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# Preliminary Evaluation of Space Station Transmission Line in a Ring Configuration

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# PRELIMINARY EVALUATION OF SPACE STATION TRANSMISSION LINE IN A RING CONFIGURATION

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## SUMMARY

The data presented in this paper are the result of a preliminary evaluation of a space station type transmission line and commercial transmission lines in a ring configuration. In a ring configuration, each node has two paths for the return current of each wire. The additional path can create an "unbalanced" condition, where the magnetic fields created by the forward and return currents do not cancel. This evaluation was to quantify the effects of the unbalanced case upon the external fields. The transmission lines evaluated were standard commercial coaxial cables, RG59 and RG213, and a space station designed flat Litz transmission line[1]. Each was evaluated in a balanced and unbalanced mode of operation. Currents and their harmonic content were recorded and compared. As expected, the harmonic content of the difference current ($I_\Delta$) was substantial for the unbalanced case as compared to the balanced case. For the balanced case, very little difference was noted among the various transmission lines evaluated. This paper will discuss the evaluation, describing the test circuit, the measurements and the resulting data.

## INTRODUCTION

Three cables, RG213, RG59 and a flat Litz transmission line (fig. 1), of equal length - 35 ft, were evaluated under identical (as near to identical as possible) conditions. In a ring configuration, each node has two paths for the return current of each wire (fig. 2). For balanced operation, the transmission line's return current (magnetic field) cancels with the forward current (magnetic field) resulting in a low self inductive cable. However, in a ring configuration this cancellation of fields is not guaranteed. With two possible return paths, an unbalanced condition can exist even in "normal" operation. This evaluation was to quantify the effects of the unbalanced case upon the external electromagnetic fields. In the balanced condition, a resistor bank of 75 Ω was used as the load. The unbalanced condition for all three cases was achieved by switching in an auxiliary load of 1670 Ω in parallel with the 75 Ω load to create an unbalance of 5 percent. Figure 3 depicts the test circuit. The cables were evaluated for both the balanced and unbalanced conditions.

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[1]Built on NASA contract NAS3-23894 by Induction General, Inc.

## BALANCED CONDITION

Comparing the balanced cases for all three transmission lines, the current $I_\Delta$ (the difference between the forward current $I_H$ and the return current $I_L$) is about 90° out phase with the source (and load) voltage. The current lags the voltage. The phase shift is due to the difference in the inductance of the center conductor and the shield. The phase shift between the line current and voltage is relatively constant for all three cables. In all cases the current lags the voltage by about 5°. This is due to the inductance of the load. A 5° phase shift would indicate an inductance of about 50 μH. The load inductance measured on an impedance bridge was about 70 μH. At the source, the phase shift for the flat Litz was less than 1° leading versus about 5° lagging for the other two cables. This may be attributed to the high capacitance, low inductance nature of the flat Litz transmission line. The low characteristic impedance of the cables produced a small voltage drop from source to load. In the case of the RG59, the voltage drop was higher due to the skin effect ($I^2R$) heating of cable. This resulted in a greater voltage drop across the cable as compared to the flat Litz and RG213, 13.7 V versus 1.1 and 1.5 V. The magnitude of $I_\Delta$ was slightly greater in the flat Litz than the RG213. $I_\Delta$ was 600 μA for the flat Litz and 540 μA for the RG213 (measurement error of at least 3 percent). However, the current spectrum as measured by the Pearson coil indicated the opposite to be true. $I_\Delta$ is the difference in the forward and return currents, phase and magnitude. In the case of the flat Litz, the return current did not divide evenly--a 10 percent difference was measured 2.7 A versus 3.0 A. See table I for complete data profile.

Pearson current monitors and a Hewlett Packard Spectrum Analyzer were used to measure the harmonic content of the difference current, $I_\Delta$. Comparing the current spectra (harmonic content of $I_\Delta$ up to the 10th harmonic) of all three cables in the balanced condition, shows that the RG213 is not a well shielded cable. RG59 was only slightly worse than the flat Litz (see fig. 4). The most noticeable difference was at the fundamental, where the flat Litz measured -75 dB versus -72 dB for the RG59 cable. Although the spectrum of the RG213 cable would indicate a higher harmonic content, the RMS value of $I_\Delta$ (measured on Fluke true RMS) was only 540 μA for the RG213 versus 600 μA for the Litz and 1000 μA for RG59. There is some question as to the accuracy of the meter when reading tens of microvolts.

## UNBALANCED CONDITION

For the unbalanced case, the auxiliary load was switched into the circuit. $I_\Delta$ increased in magnitude and equaled $I_2$, the current through the auxiliary load. The two currents were equal according to Kirchoff's law $\Sigma I = 0$, where $I_H = I_L + I_2$, $I_\Delta = I_H - I_L$. $I_2$ was in phase with both the source and load voltages due to the noninductive nature of the auxiliary load. Therefore, $I_\Delta$ was also in phase with the voltage. The line current increased due to the addition of the auxiliary load in parallel with the original. The increase in the line current led to the increase in the voltage drop across the cable. $I_2$ was the same for the flat Litz case and the RG213--about 260 mA. This was due to the fact the load voltages were about equal for the two cases--439.6 V for the Litz and 438.1 V for the RG213. The source voltages were maintained at different levels--440.7 V for the Litz, 439.8 V for RG213. The voltage drops across the flat Litz and RG213 were 1.1 and 1.7 V, respectively.

However, in the case of the RG59, the load voltage was much lower (426.1 V with Esource = 440.4 V) due to the $I^2R$ heating of the cable and subsequent IR drop. $I_2$ was only 253 mA in this case. See table I for data.

The current spectra (fig. 5) for the unbalanced condition show little difference among the cables. Flat Litz shows slight increase at 2nd - 5th (final) harmonic than RG59, about 1 to 2 dB increase. The fundamental components were about equal. The flat Litz was slightly worse than RG213 at the higher harmonics, about 0.5 to 1 dB increase. The fundamental components were about equal. Equivalent spectra would seem reasonable given the equal RMS values of $I_\Delta$ for all three transmission lines in the unbalanced case.

## CONCLUSION

As is evident from the harmonic spectra, there is a considerable difference in field strengths between the balanced and unbalanced conditions. Further investigation is necessary to determine whether such an increase is unacceptable from a system standpoint. In comparing the performance of the three transmission lines, the flat Litz construction appears to be the best shielded of the three. More stringent testing done to mil-standard specification is necessary to be able to make a complete and final performance evaluation.

TABLE I. - TEST DATA FOR BALANCED AND UNBALANCED SETUPS

| | RG 213 | | RG 59 | | Flat Litz | |
|---|---|---|---|---|---|---|
| | Balanced | Unbalanced | Balanced | Unbalanced | Balanced | Unbalanced |
| $E_S$ | 440 V | 439.8 V | 440.4 V | 440.4 V | 440.3 V | 440.7 V |
| $E_L$ | 438.5 V | 438.1 V | 426.7 V | 426.1 V | 439.2 V | 439.6 V |
| $I_{SH}$ | 5.78 A | 6.04 A | 5.63 A | 5.87 A | 5.84 A | 6.11 V |
| $I_{SL}$ A | 5.82 A | 5.82 A | 5.67 A | 5.66 A | 2.70 A | 2.69 A |
| $I_{SL}$ B | ---------- | -------- | --------- | --------- | 3.08 A | 3.09 A |
| $I_{LH}$ | 5.84 A | 6.10 A | 5.70 A | 5.94 A | 5.85 A | 6.12 A |
| $I_{LL}$ A | 5.83 A | 5.83 A | 5.68 A | 5.67 A | 2.74 A | 2.73 A |
| $I_{LL}$ B | ---------- | -------- | --------- | --------- | 3.10 A | 3.11 A |
| $I_\Delta$ (p-p) | 2.25 μV | 80 mV | 420 μV | 80 mV | 350 μA | 72 mA |
| $I_\Delta$ (RMS) | 540 μA | 261 mA | 1.0 mA | 253 mA | 600 μA | 261 mA |
| $I_z$ | ---------- | 260 mA | --------- | 253 mA | ------ | 261 mA |
| $\phi E_S I_{SH}$ | 14.4° lag | 3.6° lag | 4.7° lag | 4.32° lag | 0° | 0° |
| $\phi E_S I_{SL}$ A | 14.4° lag | 3.6° lag | 4.8° lag | 4.46° lag | 0° | 0° |
| $\phi E_S I_{SL}$ B | ---------- | -------- | --------- | --------- | 0° | 0° |
| $\phi E_S I_{LH}$ | *14.4° lag | 3.6° lag | 5.0° lag | 4.7° lag | 4.86° | 4.7° |
| $\phi E_S I_{LL}$ A | *14.4° lag | 3.6° lag | 5.08° lag | 5.0° lag | 4.7° | 4.7° |
| $\phi E_S I_{LL}$ B | ---------- | -------- | --------- | --------- | 5.0° | 5.0° |
| $\phi E_S I_\Delta$ | ~90° lag | 0° | ~90° lag | 0° | ~90° | 0° |
| $\phi E_S I_z$ | ---------- | 0° | --------- | 0° | ------ | 0° |

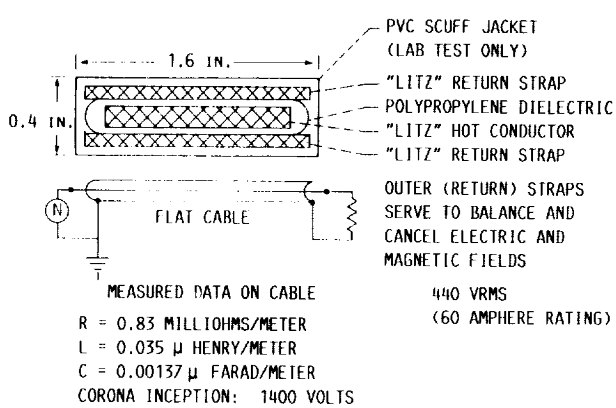


FIGURE 1. - FLAT LITZ TRANSMISSION LINE.

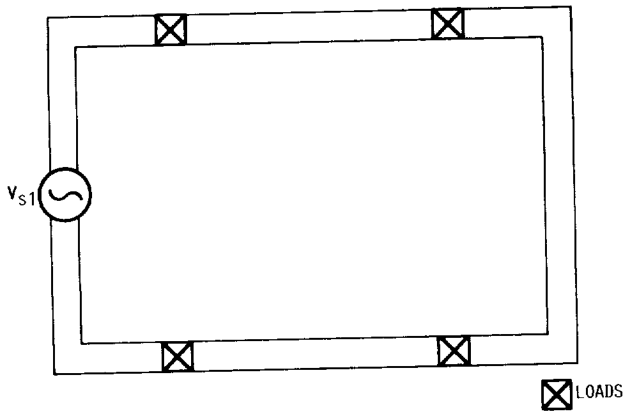


FIGURE 2. - RING CONFIGURATION.

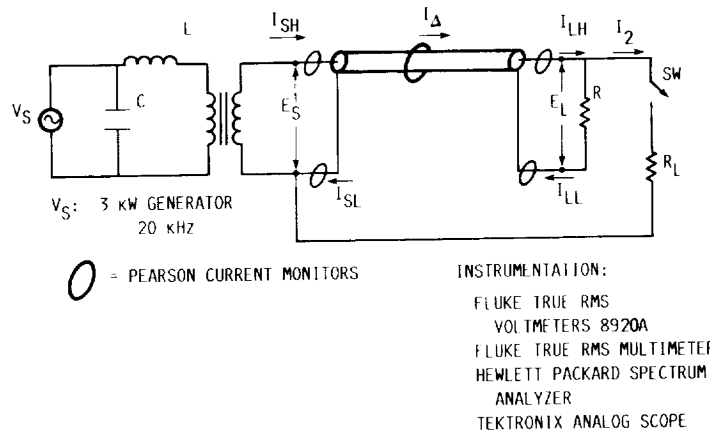


FIGURE 3. - BALANCED/UNBALANCED TEST SETUP.

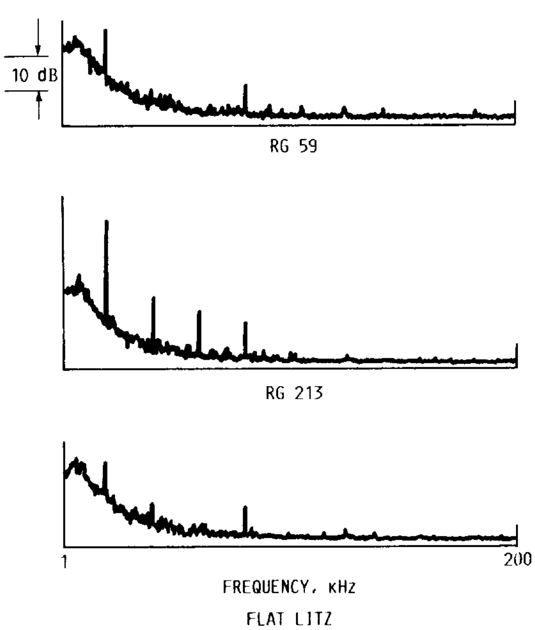


FIGURE 4. - BALANCED CONDITION.

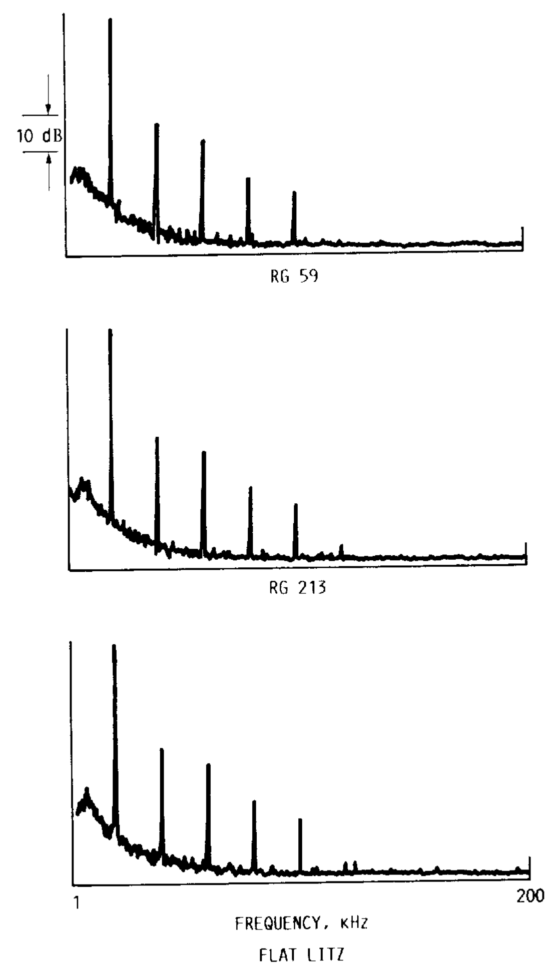


FIGURE 5. - UNBALANCED CONDITION.

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15. Supplementary Notes

16. Abstract

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