CHAPTER 5

VLF, LF, AND MF COMMUNICATIONS SYSTEM SITING

Site-requirement considerations must reflect the Radio Communication Station as a self-sustaining operational shore-based installation. Therefore, all significant factors necessary to sustain the station as an operating entity must be provided.

5.1 SITE SELECTION CONSIDERATIONS

Several factors must be considered when planning for a potential location to accommodate a Radio Transmitting Station:

- o Transmitter equipment and enclosure requirements, and configuration
- o Tuning equipment (helix, variometers, and enclosure requirements)
- o Radiation system (masts, top-loading cables, etc.)
- o Ground system
- o Housing and service buildings
- o Location with respect to Communication Center Facility Control and communication link interface requirements (landlines, microwave link, or other means)
- o Location with respect to other communication systems
- o Topography of surrounding land and site access
- o Availability of public utilities
- o Potential effect on adjacent communities
- o Total site acreage required (and allowances for site expansion)
- o General site improvement
- o Geographical location
- o Ground conductivity
- o Agreements between local governments or countries in which the station may be located

o Radio communication broadcast area coverage

o Cost considerations-land acquisition, site preparation and construction, equipment and site operation and maintenance.

If electrical performance considerations permit, site should be located far enough from salt water to avoid corrosion due to salt air (1/2 mile or greater and/or higher land); site should be as far as possible from other sources of corrosive gases and not downwind from the source in direction of prevailing wind. If such a location cannot be avoided, employ high efficiency filters on cooling air supply or outside air supply to air conditioning system.

5.2 VLF SITE CRITERIA

Each VLF Radio Transmitting Station site is selected to provide transmission coverage of fleet broadcast data within a specific geographical area. Presently seven stations, located at various parts of the world, provide coverage. The determination of transmission coverage for a specific area is the initial consideration in selection of a site. Having identified the coverage area, possible available site locations which will be capable of providing the required coverage must be evaluated. Several possible sites should be identified and ranked in order of acceptability. This is important because equipment criteria, cost factors, and the other considerations may dictate selection of the second or third possible site.

Transmitting-equipment characteristics and parameters to meet the radio transmission criteria for area coverage must be determined: specific radiated power is needed to provide designated area coverage, and the communications and performance reliability for the selected power-radiating capability. These items are also used to identify equipment configurations.

At this point, comprehensive data for each possible site is thoroughly reviewed and analyzed with respect to terrain, land availability and acquisition costs, access to the site (roads, public utilities, and communication links), and its location with respect to surrounding communities. Considerations relative to these factors are highlighted below.

The terrain topology at the available sites will determine the antenna configurations to be considered at the selected sites. The ideal VLF transmitting site location would be a flat land area on a peninsula or an area with maximum exposure in the direction of propagation. A land area of several thousand acres is required. The availability of an ample water supply for equipment and building cooling will be an important item influencing site selection.

Location of the transmitter site with respect to the Communication Center must also be considered. A minimum of two or more reliable transmission paths between the Communication Center and the transmitting site must be provided. The final site location will dictate the intersite transmission media to be used.

The logistics problem of a self-sustaining VLF station that may be remotely located will be another very important factor that must be considered when selecting a site. Items which must be considered are: operational and administrative personnel required to operate the station; housing and support of all station personnel; availability of civilian personnel from local communities to augment station administrative and maintenance functions; shipping and storage of food, fuel, materiel, and equipment parts for the total station operation.

The effect on adjacent communities and other communication systems not part of the station communication links must also be evaluated. The minimum separation distances between the VLF transmitter and other facilities in the immediate vicinity of the station should be, insofar as practical:

1/4 mile - high tension power lines (overhead) and main highways

1 mile - base housing, offices, and support facilities

3 miles - other transmitter/antenna systems, and general communication facilities

5 miles - local civilian communities and industrial complexes

25 miles - other facilities or stations where the receive function is the primary operational mode.

In addition to the site survey to determine suitability for installation of equipment, special surveys should be conducted relative to potential radiation hazards and interference created by the VLF transmissions. Detailed information concerning such considerations is contained in the Naval Shore Electronics Criteria handbook "Electromagnetic Compatibility and Electromagnetic Radiation Hazards," NAVELEX 0101, 106.

A VLF station generally requires some receiving equipment and antenna to perform a signal quality monitoring function. This equipment provides feedback-information regarding the transmitted radio signal and may be located approximately 21 miles from the transmitting antenna at the Communication Center, or other site.

The following factors have significant impact on equipment to be specified, equipment configuration and structure, and building requirements:

- Operational power requirements
- Load bearing strength of the land
- Soil conductivity.

5.2.1 Operational Power Requirements

The electrical power requirement for normal operation of a VLF station is several megawatts. Generally, commercial power is brought into the station power building and then distributed. Thus, the proximity of the potential site to commercial power must be considered. This is important for erecting a power line spur to supply the power and obtaining "right-of-way" clearance which is expensive. The electrical power required may vary, depending on geographical location. If the station is to be in the northern regions, power demands will be higher if antenna deicing equipment is required. Allowances must also be included in the electrical power budget to accommodate future equipment improvements and/or addition of new facilities.

When commercial power is not readily available at remote locations, the station must provide its own power. This immediately introduces new items that have direct impact on costs and the total land required, additional or larger power building required to house the generating equipment, and overall logistics considerations. As a point of interest, the VLF transmitting station at Cutler Maine, supplies its own electric power to operate the entire station complex. The generating plant is capable of supplying 12 megawatts of power and needs no power from commercial sources. Electrical deicing circuits capable of melting three inches of radial ice from the entire antenna array, tower lighting, and all base utility needs are also supplied by this power station.

5.2.2 Load Bearing Strength of the Land

This second factor, load bearing strength of the land, is the most significant item of the three and should be one of the first items for which accurate and complete data is obtained. Analysis of this data could immediately eliminate a possible site from consideration. The ability of the land to support the weight of the buildings, equipment, and the antenna masts, cables, and top-hat array is of major importance. By obtaining these data early, potential sites initially considered may be eliminated and therefore lessen the work to be done.

5.2.3 Soil Conductivity

The remaining factor, soil conductivity, directly affects the final configuration of the antenna ground system. A ground system serves to provide a good conducting path for ground currents and acts as a good reflector for waves originating at various points on the antenna, so that the vertical radiation pattern closely resembles an antenna located over a perfectly conducting earth. If the ground system is extensive and complete (at least two wavelengths long) so that there is no power lost in the earth, the reflection of each incident wave will be perfect. This is not the case for electrically small VLF antennas and a surrounding high conductivity surface is desirable. Earth currents in the vicinity of an antenna are created in the following manner. Displacement currents leave the antenna, flow through space, and finally flow into the earth, becoming conduction currents. As the current flows back to the antenna, it is concentrated near the surface of the earth due to the skin effect. If there are ground radials present, the earth current will be made up of that part which flows in the wires and that which flows through the earth. In general, it is important to maintain as many wire radials in the ground system as possible in order to have an efficient radiating system. Knowledge of the electrical properties, conductivity and dielectric constant, of the ground in the area is needed to determine the size and configuration of the ground systems required. A counterpoise ground system will also reduce ground losses. Fault location and ease of ground maintenance may be greatly enhanced by a counterpoise, but ice loading and/or lush vegetation underneath may increase counterpoise maintenance problems.

The conductivity and dielectric constant of the earth vary greatly according to conditions that exist for each locale. Some typical values are given in table 5-1. In general, high values of dielectric constant tend to go with large conductivities (highest conductivities obtained with wet loam), while poor conductivity and low dielectric constant are associated with dry, rocky, and sandy soil. Values of conductivity on the order of 5×10^{-14} to 10×10^{-14} electromagnetic units (emu) is considered as average to better-than-average. Sea water has a conductivity many times that of earth and possesses a very high dielectric constant.

The average conductivity of seawater is usually taken to be 4 MHOS per meter although a variation from less than 1.5 MHOS per meter (in the Arctic where there may be considerable dilution from ice and snow melt water, or in an estuarine environment) to greater than 5.5 MHOS per meter (in regions of high salinity, such as in the tropics where evaporation rate is high) is possible.

Table 5-1. Typical Values of Ground Constants

TYPE OF TERRAIN	DIELECTRIC CONSTANT	CONDUCTIVITY (emu)
Fresh water	80	1×10^{-14}
Sea water, minimum attenuation	81	4.64×10^{-11}
Flat country, marshy, densely wooded typical of Louisiana near Mississippi River	12	7.5×10^{-14}
Rocky soil, steep hills, typical of New England	14	2×10^{-14}
Sandy, dry, flat, typical of coastal country	10	2×10^{-14}

Prior to conducting ground conductivity tests at a site, the general area should be assessed to determine the order of magnitude of emu values to be expected. Since ground conductivity varies considerably from point to point within an area, at least 10 locations should be selected for study. If the soil types indicate obvious differences in the proposed site area, additional locations should be considered. Moisture content of the soil greatly affects conductivity measurements resulting in different values for the wet and dry season. Therefore, data should be taken several times during the year to obtain true characteristics for the site. The value of conductivity and dielectric constant that is effective for radio waves represents the average value for a distance below the surface of the earth. It is determined by the depth to which ground currents of appreciable amplitude exist. Depth of penetration depends on the frequency, dielectric constant, and conductivity, and is commonly 5 to 10 feet at short wave frequencies, and 50 or more feet at broadcast and lower frequencies.

There are several ways that the earth constants can be measured and once a specific method is selected, all subsequent tests must be made using the same equipments. Substituting different equipments and techniques may introduce variations in the data obtained. However, any one of the methods may be used to make comparative measurements if the procedures are carefully followed. Accurate data must be kept identifying the equipment, methods, and other pertinent information. The survey report should contain a physical description of the site, a chronological history of weather conditions and soil-moisture conditions, the nature of the soil at each measurement site, and any difficulties in obtaining measurements should be described along with the method used to solve the problem.

VLF sites are generally selected near seawater to take advantage of its high conductivity which will reduce local ground losses in the region exterior to the wired ground plane (this will generally reduce size and amount of ground plane conductor material required), reduce signal attenuation, and have a beneficial effect on the low angle cutback factor on the radiation.

The importance of obtaining accurate and complete ground conductivity data for a potential site cannot be over-emphasized. The information, aside from its direct use in antenna ground system considerations, is used for evaluating other operational aspects. Ground connections and conductivity are very important items in the power plant engineering considerations. Good connections to earth are mandatory and, depending on the earth's conductivity, the techniques to achieve this connection will be determined from this data. Common practice is the use of deep power-driven rods and chemical treatment of the soil. This information is also useful in evaluating "interference protection" where good earth connection of cabinets, cables, and equipment is important.

5.3 LF/MF SITE CRITERIA

The selection of an LF or MF transmitter site is less difficult than the selection for a VLF transmitter. Although LF and MF antenna and grounding systems are large, they are relatively small compared to VLF installations. The transmitter and the helix house required for LF or MF systems are also small in comparison to the same VLF equipment. LF transmitting systems are usually colocated with HF transmitting systems, with the LF antenna positioned a reasonable distance from the HF transmitting antennas to minimize the interference between the two antenna systems.

Since MF systems are concerned primarily with ship distress signal functions, the MF transmission site chosen is usually in close proximity to the sea, to be operated in coordination with a sea-air-rescue activity. The site may also be part of a communication facility containing LF and HF antennas. Since the emergency frequency is close to the LF band, criteria applicable to the siting of LF antennas is generally applied to MF antenna installations.

The area required for the antenna and ground system is dependent on size of the antenna required; the size of the antenna in turn is dependent on the frequency range of operation. With a single antenna-tower, the grounding system should be a radial configuration extending outward from the tower a distance at least equal to the height of the tower and/or the length of any top loading utilized. Thus, the minimum circular area required for the installation of a LF transmitting antenna system is πR^2, where R is equal to the antenna height. For an antenna height of 600 feet, the minimum area required is $\pi(600)^2 = 1,140,000$ square feet or approximately 26 acres with 1000 foot radials typical for LF systems of this weight. The transmitter may be located adjacent to the helix house (which is next to the tower) or in a transmitter building with other systems. In the latter case, the transmitter building is usually located outside the radial-system area.

Basic details and all required criteria on selecting and evaluating a proposed LF or MF transmitting site are included in NAVELEX 0101,103 (HF). However, structures and terrain features near the transmitter site may reflect the signal from the antenna or may reradiate sufficient signal to affect the performance of the antenna.

5.3.1 High-Tension AC Power Lines

Alternating-current power lines and their supporting towers near the antenna may produce objectionable reradiation. Negligible voltages are induced in the horizontal line by the vertically-polarized signal, but voltages induced in the towers may cause current to flow in closed loops formed by the towers and the horizontal grounding wires connecting the tops of the towers.

5.3.2 Large Objects

Large buildings near the transmitter site, mountains, or rugged terrain may distort the radiation pattern of antennas.

Such objects are usually too irregular to apply analytic methods to a determination of reradiation. Their effect may often be estimated on the basis of experience with similar objects. If the source of reradiation can be readily isolated, as for example a single large standpipe, field strength measurements made as part of the site survey along a direct line between the test transmitter and the reradiating object will, when plotted versus distance from the reradiating object, exhibit a standing-wave pattern from which the magnitude of reradiation can be deduced with reasonable accuracy.

Another technique in estimating reradiation is to make the site test using a simple two-element test antenna to produce a radiation pattern having deep minima. Site-test field-strength measurements in the minima will indicate reradiated and "scatter" signal. This technique is useful in situations such as rugged terrain, where reradiation cannot be ascribed to an individual source.

5.3.3 Tall Towers

These structures are usually of sufficient electrical height to be capable of substantial reradiation in high incident fields.

Reradiation from a tower of this height may be controlled by insulating the tower from ground and installing sectionalizing insulators at one or more levels. Guy wires must be insulated at suitable intervals, and transmission and AC lines must be isolated as discussed.

5.4 VLF COST - TRADEOFF FACTORS

Initially there may be as many as six or more sites being considered for the VLF transmitter station. Upon completion of the site survey, the number of acceptable sites may be reduced to two or three. Regardless of the final number, an estimated cost must be developed for the various items identified earlier. Once the estimated costs have been established, the total estimated cost for each potential site must be evaluated. The sites are ranked from lowest to highest cost, and compared with the ranking of sites according to survey-acceptability. Invariably, the ranking of sites by cost and by survey acceptability are not compatible. At this point, a detailed technical-criteria versus cost-factor analysis must be made.

The initial effort, before starting a detailed analysis, should be to identify those factors which are identical for the sites being considered. This will reduce the amount of additional data to be obtained. The most efficient approach is to identify major categories or items to be reviewed for each possible site. The various possibilities are identified in their related categories in the following paragraphs. It should be noted that many items identified under one major category affect other categorical items and should not be neglected in the related category.

5.4.1 Site

The total land area required should be evaluated considering various site layouts for building and equipment structures with the intent of reducing land-acquisition costs. Site construction and improvement factors should be reviewed. Availability of commercial power and other public utilities in lieu of providing these items as an integral part of the station should also be reviewed. Results of the ground conductivity tests should be thoroughly analyzed for impact on the antenna ground system costs.

5.4.2 Transmitter Equipment

Transmitter cost with a given power rating will vary considerably with the amount of control circuit and auxiliary equipment specified and should be analyzed in detail. The degree of optimization involved with increase related costs and should be reviewed to eliminate unnecessary refinement. Equipment specifications reflecting current technological state-of-the-art should be thoroughly reviewed; for example, solid state transmitters at high powers are, generally, more expensive in initial cost than tube transmitters. Optimizing equipment layout and operational interface could result in reducing overall cable distribution between equipments.

5.4.3 Antenna Radiating Equipment

Cost for masts, cables, and insulators should be reviewed in detail, considering technological advances in the use of materials and metals, and improved manufacturing and fabrication processes. The quantity of items or materials should be positively identified for possible price reduction per required quantity. One remote possibility that may be considered is that the originally-planned antenna configuration may be changed to reflect a new site location resulting from the initial site surveys.

5.4.4 Ground Systems

As was noted above, ground-conductivity-test results have direct impact on the material required for the radial ground system. A comprehensive analysis of ground system factors and associated cost relationships is provided in "VLF Radio Engineering" by A.D. Watts.

5.4.5 Helix House Equipment

The tuning equipment contained in the helix house and material used have been described previously. Improved inductor design and improved material may reduce costs.

Toroidally wound inductors where the flux field is entirely contained in the toroid (patented) will substantially reduce the shielding and space requirements. Such coils, wound of copper or aluminum bus as two parallel but oppositely wound halves of a toroid are used in the PA tank circuits of several VLF transmitters where coil losses are not critical.

Some additional costs may be saved by limiting the helix house shielding. If the helix house contains little ferrous material, and if the house has sufficient space around the coil for the flux path, then deck shielding, and overhead shielding, and much of the wall shielding may not be necessary.