

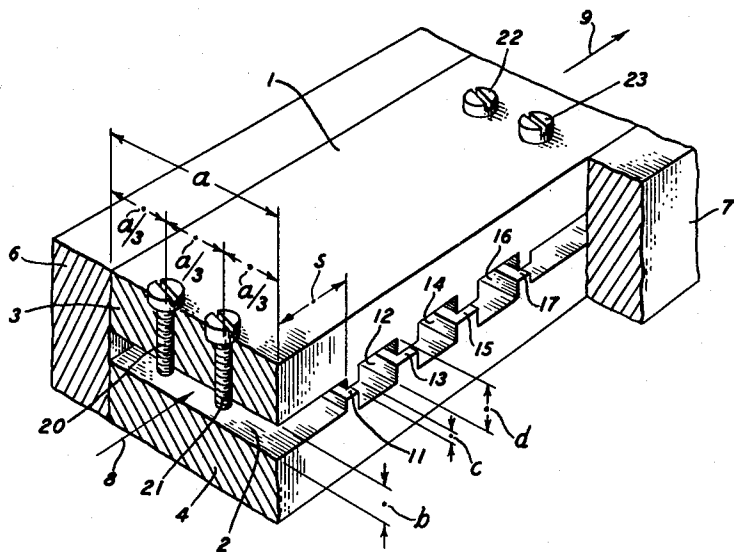
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WAVE FILTER

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1

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WAVE FILTER

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This invention relates to wave transmission networks and more particularly to a wave-guide filter of the varying-impedance type with impedance-correcting means.

The principal object of the invention is to improve the impedance and decrease the insertion loss in the transmission band of a wave-guide filter of the varying-impedance type. A further object is to maintain high attenuation in the suppression band of the filter while reducing the loss in the transmission band.

A wave guide has a natural high-pass cut-off frequency. If a low-pass structure with a higher cut-off frequency is associated with the wave guide, a band-pass filter is obtained. The low-pass structure may be a filter of the varying-impedance type built into the wave guide. The filter comprises tandem-connected sections of guide having characteristic impedances which are alternately lower and higher, or alternately higher and lower, than the terminal impedances between which the filter is designed to operate. If the wave guide is of the hollow-pipe type, with a rectangular cross section and a fixed width, the desired impedances may be obtained by making the height alternately less and greater than the height of the guide into which the filter is inserted. Band-pass wave-guide filters of this type are disclosed in Very High-Frequency Techniques, compiled by the Staff of the Radio Research Laboratory of Harvard University and published by McGraw-Hill Book Company, Inc., New York and London, 1947, volume II, pages 731 to 736.

In such a filter, each change in height of the wave guide produces a field disturbance. For the dominant transverse electric mode (TE_{10}), which is ordinarily used, each discontinuity is equivalent to the parasitic capacitive shunt susceptance. Within the filter, the effects of these susceptances may be annulled by modifying the lengths of the low-impedance sections of guide. The discontinuity susceptances at the ends of the filter, however, are not amenable to this treatment. Their presence increases the loss and degrades the impedance match in the transmission band of the filter.

In accordance with the present invention, these end susceptances are compensated for, and the impedance match in the band improved, by adding an annulling susceptance at one or both ends of the filter. These preferably take the form of capacitive screws or probes inserted into the guide through a wider wall. For best performance, the probes are symmetrically placed at points optimally spaced from each end of the filter. In order to prevent the generation of unwanted higher-order modes, which would decrease the attenuation in the suppression region of the filter, each susceptance comprises a pair of probes projecting inwardly from a wider wall of the wave guide in the same transverse plane and each spaced from a side wall approximately one-third of the width of the section.

The nature of the invention and its various objects, features, and advantages will appear more fully in the following detailed description of a typical embodiment illustrated in the accompanying drawing, the single figure of which is a perspective view, partly cut away, of a wave-guide filter of the varying-impedance type with im-

2

pedance-correcting means in accordance with the present invention.

The low-pass filter 1 is built into a wave guide 2 having a rectangular cross section of width a and height b . The wider walls of the guide 2 are formed by an upper block 3 and a lower block 4. The narrower side walls are constituted by the plates 6 and 7, which may be secured to the blocks 3 and 4 in any suitable manner. Electromagnetic waves are introduced into the guide 2 at one end, as indicated by the arrow 8, pass through the filter 1, and are propagated to a suitable load, as indicated by the arrow 9.

The filter 1 comprises seven tandem-connected sections of wave guide, numbered 11 through 17, having characteristic impedances which are alternately lower and higher than that of the guide 2 in which the filter is inserted. Since all of these sections have the same width a , the characteristic impedance is proportional to the height. Each of the sections 11, 13, 15, and 17 has a height c which is less than b , and therefore an impedance less than that of the connecting guide 2. Each of the intervening sections 12, 14, and 16 has a height d which is greater than b , and a higher impedance than the guide 2.

The guide 2 is a high-pass structure with a cut-off for the dominant mode at some frequency f_1 . As explained in the above reference, the filter 1 is designed as a low-pass structure, with a cut-off frequency f_2 higher than f_1 . The combination of wave guide and filter thus has a band-pass characteristic with the transmission band extending between f_1 and f_2 .

A change in the height of a rectangular wave guide, as from b to c or from c to d , is equivalent to a parasitic shunt capacitive susceptance. Each of the parasitic susceptances appearing between two adjacent sections of the filter can be compensated by properly adjusting the lengths of the associated low-impedance section. For example, the increase in height from c to d at the junction of the sections 11 and 12 may be taken care of by modifying the length of section 11. However, the discontinuity between the guide 2 and the low-impedance sections 11 and 17 at the ends of the filter 1 can not be treated in this way.

In accordance with the present invention, impedance-correcting means are added to take care of the end parasitic susceptances and also to improve the impedance match between the filter 1 and the guide 2 in the transmission band. As shown, these means comprise a pair of probes or screws 20, 21 at the input end and a similar pair 22, 23 at the output end. It will be understood that a single pair, at either end of the filter 1, may be used, but the two pairs provide symmetry, require less compensation at each end, and give a better impedance match between the filter and the guide. Each of the probes 20, 21, 22, and 23 projects inwardly through a tapped hole in a wider wall 3 of the guide 2. The probes forming each pair are in the same transverse plane, are spaced a distance s from the end of the filter 1, and have approximately equal projections.

There exist many combinations of probe penetration and distance s that will provide perfect impedance match at a particular frequency. The combination that usually results in the best impedance match over a specified region of the filter pass band is that combination of penetration and distance providing perfect match at the center frequency, f_0 , of the region, with the least probe penetration. The following relations apply to this case.

The magnitude, ρ , and the angle θ , of the complex reflection coefficient at the frequency f_0 at one end of the uncorrected low-pass filter 1 when terminated in the impedance of the guide 2 may be calculated or measured. For a perfect impedance match at f_0 , the minimum normalized susceptance, b_{min} , of each pair of

probes, corresponding to minimum penetration, is given by the expression

$$b_{\min} = + \sqrt{2 \left(\frac{1}{\sqrt{1-\rho^2}} - 1 \right)} \quad (1)$$

When $b_{\min}$ is known, the required penetration may be determined.

The distance s is found from

$$s = \frac{\lambda_g}{4} \left[\frac{1}{\pi} \left(\tan^{-1} \frac{2}{b_{\min}} + \theta \right) + 2n + 1 \right] \quad (2)$$

where λ_g is the wavelength in the guide 2 at f_c and n is an integer. The value of n is chosen to make s equal at least to $\lambda_g/4$, in order to prevent interaction between the probes and the discontinuity at the end of the filter, but not more than $3\lambda_g/4$, to provide an impedance match over the broadest possible band.

The maximum internal height, d , of the filter is usually made sufficiently small so that over the frequency range of interest as few as possible of the higher order modes excited by the discontinuities of the filter will propagate. However, the mode cut-off frequencies for the higher order TE_{m0} modes, where m is greater than one, depend not on the height but only on the width a of the filter 1 and the guide 2. The dimension a is always large enough to allow the propagation of the higher order TE_{m0} modes, if these modes are excited by the incident energy. The transmission characteristic of the filter for these higher modes would be considerably different than for the assumed dominant mode. In particular, the attenuation in the suppression band may be lowered considerably. The geometry of the filter 1 discourages the conversion of energy of the dominant mode into these higher order TE_{m0} modes, but, unless precautions are taken, the impedance-correcting means may perform such a conversion. Therefore, as a further important feature of the invention, the center of each of the probes of a pair is spaced a third of the width a from a narrower side of the guide 2. Thus, the probe 20 is spaced $a/3$ from the side 6 and the probe 21 $a/3$ from the side 7. The space between the probes is also $a/3$. The probes will react as shunt capacitance to the dominant mode but will not couple this mode to any TE_{m0} modes where m is even or any odd multiple of three. There will be no coupling to the even modes because of the symmetry of the probes with respect to the transverse plane, and no coupling when m is an odd multiple of three because the probes 20 and 21 are located at points where the electric fields of these modes are zero. Therefore, the first higher-order TE_{m0} mode to which energy of the incident dominant mode will couple is TE_{50} . The guide cut-off frequency for this mode is five times f_1 , and will almost always be far out in the attenuating region of the filter 1 and in a relatively unimportant frequency range.

What is claimed is:

1. In combination, two end sections of rectangular wave guide having unequal transverse dimensions, a low-pass wave filter inserted therebetween, and impedance-correcting means associated with one of the end sections, the filter comprising a plurality of sections of rectangular wave guide connected in tandem, the filter sections having characteristic impedances which are alternately lower and higher than that of the end sections, said impedance-correcting means comprising a pair of probes projecting inwardly from a wider wall of the end section in the same transverse plane, and the center of each of the probes being spaced from a side of the end section a distance approximately equal to one-third of the width of the end section.

2. In combination, two end sections of rectangular wave guide having unequal transverse dimensions, a low-pass wave filter inserted therebetween, and impedance-correcting means associated with each of the end sections, the filter comprising a plurality of sections of rectangular wave guide connected in tandem, the filter sec-

tions having characteristic impedances which are alternately lower and higher than that of the end sections, each of the impedance-correcting means comprising a pair of probes projecting inwardly from a wider wall of the end section in the same transverse plane, and the center of each of the probes being spaced from a side of the end section a distance approximately equal to one-third of the width of the end section.

3. A band-pass wave filter comprising a plurality of tandem-connected sections of rectangular wave guide having the same width and unequal transverse dimensions, the intermediate sections having heights which are alternately less and greater than the height of the end sections, and impedance-correcting means comprising a pair of probes projecting inwardly from a wider wall of one of the end sections in the same transverse plane, the spacing between the probes and the distance between each probe and the nearer side of the end section being approximately equal.

4. A band-pass wave filter comprising a plurality of tandem-connected sections of rectangular wave guide having the same width and unequal transverse dimensions, the intermediate sections having heights which are alternately less and greater than the height of the end sections, and impedance-correcting means associated with each of the end sections, each of the impedance-correcting means comprising a pair of probes projecting inwardly from a wider wall of the end section in the same transverse plane, and the spacing between the probes and the distance between each probe and the nearer side of the end section being approximately equal.

5. A band-pass wave filter comprising a plurality of tandem-connected sections of rectangular wave guide having the same width and unequal transverse dimensions, the intermediate sections having heights which are alternately less and greater than the height of the end sections, and impedance-correcting means associated with each of the end sections, each of the impedance-correcting means comprising a pair of probes projecting inwardly from a wider wall of the end section in the same transverse plane, and the plane being spaced from the adjoining section a distance s chosen to provide an impedance match between the end section and the adjoining section at a selected frequency f_c in the transmission band for a minimum penetration of the probes.

6. A filter in accordance with claim 5 in which s is equal at least to one-quarter but not more than three-quarters of a wavelength at f_c in the end section.

7. A filter in accordance with claim 5 in which the center of each of the probes is spaced from a side of the end section a distance approximately equal to one-third of the width of the end section.

8. In combination, two end sections of rectangular wave guide having unequal transverse dimensions, a wave transmission network inserted between the sections, the network comprising sections of rectangular wave guide and having a parasitic shunt susceptance at each end, and means associated with each of the end sections for compensating the parasitic shunt susceptance comprising a pair of probes projecting inwardly from a wider wall of the end section in the same transverse plane, the center of each of the probes being spaced from a side of the end section a distance approximately equal to one-third of the width of the end section.

References Cited in the file of this patent

UNITED STATES PATENTS

2,540,488	Mumford	Feb. 6, 1951
2,629,015	Reed	Feb. 17, 1953
2,738,468	Miller	Mar. 13, 1956
2,804,599	Broussard	Aug. 27, 1957

OTHER REFERENCES

- Microwave Theory and Techniques, Reich et al. 1953
 75 Van Nostrand, pages 336-339 and 375-381.