A NEW OPTION IN SUBSCRIBER CONTROL

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INTRODUCTION

We introduce in this paper a new concept in subscriber control based on program denial outside the home. The technique is rooted in positive trapped systems, but is believed to offer improvements in both security and in quality of recovered signal. It is optimized for protection of services having relatively low but significant penetration.

Two novel ideas are presented. The technology used for program denial is new, as is the packaging technique. The packaging is not an integral part of the program denial technology, nor is the denial technology integral to the packaging. However, the two together do form a nice package for the intended application.

BACKGROUND

Early cable television systems transmitted only on the 12 standard VHF channels. Later non-standard channels were added and a set-top converter was used to convert them to a standard channel.

With the introduction of premium services, traps were added to the system as a way to control which subscribers recieved premimum services. Negative traps were used to remove premiums for basic subscribers, but carried a significant cost disadvantage when the pay to basic ratio was low. Positive trap systems overcame this cost disadvantage by requiring traps only at the homes of the premium customers (who were already paying extra). Positive traps, however, remove part of the desired signal along with the interfering signal. This resulted in poor picture quality and violated one of the first premises of cable television, which was the delivery of a good quality signal. Also, as their technology became known, easy defeats (twin lead and aluminum foil) were discovered by pirates.

In an effort to make premiums more secure, cable operators moved to more sophisticated scrambling techniques, placing the descrambler in the subscriber's set-top converter. This limited interface continues to serve well. Additional functionality is now required by the the video revolution, with its proliferation of remote controls, VCRs and multiple TVs. Several ideas have been proposed to ease the interface between the cable system and the cable subscriber. One new system is described here-in.

This system is based on a new and improved positive trap technology. It employs an interfering signal that is much harder to remove and a trap technology that removes only a small, redundant part of the desired TV signal. this makes compensation easier. Advantages to the cable operator include removal of equipment from the subscriber's premises, a lower cost when serving multiple sets, a capital cost proportional to pay subscribers, and subscribers who perceive a higher value to their cable service. Advantages to the subscriber include easier interface to multiple sets and VCR's and the full use features included in remotes and cable-ready sets.

The system removes the cable operator's equipment from inside the home and provides a broadband outlet to the cable subscriber. This broadband signal contains all purchased premiums descrambled simultaneously and is easily routed to all TV sets and VCRs.

INTRODUCTION TO THE NEW SYSTEM

Positive trap technology has been used in the CATV industry for many years. This technology is based on the simple concept of inserting an interfering signal within a television channel at the headend and removing that interference with some form of filter at the subscriber's home. The goal of the design of this filter is to remove the interference without producing perceptible artifacts in the recovered television signal.

This technique has several attributes that may be desirable to the CATV system operator. One of these attributes is that the secured channels are scrambled on the distribution plant. Secondly, capital investment is required for filters only at the subscriber locations where premium services are being purchased.

The conventional embodiment of this technology involves the use of an L-C notch filter that is located at the subscriber's home. A notch filter (or band reject filter) is a frequency selective device that attenuates a band of frequencies while passing all others. Unfortunately L-C technology has some inherent limitations when used for this application. In the positive trap scenario it is desirable to make the notch filter as narrow as possible so that the interfering signal may be removed without removing or significantly affecting the desired television information.

One figure of merit for quantifying the performance of a notch filter is Q. Q is defined as the ratio of the notch center frequency to its 3 dB bandwidth:

$$Q = \frac{F_o}{F_{3dB}}$$

See Figure 1. Typical maximum values of Q for a conventional L-C notch filter are around 30. This means that a trap for channel 7, near 177 MHz, will have a 3 dB bandwidth of about 5.9 MHz, essentially the bandwidth of a TV channel.

In order to minimize the effect of a notch filter on the recovered signal it is important to maximize the Q (i.e. decrease the 3 dB bandwidth). It is difficult to accomplish this goal with conventional L-C technology, especially as center frequency is increased. This constraint has limited the use of positive trap technology to the low end of the CATV spectrum.

Q characteristics limit the number of choices for placement of interfering signals in positive trap scenarios. In the conventional configuration the interfering signal is placed midway between the picture carrier and the sound carrier (see Figure 2). This area of the television channel was chosen due to the relatively low energy concentration occurring during normal television programming. Any information removed from this area of the spectrum has a minimal effect on the quality of the recovered signal.

Despite this location, L-C notch filters remove significant amounts of useful information so as to noticably degrade the quality of the recovered signal. Additionally this location makes it possible for the pirate to recover an acceptable signal using components that are readily available.

The design goal for the new system was to develop a positive trap that is significantly more secure and provides an improved recovered television signal when compared to the existing L-C notch system. The heart of this new system is an improved version of the notch filter. This filter has been developed utilizing SAW (Surface Acoustic Wave) devices as resonant elements in the notch filter design. The SAW devices provide filter Q's far in excess of that of L-C technology (around 450 with SAW based notch filters as compared with 30 from L-C based filters). The resulting filter has a minimal effect on recovered signal quality. The improved notch filter supports the placement of the interfering signal in a part of the television channel that makes it much more difficult for a pirate to remove the interference using techniques generally at his disposal, without corrupting the recovered signal to the point of being virtually unusable.

NEW NOTCH

The development of an improved notch filter has necessitated the development of a new and unique SAW device as well as the utilization of this SAW device in a new filter topology.

Figure 3 shows measured data comparing the response characteristics of a SAW based notch filter to a conventional L-C based notch filter. Both filters are centered close to 200 MHz. Typical performance characteristics of a SAW based notch are given below:

1.	SAW Notch Center Frequency	199.022 KHz
2.	3 dB Bandwidth	450 KHz
3.	6 dB Bandwidth	350 KHz
4.	40 dB Bandwidth	60 KHz
5.	Passband Insertion Loss	<1 dB Max. 0.5 dB Typ.
6.	Passband Bandwidth	DC to >800 MHz
7.	Frequency Drift vs. Temp from -40°F to +140°F	-15 KHz + 5 KHz

Passband characteristics are shown in Figure 4. The low passband insertion loss makes it possible to cascade several notch filters at various frequencies. Classically, one associates SAW bandpass filters with high insertion loss. The present notch filters are not based on the same principles and the high loss conditions do not apply.

LOCATION OF JAMMING CARRIER

The drastically reduced width of the notch filter allows placement of the jamming carrier much closer to the picture carrier. This makes the pirating job much more difficult, since simple traps which might remove the jamming carrier also remove the picture carrier and essential sidebands. While traps may be constructed which yield some sort of recovered signal, considerable degradation results. Figure 5 shows the location of the jamming carrier on the vestigial sideband of the protected channel. This location was chosen because it allows reasonable jamming coupled with reasonable ability to recover a quality signal.

Several conflicting requirements are placed on the jamming signal location. A location as close as possible to the picture carrier is desired in order to improve the robustness of the system against the onslaughts of the pirates. On the other hand, a location as far as possible from the jamming carrier improves the ability of the SAW trap to recover a quality signal. The placement chosen represents the best engineering compromise between these requirements. Three considerations led to the final choice of a jamming frequency, once the approximate limitations of the technology were determined.

In order to minimize the visibility of artifacts generated by incomplete attenuation of the jamming carrier (for a legitimate subscriber), the same technique is applied as is used to minimize effects of the color subcarrier beating with the picture carrier. The offset between the jamming and picture carriers is locked to an odd harmonic of one half the horizontal line rate. It can be shown that doing so causes any beat which does result, to be stationary on the screen, and a stationary beat is considered less visible than is a moving beat. A second consideration is that the jamming carrier, being equal in amplitude to the picture carrier, must fall in one of the required offsets should the protected carrier be on one in the aeronautical band. Assuming that the picture carrier has already been offset to fall at one of the permitted offsets, it then becomes necessary to offset the jammer by a multiple of 25 KHz (for most channels) from the picture carrier, with a tolerance of 5KHz. A third criteria is that the artifacts relating to the notch must be minimized.[1] One way of doing this is to place the notch at such a point that the energy contained in the horizontal sync is minimally disturbed. Figure 6 shows the horizontal sync signal and the spectrum which results. Not shown are the 15.734 KHz components resulting from the frequency of the sync signal. These components may be shown to follow an envelope, which is shown, having a sin(x)/x shape. This envelope exhibits nulls in the spectrum at frequencies equal to the reciprocal of the width of the sync pulse, W. A standard NTSC sync pulse has a width of 4.7 microseconds, so the nulls in the spectrum occur every 212.8 KHz.

Thus, in finding frequencies suitable for the jammer, one looks for offset frequencies equal to an odd multiple of one half the line rate, which also fall very close to an aeronautical offset (in this case, we look for frequencies removed from the picture carrier by a multiple of 25 KHz.). If the chosen frequency falls close to a null in the sync spectrum, so much the better. One suitable frequency is an offset equal to 29/2 of the horizontal line rate, about 228.1 KHz from the picture carrier. This is close to an aeronautical offset, though tighter than normal tolerancs would be required to utilize an aeronautical frequency.[2] Further, it is acceptably close to a null in the sync spectrum.

MODULATION

The jamming carrier is modulated with a sine wave locked to the horizontal line rate and phased such that the envelope of the jamming signal is maximum during the middle of the TV line, when the amplitude of the picture carrier is lower. The jammer is then at minimum amplitude during the sync tip, when the picture carrier envelope is maximum. Thus, the modulation reduces the system loading. We have found that the scrambling effect is considerably enhanced by the modulation. This appears to be because the sync separator in the TV frequently takes the peak of the jammer to be sync. We are also experimenting with other forms of modulation on the jamming carrier, which appear to create additional irritation for the pirate, without being visible to the legitimate subscriber.

GENERATION OF THE JAMMING CARRIER

Figure 7 shows one possible method of generating the jamming signal. The jamming is done at the modulator IF in order to ease selection of the protected channel. Depending on the modulator, interface may be the same as interface with RF sync supression scrambling. A bandpass filter, F1, selects the picture carrier from the modulator. It is mixed with the jamming carrier from OSC 1, which in turn is locked to an offset derived as shown below. The difference frequency is recovered in lowpass filter F2, and applied to a phase detector, PD 1, along with a frequency at the correct offset. The error from the phase detector is integrated and applied to the jamming oscillator such as to keep the offset between the jamming and picture carriers equal to the frequency of offset oscillator OSC 2.

The offset oscillator is controlled within a second phaselocked loop, the reference for which is horizontal sync derived from a sync separator. Video is looped through the sync separator before being applied to the modulator. Predistortion of the video amplitude and delay is also performed, in order to compensate for the errors introduced by the trap. The horizontal sync frequency is divided by 2 and applied to phase detector PD 2. Output from OSC 2 is divided by 29 and applied to PD 2 as the other input. The error from PD 2 is integrated and used to correct the frequency of OSC 2.

Finally, the output from the jamming oscillator is modulated with a horizontal rate signal and added to the picture carrier before up conversion to the desired output channel. We should note that, in practice, the interface with the modulator may be different, but the above illustrates the technique involved. In order to set the level of the picture and jamming carriers with simple equipment, the jamming carrier generator includes provisions for individually turning off the picture and jamming carriers.

MECHANICAL ARRANGEMENT

An important feature of the system is its plastic enclosure - a UV stabilized, impact and weather resistant, tamper resistant housing in which the modular components are mounted. The primary mounting intended is to the side of a subscriber's house, similar to the interface provided by the telephone and electric companies. Other mounting methods may be used, such as mounting on a ground rod or on a post. Hasps are provided to permit locking with either a lock or a lead seal of the type used to protect power meters. Approximate outside dimensions of the box are 10 by 9.5 by 3.5 inches.

Internally, the unit includes a mounting post grid on 1.5 inch centers and is designed to accomodate suitable cable components such as ground blocks, splitters, and cylindrical traps in addition to the components of the new system. Cable entry and exit is provided for by gasketed holes in the enclosure bottom. RG59 or RG6 cable with connector installed may be inserted through the gasket while maintaining a weather and insect resistant seal. Figure 8 is an illustration of the internal component layout. Modules may be placed at any convenient location in the housing.

The modular components are designed for ease of installation and mechanical and electrical integrity. They are packaged in die-cast, tin plated zinc enclosures. Three modules have been developed to date. A filter module mounts directly to the mounting grid array and features two male push-on connectors for input and output. It contains a positive trap filter for a specific channel. Input/output and jumper modules mount to the filter modules and connect by female push-on connectors. Input/output modules provide a conversion from standard fittings to push-on and contain transient protection circuitry. Jumper modules serve simply to connect one filter to another. The push-on connectors have an integral O-ring seal to provide a pressure tight (to 10 PSIG) connection between modules. Center conductor contacts are precious metal plated and signal ground connections are tin to tin. Ground straps to connect the modules to a ground block are also available to insure a good earth ground. Captive screws are provided with each module for mounting ease.

EXPANDABILITY

Consideration has been given in the design to future applications and growth. It is anticipated that an amplifier module will be developed. Other modules are possible also. An addressability module has been discussed that would replace the input/output module and jumpers and would allow the use of existing filter modules. The addressability module would be mounted to the mounting grid array and existing filter modules would be inserted into it. The cost of an addressable upgrade would be minimized in this manner. Power would be supplied to the unit from the subscriber's residence through the center conductor of an output cable or through a separate set of wires.

Mechanically, the unit is designed to expand in two ways. First, a deeper lid would allow the mounting of electronics in the lid. The cable operator could remove the existing lid in the field and replace it with the new one. Secondly, provisions have been made for a subscriber accessable enclosure to be mounted directly below this enclsure. This enclosure would allow a subscriber or contractor access to the output cable to perform the signal splitting function or for connection to a pre-wired residence.

EVALUATION OF THE ISSUES

A number of issues must be evaluated when considering a new system like this. Cost is a major issue. The system obviously bears an initial cost for the housing. Since individual traps are employee for each channel, the cost is going to be related to the number of channels protected, in contrast to a set-top terminal which is generally insensitive to the number of channels protected. Should one configure this system with a number of channels under addressable control, the cost could become higher than that of an addressable set-top terminal, though the ability of one box to serve the entire subscriber premise is an obvious advantage.

Mounting to the side of a house as currently planned is an unusual concept in the CATV industry. This has been practiced for years by the electric and gas companies, and recently telephone companies have been using a box which performs an identical interface function. The box is a convenient point of demarcation between the subscriber's equipment and the cable company's equipment.

As currently configured, the equipment is passive, so powering is not an issue. However, future enhancements will require power. This power logically comes from the subscriber's home, but getting it to the box raises issues of safety and practicality.

Security is a big issue with any program denial technique. The system is certainly more secure than is a conventional positive trap, as a result of the proximity of the jamming carrier to the picture carrier. On the other hand, one would be reckless to assert that pirating was impossible. Rather, this system is intended to complement the contemporary notion that security must be evaluated in the context of probability of turning a pirate into a legitamate subscriber. If positive trapping has been considered a viable protection alternative, then this new system should surely allow improved confidence.

Quality of the recovered signal is thought to be better than that of a conventional positive trap system due to the narrow spectrum removed by the jamming signal. Further, since the removed signal components are duplicated in the full sideband, good compensation is possible. This compensation is added at baseband in the jamming carrier generator, and is based on measured amplitude and group delay of the baseband to baseband signal path.

As shown above, a conventional positive trapping system favors the lower part of the spectrum, generally the low and mid bands. The SAW technology employed in this new trap favors a higher portion of the spectrum. We have developed traps for channels 10 and 11 so far, and the next developments are expected to be in the lower portion of the superband spectrum, just above 216 MHz. The limit of the technology is not well known at this time, but clearly, we prefer to go towards higher frequencies.

These filters are compatible with scrambling systems, which may function on any channel including the trap-protected channel. This would be important to the operator wishing to make a transistion from scrambling to this system.[3] He may continue to operate a scrambler and descrambler while installing positive traps. After all subscribers receive the traps, he turns off the scrambler and turns on the jammer. The set-top converters should continue to function during the change-over period and after the scrambler is turned off. They may then be reclaimed by the operator at his convenience.

SYSTEM CONSIDERATIONS

While modulator interface is similar to that of an RF sync supression scrambling system, the requirements on the modulator are somewhat different. Since a second carrier equal in amplitude to the picture carrier is added, the modulator must have adequate linearity to handle it. At this early stage of development, we are unable to comment on the suitability of all modulators in existance. But, for example, a recently produced Model 6350 modulator is suitable, though we recommend some simple modifications for optimum results.

Addition of the jamming at a processor is technically feasible given the availability of a demodulated signal for phaselocking. However, baseband predistortion of the video must be accomplished somewhere in the system. Video delivered to subscribers not using a trap should not be predistorted, except possibly during a change-over period.

Transmission of a jammed signal over FM microwave links is not feasible, since the jamming signal must be added at RF. An AM microwave system theoretically can handle the scrambled signal, though generation of the transmitted signal may be complicated by the lack of sufficient upconverter linearity to handle the extra signal. This can be overcome by individually upconverting the picture and jamming signals and combining at the transmitted frequency.

Modulation on the jamming signal reduces the loading effect of the jamming carrier, though it is not eliminated. With the parameters currently planned for the system, addition of the jammer creates a peak voltage in the channel which is 4.6 dB higher than the voltage normally present on the picture carrier alone. Another way of looking at the increase is that it is equivalent in terms of system loading to adding another picture carrier, but at a level 3.1 dB below other picture carriers on the system. In most systems the increase in loading is probably not a big factor, but this needs to be examined in marginal situations.

CONCLUSION

A new positive trapping system has been shown which is believed to offer significant advantages when compared with conventional positive trap systems. These advantages accrue from the use of very narrow traps realized through the use of SAW resonators. Security is enhanced by placement of the jamming carrier very close to the picture carrier. Quality of the recovered signal is enhanced by the narrowness of the trap and the ability to place pre-corrected signals in the opposite sideband. Independent of this new technology but offered with it is a new packaging technique utilizing mounting to the side of the subscriber's house, providing a line of demarcation between the CATV system and the subscriber.

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[1] The effects of the notch may be compensated in the full sideband, but since compensation cannot be perfect, one is moved to minimize the effect of any residual errors.

[2] Presently only channels 10 and 11 are being used, so the question of aeronautical offsets is academic. In order to provide for future expandability, such offsets have been considered.

[3] The scrambling system manufacturer should be contacted before the change-out is started.

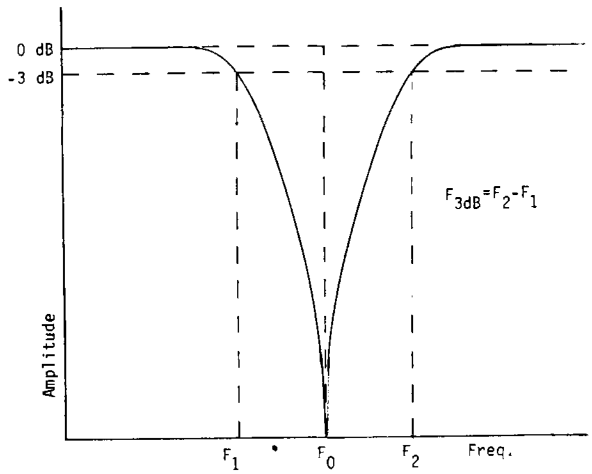

FIGURE 1 - FIGURE OF MERIT FOR A NOTCH

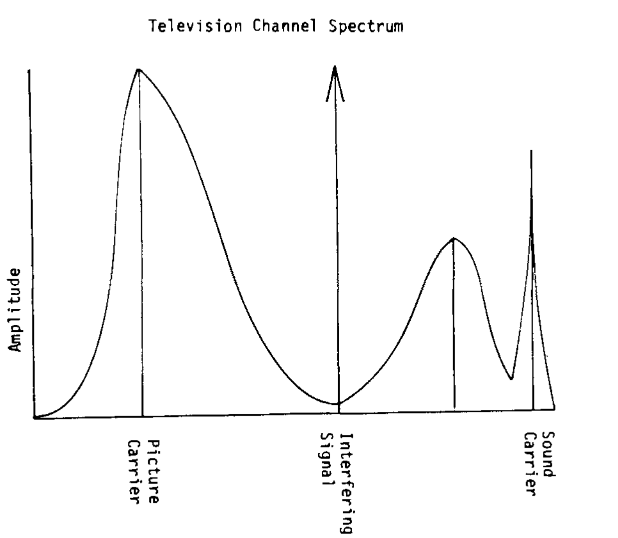

FIGURE 2 - TRADITIONAL JAMMING CARRIER PLACEMENT

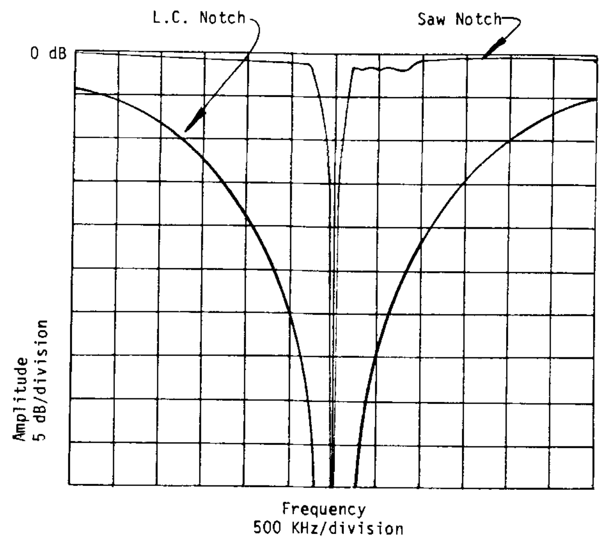

FIGURE 3 - COMPARISON OF NEW AND TRADITIONAL NOTCH PERFORMANCE

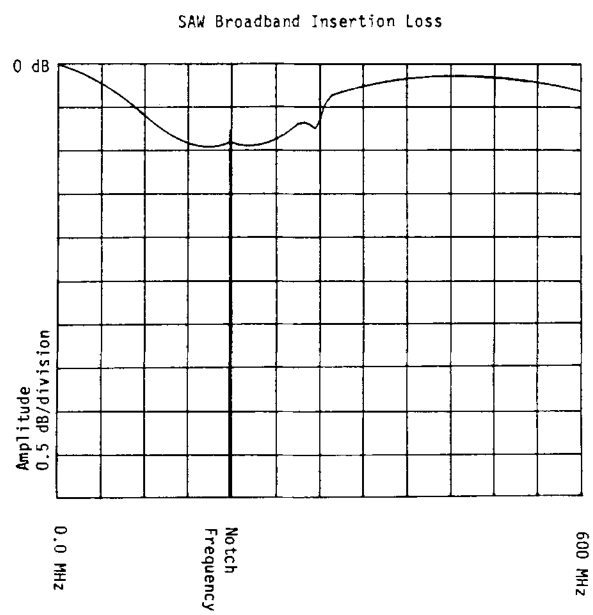

FIGURE 4 - NEW NOTCH PASSBAND CHARACTERISTICS

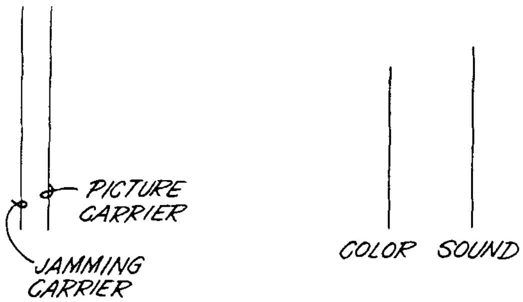

FIGURE 5 - LOCATION OF JAMMING CARRIER

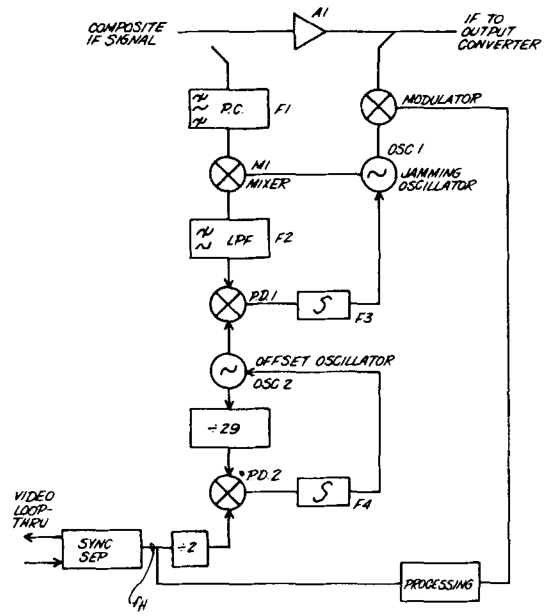

FIGURE 7 - GENERATION OF JAMMING CARRIER

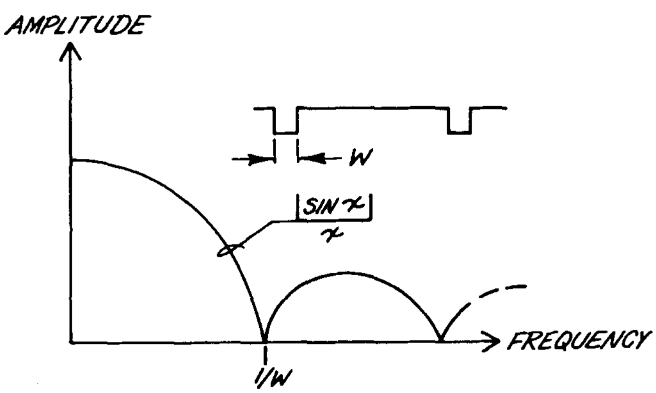

FIGURE 6 - HORIZONTAL SYNC SPECTRUM

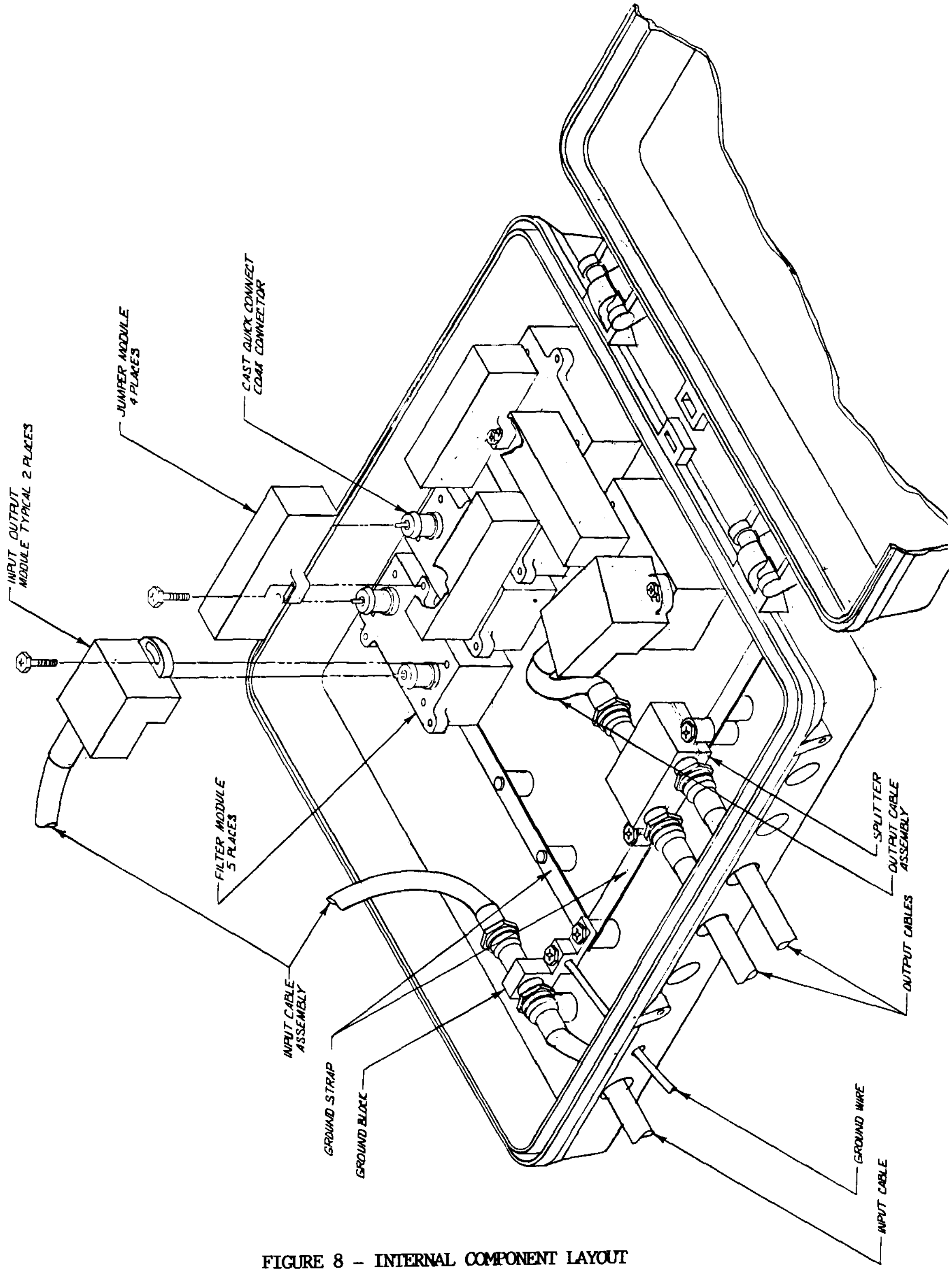

FIGURE 8 - INTERNAL COMPONENT LAYOUT