NRL Report 6045

FLEXIBLE COAXIAL CABLE

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ABSTRACT

Flexible coaxial cables of the helical dielectric and corrugated outer-conductor construction were investigated for possible use as a broadband transmission line and as a substitute for limited rotary joints for the proposed 600-ft antenna of the former Naval Radio Research Station, Sugar Grove, West Virginia.

The 7/8-in.-diam cable would have been unsuitable in broadband transmission up to 4400 Mc due to the high VSWR (exceeding 3) which occurs over a narrow bandwidth of about 100 Mc centered near 3600 Mc. This high VSWR is attributed to the cable's helical dielectric construction. As a substitute for a limited rotary joint the 7/8-in.-diam cable would have a lifetime of about 2000 bending cycles before mechanical failure of the end connectors. Fatigue fracture of the inner conductor occurred at 10,000 bending cycles. Cable of 1-5/8-in. diameter was found to have a bending life of nearly 1000 cycles before fatigue failure of the outer conductor. Above 1800 Mc this cable also appeared unusable because of high VSWR.

The mechanical limitations and anomalous performance at microwave frequencies would prohibit the use of these sizes of cable for suitable operation in the microwave region. The anomalous effect was suspected and is believed due to the helical dielectric construction. A literature search indicates that this effect has not been analytically explained. Since coaxial cables of helical dielectric construction are used in vast quantities in military and civilian applications, it is believed that information on the limitations found in this investigation will be of value to users of this type of cable.

PROBLEM STATUS

Work on this problem has been terminated. The problem will be considered closed 30 days after the issuance of this report.

AUTHORIZATION

NRL Problem R07-12

Manuscript submitted November 15, 1963.

FLEXIBLE COAXIAL CABLE

INTRODUCTION

Broadband receiving requirements extending from 50 to 4400 Mc for the proposed 600-ft antenna of the former Naval Radio Research Station, Sugar Grove, West Virginia, necessitated an equally broadband transmission line system. As part of this system two sizes of air-dielectric coaxial cables were selected: a 1-5/8-in.-diam cable to cover the lower portion of the band and a 7/8-in.-diam size to cover the upper portion. To avoid the use of rotary joints at the antenna elevation and azimuth axes, it was decided to use flexible coaxial cables. Since cables specifically designed for this purpose did not exist, a program was initiated to determine to what extent available cables met the requirements; if requirements were not met, detailed specifications for acceptable cables were to be evolved.

Briefly, the mechanical performance goals sought were 50,000 cycles of bending operation, one cycle comprising one wrap and unwrap of at least 250 degrees around an azimuth bearing with a 7-ft diameter. This would also satisfy the elevation axis requirements. Cable life under the above conditions was expected to be 20 years. Throughout the cycling lifetime the mechanical and electrical properties of the cable were to remain substantially constant so that system performance would not be degraded.

The electrical properties to be investigated under repeated flexure of the rf cables were (a) changes in the characteristic impedance and (b) deterioration of relative shielding effectiveness, i.e., the cable's ability to shield against radio-frequency interference or to cause the same. These findings would be of value for either receiving or transmitting cables.

Mechanical deterioration was expected from (a) loss of pressure in pressurized rf cables, (b) cracks in the outer conductor or shield, (c) failure of connectors, and (d) wear or abrasion of outside jackets.

A laboratory simulation program was established to determine to what extent available cables met the specifications required for the intended application. Apparatus simulating the 7-ft-diam pintle bearing was constructed and placed in operation. Preliminary investigations on 7/8-in. and 1-5/8-in.-diam coaxial cables were performed and then the program was terminated. This report describes the simulation apparatus and results of the coaxial cable preliminary investigations.

DESCRIPTION OF EQUIPMENT

Mechanical

The 600-ft antenna azimuth bearing was simulated by constructing a 7-ft-diam aluminum wheel (Fig. 1). The wheel was mounted in a screen room. The entire assembly is sketched in Fig. 2 and is shown in Fig. 3. A 1/2-hp reversing motor (Fig. 4) operated by limit switches drove the wheel. The coaxial cable under test was placed in series with the wheel drive. Cable tension was continually observed by spring balances in the cable drive (Fig. 5).

Fig. 1 - Aluminum wheel (7-ft diam) used to simulate the azimuth bearing of the proposed 600-ft antenna

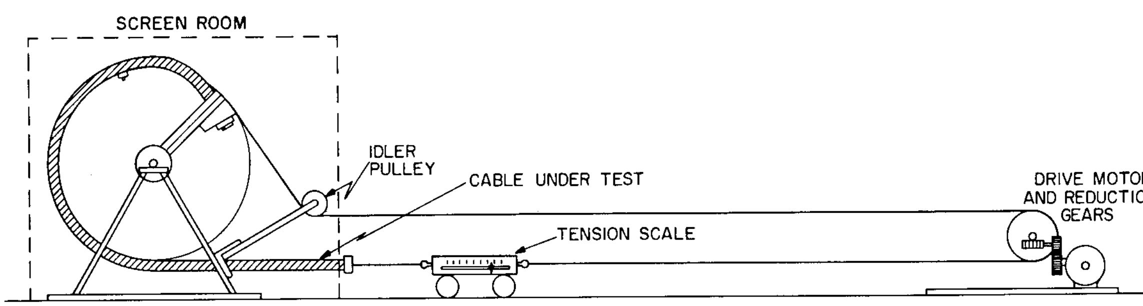

Fig. 2 - Schematic of azimuth simulator wheel and related cable-tension apparatus

Fig. 3 - Working arrangement of azimuth simulator assembly

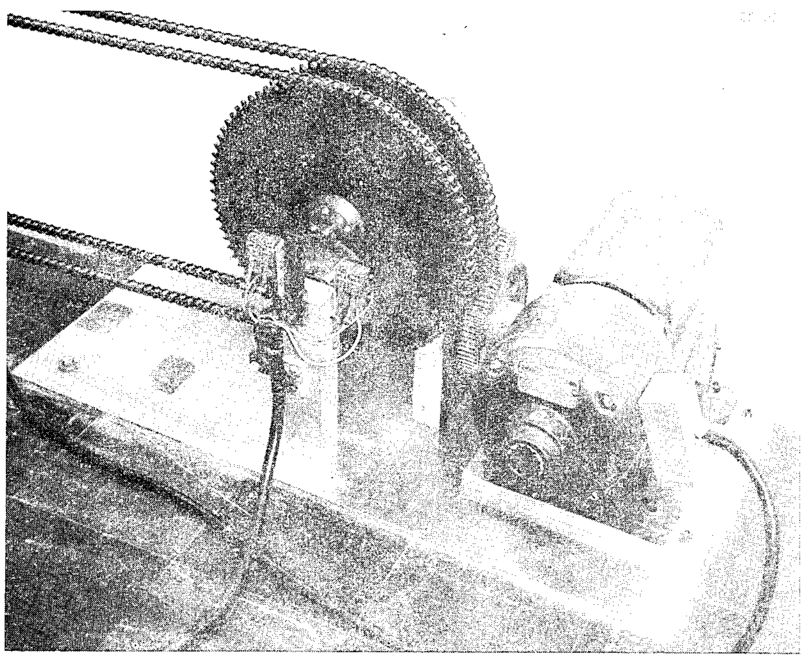

Fig. 4 - Drive motor, reduction gears, and limit switches used to rotate the azimuth simulator wheel

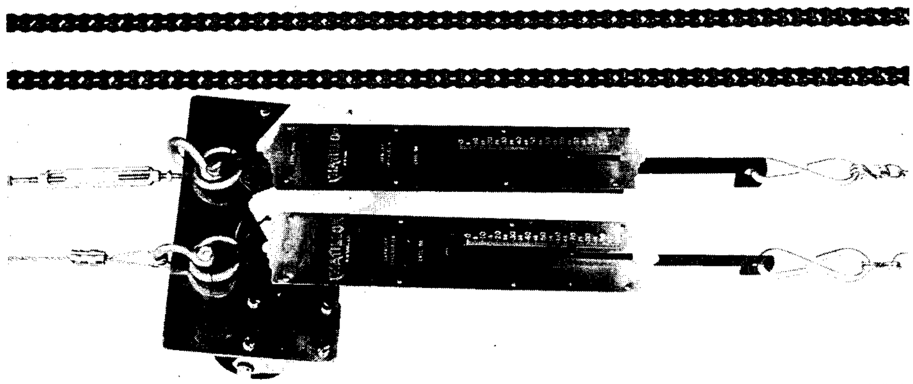

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Fig. 5 - Spring balances inserted in coaxial cable drive to measure cable tension

Electrical

It was decided that measuring the VSWR of the cable would be the best indicator of any undesirable changes in electrical properties of the cable. The method to be followed was to terminate each cable, consisting of 20-ft lengths of 7/8-in. and 1-5/8-in. flexible coaxial cables with factory-installed end fittings, in a 50-ohm load and to measure the VSWR at the opposite end of the cable. Electrical measurements were to be made at specified frequencies at mechanical bending intervals of several hundred cycles. Changes in concentricity caused by lateral displacement of the center conductor or deformation of the outer conductor, or changes in the condition of end fittings, were the anticipated causes for deterioration of VSWR.

The manufacturer's tabulated electrical characteristics for these cables are shown in Table 1. The VSWR for the 7/8-in. cable was given in graph form from 1700 to 2400 Mc. The average value appeared to be 1.03 with a peak value below 1.05. A similar plot of the 1-5/8-in. cable up to 125 Mc showed an average VSWR of about 1.05 and a peak of 1.1.

Table 1
Electrical Characteristics of Cables
Used in Bending Tests

Cable Size (in.) And Military Number	7/8 RG 269/U	1-5/8 RG 270/U
Characteristic Impedance (ohms)	50	50
Maximum Frequency (Mc)	5200	2800
Velocity (percent)	91.6	91.3
Attenuation (db/100 ft) at		
100 Mc	0.14	0.12
1000 Mc	1.6	0.98
2000 Mc	2.4	1.6

No data was available on how these characteristics would withstand repeated bending. The designed flexibility of these cables was intended to ease such installation problems of large rf systems as pulling through conduits and around obstructions, but they were not designed for the type application which is the subject of this report.

The receiver rf range that these cables were intended for was from 50 to 4400 Mc, with the 1-5/8-in. cable serving the lower portion of this range and the 7/8-in. cable the upper.

The selection of VSWR test equipment began with a comparison of an rf bridge (of foreign manufacture) covering the range 300 to 2400 Mc and a slotted line (H-P type 805A). The bridge readout consists of light spot positioned on a Smith Chart. Accuracy of this equipment is given as 3 percent in the vicinity of 50 ohms. The residual VSWR of the H-P type 805A slotted line is given as 1.04.

The bridge was terminated in a Microlab TB-5MN 50-ohm load and its VSWR measured over the range 300 to 2100 Mc. The VSWR of the same load over the same range was measured by the slotted line. The results are plotted in Fig. 6. Insertion of a precision 40-db attenuator before the Microlab load failed to improve the bridge VSWR measurement. Thus, the slotted line was selected for all measurements above 600 Mc.

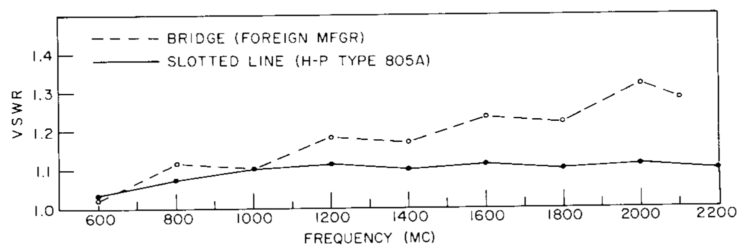


Fig. 6 - VSWR characteristics of a foreign-made bridge and an H-P type 805A slotted line

A selection of the 50-ohm terminating load was also required. Figure 7 compares the VSWR, measured with the H-P 805A slotted line over the range 1800 to 4200 Mc, of a manufactured precision load (A) with type N jack adaptor, a precision load (B) of another manufacturer, and a sliding load constructed locally at NRL.* The NRL sliding load was selected as the reference for this investigation on the basis of Fig. 7 and because its VSWR agreed very closely with independent measurements made several years ago. The sliding load technique has the additional advantage that the VSWR of the unknown is determined directly without the contribution of the sliding load itself. A more perfect match in the terminating load was not pursued further since departure from a known baseline, and not absolute values, was sought in the cable bending investigation. The large mismatch at 3300 Mc of the A termination of Fig. 7 is believed due to the additional type N adaptor required. The manufacturer's data shows a peak in the adaptor VSWR at about this frequency and a similar peak in the load itself.

Major components of the test equipment assembled to measure VSWR are sketched in Fig. 8 and shown in Fig. 9. To save time, all measurements were concentrated in the 1800 to 4200 Mc band. It was assumed that satisfactory results here would suffice for frequencies below 1800 Mc.

*W.E. Withrow, Countermeasures Branch, Radio Division

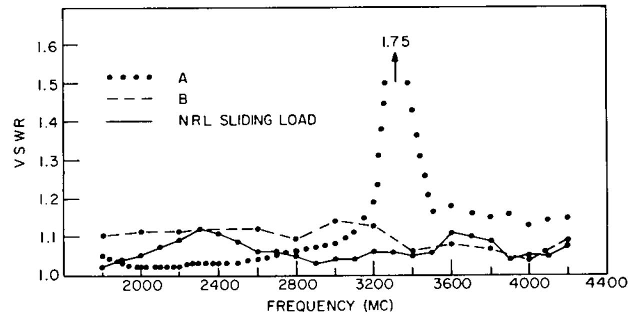


Fig. 7 - VSWR characteristics for three 50-ohm terminating loads. Loads A and B were made by different manufacturers.

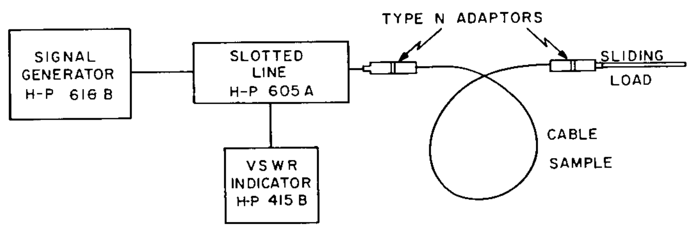


Fig. 8 - Schematic of test equipment used to measure VSWR

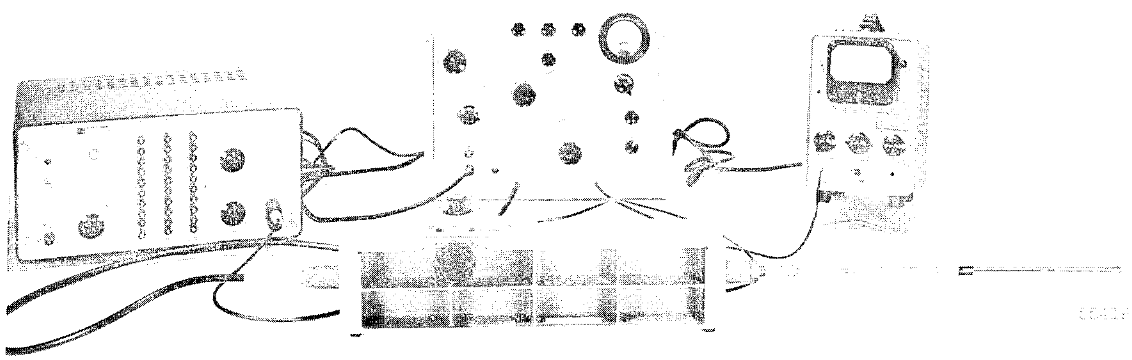
RESULTS

The following results were obtained during the preliminary mechanical adjustments of the azimuth bearing simulator and during the establishment of baseline VSWR for the coaxial cables prior to mounting and bending. The investigations were terminated at this point in the program. However, the information obtained during this preliminary phase is considered of sufficient value to justify a permanent record in the form of this report.

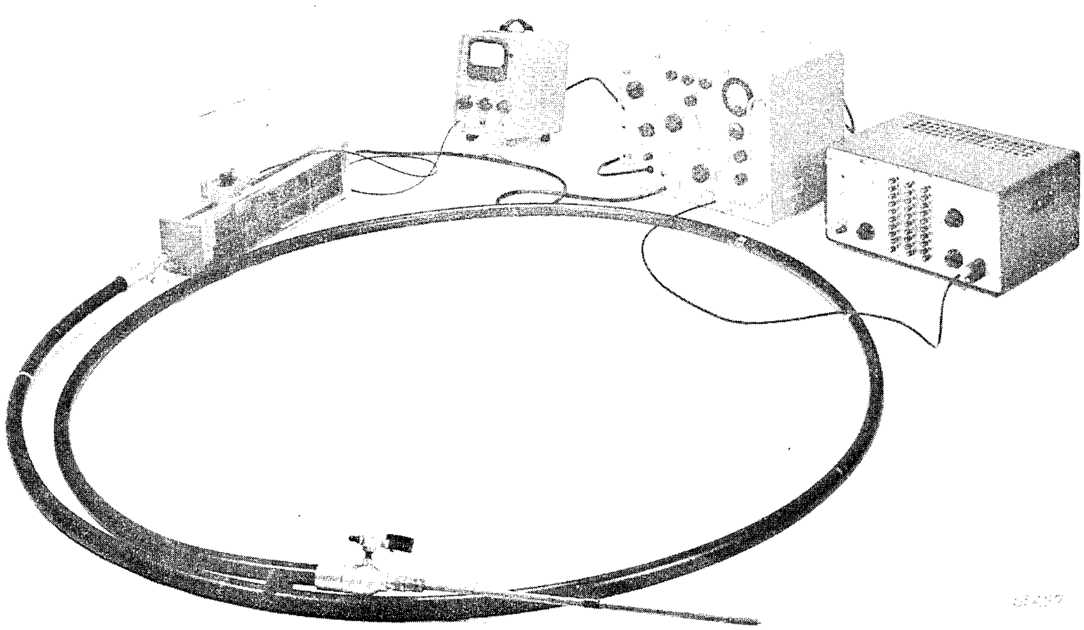
Mechanical

7/8-In. Cable – The first cable subjected to repeated flexure was a 20-ft-long, 7/8-in.-diam, air-dielectric flexible coaxial cable with a 50-ohm characteristic impedance, manufactured by a U.S. firm. Flexibility in this cable is achieved as a result of the corrugated copper outer conductor, shown in Fig. 10, which allows compressions or elongations. The inner conductor is centered by a helically wound inner spacer of polyethelene, as also shown in Fig. 10. The major mechanical characteristics of this cable are shown in Table 2.

This cable was mounted on the 7-ft-diam azimuth wheel so that a cycle of operation constituted 90 degrees of wrap and unwrap. The cycling rate was adjusted at 8 cycles per minute. This particular cable sample was not new but it was in acceptable mechanical condition.



(a)



(b)

Fig. 9 - Two views of test equipment used to measure VSWR. In the foreground of (a), from left to right, are the slotted line and the NRL sliding load; (b) shows a sample cable to be measured.

Table 2
Mechanical Characteristics of 7/8-In. Cable

Characteristic	Type or Value
Insulation	Polyethylene
Copper Outer Conductor, Major Diameter (in.)	0.358
Copper Inner Conductor, Major Diameter (in.)	1.005
Recommended Minimum Bending Radius (in.)	10
Net Weight (lb/ft)	0.421

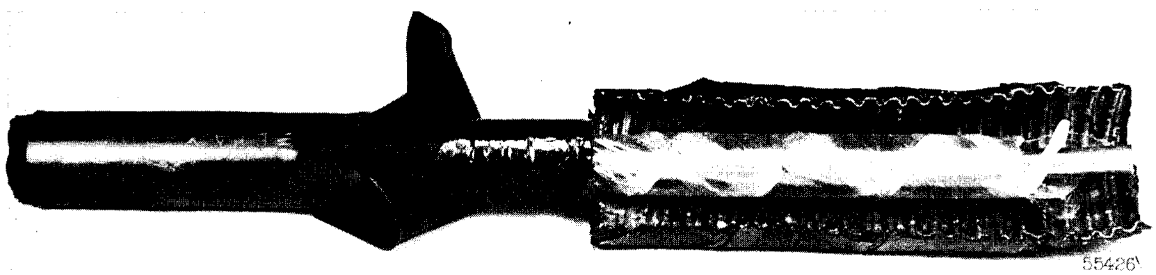


Fig. 10 - Construction of 7/8-in.-diam flexible coaxial cable showing helical dielectric and corrugated outer conductor

Table 3 summarizes the ability of this cable to withstand repeated bending. X-ray photographs of the entire cable length were taken whenever continuity checks of the inner conductor showed large changes or when visual inspection showed mechanical deterioration.

Table 3
Bending History for 7/8-In.-Diam Coaxial Cable

Number of Bending Cycles	Cable Tension (Lb)	Remarks
1930	170 to 260	Inner conductor separated from end connector at driven end (see Fig. 11(a)).
5010	300	7/8-in. linear displacement of inner conductor (see Fig. 11(b)).
6760	120 to 300	Linear displacement of inner conductor now 1-1/4 in. (see Fig. 11(c)); break in inner conductor and crushing of outer conductor at wheel clamp point (see Fig. 11(d)).
10000	150 to 300	New break in inner conductor; additional linear displacement (see Fig. 11(e)).

The separation of the inner conductor from the connector at the driven end at 1930 bending cycles (Fig. 11(a)) must have been due to the fatigue failure of the inner conductor connection to the center pin of the end connector. The two are joined by a combination of threading and soldering the inner conductor to the center pin. The 170- to 260-lb tension applied to the cable was not excessive since the tensile strength of a typical connector-cable joint is specified at 1100 lb. Further, the failure occurred after nearly 2000 cycles of operation. It appears therefore that fatigue failure of the inner conductor connection to the cable connector center pin is the first type of mechanical deterioration that is to be expected for this particular brand of flexible 7/8-in. coaxial cable.

The end connector with the separated inner conductor was removed, and the cable outer conductor was clamped to the azimuth wheel. The inner conductor was left free at the clamped end. The drive cables were connected to the coaxial end connector, as before, except the coaxial cable was now reversed, and elongations of the outer conductor due to the tension force were not transmitted to the inner conductor. No further separations of the inner conductor from the end connector occurred.

The x-ray check at 5010 cycles, Fig. 11(b), revealed a 7/8-in. linear displacement of the center conductor which indicates that the outer conductor corrugations were stretching. This certainly would have caused trouble if the inner conductor were anchored at the clamp end, probably causing inner conductor separation from end connector again. It appears that in this type of coaxial cable, which is flexed and stretched in the cyclic manner described, the inner conductor made of copper tubing carries nearly all of the tensile load since the outer conductor, by its corrugated design, can stretch appreciably before fracture. In a design where the inner conductor connection to the end connector center pin is weaker than the inner conductor itself, then early failures can be expected here, as was observed at 1930 cycles (Fig. 11(a)).

At 6760 cycles the continued stretching of the outer conductor shows up as a 1-1/4-in. linear displacement of the inner conductor (Fig. 11(c)). Further, the crushing of the outer conductor and the break of the inner conductor at the clamp point, Fig. 11(d), was due to the type of clamp and the kink put in the cable at this point. The clamp was redesigned so that stress concentration was minimized and the cable was fitted to the wheel contour. No further failures due to this cause occurred.

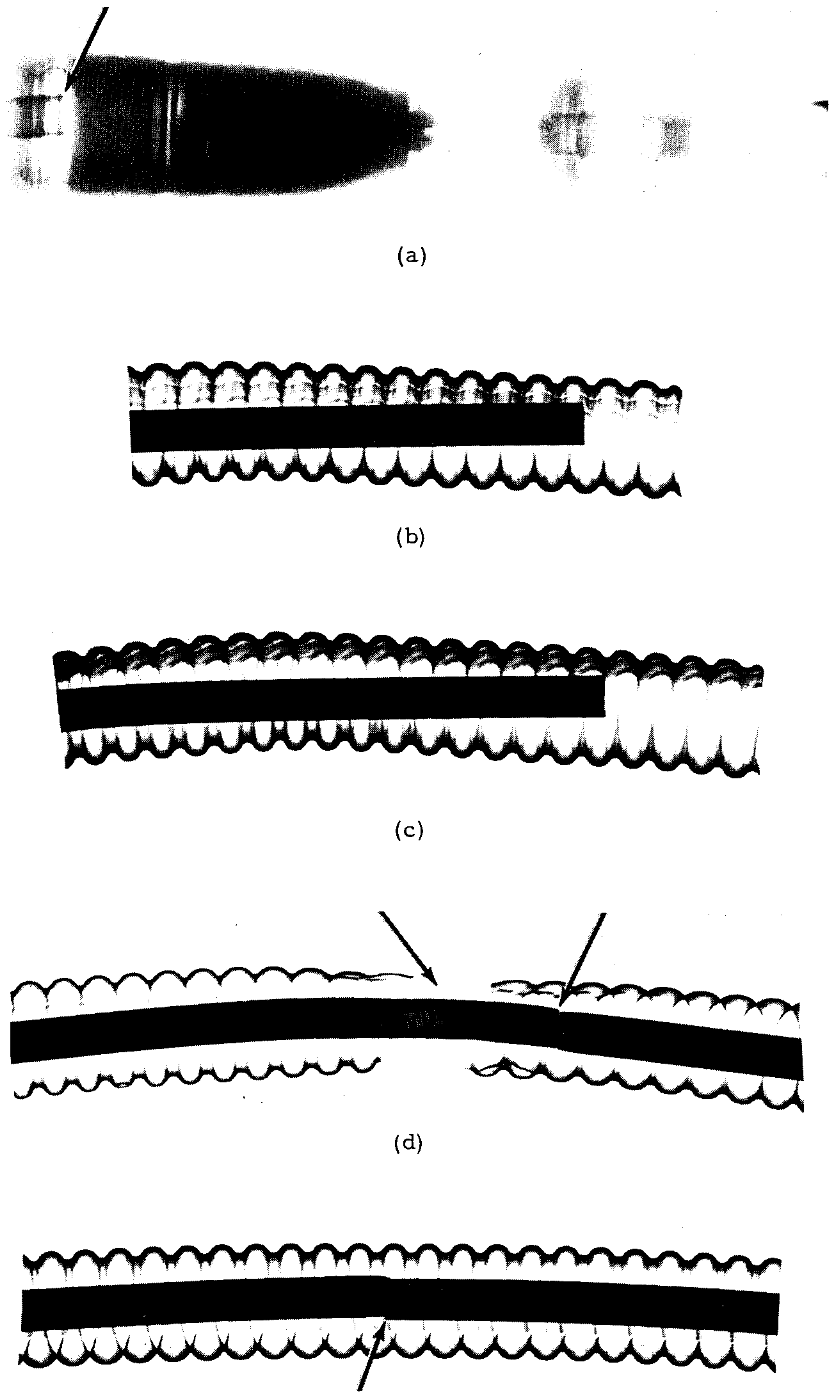
At 10,000 cycles fatigue failure of the inner conductor occurred at about midway in the cable (Fig. 11(e)). This was a material failure and was indicative of the absolute limit of this type cable for the intended application.

Concentricity changes appeared at 1930 bending cycles but were not observable on the x-rays for the remainder of the cable lifetime. The ratio of eccentricity to outer diameter, measured at 1930 cycles, was 0.075 (Fig. 12). The characteristic impedance of an eccentric line (1,2) is

$$Z_o = \frac{138}{\sqrt{\varepsilon}}\left\{\frac{D}{d}\left[1 - \left(\frac{2c}{D}\right)^2\right]\right\}^2$$

where c is the eccentricity, and D, d, and ε are the same parameters and values for the concentric coaxial cable. Using a c/D value of 0.075, as obtained from Fig. 12, the characteristic impedance of the line at 1930 bending cycles is 47 ohms. For a 50-ohm matched load the VSWR would be 1.07, which compares unfavorably with a VSWR of about 1.03 for the unflexed cable. Since it is not certain that this eccentricity was not in the cable initially, no definite conclusions can be drawn other than that variations of 3 ohms in characteristic impedance could take place during the bending lifetime of this cable.

No further observations of a mechanical nature were made because the investigation of the 7/8-in. cable was terminated at this point.



(a) (b) (c) (d) (e)

Fig. 11 - Bending history of 7/8-in.-diam coaxial cable: (a) 1930 bending cycles – separation of inner conductor from connector center pin; (b) 5010 bending cycles – linear displacement (7/8 in.) of center conductor; (c) 6760 bending cycles – increased linear displacement (1-1/4 in.) of center conductor; (d) 6760 bending cycles – break in inner conductor and crushing of outer conductor; and (e) 10,000 bending cycles – new break in inner conductor

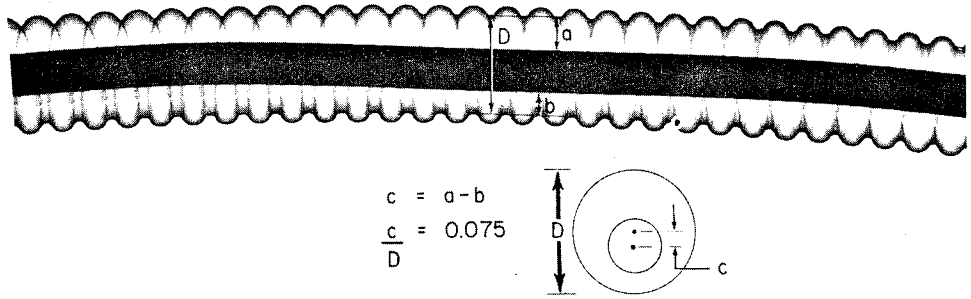


Fig. 12 - Measurement of concentricity of 7/8-in.-diam coaxial cable at 1930 bending cycles

<u>1-5/8-In. Cable</u> – Results obtained on this size cable were also derived from the preliminary "tune up" associated with the azimuth wheel simulator and its various parts, such as drive motor limit and reversing switches. A section of used 1-5/8-in.-diam flexible coaxial cable, with a 75-ohm characteristic impedance and a corrugated copper outer conductor similar in construction to the 7/8-in. cable, was employed (Fig. 13). The cable was not covered with the black polyethylene jacket.

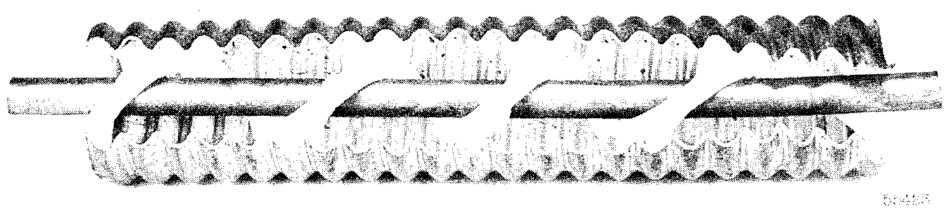


Fig. 13 - Construction of 1-5/8-in.-diam flexible coaxial cable showing helical dielectric and corrugated outer conductor

This sample of cable showed considerable mechanical handling in the past as seen by the slight kinks and small deformations at several places. However, the results are considered valid and indicate the type of failures to be expected.

The mechanical characteristics, listed by the U.S. manufacturer, are shown in Table 4.

Table 4
Mechanical Characteristics of 1-5/8-In. Cable

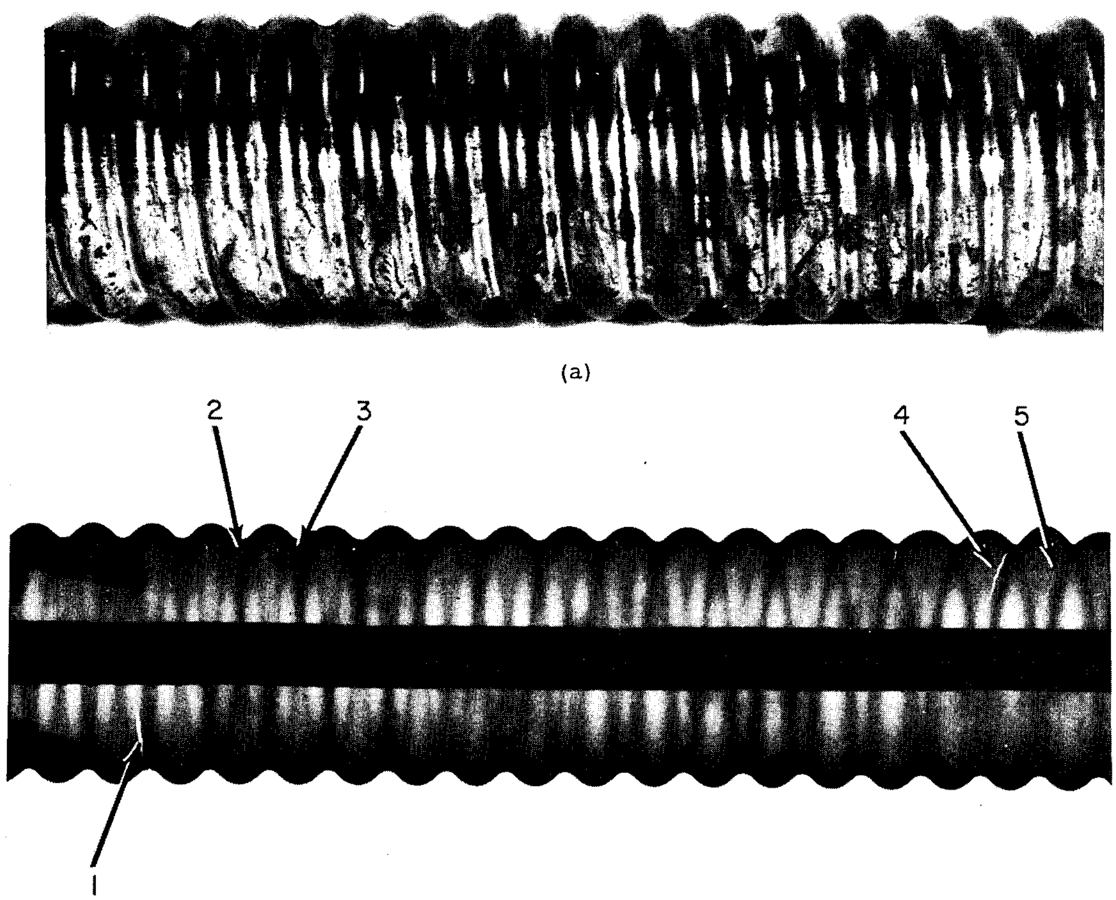
Characteristic	Type or Value
Insulation	Polyethylene
Copper Outer Conductor, Major Diameter (in.)	1.830
Copper Inner Conductor, Major Diameter (in.)	0.430
Recommended Minimum Bending Radius (in.)	20
Net Weight (lb/ft)	0.718

The cable without end connectors was mounted on the 7-ft-diam azimuth wheel so that there was 170 degrees of wrap and unwrap. The cycling rate was set at 4 cycles per minute.

Cable tension as low as 30 lb was usable, but to prevent sag and bending over the screen room sill and rubbing over the floor, tensions of 55 to 80 lb were used.

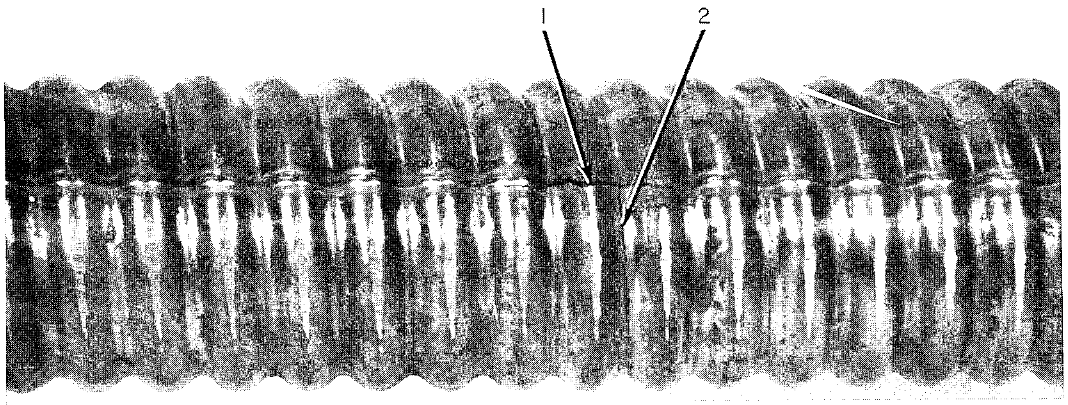
Since this cable was not covered with the black polyethylene jacket, the procedure was to visually inspect the outer copper conductor for cracks or breaks, to watch for sudden drops in tension as an indication of parting of the outer conductor, and to take x-rays for inner and outer conductor condition.

Under the above conditions and procedure, nothing occurred until 1110 wrap and unwrap cycles. At this point a crack occurred in the outer conductor, in the corrugation "valley," at about 89 in. from the driven end. Figure 14(a) is a photograph of this break; Fig. 14(b), an x-ray photograph, shows not one but four additional cracks. At a point about 6 in. from the first crack, and different from the cracks of Fig. 14, a crack across and along the weld was noted. This is seen in the photograph of Fig. 15(a). The x-ray photograph, Fig. 15(b), again shows other cracks along and across the weld not visible to the naked eye. These evidences of fatigue failure all occurred within about a one-ft length of cable.

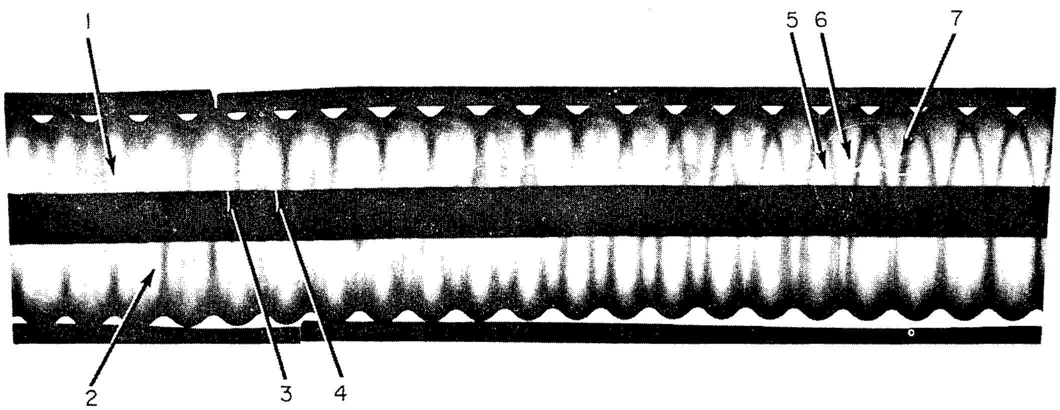


(b)

Fig. 14 - Cracks developed across outer conductor of the 1-5/8-in.-diam cable after 1110 bending cycles: (a) large crack visible to naked eye; (b) x-ray showing five cracks in same area as (a)



(a)



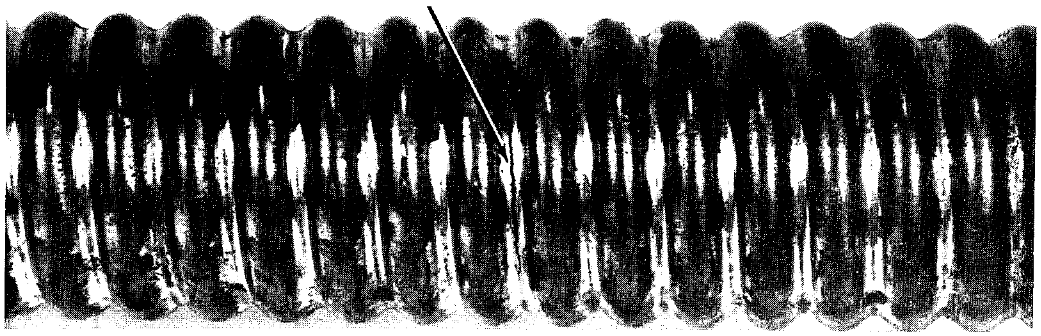
(b)

Fig. 15 - Cracks developed along and across outer conductor weld of the 1-5/8-in.-diam cable after 1110 bending cycles: (a) two cracks visible to naked eye; (b) x-ray showing seven cracks

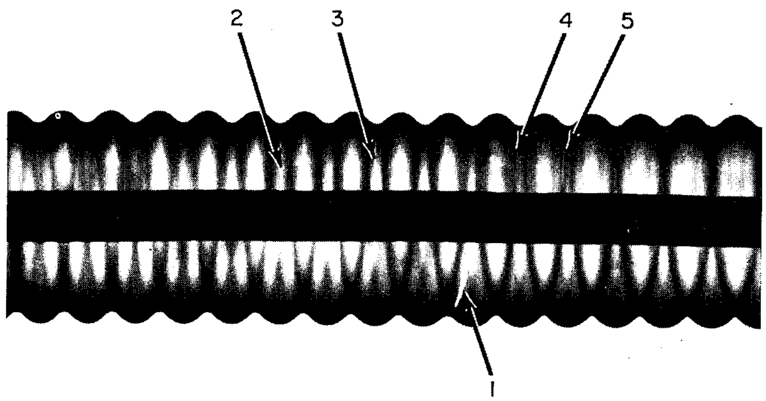
No changes in concentricity were revealed by the x-rays up to this point in bending cycle. The fractured section of cable was cut off, the remainder was mounted on the wheel, and the investigations were then resumed. The shortened length permitted only 90 degrees wrap and unwrap. The cycling rate of 4 cycles per minute was maintained, and tension varied between 55 and 60 lb.

The investigation proceeded without further deterioration until 447 bending cycles, in addition to the previous 1110 cycles, was reached. At this point a substantial crack appeared at 43 in. from the driven end and in the valley of the outer conductor corrugation. Figure 16(a) is a photograph of this fatigue failure; an x-ray photograph, Fig. 16(b), showed this crack as well as four faint ones in valley corrugations within 1-1/2 inches from the visually observed one. X-rays failed to show any other failures elsewhere along the cable. Concentricity seemed unchanged.

From the foregoing, the 1-5/8-in.-diam coaxial cable would have a relatively short life – on the order of 1000 cycles of repeated wrap and unwrap. This is due primarily to the fatigue failure of the outer conductor.



(a)



(b)

Fig. 16 - Cracks developed across outer conductor of the 1-5/8-in.-diam cable after 1560 bending cycles: (a) large crack visible to naked eye; (b) x-ray showing five cracks

The strength of the inner conductor connection to the end connector center pin would have to be checked to determine that it would not contribute to a shorter lifetime. Concentricity for this cable appeared unchanged over at least 1500 bending cycles.

Electrical

General – As in the case with the mechanical investigations, the electrical results were obtained during the preliminary or "tune-up" phase of the program. All of the following data were obtained during attempts to establish a good VSWR baseline before the new cable section was mounted on the azimuth simulator wheel.

For both the 7/8-in.- and 1-5/8-in.-diam cable the first VSWR baselines were very ragged with unacceptably high values. This was traced to the high VSWR of the adaptors used to connect the cable to the test equipment.* Another cause of high VSWR was due to

*Electronics Industries Association (EIA) adaptors on the cable, and type N adaptors on the equipment.

mismatch at a frequency whose wavelength is related to the pitch of the helically wound polyethylene inner insulator. Considerable effort was spent on the adaptor problem and in establishing the rejection bandwidth due to the helical inner insulator. Both of these problems were not fully solved because the investigation was terminated during this phase.

Adaptors – The cable samples came equipped with EIA end connectors installed at the factory. To convert the 7/8-in.-diam cable end connector from EIA to type N required a transition from 7/8 in. to 1-5/8 in., then another 1-5/8-in. single-step adaptor to type N. This was required at each end of the cable. Including the factory installed end connector, a total of three pieces was needed at each cable end, as shown in Fig. 17. The sum total of all of these fittings raised havoc with the VSWR. Figure 18 shows the VSWR of the 1-5/8-in. EIA step adaptor to type N when mounted back to back and alone, as shown in Fig. 19(a). Figure 18 also shows the VSWR of the two precision step adaptors used to convert a 7/8-in. EIA to a type N connector. This also required three pieces. The precision adaptors used to convert to type N are shown in Fig. 19(b). Although these showed some improvement, the cable manufacturer at this point furnished new design end connectors and adaptors which now required only two items to go from cable to type N. These are shown installed in the 7/8-in.- and 1-5/8-in.-diam cables, Fig. 20.

Similar adaptor discontinuities were encountered in going from 1-5/8-in. cable to type N connector by the use of tapered adaptors. Figure 21 shows the VSWR results of two precision tapers mounted back to back, as shown in Fig. 22. The poor VSWR for the tapers is believed due to the additional adaptor involved in going from taper output to type N.

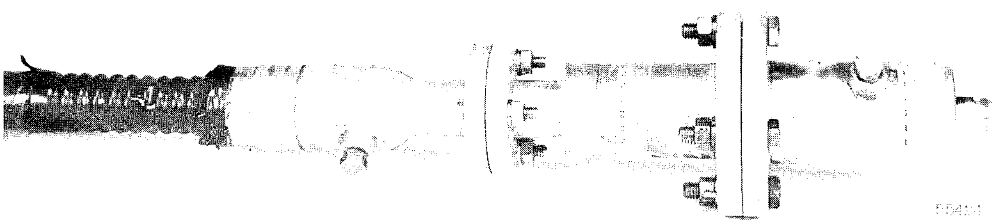


Fig. 17 - Adaptors used to convert the EIA 7/8-in.-diam-cable end connector to type N connector. Center section is transition from 7/8 in. to 1-5/8 in.; right section is 1-5/8-in. single-step adaptor for conversion to type N connector.

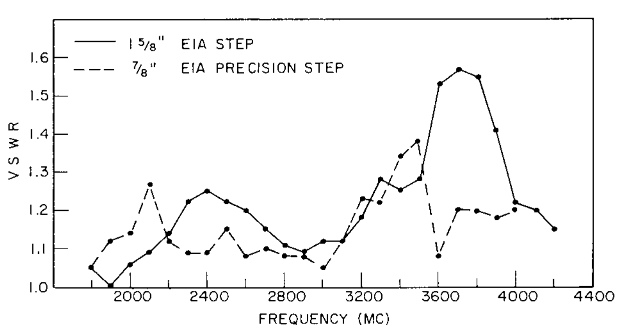
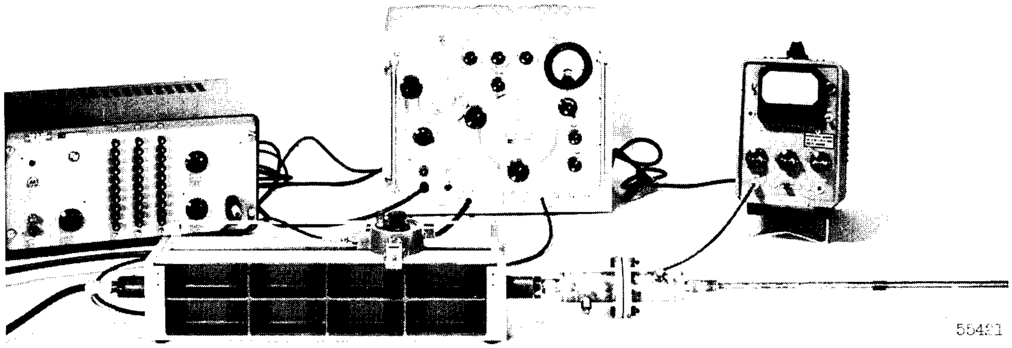
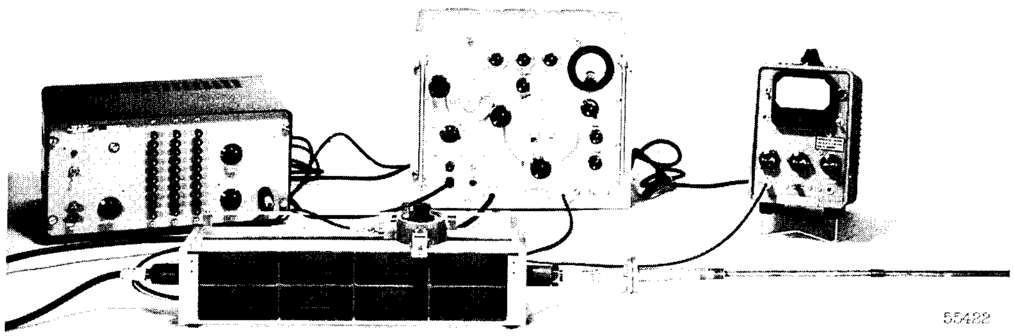


Fig. 18 - VSWR characteristics of the 7/8-in. and the 1-5/8-in. step adaptors used to convert cable end connectors to type N connectors



(a)



(b)

Fig. 19 - Method of measuring VSWR of (a) 1-5/8-in. EIA step adaptor and (b) 7/8-in. EIA precision step adaptor used to convert cable end connectors to type N connector

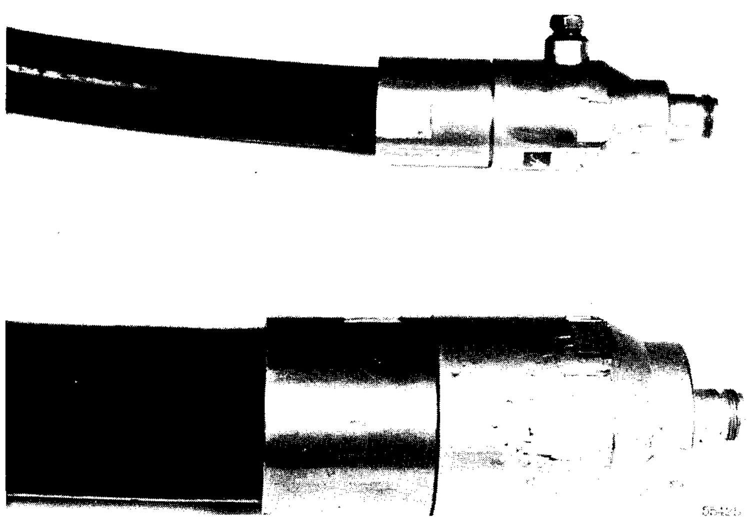


Fig. 20 - New design type N connectors for 7/8-in.-diam cable (top) and 1-5/8-in.diam cable (bottom)

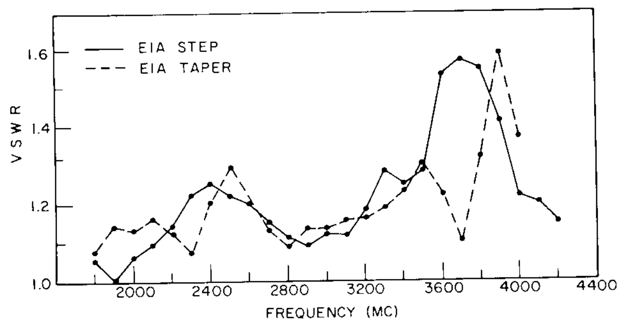


Fig. 21 - VSWR characteristics for the EIA step and the EIA taper adaptors used to convert the 1-5/8-in.-diam cable end connector to type N connector

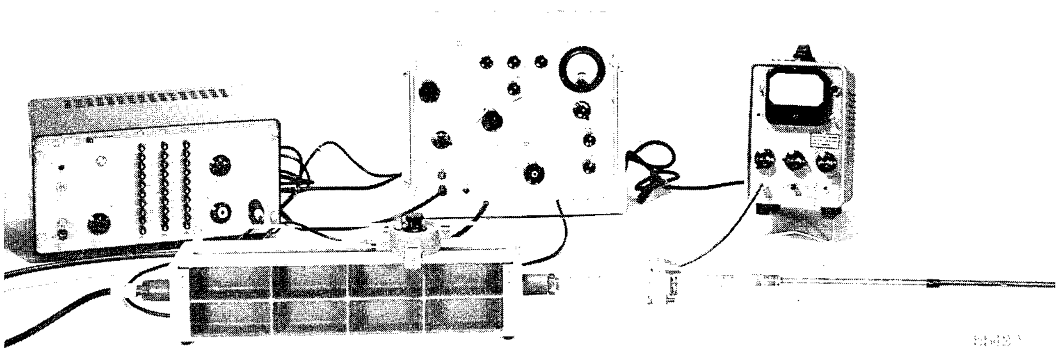


Fig. 22 - Method of measuring VSWR of two EIA taper adaptors, mounted back to back, used to convert 1-5/8-in.-diam cable end connector to type N connector

The foregoing results strongly suggested that to measure VSWR of the line itself test equipment employing connectors to directly fit on the cable end, without any adaptors, would be necessary.

VSWR Baseline, 7/8-In.-Diam Cable – With the cable manufacturer's newly designed end connectors and adaptors, attempts were next made to measure the initial or baseline VSWR with the NRL sliding load described earlier. Figure 23 shows the VSWR measured on two different days. Considering the repeatability shown and the relatively better VSWR obtained so far, it was decided to accept these as the baseline values.

The large mismatch measured at 3600 Mc was expected and is believed associated with the helical dielectric construction. The manufacturer advised that this size cable should not be used over the frequency band 3350 to 3950 Mc and stated that, for practical purposes, the "reject frequency" can be approximated by equating the pitch of the helix to the electrical half wavelength. For the 7/8-in. cable the pitch was 1.5 in. and the propagation velocity was 91.3 percent, thus giving a reject frequency of 3600 Mc. This agreed with the observed results. Such close agreement should not always be expected because there are manufacturing tolerances on the helix. In general, according to the manufacturer, the results should agree within 10 percent.

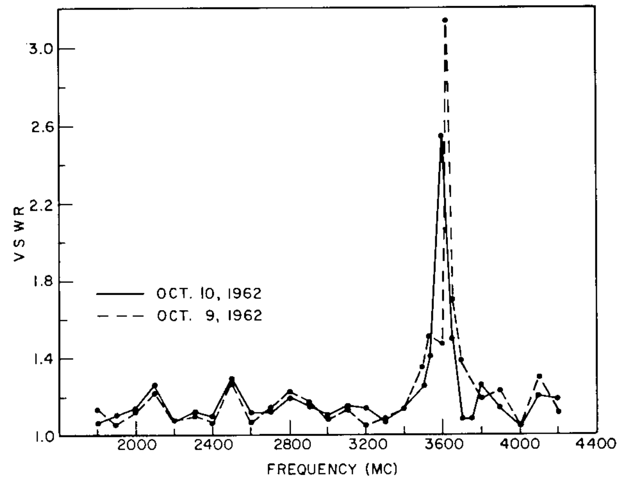


Fig. 23 - VSWR baseline characteristics obtained on two successive days for the 7/8-in.-diam cable with newly designed end connectors and adaptors

The "reject frequency" or "half-wave periodicity," terminology used by the cable industry to describe this effect, has been observed at NRL on similar helical cables manufactured by another firm. These cables had smooth outer conductors, thus eliminating outer conductor corrugations as the sole cause for the high reflections. In general, the smaller the cable the more prone it is to exhibiting this undesirable effect below its dominant mode cutoff frequency.

A search was made of the literature to determine whether the reject-frequency effect has been analyzed in detail. H. Kaden (3) and J.W.E. Griemsmann (4) have analyzed the performance of this type of cable and show, for the dominant mode, increasingly high conductor and dielectric losses, as well as increasing characteristic impedance and phase near the cutoff frequency. Neither author mentions the reject-frequency or half-wave periodicity anomaly.

An NRL investigation (5) involved extensive cable tests, but only up to 100 Mc. A check of other government laboratories indicates a similar situation of having knowledge of this performance but without a detailed explanation. For the present all that can be said is that this anomaly is due to the helically wound polyethylene insulator. Considering the broadband requirements for the Naval Radio Research Station, this type cable would have been unsuitable.

It is a curious fact that although this anomalous performance is known it is not indicated in the various manufacturer's catalogs.

VSWR Baseline, 1-5/8-In.-Diam Cable – An acceptable VSWR baseline for the 1-5/8-in.-diam cable, even with new connectors shown in Fig. 20, was not obtained up to the time the work was terminated, as is well shown in Fig. 24. The maximum frequency for this cable is given as 2800 Mc. The waveguide cutoff for a 91 percent velocity of propagation is 3000 Mc. However, from Fig. 24 it appears that use of this cable would be impracticable from 1800 Mc on up.

The helical pitch for this cable is 1.75 in., and for a 91 percent propagation velocity the reject frequency or half-wave periodicity turns out to be 3100 Mc above the dominant mode cutoff frequency.

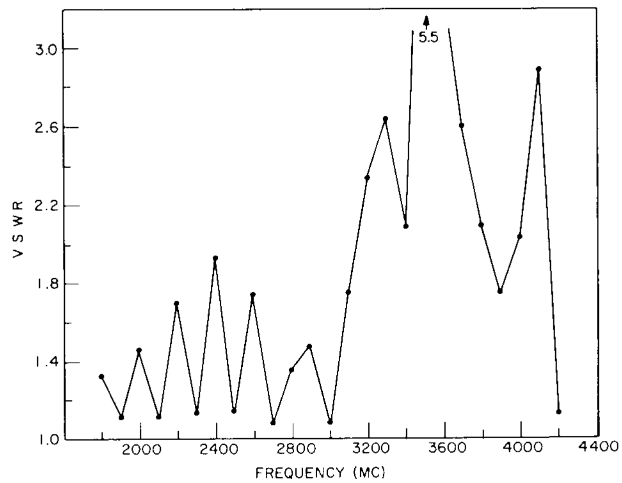


Fig. 24 - VSWR baseline characteristic for the 1-5/8-in.-diam cable

CONCLUSIONS

The 7/8-in.-diam helical dielectric flexible coaxial cable would have been unsuitable as a broadband transmission line for the proposed 600-ft antenna of the former Naval Radio Research Station, Sugar Grove, W.Va., because of the high VSWR (exceeding 3.0) over a narrow bandwidth of about 100 Mc centered near 3600 Mc. This is attributed to the cable's helical dielectric construction. As a substitute for a limited rotary joint, the cable would have been unsatisfactory because of connector failure after about 2000 bending cycles. Fatigue fracture of the inner conductor occurred at 10,000 bending cycles.

The 1-5/8-in.-diam helical dielectric flexible coaxial cable would not have been suitable as a substitute for a limited rotary joint because of fracture of the outer conductor after about 1000 bending cycles. Above 1800 Mc indications were obtained that the cable would be electrically unsuitable because of high VSWR's due, in part, to the connectors and adaptors.

ACKNOWLEDGMENTS

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REFERENCES

1. "Reference Data for Radio Engineers," 4th ed., ITT Corp., New York, 1956

2. "Microwave Transmission Circuits," Vol. 9, M.I.T. Radiation Laboratory Series, New York:McGraw-Hill, 1948

3. Kaden, H., "The Performance of Helical Membrane Coaxial Cable in the Frequency Range above 1000 Mcs," Royal Aircraft Establishment, Farnborough, England, Library Translation No. 528, Sept. 1955

4. Griemsmann, J.W.E., "An Approximate Analysis of Coaxial Line with a Helical Dielectric Support," IRE Trans., MTT-4, 13-23 Jan. 1956

5. Dinnick, G.M., Burton, J.K., and Ambrose, J.R., "Styroflex Coaxial Cable," NRL Report 4160, Oct. 1953