INGRESS - SOURCES and SOLUTIONS

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Signal ingress is a problem which has always plagued cable systems. While there has always been potential for problems from VHF television stations, with the modern cable system encountering the UHF television band, the susceptibility of cable systems to ingress interference is increasing. Immunity from ingress problems can only be achieved by maintaining system integrity at levels better than those required by specification.

Interfering signals leak into a cable system not only thru flaws in the cable system but also by way of consumer equipment, cable ready televisions and VCRs. The increase in the number of these devices as well as other factors lead to a need to be able to efficiently diagnose and cure signal ingress problems.

WHAT IS INGRESS

Ingress, as far as the CATV community is concerned, is the entrance into a cable system of any undesired external radio source. Ingress will occasionally be in the form of static or electrical noise, but it is normally considered to be interference from a radio frequency signal. Ingress of such signals will result in interference to cable pictures. Modern cable systems have sufficient isolation from ingress, or shielding, to prevent ingress of carriers in even the noisiest of radio environments. But, an awareness of ingress related problems is required by the cable system operator to enable repair of inevitable, natural, flaws in the system.

Ingress is the opposite of egress, or system radiation. The principle by which both phenomena operate is the same, related by the principle of antenna reciprocity, which is that antennas transmit and receive equally well. That cable systems do radiate energy is an established fact, that cable systems are susceptible to ingress therefore follows. As system egress levels are reduced to within regulation, effects of ingress are reduced toward acceptable levels. Still, in order to completely overcome the effects of ingress in areas where external radio signals are especially high, even defects that are otherwise insignificant must be found and corrected.

Interference due to ingress can be classified into two basic forms, either co-channel or discrete carrier. When there are one or more local VHF TV stations located near a cable system which uses a channel occupied by one of these VHF stations, there will without doubt, sooner or later, be need to correct co-channel interference between the two. Discrete carriers from communications transmitters will cause problems on mid-band and super-band cable channels. As communications transmitters include everything from car phones and personal pagers to amateurs and the National Weather Service, discrete carrier ingress can occur anywhere and often at random times.

Cable systems near the VHF TV transmitters of a large city are the systems that will likely suffer from co-channel ingress related problems. At two to five miles from a full power TV transmitter it is not uncommon to have a field strength of 35 to 40 dBmv or more, very often 25 dB more than than what is inside the cable. Levels from TV transmitters as far away as 30 miles may exceed the average levels of a CATV plant. Beyond that range the effects of ingress related co-channel interference become less noticeable.

Co-channel type ingress interference in its most basic form will appear on a TV picture as a strong beating pattern , when the cable channel is not phaselocked with the interfering station. If the cable programing is phaselocked to but not sync locked to the unwanted carrier, a wiping of the interfering stations' sync bar through the background of the desired picture is the first effect noticed. If cable programing is both phase and sync locked to the local station, as it is when operation is "on channel", the first effect will be faint ghosts in the picture, either of text characters with their high energy edges, or of the horizontal sync bar, stablized, but in the middle of the screen. The difference in the time it takes the signal to arrive at the set both through the cable and

through the air allows the channel to interfere with itself. If the two signals arrived at the same time they would mesh perfectly, all the interference would be hidden.

When operating "on channel", or with alternate programing phase-locked and sync locked to a local VHF transmitter, the cable signal must be at least 50 dB or more above any ingress from the airwave signal in order to suppress sync bar ghosting of the picture. Without sync lock, a separation of 55 dB is a minimum to prevent an annoying wiping pattern in the background. If the cable channel operates with alternate programing not phaselocked to the local TV station sharing the same channel, the cable video carrier should be 60 dB higher than any interference. In extreme cases of co-channel ingress interference, where an off air signal is only 40 or 45 dB down from the cable signal, strong ghosts or other distortions may be expected, regardless of the operating mode. Customers will surely call for service when the interference is this bad.

The effect of ingress due to discrete carrier interference is similar to second order beat problems in that both will appear on the customers set as a herringbone pattern or wavy series of vertical lines. If several unwanted carriers are present, as is often the case with channels shared by the communications bands, the effect may be a soft distortion similar in symptoms to third order product accumulation. A discrete carrier located near the color sub-carrier of a cable channel may cause a beating pattern in picture tint or, if sufficiently strong, may even drive the picture into black and white.

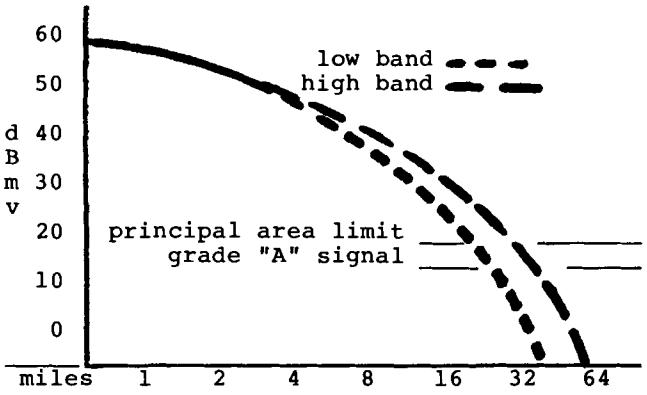
Picture distortions due to discrete beats vary depending upon the level of the beat as well as the position of the beat in the band of the cable channel. For example, an interfering carrier 30 dB down and 10 khz. from the cable video carrier will probably not cause any noticeable picture distortions. Interference located 1/2 mhz above the video carrier with a level as low as 40 dB down from it, will cause strong beats in the picture. When the interference is from a carrier located in the middle of the cable channel, 1-1/2 mhz away from the video, a rejection of up to 55 to 60 dB is necessary to prevent a "busy background" effect. The amount of immunity required by the cable system from ingress beats is the same as and can be compared to FCC specifications regarding carrier to second order beat ratios.

HOW DOES INGRESS GET IN

Ingress gets into the cable system by way of poor shielding and faulty connections. The cable acts as an antenna and will have currents from external radio fields induced onto it's shield. Electron flow, or currents, of radio frequency energy, happens only on the surface of a conductor. Under normal conditions, the cable signal energy flows on the inside surface of the shield and broadcast radio signals flow on the outer surface of the shield. A "hole" in the shield will join the two surfaces, allowing undesired currents to flow both out and in. Unbalanced current flow between the shield and center conductor of the cable will cause the undesired signal to be added to the cable signal.

Experience has shown the most common point of ingress to be a slightly loose connector. The connection is normally tight enough not to noticeably effect the cable signals, if not for the ingress problem. The connection may be just loose enough to permit air molecules to permeate between the threads and, given time, form a layer of corrosion. The improperly made connector will also permit gasses to corrode the aluminum of the shield itself, forming aluminum oxide, a poor electrical conductor. Corrosion will create a point of resistive and/or capacitive nature in the shield of the cable. This breakdown of the outside conductor is the unwanted hole in the shield.

Theory and experiment show that a mismatch on the inner conductor will not permit signals to enter the cable, only the signals inside the cable already will be affected. This can be demonstrated by cutting the center conductor short at a splice in the middle of a section of drop. The isolation is as good as the shield in this experiment. It can also be demonstrated that a single crack or hole in the shield,



FIELD STRENGTH OF TV TRANSMITTERS [3]

not completely around the cable, is in itself not a significant source of ingress. However, when the small cracks are spaced at regular distances, an effective amount of energy is transferred into the cable (as well as out).

Improper handling or installation of drop cable can cause periodic cracks in several ways. One common way a flaw may arise is when a staple gun, faulty itself or improperly used, causes a severe sharp dent in a drop wire as the staple is fired. Even though the outer shield is not actually pierced by the impact, a small crack might be created. A series of a dozen or so of these, regularly spaced 18 to 20 inches apart, can reduce the shielding of a drop, down from a nominal 90 dB, to only 50 or 60 dB of isolation at mid band frequencies. Periodic bumps and cracks in drop cable can also be caused by rough pulling the wire from boxes and reels, or flexing the cable sharply around corners, although the observed occurrence of this type of failure is rare.

One way the largest amount of unwanted signals can be transferred into the cable is by a total discontinuity of the shield due to radial cracks. Faulty connections are similar to these radial cracks. A radial crack all the way around the cable shield will typically reduce the cable signals by about 10 to 12 dB, implying, in the worst case, as low as 3dB isolation between the the outside and inside of the cable. On the other hand, a typical "bad" connector might reduce the isolation to 40 dB, with less than 1/10 of a dB reduction in cable signals.

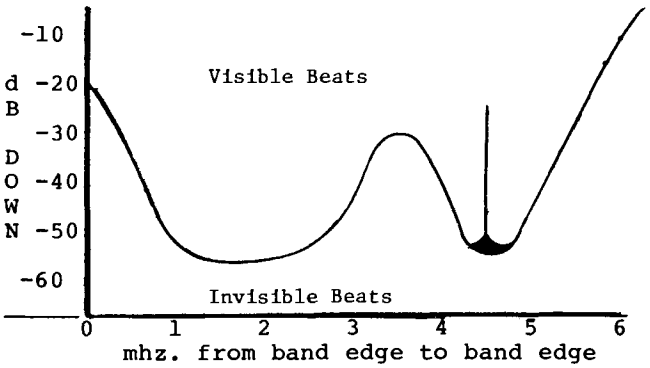
Compared to defects created by bad connections, the amount of shield provided by the wire itself is of minor importance as far as ingress is concerned. With trunk and feeder lines, the shielding is complete as possible, with more than 110 dB of isolation often the case. Flexible drop wires with foil shields under a wire braid, the type used by the cable industry, typically are rated with 85 to 100 dB shield isolation.[1] The ability of the cable shielding to physically withstand handling and to survive the elements is of more importance when selecting drop cable of this quality then the shield factor itself.

The shielding factor of the drop cable becomes significant when non standard wire is used, such as a situation in which a house has been wired by a customer using his own wire. The shield for this wire can be as low as 50 dB for wire with a heavy braid, 35 dB or so with typical 40% braid shield wire. Also, aside from the poor shield, it is almost impossible to make a proper connection to these wires as the dimensions vary greatly from type to type and it is next to impossible to find a proper fitting. The fitting must not only pass signals but must properly seal the shield from ingress as well as survive through time.

Other parts of the cable system responsible for ingress are loose amplifier covers and tap plates. Although experience is that an amplifier housing must be open and the amp's module cover almost off in order to get a significant amount of ingress into the cable itself, amplifier covers must not be ruled out.

Tap plates, however, especially when drops are connected to them, are crucial points of shielding breakdown in the feeder system . The rf shield around the edge of a tap plate can only work well when making a good pressure connection to the housing plate. Loose tap plates, with contaminants between the plate and the housing will cause a discontinuity to occur between the drop shield and the shield of the feeder cable, allowing ingress into the drop and to a lesser extent, into the feeder itself. Even when the tap plate is tight, corrosion due to moisture is frequently a problem as the rf gasket is located at the point of maximum water accumulation as a tap hangs on the feeder line. A very thin layer of waterproofing grease will aid in preventing this problem. A word of caution needed here, over zealous tightening of tap plate screws will lead to striped housing threads, clutch type torque drivers are recommended.

Studies have indicated that an unterminated tap port will provide greater RF isolation than a terminated tap port.[2] The terminator itself is a connector and hence subject to the inevitable natural corrosion of the connector threads. As the outer shell loses its ground connection, the terminator becomes a stub antenna and hence a point of ingress into the cable system. The port to port isolation of a two way splitter is normally about 25 dB and a



CARRIER/INTERFERENCE RATIO [4]

stub antenna about an inch and a half long will pick up as much as 0 dBmv of signal near a high band VHF TV station. A strong to moderate interference is observed on drops connected to adjacent tap ports.

Port to port transference is also responsible for mysterious interference problems when temporary disconnections of a neighbors drops are made. In one case, when a neighbor disconnected the cable drop from his VCR, the center conductor of the drop would contact the metallic case. The field strength of the local TV stations were about +35 dBmv in the area. This resulted in +10 dBmv of interference being back-fed into the other customers' otherwise perfect drop. And, due to the directional coupler characteristics of the tap itself, the rest of the system was uneffected. This happened every night for a few hours at a time, greatly reducing the mental stability of the service personal. The solution was simple when the reason was discovered. The customer with the VCR was given an A/B switch so he could switch inputs and still maintain system integrity.

SUBSCRIBER CAUSED INGRESS

Perhaps the most perplexing cause of ingress problems is subscriber owned equipment. It is the one part of the system over which the cable operator generally has the least control. As the consumer becomes more and more 'video active', the occurrence of ingress problems due to consumer related equipment is sure to increase. The fact that subscribers will loosen drops by simply moving converters as well as by connecting their own equipment will be a sure ingress problem from now on in any metropolitan area. In a typical case an otherwise perfectly good VCR and TV set will be connected with factory included wiring with easy to use push on fittings. The customer installs the source and will suffer the effects of ingress. Installation of quality wiring with proper connections will correct the problem. While the solution is easy, it is a service call never the less.

Another common occurrence with customer installed equipment leading to an ingress problem is the video game or computer switch normally supplied with such equipment . When installed before a cable ready TV or VCR , or indeed installed anywhere but after a converter, they will without doubt permit ingress. When video games or computers must be connected to cable ready TV sets it is necessary to install a well shielded, self terminating CATV grade A/B switch in place of the customers switch. Using these and standard adaptors available at local electronic dealers, a connection can be made that will provide a proper amount of isolation. In some extreme cases it might be necessary to replace game switches located after the converter if a local transmitter is operating in a channel adjacent to the converter output channel. The lower sideband of a broadcast station extends well into the lower channel. Suppressed properly, it nevertheless has enough strength to overcome the poor shielding of these inexpensive, manufacturer supplied switches.

Of all the ailments created by subscriber equipment, problems due to the poor shielding of some cable ready TV sets are the only truly incurable ones. The amount of ingress which is introduced by cable ready televisions varies greatly from model to model and no brand can be said to be best. There are many models of cable ready televisions that exhibit excellent shielding while other models of the same brand don't. It is also found that problems with cable ready sets depend upon the location of the set in the room , as well as the strength of the interfering local transmitter. Cable ready sets are subject to the same conditions as the rest of the cable plant and if there is a potential for ingress, it will enter the system through the poorly shielded television just as easy as it would any other part of the distribution system. It will sometimes be necessary to tell a customer there is nothing that can be done, that the set itself is the problem.

Cable converters have the critical portions of the signal path inside a tight metallic box, which constitutes a good shield. A typical television will have the shielding open on one side, or have a circuit card pass through it, with the shield only spot soldered to the circuit card, leaving gaps enough to allow more ingress than several loose fittings, plenty enough to cause problems. The set will otherwise work perfectly, on channels other than the ones occupied by any communications band or local television station. The best option the cable operator has in order to correct a ingress problem directly inside the television set, is to place a converter before the cable ready set, allowing the set to operate on a clear channel. This sometimes upsets the customer who has paid extra for the cable readiness, and often complicates the instructions of using various remotes in order to gain satisfactory operation.

Aside from placing a converter before a cable ready set, the only other practical solution to this problem is to raise the signal levels into the set to a point where the level of the interference becomes insignificant. If the cable ready TV set has a shielding factor of 40 dB for example, about the average for the a problem causing set, and the field strength of a local transmitter is 0 dBmv, an input level of

+10 dBmv to the set will a provide brute force solution. Even this solution proves impractical if the set is located only several miles from local TV transmitters, the input levels needed to mask the interference will be more than the highest level the cable system is allowed to operate at by law.

The degree of the isolation provided by cable ready sets can easily be determined by reading the strength of the known source of interference directly out of the back of a TV set and comparing this to dipole readings at the same location. If one positions the antenna for maximum receive levels , and does the same with a television receiver, with the TV set off to prevent reading RF generated by the set itself , a direct estimate of the shielding factor of the set may be made.

Cable ready VCRs present another potential source of ingress, fortunately though they do not generally appear to be as great of a problem as cable ready TVs. Although poor VCR shielding has ocasionally been the source of ingress, the cables used and other problems with connections are much more bothersome than the VCRs themselves.

A poorly shielded cable ready set can also present a problem to other sets if the field strength of a local tv transmitter is moderately strong. It is quite possible for a set with 30 dB or less shielding factor, about the worst encountered, located in a typical urban environment, to pass ingress at -10 dBmv up a drop to a splitter. There it will back-feed down the other drop leg at a level of -35 dBmv of interference versus 5 dBmv of signal, more than enough to be noticeable.

FM hook-ups create two types of ingress related problems. The first is with interference to FM services provided by the cable system, and the second with addressable converters when connected along with a FM hookup. The typical FM tuner will work perfectly well with little or no antenna connected to it in an urban environment. While the shielding of the tuner is generally very poor, it is possible to deliver quality FM signals thru a cable system. If the signal from a local FM station is delivered unshifted in frequency, FM tuners will generally be unable to distinguish between the two carriers, in the cable and off the air. If the cable operator is careful to avoid using FM channels within 400 khz of local FM transmitters for other, imported or operator generated signals, problems may generally be avoided.

The possibility of ingress into the cable system of signals which could interfere with data carriers used by addressable converters and home security systems is greatly magnified by FM tuner hook-ups. With FM transmitters often as powerful as TV stations, combined with a tuner's characteristically poor shielding, backfeed of unwanted signals into the cable can create serious problems. As the data carrier is already well below the operating level of a cable video carrier, the sidebands of a local FM station can easily distort a data carrier. Data transmissions, when distorted by interference, may contain errors resulting in random characters being received between transmissions, or worse yet, in severe cases, the corruption of a desired transmission. To avoid problems with data communications in the FM band, you may use a directional coupler between FM tap-off device and the effected equipment to prevent backfeed. The use of regular splitters in place of FM taps should be avoided.

TROUBLESHOOTING THE INGRESS PROBLEM

As the number of urban homes wired for cable increases and as older drops aproach life expectancy, the amount of service calls related to ingress is bound to increase also. The problem is compounded by the wider bandwidths of modern cable systems as they encounter more communications bands and even UHF television. Increases in the number of communications transmitters in the spectrum and the huge impact of consumer equipment will lead to the need for quick and sure means of detecting and correcting ingress problems. Even today it is often the case that a cable system in a urban area will find 10 to 15, and sometimes as much as 30, percent of its service manpower spent finding and correcting ingress related problems. Routine procedures must be taught to service employees so that they can handle the problems efficiently.

It is often difficult to distinguish between faint interference and the symptoms of amplifier distortion. However, if the interference is strong enough to cause a heavy beat, it may generally be assumed that if a amplifier was emittimg a spurious product strong enough to be clearly visible it would probability have other by-products on adjacent channels. If you have a problem with beats on one channel only, it will most probability be ingress related, a quick check of other channels will provide an answer. Also, high signal levels at a customers set will likely indicate amplifier distortions as a cause of beats, for as the levels go up, the probability of distortion increases and problems from ingress decrease.

In an area where it is expected that there will be a sufficient number of ingress calls to warrant it (an area where there are many local TV stations and etc.), it may prove very practical to leave the channel of the station most likely to leak into the system empty. The empty channel will provide a convenient way to determine the degree of system integrity. Measurements of a local station leaking into the cable on a channel not occupied by any cable channel, when compared to the levels of an adjacent cable channel, will provide a good indication of the signal to interference ratio between other local TV stations and cable signals. If the television set or converter is tuned to the channel of the local station not on the cable and a noisy but steady picture is present, a faint ghost or beat on another channel will almost certainly be caused by ingress.

The point at which the ingress first enters a feeder system can also be measured quickly by making signal/interference readings at taps, via the unused channel method. Customers will still have service while troubleshooting is being performed and this method will physically disturb the system as little as possible. This is desirable as a small movement of a slightly loose connector may be enough to correct the problem for the present, but it will likely soon start misbehaving again. Also any disturbance to perfectly good portions of the plant will often lead to them becoming less tight, resulting in more problems.

If it is necessary to maintain a signal to interference ratio of 50 dB or more between a local transmitter and a channel used in a cable system, then the levels on the unoccupied cable channel of the local TV transmitter should be -40 to -45 dBmv at the input to the set or converter. This is near or below the lower limit a normal field strength meter can read, so any deflection of the meter scale with attenuation fully down is undesirable. If the video buzz can not be heard at all, or if system generated beats at the extreme range of the meters sensitivity are heard instead, then the service technician can be assured the ingress problem is not coming from the upstream portion of the drop or feeder. The test becomes more valid as cable signal levels increase, and, as an aside, provide rough measurements of system noise.

Another practical troubleshooting practice is to disconnect the section of a suspected bad drop or feeder leg and measure the levels of the local transmitters directly out of the downstream leg. This permits a direct comparison of the signal to interference ratio to be made at any frequency desired when the levels of the cable signals at that point are known. By disconnecting different sections of a drop at a splitter and measuring ingress levels from each, a fast and sure trouble-shooting decision can be made. Readings from a disconnected section of drop, terminated at the other end, will indicate if a drop is good or if it must be serviced or possibly replaced. A drop cable in service should typically be capable of 70 dB or more isolation , so any detectable levels inside the drop would indicate the necessity for service.

As the drop is connected to the field strength meter, first insert only the center conductor of the drop in the meter, then tune to the source of off air interference and read the level (often close to or more than what is read with a dipole at the same location). If you then tighten the drop on the meter and turn the attenuator all the way down a good indication of drop integrity can be made. If an amplifier with a gain of 20 dB is placed between a good, terminated long length of drop and a meter, in an area where the field strength is 40 dB or more from off air transmitters, it is just barely possible to detect the local transmitter above the noise floor , indicating a 90 dB shield or better for the drop (and the test equipment too).

The only other practical way to detect the source of ingress is to make use of the various sensitive radiation detectors currently available from several manufacturers. Just as ingress gets in cable, signals leak out and can be detected. With this equipment, and little or no training beforehand, a technician will almost be able to walk right up to a defect causing ingress. Sensitive equipment capable of detecting radiation levels 15 to 20 dB below the FCC radiation threshold of 34 dBmv is required. A shield factor of 60 dB or more should be maintained in drops when both the field strength of the local transmitter and the signal level in the drop are 5dBmv.

Standard dipoles and meters are difficult to handle as troubleshooting aids, and very often unable to detect faint radiation from points which are, nevertheless permiting noticeable ingress interference. In areas of strong radio interference, even the more sensitive equipment is sometimes incapable of finding faint radiation from leaks permitting severe ingress , for example in drops when cable signals close to 0 dBmv and the local transmitters are above 20 dBmv at that point.

Using equipment accepted as being many times more sensitive than what is required to detect the FCC egress threshold, and

capable of being calibrated so, will also permit the technician to determine if a leak legally needs to be reported or not. Typically leaks radiate -40 dBmv or less in about 75 to 80 % of the service problems, while leaks above -25 dBmv are found less than 10% of the time. This severe a leak will normally affect customers severely, and therefore will also be corrected very quickly. It is often the case, though, that the strongest points of egress are points where the level in the feeder is the greatest, hence the points where the greatest immunity from ingress can be expected. So by no means does a lack of ingress mean that a system is tight and totally within it's requirements.

The repair actions taken to correct ingress problems due to cable faults are straightfoward and direct, tighten it, splice it, or replace it. Detection of ingress problems will require training of personnel as to the way to quickly distinguish between ingress related beats and those of amplifier distortion. Service personnel should be able to determine if customer equipment is at fault and how to bypass these problems. Additional training is required as to how to use signal level meters as a means of locating a point of ingress. Specialized equipment will make the technician more efficient and help assure FCC compliance. The routine soon will establish itself if the system is susceptible to ingress problems.

NEW BUILDS IN HEAVY INGRESS AREAS

Before any new build is first turned on, the cable operator should determine the levels of all local off air transmitters at various locations throughout the build. It will then be possible to assign character generators and other similar programing to channels likely to have interference from ingress. Phase locking and sync locking and 45 dB of system immunity is good enough for a character generator only, all that can be expected if cable ready TV sets are to be connected. The same channel will be more usable under the same conditions in total converter build.

It might also be desirable to require measurements of the ingress level present in each feeder leg as it is turned on. With the input to a section terminated, a reading should be made at the end of each leg. Accept no ingress whatsoever and require checks to be made with a spectrum anaylizer, photo's included.

Plan to put a significant amount of energy into ingress related maintenance in an urban build until you have time to correct all construction and new drop defects. Even the best of construction methods and workmanship will show some minor flaws, and a flaw can be very minor and still be a significant point of ingress. But with a properly equipped staff of technicians, the ingress problem can be overcome in a routine fashion, with luck.

ACKNOWLEDGEMENTS:

Special thanks to all the service technicians who helped gather the data and who came up with some good fixes, too.

1: Belden Corp,CATV Coaxial Cable Catalog #EL10-79, Oct. 1979, pp 15-18.

2: Reg James, Comcast Corp.Staff Engineer From a report July, 1982

3: Based on FCC Rules and Regulations,Vol III, part 73, pp189-191, 1972
From "Reference Data for Radio Engineers"; Howard W. Sams & Co., 1979, p 30-12

4: Based on Jerold "CATV Reference Guide" #RD-14, April 1983, p36