EFFECTIVENESS OF HF COVERAGE BY FIXED MONITORING STATIONS.

VOLUME 2. APPENDICES.

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CONTENTS.

APPENDIX 1.

CHARACTERISTICS OF WAVE PROPAGATION.

The following is a discussion of general principles and mechanics of the propagation of radio waves, with emphasis on the daily, seasonal and yearly variations in the propagation characteristics. It is not to be taken as a detailed analysis of wave propagation, as such is outside the scope of this report. Rather, it is to give a better appreciation of the underlying principles on the bases of which the theoretical coverage maps were obtained, and also to provide a reference for monitoring station operators, concerning the constant changes in propagation characteristics. It is felt that operators, from their past experience, have a good idea of what to expect from monitoring any given frequency band, at different times of the day, season or year, but are generally not aware of why and how these changes take place.

GENERAL NATURE OF PROPAGATION.

When a radio wave is radiated from a transmitting antenna it spreads out in all directions, decreasing in amplitude with increasing distance due to the spreading of the electromagnetic energy through larger and larger surface areas. The portion of the energy arriving at a distant receiving antenna may have travelled over any of several possible propagation paths, as indicated on the diagram below.
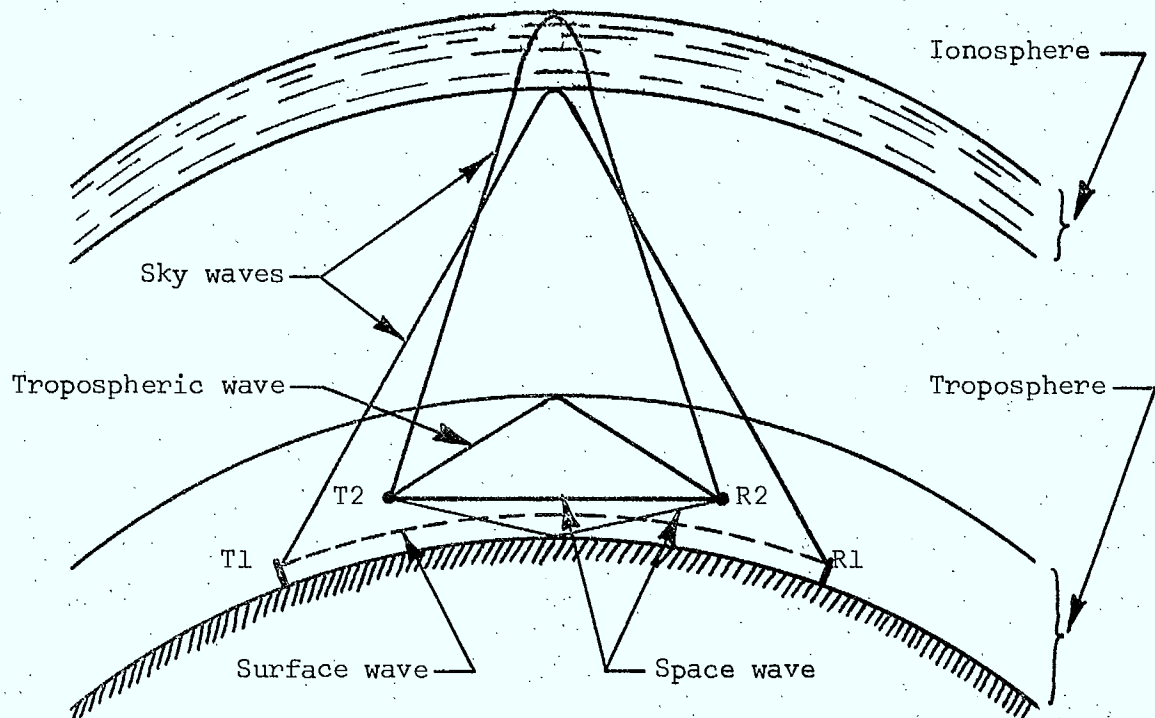
Possible propagation paths from transmitter to receiver.

Which of the several possible paths are operative in any particular instance depends upon the frequency, the separation between transmitter and receiver, and the conditions of the ionosphere and the troposphere. Although there are cases where several of these paths are operative simultaneously, it is usually found that propagation is restricted to only one or two paths, or at any rate, that the signal received over a particular path is much stronger than those received over other paths.

The surface wave.

The surface wave, as its name suggests, travels in contact with the earth's surface without any reflection. A certain portion of the total energy is continually propagated into the ground, due to penetration, and this loss increases both with distance and frequency. As a result, the surface wave is limited to relatively short distances and to the low and medium frequency bands.

The surface wave from a vertical antenna is far stronger than that from a horizontal antenna at the same height, and in both cases decreases with the height of the antenna above the ground.

The space wave.

The space wave consists of two components, the direct ray and the ground-reflected ray, as shown in the diagram below. The total field due to space wave, at a given receiving point, is the sum of the fields resulting from these two components. Whether these two components reinforce or cancel each other depends on their phase relationship. This phase difference in turn depends on frequency, the electrical constants of the earth, and the difference in path lengths of the direct and ground-reflected rays.

Although space wave has to be taken into consideration for medium frequency transmissions, their main use is above 30 MHz. At such frequencies the sky wave is normally non-existent and the surface wave is negligible, except in the immediate neighbourhood of the transmitting antenna.

Space wave components.
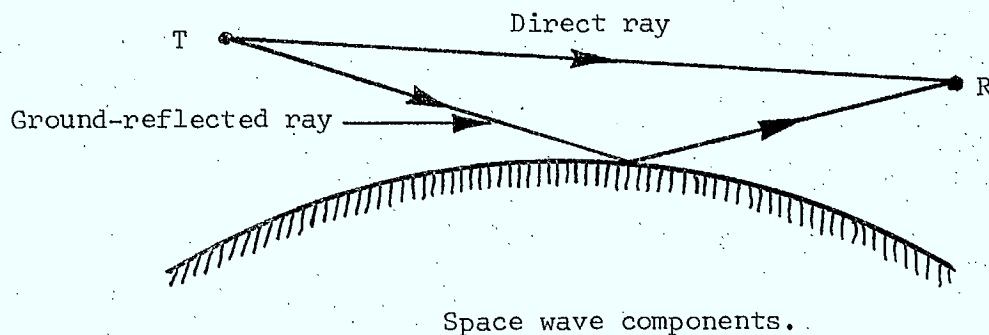
The sky wave.

Sky wave is the result of the reflection of radio waves from the
ionospheric layers of the atmosphere. The reflecting ability of these layers
depends on their relative electron density and show marked diurnal, seasonal
and yearly variations, which can be related to solar radiation and sunspot
activity.

At medium frequencies the sky wave is practically non-existent
during the daytime, due to strong absorption in the lower regions of the
ionosphere. At night time, however, the sky wave is appreciable and, if no
precautions are taken, interferes with the surface wave thereby causing
fading.

At frequencies from 3 to 30 MHz the sky wave is of major importance,
providing the mechanism by which HF propagation takes place. An important
feature of such propagation is that generally at these frequencies the sky
waves experience very little attenuation, which decreases with increasing
frequency. Consequently, a reasonable field strength may be obtained with
moderate powers, over very great distances.

At still higher frequencies, that is above 30 MHz, the maximum
electron densities in the ionosphere are rarely sufficient to reflect waves,
except for relatively short periods (eg. in the equatorial regions near the
peak of the sunspot cycle). Ionospheric transmission at these frequencies
is, therefore, mainly the result of scattering of waves by irregularities
in the electron density distribution of the ionosphere rather than gradual
refraction. The main sources of irregularities in the ionosphere are

1. turbulent mixing in the D-region;

2. ionized meteor trails;

3. F-layer irregularities, spread F; and

4. dense E-layer patches, sporadic E.

Ionospheric scatter propagation generally takes place from 30 to about 80
MHz, and can cover distances up to 2,000 km.

The tropospheric wave.

Radio waves propagated by tropospheric scattering and ducting are
called tropospheric waves.

Tropospheric scattering is caused by inhomogeneities and discon-
tinuities in the refractive index of the atmosphere. Tropospheric scatter
propagation generally takes place at frequencies between about 40 MHz and
4 GHz, and can cover distances of up to 1,000 km.

On the other hand, duct propagation takes place when two bound-
ary surfaces between layers of air, or between a layer of air and the earth's
surface, form a duct which guides radio waves with frequencies higher than

about 100 MHz for distances up to about 1,000 km. An important feature of duct propagation is that both transmitting and receiving antennas must be inside the duct.

Tropospheric propagation, because of the direct dependence on atmospheric conditions, is very much a function of the weather.

THE IONOSPHERE.

The term ionosphere refers to the ionized region of the atmosphere that has a very important influence on the propagation of radio waves. This ionized region extends from a lower limit of 50-80 km upward to a height of about 400 km.

The ionization of gas molecules in the atmosphere is a result mainly of solar radiation and cosmic rays. However, since these ions are in constant motion, a process of recombination goes on all the time. The time that it takes for recombination to occur depends on several factors, but particularly on the average distance between the particles. In the lower part of the atmosphere collisions take place so often that air molecules do not remain ionized very long. Another reason why there is relatively little ionization in the lower atmosphere is that the ultra-violet rays of the sun are largely absorbed by the upper atmosphere. As a result, there is very little ionization below about 50 km. On the other hand, above 400 km there are so few air molecules to be ionized that the density of ionization is again very low.

Because of the variation in the chemical composition of the atmosphere with height, and because different gases vary in their ability to absorb solar radiation of different frequencies, there is a tendency for the ionization to become stratified. Consequently, the curve of electron density as a function of height has several maxima, and these maxima are commonly called ionospheric layers. The number of layers, their heights above the earth and the electron density of the layers all vary from day to day, month to month, and from year to year.

There are two principal layers, called the E-layer and the F-layer. The E-layer is usually found at a height of 110 km, but may vary from 90 to 140 km. The other principal layer, the F-layer, is one layer only at night but splits into two parts during the daytime and they are designated as the F1 and F2 layers. The F1 layer is generally at a height of 180-250 km and it is usually absent at night, while it may completely disappear during the winter particularly during the more active part of the sunspot cycle. The height of the F2 layer may range between 250 and 400 km. There are other layers also of which the D-layer is the most important. The D-layer is present only in the daytime and its approximate range of height is 50-90 km.

Effect of the ionosphere on wave propagation.

Radio waves are returned to earth from the ionosphere by means of refraction, except in the case of ionospheric scatter, that is the waves are bent away from the regions of high ion density toward those of low ion density. However, since it is usually simpler and more convenient to think of

the wave as being reflected, the ionospheric layers are generally described by their virtual heights. The virtual height of an ionospheric layer is the height that a radio wave would reach if it travelled in a straight line and was reflected from a mirrorlike surface. This is shown on the diagram below, where θ is the angle of incidence.
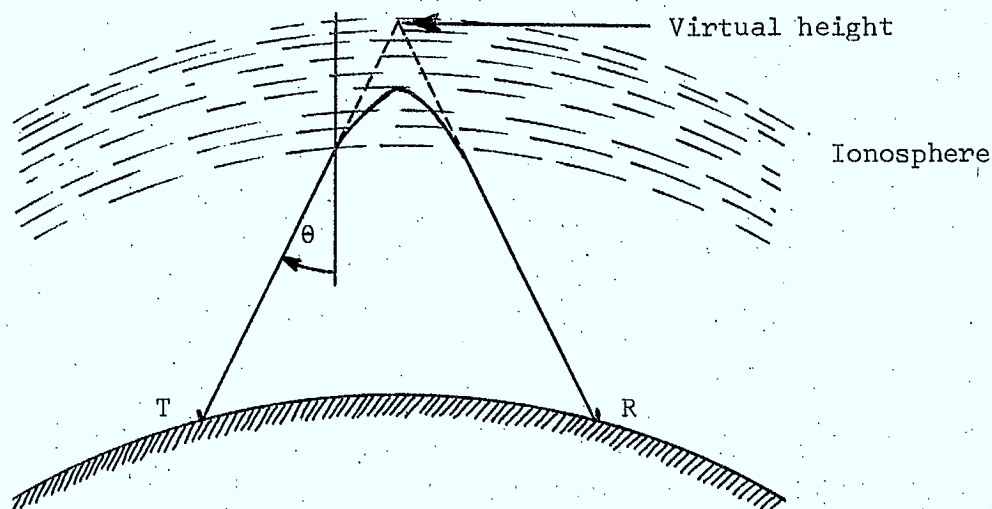
The virtual height of an ionospheric layer.

If the frequency of the transmitted wave is increased sufficiently a point is reached beyond which the wave is no longer returned back to earth and, unless reflected from a higher layer of greater ion density, it will be lost in space. The reflective power of an ionospheric layer, therefore, depends on the frequency of the radio wave, the ion density of the layer, and the angle at which the wave strikes the layer.

The highest frequency that an ionospheric layer can return back to earth, when the ray enters the ionosphere with vertical incidence, is called the critical frequency. It is a direct measure of the maximum ion density of a layer.

The critical frequency for a particular layer, however, is not the highest frequency that can be used for communication, using that layer. By increasing the angle of incidence radio waves of higher frequency will be reflected.

Owing to the curvature of the earth and the surrounding ionosphere, there is a maximum angle of incidence which can be made with the layers and this occurs when the radio waves leave the earth tangentially. In the case of the E-layer this angle is about 80°, and for the F2 layer it is about 73°. The corresponding great circle distances covered by reflections, at such angles, are 2,200 km and 3,600 km respectively.

The annular belt around a radio transmitter, where its signals can not be received, is called the skip zone. It extends beyond the ground wave range but lies within the skip distance, that is the distance from the transmitter to a point where a specified radiated frequency first returns to earth as a sky wave.

In this zone the ground-wave signals are attenuated below a usable level. The sky waves, on the other hand, entering the ionosphere at an angle of incidence smaller than a certain critical value (dependent on wave frequency) penetrate the ionosphere. Thus, the waves at and near the vertical are not reflected back to earth.

The inside radius of the skip zone is decided by the ground-wave range. For a given transmitter power, it is independent of the time of day and depends solely on frequency - the higher the frequency radiated, the smaller the inside radius of the skip zone.

The outside diameter of the skip zone is decided by the skip distance, that is, the conditions of ionospheric propagation. Because of this, it will vary with the time of day, season, and frequency.

Graphical representation of the skip distance and the skip zone is shown on the diagram below.

Skip distance and skip zone.
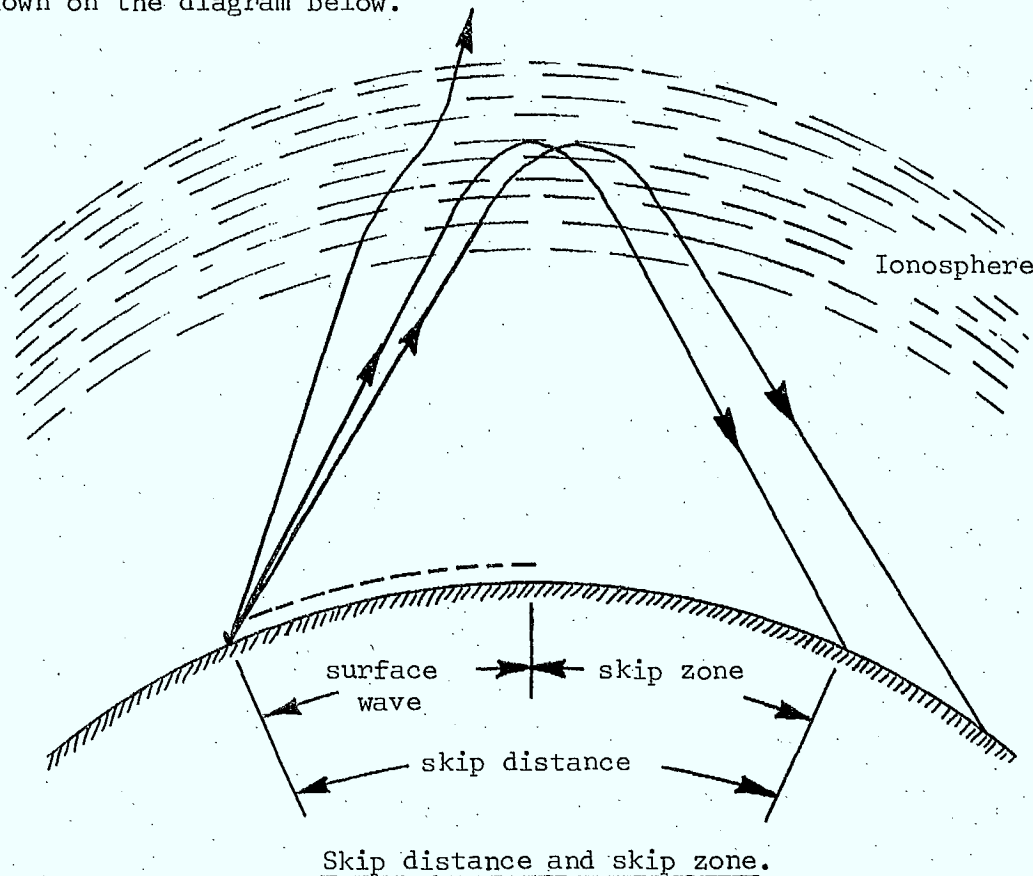
Absorption in the ionosphere.

In addition to the virtual heights and the critical frequencies, for each of the layers, the attenuation or absorption of energy from the waves by the ionosphere is an important factor in limiting radio transmission over large distances. When a radio wave passes through an ionized region it causes the electrons to vibrate. The vibrating electrons collide with neighbouring molecules and ions, and give up all or some of their

energy in the process. The amount of energy that is taken from a radio wave, and wasted in this way, increases with the distance travelled by the wave in the ionized region and with the density of the ions and air molecules in the layer. Since ultra-violet rays from the sun cause ionization to be present at lower levels in the daytime than at night, and since there are more air molecules at low altitudes, the absorption of energy is much greater during the daytime than at night, the absorption occuring mostly in the D and E layers. The maximum absorption occurs at a frequency of about 1,400 KHz, on account of a resonance condition for the electrons moving in the earth's magnetic field.

Regular variations in the ionosphere.

Characteristics of the ionosphere go through regular variations that affect the propagation of radio waves, and these variations can be predicted with fair accuracy. They are of three principle types, called the diurnal variations, seasonal variations, and sunspot cycle variations. These changes in the ionosphere are largely due to changes in radiation from the sun, so that they are mostly changes in the ion density and the virtual heights of the layers. Changes in the ion density have a direct effect on the ionospheric absorption and the critical frequency of the layers, while changes in the virtual heights affect the skip distance and, therefore, the effective area of reception.

D-layer variations: The virtual height of the D-layer does not show diurnal, seasonal, or sunspot cycle variations. The ion density, however, reaches a maximum around noon and a minimum at night, when the layer practically disappears. These diurnal variations are less during the summer and are much more pronounced in the winter. The ion density also increases proportionally with sunspot number.

E-layer variations: The E-layer maintains a substantially constant virtual height throughout the day and from season to season and is not affected by the sunspot cycle. Changes in the ion density are particularly regular for this layer from day to day and seasonally, and depend almost entirely on the position of the sun in the sky, that is the Zenith angle. The ion density is thus higher during the day than at night, and higher during the summer than in the winter. The density of ionization also varies with solar activity and is the greatest during the most active sunspot periods. Therefore, the critical frequency and the absorption are the lowest during a minimum in solar activity.

F1 layer variations: The F1 layer exists only in the daytime and its virtual height is somewhat lower at noon than at sunrise or sunset, but shows no appreciable seasonal variation. The ion density of this layer has a diurnal variation similar to that of the E-layer, the maximum occuring at noon and being less in the winter than in the summer. The close relationship between ionization density and the Zenith angle, exhibited by the E-layer, also exists for the F1 layer. The F1 layer is always present in the summer but does not necessarily exist during the winter days, particularly during the more active part of the 11 year sunspot cycle.

F2 layer variations: Although the F2 layer is the most important of the layers, for HF communications, it is also the most unstable. It varies

greatly in both virtual height and ion density during the day, from season
to season, and with sunspot cycle. The virtual height of the F2 layer is
greater in the daytime than at night during the summer, and the reverse is
true during the winter, although the summer variations are much more pro-
nounced. The ion density of the F2 layer is much higher in the winter than
in the summer. In the winter the maximum ion density tends to occur at noon,
while it is in the late afternoon during the summer. The ion density reaches
a minimum between midnight and sunrise, and this minimum is somewhat lower
in the winter than in the summer. The virtual height varies with the sunspot
cycle, and the ion density shows a very close correlation with the same.

Geographical variations: Ionospheric characteristics as a function
of local sun time are very much the same, irrespective of longitude. Lati-
tude, however, is quite important, since the varying angle of incidence of
solar radiation with latitude leads to greater ionization in equatorial re-
gions as compared to polar regions. Near the equator the average ion densi-
ties are higher and the average virtual heights lower than at the polar re-
gions. These variations in the Southern Hemisphere, except for the F2 layer,
are similar to those for the Northern Hemisphere when the reversal of sea-
sons is taken into consideration. With the F2 layer, however, the action is
the same in both hemispheres, that is there is no reversal of the seasons.

Abnormal ionospheric behaviour.

In addition to the regular ionospheric variations, that can be
predicted with fair accuracy, there are others of less predictable nature
that have an important effect on ionospheric propagation. These are brief-
ly discussed below.

Sporadic E-layer (Es) reflections: These reflections are the re-
sult of very dense electron (or ion) clouds in the E-layer, that have very
sharp boundaries. These clouds drift through space, with the result that
such reflections may come and go. The extent of these clouds may range from
one to several hundred km across, and its thickness can also vary from ex-
tremely thin to relatively thick. Sporadic E-layer reflections occur most
commonly in the summer, particularly at night, but found to some extent at
any time of day or night and occasionally at all seasons. These reflections
tend to be more frequent during the active part of the sunspot cycle, but
the correlation is not very close. They tend to be less intense the higher
the frequency, but on occasions it is possible to observe Es reflections
with vertical incidence at frequencies up to about 12 MHz. Under these con-
ditions, and because of the low height of the layer, it is possible to ob-
tain long distance sky wave communication at frequencies as high as 60 MHz,
which is about twice as high as can be returned from any of the layers by
normal refraction.

Sudden ionospheric disturbance (SID): Sky wave signals sometimes
suddenly disappear. This is the result of a burst of ionizing radiation from
a solar erruption on the sun, that causes an abnormal increase in the ab-
sorption that waves undergo on entering and leaving the ionized region. Such
a radio fade-out is usually complete within less than a minute, and can last
from ten minutes to several hours. The effect occurs simultaneously through-
out the portion of the earth illuminated by the sun, and does not occur at

night. The action of a fade-out is more intense, and the duration is longer, the lower the frequency (at least for frequencies above 1,500 KHz). The intensity of the disturbance tends to be greatest in the region where the sun's radiation is perpendicular, that is, it is greater at noon than other times of the day, and greater at the equator than at higher latitudes. There is no seasonal variation in the occurence of radio fade-outs, but they have a tendency to be more numerous in years of high sunspot numbers. These fade-outs occur only when there is a solar erruption, however, the converse does not follow since most solar erruptions fail to produce even a mild radio fade-out.

Ionospheric storms: An ionospheric storm is characterized by poor radio transmission, at frequencies above 500 KHz, and is usually accompanied by a magnetic storm. An ionospheric storm begins with a turbulent phase, that consists of a violent turbulence of the entire ionosphere in the auroral zone. This causes the normal stratification of the ionosphere to be destroyed, with the production of small clouds of ionization that move in an irregular manner. The turbulent period is follod by a moderate phase, in which the effect initiated in the auroral zone gradually extends to much lower latitudes. The ionosphere then returns to normal after a period that in severe cases may be several days.

During the turbulent phase of an ionospheric storm layers with definite virtual heights and critical frequencies tend to disappear. During the moderate phase that follows the virtual heights are abnormally great and the critical frequencies unusually low, particularly for the F2 layer. There is also a tendency for the absorption to be greater than normal.

The effects of ionospheric storms are greater near the polar regions and become negligible at the equator. Unlike radio fade-outs, the ionospheric storms may occur at night as well as in the daytime. The frequency with which these ionospheric storms occur correlates reasonably well with solar activity and so follows the 11 year sunspot cycle.

Absorption in the auroral zone: In addition to global magnetic storms, the polar regions are often the scene of local storms. These are accompanied by marked increases in radio wave absorption, especially in the auroral zone. Auroral zone absorption may last from ours to days.

Polar cap absorption: It is believed that the recurring strong ionization in the polar caps is produced by the influx of solar particles, more energetic than those responsible for absorption in the auroral zone. As in the latter, the charged particles produce a strongly ionized layer at the height of the D-layer, throughout the polar cap. This layer absorbs short waves and lasts from 10 to 300 hours.

THE TROPOSPHERE.

The lower part of the atmosphere extending upwards from the earth's surface, in which temperature decreases with height, except in local layers of temperature inversion, is called the troposphere. It extends up to a height of 8-10 km at polar latitudes, 10-12 km at moderate latitudes, and up to 16 or 18 km at the equator.

As a result of changes in the density of the air, temperature, pressure and water vapor in the air, refraction of radio waves occurs in the atmosphere. This refraction tends to bend the waves back to earth and, results in an increased transmission distance, beyond the line-of-sight.

Air in the troposphere is frequently turbulent, which causes the scattering of radio waves. These scattered radio waves may give usable reception several hundred km beyond the line-of-sight, and are characterized by attenuation that increases rapidly in directions away from the incident direction.

Another frequent phenomenon is the formation of a duct, by two boundary surfaces between layers of air, that guides radio waves between its walls. These ducts may be elevated, with both walls above the surface of the earth, or in the case of a surface duct the earth itself forms one of the walls.

While tropospheric refraction affect the propagation of radio waves at all frequencies, the tropospheric duct and scatter propagation becomes important only for VHF and UHF.

Variations in the troposphere.

The troposphere is an inhomogeneous dielectric. The properties of this dielectric vary continually with time, so that the fluctuations related to the formation, movement and disappearance of local inhomogeneities in the troposphere are superimposed on the slower variations that are caused by weather conditions. These variations affect the conditions of propagation and, as a consequence, the received field.

The field within the line-of-sight is due to the combination of the direct and ground-reflected rays. The local irregularities, that these rays encounter, affect the phase difference between them and causes fading. In some cases, fading may be due to interference between these two rays and a wave scattered from and irregularity, as the position of this irregularity varies rapidly.

All tropospheric irregularities, when illuminated by the transmitter, become sources of scattered radiation. The multitude of scattered-radiation sources produces the total field at the receiver, and the resulting fading always accompanies the reception of tropospheric scatter signals.

These variations are rapid and may last from fractions of a second to several minutes. They should not be confused with random variations in the average signal level of longer duration on which fading proper is superimposed, and which are caused by changes in the local weather conditions. Similarly, these random variations should not be confused with regular diurnal and seasonal variations.

The signal level due to scatter propagation is higher in the daytime than at night, and is higher during the summer than in the winter. At temperate latitudes, the seasonal variations in the signal level may be 10 to 12 db.

NOISE.

In every communication system noise is the limiting factor which determines whether or not the signal is usable for the transmission of information.

Radio noise can arise from natural causes, such as atmospheric and cosmic noise, or can be man-made interference.

Atmospheric noise is caused by natural electric discharges in the atmosphere, such as lightning flashes from thunderstorms. Atmospheric noise ranges from extremely low frequencies up to about 30 MHz, although the noise level is higher at low frequencies and decreases with increasing frequency. Atmospheric noise may be caused by local thunderstorms or by global sources and, since noise propagates like radio waves, it is affected by propagation characteristics. This is the reason why the atmospheric noise is generally higher at night, when there is less absorption in the lower ionosphere. It is also higher during the summer, when local thunderstorms are more frequent. The atmospheric noise level is much higher near the equator, where most thunderstorms occur, than at higher latitudes.

At frequencies exceeding 30 MHz the level of atmospheric noise is drastically reduced, because the associated waves can not be propagated by the ionosphere. Therefore, in the VHF band (about 30 to 200 MHz) the main source of interference is radio emissions coming from various radio sources in and outside the Galaxy and from the Sun. This is called cosmic noise. It has been found that galactic radio emission is extremely steady in magnitude, and variations in the emission rate are caused by variable absorption in the ionosphere. The cause of diurnal variations in the cosmic noise level lies in the fact that radio sources in outer space vary in intensity. As the earth rotates, each point on its surface comes under different radio sources, with a periodicity of 24 hours. Sudden changes occur only in solar radio emissions, especially during disturbances.

Man-made noise may arise from any number of sources, such as power lines, industrial machinery, ignition systems, etc., with widely varying characteristics. Propagation of man-made noise is principally by ground wave, therefore, it is relatively unaffected by changes in the ionosphere, and is important only in the neighbourhood of densely populated areas and industrial complexes. Man-made noise generally occurs from VLF to about 1 GHz, and its level decreases with increasing frequency.

The receiver itself is also a source of noise, which is produced by resistors, tubes, etc. The internal noise of the receiver is the limiting factor when operated at frequencies higher than about 200 MHz.

LOW AND VERY LOW FREQUENCY (LF AND VLF) PROPAGATION.

Although for distances of a few hundred km, or less, there is ground wave propagation, LF and VLF waves are mainly propagated like ionospheric waves - through consecutive reflections between the earth's surface and the lower edge of the D-layer by day, and the lower edge of the E-layer at night. It may be said that these waves travel in a spherical waveguide, formed by

the surface of the earth and the lower edge of the ionosphere.

The VLF spectrum is nominally defined as 3 to 30 KHz, but the usable band is confined to the range of 10 to 30 KHz. This is largely due to the difficulty in building efficient antennas for such wavelengths. The propagation is characterized by relatively low path attenuation, which is fairly stable with time. This feature, coupled with the fact that VLF energy is guided for long distances (5,000 to 20,000 km), between the earth and the ionosphere, makes the VLF spectrum very attractive for long distance paths when high reliability is important. The noise in this band is very high and, as a result, large transmitter powers are required. This fact, together with the narrow spectrum available, has resulted in most VLF systems having narrow bandwidth. In addition, the bandwidths of most VLF antennas are of the order of 20 to 150 Hz, and their radiation efficiency is in the order of 10 to 20% only.

The LF spectrum, 30 to 300 KHz, is characterized by higher path attenuation, lower background noise levels, and more stable propagation time delays, relative to VLF. As a result, LF systems are usually used for intermediate ranges of 1,000 to 5,000 km. Terminal equipment is usually cheaper than in the VLF case and, in addition, the available bandwidths are greater.

Diurnal variations: As a rule, the field strength rises at night and this increase is greater at higher frequencies. The underlying cause of this being that reflections from the D-layer entail larger energy losses than from the E-layer.

Seasonal variations: In the LF band, these variations are insignificant and manifest themselves only in an increase of about 20 to 50% in the summer daytime fieldstrength, as compared to that in the winter. On the other hand, there is a reduction in the night time fieldstrength in the summer, as compared to that in the winter. In the VLF band, these variations are even less significant.

Sunspot-cycle variations: These are also insignificant and take the form of an increase in daytime fieldstrength with increasing solar activity. The cause of this apparently lies in the fact that the daytime increase in the electron density of the D-layer is accompanied by an increase in its conductivity and reflectance.

Ionospheric storm variations: Ionospheric, or magnetic, storms mainly affect the upper part of the ionosphere, which does not contribute to LF and VLF propagation. Ionospheric storms have relatively little effect, and there are no black-outs at these frequencies.

Geographical variations: The propagation of LF and VLF waves is different in an east-west direction than in the north-south direction. This caused by the difference in the direction of the earth's magnetic field, relative to the transmission path, and also the fact that in the north-south direction the sun time is substantially the same along the transmission path, while this is not realized with an east-west transmission.

MEDIUM FREQUENCY (MF) PROPAGATION.

The MF band extends from 300 KHz to 3 MHz, and communication at these frequencies is characterized by both ground wave and sky wave propagation. MF waves are propagated as ground waves during the day, and as both ground and sky waves at night. It is only in the winter, and at high latitudes, that sky waves may produce sufficient signal strength during the day.

The primary reception area is characterized by ground wave propagation, and is comparatively limited because of the earth losses which increase with increasing frequency. Outside this primary reception area there is a region of fading, where the daytime reception is good the sky waves being absorbed by the lower part of the ionosphere, but the night time reception is very poor due to interference of the ground and sky waves that causes constant fading. Beyond this region of fading there is a secondary reception area, that is only reached by sky waves and reception is only possible at night.

It is clear from the above, that the ratio of the fieldstrength of ground wave to that of the sky wave should be as high as possible. This can be achieved with directional antennas. Directional antennas, which concentrate a large portion of the radiated energy along the horizontal, have an effect on the ground wave that is equivalent to increasing the transmitter power and, therefore, improve the ground wave coverage.

Diurnal variations: These are extremely pronounced in the MF band and manifest themselves in that the sky wave is completely, or almost completely, absorbed during the day. At night, the sky waves are free to propagate and, as a result, three cases of interference may present themselves, according to the distance from the transmitter.

If the receiver is close to the transmitter, the ground wave signal is stronger than the sky wave signal, even at night, and the signal strength is practically independent of the time of the day.

At greater distances from the transmitter the signal strength is decided by the ground wave during the day, while at night the sky wave is stronger than the ground wave and there is fading.

At large distances from the transmitter the ground wave signal is extremely weak, even during the day, and there is no reception. On the other hand, the sky waves may build up a strong signal at night.

It should be noted, that during the winter at high geographical latitudes the sky waves are not attenuated so strongly as they are at low latitudes and in the summer. As a result, the sky waves may well be propagated by day.

Seasonal variations: The night time electron density of the E-layer, which is the reflecting layer for MF waves, is almost independent of the season. However, the daylight electron density rises in the summer and falls markedly in the winter. Because of this, at night there is a slight increase of attenuation during the summer, while the daytime sky wave is much more attenuated in the summer than in winter.

It is important to note, however, that reception is evaluated in terms of the signal-to-noise ratio and not in absolute terms. Hence, the marked difference observed in the reception of MF waves, from summer to winter, is to be attributed not so much to variations in the signal field as to variations in the noise level. At temperate and high latitudes of the Northern Hemisphere local thunderstorms occur only in the summer, and consequently there is a substantial increase in the noise level. In the winter the situation reverses, and the signal-to-noise ratio improves considerably.

Sunspot-cycle variations: The 11 year cycle of solar activities has but an insignificant effect on the propagation of MF waves, consisting mainly in that the attenuation of the waves increases somewhat with the increasing solar activity.

HIGH FREQUENCY (HF) PROPAGATION.

The HF band extends from 3 to 30 MHz, and communication at these frequencies is characterized by sky wave propagation. Sky wave propagation enables communications to be carried out at very great distances and with moderate transmitter powers.

Attenuation of the surface wave at frequencies above 3 MHz is so great that it is of little use for communications, except at very short distances in the order of 25 km or less. The higher the frequency the more the surface wave is attenuated.

Depending on the distance, sky waves may reach the point of reception either by single reflection from an ionospheric layer (single-hop transmission) or by being reflected several times between the ionosphere and the earth's surface (multihop transmission). In general, the smaller the number of hops the better, since each additional hop introduces further losses at the reflection points.

Sky waves can be reflected from both the E and F layers of the ionosphere, depending on the frequency and angle of incidence of the waves, although the F-layer is the more important of the two. The F-layer, having greater ion density and height, can return radio waves of higher frequency and to greater distances than the E-layer. Consequently, the E-layer is usefull, especially during the summer, for short and medium range communications at the lower frequencies of the HF band, while the F-layer provides the means for long distance communications in the entire band.

Radio waves suffer attenuation in the lower ionosphere, especially in the D-layer, due to absorption. Absorption of the sky wave decreases with increasing frequency and, therefore, it is desirable to use a frequency as near as possible to the maximum usable frequency, for which prediction charts are available. In practice, however, frequencies have to be selected in the range from about 50% to 85% of the maximum usable frequency. Below this range of frequencies absorption becomes prohibitive, while frequencies above it are not reliable due to irregular changes in the ionosphere.

Another factor that has to be considered for sky wave propagation is the skip zone, that is the area where no reception is possible by either

surface or sky wave. The extent of the skip zone depends on the frequency of transmission, as well as on ionospheric conditions. The skip zone increases in area with increasing frequency, due to both the accompanying decrease in the range of surface wave and the increase in the skip distance.

In addition to the regular sky wave, propagation is also possible above about 20 MHz through the scattering of radio waves from ionospheric inhomogeneities. However, the ionospheric scatter propagation is usually masked by the stronger regular sky wave, in the HF band, and can generally be neglected at these frequencies.

As the ionospheric layers undergo diurnal, seasonal and sunspot-cycle variations, regarding their virtual height and ion density, propagation of the sky waves is affected accordingly as changes in absorption and critical frequencies take place. These changes in the sky wave propagation are described below.

Diurnal variations: Owing to higher ion densities during the day, both the E and F2 layers have higher critical frequencies. Unfortunately, absorption is also maximum during the day, which necessitates the use of higher frequencies. At night the situation reverses and there is a drop in the ion density of the E and F layers, while the D and F1 layers disappear, which leads to lower critical frequencies and negligible absorption. As a result, lower frequencies have to be used to maintain reliable communications. The atmospheric noise is generally higher at night than during the day.

Seasonal variations: Communication in the HF band is much inferior during the summer, as compared to that in the winter. This is due to the fact that the F-layer, which is the major means of sky wave propagation, has a considerably lower critical frequency during the summer than in the winter, while both absorption and atmospheric noise are much greater in the summer than in the winter.

Sunspot-cycle variations: Ion density, and therefore the critical frequency, increases with greater solar activity so that higher frequencies can be used to advantage. However, absorption and atmospheric noise also vary proportionally with solar activity, thereby limiting propagation at the lower frequencies in the HF band.

Geographical variations: The ion density, and therefore the critical frequency, decreases with increasing latitude. On the other hand, the amount of absorption and atmospheric noise also decrease at higher latitudes. Consequently, relatively low frequencies have to be used at high latitudes, while progressively higher frequencies are required as the equator is approached, for reliable communications.

The above, however, does not take into consideration the abnormal ionospheric behaviours, such as ionospheric storms, absorption in the auroral zone, and polar cap absorption, which are dominant at high latitudes but are also rather unpredictable. These phenomena were described earlier in the text.

VERY HIGH AND ULTRA HIGH FREQUENCY (VHF AND UHF) PROPAGATION.

There is no surface wave propagation at these frequencies, and usually there is no reflection from the ionosphere, so that communication must be via the space wave (direct and ground-reflected rays) for the line-of-sight transmission, and by means of tropospheric or scatter propagation for distances beyond the line-of-sight. Within line-of-sight the signal is ordinarily quite stable and free of atmospheric noise.

Beyond the line-of-sight tropospheric waves can be expected to produce at times comparatively large signal intensities which, however, are likely to be irregular and very much dependent on weather conditions. Finally, ionospheric or tropospheric scatter propagation gives fairly reliable communication, if high-power transmitters and large transmitting and receiving antennas are employed.

At these frequencies, man-made noise and the internal noise of the receiver are the limiting factors to the usability of signals for communications.

The VHF band extends from 30 to 300 MHz, and communication at these frequencies can take place by space, ionospheric-scatter, and tropospheric waves depending on the frequency and distance from the transmitter. Reliable communication is generally limited to be within the line-of-sight, by means of the space wave at all frequencies. Ionospheric-scatter propagation permits communication in the frequency range of about 25 to 60 MHz, over distances of 1,500 to 2,000 km. The troposphere expands the range of space waves through refraction and also provides the means for tropospheric scatter and duct propagation. Tropospheric scatter generally takes place between about 40 MHz and 4 GHz, and covers distances up to about 1,000 km, while duct propagation is possible above about 100 MHz and for distances up to about 800 to 1,000 km.

The UHF band extends from 300 MHz to 3 GHz. Communication at these frequencies can take place by space wave within the line-of-sight, and by tropospheric waves beyond it, as it was described above.

Diurnal variations: The field intensity, due to space wave, shows little diurnal variation within the line-of-sight, however, it is generally greater during the day than it is at night beyond the line-of-sight because of stronger refraction in the troposphere.

Seasonal variations: These are similar to the diurnal variations, and the field intensity is higher during the summer than in the winter.

Sunspot-cycle variations: There appears to be little variation of signal intensity with sunspot number.

Geographical variations: Although the space wave shows no variation with geographical location, the scatter and duct propagation is usually stronger near the equator than at higher latitudes.

It should be noted that, although these regular variations take place, and affect communications accordingly, changes in the local weather

conditions have a more pronounced effect at these frequencies.

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2. AGARD : "Propagation Factors in Space Communications", Circa Publications Inc., Pelham, N.Y., U.S.A., 1967.

3. AGARDOGRAPH (104) : "H.F. Radio Communications with emphasis on Polar Problems", Circa Publications Inc., Pelham, N.Y., U.S.A., 1967.

4. K. DAVIES : "Ionospheric Radio Propagation", National Bureau of Standards, Washington, D.C., U.S.A., 1965.

5. M. DOLUKHANOV : "Propagation of Radio Waves", Mir Publishers, Moscow, U.S.S.R., 1971.

6. W.L. EVERITT : "Fundamentals of Radio and Electronics", Prentice-Hall Inc., Engelwood Cliffs, N.J., U.S.A., 1959.

7. I.T.T.C. : "Reference Data for Radio Engineers", 4-th edition, International Telephone and Telegraph Corp., New York, N.Y., U.S.A., 1960.

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APPENDIX 2.

POWER RATINGS AND CONVERSION FACTORS.

The power of a radio transmitter, as stated by CCIR, can be expressed by any one of the following terms:

1. peak envelope power (Pp);

2. mean power (Pm);

3. carrier power (Pc).

Peak envelope power refers to the average power during one r.f. cycle, at the highest crest of the modulation envelope, taken under normal conditions.

Mean power refers to the power of a signal averaged over a sufficiently long interval, as compared to the period of the lowest frequency encountered by the modulation.

Carrier power is the power of one r.f. cycle, under conditions of no modulation.

To facilitate the comparison of assignments with the transmitter power expressed in different terms, and to relate them to the results of the CRC high frequency prediction program (which uses mean signal power), all transmitter power levels were reduced to mean signal power, using the conversion factors given by CCIR X-th Plenary Assembly, Geneva, 1963, Vol. 1.

For example, let us consider an A3A signal (single sideband, reduced carrier) with a 1 watt peak envelope power. From the CCIR tables we have the following conversion factors:

$$\frac{\text{carrier power}}{\text{peak envelope power}} = .025$$

$$\frac{\text{mean power (signal and carrier)}}{\text{peak envelope power}} = .096$$

Therefore, the carrier power = .025 x 1 = .025 watt,

total mean power = .096 x 1 = .096 watt, and

mean signal power = total mean power - carrier power
= .096 - .025
= .071 watt.

The conversion factors for the other types of emissions were arrived at the same way, and are listed in the following table.

Factors for listed transmitter power to mean signal power conversion.

Type of emission	Listed trans-mitter power	Conversion factors to convert listed transmitter power into mean signal power
A1	Pp	.5
A2	Pp	.062
A2H	Pp	.25
A3	Pm	.05
A3A	Pp	.071
A3H	Pm	.09
A3J	Pp	.1
F1-F9	Pm	1.0

APPENDIX 3.

DETAILED DESCRIPTION OF THEORETICAL COVERAGE MAPS AND THE PARAMETERS USED.

The computer facilities and the HF prediction program of the Communications Research Center, Department of Communications, were used to determine the theoretical coverage area of the monitoring stations. To make use of this program it was necessary to provide the following information:

1. location of transmitter and receiver;

   - the location of the receiver was that of the monitoring station under study,
   - the transmitters were assigned positions at various distances and azimuths from the monitoring station. For most of the stations eight locations, between 250 and 3,000 km, were used along two azimuths, one northerly and one either easterly or westerly. For some stations, the northern ones, a third southerly azimuth was also included.

2. time, month and sunspot number;

   - results were obtained for 12 intervals, throughout the day, for months 3,6,9, and 12, and for sunspot numbers 0,25,50,75, and 100.

3. signal characteristics;

   - the results were calculated for transmitter signal powers of 1,2,3, 5, and 10 watts (mean signal power), and for frequencies 2 through 25 MHz.

4. type and bandwidth of emission;

   - the tests were conducted for single-sideband suppressed carrier signals of 3 KHz bandwidth.

5. antenna characteristics;

   - the transmitter antenna was defined as an omnidirectional antenna with an efficiency of 100%,
   - the monitoring station antennas were defined as simple dipoles, 60 ft above poor ground,
   - the monitoring station antennas were assumed to have a 0 db discrimination gain.

6. required signal-to-noise ratio at the receiver;

   - the minimum signal-to-noise ratio required at the receiver for reception was set at 15 db (based on CCIR figures).

7. local noise levels;

   - the local noise levels were taken from the CCIR X-th Plenary Assembly,
     Geneva, 1963, Report 322, using the figures given for a quiet rural
     location.

The values assigned to the last three parameters are approximations
only, as no absolute figures are possible. No antenna is 100% efficient,
while the required signal-to-noise ratio at the receiver depends on the re-
ceiving facility and operator experience. The local noise level, on the
other hand, may change significantly in conjunction with changes in human
activity and local weather conditions. These values, however, may be con-
sidered as base values and the results of the computer program can be inter-
preted for different values of these parameters. For example, if the effi-
ciency of a particular antenna is only 50%, instead of being 100% as as-
sumed, this would mean that a station with a transmitter power of 2 watts
would only radiate 1 watt and, therefore, to determine the coverage of such
station we would refer to the 1 watt coverage maps. A similar interpolation
can be used when values of local noise and the required signal-to-noise
ratio at the receiver are different from the assumed values.

The results of the computer program are in terms of probability
of communication, and a sample output is shown in Figure 1. For each parti-
cular value of sunspot number, month, and frequency there are 12 probabili-
ties given, one for each two hour period of the day. To simplify the prob-
lem somewhat, it is necessary to reduce these 12 probabilities to one rep-
resentative daily average. It is quite common for these probabilities to
vary greatly during the day but, since effective monitoring does not ne-
cessarily require reliable reception during the full 24 hour period, it
had to be decided how many probabilities have to be used to produce a
realistic and meaningfull daily average. A number of representative graphs
are shown in Figures 2,3,4, and 5, indicating how the daily average changes
as a function of the number of terms used.

From these graphs two distinct patterns emerge. In the winter
there is, in most cases, little change in the result regardless of how many
terms are used, whereas in the summer the resulting average usually in-
creases steadily through 5,4,3, and 2 terms and a relatively large increase
occurs when only one term is used. It can also be observed that, when the
individual probabilities are high (the situation we are most interested in),
there is little variation in the result whether 1 or 4 terms are used in
the average. Based on these considerations, it was decided that the average
of the two highest probabilities that occur during the day would be used.
This average represents four hours of the day and, in most cases, it will
provide a reasonable indication of the probability of communication for up
to eight hours of the day.

Once it has been decided how many terms are to be used for the
daily average, a threshold value had to be determined such that if the daily
average is greater than the threshold value the transmitter in question will
be considered effectively covered, while if it is below the threshold the
transmitter would not be considered covered. In reality, of course, there
is no sharp distinction between these two situations, however, for the pur-
pose of this study such distinction had to be made. The effect of threshold

value on the coverage range is shown in Figures 6,7,8, and 9.

It can be seen from the graphs that a threshold value of .85 or greater results in little or no coverage area, and that the relative difference in coverage for values of .85 and .80 fluctuates greatly depending on the frequency. As the threshold value is lowered below .80 the coverage range steadily increases, but the reliability of reception decreases at the same time. Therefore, a threshold value of .80 was chosen which seems to represent the best compromise between high reliability, hence small and unrealistic coverage, and a large coverage area but low reliability. Consequently, within these definitions of daily average and threshold level, a transmitter is considered effectively covered if the average of the two highest probabilities of communication is greater than or equal to .80, or in other words if there is at least an 80% probability of reception, for at least 4 hours of the day.

Once the averaging method and the threshold value has been determined the daily averages were tabulated, as shown in Figure 10. With the results for all distances on each azimuth tabulated, it is a simple matter to calculate the distance at which the .80 threshold value occurs, and hence the coverage range for that particular azimuth, transmitter power, frequency, etc. can be determined. To determine the coverage area of a monitoring station, therefore, it is only necessary to calculate the coverage range for various azimuths.

Preliminary studies were conducted for the monitoring stations, as outlined above, to determine the coverage range along various azimuths. These results indicated that the coverage areas are generally circular, and that for all practical purposes they are symmetrical about the north-south axis. For these reasons, it was decided that only two azimuths are necessary to adequately define the coverage area of most monitoring stations one north and another either east or west, while for northern stations a third southerly azimuth is helpfull to define the southern limit of the coverage area.

Once the general method was established, it was necessary to determine the particular parameter values to be used. From the computer outputs data was available for five different sunspot numbers, four different months, five transmitter power levels, and 24 different frequencies; a total of 2,400 different combinations. Clearly, all of these combinations could not have been studied and the investigation had to be restricted to those parameter values which were the most relevant and informative.

The parameter values used in the study, and the reasons for their selection, are discussed below:

1. Sunspot number: A graph indicating the variations in sunspot number, from 1700 to 1960, is shown in Figure 11. It can be seen from this graph that the mean value is approximately 50 and, therefore, this was chosen as the base value for the study. However, the effect of sunspot number on the coverage area is shown in Appendix 5.

2. Month: It was found that in virtually all cases monitoring coverage is best in the winter (December) and worst in the summer (June). Therefore,

these two months were the most intensively studied. However, several maps indicating the coverage areas for March and September are included in Appendix 5.

3. Transmitter power: Maps indicating the effect of transmitter power on the coverage area can be found in Appendix 5. Generally, the winter coverage areas are very large, even at low transmitter powers, hence the results for winter coverage have only been plotted for 1 watt. On the other hand, during the summer there is virtually no coverage at 1 watt and, therefore, the results were plotted for 3 and 10 watts only.

4. Frequency: The monitoring coverage maps have been drawn up for frequencies of 3,4,5, and 7 MHz and also 9 MHz for 10 watts in the summer. As the vast majority of the assignments are concentrated at the low end of the HF band, it was felt that to be practical the coverage maps should also be limited to these frequencies. However, should the need arise, it would be a relatively simple matter to prepare coverage maps for the higher frequencies as well.

FIGURE 1.

HIGH FREQUENCY PREDICTION PROGRAM RESULTS
FOR   CIRCUIT
THE TRANSMITTER   TO RECEIVER

KEY=2 MEAN POWER=   5. WATTS, BANDWIDTH= 3.0 KHZ., REQUIRED S/N=15. DB., NOISE GRADE= 0 DB., TxCODE= 2 RxCODE= 0

Tx. COORDINATES=- 55.0 N. LAT., 122.0 W. LONG
Rx. COORDINATES=- 44.0 N. LAT., 68.0 W. LONG.
PATH LENGTH= 3098. KM.
AZIMUTH= 49.4 DEGREES (azimuth from transmitter to receiver)

MONTH= 3
SUNSPOT NUMBER= 0.

FREQUENCY (MHz.)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
0	.00	.00	.03	.07	.12	.14	.21	.32	.39	.34	.19	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
2	.52	.44	.36	.24	.22	.25	.30	.20	.07	.01	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
4	.58	.43	.22	.15	.17	.11	.13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6	.57	.35	.13	.08	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8	.77	.67	.44	.21	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
10	.76	.63	.43	.29	.26	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
12	.23	.44	.38	.39	.26	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
14	.00	.01	.13	.22	.01	.34	.31	.14	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
16	.00	.00	.00	.00	.01	.11	.23	.32	.27	.17	.07	.02	.00	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00
18	.00	.00	.00	.00	.00	.12	.25	.14	.25	.22	.16	.07	.03	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
20	.00	.00	.00	.00	.00	.01	.00	.04	.07	.05	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
22	.00	.00	.00	.00	.01	.05	.01	.13	.13	.08	.04	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Daily Averages	.77	.65	.44	.34	.26	.31	.31	.32	.33	.28	.18	.06	.02	.01	.00	.00	.00							

FIGURE 2.

DAILY AVERAGE AS A FUNCTION OF THE NUMBER OF TERMS USED IN

THE AVERAGE.

```
Station : Wetaskiwin
Power   : 1 Watt
Azimuth : 90°(1,000 km)
Month   : 12
SSN     : 50
```
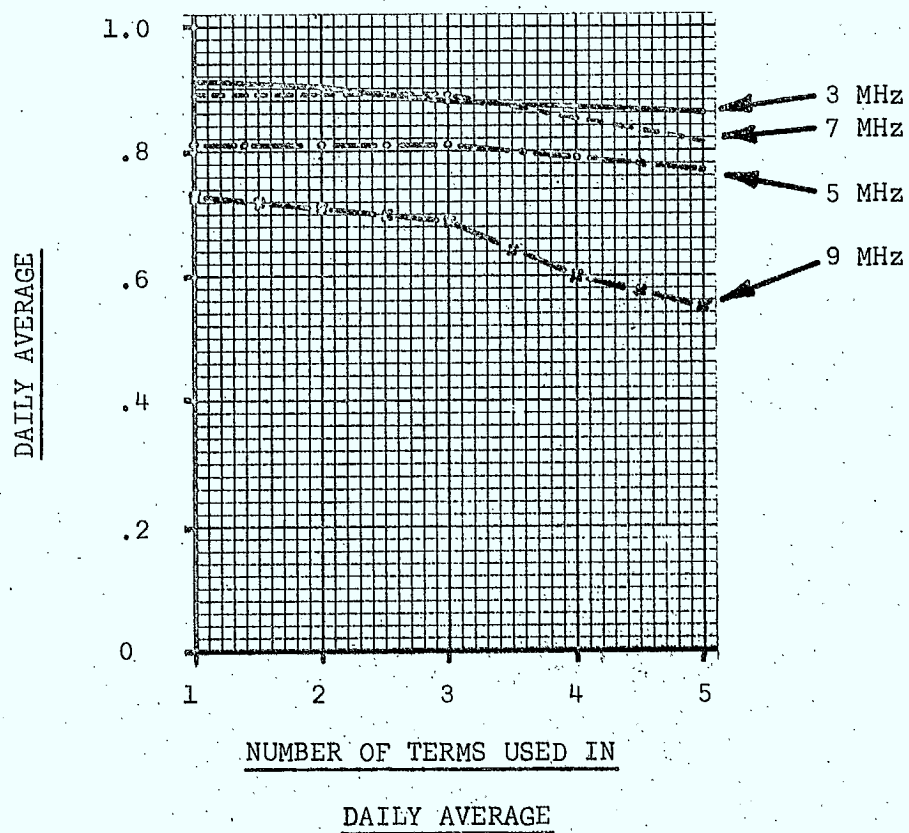
FIGURE 3.

DAILY AVERAGE AS A FUNCTION OF THE NUMBER OF TERMS USED IN

THE AVERAGE.

```
Station : Almonte
Power   : 2 Watts
Azimuth : 90°(250 km)
Month   : 6
SSN     : 50
```
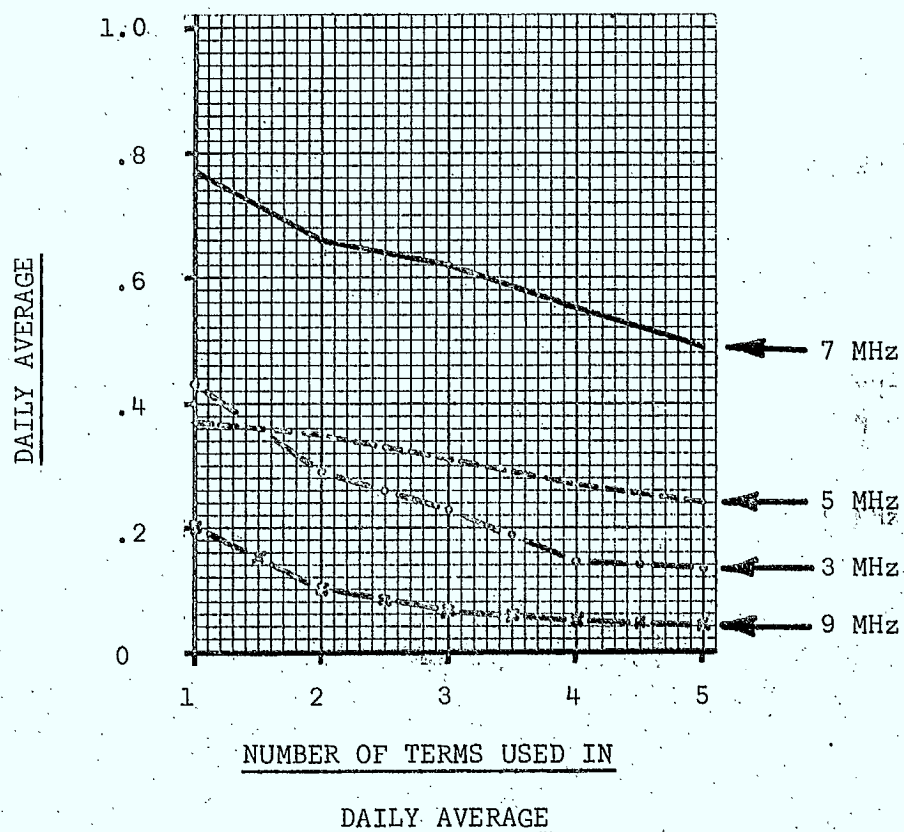
FIGURE 4.

DAILY AVERAGE AS A FUNCTION OF THE NUMBER OF TERMS USED IN

THE AVERAGE.

```
Station : Almonte
Power   : 2 Watts
Azimuth : 90°(250 km)
Month   : 12
SSN     : 50
```


NUMBER OF TERMS USED IN
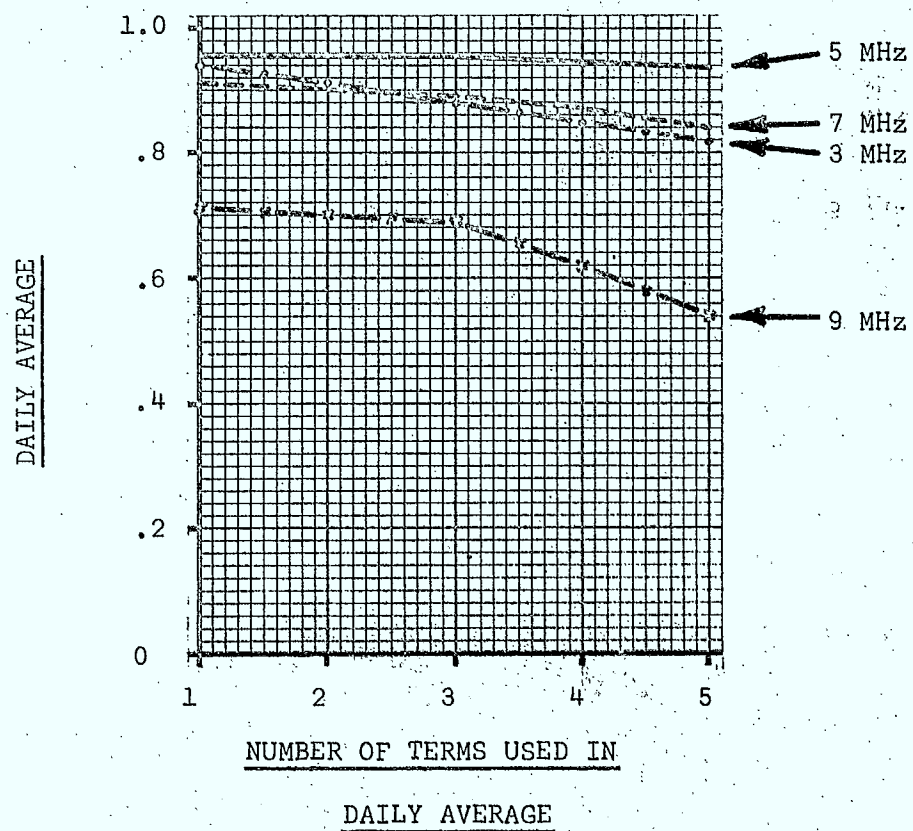
DAILY AVERAGE

FIGURE 5.

DAILY AVERAGE AS A FUNCTION OF THE NUMBER OF TERMS USED IN

THE AVERAGE.

Station : Wetaskiwin
Power   : 10 Watts
Azimuth : 90°(1,000 km)
Month   : 6
SSN   : 50

NUMBER OF TERMS USED IN

DAILY AVERAGE

FIGURE 6.

COVERAGE RANGE AS A FUNCTION OF THRESHOLD PROBABILITY.

Station : Wetaskiwin
Power   : 1 Watt
Azimuth : 90°
Month   : 12
SSN   : 50

FIGURE 7.

COVERAGE RANGE AS A FUNCTION OF THRESHOLD PROBABILITY.

Station : Senneterre
Power   : 1 Watt
Azimuth : 180°
Month   : 12
SSN   : 50
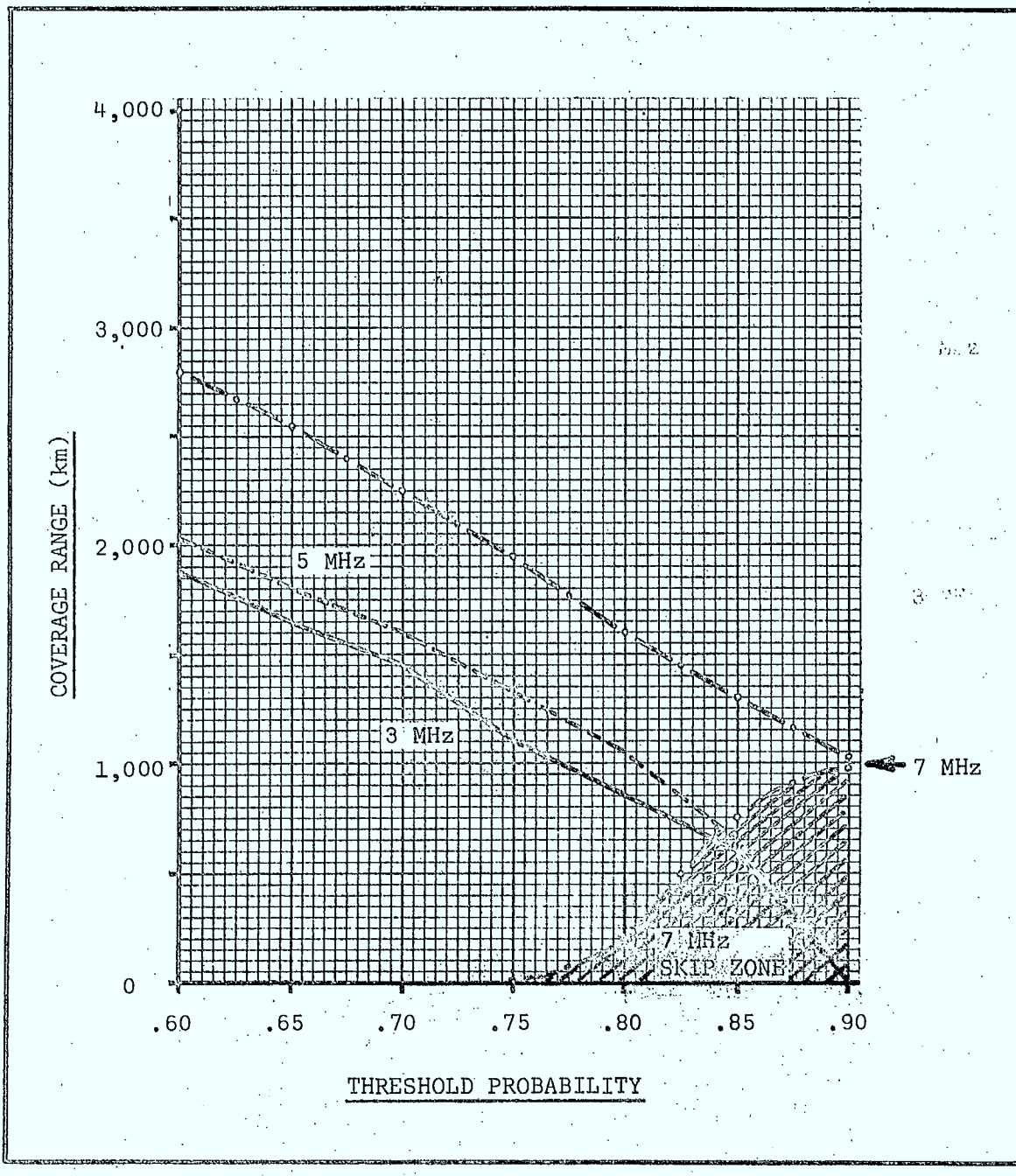
FIGURE 8.

COVERAGE RANGE AS A FUNCTION OF THRESHOLD PROBABILITY.

Station : Montague
Power   : 10 Watts
Azimuth : 180°
Month   : 6
SSN   : 50
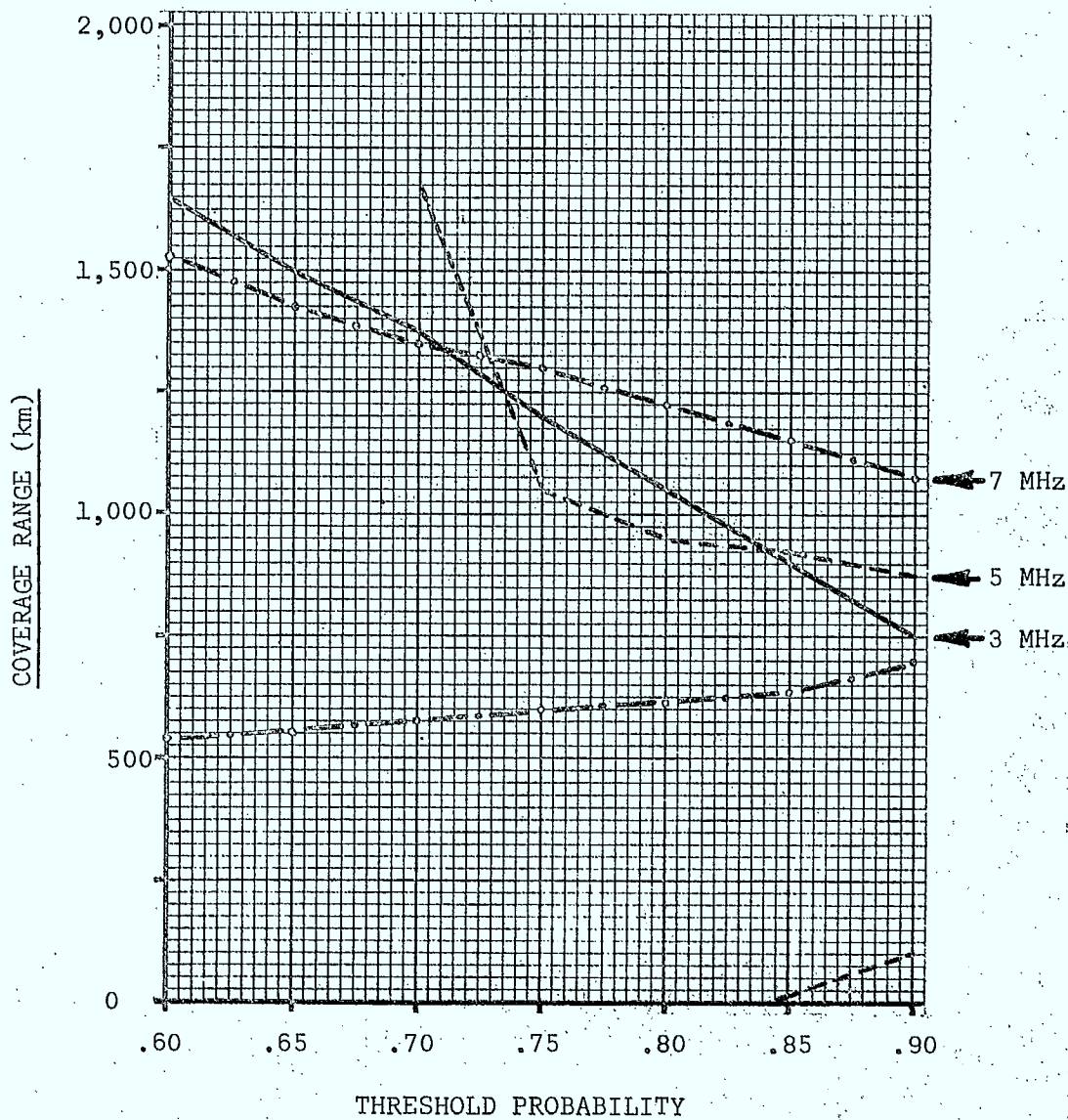
FIGURE 9.

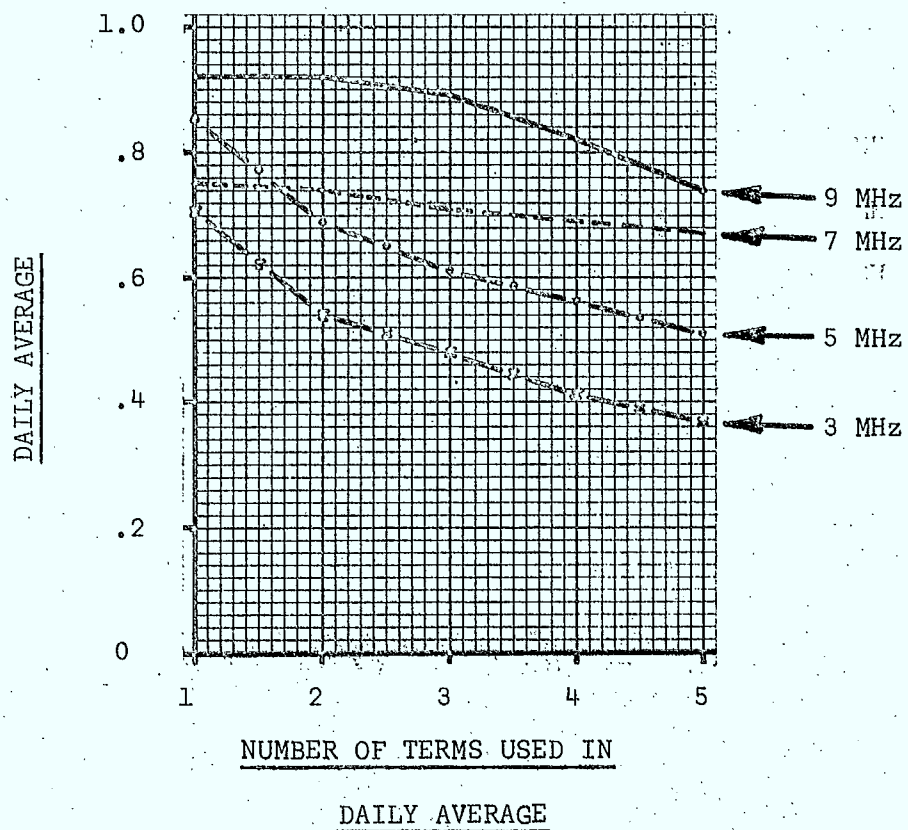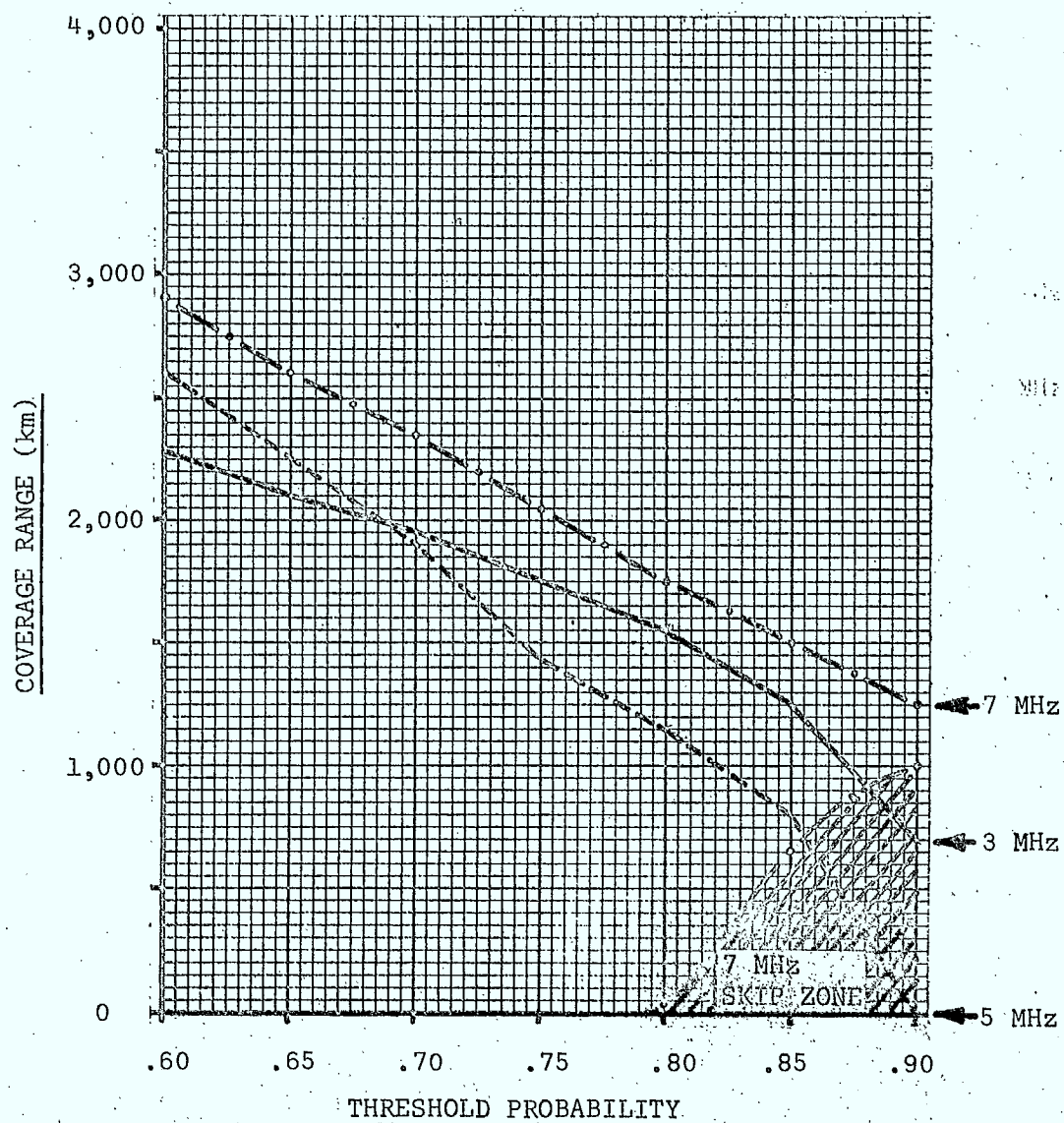COVERAGE RANGE AS A FUNCTION OF THRESHOLD PROBABILITY.

Station : Melville
Power : 10 Watts
Azimuth : 90°
Month : 6
SSN : 50
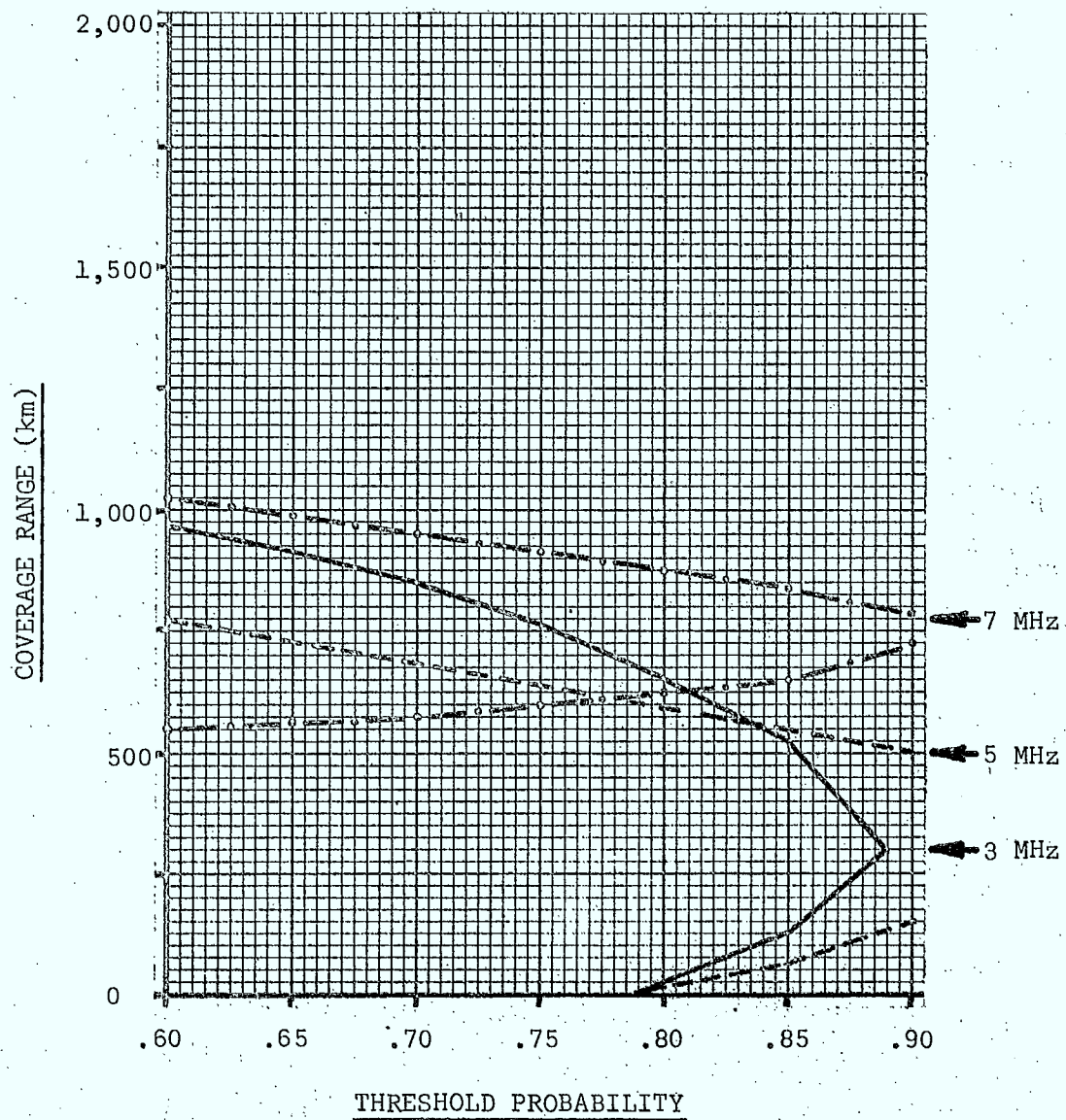
FIGURE 10.

Station: ACTON   Power: 5 watts   SSN: 50   Azimuth: 0 (North)

SUMMER

(MHz)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
250 km	-	.38	.53	.68	.88	.51	.14	.04	.00	.00	.00														
500 km	-	.31	.44	.57	.78	.95	.23	.06	.01	.00	.00	.00													
750 km	-	.17	.33	.48	.40	.76	.88	.60	.03	.01	.00	.00	.00												
1,000 km	-	.08	.20	.34	.39	.32	.57	.86	.74	.46	.36	.00	.00	.00											
1,500 km	-	.01	.06	.14	.20	.26	.25	.25	.49	.60	.68	.53	.26	.39	.31	.00	.00	.00							
2,000 km	-	.00	.01	.03	.07	.12	.16	.18	.19	.31	.34	.31	.50	.39	.20	.01	.00	.00	.00						
2,500 km	-	.00	.00	.01	.02	.04	.06	.09	.13	.15	.26	.29	.28	.27	.25	.03	.01	.00	.00	.00					
3,000 km	-	.00	.00	.00	.00	.01	.02	.05	.06	.09	.13	.17	.19	.18	.15	.05	.02	.01	.00	.00	.00				

WINTER

(MHz)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
250 km	-	.99	.98	.97	.97	.96	.94	.90	.75	.44	.14	.03	.00	.00	.00										
500 km	-	.98	.96	.98	.99	.97	.95	.94	.82	.56	.26	.08	.02	.00	.00	.00									
750 km	-	.97	.96	.97	.99	.99	.96	.96	.87	.66	.43	.22	.09	.03	.00	.00	.00								
1,000 km	-	.96	.94	.94	.95	.99	.99	.99	.91	.78	.58	.34	.24	.14	.07	.03	.01	.00							
1,500 km	-	.91	.89	.87	.90	.95	.96	.97	.97	.87	.77	.68	.58	.49	.37	.26	.23	.18	.11	.05	.02	.00	.00	.00	
2,000 km	-	.82	.81	.79	.79	.90	.91	.94	.88	.80	.72	.70	.68	.65	.63	.59	.53	.47	.37	.27	.16	.08	.03	.01	.01
2,500 km	-	.68	.69	.67	.73	.84	.87	.89	.81	.73	.65	.62	.64	.65	.64	.65	.66	.66	.63	.57	.46	.31	.20	.11	.06
3,000 km	-	.56	.56	.55	.63	.76	.82	.83	.69	.76	.67	.60	.64	.67	.69	.69	.74	.77	.77	.75	.67	.52	.39	.27	.17

FIGURE 11.
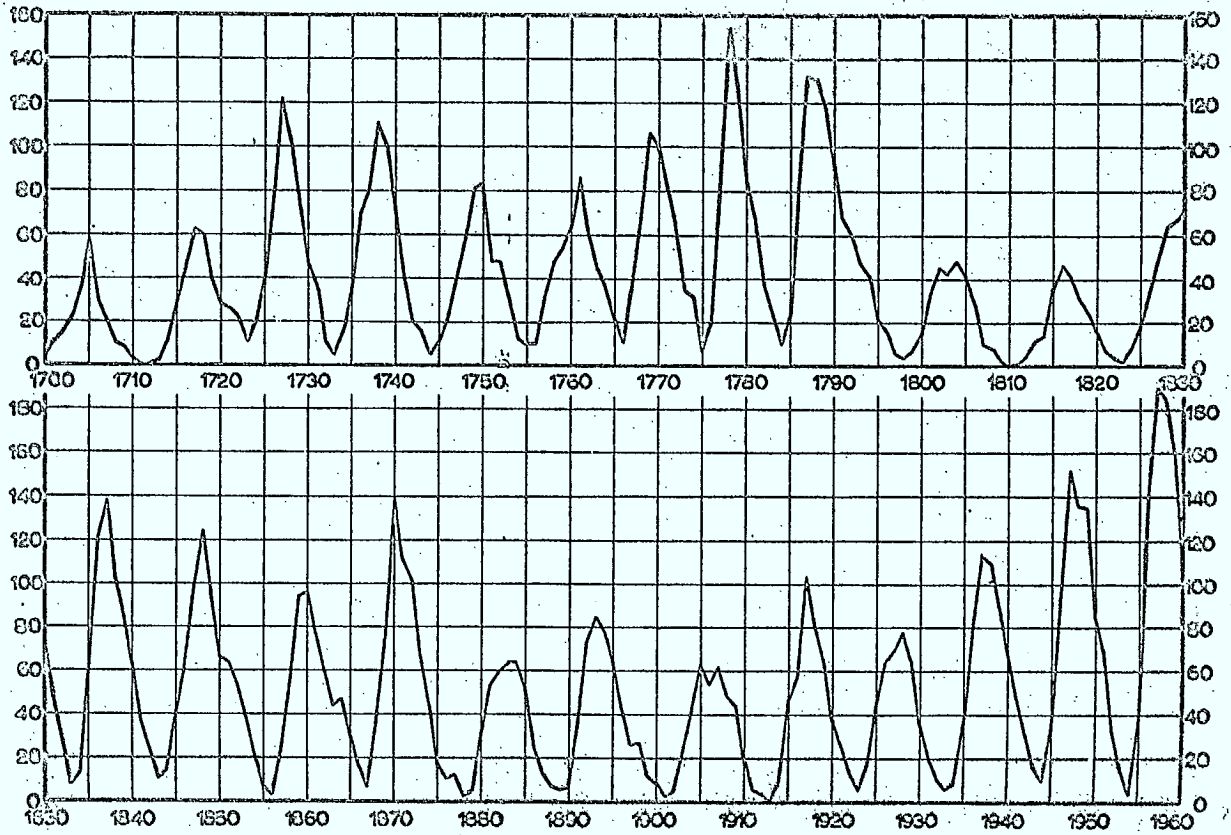
Sunspot numbers from 1700 to 1960.

APPENDIX 4.

TABLES USED FOR MONITORING TRENDS.

TABLE 1. Radio station licences in force from 1945/46 to 1971/72.

Licensing Year	Licences in Force	Licensing Year	Licences in Force
1945/46	7,427	1959/60	59,760
1946/47	8,601	1960/61	67,742
1947/48	12,799	1961/62	79,329
1948/49	13,178	1962/63	98,670
1949/50	15,316	1963/64	119,773
1950/51	16,685	1964/65	136,912
1951/52	15,685	1965/66	163,840
1952/53	15,900	1966/67	191,849
1953/54	24,006	1967/68	219,590
1954/55	26,358	1968/69	229,785
1955/56	27,458	1969/70	245,789
1956/57	34,462	1970/71	256,327
1957/58	39,716	1971/72	268,810
1958/59	52,807	-	-

NOTE: Figures up to 1969/70 are exclusive of any broadcasting ser-
vice licences. Figures from 1970/71 include licences issued
for auxiliary broadcasting service stations.

TABLE 2. Variation in frequency assignments (civil & DND) below 30 MHz.

Year	No. of frequencies assigned	No. of frequencies deleted	Increase in the number of frequency assignments
1965	2,377	671	1,706
1966	2,991	804	2,187
1967	3,915	2,432	1,483
1968	3,740	3,262	478
1969	3,292	1,381	1,911
1970	3,013	1,624	1,389
1971	6,063	3,223	2,840

TABLE 3. Variation in frequency assignments (civil & DND) above 30 MHz.

Year	No. of frequencies assigned	No. of frequencies deleted	Increase in the number of frequency assignments
1965	4,703	1,051	3,652
1966	7,329	1,782	5,547
1967	7,749	3,717	4,032
1968	7,024	4,633	2,391
1969	9,460	3,118	6,342
1970	8,143	4,178	3,965
1971	6,189	2,228	3,961

TABLE 4. HF assignment distribution.

Year	Number of Assignments				
	3 - 4 MHz	4 - 5 MHz	5 - 7 MHz	7 - 30 MHz	Total
1963	1,598	3,118	1,367	378	6,461
1964	1,841	3,586	1,732	629	7,788
1965	1,960	4,060	1,950	771	8,741
1966	2,056	4,581	2,267	850	9,754
1967	2,245	5,217	2,669	1,066	11,197
1968	2,421	5,865	3,142	1,340	12,768
1969	2,735	6,974	4,069	1,655	15,433
1970	2,957	8,313	5,289	2,020	18,579
1971	3,302	9,482	6,565	2,592	21,941

TABLE 5. VLF, LF & MF assignment distribution.

Year	Number of Assignments below 3 MHz
1963	7,632
1964	8,250
1965	8,539
1966	9,610
1967	10,093
1968	12,951
1969	13,741
1970	14,706
1971	15,609

Yearly deletions were not taken into consideration, in the above tables, since no data were available.

TABLE 6. VLF, LF and MF intercept distribution.

Monitoring Station	Number of Intercepts below 3 MHz
ACTON	394
ALMONTE	301
FT. SMITH	751
LADNER	256
MELVILLE	353
MONTAGUE	413
SENNETERRE	61
ST. LAMBERT	215
THUNDER BAY	213
WETASKIWIN	286
TOTAL:	3,243

TABLE 7. HF intercept distribution.

Monitoring Station	Number of Intercepts				
	3 - 4 MHz	4 - 5 MHz	5 - 7 MHz	7 - 30 MHz	Total
ACTON	34	507	226	130	897
ALMONTE	19	385	161	118	683
FT. SMITH	114	1,123	672	248	2,157
LADNER	90	206	190	92	578
MELVILLE	12	572	308	103	995
MONTAGUE	27	372	240	136	775
SENNETERRE	20	110	64	136	330
ST. LAMBERT	101	332	395	90	918
THUNDER BAY	21	639	155	56	871
WETASKIWIN	87	638	448	74	1,247
TOTAL:	525	4,884	2,859	1,183	9,451

TABLE 8. HF assignment distribution.

| Year | Mean Signal Power (watts) | | | | Total no. of assignments |
	0.1 - 1.0	1.1 - 2.0	2.1 - 3.0	above 3.0	
1963	2,063	1,350	458	2,590	6,461
1964	2,316	1,504	683	3,285	7,788
1965	2,486	1,563	866	3,826	8,741
1966	2,644	1,687	1,009	4,414	9,754
1967	2,913	1,843	1,198	5,243	11,197
1968	3,298	1,982	1,387	6,101	12,768
1969	4,149	2,149	1,652	7,483	15,433
1970	4,990	2,494	1,977	9,118	18,579
1971	6,054	2,632	2,374	10,881	21,941

TABLE 9. VLF, LF & MF assignment distribution.

| Year | Mean Signal Power (watts) | | | | Total no. of assignments below 3 MHz |
	0.1 - 1.0	1.1 - 2.0	2.1 - 3.0	above 3.0	
1963	4,974	599	238	1,821	7,632
1964	5,278	719	265	1,988	8,250
1965	5,328	775	288	2,148	8,539
1966	6,047	841	315	2,407	9,610
1967	6,127	942	353	2,671	10,093
1968	8,456	1,103	387	3,005	12,951
1969	8,780	1,164	453	3,344	13,741
1970	9,179	1,239	502	3,786	14,706
1971	9,569	1,319	554	4,167	15,609

Yearly deletions were not taken into consideration, in the above tables, since no data were available.

TABLE 10. VLF, LF, and MF intercept distribution.

Monitoring Station	Number of Intercepts below 3 MHz					
	below 1 watt*	1.1 - 2.0 watts*	2.1 - 3.0 watts*	3.1 - 5.0 watts*	5.1 - 10 watts*	above 10 watts*
ACTON	13	23	21	4	60	273
ALMONTE	7	14	4	2	43	231
FT. SMITH	59	90	35	66	97	404
LADNER	17	40	10	21	44	124
MELVILLE	23	55	4	39	50	182
MONTAGUE	63	33	5	12	68	232
SENNETERRE	2	7	-	-	18	34
ST. LAMBERT	3	21	2	3	29	157
THUNDER BAY	5	21	9	3	18	157
WETASKIWIN	14	47	7	19	50	149
TOTAL:	206	351	97	169	477	1,943

* Mean signal power

TABLE 11. HF intercept distribution.

Monitoring Station	Number of Intercepts					
	below 1 watt*	1.1 -2.0 watts*	2.1 - 3.0 watts*	3.1 - 5.0 watts*	5.1 - 10 watts*	above 10 watts*
ACTON	79	120	70	73	257	298
ALMONTE	59	99	52	66	166	241
FT. SMITH	343	230	265	256	594	469
LADNER	28	32	53	108	208	149
MELVILLE	207	111	91	111	237	238
MONTAGUE	31	50	53	79	350	212
SENNETERRE	33	7	49	18	133	90
ST. LAMBERT	193	89	97	83	304	152
THUNDER BAY	217	152	80	88	130	204
WETASKIWIN	177	143	123	223	334	247
TOTAL:	1,367	1,033	933	1,105	2,713	2,300

TABLE 12. Variation in the number of amateur radio licences.

Year	Number of licences	Change	%-change
1960/61	9,029	-	-
1961/62	9,347	+ 318	3.52
1962/63	10,208	+ 861	9.21
1963/64	10,640	+ 432	4.23
1964/65	11,238	+ 598	5.62
1965/66	11,704	+ 466	4.14
1966/67	12,120	+ 416	3.55
1967/68*	12,502	+ 382	3.15
1968/69	12,061	- 441	3.52
1969/70	11,906	- 155	1.28
1970/71	12,155	+ 249	2.09
1971/72	12,607	+ 452	3.71

* Licence fee was increased from $2.50 to $10.00

TABLE 13. Variation in the number of General Radio Service licences.

Year	Number of licences	Change	%-change
1962/63	13,579	-	-
1963/64	24,398	+ 10,819	79.67
1964/65	36,112	+ 11,714	48.01
1965/66	41,534	+ 5,422	15.01
1966/67	50,859	+ 9,325	22.45
1967/68	58,844	+ 7,985	15.70
1968/69	63,272	+ 4,428	7.52
1969/70	60,965	- 2,307	3.64
1970/71	59,789	- 1,176	1.92
1971/72	58,447	- 1,342	2.24

TABLE 14. Distribution of operator activities.

Year	Total man-hours possible (A)	Actual operating man-hours (B)	Other activity* man-hours (C)	Time lost A - (B + C)
1965	70,080	41,078	2,967	26,035
1966	78,840	44,567	13,877	20,396
1967	78,840	44,386	11,583	22,871
1968	78,840	52,382	16,079	10,379
1969	78,840	56,423	13,168	9,249
1970	87,680	64,261	10,894	12,525
1971	87,680	63,361	15,499	8,820

*Includes: Operator training, Assisting OIC, Acting OIC, Instructor.

TABLE 15. Approximate distribution of time spent on monitoring.

Monitoring Station	Monitoring below 30 MHz	Monitoring above 30 MHz	Routine Surveillance	Special Assignments
ACTON	25%	75%	88%	12%
ALMONTE	75%	25%	70%	30%
FT. SMITH	95%	5%	50%	50%
LADNER	50%	50%	80%	20%
MELVILLE	85%	15%	50%	50%
MONTAGUE	95%	5%	50%	50%
SENNETERRE	90%	10%	70%	30%
ST. LAMBERT	50%	50%	60%	40%
ST. REMI	0.5%	99.5%	50%	50%
THUNDER BAY	60%	40%	70%	30%
WETASKIWIN	95%	5%	80%	20%

NOTE: It is important to remember that these are only approximate figures and change from time to time.

TABLE 16. Variation in the distribution of monitoring assignments.

Year	Assignment originated by			Remarks Remarks
	Headquarters	Regional Offices	Monitoring Stations	
1962	367	152	2,086	8 stations
1963	365	197	2,207	8 stations
1964	588	207	2,087	8 stations
1965	604	195	2,367	9 stations
1966	401	257	2,549	9 stations
1967	340	210	2,750	9 stations
1968	370	230	3,000	9 stations
1969	279	290	3,200	9 stations
1970	299	301	3,610	9 stations
1971	149	234	3,726	10 stations

Note: HQ/RO assignments are becoming less due to delegating
more authority to the monitoring stations regarding
Broadcasting Stations, DND Stations and other users.

APPENDIX 5.

MAPS OF MONITORING COVERAGE AREAS.

Map No.	Name	Mean signal power (watts)	Frequency (MHz)
1	Assignment density	total	3 – 4
2	Assignment density	total	4 – 5
3	Assignment density	total	5 – 7
4	Assignment density	total	> 7
5	Observed coverage	< 1	< 3
6	Observed coverage	1 – 3	< 3
7	Observed coverage	3 – 10	< 3
8	Observed coverage	> 10	< 3
9	Assignment density	< 1	3 – 4
10	Observed coverage	< 1	3 – 4
11	Theoretical coverage (winter)	1	3
12	Assignment density	1 – 3	3 – 4
13	Observed coverage	1 – 3	3 – 4
14	Theoretical coverage (summer)	3	3
15	Assignment density	> 3	3 – 4
16	Observed coverage	3 – 10	3 – 4
17	Observed coverage	> 10	3 – 4
18	Theoretical coverage (summer)	10	3
19	Assignment density	< 1	4 – 5
20	Observed coverage	< 1	4 – 5
21	Theoretical coverage (winter)	1	4
22	Assignment density	1 – 3	4 – 5
23	Observed coverage	1 – 3	4 – 5
24	Theoretical coverage (summer)	3	4
25	Assignment density	> 3	4 – 5
26	Observed coverage	3 – 10	4 – 5
27	Observed coverage	> 10	4 – 5
28	Theoretical coverage (summer)	10	4
29	Assignment density	< 1	5 – 7
30	Observed coverage	< 1	5 – 7
31	Theoretical coverage (winter)	1	5
32	Assignment density	1 – 3	5 – 7
33	Observed coverage	1 – 3	5 – 7
34	Theoretical coverage (summer)	3	5

Map No.	Name	Mean signal power (watts)	Frequency (MHz)
35	Assignment density	> 3	5 - 7
36	Observed coverage	3 - 10	5 - 7
37	Theoretical coverage (summer)	10	5
38	Assignment density	< 1	> 7
39	Theoretical coverage (winter)	1	7
40	Assignment density	1 - 3	> 7
41	Theoretical coverage (summer)	3	7
42	Assignment density	> 3	> 7
43	Theoretical coverage (summer)	10	7
44	Theoretical coverage (summer)	10	9
45	Coverage area as a function of SSN (winter)	1	3
46	Coverage area as a function of SSN (winter)	1	5
47	Coverage area as a function of SSN (winter)	1	7
48	Coverage area as a function of SSN (summer)	10	3
49	Coverage area as a function of SSN (summer)	10	5
50	Coverage area as a function of SSN (summer)	10	7
51	Coverage area as a function of month	3	3
52	Coverage area as a function of month	3	5
53	Coverage area as a function of month	3	7
54	Coverage area as a function of power (summer)	-	3
55	Coverage area as a function of power (winter)	-	3
56	Theoretical coverage for Frobisher Bay (winter)	1	3
57	Theoretical coverage for Frobisher Bay (winter)	1	5
58	Theoretical coverage for Frobisher Bay (winter)	1	7
59	Theoretical coverage for Frobisher Bay (summer)	3	3
60	Theoretical coverage for Frobisher Bay (summer)	3	5

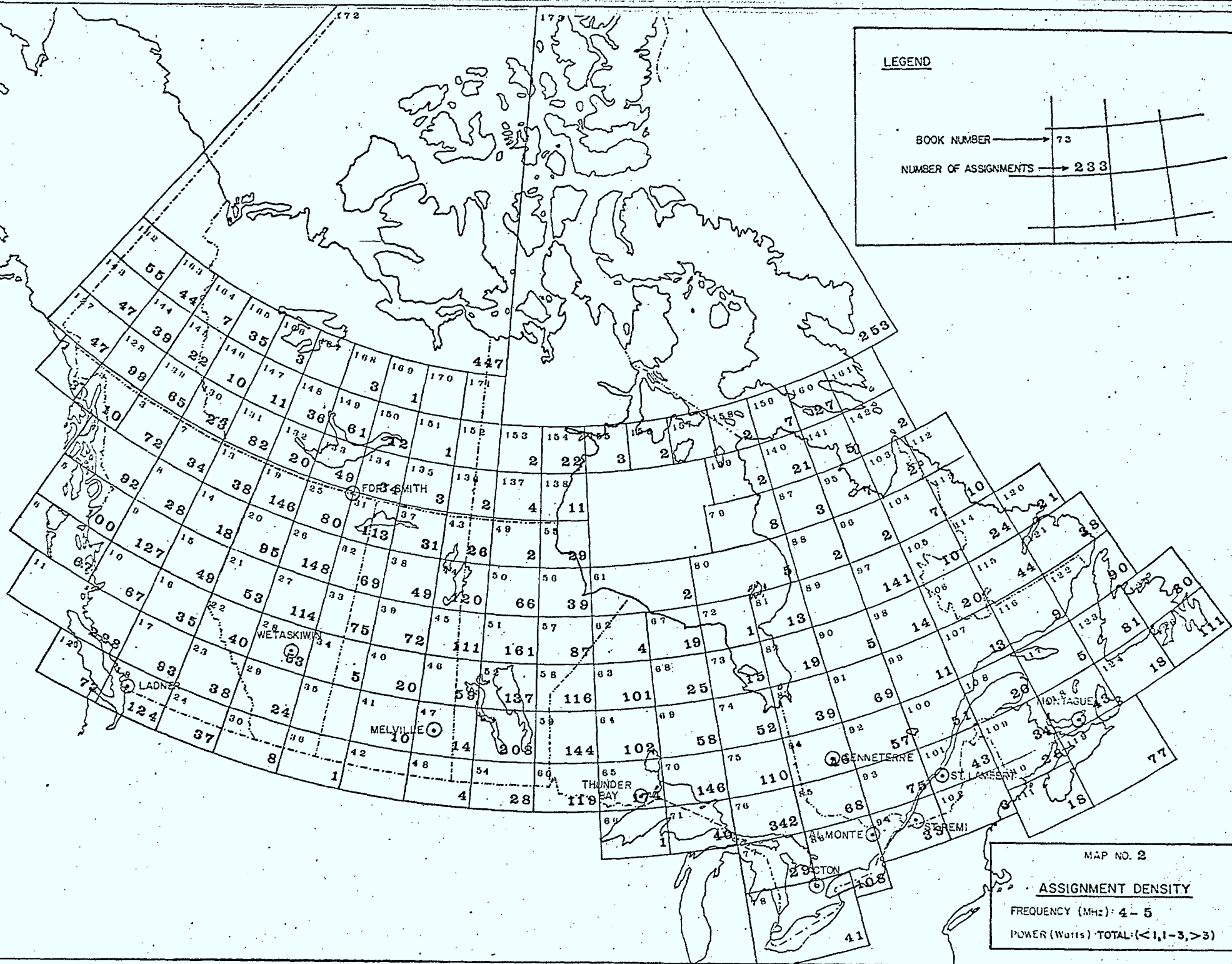| Map No.	Name	Mean signal power (watts)	Frequency (MHz)
61	Theoretical coverage for Frobisher Bay (summer)	3	7
62	Theoretical coverage for Frobisher Bay (summer)	10	3
63	Theoretical coverage for Frobisher Bay (summer)	10	5
64	Theoretical coverage for Frobisher Bay (summer)	10	7
65	Theoretical coverage for Frobisher Bay (summer)	10	9

LEGEND

BOOK NUMBER → 73

NUMBER OF ASSIGNMENTS → 2 3 3

MAP NO. 1

ASSIGNMENT DENSITY

FREQUENCY (MHz): 3 — 4

POWER (Watts) TOTAL: (<1, 1-3, >3)

LEGEND

BOOK NUMBER ──→ 73

NUMBER OF ASSIGNMENTS ──→ 233

MAP NO. 2

ASSIGNMENT DENSITY

FREQUENCY (MHz): 4 - 5

POWER (Watts) TOTAL: (<1,1-3,>3)

FORT SMITH

WETASKIWIN

LADNER

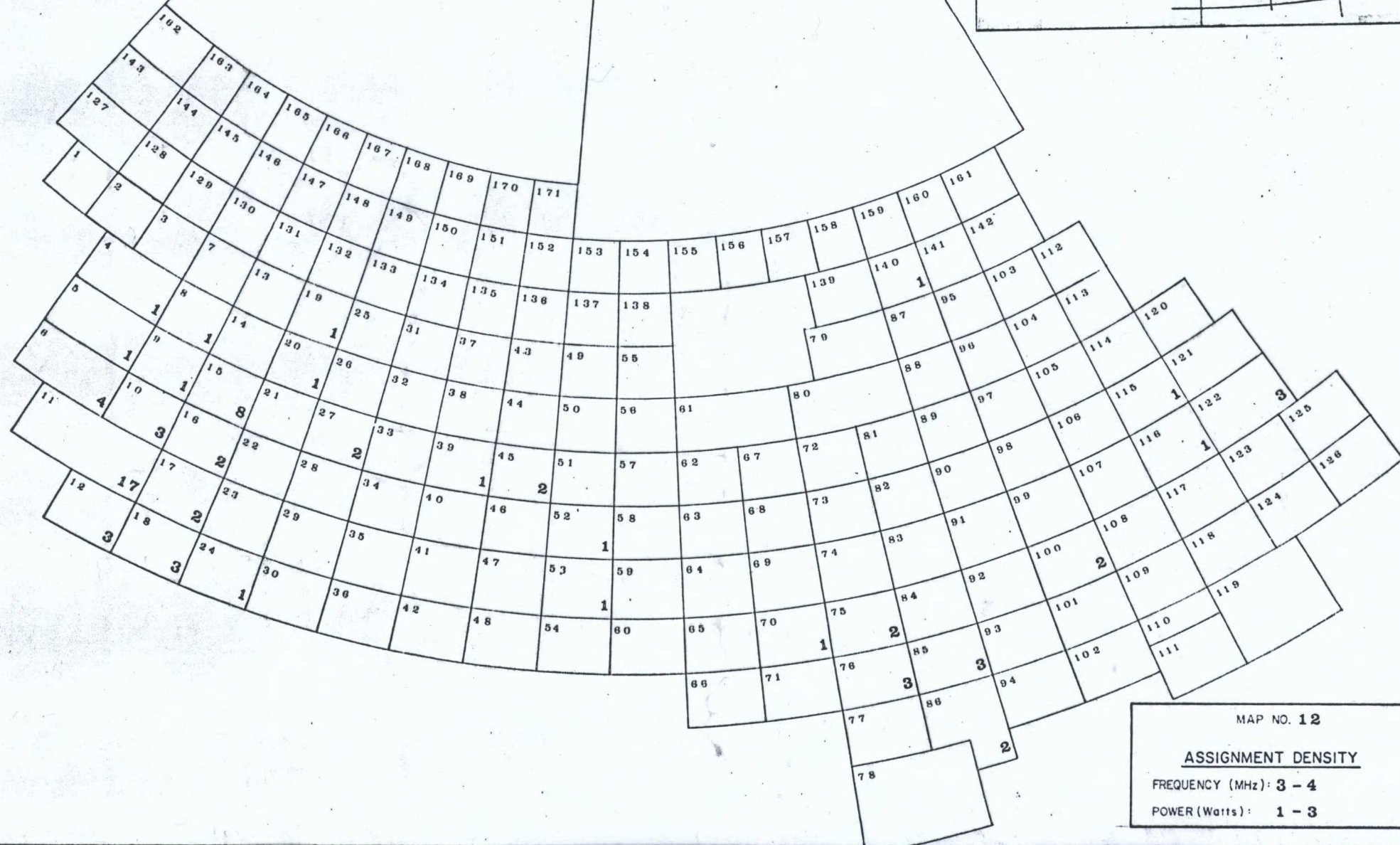MELVILLE

THUNDER BAY

SENNETERRE

ST LAMBERT

ALMONTE

ST REMI

MONTAGUE

LEGEND

BOOK NUMBER ——→ 73

NUMBER OF ASSIGNMENTS ——→ 233

MAP NO. 3

ASSIGNMENT DENSITY

FREQUENCY (MHz): 5 - 7

POWER (Watts) TOTAL: (<1,1-3,>3)

MAP NO. 4

ASSIGNMENT DENSITY

FREQUENCY (MHz) >7
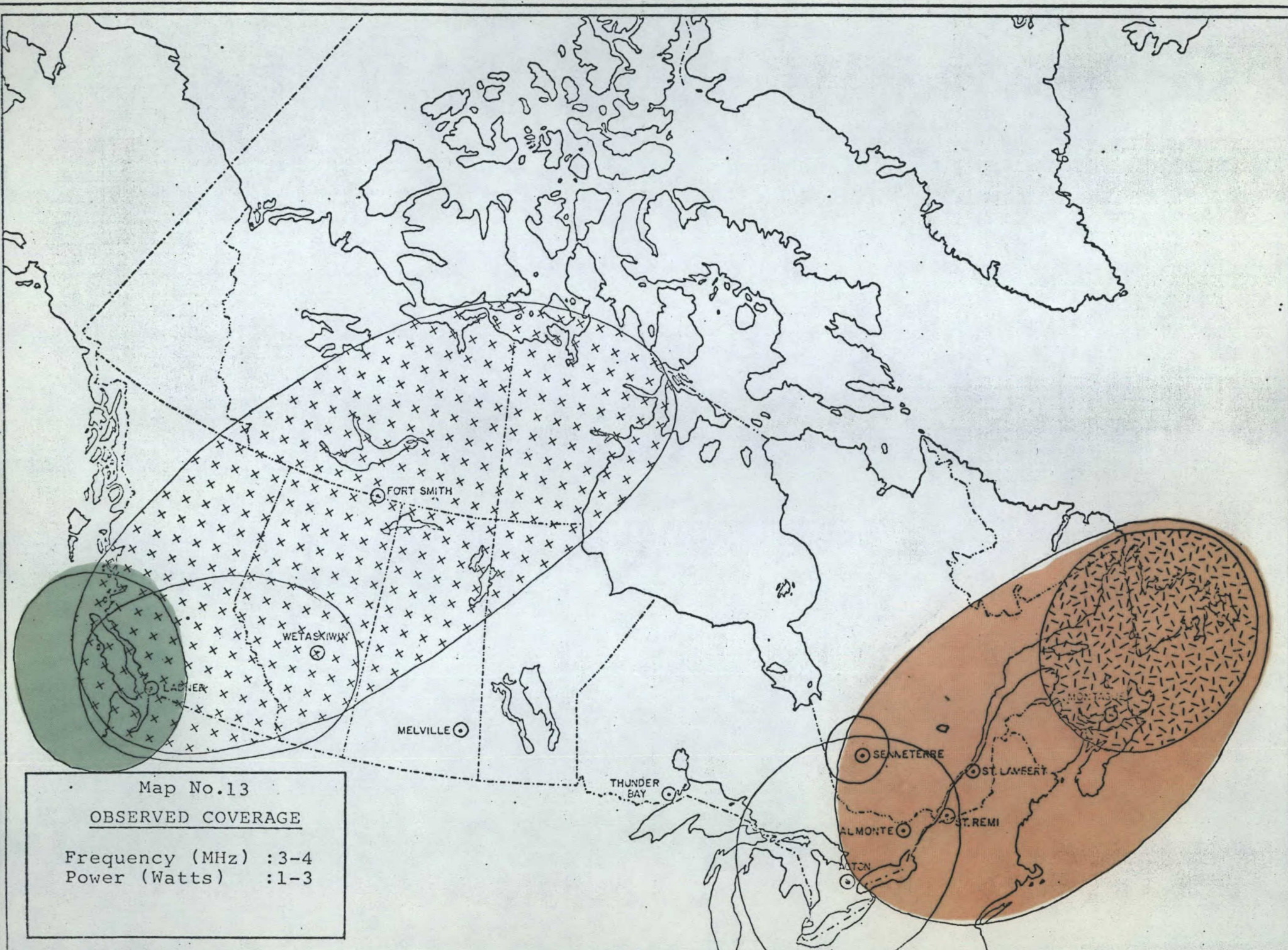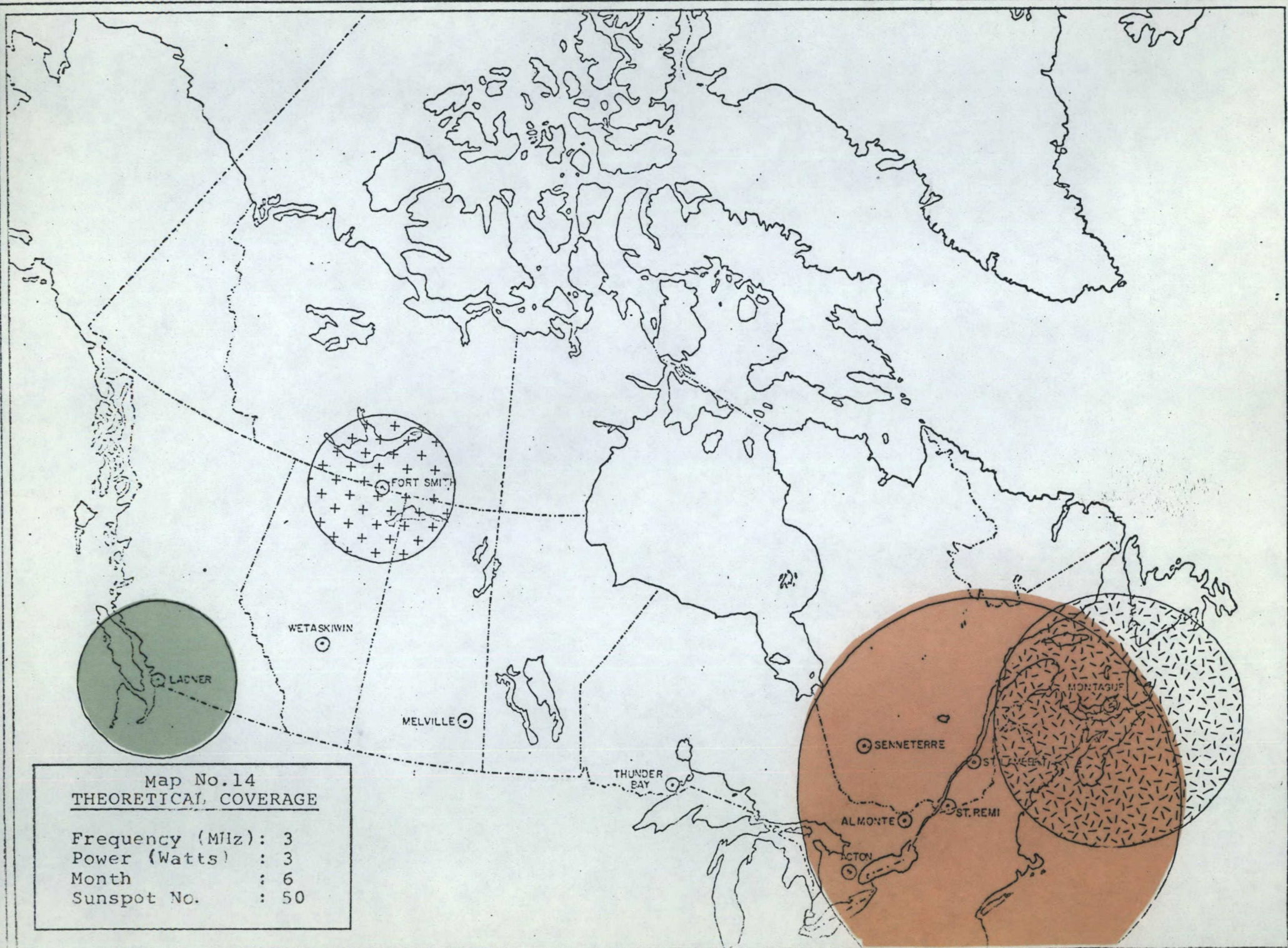
POWER (Watts) TOTAL: (<1,1-3,>3)

Map No. 5

OBSERVED COVERAGE

Frequency (MHz) :<3
Power (Watts)   :<1

FORT SMITH

WETASKIWINI

LADNER

MELVILLE

THUNDER
BAY

SENNETERRE

ST.LAMBERT
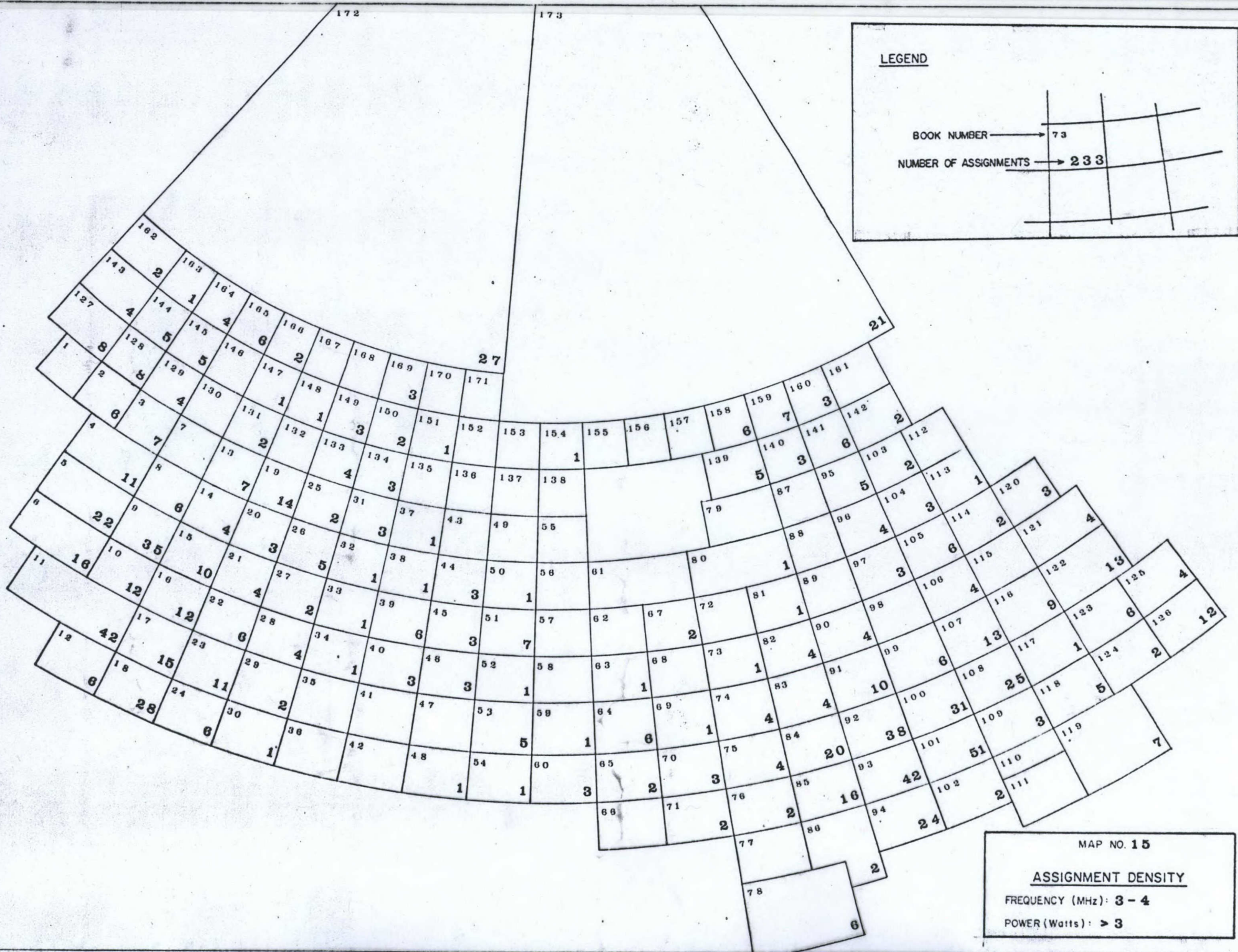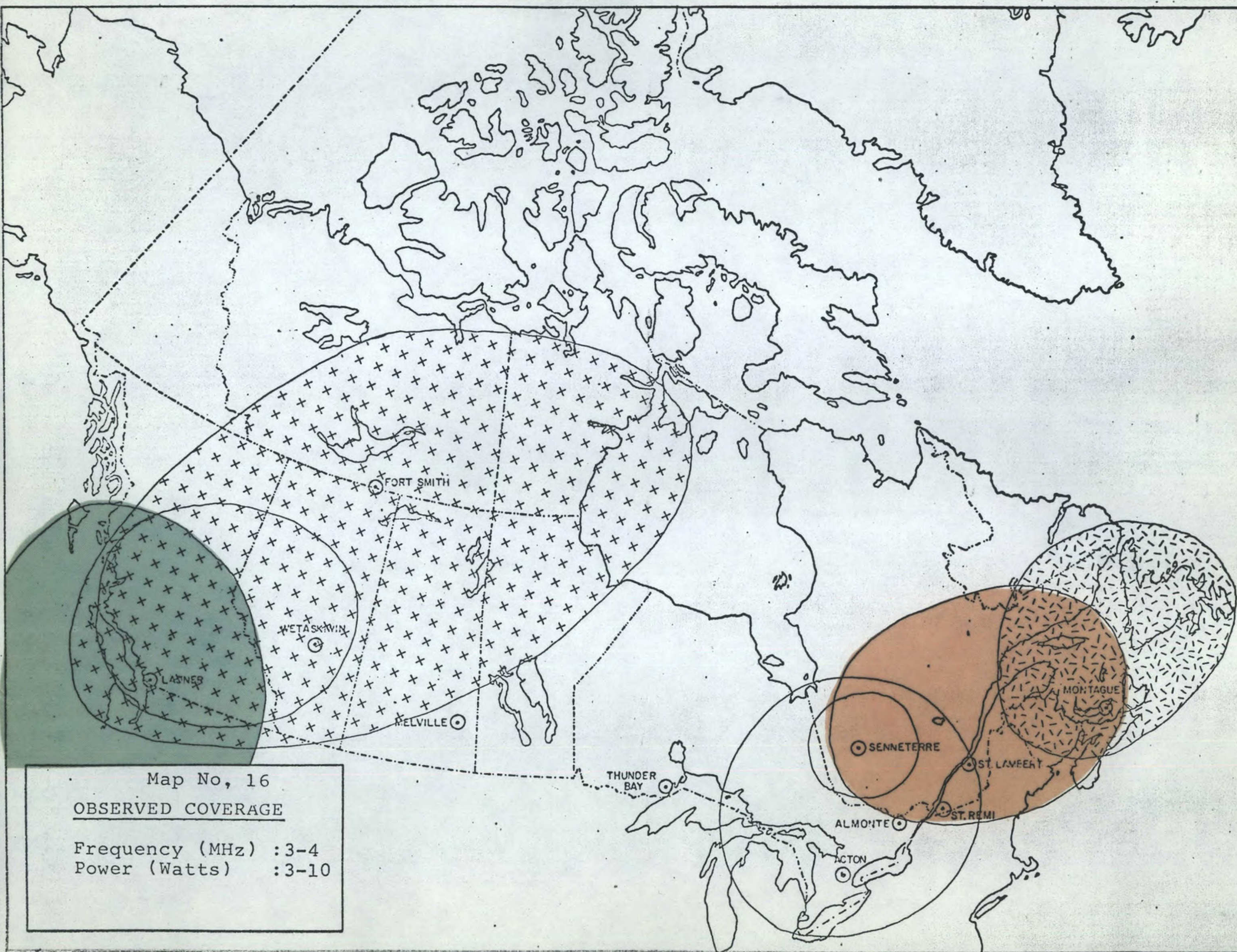
ALMONTE

ST.REMI

ACTON

MONTAGUE

Map No. 6

OBSERVED COVERAGE

Frequency (MHz) : < 3
Power (Watts)   : 1-3

Map No. 7

OBSERVED COVERAGE

Frequency (MHz) : <3
Power (Watts)   : 3-10

Map No.8

OBSERVED COVERAGE

Frequency (MHz) : < 3
Power (Watts)   : > 10

MAP NO. 9

ASSIGNMENT DENSITY

FREQUENCY (MHz): 3 - 4

POWER (Watts): < 1

Map No.10

OBSERVED COVERAGE

Frequency (MHz) : 3-4
Power (Watts)   : <1

Map No. 11

THEORETICAL COVERAGE

Frequency (MHz) : 3
Power (Watts)   : 1
Month   : 12
Sunspot No.   : 50

LEGEND

BOOK NUMBER ——————→ 7 3
NUMBER OF ASSIGNMENTS ——→ 2 3 3

MAP NO. 1 2

ASSIGNMENT DENSITY

FREQUENCY (MHz): 3 - 4

POWER (Watts): 1 - 3

Map No.13

OBSERVED COVERAGE

Frequency (MHz) : 3-4
Power (Watts)   : 1-3
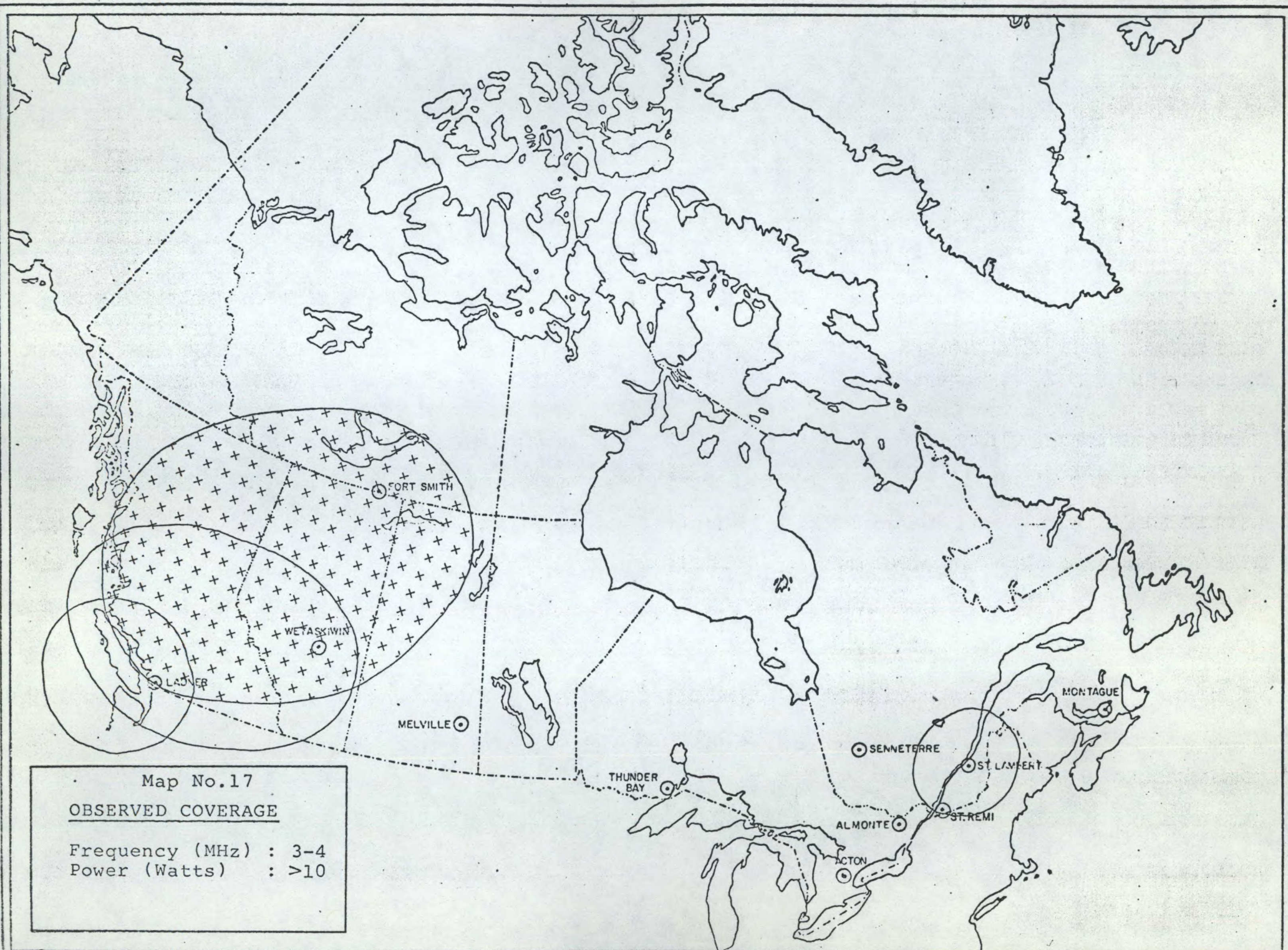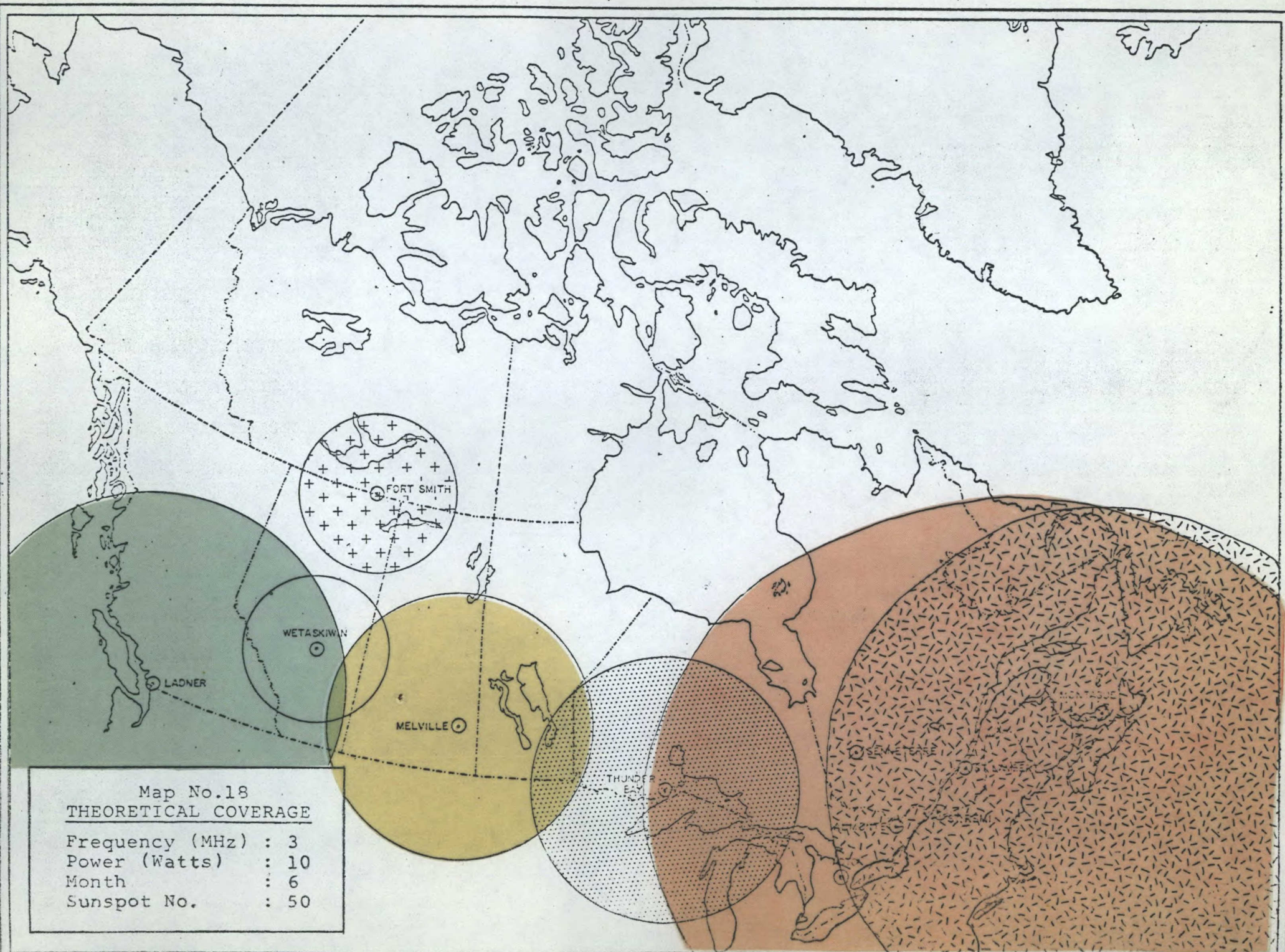
FORT SMITH

WETASKIWIN

LADNER

MELVILLE

THUNDER
BAY

SENNETERRE

ST. LAMBERT

ALMONTE

ST. REMI

ALTON

MONTAGUE

Map No.14
THEORETICAL COVERAGE

Frequency (MHz) : 3
Power (Watts)   : 3
Month   : 6
Sunspot No.   : 50

MAP NO. **15**

ASSIGNMENT DENSITY

FREQUENCY (MHz): **3 - 4**

POWER (Watts): **> 3**

Map No, 16

OBSERVED COVERAGE

Frequency (MHz) :3-4
Power (Watts)   :3-10

Map No.17

OBSERVED COVERAGE

Frequency (MHz) : 3-4
Power (Watts)   : >10

Map No.18
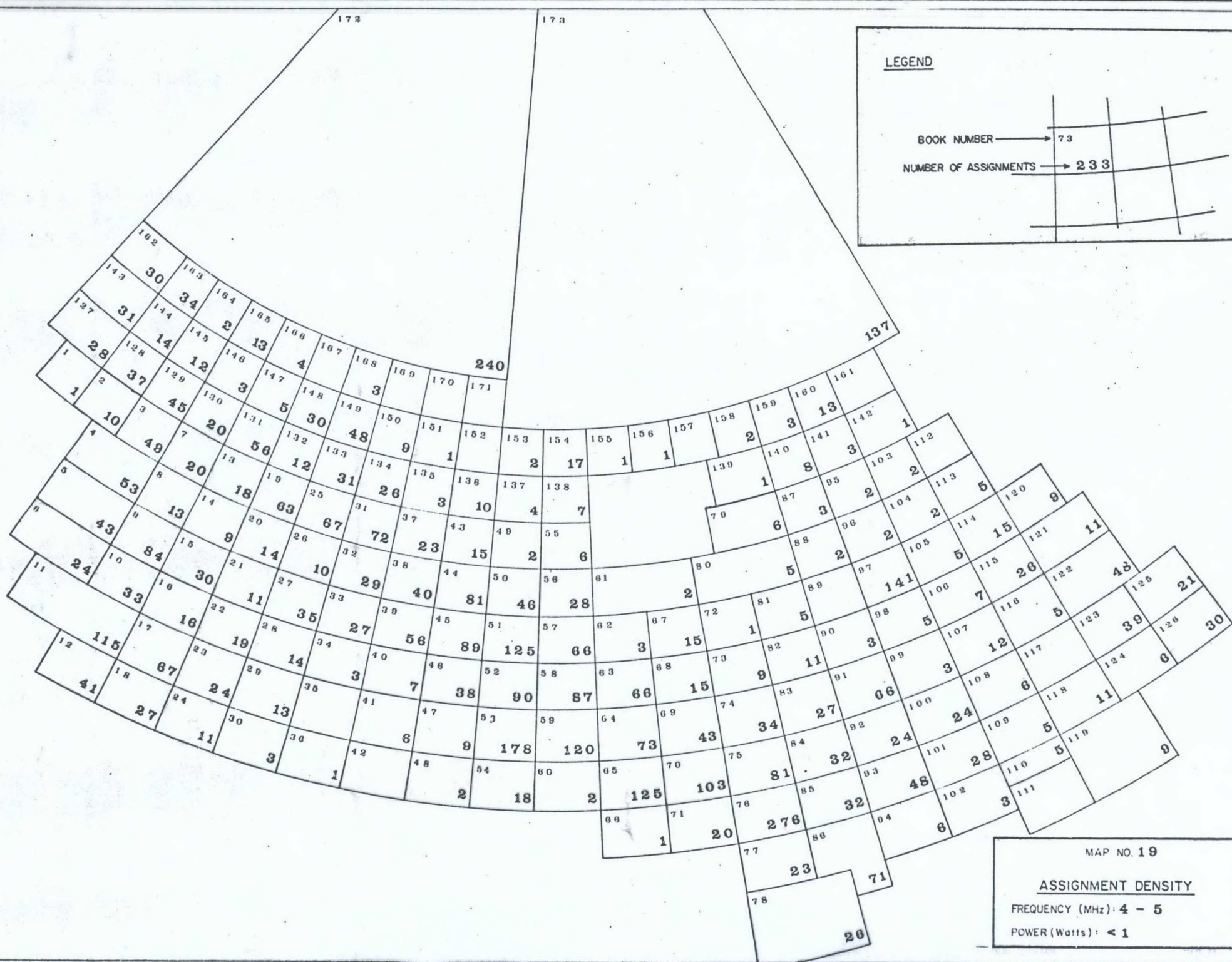THEORETICAL COVERAGE

Frequency (MHz) : 3
Power (Watts)   : 10
Month   : 6
Sunspot No.   : 50

FORT SMITH

WETASKIWIN

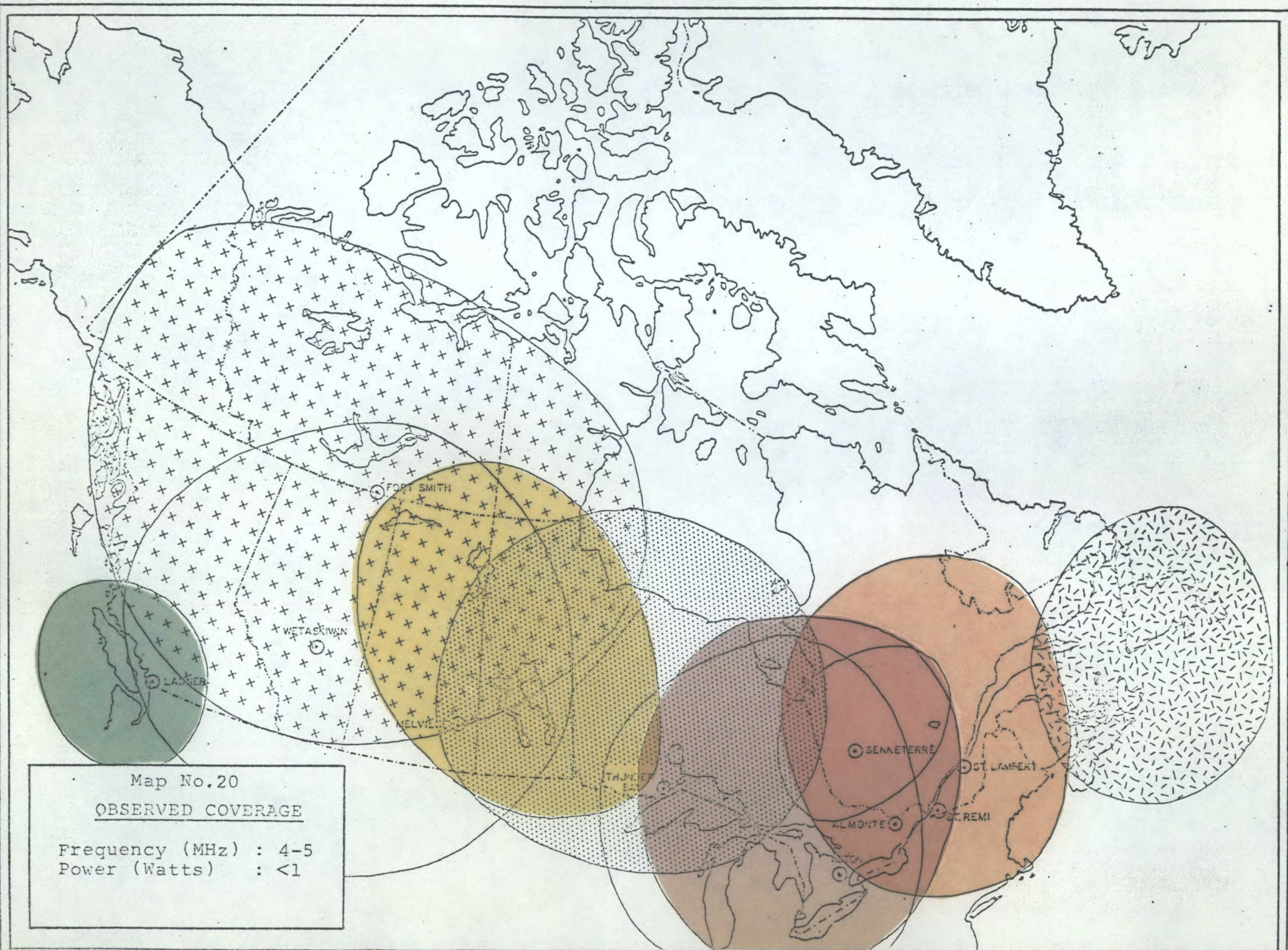LADNER

MELVILLE

THUNDER BAY

MONTAGUE

SEVERNAYE

ATIKITAY

LEGEND

BOOK NUMBER → 73

NUMBER OF ASSIGNMENTS → 233

MAP NO. 19

ASSIGNMENT DENSITY

FREQUENCY (MHz): 4 – 5

POWER (Watts): < 1

Map No.20

OBSERVED COVERAGE

Frequency (MHz) : 4-5
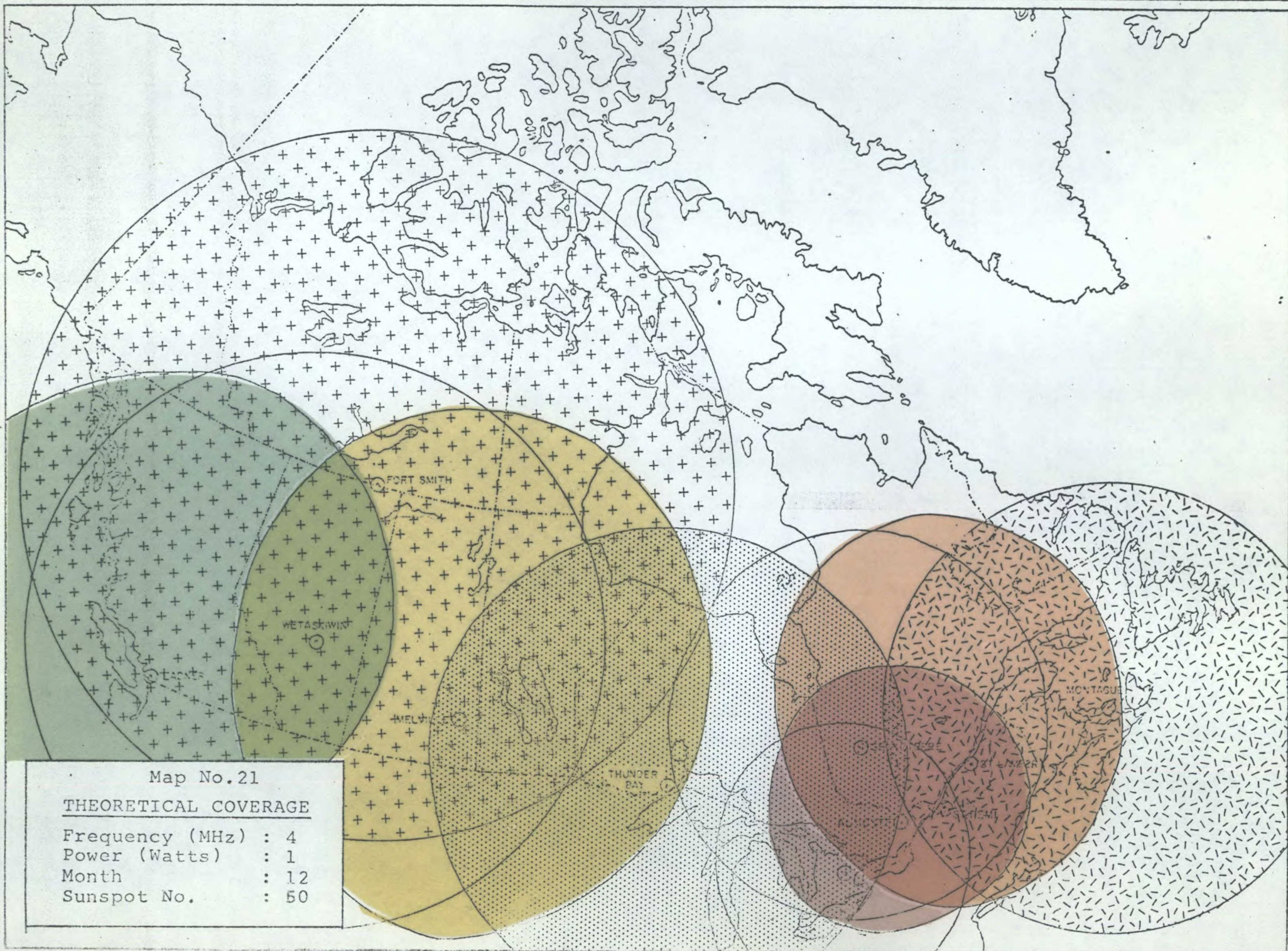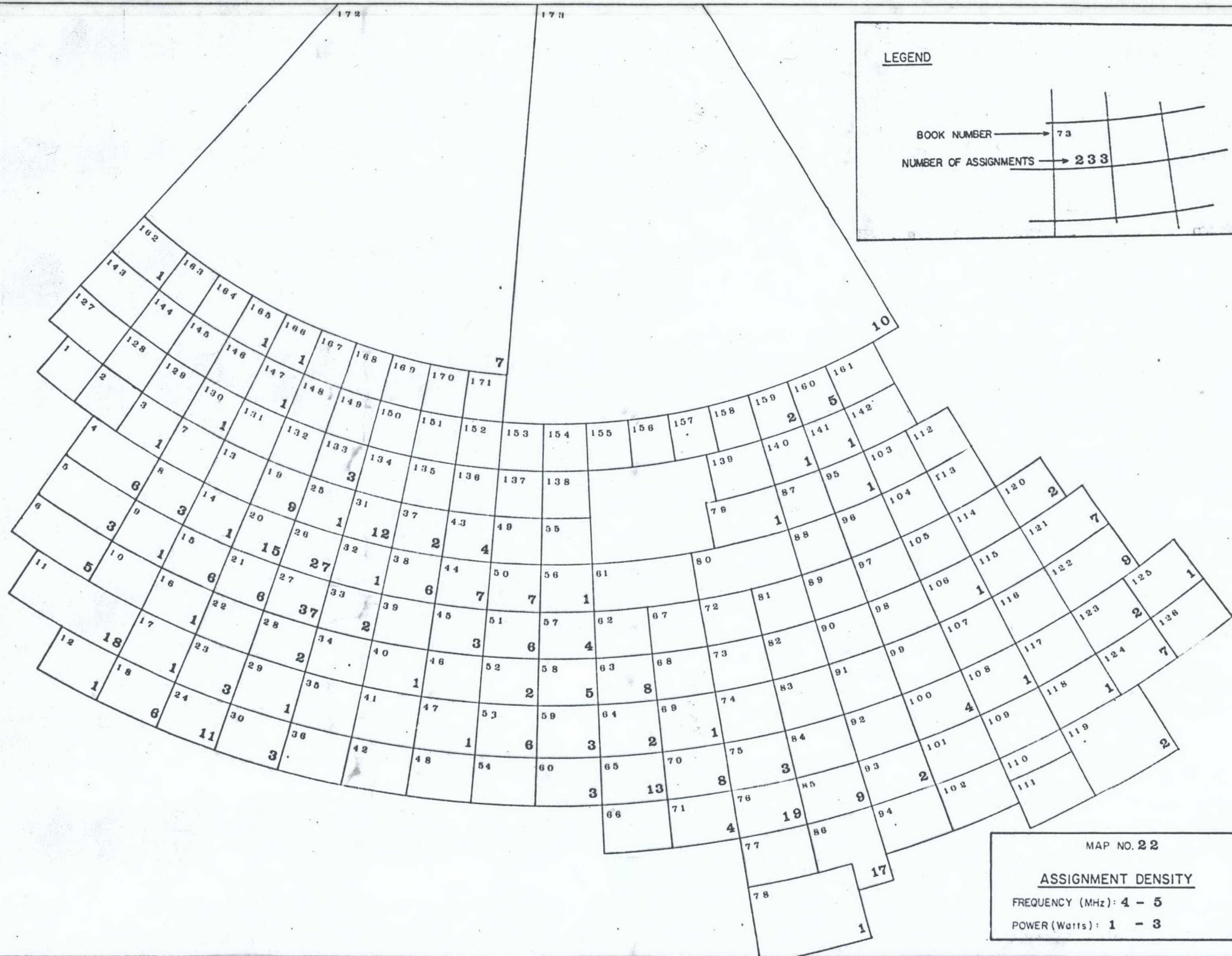Power (Watts)   : <1
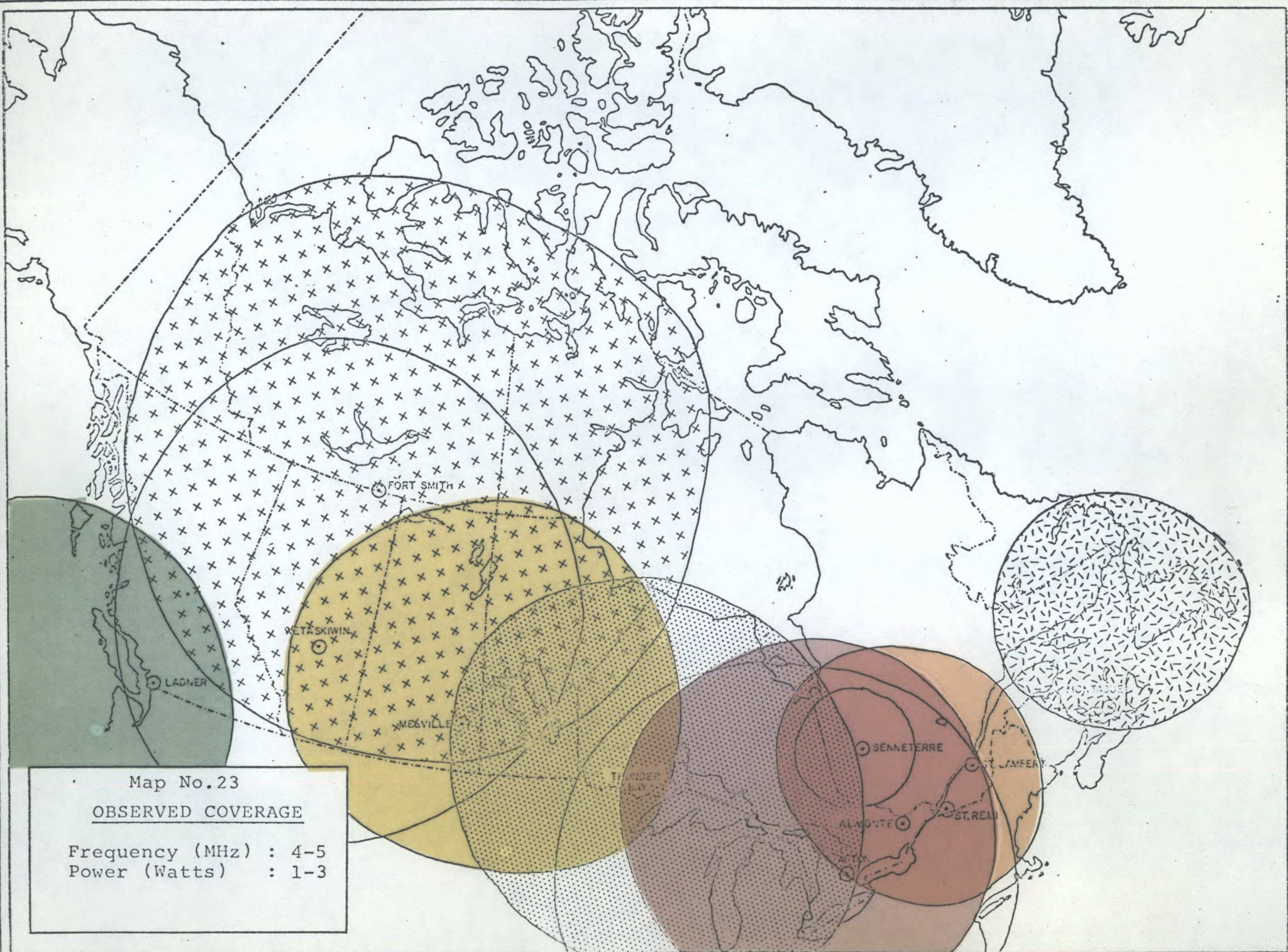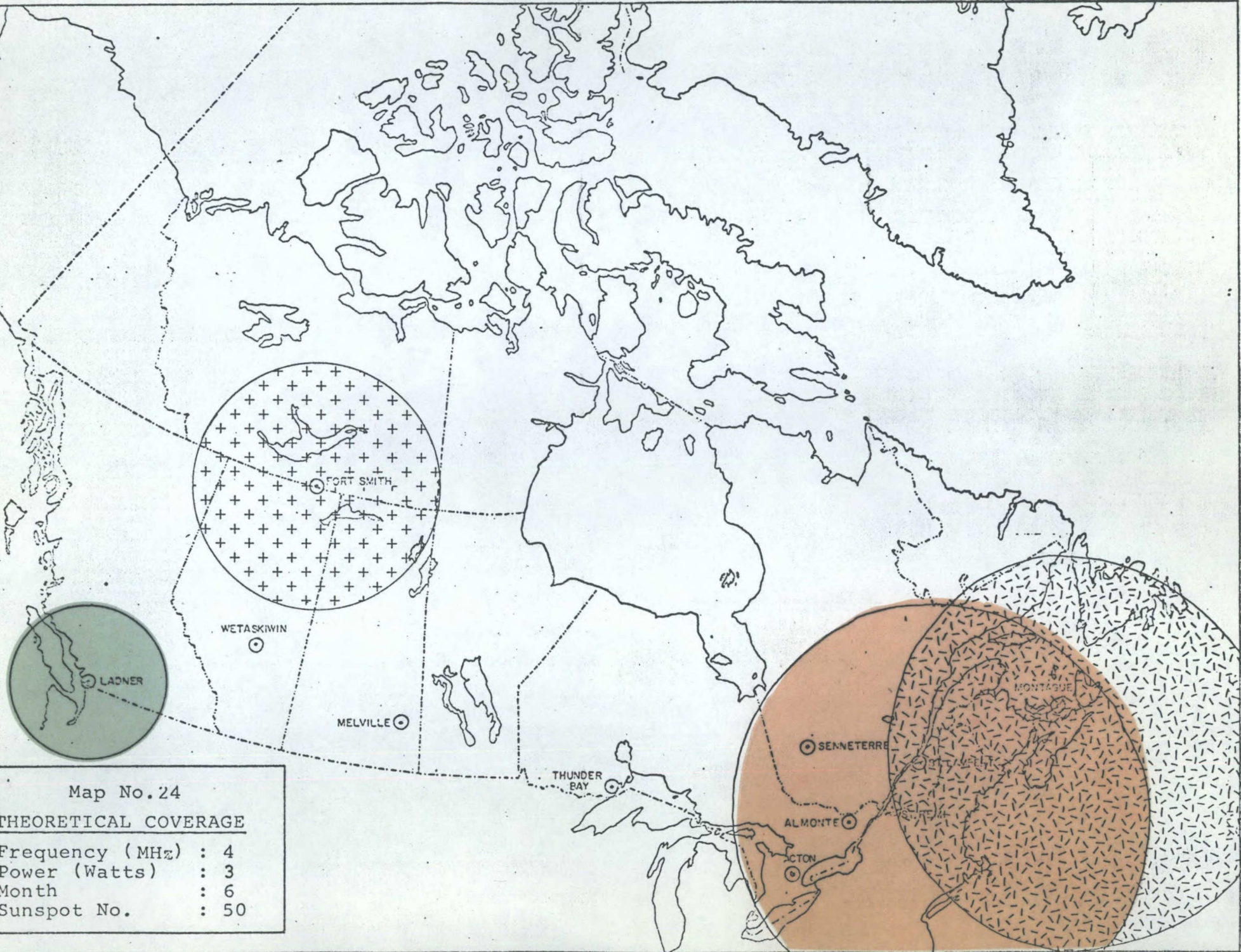
Map No.21

THEORETICAL COVERAGE

Frequency (MHz) : 4
Power (Watts)   : 1
Month   : 12
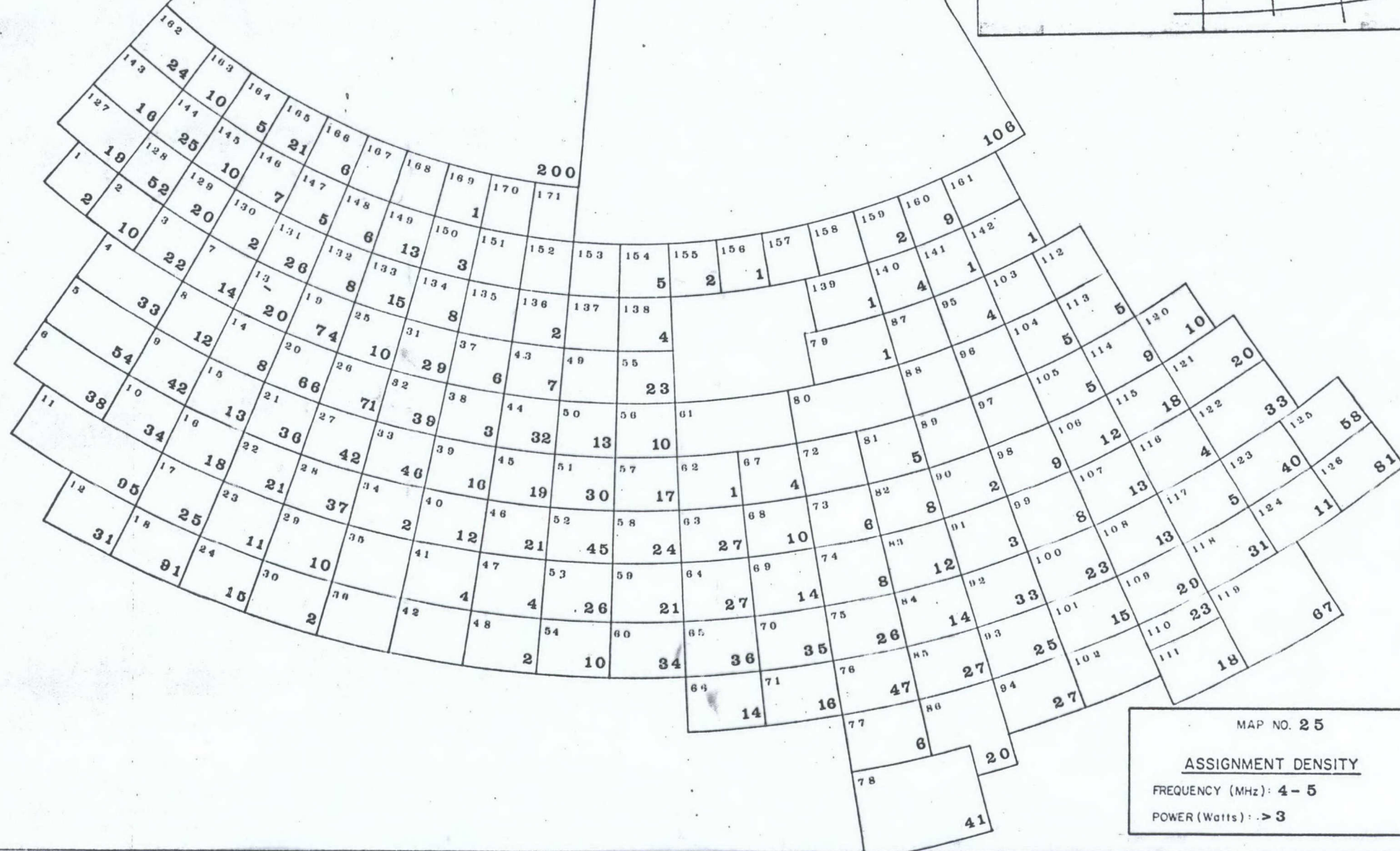Sunspot No.   : 50

MAP NO. 22

ASSIGNMENT DENSITY

FREQUENCY (MHz): 4 - 5

POWER (Watts): 1 - 3

Map No.23

OBSERVED COVERAGE

Frequency (MHz) : 4-5
Power (Watts)   : 1-3

Map No. 24

THEORETICAL COVERAGE

Frequency (MHz)	:	4
Power (Watts)	:	3
Month	:	6
Sunspot No.	:	50

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

THUNDER BAY

SENNETERRE

MONTAGUE

ALMONTE

ACTON

LEGEND

BOOK NUMBER ——→ 73

NUMBER OF ASSIGNMENTS ——→ 233

MAP NO. 25

ASSIGNMENT DENSITY

FREQUENCY (MHz): 4 – 5

POWER (Watts): > 3

Map No.26

OBSERVED COVERAGE

Frequency (MHz) : 4-5
Power (Watts)   : 3-10

Map No.27

OBSERVED COVERAGE

Frequency (MHz) : 4-5
Power (Watts) : >10

Map No. 28

THEORETICAL COVERAGE

Frequency (MHz) : 4
Power (Watts)   : 10
Month   : 6
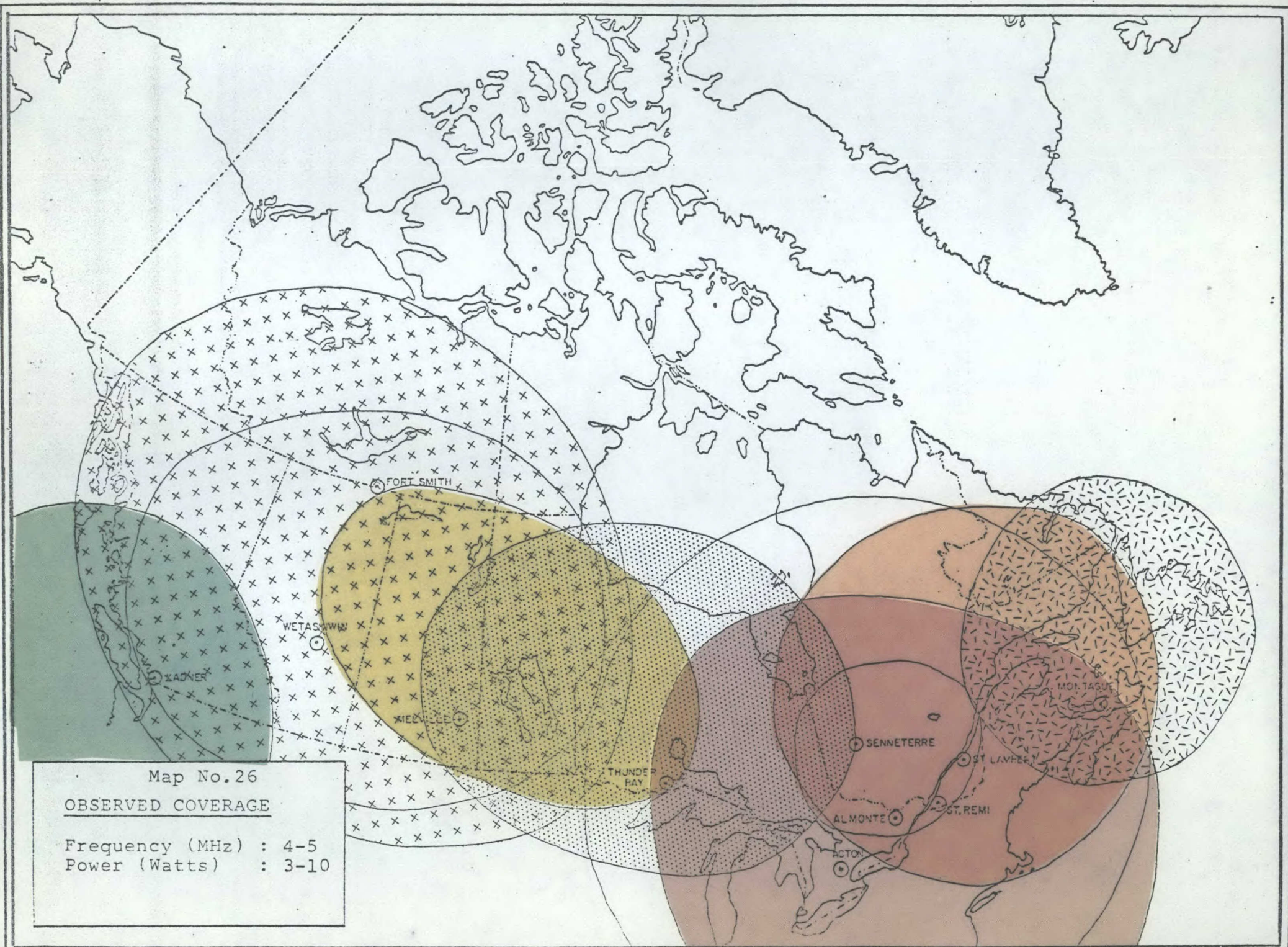Sunspot No.   : 50
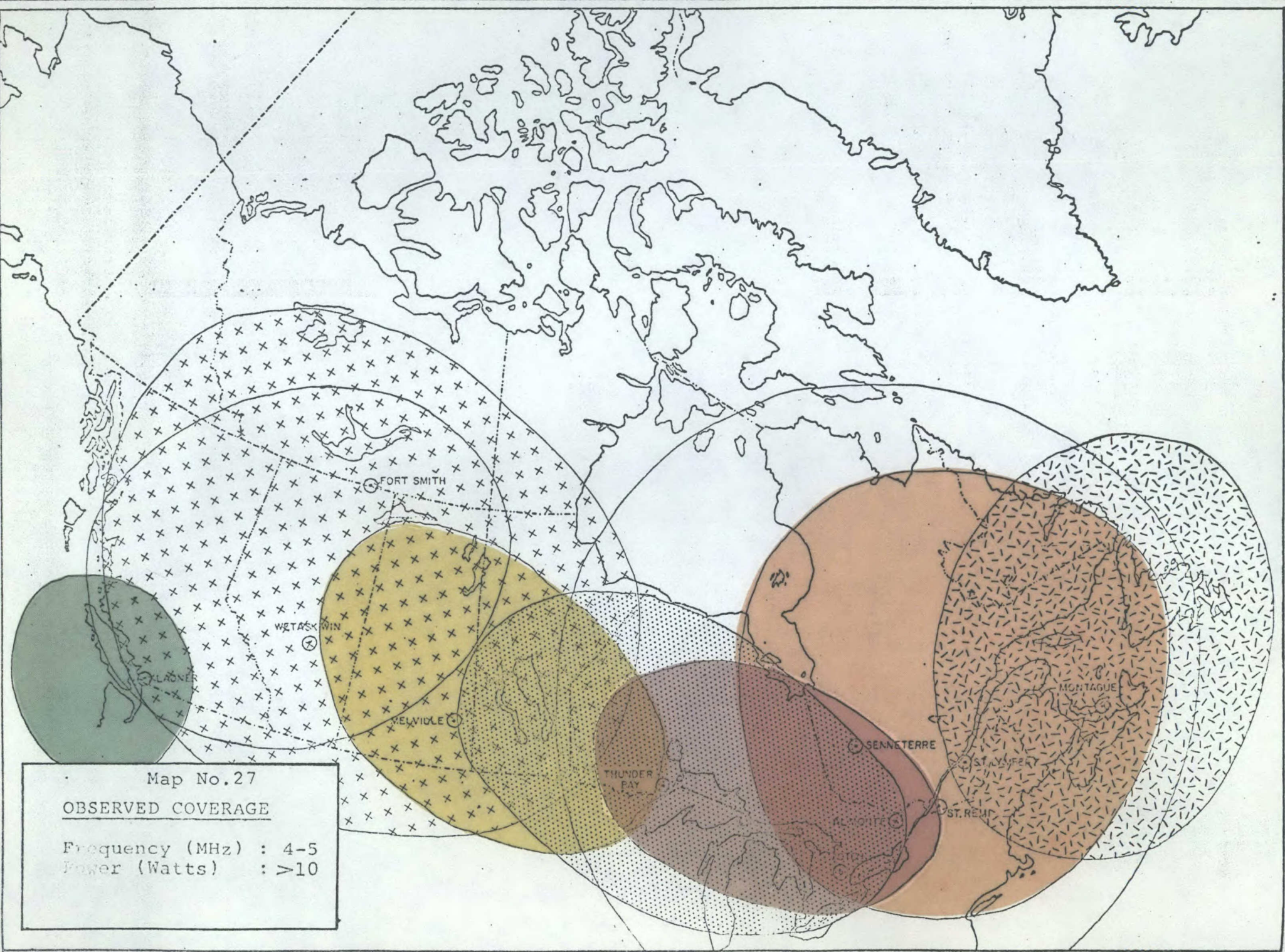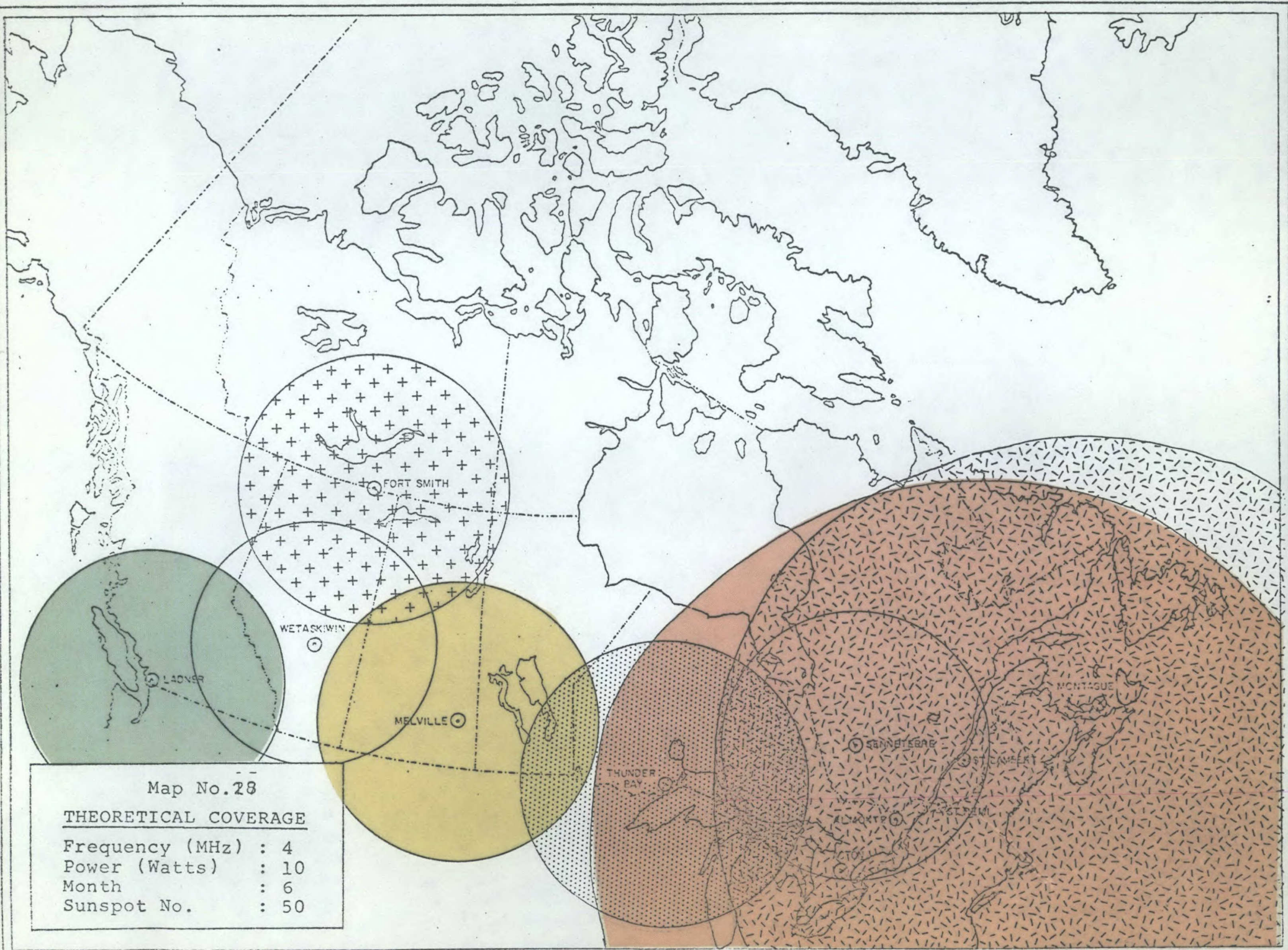
172   173

162
143   5
103
127   7   144   2
1   12   128   5   104
12   38   129   12   145   165   166
1   3   11   130   146   7   167   168   169   170   171
4   16   7   3   131   147   1   1   148   149   150   151   173
5   37   8   14   19   2   132   133   134   135   152   153   154   155   12
8   35   9   32   15   20   25   9   43   6   2   1   1   8   1   156   157   158   159   160   161
11   37   10   80   21   28   13   27   16   31   17   37   43   49   5   6   1   2   2   10   1
12   51   17   22   16   29   10   2   33   32   38   44   50   55   8   139   140   141   142   7   103   112
18   43   23   21   28   7   34   1   4   39   45   51   57   62   67   72   80   3   4   95   8   1   1   120
16   33   24   24   29   15   35   40   67   18   10   7   2   3   81   87   1   8   104   5   114   4
14   30   5   11   41   6   46   16   52   58   63   68   73   82   88   96   6   105   9   3   121   12
36   42   2   3   59   44   49   25   8   2   90   1   229   106   9   115   122   17   125   1
48   14   8   13   19   28   24   91   98   12   107   118   24   123   2   128   3
54   100   32   6   16   83   5   28   117   2
60   26   21   14   84   92   12   108   19   124   3
65   70   75   85   32   100   54   109   1   118   3
66   71   76   6   93   33   101   47   110   119   11
77   1   10   21   51   102   15   1   111
78   7   86   94
7   10

Map No. 30

OBSERVED COVERAGE

Frequency (MHz) : 5-7
Power (Watts)   : <1

Map No. 31

THEORETICAL COVERAGE

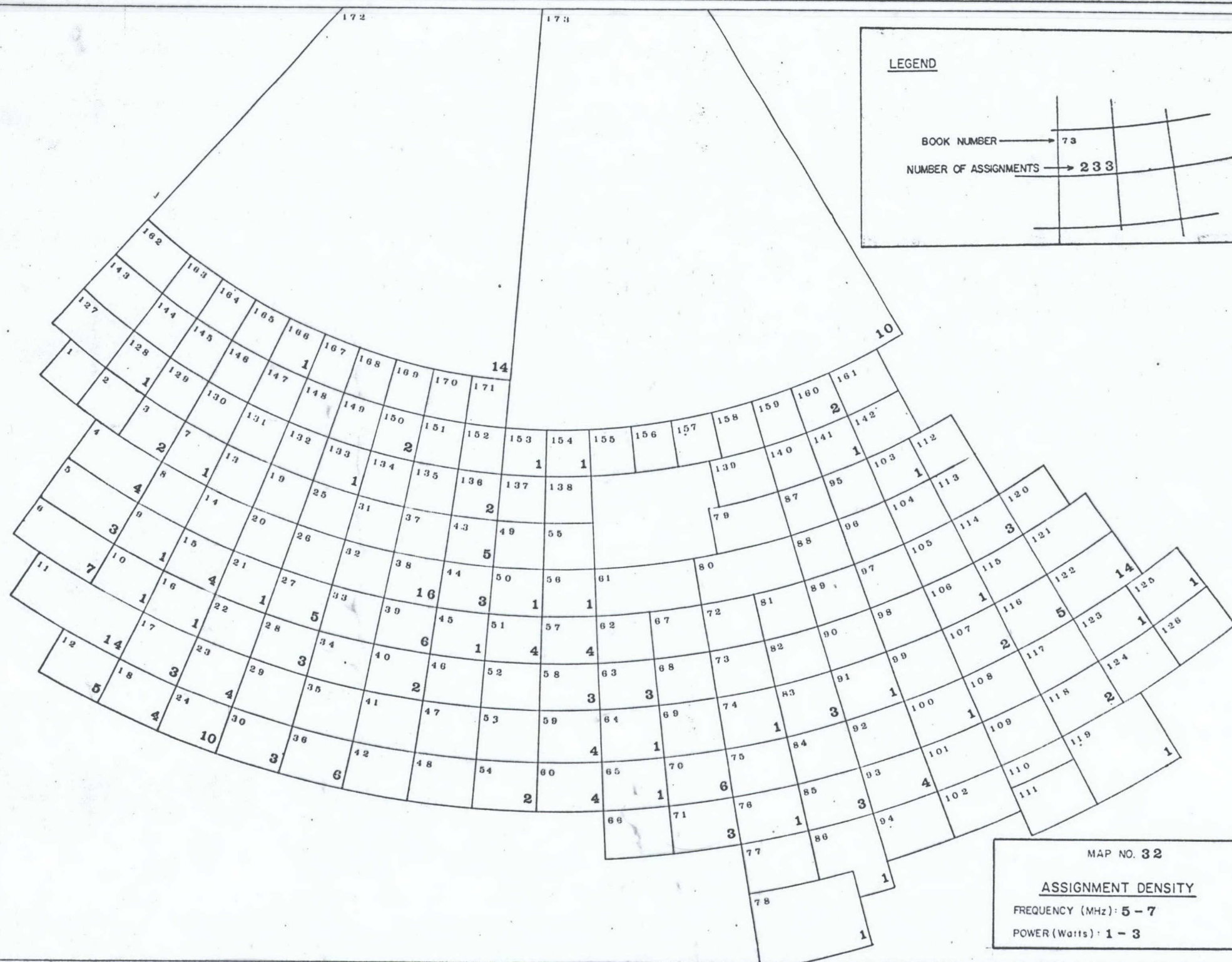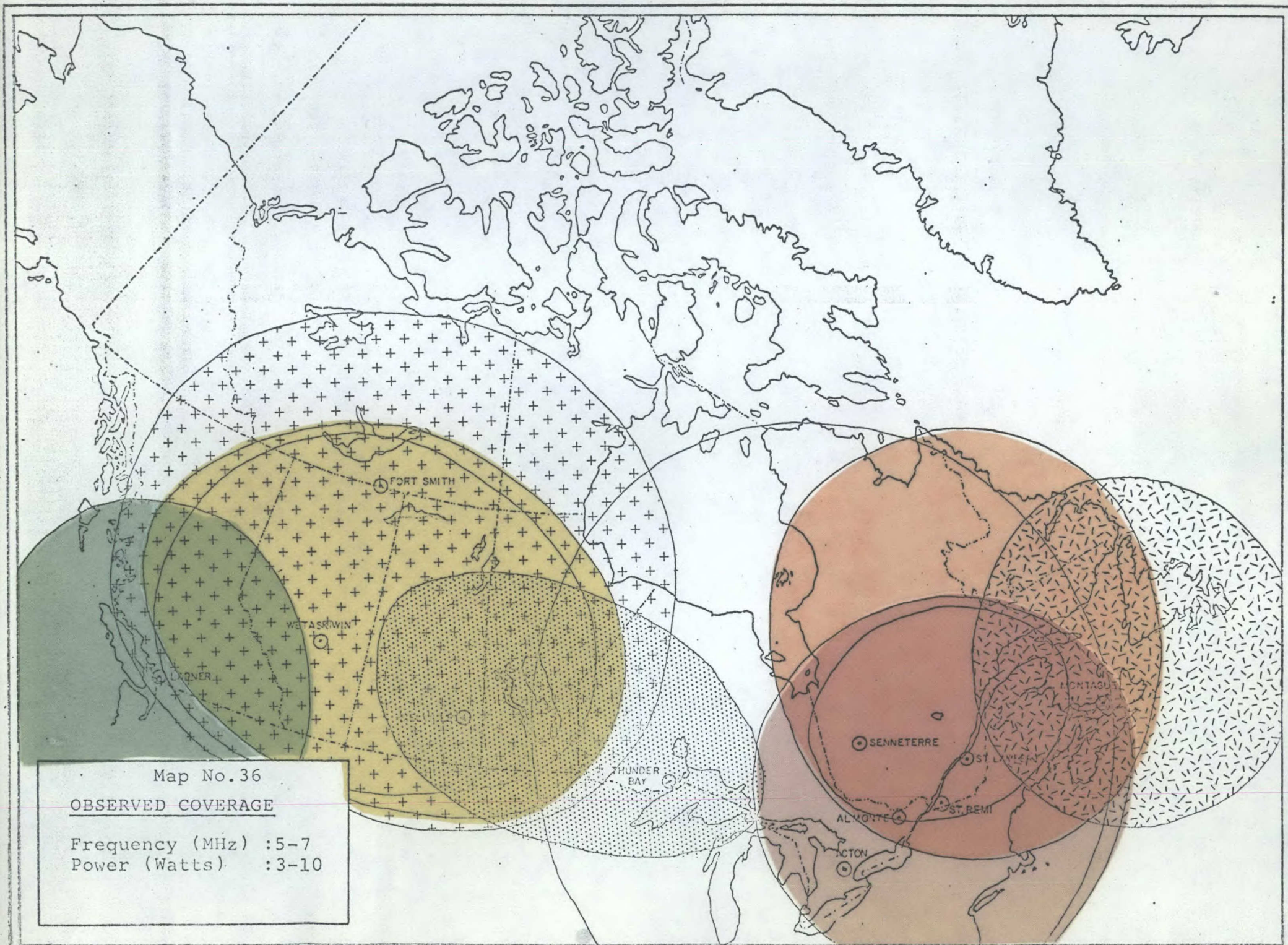|	
Frequency (MHz)	: 5
Power (Watts)	: 1
Month	: 12
Sunspot No.	: 50

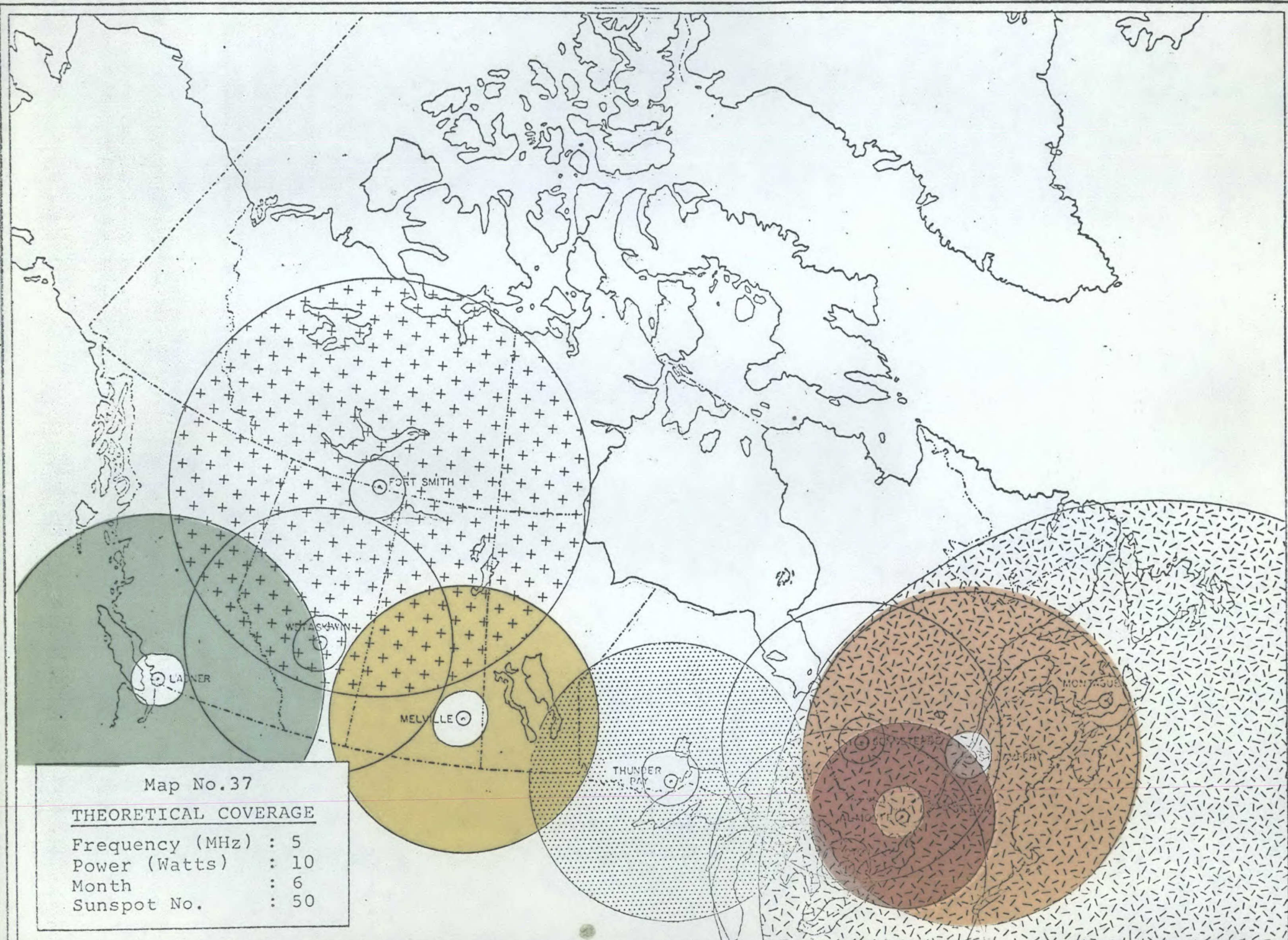LEGEND

BOOK NUMBER ⟶ 73

NUMBER OF ASSIGNMENTS ⟶ 233

MAP NO. 32

ASSIGNMENT DENSITY

FREQUENCY (MHz): 5 − 7

POWER (Watts): 1 − 3

Map No. 33

OBSERVED COVERAGE

Frequency (MHz) : 5-7

Power (Watts)   : 1-3

Map No.34

THEORETICAL COVERAGE

Frequency (MHz) : 5
Power (Watts)   : 3
Month   : 6
Sunspot No.   :50
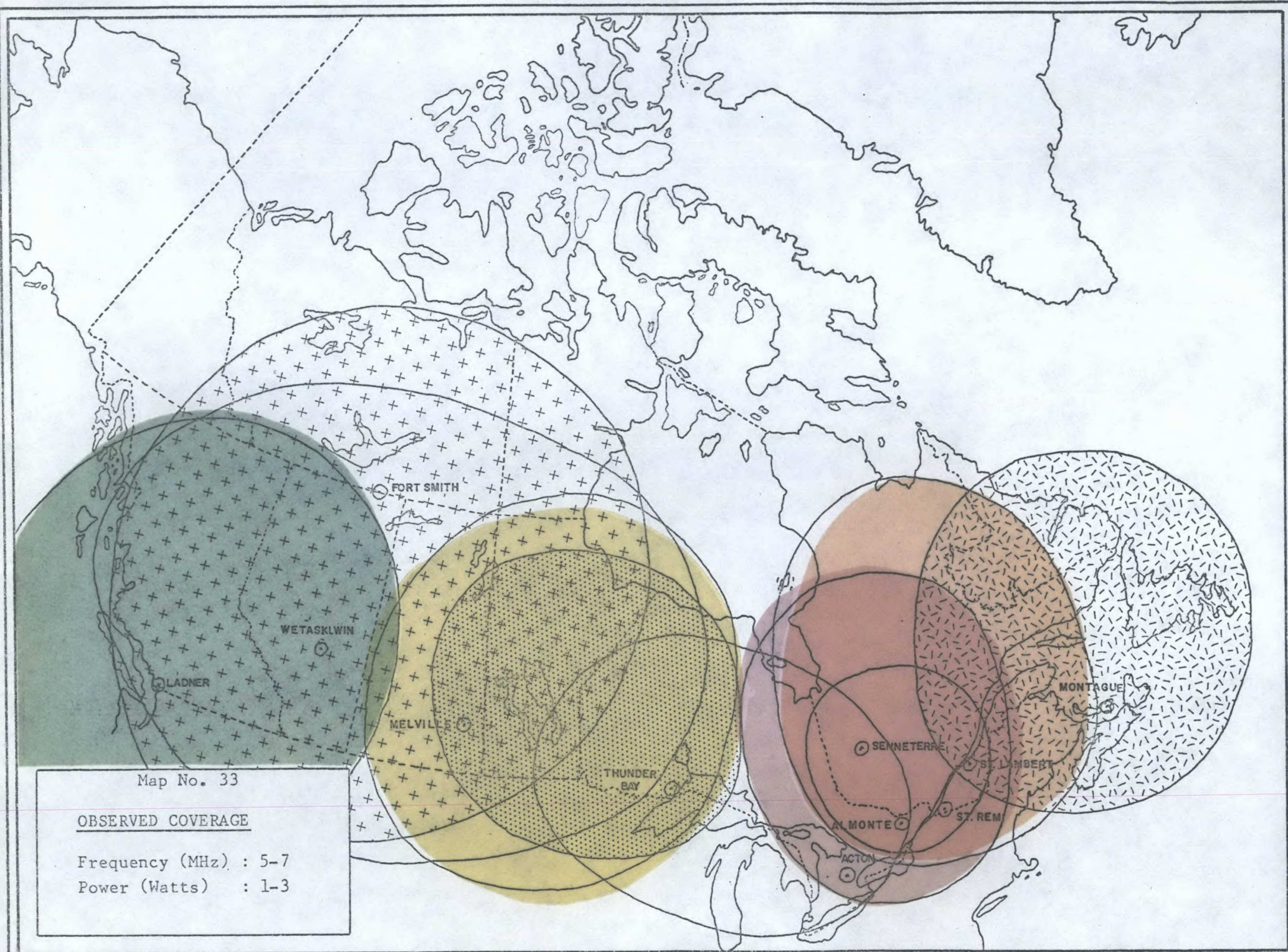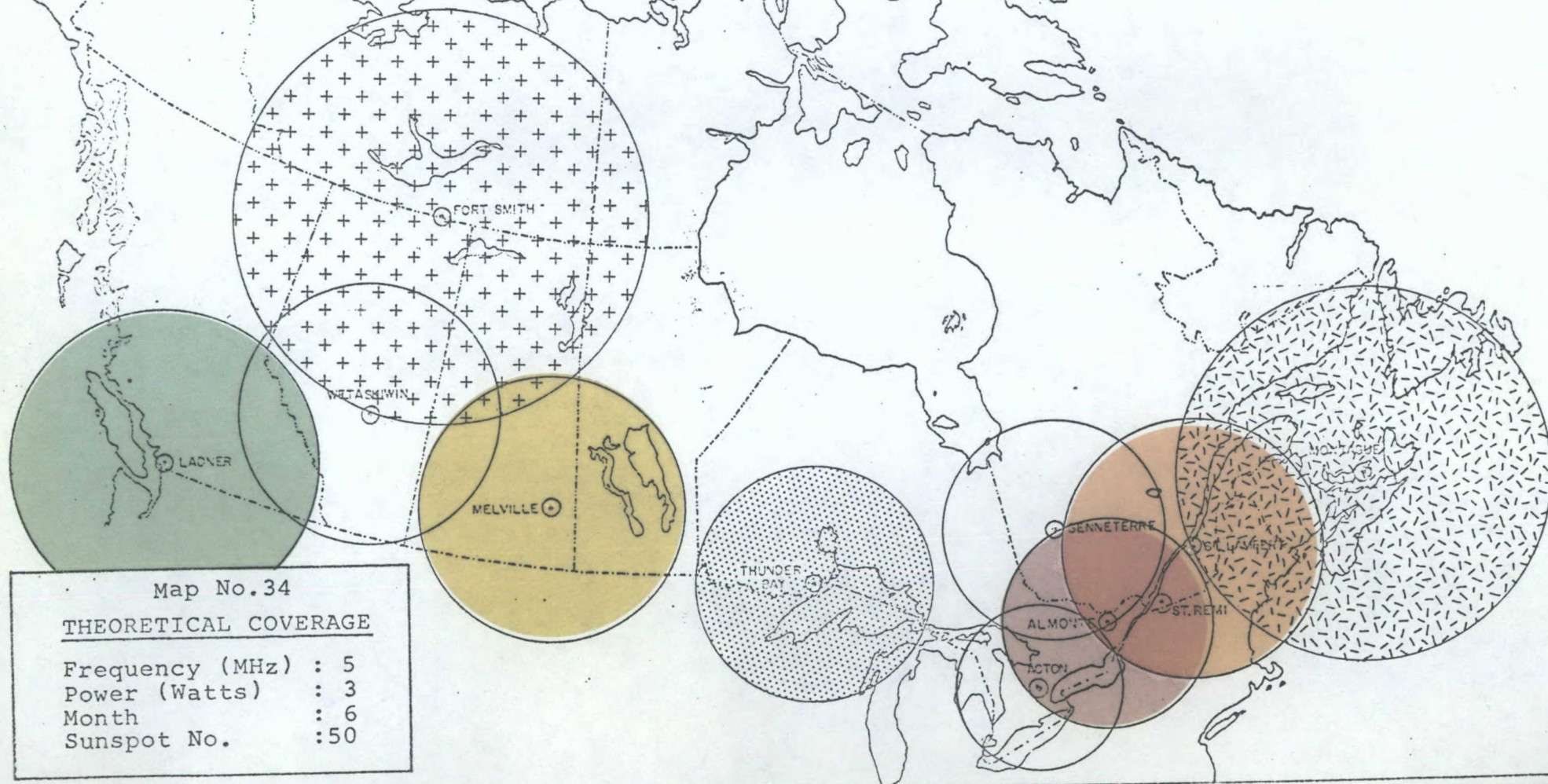
LEGEND

BOOK NUMBER → 73

NUMBER OF ASSIGNMENTS → 233

MAP NO. 35

ASSIGNMENT DENSITY

FREQUENCY (MHz): 5 – 7

POWER (Watts): > 3

Map No.36
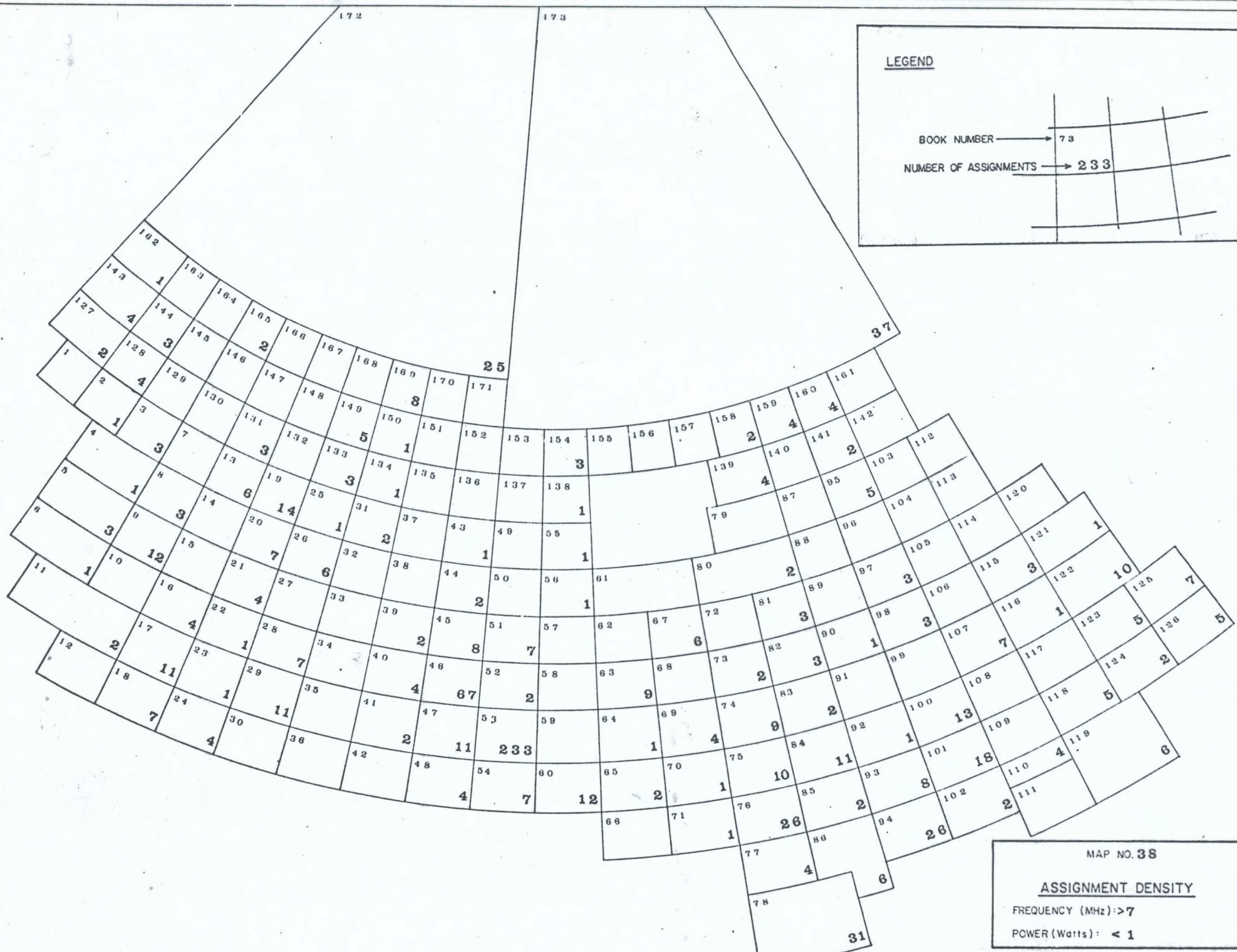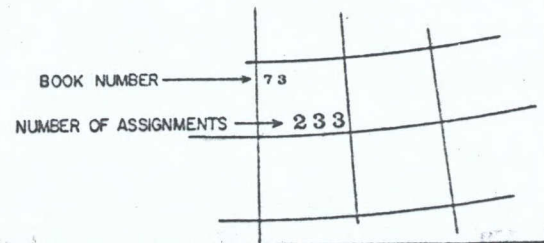
OBSERVED COVERAGE

Frequency (MHz) :5-7
Power (Watts)   :3-10

Map No.37

THEORETICAL COVERAGE

Frequency (MHz) : 5
Power (Watts)   : 10
Month   : 6
Sunspot No.   : 50

LEGEND

BOOK NUMBER ⟶ 7 3

NUMBER OF ASSIGNMENTS ⟶ 2 3 3
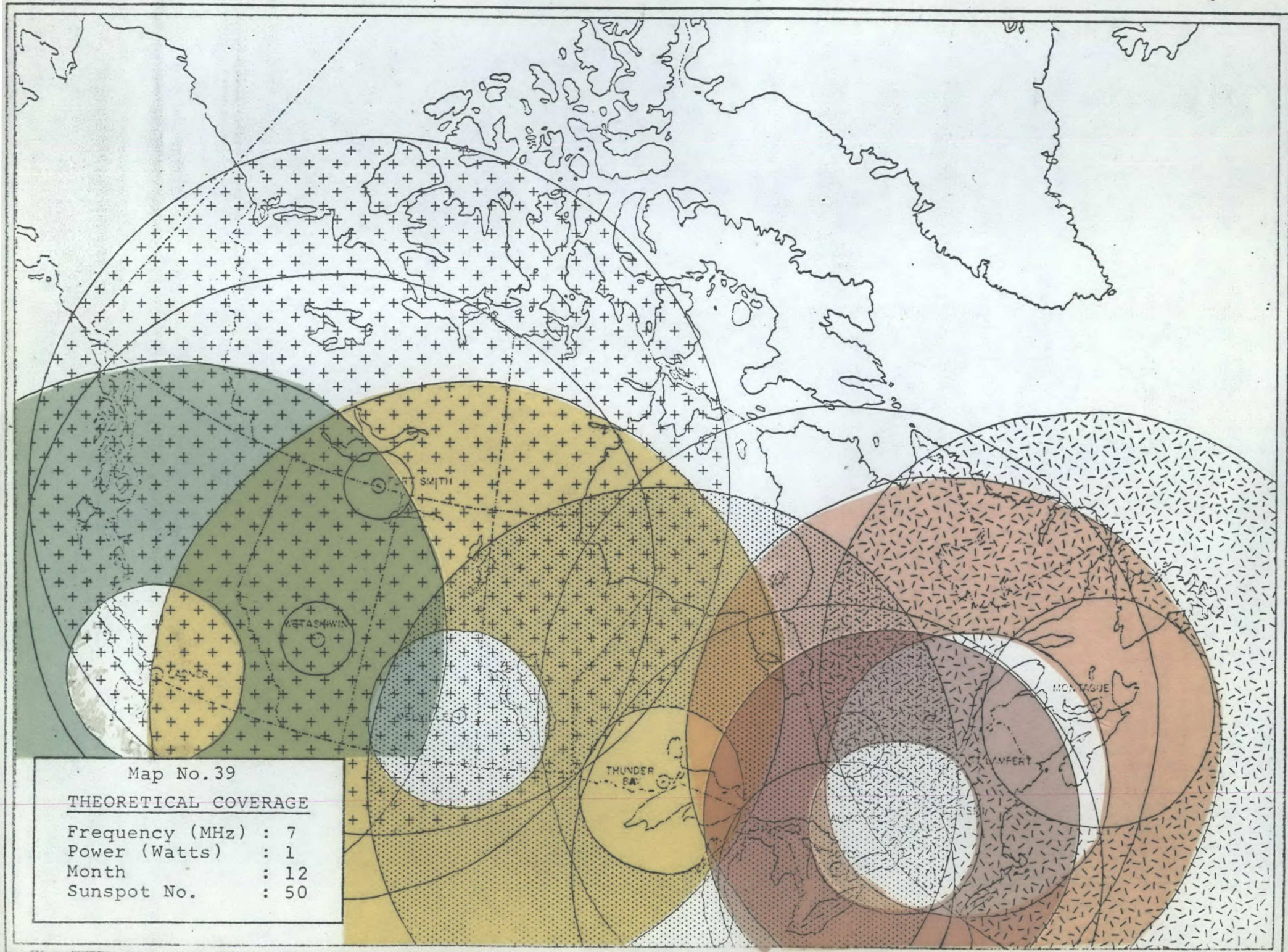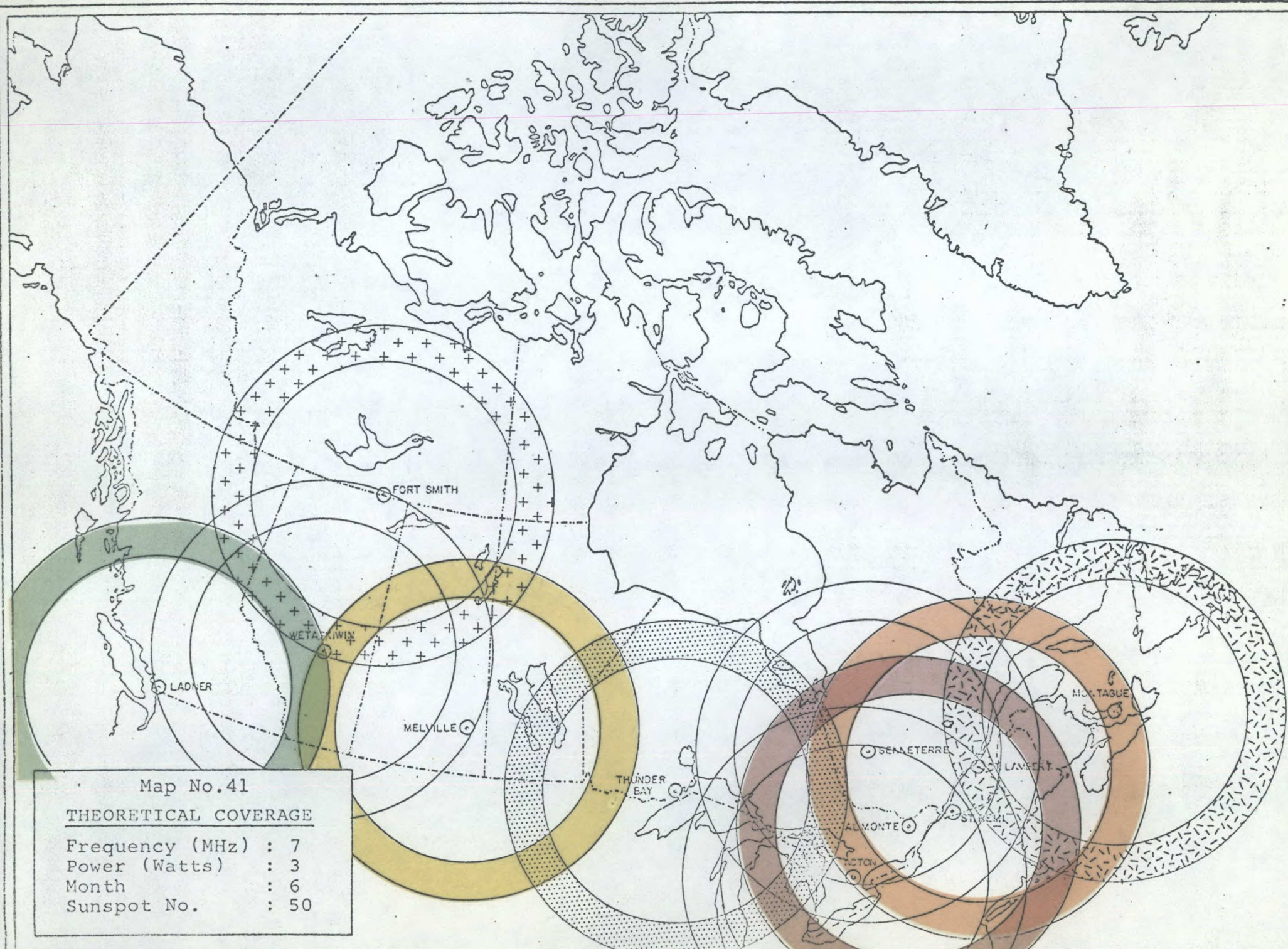
MAP NO. 38

ASSIGNMENT DENSITY

FREQUENCY (MHz): >7

POWER (Watts): < 1

Map No. 39

THEORETICAL COVERAGE

Frequency (MHz) : 7
Power (Watts)   : 1
Month   : 12
Sunspot No.   : 50

LEGEND

BOOK NUMBER ⟶ 7 3

NUMBER OF ASSIGNMENTS ⟶ 2 3 3

MAP NO. 40

ASSIGNMENT DENSITY

FREQUENCY (MHz): > 7

POWER (Watts): 1 - 3

Map No.41

THEORETICAL COVERAGE

Frequency (MHz) : 7
Power (Watts)   : 3
Month   : 6
Sunspot No.   : 50

LEGEND

BOOK NUMBER ──────→ 73

NUMBER OF ASSIGNMENTS ──────→ 233

MAP NO. 42

ASSIGNMENT DENSITY

FREQUENCY (MHz) : ＞ 7

POWER (Watts) : ＞ 3

Map No.43

THEORETICAL COVERAGE

Frequency (MHz)	:	7
Power (Watts)	:	10
Month	:	6
Sunspot No.	:	50

Map No.44

THEORETICAL COVERAGE

Frequency (MHz) : 9
Power (Watts) : 10
Month : 6
Sunspot No. : 50

Map No.44

THEORETICAL COVERAGE

Frequency (MHz) : 9
Power (Watts)   : 10
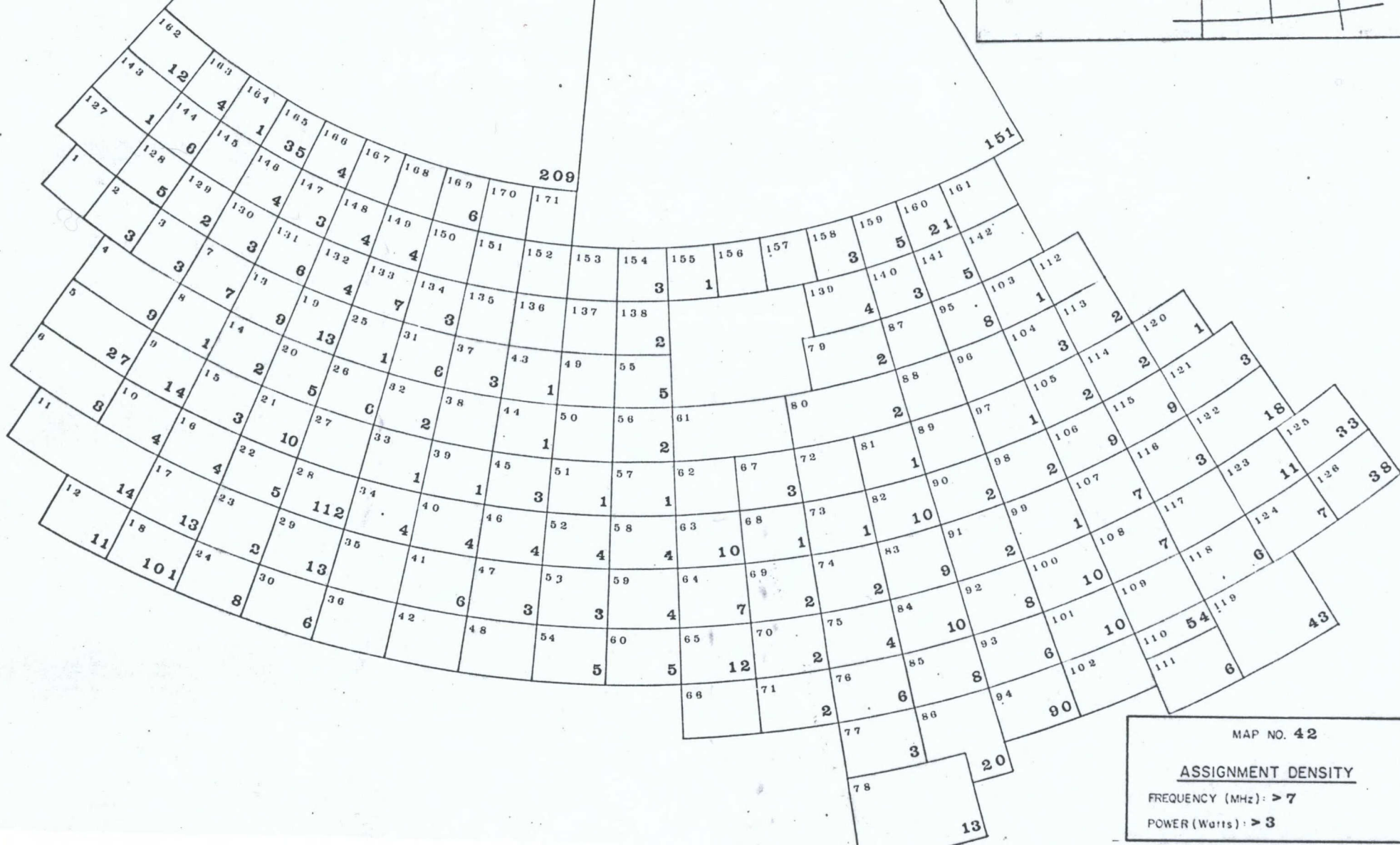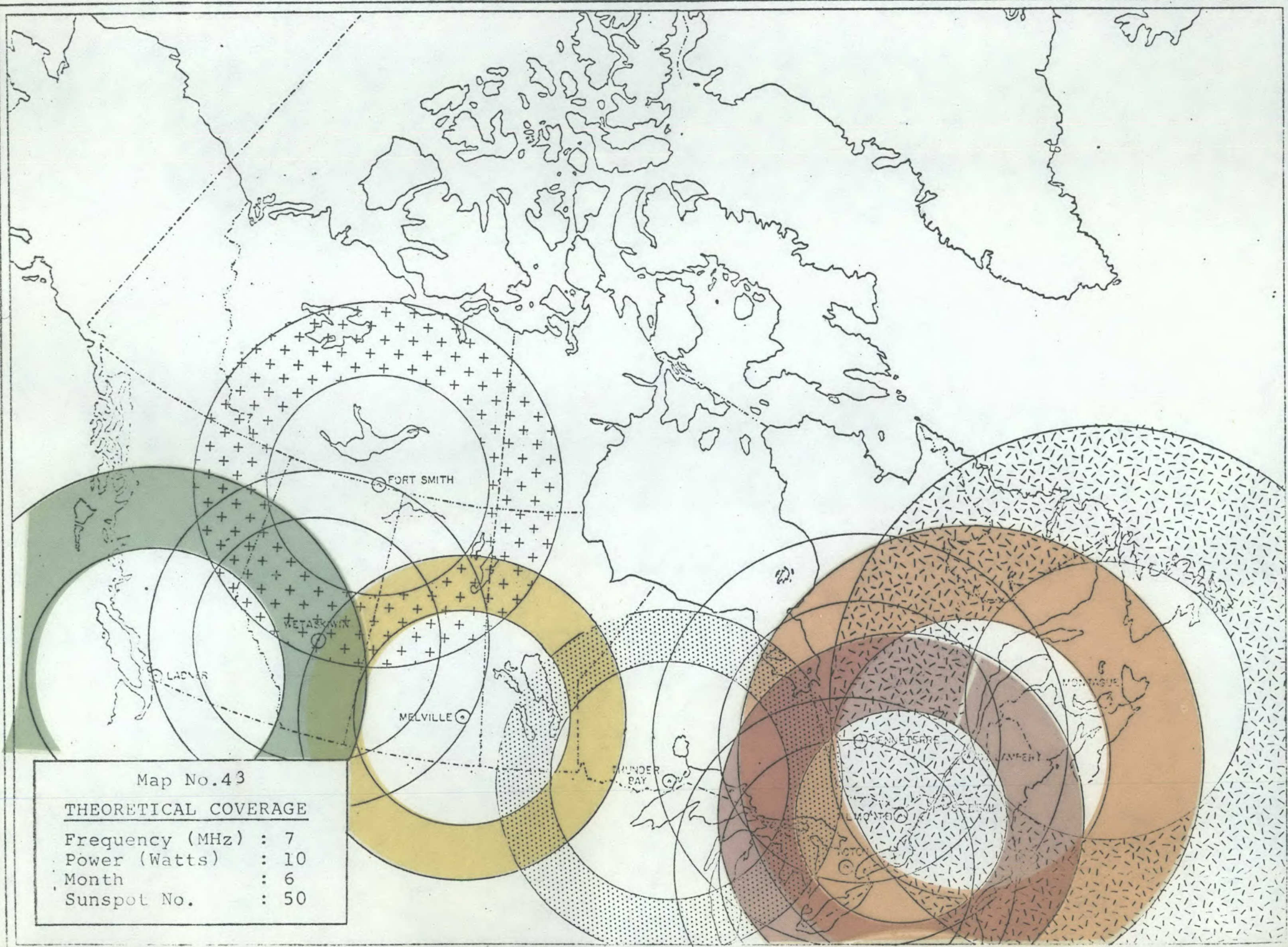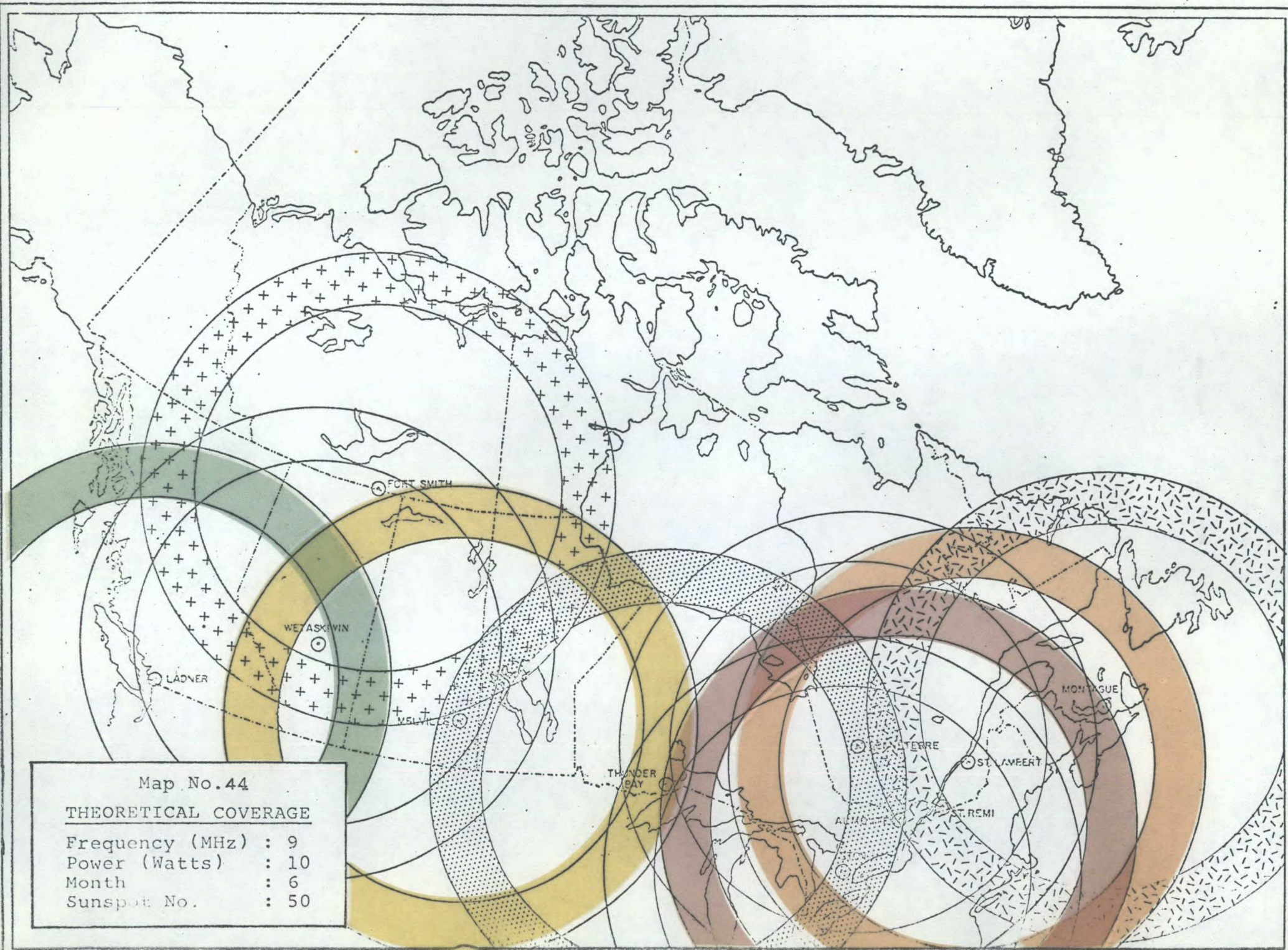Month   : 6
Sunspot No.   : 50

Map No. 45

COVERAGE AREA AS A FUNCTION OF THE SSN*

Frequency (MHz) : 3
Power (Watts)   : 1
Month   : 12
SSN* = Sunspot No.

SUNSPOT No.

0   : ------
50 : _____
100 : -.-.-.-

Map labels: FORT SMITH, WETASKIWIN, LADNER, MELVILLE, THUNDER BAY, SENNETERRE, ST.LAMBERT, ALMONTE, ST.REMI, ACTON, MONTAGUE, CANADA
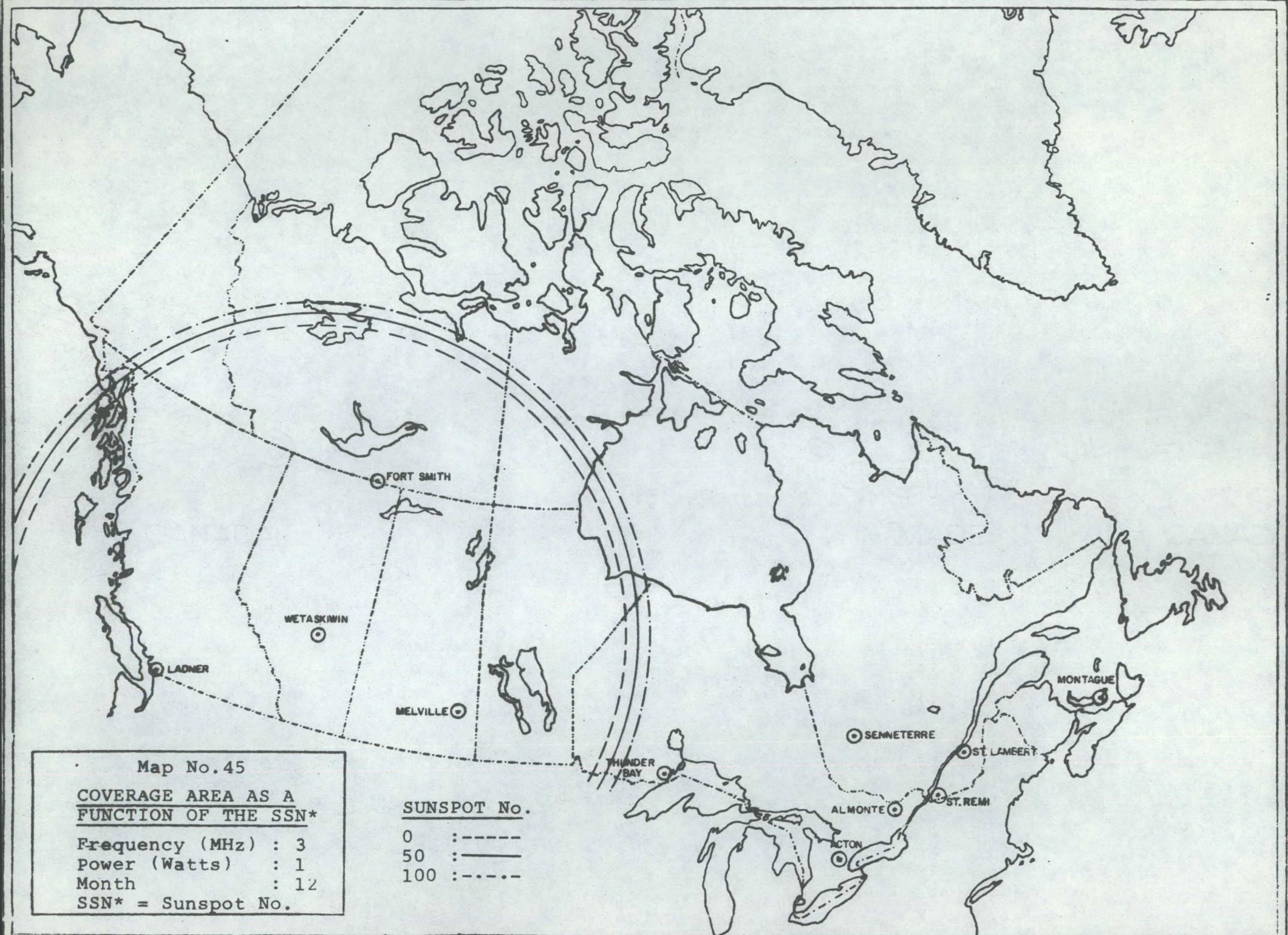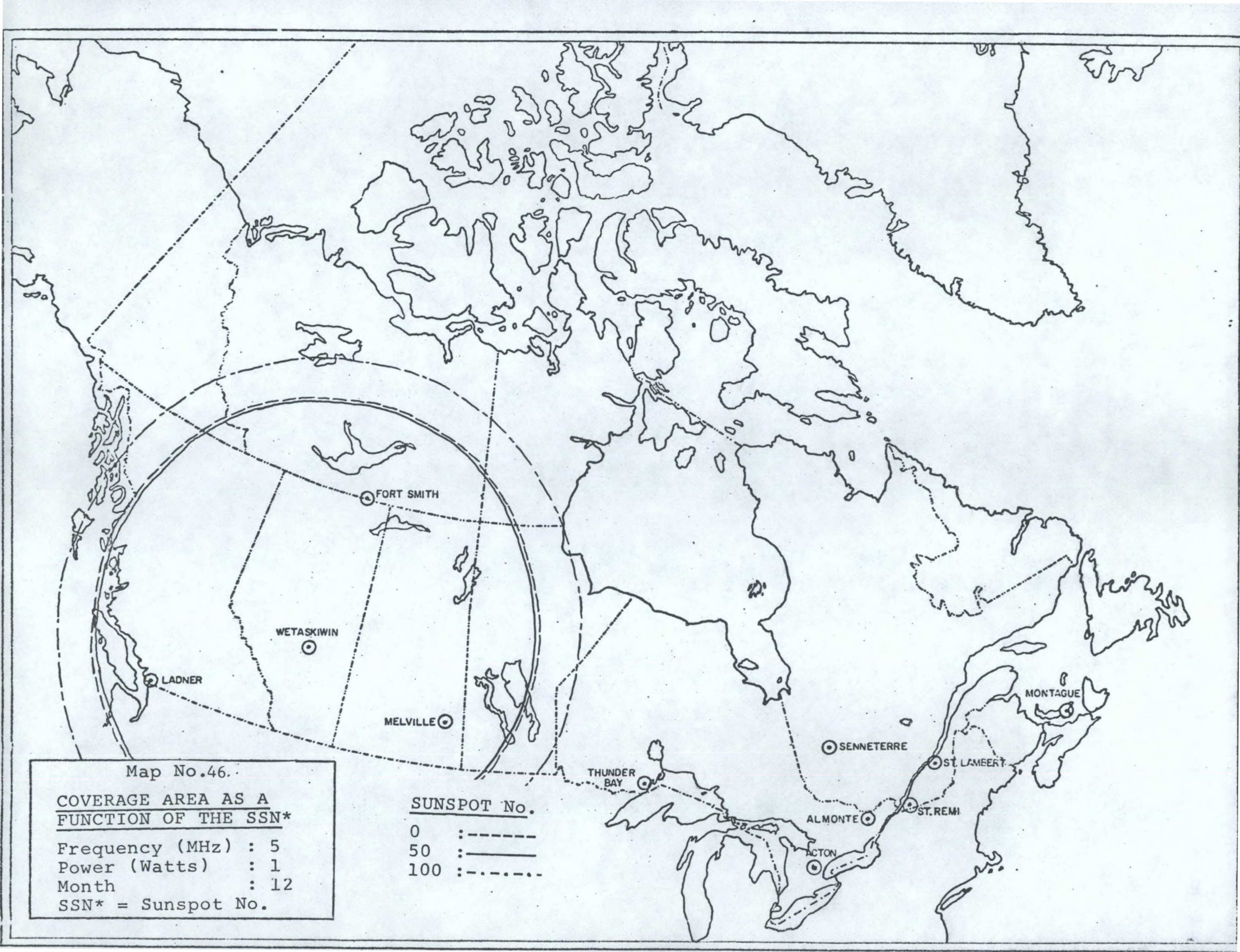
Map No. 46.

COVERAGE AREA AS A
FUNCTION OF THE SSN*

Frequency (MHz) : 5
Power (Watts)   : 1
Month   : 12
SSN* = Sunspot No.

SUNSPOT No.

0   : -------
50 : ———
100 : -·-·-·-

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

MONTAGUE

SENNETERRE

THUNDER BAY

ST. LAMBERT

ALMONTE

ST. REMI
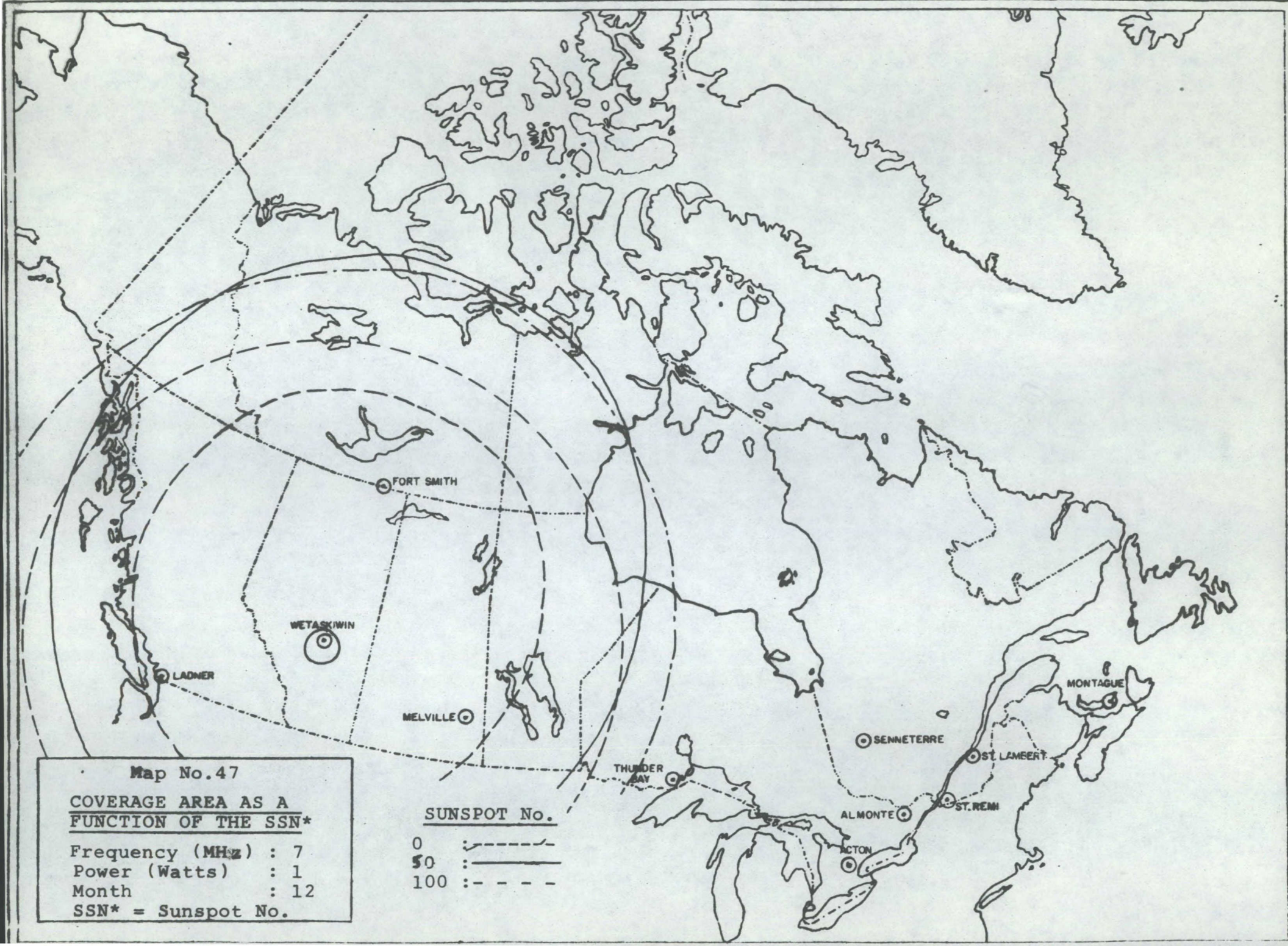
ACTON

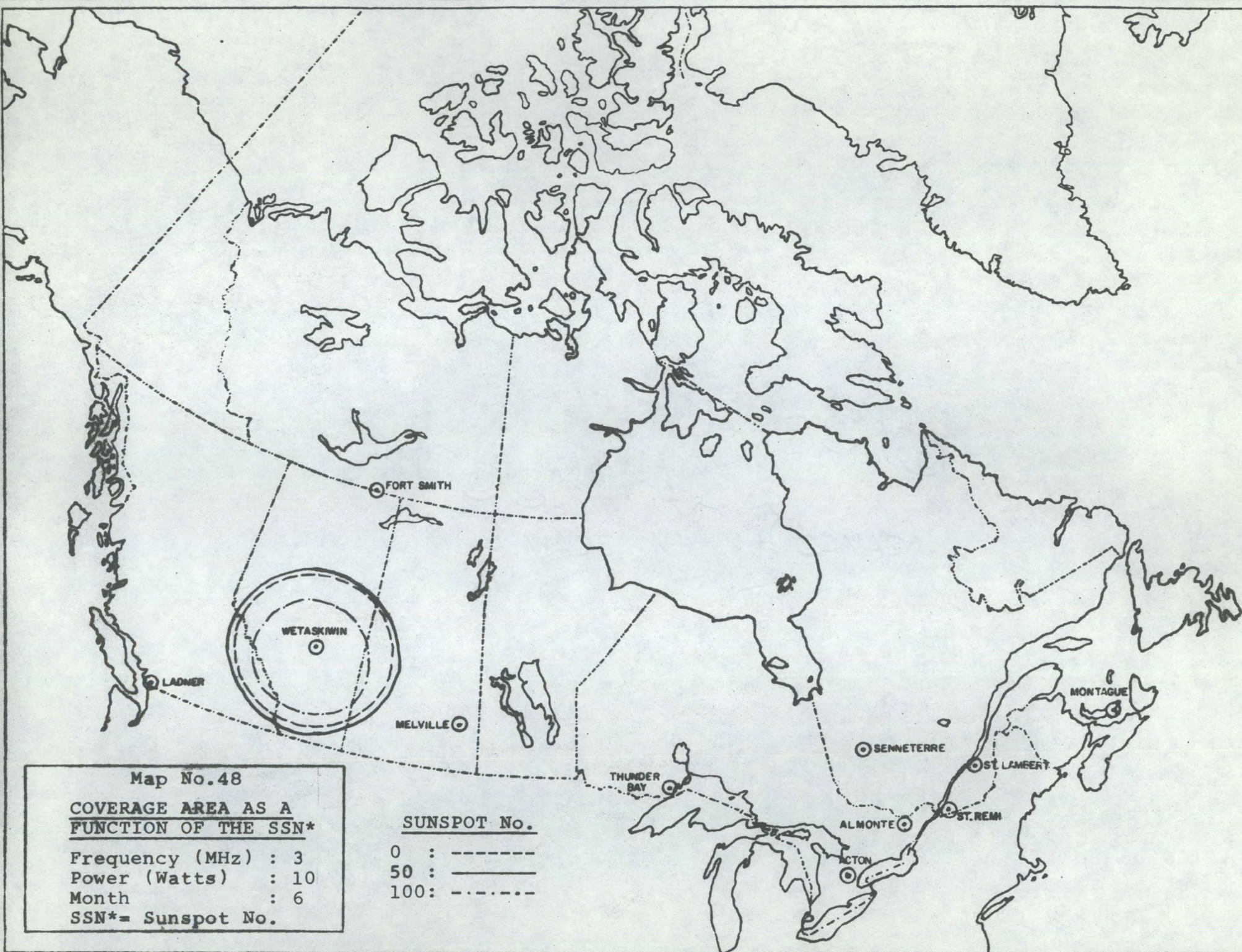Map No. 47

COVERAGE AREA AS A
FUNCTION OF THE SSN*

Frequency (MHz) : 7
Power (Watts)   : 1
Month   : 12
SSN* = Sunspot No.

SUNSPOT No.

0   : – – – – –
50 : ————
100 : – – – –

Map No.48

COVERAGE AREA AS A
FUNCTION OF THE SSN*

Frequency (MHz) : 3
Power (Watts)   : 10
Month   : 6
SSN*= Sunspot No.

SUNSPOT No.

0   : ----------
50 : _____
100: -·-·-·-·-·-

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

SENNETERRE

ST.LAMBERT

THUNDER
BAY

ALMONTE

ST.REMI

ACTON

MONTAGUE

Map No.49
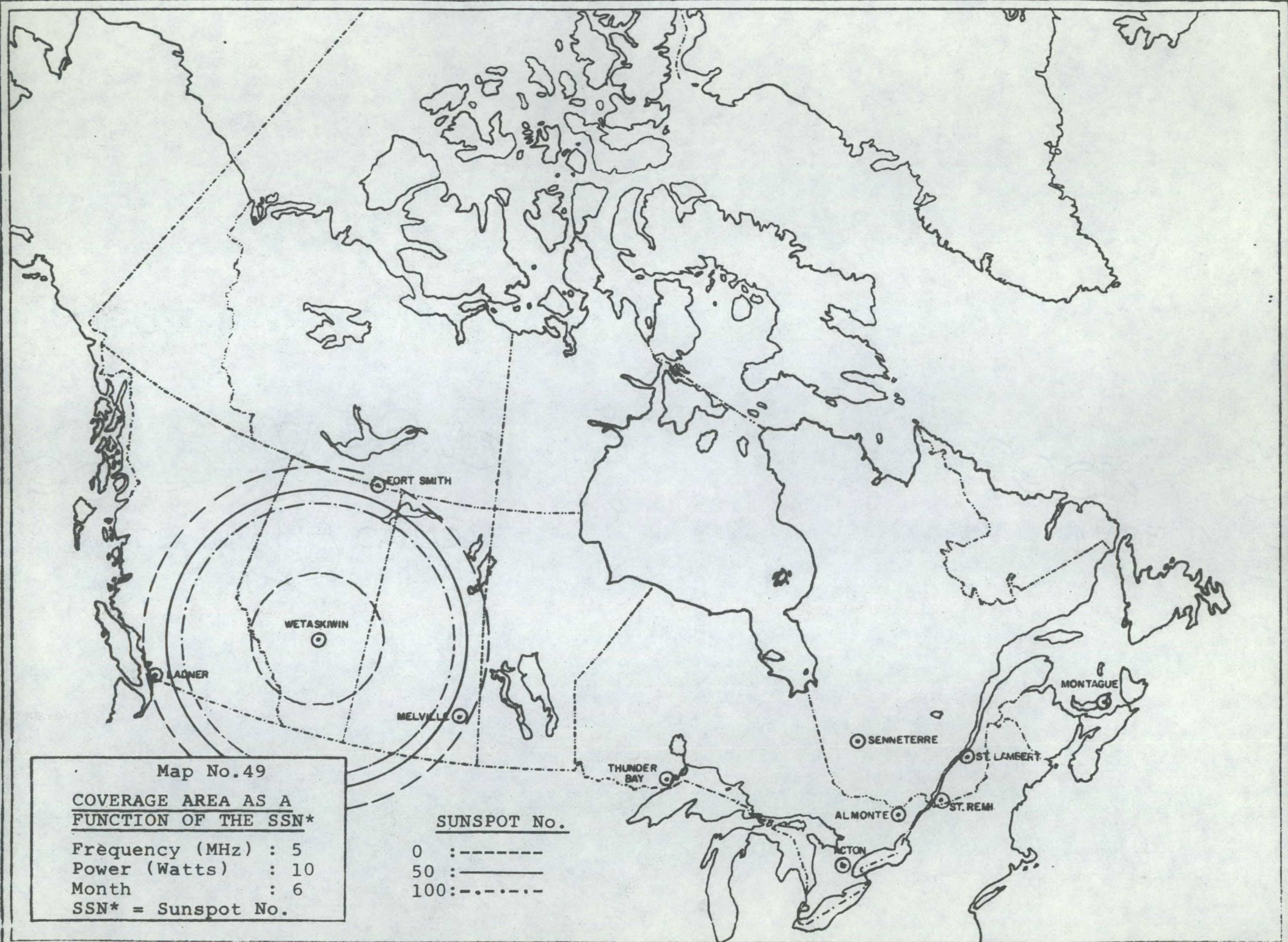
COVERAGE AREA AS A
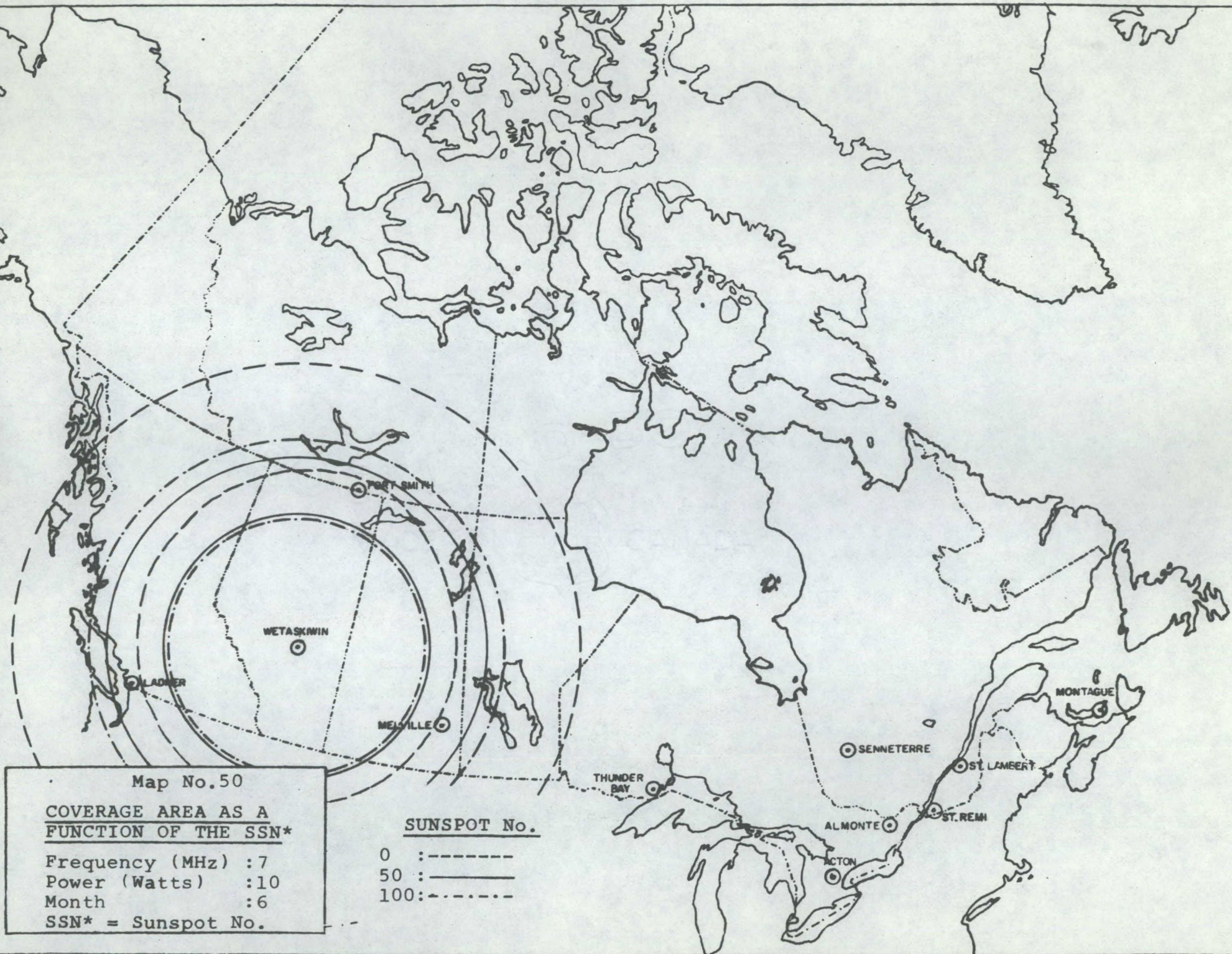FUNCTION OF THE SSN*

Frequency (MHz) : 5
Power (Watts)   : 10
Month   : 6
SSN* = Sunspot No.

SUNSPOT No.

0   : ----------
50 : ——————
100 : -·-·-·-·-

Map No.50

COVERAGE AREA AS A
FUNCTION OF THE SSN*

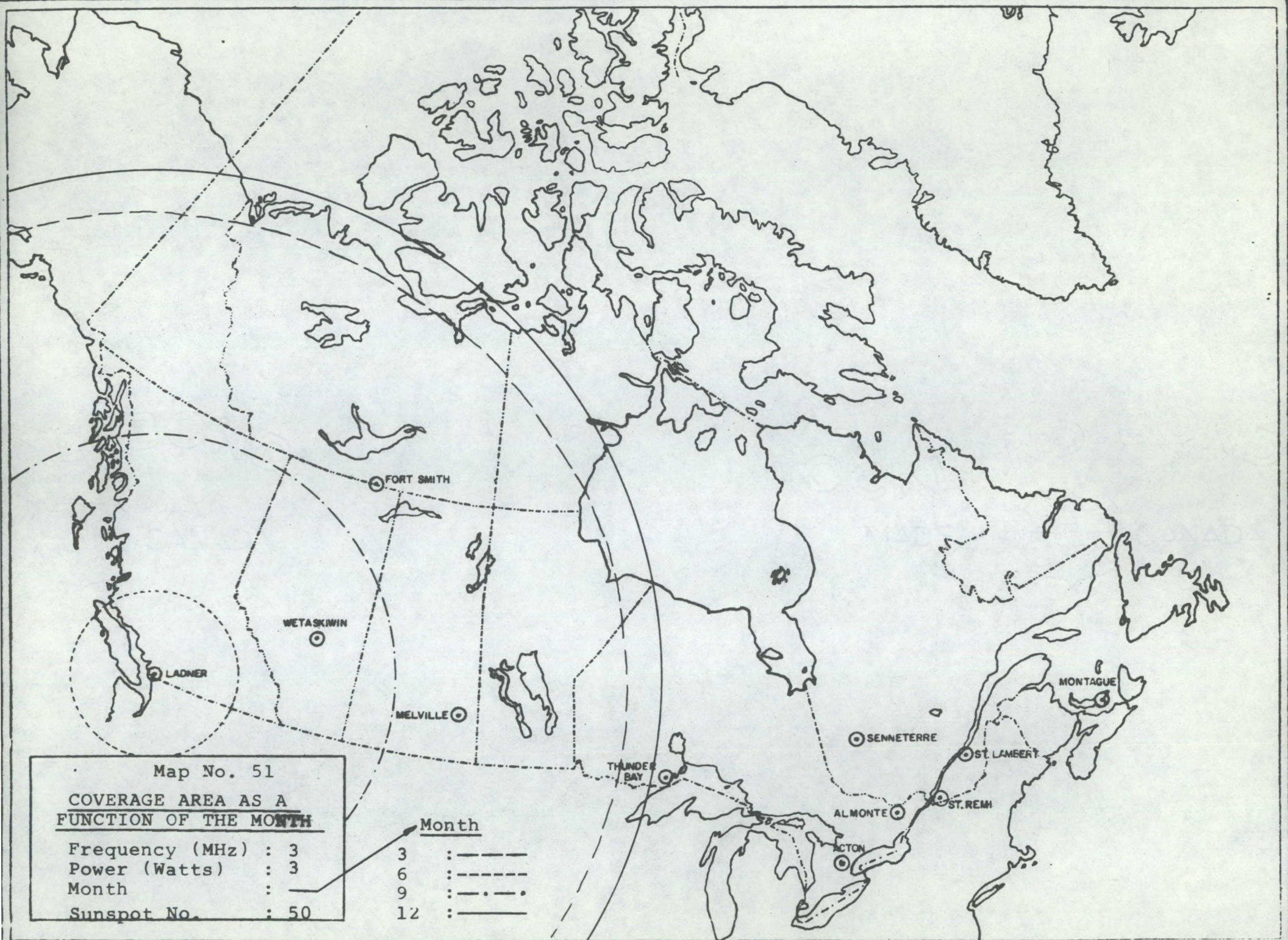Frequency (MHz) :7
Power (Watts)   :10
Month   :6
SSN* = Sunspot No.

SUNSPOT No.

0   :----------
50 :_____
100 :-----------

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

MONTAGUE

SENNETERRE

ST.LAMBERT

THUNDER
BAY

ALMONTE

ST.REMI

ACTON

Map No. 51

COVERAGE AREA AS A
FUNCTION OF THE MONTH

Frequency (MHz) : 3
Power (Watts)   : 3
Month   :
Sunspot No.   : 50

Month

3 : —————
6 : — — —
9 : —·—·—·
12 : —————

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

MONTAGUE

SENNETERRE

ST. LAMBERT

THUNDER BAY

ALMONTE

ST. REMI

ACTON

COVERAGE AREA AS A FUNCTION OF THE MONTH

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

SENNETERRE

MONTAGUE

ST. LAMBERT
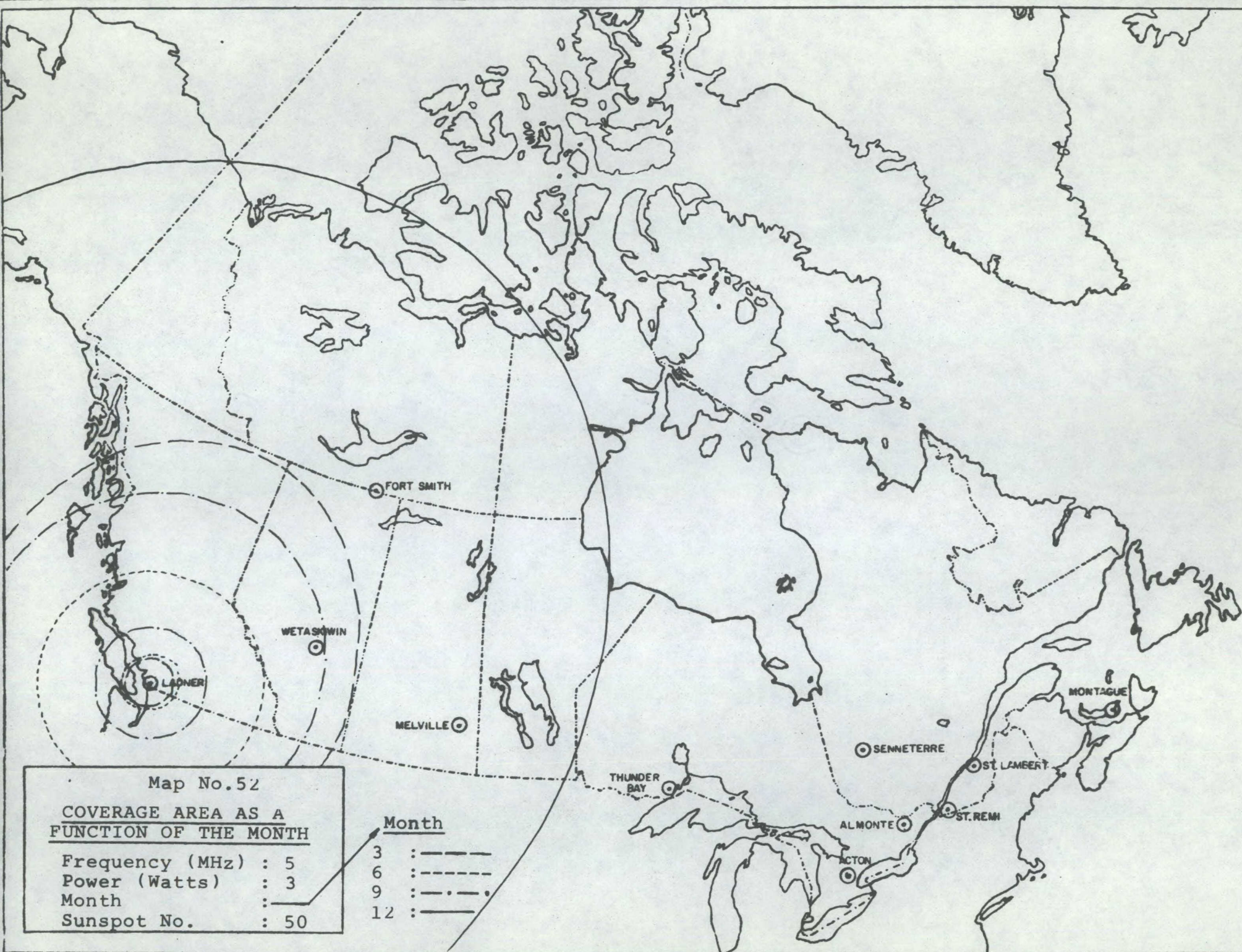
THUNDER BAY

ALMONTE

ST. REMI

ACTON

Map No. 52

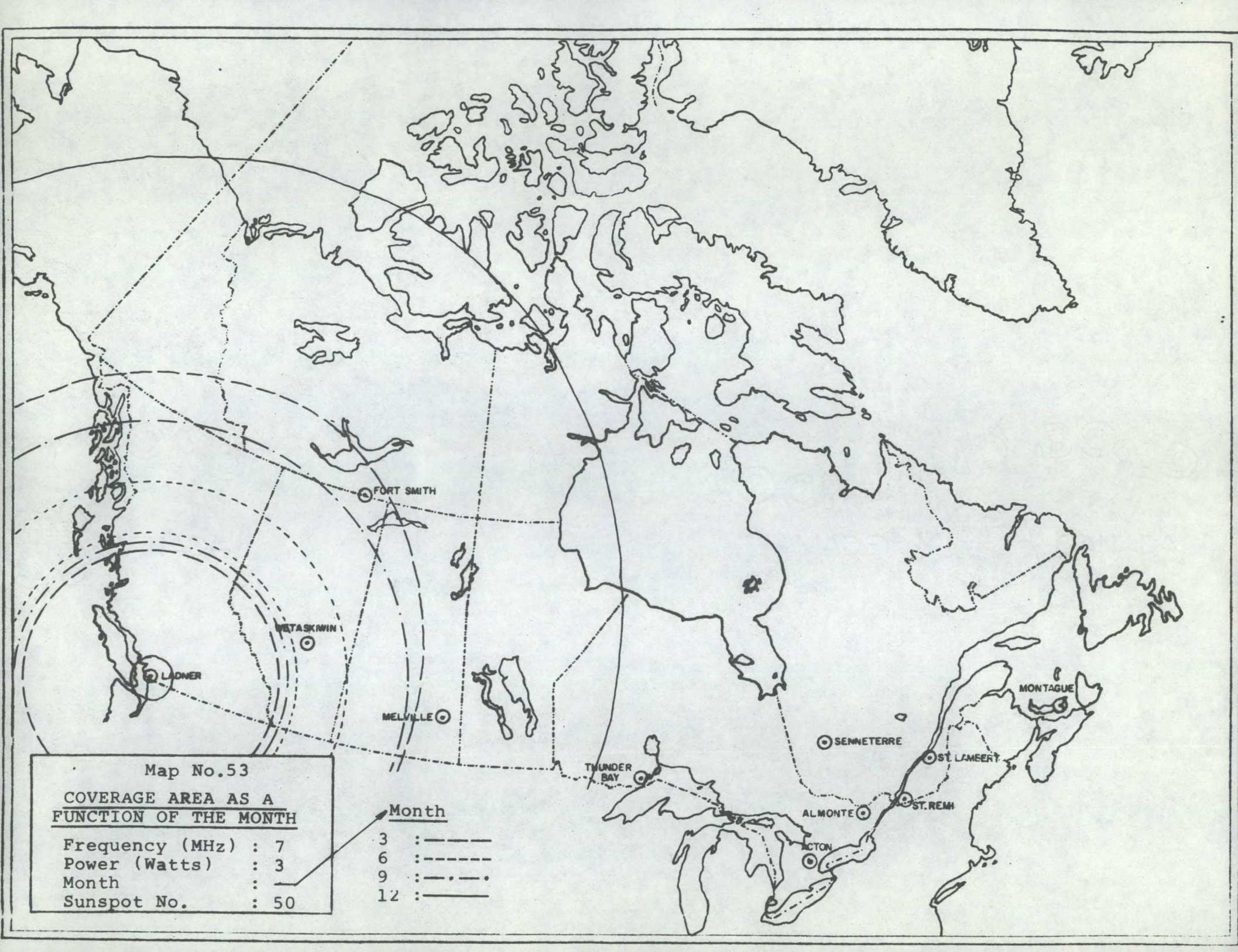COVERAGE AREA AS A
FUNCTION OF THE MONTH

Frequency (MHz) : 5
Power (Watts)   : 3
Month   :
Sunspot No.   : 50

Month

3 : ———
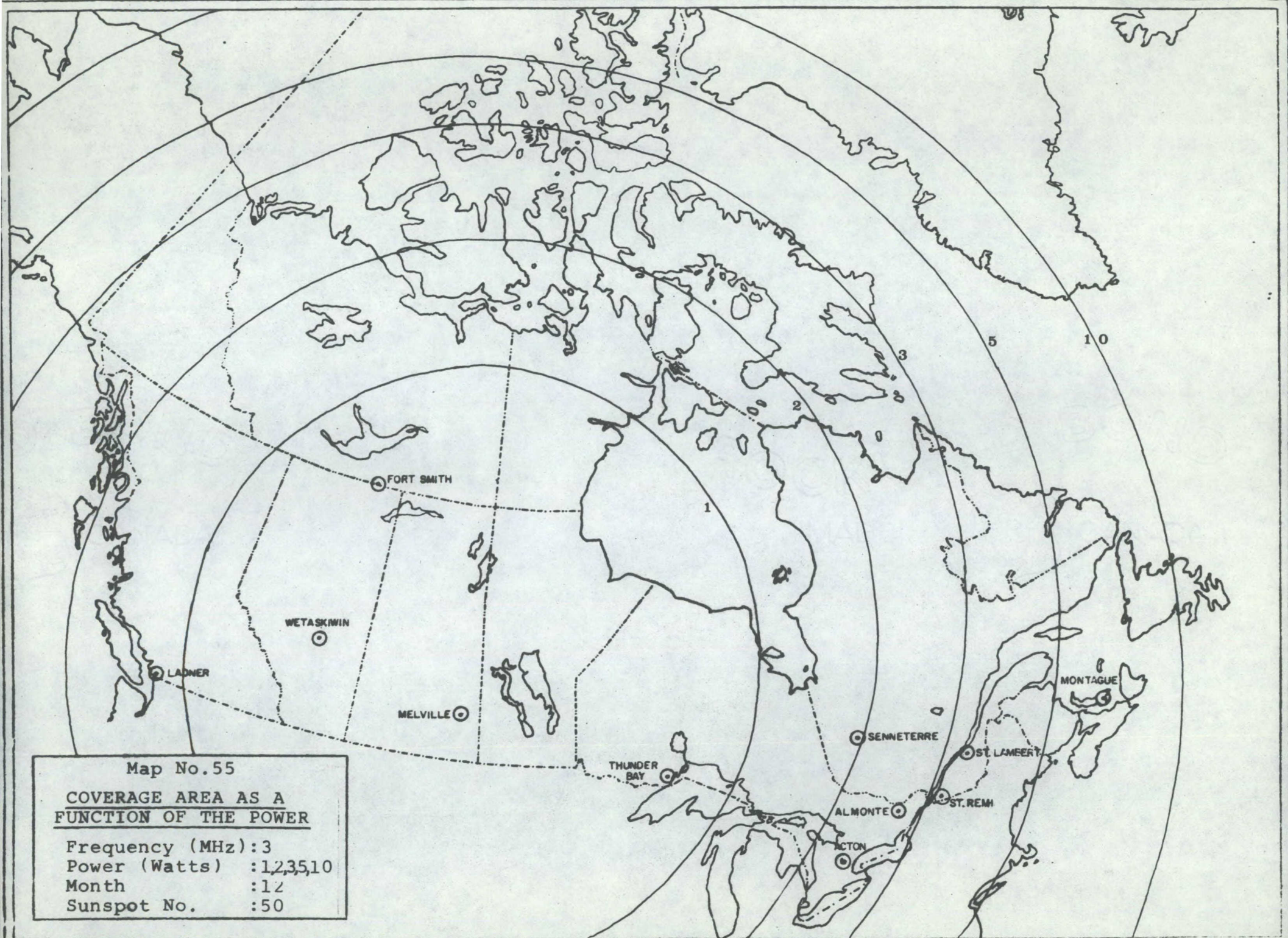6 : – – –
9 : –·–·
12 : ———

Map No.53

COVERAGE AREA AS A
FUNCTION OF THE MONTH

Frequency (MHz) : 7
Power (Watts)   : 3
Month   :
Sunspot No.   : 50

Month

3 : ― ― ―
6 : ‑ ‑ ‑ ‑
9 : ‑ · ‑ · ‑
12 : ――――

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

SENNETERRE

THUNDER BAY

ALMONTE

ST. LAMBERT

ST. REMH.

ACTON

MONTAGUE

Map No.54

COVERAGE AREA AS A
FUNCTION OF THE POWER

Frequency (MHz) : 3
Power (Watts)   : 1,2,3,5,10
Month   : 6
Sunspot No.   : 50

Map No.55

COVERAGE AREA AS A
FUNCTION OF THE POWER

Frequency (MHz):3
Power (Watts) :1,2,3,5,10
Month   :12
Sunspot No.   :50

Map No.56

THEORETICAL COVERAGE
FOR FROBISHER BAY

Frequency (MHz)	:	3
Power (Watts)	:	1
Month	:	12
Sunspot No.	:	50

Labels on map: FORT SMITH, WETASKIWIN, LADNER, MELVILLE, MONTAGUE, SENNETERRE, ST. LAMBERT, THUNDER BAY, ALMONTE, ST. REMI, ACTON

Map No. 57

THEORETICAL COVERAGE
FOR FROBISHER BAY

Frequency (MHz) : 5
Power (Watts)   : 1
Month   : 12
Sunspot No.   : 50

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

MONTAGUE

SENNETERRE

ST. LAMBERT

THUNDER BAY

ALMONTE

ST. REMI

ACTON

Map No.58

THEORETICAL COVERAGE
FOR FROBISHER BAY

Frequency (MHz) : 7
Power (Watts) : 1
Month   : 12
Sunspot No.   : 50

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

MONTAGUE
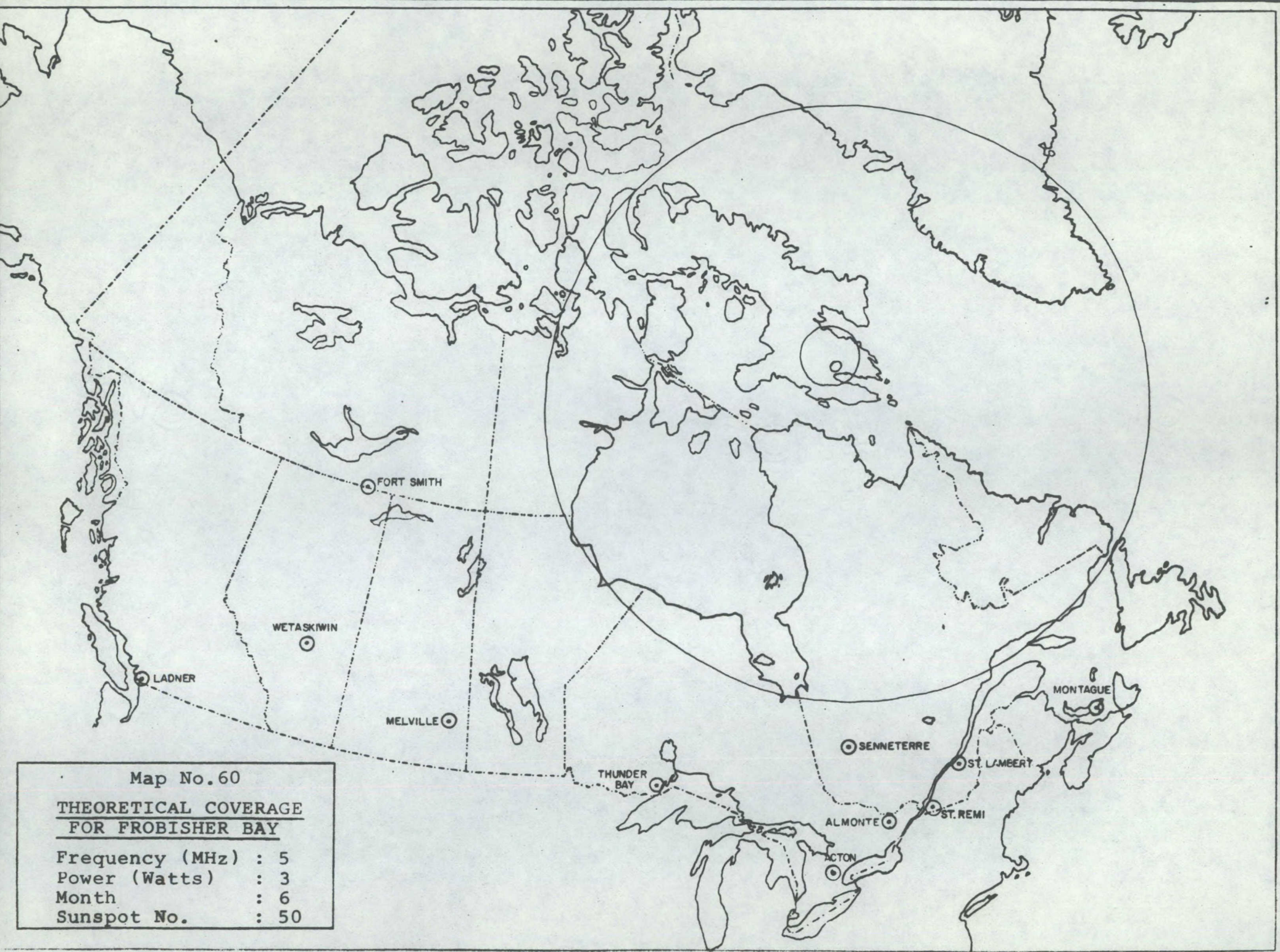
SENNETERRE

ST. LAMBERT

THUNDER BAY

ALMONTE

ST. REMI

ACTON

Map No. 59

THEORETICAL COVERAGE
FOR FROBISHER BAY

Frequency (MHz) : 3
Power (Watts)   : 3
Month   : 6
S unspot No.   : 50

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

MONTAGUE

SENNETERRE

ST LAMBERT

THUNDER BAY

ALMONTE

ST. REMI

ACTON

Map No. 60

THEORETICAL COVERAGE
FOR FROBISHER BAY

Frequency (MHz) : 5
Power (Watts)   : 3
Month   : 6
Sunspot No.   : 50

FORT SMITH

WETASKIWIN

LADNER

MELVILLE

MONTAGUE

SENNETERRE

ST. LAMBERT

THUNDER
BAY

ALMONTE

ST. REMI

ACTON
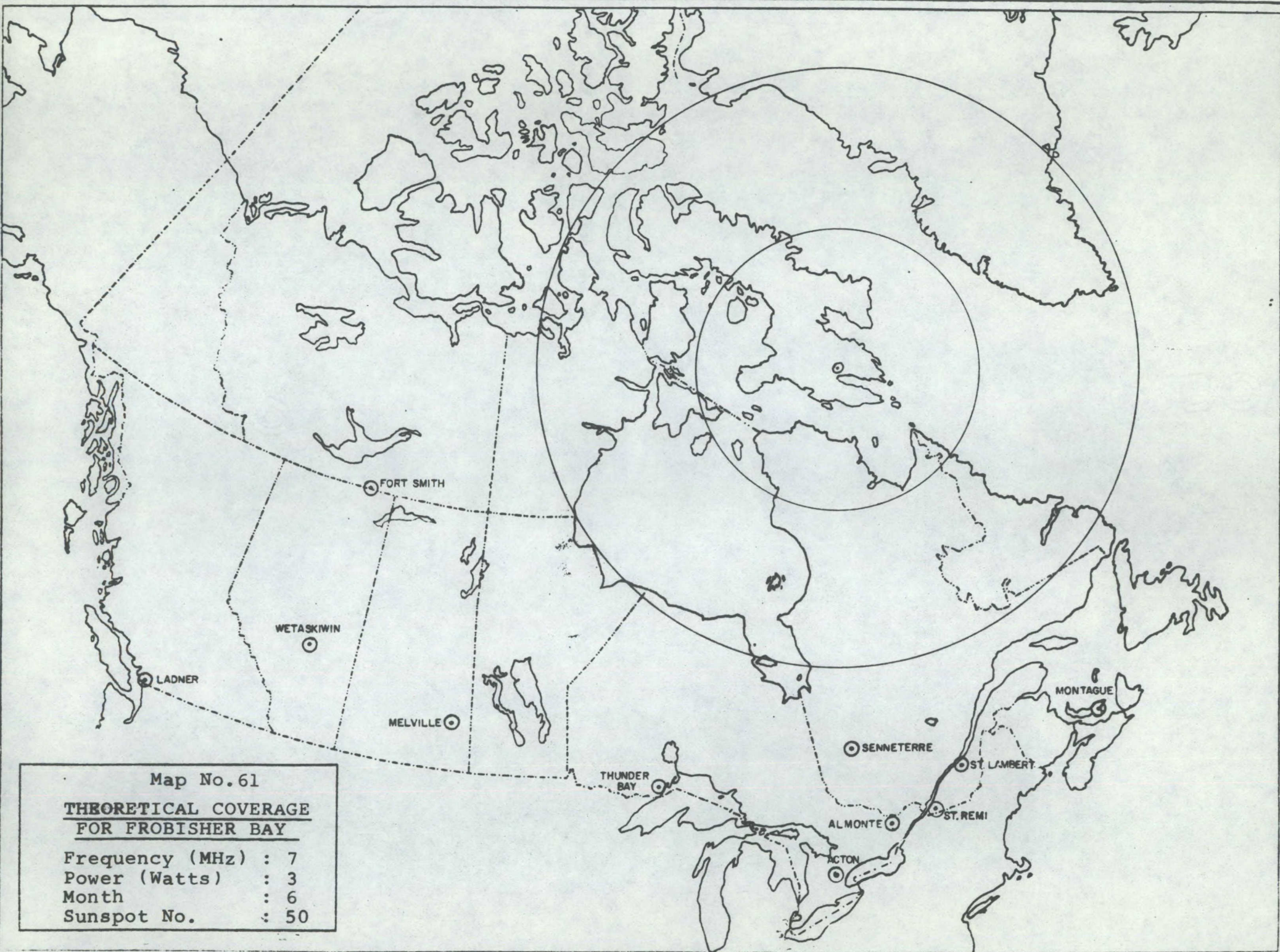
Map No. 61

THEORETICAL COVERAGE
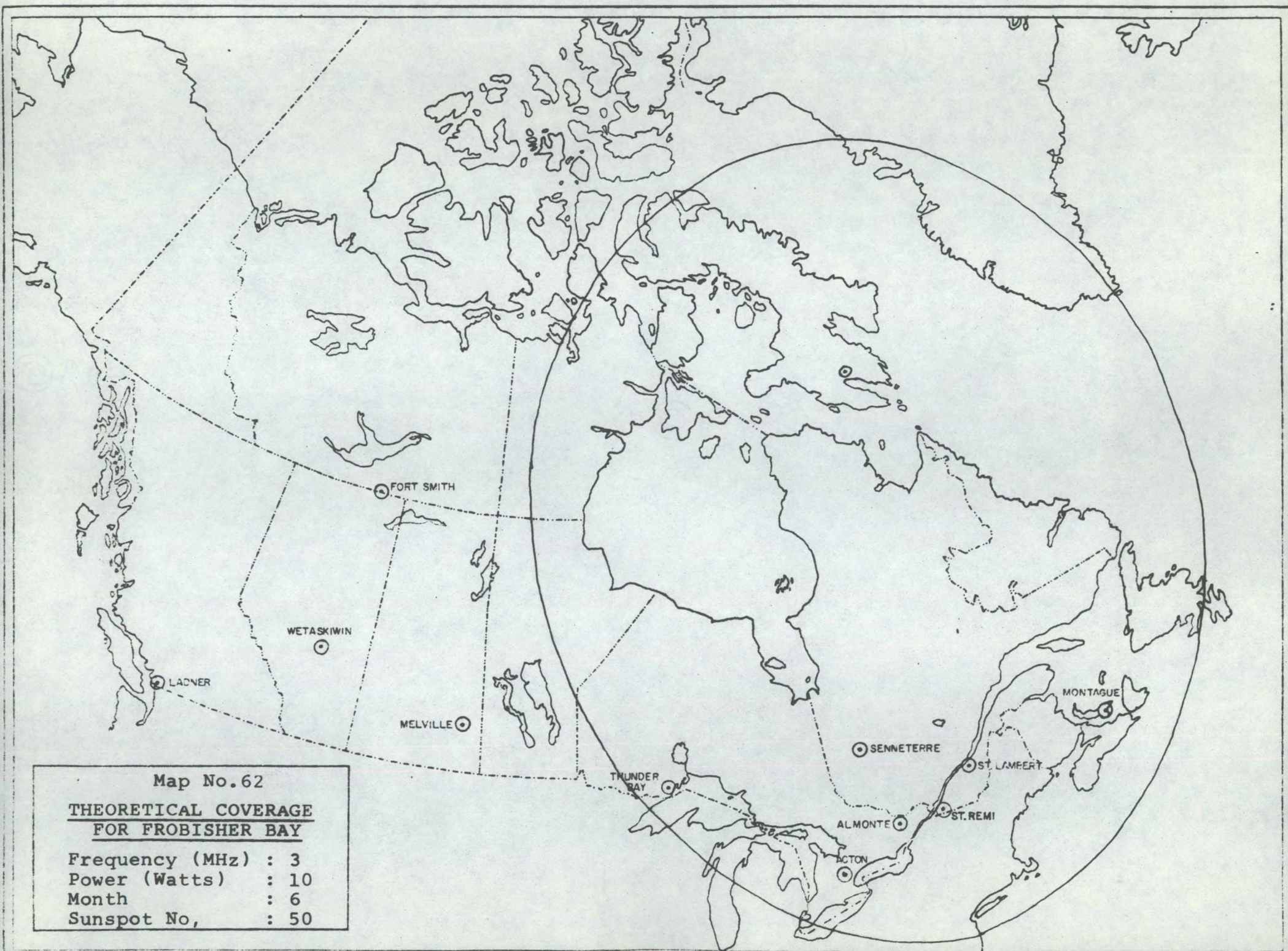FOR FROBISHER BAY

Frequency (MHz) : 7
Power (Watts)   : 3
Month   : 6
Sunspot No.   : 50

Map No. 62

THEORETICAL COVERAGE
FOR FROBISHER BAY

Frequency (MHz) : 3
Power (Watts)   : 10
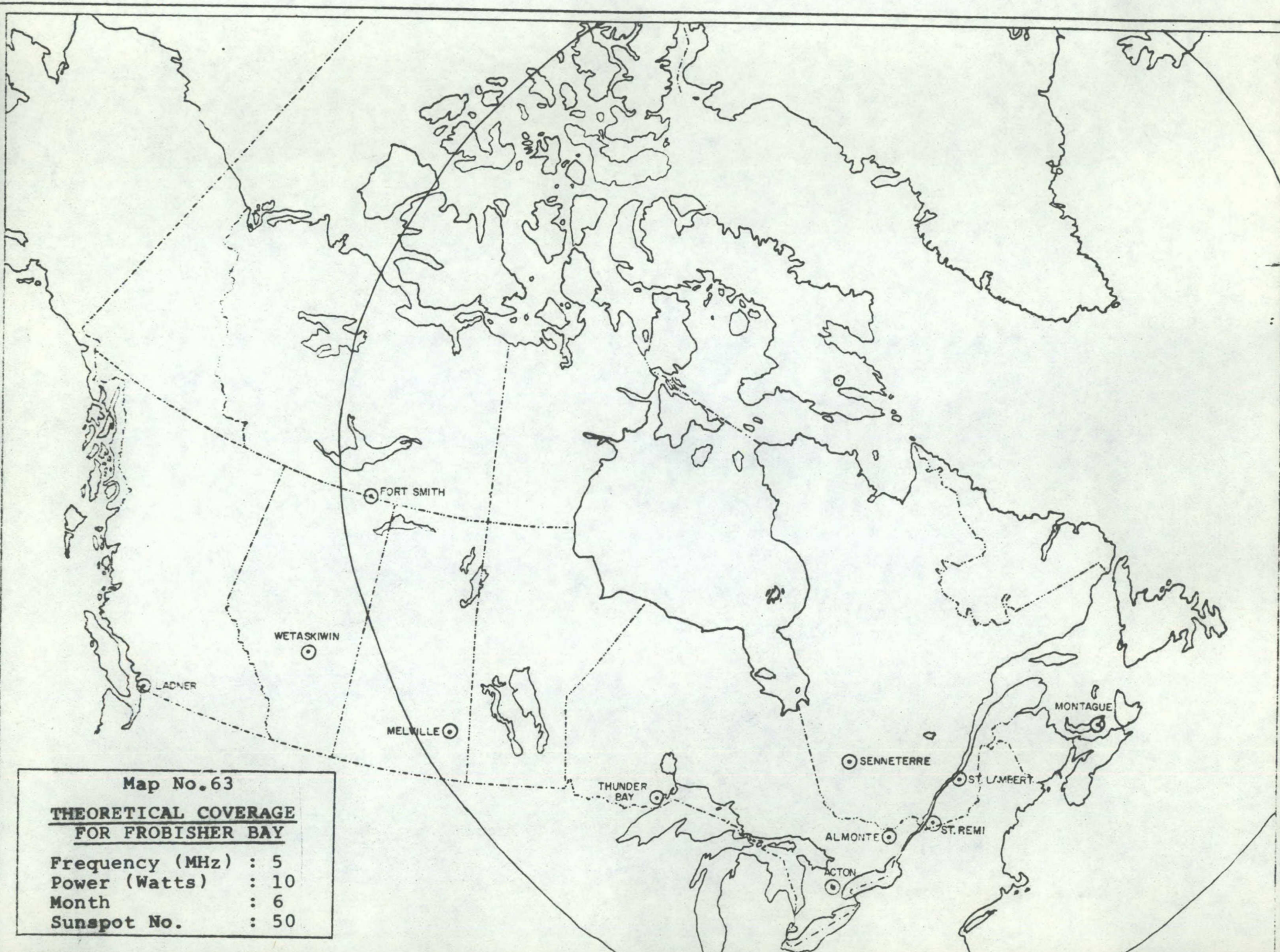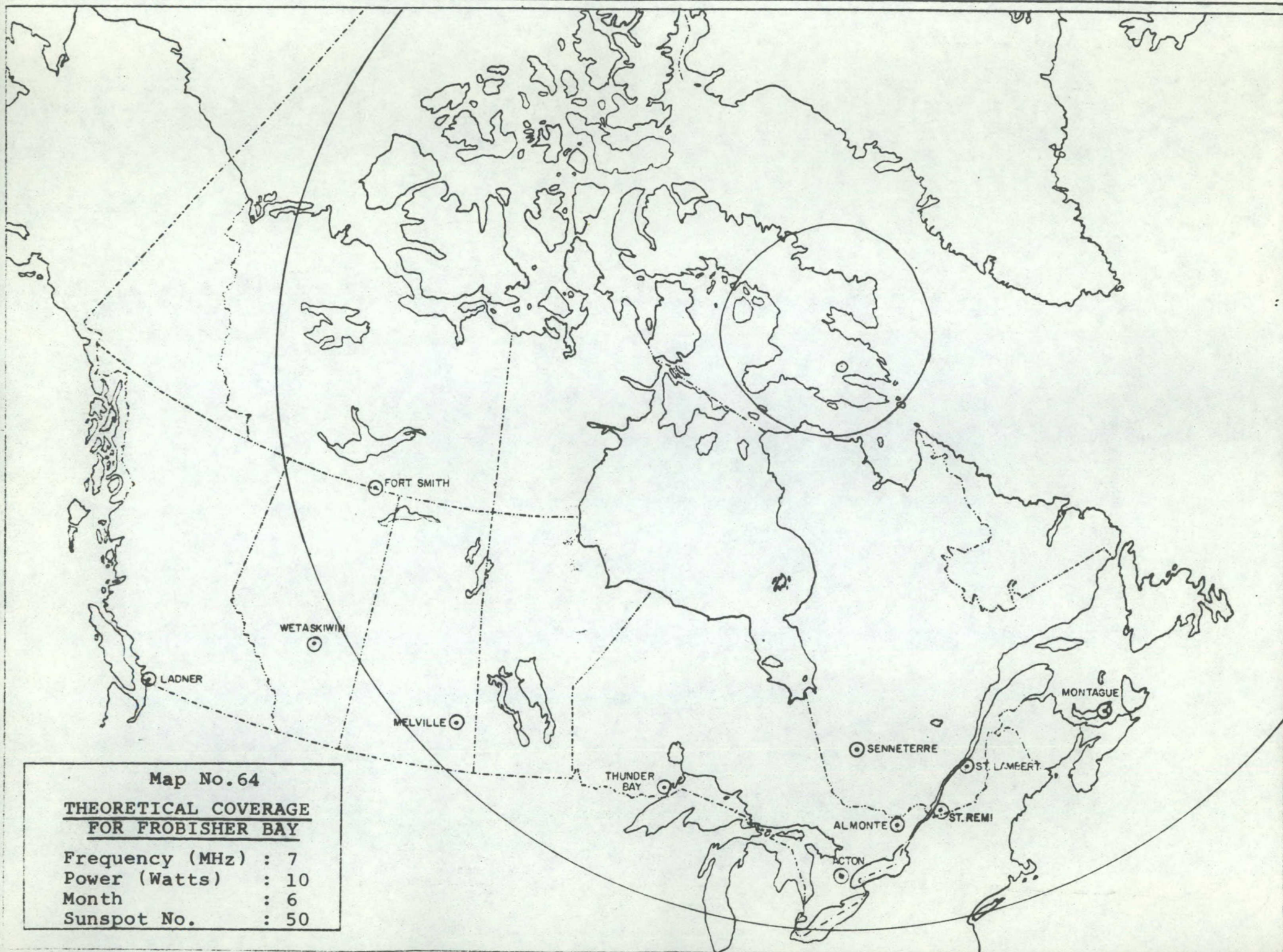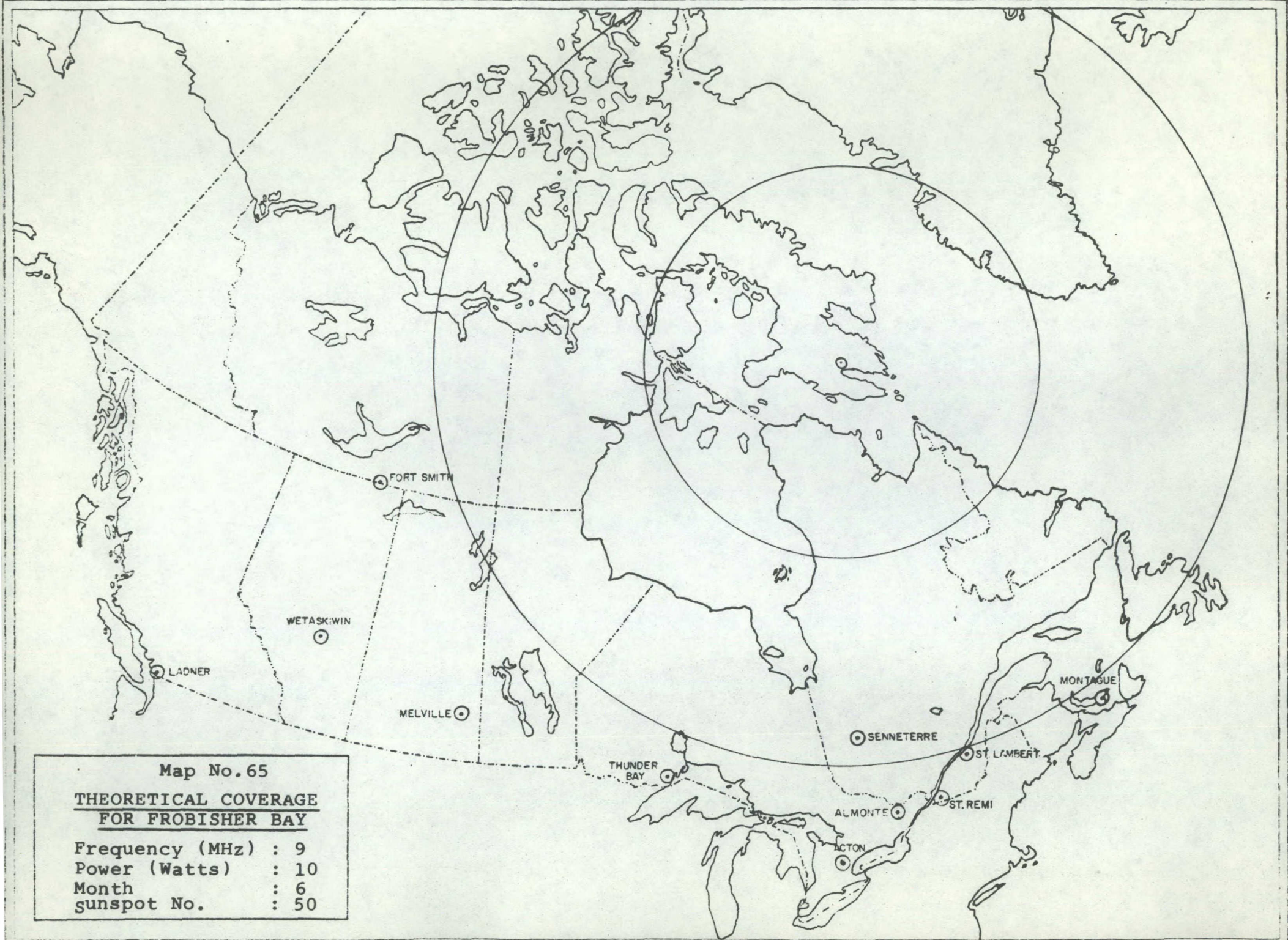Month   : 6
Sunspot No,   : 50

Map No. 63

THEORETICAL COVERAGE
FOR FROBISHER BAY

Frequency (MHz)	: 5
Power (Watts)	: 10
Month	: 6
Sunspot No.	: 50

Map labels: FORT SMITH, WETASKIWIN, LADNER, MELVILLE, THUNDER BAY, SENNETERRE, ST. LAMBERT, ALMONTE, ST. REMI, ACTON, MONTAGUE

Map No.64

THEORETICAL COVERAGE
FOR FROBISHER BAY

Frequency (MHz)	:	7
Power (Watts)	:	10
Month	:	6
Sunspot No.	:	50

Map labels: FORT SMITH, WETASKIWIN, LADNER, MELVILLE, THUNDER BAY, ACTON, ALMONTE, ST. REMI, SENNETERRE, ST. LAMBERT, MONTAGUE

Map No. 65

THEORETICAL COVERAGE
FOR FROBISHER BAY

Frequency (MHz) : 9
Power (Watts) : 10
Month   : 6
sunspot No.   : 50