ECONOMIC AND TECHNICAL ASPECTS OF A PROPOSED TELEVISION SYSTEM FOR FINLAND

by

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INTRODUCTION

Television is the most recent development in the general field of radio broadcasting. Furthermore, for both educational and entertainment purposes, it now appears that television is destined to be of even more importance than radio broadcasting. The idea of sending pictures, either still or moving, by radio is not new, but not until just before the second World War had the state of the television art reached a developmental level which was adequate for general use.

Regular, officially approved, television broadcasting having high definition had started before the war in England in 1936 and the United States in 1941. The war curtailed television development but after the war a large expansion occurred especially in the United States. Within four years ninety-five new television broadcasting stations were in operation in the United States and the number of sets in use was about four million. Because of many complaints concerning interference and for similar reasons, the Federal Communications Commission in the fall of 1948 discontinued granting construction permits for new stations, thus slowing the expansion in the United States. But, in spite of this, the number of sets kept increasing, totaling at present (1952) about sixteen million sets in use, which means about 56 per cent average saturation in the market areas, or 35 per cent average saturation considering the whole country. These figures are based on the number of families rather than on the number of individual persons.

Simultaneously, television spread in England. Because of the high population density in England and the noncommercial operation, only high-power stations are used, three such stations being in operation at present. The total number of receiving sets in England is about 1.2 million, which corresponds to about 9 per cent average saturation based on the number of families in the country.

Outside of these two countries there is no large scale activity. Some North and South American and European countries have started public television service having a few stations in operation, but the number of sets is less than a hundred thousand in each country.

There are several reasons for the slower progress in these countries. Probably the most important has been the cost of television. The cost of equipment is considerably higher than that of regular AM and FM radio-broadcast equipment, but the most severe problem is the high cost of programming. This is especially serious for those small countries which have low population density and different languages.

Another important factor in retarding television expansion outside the United States and England has been the achievements of television research. This has improved the quality of the service and reduced costs. Also, the possibilities of color television has affected television expansion. Many countries have been waiting for television to settle to at least a semi-permanent level. This is necessary to enable them to develop systems which would not soon be obsolete. Extensive studies have been made in the United States, England, France, Netherlands, Switzerland, and other countries, to decide the details of the systems to be used. Conferences have been held for the purpose of determining international television standards.

During the past few years the economy of the countries has improved noticeably and the agreement on regional standards seems to be attainable in the near future. It has therefore become feasible, and even advisable, to make economic and technical investigations of the local circumstances of a given country, and to determine if a television broadcasting system should be built. Such a study has been made for the country of Finland, and the details of the investigation, and recommendations, are reported in this thesis.

This investigation consisted of the following major parts: television standards, population coverage, technical and economical study of network elements, network systems, and as conclusions, recommendations for a proposed television system and suggestions for its gradual expansion.

The first subject, television standards, must be considered because a large group of people is concerned. When an isolated system of any type is to be built, the standards to be used can be decided at will by the designer. When a system of television is to be designed, however, isolation does not exist. Large numbers of people, and various separate countries, often are involved. Thus, the basic principles, and to some extent certain details, must be agreed on by the groups concerned. For such reasons television standards must be developed through international cooperation.

The study of population coverage contains investigations of factors which determine the audiences which can be served with television. These factors include consideration of the transmitting power to be used, a study of methods used to determine wave propagation at the frequencies in question, the reliability of these methods, and investigations of population distribution in Finland.

The technical study of network elements comprises the consideration of equipment necessary, or sometimes used, in television broadcasting. This includes layouts of the principal units of a television system which are the transmitting stations and studios. These layouts lead to a study of the economics of the subject.

After a consideration of the principles involved in estimating prices and operating expenses, the prices of equipment and accessories were determined. From these the most economical and logical network units were derived, and finally, programming costs were estimated.

The last study consists of an investigation of two different economic principles applied to television broadcasting system development. Based on this study a television system for Finland is proposed. The proposal includes development of the network, expected coverage, estimated cost, and possible method of financing the project.

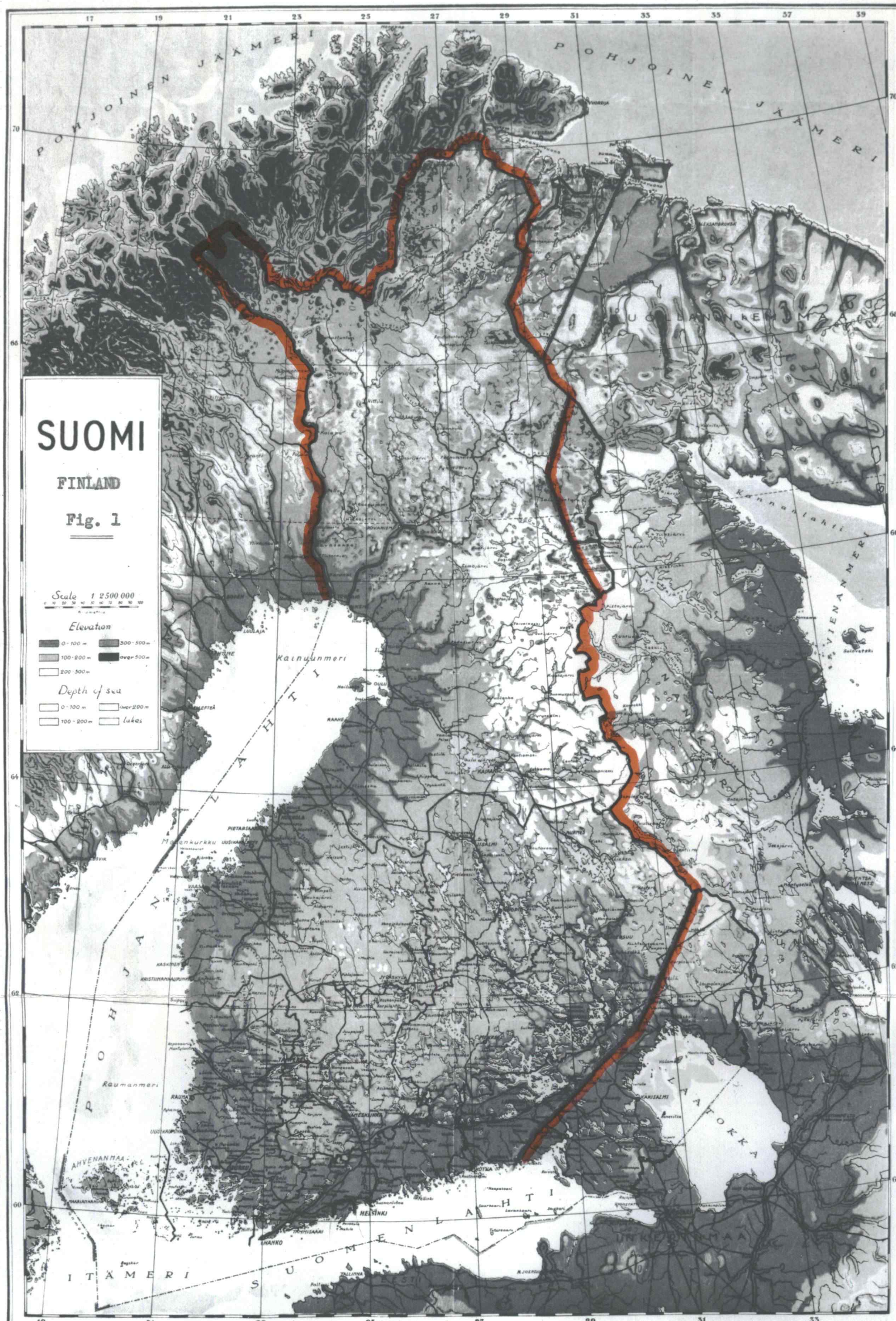
CHARACTERISTICS OF FINLAND CONCERNING TELEVISION

Geography

Finland lies between latitudes 60 and 70 degrees north and longitudes 19 and 33 degrees east from Greenwich. The length of the country is about 700 miles and the maximum width is approximately 350 miles.

The most important factor concerning television service is the topography of the country. In that respect Finland is relatively flat, as shown in Figure 1. Near the coast the elevation of the ground increases practically uniformly from sea level to about 100 meters or 330 feet over a distance of about 30 to 60 miles inland from the coast. This is good farming country. The average elevation of the rest of the South Finland varies between 80 and 130 meters, or 260 and 425 feet. This part has many lakes and forest covered gravel hills, the heights of which are about 100 to 200 feet above average terrain, the highest ones reaching 350 to 400 feet. Southern Finland resembles the state of Minnesota in the United States as far as topography is concerned.

Northern Finland, however, has somewhat higher elevation. The average elevation is around 200 meters above sea level, or about 650 feet, and the hills rise 600 to 1000 feet above average elevation, some of them even up to 2500 feet. The highest elevation in Finland is 4340 feet. There are practically no steep slopes, even low hills may be several miles wide and most of them are covered by forests.


SUOMI
FINLAND
Fig. 1
Scale 1 2 500 000
Elevation
0-100 m
100-200 m
200-300 m
300-500 m
over 500 m
Depth of sea
0-100 m
100-200 m
over 200 m
lakes
POHJOINEN JÄÄMERI
Kainuunmeri
Merenkurkku
POHJANLAHTI
Raumanmeri
AHVENANMAA
SUOMENLAHTI
ITÄMERI
LAATOKKA
VIENANMERI
Kannanlahti
HELSINKI

Since practically all the people live in Southern Finland, which has only low hills, the topography of the country is very favorable for television service as far as wave propagation is concerned. This statement applies particularly to the television bands at ultra-high frequencies of several hundred megacycles at which the coverage radius is essentially determined by line of sight. A disadvantage of this flat terrain is the difficulty of finding good sites for television stations, since the transmitting antenna should be located as high as possible to increase coverage radius. Forests, which cover about 70 per cent of the country, increase the attenuation of the waves of course, but within the line of sight this attenuation is not appreciable. The high attenuation beyond the line of sight caused by the curvature of the earth is so great that the additional attenuation because of the forests is negligible. The shadow effects of the forests are not too serious, since the trees are fairly low, around 30 to 50 feet high.

Since the weather imposes certain requirements on the equipment used, a few words will be said about it. Because of the location of Finland between the same parallels of latitude as Alaska, the climate of Finland is similar to that of Alaska at equal elevations. The average annual temperature in Finland is about 35°F, the warmest month is July and averages about 60°F, and the coldest is February averaging about 17.5°F. The highest temperature is about 85°F to 95°F, and the lowest is about -40°F, although sometimes in the northern part it falls to -60°F. The average rainfall is 21.5 inches a year and is fairly evenly distributed as to time and place. The maximum monthly average in the fall is about twice the minimum average in the spring. Maximum snow cover is in March, averaging about 26 inches. Sleet storms are very unusual.

Population Distribution

The area of Finland is approximately 130,000 square miles, or about 17 per cent less than that of California. However, the population of Finland is only approximately 4,076,000 (34, p.18) which gives an average population density of 31.4 persons per square mile, or less than half of that of California.

From the standpoint of population density, Finland can be divided in two major parts, North and South Finland. Over 96 per cent of the total population is south of the 66 degree north parallel, and furthermore about 89 per cent is south of the 64 degree north parallel. This means that north of the 64 degree north parallel the average population density is only about 2.7 persons per square kilometer or about 7.0 persons per square mile, and that south of the 64 degree north parallel the density is about 20.6 persons per square kilometer or about 53.0 persons per square mile. As shown in Figure 2, Finland does not have numerous large cities, which means that the population density in the rural areas is fairly high.

The largest city is the capital, Helsinki, on the southern coast, the population being about 400,000. Next are Turku in southwest corner of Finland, and Tampere about 160 kilometers north and west of

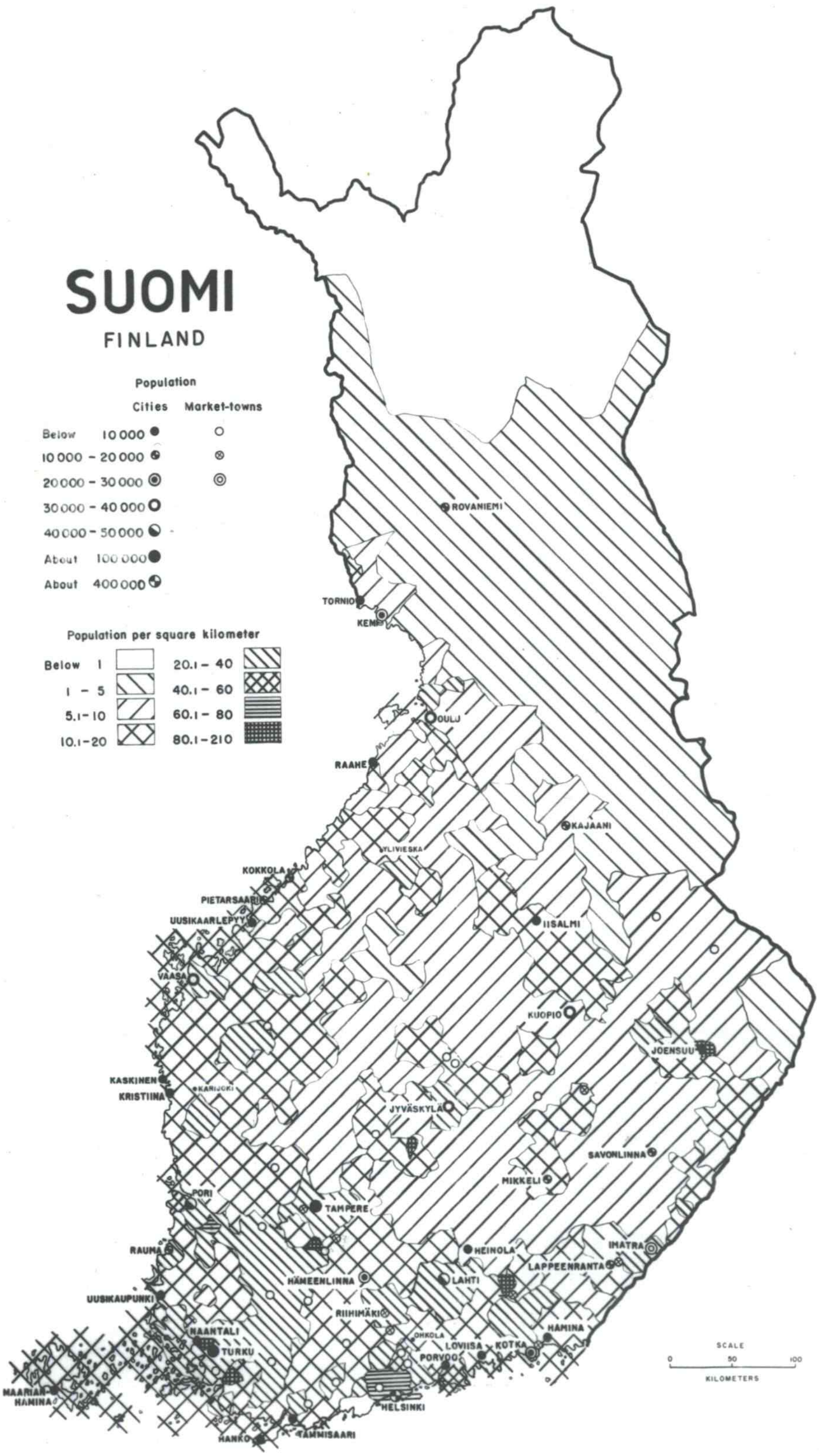


Fig. 2 Population distribution in Finland

Helsinki. Each of these cities has slightly over 100,000 inhabitants. Lahti, approximately 100 kilometers to the north and east of Helsinki, and Pori, west from Tampere on the coast, each has about 45,000 inhabitants. Four cities, Oulu, Vaasa, Kuopio, and Jyväskylä, each has a population between 40,000 and 30,000 persons.

The highest population densities in the rural areas of Finland are on the coasts, especially on the southern and the southwestern coasts. In these areas the density is 25 to 100 persons per square mile, reaching even 200 persons per square mile in some communes. A commune is the smallest area in Finland having local government. The middle part of South Finland has 13 to 50 inhabitants per square mile, some areas having even 100, a few up to 200. Figure 2 shows population densities by communes, although the figures are per square kilometer since Finland uses the metric system.

As a whole, Southern Finland is fairly evenly populated, which imposes difficulties, if large television audiences are to be served. To serve a large audience in this region, either many low-power stations or a few very high-power station must be used.

Customs and Traditions

The Finnish people as a whole may be considered quiet, deliberate, and conservative. Because of these characteristics, they prefer radio programming to be more serious than do Americans. In the present regular AM broadcasting, for instance, about 66 per cent of the music is so-called "light music," which means such programs as classical and semi-classical orchestra or band music, vocal or instrumental solos, light operas, and folk music. About 30 per cent is concert music, orchestra music, solos, symphonies, and operas, and only about 4 per cent is dance music (37, p.16). About 58 per cent of the program time is devoted to music as just described. The remaining time is devoted to material such as talks and dramas of educational and cultural nature. In other words, Finnish people like a program that is different from the type produced in the United States.

For this same reason noncommercial operation of the broadcasting system is also preferred, since the program then does not contain advertising or similar interruptions. This noncommercial operation also enables better program planning as a whole. Most Finnish people, who have had an opportunity to listen to the commercial type of program, have expressed this opinion.

The conservative nature of the Finnish people, and their culture and traditions, have an important effect on their radio broadcasting buildings and facilities. As in the whole of North Europe, in Finland the people make their cities and communities attractive and keep them clean. This brings about, for instance, very strict critique and requirements for the architecture of buildings. Especially, public buildings including post offices, railroad stations, city office buildings, churches, buildings for radio broadcasting purposes, etc., have to look distinguished.

Circumstances and experience have taught the Finnish people to obtain articles of high quality and accordingly of high price and to obtain long time service from them. This can be seen from the radios, for instance. Although the AM broadcasting radio family saturation in Finland at present is fairly high, approximately 80 per cent, there seldom is more than one radio in a family. On the other hand, the so-called "cheap" radio receiver seldom is used. Even the poorest people, when they buy a radio, buy medium or high class sets ($100 to $200), usually big wooden table models with three receiving bands are preferred. Cabinet-type radios are not numerous and small "bakelite" radios are rare.

Economy

Finland had the best economic situation in 1938, but during the second World War the decrease of production, because of total mobilization and lack of materials caused rapid lowering in living standards. After the war an industrial expansion began, especially in the metal industry, but living standards stayed low for several years, mainly because of heavy war reparation payments to Russia. Then Russia extended the payment time from six to eight years, this year (1952) being the last one. Together with industrial expansion this extension of time decreased the economic pressure considerably, enabling forward progress and an increase in living standards. The prewar level, when goods were available at reasonable prices, will be reached in the very near future, according to the progress at present.

The financing of the present AM radio broadcasting system and service in Finland is done completely by radio listeners. Every family, which has a radio or several radios usable for receiving radio broadcasting in one residence, must buy a license annually. The license fee is approximately $5.00 per year. The total income of these fees, reduced by the collecting expenses, is made available to the Finnish Broadcasting Company, which has a monopoly in radio broadcasting. With this income the Finnish Broadcasting Company supports both the broadcasting network and the programming. The Company is supposed to be nonprofitable, but the practice is, however, that all expansions of the facilities are included in the same budget, thus being paid for by the listeners, which means that expansion of capital investment in reality is a net income for the Company.

STANDARDS

Definitions

New terms are encountered in television. Some of these, which are neither familiar from other radio services nor self-explanatory, are defined in this section. Many of these standards are based on television practices in the United States (11, pp.5-7).

Antenna field gain. The term "antenna field gain" of a television antenna means the ratio of the effective free space field intensity produced at one mile in the plane of polarization expressed in millivolts per meter for one kilowatt antenna input power to a field intensity of 137.6 millivolts per meter.

Antenna height above average terrain. The term "antenna height above average terrain" means the average of the antenna heights above each point of the terrain within grade A service area.

Aspect ratio. The term "aspect ratio" means the numerical ratio of the frame width to frame height, as transmitted.

Black level. The term "black level" means the amplitude of the modulating signal corresponding to the scanning of a black area in the transmitted picture.

Compatible system. The term "compatible (color) system" means a color system, the transmission of which can be received by a black and white system.

Effective radiated power (ERP). The term "effective radiated power" means either the product of the antenna power times the antenna power gain, or the product of the antenna power times the antenna field strength gain squared.

Field frequency. The term "field frequency" means the number of times per second the frame area is fractionally scanned in the interlaced scanning.

Frame. The term "frame" means one complete picture.

Frame frequency. The term "frame frequency" means the number of times per second the picture area is completely scanned.

Grade A service. The term "Grade A service" means a service, the quality of which is acceptable to the average observer and is expected to be available for at least 90 per cent of the time at the best 70 per cent of receiver locations.

Grade B service. The term "Grade B service" means a service, the quality of which is acceptable to the average observer and is expected to be available for at least 90 per cent of the time at the best 50 per cent of receiver locations.

Interlaced scanning. The term "interlaced scanning" means a scanning process in which successively scanned lines are spaced an integral number of line widths, and in which the adjacent lines are scanned during successive cycles of the field frequency scanning.

Negative transmission. The term "negative transmission" means that a decrease in light intensity causes an increase in the transmitted power.

Positive transmission. The term "positive transmission" means that an increase in light intensity causes an increase in the transmitted power.

Progressive scanning. The term "progressive scanning" means a scanning process in which scanning lines trace one dimension substantially parallel to a side of the frame and in which successively traced lines are adjacent.

Radio relay. The term "radio relay" means the radio equipment for the transmission of a television signal from one location to another.

Scanning. The term "scanning" means the process of analyzing successively, according to a predetermined method, the light values of picture elements constituting the total picture area.

Scanning line. The term "scanning line" means a single continuous narrow strip containing highlights, shadows, and halftones which is determined by the process of scanning.

Standard television signal. The term "standard television signal" means a signal which conforms with the television transmission standards.

Television transmission standards. The term "television transmission standards" means the standards which determine the characteristics of the television signal as radiated by a television broadcast station.

Vestigial sideband transmission. The term "vestigial sideband transmission" means a system of transmission wherein one of the generated sidebands is partially attenuated at the transmitter and radiated only in part.

Video. The term "video" means a signal, which contains picture information and is obtained by scanning method.

Video bandwidth. The term "video bandwidth" means the bandwidth necessary for transmission of video signal.

Visual frequency. The term "visual frequency" means the frequency of the signal resulting from television scanning.

Visual transmitter power. The term "visual transmitter power" means the peak power output when transmitting a standard television signal.

Operation Standards

To handle international questions, determine standards, and for other similar purposes, the International Radio Consultative Committee (C.C.I.R.) was founded. The fifth Plenary Assembly of C.C.I.R. in Stockholm in 1948, decided to establish Study Group No. 11, which would deal with the television standards and some associated questions.

The Study Group has held one meeting in Zürich, July 4 to 14, 1949, and another meeting in London, May 8 to 12, 1950. This last meeting followed studies made in England, France, the Netherlands, and the United States, March 27 to May 5, 1950. A sub-group, Sub-Group Gerber, of the Study Group held one meeting in Geneva, July 24 to 28, 1950. These Study Group meetings prepared recommendations on subjects, which they agreed upon, and referred these recommendations to the sixth Plenary Assembly of C.C.I.R. in Geneva, June 4 to July 6, 1951. The Plenary Assembly adopted all the recommendations (25, p.24). These were as follows:

1. The standard operation of a television system shall be independent of the frequency of the power supply source (18, p.4).

All television systems, which are in operation at present, are synchronized with the power frequency. This makes synchronizing easier and avoids the distortion of the picture due to hum in plate voltage sources. However, if transmitter and receiver are connected to different power sources, which are not synchronized, this will cause difficulties, because of drifting of power frequencies compared to each other. Still more serious is the situation if the power supply systems have different frequencies. Thus tying the television systems to power frequencies would make international program exchange and nationwide program distribution difficult. Since the study of the additional cost of equipment capable to operate independently of the frequency of the power supply system showed that the increase was less than 2 per cent, the Plenary Assembly adopted this type of operation.

2. The standard aspect ratio of the transmitted television picture shall be 4 units horizontally to 3 units vertically (18, p.4).

Before Study Group 11 started its work, the aspect ratio 4 to 3 was used in television service in all countries but England, which had the ratio 5 to 4. The motion picture industry has been using approximately the ratio 4 to 3. Since the ratio 4 to 3 is more convenient, and it also has been more widely used than 5 to 4 ratio, unanimous agreement was achieved immediately, England also voting favorably.

3. Line interlacing shall be used in the ratio two to one (18, p.4).

The reason for using line interlacing is that it decreases the large-area flicker without additional bandwidth. For this reason the interlacing ratio should be as large as possible, but if interlacing ratio is larger than 3 to 1, the small-area flicker will become more annoying than large-area flicker. If a ratio 3 to 1 were to be used, the lines would seem to move and the so-called "line crawl" would appear. Thus the best compromise is to use an interlacing ratio of 2 to 1.

4. It shall be standard in vision transmission to use asymmetric sideband characteristics (18, p.4).

Since one sideband contains all the required information regarding the picture to be transmitted, it would be a waste of bandwidth to transmit both sidebands. On the other hand, for practical reasons complete suppression of one sideband would have an effect on the other sideband and also on the carrier. Therefore, a compromise, so-called vestigial sideband transmission, has been developed. As the name implies, part of the other sideband is transmitted also. In this way a saving in bandwidth and technically reasonable result have been accomplished. Figure 3 shows an ideal transmitter characteristic. When this is used with receiver characteristic shown in Figure 4, the final video output of the television receiver is linear.

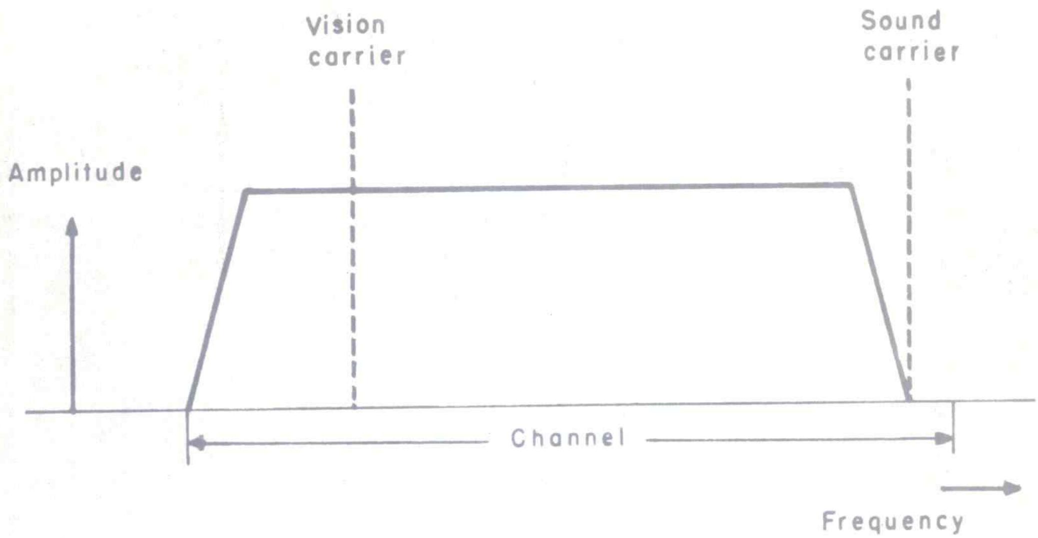


Fig. 3 Ideal vision transmitter characteristic

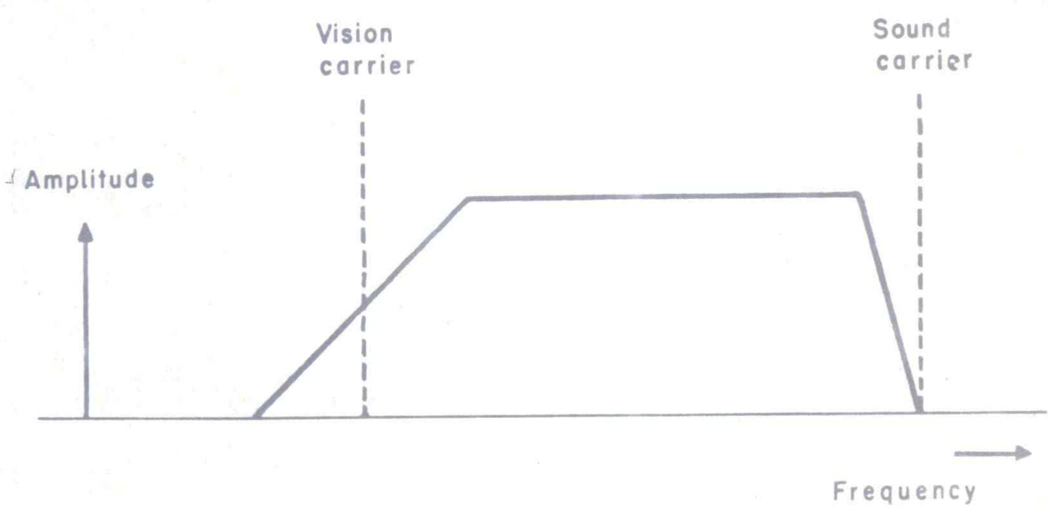


Fig. 4 Ideal vision receiver characteristic

5. There is no necessity to standardize the polarization of the radio transmission (18, p.4).

There is no appreciable difference in propagation characteristics between horizontally and vertically polarized waves at the frequencies used for television service. Thus standardizing would cause only slight saving in equipment cost. If the selection of polarization is optional, this selection can be used to avoid possible interference between stations, because stations located close together and operating on the same or adjacent frequencies can choose different directions of polarization for transmission.

In addition to these five recommendations the sixth Plenary Assembly unanimously agreed upon the following standards (25, p.24):

6. Directions of scanning.
7. Amplitude modulation of vision carrier.
8. Receiver attenuation of vision carrier.
9. Full amplitude of transmitter vision carrier.
10. Spacing of sound and vision carriers from channel edges.
11. Attenuation of vision sidebands at edge of channel.
12. Black level independent of picture content.

These standards did not encounter controversy. The exact wording of these adopted standards is published in Volume I of the final documents of the sixth Plenary Assembly of the C.C.I.R., Geneva, 1951.

The Study Group 11 and its sub-group had studied numerous other television standards, but neither they nor the sixth Plenary Assembly could agree upon them. These standards, which are the objects for further study by Study Group 11, are at present the standards about which the different countries have conflicting opinions. The opinions may differ as to what constitutes good television quality. Also, some countries have to consider their previous investments in television, in case adopted standards would differ considerably from those used in the country at present. The standards not agreed upon are as follows:

13. Number of lines per picture.

The number of scanning lines per picture determines the vertical resolution of the television image. When the first test scannings of television pictures were made with Nipkow's mechanical scanning disc, the number of lines was only about 20. This allowed but the same 20 "dots" or that many different shades of gray in the vertical direction. To increase the picture quality the number of lines was gradually increased up to 180 lines per picture. This was considered the minimum usable number of lines, but on the other hand it was about the maximum possible by mechanical disc scanning methods. Thus this number of lines was employed in some experimental television stations, and when using about the same resolution in the horizontal direction, the number of transmitted picture elements was approximately 40,000. Since 8-millimeter home moving pictures have about 50,000 elements, the television picture was somewhat inferior to home movies.

The development of electronic scanning systems made possible the use of a higher number of lines, about 240 in the beginning. The advantages of line interlacing introduced the "odd-line" principle, which was commonly accepted. One of the first odd-line numbers used was 343, but the desire toward greater definition required a still higher number of lines.

When determining the scanning standards, including the number of lines, the basic question is the number of elements required for a picture of acceptable quality.

If only quality were considered, the number of picture elements should be approximately 2 million, since this would enable one to examine the picture closely without noticing any "grain" structure in the picture. A 2-million dot television picture would have approximately the same quality as a high quality 8- by 10-inch printed photo engraving. A 1-million dot picture would correspond approximately to the 35-millimeter film quality as projected in professional theaters. If viewed from a distance of approximately 3 times the height of picture or farther, this would give detail sufficiently high for even long shots, like pictures of scenery or of a baseball game. The 200,000-dot picture is about equivalent of the average 16-millimeter home movie. Such a picture has satisfactory resolution for close-ups and medium shots, but for long shots the resolution may be insufficient. For a baseball game such resolution would hardly show more than the outline of players. Viewing distance should be at least four times the height of picture if grain structure is not to be bothersome. As mentioned before, 8-millimeter film has the equivalent of about 50,000 elements in the picture. This is hardly enough for more than close-up work, or at most for short flashes of scenes at moderate distances.

When vertical and horizontal resolution are assumed equal, and when the so-called scanning line factor is 0.75, the active scanning line percentage is 95, and the aspect ratio is 4 to 3, then the number of television lines per picture corresponding to these different picture element numbers can be computed. The results are approximately as follows:

2,000,000	elements	1700	lines
1,000,000	"	1200	"
250,000	"	610	"
200,000	"	540	"
50,000	"	270	"

This shows, that a 525-line picture, as is used at present in the United States for black and white television, corresponds approximately to average 16-millimeter home movies, as far as numerical resolution is concerned. This does not take into account certain other characteristics; for example, if line structure is apparent it is more annoying than if dot structure is visible.

Thus to improve the quality of the television picture, it is justified to select a high number of lines per frame, perhaps up to 2000, but on the other hand equipment cost rises and the bandwidth required increases as the square of the line number, if other factors are held constant. Thus, if the number of lines per frame is high, the bandwidth required by a television channel is great. This necessitates that the channel be located at very-high or ultra-high frequencies (perhaps 300 to 500 megacycles) where the required bandwidth is available. These requirements make compromise necessary.

Before the second World War, the biggest difficulty was the equipment available. The television equipment which was available for wide frequency bands and for very-high frequencies was inefficient and expensive. Since it was possible to find frequency bands at very-high and ultra-high frequencies to use for television service, each country used as high a number of lines per frame as they considered obtainable with reasonable equipment cost. England set the first standards of television for public service in 1936, and the lines per framewere 405. Next, the German standard was determined to be 441 lines. The Federal Communications Commission ruled 525 lines per frame as a standard for the United States in 1941.

The rapid development of electronic equipment during the war decreased television equipment considerations when choosing the number of lines. The question of frequency band availability has become serious. Probably because of this lack of channels the United States is going to keep 525 lines as the standard. But many countries where the channel question is not that critical (because of centralized governmental broadcasting systems, for instance) are seeking higher picture quality. France has advanced furtherest by introducing an 819-line system for public use and having two such television broadcasting stations on the air. The resolution in 819-line system is about 55 per cent higher than that of 525-line system, and it has about 2.5 times as many picture elements per frame. Experimental systems have been built using still higher line numbers, at least up to 1029 lines per frame.

It would be advantageous to have at least regional standards in Europe although it is not an absolute necessity. Television equipment would cost less especially the receiving sets. Another advantage would be an easier exchange of programs between countries, even though it can be done from one system to another using special equipment. If such international or regional standards are ever agreed upon, it is recommended that one of the best of the present systems be used. Or, if this is not feasible, then it is recommended that a new system which has real substantial advantages be developed. In any case it should be as high a definition system as available frequency bands will allow, since that is probably a more serious limitation than any equipment difficulty. The noncommercial type of operation of broadcasting service in Europe does not require so many channels as does commercial operation as in the United States.

Therefore, if worldwide bandwidth standards are not possible or advisable as yet, the European countries could use wider frequency channels, maybe 2, 3, or even 4 times as wide as used in the United States. Thus a television system for Finland having about 1000 lines per frame would be recommended, 819 or possibly 1029 lines per frame would be suitable. Even using that many lines per picture would allow enough channels, when using very-high and ultra-high frequency transmission bands, and on the other hand the band would be wide enough for good quality.

There are methods to improve the quality of the picture without increasing the bandwidth, like "dot-interlacing" and overlapping video by the use of sub-carrier, which then could be used to attain good quality of color television, added later as a compatible system preferably.

14. Number of frames per second.

Actually the determining factor is the number of fields per second, but since the line interlacing has been decided to be in ratio 2 to 1, the field rate will be twice the frame rate.

The first factor, which determines the minimum field rate, is the assurance of the continuity of motion in the picture. This requires at least 15 fields per second, otherwise movement would be "jerky." A more severe requirement than this is set by the flicker of the picture. This rises from the fact that to accomplish a sensation of a continuous picture the field rate has to be sufficiently high so that the eye stores the preceding image throughout the dark interval between fields. Otherwise, the eye will see the fields as separate pictures. In the motion picture industry 48 fields per second is considered satisfactory. However, it has been found that the higher the light intensity of the picture, the higher is the field rate required. And, the relation is such that a small increase in field rate allows a much larger increase in light intensity. For instance, an increase from 50 fields to 60 fields per second allows the light intensity to increase 5 to 8 times with the same annoyance of flicker. This means that movie films with a field rate of 48 per second, and English television with a field rate of 50 per second, have to be viewed in a darkened room, but American television with a field rate of 60 per second, can be viewed in rooms having a little daylight. On the other hand, long-persistence phosphor can be used to eliminate the flicker to about the same amount, thus allowing about 7 times the brightness with the same flicker.

Since it has been decided that the systems are to be independent of power-supply frequency, it is recommended to use 60 fields per second rather than 50 fields per second. This would allow more flexibility of the placement of receiving sets, even for daytime viewing, and it would eliminate any possible fringing caused by long-persistence phosphors. If the channel width previously recommended proves to be too great, it would probably be preferable to reduce the number of lines per frame rather than the field rate.

15. Video bandwidth.

If the number of scanning lines per frame and the number of frames per second are decided upon, then the video bandwidth determines the horizontal resolution. But since the detail of a picture should be about equal horizontally and vertically, the resolutions should be approximately equal. This means, that when two of the three factors, the number of lines per frame, the number of frames per second, or the video bandwidth are determined, the third one is essentially determined also. If some deviation from equal resolution in different directions is made, it should be in favor of vertical resolution, since therewith the visible line structure will diminish.

When vertical and horizontal resolution are taken equal, active scanning line percentage 95, scanning line factor 0.75, horizontal blanking 19 per cent, and aspect ratio 4 to 3, the required video bandwidth can be computed, giving the following values, which are in megacycles per second:

	30 Frames per Second	25 Frames per Second
405 lines per frame	2.89	2.4
525 " " "	4.85	4.04
625 " " "	6.88	5.72
819 " " "	11.8	9.8
1029 " " "	18.6	15.5
1200 " " "	25.4	21.1
1700 " " "	50.9	42.4

Assuming that, at least in Finland and possibly in the whole of Europe, channels are adopted that are 2 to 4 times as wide as used in the United States at present, it would be advisable to use 819 or possibly up to 1029 lines per picture in television broadcasting. Using 30 frames per second, this would require 12- to 19-megacycle video bandwidth.

16. Channel bandwidth.

Video bandwidth practically determines the channel bandwidth, since vestigial sideband transmission will be a standard, and sound transmission requires only narrow additional bandwidth. There are methods to improve the usage of bandwidth, as mentioned before, and the adoption of these would be advisable when adding color to the television transmission. To allow room for the suppressed sideband, and the sound transmission, the channel should be approximately 30 per cent wider than for black and white video bandwidth, which according to the preceding paragraph would mean channels 15 to 24 megacycles wide (Figure 3).

17. Designation of attenuated sideband.

These are technical details, which can be decided at will within certain limits. For easier transmitter design the attenuated sideband should not be suppressed too much, but on the other hand, the more it is suppressed the narrower can be the channel. A practical compromise would be to send with full amplitude the attenuated sideband about 15 per cent as wide as the unattenuated sideband, as is standardized in the United States, and after that have fairly sharp cut-off, to clear for the adjacent channel.

18. Polarity of vision modulation.

Both positive and negative modulation are in use at present in television systems, positive in England and France, and negative in the United States. Considering the polarity of modulation, the most important factor is the effect of noise when using the system. The most serious type of noise at very-high and ultra-high frequencies is ignition noise from motor vehicles. When a noise peak occurs during the scanning line, it causes a white spot in the picture received by positively modulated transmission, but a black spot in case of negative modulated transmission, the latter being less annoying. The disadvantage of negative modulation is that a noise peak may cause a missynchronization. However, since for the sake of good received pictures the sweep oscillator should be very stable anyway, this danger of missynchronization is not too important and thus negative polarity of vision modulation is recommended to decrease the annoyance of the noise.

19. Synchronizing waveform.

The synchronizing waveform should be as simple as possible so that the receiver circuits will not be too involved. However, the waveform must assure certain synchronization. The waveform used in the United States has proved to work satisfactorily, and the Sub-Group Gerber of C.C.I.R. also recommended that this waveform, with small changes, be used. This waveform is shown in Appendix I.

This same synchronizing waveform can be used with color television also. Some additions may be necessary, like possibly subcarrier synchronizing frequency, which can be added, for instance, on the "back porch" of the horizontal synchronizing pulse.

20. Synchronizing pulse to picture ratio.

If the ratio of the synchronizing pulse magnitude to picture signal magnitude is large, the synchronization is certain, but the amplitude difference usable for picture information is small, causing the picture quality to be poor. On the other hand, if the synchronizing pulse is decreased in percentage of the total amplitude, the picture information increases improving the quality of the picture. However, a small synchronizing pulse may make missynchronizations, due to noise for instance, much easier. The value of 25 per cent of total amplitude used for synchronizing has been found suitable.

21. Method of sound modulation.

Two methods of modulation of the television sound carrier are in use at present, amplitude modulation in England and in France, and frequency modulation in the United States.

When very-high or ultra-high frequencies are used for sound transmission, frequency modulation gives superior reproducing quality compared to amplitude modulation, especially if a large bandwidth can be used. Using 15-kilocycle frequency swing the noise suppression would be approximately 5 decibels, and with 75-kilocycle swing about 20 decibels, if the audio channel is linear to 15-kilocycles per second. If pre-emphasis is used the improvement is still greater, in practice 2 to 6 decibels more depending upon the time constant.

Since the sound channel width is negligible compared to the video channel, wide frequency swing can be used. The maximum frequency swing of 75 kilocycles which is used in regular frequency-modulation broadcasting today, is the value recommended. Suitable pre-emphasis would be 50 microseconds, which is the maximum amount that does not cause overmodulation on higher sound frequencies.

The first 12 standards were adopted by the Plenary Assembly of C.C.I.R. and the other 9 have been discussed by both the Assembly and Study Group 11, but without agreement (25, p.24). In addition to these 21 subjects there are several others which should be standardized but do not appear in the preceding discussion. The most important are as follows:

22. Radiated power of aural transmitter.

If frequency modulation is to be used in sound transmission, it will provide better performance, when noise is present, than the video transmission. Therefore, it is not necessary to use as high power for sound transmission to obtain coverage equal to that obtained with a given amount of power used in video transmission. About 50 per cent of the peak power of the video transmitter would be adequate and suitable for sound transmission.

23. Brightness characteristics.

In present-day amplitude-modulated radio broadcasting, it has been the practice to have both transmitter and receiver characteristics as linear as possible with respect to amplitude. But in television, where the signal is reproduced on the cathode-ray tube, the cathode-ray tube itself is nonlinear, following a power law. Therefore, if a receiver circuit is linear, the natural outcome would be a receiver characteristic having the power-law characteristic of screen brightness versus signal voltage.

It is relatively easy to obtain any type of characteristic by special circuits in the equipment. There are several factors, which have to be considered, when choosing the desired overall system characteristic, most of them being imposed by receiving condition. Therefore the television receiver frequency-response characteristic should be determined first. The most important controlling factors are sensitivity to modulation level changes, correction possibilities to compensate for stray light, sensitivity to bias changes, sensitivity to added noise, and sensitivity to differing brightness ranges in transmitter and receiver. All the factors are not known well enough to enable one to decide which would be the best characteristic. The clamping level of the receiver plays an important part also. A linear receiver characteristic would allow good correction for stray light, but on the other hand it makes the receiver sensitive to bias changes and added noise, and depending upon the clamping level, to the level changes too. In addition to these the brightness range in the receiver and the transmitter should be equal to avoid serious contrast distortion. If the power characteristic previously mentioned has a numerically high exponent, the sensitivity to level changes becomes severe, unless the receiver is clamped near "white" level. At the moment the most advantageous characteristic for a receiver appears to be a fairly high power characteristic, but not exponential.

Once the receiver brightness characteristic is determined, it does not necessarily follow that transmitter characteristic should be its inverse, although it is probable. It could be advantageous, for instance, to increase the contrast in the brightness range of major interest.

24. Frequencies to be used for television service.

If fairly wide channels (15 to 24 megacycles) will be used for television, they should be located at the higher of the very-high frequencies or in the ultra-high frequency band, since lower frequencies can be more advantageously used for other radio services. Additionally, equipment construction would cause difficulties on lower frequencies, when using wide bandwidths. Also, the possibility of ionospheric interference commonly occurring at lower frequencies would be diminished.

25. Channel allocation standards.

When very-high and ultra-high frequency bands are used for television service, there is usually no long distance interference between stations. Therefore each country should be allowed to choose their channels and powers to be used at will, provided the radiation of the transmission to any other country is below the limit which would assure noninterfered reception of their own television stations within grade A service area. If the radiation exceeds this limit, both the channel and power used should be approved by C.C.I.R.

Numerous investigations have been made, especially in the United States, to determine the field strengths required for the service grades defined before. The average results have been published by the Federal Communications Commission, and are as follows (12, p.3075):

Required median field strengths in db above 1 microvolt per meter.

Grade of Service	At 200 mc	At 500-900 mc
A	71 db	74 db
B	56 db	64 db

After similar studies the following field strength ratios have been found to allow the specified Federal Communications Commission grades of service.

Permissible co-channel ratios in decibels of median desired field strengths to 10 per cent undesired field strengths:

	At 50-200 mc		At 500-900 mc	
Grade of Service	Non-offset	Offset	Non-offset	Offset
A	51 db (355:1)	34 db (50:1)	53 db (447:1)	36 db (63:1)
B	45 db (178:1)	28 db (25:1)	45 db (178:1)	28 db (25:1)

No permissible adjacent channel field strength ratios need to be specified, but a separation of about 90 to 100 kilometers should be allowed between stations operating on adjacent channels.

Offset carrier operation means that stations operating on the same channel have their vision carriers separated from each other by an amount which makes interference less visible in the received picture. The optimum separation is half of the line frequency per second. However, in the United States one-third of the line frequency is used for separation, thus allowing more stations to be protected.

For satisfactory operation, reception should be interference-free within the grade A service area of the station. Therefore, the limit previously mentioned is recommended to be 20 decibels above 1 microvolt per meter or 10 microvolts per meter. Furthermore, it is recommended that the field strength be less than this value 90 per cent of the time. In other words, the countries should be free to select their channels and powers used, provided that the radiation to any other country is 10 microvolts per meter or less at least 90 per cent of the time. And, if this will be exceeded, then approval should be obtained from C.C.I.R.

COVERAGE

The number of people that will be served by a television station is determined by the transmitting power used, the propagation of radio waves from the antenna at the frequencies in question, the required minimum field strength, and the population within the area where the field strength is at least the minimum permissible. Studies of these different factors were made, except for the required field strengths as discussed before. The methods and results of the studies are explained in this chapter.

Transmitting Power

Since very-high and ultra-high frequencies are used for television broadcasting, the radiation is comparatively easy to concentrate in the direction which is the most useful, thus improving the usage of the transmitter power. The directivity of an antenna in the desired direction is usually expressed by the term "gain" of the antenna. The product of the transmitter power minus transmission line loss and the power gain of the antenna gives the effective radiated power, which is one of the factors determining the field strength. Thus the effective radiated power may differ considerably from the transmitter power.

A few years ago it was difficult to obtain high powers at the very-high and ultra-high frequencies used for television service. The powers used have been commonly from 100 watts up to about 5 kilowatts. The need of still higher power has been met by two different methods, either by circuit design which allows the use of several tubes in parallel, or by the design of new tubes which will provide the high power needed. With several tubes in parallel television transmitters have been designed at least up to 50 kilowatts in power at very-high frequencies. New tube design has produced, for instance, a high-power klystron, which can provide at least 12 kilowatts of continuous power at ultra-high frequencies, and there is no reason why klystrons of still higher power cannot be built. Because of these developments, it appears to be probable that at ultra-high frequencies 50- or 100- or perhaps even 200-kilowatt transmitters can be built in the near future.

The purpose of directional antennas in television service is usually only to avoid radiation in undesired directions like downwards and upwards, where the power would be wasted. The most common type consists of a modification of the original turnstile antenna. These antennas have circular patterns in the horizontal plane, but in the vertical plane the pattern is more or less "flattened" depending on the number of turnstile layers used.

The commonly used television antennas at present have a power gain from 1 to 7, some up to 13 at very-high frequencies, but new designs allow the gain to be increased to 20 and over. For ultra-high frequencies antennas having gains from 5 to 25 are commercially available. High-gain antennas increase the coverage radius of the station, but for other reasons a high-gain antenna is not always desirable. If such an antenna is located high above average terrain, the radiated power to the direction of the first null below the main loop may be too small to provide adequate field strength for reception at close distance. This and not the technique of antenna design will usually set the limit for the maximum gain which can be used.

With the present-day transmitters and antennas, an effective radiated power of 600 kilowatts at very-high frequencies or about 300 kilowatts at ultra-high frequencies is readily available, and probably it can eventually be increased to a few thousand kilowatts without major difficulties.

Wave Propagation

Wave propagation is affected by several factors. Some of them are as follows: frequency, polarization, antenna heights, distance, curvature of the earth, atmospheric conditions, terrain, quality of the ground, and city buildings. Since all these factors have to be considered, the wave propagation problem as a whole becomes very complicated. For practical applications, the problem must be simplified. This is possible, since in each case it is usually a question of special application. When television is considered, the frequencies of primary interest are from about 100 to 1000 megacycles per second.

At these frequencies the effect of polarization is essentially negligible. The main difference occurs, when the antenna elevation is small, less than one wavelength. At such low elevations horizontally polarized radiation is much weaker than vertically polarized, since for horizontal polarization the radiation approaches zero, when elevation approaches zero, but for vertical polarization the radiation approaches a certain constant value at zero elevation (33, p.694). This difference does not have practical effect, since antennas at ultra-high frequencies are always elevated several wavelengths high.

One of the most important factors at very- and ultra-high frequencies is the height of antennas. For example, if horizontal polarization is used and the antenna is well below the line of sight from the observation point of the field strength, and the elevation of the transmitting antenna is increased from zero, the received field strength first increases approximately linear with the height, until at very large heights the field strength begins to increase exponentially. If the transmission is vertically polarized, the only difference is that the field strength starts from a certain constant value and stays approximately constant at first, until the height has a value at which the field strength of a horizontally polarized wave would be about the same as a vertically polarized wave. Then, the field strength starts to increase and merges with the values for horizontal polarization at a moderate height.

If the antenna heights were appreciable compared to the transmission distance, then instead of exponential increase with the height increase, at large heights the field strength would vary with oscillations about approximately constant value. These oscillations are due to reflection of the waves from the surface of the earth, which alternatively add and subtract the reflected wave from the direct wave.

The same effect of reflected waves occurs, if the height of transmitting antenna and observation point are kept constant and the distance between them is increased from zero to large values. At first, when the points are close together, the reflected wave is weak compared to the direct ray, and the field strength decreases according to free-space condition. As the distance increases, the reflected wave becomes appreciable compared to the direct ray, and again alternatively adding and subtracting changes the amplitude of the field strength, thus causing oscillations in the field strength. However, the average value of the field strength follows the free-space condition. When the distance increases, the relative amplitude of the oscillation increases, since the amplitude of the reflected wave approaches that of the direct wave. Simultaneously the period of oscillations becomes longer because of geometrical reasons. Finally, at distances close to line of sight, the difference in the path of direct and reflected waves becomes less than one wavelength and the oscillation ceases, and when the length of the paths becomes equal, the field strength begins to decrease much faster than it would in free space, since the reflection coefficient is about -1.

The reason for the importance of antenna height at ultra-high frequencies is the curvature of the earth. The practical service distance is only a little more than the line-of-sight distance. Since sky-wave propagation is not possible, the field strength beyond the line of sight is largely due to ground-wave propagation.

There are three factors which enable signal transmission to the region beyond the line of sight. These are refraction, diffraction, and energy loss at the ground. The refraction is the change of direction of radiation due to the change of dielectric constant of the atmosphere with height. The dielectric constant depends on the amount of water vapor present, pressure, and temperature of the air; thus weather has an effect. In general the dielectric constant of the atmosphere varies from point to point, and for practical purposes some assumptions have to be made. In average conditions, the dielectric constant is uniform in a horizontal direction and decreases approximately linearly with height above the surface of the earth. Such conditions would cause the waves to bend toward the earth and the effect can be taken into account in computations by assuming the wave propagation to be linear, and assuming the radius of the earth to be larger than it is. A practical multiplying factor is 1.33 (3, p.1129). The average is slightly smaller in the arctic regions and larger in the tropics (27, p.1). This is an average condition and can be used for estimating purposes, but the dielectric constant under certain conditions may vary considerably from the situation previously described. This constant may even increase with height, in which case the waves bend away from earth. On the other hand, if the dielectric constant decreases faster than a certain limit, the curvature of the path of the wave is smaller than the earth's curvature, and the waves come closer to earth either striking against it or some layer of air which has a smaller gradient of dielectric constant. These phenomena cause so-called "duct transmission."

Diffraction is the phenomenon of bending of electromagnetic waves around objects. It is a fundamental property of wave motion, which enables wave propagation behind obstacles. It depends on the wavelength of the radiation, and in light propagation cannot be seen without special instruments. At 1000 megacycles the wavelength is 30 centimeters or about the same as the wavelength of 1000-cycle sound wave in air; thus a similar bending around obstacles may be expected.

The effect of the ground losses is that it causes a forward tilting of waves above the earth's surface, and thus partially guides the radiation. The effect of electrical properties of the ground is very small at ultra-high frequencies. In practical computations it is usually neglected.

The terrain including hills, trees, buildings and other obstacles, which can be neglected at low frequencies, is of primary importance at ultra-high frequencies. The radiation is mainly restricted within the line of sight. Therefore all obstacles cause "shadows" in field strength, and if the obstacle is impenetrable like a hill, the only radiation which reaches behind it is due to diffraction over and around the hill. In cities the field strength at street level is approximately 10 to 30 decibels below what it would be without the effects caused by buildings. At 100 megacycles trees cause from 2 decibels to 10 decibels loss in field strength depending on the density of the trees. Higher loss occurs for vertical polarization than for horizontal polarization. At 1000 megacycles a thick forest is practically impenetrable and diffraction determines the field strength.

The reflections of radio waves from buildings, trees, airplanes, and other similar obstacles cause multipath reception at ultra-high frequencies. Because the physical size of these obstacles is large compared to the wavelength of the transmitted signal, the reflected energy may be comparable to the energy received by direct transmission. This multipath transmission causes so-called "ghosts" in television reception, and they are difficult to avoid, unless line-of-sight transmission is available and highly directive antennas are used.

On fringe areas fading is also noticeable. This is due to sudden changes of atmospheric index of refraction, or tropospheric reflections as these phenomena are called. At ultra-high frequencies the fading may be about 15 decibels near the horizon, but far beyond that distance it may reach even 50 decibels.

All these factors are at least difficult, if not impossible, to include in formulas for computations. Many of them are not well enough known, especially in the ultra-high frequency region. Hence, such factors are neglected in making computations. However, simple transmission problems can be theoretically solved as will now be explained.

The simplest problem is encountered when the field strength must be determined at a distance from transmitting antenna, at which the effect of ground is negligible, in other words, in the free-space condition. By solving Maxwell's equations using M.K.S. units, the field intensity in the plane, perpendicular to a short dipole, is given by (38, p.69).

$$E_{fs} = 60\pi \frac{il}{\lambda d}$$

where E_{fs} is the free-space field intensity in volts per meter

i is the antenna current in amperes

l is the length of the antenna in meters

λ is the wavelength of radio waves used in meters

d is the transmission distance in meters

If the power input to the antenna is substituted in the equation, the field intensity in volts per meter is given by

$$E_{fs} = \frac{\sqrt{45gP}}{d}$$

where g is the power-gain of antenna compared to a short dipole

and P is the radiated power in watts

For half-wave dipole g is 1.09 and the field intensity (3, p.1123) is

$$E_{fs} \sim 7\frac{\sqrt{P}}{d}$$

When the transmission distance is so great that the reflected wave is appreciable compared to the direct wave, then the formulas become complicated. If a short vertical dipole is placed on a perfectly conducting plane, the field intensity in the plane is given by

$$E_\rho = \frac{\sqrt{90gP}}{d}$$

where g is the power-gain of antenna compared to a short dipole

If the power is 1 kilowatt, then this formula gives the familiar figure of 300 millivolts per meter at 1 kilometer. After theoretical investigations, A. Sommerfeld defined a factor A, which takes into account the effect of the earth, and thus gives the field intensity at the finitely conducting surface of the earth

$$E_{su} = E_\rho A$$

or in more familiar form (33, p.675)

$$E_{su} = \frac{2E_o}{d} A$$

where E_{su} is the field intensity of the surface wave (sometimes called ground wave) in volts per meter

$2E_o$ is the inverse distance field at a unit distance in volts per meter

When the elevation of both transmitting and receiving antennas is taken into account, two additional factors must be added, giving the general formula:

$$E = \frac{2\ E_o\ A\ F_1\ F_2}{d}$$

where E is the ground-wave field intensity in volts per meter

$2E_o$ is the inverse distance field at a unit distance in volts per meter

A is the attenuation factor

F_1 is the height gain factor for the transmitting antenna

F_2 is the height gain factor for the receiving antenna

d is the transmission distance in meters

From this final formula several different simplified methods have been derived for practical computations.

The Sommerfeld's attenuation factor was first applied to practice by P. P. Eckersley. Later, several others have published application methods on this subject. Investigators of transmission at ultra-high frequencies include C. R. Burrows, M. C. Gray, K. A. Norton, K. Bullington, T. L. Eckersley, and F. W. Smith. All the methods used are based on the smooth-earth theory and some of them have methods to correct values attained according to irregularities of the terrain.

To obtain for the purpose of this investigation at least an approximate comprehension of the accuracy and reliability of these different methods, a study was made comparing the theoretical results obtainable with actual measured values. To avoid all possible interfering effects the measured values have to be obtained under as ideal geographical conditions as possible. Therefore, test results measured by J. Day and L. Trolese in the Arizona desert were chosen for comparison purposes (7, pp.165-175).

The first method used was presented by K. Bullington in his article in the Proceedings of the Institute of Radio Engineers in 1947. By this method the field strengths are determined using nomographs, which are derived by theoretical calculations after simplifying assumptions are applied.

Comparing calculations were made for fixed transmitting antenna height and variable receiving antenna height both for relatively short and moderate distances. Figure 5 shows measured average field strength variations in the form of shaded areas depending on the height of receiving antenna at three different frequencies, when the transmitting antenna height is 190 feet above the terrain and the transmission distance is 26.7 miles. The field strengths are in decibels relative to free-space values. The field strengths were computed for four receiving antenna heights at each frequency, and they are shown as dots on the graph sheet. Plane earth theory was used (3, p.1126). At all frequencies, the measured values agree within 2 to 7 decibels with the computed values, except on the 5-foot height. A reason for this is that if the receiving antenna is that low, it is beyond the electrical horizon, since electrical line of sight is reached at a receiving antenna elevation of about 25 feet. Thus the plane earth theory is not usable for 5-foot elevation.

For 170 megacycles, for a transmitting antenna height of 190 feet, and for a moderate transmission distance of approximately 55 miles the variation in field strength with receiving antenna height

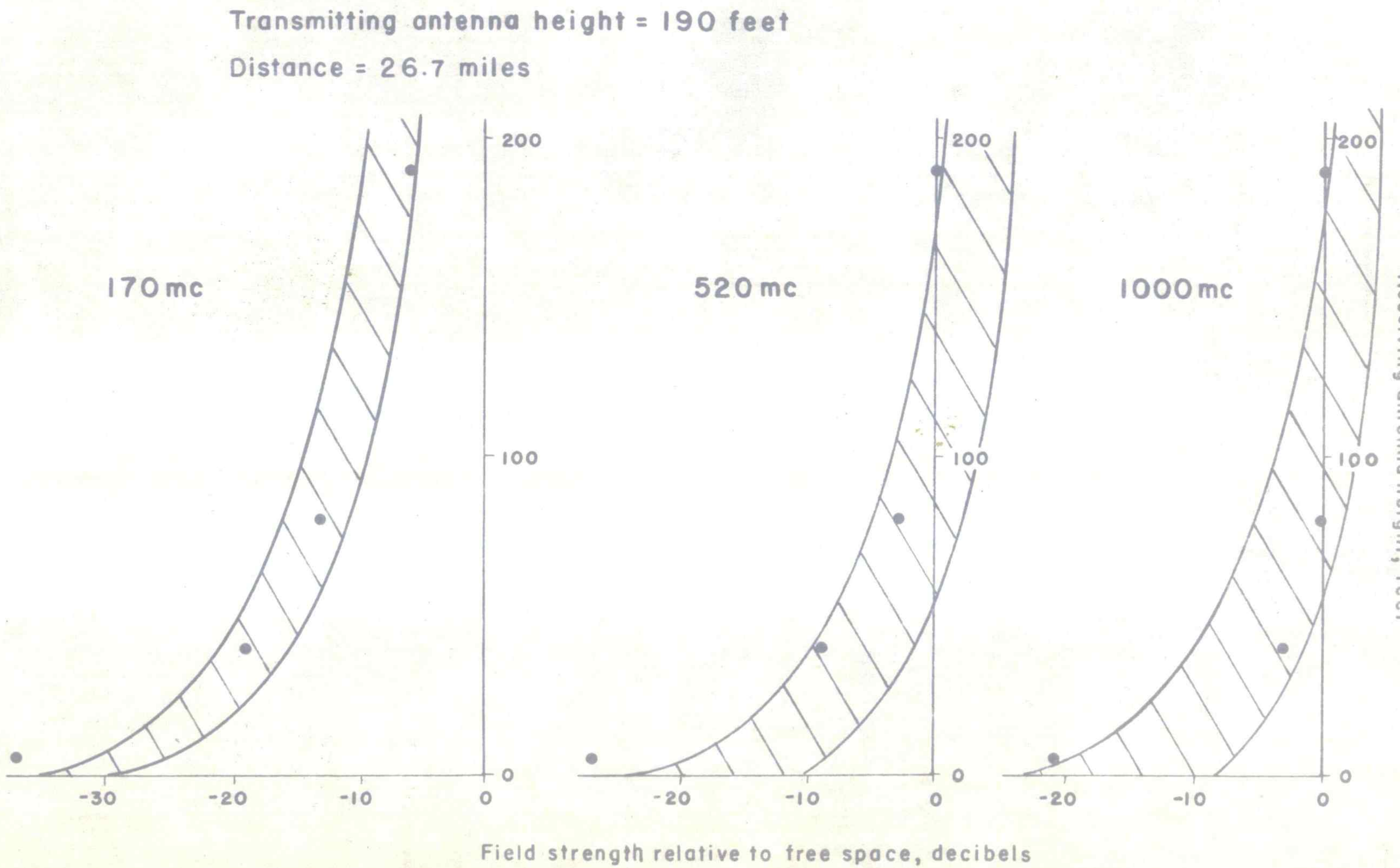


Fig. 5 Comparison of measured and computed field intensities

is as shown by the curve in Figure 6. Smooth plane earth theory can still be used at distances such as 55 miles if receiving antenna height is over the line-of-sight limit. For line-of-sight condition (electrically) the receiving antenna height must be at least 600 feet (3, p.1128). When using the plane-earth theory, the antenna heights have to be adjusted. Therefore the point where the reflection occurs on the spherical earth's surface must be determined. If the receiving antenna height were 1000 feet, this distance would be about 15 miles from the transmitting antenna. The adjusted antenna heights are now the antenna heights from the plane, which is tangent to the earth at the point of reflection. In this case they would be approximately 215 and 83 feet instead of 1000 and 190 feet. By this method the field strengths for 1000 foot and higher elevations can be computed giving values shown by dots in Figure 6. At 600-foot elevation, plane earth theory does not apply, since that is the condition of the signal grazing the earth.

Taking diffraction of the waves around the curvature of the earth into account, K. Bullington derived a nomogram which was especially intended to be used when the line-of-sight condition does not exist (3, p.1127). This method can even be used within the line of sight, although theoretically it is valid only beyond line of sight. However, if the distance between points, where the tangent lines drawn from the antenna locations to the smooth spherical surface of the earth between antennas touch the earth, is taken negative within the line of sight, the "loss" obtained from the

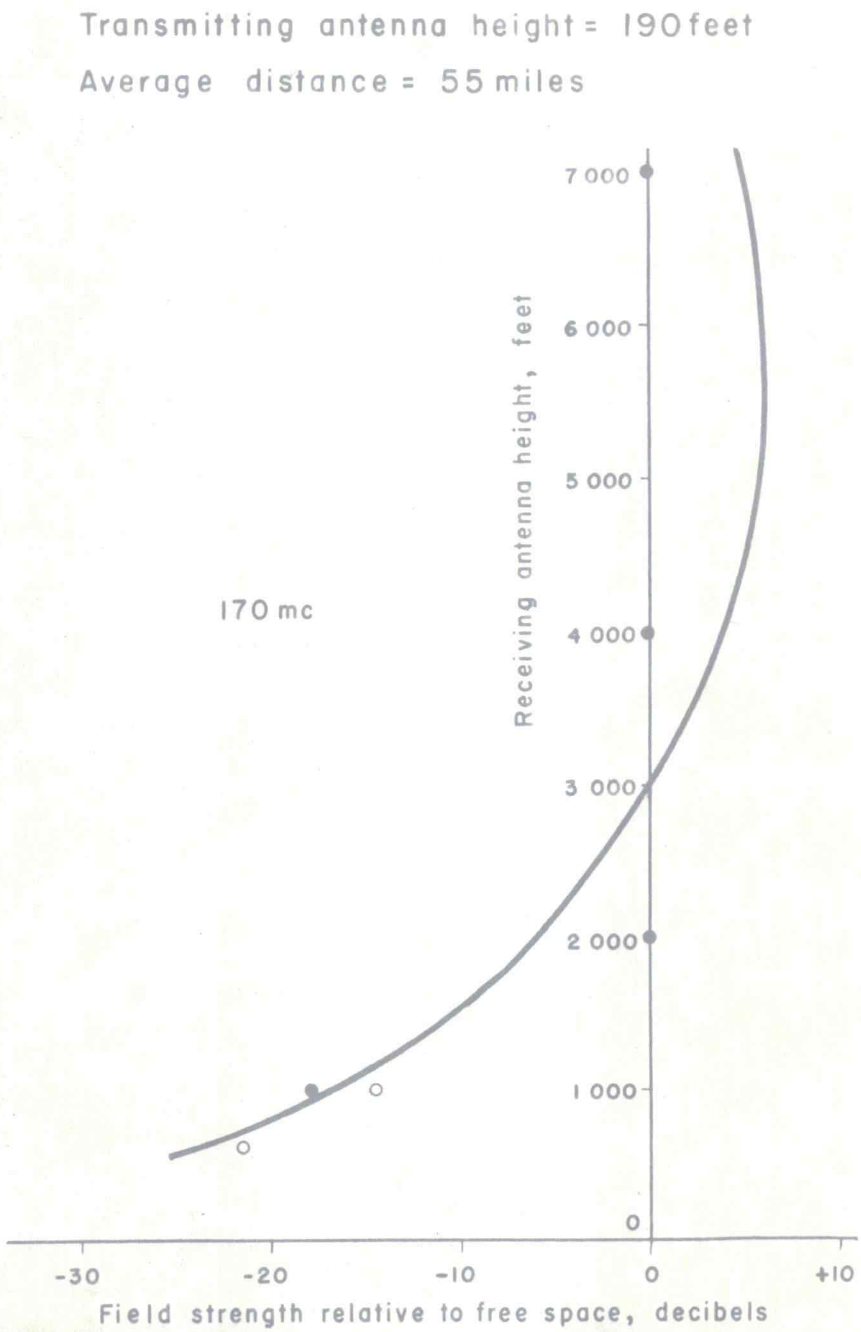


Fig. 6 Comparison of measured and computed field intensities

nomogram will be negative also, and the final result gives a relatively close value of the field strength to be expected. Using this smooth spherical earth theory the field strengths corresponding to five different heights of the receiving antenna were obtained. These values are shown by circles in the Figure 6, except the three higher elevation values, which coincide with the values previously obtained. All the results agree well enough with the measured average values, although in four out of five cases the line-of-sight condition did exist.

These calculations showed that the plane earth method of K. Bullington can be used, as long as the distance between antennas is at least approximately 20 per cent shorter than the maximum distance, at which the line-of-sight condition still obtains. However, the adjusted antenna heights should be used.

The smooth spherical earth method developed by K. Bullington is again applicable for beyond the line-of-sight and grazing conditions and somewhat within the line-of-sight, but further investigations showed that on shorter transmission distances the results were approximately 10 to 20 decibels too low (distance 26.7 miles).

Similar comparing computations were made using other simplified methods. They all have their base on the general modified Sommerfeld formula mentioned before, but the derivation of the methods has been accomplished using different simplifying assumptions.

One of the most accurately derived methods is published in Ground-Wave Field Intensities by the Radio Propagation Unit of the

U.S. Army Signal Corps (27, pp.1-59). Their method utilizes the general formula in its basic form, giving values for different factors in the form of curves.

The Radio Propagation Unit also has published Ground-Wave Field Intensities within the Line of Sight (28, pp.1-175). This utilizes the same method, but is simpler, since field intensities are computed for one kilowatt, for several antenna height combinations, for several ground constants, and for various frequencies. Intensities are presented in the form of graphs. The only computations necessary are the addition of the effect of power and antenna, and possible interpolations between frequencies, antenna heights, and ground constants.

Somewhat more simplified is the method derived by T. Eckersley (10, pp.286-304), the curves of which are printed in the Radio Engineers' Handbook by F. E. Terman (33, pp.756-758). Those curves neglect the refraction of the waves in the atmosphere.

Some results from the computations made by these different methods are in Table I. Calculations were made for two transmission distances, three antenna heights, and two frequencies, which are in the region of primary importance. The four values in parentheses were obtained by the method R 3 of the Radio Propagation Unit and are calculated using antenna height gain factors, although antenna height conditions were not fulfilled and thus the antenna height gain factors were not supposed to be used. If these factors were not used, the errors would have been over 60 decibels. The values

TABLE I

Distance miles	Transm. and rec. antenna heights feet	Frequency mc per sec.	Measured average field intensities relative to free space db	Computed field strengths differ from measured values decibels			
				B	R 3	SR 3	E
26.7	190	170	- 10	5.5	(- 1)	- 1.5	- 5.5
26.7	100	170	- 20	- 2.5	(- 3)	- 3	- 10.5
26.7	100	520	- 5	- 1			
26.7	25	520	- 28	- 13.5			
46.3	190	170	- 25	- 3	(1)	1	- 10.5
46.3	100	170	- 40	5.5	(4)	3.5	- 11.5
46.3	25	170	- 56	- 3.5	- 5	- 5	- 17.5

B - method by K. Bullington

R 3 - method by Radio Propagation Unit (Ground-wave field intensities)

SR 3 - method by Radio Propagation Unit (Ground-wave field intensities within the line of sight)

E - method by T. Eckersley

obtained by Eckersley's method are based on 150-megacycle frequency instead of 170 megacycles per second, but the difference is negligible.

Good agreement was obtained at very-high frequencies using both Bullington's method and method SR 3 of the Radio Propagation Unit. Method R 3 of Radio Propagation Unit gave also very good results, if the antenna height gain factors were used. Eckersley's method may be used, but especially on longer distances the values are too low. The reason for this is that the effect of refraction of waves in the atmosphere is appreciable at longer distances, and cannot be neglected as has been done in this method. At ultra-high frequencies the Bullington method is the only one available and the results are usable, although the agreement with the Arizona desert investigation is not always too good.

The simplest method to use is the method published by Federal Communications Commission (12, pp.3082-3085). It is intended to be used for predicting television service areas mainly for application filing purposes.

The method is graphical and the graphs are derived theoretically from the modified Sommerfeld formula mentioned before. The method takes into account all factors, but ground constants, and the earth is assumed to be a smooth sphere. Since the propagation of the radio waves does not generally change rapidly, when the frequency changes, the same curves are used for a wide frequency range, for example from 200 to 900 megacycles. The receiving antenna elevation is assumed to be 30 feet. The graph sheets for this method are included as the Appendix II.

According to calculations made at 170 megacycles, the values obtained by using this method were 11 to 5 decibels below the average values measured on the Arizona desert at 26.7 and 46.3 mile distances respectively, when the transmitting antenna height was 190 feet. By Bullington's method, calculated values from 7 to 1 decibels below the measured values were obtained. Thus the Federal Communications Commission's graphs gave a little lower values (4 db) than Bullington's method, which is reasonably close agreement for wave propagation computations. In addition, the lower values probably agree better with the actual field strengths for typical television conditions where the terrain is not so ideal as in the Arizona desert. Because of the simplicity of the method of the Federal Communications Commission, and because of the validity of this method at least as indicated by the preceding comparisons, the F.C.C. method was used in all later investigations included in this thesis.

Population Study

When the coverage of a television station is to be computed, it is necessary to determine the total population within the area to be served. If cities or towns are in the vicinity, their population can be included in the potential audience only if they are within the grade A service area. But when a television network of several stations must be designed, somewhat more knowledge about population is necessary if an extensive economic study is to be done. Information must be available for instance as to the change in audience if different coverage radii are used. The most useful form of population distribution information is a curve or table showing the population covered versus the distance from each probable transmitter location, for both total population and for rural population. The so-called rural population curve may include also the city or town where the station is located, since that will be inside grade A service area anyway. Because this kind of information about Finland was not available, the study reported in this section was made to obtain this knowledge.

The smallest areas in Finland, which have local government, are called communes. The average area of a commune is approximately 550 square kilometers or about 200 square miles. The average population is approximately 5000 persons per commune (34, pp.1-18). From smaller areas no accurate population data are available. Therefore a method had to be devised, which would give the smallest possible error in the curve values, with reasonable amount of work. For investigation purposes the city of Rovaniemi in northern Finland was chosen as a possible television station location (somewhat north of the 66 degree north parallel, Figure 1). Rovaniemi is especially suitable for this purpose, since there are very few communes within the 200 kilometer distance from the city. The 200 kilometer distance was chosen since that is large enough, when considering television stations of any practical power.

Since no accurate population distribution information of the communes was available, it was considered that the population would increase approximately linearly with the distance from Rovaniemi within the area of each commune. Figure 7 shows, then, the population of each commune as it increases the total population versus distance from Rovaniemi. The total population versus distance, as shown in Figure 8, is obtained by summation of the curves in Figure 7. If cities are not included, the rural population (including the city of Rovaniemi for reasons previously mentioned) will follow the curve shown in Figure 9. These two curves, Figures 8 and 9, give the information necessary for economic investigations, and they are fairly accurate. The accuracy of such curves will be still higher, when cities in southern Finland are considered, since there, a 200-kilometer circle includes over 200 communes instead of about 40 as in the case of Rovaniemi. Because such curves have to be made for about 25 different cities the work is excessive and some simplified method must be used.

Investigations have shown that a relatively accurate curve with a reasonable amount of work was attainable if the population of each commune was assumed to be concentrated at the middle point of the commune. The distance from the station location was divided in 10 kilometer sections, except the first and last, which were 5 kilometers. The populations of communes, the middle points of which were within the same distance section, were added together. By adding these sums the ordinates of the points in Figure 10 (in

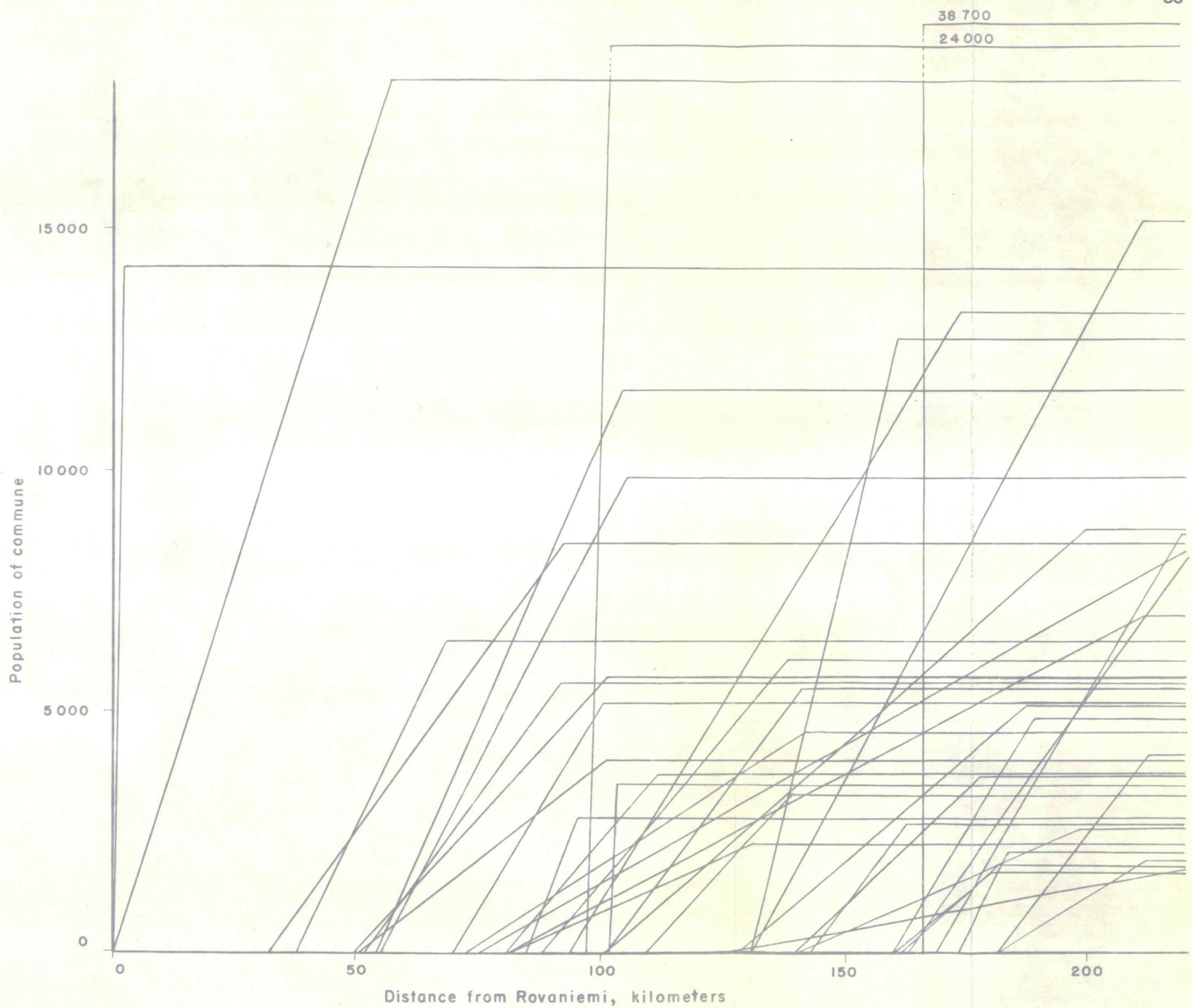


Fig. 7 Effect of the population of each commune on the total population within a radius from Rovaniemi

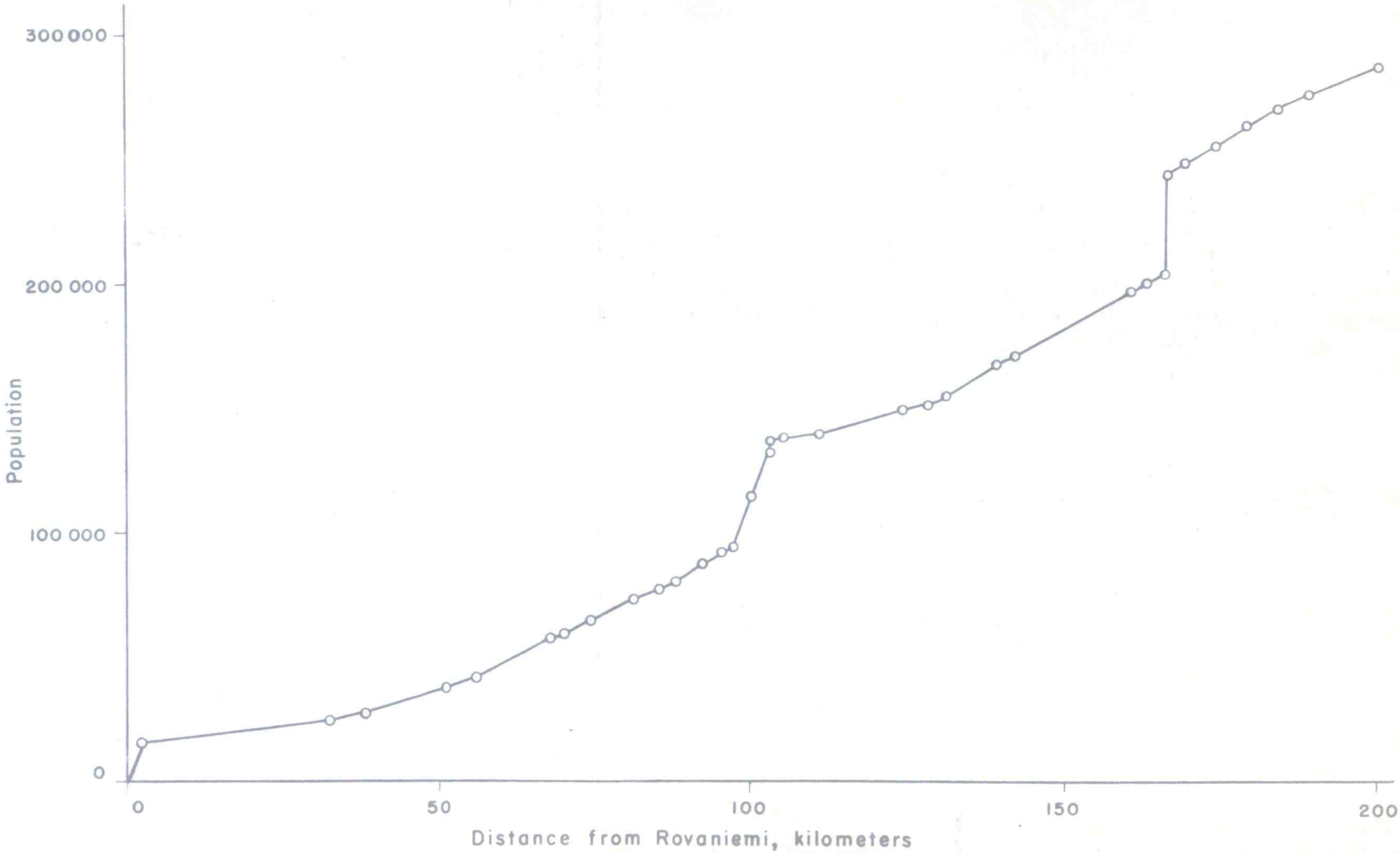


Fig. 8 Population versus distance from Rovaniemi

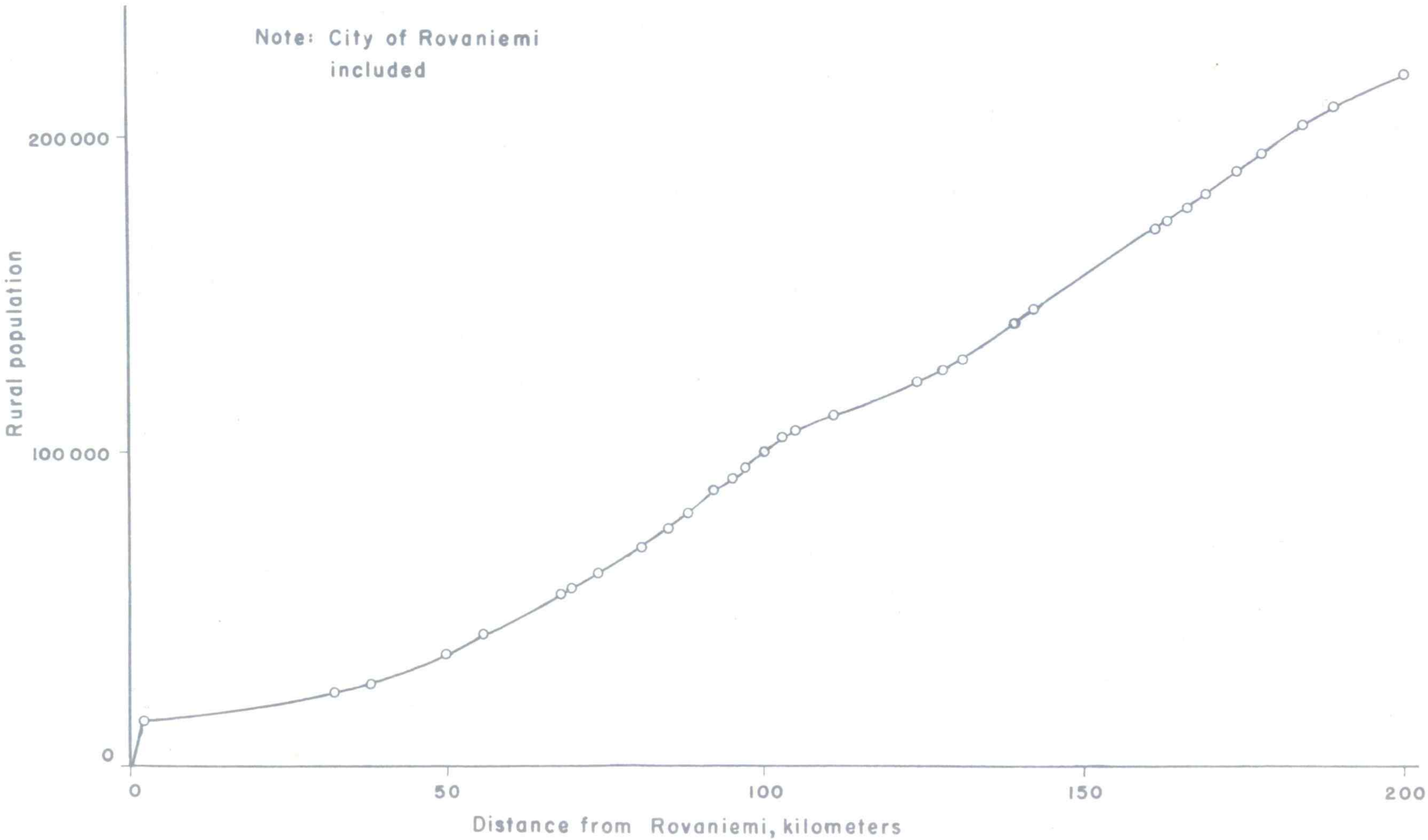


Fig. 9 So-called rural population versus distance from Rovaniemi

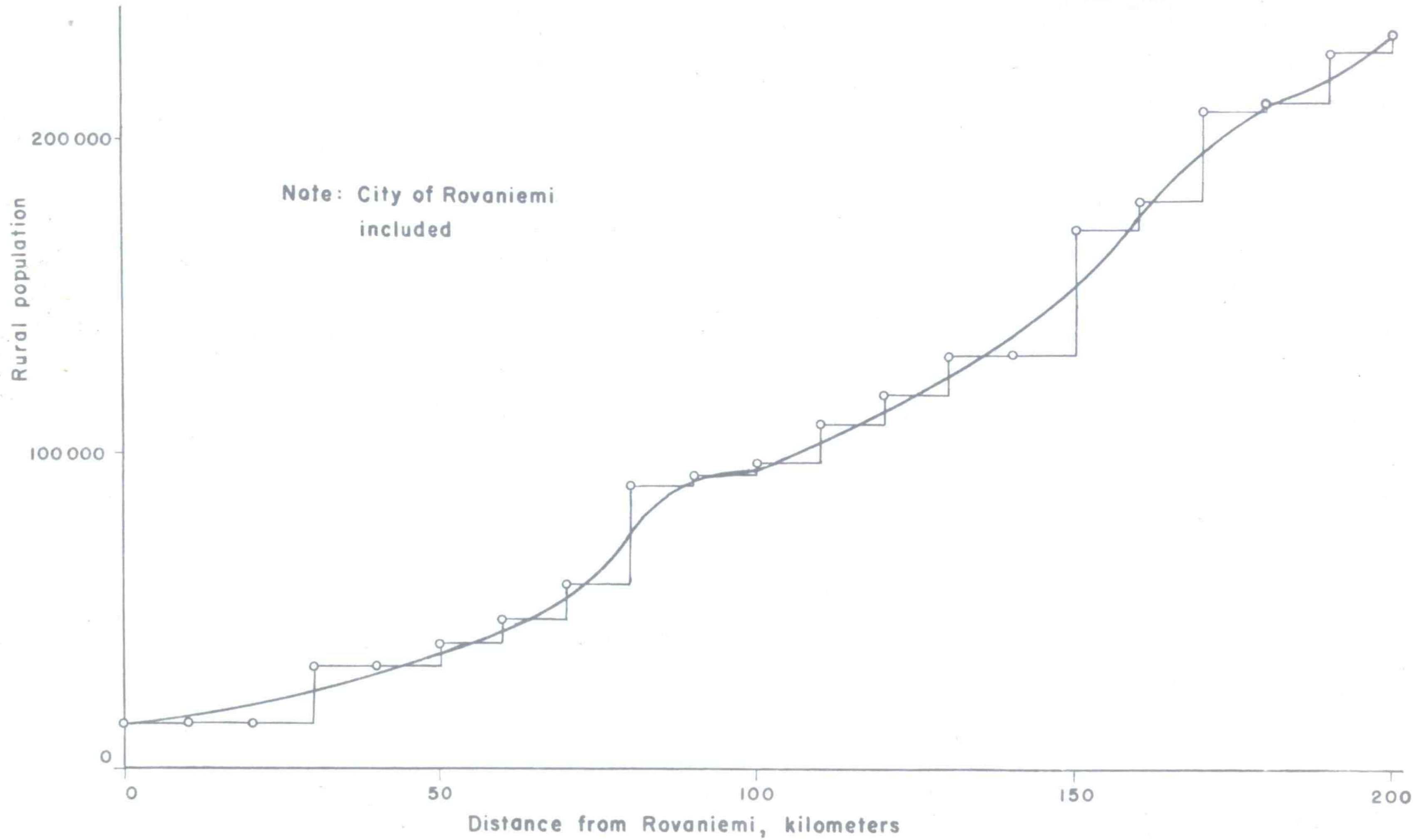


Fig. 10 So-called rural population obtained by approximative method versus distance from Rovaniemi

case of Rovaniemi) were obtained and plotted, using the middle values of distance sections as abscissa values. If a smooth curve is drawn through the middle point of each step in the step curve thus obtained, the curve obtained does not deviate appreciably from the curve in Figure 9. The maximum difference was about 6 per cent. In southern Finland, where communes are much smaller, the deviation would probably be below 1 or 2 per cent. It was found that a 10-kilometer distance section was approximately the maximum usable, since any larger step would cause appreciable errors in the ordinates of the curve. This method can be used only to obtain curves for rural populations, since sudden changes like those caused by cities or market-towns would not show in the curve.

As an example, tables and curves of computations about the city of Lahti are included. Table II shows the tabulation of Finnish-speaking rural population plus the population of Lahti, versus distance from Lahti. Table III shows the Finnish-speaking urban population versus distance from Lahti. Similar tables were prepared for the Swedish-speaking part of the population. It is advisable to investigate the distribution of both languages at least for program distribution purposes, since they both are official languages in the country and approximately 9 per cent of the Finnish nation speaks the Swedish language. The Swedish language is used only on the coasts, especially near Helsinki, Turku, and Vaasa, and on the islands of Ahvenanmaa in the southwest corner of the country. The rural population plus the city population of Lahti versus distance

TABLE II. LAHTI

	Distance from Lahti, kilometers																				
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
Population of communes (Finnish speaking)	45190	11311	14878	3365	2270	4126	5637	4685	11151	11530	11103	659	8298	2436	410	2192	7261	391	3987	6737	1844
			6296	9012	11220	2683	1159	2354	6792	3559	4090	4197	1380	3948	4297	5747	10583	1281	3087	5907	714
			9619	3083	2633	193	2751	9870	2188	2149	11029	3808	903	2072	4207	10372	10176	2859	1753	1902	12224
				10841	7583	9546	6576	6413	9492	4850	10540	4890	1040	2168	2963	3798	2716	2741	10580	6162	5614
					5948	12171	5634	4798	5264	2060	11080	3391	3790	2616	8112	3483	2329	6827	4375	1563	2109
						6302	5413	2184	3476	4922	5006	7940	6049	3201	3888	2878	4197	3112	5390	1639	5200
						2407	9970	14754	6443	11779	8001	4514	4434	11698	8214	1857	4553	8627	5951	4191	5083
						9434		6722	4080	5888	7908	8934	4129	3295	2447	10880	2305	8526	1324	2918	3183
						3802		4617	15918	2329	7470	8276	4867	1341	9515	2986	9788	7543	4064	1675	11329
						18314			10175		1997	2514	9664	5650	6956	2806	5635	4244	3439	3397	
											5749	4617	6324	5201	5428	5286	2461	2376	3651	8871	
												5402	174	11265	20436	1868	3772		1466	1131	
												2570	4410	4058	5867	1784	9828		1245	3723	
												6505	6822	3164		13141	8217		3766	12459	
													13540	2911		6436	3376		3173	5172	
														10858		11243	9795		9612	7076	
														3623			14100		12326	2519	
																	3522		3356	11854	
																				2489	
																				8481	
Sums of columns	45190	11311	30793	26301	29654	68978	37140	56397	74979	49066	83973	68217	75824	79505	82740	86757	114614	48527	82545	99866	47300
Halves of sums		5656	15397	13151	14827	34489	18570	28199	37490	24533	41987	34109	37912	39753	41370	43379	57307	24264	41273	49933	
Population within radius above	45190	50846	71899	100447	128422	177738	230797	277566	343254	405276	471796	547891	619911	697576	778698	863447	964132	1045703	1111239	1202444	1299677

TABLE III. LAHTI

Distance from Lahti km	City or market-town	Finnish speaking urban population: in the city or town	Finnish speaking urban population: within radius at left
31	Heinola	8491	8491
55	Riihimäki	16971	25462
58	Kouvola	10551	36013
60	Hyvinkää	13383	49396
65	Järvenpää	7601	56997
65	Hämeenlinna	22612	79609
67	Porvoo	3457	83066
68	Loviisa	967	84033
72	Kerava	7647	91680
87	Karhula	19640	111320
91	Kotka	24528	135848
93	Valkeakoski	11916	147764
94	Karkkila	4503	152267
96	Hamina	7144	159411
99	Toijala	5814	165225
99	Helsinki	279281	444506
100	Kauniainen	1109	445615
111	Forssa	9031	454646
116	Mikkeli	15955	470601
120	Tampere	102910	573511
120	Lohja	6140	579651
128	Nokia	16060	595711
130	Mänttä	5969	601680
135	Lappeenranta	17332	619012
139	Jyväskylä	30881	649893
140	Lauritsala	10664	660557
142	Loimaa	5510	666067
147	Karjaa	568	666635
153	Vammala	1116	667751
154	Salo	9343	677094
163	Ikaalinen	500	677594
165	Tammisaari	689	678283
165	Pieksämäki	7907	686190
170	Imatra	28441	714631
174	Suolahti	5027	719658
178	Äänekoski	6077	725735
190	Varkaus	17783	743518
195	Turku	89039	832557
197	Hanko	1546	834103
197	Savonlinna	11867	845970
198	Parainen	1639	847609

from Lahti is shown in Figure 11 for both languages. These two curves and two tables of urban population give all population information necessary for each location of a television station.

A complete population study like the one just described was made for the 14 largest cities of Finland (population in parentheses).

Helsinki	(375,981)	Kuopio	(33,305)
Turku	(103,899)	Jyväskylä	(30,881)
Tampere	(102,910)	Kotka	(24,528)
Lahti	(45,190)	Kemi	(23,959)
Pori	(43,983)	Hämeenlinna	(22,612)
Oulu	(38,703)	Lappeenranta	(17,332)
Vaasa	(36,178)	Mikkeli	(15,955)

Besides these 14 cities, six other possible television station locations were chosen and population studies were made for them. They are:

Rovaniemi	Joensuu
Kokkola	Tammisaari
Kajaani	Riihimäki

During the economic investigations, partial population studies were necessary for four additional locations:

Ohkola	Savonlinna
Ylivieska	Karijoki

All the population data used were based on 1951 census, which gives the population as of January 1, 1951 (34, pp.1-18).

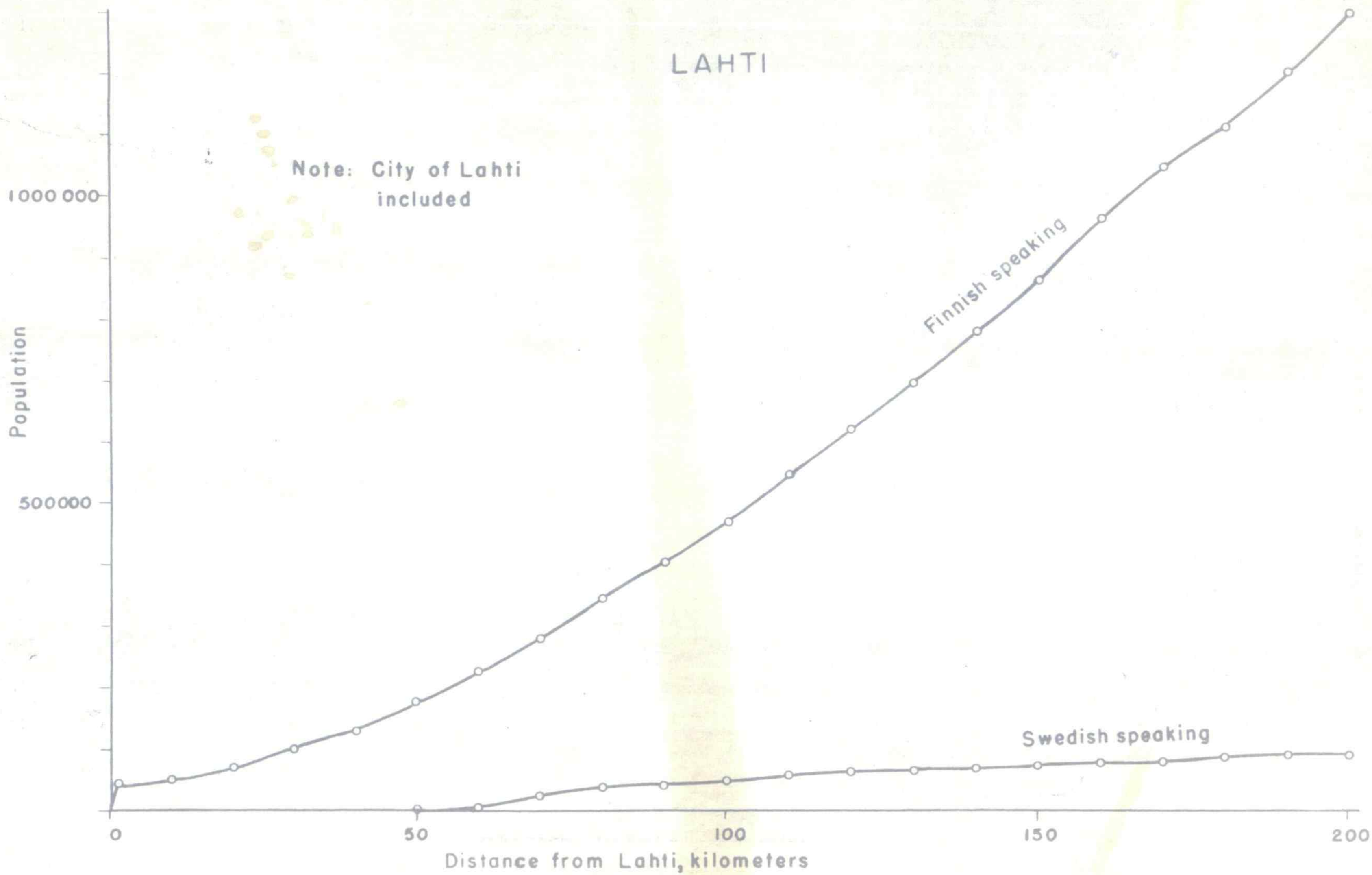


Fig. 11 So-called rural population versus distance from Lahti

TECHNICAL AND ECONOMIC CONSIDERATION OF NETWORK ELEMENTS

A technical study of the equipment required for a television system is made in the following pages. The details have been extended as far as necessary for carrying out the investigations concerning the whole network of several television stations. The study was based mainly on technical information available from television practices in the United States. Besides a technical study, an economic study is necessary to enable one to design the most economical and logical network units for a final television system; such an economic study also is included in the following pages.

All prices are as they would be in Finland, although for practical reasons they may be expressed in dollars. The present-day (1952) official exchange ratio has been used, according to which 231 Finnish marks correspond to one American dollar. Figures such as the price of antenna towers and buildings, the cost of electricity and wages of personnel are based on information obtained from Finland, but the prices of the equipment, the prices of which are not available from Finland, are averages of the prices of two or three large companies in the United States which are manufacturing television equipment. To cover the transportation cost, possible customs duty and installation cost or, if the equipment would be built in Finland, to cover the higher manufacturing and installation costs, an estimated 25 per cent has been added to the American average prices.

The calculations are based on nonprofitable operation. The interest has been taken 7 per cent per year as an average, since it varies between 5 and 9 per cent at present. Where depreciation time is concerned, the facilities have been divided in two groups. For buildings and towers, a 20-year depreciation time was chosen, since brick buildings and steel towers are used. For equipment, a 5-year depreciation time has been used. A reason for the short depreciation time of equipment is that rapid advancement of television research may make the equipment relatively soon obsolete.

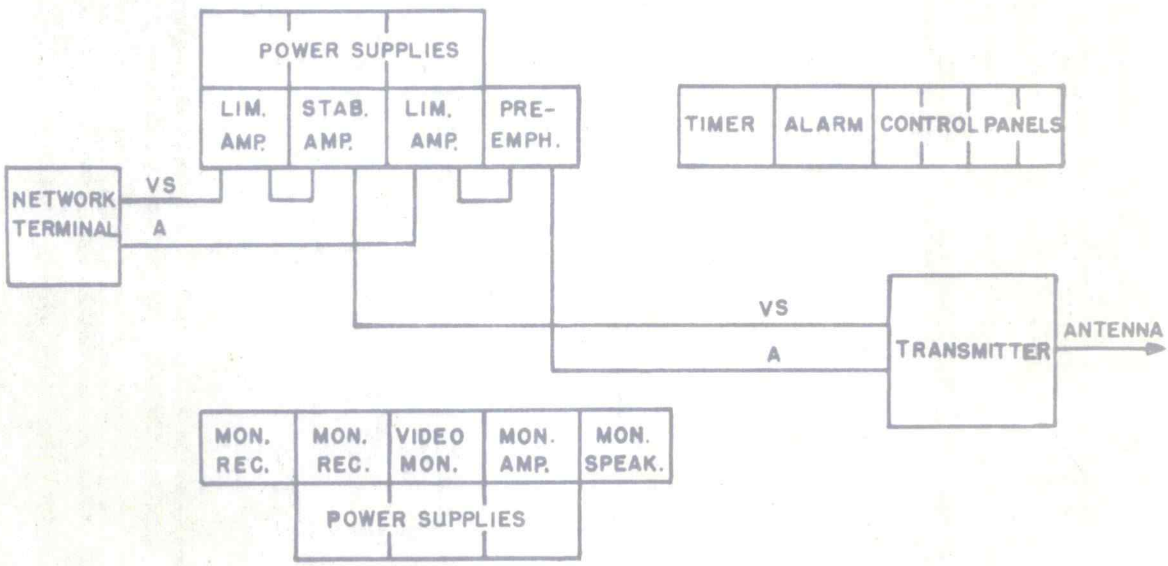
To obtain fixed annual cost, a variable depreciation percentage was chosen. For equipment, a 5-year depreciation time and 7 per cent interest give an annual cost of 24.4 per cent of the purchase price. This means that the first-year depreciation is 17.4 per cent and the fifth-year depreciation is 22.81 per cent of the purchasing price. For buildings and towers 9.45 per cent of purchasing price annual cost will provide depreciation in 20 years and with 7 per cent annual interest, the first-year depreciation is 2.45 per cent and the twentieth-year depreciation 9.04 per cent.

Before exact studies could be made, a necessary step was to form generalizod stations, without taking any possible local situations into account. These generalized stations enable plans for the whole network to be made, and such plans can be used as guides, when forming the final plan. All these investigations are made for about 200 megacycle frequency operation, since that is probably the most suitable frequency to be used for television service in Finland.

Transmitting Stations

Station block diagrams. The transmitting stations were divided into four groups according to the transmitter power. The smallest stations, up to 1 kilowatt, have been considered possible of automatic operation. They can be used in unimportant places, or in places where there is a regular attended AM broadcasting station in vicinity so that possible interruptions can be cleared rapidly. Larger stations are to be manually operated.

At the small "automatic" stations only the minimum of equipment is needed. Figure 12 shows the block diagram of such a station. After the network terminal (radio relay receiving unit), limiting amplifiers are needed, since the amplitude of received signal may vary. Limiting amplifiers are not used on the television stations for video at present, but on automatic stations it would be necessary. A stabilizing amplifier should precede the video transmitter to remove possible hum, switching, and similar transients, and to adjust the video signal to a synchronization pulse ratio suitable for the transmitter. On the audio channel, a pre-emphasis network is necessary. In addition to these, timing, alarm, and control panels are required for the transmitter, and some monitoring equipment which can be used when servicing the station. When the prices are estimated as mentioned before, the transmitter accessories alone would cost in Finland, when installed, and including a radio relay receiver, AUTOMATIC STATION $\leqq$ 1kw



LIM. AMP. = Limiting amplifier
MON. AMP. = Monitoring "
STAB. AMP. = Stabilizing "
MON. REC. = Monitoring receiver
MON. SPEAK. = " speaker
PRE-EMPH. = Pre-emphasis network
VIDEO MON. = Video monitor
A = Audio
V = Video
S = Synchronizing signal

Fig. 12 Block diagram of an "automatic station"

approximately

$22,500 or 5.2 million marks.

The same radio relay system can be used to transmit both video and audio signals, if a sub-carrier is used for audio signal.

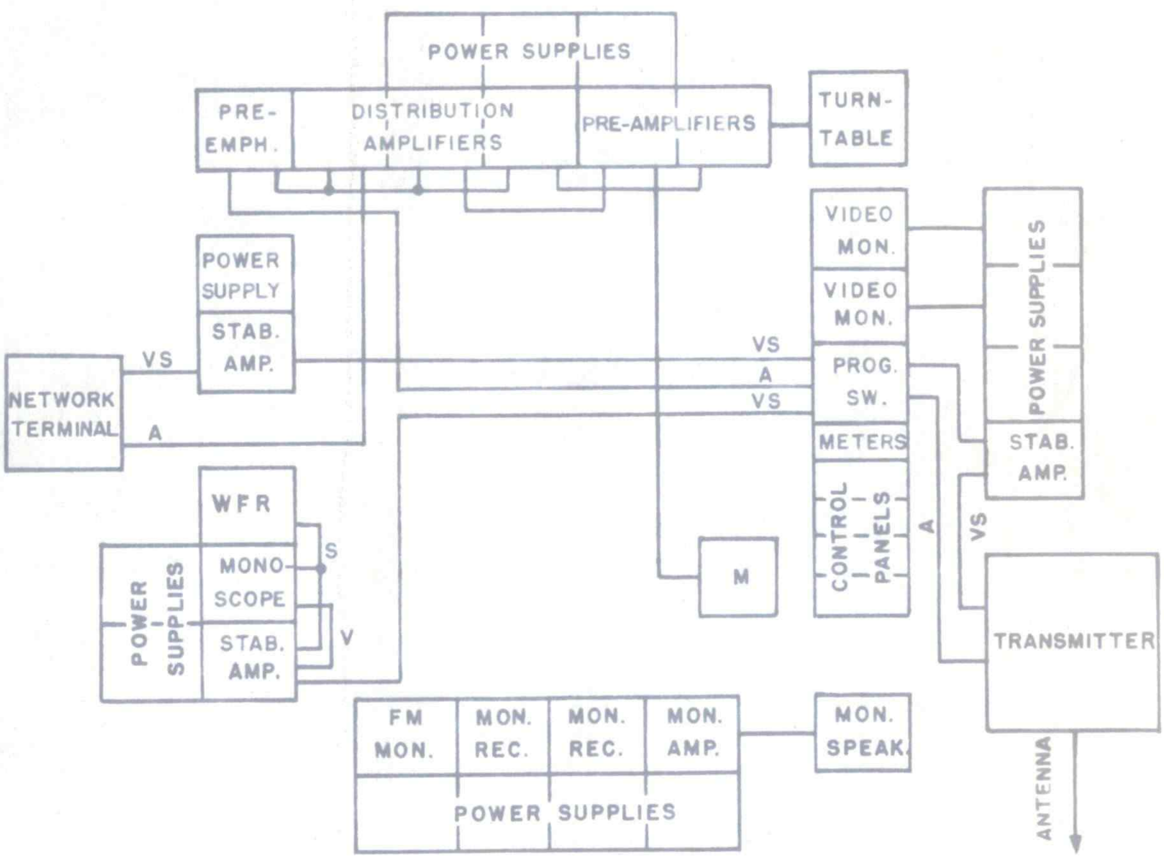
The next group of stations considered is the "small manual stations" having transmitter power of from 1 to 10 kilowatts. The block diagram for these stations would be as shown in Figure 13. This size station would not originate programs, but in case the program distribution system fails, a monoscope camera is furnished to give station identification, and microphone and turntable can be used for announcements and music. Some additional amplifiers are needed, as will be noted if Figure 13 is compared to Figure 12. Also an audio transmitter frequency and modulation monitor has been added. Limiting amplifiers are not necessary, since an operator is always on duty. The price of transmitter accessories including radio relay receiver would be approximately, when installed,

$44,600 or 10.3 million marks

without spare tubes.

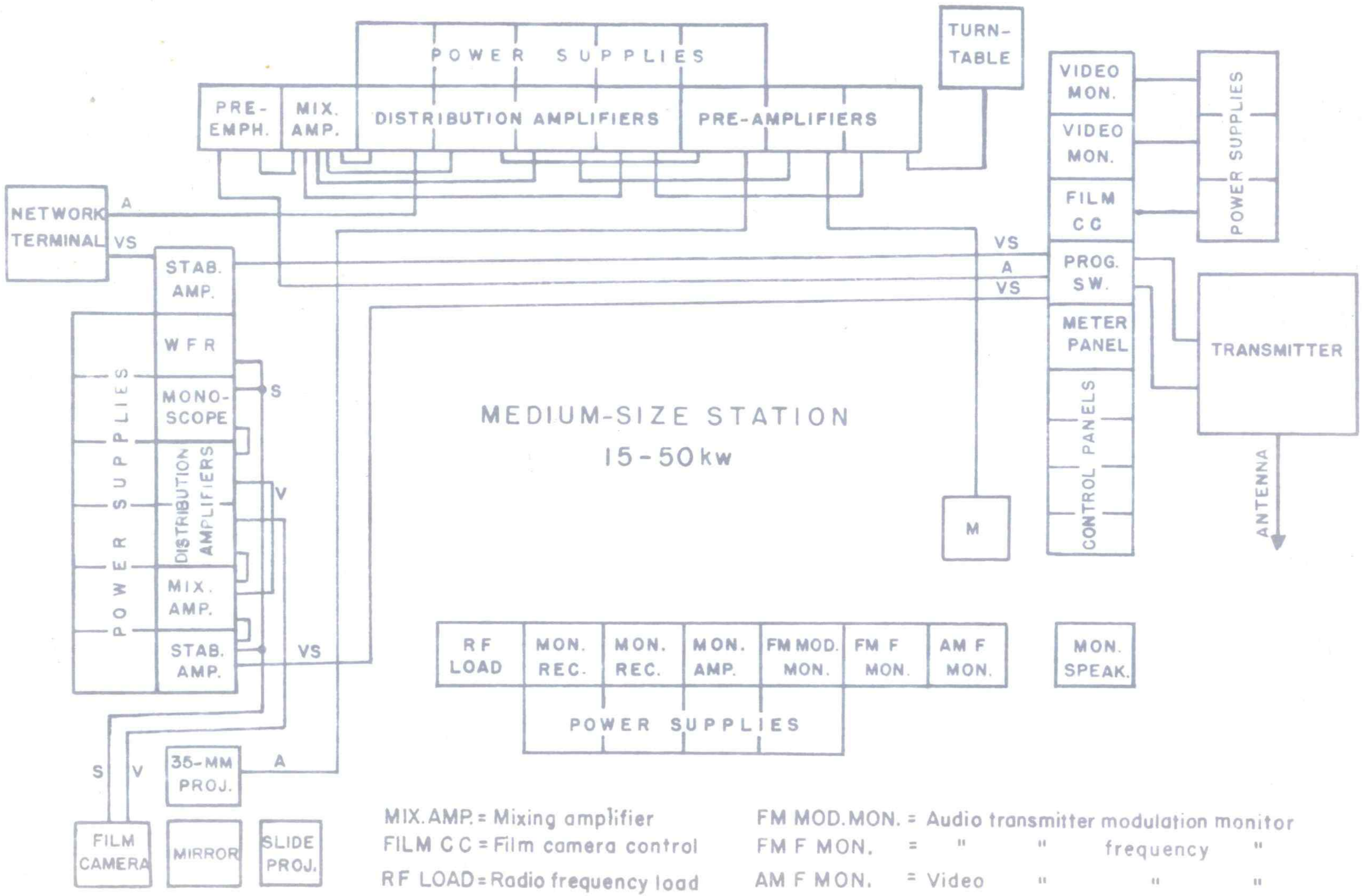
Figure 14 shows the block diagram of a "medium-size station," which are stations having transmitter power of 15 to 50 kilowatts. These stations are so large that they should have program facilities to provide continuous programming even when the program transmitting network fails. Therefore, one film camera chain, 35-millimeter film projector, and slide projector are furnished in addition to the monoscope camera. This plan has more amplifiers (like mixing

SMALL MANUAL STATION 1-10 kw



PROG. SW. = Program switching unit
FM MON. = Audio transmitter frequency and modulation monitor
M = Microphone
WFR = Wave form rack

Fig. 13 Block diagram of a "small manual station"



MIX. AMP. = Mixing amplifier
FILM C C = Film camera control
RF LOAD = Radio frequency load

FM MOD. MON. = Audio transmitter modulation monitor
FM F MON. = " " frequency "
AM F MON. = Video " " "

Fig. 14 Block diagram of a "medium-size station" amplifiers) and monitoring equipment (video transmitter frequency monitor and radio frequency load) than the preceding one. The price of transmitter accessories, installed, without spare tubes and radio frequency load but including radio relay equipment would be approximately,

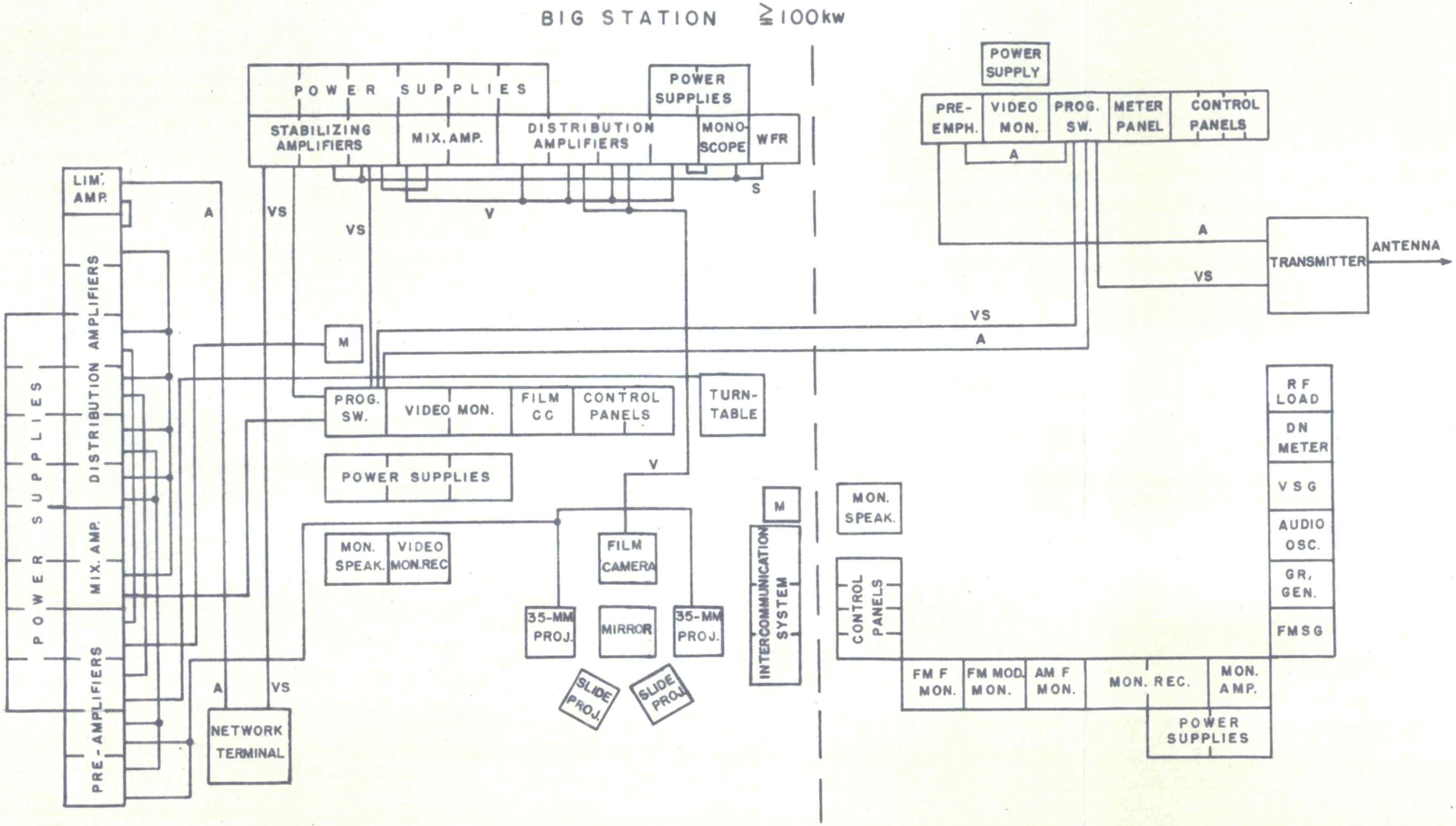
$81,500 or 18.8 million marks.

The equipment needed for the largest stations is shown in Figure 15. These "big stations" (100 kilowatts or more) would have two film projectors and two slide projectors, and somewhat more versatile switching, testing, and amplifying facilities, but basically similar to the preceding one. The transmitter accessories, again without radio frequency load and spare tubes, would cost installed approximately,

$121,800 or 28.2 million marks.

In all these television stations the programming facilities are more or less only for "emergency use," since the program will practically all be distributed from the main studios in Helsinki. The 35-millimeter projectors will probably be more useful than the 16-millimeter projectors, which are generally used in the United States, since 16-millimeter film is very little used in Finland, and all Finnish commercial moving picture features are on 35-millimeter films.

Transmitters. Television stations in the United States all have transmitters which are a combination of two different transmitters, one for video and one for audio. The transmitters employ



AUDIO OSC.	=	Audio oscillator	VSG	=	Video sweep generator
DN METER	=	Distortion and noise meter	FM SG	=	FM " "
GR. GEN.	=	Grating generator			

Fig. 15 Block diagram of a "big station"

approximately the same type of tubes, but the power output of the audio transmitter is usually about half of the power output of the video transmitter, which is obtained by using lower plate voltage in the final stage. Both high and low level modulation systems are used in the video transmitters. Although some single transmitter type, using sub-carrier for audio, for instance, may be developed, the calculations in these investigations are based on the American average prices in 1951, which are shown in Figure 16. These prices like all other American prices are adjusted for Finland by adding 25 per cent as mentioned before.

For investigation purposes eleven transmitter sizes ranging from 100 watts to 200 kilowatts were chosen. All stations below 1 kilowatt are to be automatic. Costs were computed for 1 kilowatt stations both with automatic and with manual operation.

Table IV shows the purchasing price and annual operating cost of the equipment, except transmission lines and antennas, for the different size television stations. This includes transmitter, transmitter accessories, and spare tubes, radio frequency load for stations specified before, and high-voltage power equipment. It is assumed that up to 2 kilowatt stations the power will be supplied to the station at low voltages, the higher power stations will be supplied at 10 to 20 kilovolt transmission line voltages, as is usually done in Finland. In the latter case the prices of transformers, disconnecting switches and for larger stations oil circuit breakers and some accessories are included. Table IV gives also the

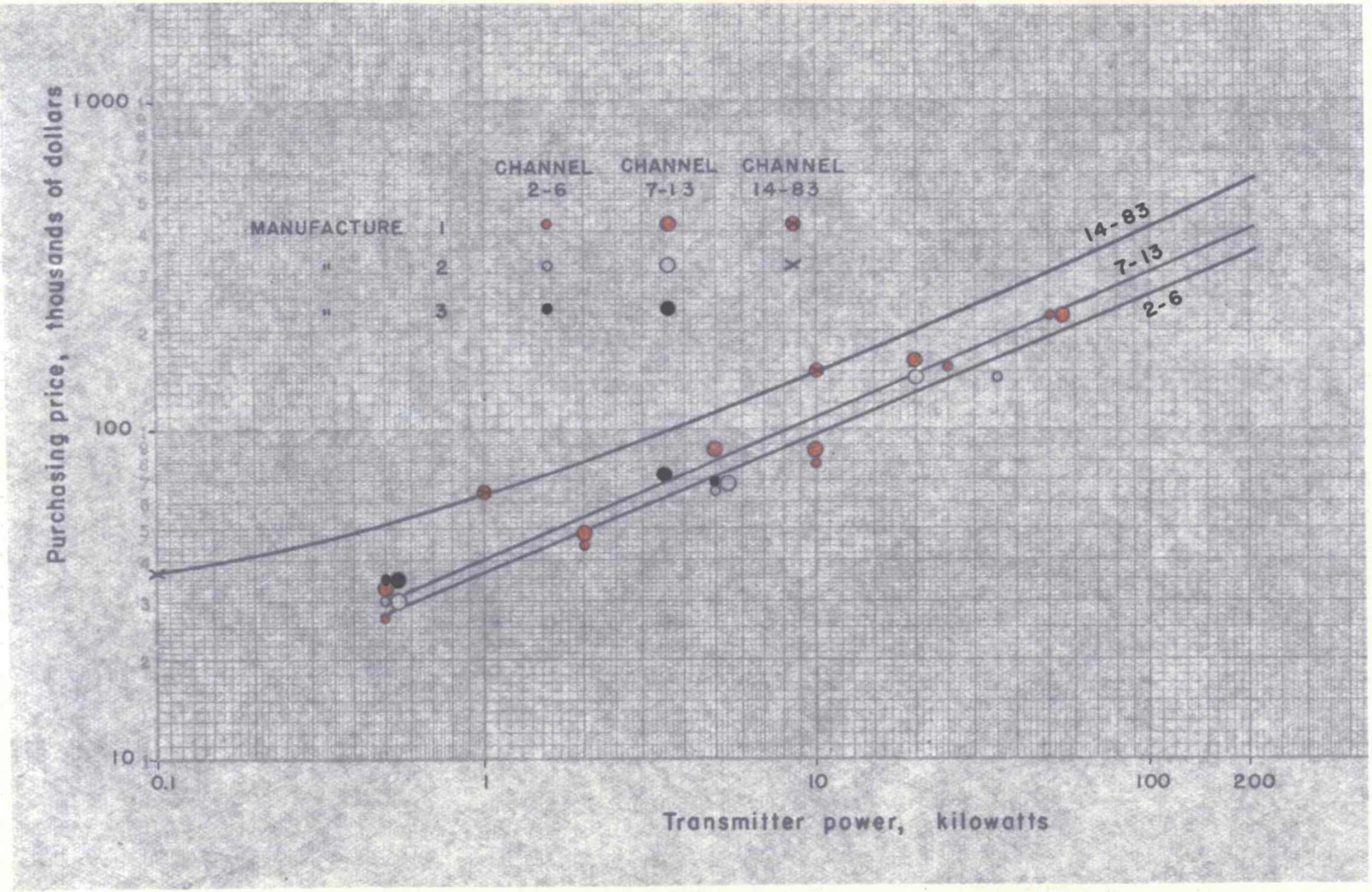


Fig. 16 Television transmitter prices in the United States

TABLE IV

Cost of a television station without transmission line, antenna, tower, building, and site costs

Transmitter power, kw		0,1	0.25	0.5	1 autom.	1 manual	2	5	10	25	50	100	200
Purchasing price of transmitter, accessories, spare tubes, RF load and high voltage equipment.	$	56500	57500	60000	72500	97100	114600	151900	187300	296000	369400	509900	642000
	mill mk	13.1	13.3	13.9	16.8	22.4	26.4	35.1	43.3	68.4	85.4	118.0	148.5
Annual operating cost of the above	$	13800	14000	14600	17700	23700	28000	37000	45700	72200	90200	124400	156700
	mill mk	3.2	3.24	3.38	4.09	54.8	64.7	8.55	10.6	16.7	20.8	28.8	36.2
Power consumption kw		3	3	3	5.5	8.5	13.2	26	46	100	185	340	630
Annual power cost 6 hrs per day	$	128	128	128	235	363	564	1111	1965	4270	7900	14520	26910
	mill mk	0.03	0.03	0.03	0.054	0.084	0.13	0.257	0.454	0.987	1.83	3.36	6.22
Salaries of personnel	$					5724	5724	8620	10312	12424	12424	14376	14376
	mill mk					1.32	1.32	1.99	2.38	2.87	2.87	3.32	3.32

annual power cost of the station and wages of the personnel. The power cost is based on six-hour operation per day and the price of the electricity is taken as the average of the total power cost of the Finnish broadcasting network in 1950. This average was

4.5 marks or 1.95 cents per kilowatt-hour.

The wages of the personnel are based on the Table V, which gives the average wages as they were in 1951.

Buildings. Buildings are assumed to be brick buildings. The automatic stations should have space for only the transmitter equipment and storage. All manual stations need room for a shop, and stations from 5 kilowatts up require a high voltage room, an office, and an apartment for a janitor. Larger stations require garage and projection room, and extra space for heating room, hall and similar purposes. Table VI shows the estimated areas and prices for stations of different sizes. Cost per square foot has been estimated fairly high, but the prices of these buildings agree with the actual prices in Finland. The latest large broadcasting station in Finland is the new 100-kilowatt AM-station in Helsinki. The building for that cost approximately $138,000 in 1950, which agrees with the corresponding estimated price for a television station. Besides transmitter building manually operated stations should have also residence building for a chief engineer.

Transmission lines. Since very-high and ultra-high frequencies are used for television service, the only practical transmission line from transmitter to antenna is a coaxial line. The line has to be

TABLE V

Personnel needed in a television station and their salaries

Transmitter power, kw	Chief engineer	First engineer	Second engineer	Janitor	Charwoman	Secretary
1	1		2			
2	1		2			
5	1	1	1	1	1	
10	1	1	2	1	1	
25	1	1	2	1	1	1
50	1	1	2	1	1	1
100	1	1	3	1	1	1
200	1	1	3	1	1	1
Monthly salary marks	45,000-60,000	40,000	32,500	28,000	23,000	28,000
Annual salary dollars	2340-3120	2076	1692	1452	1200	1452

TABLE VI

Size and cost of transmitter building of television station

Transmitter power kw	Building area square feet	Price per square foot	Purchasing price		Annual operating cost	
			$	million marks	$	million marks
0.1	225	24	5,400	1.249	510	0.118
0.25	230	24	5,520	1.275	522	0.121
0.5	240	24	5,760	1.33	544	0.126
1 automatic	290	24	6,960	1.608	658	0.152
1 manual	830	20	16,600	3.835	1570	0.363
2	930	20	18,600	4.3	1758	0.406
5	2190	20	43,800	10.12	4140	0.957
10	2930	20	58,600	13.55	5540	1.28
25	3700	20	74,000	17.1	7000	1.62
50	4370	24	104,900	24.25	9910	2.29
100	5440	24	130,700	30.2	12350	2.86
200	6690	24	160,700	37.1	15180	3.51

gas-insulated to reduce losses. The safest way to prevent flashovers and to control the condition of transmission lines is to use slight gas pressure in the lines. The pressure keeps the moisture out and warns about possible leaks. Standard sizes in the United States are 7/8-inch, 1 5/8-inch, 3 1/8-inch and 6 1/8-inch line in television stations. The calculations have been made using these same sizes and in addition 9-, 10-, 12-, and 14-inch sizes, which all have approximately 51-ohm characteristic impedance.

When the most economical transmission line diameter has to be determined for certain size transmitter, the length of the transmission line has to be known. By plotting the total annual operating cost without the antenna, versus power delivered to the antenna as shown in Figure 17, the tangent from the origin to the curve shows the diameter which gives the maximum power per unit cost. In the example just given, the closest standard diameter is 6 1/8 inches. Of course, some other transmitter and transmission line combination may be still more economical. Or, if initial investment is to be considered, some smaller size transmission line may be preferred. At higher transmitter powers again, the economical optimum size may be impossible to use because of too small power carrying capacity. Also possible later power increase has to be considered.

When different transmitter and transmission line combinations are considered, a series of curves will be obtained as in Figure 18. In this example at transmitter powers from 100 watts up to 25 kilowatts the closest standard coaxial cable diameter to the optimum was

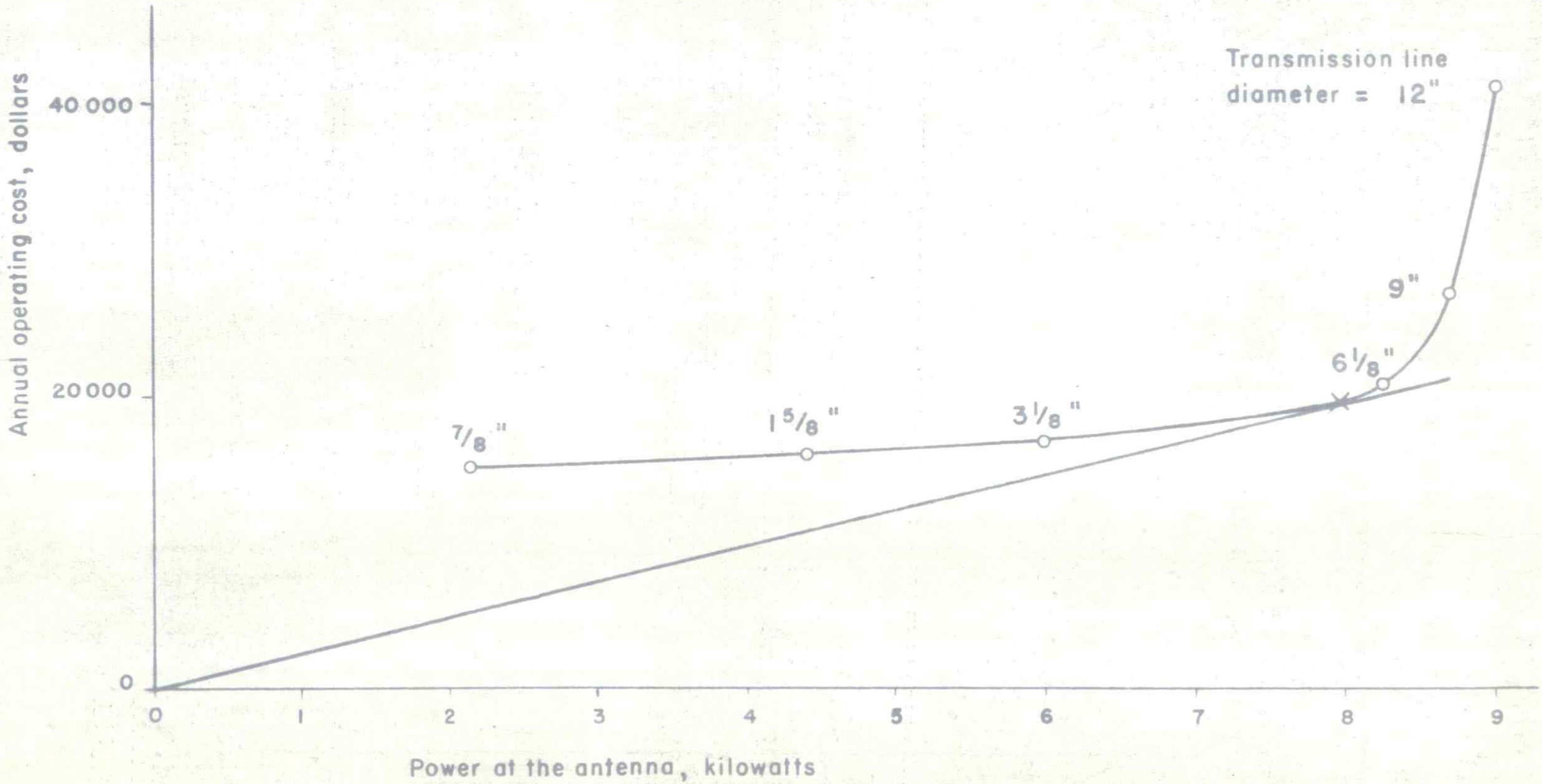


Fig. 17 Method of determining the economical optimum diameter for transmission line

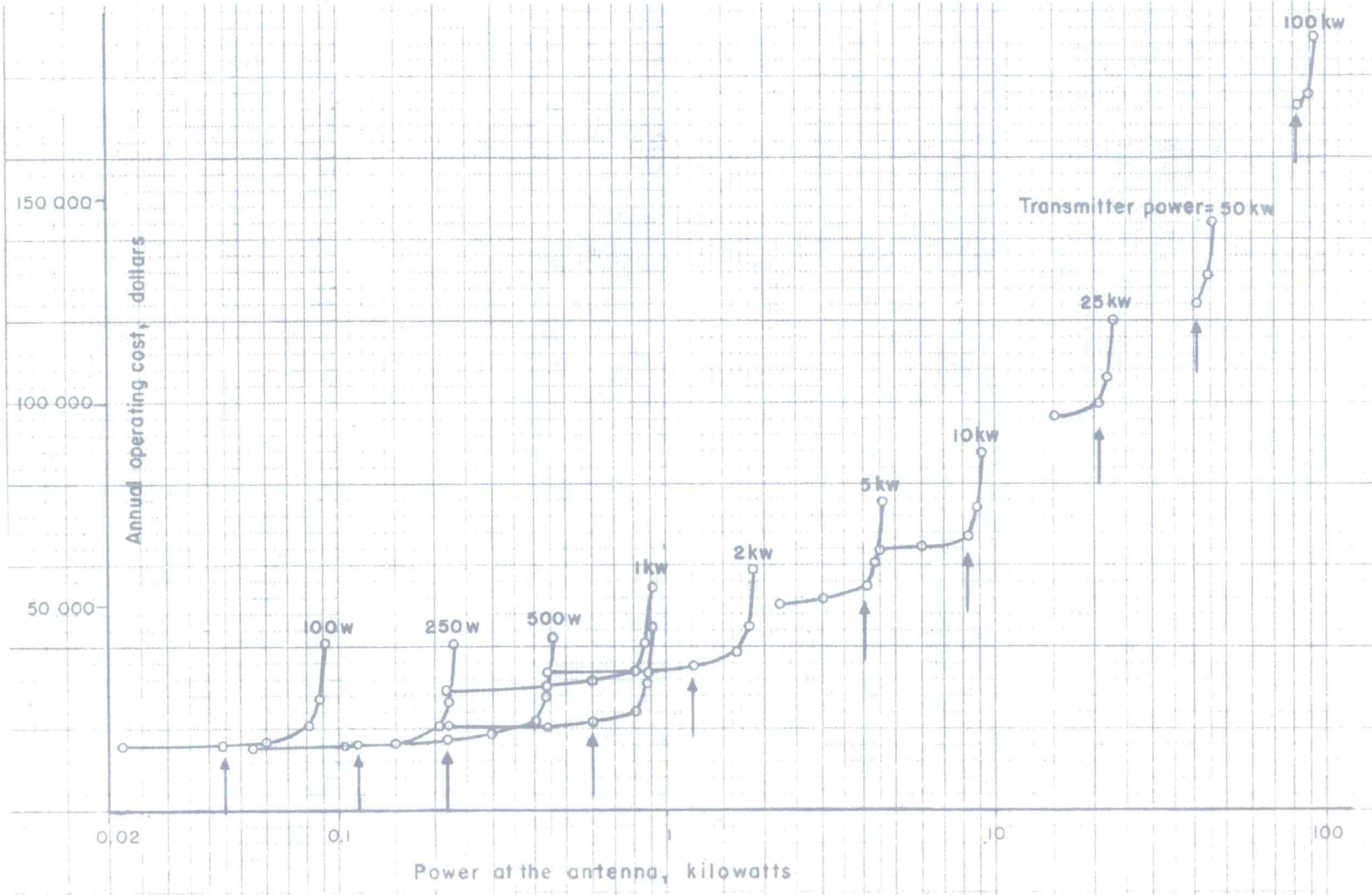


Fig. 18 **Curves for selection of the proper transmission line diameters for each transmitter size**

6 1/8 inches, but as shown in the figure by arrows the chosen diameters were smaller for the transmitters at the lower powers. One reason for this choice is that some other combination of larger transmitter and smaller cable would give more economically the same power at the antenna. Power capacity, possible reserve in the power capacity, and economic preference between single and dual line were considered also (26, pp.101-102).

Antennas. The simplest antenna for nondirectional operation is some variation of the original turnstile antenna. An additional requirement compared to general radio uses is the wide band characteristics necessary to handle a television signal. In the Alexandra Palace station, in London, the dipoles comprising the turnstile antenna are made thick, but in the United States the so-called "bat-wing" type is the most common. At 200 megacycles bat-wing antennas can be built using up to 12 turnstile layers having a gain of about 13. For mainly mechanical reasons no higher gain bat-wing antennas can be built. If higher gains are required, some other construction method like "super-gain antennas" have to be used. Instead of the pole in bat-wing (super-turnstile) antennas, the super-gain antenna employs preferably square tower construction, upon which dipoles and shields are placed on four sides, or if a directional pattern is wanted only on three, two, or one side. Using super-gain antenna construction very high gains can be obtained. Directional patterns are sometimes wanted, on sea-shore, for instance. These can be attained using different numbers of dipoles on different sides of the tower and feeding them in proper phase. For ultra-high frequencies, new constructions like the helical and the slot antenna have been developed.

When all other factors including the antenna height above terrain are known, the same method as used to determine the most economical transmission line and transmitter combination can be used to determine the most economical transmitter and antenna combination by plotting annual operating cost versus effective radiated power instead of power at the antenna like in Figures 17 and 18.

Figure 19 shows an example. For high-gain antennas the close-range field intensity has to be checked as previously mentioned (26, pp.83-155).

Towers. Either self-supporting or guyed towers can be used depending upon the space available. In Finland practically only guyed towers are used, because broadcasting stations are seldom located in the crowded part of a city. If they are so located, they are in parks or similar places, where guyed towers can be used.

In television, the antenna height is of primary importance and since Finland does not have conveniently-located mountain tops, towers as high as practicable should be used. They should be built preferable, in Finland. The tower prices used were based on information obtained from Finland, and they were approximately 20 per cent higher than the prices in the United States.

Generalized stations. To determine the generalized stations, or the most economical and logical stations, four tower heights were

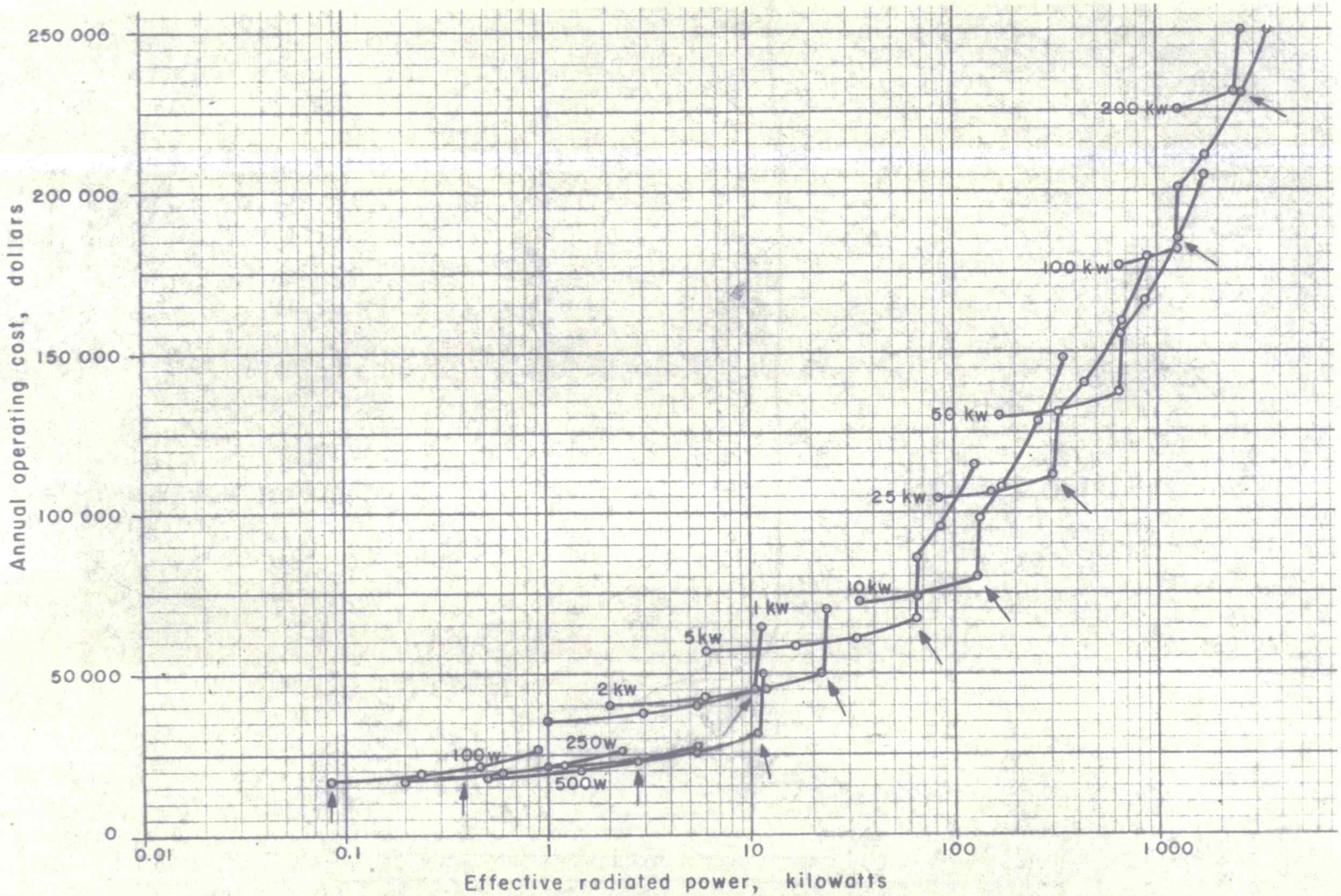


Fig. 19 Curves for selection of the proper antenna for each transmitter size

chosen for computation purposes. These were 200, 400, 820, and 1640 feet. For these different tower heights and for different size stations the most suitable transmission lines and antennas were determined using the method described before. The total cost was calculated, and the grade B service distances determined using Federal Communications Commission's designing curves (Appendix II). The annual operating cost and service distance were plotted versus effective radiated power having tower heights as parameters. These curves can be combined by transforming them to show annual operating cost versus effective radiated power, the service distances being parameters. The minimums of the curves give the most economical effective radiated powers for certain service distances, and corresponding transmitter and tower combinations can be determined based on all other previously considered factors. Table VII shows the results which indicate that economically, about 1 kilowatt station should have a tower approximately 1600 feet high, in other words as high towers should be used as other factors like initial cost and servicing allow. Towers 1600 feet high are not advocated for practical reasons.

Based on these computations and taking practical factors into account, generalized stations were determined. Table VIII contains the summary of the values. Antenna bay-numbers up to 12 refer to super-turnstile antennas and above that to super-gain antennas. In this table the terrain is assumed to be flat, and the cost includes the total station cost, installed, without possible power-supply

TABLE VII

Most economical transmitter-tower combinations

Grade B service distance km	Effective radiated power kw	Corresponding transmitter power kw	tower height feet
20	0.6	0.3	250
30	0.8	0.35	400
40	1.3	0.425	550
50	3.2	0.6	600
60	3.2	0.65	900
70	3.8	0.8	1200
80	3	0.8	1600
90	10	1.6	1600
100	30	3	1600
110	100	10	>1600
120	320	30	>1600

T A B L E VIII

Generalized television stations

Transmitter power kilowatts		0.1	0.25	0.5	1 autom.	1 manual	2	5	10	25	50	100	200
Tower height	m	30	60	100	150	150	150	200	200	200	250	300	400
	ft	100	200	328	500	500	500	655	655	655	820	985	1300
Antenna bay-number		1	2	6	12	12	12	12	12	12	30	40	40
Electrical antenna height, feet		105	208	347	538	538	538	693	693	693	753	896	1211
Transmission line diameter, inches		2x7/8	2x7/8	2x1 5/8	3 1/8	3 1/8	3 1/8	6 1/8	6 1/8	6 1/8	6 1/8	2x6 1/8	10
Transmission line efficiency, per cent		78	67	72.5	73.5	73.5	73.5	87	87	87	85.5	83	84
Effective radiated power, kilowatts		0.098	0.402	2.48	9.78	9.78	19.55	57.9	115.8	289	1189	3070	6220
Purchasing price	$	76220	84910	112280	187350	231590	251090	350900	403100	527200	869750	1184900	1503600
	mill.mk	17.6	19.6	26	43.4	53.5	58	81.1	93.1	121.8	201	274	348
Annual operating cost	$	16730	18380	23440	36530	50230	54920	74740	87580	119950	196220	269770	337190
	mill.mk	3.9	4.3	5.4	8.4	11.6	12.7	17.3	20.2	27.7	45.4	62.4	77.9
Service radii, km	A	3.54	7.25	14.5	28.2	28.2	32.2	49.1	55.5	64.4	77.3	89.4	104.6
	B	8.53	17.2	35.4	57.9	57.9	64.4	78.1	83.7	91.8	104.6	117.5	132.8

transmission line cost. A residence building for the chief engineer is included. No depreciation has been computed for the station site. Service radii have been determined using Federal Communications Commission's graphs (12, pp.3082-3084). These generalized television stations have been later used for designing networks of several television stations.

Similar studies as the one just described were made specifically for Helsinki. The television station was to be located at the present 100-kilowatt AM broadcasting station, and one of the present self-radiating towers was to be used to support the television antenna. The towers are 500 feet high and located nearly at sea level. Television transmitters up to 2 kilowatts in power can be housed to the same building with AM station, but for a higher power station, a separate building has to be built. The computations showed that by placing the television station at a present AM broadcasting station and utilizing its tower approximately 10 to 30 per cent of the purchasing price and about 5 to 15 per cent of the annual operating cost can be saved.

If a television station is to be close to the seashore, a directional antenna may be advantageous. However, if the transmitter power is small, 5 kilowatts or less, a standard bat-wing antenna was found to be as cheap as or cheaper than a modified super-gain antenna for the same service radius. At a power of 25 kilowatts or more, a modified super-gain antenna having approximately a pattern of the form of cycloid results in a saving of about 20 per cent in annual operating cost for the same service radius. Such an antenna should have about eleven times as many antenna elements in the direction inland as on the side of the sea (26, pp.107-109).

As mentioned before the first null below the main loop is the limiting factor of highly directional antennas. In the case of Helsinki calculation was made for the 500-foot tower and 60-layer super-gain antenna. The null was estimated to be about 2 per cent (unusually low) of the field intensity of the main loop at the same distance. The calculated field intensity was about six times that required for grade A service. Thus even 60 layers can be used in Helsinki if the tower is no more than 500 feet high. However, tilting of the beam is recommended.

Studios

In the proposed television system for Finland there will be a main studio in Helsinki. Since noncommercial type of operation will be used and since Helsinki has much better possibilities for good programming than any other city in the country, the Helsinki studios will probably be fully developed before additional studios will be built. Therefore in this investigation only studios for Helsinki have been considered, and all programs are assumed to originate there. Four different size studio facility combinations are described in the following.

The smallest possible studio facility is a film studio. There has to be one film camera chain, two (probably 35-millimeter) film projectors and two slide projectors. Since plain film programs would not be preferable, remote pick-up equipment is included, having two camera chains, portable radio-relay equipment, and mobile unit. In the studio two announcing booths would be practical. In addition amplifying, switching, and monitoring equipment are needed, plus monoscope and network terminal equipment.

The next size would have one live-talent studio with two cameras, and a film studio with one film camera chain, one 35-millimeter film projector and a slide projector (26, pp.312-315). A combined studio and master control room can be used. A remote pick-up equipment with two cameras and a mobile unit should be available. With this amount of equipment, daily live-talent programs of about three hours can be produced and a personnel of about 30 persons is needed.

The next size studio facility would have two live-talent studios. In this type, separate control rooms should be provided for both studios, which would have a total of six cameras. Film studio should have two or maybe three camera chains, four 35-millimeter projectors and two 16-millimeter projectors. A separate master control room is necessary for flexible operation and the switching is best done by relays to make future expansions easier. Also a film studio control room is useful. Two sets of remote pick-up equipment with two camera chains and a mobile unit for each set should be provided, (26, pp.321-325). The program capacity of two-studio system is approximately six hours daily and a personnel of about 60 persons is needed.

For extensive programming three live-talent studios are required. This system can be easily expanded from the previous one by adding a large studio with five camera chains, a separate control room and switching facilities in the master control room. With these facilities approximately nine to twelve hours daily of live-talent programming is possible using a personnel of about 90 persons.

For these four different studio facility sizes equipment costs were determined, necessary room areas calculated, the cost of buildings computed, wages of personnel, and probable power cost determined. This information has been gathered into Table IX. The annual operating cost in the table is the total programming cost, including such items as the payment for artists. Corrected area of the building means that studio areas have been added twice, since studios are two stories high. The figures from Table IX were later used when computing the total cost of a television network.

Program Distribution System

When a centralized programming is used, the program distribution system is of primary importance. The present-day radio AM-program distribution is accomplished completely by telephone circuits in Finland but for television it is impossible to use such circuits because of the bandwidth required. Three systems are possible for television program transmission. These are coaxial cable, radio relay, and films by mail.

TABLE IX

Studio information

Number of studios		1	2	3
studio cameras		2	6	11
film cameras	1	1	3	3
field cameras	2	2	4	4
Studio area, square feet		2000	7400	14700
Building are, square feet	2490	7960	24955	51900
Number of stories in building	1	1	4	4 or 8
Price per corrected area, $/sq.ft	24	24	20	20
Purchasing price of building $	59,760	239,040	647,100	1,332,000
Purchasing price of building mill. mk	13.8	55.22	149.48	307.69
Total purchasing price $	217,760	466,940	1,357,900	2,217,800
Total purchasing price mill. mk	50.3	108	314	513
Annual operating cost of studios $	80,060	287,200	637,900	942,300
Annual operating cost of studios mill. mk	18.5	66.4	147.5	218
Daily program time, hrs	3	3	6	9
Approximative personnel	9	32	60	90

Coaxial cables and also specially equalized "telephone" wire pairs can be used for a wide bandwidth, but their installation and maintenance cost is likely to be high. Also the many repeaters required add costs and inconveniences to these circuits. Mail can be used for programs which are not important as far as the time is concerned. However, since local programming will be very slight, news and special features require immediate program distribution. The slow distribution by mail is a disadvantage. Also, if mail is used extensively for program distribution, film camera equipment and projectors and operators are required at every transmitting station, which would increase the cost considerably. The most practical system, as proven by experiences in television networks, is a radio-relay distribution network. Thus a few words will be said about radio-relay transmission systems in the following pages.

Radio relays for television purposes operate at ultra-high or usually at super-high frequencies, from 2000 to 10,000 megacycles per second. At these frequencies a very highly directional antenna system can be utilized. For instance, at 7000 megacycles a 6-foot parabolic reflector will give a power gain of approximately 11,000. The high gain allows small transmitter powers to be used, and additionally, when both transmitter and receiver have a highly directional antenna, the transmission path is selective and certain noise, interference, and reflections can be avoided. Since line-of-sight condition has to be obtained, the earth's curvature imposes the necessity of repeater stations. These repeaters can be unattended and remotely controlled. Radio-relay circuits have been used in the United States having up to 60-mile spans, but shorter spans are preferred to ensure reliable service. The beam should clear the earth by at least about 100 feet. In the television practices in the United States, radio relays for local program service have been used only to transmit the video signal, and for audio signal the regular telephone facilities have been utilized. However, in Finland for nation-wide program service both signals should be transmitted through the same radio-relay distribution system. If the radio-relay equipment is designed for a slightly wider bandwidth than is required for video only, the audio signal can be transmitted simultaneously with the video signals using a sub-carrier system.

A study was made to determine the optimum tower height for radio-relay repeater. The earth's surface was assumed to be smooth and spherical, and long distance was to be covered. Based on annual operating cost determined as explained before and assuming only one relay system on the towers, it was found that the height of 300 feet would give the most economical operation, approximately 202 dollars per mile, but the variation in cost is only about 3 per cent, when using tower heights from 250 to 400 feet. If 200-foot towers were used the annual cost would be approximately 235 dollars per mile or about 15 per cent higher than with 300-foot towers. With 200-foot towers about 28-mile or 46-kilometer span can be used, 300-foot height would allow about 40-mile or 64-kilometer span to be used. These are much shorter distances than have been used in the United States. However, higher than about 250-foot towers should not be used because of maintenance difficulties. The tower prices were assumed to be about 50 per cent higher than the regular guyed antenna tower prices, since additional to those they have to have cover or room for equipment, possible heating equipment, and better stairs for maintenance.

PROGRAMS

Programming cost forms a great part of the total cost of providing television service. When investigating the feasibility of a system, the cost of programming has to be estimated, although in practice it may vary considerably. Therefore a study was made of the probable distribution of the program time for different kinds of programs, and the probable cost was estimated.

A study was made of the time distribution of the programs of a large American television company during a 5-year period (8, pp.204-211). The number of programs was changed to probable percentage of program time. On the other hand, similar study was made of present-day AM radio programs in Finland (37, pp.9-38). By comparing these and taking the different nature of the programs into account, an estimated distribution of television program time for a Finnish system was obtained. In the United States the greater part, sometimes up to 90 or 100 per cent, of programs is from film, and live-talent cost is correspondingly less. But, in Finland probably nearly all program will be live-talent features, since practically all program will be produced in Finland and can be transmitted simultaneously through the whole network without using film recording. On the other hand, the professional film industry does not produce many films that they can be counted on. Because of language difficulties, program exchange between countries will probably be small. Accordingly, it was assumed that approximately 80 per cent of program time will be live-talent features and the rest, 20 per cent, films. The estimated program time distribution is as follows:

Religion	4
Science Monologs Discussions Art Hobbies Education Sports	29
Drama Revue Opera	33
Children's program	5
Variety Dance	5
Music	14
Special features	3
News	7
	100 per cent

This includes the film programs also, half of that being in dramas.

The cost of programming was estimated using the cost of the present-day AM radio programs in Finland as a comparison. The total "person-hour" amount of performers in a year was calculated as closely as possible, and knowing the sum paid to the performers during the same time, the average wages of performers per hour were computed. The average wages per program hour were

$29 or 6700 marks per hour.

By computing the person-hour amount for the television program specified above, the average number of performers in an hour turned out to be

5.24 performers per hour.

This gives the cost of program, as far as the performers are concerned,

$152 or 35,100 marks per hour.

The annual pay to the performers is then

$44,400 or 10.28 million marks

per total daily program hour. This value has been used, when preparing the annual cost of studios for Table IX.

BROADCASTING SYSTEMS

In the preceding chapters studies have been made of the different factors which affect the design of a television network of several stations for Finland. Such factors are wave propagation at frequencies used for television service, population distribution, technics and economy of network elements, and the nature and cost of programming. Generalized transmitting stations and different size studio units have been designed, and their costs determined. Using this knowledge, plans for the final television network can be made. When making a plan for a network, two different principles can be applied, so-called "minimum cost per person principle" and "equal cost per person principle." Using both of these principles, preliminary plans were made for television broadcasting systems and the results obtained are explained in this chapter.

Minimum Cost per Person Plan

When a television broadcasting network is to be designed for the whole country, the minimum cost per person principle means that for any certain coverage a plan is to be made which is the cheapest per person for the number of people covered. This means that if a network is to be expanded, either a new station has to be built, or a previous one enlarged, depending on which one gives more additional population coverage per unit cost. The determining factor is the annual operating cost, assuming that the capital needed is available. However, since it would be unfair to disfavor a group of people only because they live far from the main studio, it was considered that the cost of the program distribution system was to be excluded when making the plans.

First, a study was made of the annual operating cost per person of a television station within a service area for stations of different size, and for each logical station location. The terrain was assumed to be flat. Some of the curves thus obtained are shown in Figure 20. As can be seen from the figure, the cost per person first decreases, when the power increases, except in case of Helsinki. But, when the power exceeds about 1 kilowatt, the cost begins to increase. Based on this economical optimum at 1 kilowatt power, it was considered that smaller than 1 kilowatt stations should not be used. In Helsinki, less than 1 kilowatt power is undesirable because of the size of the city. In the case of Riihimäki it was found that the economical optimum was power of about 35 kilowatts. The reason is that at that high power the station would cover three cities including Helsinki, thus obtaining a large coverage.

The curves of Figure 20 were then used for making the minimum cost per person plans for different coverage percentages. It was decided that only 1, 5, 25, 50, 100, and 200 kilowatt stations would be used, to reduce the number of different sizes. The plans were made by expanding the network either by new stations or by enlarging the previous ones, depending on which choice was cheaper

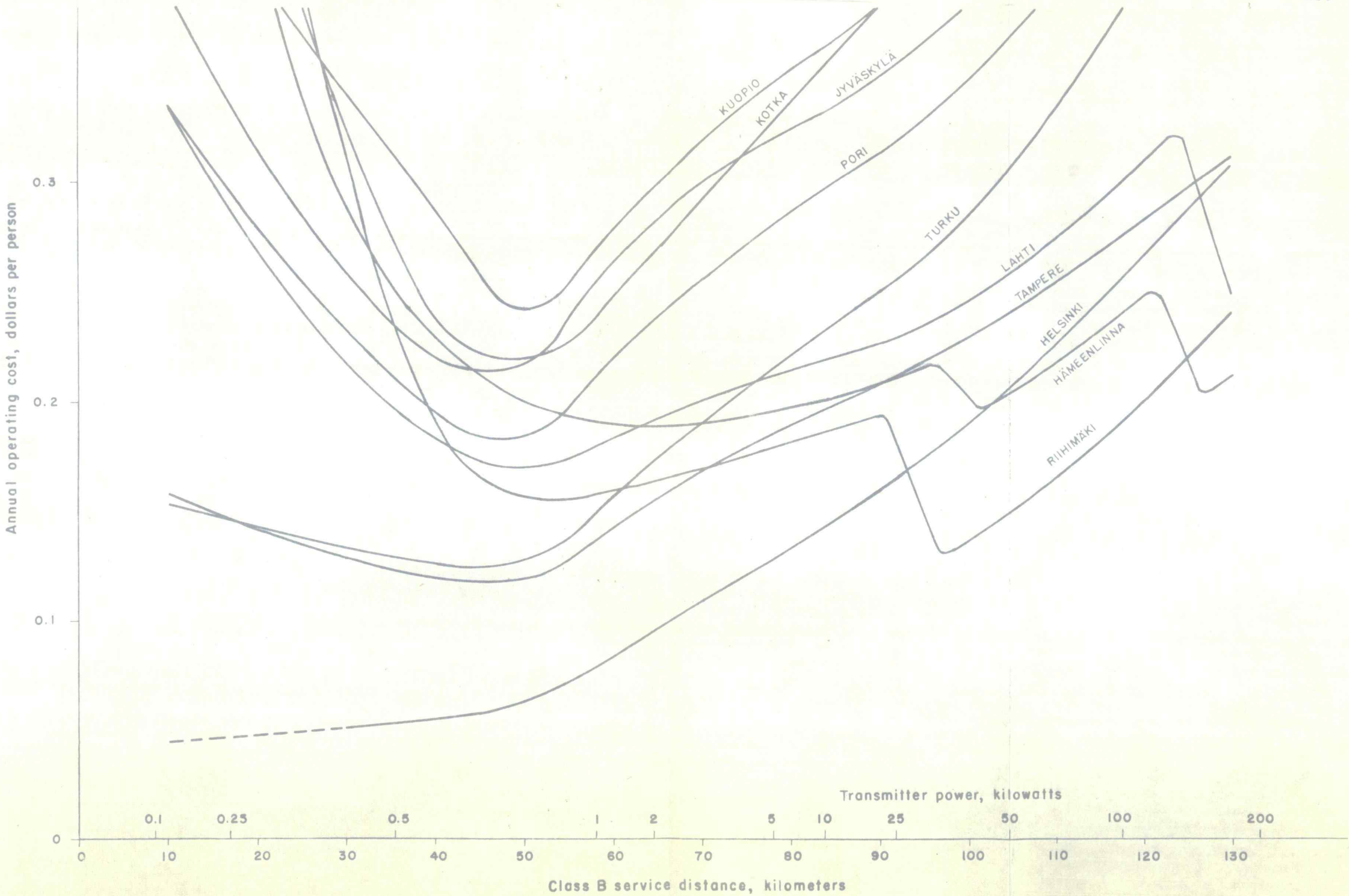


Fig. 20 Annual operating cost per person versus service distance for each probable station location

per additional audience insofar as annual operating cost is concerned. The plans for different coverages are shown in Figures 21 to 25 in the order of expanding coverage. As can be seen from the figures nearly all stations are 1 kilowatt stations. Even in a plan for about 80 per cent total population coverage only three stations are 5 kilowatt stations. The reason is that usually more population coverage is obtained per unit cost, when a new station is built, than by increasing the power of an existing station, when program distribution cost is ignored. Table X shows more detail about calculated system networks. Also the network cost is included in the table, but without studio and program costs. This total network cost includes the cost of the radio-relay system. The cost of the radio-relay system has been determined using the same principles as were used in the final plan, which is explained on later pages, except that the terrain was neglected. Expenses are based on daily 6-hour on-the-air time, and all program material is assumed to be distributed from Helsinki.

Equal Cost per Person Plan

The equal cost per person principle is another way to consider the problem of designing a television network for a country. The largest possible audience is not sought as in the preceding method, but it is considered that the network expenses, without studio and program cost, should be divided in proportion to the audience, or population coverages of different stations. By this method there

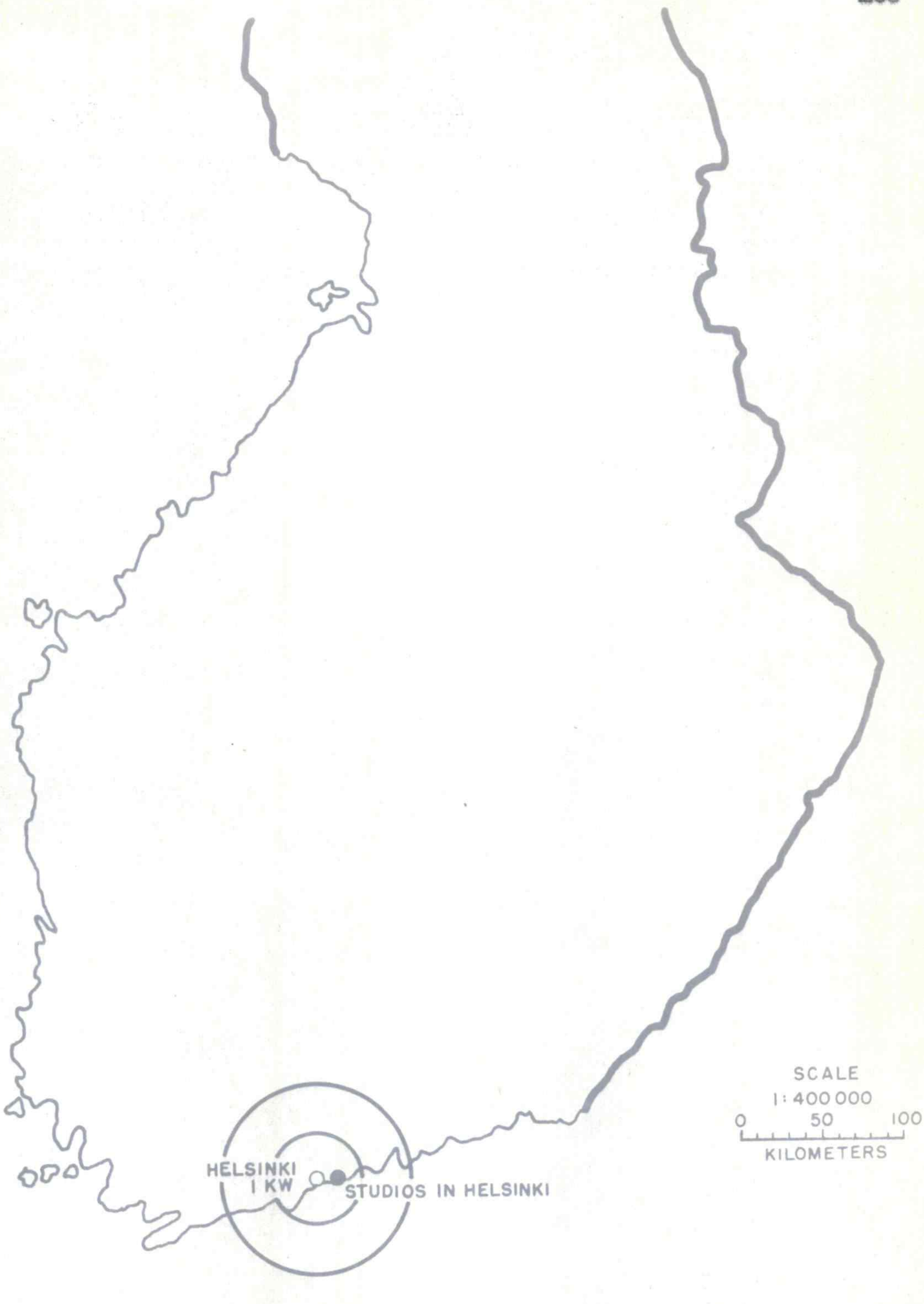


Fig. 21 Minimum cost per person plan for 12.33 per cent coverage

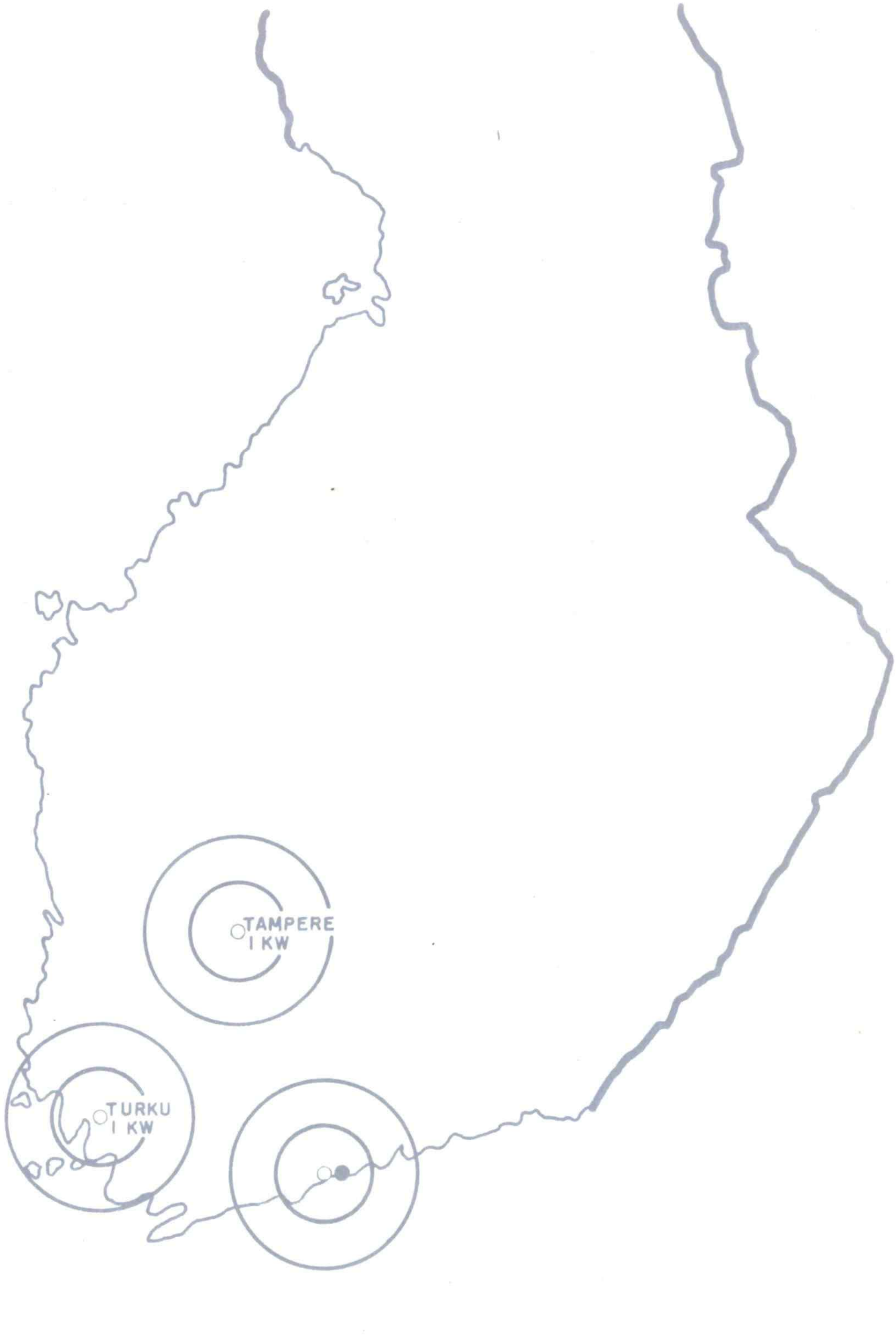


Fig. 22 Minimum cost per person plan for 26.3 per cent coverage

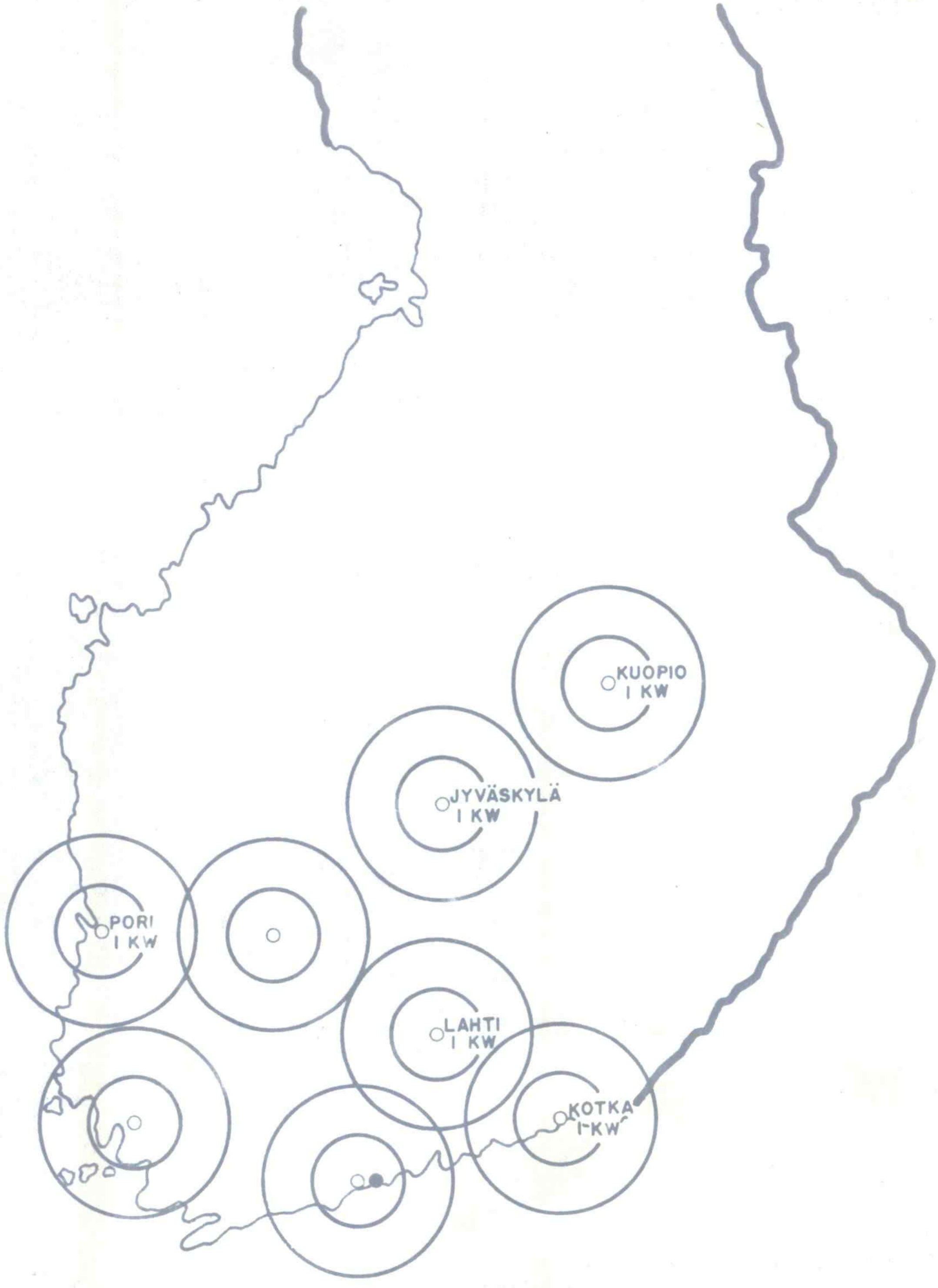


Fig. 23 Minimum cost per person plan for 47.4 per cent coverage

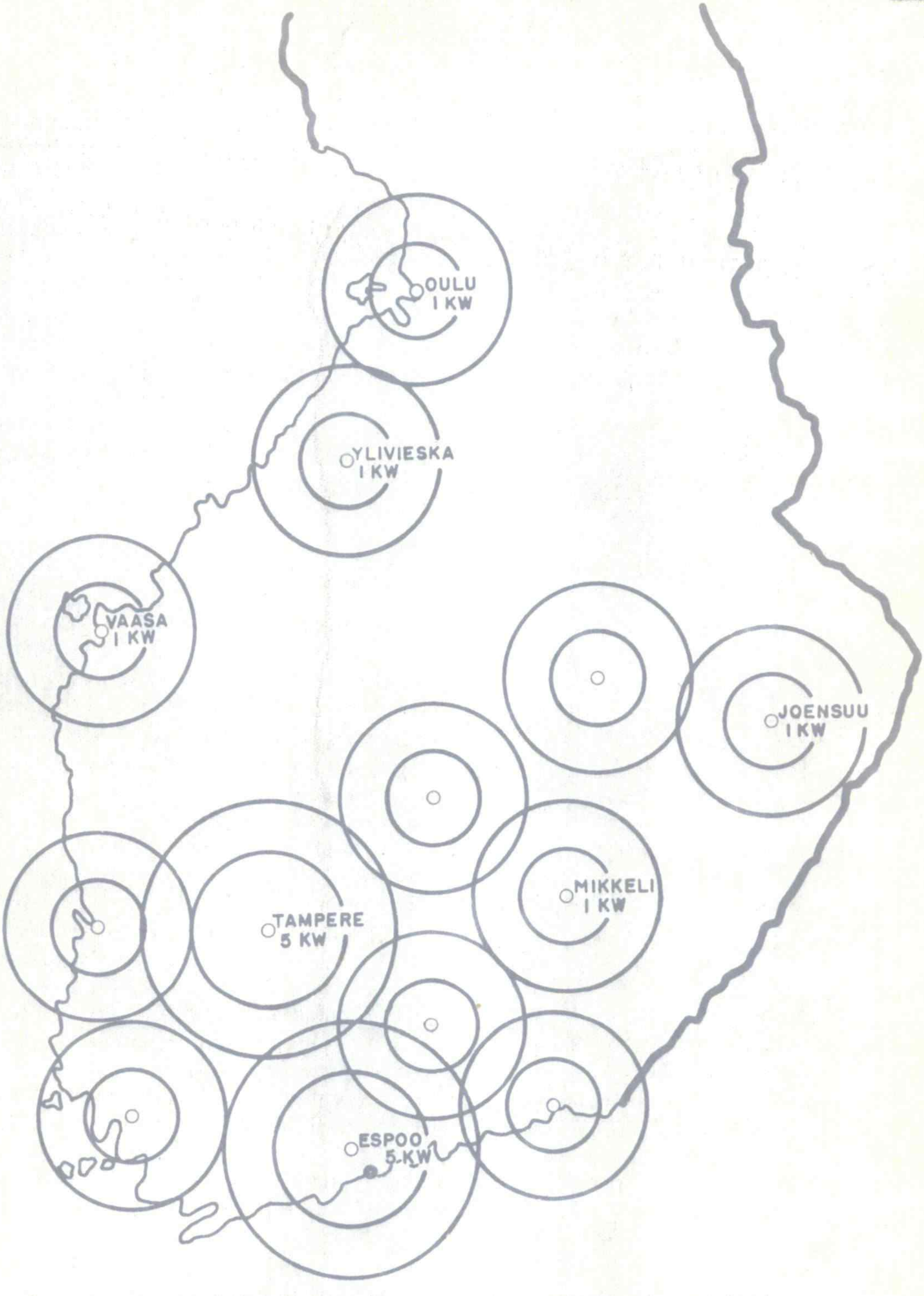


Fig. 24 Minimum cost per person plan for 67.4 per cent coverage

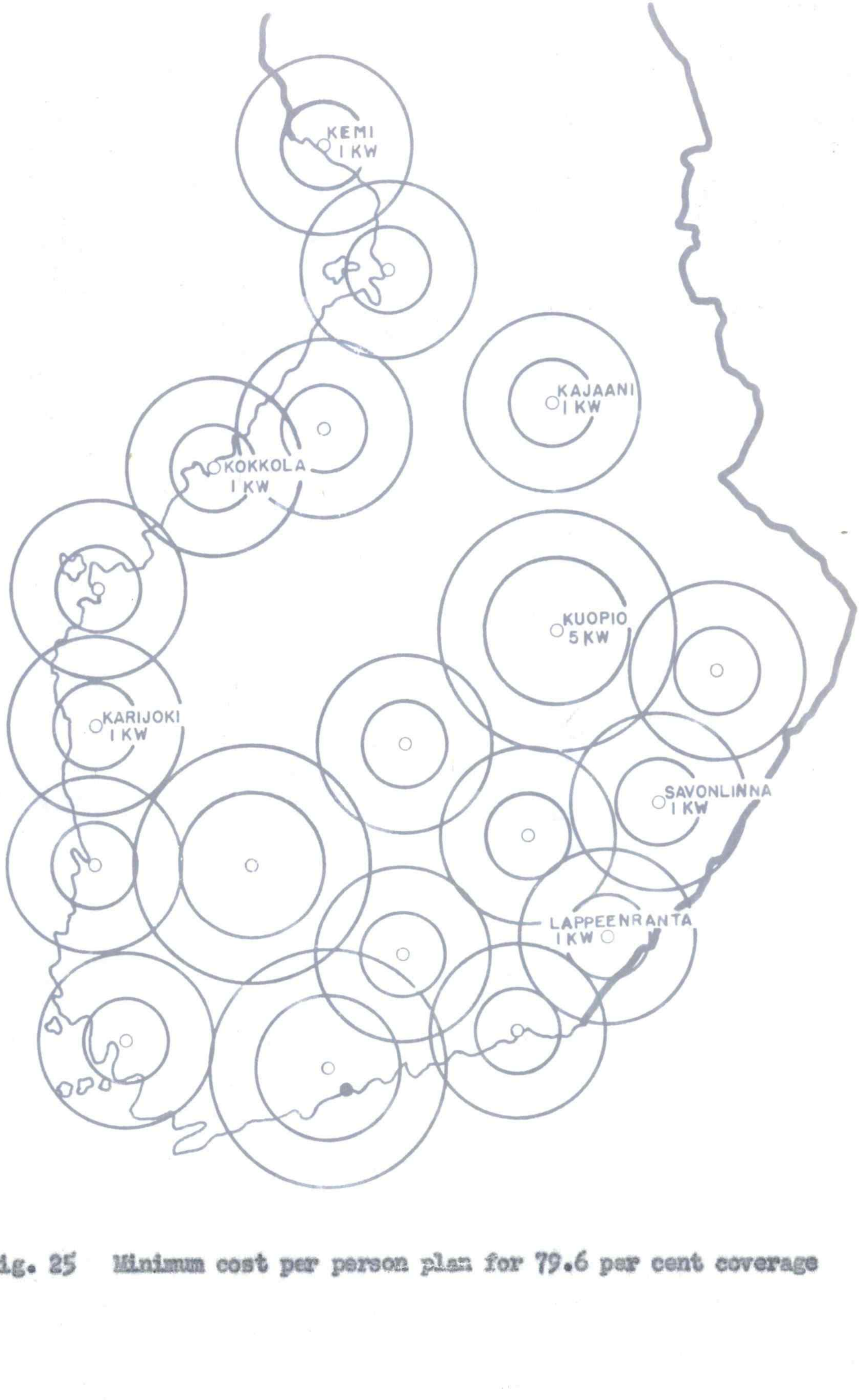


Fig. 25 Minimum cost per person plan for 79.6 per cent coverage

T A B L E X

Minimum cost per person plan

Coverage, per cent of total population, persons	12.33 503,000	26.3 1,072,000	47.4 1,931,000	67.4 2,746,000	79.6 3,244,000
Stations:					
Helsinki	1 kw ap	1 kw ap	1 kw ap		
Espoo				5 kw	5 kw
Turku		1 kw ap	1 kw ap	1 kw ap	1 kw ap
Tampere		1 kw m	1 kw m		
Ylöjärvi				5 kw	5 kw
Lahti			1 kw ap	1 kw ap	1 kw ap
Pori			1 kw m	1 kw m	1 kw m
Jyväskylä			1 kw m	1 kw m	1 kw m
Kuopio			1 kw ap	1 kw ap	5 kw
Kotka			1 kw a	1 kw a	1 kw m
Joensuu				1 kw(a)	1 kw(a)
Vaasa				1 kw(a)	1 kw(a)
Ylivieska				1 kw(a)	1 kw m
Mikkeli				1 kw a	1 kw m
Oulu				1 kw(a)	1 kw(a)
Karijoki					1 kw a
Savonlinna					1 kw a
Lappeenranta					1 kw a
Kokkola					1 kw a
Kajaani					1 kw a
Kemi					1 kw m
Number of stations total	1	3	8	13	19
1 kw	1	3	8	11	16
5 kw				2	3
Purchasing price $	131,650	678,190	2,037,520	3,745,830	5,645,140
mill.mk	30.4	156.6	471	865	1,303
$ per person	0.261	0.632	1.055	1.364	1.74
mk per person	63	146	244	315	402
Annual operating cost $	32,390	150,340	451,510	786,180	1,187,450
mill.mk	7.48	34.8	104.1	181.5	274
$ per person	0.064	0.14	0.234	0.286	0.366
mk per person	14.8	32.4	54.1	66.1	84.6

a - automatic station
(a) - " " near regular AM broadcasting station
m - manually operated station
p - station located at AM broadcasting station using the same tower

will be high-power stations in regions where the population density is high, thus providing saturated field strength and better service. In this case the effect of program distribution system should be neglected also.

The equal cost per person principle was applied by obtaining guiding station sizes from Figure 20, which give the same annual operating cost per person and correcting the values taking the overlapping of service areas into account. On overlapping areas only half of the population was counted as coverage for each station. This plan was also prepared for different coverage percentages. The location of stations and the coverage areas are shown in Figures 26 to 31, and Table XI gives more information about these plans. By this method there would be several high-power stations in the southwest corner of the country, and large overlapping service areas. Again the cost figures given contain the network cost only, including radio-relay system, but without studio and program costs.

Critique

To compare the two preceding methods economically, the annual operating cost per person of both systems were plotted versus population coverage per cent of total population of the country. These curves are shown in Figure 32. The equal cost per person principle gives higher total network cost, but the difference is not as great as might be expected. A reason is that the cost includes

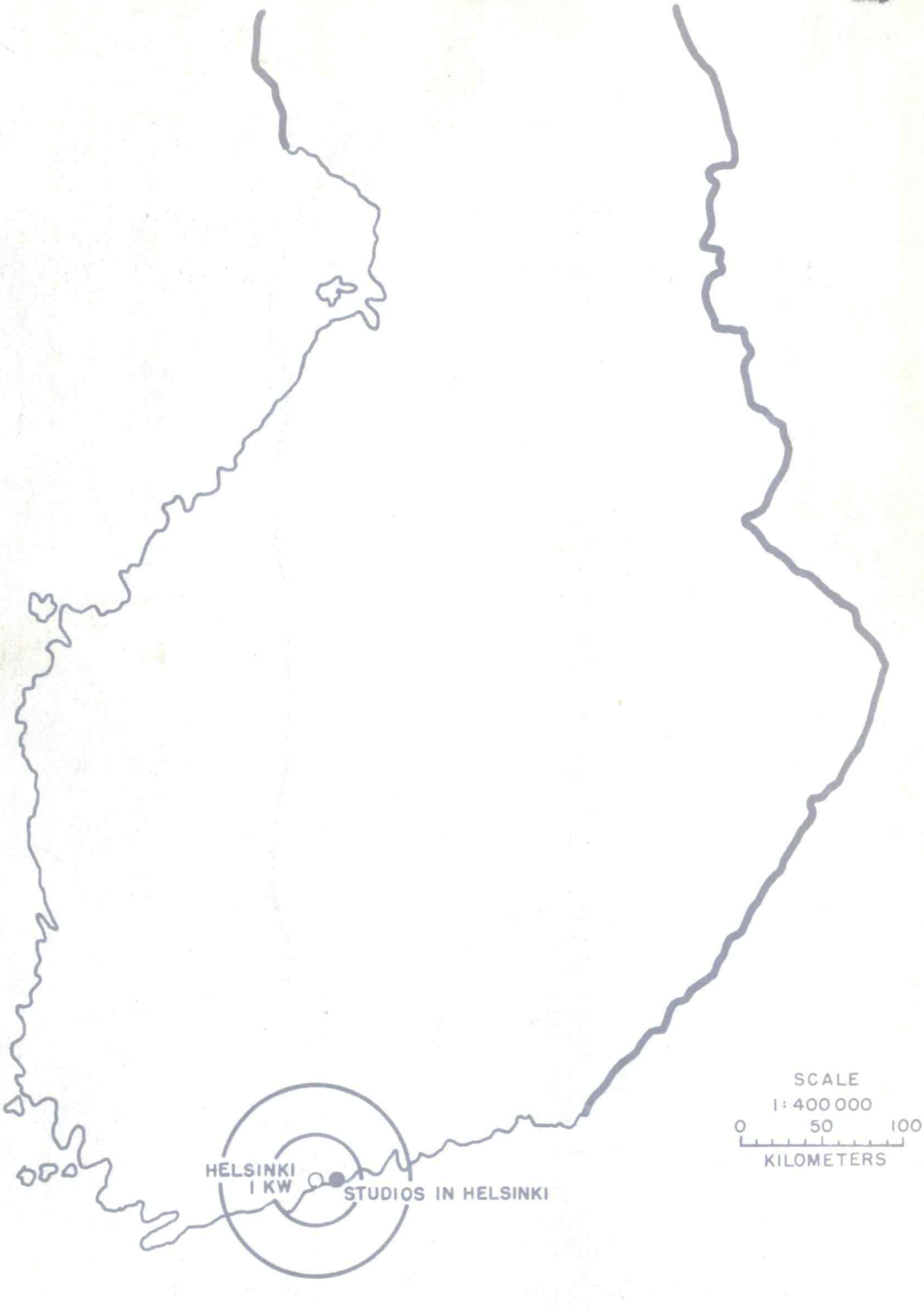


Fig. 26 Equal cost per person plan for 12.33 per cent coverage

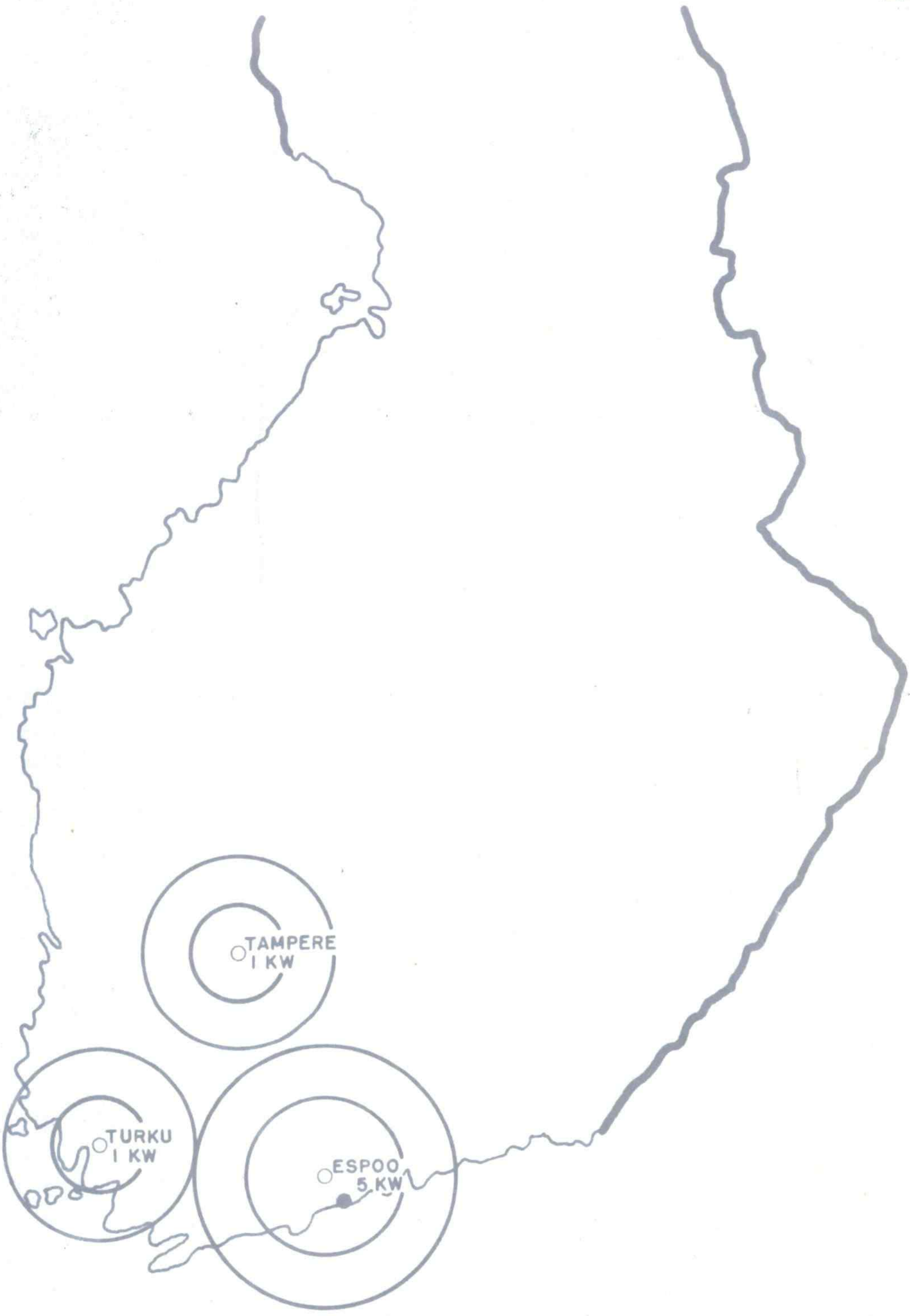


Fig. 27 Equal cost per person plan for 29.7 per cent coverage

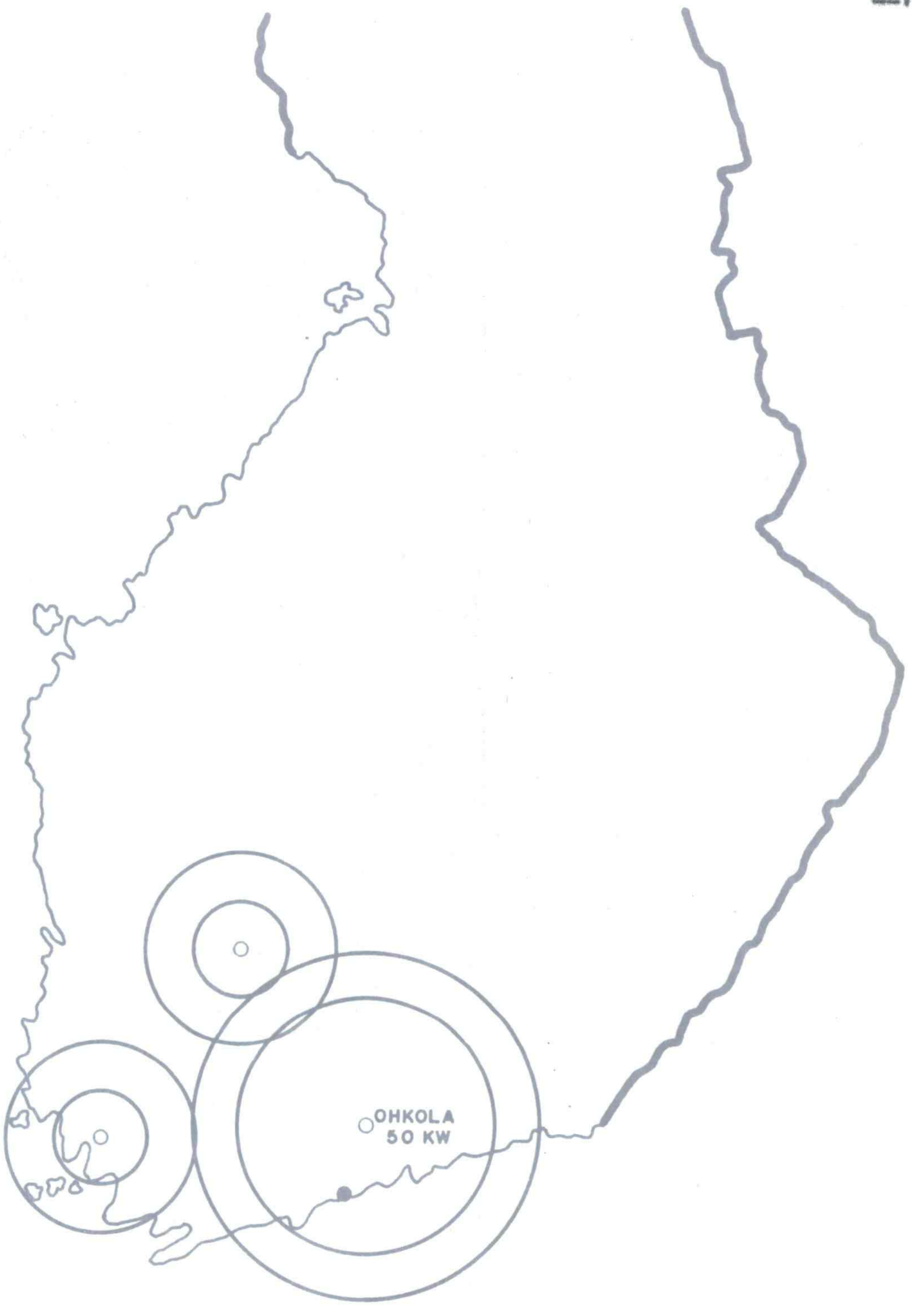


Fig. 28 Equal cost per person plan for 38.3 per cent coverage

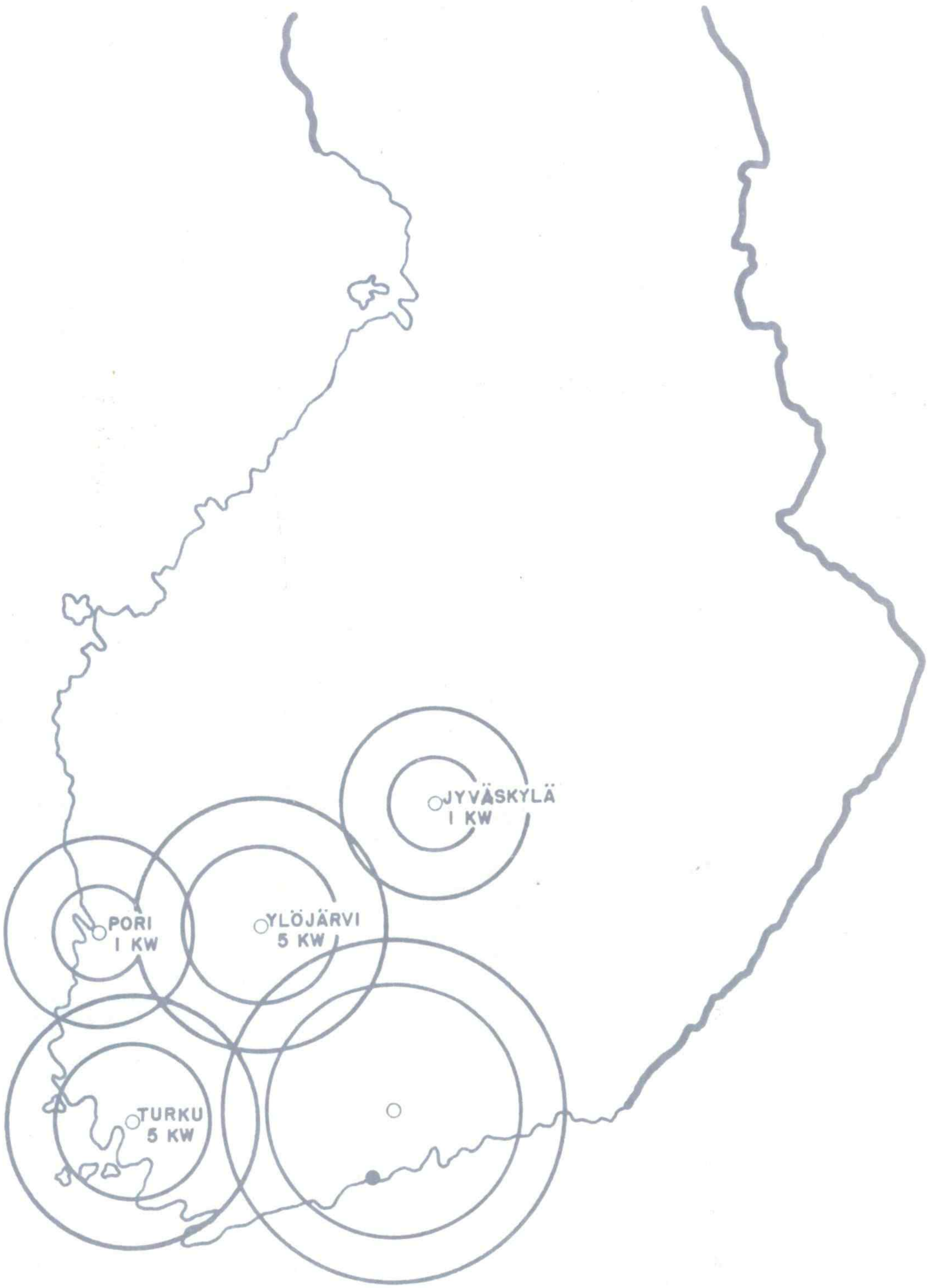


Fig. 29 Equal cost per person plan for 49.6 per cent coverage

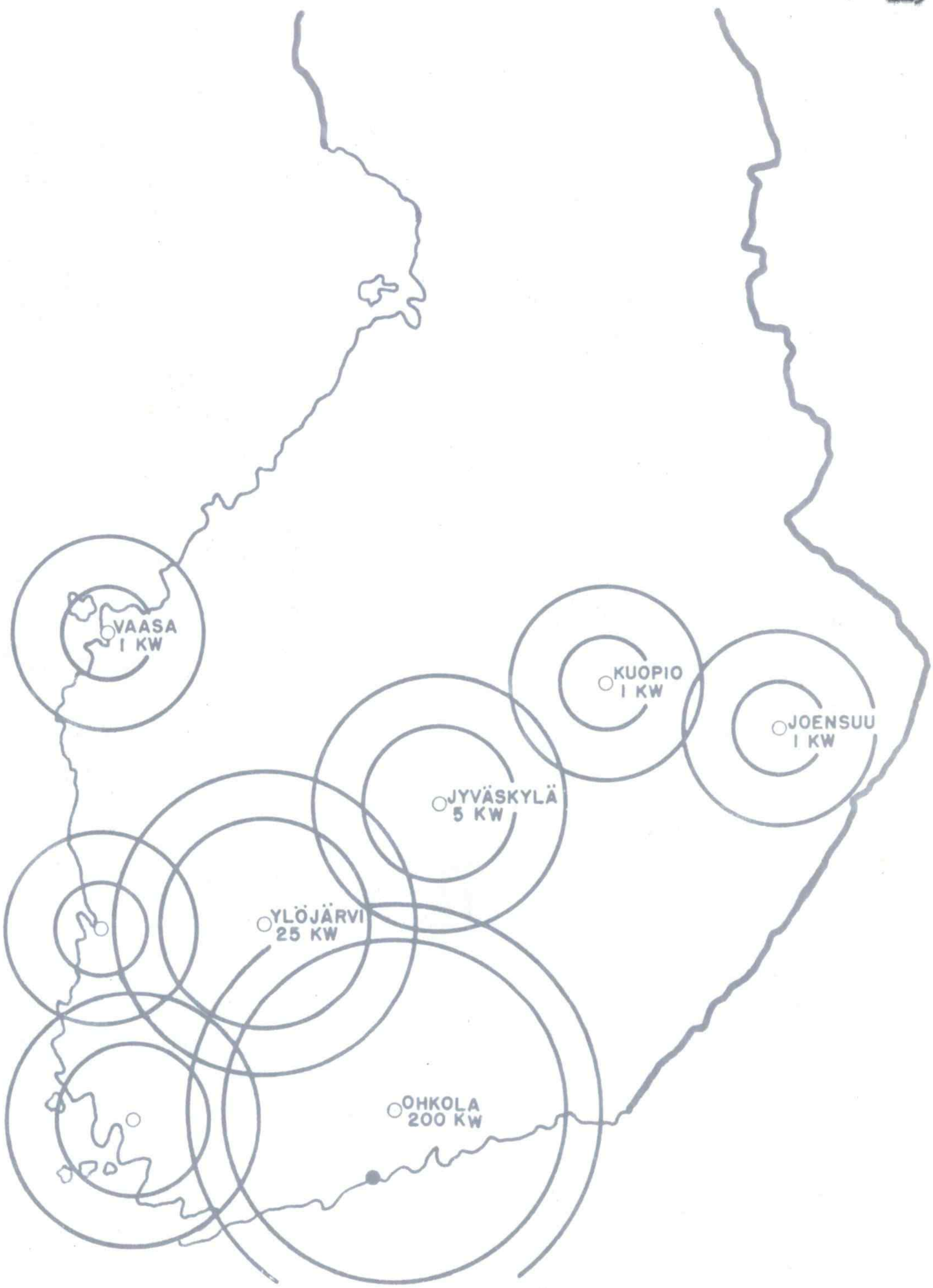


Fig. 30 Equal cost per person plan for 67.1 per cent coverage

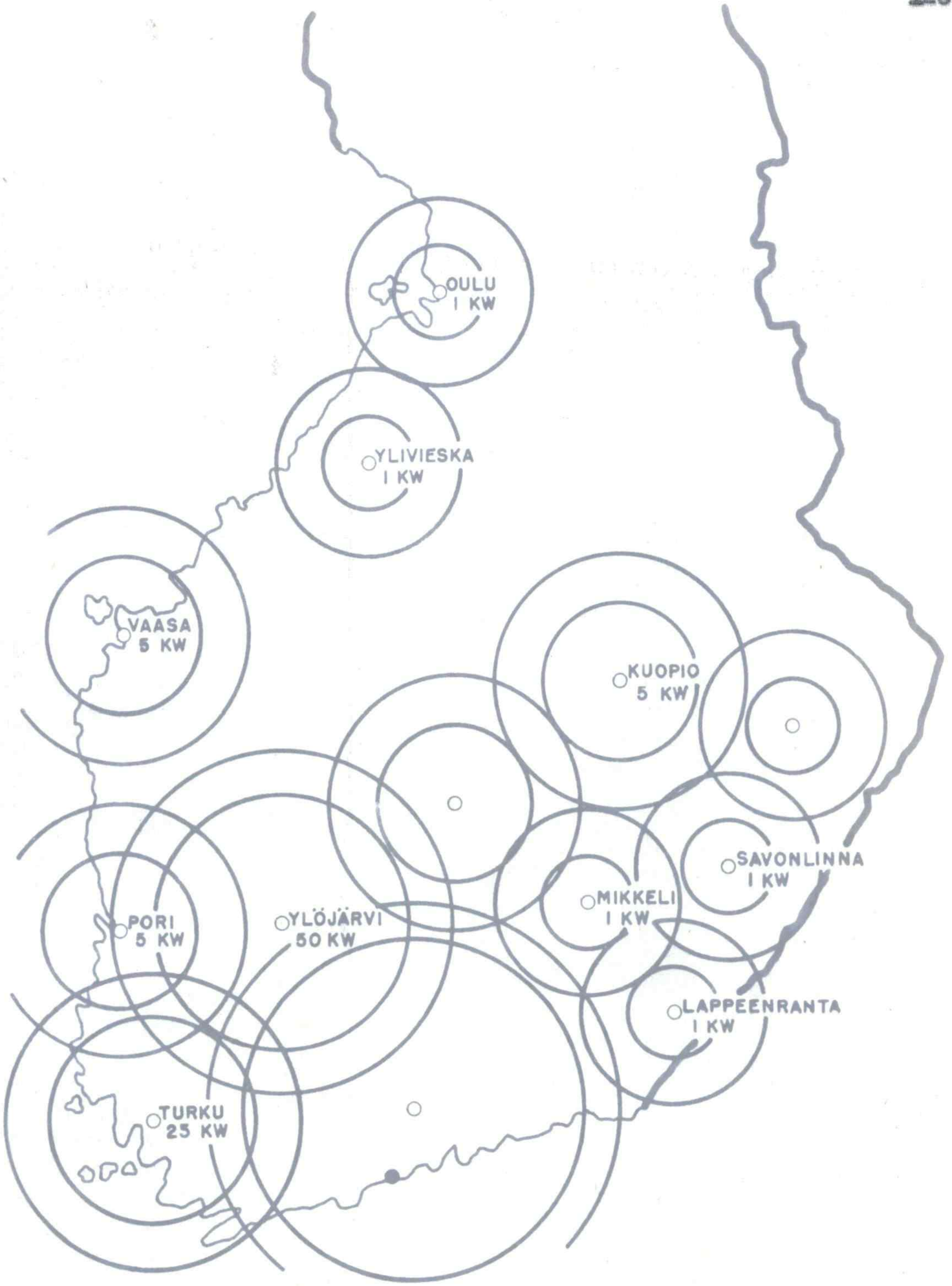


Fig. 31 Equal cost per person plan for 82.1 per cent coverage

T A B L E XI

Equal cost per person plan

Coverage, per cent of total population, persons	12.33 503,000	29.7 1,211,000	38.3 1,560,000	49.6 2,023,000	67.1 2,735,000	82.1 3,344,000
Stations:						
Helsinki	1 kw ap					
Espoo		5 kw				
Ohkola			50 kw	50 kw	200 kw	200 kw
Turku		1 kw ap	1 kw ap	5 kw	5 kw	25 kw
Tampere		1 kw m	1 kw m			
Ylöjärvi				5 kw	25 kw	50 kw
Pori				1 kw m	1 kw m	5 kw
Jyväskylä				1 kw m	5 kw	5 kw
Kuopio					1 kw ap	5 kw
Joensuu					1 kw (a)	1 kw (a)
Vaasa					1 kw (a)	5 kw
Ylivieska						1 kw (a)
Oulu						1 kw (a)
Mikkeli						1 kw m
Lappeenranta						1 kw a
Savonlinna						1 kw a
Number of stations						
total	1	3	3	5	8	13
1 kw	1	2	2	2	4	6
5 kw		1		2	2	4
25 kw					1	1
50 kw			1	1		1
200 kw					1	1
Purchasing price $	131,650	897,440	1,416,290	2,474,730	4,221,840	6,694,290
mill.mk	30.4	207.5	327	571	975	1,547
$ per person	0.261	0.74	0.907	1.222	1.543	2.002
mk per person	63	171	209.5	282.5	356.5	462
Annual operating cost $	32,390	192,690	314,170	541,770	921,730	1,446,430
mill.mk	7.48	44.5	72.5	125.3	213	334
$ per person	0.064	0.159	0.202	0.268	0.337	0.433
mk per person	14.8	36.8	46.7	61.9	77.9	100

a - automatic station
(a) - " " near regular AM broadcasting station
m - manually operated station
p - station located at AM broadcasting station using the same antenna tower

radio-relay system expenses also, and although the transmitter station cost may differ considerably in these two plans, the minimum cost per person plan requires more radio-relay equipment thus reducing the difference. The maximum difference is approximately 17 per cent.

In addition to the somewhat more expensive network, the equal cost per person plan has a disadvantage on high coverage percentages, when the overlapping of service areas of different television stations becomes excessive in the regions of high population density.

Advantages of large stations are that they provide higher, more saturated field intensities in densely populated areas, which is important, if noise is present. Another advantage is that the number of stations is smaller and also usually requires less radio-relay equipment, which reduces the maintenance problem.

These plans were made without taking terrain into account, either as concerning transmitting stations or the radio-relay systems. This is likely to make the cost figures too high. However, these plans can be used as guides when making the final plan. According to these plans, it appears that probably the most suitable plan would be a compromise between the two.

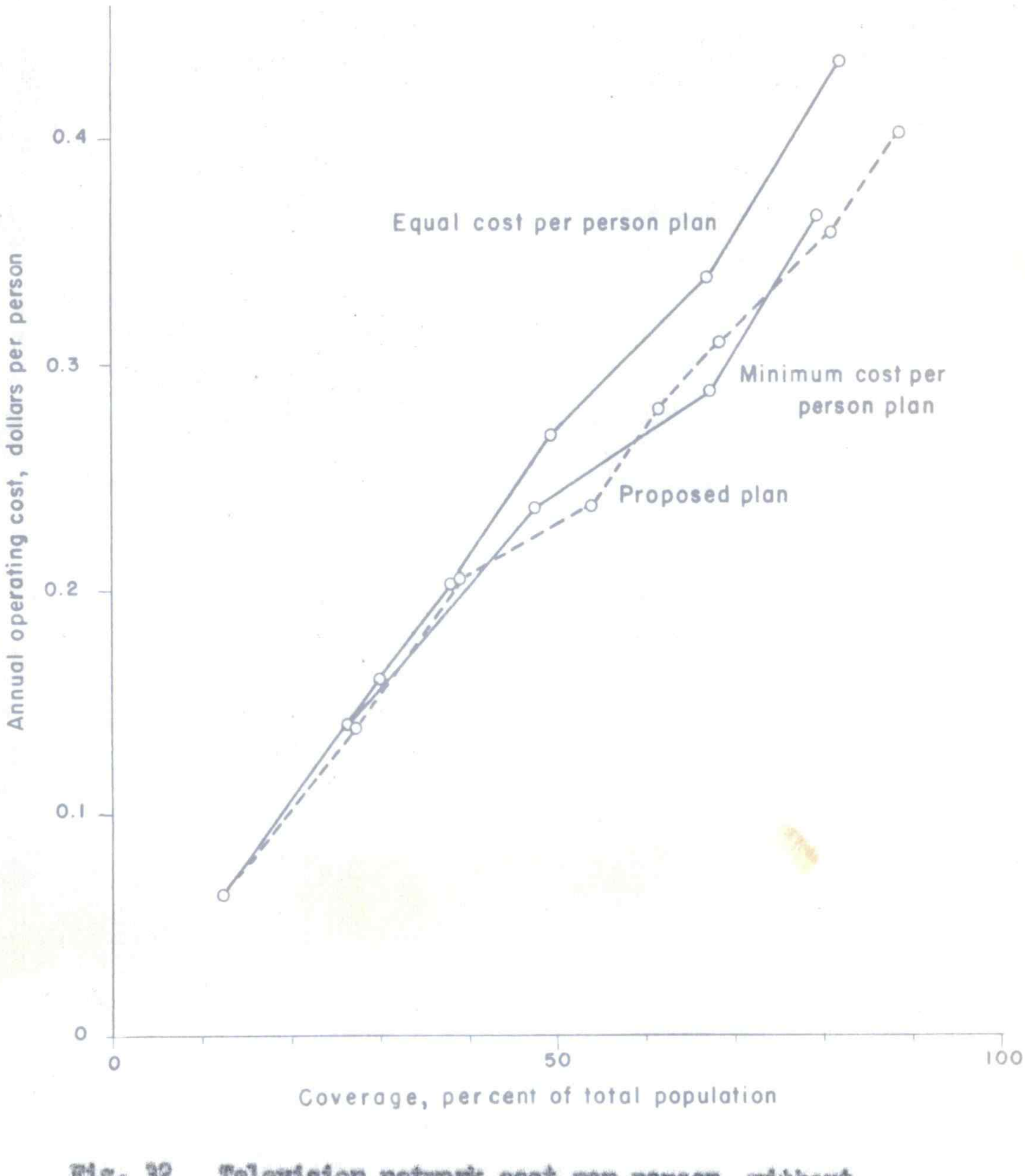


Fig. 32 Television network cost per person, without studio and programming costs, for the different plans and different coverages

PROPOSED SYSTEM

The study on the preceding pages showed that both the minimum cost per person plan and the equal cost per person plan have disadvantages, when principles are applied strictly theoretically. However, much of the disadvantage can be avoided or at least reduced by finding proper compromise between the systems. Using the two preceding plans as guides, a compromising proposal for a television network for Finland and its development was made. To obtain reasonably accurate results, the investigation was carried further as to the details. Finally a possible financing method is suggested. These proposals are explained on the following pages.

Development and Cost of the System

To obtain high field intensities in densely populated areas and keep the amount of equipment as small as possible, the equal cost per person principle was closely followed for smaller coverage percentages. However, for large coverages more and smaller stations were used than would be the case by equal cost per person principle, thus showing a tendency toward the minimum cost per person principle. The latter would avoid the wasting of power for too extensive overlapping of service areas.

The stations proposed for different coverages are shown in Table XII. The station units are taken from generalized stations,

T A B L E XII

Proposed stations

Approximative coverage, per cent of total population	12.5	30	40	50	60	70	80	90
Stations:								
Helsinki	1 kw ap	1 kw ap						
Ohkola			50 kw	50 kw	50 kw	50 kw	100 kw	100 kw
Turku		1 kw ap	1 kw ap	1 kw ap	5 kw	5 kw	5 kw	5 kw
Tampere		1 kw m	1 kw m	1 kw m				
Ylöjärvi					5 kw	5 kw	25 kw	25 kw
Pori				1 kw m	1 kw m	1 kw m	1 kw m	1 kw m
Jyväskylä				1 kw m	1 kw m	5 kw	5 kw	5 kw
Kuopio				1 kw ap	1 kw ap	5 kw	5 kw	5 kw
Joensuu					1 kw(a)	1 kw(a)	1 kw(a)	1 kw(a)
Vaasa					1 kw ap	1 kw ap	5 kw	5 kw
Ylivieska						1 kw(a)	1 kw(a)	1 kw(a)
Oulu						1 kw ap	1 kw ap	1 kw ap
Mikkeli							1 kw m	1 kw m
Lappeenranta							1 kw a	1 kw a
Savonlinna							1 kw a	1 kw a
Kotka								1 kw a
Karijoki								1 kw a
Kokkola								1 kw a
Kajaani								1 kw m
Kemi								1 kw m

a - automatic station
(a) - " " near regular AM broadcasting station
m - manually operated station
p - station located at a present-day AM broadcasting station and utilizes its tower

Table VIII, and applied to each specific location. If the present-day AM radio broadcasting station in the same area has at least a 100-meter (328-foot) tower, the 1 kilowatt television station is assumed to be located at the AM station utilizing the same building and antenna tower. Because of the extreme importance of tower height for television station, lower than 328-foot towers are not advisable, and if a new tower is to be built, it should be at least 500 feet high. For a new location of a television station the most suitable place was chosen taking the height of the location and the population distribution into account. The proposed locations are shown in Table XIII. The locations are generally about 1 to 3 miles from the closest city, a few are farther away, the most distant being 11 miles away from Joensuu. The station of Ohkola is not close to a large city, since it was intended to serve a large area on the southern coast including three cities, Helsinki, Lahti, and Hämeenlinna, in this densely populated area.

For each station location, a study of terrain elevation was made. Therefore, 8 radials were drawn from the station location to the main directions of the compass. The elevation contour of each radial was determined from topographical maps. The length of radials was taken approximately equal to the grade A service distance of the station in question. As an example, the elevation contours of radials of the Joensuu station are shown in Figures 33, 34, and 35. After the average elevation of each radial was determined, the average of these gives the average terrain

TABLE XIII

Station locations

Station	Location	Geographical location north	Geographical location east	Dist. from main city km	Elevation of station location m	Elevation of station location ft	Average terrain elevation m	Average terrain elevation ft	Average terrain elevation within dist. km	Location elevation above ave. terrain ft
Helsinki	Hagalund	60°11'	24°48'35"	7.5	5	16	28.1	92	0-30	-76
Ohkola	Jätyri	60°34'06"	25°12'	46	118	387	75.6	248	2-75	139
Turku 1 kw		60°26'22"	22°18'19"	2	20	65	30	98	0-50	-32.5
" 5 kw	Littoinen	60°28'	22°22'24"	5	64.9	213	30	98	0-50	115
Tampere	Pyynikki	61°29'56"	23°43'44"	2	151.7	497	106	348	2-50	149
Ylöjärvi		61°35'	23°38'54"	11	171.8	563	106	348	2-50	215
Pori	Nakkila	61°22'	21°46'36"	13.5	51.2	168	35.5	116	0-30	52
Jyväskylä	Laajavuori	62°15'30"	25°41'06"	4	227.1	745	132.5	434	0-50	311
Kuopio 1 kw	Huuhanmäki	62°53'09"	27°39'04"	2	150	492	109.6	359	2-50	133
" 5 kw	Puijo	62°54'32"	27°39'35"	2.5	232	760	109.6	359	2-50	401
Joensuu	Pyytivaara	62°44'48"	29°54'30"	18	230.5	756	115	377	2-30	379
Vaasa 1 kw		63°05'20"	21°38'10"	1,5	6.2	20	17.5	57	0-50	-36.7
" 5 kw	Öberget	63°02'14"	21°34'56"	7	48.3	158	17.5	57	0-50	101
Ylivieska		64°06'	24°37'		86	282	73.5	241	0-30	41
Oulu		64°59'57"	25°28'08"	1	10	33	19.3	63	0-30	-30
Mikkeli	Vuolinko	61°42'48"	27°12'54"	4	140	459	103	338	0-30	121
Lappeenranta	Haukilahti	61°06'20"	28°25'13"	13.5	110	361	84.6	277	0-30	84
Savonlinna	Pihlajanniemi	61°50'18"	28°50'42"	4	100	328	86.4	283	0-30	45
Kotka	Kymi	60°31'19"	26°54'42"	5.5	56.6	186	26.4	87	0-30	99
Karijoki	Pyhävuori	62°15'30"	21°38'12"		130	426	55	180	2-30	246
Kokkola		63°50'18"	23°07'24"		10	33	10.3	34	0-30	-1
Kajaani	Rupukkavaara	64°14'	27°58'12"	12	299	980	172.5	565	2-30	415
Kemi	Kallinkangas	65°49'05"	24°31'37"	8.5	56.7	186	28.5	94	0-30	92

JOENSUU

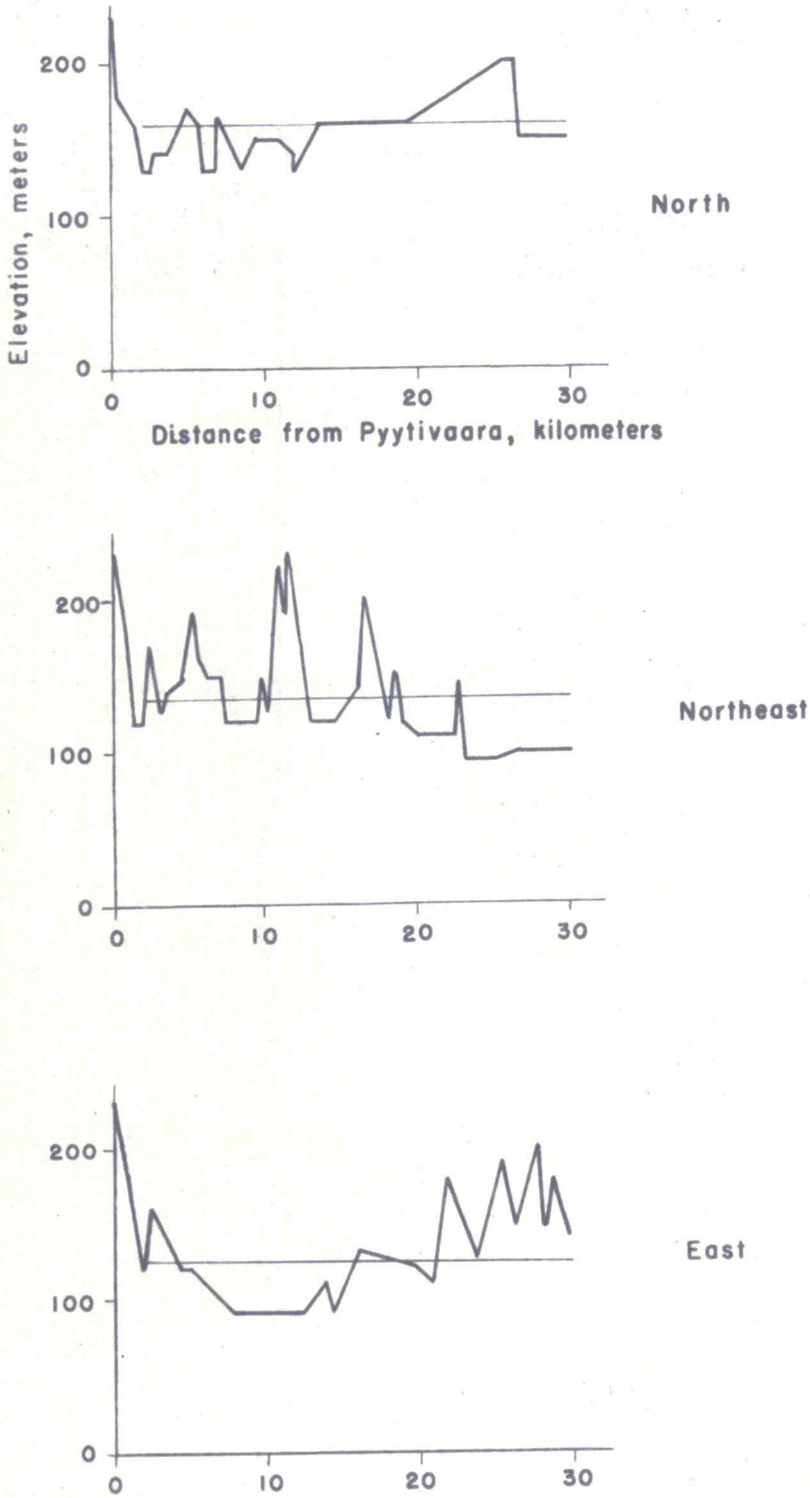


Fig. 33 Elevation of radials of Joensuu television station

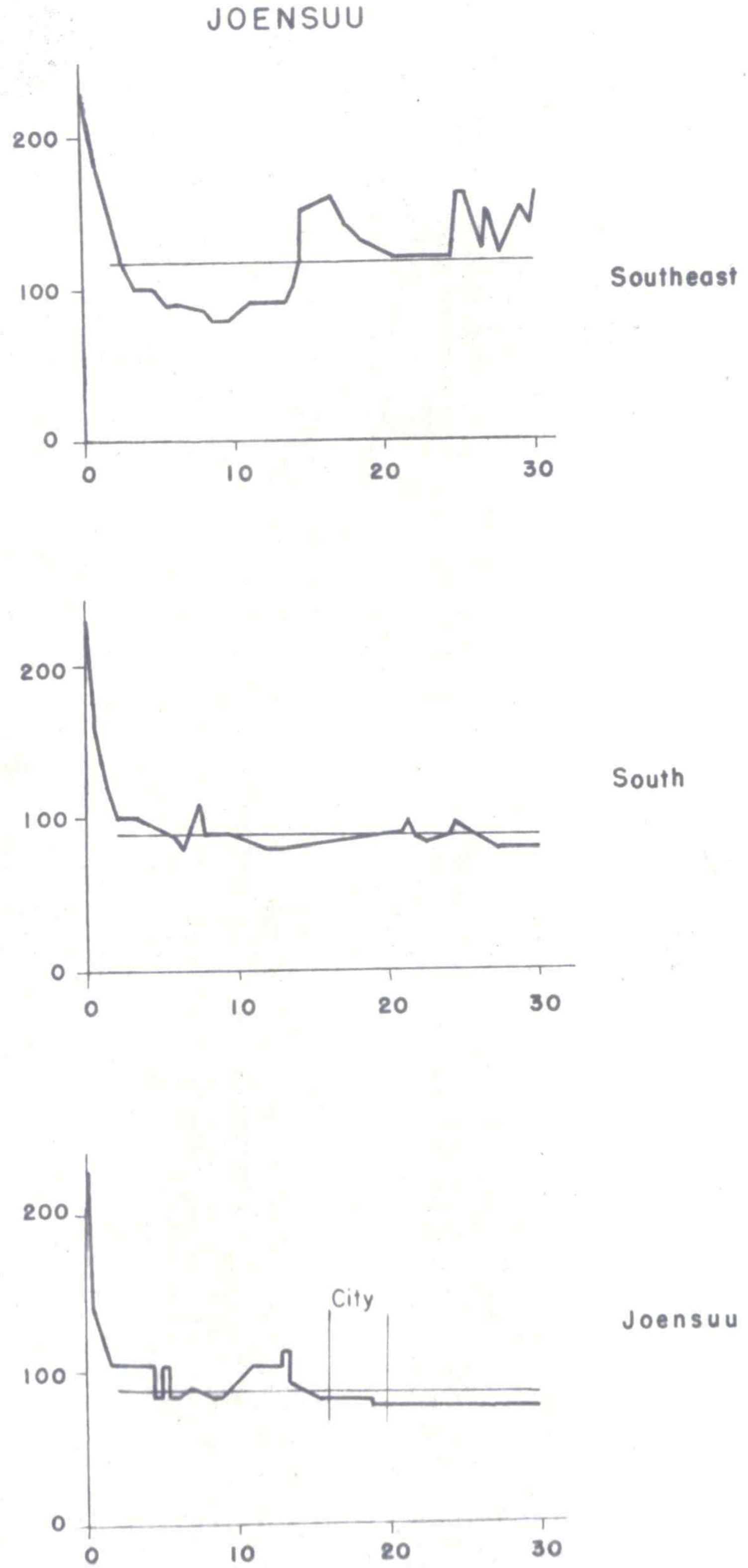


Fig. 34 Elevation of radials of Joensuu television station

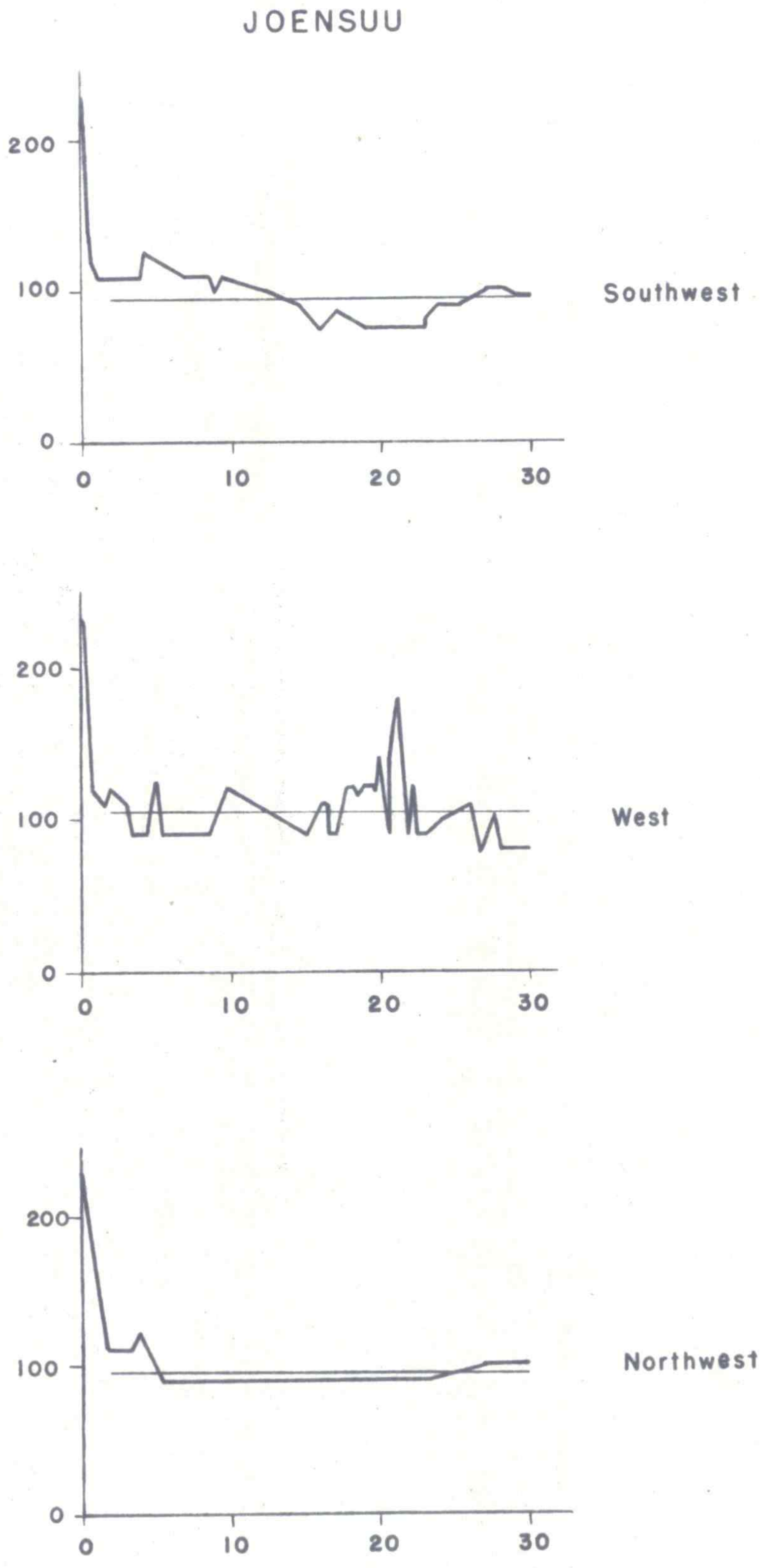


Fig. 35 Elevation of radials of Joensuu television station

elevation close enough for television station design purposes. If the station location was exceptionally high compared to the average elevation, the nearby area within 2 kilometers was excluded from the elevation computations. To be able to determine the probable field intensity in the principal city, a radial through the city was also drawn and average elevation for the radial determined. The elevation of each station location and the average terrain elevation computation information are shown in Table XIII.

When the elevation information was obtained, it was possible to determine the probable service distances. This was done by using Federal Communications Commission's graphs (Appendix II) and the distances are shown in Table XIV. Corresponding service areas for different population coverage percentages are presented in Figures 36 to 43. The population coverages were obtained by service distances (Table XIV), and curves and tables of population distribution, which were explained in preceding chapters. The overlapping of service areas was taken into account and the audience of these areas was divided equally between the stations, which were to serve the area. The total coverages are shown in Table XV.

A point, which has to be especially considered, is the field intensity in the principal city areas. It is considered that the principal city field intensity should be, at 200 megacycles, at least 77 decibels above one microvolt per meter (12, p.3077), to assure first-class service. Therefore field intensities for each case in the principal city were calculated, and the values are shown

T A B L E XIV

Technical details of proposed stations

Station	Tower height m	ft	Antenna bay-number	Transmission line	Electrical height of antenna, ft	Effective radiated power, kw	Service distance, kilometers Grade A	Grade B
Helsinki 1 kw	150	500	12	3 1/8"	424	7.98	22.5	51.5
Ohkola 50 kw	250	820	30	6 1/8"	892	1189	80.5	109.5
Ohkola 100 kw	250	820	40	2x6 1/8"	870	3180	88.5	117
Turku 1 kw	150	500	12	3 1/8"	467	9.92	25	53.9
Turku 5 kw	200	655	12	6 1/8"	808	57.9	53.1	82.1
Tampere 1 kw	150	500	12	3 1/8"	687	9.78	32.2	64.4
Ylöjärvi 5 kw	200	655	12	6 1/8"	908	57.9	56,4	84.5
Ylöjärvi 25 kw	200	655	12	6 1/8"	908	289	70.9	98.1
Pori 1 kw	150	500	12	3 1/8"	590	9.78	29	60.4
Jyväskylä 1 kw	200	655	12	6 1/8"	1004	11.6	41.9	75.7
Jyväskylä 5 kw	200	655	12	6 1/8"	1004	57.9	59.5	87.7
Kuopio 1 kw	150	500	12	3 1/8"	671	9.78	31.4	64.4
Kuopio 5 kw	200	655	12	6 1/8"	1094	57.9	61.2	91
Joensuu 1 kw	150	500	12	3 1/8"	917	9.78	36.2	72.5
Vaasa 1 kw	100	328	12	3 1/8"	329	7.98	19.3	44.3
Vaasa 5 kw	200	655	12	6 1/8"	794	57.9	52.3	81.4
Ylivieska 1 kw	150	500	12	3 1/8"	579	9.78	29	60.4
Oulu 1 kw	100	328	12	3 1/8"	336	7.98	20.1	45.1
Mikkeli 1 kw	150	500	12	3 1/8"	659	9.78	31.1	62.8
Lappeenranta 1 kw	150	500	12	3 1/8"	622	9.78	29	61.2
Savonlinna 1 kw	150	500	12	3 1/8"	583	9.78	29	60.4
Kotka 1 kw	150	500	12	3 1/8"	637	9.78	30.6	62
Karijoki 1 kw	150	500	12	3 1/8"	784	9.78	34.6	67.6
Kokkola 1 kw	150	500	12	3 1/8"	537	9.78	27.9	58
Kajaani 1 kw	150	500	12	3 1/8"	953	9.78	38.6	72.5
Kemi 1 kw	150	500	12	3 1/8"	630	9.78	30.3	61.2

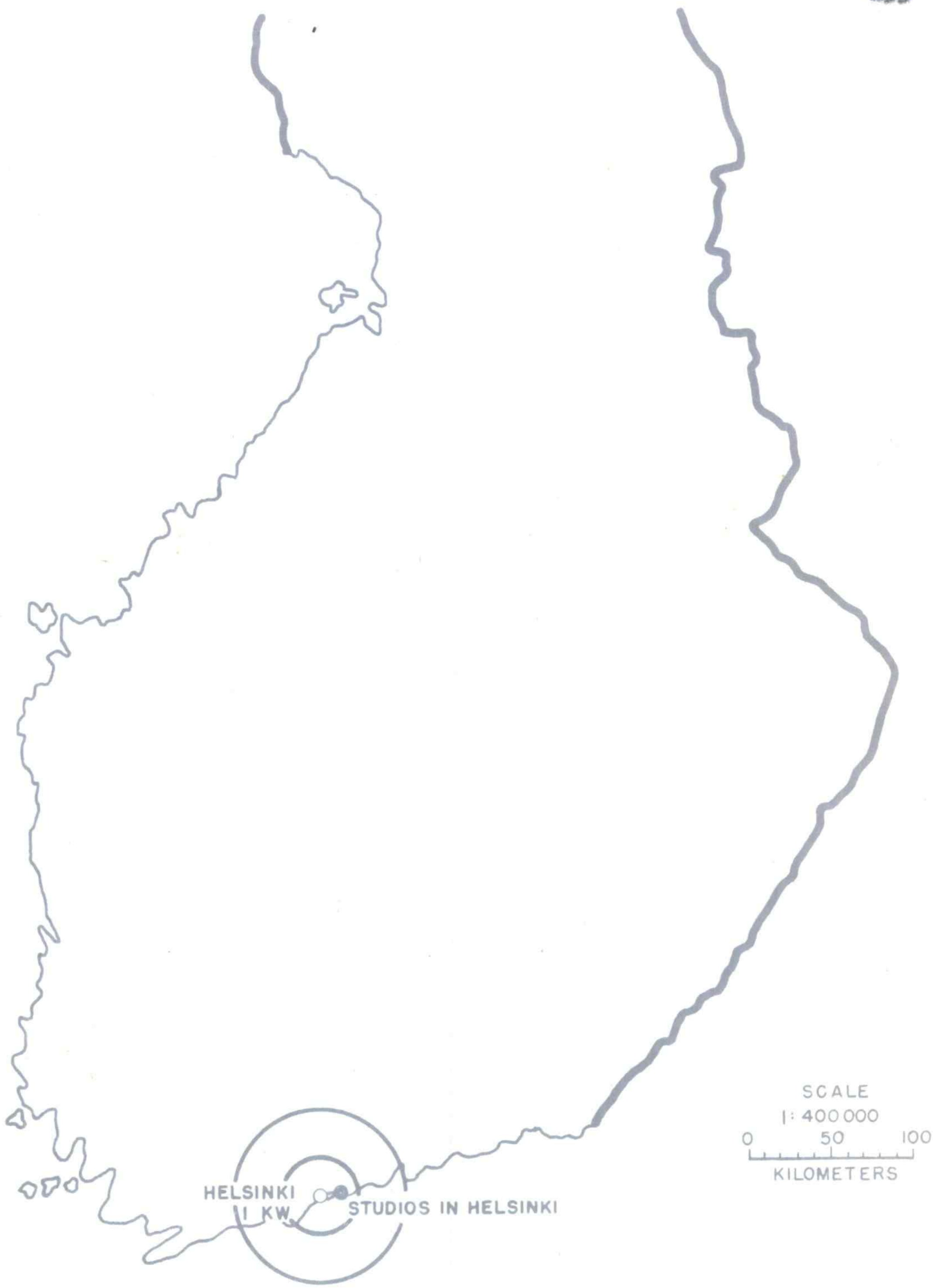


Fig. 36 Proposed plan for 12.4 per cent coverage

Fig. 37 Proposed plan for 27.25 per cent coverage

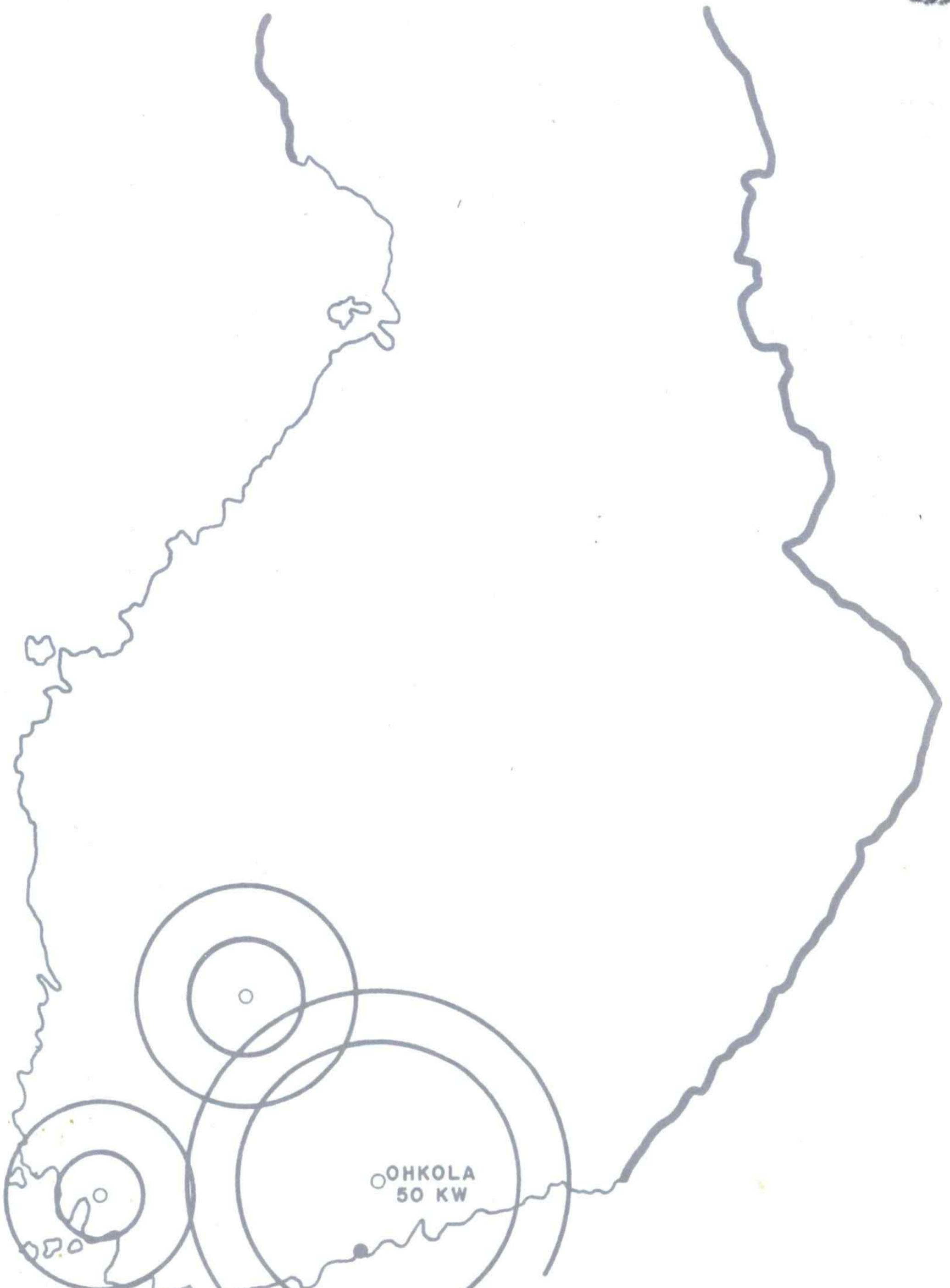


Fig. 38 Proposed plan for 38.75 per cent coverage

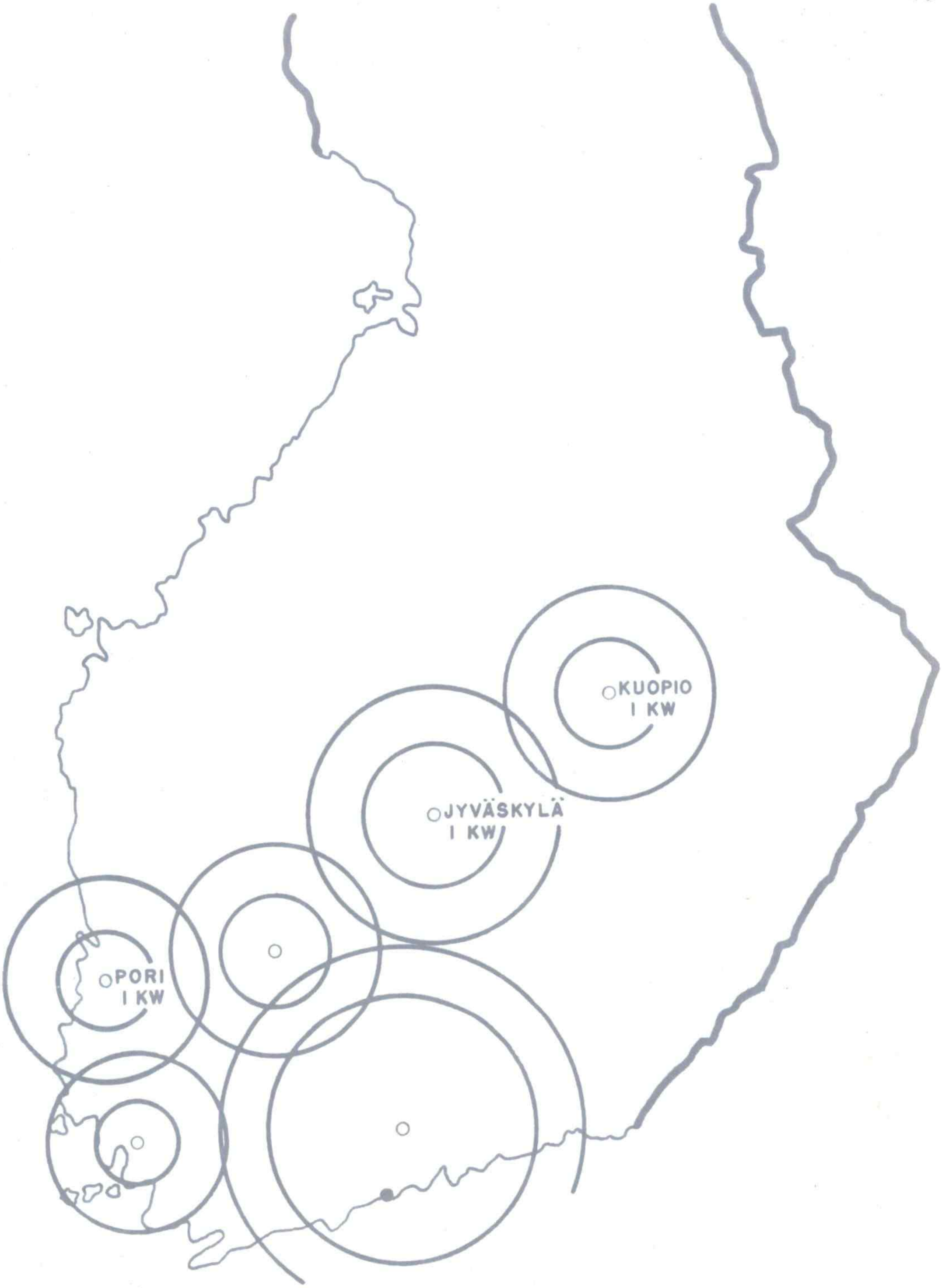


Fig. 39 Proposed plan for 53.75 per cent coverage

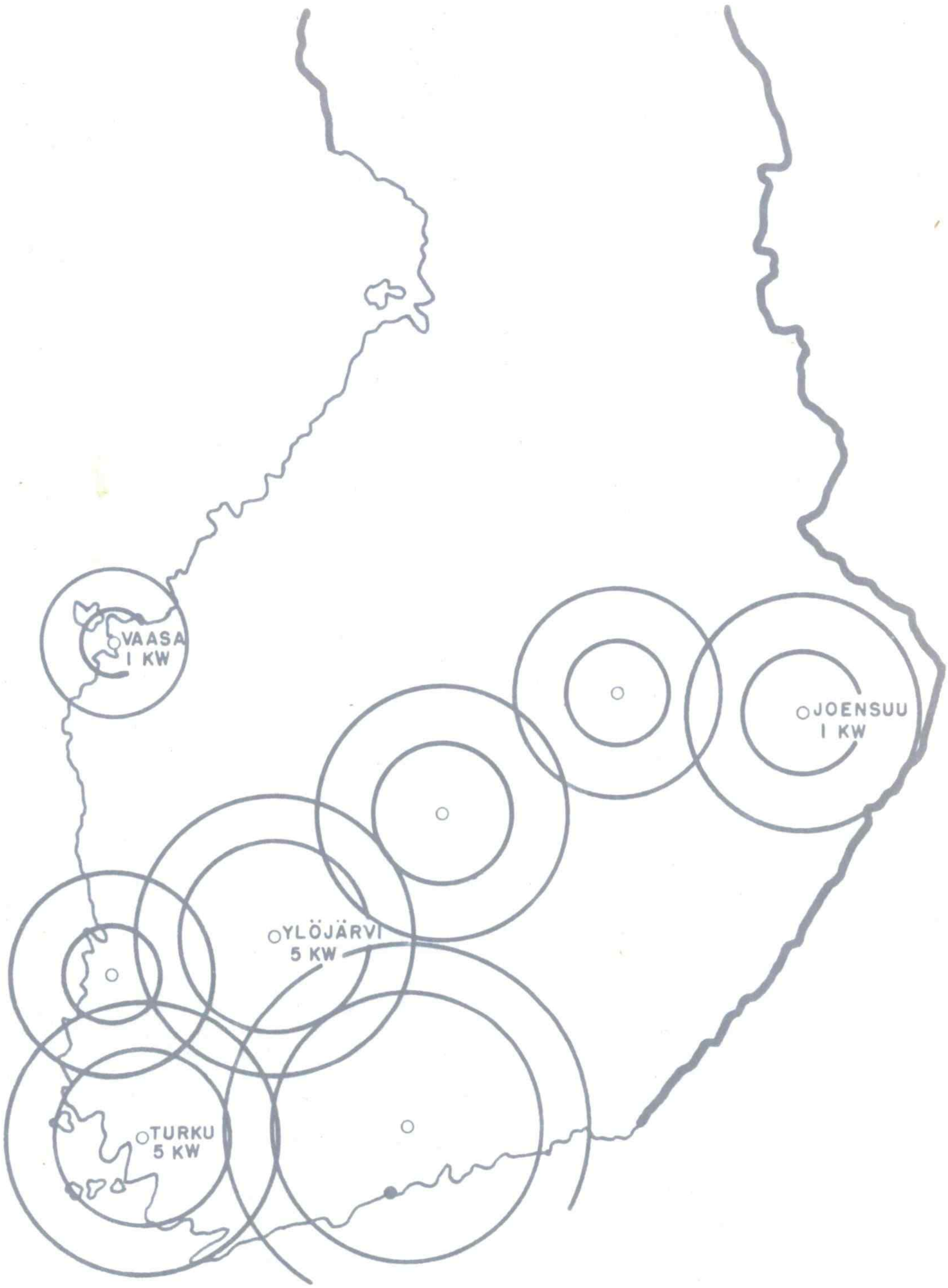


Fig. 40 Proposed plan for 61.7 per cent coverage

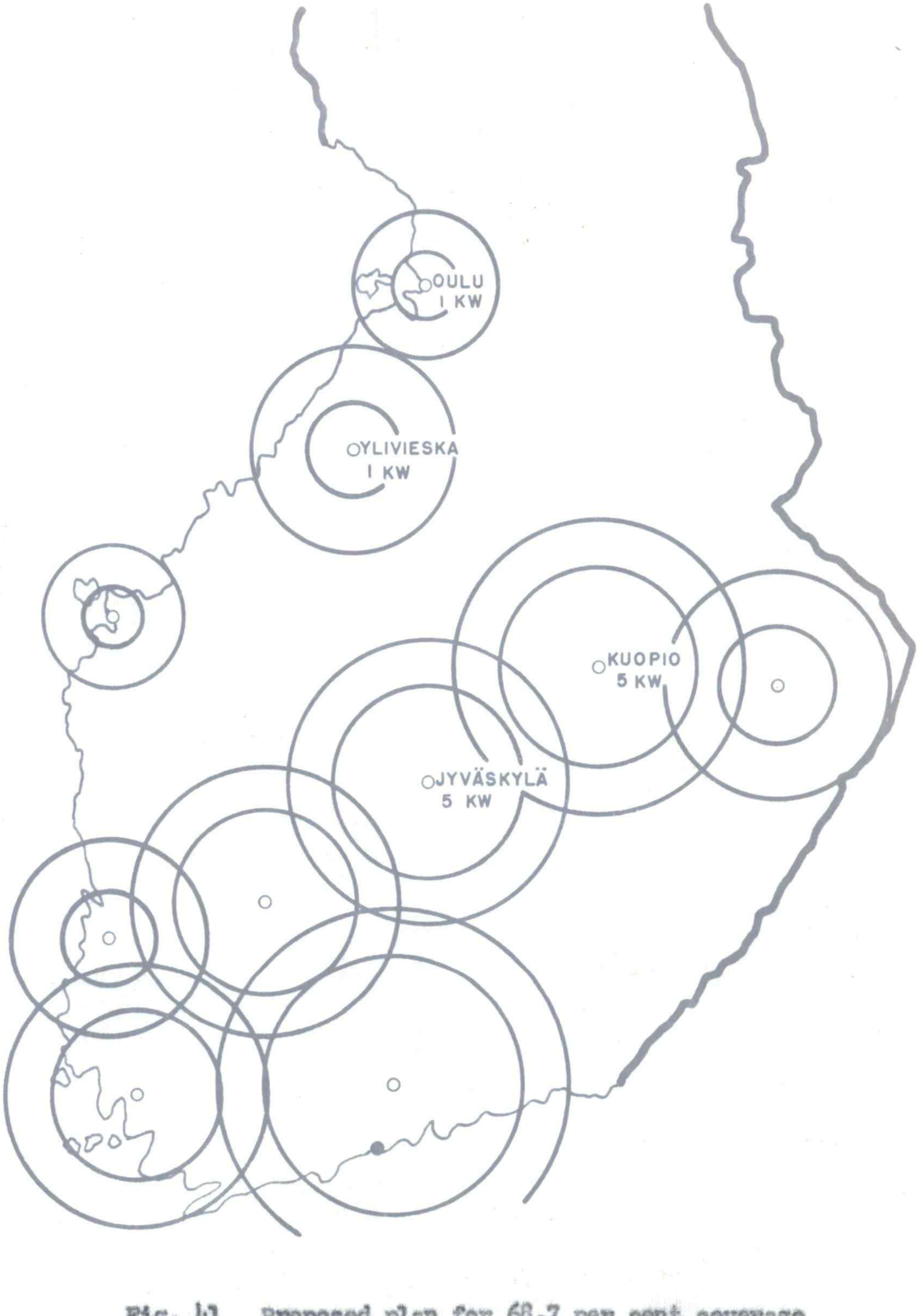


Fig. 41 Proposed plan for 68.7 per cent coverage

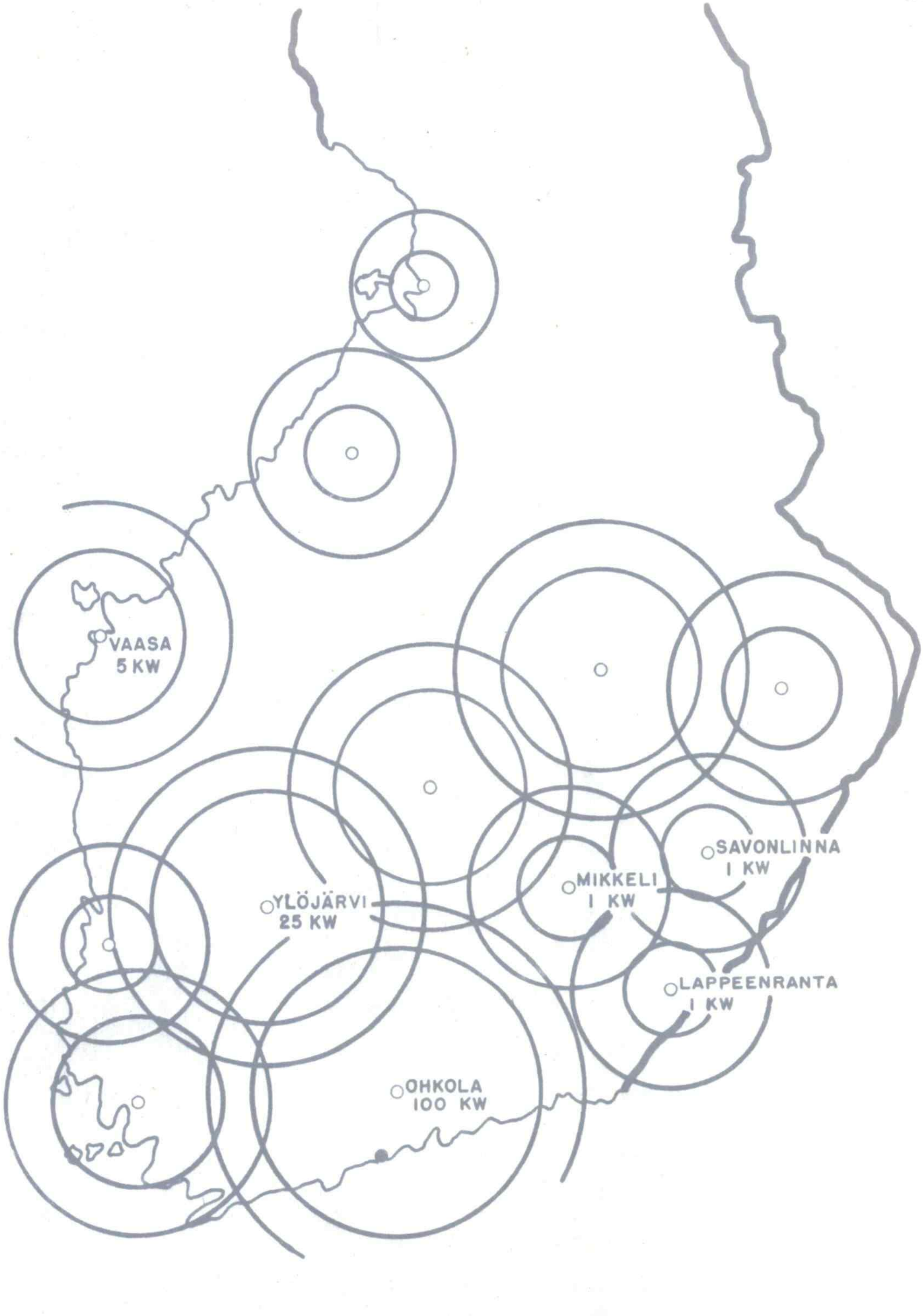


Fig. 42 Proposed plan for 80.9 per cent coverage

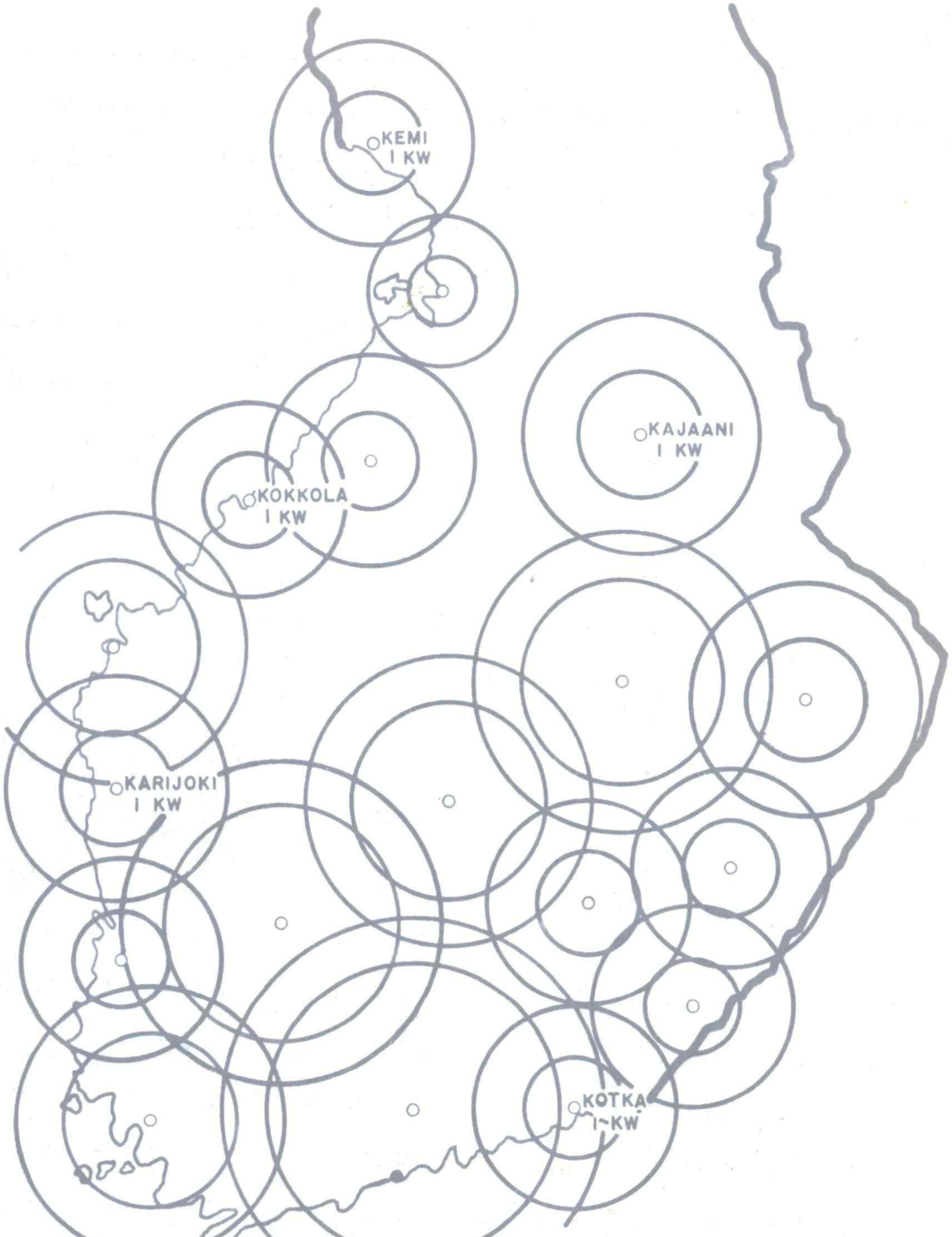


Fig. 43 Proposed plan for 88.6 per cent coverage

TABLE XV

Population coverage

Approximative coverage, per cent of total population	12.5	30	40	50	60	70	80	90
Number of stations:								
total	1	3	3	6	8	10	13	18
1 kw	1	3	2	5	5	5	7	12
5 kw					2	4	4	4
25 kw							1	1
50 kw			1	1	1	1		
100 kw							1	1
Accurate population coverage, persons	505,000	1,111,000	1,580,000	2,193,000	2,517,000	2,801,000	3,299,000	3,615,000
per cent of total population	12.4	27.25	38.75	53.75	61.7	68.7	80.9	88.6

in Table XVI. In every principal city the predicted value is well above the limit mentioned, and in other cities above grade A service limit. The most interesting is the Ohkola station, since it is supposed to serve three cities fairly far away from the station. But, with 50 kilowatts of power, the field intensity should exceed the minimum by 13, 7, and 3 decibels in the order of decreasing importance. Since there are hills approximately 100 feet high between the station and the cities, close to the cities, the field intensity would be somewhat smaller. In locations immediately behind a 100-foot hill a reduction of approximately 6 decibels average can be expected (4, p.4). Even this reduction leaves Helsinki well above, and Lahti slightly above, the "principal city service" minimum, and Hämeenlinna well above regular city service value, which probably would be enough, since Hämeenlinna has only about 23,000 inhabitants.

Thus all the major factors of transmitting stations have been determined. To complete the network, the program distribution system is to be designed. Because of maintenance difficulties it was decided that there should be enough repeaters to avoid higher towers than about 250 feet. Many probable repeater locations including several alternative possibilities were selected. Then elevation contours for each span were determined from topographical maps. Figure 44 shows an example. Only peak values are plotted, and not the whole contour. Rectangular coordinates were used for elevations and the earth's curvature was taken into account

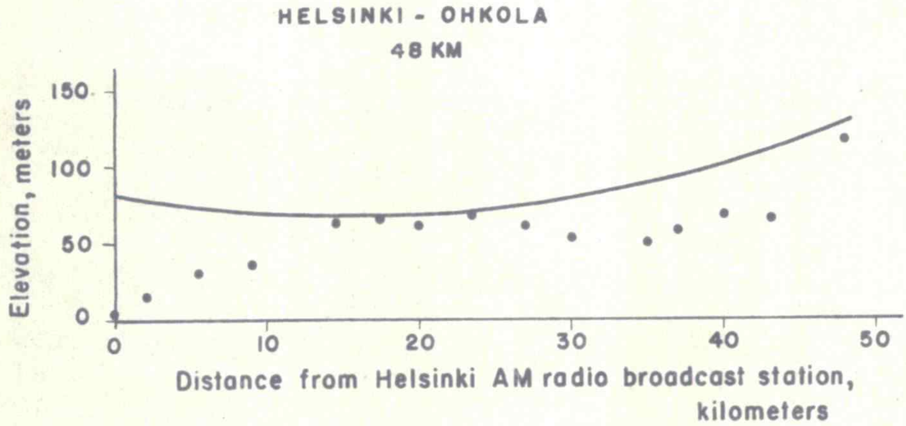
TABLE XVI

Field intensity in principal cities

Station	City	Field intensity in decibels above one microvolt per meter
Helsinki 1 kw	Helsinki	91.5
Ohkola 50 kw	Helsinki	90
"	Lahti	84
"	Hämeenlinna	80
Ohkola 100 kw	Helsinki	94.5
"	Lahti	88
"	Hämeenlinna	83.5
Turku 1 kw	Turku	110
Turku 5 kw	Turku	108.3
Tampere 1 kw	Tampere	110.7
Ylöjärvi 5 kw	Tampere	98.8
Ylöjärvi 25 kw	Tampere	105.8
Pori 1 kw	Pori	83.5
"	Rauma	72
Jyväskylä 1 kw	Jyväskylä	104.4
"	Äänekoski	72.4
Jyväskylä 5 kw	Jyväskylä	111.3
"	Äänekoski	79.7
Kuopio 1 kw	Kuopio	111
Kuopio 5 kw	Kuopio	117
Joensuu 1 kw	Joensuu	84
Vaasa 1 kw	Vaasa	111
Vaasa 5 kw	Vaasa	104.5
Mikkeli 1 kw	Mikkeli	102.5
Lappeenranta 1 kw	Lappeenranta	83
"	Imatra	76
Savonlinna 1 kw	Savonlinna	101.7
Kotka 1 kw	Kotka	99
"	Hamina	82
Kokkola 1 kw	Pietarsaari	71.5
Kajaani 1 kw	Kajaani	91
Kemi 1 kw	Kemi	91
"	Tornio	80.5

by assuming radio wave propagation to be curved as Figure 44 shows. Usually the earth's curvature is included into the elevation values and thus the wave propagation kept straight, but the method above saves much work. The most suitable grazing beam was drawn in each graph, and the required tower heights were obtained by adding to the values read from the graphs, the clearance required, which was assumed to be about 100 feet. The selected repeater locations, their elevations, and required tower heights are shown in Table XVII. All the repeaters are to be remotely controlled. To obtain as trouble-free operation as possible, it was considered that if a television radio-relay system is to serve a larger station than 1 kilowatt, or if it is to serve more than two stations or sometimes for serving important places, it should have stand-by equipment, which will take over if the regular channel fails. The program distribution system for different coverage percentages is shown in Figures 45 to 51.

Based on these proposals, the cost of the whole television network for these different coverages was computed. This cost was determined as in the previous plans. The cost of the complete television network, without studio and programming costs, is shown in Table XVIII. Also the purchasing price of additional equipment is shown, when the network is expanded from the preceding size. If a station has to be moved to another location, it has been assumed that about 65 to 70 per cent of the initial purchasing value can be utilized. The annual operating cost figures from Table XVIII



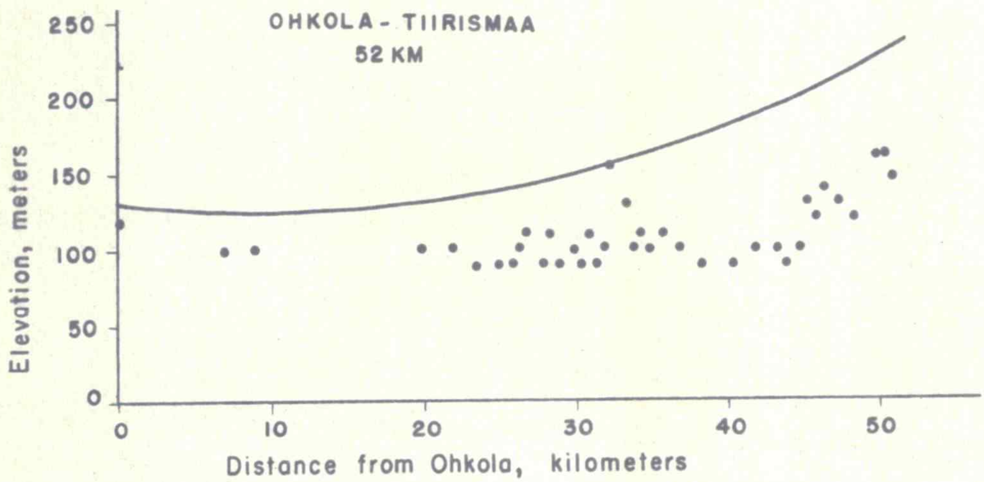


Fig. 44 An example of determining the required tower heights for a radio-relay system

T A B L E   XVII

Repeater locations, their elevations, and tower heights required

Repeater location	Geographical location		Elevation of repeater location		Tower height required	
	north	east	m	ft	m	ft
Lohja	60°16'24"	24°09'	118	387	45	147
Muurla	60°22'24"	23°22'	120	393	20	66
Tiirismaa	61°00'24"	25°31'42"	223	730	40/0*	131/0*
Kuohijoki	61°17'30"	24°46'	150	492	0/40*	0/131*
Ohkola	60°34'06"	25°12'	118	387	40/0*	131/0*
Soiniharju	61°46'30"	22°43'30"	186.2	610	35/15*	115/49*
Perävuori	61°38'36"	25°23'12"	201	660	25	82
Istunmäki	62°41'30"	26°24'	189	620	35/10*	115/33*
Lauhavuori	62°11'	22°11'30"	223	730	55	180
Nori	62°34'	22°	100	328	55	180
Maarianvaara	62°51'30"	28°54'	242	793	40/0*	131/0*
Keitelepohja	63°11'30"	25°44'	148	485	55	180
Pitkäharju	63°38'30"	25°34'	217	712	15	49
Vihanti	64°32'30"	25°	80	262	80	262
Matarusmäki	61°39'48"	26°15'30"	201	660	0	0
Puumala	61°33'18"	28°10'12"	110	361	40	131
Lappträsk	60°39'36"	26°07'12"	84	276	30	99
Kannus	63°54'	24°07'	96	315	35	115
Ii	65°23'12"	25°18'42"	8	26	45	147
Pölömäki	63°22'30"	27°07'30"	252	826	0	0
Murtomäki	64°	27°24'	275	902	50	164

* - the two heights are necessary in two different stages of the developement of the plan

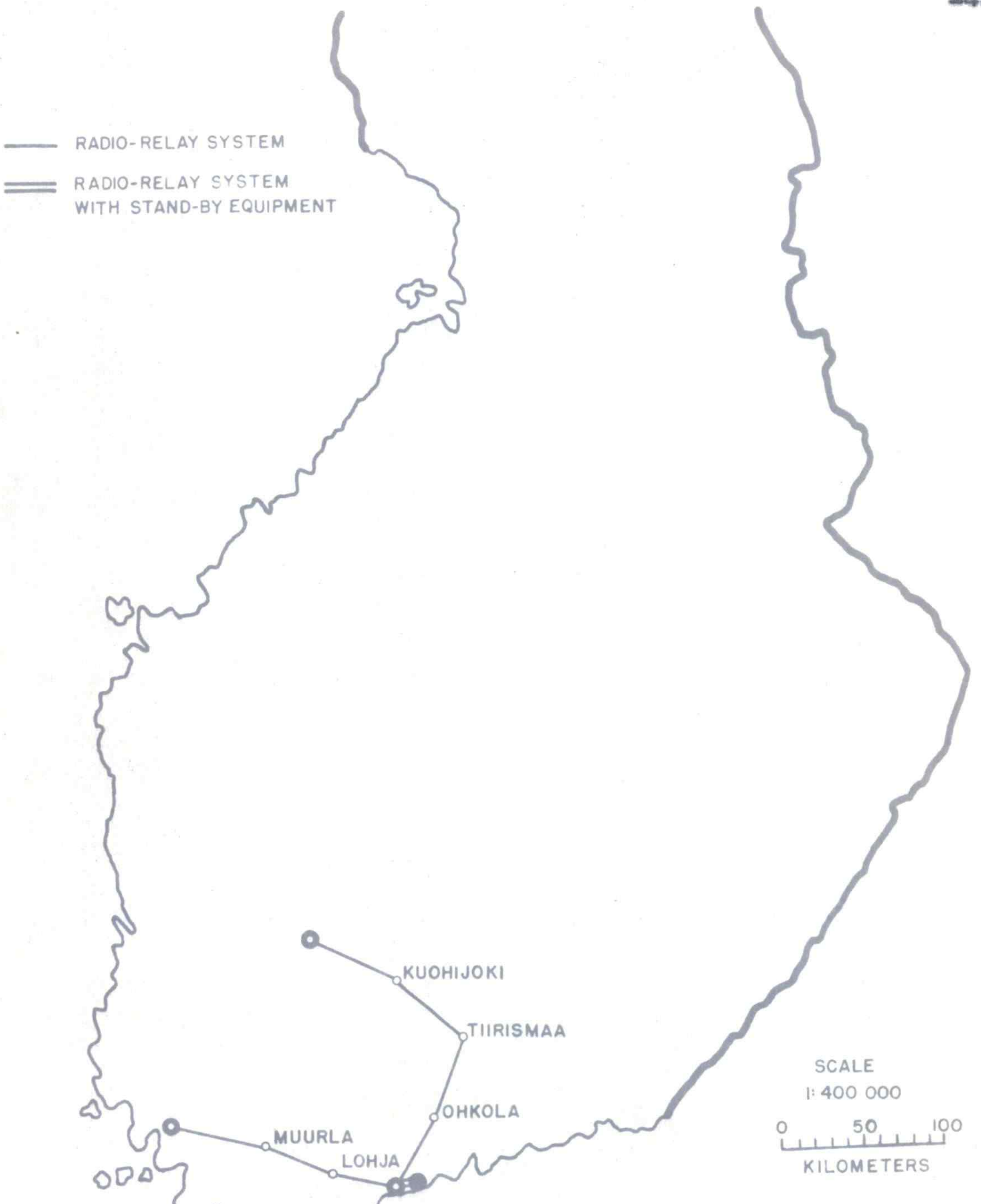


Fig. 45 Radio-relay system of proposed plan of 27.25 per cent coverage

Fig. 46 Radio-relay system of proposed plan of 38.75 per cent coverage

Fig. 47 Radio-relay system of proposed plan of 53.75 per cent coverage

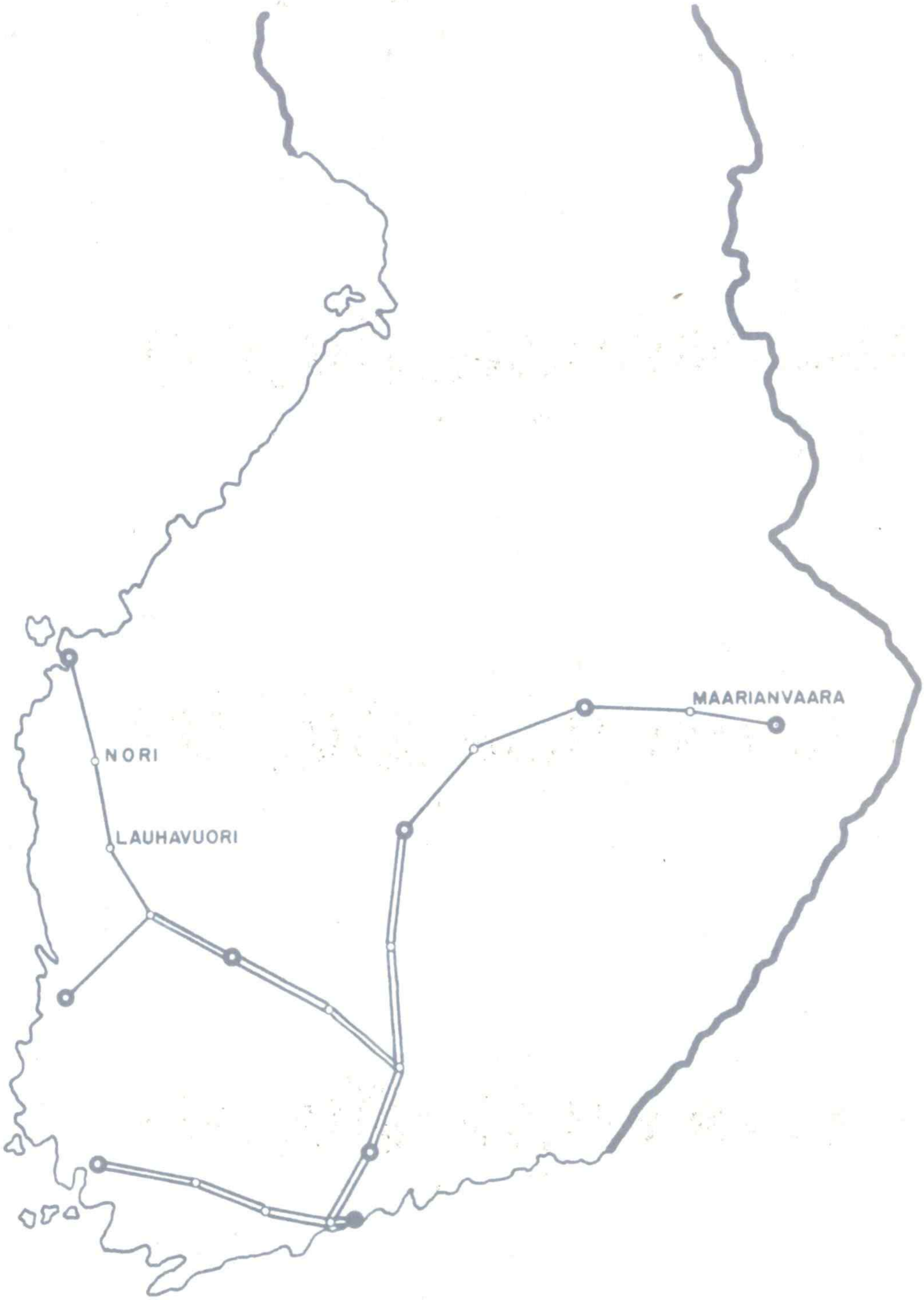


Fig. 48 Radio-relay system of proposed plan of 61.7 per cent coverage

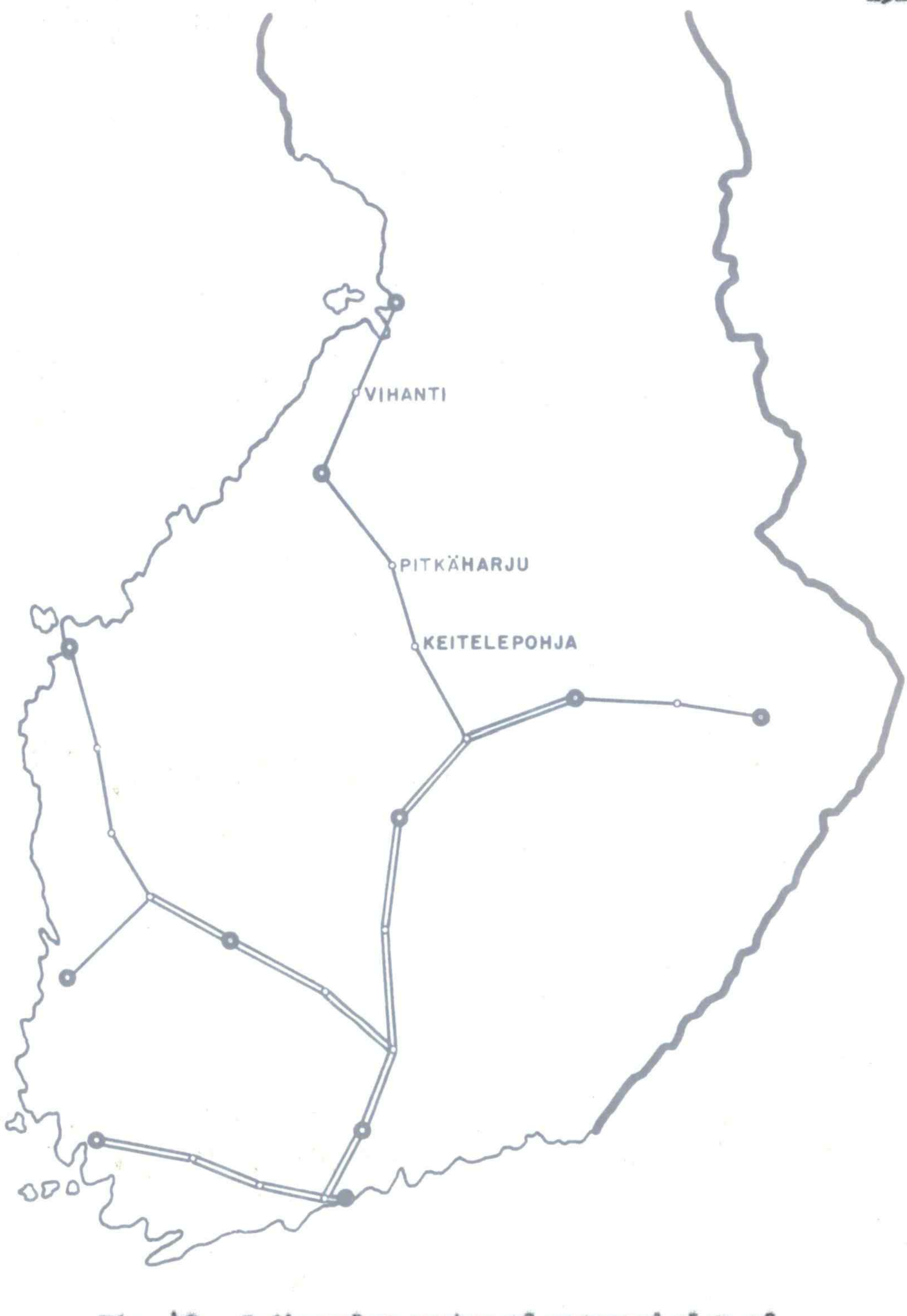


Fig. 49 Radio-relay system of proposed plan of 68.7 per cent coverage

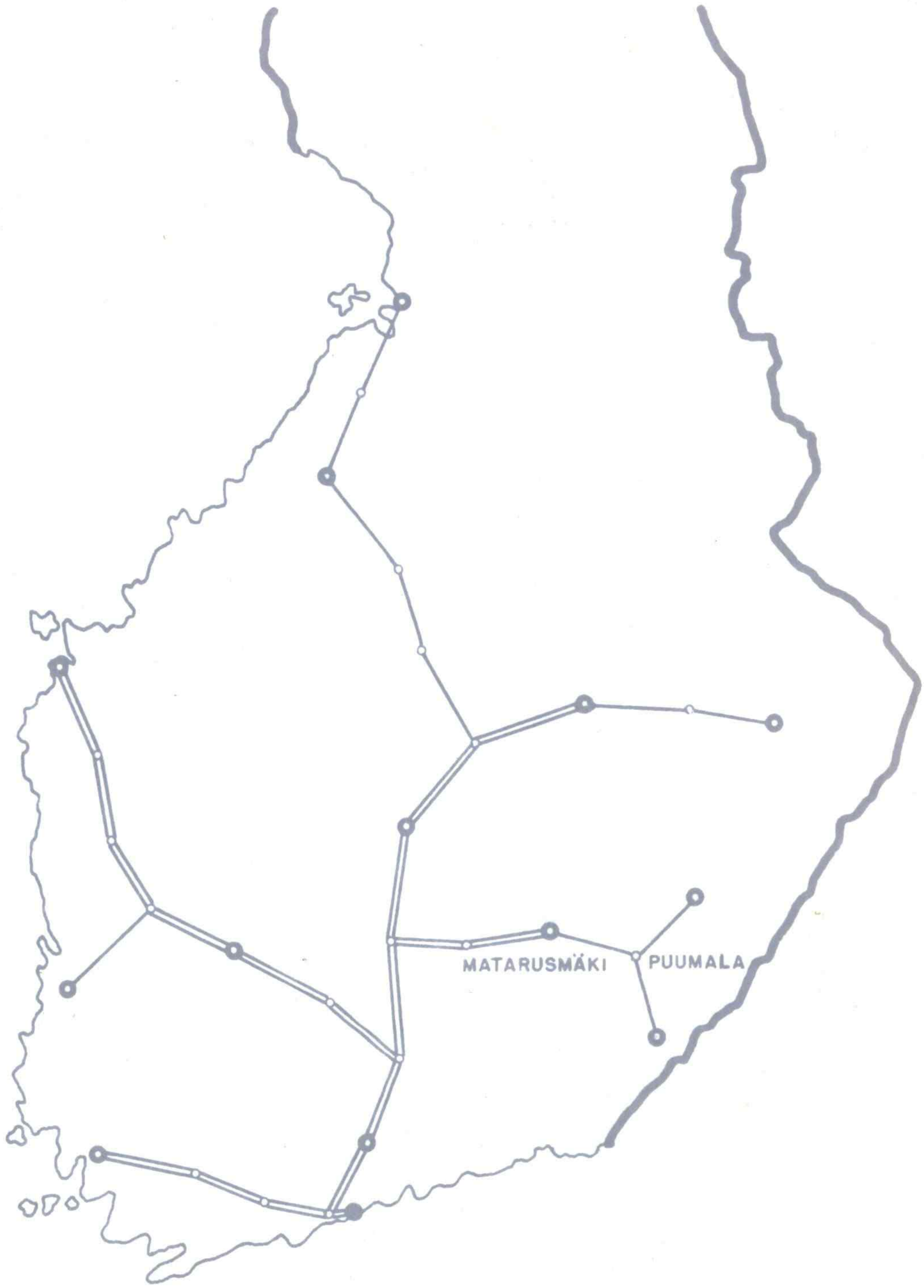


Fig. 50 Radio-relay system of proposed plan of 80.9 per cent coverage

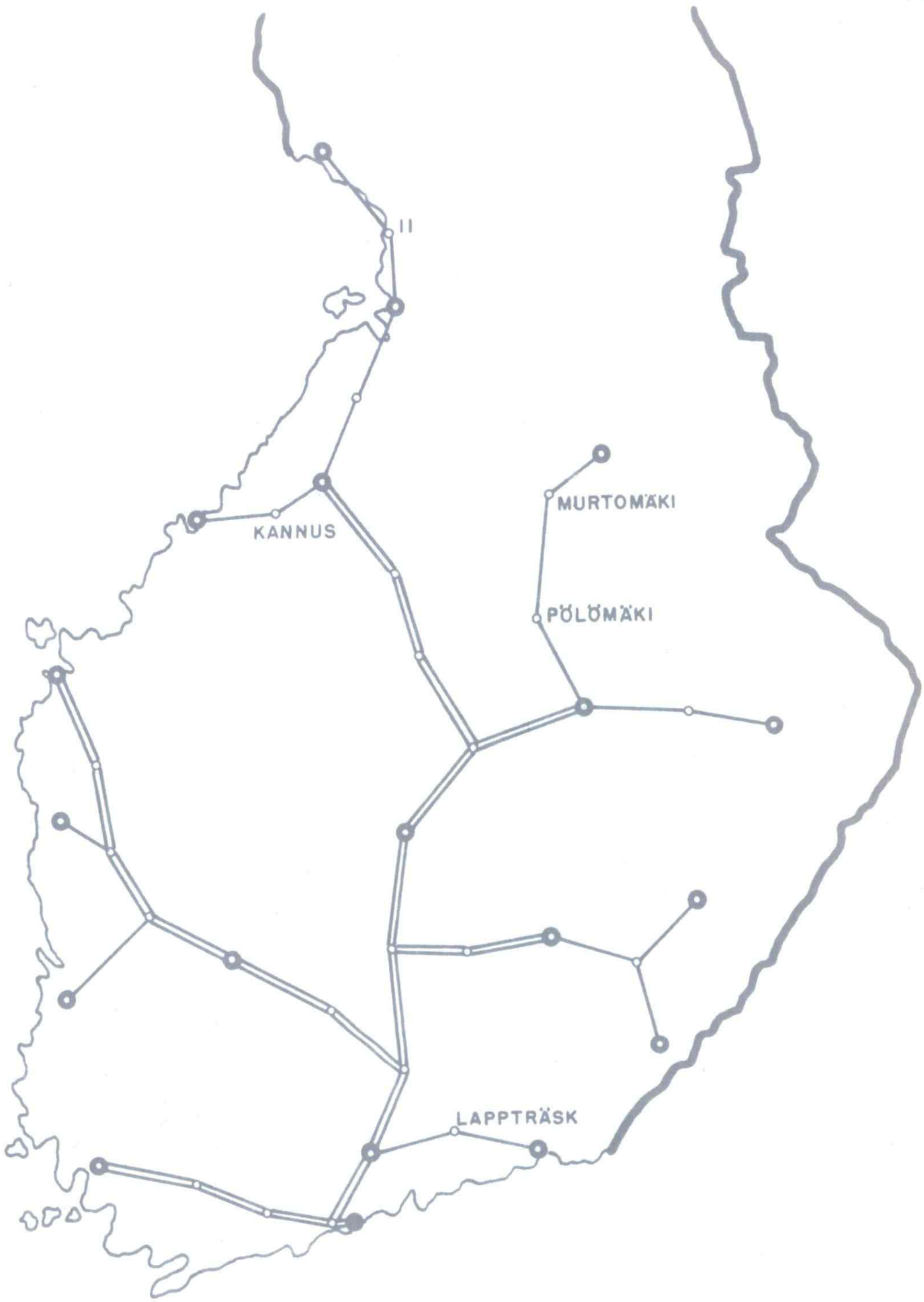


Fig. 51 Radio-relay system of proposed plan of 88.6 per cent coverage

T A B L E XVIII

Network cost without studio and programming costs

Coverage, per cent of total population		12.4	27.25	38.75	53.75	61.7	68.7	80.9	88.6
Purchasing price	$	131,650	663,690	1,437,890	2,339,880	3,230,440	3,986,940	5,378,730	6,657,860
	mill.mk	30.4	153.3	332	541	746	921	1,242	1,540
	$ per person	0.261	0.597	0.910	1.068	1.285	1.425	1.63	1.84
	mk per person	63	138	210	246.5	297	329.5	376.5	425
Additional purchasing price	$	131,650	532,040	905,850	809,890	1,007,700	797,000	1,431,340	1,279,130
	mill.mk	30.4	123	209.5	187	232.7	184.1	330.6	295.5
	$ per person	0.261	0.479	0.573	0.369	0.401	0.285	0.434	0.354
	mk per person	63	110.8	132.3	85.3	92.7	65.9	100.2	81.8
Annual operating cost	$	32,390	153,830	322,800	519,970	700,650	864,680	1,182,840	1,451,450
	mill.mk	7.48	35.5	74.6	120.1	162	199.8	273.5	335
	$ per person	0.064	0.138	0.204	0.237	0.279	0.309	0.359	0.402
	mk per person	14.8	31.9	47.1	54.7	64.5	71.4	83	92.8

have been plotted in Figure 32 to enable comparison of the proposed plan to the minimum cost per person plan and to the equal cost per person plan. As can be seen, the cost of the proposed television system follows approximately the cost of minimum cost per person plan, although the equal cost per person plan has been approximately followed. The reason is that proper selection of locations both for stations and repeaters decreases the cost per person by increasing the population coverage.

For the total television system cost, studio and programming cost from Table IX was added to the network cost in Table XVIII. The program time has been assumed first to be 3 hours daily, later increasing to 6 and 9 hours per day. The figures obtained are shown in Table XIX.

Consideration of Financing

A television system for Finland will probably be financed by the revenue from television receiver licenses. Therefore, a study was made of the probable rate of increase of the number of licenses. Appreciable experience with television service has been attained only in the United States. It was found that in television service areas in the United States, the increase in number of receiving sets has been approximately linear with time. The number of annual additional sets has been about 5 per cent of total population in the service area, which means that the area would be saturated within about 5 years. On the other hand, the corresponding

T A B L E XIX

Total cost of television network system

Coverage, per cent of total population	12.4	27.25	38.75	53.75	61.7	68.7	80.9	88.6
Number of stations	1	3	3	6	8	10	13	18
Program time, hours per day	3	3	6	6	6	9	9	9
Required number of studios	1	1	2	2	2	3	3	3
Purchasing price $	598,590	1,130,630	2,795,790	3,697,780	4,588,340	6,204,740	7,596,530	8,875,660
mill.mk	138.3	261	645	854	1,060	1,433	1,756	2,052
$ per person	1.187	1.018	1.769	1.685	1.823	2.216	2.300	2.455
mk per person	274	235	409	389	421	511	531	567
Additional purchasing price $	598,590	532,040	1,936,950	809,890	1,007,700	1,656,900	1,431,340	1,279,130
mill.mk	138.3	123	447.5	187	232.7	383	330.6	295.5
$ per person	1.187	0.479	1.225	0.369	0.401	0.591	0.434	0.354
mk per person	274	110.8	283	85.3	92.7	136.5	100.2	81.8
Annual operating cost $	319,590	441,030	960,700	1,157,870	1,338,550	1,806,980	2,125,140	2,393,750
mill.mk	73.8	102	222	267.5	309.5	417.5	491	553
$ per person	0.633	0.397	0.608	0.528	0.532	0.645	0.644	0.662
mk per person	146.3	91.7	140.5	122	123	149	148.8	153

annual increase of number of the regular AM radio broadcasting receiving licenses has been in Finland about 1 to 1.5 per cent of the total population. Based on these figures, it was assumed that in Finland the annual increase in the number of the television receiving sets would be approximately 2 per cent of the population within the television service areas. The reasons were: (1) The television sets will probably cost only about twice as much as the AM receiving sets, which are commonly used in Finland, (2) Television is probably more attractive than AM radio broadcasting service, (3) The densely populated areas, which will be served, are the wealthy regions of the country. The 2 per cent annual increase would mean about 13-year saturation time in each service area.

Following approximately the custom of financing radio broadcasting service in Finland as explained before, the financing of the proposed television system could be done the following way. Since in the beginning the coverage area would be small and the saturation in the area also small, the annual revenue would be small. To speed up expansion, a station for each of the three largest cities should be built simultaneously with a studio in Helsinki by obtaining a loan of about

$1,176,320 or 272 million marks.

The first year only film programs should be used. Even then, the annual operating cost would exceed the revenue during the year. This loss is included in the loan above. If the annual increase of the number of sets is 2 per cent of population covered, and if the license fee is about twice that of the present-day AM broadcasting radio receiver license fee or about $10 per year, 80 per cent live talent programming can be started in the second year, 3 hours daily. The first system expansion would be during the seventh year, and from then on expansion would occur each year according to the proposed plan. By this method the 88.6 per cent coverage would be obtained within eleven years. The development of the system is shown by figures in Table XX and the corresponding predicted number of licenses versus time in Figure 52. The first-year loss is assumed to be paid during the second and third years, but the rest of the loan is left to be paid after the system is fully developed.

TABLE XX

Financing plan for the proposed television system

Year		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Coverage, per cent of total population		27.25	27.25	27.25	27.25	27.25	27.25	38.75	53.75	61.7	61.7	68.7	88.6
Number of stations		3	3	3	3	3	3	3	6	8	8	10	18
Program time, hours per day		3 (film)	3	3	3	3	3	6	6	6	6	9	9
Estimated number of licenses		22,220	44,440	66,660	88,880	111,100	133,320	164.920	208,780	259,120	309,460	365,480	437,780
Revenue	$	222,200	444,400	666,600	888,800	1,111,000	1,333,200	1,649,200	2,087,800	2,591,200	3,094,600	3,654,800	
	million mk	51.4	102.7	154	205.4	256.5	308	381	483	598	715	845	
Annual operating cost	$	267,890	441,030	441,030	441,030	441,030	441,030	960,700	1,157,870	1,338,550	1,338,550	1,806,980	2,393,750
	million mk	61.9	102	102	102	102	102	222	267.5	309.5	309.5	417.5	553
Net income	$	-45,690	3,370	225,570	447,770	669,970	892,170	688,500	929,930	1,252,650	1,756,050	1,847,820	
	million mk	-10.56	0.78	52.1	103.4	154.5	206	159	215.5	288.5	405.5	427.5	
Balance from preceding year	$		-48,900	-48,700	176,870	624,640	1,294,610	249,830	128,440	50,670	1,303,320	1,402,470	
	million mk		-11.3	-11.25	40.9	144.4	299	57.7	29.7	11.7	301	324	
Purchasing price of new facilities	$						1,936,950	809,890	1,007,700		1,656,900	2,710,470	
	million mk						447.5	187	232.7		383	626.1	
Balance	$	-45,690	-45,530	176,870	624,640	1,294,610	249,830	128,440	50,670	1,303,320	1,402,470	539,820	
	million mk	-10.56	-10.52	40.9	144.4	299	57.7	29.7	11.7	301	324	124.8	
Loan facilities	$	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	
	million mk	261.5	261.5	261.5	261.5	261.5	261.5	261.5	261.5	261.5	261.5	261.5	
operating cost	$	45,690	45,530										
	million mk	10.56	10.52										
total	$	1,176,320	1,176,160	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	1,130,630	
	million mk	271.6	271.56	261.5	261.5	261.5	261.5	261.5	261.5	261.5	261.5	261.5	

Annual increase of the number of licenses assumed to be 2 per cent of population covered.

License fee assumed to be 10 dollars or 2310 marks per year.

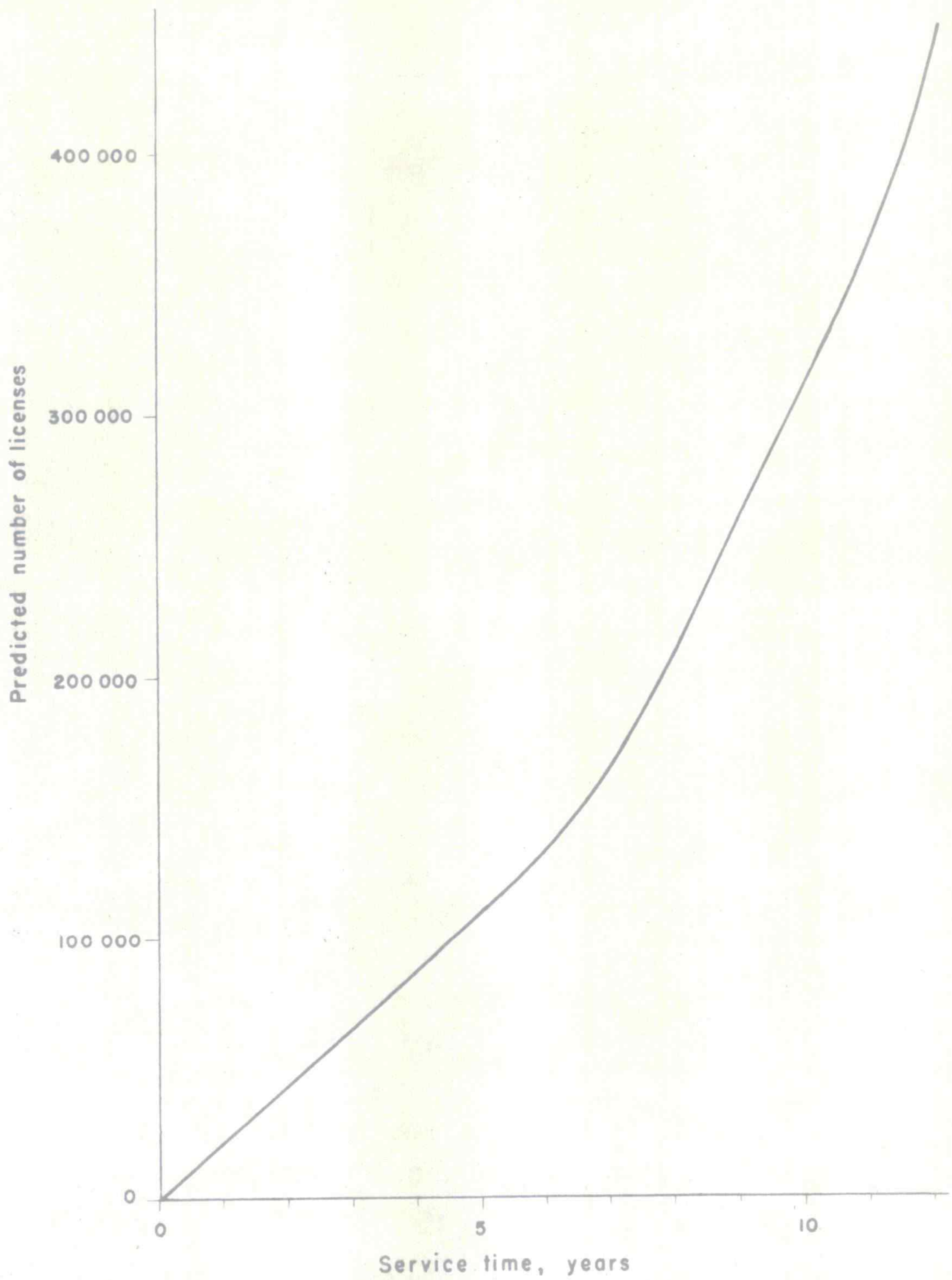


Fig. 52 Predicted number of television receiving licenses versus time

CONCLUDING RECOMMENDATIONS

In the preceding pages a technical and economic study of a television system for Finland was made. Finland is a relatively small country with modest living standards. The study was extensive, taking into account the economy, customs, population distribution, geography, and terrain of the country. The equipment has been considered both on the basis of black and white technique at present and possible future developments of color television.

Based on the investigations a recommended system is presented in the preceding pages which would be flexible enough to adapt possible future improvements. Because the system would be of the centralized non-commercial type, all programming would originate in studios in Helsinki. At first, three 1-kilowatt stations are recommended to be built. These would be in Helsinki, Turku, and Tampere. The three stations would provide the country with adequate television service for from 5 to 7 years. The first year only film programs can be afforded, but during the second year live-talent programming can be started.

During the first 6 years a 50-kilowatt station can be built to Ohkola starting the service in the seventh year. The 1-kilowatt station in Helsinki may be left for more flexible service (Swedish programs, for instance) or may be moved to a new location. After this a gradual expansion of both network system and programming would occur. The next year new 1-kilowatt stations can start television broadcasting in Pori, Jyväskylä, and Kuopio. The following year the power of the station of Turku can be increased to 5 kilowatts, and a new 5-kilowatt station built in Ylöjärvi near Tampere. The 1-kilowatt station from Tampere would be moved to Vaasa, and a new one built to Joensuu.

During the eleventh year Jyväskylä and Kuopio would operate at increased power of 5 kilowatts, and Ylivieska and Oulu have new 1-kilowatt stations. By the end of the eleventh year, the television broadcasting system would have expanded to cover 88.6 per cent of the total population of Finland. This is considered essentially complete television coverage and no further studies were made. The power of the stations of Ohkola, Ylöjärvi, and Vaasa would have been increased to 100, 25, and 5 kilowatts respectively, and 1-kilowatt stations would have been built to Mikkeli, Lappeenranta, Savonlinna, Kotka, Karijoki, Kokkola, Kajaani, and Kemi.

The license fee is recommended to be approximately 10 dollars per year. If the development of the television broadcasting system were made following the recommendations above, this license fee would make the broadcasting company financially stable and capable of the development and shift to color television when this has reached the stage to be suitable to be applied.

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APPENDICES

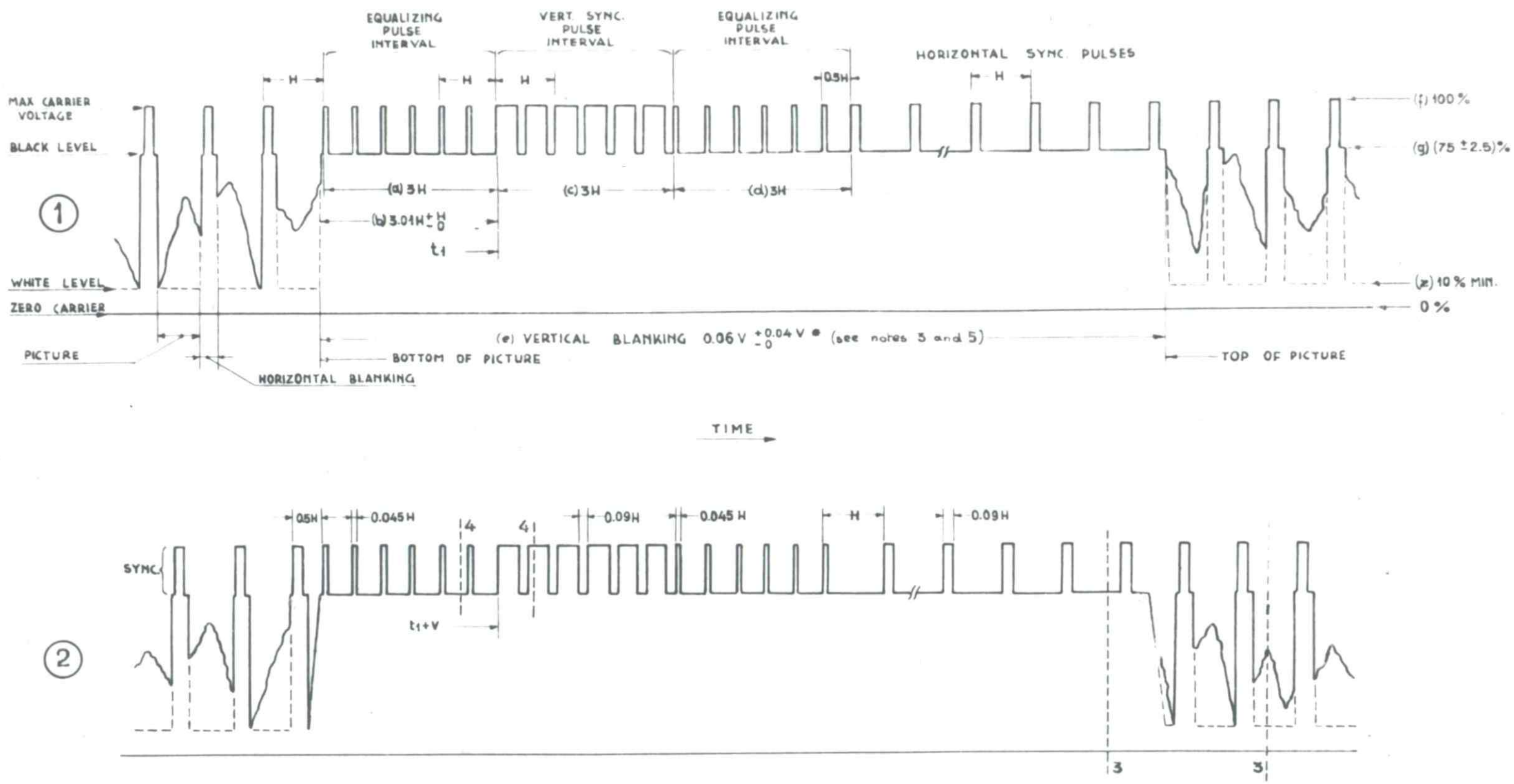
APPENDIX I

Appendix I shows the synchronizing waveforms as a reprint from "Standards for the international 625-line black and white television system" by International Radio Consultative Committee.

MEETING SUB-GROUP GERBER
C.C.I.R.
GENEVA, 1950

Annex I
to Doc. 7-E (Final)
10th Oct., 1950
page 5

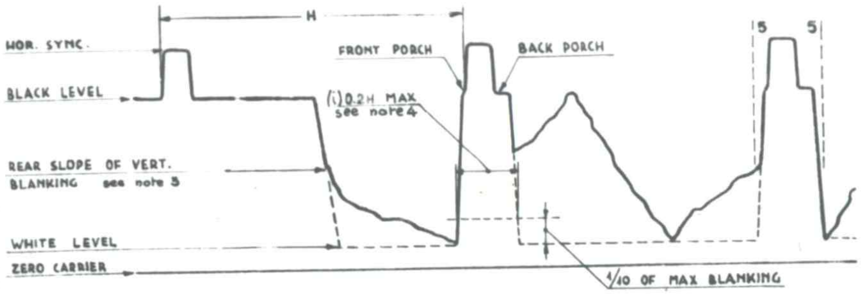
SYNCHRONIZING WAVEFORM



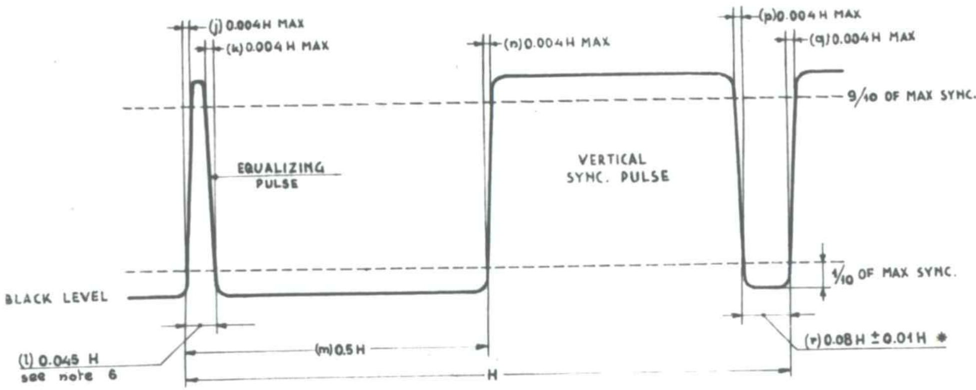
Horizontal dimensions not to scale

FIGURE 1

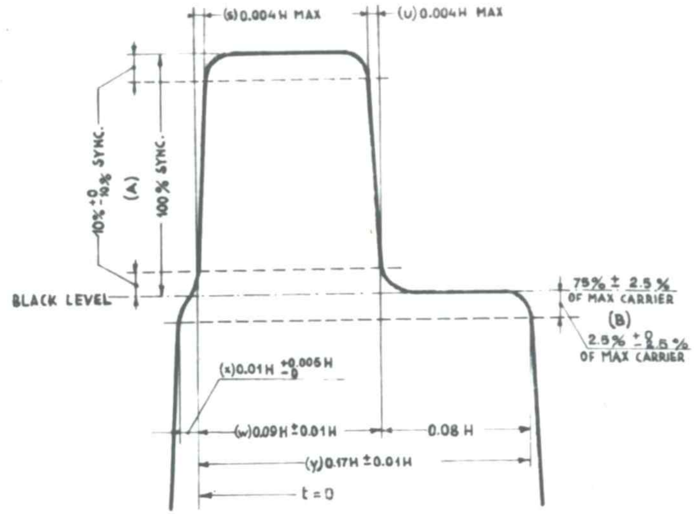
DETAILS OF SYNCHRONIZING WAVEFORM



③ Detail between 3-3 in ② of fig. 1



④ Detail between 4-4 in ② of fig. 1



(A) Measured prior to modulation

(B) Measured after ideal detection

⑤ Detail between 5-5 in ③

FIGURE 2

N O T E

(see figure 1 and 2)

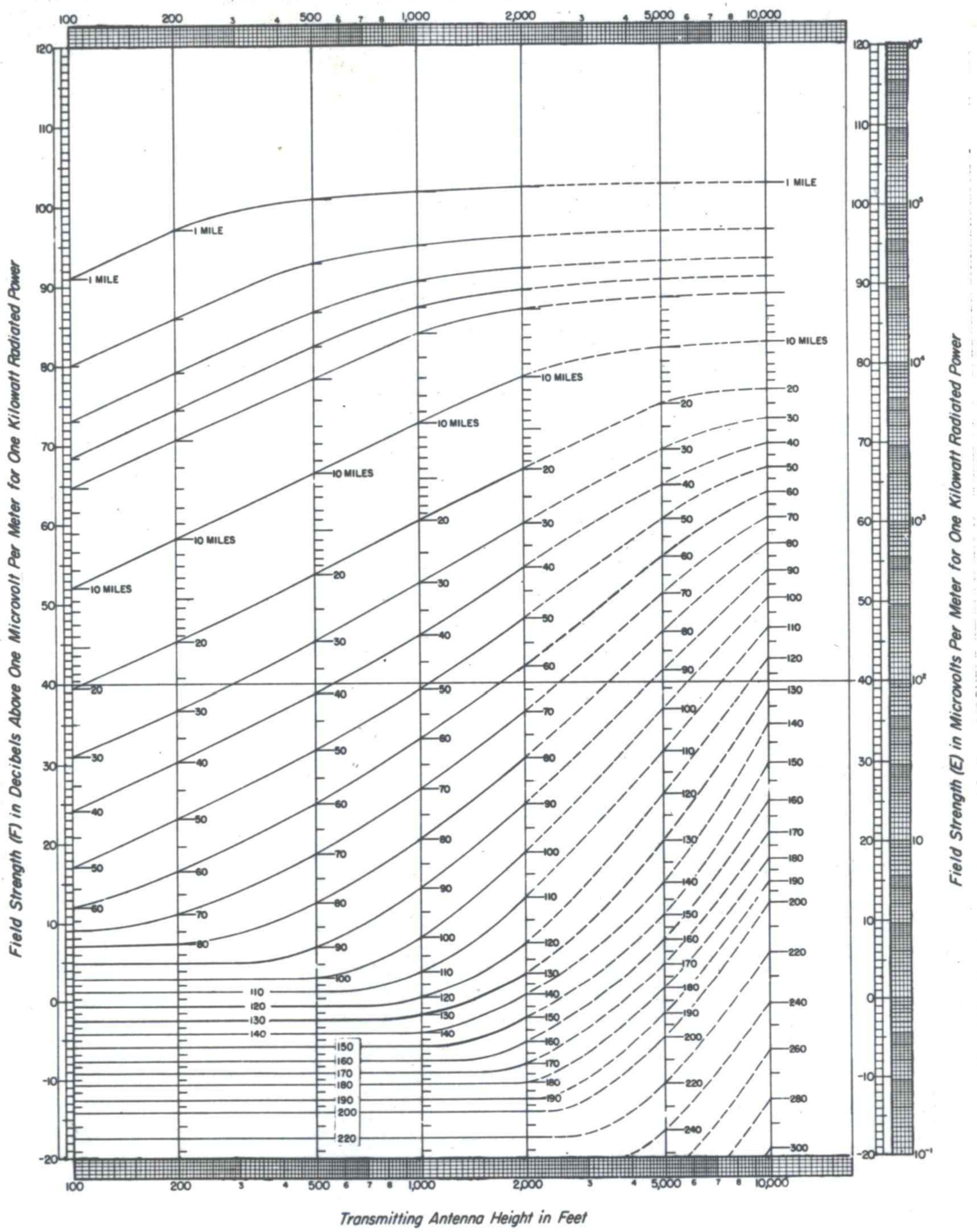
1. H = Time from start of one line to start of next line.
2. V = Time from start of one field to start of next field.
3. Leading and trailing edges of vertical blanking should be complete in less than 0.1 H.
4. Leading and trailing slopes of horizontal blanking must be steep enough to preserve min. and max. values of (x + y) and (i) under all conditions of picture content.

*5. Dimensions marked with an asterisk indicate that tolerances given are permitted only for long time variations and not for successive cycles.

6. Equalizing pulse area shall be between 0.45 and 0.5 of the area of a horizontal sync. pulse.

APPENDIX II

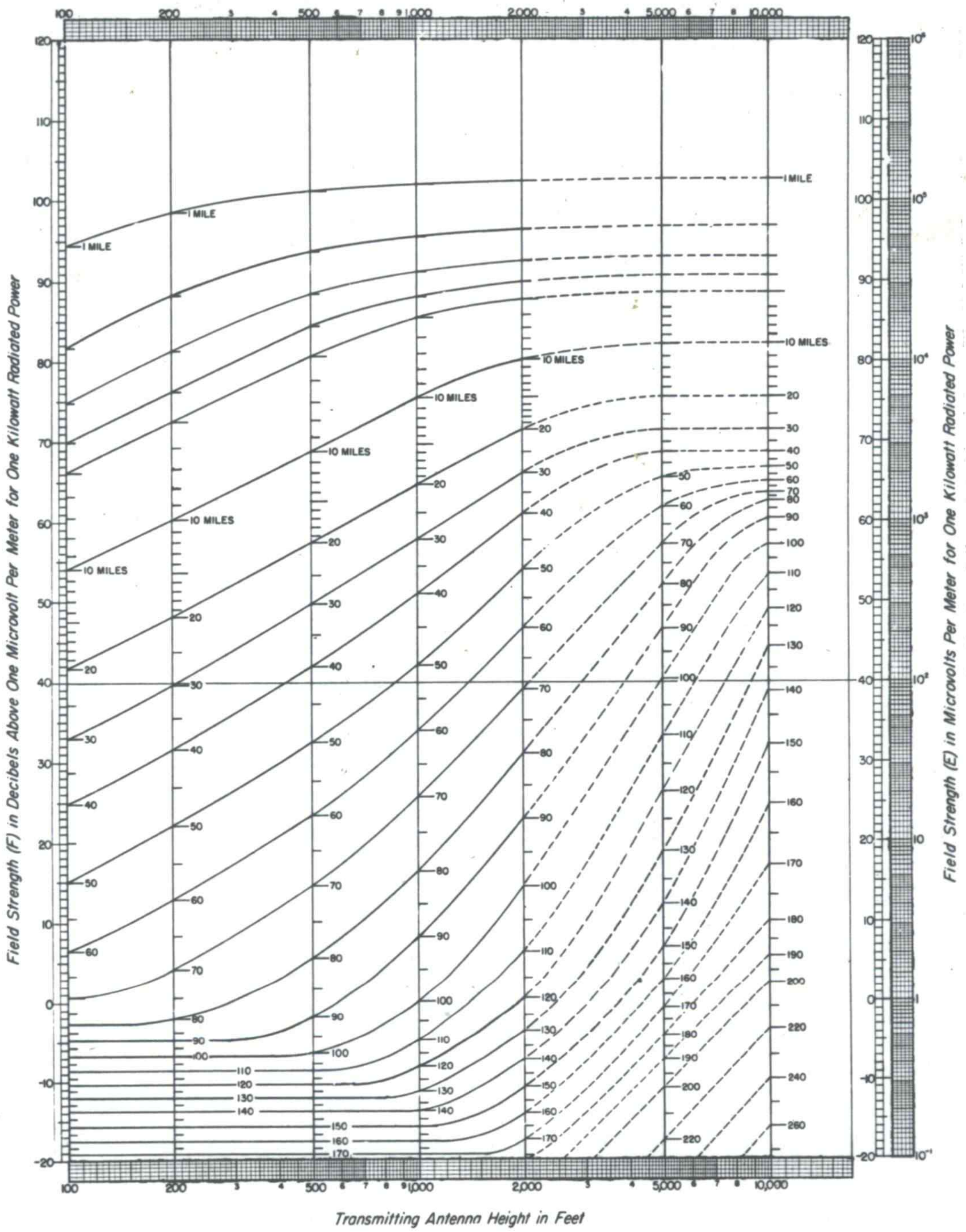
Appendix II shows graphs to be used for field intensity computations as a reprint from "Television broadcast service, third notice of further proposed rule making" by Federal Communications Commission.



APPENDIX V

FIGURE I - TELEVISION CHANNELS 2 - 6

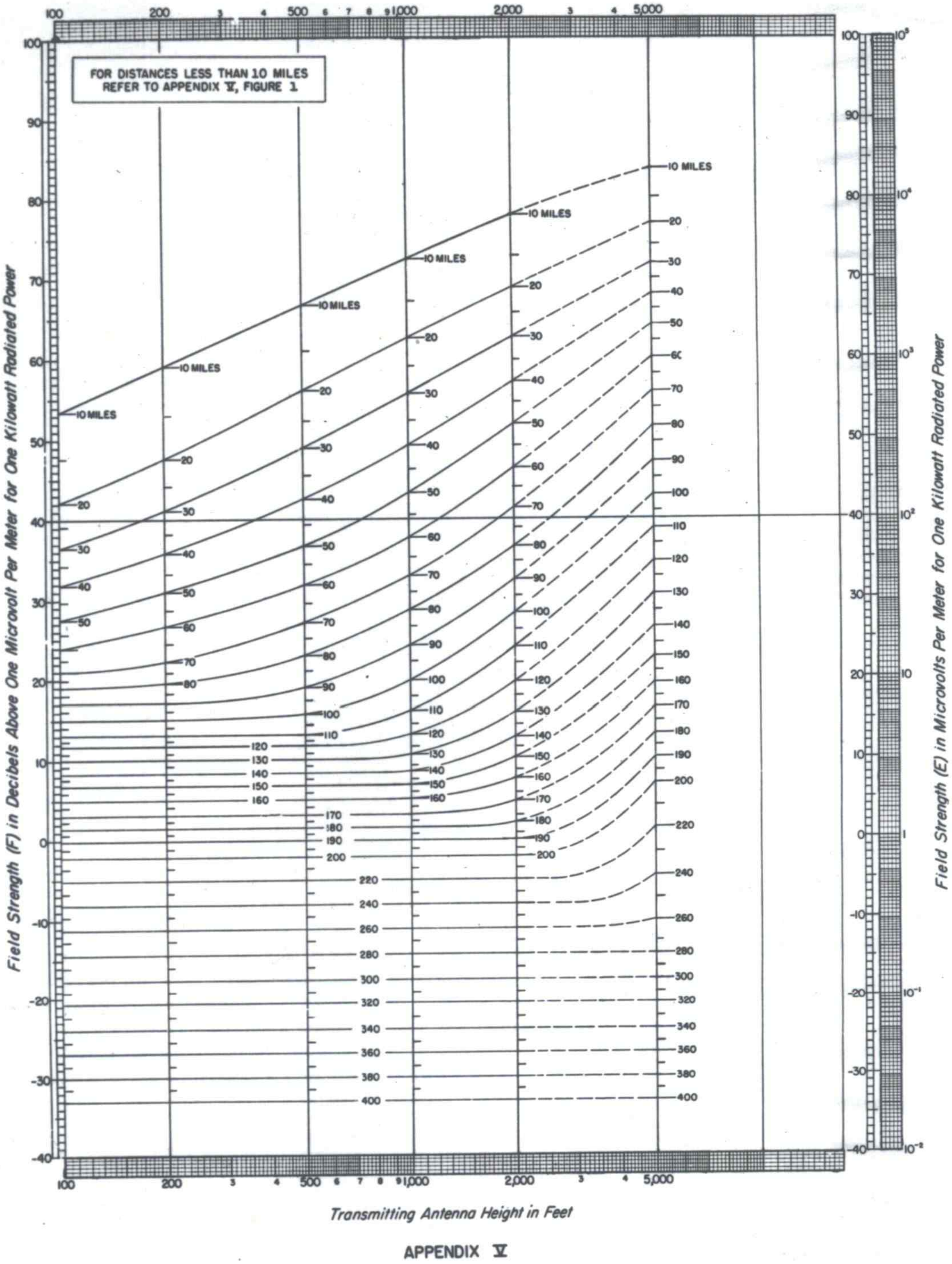
EXPECTED FIELD STRENGTH EXCEEDED AT 50 PERCENT OF THE POTENTIAL RECEIVER LOCATIONS FOR AT LEAST 50 PERCENT OF THE TIME AT A RECEIVING ANTENNA HEIGHT OF 30 FEET.



APPENDIX V

FIGURE 2 - TELEVISION CHANNELS 7 - 83

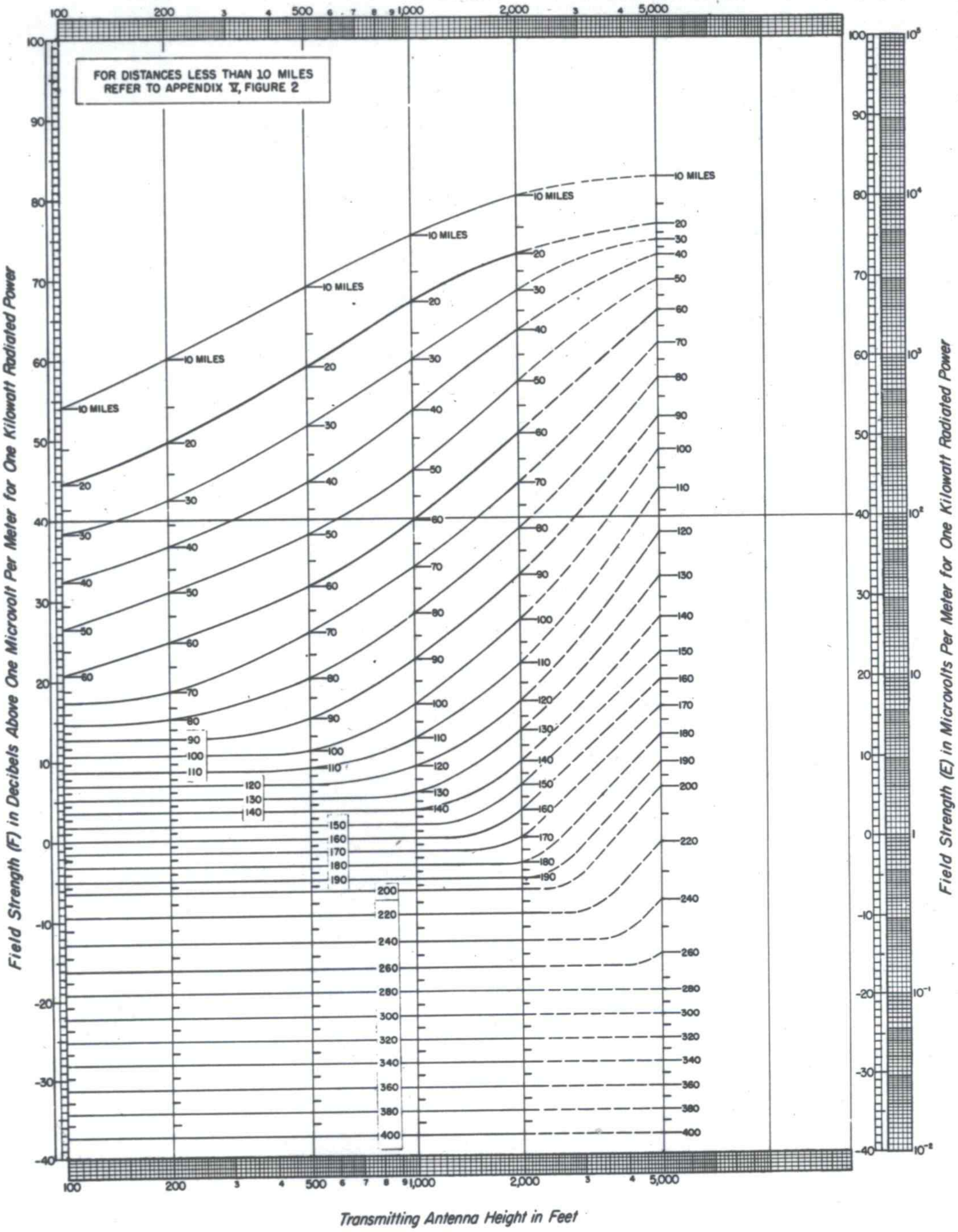
EXPECTED FIELD STRENGTH EXCEEDED AT 50 PERCENT OF THE POTENTIAL RECEIVER LOCATIONS FOR AT LEAST 50 PERCENT OF THE TIME AT A RECEIVING ANTENNA HEIGHT OF 30 FEET.



APPENDIX V

FIGURE 3 - TELEVISION CHANNELS 2 - 6

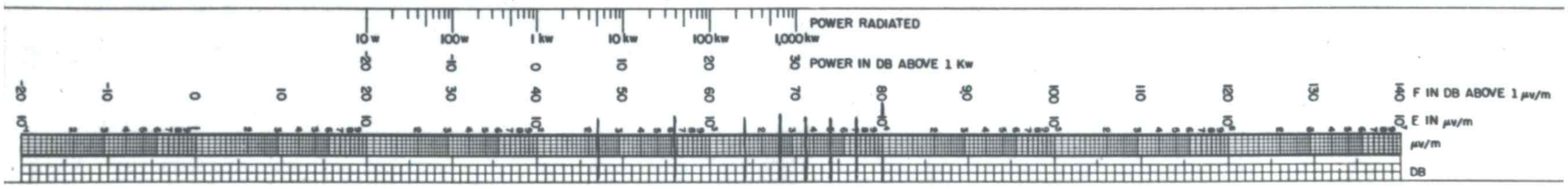
EXPECTED FIELD STRENGTH EXCEEDED AT 50 PERCENT OF THE POTENTIAL RECEIVER LOCATIONS FOR AT LEAST 10 PERCENT OF THE TIME AT A RECEIVING ANTENNA HEIGHT OF 30 FEET.

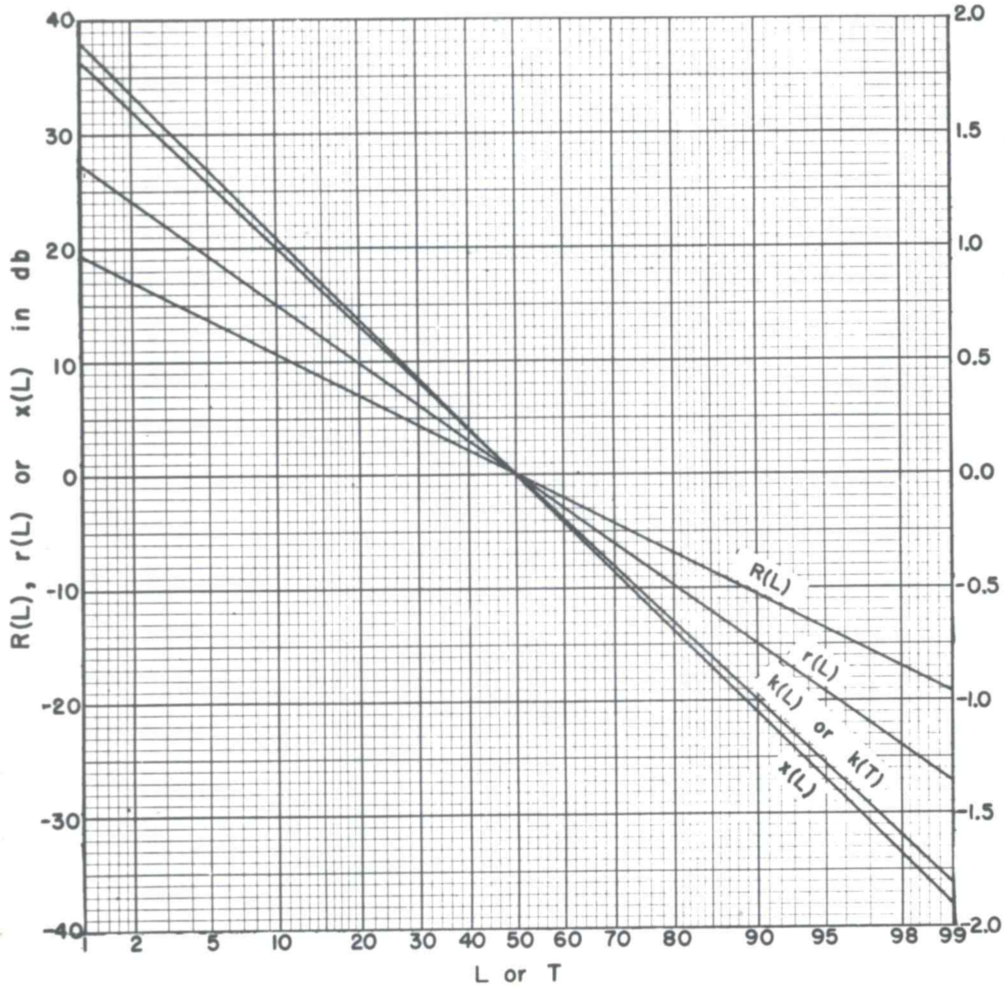


APPENDIX V

FIGURE 4 - TELEVISION CHANNELS 7 - 83

EXPECTED FIELD STRENGTH EXCEEDED AT 50 PERCENT OF THE POTENTIAL RECEIVER LOCATIONS FOR AT LEAST 10 PERCENT OF THE TIME AT A RECEIVING ANTENNA HEIGHT OF 30 FEET.


POWER RADIATED
10 w
100w
1 kw
10 kw
100 kw
1,000 kw
POWER IN DB ABOVE 1 Kw
F IN DB ABOVE 1 μv/m
E IN μv/m
μv/m
DB

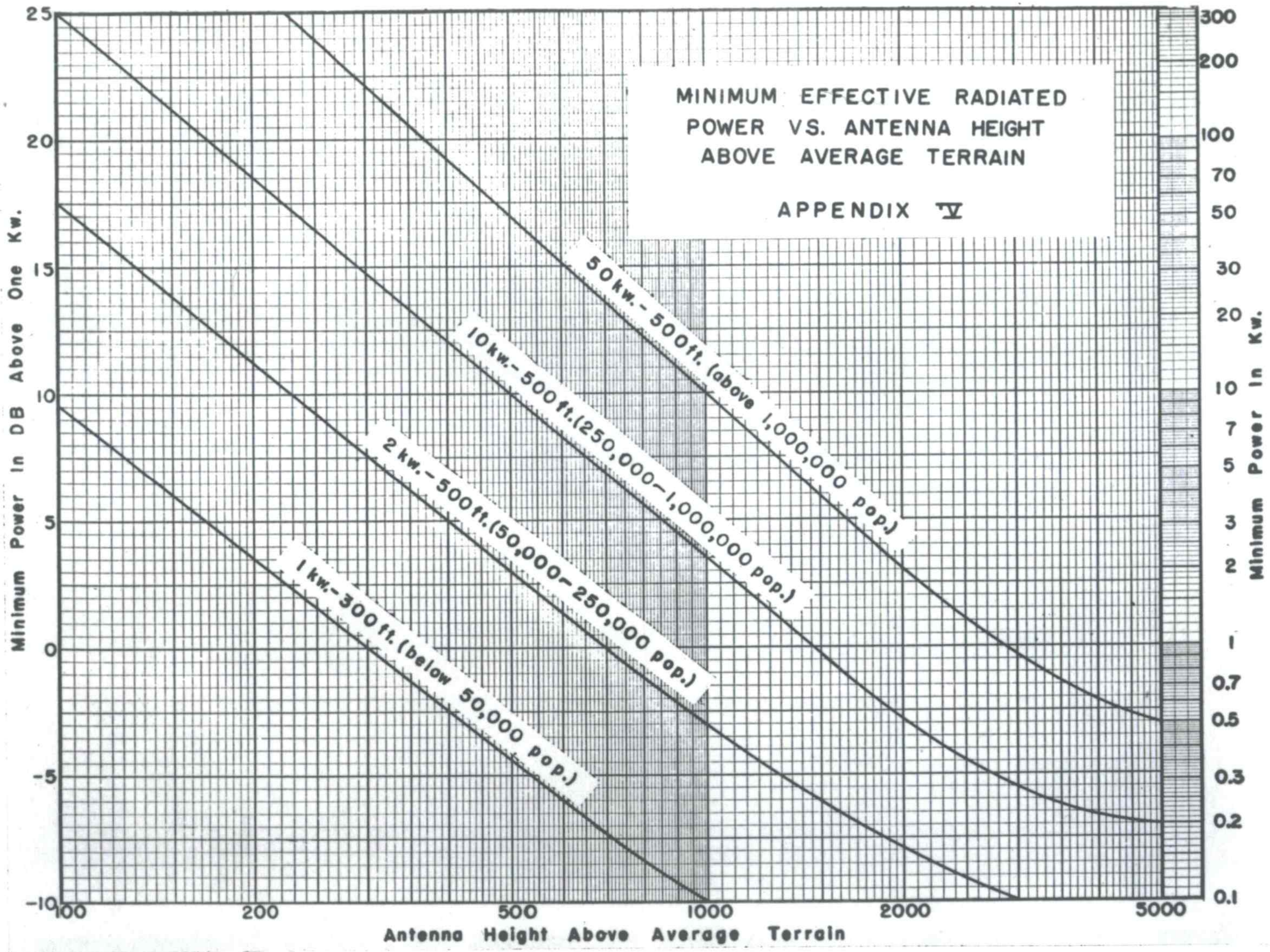


EXPECTED PERCENTAGE OF THE RECEIVING LOCATIONS, L, OR PERCENTAGE OF THE TIME, T, AT WHICH THE ORDINATE VALUE WILL BE EXCEEDED

APPENDIX V, FIGURE 5

F.C.C. - Washington, D.C.

61004


MINIMUM EFFECTIVE RADIATED POWER VS. ANTENNA HEIGHT ABOVE AVERAGE TERRAIN
APPENDIX V
50 kw. - 500 ft. (above 1,000,000 pop.)
10 kw. - 500 ft. (250,000-1,000,000 pop.)
2 kw. - 500 ft. (50,000-250,000 pop.)
1 kw.- 300 ft. (below 50,000 pop.)
Minimum Power In DB Above One Kw.
Minimum Power In Kw.
Antenna Height Above Average Terrain
25
20
15
10
5
0
-5
-10
100
200
500
1000
2000
5000
300
200
100
70
50
30
20
10
7
5
3
2
1
0.7
0.5
0.3
0.2
0.1