CABLE FILTERS — Band Pass or Band Stop in the Wire

Cable filters, assembled from segments of transmission line, have been in use since the 1930's for filtering, impedance matching, and diplexing. New technology provides all the various half- and quarter-wavelength conductor elements for such a filter fitting inside a single braided shield, with automation greatly reducing the cost. To the engineer concerned with EMI, this technology makes available a filter with design flexibility. It can be made to pass or reject a notch or band from 30 MHz to 1 GHz. Multiple frequency traps are easily built into a single cable.

Because of its form, the cable filter also has physical flexibility—it shares most physical properties with regular RG-59. This filter logically replaces a cable connection between two components. In this way it makes practical rejection or isolation ratings of more than 100 dB, while not requiring space within a component. A cable filter maintains good isolation through physically separated input and output; "blowby" is insignificant. To prevent leakage into or out of the cable itself, it can be supplied with foil between two braids for the shield. If the frequency, function, and form of a cable filter is appropriate, cost is no object. In quantity production even a multisection cable filter seldom costs over $10.

Is a Cable Filter for You?

In considering a cable filter for EMI applications, its most obvious constraint is the cable form. Is there room in your design, at an appropriate filtering point, for a cable several wavelengths long? The connection need not be restricted to signal leads as some cable filters can carry 500W continuously (750W intermittantly) in the RG-59 size; more in the RG-6 size. A cable filter thus might replace a line cord and RF filter. Impedance of 50 or 75 ohms is standard. Other values can be made, within the limits of conductor and braid diameters. Filters with impedances of 37.5 to 93 ohms have been produced.

Stability of cable filters is extremely good, as there are no temperature sensitive components. Drift is only 0.01% per degree Fahrenheit. Electrical performance, summarized in Table 1, depends on the dielectric molded into the cable. The four types (A to D) represent a tradeoff between sharpness and rejection. In general, the greater the bandwidth tolerated, the greater the depth of rejection.

Table 1 Performance of cable filter traps

	Filter type A	B	C	D
1 Section				
Bandwidth (%)	3.27	5.80	8.87	14.68
Rejection (dB)	8—14	12—20	14—25	18—27
2 Sections				
Bandwidth (%)	4.33	6.74	10.72	16.50
Rejection (dB)	18—31	25—49	29—55	43—59
3 Sections				
Bandwidth (%)	4.87	7.09	11.36	17.40
Rejection (dB)	28—46	39—73	44—83	62—90
4 Sections				
Bandwidth (%)	6.08	8.15	13.14	19.65
Rejection (dB)	37—65	54—95	66—115	84—120

While Table 1 gives approximate values for attenuation, a more exact "total rejection" rating results from using Figures 1 and 2 with the equation:

$$\text{Total Rejection} = R + (R + r)(n - 1)$$

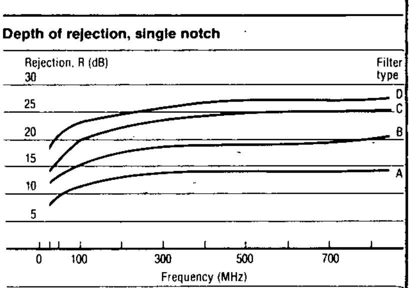

FIGURE 1

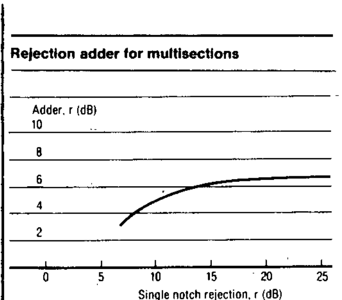

FIGURE 2

where R is the single section notch rejection from Figure 1, r is the "adder" rejection from Figure 2, and n is the number of filter sections in the cable. Bandwidth values in Table 1 are exact. At any design frequency, the minimum bandwidth for a given type of filter design is simply the center frequency multiplied by the percent bandwidth. Stagger tuning of multiple filter sections can substantially broaden the bandwidth. The tradeoff is reduced depth of rejection, as indicated in Figure 3, but more sections (raising n) will increase rejection again.

Examples

The popularity of computerized TV games raises a possibility of interference generated by the RF modulator that converts the digital display into a signal for a TV's antenna terminal. If the game were intended for a single channel, a band pass cable filter (from the modulator to the TV set) could attenuate most other channels by more than 50 dB. Within the 6 MHz band for the one channel, 2 for example, loss would be less than 3 dB (Figure 4). The slope of the response curve either side of the pass band is quite steep, exceeding 60 dB per octave.

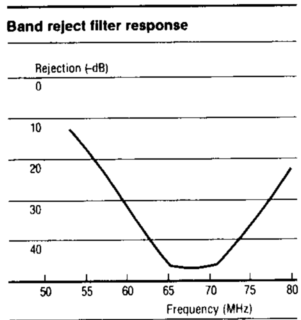

FIGURE 3

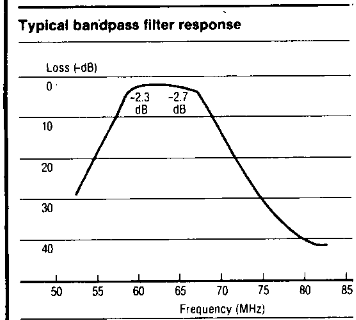

FIGURE 4

To realize this example would require a 9 ft. cable filter; for other channels, cable length is directly proportional to wavelength and number of sections.

The most popular application of cable filters to date is in the cable TV industry. When a subscriber does not buy a specific premium channel or block of channels, like Home Box Office, the cable operator inserts a filter cable as part of the drop line from the distribution cable to the subscriber's set. The trap prevents reception of those pay channels.

Even outside, exposed to weather, temperature changes, and physical stress on a pole, cable filters can deliver at least 65 dB attenuation. At that reduced level the premium channel becomes indistinguishable from background noise; it effectively never enters the subscriber's premises. Other channels see the filter as a standard coax cable with an insertion loss of less than 1 dB.

How Cable Filters Work

A notch or band stop cable filter operates on the same principle as the transmission line filter where a quarter wavelength stub is attached between the line and ground. Direct connection in this manner results in a fixed bandwidth. Filter cable capacitively couples the quarter wavelength stubs to permit variable bandwidth. Both line conductor and the stubs are built as continuous, parallel wires inside a single braided shield. During manufacture, one of the wires is cut at appropriate intervals into quarter wavelength sections. Each section is grounded at one end to the braid. Unused sections of the second wire simply float.

The band pass cable filter is based on the interdigital stripline filter, in which half wavelength elements arranged in staggered vertical arrays transmit the signal via electromagnetic coupling. The cable equivalent staggers the arrays horizontally, on three levels. Each level originates as a continuous solid wire conductor when the cable filter is extruded during manufacture. The three center wires are then cut as needed to form half and quarter wavelength elements. Since the spacing between conductors is fixed, the coupling between elements is controlled by adjusting the amount of overlap at the ends of adjacent elements. As with notch filters, unused sections of the center conductors float without electrical effect.

Making the Decision

If your interference problem is keeping in (or out) all but a single band of frequencies in the VHF/UHF region, or if there are specific frequencies to trap, then a cable filter should be considered. A physical layout of the system that includes a standard coax cable is a strong indication that the cost/benefit ratio is optimized by a cable filter.

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