

[54] **TRANSMITTER COMBINER HAVING COUPLED TUNED CIRCUITS**

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[52] U.S. Cl. **333/5, 325/171, 333/6, 333/26, 333/82 B, 343/858**

[51] Int. Cl. **H01p 5/12**

[58] Field of Search **333/4, 5, 6, 8, 77, 333/78, 82 B; 343/858, 889, 865; 334/45, 46; 329/142; 325/171**

[56]

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UNITED STATES PATENTS

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Primary Examiner—Paul L. Gensler

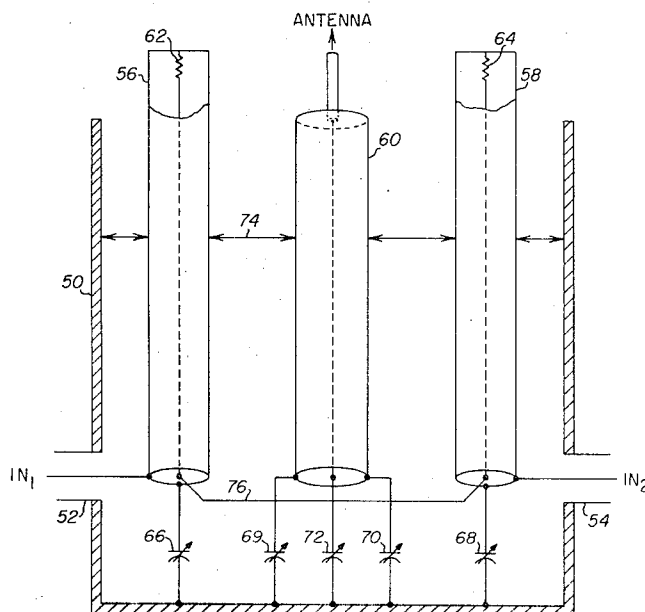
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[57]

ABSTRACT

A hybrid coupler for coupling a plurality of transmitters to a single antenna. Inductive coupling through use of variable length transmission line stubs affords tuning over a wide transmission frequency range.

4 Claims, 7 Drawing Figures



4 Sheets-Sheet 1

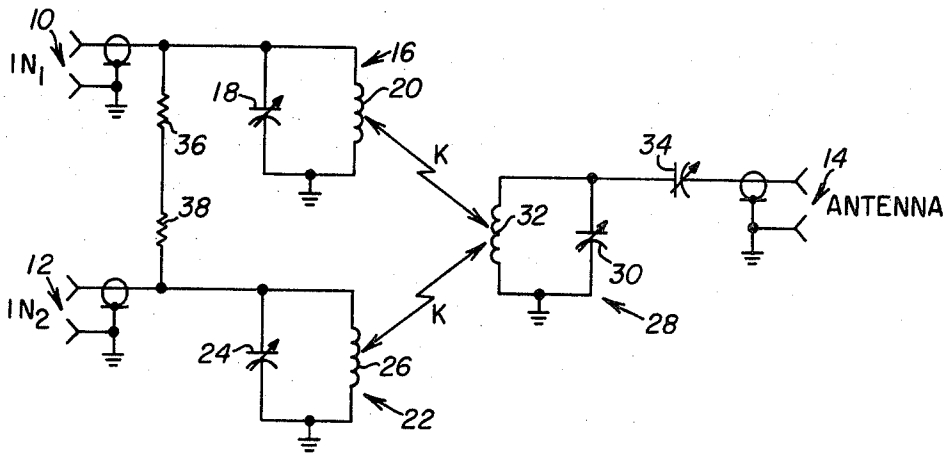


FIG. 1

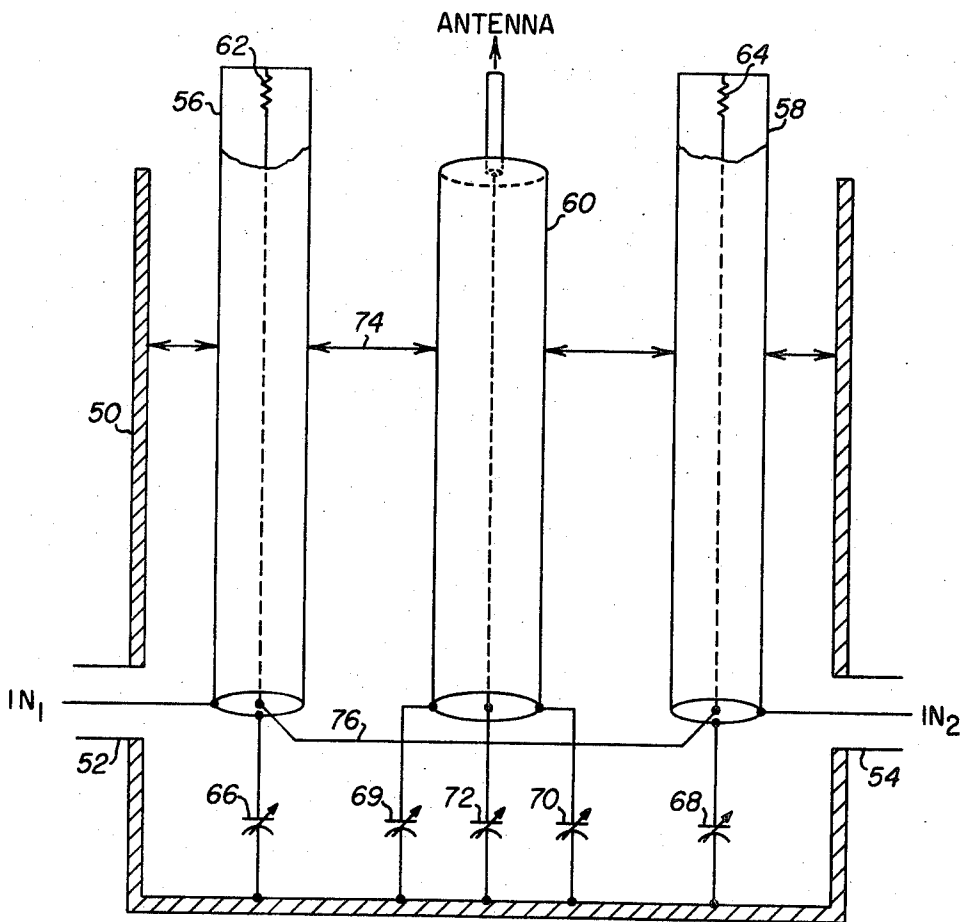


FIG. 2

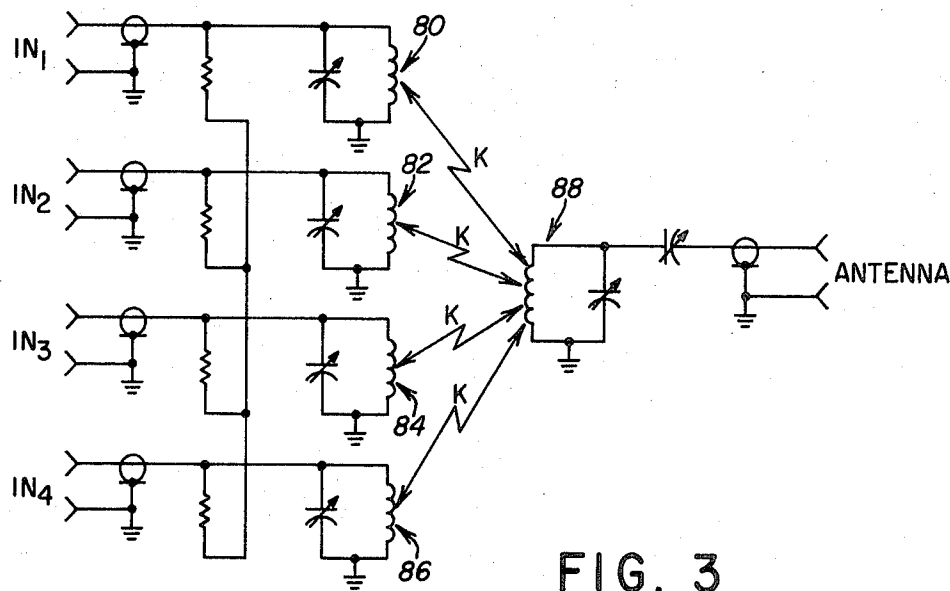


FIG. 3

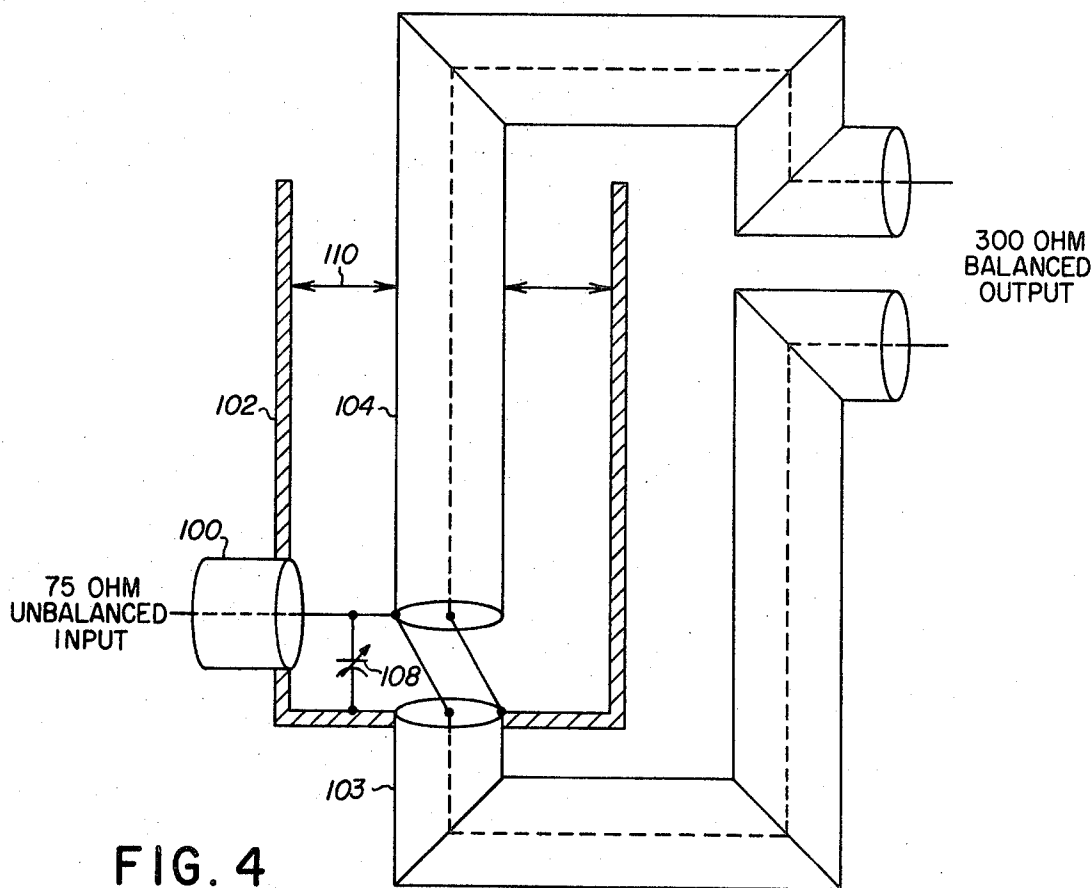
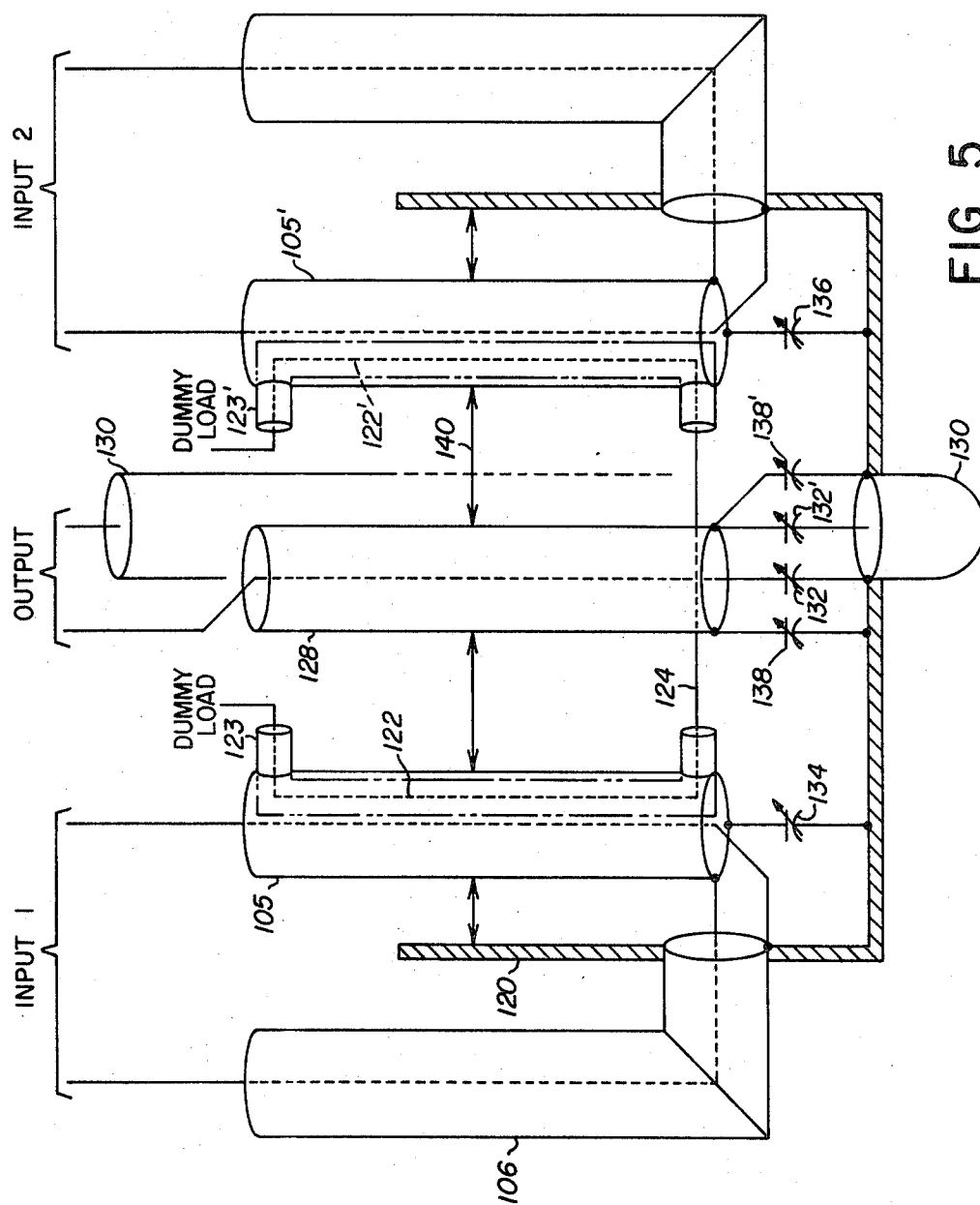


FIG. 4



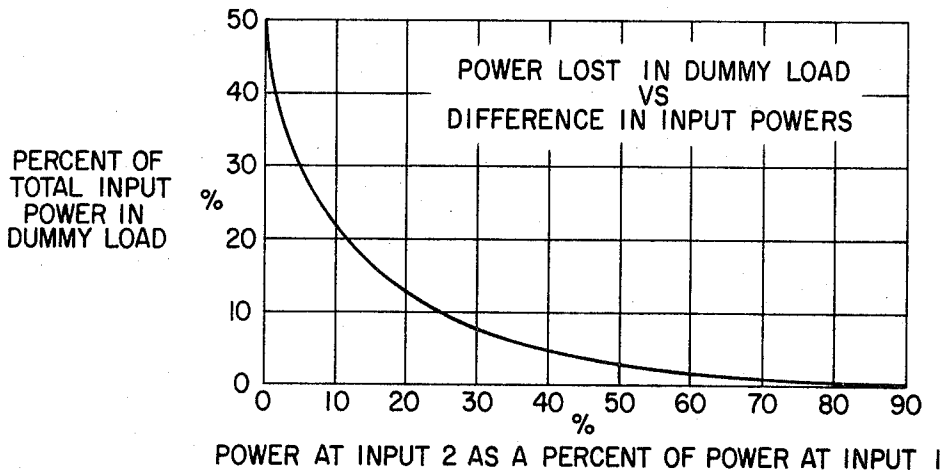


FIG. 6

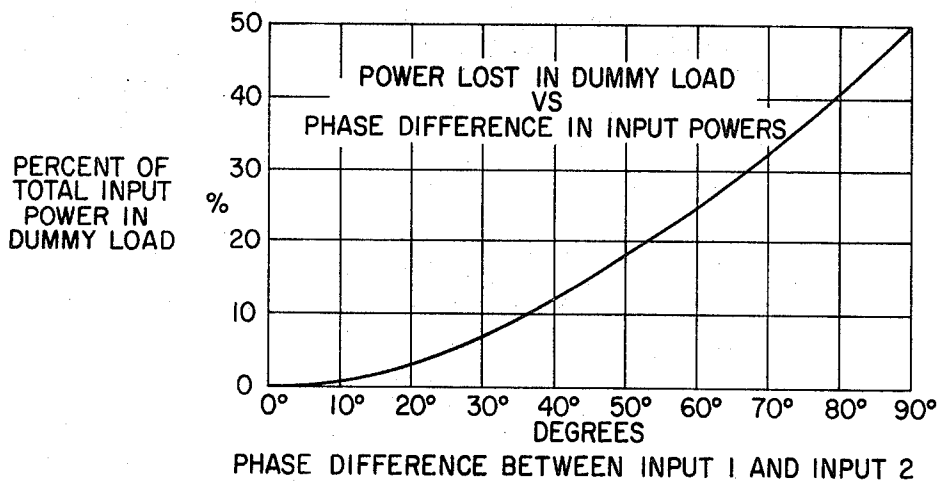


FIG. 7

TRANSMITTER COMBINER HAVING COUPLED TUNED CIRCUITS

This invention relates generally to radio transmission equipment, and more particularly to means for combining the output of a plurality of radio transmitters for broadcast from a single antenna.

The power of a radio transmission means may be increased through the use of a plurality of transmitters concurrently driving an antenna. A necessary element in such an arrangement is suitable combining means which will provide isolation of the transmitter inputs from each other and will deliver substantially all of the power of the transmitters to the antenna. Hybrid couplers for accomplishing this are known in the art. Typically, for combining two transmitters the hybrid combiner comprises transmission lines interconnecting the transmitters along two paths. One path is one-half the operating frequency wavelength in length and the antenna is connected to the midpoint thereof. The other transmission line path may be one wavelength in length such that the two paths differ in electrical length by 180 electrical degrees, whereby the coupling between transmitters along the two paths cancel. However, such a hybrid combiner is inherently limited in application to fixed frequencies or narrow bands of frequencies.

An object of the present invention is an improved combiner which is tunable over a wide frequency range.

Another object of the invention is a hybrid combiner for high-power transmitters which is compact.

Features of the invention include the use of tunable transmission line stubs for coupling transmitter inputs to the antenna output and interconnectively loading the two transmitters. Balun means may be provided for impedance transformation when interconnecting balanced and unbalanced lines.

These and other objects and features of the invention will be readily apparent from the following detailed description and appended claims when taken with the drawings, in which:

FIG. 1 is an electrical schematic of a combiner for two transmitters in accordance with the present invention;

FIG. 2 is a plan view partially in section of an implementation of the circuit of FIG. 1 for unbalanced inputs and an unbalanced output;

FIG. 3 is an electrical schematic of a combiner for four transmitters in accordance with the present invention;

FIG. 4 is a plan view in section of balun means which may be included in a combiner in accordance with the invention employing both balanced and unbalanced inputs and outputs;

FIG. 5 is a plan view in section of a combiner in accordance with the invention for balanced inputs and a balanced output;

FIG. 6 is a graph of power loss versus transmitter power when two transmitter power outputs are unequal; and

FIG. 7 is a graph of power loss versus phase difference between two transmitters.

Referring now to the drawings, FIG. 1 is an electrical schematic of one embodiment of a combiner in accordance with the present invention. In this embodiment provision is made for coupling two transmitters to the same antenna, one transmitter being connected to

input 10 and the second transmitter being connected to input 12 with the antenna connected to output 14. As opposed to prior art combiners which utilize coaxial lines for interconnecting the transmitters to an antenna, the present invention utilizes magnetic coupling. Connected to input 10 is a first tuned circuit 16 including variable capacitor 18 and inductor 20. Similarly, tuned circuit 22 is connected to input terminal 12 and includes tuned capacitor 24 and inductor 26. Another parallel tuned circuit 28 including variable capacitor 30 and inductor 32 is connected through variable capacitor 34 to the output terminal 14. Inductive elements 20 and 26 are each coupled to inductive element 32 by the same coupling factor, K.

Serially connected between the input terminals 10 and 12 are resistors 36 and 38. The resistors function as a dummy load with each resistance equivalent to the input resistance at an input terminal. As will be described further below, power loss in the dummy load is negligible when the transmitters are in phase at substantially the same power and the combiner is tuned to the operating frequency.

In implementing the circuit illustrated in FIG. 1, the inductive elements 20 and 26 comprise adjustable transmission line stubs which are terminated in the dummy load resistors 36 and 38, respectively. This implementation is illustrated in the partial section view of the combiner in FIG. 2. Referring to FIG. 2, a cavity 50 is shown in section and includes inputs 52 and 54 for receiving the transmitter outputs. Within cavity 50 are adjustably tunable coaxial transmission line stubs 56 and 58, which receive the input power and a third adjustable transmission line stub 60 which provides the output to the antenna. Stubs 56 and 58 are terminated with resistors 62 and 64, respectively, which when transposed to the input to the stubs are equivalent to the characteristic input impedance at the input terminal.

Stubs 56 and 58 respectively comprise the inductive elements 20 and 26 of FIG. 1, and variable capacitors 66 and 68 connected between stubs 56 and 58, respectively, and the cavity wall comprise the tuning capacitors 18 and 24 of FIG. 1. Variable capacitors 69 and 70 are connected in parallel between the outer conductor of stub 60 and the cavity wall and comprise the variable capacitor 30 of FIG. 1 and the tuned circuit with stub 60. Variable capacitor 72 connected between the center conductor of stub 60 and the cavity wall is equivalent to variable capacitor 34 of FIG. 1. A shorting plane 74 is provided between the stubs and the cavity wall for adjusting the effective lengths of the stubs. Conductor 76 interconnects the center conductor of stubs 56 and 58, thereby effectively interconnecting dummy load resistors 62 and 64.

In tuning the combiner, capacitors 66 and 68 which are connected between the cavity and the outer portions of stubs 56 and 58, respectively, may be ganged for simultaneous tuning. Similarly, capacitors 69 and 70 which comprise part of the tuned circuit with the output stub 60 may be ganged for simultaneous tuning. Capacitor 72 connecting the center conductor of stub 60 to the cavity, however, must be tuned separately. For tuning of the stubs to the desired operating frequency and matching the loaded transmission line effective impedance, ground plane 74 is movable within cavity 50 in a direction parallel to the axes of the stubs whereby the effective length of the stubs may be al-

tered. The stubs when tuned provide a quarter-wave coupling network between each transmitter input and the antenna output. Thus, four servos may be employed in automatically tuning the combiner; three for the capacitors and one for the shorting plane 74.

In tuning the coupler to a desired transmitting frequency, the stubs are first adjusted to a preselected length corresponding to the frequency by moving the shorting plane 74. Next, capacitors 18 and 24 are varied to tune circuits 16 and 22 to the frequency. This may be advantageously accomplished in conjunction with the servo drive by comparing the phases of the current and voltage into either tuned circuit, and varying the capacitance until the voltage and current are in phase. Thereafter, capacitor 30 in tuned circuit 28 is varied until circuit 28 is properly tuned. Again, this is advantageously accomplished in conjunction with the servo drive by measuring the phase differential between the voltage across tuned circuit 16 and the voltage across tuned circuit 28. Because of the inductive coupling of the two circuits, the voltage phase for circuit 28 will lag the voltage phase for circuit 16 by 90° when both circuits are properly tuned. Capacitor 34 is then adjusted to insure impedance matching of the antenna load to either transmitter. Again, this may be advantageously accomplished with the servo drive by dividing measured transmitter output voltage by measured transmitter output current to determine input impedance. Since the tuning of capacitor 34 will have some effect on tuned circuit 28, tuning of capacitor 30 and of capacitor 34 may have to be repeated to effect proper coupler tuning. Preferably, the tuning of these capacitors is accomplished concurrently rather than alternatively.

It is to be appreciated that capacitor 34 could be eliminated, but this would require adjustment of stub lengths to accomplish fine tuning of the coupler. This is to be avoided for high power applications because of the necessity of having sliding contacts on the stubs while the transmitters are in operation. Alternatively, a variable inductor may be used in lieu of capacitor 34, but again this would entail sliding contact adjustments thereof while the transmitters are operating. Thus, use of variable capacitor 34 is the preferred embodiment.

It is to be appreciated that the combiner is not limited to two transmitters, but may be used to combine a plurality of transmitters to a single antenna. FIG. 3, similar to FIG. 1, is the electrical schematic of combiner with four transmitters feeding the antenna. The four tuned circuits 80, 82, 84, and 86 on the input side of the combiner are respectively coupled to tuned circuit 88 on the output side of the combiner with each of the tuned circuits comprising a coaxial stub and a variable capacitor. A combiner for three transmitters would be similar but would use only three tuned input circuits, for example.

The embodiment of FIG. 2 provides a combiner for coaxial or unbalanced inputs and outputs. However, by incorporating the teachings of U. S. Pat. No. 3,265,994 to Bruene and DeLong the combiner may be used with a tuned balun between an unbalanced line and a balanced line. For example, FIG. 4 illustrates the tuned balun portion for receiving an input from an unbalanced line and providing the output necessary for feeding a balanced line combiner. In accordance with the teachings of the Bruene and DeLong patent, *supra*, the coaxial unbalanced input 100 is fed into cavity 102

with the center conductor of input 100 connected to the outer conductor of coaxial line 104 and to the inner conductor of coaxial line 103. The outer conductors of line 100 and line 103 are mounted to and electrically connected with cavity wall 102. A variable capacitor 108 and an adjustable shorting plate 110 provide proper adjustment of the balun to achieve the desired balanced impedance transformation at the outputs of coaxial lines 104 and 103 for the desired operating frequency. For example, with a 75 ohm unbalanced input the tuned balun may provide a four-to-one impedance transformation to achieve a 300 ohm balanced output. Conversely, balun means may be employed to convert balanced inputs to an unbalanced output in accordance with the Bruene and DeLong teachings.

FIG. 5 is a plan view in section of a combiner for balanced inputs and a balanced output. Input coaxial line 106 is connected to the wall of cavity 120 and input coaxial line 105 extends through the wall into the cavity 120 and functions as an adjustable stub. The center conductor of coaxial line 106 is connected to the outer conductor of coaxial line 105 while the center conductor of transmission line 105 is connected to the cavity wall and the outer conductor of transmission line 106. Mounted within transmission line 105 is a second coaxial transmission line 122 with connector 123 provided for receiving a dummy load. The corresponding stub for the second input, labeled 105', is provided with a similar transmission line 122' which receives a dummy load at connector 123'. The center conductors of transmission lines 122 and 122' are interconnected by conductor 124.

In this embodiment transmission lines 105 and 105' function as the variable tuned stubs and are magnetically coupled with transmission line 128 of the output. It will be noted that the balanced output comprises line 128 and a second transmission line 130 which is mounted to the bottom of cavity 120 and extends externally to cavity 120 to the top thereof. Within cavity 120 the center conductor of transmission line 128 is connected through variable capacitor 132 to the cavity wall and to the outer conductor of transmission line 130. Also within cavity 120 the outer conductor of transmission line 128 is connected through variable capacitor 132' to the inner conductor of transmission line 130. Capacitors 132 and 132' may be ganged and function similar to capacitor 34 of the schematic shown in FIG. 1. Variable capacitor 134 connecting the outer conductor of transmission line 105 to the cavity wall comprises a tuned circuit with transmission line 105. Similarly, variable capacitor 136 which is connected between the outer conductor transmission line 105' and the cavity wall comprises a tuned circuit with transmission line 105'. Capacitors 138 and 138' may be ganged and comprise a tuned circuit with stub 128. Shorting plane 140 within cavity 120 is adjustable to effect the desired tuning of the combiner for the operating frequency.

Thus, in the combiner of FIG. 5 for balanced inputs and a balanced output, as opposed to the unbalanced inputs and unbalanced output for FIG. 2, each input and/or output comprises two coaxial lines with one of the coaxial lines functioning as the adjustable stub.

When the inputs are in phase and of equal power level the loss within the combiner is on the order of only one to two percent which occurs mostly in the vacuum tuning capacitors. FIG. 6 is a graph illustrating the

5

input power loss in the dummy load at different levels of power at the two inputs, given with the first input power as a percentage of the second input power. It will be noted that virtually no power is lost in the dummy load when the second input power is at least 90 percent of the first input power. As the power at the second input is reduced down to a zero level the loss in the dummy load increases significantly until half of the input power is lost in the dummy load.

FIG. 7 is a similar plot showing power loss in the dummy load versus phase difference between two inputs in electrical degrees. Again, so long as the transmitters are in phase and operating at substantially the same power level there will be no loss in the dummy load. However, as the phase difference between the two inputs increases up to 90° the power loss in the dummy load increases to 50 percent of the input power.

Following is a specification summary for one embodiment of the combiner:

Frequency Range	3.95-26.5 MHz
Power	800 KW Average, 2 MW Peak
Input Impedance	300 Ohm Balanced
Output Impedance	300 Ohm Balanced
Tune Time	12 seconds maximum
Input Coax Size	10 inches OD
Output Coax Size	12 inches OD
Dummy Load Coax Size	3½ inches OD
Overall Combiner Size	5 ft. × 18 ft. × 7 ft.

Combiners in accordance with the present invention have proved to be efficient for high power use and applicable over a wide frequency range due to ease of tuning. While the invention has been described with reference to specific embodiments, the description is illustrative and is not to be construed as limiting the scope of the invention. Various modifications and changes may occur to those skilled in the art without departing from the spirit and scope of the invention as defined by the appended claims.

I claim:

1. Means for combining the outputs from a plurality

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of radio transmitters for broadcast from a single antenna comprising at least first and second tuned circuits each including a variable capacitive element and a variable inductive element connected in parallel, first input means for applying a first transmitter output to said first tuned circuit, second input means for applying a second transmitter output to said second tuned circuit, dummy load means connected between said two input means, a third tuned circuit including a variable capacitive element and a variable inductive element connected in parallel, cavity means, said inductive elements comprising coaxial transmission line stubs within said cavity means, movable shorting plane means for varying the electrical lengths of said stubs whereby said inductive elements of said first and second tuned circuits are tunably magnetically coupled with said inductive element of third tuned circuit, and output means for applying an induced voltage in said third tuned circuit to antenna means.

2. Means as defined by claim 1 wherein said inputs and said output are unbalanced and said dummy load means comprise resistive means in said transmission line stubs in said first and second tuned circuits, and including conductive means interconnecting the center conductors of said stubs in said first and second tuned circuits.

3. Means as defined by claim 1 wherein said inputs and said output are balanced and said dummy load means comprise resistive means connected to first and second transmission lines, said first and second transmission lines extending within said transmission line stubs in said first and second tuned circuits, respectively, and means within said cavity interconnecting the center conductors of said first and second transmission lines.

4. Means as defined by claim 1 wherein said inputs are unbalanced and said output is balanced and further including balun means within said cavity.

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