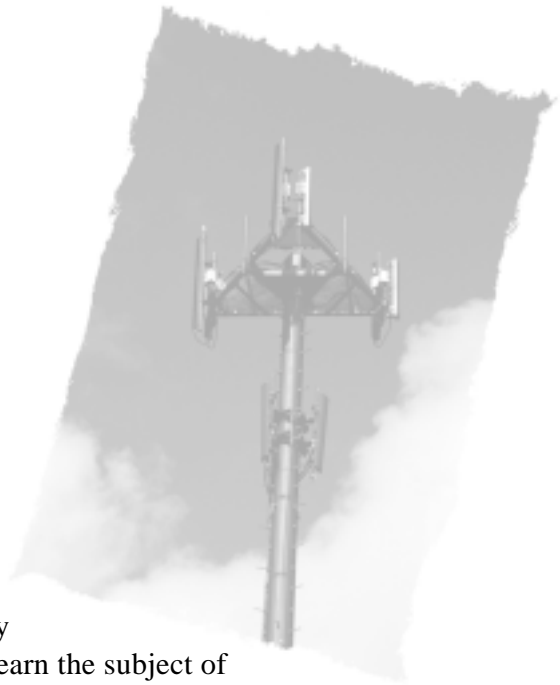


1

Basic Concepts



This chapter introduces you to the minimum vocabulary and concepts you will need to learn the subject of RF. Before you learned to read and write, you needed to learn your ABCs. This chapter is the ABCs of RF. In it you will be reintroduced to terms you probably learned back in high school, like scientific prefixes. You will also be introduced to some terminology common to all fields of electronics, not just RF, like watts, circuit, and Hertz. And of course the term RF—with all its meanings—will be thoroughly explained.

An important concept introduced in this chapter is the block diagram, which is a graphical depiction used to illustrate RF hardware. In this chapter it is used to show the two basic building blocks of *all* wireless systems: transmitters and receivers. The two forms which electrical energy can take are discussed, along with the two types of electrical signals: analog and digital.

Frequency, the single most important concept to understanding RF, is explained in full detail. And finally, a surprising aspect of wireless communications is highlighted—the fact that wireless communication actually involves combining two different forms of electrical energy: one to store the information and one to carry the information.

INTRODUCTION

WARNING! This book is an oversimplification of a very complex topic. (Your best bet is to keep it away from RF engineers.) When you are done with this book you will not be able to design RF circuits—nor should you want to. However, you should be able to converse intelligently about RF and wireless concepts, understand the lingo, and generally visualize what is going on.

The driving force behind this book is simplicity. It is meant to facilitate a qualitative understanding of an inherently quantitative topic. Many analogies and metaphors are used throughout the book to help you visualize concepts, and where there is a choice between simplicity and factual rigor, the book tends to err on the side of simplicity. My feeling is you don't need to know how to grow tomatoes to eat a pizza and you don't need to know Maxwell's equations¹ to understand RF.

This book is intended for people working in and around the RF and wireless industry without a technical degree. The assumption I have made is that you know absolutely nothing about electronics, RF, or any other arcane science. And in an effort to keep things fun, I have included only one formula for you to memorize in the entire book; here it is:

$$B = M$$

This equation means the more books which are bought, the more money I make. That's it—you can kick back and relax.

In this book the terms *RF* and *wireless* are used interchangeably just to break up the monotony. Wireless is primarily a marketing term used to describe a subset of newer, RF applications, which include things like cellular telephony and paging, to mention a few. In this book the cellular phone is frequently used as an example to help you visualize what is going on. In fact, it is beat to death. Oh well, it is simple, everyone knows what it is, and it gets the point across. Remember, the goal here is simplicity.

There are two things to note. First, this book uses block diagrams to describe RF systems. If there were another way, I would have chosen it. Unfortunately, it is the simplest way to explain what is going on. Block diagrams

1. Why are you looking down here? I just told you that you don't need to know it.

consist of strange symbols connected by lines in a systematic way. In some ways, block diagrams are like a foreign language which RF engineers use to communicate what is happening in their RF world. When you are done reading the book, you will be able to interpret rudimentary block diagrams. It will be like vacationing in France after listening to a Berlitz tape on French for half an hour. You'll know just enough RF to get into trouble.

Second, every attempt is made in this book to keep the subject matter fun. Heaven knows the subject matter can use it.

VOCABULARY

Before you begin this journey, there are a few terms with which you need to become familiar. First and foremost is the term RF. The literal meaning of RF is *Radio Frequency*. However, it is more often used in its figurative sense as both a noun and an adjective. You can generate RF (a noun) or you can generate an RF signal (an adjective). (RF can also be used to describe a range of frequencies, but more about that later.) As will be explained shortly, when used in this book, it is best to think of RF as an electrical signal which is on the move.

Prefixes

Next, you will need to know the prefixes for the powers of ten (remember chemistry?). There are only four of any consequence and they are listed in Table 1-1.

Table 1-1 Some Useful Prefixes in RF

Prefix	Meaning	Example	Interpretation
milli (m)	1/1000 th	5 mW	0.005 Watts
kilo (k)	1000	3 kg	3000 grams
Mega (M)	1 million	2 MHz	2 million Hertz ^a
Giga (G)	1 billion	100 Gigabucks	Bill Gates' net worth

a. You don't know what this is yet.

Basic Electronics Terminology

Table 1–1 introduces you to another word you will need to know: watts. Watts are the unit of measure for power. If you don't know what watts are, just imagine touching a burning light bulb. A word related to power is energy, which is power times time. If a 100 watt light bulb burns for two hours, it equals 200 watt-hours of energy. If you want to envision what energy is, just imagine touching a burning light bulb for two hours. A word of caution, though—in the strange world that is RF, the words power and energy are often used interchangeably.

Two words closely related to power and energy are *voltage* and *current*. Voltage is just an electric potential, and there are two kinds: AC (alternating) voltage is the type found in a wall outlet; DC (direct) voltage is the type found in a battery. Current is simply electrons on the move. Like voltage, current can also be made either alternating or direct. The exact relationship between voltage, current, and power is simple: voltage times current equals power.

An important word related to current and voltage and one used quite often is *circuit*. A circuit is an interconnection of a bunch of electrical stuff. Electrical circuits are sometimes manufactured on something called *printed circuit boards* (PCB). If you have ever seen the inside of a computer, VCR, or any other electrical appliance, you have seen a PCB. It is just a hard, thin, plastic board with electrical stuff mounted all over it.

A word you will see occasionally is *microwaves*. It is often used interchangeably with the term RF, but is mostly used to describe a range of frequencies. *Millimeter wave(s)* is also used to describe a range of frequencies.

You have probably figured out by now that the word *frequency* is very important in the world of RF. This word will be explained in detail later, but its importance cannot be over-emphasized. If you are going to understand the concept of RF at any level, you will eventually need to grasp the concept of frequency. If you already understand what frequency is, you've got it made. If you think it has to do with how often something occurs, you're right. Stay tuned.

Since I'm going to be using the cellular phone to explain how RF things work, another word you will want to be familiar with is *basestation*. Cellular basestations consist of, among other things, those blue or gray steel towers by the side of the road which are owned by the cellular providers and are used to communicate with cellular phones.

In the world of RF, all terminology eventually gets replaced by its acronym, and so it shall be in this book. After a concept is explained and the acronym noted in parentheses, the remainder of the book will use the concept and the acronym interchangeably. Cheer up. By choosing to use acronyms, several hundred pages are eliminated from your reading. Not to worry though, Appendix A contains nothing but acronyms to help you navigate the waters.

RF BASICS

Transmitters and Receivers

Electrical energy moves from place to place in one of two ways. It either flows as current along a conductor (a bunch of electrons moving down a metal wire), or it travels in the air as invisible waves. In a typical wireless system, the electrical energy starts out as current flowing along a conductor, gets changed into waves traveling in the air, and then gets changed back into current flowing along a conductor again (see Figure 1–1).

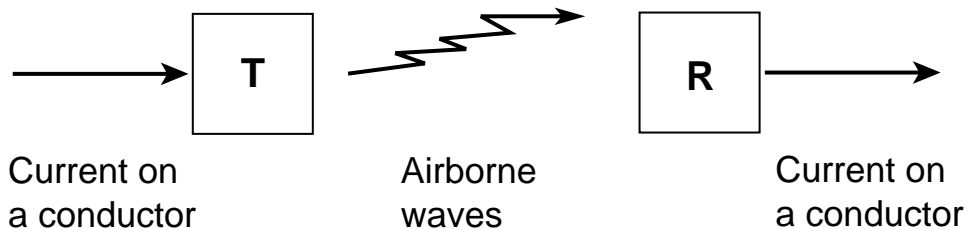


Figure 1–1 Block diagram of a generic wireless system.

In Figure 1–1, the electrical signal flows as current along a conductor (from the left) into the box marked “T.” Inside box T, a bunch of stuff happens and out comes essentially the same electrical signal—only this time it is traveling through the air. Box T is known as the *transmitter*. It turns electrical current into airborne waves. Now traveling at the speed of light, the airborne signal reaches the box marked “R.” Inside of the box marked R, some more stuff happens and out pops, you guessed it, the same electrical signal as current flowing along a conductor. Box R is known as the *receiver*. It turns airborne waves into electrical current.

Did You Know?

Sometimes RF engineers combine a transmitter and a receiver into a single functioning unit. Now what do you suppose they call this ingenious amalgam? A *transceiver*.

Signals

Analog Signals

Electrical energy (either current or waves) can actually store information if it is made to vary (in intensity) over time. When electrical energy varies over time in a controlled manner it is called a *signal*. Signals fall into one of two general categories: *analog* or *digital*. For those of you who were unfortunate enough to have suffered through high school trigonometry, you probably remember the sine wave. At the risk of stirring up horrible memories, there is a sine wave shown in Figure 1–2. As time goes by (moving from left to right in Figure 1–2), the intensity of a sine wave grows to some maximum at point B, then back to zero at point C, and on to some minimum value at point D, before finally returning to zero at point E and starting the whole process all over again and again and again.

A sine wave is an example of an analog signal. Whether it is current flowing down a wire or a wave traveling in the air, a sine wave signal varies (in intensity) exactly as shown in Figure 1–2. In the RF world, the intensity of a signal is almost always a measure of power (remember watts?). The number of times a signal goes through a complete up and down cycle (from point A to point E) in one second is the signal's *frequency* (measured in Hertz² and abbreviated Hz). If you find it difficult to remember what Hertz means, every time you hear the word Hertz just replace it with the term “cycles per second.” To get an appreciation for how fast these signals go up and down, a 900 MHz (megahertz) signal utilized in cellular telephony, not a particularly high frequency by today's standards, exhibits 900 *million* ups and downs in a single second. Wow!

2. Now you know what this is.

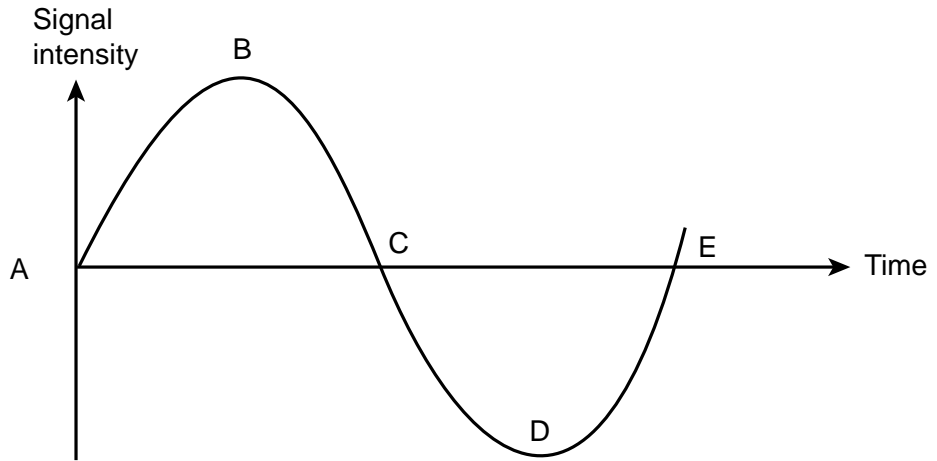


Figure 1-2 A sine wave.

Frequency

As mentioned in the introduction, the concept of frequency is key to understanding RF, because all RF stuff is frequency-dependent. That is, it can distinguish between two different signals *solely* on the basis of their different frequencies. Frequency is what separates one RF signal from another and it is what distinguishes one wireless application from another. Table 1-2 contains a sample of different wireless activities at different frequencies. You may not know what they all are yet, but you can still observe two things. First, notice how many different frequency-dependent applications there are—this is just a small sample—and second, the table is organized in such a way as to give you an appreciation for the difference in magnitude of all the frequencies.

Table 1-2 The Frequency of Various Activities

Frequency in Hertz	Application
60	Electrical wall outlet
2,000	The human voice
530,000	AM radio
54,000,000	TV channel 2 (VHF)

Table 1–2 The Frequency of Various Activities (Continued)

Frequency in Hertz	Application
88,000,000	FM radio
746,000,000	TV channel 60 (UHF)
824,000,000	Cellular phones
1,850,000,000	PCS phones
2,400,000,000	Wireless LAN
2,500,000,000	MMDS
4,200,000,000	Satellite big dish
9,000,000,000	Airborne radar
11,700,000,000	Satellite small dish
28,000,000,000	LMDS
500,000,000,000,000	Visible light
1,000,000,000,000,000,000	X-Files

Table 1–3 uses frequency to quantify some terms introduced earlier. These are not strict definitions, but rather general guidelines.

Table 1–3 Some Frequency Range Definitions

Term	Frequency Range
RF frequency	Less than 1 GHz
Microwave frequency	Between 1 GHz and 40 GHz
Millimeter wave frequency	Greater than 40 GHz

Apparently back in the old days, describing a signal’s frequency based solely on a number was too simple, so early RF engineers decided to use letters to reference certain frequency ranges called *bands*. To make matters worse, just when everyone memorized these bands, they went ahead and changed them all. Just by way of entertainment, I have included some of the more popular (old) band designations in Table 1–4. Now when somebody describes a satellite as working in “C-Band,” you will at least have an idea what range the signal’s frequency is in.

You now know that a signal at 3 GHz can be referred to as either a 3 GHz signal, a microwave signal, or an S-Band signal.

Table 1–4 Some Frequency Band Definitions

Band	Frequency Range
L-Band	1.0-2.0 GHz
S-Band	2.0-4.0 GHz
C-Band	4.0-8.0 GHz
X-Band	8.0-12.0 GHz
Ku-Band	12.0-18.0 GHz

Did You Know?

Somewhere around 1889 a German physicist named Heinrich Hertz actually succeeded in generating the first airborne RF waves in his laboratory. For all his daring and brilliance, the RF engineers of the world have honored him by using his name as the unit of measure for frequency. I guess we're lucky the first RF wave wasn't generated by Heinrich Schmellingstonberger.

Digital Signals

The other type of electrical signal is a digital signal, which is the same type used in a computer. Unlike the (analog) sine wave signal, which varies gradually between its high points and low points, a digital signal is one which varies instantaneously between two electrical values. For all practical purposes, there are no values between the high and low levels in a digital signal. A digital signal is shown in Figure 1–3. Notice there are only two signal levels: up and down (high and low). Digital signals can represent information in the pattern of highs and lows. For instance, a certain pattern of highs and lows can be used to represent your voice as you talk on a cellular phone.

While digital signals are used to “represent” information, they aren't used to “carry” information over the air. Only analog signals (sine waves) are used to carry information “on their backs” as they travel through the air. These analog “carrier” signals can carry either analog or digital “information” signals. The process of combining information signals on top of carrier

signals is called *modulation*, to be discussed later. When an information signal is combined with a carrier signal the result is known as wireless communications, and the analog signal doing the carrying is called RF or the *carrier* (go figure). An example of analog wireless communications is cellular telephony, the first generation of cellular phones. An example of digital wireless communications is Personal Communication Services (PCS), the second generation of cellular telephony. Both generations use RF to carry different formats of information.

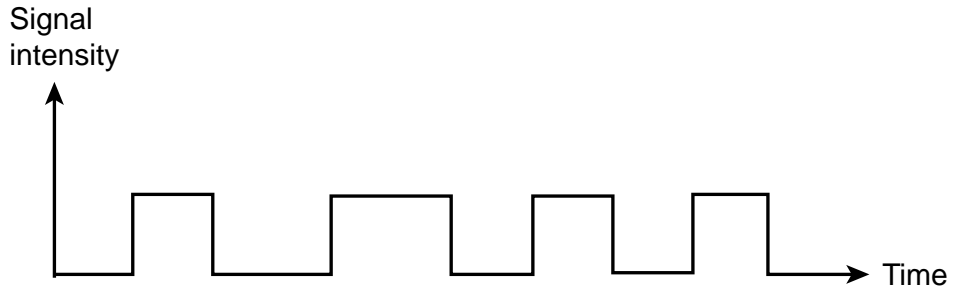


Figure 1-3 A digital signal.

Did You Know?

When a transmitter is always on and the RF signal comes out uninterrupted or continuously, that RF signal is referred to as a continuous wave (CW) RF signal. As you will learn later, there are actually wireless applications in which the transmitter is turned off and on rapidly, and the RF wave is not continuous. You might think that this type of RF signal would be referred to as a “discontinuous” wave RF signal, but it isn’t. Just to keep things interesting, RF engineers refer to that type of RF signal as a pulsed RF signal.

You may be wondering which is better— analog or digital wireless communications? The simple answer is it depends, as both approaches have their pluses and minuses. Two things are certain, though. First, digital wireless communications is newer than analog so most wireless communication today (circa 1999) is still analog, and second, digital wireless communication interacts seamlessly with all other digital appliances, like computers. For this reason alone, I think it is safe to say that most, if not all, new wireless communications systems coming on line in the future will be digital.

