

**CLAIMS**

1. A method for wireless communications by a base station (BS), comprising: generating a primary synchronization signal (PSS) utilizing a first code sequence and a cover code applied to the first code sequence over a first number of symbols within one or more subframes, wherein the cover code comprises at least one of a computer generated binary sequence, a Walsh code, or a Barker code; and transmitting the PSS to a first type of a user equipment (UE) that communicates on one or more narrowband carrier regions relative to a wider carrier bandwidth.
2. The method of claim 1, wherein the first code sequence is generated using at least one of a computer generated sequence (CGS), a modified Zadoff-Chu sequence with a reduced alphabet, a Walsh code, a Barker code, or a truncated Zadoff-Chu sequence.
3. The method of claim 1, further comprising: generating a secondary synchronization signal (SSS) based on a second code sequence over a second number of symbols within one or more subframes; and transmitting the SSS to the first type of the UE.
4. The method of claim 3, wherein PSS and SSS are transmitted using non-overlapping resources.
5. The method of claim 4, wherein PSS and SSS are transmitted in separate subframes.
6. The method of claim 3, wherein the first number of symbols are mapped to resource elements that have a same subcarrier spacing as resource elements used to communicate with a second type of UE that communicates on the wider carrier bandwidth.
7. The method of claim 6, wherein the PSS and SSS are transmitted using resource elements not used for communicating with the second type of UE.
8. The method of claim 3, wherein: the first number of symbols are within a first subframe; and the second number of symbols are within a second subframe.
9. The method claim 8, wherein transmitting the PSS and SSS comprises time multiplexing the PSS and SSS sequences within at least one of the first and second subframes, and wherein the PSS and SSS occupy different orthogonal frequency division multiplexing (OFDM) symbol locations with at least one subframe.

10. The method of claim 3, wherein the second code sequence comprises a Zadoff-Chu sequence, a truncated Zadoff-Chu sequence, or a computer generated polyphase sequence.

11. The method of claim 3, wherein the SSS is used to convey a cell identification (cell ID) and additional system information.

12. The method of claim 11, wherein the additional system information comprises at least a subframe ID.

13. A method for wireless communications by a first type of user equipment (UE), comprising: detecting, within one or more narrowband carrier regions relative to a wider carrier bandwidth, a primary synchronization signal (PSS) generated utilizing a first code sequence and a cover code applied to the first code sequence over a first number of symbols within one or more subframes, wherein the cover code comprises at least one of a Walsh code, a Barker code, or a computer generated binary sequence; and performing time synchronization and a frequency synchronization based on the PSS.

14. The method of claim 13, wherein performing the frequency synchronization comprises: performing a fractional frequency offset correction, from the PSS, based on autocorrelation in time domain of the time synchronized PSS or based on multiple hypothesis testing and frequency binning; and performing an integer frequency offset correction, from the PSS, based on cross correlation in frequency domain between the PSS and a local replica of the received signal.

15. The method of claim 13, wherein the first code sequence is generated using at least one of a generated sequence (CGS), a modified Zadoff-Chu sequence with a reduced alphabet, a Walsh code, a Barker code, or a truncated Zadoff-Chu sequence.

16. The method of claim 13, further comprising: performing a maximum-likelihood time offset estimation based on the PSS, wherein the time offset is uncorrelated with a frequency offset; detecting, within the one or more narrowband carrier regions, a secondary synchronization signal (SSS) generated based on a second code sequence over a second number of symbols within the one or more subframes; and performing at least one of fine time synchronization or fine frequency synchronization based on the SSS, to refine the time and frequency synchronization.

17. The method of claim 16, wherein PSS and SSS are detected in non-overlapping resources.

18. The method of claim 17, wherein PSS and SSS are detected in separate subframes.

19. The method of claim 16, wherein performing the fine timing synchronization comprises performing cross correlation in time domain on the SSS.

20. The method of claim 16, wherein the first number of symbols are mapped to resource elements that have a same subcarrier spacing as resource elements used to communicate with a second type of UE that communicates on the wider carrier bandwidth.

21. The method of claim 20, wherein the PSS and SSS are transmitted using resource elements not used for communicating with the second type of UE.

22. The method of claim 16, wherein: the first number of symbols are within a first subframe; and the second number of symbols are within a second subframe.

23. The method of claim 16, wherein the second code sequence comprises a Zadoff-Chu sequence, a computer generated polyphase sequence, or a truncated Zadoff-Chu sequence.

24. The method of claim 16, further comprising determining, from the SSS, a cell identification (cell ID) and additional system information.

25. The method of claim 24, wherein the additional system information comprises at least a subframe ID.

26. The method of claim 16, wherein performing the fine time synchronization comprises: performing a timing offset correction based on a maximum likelihood (ML) estimation by coherently combining all co-phased symbol pairs according to a pattern of the cover code, wherein a range of the combining spans across the one or more subframes; and normalizing a cost function by a power of the PSS sequence to reduce sensitivity to signal to noise ratio (SNR) levels.

27. The method of claim 26, wherein the combining of the co-phased symbol pairs comprises: performing autocorrelation between delayed samples of the PSS, wherein a lag size of the delayed samples is a configurable parameter based on PSS time domain resource allocation.

28. The method of claim 26, wherein a pattern of the cover code is selected to shape the ML estimation of the timing offset into a desired form.

29. An apparatus for wireless communications, comprising: at least one processor configured to generate a primary synchronization signal (PSS) utilizing a first code sequence and a cover code applied to the first code sequence over a first number of symbols within one or more subframes, wherein the cover code comprises at least one of a Walsh code, a Barker code, or a computer generated binary sequence; and a transmitter configured to transmit the PSS to a first type of a user equipment (UE) that communicates on one or more narrowband carrier regions relative to a wider carrier bandwidth.

30. The apparatus of claim 29, wherein the first code sequence is generated using at least one of a computer generated sequence (CGS), a modified Zadoff-Chu sequence with a reduced alphabet, a Walsh code, a Barker code, or a truncated Zadoff-Chu sequence.

31. The apparatus of claim 29, wherein: the at least one processor is configured to generate a secondary synchronization signal (SSS) based on a second code sequence over a second number of symbols within one or more subframes; and the transmitter is configured to transmit the SSS to the first type of the UE.

32. The apparatus of claim 31, wherein PSS and SSS are transmitted using non-overlapping resources.

33. The apparatus of claim 32, wherein PSS and SSS are transmitted in separate subframes.

34. The apparatus of claim 31, wherein the first number of symbols are mapped to resource elements that have a same subcarrier spacing as resource elements used to communicate with a second type of UE that communicates on the wider carrier bandwidth.

35. The apparatus of claim 34, wherein the PSS and SSS are transmitted using resource elements not used for communicating with the second type of UE.

36. The apparatus of claim 31, wherein: the first number of symbols are within a first subframe; and the second number of symbols are within a second subframe.

37. The apparatus claim 36, wherein transmitting the PSS and SSS comprises time multiplexing the PSS and SSS sequences within at least one of first and second subframes, and wherein the PSS and SSS occupy different orthogonal frequency division multiplexing (OFDM) symbol locations with at least one subframe.

38. The apparatus of claim 31, wherein the second code sequence comprises a Zadoff-Chu sequence, a truncated Zadoff-Chu sequence, or a computer generated polyphase sequence.

39. The apparatus of claim 31, wherein the SSS is used to convey a cell identification (cell ID) and additional system information.

40. The apparatus of claim 39, wherein the additional system information comprises at least a subframe ID.

41. An apparatus for wireless communications, comprising: at least one processor configured to detect, within one or more narrowband carrier regions relative to a wider carrier bandwidth, a primary synchronization signal (PSS) generated utilizing a first code sequence and a cover code applied to the first code sequence over a first number of symbols within one or more subframes, wherein the cover code comprises at least one of a Walsh code, a Barker code, or a computer generated binary sequence, and perform time synchronization and a frequency synchronization based on the PSS; and a memory coupled with the at least one processor.

42. The apparatus of claim 41, wherein the at least one processor is configured to perform the frequency synchronization by: performing a fractional frequency offset correction, from the PSS, based on autocorrelation in time domain of the time synchronized PSS or based on multiple hypothesis testing and frequency binning; and performing an integer frequency offset correction, from the PSS, based on cross correlation in frequency domain between the PSS and a local replica of the received signal.

43. The apparatus of claim 41, wherein the first code sequence is generated using at least one of a generated sequence (CGS), a modified Zadoff-Chu sequence with a reduced alphabet, a Walsh code, a Barker code, or a truncated Zadoff-Chu sequence.

44. The apparatus of claim 41, wherein the at least one processor is configured to: perform a maximum-likelihood time offset estimation based on the PSS, wherein the time offset is uncorrelated with a frequency offset; detect, within the one or more narrowband carrier regions, a secondary synchronization signal (SSS) generated based on a second code sequence over a second number of symbols within the one or more subframes; and perform at least one of fine

time synchronization or fine frequency synchronization based on the SSS, to refine the time and frequency synchronization.

45. The apparatus of claim 44, wherein PSS and SSS are detected in non-overlapping resources.

46. The apparatus of claim 45, wherein PSS and SSS are detected in separate subframes.

47. The apparatus of claim 44, wherein the at least one processor is configured to perform the fine timing synchronization by performing cross correlation in time domain on the SSS.

48. The apparatus of claim 44, wherein the first number of symbols are mapped to resource elements that have a same subcarrier spacing as resource elements used to communicate with a second type of UE that communicates on the wider carrier bandwidth.

49. The apparatus of claim 48, wherein the PSS and SSS are transmitted using resource elements not used for communicating with the second type of UE.

50. The apparatus of claim 44, wherein: the first number of symbols are within a first subframe; and the second number of symbols are within a second subframe.

51. The apparatus of claim 44, wherein the second code sequence comprises a Zadoff-Chu sequence, a computer generated polyphase sequence, or a truncated Zadoff-Chu sequence.

52. The apparatus of claim 51, wherein the at least one processor is configured to perform the fine time synchronization by: performing a timing offset correction based on a maximum likelihood (ML) estimation by coherently combining all co-phased symbol pairs according to a pattern of the cover code, wherein a range of the combining spans across the one or more subframes; and normalizing a cost function by a power of the PSS sequence to reduce sensitivity to signal to noise ratio (SNR) levels.

53. The apparatus of claim 52, wherein the combining of the co-phased symbol pairs comprises: performing autocorrelation between delayed samples of the PSS, wherein a lag size of the delayed samples is a configurable parameter based on PSS time domain resource allocation.

54. The apparatus of claim 52, wherein a pattern of the cover code is selected to shape the ML estimation of the timing offset into a desired form.

55. The apparatus of claim 44, wherein the at least one processor is further configured to determine, from the SSS, a cell identification (cell ID) and additional system information.

56. The apparatus of claim 55, wherein the additional system information comprises at least a subframe ID.

57. A non-transitory computer readable medium having instructions stored thereon for: generating a primary synchronization signal (PSS) utilizing a first code sequence and a cover code applied to the first code sequence over a first number of symbols within one or more subframes, wherein the cover code comprises at least one of a Walsh code, a Barker code, or a computer generated binary sequence; and transmitting the PSS to a first type of a user equipment (UE) that communicates on one or more narrowband carrier regions relative to a wider carrier bandwidth.

58. A non-transitory computer readable medium having instructions stored thereon for: detecting, within one or more narrowband carrier regions relative to a wider carrier bandwidth, a primary synchronization signal (PSS) generated utilizing a first code sequence and a cover code applied to the first code sequence over a first number of symbols within one or more subframes, wherein the cover code comprises at least one of a Walsh code, a Barker code, or a computer generated binary sequence; and performing time synchronization and a frequency synchronization based on the PSS.