RF SHIELDING MEASUREMENTS USING THE UACC RF CHAMBER

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ABSTRACT

Due to the increasing concern for RF shielding, UACC Engineering sought some means of shielding evaluation of the products used in the field. Devices are available to make these measurements in a lab environment on aluminum and drop cables, such as the Belden SEED, but similar devices to test other CATV system components including amplifiers, subscriber taps, system passives, and drop passives are not commercially available at a reasonable price.

Therefore, UACC Engineering designed and built a device very similar to but much larger than the Belden SEED to measure the RF shielding of CATV components other than cable. The original purpose of the chamber was to determine relative values of RF shielding from product to product. However, it has also revealed great differences in RF shielding between various models of CATV components allowing UACC to set minimum RF shielding specifications for approved products. Additional research has been done to determine correlation factors of RF shielding measurement to signal leakage levels measured in actual operating conditions.

A DEFINITION OF RF SHIELDING

Over the past several years, the terms "RF shielding", "shielding effectiveness", and "shielding isolation" have been used interchangeably as the electrical characteristic of an electronic device which impedes signal egress (leakage) and ingress. In greater detail, Belden defines shielding effectiveness for use with their SEED as the ratio in decibels between a reference signal applied to a sample cable length and the signal radiated by that cable. The value of the radiated signal is determined by direct measurements from the SEED output.

UACC Engineering defines "RF shielding" by a slightly different method in order to be capable of correlation with field measurements. At UACC, it is defined as the ratio in decibels between a reference signal applied to a sample device and the input signal available to a leakage antenna due to the shielding characteristic of the sample device. If the leakage antenna is assumed to be either an isotopic or a dipole radiator, fairly accurate correlation has resulted between Belden SEED and UACC chamber type measurements and field measurements using known antennas at known distances from the device under test.

RF CHAMBER DESIGN

The development of the UACC RF shielding measurement chamber is directly attributable to a need by UACC approximately three years ago for shielding effectiveness data on CATV components other than aluminum and drop cable. All components of a CATV system can contribute to egress and ingress problems; therefore, UACC Engineering decided to develop a shielding measurement method for devices such as drop and distribution passives, amplifiers, converters, and other CATV components.

The idea for the UACC RF chamber came from that of the Belden SEED. The Belden SEED is essentially a five foot long 50-ohm coaxial cable with a tubular center conductor and air dielectric. Sample lengths of drop cable are placed inside the tubular center conductor, a reference signal is applied to the sample, and leakage is picked up by the SEED center conductor to be measured. The Belden SEED has become an industry standard with its ease of operation, repeatability of results, and compatibility with common CATV test equipment. For these reasons, UACC Engineering chose to build its shielding chamber similar to, but larger than, the SEED. The purpose of the larger size was for measuring shielding on larger CATV components.

The UACC RF shielding measurement system, which is shown in Figure (1) has been operational for approximately three years. The original version of the

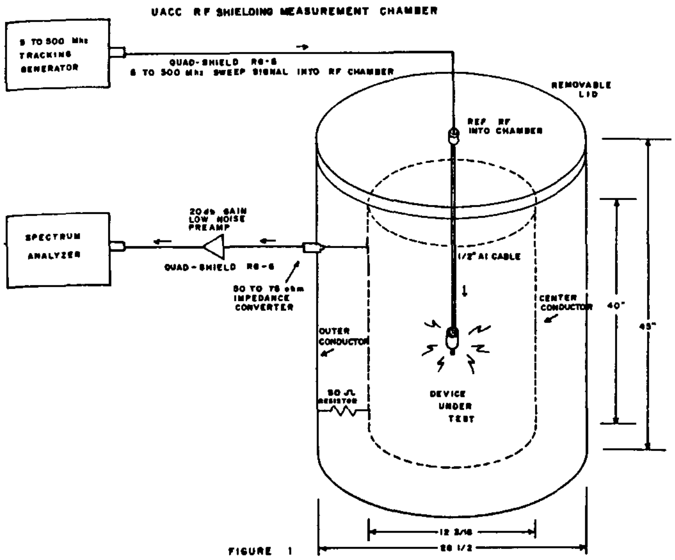

FIGURE 1

chamber was a 75-ohm device, but later it was changed to 50-ohms to allow for larger test devices to be placed inside the larger center conductor of the 50-ohm system. It was undesirable to make the original 75-ohm chamber larger because of space limitations in the UACC Lab. The dimensions of the RF chamber were determined by the following formula for the characteristic impedance of a coaxial cable.

$$Z = [138 \log(D/d)]/\sqrt{K} \qquad (1)$$

where

Z = characteristic impedance of a coaxial cable
D = inside diameter of the outer conductor
d = outside diameter of the center conductor
K = dielectric constant = 1.0 for air

From equation (1), the ratio D/d is approximately 2.3 for a 50-ohm coax with air dielectric. The UACC chamber dimensions were determined by using this ratio in conjunction with the maximum useable diameter of the outer conductor due to space limitations. The overall height or length of the 50-ohm chamber was determined strictly on a practical, workable basis.

RF CHAMBER CONSTRUCTION

Having determined the physical dimensions of the test chamber, the next step was to have the device built. It was decided to build the chamber out of sheetmetal due to cost factors. Removable lids or end covers were built for the large coaxial chamber to work with the outer conductor in maintaining an interference-free measurement system. One of the lids was made to be easily removable for purposes of placing test samples inside the center conductor for shielding measurements. This same lid is also used to support the hard line cable which supports the test sample in the center of the chamber and feeds the reference signal to the sample. To finish the chamber construction, one end of the center conductor was terminated with a 50-ohm resistor to the outer conductor and the other end of the center conductor was wired directly to the center pin of the chamber 50-ohm output N-connector. A 50/75-ohm impedance converter was attached to the output connector to allow 75-ohm shielded cables to be used in the measurement process.

RF CHAMBER OUTPUT RETURN LOSS

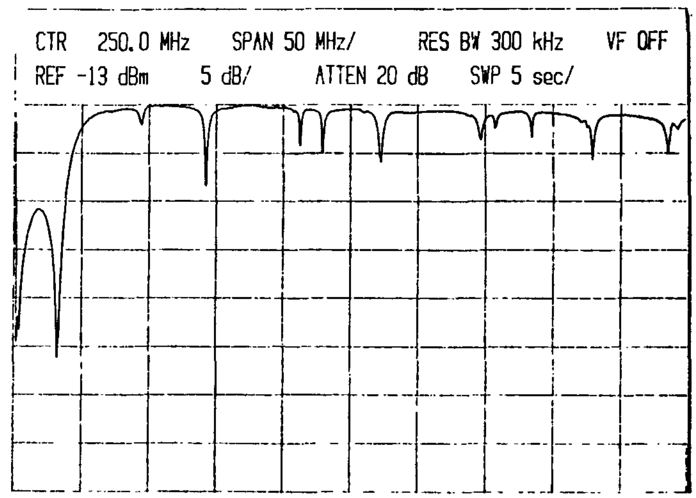

FIGURE 2

RF CHAMBER TESTING

A return loss measurement from 10 to 500 MHz of the 50-ohm system was done after the RF chamber was constructed to determine the extent of the mismatches in the chamber and to determine the resonant frequencies of the RF chamber. The return loss plot, which is shown in Figure (2), reveals that the chamber is a poor 50 ohm broadband system; however, certain resonant frequencies did show a respectable match indicating the "antenna system" was tuned at some frequencies. Some of these frequencies are used later in this paper to determine the RF shielding of the test sample. The overall poor return loss of the coaxial chamber has not been explained, but could possibly be due to the methods of terminating the coax with only a simple 50-ohm resistor and wiring the coax center conductor to the output with little concern for match. Again, this RF chamber was originally built only for relative measurements between similar sample components and its cost, ease of operation, and repeatability of results were the only major design concerns.

RF CHAMBER OPERATION

Obtaining RF shielding results from the chamber is a fairly straight-forward procedure. The first step is to establish a reference leakage noise floor of the system. This is accomplished by feeding the reference signal into a known, well shielded terminator inside the RF chamber and checking for no chamber output leakage levels above the noise floor of the receiving measurement system. The reference signal in the UACC Lab is usually a zero dBm (48.75 dBmV), 10 to 500 MHz sweep signal and the receiving measurement system consists of a broadband 20 dB gain, low noise figure preamplifier and a 300 KHz bandwidth spectrum analyzer. The preamplifier greatly increases the sensitivity of the system yielding a receive system noise floor which is approximately 110 dB down from the reference level which is supplied to the test component. This difference between the reference level and the system noise level is the maximum value of RF shielding that can be measured with this system. Decreasing spectrum analyzer bandwidth can extend the range a little more, but measurements of 110 dB have been sufficient in the past.

Figures (3) and (4) show plots of the RF shielding as given by the RF chamber on two different drop two-way splitters. UACC Engineering has always used the maximum peak on the frequency/shielding plot to determine the RF shielding of a particular component. For example, the shielding of the unit plotted in Figure (3) would be -54 dB because the highest peak at 355 MHz is that value. Likewise, the component plotted on Figure (4) would have an RF shielding of -46 dB.

RF SHIELDING
SAMPLE A

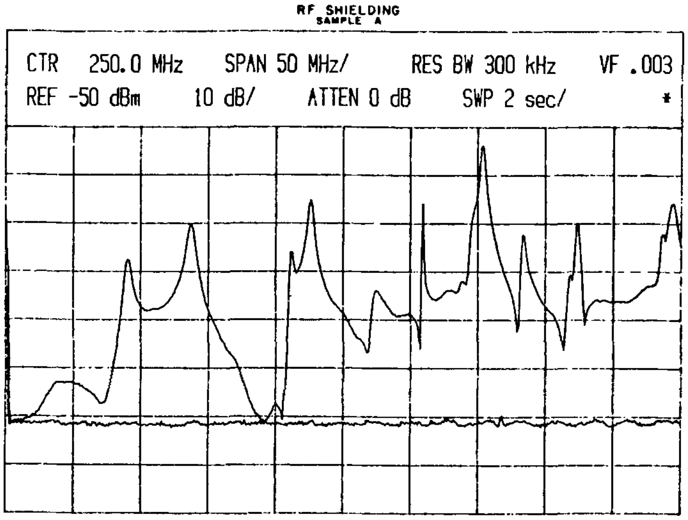

FIGURE 3

A comparison of both plots will show similar responses with the RF shielding showing definite resonant frequencies.

RF SHIELDING
SAMPLE B

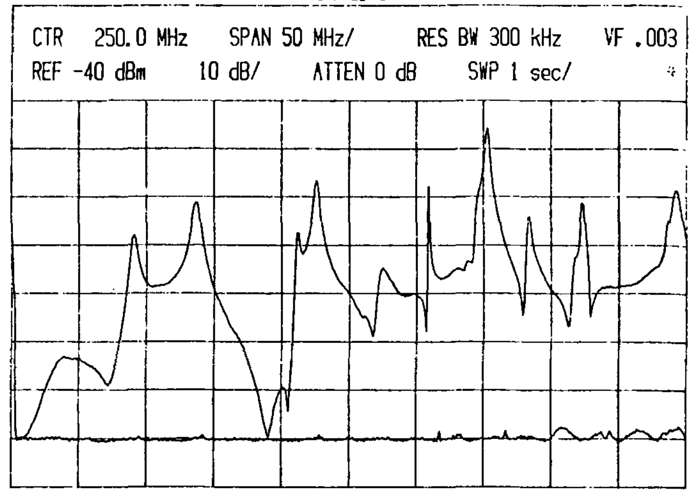

FIGURE 4

These resonant frequencies coincide similarly with the resonant frequencies shown by the return loss plot of the chamber given in Figure (2). Therefore, the chamber is only yielding RF shielding data at certain frequencies. Normally, this type of measurement is sufficient, but if an approximation is needed for other frequencies, a line connecting the major shielding peaks can be used to yield the necessary data. This has been done in figures (5) and (6).

Another interesting point shown by the plots is that of decreased RF shielding as the frequency increases from approximately 90 MHz to 355 MHz. This does not seem surprising due to the fact that drop two-way splitters radiate from slots around the back plate. This would essentially radiate similar to a slot antenna, which typically has a radiation efficiency that increases with frequency.

One last interesting point of the shielding plots is that the major peak at 355 MHz is possibly due to the fact that the chamber center conductor is approximately one wavelength long at 355 MHz. Also, the peak at 89 MHz corresponds to a quarter-wavelength chamber center conductor at that frequency. It will be shown later that the 89 MHz peak yields the best correlation to field type measurements. This may imply that the chamber type measurement approximates that of a quarter-wave antenna.

The absolute RF shielding levels at different frequencies yielded by the chamber measurements may seem somewhat vague at this point in the paper. Correlation to some actual field measurements of signal leakage from these sample components may help the reader's response to the chamber measurements. This will be discussed in the following section.

EXTRAPOLATED RF SHIELDING
SAMPLE A

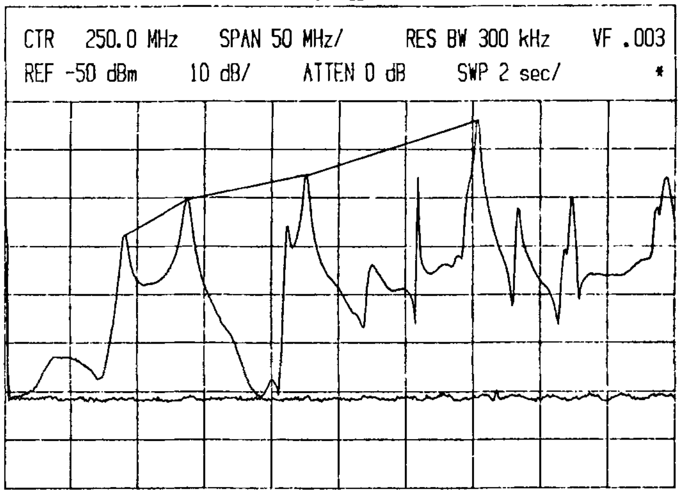

FIGURE 5

EXTRAPOLATED RF SHIELDING
SAMPLE B

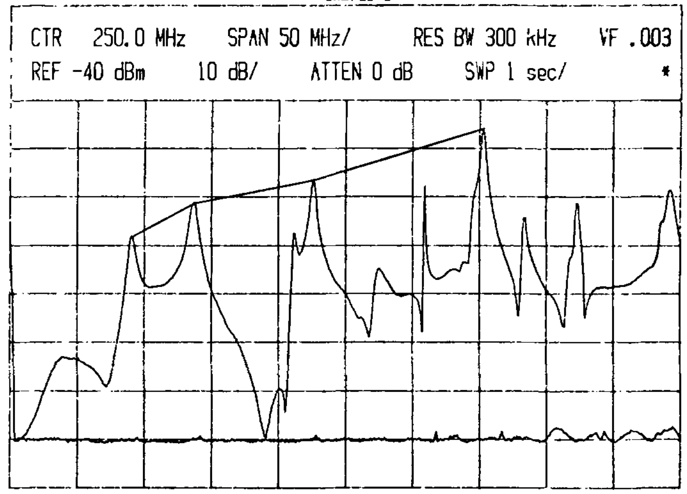

FIGURE 6

CORRELATION TO FIELD MEASUREMENTS

Over the past few years, UACC Engineering has operated the RF chamber as a relative measurement device only. When sample components of one type were shown to have better shielding than another type in the RF chamber, measurements in the field would show the same results. However, no work was previously done to determine whether or not the RF chamber could be used to predict actual egress or ingress levels from chamber tested components. The next few paragraphs will describe the testing done to show that correlation does exist and that the correlation is frequency dependent. The approach taken to determine correlation between chamber and field measurements was to take the two two-way splitters tested in the chamber and measure the leakage levels at three different frequencies with a tuned dipole antenna at known distances from the two-way splitter. The measured levels would then be compared to predicted levels calculated by using the chamber shielding data and standard antenna gain and path loss formulas.

The three frequencies used were resonant frequencies of the chamber and the distance used from the splitter sample to the measurement dipole was 20 feet. Some measurements were taken at ten feet, but near field interactions at lower frequencies forced the distance to be 20 feet. The splitter was elevated approximately seven feet off the ground by a non-conductive pole and the splitter was fed its reference signal by well-shielded drop cable with properly installed F-fittings. The test was set up to insure that all leakage measured originated from the sample splitter.

An accurate c.w. frequency generator was used to feed the test splitters with 56 dBmV of RF level at the following frequencies: 89 MHz, 226 MHz and 355 MHz. All of these are resonant frequencies of the RF chamber. The receive measurement system consisted of a tuned dipole antenna, tunable bandpass filter, preamplifier, and a spectrum analyzer. The bandpass filter was necessary to prevent the analyzer from overloading due to random off-air pickup by the dipole. The preamplifier was used to increase the sensitivity of the measuring system. The losses and gains of these devices were accounted for in the measurement process. The receive levels at the antenna output were obtained by recording the maximum levels observed while peaking the main radiation lobe and the polarization of the dipole antenna. These recorded levels were the ones used for comparison to the predicted antenna levels.

Predicting antenna receive levels involves use of the following formula found in the Radio Engineers Handbook:

$$Pr = Pt\ Gr\ Gt\ \lambda^2 / (4\pi R) \qquad (2)$$

where

- Pr = receive antenna output power in watts
- Pt = transmit antenna input power in watts
- Gr = receive antenna gain over isotopic
- Gt = transmit antenna gain over isotopic
- λ = wavelength in meters
- R = path distance in meters

In this case, $Gr = 1.64$ for a dipole antenna and $R = 6.1$ meters for a path distance of 20 feet. Also past experience with leakage calculations at UACC have shown that Gt (gain of leakage antenna) may equal 1 or 1.64 for field calculations. For the purposes of this paper, it seems reasonable to approximate the actual leak as an isotopic antenna with $Gt = 1$. There is only a 2 dB difference in gain between an isotopic and dipole antenna.

Using this given information the formula becomes

$$Pr/Pt = 0.00028\lambda^2 \quad (3)$$

which is a formula for the overall gains and losses of the antennas and the 20 foot path. This formula may then be written in decibel terms to produce the following:

$$Pr(dBmV) = Pt(dBmV) + [10 \log(0.00028\lambda^2)]dB \quad (4)$$

Next, the RF shielding term S obtained from the RF chamber plots may be added to the above formula to create the final formula for predicting antenna receive levels.

$$Pr(dBmV) = Pt(dBmV) + [10 \log(0.00028\lambda^2)] (dB) + S(dB) \quad (5)$$

The term S will be a negative number directly attainable from the shielding plots for the particular frequency in consideration. From the above formula, the predicted antenna receive level can be calculated by knowing the reference level Pt, the wavelength and the RF shielding S.

Comparison of actual measured receive levels and predicted receive levels yielded some reasonably satisfactory results. The results revealed correlation of 1 dB or better at 89 MHz, 2 to 4 dB at 226 MHz and 7 to 9 dB at 355 MHz. Since there always seems to be a few dB of error with any field type antenna measurement, the results just given seem to be very reasonable. Based on these results, the RF chamber seems to be a fairly accurate method of measuring absolute values of RF shielding.

SETTING STANDARDS

UACC has a minimum RF shielding specification of -100 dB for all CATV components to be placed in UACC systems. UACC Engineering has accepted products with -90 dB shielding because alternatives were not available. This specification is based on worse case calculations of interference based on CATV plant egress and ingress. Without devices such as the Belden SEED and the UACC RF chamber, these specifications would be very difficult to verify and enforce.

CONCLUSION

The UACC RF chamber is a proven, low cost, easy to operate, and repeatable method of obtaining RF shielding performance on almost any type of CATV equipment. For a few years, the RF chamber has been considered only a relative measurement of RF shielding. The testing presented in this paper show that the chamber can be used fairly accurately as an absolute measure of RF shielding. The CATV industry as a whole needs to realize the importance of RF shielding and become more involved in the selection of components to be placed in CATV systems.

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