N. Eng. 70-C

FR-1115

REPORT NO. R-1115

DATE 22 January 1935

SUBJECT

Characteristic Impedance and Attenuation of Transmission Line at Frequencies of 30 and 40 mcs.

BY

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U. S. GOVERNMENT PRINTING OFFICE: 1934

4—7456

22 January 1935

NRL Report No. R-1115
BuEng.Prob.No. M15-3

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

Characteristic Impedance and Attenuation of Transmission Line at Frequencies of 30 and 40 mcs.

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Washington, D. C.

Number of Pages: Text - 4 Tables - 1 Plates - 1

Authorization: BuEng.let. S67/L5(11-24-W8) of 27 Nov. 1934.

Date of Test: December 15, 1934, to January 8, 1935.

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Distribution:
BuEng. (5)

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APPENDICES

AUTHORIZATION FOR TEST

1. This work was authorized by Bureau of Engineering letter 367/L5(11-24-W8) of 27 November 1934, reference (a).

OBJECT OF TEST

2. The object of the tests was as follows:

(a) To measure the characteristic impedance and attenuation of a transmission line of the twisted cable type, at frequencies of 30 and 40 mcs, submitted by the U.S. Forest Service.

ABSTRACT OF TEST

3. As a matter of comparison and for information, two twisted cable transmission lines of different construction and composition than that of the submitted line were also measured. One of these cables is that as supplied by the General Electric Company with their all wave, noise reducing antenna system. The other cable is standard commercial type twisted lamp cord. All three types of cables were measured for impedance at both 30 and 40 mcs., and for attenuation at 40 mcs. The capacity, inductance and power factor were measured at a frequency of 1000 cycles. The attenuation of the Forest Service transmission line was also measured at 40 mcs with the outer rubber covering removed.

Conclusions

(a) The average value of characteristic impedance obtained at 30 and 40 mcs. for the Forest Service sample transmission line is 82 ohms.

(b) The value of attenuation at 40 mcs. for this line measured with a terminating impedance of 80 ohms is .088 decibels per foot with rubber cover and .106 decibels per foot without rubber covering.

(c) The capacity, measured at a frequency of 1000 cycles is 24.1 micro-micro farads per foot.

(d) The inductance, measured at a frequency of 1000 cycles is 1.06 micro-henries per foot.

(e) The d.c. resistance is .022 ohms per foot.

(f) The power factor, measured at a frequency of 1000 cycles is .044%.

DESCRIPTION OF MATERIAL UNDER TEST

4. The Forest Service type transmission line is very flexible and composed of two insulated conductors, twisted together and covered with a rubber compound. The conductors are twisted approximately six times per inch, the outer diameter being 1/4 inch.

5. The conductors are composed of 10 strands of No. 30 B&S gauge tinned copper wire, covered by two layers of silk insulation which in turn are covered by a cotton sleeve. The conductors are seperated by a cotton cord 3/32" in diameter and are enclosed by a rubber compound approximately 1/16" in thickness.

METHOD OF TEST

6. The capacity, inductance and power factor were measured at 1000 cycles on a precision impedance bridge.

7. The attenuation was measured at a frequency of 40 mcs. by terminating the line with the proper impedance, a radio frequency milliammeter being connected in series with the terminating impedance. The current in the line was noted, then a known length of line was cut off and the current again noted; the attenuation was then obtained by the formula,

$$\alpha = 20 \log \frac{I}{I}$$

where α is the attenuation factor in db and I is current in line.

8. Several methods of measuring characteristic impedance were employed but only one method gave consistent results. It should be noted that with some methods, correct results were obtained on parallel and concentric lines of air dielectric and known impedance; however, these same methods applied to twisted lines, having rubber and other materials for dielectric spacing, gave very inconsistent results varying as much as 200%.

9. The method decided upon was that of Hund (High Frequency Measurements, by August Hund, 1933, Chapter XV, page 387), which consists of connecting the unknown line across a tank circuit which is then tuned to resonance; a length of the line corresponding to an electrical length of 1/8 wave length is then cut off and a variable capacity connected across the shortened length of line; this capacity is varied until the circuit is again in resonance; the capacity reactance of the capacity value at resonance is then equal to the impedance of the line. The method is fairly smooth in operation; however, care must be taken to construct a tank circuit which offers symmetrical input to the line as the stray capacity must be equal on each side of the line input. The tuning for resonance after cut off is fairly broad when measuring a line of high attenuation such as were measured, but not broad enough to give serious errors in results. This is considered in "Discussion of

Probable Errors". A schematic diagram of the above method is contained in Plate 1.

10. The characteristic impedance was also measured at 1000 Kcs. and 5000 Kcs. on a radio frequency bridge. This was done by measuring the surge impedance with the line open and shorted; the characteristic impedance is then $Z_o = \sqrt{Z_{so}\, Z_{sc}}$. The use of the values for impedance obtained at 30 and 40 mcs. is discussed in "Discussion of Probable Errors".

DISCUSSION OF PROBABLE ERRORS

11. It should be noted that no existing published technique concerning the measurement of transmission line constants is satisfactory at super-frequencies.

12. The error in the measurement of the capacity, inductance and power factor at 1000 cycles is less than 0.5%.

13. The error in the measurement of the attenuation at 40 mcs. is in the order of 5%. It is considered, for lines of the measured attenuation, a mis-match of terminating impedance of 5% would be of small importance as compared to the high line losses.

14. The error in the measurement of impedance at 1000 and 5000 Kcs. as measured with a radio frequency bridge is approximately 2%; however, these values cannot be considered reliable at any other than the frequencies at which measured because of the variation of losses in the insulation with frequency.

15. The error in the measurement of the characteristic impedance at 30 and 40 mcs. using the method described is in the order of 10%. This error is due to the difficulty in cutting the line to an exact electrical length, due to the twist of the conductors and the reduced propagation. Also the tuning of the inserted capacity is fairly broad due to the high attenuation of the line. A variation of this capacity of only 2 mmf., or 7% variation of the resonance peak, will result in a corresponding error of 7% of measured impedance.

RESULTS OF TEST

16. The results of the tests show that the characteristic impedance and attenuation of the Forest Service cable is commensurate with that of cables of other like construction and size. The measurements show from the attenuation of this cable (which is .088 db. per foot) that a loss of one-half power will occur in a length of 34 feet.

17. Removing the outer rubber covering, the attenuation at 40 mcs. is .106 decibels per foot; this increase of 15% in attenuation is probably due to concentration of field about the conductors and also

the change in leakage current. A loss of one-half power will occur in a length of 28 ft. with the rubber covering removed.

18. The construction of this cable is considered inferior to that of the other lines tested in that the insulation between conductors of the Forest Service cable is of poorer quality than that of the other cables. This practically limits the use of this type cable to operation at low power when used for transmission purposes.

19. The cable is considered fairly satisfactory for receiver operation on frequencies up to 40 mcs. However, due to the high attenuation of the Forest Service cable, satisfactory results will be attained only with such short lengths that the receiver will not have to be operated at extremely high gain and thus seriously lower the signal to noise ratio.

20. The cable, when attached to the antenna, should be arranged or insulated at the oper end so as to prevent water from reaching its interior, as the insulation between conductors is such as to absorb quantities of water and this would ultimately result in noise or complete inoperation of the line.

21. With the removal of the outer rubber covering the line is not adaptable to use in the open, the insulation around the conductors after removal of outer rubber covering being extremely susceptible to moisture.

CONCLUSIONS

22. The average value of characteristic impedance obtained at 30 and 40 mcs. for the Forest Service sample transmission line is 82 ohms.

23. The value of attenuation at 40 mcs. for this line measured with a terminating impedance of 80 ohms is .088 decibels per foot with rubber cover, and .106 decibels per foot without rubber covering.

24. The capacity, measured at a frequency of 1000 cycles is 24.1 micro-micro farads per foot.

25. The inductance, measured at a frequency of 1000 cycles is 1.06 micro-henries per foot.

26. The d.c. resistance is .022 ohms per foot.

27. The power factor, measured at a frequency of 1000 cycles is .044%.

TABLE 1

DATA RECORDED DURING TEST

Characteristic Impedance (ohms)

	30 mcs.	40 mcs.	Ave.	1000 Kcs.	5000 Kcs.	Ave.
Forest Service	84	80	82	105	97	101
General Electric	76	70	73	115	104	109
Lamp cord	67	62	64	125	117	121

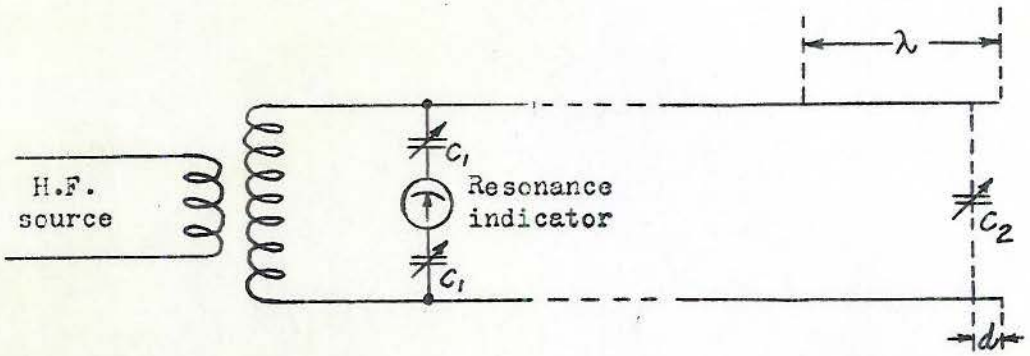
Attenuation, 40 mcs.
80 ohm terminating impedance.

	With outer covering			Without outer covering		
	Line I	Line I (Line cut 17 ft.)	Db. per ft.	Line I	Line I (Line cut 8.3 ft.)	Db. per ft.
Forest Service	.053	.063	.088	.052	.058	.106
General Electric	.096	.108	.091			
Lamp cord	.048	.064	.145			

	Capacity (1000 cycles) $\mu\mu$f. per ft.	Inductance (1000 cycles) μh. per ft.	Power Factor (1000 cycles) %	d.c. Resistance ohms per ft.
Forest Service	24.1	1.06	.044	.022
General Electric	19.6	1.05	.086	.021
Lamp cord	15.8	.350	.047	.0076

PLATE 1

METHOD USED FOR MEASUREMENT OF CHARACTERISTIC IMPEDANCE



The line is tuned for resonance by means of C_1. Next, the line is shortened by a distance d equal to $\lambda/8$. The line angle corresponding to this distance is then $Bd = \frac{2\pi d}{} = \frac{\pi}{4}$. For sinusoidal excitation and such a short distance d, there is for the reactance of the short piece d the value $j\sqrt{\frac{L}{C}} \cot \frac{\pi}{4} = jZ_o$. Hence, by inserting a condenser C_2 at a distance d from the free end and making its reactance $1/jwC_2$ equal to $xd = jZ_o$ we find that $Z_o = \frac{1}{(\omega C_2)}$. This is done as described by varying the capacity C_2 until resonance is again established.