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ELECTROMAGNETIC INTERFERENCE IMPACT ON RAILROAD CLASSIFICATION YARDS

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INTRODUCTION

The electromagnetic environment in the modern railroad classification yard has become increasingly complex in recent years due to widespread application and concentration of electrical and electronic systems. This electromagnetic environment encompasses the frequency range from direct current (DC) to over ten GHz and is characterized by electrical noise levels predominantly caused by transients of collapsing electrical fields of heavy equipment such as switches, retarders and traction equipment. These noise levels are becoming increasingly disturbing in view of the low level signals used for control, signaling and communication. This kind of interference can cause mis-switches, degradation of car control or misinformation, which can lead to costly down-time of the classifying operation or even worse such as catastropic failure. One sign of the severity of the problem is the lengthy debugging time for new yards.

Many devices are used to assist in the automation for both control processes and information processes. The techniques which allow automated processes usually employ minicomputer(s), control devices such as retarders and switch machines for braking and switching, and sensing devices for rollability, weight, wind velocity, counting wheels and speed. Often, process control and information processing computers operate from low level digital signals. These signals are vulnerable to many sources of electromagnetic interference.

The Federal Railroad Administration, Office of Research and Development, recognizing the adverse effects that this environment can have on the operation of a yard and the increasing importance of understanding this environment, initiated a project to develop information and establish a data base on the classification yard electromagnetic environment. To perform this research, the FRA requested the Electromagnetic Compatibility Analysis Center (ECAC) of Annapolis, Maryland to undertake a study of the electromagnetic interference/electromagnetic compatibility (EMI/EMC) situation in the classification yard. Specifically, the objectives of the project were to characterize this electromagnetic environment and identify the relationship between systems and the environment.

The project meeting these initial objectives is now essentially complete. It was performed through the coordination of the Inductive Interference Committee of the Communication and Signal Section, Association of American Railroads. Also, the project was performed with the participation of three railroads: Southern, Santa Fe, and Richmond, Fredericksburg & Potomac. These railroads allowed the ECAC test team to visit and make measurements in their classification yards: Sheffield Yard, Barstow Yard, and Potomac Yard, respectively. Equipment was also loaned by these railroads to ECAC for interference susceptibility testing.

The results of this project are documented in an ECAC final report which provides a data base containing measured electromagnetic characteristic values for yard equipment. The following paper has utilized this data as a basis for analyzing the electromagnetic environment's impact on yard operations.

BACKGROUND

The railroad classification yard is an essential part of railroad operations. Yards are used primarily for the assembly and/or disassembly of freight trains. There are two types of classification yards- flat and hump. A flat yard has a relatively flat topography and is generally configured as a series of tracks connected as a ladder. In a flat yard cars are "kicked or bumped" by a switch engine at the lead track and then uncoupled and allowed to roll to the proper classification track. Operations are usually manual processes.

Hump yards are designed to handle a greater number of cars and more trains in a given time period. The hump yard uses gravity to accelerate cars down a grade into the proper classification tracks as shown in Figure 1. The hump crest and typical elevation profile along with the various inputs and outputs required for car control down the hump are shown in Figure 2. The hump yard concept encourages automation because of its speed of operation. This automation had led to a proliferation of electrical and electronic devices which has resulted in a very complex and congested electromagnetic environment. This paper, therefore, focuses on the hump yard operation relative to its electromagnetic environment.

Hump Yard Operation

The basic elements used for controlling the humping operation are retarders, switch machines and computer(s). To control the speed of cars as they proceed down the hump track, wheel brakes called retarders

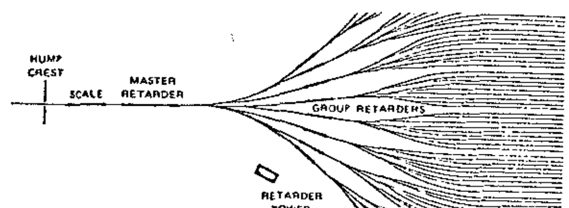


FIGURE 1. HUMP CLASSIFICATION YARD

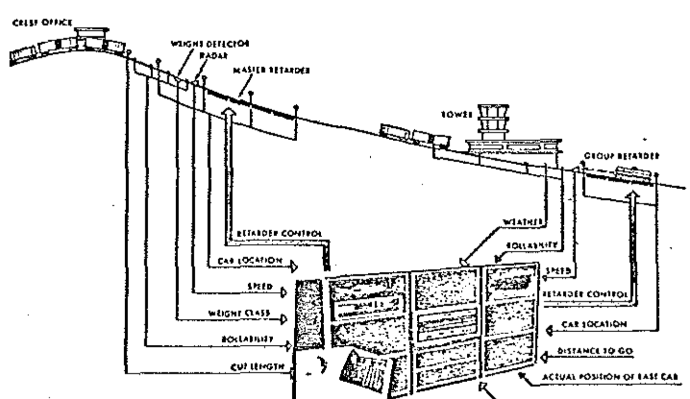


FIGURE 2. COMPUTER AUTOMATED HUMP CREST AND ELEVATED PROFILE

grip the wheels and slow the car in order to allow the car to couple with the train at the proper speed (approximately 4 mph) without causing lading damage. Switching the cars to the proper track and controlling the speed of the cars are handled mechanically by electric motors or electropneumatic units which move the switch points and retarder brake shoes, respectively. These units operate at a level of control voltage of up to several hundred volts direct current. This operating voltage is controlled by relays (electromechanical contactors) or by solid state switches. These relays and switches in turn operate at low DC voltages of 12 to 28 volts. If computers are used as the control source , then the control signals must be converted to even lower voltages of around 5 volts.

Besides the basic elements mentioned above, the humping process is controlled by an array of input/output parameters as per Figure 2, which allow accurate control of the car with the maximum efficiency. The humping process extends from the hump crest through the entire hump profile where a full complement of electrical and electronic devices are arranged to provide complete monitoring and control functions for the operator or control computer governing the hump sequence. As the car proceeds over the crest, it is uncoupled and passes an electronic scale for weighing, a wheel detector or track circuit for detection and input to the retarder circuits and is scanned by a doppler radar unit for velocity determination. These devices all feed input information to the process control computer (automated hump yard) for use in setting the retarder grip force.

The retarders, both master and group depending on the particular yard design, may also be in close vicinity to presence detectors. These detectors indicate the presence of a car through inductive tuning either with a coil around the track section or by using a pair of shunted rail sections as the sensor, as shown in Figure 3. This detector can be installed without the necessity of insulated track joints.

Classification Yard Measurements

The basis of the analysis for this paper is from the measured data developed by ECAC as documented in their final report. To better understand this analysis, a brief description of the measurement effort is now provided.

This yard measurement effort of the EMI/EMC aspects was initiated by an extensive study of literature concerned with classification yard equipment and design. Both past and current books, articles and periodicals were used as sources with emphasis on world wide class yard designs. The EMI/EMC measurement aspects of current yard technology were evaluated for application to the study.

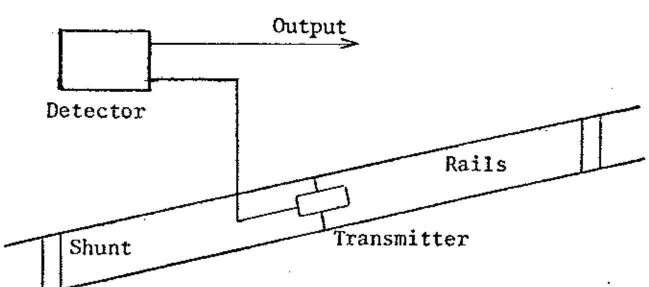


Figure 3. Shunted rail presence detector

To properly characterize the class yard EM environment, the equipment used had to be identified and classed as a potential source and/or victim of electrical interference. The process was initiated with visits to three representative class yards selected by type of operation, degree of automation, and location. Items determined to be sources were listed by yard and appropriate tests for signal level measurements were formulated. Items determined to be potentially susceptible to interference were arranged by yard and also by availability for testing at ECAC. Laboratory testing was deemed necessary for certain items to allow for measurements in a controlled EM environment.

The measurements for both conducted and radiated interference discussed above were conducted at the three participating yards and ECAC. Source measurements were conducted at Potomac Yard, Sheffield Yard and at Barstow yard. Susceptibility measurements were conducted at ECAC using the results of the source measurements to simulate the noise environments observed in the yards. Data obtained from the measurements was compiled and plotted in terms of field strength vs. frequency for the sources and in signal strength vs. susceptibility threshold for each device. The threshold values not specified by the equipment manufacturer, were determined to be the transition point from "normal" to "abnormal" operating level. The data base formed by this EMC study was compiled and formatted for convenient use by railroads interested in upgrading or designing new class yards.

EMI Impact

To fully appreciate the effects of electromagnetic interference on the actual yard operations, a series of cars will be taken through the humping sequence and then various malfunctions due to possible interference introduced. Referring to Figure 2, the car being humped passes over the crest and is uncoupled to roll free down the grade. The car passes over the electronic weigh scale and the scale value is input to the process computer. As the car proceeds, a wheel detector indicates that the car is approaching the retarder and speed direction doppler radar. The computer uses this information and the weight scale value and sets the retarder to the braking force necessary to assure the proper exit speed.

The exit speed of the car after it leaves the retarder must be accurate or an incorrect coupling velocity at the selected class track may result. This range of exit velocities may extend over a couple of miles per hour, since the next retarder in the hump sequence, the group retarder (see Figure 1) can correct an improper car speed. The radar unit associated with the required group retarder must be very accurate since the car leaving it will have, in general, had its class track entry velocity adjusted for the last time.

Additional devices are used to determine car location and direction during the humping sequence. Wheel detectors determine position and track circuits and presence detectors indicate track occupancy for the retarders and switches. Malfunctions due to interference to these devices may result in incorrect retarder operation or a mis-switch or split switch of a car during a humping operation and can lead to costly down time over a period of a few minutes to many hours. During the measurement phase of the EMC study, several instances of lengthy down time were observed at the various yards participating in the study. These problems ranged from track circuit interference to other nearby track circuits to radar diode degradation resulting in incorrect car velocity values.

EM interference does not necessarily produce the greatest problem by causing a device to completely malfunction. In this case the computer would sense the complete malfunction and stop operations. Generally interference manifests itself more subtly by causing a device to produce an incorrect output value that is still within acceptable limits of the computer software.

Based on the measured data for the various devices, as previously mentioned in this paper, four items are selected that are not only potential generators of interference but in some cases are more problematic by being susceptible to outside interfering signals. These devices operate in close proximity to the hump area and as such produce comlex interactions during the humping operation.

Speed Detection Radar

The doppler radar units used with most yards at present are based on a continuous wave (CW) oscillator and a diode detector. The CW signal in the 10.5 GHz range is transmitted to the rolling car and is reflected back to the detector diode which detects the doppler frequency change. The slight shift in frequency is converted to an amplitude change and serves as an indicator of the car velocity. The amplitude is then converted to a format acceptable to the computer interface and becomes an indicator of car speed.

Measured data obtained during the ECAC EMC study of yard equipment susceptibility indicates that the performance of the mixer-detector diodes in the radar units could be degraded by various levels of pulsed interference. Yard source measurements demonstrated that various devices near the radar units such as retarder and the electropneumatic valves of switch machines generate transients of sufficient amplitude to cause interference. As the amplitude and repetition rate of the pulsed interference increases, the DC output level from the frequency-to-amplitude converter decreases thereby giving an incorrect velocity reading.

Presence Detector

Presence detectors are devices designed to
register the presence of a freight car within a 8
detector wire loop or within an inductive tuning circuit composed of two sections of shunted rail as shown in Figure 3. These units have a local oscillator that generates a CW signal at one of several frequencies in the range of 40 kHz to 110 kHz.

The introduction of a freight car or other disturbing body changes the tuning of the unit and is detected as a frequency increase at the converter. Use of one type of these detectors, the wire loop, is as an occupancy indicator for a track switch as in Figure 4.

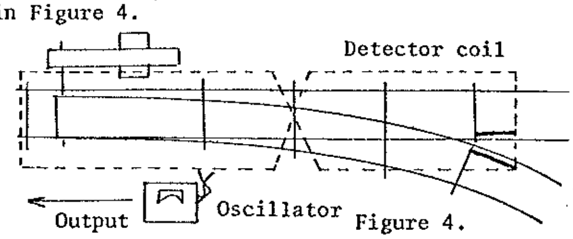


Figure 4.

The failure of the detector to protect the switch during occupancy could lead to a car derailment or a split switch where one car truck passes the switch points and then the switch throws and routes the other truck down the wrong track. Also interference from a surrounding source, either radiated or conducted into the presence detector could lock the unit in a non-presence state and defeat the switch protection concept.

Measurements on the shunted rail presence detector have shown that it is possible to create this condition with rail currents from nearby high frequency track circuits or in the case of the wire loop, nearby sources of radiated interference. Preliminary data indicates that the detector is susceptible to conducted CW interference of values as low as 10 milliamps of current at a frequency of 100 kHz. There are indications that the wire loop presence detector is also susceptible to nearby EM fields from HV power lines and overhead catenary wires.

Track Circuits

Two types of track circuits were evaluated for EMI conditions during the EMC study. Figure 5 shows the standard alternating current (AC) track circuit. This circuit holds the track relay closed until a car axle wheel set shunts the diode and allows the relay to drop out. These circuits are generally short (100-200 feet in length) in the class yard and are used as control points for retarders.

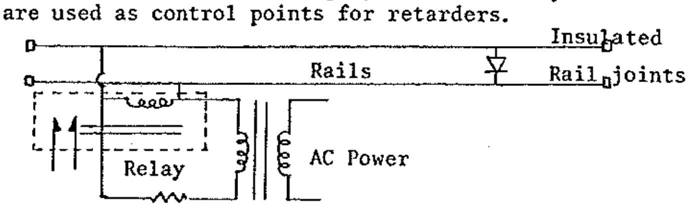
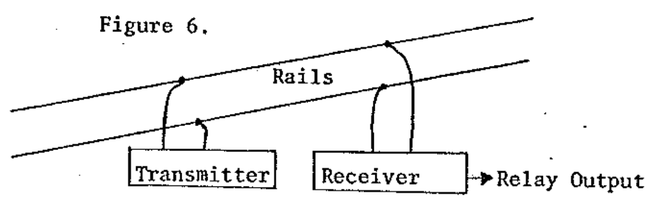


Figure 5. AC track circuit

Figure 6 shows the high frequency pulsed track circuit as found in some yards. This device uses a transmitter operating at a high frequency (approximately 100 kHz) and a tuned receiver. The wheel set shunts the signal and allows the receiver to drop out.

Figure 6.



Track circuit measurements conducted on both AC and high frequency units indicate susceptibility to interference from both rail conducted signals from low frequency power circuits and induced fields from adjacent presence detectors or high frequency signal sources.

Wheel Detectors

The devices are usually magnetic pick-up heads mounted on the rail with the associated electronics necessary to perform the car count and indicator functions mounted nearby. Wheel detectors may be unidirectional or bidirectional. Figure 7 shows a typical detector installation.

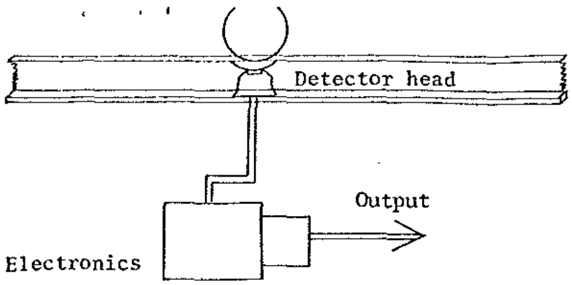


Figure 7. Wheel detector

The wheel detector tested performed two functions in conjunction with the associated electronics. The first function was that of an indicator of a wheel set and the second as a wheel counter. Strong rail currents in the mounted rail, pulsed at various rates, of sufficient amplitude and at the same repetition rate as the detector count rate, caused the unit to lock-out and not indicate a detectable object. Interference of this type disabled both the detector and wheel counter functions. For interfering rail currents as low as 1.6 amps, at 25 and 60 Hz, the wheel detector indicated a false car presence.

Source Determination

In order to evaluate the nature of the interference so that solutions can be recommended, a knowledge of not only the susceptibility of the device under consideration but also the nature of the signal spectrums generated by surrounding equipment is necessary. The various devices evaluated in the EMC study were characterized by signal strength over a broad frequency range and by type of generated interference.

The data base formulated from the yard measurements conducted at the participating yards includes broad signal spectra for each potential interfering source and interference susceptibility curves over the frequency ranges of interest for potential victims.

By applying the data on individual devices to specific cases of existing or potential interfering relationships, the yard communications and signal engineer or yard designer can save time and expense in yard operations. Information concerning potential interference at a specific device can be related to a nearby potential source and predicted signal levels used to optimize device placement and required shielding and cabling. This application is demonstrated in Figure 8. The position of the radar as shown exposes the mixer diode to excessive transient levels, however placement of the radar unit can be adjusted to minimize the signal level seen by the radar antenna.

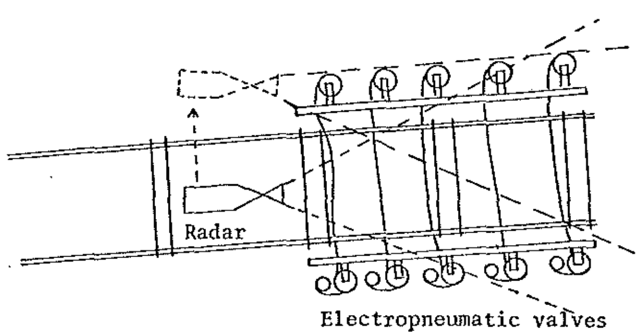


Figure 8. Radar-retarder interaction

Corrective Recommendations

Applying corrective measures to susceptible devices requires individual solutions tailored to a specific situation. In the case of the doppler radar diode degradation, experiments at ECAC demonstrated the feasibility of using bypass capacitors to reduce the interference effects at the detector. The degradation appeared to be related to both the pulse amplitude and the total transient energy delivered to the diode. The bypass capacitance provided a pulse amplitude reduction ratio of as much as 6 to 1 over an unbypassed unit configuration.

The presence detector and track circuit problems can be alleviated by the proper selection of non interfering operating frequency values and by ensuring the required separation between devices around the hump. Adjusting device signal levels to those values just necessary to permit normal functioning and where possible lower sensitivity levels to the minimum values required for normal device operation. These recommendations apply especially to the presence detector units due to the sensitivity of the detector oscillator to mixing of the signal harmonics in the tuned circuit front end. In the case of the wheel detectors, proper filtering at the front end will help alleviate the lock-out problem as will improved shielding of the pickup head and cabling to the associated electronics.

Future yard upgrades to computer control and the design of future yard configurations can benefit from improved EMI/EMC design criteria based on measured data and good EMC practice. Anticipated application of this type of information will certainly enhance the efficiency and operating reliability of individual yards of the U.S. railroads.