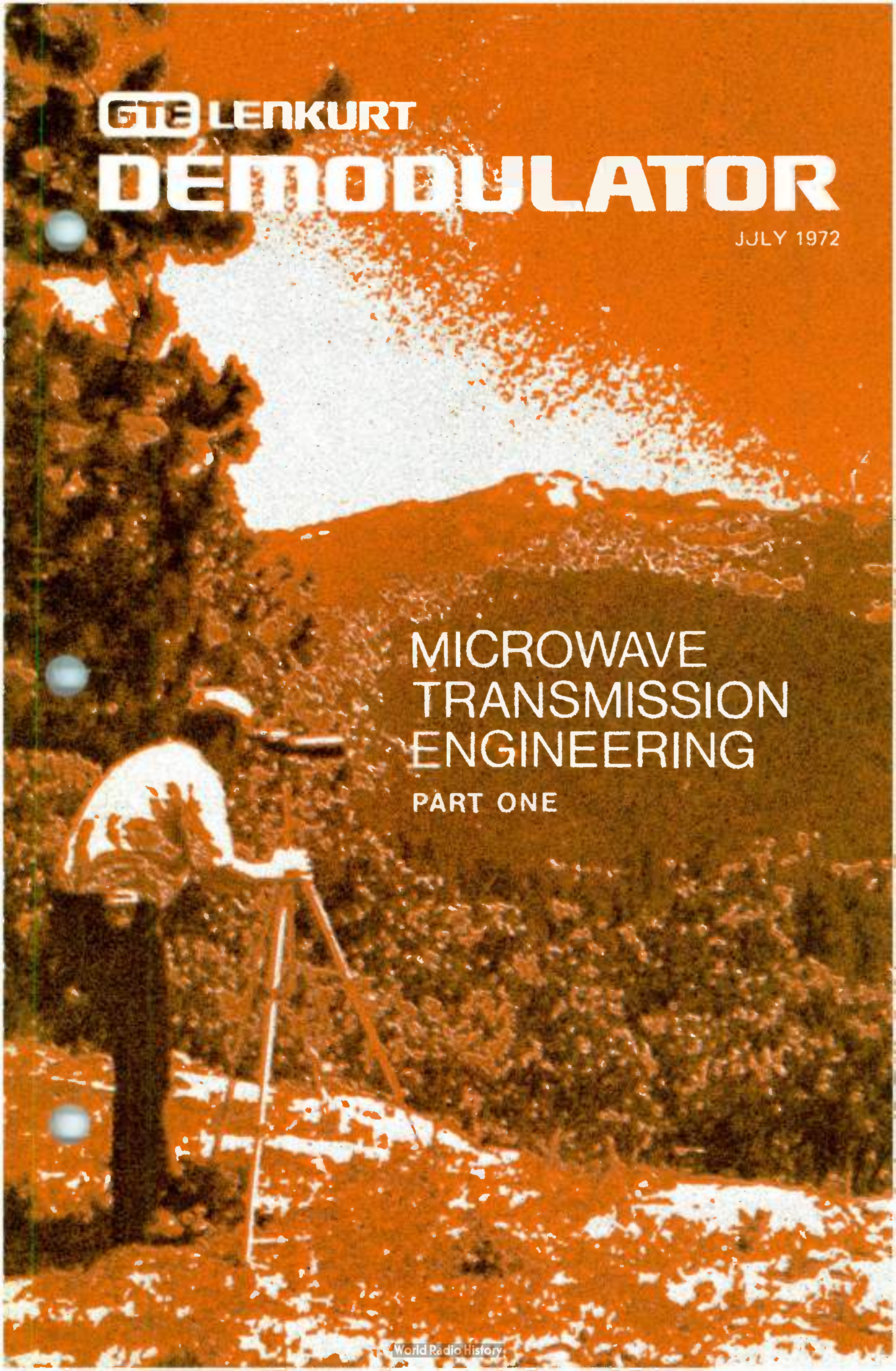

GTE LENKURT

DEMODULATOR

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MICROWAVE TRANSMISSION ENGINEERING

PART ONE

Microwave transmission engineering requires collecting large quantities of data and involves a precise study of the terrain along the proposed microwave path. Interpretation of this information, based on theory and practice, provides the basis for final microwave system design.

The basic purpose in engineering a microwave path is to achieve a path which will meet the requirements for long term median noise, and which will also ensure that outages due to fading below a predetermined level are minimized. In general, and particularly in high-density systems, it is necessary to consider interference noise, waveguide and feeder distortion, and basic thermal and intermodulation noise.

The microwave transmission engineer has to work with many different factors, some of which interact with each other, in order to come up with solutions which are satisfactory both technically and economically. Before starting on any actual path layouts some comprehensive decisions will have to be made as to what the microwave system must do, such as the number of channels for present and future needs, type of noise performance necessary, and kind of reliability required. The decisions may even be more detailed, for example, choice of particular frequency band and type of protection arrangement may be specified. Some of these decisions may come as a result of preliminary path study; however, in any event, they must all be firmed up before final path survey work is undertaken. Figure 1 illustrates some of the "tools" used for preliminary path studies.

Preliminary Planning

The first practical aspect of laying out a system is to know the points the system will connect. The simplest system would be a one hop system, from Town A to Town B 25 miles away, in flat country where a line-of-sight path can be easily achieved. If the distances involved are greater, or the intervening terrain unfavorable, it may be necessary to use more than one hop. The system would then require the use of repeaters.

In relatively flat country, a practical rule of thumb is that repeater spacings are generally limited to about 25 or 30 miles, unless extremely high towers are practical. On long systems where several repeaters are needed, and particularly where a number of points are to be served by the system, a number of choices of route may be

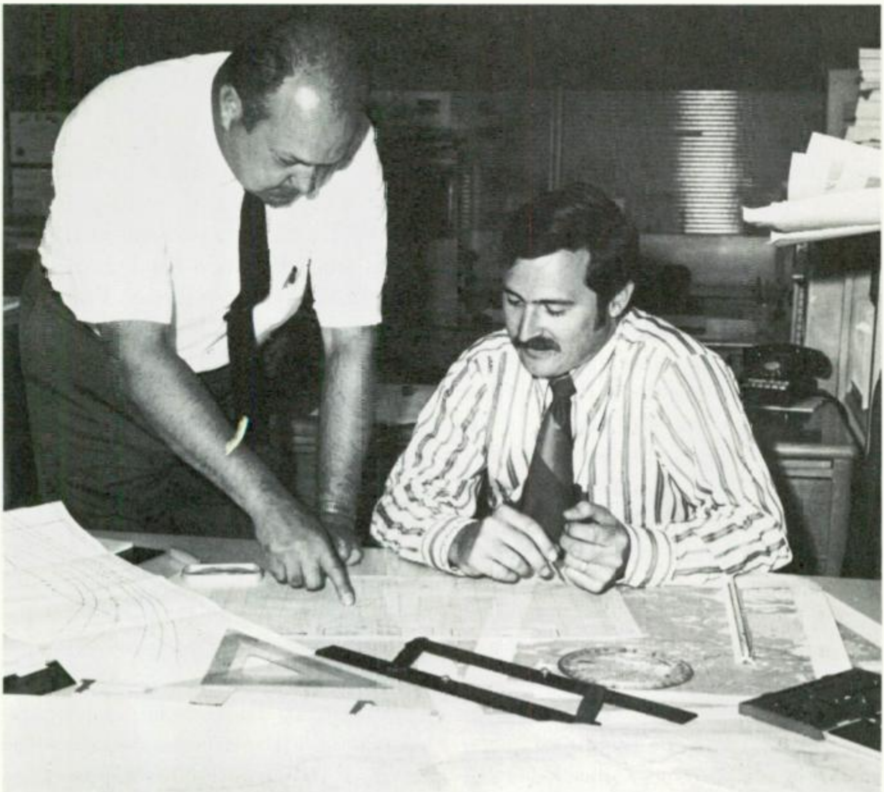

Figure 1. Some of the common tools used in preliminary path surveys include drafting instruments, topographical maps, equivalent earth profile templates, and preliminary profile charts.

available, and considerable study may be needed to select a favorable one. Figure 2 shows a system layout with the necessary repeaters.

Regardless of the system size, for proper system operation, it is necessary for each path to have adequate clearance under all expected atmospheric conditions. To determine clearances, the actual topography of the path and also the height and location of any obstacles along the path, such as buildings and trees, must be known. The topography of an area can be studied prior to going out in the field through the use of topographical maps.

In most cases it will be found that a thorough map study will narrow the problem down considerably, particularly in the case of multi-repeatered systems with a wide range of path choices. By checking a number of possible routes from map data alone, it will usually be possible to narrow the choice down to a few alternate possibilities, thus greatly reducing the amount of field work.

If good topographical maps are available, the routes to be studied are then drawn on the maps and preliminary profiles prepared. The actual field survey then becomes a matter of traveling along each path making checks on terrain elevations at critical points. Information about the types, sizes, locations, and characteristics of any obstacles such as buildings, trees, or water towers along the path, and for a short distance on either side of it, must be gathered. Other pertinent data such as the location of large bodies of water or flat bare fields which could provide efficient reflection points should be recorded.

Path Profiles

A profile chart is prepared after tentative antenna sites have been selected, and the relative elevation of the terrain between these sites has been determined. It is not always necessary to make a complete profile of all the intervening path, in some cases only the end sites and certain hills or ridges that might obstruct the path are needed for the profile.

Microwaves generally travel in straight lines; however, the beam may be bent toward the earth by atmospheric refraction. The amount of bending, which varies with atmospheric conditions, must be considered when drawing the profile. The degree and direction of bending is called K. This factor, K, multiplied by the actual earth radius, R, gives a curve equivalent to the relative curvature of the microwave beam with respect to the curvature of the earth.

This relative curvature can be shown graphically; either as a curved earth with radius KR and a straight-line microwave beam, or as a flat earth with a microwave beam having a curvature of KR. The second method permits illustration and investigation of several K values on the same chart, and eliminates the need for special earth curvature graph paper (see Figure 3).

A path profile plotted on rectangular graph paper with no earth curvature, and with a microwave beam drawn as a straight line between the antennas represents conditions when the beam has a curvature identical to that of the earth, and the equivalent earth radius, K, is equal to infinity. This is one of the extreme conditions that must be investigated when making a study of the effect of abnormal atmospheric conditions on microwave propagation. To complete a propagation study, it is necessary to show the path of the beam relative to the earth, for other expected values of K. In all cases, it is of interest to study the path under normal atmospheric conditions when K is equal to 4/3. Standard templates are used for the different values of K so that the transmission engineer need only gather the information about the intervening terrain for each profile needed (see Figure 3).

Field Survey

Final site selections must be made after preliminary planning has determined such things as operational requirements, expansion potential, reliability requirements, and costs; the points to be served have been fixed; the most likely paths to serve these points have been narrowed by map

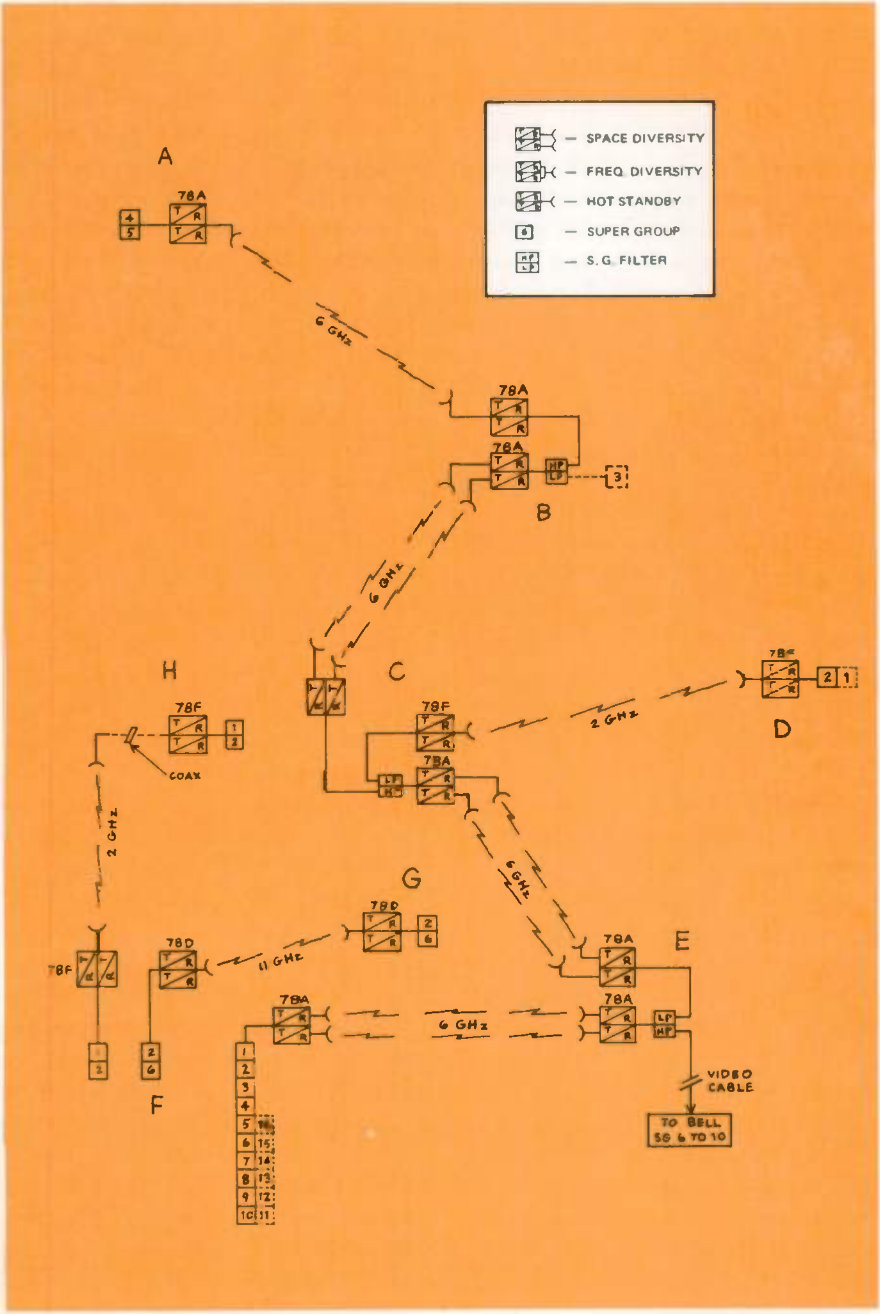

Figure 2. In laying out a microwave system, a block diagram is prepared showing all the required repeater stations.

studies; and the required system capacity has been determined. At this point the actual field survey will be undertaken.

The field survey includes more than the name implies. Actual elevation measurements, judgements of the actual terrain along each path and data concerning obstructions and possible reflections are recorded. The existence of paralleling or intersecting foreign systems and interference possibilities are indicated and the various data concerning regular and alternate sites are obtained. The preliminary profiles made from the map study become a tool for the field survey.

Probably the central problem of the microwave engineer, when he goes out in the field, is the effect of the earth itself, that is, the terrain and obstructions along the path. In fact it is this combination of terrain and atmosphere, unique to every path, which determines the propagation variations.

Accurate gathering of information about the terrain and atmosphere is extremely important when engineering a microwave system. Obtaining precise path profiles and accurate data on height and location of obstacles is the foundation of all microwave engineering, and is the principal problem facing the engineer responsible for laying out a system.

Terminal sites are often locations of existing structures or facility terminals, but intermediate sites are located with considerable emphasis on factors having to do with propagation over the intermediate paths and possible interference from sources internal or external to the system. The choice of intermediate repeater sites is greatly influenced by the nature of the terrain between sites. Preliminary map studies should have narrowed down the choices. These preliminary choices are supplemented, corrected or actually replaced as a result of the field data gathered. In the absence of actual path tests, the information brought in from the field survey constitutes almost all of the factual data about the route. From this data final judgments are made to determine the expected service performance of the system when installed.

The complexity of the required path studies varies widely depending on a great many factors. In some cases it may be possible to make a simple visual determination of path clearance by optical testing methods such as flashing, optical surveying, and "balloon" flying (see Figures 4 and 5). But, in other instances it may be necessary to conduct extensive field studies of the terrain using transit, rod, and chain, or precision altimeters to locate and describe obstacles and potential reflection points along the proposed microwave path.

Accuracy

A point that needs to be emphasized is the need for precisely locating everything at the site and along the path. As well as knowing where the obstacles are located, sites for station locations must be reported to the FCC with an accuracy of ±1 second of latitude and of longitude. For this final location determination, it is often advisable to have the precise sites determined by surveying.

Apart from the accuracy needed to meet the FCC requirements, there is a

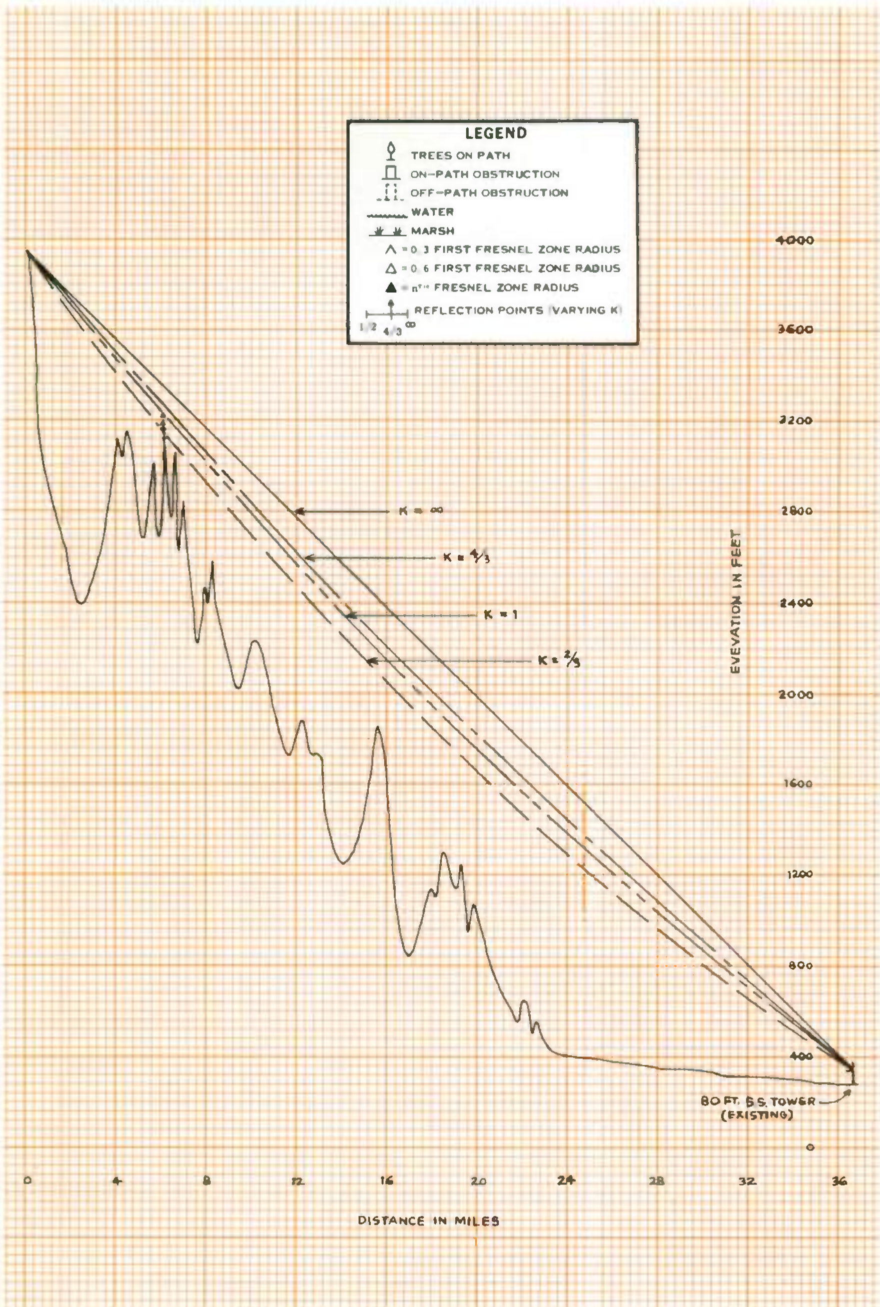

Figure 3. Plotting profile charts using a flat earth and a curved microwave beam allows the consideration of several values of K on the same chart.

Figure 4. The auxiliary equipment needed for "balloon" flying includes a helium source, VHF radio, and a calibrated, motor-driven reeling mechanism.

need for accuracy to make the overall survey data meaningful to the transmission engineer. And in this case the accuracy requirement is not only for the location of the end points, but the location of the path itself. Very often the question of whether a particular terrain feature, or a building constitutes an obstruction hinges on whether or not it is exactly on the proposed path. If the obstruction is as little as a hundred feet off the path it may not have any bearing on the propagation. In the middle of a path it is possible to have an uncertainty of 100 feet as to where the path actually lies. One solution is to locate the path as accurately as possible, then assume that anything lying within about a quarter of a mile on either side of it is "on path." This sort of assumption is usually feasible in flat terrain, though it may sometimes make a path look bad when it really isn't. But in hilly terrain moving a path a quarter of a mile to one side may make it a totally different problem; so, the need for accuracy is great.

It is not always easy to determine the exact location of a path. The problem is accentuated in roadless country, or in hilly and forested terrain. In such cases the microwave transmission engineer often has the feeling he's working in the dark, and a great deal of ingenuity may be needed to find out when and where is he on path.

Near-end obstructions are just as important as distant ones and in cities, for example, it will often be found that moving a site only a few feet may make the difference between having a clear path and an obstructed one. Getting in and out of big cities is often one of the most complicated parts of the microwave transmission engineering. Often tower height limitations make it mandatory that the first hop be a short one.

Additional Information

In addition to the path profile and clearance data, the microwave transmission engineer must compile a great deal of other pertinent field information, some of which affects present transmission engineering decisions and some of which is for future microwave system considerations.

The location of each repeater site should be given by latitude and longitude, by word description, and by access route. The description should be adequate to allow someone who has never been there to locate not only the site, but in many cases the exact point where the tower will be located. Staking of sites is not always possible due to future negotiations regarding land purchases.

The accessibility of the site should be given by such information as the condition of existing roads, or amount of new road construction required. When construction of access roads is required, estimates of the relative difficulty or ease of construction should be indicated, since road costs can have a sizeable effect on the overall economics of the site. The type of vehicle necessary to gain access to the site should also be determined along with the travel time from the nearest highway to the antenna site.

Part of the accessibility of the site deals with the availability of commercial power. If power is not readily available at the site, details regarding the feasibility and probable cost of constructing new power lines should be determined.

FCC and FAA regulations require that microwave site applications provide such information as the distance and direction to the nearest airport, commercial or military. This information can be determined primarily from the study of maps.

Details about the site are also helpful before any construction takes place. For example, it is helpful to

Figure 5. Optical surveying using a transit is a frequently used field technique.

know the type of soil on which the building and tower will be constructed. When considering the costs of developing the site it is also helpful to know the amount of clearing and leveling, if any, that must be done to the site before it can be developed.

Along these same lines it is essential to know the total amount of land available for building and tower construction, and if there are any building codes that might dictate the type of construction that has to be used. And, existing buildings already on the site might be used for the station, thereby minimizing construction costs.

It is also necessary to have some indication of the types of weather that can be expected in the site area and along the path. Specific bits of information such as the amount of snow and ice accumulation that can be expected, the maximum expected wind velocity, and the temperature range expected are all useful.

It is highly advantageous, where possible, to establish any new stations on sites which are either on or close to existing roads and power lines. In some cases a site having such a condition may be preferable to another site which would allow lower tower heights, but would require considerable road and power construction.

In hilly or mountainous areas, elevated sites can often be found which would be ideal repeater locations from the transmission standpoint, but so inaccessible that inordinate expense would be involved in bringing in roads and power. In more fortunate situations access may be available, or a site already developed by someone else may offer possibilities.

In evaluating access difficulties, "worst season" conditions should be used. Snow, ice, and mud can be rather impressive barriers to easy entrance and exit. Snow and ice, in large quantities, can also have harmful effects on microwave stations, towers, and antenna systems, and in areas where such things are common, careful consideration should be given to their possible effects.

A problem which must be considered in planning new microwave systems or in adding new frequencies is coordination with existing systems operating in the same microwave bands. Such coordination will often involve only suitable frequency selections for the system, but in heavily congested areas it may not be possible to obtain completely clear frequencies and in such cases it may become necessary to provide enough geographical and angular separation between the paths of the proposed system and existing systems to allow them to exist in harmony with each other.

More on Techniques

The next issue of the GTE Lenkurt Demodulator will cover the actual techniques that are used to support these principles of microwave transmission engineering. Such things as the methods used to determine path clearances, how to perform path tests, and frequency coordination studies will be covered in detail.

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