March 13, 1962 D. F. BOWMAN 3,025,481

TRANSMISSION LINE DIRECTIONAL COUPLER
IMPEDANCE MATCHING TUNER

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FIG. 1.

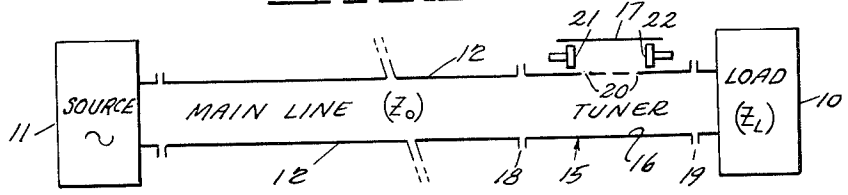


FIG. 2.

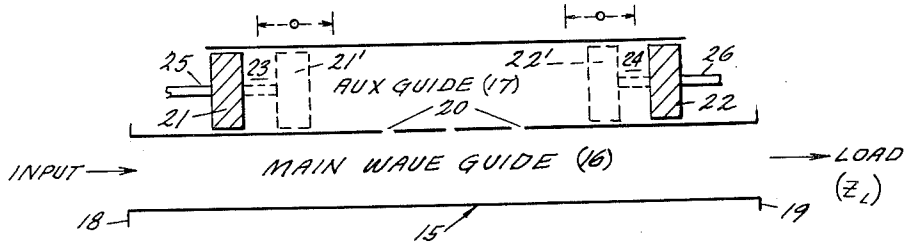


FIG. 3.

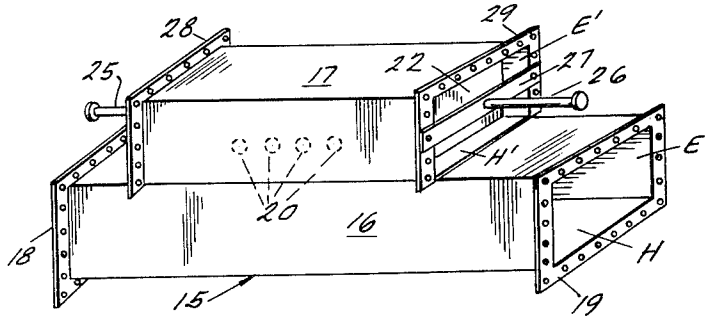
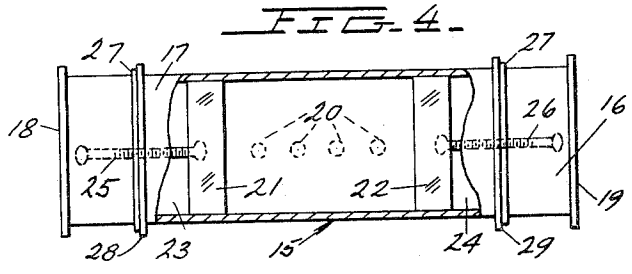


FIG. 4.



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FIG. 5.

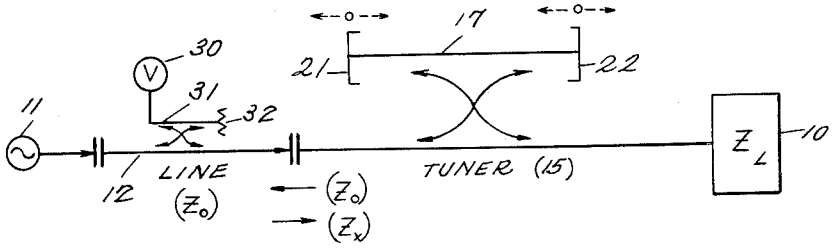


FIG. 6.

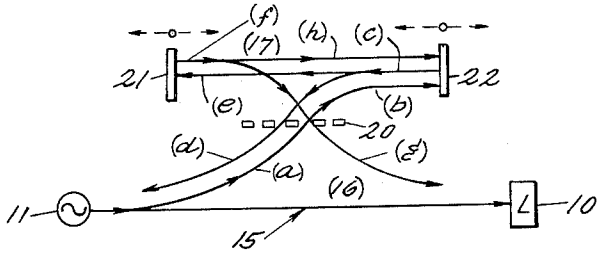


FIG. 7.

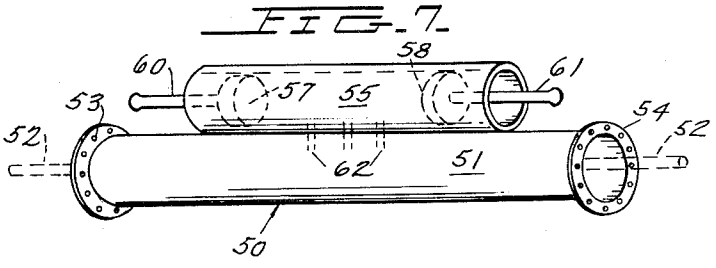
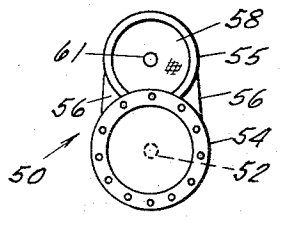


FIG. 8.



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TRANSMISSION LINE DIRECTIONAL COUPLER IMPEDANCE MATCHING TUNER

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8 Claims. (Cl. 333—33)

My invention relates to tunable directional couplers for high frequency transmission lines, and more particularly relates to novel directional coupler impedance tuners for transmission lines operating in the general range of about 200 to 1,000 megacycles.

When a load is energized through a transmission line, it is electrically desirable to have its connection match the characteristic impedance of the line. Thus, when a transmitter antenna is fed from a remote source through a wave guide, the use of a tuner between the antenna and wave guide that would match the wave guide impedance, results in more efficient transfer of high frequency energy to the same antenna with negligible reflections or VSWR.

In accordance with my invention, a directional coupler is used to sample the wave energy passing through the basic transmission line or wave guide, and two opposed short circuiting plungers are adjustably positioned in the path of the wave sample to effect a resultant impedance at the coupler input that matches that of the transmission line.

In one form of the invention, an auxiliary wave guide is juxtaposed with a main wave guide section or link, with coupling holes arranged therebetween for the directional coupling. A short circuiting plunger is adjustably positioned at either end of the auxiliary wave guide. The optimum position for each plunger is determined for an installation by a simple test procedure, as set forth hereinafter.

My novel tuner has a substantially greater impedance tuning range than that of prior tuners. The directional coupler tuner lies flat along the main transmission line, with relative economy of space. The invention coupler of the present invention is self-contained, and does not leak signal energy. It is readily tunable, stable, and easy to operate. Its principles, features and advantages are applicable to various types and shapes of transmission lines, including coaxial cables. It is adaptable for efficient use in high power systems.

It is among the objects of the present invention to provide a novel impedance tuner for transmission lines.

Another object of this invention is to provide a novel directional coupler tuner of relatively wide impedance matching capability.

A further object of my invention is to provide a novel tuner for linking a transmission line to a load, that is adjustable to substantially match to the impedance of the line.

Still another object of this invention is to provide a novel directional coupler tuner arranged flat along the transmission line, with two auxiliary opposed short circuiting pistons that adjust for matching impedance.

Still a further object of this novel invention is to provide a directional coupler tuner that is essentially self-contained, stable and highly efficient.

Another object of my invention is to provide a novel tuner in which adjustments of short circuit plungers can readily be made to control either the magnitude or phase of the reflection coefficient substantially independent of one another.

These and further objects of the invention will become more apparent from the following description of exemplary embodiments thereof, taken in connection with the drawings, in which:

FIGURE 1 is a diagram of a high frequency transmission system incorporating one form of the invention impedance matching tuner.

FIGURE 2 is an enlarged diagram of the directional coupler tuner of FIGURE 1.

FIGURE 3 is a perspective illustration of the directional coupler tuner of FIGURES 1 and 2.

FIGURE 4 is a top plan view of the tuner of FIGURE 3, with the top section partially exposed.

FIGURE 5 is a schematic diagram of the transmission system of FIGURE 1, in the process of impedance adjustment.

FIGURE 6 is a graphical showing of the operation of the tuner of the invention, in its transient phase.

FIGURE 7 is a perspective illustration of a modified directional coupler tuner; and FIGURE 8 is an end view thereof.

A typical system utilizing the invention tuner is shown in FIGURE 1. The load **10** may comprise the transmitter antenna of a high power radar or communication system. Its basic load impedance is Z_L, generally a complex value containing both resistive and reactive components. The energy source **11** generates the power transmitted to load **10** through main transmission line **12**. The characteristic impedance of the transmission line **12** is designed to closely match the output impedance of the source **11**. The tuner **15** establishes a link between main line **12** and the load **10**, and is adjustable to effect a practical impedance match to the line impedance Z_0. In this way, efficient power transfer at lowest VSWR is effected to load **10**.

Where transmission line **12** is a wave guide of rectangular cross-section, typical dimensions for a 1,000 megacycle guide is 7.7″ x 3.85″ or 9.75″ x 4.875″. For lower frequencies, the wave guide correspondingly increases in size. The invention tuner is practically applied in systems in the about 200 to 1,000 megacycle range. For above 1,000 megacycle signals, simpler tuner means can be employed.

The tuner wave guide link **15**, as shown in FIGURES 1 through 4, has a main wave guide section **16**, and a contiguous auxiliary wave guide section **17**. The main guide **16** is preferably made of the same transverse (E, H plane) dimensions as those of the main transmission (wave guide) line **12**, which dimensions are proportioned for the signal frequency used, of source **11** along conventional practice. Tuner **15** is mechanically coupled by flange **18** to line **12**; and flange **19**, to load **10**.

A series of openings **20** are arranged between the main and auxiliary guide sections **16**, **17**, in the common face thereof. Openings **20** may be a series of simple holes or rectangular slots. They are proportioned to effect directional coupling between the sections **16** and **17**, and the passage of energy to the auxiliary guide in the order of 1 to 5% of the main power through guide **16**.

A metallic piston or plunger **21**, **22** is placed at the respective open end regions **23**, **24** of auxiliary guide **17**. Pistons **21**, **22** are longitudinally adjustable. They are shaped and proportioned to make a close fit in the guide regions **23**, **24** to effect respective short circuits across the auxiliary wave guide **17** thereat. Plungers **21**, **22** thereby serve as variably positioned reflectors in the auxiliary guide of the energy directionally coupled thereto.

Pistons **21** and **22** are respectively linked with rotatable threaded rods **25** and **26**, as seen in FIGURES 2, 3, 4. Rods **25**, **26** coact in the threaded aperture of a cross-plate **27** at each flange **28**, **29** of the auxiliary guide **17**. Manual rotation of the extending portions of rods **25**, **26** serves to precisely position the closely fitted pistons **21**, **22** in the auxiliary guide section **17**. Once positioned, in accordance with the adjusting procedure described in

connection with FIGURE 5 herein after, the pistons 21, 22 are designed to remain mechanically fixed.

In the preferred embodiment of tuner 15, the transverse (E', H' planes) dimensions of the auxiliary wave guide are made the same as those of the main guide (E, H planes). In a typical application for a 400 megacycle system, the E and E' dimension is 10.5 inches; the H and H' dimension, 21 inches. The length of the main guide section 16 is 12 feet; and the auxiliary section 17 is 11 feet. The directional coupling hole array 20 extends over about one-half the longitudinal extent of auxiliary section 17. The design of the coupling array 20 can be by any of the techniques known in the art. The pistons 21, 22 may each be displaceable for about one-fifth the length of auxiliary guide 17, up to the array 20, to effect a wide impedance matching action.

FIGURE 5 is a schematic diagram of the procedure for adjusting the invention tuner 15 in the system. A voltmeter 30 is connected to one end of a directional coupler pick-off unit 31 at the main transmission line 12, near the tuner 15. A suitable matching load 32 is connected to the other end of pick-off 31. Each plunger 21, 22 is then adjusted longitudinally successively for minimum readings of voltmeter 30. Such successive adjustment is continued until the reading on voltmeter 30 becomes zero. This condition indicates the balancing of the impedance Z_x (looking into the tuner 15) with that of the line 12, namely Z_0.

The physical action of the tuner hereof may be explained in mathematical terms. However, this involves complex equations with vector factors. Essentially, the interactions may be generally understood by reference to the transient diagram, FIGURE 6. The directional coupling is proportioned to transfer in the order of 1 to 5% of the main wave energy through the transmission line to the auxiliary line 17. This occurs across the coupling hole array 20. The short circuiting plungers 21, 22 serve as true reflectors of incident radio energy. Their reflection coefficient is always near unity in magnitude, e.g. 0.99. However, the phase angle of the wave energy reflected depends upon the positions of the plungers in the auxiliary guide 17.

Referring to FIGURE 6, wave energy *a* is coupled into the auxiliary guide 17 through hole array 20 and impinges upon the face plunger 22. The magnitude of this impinging signal at *b* is, for example, 2% of the main wave magnitude. The reflected signal *c* is practically the same or 2% value, and produces the waves *d* and *e*, Wave *d* is coupled to main guide 16 at 2% of 2% magnitude, or .04%, in the reverse direction to wave *a*. The signal *e* is about 98% of 2% or 1.96% in value. Wave *e* reflects from face of plunger 21 into wave *g* and *h*. The wave *g* is therefore 2% of 1.96%, or .039 in value. Wave *h* is 98% of 1.96%, or about 1.92%.

The transient action continues, with wave *h* being reflected by plunger 22, with 2% of its energy following the *d* wave path; and 98%, to plunger 21; etc. A number of waves accumulate in the wave *d* and *g* paths across the main guide section 16 of the tuner. The phase of the cumulative reflected waves are primarily dependent upon the respective positions of plungers 21, 22 in the auxiliary guide 17. The steady state arrives rapidly, and determines the effective vector impedance of the tuner 15. By simply adjusting the plungers 21, 22 for zero voltage at 30 (FIGURE 5), the effective impedance Z'_x at the tuner input is made to match that of the transmission line Z_0, as aforesaid.

Another way of describing this operation is that suitable adjustments will make wave *d* equal and opposite to that portion of the reflected wave from source 11 which returns to the load 10. Thus the net reflected wave is made zero.

FIGURES 7 and 8 illustrate the invention tuner principle applied to a cylindrical wave guide or coaxial line. Directional coupler tuner 50 has a main transmission

line guide section 51 that is cylindrical. If a coaxial line system is used, a central conductor such as 52 would be located in the main and auxiliary lines. End flanges 53, 54 are used to mechanically couple guide tube 51 into the system. The auxiliary guide 55 is secured onto main guide 51, juxtaposed therewith, and coupled at 56, 56.

The tuning short circuiting plungers 57, 58 are adjustable at the end regions of auxiliary guide 55, through respective rods 60, 61. The coupling hole array between main and auxiliary guides 51, 55 is indicated at 62. The impedance matching is effected similarly to that outlined for tuner 15 in connection with FIGURE 5 hereinabove.

I have described my invention in connection with its principle use, namely as a tuner to match on otherwise mismatched load. However, it is noted that my device is equally useful in mismatching a matched load. This would be desirable for certain tests as for example on transmitters. Thus, my novel unit, although referred to as a tuner, can be applied to achieve either a matched or mismatched condition.

Although the invention has been set forth with exemplary constructions and arrangements, it is to be understood that the features, principles and manner of application thereof may be varied by those skilled in the art, without departing from the broader spirit and scope of the invention as defined in the following claims.

I claim:

1. A high frequency directional coupler impedance tuner comprising a main wave guide member having a constant cross section, an auxiliary wave guide member having a constant cross section being juxtaposed with said main section in the longitudinal direction with an array of coupling openings between said sections to effect directional coupling therebetween, said auxiliary wave guide member having an interior cross-section comparable to that of said main wave guide member, and a short-circuiting piston adjustably positionable at each end of said auxiliary section, said coupling array being proportioned to introduce signal energy into said auxiliary section to the extent of a minor fraction of the signal energy passing through said main section, said coupling array being operatively positioned to introduce a portion of the signal energy into said auxiliary section before the signal energy reaches a load, and mechanism for individually positioning said pistons in the auxiliary section to effect impedance balancing by the tuner.

2. A directional coupler tuner as claimed in claim 1, in which the minor fraction of said coupling is of the order of about 1% to about 5%.

3. A high frequency directional coupler impedance tuner link for substantially matching the impedance of a load to that of a transmission member comprising a guide main section comparable in transverse form to the transmission member and connectable therewith at its one end and to the load at its other end, an auxiliary section extending laterally from said main section in the longitudinal direction with an array of coupling openings between said sections to effect directional coupling therebetween, said auxiliary section having a constant cross-section comparable to said guide main section and short-circuiting means positionable at each end of said auxiliary section, said coupling array being proportioned to introduce signal energy into said auxiliary section to the extent of a minor fraction of the signal energy passing through said main section to the load, said coupling array being operatively positioned to introduce a portion of the signal energy into said auxiliary section before the signal energy reaches a load, and mechanism for individually positioning said means in the auxiliary section to effect substantial impedance balance of the tuner having the load connected with the transmission member connected to the balancing end thereof.

4. A directional coupler tuner as claimed in claim 3, in which the minor fraction of said coupling is less than about 5%.

5. A high frequency directional coupler impedance tuner link for substantially matching the impedance of a load to that of a transmission member comprising a wave guide main section substantially equal in transverse form to the transmission member and connectable therewith at its one end to the transmission member and to the load at its other end, an auxiliary section juxtaposed with said main section in the longitudinal direction with an array of coupling openings centrally between said sections to effect directional coupling therebetween, said auxiliary section having a hollow constant transverse form substantially equal to that of said main section, and a short-circuiting plunger adjustably positionable at each end of said auxiliary section, each plunger having a cross-sectional form substantially identical to the transverse hollow area of said auxiliary section and in contact therewith, said coupling array being proportioned to introduce signal energy into said auxiliary section of the order of less than 5% of the signal energy passing through said main section to the load, said coupling array being operatively positioned to introduce a portion of the signal energy into said auxiliary section before the signal energy reaches a load, and mechanism for individually positioning said plungers in the auxiliary section to effect an impedance matching of the tuner having the load connected to its other end with the transmission member connected to the matching one end thereof.

6. A high frequency transmission line directional coupler impedance tuner link for substantially matching the impedance of a load to that of the transmission line comprising a wave guide main section substantially equal in transverse form to the transmission line and connectable at its one end to the transmission line and to the load of its other end, an auxiliary section juxtaposed with said main section in the longitudinal direction with an array of coupling openings centrally between said sections to effect directional coupling therebetween, said coupling

array being operatively positioned to introduce a portion of the signal energy into said auxiliary section before the signal energy reaches a load, said auxiliary section having a hollow constant transverse form substantially equal to that of said main section, and a short-circuiting plunger adjustably positionable at each end of said auxiliary section, each plunger having a cross-sectional form substantially identical to the transverse hollow area of said auxiliary section and in contact therewith with a plane face facing inwardly of the auxiliary section, said coupling array being proportioned to introduce signal energy into said auxiliary section to the extent of a minor fraction of the signal energy passing through said main section to the load, and mechanism for individually positioning said plungers in the auxiliary section to effect an impedance balancing of the tuner having the load connected to its other end with the transmission line connected to the balancing end thereof.

7. A directional coupler tuner as claimed in claim 6, in which said main section is in the form of a cylindrical tube.

8. A directional coupler tuner as claimed in claim 6, in which said main section is in the form of a coaxial cable.

References Cited in the file of this patent

UNITED STATES PATENTS

2,438,735	Alexanderson	Mar. 30, 1948
2,591,980	Van Hofweegen et al.	Apr. 8, 1952
2,671,883	Dicke	Mar. 9, 1954
2,819,453	Cohn	Jan. 7, 1958

OTHER REFERENCES

Jakes: Broad-Band Matching With a Directional Coupler, Proceedings of the IRE, October 1952, pages 1216–1218, vol. 40, Issue 10.