Hidden Influences on Drop Reliability:
Effects of Low Level Currents on F-Interface Corrosion and Performance

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ABSTRACT

The CATV drop, the source of a high percentage of trouble calls, has a lifetime greatly dependent upon corrosion at the F-Interface. This corrosion can be influenced in many ways, including the presence of currents on the drop.

Many emerging technologies, such as those required for signal security and on-premise amplification, will have power requirement schemes which draw from the subscriber premise or mainline via the drop. In addition, many drops currently carry stray sheath currents originating from stray effects of power on the feeder. As a result, the drop can see many waveforms of primarily low level AC and DC currents.

As part of a CableLabs funded project, this paper explores the nature of existing and future current loads on the drop and how these different forms effect corrosion of the F-interface. Practices are suggested which may improve reliability and performance based on findings.

INTRODUCTION

This is the second phase of a three phase CableLabs project, the three phases being 1) Basic corrosion in the drop and the effects of CASS, Copper Acetic Acid Salt Spray[6] 2) the effects of low currents, simulating ground currents and 3) the comparison of CASS conditioned samples to actual field aged samples.

In this phase, we first look at the basic driving forces of corrosion to understand why externally induced currents can have an effect on corrosion. Then the types of currents that may be seen on the drop are examined as well as engineering practices that may influence these. Finally, results of CASS and low current conditioning of f-interface components are summarized with recommendations.

Background, Electrochemistry

At a typical corrosion sight, an electrochemical reaction occurs which can be modeled with a simple voltaic cell. Three conditions must be present for wet corrosion, the most common type, to occur, **Figure 1**.

1) Two dissimilar metal surfaces must exist at the site
2) An electrolyte (eg, liquid solution) must be present and in contact with the two surfaces
3) The surfaces must be in electrical contact with each other.

Corrosion occurs when ions in the liquid solution chemically react with one of the metal surfaces, known as the cathode, causing positively charged metal ions to enter the solution, leaving this metal with a negative charge. This is known as the 'oxidation' reaction. The other metal, the anode, develops a positive charge as its electrons free react to the positive ions in the solution. This is the 'reduction' reaction. Due to the difference in charge, a voltage potential occurs between the metals and a current flow results.

In the case of the familiar car battery, as shown, lead is the reactant at one electrode (anode) and lead dioxide is the reactant at the other electrode (cathode).

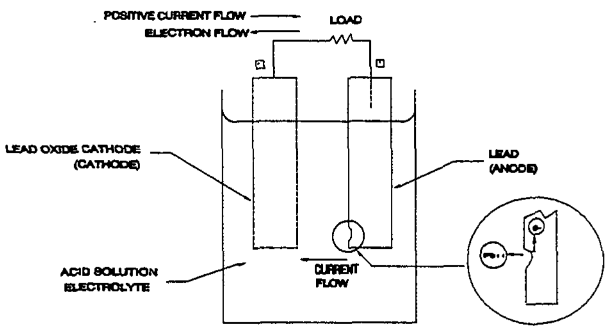


Figure 1. *Battery Cell, analogous to the corrosion dynamic.*

In the battery described above, one electrode is oxidized, one electrode is reduced, and the electrons flow in the outer electrical circuit. In freely corroding systems there is no outer electrical circuit. Therefore, the oxidation (which is the corrosion reaction) must occur in local proximity to the accompany reduction as in **Figure 2.**

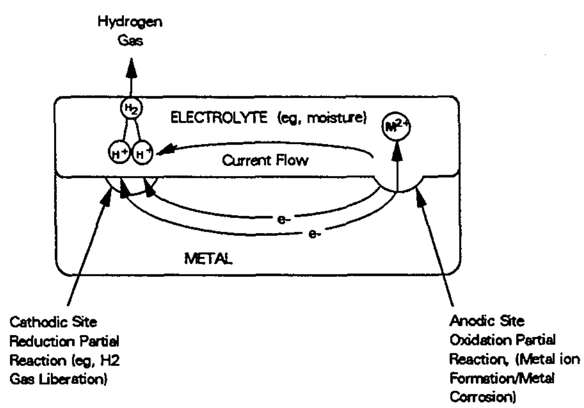


Figure 2: *Corrosion of Single Metal in Presence of Electrolyte.*

In the case of a single, 'freely corroding' metal, the oxidation and reduction can occur on separate surfaces (that are electrically connected). However, it is still very likely that the reactions are in close proximity to each other.

Corrosion is an electrochemical process and as such it is driven by the voltage difference between the oxidation reaction and the reduction reaction, as in our battery above. An example of an oxidation would be the dissolution of iron to form iron ions, and an example of the concurrent reduction is the reduction of protons to form hydrogen. (if you drop iron in acid you will see a high degree of bubbling, which is hydrogen evolution.) Some metals have different driving forces (voltages) so it is expected that some metals will corrode less than others. We also see that the corrosion rate will depend on the reduction reaction. If no electrochemical reduction could occur, no corrosion could occur. Typical reductions that accompany the corrosion reaction are proton (or water) reduction to form hydrogen (as mentioned above), and the reduction of oxygen to form water.

Galvanic Corrosion

Since voltages are involved in the driving force for corrosion, we can change the voltage of a given metal to effect a change in the corrosion rate of the metal. One way to change the potential of a metal is to connect it to another metal that has a different potential. This is referred to as galvanic coupling.

A typical CATV galvanic couple involves copper of a center conductor (cathode) and tin of a port female contact (anode). When a galvanic cell develops, the sacrificial, or anodic metal typically deteriorates at an accelerated rate relative to its freely corroding state. **Figure 3** suggests that many potential combinations of galvanic corrosion cells may occur in an f-interface.

In summary, we see that the rate of corrosion depends on the type of metal and the environment of the metal. The environment of the metal includes any coupling to one or more metals, the chemical composition, and the temperature.

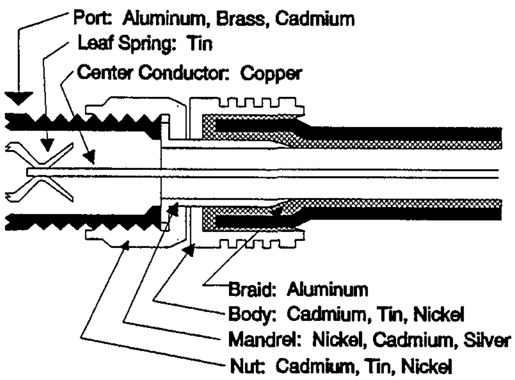


Figure 3. *F-interface. The materials shown are those typically found at the surface of the given parts. Base metal of connectors are usually brass (copper, zinc, lead).*

Impressed Currents

As corrosion is a current related phenomena, induced external currents can also significantly affect the rate of corrosion. Depending upon the direction of induced current, the reaction can be accelerated or hindered. In most drops, connections are mirrored on either side of a ground block or cable ends. In this case the induced current tends to drive the corrosion rate in one direction on one connector while in the opposite direction in the other. Therefore, inducing currents can have a positive effect on connections in one direction and negative in other.

The use of impressed currents to reduce the corrosion rate is known as cathodic protection. Aluminum, the weakest material in the melange of f-interface materials, is very sensitive to the level of impressed current. 'Overprotection' can occur if cathodic influence is to high. This is due to the quite unique *amphoteric* nature of Aluminum, whereby too much current causes increased corrosion.. It is for this reason that it is difficult to rely on cathodic or other impressed load methods to reduce Aluminum corrosion.

Currents On the Drop

To address loading these concerns, it is important to understand the types of drop currents that can exist and practices that affect their levels. Low level currents are ubiquitous in the feeder portion as well as other parts of the CATV system. The reasons for low level currents on the drop vary. Two types of currents can exist in a system drop. These are 1) 'sheath' currents', which are low level currents most prevalent between the tap and ground block and 2) power load currents on the drop used for powering active devices outside of the home.

Sheath Currents

Many drops experience small AC loads on the drop in the form of 'sheath currents'. Typical current levels have been documented for two different systems in **Figure 4a**. Note the wide variation of levels and presence of these currents. Of the homes that had measurable sheath currents, the average was approximately 173 milliamps **(Figure 4b)**.

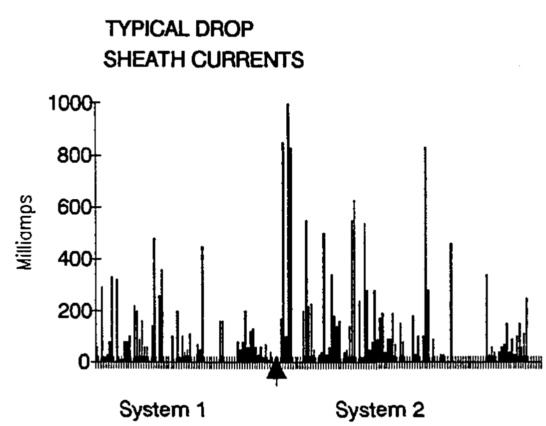


***Figure** 4a, Typical sheath current values. Measured at two different systems. Courtesy Scientific Atlanta.*

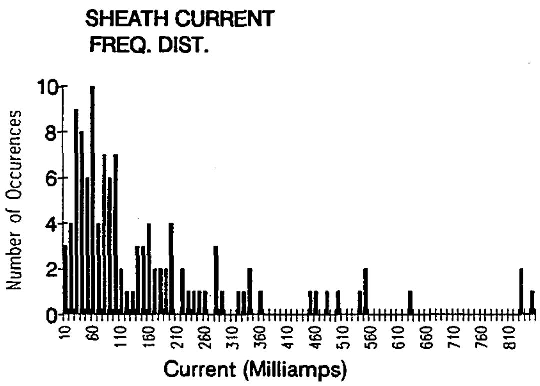


Figure 4b. Sheath Current Frequency Distribution for the above systems. Shows number of subs at each current level. Average of all subs=114 mA. Average of subs with measurable sheath current = 173.5 mAmps. Std Deviation = 191.1 Percentage of subs with measurable sheath current = 66%. Courtesy Scientific Atlanta.

These currents are often the result of distribution line Longitudinal Sheath Currents, generated on the feeder line, finding a path down the drop. Current first develops on the outside conductor of the distribution line due to bonding with a non-neutral utilities 'neutral' [1]. If this current is not grounded well or often enough along the distribution plant, much of the sheath current will go to ground via the drop to the ground block.

Grounding and other Current Influences

Many practices currently exist for grounding along a distribution line that are meant to minimize sheath currents and to avoid damage due to lightning or other surges. Typical practices include bonding the feeder to the utilities 'neutral' at regular intervals, grounding at every active device, and grounding at the 'end of line' device (eg, terminating tap). Many practices are governed by city ordinances as well. Each of these practices, particularly the regularity of these grounds, has varying effects on the degree of resulting sheath currents.

A typical CATV grounding is represented by **Figure 5**. This shows the power line, its so-called 'neutral', and the CATV system plant. The power company typically runs three power lines with a common neutral. With any imbalance in these loads, a current is set up in the 'neutral'. As a result, it is not uncommon for the neutral to carry significant currents[1].

If we look at the schematic of current distribution, we see that the cable system, the power company, and the neutral-to-earth grounds all share longitudinal sheath currents originally generated on the power company lines, **FIGURE 6**. This schematic shows that the distribution plant consists of parallel circuits to three types of major grounds. The current in any one of the potential ground paths will be inversely proportional to their equivalent resistances. If the resistance of the ground is not low, much of the load will be shared by the CATV system. Up to 50 amps[1] can be expected on the CATV system due to the unbalanced load from just one power drop outage.

Grounding of the CATV System

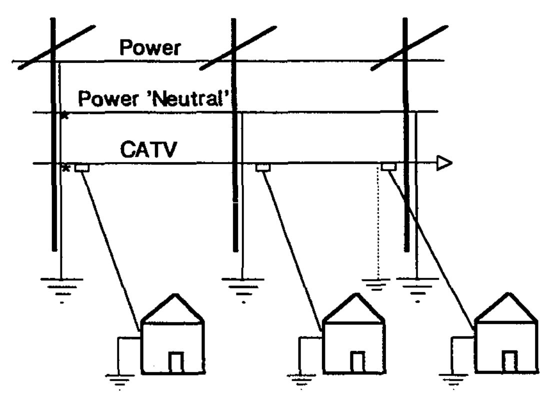


Figure 5. Typical grounding of the CATV plant. Additional grounds (dotted line), are made at various intervals depending on the system.

Further detail of the CATV feeder ground resistance distribution, **Figure 7**, shows the effect of drops on the ground paths. If any drops are not grounded, it can be shown that other drops will carry more of the distributed current. Also, if grounds were driven at every pole, the drop current sharing would decrease dramatically.

Clearly, the frequency and quality of many grounds contribute to the level of sheath currents on each drop. Any ground potential, such as the potential between the soil around the ground wire and the nearest feeder strand ground, may also set up a drop sheath current. In summary, the following will minimize sheath current on the drop.

1. Frequent grounding of the feeder (best at every pole).

2. Quality, low resistance feeder grounds.

3. Consistent grounding of drops.

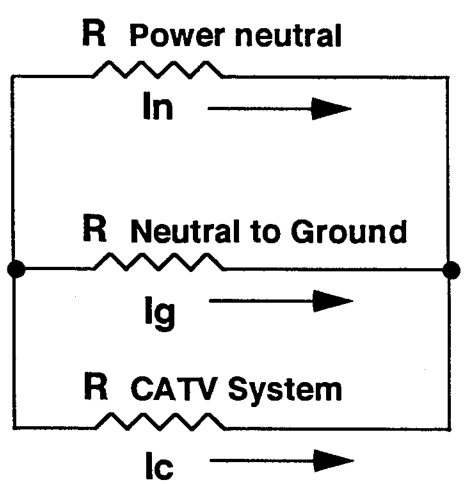


Figure 6. Ground current distribution in the feeder/drop environment.

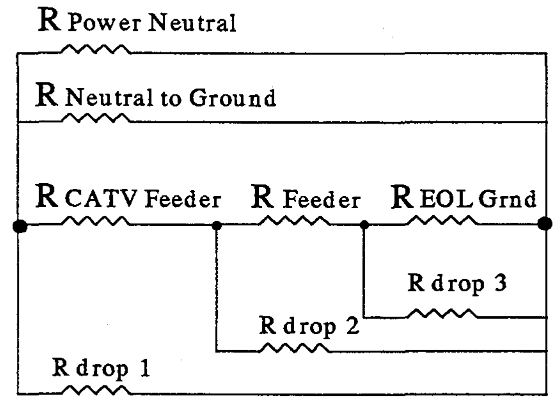


Figure 7. Expanded current distribution showing the effect of drops.

<u>Active device loads</u>

Some current and many emerging technologies such as interdiction, drop amplifiers, point of entry devices, and active taps are or will utilize AC and DC currents carried by the drop. These follow the standards set by UL 1409 and other manufacturing requirements. In general, these devices operate below 20 volts and around 200 milliamps, 4 watts being the approximate average load. As both the current imposed by active devices and that typically found in the form of sheath currents are roughly 200 milliamps, this was the value chosen to condition samples.

OBJECTIVES

To see how these currents can actually electrically and physically effect the f-interface and hence the drop system, this study has been set up to explore corrosion of samples at the 200 milliamp level. The objective of this series of tests was to determine the following.

1) Effects of currents on the electrical performance of the CASS exposed f-interface.

2) Effects of currents on the physical degradation of CASS exposed f-interface components.

3) Any correlation between material and electrical deterioration of the f-interface.

With appropriate current levels determined, the goal is to seek information at the typical level. Future tests could explore different waveforms, pulsed currents, and other methods. The methodology for this series of testing is described below followed by results.

PROCEDURE

CASS Electrical Performance

In order to determine the effects of various loads on corrosion with CASS salt fog conditioning, performance of samples were compared after being organized into the following categories. The nominal power levels chosen are those which can be expected to be found due to sheath currents (primarily AC) and active drop devices (AC or DC) as mentioned above.

CASS with no load
CASS with AC, 200 mAmps, 15V
CASS with DC, 200 mAmps, 15V

As control categories, the variations of these loads were also measured without CASS conditioning. Effects were sought in two ways. First, F connector interface degradation versus time for these different conditions were characterized from a performance standpoint. Performance measurements were signal transmission, inner and outer conductor contact resistance, and signal egress.

Secondly, analysis of the corresponding physical material degradation was observed by Electron Microscopy.

Powering Configuration

Ten samples each of DC and AC loaded connectors were subjected to CASS while 6 control samples were left in room temperature conditions throughout the test period. Samples consisted of standard hex crimp connectors and 60% shield PVC jacketed cable. The basic layout, shown in **Figure** 6, consisted of two hex crimp F-connectors, spliced together with an F-81 barrel splice. Each splice assembly was mounted securely to stabilizing boards. The splice was connected to ten feet of quad cable on either side each of which extended outside of the CASS environmental chamber. These non-conditioned cable ends were used to measure the electrical characteristics of the internal sample.

Samples were loaded as shown in **Figure** 7 Two power supplies fed 8 samples each, both in the case of the DC and AC. Currents were monitored daily for proper loading. Preliminary tests showed that the number of connections per supply must be kept low, for as the resistance of samples rose over time, the load necessary could exceed the capabilities of the supply and be difficult to monitor on a daily basis.

Measurements were conducted over a 56 day period, with electrical performance measurements taken at graduated intervals. Data was collected after 1, 3, 7, 14, 21, 28, 35, 42, 49 and 56 days. The line diagram for equipment used for each of the measurements are shown in **Figures** 10, 11, and 12 respectively.

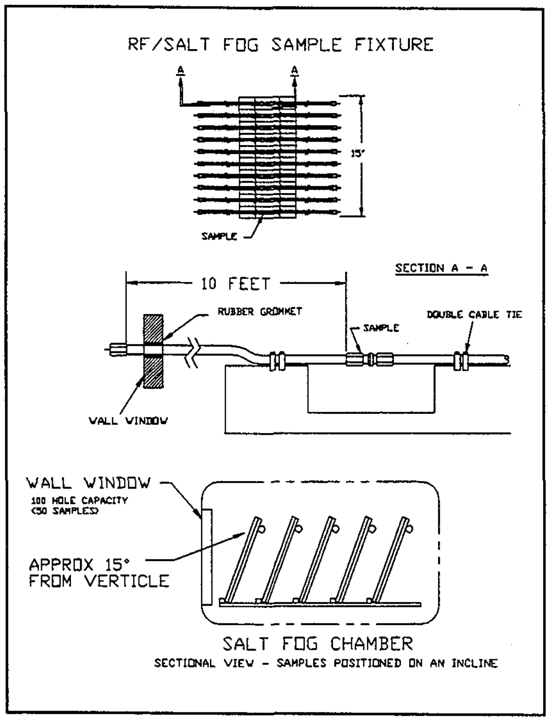


Figure 8: Layout of CASS chamber and configuration for sample stabilization.

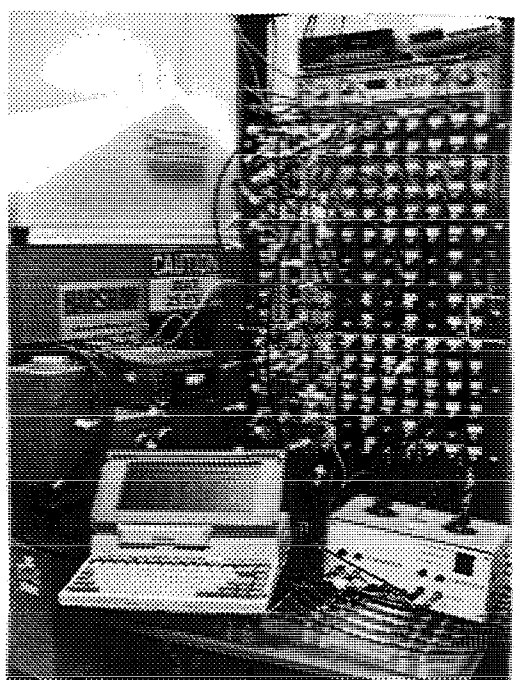


Figure 9a. CASS Chamber with Control Panel/Computer

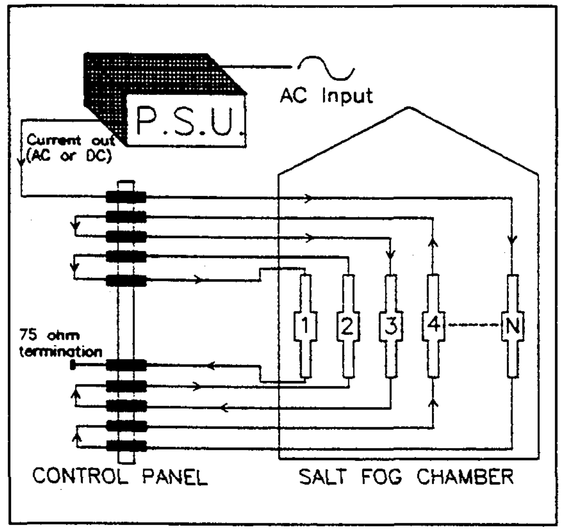


Figure 9b. Line Diagram of current loading scheme.

Signal Egress

Signal egress measurements, **Figure** 10, were taken using an HP 11940A close-field probe. The probe is a balanced magnetic field sensor which provides an output voltage proportional to the strength of the magnetic field at its tip.

Egress measurements were probed at the rear of each of the two connectors, A and B, where the jacket meets the connector. The chamber was temporarily turned off and the lid removed for ventilation while taking egress readings. Samples remained otherwise undisturbed through the duration of tests. Other measurements were conducted outside of the chamber whereby the cable terminates externally.

The voltage values were read into a PC using a program which reads, stores, displays, and charts results. The frequency range taken was between 0 and 1000 Mhz. Egress levels are displayed in dB micro volts. The near field probe is useful as a relative measurement device, with one drawback the difficulty in correlating to shielding effectiveness. Typically, a very corroded sample degrades 10-20 dB. Also, the probe is very sensitive to physical handling. As a result, measurements for this study appear to be out of calibration. However, past studies do show some correlation to outer contact resistance measurements. Therefore, results are based primarily on contact resistance.

Contact Resistance

Contact resistance measurements, **Figure 11**, were taken on either end of the conductor under test. using a Cambridge Technology Model 510 Micro-Ohmmeter.

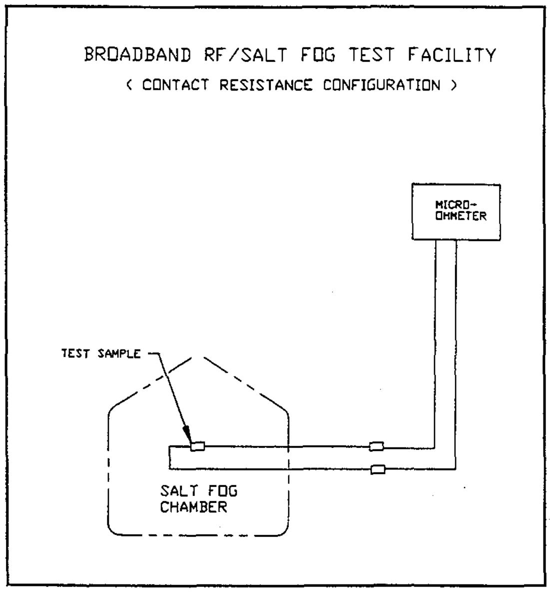


***Figure 11:** Contact Resistance measurement setup.*

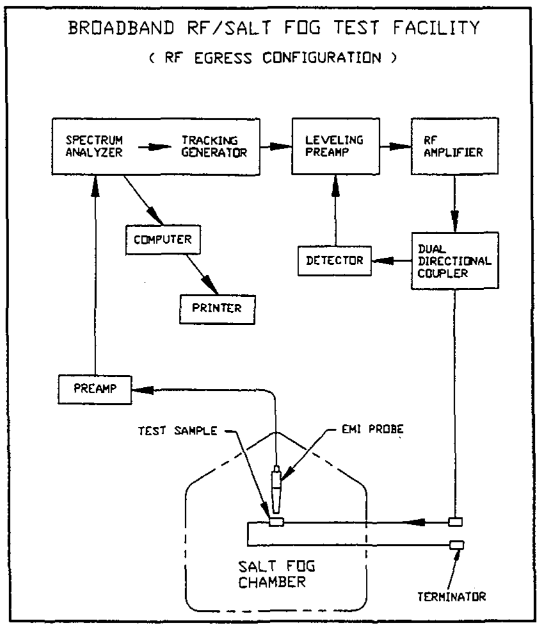


***Figure 10:** Configuration of equipment for signal egress measurements.*

Signal Transmission

Signal transmission is measured with the equipment shown in **figure** 12. Radio Frequency signal is provided by the internal tracking generator of the HP 8590B Spectrum Analyzer. The signal was subsequently amplified by the Amplifier Research Amplifier and pre-amp. A feedback loop was constructed to keep the swept signal in range and consistent. This signal was transmitted into the drop sample and received directly by the spectrum analyzer. The results were automatically read, stored, and displayed through an IEEE interface. Again the frequency range was from 0 to 1000 Mhz. Signal level is shown in dBmV.

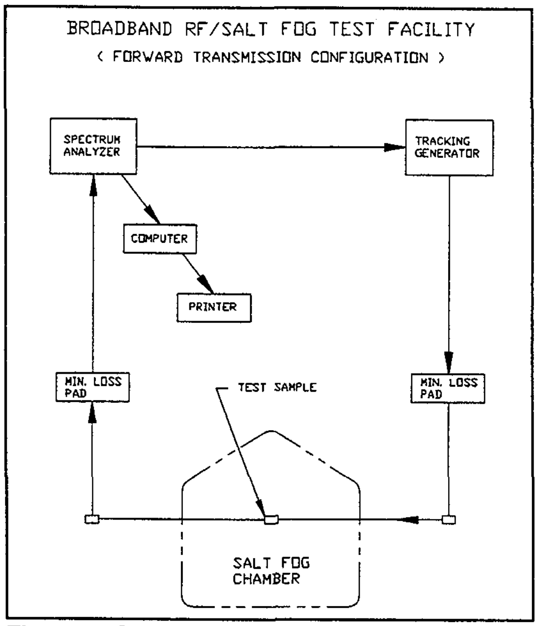


Figure 12: Setup for signal transmission measurement.

Microscopy and Material Characterization Procedure

After samples were tested for electrical performance degradation during CASS exposure, samples were examined for corresponding moisture paths and material change.

SEM

The scanning electron micro- scope was used to take electron generated micrographs for the purpose of showing paths of moisture salt spray product deposition. Note that the presence of salt spray products doesn't necessarily mean that significant corrosion has occurred. It does, however, show that an electrolyte is present. Actual corrosion is evident when material has been extracted (ie plating goes away exposing the base metal).

Energy Dispersive X-Ray Spectroscopy, allows one to determine the locations of material degradation (actual corrosion), particularly where plating has been removed and base metal is exposed.

DISCUSSION

1) There will be minimal or no deterioration, with respect to currents on the drop, as long as moisture sealing is used. As shown in resistance data, **Figure 13**, regardless of the presence of load, no degradation occurs without CASS/moisture exposure. The virtually equal, flat profile, dotted lines in this graph represent non CASS samples.

2) When f-interfaces are exposed to CASS, deterioration occurs from most to least rapidly in the following order, DC, AC, and no load. In **Figure 13**, the outer conductor resistance measurements show substantial degradation of CASS samples in that order. It is known that the ratio of resistances, outer to inner, reflects the impedance match and hence the return loss and shielding effectiveness of the interface. As shown, this ratio has substantially changed with current loading as compared to no loading.

3) The inner (center conductor) resistance, when exposed to CASS, was to a high degree variable and intermittent, **Figure 13.** Loaded samples did appear to be slightly more variable. However, again there is no effect when the samples were kept free of the corrosive environment.

4) As variability in electrical performance occurred via center conductor components, the degree of moisture migration into their interfaces varied as well. It appears from micrographs that substantial variability exists between samples regarding the degree of moisture migrating to the center conductor contacts. **Figure 15** shows a typical sample whereby substantial moisture has penetrated one side of the contact while the other remained relatively clean. Due to this occurring in many samples, the degree of moisture contacting the center conductor could not be considered controlled. Micrographs show consistent moisture and corrosion

occurring at the outer conductor interfaces, typically appearing as in **Figure 16.** Compared to the moisture path leading to the outer shield and the connecter outer conductor pieces, the path of moisture to the center conductor has many barriers. This may explain the variance in results relative to the outer resistance results of **Figure 13.**

Other factors which may have caused variance of center conductor related performance are fretting corrosion and the spring effect of the f-81 interface. Fretting corrosion, caused by micro-motions in the contact areas, creates repeated opportunity for oxide layers to develop between contacts. Conversely, contact at the cc f-81 interface may be restored when minimal vibration causes oxide layers and corrosion products to be dislodged and the spring regains contact due to constant compression inward against the cc. Measures were taken to minimize these occurrences by stabilizing samples, however, small yet significant movements may have occurred. These counteracting actions may explain rapid performance losses followed by rapid gains.

5) Signal transmission, unlike center conductor contact resistance, showed almost no change over the time tested, **Figure 14.** The gap caused by corrosion between the center conductor and the f-81 leaf spring only affects the signal transmission slightly. However it greatly affects resistance. As many pressure 'probing' tap manufacturers have shown , RF transmission can occur with a small gap between contact surfaces, whereas resistance increases dramatically or goes infinite with only a slight gap. Due to the transmission less sensitive nature, significant deterioration (10-20 dB down) could be expected to follow the resistance results if the test time were extended.

It is recommendation for further reasearch to extend the test period and/or use lower quality, larger opening F-81's, to advance the corrosion process and assure all contacts see uniform corrosion potential moisture exposure.

RECOMMENDATIONS

It has been shown that currents can be detrimental to the life of the drop. In order to minimize the effects of low level currents from sheath or active drop devices, the following are recommended.

1) Means of sealing the f-interface should be used. This will avoid any effects that currents may have on deteriorating the drop.

2) Means for powering external to the standard coaxial cable RF conductors should be considered, such as a messengered type of coextruded conductor.

3) If existing drop is to used as a current carrying media, AC current is recommended over DC. The ideal level of current loading from a corrosion standpoint is left for further study.

4) Efforts should be made to minimize the level of sheath currents on the drop. The following practices are recommended.

a) Use proper procedures to assure sufficient grounding at the terminating tap.

b) Ground at frequent and regular intervals along the distribution lines.

c) When feasible, assure that no stray currents or other conditions exits which may cause a potential difference between the grounding of the drop and the distribution line. The age and condition of the Utilities grounds are not always trivial and should be considered.

d) Operators are encouraged to get involved in the formation of standards and practices currently being drafted. The SCTE and CableLabs are currently developing sound advice and recommended practices in this area.

Figure 13

F-Interface Corrosion Studies
Effect of Current and CASS on Contact Resistance

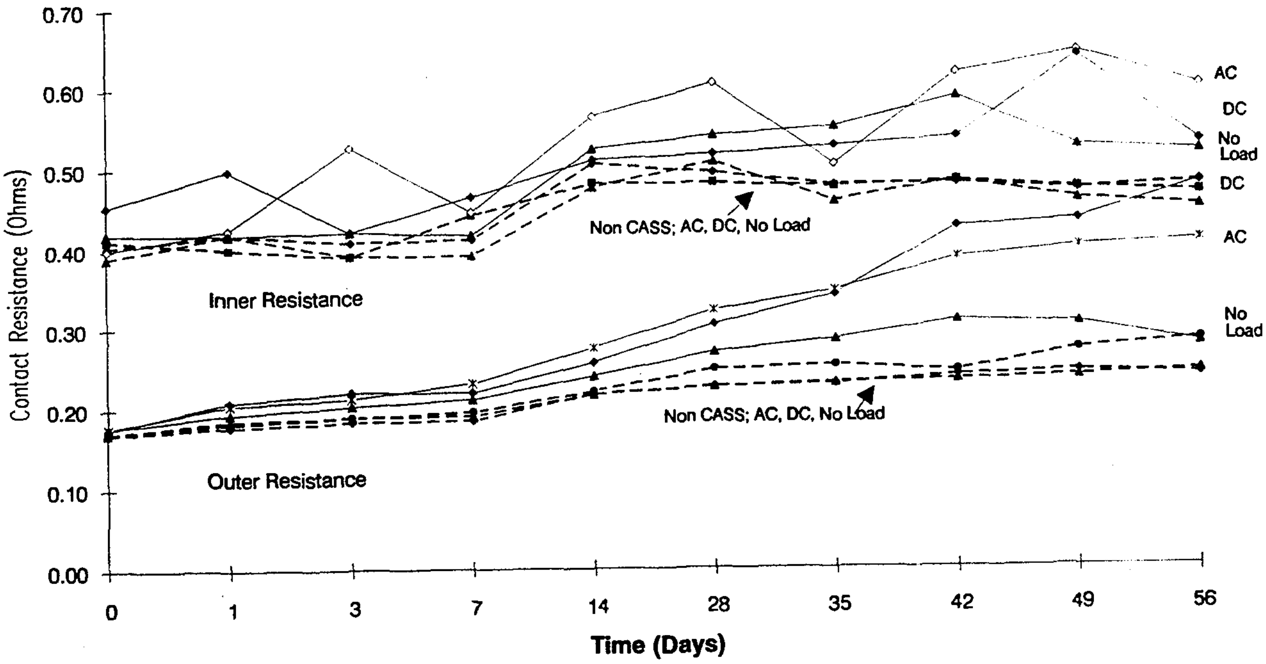


Figure 14

Cablelabs F-Interface Studies
Effect of Current and CASS on Transmission

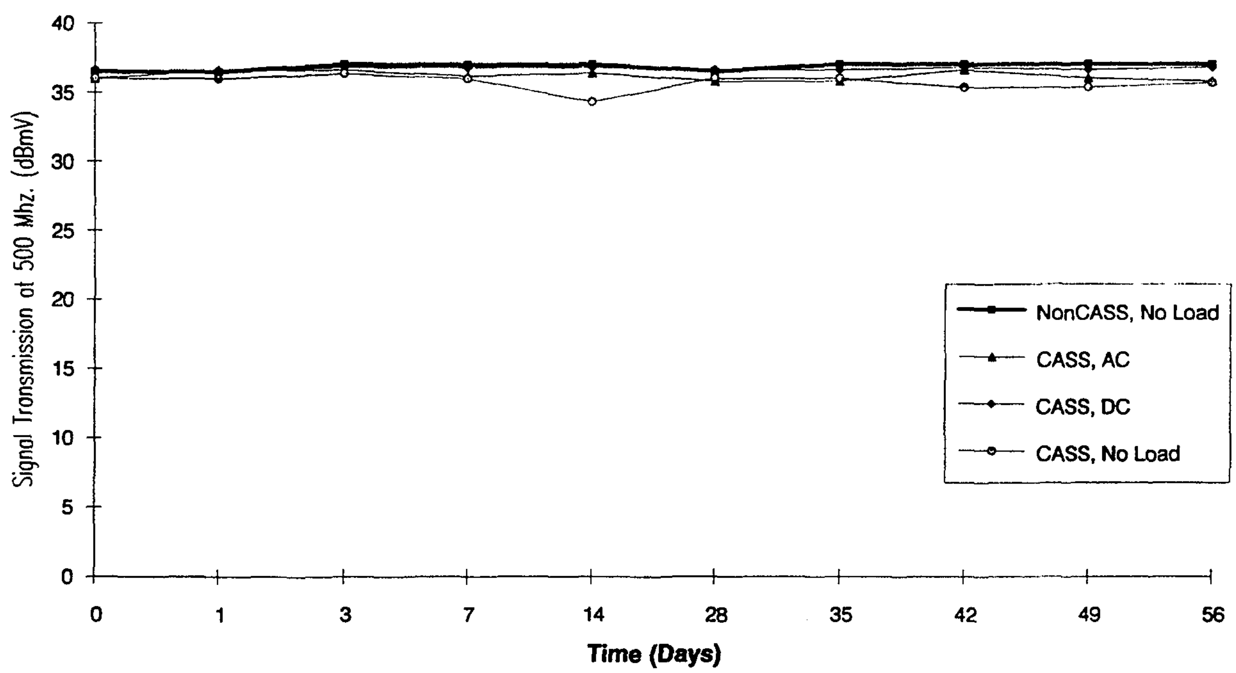
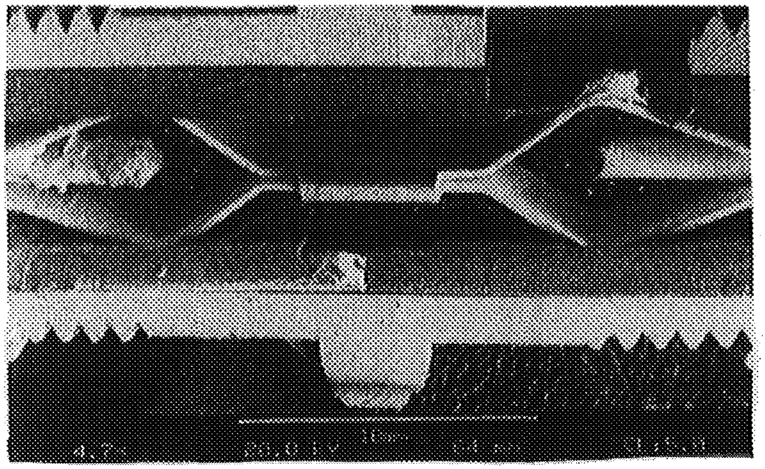
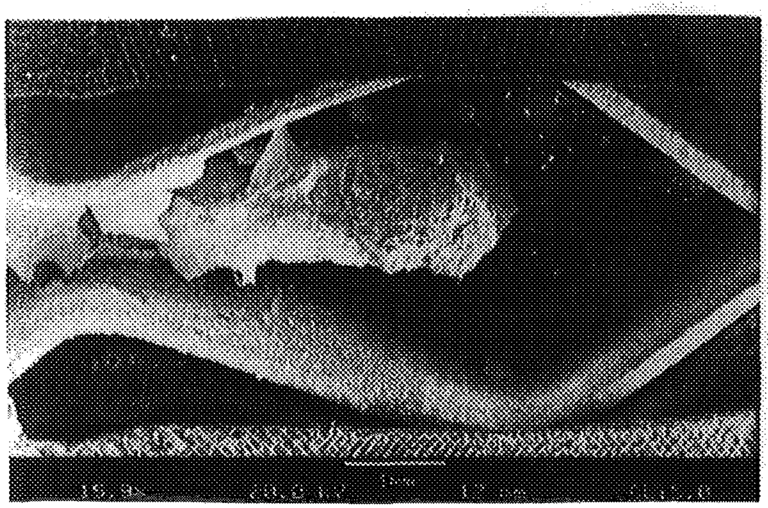


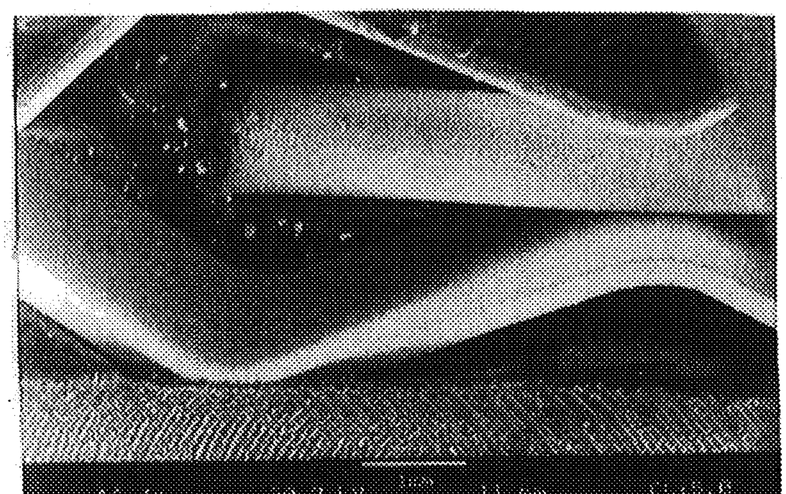
FIGURE 15
Typical variance in Moisture Migration, F-81 Splice Center Conductor Contact Area



Cass Exposed
Internal Contacts

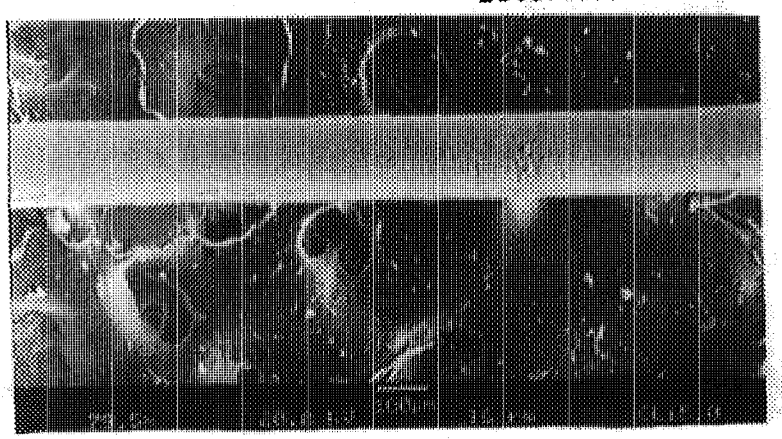


Cass Exposed, Right Contact Area

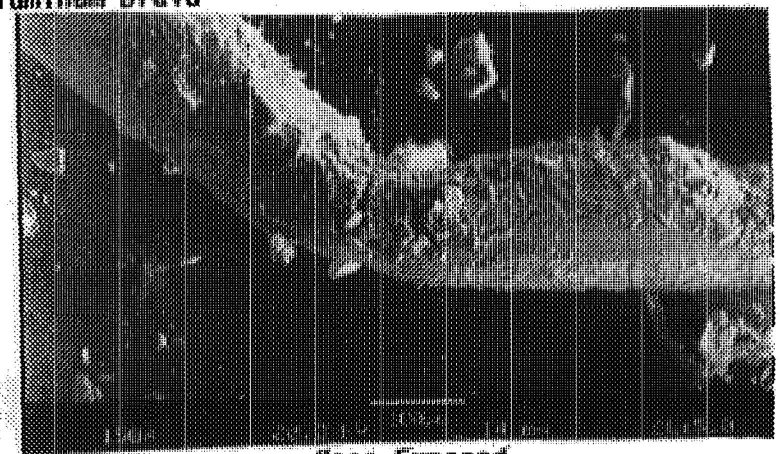


Cass Exposed, Left Contact Area

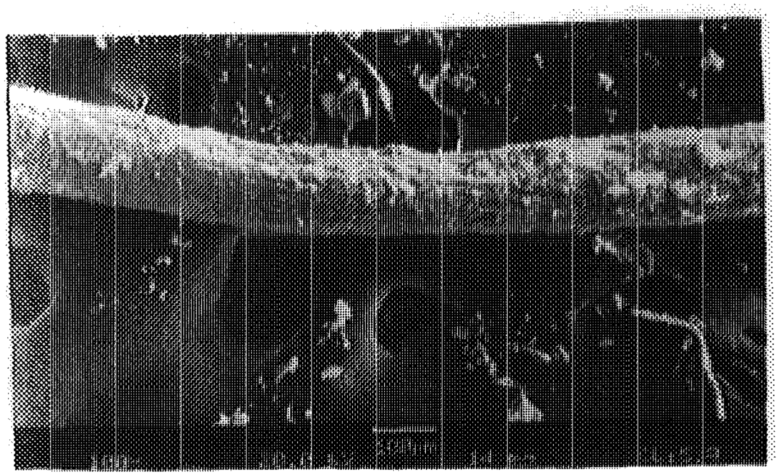
FIGURE 16
Deterioration of the Aluminum Braid



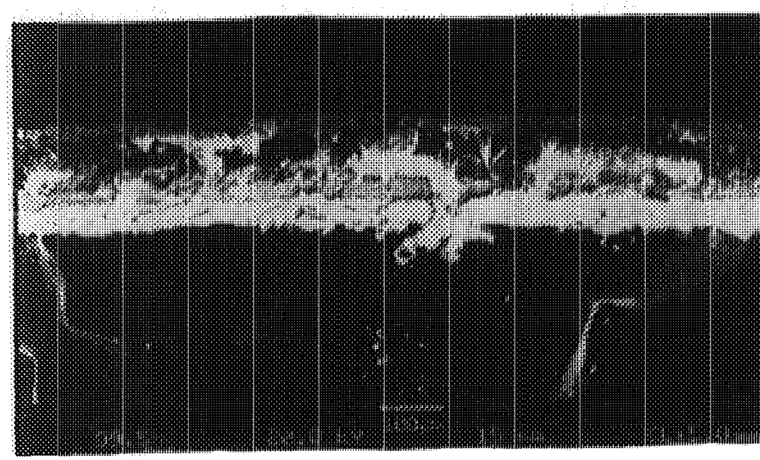
Unconditioned



Cass Exposed



Cass Exposed, Left DC Current



Cass Exposed, Right DC Current

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