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TEM MODE COUPLER HAVING AN EXPONENTIALLY VARYING COEFFICIENT OF COUPLING

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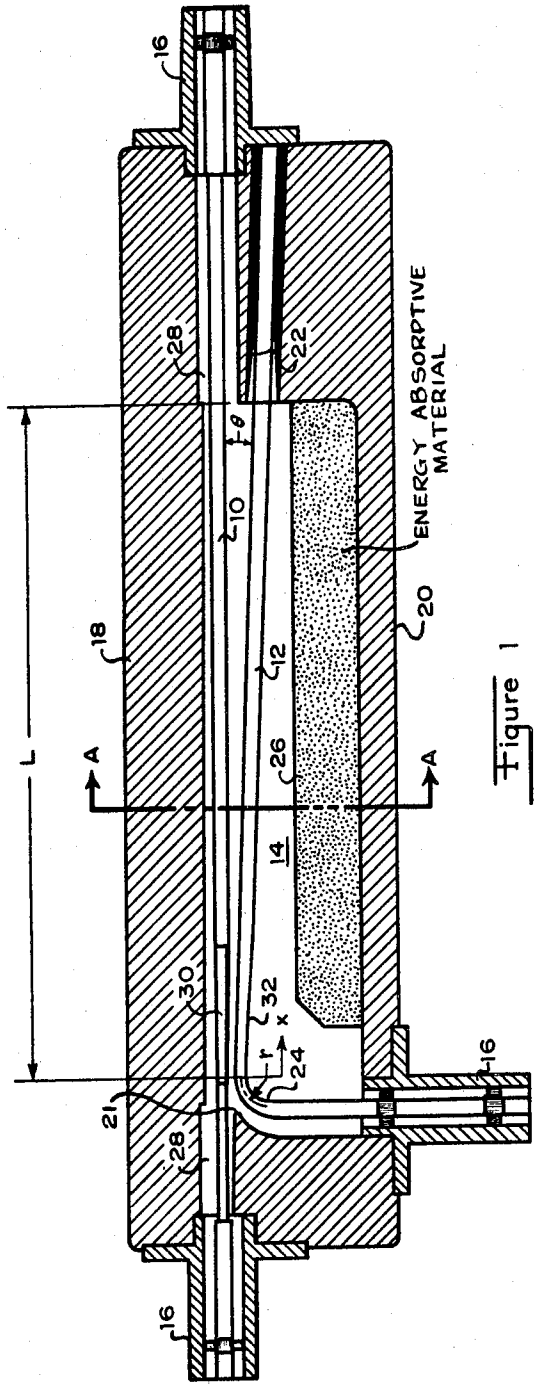


Figure 1

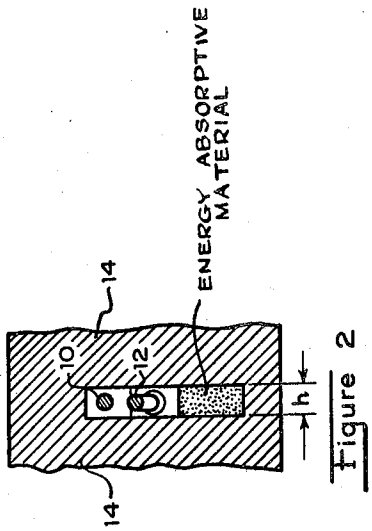


Figure 2

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TEM MODE COUPLER HAVING AN EXPONENTIALLY VARYING COEFFICIENT OF COUPLING

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ABSTRACT OF THE DISCLOSURE

Primary and auxiliary inner conductors are mounted within an outer conductor in transverse electric and magnetic field coupling proximity. The spacing between the inner conductors increases at a constant angle in one direction from a region of tight coupling to a region of looser coupling where the auxiliary conductor terminates in a load that is axially aligned therewith. This provides an exponentially varying coefficient of coupling between the inner conductors. An inner portion of the outer conductor protrudes between the inner conductors near the region of tight coupling at a point where the auxiliary conductor diverges abruptly from the primary conductor to a connector terminal mounted in a side of the outer conductor. This minimizes non-exponential coupling between the inner conductors. The cross-sectional area of the inner conductors and the spacing between the inner sidewalls of the outer conductor and the inner conductors vary to provide the inner conductors with a substantially constant characteristic impedance and to provide the primary conductor with a low reflection transition into a pair of connector terminals mounted in the opposite ends of the outer conductors. An energy absorbent body is mounted within the outer conductor adjacent to at least one of the inner conductors to suppress spurious TE and TM modes that may be caused by the enlargement of the outer conductor to accommodate the increasing spacing of the inner conductors throughout the coupling region.

This invention relates to exponential TEM mode couplers.

It is the principal object of this invention to provide an exponential TEM mode coupler having a substantially constant characteristic impedance for operation over a very broad frequency range.

Another object of this invention is to provide a very broad-band TEM mode coupler in which spurious TE and TM modes are suppressed.

In accordance with the illustrated embodiment of this invention there is provided an exponential TEM mode coupler comprising diverging primary and auxiliary conductors positioned within an outer conductor in transverse electric and magnetic field coupling proximity to provide an exponentially varying coefficient of coupling. The primary conductor is connected between a pair of coaxial transmission line connectors mounted in the opposite end sections of the outer conductor. The spacing between the inner surfaces of the opposite side-walls of the outer conductor is reduced at each end of the coupling region to provide the primary conductor with a low reflection transition into the coaxial transmission line connectors. A side-wall having a sloping inner surface is positioned near the primary conductor, and the auxiliary conductor is provided with a flattened portion of varying cross-sectional area to give the TEM mode exponential coupler a substantially constant characteristic impedance. The auxiliary conductor terminates in a load which is aligned therewith and mounted in the other side-wall of the outer conductor at the more loosely coupled end of the primary and auxiliary conductors. A body of absorbent material is mounted on the inner surface of this side-wall adjacent to the auxiliary conductor for suppressing spurious TE and TM modes.

Other and incidental objects of this invention will become apparent from a reading of this specification and an inspection of the accompanying full scale drawing in which:

FIGURE 1 is a sectional top view of an exponential TEM mode coupler for a frequency range of from 0.5 to 12.4 kilomegacycles per second; and

FIGURE 2 is a sectional end view of the coupler of FIGURE 1 taken along the line A—A.

Referring now to FIGURES 1 and 2, there is shown an exponential TEM mode coupler comprising circular primary and auxiliary conductors **10** and **12** which are symmetrically supported between a pair of parallel ground planes **14** to minimize the excitation of TE and TM modes. These primary and auxiliary conductors **10** and **12** are positioned in transverse electric and magnetic field coupling relationship at an angle θ over the length L to provide an exponential variation of coupling coefficient K with distance x measured from the tightly coupled end of the primary and auxiliary conductors **10** and **12** along the longitudinal axis of the coupler. Thus,

$$K(x)=K_0e-x/x_0$$

where x is measured from the tightly coupled end of the primary and auxiliary conductors **10** and **12**, K_0 is the coupling coefficient at this tightly coupled end, and x_0 is the distance along x in which $K(x)$ is reduced by the factor e^{-1} or, in other words, changes by 8.68 decibels. The angle θ is generally made less than ten degrees to obtain good directivity. As the angle θ is decreased, the lower limit of the operating range of the coupler is also decreased. The upper limit of the operating range of the coupler is theoretically infinite because of the assymmetrical exponential variations of $K(x)$ with x, where coupling is initiated abruptly at the tightly-coupled end of conductors **10** and **12**. A smaller ripple of coupling coefficient is obtained over the operating range of the coupler for larger spacing between the loosely coupled ends of the primary and auxiliary conductors **10** and **12**. Thus, it is normally desirable to have a small angle θ and a sufficient length L to provide a substantially greater spacing between the primary and auxiliary conductors **10** and **12** at their loosely-coupled end than at their tightly-coupled end. This provides a very broad-band exponential coupler having a small ripple of coupling coefficient.

Primary conductor **10** is connected between and supported by a pair of coaxial transmission line connectors **16** mounted in the opposite end sections of side-walls **18** and **20**. The spacing between the inner surfaces of the side-walls **18** and **20** is greatly reduced at the opposite ends of the coupling region to provide the primary conductor **10** with a low reflection rectangular transition **28** into the coaxial transmission line connectors **16**. The loosely-coupled end of auxiliary conductor **12** terminates in a load **22** which is aligned with the auxiliary conductor at the angle θ for good directivity and mounted in an end section of side-wall **20**. The tightly-coupled end of auxiliary conductors **12** turns a corner **24** of radius r and is connected to a coaxial transmission line connector **16** mounted in side-wall **20**. A tip portion **21** of side-wall **20** protrudes between the primary and auxiliary conductors **10** and **12** near the point where the spacing between them begins to increase at the constant angle θ. This tip portion **21** minimizes non-eponential coupling between the primary and auxiliary conductors **10** and **12** and, as described in Richard C. Harmon's copending patent application Ser. No. 301,450 entitled High Directivity TEM Mode Coupler, filed on Aug. 12, 1963, and issued as U.S. Patent 3,204,206 on Aug. 31, 1965, increases the

directivity of the coupler. Side-walls **18** and **20** and the parallel ground planes **14** form a rectangular outer conductor at ground potential. The ratio of the spacing *w* between the inner surfaces of side-walls **18** and **20** to the spacing *h* between the inner surfaces of the parallel ground planes **14** is large (generally between 2 and 10) thereby making the dimensions of the coupler less critical and making it easier to accurately provide the desired characteristic impedance. However, this large ratio may allow excitation and propagation of TE and TM modes over the broad operating frequency range of the exponential TEM mode coupler. Thus, a body of absorptive material **26** is positioned between the ground planes **14** on the inner surface of side-wall **20** adjacent to the auxiliary conductor **12** to damp these spurious TE and TM modes. The volume of this body of absorptive material **26** is selected to be sufficient to damp all TE and TM modes over the broad operating frequency range of the coupler so as to eliminate their undesirable effect on the normal TEM mode operation of the coupler. But a minimum spacing is maintained between the outer surface of the body of absorptive material **26** and the auxiliary conductor **12** so that a negligible amount of energy is coupled from the normal TEM mode of operation. This minimum spacing normally should be at least equal to the spacing *h* between the parallel ground planes **14**. It should be noted that a body of absorptive material such as that shown in the drawing might be used to suppress spurious TE and TM modes in any broad-band TEM mode coupler in which they may appear. Side-wall **18** is positioned close enough to the primary conductor **10** so that there is insufficient room for the excitation and propagation of TE and TM modes between the primary conductor **10** and the side-wall **18**. Thus, damping is only required on the auxiliary conductor side of the coupler shown in the drawing.

The exponential variation of coupling coefficient K with distance *x* along the longitudinal axis of the coupler has the effect of altering the characteristic impedance of the coupler. To compensate in part for this effect and provide the primary conductor **10** with a substantially constant characteristic impedance, side-wall **18** is provided with a sloping inner surface so that the spacing between it and primary conductor **10** increases with distance towards the tightly coupled end of the primary and auxiliary conductors **10** and **12**. In the region of tightest coupling between the primary and auxiliary conductors **10** and **12** a small portion **30** of the primary conductor **10** is tapered to provide further compensation as required to maintain the desired characteristic impedance along the primary conductor **10**. This portion **30** of primary conductor **10** is shown greatly exaggerated in FIGURE 1 of the scale drawing, but it uniformly decreases in diameter by about four mils over one inch of length. In lieu of sloping the inner surface of side-wall **18**, the primary conductor **10** might be similarly tapered along the entire length L thereof to provide a constant characteristics impedance along the primary conductor **10**. The auxiliary conductor **12** is flattened on one side in the region of tighest coupling to provide a portion **32** of varying cross-sectional area for maintaining a substantially constant characteristic impedance along the auxiliary conductor **12**. This portion of the auxiliary conductor **12** is also shown greatly exaggerated in FIGURE 1 of the scale drawing, but it uniformly increases in cross-sectional area on either side of the corner **24** where the outer edge of the auxiliary conductor **12** is machined away to a depth of about thirty-five mils. It is much easier to flatten a portion of the auxiliary conductor **12** on one side in this manner than to taper the auxiliary conductor and provide a uniformly varying diameter.

We claim:

1. A broad-band TEM mode coupler comprising:

a first electromagnetic wave energy transmission path including a first conductor positioned within an outer conductor; and

a second electromagnetic wave energy transmission path including a second conductor positioned within said outer conductor;

said first and second conductors being positioned in transverse electric and magnetic field coupling proximity with a finite spacing between the adjacent edges of said conductors;

said finite spacing increasing with distance in one direction along said conductors to provide an exponentially varying coefficient of coupling therebetween;

at least one of said first and second conductors having portions of different cross-sectional area to provide at least one of said first and second electromagnetic wave energy transmission paths with a substantially constant characteristics impedance.

2. A broad-band TEM mode coupler as in claim **1** wherein:

said outer conductor has a sidewall positioned near said first conductor; and

the spacing between said sidewall and said first conductor increases with distance in a reverse direction along said conductors to provide said first electromagnetic wave energy transmission path with a substantially constant characteristic impedance.

3. A broad-band TEM mode coupler as in claim **1** wherein:

a body of absorptive material is mounted on the inner surface of said outer conductor adjacent to said second conductor for damping spurious TE and TM modes in the operating range of said coupler;

said body of absorptive material being spaced from said second conductor to couple a minimal amount of energy from said TEM mode of operation.

4. A broad-band TEM mode coupler as in claim **1** wherein:

said first conductor is supported between and connected to a pair of coaxial transmission line connectors mounted in said outer conductor; and

the spacing between the sidewalls of said outer conductor is reduced near at least one end of the coupling region to provide a low reflection transition into at least one of said coaxial transmission line connectors for said first conductor.

5. A broad-band TEM mode coupler as in claim **1** including a load for terminating said second conductor near the region of loosest coupling between said first and second conductor, said load being axially aligned with said second conductor.

6. A broad-band TEM mode coupler as in claim **1** including means positioned between said first and second conductors near the region of tightest coupling therebetween for reducing non-exponential coupling between said first and second conductors.

7. An exponential TEM mode coupler comprising:

a first electromognetic wave energy transmission path including a first conductor mounted within an outer conductor; and

a second electromagnetic wave energy transmission path including a second conductor mounted within said outer conductor;

said first and second conductors being positioned in transverse electric and magnetic field coupling proximity with a finite spacing between the adjacent edges of said conductors;

said finite spacing increasing with distance at a constant angle in one direction along substantially the entire length of the coupling region between said conductors to provide an exponentially varying coefficient of coupling therebetween.

8. An exponential TEM mode coupler as in claim **7** including means positioned between said first and second conductors near the region of tightest coupling for reducing nonexponential coupling between said first and second conductors.

9. An exponential TEM mode coupler as in claim 8 wherein said coupler includes at least one energy absorbing body positioned within said outer conductor along a sidewall of the outer conductor and a finite distance from one of said first and second conductors to damp spurious TE and TM modes.

10. An exponential TEM mode coupler as in claim 9 including a load terminating said second conductor near the region of loosest coupling, said load being axially aligned with said second conductor at said constant angle with respect to said first conductor.

11. An exponential TEM mode coupler as in claim 10 wherein at least one of said first and second conductors has portions of different cross-sectional area near the region of tightest coupling for maintaining a substantially constant characteristic impedance along at least one of said electromagnetic wave energy transmission paths.

12. An exponential TEM mode coupler as in claim 11 wherein:

said first and second conductors are circular; and

at least one of said first and second conductors has a flattened portion near the region of tightest coupling for maintaining a substantially constant characteristic impedance along at least one of said electromagnetic wave energy transmission paths.

References Cited

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H. K. SAALBACH, *Primary Examiner.*

PAUL L. GENSLER, *Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,390,356 June 25, 1968

Auber G. Ryals et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 25, "$K(x) = K_0e-x/x_0$" should read -- $K(x) = K_0e^{-x/x_0}$ --. Column 2, line 36, "variations" should read -- variation --; line 66, "non-eponential" should read -- non exponential --. Column 4, line 16, "characteristics" should read -- characteristic --.

Signed and sealed this 11th day of November 1969.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents