GTE LENKURT

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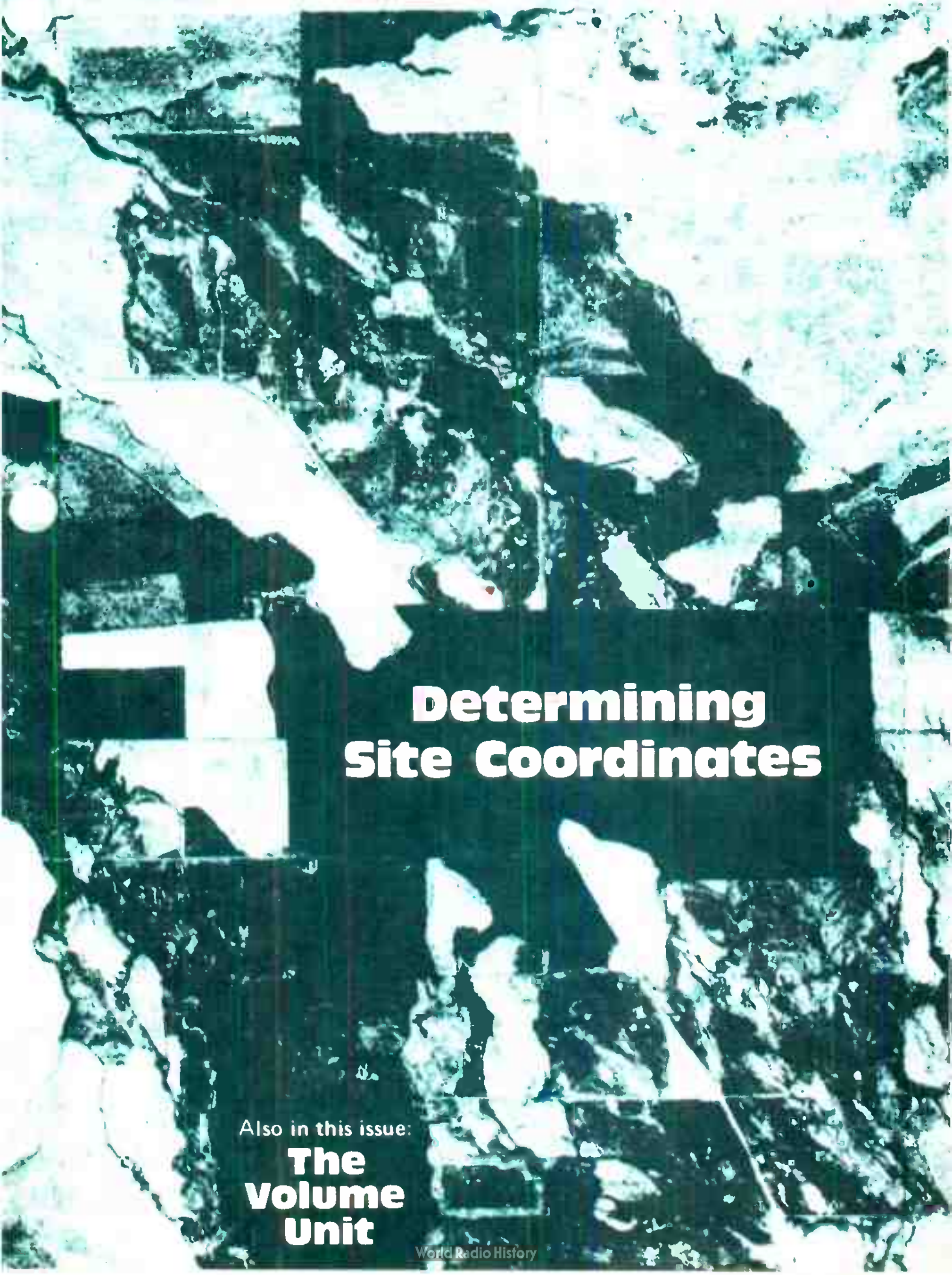

Determining Site Coordinates

Also in this issue:

The Volume Unit

The Federal Communications Commission of the United States requires that the geographical coordinates of the antenna site be furnished on applications for a radio station license and construction permit. Microwave transmission engineers regularly determine the coordinates of a site by carefully plotting the site on a topographic map and measuring its location relative to known lines of latitude and longitude. Two methods of measurement are in common use. Site coordinates can be determined by either method to the degree of accuracy expected by the Commission.

Whenever someone describes the location of something, he may mention how far and in what general direction it is from some other identifiable and familiar object, structure or landmark. Thus, a farmer might describe the location of his water well as so many paces due east of a certain gate in his fence line. With this description anyone knowing where the fence gate is and which direction is east could probably find the well without difficulty. But a stranger to the area would likely consider this kind of information insufficient.

Another method that is commonly used to relate where something is located, is to define it in terms of its territorial boundaries. Most inhabited places in the world can be quite precisely located by means of an address. An address is nothing more than an orderly listing of the various well-defined boundaries within which a place is situated. The postal services of the world rely on the public's use of such a format to designate the place of origin and the destination of the mails. As long as the address is correct and complete, delivery of the mail to the proper location is generally assured.

There is yet another and more precise means of pinpointing places on the globe that navigators, surveyors, construction engineers, cartographers, and others interested in the many features of the earth's surface are inclined to use: the geographical coordinate system of latitude and longitude. Within this system the location of any place, whether it be on land or water, can be identified with as great a degree of accuracy as the accuracy of the tools with which the measurements of distance and direction are made. The Federal Communications Commission (FCC) of the United States requires that this geographical coordinate system be used in the application for a radio station construction permit to record where the station's transmitting antenna or antenna tower is to be placed. The coordinates of the site are to be accurate to the nearest second or within one second of latitude and longitude, depending on the type of radio service. "How do I go about determining the geographical coordinates of a site to that degree of accuracy?" is a question that probably arises in the minds of most applicants filing for a radio station license for the

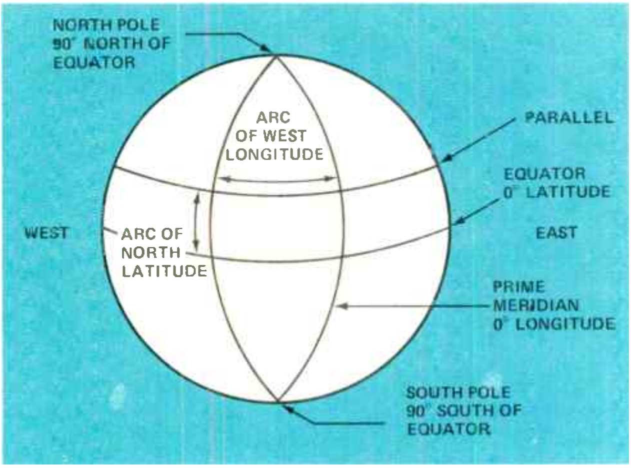

Figure 1. Lines of latitude (parallels) appear on the surface of a global map of the earth as concentric circles parallel to the equator. Lines of longitude (meridians) appear as great circles that pass through the north and south poles.

first time. One answer to the question is offered in the following paragraphs.

The Coordinate System

The present-day geographical coordinate system has its roots in a work of the second century Egyptian historian and geographer, Ptolemy. In his atlas he catalogued places and positioned them on a map of his contemporary world by means of latitude and longitude. Similarly, on maps of today's world, the horizontal position of a place is fixed by its relation to recognized standard parallels of latitude and standard meridians of longitude. Parallels and meridians are simply imaginary lines, certain ones of which are commonly traced out on flat and global maps of the world.

Figure 1 shows how these lines appear on a global map. This type of map presents a spherical view of the earth — the earth, in fact, is not a perfect sphere, but an oblate spheroid — on which parallels of latitude appear as concentric circles drawn parallel to the equator, the reference parallel, about the globe's axis of rotation. Meridians of longitude appear on the globe as circles, generally referred to as great circles, converging on and passing through the north and south poles. The most widely accepted reference or prime meridian is that half of a great circle extending from the two poles on which lies a hill, the former site of the Royal Greenwich Observatory in Greenwich, England. But in Russia the prime meridian at times has been taken to be the meridian that passes through the Kremlin. In this discussion the Greenwich meridian and the equator are taken to be respectively the reference meridian and the reference parallel. Since they serve as the reference lines in the geographical coordinate system, the Greenwich meridian is designated the zero degree (0°) line of longitude, and the equator is designated the zero degree of latitude. All other lines of longitude and latitude are reckoned in units of angular arc (degrees, minutes, seconds) from these two reference lines. All other lines of longitude lie so many units of angular arc east or west of the Greenwich meridian. Likewise, all other lines of latitude lie so many units of angular arc north or south of the equator. The meridian of 180° lies halfway around the earth from the Greenwich meridian and, except near certain land masses, serves as the international date line. The two poles, north and south points on the earth's axis of rotation, are the north and south parallels of 90°. Thus, in the geographical coordinate system, every spot on the earth's surface can be said to be somewhere from 0° to 90° north or south of the equator and from 0° to 180° east or west of the Greenwich meridian. Of course, no north or south direction is given any point located on the equator; neither is an east or west direction given a point on the Greenwich meridian. But the coordinates of all other points on the face of the globe have a north, south, east, or west direction from these two reference lines.

One aspect of the geographical coordinate system that reportedly puzzles many is the use of degrees, minutes, and seconds in designating the coordinates of a point. Part of the bewilderment appears to stem from a misunderstanding of the numerical relationship between the three units of measure. There may also be a difficulty in grasping why these units of measure are considered appropriate to this coordinate system.

Students learn in plane geometry that the degree is a unit used to measure angles. Its value is based on a division of the circumference of a circle into 360 arcs of equal length. The central angle formed by two radii subtended by one of these arcs is equal to one degree (1°). If a one degree arc is divided into 60 arcs of equal length, then the central angle subtended by one of these arcs is equal to one minute (1′). If a one minute arc is divided into 60 arcs of equal length, then the central angle subtended by one of these arcs is equal to one second (1″). Central angles subtended by arcs less than one second in length are ordinarily measured in decimal fractions of a second. Figure 2 depicts these relationships. In summary, this system of angular measurement is based on the division of the central angle of a circle into 360 degrees, a degree into 60 minutes, a minute into 60 seconds, and a second into decimal fractions. It is to be noted that these numerical dimensions of an angle are purely arbitrary, that the division of the circle into 360 equal parts probably originated with ancient astronomers who observed that the earth completed its circle of orbit around the sun in approximately 360 days. However, in some areas of the world today, the circle is divided into 400 rather than 360 degrees of arc.

Since the units of angular measurement are based on an arbitrary division of the circumference of the circle, a plane geometric figure, their use in a coordinate system devised to locate points on the surface of a sphere, the related solid geometric figure, should not appear inappropriate. Inasmuch as the earth can be viewed as a sphere—granted that it is more accurately described as an oblate spheroid or ellipsoid flattened at the poles because of the centrifigal force caused by the earth's rotation around its axis—the degree, minute and second as units of angular measurement can properly be applied to the geographical coordinate system.

Maps

The majority of individuals interested in obtaining the geographic coordinates of a site are not equipped with the instruments, knowledge, and experience required to derive site coordinates from measurements made in the field. Consequently, they will ordinarily rely entirely on the work done and the information compiled by one or more agencies of the local, state, provincial, or national governments. In most parts of the world these agencies conduct numerous types of surveys to

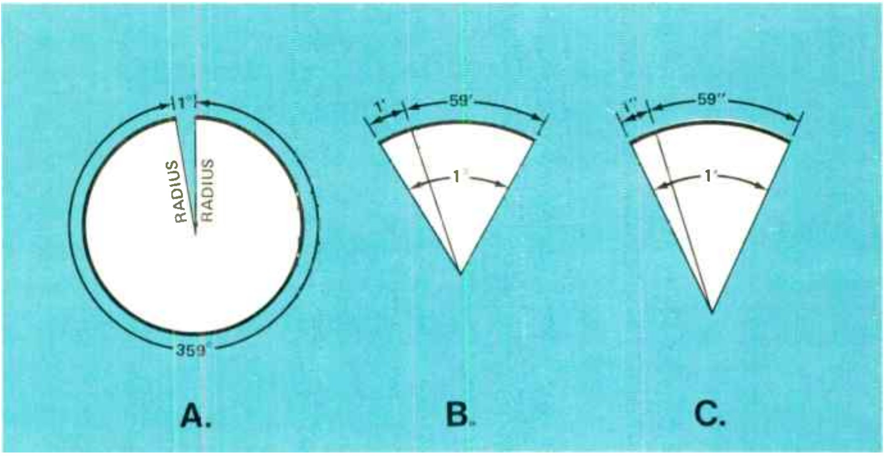

Figure 2. The degree, minute, and second are units of angular measurement whose dimensions are based on arbitrary divisions of the circumference of the circle. The circumference is commonly divided into 360 one degree arcs (A). Each one degree of arc is further divided into 60 one minute arcs (B). Each one minute of arc is then divided in 60 one second arcs (C).

gather pertinent geodetic, geological, and geographic data and to develop from such data all sorts and sizes of maps and tables. The agencies then make copies of most of these maps and tables available for purchase by the public.

The Congress of the United States has established an agency in the Department of the Interior, the United States Geological Survey, to develop and publish maps of appropriate scale and accuracy for all of the country. This agency has been engaged for many decades in the production of several series of general-purpose topographic maps from survey information collected by its own survey teams as well as by those of other local, state and Federal agencies, notably the United States Coast and Geodetic Survey. These maps are printed on rectangular sheets of paper that vary in size according to the series of the map and the part of the country presented. The two series of quadrangle maps most suited for determining site coordinates are the 7-1/2-minute and 15-minute series. The first of these series presents terrestrial areas bounded by seven-and-a-half minutes of latitude and longitude; the second, areas bounded by fifteen minutes. Maps in the 7-1/2 minute series are drawn to a scale or map-to-earth-surface ratio of 1: 24,000; maps in the 15-minute series to a scale of 1: 62,500. Topographic maps of more than three quarters of the United States are now available in one or the other of these series. The entire country will eventually be covered by maps in either of these series. Indexes of published maps are available free on request to the U.S. Geological Survey, Washington, D.C. 20242, or U.S. Geological Survey, Federal Center, Denver, Colorado 80225.

All maps in these series are based on the North American horizontal datum of 1927 and the National Geodetic vertical datum of 1929. A datum in surveying terminology is a measured reference point to which all other measurements in a survey are made. The North American horizontal datum is the Meades Ranch triangulation station located about 12 miles north of Lucas, Kansas. The U.S. Coast and Geodetic Survey in 1927 established this station as the permanent reference point for its transcontinental triangulation survey. It is now the datum for all triangulation networks of the entire North American continent. By means of astronomical and geodetic observations made with precision instruments, and from subsequent computations, the latitude and longitude of this station and its azimuth to another nearby permanent station, Waldo, were determined to one thousandth of a second accuracy. The National Geodetic vertical datum is mean sea level, which is established as the average height of the surface of the sea for all stages of the tide measured over a 19-year period.

In addition to these horizontal and vertical datums, U.S. Geological Survey topographic maps use the Clarke spheroid or ellipsoid of 1866 as the reference for the size and shape of the earth's surface at average sea level. Alexander Clarke, a Scottish geodesist, computed the length of the polar axis of this representative figure of the earth to be 41,710,242 feet and the equatorial axis to be 41,852,124 feet in length. Since then other values that are now considered more accurate have been computed.

Although these topographic maps are based on quite accurately measured horizontal, vertical, and surface references, the plotting of information, based on these references, onto maps must not be construed to be done to the same degree of accuracy. The national standards adopted for horizontal accuracy require that at least 90 percent of the well-defined map points shall be plotted correctly within one-fiftieth of an inch on the published maps. The standards for vertical accuracy require that at least 90 percent of the elevations interpolated from the contour lines shall be correct within one-half the contour interval. Contour intervals vary with the terrain being mapped.

Since the FCC requires that microwave towers and antenna sites be plotted on U.S. Geological Survey maps, if available, and accompany the request for a station construction permit and license, it has been traditionally assumed that the same maps may also be used to obtain the geographical coordinates of the site. It may be necessary to conduct a field survey in order to establish antenna sites that provide a clear transmission path. It may also be necessary to perform a cadastral survey of the sites in order to establish property line boundaries. But once a site is decided on, its coordinates can be determined with sufficient accuracy from measurements made on a topographic map.

Methods

There are two basic methods that can be used to determine site coordinates from a topographic map. The accuracy of either method is dependent primarily on three elements: the accuracy of the map, the accuracy of the measuring tool, and the accuracy of the measurement itself.

The horizontal accuracy of topographic maps published by the U.S. Geological Survey has already been stated. (Vertical accuracy is not relevant to the determination of site coordinates.) In terms of ground measurement the standard for horizontal accuracy means that at least 90 percent of the well-defined map points on 1: 24,000 scale maps are accurately plotted within a tolerance of 40 feet on the ground. Points on 1: 62,500 scale maps are plotted within a tolerance of 100 feet. One hundred feet is slightly less than one second of latitude or longitude measured near the equator and becomes greater than one second of latitude as one draws nearer the poles. Immediately, the difficulty of obtaining site coordinates from a map to within one-second accuracy becomes apparent. Maps of other parts of the world usually pose a similar, if not greater, difficulty to the precise measurement of coordinates.

The physical condition of a map can also affect the accuracy of measurements made on it. Most purchased maps are printed on paper that can stretch or shrink with frequent use and exposure to the weather. The dimensions of a map can change if it is mishandled or mistreated.

The tool used to make measurements on the map can also affect the accuracy with which site coordinates are determined. Usually, a good quality triangular engineer's ruler contains a sufficient number of graduated scales to fit the requirements of any measurement to be made. The degree of accuracy with which the measurements can be made will vary directly as the scale that is used. As the scale increases, the accuracy increases.

Finally, the amount of care exercised in plotting the site on the map, and then in measuring its location with respect to certain reference lines will probably have more of an effect on accuracy than any of the items already mentioned.

The plotting of a site onto a map can be done from descriptive data detailing its location, but generally it is more accurately performed in the field where the person doing the plotting can observe how other identifiable landmarks nearby are related in distance and direction to the site. A dot can be made with a fine-pointed pen or pencil to mark the site on the map, and a fine, half-inch vertical and horizontal line can be drawn through the dot for easy location later.

Once the site is plotted on the map, one of two methods may be used to obtain the coordinates of the site. Either method can be applied to a map drawn to any scale. In the examples to be given here, the sites are plotted on 7-1/2-minute maps.

The sites are first enclosed within a quadrange of four reference lines drawn through graticules (crosses) printed on the maps, as shown in Figures 3 and 4. In Figure 3, the four lines drawn through the four graticules to enclose Site A mark the lines of longitude at 82° 17′30″ W and 82° 20′00″ W, and the lines of latitude at 27° 02′30″ N and 27° 05′00″ N. In Figure 4 the reference lines enclosing Site B are drawn through graticules marking the lines of longitude at 82° 20′00″ W and 82° 22′30″ W, and lines of latitude at 27° 02′30″ N and 27° 05′00″ N.

The first method for determining geographical coordinates, the direct reading method, is demonstrated in Figure 3. Between the two latitude reference lines of 27° 02′30″ N and 27° 05′00″ N there are 2′30″ or a total of 150″. A scale is selected on the engineer's ruler so that when the ruler is laid diagonally between the two latitude reference lines with the scale's edge on Site A, the distance between the two lines corresponds to 150, or some multiple thereof, graduations on the scale. In Figure 3 each graduation of the scale represents one second of latitude. Accordingly, Site A lies approximately 53.6″ north of the 27° 02′30″ N latitude reference line. Therefore the latitude of Site A is 27° 03′23.6″ North.

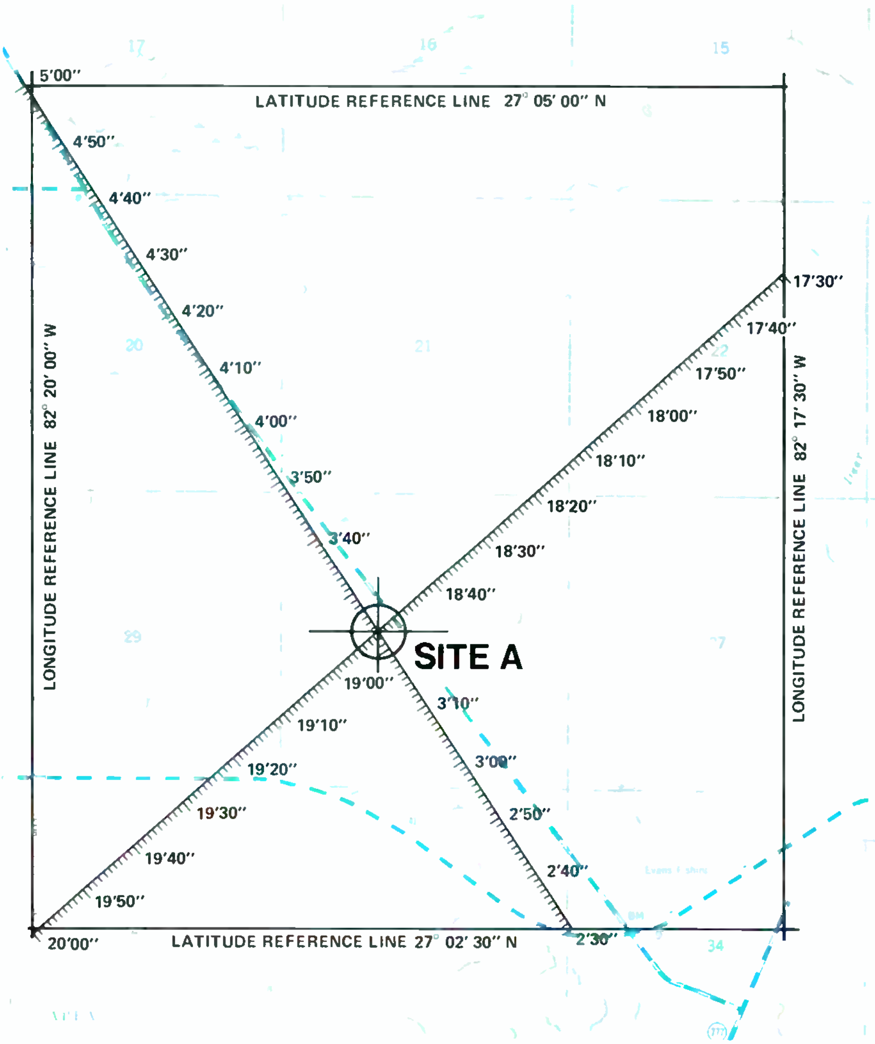

Figure 3. In the application of the direct reading method the geographical coordinates of Site A are read directly from the scale on the engineer's ruler.

The longitude of Site A is determined in a similar manner. However, it is advisable that two measurements be made to obtain the longitude of a site: one made with the ruler placed diagonally from upper left to lower right of the two longitude reference lines; the other, from the upper right to the lower left. The reason for making this twofold measurement is that the lines of longitude, though they may appear to be parallel, are not. The lines are actually converging as they approach the north and south poles. Hence, this convergence is detected more readily on maps of areas nearer the polar regions. Topographic maps from the U.S. Geological Survey, in projecting the spherical surface of the earth onto a flat surface, utilize one or another of two common map projections known as the Lambert Conformal Conic Projection and the Transverse Mercator Projection. Convergence of lines of longitude occurs on maps drawn in either of these projections, but it is more evident on maps using the Lambert Conformal Conic Projection.

Again refer to Figure 3 in which the difference between the two reference lines of longitude is equal to 150″. Only one of the two recommended measurements of longitude, from upper right to lower left, is depicted. On some maps there will be no perceptible difference in the two measurements. In which case the longitude is read directly from the scale of the ruler. The reading of the scale at Site A in Figure 3 is 81″ west of longitude reference line 82° 17′30″ W. So, the longitude of Site A is 82° 18′51″ West. If there is a perceptible difference in the two measurements, then the two different scale readings are added together and their average is taken to be the correct reading. Thus, if the one diagonal measurement of Site A is a scale reading of 79″ W and the second is a scale reading of 83″ W, then the averaged reading, 81″ W, is taken to be the correct reading.

Some manufacturers of engineering drafting tools offer for sale triangular rulers on which scale graduations are marked in seconds of latitude and longitude. They are specifically designed for use on 7-1/2-minute and 15-minute maps. However, the scales of the ruler provide direct readings that are valid only on topographic maps of areas that lie within 49° North and 49° South latitudes. The ruler contains three separate scales with which to measure longitude. The scale to be used is dependent on the latitude of the mapped area. Each scale is based on the average amount of convergence of the meridians within three different bands of latitude, 0° to 30°, 30° to 41°, and 41° to 49°. The engineer's ruler does not suffer such a limitation in its usage.

The second method of obtaining site coordinates from a map is called the ratio method. Again, the site is first located on the map and is enclosed by latitude and longitude reference lines drawn through the printed map graticules. Then two more lines are drawn which intersect at the site. One line passing through the site is drawn parallel to the reference longitude line; the other is drawn parallel to the reference latitude line. Figure 4 is an example of the application of this method.

A scale on the engineer's ruler is selected that will measure with sufficient accuracy the distance between the two latitude and two longitude reference lines. These distances are measured along the two intersecting site lines. In Figure 4 the distance between the two latitude reference lines measures 453 divisions on the selected scale; the distance between the two longitude reference lines measures 406 divisions.

Next, the distance from the site to one reference latitude line and one reference longitude line is measured along the two site lines with the same scale of the ruler. In the example, Site B is 421 scale divisions north of latitude reference line 27° 02′30″ N and 202 scale divisions west of longitude reference line 82° 20′00″ W.

Finally, the latitude and longitude of the site are determined by setting up proportions between ratios of distances measured in scale divisions and in coordinate seconds. The unknown, X″, is the number of seconds of latitude or longitude the site lies from the reference lines. Note that the coordinate distance between both sets of reference lines is 2′30″ or 150″.

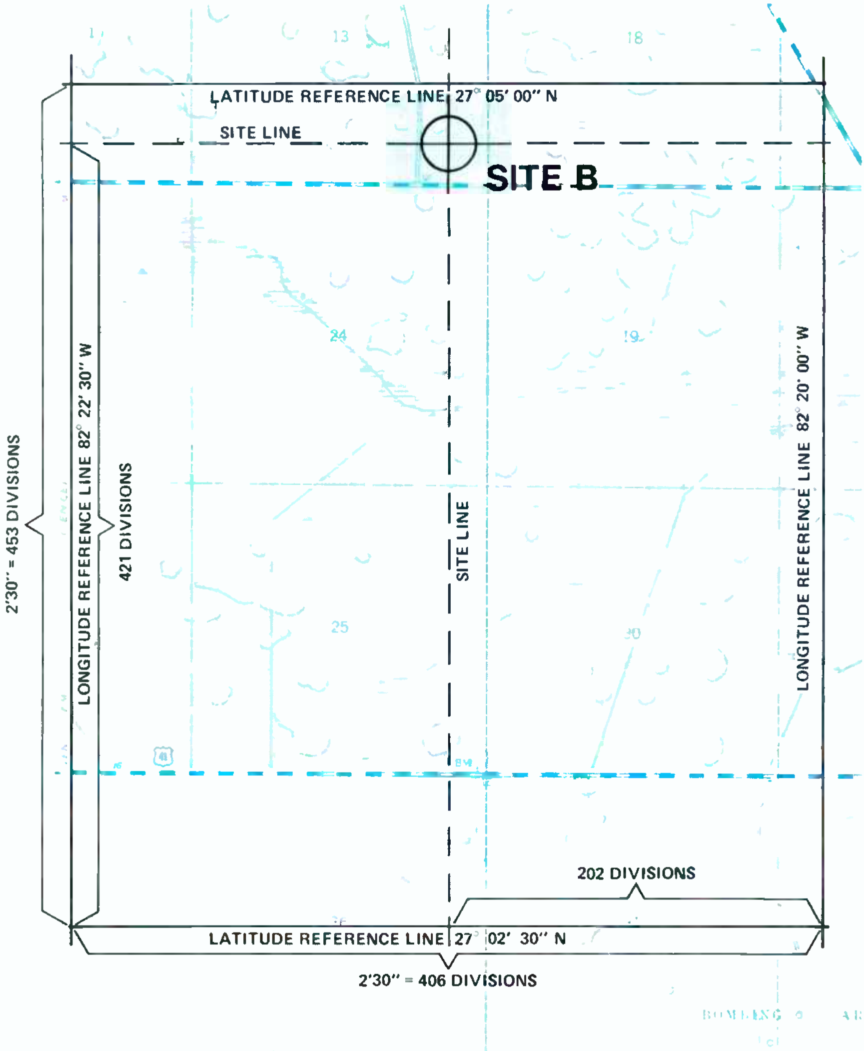

Figure 4. In the application of the ratio method the geographical coordinates of Site B are obtained from the solution of a proportion set up between two measurement ratios.

The proportion to determine the number of seconds of latitude Site B lies from the reference latitude line is:

$$\frac{X'' \text{ Lat.}}{150''} = \frac{421 \text{ Div.}}{453 \text{ Div.}}$$

$$X'' \text{ Lat.} = \frac{(150'')(421)}{(453)}$$

$$X'' \text{ Lat.} = 139.4''$$

The X″ latitude value is added to the reference latitude.

$$\begin{array}{lr} \text{Ref. Lat.} & 27^\circ\ 02'\ 30.0''\ \text{N} \\ \text{X}''\ \text{Lat.} & +\qquad 139.4''\ \text{N} \\ \hline & 27^\circ\ 02'169.4''\ \text{N} \end{array}$$

Convert 169.4″ to minutes and seconds. The latitude of Site B is 27° 04′ 49.4″ N.

A similar proportion is set up to determine the longitude of Site B.

$$\frac{\text{X}''\ \text{Long.}}{150''} = \frac{202\ \text{Div.}}{406\ \text{Div.}}$$

$$\text{X}''\ \text{Long.} = \frac{(150'')\ (202)}{(406)}$$

$$\text{X}''\ \text{Long.} = 74.6''$$

Add X″ longitude to the reference longitude.

$$\begin{array}{lr} \text{Ref. Long.} & 82^\circ\ 20'\ 00.0''\ \text{W} \\ \text{X}''\ \text{Long.} & +\qquad 74.6'' \\ \hline & 82^\circ\ 20'\ 74.6''\ \text{W} \end{array}$$

Convert 74.6″ to minutes and seconds, and the longitude of Site B is 82° 21′ 14.6″ W.

Conclusion

There are other methods of obtaining site coordinates from topographic maps published by the U.S. Geological Survey, but they ordinarily involve other coordinate systems in which the geographical coordinates of a station can only be determined by referring to tables in which the coordinates of the two systems are correlated. For example, on the borders of most topographic maps are printed tick marks which relate lines of latitude and longitude to lines of state survey grids and to lines of the U.S. Army's Universal Transverse Mercator Grid. But there hardly seems to be any point in resorting to these systems to obtain site coordinates when they can be determined directly and more simply by one of the methods described previously. Again, the accuracy of determining the geographical coordinates of a site, as required by the FCC, by either of these methods will always depend on the accuracy of the map, the accuracy of the scaled ruler, and the accuracy of the measurement.

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The Volume Unit

Nearly forty years ago a group of telephone and broadcast engineers in the United States jointly developed and adopted a standard to measure the magnitude of a complex audio-frequency signal in an electrical circuit. The instrument with which such measurements were to be made became known as the Standard Volume Indicator calibrated to measure signal volume (magnitude) in vu (volume units).

The volume indicator is an instrument primarily designed to provide a visual indication of the magnitude of non-periodic electrical signals such as those which speech and music waves produce in a telephone or radio program circuit. The need for such a measuring device was first recognized during preliminary tests of the public address system set up over telephone circuits that enabled large audiences in several cities of the United States to hear the ceremonies attendant upon the burial of the Unknown Soldier on Armistice Day 1921. It was observed during some of the tests that distortion due to overloading of an amplifier was more objectionable when heard in a loud speaker than when heard in an ordinary telephone receiver. The speech level at which the amplifiers in the telephone repeaters appeared on the verge of overloading, as evidenced by audible distortion, was determined experimentally. This level, of course, was chosen to be the reference volume against which the volume indicator would measure all other speech signals.

The instrument itself was simply comprised of a potentiometer at its input for adjusting the sensitivity in 2 dB steps, and a triode vacuum tube detector whose output drove a d.c. milliammeter. The operator of the device adjusted the potentiometer so that the levels of the measured speech signals produced a maximum movement of the milliammeter needle to the mid-scale point on an average of once every ten seconds. Occasional greater deflections he disregarded. He then read the volume level from the setting of the potentiometer which was marked in decibels with respect to the reference volume. (It is perhaps worth noting that the volume indicator provided no control of speech levels in the telephone circuits; it merely provided a visual indication of the levels.)

During the next several years following its birth, this first instrument spawned a host of similar volume indicators, but there was a lack of uniformity in their design and their use. By the late 1930's the telephone and broadcast industries were acutely aware that this variety of instruments was creating considerable confusion and misunderstanding, especially whenever one group attempted to correlate its measurements with those of another. Standardization was the obvious remedy for this undesirable situation. Though prior attempts at standardization by other associations had failed, during 1938 and 1939 engineers of Bell Telephone Laboratories, Columbia Broadcasting System, and National Broadcasting Company collaborated to develop a new volume indicator, a new volume reference level, and a new terminology for expressing measurements of volume level. The American Standards Association adopted and published in 1942 the results of this cooperative effort in the form of a standard titled "Volume Measurements of Electrical Speech and Program Waves."

Characteristics

In their formulation of the characteristics a general purpose volume indicator should have, the engineers gave prime consideration to three uses the instrument would most likely be called upon to serve:

(1) To indicate a suitable level for a speech or program wave so that it is not audibly distorted when transmitted through an amplifier, program circuit, radio transmitter or the like.

(2) To check transmission gains and losses in an extended program network by simultaneous measurements at a number of points on particular peaks of transmitted program waves.

(3) To indicate the comparative loudness with which programs will be heard when finally converted to sound.

One instrument to serve all three uses was necessarily a compromise of the ideal instrument for each service.

From the results of extensive and varied tests conducted with trained observers the engineers concluded that there was no appreciable difference between measurements made with rms meters and peak-reading meters to indicate speech and program levels at which audible distortion due to overload occurred. Nor did they find any significant advantage in the use of one over the other to determine levels of equal loudness in several types of speech and program material. They did discover, however, that on a 1,900 mile long program test circuit that was lined up so that either volume indicator read the same at both ends of the circuit on a 1000 Hz sine wave, there was considerable disagreement between program level readings taken with peak meters at each end of the circuit. There was only a minor difference in the readings taken with two rms meters. The large variance in the peak meter readings was attributed partly to the cumulative effects of the slight non-linearity in the many vacuum tube amplifiers and loading coils in the circuit, and partly to the phase changes which alter the wave front and amplitude of the peaks. This marked advantage of the rms instrument coupled with the fact that it could be made of sufficient sensitivity for most purposes without the use of vacuum tubes and their attendant power supplies, an advantage not shared by peak-reading instruments at that time, convinced the engineers to develop the rms type instrument.

In establishing the dynamic and electrical characteristics of the instrument, the engineers sought the opinions of technicians accustomed to reading volume indicators. The conclusions they drew from this survey, as finalized in the American Standard Practice, were that the meter should be slightly less than critically damped so that when a sinusoidal voltage between frequencies of 35 and 10,000 Hz, of such amplitude as to give reference deflection (the point on the meter scale marked 0 vu, 100, or both) under steady-state conditions is suddenly applied, the meter pointer should reach 99 percent of reference deflection in 0.3 second, ±10 percent, and should then overswing reference deflection by at least 1.0 percent and not more than 1.5 percent. They felt this slightly underdamped meter movement would cause less eye strain in watching the pointer dance about in response to program waves than a critically damped or slightly over-damped movement. Moreover, the momentary pause in the pointer's downward movement permitted more precise observations of maximum excursions of the pointer to be made.

To further help reduce eye fatigue the engineers selected a meter scale of buff-colored background sufficiently large to accommodate the number of division markings required to measure the range of volume levels that were likely to be encountered. Figure 1 is a picture of one such meter scale, the type A scale commonly used by the telephone industry. The main division markings and the associated numerals above the arc denote vu's; the less conspicuous scale divisions and numerals printed below the arc show percentage utilization of the circuit's volume capacity. On the other standard scale, the type B scale, which the broadcast industry generally prefers, the percentage scale is printed above the arc; the vu scale is printed below.

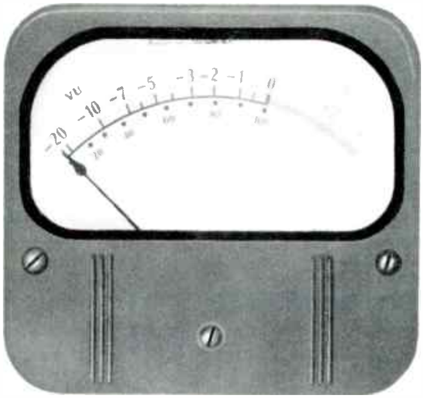

Figure 1. The meter scale on the standard volume indicator is either the type A scale shown here, or the type B scale on which the positions of the vu and percentage scales are reversed.

In addition to the meter and its circuitry, the standard volume indicator contains either an attenuator (adjustable loss) or pad (fixed loss). It is important to recognize that when an attenuator is supplied, the adjustable steps marked on its scale are vu's and not decibels of attenuator loss. The vu measurement of a signal on such an instrument, therefore, is the algebraic sum of the vu reading on the meter scale and on the attenuator scale.

Some volume indicators are designed to measure across 150 ohm circuits, but most are intended for bridging measurements on 600 ohm circuits, although one version contains an impedance selector switch which enables terminated measurements to be made with the instrument. During calibration the instrument is to be connected across the resistive circuit impedance for which it is designed. A correctly calibrated instrument indicates 0 vu (algebraic sum of meter and attenuator scales) when a source of sinusoidal voltage is adjusted to develop one milliwatt in the calibration circuit impedance.

It should be emphasized here that only sine-wave power of one milliwatt will indicate 0 vu, or reference volume, on the volume indicator. Complex speech or program waves measured across the stated circuit impedance whose intensity is such so as to produce 0 vu readings will have instantaneous peaks of power which are several times one milliwatt and an average power which is only a small fraction of a milliwatt. Reference volume, therefore, is properly defined as that level of program which causes a standard volume indicator, when calibrated and used in the accepted way, to read 0 vu. Moreover, use of the term vu as a measure of volume is properly restricted to expressing readings made with a standard volume indicator with respect to reference volume, or 0 vu.

Methods of Reading

Over the years there appears to have developed a difference of opinion as to how the volume indicator is to be read. The engineers who originated the instrument suggested that the step attenuator, if possible, be so adjusted that the extreme deflections of the instrument needle just reach a scale reading of zero on the vu scale or 100 on the percentage scale. In their opinion the needle deflections should be observed for about a one minute period of program material and for about 5 to 10 seconds of message telephone speech. The volume level was read directly from the attenuator scale or, when the attenuator could not be adjusted to give a 0 vu or 100 percent meter scale reading on maximum deflections, algebraically summed with the meter scale reading. The American Standards Practice recommends this same method, but allows the exclusion of one or two occasional deflections of unusual amplitude. However, the common telephone industry practice is to visually average the peak swings, excluding the highest one or two, over a few seconds interval.

Studies have shown that different observers show different biases in their reading the meter. The range of bias, even among trained observers, is reported to be 3 to 4 vu. This observer bias, when combined with seemingly slight variations in meter reading methods, can result in the transmitted volume in the system being set too high or too low. The transmission system operating under these conditions may exhibit a poor signal-to-noise ratio, or excessive crosstalk, overmodulation of a carrier, or some type of audible distortion.

To some, this reliance on human visual judgement is a marked shortcoming of the standard volume indicator. Consequently they promote and support the development of other instruments that will give more objective volume measurements. Others, however, contend that the present instrument adequately fills the need for which it was intended. Nevertheless, work is going on now to revise the current standard practice and broaden its application. It is likely that the revision will define the characteristics of other volume indicators in addition to the current standard to permit the application of current technology to this type instrument. But it is unlikely the revised practice, in defining several volume indicators as standard, will overlook the necessity for a simple method of correlating measurements made with different instruments. Otherwise, the telephone and broadcast industries will be confronting again the situation that originally prompted them to develop a standard volume indicator.

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