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NOISE SIGNALS AND CARRIER MODULATION ARISING IN ELECTRICAL CABLES DURING NUCLEAR PULSE IRRADIATION

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Summary Electrical noise signals generated in coaxial and other cables by pulsed nuclear radiation were measured as a function of applied voltage and exposure history. In consecutive exposures the signal magnitude and polarity was found to be strongly affected by "training" and "memory" effects. Unexpectedly large signals in the cable shield were identified as the cause for oscillatory signals in the center conductor and for the occurence of parasitic leakage currents in nearby conductors. An RF signal transmitted through RG62 A/U cable undergoes a temporary attenuation during the radiation pulse while it passes through RG59 B/U without measurable degradation. Definite rules are given for minimizing cable noise signals in nuclear pulse radiation measurements.

Introduction

In measuring the performance characteristics of electronic parts, devices and circuits during their exposure to nuclear radiation pulses the transmission lines connecting the test objects with the remote instrumentation require careful consideration. Aside from the fact that their length imposes certain restrictions upon the sensitivity of the measurements, unknown or unpredictable noise signals generated in the cable and inseparably superposed upon the response signal of the test object may render the observed results worthless or even misleading. In addition to the generation of noise signals, nuclear pulse radiation may temporarily affect the transmission characteristics of the cable thereby causing amplitude and phase changes of transmitted RF carrier signals.

It has been the objective of our work to establish the nature and magnitude of these two types of cable effects and to develop guidelines for their minimization in actual use.

Cable noise measurements performed in two previous experiments by our group have been reported elsewhere[1, 2], and a detailed account of the results to be summarized here will be available soon.[3] All of these experiments were conducted at the Sandia Pulse Reactor Facility (SPRF) Albuquerque, N.M.[4] This reactor is a bare critical assembly yielding a mixed neutron and gamma radiation pulse of approximately 100 micro-second duration at an average dose rate of 10^{17} n/cm^2 ·sec and 10^7 rad/sec respectively.

By far the greatest part of our work was devoted to two coaxial RF cable types, namely RG59 B/U and RG62 A/U according to MIL-C-17/29A and MIL-C-17/30 respectively. In the RG59 B/U cable the dielectric is extruded onto the center conductor and fills the entire space between the center conductor and the shield while in the RG62 A/U cable an open air space is maintained around the center conductor by a helically wound polyethlene spacer filament, and the wall thickness of the dielectric is reduced accordingly.

Two additional cable types for which some results will be reported are the tri-coaxial cable known commercially as "21-527" and a commercial multi-conductor mylar ribbon cable. The tri-coaxial cable consists of regular RG59 B/U cable with an added shield and outer jacket. The multi-conductor cable contains eight copper conductors with a cross-section of .062" x .0027" spaced .125" center-to-center which are molded between two layers of mylar tape 1.125" x .005".

The length of the cable samples for the noise measurements was 50 ft. and those used in the RF transmission experiment were 100 ft. long. In both cases the cable samples extended to the outside of the reactor building in order to avoid the use of connectors within the radiation field.

Noise Signal Measurements

Method

The primary noise signal induced in the cable consists usually of a current pulse strongly resembling the radiation pulse in shape and duration. Under the conditions of our experiments the magnitude of the signal peak values ranged over three decades, namely from a few micro-ampere to about 10 milli-ampere.

The signals are measured by means of the simple circuit shown in Fig. 1. It permits the independent observation of the signals generated in the center conductor and the shield leg with or without an applied voltage by means of the measuring resistor inserted in each leg. This resistor was always 1,000 ohm in the center conductor and either 1,000 ohm or 100 ohm in the shield. The signals are photographically recorded as single sweep oscilloscope traces triggered by the burst initiation signal from the reactor.

Experimental Plan

In all noise signal measurements a number of cable samples was grouped together and observed through a sequence of six consecutive exposures within a ten hour period. For all samples the first three exposures were repetitive, i.e. all conditions were maintained unchanged; those samples which had carried an applied voltage during the first three shots went through a cycle of no-voltage, re-applied voltage and reversed polarity in the fourth, fifth and sixth exposure. The magnitude of the applied voltage was always 268 volt.

In one group of measurements both cable conductors were kept at equal potential above or below the ground potential, while in the second group only one conductor, either the center or the shield carried an applied voltage thus creating a potential difference across the cable dielectric. These two conditions were found to cause strong and characteristic differences in the cable response behavior thus providing a natural and meaningful grouping for the review of our results.

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Results

Conductors at Equal Potential In this category we consider first the elementary case in which no voltage is applied to either conductor. The results obtained in three consecutive exposures of one sample each of RG59 B/U and RG62 A/U cable are compared in Table 1 in which the peak values of the current signals observed in the center conductors and the shields are listed in micro-ampere.

Several typical differences between the two cable types are readily apparent. The center conductor signal of the RG59 B/U cable is so small that we needed additional preamplifiers for its measurement. In three exposures it drifts from -5 ua to smaller but positive signals. At such low signal levels the change in polarity is not necessarily significant. The RG62 A/U center conductor, on the other hand, shows a very strong signal of +750ua in the first shot, but changes to much smaller and negative values in the second and third exposure.

The shield signal of RG59 B/U remains unchanged at -100 ua through all three shots, while that of RG62 A/U mirrors the behavior of its center conductor in dropping from the strong initial signal of -1,000 ua to a level below -200 in the subsequent shots.

If we compare the signals from both cables in the third shot with those in the first we note that the response of RG62 A/U is closely approaching that of RG59 B/U, and if we make allowance for the scatter of data which is commonly encountered in measurements of this type we conclude that the cables can no longer be distinguished from each other by their noise signals.

It should be noted that in both cables the shield signal exceeds that of the center conductor by approximately two orders of magnitude. This disparity is probably caused by the fact that the shield braid by virtue of its much larger area and relatively thin insulation is "coupled" much more closely to the ionized environment than the center conductor.

The drastic reduction of the noise signals in consecutive exposures under unchanged conditions of applied voltage exemplified by the RG62 A/U cable will henceforth be called "training". A satisfactory explanation for this effect and for the drastically different behavior of the two cable types with respect to training is still lacking.

The second case of equipotential conductors studied is that in which a voltage of 268 volt was applied to the center and the shield simultaneously. The observed response signals are reproduced schematically in Fig. 2 for RG59 B/U and in Fig. 3 for RG62 A/U. The voltage schedule used in this six series was the normal sequence of three shots at +268V followed by one shot each at 0 volt, +268V and -268V.

In Shot 4, the no-voltage shot, the signals were smaller than had been expected and therefore the sensitivity of the measurement was insufficient to determine their precise values. We can state, however, that they are compatible with the data listed in Table 1 for the third shot.

The strong positive response of the RG62 A/U center conductor in the first shot duplicates in polarity and magnitude the behavior in the first no-voltage shot in Table 1, and its subsequent drastic decrease follows also the pattern of its counterpart. We note therefore that the training effect of the RG62 A/U cable occurs in both equi-voltage cases.

The remaining results shown in Figs. 2 and 3 differ dramatically from those covered so far. The signals from the center conductors are no longer unidirectional pulses but single cycle sinusoids with peak-to-peak values between 150 and 200 ua. The shield signals maintain their single pulse nature, but their peak values are increased to a range from 3,000 to 3,500 ua, and their polarity is governed by that of the applied voltage.

The high values of the shield signals had been more or less expected in view of results of earlier measurements[2] in which the voltage had been applied to the shield, and they are also plausible because of the relatively intimate contact between the shield and its environment as mentioned before.

The oscillatory response of the center conductor, however, was at first quite puzzling. While signals of this type had been observed by many workers in this field they were usually considered as curious anomalies until an analysis in terms of lumped-circuit parameters pointed to a possible explanation.[5]

In Figs. 2 and 3 our scale factors are chosen in a ratio of 20 to 1 for the center conductors and the shield signals respectively. In this presentation, a typical oscillatory peak-to-peak center signal of 150 ua is equal in size to a 3,000ua signal from the shield. Since practically all of the oscillatory signals agree very closely in their magnitude as depicted with their companion shield values we conclude that a fixed relationship between these signals must exist such that 5 percent of the shield signal are transformed into the oscillatory center response.

This relationship was identified as straightforward differentiation. In Fig. 4 we have replotted our circuit showing the cable capacitance of 1,640 uuf and the measuring resistor R_s in the shield leg which was either 100 ohm or 1,000 ohm. In the analysis the shield current is represented by a single cycle of a sine wave beginning and ending at its negative peak value. The ratio of the differentiated current in the center conductor and the signal current in the shield becomes 5 per cent for R_s = 1,000 ohm and .5 per cent for R_s = 100 ohm when the pulse duration is about 200 us. This compares very favorably with the actual pulse duration considering the oversimplification in the analysis. Direct electrical simulation measurements confirmed the origin and nature of the oscillatory signal beyond any doubt.

If the contribution from the differentiated shield current to the center conductor signal is subtracted from the observed values, we obtain the same response behavior as in the no-voltage case, namely, very small values for RG59 B/U throughout and equally small values for RG62 A/U, but for this cable only after it has gone through at least one training shot with a very strong signal.

The behavior of the equipotential RG 59B/U coaxial cable was compared with that of its modified version, the tri-coaxial cable, type 21-527, which differs from it by an additional shield braid and jacket. Two samples of this cable were subjected to the usual six-shot cycle. The circuit diagram is shown in Fig. 5. In the first two shots +268V was applied to the center conductor and the inner shield, in the third shot only to the center conductor, and in the fourth, fifth and sixth shots the normal routine of no-voltage, +268 and -268V was followed. The inner shield was left floating in the third shot. The measuring resistor in the center conductor was 1,000 ohm and in both shields, 100 ohm.

The two samples differed in one respect; while one was electrically open at the exposed end, the center conductor of the other one was connected to the outer shield by means of a 100 kilo-ohm carbon film resistor so that a quiescent current of 2.7 milli-ampere was flowing during exposure.

The observed signals are listed in Table 2. Several facts deserve notice. The center conductors of both samples agree in their signals as close as we can measure them through all six shots. Their magnitude is reasonably close to that of the regular RG59 B/U cable. In Shot 3 we see an oscillatory signal possibly due to the fact that the shield was floating in this case. In Shots 5 and 6 the signals become very small.

In spite of the applied voltage of +268V the signal from the inner shield is below 100 ua in magnitude. This remarkable difference from the behavior of the RG59 B/U cable must be credited to the presence of the outer shield which appears to provide electrostatic protection from interaction with the ionized environment.

The polarity of the inner shield signal current is determined by that of the applied voltage, but an interesting discrepancy occurs in Shot 4 where the voltage is removed. For the two samples the signal assumes values of +20 ua and +15 ua which contrast sharply with the level of -100 ua to -200 ua listed in Table 1 as typical examples for the RG59 B/U and RG62 A/U configuration. Obviously, the difference is being caused by the presence of the outer shield in the 21-527 cable; quite possibly the small positive response signals reflect more closely the intrinsic behavior of the inner shield than the larger negative values, but more data are required for any such assertion.

The current values of the outer shield itself are in most cases highly irregular. Only the -50 ua value for both samples in Shot 4 without applied voltage and the -100 ua to -200 ua values for sample 21-527-2 in Shots 2, 3 and 5 are in keeping with the shield behavior as we have described it before. The remaining values, however, ranging for no apparent reason from +700 ua to -800 ua are quite obviously anomalous. We have been able to identify the nature and source of these erratic signals as parasitic leakage currents injected into the grounded shield from nearby samples above ground potential. This type of interaction is discussed in more detail in another section below.

Originally, the experiment with the tri-coaxial cable had been planned for the purpose of monitoring the 100 Kilo-ohm carbon film resistor through the radiation pulse. We find that the signals from both cable samples are practically indistinguishable for any given shot, i. e. their difference does not exceed our measuring sensitivity of ± 5 ua. This is true despite the fact that the sample with the attached resistor carried a quiescent current of 2.7 milli-ampere. We conclude therefore that this current flow did not change by more than ± 5 ua and that consequently the resistor maintained its value within ± .2 percent during the radiation pulse. The practical usefulness of this measuring method is well demonstrated by this first result and further refinements will improve its sensitivity.

Conductors at Different Potentials The multi-conductor ribbon cable (henceforth referred to as MCC) was briefly described in the introduction. One sample was exposed to the usual six-shot sequence and four of its eight conductors were individually monitored. Conductors 1 and 2 were always kept at ground potential. Conductors 5 and 8 carried an applied voltage of +268V and -268V respectively through the first three exposures; these were followed by a no-voltage shot and by two final exposures where both conductors were at the same potential of +268V and -268V respectively. The two upper lines in Fig. 6 are a reproduction of the signals from Conductors 1 and 2, while the responses of Conductors 5 and 8 are shown in the remaining two rows. In the first exposure, the signal magnitude of both conductors with applied potential is very high. It drops considerably in the second shot and stays at this level during the third repetitive exposure. The polarity of the currents is the same as that of the applied voltage. The sharp and apparently irreversible decline of the signal magnitude after the first shot is the familiar training effect as already described for RG62 A/U with equal center and shield potentials. Removal of the voltage in Shot 4 results in a current pulse of the same size as in Shot 3, but its polarity is opposite; re-application of the potential in the fifth shot brings the signal back in polarity and level to its response in Shot 3 where the same voltage was applied. Upon reversing the sign of the applied voltage in the last exposure the polarity of the observed noise signals reverses accordingly while their absolute magnitude is about twice that of the previous response.

The behavior of the cable during the sequence of application, removal, re-application, and reversal of the voltage is strongly reminiscent of a bi-stable memory. Using computer terminology in describing this behavior, a "write" process, i.e. a storage of charges in the cable, would occur during the initial series of three exposures with the potential applied; in the subsequent no-voltage shot these stored charges are released and appear as a "readout" signal. This model is consistent with the dependence of the readout signal polarity on the sign of the potential in the preceding exposure, the repetition of the write signal upon re-application of the voltage, and its doubling in absolute magnitude when the applied voltage is reversed.

The memory effect is by no means limited to the MCC but it occurs likewise in the RG59 B/U and RG 62 A/U cables whenever the applied potential undergoes the appropriate changes between successive shots. This fact is illustrated in Fig. 7, which represents a summary of our results on all three cable types. The values of the observed peak currents are plotted versus the shot number, and the voltage schedule is listed in the table at the bottom of the diagram.

In order to compare these values we plotted all response signals obtained in the first shot in the "up" direction and those reversing their polarity in later shots in the "down" direction. Furthermore, the scale factor on the left ordinate is one hundred times larger than that on the right hand side. The first scale applies to both the RG62 A/U and the MCC and the second one to RG59 B/U.

It is indeed remarkable how all these values group themselves into the typical training and memory pattern discussed for the MCC before, namely the reduction of the signal magnitude in the repetitive three-shot series followed by the readout, write and reversal signals in the subsequent shots with changing potential.

The physical mechanism involved in the storage and release of the "impressed information" is not known. It could be hypothesised, however, that under the combined influence of an existing electrical field and a radiation pulse a space charge is formed at the interface of the conductor and the adjacent dielectric which persists after cessation of the irradiation. By removing the field in the subsequent exposure the radiation causes equalisation of the charges by allowing a current to flow in either direction between the surface of the dielectric and the conductor; the direction of this current is determined by the polarity of the charges trapped at the interface, and this depends on the field direction in the preceding voltage shot.

We return to Fig. 6 in order to discuss the response of the MCC Conductors 1 and 2 which were kept at ground potential in all exposures. As expected the signals are considerably smaller than those in the voltage carrying conductors, but they show glaring anomalies in magnitude and polarity. Instead of maintaining a given signal level or exhibiting a monotonic decline they drop abruptly in Shot 4, return to their previous magnitude in Shot 5 and reverse their polarity in Shot 6. It is fairly obvious that this pattern is nothing but a somewhat reduced mirror image of the signals from Conductor 5. We assume therefore that during the radiation pulse a leakage path is created between the conductors thus permitting a considerable portion of the signal current flowing in Conductor 5 to return to ground via Conductors 1 and 2.

The parasitic interaction of signal currents was observed in several other instances. Its effect on the behavior of the outer shield of the 21-527 cable was already mentioned, and whenever shields of neighboring cables carried different voltages a fairly strong leakage current was usually detectable. Quite possibly the magnitude of the parasitic interaction may have been enhanced by a metal strap across the wooden tray used to hold the cable samples in their grooves.

We have yet to discuss the response of the coaxial cable shields when the potential is applied either to the center conductor or to the shield itself.

In the first case the shield signals of the RG59 B/U cable are always negative regardless of the polarity of the applied voltage and the exposure history. In the first three repetitive shots their magnitude is constant at about -150 ua. In the subsequent removal, re-application and reversal of the potential the shield current undergoes minor fluctuations which reflect the changes caused in the center conductor by the memory effect.

The shield signals of the RG62 A/U cable are much more strongly influenced by the application of a voltage to the center conductor. Both conductors yield signals of equal magnitude and opposite polarity in any given shot; whenever the center conductor signal changes its magnitude or sign on account of the training and memory effect the shield signal changes accordingly. The shield signal range roughly from +2,500 ua to -2,500 ua as compared to the range from -50 ua to -200 ua in the RG59 B/U cable.

If the voltage source is applied to the shield itself the shield response signals increase greatly for both cable types, namely to values between 4,000 ua and 8,000 ua, and the polarity is determined by the applied potential. This behavior is very similar to that encountered in the case of equal voltage applied to both conductors. In RG59 B/U the similarity extends also to the behavior of the center conductor which is dominated by the contribution from the differentiated shield current. Although this contribution must be also present in the RG62 A/U cable it is completely swamped by the ordinary center conductor signals. These signals are of the same magnitude as those observed when the voltage is applied to the center conductor itself. Their polarity is governed by the sign of the potential gradient across the dielectric.

The difference in the response of the two cable types is believed to stem directly from the difference in their construction. It is assumed that the air space surrounding the center conductor of the RG62 A/U cable becomes conductive by ionization during the radiation pulse, thereby causing a large capacitance increase in the exposed part of the cable. In the presence of a voltage source on either conductor this will cause charging currents to flow in both conductors.

RF Carrier Modulation

The first measurements on RF transmission through cables exposed to nuclear radiation were made in an earlier experiment.[3] An unmodulated carrier signal of about 1 Mc/s and 1 volt amplitude was found to pass through RG59 B/U cable without noticeable degradation but to suffer a pronounced temporary attenuation when transmitted through RG62 A/U cable. Measurements at a signal level ranging from 35 mv to 430 mv were included into the present experimental series in order to determine whether an effect would become observable in the RG59 B/U cable and whether the magnitude of the effect in RG62 A/U would change at the lower signal level.

The measurements were limited to one 100 ft. sample of each of the two cable types. Their center portion, about 20 ft. in length, was wound into a flat spiral coil and mounted for maximum exposure close to the reactor surface; an additional total of 30 ft. was inside the reactor room forming straight leads to and from the spiral portion. The cables were terminated at the input and output by resistors matching their characteristic impedance. The elimination of superposed low frequency noise signals was attempted in some measurements by insertion of a

50 kc/s high-pass filter.

The oscilloscope traces and the data obtained are shown in Fig. 8. In all four shots the peak-to-peak amplitude of the RG59 B/U output signal inmains unchanged. In the signal transmitted through the RG62 A/U cable, however, attenuation occurs in all cases and its amount varies between 13 and 18 per cent. As much as can be determined from the available results the percentage of attenuation does not depend on the signal amplitude and there is also no change due to training effects in repetitive shots. The complete suppression of the regular noise signal by the filter insertion is evident.

These results are in keeping with the earlier observations. We believe that the attenuation is caused by a temporary change in the transmission characteristics of the cable, possibly by the increase in effective cable capacitance by the ionization of the air around the center conductor.

A direct measurement of the impedance change in terms of amplitude and phase shift was attempted by means of the circuit and formulas shown in Fig. 9. The two resistors at the input end of the cable are chosen so that together they match its characteristic impedance; the one used as current measuring resistor was kept as small as possible in order to preserve the constant-voltage characteristics of the source. The RF voltage is coupled into the test circuit by a transformer, thus permitting the oscillator, the cable and the oscilloscope to be grounded. The high-pass filter for the suppression of the ordinary cable noise signals was used in these measurments also.

Measurements were attempted on cables with various terminations as listed in Figure 10. For the phase measurement the current and voltage signals are expanded so that only one cycle appears on the oscilloscope; the amplitude is displayed over approximately five times the pulse duration. The resolution of the measurements as established by calibration was found to be quite poor for the intended purpose; it was limited to about ± 15% for the resistance values and to about ± 20% or even ± 40% for the capacitance changes. It is therefore not surprising that we were unable to find any deviation exceeding our sensitivity threshold. We hope, however, to refine the method by parameter optimization and to demonstrate its capabilities and usefulness in future experiments.

Conclusions

The noise signals arising in the individual conductors of RG59 B/U, RG62 A/U and multi-conductor ribbon cable during nuclear pulse irradiation were found to depend in a rather complex fashion on the cable type, circuit parameters, applied voltage, potential gradient, and exposure history. Several processes affecting the nature and magnitude of the response signals were separately identified for the first time; they are: training, memory, differentiation, parasitic leakage and, possibly, capacitance change by air ionization.

Novel methods utilized in these experiments include: dc measurement of resistance changes by comparison with a dummy cable, RF measurement of impedance changes by monitoring phase and amplitude, and the suppression of superposed noise signals in RF measurements by filtering.

On the basis of the results obtained in this work the following rules were established for minimizing the contribution from cable noise signals in the measurement of transient effects on other test objects:

Use short straight cable runs pointing radially toward the radiation source.
Space cables uniformly apart avoiding inadvertent leakage paths between cables and to the ground (metal stands, holders, plates, etc.)
Provide low resistance ground connection for all cable shields.
Use minimum operating voltage or tri-coaxial cable with outer shield grounded.
Use high-pass suppression filter in RF measurements.
Pre-expose the cable without the test object at least once with the appropriate voltage applied before making a measurement.
Record cable exposure history and use cable only under conditions for which they have been trained.
When using compensation by dummy cable, train both cables together and monitor their signals independently during the training shots and the measurement.

Acknowledgements

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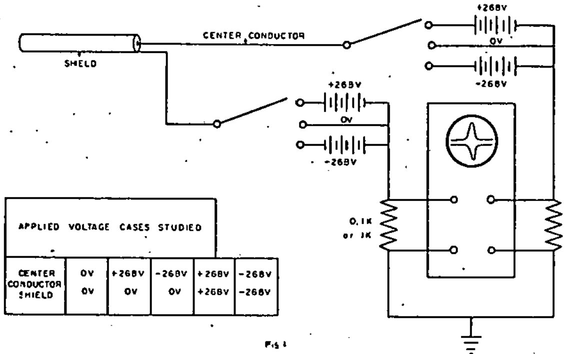
CABLE TYPE	CONDUCTOR	EXPOSURE FIRST	EXPOSURE SECOND	EXPOSURE THIRD
RG 59B/U	CENTER	−5	+1.5	+1
	SHIELD	−100	−100	−100
RG 62A/U	CENTER	+750	< −100	< −5
	SHIELD	−1,000	−150	−170

TABLE 1

NOISE CURRENT SIGNALS
OF RG-59B/U AND RG-62A/U CABLES
WITHOUT APPLIED VOLTAGE
(Tabulated Values in Micro-Ampere)

TEST CIRCUIT FOR CABLE NOISE SIGNAL MEASUREMENT



APPLIED VOLTAGE CASES STUDIED					
CENTER CONDUCTOR	0V	+268V	−268V	+268V	−268V
SHIELD	0V	0V	0V	+268V	−268V

Fig 1

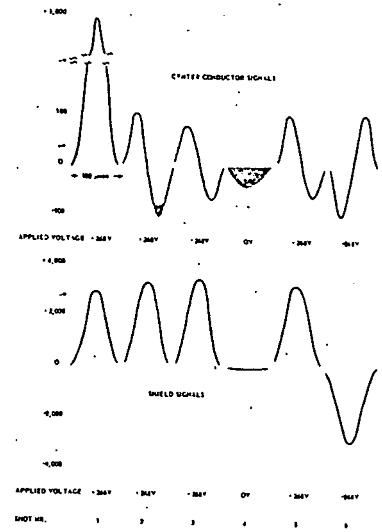


Fig 3

DIFFERENTIATION OF SHIELD SIGNALS

RG-62A/U CABLE WITH ± 268V ON BOTH CONDUCTORS

SAMPLE NR.	CONDUCTOR	APPLIED VOLTAGE	EXPOSURE 1	2	3	4	5	6
21 −527 −1 W.O Resistor	CENTER	+268 / 0 / −268	No Reading	−10	+15 / −5	−10	< −10	< ±5
	INNER SHIELD	+268 / 0 / −268	+100	+85	FLOATING	+20	+60	−70
	OUTER SHIELD	0	No Reading	+200*	−500*	−50	−800*	+700*
21 −527 −2 With Resistor	CENTER	+268 / 0 / −268	No Reading	−10	+10 / −5	−10	< −10	−5 / +5
	INNER SHIELD	+268 / 0 / −268	< +100	+50	FLOATING	+15	+50	−50
	OUTER SHIELD	0	No Reading	−150	−100	−50	−200*	+200*

TABLE 2

NOISE CURRENT SIGNALS OF TRI-COAXIAL CABLE TYPE 21-527 WITH CENTER CONDUCTOR AND INNER SHIELD AT EQUAL POTENTIAL AND OTHER SHIELD GROUNDED
(TABULATED VALUES IN MICRO-AMPERE)

*THESE VALUES ARE AFFECTED BY PARASITIC INTERACTION

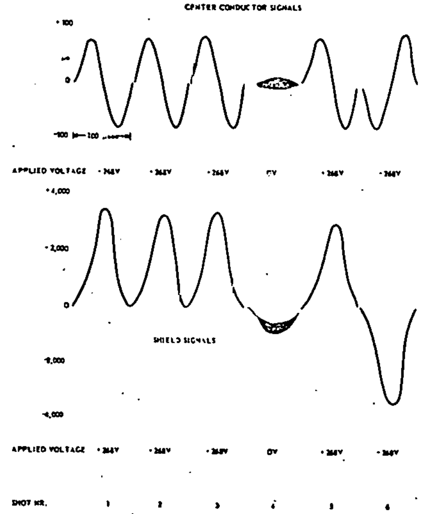
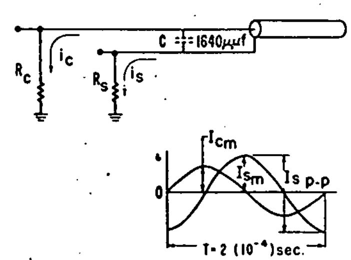


Fig 2

DIFFERENTIATION OF SHIELD SIGNALS

RG-59B/U CABLE WITH ± 268V ON BOTH CONDUCTORS



$$i_c = CR_s \frac{d}{dt} I_s = CR_s I_{sm} \frac{d}{dt}(-\cos \omega t) = \omega CR_s I_{sm} (\sin \omega t)$$

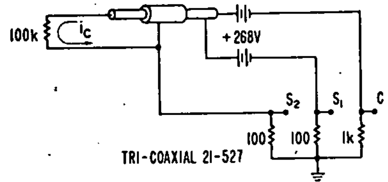
$$\frac{I_{cm}}{I_{sm}} = \omega CR_s = \frac{2(3.14)(1640\times10^{-12}) R_s}{2(10^{-4})}$$

= 0.51% FOR R_s = 100 OHM

= 5.1% FOR R_s = 1000 OHM

CENTER CONDUCTOR NOISE SIGNAL
CAUSED BY DIFFERENTIATION OF SHIELD CURRENT

Fig 4



GUARD CIRCUIT FOR RESISTANCE MEASUREMENTS

Fig 5

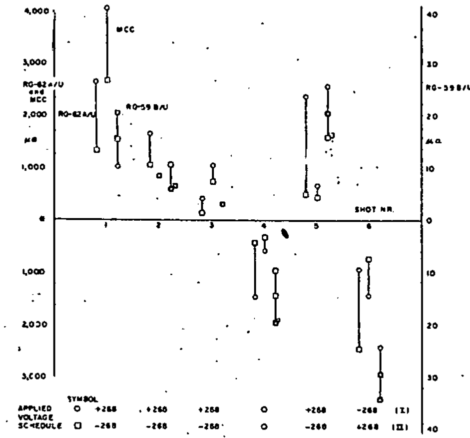
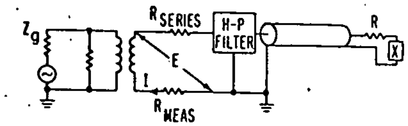


Fig 7

TRAINING AND MEMORY EFFECTS IN RG 59B U, RG-62A U AND MULTI-CONDUCTOR MYLAR RIBBON CABLE. (MCC)



$$\Delta R = R_2 - R_1 = \frac{\left|\frac{E}{I_2}\right|}{\sqrt{1+\tan^2\theta_2}} - \frac{\left|\frac{E}{I_1}\right|}{\sqrt{1+\tan^2\theta_1}}$$

$$\Delta X = X_2 - X_1 = \frac{\tan\theta_2\left|\frac{E}{I_2}\right|}{\sqrt{1+\tan^2\theta_2}} - \frac{\tan\theta_1\left|\frac{E}{I_1}\right|}{\sqrt{1+\tan^2\theta_1}}$$

THE DETERMINATION OF DYNAMIC IMPEDANCE CHANGE BY R-F AMPLITUDE AND PHASE SHIFT MEASUREMENTS

Fig 9

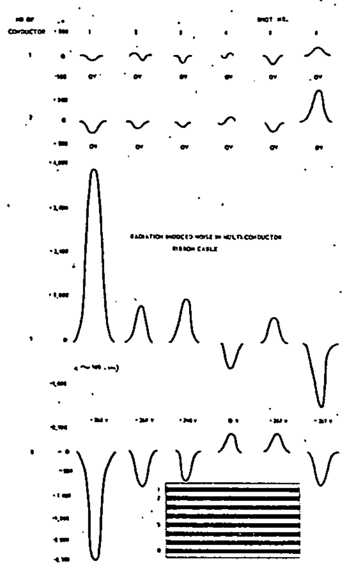
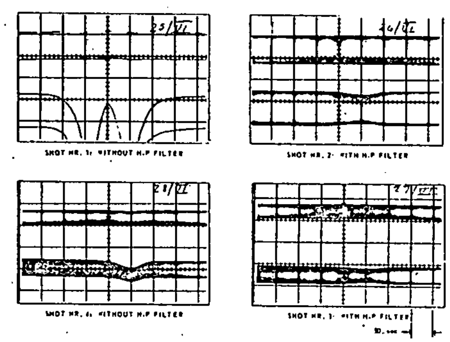


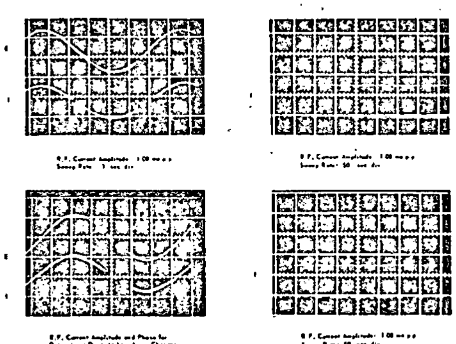
Fig 6



	SHOT NR.	1	2	3	4
RG-59B U	Δ R.F. Amp (%)	0	0	0	0
UPPER TRACE	Noise W.O Filter (µa)	67			34
1.25 MC S	W Filter		0	0	
RG-62A U	Δ R.F. Amp (%)	off scale	16	18	15
LOWER TRACE	Noise W.O Filter (µa)	> 1000			107
1.50 MC S	W Filter		0	0	
R.F. Amp (µa p-p)		~ 70		~ 40	

COMPARISON OF THE RADIATION EFFECTS ON R.F. TRANSMISSION THROUGH RG-59B U AND RG-62A U COAXIAL CABLES

Fig 8



CABLE TYPE	TERMINATION	FREQ	PART CHANGE RESOLUTION
RG-59 B U	Open 75 500	1.25	* ± 15% 300
RG-62 A U	Open 93 500	1.50	± 13% ± 100
TV	Open 300	1.53	± 45%

* The above traces were taken on a 75 Sample attached to RG-59 B U.

Comparison of R.F. Current Amplitude and Phase Before and During Irradiation for Determining Dynamic Impedance Changes.

Fig 10