RF power options in ZigBee solutions

While ZigBee is a "low-power" standard, "high-power" product versions are much needed—and are very much ZigBee standard.

By Tim Cutler

Among the new ZigBee wireless standard's many desirable attributes, "low power" is perhaps the most frequently mentioned. That descriptor sits at the center of the ZigBee Alliance mission statement, and also forms the last two words of the alliance's stated objectives. The emphasis is there for good reason: Designed to deliver wireless networking to even the most humble devices—including devices that run on batteries lasting for years—ZigBee has to be extremely power-miserly to meet its objectives.

Despite this, manufacturers are beginning to introduce ZigBee products distinguished by power ratings. They are offering radios with 1 mW RF power and even high-power versions with 100 mW RF power. Are these manufacturers deviating from the ZigBee specification? In actuality, manufacturers of ZigBee radios with higher RF power create them for very good reasons, grounded in the realities of successful wireless applications. They are also faithful to the ZigBee specification and what it means by "low power." By separating product lines along RF power differences, manufacturers give design engineers an important option for their ZigBee implementations. Choosing relative to that option is a matter of matching power capabilities to application needs.

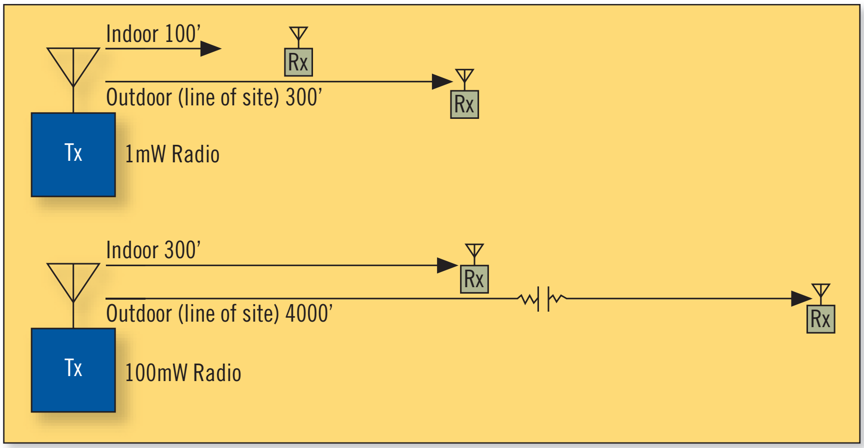

Figure 1. Adding RF amplifiers to ZigBee radios can dramatically increase the transmission range while still adhering to the 802.15.4 specification.

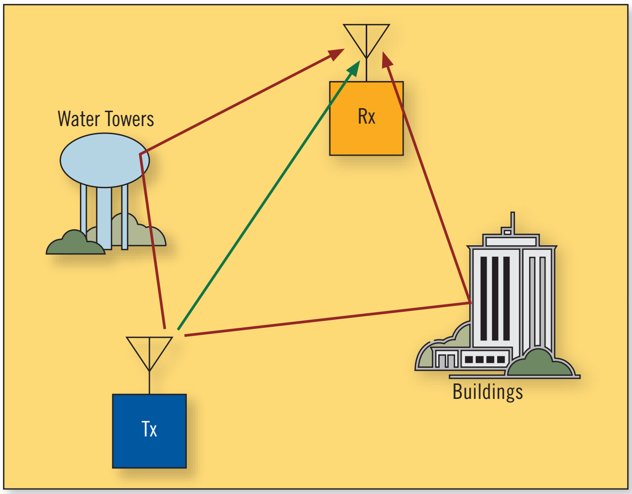

Figure 2. High RF power can help address the issue of multipath fading that can impede wireless transmission.

Understanding ZigBee's "low-power consumption"

ZigBee's low-power consumption is rooted not in RF power, but in a sleep mode specifically designed to accommodate battery-powered devices. Any ZigBee-compliant radio can automatically switch to sleep mode when it's not transmitting and remain asleep until it needs to communicate again. For radios connected to battery-powered devices, this mode results in extremely low duty cycles and very low average power consumption.

When a radio is in sleep mode, its RF power rating is irrelevant. The RF power affects power consumption only when the radio is transmitting. Consider, for example, that a ZigBee radio with 100 mW RF power will typically consume 150 mA at 3.3 V when transmitting, compared to 75 mA at 3.3 V for a radio with 1 mW RF power. The 100 mW radio consumes twice as much power—but only when actively transmitting. As long as the high-power radio's low noise amplifier is turned off, power consumption while sleeping is roughly equivalent to that of a low-power radio.

If the high RF power radio is awake and transmitting 5% of the time, which would indicate a very active radio, the extra average power consumption is roughly 5%. This additional power consumption means that a battery nominally lasting five years with a 1 mW radio would now only last four years and nine months with a 100 mW radio. As this example illustrates, ZigBee radios with higher RF output ratings are still excellent candidates for use with battery-powered devices.

It's important to note that the ZigBee Alliance doesn't itself specify anything for RF power. ZigBee's RF power specification comes from IEEE 802.15.4, which specifies a minimum power output rating of 1 mW, with no specified maximum. The de facto 100 mW "high power" level relates to the European limit of 100 mW EIRP, including antenna gain.

Why low RF power products?

If 100 mW radios are viable for use with battery-powered devices, then why even have 1 mW RF power ZigBee products? The reason is simple. These low RF power products meet many application needs without adding unnecessary expense.

ZigBee chipsets all come with an RF power rating of around 1 mW. Creating a ZigBee module or packaged radio with 100 mW RF power requires the addition of an RF power amplifier. While the added cost of the amplifier is modest—for modules, it typically accounts for about $10 per unit at low quantities—the per-module cost can add up in a multinode network. This is exactly the expense manufacturers want to avoid unless required by the application.

ZigBee products with 1 mW RF output power are typically deployed where nodes are all in close proximity. Radios of this type have an indoor transmission range of around 100 feet (30 m), which is ample for applications in which transmission is unobstructed and in close range, such as home automation and some closely contained industrial applications.

Why high RF power products?

Many industrial applications greatly exceed the range of a 1 mW RF output radio or require transmission to rise above the noise floor. For these applications, the cost of the amplified radio is extremely well justified.

Radios that are 100 mW offer an indoor range of around 300 feet (100 m) and an outdoor line-of-site range of about 4000 feet (1200 m) (Figure 1). The much longer ranges make these products suitable for industrial applications in large factory settings and in outdoor installations, where nodes are often at intervals that cannot be spanned by unamplified ZigBee radios.

ZigBee radios with 100 mW RF power satisfy the range requirements of all but the most far-flung applications. While nodes within an indoor sensor application often are located at intervals greater than the 100-foot indoor range of low RF power radios, they are seldom spaced further apart than the 300-foot indoor range of 100 mW radios. In those instances where a link's span exceeds range, it can be accommodated by an intermediary ZigBee router functioning as a repeater.

In outdoor applications, the line-of-site range of a 100 mW ZigBee radio allows nodes to be placed as much as three-quarters of a mile apart. While this range is less than that of some competing technologies, it does allow ZigBee to be used in a wide variety of outdoor applications.

Related to the distance advantage of higher RF power is the technique's resistance to multipath fading. Multipath fading occurs when a radio signal is reflected by terrestrial objects, which cause copies of the signal to reach its destination by multiple paths (Figure 2). When the signals arrive at nearly the same time, but out of phase, multipath fading can cause cancellation. It also reduces received signal strength, which adds to the path loss. This can cause the received signal to fall below the receive sensitivity of the radio or cause the signal-to-noise ratio to fall below what is needed to receive the signal without error. Increasing RF power compensates for some forms of multipath, thereby ensuring that the most direct path delivers a strong signal that negates the multipath effect.

Applications for low/ high-power ZigBee radios

Whether low or high RF power is better for a given ZigBee application depends primarily on that application's need for range and resistance to multipath fading. These applications include:

■ Low RF power. A common example of ZigBee networking with low RF power is office lighting. In this application, light switches containing battery-powered ZigBee radios turn lights on and off by issuing commands to ZigBee radios in fluorescent tubes, with no wires between the switch and fixture (representing tremendous cost savings in eliminating electrical runs). Button-cell batteries in the light switches last for years, with the radio waking up and using battery power only when flipped on or off to transmit the new state to the fluorescent tubes. They then go immediately back to sleep. As switches and light fixtures are in close proximity, and ZigBee routers in the fluorescent tubes can relay commands to other routers, the application would work well using ZigBee radios with only 1 mW RF power.

■ Low and high RF power mixed. Some applications feature a mixture of short-range and longer-range wireless links. When a large number of those links can be satisfied by low RF power radios, it can be beneficial to mix the two radio types. Consider containerized shipping, in which a single cargo ship can transport thousands of containers, each with sensors to monitor temperature, tampering, etc. Each container can have a 1 mW RF power ZigBee radio for relaying sensor data, while the ship itself can have 100 mW ZigBee radios functioning as routers placed throughout as data collection points. The container radios can then relay sensor data over short links to the routers, which, in turn, can forward the data over longer distances to a ZigBee Ethernet gateway for delivery to a monitoring program.

■ High RF power. Some applications require all radios in a network to be of the high RF power variety. Consider homeland security, for example, where first responders populate areas of incident with multiple sensors to detect the presence of nuclear, biological or chemical (NBC) agents. ZigBee radios in such an application should all have high RF power. This way, the devices can be placed as far apart as needed and still ensure that transmissions aren't impeded by multipath fading due to buildings and other terrestrial objects. This application would also benefit enormously from ZigBee's mesh networking capability, with the network self-forming wherever radios are placed.

Conclusion

The availability of ZigBee radios with high and low RF power options is key to ZigBee's appeal in industrial settings, allowing design engineers to tie radio selections directly to range requirements. Along with ZigBee's many other industrial-friendly features, including mesh networking and extremely low radio cost, RF power options should go a long way toward helping this new standard advance as a leading technology for industrial wireless applications. **EWT**

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