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TUNABLE MICROWAVE TIME DELAY EQUALIZER

Filed Dec. 29, 1966 2 Sheets-Sheet 1

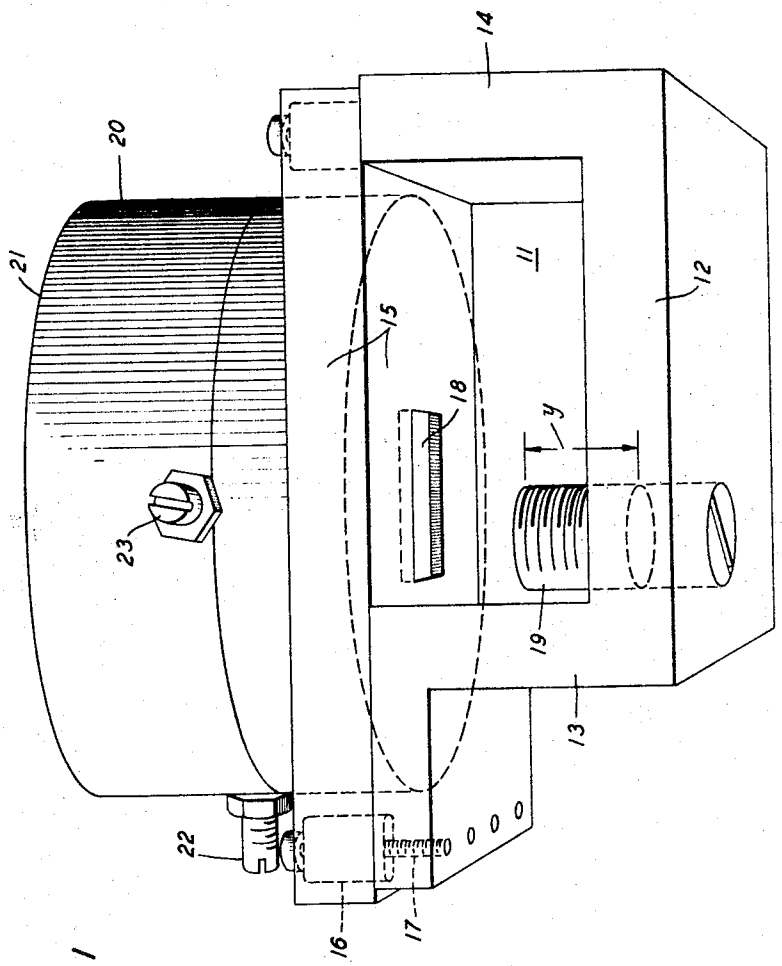


FIG. 1

INVENTORS: T. A. ABELE
H-C WANG

BY Ray M. Porter
ATTORNEY

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FIG. 2

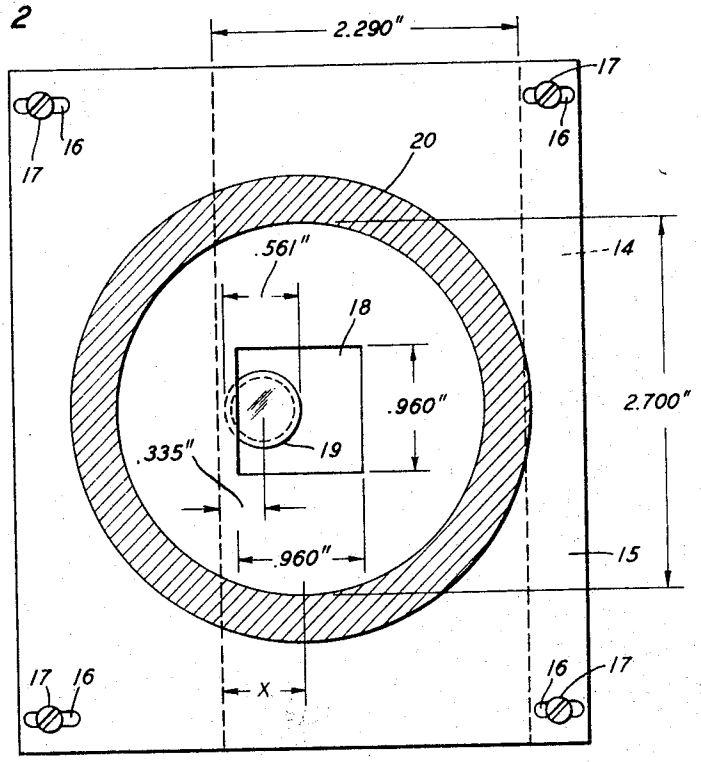
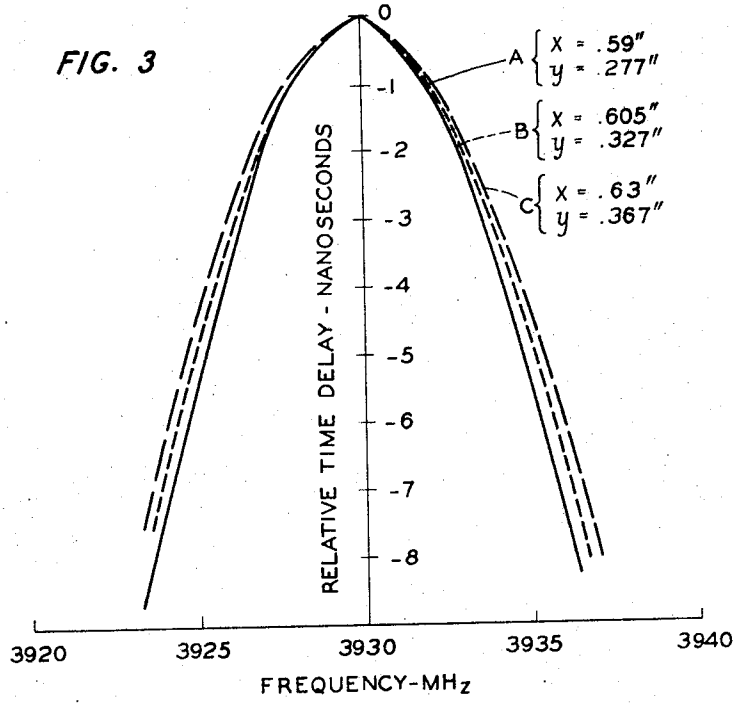


FIG. 3



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3,466,573

TUNABLE MICROWAVE TIME DELAY EQUALIZER

Thomas A. Abele, Andover, and Han-Chiu Wang, Lawrence, Mass., assignors to Bell Telephone Laboratories, Incorporated, Murray Hill and Berkeley Heights, N.J., a corporation of New York

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U.S. Cl. 333—28 6 Claims

ABSTRACT OF THE DISCLOSURE

A time delay equalizer of the type in which a cylindrical cavity simultaneously resonant in two orthogonal modes is coupled to a rectangular waveguide. Specifically, the coupling comprises a relatively large transversely movable aperture in a common wall between the end of the cavity and one wide wall of the guide and a relatively large probe extending an adjustable height in the guide from the other wide wall at a point between the axis of the aperture and a narrow wall. Simultaneous adjustment of the aperture position and the height of the probe varies the shape of the time delay vs. frequency characteristics introduced by the cavity without producing an impedance discontinuity.

Background of the invention

The invention relates to a time delay equalizer for electromagnetic wave networks and more particularly to an equalizer of the type known to the art as the "dual mode cavity resonator."

As previously taught by L. C. Tillotson in Patent 2,795,763, granted June 11, 1957 and more recently by S. B. Cohn in Patent 3,277,403, granted Oct. 4, 1966, a dual mode resonator coupled to a waveguide and connected to a microwave network can equalized typical distortion in the shape of the time delay vs. frequency characteristic of electromagnetic wave energy traveling through the network provided the two modes of the cavity are at the same resonant frequency, are of equal amplitude and in phase quadrature with each other, introduce a transmission coefficient that complements the time delay vs. frequency characteristic of the network, and do not introduce any mismatch.

As simple and as useful as such a component appears to be, it has been found in practice that it is impossible to precisely estimate in advance the time delay vs. frequency characteristic to be equalized and then to specifically design a cavity and its coupling mechanism to this characteristic. In other words some adjustment of each equalizer for each application is essential. This requires a continuous adjustability of the loaded Q of the cavity without introducing losses due to reflections at the aperture. No method suitable for this purpose is known in the art.

Summary of invention

In accordance with the present invention a particular coupling means between a rectangular waveguide and a cylindrical equalizing cavity has been developed having plural adjustable parameters which when made simultaneously in proper senses can shape the time delay vs. frequency characteristic introduced and at the same time maintain reflection losses at a minimum. In particular the coupling means comprises a large aperture that can be moved transversely across the wide dimension of the guide and a large conductive probe of adjustable height located between the axis which extends through the center of the aperture and the narrow wall of the guide. According to a preferred embodiment, the aperture is a square

approximately one-quarter wavelength on a side and the probe is a cylinder approximately one-half of this dimension in diameter. The specific dimension of the aperture can vary from approximately one-eight to three-eighth wavelength depending upon the time delay vs. frequency characteristic to be equalized. Large apertures produce broader characteristics. Contrasting with a probe of this dimension, the small, nonresonant probe used by the prior art to introduce a reactance for impedance matching would not be expected to change the time delay vs. frequency characteristic of a cavity resonator equalizer. In the structure according to the invention the large size and asymmetrical location of the probe has been found to increase the coupling coefficient between the guide and the cavity and in turn to broaden the time delay vs. frequency characteristic when the probe length is increased. Simultaneous transverse movement of the aperture maintains the reflection loss at a minimum.

Brief description of drawing

FIG. 1 is a perspective view of a cavity equalizer in accordance with the invention;

FIG. 2 is a cross-sectional view of FIG. 1 indicating typical dimensions for a given embodiment; and

FIG. 3 shows typical time delay vs. frequency characteristics for several adjustments of the structure of FIG. 1.

Description of illustrative embodiment

Referring more particularly to FIG. 1, an illustrative embodiment of an equalizer in accordance with the invention is shown comprising a short section of conductively bounded rectangular waveguide **11** which can be connected to the conventional flanges of connecting waveguides of the network to be equalized. Guide **11** is formed of a first casting comprising a channel including one wide wall **12** integrally formed with narrow walls **13** and **14** and a separate top wall **15** suitably bolted by screws **17** to walls **13** and **14** through elongated holes **16** so that wall **15** may be moved transversely (perpendicular to narrow walls **13** and **14** and to the longitudinal axis of guide **11**). A square aperture **18** is located in wall **15** in such position that transverse movement of wall **15** carries aperture **18** between one position in which one edge thereof is substantially adjacent to wall **13** and in another in which the opposite edge thereof substantially coincides with the center plane of guide **11**. A large threaded probe **19** extends through a threaded hole in wall **12**. Centered above aperture **18** is a closed cylindrical cavity **20** which as illustrated has a top wall **21** and utilizes a reduced thickness portion of wall **15** of guide **11** as the bottom wall of the cavity. It should be understood, of course, that other physical constructions can be utilized.

The distance between the bottom wall **15** and the top wall **21** of cavity **20** determines its basic resonant frequency and should in general be one-half wavelength, or a multiple thereof, at the center of the band to be equalized. Tuning screws **22** and **23**, respectively aligned with the transverse and longitudinal dimensions of guide **11**, provide fine tuning of the resonant frequency in accordance with well-known cavity tuning principles.

Since the relative sizes of the components described and their locations are important with respect to the invention, dimensions of a typical embodiment are illustrated on the cross-sectional view of FIG. 2. The waveguide channel has the conventional internal dimensions of 1.145" x 2.290" and the embodiment is designed to equalize around a midband frequency of 3930 mHz. (a guide wavelength of 3.98 inches in guide **11**). An embodiment designed to operate at another frequency would be proportionaly scaled. In this connection, several gen-

eralizations can be made in terms of λg, the guide wavelength at a given midband frequency in guide **11**. For the particular time delay vs. frequency characteristics shown in FIG. 3 aperture **18** should be in the order of $\lambda g/4$ on each side and should have an average position x measured from the nearer narrow wall **13** to the center of aperture **18** of $\lambda g/6$ or $\lambda g/7$. Probe **19** should have a diameter in the order of one half the dimension of aperture **18** or $\lambda g/8$ and should be located as close to the nearer narrow wall **13** as is physically practical. The average penetration y of probe **19** is slightly greater than one half its diameter. For wider or narrower time delay vs. frequency characteristics than those shown in FIG. 3 the dimensions of the aperture can be made between $3\lambda g/8$ and $\lambda g/8$ respectively on each side and all other dimensions will have to be varied accordingly.

With these proportions, the structure of FIG. 1 can be used to neutralize the delay distortion introduced, for example, by one or more microwave bandpass filters of the type which typically introduce a time delay vs. frequency distortion that is minimum at the center of the band and increases on either side thereof to the filter cutoff frequency. To equalize such a characteristic the invention introduces a time delay vs. frequency characteristic of adjustable shape that varies in the opposite manner, that is, a characteristic that is maximum at the center of the band and decreases on either side thereof. It is critically important that the cavity does not introduce reflection losses or dissipation losses.

Operation of the invention depends upon the fact that the transverse and longitudinal magnetic field components of the wave propagating in one direction along guide **11** couple respectively to separate cross-polarized modes in cavity **20** through aperture **18**. These modes are in phase quadrature to each other since the transversal and longitudinal magnetic field components in waveguide **11** are in phase quadrature. In addition both modes are of equal amplitude since aperture **18** is located in a region where the magnetic field components in the waveguide **11** are of equal amplitude. Each mode carries energy back into guide **11** and since they are equal in amplitude their relative phases cause them to cancel with each other in guide **11** at every frequency for propagation in the backward direction, that is, for travel toward the input. In the forward direction, they add and introduce a time delay that is a function of frequency. It has been recognized that the precise time delay vs. frequency shape of the transmission coefficient depends upon the coupling coefficient between the modes in cavity **20** and fields within guide **11**. While this coupling coefficient could be varied by varying the size of aperture **18**, the mechanical problems so involved would produce an impractical structure. In accordance with the invention it has been found that increasing the penetration of probe **19**, of the size and in the location described, accompanied by a movement of aperture **18** toward the center of guide **11**, increases the coupling coefficient without unbalancing the two cavity modes. Ordinarily increasing the penetration of a reactive probe merely increases the reactance which it introduces in the waveguide. The unexpected performance observed for the invention can be explained in a qualitative way, which may not be rigorous from a mathematical standpoint, by recognizing that the relatively large size of both aperture **18** and probe **19** produces substantial local perturbation of the magnetic field components in guide **11**. Increasing the penetration of probe **19** appears to increase the field concentration near top wall **15** at the location of aperture **18** in a manner analogous to reducing the height of the guide. However, the longitudinal component of the wave field is increased more than is the transverse component. Therefore simultaneous transverse movement of aperture **18** equalizes the amplitudes of the modes. While applicant does not wish to be bound by the foregoing explanation, the experimental data illustrated in FIG. 3 appears to confirm it. Thus curves A, B, and C respectively, of FIG. 3 are plots of the time delay in nanoseconds vs. frequency in mHz. for three indicated insertions g of screw **19** in a structure otherwise having dimensions shown in FIG. 2. In each case the indicated position x of aperture **18** retains a return loss in excess of 40 db over a band greater than 10 times that of the equalizer band itself. A selection from curves A, B, and C or from a curve of intermediate shape can precisely match the shape of the time delay distortion to be equalized.

While the shape of aperture **18** has been illustrated as square and the cross section of probe **19** as circular, it should be understood that other shapes for each may be employed provided their relative dimensions remain substantially the same as those described. Thus, aperture **18** may be circular and probe **19** square or both components may have the same shape.

In all cases it is to be understood that the above-described arrangements are merely illustrative of a small number of the many possible applications of the principles of the invention. Numerous and varied other arrangements in accordance with these principles may readily be devised by those skilled in the art without departing from the spirit and scope of the invention.

We claim:

1. A time delay equalizer for introducing a shaped time delay vs. frequency characteristic to electromagnetic wave energy of the type in which a length of conductively bounded rectangular waveguide having a pair of wide walls and a pair of narrow walls is coupled to orthogonal modes in a cavity structure characterized in that said guide and said cavity are coupled by an aperture on one wide wall of said guide and a probe extends from the other wide wall in opposition to said aperture at a point between the aperture center and the nearer narrow wall of said guide.

2. The equalizer according to claim **1** wherein said aperture is adjustable in transverse position on the wide wall of said guide and said probe is adjustable in its extent into said guide.

3. The equalizer according to claim **1** wherein said aperture has a minimum cross-sectional dimension of at least one-eighth of the guide wavelength of wave energy in the band to be equalized.

4. The equalizer according to claim **1** wherein said aperture has a minimum cross-sectional dimension of substantially one-quarter of the guide wavelength of wave energy in the band to be equalized.

5. The equalizer according to claim **3** wherein said probe has a minimum cross-sectional dimension at least half said cross-sectional dimension of said aperture.

6. The equalizer according to claim **3** wherein said aperture is square and said probe is a circular cylinder.

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HERMAN KARL SAALBACH, Primary Examiner

T. VEZEAU, Assistant Examiner

U.S. Cl. X.R.

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