IV-2. High-Power Filters for the Suppression of Spurious Frequencies

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The rapidly increasing number of high-power transmitters are creating a serious problem in radio frequency interference.[1] A large part of this problem is the emission of harmonic and other spurious frequencies, which can be eliminated without affecting the signal bandwidth of the transmitter. Various types of filter have been investigated both analytically and experimentally; this paper will review some of this work. The intention is to compare different situations and different filters, rather than to treat any one filter in detail.

It is possible to reduce the emission of spurious power by design modifications to the high-power tube, or by incorporating a filter as an integral part of the output circuit of the tube, but this approach will not be further discussed here.

The more usual approach is to fit a filter into the transmission line between the transmitter and the antenna. Factors which must be considered are the location, size and complexity of the filter, as well as its power-handling capability, VSWR and dissipation loss in the passband, VSWR and attenuation in the stop band, rate of cut-off, passband and stop-band bandwidth, as well as whether it should be an absorbing or a reflecting filter in the stop band.

Leaky-wave filters[2,3,4] have been used extensively where low-pass absorbing filters are specified. They are well suited to absorbing undesired frequencies from roughly the second to the fifth harmonic, inclusive. Each

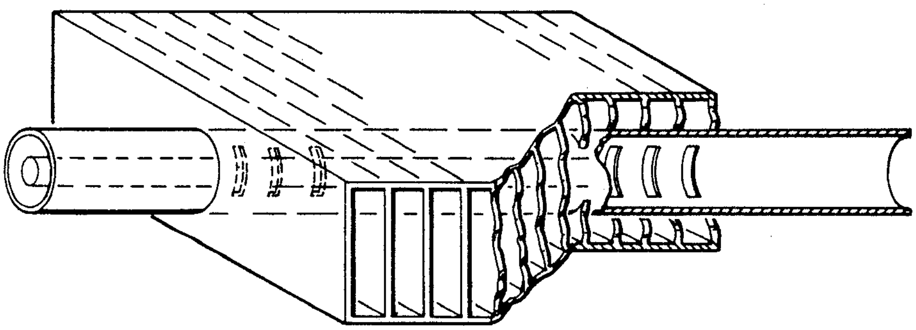

Fig. 1. Leaky-wave filter in coaxial line (from *Microwave J.*, Ref. 4).

filter requires a multiplicity of waveguide and absorbing loads, into which the spurious power is coupled. This coupling decreases with increasing frequency, and so the attenuation falls off as the frequency increases. A leaky-wave filter in coaxial line is shown in Fig. 1.[4]

Waffle-iron filters[5,6,7] are low-pass reflecting filters. They are compact and can be made to yield high attenuation over a wide stop-band. Power handling can be a problem, and the reflection (rather than absorption) in the stop-band is sometimes undesirable. A waffle-iron filter consisting of four separate filters in parallel to increase the peak power capability is shown in Fig. 2.

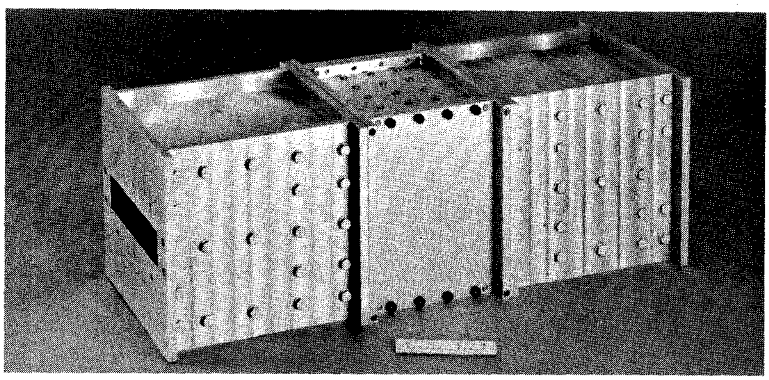

Fig. 2. Four-layer waffle-iron filter.

A waffle-iron filter, or other similar reflection filter, can be combined with a *harmonic pad* to effectively turn the reflection filter into an absorption filter. A harmonic pad is a device with (ideally) no attenuation in the pass-band, and with a few decibels of attenuation in the stop-band; it can be shown that three or more decibels should be sufficient for most applications. Harmonic pads may consist of short sections of leaky-wave filter, or they may be made from *directional couplers.*[8] Two 3-db short-slot couplers have been combined into a 0-db coupler (Fig. 3), making a very satisfactory harmonic pad.[8] Leaky-wave pads attenuate better at lower frequencies (around the 2nd and 3rd harmonics), while directional-coupler pads attenuate better at higher frequencies (beyond about the 4th harmonic).

Bandpass filters consisting of coupled cavities can be made to reject spurious frequencies close to the transmitter passband.[19] The narrow bandwidth desirable in this case reduces the power-handling capability, and for the narrowest bandwidths may further complicate the filter by requiring it to be tunable.[9] A high-power tunable microwave filter using three TE_{01}-mode cylindrical cavities is shown in Fig. 4.[9]

Band-stop filters are useful where transmitter A interferes with a particular system B which operates in a frequency band to which transmitter A contributes spurious power. Then a band-stop filter may be fitted to the output of transmitter A to suppress those frequencies which are in the operating band of system B. One type of waveguide[10,11] band-stop filter consists of stubs coupled to the main line and spaced a quarter wavelength apart at

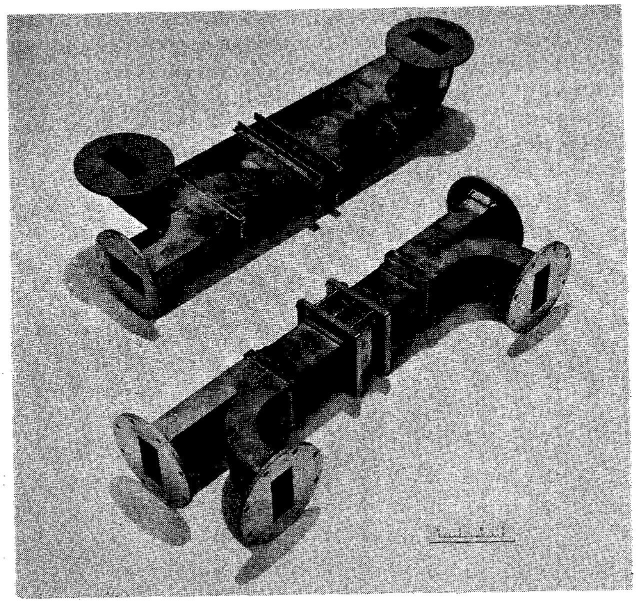

Fig. 3. Short-slot directional couplers used as harmonic pads (from *Microwave J.*, Ref. 8).

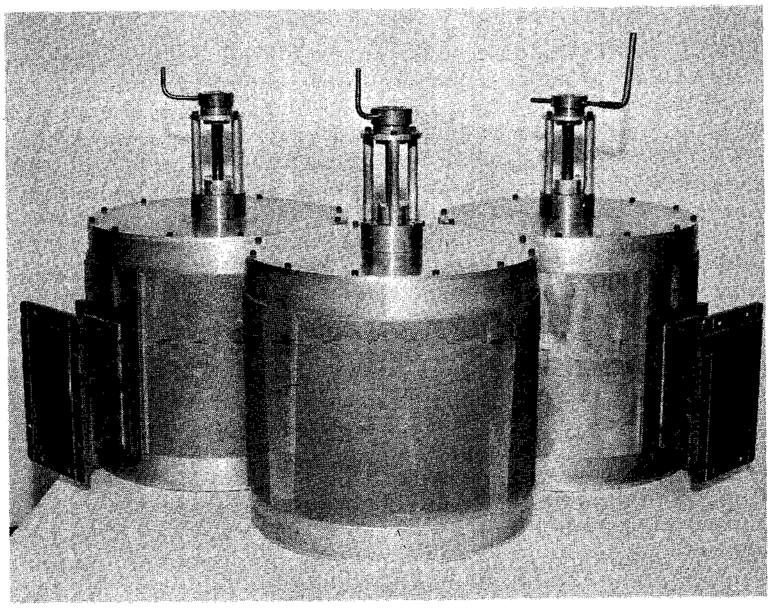

Fig. 4. High-power tunable bandpass filter.

band center. Another type of waveguide band-stop filter now being considered should be more suitable for high-power applications. This consists of a stepped-impedance filter.

This review is not exhaustive. For instance, no mention has been made of frequency selective ferrite attenuators,[12] or filters using cutoff waveguides,[13,14] nor has mention been made of methods of measuring the spurious power.[15-18]

ACKNOWLEDGMENT

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REFERENCES

1. V. G. Price and W. A. Edson, "A Survey of High Power Microwave Filters," *Electronic Ind.*, Vol. 22, pp. 106–110 (November 1963).
2. V. Met, "Absorptive Filters for Microwave Harmonic Power," *Proc. IRE*, Vol. 47, pp. 1762–1769 (October 1959).
3. V. G. Price, et al., "Harmonic Suppression by Leaky-Wall Waveguide Filter," *1959 IRE WESCON Convention Record*, Pt. 1, pp. 112–118.
4. E. G. Cristal, "A 1-5/8 inch Coaxial Leaky-Wave Filter for the Suppression of Spurious Energy," *Microwave J.*, Vol. 6, No. 9, pp. 72–76 (September 1963).
5. E. Sharp, "A High-Power Wide-Band Waffle-Iron Filter," *IEEE Trans. on Microwave Theory and Techniques*, Vol. MTT-11, pp. 111–116 (March 1963).
6. L. Young and B. M. Schiffman, "New and Improved Types of Waffle-Iron Filters," *Proc. IEE* (London), Vol. 110, pp. 1191–1198, July 1963.
7. L. Young, "Postscript to Two Papers on Waffle-Iron Filters," *IEEE Trans. on Microwave Theory and Techniques*, Vol. MTT-11, pp. 555–557 (November 1963).
8. L. Young, "Waveguide 0-db and 3-db Directional Couplers as Harmonic Pads," *Microwave J.*, March 1964.
9. E. M. T. Jones, "A Three Cavity High-Power L-Band Filter Tunable from 1250–1350 Mc," Technical Note 2, SRI Project 2797, Stanford Research Institute, Contract AF 30(602)-1998, February 1961.
10. L. Young, G. L. Matthaei and E. M. T. Jones, "Microwave Band-Stop Filters with Narrow Stop Bands," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-10, pp. 416–427 (November 1962).
11. B. M. Schiffman and G. L. Matthaei, "Exact Design of Band-Stop Microwave Filters," *IEEE Trans. on Microwave Theory and Techniques*, January 1964.
12. B. I. Duncan, et al., "S- and L-Band Ferrite Attenuators," Final Report, Contract AF 30(602)-1724, May 1960.
13. E. N. Torgow, "Hybrid Junction Cut-off Waveguide Filters," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-7, pp. 163–167 (January 1959).
14. P. A. Rizzi, "Microwave Filters Utilizing the Cut-off Effect," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-4, pp. 36–40 (January 1956).

15. V. G. Price, "Measurement of Harmonic Power Generated by Microwave Transmitters," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-7, pp. 116–120 (January 1959).
16. E. Sharp and E. M. T. Jones, "A Sampling Measurement of Multimode Waveguide Power," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-10, pp. 73–82 (January 1962).
17. J. J. Taub, "A New Technique for Multimode Power Measurement," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-10, pp. 496–505 (November 1962).
18. B. M. Schiffman, L. Young and R. B. Larrick, "Thin-Film Waveguide Bolometers for Multi-Mode Power Measurement," *IEEE Trans. on Microwave Theory and Techniques*, March 1964.
19. H. A. Wheeler, H. L. Bachman, "Evacuated Waveguide Filter for Suppressing Spurious Transmission from High-Power S-Band Radar," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-7, pp. 154–162 (January 1959). (Correction, p. 369, July 1959.)