Improving Highway Advisory Radio Predictability and Performance

Requested by
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Final

The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field.

Executive Summary

Background

Highway Advisory Radio (HAR) stations, sometimes referred to as Travelers' Information Stations (TIS), allow highway agencies to broadcast important messages about traffic, weather and roadway conditions to motorists. Caltrans has deployed HAR stations across the state, but performance is often unpredictable, with signal strength often failing to meet the state's intended design criteria.

Caltrans sought to better understand the underlying design factors involved with HAR signal transmission. The agency wanted to know what research, guidelines, specifications or practices among other agencies were available to improve the design and deployment of HAR stations. Caltrans' ultimate goal is to achieve more uniform and predictable signal strength and quality.

This Preliminary Investigation is limited in scope to AM band HAR stations and is focused on design factors related to radio wave propagation; topography; environmental characteristics (geology, ground conductivity); relevant system components and configurations (antennae, grounding); and related factors affecting HAR performance.

Summary of Findings

We did not identify any existing guidance documents or specifications that directly address Caltrans' inquiry, but the findings of this investigation suggest that performance issues with HAR are a common problem. Moreover, HAR users and suppliers alike have developed approaches, which are not necessarily formalized, to help optimize HAR performance.

Survey of States

Through the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee (RAC), we distributed a survey to the states regarding their experience with HAR.

The survey sought to learn the extent of states' deployment of HAR stations and to collect any available design or specification documentation.

Six states responded to the survey. Noteworthy findings among the responses include these points:

- Three of the responding states reported using HAR stations, and the other three either do not use them or have moved toward phasing them out of service.
- None of the states provided design guidance or specifications addressing the signal quality concerns of interest to Caltrans.
- Three states expressed concern over HAR effectiveness, citing signal strength or topography as barriers to effective HAR use.
- Three states described a trend toward the use of a 511 Traveler Information System as an alternative to HAR stations.

Practitioner and Expert Interviews

We spoke with representatives across the industry to establish the availability of clear guidance on this topic, including specification documents or research at the state or national level.

- Representatives within **Caltrans**, both at headquarters in Sacramento and in District 4, discussed HAR design and installation and the impact on signal quality. It was noted that project requirements for any given HAR deployment often make it difficult or impossible to place the HAR station in an ideal location for optimum signal strength. Competing radio signals from neighboring high-power commercial stations also lead to reduction in signal clarity.
- Representatives of **National Associations**, including AASHTO and the Transportation Research Board (TRB), were unaware of any research that addressed this specific topic.
- Three different **HAR Vendors** shared relevant design considerations with us. Some common themes arose among these conversations. It was noted that considerations for HAR stations are often not the same as those for high-power commercial AM radio stations:
    1. It is not economically feasible to design or install same antenna or counterpoise that would be used with a high-power station.
    2. Ground conductivity and its impact on ground wave propagation are too variable in the small range of an HAR station to be factored into the design or installation process.
- Interview subjects universally stressed the importance of system grounding, though they acknowledged that practical limitations—both geographical and financial—often make it necessary to choose the best grounding option available under given circumstances.
- Interview subjects similarly addressed siting. Wide open spaces are ideal for AM radio wave transmission, but often siting is constrained by project needs and Federal Communications Commission (FCC) licensing. The need for careful FCC compliance in licensing an HAR station was cited by most interview subjects.

Research and Guidance Documents

A review of literature on this topic yielded results in four different areas:

- **Caltrans Specifications** include the agency's internal documentation related to HAR: two standard special provisions for HAR, a set of HAR antenna installation plan drawings, and Caltrans' HAR maintenance manual. These are included as Appendices to this investigation.
- **HAR-Specific Resources** include documentation and reports conducted either by or for federal and state agencies that address installation, performance and characteristics of HAR stations. These reports make many of the same general observations about HAR performance as those stated by interview subjects. This investigation includes nine relevant resources published between 1981 and 2010.
- **AM Radio Fundamentals** do not refer to HAR specifically but address general questions related to AM radio design and signal propagation. Some of these provide fundamental guidance of AM radio propagation, and these may be relevant to the design and implementation of HAR stations. The investigation includes six resources dating back to 1942.

- Finally, **Regulatory Information** addresses requirements related to FCC licensure and operation of HAR stations. Although these are generally not technical in nature, these three web sites provide a complete picture of the regulatory framework governing HAR deployment.

Gaps in Findings

Lacking in these findings was a document specifically addressing Caltrans' stated question on HAR design. The survey results, interviews and guidance documents collectively represent experiential knowledge and general guidelines, but there is no definitive document that states best practices for designing, siting or grounding HAR stations to achieve scientifically predictable results.

The fairly low survey response rate suggests that there may be more experience at the state level than is evident in these findings. However, the literature searches conducted as part of this Preliminary Investigation do not indicate the likelihood of specifications that more directly address Caltrans' concerns.

Next Steps

All vendors we spoke with stated their willingness to discuss Caltrans' specific technical questions in greater detail. It is possible that a targeted research project could lead to definitive design guidance for improving HAR signal strength, quality and predictability. However, practical limitations on where HAR stations ultimately need to be placed may limit the value of such guidelines.

Considerable experience on this topic appears to be available across the Caltrans community. A coordinated sharing of current practices among Caltrans and its HAR vendors may yield best practices that could immediately improve HAR deployment in different districts. This could be accomplished through facilitated dialogue or a peer exchange.

Contacts

During the course of this Preliminary Investigation, we spoke to or corresponded with the following individuals:

Caltrans

Ferdinand Milanes
Chief, Office of Radio Communications Engineering
(916) 654-5642, ferdinand_milanes@dot.ca.gov

Charles Price
Chief, Electrical Systems
District 4
(510) 286-4478, charles_price@dot.ca.gov

Michael Lee
Chief, Electrical Systems Hardware Support
District 4
(510) 286-6142, michael_p_lee@dot.ca.gov

Other State Transportation Agencies

Maryland DOT
Thomas Hicks
Director, Office of Traffic and Safety
(410) 787-5813, thicks@sha.state.md.us

Virginia DOT
Bill Brown
Radio Manager
Chair, AASHTO Special Committee on Wireless Technology
(804) 692-2520, bill.brown@vdot.virginia.gov

National Associations

AASHTO Special Committee on Wireless Technology
William Brownlow, AASHTO
Telecommunications Manager
(202) 624-5817, wbrownlow@aashto.org

TRB Intelligent Transportation Systems Committee (AHB15)
Richard Cunard, TRB Representative
Traffic and Operations Engineer
Senior Program Officer
(202) 334-2963, rcunard@nas.edu

HAR Vendors

Information Station Specialists
Bill Baker
(616) 772-2300, ext. 102, bill@theradiosource.com

RadioSoft
Peter Moncure
Vice President of Engineering
(706) 754-2725, pmoncure@radiosoft.com

Vaisala
Mark Feldman
Pacific Sales Manager, Roads Division
(314) 705-0522, mark.feldman@vaisala.com

Jerry Waldman
(314) 705-0179, jerry.waldman@vaisala.com

Survey of States

We conducted a brief online survey of members of AASHTO's RAC to gather information from state departments of transportation (DOTs) on their experience with HAR station design, specification and optimization. The survey consisted of the following questions:

The California Department of Transportation is interested in optimizing its fixed Highway Advisory Radio (HAR) installations and is looking for detailed engineering documentation on how to design a system to a specified, consistent level of performance. It is not looking for practices regarding when to use HAR or how to put the components together, but is looking to deepen its understanding of the physics involved in its AM radio transmissions given different characteristics (e.g., soil type) of an HAR installation.

Please forward this to the individual(s) at your agency most involved in HAR. This person's role will vary by agency and may be in ITS, electrical design or some other group.

1. Does your agency make substantial use of fixed HAR transmitters (using the AM spectrum) to provide traveler information?

2. If you use vendors to design your HAR transmitter configurations, please provide their names and contact information.

3. If you design and construct your own HAR systems, do you have design specifications and/or a design guide for these that you would be willing to share with Caltrans? If so, please include a URL or attach the document.

4. Please provide the name and contact information of the person(s) at your agency most involved with HAR design as described above.

Summary Results

We received responses from six state transportation agencies: Louisiana, Maryland, Missouri, New Jersey, Oregon and West Virginia. Findings and common themes in survey responses are given below.

Use of HAR Stations

- Maryland and Oregon report using HAR stations.
- New Jersey has 13 stations in use, but the state has not installed a new station in a decade.
- Louisiana and Missouri described generally inactive HAR programs, and each reported having a few remaining HAR stations in place.
- West Virginia reports a few county-operated HAR stations in place, but none operated by the state.

Design and Specifications

- Louisiana offered to provide vendor specifications.
- Maryland's specifications are based on the vendor's designs for warranty purposes.
- Missouri did not work with vendors for its HAR design and stated that any existing state specifications would be outdated.

Effectiveness
Concern with HAR effectiveness was a repeated theme in the survey responses:

- Louisiana described "serviceability and effectiveness of these systems were less than satisfactory."
- New Jersey cited "weak signal and radio interference experienced at most of our HAR sites."
- West Virginia stated that "due to our topography, it is very difficult to deploy HARs" and that "HARs are too site-specific."

511
Louisiana, Missouri and West Virginia described the trend in their respective states toward 511 as a preferred method for communication with motorists.

Vendors
Vendors noted in survey responses include Vaisala and Information Stations Specialists. We interviewed representatives from both companies; see the **Practitioner and Expert Interviews** section of this Preliminary Investigation.

Complete Results

The full text of each survey response follows.

Louisiana
Contact: Stephen Glascock, Intelligent Transportation Systems Director, Louisiana Department of Transportation and Development, (225) 379-2516, stephen.glascock@la.gov.

1. Agency use of HAR? No. Louisiana had two fixed HAR sites installed in 2010 along the I-49 corridor in the central part of the state to transmit major incident and emergency level information. Prior to that installation, the Department of Transportation and Development had two other implementations of HAR, one in the Baton Rouge region and one in the Lake Charles region. These systems were installed as part of Interstate construction projects in the mid- to late 1990s and remained in operation after the projects were completed until the mid-2000s. In our view, serviceability and effectiveness of these systems were less than satisfactory and thereby disabled once the statewide 511 system was implemented.

2. HAR vendor contact: Vaisala (formerly Quixote Traffic Products). No specific vendor contact. This system was installed as part of an ITS Design-Build project through a general contractor.

3. Design specifications or guidance: We will be happy to furnish any vendor specifications or cut sheets provided as part of the ITS project that installed the above mentioned system, but they should be readily available on the vendor's web site.

4. Agency contact for HAR design: Adam Moncivaez, Statewide TMC Supervisor, Louisiana Department of Transportation and Development, (225) 379-2577, adam.moncivaez@la.gov.

Maryland
Contact: John Young, Senior Engineer, ITS Engineering, Maryland State Highway Administration, (410) 787-5869, jyoung@sha.state.md.us.

Note: We first spoke with Maryland's director of traffic and safety Tom Hicks at the suggestion of TRB's Rich Cunard. See the ***Practitioner and Expert Interviews*** *section of this Preliminary Investigation for details. After we outlined the topic of this Preliminary Investigation for Hicks, he forwarded these survey questions to John Young, whose answers are given here.*

I used to write the specifications for the radios, at which time we were committed to a company called Information Station Specialists (ISS). However, that function was taken over by our Communications Division some time ago, since they hold our state's FCC license. It's my understanding that we use a different brand now. I have requested information from them.

Please feel free to contact Phil or me with any questions that you might have. I have all of our previous (ISS brand) monopole HAR details and specifications, as well as information regarding buried-cable radio systems. However, the only entities that I'm aware of these days using buried cable are those who have the capability of carefully controlling their environment, like airports, tunnels and parks (DisneyWorld). Our buried cable was damaged on an almost weekly basis by guardrail installers, errant semi trucks and so forth, so we never pursued that option.

1. Agency use of HAR? Yes, we do. Our statewide license allows for several different frequencies, which we use for specific corridors. I have included Mr. Phillip Lazarus, our chief electrical engineer at the Office of Communications, on the cc list so that he might elaborate on the frequencies used.

2. HAR vendor contact: I don't believe we allow them to design our systems, per se, but when I wrote the specifications and details, they were based on our ISS's design. And that vendor provided CADD details, sample purchase specifications and on-site technical assistance to a degree that might have suggested that they were designing our systems. But this was often a requirement by the various companies in order to ensure that the equipment was being installed in accordance with the terms of their warranty. When I designed and installed the state's first "leaky cable" buried antenna HAR, the area engineer for that company (LPB, or Low Power Broadcasters) was on-site almost daily.

3. Design specifications or guidance: We would be delighted to share this information with Caltrans. Again, I have copied Phil so that he can provide more insight.

4. Agency contact for HAR design: Our engineering chief in this area is:

Mr. Phillip Lazarus
Assistant Division Chief–Technical Support
Communication Division
State Highway Administration
5901 Baltimore National Pike
Baltimore, MD 21228
Phone: (410) 747-8590
Fax: (410) 744-4716
plazarus@sha.state.md.us

Missouri

Contact: Bill Stone, Organizational Performance Administrator, Missouri Department of Transportation, (573) 526-4328, william.stone@modot.mo.gov.

1. Agency use of HAR? No, MoDOT has a few still in operation, but overall has not had any substantial use for nearly 10 years or so.

2. HAR vendor contact: MoDOT did not use vendors for the design of our systems.

3. Design specifications or guidance: Again, since we have not had much use of HAR, the specifications that we have would be outdated and would be reviewed prior to any future installations.

4. Agency contact for HAR design: Rick Bennett, Traffic Liaison Engineer, Missouri Department of Transportation, (573) 526-4842, richard.bennett@modot.mo.gov.

New Jersey

Contact: James Hogan, Executive Director, Statewide Traffic Operations, New Jersey Department of Transportation, (609) 530-4690, jim.hogan@dot.state.nj.us.

1. Agency use of HAR? We have 13 transmitters throughout the state. We did depend on these for traveler information prior to developing our 511 system. We haven't built a new transmitter in about a decade due to the weak signal and radio interference experienced at most of our HAR sites.

2. HAR vendor contact: See answer above.

3. Design specifications or guidance: See answer 1.

4. Agency contact for HAR design: See answer 1.

Oregon

Contact: Doug Spencer, Standards Engineer, Intelligent Transportation Systems, Oregon Department of Transportation, (503) 856-6528, doug.l.spencer@odot.state.or.us.

I am responsible for the design of ITS devices for the Oregon Department of Transportation including Highway Advisory Radios. Our office has a price agreement with Highway Information Systems (HIS), now owned by Vaisala. We procure their equipment but our staff designs the installation.

There really is not much to HAR. The ground plane and the soil type are the main things. It is very difficult for us to perform a soil sample for HAR due to the limit amount of funding these projects receive. Therefore, we typically install two chemical ground rods as opposed to the typical radials recommended by the manufacturer.

We have discussed this topic with Caltrans District 2 staff on occasion. Caltrans has more HARs than us. I don't believe we have anything further to contribute in this matter. I would suggest you follow up with Ian Turnbull, Caltrans District 2.

West Virginia

Contact: Bruce Kenney, Intelligent Transportation Systems Coordinator/Systems Management Engineer, West Virginia Department of Transportation, (304) 558-9449, bruce.e.kenney@wv.gov.

1. Agency use of HAR? Although we do have a few county-operated HARs, our state does not utilize HARs for a variety of reasons. Some primary reasons are that due to our topography, it is very difficult to deploy HARs, we are employing a statewide 511 system, and we feel that HARs are too site-specific, ergo our 511 system.

2. HAR vendor contact: [No response.]

3. Design specifications or guidance: [No response.]

4. Agency contact for HAR design: [No response.]

Practitioner and Expert Interviews

Interviews with HAR users and experts in HAR design and installation provided insights on the type of information available on this topic. These calls complemented the outreach to other state DOTs through the survey process, and they included contacts within Caltrans to complete the picture of HAR practices around the state of California.

Caltrans

We contacted Caltrans' Office of Radio Communications Engineering at headquarters in Sacramento as well staff in the agency's districts involved in HAR design and deployment.

Ferdinand Milanes, chief of the Office of Radio Communications Engineering, advised that decision points usually dictate the location of HAR installations, and that the agency installs the best grounding possible given constraints on where the station is located. Limitations such as shoulder space affect what kind of grounding the agency can install. Obtaining the desired frequency is another concern at the agency level. Milanes also discussed the importance of cellphone coverage in the area, as many districts use cellphones to control the HARs, and maintaining that communication link is critical for successful operation.

In response to a request for information about practice at the regional level, Charles Price in District 4 put us in touch with Michael Lee, chief of electrical systems hardware support for that district. Lee told us that the district did not have any specific guidance documents that relate site characteristics (soil type, geography, etc.) to HAR performance. He discussed broadcasting challenges related to geography, such as hills throughout the region as well as low HAR signal strength compared with commercial stations operating at nearby frequencies. He said that the district makes use of synchronized transmitters when possible, which allow travelers to experience a seamless and unnoticeable transition from one HAR station coverage area to the next.

National Associations

AASHTO
Special Committee on Wireless Technology
http://www.transportation.org/?siteid=78

We spoke to Bill Brown, radio manager for Virginia DOT and chair of AASHTO's Special Committee on Wireless Technology. Brown described in general terms the importance of establishing a ground plane for HAR stations to ensure a strong signal, but said he was unaware of specific research in this area. Brown suggested that we speak with Information Station Specialists, an HAR provider based in Zeeland, MI. He noted that this company offers technical support, site surveying and planning, and he said that some of the HAR systems in Virginia were purchased through this company.

AASHTO's Bill Brownlow, the association's representative on the Special Committee on Wireless Technology, suggested that we contact Peter Moncure of HAR consultant RadioSoft, based in Toccoa, GA:

> "Peter Moncure is the vice president of RadioSoft, the firm AASHTO contracts with to perform our radio frequency coordination. Peter has more than 30 years experience in RF engineering and is recognized as an expert in radio propagation by the Federal Communications Commission. Peter also served as a member of the Telecommunications Industry Association (TIA) working group defining standards for the modeling of radio wave propagation and as AASHTO's technical representative to the Land Mobile Communications Council's Spectrum Committee."

Telecommunications Industry Association
Committee TR-8.18 Wireless Systems Compatibility—Interference and Coverage
http://www.tiaonline.org/standards/committees/committee.cfm?comm=tr-8 and select "TR-8.18" from the drag-down menu.

As noted, RadioSoft's Peter Moncure served as a member of the TIA. Our interview with Moncure follows in the **HAR Vendors** section of this Preliminary Investigation.

TRB
Intelligent Transportation Systems (AHB15) Committee
http://trb.org/CommitteeandPanels/Public/OnlineDirectory.aspx#DetailsType=Committee&ID=2074

We spoke with TRB committee representative Richard Cunard who was unaware of any specific research, either completed or in progress, related to HAR design and performance. He provided links to selected citations that address user experiences with HAR. These are included among the citation that appear in the **Research and Guidance Documents** section of this Preliminary Investigation.

Cunard also suggested that we speak with Maryland DOT. See Maryland's survey response in the **Survey of States** section of this Preliminary Investigation.

HAR Vendors

Information Station Specialists
http://www.theradiosource.com

We spoke with Information Station Specialists, a company based in Zeeland, MI, with 30-plus years of experience designing HAR stations and installing HAR equipment, including the design of some of Caltrans' systems. Bill Baker provided information on the company's approach to maximizing HAR performance through installation planning.

Baker said that for any HAR system, the first step is to define the geographic parameters. For a highway department, this would mean establishing the location of the motorists that need to hear the communicated message. Once this is established, selection begins for a reasonable location—both from a cost and an engineering standpoint—to meet the communication goal.

The company does not have detailed specification documents on site selection and installation considerations, but provides general guidance online at http://www.theradiosource.com/services-planning.htm. As an example, the planning steps for the ITS6000 Highway Advisory Radio System (http://www.theradiosource.com/products-its-plan.htm) are reproduced in part below. These address some considerations common across HAR installations.

Step 1: Conduct a frequency search.

Contact ISS to order a frequency search. Just provide the general area where the radio station(s) might be located. The $790 per-location cost includes the license-application work, as well, once you decide to move forward. ISS will develop a list of AM frequencies that are available and send them to you with our suggestions and instructions on how to monitor them.

Step 2: Survey onsite listening.

Survey the highways where listening is required with an automobile digital AM radio tuned to your candidate frequencies. Monitor all the candidate frequencies throughout the listening areas at least once during daylight hours and at least once after dark. Report your results to ISS, using the frequency-monitoring form. (See the "Why Nighttime Monitoring Is Important" web page.)

Step 3: Choose a general location for coverage.

On a local map, find the approximate geographic center of the listening area you want to cover. The HAR signal will propagate to a radius of 3-5 miles from this point in all directions. If this coverage does not encompass the highways that require coverage, consult with ISS regarding adding satellite stations. If a specific highway or intersection is critically important to cover, consider locations within ½ mile. Mark the map to show the area within which the antenna should be located to meet your coverage goals. Consider where signs will be placed to announce to motorists entering the area that the signal is available. (Resource: Read ISS' TechTalk article "Useful tips for placing road signs.") NOTE: ISS does not recommend installing antennas on rooftops or within 50 feet of buildings that contain electronics because of the potential for interference and equipment damage. This does not apply to non-building oriented situations such as isolated-style installations in which a cabinet with the electronic equipment is attached to the antenna support pole.

Step 4: Determine the desired National Weather Service All-Hazards Alert system notification coverage.

Verify reception of a National Weather Service channel (162.400-162.550 MHz) at the desired location. See coverage areas online at this NOAA web link (www.nws.noaa.gov/nwr/).

Step 5: Choose a specific antenna location.

For best coverage, the immediate location should be free of objects that exceed 25 feet (about 2 stories.) This includes tall buildings, trees, terrain features, lighting, power and communication poles and towers, overpasses and highway signs. Make certain 120VAC power and telephone service are available at the site and that there is a 40'-by-40' area of open ground for cabinet and antenna installation. A conventional, vertical profile or super antenna system may be used. Consult ISS for assistance.

Baker summarized that among the initial planning steps, the three most critical are frequency selection, site selection on a macro scale and site selection on a micro scale. He noted that rather than following this approach, some HAR users will first decide upon frequency and siting of HAR stations prior to consideration of whether the resulting station can meet the required communication needs. This can sometimes limit the performance of the HAR station, and it is not Information Station Specialists' preferred design approach.

For example, Baker said that a critical factor for an AM radio siting is openness of location. Coverage in an open valley can be as good as a high location (unlike FM, where height of antenna installation is the primary concern). It is important to avoid crowding by structural and environmental features. It is possible, but not preferable, to install an HAR station near a structure, and performance will suffer.

Baker also addressed the question of ground conductivity, a concern for the design of commercial AM radio stations. Based on the company's experience, this is only an issue in rare cases of extremely poor conductivity. Current HAR systems allow throttling of power up to 10 watts to compensate for poor ground conductivity and to produce the maximum signal strength allowable by the FCC. As a result, ground conductivity is very seldom a factor affecting signal propagation.

RadioSoft
http://www.radiosoft.com

RadioSoft's Peter Moncure had the opportunity to review the AASHTO survey questions and responded via email:

> In a nutshell, low-power AM without a suitable counterpoise is so highly determined by very local ground conductivity that good prediction is impossible. There is considerable variation in specific antenna installations as well. I could help some.

We followed up with a telephone interview with Moncure. He described how generally the design guidelines and calculations associated with large commercial AM stations don't apply to small-scale AM HAR stations. Moncure discussed with us some of the fundamental differences in approaching the design and deployment of HAR stations:

- Since the primary method of AM radio wave propagation is through the ground, it is highly dependent on the conductivity of the soil. For a commercial (e.g., 50,000-watt) station, the broadcast distances are great enough that variation in conductivity may be ignored, and the gross conductivity values provide a good idea of how radio signals will propagate. The broadcast range of an HAR station is so small—typically less than five miles—that the conductivity variations make a big difference. It is unusual to attempt to measure and account for ground conductivity when installing HAR stations.

- AM broadcast calculations assume a counterpoise, a grounding system that typically involves 120 copper wires radiating outward a distance of one-quarter of the broadcast wavelength (for a 640-kHz broadcast, that length is 384 feet). Due to the high cost of such a ground network, this is not constructed for HAR stations.

- Similarly, for HAR stations, it is unrealistic to install an AM antenna at an ideal height of one-quarter of the broadcast wavelength. Due to costs, zoning issues and construction considerations, it is typical instead to use a lower-efficiency antenna system.

The variation in the grounding systems and the small radius of operation for HAR stations result in propagation characteristics that can vary significantly, as much as ± 15 decibels, which makes performance hard to predict. Rather than following strict design guidelines, Moncure approaches performance questions by collecting information on the planned grounding and installation characteristics and suggests adjustments based on experience to achieve the desired broadcast range. For a given system, proper grounding can mean the difference of broadcasting two blocks or two miles, and an experienced installer can help direct siting and grounding decisions that will lead to desired performance.

Vaisala
http://www.vaisala.com/en/roads/products/highwayadvisoryradio

DOT representatives both from Oregon and Louisiana suggested that we contact Vaisala, a Louisville, CO-based firm whose products include HAR stations and related TIS. We spoke with Vaisala's Mark Feldman in the Sacramento, CA, area and Jerry Waldman in Missouri.

Feldman noted that Caltrans has approximately 175 HAR stations across its 12 districts, though different districts may have varying experience with HAR and approach installation differently. Vaisala has supplied all HAR equipment to Caltrans for the last seven to eight years, and Vaisala's equipment is compliant with all of Caltrans' specifications. Feldman noted that there is significant expertise within the Caltrans Office of Radio Communications Engineering, particularly the state's HAR specialist Matt Johns.

Feldman offered general guidelines related to installing HAR stations:

- It is important to survey the installation site and consider geography and terrain, such as mountains or large hills. However, right of way limitations typically put constraints on where HAR stations may be placed.

- In California, antenna height is limited to 49.2 feet above the surrounding terrain. An antenna must be mounted on a nonconducting pole with no other electrical equipment on it; the typical mount is a telephone pole or fiberglass pole. Usually Caltrans mounts the radio transmitters on a Model 334 Controller Cabinet located five feet from the antenna pole.

- Several considerations surround system grounding. Different districts use different configurations of straight-down grounding (single versus multiple tubes). Climate and the water table also play a role in grounding, particularly in arid areas where ground moisture changes seasonally. In these regions, the radio signal degrades when the earth dries out in the summer, and it strengthens in wetter seasons. Some regions adjust the signal strength semiannually to compensate for such changes in grounding conditions.

Research and Guidance Documents

Caltrans Specifications

Caltrans has documented its internal guidance and specifications related to highway advisory radio. These resources are attached as appendices to this investigation.

Appendix A. Caltrans Standard Special Provisions for Highway Advisory Radio.
This document addresses a range of provisions for HAR use in California, including transmission, power, and control equipment; transient/lightning protection; antenna and ground systems; installation; service manuals; cables and connectors; and system testing.

Appendix B. Caltrans Standard Special Provisions for Fiberglass HAR Poles.
This document details Caltrans' special provisions for fiberglass-reinforced plastic poles for HAR. It includes language on pole standards, strength requirements, construction, exterior projection, packaging, and installation.

Appendix C. Caltrans HAR Antenna Installation Plans.
These plan drawings present details for three types of HAR antenna installations: triad grounding systems, ground pole plane systems, and ground rod systems.

Appendix D. Caltrans HAR Maintenance Manual, 2003.
This document outlines standard procedures for the maintenance of HAR throughout California. It includes general descriptions of preventive and corrective maintenance, maintenance priorities, typical maintenance activities, and other definitions and procedures required to keep HAR systems in good operating condition.

HAR-Specific Resources

These transportation resources provide additional information on HAR station design and deployment. While they do not provide strict specifications on how to produce a desired broadcast range, they represent guidelines that assist other states in deploying HAR successfully.

Mn/DOT Intelligent Transportation System (ITS) Design Manual, 2010.
http://www.dot.state.mn.us/trafficeng/publ/2010_ITS_Manual.pdf
Minnesota DOT addresses HAR performance and installation considerations in section 5.8 of its ITS design manual. The following passages, excerpted from pages 61 to 63 of the PDF, address installation considerations both for 10-watt transmitters and for low-power transmitters that do not fall under the licensing scope of the FCC.

> 5.8 Highway Advisory Radio (HAR)
>
> "The localized transmissions may cover areas that range from 5 miles to 30 miles depending upon the terrain and technologies used. The radio transmissions may be either at fixed permanent locations or mobile devices that may be temporarily located and moved as needed."
>
> 5.8.1.1 10-Watt AM Transmission (FCC Licensed)
>
> "When properly maintained and installed, 10-watt transmitters have a broadcast radius of approximately 3–5 miles depending on topography, atmospheric conditions, and the time of day.

"The characteristics of the broadcast are also affected by the frequency used. The lower ranges of the band (e.g., 530 kHz) are adversely affected by power lines (because of its long wavelength). It also has problems with signal fade, which causes distorted transmission for a reasonable distance along the outer (fringe) areas of the coverage area. Because of this, it is uncommon to find any commercial broadcasters on this end, which is an advantage. On the other end of the spectrum, power lines have less impact on the signal, and a crisper fringe transmission."

5.8.1.3 Low-Power AM Transmission (No FCC License Required)

"Low-power HAR has been developed as a means of tightly controlling the broadcast zone and thereby limiting interference from adjacent zones. Low-power HAR differs from the previously discussed 10-watt HAR in that its broadcast radius (per transmitter) is generally limited to 500 feet to 1500 feet. By FCC regulation, each transmitter is limited to a maximum 0.1 watt power input to the final frequency stage, and the total length of the transmission line, antenna, and ground lead can not exceed 3 meters. Whereas this limits its broadcast range, it also provides for a reasonably well-defined area of influence, which, through an interconnection and synchronizing process, permits upwards of 100 transmitters to be coordinated into larger and well-defined saturation zones. Once a car leaves this broadcast area, the signal quality becomes too weak to be heard. This permits a second zonal configuration to be established nearby, transmitting a different message on the same frequency.

"By using this concept, a series of zones all operating on the same frequency, may be established whereby unique site-specific messages may be transmitted to provide condition updates in advance of decision points. Aside from the flexibility provided in establishing multiple message zones, low-power HAR may also broadcast over any available AM radio frequency without the need to obtain additional FCC licensing approval. Though the ability to install a system without FCC approval provides the user with great flexibility in installing a system wherever desired, there is no guarantee that once installed, it will not be interfered with by some future more powerful transmission.

"The relatively low signal strength must compete with a variety of obstacles, including overpowering commercial broadcasts, signal skip (particularly at night), and poor signal propagation. These difficulties can be overcome by saturating an area (zone) with multiple transmitters and synchronizing their broadcasts. However, this concept is relatively new and, very expensive as the number of transmitters required is large."

PennDOT Publication 646: Intelligent Transportation Systems Design Guide, draft posted 2010.
ftp://ftp.dot.state.pa.us/transfer/ClearanceTransmittals_1/BHSTE/Pub%20646%20ITS%20Design%20Guide%201st%20Draft/DRAFT%20Pub646%20ITS%20Design%20Guide%20-%20BQAD%20review%20comments.docx
In this draft guidance document, Pennsylvania DOT discusses the range of options for HAR transmission, including 10-watt and low-power AM as well as FM and digital. The document notes that 10-watt AM is "the most common method, and the one currently prevalent in Pennsylvania. … In the interest of standardization, new HAR deployments should utilize this transmission method. The maximum broadcast range, operating under ideal conditions (no buildings, flat terrain, etc.) is usually six to ten miles. Actual broadcast distance, for HAR currently deployed, is in the range of three to five miles. This is highly dependent on topography, atmospheric conditions, and the time of day."

Virginia DOT Highway Advisory Radio Replacement Analysis, Glenn Havinoviski, Wilbur Smith and Associates, and David Sutton, Virginia Department of Transportation, 2006.
http://www.itsva.org/resources/files/Havinoviski2006.pdf
This presentation to ITS Virginia compares benefits and costs of replacing a multitransmitter HAR system with a high-power transmitter to provide wide-area coverage in Virginia's Hampton Roads area. It cites issues with current HAR systems, including transmission limitations at night and during inclement

weather and problems with transmitter grounding. These result in a reduced broadcast radius compared with the intended design of the HAR.

Highway Advisory Radio (HAR) Systems, Thomas Nemeth, Edip Niver and Thomas Batz, National Center for Transportation and Industrial Productivity, New Jersey Institute of Technology, 2002.
http://transportation.njit.edu/nctip/final_report/HAR.pdf
In this research project conducted for New Jersey DOT, investigators experimentally mapped broadcast range of HARs using a network of vehicles equipped with radios. As stated in the abstract, "All operational HAR transmitters in New Jersey were identified and their coverage zones were quantitatively characterized in terms of the signal to noise ratio at the receiver. These experimental results were then compared to subjective qualitative audio reception, and detailed maps of HAR coverage zones along New Jersey highways were generated. Knowledge of current deployments of HAR around the country, and information concerning availability and pricing by vendors, were compiled. Finally, recommendations for existing and future implementations of HAR systems in the State of New Jersey were made."

Implementation of Highway Advisory Radio (HAR) for Construction Zones in Louisiana, Brian Wolshon, Christopher Schwehm, Louisiana Transportation Research Center, Report No. FHWA/LA.00/339, 1999.
http://www.ltrc.lsu.edu/pdf/2008/fr_339.pdf
On page 41 of the PDF, this report addresses how site-specific features of HAR "are associated with the basic operation of the system and can significantly impact the broadcast quality, range and clarity." The report lists and addresses items critical to site-specific evaluation:

- The proximity of the transmitter to tall trees, buildings and metal structures.
- The proximity of the transmitter and sign beacon flash activation system to electric power lines.
- The soil composition and elevation of ground water table in the vicinity of the transmitter.
- The proximity of the transmitters and flash activations system relative to utility services.

Virginia Department of Transportation HAR Operational Guidelines, 1995.
http://trid.trb.org/view.aspx?type=MO&id=448148
These guidelines were developed to help Virginia DOT personnel effectively operate HAR systems and include a section on transmitter placement. The guidelines are based on the research report **An Investigation of Operational Procedures for Highway Advisory Radio Systems**. (See the next citation in this Preliminary Investigation.)

An Investigation of Operational Procedures for Highway Advisory Radio Systems, Brian Smith, Catherine McGhee, Bruce Newman, Steven Jones, Jr., and Amy O'Leary, Virginia Transportation Research Council, Report No. VTRC 96-R4, 1995.
http://trid.trb.org/view.aspx?type=MO&id=454951
This report includes a section titled "Transmitter Placement and Technology" on pages 14 and 15 of the PDF. The following items are excerpted from this section:

> "Site visits in Virginia, and interviews with HAR operators in other states, revealed that the HAR transmitters currently in use do not generate high-quality signals. While careful attention to tuning and a properly-installed ground plane can improve signal quality, the primary problems are the low power and frequency restrictions imposed by the FCC … .
>
> "VDOT has also taken steps to address the problem of HAR signal quality. First, the Department has acquired a license to operate on 650 AM in Northern Virginia. This frequency alleviates some of the signal strength problems associated with broadcasting on the ends of the AM band (at either 530 AM or 1610 AM). However, the transmitter power is still limited to 10 watts. In addition, VDOT is attempting to procure new HAR transmitters in the Hampton Roads region which the manufacturer

claims will have the capability of broadcasting up to 40 km (25 miles) without exceeding the FCC's 10-watt limit.

"Another variable affecting transmitter placement is the quality of automobile radio receivers. During site visits in Virginia, it was discovered that radios in different automobiles can vary dramatically in their capability to receive HAR signals. For example, in one vehicle, the HAR signal was clearly received 8 km (5 miles) from the transmitter, while in another vehicle the signal was not received until it was well within 1 km (0.6 miles) of the transmitter.

"Finally, two different antenna configurations available for HAR systems were investigated. VDOT currently uses vertical monopole antennae which have generated signals intelligible 5 to 13 km (3 to 8 miles) from the transmitter, thus allowing messages to be heard for as long as 15 minutes. The monopole antenna represents about $1,000 of a system's total cost. However, another option some agencies have used is the "leaky" cable antenna, which is buffed or hung along the roadway and radiates a weak signal just strong enough to be detected along the length of the cable.

"Radiating cable antennae are restricted to a maximum length of 3.0 km (1.86 miles). Thus, they can broadcast messages that are heard by traffic for about two minutes, assuming motorists are tuned in as the coverage begins. Capital costs for cable antennae may range from $16 to $23 per meter ($5 to $7 per linear foot). A 3.0 km (1.86 miles) antenna may cost on the order of $50,000. In addition, installation and maintenance costs of cable antennae are very high. Trenching costs for burying the cable to protect against vandalism and the environment are approximately $5.75 per meter ($1.75 per linear foot) under normal conditions."

An Assessment of the Future of Travelers' Information Stations, William B. Grant and Ray E. Thompson, U.S. Department of Commerce, 1985.
http://www.its.bldrdoc.gov/pub/ntia-rpt/85-178/85-178_ocr.pdf
This report addresses technical considerations for HAR, referred to throughout as Travelers' Information Stations or TIS. Section 5 of the report, "Sharing Problem Analysis," addresses several concerns related to AM spectrum broadcasting for TIS. Topics in this section include:

- Current limitations on TIS coverage (page 69 of the PDF).
- Desired coverage considerations (page 70).
- Coverage considerations for low-power communication devices (page 84).

The chapter includes a number of related tables and figures as well.

Systems Analysis and Design Guidelines for Highway Advisory Radio, H. C. Turnage, National Technical Information Service, Report No. FHWA-RD-80-177, 1981.
http://trid.trb.org/view.aspx?type=MO&id=171516
This project consisted of seven tasks related to HAR: analytical and empirical analysis of HAR system components; HAR system installation, operations and maintenance; HAR visual signing and messages; technical advice; HAR system design guidelines; recent HAR developments; and the development of a users' guide.

FHWA published the following five additional reports under this contract presenting a range of guidance related to highway advisory radio.

Systems Analysis and Design Guidelines for Highway Advisory Radio: Executive Summary, H. C. Turnage, National Technical Information Service, Report No. FHWA-RD-80-176, 1981.
http://trid.trb.org/view.aspx?type=MO&id=171515
This document is an executive overview of the HAR research program described in the summary above.

Highway Advisory Radio Guide, H. C. Turnage, National Technical Information Service, Report No. FHWA-RD-80-166, 1981.
http://trid.trb.org/view.aspx?type=MO&id=171520
This report is a planning guide for users and potential users of HAR systems. It contains introductory material on HAR and its applications, specific instructions regarding FCC license applications for HAR stations, descriptions and specifications of HAR components, installation recommendations, operation and maintenance information, and recommendations pertaining to HAR message preparation.

Highway Advisory Radio System Design Guidelines, H. C. Turnage, National Technical Information Service, Report No. FHWA-RD-80-167, 1981.
http://trid.trb.org/view.aspx?type=MO&id=171519
Individual chapters of this report address FCC requirements and restrictions, factors affecting HAR reception, HAR system design options, HAR transmitters, monopole antennas, cable antennas, audio recorders and reproducers, telephone line interfacing, signing, audio message preparation, and HAR system costs. The report also includes one complete design example.

Mathematical Analysis of Electromagnetic Radiators for Highway Advisory Radio. Volume I: Vertical Monopoles, T. E. Baldwin, J. J. Foster, J. K. Raines, and H. K. Schuman, National Technical Information Service, Report No. FHWA-RD-80-178, 1981.
http://trid.trb.org/view.aspx?type=MO&id=171517
This report presents mathematical analysis of the radiation characteristics of HAR vertical monopoles. The two types of analysis considered in this effort were modeling of antennas by method of moments techniques and modeling by an equivalent circuit representation. Computer simulations compared the predictions of the models with measured radiation characteristics of actual HAR monopoles.

Mathematical Analysis of Electromagnetic Radiators for Highway Advisory Radio. Volume II: Cable Antennas, J. K. Raines, National Technical Information Service, Report No. FHWA-RD-80-179, 1981.
http://trid.trb.org/view.aspx?type=MO&id=171518
This report contains the results of the mathematical analysis of buried cable antennas for HAR applications. The two types of cables modeled in this effort were buried slotted cables with arbitrary slot aperture angle and buried spiral wound cables. Results of computer simulations were compared with measurements made on actual HAR cables.

AM Radio Fundamentals

These resources describe fundamentals of AM radio and the physics underlying ground wave propagation. Factors that affect signal strength have been highlighted.

Essentials of Radio Wave Propagation, Christopher Haslett, Cambridge University Press, 2008.
http://www.worldcat.org/title/essentials-of-radio-wave-propagation/oclc/166357691
Much of this resource focuses on higher frequencies associated with digital mobile technologies. However, Chapter 2, "Point-to-Area Transmissions," presents the mathematics that relate power density and electric field strength (page 28), converting from field strength to received signal power (page 30), and predicting field strength at a distance (page 31).

Standard Handbook of Broadcast Engineering, Jerry Whitaker (editor-in-chief), McGraw-Hill, 2005.
http://www.worldcat.org/title/standard-handbook-of-broadcast-engineering/oclc/439033792
Chapter 2.1, "Radio Broadcast Systems," addresses the basics of field strength and propagation of radio waves. As stated on page 2-7, "If the transmitted power, antenna radiation characteristics, and ground conductivity are known, the extent of coverage (or interference) in a given direction for a particular station can be calculated with a high degree of accuracy. These calculations form the basis of the FCC's station allocation system and are based on field intensities with the unit of measure as volts per meter (the voltage induced in an antenna 1 m in length)."

Field Antenna Handbook, U.S. Marine Corps, Publication No. MCRP 6-22D, 1999.
http://www.aresmat.us/ArmyMARS/Antennas/Resources/usmc-antenna-hb.pdf
The fundamentals of AM radio wave characteristics and propagation are explained and illustrated in this online resource.

Handbook of Radio and Wireless Technology, Stan Gibilisco, McGraw-Hill, 1999.
http://www.worldcat.org/title/handbook-of-radio-and-wireless-technology/oclc/39261799
Chapter 1, "Electromagnetic Waves," addresses topics such as propagation modes (page 13), which includes a discussion of ground wave propagation, and propagation at various frequencies (page 21).

The Radio Manual, George Sterling and Robert Monroe, D. Van Nostrand Company, 1950.
http://www.worldcat.org/title/radio-manual/oclc/1468320
The fundamental of AM radio are presented in Chapter 6, "Amplitude Modulation" (page 152). Chapter 16, "Radio Wave Propagation" (page 675), describes propagation of different kinds of waves, including AM ground waves.

Fundamentals of Radio, Edward Jordan, Paul Nelson, William Osterbrock, Fred Pumphrey, Lynne Smeby and W. L. Everitt (editor), Prentice-Hall, 1942.
http://www.worldcat.org/title/fundamentals-of-radio/oclc/5847863
Chapter 15, "Radio Wave Propagation," describes the principles underlying ground wave propagation. Figure 15-2, Effect of Frequency and Ground Conductivity upon the Strength of the Ground-Wave Signal (page 342), is reproduced below. The plot shows field strength, measured in milllivolts per meter, versus distance, measured in miles. Six lines are plotted: 500 kHz (shown as kc, or kilocycles per second), 1,500 kHz and 3,000 kHz, each in earth with good conductivity and with poor conductivity.

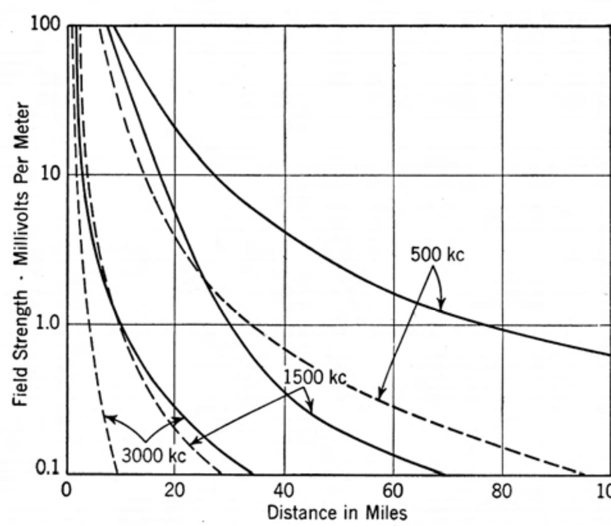


FIG. 15-2. Effect of Frequency and Ground Conductivity upon the Strength of the Ground-wave Signal. Solid lines: fairly good conductivity (100×10^{-15} e.m.u.). Dashed lines: poor conductivity (20×10^{-15} e.m.u.).

Regulatory Information

The following web resources provide additional regulatory information related to HAR and low-power AM radio.

FCC regulations on HAR
http://frwebgate.access.gpo.gov/cgi-bin/get-cfr.cgi?TITLE=47&PART=90&Section=242&TYPE=TEXT
The U.S. Code of Federal Regulations, Title 47, Part 90, Section 242, governs TIS and, specifically, FCC licensing for HAR stations.

FCC's AM Broadcast Radio Stations web page
http://www.fcc.gov/mb/audio/am.html
This page contains links to numerous pages within the FCC web site that address regulatory and technical information on AM radio.

FCC's Low Power Broadcast Radio Stations web page
http://www.fcc.gov/mb/audio/lowpwr.html
The FCC's Audio Division assembled general information to answer commonly received questions on the subject of low-power and micro-power radio stations. Requirements for licensure is a main topic of this page.

Caltrans Standard Special Provisions for Highway Advisory Radio

10-3.20 HIGHWAY ADVISORY RADIO SYSTEM

DESCRIPTION

The highway advisory radio (HAR) system shall consist of AM broadcast band radio equipment for a fixed location.

All work shall comply with the Code of Federal Regulations (CFR), Title 47, Section 90.242.

The HAR system shall include one AM transmitter, coupler, audio processor, telephone line interface, solid-state recorder/player, one antenna, fiberglass pole, grounding system, transient lightning suppression, battery back-up/charging systems, external digital recorder/player microphone, (or broadcast quality headset with noise canceling microphone), and control speaker phone.

The outside of each equipment packing container shall be marked with the Caltrans contract number and the make, model number, serial number, and installed operating frequencies of the unit within.

Test methods followed by the State for evaluation of supplied equipment will follow EIA recommendations where applicable.

Prototype equipment will not be acceptable. Only equipment previously marketed and sold for at least 6 months prior to the advertising date will be acceptable.

Any semiconductor devices or components utilized in the radio equipment which are not available from a minimum of two manufacturers shall have five such devices or components provided for each device utilized in the radio equipment.

All manuals, warranty forms, and license forms shall be submitted with the unit(s) for acceptance.

All equipment shall be warranted against defects and any failures which may occur through normal use for one year from the date the equipment is placed in service.

Proper contact protection shall be placed at all high voltage connections to prevent accidental contact with operators and operator's tools and equipment.

The HAR system may consist of equipment from multiple manufacturers but shall be integrated to be fully functional.

The HAR system shall be designed to operate in conformance with CFR Title 47, Section 90.242 of the FCC rules and regulations.

Enclosures and all radio, electrical, and mechanical equipment shall be designed to be card rack or shelf mounted inside a Caltrans standard Model 332/334 controller cabinet enclosure as described in Section 86-3.01, "Controller Assemblies," of the Standard Specifications. Card rack mountable equipment shall be provided with slotted mounting holes and shall be compatible with an EIA-310B rack.

The equipment shall be designed and installed in such a way to be easily accessible for maintenance.

TRANSMITTERS

The transmitters shall be the type certified and accepted by the FCC for travelers information stations (TIS) service, and shall operate in a range from 530 kHz to 1700 kHz.

Each transmitter shall have the capability of remote and local control. The ability to broadcast live messages from the transmitter site and the ability to record and broadcast from the Transportation Management Center (TMC) shall be provided.

Adjustment of RF power output shall be made by using an easily accessible control and shall be adjustable over the transmitter output power range specified herein.

Built-in, switchable meters shall indicate relative percentage of modulation and forward/reflected RF output power levels.

A provision for automatic station identification using stored, digitized audio shall be provided every 30 minutes while transmitting.

Operating temperature range shall be from -30 to 60 °C. Operating humidity range shall be from 20 percent relative at 30 °C to 95 percent relative at 50 °C.

The HAR shall deliver a 0.6 mV/ft signal, minimum, at a distance of 0.93 miles from the station with a maximum transmitter output of 10 watts.

The transmitter shall withstand an overload mismatched output (including an open or short circuit) for a period of 5 minutes at 10 watts output without overheating or component failure. The transmitter shall automatically resume normal operation when the mismatched output load is removed.

The transmitter RF power output level shall be rated at 30 watts, maximum. The transmitter output level shall be adjusted from a minimum of 2 watts to no more than 10 watts. A warning label shall be securely attached to the transmitter next to the adjustment output control and shall read as follows, "DO NOT EXCEED 10 WATTS".

Transmitter	
RF Power Output	Adjustable to 10 W
Type of Emission	Amplitude modulation (A3)
Frequency Range	From 500 kHz to 1.7 MHz
Frequency Stability	±0.004 percent (From 0 to 35 °C)
Carrier Shift	2 percent Max
Harmonic Attenuation	45 dB or better
Noise	-60 dB below 95 percent modulation (From 100 Hz to 3 kHz)
Audio input	600 Ω balanced
(for 100 percent modulation)	-30 dBm Min
Frequency Response	From 20 Hz to 15 kHz ±1.0 dB Max
Audio Distortion	Less than 1.2 percent at 99 percent modulation (From 100 Hz to 3 kHz)
Modulation Monitoring	100 percent peak flasher Built-in envelope detector
Modulation Limiting	Built-in 100 percent peak modulation limiter 20 dB gain reduction: defeatable
Power Consumption	1.5 A at 12 V(dc)

Transmitter Station

The transmitter station shall include the amplitude modulation (AM) transmitter and antenna system, digital recorder system, lightning protection, controls, dual tone multi-frequency (DTMF) telephone handset, back-up system, conduit, wiring and other hardware required for proper operation. The transmitter station shall be housed in a Model 332/334 cabinet enclosure.

The operating frequency of the transmitter shall be 1610 kHz as shown on the plans.

POWER/VOLTAGE STANDING WAVE RATIO (VSWR) METER

One radio frequency (RF) power/VSWR meter shall be included with the transmitter. The power/VSWR meter shall measure output power between the antenna and the RF output of the transmitter coupler. The power/VSWR meter shall have the following features and requirements:

A. Meter.--Displays forward RF power, reflected RF power and SWR. Uppermost scale is for high (H) and low (L) power SWR reading. Low power SWR scale is for RF power below 30 W. High power SWR scale is for RF power over 30 W. Second and third scales are for RF power measurement, which are 30 W, 300 W and 3 kW full scales.
B. Range Switch.--Selects full scale RF power reading between 30 W, 300 W and 3 kW.
C. Function Switch.--Selects measurement function between RF power and SWR.
D. Calibration Knob.--Sets RF power to full scale reading depending on transmitting RF power to measure SWR. Readings increase as the knob is being turned clockwise in transmission.
E. Power Direction Switch.--Selects RF power measurement between forward RF power and reflected RF power.
F. Meter Zero Adjustment Screw.--Adjusts the meter indicator to zero position with regular screwdriver if the indicator is far from zero position when the unit is not in use.
G. Transceiver.--RF power input from a radio equipment which is to be connected by 50 Ω coaxial cable with UHF connector.
H. Antenna.--RF power output to an antenna or a dummy load which is to be connected by 50 Ω coaxial cable with UHF connector.
I. 13.8 V(dc).--(dc) power source for meter illumination and LED display. Acceptable DC voltage range is from 11 V(dc) to 15 V(dc). Connect red line for positive and black line for negative polarities. This power source is not essential for measuring purpose.

COUPLER UNIT

The coupling unit shall:

A. Isolate the transmitter from high voltage through the use of high-pass capacitors and fuses.
B. Compensate for antenna system impedance mismatch through the use of multi-tap toroidal transformers.
C. Compensate for antenna stray reactance through the use of a decade system of capacitor combinations.
D. Include an internal VSWR meter and include controls for correcting load impedance and reactance.

HAR POWER AND BACK-UP EQUIPMENT

Equipment necessary for operation and backup of the HAR shall be included as part of the system and shall conform to the following.

Primary Power Input Provisions

Operation shall be from 117 ±10 percent V(ac), 60 ±3 Hz single phase, at a power input not to exceed 150 watts, continuous.

The primary input power shall be controlled by a circuit breaker mounted on the front panel labeled "AC POWER".

An AC power light indicator shall be provided on the front panel.

Interface Unit

The highway advisory radio system shall be supplied with an interface unit containing all system power control including chargers, isolation relays, metering, switches, fuse indicators and audio/power arrestors. The interface unit shall plug into 120 V(ac) power in the cabinet via a standard 120 V(ac) cord and plug. Barrier strips on the rear provide for telephone line input and output, battery charge/discharge and 24 V power distribution to components. "HAR INTERFACE" shall be marked on the outside of the unit.

Main Power Back-up

In the event of AC power loss, the HAR system shall automatically switch to a battery back-up system and continue to operate without degradation of performance for a period of not less than 12 hours.

The battery back-up system shall utilize a battery charger and gel cell batteries. The battery back-up system shall maintain the batteries without overcharging. The batteries shall not emit any corrosive, toxic, or explosive gasses.

The HAR system shall resume normal operation after AC power has been restored.

Indicator lights shall be provided to show when the unit is operating on AC power, or when it is operating on battery back-up. A voltmeter shall show the condition of the battery back-up system.

A front panel switch labeled "DC POWER" shall activate DC operation for the HAR system.

Fuse protection shall be provided on the battery charger and on the front panel for DC load.

The battery charger shall be designed for floating service and have an adjustable output voltage. The battery charger shall be the complete shut off type (fully automatic) and shall bring completely discharged batteries to a fully charged condition within 12 hours. The battery charger shall be designed to operate in unventilated area.

When the HAR is operating on battery back-up, the system shall automatically disconnect the HAR, to protect the batteries from damage caused by too deep a discharge. The disconnect threshold shall be adjustable over the range of either from 20.0 to 24.0 V(dc) for a 24 volt system or from 10 to 12 V(dc) for a 12 volt system.

The batteries shall not discharge to less than 10 V(dc) for a 12-volt system, or 20 V(dc) for a 24-volt system, when supplying 4.0 amperes for a period of 30 hours at 30 °C. They shall be organized as a group of two 12 volt batteries and mounted on a wooden frame at the bottom of the controller cabinet enclosure.

The batteries shall be easily accessible and removable from the cabinet for service or replacement using connectors that do not require the use of hand tools. If 2 connectors are identical, and used for different purposes, they shall be clearly marked or polarized differently to ensure proper installation after repair or replacement of component parts. When the battery back-up system is disconnected from the cabinet, the station shall be capable of continued operation solely on AC power without having to connect, jump, or bypass any other device. Only relay, contact, and switch type devices shall be used to make a clean procedure of removal.

HAR OPERATION CONTROL EQUIPMENT

Equipment necessary for local and remote control of the HAR operations shall be included as part of the system and shall comply with the following.

Local Control Facilities

Local operator control of all essential features of the highway advisory radio station shall be accomplished either by the use of a standard dual tone multi-frequency (DTMF) telephone or by necessary discrete front panel controls.

Remote Control Facilities

A telephone line interface shall be provided so that the HAR may be connected to and controlled through a voice-grade dial-up telephone line, leased telephone line, or cellular telephone line with appropriate interface. The telephone line interface shall have a standard RJ-11 connector.

The HAR shall be equipped with a telephone line interface so that it will be possible to access, monitor and control the message being transmitted. The audio for the monitor function shall be obtained by demodulating the transmitter audio.

HAR MESSAGE STORAGE AND MANAGEMENT EQUIPMENT

Equipment necessary for storage and management of messages shall be included as part of the HAR and shall comply with the following.

Message Management

The HAR shall be able to receive a live or recorded message from a remote location via the telephone line and/or cellular telephone line or from the operator at the station location. This feature shall not require the use of hand tools.

The message shall be stored in a solid-state recorder/player, with the ability for selecting and checking the message prior to transmission.

Solid-state Recorder/player

Non-volatile solid-state memory shall be used for message storage. Magnetic media will not be acceptable.

A DTMF decoder shall be provided for programming and control of the recorder using a standard DTMF telephone. This function shall be possible, both remotely, via the telephone line interface, and at the station location. The DTMF tones shall not be recorded on the message.

Memory storage capacity shall be provided for a minimum of 250 different messages, with a minimum of 860 seconds total recording time. The length of each message shall be continuously variable up to the total recording time available.

The recorder shall have the flexibility for messages to be organized into a minimum of 20 different playlists with a minimum total of 100 different messages contained within the 20 playlists.

An internal clock shall be provided to select and control message play-back by day, hour and minute.

The system shall allow the recording of a message while another message is being broadcast.

Recording features shall include:

A. Monitor off-air RF output of transmitter
B. Recording message
C. Playback of recorded message
D. Erasing of message
E. Set time spacing between messages
F. Set playlist sequence
G. Hear playlist sequence
H. Set recording source input (dynamic microphone, cassette player (auxiliary audio input), and control telephone)
I. Set recording speed
J. Set background source materials message.
K. Set alternate audio source
L. Set clock time and day of the week (clock time shall be in military time and day of week shall be from 1 to 7, where 1 is Sunday)
M. Set message schedules
N. Hear message schedules
O. Cancel message schedules
P. Set playlist number
Q. Hear playlist number
R. Cancel playlist number
S. Stop record
T. Set remote record security code

Note 1: The days of the week shall be numbered consecutively from 1 to 7 beginning with Sunday.

The functions of recording and editing shall be accessible remotely or locally.

The recorder shall be able to be configured in the message repeater mode using DTMF tones.

Frequency response shall be from 200 to 10,000 Hz.

The solid state recorder/player shall have the following functions:

Recorder/Player Function	Function Access Tone	Command Action Tone
Turn transmitter on	*62#	2008#
Turn transmitter off	*62#	2009#
Recording message	*1#	(message number)#
Playback of recorded message	*2#	(message number)# 999# playback all in order (1000+message number)#beginning only 1999# beginning of all
Erasing of message	*3#	(message number)#
Set time spacing between messages	*4#	(spacing in seconds)#
Set selected message sequence	*5#	(Message number)#(message number)#, etc. 999# play all in order % repeat
Hear selected message sequence	*6#	
Cancel selected message sequence	*5#	0#
Set local recording source	*7#	1# Dynamic microphone 2# Cassette Player aux 3# Control telephone
Set recording speed (see note 1)	*8#	1# 859 seconds 1004# 644 seconds 2# 481 seconds 1011# 266 seconds
Set single audio source	*9#	0# Prevents play through
Set clock time and day of the week	*21#	(Day number)# (Four digit military time)#
Create play list number	*41#	(Play list number)# (Message number)#(message number)#, etc.
Hear play list number	*42#	(Play list number)#
Schedule play list	*43#	(Play list number)#
Cancel play list number	*44#	(Play list number)# 999# Cancel all play lists
Schedule play list by day	*22#	(Day number)#(time)#(1000+Play list)
Cancel schedule	24#	(Day number)# 999# Cancel entire week
Terminate programming	*51#1#	
Stop record	#	
Transmitter audio monitor	*62#	7900#
Set remote record security code	*71#	(New code)#

The above described equipment is available from Information Station Specialists, Zeeland, Michigan, (tel) 616-772-2300.

Memory Power and Back-up

The recorder shall operate on 24 V(dc) ±5 percent at a total power consumption not to exceed 10 watts from the source. The recorder memory back-up shall operate on 8 to 24 V(dc).

In the event of AC power loss to the digital recorder, the memory power back-up shall automatically maintain messages in the memory for up to two weeks.

HAR TRANSIENT / LIGHTNING PROTECTION

The transient/lightning (T/L) protection shall be provided for the power line, telephone line, and antenna system.

The (T/L) protection for the power line shall provide as a minimum protection the following:

Number of AC outlets (minimum):	5
Turn-on voltage:	200 V
Energy rating (minimum): IEEE 8/20 waveform	700 J
Peak current (minimum):	20,000 A
Stand-by current (maximum), for 60 Hz:	1 mA

The (T/L) protection for the telephone line shall provide as a minimum protection the following:

Clamping voltage:	200 V ±10%
Energy rating (minimum):	400 J
Series resistance (max.):	30 ohms
Response time (maximum):	1 ns

The (T/L) (lightning arrestor) protection for the antenna system shall provide as a minimum protection the following:

Clamping voltage:	90 volts ±10%
RF power (minimum):	35 W
Frequency range:	From 500 kHz to 2 MHz
VSWR (maximum):	1.2 to 1
Insertion loss (maximum):	0.2 dB
Surge current (minimum): IEEE 8/20 waveform	17,000 A
Response time (maximum):	5 ns

ANTENNA

The antenna shall be a center-loaded vertical whip type with loading coil.

The antenna shall be designed to be mounted on a fiberglass pole as shown on the plans. The length of the antenna shall be tuned for the selected frequency and shall not be less than 10 feet and not more than 25 feet. The top of the antenna shall extend 49 feet above ground level.

The antenna shall be anodized aluminum with a tuning tip. The tip shall be adjustable for precise tuning and shall be made of stainless steel tubing.

The antenna shall be the weather resistant type and shall operate within a temperature range of -40 to 85 °C. It shall withstand wind velocities of 80 miles per hour without any discernible damage while remaining functional.

The maximum weight of the complete antenna including lower base, loading coil form, mid tip pipe and adjustable stainless steel tip shall not exceed 12 lbs.

The lower base of the antenna shall be aluminum with gold anodized finish.

The loading coil shall be a continuous filament glass fabric and the coil shall be made of enameled close wound copper wire.

The antenna mounts shall be the "high impact thermoplastic split" type and shall provide 360 degree support to the antenna. All other mounting hardware shall be stainless steel or cadmium plated.

Attention is directed to the requirements for fiberglass highway advisory (HAR) pole, in these special provisions.

GROUND SYSTEM

The ground system shall be the triad ground type as shown on the plans and described in these special provisions. The ground system shall allow the maximum FCC field strength to be achieved on any frequency from 530 kHz to 1700 kHz with 10 watts or less of output power.

Triad Ground System

The triad ground system shall use three 2" x 20' copper pipes placed in 6 inch minimum x 10 feet depth, vertically drilled holes and backfilled with bentonite slurry.

Each ground rod shall be a UL listed ground electrode designed for the purpose. The Contractor shall provide the Engineer with a certificate of compliance from the manufacturer in accordance with the provisions of Section 6-1.07, "Certificates of Compliance," of the Standard Specifications for the ground rods and bentonite backfill material. The certificate of compliance shall be provided to the Engineer for approval, prior to ordering or shipping the material.

Each ground rod shall be a 2.125-inch outside diameter hollow tube of Type K copper, with nominal 0.083-inch wall thickness, 20 feet in length. The top end of each rod shall have a shop welded ground connection with a 4/0 gage, minimum, copper pigtail. The ends of the rods shall have a press-on end caps.

The breather and weep holes on the top and bottom of the rods, as shown on the plans, shall be protected with tape until the installation of the rod. The Contractor shall remove the tapes and provide them to the Engineer before installation.

The drilled hole shall be backfilled with 100 percent bentonite clay slurry and consolidated around the rod. The bentonite slurry shall be placed in the presence of the Engineer. Two working days notice shall be provided to the Engineer prior to backfilling.

The bentonite backfill material shall be a natural volcanic, non-corrosive form of bentonite clay grout. The backfill material shall be capable of absorbing 14 gallons of water per 50 pounds to obtain an optimal 30 percent solids density. The pH value shall be 8-10 with maximum resistivity of 1 Ω/ft at 30 percent solids density.

The ground rods shall be connected to surge arrestor ground lugs. The ground wire splice to the pigtails shall be made by a UL listed exothermic (Cadweld, or similar) connection method. Soldering, brazing, or field welding will not be acceptable.

The ground rods shall be filled with non-hazardous Calsolyte to enhance grounding performance. The filler shall hygroscopically extract moisture from the air to activate the electrolytic process, improving ground performance. The ground rods system shall be 100 percent self activating and maintenance free. No additions of chemicals or water solutions shall be required.

Protective Pull Box

The protective pull box shall be made of reinforced concrete with lift holes and a vented cast iron grate cover to permit air circulation into the "breather" holes of the ground rod(s).

HAR INSTALLATION

HAR equipment shall be installed at the locations shown on the plans. The Contractor shall terminate the power conductors on the TBS terminal of the controller cabinet enclosure. The Contractor shall terminate the telephone cable at the barrier strips on rear of the telephone line interface unit.

The installation shall be under the immediate supervision of a person holding an FCC general class radio telephone operators license.

SERVICE MANUALS

The Contractor shall provide 5 service manuals which will contain the following described sections.

Introduction

Each manual shall contain a general information section which shall include the following items:

A. A list of applicable sub-assemblies that comprise the specified equipment.
B. Overall description of the equipment design features, performance, and applications.
C. Equipment specifications summary.
D. Equipment installation instructions, if applicable.

Theory of Operation Section

Each manual shall contain equipment theory of operation section which shall include the following items:

A. Theory of operation of the standard equipment, with unique or unusual circuitry described in detail.
B. Theory of operation reflecting any modifications to the standard equipment.

Maintenance Section

Each manual shall contain an equipment maintenance section which shall include the following items:

A. Recommended test equipment and fixtures, or minimum operational and performance requirements for appropriate test equipment.
B. Troubleshooting information and charts.
C. Removal and installation procedures for replacing assemblies and subassemblies, if not obvious or if improper sequencing of steps may result in component damage.

Replacement Parts Section

Each manual shall contain an equipment replacement parts section which shall include a component parts list(s) including electrical parts, mechanical parts, and assemblies. All semiconductors shall be identified by the supplier's numbers and, as applicable, by JEDEC numbers.

Diagram Section

Each manual shall contain an equipment diagram section which shall include the following items:

A. Schematic diagram(s) identifying all circuit components and showing normal test voltages and levels.
B. An overall functional block diagram.
C. Detailed interconnecting diagram(s) showing wiring between modules, circuit boards, and major components.
D. Pictorial circuit board layout diagram(s) showing both component placement and printed wiring detail.
E. Diagram(s) showing location of circuit boards and other subassemblies.
F. Exploded view diagram(s) of complex mechanical assemblies.

Physical Requirements

Each manual shall conform to the following physical requirements:

All pages, including latest revisions, shall be securely fastened together between protective covers (loose-leaf ring binding is acceptable).

No page shall be subject to fading from exposure to any normal source of ambient lighting (ozalid reproduced pages are not acceptable).

The cover or first page shall be marked in any manner to show the Caltrans Contract number and advertising and bid opening dates.

ARRESTOR ENCLOSURE

The arrestor enclosure shall be a NEMA Type 3R with hinged cover, with dimensions of 12" x 10" x 6" (±0.25"), and shall have provisions for padlocking. A 4" x 4" x 0.1" aluminum plate shall be installed vertically, facing the door, in the enclosure as shown on the plans. The Contractor shall terminate the ground conductor(s) with an aluminum-copper NEMA one and/or three bolt hold tongue. The ground conductor(s) and lightning arrestor shall be mounted on the aluminum plate.

ANTENNA COAXIAL CABLE (ACC)

The ACC shall consist of an RG-8/U single foil single braid flexible coaxial cable with a solid bare copper center conductor, Cellular Polyethylene dielectric, 97 percent tinned copper braid, and 100 percent shield coverage and shall conform to the following requirements:

Electrical Characteristics	
Capacitance	26 pF/ft (nominal)
Impedance	50 ohms (nominal)
Velocity of Propagation	78% (nominal)
DC Loop Resistance	1.2 ohms per 1000 ft. (nominal) at 20 °C.

Attenuation at 20 °C.	
Frequency (MHz)	Nominal dB/100 ft
10.0	0.50
50.0	1.20
100.0	1.6
200.0	2.4

Physical Dimensions	
	Nominal OD (inches)
Center conductor	0.103
Dielectric	0.285
Outer jacket	0.405

ANTENNA FEEDING CABLE (AFC)

The AFC shall consist of a No. 12 AWG solid copper conductor. The AFC shall have a length necessary to connect the lighting arrestor and the antenna without causing stress to the cable and shall be terminated with a UHF plug and a reducing adapter as specified in these special provisions.

After installing the AFC between the arrestor enclosure and the antenna, the Contractor shall seal the 1 1/2" nipple near the top of the fiberglass pole.

COAXIAL CABLE CONNECTORS (FOR TYPE ACC AND AFC)

Coaxial cable connectors for attaching Type ACC and AFC including the reducing adapter shall be UHF Standard and meet the following requirements:

Electrical Characteristics	
Impedance:	50 ohms (nominal)
Frequency Range:	From 0 - 300 MHz
Voltage Rating:	500 V peak

Mechanical	
Mating:	Standard size: 5/8" - 24 threaded coupling Push-on mates with any standard size threaded receptacle
Method of Attachment:	Clamp and Crimp.
Composition:	Bodies - Brass or die cast zinc Contacts - brass, silver plated Insulators - TFC, copolymer of styrene, polystyrene, mica-filled phenolic or, PBT polyester or equal Plating- ASTRO plate and silver Other metal parts- Brass

Environmental	
Temperature	From -55 °C to +165 °C
Moisture	Weather resistant design.

SYSTEM TESTING

Ground System Testing

The Contractor shall take certified measurements after the installation of the ground system.

The testing shall utilize an earth resistance meter and be conducted in accordance with IEEE Standard 3-point fall of potential method.

The Contractor shall provide all test equipment, take and document resistivity measurements on the grounding system as specified in these special provisions and submit the test results to the Engineer for approval.

Cable Testing

The antenna coaxial cable (ACC) will be tested by the Engineer. Those cables found to have faults shall be replaced. The testing shall utilize a time domain reflectometer.

A fault in a length of cable is defined as any of the following:

A. A return loss measurement indicating that there is a short in the cable.
B. A return loss measurement indicating a cut or open circuit in the cable.
C. A visual inspection which reveals exposure or damage to the cable shielding.
D. A return loss measurement less than 30 db anywhere along the cable.

HAR Testing

After all HAR equipment has been installed, the Contractor shall test the HAR.

Minimum test equipment required for testing the HAR shall consist of:

A. Dummy load, 50 ohms
B. Power meter
C. Communications monitor
D. Field strength meter

The Contractor shall tune the HAR with the impedance matching network of the coupling unit by adjusting the stainless steel tip of the antenna.

The HAR shall be considered tuned when the system's voltage standing-wave ratio (vswr) is at the lowest possible value (1.2:1 or better) as directed by the Engineer.

After the HAR has been tuned, the Contractor shall record and transmit a test message with the output power level of the transmitter set at approximate 10 watts or lower. Modulation shall be adjusted between 85 to 95 percent as specified by the FCC for the standard AM broadcast band.

The Contractor shall make actual on-the-air field strength measurements. A sufficient number of points shall be selected in order to determine the distance at which the attenuated field of 0.6 mV/ft exists, as measured with a calibrated standard field strength meter. This may be done in a 5 to 8 radial directions facilitating a plot of a 0.6 mV/ft at a distance of 0.93 miles from the HAR antenna. If the measured field exceeds 0.6 mV/ft at a distance of 0.93 miles, the transmitter output power shall be decreased accordingly and if the measured field is less than 0.6 mV/ft at the same distance then the power may be increased, up to a maximum of 10 ERP, as directed by the Engineer.

At the completion of all HAR testing the Contractor shall submit a written report of all measurements to the Engineer for approval. The report shall include a map, with scale, showing a 0.6 mV/ft contour based on the actual on-the-air field strength measurements. The VSWR, percent modulation and transmitter output power measurements shall be tabulated.

Caltrans Standard Special Provisions for Fiberglass HAR Poles

10-3.__ FIBERGLASS HIGHWAY ADVISORY RADIO POLES

Highway advisory radio (HAR) poles shall be fiberglass-reinforced plastic (FRP) poles conforming to these special provisions.

Fiberglass-reinforced plastic pole standards shall consist of round, fiberglass-reinforced plastic poles and bases. Fiberglass-reinforced plastic poles shall be hollow, tapered or with tapered sections, non-conductive and chemically inert.

Fiberglass-reinforced plastic pole standards shall conform to the details shown on the plans and shall conform to the requirements in "Standard Specifications for Structural Supports for Signs, Luminaires, and Traffic Signals" published by AASHTO, and ANSI Standard: C136.20, " Roadway Lighting Equipment - Fiber-Reinforced Plastic (FRP) Lighting Poles."

For standards specified or shown as "Breakaway" type, fiberglass-reinforced plastic pole standards shall conform to the requirements in National Cooperative Highway Research Program Report 230, "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances." Design wind velocity for Highway Advisory Radio standard systems shall be 80 mph.

For standards not specified or shown as "Breakaway" type, fiberglass-reinforced plastic pole standards shall not have the machined groove inside the anchor base casting as shown in the "Aluminum Anchor Base Elevation" detail shown on the plans.

The poles shall withstand the bending strength test load shown in the following table. The poles shall withstand this load with the handhole in compression. The poles shall not exceed a maximum deflection of 13 percent of the length of the pole above the ground line when subjected to the deflection test load shown in the following table:

TEST LOAD TABLE

Standard Type	Bending Strength Test Load	Deflection Test Load
Type 15F, Type 15F (Breakaway)	541 lbs	361 lbs
Type 21F, Type 21F (Breakaway)	576 lbs	384 lbs

Test loads shall be applied in conformance with the requirements in Section 12, "Pole Deflection Measurements," of ANSI Standard: C136.20. Poles shall be loaded 12 inches below the tip.

Fiberglass-reinforced plastic pole standards shall be the anchor base type unless otherwise designated.

The manufacturer of fiberglass-reinforced plastic pole standards shall have an approved testing and quality control program on file at the Transportation Laboratory prior to fabricating pole standards for this contract.

The Engineer shall be provided a Certificate of Compliance from the manufacturer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications. The certificate shall certify that the pole standards conform to the requirements in the specifications and were manufactured in conformance with the approved testing and quality control program. The certificate shall also include the date of the certificate, reference job number, manufacturer product catalog number, pole type number, dates of manufacture and the signature of the manufacturer's management person responsible for the testing and quality control program.

CONSTRUCTION

Poles shall be constructed from ultraviolet-resistant resin which shall be pigmented light gray and be of uniform color throughout the entire body of the pole. The finish of poles shall be smooth.

Each pole shall have 3 handholes and handhole covers. The cover over the handhole nearest the base shall bear the name of the manufacturer. The handhole covers shall be securely attached to the pole with tamper-resistant hardware. The handholes shall be located as shown in the plans.

The base shall be bonded to the pole with a suitable adhesive and coated with an aliphatic-type acrylic-modified polyurethane finish. For new installations, adapter plates shall not be used to attach the pole standards to the foundation.

Direct burial poles shall have a 2" x 6" nominal size, grommeted conduit/conductor entrance located 24 inches ± one inch below finished grade after installation. The entrance shall be located directly below the handhole.

The butt end of the direct-burial poles shall be flared, or modified by some other acceptable means, to increase the resistance to rotation and pullout and provide additional ground bearing resistance.

Each pole standard shall be provided with a removable aluminum or galvanized steel pole top cap.

Each pole standard shall have an identification plate conforming to the provisions in Section 86-2.04, "Standards, Steel Pedestals and Posts," of the Standard Specifications. The identification plate shall show the pole standard type, manufacturer's name, manufacturer's part number and the year of fabrication. If the fiberglass-reinforced plastic pole standard is a breakaway type, the identification plate shall include the word "BREAKAWAY." The plate shall be located either on the anchor base or just above the base handhole.

EXTERIOR PROTECTION

An aliphatic-type acrylic-modified polyurethane coating shall be applied to the exterior of the fiberglass pole. The coating shall be semi-gloss, highly weather resistant and light gray in color matching the color of the resin and shall have a minimum 3-mil dry film thickness. A one-quart can of the coating matching the poles shall be supplied with each order of poles. The polyurethane coating shall be tested for adhesion to the pole surface in conformance with the requirements in ASTM Designation: D 3359, Method A, and shall have a scale rating of 5A. The adhesion testing shall be conducted before and after the accelerated weathering evaluation.

The finished surface of the poles shall withstand a minimum of 2500 hours of accelerated weathering when tested in conformance with the requirements in ASTM Designation: G154, Cycle 2.

After testing, the finished surface of the poles shall exhibit the following:

Fiber exposure	None
Crazing	None
Checking	None
Chalking	Very slight
Change in color	May dull slightly
Paint adhesion	5A scale rating, per ASTM Designation: D 3359, Method A using Permacel 99 tape.

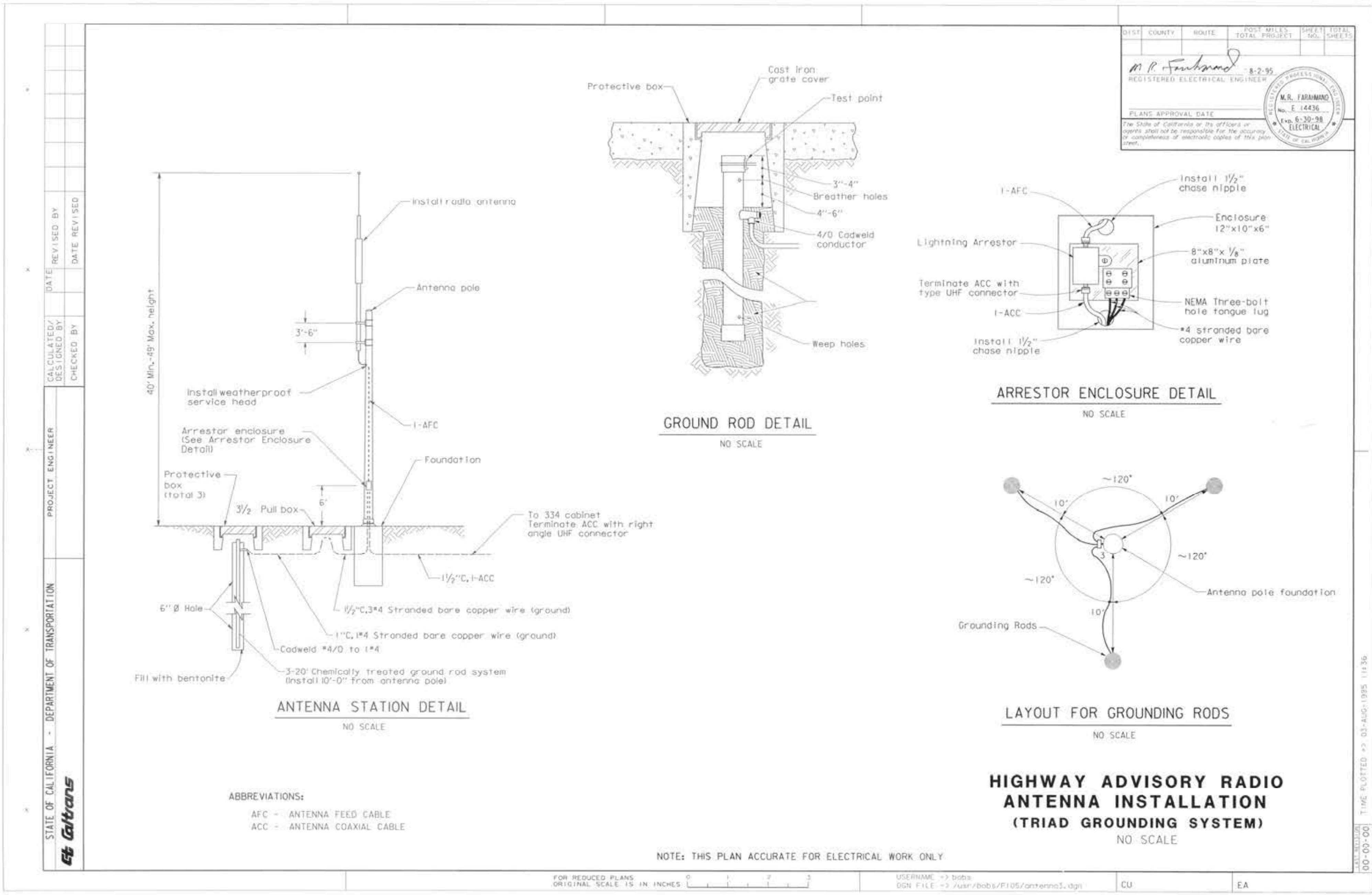
PACKAGING

Each pole shall be spiral wrapped in its entirety with a weatherproof wrap for protection during shipping and storage.

INSTALLATION

Installation and backfilling for direct burial poles shall be in conformance with the provisions wood poles in Section 86-2.12, "Wood Poles," of the Standard Specifications.

APPENDIX C


Install radio antenna
Antenna pole
3'-6"
40' Min.-49' Max. height
Install weatherproof service head
1-AFC
Arrestor enclosure (See Arrestor Enclosure Detail)
Foundation
Protective box (total 3)
6'
3½ Pull box
To 334 cabinet Terminate ACC with right angle UHF connector
1½"C, 1-ACC
6" Ø Hole
1½"C,3#4 Stranded bare copper wire (ground)
1"C, 1#4 Stranded bare copper wire (ground)
Cadweld #4/0 to 1#4
Fill with bentonite
3-20' Chemically treated ground rod system (Install 10'-0" from antenna pole)
ANTENNA STATION DETAIL
NO SCALE
Protective box
Cast iron grate cover
Test point
3"-4"
Breather holes
4"-6"
4/0 Cadweld conductor
Weep holes
GROUND ROD DETAIL
NO SCALE
1-AFC
Install 1½" chase nipple
Enclosure 12"x10"x6"
Lightning Arrestor
8"x8"x ⅛" aluminum plate
Terminate ACC with type UHF connector
1-ACC
NEMA Three-bolt hole tongue lug
#4 stranded bare copper wire
Install 1½" chase nipple
ARRESTOR ENCLOSURE DETAIL
NO SCALE
~120°
10'
10'
~120°
~120°
3
Antenna pole foundation
10'
Grounding Rods
LAYOUT FOR GROUNDING RODS
NO SCALE
DIST COUNTY ROUTE POST MILES TOTAL PROJECT SHEET NO. TOTAL SHEETS
8-2-95
REGISTERED ELECTRICAL ENGINEER
PLANS APPROVAL DATE
M.R. FARAHMAND
No. E 14436
Exp. 6-30-98
ELECTRICAL
STATE OF CALIFORNIA
The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.
HIGHWAY ADVISORY RADIO
ANTENNA INSTALLATION
(TRIAD GROUNDING SYSTEM)
NO SCALE
ABBREVIATIONS:
AFC - ANTENNA FEED CABLE
ACC - ANTENNA COAXIAL CABLE
NOTE: THIS PLAN ACCURATE FOR ELECTRICAL WORK ONLY
STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans
PROJECT ENGINEER
CALCULATED/DESIGNED BY
CHECKED BY
DATE REVISED BY
DATE REVISED
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DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

M. R. Farahmand 8-2-95
REGISTERED ELECTRICAL ENGINEER

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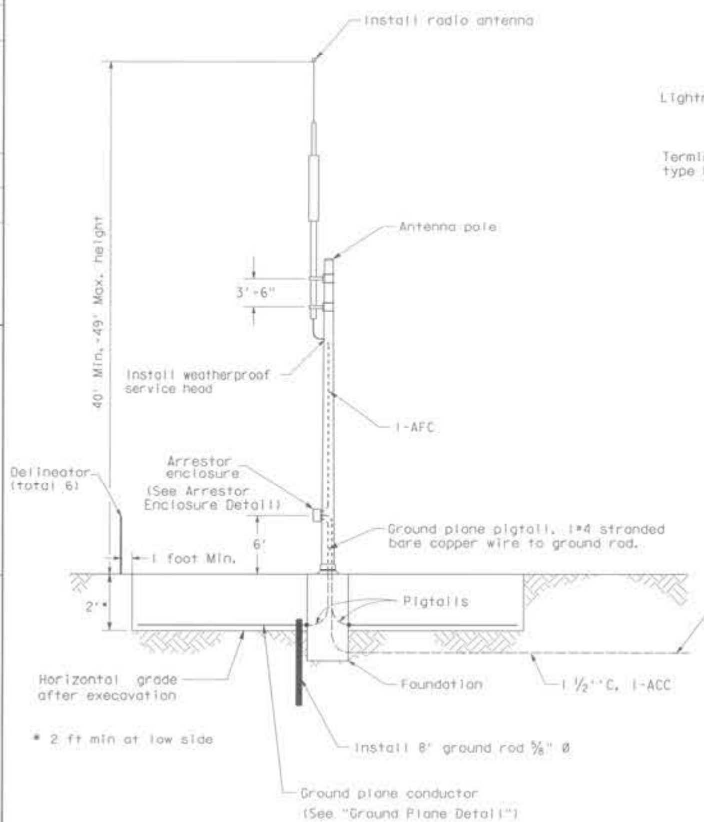
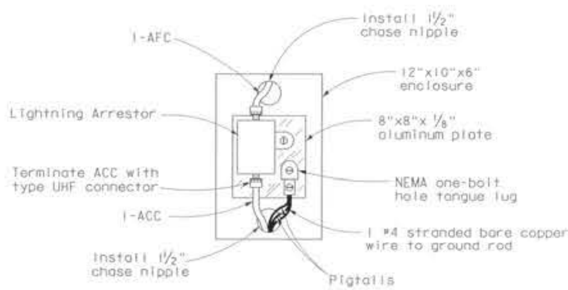
ELECTRICAL
STATE OF CALIFORNIA



* 2 ft min at low side

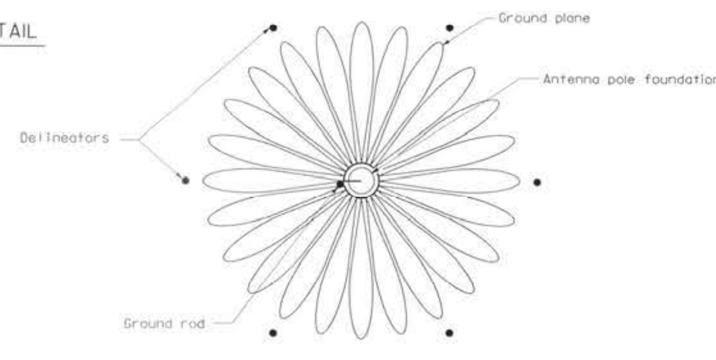
ANTENNA STATION DETAIL

NO SCALE



ARRESTOR ENCLOSURE DETAIL

NO SCALE



GROUND PLANE DETAIL

NO SCALE

NOTE:

1. See special provision for radius and number of turns.
2. See Highway Advisory Radio Antenna Pole sheet for pole details.

HIGHWAY ADVISORY RADIO ANTENNA INSTALLATION (GROUND POLE PLANE SYSTEM)

NO SCALE

ABBREVIATIONS:

AFC - ANTENNA FEED CABLE
ACC - ANTENNA COAXIAL CABLE

This plan accurate for electrical work only.

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans
TRAFFIC ELECTRICAL
PROJECT ENGINEER
CALCULATED/DESIGNED BY | CHECKED BY
DATE | REVISED BY | DATE REVISED

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

M. R. Farahmand 8-2-95
REGISTERED ELECTRICAL ENGINEER

PLANS APPROVAL DATE

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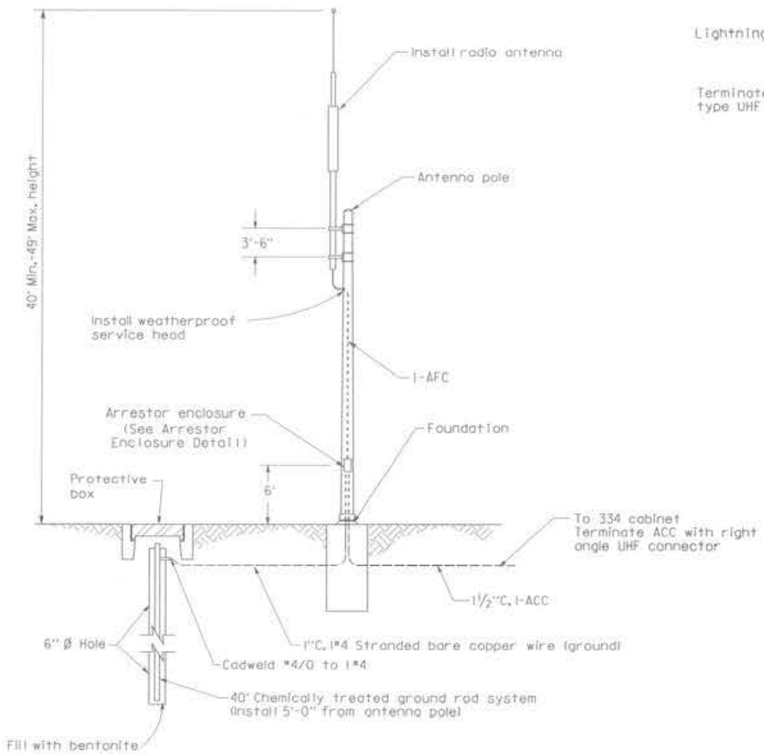
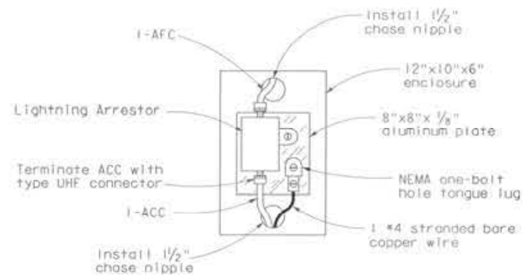
REGISTERED PROFESSIONAL ENGINEER — M.R. FARAHMAND — No. E 14436 — Exp. 6-30-98 — ELECTRICAL — STATE OF CALIFORNIA



ANTENNA STATION DETAIL

NO SCALE



ARRESTOR ENCLOSURE DETAIL

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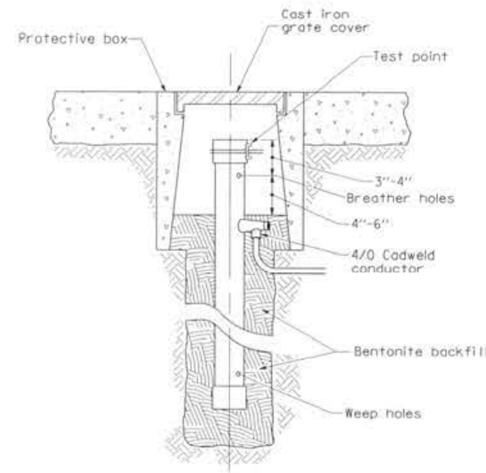

GROUND ROD DETAIL

NO SCALE

HIGHWAY ADVISORY RADIO ANTENNA INSTALLATION (GROUND ROD SYSTEM)

NO SCALE

ABBREVIATIONS:

AFC - ANTENNA FEED CABLE
ACC - ANTENNA COAXIAL CABLE

This plan accurate for electrical work only.

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans

PROJECT ENGINEER | CALCULATED/DESIGNED BY | CHECKED BY | DATE | REVISED BY | DATE REVISED

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HAR

Highway Advisory Radio

Maintenance Manual

Prepared by Caltrans Maintenance Program
Office of Radio Communications

Version 3.0-June 2003
Extended Coverage System Included

TABLE OF CONTENTS

1. INTRODUCTION

The California Department of Transportation (Caltrans) utilizes a Highway Advisory Radio (HAR) system as means to provide travel related information to motorists through standard AM receivers.

The HAR operates as a Travel Information Station (TIS) and is licensed by the Federal Communications Commission (FCC). The HAR messages are broadcast from low power transmitters that are located along the roadside. The system sites can be permanent or mobile. A message sign (permanent or mobile) instructs motorists to tune to one or more frequencies on their AM radio to receive an audio message when approaching a HAR system.

The HAR messages are warnings, advisories, and directions, or any of a wide variety of informative non-commercial material related to current road conditions. The broadcast messages are typically less than one minute in length.

FCC restrictions dictate the location of all HAR systems. The FCC restrictions are based on the proximity of the HAR systems to air, train, and bus transportation terminals, public parks and historical sites, interstate highway interchanges, bridges, and tunnels.

The typical HAR system site is remotely controlled. HAR messages typically originate from Caltrans locations within the District and are then transmitted to one or more HAR system sites, via landline or cellular telephone. The received message is pre-recorded at the digital interface. Caltrans personnel can then remotely control the HAR to broadcast the pre-recorded messages repeatedly in a predetermined program sequence. The message length is designed to allow a passing motorist the opportunity to receive the message twice while traveling in system range at the maximum allowable speed. Caltrans is responsible for monitoring and maintaining the system and changing the message content as the situation warrants.

In order to ensure the proper operation of the HAR system sites, periodic preventive and corrective maintenance is required to be performed by qualified experienced field technicians.

Extended Coverage Highway Advisory Radio System. This version of the HAR manual (Version 2.0) has been updated to include information about the new extended coverage HAR system. The extended coverage HAR system differs from the standard HAR system in three areas: it has a synthesized transmitter, it uses a tuner instead of a coupler, and it uses a forty-nine foot whip antenna (Superstation 3000).

Throughout the manual a distinction has been made between the maintenance requirements of the extended coverage HAR system where they differ from the standard HAR system. Manufacturers literature has also been added to the manual for the extended coverage HAR system equipment.

The maintenance of the extended coverage HAR system is very similar to the standard HAR system, however the updated connection diagram and manufacturers literature should be referenced to determine the specific differences. The antenna and tuner used with the extended coverage HAR system are maintenance-free items, requiring repairs for physical damage only. The antenna is cut to frequency at the factory and the tuner is made up entirely of passive components, therefore once it has been tuned at the time of installation, no further adjustment is required.

1.1. PURPOSE OF THIS DOCUMENT

This document outlines standard procedures for the maintenance of Highway Advisory Radio (HAR) installations throughout the state. These procedures provide basic information regarding maintenance activities that are required to keep the systems in good operating condition, including general descriptions of preventive and corrective maintenance, maintenance priorities, typical maintenance activities, and other aspects that define the requirements for maintaining HAR system sites.

This document lists the steps in performing preventive and corrective maintenance at HAR installations. Also included are lists of test equipment to be used while performing specific maintenance tasks, and block diagrams.

This document has been updated to include the maintenance information for the new extended coverage HAR system. Notations have been made where the maintenance requirements for the extended coverage HAR system are different than the standard HAR system. If notation is made, it shall be assumed that the requirements are the same.

~~1.1.1.~~

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1.2. PREVENTIVE AND CORRECTIVE MAINTENANCE

The following sub-sections define major categories of the required maintenance activities for the HAR system sites. The information is derived from maintenance requirements outlined in the HAR Instruction manual and the Caltrans HAR Design and Operations Guide; and from conversations with vendors, Caltrans personnel, and HAR maintenance providers.

There are two types of maintenance that must be performed to keep the HAR systems in proper operating condition: preventive maintenance (normally scheduled) and corrective maintenance (normally unscheduled). If a problem is not crucial and its repair can be delayed, the problem can usually be corrected as part of a scheduled preventive maintenance activity. Preventive maintenance can also be performed during an unscheduled corrective maintenance trip. The following table provides examples of these situations:

TYPE OF MAINTENANCE	PREVENTIVE	CORRECTIVE
SCHEDULED	Replace backup batteries	Replace DC indicator light
UNSCHEDULED	Noticed coax connector was loose, and tightened it while performing other corrective maintenance	Remounted antenna knocked down by high winds

Table 1 - Types of Maintenance

1.3. PREVENTIVE MAINTENANCE

Preventive Maintenance (PM) is maintenance that must be performed on a periodic scheduled basis to assure that the HAR system site equipment is operating at peak or near peak efficiency. PM can also be performed on a non-scheduled basis when a qualified technician is making repairs, and it is cost effective to perform PM after repairs are completed. In areas with multiple HAR system sites, certain PM tasks can be scheduled in such a way that many of the locations can be covered in one trip (i.e. The field strength measurements and antenna tuning can be done at several closely spaced HAR system locations with a technician and a bucket truck operator. This systematic scheduling for multiple sites reduces travel and coordination time and allows for efficient PM.) In areas where the HAR system locations prohibit multiple site visits within a short period, a full PM at one site is the most cost-effective approach. The scheduling of the PM tasks for all the HAR system modules should be based on the manufacturer's recommended maintenance intervals. The scheduled intervals are noted in Section 4.

PM activities, described herein, are based on recommendations of the equipment manufacturers and installers, installation documentation, and technical personnel who have serviced HAR installations. The recommended scheduled maintenance activities are used to calculate estimated workloads for crews servicing the HAR system sites.

This maintenance specification contains the required preventive maintenance that is to be performed on a scheduled periodic basis. In addition, this specification contains several corrective maintenance procedures in the form of trouble shooting guidelines. For more detailed information about each specific module, refer to the equipment manual or contact the module manufacturer directly.

1.4. CORRECTIVE MAINTENANCE

Corrective maintenance (CM) is also required for the HAR system to operate properly. The best estimates for projecting a CM workload are based on accumulated CM data, estimated statistical failure rate provided by each module manufacturer, and an algorithm that takes into account accumulated CM data and estimated failure rates. The greater the amount of accumulated CM data the more accuracy can be built into the estimated CM work loads. Also, because of the diverse climate within California, CM data from as many different locations in each climate type adds to the accuracy of a typical predictive CM workload.

Most of the CM estimates in this document are based on previous experience performing similar maintenance tasks on existing HAR systems installations

1.5. CORRECTIVE MAINTENANCE PRIORITIES

These categories define existing response priority times in the following manner:

Priority	Description
1	An immediate response is required
2	This requires early attention and should be undertaken during the next work day
3	This work requires early attention and should be undertaken within 48 hours
4	This work should be undertaken within one month

Table 2 - Existing Response Priority Times

The following are the reasons, in priority order, for maintaining HAR radio installations:

1. Public Safety
2. Traffic Control and Service
3. Preservation of the System site/Operational Integrity
4. General Appearance of Equipment

Corrective Maintenance activities and work plans are based on these priorities. If workload exceeds resources, the highest priority items will be maintained first. HAR system sites should be treated as top priority as their function can be critical to public safety.

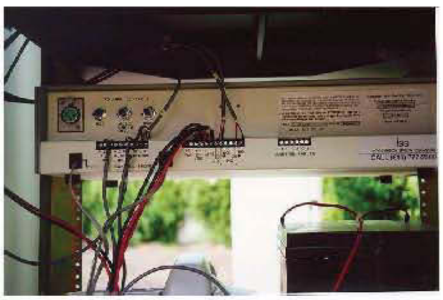
CM response priorities are specified for HAR system site equipment in table 2. Several factors contributed to these response priorities including the importance to traffic management functions. Failure rates were estimated from the collective experience of the contractor that performed many of the HAR installations, the contractor that serviced HAR system sites, and technicians employed by Caltrans.

Failed Item	Response Priority
AM Antenna	1
Lightning Arrestor	1
AM Transmitter Coupler	1
Microphone	4
Cellular Telephone Antenna	1
RFI Filter for Cellular Telephone	3
Cellular Telephone	2
Telephone Line Surge Arrestor	2
Digital Voice Recorder	1
Control Telephone	4
Low Voltage Battery Cutoff Relay – 12VDC	3
Recorder Battery Backup	3
Low Voltage Battery Cutoff Relay – 24VDC	3
Recorder Backup Battery Charger	2
Power Surge Arrestor	1
24V Battery Charger	2
Charger Shedding Relay	3
12V Gel Cell Batteries	3
DC Indicator Light	4
AC Indicator Light	4
Voltmeter	4

Table 3 - Maintenance Priority List

2. TYPICAL HAR INSTALLATIONS

Shown below are photographs of a typical HAR system site.



Connections to Message Recorder – Red Bluff

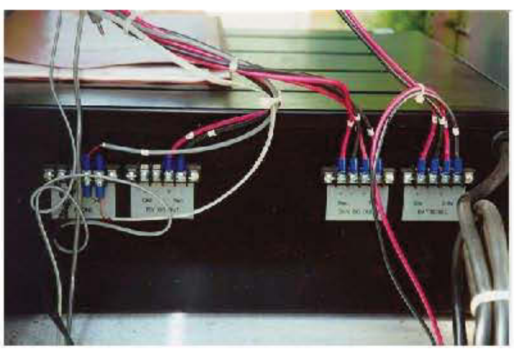
Interior Front View – Red Bluff

Interior Rear View – Red Bluff

Site Cabinets (HAR Far right) – Red Bluff

Antenna Installation – Red Bluff

Site View – Red Bluff



DC Power Wiring – Red Bluff

Feedline Lightning Arrestor – Red Bluff

Shown below are photographs of a typical extended coverage HAR system site.

Site View - Redding

Interior Front View – Redding

Extended Coverage
HAR Installation - Redding

Interior Rear View - Redding

3. HAR LOCATIONS

As of June 1998, there are 66 permanent HAR systems in 11 of the 12 Caltrans districts. Some have been in operation for years and several have been just recently installed.

The following table lists the number of fixed HARs within each Caltrans District.

District	1	2	3	4	5	6	7	8	9	10	11	12	Total
No. of HARs	7	13	25	40	3	17	19	6	1	6	4	2	136

Table 4 - Fixed HARS Within Each Caltrans District

District	1	2	3	4	5	6	7	8	9	10	11	12	Total
No. of HARs	1	2	3	0	0	6	1	1	0	2	1	1	18

Table 5 - Mobile HARS Within Each Caltrans District

Maps showing specific HAR locations are shown in the following pages.

4. PREVENTIVE MAINTENANCE (PM) ACTIVITIES

The following sections outline the basic information regarding maintenance activities that are required to keep the HAR system equipment in proper operating condition. The activities include descriptions of preventive and corrective maintenance, maintenance priorities, typical maintenance activities, and other aspects that define requirements for maintaining the HAR system sites.

There are 26 recommended PM tasks. Included in this section is a table with task numbers, descriptions, and recommended PM intervals and recommended PM task procedures. A sample of a PM logbook is also supplied.

The tuning of the antenna may require the use of a bucket truck. Also, certain PM tasks may be accomplished more efficiently with two people such as adjusting the field strength of a HAR system site.

4.1. PREVENTIVE MAINTENANCE TASK LIST AND TIME ESTIMATES TO PERFORM PM TASKS

The following table lists the recommended Preventive Maintenance tasks and the recommended PM interval for each task.

Task	Description	Task Time (min.)	Recommend PM Interval Frequency
4.2.1	Remotely Monitor HAR	N/A	Every Time
4.2.2	Inspect and Clean the HAR cabinet and change filter	10	Every 6 mo.
4.2.3	Visually inspect all of the major HAR modules	5	Every 6 mo.
4.2.4	Check Transmit Frequency Tolerance	30	Annually
4.2.5	Check VSWR	30	Every 6 mo.
4.2.6	Retune Antenna Coupler or Tuner [6]	15	As Req'd
4.2.7	Retune HAR Vertical Antenna [7]	120	As Req'd
4.2.8	Measure field strength of system at 1.5 km (.93mi.)	15	Every 6 mo.
4.2.9	Set Audio Level	5	Every 6 mo.
4.2.10	Verify operation of 12V Battery Charger	5	Every 6 mo.
4.2.11	Verify operation of 12V Low Voltage Battery Cutoff Relay	10	Annually
4.2.12	Verify Voltage of 12V Recorder Battery	5	Annually
4.2.13	Verify Voltage of 12V Main Batteries	5	Every 6 mo.
4.2.14	Replace 12V Main System Batteries[1]	30	As Req'd
4.2.15	Verify operation of 24V Battery Charger	5	Annually
4.2.16	Verify operation of 24V Low Voltage Battery Cutoff Relay	10	Annually
4.2.17	Replace 12V Recorder Backup Battery[1]	20	As Req'd
4.2.18	Verify Operation of Cellular Telephone[2]	3	Annually
4.2.19	Verify Operation of Control Telephone	3	Annually
4.2.20	Verify Operation of Message Recorder	20	Every 6 mo.
4.2.21	Check DC Indicator Light	1	Every 6 mo.
4.2.22	Check AC Indicator Light	1	Every 6 mo.
4.2.23	Verify Microphone Operation	5	Annually
4.2.24	Check Ground Plane Connections	10	Annually
4.2.25	Recharge Chemical Ground (where applicable)[3]	20	As Req'd
4.2.26	Verify Operation of Charger Shedding Relay	10	Annually
	Total expected time to perform a 6 month PM[4]	1.6 hrs	
	Total expected time to perform complete annual PM[5]	3.4 hrs	

Table 6 - Preventive Maintenance Tasks and Recommended PM Interval

Note:

1. If the batteries are lead-acid and over a year old, then replace the batteries with sealed batteries utilizing gelled electrolyte.
2. A cellular telephone is not installed at all locations.
3. If system performance is still degraded after performing all PM tasks, then recharge the chemical ground.
4. The expected time excludes annual PM tasks and "As Req'd" PM tasks.
5. The expected time excludes "As Req'd" PM tasks.

6. The coupler is used with the standard HAR system and the tuner is used with the new extended coverage HAR system. The tuner consists entirely of passive components, therefore once it has been tuned at the time of installation the only maintenance required is for physical damage.
7. No preventative maintenance is required for the Superstation 3000 antenna used with the extended coverage HAR system. The antenna is cut to a specific frequency at the time of installation.

Before performing PM at an HAR system, the field technician shall notify TMC personnel at the District Office. Caltrans personnel will remotely program test messages into the HAR recorder and program the HAR system to broadcast the test messages. The field technician shall also notify TMC personnel upon completion of PM.

If any module or component being tested during PM fails, that module shall be replaced with a spare. The defective module or component shall then be repaired, returned to the factory, Caltrans electrical shop, or replaced as necessary.

The equipment at HAR sites has been furnished and installed over a number of years. The equipment may differ slightly from a newer HAR site to an older HAR site. Because not all of the equipment at each site will be the same, some of the PM procedures may not be applicable.

Note: *The control telephone is for entering commands to control the message recorder and its functions. The control telephone cannot be used to make outgoing calls when connected to the message recorder.*

4.2. PREVENTIVE MAINTENANCE PROCEDURES AND CHECK LIST

4.2.1. Remotely Monitor and Program the HAR Site

☐ 1. Notify Caltrans TMC personnel to remotely program and broadcast test messages into the HAR being serviced.

☐ 2. Monitor the HAR broadcast to verify that the transmitter and recorder are functioning by remote control.

~~1.1.2.~~4.2.2. Inspect and Clean HAR Cabinet.

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☐ 1. Remove any excess dirt and dust both inside and out.

☐ 2. Inspect all weather seals.

☐ 3. Inspect all electrical, communications, and other wiring at their points of penetration into the cabinet.

☐ 4. Look for any collection of moisture within the cabinet.

☐ 5. Check cabinet fan and change filter.

4.2.3. Visually Inspect all Major HAR Modules and Internal Wiring

☐ 1. Inspect the internal wiring for any obvious abnormalities.

☐ 2. Visually inspect all major modules including the recorder, transmitter, cellular telephone, HAR and Cellular telephone antennas, etc.

4.2.4. Check Transmitter Frequency Tolerance

☐ 1. Disconnect the feedline from the coupler or tuner (the tuner is used with the Superstation 3000 antenna).

☐ 2. Connect the coupler to communications monitor.

☐ 3. Key the transmitter, carrier only, and measure the carrier frequency. If the carrier frequency varies from the manufacturer's frequency stability specification, (±0.02% from 0° to 35°C for Radio Systems TR-20 transmitter), then replace the transmitter and have it serviced.

4.2.5. Measure VSWR

☐ 1. Insert a through line wattmeter just before the surge arrestor and measure forward and reflected power. The VSWR ratio should be less than 1.2:1.

4.2.6. Retune Antenna Coupler (tuner does not require retuning)

☐ 1. Set the Function Switch to the "Match" position and adjust SWR CAL clockwise until meter reads full scale (Line above 20W).

☐ 2. Change Bridge Switch to REF. Meter should now be showing SWR. The needle should be within the green area.

☐ 3. To adjust for best SWR, the Reactance Correction and Impedance Select switches are used. Start with coarse reactance (initially set at 10); adjust reactance and watch for the needle to drop. If it doesn't drop, return switch to 10. Then adjust the coarse impedance (initially set at 3). Follow the same procedure for this switch. Also adjust fine reactance, then fine impedance. The idea is to get the needle as close to 0 (zero) as possible.

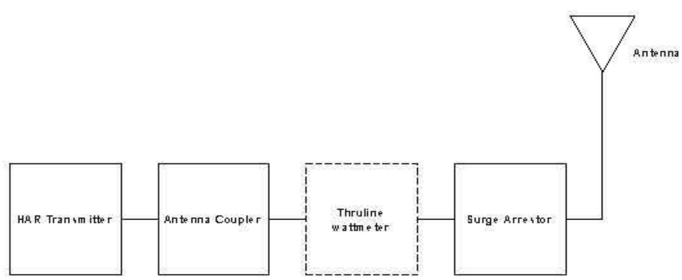
☐ 4. Set Function switch to Operate. Meter will read 0 (zero), indicating an approximate 1 to 1 SWR match into the wire antenna.

☐ 5. If after retuning the antenna coupler VSWR cannot be reduced to near zero then perform the PM procedures for retuning the vertical HAR antenna.

4.2.7. Retune Vertical HAR Antenna

Note: *The antenna should only be retuned when necessary to avoid damage to the compression fitting at the tuning tip and any antenna connection.*

☐ 1. Connect a Thruline Wattmeter (or equivalent) in series with the transmitter and the coaxial cable (just before the surge suppressor and after the antenna coupler) and measure forward and reflected power. If forward power is less than 10 times the reflected power, proceed with the remaining tuning steps; otherwise, continue to the next PM task.



- ☐ 2. Turn the transmitter power switch on. The internal LED beside the switch will light. Rotate the Power Set potentiometer to about 3. Leave the potentiometer at this setting throughout antenna tuning.
- ☐ 3. Allow the transmitter to run for 20 minutes before you begin tuning.
- ☐ 4. Turn off the transmitter if the antenna's tip cannot be reached conveniently. The transmitter may be left on during tuning if the antenna's tip can be reached via bucket truck or by swinging it down briefly for adjustment. IMPORTANT: Damage can result to the Transmitter should the antenna contact the groundplane or the ground in the process of operation or tuning.
- ☐ 5. Slide the antenna's tip up or down in 1/2" increments, marking test positions with a pen or scribe.
- ☐ 6. Turn the transmitter back on if it has been turned off.
- ☐ 7. Check forward to reflected power ratio for a reading of 10:1. Continue to perform steps 3, 4, 5, 6, and 7 until the tip position yields the highest forward to reflected power ratio.
- ☐ 8. When tuning is complete, tighten the nut at the top of the antenna top section to hold the tip at this length. Use two wrenches to rotate the nut one full turn. Use silicone around the top and bottom of the nut to retard weathering.
- ☐ 9. Make the final setting on the transmitter's Power Set potentiometer by testing the field strength at 1.5 kilometers (.93 miles) from the transmitter site (line of sight distance) in all accessible directions. FCC rules and regulations require that the field intensity of an HAR does not exceed 2.0 mV/m at 1.5 km in any direction of the transmitter.
- ☐ 10. Retune antenna coupler. See Task 4.2.6.

4.2.8. Measure Transmitter Field Strength

Note: *If the antenna is to be retuned during this PM trip, then be sure to tune the antenna coupler before performing this PM procedure.*

- ☐ 1. Turn on the transmitter.
- ☐ 2. Using the modified FIM41 Field Intensity Meter (or equivalent), measure the field strength of the HAR transmitter at a location 1.5 km (.93 mi.) from the antenna.
- ☐ 3. If the field strength is other than 2.0 mV/m return to site and adjust transmit power to obtain a 2.0 mV/m reading by turning the "power set" control. (Note: FCC regulations allow for a maximum of 10W transmitter output power.)
- ☐ 4. Repeat Steps 2 and 3 until a reading of 2.0 mV/m is obtained.
- ☐ 5. Turn off the transmitter.

4.2.9. Set the Audio Level

- ☐ 1. The transmitter's Audio Level potentiometer is set as soon as a test message has been recorded on the AP55 Digital Voice Recorder.
- ☐ 2. Program the recorder to begin repeating a message for broadcast.
- ☐ 3. Rotate the potentiometer clockwise until the LED flasher at the top of the main board begins flashing.
- ☐ 4. Monitor the sound of the output across a nearby radio receiver while setting the audio level.
- ☐ 5. Set the Audio Level potentiometer so that the flasher flashes with each word or just occasionally, but does not stay on continuously, and the signal sounds clear. This will be the permanent setting for this potentiometer unless the output level of the Digital Voice Recorder is adjusted up or down later. If this is done, readjust the Audio Level potentiometer again to compensate for the new output level from the recorder. Compensation may have to be made for lower levels on recordings made by telephone. The Modulation Meter on the transmitter's front panel will show movement in the midrange during normal modulation levels.
- ☐ 6. Discontinue the repeating messages and delete the play list.

4.2.10. Verify Operation of 12V Battery Charger

- ☐ 1. With the battery charger connected to the 12V Recorder Battery, measure the charger output voltage.
- ☐ 2. The charger should read 13.7V ±.1V.

4.2.11. Verify Operation of 12V Low Voltage Battery Cutoff Relay

- ☐ 1. Set variable power supply for 12V DC.
- ☐ 2. Remove battery connections to the 12V Low Voltage Battery Cutoff Relay and replace them with the 12V DC output of the variable power supply.
- ☐ 3. Monitor the load voltage at the terminal block on the interface panel.
- ☐ 4. Slowly reduce the output of the variable power supply until the load is disconnected. (This should occur at 11V DC ±.5V.)

4.2.12. Verify Voltage of 12V Recorder Backup Battery

- ☐ 1. Turn off AC power.
- ☐ 2. Measure voltage at the terminal block on the Interface Panel.
- ☐ 3. If the voltage is less than 11.7 volts, then replace the 12V Recorder Backup Battery.

4.2.13. Verify Voltage of Main System 12V Batteries

- ☐ 1. Turn off AC power.
- ☐ 2. Read the voltage on the voltmeter on the HAR Interface.
- ☐ 3. If the voltage is less than 23.4V, then remove all battery connections and measure the voltage of each battery. Each battery should measure 11.7V or higher. If only one battery fails the voltage test, replace the failed battery. If both batteries have been in use for more than one year, replace both batteries.

4.2.14. Replace the Main System 12V Batteries

- ☐ 1. Turn off AC power.
- ☐ 2. Remove the Main System 12V Batteries.
- ☐ 3. Examine the battery cables for corrosion or damage.
- ☐ 4. Clean the terminals of the new batteries and existing battery cables.
- ☐ 5. Install the new batteries.

4.2.15. Verify Operation of 24V Battery Charger

- ☐ 1. With the battery charger connected to the Main System Batteries, measure the charger output voltage.
- ☐ 2. The charger output voltage should read 27.6V $\pm$ 0.1V.

4.2.16. Verify Operation of 24V Low Voltage Battery Cutoff Relay

- ☐ 1. Set variable power supply for 24V DC.
- ☐ 2. Remove battery connections to the 24V Low Voltage Battery Cutoff Relay and replace them with the 24V DC output of the variable power supply.
- ☐ 3. Monitor the load voltage at the terminal block on the interface panel.
- ☐ 4. Slowly reduce the output of the variable power supply until the load is disconnected. (This should occur at 22V DC $\pm$ 0.5V.)

4.2.17. Replace 12V Recorder Backup Battery

- ☐ 1. Turn off AC power.
- ☐ 2. Remove the 12V Recorder Backup Battery.
- ☐ 3. Clean the terminals of the new battery and battery cables.
- ☐ 4. Install the new battery.

4.2.18. Verify Operation of Cellular Telephone (if applicable)

- ☐ 1. Have Caltrans TMC personnel call the HAR site and turn on a test a message.

4.2.19. Verify Operation of Control Telephone (if applicable)

- ☐ 1. Lift the control telephone off hook.
- ☐ 2. If command list is played, place the control telephone back on hook.
- ☐ 3. Seal the Control Telephone in a plastic bag to provide corrosion protection.

4.2.20. Verify Operation of Message Recorder

The essential operations of the message recorder are confirmed during the other PM procedures.

4.2.21. Verify Operation of the DC Indicator Light

- ☐ 1. Turn the DC power switch off and on; the DC indicator light should respond accordingly.

4.2.22. Verify Operation of AC Indicator Light

- ☐ 1. Turn the AC power switch off and on; the AC indicator light should respond accordingly.

4.2.23. Verify Operation of Microphone (If present)

The microphone test consists of programming a message into the recorder and monitoring the message. All commands to operate the recorder are entered through the control phone or cellular telephone.

- ☐ 1. Lift the control phone off hook and set the local input to the microphone.
- ☐ 2. Listen to the instructions using the control phone.
- ☐ 3. Enter the test message number.
- ☐ 4. Record a 5-second test message.
- ☐ 5. Monitor the test message for accuracy and clarity.
- ☐ 6. Erase the test message.
- ☐ 7. Place the control phone back on hook.

4.2.24. Check Ground Plane Connections

☐ 1. Where the ground plane consists of runs of large diameter cable clamped to a ground rod, examine the ground clamp for a good connection by checking the continuity between the ground plane and the ground rod, or weld the large diameter cable to the ground rod using Cadweld or equivalent welding system.

☐ 2. Remove AC power and verify that each connection to the ground plane has a resistance of 1 ohm or less.

4.2.25. Recharge Chemical Ground (where applicable)

☐ 1. Inspect the chemical ground rod. If the ground rod is an XIT type, then proceed to the next PM task. (XIT grounds have a 30 year life expectancy.)

☐ 2. For non-XIT grounds, check the chemical container. If the container is empty refill with Epsom salt.

☐ 3. Inspect all ground connections (including ground clamps, ground welds, and ground clamps) for good connections by performing continuity checks and physical inspections.

4.2.26. Verify Operation of Charger Shedding Relay

☐ 1. Unplug AC power.

☐ 2. Verify that the voltage at the terminals of the charger shedding relay that are connected to the 24V Battery Charger measures 0 volts.

5. CORRECTIVE MAINTENANCE (CM)

CM consists primarily of trouble shooting various modules of the HAR transmitter station. The field technician shall respond to all CM requests within a 24 hour period. The following is a list of recommended trouble shooting procedures that are included to assist with CM, but in no way constitutes a complete list of all trouble shooting procedures.

5.1. FUSES AND CIRCUIT BREAKERS

The first checks in the event of a transmitter failure are the fuses and circuit breakers. Check fuses visually and with DVM meters. If fuses are good, continue with CM procedures.

5.1.1. Circuit Breakers

1. Check the Main 120V AC Circuit Breaker for the station
2. The Power Surge Arrestor has a pushbutton circuit breaker next to its on/off switch

5.1.2. System Fuses

1.	DC Power Fuse 10A AGC	In HAR Interface (T19)
2.	AC Power Fuse 10A AGC	In HAR Interface (T19)
3.	Cellular Telephone/Interface	

5.1.3. Module Fuses

1.	Transmitter Power Fuses	3A AGC slow blow	Main exciter board)
2.	Transmitter RF Fuses	4A AGC fast blow	Left inner wall
3.	24V DC Batt. Charger	KTK 2 1/2 (AC)	Side, in HAR Interface (T19)
4.	24V DC Batt. Charger	BAF 20 (DC)	Side, in HAR Interface (T19)
5.	12V DC Batt. Charger	2 A AGC	in HAR Interface (T19)
6.	Antenna Coupler	4 A AGC	on Antenna Coupler Board

5.2. MESSAGE IS NOT RECEIVED AT ANY DISTANCE

Section A

1A) Verify with the Field Intensity Meter that there is/not a carrier being broadcast.

2A) If a carrier is not present, refer to line 1B below.

3A) If a carrier is present but level is very low, refer to line 8B below.

4A) If a carrier is present at close to original levels, refer to Section C below.

Section B

Carrier not present. Check:

1B) Transmitter internal Power Switch ON. (The internal LED by internal power switch is lighted.) If ON, skip ahead to 8B. If LED does not light, test the following:

2B) Test Transmitter Power fuse (rear inside). Replace with 3A slow-blow if defective.

3B) Check the power switch on Power Surge Arrrestor. The power switch should be on.

4B) Check that 24V power is present on voltmeter T8. If not, test for internal Charge (T7) defect, or defect in T5 Charger Shedding Relay or (T6) Low Voltage Disconnect that would open relays. If 120V AC power is present on (T7) Charger inputs, (T5) relay contacts should be closed. If 24V DC is present on Charger (T7) output, (T6) Disconnect Relays should be closed.

5B) If 120V AC power has been interrupted and batteries have been exhausted, battery charge should test at approximately 22 volts. Restore 120V AC power.

6B) Check Digital Voice Recorder programming. If Transmitter has been powered down via DTMF command, it must be turned on again by entering *62#, 2008#.

7B) All wires and connectors for tightness.

8B) If the internal power LED in the transmitter is ON, check that the Antenna Cable (Wire #1) is attached to the T16 Antenna Base and that the groundplane is connected to the ground lug in the cabinet and the cabinet frame.

9B) Transmitter Power Set potentiometer is not turned down (counterclockwise). Set potentiometer to yield 2.0 mV/m at 1.5 km (.93 mile).

10B) Transmitter RF fuse (left inside) tests positive. Replace with 4A fast-blow if defective.

11B) If all of the above are affirmative, feel the Transmitter's heat sink. If it is cold, the output transistors may have failed. Service Transmitter.

Section C
Carrier is present. This may indicate that the audio modules are not delivering audio to the transmitter. Check:

1C) The internal audio limiter "flasher" LED at the top of the transmitter's main board (the board that faces outward through the access door). The "Audio Set" internal adjustment just below the flasher LED (on the same board) controls the percentage modulation and can be adjusted so that this LED will flash as audio is modulated and broadcast. If this potentiometer has been turned down (counterclockwise from the blue side), audio will not be broadcast. If rotating the potentiometer upward does not cause the LED to begin flashing, check the following:

2C) Audio wire connections between the Transmitter and the Digital Voice Recorder appear to be connected tightly.

3C) Access the Digital Voice Recorder and enter * 2 # to determine if recorded messages are intact. If they have becomes erased through an outage of power, rerecord the messages and schedule them to broadcast. Check the (T10) Recorder Battery Backup Charger for output and (T11) Recorder Backup Battery for charge. Failure of either could cause messages to be erased during a lengthy power interruption.

4C) If, in step 3C, it is found that recorded messages are intact and scheduled, but broadcasting is not occurring (with presence of carrier), check the following:

T17 Control Telephone - if it is "off hook" and/or if the "speakerphone" button is depressed, audio will not be sent from the Voice Recorder to the Transmitter.

The blue "MSG" potentiometer on the T12 Digital Voice Recorder - if it is turned counterclockwise, audio will not be sent to the Transmitter.

5C) If audio is reestablished between the Digital Voice Recorder and the Transmitter, check the flasher and Audio Set control described in 1C and adjust to flash accordingly. See Page 15 in the preceding General Information Section.

6C) If audio is not reestablished, the transmitter or digital message programmer may require service.

Section D

Signal is heard but range is reduced.

1D) If audio is being heard but with reduced range, check the intensity of the field near the transmitter with transmitter power at full on the Power Set potentiometer (at fully clockwise as viewed from blue wheel side of potentiometer). Before bringing the potentiometer to full power, reference the power setting on a wattmeter so that you can return to that setting after testing is completed. If the field, only a few feet from the antenna, is less than 5 volts/meter, refer to section E below.

2D) If the field is about 10 volts per meter only a few feet from the antenna, refer to section F below.

Section E

Low range and low field - If low field is determined, it can normally be affirmed by checking with a wattmeter. The Forward Power reading on the meter will be lower than normal.

1E) Is the antenna tip extended to the appropriate extension length? Retune if necessary.

2E) Is the Power Set internal control potentiometer in the transmitter turned up to the proper level to deliver 2.0 mV/m at the 1.5 km measurement point? If it has been turned on (counterclockwise), lower than normal field readings will result. Check the transmitter and reset the Power Set level if necessary. Check the wattmeter to see that power has returned to normal set levels for legal operation in your area.

3E) Is the connection between Wire #1 and T16 Antenna base loose or corroded?

4E) Are the T7 24V Battery Charger and T1/T2 24V Main System Batteries delivering full system power? Check the (T8) System Voltmeter. If the reading is less than 24 V DC, batteries may need to be recharged via 120V power or the charge is not producing the required voltage. Service of the 24V charger may be required.

5E) If all of the above check out, one or both of the transmitter's output transistors may be defective.

Section F

Low range and normal field - Normally caused by environmental factors or lack of modulation.

1F) Examine the area to check if there is anything near or "crowding" the system antenna that may be attenuating its signal. This can happen most easily on 530 KHz. Typical offenders: Tall nearby trees, buildings, other antennas, towers, or steel light poles. Ideally, nothing conductive or nonconductive should parallel the antenna for 100 feet laterally on 530 KHz, 50 feet laterally on 1610 KHz. Nothing should be taller than the antenna tip for a 200 foot radius on 530 KHz, 100 foot radius for 1610.

2F) Nearby steep terrain features can attenuate signals in the areas of the features and beyond in those directions.

3F) Overhead power lines can produce an effect that appears to lower signal levels by introducing interference that can make the signal. This most often happens on the lower frequencies and most affects the signal in the area of the lines only. Range in areas not in proximity to the lines is not affected.

4F) Monitoring behind large structures and tall terrain features can create effect of low signal in immediate proximity to the structures of features.

5F) The impression of low range with a normal carrier level can be created by operating the transmitter with the Audio Set control potentiometer set too low. This creates a low modulation situation that reduces listenable range. Reset the transmitter's audio level potentiometer to cause the flasher LED inside the transmitter to flash. If flashing will not initiate, go to step 2C and continue in Section C.

6F) If the RX (receive) volume of the (optional) Cellular Telephone & interface is set too low, low modulation/low range will be the result.

Section G
Audio quality is poor.

1G) Monitor broadcast messages on the Digital Voice Recorder. If messages sound good when monitored using the * 2 # command on the Digital Voice Recorder, go to 1C above and continue in Section C. If messages sound as if they have been recorded badly, continue below.

2G) If messages have been recorded via microphone or control telephone, try rerecording. Background noise from nearby traffic can cause a poor quality sound. The microphone will produce a superior recording to the control telephone's handset. Try using the microphone if your previous recordings have been made with the handset. Put the mic about 2" from your mouth, being careful to direct your breath away from the mic to reduce "popping". To switch between sources (microphone and Control Telephone), the Digital Voice Recorder's input source must be changed with the * 7 # command.

3G) Audio quality of all recordings is improved with the faster recording sampling rates. To switch to a faster (or slower) rate, use the * 8 # command.

4G) If messages have been recorded by land-line telephone, the quality of the telephone itself and the line make a great deal of difference in the sound of recorded messages. Consider adding a remote audio board to your telephone system to allow better quality recordings via telephone.

5G) If the RX volume of the optional Cellular Telephone & Interface is set too high, distortion may occur. If set too low, background noise may be present with low modulation.

6. SITE DOCUMENTATION REQUIREMENTS

The following are required at each site:

- Preventive Maintenance Log
- Corrective Maintenance Log
- FCC License

Samples of site documentation appear on the following pages.

Caltrans Preventive & Corrective Maintenance Log

For

Non-Mobile Highway Advisory Radio System Sites

Cover Sheet

HAR PREVENTIVE MAINTENANCE LOG

Task No.	Description	Expected Task Time (min.)	Recommend PM Interval	Done (Y or N)	Were Repairs made?	Date of PM
1	Remotely Monitor HAR during approach	N/A	every 6 mths			
2	Inspect and Clean the HAR cabinet	10	every 6 mths			
3	Visually inspect all of the major HAR modules	5	every 6 mths			
4	Check and Adjust Crystal Drift	30	annually			
5	Check VSWR	30	every 6 mths			
6	Retune Antenna Coupler or Tuner[6]	15	every 6 mths			
7	Retune HAR Antenna[7]	120	As Required			
8	Measure field strength of transmitter at 2 km (.93mi.)	15	annually			
9	Set Audio Level	5	every 6 mths			
10	Verify operation of 12V Battery Charger	5	annually			
11	Verify operation of 12V Low Voltage Battery Cutoff Relay	10	annually			
12	Verify Voltage of 12V Recorder Battery	5	annually			
13	Verify Voltage of 12V Main Batteries	5	every 6 mths			
14	Replace 12V Batteries	30	As Required			
15	Verify operation of 24V Battery Charger	5	annually			
16	Verify operation of 24V Low Voltage Battery Cutoff Relay	10	annually			
17	Replace 12V Recorder Backup Battery[1]	20	every 6 mths			
18	Verify Operation of Cellular Telephone[2]	3	annually			
19	Verify Operation of Control Telephone	3	annually			
20	Verify Operation of Message Recorder	20	every 6 mths			
21	Check DC Indicator Light	1	every 6 mths			
22	Check AC Indicator Light	1	every 6 mths			
23	Verify Microphone Operation (where applicable)	5	annually			
24	Check Ground Plane Connections	10	annually			
25	Recharge Chemical Ground[3] (where applicable)	20	As Required			
26	Charger Shedding Relay	10	annually			
	Total expected time to perform a 6 month PM[4] =	1.6 hrs				hours
	Total expected time to perform a complete annual PM[5]	3.4 hrs				

Notes:

1. If batteries are lead acid and over a year old, then replace them with sealed batteries utilizing gelled electrolyte.
2. A celluar telephone is not installed at all locations.
3. If system performance is still degraded after performing all PM tasks, then recharge the chemical ground.
4. The expected time excludes annual PM tasks and "As Required" PM tasks.
5. The expected time excludes "As Required" PM tasks.
6. Retuning not required with Superstation 3000 antenna

Date:_______________
Person Performing CM:________________________
Caltrans Person Contacted:_____________________

HAR CORRECTIVE MAINTENANCE LOG

Item No.	Item Description	Date Repaired	Action required to Repair	Further Action Required?	Notes
1	Transmitter				
2	Transmitter Coupler or Tuner				
3	HAR Antenna				
4	HAR Feedline				
5	Feedline Lightining Suppressor				
6	12V Battery Charger				
7	12V Low Voltage Battery Cutoff Relay				
8	12V Recorder Battery				
9	24V Battery Charger				
10	24V Low Voltage Battery Cutoff Relay				
11	12V Main Batteries				
12	Surge Suppressor(s) for Telephone Line				
13	Control Telephone				
14	Cellular Telephone[1]				
15	Cellular Telephone Feedline[1]				
16	Cellular Telephone Antenna[1]				
17	Message Recorder				
18	DC Indicator Light				
19	AC Indicator Light				
20	Voltmeter				
21	Microphone				
22	AC Power Surge Suppressor				
23	Charger Shedding Relay				
24	Other				

Notes:

1. A celluar telephone is not installed at all locations.

Date:________________
Person Performing CM:_________________________
Caltrans Person Contacted:_____________________

EXAMPLE

Federal Communications Commission
Gettysburg, PA 17325-7245

RADIO STATION LICENSE

Licensee Name: CALIFORNIA, STATE OF

Radio Service: PL LOCAL GOVERNMENT — License Issue Date: 911009
Call Sign: WNXK966 — File Number: 9105254851 — License Expiration Date: 961009
Frequency Advisory No
Number of Mobiles by Category Vehicular - ****** Portable - ******Aircraft - ******Marine - ******Pagers*******

911010N 834 1 12

CALIFORNIA, STATE OF
GENERAL SERVICES DEPT GLEN NASH
601 SEQUOIA PACIFIC BLVD
SACRAMENTO CA 958140282

Station Technical Specifications

FCC ID	Frequencies (MHz)	Station Class	No. of Units	Emission Designator	Output Power (Watts)	E.R.P. (Watts)	Ground Eleva	Ant. Hgt. To Tip	Antenna Latitude	Antenna Longitude
1:	1.61000	FB	1	6K00A3E	10.000	10.000	414	49	35-38-44	119-13-06
2:	1.61000	FB	1	6K00A3E	10.000	10.000	345	49	35-12-32	119-00-31
3:	1.61000	FB	1	6K00A3E	10.000	10.000	330	49	35-12-33	119-09-41
4:	1.61000	FB	1	6K00A3E	10.000	10.000	295	49	35-25-04	119-25-17
5:	1.61000	FB	1	6K00A3E	10.000	10.000	260	49	35-36-59	119-39-01

	TRANSMITTER STREET ADDRESS	CITY	COUNTY	STATE
1:	INT RT 99 AND WHISTLER RD	MC FARLAND	KERN	CA
2:	INT RT 99 AND BEAR MOUNTAIN BLVD	GREENFIELD	KERN	CA
3:	INT I5 AND BEAR MOUNTAIN BLVD	OLD RIVER	KERN	CA
4:	I5 BUTTONWILLOW REST STOP	BUTTONWILLOW	KERN	CA
5:	INT I5 AND RT 46	LOST HILLS	KERN	CA

CONTROL POINTS:INT RT 99 AND WHISTLER RD MC FARLAND CA:INT RT 99 AND BEAR MOUNTAIN BLVD GREENFIELD CA:INT I5 AND BEAR MOUNTAIN BLVD OLD RIVER CA:I5 BUTTONWILLOW REST STOP BUTTONWILLOW CA:INT I5 AND RT 46 LOST HILLS CA:TRANSPORTATION DEPT 1352 W OLIVE AVE FRESNO CA
CONTROL POINT PHONE: 209-488-4066

SPECIAL COND: SEE ATTACHED #39, SP:THE FREQUENCY BAND 1605-1705 KHZ HAS BEEN REALLOCATED TO AM BROADCAST. CONTINUED OPERATION MAY REQUIRE A CHANGE IN FREQUENCY PENDING FURTHER PROCEEDINGS ON GEN DOCKET 84-467.

EMISSION DESIGNATOR(S) CONVERTED TO CONFORM TO DESIGNATOR(S) SET OUT IN PART 2 OF THE COMMISSION'S RULES.

PAGE 1 OF 1

FEDERAL COMMUNICATIONS COMMISSION

This authorization becomes invalid and must be returned to the Commission if the stations are not placed in operation within eight months unless an extension of time has been granted. EXCEPTION: 800 MHz trunked and certain 900 MHz station licenses cancel automatically if not constructed within one year

FCC 5
September

7. RECOMMENDED TEST EQUIPMENT

Field Intensity Meter: Potomac FIM41 (equivalent or better)
This is a broadcast band meter with a special modification to read 530KHz (The modification can be supplied by the factory at no extra charge when the meter is ordered). This meter is required to determine the field intensity at the 1.5 km (.93mi.) measurement distance. A maximum of 2.0 mV/m is allowable.

Digital Multimeter: Fluke 76 Series II (equivalent or better)
Useful to check continuity between wires, connectors, terminals, groundplanes, etc., and check voltages and current as part of the general troubleshooting process.

Through Line Watt Meter: Bird Thruline 4410-A meter with 4410-2 slug (or equivalent)
Useful for checking output and reflected power to more precisely tune the antenna.

Variable DC power supply: Newmar VARI-COM 20 (equivalent or better)
This device is to be used to verify the operation of the relays associated with low voltage disconnect and parasitic power drains.

Communications Monitor: IFR 1500 (equivalent or better)
Useful for checking audio quality of broadcast, checking deviation level of carrier, verifying output power and other system performance parameters.

Frequency Counter: HP 53181A (or equivalent)
For adjusting crystal drift.

8. GLOSSARY - HIGHWAY ADVISORY RADIO TERMS

ACOUSTIC FEEDBACK – The howling caused when a microphone picks up vibration from its own speaker system.

AM – An abbreviation for amplitude modulation (see modulation).

ANTENNA HEIGHT ABOVE AVERAGE TERRAIN (AAT) – Height of the center of the radiating element of the antenna above the average terrain.

ANTENNA HEIGHT ABOVE SEA LEVEL – The height of the topmost point of the antenna above mean sea level.

ANTENNA STRUCTURE – Structure on which antenna is mounted.

ASSIGNED FREQUENCY – Center of a frequency band assigned to a station.

ASSIGNED FREQUENCY BAND – The frequency band, the center of which coincides with the frequency assigned to the station, and the width of which equals the necessary bandwidth plus twice the absolute value of the frequency tolerance.

AUTHORIZED BANDWIDTH – The frequency band specified in kilohertz and centered on the carrier frequency containing those frequencies upon which a total (99 percent) of the radiated power appears, extended to include any discrete frequency upon which the power is at least 0.25 percent of the total radiated power.

AUTOMATIC VEHICLE MONITORING (AVM) – The use of non-voice signaling methods from and to vehicles to make known at fixed points the location of the vehicles. AVM systems may also transmit status and instructional messages related to the vehicle involved.

AVERAGE TERRAIN – The average elevation of terrain between 2 and 10 miles from the antenna site.

BASE STATION – A station at a specified site authorized to communicate with mobile stations.

BIAS – A high frequency alternating current fed into the recording circuit and used as a carrier of the audio signals to the record head, as well as current to the erase head.

CABLE ANTENNA – Transmission lines so designed that fields are not totally defined. Length cannot exceed 3 km and may feed up to 50 watts of power provided that the 2.0 mV/m at 50 m limit is not exceeded.

CARRIER FREQUENCY – The frequency of an unmodulated electromagnetic wave.

CHANNEL – Complete sound or signal path of a sound system.

CHANNEL LOADING – The number of mobile transmitters authorized to operate on a particular channel within the same service area.

CONSOLE – In HAR applications, the position from which the HAR operator controls the program material fed to the transmitter.

CONTROL POINT – Any place from which a transmitter's functions may be controlled.

CONTROL STATION – An Operational Fixed Station the transmissions of which are used to control automatically the emissions or operation of another radio station at a specific location.

dB – Abbreviation for decibel.

dBm – Abbreviation for "decibels above 1 milliwatt."

DECIBEL – a relative measure of sound intensity. One dB is the smallest change in sound volume that the human ear can detect. The term is also used to express relative intensity of electrical and radio signals.

DISPATCH POINT – Any place from which radio messages can be originated under the supervision of a control point.

DISTORTION – Any difference between the original recorded sound and reproduced sound. The term is also used in connection with sound transmitted over a radio system. The distortion is then the difference between the original sound and that received by the receiver.

DTMF – Dual tone multi-frequency telephone handset.

DYNAMIC MICROPHONE – An electromagnet type which employs a moving coil in the magnetic field.

DYNAMIC RANGE – The ratio between the softest and loudest sounds a tape recorder or radio can reproduce without distortion.

EFFECTIVE RADIATED POWER (ERP) – The power supplied to an antenna multiplied by the relative gain of the antenna in a given direction.

ELECTRIC FIELD – One of two components of a radio (electromagnetic) wave, the other component is the magnetic field. The strength of the electric field is expressed in volts, millivolts or microvolts.

EQUALIZATION – The manipulation of frequencies that are required to meet the recognized standards of recording and producing techniques.

FCC – Federal Communication Commission

FHWA – Federal Highway Administration.

FIELD STRENGTH – The strength of a radio wave, usually expressed in terms of its electric field component.

FIXED RELAY STATION – A station at a specified site used to communicate with a station at another specified site.

FLAT RESPONSE – Any audio system is specified as having an essentially flat frequency response if it is rated plus or minus 3 db from 50 to 14,000 Hz. In any HAR system a flat response greater than 3000 Hz is not necessary because of the limitations of the telephone line and transmitter.

FLUTTER – Very short and rapid variations in tape speed.

GAP – The distance between the poles of tape heads usually measured in microns.

GROUND PLANE – Ideally, a perfectly conducting surface of infinite extent forming a part of an antenna system. In HAR monopole applications, the earth itself may suffice as an imperfect ground plane. The ground plane can be improved by installing copper wire radials oriented around the base of the antenna like spokes of a wheel.

HAR – Highway Advisory Radio. A general term describing methods and equipment used to provide information to motorists via their AM radio receivers.

HARMFUL INTERFERENCE – An emission, radiation, or induction which specifically degrades, obstructs, or interrupts the service provided by another station operations.

HEAD – An electromagnetic device across which the tape is drawn and which magnetizes the iron oxide coating on the tape.

HEAD ALIGNMENT – The correct position of the tape head and gap with respect to the magnetic tape.

HERTZ – Frequency in cycles per second.

HUM – Low frequency noise in an audio component usually induced from the power line or stray magnetic fields.

Hz – Abbreviation for Hertz.

IMPEDANCE – Measured in ohms, it is the AC resistance of any electrical system. Referred to as “high” or “low” impedance. For best results in connecting two components, output and input impedances must match.

INTERCONNECTION – The connection, through automatic or manual means, of private land mobile radio stations with facilities of the public switched telephone network. It permits the transmission of messages or signals between points in the wire line or radio network of a public telephone company and persons served by private land mobile radio stations. Wire line, radio circuits, or links furnished by common carriers (which are used by licensees or other authorized persons for transmitter control, or as an integral part of an authorized private internal system of communication, or as an integral part of dispatch point circuits in a private land mobile radio station) are not considered to be interconnection for purposes of this FCC rule.

INTERNAL SYSTEM – An internal system of communication is one of which all messages are transmitted between the fixed operating positions located on premises.

ITINERANT OPERATION – Operation of a radio station at unspecified locations for varying periods of time.

kHz – Abbreviation for kilohertz.

KILOHERTZ – Frequency in thousands of cycles per second.

KILOMETER – 0.62 miles.

km – An abbreviation for kilometer

LAND MOBILE RADIO SERVICE – A mobile service between base stations and land mobile stations or between land mobile stations.

LAND MOBILE RADIO SYSTEM – A regularly interacting group of base, mobile and associated control and fixed relay stations intended to provide land mobile radio communications service over a single area of operation.

LAND STATION – A station in the mobile service not intended to be used while in motion.

m – An abbreviation for meter.

MAGNETIC FIELD – One of the two components of a radio wave.

MEGAHERTZ – Frequency in millions of cycles per second.

METER – 3.28 feet.

MHz – Abbreviation for megahertz.

MOBILE RELAY STATION – A base station, in the mobile service, authorized to re-transmit automatically on a mobile service frequency communications which originate on the transmitting frequency of the mobile station.

MOBILE REPEATER STATION – A mobile station authorized to re-transmit automatically on a mobile service frequency, communications to or from hand carried transmitters.

MOBILE SERVICE – A service of radio communication between mobile and base stations, or between mobile stations.

MOBILE STATION – A station in the mobile service intended to be used while in motion or during halts at unspecified points. This includes hand carried transmitters.

MODULATING SOURCE – In HAR applications, the recorder, reproducer or microphone used to generate the program material used to modulate the transmitter.

MODULATION – Any method for compressing voice, audio, or any other form of information onto a radio frequency carrier. Techniques include amplitude modulation (AM), frequency modulation (FM) and phase modulation (PM). HAR systems are restricted to use of AM.

MONITOR HEAD – The head on a tape recorder which, when connected to the proper circuitry, makes it possible to listen to the material directly off the tape while the recording is being made.

MONOPOLE – A type of antenna consisting of an elongated conducting structure, such as a wire, rod, whip, tower, etc., usually operated perpendicular to a conducting ground plane. It may be thought of as one-half of a dipole, which requires no ground plane.

MUTCD – Municipal Uniform Traffic Control Devices.

mV/m – An abbreviation for millivolts per meter, an expression for field strength.

NAB CURVE – Standard playback equalization curve set by the National Association of Broadcasters.

OPERATIONAL FIELD STATION – A fixed station, not open to public correspondence, operated by, and for the sole use of those agencies operating their own radio communication facilities.

OUTPUT POWER – The radio frequency output power of a transmitter's final radio frequency stage as measured at the output terminal while connected to a load of the impedance recommended by the manufacturer.

PAGING – A one-way communications service from a base station to mobile or fixed receivers that provide signaling or information transfer by such means as tone, tone-voice, tactile, optical readout, etc.

PLAYBACK – Reproduction of the sound previously recorded.

PM - Preventive Maintenance

POLARIZATION – The orientation of the electric field component of a radio wave.

PRIVATE CARRIER – An entity licensed in the private services and authorized to provide communication services to other private services on a commercial basis.

RADIO DETERMINATION – The determination of position, or the obtaining of information relating to position, by means of the propagation of radio waves.

RF BRIDGE – An instrument used to adjust the antenna settings by reading both resistance and reactance values.

SECONDARY OPERATION – Radio communications which may not cause interference to operations authorized on a primary basis and which are not protected from interference from those primary operations.

SIGNAL BOOSTER – A device which automatically amplifies and transmits received base station transmissions with no change in frequency or authorized bandwidth.

SIGNAL-TO-NOISE RATIO – The ratio, expressed in db, between the pure sound and the noise background picked up from recording, reproduction, and transmission.

SPECIALIZED MOBILE RADIO SYSTEM – A radio system in which licensees provide land mobile communications serving (other than radio location services) in the 800 MHz and 900 MHz bands on commercial basis to entities eligible to be licensed by FCC.

STANDARD METROPOLITAN STATISTICAL AREA (SMSA) – A city of 50,000 or more population.

STATION AUTHORIZATION – A license issued by the FCC for the operation of a radio station.

TMC – Transportation Management Center

TRAVELERS' INFORMATION STATION (TIS) – A base station in the Local Government Radio Service used to transmit non-commercial, voice information pertaining to traffic and road conditions, traffic hazards and traveler advisories, directions, availability of lodging, rest stops, and service stations, and descriptions of local points of interest.

TRUNKED RADIO SYSTEM – A method of operation in which a number of radio frequency channel pairs are assigned to mobile and base stations in the system for use as a trunk group.

TUNER – Used to compensate for an antenna system impedance mismatch, including the pure resistive and the reactive mismatch between the resonant frequency of the antenna and the carrier frequency, through the use of a network of air wound inductors and high voltage rated capacitors.

VERTICAL POLARIZATION – A term used to describe a radio wave with respect to the direction in which the electric field component is oriented. A vertical monopole will produce a vertically polarized radio wave. Radio waves can also be polarized horizontally, diagonally, or circularly.

VSWR – Voltage Standing Wave Ratio.

VU METER – A volume unit meter which indicates the relative levels of sound being recorded or played out.

9. RECOMMENDED PM SUPPLIES AND REPLACEMENT PARTS LIST

Charging material for chemical grounds

Epsom Salt (available at most pharmacies and department stores)

Ground Rod Welding Materials

Flint Ignitor Model: T320; Mfr.: Erico Inc.

Cable to 5/8" Ground Rod Weld kit – "**One Shot**"

Connection to AWG 6 and AWG 8 solid cable - Model: GR-161G

Connection to AWG 3 and AWG 4 solid cable - Model: GR-161L

Connection to AWG 1 and AWG 2 solid cable - Model: GR-161V

Connection to AWG 2/0 and AWG 1/0 solid cable - Model: GR-161C

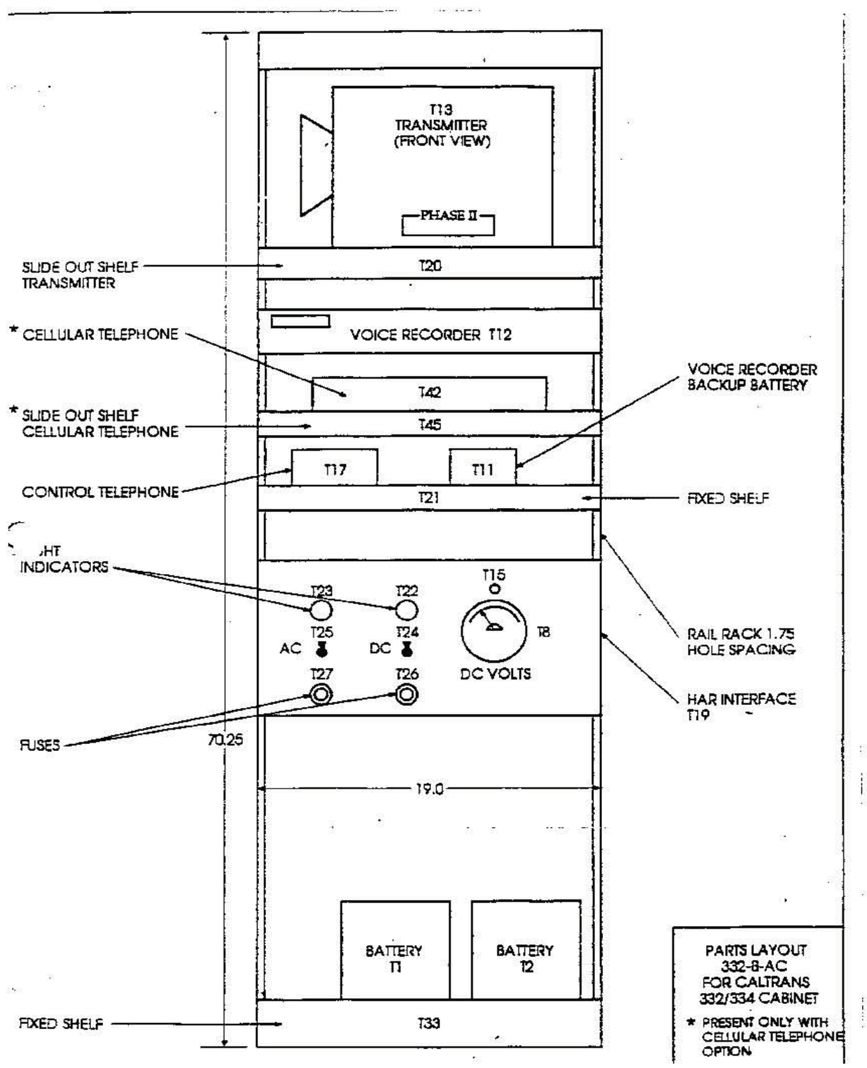
Standard HAR Replacement Parts List

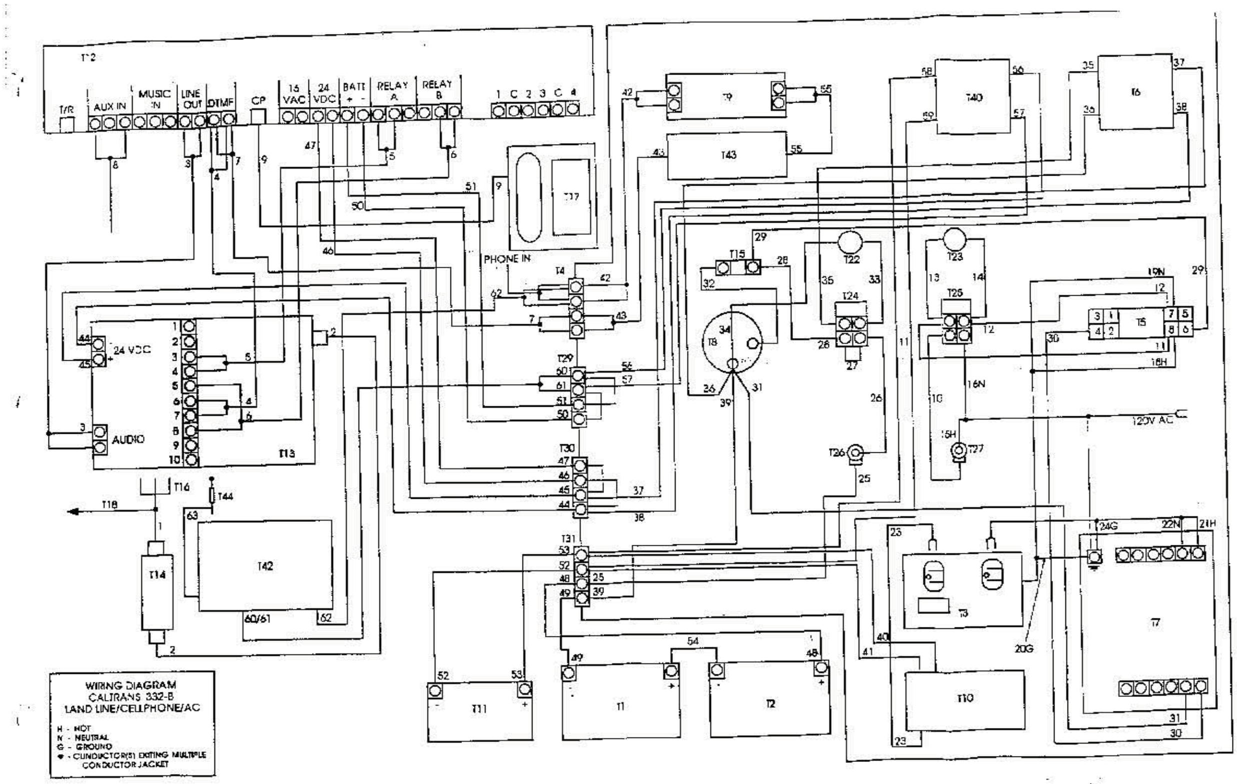
Part No.	Part Description	Part Mfr	Mfr Part No.	Recommend Quantity
T1, T2	Sealed Gelled Electrolyte 12V Battery	MK	27 Gel (or equivalent)	1
T2	Power Surge Arrestor	Polyphaser	IS-PLDO	1
T5	Charger Shedding Relay	Potter & Brumfield	CSL-38-30010	1
T6	Low Voltage Battery Disconnect Relay (24V)	Potter & Brumfield	LVD-8-16-24V	1
T7	24V Battery Charger	Schauer	TB5024/WF-6035-01	1
T8	Voltmeter	Clark Bros.	SVK-136-30	1
T10	Recorder Backup Battery Charger	Racom	BB3	1
T11	Recorder Backup Battery	Powersonic	122260	1
T12	Digital Message Recorder	Alarmco	AP55 DRAM860-TC-OR	
T13	Transmitter / Coupler	Radio Systems	TR20TIS-CP15-OR55-24-MM-USO	
T16	AM Antenna[2]	Morad	SF****SPRS[1]	1
T26	DC Fuse	Bussman	10A AGC	1
T27	AC Fuse	Bussman	10A AGC	1
T40	Low Voltage Cut-Off Relay[3] (12V)	Bobier	LVD-8-16-12V	1
T42	Cellular Telephone & Interface	Tellular	Phonecel SX	
T44	Cellular Telephone Antenna & Mount	Maxrad	26331/85618	1
F1	Transmitter Fuse	Bussman	2A MDL	1
F101	Transmitter Fuse	Bussman	4A AGC	1
F1, F2, F3	Coupler Fuse	Bussman	4A AGC	4
F1, F2	Digital Recorder Backup Battery Fuses	Bussman	8A AGC	3
T17	Control Phone	----	Any single line speaker phone	1
None	Cabinet Fan	warehouse[4]		2
None	Cabinet Air Filter	warehouse[4]	4130-20088	5

Notes:
1. Item T16 "****" represents the antenna frequency in kHz of the antenna
2. Available if needed
3. Older models only
4. Items are stored in Caltrans warehouse
5. Please refer to the Manufacturer's Literature section to reference the part number to their physical and circuit locations.

10. MANUFACTURER'S LITERATURE

The following pages include reproduction of manufacturer's literature for HAR equipment.


T13
TRANSMITTER
(FRONT VIEW)
PHASE II
SLIDE OUT SHELF
TRANSMITTER
T20
VOICE RECORDER T12
* CELLULAR TELEPHONE
T42
* SLIDE OUT SHELF
CELLULAR TELEPHONE
T45
VOICE RECORDER
BACKUP BATTERY
T17
T11
CONTROL TELEPHONE
T21
FIXED SHELF
INDICATORS
T23
T22
T15
T25
T24
AC
DC
T8
DC VOLTS
T27
T26
RAIL RACK 1.75
HOLE SPACING
HAR INTERFACE
T19
FUSES
70.25
19.0
BATTERY
T1
BATTERY
T2
FIXED SHELF
T33
PARTS LAYOUT
332-8-AC
FOR CALTRANS
332/334 CABINET
* PRESENT ONLY WITH
CELLULAR TELEPHONE
OPTION


WIRING DIAGRAM
CALTRANS 332-B
LAND LINE/CELLPHONE/AC
H - HOT
N - NEUTRAL
G - GROUND
• - CONDUCTOR(S) EXITING MULTIPLE CONDUCTOR JACKET

Parts Identification Table

Part No.	Part Description
T1	12V Main Battery
T2	12V Main Battery
T3	Power Surge Arrestor
T4	Barrier Strip
T5	Charger Shedding Relay
T6	Low Voltage Battery Disconnect
T7	24V Battery Charger (for Main Batteries)
T8	Voltmeter
T9	Telephone Line Surge Arrestor
T10	12V Battery Charger (for Recorder Battery)
T11	12V Recorder Backup Battery
T12	Digital Voice Recorder
T13	AM Transmitter & Coupler
T14	Lightning Arrestor (antenna)
T15	Voltmeter Pushbutton
T16	AM Antenna
T17	Control Telephone
T18	Groundplane
T19	HAR Interface
T20	Slide Out Shelf (Transmitter)
T21	Fixed Shelf
T22	DC Power Indicator
T23	AC Power Indicator
T24	DC Power Switch
T25	AC Power Switch
T26	DC Power Fuse
T27	AC Power Fuse
T28	Microphone
T29	Barrier Strip
T30	Barrier Strip
T31	Barrier Strip
T32	Antenna Mount
T33	Fixed Shelf (for Batteries)

Replacement Parts List

Part No.	Part Description	Part Mfr	Mfr Part No.	Recommend Quantity
T1, T2	Sealed Gelled Electrolyte 12V Battery	MK	27 Gel (or equivalent)	1
T2	Power Surge Arrestor	Polyphaser	IS-PLDO	1
T5	Charger Shedding Relay	Potter & Brumfield	CSL-38-30010	1
T6	Low Voltage Battery Disconnect Relay (24V)	Potter & Brumfield	LVD-8-16-24V	1
T7	24V Battery Charger	Schauer	TB5024/WF-6035-01	1
T8	Voltmeter	Clark Bros.	SVK-136-30	1
T10	Recorder Backup Battery Charger	Racom	BB3	1
T11	Recorder Backup Battery	Powersonic	122260	1
T12	Digital Message Recorder	Alarmco	AP55 DRAM860-TC-OR	
T13	Transmitter / Coupler	Radio Systems	TR20TIS-CP15-OR55-24-MM-USO	
T16	AM Antenna[2]	Morad	SF****SPRS[1]	1
T26	DC Fuse	Bussman	10A AGC	1
T27	AC Fuse	Bussman	10A AGC	1
T40	Low Voltage Cut-Off Relay[3] (12V)	Bobier	LVD-8-16-12V	1
T42	Cellular Telephone & Interface	Tellular	Phonecel SX	
T44	Cellular Telephone Antenna & Mount	Maxrad	26331/85618	1
F1	Transmitter Fuse	Bussman	2A MDL	1
F101	Transmitter Fuse	Bussman	4A AGC	1
F1, F2, F3	Coupler Fuse	Bussman	4A AGC	4
F1, F2	Digital Recorder Backup Battery Fuses	Bussman	8A AGC	3
T17	Control Phone	----	Any single line speaker phone	1
None	Cabinet Fan	Warehouse[4]		2
None	Cabinet Air Filter	Warehouse[4]	4130-20088	5

Notes:
1. Item T16 "****" represents the antenna frequency in kHz of the antenna
2. Available if needed
3. Older models only
4. Items are stored in Caltrans warehouse