Washington State
Department of Transportation

TST: HIGHWAY ADVISORY RADIO (HAR)

STUDENT HANDBOOK

ATMS CODE: CUB

Instructors:
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HIGHWAY ADVISORY RADIO (HAR)

Table of Contents

Course Title: TST: Highway Advisory Radio (HAR)

Course Code: CUB
Class Size: 10
Hours: 4

Course Description:
To teach TST personnel installation principles, maintenance and troubleshooting specific to HAR systems.

Course Objectives: By the end of this course, you'll be able to:

1. Describe the basic elements of the Highway Advisory Radio System.
2. Describe how to commission a site.
3. List the steps necessary to perform preventative maintenance on a HAR site.
4. Demonstrate the basic steps in troubleshooting a HAR System.

Attendees: TST A, B, C, and D personnel.

Comments: None

Program Name: Maintenance
Program Code: 4
Source Code: 1
Curriculum: CC 01- Miscellaneous Courses
Prerequisites: None

Outcome #1 Pre-test.

1. HAR is an acronym standing for ____________ ___________ ____________.

2. The three primary components that make up HAR system are:

   - ______________________
   - ______________________
   - ______________________

3. The traveling public is notified to tune into a HAR broadcast by what means?

   ____

4. As a general rule HAR signs should be placed with in a ______ to ______ mile radius of the transmitter/antenna location.

5. The two most common AM frequencies used for HAR are ________kHz and _______kHz.

Outcome #1 Post-test.

1. HAR is an acronym standing for ____________ ___________ ____________.

2. The three primary components that make up HAR system are:

   - _____________________
   - _____________________
   - _____________________

3. The traveling public is notified to tune into a HAR broadcast by what means?

   ____

4. As a general rule HAR signs should be placed with in a ______ to ______ mile radius of the transmitter/antenna location.

5. The two most common AM frequencies used for HAR are ________kHz and _______kHz.

3 Basic Elements of a Highway Advisory Radio

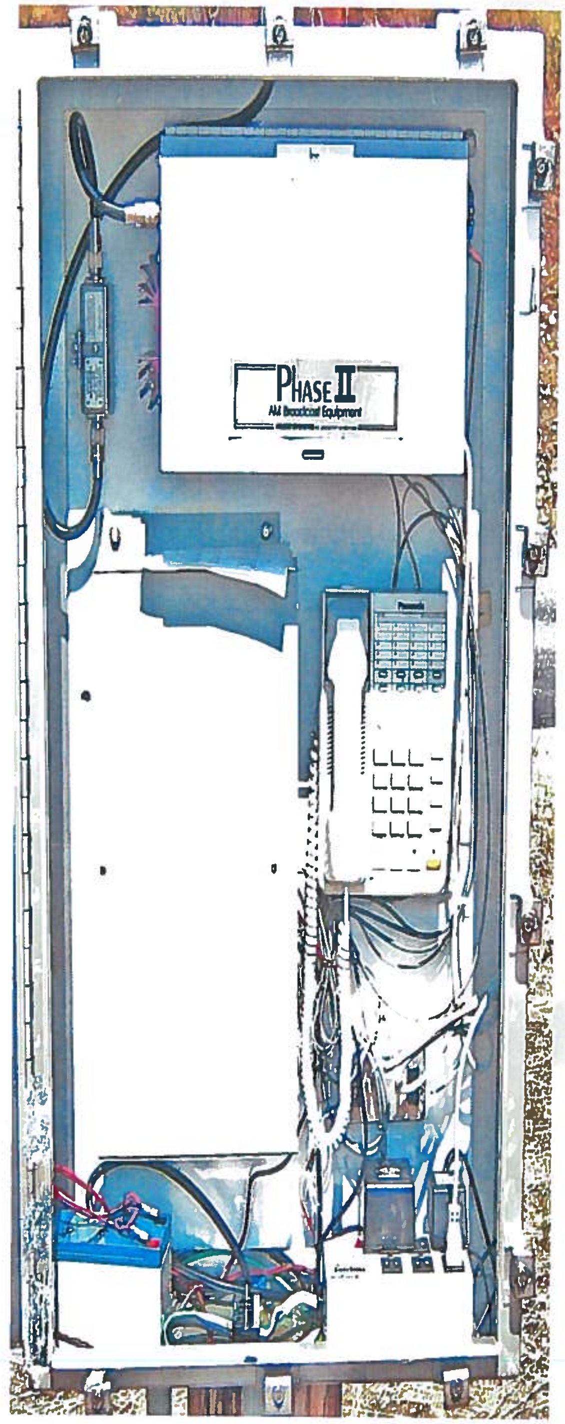
1. Message Programmer/Voice Recorder
2. Transmitter
3. Antenna System

Message Programmer/Voice Recorder

Information Station Specialists

With the TR20 Transmitter

AP55 Digital Message Programmer



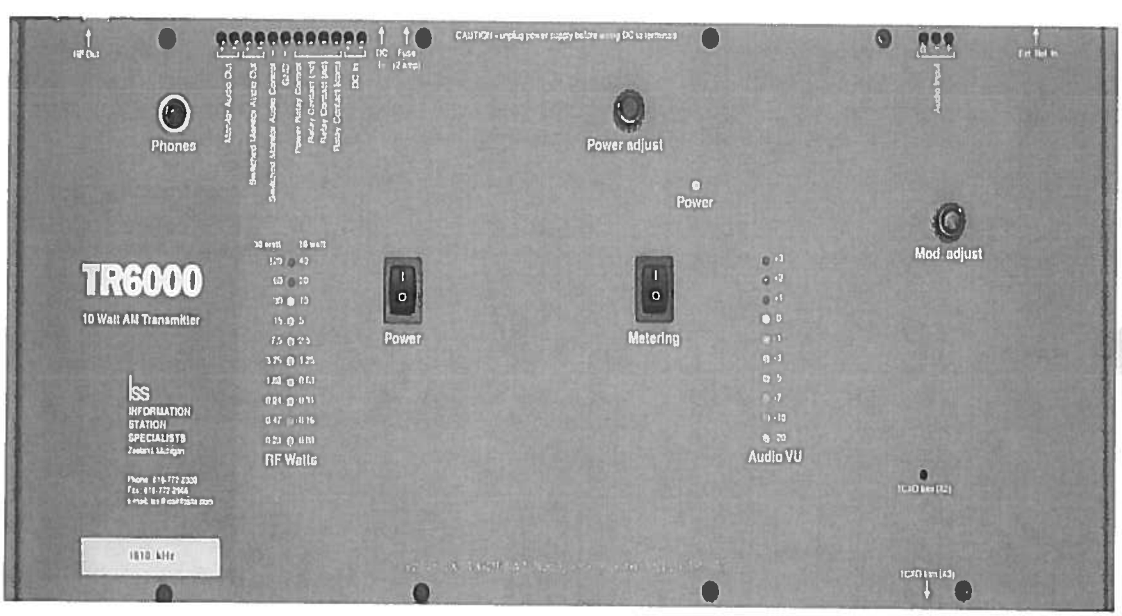
Message Programmer/Voice Recorder

Information Station Specialists

With the TR-6000 Transmitter

Either the

IP8/AP55 Digital Message programmer



Message Programmer/Voice Recorder

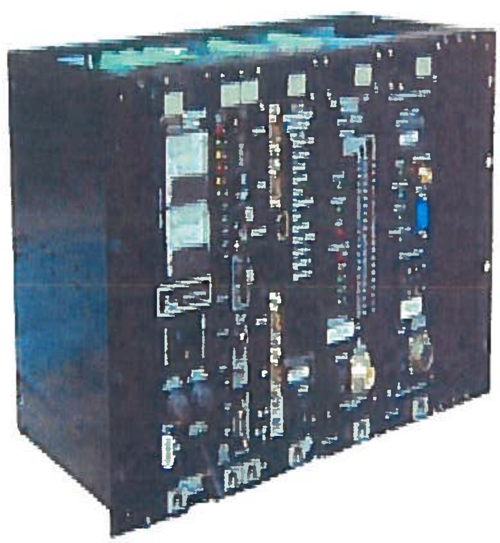
Highway Information Systems, Inc. (H.I.S.)

DR1500AM

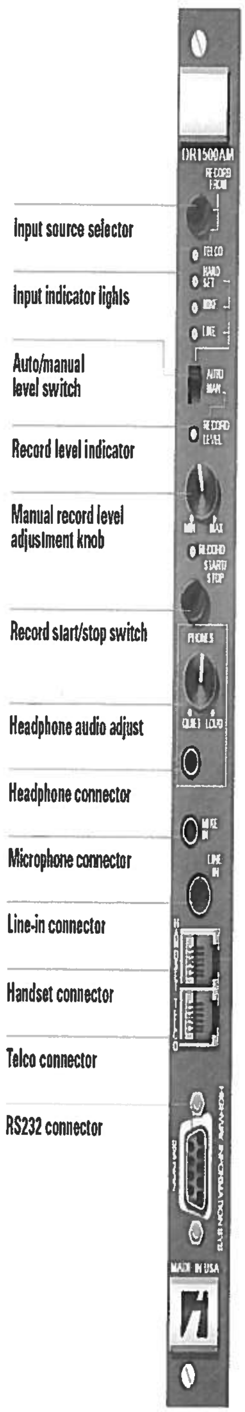
Digital Recorder/Player

Message Programmer/Voice Recorder

Essentially all do the same job



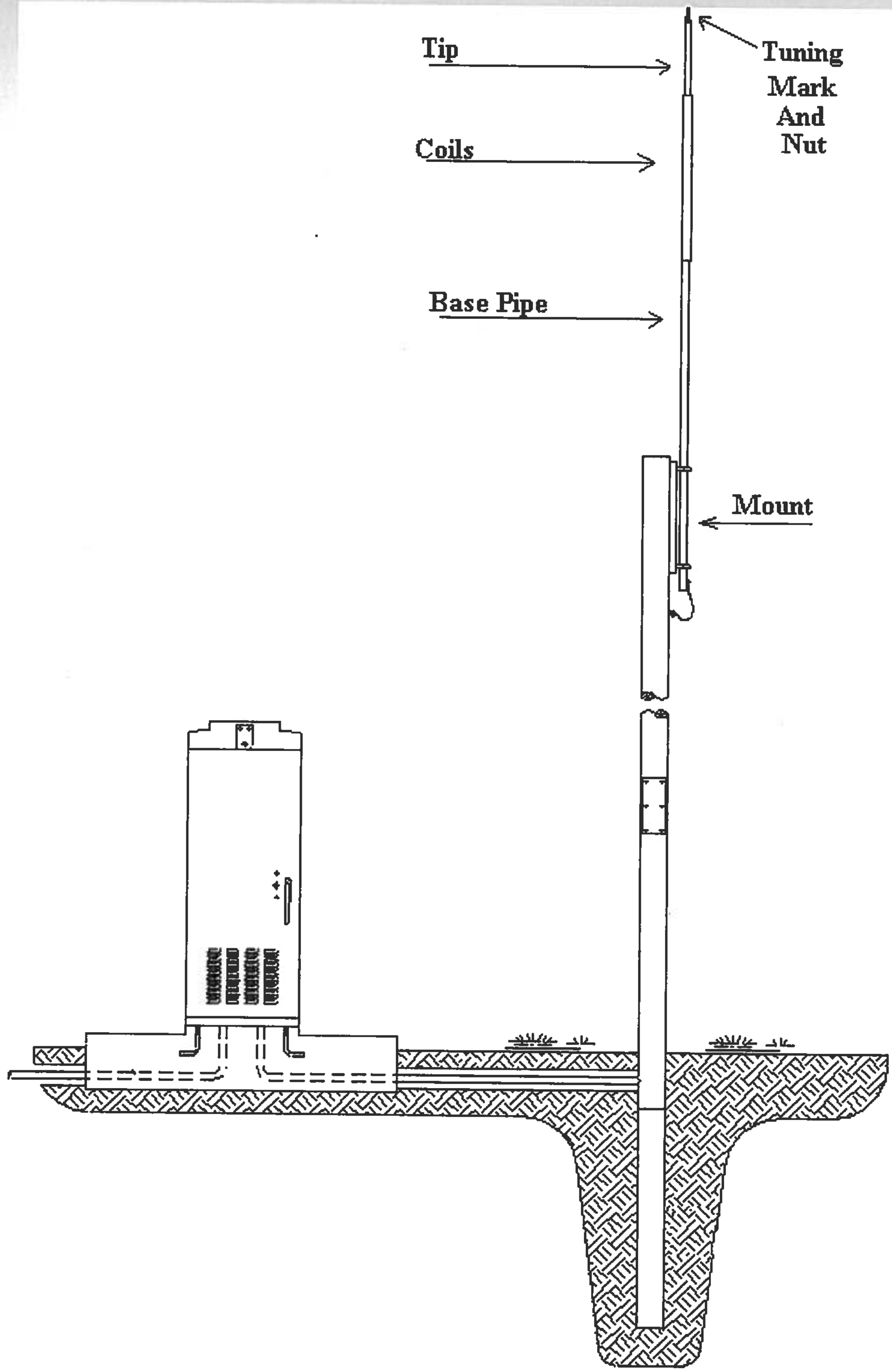
Message Programmer/Voice Recorder



Multiple Input Modes:

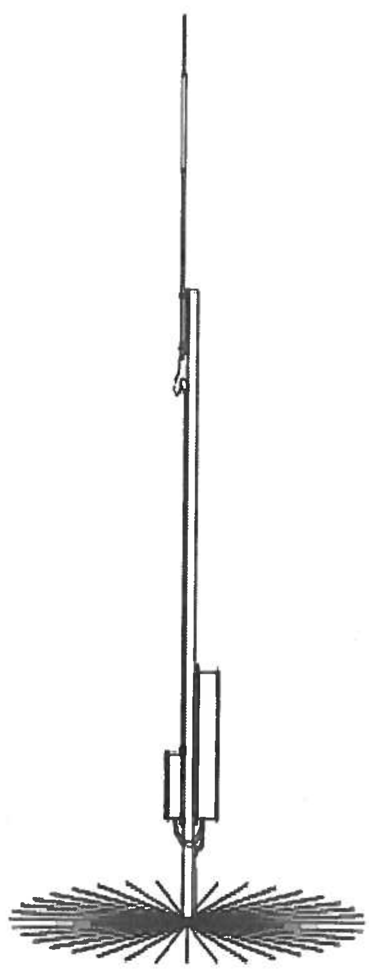
- Telephone
- Handset
- Microphone
- Aux. Inputs
- Ethernet

Antenna



Antenna

- The second half of the antenna system is called a **ground plane.**



Outcome #1 Post-test.

1. HAR is an acronym standing for Highway Advisory Radio.

2. The three primary components that make up HAR system are:

   - Antenna System
   - Transmitter
   - Message Programmer/Voice Recorder

3. The traveling public is notified to tune into a HAR broadcast by what means?

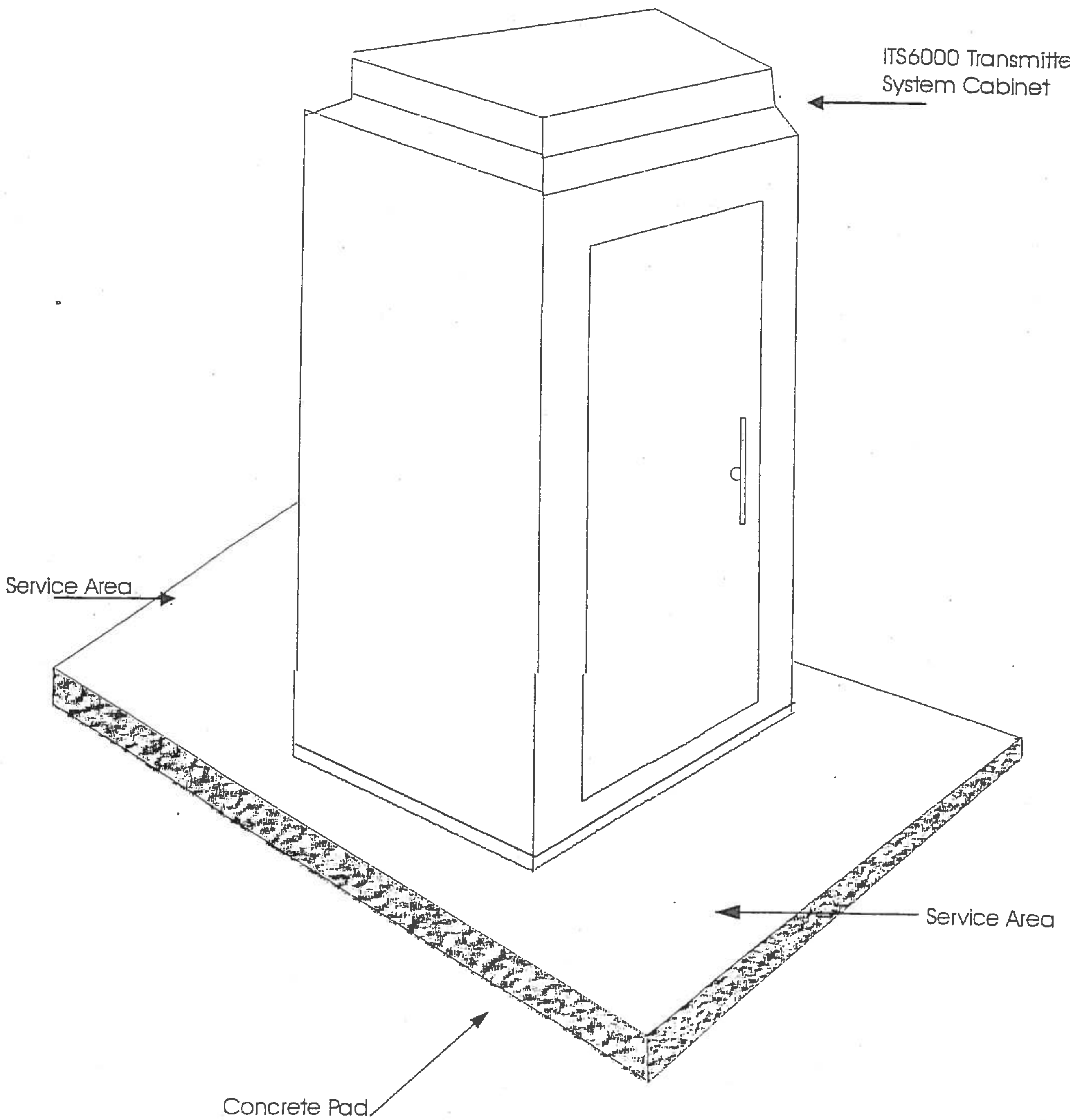
   Signs and Beacons

4. As a general rule HAR signs should be placed with in a 2.5 to 3 mile radius of the transmitter/antenna location.

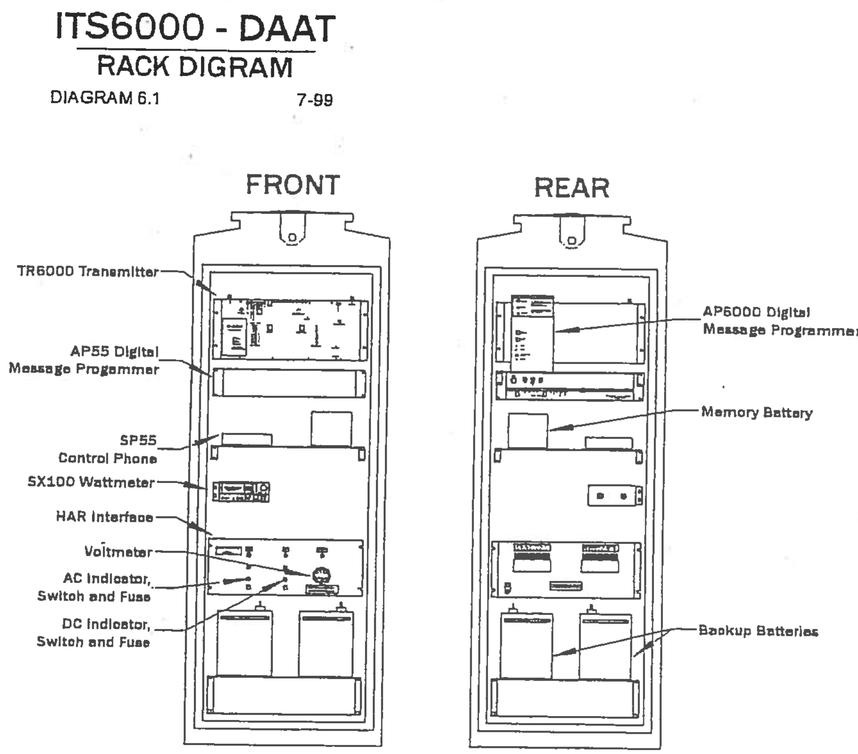
5. The two most common AM frequencies used for HAR are 530 kHz and 1610 kHz.

ITS6000 Transmitter Site Plan 3.2

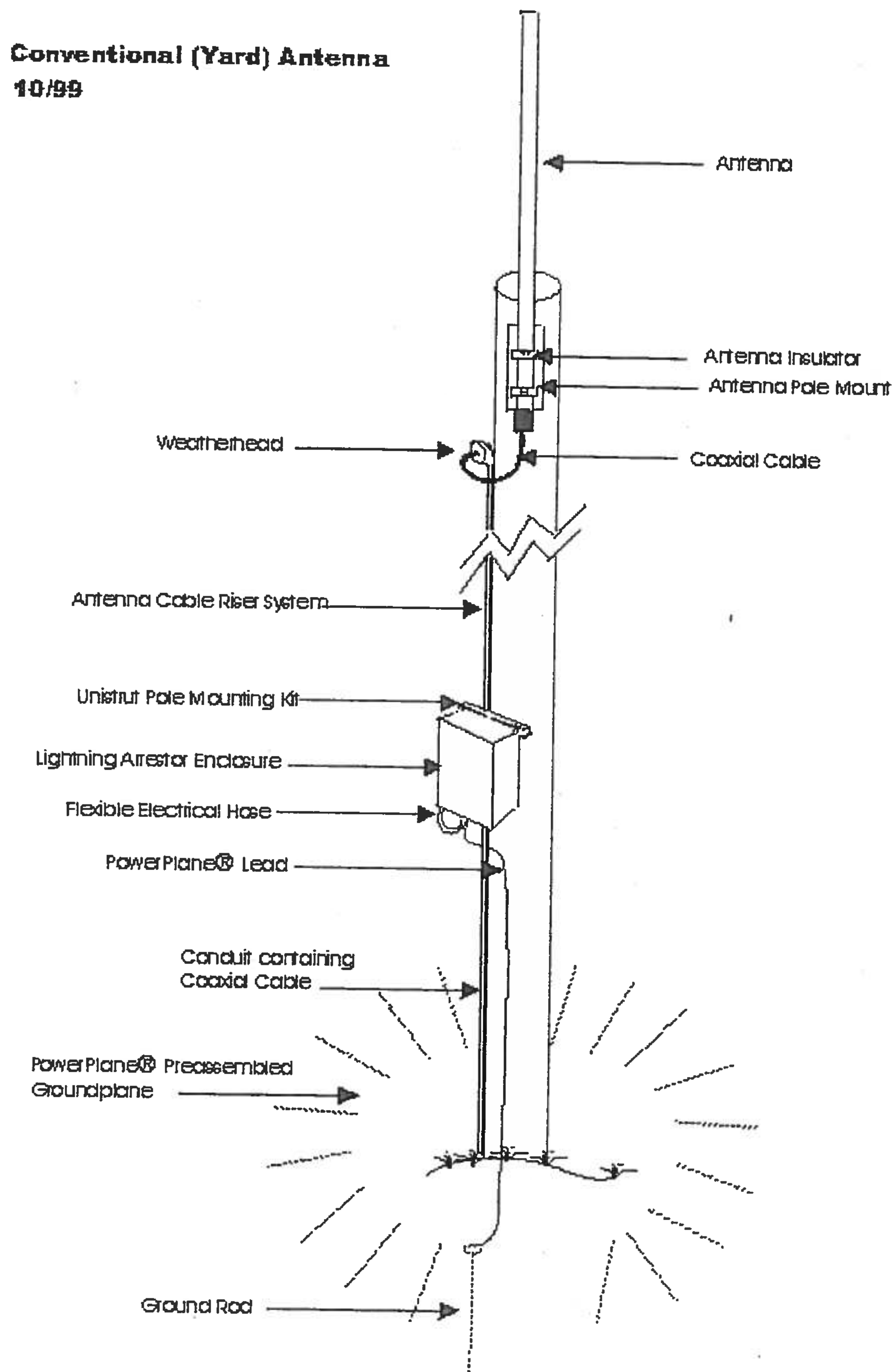
ITS6000 Transmitter Site Plan Diagram
Diagram 3.2
8-99



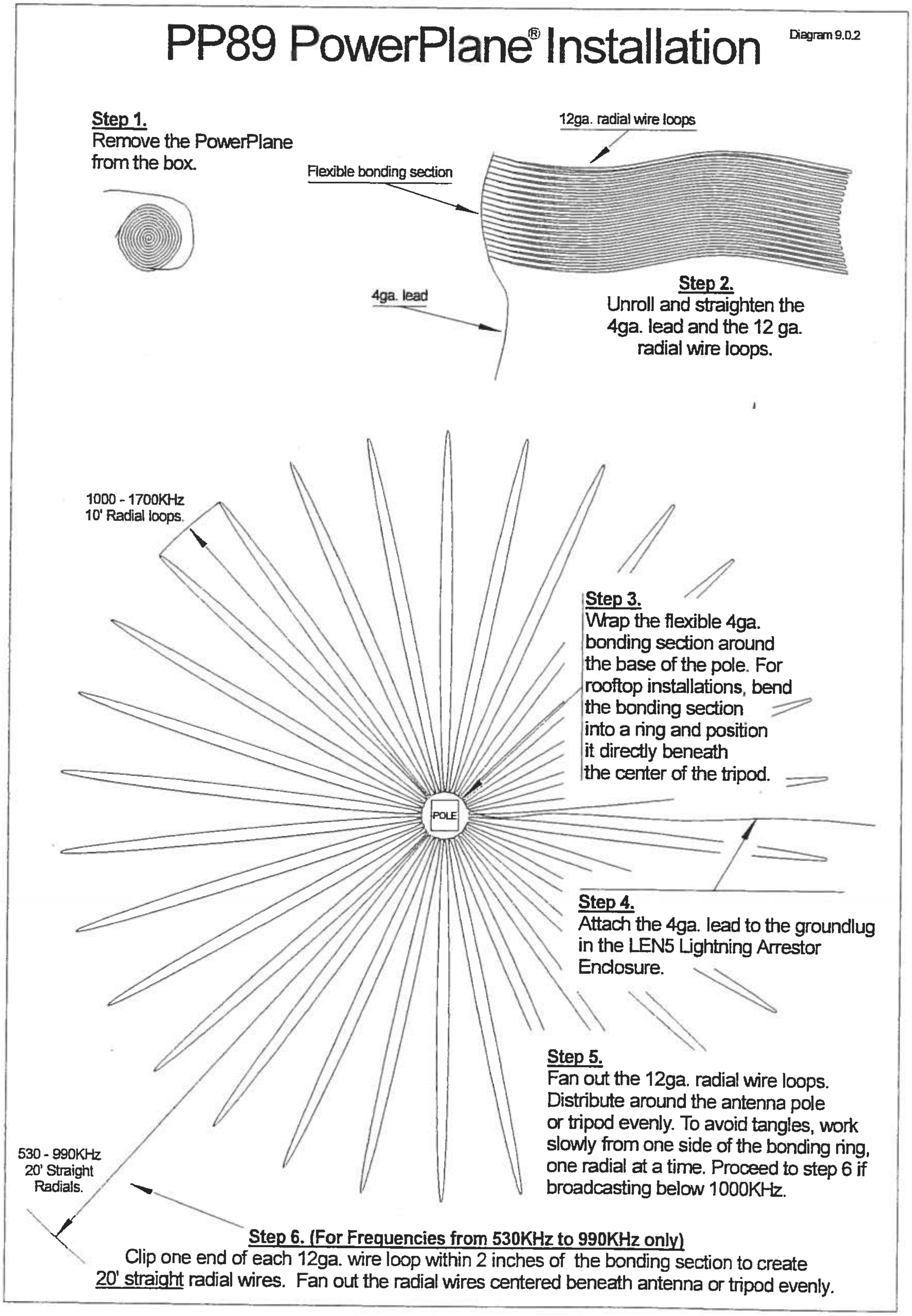
ITS6000-DAAT Rack Mounting Diagram 6.1



HAR Antenna Installation Diagram 1.5



PowerPlane Groundplane Installation Diagram 9.0.2



Measure from the top of the white tip ball down the tip and make your own tuning mark at the following distance:

540	70 5/8"	1430	17 1/4"	1570	4 11/16"
550	61 5/8"	1440	16 1/4"	1580	4"
560	53 7/16"	1450	15 5/16"	1590	3 1/4"
570	45 3/8"	1460	14 3/8"		
580	38 3/8"	1470	13 5/16"	1600	2 7/16"
590	31 3/16"	1480	12 7/16"	1620	8 3/16"
		1490	11 1/2"	1630	7 5/16"
600	25 1/16"			1640	7"
610	19"	1500	10 1/8"	1650	6 5/16"
620	12 7/8"	1510	9 13/16"	1670	5"
630	6 11/16"	1520	8 7/8"	1680	4 ¼"
		1530	8"	1690	3 ½"
1400	20 3/16"	1540	7 1/16"	1700	2 ¾"
1410	19 3/8"-	1550	6 7/16"		
1420	18 5/16"	1560	5 9/16"		

Tighten the locking nut at the top of the midtip just enough so the tip stays in place firmly without sliding. This nut will not be tightened down permanently until final antenna tuning has taken place. Until then, do not allow the antenna to become wet, as moisture may enter internal parts, unless the nut is well siliconed.

Remove the front halves of the Antenna Insulators on the Antenna Pole Mount (already attached to the pole). Slide the antenna into the back halves so that the antenna's base rests in the insulators. Replace the front halves and tighten the hardware just enough to hold securely. It may need to be removed again during the tuning process, unless you have a lift or another means to reaching the top of the antenna.

Cable Attachment

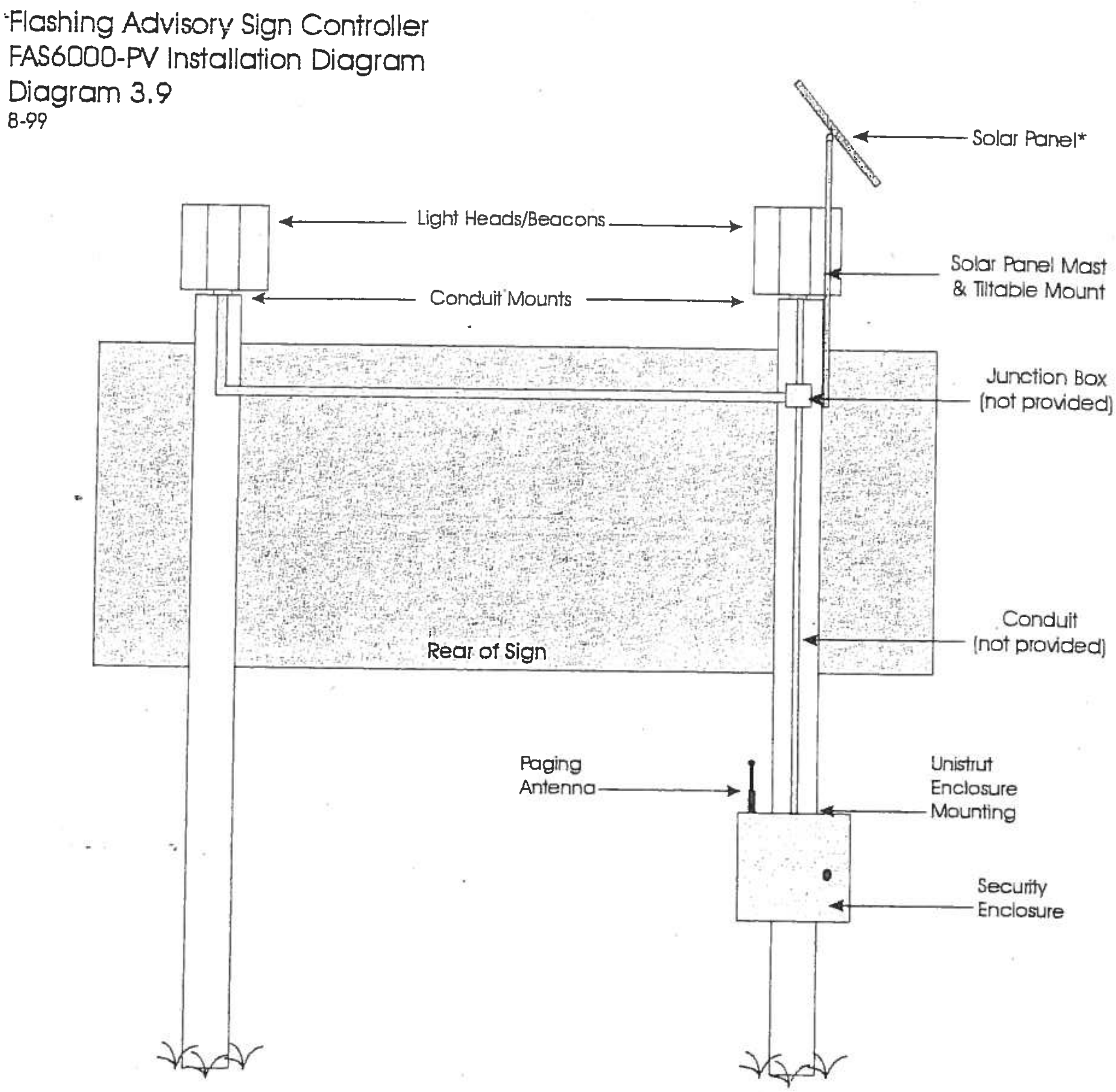
Using the stainless steel ¼" hardware provided, bolt the ring lug of the coaxial cable to the base section of the antenna. You may leave this connection unweatherproofed if it is to be disconnected during the antenna-tuning step. When the installation is complete, tape the silicone this connection thoroughly, to prevent oxidization and degradation of the signal.

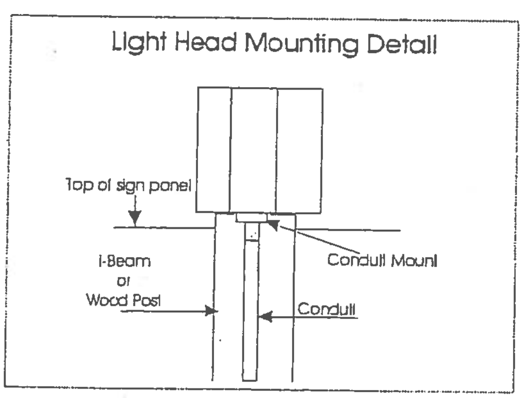
➡ **Note: Leave a small drip-loop in the coaxial cable to prevent water entry into the pole.**

Antenna-Tuning

Turn on the AC and DC power switches on the Power Management Interface. Both indicators should light to indicate the presence of external AC power and internal DC power respectively.

FAS6000-PV Installation Diagram





*Orient Solar Panel Directly South.
Tilt at prescribe angle.

FCC (Federal Communications Commission)
Regulations and Rules, Part 90

Section 90.242 Travelers Information Stations.

1. Travelers Information Stations or HAR may be assigned to frequencies ___________ through ___________ in 10 kHz increments.
2. The antenna height above ground level shall not exceed _______________________.
3. Transmitter RF output power shall not exceed _________ to comply with field strength limits.
4. The field strength of the radiating antenna's emission shall not exceed ________ when measured with a standard field strength meter at a distance of _____________________ from the transmitting antenna system.
5. Each application for a station or system shall be accompanied by a _________ showing the geographical location of each _____________________ and an estimate of the ___________________ at the contour of the desired coverage area.

FCC (Federal Communications Commission) Regulations and Rules, Part 90

Section 90.242 Travelers Information Stations.

1. Travelers Information Stations or HAR may be assigned to frequencies 530 through 1710 in 10 kHz increments.
2. The antenna height above ground level shall not exceed 15 meters or 49.2 feet.
3. Transmitter RF output power shall not exceed 10 watts to comply with field strength limits.
4. The field strength of the radiating antenna's emission shall not exceed 2mv/meter when measured with a standard field strength meter at a distance of 1.5 kilometers / .93 miles from the transmitting antenna system.
5. Each application for a station or system shall be accompanied by a map showing the geographical location of each transmitter site and an estimate of the signal strength at the contour of the desired coverage area.

HIGHWAY ADVISORY RADIO TRANSMITTER (HART) Commissioning CHECKLIST

LOCATION________________________________ CS________ SC________

DATE ______________________________ SR _________ Mile Post_________

BY ___________________________ Contract Number ___________

Frequency ___________________________

Check each item listed.

1. ____ Conduct visual inspection of site to include antenna, cabling, exterior of cabinet, and base.
2. ____ Measure antenna height. __________ Feet. (It must be lower than 49.2 feet)
3. ____ Visually inspect RF connectors, surge protectors, antenna, cabinet, and wiring condition.
4. ____ Disconnect antenna cable from equipment and MOhms it. _______ MOhms.
5. ____ Using Ground Resistance Tester, test ground plane resistance. ______ Ohms.
6. ____ If a portable HAR, Check Ground plane connectors and clean if necessary.
7. ____ Test GFCI receptacle by pressing test button and resetting.
8. ____ Verify AC input voltage to cabinet. ________AC.
9. ____ Verify output of 24VDC power supply. ________VDC.
10. ____ Verify 24v/12v DC converter. __________VDC.
11. ____ Test battery voltage. Record reading on battery itself.
12. ____ Using SWR meter to tune in antenna. It needs to be less than 10% reflected power.

FWD POWER	MAX 10 WATTS (Carrier Only)	__________Watts
REF POWER	MAX 1.1 WATTS @ 10WATTS FWD	__________Watts
SWR	<2:1 SWR or 10:1 FWD/REF WATT RATIO	__________ SWR

13. ____ Call TMC or Radio to activate unit and broadcast test message.
14. ____ Using a portable AM receiver check that the Output Frequency is 530 kHz +/- 10Hz ; 1580 kHz +/- 10 Hz; 1610 kHz +/- 10Hz.
15. ____ Using FIM, measure and record FI at set benchmark locations. Adjust as necessary. Record bench mark locations on a map and place in cabinet. Foreward on a copy of the benchmarks and map to Headquarters radio. Place a copy of Licence and Call signs in the cabinet
16. ____ Verify Transmitter Modulation. [ITS-6000 Manual pg. 23]

17. ____ Call TMC or Radio to de-activate unit.

18. ____ Verify that both the fan and heater activate when thermostat meets temperature.

19. ____ If HAR is solar, check hardware for tightness on solar panel.

20. ____ If HAR is portable, Check tail/running lights.

21. ____ If HAR is portable, check air pressure in tires. ________ PSI.

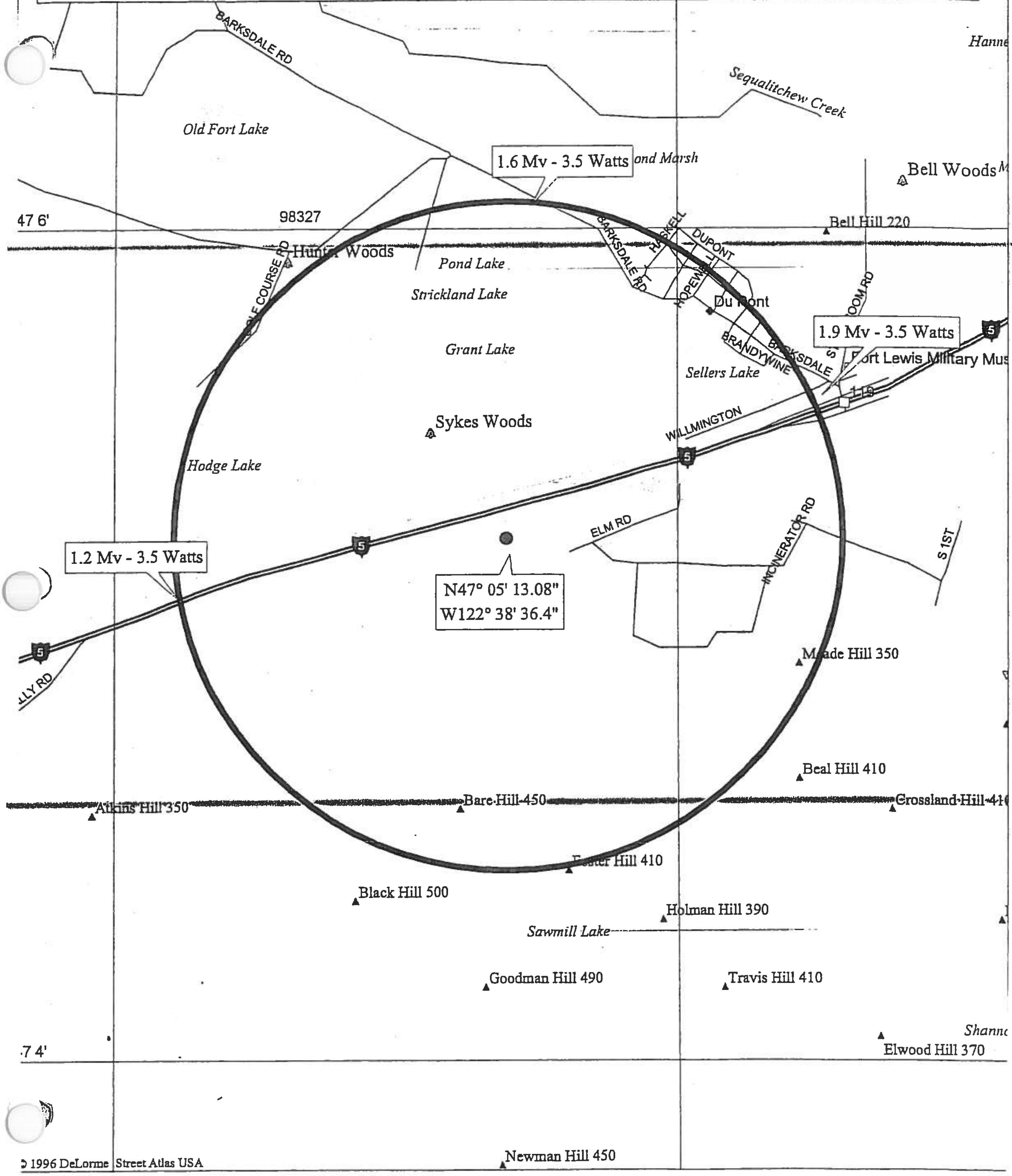
Documentation:

____ Record maintenance performed in the Maintenance Log Book.

COMMENTS:____

Recommended map for foreword to Headquarters Radio.

DuPont HAR



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LOCATION_________________________________ CS_______ SC_______

DATE _________________________________ SR ________ Mile Post________

BY _________________________________ Contract Number _____________

Frequency _________________________________

Antenna Height ________________

Transmitter output wattage ______________________

Reflected Wattage __________________________

Establish 3 benchmark locations .93 miles from the transmitter site measure FI using a

________________ FIM, serial #_____________, Calibrated _______________.

Draw up a map below showing SR and MP for Benchmarks and transmitter site. Include the FI reading at each benchmark.

Pre-Activity Safety/Hazard Assessment Plan

Date: __________

Crew Members: ____

Locations:

SR _____	Cross St. ______________________	Function _______	TCP# _________
SR _____	Cross St. ______________________	Function _______	TCP# _________
SR _____	Cross St. ______________________	Function _______	TCP# _________
SR _____	Cross St. ______________________	Function _______	TCP# _________
SR _____	Cross St. ______________________	Function _______	TCP# _________
SR _____	Cross St. ______________________	Function _______	TCP# _________
SR _____	Cross St. ______________________	Function _______	TCP# _________
SR _____	Cross St. ______________________	Function _______	TCP# _________

Weather Conditions: ___________________________

Notifications: ☐ TMC ☐ WSP ☐Media ☐ Signal Shop

Vehicle Checklist:

☐ Pre-Trip Inspection ☐ 1st Aid Kit ☐ Cones ☐ Signs ☐ Fire Extinguisher

☐ Radio/Phone List ☐ Medical Facilities List ☐ Defibrillator

Special Equipment:

☐ VMS ☐ HART/HARS ☐ TMA ☐ Radio/Nextel

PPE's:

☐ Vest ☐ Hard Hat ☐ Safety Glasses ☐ Gloves ☐ Hearing Protection ☐ Safety Harness

☐ Attenuator ☐ Safety Boots ☐ ___________ ☐ ___________

Identify Hazards	Identify Preventative Measures
☐ Overhead/Underground Utilities ☐ High Loads ☐ Sight Distances ☐ Uneven Terrain ☐ Other	

(List Additional Info. On Back)

HIGHWAY ADVISORY RADIO SIGN/BEACON (HARS) P.M. CHECKLIST

LOCATION________________________________ CS________ SC________

DATE ________________________________ Mile Post_________

BY ________________________________ Work Order 2515

Notify TMC and verify equipment status.

Check each item listed.

1. ____ Poles (Wood and /or Steel) for decay and/or corrosion.
2. ____ Visually inspect Beacon heads for wear, paint, alignment, tightness, and drain holes.
3. ____ Check all underground junction boxes for elevation, dirt level, debris and conduit bonding.
4. ____ Relamp, clean lens and reflector. 69W _____, LED _____.
5. ____ Check the mounting hardware for the Solar Panels and equipment.
6. ____ Clean the face of the Solar Panel with glass cleaner.
7. ____ Inspect battery for leakage and corrosion at terminal post.
8. ____ Test battery state. If less than 50% of initial reading, replace battery.
9. ____ Verify Voltage for :

Battery voltage ________VDC

Solar Panel Output ______ VDC

Battery Charger ________ VDC

Input AC ________ AC

---

9. If equip:

_____ Replace desiccant solution.

_____ Verify Fan/Heater operation.

10. ____Call TMC or Radio to Activate / De-activate unit.
11. ____ Clean Cabinet.

Documentation:

____ Record maintenance performed in the Maintenance Log Book.

COMMENTS: ____.

HIGHWAY ADVISORY RADIO TRANSMITTER (HART) P.M. CHECKLIST

LOCATION________________________________ CS________ SC________

DATE ________________________________ Mile Post_________

BY ________________________________ Work Order 2515

Notify TMC and verify equipment status.

Check each item listed.

1. ____ Conduct visual inspection of site to include antenna, cabling, exterior of cabinet, and base.
2. ____ Visually inspect RF connectors, surge protectors, antenna, cabinet, and wiring condition.
3. ____ Disconnect antenna cable from equipment and MOhms it. _______ MOhms.
4. ____ If a portable HAR, Check Ground plane connectors and clean if necessary.
5. ____ Test GFCI receptacle by pressing test button and resetting.
6. ____ Verify AC input voltage to cabinet. ________AC.
7. ____ Verify output of 24VDC power supply. ________VDC.
8. ____ Verify 24v/12v DC converter. __________VDC.
9. ____ Inspect backup batteries for leakage and corrosion at the terminal posts.
10. ____ Test batteries state of charge. If less than 50% of initial reading, replace batteries.
11. ____ Using SWR meter check that below items are within tolerance and record.

FWD POWER	MAX 10 WATTS (Carrier Only)	__________Watts
REF POWER	MAX 1.1 WATTS @ 10WATTS FWD	__________Watts
SWR	<2:1 SWR or 10:1 FWD/REF WATT RATIO	__________ SWR

12. ____ ~~Call TMC or Radio to activate unit and broadcast test message.~~
13. ____ Using a portable AM receiver check that the Output Frequency is 530 kHz +/- 10Hz ; 1580 kHz +/- 10 Hz; 1610 kHz +/- 10Hz.
14. ____ Using FIM, measure and record FI at set benchmark locations. Adjust as necessary.
15. ____ Verify Transmitter Modulation. [ITS-6000 Manual pg. 22]
16. ____ Call TMC or Radio to de-activate unit.
17. ____ Verify that both the fan and heater activate when thermostat meets temperature.

18. ____ Inspect for Pests entering cabinets.

19. ____ Vacuum out Cabinet.

20. ____ Clean or replace cabinet filter.

21. ____ If HART is solar, Clean Solar panels with Glass Cleaner, and check hardware for tightness.

22. ____ If HART is portable, grease axel at grease zerks.

23. ____ If HART is portable, Check tail/running lights.

24. ____ If HART is portable, check air pressure in tires. ________ PSI.

<u>Documentation:</u>

____ Record maintenance performed in the Maintenance Log Book.

COMMENTS:____

6. *Battery Testing* can be done in more than one way. The most popular is measurement of specific gravity and battery voltage. To measure specific gravity buy a temperature compensating hydrometer and measure voltage, use a digital D.C. Voltmeter. A good digital load tester may be a good purchase if you need to test batteries sealed batteries.

You must first have the battery fully charged. The surface charge must be removed before testing. If the battery has been sitting at least several hours (I prefer at least 12 hours) you may begin testing. To remove surface charge the battery must experience a load of 20 amps for 3 plus minutes. Turning on the headlights (high beam) will do the trick. After turning off the lights you are ready to test the battery.

State of Charge	Specific Gravity	Voltage	
		12V	6V
100%	1.265	12.7	6.3
*75%	1.225	12.4	6.2
50%	1.190	12.2	6.1
25%	1.155	12.0	6.0
Discharged	1.120	11.9	6.0

*Sulfation of Batteries starts when specific gravity falls below 1.225 or voltage measures less than 12.4 (12v Battery) or 6.2 (6 volt battery). Sulfation hardens the battery plates reducing and eventually destroying the ability of the battery to generate Volts and Amps.

Load testing is yet another way of testing a battery. Load test removes amps from a battery much like starting an engine would. A load tester can be purchased at most auto parts stores. Some battery companies label their battery with the amp load for testing. This number is usually 1/2 of the CCA rating. For instance, a 500CCA battery would load test at 250 amps for 15 seconds. A load test can only be performed if the battery is near or at full charge.

The results of your testing should be as follows:

Hydrometer readings should not vary more than .05 differences between cells.

Digital Voltmeters should read as the voltage is shown in this document. The sealed AGM and Gel-Cell battery voltage (full charged) will be slightly higher in the 12.8 to 12.9 ranges. If you have voltage readings in the 10.5 volts range on a charged battery, that indicates a shorted cell.

If you have a maintenance free wet cell, the only ways to test are voltmeter and load test. Most of the maintenance free batteries have a built in hydrometer that tells you the condition of 1 cell of 6. You may get a good reading from 1 cell but have a problem with other cells in the battery.

When in doubt about battery testing, call the battery manufacturer. Many batteries sold today have a toll free number to call for help.

Hands On:

1. Assemble & Stand Antenna

2. Deploy Groundplanes

3. Select Dummy Load

4. Turn On Transmitter

5. Select Recording Input

6. Record Message "This is a Washington State Highway Advisory Radio Test: Test….1,2,3 Test....1,2,3"

7. Transmit& Monitor Message

8. Erase Message & End Transmit

Set Up the Photovoltaic Array

Using the tamperproof bit and tool provided, rotate the array so that its front faces south.

Tilt the array down to the proper seasonal setting:

March 1 - October 30	Use setting MAR-OCT
November 1 - February 29	Use setting NOV-FEB

Note: RoadRunnR can operate with the array horizontal, but long-term operation may be affected.

IMPORTANT: Make certain that the array's operating location will not allow it to touch the trailer or the broadcast antenna.

Tighten hex setscrews and tamperproof sleeve screw to prevent theft.

Antenna

Remove the antenna from its storage tube and assemble it on the Antenna Base Pipe Extender. Close the storage tubes and replace the rubber strap.

Attach the chain (toolbox) from the Extender to the clip on the Electronics Enclosure. Slide into its female upper-end the corresponding male end of the antenna's base pipe. Secure the two with the setscrews on the Extender. Next, attach the coil using the three hex bolts (also in the toolbox).

For frequencies above 1000: Slide out the stainless steel antenna tip to the scribed tuning mark.

For frequencies below 1000: Attach the antenna's midtip in the upper end of the coil and secure with setscrews. Slide out the stainless steel antenna tip from the upper end of the midtip, to the scribed tuning mark.

Stand Antenna in its mounts and snap in place with the strap. If RoadRunnR will be in place for some time, you may replace the hand-strap with a steel bolt-in strap, found in the toolbox. (The steel strap makes the antenna more difficult to remove from the trailer.)

IMPORTANT: Remove the chain from the Extender and place back in the toolbox.

Groundplanes and Ground Rod

Deploy Groundplane(s) and plug Groundplane cables into Groundplane Jacks just beneath the antenna. Use both vinyl Groundplane Mats, one beside the trailer (right side) and one just behind. Locate both mats within 12" (horizontally) of the trailer.

Plug Ground Rod Cable into the third external jack on the Electronics Enclosure. Drive the stake into the ground beneath or immediately beside the trailer to provide lightning

Preprogramming the AP55 Digital Message Programmer

Initial Setup

Each time the digital message programmer is started from an unpowered state, it is preprogrammed for operation.

To preprogram the unit, lift the handset of the control phone. You will hear the voice prompter of the programmer speaking to you.

Press	Action
*4# then 0#	This causes the spacing between broadcast messages to be zero.
*7# then 3#	This enables the control phone for test recording. (Later you may wish to change this setting, to allow recording by microphone or cassette player.)
*8# then 1#	This sets the recording speed to "Speed 1," which gives you the maximum in recording time. (On initiation, the AP55 will begin at Speed 2, which will yield roughly 50 percent of the usable recording time of Speed 1.)
*62# then 2008#	This sets the transmitter to be on.

Recording a Test Message

Press *1# then 1#. Speak into the control phone handset. Press # when you are finished. You have just recorded Message 1.

To select the test message for broadcast, press *5# then 1#. The AP55 Digital Message Programmer is now playing Message 1 to your transmitter for broadcast.

Set Transmitter Modulation

Identify the "Modulation Adjust" control on the transmitter. While listening to a monitor radio and watching the "Audio VU" LED scale, slowly turn this knob clockwise. You will hear the test message you have recorded begin to be broadcast over the monitor radio and the scale will begin to pulsate.

It is often best to monitor an automobile radio that is parked 50 or more feet from the antenna. (Radios closer than 50 feet may exhibit distortion from the strong field intensity.)

Generally, this level is set as loud as possible, such that the audio sounds undistorted on the monitor radio. An acceptable audio level displayed on the "Audio VU" scale, typically

Quick-List of Programming Commands

Set Up Commands

Mandatory Setup Commands

*4# Set Spacing Command
*8# Set Recording Speed Command

Optional Setup Commands

*7# Recording Source Input Command
*21# Set Clock Command
*71# Remote Record Security Code Command

Access Commands

Access

Call Telephone Number
Key in access code * - CODE - #

Terminate Call

*51# then 1#

Control Commands

Recording Commands

*1# Record Command
*2# Monitor Command
*3# Erase Command

Simplified Message Sequences

*5# Selected Messages Command
*6# Check Sequence Command

Create And Schedule "Playlists"

*22# Day/Clock Command
*41# Create Playlists Command
*42# Check Playlists Command
*43# Schedule Playlist TFN Command
*44# Cancel Playlist Command

Remote Control

*62# 2008# Transmitter On
*62# 2009# Transmitter Off
*62# 7900# Monitor broadcast

PRECISION SWR·POWER METER

DIAMOND ANTENNA

Operation Instructions **SX-100**

The SX-100 is an insertion type SWR/POWER meter being connected between a transmitter and an antenna. Transmitting power and SWR can be measured with very simple operations.
In addition with those conventional measurement, PEP (peak envelope power) on SSB mode can be measured with a PEP monitor function. With our DIAMOND's wideband and low insertion loss directional coupler those measurements can be performed with minimum effect in transmission line.

Before using the unit

1. Do not intend to open the housing or touch any place inside, since it may invite malfunction of the unit and causes measurement error. Especially directional coupler section is not serviceable without specially prepared measurement tools. Note that warranty will not cover a unit which is modified in any part of the unit by a user.
2. Since the unit displays RF power at input end of the system, if RF power at output end is required, subtract the amount equivalent to the insertion loss from the displayed RF power.
3. When being operated on SSB mode, RF power displayed with PEP MONI function is approximately 70 to 90 percent of peak power at normal talking level. It is because of the time constant in CR circuit, the unit is not able to display 100 percent peak power.

Note on operations

1. The unit has the following band coverage;
   SX-100 : 1.6-60MHz
2. Measurable power range of the unit is up to 3KW in intermittent mode. If transmitted on FM, CW, RADIO FAX or RTTY mode, do not exceed its continuous maximum power at the following power range. Otherwise pickup unit of the directional coupler section may burn out.

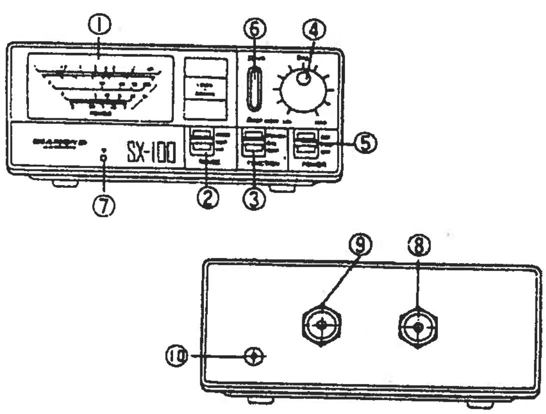
SX-100			
1.6	-	3.5MHz	1KW
3.5	-	60MHz	1.2KW

3. Since the unit consists of delicate mechanism, do not drop it or subject it to hard blow.

Description of panel features

1. 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 20W.
   High power swr scale is for RF power over 20W.
   Second and third scales are for RF power measurement which are 30W, 300W and 3KW full scales.
2. Range switch
   Selects full scale RF power reading between 30W, 300W, and 3KW.
3. Function switch
   Selects measurement function between RF power and swr.
4. 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.
5. Power direction switch
   Selects RF power measurement between forward RF power and reflected RF power.

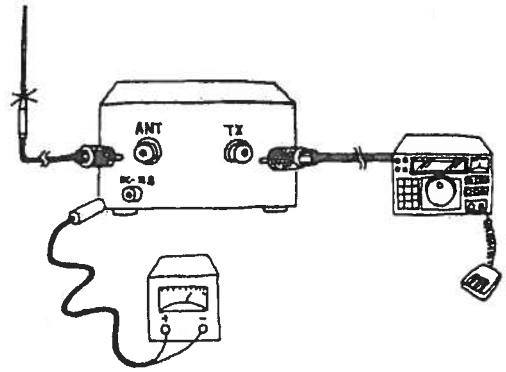
6. Average/PEP monitor switch
   In ordinary RF power measurement, set the switch to the 〔⊓〕 positios to display average RF power.
   In SSB RF power measurement, set the switch to the 〔▭〕 positions to display PEP RF power.
7. Meter zero adjustment screw
   Adjusts the meter indicator to zero position with regular screwdriver if the indicator is far from zero position when the unit is not in use.
8. Transceiver
   RF power input from a radio equipment which is to be connected by 50 ohm coaxial cable with UHF connector.
9. Antenna
   RF power output to an antenna or a dummy load which is to be connected by 50 ohm coaxial cable with UHF connector.
10. 13.8VDC
   DC power source for meter illumination. Acceptable DC voltage range is from 11VDC to 15VDC. Connect red line for positive and black line for negative polarities. This power source is not essential for measuring purpose.



Installation

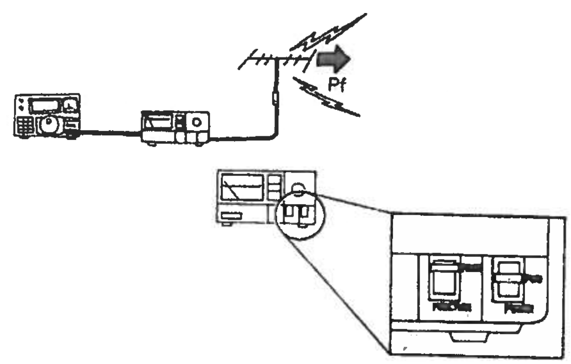
Connection

1. Connect transceiver input of the unit to antenna output of a radio equipment with a coaxial cable with an UHF connector and antenna output of the unit to an antenna feedline or dummy load.
2. If meter illumination is required, connect DC power cable supplied between a power source and DC inlet at the back panel as shown in the below figure. DC power source has to be between 11VDC to 15VDC. Red line has to be connected to positive polarity and black to negative polarity.



Measure forward RF power

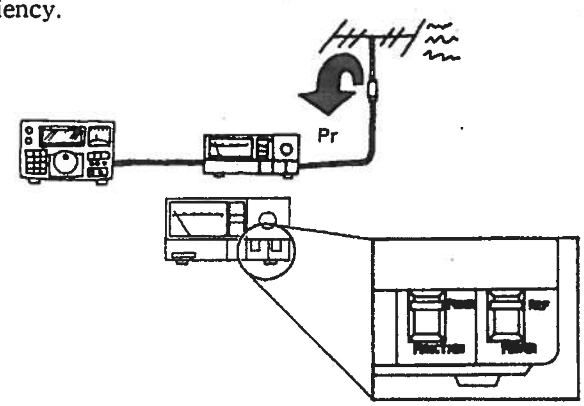
Measure how much RF output power is being applied from a radio equipment to an antenna. In case of forward RF power, the more indicator indicates RF power, the more RF power is applied to the antenna, provided that reflected RF power is minimum.



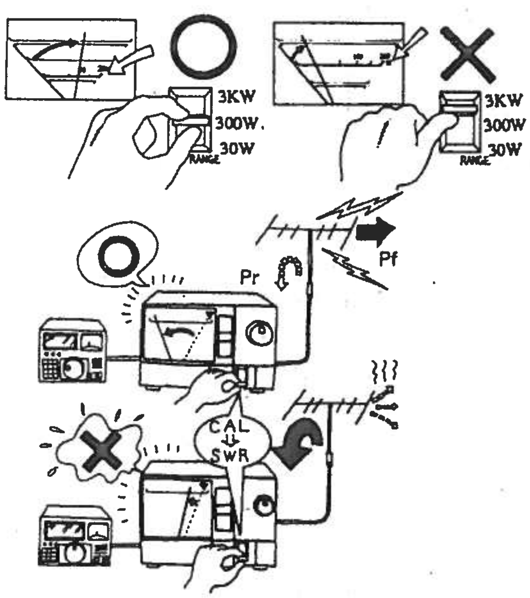
1. Set the FUNCTION switch to the POWER position.
2. Set the POWER switch to the FWD position.
3. Set the RANGE switch to appropriate RF power range. If a radio equipment is 10W RF output power, set the switch to the 30W position. If the equipment is 100W RF output power, then set the switch to 300W position.
4. Confirm to see if antenna output is connected to an antenna or dummy load.
5. Set the radio equipment on transmission, except SSB mode. Then indicator indicates forward RF power proportional to the output RF power of the equipment.
6. In SSB mode, peek envelope power can be monitored by setting the AVG PEP MONI switch to the PEP MONI position and talking to a microphone.

Measure reflected RF power

In case of reflected RF power, the less indicator indicates reflected RF power, the better an antenna connected propagate transmitting power efficiently. Reflected RF power in this case amount of transmitting power which can not be propagated by the antenna due to its problem in propagation efficiency.



1. Set the FUNCTION switch to the POWER position.
2. Set the POWER switch to the REF position.
3. Set the RANGE switch to appropriate RF power range. If a radio equipment is 10W RF output power, set the switch to the 30W position. If the equipment is 100W RF output power, then set the switch to 300W position.
4. Confirm to see if antenna output is connected to an antenna or dummy load.
5. Set the radio equipment on transmission. Then the meter indicates reflected RF power.
6. If the meter does not indicate any power, set the RANGE switch to the lower power range.



Measure swr

1. Set the FUNCTION switch to the CAL position.
2. Turn CAL knob counterclockwise fully to the MIN position.
3. Set the radio equipment on transmission and turn CAL knob clockwise to set the meter indicate "▼" position.
4. While the equipment is kept on transmission, set the FUNCTION switch to the SWR position. Then, the indicator indicates swr of the antenna. Note that there are two scales H and L for swr reading. If transmitting RF power is less than 20W then read L position, and the power is more than 20W then read H position.

※Relationship between reflected RF power and swr is as follows.

SWR	1.0	1.1	1.2	1.5	2.0	2.5	3.0
Reflected RF power (%)	0	0.22	0.8	4.0	11.1	18.4	25.0

5. Calculation of swr value is as follows.

$$SWR=\frac{\sqrt{Pf}+\sqrt{Pr}}{\sqrt{Pf}-\sqrt{Pr}}$$

Where Pf = forward RF power
Pr = reflected RF power

Note

If swr reading and calculated swr value differs considerably, calculated swr value is more accurate due to frequency response of pickup diode used in the directional coupler section.

If swr is too high

If swr of the antenna is too high, see if antenna is correctly assembled and soldered, or coaxial cable and connector are correctly assembled and soldered. Installation location of the antenna, surrounding buildings and so on, can also be a cause of high swr value.

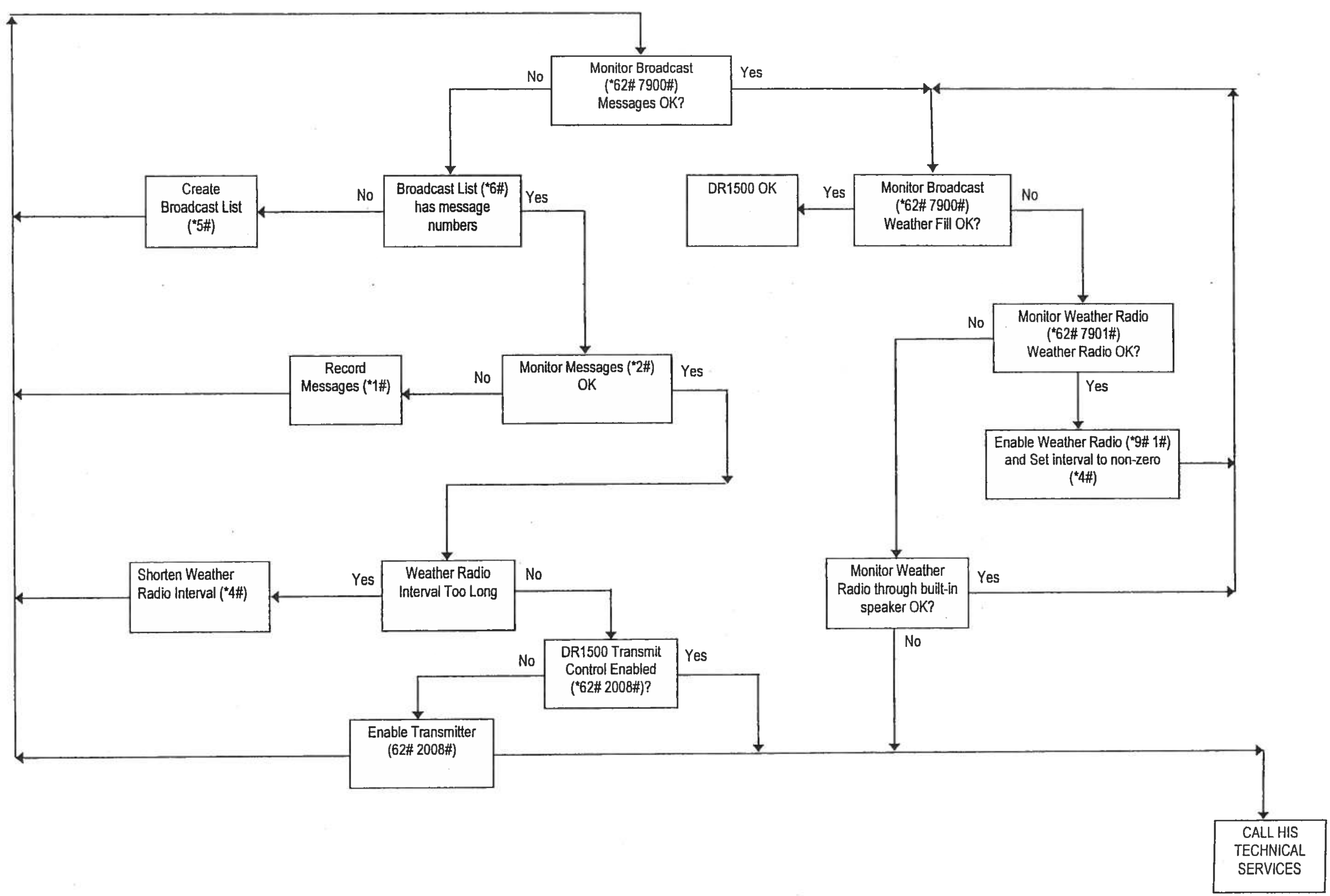
Specifications

	SX-100
Frequency range	1.6—60MHz
Power range	30W/300W/3KW intermittent use
Accuracy of full scale	±10%
Minimum power at swr measurement	3W
Measurement range at swr measurement	1.0~∞
Insertion loss	0.1dB maximum
Measurement functions	Forward RF power, Reflected RF power SWR and PEP monitor
Impedance	50 ohms
Connectors	UHF female
Dimentions	155×63×103 mm (W/H/D) (6.1"×2.4"×4.1")
Weight	640g (1.41lbs.)
Accessories	Operation instructions DC power cable

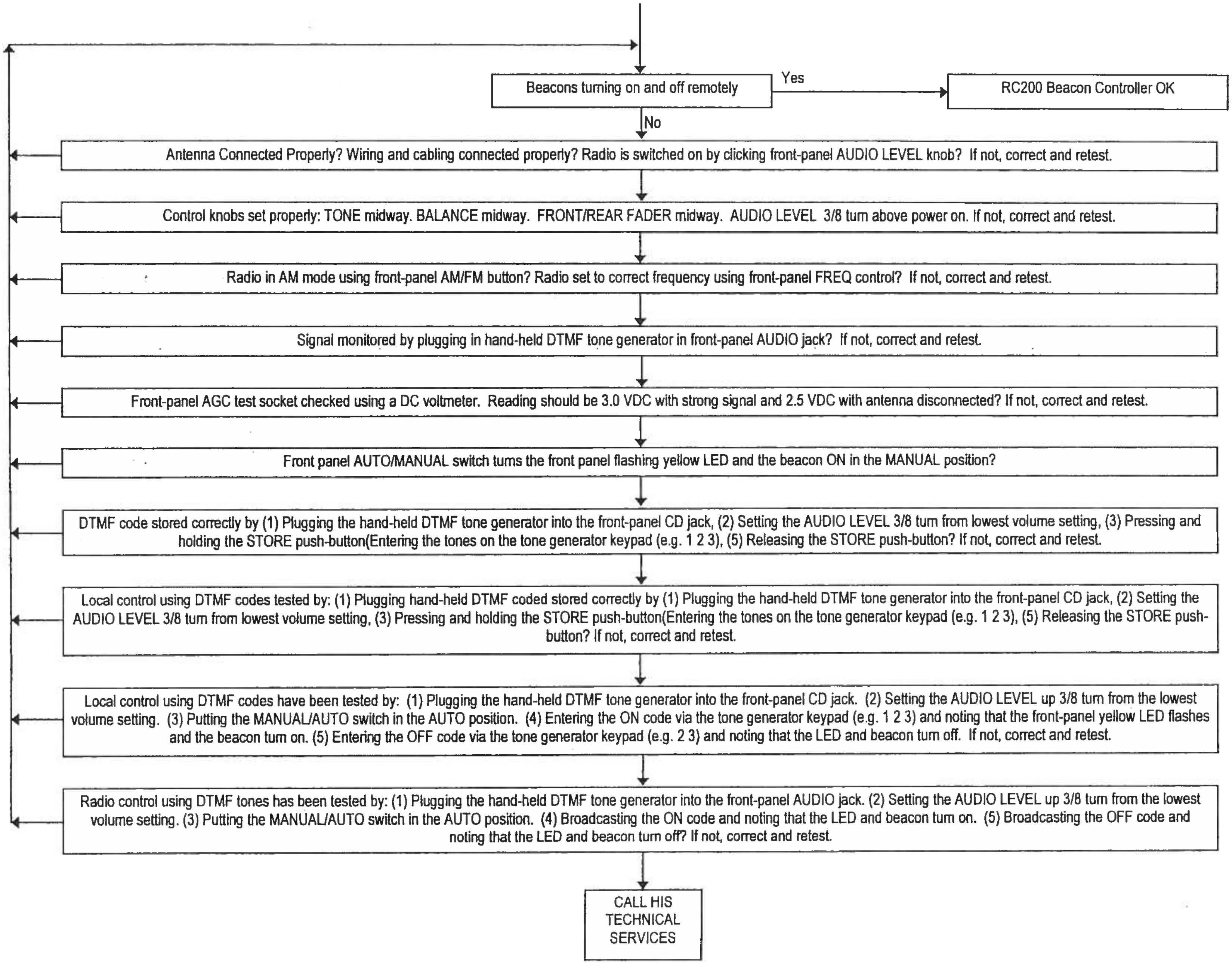
Troubleshooting HAR

- Basic Elements of HAR
  - Antenna
    - Cable
    - Connections
    - Coils
  - Message Programmer/Recorder
    - Communications
    - Hardware
    - Software
  - Transmitter
  - Power Supply
    - AC Input
    - Battery Charger
    - Batteries

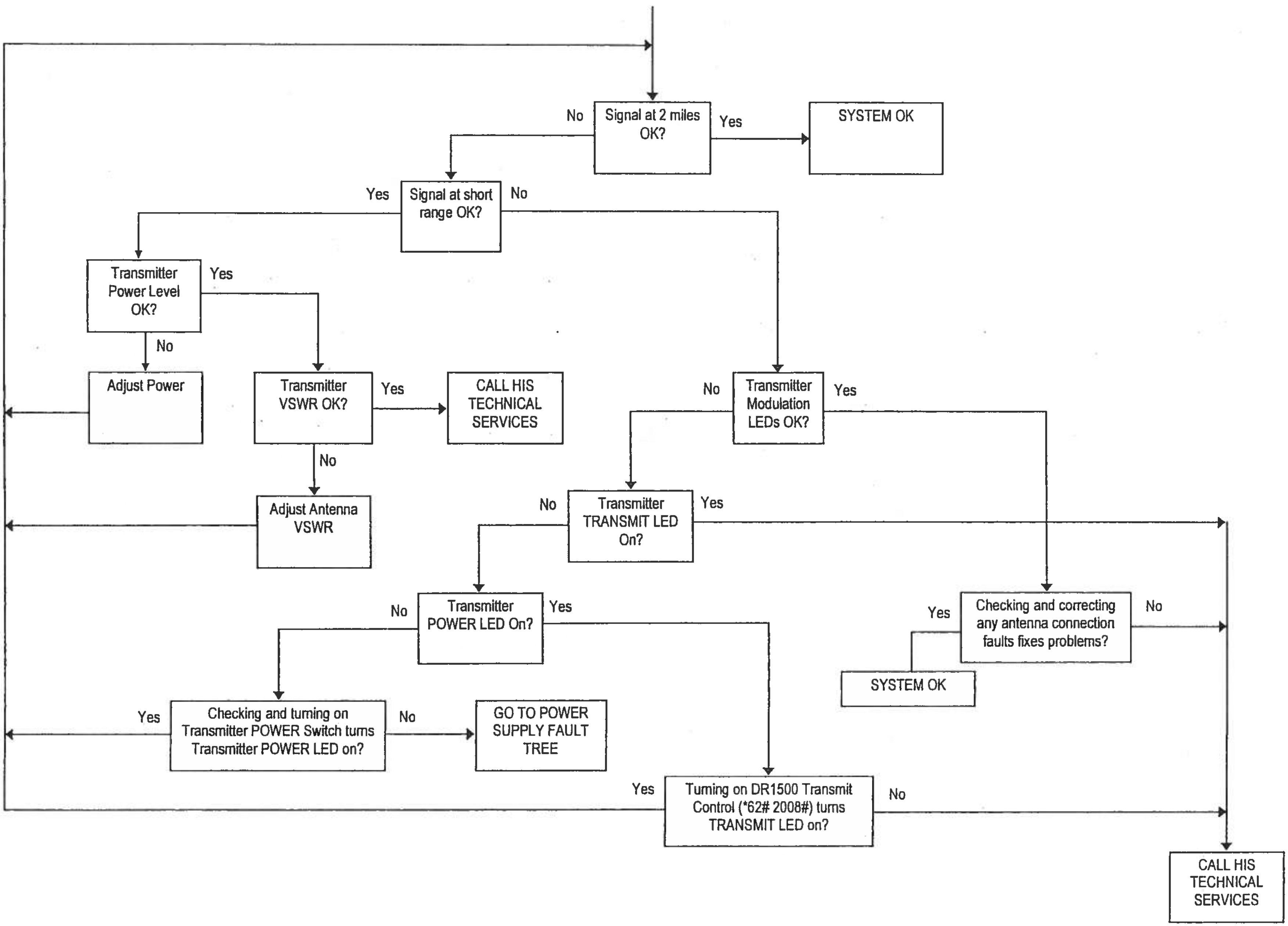
DR1500AM Recorder Player Fault Isolation Tree



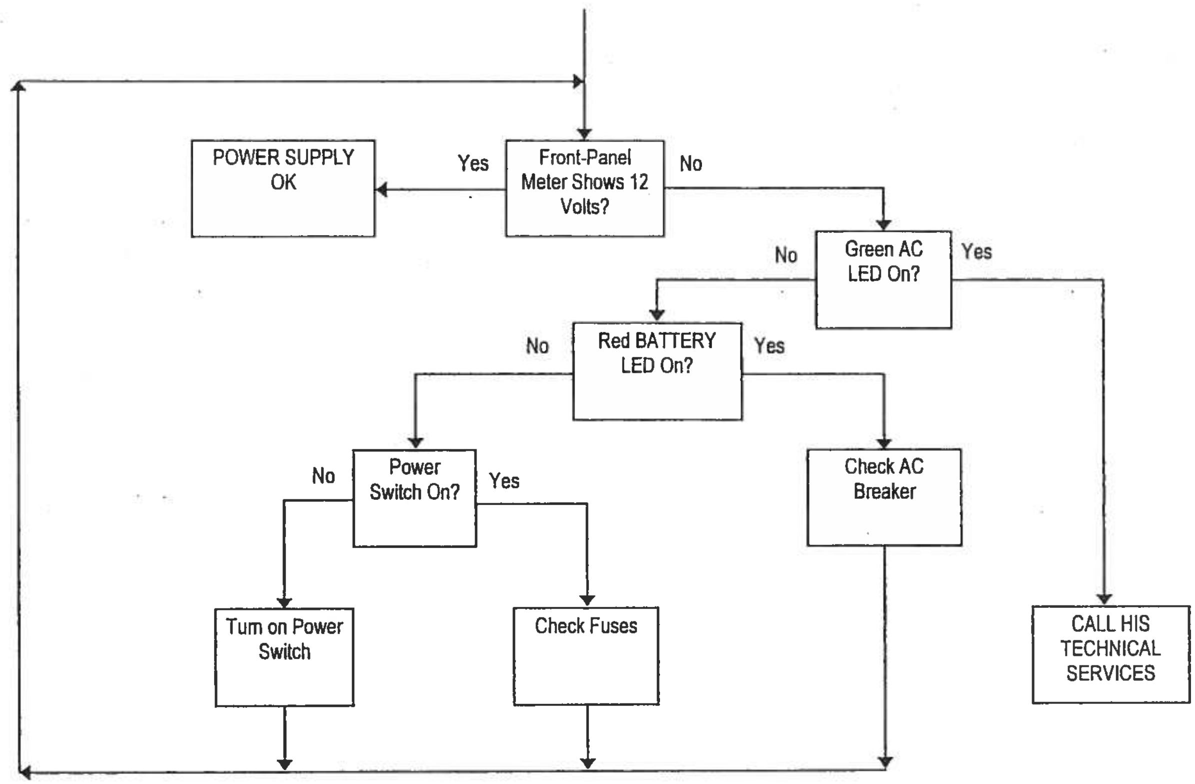
RC200 Flashing Beacon Fault Isolation Tree



DRTXM2 Transmitter Fault Isolation Tree



Power Supply Fault Isolation Tree



.roubleshooting Guide

Power Check

Your first check in the event of failure is fuses, arrestors and circuit breakers.

Under AC power: circuit breakers:

Check the supply circuit breaker if 120VAC power is feeding the station.

Additionally, RoadRunnR's power surge arrestor has a pushbutton circuit breaker on the side of the chassis. Press this button to reset the breaker. If a major power surge has been arrested, this unit may have sacrificed itself. Check 120VAC output from the outlets. Replace if defective.

Under photovoltaic power: circuit breakers:

Check the 2 battery circuit breakers.

Under AC or photovoltaic power: component fuses:

ansmitter power fuse: (2A AGC).

Check fuse with a VOM meter. If fuses are good, continue below:

Determine Difficulty

Determine which condition fits the difficulty your Travelers Information Radio Station is experiencing:

- "No broadcast is heard at any distance."
- "Signal is heard but range is reduced."
- "Audio quality is poor."

"No Broadcast is Heard at Any Distance"

Verify with the Wattmeter if there is a carrier being broadcast. A carrier is present if there is forward power displayed on the wattmeter. A less definite indicator of carrier is that the broadcast frequency becomes quiet, as monitored on a vehicle radio, the closer ·'our approach the antenna location.

carrier is present at full level but no audio is heard, refer to Section B, below.

If carrier is not present, refer to Section A.

Section A – carrier not present:

Check:

Transmitter "Power" switch is ON and the power LED is lighted.

If the switch is OFF, turn the switch ON and continue:

If the switch is ON and the LED is not lighted, test the following:

Test transmitter power fuse. Replace with 2A AGC slow-blow if defective.

If AC-powered, check power switch on power surge arrestor. It should be on. Also, make certain the red "Test Stop" button has not been pressed on the 24V Power Supply/Battery Charger. Press the green "Restart" button, if it has.

If solar-powered, disconnect switch on the photovoltaic controller is ON (not lighted).

Test the voltage from the transmitter's 24VDC power supply and battery charger. It should show 24 volts or more.

If the switch is ON and the LED is lighted, check:

All wires and wire and cable connectors in the system for tightness.

The coaxial cable is attached to the antenna base and the groundplanes are plugged in.

The transmitter power control is not turned down (counterclockwise). Set the control to yield 2.0 mV/m at .93 mile.

If all of the above are affirmative, call ISS.

Section B – carrier is present:

Gain access to the digital message programmer and use * 2# to determine if recorded messages are intact. If they have become erased through an outage of power, rerecord the messages and schedule them to broadcast.

Check "Antenna Switch." It should be set to "Antenna."

Check to see if messages are properly programmed to broadcast by accessing the digital message programmer.

Audio wire connections between the transmitter and the digital message programmer appear to be connected tightly.

Check the "Mod Adjust" control on the transmitter. It should be set so that the "Audio VU" LEDs indicate that modulation is occurring. ***If this control has been turned down,*** turn it back up so that audio peaks just touch the red, or to the level you prefer.

Control telephone - ***if it is "off hook"*** broadcasting will not take place.

If the blue "MSG" pot on the digital message programmer is turned counterclockwise, audio will not be sent to the transmitter. This control should be fully clockwise.

If audio is not reestablished, contact ISS.

"Broadcast is Heard but Range is Reduced"

If audio is being heard, but with reduced range, either the level of signal from the transmitter or the level of audio from the digital message programmer is low.

Section C – low signal from transmitter:

Is the antenna tip extended to the appropriate extension length? Retune if necessary. If the antenna is mistuned, the Wattmeter will show a lower than 10:1 ratio of forward to reflected power.

Does the antenna appear to be damaged by lightning? Look for black marks, especially at the top and on the white loading coil section.

Is the "Power Adjust" control on the transmitter turned up to the proper level to deliver 2.0 mV/m at the .93 measurement point? ***If it has been turned down (counterclockwise),*** lower than normal field will result. Check the transmitter and reset the level if necessary. Check the Wattmeter to see that power has returned to normal set levels for legal operation in your area.

Is the ring lug connection between Antenna Cable and Antenna base loose, disconnected or corroded?

If all of the above check out, contact ISS.

Section D – low audio level from the digital message programmer:

See Section B above.

Section E – low range from environmental factors:

Is there 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 or towers, steel light poles. Ideally, nothing, conductive or nonconductive, should parallel the antenna within 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 kHz.

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

Overhead power lines can produce an effect that appears to lower signal levels by introducing interference that can mask the signal. This effect is most intense on the 530-kHz frequency (but can happen on any frequency) and most affects the signal in the area of the lines only. Range in areas not in proximity to the lines are not affected.

Monitoring behind large structures and tall terrain features can create the effect of a low signal in the immediate proximity of the structures of features.

"Audio Quality is Poor"

Monitor the broadcast messages on the digital message programmer. ***If messages have been recorded via microphone or control phone and sound poor,*** try re-recording. Background noise from nearby traffic can cause a poor quality sound. The microphone will produce a superior recording to the control telephone's 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 message programmer's input source must be changed with the * 7# command.

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.

If messages have been recorded by landline 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.

Broadcast audio quality can sound poor if the transmitter and digital message programmer are in close proximity to one another but their chassis are not electrically connected. Check to be certain that the silver drain wire in the audio cable between the two components is connected properly: to Music G terminal on the digital message programmer and to the "G' terminal on the transmitter.

How Radio Works

by Marshall Brain

Browse the article How Radio Works

Introduction to How Radio Works

"Radio waves" transmit music, conversations, pictures and data invisibly through the air, often over millions of miles -- it happens every day in thousands of different ways! Even though radio waves are invisible and completely undetectable to humans, they have totally changed society. Whether we are talking about a cell phone, a baby monitor, a cordless phone or any one of the thousands of other wireless technologies, all of them use radio waves to communicate.

Radio Image Gallery

Radio waves control everything from wireless networks to garage door openers. See radio pictures.

Here are just a few of the everyday technologies that depend on radio waves:

- AM and FM radio broadcasts
- Cordless phones
- Garage door openers
- Wireless networks
- Radio-controlled toys
- Television broadcasts
- Cell phones
- GPS receivers
- Ham radios
- Satellite communications
- Police radios
- Wireless clocks

The list goes on and on... Even things like radar and microwave ovens depend on radio waves. Things like communication and navigation satellites would be impossible without radio waves, as would modem aviation -- an airplane depends on a dozen different radio systems. The current trend toward wireless Internet access uses radio as well, and that means a lot more convenience in the future!

Tune In

- HD Radio
- Ham Radio
- Satellite Radio

The funny thing is that, at its core, radio is an incredibly simple technology. With just a couple of electronic components that cost at most a dollar or two, you can build simple radio transmitters and receivers. The story of how something so simple has become a bedrock technology of the modern world is fascinating!

In this article, we will explore the technology of radio so that you can completely understand how invisible radio waves make so many things possible!

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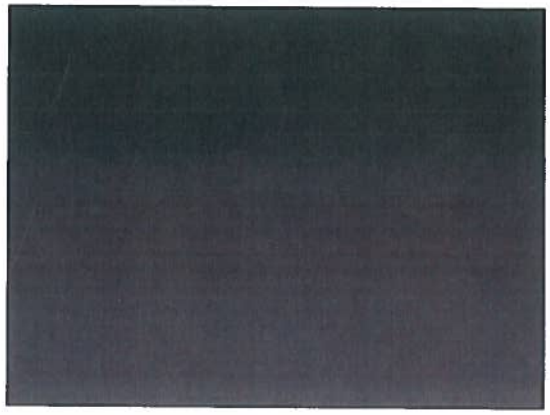
ATTENTION! We recently updated our privacy policy. The changes are effective as of Thursday, October 30, 2008.
To see the new policy, click [here]. Questions? See the policy for the contact information.



Tiny Radio Plays Big Sound
Researchers recently tested the world\'s smallest radio. (February, 2008)

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The Simplest Radio

Radio can be incredibly simple, and around the turn of the century this simplicity made early experimentation possible for just about anyone. How simple can it get? Here's an example:

tets
test

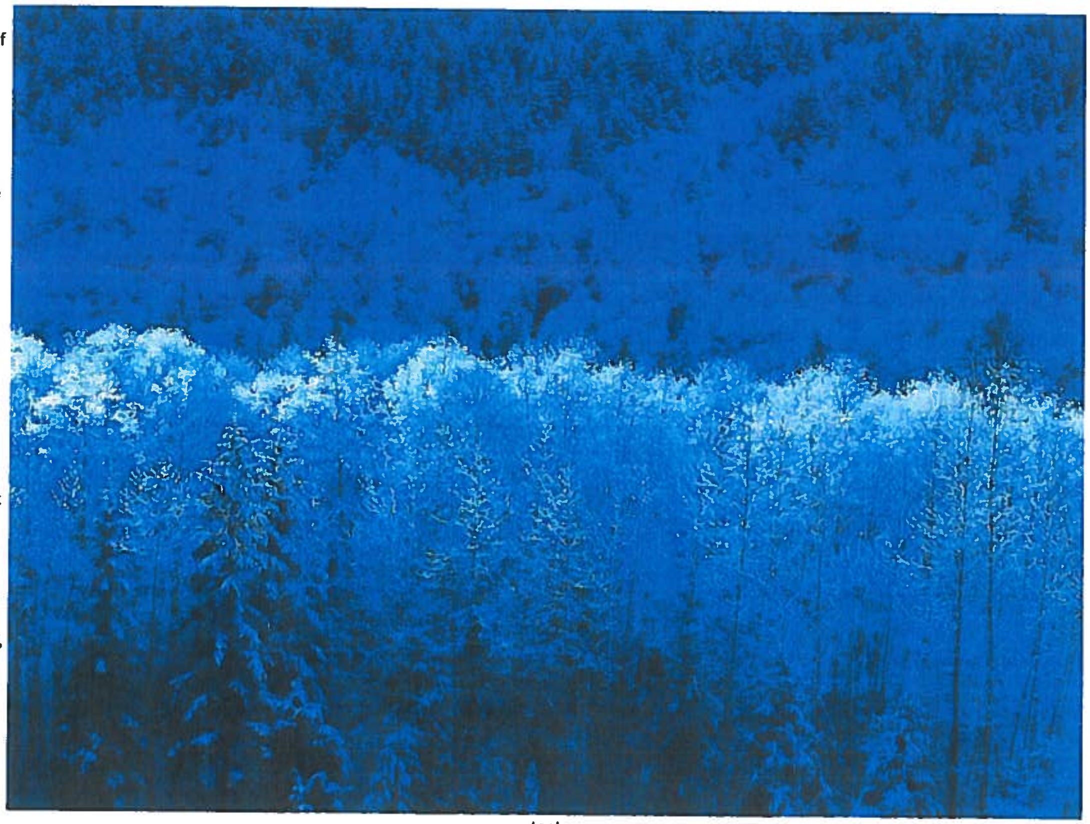
- Take a fresh 9-volt battery and a coin.
- Find an AM radio and tune it to an area of the dial where you hear static.
- Now hold the battery near the antenna and quickly tap the two terminals of the battery with the coin (so that you connect them together for an instant).
- You will hear a crackle in the radio that is caused by the connection and disconnection of the coin.

By tapping the terminals of a 9-volt battery with a coin, you can create radio waves that an AM radio can receive!

Your battery/coin combination is a radio transmitter! It's not transmitting anything useful (just static), and it will not transmit very far (just a few inches, because it's not optimized for distance). But if you use the static to tap out Morse code, you can actually communicate over several inches with this crude device!

A (Slightly) More Elaborate Radio

If you want to get a little more elaborate, use a metal file and two pieces of wire. Connect the handle of the file to one terminal of your 9-volt battery. Connect the other piece of wire to the other terminal, and run the free end of the wire up and down the file. If you do this in the dark, you will be able to see very small 9-volt sparks running along the file as the tip of the wire connects and disconnects with the file's ridges. Hold the file near an AM radio and you will hear a lot of static.



test
test

In the early days of radio, the transmitters were called spark coils, and they created a continuous stream of sparks at much higher voltages (e.g. 20,000 volts). The high voltage created big fat sparks like you see in a spark plug, and they could transmit farther. Today, a transmitter like that is illegal because it spams the entire radio spectrum, but in the early days it worked fine and was very common because there were not many people using radio waves.

Radio Basics: The Parts

As seen in the previous section, it is incredibly easy to transmit with static. All radios today, however, use **continuous sine waves** to transmit information (audio, video, data). The reason that we use continuous sine waves today is because there are so many different people and devices that want to use radio waves at the same time. If you had some way to see them, you would find that there are literally thousands of different radio waves (in the form of sine waves) around you right now -- TV broadcasts, AM and FM radio broadcasts, police and fire radios, satellite TV transmissions, cell phone conversations, GPS signals, and so on. It is amazing how many uses there are for radio waves today (see How the Radio Spectrum Works to get an idea). Each different radio signal uses a different sine wave **frequency**, and that is how they are all separated.

Any radio setup has two parts:

- The **transmitter**
- The **receiver**

The transmitter takes some sort of message (it could be the sound of someone's voice, pictures for a TV set, data for a radio modem or whatever), encodes it onto a sine wave and transmits it with radio waves. The receiver receives the radio waves and decodes the message from the sine wave it receives. Both the transmitter and receiver use **antennas** to radiate and capture the radio signal.

Radio Basics: Real-life Examples

A baby monitor is about as simple as radio technology gets. There is a transmitter that sits in the baby's room and a receiver that the parents use to listen to the baby. Here are some of the important characteristics of a typical baby monitor:

- Modulation: Amplitude Modulation (AM)
- Frequency range: 49 MHz
- Number of frequencies: 1 or 2
- Transmitter power: 0.25 watts

(Don't worry if terms like "modulation" and "frequency" don't make sense right now -- we will get to them in a moment.)

A typical baby monitor, with the receiver on the left and the transmitter on the right: The transmitter sits in the baby's room and is essentially a mini "radio station." The parents carry the receiver around the house to listen to the baby. Typical transmission distance is limited to about 200 feet (61 m).

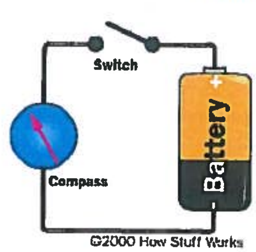
A cell phone is also a radio and is a much more sophisticated device (see How Cell Phones Work for details). A cell phone contains both a transmitter and a receiver, can use both of them simultaneously, can understand hundreds of different frequencies, and can automatically switch between frequencies. Here are some of the important characteristics of a typical analog cell phone:

- Modulation: Frequency Modulation (FM)
- Frequency range: 800 MHz
- Number of frequencies: 1,664 (832 per provider, two providers per area)
- Transmitter power: 3 watts

A typical cell phone contains both a transmitter and a receiver, and both operate simultaneously on different frequencies. A cell phone communicates with a cell phone tower and can transmit 2 or 3 miles (3-5 km).

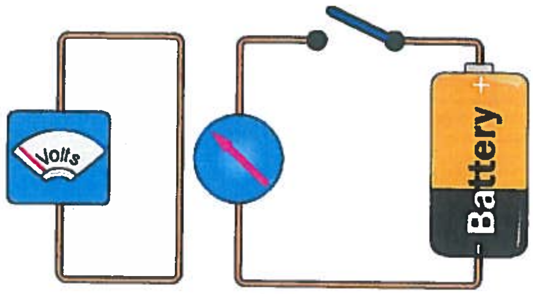
Simple Transmitters

You can get an idea for how a radio transmitter works by starting with a battery and a piece of wire. In How Electromagnets Work, you can see that a battery sends electricity (a stream of electrons) through a wire if you connect the wire between the two terminals of the battery. The moving electrons create a magnetic field surrounding the wire, and that field is strong enough to affect a compass.



Let's say that you take another wire and place it parallel to the battery's wire but several inches (5 cm) away from it. If you connect a very sensitive voltmeter to the wire, then the following will happen: Every time you connect or disconnect the first wire from the battery, you will sense a very small voltage and current in the second wire; any changing magnetic field can induce an electric field in a conductor -- this is the basic principle behind any electrical generator. So:

- The battery creates electron flow in the first wire.
- The moving electrons create a magnetic field around the wire.
- The magnetic field stretches out to the second wire.
- Electrons begin to flow in the second wire whenever the magnetic field in the first wire changes.



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One important thing to notice is that electrons flow in the second wire only when you connect or disconnect the battery. A magnetic field does not cause electrons to flow in a wire unless the magnetic field is **changing**. Connecting and disconnecting the battery changes the magnetic field (connecting the battery to the wire creates the magnetic field, while disconnecting collapses the field), so electrons flow in the second wire at those two moments.

Simple Transmitters: Make Your Own

To create a simple radio transmitter, what you want to do is create a **rapidly changing electric current** in a wire. You can do that by rapidly connecting and disconnecting a battery, like this:

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When you connect the battery, the voltage in the wire is 1.5 volts, and when you disconnect it, the voltage is zero volts. By connecting and disconnecting a battery quickly, you create a square wave that fluctuates between 0 and 1.5 volts.

A better way is to create a continuously varying electric current in a wire. The simplest (and smoothest) form of a continuously varying wave is a sine wave like the one shown below:

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A sine wave fluctuates smoothly between, for example, 10 volts and -10 volts.

By creating a sine wave and running it through a wire, you create a simple radio transmitter. It is extremely easy to create a sine wave with just a few electronic components -- a capacitor and an inductor can create the sine wave, and a couple of transistors can amplify the wave into a powerful signal (see How Oscillators Work for details, and here is a simple transmitter schematic). By sending that signal to an antenna, you can transmit the sine wave into space.

> **Frequency**
>
> One characteristic of a sine wave is its **frequency**. The frequency of a sine wave is the number of times it oscillates up and down per second. When you listen to an AM radio broadcast, your radio is tuning in to a sine wave with a frequency of around 1,000,000 cycles per second (cycles per second is also known as **hertz**). For example, 680 on the AM dial is 680,000 cycles per second. FM radio signals are operating in the range of 100,000,000 hertz, so 101.5 on the FM dial is a transmitter generating a sine wave at 101,500,000 cycles per second. See How the Radio Spectrum Works for details.

Transmitting Information

If you have a sine wave and a transmitter that is transmitting the sine wave into space with an antenna, you have a radio station. The only problem is that the sine wave doesn't contain any information. You need to **modulate** the wave in some way to encode information on it. There are three common ways to modulate a sine wave:

- **Pulse Modulation** - In PM, you simply turn the sine wave on and off. This is an easy way to send Morse code. PM is not that common, but one good example of it is the radio system that sends signals to radio-controlled clocks in the United States. One PM transmitter is able to cover the entire United States!

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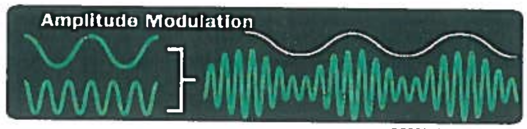
- **Amplitude Modulation** - Both AM radio stations and the picture part of a TV signal use amplitude modulation to encode information. In amplitude modulation, the amplitude of the sine wave (its peak-to-peak voltage) changes. So, for example, the sine wave produced by a person's voice is overlaid onto the transmitter's sine wave to vary its amplitude.



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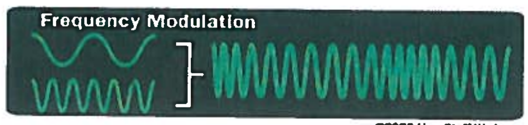
- **Frequency Modulation** - FM radio stations and hundreds of other wireless technologies (including the sound portion of a TV signal, cordless phones, cell phones, etc.) use frequency modulation. The advantage to FM is that it is largely immune to static. In FM, the transmitter's sine wave frequency changes very slightly based on the information signal.



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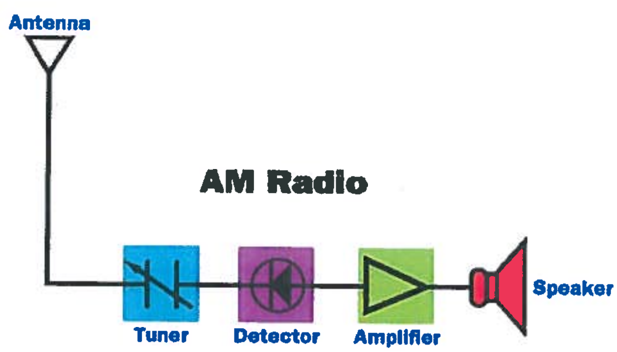
Once you modulate a sine wave with information, you can transmit the information!

Receiving an AM Signal

Here's a real world example. When you tune your car's AM radio to a station -- for example, 680 on the AM dial -- the transmitter's sine wave is transmitting at 680,000 hertz (the sine wave repeats 680,000 times per second). The DJ's voice is modulated onto that carrier wave by varying the amplitude of the transmitter's sine wave. An amplifier amplifies the signal to something like 50,000 watts for a large AM station. Then the antenna sends the radio waves out into space.

So how does your car's AM radio -- a receiver -- receive the 680,000-hertz signal that the transmitter sent and extract the information (the DJ's voice) from it? Here are the steps:



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- Unless you are sitting right beside the transmitter, your radio receiver needs an **antenna** to help it pick the transmitter's radio waves out of the air. An AM antenna is simply a wire or a metal stick that increases the amount of metal the transmitter's waves can interact with.
- Your radio receiver needs a **tuner**. The antenna will receive thousands of sine waves. The job of a tuner is to separate one sine wave from the thousands of radio signals that the antenna receives. In this case, the tuner is tuned to receive the 680,000-hertz signal.

  Tuners work using a principle called **resonance**. That is, tuners **resonate** at, and amplify, one particular frequency and ignore all the other frequencies in the air. It is easy to create a resonator with a capacitor and an inductor (check out How Oscillators Work to see how inductors and capacitors work together to create a tuner).
- The tuner causes the radio to receive just one sine wave frequency (in this case, 680,000 hertz). Now the radio has to extract the DJ's voice out of that sine wave. This is done with a part of the radio called a **detector** or **demodulator**. In the case of an AM radio, the detector is made with an electronic component called a **diode**. A diode allows current to flow through in one direction but not the other, so it clips off one side of the wave, like this:

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- The radio next **amplifies** the clipped signal and sends it to the speakers (or a headphone). The amplifier is made of one or more transistors (more transistors means more amplification and therefore more power to the speakers).

What you hear coming out the speakers is the DJ's voice!

In an FM radio, the detector is different, but everything else is the same. In FM, the detector turns the changes in frequency into sound, but the antenna, tuner and amplifier are largely the same.

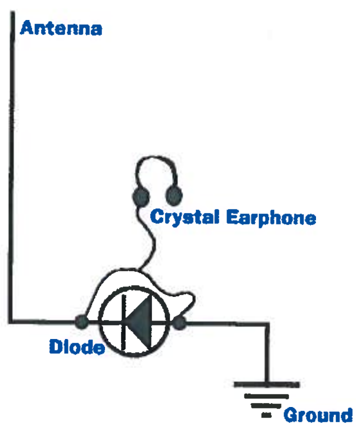
The Simplest AM Receiver

In the case of a strong AM signal, it turns out that you can create a simple radio receiver with just two parts and some wire! The process is extremely simple -- here's what you need:

- **A diode** - You can get a diode for about $1 at Radio Shack. Part number 276-1123 will do.
- **Two pieces of wire** - You'll need about 20 to 30 feet (15 to 20 meters) of wire. Radio Shack part number 278-1224 is great, but any wire will do.
- **A small metal stake** that you can drive into the ground (or, if the transmitter has a guard rail or metal fence nearby, you can use that)
- **A crystal earphone** - Unfortunately, Radio Shack does not sell one. However, Radio Shack does sell a Crystal Radio Kit (part number 28-178) that contains the earphone, diode, wire and a tuner (which means that you don't need to stand right next to the transmitter for this to work), all for $10.

You now need to find and be near an AM radio station's transmitting tower (within a mile/1.6 km or so) for this to work. Here's what you do:

- Drive the stake into the ground, or find a convenient metal fence post. Strip the insulation off the end of a 10-foot (3-meter) piece of wire and wrap it around the stake/post five or 10 times to get a good solid connection. This is the ground wire.
- Attach the diode to the other end of the ground wire.
- Take another piece of wire, 10 to 20 feet long (3 to 6 meters), and connect one end of it to the other end of the diode. This wire is your antenna. Lay it out on the ground, or hang it in a tree, but make sure the bare end does not touch the ground.
- Connect the two leads from the earplug to either end of the diode, like this:



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Now if you put the earplug in your ear, you will hear the radio station -- that is the simplest possible radio receiver! This super-simple project will not work if you are very far from the station, but it does demonstrate how simple a radio receiver can be.

Here's how it works. Your wire antenna is receiving all sorts of radio signals, but because you are so close to a particular transmitter it doesn't really matter. The nearby signal overwhelms everything else by a factor of millions. Because you are so close to the transmitter, the antenna is also receiving lots of **energy** -- enough to drive an earphone! Therefore, you don't need a tuner or batteries or anything else. The diode acts as a detector for the AM signal as described in the previous section. So you can hear the station despite the lack of a tuner and an amplifier!

The Crystal Radio Kit that Radio Shack sells (28-178) contains two extra parts: an inductor and a capacitor. These two parts create a tuner that gives the radio extra range. See How Oscillators Work for details.

Antenna Basics

You have probably noticed that almost every radio you see (like your cell phone, the radio in your car, etc.) has an **antenna**. Antennas come in all shapes and sizes, depending on the frequency the antenna is trying to receive. The antenna can be anything from a long, stiff wire (as in the AM/FM radio antennas on most cars) to something as bizarre as a satellite dish. Radio transmitters also use extremely tall antenna towers to transmit their signals.

The idea behind an antenna in a radio transmitter is to launch the radio waves into space. In a receiver, the idea is to pick up as much of the transmitter's power as possible and supply it to the tuner. For satellites that are millions of miles away, NASA uses huge dish antennas up to 200 feet (60 meters) in diameter!

The size of an optimum radio antenna is related to the frequency of the signal that the antenna is trying to transmit or receive. The reason for this relationship has to do with the **speed of light**, and the distance electrons can travel as a result. The speed of light is 186,000 miles per second (300,000 kilometers per second). On the next page, we'll use this number to calculate a real-life antenna size.

Antenna: Real-life Examples

Let's say that you are trying to build a radio tower for radio station 680 AM. It is transmitting a sine wave with a frequency of 680,000 hertz. In one cycle of the sine wave, the transmitter is going to move electrons in the antenna in one direction, switch and pull them back, switch and push them out and switch and move them back again. In other words, the electrons will change direction four times during one cycle of the sine wave. If the transmitter is running at 680,000 hertz, that means that every cycle completes in (1/680,000) 0.00000147 seconds. One quarter of that is 0.0000003675 seconds. At the speed of light, electrons can travel 0.0684 miles (0.11 km) in 0.0000003675 seconds. That means the optimal antenna size for the transmitter at 680,000 hertz is about 361 feet (110 meters). So AM radio stations need very tall towers. For a cell phone working at 900,000,000 (900 MHz), on the other hand, the optimum antenna size is about 8.3 cm or 3 inches. This is why cell phones can have such short antennas.

You might have noticed that the AM radio antenna in your car is not 300 feet long -- it is only a couple of feet long. If you made the antenna longer it would receive better, but AM stations are so strong in cities that it doesn't really matter if your antenna is the optimal length.

You might wonder why, when a radio transmitter transmits something, radio waves want to propagate through space away from the antenna at the speed of light. Why can radio waves travel millions of miles? Why doesn't the antenna just have a magnetic field around it, close to the antenna, as you see with a wire attached to a battery? One simple way to think about it is this: When current enters the antenna, it does create a magnetic field around the antenna. We have also seen that the magnetic field will create an electric field (voltage and current) in another wire placed close to the transmitter. It turns out that, in space, the magnetic field created by the antenna induces an electric field in space. This electric field in turn induces another magnetic field in space, which induces another electric field, which induces another magnetic field, and so on. These electric and magnetic fields (electromagnetic fields) induce each other in space at the speed of light, traveling outward away from the antenna.

For more information on radio and related topics, check out the links on the next page.

Lots More Information

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More Great Links

- United States Early Radio History
- History of American Broadcasting
- Crystal Set Society
- National Radio Astronomy Observatory
- Yahoo! Directory: War of the Worlds Broadcast (1938)