

Nov. 11, 1952

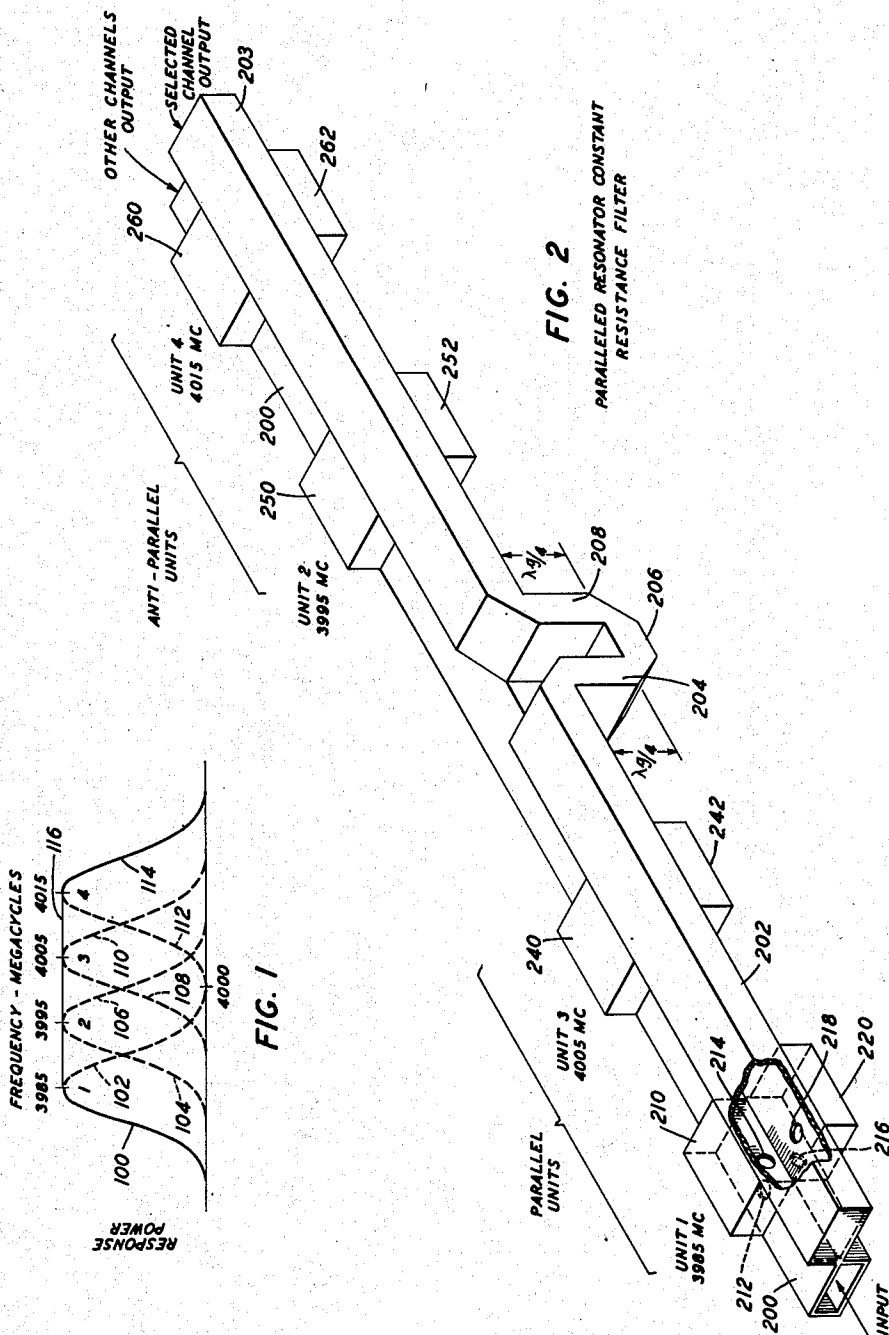
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2,617,881

PSEUDOHYBRID MICROWAVE FILTER

Filed Oct. 7, 1949

2 SHEETS—SHEET 1



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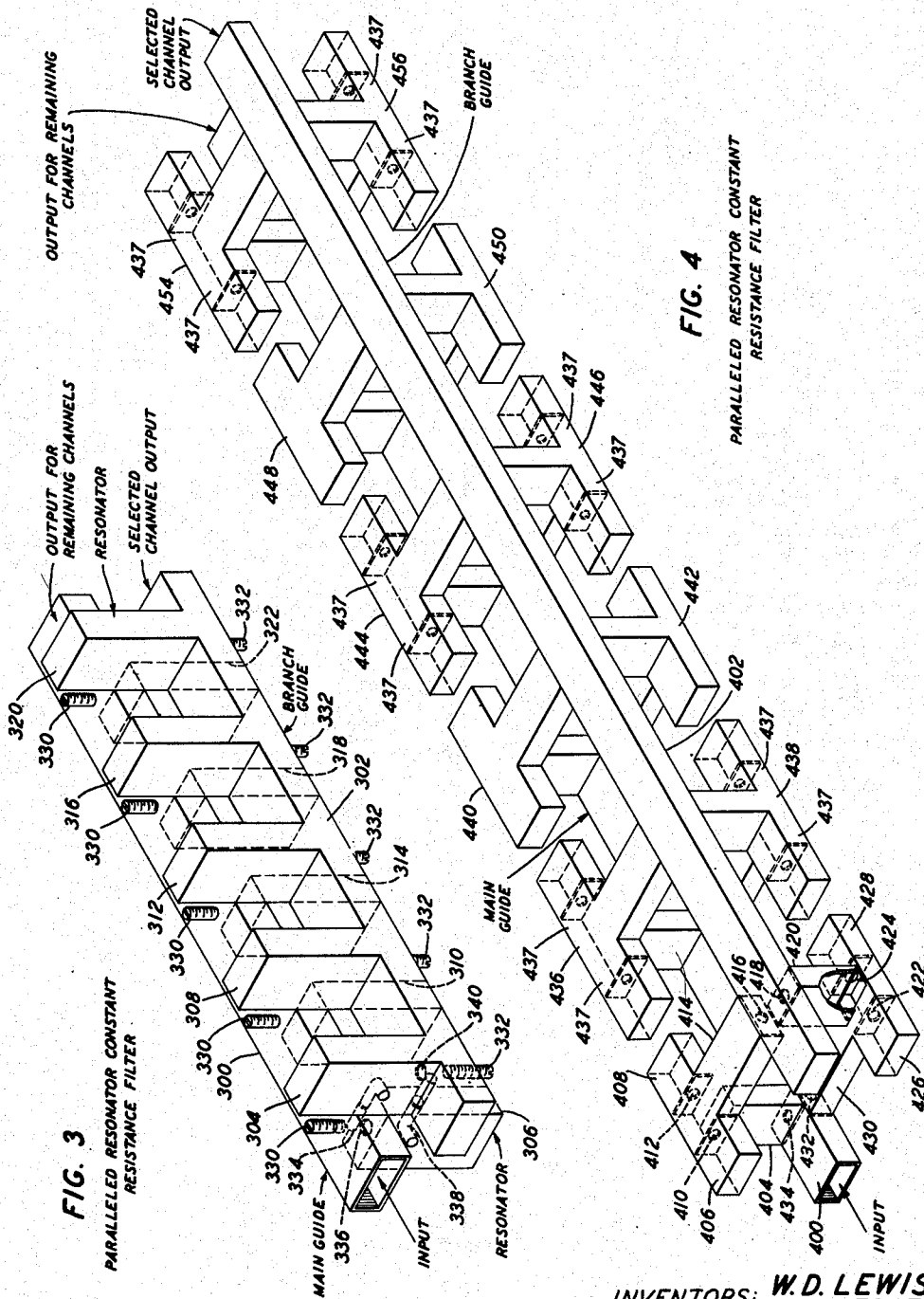
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2 SHEETS—SHEET 2



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PSEUDOHYBRID MICROWAVE FILTER

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12 Claims. (Cl. 178-44)

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This invention relates to improved microwave, wave filter structures. More particularly, it relates to microwave filters of the type in which frequency selective transmission between two microwave transmission lines is effected by the combined action of a plurality of pairs of resonant structures interconnecting the transmission lines, at a like plurality of points spaced along the transmission lines, each pair of structures being coupled to each wave guide in a particular manner whereby each pair, together with the particular coupling arrangements, constitute a "constant resistance filter," and the entire structure is therefore also of the constant resistance type.

For the purposes of this application the term "microwave" is to be understood to include frequencies from approximately 100 megacycles and higher.

The devices of the invention comprise various and sundry combinations of principles and of features of structures disclosed in applicant Lewis' copending application Serial No. 120,142, filed October 7, 1949, and those disclosed in applicant Pierce's copending application Serial No. 25,027, filed May 4, 1948.

In other words, the present joint application is concerned with structures which comprise pluralities of constant resistance pseudohybrid structures of types disclosed in the above-mentioned sole application of Lewis combined in accordance with principles disclosed and explained in the above-mentioned sole applications of Lewis and Pierce, whereby unitary structures which have novel characteristics of a most useful nature are readily realized.

An object of the invention is therefore to provide novel forms of constant resistance microwave transducers. (The term transducer is to be understood to include wave filters and equalizers.)

A further object of the invention is to provide microwave transducers which combine the advantages of the paralleled resonator structures of the above-mentioned sole application of applicant Pierce with the pseudohybrid structures of the above-mentioned sole application of applicant Lewis.

A still further object of the invention is to provide microwave transducers which combine the advantages of the paralleled resonator structures of the above-mentioned sole application of applicant Pierce with the pseudohybrid constant resistance structures of the above-mentioned sole application of applicant Lewis.

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Other and additional objects will become apparent during the course of the following description of specific illustrative structures of the invention and from the appended claims.

The nature and principles of the invention will be more readily understood from the following detailed description of the several specific structures of the invention shown in the accompanying drawings in which:

Fig. 1 illustrates one way of providing a broad band transmission characteristic by the addition of the transmission characteristics of a plurality of relatively more narrow bandpass structures;

Fig. 2 shows a structure of the invention in which a plurality of one form of constant resistance pseudohybrid filters are arranged to constitute a constant resistance "paralleled resonator type" of filter structure;

Fig. 3 is similar to Fig. 2 except that a plurality of a second form of pseudohybrid filters are employed; and

Fig. 4 is also similar to Fig. 2 except that a plurality of pairs of constant resistance pseudohybrid filters are employed.

In more detail, in Fig. 1, four relatively narrow pass-bands centered about 3985, 3995, 4005 and 4015 megacycles, respectively, are superimposed and combined to provide a wide pass-band extending from 3985 to 4015 megacycles, inclusive. The four narrow pass-bands are those defined by the curved lines 100, 102; 104, 106; 108, 110; and 112, 114, respectively. The broad pass-band, formed by the joint contributions of all four narrow bands, is that defined by the solid line 116 and the lowermost and uppermost narrow band edges 100 and 114, respectively. The four narrow pass-bands can, by way of example, be those of units 1 to 4, inclusive, respectively, of Fig. 2, described in detail, immediately below.

In Fig. 2 a main wave guide 200 is, by way of example, a microwave transmission line carrying a plurality of frequency bands each of which bands constitutes a communication channel such as a television program channel.

It is desired to branch off one of these frequency bands, for example, the band extending between 3985 to 4015 megacycles, inclusive, and to direct the branched channel into a branch wave guide 202, 210; the other channels continuing undisturbed along wave guide 200. For this purpose four narrow band constant resistance pseudohybrid band-pass filter units, designated in Fig. 2 as units 1, 2, 3 and 4, respectively, and having narrow pass-bands as illus-

trated in Fig. 1, for example, centered about mid-band frequencies 3985; 3995; 4005 and 4015 megacycles, respectively, are connected between the main guide 200 and the branch guide 202, 203 in parallel relation as shown in Fig. 2.

Each of these unit narrow band pseudohybrid band-pass wave filters can be of the type illustrated in Fig. 16 of applicant W. D. Lewis' above-mentioned copending application and described in detail in that application. As shown for unit 1 in Fig. 2 of the accompanying drawings, each unit can comprise two resonators, or resonant cavities, 210, 220 electrically coupled loosely by apertures or irises 212, 216 and 214, 218 to wave guides 200 and 202, respectively. In more detail, cavity 210 is coupled to the wider side of guide 200 by iris 212 and to the more narrow side of guide 202 by iris 214, whereas cavity 220 is connected to the more narrow side of guide 200 by iris 216 and to the wider side of guide 202 by iris 218. The irises 212, 214, 216 and 218 are displaced to one side of the lateral center line of their respective cavities 210 and 220, as shown, to avoid an unwanted balance which might be unwittingly achieved and would prevent the passage of energy through the cavity. The optimum displacement is that which places the irises one-quarter wavelength further from one side wall than the other, though any displacement will preclude the establishment of a perfect balance. The side walls in this instance are to be regarded as those adjoining the smaller ends of the wall in which the particular iris is situated.

Units 2, 3 and 4 of Fig. 2 are substantially identical to unit 1 except that their respective cavities 250, 252; 240, 242; and 260, 262, are tuned to resonance near the mid-frequencies 3995, 4005 and 4015 megacycles, respectively, of their pass-bands, while those of unit 1 are tuned to resonance near the mid-frequency 3985 megacycles of its pass-band assuming, for example, that units 1 to 4 of Fig. 2 have the four pass-bands as shown from left to right in Fig. 1, respectively.

The branch guide 202, 203 has inserted near its center point an additional half wavelength comprising the two vertical quarter wavelength legs 204 and 208. The lower ends of these are joined by the horizontal portion 206. This arrangement provides a phase shift of substantially 180 degrees between the components of energy reaching the branch guide through units 1 and 3 and the components reaching the branch guide through units 2 and 4. This is desirable since, as is well known to those skilled in the art, there is an inherent phase shift of 180 degrees between the lower and higher ends of a frequency band when transmitted through a band-pass filter. By adding 180 degrees to the filters of alternate pass bands in an arrangement as described in connection with Fig. 2 (the transmission characteristics of which are illustrated in Fig. 1) the frequencies of the upper ends of the pass-bands of units 1 and 3, for example, are brought into phase with the frequencies at the lower ends of the pass-bands of units 2 and 4, respectively. If this is not done the uniformity of transmission throughout the entire composite band, i. e. from 3985 to 4015 megacycles of Fig. 1, for example, will be destroyed over small frequency intervals about the points where adjacent bands cross over or intersect each other, i. e., about the points at which curves 102 and 104; 106 and 108; and 110 and 112, intersect. In some instances these disturbances (narrow attenuation intervals) at

cross-over points may not be objectionable, particularly if no essential signal elements are present in these narrow frequency intervals, in which instances it is not necessary to provide for the additional 180-degree phase shift of alternate channels. The equivalent of the above-described phase shift can, alternatively, be introduced by an appropriate selection of coupling means between the cavities and the branch guide as is disclosed and described in detail in connection with several specific coupling arrangements shown in the drawings accompanying applicant Pierce's above-mentioned copending application. (See also the coupling arrangement employed in Fig. 3 described below.)

Assuming that all channels of the system are introduced into the left end of guide 200, the selected or branched channel will appear at the right end 203 of guide 202 and the other channels will be transmitted to the right end of the main guide 200. The left end of guide 202 is preferably terminated in its characteristic impedance at a distance of an odd number of quarter wavelengths of the median frequency of the band of frequencies to be branched off to guide 202, from the coupling point of the nearest unit (unit 1). As is well known to those skilled in the art, the characteristic impedance of a wave-guide transmission line is substantially a pure resistance and a wave guide can therefore readily be terminated in its characteristic impedance by inserting at the end thereof a suitable amount of resistance material such as carbon particles or dielectric members coated with colloidal carbon. If the system is perfectly balanced, or if minor impedance irregularities are not objectionable, it can simply be short-circuited at one-quarter wavelength, or an odd number of quarter wavelengths, from the coupling point of the nearest unit (unit 1).

Since units 1 to 4, inclusive, are each constant resistance structures, per se, the spacing between coupling points of successive units can be chosen purely from the standpoint of mechanical convenience in constructing and assembling the complete structure. Should problems of interaction and impedance irregularities be encountered (they should be very small and for most purposes entirely negligible in a carefully designed and constructed over-all assembly) they can be further minimized by spacing the units along the guides 200 and 202 so that the coupling points of successive units along each guide are spaced an odd number of quarter wavelengths apart (of the median frequency of the band of frequencies to be transmitted to guide 202). Alternatively, any of the several other different intervals and spacings shown and described in the applicant Pierce's above-mentioned copending application can be employed.

In Fig. 3 an alternative form of structure of the invention is shown which differs from that of Fig. 2 principally in that a plurality of constant resistance pseudohybrid microwave wave filters of the type shown in Fig. 17 of applicant Lewis' above-mentioned copending application is employed to couple the main and branch wave guides 300 and 303, respectively.

In more detail, each of these pseudohybrid filters (five are shown by way of example) comprises two resonators which for the extreme left unit are designated 304 and 306. Each of these resonators is coupled to both wave guides, resonator 304 being coupled to main guide 300 by member 334 which constitutes a coupling loop

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to the cavity and its free end is a probe into guide 300. The degree of coupling of guide 300 to the probe is determined by the extent to which screw 330 is caused to protrude into guide 300, since the probe is perpendicular to the electric vector of the wave energy in guide 300 and would not be coupled to the wave except for the distortion of the wave caused by protrusion of screw 330 into it. Cavity 304 is also coupled to guide 302 through an orifice 340 in the upper (broader) surface of the guide. Similarly, cavity 306 is coupled by element 338 and adjusting screw 332 to guide 302 and by orifice 336 to the lower (broader) side of guide 300.

Successive units along the guide from left to right comprise the pairs of resonators 308, 310; 312, 314; 316, 318; and 320, 322, respectively, and are coupled to the guides 300 and 302 as described above for the first unit at the extreme left. To provide a smooth over-all composite pass-band, as described in detail in connection with Fig. 2, in several of the units (for example in the second and fourth units) the loop portion of the probe can be turned through 180 degrees to provide the contrary coupling for them which was provided in Fig. 1 by insertion of the 180-degree loop of Fig. 1 comprising portions of wave guide 204, 206, 208.

Each unit passes a relatively narrow band of frequencies, the five units in conjunction passing a sufficiently broad band of frequencies to constitute a communication frequency channel suitable, for example, for a television channel.

Assuming that several broad band channels of a complex system are introduced into the left end of main guide 300, one will pass through the five units and appear at the right end of guide 302, the others passing freely to the right end of main guide 300. The left end of guide 302 is preferably terminated in its characteristic impedance as described for guide 202 of Fig. 2. Alternative arrangements of the termination and center to center spacings of the coupling points for successive coupling units along the wave guides can also be as described for the over-all structure of Fig. 2.

In Fig. 4 a third alternative structure of the invention is shown which differs from those of Figs. 2 and 3 mainly in that a plurality of pseudohybrid microwave wave filters of the type shown in Fig. 19 of applicant Lewis' above-mentioned copending application are used to couple the main guide 400 and the branch guide 402. The left end of guide 402 is preferably terminated in its characteristic impedance or it may be terminated in any of the alternative ways described above in connection with Fig. 2.

Each of the six pairs of connecting structures joining guides 400 and 402 can comprise a pair of pseudohybrid band-pass filters substantially as shown in detail for the pair at the left end of the figure. Of this pair the upper pseudohybrid band-pass filter comprises vertical arm 404, horizontal arm 414 and two lateral arms comprising resonant cavities 406, 408 coupled by irises 410, 412, respectively, to the throat section of the pseudohybrid junction as disclosed and described in detail in applicant Lewis' above-mentioned copending application.

Similarly, the lower pseudohybrid band-pass filter comprises vertical arm 420, horizontal arm 430 and resonant cavity, lateral arms 426, 428 coupled by irises 422, 424, respectively, to the throat section of the pseudohybrid junction. The two pseudohybrid band-pass filters just described

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connect through irises 432 and 434 to guide 400 and through irises 416 and 418 to guide 402 forming two pseudohybrid junctions as shown and described in applicant Lewis' above-mentioned copending application. The other pairs of connecting structures, namely, 436, 438; 440, 442; 444, 446; 448, 450; and 454, 456 are of the same kind as the extreme left pair described in detail above but are designed to pass five other narrow frequency bands, the six bands taken together providing for branching off to guide 402 a channel of frequencies of suitable width for some specific use such as a television channel. Center-to-center intervals between the coupling points of successive filter pairs and the left end of guide 402 to nearest pair coupling point spacing, can be the same as for the structures of Figs. 2 and 3 as described above. In this instance the additional 180-degree phase shift for alternate pairs of coupling filters can be obtained by inserting a one-quarter wavelength of wave guide between the iris and the throat section of the pseudohybrid junction of the two filters of the pair as indicated for filters 436, 438; 444, 446 and 454, 456. Specifically in these cases a one-quarter wavelength of wave guide 437 is added between each lateral cavity and the throat section of its associated filter, as shown in Fig. 4. Alternatively, the three units just described can be grouped at the right, the extra quarter wavelengths of wave guide 437 can be omitted, and an extra half wave loop can be added in either guide 400 or guide 402 (preferably 402 since it carries only energy of the channel to be branched off) between the groups precisely as was done in Fig. 2. A further alternative is, of course, to employ appropriate coupling means such as the loop and probe coupling of Fig. 3 and reverse the phase of the coupling of those units for which a 180-degree phase shift is desired.

Numerous and varied additional arrangements in accordance with the principles and within the scope of the invention can, obviously, readily be devised by those skilled in the art. The above-described embodiments are merely illustrative. By way of example, coaxial structure can be substituted for part or all of the wave-guide structure of the above embodiments without departing from the spirit and scope of the invention.

What is claimed is:

1. A microwave electromagnetic wave transducer comprising a plurality of pairs of electromagnetic wave resonating structures interconnected between two electromagnetic wave wave guides, one resonating structure of each pair being loosely coupled in parallel relation with a first of said wave guides and loosely coupled in series relation with the second of said wave guides, the other resonating structure of said pair being loosely coupled in series relation with the first wave guide and loosely coupled in parallel relation with the second wave guide, the two coupling points of each pair to each wave guide being centered in a common plane perpendicular to the longitudinal axis of the wave guide.

2. The transducer of claim 1, the two resonating structures of each pair comprising resonant cavities having the same resonance frequency, said resonance frequency being different from that of any of the other pairs of cavities of the said plurality of pairs.

3. The transducer of claim 1, the two resonating structures of each pair comprising substantially identical electromagnetic wave pseudohybrid microwave wave guide band-pass wave filters,

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the bands, passed, by the wave filters of successive pairs being displaced in frequency with respect to each other.

4. The transducer of claim 1, the couplings between the resonant structures and the wave guides being effected by irises.

5. The transducer of claim 1, a portion of the couplings between the resonant structures and the wave guides being effected by loop and probe coupling devices.

6. The transducer of claim 1 in which one wave guide includes an additional half wavelength of the median frequency of the range of frequencies to be transmitted between said two wave guides, as compared with the other wave guide, said additional half wavelength being situated between the coupling points of two portions of said plurality of pairs of resonating structures.

7. A high frequency, electromagnetic wave, transducer comprising a plurality of pairs of high frequency, electromagnetic wave, resonant structures coupled between two high frequency, electromagnetic wave, wave guides of rectangular cross-section, one cross-sectional dimension of each wave guide being greater than the other cross-sectional dimension of the same wave guide, one of the resonant structures of each pair being coupled to a side of smaller cross-sectional dimension of one wave guide and a side of greater cross-sectional dimension of the second wave guide, the other resonant structure of the same pair being coupled to a side of greater cross-sectional dimension of said one wave guide and a side of smaller cross-sectional dimension of said other guide, the two points of coupling to each guide of each pair being in a common cross-sectional area perpendicular to the longitudinal axis of the guide.

8. The arrangement of claim 7 in which successive coupling areas are at corresponding intervals along both said guides.

9. The arrangement of claim 7 in which one end of one of said wave guides is terminated and the coupling points of the nearest pair of said

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resonant structures to said one of said wave guides are spaced an odd number of quarter wavelengths of the median frequency of the range of frequencies to be transmitted between said two wave guides from said, terminated wave-guide end.

10. In a microwave electromagnetic wave wave-guide transducer a plurality of pair of electromagnetic wave resonating structures coupled between two electromagnetic wave wave guides each pair of resonators having a common resonant frequency which differs from the resonant frequency of each of the others of said pairs, the two coupling points of each pair of resonators to each wave guide being displaced 90 degrees from each other in a common plane perpendicular to the longitudinal axis of the wave guide the planes of coupling of said pairs of resonators to said wave guides being spaced along both of said wave guides.

11. The structure of claim 10 in which the coupling points of successive pairs of resonating structures are spaced at intervals of an odd number of quarter wavelengths of the median frequency of the frequency range to be transmitted between said wave guides, with respect to the next adjacent pairs of resonating structures.

12. The structure of claim 10 in which the couplings of a portion of said plurality of resonating pairs to one of said wave guides are in phase opposition with respect to the couplings of the remainder of said pairs to said one of said wave guides.

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