host system 130 calculates a complex voltage and current V, I, and ϕ, e.g., a second complex voltage and current, at the output, e.g., the model node N4m, of the impedance matching model 104. The complex voltage and current at the model node N4m is stored in the storage HU 162 and/or another storage HU, e.g., a compact disc, a flash memory, etc., of the host system 130. The complex V, I, and ϕ includes a voltage magnitude V, a current magnitude I, and a phase ϕ between the voltage and current.

[0056] The output of the impedance matching model 104 is coupled to an input of the RF transmission model 161, which is stored in the storage hardware unit 162. The impedance matching model 104 also has an input, e.g., a node N3m, which is used to receive the complex voltage and current measured at the node N3.

[0057] The RF transmission model 161 includes the portion 173, another portion 197, and an output N2m. An input of the portion 173 is the input of the RF transmission model 161. An output of the portion 173 is coupled to an input of the portion 197. The portion ~~172~~173 has similar characteristics as that of the portion 169 and the portion 197 has similar characteristics as that of the portion 195.

[0058] Based on the complex voltage and current measured at the model node N4m, the processor of the host system 130 calculates a complex voltage and current V, I, and ϕ, e.g., a third complex voltage and current, at the output, e.g., the model node N1m, of the portion 173 of the RF transmission model 161. The complex voltage and current determined at the model node N1m is stored in the storage HU 162 and/or another storage HU, e.g., a compact disc, a flash memory, etc., of the host system 130.

[0059] In several embodiments, instead of or in addition to determining the third complex voltage and current, the processor of the host system 130 computes a complex voltage and current, e.g., an intermediate complex voltage and current V, I, and ϕ, at a point,

(Figure 1). The method 102 is executed by one or more processors of the host system 130 (Figure 1). In an operation 106, the complex voltage and current, e.g., the first complex voltage and current, measured at the node N3 is identified from within the storage HU 162 (Figure 1). For example, it is determined that the first complex voltage and current is received from the voltage probe 110 (Figure 1). As another example, based on an identity, of the voltage probe 110, stored within the storage HU 162 (Figure 1), it is determined that the first complex voltage and current is associated with the identity.

[0064] Furthermore, in an operation 107, the impedance matching model 104 (Figure 1) is generated based on electrical components of the impedance matching circuit 114 (Figure 1). For example, connections between electrical components of the impedance matching circuit 114 and characteristics of the electrical components are provided to the processor of the host system 130 by the user via an input device that is coupled with the host system 130. Upon receiving the connections and the characteristics, the processor generates elements that have the same characteristics as that of electrical components of the impedance matching circuit 114 and generates connections between the elements that have the same connections as that between the electrical components.

[0065] The input, e.g., the node N3m, of the impedance matching model ~~163~~104 receives the first complex voltage and current. For example, the processor of the host system 130 accesses, e.g., reads, etc., from the storage HU 162 the first complex voltage and current and provides the first complex voltage and current to the input of the impedance matching model 104 to process the first complex voltage and current.

[0066] In an operation 116, the first complex voltage and current is propagated through one or more elements of the impedance matching model 104 (Figure 1) from the input, e.g., the node N3m (Figure 1), of the impedance matching model 104 to the output, e.g., the node N4m (Figure 1), of the impedance matching model 104 to determine the second

voltage and current received at the node 261 is the same as the complex voltage and current measured at the node N5 (Figure 1). When both the 2 MHz and 27 MHz RF generators are on and the 60 MHz RF generator is off, the complex voltages and currents V2, I2, ϕ2, V27, I27, and ϕ27 are an example of the second complex voltage and current. Moreover, similarly, when the 60 MHz RF generator is on and the 2 and 27 MHz RF generators are off, a complex voltage and current V60, I60, and ϕ60 at the output 259 is determined based on a complex voltage and current received at a node 265 and characteristics of an inductor LPF1, a capacitor C1, a capacitor C2, an inductor L4, a capacitor 269, and an inductor L1. The complex voltage and current V60, I60, and ϕ60 includes the voltage magnitude V60, the current magnitude I60, and the phase ϕ60 between the voltage and current. When the 2 MHz, 27 MHz, and the 60 MHz RF generators are on, the complex voltages and currents V2, I2, ϕ2, V27, I27, ϕ27, V60, I60, and ϕ60 are an example of the second complex voltage and current.

[0068] In an operation 117, the RF transmission model 161 (Figure 1) is generated based on the electrical components of the RF transmission line 113 (Figure 1). For example, connections between electrical components of the RF transmission line 113 and characteristics of the electrical components are provided to the processor of the host system 130 by the user via an input device that is coupled with the host system 130. Upon receiving the connections and the characteristics, the processor generates elements that have the same characteristics as that of electrical components of the RF transmission line 113 and generates connections between the elements that are the same as that between the electrical components.

[0069] In an operation 119, the second complex voltage and current is propagated through one or more elements of the RF transmission model portion 173 from the input of the RF transmission model portion 173~~113~~ to the output, e.g., the model node N1m (Figure 1), of the RF

cylinder 148 lies an insulator 190~~189~~ and an RF rod 142. A combination of the cylinder 148 and the RF rod 142 is an example of the portion 169 (Figure 1) of the RF transmission line 113 (Figure 1). The RF transmission line 113 is bolted via bolts B1, B2, B3, and B4 with the impedance matching circuit 114. In one embodiment, the RF transmission line 113 is bolted via any number of bolts with the impedance matching circuit 114. In some embodiments, instead of or in addition to bolts, any other form of attachment, e.g., glue, screws, etc., is used to attach the RF transmission line 113 to the impedance matching circuit 114.

[0075] The RF transmission rod 142 is coupled with the output of the impedance matching circuit 114. Also, an RF strap 144, also known as RF spoon, is coupled with the RF rod 142 and an RF rod 199, a portion of which is located within a support 146, e.g., a cylinder. In an embodiment, a combination of the cylinder 148, the RF rod 142, the RF strap 144, the cylinder 146 and the RF rod 199 forms an RF transmission line 181, which is an example of the RF transmission line 113 (Figure 1). The support 146 provides support to the plasma chamber. The support 146 is attached to the ESC 177 of the plasma chamber. An RF signal is supplied from the x MHz generator via the cable 150, the impedance matching circuit 114, the RF rod 142, the RF strap 144, and the RF rod 199 to the ESC 177.

[0076] In one embodiment, the ESC 177 includes a heating element and an electrode on top of the heating element. In an embodiment, the ESC 177 includes a heating element and the lower electrode. In one embodiment, the ESC 177 includes the lower electrode and a heating element, e.g., coil wire, etc., embedded within holes formed within the lower electrode. In some embodiments, the electrode is made of a metal, e.g., aluminum, copper, etc. It should be noted that the RF transmission line 181 supplies an RF signal to the lower electrode of the ESC 177.

[0077] Figure 5A is a block diagram of an embodiment of a system 171 used to illustrate a circuit model 176 of the RF transmission line 113 (Figure 1). For example, the

[0081] A power supply 206 provides power to the heating element 196~~192~~ via a filter 208 to heat the heating element 196 and a power supply 204 provides power to the heating element 198 via a filter 202 to heat the heating element 198. In an embodiment, a single power supply provides power to both the heating elements 196 and 198. The filter 208 filters out predetermined frequencies of a power signal that is received from the power supply 206 and the filter 202 filters out predetermined frequencies of a power signal that is received from the power supply 204.

[0082] The heating element 198 is heated by the power signal received from the power supply 204 to maintain an electrode of the ESC 201~~198~~ at a desirable temperature to further maintain an environment within the plasma chamber 135 at a desirable temperature. Moreover, the heating element 196 is heated by the power signal received from the power supply 206 to maintain the ER 194 at a desirable temperature to further maintain an environment within the plasma chamber 135 at a desirable temperature.

[0083] It should be noted that in an embodiment, the ER 194 and the ESC 201 include any number of heating elements and any type of heating elements. For example, the ESC 201 includes an inductive heating element or a metal plate. In one embodiment, each of the ESC 201 and the ER 194 includes one or more cooling element, e.g., one or more tubes that allow passage of cold water, etc., to maintain the plasma chamber 135 at a desirable temperature.

[0084] It should further be noted that in one embodiment, the system 200 includes any number of filters. For example, the power supplies 204 and 206 are coupled to the ESC 201 and the ER 194 via a single filter.

[0085] Figure 7A is a diagram of an embodiment of a system 217 used to illustrate a model of the filters 202 and 208 (Figure 6) to improve an accuracy of the variable.

The system 217 includes the tunnel and strap model 210 that is coupled to a model 216, which includes capacitors and/or inductors, and connections therebetween of the filters 202 and 208. The model 216 is stored within the storage HU 162 (Figure 1) and/or the other storage HU. The capacitors and/or inductors of the model 216 are coupled with each other in a manner, e.g., a parallel manner, a serial manner, a combination thereof, etc. The model 216 represents capacitances and/or inductances of the filters 202 and 208.

[0086] Moreover, the system 217 includes a cylinder model 211, which is a computer-generated model of the RF rod 199 (Figure 4) and the support 146 (Figure 4). The cylinder model 211 has similar characteristics as that of electrical components of the RF rod 199 and the support 146. The cylinder model 211 includes one or more capacitors, one or more inductors, connections between the inductors, connections between the capacitors, and/or connections between a combination of the capacitors and inductors.

[0087] The processor of the host system 130 (Figure 1) calculates a combined impedance, e.g., total impedance, etc., of the model 216, the tunnel and strap model 210, and the cylinder model 211. The combined impedance provides a complex voltage and impedance at the node N2m. With the inclusion of the model 216 and the tunnel and strap model 210~~214~~ in determining the variable at the node N2m, accuracy of the variable is improved. It should be noted that an output of the model 216 is the model node N2m.

[0088] Figure 7B is a diagram of an embodiment of a system 219 used to illustrate a model of the filters 202 and 208 (Figure 6) to improve an accuracy of the variable. The system 219 includes the tunnel and strap model 210 and a model 218, which is coupled in parallel to the tunnel and strap model 210. The model 218 is an example of the model 216 (Figure 7A). The model 218 includes an inductor Lfilter, which represents a combined inductance of the filters 202 and 208. The model 218 further includes a capacitor Cfilter, which represents directed combined capacitance of the filters 202 and 208.

[0096] In one embodiment, the driver 228 generates an RF signal having a drive power value that is a function of the power value P1 and/or having a drive frequency value that is a function of the frequency value F1. For example, the drive power value is within a few, e.g. 1 thru 5, watts of the power value P1 and the drive frequency value is within a few, e.g. 1 thru 5, Hz of the frequency value F1.

[0097] The amplifier 230 amplifies the RF signal having the power value P1 and/or the frequency value F1 and generates an RF signal 215 that corresponds to the RF signal received from the driver 228. For example, the RF signal 215 has a higher amount of power than that of the power value P1. As another example, the RF signal 215 has the same amount of power as that of the power value P1. The RF signal 215 is transferred via a cable 223~~217~~ and the impedance matching circuit 114 to the known load~~ 112 (Figure 2)~~.

[0098] The cable 223~~217~~ is an example of the cable 150 or the cable 152 (Figure 1). For example, when the RF generator 220 is an example of the x MHz RF generator (Figure 1), the cable 223~~217~~ is an example of the cable 150 and when the RF generator 220 is an example of the y MHz RF generator (Figure 1), the cable 223~~217~~ is an example of the cable 152.

[0099] When the power value P1 and/or the frequency value F1 are provided to the DAS 232 by the parameter control 222 and the RF signal 215 is generated, a VI probe 238 measures values of the variable at the output 231 that is coupled to the cable 223~~217~~. The VI probe 238 is an example of the VI probe 110 or the VI probe 111 (Figure 1). The VI probe 238 sends the values of the variable via a communication device 233 to the host system 130 for the host system 130 to execute the method 102 (Figure ~~2~~3) and other methods described herein. The communication device 233 is an example of the communication device 185 or 189 (Figure 1). The communication device 233 applies a protocol, e.g., Ethernet, EtherCAT, USB, serial, parallel, packetization, depacketization, etc., to transfer data from the VI probe 238 to the host system 130. In various embodiments, the host system 130 includes a

communication device that applies the protocol applied by the communication device 233. For example, when the communication 233 applies packetization, the communication device of the host system 130 applies depacketization. As another example, when the communication 233 applies a serial transfer protocol, the communication device of the host system 130 applies a serial transfer protocol.

[00100] Similarly, upon receiving the power value P0 and/or the frequency value F0, the parameter control 224 provides the power value P0 and/or the frequency value F0 to the driver 228. The driver 228 creates an RF signal having the power value P0 and/or the frequency value F0 and provides the RF signal to the amplifier 230.

[00101] In one embodiment, the driver 228 generates an RF signal having a drive power value that is a function of the power value P0 and/or having a drive frequency value that is a function of the frequency value F0. For example, the drive power value is within a few, e.g. 1 thru 5, watts of the power value P0 and the drive frequency value is within a few, e.g. 1 thru 5, Hz of the frequency value F0.

[00102] The amplifier 230 amplifies the RF signal having the power value P0 and/or the frequency value F0 and generates an RF signal 221 that corresponds to the RF signal received from the driver 228. For example, the RF signal 221 has a higher amount of power than that of the power value P0. As another example, the RF signal 221 has the same amount of power as that of the power value P0. The RF signal 221 is transferred via the cable 223~~217~~ and the impedance matching circuit 114 to the known load~~ 112 (Figure 2)~~.

[00103] When the power value P0 and/or the frequency value F0 are provided to the DAS 232 by the parameter control 224~~222~~ and the RF signal 221~~121~~ is generated, the VI probe 238 measures values of the variable at the output 231. The VI probe 238 sends the values of

the variable to the host system 130 for the host system 130 to execute the method 102 (Figure 2).

[00104] It should be noted that the in one embodiment, the VI probe 238 is decoupled from the DSP 226. It should further be noted that the RF signal 215 generated during the state S1 and the RF signal 221 generated during the state S0 are portions of a combined RF signal. For example, the RF signal 215 is a portion of the combined RF signal that has a higher amount of power than the RF signal 221, which is another portion of the combined RF signal.

[00105] Figure 9 is a block diagram of an embodiment of a system 250 in which the VI probe 238 and the communication device 233 are located outside the RF generator 220. In Figure 1, the VI probe 110 is located within the x MHz RF generator to measure the variable at the output of the x MHz RF generator. The VI probe 238 is located outside the RF generator 220 to measure the variable at the output 231 of the RF generator 220. The VI probe 238 is associated, e.g., coupled, to the output 231 of the RF generator 220.

[00106] Figure 10 is a block diagram of an embodiment of a system 128 in which the values of the variable determined using the system 126 of Figure 1 are used. The system 128 includes an m MHz RF generator, an n MHz RF generator, an impedance matching circuit 115, an RF transmission line 287, and a plasma chamber 134. The plasma chamber 134 may be similar to the plasma chamber 175.

[00107] It should be noted that in an embodiment, the x MHz RF generator of Figure 12 is similar to the m MHz RF generator and the y MHz RF generator of Figure 12 is similar to the n MHz RF generator. As an example, x MHz is equal to m MHz and y MHz is equal to n MHz. As another example, the x MHz generator and the m MHz generators have similar frequencies and the y MHz generator and the n MHz generator have similar

frequencies. An example of similar frequencies is when the x MHz is within a window, e.g., within kHz or Hz, of the m MHz frequency. In some embodiments, the x MHz RF generator of Figure 12 is not similar to the m MHz RF generator and the y MHz RF generator of Figure 12 is not similar to the n MHz RF generator.

[00108] It is further noted that in various embodiments, a different type of sensor is used in each of the m MHz and n MHz RF generators than that used in each of the x MHz and y MHz RF generators. For example, a sensor that does not comply with the NIST standard is used in the m MHz RF generator. As another example, a voltage sensor that measures only voltage is used in the m MHz RF generator.

[00109] It should further be noted that in an embodiment, the impedance matching circuit 115 is similar to the impedance matching circuit 114 (Figure 1). For example, an impedance of the impedance matching circuit 114 is the same as an impedance of the impedance matching circuit 115. As another example, an impedance of the impedance matching circuit 115 is within a window, e.g., within 10-20%, of the impedance of the impedance matching circuit 114. In some embodiments, the impedance matching circuit 115 is not similar to the impedance matching circuit 114.

[00110] The impedance matching circuit 115 includes electrical components, e.g., inductors, capacitors, etc. to match an impedance of a power source coupled to the impedance matching circuit 115 with an impedance of a load coupled to the circuit 115. For example, the impedance matching circuit 114 matches an impedance of the m MHz and n MHz RF generators with an impedance of the plasma chamber 134. In one embodiment, impedance matching circuit 115 is tuned to facilitate a match between an impedance of m MHz and n MHz RF generators coupled to the impedance matching circuit 115 and an impedance of a load.

the impedance matching circuit 115 to the ESC 192, the process gas is ignited to generate plasma within the plasma chamber 134.

[00115] It should be noted that the system 128 lacks a probe, e.g., a metrology tool, a VI probe, a voltage probe, etc., to measure the variable at an output 283 of the impedance matching circuit 115 or at a point on the RF transmission line 287. The values of the variable at the model nodes N1m, N2m, and N4m are used to determine whether the system 128 is functioning as desired.

[00116] It should also be noted that in an embodiment, the system 128 includes any number of RF generators coupled to an impedance matching circuit.

[00117] Figures 11A, 11B, and 11C are diagrams of embodiments of graphs 268, 272, and 275 that illustrate a correlation between voltage, e.g., root mean square (RMS) voltage, etc., that is measured at the output, e.g., the node N4, of the impedance matching circuit 114 (Figure 1) within the system 126 (Figure 1) by using a voltage probe and a voltage, e.g., peak voltage, etc., at a corresponding model node output, e.g., the node N4m, determined using the method 102 (Figure 2). Moreover, Figures 11A thru 11C are diagrams of embodiments of graphs 270, 274, and 277 that illustrate a correlation between current, e.g., RMS current, etc., that is measured the output, e.g., the node N4, of the system 126 (Figure 1) by using a current probe and a current, e.g., RMS current, etc., at a corresponding output, e.g., the node N4m, determined using the method 102 (Figure 2).

[00118] The voltage determined using the method 102 is plotted on an x-axis in each graph 268, 272, and 275 and the voltage determined using the voltage probe is plotted on a y-axis in each graph 268, 272, and 275. Similarly, the current determined using the method 102 is plotted on an x-axis in each graph 270, 274~~227~~, and 277 and the current determined using the current probe is plotted on a y-axis in each graph 270, 274~~227~~, and 277.

[00134] It should be noted that although the above-described embodiments relate to providing an RF signal to the electrode of the ESC 177 (Figure 1) and the ESC 192~~163~~ (Figure 10), and grounding the upper electrodes 179 and 264 (Figures 1 and 10), in several embodiments, the RF signal is provided to the upper electrodes 179 and 264 while the lower electrodes of the ESCs 177 and 163 are grounded.

[00135] Embodiments described herein may be practiced with various computer system configurations including hand-held hardware units, microprocessor systems, microprocessor-based or programmable consumer electronics, minicomputers, mainframe computers and the like. The embodiments can also be practiced in distributed computing environments where tasks are performed by remote processing hardware units that are linked through a network.

[00136] With the above embodiments in mind, it should be understood that the embodiments can employ various computer-implemented operations involving data stored in computer systems. These operations are those requiring physical manipulation of physical quantities. Any of the operations described herein that form part of the embodiments are useful machine operations. The embodiments also relates to a hardware unit or an apparatus for performing these operations. The apparatus may be specially constructed for a special purpose computer. When defined as a special purpose computer, the computer can also perform other processing, program execution or routines that are not part of the special purpose, while still being capable of operating for the special purpose. In some embodiments, the operations may be processed by a general purpose computer selectively activated or configured by one or more computer programs stored in the computer memory, cache, or obtained over a network. When data is obtained over a network the data may be processed by other computers on the network, e.g., a cloud of computing resources.

matching model coupled between the input of the impedance matching model and the intermediate node; and

determining the second complex voltage and current based on the intermediate complex voltage and current and characteristics of one or more elements of the impedance matching model coupled between the intermediate node and the output of the impedance matching model.

13. The method of claim 1, wherein the RF transmission model includes a model of an RF tunnel and a model of an RF strap, the RF tunnel model coupled with the RF strap model.

14. The method of claim 1, wherein the circuit~~electrical~~ components of RF transmission line include a combination of capacitors and inductors, wherein the elements of the RF transmission model have similar characteristics as that of the circuit~~electrical~~ components of the RF transmission line.

15. The method of claim 1, wherein propagating the second complex voltage and current through the one or more elements of the RF transmission model portion from the input of the RF transmission model to the output of the RF transmission model portion to determine the third complex voltage and current comprises:

determining an intermediate complex voltage and current within an intermediate node within the RF transmission model portion based on the second complex voltage and current and characteristics of one or more elements of the RF transmission model portion coupled between the input of the RF transmission model and the intermediate node; and

current, wherein the second complex voltage and current is at the output of the impedance matching model;

generating an RF transmission model based on electrical components defined in the RF transmission line, the RF transmission model having an input and an output, the input of the RF transmission model coupled to the output of the impedance matching model, the RF transmission model having a portion that includes one or more elements;

propagating the second complex voltage and current through the one or more elements of the RF transmission model portion from the input of the RF transmission model to an output of the RF transmission model portion to determine a third complex voltage and current, wherein the third complex voltage and current is at the output of the RF transmission model portion; and

providing the third complex voltage and current for storage to a storage hardware unit.

17. The system of claim 16, wherein the voltage and current probe is calibrated to comply with a pre-set formula.

18. The system of claim 17~~16~~, wherein the pre-set formula is a standard, wherein the standard is a National Institute of Standards and Technology (NIST) standard, wherein the voltage and current probe is coupled with an open circuit, a short circuit, or a load to calibrate the voltage and current probe to comply with the NIST standard.

19. A computer system for determining a value of a variable on a radio frequency (RF) transmission model, the computer system comprising: