Then we tried shooting from both ends, hoping they would twist together. (Laughter) We stood there for close to a week. We had to solve the problem. That was the important thing. We did manage it.

When I talk about an industrial vacuum cleaner I am talking about a device that has a large volume of air. You have got to get the air going through. The air at the manhole we started with was so slight that you had to put your ear against it to even be able to hear any airflow. You could just detect it. I guess we had a religious service the morning before, with all faiths present. It did work.

CHAIRMAN PENWELL: If CATV can continue to innovate like that, we're not dead.

Gentlemen, I want to thank you very much for your time. Perhaps if there are further questions you might try to buttonhole the speakers out in the hall. We have to move along. We are back on schedule now. For the benefit of those who came in late, we didn't have a projector when we started the session, and the second and third presentations require a projector.

Our next speaker, Mr. Pai, has been with CATV and Craftsman Electronics Products for the past three years. Mr. Pai will speak on "Analysis of the Directional Tap in System Design". Mr. Pai.

(Mr. Pai read his paper, marked No. 2.) (Applause)

ANALYSIS OF THE DIRECTIONAL TAP IN SYSTEM DESIGN

by

S. W. Pai

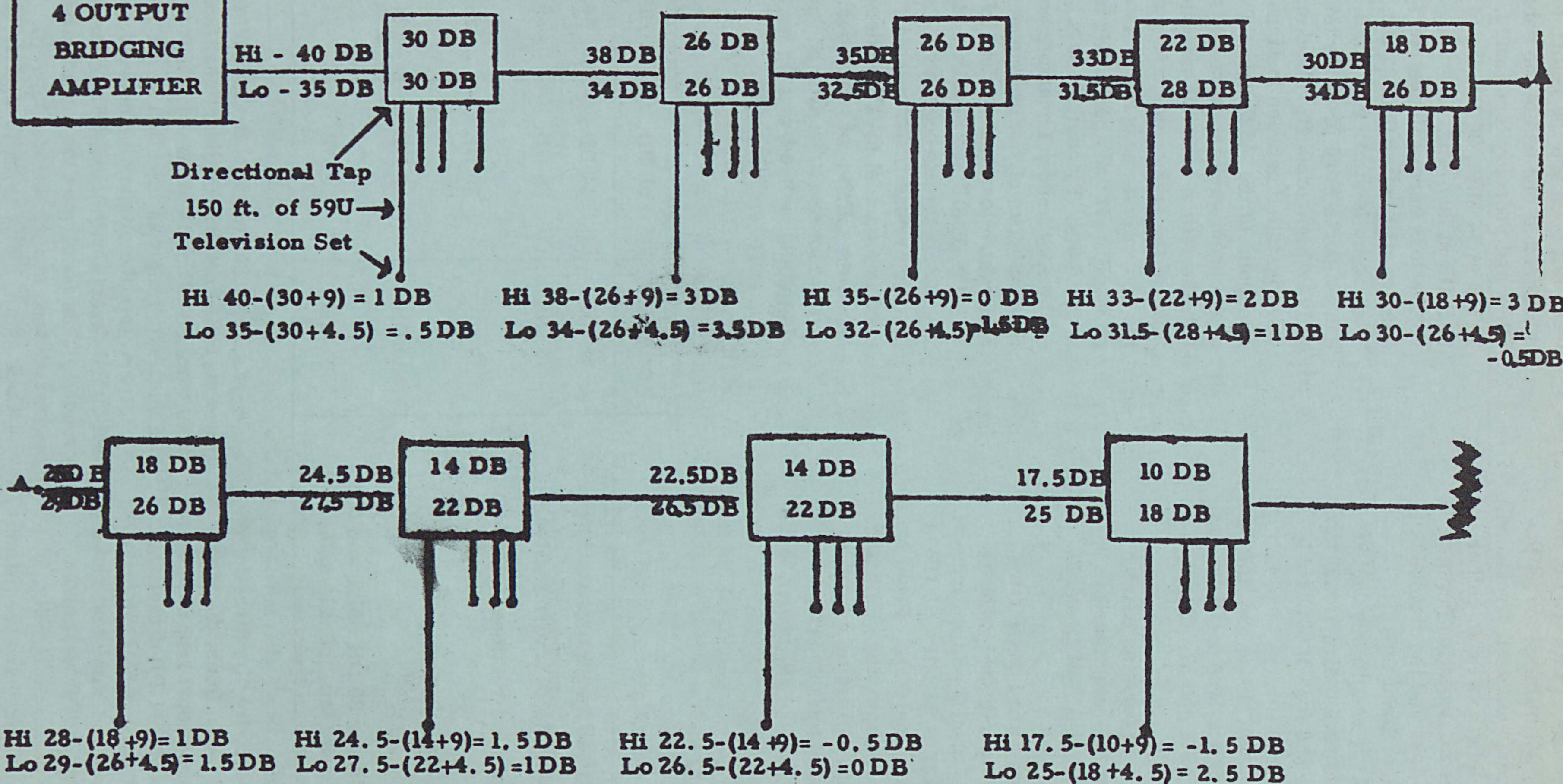
For years, the technique of tapping off signal from CATV feederline to the customer's set has mainly relied on the pressure tap. Although the design and construction of the pressure tap has been constantly improved -- such as, from capacitive tap to backmatch tap. However, the inherited problem both in the circuit design and mechanical construction of the pressure tap limit its performance in today's sophisticated system, especially since the information carried by the CATV system and the length of the feederline are constantly increasing, coupled with the increased demand for better color signal by the customers. Therefore, a better method of tapping off the feederline must be devised; and the directional tap is the most feasible answer at the present time. The advantage of the directional tap vs. pressure tap is, of course, obvious; and also the characteristics of the directional tap probably are well known by this time in the field of CATV. Unfortunately, even today, the advantages of the directional tap have not been fully utilized by many of the system designers. It is the purpose of this paper to present some of the advantages of the sloped directional tap and the distinct characteristics of the directional tap as a feederline tap off device. Figure 1 is a layout of a typical CATV feederline:

The length of the feederline is approximately 900 feet of .412 aluminum cable with nine directional taps spaced approximately 120 feet apart. The feederline is connected to one of four outputs of the bridging amplifier which provides an output of 40 DB on hi channel and 35 DB on low channel. Let's also assume 150 feet of RG59/U is the average length for the house drop. The DB value in the block designates the in-to-tap attenuation value of each particular directional tap. The top figure is for hi channel and the lower figure is for low channel when the signal is tapped off from the first directional tap through a 150 feet of RG-59/U to the customer's television set. Of course, the signal at the input of the set would be approximately 40 - (30 + 9) = 1 DB for hi channel and 35 - (30 + 4.5) = .5 DB for low channel; the signal for the second set is 3 DB for hi channel and 3.5 DB for low channel; and, the third set is zero (0) DB for hi channel and 1.5 DB for low channel. Because of the difference of the cable attenuation vs. frequency at the input of the forth directional tap, hi channel is 33 DB and the low channel is 31.5 DB. Therefore, in order to provide uniform signal level at the set, a sloped in-to-tap attenuation should be introduced to this particular tap. This would provide 2 DB at the hi channel and 1 DB at the low channel for the television set. When the signal travels further down the feederline, as you can see, the level difference between hi channel and low channel increases. When it reaches the end of the feederline, coupled with the RG-59/U house drop, the difference of the signal level between hi channel and low channel is almost intolerable. Therefore, more slope is needed. At the last directional tap, the in-to-tap attenuation is 10 DB for hi channel and 18 DB for low channel. The level at the television set is 1.5 DB for hi channel and 2.5 for low channel. Now, it is evident if a tap off device does not provide a certain amount of slope, especially when the tap locations are approaching the end of the feederline, a uniform signal level cannot be obtained at the customer's set by economical means with a non-sloped tap. Consequently, this would cause undesirable picture quality and an unsatisfied customer.

From the previous illustration, we can easily say the sloped directional tap has the following advantages:

1. Provides uniform signal level at the input of the television set.
2. More taps can be installed with minimum signal loss.

SLOPED DIRECTIONAL TAP



NOTE:

1.) Directional Tap: All with 4 tap ports.
2.) Directional Tap Spacing: 120 ft. .412 cable.
3.) House Drop: 150 ft. R G 59/U
4.) Attenuation of 120 ft. .412 cable.

54 MHz	1 DB approximately
216 MHz	2 DB approximately

5.) Attenuation of 150 ft. RG-59/U cable.

54 MHz	4.5 DB approximately
216 MHz	9 DB approximately

Figure 1

3. Easier layout for the system designers. Since the through loss of this type of directional tap has a similar slope as the cable, one may consider each directional tap as a certain length of cable rather than a complicated calculation between the sloped cable loss and the flat loss of other types of directional taps.

Now let's look at some of the results conducted by our Engineering Department on the directional tap.

A length of approximately 850 feet of .412 cable was used (Fig. 2)

1. With 75 ohm termination at one end, the return loss at the other end was 44 DB at 54 MHz, 44 DB at 216 MHz and 37.5 DB at 290 MHz.
2. When the same cable is terminated with 50 ohm termination, the return loss is 26 DB at 54 MHz, 38 DB at 216 MHz and 36 DB at 290 MHz.
3. Nine directional taps were installed with one end of the cable terminated. The return loss of the cable and the nine directional taps was 35 DB at 54 MHz, 30 DB at 216 MHz and 25 DB at 290 MHz. From No. 2 and No. 3 it clearly shows the mismatch introduced by the nine directional taps, to be less than the mismatch introduced by the 50 ohm termination (14 DB return loss).
4. The tap ports of all nine directional taps were left open and the return loss was measured at one end of the cable with the other end properly terminated. It was 30 DB at 54 MHz, 26 DB at 216 MHz and 24.5 DB at 290 MHz. By doing so, the return loss across the entire VHF TV band is still better than 25 DB.
5. The set-up is similar to No. 3. All the unused ports were properly terminated, and two high attenuation backmatch taps were installed between the input and the mid-point of the .412 cable. The values of the backmatch tap were 30 DB and 25 DB, the return loss was measured at the input of the .412 cable. The results of the return loss measurements were 25 DB at 54 MHz, 12 DB at 216 MHz and 15 DB at 290 MHz. By comparing No. 3 and No. 5, the additional mismatch introduced by the two backmatch taps caused the system return loss to decrease by 10 DB at 54 MHz, 18 DB at 216 MHz and 10 DB at 290 MHz. Of course, the condition would be much worse if the backmatch tap was used in an actual CATV feeder-line, because the number of taps would be increased and the lower attenuation backmatch taps also would be used.

Figure 2

	54 MH_z	216 MH_z	290 MH_z
1. Return loss of cable with 75 ohm termination.	44 DB	44 DB	37.5 DB
2. Return loss of cable with 50 ohm termination.	26 DB	38 DB	36 DB
3. Return loss of cable and 9 directional taps with 75 ohm termination.	35 DB	30 DB	25 DB
4. Same as No. 3 but open termination on all directional taps' tap ports.	30 DB	26 DB	24.5 DB
5. Same as No. 3 but with one 30 DB BMIT and one 25 DB BMIT close to the input of .412 cable.	25 DB	12 DB	15 DB

Now, let's look at the directivity of a directional tap and backmatch tap (Fig. 1 & 3). Inject the signal to the tap port of the 10 DB directional tap, the measure the level at the tap port of the 14 DB directional tap. The total attenuation is 62 DB at 54 MHz and 67 DB at 290 MHz. Let's duplicate the same test under identical conditions through two 12 DB backmatch taps. The total attenuation is 35 DB at 54 MHz, 51 DB at 290 MHz. Now, you can clearly see the difference in attenuation between directional tap and backmatch tap. The same test was performed between an 18 DB and 22 DB directional tap. The results were 99 DB at 54 MHz and 86 DB at 290 MHz. If a backmatch tap was installed ahead of the 18 DB directional tap, the attenuation between the 18 DB and 20 DB directional tap would be drastically decreased. This illustrates the incompatibility of backmatch taps and directional taps.

Once again, let us refer to Fig. 1. An off air signal was fed to the input of the .412 cable and the

Figure 3

	54 MH_Z	290 MH_Z
Attenuation of tap ports between 10 DB and 14 DB directional tap.	62 DB	67 DB
Attenuation between two 12 DB BMIT.	35 DB	51 DB
Attenuation of tap ports between 18 DB and 22 DB directional tap.	99 DB	86 DB

150 feet RG-59/U on all tap ports.

television set was connected to the tap port of the 10 DB directional tap. Then we injected 1,000 Hz modulated CW signal (same frequency as the off air signal) into the tap port of the 14 DB directional tap. The CW signal was increased until the 1,000 Hz tone could just be heard on the TV set. At this point the output of the CW generator read approximately 40 DB.

This test was repeated with the CW signal injected into a 12 DB backmatch tap with approximately the same location as the 14 DB directional tap. Again the output signal was increased until the 1,000 Hz tone could be heard on the TV set. The output level of the generator (CW) at this time read approximately 15 DB, which is 25 DB lower than when tested with the 14 DB directional tap.

Let us again measure the return loss, but this time from the opposite end of the .412 cable (Fig. 4).

1. All of the tap ports of the (9) directional taps and the .412 cable were terminated. The return loss of this system was 26 DB at 54 MHz, 23.3 DB at 216 MHz and 23.7 DB at 290 MHz.
2. When the tap ports of all the directional taps were open, the return loss read 25.6 DB at 54 MHz, 23.2 DB at 216 MHz and 24 DB at 290 MHz. As one may see, the return of No. 1 and No. 2 is almost identical. This of course, clearly demonstrates the ability of the directional tap for rejecting the reflections from the tap ports.

All of the aforementioned tests were based on the principal of frequency domain, and the following results were obtained with a TDR.

3. The hookup was identical to No. 1, except a 1 ns. 1 v pulse was fed into the input of the .412 cable. Here (9) discontinuities were evident.
4. This was a TDR test of No. 2 and only (4) smaller discontinuities appeared.

We now have confirmed the advantages of the directional tap by both, frequency domain and time domain methods.

Bear in mind, that the illustrations we used here, are typical and not necessarily an absolute guideline. Generally, the characteristics of the directional tap would still remain the same. In most cases you may still refer to these illustrations in designing a new system layout.

Figure 4

	54 MH_Z	216 MH_Z	290 MH_Z
1. Return loss of cable and 9 directional taps at opposite end with 75 ohm termination on .412" cable.	26 DB	23.3 DB	23.7 DB
2. Same as No. 1 but open terminations on all directional taps' tap ports.	25.6 DB	23.2 DB	24 DB
3. Same as No. 1 but use TDR method p = .02/cm pulse = 1 ns.	9 discontinuity showed		
4. Same as No. 2 but use TDR method.	4 discontinuity showed		

(Mr. Pai read his paper, marked No. 2.)
(Applause)

CHAIRMAN PENWELL: Are there any questions? If not, we will proceed.

Brian Jones, from Fairchild, is still with us. Come up, Brian. Brian is our next speaker. He was born and educated in England, and has worked for the Canadian Defense Research Board on transistor circuits. He has worked for Fairchild Semi-Conductor on high frequency transistor applications, Westinghouse Electric Corporation on integrated circuit design, and has worked for C-Cor Electronics on CATV and high frequency amplifier design. Presently he is with Fairchild in Palo Alto, California.

DISTORTION, VSWR and REVERSE TRANSMISSION IN BROADBAND TRANSISTOR AMPLIFIERS

by

BRIAN L. JONES

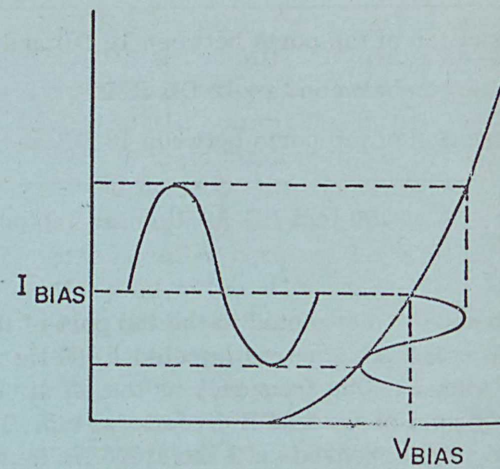
Transistor amplifiers produce distortion. This is a commonplace to everyone who is familiar with the cross-modulation of an overloaded CATV amplifier. Such amplifiers have a certain VSWR when introduced into a 75 Ω system and if this ratio is too high, reflections appear on the picture in the form of "ghosts". If an amplifier is inserted into a system backwards, that is, with the input signal to the output and the output signal to the input, the signal will be attenuated instead of amplified. The ratio of the input power to the output power under such circumstances is known as the reverse transmission. Similarly the gain of the amplifier is the forward transmission.

Now it may not be immediately obvious what connection these quantities may have and the purpose of this talk is to point out the inter-relationship between them. In order to do this I shall start by discussing some of the properties of transistors.

Figure 1 shows a typical curve of the relationship between collector current and base-emitter voltage of a transistor. This characteristic, a non-linear input voltage/output current relationship is the main source of distortion of transistors. This is illustrated by a sine-wave base emitter voltage which produces the distorted collector-current shown in the slide. It can be shown very easily mathematically that if the input signal voltage consists of two or more amplitude-modulated RF signals, cross-modulation will result. The forward transmission of the transistor is non-linear and shows distortion.

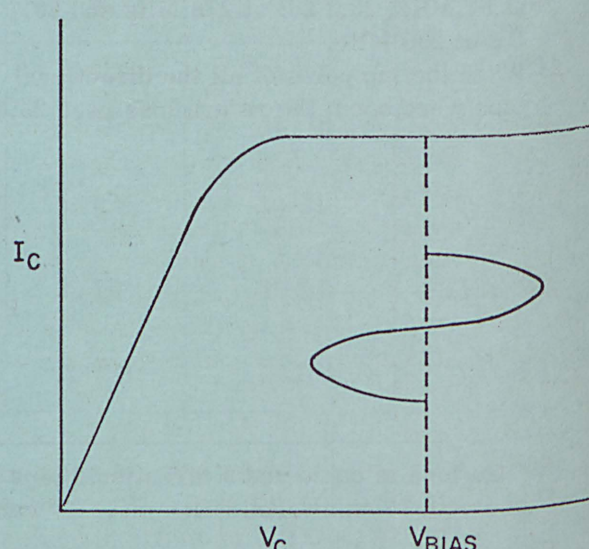
But what about the reverse transmission? If we apply a voltage to the collector of a transistor, will the resulting current show distortion? At first sight,

Figure 1



it would appear not. The low frequency collector characteristics are shown in Figure 2. It would appear that the collector current remains nearly constant regardless of the voltage swing on the collector. The transistor is a good constant current source at low frequencies; that is, it's output current depends only on the base voltage. It is also clear from this figure that what happens at the output has very little effect on the input, i.e., the transistor has a low reverse transmission.

Figure 2



At high frequencies, however, none of the foregoing remains true. There are certain undesirable properties of the transistor, known as parasitics, which give the transistor considerable reverse transmission. Figure 3 shows the two main parasitic resistances: the emitter inductance and the