## SUMMARY

**[0006]** The innovations described in the claims each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of the claims, some prominent features of this disclosure will now be briefly described.

[0006a] In an aspect, the present disclosure refers to a power amplifier system arranged for dual connectivity, the power amplifier system comprising:

a first power amplifier including an output configured to provide a radio frequency signal, the first power amplifier configured to be active in a dual connectivity mode and to be active in a different mode;

a second power amplifier configured to be active in the dual connectivity mode such that the first power amplifier and the second power amplifier are concurrently active in the dual connectivity mode, and the second power amplifier is configured to be inactive in the different mode;

radio frequency front end processing circuitry including a first radio frequency signal path and a second radio frequency signal path; and

a switch configured to electrically connect the output of the first power amplifier to the first radio frequency signal path in the dual connectivity mode and to electrically connect the output of the first power amplifier to the second radio frequency signal path in the different mode.

[0006b] In an aspect, the present disclosure refers to a method of transmitting radio frequency signals, the method comprising:

generating a first radio frequency signal in a dual connectivity mode using a first power amplifier;

generating a second radio frequency signal in the dual connectivity mode using a second power amplifier;

wirelessly transmitting the first radio frequency signal and the second radio frequency signal in the dual connectivity mode;

changing a mode of operation from the dual connectivity mode to a different mode, the first power amplifier being active in the different mode;

electrically connecting an output of the first power amplifier to a different radio frequency signal path for the different mode than for the dual connectivity mode; and deactivating the second power amplifier for the different mode.

[0006c] In an aspect, the present disclosure refers to a wireless communication device arranged for dual connectivity, the wireless communication device comprising:

a first power amplifier including an output configured to provide a first radio frequency signal, the first power amplifier configured to be active in a dual connectivity mode and to be active in a different mode;

a second power amplifier configured to be active in the dual connectivity mode such that the first power amplifier and the second power amplifier are concurrently active in the dual connectivity mode, the second power amplifier is configured to be inactive in the different mode; and

a plurality of antennas including a first antenna and a second antenna, the first antenna configured to transmit the first radio frequency signal in the dual connectivity mode, and the second antenna configured to transmit a second radio frequency signal from the second power amplifier in the dual connectivity mode.

[0006d] In an aspect, the present disclosure refers to a power amplifier system comprising:

a first power amplifier configured to be active in a first mode and to be active in a second mode, the first power amplifier including an output configured to provide a radio frequency signal associated with a different radio access technology in the first mode than in the second mode;

a second power amplifier configured to be active in the first mode such that the first power amplifier and the second power amplifier are concurrently active in the first mode, and the second power amplifier is configured to be inactive in the second mode; and

a switch configured to electrically connect the output of the first power amplifier to a first radio frequency signal path in the first mode and to electrically connect the output of the first power amplifier to a second radio frequency signal path in the second mode.

[0006e] In an aspect, the present disclosure refers to a wireless communication device arranged for multiple modes, the wireless communication device comprising:

a first power amplifier configured to be active in a first mode and to be active in a second mode, the first power amplifier including an output configured to provide a first radio frequency signal associated with a different radio access technology in the first mode than in the second mode;

a second power amplifier configured to be inactive in the second mode; and

a plurality of antennas including a first antenna and a second antenna, the first antenna configured to transmit the first radio frequency signal from the first power amplifier in the first mode, and the second antenna configured to transmit a second radio frequency signal from the second power amplifier in the first mode.

[0006f] In an aspect, the present disclosure refers to a method of generating radio frequency signals, the method comprising:

generating radio frequency signals in a first mode using a first power amplifier and a second power amplifier that are concurrently active;

activating the first power amplifier for radio signal amplification in a second mode, the power amplifier providing radio frequency signal amplification associated with a different radio access technology in the second mode than the first mode; and deactivating the second power amplifier for the second mode.

**[0007]** One ~~aspect~~ example of this disclosure is a power amplifier system arranged for dual connectivity. The power amplifier system includes a first power amplifier, a second power amplifier, radio frequency processing circuitry, and a switch. The first power amplifier includes an output configured to provide a radio frequency signal. The first power amplifier configured to be active in a dual connectivity mode and to be active in a different mode. The second power amplifier is configured to be active in the dual connectivity mode such that the first power amplifier and the second power amplifier are concurrently active in the dual connectivity mode. The radio frequency front end processing circuitry includes a first radio frequency signal path and a second radio frequency signal

path. The switch is configured to electrically connect the output of the first power amplifier to the first radio frequency signal path in the dual connectivity mode and to electrically connect the output of the first power amplifier to the second radio frequency signal path in the different mode.

**[0008]** The different mode can be a cellular communication mode. The radio frequency signal can have a lower power in the dual connectivity mode than in the different mode. The different mode can be a second generation mode. The second power amplifier can be inactive in the different mode.

**[0009]** The dual connectivity mode can be a non-standalone fifth generation mode. The radio frequency signal can be a Long Term Evolution signal in the dual connectivity mode, and the second power amplifier can provide a New Radio signal in the dual connectivity mode. The radio frequency signal can be a New Radio signal in the dual connectivity mode, and the second power amplifier can provide a Long Term Evolution signal in the dual connectivity mode.

**[0010]** The first signal path can be operatively coupled between the switch and a first antenna, and the second signal path can be operatively coupled between the switch and a second antenna. The first antenna can be configured to transmit the first radio frequency signal in the dual connectivity mode, and the second antenna is configured to transmit the second radio frequency signal in the dual connectivity mode.

**[0011]** The power amplifier system can further include an input switch configured to electrically connect a first transmitter to an input of the first power amplifier in the dual connectivity mode, and to electrically connect a second transmitter to the input of the first power amplifier in the different mode.

**[0012]** The power amplifier system can further include a load line coupled to the output of the power amplifier, in which the load line can provide a first impedance in the dual connectivity mode and provide a second impedance in the different mode.

**[0013]** The first power amplifier can have a larger bandwidth in the dual connectivity mode than in the different mode.

**[0014]** Another ~~aspect~~ example of this disclosure is a method of transmitting radio frequency signals. The method includes generating a first radio frequency signal in a dual connectivity mode using a first power amplifier; generating a second radio frequency signal in the dual connectivity mode using a second power amplifier; wirelessly transmitting the first radio frequency signal and the second radio frequency signal in the dual connectivity mode; changing a mode of operation from the dual connectivity mode to a different mode, the first power amplifier mode being active in the different mode; and electrically connecting an output of the first power amplifier to a different radio frequency signal path for the different mode than for the dual connectivity mode.

**[0015]** The first and second radio frequency signals can be uplink signals. The wirelessly transmitting can include transmitting the first radio frequency signal from a first antenna and wirelessly transmitting the second radio frequency signal from a second antenna in the dual connectivity mode. The method can include deactivating the second power amplifier for the different mode.

**[0016]** Another ~~aspect~~ example of this disclosure is a wireless communication device arranged for dual connectivity. The wireless communication device includes a first power amplifier, a second power amplifier, and a plurality of antennas. The first power amplifier includes an output configured to provide a first radio frequency signal. The first power amplifier is configured to be active in a dual connectivity mode and to be active in a different mode. The second power amplifier configured to be active in the dual connectivity mode such that the first power amplifier and the second power amplifier are concurrently active in the dual connectivity mode. The plurality of antennas includes a first antenna and a second

antenna. The first antenna is configured to transmit the first radio frequency signal in the dual connectivity mode. The second antenna is configured to transmit the second radio frequency signal in the dual connectivity mode.

**[0017]** The wireless communication can include radio frequency front end processing circuitry including a first radio frequency signal path and a second radio frequency signal path, and a switch configured to electrically connect the output of the first power amplifier to the first radio frequency signal path in the dual connectivity mode and to electrically connect the output of the first power amplifier to the second radio frequency signal path in the different mode.

**[0018]** The first radio frequency signal can be a Long Term Evolution signal in the dual connectivity mode, and the second radio frequency signal can be a New Radio signal in the dual connectivity mode. The first radio frequency signal can be a New Radio signal in the dual connectivity mode, and the second radio frequency signal can be a Long Term Evolution signal in the dual connectivity mode.

**[0019]** The different mode can be associated with a different radio access technology than radio access technologies associated with the dual connectivity mode.

**[0020]** The second power amplifier can be inactive in the different mode. The different mode can be a second generation mode.

**[0021]** The second antenna can be in communication with an output of the first power amplifier in the different mode. Alternatively, a third antenna of the plurality of antennas can be in communication with an output of the first power amplifier in the different mode.

**[0022]** The wireless communication device can be a mobile phone.

**[0023]** Another ~~aspect~~ example of this disclosure is a power amplifier system that includes a first power amplifier, a second power amplifier, and a switch. The first power amplifier is configured to be active in a first mode and to be active in a second mode. The first power amplifier includes an output configured to provide a radio frequency signal associated with a different radio access technology in the first mode than in the second mode. The second power amplifier is configured to be active in the first mode such that the first power amplifier and the second power amplifier are concurrently active in the first mode. The switch is configured to electrically connect the output of the first power amplifier to a first radio

frequency signal path in the first mode and to electrically connect the output of the first power amplifier to a second radio frequency signal path in the second mode.

**[0024]** The first mode can be a dual connectivity mode. The first mode can be a carrier aggregation mode. The first mode can be a multiple-input multiple-output mode.

**[0025]** The radio frequency signal can be associated with a fourth generation technology in the first mode and a second generation technology in the second mode. The radio frequency signal can be associated with a fifth generation technology in the first mode and a second generation technology in the second mode.

**[0026]** The second power amplifier can be inactive in the second mode. The second mode can be a second generation mode.

**[0027]** The power amplifier system can include radio frequency front end processing circuitry that includes the first radio frequency signal path and the second radio frequency signal path.

**[0028]** Another ~~aspect~~ example of this disclosure is a wireless communication device arranged for multiple modes. The wireless communication device includes a first power amplifier, a second power amplifier, and a plurality of antennas. The first power amplifier is configured to be active in a first mode and to be active in a second mode. The first power amplifier includes an output configured to provide a first radio frequency signal associated with a different radio access technology in the first mode than in the second mode. The second power amplifier is configured to be active in the second mode. The plurality of antennas includes a first antenna and a second antenna. The first antenna is configured to transmit the first radio frequency signal from the first power amplifier in the first mode. The second antenna is configured to transmit a second radio frequency signal from the second power amplifier in the first mode.

**[0029]** The wireless communication device can include radio frequency front end processing circuitry including a first radio frequency signal path and a second radio frequency signal path, and a switch configured to electrically connect the output of the first power amplifier to the first radio frequency signal path in the first mode and to electrically connect the output of the first power amplifier to the second radio frequency signal path in the second mode.

**[0030]** The first mode can be a dual connectivity mode. The first mode can be a multiple input multiple-output mode.

**[0031]** The first radio frequency signal can be associated with a first cellular radio access technology in the first mode, and the second radio frequency signal can be associated with a second radio access technology in the first mode, where the second radio access technology being different than the first radio access technology. The first radio frequency signal can be a Long Term Evolution signal in the first mode, and the first radio frequency signal can be a second generation technology signal in the second mode. The first radio frequency signal can be a New Radio signal in the first mode, and the first radio frequency signal can be a second generation technology signal in the second mode.

**[0032]** The first antenna can be in communication with an output of the first power amplifier in the second mode. The second antenna can be in communication with an output of the first power amplifier in the second mode. A third antenna of the plurality of antennas can be in communication with an output of the first power amplifier in the second mode.

**[0033]** Another ~~aspect~~ example of this disclosure is a method of generating radio frequency signals. The method includes generating radio frequency signals in a first mode using a first power amplifier and a second power amplifier that are concurrently active; and activating the first power amplifier for radio signal amplification in a second mode, the power amplifier providing radio frequency signal amplification associated with a different radio access technology in the second mode than the first mode.

**[0034]** The first mode can be a dual connectivity mode, and the second mode can be a second generation (2G) mode.

**[0035]** The method can include electrically connecting an output of the first power amplifier to a first signal path for the first mode, and electrically connecting the output of the first power amplifier to a second signal path for the second mode.

**[0036]** The method can include deactivating the second power amplifier for the different mode.

**[0037]** For purposes of summarizing the disclosure, certain examples, advantages and novel features of the innovations have been described herein. It is to be understood that not necessarily all such advantages may be achieved in accordance with any particular

WHAT IS CLAIMED IS:

1. A power amplifier system arranged for dual connectivity, the power amplifier system comprising:

a first power amplifier including an output configured to provide a radio frequency signal, the first power amplifier configured to be active in a dual connectivity mode and to be active in a different mode;

a second power amplifier configured to be active in the dual connectivity mode such that the first power amplifier and the second power amplifier are concurrently active in the dual connectivity mode, and the second power amplifier is configured to be inactive in the different mode;

radio frequency front end processing circuitry including a first radio frequency signal path and a second radio frequency signal path; and

a switch configured to electrically connect the output of the first power amplifier to the first radio frequency signal path in the dual connectivity mode and to electrically connect the output of the first power amplifier to the second radio frequency signal path in the different mode.

2. The power amplifier system of claim 1 wherein the different mode is a cellular communication mode.

3. The power amplifier system of claim 1 wherein the radio frequency signal has a lower power in the dual connectivity mode than in the different mode.

4. The power amplifier system of claim 1 wherein the different mode is a second generation mode.

~~5. The power amplifier system of claim 1 wherein the second power amplifier is inactive in the different mode.~~

~~6.~~5. The power amplifier system of claim 1 wherein the dual connectivity mode is a non-standalone fifth generation mode.

~~7.~~6.The power amplifier system of claim 1 wherein the radio frequency signal is a Long Term Evolution signal in the dual connectivity mode, and the second power amplifier is configured to provide a New Radio signal in the dual connectivity mode.

~~8.~~7.The power amplifier system of claim 1 wherein the radio frequency signal is a New Radio signal in the dual connectivity mode, and the second power amplifier is configured to provide a Long Term Evolution signal in the dual connectivity mode.

~~9.~~8.The power amplifier system of claim 1 wherein the first signal path is operatively coupled between the switch and a first antenna, and the second signal path is operatively coupled between the switch and a second antenna.

~~10.~~9. The power amplifier system of claim ~~9~~ 8 wherein the first antenna is configured to transmit the radio frequency signal in the dual connectivity mode, and the second antenna is configured to transmit a second radio frequency signal from the second power amplifier in the dual connectivity mode.

~~11.~~10. The power amplifier system of claim 1 further comprising an input switch configured to electrically connect a first transmitter to an input of the first power amplifier in the dual connectivity mode, and to electrically connect a second transmitter to the input of the first power amplifier in the different mode.

~~12.~~11. The power amplifier system of claim 1 further comprising a load line coupled to the output of the power amplifier, the load line being configured to provide a first impedance in the dual connectivity mode and to provide a second impedance in the different mode, the first impedance being different than the second impedance.

~~13.~~12. The power amplifier system of claim 1 wherein the first power amplifier is configured to have a larger bandwidth in the dual connectivity mode than in the different mode.

~~14.~~13. A method of transmitting radio frequency signals, the method comprising:

generating a first radio frequency signal in a dual connectivity mode using a first power amplifier;

generating a second radio frequency signal in the dual connectivity mode using a second power amplifier;

wirelessly transmitting the first radio frequency signal and the second radio frequency signal in the dual connectivity mode;

changing a mode of operation from the dual connectivity mode to a different mode, the first power amplifier ~~mode~~ being active in the different mode; ~~and~~

electrically connecting an output of the first power amplifier to a different radio frequency signal path for the different mode than for the dual connectivity mode; and

deactivating the second power amplifier for the different mode.

~~15. The method of claim 14 further comprising deactivating the second power amplifier for the different mode.~~

~~16.~~14. A wireless communication device arranged for dual connectivity, the wireless communication device comprising:

a first power amplifier including an output configured to provide a first radio frequency signal, the first power amplifier configured to be active in a dual connectivity mode and to be active in a different mode;

a second power amplifier configured to be active in the dual connectivity mode such that the first power amplifier and the second power amplifier are concurrently active in the dual connectivity mode, the second power amplifier is configured to be inactive in the different mode; and

a plurality of antennas including a first antenna and a second antenna, the first antenna configured to transmit the first radio frequency signal in the dual connectivity mode, and the second antenna configured to transmit ~~the~~ a second radio frequency signal from the second power amplifier in the dual connectivity mode.

~~17.~~15. The wireless communication device of claim ~~16~~ 14 further comprising radio frequency front end processing circuitry including a first radio frequency signal path and a second radio frequency signal path, and a switch configured to electrically connect the output of the first power amplifier to the first radio frequency signal path in the dual connectivity mode and to electrically connect the output of the first power amplifier to the second radio frequency signal path in the different mode.

~~18.~~16. The wireless communication device of claim ~~16~~ 14 wherein the first radio frequency signal is a Long Term Evolution signal in the dual connectivity mode, and the second radio frequency signal is a New Radio signal in the dual connectivity mode.

~~19.~~17. The wireless communication device of claim 14~~16~~ wherein the first radio frequency signal is a New Radio signal in the dual connectivity mode, and the second radio frequency signal is a Long Term Evolution signal in the dual connectivity mode.

~~20.~~18. The wireless communication device of claim 14~~16~~ wherein the different mode is associated with a different radio access technology than radio access technologies associated with the dual connectivity mode.

~~21.~~19. A power amplifier system comprising:

a first power amplifier configured to be active in a first mode and to be active in a second mode, the first power amplifier including an output configured to provide a radio frequency signal associated with a different radio access technology in the first mode than in the second mode;

a second power amplifier configured to be active in the first mode such that the first power amplifier and the second power amplifier are concurrently active in the first mode, and the second power amplifier is configured to be inactive in the second mode; and

a switch configured to electrically connect the output of the first power amplifier to a first radio frequency signal path in the first mode and to electrically connect the output of the first power amplifier to a second radio frequency signal path in the second mode.

~~22.~~20. The power amplifier system of claim ~~21~~ 19 wherein the first mode is a dual connectivity mode.

~~23.~~21. The power amplifier system of claim 19~~21~~ wherein the first mode is a carrier aggregation mode.

~~24.~~22. The power amplifier system of claim 19~~21~~ wherein the radio frequency signal is associated with a fourth generation technology in the first mode and a second generation technology in the second mode.

~~25.~~23. The power amplifier system of claim 19~~21~~ wherein the radio frequency signal is associated with a fifth generation technology in the first mode and a second generation technology in the second mode.

~~26. The power amplifier system of claim 21 wherein the second power amplifier is configured to be inactive in the second mode.~~

~~27.~~24. The power amplifier system of claim 19~~21~~ wherein the second mode is a second generation mode.

~~28.~~25. A wireless communication device arranged for multiple modes, the wireless communication device comprising:

a first power amplifier configured to be active in a first mode and to be active in a second mode, the first power amplifier including an output configured to provide a first radio frequency signal associated with a different radio access technology in the first mode than in the second mode;

a second power amplifier configured to be inactive in the second mode; and

a plurality of antennas including a first antenna and a second antenna, the first antenna configured to transmit the first radio frequency signal from the first power amplifier in the first mode, and the second antenna configured to transmit a second radio frequency signal from the second power amplifier in the first mode.

~~29.~~26. The wireless communication device of claim 25~~21~~ further comprising:

radio frequency front end processing circuitry including a first radio frequency signal path and a second radio frequency signal path; and

a switch configured to electrically connect the output of the first power amplifier to the first radio frequency signal path in the first mode and to electrically connect the output of the first power amplifier to the second radio frequency signal path in the second mode.

~~30.~~27. The wireless communication device of claim 25~~21~~ wherein the first mode is a dual connectivity mode.

~~31.~~28. The wireless communication device of claim 25~~21~~ wherein the first mode is a multiple-input multiple-output mode.

~~32.~~29. The wireless communication device of claim 25~~21~~ wherein the first radio frequency signal is associated with a first cellular radio access technology in the first mode,

and the second radio frequency signal is associated with a second radio access technology in the first mode, the second radio access technology being different than the first radio access technology.

~~33.~~30. The wireless communication device of claim ~~21~~ 25 wherein the first radio frequency signal is a Long Term Evolution signal in the first mode, and the first radio frequency signal is a second generation technology signal in the second mode.

~~34.~~31. The wireless communication device of claim ~~21~~ 25 wherein the first radio frequency signal is a New Radio signal in the first mode, and the first radio frequency signal is a second generation technology signal in the second mode.

~~35.~~32. The wireless communication device of claim ~~21~~ 25 wherein the first antenna is in communication with an output of the first power amplifier in the second mode.

~~36.~~33. The wireless communication device of claim ~~21~~ 25 wherein the second antenna is in communication with an output of the first power amplifier in the second mode.

~~37.~~34. The wireless communication device of claim ~~21~~ 25 wherein a third antenna of the plurality of antennas is in communication with an output of the first power amplifier in the second mode.

~~38.~~35. A method of generating radio frequency signals, the method comprising:

generating radio frequency signals in a first mode using a first power amplifier and a second power amplifier that are concurrently active; ~~and~~

activating the first power amplifier for radio signal amplification in a second mode, the first power amplifier providing radio frequency signal amplification associated with a different radio access technology in the second mode than the first mode; and

deactivating the second power amplifier for the second mode.

~~39.~~36. The method of claim ~~38~~ 35 wherein the first mode is a dual connectivity mode, and the second mode is a second generation mode.

~~40.~~37. The method of claim ~~38~~ 35 further comprising electrically connecting an output of the first power amplifier to a first signal path for the first mode, and electrically connecting the output of the first power amplifier to a second signal path for the second mode.