CLAIMS

What is claimed is:

1. A radio frequency (RF) control system comprising:

a power amplifier that outputs a RF signal to a load;

a sensor monitoring the RF signal and generating a sensor signal based on the RF signal;

an energy detection circuit determining an energy of the RF signal in accordance with the sensor signal; and

a power amplifier energy adjustment circuit generating a control signal for varying the RF signal in accordance with the energy determined by the energy detection circuit.

2. The RF control system of claim 1 further comprising a power detection circuit determining a power of the RF signal in accordance with the sensor signal.

3. The RF control system of claim 2 further comprising a power amplifier power adjustment circuit generating a power compensation signal in accordance with the power determined by the power detection circuit.

4. The RF control system of claim 3 further comprising a power summer circuit receiving and summing and output signal from the power detection circuit and a power setpoint signal, wherein output of the power summer circuit is input to the power adjustment circuit and wherein the power compensation signal varies in accordance with the output of the power summer circuit.

5. The RF control system of claim 2 further comprising an energy summer circuit receiving and summing an output signal from the energy detection circuit and an energy setpoint signal, wherein the output of the energy summer circuit is input to the power amplifier energy adjustment circuit and wherein the control signal from the power amplifier energy adjustment circuit varies in accordance with the output of the energy summer circuit.

6. The RF control system of claim 5 wherein the energy summer circuit receives an external energy measurement signal, wherein the external energy measurement signal varies in accordance with a signal output by a sensor external to the power delivery control system.

7. The RF control system of claim 6 wherein the sensor external to the power delivery control system is positioned between a matching network and the load.

8. The RF control system of any one of claims 1 to 7 wherein the sensor before a matching network is connected to the load.

9. The RF control system of any one of claims 1 to 8 wherein the RF signal is a continuous wave signal.

10. The RF control system of any one of claims 1 to 8 wherein the RF signal is a pulsed signal.

11. The RF control system of claim 10 wherein the RF signal includes a sinusoidal signal and a modulation signal modulating the sinusoidal signal and wherein the energy detection circuit determines the energy of the modulation signal to determine the energy of the RF signal.

12. The RF signal of claim 11 wherein the energy detection circuit determines the energy of the modulation signal in blocks, wherein each block is a predetermined length of time, and the energy for the RF signal is determined by adding the energy determined for each block.

13. The RF signal of claim 11 wherein the modulation signal has the shape of at least one of a square wave, sawtooth, a sinusoidal signal, or a combination thereof.

14. A radio frequency (RF) control system comprising:

a power amplifier that outputs a RF signal to a load;

a sensor monitoring the RF signal and generating a sensor signal based on the RF signal;

an energy detection circuit determining an energy of the RF signal in accordance with the sensor signal;

a power detection circuit determining a power of the RF signal in accordance with the sensor signal; and

a power amplifier energy adjustment circuit generating a control signal for varying the RF signal in accordance with the energy determined by the energy detection circuit and the power determined by the power detection circuit,

wherein the RF signal includes a first signal and a first modulation signal modulating the first signal and wherein the energy detection circuit determines the energy of the first modulation signal to determine the energy of the RF signal.

15. The RF control system of claim 14 wherein the first modulation signal includes a first characteristic portion and a second characteristic portion.

16. The RF signal of claim 15 wherein the energy detection circuit determines the energy of the first modulation signal in blocks, wherein each block is a predetermined length of time, and the energy for the RF signal is determined by adding the energy determined for each block.

17. The RF signal of claim 16 wherein the first characteristic portion comprises a first number of blocks and wherein the energy determined for the first number of blocks is added to determine the energy for the first characteristic portion.

18. The RF signal of claim 17 wherein the second characteristic portion comprises a second number of blocks and wherein the energy determined for the second number of blocks is added to determine the energy for the second characteristic portion.

19. The RF signal of any one of claims 14 to 18 wherein the RF signal further includes a second modulation signal modulating the first modulation signal to define a composite modulation signal, wherein the compounds and modulation signal modulates the first signal.

20. The RF control system of claim 19 wherein the composite modulation signal includes a first characteristic portion and a second characteristic portion.

21. The RF signal of claim 20 wherein the energy detection circuit determines the energy of the composite modulation signal in blocks, wherein each block is a predetermined length of time, and the energy for the RF signal is determined by adding the energy determined for each block.

22. The RF signal of claim 21 wherein the first characteristic portion comprises a first number of blocks and wherein the energy determined for the first number of blocks is added to determine the energy for the first characteristic portion.

23. The RF signal of claim 17 wherein the second characteristic portion comprises a second number of blocks and wherein the energy determined for the second number of blocks is added to determine the energy for the second characteristic portion.

24. A radio frequency (RF) control system comprising:

a plurality of power amplifiers that outputs a respective RF signal to a load, each power amplifier including:

a power amplifier that outputs a RF signal to a load;

a sensor monitoring the RF signal and generating a sensor signal based on the RF signal;

an energy detection circuit determining an energy of the RF signal in accordance with the sensor signal; and

a power amplifier energy adjustment circuit generating a control signal for varying the RF signal in accordance with the energy determined by the energy detection circuit;

a RF delivery coordination module, the RF delivery coordination module controlling the phase between the respective RF power supplies.

25. The RF control system of claim 24 wherein at least one of the plurality of power amplifiers further comprises a power detection circuit determining a power of the respective RF signal in accordance with the respective sensor signal.

26. The RF control system of claim 25 wherein at least one power amplifier further comprises a power amplifier power adjustment circuit generating a power compensation signal in accordance with the power determined by the respective power detection circuit.

27. The RF control system of claim 26 wherein at least one power amplifier further comprises a power summer circuit receiving and summing in output signal from the respective power detection circuit and a power setpoint signal, wherein output of the power summer circuit is input to the respective power adjustment circuit and wherein the respective power compensation signal varies in accordance with the output of the respective power summer circuit.

28. The RF control system of claim 25 wherein at least one power amplifier further comprises an energy summer circuit receiving and summing an output signal from the respective energy detection circuit and an energy setpoint signal, wherein the output of the respective energy summer circuit is input to the respective power amplifier energy adjustment circuit and wherein the control signal from the respective power amplifier energy adjustment circuit varies in accordance with the output of the respective energy summer circuit.

29. The RF control system of any one of claims 25 to 28 wherein the RF delivery coordination module controls the phase between respective pairs of RF power supplies.

30. The RF control system of any one of claims 25 to 28 wherein the RF delivery coordination module controls the phase between respective pairs of RF power supplies in accordance with a timing signal, and the phase is determined relative to the timing signal.

31. A radio frequency (RF) control system comprising:

a plurality of power amplifiers that outputs a respective pulsed RF signal to a load, each power amplifier including:

a power amplifier that outputs a RF signal to a load;

a sensor monitoring the RF signal and generating a sensor signal based on the RF signal;

an energy detection circuit determining an energy of the RF signal in accordance with the sensor signal; and

a power amplifier energy adjustment circuit generating a control signal for varying the RF signal in accordance with the energy determined by the energy detection circuit;

a RF delivery coordination module, the RF delivery coordination module synchronizing the respective RF power supplies.

32. The RF control system of claim 31 wherein each respective RF signal includes a respective first signal and a respective modulation signal modulating the respective first signal and wherein the energy detection circuit determines the energy of the respective modulation signal to determine the energy of the respective RF signal.

33. The RF control system of claim 32 wherein the respective energy detection circuit determines the energy of the respective modulation signal in blocks, wherein each block is a predetermined length of time, and the energy for the respective RF signal is determined by adding the energy determined for each block.

34. The RF control system of any one of claims 31 to 33 wherein the RF delivery coronation module synchronizes the modulation signal for each of the plurality of power amplifiers.

35. The RF control system of any one of claims 31 to 34 wherein the modulation signal has the shape of at least one of a square wave, a sawtooth, a sinusoidal signal, exponential, Gaussian, or a combination thereof.

36. The RF control system of any one of claims 31 to 35 wherein the RF delivery coordination module controls the phase between respective pairs of RF power supplies.

37. The RF control system of any one of claims 31 to 35 wherein the RF delivery coordination module controls the phase between respective pairs of RF power supplies in accordance with a timing signal, and the phase is determined relative to the timing signal.

38. The RF control system of any one of claims 31 to 35 wherein the RF delivery coordination module further controls a phase between the RF signal and the control signal.

39. The RF control system of claim 38 wherein the control signal ceases application of the RF signal and reinitiation of the RF signal commences at one of a predetermined level or a level returning to the level when the control signal ceased application of the RF signal.

40. The RF control system of claim 39 wherein the level at which the RF signal is reinitiated varies in accordance with the energy of the RF signal for a predetermine time prior to when the ceases application of the RF signal.

Claims

What is claimed is:

1. A radio frequency (RF) control system comprising:

a power amplifier that outputs a RF signal to a load;

a sensor monitoring the RF signal and generating a sensor signal based on the RF signal;

an energy detection circuit determining an energy of the RF signal in accordance with the sensor signal; and

a power amplifier energy adjustment circuit generating a control signal for varying the RF signal to a predetermined energy setpoint in accordance with the energy determined by the energy detection circuit.

2. The RF control system of claim 1 further comprising a power detection circuit determining a power of the RF signal in accordance with the sensor signal.

3. The RF control system of claim 2 further comprising a power amplifier power adjustment circuit generating a power compensation signal in accordance with the power determined by the power detection circuit.

4. The RF control system of claim 3 further comprising a power summer circuit receiving and summing an output signal from the power detection circuit and a power setpoint signal, wherein output of the power summer circuit is input to the power adjustment circuit and wherein the power compensation signal varies in accordance with the output of the power summer circuit.

5. The RF control system of claim 2 further comprising an energy summer circuit receiving and summing an output signal from the energy detection circuit and an energy setpoint signal, wherein the output of the energy summer circuit is input to the power amplifier energy adjustment circuit and wherein the control signal from the power amplifier energy adjustment circuit varies in accordance with the output of the energy summer circuit.

6. The RF control system of claim 5 wherein the energy summer circuit receives an external energy measurement signal, wherein the external energy measurement signal varies in accordance with a signal output by a sensor external to the RF control system.

7. The RF control system of claim 6 wherein the sensor external to the RF control system is positioned between a matching network and the load.

8. The RF control system of claim 1 wherein the sensor before a matching network connected to the load.

9. The RF control system of claim 1 wherein the RF signal is a continuous wave signal.

10. The RF control system of claim 1 wherein the RF signal is a pulsed signal.

11. The RF control system of claim 10 wherein the RF signal includes a sinusoidal signal and a modulation signal modulating the sinusoidal signal and wherein the energy detection circuit determines the energy of the modulation signal to determine the energy of the RF signal.

12. The RF signal of claim 11 wherein the energy detection circuit determines the energy of the modulation signal in blocks, wherein each block is a predetermined length of time, and the energy for the RF signal is determined by adding the energy determined for each block.

13. The RF signal of claim 11 wherein the modulation signal has a shape of at least one of a square wave, sawtooth, a sinusoidal signal, or a combination thereof.

14. A radio frequency (RF) control system comprising:
a power amplifier that outputs a RF signal to a load;
a sensor monitoring the RF signal and generating a sensor signal based on the RF signal;
an energy detection circuit determining an energy of the RF signal in accordance with the sensor signal;
a power detection circuit determining a power of the RF signal in accordance with the sensor signal; and a power amplifier energy adjustment circuit generating a control signal for varying the RF signal in accordance with the energy determined by the energy detection circuit and the power determined by the power detection circuit,
wherein the RF signal includes a first signal and a first modulation signal modulating the first signal and wherein the energy detection circuit determines the energy of the first modulation signal to determine the energy of the RF signal.

15. The RF control system of claim 14 wherein the first modulation signal includes a first characteristic portion and a second characteristic portion.

16. The RF signal of claim 15 wherein the energy detection circuit determines the energy of the first modulation signal in blocks, wherein each block is a predetermined length of time, and the energy for the RF signal is determined by adding the energy determined for each block.

17. The RF signal of claim 16 wherein the first characteristic portion comprises a first number of blocks and wherein the energy determined for the first number of blocks is added to determine the energy for the first characteristic portion.

18. The RF signal of claim 17 wherein the second characteristic portion comprises a second number of blocks and wherein the energy determined for the second number of blocks is added to determine the energy for the second characteristic portion.

19. The RF signal of claim 14 wherein the RF signal further includes a second modulation signal modulating the first modulation signal to define a composite modulation signal, wherein the composite modulation signal modulates the first signal.

20. The RF control system of claim 19 wherein the composite modulation signal includes a first characteristic portion and a second characteristic portion.

21. The RF signal of claim 20 wherein the energy detection circuit determines the energy of the composite modulation signal in blocks, wherein each block is a predetermined length of time, and the energy for the RF signal is determined by adding the energy determined for each block.

22. The RF signal of claim 21 wherein the first characteristic portion comprises a first number of blocks and wherein the energy determined for the first number of blocks is added to determine the energy for the first characteristic portion.

23. The RF signal of claim 22 wherein the second characteristic portion comprises a second number of blocks and wherein the energy determined for the second number of blocks is added to determine the energy for the second characteristic portion.

24. A radio frequency (RF) control system comprising:

a plurality of power amplifiers that outputs a respective RF signal to a load, each power amplifier including:

a power amplifier that outputs a RF signal to a load;

a sensor monitoring the RF signal and generating a sensor signal based on the RF signal;

an energy detection circuit determining an energy of the RF signal in accordance with the sensor signal; and

a power amplifier energy adjustment circuit generating a control signal for varying the RF signal in accordance with the energy determined by the energy detection circuit; and

a RF delivery coordination module, the RF delivery coordination module controlling the phase between the respective power amplifiers.

25. The RF control system of claim 24 wherein at least one of the plurality of power amplifiers further comprises a power detection circuit determining a power of the respective RF signal in accordance with the respective sensor signal.

26. The RF control system of claim 25 wherein at least one power amplifier further comprises a power amplifier power adjustment circuit generating a power compensation signal in accordance with the power determined by the respective power detection circuit.

27. The RF control system of claim 26 wherein at least one power amplifier further comprises a power summer circuit receiving and summing in output signal from the respective power detection circuit and a power setpoint signal, wherein output of the power summer circuit is input to the respective power adjustment circuit and wherein the respective power compensation signal varies in accordance with the output of the respective power summer circuit.

28. The RF control system of claim 25 wherein at least one power amplifier further comprises an energy summer circuit receiving and summing an output signal from the respective energy detection circuit and an energy setpoint signal, wherein the output of the respective energy summer circuit is input to the respective power amplifier energy adjustment circuit and wherein the control signal from the respective power amplifier energy adjustment circuit varies in accordance with the output of the respective energy summer circuit.

29. The RF control system of claim 25 wherein the RF delivery coordination module controls the phase between respective pairs of RF power supplies.

30. The RF control system of claim 25 wherein the RF delivery coordination module controls the phase between respective pairs of RF power supplies in accordance with a timing signal, and the phase is determined relative to the timing signal.

31. A radio frequency (RF) control system comprising:
a plurality of power amplifiers that outputs a respective pulsed RF signal to a load, each power amplifier including:
a power amplifier that outputs a RF signal to a load;
a sensor monitoring the RF signal and generating a sensor signal based on the RF signal;
an energy detection circuit determining an energy of the RF signal in accordance with the sensor signal; and
a power amplifier energy adjustment circuit generating a control signal for varying the RF signal in accordance with the energy determined by the energy detection circuit; and
a RF delivery coordination module, the RF delivery coordination module synchronizing the respective RF power amplifiers.

32. The RF control system of claim 31 wherein each respective RF signal includes a respective first signal and a respective modulation signal modulating the respective first signal and wherein the energy detection circuit determines the energy of the respective modulation signal to determine the energy of the respective RF signal.

33. The RF control system of claim 32 wherein the respective energy detection circuit determines the energy of the respective modulation signal in blocks, wherein each block is a predetermined length of time, and the energy for the respective RF signal is determined by adding the energy determined for each block.

34. The RF control system of claim 31 wherein the RF delivery coordination module synchronizes the respective modulation signal for each of the plurality of power amplifiers.

35. The RF control system of claim 31 wherein the modulation signal has a shape of at least one of a square wave, a sawtooth, a sinusoidal signal, exponential, Gaussian, or a combination thereof.

36. The RF control system of claim 31 wherein the RF delivery coordination module controls the phase between respective pairs of RF power supplies.

37. The RF control system of claim 31 wherein the RF delivery coordination module controls the phase between respective pairs of RF power supplies in accordance with a timing signal, and the phase is determined relative to the timing signal.

38. The RF control system of claim 31 wherein the RF delivery coordination module further controls a phase between the RF signal and the control signal.

39. The RF control system of claim 38 wherein the control signal ceases application of the RF signal and reinitiation of the RF signal commences at one of a predetermined level or a level returning to the level when the control signal ceased application of the RF signal.

40. The RF control system of claim 39 wherein the level at which the RF signal is reinitiated varies in accordance with the energy of the RF signal for a predetermine time prior to when the ceases application of the RF signal.

41. A radio frequency (RF) control system comprising:
a power amplifier that outputs a RF signal to a load;
a sensor monitoring the RF signal and generating a sensor signal based on the RF signal;
a power determination circuit determining a power in accordance with the sensor signal and generating a power signal;
an energy detection circuit determining an energy of the RF signal in accordance with the power signal; and
a power amplifier energy adjustment circuit generating a control signal for varying the RF signal in accordance with the energy determined by the energy detection circuit.

42. The RF control system of claim 41 further comprising a power amplifier power adjustment circuit generating a power compensation signal in accordance with the power determined by the power determination module.

43. The RF control system of claim 42 further comprising a power summer circuit receiving and summing an output signal from the power determination module and a power setpoint signal, wherein output of the power summer circuit is input to the power adjustment circuit and wherein the power compensation signal varies in accordance with the output of the power summer circuit.

44. The RF control system of claim 41 further comprising an energy summer circuit receiving and summing an output signal from the energy detection circuit and an energy setpoint signal, wherein the output of the energy summer circuit is input to the power amplifier energy adjustment circuit and wherein the control signal from the power amplifier energy adjustment circuit varies in accordance with the output of the energy summer circuit.

45. The RF control system of claim 44 wherein the energy summer circuit receives an external energy measurement signal, wherein the external energy measurement signal varies in accordance with a signal output by a sensor external to the RF control system.

46. The RF control system of claim 45 wherein the sensor external to the RF control system is positioned between a matching network and the load.

47. The RF control system of claim 41 wherein the sensor is positioned before a matching network connected to the load.

48. The RF control system of claim 41 wherein the RF signal is a continuous wave signal.

49. The RF control system of claim 41 wherein the RF signal is a pulsed signal.

50. The RF control system of claim 49 wherein the RF signal includes a sinusoidal signal and a modulation signal modulating the sinusoidal signal and wherein the energy detection circuit determines the energy of the modulation signal to determine the energy of the RF signal.

51. The RF signal of claim 50 wherein the energy detection circuit determines the energy of the modulation signal in blocks, wherein each block is a predetermined length of time, and the energy for the RF signal is determined by adding the energy determined for each block.

52. The RF signal of claim 50 wherein the modulation signal has a shape of at least one of a square wave, sawtooth, a sinusoidal signal, or a combination thereof.