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BROAD BAND ANTENNA SYSTEM

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FIG. 1

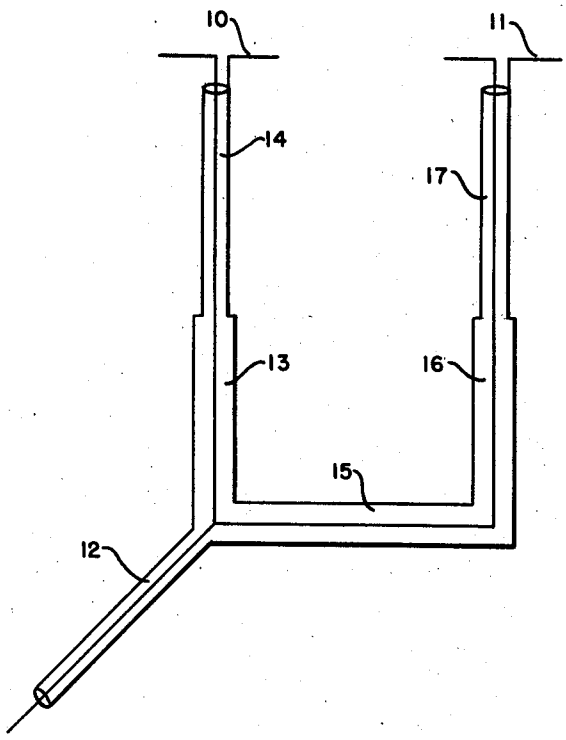
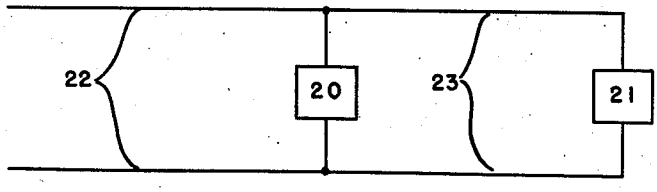


FIG. 2



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BROAD BAND ANTENNA SYSTEM

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4 Claims. (Cl. 250—33.59)

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This invention relates generally to electrical apparatus and more particularly to a radio frequency transmission line phasing unit.

Often it is desirable to provide an antenna array wherein one radiating element of the array is electrically out of phase a fixed amount with respect to other radiating elements of the array. For example, it may be desirable to excite two antennas from a single source of radio frequency energy in such a manner that the currents in the two antennas are 90 degrees out of phase.

At relatively high radio frequencies such a phase difference may be readily accomplished at a fixed operating frequency by having the feeder line to one antenna longer than that of the other by an amount corresponding to the desired phase difference.

Although such a phase difference may be readily accomplished, satisfactory operation of such a system is normally limited to a single frequency, or at best, a relatively small band of frequencies.

It is an object of the present invention to provide a broad band antenna system having radiating elements which are electrically 90 degrees out of phase with each other and where this phase difference is maintained substantially constant over a broad operating frequency band.

More specifically, it is an object of this invention to transmit radio frequency energy from a single source to two antenna loads which have the same impedance characteristics dependent on frequency, wherein the current in one load is out of phase by an odd multiple of 90 electrical degrees with that of the other load and wherein this phase relation is maintained substantially constant over a wide range of operating frequencies.

Operation over a broad band of frequencies is made possible in such a system by designing the antenna loads to have a selected value of input impedance. When antenna loads with the proper input impedance values are used with the appropriate phasing line which will be described hereinafter, the phase difference between the currents in the two antenna loads remains substantially constant over a wide range of operating frequencies, since the reactive components of the impedances of the antenna radiating elements vary with respect to frequency in such direction and magnitude as to compensate for the variations in the electrical length of the phasing system. This phenomenon results from the impedance variations of the antenna loads as the operating frequency is varied.

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Other objects, features, and advantages of this invention will suggest themselves to those skilled in the art and will become apparent from the following description of the invention taken in connection with the accompanying drawing in which:

Fig. 1 is a schematic representation of a device embodying the principles of this invention; and,

Fig. 2 is a schematic electrical circuit of two loads energized from a common radio frequency energy source.

Referring now to Fig. 1, an antenna system embodying the principles of this invention consists of two antenna loads 10 and 11, which are shown as dipoles, having identical impedance characteristics and whose currents are 90 electrical degrees out of phase and which are fed from a common transmission line 12. Transmission lines 13 and 14, each approximately a quarter of a wavelength long, referred to the midpoint of the operating frequency band, are connected between the antenna load 10 and the common transmission line 12. Hereinafter any line referred to in this specification as being a portion of a wavelength long will be understood to have a length relative to the midpoint of the operating frequency band. Transmission lines 13 and 14 provide an impedance match between the impedance of the antenna load 10 and an impedance which is approximately twice the characteristic impedance of the common transmission line 12. Transmission lines 15, 16 and 17 connect load 11 to line 12. Line 15 is a quarter-wave phasing line which provides 90 electrical degrees phase difference between the currents in loads 10 and 11, and which has a characteristic impedance approximately twice the characteristic impedance of line 12. Lines 16 and 17 are each approximately one-quarter wavelength long and provide an impedance match between load 11 and line 15. Line 12 feeds lines 13 and 15 in parallel, and since the impedance looking into each of the lines 13 and 15 is approximately twice the characteristic impedance of line 12, the impedance looking into lines 13 and 15 in parallel substantially matches the characteristic impedance of line 12.

The impedance characteristics of antenna loads 10 and 11 have been chosen such that the reactive components of the impedances of these antennas vary with respect to frequency in such a way as to compensate for the variation in the electrical length of the phasing line 15 whereby the currents in antennas 10 and 11 remain at a substantially constant phase difference of 90 elec-

trical degrees over a wide range of operating frequencies.

The possibility of making such a strategic selection of the impedance characteristic of the antenna loads may be appreciated by reference to Fig. 2 in which two loads **20** and **21** having identical impedance characteristics of a value Z_{L1} and Z_{L2}, respectively, are fed from a common transmission line **22**, load **21** being connected to line **22** by means of a phasing line **23** having a value of characteristic impedance equal to Z_0 and a length θ of 90 electrical degrees relative to the midpoint of the operating frequency band.

For such a system as shown in Fig. 2 wherein two loads Z_{L1} and Z_{L2} of identical impedance characteristics are fed by a common source such that the current in one load is maintained 90 electrical degrees out of phase with the current at the other load, it is possible to derive mathematically the following formula:

$$Z_{L1} \text{ or } Z_{L2} = Z_0 \frac{\sin\theta - j\sin\theta\cos\theta}{\cos^2\theta + 1}$$

wherein Z_0 is the characteristic impedance and θ is the electrical length of the phasing line.

Thus it is seen that the ideal antenna impedance is a function of the length and the characteristic impedance of the phasing line.

Using the above equation as a basis for the design of an antenna system as shown in Fig. 1 it has been found experimentally that such an antenna system has an operating frequency range substantially greater than antennas of prior art. For example, a conventional antenna system having a band width of 1.2:1, when replaced by a similar antenna incorporating the principles of this invention, results in an antenna system having a band width of 1.5:1.

While there has been here described one embodiment of the present invention, it will be manifest to those skilled in the art that various changes and modifications may be made therein. It is therefore aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A broad band antenna system including two antennas having the same impedance characteristics, a first radio frequency transmission line common to both of said antennas, a second radio frequency transmission line connected to said first line, said second line being approximately one-fourth wavelength long at the midpoint of the operating frequency band and having twice the value of characteristic impedance of said first line, a third radio frequency transmission line connected to said first line in parallel with said second line, said third line being approximately one-half wavelength long at the midpoint of the operating frequency band and having twice the value of characteristic impedance of said first line and a pair of impedance transformers coupled one between said line and one of said antennas and the other between said third line and the other of said antennas, said transformers having an impedance at the ends thereof coupled to said first and second lines, when terminated by said antennas, throughout the operating frequency band of substantially

$$Z_0 \frac{\sin\theta - j\sin\theta\cos\theta}{\cos^2\theta + 1}$$

where Z_0 is twice the characteristic impedance of said first line and θ is half the electrical length of said third line throughout said operating frequency band whereby the currents in said antennas remain at a substantially constant phase difference of 90 electrical degrees over a wide range of operating frequencies.

2. A broad band radio frequency antenna system comprising two antennas having the same impedance characteristics, a first transmission line for feeding radio frequency energy to both of said antennas, a second transmission line of an impedance Z_0 substantially twice the impedance of said first line and an electrical length θ_0 at the mid-frequency of the operating frequency band, said second line being coupled at one end to said first line, and a pair of impedance transformers coupled one between said first line in parallel with said second line and one of said antennas and the other between said second line and the other of said antennas, said transformers having an impedance at the end thereof coupled to said first and second lines, when terminated by said antennas, throughout the entire operating frequency band substantially equal to

$$Z_0 \frac{\sin\theta - j\sin\theta\cos\theta}{\cos^2\theta + 1}$$

where θ is the electrical length of said second line throughout the entire operating frequency band whereby said antennas are fed with energy θ_0 out-of-phase throughout said entire operating frequency band.

3. A broad band radio frequency antenna system comprising two antennas, first transmission means for feeding radio frequency energy to both said antennas, second transmission means of characteristic impedance Z_0 proportional to the impedance of said first transmission means and of an electrical length of θ_0 at the mid-frequency of the operating frequency band, said second transmission means being coupled to said first transmission means, and a pair of impedance transformers coupled one between said first transmission means in parallel with said second transmission means and one of said antennas and the other between said second transmission means and the other of said antennas, said transformers having impedances at the ends thereof coupled to said first and second transmission means, when terminated by said antennas, proportional throughout the entire operating frequency band to Z_0 times the fraction

$$\frac{\sin\theta - j\sin\theta\cos\theta}{\cos^2\theta + 1}$$

where θ is the electrical length of said second transmission means throughout said operating frequency band whereby said antennas are fed with energy θ_0 out-of-phase for all frequencies within the operating frequency band.

4. A broad band radio frequency antenna system including two antennas having the same impedance characteristics, a first radio frequency transmission line common to both of said antennas, a second radio frequency transmission line connected to said first line, said second line being approximately one-fourth wavelength long at the midpoint of the operating frequency band and having twice the value of characteristic impedance of said first line, a third radio frequency transmission line connected between said second line and one of said antennas, said third line being approximately one-fourth wavelength long at the midpoint of the operating frequency band and having a value of characteristic impedance

to provide an impedance match between said second line and said one of said antennas, a fourth radio frequency transmission line connected to said first line in parallel with said second line approximately one-half wavelength long at the midpoint of the operating frequency band and having twice the value of characteristic impedance of said first line, a fifth radio frequency transmission line connected between said fourth line and the other of said antennas, said fifth line being approximately one-fourth wavelength long at the midpoint of the operating frequency band and having a value of characteristic impedance to provide an impedance match between said fourth line and said other of said antennas, said third and fifth lines, when terminated by the impedance of said antennas, having impedances at their points of connection to said second and fourth lines respectively substantially equal throughout the operating frequency band to

$$Z_0\frac{\sin\theta-j\sin\theta\cos\theta}{\cos^2\theta+1}$$

where Z_0 is twice the characteristic impedance of said first line and θ is half the electrical length of said fourth line throughout the operating frequency band.

JESSIE A. NELSON.

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