POWER SPLITTER

FIELD OF THE INVENTION

[0001] The present invention relates to power splitters and in particular to power splitters for differential power distribution. In a first arrangement, the invention provides a broadband, passive, divide by N power splitter that may be advantageously employed in providing power to multiple electrodes within a plasma source.

BACKGROUND

[0002] To energize multiple electrodes in a plasma source using a single RF power source, one needs to split the power into multiple channels. In the case of a plasma source topology with alternate electrodes 180 degrees out of phase with each other—such as that described in PCT/EP2006/062261 the content of which is incorporated herein by reference, where each of the electrodes may be out of phase with that of its neighbour, then it is useful to be able to provide push-pull pairs.

[0003] A classical solution to this problem would be to use a 180-degree splitter, followed by a series of N:1 splitters, where 2:1 and 4:1 splitters are typical in high power application, and higher values of n can be found for low power cases. Phase errors between output channels will typically be a couple of degrees, amplitude imbalance of 5%, and power loss of 3%; To create a 1:128 divider using a series of 2:1 splitters would end up in substantial power loss and errors in power to a specific electrode receiving only 70% of the power it should receive (0.95^7). In addition, the systems only function properly with the input and output impedances are matched, typically at 50 Ohms. Because the plasma load on the electrode will be substantially non-50-Ohm, an impedance matching network will be required between the final stage splitter output and the electrode for each electrode. This adds to the cost, complexity, and electrode-to-electrode variation for such a solution. Additionally, such a solution is only matched to specific electrode numbers, where the number of electrodes is factored into the types of splitters (for example a 7×10 electrode array would need the 180-degree splitter, a 5:1 splitter, and a 7:1 splitter) so each solution could require a different engineering solution for the splitters. Further still, the high power splitters (particularly odd-number splittings like 5, 7) are frequency specific, so operating at different frequencies would require different engineering solutions.

[0004] For reasons of simplicity, cost savings, and uniformity, it is desirable to have a solution in which the impedance matching is done prior to the splitter, the power splitter is ‘passive’, the splitter is broad-band (same concept for VHF and UFH frequency range—30-3000 MHz), and that the splitter be able to perform 1:N splitting for large and arbitrary N (advantageously employing a similar design for, N=30, 32, 36 for 3×10, 4×8, 6×6 electrode arrays). There is a further need for a power splitter that can be implemented with high total power efficiency, and drive an output impedance that can drive the plasma electrodes directly and could be configured to drive pairs of electrodes in differential (push-pull) mode.

SUMMARY

[0005] These and other problems are addressed by a power splitter provided in accordance with the teaching of the invention. Such a splitter is provided by providing a plurality of secondary windings arranged about a transmission line, the transmission line operably providing an azimuthal magnetic field which inductively couples power into the secondary windings to provide a splitting of the power from the transmission line. It will be appreciated that the number, N, of the secondary windings forming what may be considered a secondary transformer, will determine the splitting ratio, N, of the power splitter. When used with a power source, with the N-secondary transformer located in the region of the high magnetic field, it is possible to inductively couple power into the windings of the N-secondaries via the magnetic field and that power may then be selectively coupled to individual electrodes of the plasma source.

[0006] Where it is desirable to provide a configuration where a plurality of electrodes are arranged relative to one another in an array with neighbouring electrodes being out of phase with one another, the secondary windings may be arranged in a push pull configuration, such that each winding has a first and second end, each of the ends operably coupled to a respective one of the electrodes. In such an arrangement, the number of windings required is N/2 the number N of the electrodes.

[0007] The power splitter may also include an impedance matching circuit. The impedance matching circuit may be provided by a stub tuner. The output of the stub-tuner is connected to a section of transmission line and may be used to match the impedance of the transmission line and the associated power source, to that of the transmission line with additional load formed by the N secondary windings.

[0008] In a preferred arrangement the transmission line is provided as a coaxial line. A typical coaxial transmission line will include an inner core or central conductor separated from an outer shield by a dielectric. Such configurations are advantageous in that the transmission of energy in the line occurs totally through the gap between the conductors.

[0009] Where the transmission line is in an open configuration a standing wave will develop within the transmission line with a ½ wavelength node to node periodicity. Such an arrangement could be usefully employed for high UHF frequencies where wavelengths are short.

[0010] In a preferred arrangement however, the transmission line is shorted. This results in generation of a standing wave on the transmission line, with the short causing a zero-voltage point (a node) and simultaneously a maximum in current (anti-node). This high RF current results in a high azimuthal magnetic field generated in the region of the transmission line short, which is desirably provided at an end of the transmission line. By locating the secondary windings in this region it is possible to couple power into the secondary windings in a comparably broadband fashion.

[0011] While advantageously employed within the context of plasma sources where a plurality of individual electrodes are powered using such a power coupler, it will be understood that by providing a broadband coupler that a power coupler in accordance with the present teaching could also be usefully employed in any RF application that requires a splitting of power from a power source. Exemplary applications would include RADAR, television or radio antennae, mobile telecommunication antennae and the like. Depending on the application, the device may be operating as a signal splitter as opposed to a conventional power splitter but it will be appreciated that the functionality of the azimuthal coupling of the signal from the transmission line into the secondary windings benefits from the same efficiency as provided in the context of splitting of power signals.