THICK FILM TECHNOLOGY FOR PAY TV SECURITY; THE T.E.S.T. SYSTEM

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Abstract

The TEST System for pay-TV security consists of adding a modulated rf signal to the pay-TV channel transmission. The frequency of the rf signal falls within the band of frequencies of the pay-TV channel. The TV receiver set is unable to reconstitute coherent picture or sound, while this added signal is present in the transmission. Regular reception is restored for subscribers by removing the interfering rf signal at the TV receiver set. Thick film technology facilitates the realization of stringent requirements of stability for the components of the System.

Introduction

The need for practical systems offering security for pay TV has become increasingly apparent. Both active and passive systems have been developed and are marketed at present which claim to prevent non-subscribers from watching pay TV premium channels. Some of the accepted systems include trapping at the pole, converters, switchable taps, and various encoding-decoding systems. In general, it has been true that the cost of these systems was directly proportional to the degree of security they offered. It seems fair to say, however, that there is no fully secure system, and that the ultimate solution to pay TV security lies in catching and prosecuting those who illegitimately watch pay TV programs. Still, it remains necessary to secure pay TV transmissions to some extent in order to make pay TV a realistic business proposition.

The proprietary TEST System offers a novel solution to the problem of pay TV security. Its theoretical foundation is clear and concise, its implementation is ideally suited to high technology mass production, resulting in low cost to the user. It will become apparent from the discussion below, that the System is universally applicable, i.e. it will function not only in CATV, but in MDS and over the air systems as well.

Following an analysis of the theoretical basis of the TEST System, the basic components will be described in detail. Engineering considerations of general interest to user and a review of the merits of the System will be presented in the concluding section of the paper.

Theory

It is well known that a TV receiver will detect as video information the presence of a single frequency sinosoidal signal, located between the visual and aural carriers of a TV channel. When such a signal is not part of the regular picture material, it will be observed as interference, or disturbance of the intended picture.[1]

The degree of disturbance by this (scrambling) signal primarily depends on the combination of the following factors:

1. Level of the scrambling signal relative to the visual and aural carriers.
2. Frequency of the scrambling signal, i.e. the position of this signal in the frequency domain relative to the visual and aural carriers.
3. Modulation of the scrambling signal.

Relative level:

It turns out that the threshhold of interference by the scrambling signal is a strong function of the signal's frequency and modulation. Considering a pure sinosoidal rf scrambling signal, however, experiments indicate that the threshhold of interference is at the -45dB level with respect to the visual carrier, when the scrambling signal is anywhere between the visual and aural carriers. The threshhold of interference is as low as -60dB at certain frequencies within the TV channel band. The degree of interference by the scrambling signal becomes more severe with increasing level, and the picture is greatly impaired at the 0dB level.

Relative frequency:

In general, for a given relative level of the scrambling signal, the picture quality becomes more objectionable as the scrambling signal is moved closer in frequency to the visual carrier. The sound quality is degraded in a similar fashion when the scrambling signal is moved close in frequency to the aural carrier. There is, however, no simple mathematical relationship between the frequency of the scrambling signal and the level of interference observed.[2] In addition to these effects, there are certain other phenomena which are noticeable as the frequency of the scrambling signal is varied. There are frequencies which are more effective in disrupting picture and sound reception than others; e.g. if the scrambling signal is harmonically related to the line scanning frequency (15.734Hz) and/or the carrier frequencies. TV reception is of much poorer quality than if some other frequencies are chosen.

Modulation.

Modulation of the scrambling signal increases the level of interference with TV reception. AM modulation is generally more effective than FM, and modulating frequencies below 100Hz result in greater scrambling of the picture material than if some other frequencies were used.

It can be seen from the preceding brief analysis that a proper choice of scrambling signal, i.e. one of a certain level, a selected frequency, and one which is AM modulated, will make enjoyable TV reception impossible. It must be remembered, however, that the scrambled picture and the degree of annoyance caused by it is perceived in the mind of the observer, therefore it is difficult to objectively determine and define just what is "enjoyable".

Although the idea of purposefully injecting a scrambling signal is new, the phenomenon of single frequency interference has been dealt with before.[3] Specifically, in CATV engineering one is sometimes faced with the problem of interference created by the presence of several TV channels, and non-linear devices on the cable. In these situations the source of interference is outside the channel of interest (where the disturbance is noted) as, for example in the case of adjacent channel interference. A sharply tuned notch filter is frequently used by engineers to attenuate the single frequency causing the interference, i.e. the adjacent carriers.

The novel modification of this procedure incorporated in the TEST System is that it is also possible to remove an in channel single frequency interference, such as a scrambling signal, by means of a sharply tuned notch filter. If the notch filter, or Descrambler, attenuates the scrambling signal to at least the -45dB level, TV reception may become acceptable in most cases. Figures 1a. and 1b. depict schematically the frequency spectrum of a TV channel with the scrambling signal present, and with the scrambling signal removed.

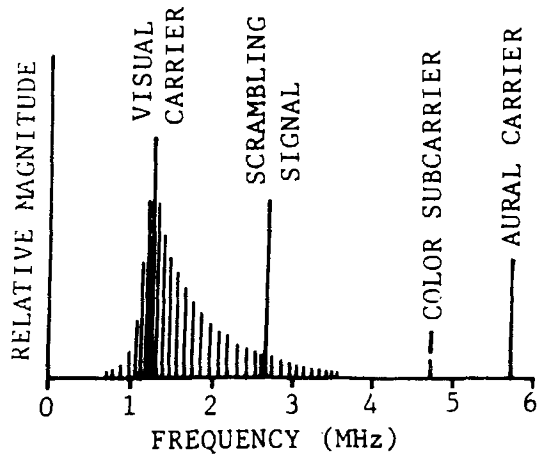

Figure 1a.

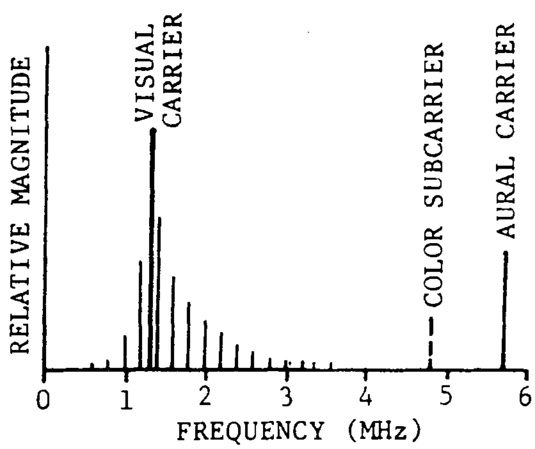

Figure 1b.

In practice, it is not possible to remove a single frequency. A notch filter removes a band of frequencies about the undesired signal.[4] This means, of course, that regular picture material is removed from the transmission along with the interfering signal. There are, thus, stringent design considerations for the Descrambler, even though in theory it is merely an in channel notch filter.

The principle of the TEST System is the inserting of a scrambling signal into a particular TV channel, e.g. between the visual and aural carriers, and thereby obliterating the received picture and sound. The reception may be restored, or descrambled, for a subscriber by removing the scrambling signal at the TV set. Figure 2. is a block diagram of a typical CATV facility equipped with the TEST System.

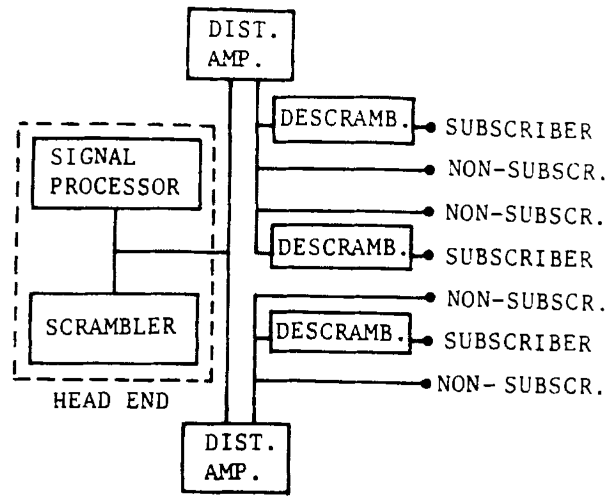

Figure 2. The Scrambler Unit

The scrambling signal is generated by the Scrambler which is located typically at the head-end of a CATV facility, as indicated in Figure 2. The function of the Scrambler is best understood through a practical example.

If it is desired to scramble Ch4 for purposes of payTV security, the following choice of parameters for the scrambling signal will render reception unenjoyable without the use of the TEST Descrambler unit.

Scrambling signal frequency:	69.507 MHz ± 1KHz
Frequency difference between scrambling signal and visual carrier:	2.257 MHz ± 1KHz
Level of scrambling signal relative the visual carrier:	0 dB
Modulation of scrambling signal:	15 Hz AM 1 KHz AM
% modulation of scrambling signal:	80%

Table 1.

It can be noted from Table 1. that the scrambling signal is very nearly midway between the Ch 4 visual and the aural carriers. The frequency spectrum is shown in Figure 4.

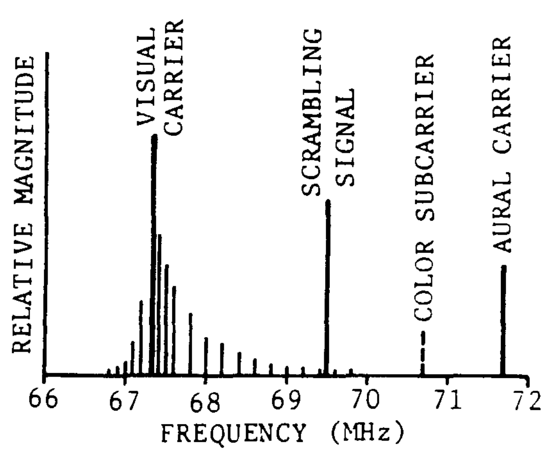

Figure 4.

Systematic investigations indicate that this choice of parameters is just one of several which will function well in the TEST System. In this instance, the scrambling signal has the following effect on TV reception.

1. The 2.242 MHz signal is detected and amplified along with regular video information by the TV set. Because of the 1 KHz AM modulation the interference appears as a set of horizontal bars across the receiver screen. The 15 Hz AM modulation interferes with the A.G.C. and vertical synchronizing pulses, and causes the picture to roll and jump.
2. The beat and harmonics generated by the video detector become part of the 4.5 MHz sound information. The 1KHz AM modulation, passing through the limiters, is detected and amplified by the audio circuits such that the 1 KHz tone [illegible] the speakers overrides regular sound material. Additionally, the 15 Hz AM modulation is audible as a "chirping" sound.

This frequency of 2.257 MHz interleaves the scrambling signal between harmonics of the scanning frequency, which arrangement facilitates the eventual descrambling process. This frequency of 2.257 MHz also positions the scrambling signal away from the chroma information, so that colors are not disturbed when the scrambling signal is removed.

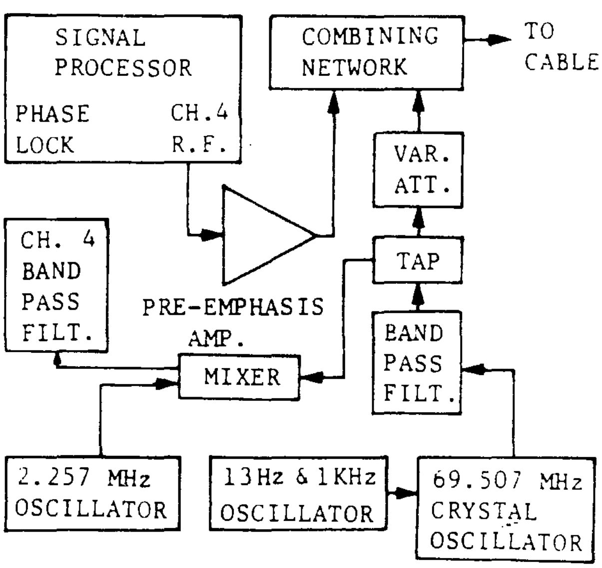

Figure 5

Figure 5. is a block diagram of the Scrambler unit and of the connections to other parts of a typical CATV head-end installation. The 69.507 MHz signal is generated by the crystal controlled rf oscillator. The crystal is maintained in an oven for added stability. A series of band pass filters reduce the harmonic content to -70 dB with respect to the fundamental. Another highly stable crystal oscillator, operating at 2.257 MHz, is used to produce a reference for the visual carrier. This 2.257 MHz signal is then mixed with the 69.507 MHz scrambling signal, and it is to this frequency, i.e. to 69.507 MHz-2.257 MHz, or to 67.250MHz, that the visual carrier of Ch 4 is phase locked. Consequently, the 2.257 MHz frequency difference is insured to remain constant for the system.

The pre-emphasizing amplifier processes the rf band containing Ch 4 in such a way as to counter balance the degradation anticipated from the descrambling process. It amplifies the band symmetrically about the 69.507 MHz point. Figure 6. shows the frequency response of the pre-emphasizing amplifier, providing approximately 12dB gain at 69.507 MHz.

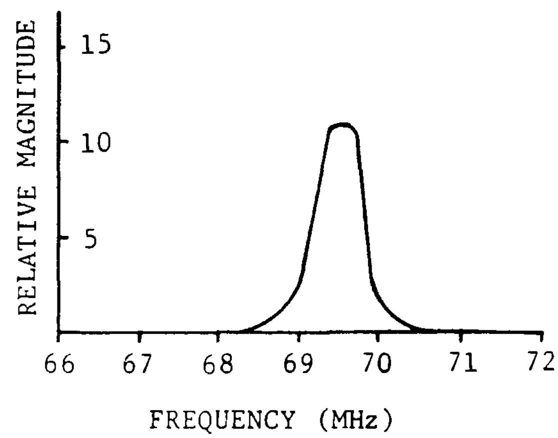

Figure 6.

The pre-emphasized Ch 4 band is then combined with the 69.507 MHz scrambling signal and is coupled into the cable system via an impedence matching device. The frequency spectrum of the transmitted rf band is pictured in Figure 7.

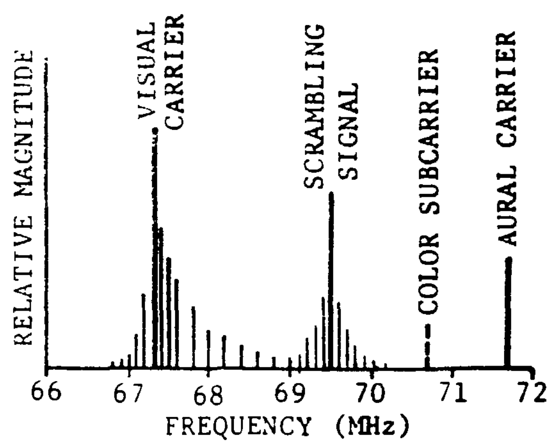

Figure 7.

The Descrambler

The descrambling process consists of removing the scrambling signal from the Ch 4 rf band. This is accomplished by connecting a Descrambler unit in the subscriber's drop line. The Descrambler unit, as described below, is designed to be located indoors, mounted on the baseboard close to the TV receiver set.

As mentioned before, the Descrambler is a sharply tuned LC notch filter whose frequency spectrum is symmetric about the scrambling signal. It is a completely passive device requiring no power for its operation. The ultimate attenuation of the Descrambler is in excess of 60 dB at 69.507 MHz, the notch being sufficiently wide to remove the AM sidebands of the scrambling signal, but being sufficiently narrow to prevent serious degradation of the video information. Outside the notch, the Descrambler offers a nearly perfect 75 Ohm impedence match, and transmission is attenuated less than 1 dB. A bandwidth of 1.25 MHz at the 3 dB level is typical. Figure 8a. shows the frequency response of the Descrambler, while Figure 8b. shows the frequency response of the pre-emphasizing amplifier superimposed on Figure 8a. It can be seen that the ultimate bandwidth of the Descrambler as employed in the TEST System is less than 0.5 MHz at the 3 dB point.

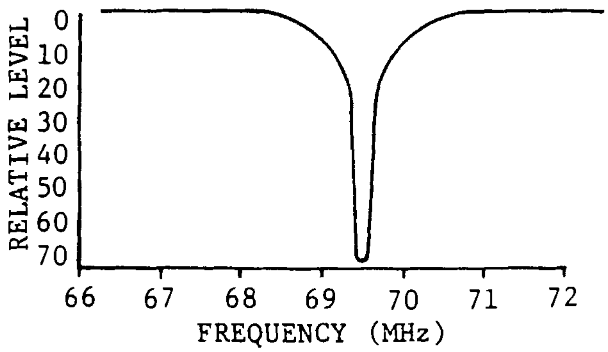

Figure 8a.

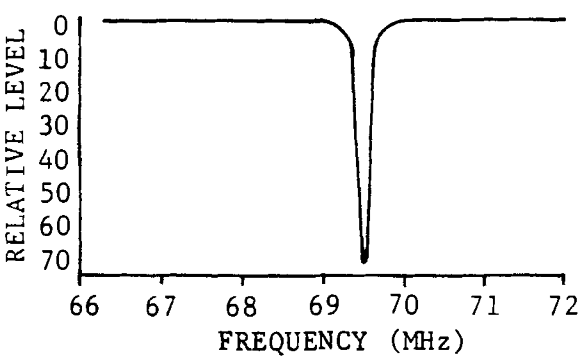

Figure 8b.

Stability is the primary consideration in the design of the Descrambler. Short and long term changes in the environment must be considered. In particular, changes in temperature will cause thermal expansion of the components and hysteresis effects become noticeable. In order to minimize such environmental impact, the Descrambler components are made out of some of the most stable materials available, i.e. from glass and ceramics. In order to take advantage of the great thermal and mechanical stability of these substances, a certain means of depositing conductors on glasses and ceramics has to be employed. The so-called thick film technology is ideally suited for the purpose.

The thick film process, as it applies to the Descrambler, consists of screening a conductive thick film paste onto a ceramic or glass substrate. The screened on silver pattern is dried and subsequently fired at temperatures up to 1500°F., so that it is permanently fused to the substrate. Special kilns provide the proper temperature profile for this process.

Except for inductors, all parts of the Descrambler, that is all conductors and capacitors are screened onto an NPO type ceramic substrate. This particular kind of ceramic has very nearly zero temperature coefficient for its dielectric constant, as well as very nearly zero hysteresis. Along with glass, its thermal expansion coefficient is of the order of one part in a million. In other words, capacitors made from NPO dielectrics have both short and long term thermal stability. The actual capacitors in the Descrambler are of parallel plate design, thus both sides of the NPO substrate are utilized.

The inductors are supported by low loss electronic glass substrates. The silver thick film paste is printed on the cylindrical glass by a special technique. The pattern is fired onto the glass in a manner already described, except, of course, a different temperature profile is required.

In order to facilitate the high Q required, the conductivity of the fired film is increased by a silver electroplating process.

In the event that the notch of the Descrambler is off the desired frequency because of variations in the manufacturing process, the unit can be fine tuned by the laser trimming process. In this procedure, various portions of the conducting surfaces are burnt off from the substrate by a guided laser beam.

The stability of the Descrambler is further enhanced by the rigid, thick walled die cast aluminum enclosure. It is, of course, in the subscriber's interest to prevent the Descrambler from being damaged, nevertheless the sturdy enclosure is necessary to minimize unintentional damage. A unique feature of the Descrambler is the Deactivator device which makes the unit virtually theft proof. The design of this feature incorporates a spring loaded trigger mechanism which is released when the unit is tampered with. This might happen, for example, when someone unauthorized attempts to remove the Descrambler from the base board. Since a special tool is required to turn the uniquely shaped screw that holds the unit to the board, force would have to be applied to pry the unit off the wall. This forceful removal releases the Deactivator, which, shattering the glass and ceramic substrates, renders the Descrambler totally inoperative.

* * *

It should be apparent from the preceding discussion that the sole modification of the TV channel is the addition of what amounts to another carrier signal. This third carrier, the scrambling signal, doesn't, however, interact with the rest of the rf information in the channel, because the scrambling signal is combined with the regular transmission through a linear network. The actual "scrambling" is accomplished by the receiver, which is unable to reconstitute a coherent TV picture while the scrambling signal is present. The scrambling signal, located as it is in the TV channel, is readily processed by the line amplifiers of a cable system. For the same reason, the scrambling signal is compatible with AML, and MDS as well. Any small increase in distortion, if it occurs, can be eliminated by slightly reducing the overall level of the channel band.

It is reasonable to conclude then, that the TEST System does provide a degree of security adequate for most pay-TV operations. Its salient features are:

1. Low cost. Initial capital outlay is low, since one Scrambler unit readily handles an entire cable system. Only paying customers are supplied with the Descrambler.

2. Simplicity, and inherent reliability of operation. Easy to service and maintain.

3. Flexibility. Centrally controlled scrambling, turning scrambling on or off at will, provides great advantage from a promotional as well as from an engineering viewpoint.

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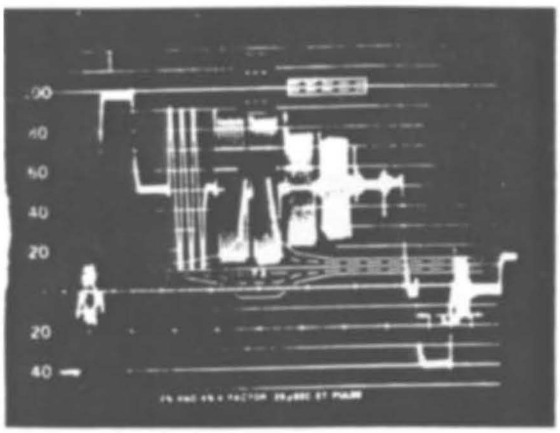

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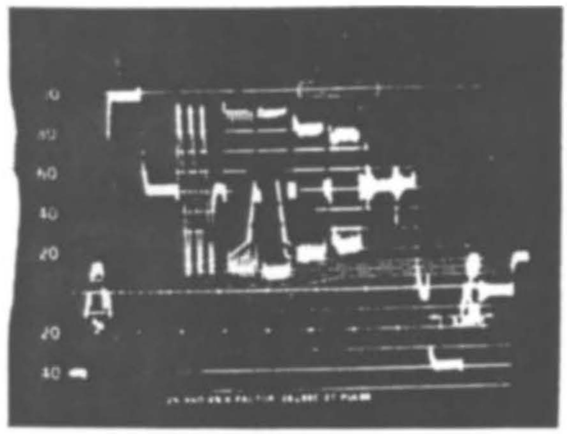

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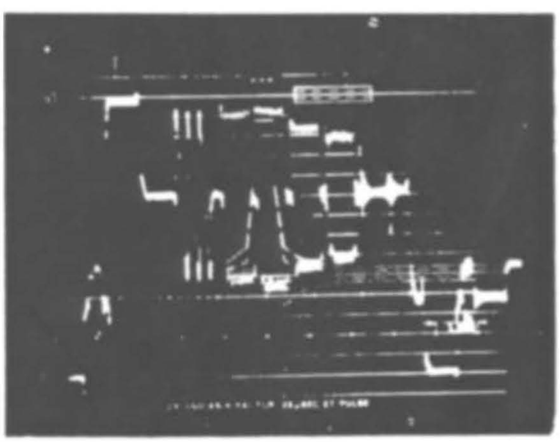

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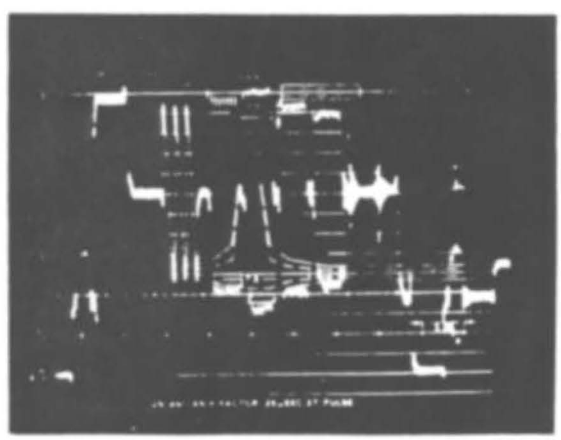

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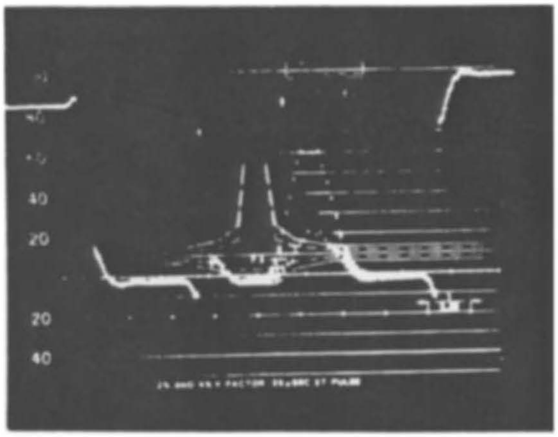

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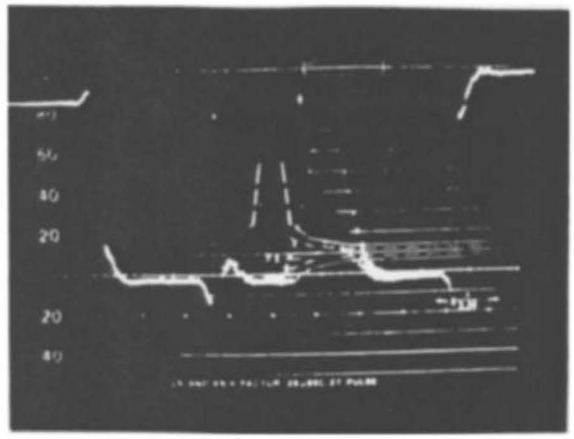

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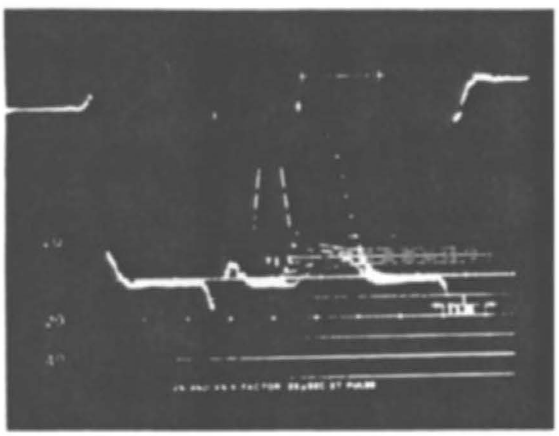

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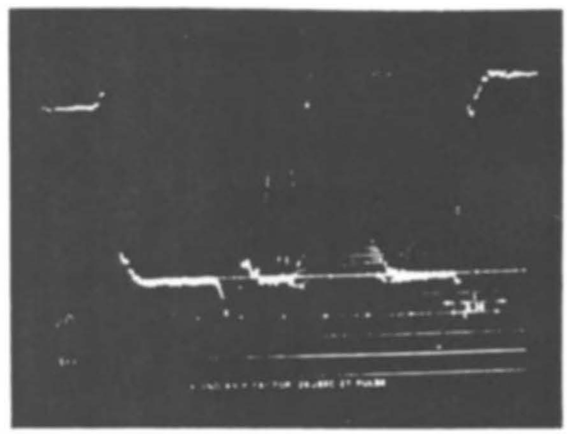

4A