March 10, 1964 W. V. TILSTON 3,124,768

RESONATOR FILTERING SYSTEM

Filed Dec. 15, 1958 3 Sheets-Sheet 1

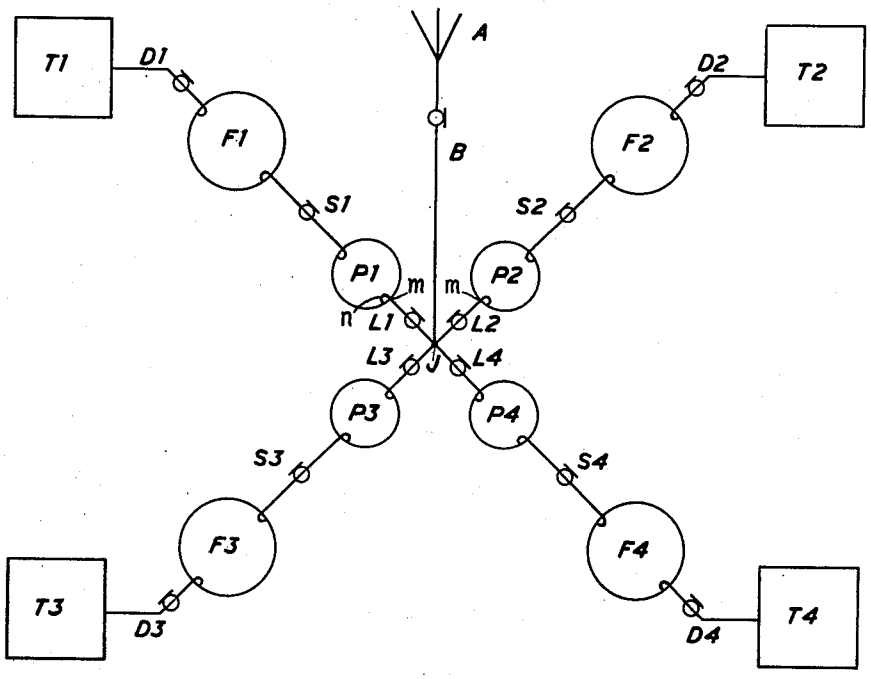


FIG. 1

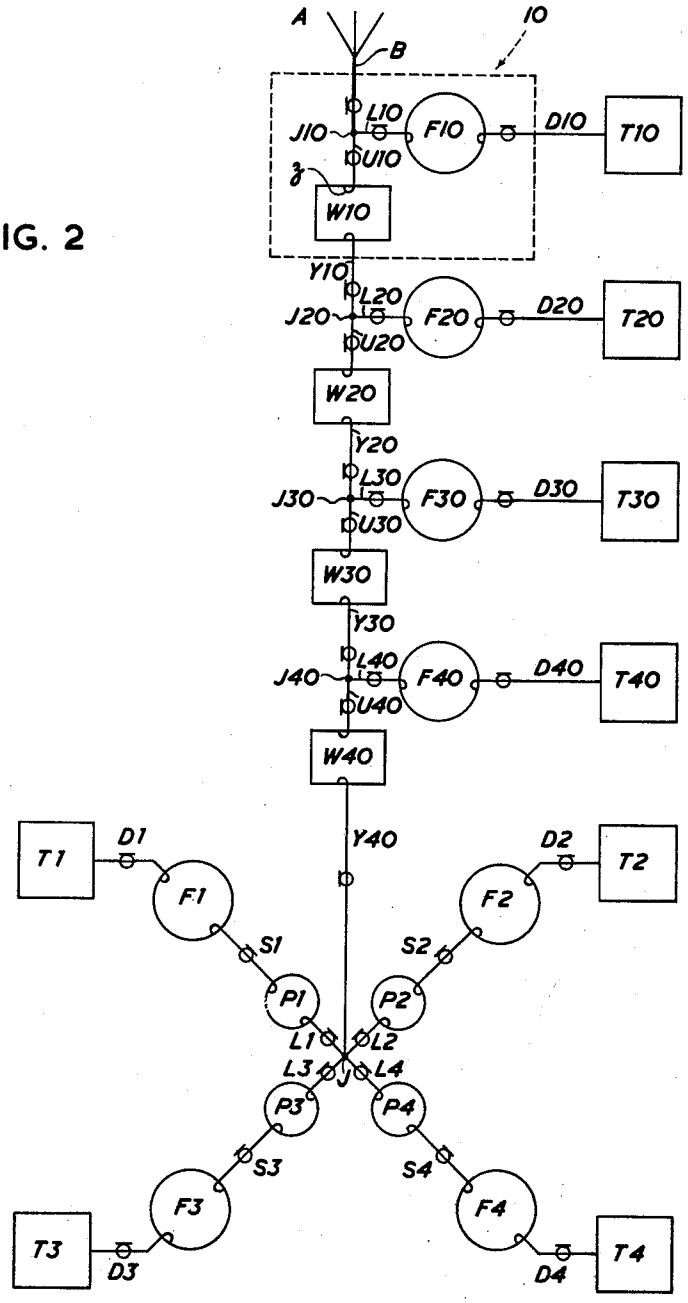
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RESONATOR FILTERING SYSTEM

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FIG. 2



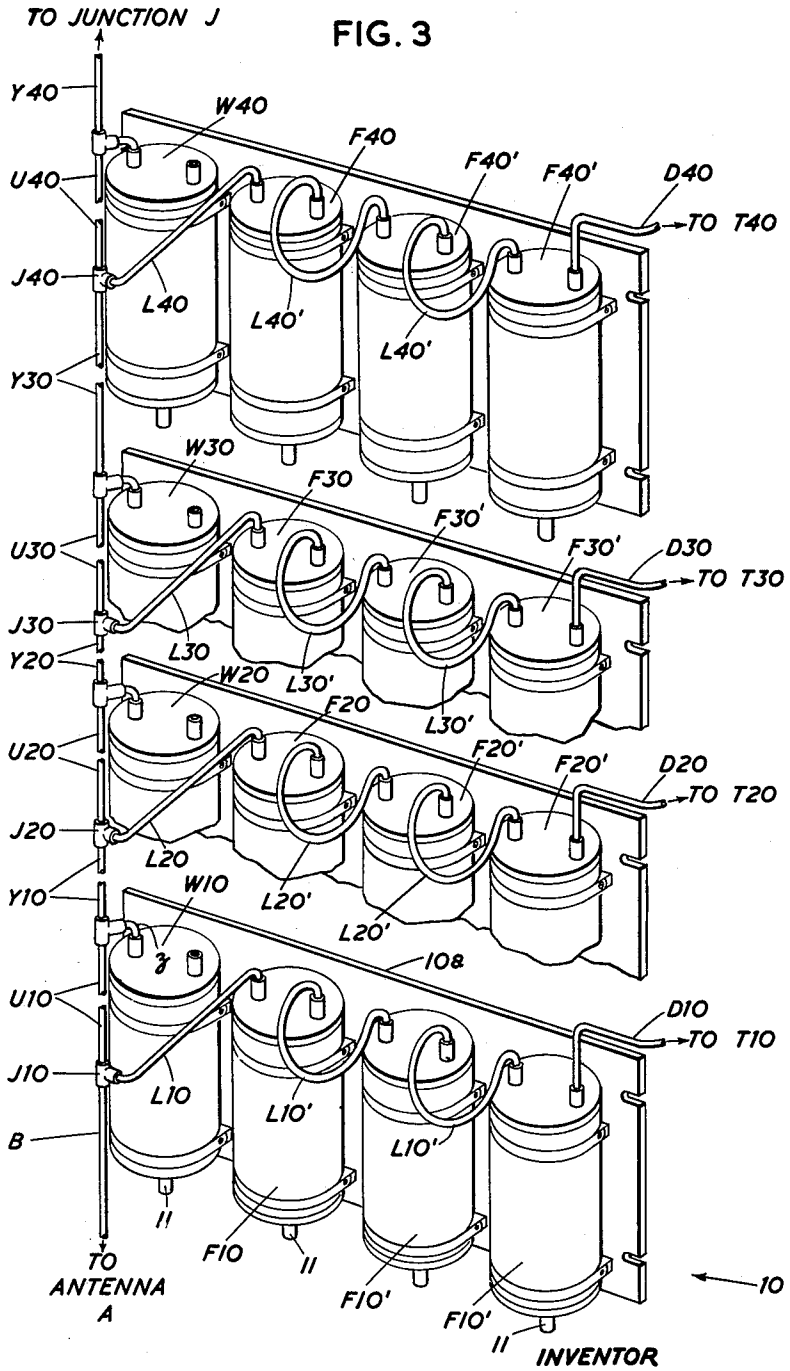
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RESONATOR FILTERING SYSTEM

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FIG. 3



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3,124,768

RESONATOR FILTERING SYSTEM

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15 Claims. (Cl. 333—9)

This invention relates to a filtering system using resonators, and is particularly concerned with coupling cavity resonators to allow a number of signalling devices to be coupled to the same antenna.

It is often desired to operate a number of transmitters or receivers at a single location using a single antenna, the transmitters or receivers operating at different frequencies all of which lie within an assigned band. The band width rarely extends over a range where the frequency at the top of the band is greater than twice the frequency at the bottom of the band. Thus, the international commercial bands are 30 to 50 megacycles, 70 to 90 megacycles, 150 to 174 megacycles, 450 to 470 megacycles and 800 to 960 megacycles, whereas other bands, 115 to 156 megacycles and 225 to 400 megacycles, are reserved for military use.

In order to connect several signalling devices, tuned to different frequencies, to one antenna, filters are commonly used to isolate one signalling device from another. Thus, filters are commonly inserted between the antenna and a plurality of transmitters, or between the antenna and a plurality of receivers, or between the antenna and a plurality of both transmitters and receivers. For frequencies over a few megacycles, cavity resonators provide convenient filters, and these have been connected to a common junction for the antenna through resonant transmission lines, the latter generally consisting of short coaxial cables. The lengths of the transmission lines are chosen to minimize the mismatch seen by one signalling device due to the loading at the antenna junction caused by the lines to the other signalling devices, and in many cases a successful arrangement can be obtained. However, as the number of signalling devices, and thus the number of cavity resonators, is increased, or as the size of the resonators is increased (as must be done for lower frequencies), the physical dimensions of the cavity resonators make it impossible to connect more than a limited number to a common junction through the optimum short lengths of transmission lines. Various supplementary impedance matching devices have been used in attempts to overcome this difficulty, but with only qualified success.

It is an object of this invention to provide simple and improved arrangements for coupling a plurality of resonators and particularly cavity resonators to a common junction or antenna with optimum lengths of resonant transmission lines and adequate physical space for the resonators.

It is another object to provide an arrangement wherein the number of signalling devices can easily be increased, and wherein the frequency at which a signalling device operates can readily be changed.

The invention is illustrated by the arrangements shown in the accompanying drawings, in which similar components are designated by the same reference characters in the different figures, and in which:

FIG. 1 is a schematic circuit diagram showing an arrangement of cavity resonators and transmission lines coupling four transmitters to a common antenna;

FIG. 2 is a schematic circuit diagram showing another arrangement embodying the circuit of FIG. 1; and

FIG. 3 shows a typical physical arrangement of resonators and lines in a circuit similar to part of FIG. 2.

Referring to FIG. 1, four transmitters T1, T2, T3 and T4, tuned to different frequencies *f1*, *f2*, *f3* and *f4* respectively within an assigned band, are coupled to a common junction J, in order to transmit from a common antenna A which is connected to the junction J by a coaxial transmission line B. In order to isolate the transmitters from one another, four cavity resonators F1, F2, F3 and F4 are provided, and are coupled to the transmitters T1, T2, T3 and T4 by coaxial transmission lines D1, D2, D3 and D4 respectively of any desired length. Each isolating resonator F acts as a filter, being tuned to pass the frequency of the transmitter to which it is coupled (and a narrow range of frequencies about that frequency) and to block the frequencies of the other transmitters. The resonators F are preferably large in physical dimensions in order to have a sufficiently high Q to give good isolation for their respective transmitters T.

From the junction J radiate four coaxial transmission lines L1, L2, L3, L4 of the transmitters T1, T2, T3, T4 respectively. If the end *m* of the line L1 is coupled to a cavity resonator, for example by means of a loop coupling *n*, and the effective electrical length of the line L1 including the coupling *n* is approximately one quarter of each of the wave lengths corresponding to the frequencies *f2*, *f3* and *f4*, then with the resonator tuned to resonate at *f1*, but not at *f2*, *f3* or *f4*, the line L1 at frequencies *f2*, *f3* and *f4* resembles a short circuited quarter wave line and thus offers high impedance to the latter frequencies while at the same time offering low impedance to *f1*. Similar considerations apply to the lines L2, L3 and L4, so that each line passes the frequency of only its own transmitter. The common practice (not illustrated in the drawings) is to locate the resonators F1, F2, F3 and F4 at the ends *m* of the lines L1, L2, L3 and L4 respectively and, by couplings *n*, to couple the ends *m* directly to the resonators F1, F2, F3 and F4, choosing the effective electrical lengths of the lines L1, L2, L3 and L4, including the couplings *n*, to be approximately one quarter of the wave length corresponding to a frequency at the middle of the band within which the frequencies *f1*, *f2*, *f3* and *f4* fall, in order to obtain satisfactory impedance matching. Or, similar results may be obtained by probe coupling the ends *m* of the lines L to the resonators F and making the effective electrical lengths of the lines L, including the couplings, one half the wave length corresponding to the mid-frequency of the band. However, the size of the isolating cavity resonators F may make it impossible to locate all the resonators F at the ends *m* of quarter or half wave lines, and the problem of physical space becomes even greater as the number of transmitters T and accompanying resonators F and lines L is increased. For narrower bands within which the transmitters operate, or where the allowable operating tolerances are not severe, it may be possible to use lines L of effective electrical lengths that are small multiples of one quarter or one half of the wave length corresponding to the mid-band frequency, thus lengthening the lines L and increasing the available room for cavity resonators at their ends *m*, but the longer the lines L the lower their impedances become to frequencies off the mid-band frequency and the impedance matching becomes less and less satisfactory.

The arrangement shown in FIG. 1 makes it possible to use optimum short lengths for the lines L while still providing adequate physical space for several large isolating cavity resonators F. In this arrangement, the ends *m* of the lines L1, L2, L3 and L4 are directly coupled to cavity resonators P1, P2, P3 and P4 respectively, these resonators being tuned to the same frequencies as the resonators F1, F2, F3 and F4 but being of smaller physical dimensions. Thus, the resonator P1, for example, is tuned to resonate at the frequency *f1*, and to block the frequencies *f2*, *f3* and *f4*. As in conventional arrangements the effective electrical length of each line L1, L2,

L3 and L4, including the effective length added by its coupling *n* to a resonator P, is made one quarter of the wave length corresponding to the frequency in the middle of the band that includes *f*1, *f*2, *f*3 and *f*4. Because the line L1, for example, is terminated by the resonator P1 it offers high impedance to the frequencies *f*2, *f*3 and *f*4 but low impedance to *f*1, so that adequate impedance matching is obtained at the junction J. Since the additional resonators P1, P2, P3 and P4 are small compared to the resonators F they have relatively low Q's, but they are connected, by means of coaxial transmission lines S1, S2, S3 and S4, in series with the larger high Q resonators F1, F2, F3 and F4, and these larger resonators provide most of the isolation for the transmitters. The effects of the lines S on the impedance seen at the junction J are of a second order, and these lines can therefore be of any convenient lengths. Thus the additional resonators P and lines S provide convenient means for coupling the large isolating resonators F to the ends *m* of the lines L while physically spacing the resonators F away from the ends *m* at locations where there is adequate room for the resonators F. In installations where there is sufficient room, some of the resonators F may, of course, be located at and coupled directly to the ends *m*, with only one or more of the resonators F spaced farther away by means of the additional resonators P and lines S.

The additional resonators P raise the insertion loss on resonance somewhat, and the number of transmitters that can be coupled to the common junction J depends upon the frequency separation between the transmitters and the insertion loss on resonance that can be tolerated.

In FIG. 2 is shown another arrangement providing adequate phyical space for a still greater number of signalling devices to be coupled through cavity resonators to a common antenna. In FIG. 2 one group of transmitters T1, T2, T3 and T4 is coupled to a common junction J in the same manner as the transmitters of FIG. 1, but provision is made for the coupling of another group of transmitters T10, T20, T30 and T40 along a network extending from the common antenna A to the junction J. This network in the embodiment illustrated consists of four filtering units, a typical one of which is encompassed by the dashed line in FIG. 2 and indicated by reference numeral 10. This typical unit 10 includes a first coaxial transmission line L10 and a second coaxial transmission line U10 each having one end at a junction J10 which is coupled by a coaxial transmission line B to the antenna A. Located at and coupled to the opposite end of the line L10 is a high Q cavity resonator F10, and the resonator F10 is coupled by a coaxial transmission line D10 of any convenient length to the transmitter T10 which the resonator F10 is tuned to isolate. The line L10 can be very short, preferably of an effective electrical length (which includes its coupling to the resonator F10) equal to one quarter the wave length corresponding to the frequency at the middle of the band of frequencies in which all the transmitters T1, T2, T3, T4, T10, T20, T30 and T40 broadcast, the line L10 and resonator F10 thus being coupled together and tuned to pass the frequency of their transmitter T10 but block the frequencies of the other transmitters.

At the end of the line U10 opposite the junction J10 is located and coupled a cavity resonator W10, and a coaxial transmission line Y10 of any convenient length couples the resonator W10 to the junction J20 of the next filtering unit, which is provided for the transmitter T20. The line U10 and resonator W10 are coupled together and tuned to have high impedance to the frequency of the transmitter T10 and low impedance to the frequencies of the other transmitters. The effective electrical length of line U10 (which includes its coupling *z* to the resonator W10) is therefore preferably one quarter the wave length corresponding to the frequency at the middle of the band of frequencies in which all the transmitters T1, T2, T3, T4, T10, T20, T30 and T40 broadcast, or in other words the lines U10 and L10 are preferably substantially the same length, and this length is common to the other lines U and L in FIG. 2. The coupling *z* of the line U10 to the resonator W10 can be adjusted to vary the impedance seen from the junction J10: for example, with a loop coupling *z*, adjustment of the length of the loop changes the effective electrical length of the line U10.

The line Y10 is connected to the junction J20 of the next filtering unit wherein the line L20 and filter F20 pass energy on the frequency of the transmitter T20 but block other frequencies, and the line U20 and resonator W20 prevent energy of the frequency of transmitter T20 from entering line Y20 but allow the other frequencies to pass with as little attenuation as possible. The other units, for the transmitters T30 and T40, are connected in cascade by the lines Y and operate in a similar manner. Thus the filters F10 to F40 provide isolation for their respective transmitters T10 to T40, and the filters W10 to W40 furnish the necessary impedance matching so that, for example, signals from the transmitter T30 are confined to the path D30, F30, L30, J30, Y20, W20, U20, J20, Y10, W10, U10, J10 and B and thus pass with little attenuation to the antenna A. Each unit, typified by the unit 10, thus has a first branch having a resonator F tuned to pass only the frequency of the signalling device T of the unit, and a second branch having a resonator W tuned to block only the frequency passed by the first branch, and to pass the frequencies (whether higher or lower) of the other signalling devices, the second branches of the different units being connected in series.

In FIG. 2 the number of cascaded units, typified by the unit 10, can be increased or decreased considerably, the lengths of the lines L and U giving optimum performance regardless of the number of units that are added, provided that all the transmitters associated with the units operate within the band for which the lengths of the lines L and U have been chosen. The lines Y may be lengthened as needed since their lengths are not critical. Addition of units similar to the unit 10 in the network between the junctions J and J10 has little effect on other units already in the network or on the equipment connected to the junction J. In other words, it is not necessary to design separately for different numbers of transmitters within the band. The insertion loss of the units on resonance increases progressively from junction J10 to junction J, being least for the unit 10 nearest the antenna A and most for the equipment connected to the junction J that is the most remote from the antenna. The amount of insertion loss that can be tolerated is one of the factors which determines the number of units which can be added. Should it be desired to have equal insertion losses for all units, this may be achieved by adjusting the Q's of the filters.

In FIG. 2 all the lines L and U can be of the same length, and each resonator F, P and W can be identical to every other resonator F, P and W respectively, with variable tuning for the resonators, so that any transmitter or receiver whose broadcasting and receving frequency is within the assigned band can be connected to any one of the lines D.

It may be possible in an arrangement like FIG. 2 to connect additional equipment to any of the junctions, or to eliminate some or all of the filters P and lines S where space permits, or to connect to the junction J a simple resistive load or other equipment having no filters. Thus, there may be connected to the junction J a transmitter for transmitting or searching anywhere in the band, except in the frequencies of the transmitters T10 to T40, with very little attenuation and with as much ease as if this searching transmitter were working alone into the antenna; such an arrangement may be very useful if transmitters T10 to T40 are being jammed.

It will be seen, therefore, that the arrangements herein specifically described make possible the coupling of a number of signalling devices to a common antenna despite the use of physically large cavity resonators and short

transmission lines for impedance matching. While in the embodiments described the signalling devices have been described as transmitters, any or all of the signalling devices could be receivers operating within the same band.

In FIG. 3 is shown a physical layout including four cascaded units similar to the unit **10** of FIG. 2 and arranged with the antenna line B at the bottom and with the line Y40 at the top. In this embodiment of the invention the isolating resonator F10 is coupled by its quarter wave length line L10 to the junction J10, and is coupled through cascaded resonators F10′ and line D10 to its transmitter or receiver T10 (not shown), quarter wave length lines L10′ being provided for the resonators F10′. The resonators F10′ serve to improve the isolation of the transmitter or receiver T10, and of course the three resonators F10 and F10′ shown could be replaced by a single, larger resonator F10. The lines U10 and Y10, to and from the resonator W10, have a common coupling z to the resonator. The resonators F10, F10′ and W10 of the unit **10** are conveniently clamped onto a common support **10***a*, with tuning knobs **11** provided at their lower ends. The other units are similar to the unit **10**.

As an example of the physical dimensions of the resonators and lines, if the transmitters or receivers of the system shown in FIG. 3 operate at different frequencies within the band 150 to 174 megacycles, whose mid-band frequency is 162 megacycles, each of the lines L and U, taken with its coupling or couplings to the resonators, could have an effective electrical length equivalent to a length in air of

$$\frac{1}{4}\times\frac{300{,}000{,}000}{162{,}000{,}000}=0.463 \text{ meter}=18.2 \text{ inches}$$

which would mean that for typical coaxial cables the actual physical lengths might be approximately 12 inches. The resonators F and W might have diameters of approximately 3 inches and lengths of approximately 18 inches.

Modifications not specifically mentioned herein will no doubt occur to those skilled in the art, and while the following claims are intended to cover the specific embodiments of the invention that have been herein described and illustrated, the claims are not intended to be limited to these specific embodiments.

What I claim as my invention is:

1. A filtering system comprising a plurality of cavity resonators, a short impedance matching transmission line for each of the resonators, each line having one end at a common junction of the lines, the resonators being of too large physical dimensions to be all located at and coupled directly to the opposite ends of the lines, and means for coupling the resonators to said opposite ends of the lines with adequate physical space for the resonators, said means including, between and in series with at least one of the resonators and its line, an additional cavity resonator of smaller physical size than said one resonator and located at and terminating said opposite end of the line of said one resonator, and an additional transmission line coupling said additional resonator and said one resonator.

2. A filtering system comprising a plurality of isolating cavity resonators each tuned to pass a predetermined frequency and block the frequencies to which the others of the cavity resonators are tuned, a transmission line for each of the resonator, each line having one end at a common junction of the lines, and means for coupling the resonators to the opposite ends of the lines and thus to the junction, said means including means for physically spacing the resonators away from said opposite ends of the lines, the spacing means including, in series with each isolating resonator and its line, an additional cavity resonator located at said opposite end of the line, the line and the additional resonator being coupled together and tuned to have low impedance to the frequency which their isolating resonator is tuned to pass and high impedance to the other frequencies, the spacing means also including an additional transmission line between each additional resonator and its isolating resonator, the isolating resonators being of too large external physical dimensions to be all located at and coupled directly to said opposite ends, but the additional resonators being of sufficiently small external dimension to be all located at and coupled directly to said opposite ends.

3. A filtering system as claimed in claim 2, wherein the effective electrical lengths of the transmission lines ending at said junction are approximately one quarter or approximately a small multiple of one quarter of the wave lengths corresponding to the frequencies which the isolating resonators are tuned to pass.

4. A filtering system for coupling to a common antenna plurality of signalling devices tuned to different frequencies, comprising an isolating cavity resonator coupled to each of the signalling devices and tuned to pass the frequency of the signalling device to which it is coupled and block the frequencies of the other signalling devices, a transmission line for each of the resonators, the effective electrical length of each line being of a value approximately one quarter of the wave length corresponding to each of the frequencies to which the signalling devices are tuned, or of approximately a small multiple of said value, each line having one end at a common junction for the antenna, the reasonators being of too large external physical dimensions to be all located at and coupled directly to the opposite ends of the lines, and means for coupling the resonators to said opposite ends of the lines, said means including, between and in series with each of the isolating cavity resonators and its transmission line, an additional cavity resonator located at said opposite end of the line and of smaller physical size and consequently lower Q than the isolating resonator, the line and the additional resonator being coupled together and tuned to have low impedance to the frequency of the signalling device to which the isolating resonator is coupled and high impedance to the frequencies of the other signalling devices, said means also including an additional transmission line coupling the additional resonator and the isolating resonator.

5. A filtering system as claimed in claim 4, wherein the transmission lines having one end at the common junction are all of effective electrical lengths approximately one quarter of the wave length corresponding to a frequency at the middle of a band that includes the frequencies to which all the signalling devices are tuned.

6. A filtering system for a high frequency antenna, comprising a first plurality of signalling devices tuned to different frequencies, a filtering unit for each signalling device, each unit including a first and a second transmission line, one end of the first line having a junction with one end of the second line each unit also including a first and a second cavity resonator located at the opposite end of the first and second line respectively of the unit, the first resonator of each unit being coupled to the signalling device for the unit, the first line and resonator of the unit being coupled together and tuned to pass the frequency of the signalling device for the unit and block the frequencies of the other signalling devices, the second line and resonator of the unit being coupled together and tuned to have high impedance to the frequency of the signalling device for the unit and have low impedance to the frequencies of the other signalling devices, means coupling the junction of one of the units to the antenna, means coupling the other units in cascade with said one unit, with the junction of each succeeding unit coupled to the second resonator of the preceding one, a second plurality of signalling devices tuned to different frequencies all of which are passed by the second lines and resonators of the units, an isolating cavity resonator coupled to each of said second plurality of signalling devices and tuned to pass the frequency of the signalling device

to which it is coupled and block the frequencies of the others of the second plurality of signalling devices, an impedance matching transmission line for each of the isolating resonators, the impedance matching lines each having one end at a common junction, means coupling the last mentioned junction to the second resonator of the last of said cascaded units, means coupling the isolating resonators to the opposite ends of the impedance matching lines and thus to the last mentioned junction, the last mentioned means including, between and in series with each of the isolating resonators and its impedance matching line, an additional cavity resonator located at said opposite end of the impedance matching line, the impedance matching line and the additional resonator being coupled together and tuned to have low impedance to the frequency of the signalling device to which the isolating resonator is coupled and high impedance to the frequencies of the others of the second plurality of signalling devices, the last mentioned means also including an additional transmission line coupling the additional resonator and the isolating resonator, the isolating resonators being of too large external physical dimensions to be all located at and coupled directly to said opposite ends of the impedance matching lines, but the additional resonators being of sufficiently small external dimensions to be all located at and coupled directly to said opposite ends of the impedance matching lines.

7. A filtering system as claimed in claim 6, wherein all the signalling devices are tuned to frequencies within a given frequency band, and each transmission line of said units and each said impedance matching transmission line has an effective electrical length less than the wave length corresponding to a frequency at the middle of said band.

8. A filtering system for coupling to a common antenna a plurality of signalling devices tuned to different frequencies, comprising a filtering unit for each signalling device, each unit including a first and a second transmission line, one end of the first line having a junction with one end of the second line, each unit also including a first and a second cavity resonator located at the opposite end of the first and second line respectively of the unit, means for coupling the first resonator of each unit to the signalling device for the unit, the first line and resonator of the unit being coupled together and tuned to pass the frequency of the signalling device for the unit and block the frequencies of others of the signalling devices, the second line and resonator of the unit being coupled together and tuned to have high impedance to the frequency of the signalling device for the unit and low impedance to the frequencies of said others of the signalling devices, means for coupling the junction of one of the units to the antenna, and means for coupling the other units in cascade with said one unit, with the junction of each succeeding unit coupled to the second resonator of the preceding one.

9. A filtering system as claimed in claim 8, wherein the effective electrical length of each said transmission line is approximately one quarter or approximately a small multiple of one quarter of the wave lengths corresponding to the frequencies to which the signalling devices are tuned.

10. A filtering system comprising a plurality of filtering units each including a first and a second transmission line, one end of the first line of each unit having a junction with one end of the second line of the unit, each unit also including a first and a second resonator located at the opposite end of the first and second line respectively of the unit, the first line and resonator of each unit being coupled together and tuned to pass a predetermined frequency, the frequency for which the first line and resonator of each unit are tuned being different than that for which the first lines and resonators of others of the units are tuned and the first line and resonator of each unit blocking the frequencies for which the first lines and resonators of said others of the units are tuned, the second line and resonator of each unit being coupled together and tuned to have high impedance to the frequency for which the first line and resonator of the unit are tuned, the second line and resonator of each unit having low impedance to the frequencies for which the first lines and resonators of said others of the units are tuned, and means for coupling the units in cascade, with the junction of each succeeding unit coupled to the second resonator of the preceding one.

11. A filtering system for coupling to a common antenna a plurality of signalling devices tuned to different frequencies, comprising a filtering unit for each signalling device, each unit including a first branch and a second branch, the second branches of the different units being in series, the first branch of each unit having resonator means tuned to pass only the frequency of the signalling device of the unit, the second branch of each unit having resonator means tuned to block only the said frequency of the signalling device of the unit and pass both higher and lower frequencies of other signalling devices.

12. A filtering system as claimed in claim 11 for signalling devices whose frequencies all lie within a band, the resonator means of the first branch of each unit being tunable to pass any desired frequency within the band and the resonator means of the second branch of the unit being correspondingly tunable to block said desired frequency whereby any one of the signalling devices can be coupled to the first branch of any one of the units.

13. A filtering system as claimed in claim 12, wherein the several filtering units are of the same size and structure.

14. A filtering system as claimed in claim 12, wherein the resonator means are cavity resonators.

15. A filtering system as claimed in claim 14, wherein the several filtering units are of the same size and structure.

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