MICROWAVE SITE SELECTION IN UNDEVELOPED COUNTRY

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Summary

This article discusses a method by which microwave systems are laid out in rugged undeveloped country, where maps alone cannot be used to indicate path clearance. The first step is to gather all available information and, by careful study of the topography, to lay out several possible microwave routes.

The next step is to conduct a methodical low level aerial survey by means of inexpensive light aircraft, making descriptive notes of the proposed relay sites and measuring the height of all hills on or close to the propagation line. If the first plan fails the height data obtained contribute to a more enlightened second plan and the process is repeated until an attractive system develops.

A third step is necessary in order to establish tower heights and assure that sites picked out from the air are practical from an installation viewpoint. Field parties carrying simple equipment visit the sites and conduct additional tests, on the basis of which tower heights are computed and construction parties are able to move in.

Introduction

In laying out a microwave system the engineer is faced with several conflicting requirements. On the one hand the repeaters should be placed on high hills, or high towers should be used, so that adequate clearance is obtained over the paths. Adequate clearance for a high reliability system requires the full first Fresnel zone, over trees, assuming that the earth's radius is four-thirds of its true value. Any decrease in tower heights below this value can be expected to result in increased propagation outages and decreased system reliability. The paths chosen should be as free as possible from conditions giving rise to abnormal propagation. Large reflecting surfaces, for example, so located that they might result in multiple path transmission, should be avoided.

On the other hand, for the sake of economy, the stations should use the shortest possible towers and should be spaced far apart, but located close to existing roads or railways. The well-designed microwave system is one which arrives at a good compromise of these conflicting requirements and in undeveloped country the location of repeaters presents some unusual problems, due to the lack of topographic information.

Geographic Considerations

One requirement which all microwave systems have in common is that repeaters must be visited periodically for fuelling or maintenance and hence should be located close to existing transportation lines. The general route of the system is thus fixed by the end-points and the road or railway it is likely to follow. The problem is to find points close to transportation which are high enough above intervening land to provide clearance for microwave beams, with repeaters economically spaced. If the stations are spaced far apart it becomes very difficult to find intervisible points and fading margins are reduced while the likelihood of fading is increased. If, on the other hand, stations are placed close together the number of repeaters and consequently the cost of the system, rise, while the distortion inherent in the relaying process is increased as it would be in a wire line system using carrier repeaters. Our experience over a large number of installations in northern Canada has been that repeaters are spaced approximately twenty-five miles apart. They are usually located less than a mile from an existing road or railway and seldom more than six hundred feet above it.

Northern Canada, excluding the arctic regions, is generally covered with evergreen forest, varying in height from a few feet in the north to well over a hundred feet in the southern regions. Wherever roads or railways have been built small settlements have sprung up, supported usually by the lumbering, mining or transportation industries. The northland taxi service is provided by a number of small aviation companies operating seaplanes out of the larger settlements and every lake of any size is a potential airport. Communications systems tend to follow the pattern of long lines connecting important centers, with very little traffic dropped or inserted along the way. The routes run largely through wooded country subject to storms, forest fires, rock and snow slides and other hazards to wire-line operation. These are clearly applications for microwave radio but the problem of where to locate repeaters may be somewhat difficult.

Photographic Methods of Site Selection

Since photography of most of Canada is available from the National Library, our early approach was to obtain this photography and examine it with simple stereoscopic instruments. Most of this photography is to a scale of 1320 feet to the inch, while a few areas, taken recently, are to a scale of one mile to the inch. We soon learned that this approach was subject to very serious limitations. Each pair of photographs covers a very small portion of the microwave path and one known elevation has to appear on every pair. In addition, two more elevations are needed for levelling unless there is a large body of water showing on the prints. It was apparent that the use of old large-scale photography was out of the question; while modern small-scale photography might be useful in special cases. Using complicated map-making machinery it is possible to assemble a long strip of photographs, taken by an aircraft during a single flight, and correct for errors, so that elevations along the line of flight can be read off with good accuracy. However, the line must not cross several different strips of photography or the errors become serious and it is unlikely that a microwave propagation line will coincide with the line flown by an aircraft on an earlier mapping survey. Another possibility is that the microwave route might be photographed and sites selected from the resulting prints. Modern aerial cameras give a strip not more than about eight miles wide and, if the route deviates far from a straight line for geographic reasons, as do our northern roads and railways, many possible alternatives will not be contained in such a narrow strip.

Direct Methods of Site Selection

Gathering Data

After experimenting with different techniques, it was decided to work directly on the territory concerned and to reserve photographic methods for the solution of special problems. In selecting the sites for a microwave system the first step is to obtain all the information that is available about the region and to prepare a siting plan on this basis. The federal government is our chief map-making agency and has prepared eight miles to the inch sheets covering the entire country. There are maps to a larger scale of many districts but in general they contain little height information north of a line through the St. Lawrence River, the Ottawa River and the Upper Great Lakes. Fig. 1 shows the area which has been contoured at twenty-five foot intervals. It is roughly equal to the New England states while the area which is not contoured adequately for microwave site selection is approximately equal to the remainder of the United States. Good plan maps have been prepared by the provincial governments and in local areas mining and timber operators have also had a hand in map-making. Accurate height information is sometimes obtained where road, railway or hydro-electric surveys have been made, but often the first clue to the height configuration is found in the drainage of a region. Watersheds indicate the heights of land, rivers indicate the general slope and roads, railways and rivers often loop around individual hills of significant height. Several possible microwave schemes are plotted since it is unlikely that any one path chosen with this limited information will prove satisfactory. No attempt is made at this time to pin-point the repeater sites but general areas are marked on the maps in which repeaters are likely to be located.

Aerial Survey

The next step is to survey the route from low-flying aircraft and arrangements to do this work have been made with several northern aviation companies. The pilots are trained by our engineers and very quickly pick up the flying techniques involved. The aircraft used must be slow flying and manoeuverable and able to take off from relatively small lakes. It should be fitted with an accurate sensitive altimeter although a second calibrated instrument is used by the radio engineer. A good communication system is also required between the pilot and our engineer during flight. The technique is simply one of slow careful probing of the route to pick up the greatest amount of information. Our engineer in the aircraft first surveys the regions marked on the maps to select the most promising hilltops for repeater sites, pin-pointing them and making notes of the best access route and of any distinguishing features which will help to identify them from the ground.

The next operation is to measure the height of all important hills close to the line joining the repeater sites. The sensitive aneroid altimeter is used, but since barometric changes during flight may introduce serious errors, some reference elevation is chosen. The absolute value of this reference need not be known since we are interested mainly in relative heights along a line between two proposed relay sites. The height of hills is measured simply by flying close to the summit and sighting over one wingtip along a horizontal line to be sure the aircraft is on the same elevation as the hilltop. The height of this hill is recorded with the time of the observation and the pilot then flies to the next hill on the track where the measurement is repeated. Periodically, he flies back to the reference elevation and measures its height, noting the time, so that changes in barometric pressure are detected and allowed for. Flying of this nature can be carried out only when the air is calm, usually during the first few hours after sunrise.

When all the data over the proposed path have been collected, the aircraft lands and the corrected elevation measurements are plotted on 4/3 earth curvature graph paper so that a profile of the proposed path is obtained. Fig. 2 is a profile of a typical path. On this graph paper the vertical scale is 250 feet to the inch while the horizontal scale is 5 miles to the inch. Hence the earth's bulge is very much magnified and the zero or sea level curve is a parabola centered on the sheet. If this curve represented the true earth radius to the scale shown, radio and light waves would normally curve down, increasing the distance to the horizon. The same result is obtained if the radio waves are drawn as a straight line and the curvature of the earth is increased to 4/3 its true value. This 4/3 earth curvature graph paper is widely used in radio propagation analysis.

From this profile the necessary tower heights are calculated. If very short towers or no towers at all are required, it is usually possible to move the site closer to existing roads or railways, while if tower requirements are more than about 200 feet, it may be possible to reduce tower height, by selecting a different hilltop, with an overall decrease in the cost of the system. For this reason it is often necessary to revise the sites originally chosen and re-fly the path. Since the new plan is based on an accumulation of accurate height information it is much more likely to succeed, although a third attempt is occasionally required.

In this manner, step by step, the route is laid out. It is done at low cost quickly since only two men and small local aeroplanes are used. The system is flexible and there is good assurance that not only a workable route, but the most economical route has been selected and that all alternatives have received consideration. The survey at this stage is often of value to the company which is planning a communication system because a fairly accurate cost estimate is possible when the number of repeaters and their distance from existing roads or railways are known. In remote regions the acquisition of land is usually a simple matter but, where problems are likely to arise, options can be obtained at this stage without arousing the suspicion of the owners by the presence of surveyors.

Visiting the Sites

The third step is to visit the sites on foot to gather more information concerning the location of buildings and access roads and the exact tower heights required, and to mark the sites for construction people who will come later. Two adjacent repeater sites are visited at the same time, and a party of two, usually an engineer and assistant, visits each site.

We were fortunate in having several people, both at the engineering and technician level, with what might be termed "backwoods" experience. They either grew up in Northern Canada or served there during the war, but we found that none of these could climb trees, using spurs and ropes, to make the necessary observations in wooded country. A course was arranged at the forestry school of the Ontario Hydro Electric Power Commission where the men were taught to climb trees and remove branches and tops safely. At the completion of this course and after a few weeks of experience, they could cut the limbs and the top from a 100 foot tree, rig a hoisting line and raise a number of surveying instruments to the top of the pole in less than an hour. The fact that a serious accident has not occurred in several years of operation reflects great credit on the men who conducted this course.

In practice, the crews leave their base around noon to visit the microwave sites. The men leave the road or railway at the point indicated by the aerial survey and proceed by compass in the general direction of the site, until a hilltop is reached which they think is the one they are looking for. The tallest tree on the hilltop is climbed for the purpose of fixing the position of the party and it is usually possible to recognize features described in the aircraft notes. Roads, streams, lakes or fire towers allow the men to pin-point themselves and they usually find that they are not on the hill selected from the aircraft, which shows up as higher ground a short distance farther on. The bearing and distance of this are taken and the party continues walking. The second or third hill is usually the right one and trees are selected near its summit which are suitable for tests in the direction of the adjacent site.

The object of the tests which follow is to establish, by means of a beam of light, the line which grazes obstructions between the sites and it is usually necessary to observe at several different elevations down the slope rather than at one point at the top of the hill. Several trees at different levels are limbed and topped so that the view in the required direction is unobstructed. At this time contact with the other party may be established by vhf radio according to a prearranged schedule. Portable radios of the "walkie-talkie" variety have been used quite successfully. Transmitters of 1-2 watts output are adequate for voice communication between hilltops separated by as much as thirty miles.

The ideal time for the light tests is when the sky is dark enough for observers to see a lantern at the opposite end of the path, yet light enough to permit sketching the horizon profile and the position and relative height of intervening hills. Fig. 3 shows a sketch of the lanterns used for clearance tests. The lamp housing is fitted with a pistol grip, trigger switch and tubular metal sight and is similar in appearance to the Aldis Lantern widely used for signalling to aircraft during the war.

In use, each observer holds his lantern horizontally and swings it over a small arc in the direction of the other station. The first observer to see the flashing light sights his own on it and the two very quickly lock together. Having established contact, first one observer and then the other goes to successively lower stations until the grazing line is established. If the line is obstructed by only one hill this technique will fix its location and relative height. If there are two obstructions, one controlling from each end and their location was previously plotted from the aircraft, this method will fix the height of both. When the tests are finished the party may return to base or wait on the hilltop until dawn, depending on the difficulty of the path. On the return trip a trail is carefully blazed on the tree trunks so that construction people returning several months later are able to find the sites.

Failure to obtain visual contact may be due to one of the following reasons which are listed in order of likelihood:

(1) Inadequate visibility.

(2) Failure of one party to reach its site.

(3) Obstructions along the path.

(4) Abnormal bending of light rays.

On at least half of the evening during the summer, it is impossible to see a light at a distance of 25-30 miles. The presence of haze is usually detected by the brightness of the beam in front of the spotlamp or by observing settlements or other lights at known distance. If visibility is poor, no attempt is made to carry out the tests; but parties sometimes set out when visibility is good and find, by the time they have reached their sites, that it has deteriorated to the point where tests cannot be completed. If visibility is in doubt the tests are repeated on another night.

Failure of one party to reach its objective is usually indicated by lack of radio contact, although the possibility of radio failure must be borne in mind and the light tests are attempted, in any case, according to a pre-arranged schedule.

Obstructions along the path are seldom troublesome when an aircraft is used for the initial survey, since the light tests tend to confirm the aircraft results within a few feet and there is reasonable assurance before the party sets out that a path is unobstructed.

The abnormal bending of light rays has not been detected in our work although its possibility is always kept in mind. If serious disagreement were observed between the clearance values obtained by aircraft and light tests, the latter would be repeated at different times until the possibility of abnormal conditions was ruled out.

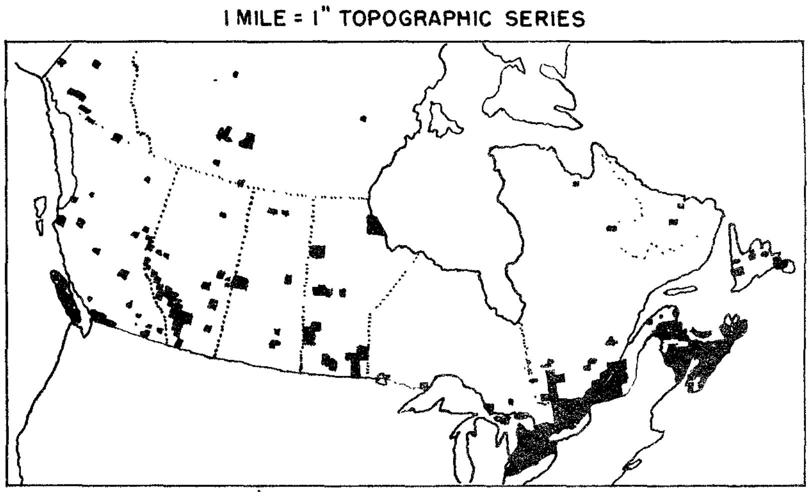

Fig. 1 - Map coverage of Canada.

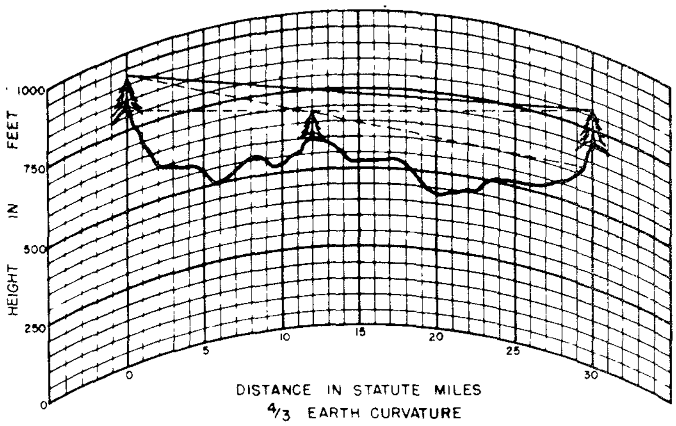

Fig. 2 - Microwave path profile

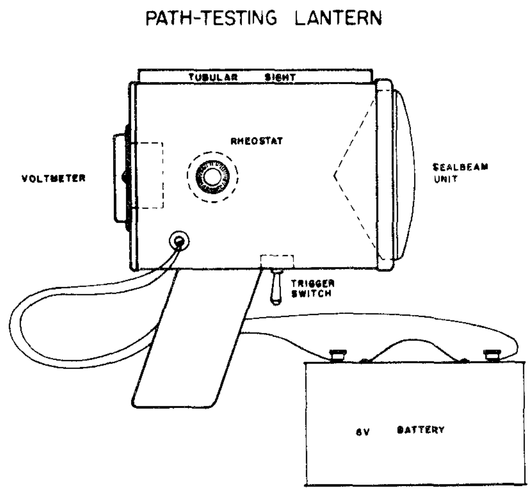

Fig. 3 - Path-testing lantern.