What's The Difference Between EM Near Field And Far Field?

Electronic Design
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Radio waves should really be called electromagnetic or EM waves simply because they consist of a magnetic field and an electric field. A signal from a transmitter applied to an antenna generates the fields. The antenna is the transducer and interface to free space.

As it turns out, an electromagnetic field's characteristics change depending on the distance from the antenna. This varying field is typically divided into two segments—the near field and the far field. A good knowledge of their differences goes a long way toward understanding radio-wave propagation.

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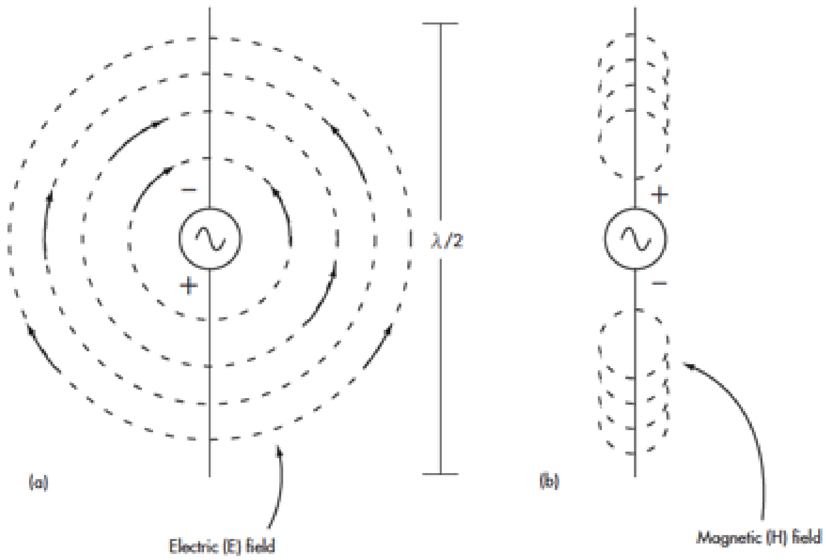
Electromagnetic Waves

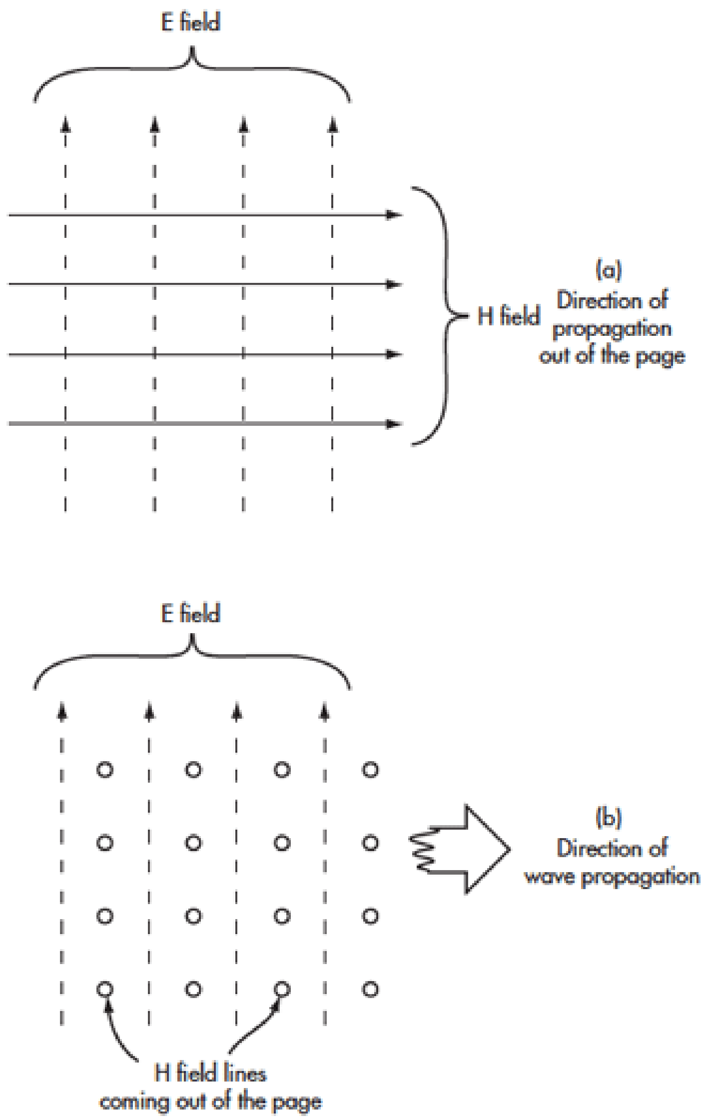
Figure 1 shows how a classic half-wave dipole antenna creates the electric and magnetic fields. The transmitted signal is a modulated sine-wave voltage alternating in polarity, producing an electric (E) field between the antenna elements that switches polarity each half cycle. Current in the antenna elements produces a magnetic (H) field that changes orientation each half cycle. The fields are at right angles to one another.



1. The electromagnetic field around a half wave dipole consists of an electric (E) field (a) and a magnetic (H) field (b). The fields are spherical and cut across one another at right angles.

The fields around the antenna are spherical or curved, especially near the antenna. As these fields travel out from the antenna, rounding becomes less pronounced, turning more planar in character. The receiving antenna usually perceives a planar wave.

Though the fields exist around the antenna, they propagate away from the antenna perpendicular to the two fields *(Fig. 2)*. At some point beyond the antenna, the fields detach themselves into packets of energy and propagate independently. In fact, they support and regenerate one another along the way. This “independent” wave is the actual radio wave.



2. At a distance from the antenna, the E and H fields are essentially planar and intersect at right angles. Note the direction of propagation, which is perpendicular to both fields. At (a) the direction of propagation is perpendicular to the field lines shown either into or out of the page. In (b) the magnetic field lines are coming out of the page. You can picture them as lines with arrow points shown as dots.

The Near Field

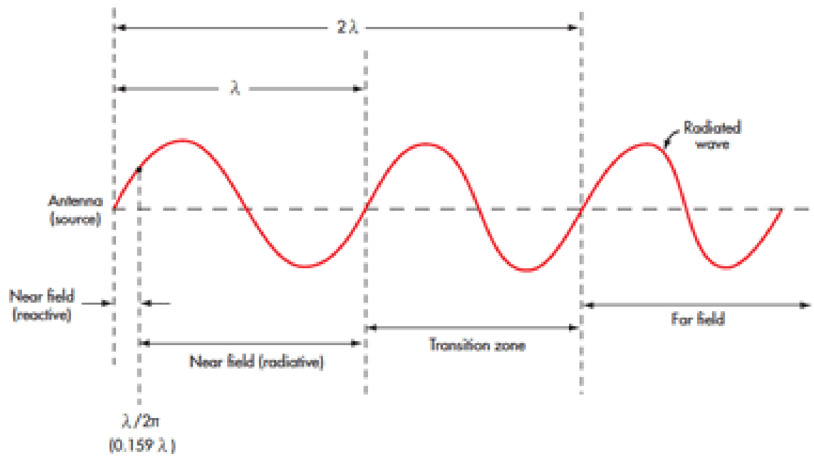
There's seemingly no formal definition for the near field—it depends on the type of application and the antenna. The most agreed upon definition submits that the near field is less than one wavelength (λ) from the antenna. Wavelength in meters is given by:

$\lambda = 300/f_{MHz}$

One readily acknowledged distance from the antenna of the near field is calculated as:

$\lambda/2\pi = 0.159\lambda$

Figure 3 shows the radiated sinusoidal wave as well as the near and far fields. The near field is generally said to be divided into two areas, the reactive and the radiative. In the reactive area, the E and H fields are the strongest and can be measured separately. One field or the other will likely dominate, depending on antenna type. A loop antenna, for example, is dominated by the magnetic (H) field. The loop antenna appears to be the primary as a transformer because of the large magnetic field it generates.



3. Boundaries of the near and far fields are shown with respect to wavelengths at the operating frequency. The antenna is assumed to be at the left and beginning of the wave.

In the radiative area, the fields begin to radiate. It represents the beginning of the far field. In the near field, the strength of the fields varies inversely with the cube of the distance from the antenna ($1/r^3$).

The transition zone in Figure 3 refers to the somewhat undefined area between the near and far fields. (Some models don't define a transition zone.) In this figure, the far field begins at a distance of 2λ and beyond.

The Far Field

Much like the near field, definitions vary on the beginning of the far field. Some say 2λ, while others insist that it is 3λ or 10λ from the antenna. Another definition indicates that it starts at 5λ/2π, while still another says that it depends on the largest dimension of the antenna D or $50D^2/\lambda$.

Then there are those who claim that this fuzzy boundary between near and far fields begins at $2D^2/\lambda$. Others will say that the far field begins where the near field leaves off, or as indicated earlier, λ/2π.

The far field is the real radio wave. It propagates through space at a speed of just about 300 million meters per second, which is the speed of light or nearly 186,400 miles per second. The E and H fields support and regenerate one another as their strength decreases inversely as the square of the distance ($1/r^2$). Maxwell described this phenomenon in his infamous equations.

Maxwell's Equations

In the late 1870s, before the invention of radio, Scottish physicist James Clerk Maxwell predicted the arrival of electromagnetic waves. Using the laws known at the time from Ampere, Faraday, Ohm, and others, he came up with a set of equations that illustrates how one type of field generates the other, and as they propagate, the two coexist in a supporting relationship. In the late 1880s, German physicist Heinrich Hertz proved Maxwell's theory.

Maxwell developed four basic equations that show the relationship of the electric and magnetic fields as they vary with time. Basically, the electric field changing over time appears to produce charges in motion or current flow that sets up a magnetic field. Other equations say that as the magnetic field varies it can set up an electric field. The waves propagate through space by themselves after leaving the antenna. Those equations aren't shown here, but you may recall that they involve partial differential equations.

Applications

The far field propagates through space, and its strength is defined by the Friis formula:

$P^r = P_t G_r G_t \lambda^2 / 16\pi^2 r^2$

where P_r = power received; P_t = power transmitted; G_r = receive antenna gain (power ratio); G_t = transmit antenna gain (power ratio); and r = range or distance from antenna. The formula is valid for free space, line of sight, with no obstructions.

Two important facts arise in this discussion. The received power varies inversely with the square of the range r. It also varies with the square of the wavelength, meaning that longer waves at lower frequencies travel farther. For example, a 900-MHz signal will travel farther than a 2.4-GHz signal for similar power and antenna gains. This expression can be used to analyze all modern wireless applications in terms of approximating signal strength.

To accurately observe signal propagation, one must plot the antenna's radiation pattern in the far field. In the reactive zone of the near field, the receiving antenna may interact with the transmitting antenna via capacitive or inductive coupling and thus give false results. On the other hand, it's been shown that a radiation pattern in the near field can be accurately plotted if special measurement equipment is available.

The near field has also proved useful in communications. This mode is used for applications such as radio-frequency identification (RFID) and near-field communications (NFC).

RFID is the electronic equivalent of bar coding. A thin tag containing a chip that integrates memory and specific electronic code is attached to the item to be identified, tracked, or otherwise processed. The tag, which also includes a passive transceiver, is passed near a "reader" transceiver that emits a strong RF signal picked up by the tag. Both reader and tag antennas are usually loops serving as the primary and secondary of a transformer.

The signal picked up by the tag is rectified and filtered into dc, which provides power to the tag memory and transmitter. The transmitter then sends the code to the reader for identification and further processing. Active tags using a battery sometimes extend the read range beyond the near field. RFID tags come in different frequency ranges, such as 125 kHz, 13.56 MHz, and 900 MHz.

At 900 MHz, the wavelength is:

$\lambda = 300/f_{MHz}$

$\lambda = 300/900 = 0.333$ meter or 33.33 cm

Subsequently, the near field is calculated as:

$\lambda/2\pi = 0.159\lambda = 0.159(0.333) = 0.053$ meter (about 2 inches)

Read ranges usually extend somewhat beyond this point. Therefore, it may actually spill into the far field at this frequency.

NFC also employs a memory and special coding similar to that of a credit card. An internal transceiver, usually battery powered, can transmit the code to a reader. It also uses the near field as the read range, and it's typically only inches. The NFC frequency is 13.56 MHz, representing a wavelength of:

$\lambda = 300/f_{MHz}$

300/13.56 = 22.1 meters or 72.6 feet

The near field is within:

$\lambda/2\pi = 0.159\lambda = 0.148(72.6) = 11.5$ feet

Because less power is used, the actual read range is rarely greater than a foot.

NFC is expected to be the technology to implement the "digital wallet." With this application, consumers make payments using NFC-enabled smart phones rather than a credit card.

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