500 KV TRANSMISSION LINE RADIO NOISE PERFORMANCE

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ABSTRACT

The extensive analyses of the radio noise characteristics of two 500kV lines near Atlanta Georgia are presented. Comprehensive analytical work and an extensive series of field measurements at twenty field locations are reported. Field measurements were conducted before, during, and after construction. Unique measurements of shielding effects are included. Selected night and loop antenna measurements were recorded, also. The results have been compared and interpreted for application in the design of future 500kV lines.

INTRODUCTION

The prediction of the radio noise produced by EHV transmission lines has been discussed for many years[1.2.3.4.5]. The Atlanta #1 and Norcross lines were considered to be excellent candidates for extensive pre and post construction radio noise field measurements. Twenty areas along these lines were chosen as relatively accessible measurement locations. The original study objectives may be listed as follows:

1. Verify prior calculations of noise levels by comparing them with field measurements using the normal prediction method and using rain cage test results from Project UHV.[4]
2. Extend RN calculations to long term statistical predictions based on weather data from Atlanta, Georgia.[5]
3. Present signal-to-noise (S/N) ratios for both calculated and measured RN levels.
4. Compare signal strength measurements to Radio Station predictions.
5. Compute and describe statistically the Quality of Radio Reception near the rights-of-way.[5]

This paper summarizes the results of a complete analysis as highlighted by the flow chart shown in Figure 1.

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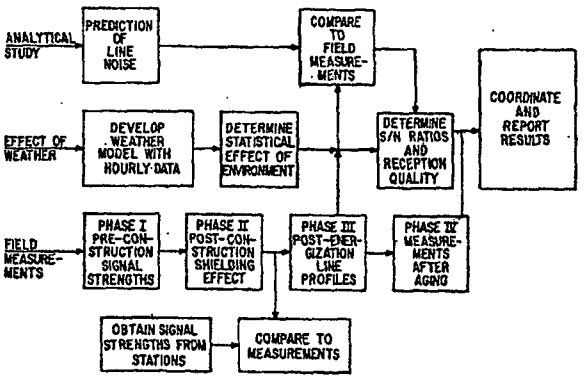

Fig. 1 500-kV line noise study program.

This program was divided into three basic areas: analytical work, the effect of weather, and the field measurements. Each of these topics is discussed in separate sections followed by the coordination of results.

Shown in Figure 2 is a sketch of the tower configuration used for the Atlanta #1 and Norcross 500kV lines of the Georgia Power Co. A triangular bundle of three 1.259" diameter (bluejay) conductors are considered. The radio noise profiles are computed using the techniques described in Reference 5. The base case profiles are based on the assumptions listed in Table I.

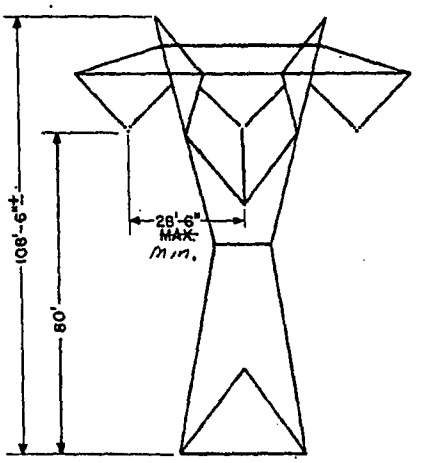

Fig. 2. 500 kV tower configuration.

Table I. BASE CASE CONDITIONS

Variables	Value
Voltage	5 50kV
Surface Factor	0.7
Frequency	1000k Hz
Ground Resistivity	62.7 Ohmeters
Relative Humidity	50 Percent
Relative Air Density	1.0 per unit
Wind Speed	0 km/hr
Precipitation	(None (Fair Weather) (Heavy Rain (Foul Weather)

The effect of variation in the above variables is discussed in Reference 7. The results are presented in Figure 3.

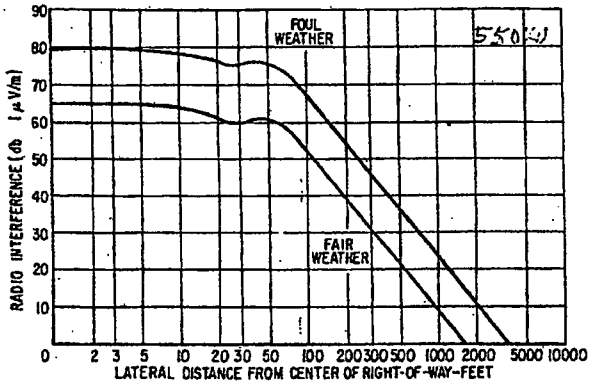

Fig. 3. Predicted radio noise profile for fair and foul weather.

These results are compared to the field measurements in the coordination of results.

EFFECT OF WEATHER

Hourly weather data from Atlanta, Georgia was obtained and processed[6] in order to determine the expected statistical variations due to changing weather patterns. For each hour over a ten (10) year period, the correction to the base case was computed based on the correction factors in Reference 7. These corrections may be displayed in a histogram as shown in Figure 4.

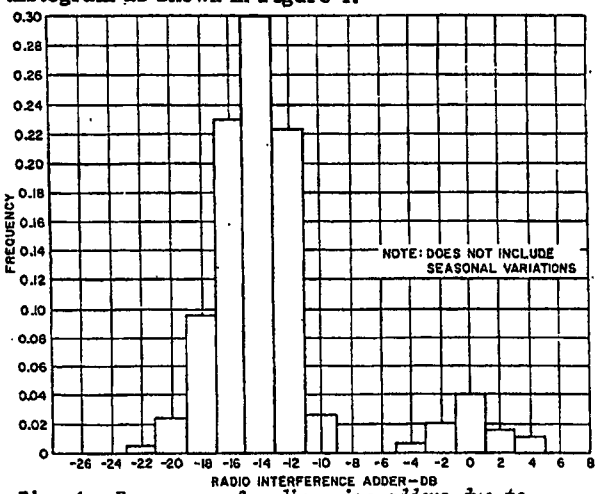

Fig. 4. Frequency of radio noise adders due to atmospheric variations in Atlanta, Georgia.

This data may be added to the foul weather base case corrected for non weather variables to produce a histogram of expected radio noise generation. Seasonal variations have not been included. They would be expected to add a variation of ± 6dB to the fair weather portion of the histogram. In foul weather the effect of droplets on the conduction tends to overwhelm the seasonal variations.[4]

FIELD MEASUREMENTS

Measurements on both transmission lines (Atlanta #1 and Norcross 500kV lines) have been made in wet and dry weather, day and night during four phases of their history.

Phase I	Pre-Construction
Phase II	Post-Construction Pre-Energization
Phase III	Post-Energization
Phase IV	After Aging

The radio noise data described were collected using the Stoddart Model NM 20B radio noise meter. Both rod and loop antena measurements have been made. The measurement locations along the line are indicated on the map in Figure 5. At each location, measurements are taken directly under the outside phase conductors. Also, appropriate spatial profiles have been measured and the measurement locations are noted. Careful attention has been given to selection of each measurement location, calibration of the instruments, the background noise level. The measurement techniques used are consistent with the guidelines described in Reference (8). During the measurement periods, the line was energized from between 495 kV to 525 kV. All measurements, unless otherwise noted, have been corrected to 500 kV using the correction technique presented in Reference 7.

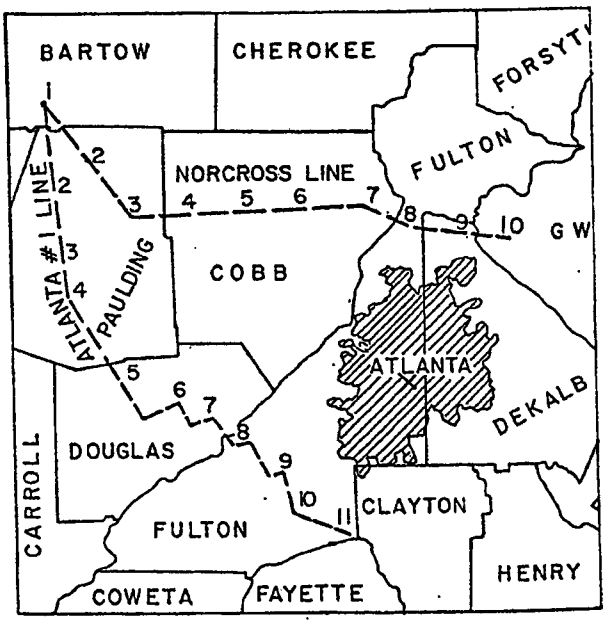

Fig. 5. Measurement locations.

A typical measurement location is illustrated by the pictures in Figure 6 and Figure 7. These pictures were taken from measurement location number 6 on the Norcross line looking east and west. Over ten thousand readings have been made during the four measurement phases at the 20 locations. Several hundred of these measurements have been made under foul weather.

Phase I - Pre-Construction

During September and November radio station signal strengths and background noise measurements were made. Typical results are shown in Tables II and III for the signal strengths and background noise respectively. Tables II and III give the measurements in decibels above 1 microvolt per meter. The measurement locations may be obtained from Figure 5. Table IV gives the results of some night measurements and Table V gives

Fig. 6. Norcross line - position #6 - looking east.

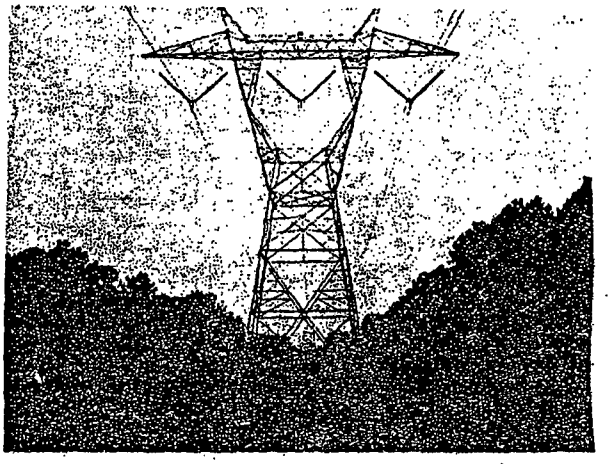

Fig. 7. Norcross line - position #6 - looking west.

TABLE II. SIGNAL STRENGTH MEASUREMENTS

STATION	FREQUENCY	ATLANTA #1 LOCATION 10				NORCROSS LOCATION 2				NORCROSS LOCATION 6				NORCROSS LOCATION 9			
		PHASE I	PHASE II	PHASE III	PHASE IV	PHASE I	PHASE II	PHASE III	PHASE IV	PHASE I	PHASE II	PHASE III	PHASE IV	PHASE I	PHASE II	PHASE III	PHASE IV
WDAK	540	52	55	50	57	47	*	*	52	56	53	54	*	48	55	49	*
WGGA	550	59	63	*	63	58	58	*	*	63	64	*	61	70	71	*	68
WPLO	590	87	86	78	88	67	63	59	61	70	78	78	79	99	99	96	100
WTRP	620	58	61	55	62	50	53	*	*	49	49	56	*	*	51	50	*
WRNG	680	76	84	87	85	67	74	69	71	81	80	80	69	94	104	97	100
WSB	750	88	95	89	87	76	74	75	72	92	88	89	82	110	111	102	110
WQXE	790	79	80	81	76	68	66	59	67	78	70	73	64	94	93	84	84
WGST	920	78	78	65	70	62	59	55	64	74	76	71	61	90	90	75	88
WIIN	970	68	76	72	74	65	64	56	63	74	72	69	60	80	81	75	80
WGUN	1010	80	80	77	76	70	67	59	58	75	72	71	63	97	97	89	96
WBIE	1080	72	63	*	73	65	76	*	*	123	121	*	117	83	65	*	86
WGKA	1190	66	61	63	68	55	49	56	58	66	59	69	60	68	70	59	62
WFOM	1230	60	56	*	55	60	60	*	*	92	95	*	89	69	67	*	52
WTSH	1260	84	*	78	73	59	58	53	58	70	70	70	60	69	69	59	*
WHIE	1320	63	57	*	53	50	*	*	*	50	*	*	*	51	51	*	52
WGAA	1340	73	67	71	66	67	68	55	53	60	60	65	50	71	57	63	59
WAOK	1380	80	73	62	70	57	54	*	*	74	70	71	71	71	74	58	68
WYZE	1480	76	71	74	69	52	48	51	*	68	58	67	53	73	*	69	*
WYNX	1550	70	64	*	64	68	69	*	66	98	93	*	92	78	56	*	70
WACX	1600	65	54	*	55	59	60	*	60	70	71	*	66	55	54	*	53

*Note: 1. Measurements in dB above 1 uvolt/meter Quasi Peak
2. Locations from Figure 5
3. Several Measurements Not Made.

TABLE III. NOISE MEASUREMENTS

FREQUENCY	ATLANTA #1 LOCATION 10				NORCROSS LOCATION 2				NORCROSS LOCATION 6				NORCROSS LOCATION 9			
	PHASE I	PHASE II	PHASE III	PHASE IV	PHASE I	PHASE II	PHASE III	PHASE IV	PHASE I	PHASE II	PHASE III	PHASE IV	PHASE I	PHASE II	PHASE III	PHASE IV
170	*	*	68	65	*	*	68	54	*	*	53	57	*	*	64	64
500	21	23	*	53	20	28	*	51	20	21	*	50	32	41	*	54
640	20	22	62	*	20	29	57	*	22	24	52	*	32	34	47	*
720	19		63	50	19	*	55	47	20	*	47	*	37	*	44	*
1140	19	17	60	48	15	25	53	*	21	29	44	*	25	32	42	*
1620	16	*	*	44	17	*	**	41	19	*	*	40	31	*	*	48
2200	17	18	*	33	17	21	*	37	10	17	*	35	20	24	*	39
4000	15	*	*	27	12	13	*	27	15	17	*	29	19	15	*	41
8300	8	6	*	17	8	7	29	17	8	*	*	25	17	12	*	38
15000	12	9	20	14	7	8	*	14	11	14	*	16	9	8	*	31
32000	5	8	9	11	3	8	7	9	4	7	19	16	3	11	2	16

*Note: 1. Measurements in dB above 1 μvolt/meter Quasi Peak
2. Locations from Figure 5
3. Several Measurements Not Made.

TABLE IV. LOOP ANTENNA MEASUREMENTS

STATION	FREQUENCY	ATLANTA #1 LOCATION 2 MAX	LOCATION 2 MIN	LOCATION 6 MAX	LOCATION 6 MIN	LOCATION 10 MAX	LOCATION 10 MIN
WDAK	590	56	36	59	35	72	34
WTRP	620	41	30	45	34	47	32
WRNG	680	58	35	60	32	65	38
WSB	750	67	46	63	33	80	62
WQXI	790	58	36	61	37	72	45
WGST	920	55	35	61	38	70	48
WIIN	970	55	39	57	42	66	44
WGUN	1010	60	40	63	35	74	38
WGKA	1190	45	27	44	37	57	35
WTJH	1260	49	31	57	44	77	53
WGAA	1340	53	39	49	47	63	39
WAOK	1380	49	31	*	*	69	36
WYZE	1480	45	30	*	*	70	46

*Several measurements not made.

TABLE V. NIGHT SIGNAL STRENGTHS

STATION	FREQUENCY	ATLANTA LOCATION 10	NORCROSS LOCATION 6	NORCROSS LOCATION 9
WSN	650	88	71	*
WMAQ	670	80	74	*
**	700	79	80	74
WSB	750	93	86	112
WFAA	820	84	78	78
WCBS	880	79	80	79
WKYZ	1100	76	75	69
WWVA	1170	65	64	54
**	1530	85	77	81

*Several measurements not made.
**From Cincinati, Ohio

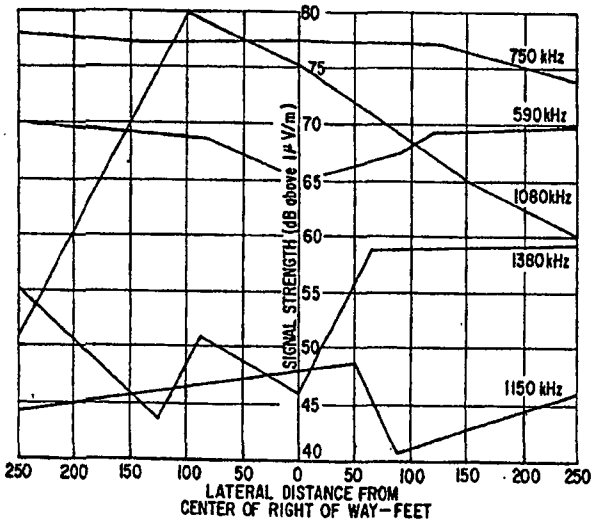

Fig. 8. Post-construction signal strength profile.

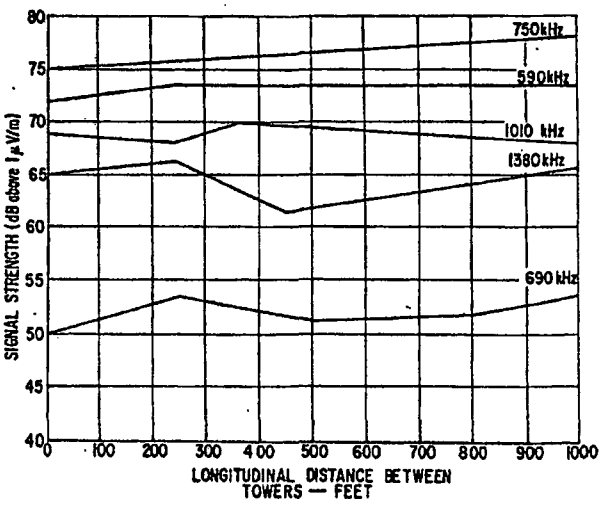

Fig. 9. Post-construction signal strength profile.

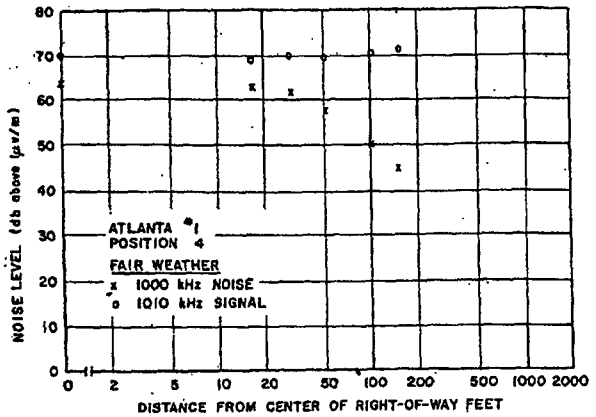

Fig. 10. Post energization noise and signal profile.

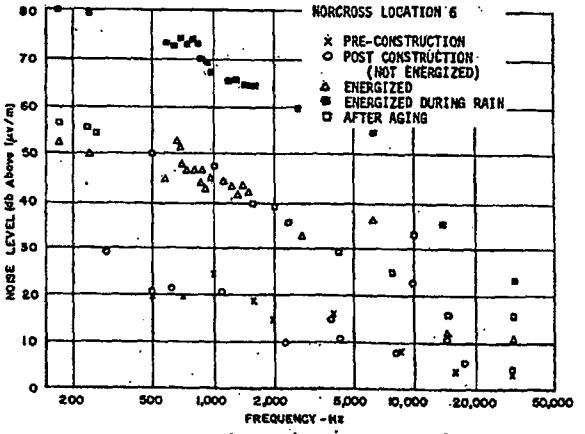

Fig. 11. Line noise measurements.

the minimum and maximum loop antenna recordings. Due to the large volume of data taken, only typical data is presented. The conclusions are based on all the data, and the data presented is intended to show typical trends.

Phase II - Post-Construction Pre-Energization

The radio station signal strengths and background noise measurements were repeated for comparison and typical results are shown in Tables II and III, respectively. These signal strength measurements (Table II) averaged 3.7 db less. This change could be explained by a general shielding effect or a seasonal variation. Phase I measurements were made in the fall and Phase II in the Spring. Some individual changes were significant, and profiles were then taken. Typical lateral and longitudinal profiles are shown in Figures 8 and 9, respectively. These show in more detail the distortion produced by coupling to the line and reradiation. The profiles taken at midspan were generally not symmetrical, however, the major effects tend to be localized within the right-of-way.

Phase III - Post Energization

Again signal strengths were measured and the typical results are shown in Table II. The noise measurements were made in generally fair weather. However, several sets of readings were taken during rain. Noise and signal profiles were taken to estimate actual signal-to-noise ratios. Figure 10 shows a typical result.

Phase IV - After Aging

After the conductors have been permitted to age for about a year, measurments were re-made. The signal strengths are recorded in Table II and the noise measurements in Table III.

COORDINATION OF RESULTS

Since extensive data was taken, one of the most difficult tasks is to interpret general results without becoming hopelessly involved with a sea of numbers. It is with this philosphy in mind that the following summaries are presented.

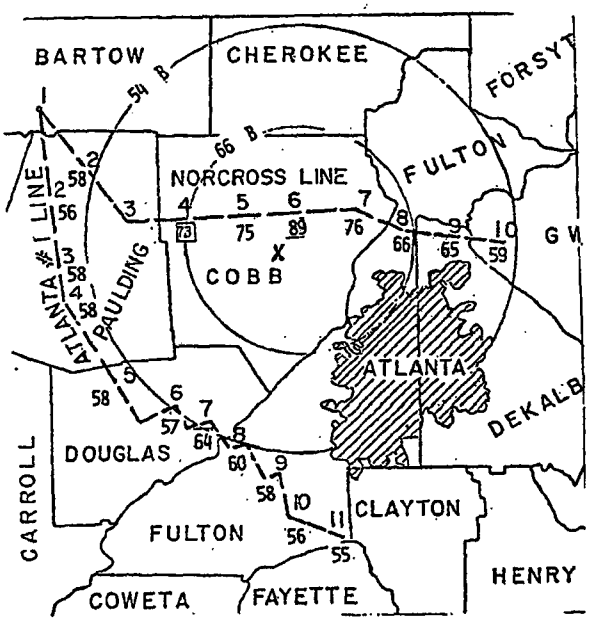

Fig. 12 Signal strength measurements.

Radio Station Signal Strengths

Several local radio stations provided data for their predicted signal strengths in the Atlanta area. A typical comparison to the field measurements is shown in Figure 11. Generally, the field measurements were consistent with the predicted signal levels. Table II indicates the typical fluctuations for the different field measurement periods.

Noise Comparisons

Table III presents noise measurements for all four phases of field measurements through a wide frequency range. An excellent example of the data is available in the history of measurements at location 6 of the Norcross line. Figure 12 shows pre-construction, after energizing, during rain and after aging measurements. The dramatic effect

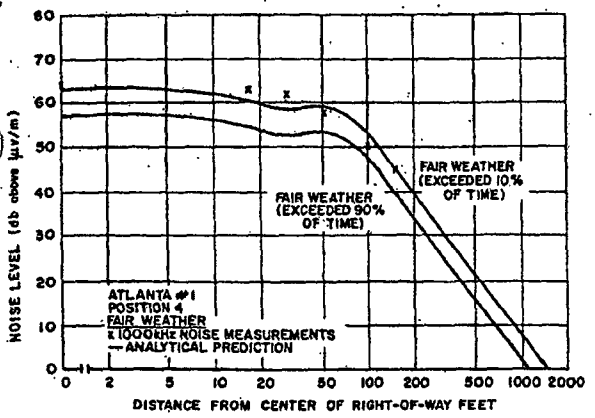

Fig. 13. Measurements compared to prediction.

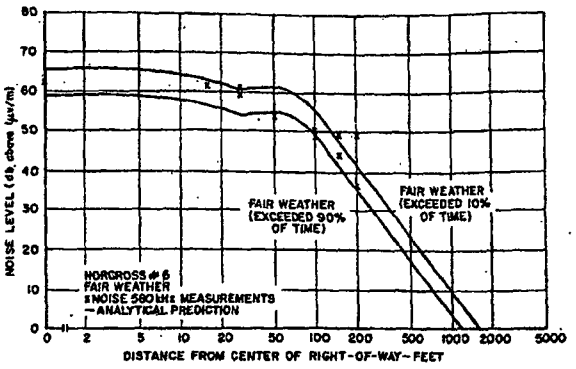

Fig. 16. Measurements compared to prediction.

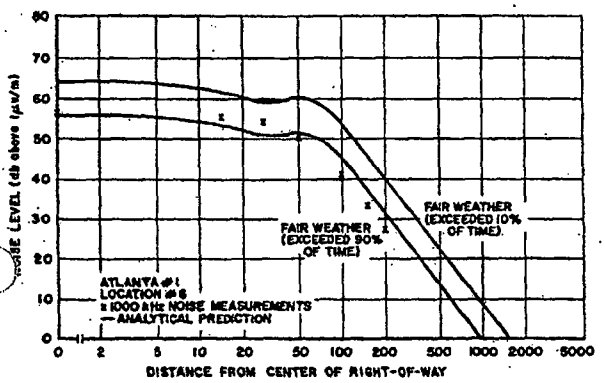

Fig. 14. Measurements compared to prediction.

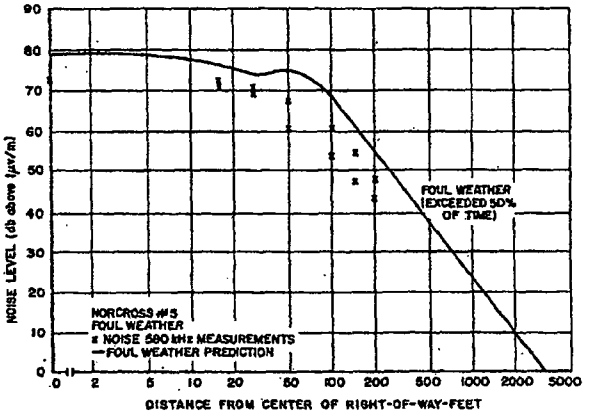

Fig. 17. Measurements compared to prediction.

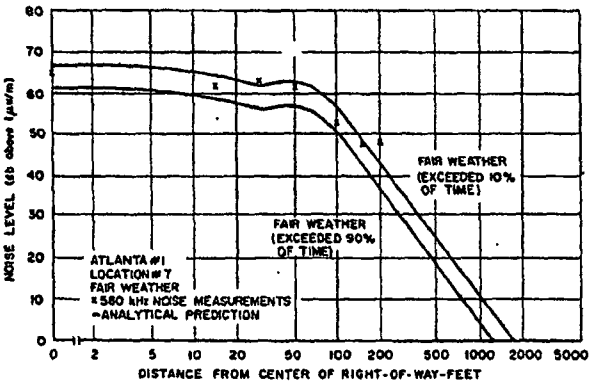

Fig. 15. Measurements compared to prediction.

after aging measurements. The dramatic effect of rain is clearly noted. An average increase of over 20dB is evident throughout the entire frequency spectrum.

Noise Profiles

One of the criteria for modern radio noise programs is to predict field measurements. During the Phase III field program, an excellent opportunity for measuring noise profiles was provided. In addition, several profiles were taken under foul weather conditions. The computed profiles shown earlier in Figure 3 must be modified before direct comparisons can be made. First the weather corrections were added to develop a statistical prediction. Then corrections for line voltage and frequency were applied.

Seasonal effects have not been included but an additional variation of ±6db might be expected.

Figures 13, 14, 15 and 16 present profile comparisons for four different measurement locations in fair weather. Agreement is excellent. Figures 17 and 18 show two foul weather profiles taken at Norcross location 5. Agreement in this case is good.

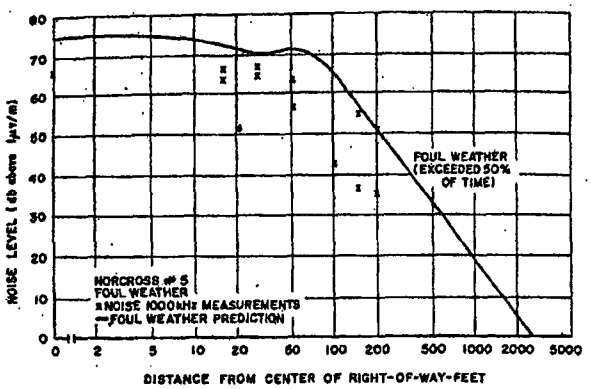

Fig. 18. Measurements compared to prediction.

CONCLUSIONS

The significant conclusions may be summarized as follows:

1. Radio station predicted field strengths agree well with measurements.
2. Noise predictions, including the statistical weather effects,5 agree well with field measurements.
3. Fair weather conditions prevail some 91% of the time.
4. Shielding effects of transmission line may produce substantial variations in the signal pattern. However, these variations do not have a significant effect outside the right-of-way.
5. Aging has tended to reduce the line noise levels, but the effect has been minor.

This data has been applied to help select a right-of-way width. The intent is to minimize the effect on the public. That is, to acquire the smallest right-of-way width possible without introducing objectionable radio interference. After extensive considerations, it was concluded that a width greater than 150 feet would restrict public uses unnecessarily and there would not be objectionable interference at this distance.

REFERENCES

(1) G. E. Adams, "An analysis of the radio-interference characteristics of bundled conductors,", AIEE TRANS. (PAS), Pt. III, Vol. 75, pp. 1569 - 1584, February 1956.

(2) IEEE Committee Report, "Transmission system radio & influence," IEEE TRANS., PAS 31 TP 65 - 65

(3) J. J. Clade, C. H. Gary, M. R. Moreau, "Usage and checking of the theoretical relations between fields, currents and excitation functions in radio frequencies in the case of short test lines," IEEE TRANS. 69TP 64-PWR Winter Power Meeting, January 1969.

(4) G. W. Juette, L. E. Zaffanella, "Radio noise, audible noise and corona loss of EHV and UHV transmission lines under rain: predetermination based on cage tests," IEEE TRANS. (PAS) Vol. 89, No. 6, pp. 1168 - 1178, July/August 1970.

(5) K. W. Priest, G. K. Carter and G. W. Juette, "Calculation of the radio interference statistics of transmission lines," IEEE TRANS. PAS, Vol. 91, No. 1, pp. 92 - 98 January/February 1972.

(6) J. G. Anderson, L. O. Barthold, "METIFOR - a statistical method for insulation design of EHV transmission lines," IEEE TRANS. PAS Vol. 83, pp. 271 - 280, March 1964.

(7) J. G. Anderson, M. Baretsky, J. J. LaForest, D. D. MacCarthy, F. A. Fisher, E. F. Magnusson, K. O. Tangen, EHV Transmission Line Reference Book New York: Edison Electric Institute, 1968.

(8) Institute of Electrical and Electronic Engineers (IEEE), 345 East 47th Street, New York, N.Y. 10017. "IEEE Trial Use Standard Procedures for the Measurement of Radio Noise from Overhead Power Lines," Std. 430-1972.

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