Monolithic Crystal Filter Application in Amateur VHF Repeaters

BY JOSEPH M. HOOD,* K2YAH

RECEIVER FRONT END intermodulation-distortion products (IMD) in vhf repeater service can be a difficult problem to resolve. Even with the best commercial-quality receiver using field-effect transistors, a repeater located in a metropolitan area with a high density of 150- to 160 MHz business-band signals has a high probability of experiencing problems from receiver front-end IMD. Furthermore, unless the repeater receiver is located some distance from population centers, front-end overload problems from strong adjacent-channel amateur signals can also be severe.

Solutions – Band-pass Cavity

A band-pass cavity network can be quite effective in eliminating the IMD problem from signals which are several MHz removed from the repeater input frequency. However, if we refer to Fig. 1, which shows the typical attenuation versus frequency characteristics of a band-pass cavity, it is apparent that the cavity offers very little attenuation of adjacent-channel amateur signals. Even if two cavities are used, the selectivity is not sufficiently improved for adjacent-channel problems. Furthermore, the band-pass network does little to attenuate the repeater transmitter noise sometimes experienced with 600-kHz input-to-output frequency spacing.

Cost is another consideration; a typical price for a single band-pass cavity at 146 MHz is in the $100 region. The selectivity-per-dollar quotient for a band-pass cavity network is 1.8 (a Q of 180 per $100 cost). As will be shown, this is poor when compared to the monolithic crystal filter.

Solution – The Monolithic Crystal Band-pass Filter

The crystal-filter approach to reducing or eliminating IMD and overload offers several significant advantages. Obviously, the selectivity of a monolithic crystal filter is superior to that of a band-pass-cavity network as can be seen in Fig. 2. Response is down 3 dB at ±19 kHz (the approximate bandwidth of a 6 kHz, fm signal) which means the filter Q is approximately 7300. Response is down 40 dB at ±38 kHz and goes to an attenuation exceeding 50 dB at frequencies greater than 60 kHz from the filter center frequency.

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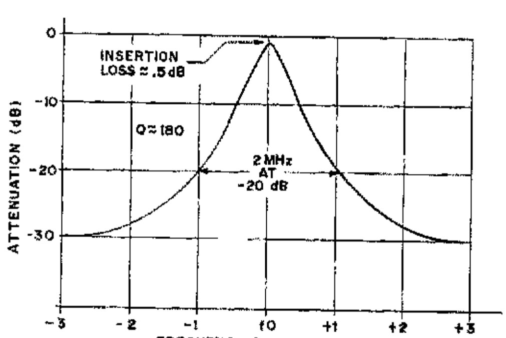

Fig. 1 – A typical response curve of a single cavity shows a bandwidth of 2 MHz at the –20 dB points.

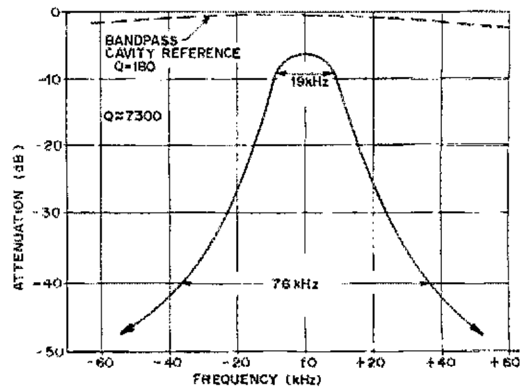

Fig. 2 — The response curve for the Piezo Technology TM-4133VBP crystal filter shows a more narrow characteristic. At the −3 dB points the bandwidth is 19 kHz, and at −40 dB it is 76 kHz. The improved selectivity is an aid in rejecting adjacent-channel energy as well as signals from strong out-of-band transmitters in the commercial or entertainment services.

Physical size is also an advantage. The band-pass cavity will require a volume of 1.5 cubic feet. The monolithic filter and associated components can be packaged in one-third cubic feet of space with the filter itself requiring a volume of approximately 1 × 1-1/2 × 3 inches.

The crystal filter also has some disadvantages and characteristics which one should be well aware of before proceeding on this approach. The most obvious disadvantage is that, unlike a cavity network, the filter cannot be tuned. Once a filter is purchased for a given input frequency, that frequency is the only one it is good for. However, since the input and output frequencies of amateur repeaters should be selected by first consulting the area repeater council (to reduce the chance that the selection will result in an interference problem within the area) and since frequencies so chosen become unchangeable for obvious reasons, this disadvantage is small.

The crystal filter has an insertion loss which can be considerable. The particular model in use in Rochester on the WR2AEI repeater is a model TM-4133 VBP manufactured by Piezo Technology Incorporated of Orlando, Florida. This model is specified to have an insertion loss less than 6.0 dB. The insertion loss of our particular filter was 5.5 dB as measured with a Hewlett Packard model 3200B vhf oscillator, KAY model 431C step attenuator and Tektronics 7L12 spectrum analyzer. This magnitude of insertion loss in the receiver input is, of course, intolerable in the repeater system. However, the problem can be overcome with a properly designed preamplifier inserted between the filter and the receiver input. The preamplifier design details will be discussed later.

The crystal filter is designed for operation in a 50-ohm system. This means that, in order to meet its frequency-response and insertion-loss requirements, the filter must see a 50-ohm source and load impedance. If these impedances are not tightly controlled, the filter may not perform as specified. Since many receiver inputs do not present a true 50-ohm VSWR load, the preamplifier used to make up the insertion loss also serves as a controlled termination for the filter, thus eliminating receiver input-impedance variations as a source of trouble.

The crystal filter is also an extremely delicate device. It cannot absorb large amounts of power and survive the experience. The TM-4133 VBP filter specification states that the filter will not

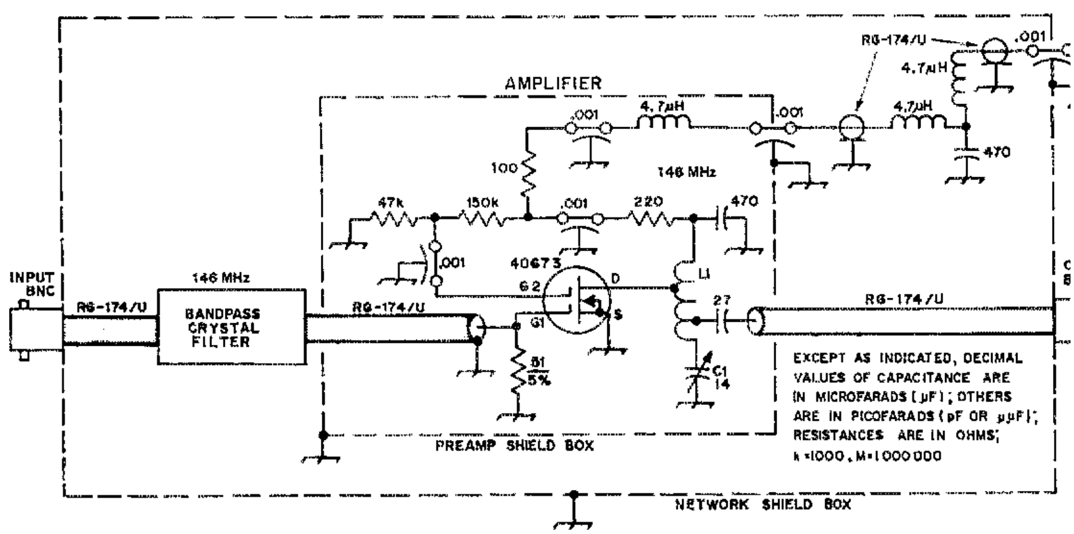

Fig. 3 — Schematic diagram of the preamplifier used in conjuction with the filter. The amplifier makes up for the insertion loss of the filter as well as providing a proper termination.

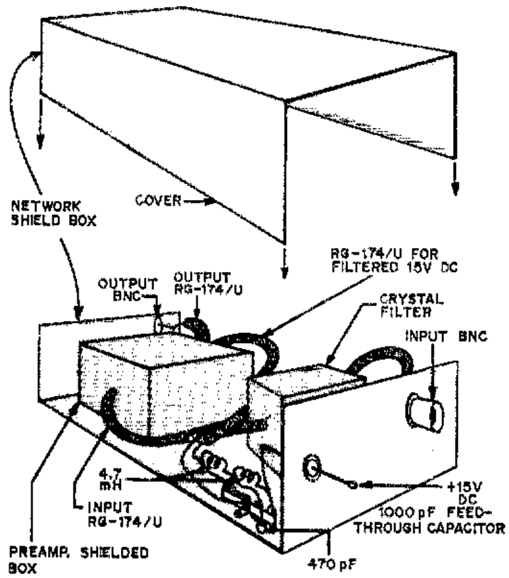

Fig. 4 — The crystal filter and the preamplifier are housed in individual shielded boxes, and the whole assembly is placed in a larger metal enclosure. Good shielding and filtering are essential to proper operation of the filter/preamplifier combination ahead of a repeater receiver.

withstand power in excess of 10 milliwatts at its design center frequency. This should be no problem in repeater applications where great care is taken to maximize the transmitter to receiver isolation. In fact, unless the power level at the receiver input is several orders of magnitude less than 10 milliwatts, the repeater will experience terminal desensitization. Seriously, though, if a shared tower is used for the repeater and other services have antennae in close proximity to the receiving antenna or feed line, a measurement of the transmitter power coupled into a 50-ohm termination at the receiver end of the feed line is in order. If power in excess of 10 mW at any frequency is encountered, a band-reject or suck-out cavity tuned to the power-source operating frequency and placed in the receiver-input feed system is in order.

Preamplifier

The insertion loss encountered and the need to provide a known 50-ohm termination for the crystal filter make the use of a preamplifier between the filter and the repeater receiver input mandatory. The preamplifier should have the following characteristics:

1) Gain of 6 dB minimum, 8 dB maximum.
2) Input impedance of 50 ohms.
3) High linearity – (low cross modulation/intermodulation susceptibility).
4) Noise figure less than 4 dB.
5) No neutralization – unconditionally stable.
6) Operation from +15 V dc supply.
7) Output network compatible with most receiver inputs.

A 40673 dual-gate MOSFET was selected for the task. This device has cross-modulation performance characteristics superior to most bipolar and junction field-effect transistors and has a low noise figure. The preamplifier circuit details are shown in Fig. 3.

The preamplifier was constructed on an etched circuit board and mounted inside a small 1-1/2 × 2-1/2 × 2 inch aluminum Minibox. A length of RG-174/U coaxial cable was brought out through the enclosure for input and output connections. The +15 V supply feedthrough capacitor was mounted in the enclosure wall. Constructional technique is very important. Use good quality, low inductance feedthrough capacitors where called for and keep all leads short and direct. To minimize lead length the gate 2 bypass capacitor body was soldered directly to the ground foil of the circuit board with one of its ungrounded terminals touching the gate 2 pad for later soldering to the 40673.

A terminated input configuration was selected to minimize the inductive and capacitive coupling effects between input and output circuits. Also, a tuned circuit at the input would add no additional selectivity to the system since the crystal-filter Q is much greater than any tuned LC network.

Network Packaging

When completed and tested, the preamp and crystal filter are mounted in a larger 2 × 4 × 6 inch aluminum enclosure as shown in Fig. 4. Additional rf filtering is added to the +15 V line as shown in Figs. 3 and 4. This filtering is important since any rf leakage into the package degrades the performance of the system. Shielding the +15 V line back to the supply should be considered.

Network Performance

The performance of the amplifier and crystal filter network in the WR2AEI repeater has been excellent. The preamplifier gain was equal to the filter insertion loss resulting in a net insertion loss of zero for the system. Our receiver IMD problems have been greatly reduced and susceptibility of the repeater receiver to strong adjacent-channel signals has been eliminated.

A check of the filter frequency response with the vhf oscillator and 7L12 spectrum analyzer showed that the response, when properly terminated, was identical to the response when terminated by the preamplifier. The only difference in the two curves was in the insertion loss, which increased to 5.5 dB with the preamplifier removed from the circuit.

Cost

As for cost, the crystal-filter network cost compares very favorably with that of a single

(Continued on page 48)

CONTROL CABLE FOR ANTENNA ROTATORS

Technical Editor, *QST*:

I am writing to bring an item of information to the attention of those readers who are planning to install antenna rotators in the near future. A number of companies are selling a flat cable with polyethylene insulation for use as antenna rotator control cables and are claiming it is appropriate for both indoor and outdoor use. However, the insulation becomes extremely brittle from exposure to an outdoor environment. I have recently replaced a seven-year-old piece of cable and found it to be so brittle that it would crumble to powder in my bare hands. As the insulation breaks down adjacent wires can touch, and damage can result to the rotator (rendering it inoperative in my case). The breakdown first appears as a series of hairline cracks transverse to the direction of the wires.

I have talked to another ham who had the same problem and we both agree that the best types of insulation for cables are vinyl plastic and certain types of rubber, especially neoprene rubber. In addition, the round cables are preferable to the flat cable in many cases because the round cables have each wire separately insulated as well as having a separate layer of insulation for the entire cable, whereas many of the flat cables are merely a piece of plastic with imbedded wires.

The cable I am switching to is a vinyl-insulated cable by Belden which is carried by many stores as well as by Lafayette Radio Electronics. The series includes five-wire cables in both eighteen (8465) and twenty-two (8445) gauge wire, an eight conductor cable (8448) which is excellently suited for Cornell-Dublier Ham-M and CD-44 rotors, as well as a variety of other configurations to suit virtually all types of rotors. However, these are not listed or displayed as rotator cables in most places, but as communications cable or simply as multiconductor cable. The three cables mentioned specifically above are all available from Lafayette Radio Electronics. Use of these cables or similar cables by other manufacturers will result in much longer life for the control cables, probably as long as the antenna feed line itself. – *Bradley A. Ross, WA3FCY, 122 Maple Ave., Bala-Cynwyd, PA 19004.*

BALL-POINT-PEN TEST PRODS

Technical Editor, *QST*:

Using ball-point pens for test prods, as suggested earlier in *QST*,[4] occurred to me a few years ago. My first trial was also my last because in its first use it produced a shock as well as a meter reading. The reason is that, while most plastics have good bulk insulating properties, some of them are capable of absorbing considerable surface moisture. The sweat from my fingers was sufficient to provide the leakage current that convinced me to use commercial prods in the future. – *William Nighman, W4ZSH, 8806 Overhill Rd., Richmond, VA 23229.*

[4] Socci, "Ball-Point Pen Test Prods," *QST*, September, 1974, p. 50.

FEEDBACK

James H. Fox, WA9BLK, writes that because of precise timing relationships, dirty key contacts may cause a dash to be produced when a dot is keyed in the Integrated Keyer/T-R Switch (*QST* for January, 1975). The possibility of this happening can be eliminated by changing four components. Change R2 from 270 Ω to 1500 Ω. Replace CR3 with a 1000-Ω resistor, and CR4 with a 470-Ω resistor. Replace R3 with a silicon diode (1N914 or equiv.); connect the anode to the dot side of the key, and the cathode to pin 6 of U3B.

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In Part I of "The Mavti-'40," *QST* for June 1975, the value of R19 (base of Q8 in Fig. 1) should be shown as 6.8 ohms.

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The following were erroneously listed in Silent Keys for May, 1975: Harvey L. Williams, W6KUP, Joseph W. Bell, W6BJO and Floyd E. Cummings, Jr., W6OSX.

Monolithic Crystal

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cavity. The device we purchased from Piezo Technology Inc. had a price of about $140, including shipping charges. The "preamp" can be built for almost nothing, so a total cost for the network is in the $150 area. This provides a considerably higher selectivity per dollar quotient of 48 (a *Q* of 7300 per $150 cost) than compared to the 1.8 figure attainable with the band-pass cavity.

Installation Tests

A final word about installation and adjustment. The preamplifier should be tuned in the installed configuration in the repeater system. Normal receiver sensitivity measurements and receiver desensitization tests should be made on the system before and after installation to confirm proper operation. The repeater should not cycle when in its operating configuration with its squelch set at threshold, and a weak, *radiated* signal from a nearby source is slowly decreased in amplitude until the receiver squelch just closes, causing the repeater transmitter to go off. If the system cycles it means there is probably some receiver desensitization indicating inadequate receiver to transmitter isolation. Resolution of this problem is discussed in the ARRL *FM and Repeater Handbook*, chapter on Repeater Technical Problems and Cures.

Conclusion

The cost/performance comparison between a cavity system and the crystal-filter network for use in amateur repeater service indicates that, since costs are comparable, the crystal-filter approach should be considered even if a repeater system may only require a cavity network. If care is taken in the design, layout and construction of a crystal-filter/preamplifier network, the result will provide the optimum in receiver front-end selectivity in a smaller package and for about the same expenditure as for a cavity network. QST