June 9, 1953 H. P. THOMAS 2,641,646

COAXIAL LINE FILTER STRUCTURE

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Fig. 1.

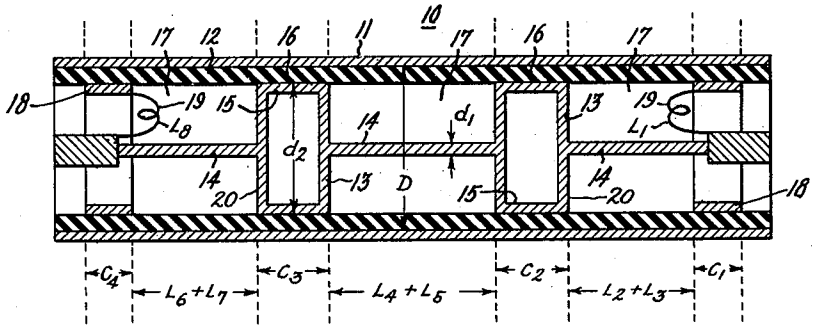
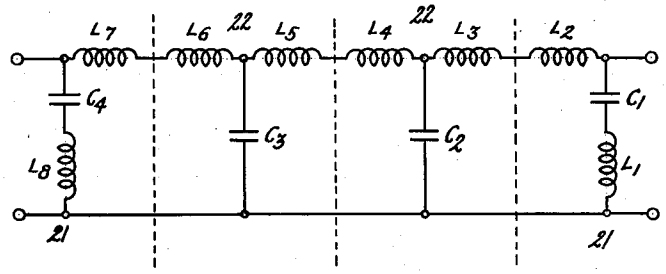


Fig. 2.



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COAXIAL LINE FILTER STRUCTURE

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3 Claims. (Cl. 178—44)

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My invention relates to filter devices and more particularly to filters adapted to be employed with ultra high frequency electromagnetic waves.

In many ultra high frequency devices it is highly desirable to suppress electromagnetic energy of a particular band of frequencies, conventionally referred to as the "stop bands," while permitting energy of other frequencies, conventionally called the "pass band," to be conducted or radiated with little or no attenuation. Such filtering means are useful, for example, in minimizing undesirable harmonic radiation from high frequency transmitters such as frequency-modulated broadcasting transmitters or television transmitters. For optimum performance such filters should cause no appreciable insertion loss or attenuation to a wide band of pass frequencies and should quickly reach a high attenuation which is maintained throughout the stop band of frequencies. While filters having the above desirable characteristics are easily constructed for low frequencies by the use of lumped inductive and capacitive elements, many difficulties arise in the construction of such filters for use at ultra high frequencies because of the extremely small values of inductance and capacity which must be employed. Accordingly, an object of my invention is to provide an ultra high frequency filter device which causes a small pass band insertion loss, has a large pass band width with a substantially flat pass band response, and yet has a sharp cut-off characteristic with high attenuation throughout the stop band.

In general, an ultra high frequency filter structure embodying my invention comprises a length of concentric transmission line having axially spaced sections of relatively small interconductor spacing alternating with sections of relatively large interconductor spacing. The sections of small interconductor spacing act effectively as a shunt capacitance while the sections of large interconductor spacing act effectively as a series inductance. Sections of small interconductor spacing are provided at either end of the filter and means are also provided whereby inductance is connected in series with the shunt capacitance of these end sections. The characteristics of the filter are determined primarily by the respective length of the various sections as well as by their interconductor spacing.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, together with further objects and advantages thereof can best be understood by

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reference to the following description taken in connection with the accompanying drawing in which Fig. 1 is a longitudinal cross-sectional view of a low pass filter structure embodying my invention, and Fig. 2 is a simplified diagram of an equivalent circuit of the filter shown in Fig. 1. In the drawing similar reference numerals indicate corresponding parts.

Referring to Fig. 1, I have shown my invention in the form of a filter 10 comprising an outer tubular conductor 11 which surrounds a close-fitting, tubular, dielectric insulating member 12. An inner concentric tubular conductor 13 has axially spaced portions 14 of relatively small diameter d_1 alternating with expanded portions 15 of relatively large diameter d_2. The peripheries of the two conductors cooperate to define axially spaced chambers or sections 16 having relatively small interconductors spacing alternating with chambers or sections 17 having relatively large interconductor spacing. The sections 16 and 17 function as distributed inductance and capacitance along the length of the filter 10; the sections 16 acting effectively as a shunt capacitance and the sections 17 acting effectively as a series inductance. At either end within the filter 10, I provide a cylindrical conducting member 18 which is held in position as a close fit against the dielectric member 12. These conducting members 18 are also capacitive in effect, but are not in direct electrical contact with the inner concentric conductor 13 as are the similarly positioned expanded portions 15 of the inner conductor 13. An inductance means 19, preferably comprising an inductance coil of one or two turns of heavy wire or copper tubing, is connected between each conducting member 18 and the inner conductor 13 and cooperates with the capacitance produced thereby to provide a shunting series resonant circuit tuned to the uppermost frequency of the pass band for reasons to be more fully explained hereinafter.

Since the power losses in the small diameter portions 14 of the inner conductor 13 are considerably greater than for the usual concentric transmission line having an outer conductor of comparative diameter, this inner conductor portion 14 is perferably composed of a solid copper rod soldered or brazed into heavy copper end plates 20 in the expanded portions 15 of the inner conductor 13. This construction tends to prevent an excessive temperature rise by permitting heat to be conducted axially to the expanded portions 15 where it is radiated to the outer conductor 11.

The relative size as well as the spacing between the various component sections of the filter 10 of Fig. 1 are determined by parameters which can best be understood by reference to the equivalent circuit diagram of Fig. 2. As will be immediately recognized by those skilled in the art, the circuit of Fig. 2 represents a conventional low-band-pass ladder-type filter having m-derived terminal half-sections 21 and intermediate T-sections 22 having matched image impedances. The values of the inductive and capacitive elements in the terminating half sections 21 are determined according to well known formulas with the use of a design parameter "m" usually assigned a value of approximately 0.6 in order to produce a relatively flat terminal image impedance curve. When the terminating half sections 21 are designed for the same cut-off frequencies, i. e., the frequencies that mark the edge of the pass band, and the same load resistance as the intermediate sections; their image impedances will match that of the intermediate sections at one pair of terminals. A filter of this type has its internal image impedances matched throughout, and, as a consequence, the terminal image impedance has the flat m-derived image impedance characteristic mentioned above. Therefore, the pass band insertion loss is relatively small and a flat pass band response is obtained. Furthermore, a point of extremely high attenuation is reached at a frequency slightly above the cut-off frequency in order to produce a sharp cut-off characteristic. A high increasing attenuation of the frequencies beyond the pass band is provided in a well known manner by the intermediate T sections of the filter.

The values of the various inductive and capacitive elements as designated in the circuit of Fig. 2 can be determined from the following formulas:

$$L_1 = L_8 = \left[\frac{1-m^2}{8m}\right]\frac{R}{\pi f_c}$$

$$L_2 = L_7 = \frac{mR}{2\pi f_c}$$

$$L_3 = L_4 = L_5 = L_6 = \frac{R}{\pi f_c}$$

$$C_1 = C_4 = \frac{m}{2\pi f_c R}$$

$$C_2 = C_3 = \frac{1}{\pi f_c R}$$

where m is the design parameter, usually assigned a value of 0.6; R is the load resistance; and f_c is the highest frequency of the pass band.

The proper values of inductance and capacitance in the filter 10 shown in Fig. 1 as determined from the above formulas are obtained by a proper construction of the various inductive and capacitive sections of the filter 10. I have indicated by similar reference letters the various sections along the axis of the filter 10 which correspond to the various inductive and capacitive elements in the circuit diagram of Fig. 2.

The actual length of each section can be easily determined. The inductance of the sections 17 having an inner diameter d_1, can be found from the approximate relationship:

$$L = \frac{\log D/d_1}{500} \text{ microhenries per centimeter of axial length}$$

where D is the inner diameter of the outer conductor 11. The capacitance of the sections represented by C_1, C_2, C_3 and C_4, having an inner diameter d_2 can be found from the approximate relationship:

$$C = \frac{1}{1.8 \log D/d_2} \text{ micro-microfarads per centimeter of axial length}$$

I have found, however, that the length of the capacitive sections should actually be slightly smaller than the mathematically determined value due to the fringing of the electrostatic flux lines at the ends of the cylinders. The proper length of the inductance coil 19 connected between the conducting member 18 and the inner conductor 13 at either end of the filter 10, and comprising the inductances L_1 and L_8, can be easily determined by the use of known methods and charts.

It is to be understood that although I preferably employ a dielectric cylindrical member 12 in order to maintain the inner and outer conductors of the filter 10 in a proper spaced apart relation, many other supporting means well known to the art may alternatively be employed. It is also to be understood that although I have shown one particular embodiment of my invention many modifications may be made and I therefore maintain by the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A high frequency ladder type filter comprising co-extensive inner and outer conductors, means providing a plurality of axially separated sections of relatively small interconductor spacing within said filter to produce distributed shunt capacitances of predetermined magnitudes, means providing a plurality of axially separated sections of relatively large interconductor spacing within said filter alternating with said first sections to produce distributed series inductances of predetermined magnitudes, a pair of conducting members respectively located at either end of said filter intermediate said inner and outer conductors but out of direct electrically conductive contact therewith, each of said conducting members having an outer peripheral surface in closely spaced relation to the inner peripheral surface of said outer conductor to provide a shunt capacitance therewith, and inductance means connected between said inner conductor and each of said conducting members to provide terminating sections including a shunting series resonant network.

2. A high-frequency ladder type filter comprising a tubular outer conductor, a substantially concentric inner conductor, said inner conductor having at least one enlarged section extending radially outward from said inner conductor, said enlarged section being axially spaced from either end of said filter, a pair of identical annular conducting members respectively located at either end of said filter between said inner and outer conductors but out of direct electrically conductive contact therewith, said enlarged section and said conducting members having outer peripheral surfaces in closely spaced relation to the inner peripheral surface of said outer conductor to produce distributed shunt capacitances of predetermined magnitudes, said enlarged section being separated from each of said end sections by sections of greater interconductor spacing constituting distributed series inductance of predetermined magnitudes, and a pair of identical inductance means connected between said

inner conductor and each of said annular conducting members respectively, each of said inductance means cooperating with said conducting members to provide a relatively flat terminal image impedance.

3. A high frequency ladder type filter comprising a tubular outer conductor, a substantially concentric inner conductor having a plurality of axially spaced enlarged portions separated from each other and from either end of said filter by reduced portions to provide axially spaced filter sections of relatively large interconductor spacing alternating with filter sections of relatively small interconductor spacing, a pair of cylindrical conducting members respectively located at either end of said filter within said outer conductor in radially spaced relation to said reduced end portions of said inner conductor, each of said conducting members being of substantially identical construction and having an outer peripheral surface in closely spaced relation to the inner peripheral surface of said outer conductor to provide end sections of relatively small interconductor spacing, insulating means located between said conducting members and said outer conductor for maintaining said closely spaced relation, and a pair of substantially identical inductance coils connected respectively between each of said cylindrical conducting members and an adjacent reduced end portion of said inner conductor to provide a shunting series resonant terminating network.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,423,797	Reber	July 8, 1947
2,438,913	Hansen	Apr. 6, 1948
2,521,842	Foster	Sept. 12, 1950

FOREIGN PATENTS

Number	Country	Date
245,847	Germany	Nov. 30, 1946

OTHER REFERENCES

"An Ultra-High-Frequency Low-Pass Filter of Coaxial Construction," by Cuccia and Hegbar. Pub. in RCA Review in December 1947, vol. VIII, No. 4 (pages 743–750 incl.) 178–44.2A.

"Communication Circuits," by Ware and Reed. Copyright 1942. Pub. by John Wiley and Sons, Inc., New York. Copy in Div. 69.