Bellcore

Bell Communications Research

Bellcore Practice
BR 940-500-100
Issue 1, March 1992

RADIO ENGINEERING

BCC/BELLCORE HF RADIO NETWORK

Produced by Project 431801, National Security Emergency Preparedness, part of the NSEP Product; in collaboration with Project 422241, Digital Network Transition Engineering - Transmission, part of the End-to-End Transmission, Synchronization, and Performance Product.

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1. INTRODUCTION

1.01 This practice provides engineering information for ongoing growth and rearrangement of the BCC-Bellcore high-frequency (HF) emergency radio network. This network is a back-up facility, part of the Bellcore/BCC Emergency Action and Management System (BEAMS), which complements the private-line voice/data capabilities of that network.

1.02 When this BR is reissued, reasons for the reissue will be listed here.

1.03 BR 940-500-100 collects and updates information formerly contained in a series of Information Letters: IL 85/04-045, IL 85/10-038, IL 86/07-036, IL 87/06-022, IL 89/03-050, and IL 90/11-031. (Titles of these and other source material are given in the References section.) This BR includes specialized material on electromagnetic pulse (EMP) treatment in Appendix A, and a convenient checklist for verifying the quality of a station installation in Appendix B.

1.04 The HF network connects emergency centers of Bellcore Client Companies (BCCs) - both Region and local-company - with Bellcore, Federal agencies, and amateur radio stations. The network is intended to pass critical National Security Emergency Preparedness (NSEP) status reports and other network-restoration messages among local, Region, Bellcore, and Government work groups.

1.05 The network comprises individually licensed stations, each potentially able to communicate with any other. Most sites have transceivers (transmitter-receivers) of medium power (120 watts peak envelope power or PEP) and simple fixed wire antennas. Some points are equipped with higher-power amplifiers and/or rotatable directional antennas. All stations provide voice operation; some are equipped for data-terminal operation and/or telephone ("phone patch") interconnection. A few are remotely controlled from emergency operating centers. Several Regions have a group of portable "flyaway" transceivers licensed as portable stations. These are complete voice stations with antenna kits in a carrying case, suitable for sending into an area where serious storm damage is expected.

1.06 Besides reaching BCC emergency centers, the network may interoperate with HF emergency networks of several Federal Government agencies. It participates in scheduled test exercises with them. These include the National Telecommunications Coordinating Network (NTCN) sponsored by the Federal Emergency Management Agency (FEMA). The latter operates a program called SHARES (SHAred RESources) involving the HF stations of a variety of agencies.

1.07 The Bellcore NSEP organization has produced, and periodically updates, the Operations Guide for the network (SR-CSP-000807). Some client companies produce their own, customized, versions of the Guide. This document is effectively the operating practice for the network. Since it contains sensitive details, it is under controlled distribution through local NSEP contacts. While intended primarily for placement at the radio itself, it provides useful insight to site planners, FCC coordinators, maintenance engineers, training personnel, and other non-operators of the system. The SR provides a station list, the current version of the authentication table, a procedure for operating data terminals, and propagation charts. Stations having directional antennas have been provided with customized station lists with site-specific pointing directions.

2. HF RADIO TRANSMISSION

2.01 Radio in the HF spectrum, 3 to 30 MHz, operates over long distances by propagation of radio waves through the earth's ionosphere and back to earth. Ionospheric paths are the usual medium, although there is some transmission by ground wave over short distances (up to 20 to 50 miles, depending on frequency and ground conductivity). Ground-wave transmission performs best with vertically polarized antennas. For an ionospheric path, polarization of the wave is immaterial; the refraction process depolarizes the signal. These considerations are widely different from those applying to microwave or VHF radio systems, which are more familiar to most telecommunications engineers.

2.02 HF signals achieve long distances by refraction in the ionosphere at an altitude of 60 to 200 miles above the earth. The signal travels upward and is bent back toward the distant station by layers of ionized gases. The distance attained depends on the relative densities of ionized and absorbing layers, which in turn vary with the level of sunlight - functions of time of day and season - and the occurrence of irregularities in the sun (sunspots).

2.03 Figure 1 shows two paths between stations. During the day, the controlling layer in the ionosphere is the "E" layer, at an effective or "virtual" height of roughly 60 miles. It refracts signals at moderate frequency (about 5-10 MHz) back to the earth at distances of about 200-1000 miles. Receiver R1 receives its signal via this path. Signals of higher frequency (approximately 10-25 MHz) pass through the "E" layer and are refracted by a higher "F1" or "F2" layer, reaching transcontinental distances and beyond. Receiver R2 obtains its signal this way. Signals of higher frequency yet pass through the "E" and "F" layers and do not return to earth. There is a "D" layer, below the "E" layer, that is dense enough during the day to absorb the signal partially.

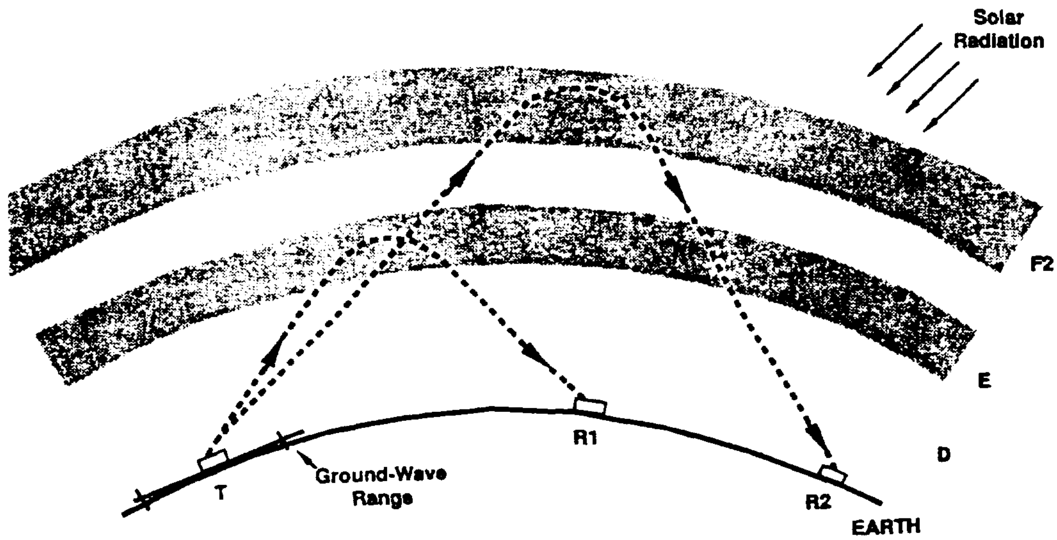

Fig. 1 - Ionospheric Paths

2.04 At night, with sunlight absent, most of the ions recombine. The E-layer effectively disappears; the F1 and F2 layers merge into a single layer at about 200 miles' altitude. Signal absorption in the D-layer (below the E-layer) diminishes.

2.05 Returning to the ground wave: at the extreme of ground-wave coverage, severe fading occurs because of interference between the ground wave and the sky wave. Farther away, a ring of territory around the transmitter receives no useful signal; this "skip" zone is between the end of ground-wave range and the beginning of reliable sky-wave coverage.

2.06 Because the portion of the ionosphere that is dense enough to provide refraction changes height during the day, and because paths vary as to length, the vertical radiation patterns of the antennas affect the received signal level. For a given path to work, both antennas must provide appreciable radiation and reception at the relevant elevation angle. Typical elevation angles for short and long paths are as follows:

	Elevation Angle	
Path	Day	Night
Short (200 mi.)	31°	60°
Long (2000 mi.)	0°	4°

The requirement for appreciable radiation at high elevation angles penalizes vertical antennas used on short paths.

2.07 Sun-spot effects, which come and go in an 11-year cycle, affect the level of ionization and the degree of signal absorption. So do changes in season and irregular actions of the sun (solar flares) that also cause the Northern Lights. Sunspot activity peaked in mid-1989, will go to minimum about 1995, then will peak again about 2000.

2.08 The net effect of ionization and absorption is that, for each path and each combination of time of day and other variables, there is a Maximum Usable Frequency (MUF) that will propagate. Signals appreciably higher in frequency are lost. Much below the MUF, the signal is weak and atmospheric noise predominates. Also much below the MUF, multipath distortion makes data transmission at speeds as low as 300 bps difficult and even gives voice signals a hollow sound. A working frequency of about 90% of the MUF is generally desirable.

2.09 Figure 2 illustrates the variation of MUF with time for a particular set of conditions. In particular, this graph is for a 300-mile path in the Midwest, near the middle of the sunspot cycle. However, the shape of the curve is typical of all such curves: a higher level of solar activity shifts the curve upward; a lower level, downward. Note that, at midday, the MUF is in the frequency range where a log-periodic array (LPA) is feasible as the antenna; at night, the MUF drops below this range and a wire or vertical antenna must be used.

2.10 The level of atmospheric and man-made noise also affects the radio path. The level of natural background noise, mainly thunderstorm static, depends on season, location, and conditions for propagation from long distances. The level is greatest at southern latitudes at night during the summer season, and least at northern locations during the day in the winter. (At a given moment, the noise in Florida may be 25 dB higher than in Maine.) The amount of man-made noise naturally depends on location, and is roughly 15 dB higher at urban sites than suburban. The general level of noise varies with frequency: it is about 19 dB higher at 2.0 MHz than at 20 MHz.

2.11 Because the best radio channel for HF communication varies with so many factors, stations in the HF network are licensed by the FCC to operate on 40-plus channels in the Industrial Radio Services. This meets the additional need to avoid interference with other users. These frequencies are shared with other users, such as state disaster-relief agencies in the Midwest, power companies, the petroleum industry, etc. In special circumstances, the U. S. Government authorizes operation on military or government frequencies.

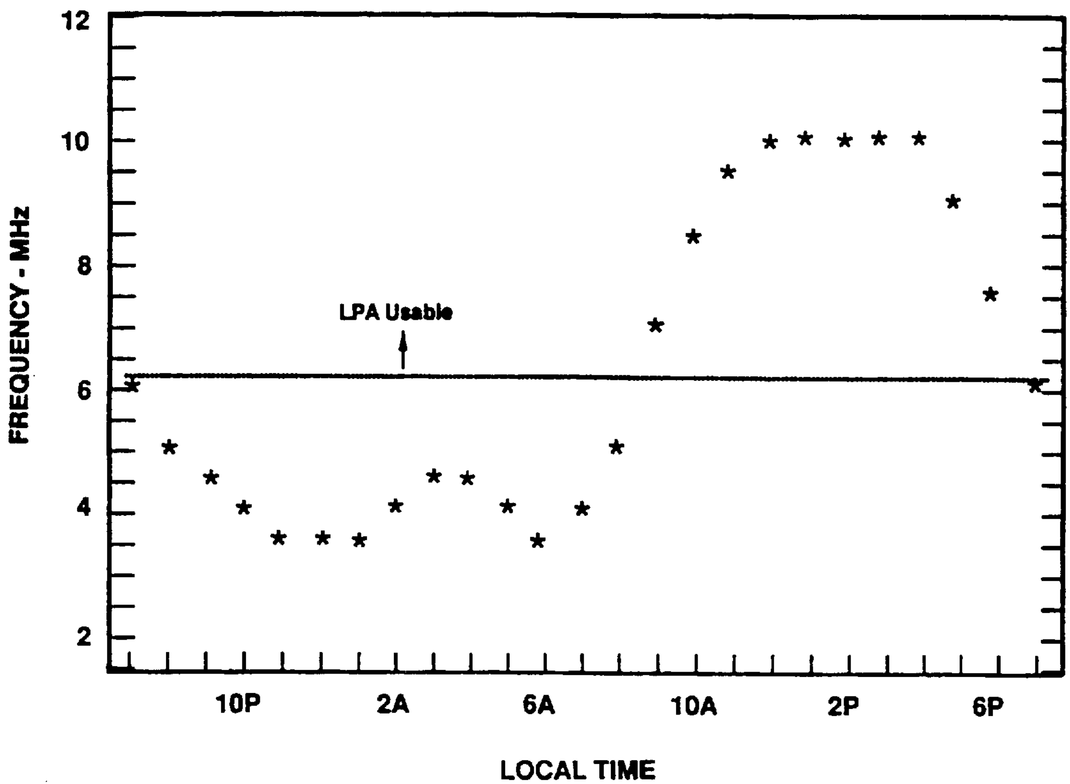

Fig. 2 - Maximum Usable Frequency Versus Time of Day

2.12 The general usability of frequencies is as follows:

- Those in the 2.0-3.2 MHz area are most useful during daylight hours on paths up to about 200 miles. Atmospheric noise tends to be high during summer months.

- Those in the 4.5-5.4 MHz area are useful for communication up to 200-300 miles during daylight and much farther at night. Atmospheric noise tends to be high during the summer, but less than on lower channels.

- Those in the 6.8-8.0 MHz area are most useful for daylight hours and communication on paths from about 300 miles to somewhat over 1000 miles. Usually distances less than 300 miles are "skipped over." Paths to farther points are often possible at night, although interference from distant stations may make some frequencies unusable.

- Those in the 8-18 MHz area are the most reliable during daylight hours on paths up to transcontinental length. Interference can be expected on these frequencies from all parts of the world, hence directive antennas that reject signals and noise from undesired directions are helpful.

2.13 The HF network came into use as the 11-year cycle for sunspot activity neared a peak. As a result of solar activity giving a generally favorable state in the ionosphere, reliability of service on the network has been rather good. Over the next few years, radio operators will need to cope with weaker and noisier signals, but the network has the margins to provide service despite weakening solar activity.

2.14 The propagation charts in the Operations Guide are updated periodically to match the level of solar activity expected in the near future. The predictions are derived by use of the IONCAP (IONospheric CAPabilities) software program provided by the National Telecommunications and Information Agency.

2.15 IONCAP studies give an idea of the reliability that can be expected from an HF network, and of the effects of progressively better (and more expensive) facilities on path reliability. Figure 3 shows the predicted reliability for voice communication on two paths, of 1100 and 2400 miles respectively.

2.16 There are numerous assumptions behind this figure. They are:

- Quiet station locations in terms of radio noise.
- Low sunspot count (relatively poor conditions).
- Voice operation, not data, hence no advantage from error correction.
- No improvement from use of LINked COMPressor-EXpander (LINCOMPEX) equipment.
- No significant interference.
- Reliability figured across a 24-hour day.
- Full access to frequencies.

2.17 To illustrate, the 2400-mile path (New Jersey-California) is expected to yield reliability of only about 36% on a 24-hour basis with 120-W transceivers and simple vertical antennas at both ends. Converting to Yagi antennas with gains of about 4 dB each doubles the reliability, to about 72%. Going to 1-kW transceivers with an improvement of 9 dB, and/or converting to log-periodic antennas with 11-dB gains each, would push the reliability higher. So would switching to data operation during times of poor propagation, or adding LINCOMPEX equipment at any time.

2.18 As with any radio signal, fading occurs on HF paths. HF stations designed for fixed point-to-point paths commonly use receivers with dual or triple space diversity. This feature is not used in the HF network, however, because antenna separations of 1000 feet or so are required for space diversity. Frequency diversity is impractical because of spectrum shortage.

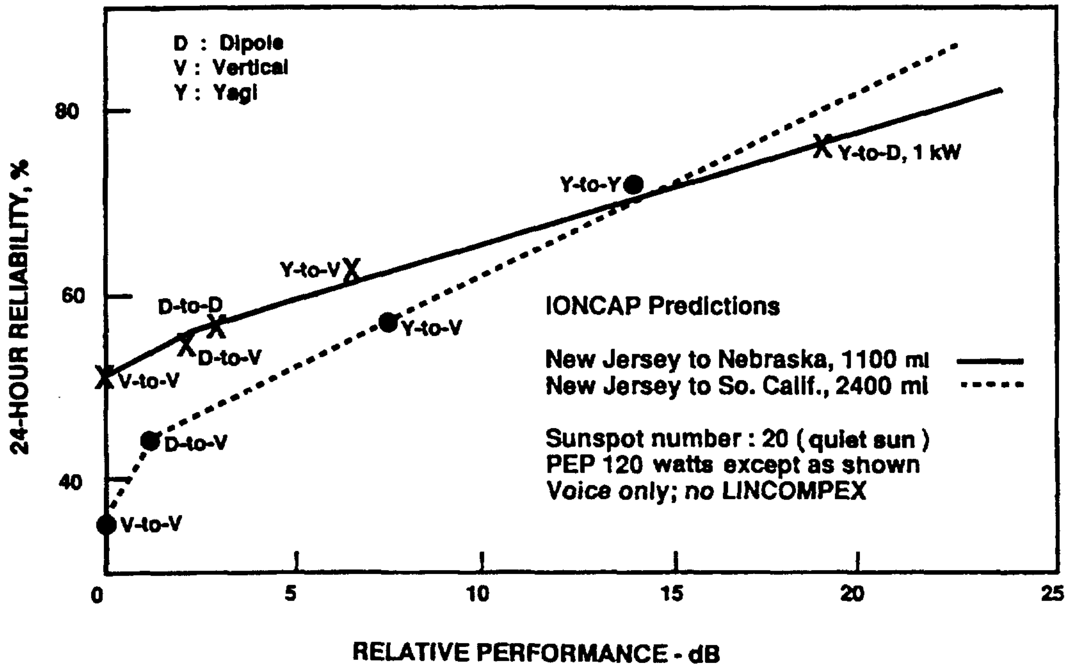

Fig. 3 - Predicted Reliabilities of Two Paths

3. EQUIPMENT

Transceivers

3.01 Transceivers in the HF network are all-solid-state, frequency-synthesized designs with memory-based channel selection. Frequency resolution of the synthesizers is 0.1 kHz to fit the frequency plan. The great majority have 120-watt PEP. Stations at some sites have data terminals allowing low-speed, high-reliability transmission of radiograms with automatic storage and transmission. Such terminals operate at a speed of 50 baud, using an ARQ (Automatic Repeat reQuest) protocol for low error rate in the presence of radio fading and multipath distortion.

3.02 HF stations in emergency centers are often colocated with Telephone Maintenance, cellular, and other radios. There may be dual HF radios for simultaneous handling of intra- and inter-Region traffic. In some cases a station for use by amateur operators, on amateur frequencies, is in the same center. Where multiple radios are present, the provision of headsets is advisable for operator comfort. Operating experience under busy conditions indicates that it is preferable to place operators out of each other's line of sight of, e. g., back-to-back.

3.03 It is sometimes necessary to locate the radio remotely from the operating site, either where the emergency center is normally unattended or where the center lacks a suitable antenna location. Remote-control systems are available for use on a regular 3002-type two-wire voiceband private line. Likewise, rotators for LPA antennas can be remote-controlled.

3.04 Telephone-patch couplers are available, but must be used consistent with Part 68 of the FCC Rules. If not registered, they must be connected to the network through a registered protective connecting arrangement.

LINCOMPEX

3.05 The LINCOMPEX is an audio-processing option for improving the performance of an HF channel. It comprises a speech-volume compressor at the transmitting end and a complementary expander at the receiver. It is an available option for transceivers, either built into the transceiver or as an external device. Its use is recommended generally, since using it *at both ends* of the radio path improves the performance of the path more than going to high-power transceivers. It is far less expensive as well.

3.06 Ordinary compressor-expander systems, as a means of reducing the user-perceived noise on a circuit, are not applicable to HF systems because the expander amplifies noise bursts as well as speech. The LINCOMPEX differs in that a control tone *links* the expander to the compressor. The result is that the expander opens up only when commanded by the sending end; it thus responds only to the talker volume at the sending end. The compressor is a "stiff" volume limiter instead of a normal 2:1 compressor. LINCOMPEX systems were known some time ago to be expensive but highly effective. The difference is that the hardware, through digital design and large-scale integration, is now affordable for use even in small stations like those of the HF network. The basic features of LINCOMPEX have been standardized via CCIR Recommendation 455-1; however, additional features are now available, like automatic cancellation of frequency offset in the radio. The LINCOMPEX feature can be switched out for communication with stations lacking it.

3.07 Modern LINCOMPEX equipment, with its improvement in effective radio performance of about 14 dB, became available as the current solar cycle began to decline. Its use should thus make up for the expected reduction in path quality. For existing radios, the equipment is available as either a retrofit ("implant") or an external unit. The external version is usable, with the proper cabling, with essentially any radio.

3.08 For a description of LINCOMPEX equipment, the maker's instruction book will provide details. For general operating theory, practice 403-311-100 provides a description of an earlier analog version of the equipment.

Automatic Link Establishment

3.09 It is highly desirable in an HF network to have automatic testing of the several frequencies that may be available, to determine the one having best propagation at the time of use. A selective-calling feature is similarly desirable, to allow a station to alert another specific station or group of stations.

3.10 The NSEP HF network came into use with a vendor-proprietary link-establishment termed Transcall. Later on, the Federal Government adopted a non-proprietary standard for Automatic Link Establishment (ALE) systems. These systems, in essence, allow a pair of radio stations to test a group of frequencies, choose the frequency that is functioning best at the moment, notify the calling operator that the link is set up, and alert the called operator that a call is coming in. Network-management functions like status reporting are included. The standard, FED-STD-1045, applies to Federal agencies and has been taken up as a military standard (part of MIL-STD-188) by the military departments. State governments are likewise adopting it for their emergency networks, to allow interoperation with such Federal agencies as FEMA.

3.11 The standard represents a goal for the HF network because it allows interagency compatibility and can replace noncompatible ALE-type systems. It also provides a simple digital "order wire" capability whereby stations can exchange 90-character data messages under propagation conditions too poor to support speech. It is expected that the new system will be phased-in relatively quickly. Inclusion of FED-STD-1045 equipment is desirable for new purchases and for refitting of existing stations.

3.12 Commercial ALE terminals consist of an ALE controller, keyboard, and monitor. Existing transceivers may require upgrading with a "fast synthesizer" module for use with the new external controller.

Antennas

3.13 Most antennas used in the NSEP network are "delta loops" or "broadband dipoles" that are compatible with the transceiver over the full set of channels. The performance of a simple wire antenna (e. g., a basic dipole) depends on the operating channel. Because the dipole's pattern changes with frequency, the radiation toward a particular station may be strong on one channel but weak on a channel much higher or lower, where a pattern null points toward that station. The delta loop avoids much of this variability. It also provides sizable radiation at high vertical angles for use on short paths.

3.14 A vertical antenna is usually 16 to 32 feet long. Its radiation pattern is omnidirectional. It normally involves an automatic tuner mounted at the base, which lets it work over a large range of channels. However, it tends to receive more (vertically polarized) noise than other types. Being electrically short (much shorter than a quarter of a wavelength), it has low radiation resistance and relatively low transmitting efficiency. It is most useful for distances up to 30 miles and beyond about 300 miles, where a relatively low angle of radiation is desirable. It lacks strong radiation at high angles, and is thus poor for short paths. It is inconspicuous and needs little support or roof area. However, the automatic tuner, with its control cabling connected to the transceiver, involves an exposure for lightning-induced currents to damage the transceiver. The tuner is relatively slow in changing channels and thus may not be able to follow an ALE system that rapidly sends on a group of channels in succession.

3.15 A delta loop antenna is a wire triangle with one apex supported as high as feasible. A matching/dissipation network gives a fairly good standing-wave ratio (SWR) over the 2-30 MHz HF band. The pattern includes significant radiation at high vertical angles, a necessity for good coverage of stations within 300-600 miles. For operation as low as 2 MHz, it requires a clear space 100 to 150 feet wide. However, it is inconspicuous.

3.16 A directional antenna is usually a set of horizontal elements mounted on a boom, atop a tower. The lengths of the elements taper in a logarithmically-periodic fashion based on operating frequency, giving rise to the name "log-periodic array" or LPA. A motor drive points the antenna in any compass direction. Such an antenna operates over a broad range of frequencies, usually 6-30 MHz, but is unusable at lower frequencies. It provides a large power gain in the desired direction, both transmitting and receiving, of about 11 dB, and rejects noise and interference received from other directions. The 3-dB beamwidth is about 30°. As a result, it must be aimed toward the desired station, an inconvenience for exercises in Region networks where the outlying stations are at widely different compass bearings. As a result, many stations have two antennas, an LPA and a delta loop, with a transfer switch. The LPA is relatively expensive. It requires appreciable height above ground to be effective and is conspicuous. Hence it may involve zoning problems in populated areas.

3.17 The SWR performance of HF antennas can be satisfactory over a wide frequency range. Figure 4 shows the measured SWRs of three antennas. One curve covers an LPA at an 85-foot elevation. Two more curves apply to delta loops. One is for a loop in the clear, with its apex supported from the 55-foot point on the same tower as the LPA and the lower portion about 20 feet above poorly conducting ground. The other pertains to a typical rooftop installation, with apex at about 25 feet and lower part about 10 feet above the (conducting) roof. The SWR measurements were corrected to account for the losses in the feedline, which otherwise make the SWR at the transceiver appear better than it actually is at the antenna. The measured values are low enough that there is little danger of activating the power-foldback circuit in the transceiver. In comparison with VHF or microwave antennas, the return-loss figures corresponding to these SWR values are relatively poor, but the bandwidth of the antenna is far greater, amounting to four octaves.

3.18 It is sometimes attractive to use an existing microwave or cell-site tower as a vertical radiator. In these cases the base of the tower is solidly grounded. Such towers can be shunt-fed, with a wire attached at about 20% of the total height of the tower, sloping at an angle of about 45° and connecting to an antenna tuner.

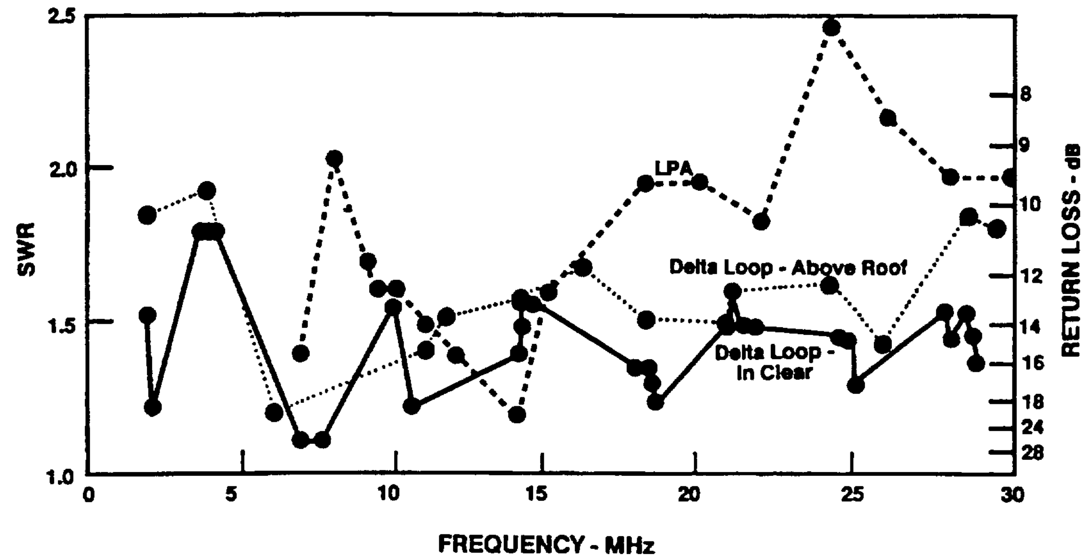

Fig. 4 - Measured Standing-Wave Ratios of Three Antennas

Transmission Lines

3.19 To assist the selection of antenna feedlines for specific installations, the following transmission data on 50-ohm coaxial feedlines will be helpful. Loss is given in dB per 100 feet at 18 MHz; power rating is in kW at 18 MHz. At lower frequencies, loss decreases and power rating increases as the square root of the ratio of the frequency to 18 MHz.

Line Type	Loss	Power
RG-58A/U	1.61	0.14
RG-8A/U or RG-213/U	0.88	0.50
RG-17A/U or RG-218/U	0.31	1.6
1/2" typical corrugated foam	0.28	4.5
7/8" typical corrugated foam	0.15	13.1

3.20 The power ratings above are based on long-term average power, assuming a high SWR (3:1) and considering both heating effects and voltage limits. The ratings are thus highly conservative for an SSB or data operation like the NSEP network.

3.21 These figures will aid in choosing a cable small enough to be economical and easy to install, while large enough to carry the transmitter power with acceptable transmission loss. A loss of one or two dB at 18 MHz is commonly accepted. In particular, RG-213/U is satisfactory for runs up to about 250 feet; for longer distances, a somewhat heavier cable is desirable to limit the loss of power to the same one or two dB from transmitter to antenna. In the receive direction, loss is not critical because the signal-to-noise ratio of the signal is limited by atmospheric noise at the antenna, not by noise generated in the receiver. For installation in plenum chambers in office buildings, fire-rated versions of RG-58A/U (and some of the heavier cables) are available and may be used in combination with heavier cables outside the plenum area if desired.

4. INSTALLATION CONSIDERATIONS

EMP/Lightning Protection Basics

4.01 While cost reasons rule out full EMP protection for this network, it is necessary and practical to protect against lightning. The National Communications System office of the Federal Government has published a technical report that recommends protection measures for EMP: NCS TIB 91-12, "Basic Protection Against High-Altitude Electromagnetic Pulse for Telecommunications Central Offices and Similar-Type Facilities (An Above-Baseline Standard)." Appendix A to this BR gives the detailed engineering principles of protecting against equipment failure caused by lightning and EMP. The installation checklist in Appendix B calls for verifying that suitable ground connections and lightning protectors are present on antenna, power, and miscellaneous wiring in the station.

4.02 If lightning strikes an antenna tower, a current of typically 10,000 to 20,000 amperes flows in the tower and the shields of all antenna cables attached to the tower. Hence the need to drain off this current lest it damage the radio or induce large voltages on wiring inside the radio building.

4.03 The normal approach to lightning protection includes bonding the shield of every antenna cable to building ground where it enters the structure. Otherwise the unbonded shield of any antenna line - for a cellular telephone, Telephone Maintenance radio transceiver, television receiver, weather radio, etc. - can induce equipment-damaging electromagnetic surges into the equipment room. Lightning protection of radio sites is covered in IL 87/07-059 and in practices (760-220-110, 760-220-120, 760-925-125, and BR 876-210-100). The basics are as follows:

- Coordinate the protection: bond all cable shields to building ground where they enter the building. This applies to *all* antenna or control leads, not just those for the HF installation.

- At the same entrance point, locate overvoltage protectors for the antenna lines. Protectors are also placed here for leads to any other equipment that is present: control lines to a remote antenna tuner, a rotator control cable, and the power feed to the rotator. Antenna-tuner control leads run into the radio itself and are thus a particularly severe exposure as regards damage; they should be protected at the entrance point also.

- Protect the AC power service to the radio equipment with a surge arrester, preferably of the type that clamps surges occurring between wires and ground as well as between wires. It should be located at the service entrance; otherwise, in the radio room.

- Provide surge protectors on telephone lines if they are used: the "telephone patch" line and/or remote-control line.
- Bond all radio equipment together and to the station ground: data terminals, the radio(s) themselves, remote-control units, rotator controllers, etc.
- Avoid use of iron or steel fittings that encircle ground conductors - these add inductance that makes the ground lead effectively an open circuit at EMP frequencies. If a ground lead must be run in metallic conduit, bond the lead to the conduit at both ends.
- If any antenna is added later, its cable shield must be bonded to the others to avoid bypassing the existing protection.

4.04 These measures are known to be effective; solid-state radios routinely survive direct hits to the tower where such steps have been taken. Without them, failure can occur, and may be discovered only when the radio is needed in an emergency.

4.05 If it is not known how well an existing site is designed in this area, an inspection is strongly recommended. The checklist in Appendix B is intended for use in verifying quality of both existing and new sites.

Colocation with Switching Systems and Computers

4.06 Many HF installations are in buildings containing switching systems and computers. The question naturally arises as to whether the HF installation will produce enough RF field strength within the switchroom to exceed the tolerance of the switch, given that buildings usually lack special RF shielding. Likewise, there is potential for interference to HF signals from the switching system or computers.

4.07 A typical digital switch is rated at 5 V/m, or about 8 dB more tolerant than an earlier analog electronic switch. However, some switches are more exposed, with the sensitivity depending on frequency. In general, network equipment should meet the criteria of §3 of TR-NWT-001089, "Electromagnetic Compatibility Criteria for Network Telecommunications Equipment."

4.08 To predict the RF field strength induced into the switchroom, it would be necessary to calculate the RF field intensity at the roof and the shielding effectiveness of the building. Accurate estimation of near-field signal strength in a typical antenna-above-building situation is essentially infeasible. It involves sizable uncertainties based on near-field/far-field considerations, plus the effects of miscellaneous reflections from objects in the field of the antenna. (In the 2-to-8-MHz range, the near field extends well beyond the antenna-to-roof distance, preventing simple calculation.) Reliable prediction of the shielding provided by the roof and walls is similarly impractical. It involves unknowns as to the presence or absence of electrical bonds in reinforcing steel, etc. There is some available information in practices 010-150-003 and 760-220-100, but it is not particularly relevant for our purposes. Thus straight by-the-practices engineering is not an available choice.

4.09 To illustrate the variability of the RF levels induced into buildings: measurements have been made of RF fields induced into two buildings by simple HF antennas above their roofs. One was the CO structure mentioned above; the other, a three-story office building containing an emergency center. Considering the 2-18 MHz spectrum used for the HF network, and correcting to a power of 120 watts PEP, the highest field strength in the office building (of 72 measurements) was 54 mV/m, a negligible value. The CO structure showed higher fields: in one area not shadowed by equipment bays or cable racks, the field at one frequency approached 3.0 volts per meter. More normal locations in the CO had levels from somewhat less to negligible.

4.10 No case is known of an actual case of trouble caused by an HF station. As an example, one company had an HF installation for about 15 years in a one-story building containing an operator-services base unit. With a transmitter of two-kW PEP, both horizontal and vertical antennas, and no special construction, there was no known problem with the operator-services processor or with the baseband of an analog microwave terminal about 20 feet from the HF antenna. Nor did the processor interfere with the radio. The site was later upgraded to a digital switch and a second high-power HF installation of comparable power (with more antennas) added, again without interference.

4.11 Normal lightning-EMP bonding helps prevent intrabuilding radiation from the feedline. If trouble should appear, a simple shield of parallel wires or expanded metal on the roof would probably stop it. The same measures should keep the switch from radiating interfering signals into the radio. The use of a medium-power transceiver (120 watts PEP) provides added margin against trouble.

4.12 Where personal computers, minicomputers, or local area networks (LANs) are in the same building, there is some chance of radiation of their clock frequencies, harmonics of the clock, and other "hash" into the radio. In one case, a cluster of minicomputers on the top floor of the building was found to make a particular frequency in the 5-MHz area unusable, while the other channels were unaffected. In another case, an HF station operates with no sign of interference, with a LAN controller and its cabling immediately adjacent. The same measures that provide good installations in other respects (bonding and grounding) help the computer-radiation problem.

Colocation of HF Radios

4.13 There is a growing need to place two transceivers in a given operating site, either to allow simultaneous communication with locations within the Region and Bellcore's sites, or to handle traffic with Federal Government and Bellcore stations at the same time. Since there is concern for the safety of the transceivers, in terms of potentially harmful amounts of RF power being induced from one radio into another, measurements have been made of the degree of coupling between HF antennas mounted close to each other. The results were that coupling can be relatively minor, below the point of serious concern, with modest physical separation on the same tower or placing antennas at right angles to each other. Where significant coupling does occur, tuned traps in feedlines can be used, but at the cost of reduced flexibility in choice of operating channel.

4.14 Practice 940-200-104 provides some aid in estimating the coupling loss between two simple antennas close to each other.

5. FCC CONSIDERATIONS

5.01 The HF network is intended for commercial purposes, to be operated generally by nonlicensed personnel as part of their employment, on commercial frequencies. Thus it is governed by Part 90 of the FCC rules. Equipment must be type-accepted under relatively stringent commercial standards. Installation and maintenance tests must be logged.

5.02 Operating channels for the network are located in 28 frequency bands. The lowest potential band is 2107-2170 kHz; the highest is 23,350-24,890 kHz. Below 8100 kHz, each station is licensed for a band, and is then authorized to operate on particular spot channels listed in an FCC Public Notice. Above 8100 kHz, the station is licensed only for particular frequencies. Table A lists the bands and publicly announced spot frequencies that apply.

5.03 It is recommended that every station be licensed for the full set of bands/frequencies available at its particular location. Since, in a drill or an emergency, any station should be able to communicate with any other, full licensing is basic. Because of the processing time for the FCC to issue licenses, applications should be filed as early as possible in the construction cycle. (However, a construction permit is not required.) Portable ("itinerant") stations must be licensed like any other; if they are being added to the network, the process is by a straightforward amendment to the existing license.

5.04 For HF stations needing to have frequencies added to their existing authorizations, Table B gives an illustrative exhibit to be included with the application for additional frequency bands.

5.05 In obtaining licenses, it may not be desirable to add HF operation to a VHF Telephone Maintenance authorization: use of the same callsign has resulted in erroneous FCC citations based on database errors. A distinct callsign is more desirable.

TABLE A
FREQUENCY BANDS FOR HF RADIO

The following frequency bands are listed in FCC Public Notice 4126, Aug. 12, 1988, as available for HF emergency use under §90.266 of the FCC rules. For specific assignments in the channel plan for the NSEP HF network, see the "Channel Selection" tab in SR-CSP-000807. This table lists the actual carrier frequencies to be used, whereas frequencies "assigned" by the FCC are center-of-channel, or 1.4 kHz higher. All transmission uses the upper sideband (USB) with FCC emission designator 2K80J3E [Rules, §90.266(f)].

kHz	kHz	kHz	kHz
2107-2170	3155-3400	5005-5450	7300-8100
2194-2495	4438-4650	5730-5950	
2505-2850	4750-4995	6765-7000	

Spot frequencies listed below may be used, without coordination with the Federal Government. The frequencies between 2289.0 and 4647.0 kHz may be used by fixed, base, or mobile stations. Frequencies between 5046.6 and 7697.1 kHz may be used by fixed or itinerant-fixed (portable) stations.

kHz	kHz	kHz	kHz
2289.0	4634.5	5102.1 Note A	7480.1
2292.0	4637.5	5313.6 Note A	7483.1
2395.0	4647.0	6800.1 Note A, Night	7486.1 Note A
2398.0	5046.6 Note A	6803.1 Note A	7549.1 Day Only
3170.0	5052.6 Note A	6806.1 Note B	7552.1
4538.6 Night Only	5055.6 Note A	6855.1 Note C	7555.1 Note B
4548.6 Night Only	5061.6 Note B	6858.1 Night Only	7558.1 Note B
4575.0	5067.6	6861.1 Note B	7559.1 Note B
4610.5	5074.6 Note A	6885.1 Night Only	7562.1 Note B
4613.5	5099.1 Note A	6888.1 Night Only	7697.1

Note A: East of 108° West Longitude (roughly east of Durango, CO).
Note B: West of 90° West Longitude (roughly west of St. Louis, MO).
Note C: West of the Mississippi River; night only.
Night: From two hours before local sunset to two hours after local sunrise.
Day: From two hours after local sunrise to two hours before local sunset.

The following bands are also available for use under §90.266, but require coordination with Federal Government users via the FCC. Spot frequencies in these bands that have been cleared are listed in SR-CSP-000807.

kHz	kHz	kHz	kHz
9040-9500	13,410-13,600	18,030-18,068	21,850-21,924
9900-9995	13,800-14,000	18,168-18,780	22,855-23,200
10,150-11,175	14,350-14,990	18,900-19,680	23,350-24,890
11,400-11,650	15,600-16,360	19,800-19,990	
12,050-12,230	17,410-17,550	20,010-21,000	

TABLE B
ILLUSTRATIVE EXHIBIT

(*Name of telephone company*), licensee of station (*give call sign*), requests additional assignment of radio frequencies for provision of telephone service during national emergencies. This application requests frequencies listed in the Commission's Public Notice of August 3, 1988 ("2-25 MHz HF Frequency Bands Available for Part 90 Long Distance Communications") as follows:

Band (kHz)	Assigned Frequency (kHz)*
9040-9500	*[The actual assigned frequencies to be requested are available from SR-CSP-000807 or Bellcore NSEP contacts.]*
11400-11650	
15600-16360	
18030-18068	

* Carrier frequency, 1.4 kHz below each of these.

We are requesting the above frequencies in order to increase the reliability of communication with Bell Communications Research, Inc. (Bellcore) station WNFT417. Their license was modified in December, 1988, to include the frequencies listed, File # 8711105345. Bellcore is the centralized point of contact for the National Security Emergency Preparedness (NSEP) HF communications network. It is important that in case of an emergency, stations on this system be able to intercommunicate at any time of day, hence the added frequencies. Attached is a list of stations presently on the network.

This system will be deployed and used only in compliance with the Federal Communications Commission Rules and Regulations, Part 90.266, as an emergency order-wire system to coordinate the provision of backup facilities for wire line and point-to-point microwave communications in the event of a national emergency or national disaster.

6. ACRONYMS AND ABBREVIATIONS

6.01 The following acronyms and abbreviations are used in regard to the HF network:

ALE	Automatic Link Establishment
ARQ	Automatic Repeat ReQuest
BCC	Bellcore Client Company
BEAMS	BCC/Bellcore Emergency Alerting and Management System
CCIR	International Radio Consultative Committee
EMP	Electromagnetic Pulse
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
HF	High Frequency
IONCAP	IONospheric CAPabilities (software)
LINCOMPEX	LINked COMPressor and EXpander
LPA	Logarithmically Periodic Array
MUF	Maximum Usable Frequency
NSEP	National Security Emergency Preparedness
PEP	Peak Envelope Power
RF	Radio Frequency
SPN	Surge-Protector Network
SR	Special Report
SSB	Single SideBand
SWR	Standing-Wave Ratio
VHF	Very High Frequency

7. REFERENCES

HF Network

SR-CSP-000807	NSEP HF Radio Operations Guide (3-92 or later issue)
IL 85/04-045*	HF Radio Description and Justification
IL 85/10-038*	BOC-Bellcore HF Radio Network - Technical Information
IL 86/07-036*	BOC-Bellcore HF Radio Network - Technical Update
IL 87/06-022*	BOC-Bellcore HF Radio Network - Technical Update
IL 89/03-050*	BCC/Bellcore HF Radio Network - Technical Update
IL 90/11-031*	BCC/Bellcore HF Radio Network - Technical Update

* This practice effectively supersedes the listed ILs.

HF Systems - General

"High-Frequency Radio," in R. L. Freeman, ed., Telecommunications Transmission Handbook, 2nd ed., Wiley, 1981.

"High-Frequency Communication Circuits," in D. H. Hamsher, ed., Communication System Engineering Handbook, McGraw-Hill, 1967.

Radio-Wave Propagation

"Electromagnetic-Wave Propagation," in E. C. Jordan, ed., Reference Data for Radio Engineers: Radio, Electronics, Computer, and Communications, 7th ed., H. W. Sams, Inc., 1986.

K. Davies, Ionospheric Radio Propagation, National Bureau of Standards Monograph No. 80, U. S. Government Printing Office, 1965.

FCC Rules

Part 90, in Code of Federal Regulations, Title 47, Part 80 to End (U. S. Government Printing Office, updated annually in February. Orderable with credit card from (202) 783-3238.)

Antennas

The ARRL Antenna Book (American Radio Relay League, Inc., Newington, CT; reissued periodically)

Protection

(Also see protection references listed in Appendix A.)

010-150-003	Power Density and Safe Working Distance in Front of Radar Antennas
940-200-104	Radio Engineering - Mobile - Closely Coupled Antennas

LINCOMPEX

403-311-100	High Seas and Overseas Radio - Maritime LINCOMPEX 100/101 Terminal - Description

M. G. Schachtman, "An Improved High-Frequency Radio Telephone System Featuring Constant Net Loss Operation," *Bell System Technical Journal*, Vol. 46, No. 4 (April 1967), pp. 677-720

ALE

FED-STD-1045	Federal Standard 1045, Telecommunications: HF Radio Automatic Link Establishment, General Services Administration, Washington, DC, 1990

APPENDIX A - EMP PRINCIPLES

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1.0 INTRODUCTION

1.01 Because of the HF Radio Network's role as a backup circuit-order and emergency communication path, major operating sites should be reasonably well protected against nuclear electromagnetic pulse (EMP) effects and lightning. The effectiveness of the system is better assured if the participating companies install and maintain a reliably survivable system.

1.02 Prior to divestiture, the telecommunications industry was called upon to provide EMP-hardened long-haul transmission facilities for the military. The specifications were stringent, considerable effort was expended, and practice 760-220-110 was developed relative to this work. The EMP protection recommended for the HF network is not as severe as that needed for long-haul facilities. Selective hardening concepts are recommended. Variations occur from site to site, and some sites, such as concrete-block buildings, may require some extra effort to implement fixes. But, since some sites may be quite isolated in the event of a disaster, the presence of a reliable radio link may well be worth the associated effort and expense.

1.03 The EMP environment is described in the handbook EMP Engineering and Design Principles. A high-altitude nuclear detonation produces a pulse of electromagnetic energy, with field strength above 20 kV/m, predominantly horizontally polarized. For a field of 50 kV/m, the corresponding vertical component would be approximately 15 kV/m peak. Illumination from a single detonation can cover the surface of virtually the entire contiguous United States. The pulse duration is submicrosecond, with significant energy content below 20 MHz, which includes the HF radio band.

1.04 The parameters of the waveform, and the nature of the threat, are subjects of recent investigations. The protection measures of this BR are based partly on the foregoing description, so they may need to be reexamined in the future if the National Telecommunications System (government agency) defines a substantially different EMP environment.

1.05 To achieve reliable EMP hardness, three elements of a radio station are to be addressed:

- The antenna and its cables must be well grounded and appropriately bonded;
- The transceiver must be shielded and surge-resistant;
- Interfaces between the transceiver and its power source, public switched network, and other intra-center electronics must be shielded and surge-protected.

1.06 Data from the EMP handbook indicate that sites with good electrical protection fare well in an EMP environment. Practices 876-210-100 and 802-001-197 define the electrical protection of a radio station and its antenna. Since the installation of a radio at a site where there previously was none increases the site's lightning exposure, the radio apparatus must be well bonded, including antenna supports, ground radials, and shielded antenna cables. If a vertical antenna is used, the installation of a spark gap between the vertical element and the grounded coaxial outer conductor will reduce the propagation of a surge on the antenna feedline. This protection is needed whenever an active antenna element is not DC-grounded and connects to the signal line. In addition, rotator cables for directional arrays and control lines for automatic tuners on verticals are to be surge-protected, with arrester grounding accomplished outside the site building. This basic electrical protection is necessary for EMP compatibility.

1.07 A brief overview of EMP design considerations follows. A number of details must be addressed for each radio installation, in order to account for variability in building construction and type of transceiver/antenna selected. The EMP fixes suggested are to be made compatible with lightning protection, which, because of differences in frequency spectra of the surges, may require design tradeoffs. However, a number of techniques are available to make EMP hardness compatible with varying radio installations and building-construction techniques.

1.08 In order to describe EMP hardening concepts, a generalized radio installation is depicted in Figure A. The major elements of the system, their EMP exposures, and recommended treatment are discussed below.

2.0 ANTENNA AND CABLE

2.01 The antenna in Figure A is typically a log-periodic array, supported by a mast over a ground plane in the earth. The need for the ground plane is determined by the antenna design. A rotator is located at the top or bottom of the mast. The feedline is a heavy coaxial cable like RG-213/U. Rotator power and control lines are not shown, but are also to be shielded. Both the mast and the cable shields are bonded to the earthed ground plane. Practice 876-210-100 forms a guideline in this regard. The shielded coaxial and rotator cables enter the building with their shields well bonded to a good, effective ground in order to prevent surge currents on the shields from entering the building. Feedlines for other antennas (Telephone Maintenance radio, cellular, television, etc.) should be coordinated for protection: they should enter the building at the same bonding point and with similar protectors. Otherwise surges entering on their cables will bypass the protection built into the HF radio installation.

2.02 Alternately, instead of the array, a dipole or similar wire antenna may be run between poles, with the signal coax dropped from the center feed to earth and then run to the building. Or a monopole may be erected over a metallic ground plane, with coaxial feed at the base. The same bonding considerations apply.

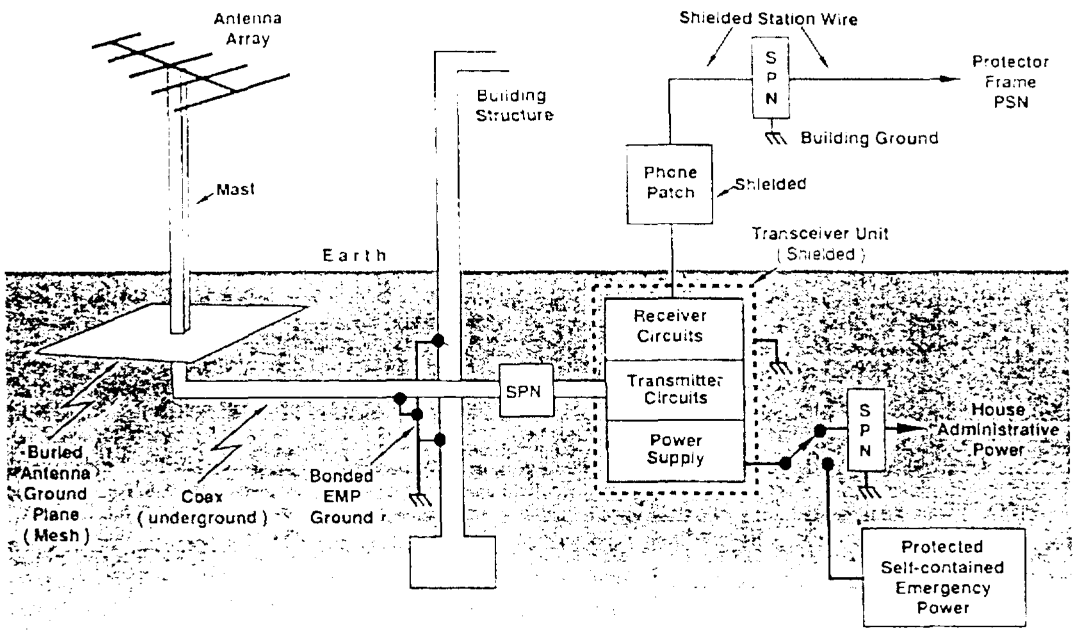

Fig. A - EMP-Protected Site

2.03 The EMP response of the antenna-cable subsystem in Figure A has three surge-coupling modes: the antenna response, the mast response, and the cable coupling from the mast and field reception below the earth. The pulsed-field response of a log-periodic or Yagi array is complex. In order to bound its response, a simple horizontal dipole 20 meters long is considered. The response of the dipole to a 50 kV/m horizontal field results in a surge of 1300 amperes peak across its terminals when they are shorted. The surge peaks at 33 nanoseconds, has a waveform like a damped sinusoidal oscillation with ringing frequency at antenna resonance, and damps out within five to ten cycles. or approximately one microsecond. The peak surge is moderately independent of resistive loads between 10 and 100 ohms, but reactive loads, i. e., tuning circuits, may shift the frequency response, time to peak, and amplitude. However, since the natural dipole resonance is 7.5

MHz in this example, the short-circuit dipole surge is indicative of surges throughout the HF band when tuning elements are attached.

2.04 Compared to a simple dipole, an antenna array's high directivity may be helpful or harmful: it reduces coupling from high-angle radiation sources significantly (advantageous); while it raises coupling from line-of-sight (center of the beam) EMP sources (disadvantageous). At center-beam reception, the mid-band gain for a Yagi, typically 6 dB, might result in a factor-of-two higher surge current (2600 A peak); a highly directional log-periodic, at 11 dB gain, might result in 4600 A peak surge. These estimates for array coupling are worst-case, because maximum gain at tuning frequency is used. The gain falls off on either side of center frequency, and so a flat dB gain estimate is conservative.

2.05 If a monopole antenna is used, the surge current at the base is induced by the 15 kV/m vertical EMP component, resulting in a current of 300 A to 1000 A, depending on the antenna support structure.

2.06 Referring again to Figure A, the mast itself will behave somewhat like a capacitively top-loaded monopole. Because it is thick, it will have a larger receiving aperture than a wire monopole, so that a 10-meter-high mast in a 15 kV/m vertical field can be expected to couple 1000 to 2000 amperes at its base, at a somewhat lower frequency than 7.5 MHz. The mast current will also couple to the coaxial-cable shield and to the rotator power-lead shields. By running these cables within the mast, from 10 to 20 dB of shielding might be obtained, so that cable-shield surge current resulting from mast coupling will be no more than 600 A.

2.07 If a simple dipole is used rather than an array, a common approach is to hang the coax from the center dipole terminals. A smaller cross section for the cable, as compared to the mast, results in 300 A on the shield, not counting the effect of the dipole as a capacitive load. Conceivably, another 300 A could be coupled when the dipole is considered part of the cable shield acting as an antenna coupler.

2.08 If the antenna design calls for an earthed metal ground plane as in Figure A, the antenna mast, coaxial-cable shield, and rotator power cable shield must be well bonded to this ground plane. A roof-mounted antenna will require a metallic mesh or solid sheet to form the ground plane. In this case, the ground plane must be connected to earth via vertical steel girders, via metal water pipes, or via the installation of thick cylindrical non-corroding conductors. It is best to run the ground conductors down to the building ground ring, and to place the antenna near the roof periphery, located apart from existing electronics in the office.

2.09 A building with rebar and Q-deck construction may offer additional ground paths only if the metal substructure is interconnected and bonded to the building ground ring. Rebars (reinforcing bars) are steel members imbedded in poured concrete. Q-decks are wide-area ribbed metal sheets laid to form the base for a floor or roof. These are structural elements and may not be reliably grounded in existing buildings.

2.10 Again referring to Figure A, the coaxial and rotator power cable proceed from an earthed mesh to the building. If the coaxial cable is strung above ground for, say, 10 meters, it may couple 3500-A or higher surges to its shield; at ground surface, the surge is estimated to be 900 A; 1 meter below ground level in poorly conducting earth, the surge is estimated to be 500 A. Some advantage is therefore obtained by placing the cable underground.

2.11 When the shield surge induced by the vertical portion of the cable (600 A) is added to the horizontal coupling (500 A, buried), a total shield surge in the range of 1000 A is induced at the building entrance, assuming an in-phase (worst-case) addition. This current must be shunted to ground at the side of the building, first, in order to prevent an increase in EMP exposure to existing office equipment, and, second, in order to protect the transceiver. When a choice is possible, it is recommended that the antenna cables' entrance be located near existing earth grounds (the building ground ring or metal water pipes). Since outside-plant cable shields are well bonded to earth, bonding of shields on the radio-antenna cables will be facilitated if they enter the building on the same side. It is advised that the antenna cable shields each be fitted with a circumferential conductive shield-bond ring tied to a wide-area metal plate. The cable passes through the center of the plate and the bond ring is tied tightly to shield and to plate, forming continuity between plate and shield. In order to achieve a low-impedance ground for the shield surge current, the plate should be mounted to a grounded metallic support on each side. The dimensions of the plate will vary, depending on the availability of grounded mounting locations. The plate should be no less than one square foot, but, in general, a wider plate with frequent ground-bond ties will give a current shunt.

2.12 As previously mentioned, the same cable-entrance technique is recommended for a roof-mounted antenna, with the antenna ground plane doubling as an EMP current shunt. When the antenna design does not call for a ground plane, it is desirable to install one anyway. The maximum dimension of the plane can be ascertained from the antenna vendor. The ground plane is to be a wide-area, thick-gauge, high-density mesh which can be earthed through multiple, independent paths. Antenna structural supports and cable shields are to be bonded to this plane. If possible, the cable shields should be bonded at the center of the plane, with the mast, and then pass through the plane so that they are below the ground plane as soon as possible. At minimum, a counterpoise which is bonded to earth (see practice 802-001-197) must be installed for lightning protection. A counterpoise would be only moderately effective for EMP, however. The earth bonding of a roof installation should be designed to shunt surge currents to the periphery of the building, or at least to girders not next to equipment bays. An antenna-cable penetration should be installed so that there is a separation of at least three meters from bays containing critical equipment and racks carrying critical interbay leads. Practice 876-210-100 provides a guideline for radio station protection.

3.0 TRANSCEIVER

3.01 The use of an EMP-hardened, test-proven transceiver is highly desirable, especially for critical stations in the network. The transceiver is to be shielded and surge-tolerant.

3.02 The antenna-response surges estimated above range from 1000 to 4600 A induced from center to shield on the coax. Thus, surge suppression is mandatory on the transceiver-antenna interface. Additional surges, in the order of 10 A or less, will be coupled through the coaxial shield. This assertion assumes that the coax and each interfacing connector are well shielded at RF. In other words, the entire signal pathway is to be RF-shielded from transceiver to antenna, including surge protectors and other possible connector interfaces.

3.03 As with the signal path, auxiliary leads such as rotator power lines are to be shielded and surge-protected at the transceiver interface. This includes the control cable from the transceiver to a remote antenna tuner, if used.

3.04 EMP surge protection on transmit-receive lines results in some special considerations. The transmitter output circuit is generally more surge-tolerant than the receiver's. Since it also operates at higher power, the transmitter's surge-protection network (a spark gap followed by a filter network) ideally would differ from the receiver's. However, the receiver is far more likely to be connected to the antenna when a surge occurs, and in a transceiver there is only one point to apply protection. A two-stage suppressor, namely, a spark gap on the antenna side followed by a solid-state suppressor, is typical protection for the transmit and receive circuits. Each stage shunts the surge from center conductor to shield, and each is isolated from the other by an impedance.

3.05 Surge-protection networks for transceivers are available with low insertion losses in the HF band. They can be made to withstand the range of input EMP signal-line surges developed at the antenna. These networks act to slow the rise of the EMP wave so that the spark gap will fire at a tolerably low voltage. The back-up solid-state suppressor for the receiver is generally needed to further reduce both the overshoot gap-firing voltage and its steady-state conduction voltage to a tolerable level. These EMP-suppressor networks can be made to be effective in, or tolerant of, lightning, but much depends on the details of the antenna feed to the coax. Antenna arrays tend to have the active element DC-tied to coax shield, with the signal line capacitively coupled, providing moderate signal-line protection to lightning. Dipoles are not tied that way, and considerable power from a direct stroke can propagate down the cable unless a protector is installed (practice 876-210-100). Under no circumstances should an antenna be unprotected. A direct lightning-stroke surge must not be allowed to enter the building on the signal cable (or rotator cable, if present). Lightning arresters are to be installed at the antenna supports, as previously mentioned, and, for a dipole or monopole with DC-isolated whip, at the whip interface to the signal cable.

3.06 The transceiver itself must be well shielded, not only for its own electromagnetic compatibility, but to prevent coupling from EMP-field penetrations into the building.

4.0 TRANSCEIVER/LOCAL EQUIPMENT INTERFACES

4.01 The transceiver may interface with the switched network via a telephone patch. It is recommended that the telephone patch unit and all interfacing cabling be shielded. In addition, the tip and ring should be surge-protected at the closest wall point where a building ground is available. The same is true for the power-line interface. Surge protectors on the AC power service cabinet should meet criteria given in TR-NWT-001011. Arresters on tip and ring leads have criteria listed in TR-NWT-000974 and TR-TSY-000070. Their use is described in BR 876-300-100.

4.02 An EMP-protected self-contained emergency power supply is desirable.

5.0 REFERENCES

IL 87/07-059	Grounding Recommendations for Rooftop-Mounted Antenna Towers
760-220-100	EMP Shielding
760-220-110	RFI Shielding
760-220-120	Lightning and Surge Protection
802-001-197	Protective Grounding Systems - General Equipment Ground Requirements for Microwave Radio Main and Auxiliary Stations
876-210-100	Electrical Protection of Radio Stations
BR 876-300-100	Electrical Protection at the Customer Premises
Select code 500-052	EMP Engineering and Design Principles, Bell Telephone Laboratories, Inc., 1975
ANSI T1.313-1991	American National Standard for Telecommunications - Electrical Protection for Telecommunications Central Offices and Similar Type Facilities [Sales Department, ANSI, 1430 Broadway, New York, NY 10018, (212) 354-3300)]

The "Grounds" for Lightning and EMP Protection, Polyphaser Corporation, Gardnerville, NV, 1990.

NCS TIB 91-12	Basic Protection Against High-Altitude Electromagnetic Pulse for Telecommunications Central Offices and Similar-Type Facilities (An Above-Baseline Standard); Office of the Manager, National Communications System, Attn: NT, 701 S. Courthouse Rd., Arlington, VA 22204-2199; (703) 692-2124; Nov. 1991
TR-TSY-000070	Customer Station Gas Tube Protector Units, Iss. 1, Feb. 1985
TR-NWT-000974	Generic Requirements for Telecommunications Line protector Units (TLPUs), Iss. 1, Aug. 1991
TR-NWT-001011	Generic Requirements for Surge Protective Devices (SPDs) on AC Power Circuits, Iss. 1, Feb. 1992
TR-NWT-001089	Electromagnetic Compatibility Criteria for Network Telecommunications Equipment," Iss. 1, Oct. 1991

APPENDIX B - STATION CHECKLIST

LIGHTNING/EMP PROTECTION

▪ Suitable protectors are present on the antenna, power, and (if applicable) telephone lines.

▪ Antenna protector is located at the building entrance and connected by a low-inductance path to building ground.

▪ Ground leads are free from steel enclosures; ground wires, where in metal conduit, are bonded to the conduit at both ends.

▪ Bends in ground leads are smooth, e. g., 12" radius, to reduce inductance.

▪ If not remote-controlled, station equipment is stored with antenna, power, and telephone lines unplugged from it.

SPARE PARTS AND TOOLS ON-SITE

▪ Spare antenna kit (100' of RG-58/U coaxial cable with "UHF" plug on one end; wire dipole, attachment ropes, ground lead).

▪ Minimum tool kit (screwdrivers, pliers, cutters, electrical tape, static-discharge wrist strap).

▪ Coaxial "barrel" connector to bypass the lightning/EMP protector during troubleshooting.

▪ Emergency 12-volt battery cable (for 120-watt transceiver), preassembled.

▪ Spare "3AG" or "MDL" (commercial, non-telephone) fuses for transceiver and related equipment. See the "Troubleshooting" tab in the Operations Guide for a table of sizes.

TRANSCEIVER PROGRAMMING

▪ Only authorized channels are programmed. Certain HF channels are restricted geographically. Having them on-call in transceiver memory is an exposure to operation on an unauthorized channel [see FCC Rules, §90.427(b)]. Suggested *omissions* from the programming are:

- For a station east of the Mississippi River: 6855.1 kHz.

- For a station with longitude on the station license less than 90° (e. g., 74° 27' 32"): 5061.6, 6806.1, 6861.1, 7555.1, 7558.1, 7559.1, and 7562.1 kHz.

- For a station with longitude on the license more than 108° (e. g., 110° 27' 32"): 4634.5, 5046.6, 5052.6, 5055.6, 5074.6, and 7486.1 kHz.

The "Channel Selection" tab in the Operations guide lists the channel numbers corresponding to these frequencies.

■ The "scan list" is programmed, with channels 1 through 9 programmed to duplicate the calling channels. (The station should be licensed for these channels, of course).

TELEPHONE COUPLER

■ Coupler is optioned so that it can "hold" the telephone line.

■ Balance control is set, and knob is marked as to correct position. The hybrid-balance control should be adjusted with a call dialed into the local balance-test number or into a telephone number in a distant office, with the telephone at the radio position on-hook.

MICROPHONE

■ Switches on bottom of base are set and taped in place: IMPEDANCE - LO; FUNCTION - NORMAL.

ANTENNA CABLES (if more than one)

■ Cables are labeled with intended direction and frequency range.

DIRECTIONAL ANTENNA (WHERE USED)

■ Normal "parking" direction for antenna is labeled on rotator.

ANTENNA STANDING WAVE RATIO

■ Best way to check is with peak-reading SWR bridge. A directional wattmeter may also be used.

■ Expedient way is to speak the number "four" slowly ("fourrrr") and see if the output meter on the transceiver shows full power on all calling channels.

LOCAL INTERFERENCE

■ Calling channels 1 through 9 are checked for local interference from personal computers or other sources of discrete-frequency noise.

FCC MATTERS

■ License is posted at transceiver (and at control point if remotely operated).

■ License lists all active bands (2194-2495, 3155-3400, 4438-4650, 5005-5450, 6763-7000, and 7300-8195 kHz), plus special frequencies above 8 MHz (see the "Channel Selection" tab of the Operations Guide).

■ If a telephone patch is used, FCC has been notified (Rules, §90.477).

■ Maintenance log is complete, with installation tests recorded and description of telephone-patch system included if used.

- Callsign is clearly posted on or near transceiver.
- If using a lighted tower, a notice is posted as to where the log is kept for the lights and where no-lights alarms are monitored.
- Transceiver channels are programmed correctly - see above.

OPERATIONS GUIDE

- Guide is present, in a clearly labeled binder at the operating location (and, if remote control is used, at the transceiver itself).
- Site-specific items are covered.
- Callsign is marked on the condensed-instructions card.
- Dummy sheets ("Not Applicable") in the "Telephone Operation" tab and/or the "Data Operation" tab if the site does not use a telephone patch and/or data terminal.
- Local instructions are present in the "Voice Operations," "Telephone Operation," and/or "Data Operation" tabs if needed to match local equipment.
- For directional-antenna sites, site-specific version of station list with pointing directions is in the "Station Directory" tab.
- Local procedures are in the "Local Information" tab.
- Dummy sheet in the "Maintenance Log" tab ("See maintenance log in Room xxx") if the log is kept elsewhere.