UNIVERSITAS KOMPUTER
INDONESIA

Chap 5 RF Signal

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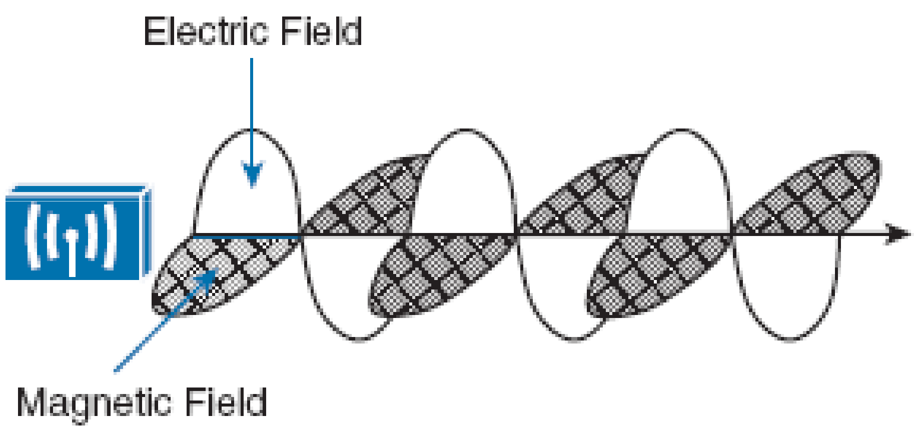
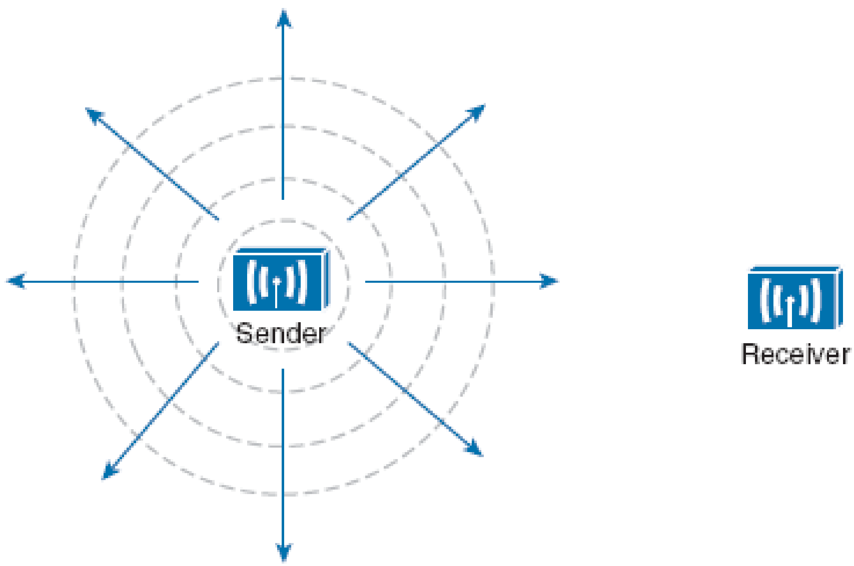
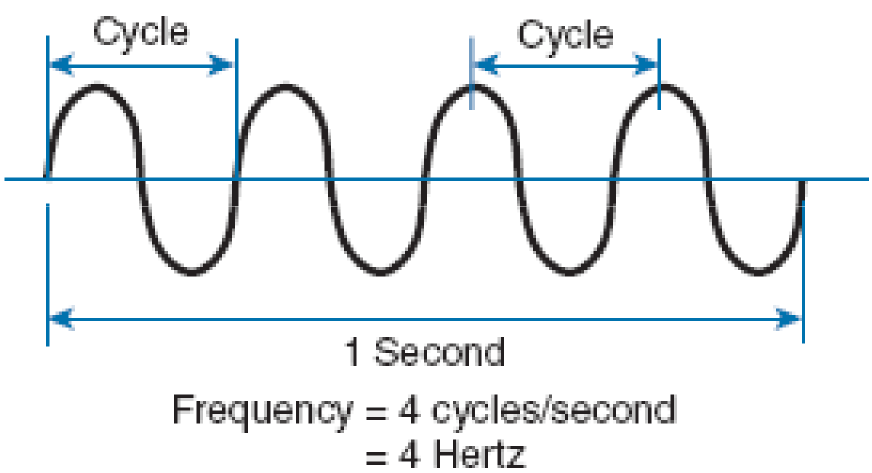
Traveling Electric and Magnetic Waves.



Wave Propagation with an Idealistic Antenna.



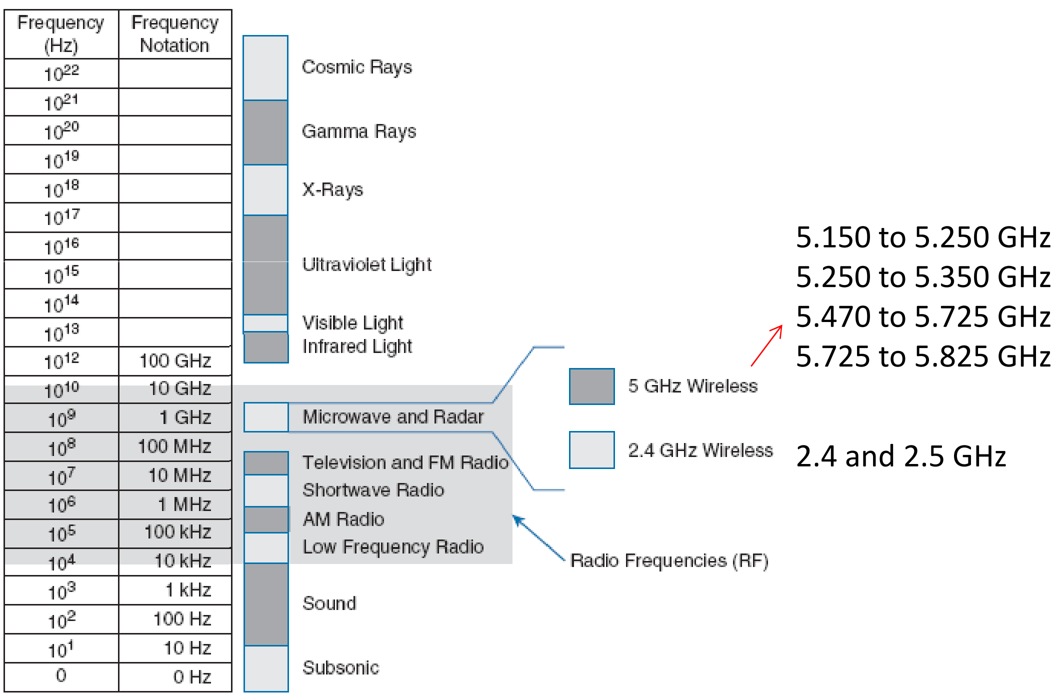
Cycles Within a Wave.



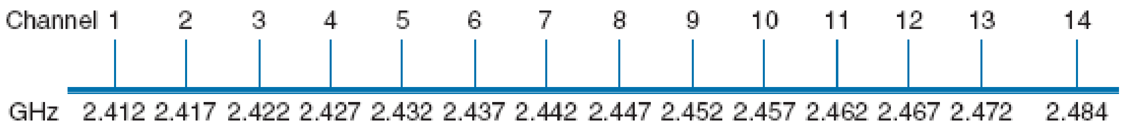
Frequency Unit Names

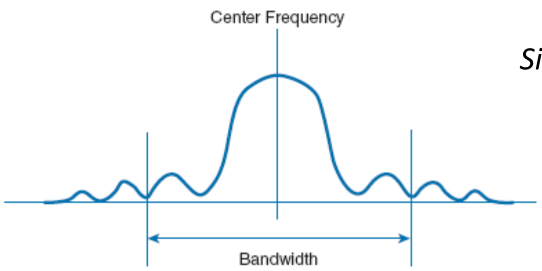
Unit	Abbreviation	Meaning
Hertz	Hz	Cycles per second
Kilohertz	kHz	1000 Hz
Megahertz	MHz	1,000,000 Hz
Gigahertz	GHz	1,000,000,000 Hz

Continuous Frequency Spectrum.



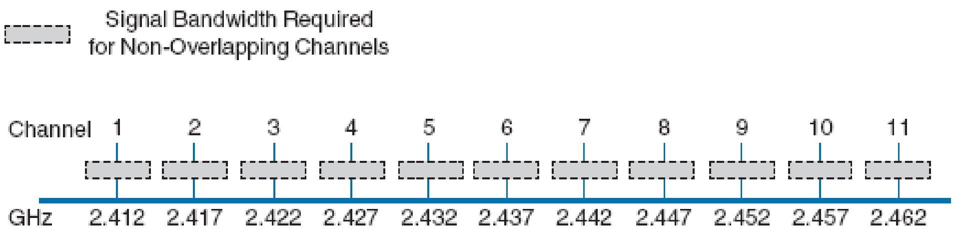
An Example of Channel Spacing in the 2.4-GHz Band.

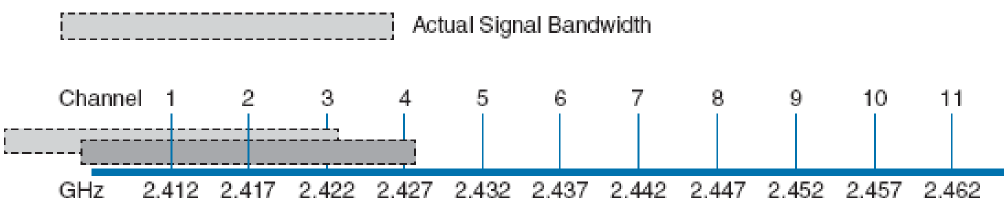




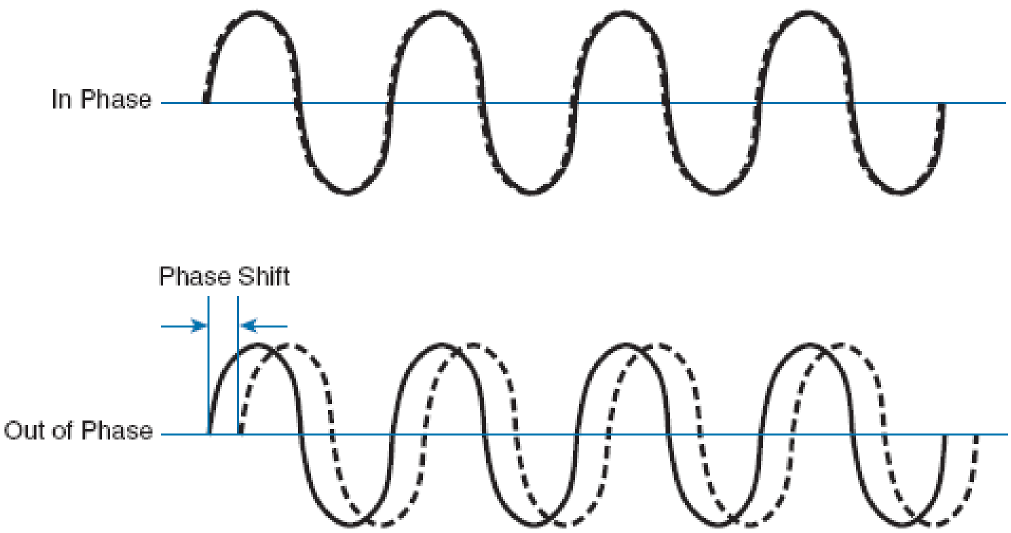
Signal Bandwidth

Examples of Channel Spacing and Overlap

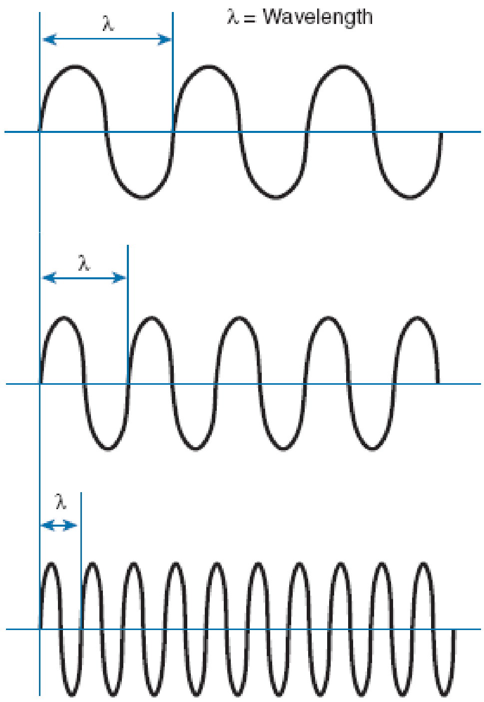




Understanding Phase

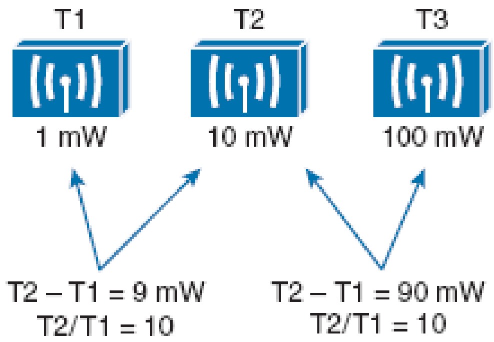


Examples of Increasing Frequency and Decreasing Wavelength.



Understanding RF Power and dB

The strength of an RF signal is usually measured by its power, in watts (W). For example,
a typical AM radio station broadcasts at a power of 50,000 W; an FM radio station might use 16,000 W. In comparison, a wireless LAN transmitter usually has a signal strength between 0.1 W (100 mW) and 0.001 W (1 mW).



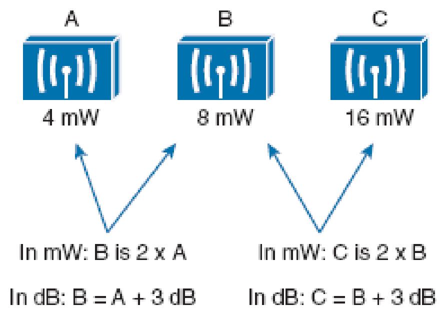
$$dB = 10(log_{10}P2 - log_{10}P1)$$

Fact 1 —A value of 0 dB means that the two absolute power values are equal.

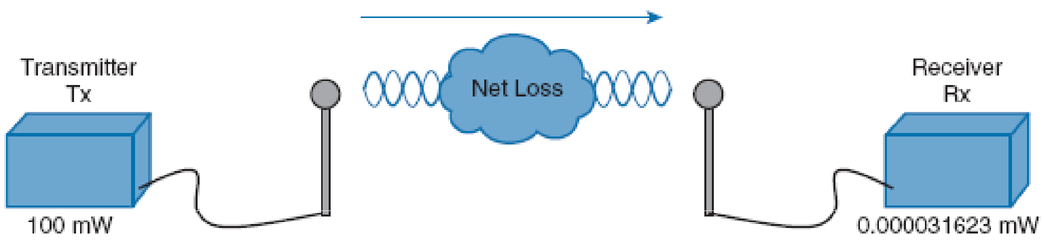
Fact 2 —A value of 3 dB means that the power value of interest is double the reference value; a value of –3 dB means the power value of interest is half the reference.

Table 1-3 *Power Changes and Their Corresponding dB Values*

Power Change	dB Value
=	0 dB
× 2	+3 dB
/ 2	−3 dB
× 10	+10 dB
/ 10	−10 dB



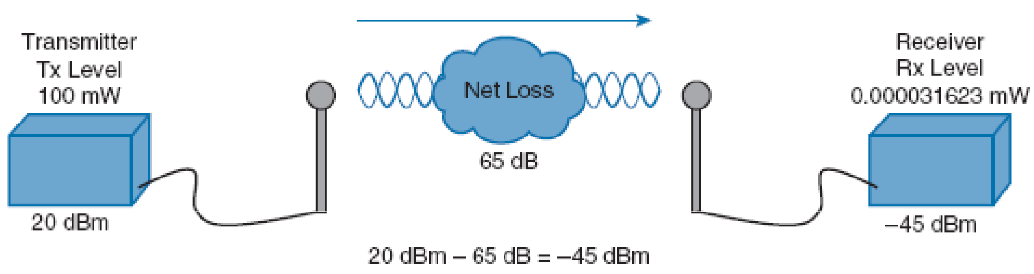
An Example of RF Signal Power Loss.



$$dB = 10 \cdot \log_{10}\left(\frac{0.000031623\ mW}{100\ mW}\right) = -65\ dB$$

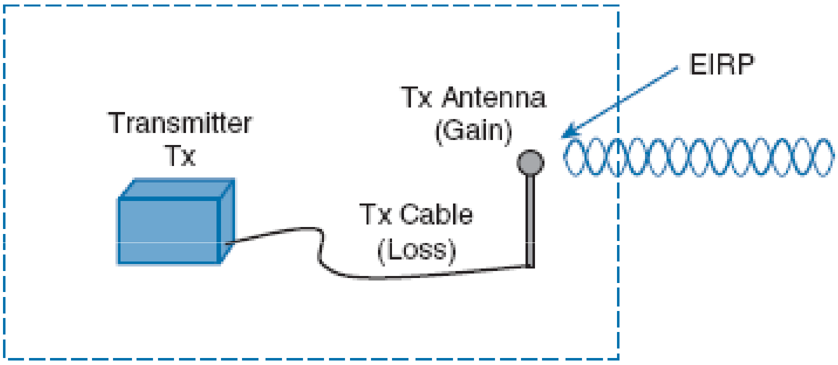
An Example of RF Signal Power Loss.

Subtracting dB to Represent a Loss in Signal Strength.



$$dB = 10 \cdot \log_{10}\left(\frac{0.000031623\ mW}{100\ mW}\right) = -65\ dB$$

Effective Isotropic Radiated Power (EIRP)

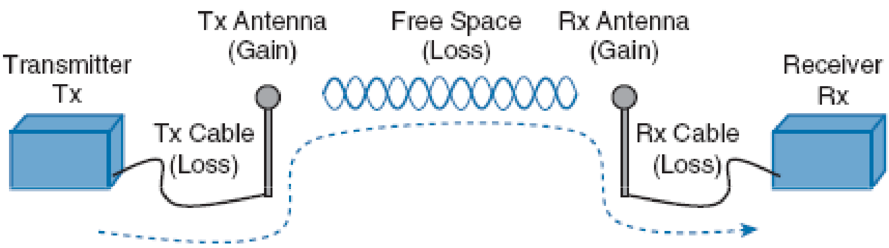


EIRP = Tx Power – Tx Cable + Tx Antenna

Suppose a transmitter is configured for a power level of 10 dBm (10 mW). A cable with 5-dB loss connects the transmitter to an antenna with an 8-dBi gain. The resulting EIRP of the system is 10 dBm – 5 dB + 8 dBi, or 13 dBm.

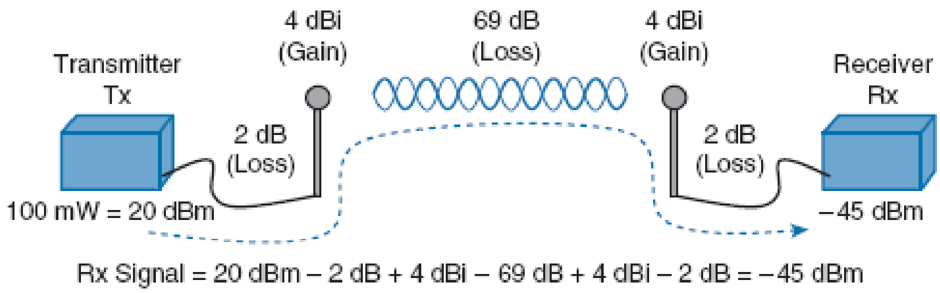
You might notice that the EIRP is made up of decibel-milliwatt (dBm), dB relative to an isotropic antenna (dBi), and decibel (dB) values

Calculating Received Signal Strength Over the Path of an RF Signal



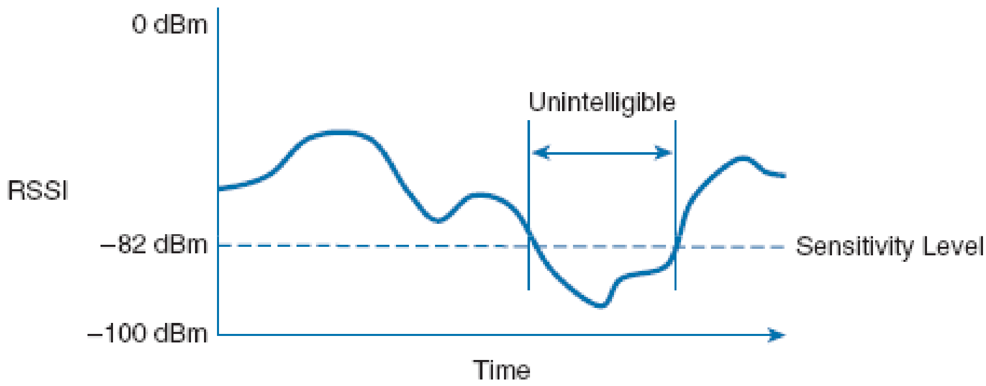
Rx Signal = Tx Power – Tx Cable + Tx Antenna – Free Space + Rx Antenna – Rx Cable

An Example of Calculating Received Signal Strength



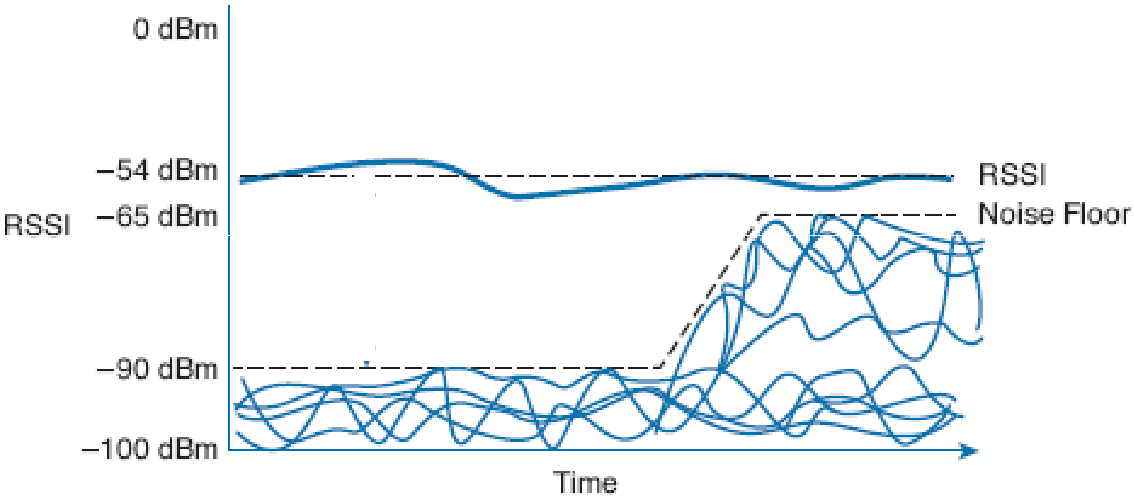
The signal begins at 20 dBm at the transmitter, has an EIRP value of 22 dBm at the transmitting antenna (20 dBm – 2 dB + 4 dBi), and
arrives at the receiver with a level of –45 dBm.

Understanding Power Levels at the Receiver

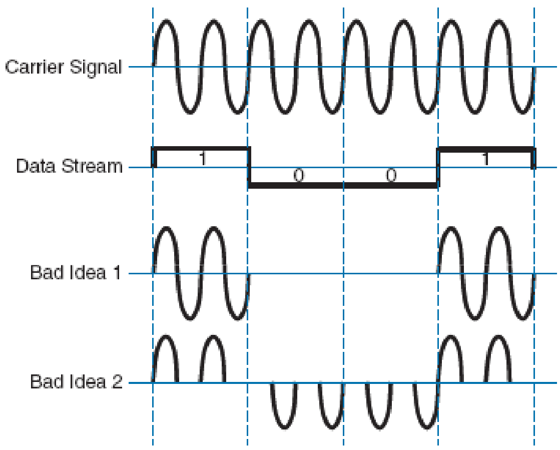


The noise level, or the average signal strength of the noise, is called the *noise floor*

An Example of a Changing Noise Floor and SNR.



Carrying Data Over an RF Signal



Poor Attempts at Sending Data Over an RF Signal

RF modulation schemes generally have the following goals:

- Carry data at a predefined rate
- Be reasonably immune to interference and noise
- Be practical to transmit and receive

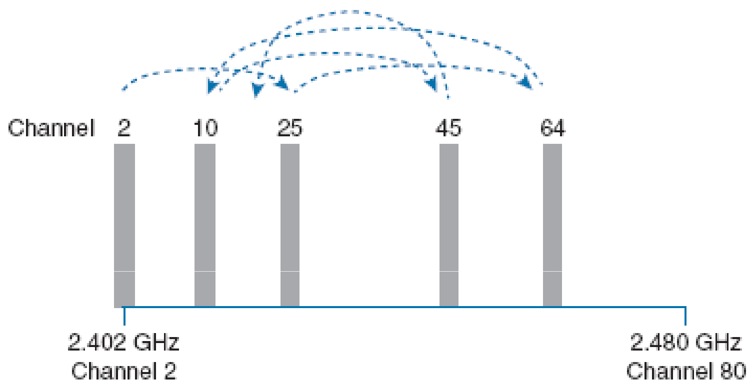
Due to the physical properties of an RF signal, a modulation scheme can alter only the following attributes:

- Frequency, but only by varying slightly above or below the carrier frequency
- Phase
- Amplitude

In contrast, wireless LANs must carry data at high bit rates, requiring more bandwidth for modulation. The end result is that the data being sent is spread out across a range of frequencies. This is known as *spread spectrum . At the physical layer, wireless LANs* can be broken down into the following three spread-spectrum categories, which are discussed in subsequent sections:

- Frequency-hopping spread spectrum (FHSS)
- Direct-sequence spread spectrum (DSSS)
- Orthogonal frequency-division multiplexing (OFDM)

FHSS

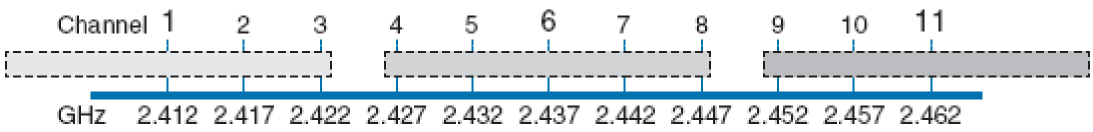


An Example FHSS Channel-Hopping Sequence.

Whatever advantage FHSS gained avoiding interference was lost because of the following limitations:

- Narrow 1-MHz channel bandwidth, limiting the data rate to 1 or 2 Mbps.
- Multiple transmitters in an area could eventually collide and interfere with each other on the same channels.

DSSS



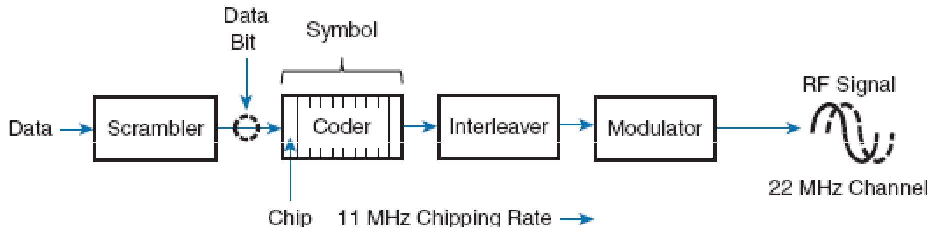
Example Nonoverlapping Channels Used for DSSS.

DSSS

DSSS transmits data in a serial stream, where each data bit is prepared for transmission one at a time. It might seem like a simple matter to transmit the data bits in the order that they are stored or presented to the wireless transmitter; however, RF signals are often affected by external factors like noise or interference that can garble the data at the receiver. For that reason, a wireless transmitter performs several functions to make the data stream less susceptible to being degraded along the transmission path:

- **Scrambler**—The data waiting to be sent is first scrambled in a predetermined manner so that it becomes a randomized string of 0 and 1 bits rather than long sequences of 0 or 1 bits.
- **Coder**—Each data bit is converted into multiple bits of information that contain carefully crafted patterns that can be used to protect against errors due to noise or interference. Each of the new coded bits is called a *chip*. The complete group of chips representing a data bit is called a *symbol*. DSSS uses two encoding techniques: Barker codes and Complementary Code Keying (CCK).
- **Interleaver**—The coded data stream of symbols is spread out into separate blocks so that bursts of interference might affect one block, but not many.
- **Modulator**—The bits contained in each symbol are used to alter or modulate the phase of the carrier signal. This enables the RF signal to carry the binary data bit values.

Functional Blocks Used in a DSSS Transmitter.



1-Mbps Data Rate

To minimize the effect of a low SNR and data loss in cases of narrowband interference, each bit of data is encoded as a sequence of 11 bits called a *Barker 11 code*. The goal is to add enough additional information to each bit of data that its integrity will be preserved when it is sent in a noisy environment.

There are only two possible values for the Barker chips—one corresponding to a 0 data bit (10110111000) and one for a 1 data bit (01001000111). The receiver must also expect the Barker chips and convert them back into single bits of data. The number and sequence of the Barker chip bits have been defined to allow data bits to be recovered if some of the chip bits are lost. In fact, up to 9 of the 11 bits in a single chip can be lost before the original data bit cannot be restored.

Each bit in a Barker chip can be transmitted by using the *differential binary phase shift keying* (DBPSK) modulation scheme. The phase of the carrier signal is shifted or rotated according to the data bit being transmitted, as follows:

0: The phase is not changed.

1: The phase is "rotated" or shifted 180 degrees, such that the signal is suddenly inverted.

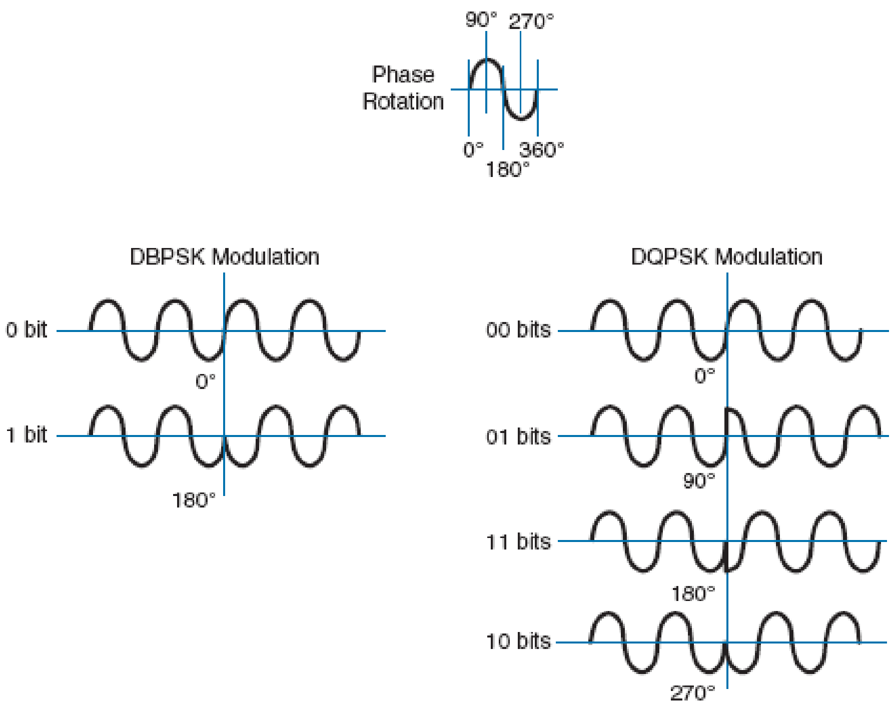
2-Mbps Data Rate

It is possible to couple the 1-Mbps strategy with a different modulation scheme to double the data rate. As before, each data bit is coded into an 11-bit Barker code with an 11-MHz chipping rate. This time, chips are taken two at a time and modulated onto the carrier signal by using *differential quadrature phase shift keying* (DQPSK). The two chips are used to affect the carrier signal's phase in four possible ways, each one 90 degrees apart (hence, the name quadrature). The bit patterns produce the following phase shifts:

- **00:** The phase is not changed.
- **01:** Rotate the phase 90 degrees.
- **11:** Rotate the phase 180 degrees.
- **10:** Rotate the phase 270 degrees.

Because DQPSK can modulate data bits in pairs, it is able to transmit twice the data rate of DBPSK, or 2 Mbps.

Example Phase Changes During DBPSK and DQPSK Modulation.



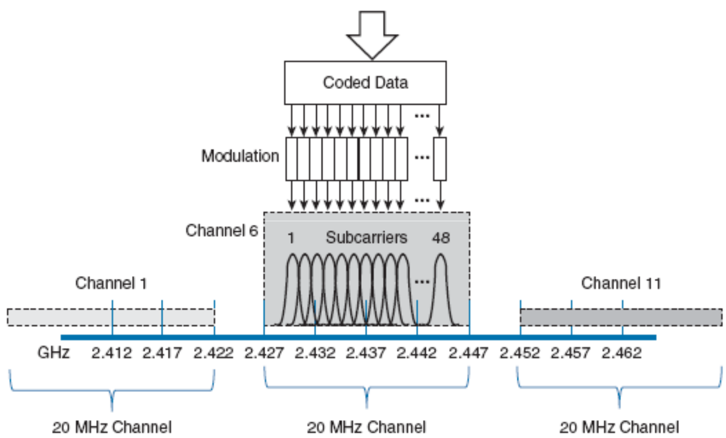
OFDM

DSSS spreads the chips of a single data stream into one wide 22 MHz channel. It is inherently limited to an 11 Mbps data rate because of the consistent 11-MHz chipping rate that feeds into the RF modulation. To scale beyond that limit, a vastly different approach is needed.

In contrast, orthogonal frequency division multiplexing (OFDM) sends data bits in *parallel* over multiple frequencies, all contained in a single 20 MHz channel. Each channel is divided into 64 subcarriers (also called subchannels or tones) that are spaced 312.5 kHz apart. The subcarriers are broken down into the following types:

- **Guard**—12 subcarriers are used to help set one channel apart from another.
- **Pilot**—4 subcarriers are equally spaced to help receivers lock onto the channel.
- **Data**—48 subcarriers are devoted to carrying data.

OFDM Operation with 48 Parallel Subcarriers



Examples of Phase and Amplitude Changes with 16-QAM.