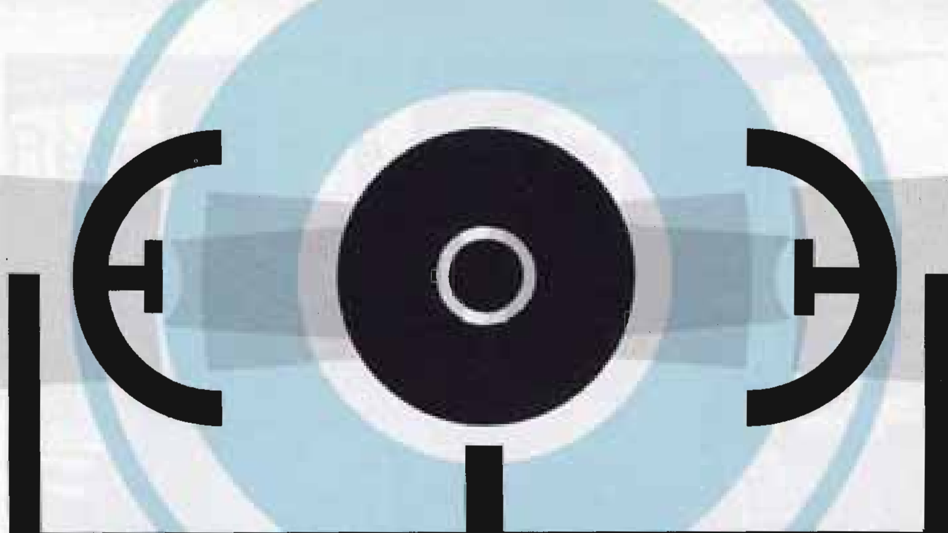

Why do antennas radiate?

by John E. Cunningham, editor of *The Electron*

In general, antennas and radiation are not well understood by electronics technicians and engineers. One of the reasons is that most texts dealing with the subject are either highly mathematical or so elementary as to be meaningless.

Perhaps the easiest way to answer the question of why antennas radiate is to turn it around and ask, "Why don't all circuits radiate?" The answer is that to some extent, at least, they do.

We can start out with a simple principle:

"Whenever an electric charge accelerates — or what is the same thing whenever an electric current changes — it makes every other charge in the entire universe move at the same frequency."

To this basic principle, we can add another:

"This influence of a moving charge on all other charges is not instantaneous — it takes time for one charge to influence another charge."

Actually the amount of time required for one charge to influence another depends on the distance between them. The "influence" travels at the speed of light which is 300 million meters per second (186,000 miles per second).

Thus, if two electric charges were separated by 186,000 miles and we moved one of these charges back and forth, the other charge would start moving back and forth one second later.

With these two principles in mind, it would seem that every electric circuit in the world would influence every other circuit; that is, every circuit would radiate.

The reason that most electric circuits do not radiate appreciably can be seen by looking at Fig. 1. At the left of the figure we have shown a transmission line.

In wire A, an electron, which carries an electric charge, is moving upward. According to our basic principles, this should make the electron at the right of the figure also move upward. If this were all there was to it, the electron at the right of the figure would indeed follow the electron in wire A. But, there is another influence.

In wire B we have an electron moving downward. This will try to make the electron at the right of Fig. 1 move downward. Since wires A and B are nearly the same distance from the electron at the right, their influences will arrive at about the same time and will cancel each other.

In all practical circuits we have equal currents flowing in opposite directions. Thus their influences will cancel each other. This gives us a clue as to what we must do to make something radiate. Before we go into this, however, let's look at the nature of this influence one electric charge has on other charges.

WHAT IS A FIELD?

The concept of "action at a distance" which we have described above is puzzling at best. From ancient times, philosophers have found that the concept of action at a distance is hard, if not impossible, to accept. The human mind cannot cope with it.

In order to remove this difficulty, early physicists invented something which they called "the ether." This ether was an invisible substance that permeated the entire universe. Whenever an electric current changed, it set up a wave in the other. It was this wave, traveling at the speed of light, that carried the influence of one electric charge to another. This avoided the unpleasant concept of action at a distance.

Unfortunately, as the science of physics advanced, the ether became more complicated. If it existed at all, it behaved very inconsistently. Finally, Albert Einstein suggested dropping the concept completely.

Even without the concept of the ether, physicists were not finished. They attributed the action at a distance to an electromagnetic field. To the technician this isn't much help. No one knows for sure what a field is, or if there really is such a thing. A field can be thought of as a mathematical fiction that describes the action at a distance which we have been talking about.

It doesn't really matter whether we believe in the existure of fields or if we're more comfortable with the concept of the ether. We can choose whichever one we like best. Remember that the complex math that we use today to describe radiation was developed by James Clerk Maxwell who did his work years ago when the ether was still a popular concept.

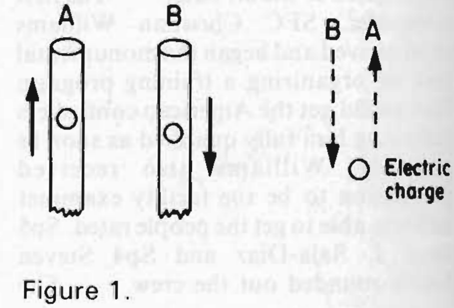

Figure 1.

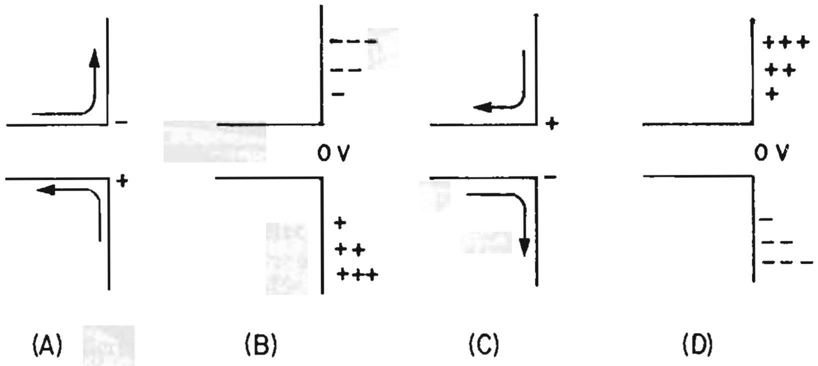

Figure 2.

BACK TO ANTENNAS

In an earlier paragraph we stated that the only reason that ordinary circuits do not radiate is that we have wires, close together, that carry equal currents in opposite directions. Thus we might guess that a good way to make something radiate would be to increase the space between our conductors. In this way, the "influences" of the charges moving in opposite directions would not arrive at a remote point at the same time. Thus there would be no cancellation.

Fig. 2 shows an ordinary two-wire transmission line connected to a half-wave dipole antenna. Let's start by considering what happens when a signal traveling down the transmission line reaches the antenna as shown in Fig. 2A. Electric charges, consider them to be electrons if you wish, start flowing toward the top of the antenna. At this point, they will flow because they have no way of knowing that they will find an open circuit when they get to the top of the antenna.

At the same time, electrons are flowing from the bottom of the antenna leaving positive charges where they came from. The procedure continues, with negative charges moving toward the top of the antenna and away from the bottom of the antenna until our negative charges get to the top of the antenna and find that they have no place to go.

Inasmuch as each half of the antenna is one-quarter wave long, the time required for the negative charges to reach the top of the antenna will be exactly one-quarter cycle of the applied signal.

At this point the voltage across the terminals of the antenna will have dropped to zero. Now we have the situation shown in Fig. 2B with negative charges at the top and positive charges at the bottom.

OPPOSITES ATTRACT?

At first glance this is indeed a puzzling situation. We have been taught that opposite charges attract each other. How do we manage to have opposite charges at the ends of our antenna? Why don't they attract each other and rush to the center of the antenna?

The answer lies in the second of our basic principles stated at the beginning of this article. Namely, it takes time for one charge to exert an influence on another charge. How much time? In this case, the charges are separated by one-half wavelength, so it will take a period of time equal to one-half cycle of the applied signal. As you will see, this works in our favor.

As our signal continues to vary through its cycle, we will reach the situation shown in Fig. 2C. Now the polarity of the signal at the antenna terminals will have reversed and current will flow in the opposite direction. Note that by this time enough current has flowed so that there are no charges at the ends of the antenna.

After the signal has gone through another quarter of a cycle, we will have the situation shown in Fig. 2D which is just the opposite of what we had in Fig. 2B.

This process will now continue with the current oscillating back and forth in the antenna at the frequency of the applied signal. The important thing to observe is that at all times, current is flowing in the same direction in all parts of the antenna. In Fig. 2A, negative charges are flowing from the bottom of the antenna toward the top. In Fig. 2C, our negative charges are flowing from the top of the antenna toward the bottom.

In a practical antenna, the gap in the middle where the transmission is connected is very small compared with the length of the antenna. If we ignore this small gap, the antenna will look electrically as shown in Fig. 3. Here we see that, at the time shown in Fig. 2A, the charges, and thus the current, are flowing as shown in Fig. 3A. Similarly at the time represented by Fig. 2C, the current is flowing as shown in Fig. 3B.

DIRECTION FLOW THAT'S DIFFERENT

The important thing to realize about these figures is that at all times the currents in the top and bottom of the antenna are flowing in the same direction. Unlike an electric circuit where we have equal currents flowing in opposite directions, in the antenna we have equal currents flowing in the same direction. Thus in a circuit the influences of the moving charges on distant charges tend to cancel, whereas in an antenna the influences on distant charges reinforce each other.

This concept of radiation, although very elementary, is essentially consistent with the highly mathematical theories of radiation, it can be used to estimate how much a given arrangement of conductors will radiate. It is also helpful in estimating how much radiation we might expect from a circuit that is not intended to radiate.

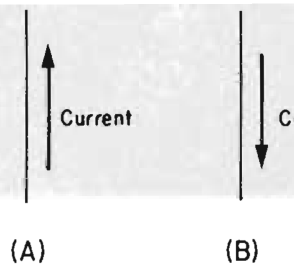

Figure 3.

In this discussion, we have tacitly assumed that current will flow from the transmission line into the antenna without any problems. Although this is true in general, in most practical instances there is an impedance matching problem at the point where the transmission line connects to the antenna. In a later article, we will discuss the impedance that we might expect to see at the connection to a practical antenna.