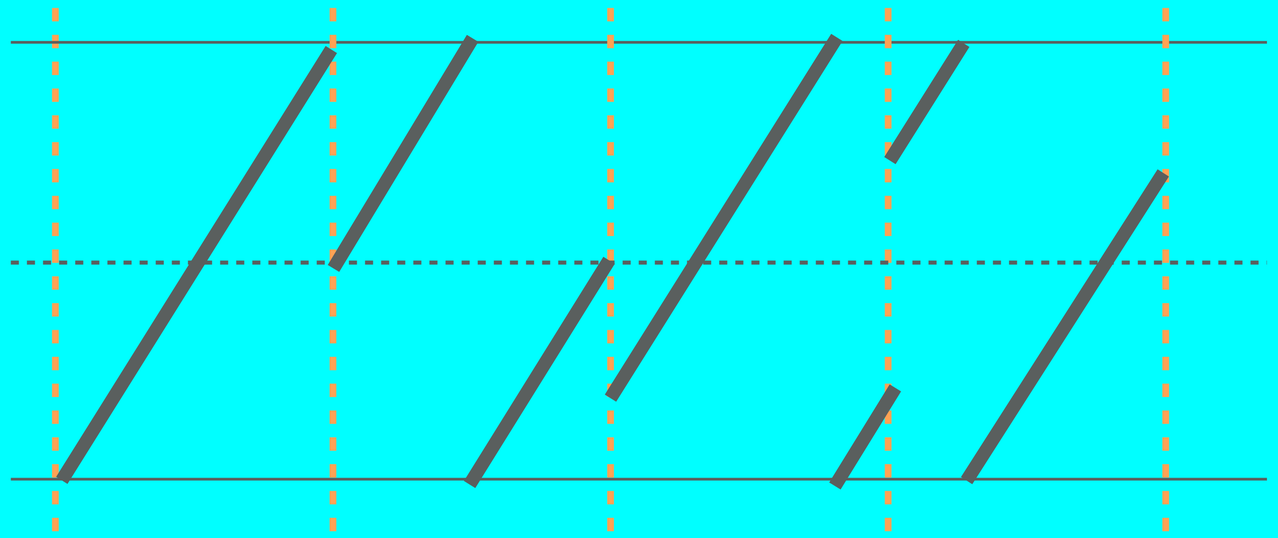
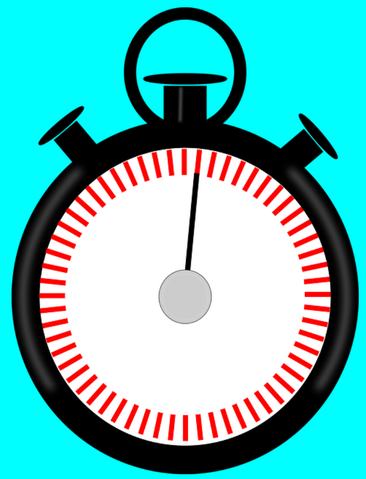
LORA / LORAWAN TUTORIAL 15

Data Rate, Chip Rate, Symbol Rate
Chip Duration & Symbol Duration





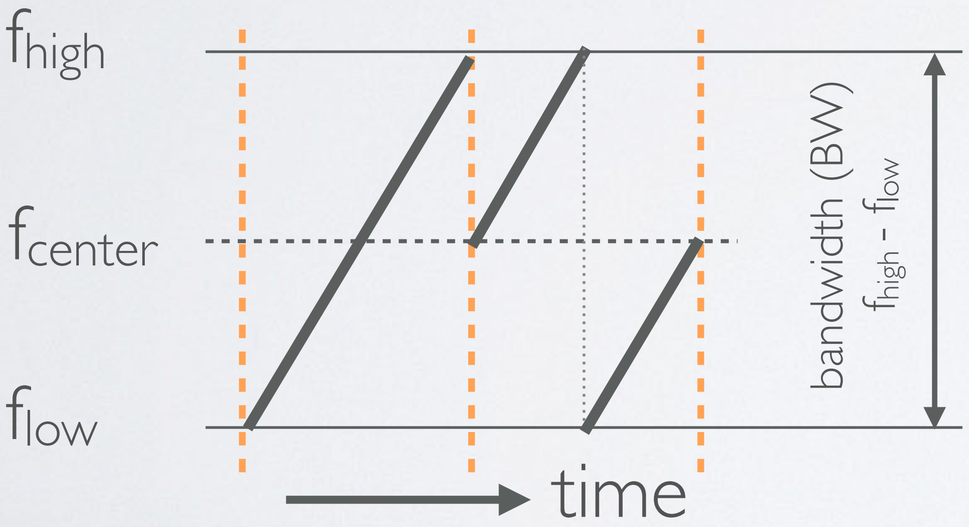
INTRO

- In this tutorial I will explain how data rate, chip rate, symbol rate, chirp duration and symbol duration are calculated.

CHIP RATE

- The unit of bandwidth (BW) is Hertz (Hz) which is the number of vibrations or wave cycles per second. This bandwidth is interchangeably with chip rate:
  BW = R_c = chip rate (chips/s) [1]

- For example: BW=125 kHz
  BW = R_c = 125000 chips/s



SF=9
Symbol carries 9 raw bits of information
Symbol holds $2^{SF} = 2^9 = 512$ chips

SYMBOL RATE

- The Symbol Rate (R_s) is calculated as follow:

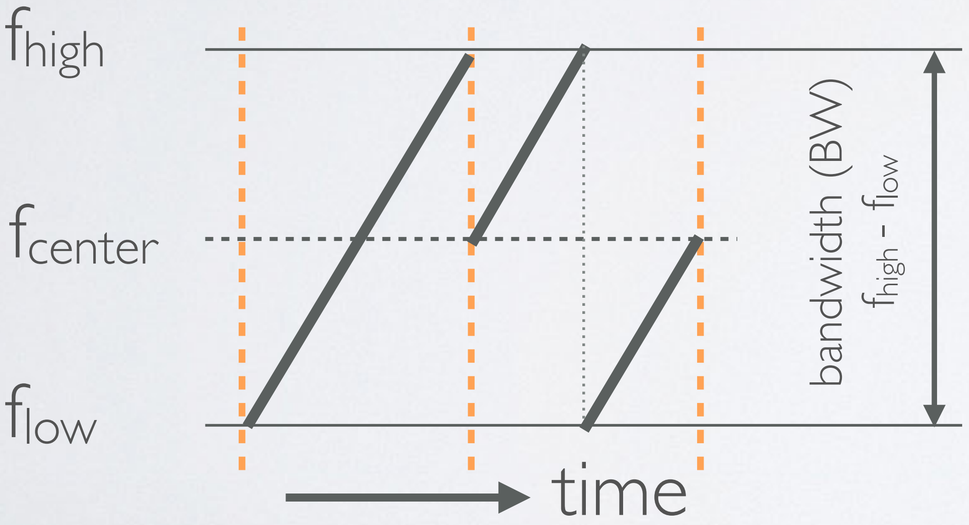
  R_s (symbols/sec) = BW / 2^{SF} = R_c / 2^{SF} [1]

  Bandwidth (BW) in Hz

  Spreading Factor (SF): 7-12

- For example: BW=125 kHz, SF=7

  R_s = 125000 / 2^7 = 977 symbols/sec



DATA RATE

- The chip rate is always higher than the symbol rate: $R_c > R_s$

- To calculate the data rate (DR) or bit rate (R_b):

$$R_b \text{ (bits/sec)} = SF \times \frac{BW}{2^{SF}} \times \frac{4}{(4 + CR)} \qquad [1]$$

Bandwidth (BW) in Hz
Spreading Factor (SF): 7-12
Code Rate (CR): 1-4

DATA RATE

- For example: SF=7, CR=1

$$BW=125\ kHz,\ R_b = 7 \times (125000 / 2^7) \times (4 / (4 + 1)) = 5.5\ kbits/s$$

$$BW=250\ kHz,\ R_b = 7 \times (250000 / 2^7) \times (4 / (4 + 1)) = 10.9\ kbits/s$$

$$BW=500\ kHz,\ R_b = 7 \times (500000 / 2^7) \times (4 / (4 + 1)) = 21.9\ kbits/s$$

- If you increase the bandwidth, the bit rate or data rate is increased.

DATA RATE

- For example: BW=125 kHz, CR=1

$$SF=7,\ R_b = 7 \times (125000/2^7) \times (4/(4+1)) = 5.5 \text{ kbits/s}$$
$$SF=8,\ R_b = 8 \times (125000/2^8) \times (4/(4+1)) = 3.13 \text{ kbits/s}$$
$$SF=9,\ R_b = 9 \times (125000/2^9) \times (4/(4+1)) = 1.76 \text{ kbits/s}$$
$$SF=10,\ R_b = 10 \times (125000/2^{10}) \times (4/(4+1)) = 0.98 \text{ kbits/s}$$
$$SF=11,\ R_b = 11 \times (125000/2^{11}) \times (4/(4+1)) = 0.54 \text{ kbits/s}$$
$$SF=12,\ R_b = 12 \times (125000/2^{12}) \times (4/(4+1)) = 0.29 \text{ kbits/s}$$

- If you increase the Spreading Factor, the bit rate or data rate is decreased.

CHIP DURATION

- Because R_c = BW [1], the chip duration is calculated as follow:

  T_c (sec) = 1 / BW

  Bandwidth (BW) in Hz

- For example: BW=125 kHz

  $T_c = 1 / 125000 = 8\ \mu s$

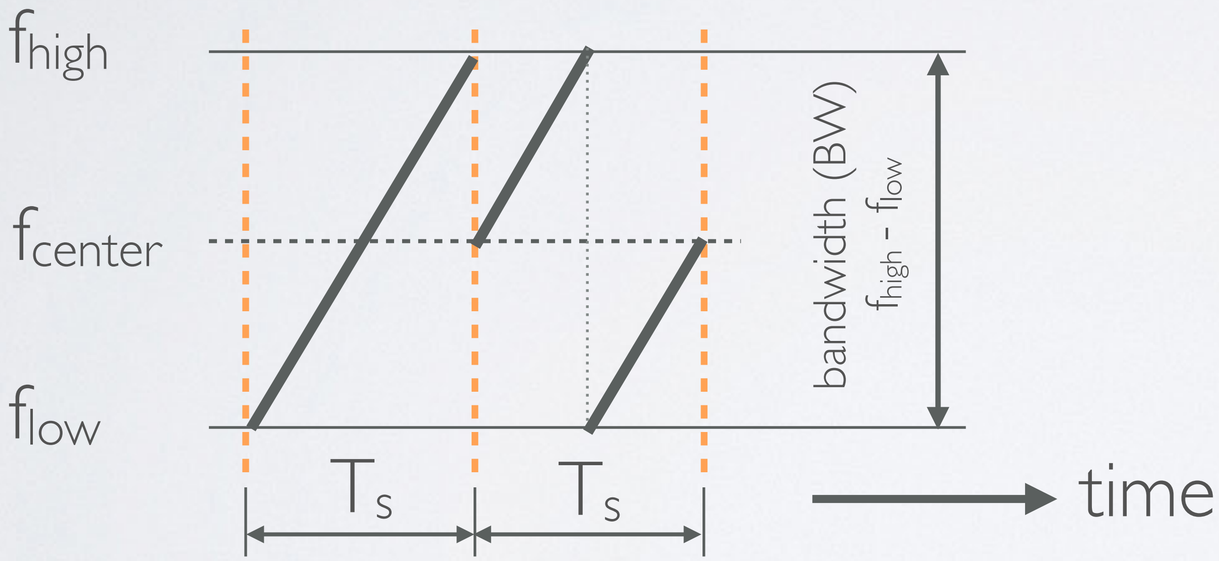
SYMBOL DURATION

- The symbol duration or sweep time is calculated as follow:

$$T_s(sec) = 2^{SF} / BW \quad [1]$$

Bandwidth (BW) in Hz

Spreading Factor (SF): 7-12



SYMBOL DURATION

- For example: SF7

  BW=125 kHz, $T_s = 2^7 / 125000 = 1.024$ ms

  BW=250 kHz, $T_s = 2^7 / 250000 = 512$ μs

  BW=500 kHz, $T_s = 2^7 / 500000 = 256$ μs

  If the BW increases, the Symbol duration decreases.

- For example: BW=125 kHz

  SF=7, $T_s = 2^7 / 125000 = 1.024$ ms

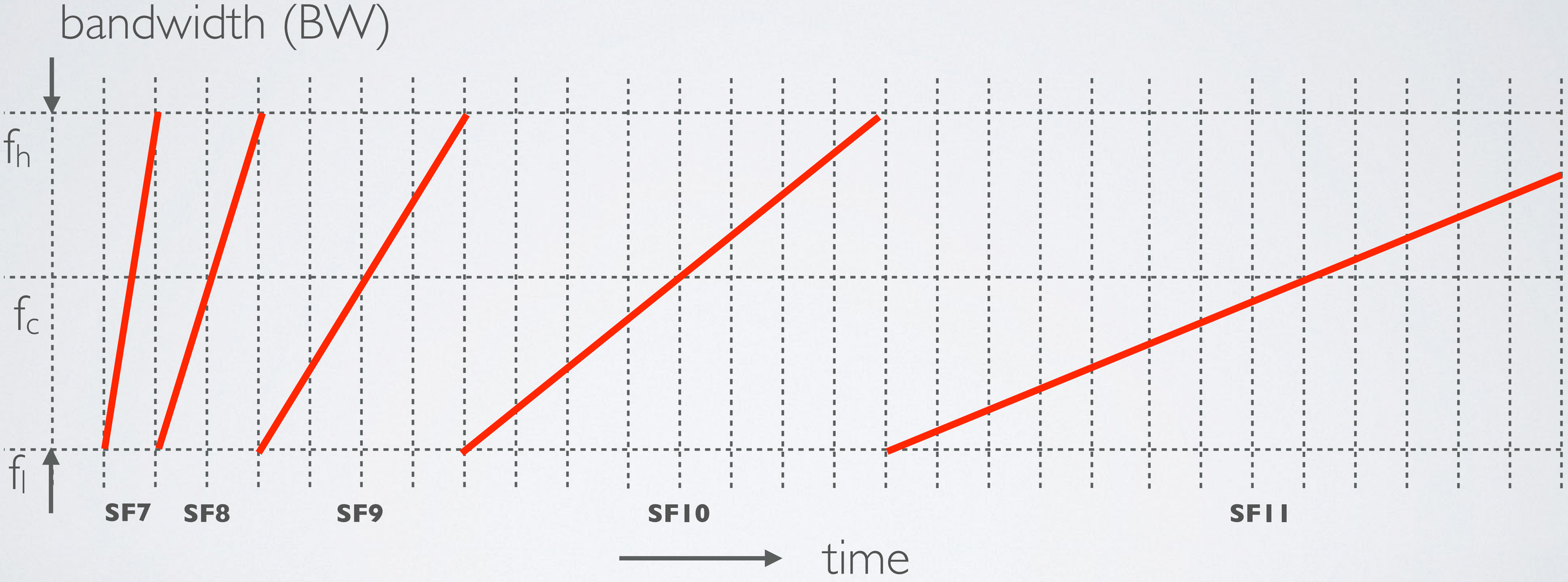
  SF=9, $T_s = 2^9 / 125000 = 4.096$ ms

  SF=12, $T_s = 2^{12} / 125000 = 32.768$ ms

  If the SF increases, the Symbol duration increases.

SPREADING FACTOR VS SYMBOL DURATION

- An overview of symbol durations with respect to different Spreading Factors.
  If the SF increases by one the symbol duration doubles.



SPREADING FACTOR IMPACT

- If you increase the SF by 1:
  - The symbol duration or sweep time doubles compared to the previous SF.
  - It reduces the bit rate approximately by half compared to the previous SF.
  - The Time on Air (ToA) (= the amount of time that the transmitter antenna is energised and transmitting data) increases which means the distance increases.
- To give you an idea what the Time on Air is for a 10 byte payload, BW=125kHz:
  SF7: ToA = 41 ms
  SF12:ToA = 991 ms
  See: https://www.loratools.nl/#/airtime

SPREADING FACTOR IMPACT

- LoRa devices uses a higher spreading factor when the signal is weak or there is lot of interference. Using a higher spreading factor means a longer Time on Air (ToA).

- If an end device is further away from a gateway the signal get weaker and therefore needs a higher spreading factor.