MEASUREMENTS AND ANALYSIS OF ELF MAGNETIC AND ELECTRIC FIELDS FOR EXISTING AND ADVANCED RAIL TRANSPORTATION SYSTEMS

FIFTH QUARTERLY PROGRESS REPORT
JUNE 1, 1992 TO AUGUST 31, 1992

ELECTRIC RESEARCH
& MANAGEMENT, INC.

11 - Advanced Systems

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FIFTH QUARTERLY PROGRESS REPORT
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prepared for:

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

UNDER CONTRACT
DTFR-53-91-C-00047

prepared by:

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SEPTEMBER 1992

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1.0 OVERVIEW

This Quarterly Progress Report covers the effort on Contract DTFR-53-91-C-00047, "Measurements and Analysis of ELF Magnetic and Electric Fields for Existing and Advanced Rail Transportation Systems" for the calendar months of June, July and August 1992. It is organized in four parts:

- Summary of Major Accomplishments;
- Technical and/or Schedule Problems;
- Actual vs. Planned Effort and Expenditures;
- Projected Activities for the Next Quarter; and
- Status Review Meetings.

2.0 MAJOR ACCOMPLISHMENTS

Contract effort during the fifth quarter focused on analysis of data from the Northeast Corridor (NEC) and Washington Metro tests, performing measurements on the Boston Metro System, and preparing the Report on the NEC measurements. There was also considerable effort this quarter preparing for the measurements on the French TGV which were to be carried out in September.

2.1 TR07 Final Report

This task was completed in the third quarter.

2.2 Portable *MultiWave*™ System

This task was essentially complete in the third quarter. Some revisions were subsequently made to the system to make it more convenient to use with the digital audio tape recorder. During the fifth quarter, only very minor changes were made to the system to allow operation and recharging from 230 V, 50 Hz European electric power.

2.3 Northeast Corridor (NEC) Measurements

All of the *MultiWave*™, DAT and Emdex data from the NEC measurements have been processed and reviewed. The Final Report is being drafted. Considerably more effort is required for adequately reporting the NEC data than for reporting the TR07 data because the NEC data actually consists of parallel tests on four different electrification technologies. The large number of tests and the need to adequately compare and contrast field conditions associated with the four technologies is resulting in longer report preparation time than anticipated.

2.4 Washington Metrorail (WMATA) Measurements

Measurements on the WMATA System were completed last quarter and the *MultiWave*™ system data have been processed and printed. Preparation of the report on WMATA has not yet begun.

2.5 Boston "T" Measurements

Measurements on the Massachusetts Bay Transit Authority (MBTA) system were carried out early in the fifth quarter. Those tests included measurements on three different subway lines, a trolley, and a trolley bus as well as at stations, along waysides, in rectifier stations and in control rooms. Because of the diversity of the MBTA system, many data sets were collected in these tests. All of the data have been converted to the frequency domain and are ready for plotting.

2.6 French TGV Measurements

Planning and coordination for measurements on the TGV consumed a significant amount of time late this quarter. Securing a carnet for shipment of the test equipment to France, acquiring the necessary surity bonds and generating the necessary export declaration forms distracted effort from data analysis and report preparation in the earlier tasks. A Test Plan for the TGV measurements was also drafted and is attached as Appendix B.

2.7 Other Activities

Bill Feero gave a presentation describing the results of the TR07 measurements and some preliminary data on the Northeast Corridor at the First World Congress for Electricity and Magnetism in Biology and Medicine in June. Copies of the slides for that talk were attached to the Fourth Quarterly Report.

Fred Dietrich prepared a brief report comparing the typical frequency signatures of magnetic fields within electrified transportation vehicles at Dr. Brecher's request. A copy of that letter report is included in Appendix C.

3.0 TECHNICAL SCHEDULE AND PROBLEMS

The field measurement phase of the project continues to progress smoothly. Analysis of the data from the *MultiWave*™ system has been highly automated and now progresses much more rapidly than it did at the start of the contract. Reporting of the results continues to be behind schedule because of time conflicts between reporting the completed measurements and conducting new measurements. That situation should improve dramatically in the next quarter because only the TGV measurements are planned, and they will be completed by mid-September. Electric Research and Management, Inc. has also successfully recruited an additional experienced engineer who will join the Company in mid-September and will be dedicated full time to this project.

4.0 LEVEL OF EFFORT AND EXPENDITURES

Figure 1 shows the projected versus actual expenditures on the contract through the first five quarters.

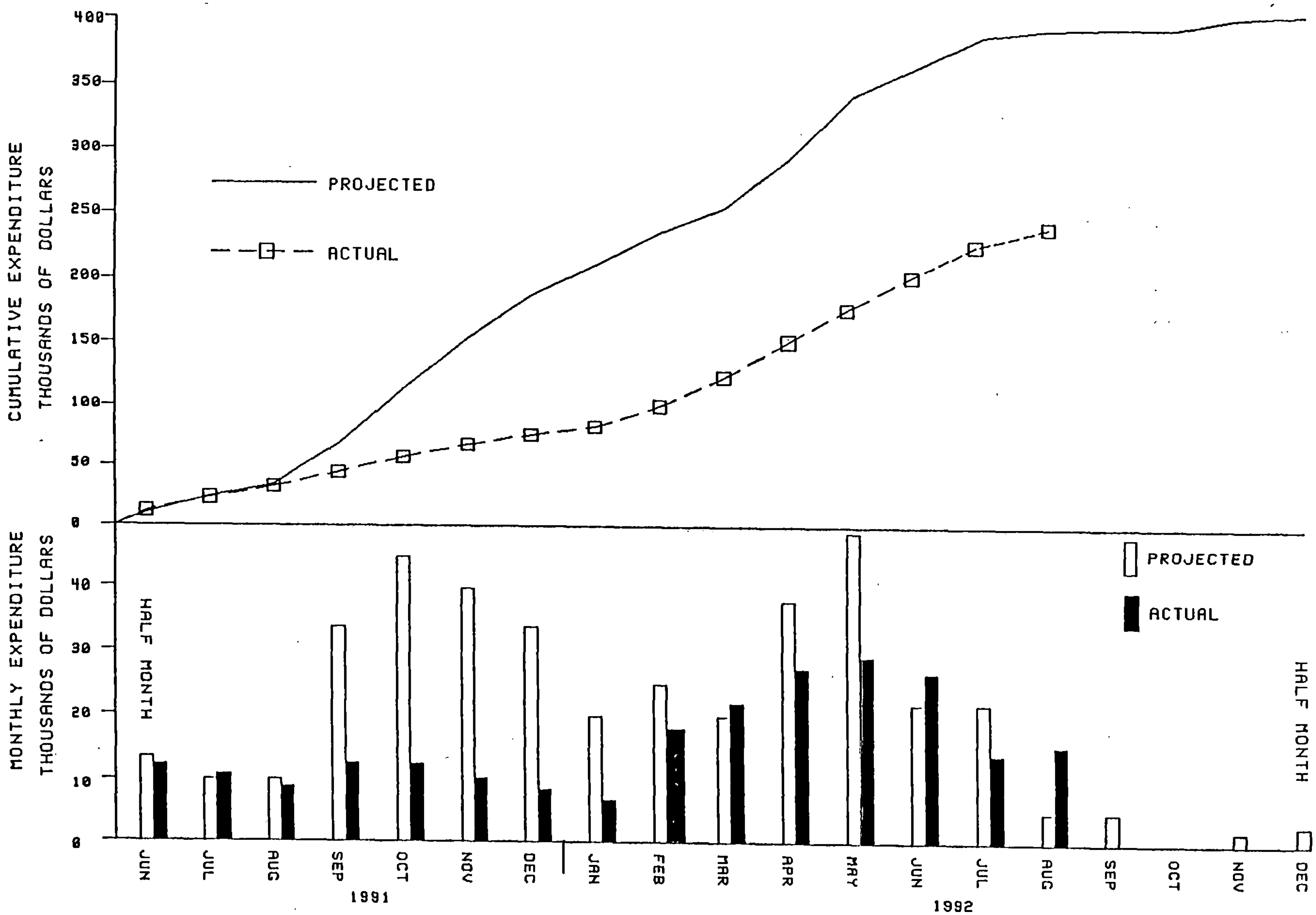

Figure 1. **Projected versus actual expenditures, June 1991 - August 1992**

5.0 PROJECTED ACTIVITIES

The following activities are projected for the next quarter:

1) Complete the Draft and Final Reports on the NEC measurements.

2) Complete the statistical analysis, Draft and Final Reports on the WMATA measurements.

3) Complete the analysis of the Boston "T" measurements and begin the report.

4) Complete the analysis of the TGV measurements and begin the Report.

5) Make a presentation on current measurement data at the 1992 Annual Review of Research on Biological Effects of Electric and Magnetic Fields Associated with Generation, Delivery, and Use of Electricity (the "Contractors' Review").

6.0 STATUS REVIEW MEETINGS

No formal status review meetings were scheduled this quarter.

APPENDIX A

DRAFT TEST PLAN FOR
ELECTRIC AND MAGNETIC FIELD MEASUREMENTS
ON THE BOSTON T SYSTEM (MBTA)

DRAFT TEST PLAN FOR
ELECTRIC AND MAGNETIC FIELD MEASUREMENTS
ON THE BOSTON T SYSTEM (MBTA)

1.0 INTRODUCTION

This test plan outlines the measurements which will be taken on the Massachusetts Bay Transportation Authority (MBTA) mass transportation system in the Boston, MA area to document the electric and magnetic field environment onboard the vehicles, at passenger stations, along the wayside, and near electric substations supplying power to the system. This test plan is organized into eleven sections. The first is this Introduction. The second describes the different vehicles which must be addressed in order to quantify the effects of differences in traction power and power control technology. The next eight sections describe measurement instrumentation, measurement personnel, the necessary support from MBTA, the measurement schedule, measurement procedures for the onboard, station, wayside and power supply measurements. The final section describes special tests which may be made to assess the field conditions in special environments.

2.0 TRACTION POWER TECHNOLOGIES

The Boston "T" system is a large network which has evolved over time. As a result, a number of traction power technologies are employed on the various lines. Consequently, this plan provides for measurements on the following lines and vehicles:

Green Line
Blue Line
Orange Line
Red Line
Red Line Mattapan Branch (High Speed Trolley)
Trolley Bus

The measurement procedures and locations will be as consistent as possible among the various systems in order to maximize the validity of comparisons between technologies.

3.0 MEASUREMENT SYSTEM

Three distinct types of instrumentation will be utilized during these tests. Each meets a different need.

The primary instrumentation package is the portable *MultiWave*™ Monitoring System consisting of two briefcase-size instrumentation cases and a probe staff. This instrument accurately characterizes field intensities as functions of frequency and location along the probe staff at discrete times.

In order to provide a continuous record of field strength between the discrete time samples of the *MultiWave*™ System measurements, the magnetic field intensity detected by one ac magnetic field sensor, one fluxgate magnetic field sensor, and the electric field sensor will be recorded continually by a digital audio tape (DAT) recorder.

EMDEX magnetic field exposure monitors will also be worn at waist height by the test engineers to maintain a continuous record of field exposure (over a limited frequency range) by personnel traveling on the train or waiting at the station.

4.0 MEASUREMENT PERSONNEL

The measurement team will consist of a minimum of four people. They will include two test engineers from Electric Research and Management, Inc., one representative of the Federal Railroad Administration, and a representative of MBTA. One additional observer from FRA may also be present for some or all of the tests.

5.0 COORDINATION WITH MBTA

The primary thrust of these measurements is to document electric and magnetic field exposure of the general public traveling onboard transit or living along the corridor. Consequently, most of the measurements will be made in public access areas. For these measurements, the minimum necessary coordination is consent to conduct the measurements, schedule and ridership information so that periods of peak ridership can be avoided. However, more extensive participation by MBTA personnel will permit a more comprehensive and perhaps higher quality measurement program. This would include measurements in areas closed to public access which would provide data on occupational exposure of MBTA personnel.

It was the intent of Electric Research and Management, Inc. when developing the measurement system and the prototype test plan for this overall project that all of the onboard measurements and station measurements be made during normal system operation. In that way, conditions during actual ridership are undoubtedly documented. The use of a dedicated vehicle has been suggested as a way of minimizing interference between the measurement team and the passengers (and vice versa). For tests on some of the lines dedicated vehicles are an acceptable alternative.

Rachel Durkee has been identified as the point of technical contact within MBTA and will be the MBTA representative within the measurement crew.

6.0 SCHEDULE

The following tentative schedule reflects previous discussions between FRA and MBTA which indicated that power personnel would be available on the first test day for measurements in and around substations and that dedicated vehicles (with no revenue passengers) would be available the second test day.

Times shown in this draft schedule are for planning purposes only. Actual times will depend on the schedule of MBTA operations, the availability of necessary MBTA personnel and equipment, and variability in travel and measurement time requirements.

TUESDAY, JUNE 9, 1992

8:00 AM	Meet at the MBTA facility at 500 Arborway.
8:45 AM	Measurements at the dispatch room at the Central Control Building.
9:30 AM	Measurements at the unit substation in the basement of the Central Control Building.
10:15 AM	Travel to the South Boston switching station and conduct measurements in and around the station.
12:45 PM	Lunch
2:00 PM	Travel to the Bennett Substation for measurements in and around the substation.
4:30 PM	Conduct measurements at wayside location as time permits.

WEDNESDAY, JUNE 10, 1992

8:00 AM	Meet at the Riverside yard for measurements on the Green Line inside the car house and enroute to Government Center.
9:30 AM	At Government Center, board the Blue Line to Wonderland. Conduct measurements on the Blue Line from Wonderland to State Station.
11:00 AM	At State Station, board the Orange Line to Oak Grove. Conduct measurements from Oak Grove to Downtown Crossing.
12:15 PM	Lunch.

1:30 PM Board the Red Line at Downtown Crossing and ride to Ashmont. Change to the high speed trolley and take measurements enroute to Mattapan and back.

2:45 PM Take measurements on the Red Line from Ashmont to Harvard Station.

4:00 PM At Harvard Station, change to a trolley bus and conduct measurements while traveling on Massachusetts Avenue to Arlington Station.

4:45 PM Begin station measurements or return to Riverside yard depending on remaining time.

THURSDAY, JUNE 11, 1992

8:00 AM Conduct station and wayside measurements at chosen locations.

12:00 M Lunch.

1:00 PM Continue station and wayside measurements.

5:00 PM Complete testing.

7.0 MEASUREMENT PROCEDURES ONBOARD THE TRAIN

Four major field sources are anticipated to contribute to the electromagnetic environment onboard the transit vehicles. They are:

1. Traction power and control equipment;
2. The third rail-track circuit, catenary-track circuit, or trolley circuit providing power to the vehicle;
3. "Hotel Power" circuits and appliances in the vehicles for light, heat, and air conditioning; and
4. External sources other than the catenary, trolley, third rail and track.

The onboard measurement plan is designed to both quantify the total field environment and to a reasonable extent determine the extent to which the above indicated sources contribute to the total field. This is done through the use of measurements at selected areas onboard the vehicle and measurements during selected operating conditions.

Measurements will be taken at three locations in the vehicle for each of the six types of vehicles to be examined.

1. Operator's Cab - Aside from the obvious effect of quantifying the occupational field exposure of the operator, these measurements will identify any ELF fields

produced by control or signal equipment within the cab. (When possible, this measure will not be performed in the active cab to avoid any possible distraction of the operator.)

2. Near the center of the vehicle at the edge of the aisle at a location above the power control equipment.

3. Near the rear of the vehicle at the edge of the aisle above the truck of the vehicle.

At each of the three locations, measurements will consist of:

1. A recording at five-second intervals of the magnetic field at four heights above the floor for the purpose of determining the temporal and vertical spatial variability of the field. This recording will cover the time from starting at one station to stopping at the next. These measurements will be made immediately behind or adjacent to the engineer's seat in the cab and at the aisle in the passenger area as identified above.

2. A recording at five-second intervals of electric field induced current in an object at 72 inches above the floor (simulating electric field induction to the head of a standing passenger).

The following measurements will be made at the location near the center of the passenger compartment.

1. A brief recording at five-second intervals of the magnetic field at four horizontal locations, each approximately 30 inches above the floor but distributed along the transverse axis of the train from midline to one side. These data will identify the spatial variability in magnetic field along that horizontal axis.

2. A brief recording at five-second intervals of the magnetic field at four horizontal locations, each approximately 30 inches above the floor, but distributed parallel to the longitudinal axis of the train along a line at the side of the center aisle. These data will identify spatial variability in magnetic field along that horizontal axis.

3. Two brief recordings at five-second intervals of electric field induced current in an object 30 inches above the floor (simulating electric field induction in the torso of a seated passenger).

In addition to the above site-specific measurements, the following additional roving, continuous, and control measurements will be made:

1. A continuous recording of the three-axis static and ELF magnetic field and vertical VHF magnetic field intensity at one reference location will be made with the DAT throughout the trip. ELF electric field will also be recorded during the period when *MultiWave*™ measurements are underway at the vehicle center location.

2. Personal exposure to magnetic fields at waist level will be recorded on two members of the measurement team who are not operating the *MultiWave*™ System.

Since most of the above identified measurements will span the time of travel from one station to the next, field levels will be recorded while accelerating, coasting, braking, and running at various speeds. Correlation between various field parameters and mode of vehicle operation will further aid in identifying the likely source of the magnetic fields.

8.0 MEASUREMENT PROCEDURES AT A STATION

The electromagnetic field environment will be measured at both ends of the station platform to best quantify and bracket the conditions which exist while transit vehicles enter and exit the station. Primary measurements will consist of a vertical profile of magnetic field levels at the point on the platform nearest the track where a person would reasonably and safely stand. Electric field induced current will also be measured at that location. If the station layout permits, an additional magnetic field level will be measured three meters in from the edge of the platform to better establish the attenuation rate of the magnetic field. Personal exposure measurements, continuous measurements, and control measurements will be made in the station in a way analogous to that done onboard the vehicle. Measurements will be made at stations serving each of the six vehicle and/or technology types identified in Section 1 above.

9.0 WAYSIDE MEASUREMENTS

Wayside measurements will be made to quantify the field environment in areas open to general public access along the system route wayside. These may be in an open area above a shallow underground section of the track, adjacent to a surface section of the track, or beneath an overpass. Specific measurement locations have not yet been established.

The field measurements at the wayside will be similar to those at the stations. Measurements will be made as near as possible to exclusion fences, barricades, etc. Field conditions between trains, as trains approach, as trains pass, and as trains depart will be recorded. If traffic is sufficiently dense, attempts will be made to collect data with two vehicles operating on parallel tracks within the same traction power block.

10.0 POWER SUPPLY

Measurements of the field environment surrounding power supply substations and transmission lines will be conducted so as to characterize the electric field induced current beneath the transmission line or near the substation fence at the point where the electric field is highest. Magnetic field measurements will be made at a point beneath the transmission line or near the substation boundary at a point where equipment configuration or line conductor sag will produce the highest field. All measurements will be made at recordings of 10-second intervals for a period of ten minutes (60 samples) to identify the full range of variability due to MBTA traffic patterns. If magnetic field conditions are sufficiently stable over time, profiles of the 25 Hz or 60Hz magnetic field will be measured in other directions from the substation or line using a computer based magnetic field meter designed to produce rapid, accurate magnetic field profile measurements.

11.0 SPECIAL TESTS

The electric and magnetic field measurements described above represent the structured component of the measurement effort. They are intended to provide field data on the MBTA System which can be compared to field data on other rail systems measured using a similar measurement protocol. However, the measurement plan also permits additional special tests which go beyond the structured component where there is a desire and opportunity to collect additional relevant data. The additional measurement locations have been suggested as areas where worker exposure is possible and therefore, fields should be measured.

1) Dispatcher area of the Central Control Building
2) Unit substation within the Central Control Building
3) Inside one or more traction power substations or accompanying high voltage switchyard.

Measurements in these areas will be structured to identify worst-case field levels in locations of expected worker exposure.

APPENDIX B

DRAFT TEST PLAN FOR
ELECTRIC AND MAGNETIC FIELD MEASUREMENTS
ON THE FRENCH TGV SYSTEM

DRAFT TEST PLAN FOR ELECTRIC AND MAGNETIC FIELD MEASUREMENTS ON THE SNCF TGV

1.0 INTRODUCTION

This test plan outlines the measurements which will be taken on SNCF high speed passenger train (TGV) operating from Paris to le Mans, France. These measurements will document the electric and magnetic field environment onboard the train, at passenger stations, along the wayside, near electric substations supplying power to the catenary system, and at a control center. This test plan is organized into ten sections. The first is this introduction. The next nine sections describe the measurement instrumentation, the measurement personnel, the necessary support from SNCF, the measurement schedule, and measurement procedures for the onboard, station, wayside, power supply, and control center measurements.

2.0 MEASUREMENT SYSTEM

Three distinct types of instrumentation will be utilized during these tests. Each meets a different need.

The primary instrumentation package is the portable *MultiWave*™ Monitoring System consisting of a briefcase-size instrumentation case and two probe staffs. This instrument accurately characterizes field intensities as functions of frequency and location along the probe staff at discrete times.

In order to provide a continuous record of field strength between the discrete time samples of the *MultiWave*™ System measurements, the magnetic field intensity detected by one AC magnetic field sensor, one fluxgate magnetic filed sensor, and the electric field sensor will be recorded continually by a digital audio tape (DAT) recorder.

EMDEX magnetic field exposure monitors will also be worn at waist height by the test engineers to maintain a continuous record of field exposure (over a limited frequency range) by personnel travelling on the train or waiting at the station.

3.0 MEASUREMENT PERSONNEL

The measurement team will consist of a minimum of three people. They will include two test engineers from Electric Research and Management, Inc. and one representative of the Federal Railroad Administration. One or more additional people representing SNCF or other involved transit authorities would be a welcome addition especially during tests in stations, along the wayside, near substations, and onboard the train during measurements in the operators compartment, where access to controlled areas may be required.

4.0 COORDINATION WITH SNCF

The primary thrust of these measurements is to document electric and magnetic field exposure of the general public travelling onboard TGV trains or living along the route. Consequently, most of the measurements will be made in public access areas. For these measurements, the minimum necessary coordination is consent to conduct the measurements, schedule and ridership information so that periods of peak passenger ridership can be avoided, and the necessary passes, tickets, etc. required to gain access to the trains and stations. However, SNCF personnel have indicated that they prefer to take a much more active role in the tests. Preliminary coordination has led to the production of this draft test plan. A meeting between measurement personnel and SNCF representatives will be held prior to the tests to finalize this test plan and select measurement sites which best meet the criteria described in sections 7, 8, 9, and 10.

It was the intent of Electric Research and Management, Inc. when developing the measurement system and the prototype test plan that all of the onboard measurements and station measurements be made during normal system operation. In that way, conditions during actual ridership are undoubtedly documented. The use of a dedicated train (or a dedicated coach in the train) has been suggested by SNCF as a way of minimizing interference between the measurement team and the passengers (and vice versa). A dedicated train would certainly simplify the measurements but may cast doubt on their relevance to conditions of actual ridership. SNCF will ultimately decide whether they shall allow measurements onboard a normal passenger carrying train (at off-peak time) or require measurements away from the general ridership in a dedicated car or train.

Section 6 below includes field measurements in the engineers compartment. This will undoubtedly require coordination through SNCF if these measurements are to be made.

5.0 SCHEDULE

This tentative schedule has been established based on a proposal by SNCF personnel. It allows more than adequate time for the proposed tests.

Monday September 7, 1992

Afternoon: Meeting with SNCF specialists to complete coordination for the tests and finalize the test plan and schedule.

Tuesday September 9, 1992

Morning: Onboard measurements in a center coach while traveling from Paris (Monparnasse station) to St-Pierre-Des-Corps (near Tours).
Morning: Onboard measurements in the front or last coach near a locomotive while traveling from St-Pierre-Des-Corps to Paris.
Afternoon: Onboard measurements in the end of the first or last coach away from the locomotive while traveling from Paris to the Vendôme station.
Afternoon: Measurements in the Vendôme station.
Afternoon: Onboard measurements in the engineers compartment of the rear locomotive while traveling from Vendôme to Paris.

Wednesday, September 10, 1992

Morning: Travel from Paris to Vendôme (no measurements required unless problems occurred on Tuesday).
Morning: Ground measurements in the Vendôme area at a wayside location, at an overpass, at an underpass and near a switching station.
Afternoon: Return to Paris (ne measurements required).
Afternoon: Measurements at the Montparnasse station.

Thursday, September 11, 1992

Morning: Travel by motor vehicle to the Gault-St. Denis substation and perform measurements.
Morning: Travel by motor vehicle to a nearby autotransformer and perform measurements.
Morning: Travel to the Chatillou control center and perform measurements.
Afternoon: Concluding meeting with SNCF personnel.

6.0 MEASUREMENT PROCEDURES FOR ONBOARD THE TRAIN

Four major field sources are anticipated to contribute to the electromagnetic environment onboard the TGV passenger trains. They are:

1. Power equipment in the locomotives.
2. The catenary-track circuit providing power to the locomotives.
3. "Hotel Power" circuits and appliances in the coaches and bar or dining car.
4. External sources other than the catenary and track.

The onboard measurement plan is designed to both quantify the total field environment and to a reasonable degree determine the extent to which the above indicated sources contribute to the total field.

This is done through the use of measurements at selected areas onboard the train and measurements during selected operating conditions.

Measurements will be taken at four locations on the train.

1. Engineers Compartment - Aside from quantifying occupational exposure of the engineer, these measurements will be the closest to the electrical equipment on the locomotives and be most likely to detect fields from that source. These tests can probably be conducted most efficiently and with the least disturbance to the train crew if done in the cab of the rear locomotive.
2. Locomotive End of the First or Last Car - These are the areas of the train where the general ridership comes closest to the locomotives and is most likely to experience fields from those sources. Since "hotel power" comes from the locomotives as well, the fields from power cables beneath the coach are likely to be highest at this point.
3. Back End of the First Car or Front of the Rear Car - Measurements at this point when viewed in light of measurements at the locomotive end of the car provide information about the attenuation rate of fields from the locomotive. Measurements at this location are also most likely to identify fields from the "hotel power" cables beneath the coach.
4. Center of a Middle Car - Measurements at this point are most likely to accurately quantify fields from the catenary-track circuit and other external sources because the test point is remote from the locomotive. This measurement will also identify any significant differences between fields at the center of a coach versus the end which may arise from sources onboard the coach.

At each of the four identified locations, measurements will consist of:

1. A five-minute recording at five second intervals (60 samples) of the magnetic field at four heights above the floor for the purpose of determining the temporal and vertical spatial variability of the field. These measurements will be made immediately behind or adjacent to the engineer's seat in the engineers compartment and at the side of the center aisle within the passenger coaches.
2. A two-minute recording at five second intervals (24 samples) of the magnetic field at four horizontal locations, each approximately 30 inches above the floor but distributed along the transverse axis of the train

from midline to one side. These data will identify the spatial variability in magnetic field along that horizontal axis.

3. A two-minute recording at five second intervals (24 samples) of the magnetic field at four horizontal locations, each approximately 30 inches above the floor, but distributed parallel to the longitudinal axis of the train along a line at the side of the center aisle. These data will identify spatial variability in magnetic field along that horizontal axis.
4. A five-minute recording (60 samples) of electric field induced current in an object at 72 inches above the floor (simulating electric field induction to the head of a standing passenger).
5. Two two-minute recordings (48 samples) of electric field induced current in an object 30 inches above the floor (simulating electric field induction in the torso of a seated passenger).
6. Continuous recording of the three-axis static and time-varying magnetic field, the electric field induced current, and the high frequency (3 kHz to 30 kHz) magnetic field will be made during an extended portion of the trip using the DAT Recorder. The magnetic field measurements will be at seat level and the electric field induced current measurements will be at a height of 72 inches (standing head level) at the edge of the center aisle except at those times where other measurements described in subparagraphs 2, 3, and 5 above are being made.
7. Personal exposure to magnetic fields at waist level will be recorded using the EMDEX recorders on the two members of the test team who are not operating the computer of the *MultiWave*™ System.

Following completion of the above described tests, remaining time on the trip will be used for recording field levels during operating conditions which may be expected to enhance field levels. Throughout these special tests, the measurements described in subparagraphs 1, 4, 6, and 7 will be carried out except that the recording time referenced in subparagraphs 1 and 4 will be adjusted as necessary to span the event of interest. The special tests will focus on field variability due to traction power requirements and due to electrification system equipment or parallel track operation.

The tests addressing operating condition effects on fields from traction equipment will be carried out at the end of a car near a locomotive. Recordings will be made at different speeds, during acceleration and braking, and when climbing steep inclines at high speed.

The tests addressing operating condition effects on fields from the electrification system or parallel track operation will be made at the center of a center car where fields from those sources can be most clearly detected without influence from fields from the locomotives or onboard "hotel power" circuits. These tests will include the operating conditions described in the preceding paragraph but also include measurements while passing substations, autotransformers, and phase breaks and measurements while approaching and passing electrified trains on parallel tracks fed from the same substation.

7.0 MEASUREMENT PROCEDURES AT STATIONS

The electromagnetic field environment will be measured at a station to document field levels at the station, assess the conditions while trains enter and exit the station and assess the conditions while a train passes at high speed without stopping (if applicable).

All station measurements will consist of a vertical profile of magnetic field levels at four levels above the floor and electric field induced current at standing head level. Measurement in passenger waiting areas will be selected to be typically of the area. Measurements on the platform will be made as near the tracks as a passenger would reasonably and safely stand. Recordings of magnetic field and electric field induced currents will be made as the train enters and exits the station or passes by the station without stopping. Recording time and interval will be selected as appropriate to accurately document the range of field conditions encountered. That is, a short recording period with samples every few seconds will be used for stations where trains pass at high speed whereas long recording periods with coarser samples will be used at stations where vehicles enter at low speed, stop, and depart at low speed.

Station measurements will be made at Montparnasse and Vendôme stations in order to characterize a large urban station and a smaller rural station.

8.0 WAYSIDE MEASUREMENTS

A set of wayside measurements will be made to quantify the field environment in areas open to general public access along the wayside. This site is not yet chosen. In order to quantify severe conditions, it should be in an area of significant grade where trains pass at high speed. For best resolution of fields from the TGV system, the sites should not be in urban or industrial areas where ambient fields are high. Additional measurements at underpasses or overpasses are desirable if suitable conditions exist. They too should be at an area with significant grade where trains pass at high speed.

The field measurements at the wayside will be similar to those at the stations. Field conditions between trains, as trains approach, as trains pass, and as trains depart will be recorded.

9.0 POWER SUPPLY

Measurements of the field environment surrounding a power supply substation, transmission line, and autotransformer will be conducted so as to characterize the electric field induced current beneath the line or near the substation fence at the point where the electric field is highest. Magnetic field measurements will be made along a line perpendicular to the line, substation boundary, or transformer at a point where equipment configuration or line conductor sag will produce the highest field. All measurements will be made at recordings of 10-second intervals for a period of fifteen minutes (90 samples) to identify the full range of variability due to railroad traffic patterns. If magnetic field conditions are sufficiently stable over time, profiles of the 50 Hz magnetic field will be measured in other directions from the substation or line using a survey-type magnetic field meter.

10.0 Control Center

Modern railroad control centers contain extensive electrical and electronic equipment. The magnetic field environment of these facilities is not known. Therefore, magnetic field measurements will be made at a dispatchers work location.

Control center measurements will consist of a vertical magnetic profile measurement at the location of the dispatchers seat, a horizontal magnetic profile at one meter above the floor from the equipment to the seat, and two electric field induced current measurements at one meter above the floor and at standing head level. Recording rate will be every five seconds for a period of two minutes (24 samples).

APPENDIX C

LETTER REPORT OF
TYPICAL FREQUENCY SIGNATURES FOR
MAGNETIC FIELDS WITHIN
ELECTRIFIED TRANSPORTATION VEHICLES

ELECTRIC RESEARCH & MANAGEMENT, INC.
2140 WILLIAM PITT WAY
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(412) 826-3222

August 21,1992

Dr. A. Brecher, DTS-24
Volpe National Maglev Initiative Office
55 Broadway
Kendall Square
Cambridge, MA 02142

SUBJECT: Typical frequency signatures for magnetic fields within electrified transportation vehicles.

Dear Aviva:

Enclosed are some typical frequency spectra for various electrically powered transportation systems. I tried to pull out data which were measured at comparable locations in the passenger compartments of the various vehicles. They are generally at seat level (about 60 cm above the ground) near the center of the vehicle and were measured during typical operating conditions. Most of the sheets show field versus frequency over time from DC to about 100 Hz in the top frame and similar plots with the static field component suppressed in the lower frame to provide more detail on the AC field components. The frequency range in the lower frame runs out as far as necessary to show all significant components within the 3 kHz bandwidth of the measurement system.

A few comments on each sheet follow:

1) TR7003 is a sample of the static and AC fields in the TR-07 vehicle as discussed in our earlier report. Static field levels vary about the 500 mG geomagnetic field. AC fields are comprised of variable frequency propulsion components and low frequency levitation and guidance control components.

2) NEC015 is on the New Haven to Boston section of the corridor. The static field is the geomagnetic field with some perturbation by iron and steel members in the coach. A 60 Hz AC field component is present due to hotel power distribution and equipment (such as air conditioning compressors, lights, etc) operated from the 60 Hz hotel power system.

3) NEC011 shows fields on the 60 Hz section of the corridor.

Static fields are still geomagnetic fields perturbed somewhat by the catenary support structures. The AC field is 60 Hz and its odd harmonics, primarily from the catenary-track circuit.

4) NEC048 shows fields on the Long Branch line. The static field is still the geomagnetic field. The AC field is 60 Hz and its odd harmonics from the catenary and track circuits. The frequency signature is similar to the 60 Hz section of the corridor except the 60 Hz fields appear lower and harmonic content is higher.

5) NEC003 applies to the 25 Hz section of the Northeast Corridor. Static field is still the geomagnetic field and the AC field components are 25 Hz and its odd harmonics from the current in the catenary and tracks.

6) MET001 is a cam control car on the WMATA system. Static fields vary due to current in the third rail, tracks, and on board wiring from the contractor shoe, controller, resistor bank, and motor. Time varying field components just represent the frequency spectra of changes in the DC current due to controller operation.

7) MET007 is a WMATA chopper controlled car. The principal field source appears to be a smoothing reactor directly beneath this measurement point. Static fields vary depending on currents through the third rail, track, and on board traction control equipment and motors. The fundamental component of the AC field is the 273 Hz chopper frequency and its harmonics (both odd and even harmonics).

8) BOS017 shows fields in a Blue Line car. It is a cam controlled car like the 1000 and 2000 series cars on the WMATA system and has magnetic field characteristics like those shown earlier in MET001.

9) BOS028 is a Red Line car which also uses cam control. its field characteristics are similar to those already described for MET001 and BOS017.

10) BOS033 shows fields on a Kinki car operating on the Green Line. Since this is another DC system, the static field is affected by catenary and track current as well as current in the on board propulsion system. AC fields consist of low frequency components from the changing DC current in the propulsion system as well as 60 Hz, 380 Hz, 720 Hz, and other ripple components in the catenary current from the rectifier station.

11) BOS034 is on a trolley bus. The field characteristics are similar to those for the green line car in BOS033.

I have not spent a lot of time on the Boston data yet so the comments on those systems are still somewhat tentative.

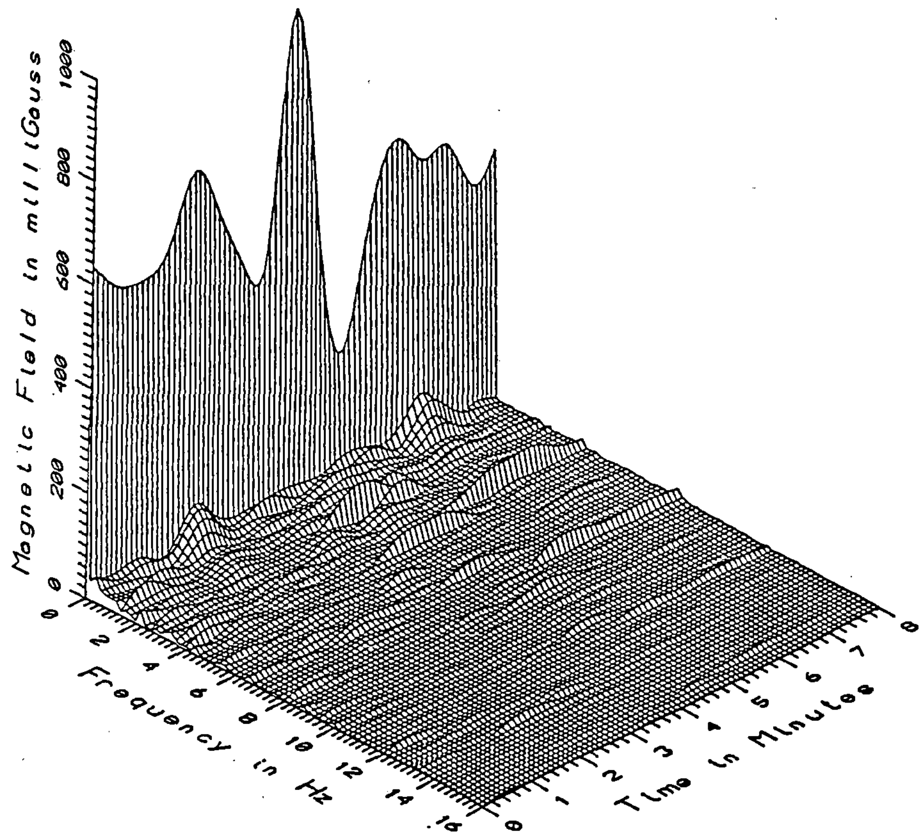
Also attached for your general information is some data on an electric van. Note the G-van has a chopper which varies somewhat around 2100 Hz (420th harmonic of the 5 Hz base frequency of the measurements). The low frequency components below about the 50th harmonic are background fields from the dynamometer and other equipment on the test floor. You will also note how low the fields are. The low fields result from several factors.

1) Vehicle is light and efficient therefore requiring little power.
2) The chopper operates at a high frequency and AC components are easily filtered out of the current.
3) Wiring is kept compact with supply and return cables close together thus reducing field production.

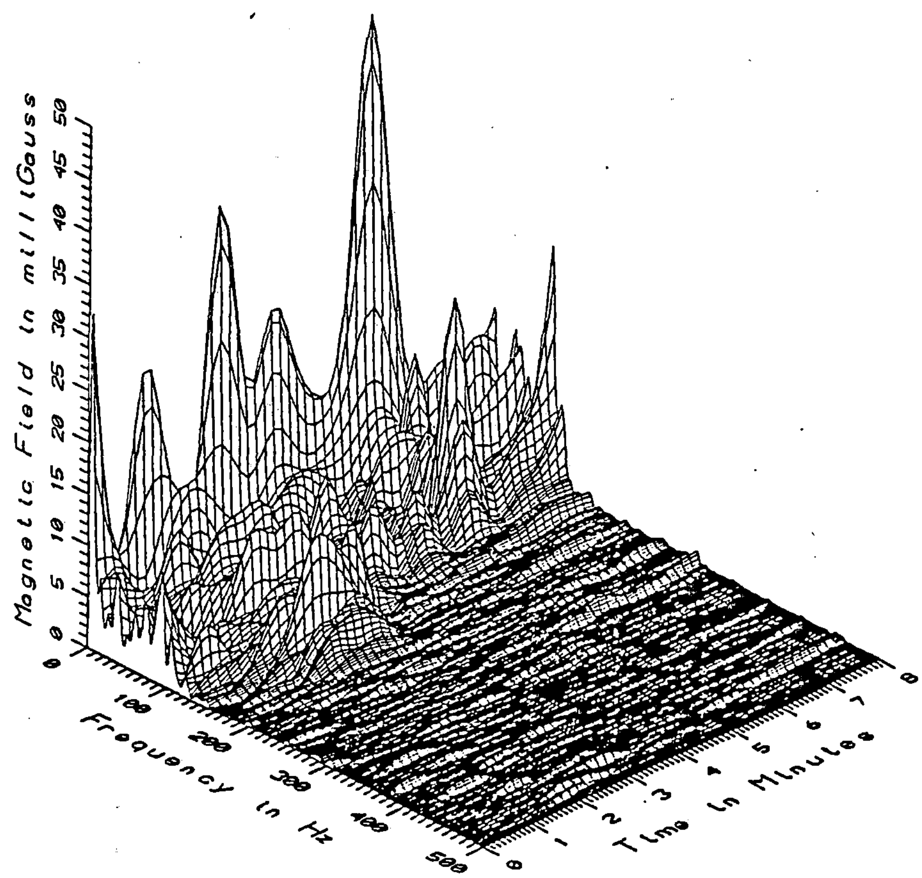
If you have any questions about these data, give me a call on Monday.

Sincerely,

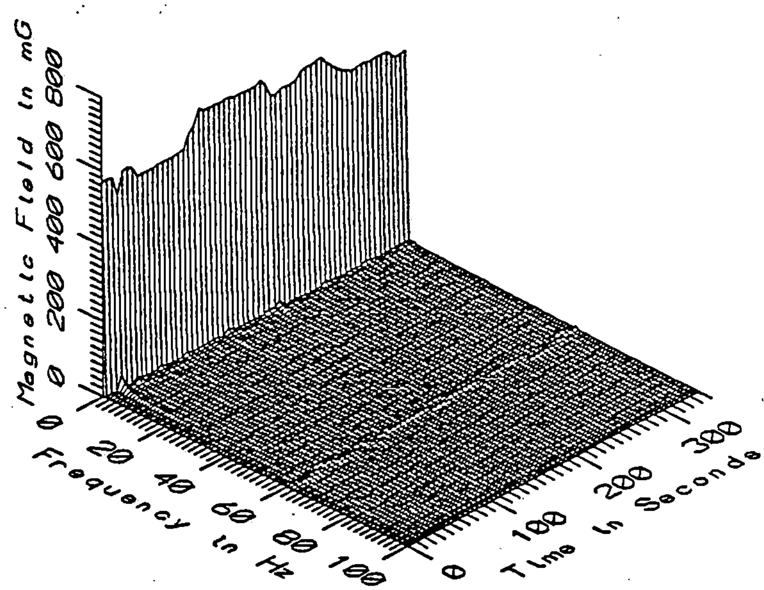
Fred M. Dietrich



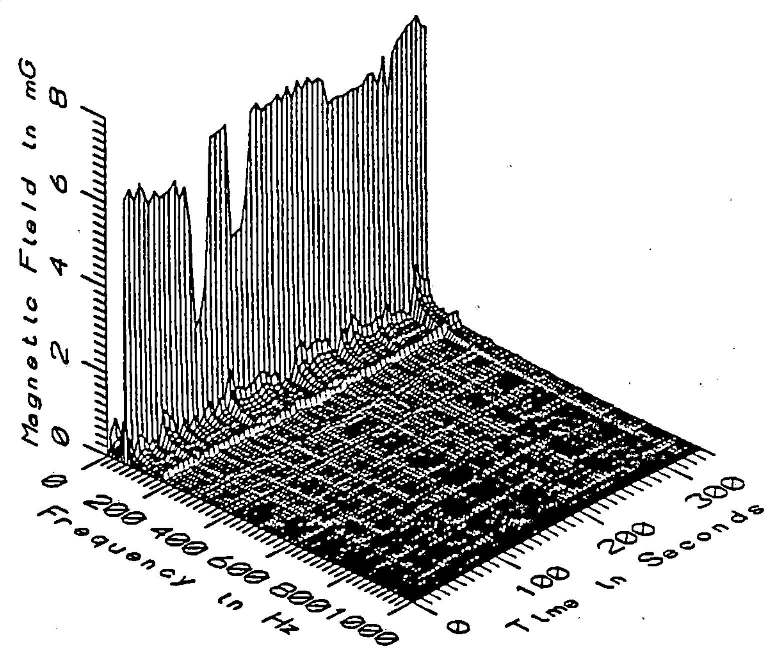
TR7003 - SEAT LEVEL - AISLE SEAT IN MIDDLE OF PASSENGER SECTION. CAR#2



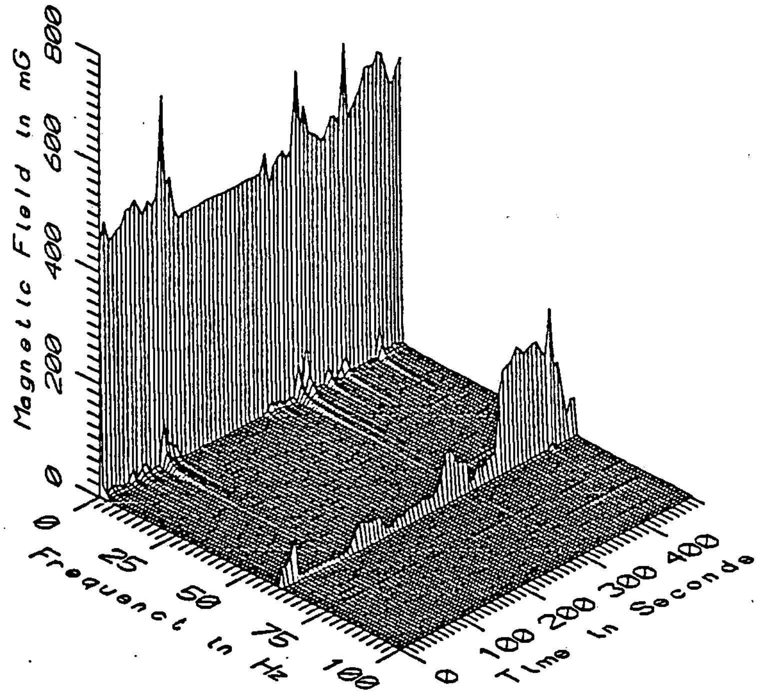
TR7003 - SEAT LEVEL - AISLE SEAT IN MIDDLE OF PASSENGER SECTION. CAR#2



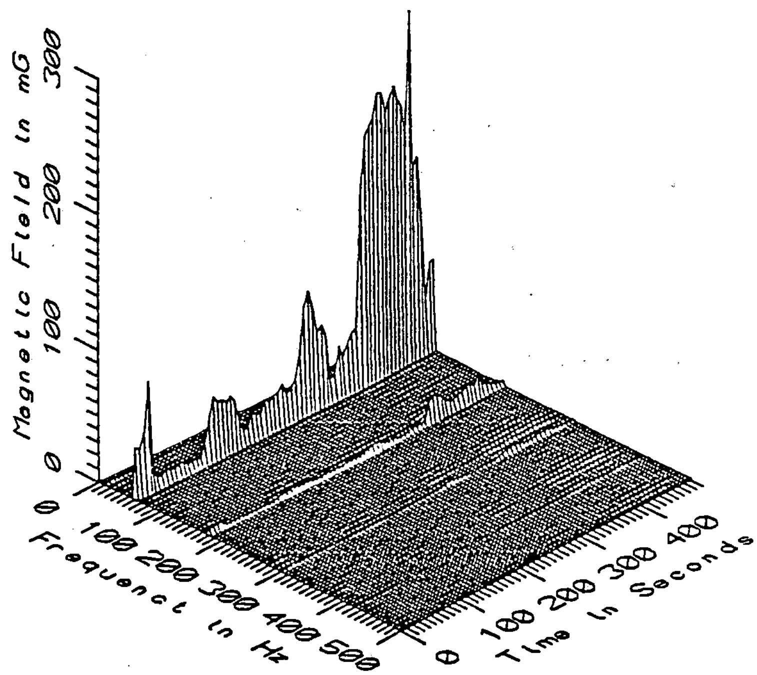
NEC015 - 60cm ABOVE FLOOR AT EDGE OF AISLE IN FIFTH COACH



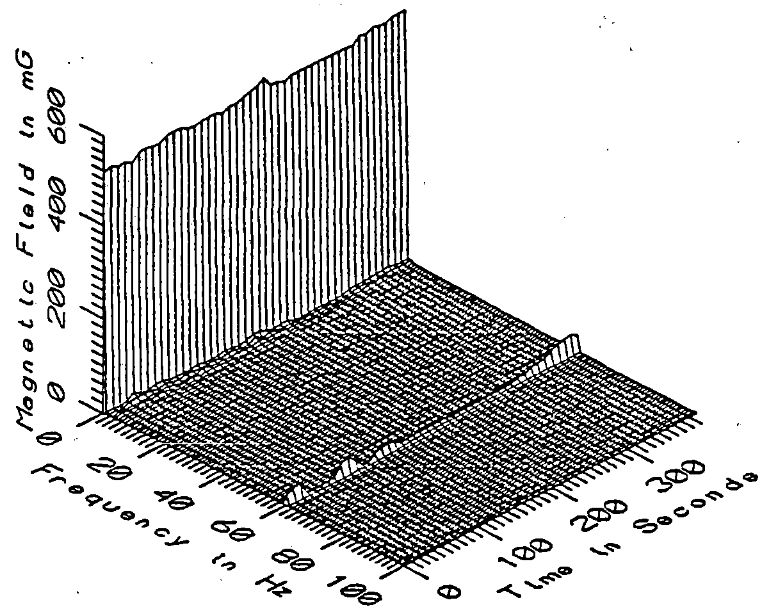
NEC015 - 60cm ABOVE FLOOR AT EDGE OF AISLE IN FIFTH COACH



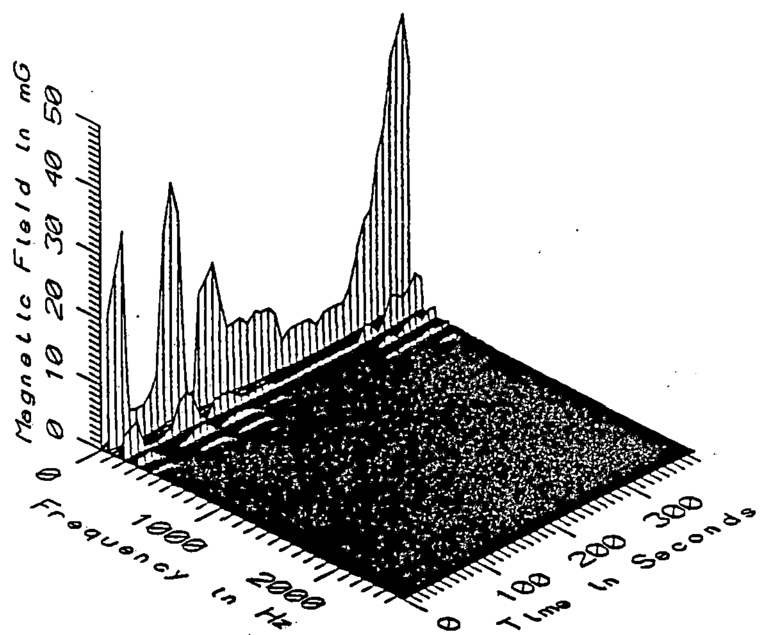
NECØ11 - 6Øcm ABOVE FLOOR AT EDGE OF AISLE IN THE SEVENTH COACH



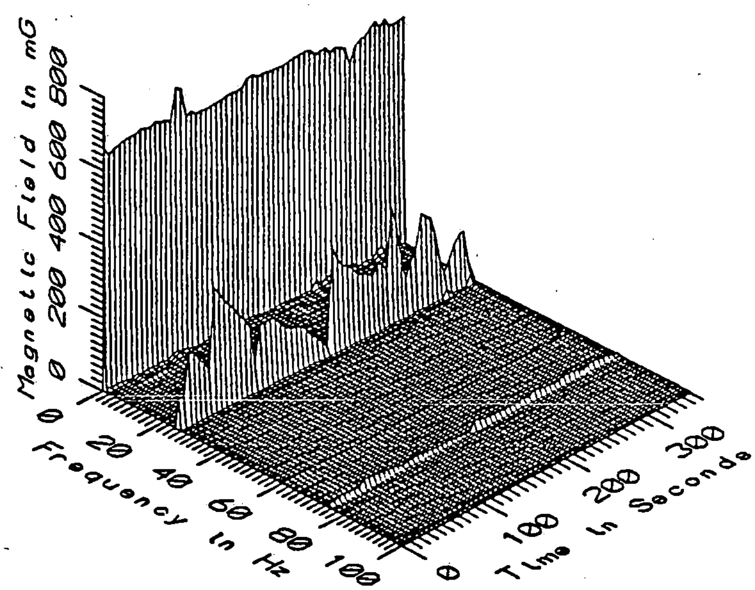
NECØ11 - 6Øcm ABOVE FLOOR AT EDGE OF AISLE IN THE SEVENTH COACH



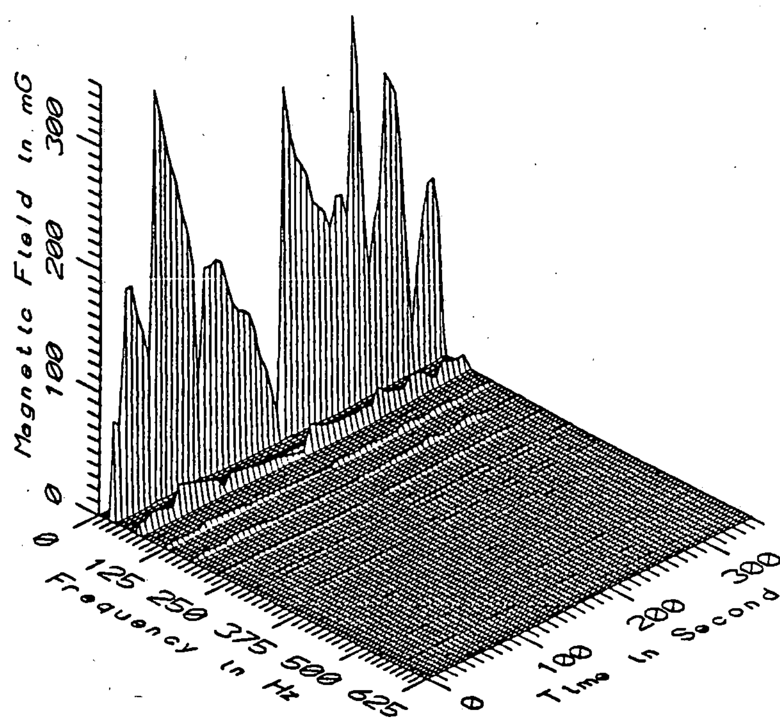
NEC048 - SET 1 - 60cm ABOVE FLOOR



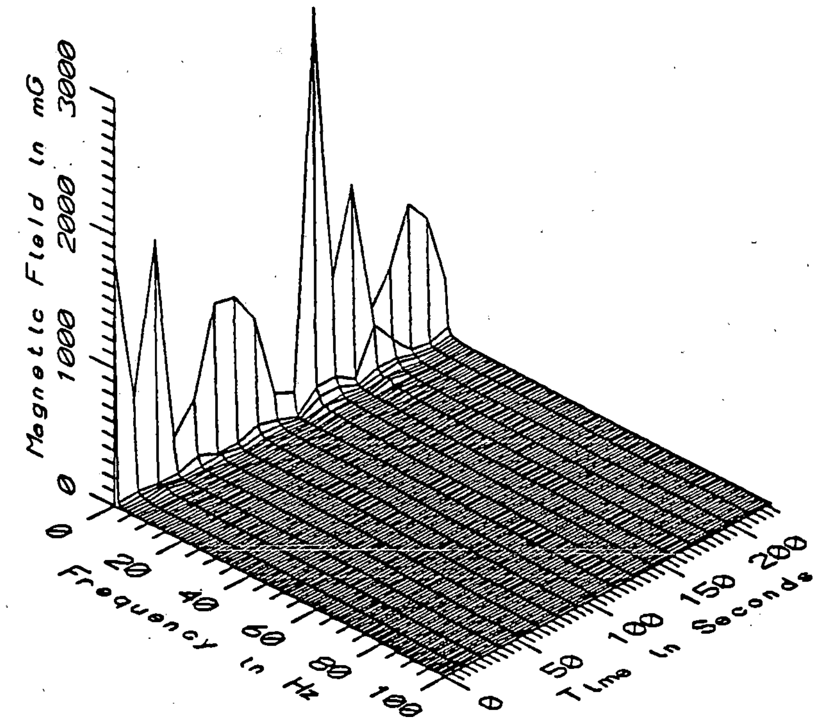
NEC048 - SET 1 - 60cm ABOVE FLOOR



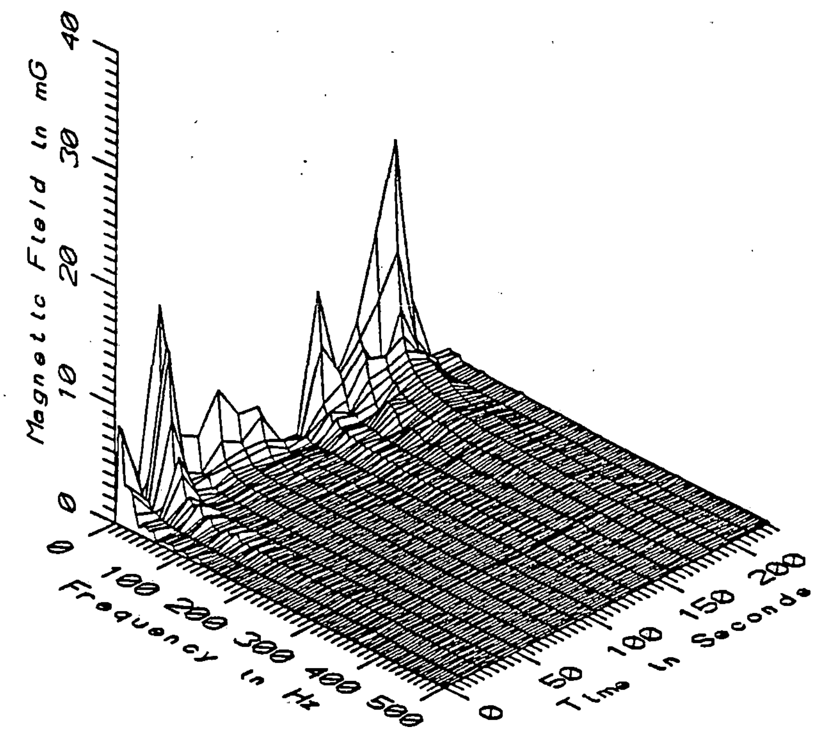
NEC003 - 60cm ABOVE FLOOR AT EDGE OF AISLE IN THE SEVENTH COACH



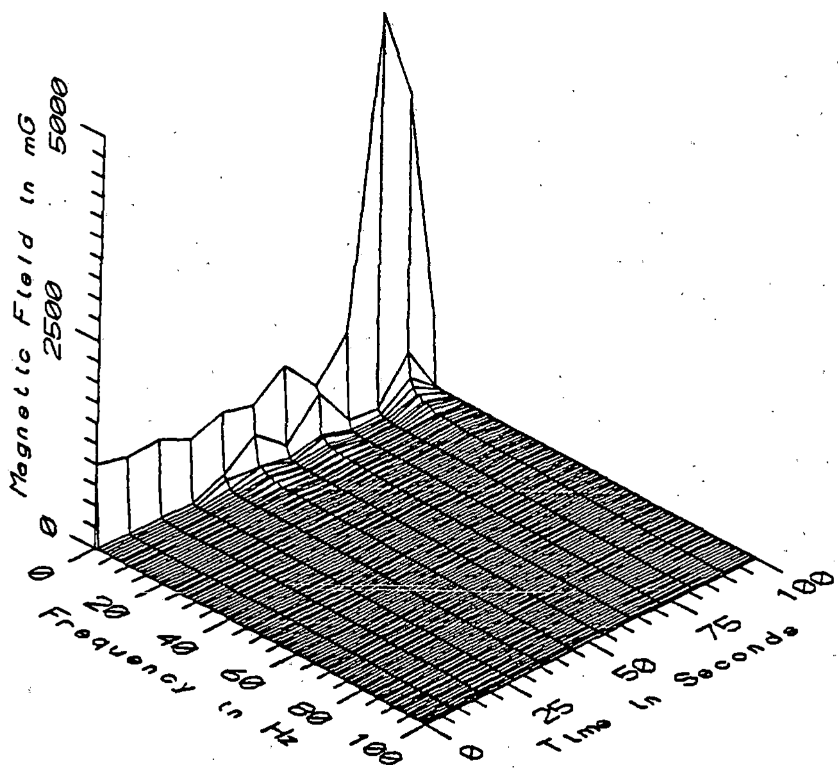
NEC003 - 60cm ABOVE FLOOR AT EDGE OF AISLE IN THE SEVENTH COACH



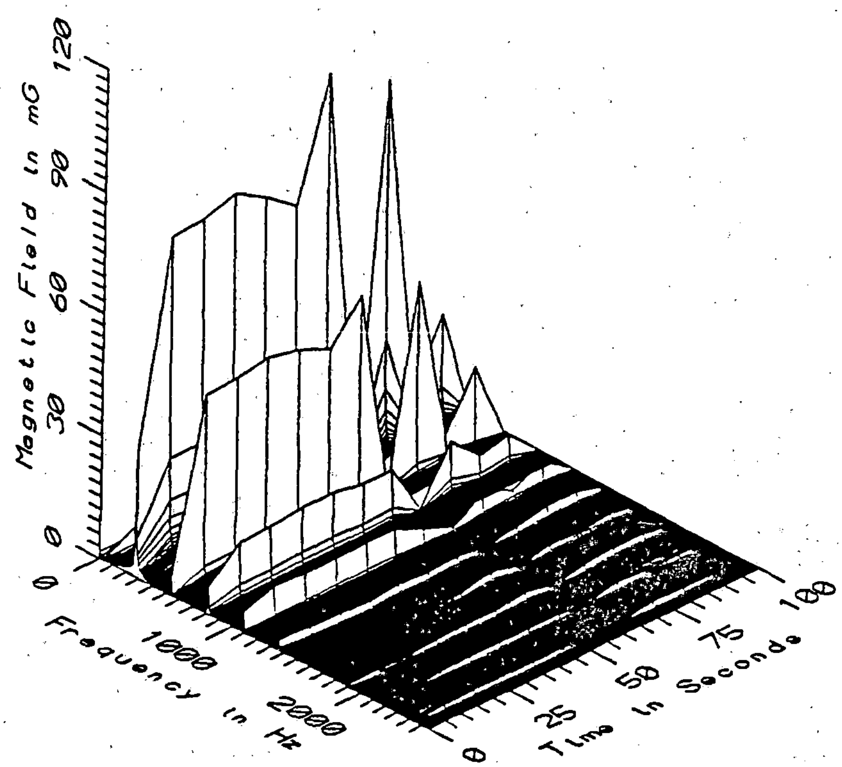
MET001 - 60cm ABOVE FLOOR, CENTER OF AISLE, CNETER OF CAR 1173



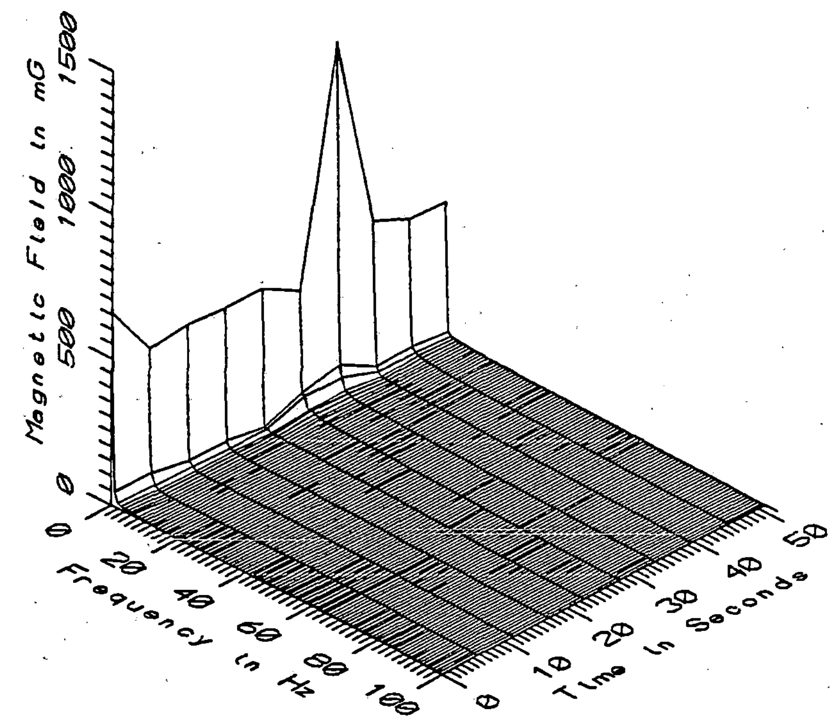
MET001 - 60cm ABOVE FLOOR, CENTER OF AISLE, CNETER OF CAR 1173



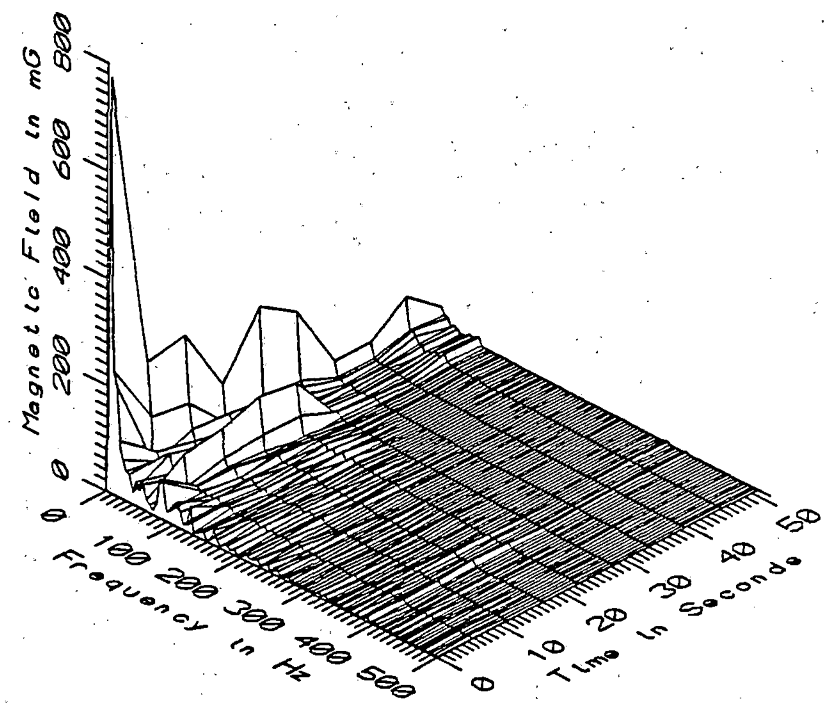
MET007 - 60cm ABOVE FLOOR, CENTER OF AISLE, CENTER OF CAR 3012



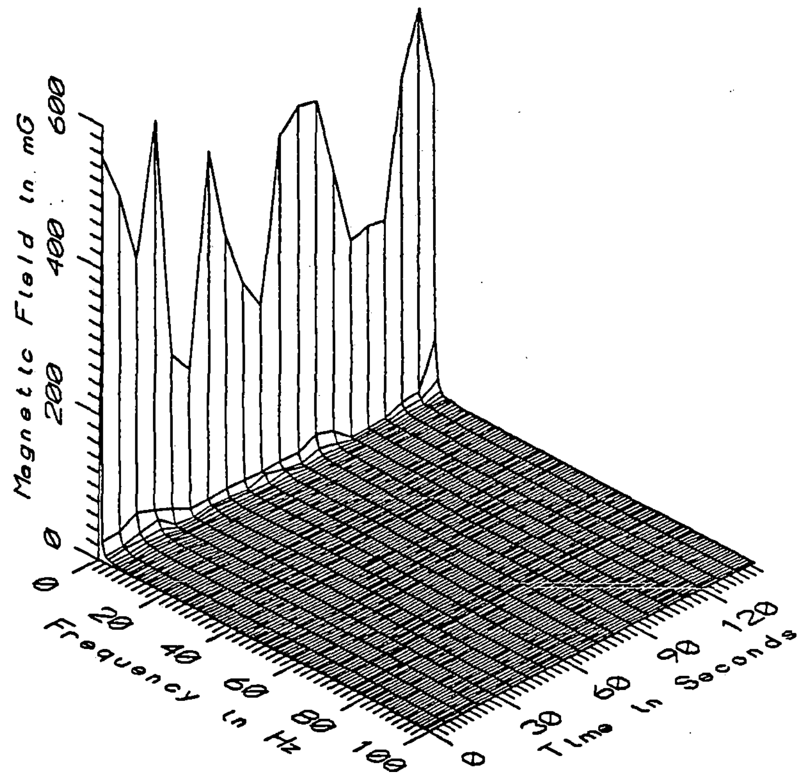
MET007 - 60cm ABOVE FLOOR, CENTER OF AISLE, CENTER OF CAR 3012



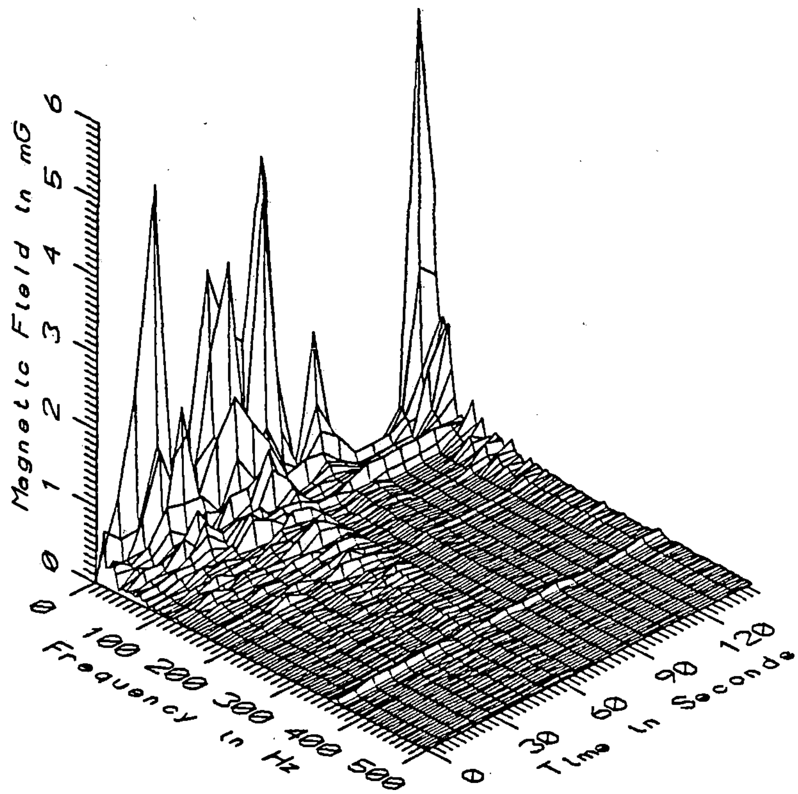
BOS017 - 60cm ABOVE FLOOR IN CENTER OF BLUE LINE CAR



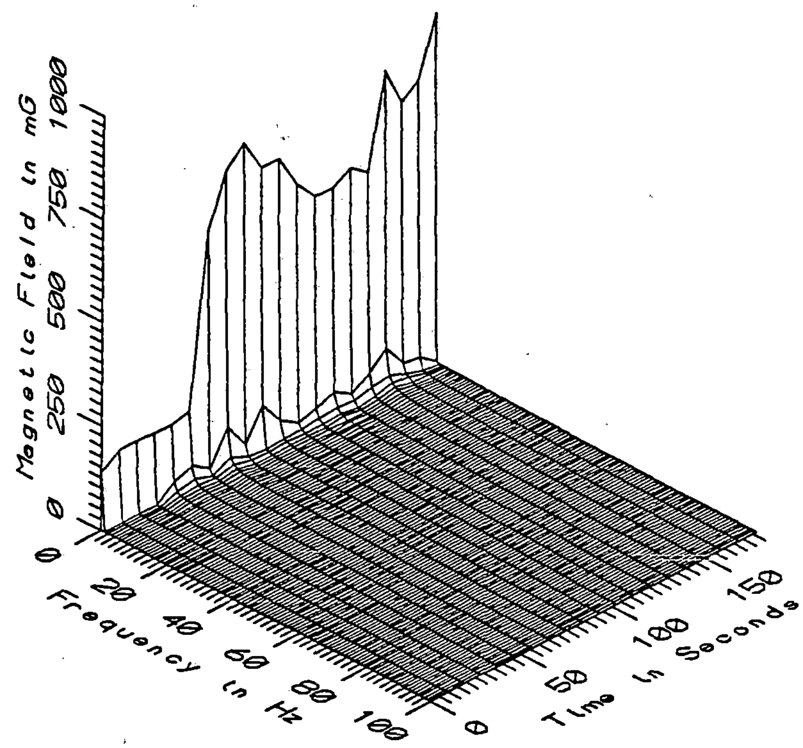
BOS017 - 60cm ABOVE FLOOR IN CENTER OF BLUE LINE CAR



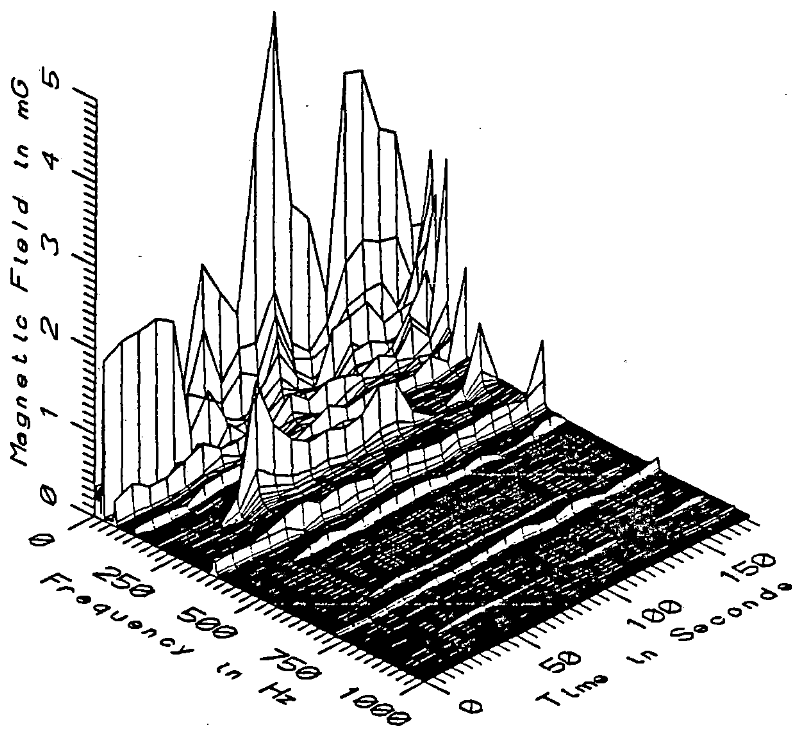
BOS028 - 60cm ABOVE FLOOR IN CENTER OF RED LINE CAR



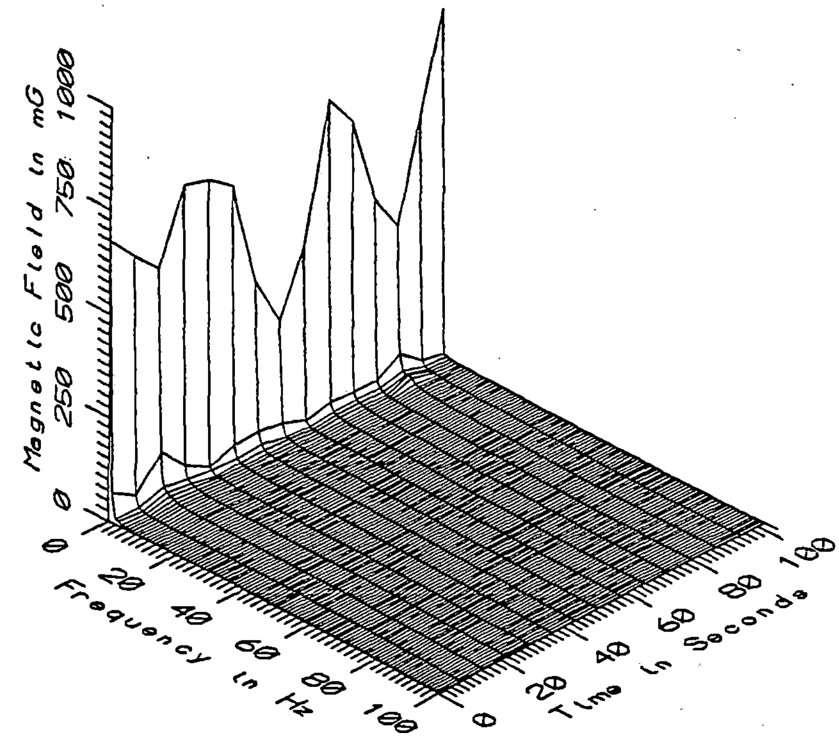
BOS028 - 60cm ABOVE FLOOR IN CENTER OF RED LINE CAR



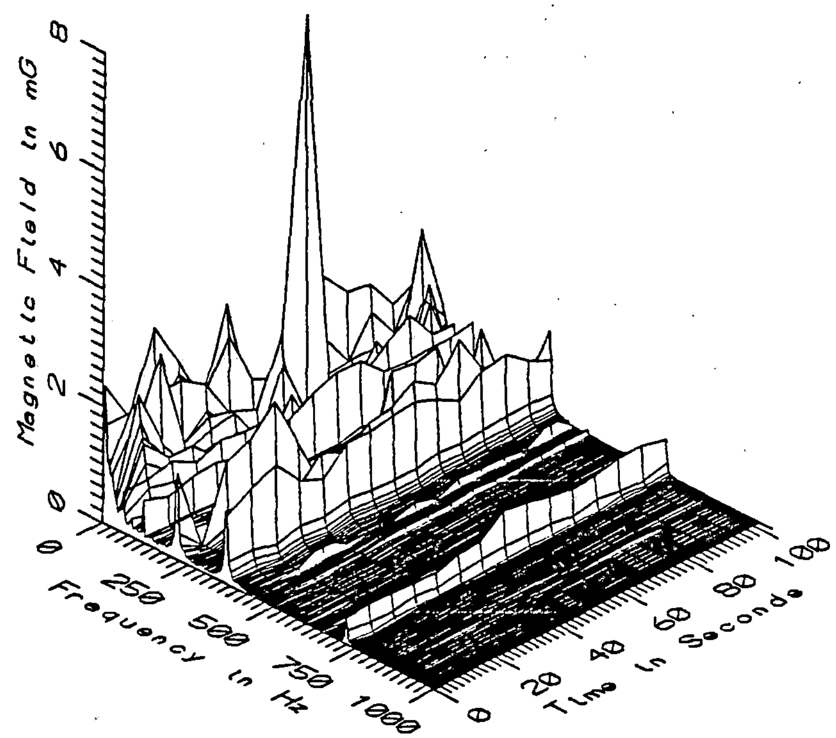
BOS033 - 60cm ABOVE FLOOR IN CENTER OF KINKI GREEN LINE CAR



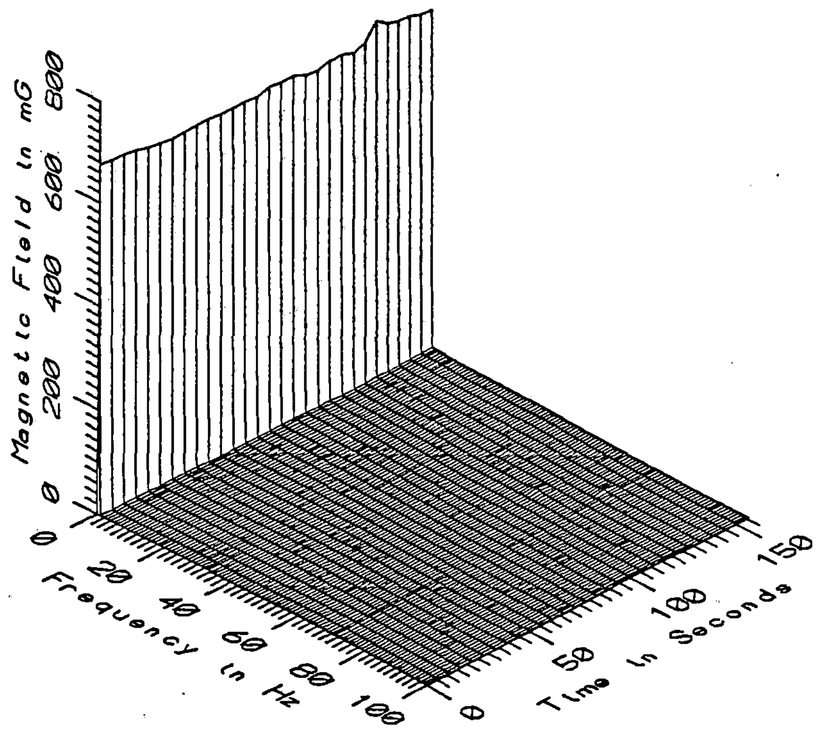
BOS033 - 60cm ABOVE FLOOR IN CENTER OF KINKI GREEN LINE CAR



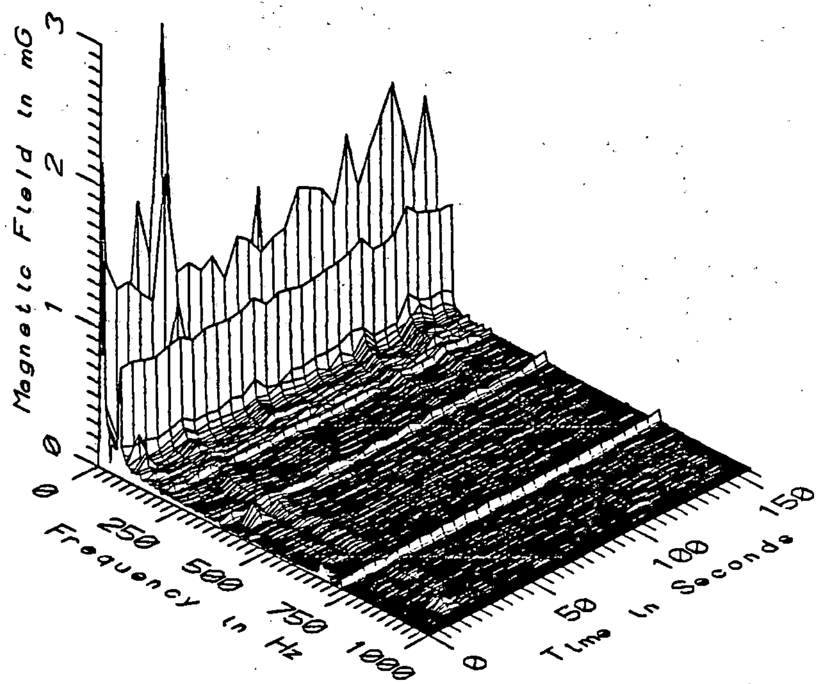
BOS034 - 60cm ABOVE FLOOR IN CENTER OF TROLLEY BUS



BOS034 - 60cm ABOVE FLOOR IN CENTER OF TROLLEY BUS

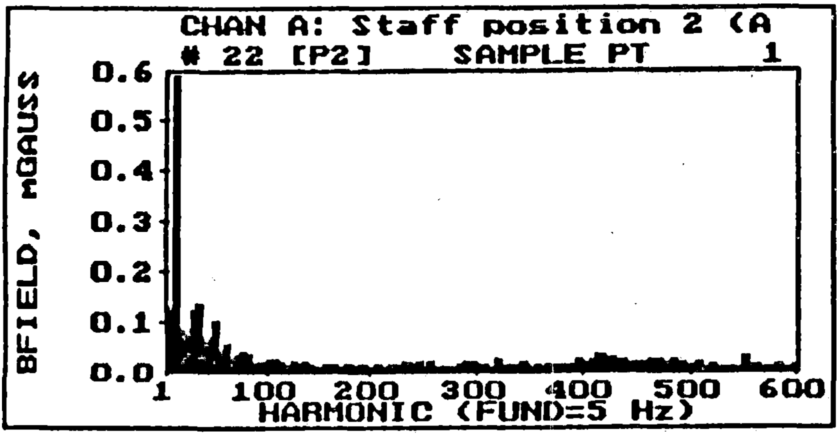


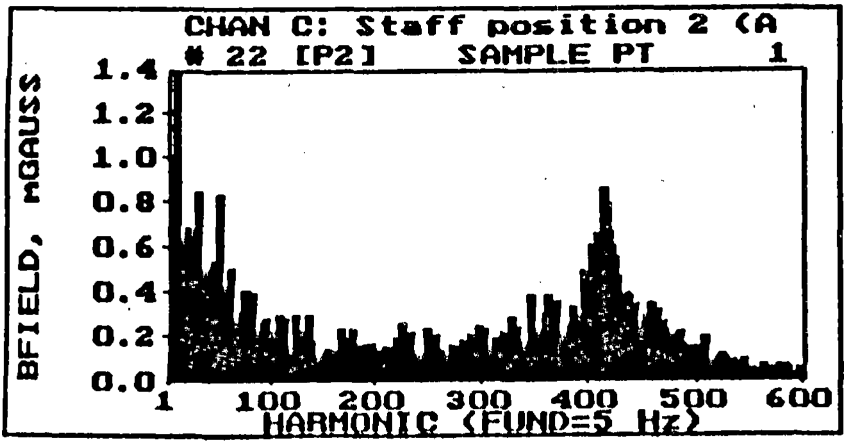
BOS030 - 60cm ABOVE FLOOR IN CENTER OF PCC TROLLEY



BOS030 - 60cm ABOVE FLOOR IN CENTER OF PCC TROLLEY

SITE: EVM016 Electric Vehicle
G-Van 30 mph





EMF Measurements June,1992

5Hz to 3kHz