taken into consideration. If a VHF post amplifier were not used, the mixer would drive the cable and the cable loss would be added directly to the conversion loss. Citing the example used previously, UHF amplifier gain 10 db with a noise figure of 4 db, mixer gain - 6 db with a noise figure of 14 db, and a 600 ft. cable run; we have an overall noise figure of 12.3 db and a signal to noise ratio of 46.9db, see Table 3.

TABLE 3

Noise Figure Improvement Due to Post Amplifier

Configuration	10 db UHF Amp + Mixer	UHF Amp + Mixer + VHF Cable Loss	UHF Amp + Mixer + Post Amp + Cable Loss
F (db)	8.1	12.3	8.9
$\frac{S}{N}$ (db)	51.1	46.9	50.3

This is an increase in noise figure of 4.2 db over the 8.1 db found previously when the VHF cable loss was not included. Addition of a 10 db gain, 7 db noise figure post amplifier results in an overall noise figure of 8.9 db which is only a 0.8 db increase and a signal to noise ratio of 50.3 db. Further improvement in noise figure could be obtained by either increasing the UHF preamplifier gain or decreasing the post amp noise figure.

In many areas there are UHF stations separated by only two to four channels. Closely spaced channels can produce interference when they mix with multiples of the crystal frequency. Also, the received power level of undesired channels may be great enough to overdrive the UHF preamplifier. To alleviate this condition, a highly selective filter is necessary.

The requirements for such a device are, first of all, a low insertion loss, since the loss can be considered as adding directly to the noise figure. The bandpass should be wide enough to pass the desired channel but with approximately 20 db rejection 6 MHz to either side of the bandpass. The extremely narrow bandwidth and high close-in rejection predicates a high insertion loss. Consequently, a compromise must be made between low insertion loss and selectivity.

There are many basic types of filters, some of these being lumped constant, helical resonator, tuned line, cavity and strip line. Lumped constants can not be used since the frequency is too high for effective use. The helical resonator degenerates to the equivalence of a tuned line due to the high Q required. Strip line techniques cannot be used to full advantage since the frequency involved is too low. This leaves the tuned line and cavity as the most likely candidates for filter construction at VHF.

CHAIRMAN SCHLAFLY: Thank you very much, Ed. The Jerrold Handbook is available at the back of the room.

The next paper will be delivered by Clay Mahronic. The title of the paper is, "Effects of Cable Length and Attenuation on Structural Return Loss." Mr. Mahronic graduated from the Illinois Institute of Technology with a BSCE. He joined Amphenol Corporation in 1962 as a project engineer. He took over the quality control department as head in 1965. Clay.

MR. CLAY MAHRONIC (AMPHENOL CORPORATION): To determine whether a coaxial cable will funtion properly in a community antenna television system, the cable's voltage standing wave ratio (VSWR) must be determined for the frequency band in which it will be used. Normally, CATV cables are manufactured in lengths of at least 1,000 feet. Small diameter variations unavoidably occur along such lengths. These diameter variations cause impedance changes which collectively raise the cable VSWR.

CATV cables are tested first from one end, and then the other. Due to variations in a cable's physical profile, the VSWR results from both ends are not always identical. This leads to the dependence of SRL results on attenuation.

Cable VSWR is most often determined with a sweep generator, electronic switch, amplifiers, detector, oscilloscope, variable attenuator and a balanced bridge with a variable load.

With the cable under test connected to the bridge, a signal proportional to the cable reflection appears at the bridge output. This output is compared with that of a variable attenuator connected to the other arm of the electronic switch. By superimposing these signals, the cable VSWR can be read out in terms of structural return loss (SRL), expressed in decibels (db). This value of SRL may then be converted to reflection coefficient and VSWR.

The unusual length of CATV cables sometimes causes VSWR due to periodicity -- a problem seldom apparent in shorter lengths.

Periodicity is the result of numerous small discontinuities -- usually diameter variations -- spaced at intervals one-half wave length apart along the cable. To a signal passing through the cable, these diameter variations appear as small changes of impedance. Each impedance variation is so minute that with the aid of a time domain reflectometer, it is difficult, if not impossible, to locate them. Moreover, the reflected voltage of each discontinuity in themselves, may be unmeasurable.

But because each discontinity is one-half wavelength apart, the individual reflections arrive at the source IN PHASE. Because CATV cables are so long, the cumulative effect of these numerous discontinuities is a high VSWR.

Figure 2 is an oscilloscope pattern of a cable suffering from periodicity. In this test, the frequency range is 4-230 Mc, swept from right to left. The upper trace is a reference line representing an SRL of 26 db or a VSWR of 1.105:1. The middle reference line is 30 db, or a VSWR of 1.065:1. The uneven trace near the base line is that of the cable under test as seen by the bridge.

The large VSWR spike near the center of the photograph is due to periodicity. The frequency at which the spike appeared was 133 megacycles. The cable is basically flat, having an SRL of greater than 30 db, except at the frequency of periodicity. At this frequency, the cable had an SRL of 19.5 db or a VSWR of 1.24:1. One-half wavelength at this frequency is three feet.

The <u>difference</u> in test results when a 1,000-foot length of cable is tested from both ends, prompted further investigation of SRL versus length. Tests were conducted on 1,000-foot lengths of .412 inch, 0.500 inch, and 0.750 inch diameter cables.

Each cable was tested at its full length. Then, 100-foot sections were removed and the remaining cable again tested to determine its SRL.

Results of these tests are displayed. Starting with the 0.750 inch cable, the SRL at 1,000 feet was 18.5 decibels. It was necessary to cut off 400 feet of cable, leaving 600 feet for test before the SRL began to rise. Cutting off an additional 200 feet of cable, leaving a 400 foot length, the SRL had risen from 18.5 db to 20.3 db. When measured in a 100-foot section, the SRL was 29 db. This curve shows that discontinuities which are further than 600 feet from the end of the cable being measured do not contribute to the total SRL of the cable.

In the .412 inch and .500 inch cables, it was necessary to remove approximately 600 feet of cable before the SRL began to rise. The higher attenuation of these cables as compared to that of the 3/4 inch cable limits even greater the length of cable that contributes to low SRL due to periodicity. In all cases, the total cable length did not contribute to the SRL. The length of cable which contributed to the low SRL was governed by three factors:

1. Frequency at which the periodicity existed.
2. Attenuation of the cable at that frequency.
3. Magnitude of the discontinuities.

To better illustrate the results of the tests, a tabulation of data on all three cables is shown. The data on the .412 inch and .500 inch cables are very similar. The total length contributing to the SRL, attenuation in db/100 feet and total attenuation necessary to limit reflections are almost identical. They do differ at the frequency in which the periodicity exists. The different frequencies is due to the spacing of the discontinuities. In both cables, it is possible to see only slightly greater than 1/3 the total number of discontinuities in a 1,000-foot length of cable. The important difference of these two columns of data is the difference in the number of discontinuities contributing to the periodicity. Since the .412 cable can see only 54 discontinuities and the total SRL of the cables are almost equal, it follows that the magnitude of the discontinuities of the smaller cable must be larger than that of the 1/2 inch cable.

Due to the lower attenuation of the 3/4 inch cable, it is possible to see discontinuities which are 500 feet away from the end of the cable being tested.

Cable attenuation, being a limiting factor on the total reflection, was not unexpected. Theoretically, an incident wave traveling down a cable is attenuated. The first discontinuity sees almost all of the incident signal. As this signal propagates down the transmission line, the attenuation of the cable reduces the magnitude of the incident signal. The discontinuities located further down the line see less and less of the input signal. Therefore, the reflected voltage is less than that of the first discontinuity.

The attenuation which reduces the incident signal, also reduces the magnitude of the reflected signal af it propagates back to the source. Therefore, it is apparent that the attenuation is the reason why the more distant discontinuities contribute very little to the total reflection.

The relationship of SRL to the frequency of periodicity and attenuation can be better understood by comparing two 3/4 inch cables which suffer from periodicity but at different frequencies.

The cable in the left hand column of Figure 5 is the same as seen in the previous figure. As a comparison, the frequency of the cable in the right hand column was assumed to be 56 megacycles. This is the same frequency as that of the .412 inch cable. At this frequency, the attenuation is .45 db/100 feet. Holding the limiting attenuation constant at 3.25 db, it is possible to see 720 feet into this cable. Even though a greater length contributes to the periodicity, the spacing of the discontinuities differs. The result is that at 56 megacycles, 103 discontinuities contribute to the total SRL while 161 can be seen at 127 megacycles. The calculated SRL at 56 megacycles was 23 db. In other words, the VSWR has been reduced from 1.27:1 at 127 megacycles to 1.15:1 at 56 megacycles even though the total length of the cable contributing to periodicity was greater. Because of the "attenuation effect" in relation to the cable size, it is evident that the 3/4 inch cable is more sensitive to reflections than that of the 1/2 inch or .412 inch cable, thereby making this a more critical product.

Length and attenuation have been shown to limit reflections resulting from periodicity. Reflections resulting from large single impedance changes-usually due to dents in the outer conductor-are also limited by cable length and attenuation.

Evidence of this effect was observed in a 1,030-foot length of cable deliberately dented with a pair of pliers. This dent, about two inches long, was placed about 100 feet from the end of the cable.

Before we see the effect of this dent, let us look again. You will notice that the SRL of the cable is greater than 30 db. Figure 6 shows that the dent has caused a considerable change in the SRL pattern. At 220 megacycles, the SRL of this cable has been reduced from greater than 30 db to less than 26 db. The decrease in SRL at the upper frequencies is much greater than that at the lower frequencies. This is because the 2-inch dent more nearly approaches a quarter wavelength at the higher frequencies. When a single discontinuity reaches 1/4 wavelength, the reflection is at a maximum.

Additional proof of the effect of attenuation on SRL can be shown by testing the far end of this cable. In this case, the dent is 930 feet away from the bridge. The previous test showed the SRL due to the dent to be less than 26 db. In this case, the attenuation of the 930 feet of cable has attenuated the reflection so that the cable is still better than 30 db.

In conclusion, we wish to point out the importance of sweep testing both ends and rating the cable based on the lower reading.

Secondly, we also wish to point out the possibility of using attenuation to improve picture transmission. As a case in point, let us assume that there are two 1,000-foot lengths of cable to be placed between amplifiers. One cable has an SRL of greater than 30 db, whereas the other cable is somewhat less than 30 db. It is suggested that the cable of higher SRL be placed at the output of the first amplifier. The second cable is then placed between the end of the first cable and the input of the second amplifier, therefore, the attenuation of the better cable shields the VSWR of the second cable. In this way, the first amplifier sees only a cable which has an SRL of greater than 30 db.

CHAIRMAN SCHLAFLY: One or two questions. Dr. Schenkel?

DR. SCHENKEL: I only want to make a couple of comments on the talk. I agree to all the fact that were brought up, but I have some doubts about some of the conclusions. And I would want to show my point of view on a couple of these conclusions.

Now first of all, about this matter of shielding a worse piece of cable by having a better piece of cable ahead of it. Now, if the return loss only presented at the amplifier would give a reflection, then I would agree to this shielding. But I think return of the cable is also indicative of the cable transmission properties. And whenever we have a spike in the cable, even if it is hidden right inside the cable, and that we don't see it, this means that in transmission there would be a somewhat rapid change of phase in this transmission. So if that thing appears close to the color carrier or the picture carrier of a TV channel, this may cause some delayed distortion of the color. So even if the return loss is hidden inside the cable, still each piece of cable should be selected for use according to its own test and how it appears in the final span.

MR. MAHRONIC: Dr. Schenkel, in answer to what you have said, I have to agree with you. But what I am trying to say is that if we have two pieces of cable, if there is a choice on where to place the cable, I would rather place the better cable at the output of the first amplifier rather than the worst cable at the output of the first amplifier.

DR. SCHENKEL: Now, second point is: I wonder why you didn't mention the interesting fact that all the numbers on the bottom row of your tables were close to 4 db. Which I think is a false indication that whenever we want to use this length of cable for periodicity, we do not have to use a complete reel, but it is enough to just cut off a length of 4 db. At the loss frequency we are going to test and sweep it, and this will give us all the indication about periodicity.

MR. MAHRONIC: Let me get this straight, Dr. Schenkel. The tests we use to check how good a cable is is either by sweep testing it or with the use of a time domain reflectometer. All these tests, the results of these tests are a function of the attenuation and we have no test that we can perform that does not hinge upon the attenuation of the particular cable. So I don't see how we are going to do this unless we cut this into 500 ft. lengths and then couple these lengths together.

CHAIRMAN SCHLAFLY: I am going to cut that discussion right there, with a little question mark in the air. We are running so short of time that I do not want to impose on the good nature and patience of our last speaker. Thank you, Clay, and thank you, Dr. Schenkel.

The last speaker on the agenda this morning concerns a very interesting item of test equipment called the spectrum analyzer. This is a most interesting and useful tool. I am anxious to hear more about it. Allen Ross, who will deliver this paper, is President of Nelson Ross Electronics. Nelson Ross Electronics specializes in Plug-In Spectrum Analyzers. Allen Ross is a graduate of City College of New York and of Brooklyn Poly-Tech. He was with Polarad Electronic Corporation before forming NRE. He spent eight years with them and was in charge of advanced development, pioneering the solid state spectrum analyzer. He was the person who first implemented the Plug In Spectrum Analyzer concept. Allen.

MR. ALLEN ROSS (NELSON ROSS ELECTRONICS): I know it is late and we are running behind, so I will try and cut right to the meat of this. The spectrum analyzer is an instrument that is probably unheard of in this particular industry. It is a useful instrument which has been around for a long time, originating with the esoteric military requirements. The state of the art in spectrum analysis has gradually improved to the point where it is possible to build spectrum analyzers which cover very wide frequency bands. There are now a few people making analyzers which permit observation of the entire CATV spectrum -- channels 2 to 13 (including all the FM in between) in one sweep. These analyzers will permit very useful advances in the systems for testing CATV transmission.

Perhaps it might be appropriate for me first to describe what a spectrum analyzer is and how it operates. I don't know how many people can see this blackboard, so I will try and use a minimum of sketches. We will start with a familiar instrument - the field strength meter. If we start by drawing the block diagram of the most basic field strength meter, what we have would be a signal input which drives a mixer, which I shall designate "M", provided with a local oscillator signal, from a black box which I will designate "LO". The resulting difference frequency drives a narrow band filter, ultimately resulting in a meter reading. Signal F plus Delta F comes from the local oscillator producing Delta F at the mixer output, and depending upon the strength of the input, we get a meter reading. Anybody who has manually tuned one of these things back and forth for a few hours from channel 2 to channel 13 can tell you it gets to be a pain in the neck after awhile. You can make a very good and accurate set of readings of the relative levels of all the picture and sound and color carriers in the system, but it is time-consuming. It would be nice if we had some sort of a system for observing the meter readings on all the channels simultaneously, so we didn't have to tune. This is exactly what a spectrum analyzer does for you.

Suppose we were to replace the meter with the vertical deflection system of an oscilloscope. This presents no basic problem. When we tune through a signal, we would see the modulation (as limited by the band pass) as a wave form on the oscilloscope.

Suppose, in addition, instead of tuning the local oscillator