3.7 CYCLIC PREFIX

- Delay spread is generated by the set of different paths between the transmitter and receiver when those paths have different delays. For example, a signal following a direct line-of-sight path would arrive before a different version of the same signal which is reflected by a distant building
- Time domain receivers typically synchronise with each delay spread component and adjust their individual timings before combining. When using a Rake receiver, each finger belonging to the Rake synchronises with a specific delay spread component. The number of delay spread components which can be combined is then limited by the number of Rake fingers. Any delay spread components which are not combined appear as interference
- LTE receivers do not need to synchronise with individual delay spread components, i.e. it is not necessary to adjust the timing of delay spread components, nor is it necessary to do any combining of delay spread components. An LTE receiver can operate directly on the aggregate received signal without considering delay spread components
- The Cyclic Prefix represents a guard period at the start of each OFDMA symbol which provides protection against multi-path delay spread. The cyclic prefix also represents an overhead which should be minimised
- The duration of the cyclic prefix should be greater than the duration of the multi-path delay spread
- LTE specifies both normal and extended cyclic prefix lengths. The normal cyclic prefix is intended to be sufficient for the majority of scenarios, while the extended cyclic prefix is intended for scenarios with particularly high delay spread. Durations for the normal and extended cyclic prefix are presented in Table 18

	Normal Cyclic Prefix		Extended Cyclic Prefix	
	15 kHz subcarriers		15 kHz subcarriers	7.5 kHz subcarriers
	160 Ts	144 Ts	512 Ts	1024 Ts
Duration	5.2 µs	4.7 µs	16.7 µs	33.3 µs
Equivalent Distance	1.6 km	1.4 km	5 km	10 km
Overhead	160 / 2048 = 7.8 %	144 / 2048 = 7.0 %	512 / 2048 = 25 %	1024 / 4096 = 25 %

Table 18 – Cyclic prefix lengths for the downlink of LTE

- The cyclic prefix is generated by copying the end of the main body of the OFDMA symbol. This is shown in Figure 25

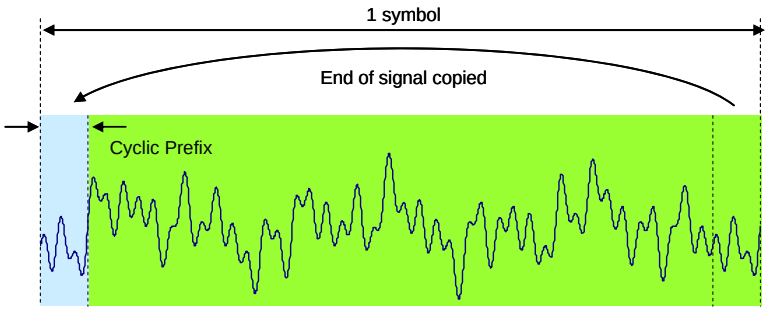

Figure 25 – Generating the cyclic prefix

- The signal is always continuous at the interface between the cyclic prefix and the main body of the symbol. This results from the main body of the symbol always including an integer number of subcarrier cycles, i.e. 1 cycle at 15 kHz, 2 cycles at 30 kHz, etc
- Figure 26 illustrates an example of 2 delay spread components. The second delay spread component is received later than the first delay spread component. A Fast Fourier Transform (FFT) processing window is defined at the receiver:
  - the processing window captures the main body of the OFDMA symbol belonging to the first delay spread component. The cyclic prefix belonging to the first delay spread component is discarded
  - the processing window captures part of the cyclic prefix and the majority of the main body of the OFDMA symbol belonging to the second delay spread component. Sections of the cyclic prefix and main body of the OFDMA symbol which fall outside the processing window are discarded
- In the extreme case, where the delay spread is equal to the duration of the cyclic prefix then the FFT processing window fully captures the cyclic prefix belonging to the delay spread component and discards a section of the main body of the ODFMA symbol which has a duration equal to the cyclic prefix
- The time domain representation of each delay spread component within the processing window is different (as shown in Figure 26). However, the frequency domain representation of each delay spread component within the processing window is identical

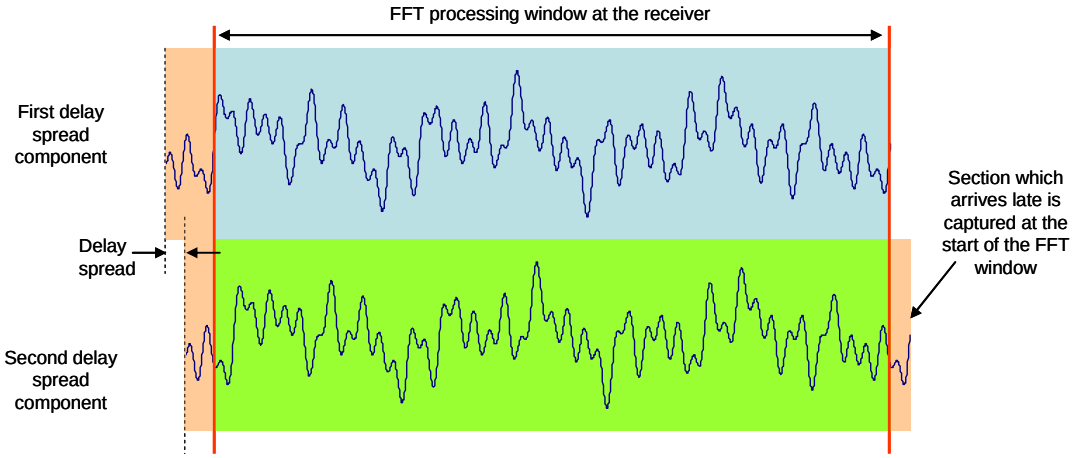

Figure 26 – Delay spread components captured by FFT processing window at the receiver

- Moving a section of the time domain signal from the end, and adding it to the start does not change the frequency content of the signal, i.e. the signal includes the same set of frequency domain components and an FFT (which quantifies the set of frequency domain components included within a time domain signal) generates the same result
- As long as the delay spread is less than the duration of the cyclic prefix, each delay spread component provides a complete representation of the signal within the FFT processing window, i.e. the same set of frequency components are generated by the FFT. This avoids the requirement to time synchronise with individual delay spread components prior to decoding
- Figure 27 illustrates the aggregate signal captured by the receiver. The aggregate signal is the sum of all the delay spread components (only 2 are shown for simplicity). The receiver can operate directly on the aggregate signal without having to extract individual delay spread components because the frequency content of the sum of delay spread components, is the same as the frequency content of each individual delay spread component. The aggregate signal captures the energy from all delay spread components so generates a higher quality result from the FFT

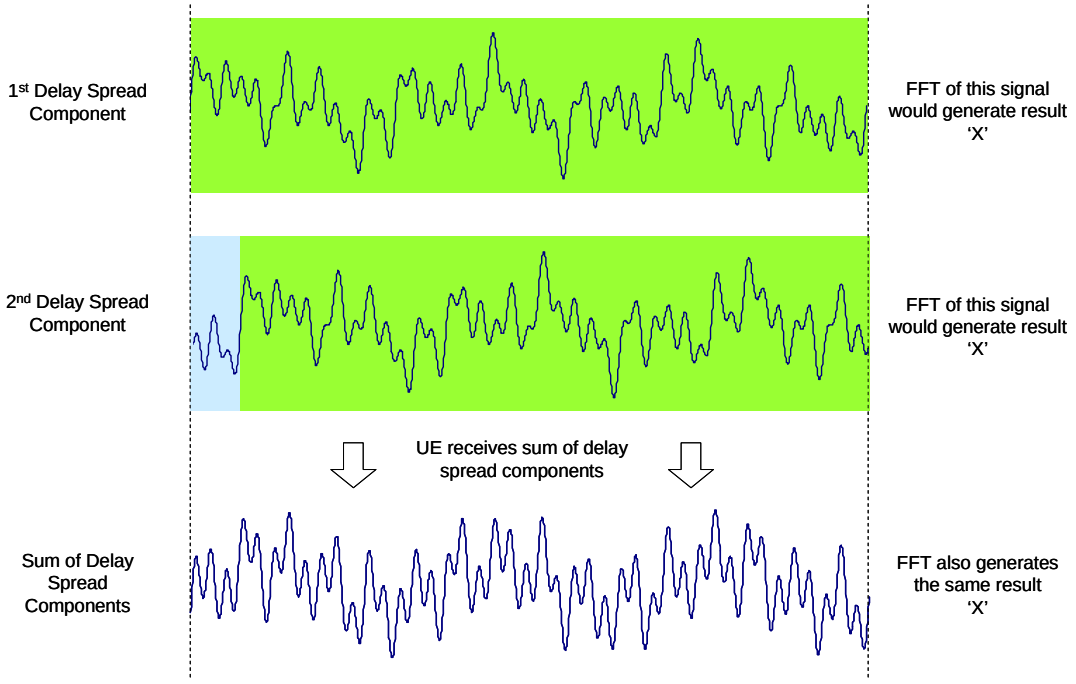

Figure 27 – Delay spread components captured by FFT processing window at the receiver

- The equation shown in section 3.5 from 3GPP TS 36.211 includes the generation of the cyclic prefix. The time variable 't' accounts for N_{CP} samples which correspond to the cyclic prefix