EARTH STATION SITE LOCATION
AN EVOLVING TECHNOLOGY

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ABSTRACT

Selection of an earth station site whether for transmission or reception of TV programming is rarely, if ever a simple process. Selection criteria such as ownership of a tract of land or colocation with existing headend or office facilities usually renders one site a very strong first choice. Conditions such as a downtown location, which render a site desirable for an office or those such as a hilltop, which are attractive for a headend generally, unfortunately, represent the worst locations for earth station facilities due to interference.

A short couple of years ago, interference effects would have negated most of the type location we are discussing. That situation is changing. As earth stations for CATV proliferate, the experience each designer encounters in solving his particular interference problem adds to the collective pool of knowledge for the benefit of the next.

LOCATION

In selecting a site location for the Warner Amex Satellite Entertainment Company Network Operations Center, numerous signal problems needed to be solved. All were. Some conventionally, others not so conventionally, using and developing methods heretofore untried. Several techniques are applicable to any site location and are treated in technical detail.

Selection criteria may be categorized as those we impose upon ourselves, such as ownership of a tract or colocation with existing facilities (offices, studios, etc.), and those largely outside of our control, which are imposed upon us by others, such as environmental impact or compatability with other frequency users in the very crowded 4 and 6GHz bands. Keep in mind, regarding the latter, as a station builder you are the newcommer and often not a very welcomed newcommer at that. Thus, you must conform to whatever conditions exist, in the spirit of community imposing minimal negative impact upon the established order. This is a wholly fair and equitable set of circumstances developed for the common good, despite what in a projects early stages seems weighted against your progress. Quite the contrary is true. The rules encourage the proliferation of new services, however, protection of existing channels (which you will become upon licensing) is a higher order of priority. Allocation or denial of frequencies will be predicted upon that. The commissions rules clearly state, when applying for transmission frequencies, your allocation must bear minimal interfering potential not only to any and all licensed existing carriers, which is fairly common knowledge, but to those not yet licensed whose application bears an earlier filing date than your own as well.

In other words, if a carrier determines that your transmissions will cause him interference, he is free to block your application. It's then incumbent upon yourself to either withdraw your application, (and find another site), or prove to the objecting carrier (with the F.C.C. as arbiter) that he can (or must) live with your signal. Too often an applicant will choose the former and abandon a site based upon an objection without further argument. This is unfortunate since in virtually all instances, many objections can be cleared through site engineering during the prior coordination stage of an application. Keep in mind, since your route is only proposed and not yet existing, the carriers objections are not measured, witnessed phenomena but only postulations. And at that, are calculated against a set of worst case parameters.

Optimizing your own calculations, and modifying the physical properties of your site can yield surprising results. How extensive this activity will be depends, of course, upon the desirability of the site. In the course of coordinating a Smithtown, Long Island location for Warner Amex Network Operations Center no fewer than 66 objections were posed, and ultimately cleared. What's more, this level of determination has become common practice. One year ago not a single transmitting video earth station existed within 35 miles of New York City. By late '82 there will be no fewer than ten operational or under construction. It's a safe assumption that all faced large numbers of objections, and obviously resolved them. These resolutions may take many not readily apparent forms, for example assume you've filed for transmitter facilities and encountered objections something not so commonly known is having satisfied the commissions criteria, no existing or future carrier may object to your application, and if it is shown that you indeed will impose objectionable interference to existing facilities, you may learn that the responsibility for eliminating the interference, surprisingly, rests not with you, but with the carrier who is being interfered with!

Consider that no efficiently engineered system utilizes more sophisticated (i.e., expensive) antennas than necessary. In the case of the common carriers, when most routes were built, satellite communication was not sufficiently developed to constitute a significant interference source. Consequently, and prudently, antenna systems installed by common carriers prior to 1978 were often of a type providing high gain and low wind loading, but poor off axis discrimination. The familiar periscope antenna is one example of such a system.

The commission in what must be considered extraordinary foresight, provided in the rules that such antenna systems would be permitted until such time as they inhibited future communications systems growth. (By being interfered with by those future systems), at which time the effected carrier must upgrade the system, or accept the potential interference and not impede the interference application! But, don't expect the affected carrier to volunteer this sort of information. You must go to the rules, and in such matters a good communications attorney in concert with a frequency coordination firm is a valuable resource. But beyond these legal and negotiable actions, the most effective and self determined measures one can take are the scientific.

It's axiomatic in designing satellite earth station facilities that, if it works in terrestrial systems, do the opposite in a satellite system. (i.e. put a tower on a hill; put an earth station in a hole.) The extent of this simple philosophy is very surprising. All of those physical obstacles which were so troublesome when path profiling microwave links and those properties of electromagnetic waves which conspired to make point to point reliability seem unachievable, will almost without exception work to the advantage of the satellite system planner.

SOME BASIC EXAMPLES

Shielding both natural and man-made has been shown to be a highly effective method of eliminating interference. Microwaves do not substantially penetrate mineral substances and are virtually devoid of ground wave components. Thus, fences, walls, buildings or earthen mounds can serve as highly effective shields when located between interference source and receiver. When a carrier objects to your application, the objection is generally a computer spit out based upon a flat earth model. Careful examination of USGS contour maps and great circle calculations will go far in reducing interference impact. After a tentative site has been selected and interference sources identified, a path profile may be undertaken. The objective being to determine the extent of terrain shielding existing between your site and the interference source(s). In the case of transmitting earth station interference is both received and generated. Given antenna reciprocity theory, however, both may be handled similarly. A path profile is best plotted on rectilinear graph paper with obstacle information taken from USGS topographical charts of 1:7500 scale. Draw straight lines on the topos between your site and the interference sites, identify obstacle elevations between them and transfer this data to the graph paper in the 'y' axis.

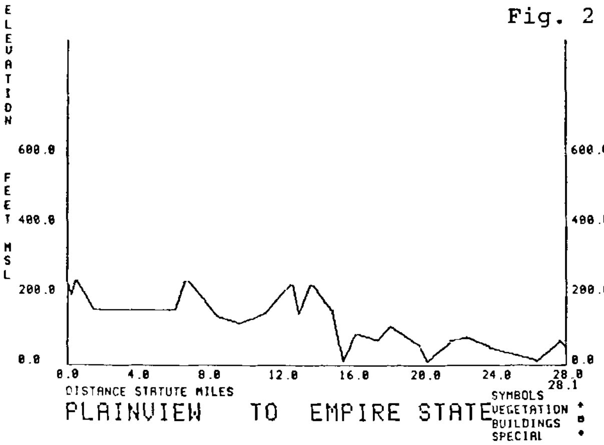


Fig. 2

Mark the midpoint between the two objects. This is maximum earth bulge and should be considered an obstacle. Transposing all major vertical elevations from the contour map to the 'y' axis graph sheets will yield a vivid representation of your line of site situation. Earth curvature (bulge) should be added to each obstacle height as it effectively raises those obstacles higher into the path. Earth bulge (h) may be calculated as follows:

$$h = 0.677\ (d_1 d_2)$$

where: (1)

d_1 = distance from near end of interference path to obstacle.

d_2 = distance from far end of interference link to obstacle.

Determination of actual relative obstacle heights is probably the single most important factor under the control of the designer as it will affect a parameter known as "takeoff angle" between the interference site and the candidate site. Every degree of takeoff angle we build into our model will contribute about 12dB of attenuation between interference source and sink, and can be controlled to considerable degree by site engineering.

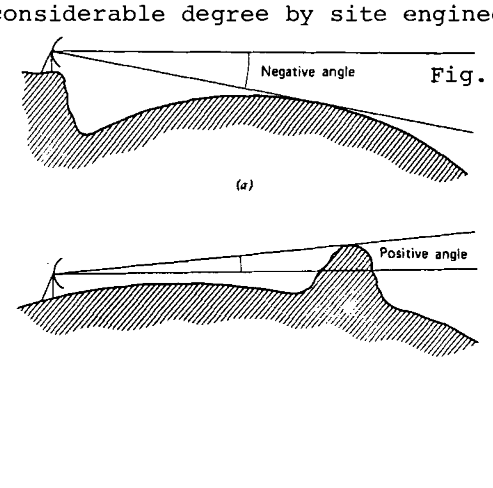


Fig. 3

DIFFRACTION & REFRACTION

Radio waves travelling through the atmosphere do not follow true straight lines, even at microwave frequencies, they are actually refracted, or bent. More importantly, they may also be diffracted. In designing the Warner Amex Smithtown site the phenomenon of ray diffraction was applied extensively. To make the equation for earth bulge (Eq-1) more effective, it may be modified to include the effects of departure from straight line propagation, which is assumed in (Eq-1).

Refraction

Refraction may cause a transmitted wave to be "bent" toward or away from the earth. If it is bent away from the earth, it is effectively the same as if earth bulge were increased. The effects of refraction may be determined mathematically through the inclusion of a K factor to (Eq-1) as follows:

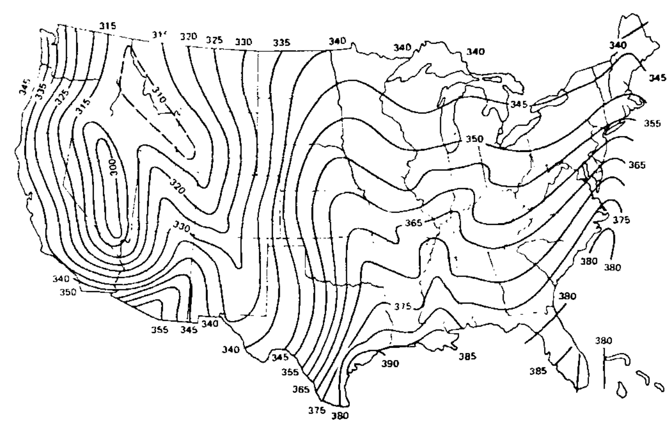
$$d(\text{ft}) = \frac{0.667\ d_1 d_2}{K}$$

where: (2)

$d_1 d_2$ are expressed in miles

$$K = \frac{\text{effective earth radius}}{\text{true earth radius}}$$

The standard K factor is 4/3 and as such, will yield negative results in most cases. This should not, however, be accepted carte blanche when optimizing a candidate site. Refer to the sea level refractivity chart below.

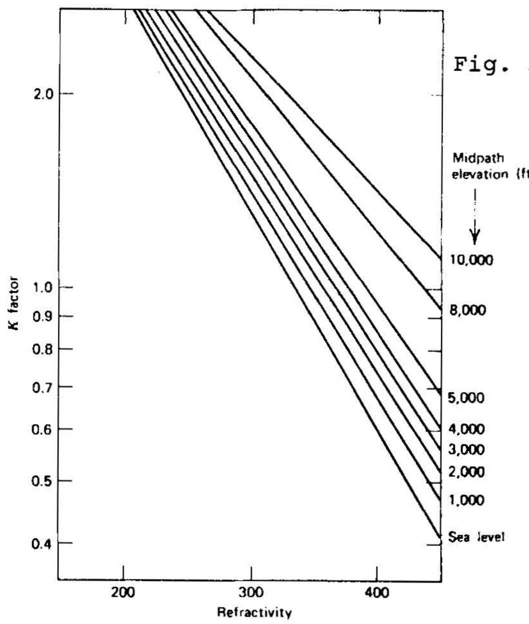


Sea level refractivity (N_o) index for the continental United States—maximum for worst month (August).

Fig. 4

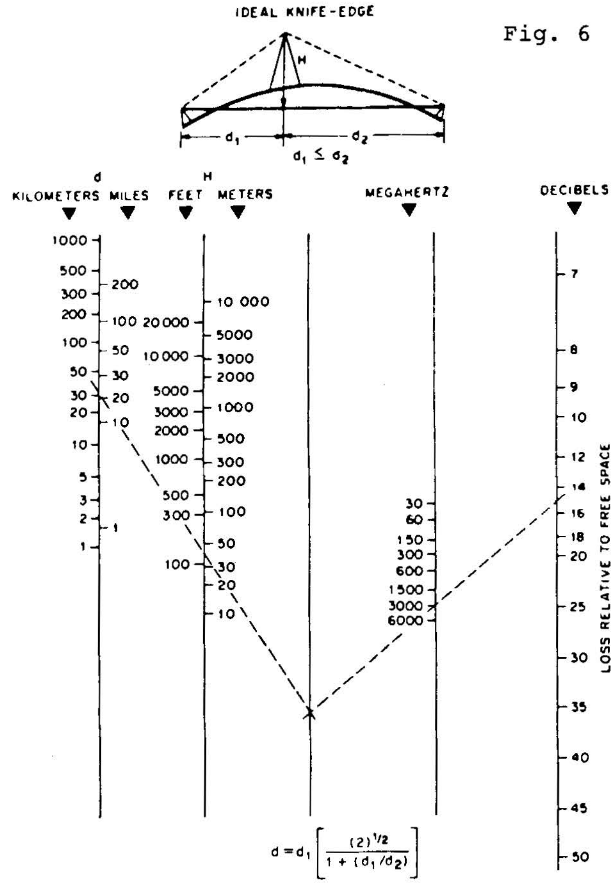
Find the refractivity index for the area of interest. Apply this to the chart of Figure (5) to determine K factor, and subsequent effect upon midpath earth bulge. As can be seen, for K factors of less than 1, a significant improvement in terrain blockage can be achieved.

Fig. 5



K factor scaled for midpath elevation above mean sea level.

Fig. 6



Diffraction

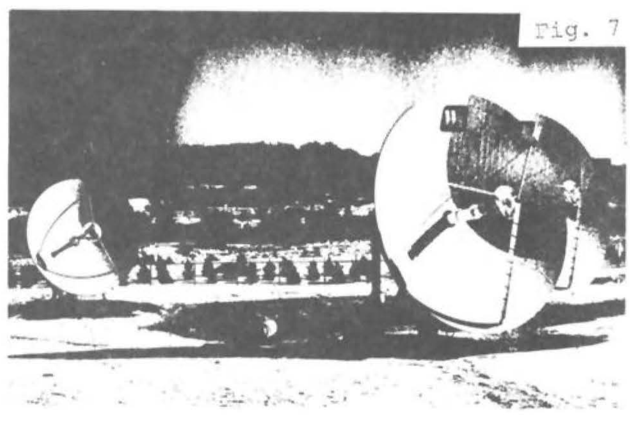
The other factor which must be added to obstacle height when optimizing shielding pertains to the effects of diffraction. A wave front exhibits expanding properties as it travels through space. These result in phase transitions and reflections as the expanding wavefront passes over obstacles.

As with refraction these properties, known as fresnel effect, result in increases or decreases in signal strength, relative to free space propagation. The graph of figure (6) approximates the diffraction effect to a propigating wave when fresnel clearance is disrupted by an obstacle. In this case, an ideal knife edge. First fresnel zone clearance may be estimated by the formula:

$$R = \frac{13.58\sqrt{\lambda d_1 d_2}}{D} \qquad (3)$$

where λ = wavelength of signal (ft)
d_1 = distance from transmitter to path obstacle (statute mi)
d_2 = distance from path obstacle to receiver (statute mi)
$D = d_1 + d_2$ (total path length in statute mi)

If fresnel zone clearance is not present between your antenna centerline and that of the interference facility some diffraction loss exists, and may be considered in your optimal model. Surprisingly effective results may be obtained by deliberate injection of diffracting apparatus into the interference path. These may take the very substantial form of an earthen mound or be as simple as metal fencing, properly placed. In the case of a new building facility, such as Warner Amex at Smithtown, interactive location of antennas



and building contributed a diffraction. When coupled with terrain modification and diffraction fencing all of which are minimally visible figure (7) resulted in diffraction losses in excess of -60dB to interfering signals.

Contrary to advice that the site was not clearable and using the above mentioned techniques it was determined that a strong possibility of natural and artificial interference attenuation could be brought to bear at this site. Once this evidence was gathered three days were spent by both myself and the building architect at Compucons computer in Dallas. Various combinations of building size, location, and elevation were tried and fed to the computer along with antenna locations and elevations in an effort to achieve optimum diffraction losses. After what seemed inumerable postulations and the application of an unorthodox double diffraction fence atop the building, (not visible) the right combination was found and ultimately cleared the site to the satisfaction of all carriers and the commission.

CONCLUSION

We've discussed one aspect of a very large project, the successful completion of which was an industry first.

Two factors were above all responsible for that success. The skill and resources of the Compucon Corporation, whose willingness to apply unorthodox techniques in a sustained effort, finally worked. And, the complete design freedom enjoyed under a very courageous and farsighted management at Warner Amex Satellite Entertainment Company.

REFERENCES

1. Roger L. Freeman, Telecommunication Transmission Handbook, John Wiley & Sons, New York

2. Howard W. Sams, I.T.T. Reference Data for Radio Engineers, 6th Edition.