

## 2 PHYSICAL CHANNEL

### 2.1 FREQUENCY BAND AND RF CHANNELS

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Country	Frequency Range	RF Channels	
Europe* & USA	2400 - 2483.5 MHz	$f = 2402 + k$ MHz	$k = 0, \dots, 78$
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Table 2.1: Available RF channels

\*. except Spain and France

### 2.2 CHANNEL DEFINITION

The channel is represented by a pseudo-random hopping sequence hopping through the 79 or 23 RF channels. The hopping sequence is unique for the piconet and is determined by the Bluetooth device address of the master; the phase in the hopping sequence is determined by the Bluetooth clock of the master. The channel is divided into time slots where each slot corresponds to an RF hop frequency. Consecutive hops correspond to different RF hop frequencies. The nominal hop rate is 1600 hops/s. All Bluetooth units participating in the piconet are time- and hop-synchronized to the channel.

### 2.3 TIME SLOTS

The channel is divided into time slots, each 625  $\mu$ s in length. The time slots are numbered according to the Bluetooth clock of the piconet master. The slot numbering ranges from 0 to  $2^{27}-1$  and is cyclic with a cycle length of  $2^{27}$ .

In the time slots, master and slave can transmit packets.

A TDD scheme is used where master and slave alternatively transmit, see Figure 2.1 on page 44. The master shall start its transmission in even-numbered time slots only, and the slave shall start its transmission in odd-numbered time slots only. The packet start shall be aligned with the slot start. Packets transmitted by the master or the slave may extend over up to five time slots.

### 3.2.1 In-band Spurious Emission

Within the ISM band the transmitter shall pass a spectrum mask, given in [Table 3.2](#). The spectrum must comply with the FCC's 20-dB bandwidth definition stated below, and should be measured accordingly. In addition to the FCC requirement an adjacent channel power on adjacent channels with a difference in channel number of two or greater an adjacent channel power is defined. This adjacent channel power is defined as the sum of the measured power in a 1 MHz channel. The transmitted power shall be measured in a 100 kHz bandwidth using maximum hold. The transmitter is transmitting on channel M and the adjacent channel power is measured on channel number N. The transmitter is sending a pseudo random data pattern throughout the test.

Frequency offset	Transmit Power
$\pm 550$ kHz	-20 dBc
$ M-N  = 2$	-20 dBm
$ M-N  \geq 3$	-40 dBm

Table 3.2: Transmit Spectrum mask.

**Note:** If the output power is less than 0dBm then, wherever appropriate, the FCC's 20 dB relative requirement overrules the absolute adjacent channel power requirement stated in the above table.

"In any 100 kHz bandwidth outside the frequency band in which the spread spectrum intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in § 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in § 15.205(a), must also comply with the radiated emission limits specified in § 15.209(a) (see § 15.205(c))."

FCC Part 15.247c

Exceptions are allowed in up to three bands of 1 MHz width centered on a frequency which is an integer multiple of 1 MHz. They must, however, comply with an absolute value of -20 dBm.

### 3.2.2 Out-of-Band Spurious Emission

The measured power should be measured in a 100 kHz bandwidth.

Frequency Band	Operation mode	Idle mode
30 MHz - 1 GHz	-36 dBm	-57 dBm
1 GHz – 12.75 GHz	-30 dBm	-47 dBm
1.8 GHz – 1.9 GHz	-47 dBm	-47 dBm
5.15 GHz – 5.3 GHz	-47 dBm	-47 dBm

Table 3.3: Out-of-band spurious emission requirement

## 10 CHANNEL CONTROL

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### 10.1 SCOPE

This section describes how the channel of a piconet is established and how units can be added to and released from the piconet. Several states of operation of the Bluetooth units are defined to support these functions. In addition, the operation of several piconets sharing the same area, the so-called scatter-net, is discussed. A special section is attributed to the Bluetooth clock which plays a major role in the FH synchronization.

### 10.2 MASTER-SLAVE DEFINITION

The channel in the piconet is characterized entirely by the master of the piconet. The Bluetooth device address (BD\_ADDR) of the master determines the FH hopping sequence and the channel access code; the system clock of the master determines the phase in the hopping sequence and sets the timing. In addition, the master controls the traffic on the channel by a polling scheme.

By definition, the **master** is represented by the Bluetooth unit that initiates the connection (to one or more **slave** units). Note that the names 'master' and 'slave' only refer to the protocol on the channel: the Bluetooth units themselves are identical; that is, any unit can become a master of a piconet. Once a piconet has been established, master-slave roles can be exchanged. This is described in more detail in [Section 10.9.3 on page 123](#).

### 10.3 BLUETOOTH CLOCK

Every Bluetooth unit has an internal system clock which determines the timing and hopping of the transceiver. The Bluetooth clock is derived from a free running native clock which is never adjusted and is never turned off. For synchronization with other units, only offsets are used that, added to the native clock, provide temporary Bluetooth clocks which are mutually synchronized. It should be noted that the Bluetooth clock has no relation to the time of day; it can therefore be initialized at any value. The Bluetooth clock provides the heart beat of the Bluetooth transceiver. Its resolution is at least half the TX or RX slot length, or 312.5  $\mu$ s. The clock has a cycle of about a day. If the clock is implemented with a counter, a 28-bit counter is required that wraps around at  $2^{28}-1$ . The LSB ticks in units of 312.5  $\mu$ s, giving a clock rate of 3.2 kHz.

The timing and the frequency hopping on the channel of a piconet is determined by the Bluetooth clock of the master. When the piconet is established, the master clock is communicated to the slaves. Each slave adds an offset to its native clock to be synchronized to the master clock. Since the clocks are free-running, the offsets have to be updated regularly.

The clock determines critical periods and triggers the events in the Bluetooth receiver. Four periods are important in the Bluetooth system: 312.5  $\mu$ s, 625  $\mu$ s, 1.25 ms, and 1.28 s; these periods correspond to the timer bits CLK<sub>0</sub>, CLK<sub>1</sub>, CLK<sub>2</sub>, and CLK<sub>12</sub>, respectively, see [Figure 10.1 on page 96](#). Master-to-slave transmission starts at the even-numbered slots when CLK<sub>0</sub> and CLK<sub>1</sub> are both zero.

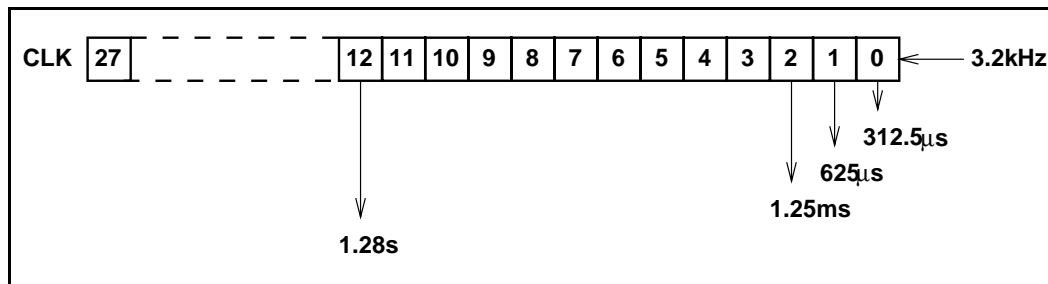


Figure 10.1: Bluetooth clock.

In the different modes and states a Bluetooth unit can reside in, the clock has different appearances:

- CLKN            native clock
- CLKE            estimated clock
- CLK             master clock

CLKN is the free-running native clock and is the reference to all other clock appearances. In states with high activity, the native clock is driven by the reference crystal oscillator with worst case accuracy of +/-20ppm. In the low power states, like **STANDBY**, **HOLD**, **PARK**, the native clock may be driven by a low power oscillator (LPO) with relaxed accuracy (+/-250ppm).

CLKE and CLK are derived from the reference CLKN by adding an offset. CLKE is a clock estimate a paging unit makes of the native clock of the recipient; i.e. an offset is added to the CLKN of the pager to approximate the CLKN of the recipient, see [Figure 10.2 on page 97](#). By using the CLKN of the recipient, the pager speeds up the connection establishment.

CLK is the master clock of the piconet. It is used for all timing and scheduling activities in the piconet. All Bluetooth devices use the CLK to schedule their transmission and reception. The CLK is derived from the native clock CLKN by adding an offset, see [Figure 10.3 on page 97](#). The offset is zero for the master since CLK is identical to its own native clock CLKN. Each slave adds an appropriate offset to its CLKN such that the CLK corresponds to the CLKN of the master. Although all CLKNs in the Bluetooth devices run at the same nominal rate, mutual drift causes inaccuracies in CLK. Therefore, the offsets in the slaves must be regularly updated such that CLK is approximately CLKN of the master.

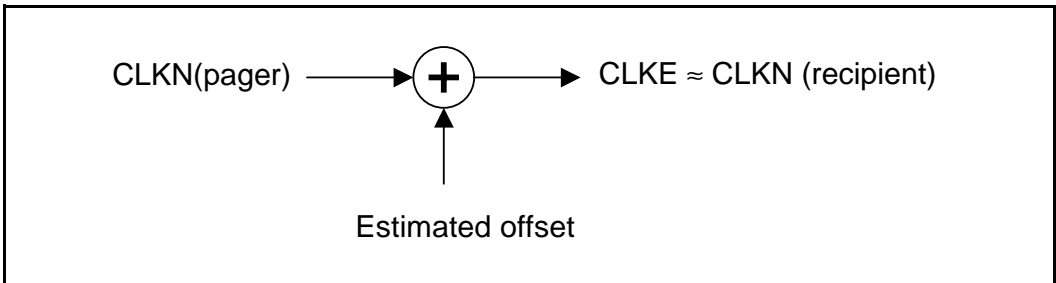


Figure 10.2: Derivation of CLKE

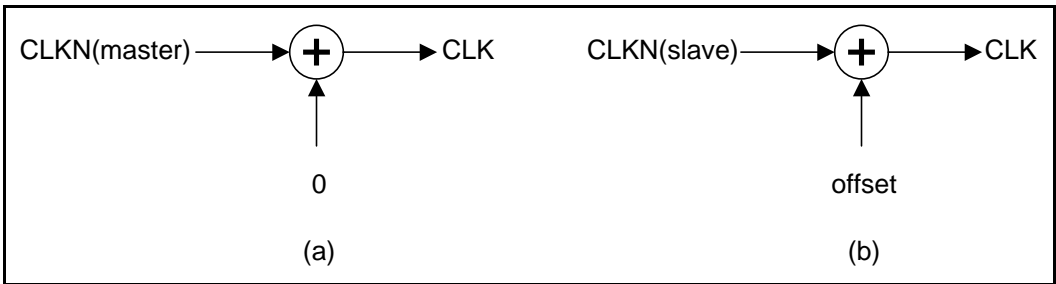


Figure 10.3: Derivation of CLK in master (a) and in slave (b).

## 10.4 OVERVIEW OF STATES

Figure 10.4 on page 98 shows a state diagram illustrating the different states used in the Bluetooth link controller. There are two major states: **STANDBY** and **CONNECTION**; in addition, there are seven substates, **page**, **page scan**, **inquiry**, **inquiry scan**, **master response**, **slave response**, and **inquiry response**. The substates are interim states that are used to add new slaves to a piconet. To move from one state to the other, either commands from the Bluetooth link manager are used, or internal signals in the link controller are used (such as the trigger signal from the correlator and the timeout signals).

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