Dec. 1, 1959 T. E. HATTERSLEY 2,915,716

MICROSTRIP FILTERS

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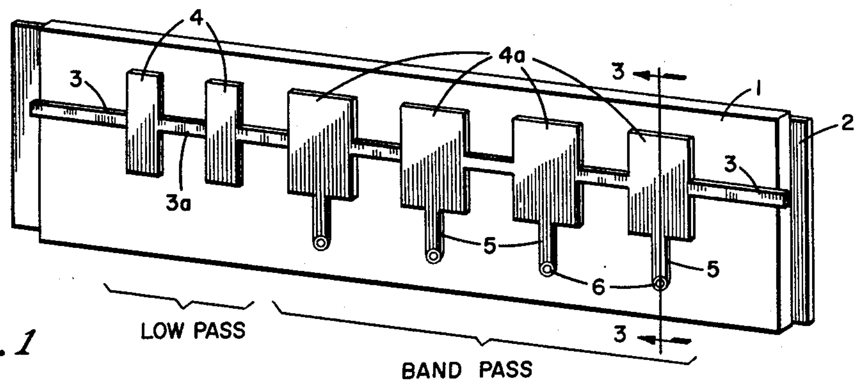

Fig. 1

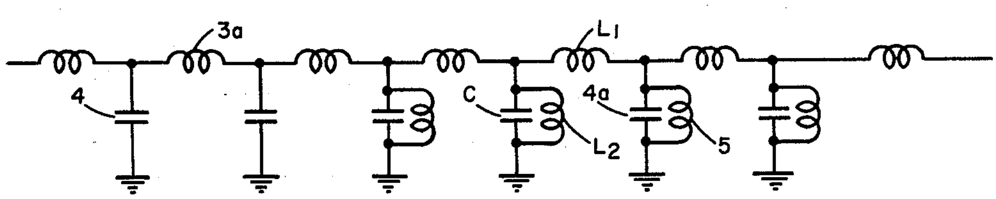

Fig. 2

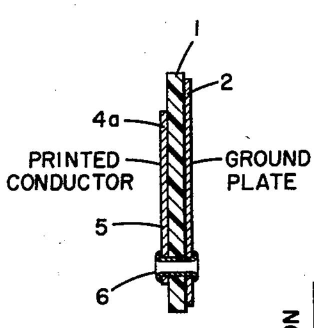

Fig. 3

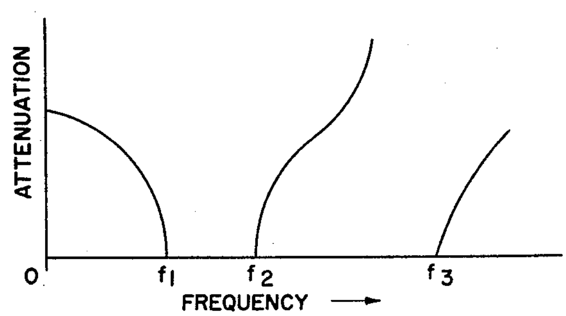

Fig. 4

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MICROSTRIP FILTERS

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1 Claim. (Cl. 333—73)

This invention relates to microwave circuits, and is particularly directed to filters constructed by "printed circuit" techniques.

The design of filters with lumped reactance elements has long since been standardized, but the frequencies contemplated are in the longer wavelengths compared to the so-called microwave bands where the wavelengths approach the physical dimensions of the reactance elements to be used. The introduction of transmission lines such as wave guides, coaxial cables, parallel wires, and the like, have facilitated the transporting of microwave energy from one point to another with limited controlled radiation, but has aggravated the problems of filter design. Obviously, lumped reactances connected to or near such lines cause discontinuities which disturb wave motion and generally destroy the very characteristics for which the lines were selected.

The object of this invention is to provide an improved filter for electric or magnetic wave energy in the microwave bands of frequencies, and in which wave motion phenomena of the resonant transmission lines is fully utilized.

The objects of this invention are attained in a transmission line comprising a sheet of insulating material of uniform predetermined thickness and dielectric constant, having a ground plate of extended area adhered to one face of the sheet, and having a thin strip conductor of small cross section and extended length adhered to the other face to produce a resonant transmission line. The filter is characterized by tabs of thin metal adhered to said other face and integrally joined along their edges to said line conductor, said tabs being of extended area to present a relatively large lumped capacity with said ground plate, compared with the capacity of the connected portion of said line. Some of the tabs are in turn integrally joined to thin metal stubs adhered to said other face of the insulating sheet, and so terminated at their outer ends as to present lumped inductive reactance in parallel with the capacitive reactance of the tabs.

Other objects and features of this invention will become apparent to those skilled in the art by referring to specific embodiments described in the following specification and shown in the accompanying drawing, in which:

Fig. 1 is a partly sectioned plan view of a filter embodying this invention,

Fig. 2 is a circuit diagram which is the equivalent of the circuit of Fig. 1,

Fig. 3 is a cross sectional view of the device taken on line 3—3 of Fig. 1, and

Fig. 4 is a graph showing typical frequency characteristics of the filters of this invention.

In Fig. 1 is shown the sheet **1** of insulation, having a relatively high dielectric constant and low high-frequency loss characteristics. The sheet is of extended surface area, and is quite thin. Polystyrene, polyethylene, or insulators commercially known under the trademarks or trade names "Formica" or "Teflon" or "Resolite" are well

adapted to the high frequency uses contemplated here. "Teflon" is polytetrafluorethylene. "Formica" and "Resolite," sometimes "Resilyte," are usually either melamine-formaldehyde or phenolformaldehyde employed as a filler for cotton, asbestos, glass, or cellulose fabrics.

To one side of the sheet is adhered a thin metal ground plate **2**. The plate **2** is large in surface area and underlies and extends well beyond the boundary of the circuits printed on the other face of the sheet. The ground plate, for economic and electrical reasons, may conveniently comprise copper foil firmly bonded as by a thermosetting adhesive to the one side of the insulating sheet.

To the other side of the sheet is the strip conductor **3**, which also may be copper foil, tailored to the desired size and shape and glued firmly to the face of the sheet. Alternatively, the metal of strip conductor **3** may be prepared by applying an ink of powdered metal appropriately painted on the sheet and baked in a reducing atmosphere to bond the metal to the sheet in low resistance strips. A third and more common alternative comprises cladding overall the front side of the sheet, protecting selected portions of the clad jacket with a photoresist, exposing to strong light, and etching away the undesired portions of the jacket.

According to an important feature of this invention, tabs **4** and **4***a* are formed on the insulating sheet integrally with the conductor **3**, and are spaced along the conductor as shown. The tabs are shown in pairs, symmetrically on either side of the conductor **3**, although symmetry is not indispensable. The spacing between the tabs, and the length of the conductor **3** between the tabs, are preferably such that at the contemplated operating frequency the sections of the line conductor appear as inductive reactances between the tabs. Accordingly, line sections **3***a* comprise finite inductances in series with line **3**; with capacities **4** connected in shunt to the line, as shown in Fig. 2. A plurality of series inductances and parallel capacities comprise the ladder of a low pass filter, attenuating all frequencies above the frequency determined by the length of sections **3***a* and the areas of tabs **4**. The cutoff frequency, f_3, Fig. 4, of such a filter is proportional to $R\pi L$ or $1/\pi CR$, where L is the series inductance of each section, C is the adjacent shunt capacity and R is the load resistance at the receiving end of the filter.

The low pass filter sections, **4** and **3***a*, are connected in series with a band pass filter comprising the capacities of tabs **4***a*. For band pass characteristics, effective inductive reactances must be coupled in parallel to the capacitive reactances of the tabs **4***a*. For this purpose according to this invention, stubs **5** are formed of metal foil on the face of the sheet, integrally joined at one end to the edge of the tabs **4***a* and appropriately terminated at their other or outer ends. According to this invention the stubs are short circuited at their outer ends to the ground plate **2**. Eyelets **6** in the example shown are driven through the sheet to electrically connect the ground palte **2** to the outer ends of the stubs, as best shown in Fig. 3. The stubs are of such a length, respectively, that they present a predetermined effective inductive reactance to the edge of the connected tabs. This length is preferably less than about 1/12 wavelength of the shortest wave of the band to be passed.

Each section of either filter may be selected in its constants by computing the surface areas of the tabs **4** and **4***a* for a given insulator and adjusting the lengths of stubs **5** to alter the width of the pass band and to shift the cutoff frequency of the low pass filter. If f_1 is the lower frequency limit of the pass band and f_2 is the upper limit of the pass band, see Fig. 3, and L_1 is the series inductance and L_2 is the shunt inductance, and the several capacities, C, are equal, with a load resistance R, then the relationships of the parameters of the band pass filter of this invention may be simply stated as: $L_1=R\pi(f_1+f_2)$ and $L_2=(f_2-f_1)R/4\pi f_1^2$. Accordingly, the width of the pass band is conveniently adjusted, and the spacing thereof from the cutoff frequency of the low pass filter is easily controlled. A band pass has been constructed to cover a two-to-one frequency range, and with the low pass filter in combination therewith, harmonic components and spurious responses are effectively suppressed. The pass band f_1 to f_2, and the low pass, f_3, characteristics are separately shown in Fig. 4 before combining.

To determine the inductance and capacities as a practical matter it is convenient to assume a lossless transmission line and to employ basic transmission line formulas such as

$$Z_0=\sqrt{\frac{L}{C}}$$

and

$$v=\frac{1}{\sqrt{LC}}$$

where v is velocity of propagation, Z_0 is characteristic impedance, L is inductance and C is capacitance. Inductance in henries per meter may be obtained directly from Z_0/v, while capacity in farads per meter may be obtained from $1/Z_0v$ to accommodate the series and shunt elements of a filter of any given characteristics. Of course, the wider the line **3**, the greater is the capacities per unit length of the line.

The formed tabs and stubs do not present discontinuities to the evenly distributed constants of the transmission line **3**, and present very low insertion losses to the line. The physical thickness of the filters, comprising the sheet **1** and metal foil parts **2** and **3**, may be but a few thousandths of an inch, thus requiring volumetric space extremely small compared to the space required of filters composed of the usual lumped elements. Filter cards of the type shown are readily replaceable in a chassis, should substitution of frequency characteristics be desired. Extensive experimentation has shown that the electrical characteristics of the filters of this invention are extremely stable with age and with environmental changes.

While a specific embodiment of this invention has been shown and described, other modifications will readily occur to those skilled in the art. It is not, therefore, desired that this invention be limited to the specific arrangement shown and described, and it is intended in the appended claim to cover all modifications within the spirit and scope of this invention.

What is claimed is:

A band pass filter comprising a sheet of insulating material, a ground plate of extended area adhered to one face of said sheet, an elongated strip conductor of limited area adhered to the other face of said sheet, spaced foil-like tabs adhered to said other face and electrically joined to said strip conductor, said tabs being of extended area providing lumped capacities with said ground plate larger than those of the connected portions of said strip, and foil-like stubs of less width than said tabs adhered to said other face and electrically connected to said ground plate and at least some of said tabs, the length of said strips between the tabs being adjusted so that the inductive reactance L_1, thereof is proportional to $R/\pi(f_1+f_2)$, and the length of said stubs, for a selected termination, being adjusted so that the inductive reactance, L_2, thereof is proportional to $(f_2-f_1)R/\pi f_1^2$, where R is the resistance of the load at the end of said strip, and where f_1 and f_2 are, respectively, the lower and upper frequency of the desired pass band.
sired pass band.

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