Bluetooth radio interface, modulation, & channels

- overview of the Bluetooth radio interface or air interface, the forms of modulation used, Bluetooth power levels and Bluetooth channels.

The Bluetooth radio interface has been designed to enable communications to be made reliably over short distances. The radio interface is relatively straightforward, although it has many attractive features.The Bluetooth radio interface supports a large number of channels and different power levels, as well as using reliable forms of modulation.

Bluetooth radio interface basics

Running in the 2.4 GHz ISM band, Bluetooth employs frequency hopping techniques with the carrier modulated using Gaussian Frequency Shift Keying (GFSK).

With many other users on the ISM band from microwave ovens to Wi-Fi, the hopping carrier enables interference to be avoided by Bluetooth devices. A Bluetooth transmission only remains on a given frequency for a short time, and if any interference is present the data will be re-sent later when the signal has changed to a different channel which is likely to be clear of other interfering signals. The standard uses a hopping rate of 1600 hops per second, and the system hops over all the available frequencies using a pre-determined pseudo-random hop sequence based upon the Bluetooth address of the master node in the network..

During the development of the Bluetooth standard it was decided to adopt the use of frequency hopping system rather than a direct sequence spread spectrum approach because it is able to operate over a greater dynamic range. If direct sequence spread spectrum techniques were used then other transmitters nearer to the receiver would block the required transmission if it is further away and weaker.

Bluetooth modulation

The format originally chosen for Bluetooth in version 1 was Gaussian frequency shift keying, GFSK, however with the requirement for higher data rates two forms of phase shift keying were introduced for Bluetooth 2 to provide the Enhanced Data Rate, EDR capability.

Gaussian frequency shift keying: When GFSK is used for the chosen form of Bluetooth modulation, the frequency of the carrier is shifted to carry

the modulation. A binary one is represented by a positive frequency deviation and a binary zero is represented by a negative frequency deviation. The modulated signal is then filtered using a filter with a Gaussian response curve to ensure the sidebands do not extend too far either side of the main carrier. By doing this the Bluetooth modulation achieves a bandwidth of 1 MHz with stringent filter requirements to prevent interference on other channels. For correct operation the level of BT is set to 0.5 and the modulation index must be between 0.28 and 0.35.

Phase shift keying: Phase shift keying is the form of Bluetooth modulation used to enable the higher data rates achievable with Bluetooth 2 EDR (Enhanced Data Rate). Two forms of PSK are used:

- *π/4 DQPSK:* This is a form of phase shift keying known as π/4 differential phase shift keying. It enables the raw data rate of 2 Mbps to be achieved.
- *8DPSK:* This form of Bluetooth modulation is eight point or 8-ary phase shift keying. It is used when link conditions are good and it allows raw data rates of up to 3 Mbps to be achieved.

The enhanced data rate capability for Bluetooth modulation is implemented as an additional capability so that the system remains backwards compatible.

The Bluetooth modulation schemes and the general format do not lend themselves to carrying higher data rates. For Bluetooth 3, the higher data rates are not achieved by changing the format of the Bluetooth modulation, but by working cooperatively with an IEEE 802.11g physical layer. In this way data rates of up to around 25 Mbps can be achieved.

Bluetooth power levels

The transmitter powers for Bluetooth are quite low, although there are three different classes of output dependent upon the anticipated use and the range required.

Power Class 1 is designed for long range communications up to about 100m devices, and this has a maximum output power of 20 dBm.

Next is Power Class 2 which is used for what are termed for ordinary range devices with a range up to about 10m, with a maximum output power of 6 dBm.

Finally there is Power Class 3 for short range devices. Bluetooth class 3 supports communication only up to distances of about 10cm and it has a maximum output power of 0 dBm.

Power control is mandatory for Bluetooth Class 1, but optional for the others, although its use is advisable to conserve battery power. The appropriate power elvel can be chosen according to the RSSI, Received Strength Signal Indictor reading

Bluetooth power level choice and RSSI

In order to conserve battery power, the lowest transmitted power level consistent with a reliable link should be chosen. Assuming that power level control is available, the power level is chosen according to an RSSI reading. If the RSSI indication falls below a given level, the Bluetooth power level can be increased to bring the RSSI level up to an accepted level.

The value of any RSSI figure is arbitrary as it is simply used to provide an indication of when the signal level and hence the transmitted power level needs to be increased or decreased.

The Bluetooth specification does define a maximum bit error rate of 0.1% and this equates to a minimum requirement for the receive sensitivity of -70dBm. This figures for sensitivity then lead to the distances achievable for the different power levels, although today's receivers are generally more sensitive than those that were used to baseline the specification at its launch..

The Bluetooth radio interface provides rugged physical layer without any unnecessary complications to carry the required data from one device to the next. With many devices being physically small and not having large battery capacity levels, the radio interface has been designed to keep power consumption low, while still providing the required capabilities.