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Analysis and validation of the electric terrain conductivity map of Mexico

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RESUMEN

En este trabajo se plantea la necesidad de implementar un nuevo mapa de la conductividad del terreno, tal que pueda ser usado para una adecuada y eficiente planificación del servicio de radio-difusión en ondas medias en México.

Se propone la utilización del Método de Atenuación del Campo con una metodología que simplifica la medición y el procesamiento de los datos registrados en los trabajos de campo, permitiendo obtener de manera precisa y bajo costo, los valores de conductividad eléctrica equivalente que caracterizan al territorio nacional.

PALABRAS CLAVE: Método de Atenuación del Campo, conductividad eléctrica, ondas medias, radio-difusión, cobertura, mapa de la conductividad del terreno, México.

ABSTRACT

This paper deals with the necessity of implementing a new electric ground conductivity map for planning and development of a medium-wave broadcasting service in Mexico.

The use of the Field Attenuation Method with a methodology that simplifies the operations and implementation of the work would allow for more efficient fieldwork, and would enable us to obtain precise information about the equivalent electric conductivity throughout Mexico.

KEY WORDS: Field Attenuation Method, electric conductivity, medium-wave, broadcasting, covering, terrain conductivity map, Mexico.

INTRODUCTION

The exploitation of medium-wave broadcasting, the elaboration of methods for their modernization, and the planning of new transmitters should not be carried out without first conducting a detailed analysis of the emitted fields and the radio-wave diffusion. Knowledge of the equivalent electric conductivity of the ground is especially important for the correct planning of medium-wave broadcasting projects. For example, if a l000 kHz broadcasting service is setup to provide a radial coverage of 120 km with a minimum field intensity of 0.5 mV/m, and if one assumes that the equivalent electric conductivity of this region is 10 mS/m, then a 5 kW transmitter is sufficient to provide the desired radial coverage and field intensity. However, if the actual equivalent electric conductivity of the ground is 5 mS/m, then the radial coverage of the 5 kW transmitter is only 90 km and, therefore, the system would fail to provide the desired radial coverage and field intensity. Further, if the actual equivalent electric conductivity of the region is greater than 10 mS/m, then one could use a less powerful transmitter which would save energy and materials and which would also avoid interference with other emissions of similar frequency. Because of this, it is necessary to construct an accurate nation-wide map of the equivalent electric conductivity of the ground for planning regional medium-wave broadcasting services.

Typically, equivalent electric conductivity is determined via measurements of the intensity of the field emitted from several transmitters (Stokke, 1978). To construct a nation-wide map of the equivalent electric conductivity using this procedure is not practical given the time and costs involved. Thus, in Mexico a l:3 500 000 scale national map of the electrical conductivity (S.C.T., 1981, Figure 1) of the ground was constructed by determining, for the most part, this conductivity indirectly from geological, geomorphological, edaphological characteristics, etc. However, this map should not be considered entirely accurate due to the impossibility of taking into account all the various factors that influence the magnitude of the equivalent electric conductivity in a given region (Fernández, 1975).

The present study focuses on the necessity of creating a more accurate map of the ground conductivity based on data obtained from measurements of the electromagnetic field emitted by several medium-wave broadcasting transmitters, using a simplified and efficient method to considerably lower the cost of fieldwork.

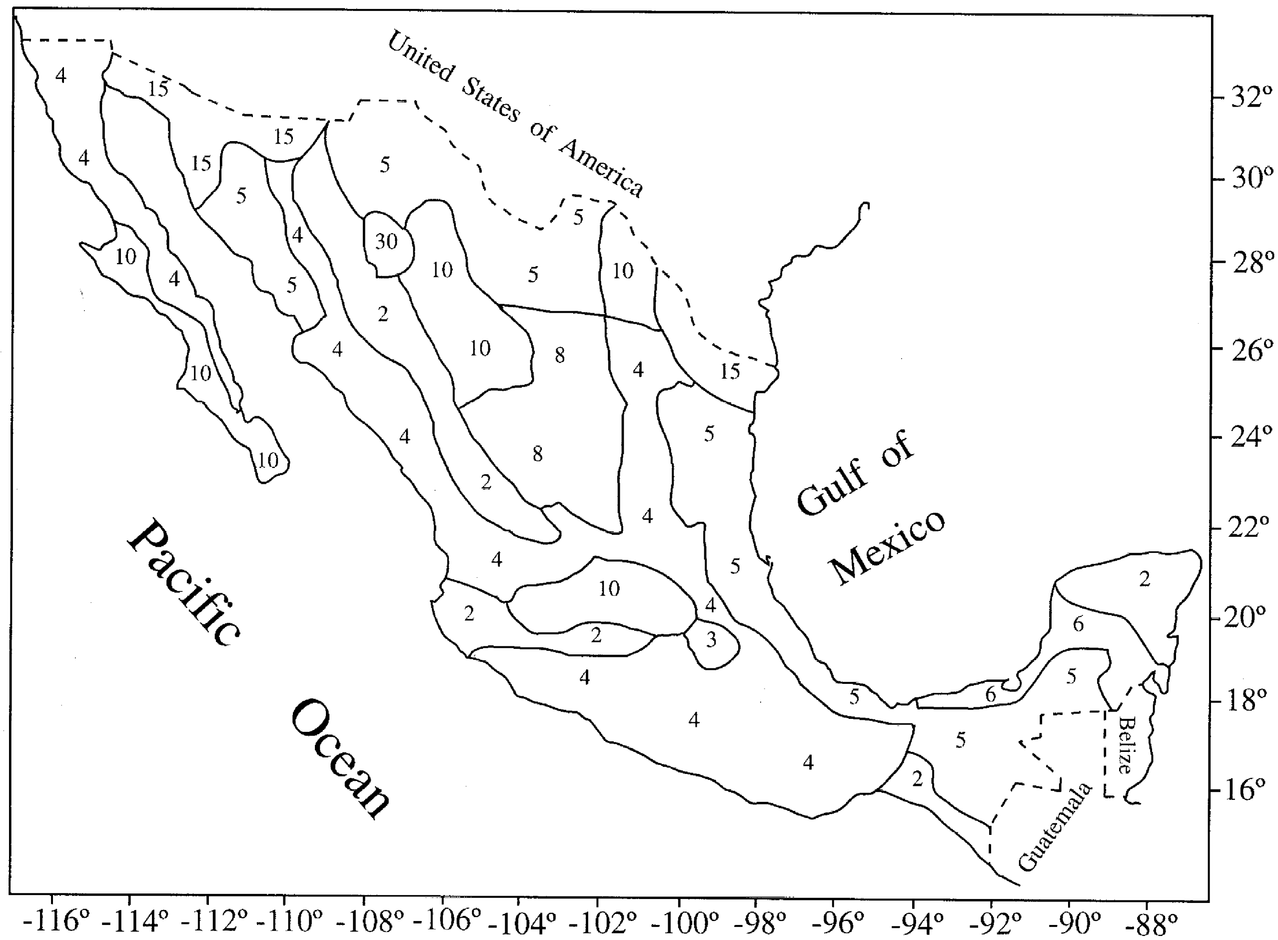

Fig. 1. Simplified map of the electric terrain conductivity of the Mexican Republic (S.C.T., 1981). The values on the map are given in mS/ m.

THE EQUIVALENT ELECTRIC CONDUCTIVITY

Middle band radio-waves propagate both through the earth's surface and through the atmosphere (Figure 2). Of particular interest to the determination of the equivalent electric conductivity of the ground are the emitted waves travelling, for the most part, along the earth's surface, or *surface waves*. The amplitude of these waves is attenuated, the amount of attenuation, W, being a function of the wavelength emitted, λ, the distance from the transmitter, *R*, and the equivalent electric conductivity of the ground between the transmitter and receiver, σ_{eq}. The relationship between the field intensity, *E*, at a distance R from the transmitter generated by a medium-wave transmitter and σ_{eq}, is

$$E = \frac{245\sqrt{PD}}{R} W(R, \lambda, \sigma_{eq}), \qquad (1)$$

where: *E* - Field Intensity at R distance from the transmitter (mV/m).

D - Directional gain coefficient (non-dimensional).

P - Transmitter power (kW).

W - Attenuation (non-dimensional).

λ - Wavelength (meters).

σ_{eq} - Equivalent electric conductivity of ground (mS/m).

R - Distance between measuring point and transmitter (meters).

Three other waves (Figure 2) are also present that may interfere with the surface wave: namely, the *direct wave*, the reflected or *indirect wave*, and the *sky wave*. The direct wave travels a straight path through the air from the transmitter to the receiver. The reflected or indirect wave is reflected once from the earth's surface. Its travel path length is roughly equal to that of the direct wave, however, its polarity is opposite that of the direct wave. Thus, these two waves cancel at the receiver.

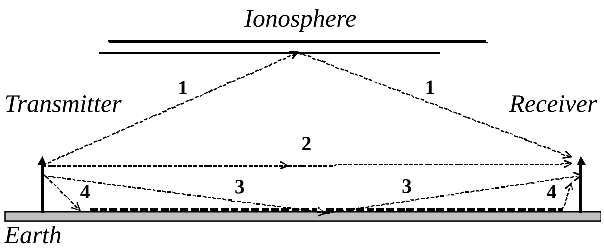

Fig. 2. Type of radio-waves and its paths from transmitter to receiver. 1) sky wave, 2) direct wave, 3) reflected wave, 4) surface wave.

The energy reflected at the base of ionosphere layer E is termed the sky wave. The sky wave produces amplitude variations of the surface wave signal, which adversely affects the determination of the equivalent electric conductivity. During the day, layer D of the ionosphere strongly absorbs these waves, thus the problems associated with the sky waves are only apparent at night, when layer D vanishes. In other words, the reception is stable during the daytime, while at night, the volume and quality of the reception are frequently unstable.

In practice, the equivalent electric conductivity can be expressed in terms of the "effective electric conductivity", σ_{eff} and the "apparent electric conductivity", σ_r, which is due to topographic relief, via the relationship

$$\sigma_{eq}^{-\frac{1}{2}} = \sigma_{eff}^{-\frac{1}{2}} + \sigma_r^{-\frac{1}{2}} \quad . \tag{2}$$

Other factors, such as the presence of dams, vegetation and the temperature also influence the equivalent electric conductivity; however, their effects are not significant for the medium-wave frequency band.

The effective electric conductivity is a function of the following three factors (C.C.I.R., 1974):

(1) Physical and mineral characteristics of the medium through which the wave is transmitted: Metallic elements and-or salts present within the transmission medium are significant factors affecting the conductivity. Their presence or absence increases or decreases the conductivity, respectively (Keller and Frischknecht, 1966). Since the attenuation is inversely proportional to the equivalent electric conductivity (Figure 3), the presence of these elements decreases the degree of attenuation.

(2) Humidity of the ground: The humidity of the ground is an important factor affecting the electrical conductivity. Even if a medium is resistive, if it has high porosity and the pores are saturated with a conductive fluid (water and salts), the electric conductivity is increased considerably (Keller and Frischknecht, 1966).

(3) Frequency of the wave: The frequency of the wave is one factor which controls how deep the electric field will penetrate within the ground, the depth of penetration being inversely proportional to the frequency. Thus, the effective electric conductivity determined from lower frequency waves will depend on the electric conductivity of the material lying

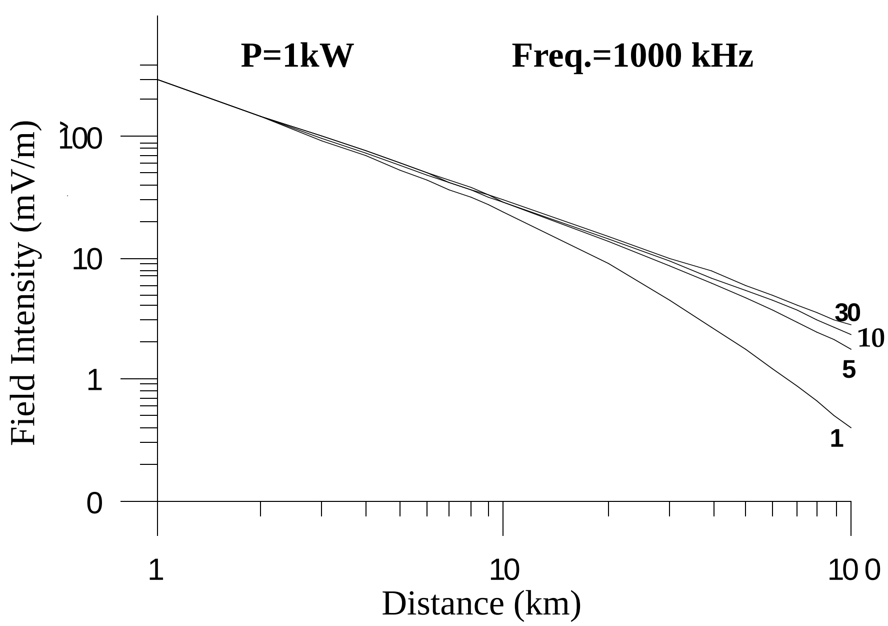

Fig. 3. Relation between field intensity and the distance to the transmitter that emitted with a power of 1 kW, a radio-wave with frequency of 1000 kHz . The values of the curves are the electrical conductivity given in mS/m.

at deeper depths than that determined from higher frequency waves. If the electric conductivity of the deeper material is different than the upper material, the equivalent electric conductivity determined from low frequency waves will differ from that calculated from high frequency waves. Skin depth, δ, defined as the depth at which the magnitude of the field is 37% of its surface value (Orellana, 1974), is given by

$$\delta \approx 503\sqrt{\frac{1}{f\sigma}} \tag{3}$$

where: f - frequency of wave (Hertz).

σ - electrical ground conductivity (mS/m).

δ - skin depth (meters).

The depth of penetration is also inversely proportional to the electric ground conductivity. If the ground is highly conductive, the energy is channeled within a region located just under the surface, little energy penetrates deeper into the ground. This effect allows the signal to be detected at large distances. In contrast, when the electric ground conductivity is low, waves penetrate deeper into the medium, and the distance from the transmitter at which the signal can be detected is less than that associated with a highly conductive medium.

The apparent electric conductivity arises from the effects of irregularities of the relief.

The fundamental role of the relief in the diffusion of electromagnetic waves is well known, and empirical algorithms (e.g. Kashprovskii, 1965; Kuzubov 1966) have been established to quantify its effect on the equivalent electric conductivity. One such relationship (Kuzubov, 1966) which has been implemented successfully in Cuba (Delgado and Pascual, 1999) is

$$\sigma_r = 0.168\frac{\mathrm{L}^3}{\mathrm{H}^4} \tag{4}$$

where: L - average length of terrain elevations (meters).

H - average height of terrain elevations (meters).

σ_r - apparent electric conductivity due to the relief (mS/m).

The influence of relief in the scattering of radio-waves can be so large that it dominates the physical-chemical properties of the medium, becoming the controlling factor determining the propagation of the surface wave. This scattering effect has been analyzed as a decrease of the equivalent electric conductivity of the ground in the path from the transmitter to the receiver.

DATA

The data used in this study consist of a compilation of all available electromagnetic field intensity measurements, carried out with diverse objectives, obtained from multiple technical reports (TEC reports, Table 1) of the Department of Radio of the Secretaría de Comunicaciones y Transportes (S.C.T.) located in Mexico D.F.

These data have been collected at transmitters in almost all the states of Mexico. Also, the Electric Terrain Conductivity Map of Mexico to scale 1:3 500 000 (S.C.T., 1981, Figure 1) is used for comparison.

Table 1

Example of data used for the calculation of the electric equivalent conductivity.

Transmitter: XELTZ-AM		Located: El Puertecito (Aguascalientes)
Frequency: 740 KHz		Power: 1 kW
Profile's Azimuth (degrees): 186		
Distance (km)	Field Intensity (mV/m)	Notes
1.4	191	———
2.2	130	———
2.8	95	———
3.5	75	———
4.5	52	Close to power line
5.5	42	———
6.5	35	———
7.5	28	———
8.5	20	Close to power line
11.5	19	———
14.5	15	———
16.0	14	———
17.5	12	———
20.5	10	———

METHODS

In a region of flat topography, which is free of obstacles such as forests, dams, buildings, etc., the value of the equivalent electric conductivity will be roughly equal to the effective electric conductivity. However, generally this is not the case, and as a result, the equivalent electric conductivity depends on several factors which are not easily determined. One could assign an approximate value according to the relief and soil type present in an area (Pascual *et al*., 1995); however, the accuracy of this estimation would be quite uncertain.

To establish an accurate value of the equivalent electric conductivity, it is necessary to either (A) use equivalent electric conductivity patterns taking into account all the influential factors, or (B) calculate the equivalent electric conductivity from actual measurements of the electromagnetic field intensity.

To employ the first option, it is first necessary to establish the patterns from actual measurements of the electromagnetic field intensity. Although this option has been employed successfully in Cuba (Barandela and Delgado, 1993), in general, the accuracy of this method is questionable as local factors may differ from those present in the area where the pattern was established.

The second option is the most accurate. However, it is very expensive to use the traditional method whereby measurements are obtained along extended profiles, oriented at several azimuths with respect to the transmitter location. In addition to the expense, the traditional method has two other drawbacks (Stokke, 1978); namely, (I) in most cases, the desired measuring point is not easily accessible (i.e. absence of roads or highways), or the site is not ideal for obtaining good measurements (i.e. presence of high-tension lines, overpopulation, etc.), and (II) the value of the conductivity determined by the hand-graphical method is subject to interpretation biases. i.e., it depends on who is reading the charts. To alleviate these drawbacks, the simplified field attenuation method, presented in the following section, is used in our study.

Although other simplified methods have been proposed, such as the Wave-Tilt method (Delgado and Pascual, 1999), our opinion is that the Field Attenuation Method with simplified methodology is the most appropriate method for regional surveys due to the considerable savings in the time required to make the measurements. This has been shown to be the case in Cuba (Delgado and Pascual, 1999) where the simplified wave attenuation method was conducted jointly with the Wave-Tilt method. The two methods produced similar results, however, the need to orient the antenna in the Wave-Tilt Method considerably increases the time needed to make the measurements.

The Field Attenuation Method with Simplified Methodology

The Field Attenuation Method determines the attenuation of the electromagnetic field strength when the surface-wave is propagated along a particular path (Kashprovskii and Kuzubov, 1971). In this work, the equivalent electric conductivity was calculated from measurements of the electromagnetic field employing the following simplified methodology (C.C.I.R., 1982: Pascual *et al*., 1995). In this method, the electromagnetic field intensity Ei is determined for each measurement location, i. As most antennas used by medium-wave broadcasting are of the vertical dipole type, equation 1 becomes

$$E_i = \frac{300\sqrt{P}}{R_i} W_i \quad . \tag{5}$$

The value E_i is compared with the electromagnetic field intensity measured near the transmitter, which is assumed to be equivalent to the field intensity output from the transmitter E_0. From this comparison, it is possible to determine the attenuation W of the electromagnetic wave at a distance R_i from the transmitter. Specifically, given n+1 pairs of values R_i and E_i (i = 0, l ,.....n), E_i (equation 5) is normalized by E_0, to yield the set of equations

$$\frac{E_i R_i}{E_0 R_0} = \frac{W_i}{W_0} \ \ ; \ \mathrm{i} = 1, 2, \ ..., \ \mathrm{n} \ , \tag{6a}$$

where W_i is the attenuation function at measurement point i. If we assume that the point of reference at which we measured E_0 and R_0 is sufficiently close to the transmitter, then $W_0 \approx 1$ if so then equation (6a) can be rewritten as

$$W_i = \frac{E_i R_i}{E_0 R_0} \ \ ; \ \mathrm{i} = 1, 2, \ ..., \ \mathrm{n}. \tag{6b}$$

It is important to position the initial point R_0 sufficiently close to the transmitter so that the error in assuming that W_0 = l is small. However, if the point is too close to the transmitter, not only will the radiated component be measured, but also an induced and static component as well (i.e. W_0 will be greater than unity). Several empirical studies (e.g., Kashprovskii and Kuzubov, 1971) have been undertaken to determine acceptable distances for Ro. Such studies indicate that, in general, any value of R_0 for which $1.5\lambda \leq R_0 \leq \lambda^2\sigma$ is acceptable, and that this condition is achieved in practice at a distance of 1 km. When R_0=1 km, equation 6b simplifies to

$$W_i = \frac{E_i R_i}{E_0} \tag{7}$$

The electric conductivity can be calculated from W via the concept of the numeric distance, ρ, via the relationship

$$\rho_i = \frac{(0,3 - W_i) + \sqrt{(0.009 + 4.2W_i - 3.2W_i)}}{1.2W_i} \quad . \tag{8}$$

In conjunction with the relationship between the numeric distance and the electric parameters of the terrain (Keller and Frischknecht, 1966), which for a homogeneous medium is

$$\rho_i = \frac{\pi * R_i * f)}{1.8 * 10^4 \sigma\lambda} \ , \tag{9}$$

where: σ - electric conductivity (mS/ m).
λ - wavelength (meters).
f - frequency of the radio-wave (MHz).
R_i - distance from the transmitter to measurement point i (km).

If $f = c/\lambda$, where c is the speed of light (3 x 10^5 km/s), then:

$$\rho_i = \frac{30 * \pi * R_i}{1.8 * \sigma \lambda^4} \quad .$$

For a homogeneous medium with plane horizontal surface, $\sigma = \sigma_{eq}$ and σ_{eq} can be obtained from the relationship:

$$\sigma_{eqi} = 52.36 * 10^3 \frac{R_i}{\lambda^2 \rho_i} \quad . \qquad (10)$$

Equation 10 is not strictly applicable if the conductivity of the terrain changes along the profile. However, in practice this restriction is circumvented by measuring, at each point of the profile, the intensity of the field generated by several transmitters. For example, given two transmitters operating at different frequencies (Figure 4), and given an inhomogeneous medium located between the two transmitters which consists of two zones of differing σ_{eq} (the boundary between these zones being located between points 3 and 4), then the electric field strength for each transmitter can be measured at points $i(i = 1, 2, ..., n)$ located between the transmitter. Let $\sigma_{i,j}$ be the value of the equivalent electric conductivity measured a point *i* with respect to transmitter *j*.

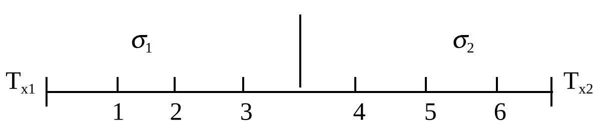

Fig. 4. Profile of measurements (from the point 1 to the n) carried out with regard to the transmitters T_{x2} and T_{x2} on a heterogeneous medium with conductivities σ_1 and σ_2.

In the case illustrated in Figure 4, *i*=1,2.....,n, and *j*= 1, 2. If the medium between the two transmitters is homogeneous, then $\sigma_{1,1} = \sigma_{1,2}$ and the use of equation 10 is valid. If $\sigma_{1,1}$ is not equal $\sigma_{1,2}$ (as is the each for the situation presented in Figure 4) then the medium is inhomogeneous and one proceeds as follows. The values $\sigma_{1,1}$ (i = 1 ,2,...,n) are calculated and compared with $\sigma_{1,1}$. Next, one determines the measurement point k at which $\sigma_{k,1}$ is not equal to $\sigma_{1,1}$ (in the case illustrated in Figure 4, k= 4). Then the medium between transmitter 1 and point k-1 is homogeneous and equation 10 is valid for calculating σ_{eq} from the signal received from transmitter 1 at points 1 to k-1 . At points k to n, σ_{eq} is calculated from the signal received from transmitter 2.

This procedure was used in determining σ_{eq} along several profiles from a series of measurements of the electromagnetic field generated by transmitters located in different parts of Mexico.

RESULTS AND DISCUSSION

National Study

The first step of the analysis was a compilation of all the intensity measurements filed in the TEC reports (Table 2). Such information is available for transmitters located in almost every state of Mexico (Figure 5a).

Two difficulties were encountered when trying to use this information to determine σ_{eq}. First, in most cases, the main objective of the original measurements was to verify the correct operation of the transmitters, and not to determine σ_{eq}. Consequently, the extent and location of the measured profiles are not entirely ideal for our objectives. Second, in general, there is no measurement of E_0 at 1 km from the transmitters. However, this problem can be resolved in that E_0 can he calculated from the radiated power (P) from

$$E_0 = 300\sqrt{P} \quad . \qquad (11)$$

Regardless typical values of σ_{eq} could be obtained in small regions in some of the states of Mexico and compared with the estimated values (Table 2), comprising the 1:3 500 000 scale Electric Terrain Conductivity Map of Mexico (S.C.T., 1981; Figure 1).

This comparison indicates that there is a significant difference between the calculated σ_{eq} and those of the S.C.T. map. Thus, if our methods indeed produced reliable values, then our results indicate that the estimation method is insufficient to produce accurate values of σ_{eq}, most likely due to the difficulty of considering every factor which may influence σ_{eq}.

Local study around the cities of Chihuahua and Cuauhtemoc

In order to stress the importance of having an accurate map of the equivalent electric conductivity of the ground, we selected work carried out by the Engineering Department of the Cámara Nacional de la Industria de la Radio y Televisión (C.N.I.R.T., 1996) in the state of Chihuahua. Our study attempts to verify the western extent of the previously determined coverage area for the 5, 2.5 and 0.5 mV/m power levels of the XEFI-AM transmitter (f=580 kHz) located in the city of Chihuahua.

To accomplish this, we selected the appropriate electric field measurements included in TEC reports for the XERPC-AM transmitter station located in the city of Chihuahua and the XEPL-AM transmitter station located in the city of Cuauhtemoc (Figure 5b). Employing the Field Attenuation Method with simplified methodology, a value for σ_{eq} of 3 mS/m was determined for the region between these two stations.

Table 2

Results obtained from measurements (re-calculated values) and their comparison with assigned values on map (S.C.T., 1981).

Indicator	Location City (State)	Frequency (kHz)	Power (kW)	Approximate studied area (km^2)	σ_{eq} (mS/m) re-calculated	σ_{eq} (mS/m) on map (S.C.T., 1981)
XECAH-AM	Cacahoatan (Chiapas)	1350	5	353	1	2
XEKJ-AM	Acapulco (Guerrero)	1400	0.5	905	1	4
XECHG-AM	Chilpancingo (Guerrero)	680	1	1810	1 and 0.5	4
XEPI-AM	Tixtla (Guerrero)	1250	2.5	1520	1	4
XELTZ-AM	El Puertecito (Aguascalientes)	740	1	3020	5 and 7	4
XEDR-AM	Pachuca (Hidalgo)	1420	1	1960	3	4
XEQB-AM	Tulancingo (Hidalgo)	1340	1	1960	3	4
XEZOL-AM	Juárez (Chihuahua)	860	1	982	5	10
XETP-AM	Casas Grandes (Chihuahua)	1010	1	1385	3 and 5	4
XEPL-AM	Cuauhtemoc (Chihuahua)	550	5	1385	3	10 and 30
XERPC-AM	Chihuahua (Chihuahua)	790	5	2460	3	10
XETAB-AM	Villahermosa (Tabasco)	1410	5	1243	3 and 10	6
XEXW-AM	Nogales (Sonora)	1300	1	200	1 and 3	15
XEOBS-AM	Obregón (Sonora)	1070	1	795	1 and 5	5
XEIB-AM	Caborca (Sonora)	1170	0.25	1016	1 and 3	4
XETCH-AM	Etchojoa (Sonora)	1130	5	645	1 and 3	4
XEOPE-AM	Mazatlán (Sinaloa)	630	4	286	1 and 3	4
XECSI-AM	Culiacán (Sinaloa)	750	1	1345	1 and 3	4
XECF-AM	Los Mochis (Sinaloa)	1410	1	268	15 and 30	4
XEZAJ-AM	Zapotan (Jalisco)	1220	1	1126	1, 3 and 7	4
XEMZA-AM	Cihuatán (Jalisco)	560	10	447	1	4
XELB-AM	La Barca (Jalisco)	1090	5	1243	1 and 3	4
XEZV-AM	Tlapa (Guerrero)	800	3	535	1 and 3	4
XEMAC-AM	Manzanillo (Colima)	1330	0.5	703	1 and 7	4
XEOF-AM	Cortazar (Guanajuato)	740	0.5	796	0.5 and 1	10
XESAL-AM	Saltillo (Coahuila)	1220	1	1243	1 and 3	4
XELZ-AM	Torreón (Coahuila)	710	1	1127	1 and 3	8
XETAR-AM	Guachochi (Chihuahua)	870	10	673	1 and 3	2
XEVFS-AM	Las Margaritas (Chiapas)	1030	4	616	1 and 3	5
XETEB-AM	Tenabo (Campeche)	920	1	522	1	5
XEXPU-AM	Xpujil (Campeche)	700	5	894	1 and 5	6
XEHG-AM	Mexicali (B.C.N.)	1370	0.5	1243	1 and 3	4

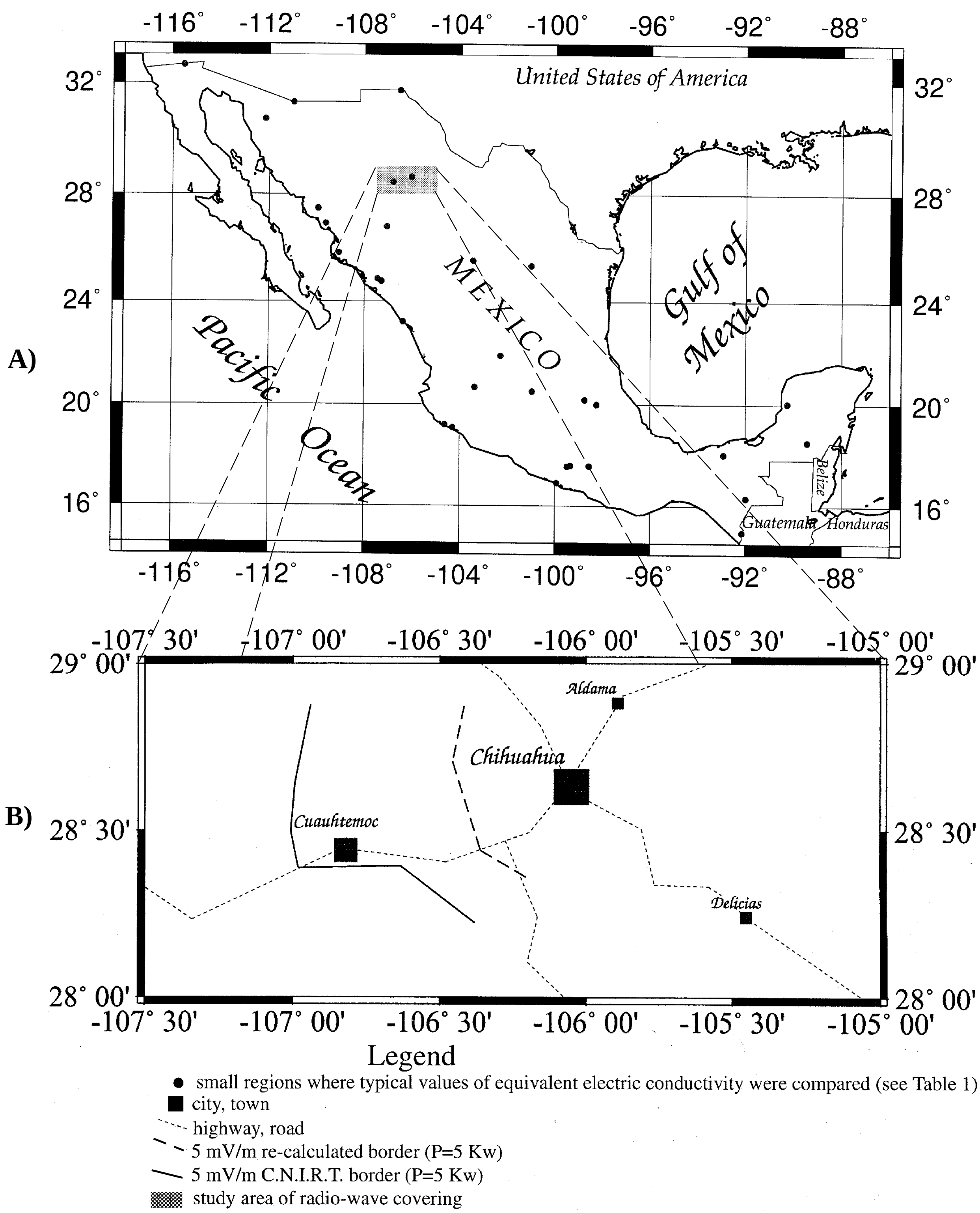

Fig. 5. Results obtained by application of the field attenuation method with simplified methodology. A) Location of the transmitters used in the re-calculation of the equivalent electric conductivity (national study). B) Local study about the covering of the XEFI-AM transmitter located in Chihuahua city.

The numerical distances ρ were then calculated with increasing distance from the XEFI-AM transmitter using an equivalent electric conductivity of 3 mS/m. The corresponding attenuation values W_i were next calculated from the relationship

$$W_i = \frac{2 + 0.3\rho_i}{2 + \rho_i + 0.6\rho_i^2} \quad . \tag{12}$$

Lastly, the field intensities were calculated at distances Ri for daytime and nighttime power levels (5 kW and 0.25 kW, respectively) employing equation 5.

To establish a comparison of our results with those presented in C.N.I.R.T. (1996), profiles 6 (azimuth 225°) and 7 (azimuth 270°) of that report were selected as they are located within the region where the equivalent electric conductivity was re-calculated. The comparison (presented in Tables 3 and 4, and illustrated in Figure 5b) indicates that the coverage area determined in the C.N.I.R.T. report is too large. The differences are most likely the result of the values of the equivalent electric conductivity used in the two determinations; the report uses the map values of 10-30 mS/m, whereas our determination uses a value of 3 mS/m.

The comparison clearly illustrates that an accurate map of the equivalent electric conductivity of the ground is of great importance in correctly planning medium-wave broadcasting services.

CONCLUSIONS

The results of our study indicate the necessity of constructing a new, more accurate map of the electric conductivity of Mexico. Because it is difficult to account for all the factors influencing the electric conductivity of the ground, previously employed estimation methods do not provide accurate results. Thus, the use of the Field Attenuation Method is recommended for obtaining the data needed to produce the new map. Also, the use of the simplified methodology would reduce considerably the cost of the fieldwork. For this purpose, in each state of Mexico, transmitters must be selected to provide adequate coverage of the area in which the electromagnetic field will be measured. Also, an effort should be made to establish that distance between the measurement point to the transmitter never exceeds 100 km and the distance between adjacent measurement points lies between 5 to 10 km. These criteria are needed to ensure an adequate set of measurements from which a new map can made of the electric conductivity of the ground for Mexico.

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Table 3

Comparison of the calculated covering to profiles 6 and 7, to daytime power (P= 5 kW).

Profile	Azimuth	C.N.I.R.T., 1996 border 5 mV/m	Re-calculated border 5 mV/m	C.N.I.R.T., 1996 border 0.5 mV/m	Re-calculated border 0.5 mV/m
6	225°	59 km	41.5 km	133 km	122.5 km
7	270°	100 km	41.5 km	206 km	122.5 km

Table 4

Comparison of the calculated covering to profiles 6 and 7, to nighttime power (P= 0.25 kW).

Profile	Azimuth	C.N.I.R.T., 1996 border 5 mV/m	Re-calculated border 5 mV/m	C.N.I.R.T., 1996 border 2.5 mV/m	Re-calculated border 2.5 mV/m
6	225°	24 km	18 km	42 km	27 km
7	270°	24 km	18 km	52 km	27 km

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