What Is RF and Why Do We Use It?

Chapter 1 - Introduction to RF Principles and Components

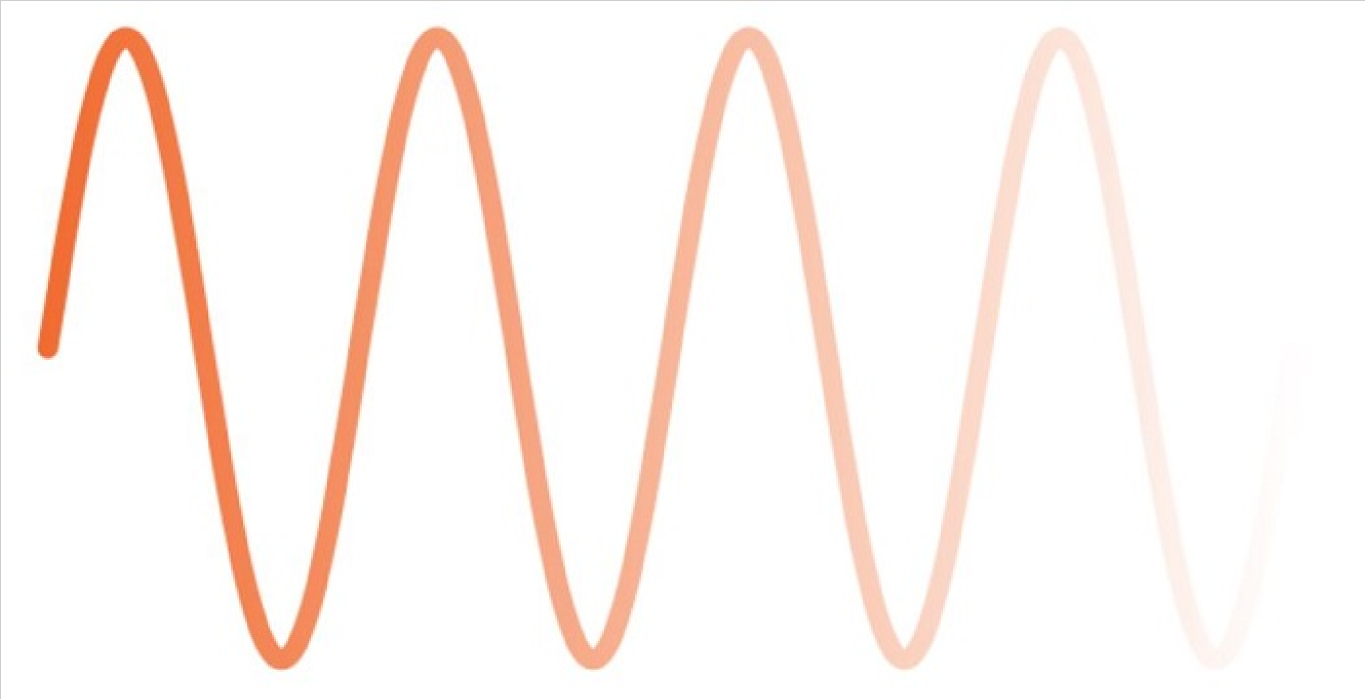
PDF Version

Learn about electromagnetic radiation and why it is so useful for wireless communication.

When we think of electricity, we naturally think of wires. From high-voltage transmission lines to tiny traces on a printed circuit board, wires are still the fundamental means of transferring electrical energy from one location to another.

But history has consistently demonstrated that human beings are rarely, if ever, satisfied with the fundamental way of doing things, and thus we should not be surprised to learn that the proliferation of electricity was followed by widespread efforts to free electrical functionality from the constraints of physical interconnections.

There are various ways to incorporate "wireless" functionality into an electrical system. One of these is the use of electromagnetic radiation, which is the basis for RF communication. However, it's important to recognize that electromagnetic radiation is not unique in its ability to extend electrical circuitry into the wireless domain. Anything that can travel through a nonconductive material—mechanical motion, sound waves, heat—could be used as a (perhaps crude) means of converting electrical energy into information that does not rely on conductive interconnections.



Carefully manipulated sinusoidal voltage (or current) signals are the foundation of the modern wireless age.

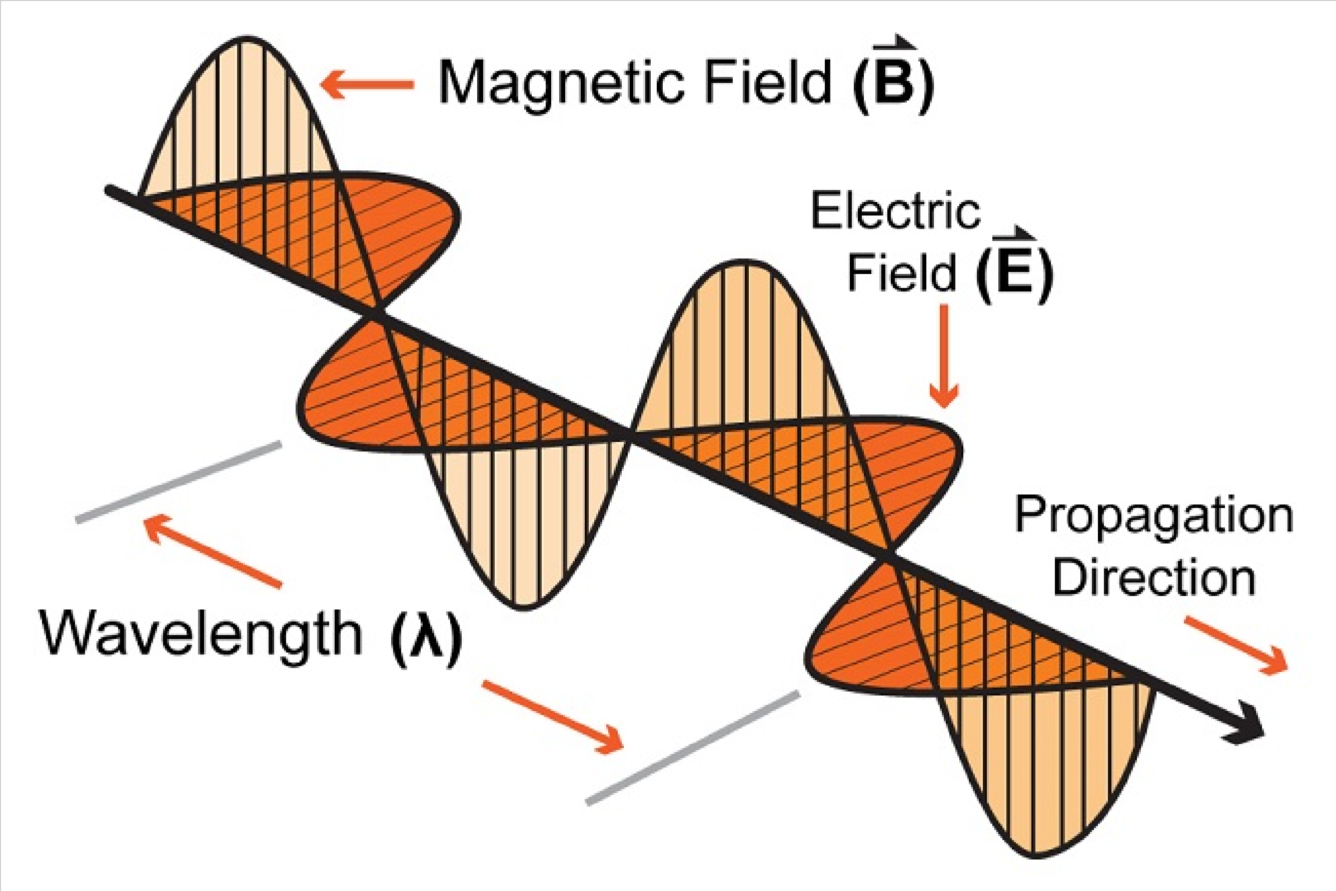
With this in mind, we can ask ourselves the more relevant questions: Why is electromagnetic radiation the preferred method? Why are other types of wireless communication of such secondary importance? Before we answer these questions, let's make sure we understand what electromagnetic radiation is.

Fields and Waves

You could spend years studying the details of electromagnetism. Fortunately, you don't need that sort of expertise to successfully design and implement RF circuits. But you do need to have a basic idea of the mysterious energy being emitted from your device's antenna.

As the name implies, electromagnetic radiation involves both electric fields and magnetic fields. If you have voltage—such as the voltage across the impedance of an antenna—you have an electric field (from a mathematical standpoint, electric field is proportional to the spatial rate of change of voltage). If you have electric current—such as the current passing through the impedance of an antenna—you have a magnetic field (the strength of the field is proportional to the magnitude of the current).

The electric and magnetic fields are present even if the magnitude of the voltage or current is constant. However, these fields would not *propagate*. If we want a wave that will propagate out into the universe, we need *changes* in voltage and current.



The electric and magnetic components of an electromagnetic wave are represented as perpendicular sinusoids.

The key to this propagation phenomenon is the self-sustaining relationship between the electric and magnetic components of electromagnetic radiation. A changing electric field generates a magnetic field, and a changing magnetic field generates an electric field. This mutual regeneration is manifested as a distinct entity, namely, an electromagnetic wave. Once generated, this wave will travel outward from its source, careening day after day, at the speed of light, toward the depths of the unknown.

Creating EMR vs. Controlling EMR

Designing an entire RF communication system is not easy. However, it is extremely easy to generate electromagnetic radiation (EMR), and in fact you generate it even when you don't want to. Any time-varying signal in any circuit will generate EMR, and this includes digital signals. In most cases this EMR is simply noise. If it's not causing any trouble, you can ignore it. In some cases it can actually interfere with other circuitry, in which case it becomes EMI (electromagnetic interference).

We see, then, that RF design is not about merely generating EMR; rather, RF design is the art and science of generating and manipulating and interpreting EMR in a way that allows you to reliably transfer meaningful information between two circuits that have no direct electrical connection.

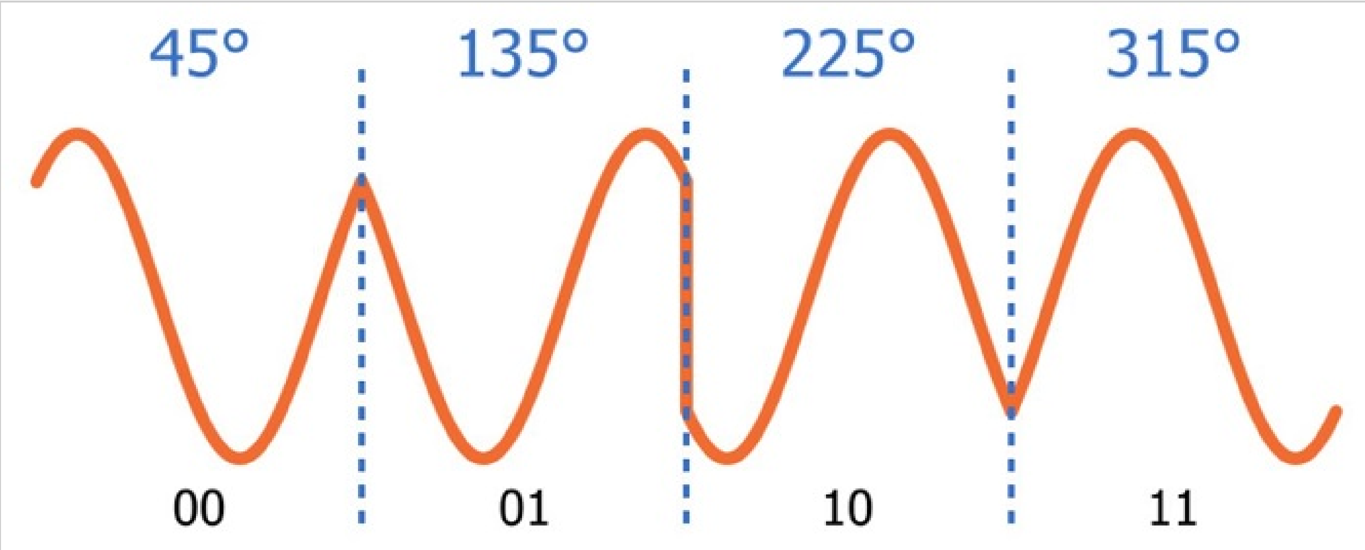
Why EMR?

Now let's return to the question of why EMR-based systems are so common compared to other forms of wireless communication. In other words, why does "wireless" almost always refer to RF when various other phenomena can transfer information without the aid of wires? There are a few reasons:

Scroll to continue with content

Agility

EMR is a natural extension of the electrical signals used in wired circuits. Time-varying voltages and currents generate EMR whether you want them to or not, and furthermore, that EMR is a precise representation of the AC components of the original signal.



Each portion of this intricate [QPSK](#) waveform transfers two bits of digital information.

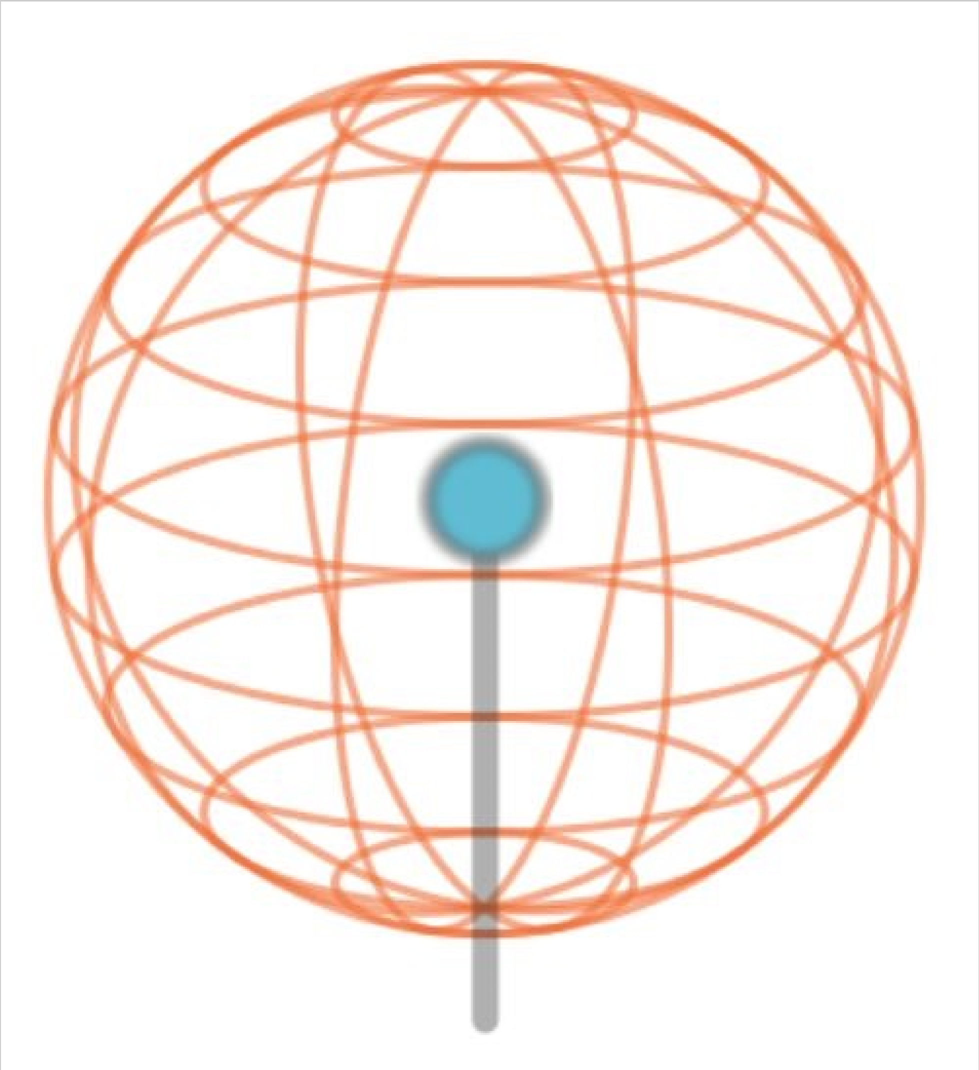
Let's consider an extreme (and completely impractical) counterexample: a heat-based wireless communication system. Imagine that a room contains two separate devices. The transmitter device heats up the room to a certain temperature based on the message it wants to send, and the receiver device measures and interprets the ambient temperature. This is a sluggish, awkward system because the temperature of the room cannot precisely follow the variations of an intricate electrical signal. EMR, on the other hand, is highly responsive. Transmitted RF signals can faithfully reproduce even the complex, high-frequency waveforms used in state-of-the-art wireless systems.

Speed

In AC-coupled systems, the rate at which data can be transferred depends on how quickly a signal can experience variations. In other words, a signal must be *doing something*—such as increasing and decreasing in amplitude—in order to convey information. It turns out that EMR is a practical communication medium even at very high frequencies, which means that RF systems can achieve extremely high rates of data transfer.

Range

The pursuit of wireless communication is closely linked to the pursuit of long-distance communication; if the transmitter and receiver are in close proximity, it is often simpler and more cost-effective to use wires. Though the strength of an RF signal decreases according to the inverse-square law, EMR—in conjunction with modulation techniques and sophisticated receiver circuitry—still has a remarkable ability to transfer usable signals over long distances.



The intensity of EMR decreases exponentially as the emitted energy propagates outward in all directions.

No Line of Sight Needed

The only wireless communication medium that can compete with EMR is light; this is perhaps not too surprising, since light is actually very-high-frequency EMR. But the nature of optical transmission highlights what is perhaps the definitive advantage offered by RF communication: a clear line of sight is not required.

Our world is filled with solid objects that block light—even very powerful light. We have all experienced the intense brightness of the summer sun, yet that intensity is greatly reduced by nothing more than a thin piece of fabric. In contrast, the lower-frequency EMR used in RF systems passes through walls, plastic enclosures, clouds, and—though it may seem a bit strange—every cell in the human body. RF signals are not completely unaffected by these materials and, in some cases, significant attenuation can occur. But compared to light, (lower-frequency) EMR goes just about anywhere.

Summary

- "RF" refers to the use of electromagnetic radiation for transferring information between two circuits that have no direct electrical connection.
- Time-varying voltages and currents generate electromagnetic energy that propagates in the form of waves. We can wirelessly transfer analog and digital data by manipulating and interpreting these waves.

- EMR is the dominant form of wireless communication. One alternative is the use of light (such as in fiber optics), but RF is much more versatile because lower-frequency EMR is not blocked by opaque objects.

- Back to Index
- Textbook Index
- Learning to Live in the Frequency Domain

Continue to site
QUOTE OF THE DAY
“
”
-