The Lenkurt®

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DEMODULATOR

communications and the environment

Proper application of today's communication technology can bring people together and improve the atmosphere in which they live.

Environment includes not only geographic features, but also the people and the subsequent culture of an area. Present communication links can be expanded for environmental channels – voice and video channels for education and exchange of ideas, as well as data channels for earth resources management. This expansion can be realized by utilizing today's communications technology.

Remote data collection and centralized computer analysis of the data can provide an efficient means of measuring, analyzing, and correcting environmental pollution. By providing more channels of communication, more opportunities for expression of ideas through dialogue would be available. These communication channels can be provided by increased two-way video, voice, and data communication.

Pollution Control

Although it is not physically or financially feasible to establish manned laboratories in every geographic location where pollution is most likely to occur, it is possible, by means of a network of unmanned data collection stations, to sample the surroundings and transmit information on air, earth, and water conditions to a central processing laboratory for analysis. In this way, computer technology and remote data acquisition can contribute to pollution control.

Prototype pollution monitoring systems are presently in operation. What look like ordinary navigation buoys are really ocean pollutant detectors. Instrumented buoys, anchored in oceans and inland waterways are equipped with sensor systems and automatic data handling equipment. These unattended buoys are able to measure and transmit such data as water and air temperature, wind speed and direction, and barometric pressure. Such systems are being designed for low-power consumption and long-life expectancy which should provide easily-maintained, low-cost environmental monitoring. A network of ocean monitoring buoys, or stations can communicate with a central processor either over a direct microwave link or via satellite relay links (see Figure 1).

Another pollution detection device now under development employs a patrol aircraft that measures the changes in microwave radiation from the surface of the water (see Figure 2); thereby, determining what the pollutant is – oil or gas – and how thick the spill is.

Similar tests can also be made on the atmosphere to detect air pollution. The proper transmission links permit measurement at many remote locations and processing at one location. Depending upon the results of the analyzed data, the proper corrective

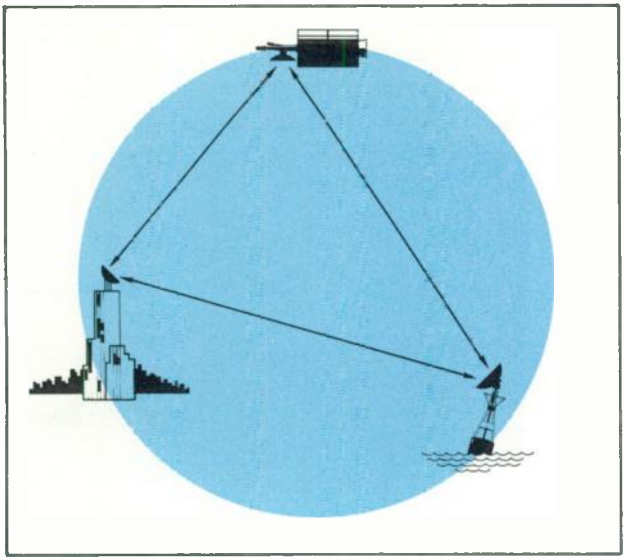


Figure 1. Satellite relay techniques are used to monitor natural resources when a direct microwave link is not practical or feasible.

actions can be transmitted by the central processor for the particular pollution location.

Information can be transmitted from the data collection points to a central processor by microwave techniques. For getting information from the remote data collection points, satellites seem to offer a convenient means. In some cases, depending upon the type of data being collected, the satellite may be able to actually gather the raw data and transmit it directly to the central processor without a surface-collection system.

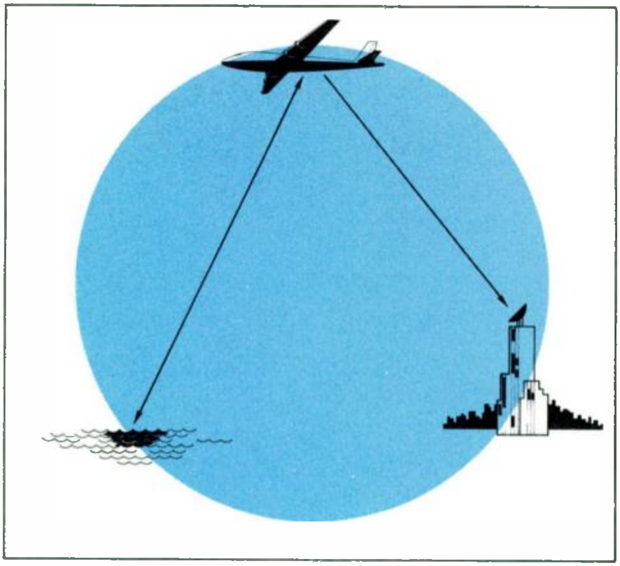
Satellite Network

A network of satellites and surface-probing sensor systems may be used to study natural resources. In addition to the oceans and air, this network can take inventory of what, where, and how well forests and crops are growing, and the condition of the soil and its ability to be put to work; thus permitting regional, national, or global predictions of crop yields, livestock inventory, and patterns of fire, insect, and disease damage. Information about stream and river flow, excess surface water, pollution, and glacial action can be studied in order to plan better irrigation and flood control systems, develop and maintain water resources, and control erosion.

Air pollution is generally correlated with population distribution and geographic features that can be studied with satellite mapping techniques. Detailed maps of the earth's features can be used for planning land use, urban development, and transportation facilities. Aerial data collection can also be used to map ocean currents, ice, and other navigational hazards. Fish and other marine biology of interest, as well as pollutants, can be studied for the seafood industry, shipping, and marine ecology.

Surface-collection relay satellites and remote-sensing satellites, along with non-satellite remote sensing devices – including sounding rockets, balloons, aircraft, buoys, and ground-based platforms – are capable of transmitting the gathered information

Figure 2. Airborne systems detect petroleum spills in the ocean and transmit the information to a central office for cleanup operations.



to a central computer. The computer's role in this overall environmental management system is that of soothsayer — if, for example, a decision were made to irrigate thousands of square miles of desert to create a new agricultural area, the computer could predict such things as the plan's effect on: climate, population, water resources, and international trade.

In order to manage world resources effectively, adequate information must be available. Information has for centuries been gathered by man on the surface of the earth. In recent times, aerial observations have broadened the field of view, the amount, and the usefulness of the information. With the mass acquisition of data and sophisticated computer processing, it may be possible to stem the tide of diminishing resources, and pollution of the existing resources.

Human Environment

Solving the problems of an area's pollution and diminishing natural resources will do little to improve the total environment, if the people in the area are unable to communicate and clear up differences. These differences often represent a widening gap between expectations, and reality. In an affluent society, we expect more, and better communications are raising these expectations. Through proper education and exchange of ideas it is possible to bring expectations in line with reality.

The areas of communication offered to bring expectations closer to reality include: education, community expression, cultural enrichment, and politics. Some specific services offered include: home library service, facsimile, delivery of mail, crime detection and prevention, remote data acquisition and central processing, educational television, remote participation at conferences, and armchair shopping.

Expanded Services

These new services can be divided into two classes: one-way transmission with no interaction between transmitter and receiver; and two-way trans-

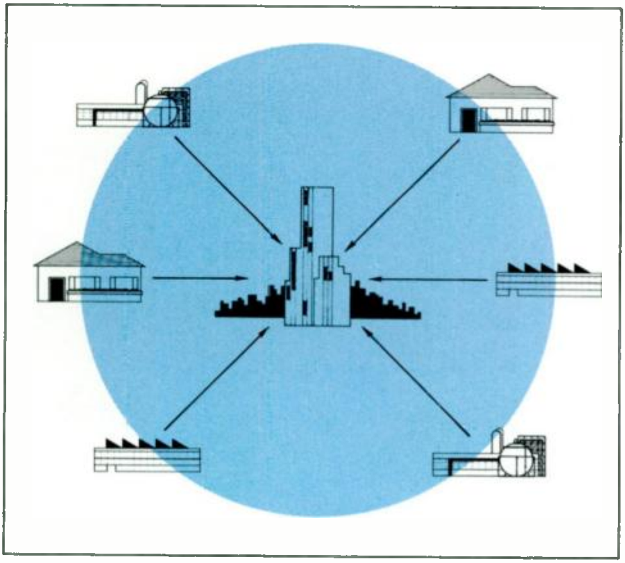


Figure 3. Utility meter-reading employs one-way transmission from many subscribers to one central office.

mission where there is a transmitter and receiver on both ends which provides the opportunity for interaction and response.

Utility meter-reading is one-way transmission from many subscribers to a central office where the information is processed (see Figure 3). The gathered data from each subscriber is sent through a central processing unit for charge computation. The actual billing could be included in the processing, which would make meter-reading a two-way transmission process. But, it is more likely that billing will continue to use a centralized mail distribution system, since it would not be economical for utilities to operate their own video or data transmission system.

Facsimile (the art of sending pictures or other printed material) is a form of one-way transmission in that there is no interaction between the transmitter and receiver, but both terminals are transmitter/receivers. As technology advances, it may eventually become economical to bring facsimile into the home for such things as home library service and newspaper distribution – if a printed copy of the transmitted image is desired. The transmission of color is possible as demonstrated by color television, but a color facsimile printout device needs to be perfected. Law enforcement agencies are using black and white facsimile printers to speed information across the country for crime detection and prevention. The addition of color would offer improved image recognition.

If printed copy is not needed a video system like television provides readable, although not permanent, written material. The information is read directly off the screen and when finished, the viewer terminates the signal. Cable television, with local programming, could provide channels to bring these services – library and newspaper – into the home. Video-phone service could also bring these visual images into the home.

Mail transmission and distribution, as well as video-phone, is a two-way transmission service that could use

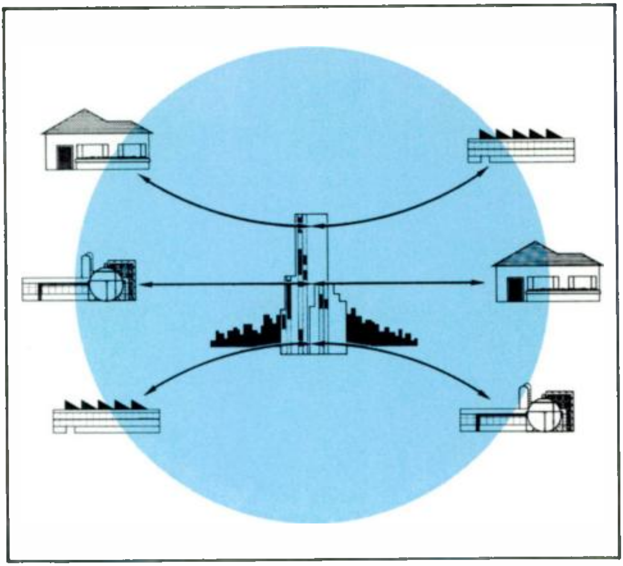


Figure 4. Mail transmission and distribution, as well as video-phone, uses a switched network.

the same transmission and distribution plan that is presently used for telephone service. That is, a switched network where an individual sends his message through a central office which redirects the message to the receiver (see Figure 4). With mail transmission and distribution, the service need not be completed at the same time; therefore, delaying the interaction or response. This delay would provide for more efficient use of the transmission channels – transmitting mail in non-peak hours. Mail transmission and distribution will not eliminate the letter carrier, but it can relieve the letter carrier of over 75% of his load without transmitting actual correspondence – personal, business, and government letters – over the air or through a cable. The receiver for such a system could be either a facsimile printer or a video screen depending upon whether printed copy is needed for future use. Another plan gives the sender a choice of transmission modes – instantaneous transmission over telegraph lines to the receiving "post office" where a letter carrier would deliver the message or letter "posting" common today where the original document is "hand" carried to its destination.

Totally automated system monitoring is a two-way system using programmed transmitter/receiver terminals. This is essentially the same technique used for natural resource control, but also used for monitoring other remote systems. Remote data access and central processing also includes time-sharing computer service. As the complexity and cost of these terminals is reduced, more people will take advantage of the benefits offered.

Educational television and remote conference participation are similar to video-phone with instantaneous voice and video communication. Where these services differ from video-phone is that there is a central transmitter/receiver and many remote transmitter/receivers that interact with the central unit (see Figure 5). Using such a service, government officials have direct contact with their constituents. This service has the greatest potential

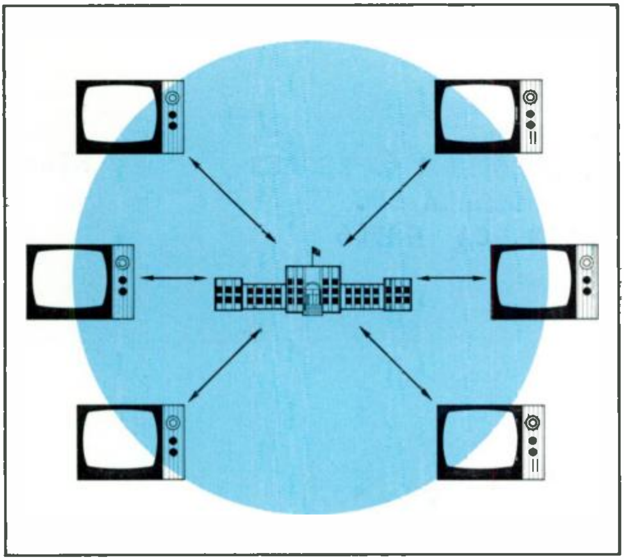


Figure 5. There is two-way communication between one central location and many remote subscribers for educational television and remote conference participation.

for bringing people together because it is possible to clear up any misunderstandings that might arise before they have a chance to cause dissention in the ranks. This service could put expectations and reality into proper perspective. Communities can express themselves over a two-way voice/video channel so the public has the opportunity to know the full story and to express their approval or objection. And, educational television provides the means for educating large masses in one geographic region or select groups scattered over several regions. Increased educational facilities provide the means to close the gap between expectations and reality.

New Direction

Expanded means of communication have the potential to provide a more efficient society with an informed public living in a healthy, plentiful environment. Presently, the possibilities are practically unlimited, but so are the possibilities for this expansion getting out of control. If the best interests of the public are to be realized, the most efficient and most economical systems must be put into effect. None of these expanded services will be totally adopted unless present costs can be substantially reduced. Technology has developed these services, economics will dictate their future.

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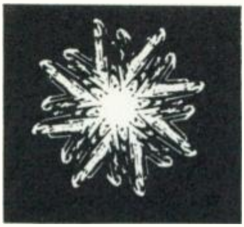
crystal filters ○ part two



Multi-electrode crystal resonators have substantially reduced the size and cost of crystal filters and offer improved design of multiplex systems.

In multiplex systems using LC channel filters, as much as 75 percent of the volume is taken up by the filters. Size reduction and improved performance are possible with the new technology of high-frequency crystal filters. The advent of filter size-reduction served as the impetus to further miniaturization such as the introduction of integrated circuits to produce an even smaller, more economical multiplex package.

Typical high-frequency crystal filters have as much as a 20:1 size reduction compared with LC filters for similar operations. In addition to the size reduction, crystal filters operate with greater stability over a wider range of temperatures than LC filters. Whereas LC channel filters were designed with a center frequency usually below 100 kHz, the optimum center frequency for low cost crystal filters is about 8 MHz. Multiplex systems can be designed to take advantage of the small size and high stability of these high-frequency crystal filters.

Coupled Crystal Resonators

High-frequency crystal resonators use AT-cut quartz wafers that have metal-film electrodes plated on the surface of the wafer (see Figure 1). By applying the correct frequency signal to such a crystal resonator, the crystal will mechanically vibrate and electrically behave like a resonant circuit. By coupling several such resonators together, it is possible to build a filter that has a suitable frequency response for operation as a bandpass filter. When each wafer contains a single electrode pair, the resonators are coupled electrically with shunt capacitors to form crystal filters.

Energy trapping is used to minimize the unwanted modes of vibration in high-frequency crystal resonators with plated metal-film electrodes. When the mass of the electrodes is large enough, the desired mechanical vibrations are

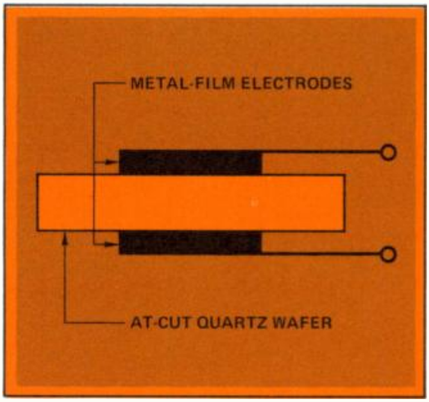


Figure 1. High-frequency crystal resonators have metal-film electrodes plated on the surface of AT-cut quartz crystal wafers.

confined primarily to the area under the resonator electrodes.

It is possible, however, to "let" the energy out into the unplated areas of the crystal wafer in a controlled manner by adjusting the amount of metal in the plated electrodes. The vibrations that do get into the unplated areas are vibrating at the resonant frequency of the crystal but the amplitude of the vibration decays exponentially with distance. It was discovered that these untrapped vibrations could be put to work rather than letting them decay. By placing another identical electrode pair close to the first one it is possible to set the second pair in resonance by these untrapped vibrations, since the resonant frequency of the second pair is the same as the first.

Electrode pairs are acoustically coupled when the resonant vibrations of one pair set another pair in resonance using the crystal as the only connection between them. Consequently, the crystal areas plated with metal-film electrodes form mechanically resonant systems, coupled by the transmission of energy through the unplated quartz wafer.

The principle of acoustical or mechanical coupling can be illustrated by common materials such as a thick sheet of foam rubber and two identical metal blocks resting on top of the foam. Application of an alternating force to the top of one block will set it in vibration and if the other block is close enough, it too will vibrate because the foam rubber is capable of transmitting the vibrations. The blocks must be close together to be coupled because most of the energy is trapped under the vibrating block and the little that does escape is quickly attenuated by the foam rubber. Elaborating on the mechanical coupling, a mechanical model can be developed for acoustically coupled crystal resonators. Figure 2 shows such a mechanical model.

The amount of coupling between adjacent resonators depends upon the dimensions of the resonators, the thickness of the metal electrodes, and the spacing between resonators. Consequently, by changing these three vari-

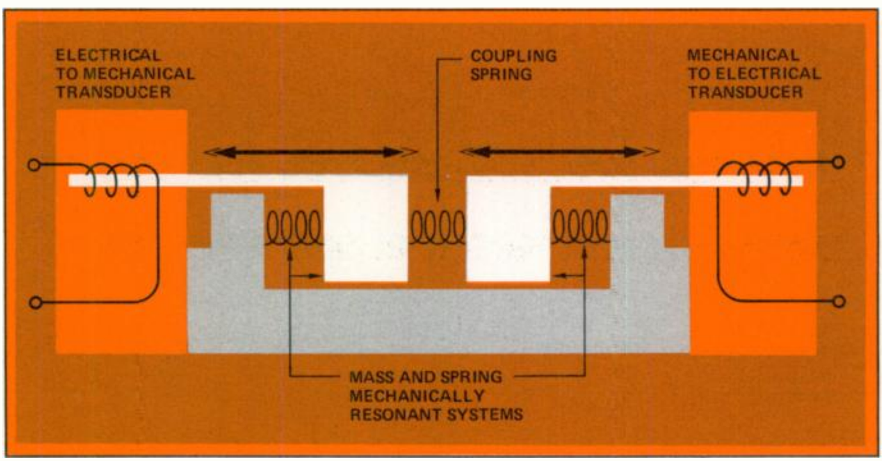


Figure 2. A mechanical model can be used to explain acoustically coupled crystal resonators.

ables it is possible to control the degree of acoustical coupling.

Multi-Electrode Resonators

When all the resonators of a bandpass crystal filter are put on a single quartz wafer, the filter is referred to as monolithic. Figure 3 shows a monolithic crystal filter. It was the discovery that individual crystal resonators could be acoustically coupled rather than just electrically coupled that has led to the substantial reduction in both size and cost of crystal filters. As many as ten resonators have been placed on a single crystal wafer. With the proper arrangement of the electrode areas, it is possible to make relatively complex filters in a monolithic form. The center frequency of such monolithic crystal filters is in the range from 5 - 150 MHz with passbands ranging from 0.001 - 0.1 percent of the center frequency. Figure 4 shows the improved performance of each additional stage of a monolithic crystal filter.

Although it is possible to place as many as ten resonators on a single crystal wafer, it is sometimes more reasonable to group several simpler multi-electrode resonators together. In this way the filter uses a combination of acoustical and electrical coupling between the individual resonators. Each of the simple monolithic structures are electrically coupled with a shunt capacitor. Such a filter, combining the advantages of both structures, is referred to as a polylithic crystal filter.

Lenkurt uses polylithic filters for its new 36A multiplex system. These filters have a center frequency above 8 MHz. Figure 5 compares the size of one of Lenkurt's polylithic filters, which occupies only one cubic inch, with a convential LC filter.

Computer-Aided Design

Computers are often used in the design of LC bandpass filters. The same technique is being used in the design of crystal filters. With the proper computer program and the desired center frequency and bandwidth the necessary component values for an LC resonator can be calculated.

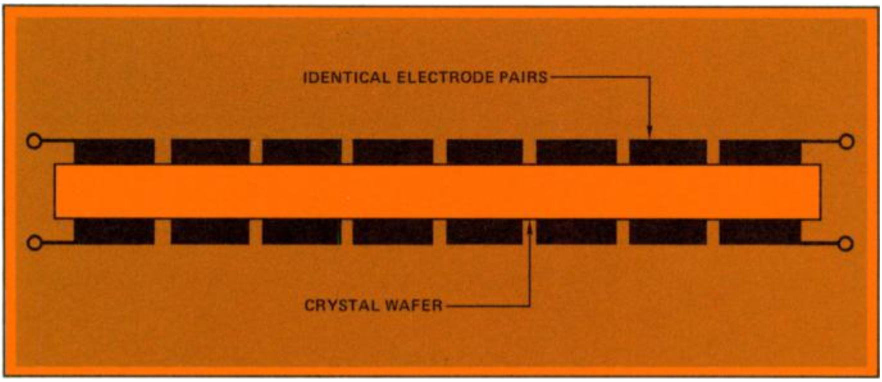


Figure 3. A monolithic crystal filter is a single crystal wafer with acoustically coupled resonators formed by plating identical electrode pairs on the crystal surface. Crystal filters are bi-directional; therefore, either end may be used as input or output.

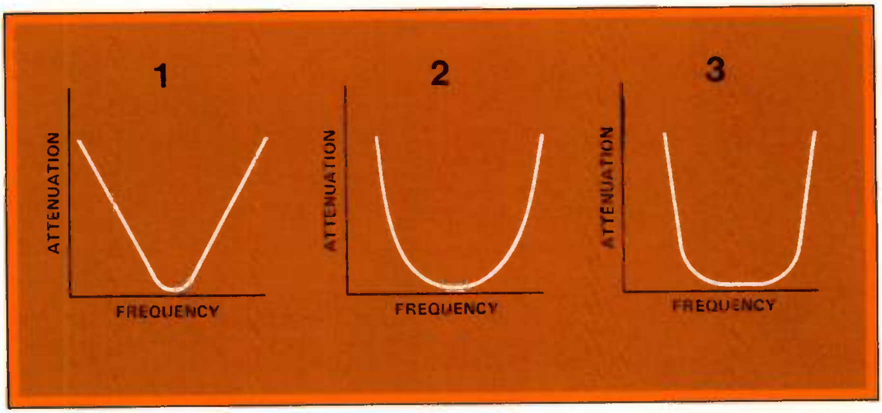


Figure 4. Each successive stage of a monolithic crystal filter improves the performance. The curves shown illustrate the successive improvement for three stages of a monolithic filter.

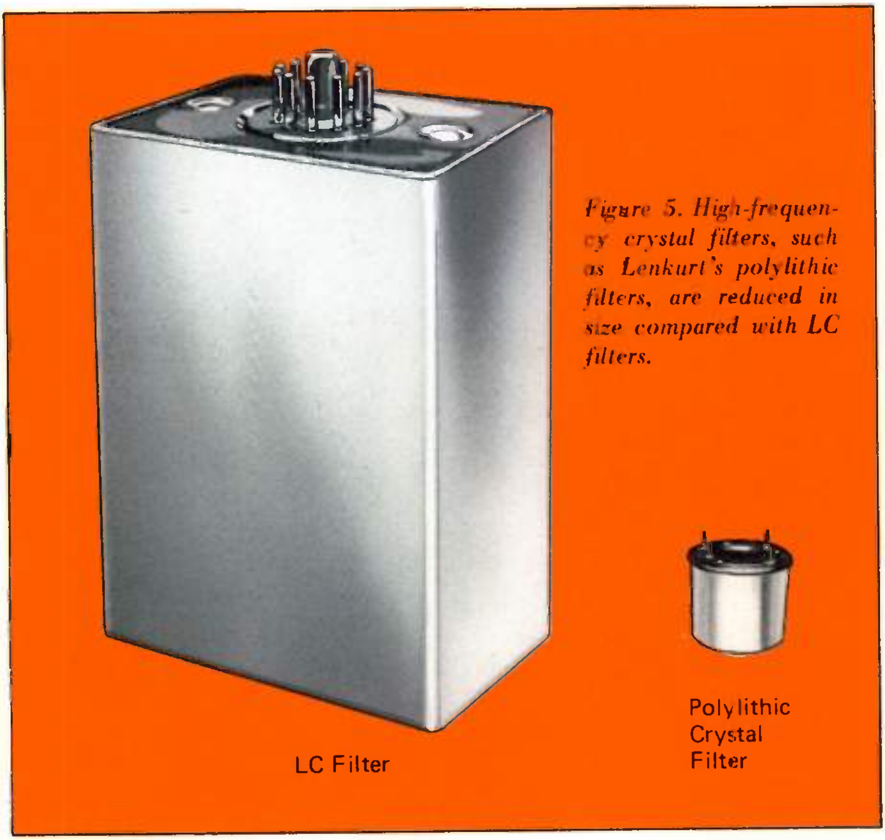


Figure 5. High-frequency crystal filters, such as Lenkurt's polylithic filters, are reduced in size compared with LC filters.

In designing a crystal filter for a particular resonant frequency, the desired information from the computer is the crystal size and shape and the dimensions of the electrodes. For multi-electrode crystal resonators, the spacing of the electrodes is also necessary. Using established computer programs, it is possible to calculate the component values for an equivalent LC resonator and from these values, the crystal filter requirements.

The circuit shown in Figure 6 illustrates the four electrical components needed to produce an electrical resonator equivalent to a two resonator crystal. Knowing these four component values, the dimensions of the electrodes and their spacing can be calculated. The optimum dimensions of an AT-cut crystal wafer are a function of the coefficients of elasticity of the crystal material used. The thickness of the crystal wafer is a function of the desired center frequency, since the resonant frequency depends solely on the wafer's thickness. The vibrations of the resonator never reach the edges of the plate because they are trapped under the electrodes; therefore, the lateral dimensions cannot affect the resonant frequency.

Applications

The use of a two-step modulation scheme is one change in multiplex systems using high-frequency crystal filters. This new modulation technique translates the voice channel to an intermediate frequency (approximately 8 MHz) before filtering. In the second modulation step the filtered channel is translated to its appropriate frequency allocation for transmission.

Sophisticated mechanical design is also necessary when operating with radio frequencies. In the 8 MHz range, electromagnetic energy is being radiated by the wires and components used in the system. To minimize the possibility of electrical coupling between components due to radiated energy, sections of a high-frequency system are shielded from each other using metal plates and enclosures. Likewise the circuit path lengths used at this frequency are kept short to minimize the radiating and absorbing (transmitting and receiving) surfaces. Coaxial cable with its built-in shield, can be used where it is necessary to have long connecting wires and where external shielding is impractical. Figure 7 shows a multiplex channel unit from Lenkurt's 36A system which uses

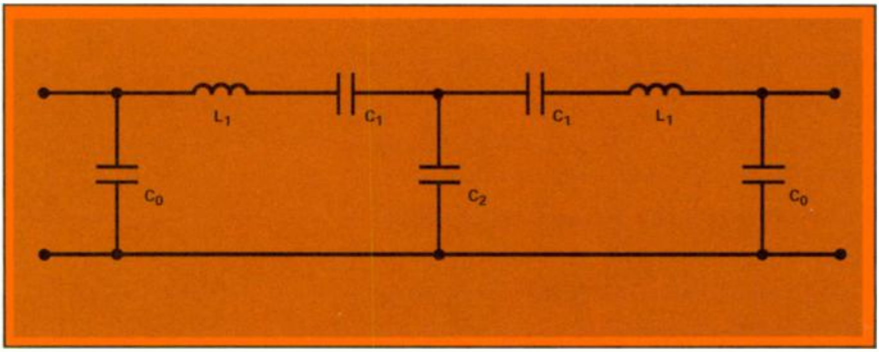


Figure 6. By knowing the values of the four electrical components illustrated, the equivalent two resonator crystal can be designed.

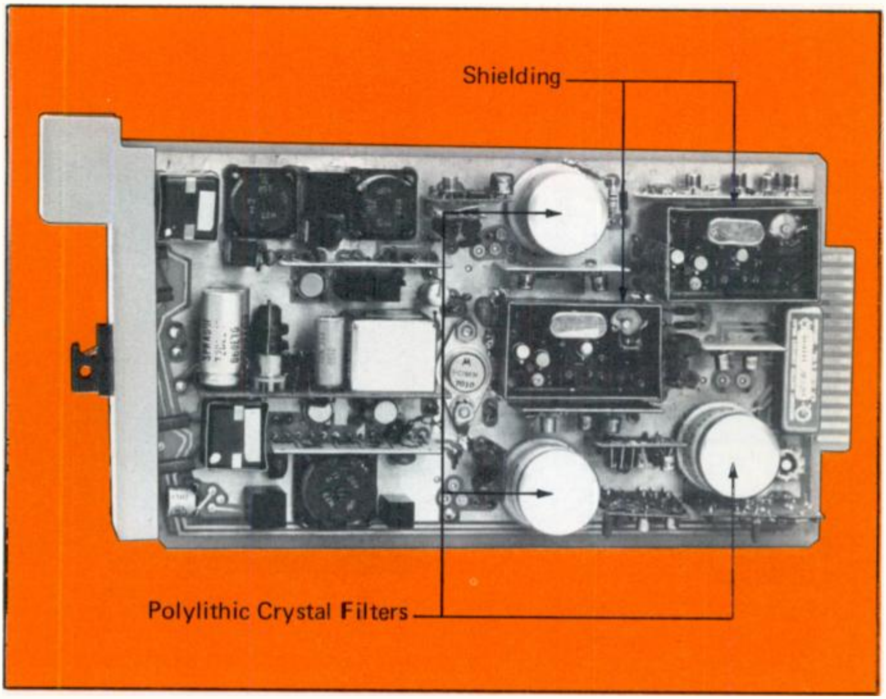


Figure 7. The channel unit for Lenkurt's 36A multiplex system illustrates the shielded, compact design used in high-frequency systems.

three polylithic crystal filters operating in the 8 MHz range. Such a unit is compact and shields the high-frequency sections.

Two polylithic crystal filters in Lenkurt's 36A system are used as channel bandpass filters – one for transmit and one for receive. The third is a narrowband carrier selection filter used to select the channel carrier from the multi-channel received signal. The recovered carrier is used at the receiver to demodulate the voice signal and to operate the signaling relay. The small size of these filters has permitted the placing of a complete 36A channel unit on a single printed circuit card.

What Next?

The development of monolithic and polylithic crystal filters with their stable, narrowband, high-frequency operation and the added advantages of simplicity, small size, and economy, has done a lot to push crystal filters closer toward their introduction into broader fields than the field of highly complex technical instrumentation.

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