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Collins et al.

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[54] ELECTRONICALLY TUNED VHF/UHF MATCHING NETWORK

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[21] Appl. No.: **558,290**

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[51] **Int. Cl.^{5}** **H01P 5/04**
[52] **U.S. Cl.** **333/33**; 333/24.1; 333/160
[58] **Field of Search** .... 333/160, 161, 156, 17.3, 333/32, 33, 24.1, 205, 207, 22 F, 24.2

[56] **References Cited**

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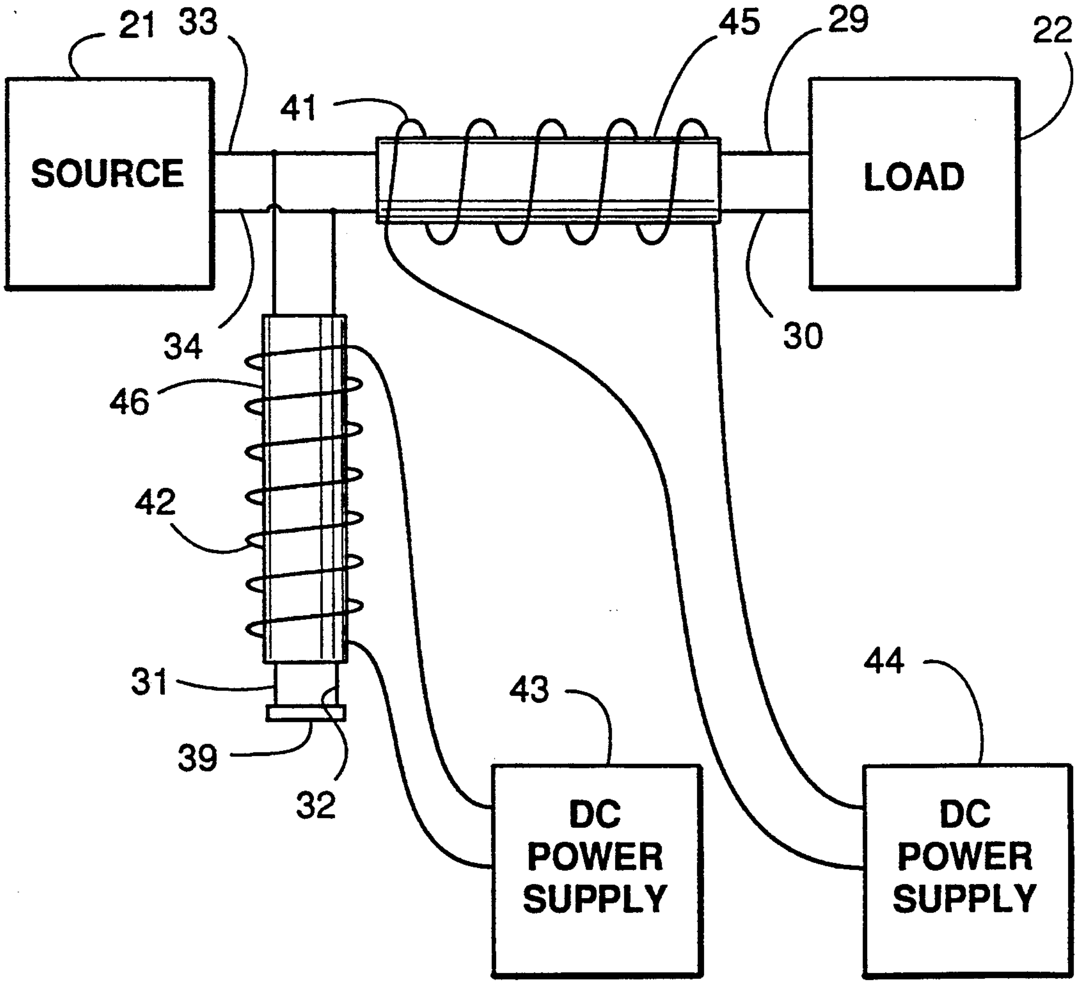
Moreno, *Microwave Transmission Design Data*, Dover Publ., N.Y., N.Y., 1948, title page and pp. 103–106.

Primary Examiner—Paul Gensler
Attorney, Agent, or Firm—Robert J. Stern; Douglas L. Weller; Paul L. Hickman

[57] **ABSTRACT**

A matching network matches an output impedance of a source with an input impedance of a load. The matching network includes a plurality of transmission line stubs. Each transmission line stub includes a first transmission line conductor, a second transmission line conductor running parallel to but not in electrical contact with the first transmission line conductor, and ferrite dielectric material between the first transmission line conductor and the second transmission line conductor. A magnetic field is used to vary the relative permeability of the ferrite dielectric material.

21 Claims, 3 Drawing Sheets



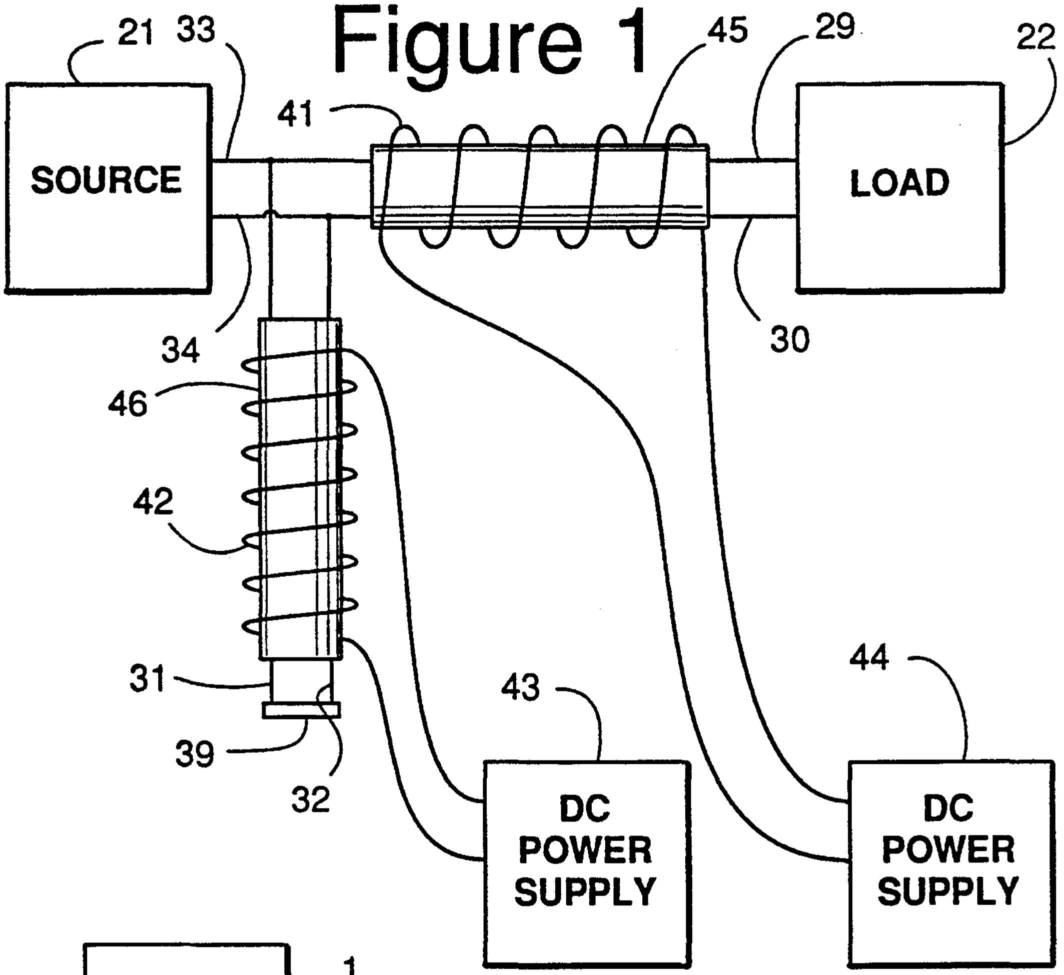


Figure 1

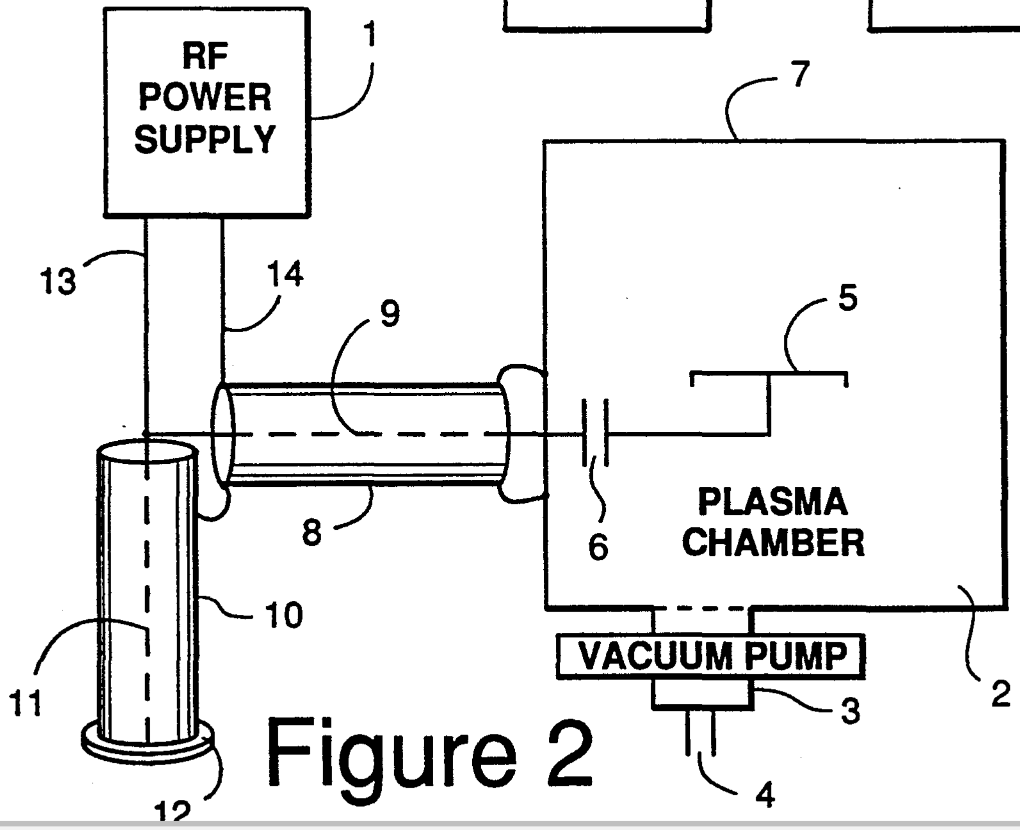
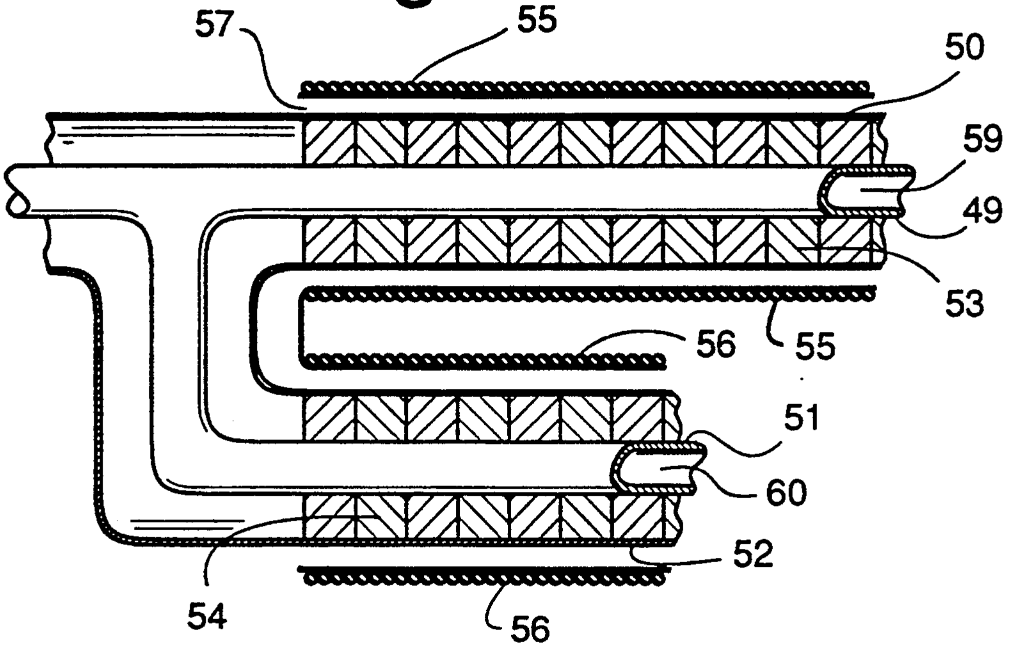


Figure 2

Figure 3



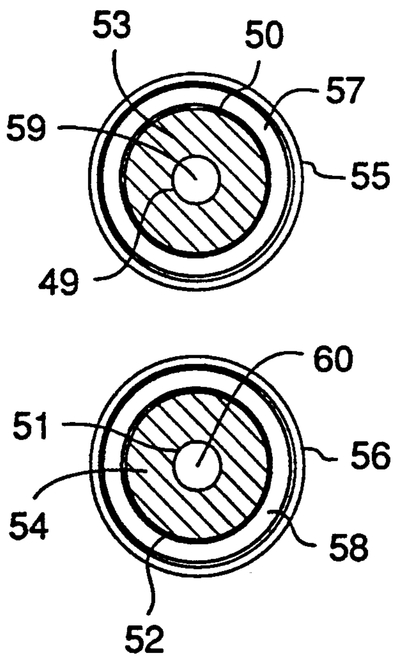


Figure 4

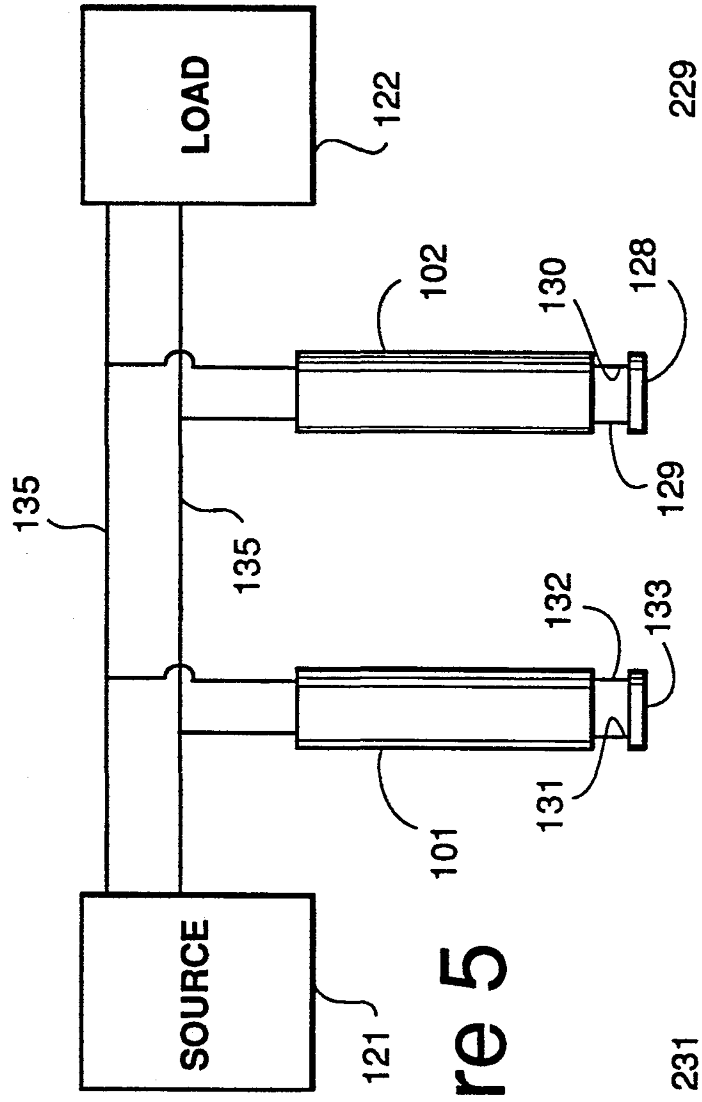


Figure 5

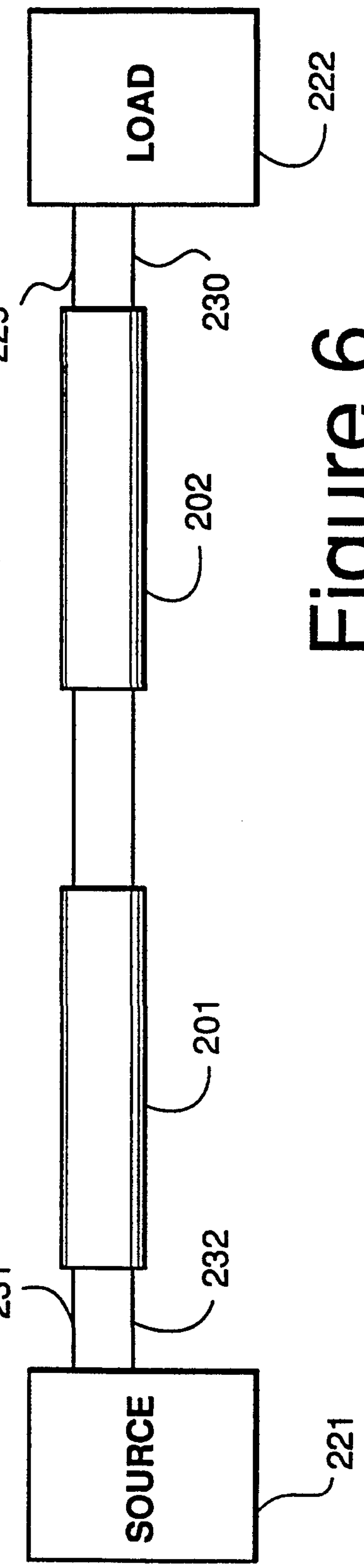


Figure 6

ELECTRONICALLY TUNED VHF/UHF MATCHING NETWORK

BACKGROUND

The present invention concerns the connection of a first electrical circuit to a second electrical circuit using a matching network so as to provide maximum power transfer between the first electrical circuit (the "source") and second electrical circuit (the "load").

Maximum power is transferred from the source to the load when the output impedance of the source is the complex conjugate of the input impedance of the load. In most cases the output impedance of the source is not naturally equal to the complex conjugate of the input impedance of the load; therefore, matching networks are placed between the source and load when power control and efficiency are critical. A matching network operates properly when the input impedance of the matching network is the complex conjugate of the output impedance of the source, and the output impedance of the matching network is the complex conjugate of the input impedance of the load. In this way power may be transferred from a source through a matching network to a load with minimal loss of power through power reflection, heat dissipation, etc.

In cases where the input impedance of the load varies during operation it is necessary to make adjustments to the matching network to maintain maximum power transfer from the source to the load. Typically, matching networks are designed such that variations in the input impedance of the load will result in a variation of the impedance of the matching network, the input impedance of the matching network being held constant. Further, in many applications the output impedance of a source is an output resistance with a negligible imaginary component. Therefore, in some prior art applications, the impedance magnitude and the impedance phase angle is measured at the input of the matching networks. Variable capacitors or inductors within the matching network are varied until the input impedance of the matching network matches the output impedance of the source network, that is until the impedance phase angle is zero and the impedance magnitude matches the magnitude of the output resistance of the source. The variable capacitors or inductors are placed in the matching network so that for every predicted variance in the input impedance of the load there is a solution in which the variable capacitors are set to values so that for the input of the matching network the impedance phase angle is zero and the impedance magnitude matches the magnitude of the output resistance of the source.

In U.S. Pat. No. 4,951,009 by Kenneth Collins et al., entitled "Turning Method and Control System for Automatic Matching Network", techniques are discussed in which variable impedance elements are used to replace variable capacitors and variable inductors. The variable impedance elements are constructed using magnetically saturable reactors, such as a transformer composed of primary and secondary windings wound around a non-linear ferromagnetic core.

Reflective power is removed by "dithering". What is meant by dithering is varying at a known frequency or frequencies the impedance through the first variable impedance element and the impedance through the second variable impedance element. A control circuit separates out the component of the change in reflected power which is due to dithering of the first variable impedance element from the change in reflected power which is due to dithering of the second variable impedance element. Using the components of change, the control circuit continuously varies the steady state impedance of the first variable impedance and the steady state impedance of the second variable impedance in directions which minimize the reflected power. The dithered method of tuning and control always converges to a unique matching solution, even for non-linear, dynamic loads. Convergence can be very fast by using high dither frequencies and magnetic dithering. The use of saturable reactors allows the variance of matching network impedance elements quickly and without moving parts.

While the matching network discussed in U.S. Pat. No. 4,951,009 works well for signals in the radio frequency range (frequency less than or equal to 30 Megahertz), for high power signals in the very high frequency (VHF) range (30–300 megahertz) or in the ultra high frequency (UHF) range (300–3000 megahertz), parasitic impedances within the magnetically saturable reactors are sufficiently large to cause non-ideal operational characteristics.

One alternate approach for matching networks which handle high power signals in the VHF or UHF range is to use a distributed parameter approach. In the distributed parameter approach transmission line sections or stubs are used to match impedances. In the prior art, the impedance of each transmission line stub may be varied by mechanically moving a short circuit or tap which is connected to the transmission line stub. However, when it is desired to quickly change impedances of a matching network, for example in a dithering process, such mechanical movement is unacceptably slow and unreliable.

SUMMARY OF THE INVENTION

In accordance with the preferred embodiment of the present invention, a matching network is presented. The matching network matches an output impedance of a source with an input impedance of a load. The matching network includes a plurality of transmission line stubs. Each transmission line stub includes a first transmission line conductor, a second transmission line conductor running parallel to but not in electrical contact with the first transmission line conductor, and ferrite dielectric material between the first transmission line conductor and the second transmission line conductor. A magnetic field is used to vary the relative permeability of the ferrite dielectric material. Throughout the discussion of the present invention, the term ferrite dielectric material means ferromagnetic or antiferromagnetic dielectric material.

In the preferred embodiment of the present invention the first transmission line conductor and the second transmission line are coaxial. These may be implemented by electrically conducting pipes placed one inside the other. Deionized water may be flowed through the inner pipe to remove heat generated by the transmission line stub. Alternately, some other fluid, such as air, may be flowed through the inner pipe to remove heat generated by the transmission line stub. Similarly air (or some other fluid such as deionized water) may be flowed on the outside of the outer electrically conducting pipe.

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