DIRECTIONAL COUPLER WITH MULTIPLE ARRANGEMENTS OF TERMINATION

BACKGROUND

1. Related Applications

This application claims priority to and the benefit of U.S. Provisional Application No. 63/195,823, filed June 2, 2021 and titled DIRECTIONAL COUPLER WITH MULTIPLE ARRANGEMENTS OF TERMINATION, which is incorporated in its entirety herein by reference.

2. Field of Invention

The present disclosure relates generally to directional couplers. More particularly, aspects of the present disclosure relate to systems and methods for improving coupler performance using multiple termination arrangements.

SUMMARY

According to some examples of the disclosure, a radio frequency signal coupler is provided. The radio frequency signal coupler comprises an input port, an output port, a main transmission line extending between the input port and the output port, a coupled transmission line electromagnetically coupled to the main transmission line, at least one coupled port coupled to the coupled transmission line, and a plurality of termination ports connected to the coupled transmission line, Each termination port of the plurality of termination ports is connected to the coupled transmission line at a different location to provide a plurality of coupling factors corresponding to a plurality of signal frequencies.

In one aspect, the present disclosure refers to a radio frequency signal coupler comprising, an input port, an output port, a main transmission line extending between the input port and the output port, a continuous coupled transmission line electromagnetically coupled to the main transmission line, at least one coupled port coupled to the continuous coupled transmission line, and a plurality of termination ports configured to selectively couple to the continuous coupled transmission line to provide a plurality of coupling factors corresponding to a plurality of signal frequencies, at least one termination port of the plurality of termination ports configured to selectively couple to the continuous coupled transmission line at a location between a first end and

a second end of the continuous coupled transmission line, and at least one different termination port of the plurality of termination ports configured to selectively couple to the continuous coupled transmission line at a different location than the at least one termination port, the plurality of termination ports being configured to selectively couple to the continuous coupled transmission line, and at least two termination ports having different termination impedance and being configured to be selectively coupled to the continuous coupled transmission line simultaneously.

In some examples a plurality of termination impedances are coupled to the plurality of termination ports. In various examples, a plurality of switches configured to selectively connect the plurality of termination impedances to the plurality of termination ports are provided. In some examples, termination impedance of the plurality of termination impedances includes a fixed impedance and/or an adjustable impedance. In some examples, the switches of the plurality of switches are symmetrically coupled to the coupled transmission line and configured to selectively couple the impedances of the plurality of termination impedances based on a radio frequency signal being received at the input port or the output port.

In various examples a first termination impedance of the plurality of termination impedances is coupled to a first termination port of the plurality of termination ports and a second termination impedance of the plurality of termination impedances is coupled to a second termination port of the plurality of termination ports. In some examples the first termination impedance is tuned to a first signal frequency of the plurality of signal frequencies and the second termination impedance is tuned to a second signal frequency of the plurality of signal frequencies. In numerous examples the first termination port is connected to the coupled transmission line at a first location to provide a first coupling factor corresponding to the first signal frequency and the second termination port is connected to the coupled transmission line at a second location to provide a second coupling factor corresponding to the second signal frequency.

In some examples the first coupling factor corresponds to a first length of the coupled transmission line between the first termination port and the at least one coupled port and the second coupling factor corresponds to a second length of the coupled transmission line between the second termination port and the at least one coupled port. In numerous examples the first coupling factor is selected to provide a desired level of insertion loss at the first signal frequency and the second coupling factor is selected to provide a desired level of insertion loss at the second signal frequency. In various examples the first coupling factor at the first signal frequency is substantially similar to the second coupling factor at the second signal frequency.

In some examples the radio frequency signal coupler is configured to minimize insertion loss between the input port and the output port at the first and second signal frequencies. In numerous examples the at least one coupled port includes a first coupled port configured to provide a first coupled signal when an input radio frequency signal is received at the input port. In various examples the radio frequency signal coupler is configured to maintain a substantially constant power level of the first coupled signal at the first and second signal frequencies. In some examples the at least one coupled port includes a second coupled port configured to provide a second coupled signal when an input radio frequency signal is received at the output port. In numerous examples the radio frequency signal coupler is configured to maintain a substantially constant power level of the second coupled signal at the first and second signal frequencies.

According to some examples of the disclosure, a method of reducing insertion loss in a radio frequency coupler is provided. The method includes receiving a radio frequency (RF)

signal on a first transmission line that is electromagnetically coupled to a second transmission line, the RF signal having a frequency that is one of a first frequency and a second frequency different than the first frequency, inducing an induced RF signal on the second transmission line based on the RF signal, the induced RF signal having one of the first frequency and the second frequency corresponding to the frequency of the RF signal, terminating the induced RF signal having the first frequency at a first position along a length of the second transmission line to provide a first coupled signal with a first coupling factor, and terminating the induced RF signal having the second frequency at a second position along the second transmission line to provide a second coupled signal with a second coupling factor that is substantially the same as the first coupling factor.

In another aspect, the present disclosure refers to a method of reducing insertion loss in a radio frequency coupler, the method comprising, receiving a radio frequency (RF) signal on a first transmission line that is electromagnetically coupled to a continuous second transmission line, the RF signal having a frequency that is one of a first frequency and a second frequency different than the first frequency, inducing an induced RF signal on the continuous second transmission line based on the RF signal, the induced RF signal having one of the first frequency and the second frequency corresponding to the frequency of the RF signal, terminating the induced RF signal having the first frequency at a first position along a length of the continuous second transmission line to provide a first coupled signal with a first coupling factor, and terminating the induced RF signal having the second frequency at a second position along the continuous second transmission line to provide a second coupled signal with a second coupling factor that is substantially the same as the first coupling factor.

In yet another aspect, the present disclosure refers to a radio frequency signal coupler comprising, an input port, an output port, a main transmission line extending between the input port and the output port, a continuous coupled transmission line electromagnetically coupled to the main transmission line, at least one coupled port coupled to the continuous coupled transmission line, and a plurality of termination ports configured to selectively couple to the continuous coupled transmission line to provide a plurality of coupling factors corresponding to a plurality of signal frequencies, at least one termination port of the plurality of termination ports configured to selectively couple to the continuous coupled transmission line at a location between a first end and a second end of the continuous coupled transmission line, and at least one different

termination port of the plurality of termination ports configured to selectively couple to the continuous coupled transmission line at a different location than the at least one termination port, the radio frequency signal coupler being configured to maintain a substantially constant power level of a first coupled signal at a first signal frequency of the plurality of signal frequencies and at a second signal frequency of the plurality of signal frequencies, and to maintain a substantially constant power level of a second coupled signal at the first signal frequency and the second signal frequency.

In some examples, the method includes adjusting at least one impedance of a plurality of impedances coupled to the second transmission line to change the coupling factor of the first and second transmission lines. In various examples wherein the second transmission line has one or more switches coupled to the plurality of impedances, the method includes selectively switching the switches on or off based on at least one of a direction or frequency of the RF signal. In numerous examples, the method includes selecting the first and second positions to maximize directivity at the first and second frequencies, maximize isolation at the first and second frequencies, minimize the first coupling factor at the first frequency, and minimize the second coupling factor at the second frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

Various aspects of at least one embodiment are discussed below with reference to the accompanying figures, which are not intended to be drawn to scale. The figures are included to provide illustration and a further understanding of the various aspects and embodiments, and are incorporated in and constitute a part of this specification, but are not intended as a definition of the limits of the invention. In the figures, each identical or nearly identical component that is illustrated in various figures is represented by a like numeral. For purposes of clarity, not every component may be labeled in every figure. In the figures:

FIG. 1 is a block diagram of a front end module;

FIG. 2 is a schematic diagram of a radio frequency coupler;

CLAIMS

1. A radio frequency signal coupler comprising:

an input port;

an output port;

a main transmission line extending between the input port and the output port;

a continuous coupled transmission line electromagnetically coupled to the main transmission line;

at least one coupled port coupled to the continuous coupled transmission line; and

a plurality of termination ports configured to selectively couple to the continuous coupled transmission line to provide a plurality of coupling factors corresponding to a plurality of signal frequencies, at least one termination port of the plurality of termination ports configured to selectively couple to the continuous coupled transmission line at a location between a first end and a second end of the continuous coupled transmission line, and at least one different termination port of the plurality of termination ports configured to selectively couple to the continuous coupled transmission line at a different location than the at least one termination port, the plurality of termination ports being configured to selectively couple to the continuous coupled transmission line, and at least two termination ports having different termination impedance and being configured to be selectively coupled to the continuous coupled transmission line simultaneously.

2. The radio frequency signal coupler of claim 1 further comprising a plurality of termination impedances coupled to the plurality of termination ports.

3. The radio frequency signal coupler of claim 2 further comprising a plurality of switches configured to selectively connect the plurality of termination impedances to the plurality of termination ports.

4. The radio frequency signal coupler of claim 3 wherein the switches of the plurality of switches are symmetrically coupled to the continuous coupled transmission line and

configured to selectively couple the impedances of the plurality of termination impedances based on a radio frequency signal being received at the input port or the output port.

5. The radio frequency signal coupler of claim 2 wherein each termination impedance of the plurality of termination impedances includes a fixed impedance and/or an adjustable impedance.

6. The radio frequency signal coupler of claim 2 wherein a first termination impedance of the plurality of termination impedances is coupled to a first termination port of the plurality of termination ports and a second termination impedance of the plurality of termination impedances is coupled to a second termination port of the plurality of termination ports.

7. The radio frequency signal coupler of claim 6 wherein the first termination impedance is tuned to a first signal frequency of the plurality of signal frequencies and the second termination impedance is tuned to a second signal frequency of the plurality of signal frequencies.

8. The radio frequency signal coupler of claim 7 wherein the first termination port is connected to the continuous coupled transmission line at a first location to provide a first coupling factor corresponding to the first signal frequency and the second termination port is connected to the continuous coupled transmission line at a second location to provide a second coupling factor corresponding to the second signal frequency.

9. The radio frequency signal coupler of claim 8 wherein the first coupling factor corresponds to a first length of the continuous coupled transmission line between the first termination port and the at least one coupled port and the second coupling factor corresponds to a second length of the continuous coupled transmission line between the second termination port and the at least one coupled port.

10. The radio frequency signal coupler of claim 8 wherein the first coupling factor is selected to provide a desired level of insertion loss at the first signal frequency and the second

coupling factor is selected to provide a desired level of insertion loss at the second signal frequency.

11. The radio frequency signal coupler of claim 10 wherein the first coupling factor at the first signal frequency is substantially similar to the second coupling factor at the second signal frequency.

12. The radio frequency signal coupler of claim 10 wherein the radio frequency signal coupler is configured to minimize insertion loss between the input port and the output port at the first and second signal frequencies.

13. The radio frequency signal coupler of claim 12 wherein the at least one coupled port includes a first coupled port configured to provide a first coupled signal when an input radio frequency signal is received at the input port.

14. The radio frequency signal coupler of claim 13 wherein the radio frequency signal coupler is configured to maintain a substantially constant power level of the first coupled signal at the first and second signal frequencies.

15. The radio frequency signal coupler of claim 14 wherein the at least one coupled port includes a second coupled port configured to provide a second coupled signal when an input radio frequency signal is received at the output port.

16. The radio frequency signal coupler of claim 15 wherein the radio frequency signal coupler is configured to maintain a substantially constant power level of the second coupled signal at the first and second signal frequencies.

17. A method of reducing insertion loss in a radio frequency coupler, the method comprising:

receiving a radio frequency (RF) signal on a first transmission line that is electromagnetically coupled to a continuous second transmission line, the RF signal having a

frequency that is one of a first frequency and a second frequency different than the first frequency;

inducing an induced RF signal on the continuous second transmission line based on the RF signal, the induced RF signal having one of the first frequency and the second frequency corresponding to the frequency of the RF signal;

terminating the induced RF signal having the first frequency at a first position along a length of the continuous second transmission line to provide a first coupled signal with a first coupling factor; and

terminating the induced RF signal having the second frequency at a second position along the continuous second transmission line to provide a second coupled signal with a second coupling factor that is substantially the same as the first coupling factor.

18. The method of claim 17, the method further comprising adjusting at least one impedance of a plurality of impedances coupled to the continuous second transmission line to change the coupling factor of the first transmission line and the continuous second transmission line.

19. The method of claim 18, the continuous second transmission line having one or more switches coupled to the plurality of impedances, the method further comprising selectively switching the switches on or off based on at least one of a direction or frequency of the RF signal.

20. The method of claim 17, the method further comprising selecting the first and second positions to maximize directivity at the first and second frequencies, maximize isolation at the first and second frequencies, minimize the first coupling factor at the first frequency, and minimize the second coupling factor at the second frequency.

21. A radio frequency signal coupler comprising:

an input port;

an output port;

a main transmission line extending between the input port and the output port;

a continuous coupled transmission line electromagnetically coupled to the main transmission line;

at least one coupled port coupled to the continuous coupled transmission line; and

a plurality of termination ports configured to selectively couple to the continuous coupled transmission line to provide a plurality of coupling factors corresponding to a plurality of signal frequencies, at least one termination port of the plurality of termination ports configured to selectively couple to the continuous coupled transmission line at a location between a first end and a second end of the continuous coupled transmission line, and at least one different termination port of the plurality of termination ports configured to selectively couple to the continuous coupled transmission line at a different location than the at least one termination port,

the radio frequency signal coupler being configured to maintain a substantially constant power level of a first coupled signal at a first signal frequency of the plurality of signal frequencies and at a second signal frequency of the plurality of signal frequencies, and to maintain a substantially constant power level of a second coupled signal at the first signal frequency and the second signal frequency.