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An Updated Noise Model for Use in IONCAP

A. D. Spaulding
F. G. Stewart

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
Alfred C. Sikes, Assistant Secretary
for Communications and Information

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AN UPDATED NOISE MODEL FOR USE IN IONCAP

A. D. SPAULDING & F. G. STEWART*

This report presents an updated and improved noise model designed for use in the HF propagation prediction program, IONCAP. The model has, however, much more general applicability, since the frequency range 10 kHz to 30 MHz is covered. The report gives the history, as near as can be determined, of the existing noise routines, and then develops the updated model based on current information. The three noise sources - atmospheric, man-made, and galactic are treated and a more appropriate means of combining these three sources is developed. Examples of the use of the improved model in IONCAP are included and comparisons made with the existing model.

Key Words: Atmospheric noise, galactic noise, IONCAP, man-made noise, noise model, overall operating noise threshold

1. INTRODUCTION and BACKGROUND

The determination of radio communication system performance is a matter of proper statistical treatment of both the desired signal and the real world noise (or interference) processes. In general, system performance is highly dependent on the detailed statistical characteristics of both the signal and the noise as well as the single parameter: signal-to-noise ratio. Often, the signal-to-noise ratio (and its variation with time and location) is the only parameter considered. In general, we have a number of noise processes to consider: the noise internally generated by the receiving system; natural noise, i.e., atmospheric and galactic; unintentionally radiated man-made noise; and intentionally radiated noise, e.g., undesired (by us) signals. While, depending on frequency, time, and location, one of these noises may dominate, all (or various combinations) may need to be considered. This is especially true at HF frequencies. The various ionospheric propagation prediction programs such as IONCAP (Ionospheric Communication Analysis and Prediction Program) use algorithms to predict the appropriate (atmospheric, galactic, and man-made) noise levels and combine them to obtain an estimate of the overall interfering noise level and its statistical variation. In the current version of IONCAP (Teters et al., 1983), this is accomplished by

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*The authors are with the Institute for Telecommunication Sciences, National Telecommunications and Information Administration, U. S. Department of Commerce, Boulder, CO 80303-3328.

various subroutines, the main one being termed GENOIS. The noise subroutines have evolved over approximately the past 20 years and are in need of updating, both in terms of the noise levels used and how they are combined. It is the purpose of this report to attempt to explain the development of the current noise routines, especially with regard to man-made noise, to point out the areas where they are no longer valid, and to develop an updated and improved version. The improved version is changed only internally, so that it can be used directly in the existing programs. Modernizations which would require changes in the entire program (e.g., IONCAP) are not made, but left for an overall updating. The existing noise models which are used in the update are the new CCIR Report 322-3 (1986) for atmospheric noise and CCIR Report 258-4 (1982) for man-made noise. The particulars that resulted in Report 322-3 are given by Spaulding and Washburn (1985) and for Report 258-4 by Spaulding and Disney (1974).

We start with some basic definitions for review and to point out how the receiving system's internal noise is combined with the external noise to obtain an overall noise operating threshold. While this is, by now, well known material, it will provide the basic definitions we will use later, treat one of the noises (internal) listed above, and show how a receiving system's sensitivity enters into the picture. Basically we need a receiving system with a sensitivity no greater than that governed by the external noise. Worldwide minimum noise levels have been estimated for this purpose (CCIR Report 670, 1978).

The predetection signal-to-noise ratio is an important system design parameter and is always required knowledge (required but seldom sufficient) when determining the effects of the external noise on system performance. It is useful to refer (or translate) the noise from all sources to one point in the system for comparison with the signal power (desired signal). A unique system reference point exists: the terminals of an equivalent lossless antenna having the same characteristics (except efficiency) as the actual antenna (see CCIR Report 413). Consider the receiving system shown in Figure 1. The output of block (a) is this unique reference point. The output of block (c) represents the actual (available) antenna terminals to which one could attach a meter or a transmission line. Let s represent the signal power and n the average noise power in watts that would be observed at the output of block (a) in an actual system (if the terminals were accessible). We can

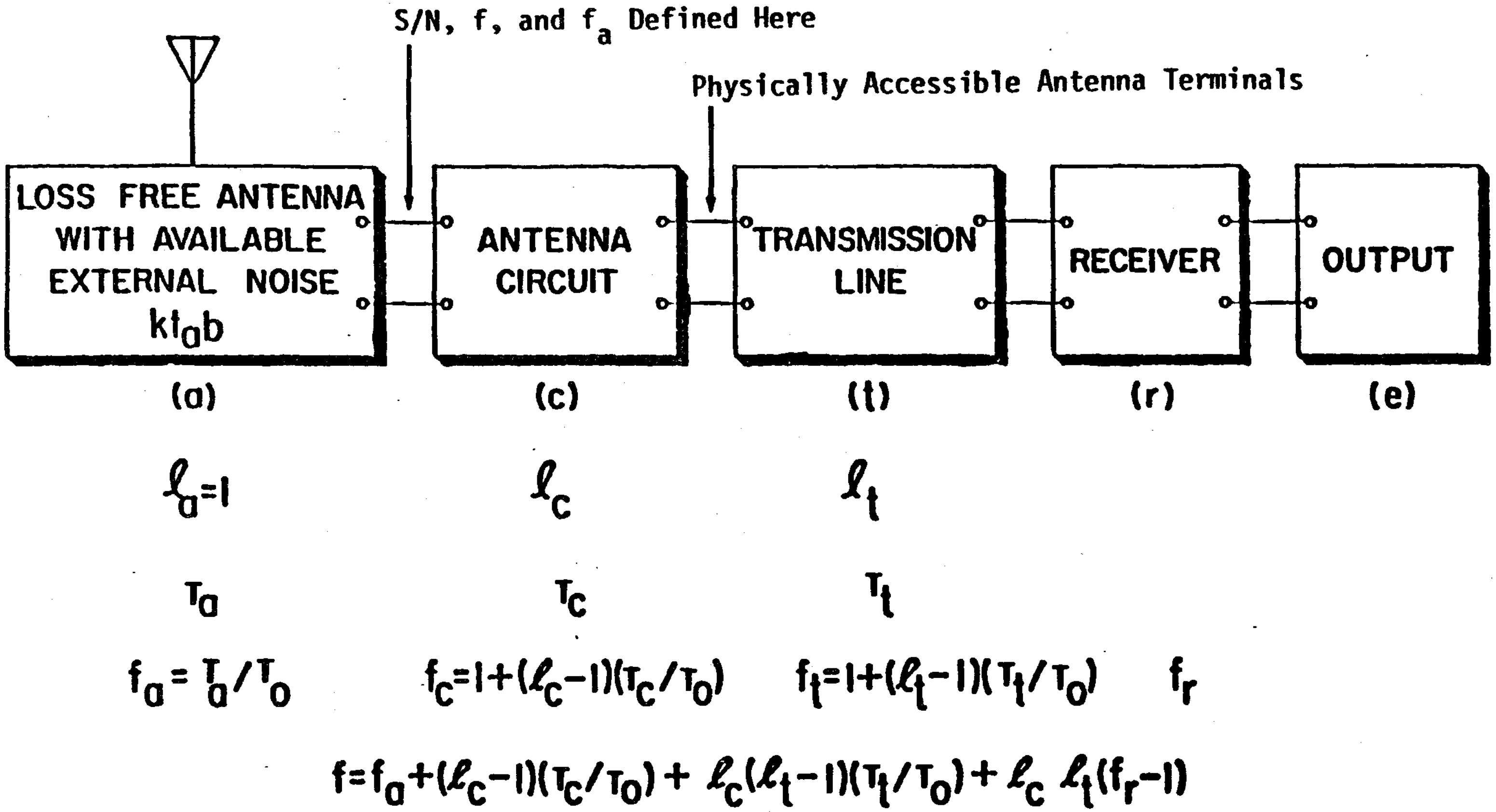

Figure 1. The receiving system and its operating noise factor, f.

define a receiving system overall operating noise factor, f, such that $n = fkT_0b$, where k = Boltzmann's constant = 1.38×10^{-23}J/K, T_0 = the reference temperature in K taken as 288 K, and b = the noise power bandwidth of the receiving system in Hertz.

We can also define a system overall operating noise figure $F = 10 \log_{10} f$ in decibels. The ratio s/n can be expressed in decibels:

$$(s/n)_{dB} = S - N \qquad (1)$$

where

S = the desired average signal power in dB (1W)
  = $10 \log_{10} s$, and
N = the average system noise power in dB (1W)
  = $10 \log_{10} n$.

Let us now explore the components of n in greater detail with emphasis on environmental noise external to the system components.

For receivers free from spurious responses, the system noise factor is given by

$$f = f_a + (\ell_c - 1) \frac{T_c}{T_o} + \ell_c(\ell_t - 1) \frac{T_t}{T_o} + \ell_c \ell_t (f_r - 1), \qquad (2)$$

where

f_a = the external (i.e., antenna) noise factor defined as

$$f_a = \frac{P_n}{kT_o b};$$

F_a = the external noise figure defined as $F_a = 10 \log f_a$;
P_n = the available noise power from a lossless antenna [the output of block (a) in Figure 1];
ℓ_c = the antenna circuit loss (available input power/available output power);
T_c = the actual temperature, in K, of the antenna and nearby ground;
ℓ_t = the transmission line loss (available input power/available output power);
T_t = the actual temperature, in K, of the transmission line; and

f_r = the noise factor of the receiver ($F_r = 10 \log f_r$ = noise figure in dB).

Let us now define noise factors f_c and f_t, where f_c is the noise factor associated with the antenna circuit losses,

$$f_c = 1 + (\ell_c - 1) \frac{T_c}{T_o}, \tag{4}$$

and f_t is the noise factor associated with the transmission line losses,

$$f_t = 1 + (\ell_t - 1) \frac{T_t}{T_o}. \tag{5}$$

If $T_c = T_t = T_o$, (2) becomes

$$f = f_a - 1 + f_c f_t f_r. \tag{6}$$

Note specifically that even when $f_c = f_t = 1$ (lossless antenna and transmission line), then $F = F_a + F_r$.

Relation (3) can be written

$$P_n = F_a + B - 204 \text{ dB(1W)}, \tag{7}$$

where $P_n = 10 \log p_n$ (p_n = available power at the output of block (a) in Figure 1, in watts); $B = 10 \log b$; and $-204 = 10 \log kT_o$. For a short ($h << \lambda$) grounded vertical monopole, the vertical component of the rms field strength is given by

$$E_n = F_a + 20 \log f_{MHz} + B - 95.5 \text{ dB(1}\mu\text{V/m)}. \tag{8}$$

where E_n is the field strength [dB(1μV/m)] in bandwidth b (Hz) and f_{MHz} is the center frequency in MHz. Similar expressions for E_n can be derived for other antennas (Lauber and Bertrand, 1977). For example, for a halfwave dipole in free space,

$$E_n = F_a + 20 \log f_{MHz} + B - 98.9 \text{ dB(1}\mu\text{V/m)}. \tag{9}$$

The external noise factor is also commonly expressed as a temperature,

T_a, where by definition of f_a

$$f_a = \frac{T_a}{T_o}, \tag{10}$$

and T_o is the reference temperature in K and T_a is the antenna temperature due to external noise (in K).

More detailed definitions and discussions (including the case with spurious responses) are contained in CCIR Report 413 (1966).

Note that f_a is a dimensionless quantity, being the ratio of two powers (or, equivalently, two temperatures). The quantity f_a, however, gives, numerically, the available power spectral density in terms of kT_o and the available power in terms of kT_ob.

We express all our external noises in terms of f_a. The next section of this report covers the new atmospheric noise estimates. Section 3 covers man-made and galactic noise and Section 4 details the combining of the three f_a's (atmospheric, man-made, and galactic) to obtain the overall f_a and its statistical variation. All of the techniques used are different from those in the current routines. Section 5 then presents various comparisons between the results (outputs) of the new routines developed here and the current ones.

2. ATMOSPHERIC NOISE

Research pertaining to atmospheric noise dates back to at least 1896 (A.C. Popoff); however, the research leading to the first publication of predictions of radio noise levels was carried out in 1942 by a group in the United Kingdom at the Interservices Ionosphere Bureau and in the United States at the Interservice Radio Propagation Laboratory (I.R.P.L., 1943). Predictions of worldwide radio noise were published subsequently in RPU Technical Report No. 5 (1945) and in NBS Circular 462 (1948), NBS Circular 557 (1955), and CCIR Report 65 (1957). All these predictions for atmospheric noise were based mainly on weather patterns and measurements at very few locations and over rather short periods of time.

Starting in 1957, average power levels (f_a) of atmospheric noise were measured on a worldwide basis starting with a network of 16 identical recording stations. The frequency range 13 kHz to 20 MHz was covered, and measurements of f_a were made using a bandwidth of 200 Hz. Other statistical parameters of the noise process were also measured but are not of concern to us here.

The data from this worldwide network were analyzed by the Central Radio Propagation Laboratory (CRPL) of NBS and the results published in the NBS Technical Note Series 18. The first in this series was published in July 1959 and covered July 1957 - December 1958. After this, one in the series was published every quarter until No. 18-32 for September, October, and November, 1966. These Technical Notes gave, for each frequency and location, the month-hour median value of F_a along with D_μ and D_ℓ, the upper and lower decile values; i.e., the values exceeded 10 percent and 90 percent of the time. In addition, the corresponding season-time block values were given for the four seasons, winter (December, January, and February), spring (March, April, and May); summer (June, July and August); and fall (September, October, and November); (reversed in the Southern Hemisphere), and six four-hour time blocks (0000-0400, etc.).

In 1964, CCIR Report 322, "World Distribution and Characteristics of Atmospheric Radio Noise", was published by the International Telecommunication Union (ITU) in Geneva. This report (small book, actually) presents the worldwide predictions of F_a, and its statistical variations for each season-time block and is based on all the available measurements to that date. In 1983, CCIR Report 322 was reprinted as CCIR Report 322-2 with a revised text and title, but with the same atmospheric noise estimates. Report 322 gives worldwide maps of the time block median value of F_a, F_{am}, at 1 MHz. The F_{am} for other frequencies, 10 MHz to 30 MHz, is given by "frequency law" curves. The statistical variations of F_a are given as a function of frequency, by D_μ, D_ℓ, σ_{D_μ}, σ_{D_ℓ}, and $\sigma_{F_{am}}$. Other atmospheric noise parameters are also given.

In 1965 (Lucas and Harper), numerical representation of CCIR Report 322-1 became available. It is this numerical representation that is contained in the current noise subroutines used in IONCAP (for example). The numerical representation of Lucas and Harper was obtained by the numerical mapping of values obtained from the CCIR 322-1 MHz maps, rather than by numerical mapping of the original data points (84 longitude, 100 latitude grid points) which produced the CCIR 322 maps. This procedure gave differences of over 10 dB occasionally being noted between the CCIR 322 maps and the Lucas and Harper numerical representation. The numerical representation of the frequency variation of F_{am} and D_{μ} and D_{ℓ} variation given by Lucas and Harper are "precise" being the same numerical routine used to produce these parts of CCIR 322. In 1970, Zacharisen and Jones developed 1 MHz noise maps in universal time (rather than local time as in CCIR 322) using the "original" Report 322 data; i.e., the 84 x 100 grid points. Mapping in universal time produces quite high gradients, and the Zacharisen and Jones maps are also substantially different than the CCIR 322 maps for some times and locations. Also using the original data used to plot the contour maps in Report 322, Sailors and Brown (1982, 1983) developed a simplified atmospheric noise numerical model suitable for use on minicomputers. This model is a simplified (fewer coefficients) version of the Zacharisen and Jones maps, and therefore even less accurate.

CCIR Report 322 was originally published in 1964 and was an output document of the CCIR Xth Plenary Assembly held in Geneva in 1963. The atmospheric noise data used were the data from the worldwide network of recording stations through 1961; that is, the data were from July, 1957 through October, 1961. Since then, much additional data have become available. Data from the worldwide network through November of 1966 and many years of data from 10 Soviet measurement locations are now available along with data from Thailand from March, 1966 to February, 1968. All these data have been analyzed and an updated set of atmospheric radio noise estimates produced, essentially in the CCIR Report 322 format. The details of this analysis, new 1 MHz noise maps, etc. are given by Spaulding and Washburn (1985). These new and greatly improved atmospheric noise estimates are also contained in CCIR Report 322-3, an output document of the CCIR XVI Plenary Assembly, Dubrovnik, Yugoslavia, 1986; currently being printed by the ITU. Figures 2 and 3 are Figures 2a, 2b, and 2c from CCIR Report 322-3. (Actually, since 322-3 is currently being printed, Figures 2 and 3 are from the Dubrovnik documents.) Note that as in earlier versions of Report 322, the 1 MHz maps are split at the equator, so that the maps are for a given season, rather than a given three month period, as in Spaulding and Washburn. All the data is identical, however. All of Report 322-3 is available in numerical form, and unlike the earlier versions of 322 and its numerical representation, the numerical version of 322-3 is exact. That is, the numerical version and the graphical version give precisely identical values for all the parameters, including the 1 MHz F_{am} value.

As with the Lucas and Harper maps, the new 1 MHz F_{am} maps are given by a

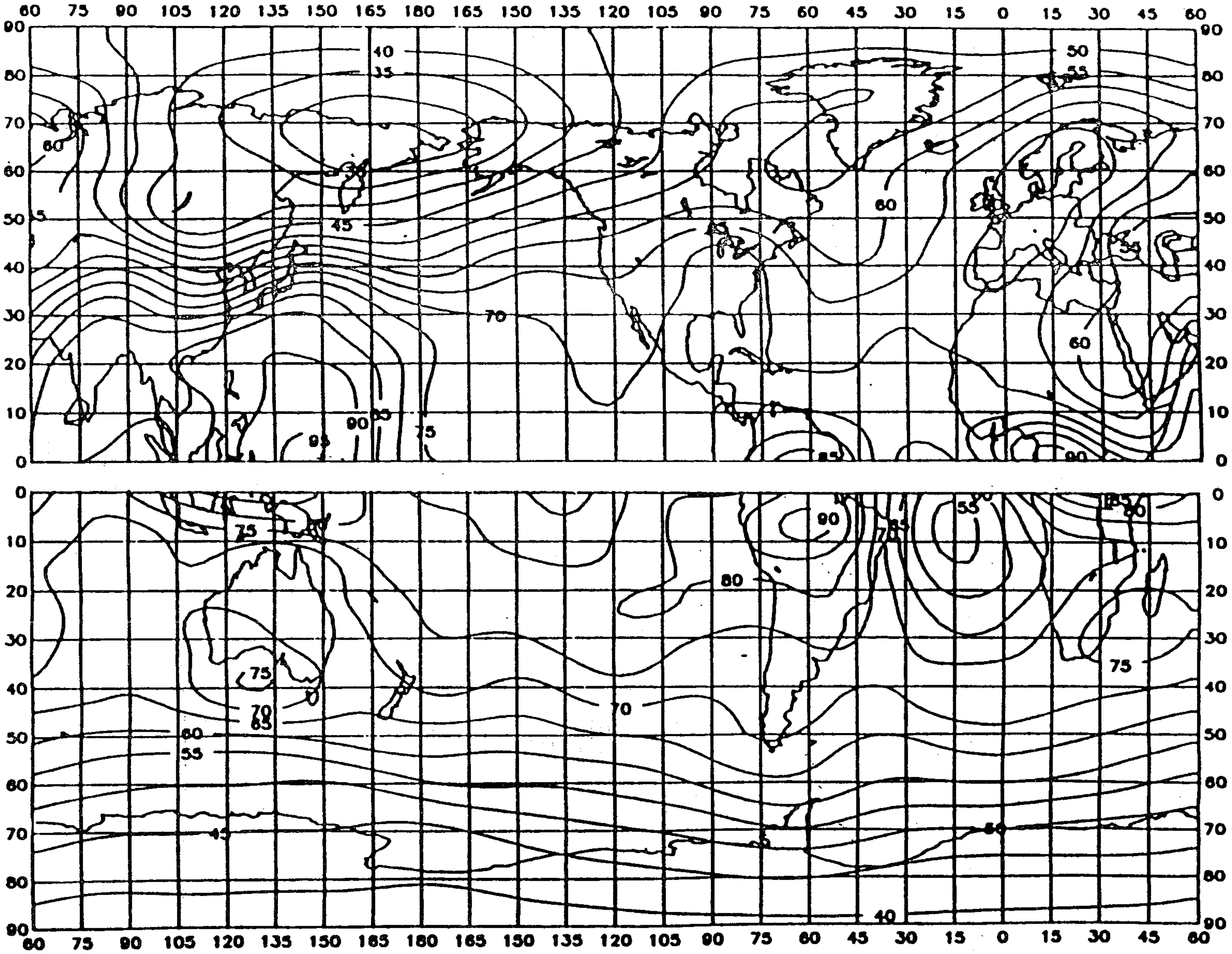

FIGURE 2a – *Expected values of atmospheric radio noise, F_{am} (dB above kT_0b at 1 MHz)*
(Winter; 0000-0400 LT)

Figure 2. Figure 2a from CCIR Report 322-3.

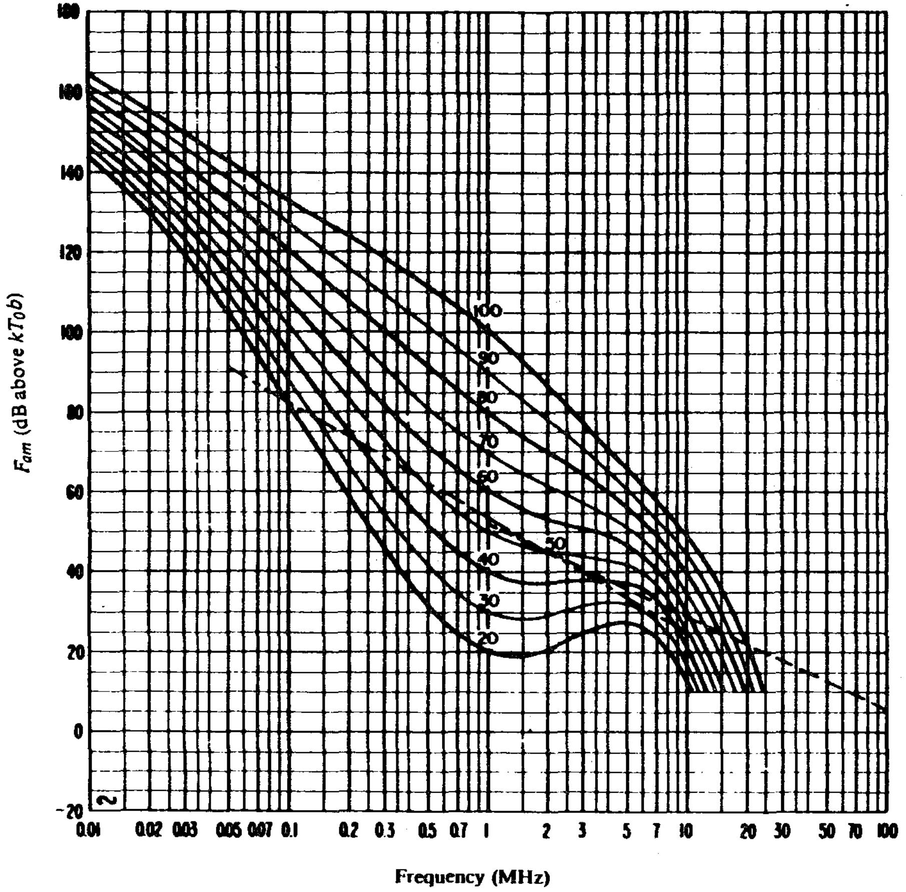

FIGURE 2b – *Variation of radio noise with frequency*
(Winter; 0000-0400 LT)

——————— Expected values of atmospheric noise

— · — · — · — Expected values of man-made noise at a quiet receiving location

— — — — — Expected values of galactic noise

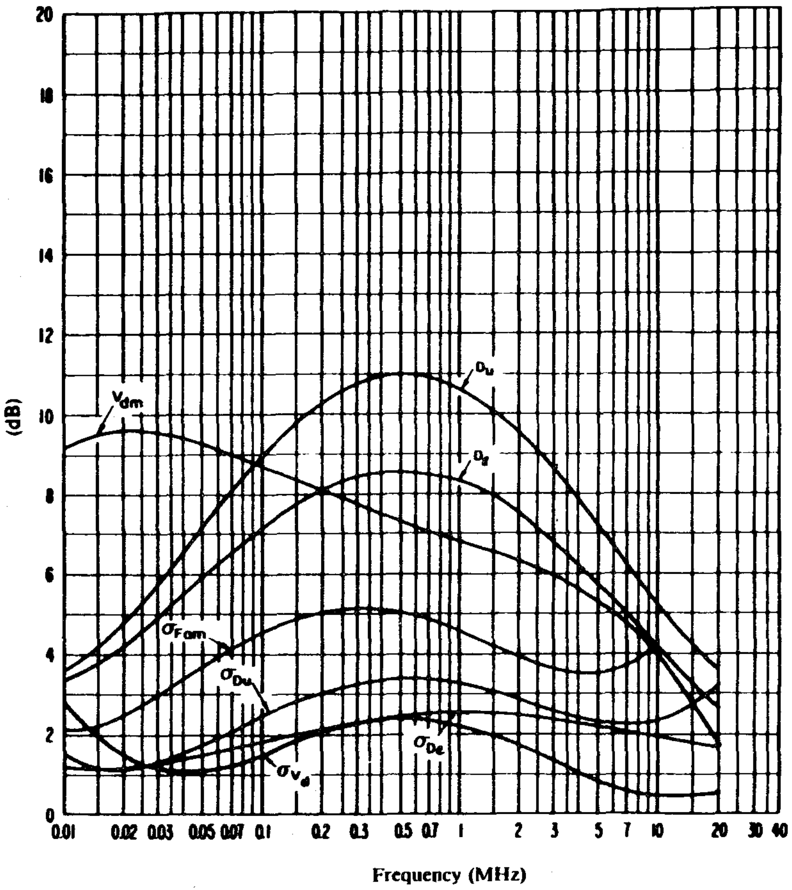

FIGURE 2c – *Data on noise variability and character*
(Winter; 0000-0400 LT)

$\sigma_{F_{am}}$: Standard deviation of values of F_{am}

D_u : Ratio of upper decile to median value, F_{am}

σ_{D_u} : Standard deviation of values of D_u

D_l : Ratio of median value, F_{am}, to lower decile

σ_{D_l} : Standard deviation of value of D_l

V_{dm} : Expected value of median deviation of average voltage. The values shown are for a bandwidth of 200 Hz.

σ_{V_d}: standard deviation of V_d

Figure 3. Figures 2b and 2c from CCIR Report 322-3.

two-dimensional Fourier sine series,

$$F_{am}(x,y) = \sum_{k=1}^{29} \left(\sum_{j=1}^{15} b_{j,k} \sin jy + \chi_k \right) \sin kx + \alpha + \beta x, \quad (11)$$

where

x = latitude in radians $(0 \rightarrow \pi)$ or degrees North of South pole x $\pi/180$

y = longitude in radians $(0 \rightarrow \pi)$ or degrees East of Greenwich x $\pi/360$,

χ_k = longitude coefficient such that $F_{am}(x,o) = F_{am}(x,\pi)$,

and α and β are coefficient such that there is only one value at the North and South poles for every longitude. The details of the mapping are contained in Spaulding and Washburn (1985).

The frequency variation of F_{am} (Figure 3) is given by

$$F_{am}(x,z) = A_1(z) + A_2(z)x + A_3(z)x^2 + \ldots + A_7(z)x^6. \quad (12)$$

where

$$A_i(z) = B_{i,1} + B_{i,2}z, \quad i = 1,7. \quad (13)$$

z = the 1 MHz F_{am}(from the contour maps), and

$$X = \frac{8 \times 2^{\log_{10} f} - 11}{4}, \quad (14)$$

where f is the frequency in MHz. Also $F_{am}(-0.75,z) = z$ (i.e., the 1 MHz value must equal z). So 14 coefficients represent each of the 24 sets of frequency variations (each season and 4-hour time block).

The other parameters of concern here, D_μ, D_ℓ, σ_{D_μ}, σ_{D_ℓ}, and $\sigma_{F_{am}}$ are all given by

$$p(x) = A_0 + A_1x + A_2x^2 + A_3x^3 + A_4x^4, \quad (15)$$

where $x = \log_{10}(f_{MHz})$, and f_{MHz} is the frequency in MHz.

All the coefficients, $b_{j,k}$, χ_k, α, β for the 1 MHz maps, the $B_{i,1}$, $B_{i,2}$, and the 5 sets of A_i, i = 0, 4, for each of the 24 season/time blocks are given in Spaulding and Washburn along with computer algorithms for their use. In the program IONCAP, the SUBROUTINE ANOIS1 determines the 1 MHz atmospheric noise value by calling SUBROUTINE NOISY, which uses the $b_{j,k}$, χ_k, α, and β coefficients via (11). In NOISY the $b_{j,k}$ χ_k coefficients and in the array P (29, 16, 8), the α and β coefficients are in ABP (2, 8). The F_{am} at the desired frequency and D_μ, D_ℓ, σ_{D_μ}, σ_{D_ℓ}, and $\sigma_{F_{am}}$ at this frequency are calculated by SUBROUTINE GENFAM. The F_{am} frequency variation coefficients are in array FAM (14, 12) and the coefficients for the other 5 parameters are in array DUD (5, 12, 5). These arrays are only for one season. The 1 MHz maps are in terms of three month periods and P (29, 16, 8) and ABP (2, 8) are for one three-month period, six four-hour time blocks (the sets of coefficients for the "7 and 8" indices are maps of the continental outline and the ratio of F-layer heights to its semi-thickness). The other parameters are given as seasonal variations (not 3 month), so the arrays FAM and DUD have the dimension 12 (rather than 6) so that they include the 6 time-block sets for the Northern Hemisphere and the 6 time-blocks for the Southern Hemisphere. That is, for example, if the month for which IONCAP is being run is say, March, this is Spring in the Northern Hemisphere and Fall in the Southern Hemisphere, so that both the Spring and Fall coefficients are required for the three month period, March, April, and May. In IONCAP when the season is changed, new arrays P, ABP, FAM and DUD (as well as others) must be read in. For modern computers, this is very inefficient. In any case, the new coefficients P (29, 16, 6) and ABP (2, 6) (the "7 and 8" are the same) for the new 1 MHz F_{am} maps have been installed in IONCAP. Except for this change, SUBROUTINES ANOIS1, NOISY AND GENFAM have been altered as explained below, and all the significant improvements are in SUBROUTINE GENOIS, which is the main noise routine.

It has been shown that the variation of f_a for a given season and time block can be adequately represented by two log-normal distributions (i.e., dB values, F_a, normally distributed), one above the median value and one below. Therefore, the variation is given by F_{am}, D_μ, and D_ℓ. This is best explained with an example. Suppose we wanted F_a and its variation for the Winter Season, 0000-0400 time block, for Boulder, Colorado at 3 MHz. From Figure 2 (2a of CCIR 322-2) F_{am} at 1 MHz is 66 dB. From Figure 3 (2b of CCIR 322-3) this translates to 55 dB at 3 MHz. From Figure 3, (2c of CCIR 322-3) the values for the other parameters are

$$D_{\mu} = 8.6 \text{ dB},\ D_{\ell} = 6.8 \text{ dB},\ \sigma_{D_{\mu}} = 2.6 \text{ dB},\ \sigma_{D_{\ell}} = 2.4 \text{ dB, and } \sigma_{F_{am}} = 3.7 \text{ dB}.$$

The sigmas account for the entire Earth's surface being covered by one value of D_{μ}, etc. and represent a location variability and the year-to-year variability. Figure 4 shows the distributions of F_a values estimated via the data above

$$(F_{am},\ D_{\mu},\ D_{\ell},\ \sigma_{D_{\mu}},\ \sigma_{D_{\ell}},\text{ and } \sigma_{F_{am}}).$$

On Figure 4, for the given F_{am}, all the data measured at Boulder will essentially lie between the two dotted lines with the solid line being the estimate of the distribution of F_a for this season and time block. In determining the overall variability, however, the $\sigma_{F_{am}}$ must also be considered. This is covered in detail in Section 4, where all the noises are combined and the overall variations determined.

In IONCAP, in the computation of the signal-to-noise ratio, the signal is calculated as a month/hour median with corresponding variations (σ). As we noted above the atmospheric noise values are calculated for season (3 month), 4-hour, time-blocks.

The routine GENOIS obtains a 3 month/1-hour value for F_{am} and all the variation parameters by linear interpolation between adjacent 4-hour time blocks (for the given season). This is done by calling GENFAM twice, using indices (for the required 4-hour time-blocks) generated in SUBROUTINE ANOIS1. The interpolation gives values at the beginning of the required hour. The F_{am} value, for example, that is obtained from CCIR 322 is placed at the center of the time block (beginning of third hour) and is, therefore, the value returned by the interpolation for the third hour. Some consideration was given to changing the interpolation to obtain values at the midpoint of each hour. This would involve extensive modification to ANOIS1 as to how the required indices are generated. Since the indices that are currently generated in ANOIS1 are used throughout IONCAP and not only in GENOIS, this was not done. Also, as noted below, it would result in no statistical improvement and

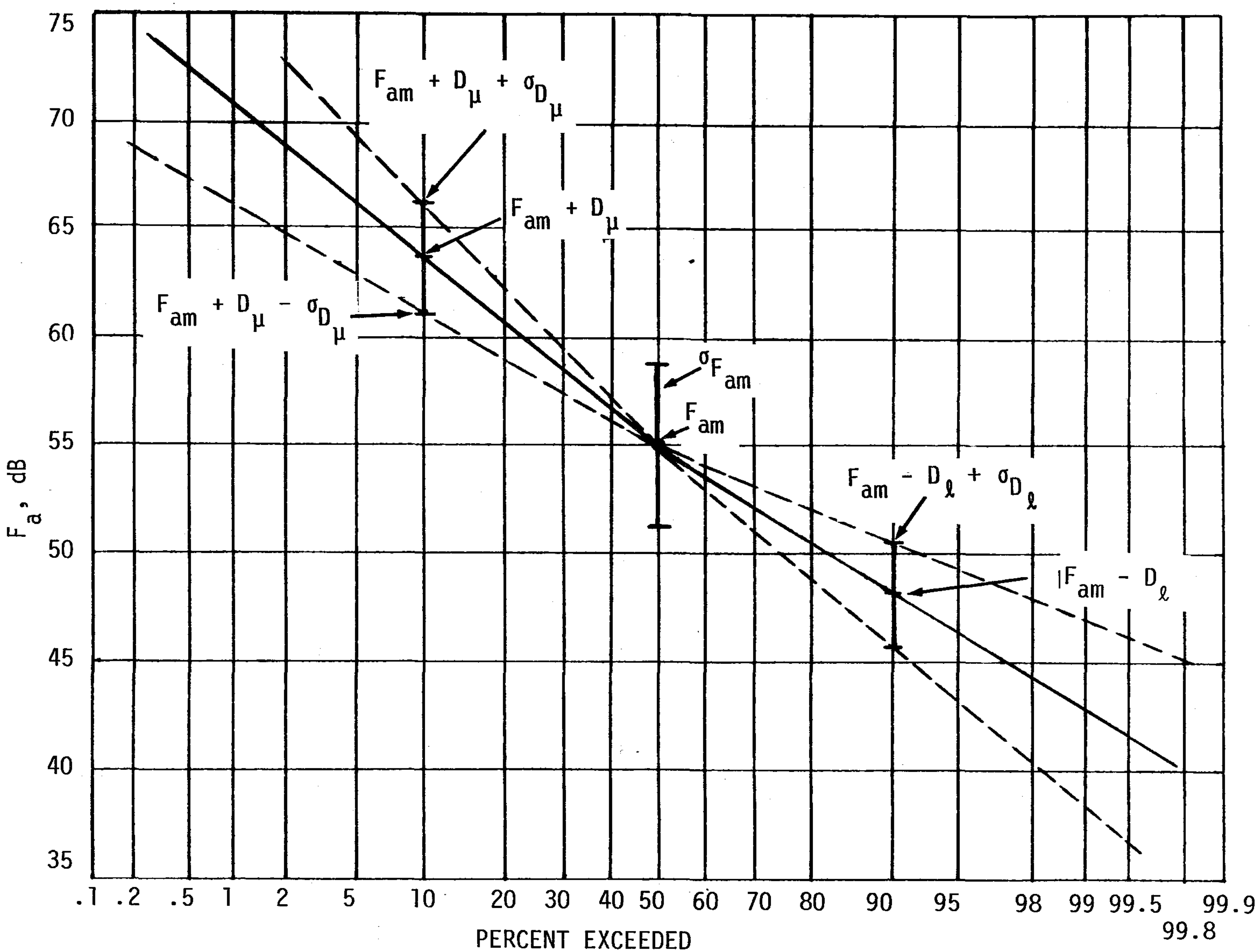

Figure 4. The distribution of F_a values for atmospheric radio noise at Boulder, Colorado 3 MHz, for the Winter Season, 0000-0400 hours.

would only be cosmetic.

The question also arises as to the suitability of using the variation parameters D_μ and D_ℓ which were calculated for a season 4-hour time-block for the season 1-hour time block. If the season 4-hour data is homogeneous, then the statistics estimated from this population should apply to sub-populations. When the original D_μ and D_ℓ estimates were obtained, they were calculated simply by averaging the month-hour values. These are the values given in CCIR Report 322-1 and are as reported in the earlier volumes of the Tech Note 18 series (i.e., before October 1961). The D_μ and D_ℓ's given in the later Tech Note 18's were calculated from the raw data; that is, from all the hourly values for the entire season 4-hour time-block, rather than from averaging the month-hour values. In the analysis of the totality of data (Spaulding and Washburn, 1985) that lead to CCIR Report 322-3, the D_μ and D_ℓ's "correctly" computed were not significantly different from those computed earlier as given in 322-1. Therefore the variation parameters, including the frequency variation of F_{am}, are the same in 322-3 as in 322-1. This gives some indication, at least, that use of the existing season 4-hour values is acceptable for the season 1-hour values. The interpolation on F_{am} to obtain a 1-hour value from the 4-hour value was initiated originally, apparently, to avoid the annoying occasional sharp discontinuity between adjacent time blocks. No increase in statistical significance, however, is gained. The linear interpolation on

$$D_\mu,\ D_\ell,\ \sigma_{D_\mu},\ \sigma_{D_\ell},\ \text{and}\ \sigma_{F_{am}}$$

makes little difference, since these change quite slowly between time blocks (for any given frequency).

Some thought was also given to what would be involved and if anything would be gained if the interpolation was continued (across adjacent seasons) to obtain a month-hour value from 3-month-hour values. From above, it is clear that nothing of any statistical importance would be gained. Also, as noted earlier, going from one season to the next requires the obtaining of completely new sets of coefficients due to how IONCAP is constructed. Doing interpolation between seasons would significantly more than double the running time of the noise value computation. That is, GENOIS would need to call GENFAM four times instead of two and the second two would require obtaining different sets of the coefficient arrays (P, ABP, and DUD). All this would gain nothing. Even so, some preliminary calculations were made to note how the resulting month-hour values of F_{am} might differ from the 3-month-hour values. For the very few examples looked at, no sharp differences were noted.

The above covers the determination of the atmospheric noise F_{am} value and its statistical variation. Man-made noise and galactic noise have f_a values that also are log-normally distributed. The next section covers the estimation of the man-made noise value, its variation, and the galactic noise value and its variation. Then Section 4 covers the addition of the three noises to obtain the overall external f_a and its variation.

3. MAN-MADE AND GALACTIC NOISE

As noted in the introduction, one of the major changes in the SUBROUTINE GENOIS was to replace the current man-made noise estimates with the much more modern ones as given in CCIR Report 258-4 (1982). As will be shown, these estimates are substantially different than the ones currently used, and this, in some situations, will greatly affect the calculated signal-to-noise ratio.

Figure 5 shows the man-made noise levels from CCIR Report 258. These levels and all the associated statistics are directly from Spaulding and Disney (1974), which gives the details of the measurements and analysis giving rise to these estimates. Most of the measurements that went into the estimates were from throughout the continental U.S. The quiet rural curve is from CCIR Report 322 and is based on world-wide measurements. As noted in Report 258, numerous measurements made throughout the world since these estimates were developed generally follow them quite closely for the various areas (i.e., business, residential, etc.) and therefore the Report 258 estimates serve well throughout.

As an additional example of the applicability of the Report 258 estimates, Figure 6 shows recently analyzed noise measurements from Moscow. When the new atmospheric worldwide noise estimates were obtained (Spaulding and Washburn, 1985), some of the "new" data used was from 10 Soviet measurement locations. One of these was Moscow. For Moscow, data are available from March 1958 through December 1964. The frequencies were 12, 25, 35, 60, 100,

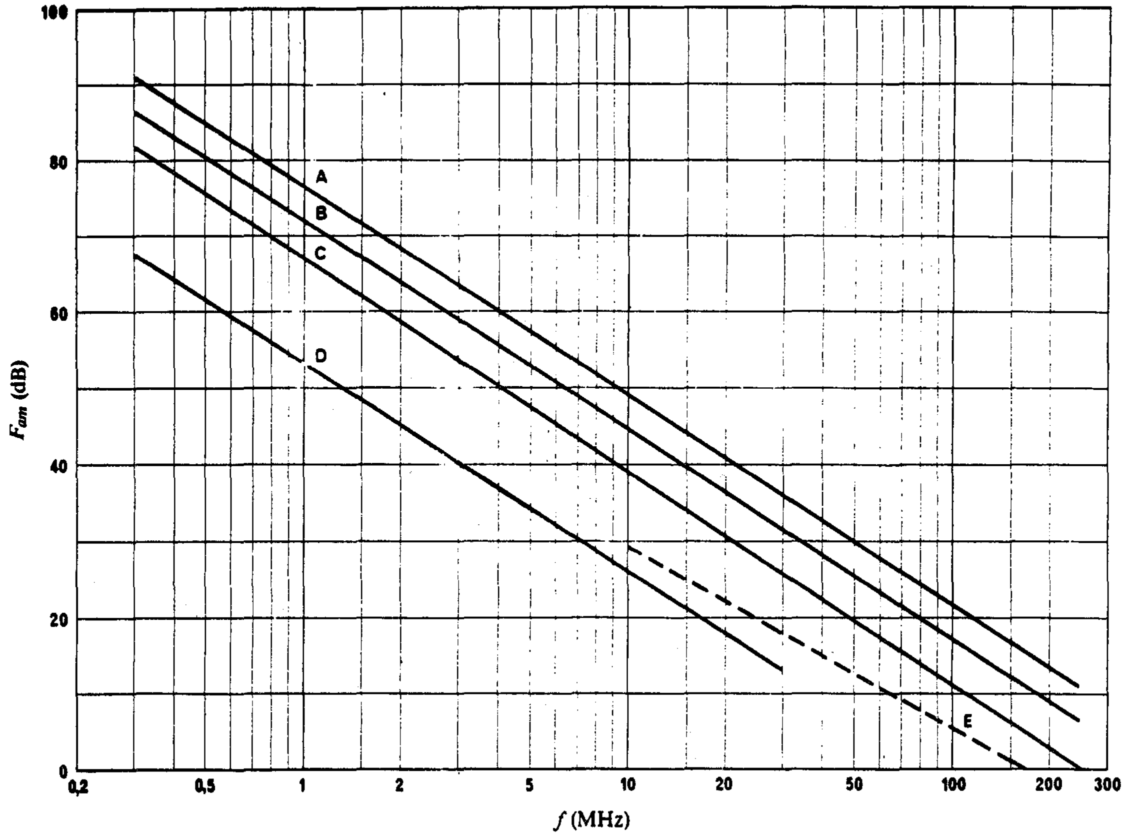

FIGURE 1 – *Median values of man-made noise power for a short vertical lossless grounded monopole antenna*

Environmental category:
A: business
B: residential
C: rural
D: quiet rural
E: galactic

Figure 5. Figure 1 from CCIR Report 258-4.

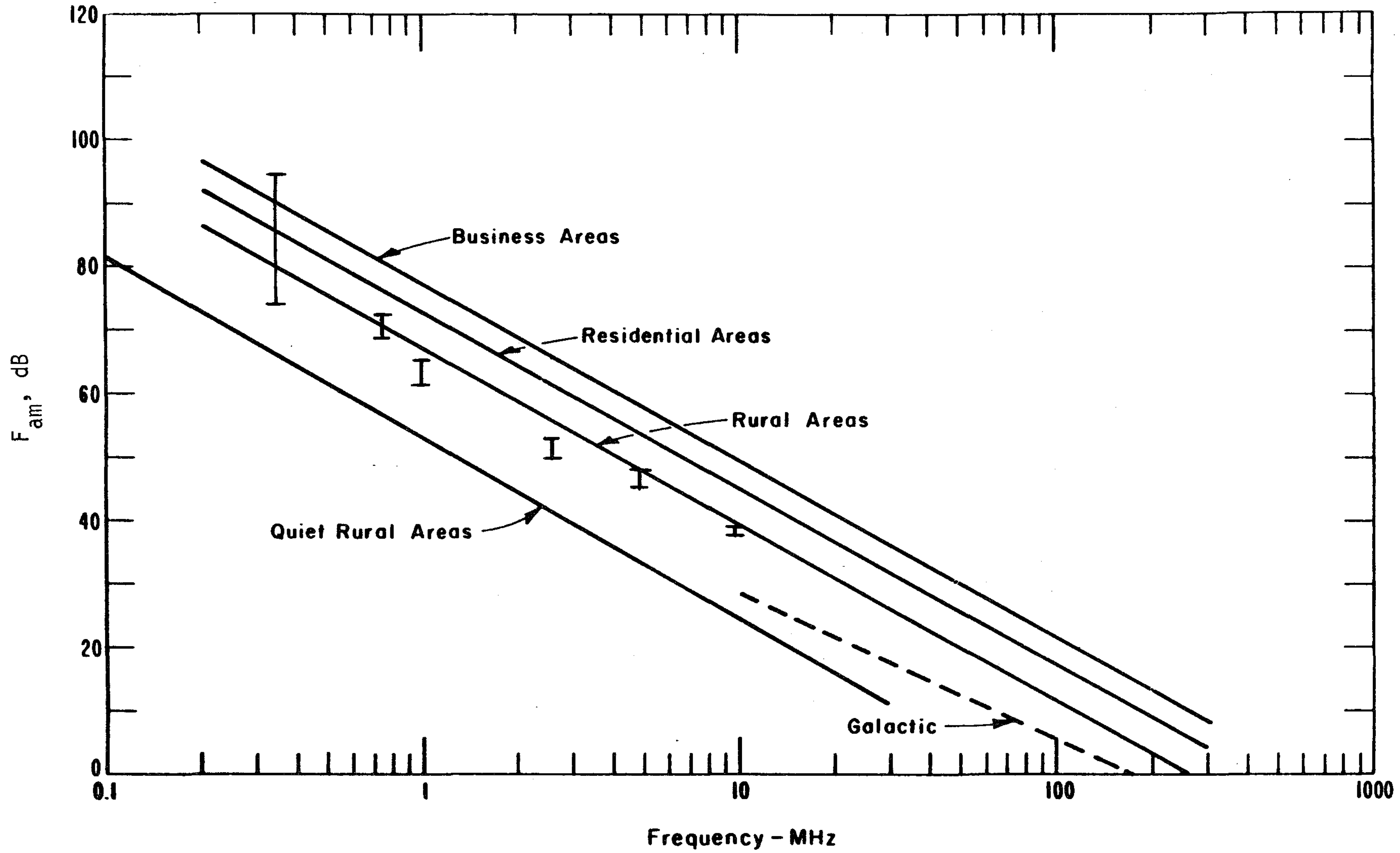

Figure 6. Figure 1 from Spaulding and Disney (1974) with Soviet Moscow noise measurements, Winter Season, 1958 - 1964.

350, 750, 1000, 2500, 5000, 7500, and 10,000 kHz. Various lower frequencies down to 3 kHz were added in October 1962. In analyzing the Soviet data, the higher frequencies were not generally analyzed as it was soon discovered that they were contaminated by man-made noise (see Spaulding and Washburn, 1985 for details). The higher frequency data for Moscow has been analyzed for the winter season (when the atmospheric noise is lowest). Figure 6 shows the range of median F_a values for each of the six 4-hour time blocks for 350, 750, 1000, 2500, 5000, and 10,000 kHz. The 350 kHz data contains atmospheric noise as shown by the large diurnal variation. However, the higher frequency measurements were, apparently, of man-made noise. Assuming that the conversion method used (Spaulding and Washburn, 1985) to obtain f_a from the parameters the Soviets measured is correct, Figure 6 indicates that the Moscow measurement location (37.3E, 55.5N) was "rural," at least in 1958 through 1964. The Soviet data at the other locations at the higher frequencies (2.5 MHz on) has not been analyzed.

In Figure 5 (or 6), the linear variations of F_{am} with frequency, including the galactic noise variations, are given by

$$F_{am} = c - d\log f, \tag{16}$$

where f is the frequency in MHz, the constants, c and d, are given in Table 1 below. Table 1 also contains constants for other environmental categories not given in Figure 5 (e.g., parks and university campuses).

TABLE 1 -- VALUES OF THE CONSTANTS c AND d

Environmental category	c	d
Business (curve A)	76.8	27.7
Inter-state highways	73.0	27.7
Residential (curve B)	72.5	27.7
Parks and university campuses	69.3	27.7
Rural (curve C)	67.2	27.7
Quiet rural (curve D)	53.6	28.6
Galactic noise (curve E)	52.0	23.0

The next change is in the values of D_μ, D_ℓ, etc. The current IONCAP values, for all man-made noise categories, are D_μ (denoted DUM) = 9 dB, D_ℓ (DLM) = 7 dB, σ_{D_μ} (SUM) = 1.5 dB, $\sigma_{F_{am}}$ (SMM) = 3 dB and σ_{D_ℓ} (SLM) = 1.5 dB. Spaulding and Disney (1974) (and CCIR Report 258) give a separate value of D_μ, D_ℓ, and $\sigma_{F_{am}}$ for each category (business, residential, and rural) and each measurement frequency (0.25 MHz - 250 MHz). An analysis of this data has led to the conclusion that it is acceptable to use, as currently, one value for each of the parameters for all three categories and all frequencies. The values used here are designed to be acceptable at all frequencies, but most appropriate for HF frequencies. These new values are

$$D_\mu = 9.7 \text{ dB},\ D_\ell = 7 \text{ dB},\ \sigma_{D_\mu} = 1.5 \text{ dB},\ \sigma_{F_{am}} = 5.4 \text{ dB, and } \sigma_{D_\ell} = 1.5 \text{ dB}.$$

It is not completely known how appropriate these values are for the quiet rural category; however, a review of the analysis of the atmospheric noise Tech Note 18 data indicate that these should also be reasonable values for this category.

As with atmospheric noise, the variation of f_a about its median value, F_{am}, for man-made noise is well represented by two log-normal distributions, one above and one below the median. Figure 7 (from Spaulding and Disney, 1974) shows an example of this. Figure 7 shows the distribution of 10 second f_a values within an hour for Boulder, CO and 20 MHz. For this sample of data, $D_\mu = 10.2$ dB and $D_\ell = 6.0$ dB.

Galactic noise can also be represented by a log-normal distribution about its median value. The current values used are still appropriate; i.e., D_μ (denoted DUG) = 2 dB, D_ℓ (DLG), = 2 dB, σ_{D_μ} (SUG) = 0.2 dB, $\sigma_{F_{am}}$ (SMG) = 0.5 dB and σ_{D_ℓ} (SLG) = 0.2 dB. The current galactic noise representation is, however, somewhat inaccurate. The current representation corresponds to values of c and d (Table 1) of 49.5 (rather than 52) and 22.0 (rather than 23.0) respectively. The galactic noise representation has, therefore, been corrected in the new subroutine GENOIS.

Each of our three noise processes, atmospheric, man-made, and galactic is given by log-normal distributions and we need to determine the sum of these three processes. This is treated in the next section, but it is interesting to present, for the record, the "history" (as well as we can determine it) of the currently used man-made noise levels and variations and contrast them with the "new" (Figure 5) values.

The current four levels are given in GENOIS by DATA Statement XNINT and are specified in terms of dB less than 1 watt, that is, the negative of the

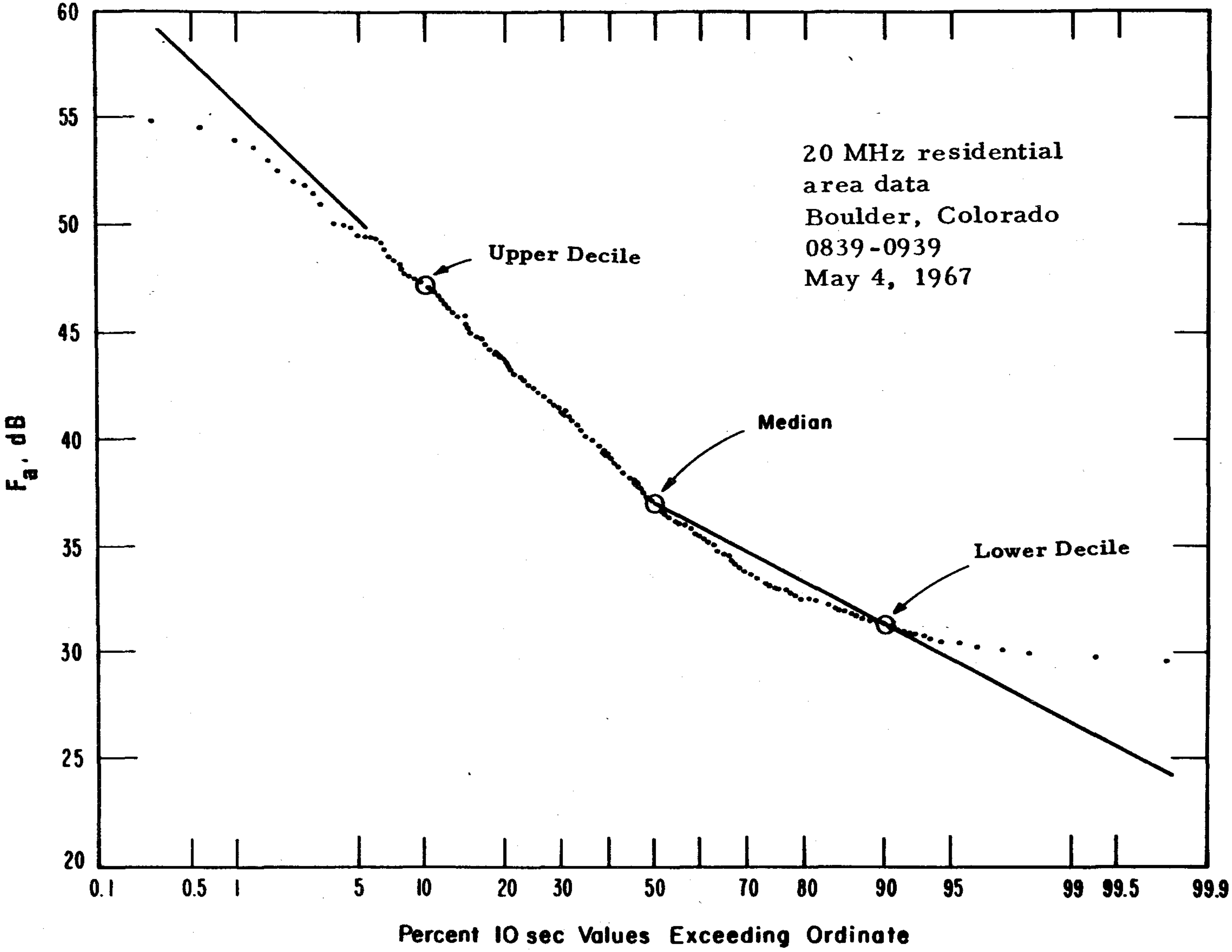

Figure 3. Distribution of F_a values for a given location.

Figure 7. Figure 3 from Spaulding and Disney (1974).

normal units dBW. The four levels are 125, 136, 148, and 164 corresponding to industrial, residential, rural, and remote unpopulous (quiet rural from CCIR 332) regions. These values are obtained from Figure 4.1 of Lucas and Haydon (1966, ITSA-1). Figure 8 shows this Figure from Lucas and Haydon (1966). The Figure supposedly relates man-made noise levels to population of a receiving area. Also the D_μ and D_ℓ values are taken to be 9 dB and 7 dB respectively. The reference to this material is Spaulding (private communication). Spaulding does not recall supplying any information in the form of Figure 8, but in any case, these estimates can be based only on very limited data. While it seems reasonable that man-made noise levels should correlate, at least broadly, with population in urban areas, attempts to correlate average noise power levels with population density, as measured in U.S. Census Bureau's standard location areas (SLA's) of 1 to 5 square miles, have not been successful (Spaulding, et al., 1971). In fact, Spaulding (1972) found no significant correlation between the average population density of an SLA (ranging from 1000 to 25,000 per square miles) to the average values of noise level taken at several locations within the SLA. The four levels (125, 136, 148, and 164) given in Figure 8 are for 3 MHz. In the original (ITSA-1) the linear slope used was 29 dB/decade of frequency versus 27.7 dB/decade (d, Table 1). In the current GENOIS, the slope (but not the 3 MHz levels) was changed to 28 dB/decade. ITSA-1 "added" the three noise processes by simply selecting the largest, using it, along with its D_μ, D_ℓ, etc. for the total. Figure 9 shows the comparison of the CCIR 258 man-made noise estimates and those currently in GENOIS.

In 1967, Spaulding and Disney prepared an estimate of the man-made radio noise expected in urban, suburban, and rural locations for the Joint Technical Advisory Committee (JTAC, 1968). These JTAC estimates are shown in Figure 10. Note the break in the JTAC curves between 10 and 20 MHz. This occurred when data were combined from measurements made by various investigators at different times, locations, and frequencies, with no one set of data covering the whole frequency range. The break seemed not unlikely at the time since between 10 and 20 MHz the predominant noise sources change from those associated with power lines to automotive ignition systems. However, the real cause was due to the incomplete frequency coverage of the measurements and the attempt to relate dissimilar parameters.

In 1969, the HF propagation program, HFMUFES, was developed (Barghausen,

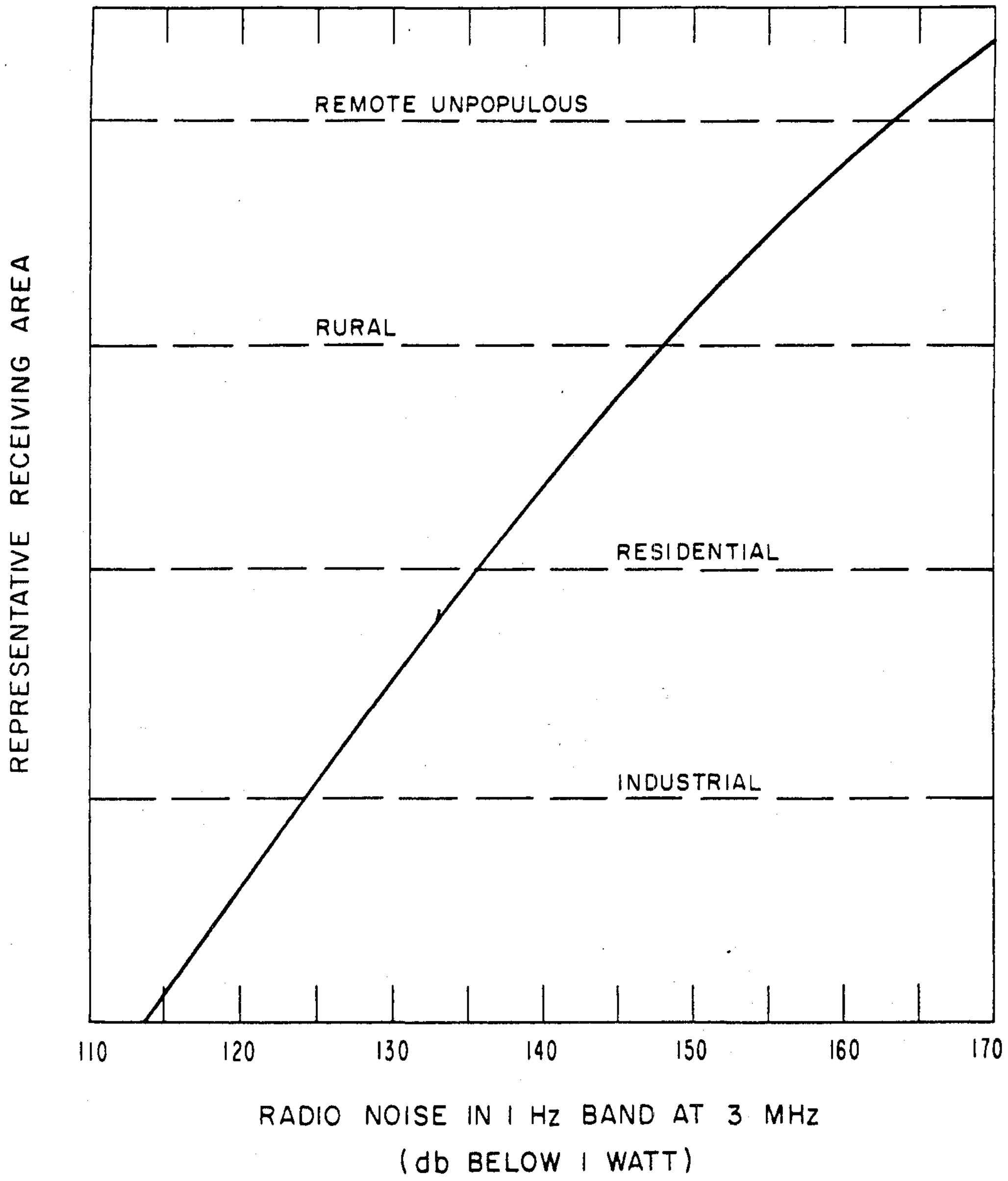

Figure 4.1. Typical Man-Made Noise Relative to Population of Receiving Area.

Figure 8. Figure 4.1 from Lucas and Haydon (1966).

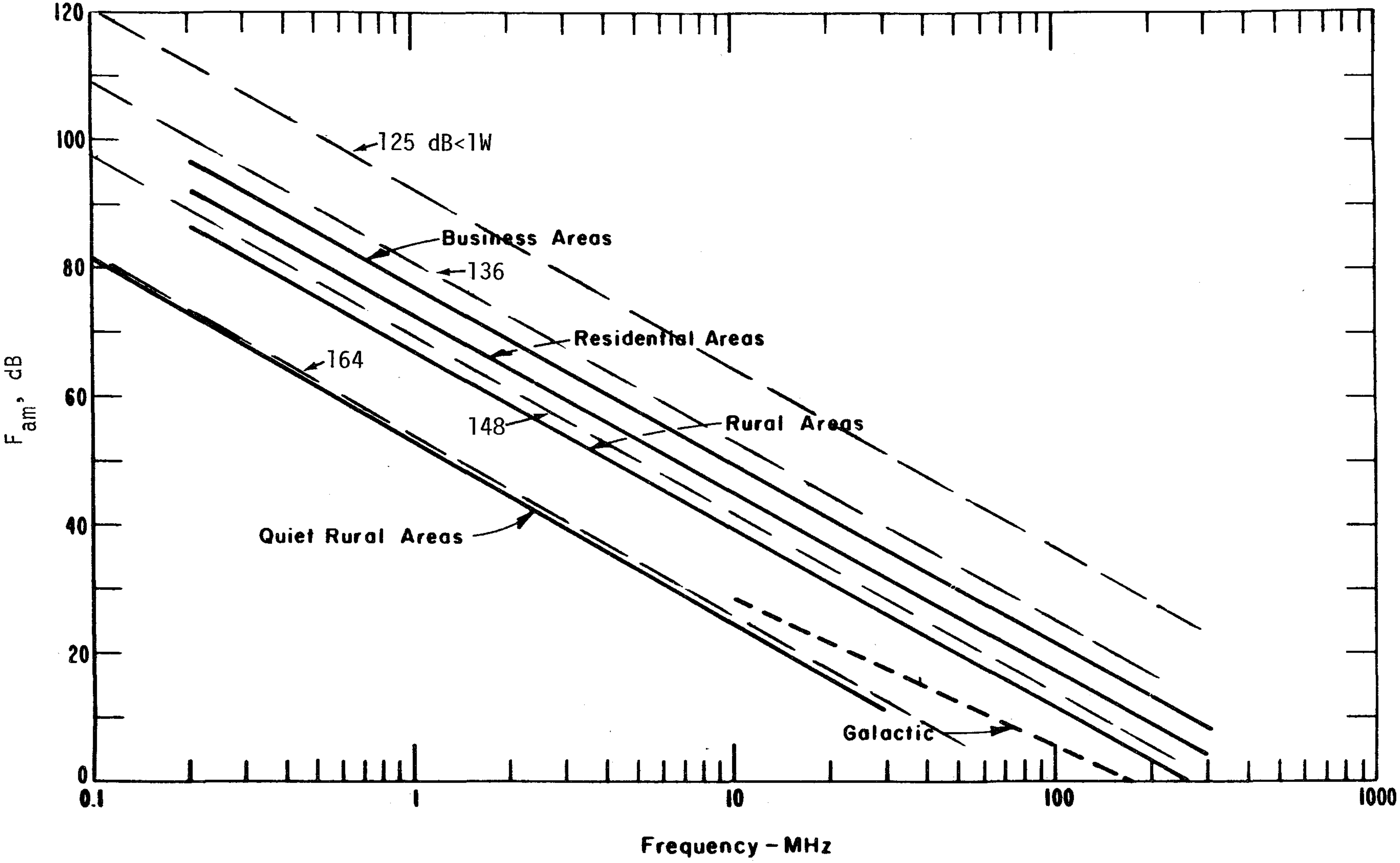

Figure 9. Comparison of the CCIR Report 258 man-made noise estimates and those currently used in GENOIS of IONCAP.

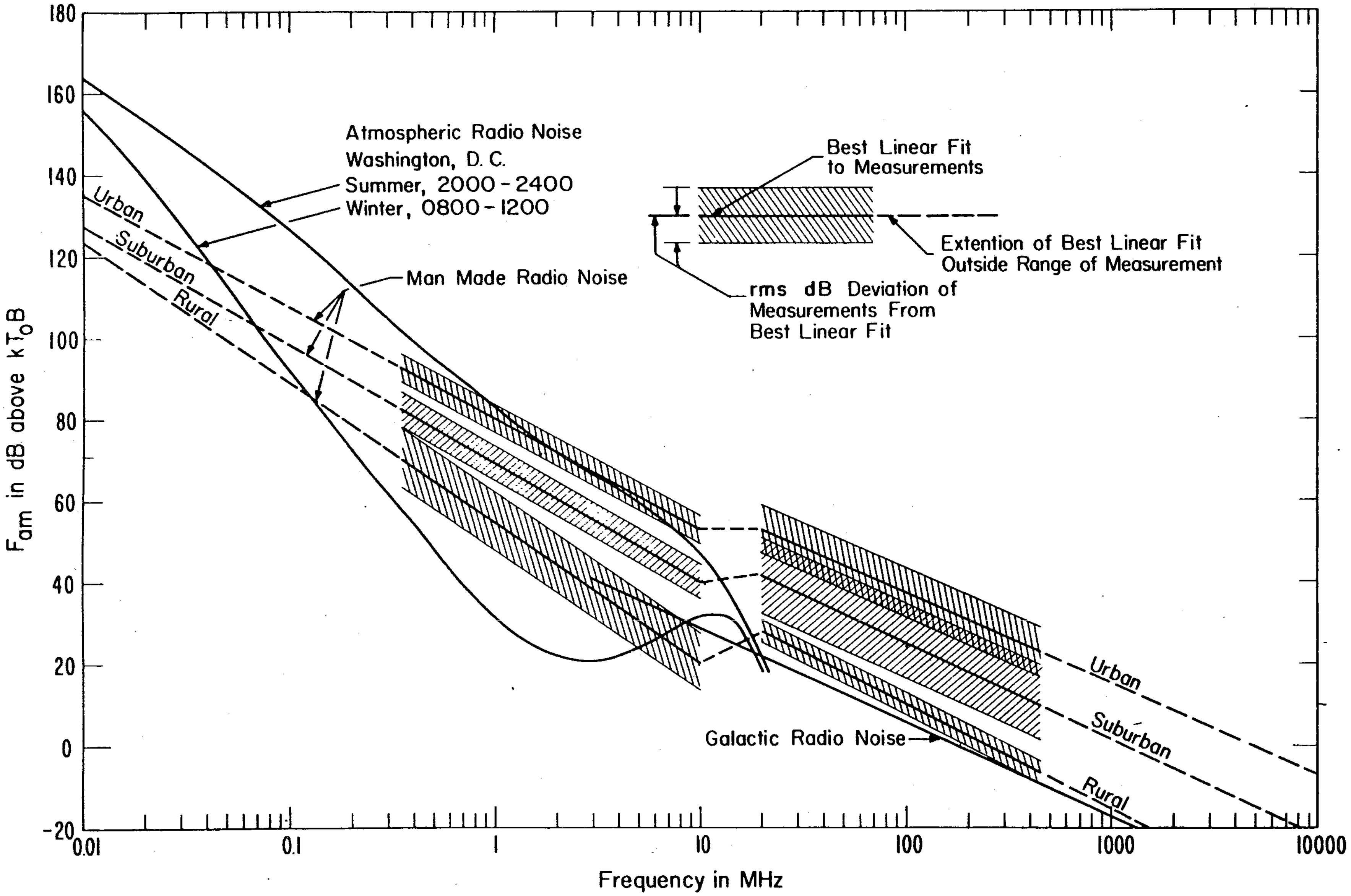

Fig. 3. Median Values of Radio Noise Power (Omnidirectional Antenna Near Surface)

Figure 10. The JTAC (1968) man-made noise radio estimates.

et al., 1969). This program uses the JTAC man-made noise estimates (Figure 10) in its noise routines. As in IONCAP, HFMUFES used linear interpolation to obtain a 3 month/1-hour F_{am}, etc. values for atmospheric noise using GENFAM and NOISY. The overall noise level is calculated in SUBROUTINE RELBIL. For man-made noise, the JTAC curves are used, with three frequency ranges $f < 10$ MHz, $10 < f < 20$, and $f > 20$ MHz. For each of these frequency ranges, and for each environmental category, urban, suburban, and rural, a different D_μ is used. Also D_ℓ is set equal to D_μ (see Table 4.1, Barghausen, et al., 1969). A $\sigma_{F_{am}} = 3.0$ dB and $\sigma_{D_\ell} = \sigma_{D_\mu} = 1.5$ dB are used. The three noise processes, atmospheric, man-made, and galactic are ordered in magnitude (median values) and either 0, 1.0, 1.8, 2.4, 3.0, 3.5, 4.0, or 4.8 dB is added to the largest value depending on the various differences between the highest noise source, second highest, and third highest (see Table 4.2 of Barghausen, et al., 1969). The D_μ and D_ℓ ($= D_\mu$) for the highest noise source is then used for the "sum" of the noise processes. Figure 11, from Spaulding and Disney (1974) shows the comparison of the JTAC man-made noise estimates and the current CCIR Report 258 estimates.

As noted above, the original subroutine GENOIS simply selected the largest noise source and its statistics for the "sum". Later GENOIS was changed to attempt to add the three noise processes to obtain the "sum" process. However, the (inappropriate) man-made noise levels were retained, although, as noted above, the linear slope was modified. The next section, then, covers the addition of the three processes.

Finally, the current IONCAP allows the user to enter his own man-made noise value (in dB > 1 watt) at 3 MHz. This feature has been maintained in the new GENOIS and functions exactly as before. (Of course, the new D_μ and D_ℓ etc. values now apply).

4. COMBINATION OF THE THREE NOISES

In this section we want to detail the changes made in GENOIS as to the technique used to find the total external noise and its distribution. As noted in the last section, the original GENOIS in ITSA-1 simply selected the largest of the three noises (atmospheric, man-made, and galactic) and used its median value and decile values for the total. Later, HFMUFES did much the same in that it used the decile and sigmas of the largest noise source, but increased the largest noise source median value by various amounts ranging from 0 to

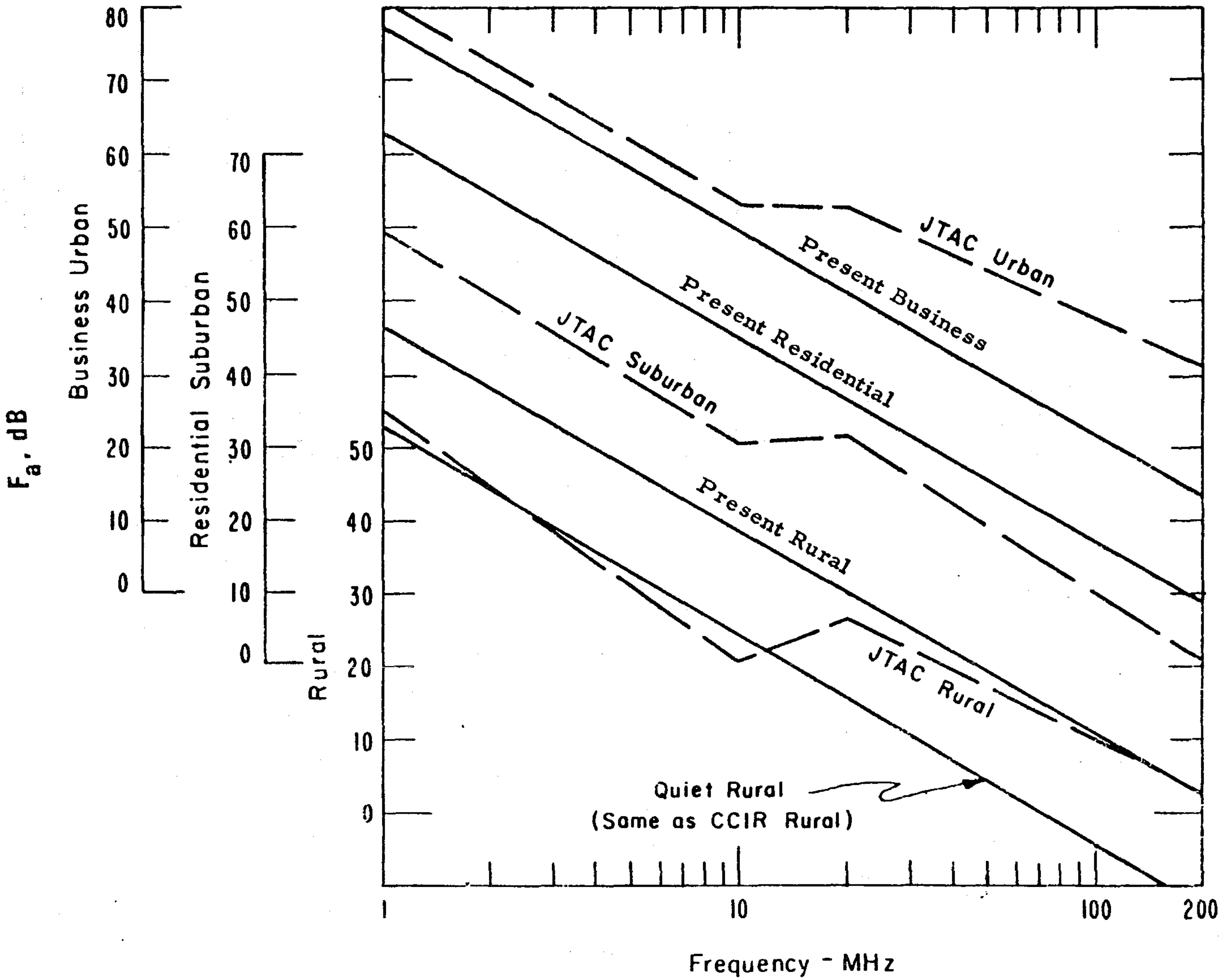

Figure 11. Comparison of present estimates with JTAC (1968) estimates.

4.8 dB, depending on the differences between the largest, next largest, etc. The current GENOIS attempts to find the sum noise process and its statistics as summarized, and commented on, below.

In the current GENOIS, the three noise median values are given by ATNOS for atmopsheric noise, GNOS for galactic noise, and XNOIS for man-made noise. The previous sections of this report detailed how these values are obtained. All three noise processes are represented by log-normal distributions. The median value of the total is obtained by summing the three individual medians, after converting to watts (ATNOS, GNOS, and XNOIS are in dBW). That is, the sum, XRNSE, is given by

$$\mathrm{XRNSE} = 10\log\left(10^{\frac{\mathrm{ATNOS}}{10}} + 10^{\frac{\mathrm{GNOIS}}{10}} + 10^{\frac{\mathrm{XNOIS}}{10}}\right). \qquad (17)$$

First, the procedure is not strictly correct, since only the <u>mean</u> values add, and for log-normal distributions, the median value and the mean value are different. As we shall see, using (17) still is reasonably accurate for most cases arising in practice.

Next, GENOIS states (via a comment statement) that "equation 37, page 29 of <u>The Theory of Errors</u> by Yardly Beers, McGraw Hill" is used to calculate the deciles and variance. Equation 37 of Beers is the standard relation that if a random variable V is given by a function of two random variables x and y,

$$V = V(x,y), \qquad (18)$$

then the variance of V is given by

$$\sigma_V^2 = \left(\frac{\partial V}{\partial x}\right)^2 \sigma_x^2 + \left(\frac{\partial V}{\partial y}\right)^2 \sigma_y^2 + \rho_{xy}\left(\frac{\partial V}{\partial x}\right)\left(\frac{\partial V}{\partial y}\right) \sigma_x\sigma_y. \qquad (19)$$

Result (19) is for two variables, but is the "same" for any number of variables. We assume independent noise sources, so that the cross correlations, $\rho_{xy} = 0$, etc. The relation (19) is, of course, an approximation for nonlinear functions, but is an arbitrarily close approximation for sufficiently small σ's ,since $D_\mu = 1.282\sigma$, (19) also could be used for decile values. GENOIS does <u>not</u> use (19) for the computation of the deciles, but uses it only for the computation of SIGM, the standard deviation of the "total" median. If (19) is used for the calculation of deciles (as was once suggested by Rosich, private communication), a very inaccurate result is obtained. This is due to the incorrect relation for the sum (17) and to the σ's (or D_μ's) for the three variables (ATNOS, GNOIS, and XNOIS) not being small. The decile values for the sum process are calculated instead by

$$\mathrm{DU} = 10 \log \left(10^{\frac{\mathrm{ATNOS + DUA}}{10}} + 10^{\frac{\mathrm{GNOIS + DUG}}{10}} + 10^{\frac{\mathrm{XNOIS + DUM}}{10}}\right) - \mathrm{XRNSE}, \qquad (20)$$

and

$$\mathrm{DL} = 10 \log \left(10^{\frac{\mathrm{ATNOS + DLA}}{10}} + 10^{\frac{\mathrm{GNOIS + DLG}}{10}} + 10^{\frac{\mathrm{XNOIS + DLM}}{10}}\right) - \mathrm{XRNSE}. \qquad (21)$$

The rational behind (20) is obvious, (20) simply adds the powers (watts) at the 10% level of the noise sources, converts back to dB and then subtacts the median, XRNSE, computed by (17). If this same rational was followed for DL (21), then this would require ATNOS - DLA rather than ATNOS + DLA, etc. The plus DLA etc. was probably used so that if only one noise source is considered, then (21) returns DL = DLA, for example, and would not if the minus sign was used. While not theoretically correct, both (20) and (21) do give reasonable estimates for most cases of interest.

The next parameter calculated is SIGM, the standard deviation of the median of the sum noise process. GENOIS uses (19) for this calculation. The three required partial derivatives are termed QPA, QPG, and QPM, and from (17)

$$\mathrm{QPA} = \frac{\partial \mathrm{XRNSE}}{\partial \mathrm{ATNOS}} = 10^{\frac{\mathrm{ATNOS - XRNSE}}{10}}, \text{ etc.} \qquad (22)$$

Therefore, using (19),

$$\mathrm{SIGM}^2 = (\mathrm{QPA \times SMA})^2 + (\mathrm{QPG \times SMG})^2 + (\mathrm{QPM \times SMM})^2 \qquad (23)$$

In the computation of the standard deviations for DU and DL, as given by (20) and (21), (19) was not used (although it should have been). From (20), DU is a function of <u>six</u> variables, ATNOS, DUA, GNOIS, DUG, XNOIS, and DUM. If (19) had been used, the required partial derivatives are

$$\frac{\partial \mathrm{DU}}{\partial \mathrm{DUA}} = \mathrm{QPA} \times 10^{\frac{\mathrm{DUA - DU}}{10}}, \qquad (24)$$

$$\frac{\partial DU}{\partial ATNOS} = QPA \times \left(10^{\frac{DUA - DU}{10}} - 1\right), \text{ etc.} \qquad (25)$$

Instead of using (19) with the six partial derivatives given by (24) and (25), the current GENOIS estimates the standard deviations of DU and DL by

$$SIGU^2 = \left(\frac{DUA \times SUA \times QPA^2}{DU}\right)^2 + \left(\frac{DUG \times SUG \times QPG^2}{DU}\right)^2 + \left(\frac{DUM \times SUM \times QPM^2}{DU}\right)^2, \qquad (26)$$

with a similar expression for SIGL. These expressions for SIGL and SIGU (the standard deviation for DU and DL) provide very poor estimates (as we shall see) and their origin is a mystery.

We now proceed with the addition and variance estimation methods used in the updated GENOIS. We start in a fairly general way. Suppose we have N noise sources, each with their f_a values log-normally distributed. We require the distribution of the sum of the N sources. It turns out that if N is large, the distribution of the sum is closely represented by another log-normal distribution. Also, if one of the N sources dominates the others, the resulting distribution cannot be far from log-normal. However, we are interested in a relatively small N (3 here) and, quite often, with sources of similar size. The resulting distribution for the sum is now definitely not log-normal and can be determined by convolution. [The current procedures in IONCAP, of course, assume the sum is log-normal.] Such convolutions of log-normal pdf's (probability density function) have been performed in the past with, for our purposes, some quite interesting results. It turns out that the method presented below will give quite accurate results for the larger noise levels (i.e., the small percentage points of the result and distribution) and appears to be most acurate around the 10% point. [For an indication of the truth of this conjecture, see Norton et al., (1952); and Appendix A of Gierhart et al., (1970)]. The method below simply determines the log-normal distribution that best approximates the true distribution of the sum.

The pdf for our i-th noise source, N_i is

$$p_{N_i}(x_i) = \frac{4.343}{x_i\sqrt{2\pi\sigma_i^2}} e^{-1/2\left(\frac{10\log x_i - \mu_i}{\sigma_i}\right)^2} \qquad 0<x_i<\infty \qquad (27)$$

and for the variable $y_i = 10 \log x_i = 4.343 \, \ell n x_i$,

$$p_{Y_i}(y_i) = \frac{1}{\sigma\sqrt{2\pi}} e^{-1/2\left(\frac{y_i - \mu_i}{\sigma_i}\right)^2}, \qquad -\infty<y_i<\infty, \tag{28}$$

that is, a normal distribution with mean μ_i(dB) and standard deviation, σ_i(dB).

For the log-normal distribution (27), by using the moment generating function for the normal distribution, it is easily shown that

$$E\left[X_i\right] = \exp\left[\mu_i/c + \frac{1}{2}\sigma_i^2/c^2\right], \tag{29}$$

and

$$E\left[X_i^2\right] = \exp\left[2\mu_i/c + 2\sigma_i^2/c^2\right], \tag{30}$$

where c = 4.343. In (29) and (30), $E[x_i]$ is the <u>mean</u> value (watts or kT_0's) and the μ_i and σ_i are dB values (dBW or dB>$1kT_0$). For atmospheric noise, say, the μ_i is ATNOS (F_{am}) and σ_i is given by DUA/1.282 (or by DLA/1.282 for the log-normal distribution representing atmospheric noise below the median level). If the calculations are carried out in terms of f_a, the dB values are for f_a and the "real" units are kTo's or if the calculations are carried out in terms of watts, the dB values are dBW and the "real" units are watts. Of course, dBW = F_a - 204 for a 1 Hz bandwidth. As we shall see, it is better numerically to carry out the computations in terms of f_a's. If we let α_i denote the mean value and β_i denote the variance, then from (29) and (30),

$$\alpha_i = E[X_i], \text{ and}$$

$$\beta_i = E[X_i^2] - E[X_i]^2$$

$$\beta_i = \alpha_i^2\left[\exp(\sigma_i^2/c^2) - 1\right]. \tag{31}$$

The above (29), (30), and (31) can be solved to give

$$\sigma_i^2 = c^2 \ell n(1 + \beta_i/\alpha_i^2), \text{ and} \tag{32}$$

$$\mu_i = c(\ell n \alpha_i - \frac{1}{2} \sigma_i^2/c^2). \tag{33}$$

Since our N log-normally distributed noise processes are independent, the mean α_T, and the variances, β_T, of the sum are given by:

$$\alpha_T = \sum_{i=1}^{N} \alpha_i, \text{ and} \tag{34}$$

$$\beta_T = \sum_{i=1}^{N} \beta_i. \tag{35}$$

Then these α_T and β_T can be used in (32) and (33) to obtain σ_T and μ_T, with the resulting pdf then given by

$$p_{Y_T}(y) = \frac{1}{\sqrt{2\pi\sigma_T^2}} e^{-1/2\left(\frac{y - \mu_T}{\sigma_T}\right)^2}, \tag{36}$$

where Y_T is the sum (in dB) of our N (3 in our case here) noise processes. Note that (29) gives the actual <u>mean</u> value of the distribution in watts which is different than the <u>median</u> value in dB converted to watts as is currently done in GENOIS (17). Also, the estimate of the variance (and therefore D_μ and D_ℓ) via (35) is a much better estimate, in general, than the procedure currently used in (20).

GENOIS has been modified to sum the three noise processes via (34) and (35). The median value and D_μ value are calculated using the three medians and three D_μ's. The D_ℓ value for the sum is calculated using the three D_ℓ's. As the next section shows, for most cases of interest in practice in IONCAP, the XRNSE, DL, and DU calculated by the current GENOIS are not substantially different than the "new" ones calculated by the new GENOIS. Some significant differences will be noted however in the SIGU (26) and SIGL. While the new GENOIS does not change XRNSE, DL, and DU significantly for the example cases shown, it does provide better estimates in general, and stands on firm theoretical ground.

The three mean values and the three variances are computed from (29) and (31) and added (34, 35). The totals are then used in (32) and (33) to obtain the new median (dB) of the overall distribution. That is, the new variance (see new GENOIS in Appendix) is given by

$$\sigma^2/c^2 = \text{SIGTSQ} = \ell n \left(1 + \frac{\text{VU}}{\text{AU}^2}\right) , \tag{37}$$

where VU denotes β_T and AU denotes α_T, and the new overall median is

$$\text{XRNSE} = 4.34294(\ell n\text{AU} - \text{SIGTSQ}/2)-204, \quad \text{(dBW)} \tag{38}$$

and the new overall D_μ is

$$\text{DU} = 5.568\sqrt{\text{SIGTSQ}}. \tag{39}$$

The last item is to calculate the "new" $\sigma_{F_{am}}$ (SIGM), σ_{D_μ} (SIGU), and σ_{D_ℓ} (SIGL) for the overall distribution.

If (19) is used directly on (38), using (29) and (31) for each of the three means and variances giving AU (the total in watts) and SIGTSQ (the total in watts squared), very extensive mathematical (and computational) complexities arise due to the interactions between the individual means and variances (29, for example). Relation (19) (which is in itself an approximation) has been used directly and it turns out that appropriate approximations are in order for the required partial derivatives. For example, we use

$$\frac{\partial \text{XRNSE}}{\partial \text{ATNOS}} = \exp[(\text{ATNOS} - \text{XRNSE})/c], \text{ etc.} \tag{40}$$

The approximation (40) is identical to QPA (22) and amounts to ignoring the σ_i's in (29). It is easy to show that using (40) (with corresponding expressions for the galactic and man-made noise contributions) greatly simplifies the calculation of $\sigma_{F_{am}}$ and still produces an acceptably accurate result. Thus, $\sigma_{F_{am}}$ (SIGM) is calculated via (23), but of course, using the XRNSE calculated by (38).

In the computation of σ_{D_μ} and σ_{D_ℓ}, as noted earlier, six partial derivatives are required, since the variations of the individual median values as well as the individual decile values are important. It turns out, although it is more difficult to show, that the partials given by (24) and (25) serve as good approximations. Therefore, the σ_{D_μ} (SIGU) is given by

$$\mathrm{SIGU}^2 = \left(\frac{\partial \mathrm{DU}}{\partial \mathrm{DUA}}\ \mathrm{SUA}\right)^2 + \left(\frac{\partial \mathrm{DU}}{\partial \mathrm{DUG}}\ \mathrm{SUG}\right)^2 + \left(\frac{\partial \mathrm{DU}}{\partial \mathrm{DUM}}\ \mathrm{SUM}\right)^2 + \left(\frac{\partial \mathrm{DU}}{\partial \mathrm{ATNOS}}\ \mathrm{SMA}\right)^2 + \left(\frac{\partial \mathrm{DU}}{\partial \mathrm{GNOIS}}\ \mathrm{SMG}\right)^2 + \left(\frac{\partial \mathrm{DU}}{\partial \mathrm{XNOIS}}\ \mathrm{SMM}\right)^2, \tag{41}$$

with a corresponding expression for σ_{D_ℓ} (SIGL).

The next section gives a few examples (paths) using IONCAP with and without the new GENOIS and with and without the new atmospheric noise and man-made noise estimates.

5. COMPARISONS AND CONCLUSIONS

As detailed in the previous sections, three major changes have been made in the noise portion of IONCAP via subroutine GENOIS: the replacement of the worldwide atmospheric radio noise estimates with the current, much improved estimates of CCIR Report 322-3; the replacement of the man-made noise estimates with the much more modern estimates of CCIR Report 258-4; and the means of summing the three noise contributions and determining the noise overall distribution and its statistical variations has been updated. While an unlimited number of examples to indicate the various changes due to the new GENOIS could be run, we show only a few here to indicate the kind of differences produced.

Table 2 shows the magnitude and direction of change between the old man-made noise model and the new man-made noise model (Figure 9). As we can see, the most significant difference is in the Business category and the difference decreases to a relatively small value in the quiet rural category. The correction in galactic noise is also displayed in Table 2 and shows a small increase from the old galactic noise values. To demonstrate the most significant effect of the changes in the man-made and galactic noise, IONCAP was run with both the old and new values and the results are displayed in Tables 3 to 6. For the Business category and the circuit shown in Tables 3 and 4, there is a significant increase in the reliability figures (REL), also the power necessary to achieve the required reliability (PRWRG) is reduced. For the Quiet Rural category and the circuit shown in Tables 5 and 6, the atmospheric noise is the dominant noise for hours 00, 06, and 12 UT. At 18 UT the man-made noise is the most significant noise, however, there is almost no difference between the old model (Table 5) and the new model (Table 6).

TABLE 2. Difference between the updated and corrected man-made noise and galactic noise values and the currently used values (i. e., new-old).

Frequency	Business	Residential	Rural	Quiet Rural	Galactic
2 MHz	-15.5 dB	-8.8	-2.1	+0.1	2.2
4	-15.4	-8.7	-2.0	-0.1	1.9
6	-15.3	-8.6	-1.9	-0.2	1.7
8	-15.3	-8.6	-1.9	-0.3	1.6
10	-15.3	-8.6	-1.9	-0.4	1.5
12	-15.2	-8.5	-1.8	-0.4	1.4
14	-15.2	-8.5	-1.8	-0.4	1.4
16	-15.2	-8.5	-1.8	-0.5	1.3
18	-15.2	-8.5	-1.8	-0.5	1.2
20	-15.2	-8.5	-1.8	-0.5	1.2
22	-15.2	-8.5	-1.8	-0.6	1.2
24	-15.1	-8.4	-1.7	-0.6	1.1
26	-15.1	-8.4	-1.7	-0.6	1.1
28	-15.1	-8.4	-1.7	-0.6	1.1
30	-15.1	-8.4	-1.7	-0.6	1.0

The changes in the atmospheric noise model described in Spaulding and Washburn (1985) affect noise levels worldwide, and in some particular areas of the world have a significant effect on the circuit performance predicted by the IONCAP program. To demonstrate the effect of this change a test point was chosen where the new coefficients significantly reduced the predicted value of the atmospheric noise. Table 7 shows the IONCAP output for the old atmospheric noise coefficients and Table 8 is a listing based on the new coefficients. At certain hours of the day, for example 00 UT, the man-made noise is more significant than the atmospheric noise and there is no detectable difference between the two models. At 1200 UT the old atmospheric noise model shows a noise level of -157 dBW at 3 MHz, while the new atmospheric model in Table 6 has a value less than the man-made noise which is a decrease of at least 7 dB. Since the atmospheric noise model at its minimum gives values close to or below the estimated man-made noise levels, there is no significant difference for this example.

Tables 9 and 10 show a communication circuit into an area where there is a considerable increase in the predicted value of the atmospheric noise. This increase is most pronounced on this circuit at hours 1200 and 1800 UT. The result of this change in the noise model is a more pessimistic prediction of circuit performance which is reflected in the service probability (S PRB) differences in Tables 9 and 10.

An example of the changes caused by correcting the computer subroutine calculation of the noise statistics is shown in Table 11. These changes are least significant when one type of noise is dominant and most significant when 2 or more of the 3 noise types are close in magnitude. Table 11 shows the changes in the statistical parameters that can be typically expected. The effect of these changes in the output of the IONCAP program may be seen by comparing Table 10 (the old model) and Table 11 (the corrected model). When one noise dominates (such as the atmospheric noise at hour 1800 UT) there is almost no difference between Tables 10 and 11.

The overall effect of the noise changes on the IONCAP predictions is restricted to the system performance parameters. One would expect a more optimistic prediction based on the man-made noise particularly in the business environment. The changes in the atmospheric noise model will give a reduction in predicted performance for some areas of the world. In areas of the world where the new atmospheric noise model gives lower values, the effect can either be miminal due to man-made and/or galactic noise dominating, or can be significant in areas where the old atmospheric noise estimates dominated.

Finally, typical differences between the old overall noise statistics and the new statistics are given in Table 12. Table 12 is for Boulder, Colorado for 1100 local time, January, for the various frequencies ranging from 2 to 30 MHz. The 3 MHz man-made noise was set at -160 dBW and the new atmospheric noise estimates were used throughout. As can be seen from Table 12, the greater differences occur when two or more of the noise levels are comparable in magnitude. Also, as noted previously, the greatest changes are in σ_{D_μ} and σ_{D_ℓ}.

All the above examples are for the month of January. Atmospheric noise is much higher in the summertime, but the above examples should serve to indicate the kind of changes the new GENOIS will produce.

TABLE 3. IONCAP output using current GENOIS, "Industrial" man-made noise and updated atmospheric noise estimates

```
                              METHOD 23   IONCAP PC.10   PAGE   1

          JAN     1970            SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.          AZIMUTHS          N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W     91.84  281.42     702.6   1301.1
                               MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO  30.0  VER MONOPOLE H      .00 L    -.50 A      .0  OFF AZ    .0
RCVR   2.0  TO  30.0  VER MONOPOLE H      .00 L    -.25 A      .0  OFF AZ    .0
POWER =  30.000 KW  3 MHZ NOISE = -125.0 DBW   REQ. REL = .90  REQ. SNR = 55.0

  UT  MUF

   .0  16.3   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
        1F2   1 E   1F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2 MODE
       23.3   5.0  25.4  18.6  17.1  17.1  17.9  19.7  25.4  25.4  25.4  25.4 ANGLE
        -88   -93   -88   -85   -85   -86   -88   -88  -101  -124  -193  -198 S DBW
       -146  -120  -125  -131  -136  -140  -142  -145  -147  -148  -151  -153 N DBW
        57.   27.   37.   46.   51.   53.   55.   56.   45.   24.  -42.  -45. SNR
        17.   37.   27.   17.   13.   11.   10.   10.   36.   57.  109.  110. RPWRG
        .57   .00   .03   .17   .31   .41   .48   .55   .25   .07   .00   .00 REL
        .23   .01   .02   .10   .17   .21   .24   .26   .13   .03   .00   .00 S PRB

  6.0   6.8   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
        1F2   1F2   1F2   1F2   1F2   1ES   1ES   1ES   1ES   1F2   1F2   1F2 MODE
       25.9  21.2  19.8  20.4  27.1   6.6   6.6   6.6   6.6  27.1  27.1  27.1 ANGLE
        -73   -72   -72   -71   -83  -107  -119  -139  -174  -180  -182  -183 S DBW
       -135  -120  -125  -131  -136  -140  -142  -145  -147  -148  -151  -153 N DBW
        62.   48.   52.   59.   53.   33.   23.    6.  -27.  -32.  -31.  -30. SNR
         5.   14.   10.    4.   16.   33.   44.   67.   93.   95.   94.   93. RPWRG
        .77   .19   .38   .75   .42   .10   .06   .01   .00   .00   .00   .00 REL
        .34   .15   .22   .37   .21   .05   .01   .00   .00   .00   .00   .00 S PRB

 12.0   5.8   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
        1F2   1F2   1F2   1F2   1F2   1ES   1ES   1F2   1F2   1F2   1F2   1F2 MODE
       28.5  29.5  23.1  22.7  28.5   6.6   6.6  28.5  28.5  28.5  28.5  28.5 ANGLE
        -78   -74   -71   -72  -103  -119  -151  -175  -176  -177  -179  -180 S DBW
       -133  -120  -125  -131  -136  -140  -142  -145  -147  -148  -151  -153 N DBW
        54.   46.   54.   58.   33.   21.   -9.  -30.  -30.  -29.  -28.  -27. SNR
        21.   17.    9.    7.   39.   60.   88.   94.   93.   92.   91.   91. RPWRG
        .48   .16   .43   .66   .11   .05   .00   .00   .00   .00   .00   .00 REL
        .22   .11   .25   .33   .05   .04   .00   .00   .00   .00   .00   .00 S PRB

 18.0  20.4   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
        1F2   1 E   1 E   1ES   1ES   1F1   1F2   1F2   1F2   1F2   1F2   1F2 MODE
       21.0   4.0   4.5   6.6   6.6  18.7  17.6  16.8  17.4  19.8  25.1  25.1 ANGLE
        -87  -188  -181  -137  -111   -94   -91   -90   -90   -88  -125  -181 S DBW
       -148  -120  -125  -131  -136  -140  -142  -145  -147  -148  -151  -153 N DBW
        61.  -68.  -57.   -5.   25.   45.   51.   54.   56.   60.   26.  -28. SNR
         9.  131.  120.   69.   39.   23.   12.   10.    7.    8.   55.  104. RPWRG
        .69   .00   .00   .00   .00   .11   .29   .43   .58   .69   .08   .00 REL
        .30   .00   .00   .00   .00   .10   .17   .23   .28   .31   .04   .00 S PRB
```

TABLE 4. IONCAP output using new GENOIS, "Business" man-made noise and updated atmospheric noise estimates

```
                              METHOD 23    IONCAP PC.20    PAGE    1

          JAN     1970               SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.             AZIMUTHS           N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W       91.84  281.42       702.6   1301.1
                              MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR    2.0  TO  30.0  VER MONOPOLE H      .00 L     -.50 A      .0  OFF AZ      .0
RCVR    2.0  TO  30.0  VER MONOPOLE H      .00 L     -.25 A      .0  OFF AZ      .0
POWER =  30.000 KW  3 MHZ NOISE = -140.4 DBW   REQ. REL = .90  REQ. SNR = 55.0

  UT  MUF

  .0 16.3   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   1 E   1F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2 MODE
     23.3   5.0  25.4  18.6  17.1  17.1  17.9  19.7  25.4  25.4  25.4  25.4 ANGLE
      -88   -93   -88   -85   -85   -86   -88   -88  -101  -124  -193  -198 S DBW
     -160  -135  -140  -146  -151  -154  -157  -159  -161  -163  -166  -168 N DBW
      72.   42.   51.   61.   65.   68.   69.   71.   60.   39.  -27.  -30. SNR
       1.   22.   11.    2.   -2.   -4.   -6.   -5.   20.   42.   94.   94. RPWRG
      .88   .07   .36   .83   .95   .97   .98   .98   .60   .22   .00   .00 REL
      .44   .07   .17   .37   .47   .52   .56   .56   .26   .10   .00   .00 S PRB

 6.0  6.8   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   1F2   1F2   1F2   1F2   1ES   1ES   1ES   1ES   1F2   1F2   1F2 MODE
     25.9  21.2  19.8  20.4  27.1   6.6   6.6   6.6   6.6  27.1  27.1  27.1 ANGLE
      -73   -72   -72   -71   -83  -107  -119  -139  -174  -180  -182  -183 S DBW
     -149  -133  -138  -145  -151  -155  -158  -160  -162  -163  -166  -168 N DBW
      76.   62.   66.   73.   67.   48.   38.   21.  -12.  -17.  -16.  -15. SNR
     -10.    0.   -6.  -12.    1.   17.   29.   52.   77.   79.   78.   77. RPWRG
      .99   .91  1.00  1.00   .88   .34   .21   .05   .00   .00   .00   .00 REL
      .61   .40   .53   .69   .44   .15   .08   .03   .00   .00   .00   .00 S PRB

12.0  5.8   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   1F2   1F2   1F2   1ES   1ES   1ES   1F2   1F2   1F2   1F2   1F2 MODE
     28.5  29.5  23.1  22.7   6.6   6.6   6.6  28.5  28.5  28.5  28.5  28.5 ANGLE
      -78   -74   -71   -72  -103  -119  -151  -175  -176  -177  -179  -180 S DBW
     -147  -135  -139  -146  -151  -155  -158  -160  -162  -163  -166  -168 N DBW
      69.   60.   68.   72.   48.   36.    6.  -15.  -15.  -14.  -13.  -12. SNR
       6.    2.   -6.   -9.   24.   45.   72.   78.   77.   76.   75.   75. RPWRG
      .81   .83   .99   .99   .34   .18   .01   .00   .00   .00   .00   .00 REL
      .40   .36   .57   .62   .15   .09   .02   .00   .00   .00   .00   .00 S PRB

18.0 20.4   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   1 E   1 E   1ES   1ES   1F1   1F2   1F2   1F2   1F2   1F2   1F2 MODE
     21.0   4.0   4.5   6.6   6.6  18.7  17.6  16.8  17.4  19.8  25.1  25.1 ANGLE
      -87  -188  -181  -137  -111   -94   -91   -90   -90   -88  -125  -181 S DBW
     -163  -136  -140  -147  -151  -155  -157  -159  -161  -163  -166  -168 N DBW
      76.  -52.  -42.   10.   40.   60.   66.   68.   71.   75.   41.  -13. SNR
      -6.  114.  104.   52.   22.    8.   -3.   -6.   -9.   -8.   39.   89. RPWRG
      .97   .00   .00   .00   .03   .69   .97   .99  1.00   .98   .26   .00 REL
      .56   .00   .00   .00   .06   .31   .50   .57   .63   .60   .11   .00 S PRB
```

TABLE 5. IONCAP output using current GENOIS, "Quiet Rural" man-made noise and updated atmospheric noise estimates.

```
                                  METHOD 23   IONCAP PC.10   PAGE   1

          JAN     1970           SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.            AZIMUTHS           N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W        91.84  281.42      702.6    1301.1
                                   MINIMUM ANGLE    .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO   30.0  VER MONOPOLE H       .00 L    -.50 A      .0  OFF AZ     .0
RCVR   2.0  TO   30.0  VER MONOPOLE H       .00 L    -.25 A      .0  OFF AZ     .0
POWER =   30.000 KW  3 MHZ NOISE = -164.0 DBW   REQ. REL = .90  REQ. SNR = 55.0

  UT  MUF

  .0 16.3   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   2 E   1F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2   1F2 MODE
     23.3  14.9  25.4  18.6  17.1  17.1  17.9  19.7  25.4  25.4  25.4  25.4 ANGLE
      -88   -93   -88   -85   -85   -86   -88   -88  -101  -124  -193  -198 S DBW
     -171  -149  -153  -157  -160  -162  -165  -169  -173  -177  -183  -186 N DBW
      83.   56.   65.   72.   75.   76.   78.   80.   72.   53.  -10.  -12. SNR
      -9.   11.    1.   -7.  -10.  -11.  -13.  -14.    9.   28.   72.   75. RPWRG
      .97   .54   .87   .98   .99  1.00  1.00  1.00   .80   .46   .00   .00 REL
      .62   .23   .41   .62   .69   .74   .78   .79   .38   .18   .00   .00 S PRB

 6.0  6.8   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   1F2   1F2   1F2   1F2   1ES   1ES   1ES   1ES   1F2   1F2   1F2 MODE
     25.9  21.2  19.8  20.4  27.1   6.6   6.6   6.6   6.6  27.1  27.1  27.1 ANGLE
      -73   -72   -72   -71   -83  -107  -119  -139  -174  -180  -182  -183 S DBW
     -156  -140  -145  -151  -158  -165  -171  -176  -179  -181  -184  -186 N DBW
      83.   68.   72.   79.   74.   58.   51.   37.    6.    1.    2.    3. SNR
     -16.   -5.  -10.  -17.   -6.    7.   15.   35.   58.   59.   58.   57. RPWRG
     1.00   .98  1.00  1.00   .97   .65   .43   .19   .00   .00   .00   .00 REL
      .76   .54   .68   .84   .59   .32   .20   .07   .01   .00   .00   .00 S PRB

12.0  5.8   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   1F2   1F2   1F2   1ES   1ES   1ES   1F2   1F2   1F2   1F2   1F2 MODE
     28.5  29.5  23.1  22.7   6.6   6.6   6.6  28.5  28.5  28.5  28.5  28.5 ANGLE
      -78   -74   -71   -72  -103  -119  -151  -175  -176  -177  -179  -180 S DBW
     -156  -147  -150  -154  -160  -166  -172  -177  -180  -182  -184  -186 N DBW
      77.   72.   78.   81.   57.   47.   21.    2.    4.    4.    5.    5. SNR
      -2.   -7.  -13.  -16.   15.   33.   58.   60.   58.   57.   56.   55. RPWRG
      .92   .98  1.00  1.00   .55   .35   .04   .00   .00   .00   .00   .00 REL
      .52   .57   .74   .78   .25   .15   .03   .00   .00   .00   .00   .00 S PRB

18.0 20.4   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   1 E   1 E   1ES   2F2   1F1   1F2   1F2   1F2   1F2   1F2   1F2 MODE
     21.0   4.0   4.5   6.6  35.5  18.7  17.6  16.8  17.4  19.8  25.1  25.1 ANGLE
      -87  -188  -181  -137  -111   -94   -91   -90   -90   -88  -125  -181 S DBW
     -179  -159  -164  -170  -171  -169  -168  -170  -173  -178  -184  -186 N DBW
      91.  -29.  -18.   33.   59.   74.   76.   79.   83.   90.   59.    5. SNR
     -22.   92.   82.   30.    4.   -6.  -13.  -16.  -20.  -23.   21.   71. RPWRG
     1.00   .00   .00   .00   .72   .97  1.00  1.00  1.00  1.00   .59   .01 REL
      .86   .00   .00   .01   .32   .57   .78   .83   .91   .91   .24   .00 S PRB
```

TABLE 6. IONCAP output using new GENOIS, "Quiet Rural" man-made noise and updated atmospheric noise estimates

```
                         METHOD 23   IONCAP PC.20   PAGE   1

       JAN    1970          SSN = 100.
BOULDER,COLORADO TO ST. LOUIS,MO.          AZIMUTHS         N. MI.      KM
40.03 N  105.30 W - 38.67 N   90.25 W      91.84  281.42     702.6   1301.1
                         MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO  30.0  VER MONOPOLE H      .00 L     -.50 A      .0  OFF AZ     .0
RCVR   2.0  TO  30.0  VER MONOPOLE H      .00 L     -.25 A      .0  OFF AZ     .0
POWER =  30.000 KW  3 MHZ NOISE = -163.6 DBW   REQ. REL = .90  REQ. SNR = 55.0

  UT  MUF

  .0 16.3  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  2 E  1F2  1F2  1F2  1F2  1F2  1F2  1F2  1F2  1F2  1F2 MODE
     23.3 14.9 25.4 18.6 17.1 17.1 17.9 19.7 25.4 25.4 25.4 25.4 ANGLE
      -88  -93  -88  -85  -85  -86  -88  -88 -101 -124 -193 -198 S DBW
     -171 -149 -153 -157 -160 -162 -165 -169 -172 -176 -183 -187 N DBW
      82.  56.  65.  72.  74.  76.  77.  80.  71.  52. -10. -12. SNR
      -8.  11.   1.  -7.  -9. -11. -13. -14.  10.  29.  75.  73. RPWRG
      .97  .54  .87  .98  .99 1.00 1.00 1.00  .79  .44  .00  .00 REL
      .61  .24  .41  .61  .69  .74  .78  .79  .38  .18  .00  .00 S PRB

 6.0  6.8  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  1F2  1F2  1F2  1F2  1ES  1ES  1ES  1ES  1F2  1F2  1F2 MODE
     25.9 21.2 19.8 20.4 27.1  6.6  6.6  6.6  6.6 27.1 27.1 27.1 ANGLE
      -73  -72  -72  -71  -83 -107 -119 -139 -174 -180 -182 -183 S DBW
     -156 -140 -145 -151 -158 -164 -170 -176 -180 -182 -185 -187 N DBW
      83.  68.  72.  78.  74.  58.  51.  37.   6.   2.   3.   3. SNR
     -16.  -5. -10. -17.  -6.   7.  15.  35.  57.  57.  56.  56. RPWRG
     1.00  .98 1.00 1.00  .97  .63  .41  .19  .01  .00  .00  .00 REL
      .76  .54  .68  .85  .59  .31  .19  .07  .01  .00  .00  .00 S PRB

12.0  5.8  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  1F2  1F2  1F2  1ES  1ES  1ES  1F2  1F2  1F2  1F2  1F2 MODE
     28.5 29.5 23.1 22.7  6.6  6.6  6.6 28.5 28.5 28.5 28.5 28.5 ANGLE
      -78  -74  -71  -72 -103 -119 -151 -175 -176 -177 -179 -180 S DBW
     -156 -147 -150 -154 -160 -166 -171 -177 -180 -182 -185 -187 N DBW
      77.  72.  78.  81.  57.  47.  20.   2.   4.   5.   6.   6. SNR
      -2.  -7. -13. -16.  16.  34.  58.  59.  56.  55.  54.  54. RPWRG
      .92  .98 1.00 1.00  .55  .34  .04  .00  .00  .00  .00  .00 REL
      .51  .57  .74  .78  .24  .15  .03  .00  .00  .00  .00  .00 S PRB

18.0 20.4  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  1 E  1 E  1ES  2F2  1F1  1F2  1F2  1F2  1F2  1F2  1F2 MODE
     21.0  4.0  4.5  6.6 35.5 18.7 17.6 16.8 17.4 19.8 25.1 25.1 ANGLE
      -87 -188 -181 -137 -111  -94  -91  -90  -90  -88 -125 -181 S DBW
     -178 -159 -164 -170 -170 -168 -168 -169 -173 -177 -185 -187 N DBW
      91. -29. -18.  33.  58.  74.  76.  78.  83.  89.  60.   6. SNR
     -21.  91.  81.  29.   5.  -6. -13. -16. -20. -23.  20.  70. RPWRG
     1.00  .00  .00  .00  .69  .97 1.00 1.00 1.00 1.00  .60  .01 REL
      .86  .00  .00  .02  .31  .56  .78  .84  .91  .90  .24  .00 S PRB
```

TABLE 7. IONCAP output using current GENOIS, "Quiet Rural" man-made noise and old atmospheric noise estimates (low atmospheric noise region)

```
                                     METHOD 23   IONCAP PC.10   PAGE   1

             JAN     1970            SSN = 100.
CANTON, CHINA TO TEST PT. ONE                AZIMUTHS           N. MI.      KM
23.00 N  113.03 E - 62.00 N  155.00 E     24.90  235.64      2894.8    5360.8
                              MINIMUM ANGLE    .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO   30.0  VER MONOPOLE H      .00 L     -.50 A      .0  OFF AZ      .0
RCVR   2.0  TO   30.0  VER MONOPOLE H      .00 L     -.25 A      .0  OFF AZ      .0
POWER = 30.000 KW  3 MHZ NOISE = -164.0 DBW   REQ. REL = .90  REQ. SNR = 55.0

  UT  MUF

   .0 23.5  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
       2F2  3 E  3 E  3 E  3F2  3F2  3F2  3F2  3F2  2F2  2F2  2F2 MODE
       7.8  1.3  1.6  2.0 14.5 11.0 10.5 10.9 12.3  4.6  9.3  9.3 ANGLE
      -124 -267 -248 -184 -142 -129 -123 -120 -120 -124 -148 -236 S DBW
      -183 -159 -164 -170 -172 -170 -170 -173 -177 -180 -184 -186 N DBW
       58. **** -85. -14.  30.  40.  47.  52.  57.  57.  36. -50. SNR
       22. 174. 150.  78.  33.  23.  17.  13.  12.  11.  45. 131. RPWRG
       .57  .00  .00  .00  .00  .01  .12  .35  .58  .57  .16  .00 REL
       .21  .00  .00  .00  .01  .04  .10  .19  .23  .26  .06  .00 S PRB

  6.0 25.8  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
       2F2  3 E  3 E  3 E  3F2  2F2  2F2  2F2  3F2  3F2  2F2  2F2 MODE
       7.9  1.4  1.7  2.0 13.5  6.7  3.9  3.7 11.4 13.5  6.6  9.6 ANGLE
      -125 -355 -339 -220 -163 -142 -133 -127 -124 -123 -124 -190 S DBW
      -184 -159 -163 -168 -168 -168 -170 -173 -176 -180 -184 -186 N DBW
       59. **** **** -53.   5.  25.  37.  45.  52.  57.  59.  -5. SNR
       21. 258. 241. 116.  58.  37.  26.  18.  12.  10.  21.  85. RPWRG
       .59  .00  .00  .00  .00  .00  .01  .08  .33  .58  .58  .00 REL
       .22  .00  .00  .00  .00  .00  .02  .08  .18  .20  .23  .00 S PRB

 12.0  8.9  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
       2F2  3F2  3F2  3F2  2F2  2F2  2F2  2F2  2F2  2F2  2F2  2F2 MODE
      11.5 17.9 14.2 13.9  7.0 11.5 11.5 11.5 11.5 11.5 11.5 11.5 ANGLE
      -121 -118 -110 -107 -112 -134 -188 -270 -360 -401 -402 -404 S DBW
      -168 -155 -157 -159 -164 -171 -175 -178 -180 -182 -184 -186 N DBW
       47.  37.  47.  52.  53.  36. -12. -92. **** **** **** **** SNR
       34.  25.  16.  10.  13.  44.  93. 172. 260. 278. 277. 277. RPWRG
       .31  .02  .16  .32  .37  .17  .00  .00  .00  .00  .00  .00 REL
       .15  .03  .12  .18  .23  .08  .00  .00  .00  .00  .00  .00 S PRB

 18.0  9.4  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
       2F2  3F2  3F2  3F2  2F2  2F2  2F2  2F2  2F2  2F2  2F2  2F2 MODE
      12.5 21.5 16.1 15.1  7.6 12.5 12.5 12.5 12.5 12.5 12.5 12.5 ANGLE
      -120 -119 -108 -105 -109 -131 -221 -354 -387 -388 -389 -391 S DBW
      -171 -156 -158 -161 -166 -172 -176 -179 -180 -182 -184 -186 N DBW
       51.  37.  50.  56.  58.  41. -45. **** **** **** **** **** SNR
       29.  28.  14.   6.   5.  39. 126. 255. 266. 265. 264. 264. RPWRG
       .39  .02  .28  .55  .66  .25  .00  .00  .00  .00  .00  .00 REL
       .18  .03  .16  .25  .34  .11  .00  .00  .00  .00  .00  .00 S PRB
```

TABLE 8. IONCAP output using current GENOIS, "Quiet Rural" man-made noise and updated atmospheric noise estimates (low atmospheric noise region)

```
                              METHOD 23   IONCAP PC.10   PAGE   1

         JAN     1970              SSN = 100.
   CANTON, CHINA TO TEST PT. ONE              AZIMUTHS           N. MI.      KM
   23.00 N  113.03 E - 62.00 N  155.00 E      24.90  235.64     2894.8   5360.8
                                   MINIMUM ANGLE     .0  DEGREES
   ITS- 1 ANTENNA PACKAGE
   XMTR   2.0  TO   30.0  VER MONOPOLE H      .00 L     -.50 A      .0  OFF AZ     .0
   RCVR   2.0  TO   30.0  VER MONOPOLE H      .00 L     -.25 A      .0  OFF AZ     .0
   POWER =  30.000 KW  3 MHZ NOISE = -164.0 DBW   REQ. REL = .90  REQ. SNR = 55.0

    UT   MUF

    .0 23.5   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
       2F2   3 E   3 E   3 E   3F2   3F2   3F2   3F2   3F2   2F2   2F2   2F2  MODE
        7.8   1.3   1.6   2.0  14.5  11.0  10.5  10.9  12.3   4.6   9.3   9.3 ANGLE
       -124  -267  -248  -184  -142  -129  -123  -120  -120  -124  -148  -236 S DBW
       -183  -159  -164  -170  -173  -171  -172  -175  -178  -181  -184  -186 N DBW
        58.  ****  -85.  -14.   31.   41.   48.   54.   59.   57.   36.  -50. SNR
        22.  174.  150.   78.   32.   22.   15.   11.   10.   10.   45.  131. RPWRG
        .57   .00   .00   .00   .00   .02   .17   .45   .64   .60   .16   .00 REL
        .21   .00   .00   .00   .01   .04   .11   .21   .24   .27   .06   .00 S PRB

   6.0 25.8   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
       2F2   3 E   3 E   3 E   3F2   2F2   2F2   3F2   3F2   3F2   2F2   2F2  MODE
        7.9   1.4   1.7   2.0  13.5   6.7   3.9  10.6  11.4  13.5   6.6   9.6 ANGLE
       -125  -355  -339  -220  -163  -142  -133  -127  -124  -123  -124  -190 S DBW
       -184  -159  -164  -170  -173  -173  -175  -178  -180  -182  -184  -186 N DBW
        59.  ****  ****  -51.    9.   30.   42.   51.   56.   58.   59.   -5. SNR
        21.  258.  240.  113.   53.   31.   20.   12.    8.    8.   21.   85. RPWRG
        .59   .00   .00   .00   .00   .00   .03   .23   .54   .65   .59   .00 REL
        .22   .00   .00   .00   .00   .00   .03   .12   .23   .21   .23   .00 S PRB

  12.0  8.9   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
       2F2   3F2   3F2   3F2   2F2   2F2   2F2   2F2   2F2   2F2   2F2   2F2  MODE
       11.5  17.9  14.2  13.9   7.0  11.5  11.5  11.5  11.5  11.5  11.5  11.5 ANGLE
       -121  -118  -110  -107  -112  -134  -188  -270  -360  -401  -402  -404 S DBW
       -172  -159  -164  -165  -170  -174  -177  -179  -180  -182  -184  -186 N DBW
        51.   41.   53.   58.   58.   40.  -11.  -91.  ****  ****  ****  **** SNR
        29.   21.    9.    3.    7.   41.   91.  172.  260.  278.  277.  277. RPWRG
        .41   .05   .42   .74   .65   .22   .00   .00   .00   .00   .00   .00 REL
        .18   .05   .21   .31   .32   .10   .00   .00   .00   .00   .00   .00 S PRB

  18.0  9.4   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
       2F2   3F2   3F2   3F2   2F2   2F2   2F2   2F2   2F2   2F2   2F2   2F2  MODE
       12.5  21.5  16.1  15.1   7.6  12.5  12.5  12.5  12.5  12.5  12.5  12.5 ANGLE
       -120  -119  -108  -105  -109  -131  -221  -354  -387  -388  -389  -391 S DBW
       -173  -159  -164  -166  -170  -174  -177  -179  -180  -182  -184  -186 N DBW
        54.   40.   55.   61.   62.   44.  -44.  ****  ****  ****  ****  **** SNR
        27.   23.    8.    0.    1.   37.  125.  255.  266.  265.  264.  264. RPWRG
        .46   .04   .50   .90   .88   .28   .00   .00   .00   .00   .00   .00 REL
        .20   .04   .24   .38   .45   .12   .00   .00   .00   .00   .00   .00 S PRB
```

TABLE 9. IONCAP output using current GENOIS, "Quiet Rural" man-made noise and old atmospheric noise estimates (high atmospheric noise region)

```
                               METHOD 23   IONCAP PC.10   PAGE   2

         JAN     1970             SSN = 100.
CANTON, CHINA TO TEST PT. TWO               AZIMUTHS           N. MI.      KM
23.00 N  113.03 E - 15.00 N  140.00 E    102.63  291.58     1601.4   2965.6
                               MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO  30.0  VER MONOPOLE H      .00 L    -.50 A      .0  OFF AZ      .0
RCVR   2.0  TO  30.0  VER MONOPOLE H      .00 L    -.25 A      .0  OFF AZ      .0
POWER =  30.000 KW  3 MHZ NOISE = -164.0 DBW   REQ. REL = .90  REQ. SNR = 55.0

  UT  MUF

  .0 33.1   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   2 E   2 E   2ES   2F2   2F2   2F2   2F2   2F2   2F2   1F2   1F2 MODE
      7.7   3.0   3.4   5.0  18.5  15.1  14.1  14.1  14.7  16.0   2.8   4.1 ANGLE
     -112  -248  -235  -145  -117  -107  -102  -100  -103  -102  -123  -114 S DBW
     -187  -159  -164  -169  -171  -170  -171  -174  -178  -181  -184  -186 N DBW
      75.  -89.  -72.   24.   53.   63.   68.   72.   74.   78.   61.   70. SNR
       5.  154.  137.   39.   11.    2.   -3.   -7.  -10.  -12.    3.   -1. RPWRG
      .85   .00   .00   .00   .42   .85   .96   .98  1.00  1.00   .82   .91 REL
      .41   .00   .00   .00   .15   .35   .48   .59   .73   .78   .40   .50 S PRB

 6.0 36.5   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   2 E   2 E   2ES   2F2   2F2   2F2   2F2   2F2   2F2   1F2   1F2 MODE
      8.8   2.8   3.2   5.0  23.9  18.9  17.0  16.5  16.7  17.5   3.8   4.5 ANGLE
     -110  -339  -328  -193  -133  -118  -110  -106  -103  -104  -121  -118 S DBW
     -188  -159  -164  -169  -169  -168  -168  -170  -174  -179  -184  -186 N DBW
      78.  ****  ****  -24.   36.   50.   58.   64.   70.   73.   63.   68. SNR
      -5.  245.  229.   87.   27.   13.    6.    0.   -5.   -9.   -1.   -5. RPWRG
      .95   .00   .00   .00   .01   .23   .66   .91   .97  1.00   .93   .98 REL
      .57   .00   .00   .00   .02   .13   .26   .40   .57   .73   .52   .63 S PRB

12.0 33.6   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   2 E   3F2   3F2   2F2   2F2   2F2   2F2   2F2   2F2   1F2   1F2 MODE
      8.7   4.3  23.6  23.0  14.1  14.3  14.6  15.1  15.9  17.2   3.4   4.7 ANGLE
     -116  -103   -99   -92   -90   -90   -91   -92   -96   -98  -117  -116 S DBW
     -187  -145  -149  -154  -159  -164  -169  -174  -178  -181  -184  -186 N DBW
      71.   41.   50.   62.   69.   74.   78.   81.   82.   82.   66.   70. SNR
       3.   22.   13.    1.   -5.  -10.  -12.  -14.  -14.  -10.    0.    2. RPWRG
      .87   .11   .32   .86   .98  1.00  1.00  1.00   .99   .98   .89   .87 REL
      .46   .08   .19   .41   .55   .64   .71   .76   .75   .64   .48   .46 S PRB

18.0 18.1   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
      1F2   3F2   3F2   3F2   2F2   2F2   1F2   1F2   1F2   1F2   1F2   1F2 MODE
      7.9  22.8  22.1  22.4  14.0  15.3   2.6   3.5  10.1   7.9   7.9   7.9 ANGLE
     -113   -96   -92   -88   -89   -93  -117  -115  -107  -118  -138  -167 S DBW
     -180  -143  -147  -153  -160  -167  -173  -177  -180  -182  -184  -186 N DBW
      68.   46.   54.   63.   70.   72.   56.   63.   72.   64.   46.   19. SNR
      11.   18.    9.    1.   -1.    1.   12.   10.    6.   17.   34.   61. RPWRG
      .76   .24   .45   .87   .91   .89   .56   .71   .83   .67   .33   .03 REL
      .36   .13   .26   .41   .48   .48   .27   .33   .40   .30   .14   .03 S PRB
```

TABLE 10. IONCAP output using current GENOIS, "Quiet Rural" man-made noise and updated atmospheric noise estimates (high atmospheric noise region)

```
                              METHOD 23    IONCAP PC.10    PAGE   2

           JAN     1970          SSN = 100.
CANTON, CHINA TO TEST PT. TWO              AZIMUTHS           N. MI.      KM
23.00 N   113.03 E - 15.00 N  140.00 E    102.63  291.58    1601.4    2965.6
                               MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR    2.0  TO   30.0  VER MONOPOLE H      .00 L     -.50 A      .0  OFF AZ     .0
RCVR    2.0  TO   30.0  VER MONOPOLE H      .00 L     -.25 A      .0  OFF AZ     .0
POWER =   30.000 KW   3 MHZ NOISE = -164.0 DBW    REQ. REL = .90  REQ. SNR = 55.0

  UT  MUF

  .0 33.1   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
     1F2   2 E   2 E   2ES   2F2   3F2   3F2   2F2   2F2   2F2   1F2   1F2 MODE
     7.7   3.0   3.4   5.0  18.5  22.9  23.4  14.1  14.7  16.0   2.8   4.1 ANGLE
    -112  -248  -235  -145  -117  -107  -102  -100  -103  -102  -123  -114 S DBW
    -187  -158  -163  -168  -168  -167  -167  -170  -174  -178  -184  -186 N DBW
     75.  -90.  -74.   22.   51.   60.   65.   68.   70.   76.   61.   70. SNR
      5.  155.  139.   41.   13.    5.    0.   -3.   -5.  -10.    3.   -1. RPWRG
     .85   .00   .00   .00   .30   .74   .89   .95   .98   .99   .81   .91 REL
     .41   .00   .00   .00   .13   .28   .40   .48   .62   .71   .40   .50 S PRB

 6.0 36.5   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
     1F2   2 E   2 E   2ES   2F2   2F2   2F2   2F2   2F2   2F2   1F2   1F2 MODE
     8.8   2.8   3.2   5.0  23.9  18.9  17.0  16.5  16.7  17.5   3.8   4.5 ANGLE
    -110  -339  -328  -193  -133  -118  -110  -106  -103  -104  -121  -118 S DBW
    -188  -152  -159  -163  -163  -162  -161  -161  -164  -169  -181  -186 N DBW
     78.  ****  ****  -29.   30.   43.   50.   55.   60.   64.   60.   68. SNR
     -5.  252.  235.   92.   33.   20.   13.    9.    5.    1.    3.   -5. RPWRG
     .95   .00   .00   .00   .00   .05   .25   .51   .73   .87   .78   .98 REL
     .57   .00   .00   .00   .01   .07   .14   .22   .33   .46   .39   .62 S PRB

12.0 33.6   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
     1F2   2 E   1F2   3F2   3F2   3F2   2F2   2F2   2F2   2F2   1F2   1F2 MODE
     8.7   4.3   5.9  23.0  23.2  23.8  14.6  15.1  15.9  17.2   3.4   4.7 ANGLE
    -116  -103   -99   -92   -90   -90   -91   -92   -96   -98  -117  -116 S DBW
    -187  -124  -133  -142  -148  -152  -155  -159  -163  -169  -180  -186 N DBW
     71.   20.   33.   50.   58.   61.   63.   65.   67.   70.   63.   70. SNR
      3.   43.   30.   13.    6.    3.    3.    2.    2.    3.    4.    3. RPWRG
     .87   .00   .03   .29   .66   .81   .83   .85   .86   .85   .80   .86 REL
     .46   .01   .03   .18   .31   .37   .38   .43   .46   .44   .41   .45 S PRB

18.0 18.1   2.0   3.0   5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0 FREQ
     1F2   2F2   3F2   3F2   2F2   2F2   1F2   1F2   1F2   1F2   1F2   1F2 MODE
     7.9  15.5  22.1  22.4  14.0  15.3   2.6   3.5  10.1   7.9   7.9   7.9 ANGLE
    -113   -96   -92   -88   -89   -93  -117  -115  -107  -118  -138  -167 S DBW
    -178  -127  -134  -143  -151  -158  -165  -171  -177  -180  -184  -186 N DBW
     65.   30.   41.   54.   62.   64.   48.   56.   69.   62.   46.   19. SNR
     13.   34.   22.   11.    7.    9.   20.   16.    9.   18.   34.   61. RPWRG
     .71   .03   .08   .45   .73   .73   .13   .54   .78   .65   .33   .03 REL
     .32   .02   .08   .23   .32   .35   .16   .25   .35   .28   .14   .03 S PRB
```

TABLE 11. IONCAP output using new GENOIS, "Quiet Rural" man-made noise and updated atmospheric noise estimates (high atmospheric noise region)

The circuit and ionospheric parameters are the same as in Tables 9 and 10.

```
                              METHOD 23   IONCAP PC.20   PAGE   2

         JAN    1970          SSN = 100.
CANTON, CHINA TO TEST PT. TWO              AZIMUTHS          N. MI.      KM
23.00 N  113.03 E - 15.00 N  140.00 E    102.63  291.58    1601.4    2965.6
                               MINIMUM ANGLE     .0  DEGREES
ITS- 1 ANTENNA PACKAGE
XMTR   2.0  TO  30.0  VER MONOPOLE H      .00 L    -.50 A      .0  OFF AZ     .0
RCVR   2.0  TO  30.0  VER MONOPOLE H      .00 L    -.25 A      .0  OFF AZ     .0
POWER =  30.000 KW  3 MHZ NOISE = -163.6 DBW   REQ. REL = .90  REQ. SNR = 55.0

  UT  MUF

  .0 33.1  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  2 E  2 E  2ES  2F2  3F2  3F2  2F2  2F2  2F2  1F2  1F2 MODE
      7.7  3.0  3.4  5.0 18.5 22.9 23.4 14.1 14.7 16.0  2.8  4.1 ANGLE
     -112 -248 -235 -145 -117 -107 -102 -100 -103 -102 -123 -114 S DBW
     -188 -157 -162 -166 -167 -167 -167 -169 -173 -178 -185 -187 N DBW
      76. -91. -74.  21.  50.  59.  64.  68.  69.  75.  62.  71. SNR
       4. 155. 138.  41.  14.   5.   1.  -2.  -5.  -9.   1.  -2. RPWRG
      .86  .00  .00  .00  .24  .72  .88  .94  .97  .99  .85  .92 REL
      .42  .00  .00  .00  .11  .27  .39  .48  .61  .70  .39  .50 S PRB

 6.0 36.5  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  2 E  2 E  2ES  2F2  2F2  2F2  2F2  2F2  2F2  1F2  1F2 MODE
      8.8  2.8  3.2  5.0 23.9 18.9 17.0 16.5 16.7 17.5  3.8  4.5 ANGLE
     -110 -339 -328 -193 -133 -118 -110 -106 -103 -104 -121 -118 S DBW
     -189 -152 -158 -163 -163 -161 -161 -161 -164 -169 -180 -186 N DBW
      79. **** **** -30.  29.  43.  50.  55.  60.  63.  59.  68. SNR
      -6. 252. 235.  93.  34.  20.  13.   9.   5.   1.   4.  -6. RPWRG
      .96  .00  .00  .00  .00  .05  .24  .51  .73  .87  .75  .99 REL
      .56  .00  .00  .00  .01  .06  .14  .22  .32  .46  .38  .59 S PRB

12.0 33.6  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  2 E  1F2  3F2  3F2  3F2  2F2  2F2  2F2  2F2  1F2  1F2 MODE
      8.7  4.3  5.9 23.0 23.2 23.8 14.6 15.1 15.9 17.2  3.4  4.7 ANGLE
     -116 -103  -99  -92  -90  -90  -91  -92  -96  -98 -117 -116 S DBW
     -188 -124 -133 -142 -148 -152 -155 -159 -163 -168 -180 -186 N DBW
      72.  20.  33.  50.  58.  61.  63.  65.  67.  70.  63.  70. SNR
       2.  43.  30.  13.   6.   3.   3.   2.   2.   3.   4.   2. RPWRG
      .88  .00  .03  .29  .66  .81  .83  .85  .86  .85  .79  .88 REL
      .46  .01  .03  .18  .31  .37  .38  .42  .45  .44  .40  .45 S PRB

18.0 18.1  2.0  3.0  5.0  7.5 10.0 12.5 15.0 17.5 20.0 25.0 30.0 FREQ
      1F2  2F2  3F2  3F2  2F2  2F2  1F2  1F2  1F2  1F2  1F2  1F2 MODE
      7.9 15.5 22.1 22.4 14.0 15.3  2.6  3.5 10.1  7.9  7.9  7.9 ANGLE
     -113  -96  -92  -88  -89  -93 -117 -115 -107 -118 -138 -167 S DBW
     -178 -127 -134 -143 -151 -158 -165 -171 -176 -181 -185 -187 N DBW
      65.  30.  41.  54.  61.  64.  48.  56.  69.  63.  47.  20. SNR
      13.  34.  22.  11.   7.  10.  20.  17.   9.  17.  33.  60. RPWRG
      .71  .03  .08  .45  .72  .73  .12  .52  .78  .65  .35  .04 REL
      .32  .02  .08  .23  .32  .35  .16  .24  .35  .29  .15  .03 S PRB
```

TABLE 12. An example of the differences in the noise parameters calculated by the current GENOIS and the new GENOIS (updated atmospheric noise estimates used in both cases and the 3 MHz man-made noise set at -160 dB)

Month	Lat.	Long.	LMT	XNOIS
1	40.0	254.7	11.0	160

Freq.	ATNOS	GNOIS	XNOIS	XRNSE	DU	DL	SIGU	SIGL	SIGM	
2.0	-179.4	-161.1	-155.1	-154.1	8.2	6.4	1.0	1.1	2.4	←Old GENOIS
	-179.4	-158.9	-155.1	-154.3	9.4	5.2	1.4	1.7	4.5	←New GENOIS
	.0	2.2	.0	-.2	1.2	-1.2	.3	.7	2.1	←Difference
4.0	-181.2	-167.7	-163.5	-162.1	7.9	6.1	.9	.9	2.2	
	-181.2	-165.8	-163.5	-162.3	9.3	4.9	1.3	1.9	4.1	
	.0	1.9	.0	-.2	1.3	-1.2	.5	1.0	2.0	
6.0	-177.3	-171.6	-168.4	-166.4	7.8	6.0	.7	.7	1.9	
	-177.3	-169.9	-168.3	-166.4	9.0	4.5	1.3	2.0	3.5	
	.0	1.7	.1	-.1	1.2	-1.5	.7	1.4	1.6	
8.0	-173.2	-174.4	-171.9	-168.3	7.8	6.2	.5	.4	2.2	
	-173.2	-172.8	-171.8	-167.7	8.2	4.6	1.5	2.1	2.6	
	.0	1.6	.1	.6	.4	-1.6	1.0	1.6	.4	
10.0	-170.5	-176.5	-174.6	-168.4	7.9	6.3	1.3	1.0	3.4	
	-170.5	-175.0	-174.5	-167.3	7.4	5.3	2.1	1.9	2.8	
	.0	1.5	.2	1.1	-.4	-1.0	.8	.9	-.6	
12.0	-169.7	-178.2	-176.9	-168.4	7.8	6.4	1.9	1.4	4.2	
	-169.7	-176.8	-176.7	-167.5	7.3	5.9	2.4	1.9	3.4	
	.0	1.4	.2	1.0	-.5	-.6	.6	.5	-.8	
14.0	-170.7	-179.7	-178.7	-169.6	7.6	6.5	2.0	1.5	4.3	
	-170.7	-178.4	-178.5	-168.7	7.1	6.0	2.5	1.9	3.6	
	.0	1.4	.2	.9	-.5	-.5	.5	.4	-.8	
16.0	-173.4	-181.0	-180.4	-172.0	7.3	6.4	1.7	1.3	4.0	
	-173.4	-179.7	-180.1	-171.1	6.9	5.8	2.3	1.9	3.3	
	.0	1.3	.2	.9	-.4	-.6	.6	.6	-.7	
18.0	-177.7	-182.1	-181.8	-175.3	7.1	6.1	1.1	.9	3.2	
	-177.7	-180.9	-181.6	-174.6	7.2	5.2	1.9	2.1	2.9	
	.0	1.2	.2	.7	.1	-1.0	.8	1.2	-.3	
20.0	-183.3	-183.1	-183.1	-178.4	6.8	5.7	.4	.4	2.1	
	-183.3	-181.9	-182.8	-178.4	8.0	4.2	1.5	2.4	2.7	
	.0	1.2	.3	.0	1.2	-1.6	1.1	2.0	.6	
22.0	-190.0	-184.0	-184.2	-180.6	6.7	5.3	.4	.4	1.5	
	-190.0	-182.9	-184.0	-181.1	8.6	3.8	1.3	2.4	2.9	
	.0	1.2	.3	-.5	1.9	-1.5	1.0	2.0	1.4	
24.0	-197.4	-184.9	-185.3	-181.9	6.6	5.1	.4	.4	1.4	
	-197.4	-183.7	-185.0	-182.6	8.8	4.0	1.3	2.3	3.1	
	.0	1.1	.3	-.6	2.2	-1.2	.9	1.9	1.7	
26.0	-205.4	-185.6	-186.3	-182.9	6.6	5.0	.4	.4	1.4	
	-205.4	-184.5	-186.0	-183.6	8.8	4.0	1.3	2.3	3.1	
	.0	1.1	.3	-.7	2.2	-1.0	.9	1.8	1.7	
28.0	-213.6	-186.3	-187.2	-183.7	6.5	5.0	.4	.4	1.4	
	-213.6	-185.3	-186.9	-184.4	8.8	4.0	1.3	2.3	3.1	
	.0	1.1	.3	-.7	2.3	-1.0	.9	1.9	1.7	

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APPENDIX

COMPUTER SOFTWARE

In this Appendix we simply list the computer programs from IONCAP that are used for the various noise calculations. The programs are given in the following order: SUBROUTINE ANOIS1, which calculates the 1 MHz atmospheric noise levels for two adjacent four-hour time blocks by calling SUBROUTINE NOISY; SUBROUTINE NOISY which uses the Fourier coefficients to compute the 1 MHz atmospheric noise value; SUBROUTINE GENFAM, which computes the atmospheric noise level at the desired frequency and the values of D_μ, D_ℓ, $\sigma_{F_{am}}$, σ_{D_μ}, and σ_{D_ℓ}; the new SUBROUTINE GENOIS, which computes the sum noise process and its statistics; and the old GENOIS for comparison. Additional information is contained in the various comment statements and the body of this report.

```
      SUBROUTINE ANOIS1
C
C     THIS ROUTINE DETERMINES THE 1 MHZ ATMOSPHERIC NOISE
C
C     FOURIER SERIES IN LATITUDE AND LONGITUDE FOR TWO DISCRETE
C     LOCAL TIME BLOCKS
C
      COMMON/ANOIS/ATNU,ATNY,CC,TM,XEFF,RCNSE,DU,DL,SIGM,SIGU,SIGL,KJ,JK
      COMMON /CON /D2R, DCL, GAMA, PI, PI2, PIO2, R2D, RZ, VOFL
      COMMON / DON / ALATD, AMIN, AMIND, DLONG, DMP, ERTR,
     1  PMP, PWR, RLAT, RLATD, RLONG, RLONGD, RSN, SIGTR,
     2 TLAT, TLATD, TLONG, TLONGD, FLUX, SSN, ATMNO, D90R, D50R,
     3 D10R, D90S, D50S, D10S
      COMMON /FILES/ LUO,LUI,LU25,LU26
      COMMON / TIME / IT, GMT, UTIME(24), GMTR, XLMT(24),ITIM,JTX
      COMMON / TWO / F2D(16,6,6), DUD(5,12,5),FAM(14,12),
     A  SYS(9,16,6), PERR(9,4,6), P(29,16,8),ABP(2,9)
C  LMT AT RCVR SITE
      IF(F2D(1,1,1)) 90, 90, 100
C.....NO IONOSPHERIC LONG TERM DATA BASE FILE
C.....SET NOISE TO ZERO HERE (-204 IN SUBROUTINE GENOIS)
C.....THE USER CAN INPUT ANY VALUE AS MAN-MADE NOISE (RESET IN GENOIS)
   90 ATNU = 0.0
      ATNY = 0.0
      RETURN
  100 CC = GMTR
      KJ= 6
      IF(CC-22.) 105,110,110
  105 KJ = CC/4. +1.
  110 TM = 4*KJ-2
      IF(CC-TM) 115,120,125
  115 JK = KJ -1
      GO TO 130
  120 JK = KJ
      GO TO 130
  125 JK = KJ+1
  130 IF(JK) 135,135,140
  135 JK =6
      GO TO 150
  140 IF(JK-6) 150,150,145
  145 JK = 1
C.....EAST LONGITUDE (IN DEGREES)
  150 CEG= RLONGD
  165 XLA = RLAT * R2D
C.....LATITUDE (IN DEGREES) "+" IS NORTH
      CALL NOISY(KJ,XLA,CEG,ATNU)
      CALL NOISY(JK,XLA,CEG,ATNY)
      RETURN
      END
```

```
      SUBROUTINE NOISY (KJ, XLA, CEG, ANOS)
C     NOISY IS A GENERAL PURPOSE ROUTINE USED TO EVALUATE A FOURIER
C     SERIES IN TWO VARIABLES.
C     KJ --- NUMBER OF FOURIER COEFFICIENT ARRAY TO BE USED
C     XLA --- GEOGRAPHIC LATITUDE, DEGREES,
C     CEG --- GEOGRAPHIC EAST LONGITUDE, DEGREES
C     ANOS --- NOISE VALUE, MEDIAN POWER DB ABOVE KTB
C     ABP --- NORMALIZING FACTORS FOR FOURIER SERIES
C     KJ = 1 TO 6 IS ATMOSPHERIC NOISE, KJ = 7 IS LAND MASS MAP AND
C     KJ = 8 IS RATIO OF F2 HEIGHT OF MAXIMUM TO SEMITHICKNESS
C
C     * NOTE - XLA, CEG, ANOS, ABP ARE NOT ALWAYS AS PREVIOUSLY DEFINED
C     FOURIER VARIABLES AND ATMOSPHERIC RADIO NOISE
C
      COMMON / TWO / F2D(16,6,6), DUD(5,12,5),FAM(14,12),
     A SYS(9,16,6), PERR(9,4,6),P(29,16,8),ABP(2,9)
      COMMON /SWTCH/ INIL,OSSN,OMONTH,OTIME,ODIP,OLAT,OLONG
      DIMENSION SX (15), SY(29), ZZ (29)
      IF (KJ - 8)105, 100, 105
C.....LIMITS OF FOURIER SERIES
 100  LM = 15
      LN = 10
      GO TO 110
C.....LIMITS OF FOURIER SERIES
 105  LM = 29
      LN = 15
C.....HALF ANGLE (IN RADIANS)
 110  Q = .0087266466 * CEG
      IF(CEG .EQ. OLONG .AND. INIL .EQ. 0) GO TO 118
C.....LONGITUDE SINES
      DO 115 K = 1, 15
 115  SX(K)=SIN(Q*K)
      OLONG=CEG
 118  CONTINUE
C.....LONGITUDE SERIES
      DO 125 J = 1, LM
      R = 0.
      DO 120 K = 1, LN
 120  R = R + SX (K) * P (J, K, KJ)
 125  ZZ (J) = R + P (J, 16, KJ)
C.....ANGLE PLUS 90 DEGREES (IN RADIANS)
      Q = .01745329252 * (XLA + 90.)
      IF(XLA .EQ. OLAT .AND. INIL .EQ. 0) GO TO 145
C.....LATITUDE SERIES
      DO 140 J=1,29
  140 SY(J)=SIN(Q*J)
      INIL=0
      OLAT=XLA
 145  CONTINUE
      R = 0.
      DO 130 K = 1, LM
  130 R = R + SY (K) * ZZ (K)
C.....FINAL FOURIER SERIES EVALUATION (NOTE LINEAR NORMALIZATION)
 135  ANOS = R + ABP(1,KJ)+ABP(2,KJ)* Q
      RETURN
      END
```

```
      SUBROUTINE GENFAM(Y2,IBLK,FREQ,Z,FA,DU,DL,DMS,DUS,DLS)
C
C     GENFAM CALCULATES THE FREQUENCY DEPENDENCE OF THE ATMOSPHERIC
C     NOISE AND GETS DECILES AND PREDICTION ERRORS FROM TABLES
C
      COMMON / TWO / F2D(16,6,6), DUD(5,12,5),FAM(14,12),
     A  SYS(9,16,6), PERR(9,4,6), P(29,16,8),ABP(2,9)
      DIMENSION V(5)
      IF(F2D(1,1,1) ) 90,90,95
C.....NO IONOSPHERIC LONG TERM DATA BASE FILE (SET IN SUBROUTINE GENOIS)
   90 FA = 0.0
      DU=9.
      DL=7.
      DUS=1.5
      DLS=1.5
      DMS=3.
      RETURN
   95 CONTINUE
      IBK=IBLK
C.....CHECK IF LATITUDE IS NORTH OR SOUTH
      IF (Y2)100, 105, 105
 100  IBK = IBK + 6
 105  U1 = - .75
      X = .43429 * ALOG (FREQ)
      U = (8. * 2. * * X - 11.) / 4.
      KOP = 1
 110  PZ = U1 * FAM (1, IBK) + FAM (2, IBK)
      PX = U1 * FAM (8, IBK) + FAM (9, IBK)
      DO 115 I = 3, 7
      PZ = U1 * PZ + FAM (I, IBK)
 115  PX = U1 * PX + FAM (I + 7, IBK)
      IF(KOP-1) 120,120,125
 120  CZ = Z * PZ + PX
      CZ = Z + Z - CZ
      U1 = U
      KOP = 2
      GO TO 110
 125  FA = CZ * PZ + PX
      DO 145 I = 1, 5
      Y = DUD (1, IBK, I)
      DO 140 J = 2, 5
      IF (J - 5)140, 130, 140
 130  IF (X - 1.)140, 140, 135
 135  X = 1.
 140  Y = Y * X + DUD (J, IBK, I)
 145  V (I) = Y
      DU = V (1)
      DL = V (2)
      DUS = V (3)
      DLS = V (4)
      DMS = V (5)
      RETURN
      END
```

```
      SUBROUTINE GENOIS
C
C     THIS ROUTINE COMPUTES THE COMBINED NOISE DISTRIBUTION
C
      COMMON / DON / ALATD, AMIN, AMIND, DLONG, DMP, ERTR,
     1  PMP, PWR, RLAT, RLATD, RLONG, RLONGD, RSN, SIGTR,
     2 TLAT, TLATD, TLONG, TLONGD, FLUX, SSN, ATMNO, D90R, D50R,
     3 D10R, D90S, D50S, D10S
      COMMON/FILES/ LUO,LUI,LU25,LU26
      COMMON/ANOIS/ATNU,ATNY,CC,TM,XEFF,RCNSE,DU,DL,SIGM,SIGU,SIGL,KJ,JK
      COMMON /TON /ADJ, ADS, ATMO, GNOS, GOT, PWRDB, ZCNSE, REL, SL, SLS
     1, SPR, SU, SUS, TIMER, XADJN, ZEFF, XNOISE, XTLOS, ZNOISE, NF
      COMMON/FRQ/FREL(29),FREQ,JMODE
      COMMON / ION / IANT(3,2), NTR(2), IEA, IFQB, IFQE, IGRAPH, IHRE,
     A IHRO, IHRS, JO, LUFP, METHOD, MONPR, NDAY, NES, NOISE, NPAT,
     B NPSL, NRSP, NUMO
      COMMON / METSET /  ITRUN, ITOUT, JTRUN(40), JTOUT(40)
      COMMON/RON/RAT(5),CLCK(5),ABIY(5),ARTIC(5),SIGPAT(5),EPSPAT(5),
     A FI(3,5),YI(3,5),HI(3,5),FX(3,5),HPRIM(30,3),HTRUE(30,3),
     B FVERT(30,3),KFX,AFAC(30,3),HNOR(3),HTR(50),FNSQ(50)
      COMMON /RTANT /XETA, XSIG, XEPS, XND, XNL, XNH, TEX (4), ITANT, IR
     1 ANT, RETA, RSIG, REPS, RND, RNL, RNH, REX(4), TEFF, REFF, KASANT
      COMMON / TWO / F2D(16,6,6), DUD(5,12,5),FAM(14,12),
     A  SYS(9,16,6), PERR(9,4,6), P(29,16,8),ABP(2,9)
      COMMON / ZON / ABPS(7), CREL(7), EFF(7), FLDST(7), GRLOS(7),
     1HN (7), HP (7), PROB (7), RELY (7), RGAIN (7), SIGPOW (7), SN (7),
     2 SPRO (7), TGAIN (7), TIMED (7), TLOSS (7), B (7), FSLOS (7), ADV
     C (7),OBF(7),NMODE(7),NPROB,NREL,TLLOW(7),TLHGH(7)
      DIMENSION XNINT(4)
C.....MAN-MADE NOISE LEVELS AS GIVEN BY CCIR REPORT 258.
      DATA XNINT /76.8, 72.5, 67.2, 53.6/
      DATA DFAC,BFAC,CFAC/7.87384,30.99872,5.56765/
C
C     7.87384=SQRT(2*1.282**2*4.34294**2)
C
C     30.99872=(1.282**2)(4.34294**2)
C
C     5.56765=4.34294*1.282
C
C.....DATA IS FA VALUES AT 1 MHZ
C.....ATNU, ATNY ARE DB .GT. KTB FOR 1 MHZ
C.....ATNZ, ATNX ARE DB .GT. KTB FOR DESIRED FREQ,DUM
C.....ATNOS, GNOS, XNOIS ARE DB .GT. KTB FOR ALL CALCULATIONS
C.....AND ARE CONVERTED TO DBW(1 HZ BWDTH) AT END OF ROUTINE
C.....UPPER LIMIT IS 55 MHZ FOR NOISE
       DUME = AMIN1(FREQ,55.)
      MAN=NOISE
C  FREQUENCY DEPENDENCE ATMOSPHERIC NOISE
      IF(F2D(1,1,1)) 85, 90, 90
C.....NO IONOSPHERIC LONG TERM DATA BASE FILE
C.....FORCE MAN-MADE NOISE OR GALACTIC NOISE
   85 ATNOS = 0.
```

```
      DUA=9.
      DLA=7.
      SMA = 3.
      SUA = 1.5
      SLA = 1.5
      GO TO 95
   90 CONTINUE
C.....FREQUENCY DEPENDENCE
      CALL GENFAM(RLAT,KJ,DUME,ATNU,ATNZ,DU,DL,SIGM,SIGU,SIGL)
      CALL GENFAM(RLAT,JK,DUME,ATNY,ATNX,DX,DQ,SIGZ,SIGX,SIGSQ)
C.....BEGIN OF INTERPOLATION ON LOCAL TIME
      SLOP = ABS(CC-TM)/4.
      ATNOS = ATNZ + (ATNX - ATNZ) * SLOP
      DUA= DU +(DX-DU)*SLOP
      DLA= DL +(DQ-DL)*SLOP
        SMA= SIGM+ (SIGZ-SIGM)*SLOP
        SUA= SIGU +(SIGX-SIGU)*SLOP
        SLA= SIGL+(SIGSQ-SIGL)* SLOP
C
C     (DUA/DFAC)**2=(DUA/1.282)**2/(2*4.34294**2)
C                    =(DUA/SQRT(2*1.282**2*4.34294**2))**2
C                    =(DUA/7.87384)**2
C
   95 AU=EXP((DUA/DFAC)**2 + (ATNOS/4.34294))
      VU=AU*AU*(EXP(DUA*DUA/BFAC)-1.)
      AL=EXP((DLA/DFAC)**2 + (ATNOS/4.34294))
C
C     DLA*DLA/BFAC=(DLA/1.282)**2/(4.34294)**2
C                 =DLA**2/30.99872
C
      VL=AL*AL*(EXP(DLA*DLA/BFAC)-1.)
C  GALACTIC NOISE
      IF(FREQ - FI(3,KFX)) 100, 100, 105
C.....GALACTIC NOISE DOES NOT PENETRATE
  100 GNOS = 0.
      GO TO 110
  105 GNOS = 52. - 23. * ALOG10(FREQ)
  110 DUG=2.
      AT=EXP((DUG/DFAC)**2 + (GNOS/4.34294))
      AU=AU+AT
      VU=VU+AT*AT*(EXP(DUG*DUG/BFAC)-1.)
      DLG=2.
      AT=EXP((DLG/DFAC)**2 + (GNOS/4.34294))
      AL=AL+AT
      VL=VL+AT*AT*(EXP(DLG*DLG/BFAC)-1.)
      SMG = .5
      SUG = .2
      SLG = .2
C  MAN MADE  NOISE
       MAN=NOISE
      XNOIS = MAN
      MA = IABS(MAN)
      ZNOISE=XNOIS
      IF(MAN) 120, 114, 115
```

```
C.....INDICATES -164 ON USER INPUT
  114 MA = 4
      GO TO 120
C.....CONVERT 3 MHZ DB .LT. 1 WATT INPUT VALUE TO FA AT 1 MHZ
  115 XNOIS=204.0-XNOIS+13.22
C.....OBTAIN FA AT DESIRED FREQUENCY
      XNOIS = XNOIS - 27.7 * ALOG10(FREQ)
      GO TO 125
C....NEGATIVE ON USER INPUT INDICATES INDEX
  120 MA = MINO(4,MA)
      CONN=27.7
      IF(MA .EQ. 4) CONN=28.6
      XNOIS = XNINT(MA) - CONN * ALOG10(FREQ)
      ZNOISE = 204.0 - XNINT(MA) + 13.22
  125 DUM=9.7
      AT=EXP((DUM/DFAC)**2+(XNOIS/4.34294))
      AU=AU+AT
      VU=VU+AT*AT*(EXP(DUM*DUM/BFAC)-1.)
      DLM=6.
      AT=EXP((DLM/DFAC)**2+(XNOIS/4.34294))
      AL=AL+AT
      VL=VL+At*AT*(EXP(DLM*DLM/BFAC)-1.)
      SUM=1.5
      SMM=5.4
      SLM=1.5
C.....RECEIVER ANTENNA EFFICIENCY
      CALL GAIN(2,KASANT,0.0,FREQ,GDUM,REFF)
      XEFF = REFF
      ZEFF=XEFF
C.....SET ARRAY FOR ALL POSSIBLE MODES
      DO 196 IM=1,6
  196 EFF(IM) = XEFF
C.....NOW DETERMINATION OF NOISE LEVEL IS ITS-78(HFMUFES4)
C.....SWITCH TO DB .GT. WATT
      ATNOS=ATNOS-204.
      GNOS=GNOS-204.
      XNOIS=XNOIS-204.
      SIGTSQ=ALOG(1.+VU/(AU*AU))
      XRNSE= 4.34294*(ALOG(AU)-SIGTSQ/2.) -204.
C.....UPPER DECILE
C
C     CFAC=4.34294*1.282
C         =5.56765
C
      DU= CFAC*SQRT(SIGTSQ)
      SIGTSQ=ALOG(1.+VL/(AL*AL))
C.....LOWER DECILE
      DL= CFAC*SQRT(SIGTSQ)
      IF(ITRUN - 8) 205, 210, 205
  205 QPA = 10. ** ((ATNOS - XRNSE) * .1)
      QPG = 10.**((GNOS -XRNSE)*.1)
C.....PREDICTION ERRORS
C.....SIGM IS MEDIAN, SIGU IS UPPER AND SIGL IS LOWER
      QPM = 10.**((XNOIS-XRNSE)*.1)
```

```
      SIGM= SQRT((QPA*SMA)**2 +(QPG*SMG)**2 +(QPM*SMM)**2)
C
C     0.23026=1.0/4.34294
C
      PV=QPA*EXP((DUA-DU)*.23026)
      SIGU= (PV*SUA)**2+((PV-QPA)*SMA)**2
      PV=QPG*EXP((DUG-DU)*.23026)
      SIGU=SIGU+(PV*SUG)**2+((PV-QPG)*SMG)**2
      PV=QPM*EXP((DUM-DU)*.23026)
      SIGU=SQRT(SIGU+(PV*SUM)**2+((PV-QPM)*SMM)**2)
      PV=QPA*EXP((DLA-DL)*.23026)
      SIGL= (PV*SLA)**2+((PV-QPA)*SMA)**2
      PV=QPG*EXP((DLG-DL)*.23026)
      SIGL=SIGL+(PV*SLG)**2+((PV-QPG)*SMG)**2
      PV=QPM*EXP((DLM-DL)*.23026)
      SIGL=SQRT(SIGL+(PV*SLM)**2+((PV-QPM)*SMM)**2)
C RCVR SITE NOISE = TOTAL NOISE + ANTENNA EFFICENCY (ADDED TO SIGNAL
C    WITH GAIN)
  210 RCNSE = XRNSE + XEFF
      ZCNSE=RCNSE
      ATMNO=ATNOS
      XADJN=1.
      XNOISE=XNOIS
      ATMO=ATNOS
      RETURN
      END
```

```
      SUBROUTINE GENOIS
C
C     THIS ROUTINE COMPUTES THE COMBINED NOISE DISTRIBUTION
C
      COMMON / DON / ALATD, AMIN, AMIND, DLONG, DMP, ERTR,
     1  PMP, PWR, RLAT, RLATD, RLONG, RLONGD, RSN, SIGTR,
     2 TLAT, TLATD, TLONG, TLONGD, FLUX, SSN, ATMNO, D90R, D50R,
     3 D10R, D90S, D50S, D10S
      COMMON/FILES/LUO,LUI,LU25,LU26
      COMMON/ANOIS/ATNU,ATNY,CC,TM,XEFF,RCNSE,DU,DL,SIGM,SIGU,SIGL,KJ,JK
      COMMON /TON /ADJ, ADS, ATMO, GNOS, GOT, PWRDB, ZCNSE, REL, SL, SLS
     1, SPR, SU, SUS, TIMER, XADJN, ZEFF, XNOISE, XTLOS, ZNOISE, NF
      COMMON/FRQ/FREL(29),FREQ,JMODE
      COMMON / ION / IANT(3,2), NTR(2), IEA, IFQB, IFQE, IGRAPH, IHRE,
     A IHRO, IHRS, JO, LUFP, METHOD, MONPR, NDAY, NES, NOISE, NPAT,
     B NPSL, NRSP, NUMO
      COMMON / METSET /  ITRUN, ITOUT, JTRUN(40), JTOUT(40)
      COMMON/RON/RAT(5),CLCK(5),ABIY(5),ARTIC(5),SIGPAT(5),EPSPAT(5),
     A FI(3,5),YI(3,5),HI(3,5),FX(3,5),HPRIM(30,3),HTRUE(30,3),
     B FVERT(30,3),KFX,AFAC(30,3),HNOR(3),HTR(50),FNSQ(50)
      COMMON /RTANT /XETA, XSIG, XEPS, XND, XNL, XNH, TEX (4), ITANT, IR
     1 ANT, RETA, RSIG, REPS, RND, RNL, RNH, REX(4), TEFF, REFF, KASANT
      COMMON / TWO / F2D(16,6,6), DUD(5,12,5),FAM(14,12),
     A  SYS(9,16,6), PERR(9,4,6), P(29,16,8),ABP(2,9)
      COMMON / ZON / ABPS(7), CREL(7), EFF(7), FLDST(7), GRLOS(7),
     1HN (7), HP (7), PROB (7), RELY (7), RGAIN (7), SIGPOW (7), SN (7),
     2 SPRO (7), TGAIN (7), TIMED (7), TLOSS (7), B (7), FSLOS (7), ADV
     C (7),OBF(7),NMODE(7),NPROB,NREL,TLLOW(7),TLHGH(7)
      DIMENSION XNINT(4)
C.....MAN-MADE NOISE LEVELS
      DATA XNINT /125., 136., 148., 164./
C.....BUT COMBINATION IS NOT
C.....CALCULATION OF NOISE LEVEL IS ITSA-1
C.....ATNU, ATNY ARE DB .GT. KTB FOR 1 MHZ
C.....ATNZ, ATNX ARE DB .GT. KTB FOR FREQ
C.....ATNOS, GNOS, XNOIS ARE DB .LT. 1 WATT IN 1 HZ BAND AT FREQ
C.....UPPER LIMIT IS 55 MHZ FOR NOISE
       DUME = AMIN1(FREQ,55.)
      MAN=NOISE
C  FREQUENCY DEPENDENCE ATMOSPHERIC NOISE
      IF(F2D(1,1,1)) 85, 90, 90
C.....NO IONOSPHERIC LONG TERM DATA BASE FILE
C.....FORCE MAN-MADE NOISE OR GALACTIC NOISE
   85 ATNOS = 204.
      DUA = 9.
      DLA = 7.
      SMA = 3.
      SUA = 1.5
      SLA = 1.5
      GO TO 95
   90 CONTINUE
```

```
C.....FREQUENCY DEPENDENCE
      CALL GENFAM(RLAT,KJ,DUME,ATNU,ATNZ,DU,DL,SIGM,SIGU,SIGL)
      CALL GENFAM(RLAT,JK,DUME,ATNY,ATNX,DX,DQ,SIGZ,SIGX,SIGSQ)
C.....BEGIN OF INTERPOLATION ON LOCAL TIME
      SLOP = ABS(CC-TM)/4.
      ATNOS = - (ATNZ + (ATNX - ATNZ) * SLOP) + 204.
      DUA= DU +(DX-DU)*SLOP
      DLA= DL +(DQ-DL)*SLOP
        SMA= SIGM+ (SIGZ-SIGM)*SLOP
        SUA= SIGU +(SIGX-SIGU)*SLOP
        SLA= SIGL+(SIGSQ-SIGL)* SLOP
C.....END OF INTERPOLATION ON LOCAL TIME
C  GALACTIC NOISE
   95 IF(FREQ - FI(3,KFX)) 100, 100, 105
C.....GALACTIC NOISE DOES NOT PENETRATE
  100 GNOS = 204.
      GO TO 110
  105 GNOS = 165. + 9.555 * ALOG(FREQ / 3.)
  110 DUG = 2.
      DLG =2.
      SMG = .5
      SUG = .2
      SLG = .2
C  MAN MADE  NOISE
       MAN=NOISE
      XNOIS = MAN
      MA = IABS(MAN)
      ZNOISE=XNOIS
      IF(MAN) 120, 114, 115
C.....INDICATES -164 ON USER INPUT
  114 MA = 4
      GO TO 120
C.....ACTUAL VALUE IF POSITIVE ON USER INPUT
  115 XNOIS = XNOIS + 12.160 * ALOG(FREQ / 3.)
      MA= -MAN
      GO TO 125
C.....NEGATIVE ON USER INPUT INDICATES INDEX
  120 MA = MINO(4,MA)
      XNOIS = XNINT(MA) + 12.160 * ALOG(FREQ/3.)
      ZNOISE = XNINT(MA)
      MA= -XNINT(MA)
  125 DUM =9.
      DLM =7.
      SUM=1.5
      SMM=3.
      SLM=1.5
C.....RECEIVER ANTENNA EFFICIENCY
      CALL GAIN(2,KASANT,0.0,FREQ,GDUM,REFF)
      XEFF = REFF
      ZEFF=XEFF
C.....SET ARRAY FOR ALL POSSIBLE MODES
      DO 196 IM=1,6
  196 EFF(IM) = XEFF
```

```
C.....NOW DETERMINATION OF NOISE LEVEL IS ITS-78(HFMUFES4)
C.....SWITCH TO DB .GT. WATT
      ATNOS = - ATNOS
      GNOS = - GNOS
      XNOIS = - XNOIS
C ADD THE NOISES (RANDOM PHASE APROXIMATION=ADD THE POWER IN WATTS)
C.....MEDIAN
      XRNSE= 4.343*ALOG((10.**(ATNOS*.1)) + (10.**(GNOS*.1))
     A +(10.**(XNOIS*.1)))
C  CALCULATE THE DECILES AND VARIANCE BY EQ. 37, P. 29 OF THE THEORY OF
C  ERROR BY YARDLEY BEERS, MCGRAW HILL.
C
C.....UPPER DECILE
      DU= ABS(4.343*ALOG(10.**((ATNOS+DUA)*.1)  + 10.**((GNOS+DUG)*.1)
     A +10.**((XNOIS+DUM)*.1))- XRNSE)
C.....LOWER DECILE
      DL= ABS( 4.343 *ALOG(10.**((ATNOS+DLA)*.1) +10.**((GNOS+DLG)*.1)
     A +10.**((XNOIS+DLM)*.1)) -XRNSE)
      IF(ITRUN - 8) 205, 210, 205
  205 QPA = 10. ** ((ATNOS - XRNSE) * .1)
      QPG = 10.**((GNOS -XRNSE)*.1)
C.....PREDICTION ERRORS
C.....SIGM IS MEDIAN, SIGU IS UPPER AND SIGL IS LOWER
      QPM = 10.**((XNOIS-XRNSE)*.1)
      SIGM= SQRT((QPA*SMA)**2 +(QPG*SMG)**2 +(QPM*SMM)**2)
      SIGU= SQRT((DUA*SUA*QPA**2/DU)**2 +(DUG*SUG*QPG**2/DU)**2
     A +(DUM*SUM*QPM**2/DU)**2)
      SIGL = SQRT((DLA*SLA*QPA**2/DL)**2 +(DLG*SLG*QPG**2/DL)**2
     A + (DLM * SLM * QPM ** 2 / DL) ** 2)
C RCVR SITE NOISE = TOTAL NOISE + ANTENNA EFFICENCY (ADDED TO SIGNAL
C   WITH GAIN)
  210 RCNSE = XRNSE + XEFF
      ZCNSE=RCNSE
      ATMNO=ATNOS
      XADJN=1.
      XNOISE=XNOIS
      ATMO=ATNOS
      RETURN
      END
```

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This report presents an updated and improved model designed for use in the HF propagation prediction program, IONCAP. The model has, however, much more general applicability, since the frequency range 10 kHz to 30 MHz is covered. This report gives the history, as near as can be determined, of the existing noise routines, and then develops the updated model based on current information. The three noise sources -- atmospheric, man-made, and galactic are treated and a more appropriate means of combining these three sources is developed. Examples of the use of the improved model in IONCAP are included and comparisons made with the existing model.

16. Key Words *(Alphabetical order, separated by semicolons)*

Atmospheric noise, galactic noise, IONCAP, man-made noise, noise model, overall operating noise threshold

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