# Digital Communication in an Analog World

**Mother Nature isn't a fan of wireless digital communication. According to her rules, all electromagnetic signals in nature, whether they are created by transceivers or star clusters, must be *analog*, which means the signals are forever changing from one fraction of a second to the next. Like waves on the ocean, electromagnetic signals are constantly varying in strength, frequency, or both.**

In contrast, *digital* signals change only in steps, one after the other — on or off, high or low, up or down, *with nothing in between*. So if all electromagnetic signals are strictly analog, how can wireless digital communication ever take place? Well...strictly speaking, *it doesn't*.

## To Bits and Back

Computers store information — everything from documents to videos — in distinct pieces known as *bits*. All bits are *binary*, which means they can only be in one of two states: either on or off, high or low, and so on. (Unless it is a quantum *qbit*, which we won't discuss here, or else we'd be up past our bedtimes.)

Imagine a hammer and a chocolate bar. The chocolate bar is a tasty, unified whole, but if you whack it with the hammer, it shatters into pieces. Now imagine that, with a magic wand, you command those chocolate fragments to reassemble themselves into the original bar. If you have all the pieces (presuming you didn't eat some), they should join and become a whole chocolate bar once again.

Here's a more realistic example. If you place a printed photograph into a scanner, its image will be converted (like the chocolate bar with the encouragement of the hammer) into separate bits — in this case, bits of digital information. You can store all these bits in a computer's memory and ask the computer to reassemble them into the original image that you can view on the screen or print to paper.

With enough power and technology, anything in our analog universe can be transformed into bits of digital information, stored, transported from place to place, and reassembled. But to accomplish this, we have to play by Mother Nature's analog rules.

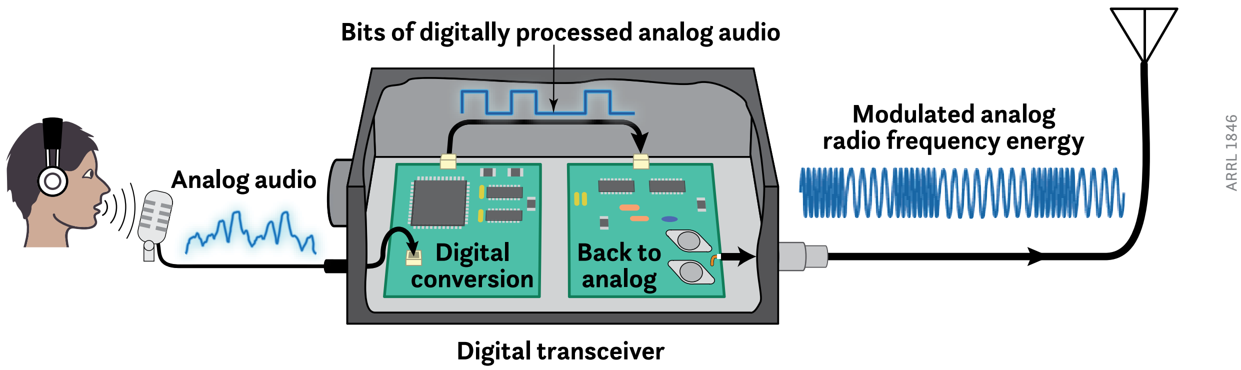
## Mother Nature's Game

The first step is to convert the digital bits into electromagnetic analog signals. Once you've done that, nature is happy to cooperate. The signals can go anywhere you desire, and at the speed of light! Of course, at the destination you must convert those analog signals back into digital bits.

We call this process "digital" communication because it involves sending digital information, but the mechanism that gets the job done is analog.

For example, let's say you own a D-STAR digital transceiver. It communicates with other D-STAR radios digitally, or so it may seem.

When you squeeze the push-to-talk button and speak into the microphone, the sound waves of your voice are converted into analog electrical signals (see below), and




those signals are converted to digital information. The digital information is rearranged and processed according to the D-STAR protocol, and then it's ready for transmission.

But, in order to be transmitted, the bits must first be converted to analog signals, which are further transformed into radio frequency (RF) energy. These analog waves of RF power leave the antenna and travel to the other D-STAR radio.

Now the process happens in reverse. The analog signals are converted back into bits, the bits are processed by the tiny computer in the radio, they are turned into analog signals, and then sent to the speaker to create sound waves for your analog ears to hear.

So-called "digital communication" requires a lot of back and forth conversion, but the information ultimately comes and goes from the antenna as an analog RF signal. Nature is very strict about this requirement. When it comes to wireless communication, it's analog or nothing.

## Modulation is the Key

If you read the article "Modulation: Changes in the Flow" in the May/June 2020 issue of *On the Air*, you know that we can change — *modulate* — an RF signal in such a way that it can carry information, including digital information. As long as you manage the digital-to-analog conversion and modulation processes correctly, you can send enormous amounts of digital information through the air, even under extremely difficult conditions.

Take digital TV as an example. If you were to tune in a digital TV signal with an analog radio receiver, all you would hear is a hissing noise. Within that noise, however, is an ingenious pattern of complex signals — all of them analog, of course — that a TV receiver converts back to the bits of information necessary to create high-resolution video images.

For a more extreme example, consider the *New Horizons* spacecraft. It was launched in 2006 to explore Pluto and beyond, and has been sending a flood of information, including stunning images, from the outer reaches of our solar system. All of this information is digital, but it leaves the spacecraft's antenna as analog RF energy, specially modulated so that it can still be converted and decoded here on Earth. It's an amazing feat of radio engineering.

## What's In it For You

As long as your radio functions properly, you don't need to care about how digital communication works, but part of the pleasure of this hobby is understanding how things work. Besides, understanding the technology can have practical applications.

For instance, in the popular HF digital mode known as FT8, digital information from your computer is converted to analog audio tones. These tones are used to modulate the RF energy generated by an SSB transceiver. But if the audio tones applied to the radio are too loud, the result will be highly distorted RF signals that are undecodable at the receiving end and cause horrendous interference to your fellow amateurs.

By understanding this process, you'll know that you need to adjust the audio levels from the computer so that you're sending clean, easily decodable signals. Some hams don't appreciate the relationship between digital information and analog modulation, but you'll see the problem right away and know how to fix it.

On the receiving side of the equation, you'll also understand how interference from other signals can wreck your digital communications. Because the analog RF signals represent digital information, a burst of interference may be all it takes to effectively obliterate many bits at the receiver. Obliterate enough of them and the result is silence!

Hopefully, you now have a basic understanding of the true nature of digital communication in our analog world.