

June 11, 1957

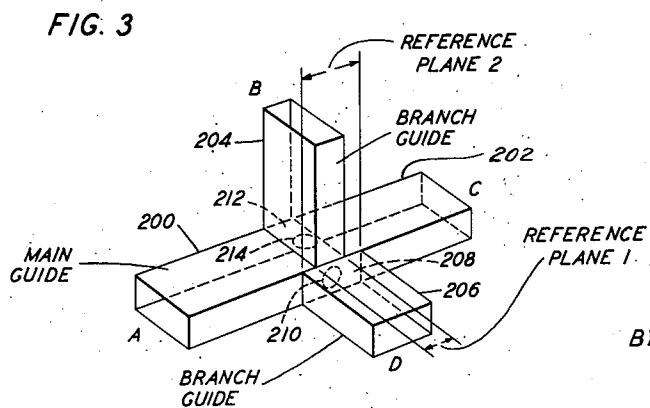
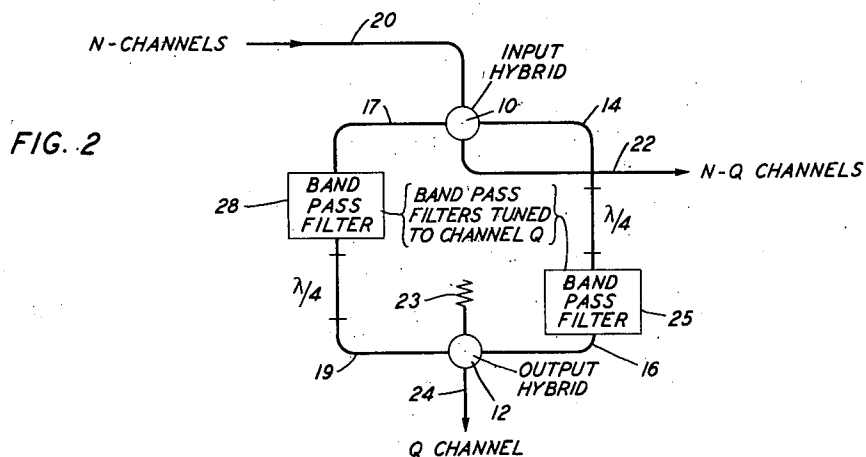
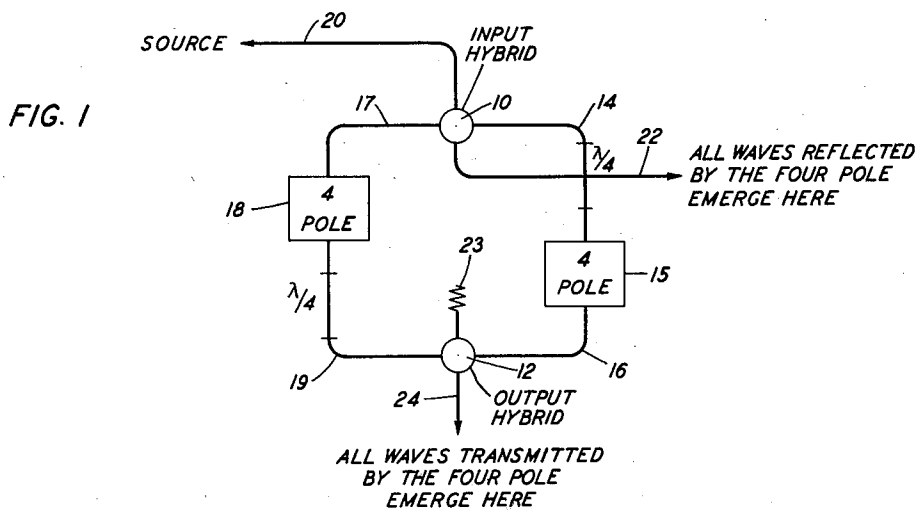
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2,795,763

MICROWAVE FILTERS

Filed May 3, 1951

6 Sheets-Sheet 1



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FIG. 4

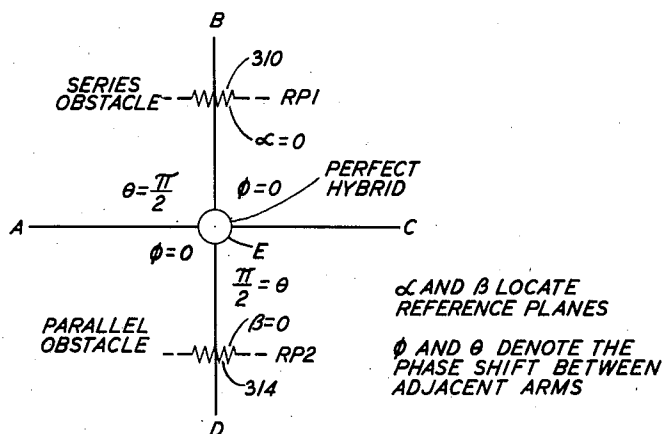


FIG. 5

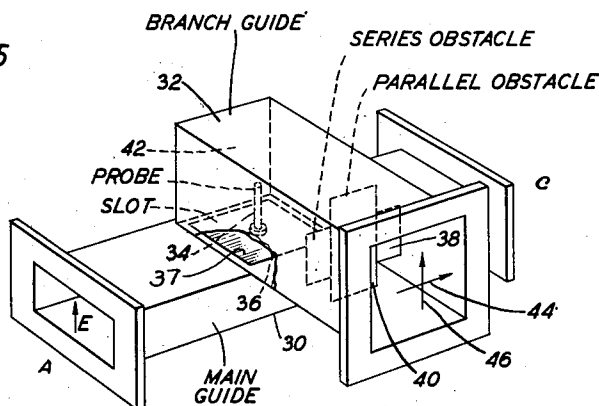
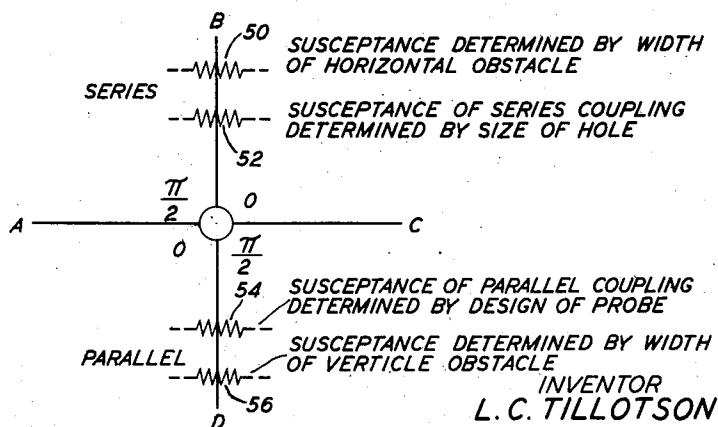


FIG. 6



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FIG. 9

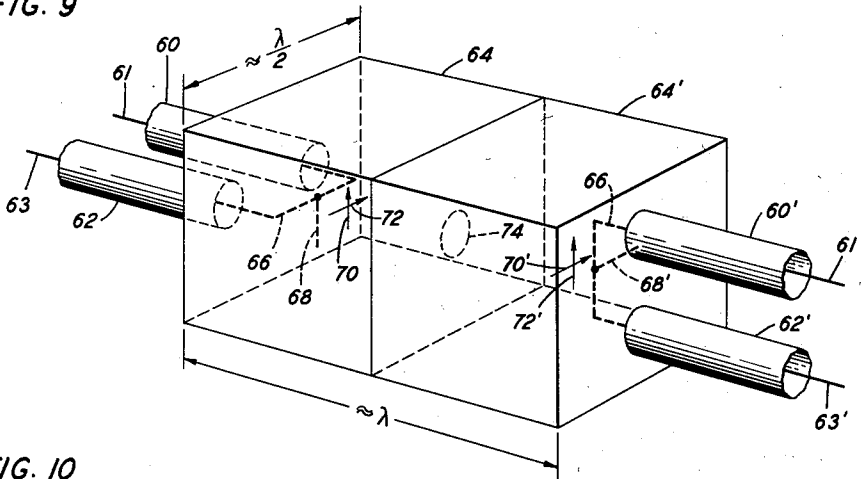


FIG. 10

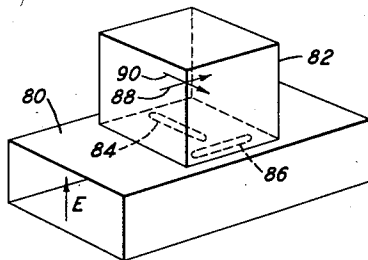


FIG. 10A

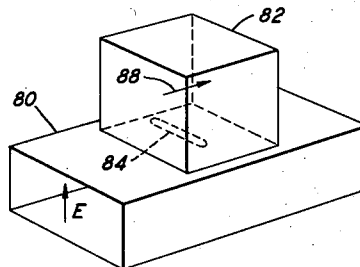
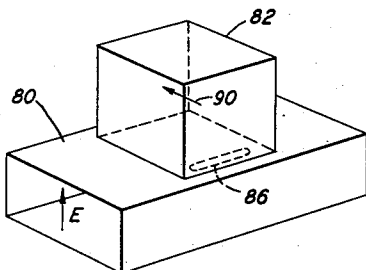


FIG. 10B



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FIG. 11

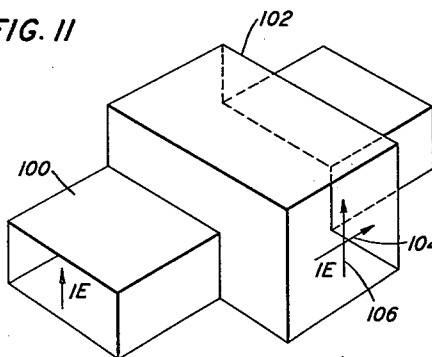


FIG. 12

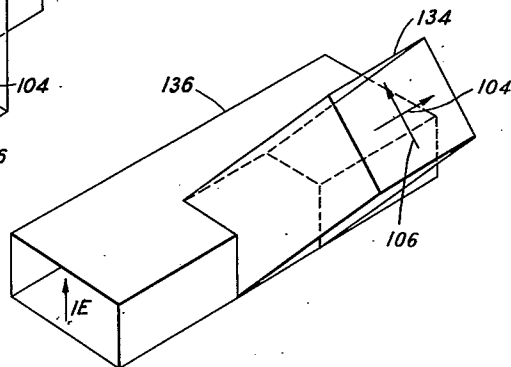
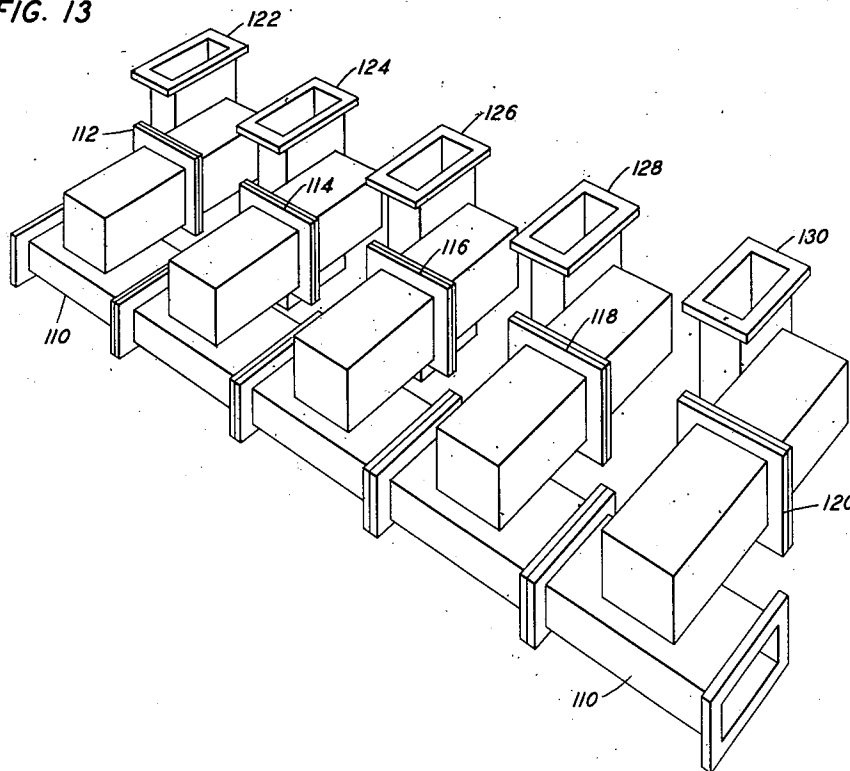


FIG. 13



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FIG. 14B

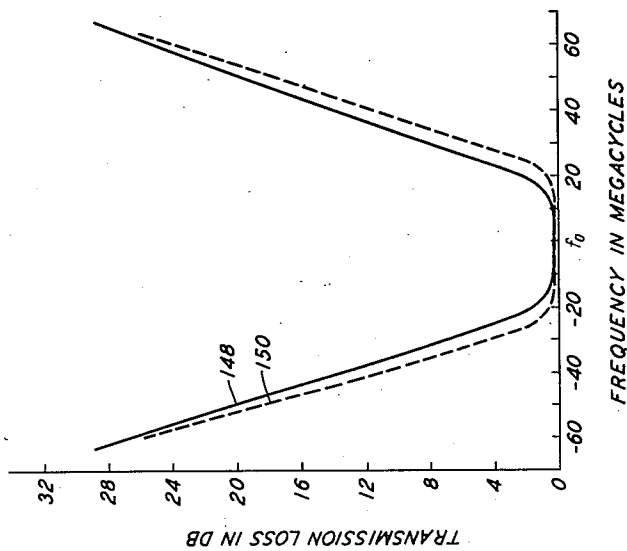
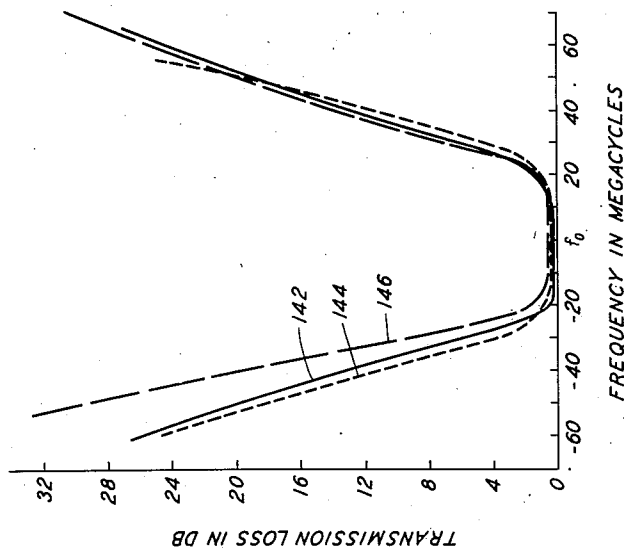


FIG. 14A



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Application May 3, 1951, Serial No. 224,320

8 Claims. (Cl. 333—73)

This invention relates to high frequency, electromagnetic wave, wave filter and related structures employing cavity type resonators in which use is made of two independent modes of wave propagation or states of resonance of one or more of said cavity resonators.

This application is related to my copending application Serial No. 217,968, filed March 28, 1951, which matured into Patent 2,724,806, granted November 22, 1955, in that it involves the use of double mode cavity resonators in ways analogous to the ways in which double mode coaxial line resonators are employed in the structures of said copending application.

A principal object of the invention is to provide new and improved high frequency electromagnetic wave hybrid type junctions and wave filters which employ double mode characteristics of one or more high frequency electromagnetic wave cavity resonators.

Other and further objects will become apparent during the following detailed description of illustrative embodiments of the invention and from the appended claims.

The principles of the invention will be more readily understood in connection with the detailed description given hereinafter of the specific illustrative embodiments, illustrated in the accompanying drawings, in which:

Fig. 1 is an electrical block schematic diagram employed in explaining certain principles underlying various structural arrangements of the invention;

Fig. 2 is an electrical schematic diagram also employed in explaining principles underlying a number of the structures of the invention;

Fig. 3 shows a so-called pseudohybrid junction of a type described in detail in the copending application of W. D. Lewis, Serial No. 120,142, filed October 7, 1949, which matured into Patent 2,649,576 granted August 18, 1953, and is the single mode equivalent of certain structures of the present invention;

Fig. 4 is a diagrammatic representation indicating the electrical properties of the structure of Fig. 3;

Fig. 5 is a structure of the invention illustrating an elementary form of the two mode pseudohybrid junction of the invention;

Fig. 6 is a diagrammatic representation illustrative of the electrical properties of the structure of Fig. 5;

Fig. 7 is a combination of two units of the type shown in Fig. 5 which provides a constant resistance type channel branching filter of the invention;

Fig. 8 shows a combination of a coaxial line and a cavity resonator with means for coupling the coaxial line to two resonant modes of the cavity structure;

Fig. 9 illustrates the use of two structures of the type shown in Fig. 8 coupled through a small orifice, the assembly providing a constant resistance channel branching filter of the invention;

Fig. 10 illustrates the combination of a section of waveguide transmission line coupled by irises to two modes of resonance in a single cavity resonator;

Figs. 10A and 10B are employed in explaining the series and parallel couplings, respectively, of the wave guide of

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Fig. 10 to its associated double mode cavity resonator;

Figs. 11 and 12 illustrate two other ways in which a rectangular wave-guide transmission line having one cross-sectional dimension substantially greater than the other can be separately coupled to both modes of a lateral wave guide of square cross section branching from said first wave guide;

Fig. 13 illustrates an assembly of five structures of the general type shown in Fig. 7 connecting along a main wave-guide transmission line to severally branch therefrom five different frequency channels;

Figs. 14A and 14B show the transmission loss versus frequency characteristics of a particular design of the five branching filter units of Fig. 13.

In more detail, Fig. 1 illustrates in electrical schematic, block diagram, form, a basic constant resistance network which is particularly well adapted for use as a channel branching filter and is of the general type shown and described in United States Patent 2,531,447, granted November 28, 1950, to W. D. Lewis. The structure comprises, as shown in Fig. 1, an input hybrid structure 10, an output hybrid structure 12, a pair of circuits comprising units 14, 15 and 16 and units 17, 18 and 19, respectively, which circuits interconnect two conjugately related arms of hybrid junction 10 to two corresponding arms of hybrid junction 12, respectively, each of said circuits comprising a four pole reactive device, 15 for the right circuit, and 18 for the left circuit, and two sections of transmission line, 14 and 16 for the right circuit, and 17 and 19 for the left circuit, the sections of lines 14 and 19 being one-quarter wavelength longer than the sections of line 16 and 17 and being assembled as shown in Fig. 1.

In operation, structures of the type represented by the diagram of Fig. 1, can, by way of example, have introduced from a source connected to the input transmission line 20, a plurality of communication channels, one of which is to be separated or branched off from the others. As described in the Lewis patent, the four pole units 15 and 18 are identical and, for the example suggested above, reflect the single channel to be branched off. As four pole unit 15 is one-quarter wavelength electrically further away from input hybrid junction 10 than four pole unit 18, the two portions of the reflected energy (within the channel to be branched off) return to hybrid unit 10, 180 degrees out of phase, and, therefore, combine in the output arm 22 of the hybrid junction with the result that the single channel to be branched off appears by itself in output arm 22. The remaining channels pass through the four pole units 15 and 18 to the output hybrid junction 12 and combine output lead 24 of said junction. The fourth terminal of output hybrid junction 12 is terminated in its characteristic impedance by resistive termination 23.

In Fig. 2, a variation of the generic arrangement of Fig. 1, as described above, is shown, the sole difference being that the reflecting four pole structures 15 and 18 of Fig. 1 are replaced by band-pass filters 25 and 28, respectively, and, for the example assumed above, the single channel to be branched off is passed through these band-pass filters to the output hybrid junction 12 and emerges on output terminal 24 of hybrid junction 12, whereas all other channels are reflected by the band-pass filters 25 and 28 and emerge from the output terminal 22 of the input hybrid junction 10. This specific form of structure is disclosed and claimed in United States Patent 2,531,419, granted November 28, 1950, to A. G. Fox. The corresponding structural features of the arrangements of Figs. 1 and 2 have been assigned corresponding identification numerals as shown in these figures.

In Fig. 3, a four branch wave-guide hybrid junction is shown, the four branches being designated A, B, C and D, respectively. In Fig. 3 all four arms 200, 202, 204

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and 206 comprise sections of wave guide of like rectangular cross-sectional dimensions, which, by way of example, for frequencies in the neighborhood of 4000 megacycles can be sections of wave guide having a shorter side cross-sectional dimension of one inch and a longer side cross-sectional dimension of 2 inches (inner dimension of a right cross section). The arrangement of Fig. 3 differs from the well-known prior art electromagnetic wave four branch wave guide "magic T" in that, at reference planes 1 and 2, arms 204 and 206 are partly closed by septa or partitions which can be plain conducting sheet members 212 and 208, respectively. Members 212 and 208 are provided with openings or irises 214 and 210, respectively, and are otherwise merely coplanar extensions of the top and side walls, respectively, of the straight section of wave guide comprising the throat or junction portion of the hybrid junction and the two arms 200 and 202.

Fig. 4 represents diagrammatically the wave-guide structure of Fig. 3 for the frequency region over which the wave-guide structure can be said to be a reasonably accurate approximation of an ideal (or perfect) four branch hybrid junction. An ideal or perfect junction is defined in the above-mentioned copending application of W. D. Lewis. Impedances 310 and 314 represent the impedances of the irises 210 and 214 of Fig. 3, respectively. As for Fig. 3, the four arms of Fig. 4 are designated A, B, C and D and the "perfect hybrid junction" is represented by the circle designated E. For a more detailed description of the hybrid junction illustrated by Figs. 3 and 4, reference may be had to the description in the above-mentioned copending application of W. D. Lewis, particularly with respect to Figs. 1, 2 and 3 of the Lewis application.

In Fig. 5, a hybrid junction, mechanically very different but electrically equivalent to that shown in Figs. 3 and 4 and described above, is illustrated. In Fig. 5, a main wave-guide transmission line 30 having a rectangular cross-sectional area, of which one dimension is substantially greater than the other, is coupled to a branch wave-guide transmission line the right cross-sectional area of which is square. Furthermore, the coupling between the two above-mentioned wave guides is duplex in that both modes of transmission, indicated by arrows 44 and 46 of Fig. 5, in the branch guide 32 are coupled, severally and independently to the main guide 30, one coupling being effected by means of probe 34 and the other coupling being effected by means of slot 36. Probe 34 can be mounted on a thin sheet 37 of low-loss dielectric material such as polystyrene, the dielectric sheet then being assembled in and cemented to the edges of slot 36. Alternatively, probe 34 may be supported from one or more of the walls of branch guide 32 by one or more suitably low-loss dielectric supporting members. The lower end of probe 34 is preferably in the plane of slot 36 and need not protrude into the main guide 30. Anyone versed in the art can obviously design numerous forms of suitable mechanical supports for probe 34 having negligible electrical loss. The coupling afforded by probe 34 is in effect a parallel coupling with the two ends A and C of the main guide 30, whereas the coupling afforded by the slot 36 is in effect a series connection between the branch guide 32 and the two ends A and C of the main guide 30. A reduction in the effective coupling at the right end of the square branch guide 32 equivalent to that effected by irises 210 and 214 of the structure of Fig. 3, is brought about by positioning the obstacles 38 and 40 in the wave guide, as shown, for the series coupling and the parallel coupling, respectively. It is, therefore, apparent that the structure of Fig. 5 can be considered to be electrically equivalent to that of Fig. 3 where the two orthogonal modes represented by arrows 46 and 44 of Fig. 5 are considered the equivalents of the connections afforded by arms B and D of the structure of Fig. 3, respectively.

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There is a further distinction, however, between the two structures, which is illustrated diagrammatically in Fig. 6, in that in each of the arms B and D two susceptances are present, one resulting from the obstacles 38 and 40 of Fig. 5 designated 50 and 56, respectively, in Fig. 6 and the other resulting from the coupling means, i. e., the probe 34 and the slot 36, designated in Fig. 6 by 52 and 54, respectively.

In Fig. 7, a combination of two of the structures shown in Fig. 5 is shown, one of the structures being turned at an angle of 90 degrees with respect to the other so that each mode will encounter the same path length between the main guide and the branch guide. Corresponding portions of the second structure are given the same designation numbers as for the first structure with a prime mark added. The branch wave guide 30' can, of course, be terminated at one end in its characteristic impedance, or simply closed as shown. The structure of Fig. 7 represents a constant resistance branching filter of the general type illustrated by the diagram of Fig. 2. The band-pass filters indicated in Fig. 2 are provided in the structure of Fig. 7 by the resonances of the two modes of the cavities in the square wave guide which is connected between the main wave guide and the branch wave guide 30', as shown in Fig. 7.

In Fig. 8, a main transmission line of coaxial form comprising conductors 60, 61, 62 and 63 is coupled to a first mode of a resonant cavity 64 by a loop 66 joining the inner conductors 61 and 63 of the two sections of the main coaxial line and extending into the cavity 64. The coaxial line connects to a second mode in cavity 64 by probe 68 which is connected to the mid-point of loop 66 and is wholly within the cavity 64. The two modes of resonance within cavity 64 are indicated by the arrows 70 and 72, the coupling loop 66 connecting to one and the coupling probe 68 connecting to the other, respectively.

The over-all structure of Fig. 8 is, therefore, the equivalent of a pseudohybrid junction, two conjugately related arms of which have been terminated by resonant cavities providing resonances corresponding to the two modes of resonance, respectively, of cavity 64 to which the loop 66 and probe 68 are respectively coupled. The degree of coupling is, of course, dependent upon the dimensions of the loop 66 and the length of the probe 68 respectively. The other two arms of the hybrid junction are supplied, of course, by the two portions of coaxial line 60, 61 and 62, 63, respectively.

In Fig. 9, a constant resistance branching filter employing in essence two structures of the type shown in Fig. 8 is illustrated. Corresponding portions between the left structure of Fig. 9 and the structure of Fig. 8 bear corresponding designation numerals and the similar portions of the right structure of Fig. 9 bear corresponding numerals with a prime mark added. Coupling between the two cavities 64 and 64' is afforded by iris 74 which is so situated as to constitute a symmetrical obstacle for both modes of propagation. The over-all structure of Fig. 9 is, like that of Fig. 7, another electrically equivalent form of the general type illustrated by the diagram of Fig. 2, the filters indicated in Fig. 4 being supplied by the resonances of the cavities 64 and 64'. The coupling loop 66' and the coupling probe 68' are turned 90 degrees with respect to loop 66 and probe 68 to afford equal length electrical paths for the two modes from left to right in Fig. 9.

In Figs. 10, 10A and 10B, a slightly different form of structure of the invention is illustrated in which coupling is effected between a main wave-guide transmission line 80 having one cross-sectional dimension substantially greater than the other and a cavity 82 having two modes of resonance indicated by the arrows 88 and 90 to which coupling is afforded by the elongated irises 84 and 86, respectively, the Figs. 10A and 10B separately illustrating the series coupling and the parallel coupling, respectively. Dimensions of the irises 84 and 86 determine,

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of course, the relative strengths of the couplings to the two modes, respectively. The structure illustrated by Figs. 10, 10A and 10B is obviously another form of pseudohybrid junction filter or equalizer having two orthogonally related arms terminated by resonant cavities the two ends of the main wave-guide transmission line 80 constituting the other pair of conjugately related arms.

In Fig. 11 a further alternative method of coupling the two modes of a branch wave guide 102 having a square cross-sectional area to a main wave-guide transmission line 100, one cross-sectional dimension of which substantially exceeds the other. As shown in Fig. 11, the method comprises omitting a section in the near side and top of wave guide 100 and notching the end of wave guide 102 to fit over the portions of wave guide 100 which have been omitted, as is clearly illustrated in Fig. 11. The strength of the couplings to the two modes can, of course, be adjusted by adjustment of the size of portion omitted from the side or the top of wave guide 100, respectively.

In Fig. 12 a still further method of coupling both modes of a branch wave guide 104 of square cross-sectional area to a main wave-guide transmission line 106, one cross-sectional dimension of which substantially exceeds the other. In Fig. 12 the square wave guide 104 intersects the main wave guide 106 at an angle, as shown, and a portion of the side of wave guide 106 is removed to afford coupling to one mode and a portion of the top of wave guide 106 is removed to afford coupling to the other mode of wave guide 104.

In Fig. 13, by way of example, an assembly which was actually constructed and successfully operated is shown. It comprises a main wave-guide transmission line 110 to which are connected five constant resistance channel branching filters of the general type illustrated in Fig. 7, namely, 112, 114, 116, 118 and 120, at regular intervals along the main wave guide 110. The five filters each pass one of five adjacent bands of frequency and their transmission loss versus frequency characteristics are illustrated in Figs. 14A and 14B by curves 142, 144, 146, 148 and 150, respectively. Thus, if a broad band of frequencies, including energy within one or more of the five channels passed by these filters, is introduced into one end of wave-guide transmission line 110, the energy within any one of the five channels will be found to appear at a predetermined one of the branch guide outputs 122, 124, 126, 128 or 130, respectively, of the five filters.

In Figs. 14A and 14B, as mentioned above, the transmission loss versus frequency characteristics of the five filters of Fig. 13 are shown. Frequency is indicated in terms of the mid-band frequency f_0 of each channel. Deviations of the frequency from mid-band toward higher frequencies are indicated in megacycles by the positive numbers 10, 20, etc., while frequencies lower than the respective mid-band frequencies are indicated in megacycles by the negative numbers -10, -20, etc.

In a set of five filters of the type shown in Fig. 13, mid-band frequencies of 3730 megacycles, 3810, 3890, 3970, 4050 and 4130, respectively, were employed and the transmission characteristics indicated in Figs. 14A and 14B were obtained for the five channels respectively.

Numerous and varied applications of the principles of the invention will readily occur to those skilled in the art. The above-described structures are merely illustrative of representative applications.

What is claimed is:

1. In combination a first section of high frequency, electromagnetic wave, wave guide having a rectangular right cross-sectional area, one cross-sectional dimension being substantially twice the other cross-sectional dimension, a second section of high frequency, electromagnetic wave, wave guide, having a square right cross-sectional area, a probe coupling means coupling one dominant mode of propagation in said second section of guide to said first section, an iris coupling means coupling the second dominant mode of propagation in said second sec-

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tion of guide to said first section, said second mode being orthogonally related to said first mode, one end of said second section of guide being closed on one side of said coupling means, said second section of guide having assembled therein at a point opposite said closed end of said section from said coupling means, a pair of orthogonally related obstacles providing predetermined susceptances to said two orthogonally related modes of propagation, respectively.

2. Two structural combinations as defined in claim 1, the open end of the second section of wave guide of one combination being connected to the open end of the second section of wave guide of the other combination, one of said combinations being turned through an angle of ninety degrees with respect to the other.

3. In combination first and second sections of high frequency, electromagnetic wave, shielded type transmission line, a third section of high frequency, electromagnetic wave, shielded type transmission line said third section of transmission line comprising a section of wave guide of substantially square cross-section adapted for transmitting independently only two dominant, orthogonally related, modes of electromagnetic wave energy, means at one end of said third section of line for severally, simultaneously and independently coupling each of said two dominant modes to a common point of said first section of transmission line and like means at the other end of said third section of line for likewise coupling each of said two dominant modes to a common point of said second section of transmission line, said last-stated coupling means being turned through an angle of ninety degrees with respect to the corresponding coupling means to said first section of transmission line, said third section of transmission line including, intermediate its ends, conductive structure providing predetermined susceptances to each of said two orthogonally related dominant modes of propagation, respectively.

4. The structural arrangement of claim 3 in which each said dominant mode of transmission through said third section of line includes at least one resonance at a particular predetermined frequency whereby the over-all structure constitutes a constant resistance, channel branching filter for branching a particular one of a plurality of frequency band channels introduced into said first section of transmission line to said second section of transmission line without disturbing the transmission of the remainder of said frequency band channels along said first section of transmission line.

5. The structural arrangement of claim 3 in which said first, second and third sections of transmission line are wave-guide transmission lines.

6. The structural arrangement of claim 3 in which said first and second sections of transmission lines are coaxial transmission lines.

7. The structural arrangement defined in claim 6 in which the third section of transmission line includes a plurality of resonances for each said dominant mode of propagation.

8. In combination first and second sections of high frequency, electromagnetic wave, coaxial transmission line and a third section of high frequency, electromagnetic wave, waveguide of square cross section, both ends of said third section of line being substantially closed, the first section of coaxial line being coupled to one end of said third, or waveguide, section by a looped portion of the inner conductor of said first section of coaxial line extending into said waveguide section in a plane parallel to two sides of the waveguide and a straight probe member attached to the center point of said looped portion and normal to the plane of the loop, the second section of coaxial line being coupled in the same manner to the other end of said waveguide section but with the loop and probe turned through an angle of ninety degrees with respect to the loop and probe, respectively, of said first section, said waveguide section including, interme-

diate its ends, conductive structure providing predetermined susceptances to each of the two orthogonally related dominant modes of transmission through said waveguide section.

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