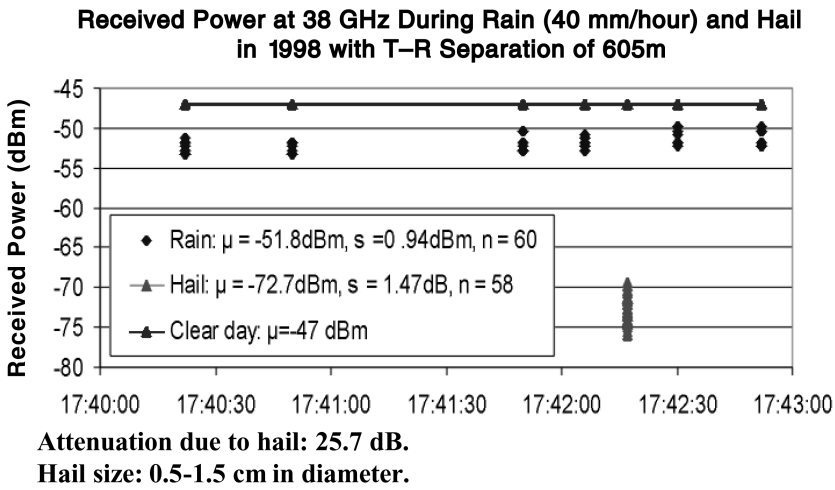


**Figure 2.8** Measured received power levels over a 605 m 38 GHz fixed wireless link in clear sky, rain, and hail [from [Xu00], ©IEEE].

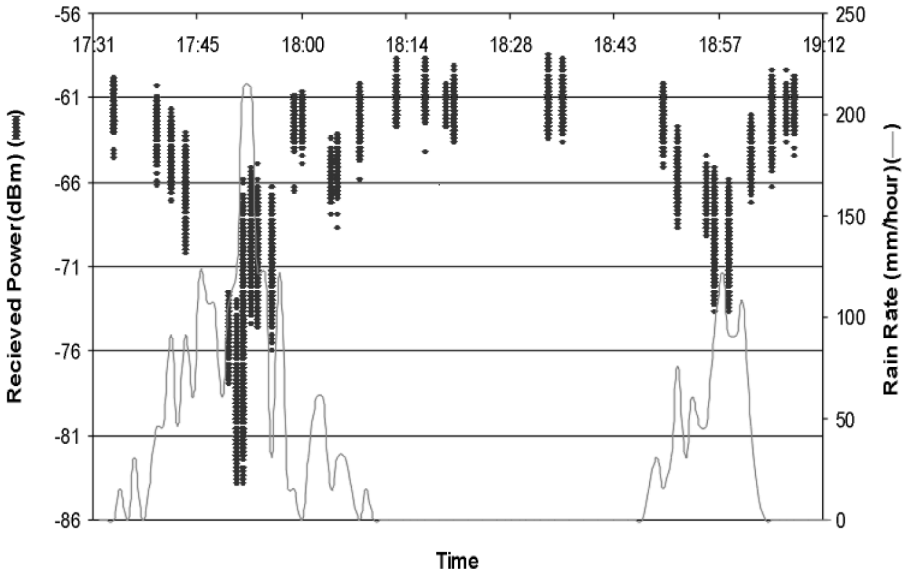


**Figure 2.9** Measured received power during rain storm at 38 GHz [from [Xu00], ©IEEE].

27 dB. As shown in Chapters 4 and 5, the attenuation caused by weather effects must be statistically accounted for in the proper design of a fixed wireless network so that an outage probability can be computed based on local rain patterns and rain statistics.

## 2.4 Wireless Local Area Networks (WLANs)

As shown in Figure 2.6, in 1997 the FCC allocated 300 MHz of unlicensed spectrum in the Industrial Scientific and Medical (ISM) bands of 5.150–5.350 GHz and 5.725–5.825 GHz for the express purpose of supporting low-power license-free spread spectrum data communication. This allocation is called the *Unlicensed National Information Infrastructure (UNII)* band.

The FCC's generous spectrum allotment followed a much earlier allocation of unlicensed spread spectrum bands by the FCC in the mid 1980s. Specifically, in the late 1980s the FCC first provided license free bands under Part 15 of the FCC regulations for low power spread spectrum devices in the 902–928 MHz, 2400–2483.5 MHz, and 5.725–5.825 MHz ISM bands.

By providing a license-free spectrum allocation, the FCC hoped to encourage competitive development of spread spectrum knowledge, spread spectrum equipment, and ownership of individual WLANs and other low-power short range devices that could facilitate private computer communications in the workplace. The IEEE 802.11 Wireless LAN working group was founded in 1987 to begin standardization of spread spectrum WLANs for use in the ISM bands. Despite the unrestricted spectrum allocation and intense industry interest, the WLAN movement did not gain momentum until the late 1990s, when the phenomenal popularity of the Internet combined with widescale acceptance of portable, laptop computers finally caused WLAN to become an important and rapidly growing segment of the modern wireless communications marketplace. IEEE 802.11 was finally standardized in 1997 and provided interoperability standards for WLAN manufacturers using 11 Mcps DS-SS spreading and 2 Mbps user data rates (with fallback to 1 Mbps in noisy conditions). With an international standard now approved, numerous manufacturers began to comply for interoperability, and the market began to accelerate rapidly. In 1999, the 802.11 High Rate standard (called IEEE 802.11b) was approved, thereby providing new user data rate capabilities of 11 Mbps, 5.5 Mbps in addition to the original 2 Mbps and 1 Mbps user rates of IEEE 802.11, which were retained.

Figure 2.10 illustrates the evolution of IEEE 802.11 Wireless LAN standards, which also include infrared communications. Figure 2.10 shows how both frequency hopping and direct sequence approaches were used in the original IEEE 802.11 standard (2 Mbps user throughput), but as of late 2001 only direct sequence spread spectrum (DS-SS) modems had thus far been standardized for high rate (11 Mbps) user data rates within IEEE 802.11. Not shown in Figure 2.10 is the IEEE 802.11a standard, which will provide up to 54 Mbps throughput in the 5 GHz band. The DS-SS IEEE 802.11b standard has been named *Wi-Fi* by the *Wireless Ethernet Compatibility Alliance (WECA)*, a group that promotes adoption of 802.11b DS-SS WLAN equipment and interoperability between vendors. IEEE 802.11g is developing *Complimentary Code Keying Orthogonal Frequency Division Multiplexing (CCK-OFDM)* standards in both the 2.4 GHz (802.11b) and 5 GHz (802.11a) bands, and will support roaming capabilities and dual-band use for public WLAN networks, while supporting backward compatibility with 802.11b technology.

The frequency-hopping spread spectrum (FH-SS) proponents of IEEE 802.11 have formed the HomeRF standard that supports frequency hopping equipment. In 2001, HomeRF developed a 10 Mbps FH-SS standard called HomeRF 2.0. It is worth noting that both DS and FH types of