QUANTIFYING RFI ISOLATION

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ABSTRACT

The cable TV industry is struggling through the process of securing their systems from radio frequency interference. (RFI) Most important is complying with the new FCC rulings. Radiation from the cable television system is a problem which must be dealt with to protect ourselves from the liability which could occur should excessive radiation be found by the FCC field audits.

There are several systems in operation today that purchased equipment (mostly passive products) which did not contain wire meshed-type gaskets for the purpose of improving the RFI shielding characteristics. Recent testing has shown that some systems may measure egress from their system above the FCC limits and the signal leak has been traced back to units not having RFI gaskets. Several devices were tested including trunk, line extenders, splitters, directional couplers, and taps. Several manufacturer's were quantified both with RFI gaskets and without. Testing was performed at the approved FCC site located at Magnavox's facilities in Knoxville, Tennessee.

The scope of this discussion is to address the electronic equipment and not other factors such as quality of installation, connectors, and cable quality. This paper will explain the physical testing facilities, test equipment setup and procedure, results of testing, and suggest some solution to potential problems.

INTRODUCTION

Is an RFI gasket necessary for CATV components to meet the FCC limits on RFI? The answer to this question is a qualified <u>YES</u>. In some systems, RFI limits can be achieved with or without an RFI gasket, but others most definitely do require these gaskets on trunk amplifiers, line extender amplifiers, splitters, directional couplers, and taps; or any other devices having high RF level input and outputs.

A wire-mesh gasket has been proven to be effective in improving RFI from products. Normally there are two types of gaskets used on any individual CATV product. One being the wire-mesh gasket, and the other a weather-sealing gasket. Experiments have been performed using integrated wire-mesh and weather-sealed gaskets. This combination has proven to be sufficiently effective on amplifiers; however, the best performance on passive products has been separate wire-mesh and weather-sealed gaskets. At Magnavox there has also been testing done with metal impregnated neopryne and conductive type weather-sealed gaskets. Neither of these two combinations have proven to be as effective as the wire-mesh gasket.

It is beneficial to be able to calculate expected RFI performance from a CATV device. Towards this end, the testing was performed to determine a corrolation between the input level and radiated output level. This would be specified in terms of RF isolation. It is also desirable to know the amount of RF isolation necessary to meet the limit set by the FCC.

As the input level to a CATV device increases or decreases, does the radiated energy increase or decrease on a consistent basis? The testing performed and the results obtained indicate a reasonable level of consistency. If the input and output levels of the devices used in a CATV system is known, as well as the RF isolation the device provides, one can theoretically calculate a level of RF radiation; or at least determine if there is sufficient head room to assure FCC compliance.

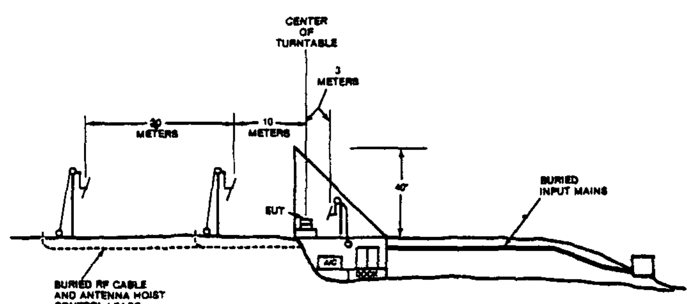
The information presented here will not allow an accurate prediction of radiated RFI energy; however, it does provide a way to determine the probability of complying or not complying with the FCC. There is conclusive evidence that some systems will have problems with passive devices not having RFI gaskets. This evidence also indicates that radiation of RF signals will take place on amplifier housings that are opened for service. The higher the input or output level, the higher the level of radiated energy. Therefore, a passive that is located closer to the output of an amplifier will tend to have a higher chance of radiation than a passive located at the end of the feeder line. Thus, when trouble shooting CATV systems for offending devices, one should look at the begininning of the feeder lines or the output of line extenders. Any system not having RFI gaskets, should retrofit the devices closest to high level bridger and line extender outputs. As a safety factor, RFI gaskets should be retrofitted in all passives and taps in a CATV system.

Suppliers of CATV devices provided an optional selection of components for the CATV operator to choose. RFI gaskets were a more expensive option on passive items, and sometimes not selected. Lower bandwidth system or systems operating with moderate feeder levels could meet FCC requirements without wire-mesh gaskets. Tap port terminators and proper base plate torque is critical in minimizing leakage. Indoor passives of the type typically manufactured offshore were major sources of egress and ingress, though major improvements have been made by some suppliers.

Test Site

Magnavox used its FCC registered test site for RFI testing. -1- It is located on the grounds of our sister company, located in Knoxville, Tennessee. The facility was designed to meet FCC Part 15 standards with future EMI Legislation in mind. Many hours of research have proven this facility to meet regulatory requirements. It houses an all-weather three meter test site, a two meter tem cell, and a conducted line radiation measurement area. The site can also be used for 10 and 30 meter testing. Reference Number 1 describes specific detail for the design of this site.

The three meter site was used for the RFI testing. Illustration Number one shows a cross view of the three 10 and 30 meter sites. Note that the three meter site is completely enclosed in a triangular building. Both the device under test (DUT) and the receving antenna are located within a triangular building. The 10 and 30 meter sites have their receiving antennas located outside of the buildings, and the device under test remains inside the building. The antenna polarization and elevation (height above the ground) are all controlled remotely from the instrumentation test area.



3 Meter Enclosed Site with 10 or 30 Meter Capabilities

ILLUSTRATION # 1

Illustration Number 2 shows the location of the measurement instrumentation. Note that all instrumentation is located below an 8 by 11 meter metal ground plane, which covers the entire three meter site. The device under test is located on a table located three meters away from a horizontally polarized antenna. The feed line for the device under test is routed from the ceiling and dropped down to the device under test such that the cable located within the test area was in the vertical plane. It was felt that this would minimize any radiation from the cable sheath. The cable length was calibrated such that the level into the device under test was known. At the receiving end a Singer Model DM105 Antenna and Balun fed a length of coaxial cable which was routed into the vertical plane down through the floor ground plane, then routed to a spectrum analyzer (HP Model 8568A). Measurements from the analyzer were calibrated to take into consideration the antenna factor and the loss in the cable. The measurement absolute level in dBmV was then taken from the analyzer.

The scope of this discussion defines RFI isolation as the difference between the dBmV measurement on the analyzer, and the highest level within the device under test. For example:

A = Amplifier Output Level (dBmV)
M = Measured Level (dBmV)
I = Isolations (dB)

1. If an amplifier has a 10 dBmV input level and a 40 dBmV output level with an analyzer measurement of -60 dBmV, the RFI isolation is defined as:

$$A_O - M \quad I$$

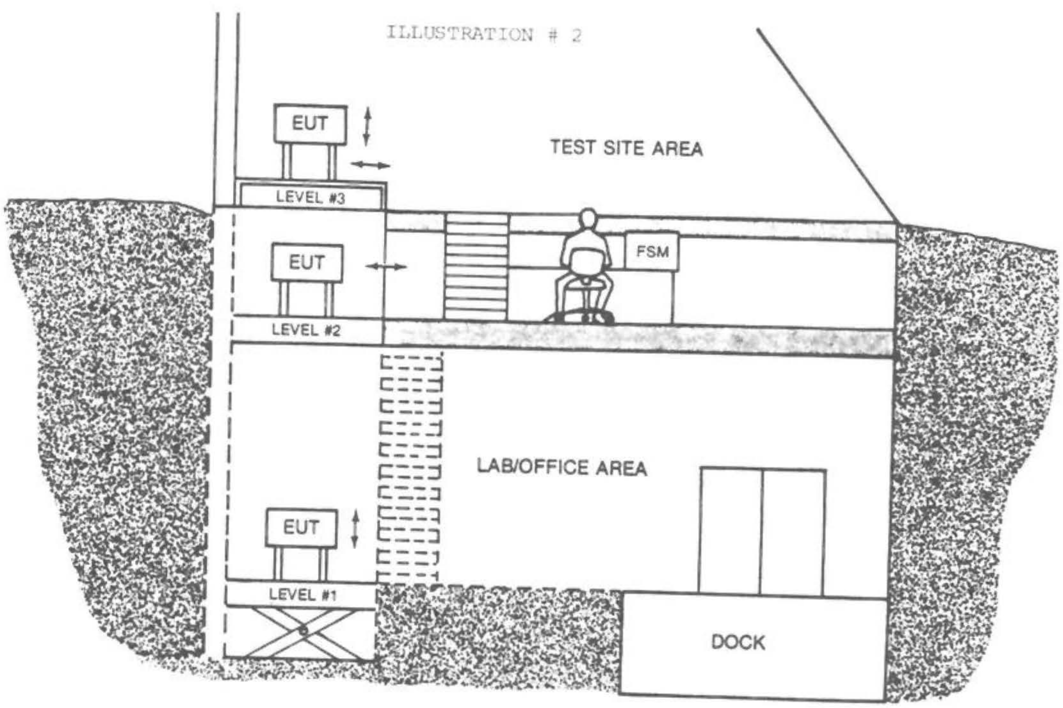
$$40 - (-60) = 100 \text{ dB}$$

If the DUT is an amplifier, the highest output level is used in the calculation.

2. If the device under test is a passive device with an input of 45 dBmV and the measurement on the analyzer was -45 dBmV, the isolation is calculated as:

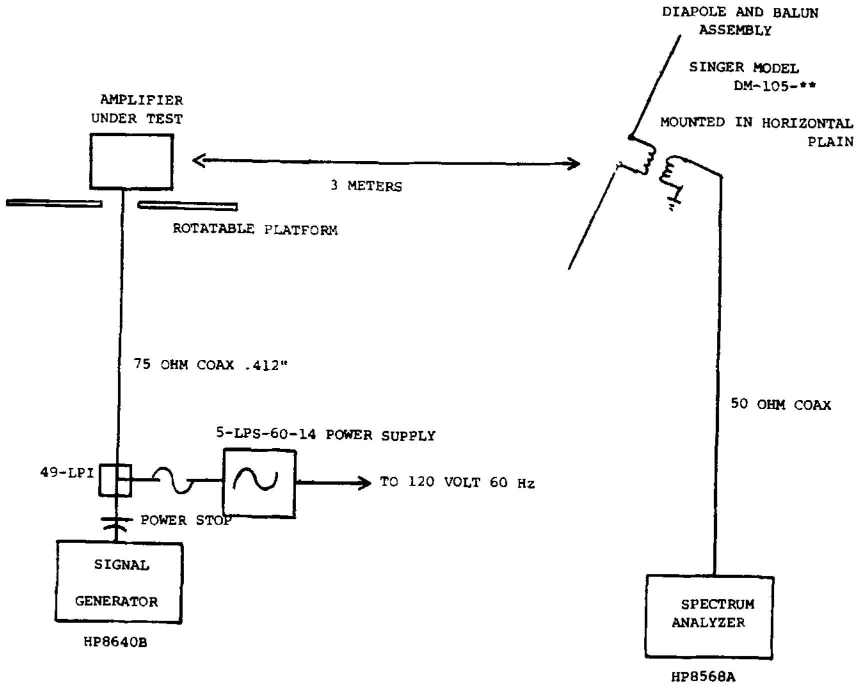
$$P_I - M = I$$

$$45 - (-45) = 85 \text{ dB}$$



3 Level Hyd-Hoist and FSM Receiving Area

ILLUSTRATION # 3



If the device is a passive product, the input level is used in the calculation of isolation.

Testing started using the test setup as in Illustration Number 3. Inconsistencies were noted, and it was determined that the spectrum analyzer noise floor was causing errors in the measurements. A low noise amplifier was added to the output of the Singer Model DM-105 antenna. This provided the dynamic range necessary for consistency. Some of the data presented was based on testing prior to the insertion of the preamplifier. The subsequent discussion on taps and the noise floor of the test set was considered in the conclusions.[1] The device under test was placed on a table which could be rotated by 360 degrees. A maximum reading on this spectrum analyzer was then recorded.

Taps

Samples of taps from 5 different vendors were tested. Magnavox taps were tested with and without wire-mesh RFI gaskets. Other manufacturers taps did not include RFI gaskets. The taps were placed on the test table with the baseplated and subscriber ports facing the antenna. All tap ports were terminated and signal was applied. The purpose of this test was to determine if any specific supplier could perform to FCC specifications without RFI gaskets. Depending on the input levels to the devices, FCC specifications could not be met by any supplier not incorporating an RFI gasket. With RFI gaskets, RFI specifications were met at the typical operating levels of 53 dBmV and even higher. To illustrate an improvement in isolation with the RFI gasket, data was taken on taps with and without RFI gaskets. Figure Number 1 illustrates samples of this data. In columns 4 and 5, RFI isolation is shown for taps containing a wire-mesh gasket. In columns 6 and 7, isolation is shown without the RFI gasket. On the average, a wire-mesh gasket improves isolation by approximately 10 dB. Typically, at the lower frequencies, there is little improvement shown with the wire-mesh gasket. At higher frequencies, there is as much as 20dB improvement in RF isolation.

FIGURE #1 ISOLATION IMPROVEMENT WITH WIRE GASKET

1	2	3	4	5	6	7
				(DB)		
	(DBmV)			Isolation		
Freq	Input to DUT	49tfc	4920/4m	4908/2m	4911/2	4900/2
30	66	103.6	109.4	110.6	107.7	108.7
54	66	104.6	105.6	105.5	109.1	108.8
125	65	80.4	99.3	100.2	91.9	95.2
135	65	77.6	100.4	99.9	92.5	91.3
185	65	70.1	101.5	100.8	83.8	85
200	65	68.3	95.9	96.5	82.1	83.9
216	65	67.5	92.2	93.3	80	81.7
330	65	67.3	94.7	96	76.8	78.4
450	58	54.9	91.1	88.4	70.9	72.2
AVERAGE	ISOLATION	77.14	98.90	99.02	88.31	89.47

note:--- The "m" in the model number indicates a wire mesh RFI gasket was installed. If "m" is not indicated tes was done without RFI gasket.

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FIGURE # 1

In order to calculate an expected level of radiation, it is important to verify that radiation decreased as level decreased. It was expected that for every dB in input level reduction, there would be a corresponding dB reduction in output radiation. From Figure Number 2, this conclusion can be drawn. Column Number 3 shows the absolute level measured on the analyzer with an input as shown in column 2. Column 4, 5, and 6 are measurements taken with the input levels reduced by 2, 6 and 8dB respectively. Each of the columns were averaged for measured signal level, and the difference between columns 4, 5, and 6 with reference to Column 3 was taken. For a 2dB reduction in input signal level, the radiated signal level reduced by 1.58dB, 6dB by 5.26dB and 8dB by 6.82dB. One would expect for a 2dB input level reduction that the output would drop by 2dB. The actual average data does not show this; however there seems to be a logical reason why this occurs. When the absolute level was measured on the analyzer, it was close to the noise floor. The noise floor added to the actual radiated signal level and caused an error. As the levels got closer and closer to the noise floor, the errors also increased. For example, reducing the input level by 2dB yielded an error of:

2 - 1.58 dB =.42 dB error

This is calculated from the difference in column four and a reduction of 2dB in input level. The error was greater in column 6 and the actual measured radiation was much closer to the noise floor. The error for an 8dB reduction is 1.18dB. This figure comes from taking the 8dB reduction in column 6 minus the difference in column 6. Column 7 in figure 2 indicates the noise floor of the test system. You can see that there is only two to three dB difference between the noise floor and the actual measurement. To confirm this logic, an exercise was performed. Refer to illustration number 4, which is a graph for correcting a spectrum analyzer measurement when the thermal noise floor is less than 16dB from the measured value. For example, refer to figure number 2. In column 4 the measured radiation level at 54 MHz is -40.9dBmV. The noise floor was -47dBmV. The difference between the noise floor and the measurement is 6.1dB. The correction factor corresponding to 6.1 from the chart in illustration number 4, is 1.2. Therefore, the correction yields a measured RFI level of -42.1dBmV. Additionally, looking at column 6 with a level measured at 54MHz, shows a -44.7dBmV (which is 2.3dB away from the noise floor). The correction factor for 2.3dBmV is approximately 3.6dB, and therefore the measured level was corrected to -48.3dBmV. Take note that there is a 6dB differential in input levels between columns 4 and 6. Subtracting the two corrected measurements:

48.3 - 42.1 = 6.2 dB difference

The expected difference in level would be 6dBmV and this illustration showed 6.2. Clearly this is within measurement accuracy.

The information obtained from our testing brings us to the conclusion that as input level to the device decreases, the output radiated level will decrease by the same amount.

FIGURE #2 INPUT LEVEL vs. RFI OUTPUT

1 FREQ	2 INPUT LEVEL (DBmV)	3 RF LEVEL MEAS'ed	4 RF @ Input -2DB	5 RF @ Input -6DB	6 RF @ Input -8DB	7 NOISE FLOOR
54	69	-39.3	-40.9	-43.1	-44.7	>-47
125	67	-35.8	-36	-40.6	-43.8	>-46
135	67	-31.4	-32.1	-36.2	-37.2	>-40
185	67	-22.8	-24.5	-28.1	-29.1	>-32
200	66	-23.9	-26.6	-29.7	-30.2	>-33
216	65	-24.7	-25.5	-30.1	-31.9	>-34
330	64	-19.5	-23	-25.9	-28.1	>-31
450	62	-11.8	-13.3	-17.6	-18.8	>-21
AVERAGE LEVEL ===		-26.15	-27.7375	-31.4125	-32.975	
DIFFERENCE REF column 3 ==			1.5875	5.2625	6.825	

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FIGURE # 2

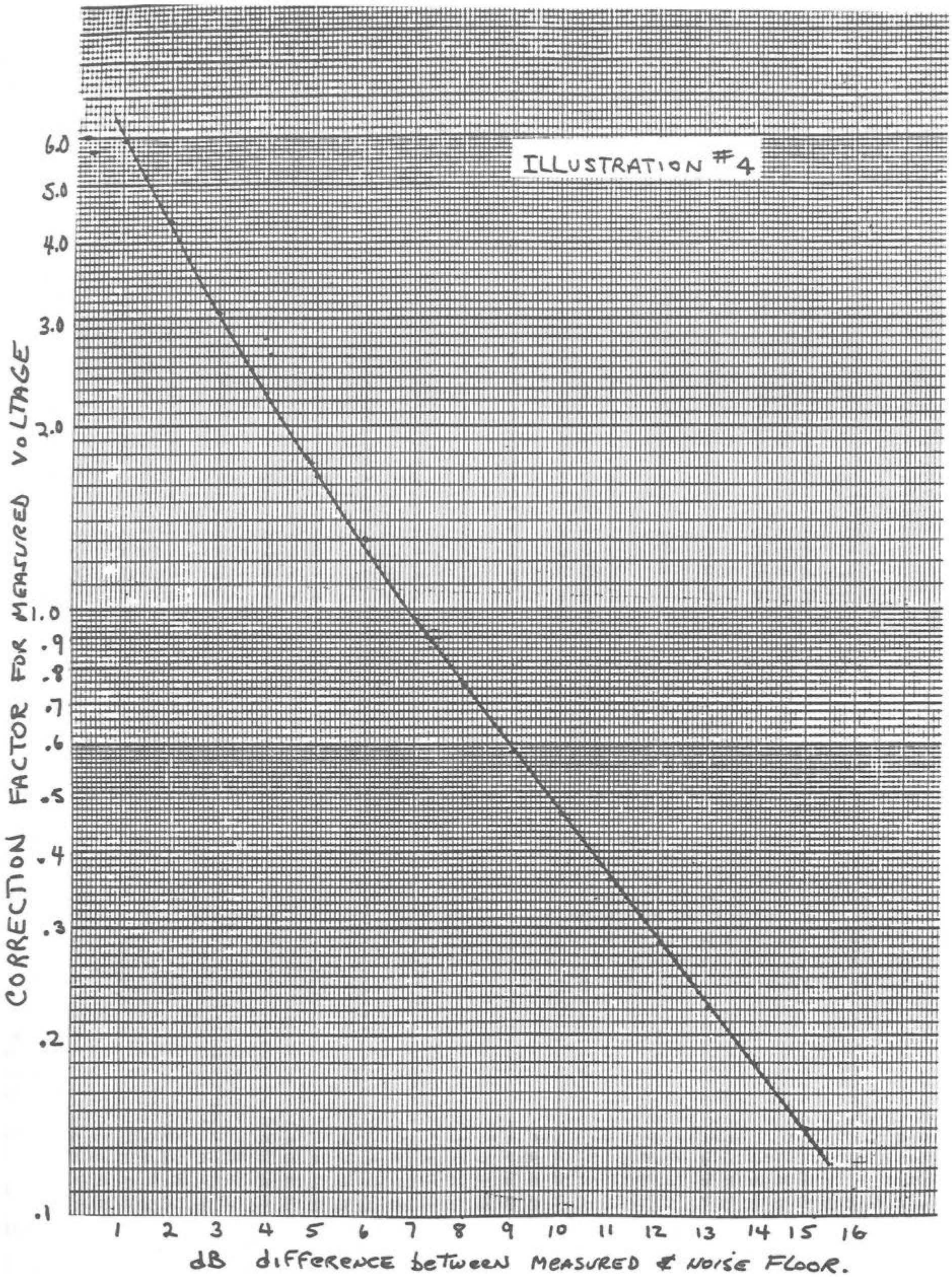
ILLUSTRATION #4
CORRECTION FACTOR FOR MEASURED VOLTAGE
6.0
5.0
4.0
3.0
2.0
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
dB difference between measured & noise floor.

There is no one supplier who can assure RFI isolation without wire-mesh gaskets. Suppliers using the RFI gasket typically have better performance records than those not using RFI gaskets; however, there are instances when the performance is much worse. Figure number 3 shows the isolation testing where products did not have RFI gaskets. As indicated by the boxed numbers, no one manufacturer could meet FCC specifications at all test frequencies.

Figure #3 Various Suppliers Products without RFI gaskets.

Tap Input Level = 53 dBmV

(DB) ISOLATION

FREQ	SUPPLIER a	SUPPLIER b	SUPPLIER c	SUPPLIER d	SUPPLIER e
54	98.5	97	93	92.4	99
125	93.5	98	90.2	[86.1]	93.1
135	90.9	93.8	88	[86.2]	88.7
185	[86.1]	97.7	[79]	98	98
200	88	88.7	[78.5]	98	98
216	86.9	[86]	[78.2]	98	98
330	84.3	82.8	[77.9]	98	98
450	[73.7]	[72.1]	[67.5]	[77.2]	[81.5]
AVERAGE	87.7375	89.5125	81.5375	91.7375	94.2875

note --- FCC Specifications could not be met without Wire RFI gasket as indicated by boxed numbers

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FIGURE # 3

Typically, a measured RF isolation of 90dBmV at frequencies between 54 and 216 MHz, will be sufficient to meet RFI requirements, provided that the highest levels at the input or output of a device do not exceed 50dBmV. For example, if a tap utilizing an RFI gasket exhibited a 90dB RF isolation, it would be expected to provide sufficient isolation and meet FCC requirements. However, if a tap without an RFI gasket was installed with a level of 50dBmV, it would be expected to radiate above the FCC requirements. High levels would be present at the output of feeder amplifiers. As the signal progresses through a tap feeder line, the signal level would be attenuated through the cable and through the passives. Since there is typically 10dB less RF isolation without a wire gasket, the level in the feeder line would have to be attenuated to 40dBmV in order to meet FCC requirements. Therefore, the section of feeder from the output of a high level amplifier through the point in the feeder line where the level was attenuated to 40dBmV would require the installation or retrofitting of RFI gaskets. The probability of an RF egress above FCC limits beyond 40dBmV is low.

Splitters and Couplers

Measurements were made on splitters and couplers, and it was found that they generally had a higher level of RF leakage without RFI gaskets. The installation of RFI gaskets provided a greater improvement than for taps. When an RFI gasket was installed, its isolation performance was comparable to a tap with an RFI gasket. Further study must be done to discover the reasons for these results. A hypothesis is that splitters and couplers are generally enclosed in larger housings. The perimeter around which RF sealing takes place is larger, and therefore provides a higher probability of an imperfect seal, resulting in a higher RFI. The wire-mesh gasket tends to seal this larger perimeter efficiently.

There is not as much data available on splitters and couplers so as to determine an average level of RFI improvement to be expected with a gasket. Therefore, projected limits of operating levels cannot be concluded. Further study will be performed on splitters and couplers.

Trunk and Line Extenders

Testing was also performed on trunk and line extender amplifiers operating with levels as high as 53dBmV. As a standard feature on most CATV amplifiers, a wire-mesh gasket is installed. To the writer's knowledge, most of the installed amplifiers have RFI gaskets. No detectable RFI levels were measured from a Magnavox amplifier with housing sealed and torqued to specification. However, when the amplifier lid was opened as is necessary when an amplifier is being serviced in the field, the level of RFI radiation far exceeded FCC limits.

To the writer's knowledge, there is no CATV trunk or line extender amplifier that does not incorporate a wire-mesh or other variation of an RFI gasket. Testing was performed on Magnavox trunk and line extender amplifier products only. Therefore, a conclusion cannot be drawn for other manufacturer's.

SUMMARY

This paper presented some conclusions based on RFI testing in an FCC approved site. It is by no means a conclusive and exhaustive study. It does, however, provide some insight and suggests minimum level of RFI Isolation. A 90dB minimum RF isolation is required. Taps without RFI gaskets have less than 90dB of RF isolation. In certain instances, taps without RFI gaskets are sufficient to meet FCC specifications. Generally, it can be stated that isolations less than 70dB can be expected from taps not having RFI gaskets. It is important to adhere to manufacturer's specifications on screw and bolt torque. An overtorqued baseplate could cause warpage and result in high levels of RF radiation. Likewise, terminators should be properly torqued on F ports. A loose F port terminator has the potential to radiate at higher levels than a completely unterminated port.

Trunk and line extender amplifiers, when sealed in compliance with manufacturer's specifications should exhibit good RFI performance, and sufficiently achieve FCC limits.

Further testing and study will be performed and hopefully provide more conclusive data.

Systems having installed products without RFI gaskets can retrofit RFI gaskets to improve performance. For example, Magnavox CATV stocks gaskets which can be ordered as replacement parts. A tool has been designed to enable in-the-field installation of these RFI gaskets. For more information contact MAGNAVOX CATV SYSTEMS, INC.

FOOTNOTES

1. Fred Fisher, "Construction of EMI Test Chamber," NAP Consumer Electronics Corporation.

2. Ken Simons, Technical Handbook for CATV Systems, Third Edition, Jerrold Electronics Corporation, Philadelphia, Pennsylvania, 1968.