too great a deterrent, and the use of pressure taps in other situations.

CHAIRMAN SCHLAFLY: Thank you, Ken. Our next speaker is Mr. Edward Wuermser of Entron Inc., to speak on UHF to VHF converters for CATV.

MR. EDWARD WUERMSER (ENTRON INC.): The general public is showing increased interest in Ultra High Frequency (UHF) TV programs and, therefore, this service must be added to CATV systems. UHF, as transmitted, is at too high a frequency to be compatible with present CATV systems because of the high cable losses (Figure 1) and difficulty in constructing distribution system amplifiers for UHF frequencies. In addition, all present CATV systems would be obsolete, since by present system standards for amplifier spacing, the number of amplifiers required would be increased two and one-half times. Also, the viewing audience would be limited since a majority of existing TV sets do not have all-channel capability; i.e., channel 2 through channel 83. Therefore, conversion to the present VHF frequency band is required.

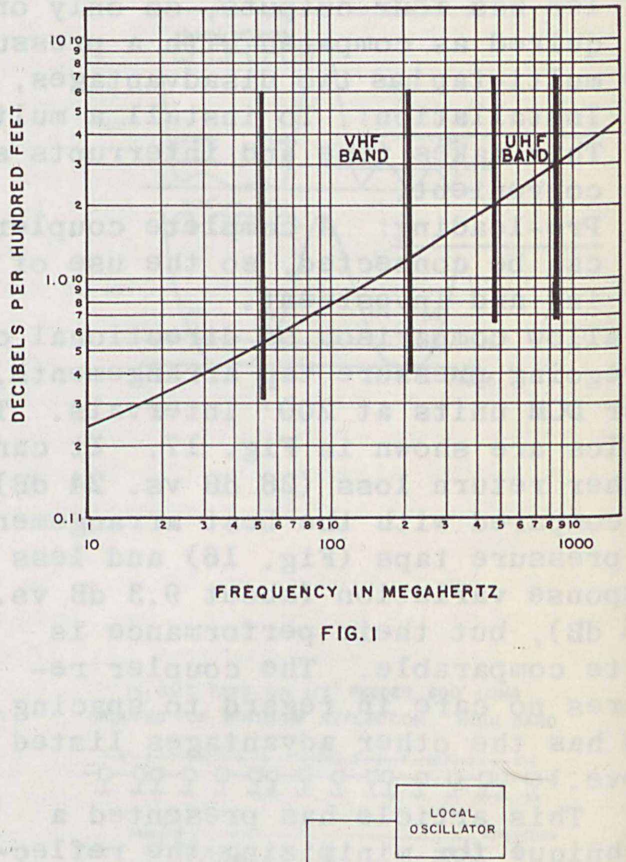

FIG. I

There are many UHF to VHF converters available for home TVs, but these are unacceptable for CATV head-end use because of high noise figures and frequency drift. Breaking a typical converter into functional blocks (Figure 2) one finds at the input, a tunable filter which, in turn, feeds a diode mixer. The converting local oscillator or (LO) is tunable so that the unit will tune over the entire UHF spectrum. The output of the mixer is fed to a filter to reject the unwanted signals. In some cases VHF amplification is provided. There are variations using a transistor mixer or using one transistor as a mixer-oscillator.

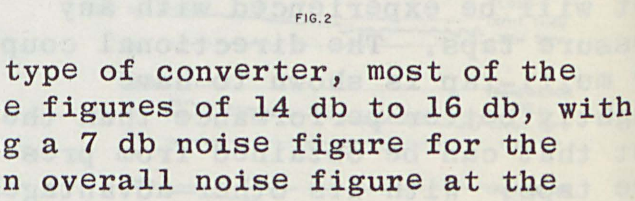

FIG. 2

Considering the noise figure of this type of converter, most of the diodes used for mixing have published noise figures of 14 db to 16 db, with conversion losses in excess of 6 db. Using a 7 db noise figure for the amplifier following the converter, gives an overall noise figure at the head-end of 16.1 db. See Table I.

TABLE I

Noise Figure Improvement Due to UHF PreAmplifier

Configuration	Mixer	Mixer + UHF CABLE Loss	10 db UHF Amp + Mixer
F (db)	16.1	24.5	8.1
$\frac{S}{N}$ (db)	43	35.7	51.1

The signal to noise ratio at the antenna with 1 mV of signal available across 75 ohms and a noise bandwidth of 4 MHz is 59.2 db. This is the maximum signal to noise ratio possible since it contains only the noise generated by the antenna source impedance. Any active device, amplifier or converter, after the antenna adds noise; thereby, decreases the signal to noise ratio. Referring to the example with a 16.1 db noise figure, the S/N = 43 db; which is below the recommended 50 db for head-end equipment.

The previous example did not take into consideration the UHF cable loss from antenna to converter. Applying a typical case, we will use channel 36, 602 MHz, and a 300 ft. run of 1/2" cable having 8.4 db attenuation. The added cable loss causes an increase in noise figure to 24.5 db and a decrease in signal to noise ratio to 35.7 db. This is below the design goal of a 40 db signal to noise ratio at the end of the system.

Consider now the above mixer preceded by a UHF amplifier and mixer mounted at the antenna, thereby deleting the 8.4 db cable loss. This produces an overall noise figure of 8.1 db and a signal to noise ratio of 51.1 db, which is better than the 50 db minimum for optimum system design. This gives a positive indication of the benefits of UHF amplification before conversion.

Next, consider the frequency drift of the inexpensive converters. Most tunable oscillators have long term stability of no better than ±.1%. When a conversion from channel 83 to channel 2 is made, the LO frequency required is 830 MHz. Therefore, the variation could be ±830 KHz and this variation in LO frequency is transferred to the VHF signal. To receive the picture properly, the individual TV set local oscillator would have to be changed in frequency with the fine tuning control. Interference is caused by the converted adjacent channels now being displaced from their normal IF frequencies and the traps for the picture and sound of the adjacent channels are no longer at the right frequency thus allowing these signals to pass through the IF and cause a low frequency beat with the video signal. The variation in frequency is acceptable for an individual set for which the converter was designed since all VHF signals are blocked out by the converter when in use and, therefore, there would be no adjacent channel to cause interference.

By using a crystal controlled oscillator and multiplying the crystal frequency up to the required LO, one can achieve a stability of ±.005%. Using the same LO frequency as in the previous example, ±.005% of 830 MHz is ±41 KHz. This slight variation is not great enough to move the adjacent channel carrier out of the traps and cause interference.

Now that the inadequencies of TV set converters and some of the remedies have been described, let us investigate the requirements of a converter for CATV use and discuss each block in the diagram (Figure 3). The portion within the dotted line will be discussed first.

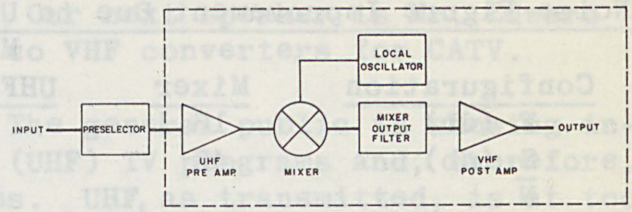

FIG.3

The UHF amplifier can be designed using either tubes or transistors. Present day tubes, ceramic planar triodes, can produce 16 db to 20 db gain with noise figures of 7 db to 9 db across the UHF band. The main disadvantages are high power consumption, the need for 2 to 3 separate supply voltages and the limited life due to the decrease in cathode emission.

Transistors, on the other hand, have lower gain, 6 db to 10 db, but also lower noise figures, 3 db to 6 db. The benefits are that only one supply voltage is required and there is no deteriation in performance with aging of the device. The shortcomings are temperature sensitivity, very little isolation between the input and output, and emitter peaking is required to obtain usable gain.

The next block is the mixer. Just as non-linearities in amplifiers cause the generation of frequency components other than those injected at the input, so will any active device, when operated non-linearly, generate frequencies other than those supplied to it. If two frequencies are injected at the input, the output will contain the two original frequencies; the sum and difference frequencies; harmonics of the frequencies, and all combinations of the sum and difference of the harmonics. A CATV converter uses the difference frequency f_1-f_2, where f_1 is the UHF signal and f_2 is the LO.

Conversion of the signal frequency with the lowest possible noise figure is the primary function of the mixer with the least loss possible. The LO, in many cases, is close in frequency to the UHF signal, therefore, care must be taken to avoid absorption of signal power by the LO source since this will decrease the available input power. Consequently, loose coupling of the LO source to the mixer is necessary, causing a loss of LO power.

The LO power delivered to the mixer diode should be greater than the signal power so that the conversion loss is determined by the LO level and not the signal level. There is a maximum limit for the LO power level delivered to the diode since as LO power is increased, the noise generated in the diode increases (Figure 4), Therefore, a trade off between high LO power for minimum conversion loss and low LO power for minimum noise generated is necessary. One other factor to consider is the change in conversion loss versus a change in LO power. As shown in figure 4, the conversion loss decreases with increasing LO power until it reaches saturation and then levels off. Operating above the knee of the curve has the advantage in that small variation in LO power level will not appreciably affect the conversion loss.

Next, we will consider the local oscillator block. As was described earlier, an oscillator operating at the LO frequency has one serious drawback. It does not have the stability required for a CATV converter, therefore a crystal oscillator-multiplier must be used. Owing to the high level required for Class C multiplication and the poor isolation of transistors, the final output of the multiplier string will contain spurious outputs which are multiples of the crystal frequency. Extensive filtering and use of overtone oscillators will decrease the level and the number of these spurious. One point to emphasize is the fact that the LO level at some points in the oscillator-multiplier may be one volt while at the mixer the signal level is only one mV. This is a 60 db difference and adding to this the requirement that spurious responses in the band be down at least 50 db from signal gives a required 110 db rejection between various points in the circuit. This virtually predicates the need for the crystal frequency to be chosen such that no multiples of the crystal frequency will fall in the output band. Since crystal activity and consequently oscillator output power decreases with increasing order of overtone, overtone crystals greater than the 7th overtone are not generally used. The choice of crystal frequency is therefore a compromise between the closeness of spurious frequencies and the activity of overtone crystals.

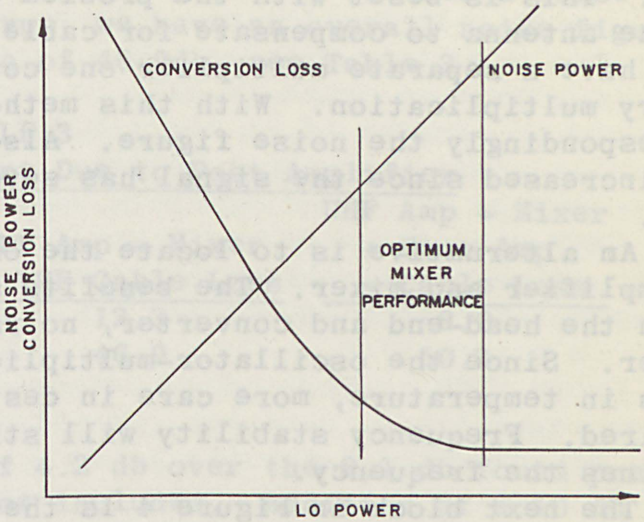

FIG. 4

The benefits of locating the UHF preamplifier and mixer at the antenna have already been shown. Next for consideration is the location of the oscillator-multiplier. Locating it in the head-end has benefits in that the design is less rigorous and less expensive parts may be used since the temperature variations in the building are not as severe as at the antenna. In addition, should maintenance be required, it would be much easier. There are several undesirable features; these being, the need for two cables interconnecting the LO and mixer, or for the single cable operation, the need of diplexers to separate signal and LO at each end of the cable. For low VHF band conversion this is no great problem since the LO frequency is well removed from the signal frequency; i.e., for channel 14 to channel 6 conversion, the LO is 388 MHz while the signal is at 88 MHz. Isolation of these two frequencies would not be too difficult. But when one considers a conversion of channel 14 to channel 13 with the need for a 260 MHz LO and signal frequency of 216 MHz, it is quite evident that the diplexer will necessarily be complex or impossible to realize.

Another factor is the cable loss from head end to antenna. To maintain the proper LO power level at the mixer, the LO power at the head-end would have to be increased to compensate for this loss. Increasing the power at the head-end compounds the problem of radiating the multiples of the crystal frequency into other head-end equipment and causing interference on other channels.

An alternative is to generate 1/2 or 1/3 of the LO frequency at the head-end and complete the multiplication at the mixer to decrease cable loss. This is beset with the problem of amplifying the sub LO frequency at the antenna to compensate for cable loss before multiplying. Rather than have a separate multiplier one could use the mixer diode for the necessary multiplication. With this method the conversion loss increases and correspondingly the noise figure. Also the spurious and image problems are increased since the signal has several high level frequencies to mis with.

An alternative is to locate the oscillator-multiplier with the UHF preamplifier and mixer. The benefits are the need of only one cable between the head-end and converter, no radiation problems and no complex diplexer. Since the oscillator-multiplier will be exposed to greater variations in temperature, more care in design and choice of components will be required. Frequency stability will still be $\pm$.005% since the crystal determines the frequency.

The next block in Figure 4 is the mixer output filter, which must reject the UHF signal, the LO frequency and all spurious-signals in the VHF output band while passing the required VHF signal with minimum loss. In addition, its input impedance must be matched to the mixer at the VHF frequency and its output impedance matched to the line or input impedance of the post amplifier. The filter input should also exhibit a low impedance to the UHF signal and LO, if a series mixer is used, and a high impedance if a shunt mixer is used. Generally, the frequencies generated in the mixer are sufficiently removed from the desired signal and simple filtering will prove adequate, except when the second harmonic of the LO minus the signal falls in the desired band, $2F_{LO}-f_{UHF}=f_{VHF}$. This is impossible to prevent and therefore, these conversions must be avoided. See Table 2.

TABLE 2

List of Impossible and Undesired UHF Conversions

	Undesired 1	Impossible 2	Undesired 1	
From ch.	22	23,24	25	to ch. 7
From ch.	25	26,27	28	to ch. 8
From ch.	28	29,30	31	to ch. 9
From ch.	31	32,37	34	to ch. 10
From ch.	34	35,36	37	to ch. 11
From ch.	37	38,39	40	to ch. 12
From ch.	40	41,42	43	to ch. 13

1- Undesired because of image frequency on adjacent channel
2- Impossible because of image frequency on same channel

Continuing through the block diagram, we come to the last block which is the VHF Post Amplifier. The need for this is based on maintaining the established noise figure of the converter. Since some antenna towers are quite high, consideration of cable loss at VHF must still be taken into consideration. If a VHF post amplifier were not used, the mixer would drive the cable and the cable loss would be added directly to the conversion loss. Citing the example used previously, UHF amplifier gain 10 db with a noise figure of 4 db, mixer gain - 6 db with a noise figure of 14 db, and a 600 ft. cable run; we have an overall noise figure of 12.3 db and a signal to noise ratio of 46.9db, see Table 3.

TABLE 3

Noise Figure Improvement Due to Post Amplifier

Configuration	10 db UHF Amp + Mixer	UHF Amp + Mixer + VHF Cable Loss	UHF Amp + Mixer + Post Amp + Cable Loss
F (db)	8.1	12.3	8.9
$\frac{S}{N}$ (db)	51.1	46.9	50.3

This is an increase in noise figure of 4.2 db over the 8.1 db found previously when the VHF cable loss was not included. Addition of a 10 db gain, 7 db noise figure post amplifier results in an overall noise figure of 8.9 db which is only a 0.8 db increase and a signal to noise ratio of 50.3 db. Further improvement in noise figure could be obtained by either increasing the UHF preamplifier gain or decreasing the post amp noise figure.

In many areas there are UHF stations separated by only two to four channels. Closely spaced channels can produce interference when they mix with multiples of the crystal frequency. Also, the received power level of undesired channels may be great enough to overdrive the UHF preamplifier. To alleviate this condition, a highly selective filter is necessary.

The requirements for such a device are, first of all, a low insertion loss, since the loss can be considered as adding directly to the noise figure. The bandpass should be wide enough to pass the desired channel but with approximately 20 db rejection 6 MHz to either side of the bandpass. The extremely narrow bandwidth and high close-in rejection predicates a high insertion loss. Consequently, a compromise must be made between low insertion loss and selectivity.

There are many basic types of filters, some of these being lumped constant, helical resonator, tuned line, cavity and strip line. Lumped constants can not be used since the frequency is too high for effective use. The helical resonator degenerates to the equivalence of a tuned line due to the high Q required. Strip line techniques cannot be used to full advantage since the frequency involved is too low. This leaves the tuned line and cavity as the most likely candidates for filter construction at VHF.

CHAIRMAN SCHLAFLY: Thank you very much, Ed. The Jerrold Handbook is available at the back of the room.

The next paper will be delivered by Clay Mahronic. The title of the paper is, "Effects of Cable Length and Attenuation on Structural Return Loss." Mr. Mahronic graduated from the Illinois Institute of Technology