9043. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

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About the ARRL

The national association for Amateur Radio

The seed for Amateur Radio was planted in the 1890s, when Guglielmo Marconi began his experiments in wireless telegraphy. Soon he was joined by dozens, then hundreds, of others who were enthusiastic about sending and receiving messages through the air—some with a commercial interest, but others solely out of a love for this new communications medium. The United States government began licensing Amateur Radio operators in 1912.

By 1914, there were thousands of Amateur Radio operators—hams—in the United States. Hiram Percy Maxim, a leading Hartford, Connecticut inventor and industrialist, saw the need for an organization to band together this fledgling group of radio experimenters. In May 1914 he founded the American Radio Relay League (ARRL) to meet that need.

Today ARRL, with approximately 150,000 members, is the largest organization of radio amateurs in the United States. The ARRL is a not-for-profit organization that:

- promotes interest in Amateur Radio communications and experimentation
- represents US radio amateurs in legislative matters, and
- maintains fraternalism and a high standard of conduct among Amateur Radio operators.

At ARRL headquarters in the Hartford suburb of Newington, the staff helps serve the needs of members. ARRL is also International Secretariat for the International Amateur Radio Union, which is made up of similar societies in 150 countries around the world.

ARRL publishes the monthly journal *QST*, as well as newsletters and many publications covering all aspects of Amateur Radio. Its headquarters station, W1AW, transmits bulletins of interest to radio amateurs and Morse code practice sessions. The ARRL also coordinates an extensive field organization, which includes volunteers who provide technical information and other support services for radio amateurs as well as communications for public-service activities. In addition, ARRL represents US amateurs with the Federal Communications Commission and other government agencies in the US and abroad.

Membership in ARRL means much more than receiving *QST* each month. In addition to the services already described, ARRL offers membership services on a personal level, such as the ARRL Volunteer Examiner Coordinator Program and a QSL bureau.

Full ARRL membership (available only to licensed radio amateurs) gives you a voice in how the affairs of the organization are governed. ARRL policy is set by a Board of Directors (one from each of 15 Divisions) elected by the membership. The day-to-day operation of ARRL HQ is managed by a Chief Executive Officer.

No matter what aspect of Amateur Radio attracts you, ARRL membership is relevant and important. There would be no Amateur Radio as we know it today were it not for the ARRL. We would be happy to welcome you as a member! (An Amateur Radio license is not required for Associate Membership.) For more information about ARRL and answers to any questions you may have about Amateur Radio, write or call:

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Fax: 860-594-0259
E-mail: **hq@arrl.org**
Internet: **www.arrl.org/**

Prospective new amateurs call (toll-free):
800-32-NEW HAM (800-326-3942)
You can also contact us via e-mail at **newham@arrl.org**
or check out *ARRLWeb* at **http://www.arrl.org/**

Chapter 1

Introduction to Antennas

This impressive collection of antennas is part of the ARRL station, W1AW

Contents

So What is an Antenna?

For something so simple to check out, and often so simple to make, an antenna is remarkably difficult for many people to understand. That's unfortunate, because for many radio systems the antenna is one of the most important elements, one that can make the difference between a successful and an unsuccessful system.

How Can You Picture Antennas?

Perhaps an analogy from *The ARRL Antenna Book* will help. You are familiar with sound systems. Whether represented by your home stereo or by an airport public address, sound systems have one thing in common. The system's last stop on its way to your ears is a *transducer*, a device that transforms energy from one form to another, in this case — a loudspeaker. The loudspeaker *transforms* an electrical signal that the amplifier delivers into energy in an acoustic wave that can propagate through the air to your ears.

A radio transmitter acts the same way, except that its amplifier produces energy at a higher frequency than the sound you can hear, and the transducer is an *antenna* that transforms the high-frequency electrical energy into an electromagnetic wave. This wave can propagate through air (or space) for long distances.

For some reason, perhaps because of our familiarity with audio systems or because you can actually hear the results in your ears, it seems easier to grasp the concept of the generation and propagation of acoustic waves than it is to understand the generation and transmission of radio waves.

The audio transmitter analogy can be continued in the receiving direction. A *microphone* is just another transducer that transforms acoustic waves containing speech or music into weak electrical signals that can be amplified and processed. Similarly, a receiving antenna captures weak electromagnetic waves and transforms them into electrical signals that can be processed in a receiver. **Fig 1-1** shows a system or block diagram of a sound system with transducers (loudspeaker and microphone) at each end.

Many of the phenomena that act upon acoustic waves also occur with electromagnetic waves. It is not an accident that a parabolic reflector radar antenna looks very much like a parabolic eavesdropping microphone, or that sonar and radar operate in the same fashion. *Sonar* relies on acoustic waves propagating through water to find and reflect back from underwater objects, such as submarines or schools of fish. Similarly, *radar* sends out electromagnetic waves through space, listening for signals reflected back from objects such as aircraft, space vehicles or weather fronts. **Fig 1-2** shows simplified system

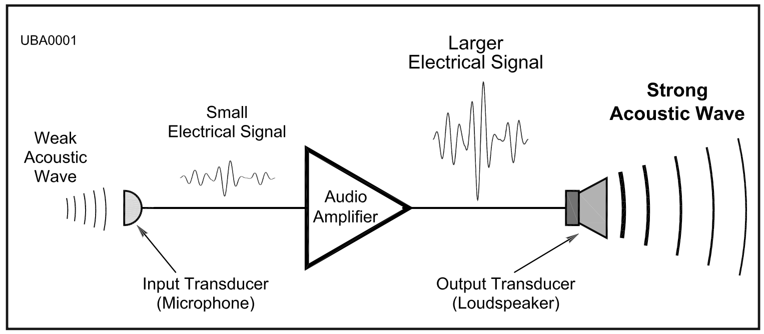

Fig 1-1 — Illustration of transducers changing one form of energy into another.

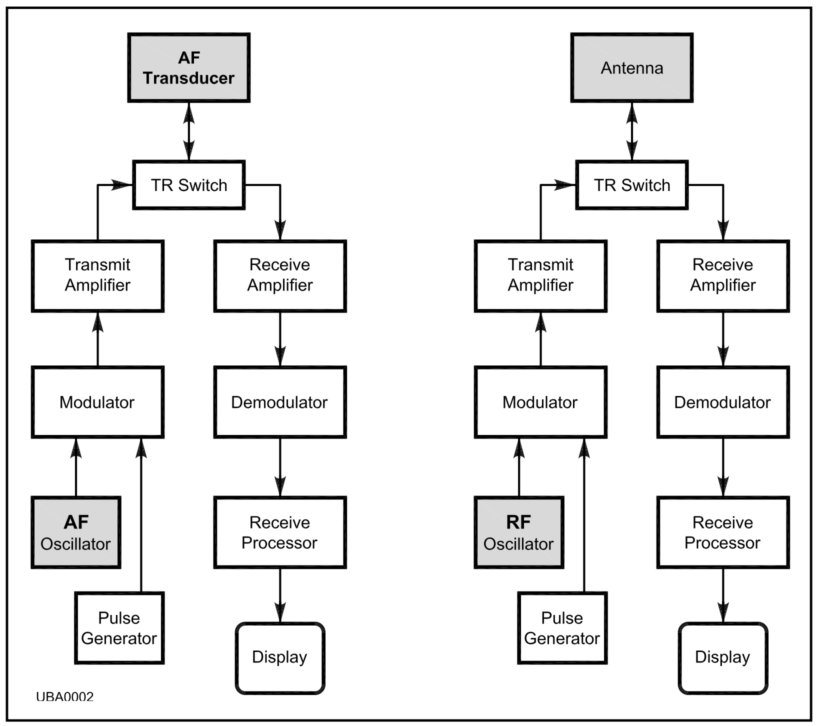

Fig 1-2 — At (A), simplified system diagram of a sonar system. At (B), simplified system diagram of a radar.

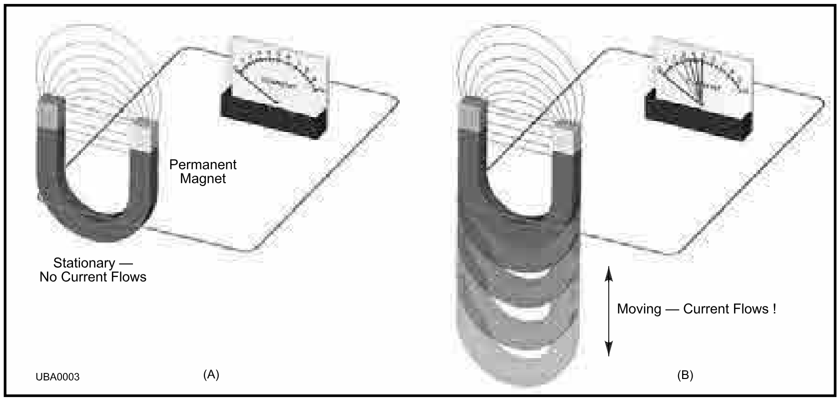

Fig 1-3 — A wire immersed in the magnetic field of a permanent magnet. At A, if everything is static there is no current flow in the wire. At B, if you move the wire up and down within the field, the wire experiences a changing magnetic field and current is induced to flow.

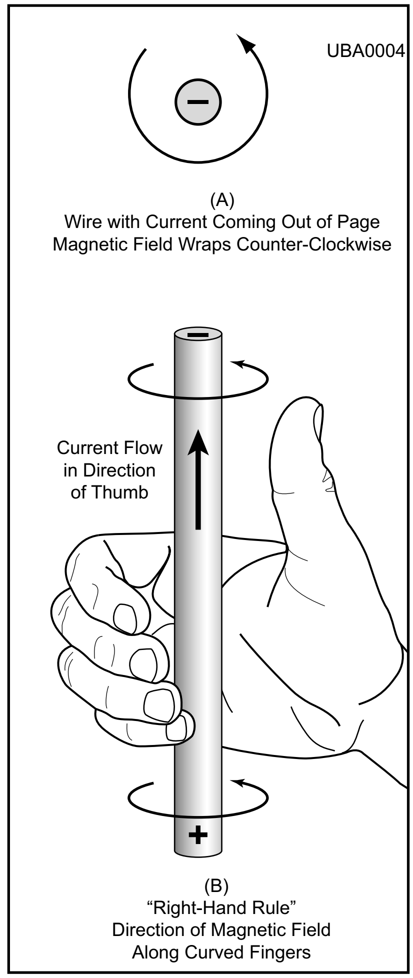

Fig 1-4 — Direction of magnetic field around a wire.

diagrams of radar and sonar systems.

While we're mentally picturing antennas, perhaps an even better analogy than acoustic waves is to compare electromagnetic waves of light to those of radio signals. Light waves propagate through space using the same mechanisms and at the same speed as radio waves. Similar parabolic shapes can reflect and focus both light and radio waves. Light needs a polished mirror as a reflector, such as the mirrored reflector in your flashlight or car headlight. I will sometimes draw on your appreciation of light reflection as I discuss some types of antennas.

What's an Electromagnetic Wave?

An *electromagnetic wave*, as the name implies, consists of a combination of the properties of both electric and magnetic fields.

Static Electric and Magnetic Fields

You are no doubt familiar with magnetism and electricity from everyday experience. One kind of magnetism and electricity is the *static* form. Static electricity is a collection of positive or negative charges that are at rest on a body until discharged by a current flow. This happens to your body when you walk across a rug on a dry day. In climates where the humidity is very low, particularly during the winter, your body can accumulate a charge, perhaps making your hair stand up. That lasts until you discharge the accumulation by touching a grounded object, such as a screw on a light switch plate, or even the long-suffering dog's nose. Then the charge is dissipated sometimes quite dramatically— with a big spark.

Similarly, a static magnetic field exists around a permanent magnet. You can observe the effect of magnetism on a compass needle or even on a screwdriver.

Static electric and magnetic fields do not result in electromagnetic waves. It is only when a magnetic or electric field is *changing* that you can have electromagnetic radiation. You can visualize the effect by considering some other things that make use of electric and magnetic fields. **Fig 1-3** shows a wire immersed in the magnetic field of a permanent magnet. If everything is static (Fig 1-3A) there is no current flow in the wire. If you change the magnetic field at the wire by moving the wire up and down within the field (Fig 1-3B), the changing magnetic field causes a current to flow. This is how an electric power generator transforms mechanical energy into electrical energy.

You could cause the same effect by keeping the wire in one position and changing the magnetic field around it. You could do this by moving the magnet, but more interestingly you could replace the permanent magnet with an electromagnet and change the current in it. This is just a *transformer*, something with which you are familiar. When you change the current in the transformer winding, you can move between electric and magnetic fields.

Direction of Fields

Both magnetic and electric fields act in particular directions. A magnetic field acts around the conductor carrying the current. The convention for its direction is that if positive current is flowing in a particular direction, the magnetic field will go around the wire, as shown in **Fig 1-4A**. This can be remembered by calling on the *right-hand rule*. This rule says that if you hold a current carrying wire in your right hand, with the current going in the direction of your thumb, the magnetic field will be in the direction of your curled fingers, as shown in Fig 1-4B.

Electric fields act between areas