Jan. 7, 1958 M. ARDITI ET AL 2,819,452

MICROWAVE FILTERS

Filed May 8, 1952 2 Sheets-Sheet 1

Fig.1

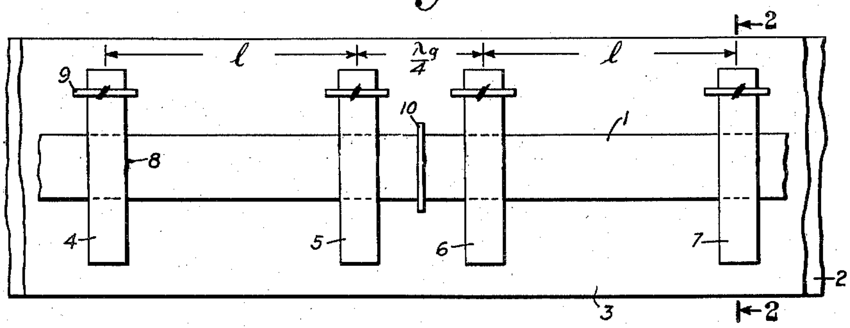


Fig.2

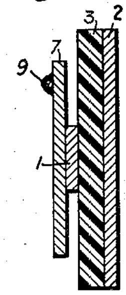


Fig.3

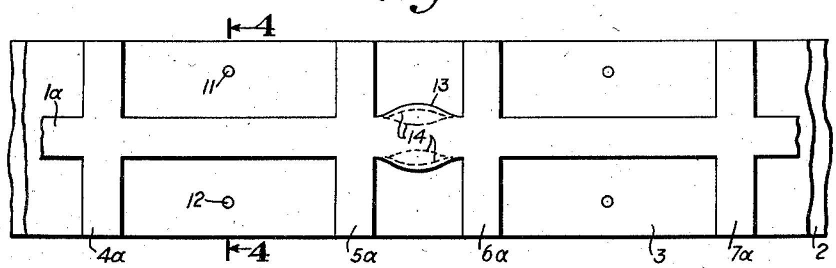


Fig.4

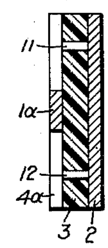


Fig.6

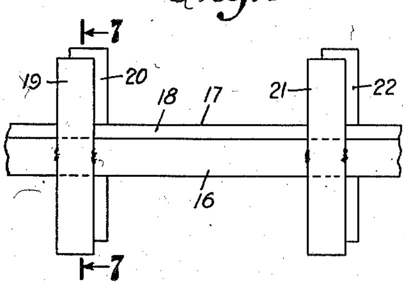


Fig.7

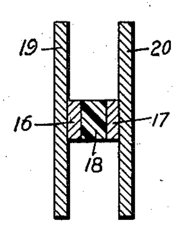
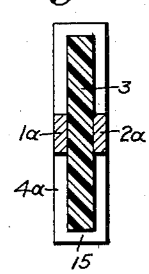


Fig.5



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MICROWAVE FILTERS

Filed May 8, 1952 2 Sheets-Sheet 2

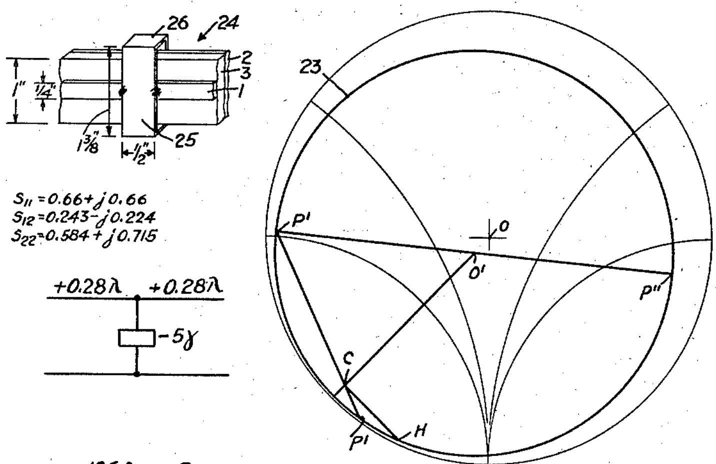


Fig. 8

Fig. 9

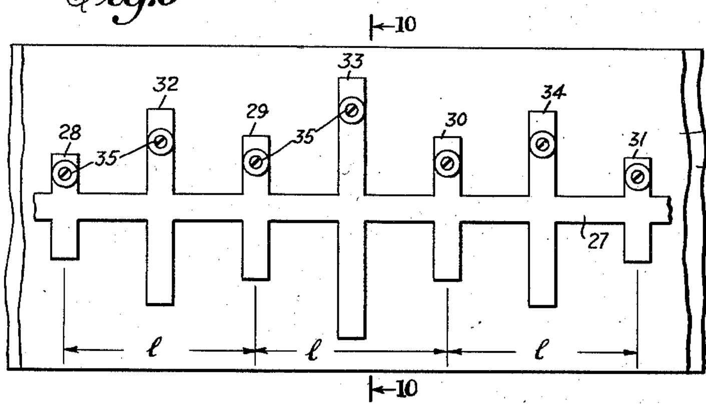


Fig. 10

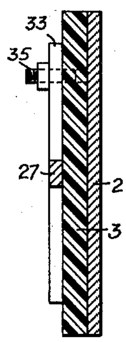


Fig. 11

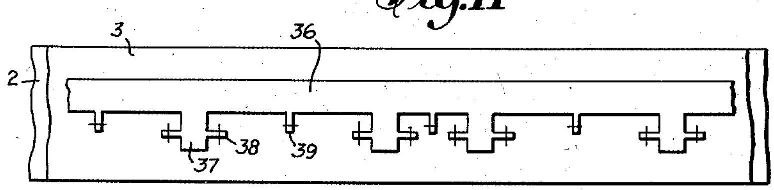
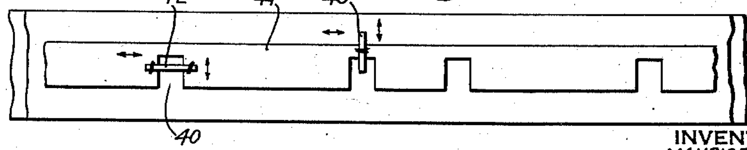


Fig. 12



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MICROWAVE FILTERS

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Application May 8, 1952, Serial No. 286,763

1 Claim. (Cl. 333—73)

This invention relates to microwave transmission systems and more particularly to microwave filters specially applicable to microwave printed transmission lines and circuitry.

In the copending applications of D. D. Grieg and H. F. Englemann, Serial No. 234,503, filed June 30, 1951, now Patent No. 2,721,312, and M. Arditi and P. Parzen Serial No. 286,764, filed May 8, 1952, now Patent No. 2,774,046 a type of microwave transmission line is disclosed comprising, in one of its simplest forms, two conductors printed or otherwise disposed in substantially parallel relation on opposite sides of a strip or layer of dielectric material a small fraction of a quarter wavelength thick. One conductor is made narrower than the other, so that the wider planar conductor appears as an infinite conducting surface to the narrower conductor, thereby insuring the mode of propagation of microwave energy therealong in the TEM mode. The dielectric between the two conductors may be of substantially the same width as the narrowest of the two conductors or wider according to the relationships desired. In our copending application Serial No. 286,761, filed May 8, 1952, we disclose filter arrangements utilizing a section of the aforementioned parallel strip type of line and spaced susceptances in the form of conductor obstacles projecting either partway or all the way across the space between the parallel strip conductors.

An object of this invention is to provide still other microwave filter arrangements which are small, light in weight, and relatively simple and inexpensive to make, also utilizing a section of the aforementioned parallel type of line.

One of the features of this invention is the manner of providing in a parallel strip type of line spaced susceptances of large value disposed as reflecting shunt impedances to define a resonant section or cavity in the parallel strip line. The susceptances, broadly speaking, may comprise the placing of two obstacles or other discontinuity structures in or on one or the other or both of the conductors of the line at spaced points to form a resonant cavity section therebetween. These discontinuities may comprise either a conductor or dielectric obstacle. For example, susceptances may be introduced in the line by placing a piece of conductor cross-wise of the line as a lumped impedance. The cross-wise conductor would be in contact with one of the line conductors with its ends either open or shorted to the other line conductor. Also such obstacles may be printed directly on the strip of dielectric along with the line conductors, and if desired, may comprise variations in the shape of the line conductors.

Another feature of the invention is the method and means for tuning the resonant spacing formed by such line conductor configurations. As more fully described hereinafter, this tuning of the resonant spacing or cavity may be accomplished in various ways, including vernier capacitive screws, line compressors or stretches, lateral line projections or protuberances and the size and position of interconnecting portions of the line conductor configurations.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a plan view of one form of filter in accordance with the principles of this invention;

Fig. 2 is a cross-sectional view taken along line 2—2 of Fig. 1;

Fig. 3 is a plan view of an alternate form of filter;

Fig. 4 is a cross-sectional view taken along line 4—4 of Fig. 3;

Fig. 5 is a cross-sectional view similar to Fig. 4 showing another modification of the invention;

Fig. 6 is a plan view of another embodiment of the invention;

Fig. 7 is a cross-sectional view taken along line 7—7 of Fig. 6;

Fig. 8 is a circle diagram based upon the Smith admittance chart used in explaining the susceptance characteristics of the plate-like obstacles used in the filters of the character disclosed herein;

Fig. 9 is a plan view of a directly coupled filter in accordance with the principles of this invention;

Fig. 10 is a cross-sectional view taken along line 10—10 of Fig. 9; and

Figs. 11 and 12 show still other modifications of this invention.

Referring to Figs. 1 and 2, the microwave transmission line shown is of the printed circuit type comprising a first or "line" conductor **1** and a second or "base" conductor **2** with a layer **3** of dielectric material therebetween. The conductive material may be applied and/or shaped or etched on a layer of dielectric material, such as polystyrene, polyethylene, quartz, "Teflon," fiberglass, or other suitable material of high dielectric quality, in the form of conductive paint or ink, or the conductive material may be chemically deposited, sprayed through a stencil, or dusted onto selected prepared surfaces of the dielectric, or by any other of the known printed circuit techniques. The spacing of the two conductors is preferably selected a small fraction in the order of about 1/10 to about 1/5 of a quarterwavelength of the microwave propagated therealong.

The microwave line of Figs. 1 and 2 is shown provided with spaced obstacles as lumped impedances in the form of short pieces of conductors **4**, **5**, **6**, and **7** disposed crosswise of the line conductor **1**. These crosswise conductor obstacles provide two resonant cavity sections of lengths "l," the cavity sections being coupled by quarter wavelength sections of line. While the crosswise conductors **4** through **7** are shown to be of the same width as the line conductor **1**, they may be of other widths either wider or narrower as desired, but always a small fraction of a quarter wavelength, depending upon the susceptance value desired. The lengths of the crosswise conductors may also vary depending upon the susceptance value desired. The susceptance value may also be varied by adjusting the position of the crosswise conductor. After the crosswise conductors have been suitably located, they may be secured to the line conductor by means of solder **8**. After securing the crosswise pieces, it may be desirable to further tune the susceptances, the cavities defined thereby or the quarter wavelength spaced therebetween by some form of vernier trimming device. Such a trimming device is shown in Figs. 1 and 2 to comprise a piece of small wire as indicated at **9** and **10**. Such piece of wire may be positioned either on the cross pieces **4** to **7** or on the line conductor **1** as may be desired. By adjusting the position of the wire, proper matching may be obtained. The optimum position of trimming pieces or wire may be determined by use of any suitable measuring technique, one satisfactory method of making such measurements being disclosed in the pending application of G. A. Deschamps, Serial No. 333,164, filed January 26, 1953. During this adjustment of the wire pieces, it is preferable to have applied thereto a piece of solder which is maintained soft by a soldering iron whereby the wire is nudged from one position to another until an optimum reading is obtained whereupon the solder is permitted to freeze.

When the proper location of the crosswise conductors is obtained, the filter may be reproduced with reasonable accuracy by photographic and printed circuit techniques. Such a filter when produced by these techniques may have the appearance shown in Figs. 3 and 4. The line conductor **1***a* and the cross-conductors *4a* through *7a* are made integral. While the cross pieces *4a* through *7a* are shown to extend completely across the dielectric **3**, it will be clear that they need not be so extended but may fall short of the width of the dielectric similarly as illustrated in Fig. 1. In order to provide for susceptance trimming, the use of small pieces of wire may also be practiced on this form of printed filter as well as several other methods. As shown in Figs. 3 and 4, one such method comprises conductive posts **11** and **12** disposed in the dielectric **3** in the resonant cavity section of the line. Another method of varying the length of line between adjacent cross pieces is that of compressing or stretching the width of the line conductor. This method is best employed by providing the line conductor with extended width with gradual curvature as indicated at **13**. If this width provides in effect too long a section, that section may be shortened in effect by slicing away edge portions of the line conductor, thus compressing it as indicated between broken lines **14**. This "lengthening" and "shortening" of the line has reference to line wavelength.

The cross pieces **4***a* through **7***a* shown in Fig. 3 may be open or closed at their ends. In Fig. 4 the cross pieces are shown to be open. In Fig. 5 the cross pieces are shown to be closed with respect to the other line conductor **2***a*, the line conductor **4***a* for example being continued by a conductor **15** for connection with conductor **2***a*. The conductor **2***a* may comprise a planar conductor extending the full width of the dielectric **3** or it may be of substantially the same width as the line conductor **1***a* as indicated in Fig. 5. The conductor **2***a* may also be provided with cross pieces the same as **4***a* through **7***a*.

Figs. 6 and 7 show another form of filter arrangement comprising two ribbon-like conductors **16** and **17** of substantially equal width separated by a similar region of dielectric **18**. The susceptance obstacles of lumped impedance in this filter comprise strips of conductive material **19**, **20** and **21**, **22** disposed on opposite sides of the line conductors. The susceptance values of these obstacles may be adjusted by adjusting relative positions, one being offset with respect to the other. The ends of these cross pieces may be either open as shown or may be closed similarly as indicated in Fig. 5.

Referring to Fig. 8, a Smith admittance chart is shown onto which a circle has been applied corresponding to test data with respect to a susceptance obstacle illustrated at **24** in Fig. 8. The line section is of the same character illustrated in Fig. 1 and is provided with like reference characters. The obstacle, however, comprises a crosswise strip **25** which is shorted at its ends to conductor **2** as indicated at **26**. It will be observed that the circle is large thereby indicating that the insertion loss of this type of obstacle is small. It also shows that the obstacle is substantially symmetrical.

Referring to Figs. 9 and 10, a directly coupled filter is therein shown comprising a line conductor **27** printed on a strip of dielectric **3** which in turn is provided with a second conductor **2** on the opposite side thereof. The line conductor **27** is provided with a series of susceptance obstacles of different lengths, the obstacles **28**, **29**, **30**, and **31** representing transformer couplings of lumped impedance between adjacent resonant sections while the susceptance obstacles **32**, **33**, and **34** determine the susceptance of the resonant sections. These crosswise obstacles may each be tuned by any one of the tuning or trimming means herein described but for purposes of illustration the tuning means is shown to be in the form of a capacitive post **35** which may be adjusted with respect to the opposite line conductor. It should also be observed that while the second conductor **2** is illustrated as a planar conductor that it may in fact correspond substantially to the shape of the line conductor **27** together with the obstacle susceptance projections thereof.

Referring now to Figs. 11 and 12, the filter may follow various line configurations incorporating susceptance obstacles of lumped impedances. In Fig. 11, for example, the line conductor **36** is shown with obstacle projections along one side thereof as indicated at **37**, the projections being of a width less than a quarter wavelength. The printed configuration may also incorporate trimming projections as indicated at **38** and **39**. These trimming projections correspond substantially to the small pieces of wire **9** and **10** illustrated in Fig. 1. Final trimming of the resonant sections and the susceptance obstacles may be accomplished by cutting away portions of these small projections **38** and **39** until the optimum susceptance is obtained. Should too much be removed, conductive material may be added by soldering. In Fig. 12 obstacles may comprise cutouts such as indicated at **40** in the line conductor **41**. The susceptance values of these recesses in the line **41** are also in the nature of lumped impedances or reflection obstacles, since the width of the slots are a small fraction of a quarter wavelength. These recesses may be tuned by means of small pieces of wire as indicated at **42** and **43**. By adjusting the position of these wires optimum tuning may be had, the wires being thereafter secured by soldering or other suitable fastening means.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claim.

We claim:

A microwave filter comprising first and second ribbon-like conductors, means disposing said conductors in dielectrically spaced substantially parallel relation a small fraction of a quarter wavelength apart to provide a waveguide, said first conductor being of a width equal to a fraction of a quarter wavelength, said second conductor being wider than said first conductor to present thereto a planar conducting surface for propagation of microwave energy in a mode approximating the TEM mode, said first conductor having laterally disposed projections extending in overlying parallel relation to the planar conducting surface of said second conductor, the width of said lateral projections being a small fraction of a quarter wavelength to present reflecting lump impedances spaced apart longitudinally of said conductors to form a resonant section therebetween, and means for adjusting the susceptance value of certain of said lateral projections, said means including a conductive screw carried by the projection for adjustment into the space between said projection and said planar conducting surface.

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