CHAIRMAN SCHLAFLY: Thank you, Gay. The next speaker is Ken Simons. It says here, Kenneth A. Simons. I don't recognize that name, Ken. Ken has been active in radio since 1927. You started very young, didn't you? He has been in TV since 1939 and with Jerrold some 15 years, since 1951 he has here, and is Vice President in Charge of Research and Development at the Hatboro, Pennsylvania laboratory. He has participated in the design of various things, like the 704B field strength meter, 900B sweep generator, starline, and other of the Jerrold products. He is a member of the NCTA Standards Committee, and is a principle contributor to the handbook that his company has reissued again this year. Mr. Simons' paper is on reducing the effects of reflection in CATV feeders.

MR. KENNETH A. SIMONS (JERROLD): The pressure tap is a convenient and economical way of connecting the customer drop to the feeder in a CATV system. Because of this convenience, the large majority of taps in use today are of this type. Hundreds of thousands of them are providing satisfactory service in systems all over the country. Unfortunately there is a penalty attached to the pressure tap's convenience. Because it must tap into the feeder cable with no opportunity for series compensation, the pressure tap inevitably introduces reflections into that cable. This article will show how these reflections are minimized by careful design, and how their adverse effect on the transmission of picture signals can be greatly reduced by grouping taps in optimum arrangements.

Up to the present time, Jerrold has manufactured four basic types of pressure tap. The earliest designs, Models PTR and PTC, employed a series resistor or a series capacitor connecting the pressure point to the center conductor of the drop line, as illustrated in Fig. 1. The resistor tap (PTR) was used for line-to-tap losses of 30 db and over, the capacitive tap for lower loss values. This design had the advantage of simplicity, and low cost. While the capacitive tap had high efficiency (i.e., the loss on the feeder line, for a given feeder-to-drop loss, was low compared to other designs) it introduced reflections on the feeder that were much worse than those introduced by transformer taps having the same line-to-tap loss.

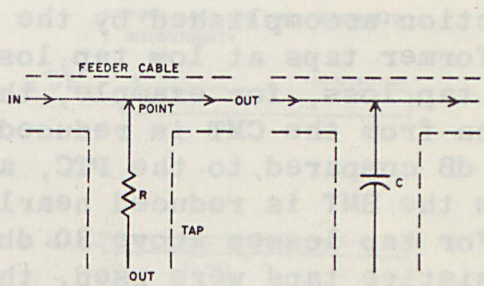


FIG 1

Fig. 2 shows the schematic diagram of a transformer-tap. A tightly coupled auto-transformer steps up the impedance of the load to a high, and essentially resistive impedance bridging the feeder line. A coupling capacitor isolates the primary at low frequencies, and a series resistor raises the output inpedance so the tap

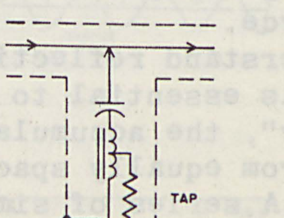


FIG 2 BMT and CMT

acts as a well-matched source for the drop line. Jerrold manufactures two kinds of transformer taps which are similar electrically but differ mechanically. The CMT tap is convenient as a replacement for the older taps. It is mechanically interchangeable with the PTR and PTC. However, the 3/8 inch hole into which these units thread is too small for optimum electrical performance. The BMT transformer tap uses a 1/2 inch hole, and the increased clearance allows a reduction in stray capacitance with a considerable improvement in high frequency performance.

Table I compares the reflections introduced into an otherwise reflectionless 75 ohm line by single taps of each type.

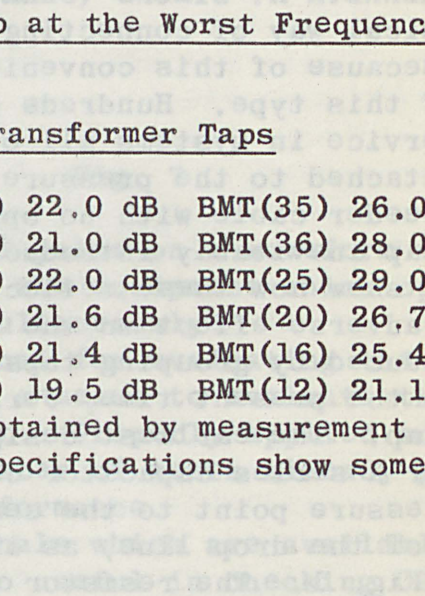
TABLE I

Reflection Introduced into a Feeder by One Tap at the Worst Frequency (216 MHz)

Loss from Line to Tap at 216 MHz	Resistive and Capacitive Taps		Transformer Taps			
35 dB	PTR(6)	26 dB	CMT(35)	22.0 dB	BMT(35)	26.0 dB
30 dB	PTR(3)	25.5 dB	CMT(30)	21.0 dB	BMT(36)	28.0 dB
25 dB	---		CMT(25)	22.0 dB	BMT(25)	29.0 dB
20 dB	PTC(W)	19.5	CMT(20)	21.6 dB	BMT(20)	26.7 dB
16 dB	PTC(R)	16.4	CMT(16)	21.4 dB	BMT(16)	25.4 dB
12 dB	PTC(Y)	14.2	CMT(12)	19.5 dB	BMT(12)	21.1 dB

Note: Reflection figures on this table were obtained by measurement of production units selected at random. Published specifications show somewhat greater reflection in each case.

Notice the substantial reduction in reflection accomplished by the use of transformer taps at low tap losses. At 16 dB tap loss, for example, the reflection from the CMT is reduced nearly 6 dB compared to the PTC, and that from the BMT is reduced nearly 10 dB. For tap losses above 30 db, where resistive taps were used, the transformer taps do not show the same improvement, but still have the important advantage of providing a back-matched source.



To understand reflections on CATV feeders it is essential to understand "periodicity", the accumulation of reflections from equally spaced discontinuities. A series of simplified examples may help to explain the effect. Fig. 3 illustrates conditions existing on a lossless 75 ohm transmission line perfectly terminated with a 75 ohm resistor. There is no reflection at any frequency (b), so the input impedance is constant at 75 ohms (c), and the application of a pulse to the input results in no echo (d).

Now consider what happens when a 3700 ohm resistor is bridged across the line at a distance from the input end equal to 1/2 wavelength at 25 MHz (Fig. 4a) This discontinuity across a 75 ohm line produces a constant 1% reflection at all frequencies (b); as a result the input impedance varies from a minimum of 73.5 ohms (75 minus 1%) when the reflected voltage wave arrives at the input 180^{o} out of phase with the input, to a maximum of 76.5 ohms (75 plus 1%) when the two waves are in phase (c). The application of a pulse to the input results in a single echo following the input pulse by a time corresponding to the round trip delay from the input to the discontinuity and back (d).

Next two equal discontinuities spaced at equal distances are bridged across the line (Fig. 5a). At zero frequency, and at multiples of the frequency at which the spacing is one-half wavelength, the two reflected waves arrive at the input with the same phase, so they add to produce a net reflection twice either one (b). At frequencies where the spacing is an odd multiple of one-quarter wavelength, the two reflected waves arrive at the input 180^{o} out of phase and cancel, so there is no net reflection at those frequencies. The input impedance varies as shown in (c), reaching a minimum of 72 ohms at the frequencies of peak reflection, and touching 75 ohms at the odd quarter-wavelength frequencies where there is no reflection. Following the input pulse there are two echoes (d).

Four discontinuities, Fig. 6(a), produce complicated variations in reflection (b) and impedance (c).

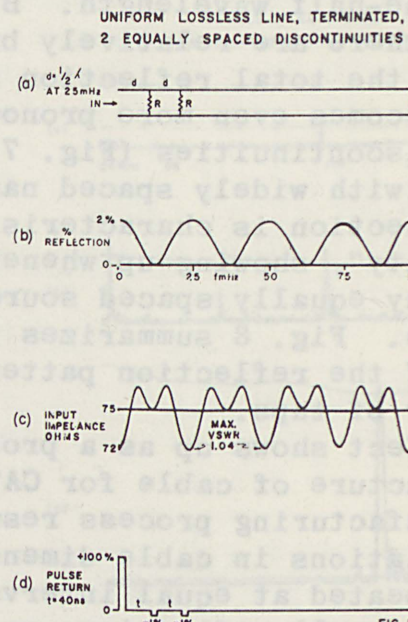


FIG 5

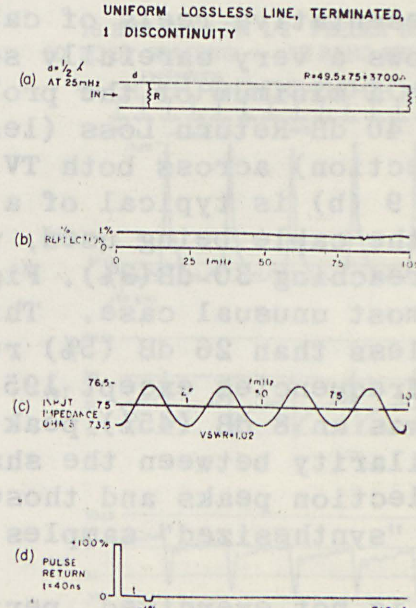


FIG 4

Certain general tendencies become clear. With many equally spaced discontinuities the reflections add to produce relatively narrow peaks of reflection centered at frequencies that are multiples of the one where the spacing is one-half wavelength. Between peaks there are relatively broad ranges where the total reflection is low. This becomes even more pronounced with eight discontinuities (Fig. 7). This pattern with widely spaced narrow peaks of reflection is characteristic of "periodicity", showing up whenever there are many equally spaced sources of reflection. Fig. 8 summarizes the dependence of the reflection pattern on the number of taps.

This effect shows up as a problem in the manufacture of cable for CATV. When the manufacturing process results in small variations in cable dimension which are repeated at equal intervals, the resulting small reflections can add to produce severe effects at certain frequencies. Great care is required in the production of this cable to avoid the problem. Figure 9 illustrates the reflection characteristics of some representative reels of cable. Fig. 9(a) shows a very carefully selected reel with a minimum of the problem greater than 40 dB Return Loss (less than 1% reflection) across both TV bands. Fig. 9 (b) is typical of a majority of the cable being used, with a few peaks reaching 30 dB(3%). Fig. 9 (c) shows a most unusual case. This reel showed less than 26 dB (5%) reflection at all frequencies except 195 MHz, where there was an 8 dB (45%) peak! Note the similarity between the shape of these reflection peaks and those shown in the "synthesized" samples preceding.

If care is not exercised, periodicity can cause problems when pressure taps are installed on a feeder. With telephone poles spaced at regular intervals along the street, there is a

UNIFORM LINE, TERMINATED
4 EQUALLY SPACED DISCONTINUITIES

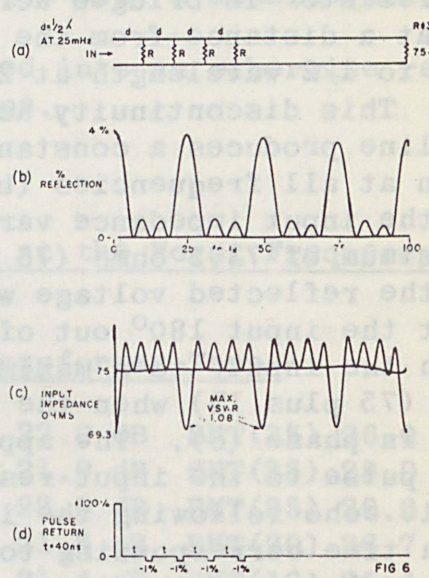


FIG 6

UNIFORM TERMINATED LINE, 8 EQUALLY SPACED DISCONTINUITIES

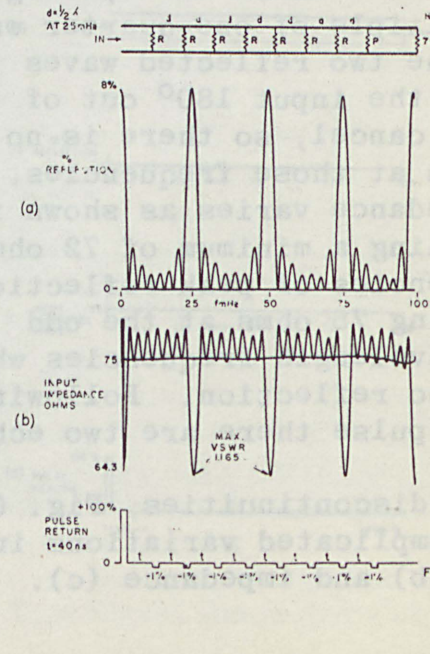


FIG 7

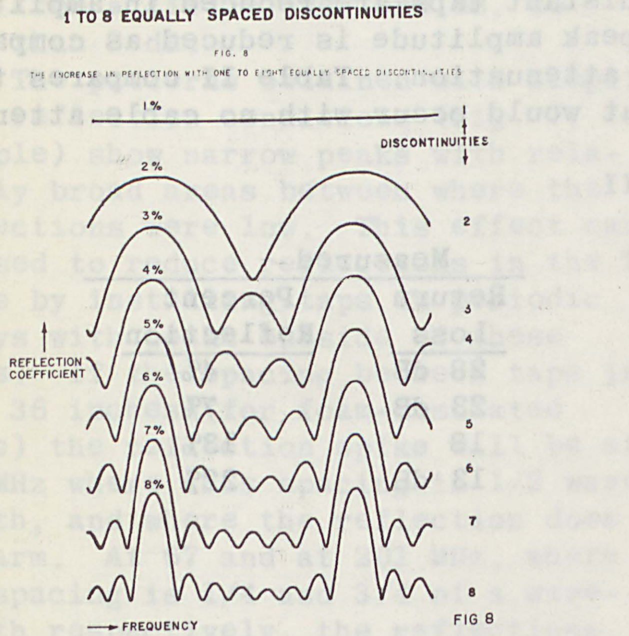


FIG 8

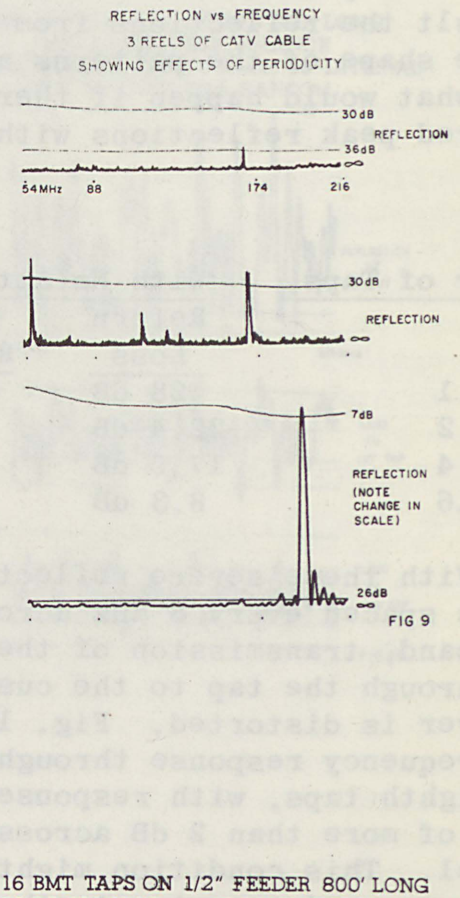


FIG 9

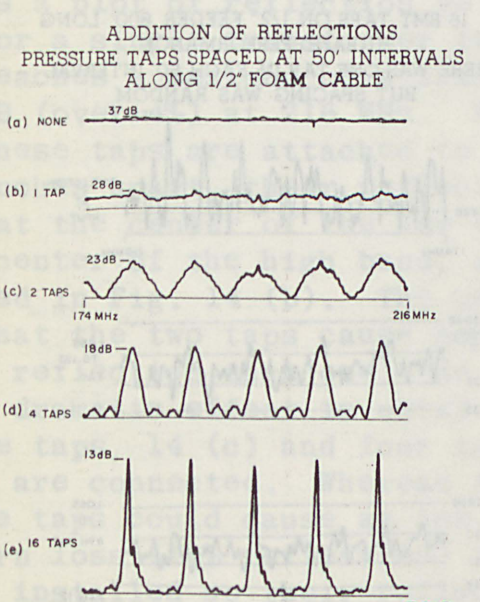


FIG 10

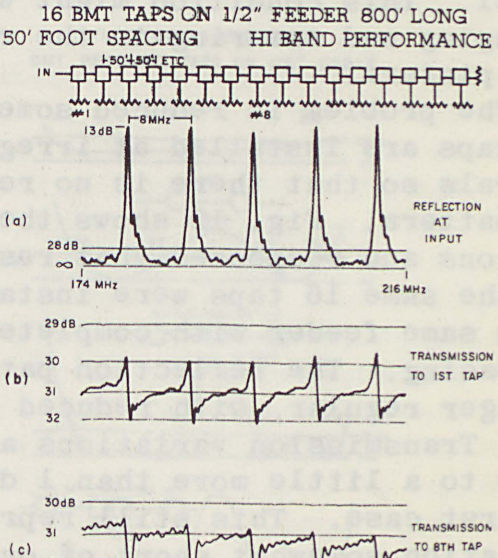


FIG 11

tendency to space taps at regular intervals along the feeder cable. This can cause severe trouble. Fig. 10 shows the neasured buildup of reflections on a feeder with various numbers of BMT taps spaced exactly 50 feet apart on a 1/2 inch foam-insulated cable.

The effects of cable attenuation can be seen by comparing this with Fig. 3 to 7, inclusive. This cable has an attenuation of about 1.3 dB. As a result the reflections from the more distant taps are reduced in amplitude, so the shape of the patterns and their peak amplitude is reduced as compared with what would happen if there were no attenuation. Table II compares the measured peak reflections with those that would occur with no cable attenuation:

TABLE II

Number of Taps	With No Attenuation		Measured	
	Return Loss	Percent Reflection	Return Loss	Percent Reflection
1	28 dB	4%	28 dB	4%
2	22.4 dB	7.7%	23 dB	7%
4	17.5 dB	13.3%	18	13%
16	8.3 dB	38.1%	13 dB	22%

With these severe reflection spikes spaced every 8 MHz across the high-band, transmission of the TV signal through the tap to the customer's receiver is distorted. Fig. 11 shows the frequency response through the first and eighth taps, with response variations of more than 2 dB across a single channel. This condition might well lead to ringing and smearing in the reproduced picture.

The problem is reduced somewhat when taps are installed at irregular intervals so that there is no repetitive pattern. Fig. 12 shows the reflections and responses that resulted when the same 16 taps were installed on the same feeder with completely random spacing. The reflection pattern is no longer regular, with reduced amplitude. Transmission variations are improved to a little more than 1 dB in the worst case. This still represents a situation somewhat short of one that would guarantee excellent picture transmission.

The importance of optimizing the design of the individual tap for minimum reflection is illustrated by Fig. 13.

16 BMT TAPS ON 1/2" FEEDER 800' LONG
HI BAND PERFORMANCE
THERE WAS ONE TAP IN EACH 50' INTERVAL
BUT SPACING WAS RANDOM

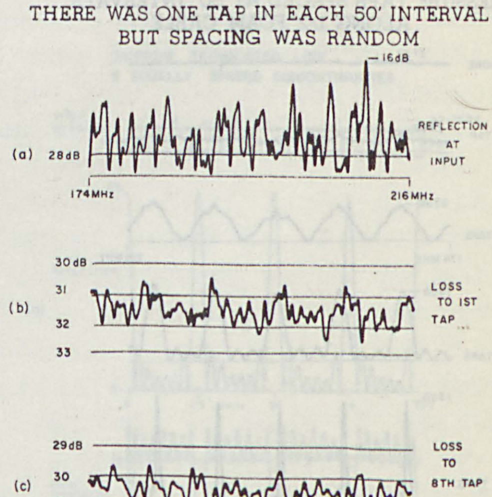


FIG 12

This shows a situation identical with Fig. 12, except that the poorer transformer taps (CMT) were substituted for the better ones. This increases the peak reflection from 16 dB (16%) to 11 d B(28%), and increases the variation from a little over one dB, to more than 3 dB.

The patterns obtained with simplified reflection conditions (Fig. 7, for example) show narrow peaks with relatively broad areas between where the reflections were low. This effect can be used to reduce reflections in the TV bands by installing taps in periodic arrays with peaks outside of these bands. If the spacing between taps is made 36 inches (for foam-insulated cable) the reflection spike will be at 135 MHz where this spacing is 1/2 wavelength, and where the reflection does no harm. At 67 and at 201 MHz, where the spacing is 1/4 and 3/4 of a wavelength respectively, the reflections from successive taps will cancel, causing a minimum effect for the TV channels between 54 and 88 and between 174 and 216 MHz.

Fig. 14 illustrates this. 14 (a) shows a plot of reflection vs. frequency for a single transformer tap (BMT25) It reaches a maximum of a little below 28 dB (over 4%) at 216 MHz. When two of these taps are attached to the line 36 inches apart, their reflections cancel at the center of the low band and the center of the high band, as illustrated in Fig. 14 (b). The net effect is that the two taps cause somewhat less reflection than one! An even more dramatic effect is obtained when three taps, 14 (c) and four taps, 14 (d), are connected. Whereas four of these taps could cause as low as 16 dB return loss (16% reflection) if they were installed so their reflections added in phase, by scientific grouping they can be made to give less reflection within the TV bands than one tap alone.

16 CMT TAPS ON 1/2" FEEDER 800' LONG
HIGH BAND PERFORMANCE
THERE WAS ONE TAP IN EACH 50' INTERVAL
BUT SPACING WAS RANDOM

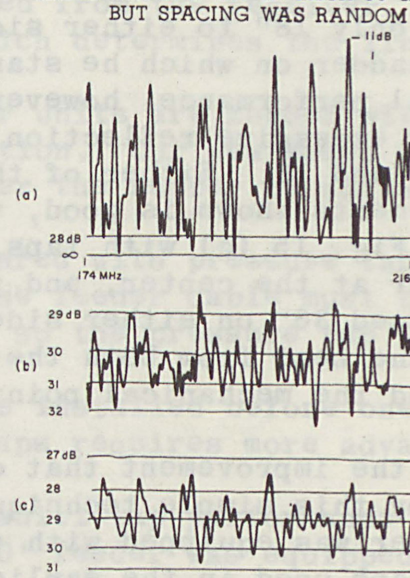


FIG 13

REFLECTION VS FREQUENCY
BMT PRESSURE TAPS ON 1/2" CABLE

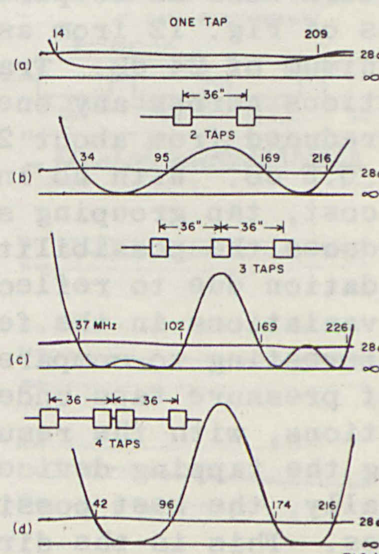


FIG 14

When four taps are to be installed at a given location, a fairly common situation in a CATV system, several arrangements are possible. Fig. 15 shows the reflection plots for some of them. The arrangement shown in Fig. 15 (a) is probably the most convenient physically, in that the installer has to reach out only 18" to either side of the pole or ladder on which he stands. Its electrical performance, however, is poor, showing excessive reflection on Channels 6, 7 and 13. Either of the other arrangements shown is good, the one shown in Fig. 15 (c) with taps close together at the center, and the other two spaced 36" on either side, seems to be the best from both the electrical and the mechanical point of view.

To show the improvement that can be obtained by this simple technique an 800 foot feeder was equipped with the same 16 BMT taps used in the earlier examples. They were installed in four groups of four, each group arranged in the pattern illustrated in Fig. 14 (d). Fig. 16 shows the result. (Note that the vertical scale of 16 (a) is doubled to exaggerate the reflections.) Grouping of the taps in this way increased the feeder return loss as compared with the conditions of Fig. 12 from as low as 16 dB to a minimum of 24 dB. Transmission variations across any one TV channel were reduced from about 2 dB down to about 0.5 dB. With no increase in equipment cost, tap grouping substantially reduces the possibility of picture degradation due to reflections and response variations in the feeder.

It is interesting to compare the performance of pressure taps under these optimum conditions, with the results obtained using the tapping device having, electrically, the best possible characteristics. This is the directional coupler multi-tap. It has three important advantages over the pressure tap:

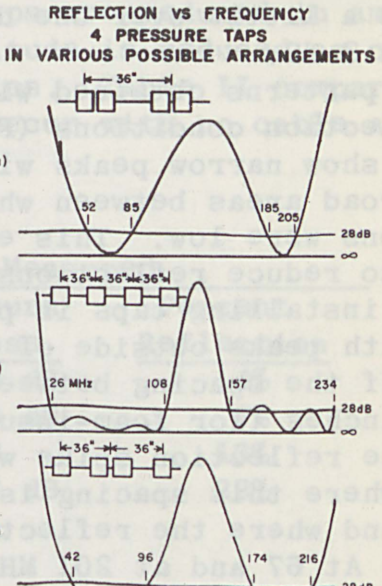


FIG 15

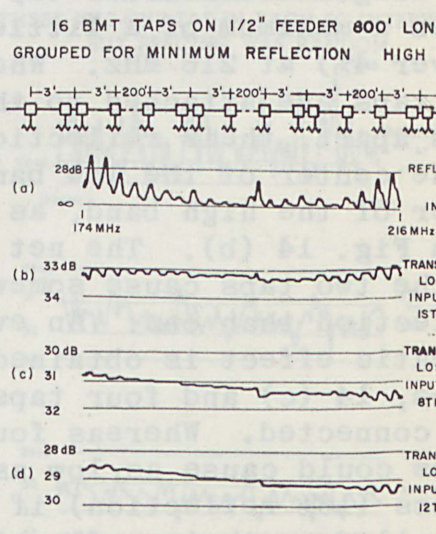


FIG 16

1. Directivity: It is more sensitive to waves coming down the feeder than to waves traveling back up the feeder, and thus discriminates against reflections or spurious signals coming from taps or receivers further down the line.
2. Lossless Backmatch: With a transformer tap approximately half the energy tapped off the line is lost in the backmatch resistor. With a directional coupler none of this energy is lost, the reverse termination acts only to absorb energy reflected from the receiver. Thus the efficiency of a directional coupler (which determines the line loss for a given tap) can be very high.
3. Multiple Outputs: This means that fewer units are needed with correspondingly fewer possibilities of reflection. Our new Model DCM coupler has four outputs, so only one-quarter the number of units are required as compared with a pressure tap.

The multi-tap has two disadvantages, as compared with pressure taps:

1. Installation: To install a multi-tap the feeder cable must be cut. This takes time and interrupts service, so the pressure tap is more convenient.
2. Pre-loading: A complete coupler must be installed before one customer can be connected, so the use of multi-taps requires more advance planning and investment.

To allow comparison of directional coupler multi-tap performance with the foregoing pressure tap arrangements, the 800' feeder was equipped with four DCM units at 200' intervals. The reflection and response characteristics are shown in Fig. 17. It can be seen that the coupler has slightly higher return loss (28 dB vs. 24 dB) as compared with the best arrangement of pressure taps (Fig. 16) and less response variation (about 9.3 dB vs. 0.5 dB), but their performance is quite comparable. The coupler requires no care in regard to spacing, and has the other advantages listed above.

This article has presented a technique for minimizing the reflections from pressure taps by careful grouping. While the best results are obtained with the better type of transformer taps (BMT), the same improvement will be experienced with any pressure taps. The directional coupler multi-tap is shown to have slightly better performance than the best that can be obtained from pressure taps. With its other advantages this suggests the use of the coupler for situations where the very best performance is desired and where the necessity of cutting the cable is not

FOUR DCM MULTITAPS ON 1/2" FEEDER 800' LONG
HI BAND PERFORMANCE

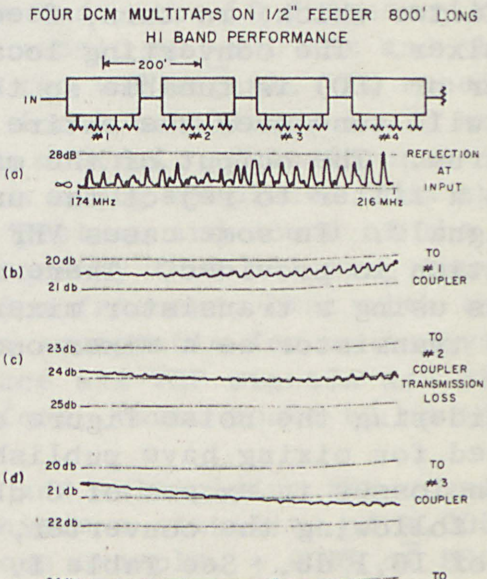


FIG 17

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.

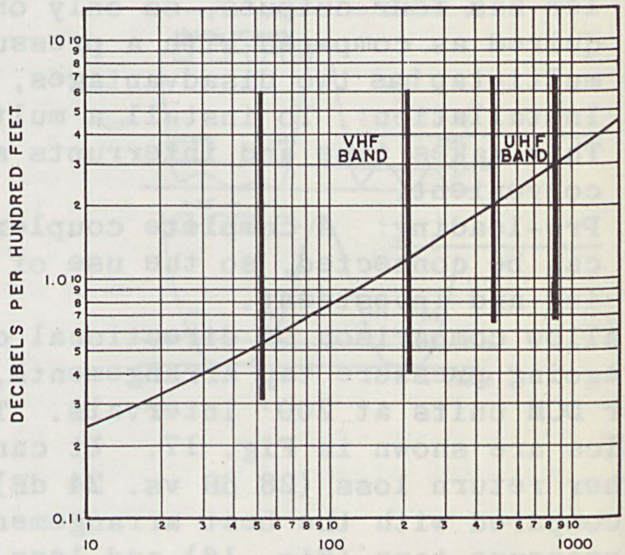


FIG. 1

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.

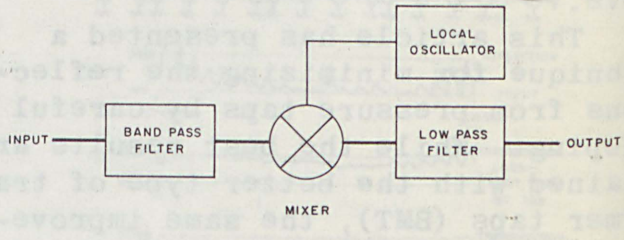


FIG. 2

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.