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September 1981

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TECHNICAL FEASIBILITY REPORT

FOR

RAILROAD MULTI-UNIT DATA ACQUISITION SYSTEM

Task D

FRA/LBL Interagency Agreement DTFR 53-80-X-00073

by

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1. FOREWARD

This technical feasibility report is the result of completion of the first step of a four-step process (described below) for extending the automatic data acquisition capability from the sensors located on the locomotive unit containing the recording and computer equipment to include sensors located on the trailing units of a multi-unit locomotive consist.

1.1 Technical Problems to be Solved

The principal problems encountered in extending the locomotive data-acquisition capability to trailing units are as follows:

a. Providing sufficient signal conditioning capability in the locomotive unit containing the Locomotive Data Recorder (LOR).

b. Reliably transporting the signals through the locomotive consist to the LOR.

The first problem is straightforward. The signal conditioning capability can be increased, within limits, to provide the necessary channel capacity. This is accomplished by fabricating and installing additional electronic hardware. The exact nature of the hardware depends on the types and numbers of additional transducers.

The second problem is really a signal-to-noise problem. Can the signals be transported from sensor to the LOR with a sufficiently good signal-to-noise ratio? That this can be done in a single locomotive has already been demonstrated, but there are some unknowns when the transport is extended over several locomotives. Some signals are relatively strong. For example, the signals from the fuel meters are 15 volts. It is quite probable that these could be successfully transported at least from an adjacent locomotive. However, other signals are much smaller. For example, the resolution of the coupler is 300 lbs. of force. A force of 300 lbs. causes a strain-gage bridge unbalance of 15 microvolts (6 orders of magnitude less than the fuel meters' signal). It would be unrealistic to predict that this signal could be transported over four locomotives without some tests. The tests (or the feasibility study) might reveal it preferable to do signal conditioning at the transducer.

1.2 Four-Step Process

To develop solutions to the above problems in a systematic manner, the following four-step subtasks would be required:

a. Step 1 - Technical Feasibility Study. The first step is to conduct a technical feasibility study. This would cover alternative methods of transporting the signals. A recommended approach would be formulated along with a test plan for verifying the feasibility of the recommended method under actual operating conditions. In this phase, the previous work would be reviewed to see if it is adaptable for this purpose.
b. **Step 2 - Cabling Fabrications.** The second step is to fabricate LDAP modifications and cabling for three locomotives.

c. **Step 3 - "Parasitic" Tests.** The third step is to conduct tests of the method recommended in step 1 by "parasiting" on an on-going measurement program. This could be done by using dummy signals provided by battery-powered sources in an operating locomotive environment.

d. **Step 4 - Sensors.** The fourth step is to specify, purchase and/or fabricate the sensors and associated equipment needed for a multi-locomotive measurement program.

This report represents the completion of Step 1, above. Although there are no plans at present to proceed with the remaining three steps for implementation of the multiple unit capability, the information contained in this report is intended to be useful to anyone considering the technical problems involved for future data acquisition systems.
2. INTRODUCTION

Performance information from the LDR-equipped locomotive is important in many types of studies, including those for train handling, fuel efficiency, maintenance scheduling, and train-safety. Similar information from locomotive units trailing the LDR-equipped unit, is likewise important. Practically any parameter monitored on the LDR unit could also be monitored on the trailing units. However, for this feasibility study, the discussion has been limited to a maximum of three trailing units, each with no more than four parameters to be measured.

Several characteristics of a multi-unit system were deemed important and were incorporated into this feasibility study. Since the pre-prototype Locomotive Data Acquisition Package (LDAP)\(^1\) has already been developed and used successfully in field tests, proving its utility and ruggedness, the multi-unit system should be viewed as an "add on" supplement to LDAP. Thus, as much of the existing LDAP system as possible should remain unchanged; therefore, the data formats and signal levels from sensors on the trailing units were chosen to be the same as in the LDR equipped unit. Also, the equipment requirements on the trailing units should be as general as possible so that LDAP, with multi-unit capability, can be implemented on many different railroads without extensive modifications. And finally, no compelling reason was found to restrict the placement of the trailing units to always be following the LDR equipped unit. In this regard, the use of the term "trailing units" is simply symbolic, since to increase flexibility, the four units (one LDR equipped unit and three "trailing units") are allowed to be in any order and to be facing either forward or backward.

\(^1\) LDAP refers to the complete system comprised of the Locomotive Data Recorder (LDR) plus the sensors.
3. POSSIBLE COMBINATIONS OF SIGNALS FROM TRAILING UNITS

In this section, the possible combinations of sensor-signals from the trailing units that could be accommodated by the LDR are considered.

In considering these signals, it is assumed that the sensors on the LDR-equipped unit will be the same as those for the 1980 field-test on the Union Pacific Railroad (except for the fuel temperatures). The fuel in/out temperatures have been excluded because a different type of fuel meter could be used, thus eliminating the need to monitor fuel temperatures.

Figure 3-1 shows the LDR signal conditioning modules with available inputs for multiple-unit operation. There are basically six types of signal inputs to the signal conditioning modules. These six types are described in the following subsection.

3.1 Types of Signal Inputs

The thermistor input channels use a thermistor bridge arrangement to monitor temperatures. A thermistor is a resistor whose resistance varies in a precise amount proportional to its temperature. Therefore, reading its resistance is equivalent to knowing the temperature of the medium surrounding the thermistor. Figure 3-1 shows that there are two thermistor modules with a total of 8 possible thermistor input channels. Two thermistor channels are used for the LDR equipped unit (air and oil temperature), leaving 6 available for the trailing units (one may be used for the coupler temperature).

The strain-gage input channels use a strain-gage in a bridge arrangement to monitor pressures. A strain-gage varies its resistance proportionally to the strain exerted on it. Therefore, reading its resistance is equivalent to knowing the strain of the surface on which it is mounted. Figure 3-1 shows the two strain-gage modules with 8 possible strain-gage input channels. Three of these inputs are used for the LDR equipped unit (air box, train brake, and independent brake pressures), leaving 5 input channels available for use by the trailing units (including the coupler pin force).

There are two types of remote amplifier modules. One module has separate power supplies (to power the remote amplifiers) incorporated inside the module; the other one does not. Both types of modules accept high level signals (up to 10VDC) from amplifiers which are at the site of the sensor. Figure 3-1 shows that all 4 of the input channels on the module with the separate power supplies are used for the LDR equipped unit (grade, traction motor current, main generator voltage, and main generator current). The 4 input channels on the module without the separate power supplies are available for the trailing units.
The digital event input channels are used for parameters which have only 2 values—for instance: open/closed, on/off, or yes/no. Typically, they are used to monitor switch or relay contact positions. Figure 3-1 shows the two digital event modules each with 8 input channels. All 8 input channels on one module are used for the LDR equipped unit (wheel slip, reverser, and throttle positions), leaving 8 input channels available for the trailing units.

The last type of signal input to the signal conditioning modules is a digital counter input. This type of input accepts a chain of pulses from a transducer, counting each pulse as it comes in. Figure 3-1 shows the digital counter module with its 3 input channels all used for the LDR equipped unit (speed, fuel flow in, and fuel flow out). No digital counter channels are available for the trailing units.

3.2 Possible Combination of Signals from Trailing Units

Table 3-1 shows the possible combinations of input signals to the LDR signal-conditioning modules if several different hardware modifications are incorporated. While the precise signal conditioning (filtering, ground isolation, etc.), for each sensor must be designed on an individual channel by channel basis, generally the input channels for the trailing units require the signal-conditioning modifications described below and summarized in Table 3-1.

Table 3-1, number 1, shows that the unused LDR thermistor channels can be used for the trailing units without any hardware modifications. The trailing-unit thermistor sensors only need to be installed and connected to the LDR equipment.

To use the five unused LDR strain-gage inputs for the trailing units, some hardware additions at the strain-gage site must be included. The output voltage from the strain-gage is less than 50 mv. Thus signal amplification is required before the signal is conducted to the LDR equipment, which may be 200 or 300 feet away. To conduct signals this distance reliably, balanced line drivers must be included with the amplifiers at the strain-gages, and corresponding line receivers must be added to the LDR equipment. These hardware additions are shown in Table 3-1, number 4: "Adding External Amplifiers and Line Drivers".

The type of remote amplifier module which has integral power supplies has no unused input channels; however, the type of remote amplifier module without the separate power supplies has all 4 inputs unused and is available for the trailing units. Actually, the isolation amplifiers inside both types of modules have a ± 15 volt isolated power supply available to supply power to a remote amplifier, but it has only 15ma of current available. This is much smaller than required by any of the transducers presently used by LDAP. If a remote amplifier needing no more than 15ma were installed on a trailing unit, it could be connected directly to an input channel on the type of remote amplifier module without separate power supplies, and no hardware modifications would be required. If additional remote amplifiers such as are presently used on the LDR equipped
unit were installed on the trailing units, they would have to be supplied power from sources other than this module. These sources are referred to in Table 3-1 number 2: "Adding External Power Supplies". These power sources could be additional isolated power supplies mounted on the rear of the NIM BIN housing the signal conditioning modules and wired through this module. Or the power supplies in the type of module which has integral power supplies could be used by connecting their outputs through this module as well as through the other type of module. Or new power supplies could be installed with the remote amplifiers on the trailing units. The decision of how best to supply power to these remote amplifiers on the trailing units should be resolved during the detailed design stage, and it is sufficient for this feasibility study to know that several possibilities exist.

The 8 unused LDR inputs to the digital-event modules in Table 3-1 may be used by the trailing units without any hardware modifications. Also shown is the fact that all the available inputs to the digital counter module are used for the LDR equipped unit. Thus 8 digital event, but no digital counter type parameters, may be recorded from the trailing units without some hardware modifications.

A method to accommodate 3 digital counter inputs from the trailing units is shown in Table 3-1, number 3: "Replacing a Digital Event Module with a New Digital Counter Module". As the title implies, a second digital counter module would be constructed and would replace one of the two digital events modules. Filtered line drivers would be required in the trailing units and corresponding line receivers in the LDR equipped unit to reduce the possibility of picking up voltage spikes generated by the environment. If these spikes were transmitted to the LDR equipped unit, the digital counter module could count them as part of the chain of pulses generated by the transducer, leading to incorrect results.

Table 3-1, number 5, lists the maximum number of additional input channels possible for each of the 4 analog-type modules, if the analog modules with no inputs from the LDR equipped unit were replaced with duplicates of one of the other modules. Figure 3-1 shows that with the proposed configuration, one single width thermistor type module, one double width strain-gage type module, and one single width remote amplifier type module have no inputs from the LDR equipped unit. These three modules could be removed, and the resulting four slot positions could be filled with duplicates of any of the four analog type modules. They could, for instance, be filled with four thermistor input type modules (the 1 existing module and 3 newly built modules), yielding an additional 12 thermistor type inputs as shown in Table 3-1, number 5(a). Similar manipulations yield a possible 4 more strain-gage type inputs (Table 3-1, number 5(b)), 8 more remote amplifiers with integral power supply type inputs (Table 3-1, number 5(c)), or 12 more remote amplifiers without integral power supply type inputs (Table 3-1, number 5(d)).

Of course, the four slot positions could be filled with a combination of two or three different types of analog modules. The important aspect here is
that many different system configurations could be realized if additional signal conditioning modules were built. Performing a similar manipulation with the digital modules was discussed in Table 3-1, number 3.

Table 3-1, number 6, lists the last hardware modification that was investigated. This modification involves multiplexing, or time sharing, several input signals into a single input channel. Both thermistor input signals from the LDR equipped unit could, for instance, be multiplexed onto only one thermistor input channel, thereby releasing the second input channel for another thermistor input signal. Connecting more than one input signal to a single input channel by multiplexing comes under the heading of "Anything is Possible". Almost an unlimited number of different combinations is possible with this modification, the only limiting factors are the amount of time and resources available to modifyLDAP. The hardware modifications are necessary for multiplexing inputs are extensive. The input signals must be sequentially connected to the input channel, and information describing which input signal is connected must be sent to the LDR equipment along with the input signal itself. This information must be reduced by the LDR equipment so that it can keep straight what data goes with which transducer. Obviously, extensive programming changes in the LDR equipment would also be necessary for data collection.

From the preceding discussion, it is apparent that the answer to the question, "What possible signals from the trailing units could be accommodated by the LDR?" is that various combinations of input signals can be accommodated depending on financial and other resource constraints. A more relevant question might be: "What input signals from trailing units should be accommodated?". Of course, this depends upon the parameters deemed important for a particular multi-unit LDAP test. Using Figure 3-1 and Table 3-1 and the previous discussion, the best set of input signals, within the scope and resource constraints of any proposed multi-unit experiment, can be selected.
Figure 3-1. LDR SIGNAL CONDITIONING MODULES
Showing Available Inputs for Multi-Unit Operation
Table 3-1

HARDWARE MODIFICATIONS TO LDR SIGNAL-CONDITIONING MODULES
vs.
POSSIBLE COMBINATIONS OF INPUT-SIGNAL CHANNELS

| Hardware Modification (in ascending complexity) and Resulting Signal Capacity | NUMBER OF NIM BIN CHANNELS |  |  |
|---|---|---|---|---|
|  | ANALOG INPUTS | DIGITAL INPUTS |  |  |
|  | Thermistor | Strain Gage | Remote Amplifier w/Power | Remote Amplifier w/o Power | Events | Counter |
| 1. No hardware changes |  |  |  |  |
| a. Total Channels | 8 | 8 | 4 | 4 | 16 | 3 |
| b. LDAP-Unit Ch. | 2 | 3 | 4 | 0 | 8 | 3 |
| c. Trailing Units Ch. | 6 | 0 | 0 | 0 | 8 | 0 |
| 2. Adding external power supplies |  |  |  |  |
| a. Total Channels | 8 | 8 | 4 | 4 | 16 | 3 |
| b. LDAP-Unit Ch. | 2 | 3 | 4 | 0 | 8 | 3 |
| c. Trailing Units Ch. | 6 | 0 | 0 | 4 | 8 | 0 |
| 3. Replacing a digital event module with a new digital counter module |  |  |  |  |
| a. Total Channels | 8 | 8 | 4 | 4 | 8 | 6 |
| b. LDAP-Unit Ch. | 2 | 3 | 4 | 0 | 8 | 3 |
| c. Trailing Units Ch. | 6 | 0 | 0 | 0 | 8 | 3 |
| 4. Adding external amplifiers and line drivers |  |  |  |  |
| a. Total Channels | 8 | 8 | 4 | 4 | 16 | 3 |
| b. LDAP-Unit Ch. | 2 | 3 | 4 | 0 | 8 | 3 |
| c. Trailing Units Ch. | 6 | 5 | 0 | 0 | 8 | 0 |
| 5. Adding various combinations of new Analog modules and deleting some old Analog modules |  |  |  |  |
| a. up to 12 more thermistor inputs |  |  |  |  |
| b. up to 4 more strain-gage inputs |  |  |  |  |
| c. up to 8 more remote amplifiers with power |  |  |  |  |
| d. up to 12 more remote amplifiers without power |  |  |  |  |
| 6. Multiplexing more input signals onto existing Analog and Digital inputs - numerous available combinations |  |  |  |  |
4. DATA TRANSMISSION BETWEEN CONTIGUOUS LOCOMOTIVE UNITS

In general, the method employed for data transmission between locomotive units depends on whether (1) the trailing units are contiguous to the LDR unit and hence interconnected via the 27-pin trainline cable or (2) there are locomotive units embedded within the train consist that are not interconnected via the trainline cable to the LDR unit. Data transmissions between non-contiguous locomotive units will be briefly discussed later, in Section 7.

In this section, data transmission methods for contiguous locomotive units are discussed. Six methods were considered and their respective advantages and disadvantages are described in subsections 4.1 through 4.2.

4.1 Capactive Coupling - Air Dielectric

This method would involve mounting a large plate on the front and back of both the LDR equipped unit and each of the 3 instrumented trailing units. The plates on adjacent locomotives would then form an air dielectric capacitor. Data transfer would be accomplished by capacitive coupling from a "driven" to a "receiving" plate.

a. Advantages. The capacitive coupling advantages are:

- no ground loops between locomotives.
- no inter-locomotive connections required.

b. Disadvantages. The disadvantages are:

- susceptible to electrostatic pick-up from external noise sources. (This susceptibility is precisely what we are trying to minimize.)
- large plate area required.
- high voltage signals required on the driven plate would mandate high voltage power supplies and personnel protection around the plates.
- inter-locomotive longitudinal movement would change the coupling capacitance and therefore have to be normalized when the data was reduced.

4.2 Inductive Coupling - Air Core

This method would involve mounting an inductor on the front and back of both the LDR equipped unit and each of the 3 instrumented trailing units. The inductors would be mounted so that when adjacent units were coupled together, their respective inductors would be in close proximity to each other.

a. Advantages. The inductive coupling with air core has the following advantages:
- no ground loops between locomotives.
- no inter-locomotive connections required.
- can be shielded to minimize electrostatic pickup from external noise sources.

b. **Disadvantages.** The disadvantages are:

- susceptible to electromagnetic pickup from external noise sources.
- coupling coefficient is poor, requiring large driving signals.

### 4.3 Inductive Coupling - Iron Core

This method would involve building inductors on "u"-shaped iron cores and then mounting the cores as in the previous case of air core inductors so that when adjacent units were coupled together the cores would mate to each other forming a complete path for the lines of flux from one core to the other.

a. **Advantages.** The inductive coupling with iron core has the following advantages:

- no ground loops between locomotives.
- inter-locomotive connection can be made to "break-away".
- coupling coefficient is good.

b. **Disadvantages.** The disadvantages are:

- sensitive to electromagnetic pickup.
- alignment between adjacent "u" shaped inductors is critical.
- coupling mechanism would have to be developed which would allow considerable inter-locomotive longitudinal and lateral movement before allowing inductors to break-away.

### 4.4 Modulated Laser Light Beam

A laser light source and receiver would be mounted on the front and back of both the LDR equipped unit and each of the instrumented trailing units. An interface would be developed to perform the light modulation for data transfer while adhering to a yet-to-be-defined data transfer protocol for both transmitting and receiving data.

a. **Advantages.** The modulated laser light beam has the following advantages:

- no ground loops between locomotives.
- no inter-locomotive connections required.
- not susceptible to electromagnetic pickup from external noise sources.
b. **Disadvantages.** The disadvantages are:

- alignment between light source and receiver is critical.
- data is lost if anything interrupts the light beam (re-transmission would be necessary).

### 4.5 Ultrasonics

A high frequency audio generator and receiver would be mounted on the front and rear of the LDR equipped unit and each of the instrumented trailing units. This method could conceivably be used for units which are not adjacent to the LDR equipped unit except for the high power levels necessary to transmit the sound waves over long distances.

a. **Advantages.** This method has the following advantages:

- no ground loops between locomotives
- no inter-locomotive connections required.
- not susceptible to electromagnetic pickup from external noise sources.

b. **Disadvantages.** The disadvantages are:

- surrounding noise spectrum may interfere with reliable data reception.
- large power levels may be required to transmit even over short distances.
- transmission would be highly directional and therefore subject to degradation when traversing hills and curves.
- precipitation decreases audio levels.

### 4.6 Cable Systems

The following systems employ "hardwired" cable to transmit the data signals through the instrumented locomotives to the LDR equipped unit. They do not require the LDR equipped unit to be the lead unit nor to be facing "forward" with respect to its direction of travel.

a. **Fiber optic cable.** The data would be transmitted between locomotives over a new cable, which would be bought or constructed, using fiber optics conductors instead of wire.

This method would have the following advantages:

- no ground loops between locomotives.
- not susceptible to electromagnetic interference from external noise sources.
- very fast data rate is possible, if logic can accept it.
The disadvantages are:
- applicable to digital transmission only.
- a "break-away" connector must be designed and built.
- this is a new technology which would require some research and education for the electronics technicians and engineers involved in its use.

b. Coaxial cable. The data would be transmitted over one or more coax cables that would interconnect all the locomotives. This would require time sharing all the data over one cable or having up to 12 separate coax cables.

This method has the following advantages:
- isolation between signal leads is good.
- applicable to both linear and digital signals.
- not susceptible to external fields from other sources.

The disadvantages are:
- 12 separate cables would be bulky and multiplexing would require additional logic hardware.
- a sturdy "break-away" connector must be developed.

c. Existing trainline cable. Data would be transmitted in a time-shared fashion over an unused pair of the 27 conductors in the existing trainline cable. This could be either by conventional digital pulse techniques or by use of carrier current over the pair of wires. Carrier current involves putting a low level, high frequency carrier signal on a pair of conductors that are also used for some other, lower frequency, signal. This high frequency carrier is then modulated to accomplish the data transfer. Carrier current is applicable to digital data transmission only.

This method has the following advantages:
- no new cables are required.
- immune to signal degradation caused by inter-locomotive movement or precipitation.
- cable is already a "break-away" type.

The disadvantages are:
- multiplexing would require a considerable amount of additional logic hardware.
- considerable filtering would be required due to very noisy signals on some of the other conductors.
- Conductors are not twisted or shielded, therefore, they are susceptible to electromagnetic interference pick-up from external sources.
- Carrier current techniques may not be possible over lines in such a noisy environment.

d. Shielded twisted pair cable. The data would be transmitted over a new cable comprised of enough twisted pairs of conductors to accommodate each of the signals over a separate pair. The pairs would be bundled together in a shielded cable which would interconnect the locomotives.

This method has the following advantages:

- Shielded twisted pairs would not be susceptible to electromagnetic pick-up from external noise sources.
- Easy to implement and electronics technicians and engineers are familiar with this technology.
- No multiplexing is required.
- Applicable to both linear and digital signals.

The disadvantages are:

- This is a second cable which must be connected to all the locomotives.
- A "break-away" connector must be developed.
- Care must be taken in the design to eliminate possible ground loops.
5. CONCLUSIONS AND RECOMMENDATIONS ON DATA TRANSMISSION METHODS

5.1 Conclusions

The disadvantages for all the transmission methods, other than hardwired cables (subsection 4.6) render them not feasible for application to the multi-unit locomotive data acquisition system.

Of the hardwired cable systems described, the two most promising are:

a. using the existing 27-pin trainline cable (subsection 4.6c)

b. using a new 12 twisted pair shielded cable (subsection 4.6d)

The main differences between these two methods are that using the existing cable involves multiplexing all the trailing unit signals onto a single pair of conductors, and also considerable filtering would be required because of the electrical noise on the other conductors. However, using a new cable involves designing a "break-away" connector, and it incorporates another cable which must be manually connected when the locomotives are coupled together.

The requirements for implementing the second method (subsection 4.6d) are less difficult to achieve. Therefore, it was concluded that this is the best method to transmit data between locomotives.

5.2 Recommendation

The recommended method for transmitting data between locomotives is via a separate cable utilizing an individual twisted-pair of wires for each data signal. This method was described in subsection 4.6d. The recommended conceptual design for implementing this method is described in the next section of this report.
6. RECOMMENDED CONCEPTUAL DESIGN FOR DATA TRANSMISSION BETWEEN CONTIGUOUS UNITS

Figures 6-1 and 6-2 show how the new cable system (described in subsection 4.6c) would be installed on a 4-unit locomotive consist. All 12 pairs of conductors are strung through the consist by "on board locomotive wiring" and the proposed "inter-locomotive cable". Each trailing unit makes use of 4 of the pairs, so with 3 trailing units all 12 pairs are used. The LDR equipped unit makes use of all 12 pairs by routing them to unused signal conditioner inputs as decided upon by using Figure 3-1 and Table 3-1. As shown in Figure 6-1, each unit has a multi-unit junction box. This junction box allows each trailing unit to connect sensor outputs to its own 4 pairs of conductors, a different 4 pairs for each trailing unit. And since the 12 pairs are routed completely through each unit, the units may be in any order and facing either direction. Also shown in Figure 6-1 is the close proximity of the present 27 wire pull-apart connector to the pull-apart for the new inter-locomotive cable. Both these connectors are needed on the front and rear of each locomotive. By placing the connectors close to each other and by attaching the new cable to the existing one by using plastic tie-wraps, it is anticipated that the problem of neglecting to manually connect the new cable to the locomotives when they are coupled together will be minimized.

Figure 6-2 is a simplified schematic of a trailing unit junction box. The junction box and the pull-apart connectors for the inter-locomotive cable are electrically isolated from the trailing unit on which they are mounted. However, since the shield covering the inter-locomotive cable is grounded to these junction boxes and the junction box in the LDR equipped unit is grounded to that locomotive, effectively all the system, including the junction boxes, is grounded to the LDR equipped unit. This one point ground eliminates ground loop currents while reducing the possibility of coupling voltage spikes onto the data signals from the locomotive environment.

Each trailing unit junction box converts the locomotive power, from either the main alternator or backup batteries of that unit, into a local isolated power source. This power source also is referenced to the locomotive frame of the LDR equipped unit. It is used to power the electronics needed by the sensor configuration selected for that particular trailing unit.

Shown in Figure 6-3 is the necessary electronics for each type of sensor. Also shown is the schematic print number for the signal conditioner modules corresponding to each type of sensor. These prints are included in the LDAP drawing supplement. The thermistor and the digital event inputs do not need any hardware in the junction box. Local isolated power must be supplied to the strain-gage transducer and to its necessary amplifier and balanced line driver. The remote amplifier, if it requires more than the 15ma of current available from the signal conditioner modules, must also be supplied local isolated power. The digital counter input uses this power for both the transducer and its filtered line driver.
The asterisks in Figure 6-2 denote that changes are necessary in the signal conditioner modules for the strain-gage and the digital counter type inputs, print numbers 4832151 ad 4832155. These changes involve the addition of line receivers to the modules since line drivers were included in the trailing unit junction boxes.

The schematic diagram for the trailing unit sensors in Figure 6-2 together with the previous discussion regarding Figure 3-1 and Table 3-1 can be used in planning a multi-unit experiment to determine the level of complexity involved for any particular combination of trailing unit sensors.
Figure 6-1. LOCOMOTIVE DATA ACQUISITION PACKAGE MULTI-UNIT CABLING
LOCOMOTIVE DATA RECORDER CONFIGURATION
UP LOCOMOTIVE 3670
LOCOMOTIVE DATA ACQUISITION PACKAGE MULTI-UNIT CABLING

Figure 6-2
7. DATA TRANSMISSION BETWEEN NON-CONTIGUOUS LOCOMOTIVE UNITS

The previous sections dealt with contiguous locomotive consists.

Assuming now, that the train contained one or more locomotives which were not adjacent to the other locomotives, a transmission method would have to be utilized which did not rely on the units being in actual contact with one another, as is the case with any of the "hardwired" cable systems.

Due to the large amount of lateral movement and deviation from a straight line possible on a train traversing hills and curves, no methods involving line of sight limitations would be acceptable. Only non-directional transmission schemes would be possible. These considerations limit the methods available to only radio transmission and the only variable for consideration is the frequency of the transmitter.

- Low frequency (below 540 kHz) - Frequency modulating - A low frequency carrier would result in a slow data rate since the frequency of the modulating signal must be much slower than the carrier. If the data were instead transmitted by amplitude modulation, the signal to noise ratio would be poor since electro-magnetic interference (EMI) is induced primarily as amplitude modulation.

- High frequency (above 50 mHz) - Frequency modulation would be possible thereby affording a better signal to noise ratio than that possible using low frequency transmission.

Use of either of these radio transmission frequencies would require FCC approval for the transmitter. And, of course, each signal would have to be multiplexed one at a time onto a single transmitter frequency. In addition, the receiver design would not be a trivial task. If remote unit capability is required on trains with non-contiguous locomotives, interfacing a commercially purchased transceiver to the LDR equipment is preferable to designing a new transceiver.
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