VANDIVERE, COHEN AND WEARN
CONSULTING ELECTRONIC ENGINEERS
WASHINGTON, D. C.

PROPAGATION (AM)

STATEMENT OF
EDGAR F. VANDIVERE, JR.
RELATIVE TO THE
EFFECT OF GROUND CONDUCTIVITY ON
INTERFERENCE LIMITATIONS PRODUCED BY
WABC AND BY WBZ
AT ALBUQUERQUE, NEW MEXICO
Dockets No. 6584-5

I am a member of the firm of Vandivere, Cohen and Wearn, consulting electronic engineers, with offices at 1420 New York Avenue, N. W., Washington, D. C. I am a professional engineer registered in the District of Columbia. My qualifications as an engineer are a matter of record with the Federal Communications Commission. The firm of Vandivere, Cohen and Wearn has been retained by Westinghouse Broadcasting Company, Inc., to prepare computations in compliance with 3.185(j) of the Rules and Standards of the Federal Communications Commission:

> "When the distance is large, more than one reflection may be involved, and due consideration must be given each appropriate vector in the vertical pattern, as well as the constants of the earth where reflection takes place between the transmitting station and the service area to which interference may be caused."

In particular:

(1) To compute the radiation patterns of WABC and of WBZ based upon parameters as noted below but especially taking into account the ground conductivity in the vicinity of the antennas; and

(2) In further compliance with the regulation cited above to compute the field strength in the principal modes of

skywave propagation from each of the antennas to the vicinity of Albuquerque, New Mexico, making use of experimentally determined reflection coefficients at the E-layer and of reflection coefficients at the ground based upon the conductivities at the intervening reflection points. The RSS of the field strength in the principal modes, for each station, then constitutes the resultant field strength for that station. According to the Rules and Standards, this resultant field strength multiplied by 20 constitutes the "interference limitation" produced at the point in question.

Radiation Patterns

The parameters assumed were:

For WBZ,

Frequency, 1030 kc

Antenna height, 500 ft = 188.4°

Orientation of the two-tower array, east-west

Tower spacing, 248.5 ft = 93.5°

Field ratio, west tower, $1\underline{/0^{\circ}}$

Field ratio, east tower, $1\underline{/86^{\circ}}$

Loss resistance, at the loop, 2 ohms

Power, 50 kw

Bearing toward Albuquerque, 268° true

Ground conductivity, 4300 mmhos/m)
) at antenna
Specific dielectric constant, 81)

Distance to Albuquerque from WBZ, 1970 mi

(The distances, then, to the end of the first hop of the second and third propagation modes are respectively 985 miles and 657 miles);

For WABC,

Frequency, 770 kc

Antenna height, 640 ft = 180°

Loss resistance, at the loop, 2 ohms

Radiation resistance, at the loop, 100 ohms

Power, 50 kw

Ground conductivity, 4 mmhos/m)
) at antenna
Specific dielectric constant, 15)

Distance to Albuquerque, 1800 mi

(The distances, then, to the end of the first hop of the second and third propagation modes are, respectively, 900 miles and 600 miles.)

Figure 1 shows a portion of the Boston and New York Local Aeronautical Charts with the locations of WBZ and WABC plotted together with the bearing toward Albuquerque. The outer limit of the area affecting the formation of the radiation pattern in the vertical plane may be reasonably set at 50 times the antenna height. An area of this size will "mirror" the entire height of the antenna down to angles of about 1° above the horizon. This distance is approximately six miles for WABC and approximately five miles for WBZ. It will be noted that from WABC the pertinent area is largely built-up, so that a conductivity of 4 mmhos/m may be a little high. In the instance of WBZ the area is almost wholly sea-water. Massachusetts seawater has a conductivity of 4300 mmhos/m according to Stratton, "Electromagnetic Theory," p.606.

Figure 2 shows a plot of the computed patterns. Because the conventional plot of radiation versus pertinent angle is difficult to read, the plot is made against "pertinent distance" assuming the average E-layer height of 95 Km. (This particular relationship between pertinent angle and pertinent distance is given by curve 1 of Figure 6A of the Rules and Standards.) The radiations into the second and third modes are noted on the graphs; viz. 2240 mv/m and 2240 mv/m respectively for WBZ; 660 mv/m and 880 mv/m for WABC.

For each station the second mode of propagation is predominant by a good margin over the third mode: The ratio of radiations into the second mode is $\frac{2240}{660} = 3.40$.

The derivation of the radiation pattern in the vertical plane of a vertical radiator reflected by a horizontal plane of finite conductivity is mathematically identical with that of the more familiar case of reflection by a plane of infinite conductivity: The direct and indirect rays from an element of current on the antenna are combined, after multiplying the indirect ray by an appropriate reflection coefficient, and the result is integrated up the length of the antenna. This results in, to fix dimensions at the same time, the field strength E mv/m in a vertical direction θ measured from the zenith at a distance d miles (assumed large with respect to antenna dimensions) for an antenna of height H over a ground of conductivity σ and specific dielectric constant κ,

$$\mathcal{E}(d,\theta;H,\sigma,\kappa) = \frac{1}{4\pi}\sqrt{\frac{\mu_0}{\epsilon_0}}\,\frac{I}{1.609}\,\mathcal{J}_{sp}(\theta;H,\sigma,\kappa)$$

$$= 18.65\,\frac{I}{d}\,\mathcal{J}_{sp},$$

in which I is the loop current in rms amperes; and μ_0 and ϵ_0 are the permeability and dielectric constants of free space: and $\mathcal{J}_{sp}$ abbreviates the "pattern" of radiation into the space wave.

$$\mathcal{J}_{sp} = \mathcal{J}(\theta,H) + \mathcal{R}_v\,\tilde{\mathcal{J}}(\theta,H),$$

in which $\mathcal{J}$ is the pattern for the direct ray alone, $\tilde{\mathcal{J}}$ its complex conjugate and $\mathcal{R}_v$ is the Fresnel reflection coefficient for "vertical" polarization.

$$\mathcal{J} = \frac{\cos(H\cos\theta) - \cos H}{\sin\theta} + j\,\frac{\sin(H\cos\theta) - \sin H\cos\theta}{\sin\theta}.$$

The reflection coefficient is (Cf. Stratton "Electromagnetic Theory," pp. 494 and 501)

$$R_v = \frac{K_1^2 \cos\theta - K_0\sqrt{K_1^2 - K_0^2 \sin^2\theta}}{K_1^2 \cos\theta + K_0\sqrt{K_1^2 - K_0^2 \sin^2\theta}},$$

in which it has been assumed, as is usual, that the permeability of the earth is the same as that of free space; θ is the angle of incidence measured from a normal to the earth's surface; K_0 and K_1 are propagation constants for free space and for the earth

$$K_0^2 = \omega^2 \mu_0 \epsilon_0,$$
$$K_1^2 = \omega^2 \mu_0 \epsilon - j\omega\sigma\epsilon_0,$$

m. k. s. units being assumed.

Determination of the Field Strengths Produced in Albuquerque

The intermediate ground conductivities affecting the second and third modes of skywave propagation were taken from the conductivity map M3 as follows: For WBZ to Albuquerque, the conductivity was taken to be 15 mmhos per meter at the one-half, at the one-third and at the two-thirds distances. For WABC to Albuquerque, the conductivity was taken to be 8 mmhos per meter at the one-half and at the one-third distances; and 30 mmhos per meter at the two-thirds distance. The conductivity at the receiving point at Albuquerque was taken as 15 mmhos per meter.

The computation is based upon analyses which I made or directed while employed in the Technical Research Division of the FCC. The first analysis was of numerous skywave data taken by the Field Division of the Engineering Department and was reported in Exhibit 23, Docket 6741, "The Report of Committee III." A subsequent analysis was made to determine the E-layer reflection coefficients implied by the data as well as the extent of the depolarization that occurred. This analysis is reported principally in the Engineering Department reports TID 4.3.1 "General Statistics for Skywave Propagation" and TID 2.5.5 "Experimental Reflection Coefficients for the E-layer." In order to deal with random phases and polarizations, the analysis is carried out in terms of the squares of rms statistics which also add, regardless of the probability laws that may obtain. One result of the analysis was that the data conformed well to the assumption of inverse distance attenuation (and did not conform to the assumption of the degree of focusing that would be produced by a uniformly curved ionosphere). Another result was an evaluation of the fraction of the skywave energy that remains in the vertical polarization after propagation. At 40° latitude (in the U. S.) this turns out to be about 75%.

For a particular mode then the computation starts with the square of the pertinent radiation from the antenna; this is attenuated by the square of the inverse distance (Figure 3, TID 2.5.5 may be used); it is further attenuated by an appropriate number of applications of the appropriate E-layer reflection coefficient (Figure 6, TID 2.5.5); it is next attenuated by an appropriate number of applications of an energy reflection coefficient at the ground, the coefficient being a weighted composite of the reflection coefficients for horizontal and vertical polarizations, the weighting being determined by the energy fraction expected. This constitutes the total receivable energy in the mode. This is then multiplied by the partition fraction to determine the amount of energy in vertical polarization and finally by the square of the ratio of the receiving antenna's effective height for skywave to its effective height for groundwave. The square root of the final product represents the annual rms of hourly rms values of the field strength in the mode in question. Multiplication of this value by the square root of the natural logarithm of 2, i.e. 83%, produces the annual rms of hourly median field strengths. To transform the annual statistical datum to some other desired reference, say the 10% value, it is necessary to compound the probability function out of those discovered for the first mode as reported in the "Report of Committee III," cited above. This has been done for the second and third modes in TID 4.1.2 "Night-to-Night Fading of Medium Frequency Skywave Modes."

Application of this process determined:

For WBZ,

$$E_{m10}^{(2)} = 309 \ \mu v/m$$

$$E_{m10}^{(3)} = 103 \ \mu v/m$$

($E_{m\,10}^{(2)}$ means value exceeded by second mode hourly median field strength on 10% of the nights)

Since the 10% datum is not far from the rms datum, it is approximately valid "to RSS" them; so

$$\sqrt{E_{m10}^{2} + E_{m10}^{(3)\,2}} = 325 \ \mu v/m$$

Limitation = 6.50 mv/m

For WABC,

$$E_{m10}^{(2)} = 122.7\ \mu v/m$$

$$E_{m10}^{(3)} = 66.7\ \mu v/m$$

$$\sqrt{E_{m10}^{(2)^2} + E_{m10}^{(3)^2}} = 139.\ \mu v/m$$

Limitation = 2.78 mv/m

Edgar F. Vandivere, Jr.

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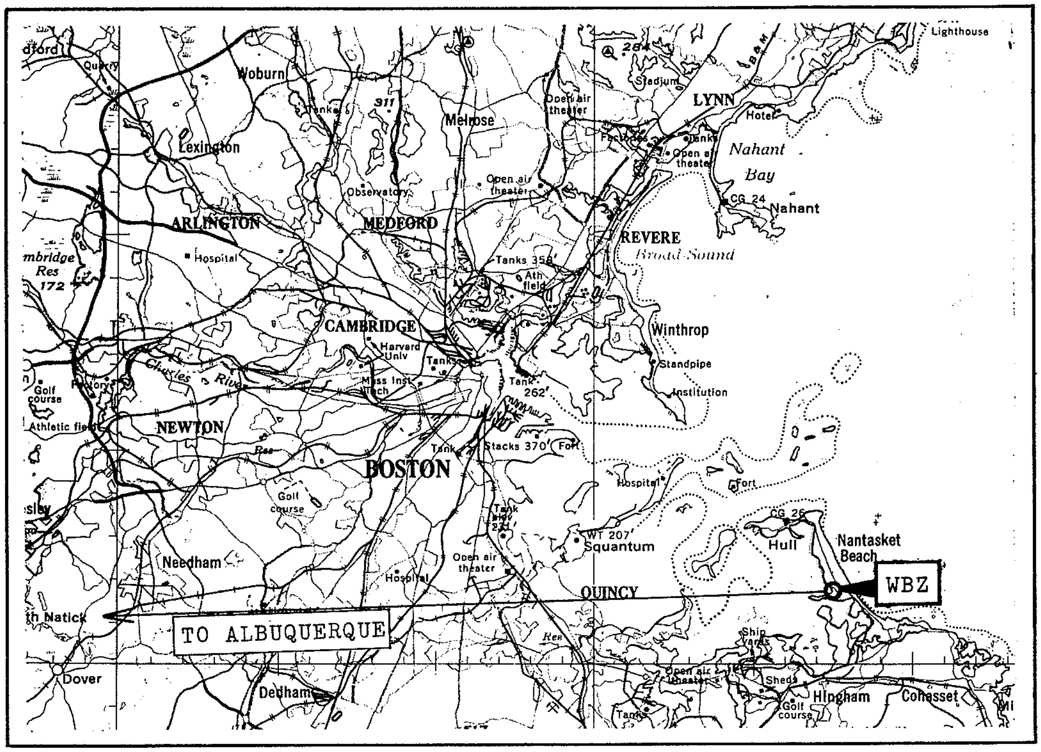
VANDIVERE, COHEN and WEARN

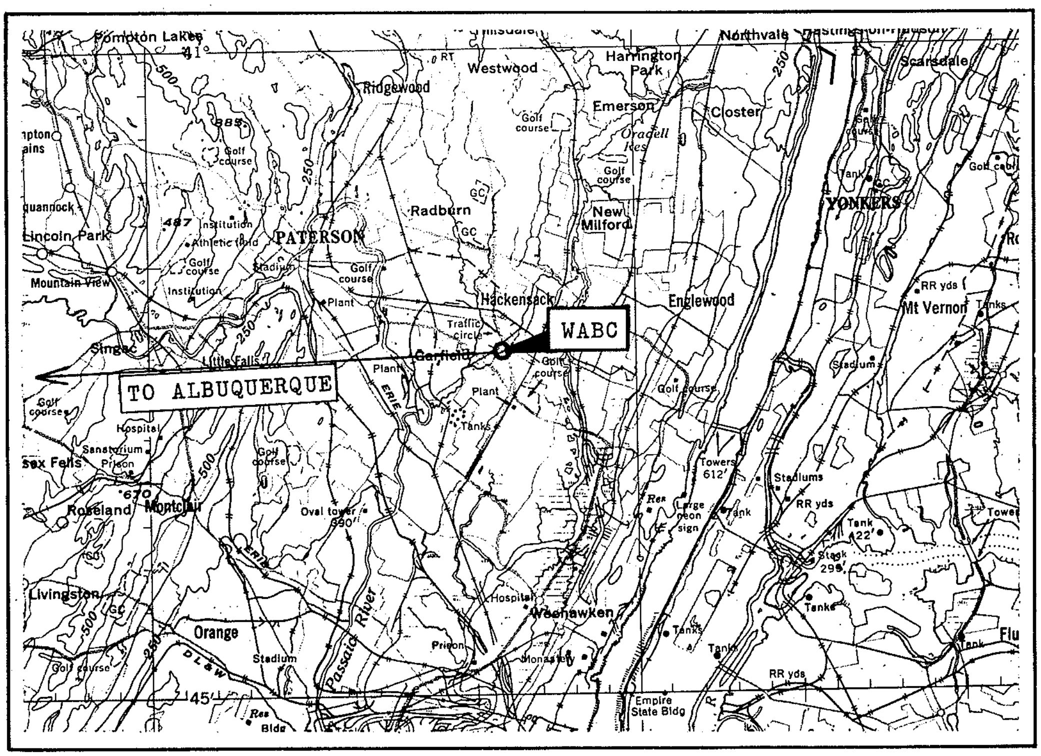
Subscribed and sworn to before me this 5th day of July, 1956.

s/ Inez M. Brooks
Notary Public, D. C.

My commission expires:
January 31, 1961

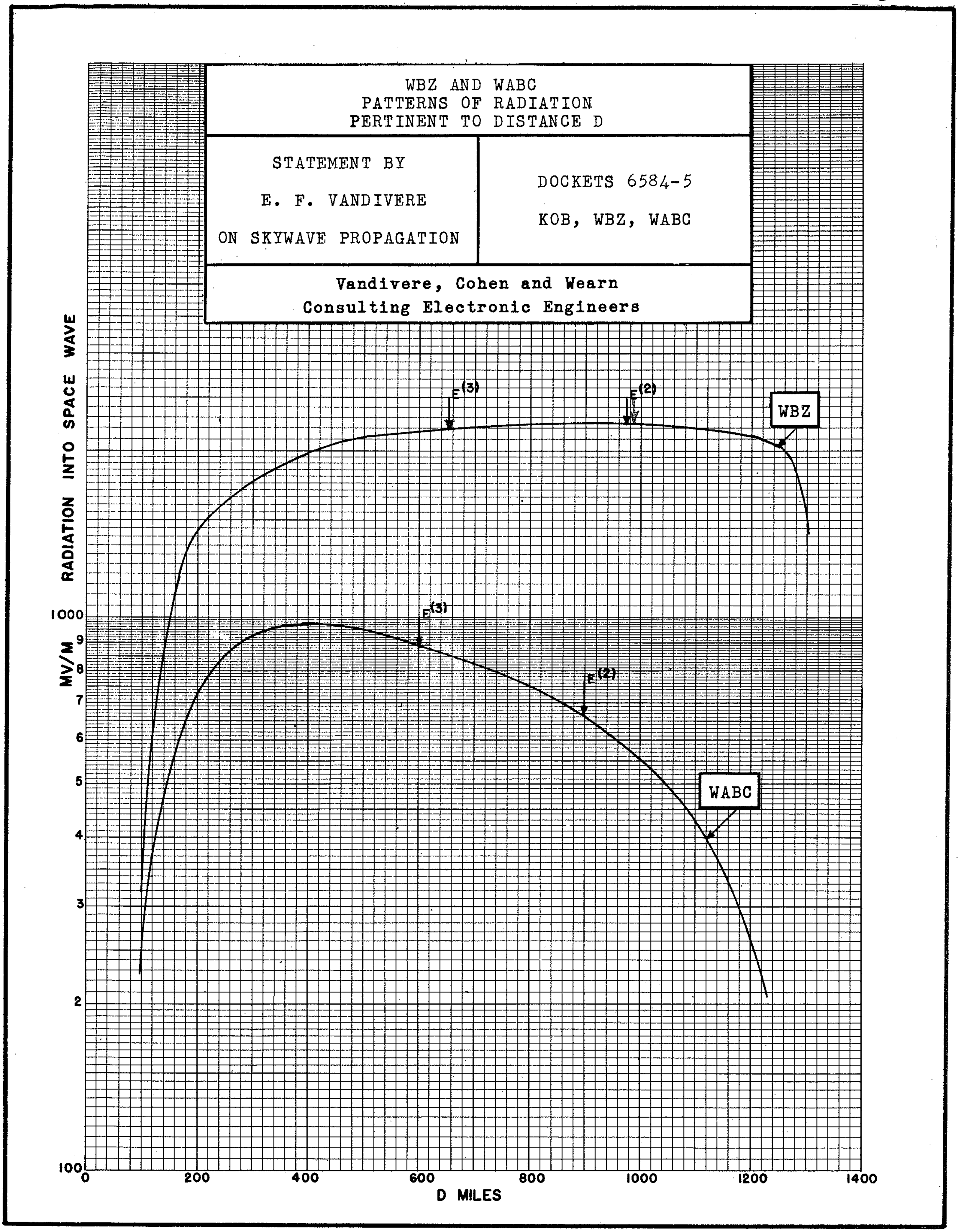
(SEAL)





WBZ AND WABC TRANSMITTER SITES
DOCKETS 6584-5

Statute Miles 5 0 5 10 15 20


WBZ AND WABC
PATTERNS OF RADIATION
PERTINENT TO DISTANCE D
STATEMENT BY
E. F. VANDIVERE
ON SKYWAVE PROPAGATION
DOCKETS 6584-5
KOB, WBZ, WABC
Vandivere, Cohen and Wearn
Consulting Electronic Engineers
RADIATION INTO SPACE WAVE
MV/M
1000
9
8
7
6
5
4
3
2
100
E(3)
E(2)
E(3)
E(2)
WBZ
WABC
0
200
400
600
800
1000
1200
1400
D MILES

VANDIVERE, COHEN AND WEARN
CONSULTING ELECTRONIC ENGINEERS
WASHINGTON, D. C.

STATEMENT OF
EDGAR F. VANDIVERE, JR.
RELATIVE TO
THE LIMITATION THAT WOULD BE PRODUCED
IN THE VICINITY OF ALBUQUERQUE, NEW MEXICO
BY RADIATION FROM WBZ AS CONTEMPLATED
IN ISSUES 20, 21, and 22 OF
DOCKETS NO. 6584-5

I am a member of the firm of Vandivere, Cohen and Wearn, consulting electronic engineers, with offices at 1420 New York Avenue, N. W., Washington, D. C. I am a professional engineer registered in the District of Columbia. My qualifications as an engineer are a matter of record with the Federal Communications Commission. The firm of Vandivere, Cohen and Wearn has been retained by Westinghouse Broadcasting Company, Inc., to compute the limitation that would be produced in the vicinity of Albuquerque, New Mexico, by radiation from WBZ as contemplated in issues 20, 21 and 22.

This statement assumes the same circumstances and physical conditions as were assumed in my statement concerning the limitation that is produced by the existing operation of WBZ, except that the following antenna is assumed:

Frequency, 1030 kc

Antenna height, 190°

Line of towers, 88° true

Tower spacing, 138.5°

Field ratio, west tower, $1\underline{/0^{\circ}}$

Field ratio, east tower, $1/\underline{41.5^{\circ}}$

Power, 50 kilowatts

Bearing toward Albuquerque, 268° true

Unattenuated ground wave radiation toward
Albuquerque, 1592 mv/m

It may be expected that a reasonable estimate of the limitation that would be produced by radiation from this antenna may be obtained from scaling down the existing limitation in the ratio of the unattenuated fields at one mile. However, because the radiation pattern in the vertical plane for the antenna described above is somewhat different from that for the existing antenna, this pattern has been computed together with its effect on radiation in the second and third skywave modes. The radiation pattern in the vertical plane for each element in the earlier statement cited above assumed a height of 188.4°. These patterns have been used in the present computation; the small difference in height was considered to be of no significance for present purposes.

The effect of the assumption of the directional antenna described above is to reduce the field strength in the second mode in the vicinity of Albuquerque from

309 to 209 microvolts per meter and that of the third mode from 103 to 71 microvolts per meter. The RSS of these is 220 microvolts per meter. This corresponds to a limitation of 4.40 millivolts per meter.

Edgar F. Vandivere, Jr.
Edgar F. Vandivere, Jr.
VANDIVERE, COHEN and WEARN

Subscribed and sworn to before me this 5th day of July, 1956.

s/ Inez M. Brooks
Notary Public, D. C.

My commission expires:
January 31, 1961

(SEAL)