Subminiature Coaxial Cable R.F. Power Ratings and Connector Characteristics

by

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AMPHENOL

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ABSTRACT

Experimental power rating values for subminiature Polyfluoron, polyethylene and Teflon dielectric coaxial cables are presented for the frequency range of 1 to 10,000 megacycles. These are maximum ratings and depend upon the safe operating temperature of the particular cable dielectric material. Six subminiature coaxial cables (1 Polyfluoron, 2 polyethylene and 3 Teflon) were investigated with the cable diameters ranging from .080 inches to .155 inches and representing characteristic impedances of 50,75, and 95 ohms. Techniques and special equipment necessary to adapt the experimental apparatus for making measurements on the subminiature coaxial cables are discussed.

In addition, these basic maximum ratings are theoretically extended to an ambient temperature range of -85°F (-65°C) to 400°F (205°C) to altitudes from sea level to 70,000 feet and the effect of VSWR on the ratings are presented.

The electrical and design characteristics of the associated Subminax R.F. connectors used with the various coaxial cables are discussed with a presentation of data on the standard Subminax connectors which were used in this investigation.

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SUBMINIATURE COAXIAL CABLE R.F. POWER RATINGS AND CONNECTOR CHARACTERISTICS

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INTRODUCTION

With the demand for miniaturization in electronic components and equipment during the last ten years, a concomitant miniaturization of R.F. coaxial cables and connectors was necessary. At the present time, subminiature cables are available in characteristic impedance values of 50, 75 and 95 ohms utilizing dielectrics of Polyfluoron, polyethylene and Teflon. As a consequence of this miniaturization program, the power ratings of the various subminiature cables will be greatly reduced in relation to the standard size RG/U cables having the same dielectric material. Designers and manufacturers of electronic equipment will need to know the power handling characteristics of these subminiature cables when incorporating subminiature coaxial cables into their circuits.

Power rating is defined as the maximum amount of input power resulting in a maximum center conductor temperature which a cable can safely transmit under matched conditions without causing dielectric deterioration, breakdown or excessive softening.

SECTION I

SUBMINIATURE R.F. CABLES

In previous works, (Reference 1) there can be found a detailed discussion and description of the experimental procedures involved in determining the power ratings of R.F. coaxial cables. As a result, only a brief description of the general test set-up will be given. A continuous wave magnetron oscillator operating at a frequency of 925 megacycles was used as the power source in conjunction with a 51.5 ohm water-cooled resistive load. The cable to be tested and the associated thermocouple temperature measuring devices were connected between the power source and load as shown in Figure 1. This set-up is very similar to that used for testing the larger size R.F. cables except that the magnitude of input power used for the subminiature cables is naturally much less.

Remembering that power rating is defined as the maximum amount of power a cable can transmit at a safe center conductor temperature under matched conditions, it is a necessary preclusion that a minimum number of discontinuities be present in the system. In order to provide the necessary inter-connection from the 3-1/8 inch air coaxial taper at the output of the power source to the subminiature cable, it was necessary to use an adapter which would present a minimum amount of discontinuity to the system at the test frequency. The cable under test was coupled to the Series "N" R.F. connector appearing at the end of the 3-1/8 inch coaxial taper by using a UG-201A/U, "N" to "BNC", 50 ohm adapter along with an Amphenol 27-28, "BNC" to Subminax, 50 ohm adapter. Similarly, this type of adapter was used to make the transition between the subminiature cable and the Series "N" connector appearing at the load.

To provide a suitable connection between the power source and load, when power rating a 75 ohm subminiature cable, a 75 ohm adapter was fabricated which is similar to the type used for the 50 ohm subminiature cables.

The next prerequisite was to obtain a matched condition for the entire system. Such a condition was obtained by properly adjusting the triple stub tuner located on the power source. A directional coupler used in conjunction with the tuner, provided a visual indication of incident and reflected power and by proper adjustment of the tuner, it was possible to obtain a reflected power meter reading of zero which would indicate a suitably matched system. It was established that the VSWR of the adapters used contributed no more than 7.5 watts of reflected power out of the total maximum input of 250 watts. This small reflection loss is considerably less than the error introduced by the inherent inaccuracy of the power indicator meter readings. It was under these conditions that the present cable measurements were performed.

Another consideration pertinent to subminiature cable power measurements is the temperature measuring technique which had to be used. When measuring center conductor temperatures of the standard size RG/U coaxial cables in previous power rating investigations (Reference 2), a quarter-wave stub was inserted into the cable near the input end. A small hole, which was drilled into the center conductor of the quarter-wave stub, allowed the thermocouple wires to be inserted down through the stub to the cable center conductor. However, the possibility of applying this method to a subminiature cable in order to get a temperature measurement is quite remote since the small size of the center conductor restricts this type of operation. Mathematically it can be shown that for subminiature cables with the very thin dielectric walls, the temperature at the dielectric surface is only a few degrees cooler than the center conductor, the estimated error being approximately one percent between the two temperatures. In actual practice, the thermal junction is inserted into the cable braid so as to get a temperature measurement at the immediate dielectric surface. No. 30, A.W.G. copper and constantan thermocouple wires were used in conjunction with a Leeds & Northrop potentiometer to make all temperature measurements. Having considered the problems and the corrective measures which were taken to minimize the discontinuities which are a part of any system comprised of R.F. connectors, cables, and adapters, the results of the initial power ratings of the various subminiature cables will be presented. A tabulation of the coaxial cable types which were power rated in the present investigation are presented in Table I along with their dimensions.

TABLE I

Cable	Dielectric	Inner Cond. Dia.	Core Dia.	Outer Cond. Dia.	Cable Dia.	Z_o
Amphenol 21-596	Polyfluoron	.019	.060	.085	.100	50
RG-174/U	Polyethylene	.019	.060	.085	.100	50
Amphenol 21-597	Polyethylene	.017	.100	.125	.150	75
RG-187/U	Teflon	.012	.063	.080	.110	75
RG-188/U	Teflon	.020	.060	.080	.110	50
RG-195/U	Teflon	.012	.102	.124	.155	95

In order to determine the power ratings for each cable at frequencies other than 925 megacycles, the relationship (Reference 2) was utilized as given below:

$$P_x = P_1 \frac{\alpha_x}{\alpha_1}$$

Where:

P_1 = Power at test frequency

P_x = Power at new frequency

α_1 = Total attenuation at test frequency

α_x = Total attenuation at new frequency

In words, this means that the power input of a cable at any frequency is inversely proportional to the total attenuation at that frequency. In conjunction with this power rating investigation, the attenuation characteristics of the subminiature cables from 1 to 10,000 megacycles was measured and is presented in the Appendix as additional data.

Since no definite maximum center conductor temperature has been established for a Polyfluoron dielectric coaxial cable, it was decided to choose 250°F (121°C) which is below the softening point of the dielectric. Based on a center conductor temperature of 250°F (121°C), Figure 2 shows a recommended power rating of 60 watts at 925 megacycles for Amphenol 21-596 Polyfluoron cable.

In order to provide a sufficient safety factor under operating conditions, the power ratings for the subminiature polyethylene cables are based on a maximum center conductor temperature of 175°F (80°C). RG-174/U, a 50 ohm cable, can handle 38 watts at the test frequency of 925 megacycles, 110 watts at 100 megacycles and 5.5 watts at 10,000 megacycles. Amphenol 21-597, a 75 ohm polyethylene cable, can handle 55 watts at 925 megacycles, 205 watts at 100 megacycles and 7.5 watts at 10,000 megacycles. A graphical presentation of the power ratings of the subminiature polyethylene cables is presented in Figure 3.

In the case of the subminiature Teflon cables, the power ratings are based on a maximum center conductor temperature of 400°F (205°C). At 925 megacycles, the 50 ohm RG-188/U cable can handle 160 watts while at 100 megacycles it can handle 400 watts and at 10,000 megacycles, 32 watts. RG-187/U, a 75 ohm cable, can handle 215 watts at the test frequency, 500 watts at 100 megacycles and 38 watts at 10,000 megacycles. The largest subminiature Teflon cable, RG-195/U, which is a 95 ohm cable, is capable of handling 265 watts at 925 megacycles, 800 watts at 100 megacycles and 50 watts at 10,000 megacycles. These three subminiature Teflon cables are compared graphically in Figure 4.

It was found that the calculated power ratings were approximately 20 percent lower than the measured values for the polyethylene cables and approximately 15 percent lower than the measured value for the RG-187/U Teflon cable, which was the only Teflon subminiature cable measured. Power ratings which are presented in Figure 4 for the RG-188/U and RG-195/U cables are calculated values as determined by applying to coaxial cables the principle of similarity for heat convection from a cylinder suspended in still air. By combining the results of the heat transfer analysis with the attenuation characteristics of the cables as given in the Appendix, it is then possible to obtain the power ratings at the desired frequency. These values, however, have been uprated by a factor of 15 percent based on the comparison of the experimental data to the calculated values of RG-187/U. At a future date, these calculated values are to be verified by measured data.

When a comparison is made of the power ratings of subminiature polyethylene and Teflon cables as in Table II, the 50 ohm RG-188/U Teflon cable shows a fourfold power capacity over the 50 ohm RG-174/U throughout the frequency range considered.

TABLE II

Cable	Dielectric	Weight Lb/Ft	Inner Cond.Dia.	Core Dia.	Z_o	Power Rating Watts 100 Mcs.	925 Mcs.	5000 Mcs.	10000 Mcs.
RG-174/U	Polyethylene	.0088	.019	.060	50	110	38	10	5.5
RG-188/U	Teflon	.0125	.020	.060	50	400	160	60	32

At frequencies above 2000 megacycles, however, this ratio becomes larger as seen in the graphical presentation of Figure 5.

Another comparison is given in Table III for RG-188/U and standard polyethylene RG-58A/U, both 50 ohm cables. Although RG-188/U is approximately two times smaller than RG-58A/U, it can handle approximately twice as much power. This is also presented graphically in Figure 6.

TABLE III

Cable	Dielectric	Weight Lb/Ft	Inner Cond.Dia.	Core Dia.	Z_o	Power Rating Watts 100 Mcs.	925 Mcs.	5000 Mcs.	10000 Mcs.
RG-58A/U	Polyethylene	.03	.035	.116	50	250	68	22	12
RG-188/U	Teflon	.0125	.020	.060	50	400	160	60	32

Although the power rating values presented in Figures 2, 3, and 4 will provide engineers and designers with suitable data at the test conditions, their usefulness can be extended to include other conditions of ambient temperature, altitude, and VSWR. To do this, it is only necessary to refer to the appropriate power rating factor curves (Reference 3) to determine the new ratings. In the case of varying ambient temperatures, the new power ratings can be determined by referring to Figures 7 and 8, which present curves of power rating factors versus ambient temperature for polyethylene and Teflon cables respectively.

Ambient temperatures above 104°F (40°C) yield power ratings less than those which are presented in Figures 3 and 4, while higher ratings result when ambient temperatures below 104°F (40°C) are encountered. To date, rating factors for Polyfluoron coaxial cables at other environmental conditions have not been determined.

If power ratings are desired at altitudes above sea level, it is only necessary to refer to Figure 9 to obtain the proper rating factor for the particular altitude in question and multiplying the rating at sea level by this new factor. An increase in altitude will always cause a decrease in the maximum power handling capacity of a cable since the heat dissipation is less at higher altitudes. This curve, it should be noted, is independent of frequency and ambient temperature.

When a VSWR greater than unity is present in a system, the maximum power rating of a coaxial cable is decreased since higher values of VSWR are the result of a mismatched condition in the system. A mismatched condition results in a lower amount of transferred power which is accompanied by higher than normal temperatures in the cable. As a result, it has been standard (Reference 4) to assume that the power ratings at higher values of VSWR can be found by taking a factor of $\frac{1}{VSWR}$ and multiplying the ratings at unity by this factor.

SECTION II

SUBMINAX R.F. CONNECTORS

By virtue of the coaxial cable miniaturization program a necessity arose for the introduction of suitable R.F. connectors which would be used on the subminiature cables. To serve as efficient connecting links between cable and equipment, these Subminax connectors must be of small size, easily assembled, mechanically durable and possess a minimum amount of electrical discontinuity. A measure of the basic excellence of a connector (in a mated condition) can be expressed in terms of the VSWR of the system. The VSWR of various Subminax connectors designed for use with the subminiature cables in the frequency range of .35 to 2.0 kilomegacycles are presented for the following connector arrangements.

1. A 27-1 Push-On Plug mated with a 27-2 Push-On Jack
2. A 27-1 Push-On Plug mated with a 27-4 Push-On Bulkhead Jack
3. A 27-1 Push-On Plug mated with a 27-5 Push-On Feed-Through mated with a 27-1 Push-On Plug
4. A 27-6 Push-On Right Angle Plug mated with a 27-2 Push-On Jack
5. A 27-7 Screw-On Plug mated with a 27-8 Screw-On Jack
6. A 27-7 Screw-On Plug mated with a 27-10 Screw-On Bulkhead Jack
7. A 27-7 Screw-On Plug mated with a 27-11 Screw-On Feed-Through mated with a 27-7 Screw-On Plug
8. A 27-26 Screw-On Right Angle Plug mated with a 27-8 Screw-On Jack

The VSWR measurements which were made on the above Subminax connector arrangements utilized the 50 ohm load termination method. A description of this technique has been discussed in Reference 5 and will not be taken up in detail at the present time. Briefly, the basic components necessary to utilize this technique include an R.F. signal generator, standing wave indicator and a slotted line with a suitable load.

In addition, adapters of the compensated step type configuration (Reference 6) were devised to effect a smooth transition from the standard coaxial connector of the slotted line to the Subminax connectors which are to be measured. The average maximum VSWR of this adapter in the frequency range of .35 to 2.0 kilomegacycles is 1.06 which was considered satisfactory for the present application.

Figures 10 through 13 present the VSWR values of the various mated connector combinations previously mentioned. In each case, the average value at each frequency of two sample connector combinations selected at random was used in the compilation of the data. An inspection of these curves shows that the VSWR of the various connector arrangements is a satisfactory 1.2 to 1 or less throughout the .35 to 2.0 kilomegacycles range. This low value of VSWR is the result of employing a bead-contact structure which matches the characteristic impedance of the associated cables; capacitive discontinuities are minimized by using compensating higher impedance line sections. This type of construction is essentially similar to the construction embodied in the Series "C" R.F. connector configuration.

As far as the Subminax right angle plugs are concerned, it can be seen in Figure 13 that a somewhat higher VSWR exists. This particular connector configuration does not present the smooth transition from cable to cable as the straight connectors and its use should be limited to applications where this higher value of VSWR will not be detrimental to satisfactory performance.

Another aspect of coaxial connector design is the voltage breakdown rating. Since the 27-9 receptacle of the Subminax series has the shortest "creep path" between the center conductor and the shell, voltage breakdown tests were conducted on a 27-9 receptacle mated with a 27-7 plug which was assembled to RG-174/U subminiature cable. The voltage breakdown results are presented in Table 4.

TABLE 4

Condition of Measurement	No. of Samples	Breakdown Voltage
Sea Level	5	1860 Volts AC(RMS) 60 Cycle
50,000 Feet	4	725 Volts AC(RMS) 60 Cycle
70,000 Feet	5	530 Volts AC(RMS) 60 Cycle

In all of the cases tested above, the breakdown occurred across the rear insert of the 27-9 receptacle.

No measured VSWR data for mated Subminax connectors having an impedance of 75 ohms has been compiled; however, the 75 ohm Subminax connectors have a bead contact structure similar to the 50 ohm Subminax connectors. It is expected that the VSWR measurements of the 75 ohm Subminax connectors will yield similar magnitudes of VSWR values when measured in a 75 ohm system.

CONCLUSION

For the first time, power rating values are presented for the subminiature Polyfluoron, polyethylene and Teflon dielectric coaxial cables over the frequency range of 1 to 10,000 megacycles. It has been shown that for equivalent size subminiature cables, those utilizing a Teflon dielectric have the ability to handle approximately four times more power than the polyethylene dielectric cables. As an example, RG-174/U polyethylene and RG-188/U Teflon subminiature cables both have dielectric diameters of .060 inches. The rating for RG-188/U of 160 watts at 925 megacycles represents a fourfold increase over the 38 watt rating of RG-174/U.

The suitability of substituting a subminiature Teflon cable for a standard polyethylene cable has been demonstrated. Although the 50 ohm RG-188/U subminiature Teflon cable is approximately half the diameter of RG-58A/U, a 50 ohm polyethylene cable, RG-188/U can handle approximately twice as much power over the 1 to 10,000 megacycle frequency range. At 925 megacycles, RG-188/U handles 160 watts while RG-58A/U handles only 68 watts.

In addition to the increased power handling capacity, RG-188/U represents a weight reduction over RG-58A/U of 2-1/2 to 1.

Physical miniaturization of electronic equipment, higher power requirements with subsequent higher ambient temperatures, present problems to the designer and manufacturer. It is felt that these new subminiature Teflon cables and Subminax connectors are particularly suitable for applications where compactness, high temperature, and high power levels are required.

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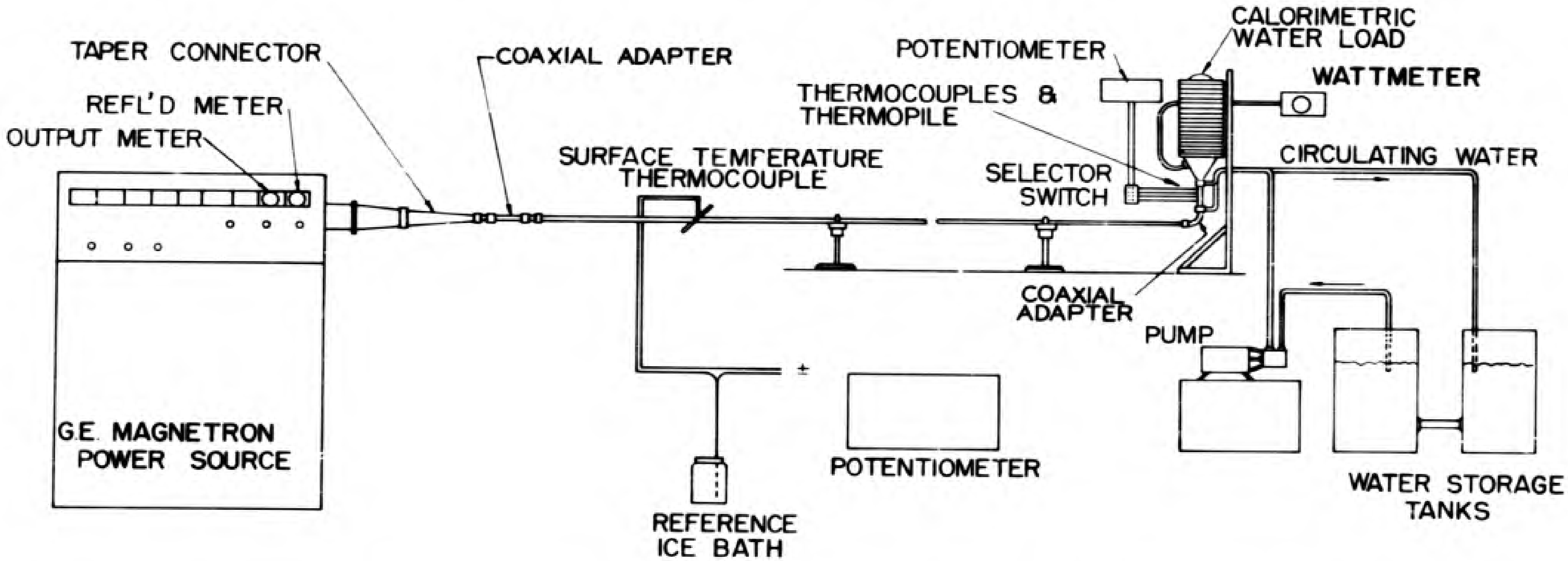


FIGURE I SCHEMATIC DIAGRAM OF POWER RATING MEASURING APPARATUS

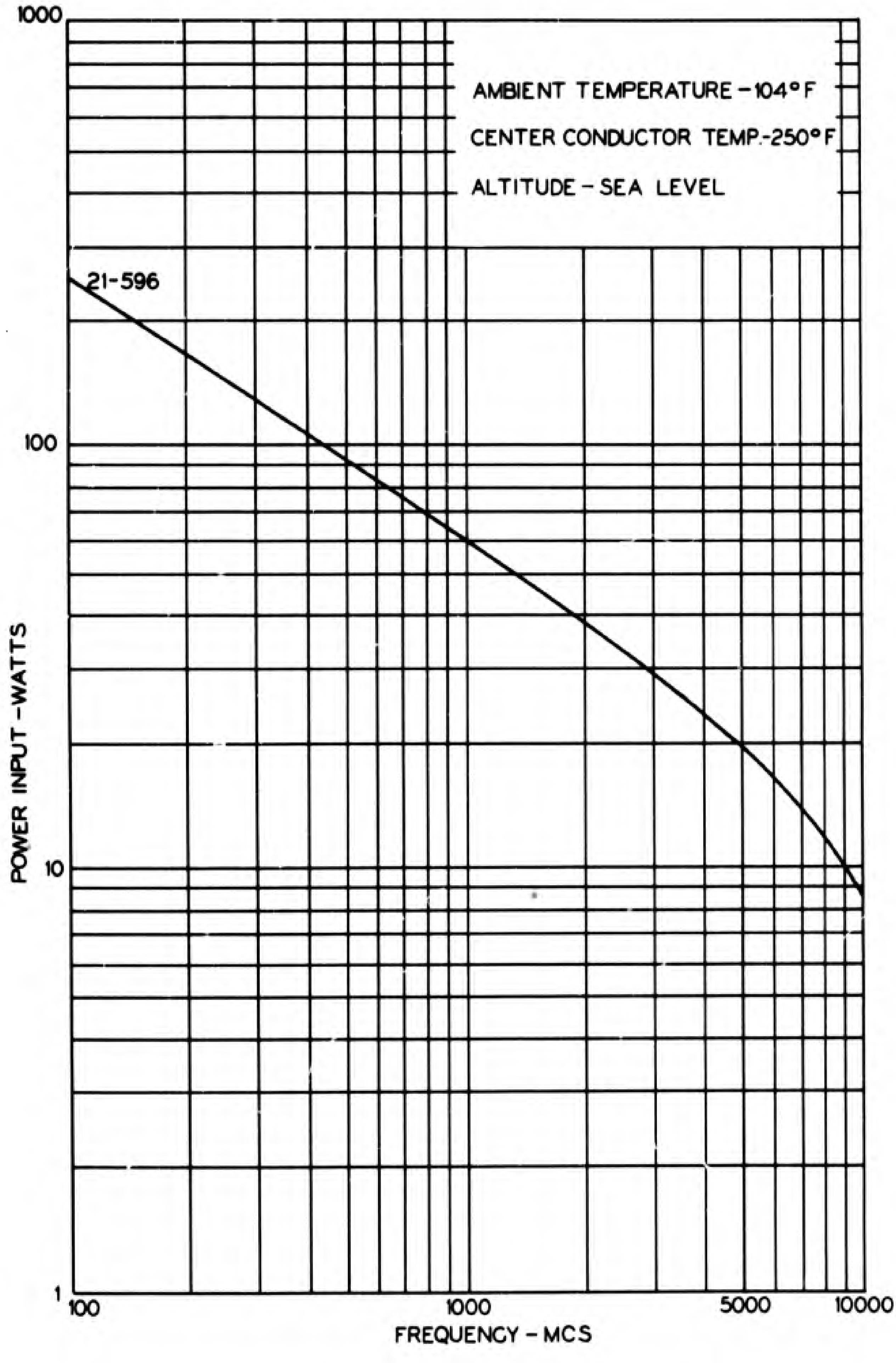


FIG. 2 POWER INPUT VS. FREQUENCY-SUB-MINIATURE POLYFLUORON DIELECTRIC CABLES

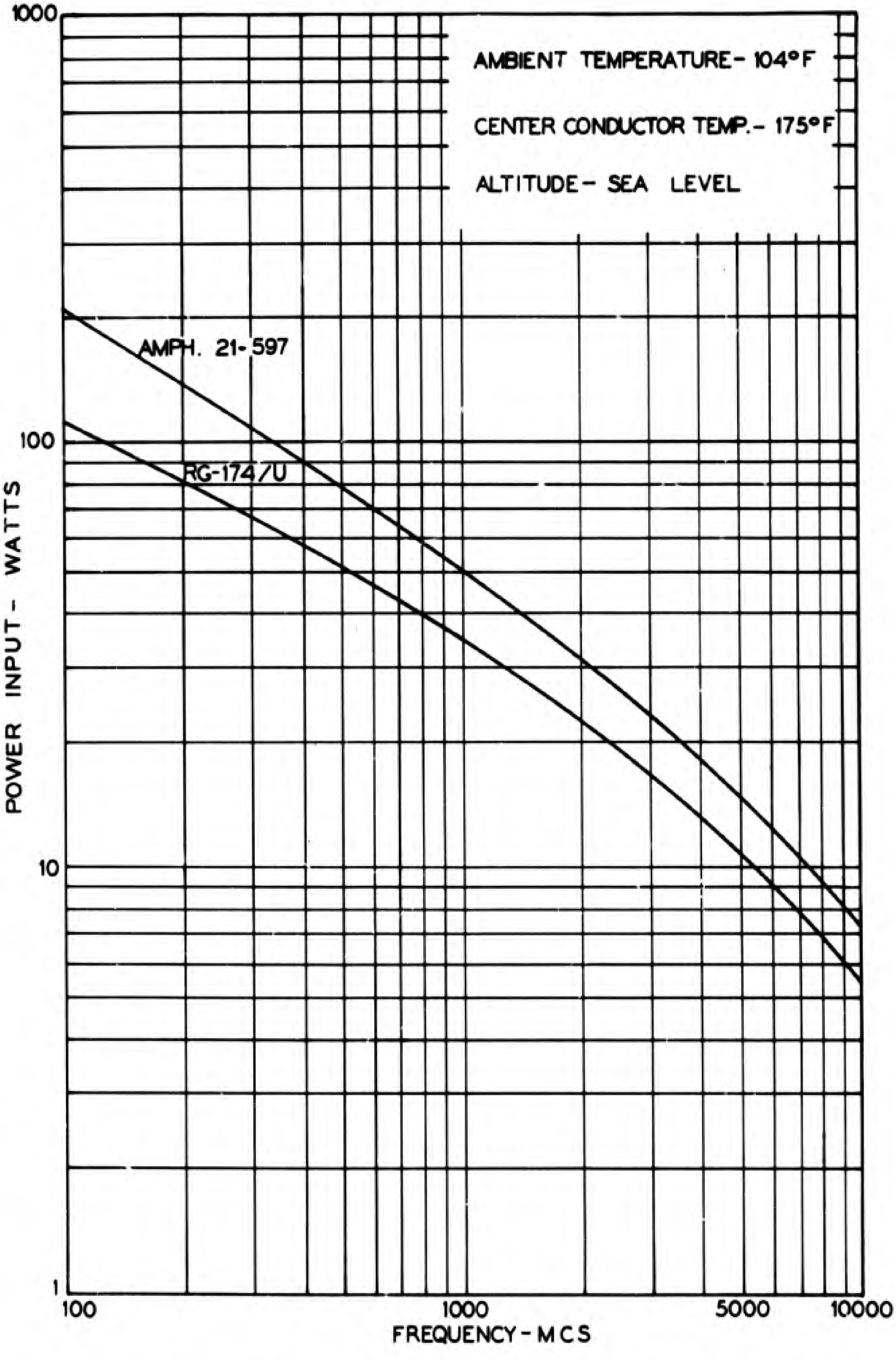


FIG.-3 POWER INPUT VS. FREQUENCY - SUB-MINIATURE POLYETHYLENE DIELECTRIC CABLES

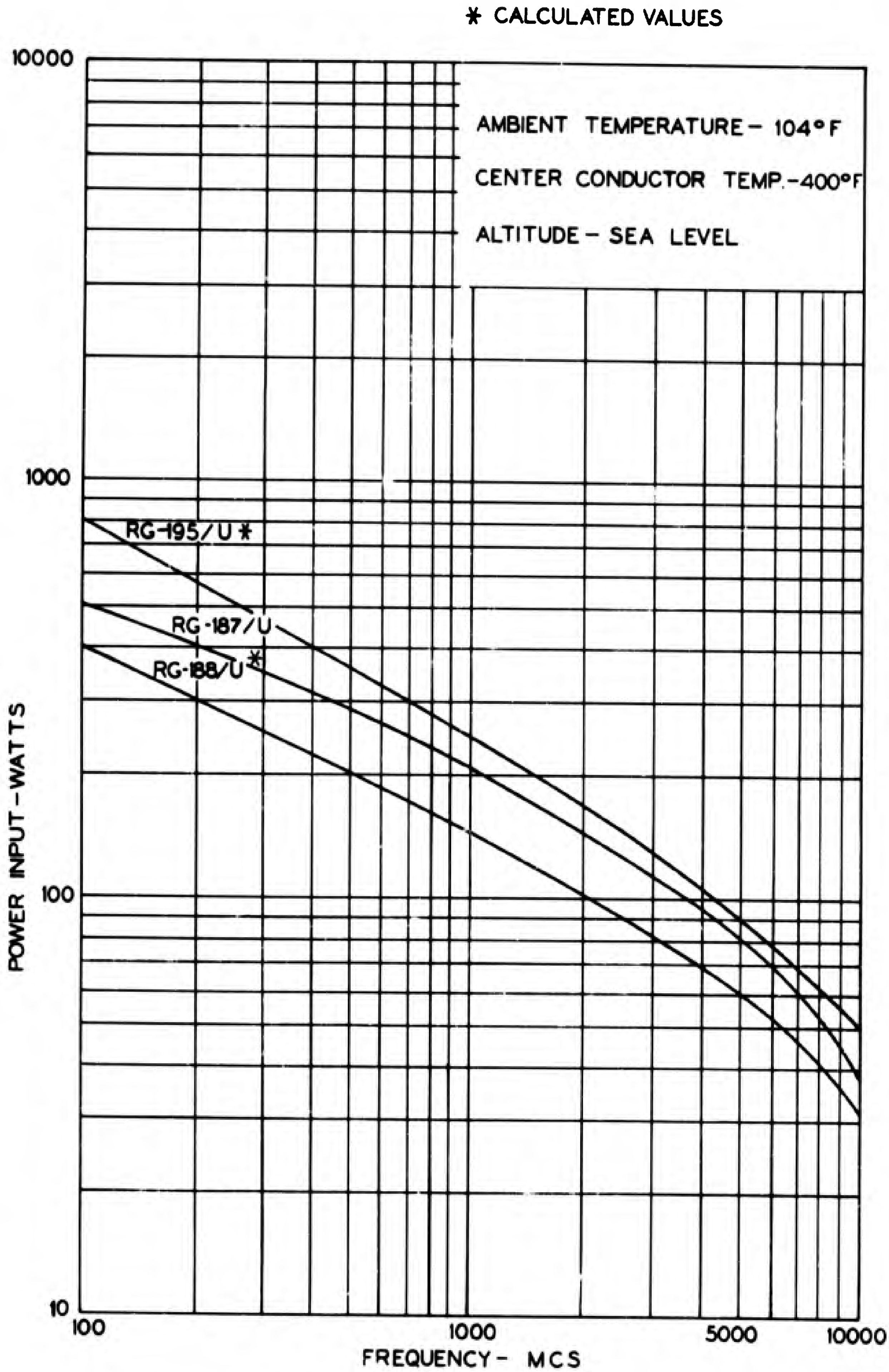


FIG. 4 POWER INPUT VS. FREQUENCY – SUB-MINIATURE TEFLON DIELECTRIC CABLES

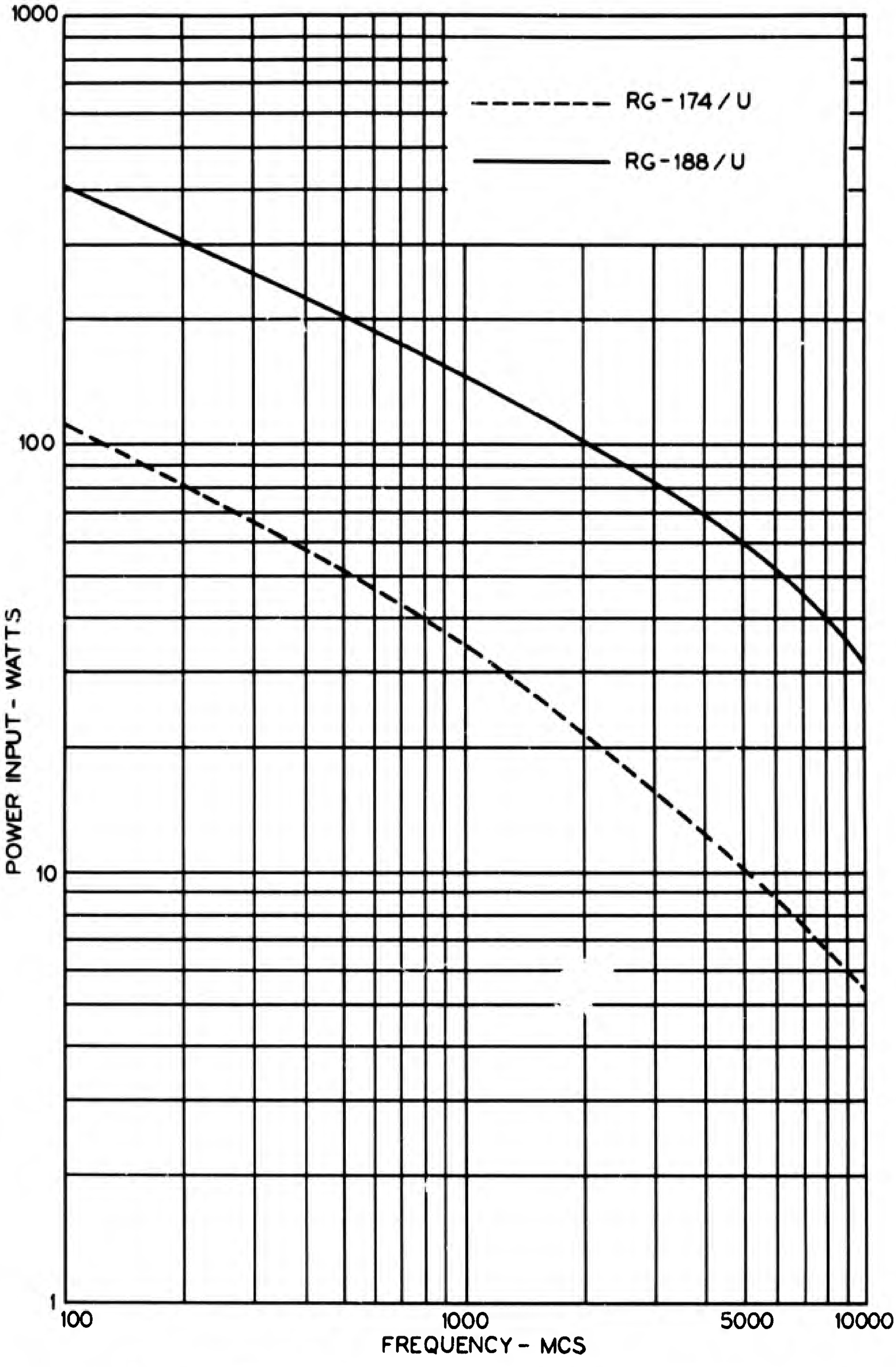


FIG. 5 - COMPARISON OF POWER RATINGS OF RG-174/U AND RG-188/U COAXIAL CABLES

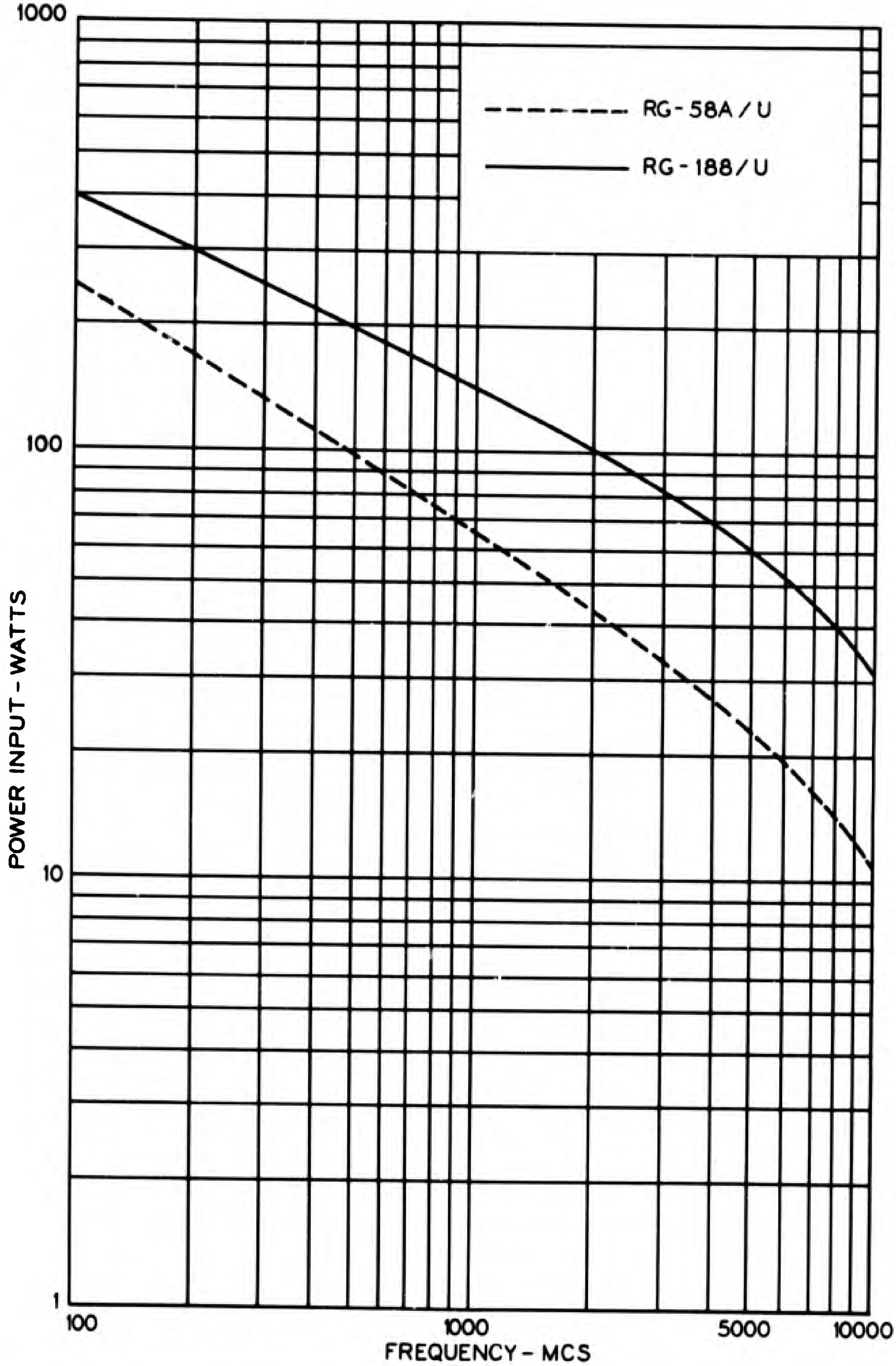


FIG.6 – COMPARISON OF POWER RATINGS OF RG-58A/U AND RG-188/U COAXIAL CABLES

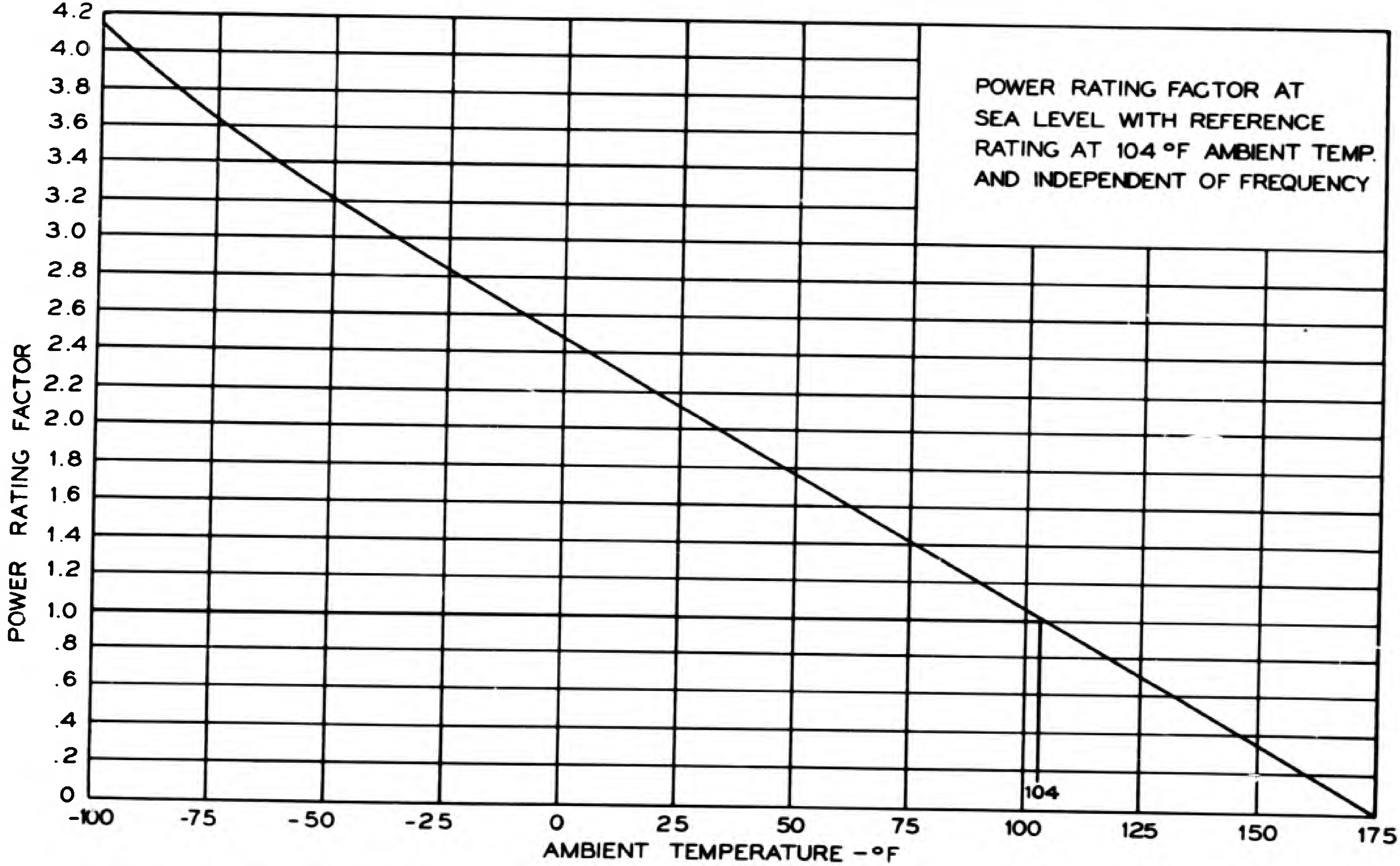


FIG.7 POWER RATING FACTOR VS. AMBIENT TEMPERATURE OF POLYETHYLENE CABLES

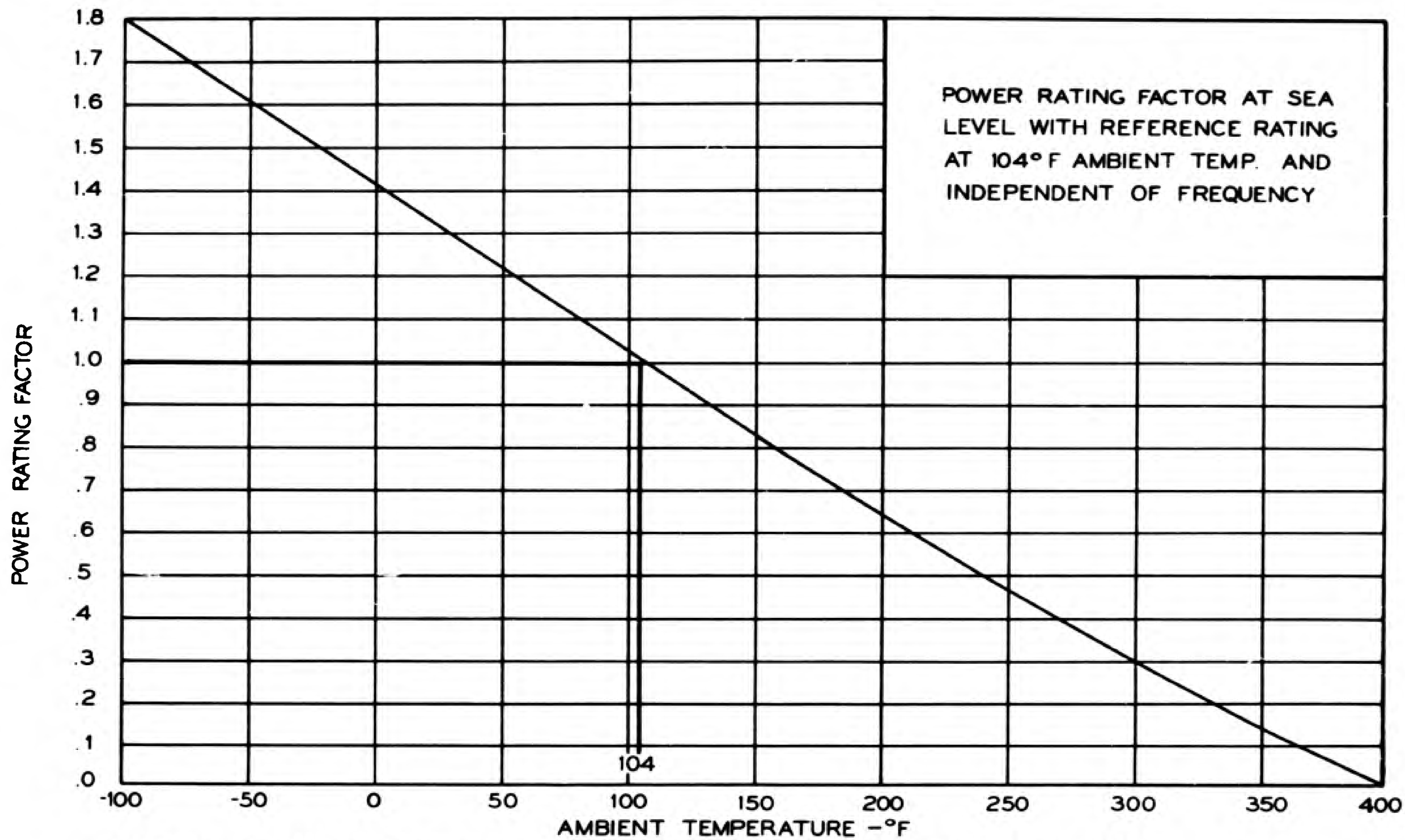


FIG.8 POWER RATING FACTOR VS. AMBIENT TEMPERATURE OF TEFLON CABLES

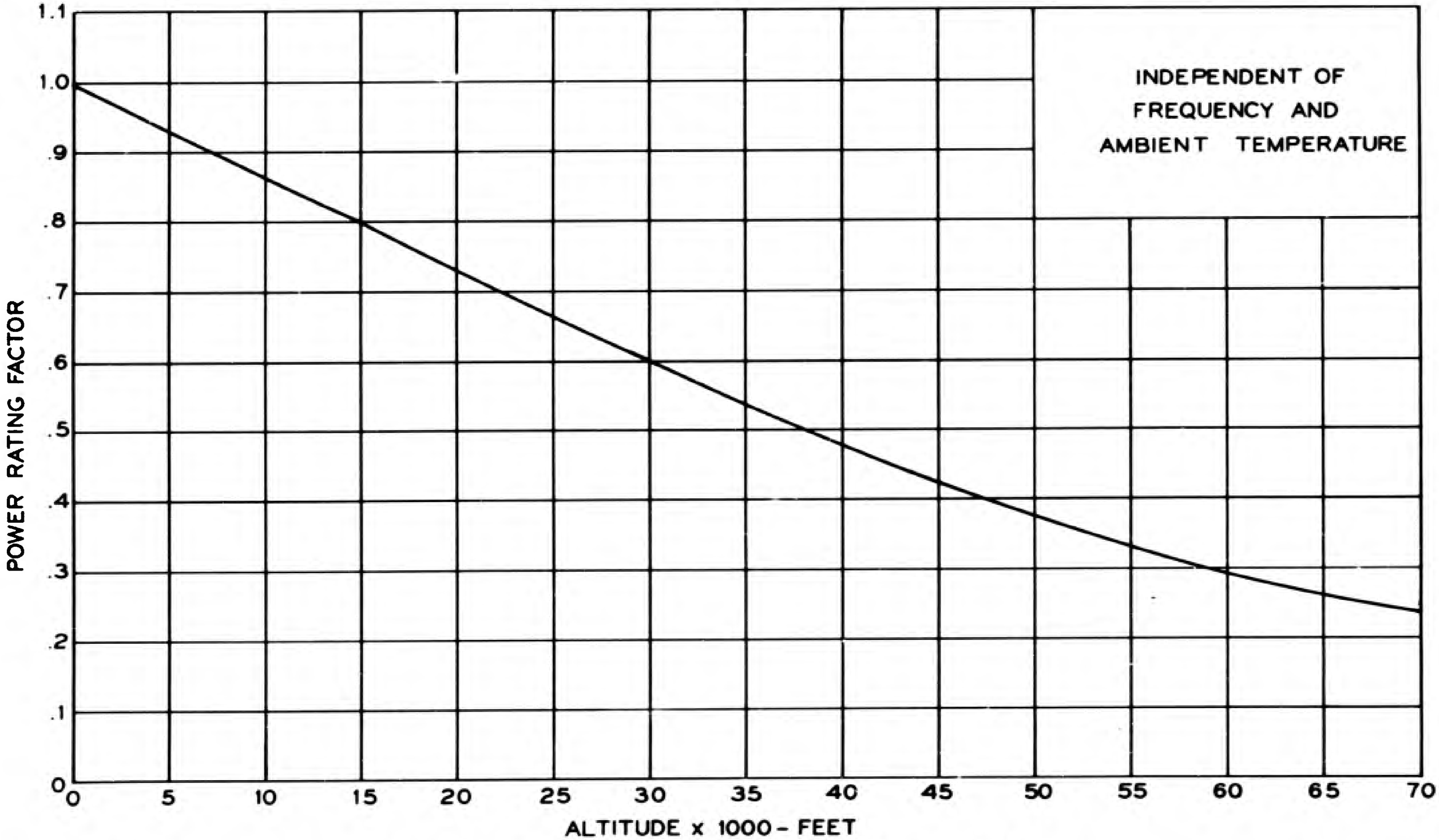


FIG. 9

POWER RATING FACTOR VS. ALTITUDE OF SUB-MINIATURE COAXIAL CABLES

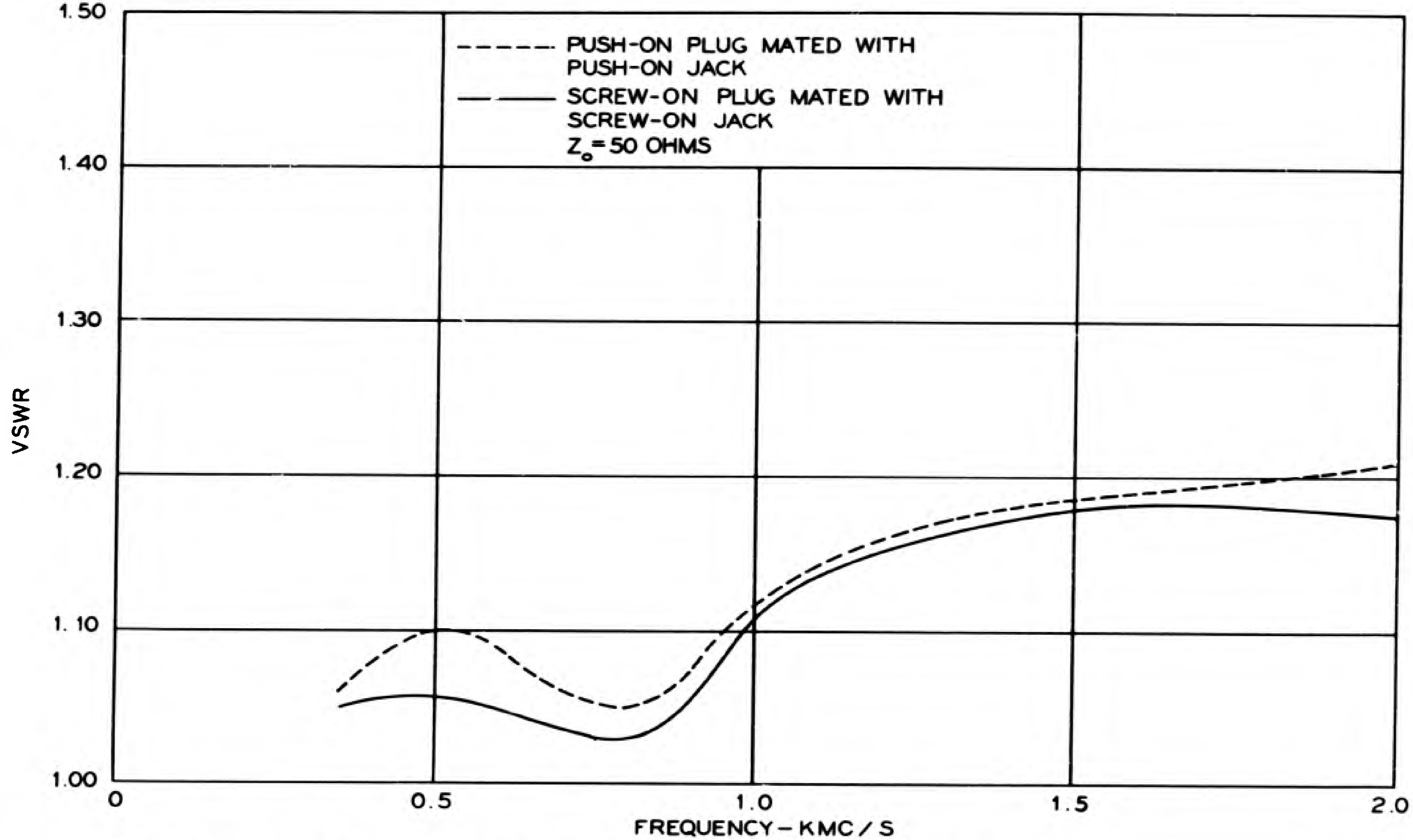


FIG.10 VSWR VS. FREQUENCY – SUBMINAX CONNECTORS

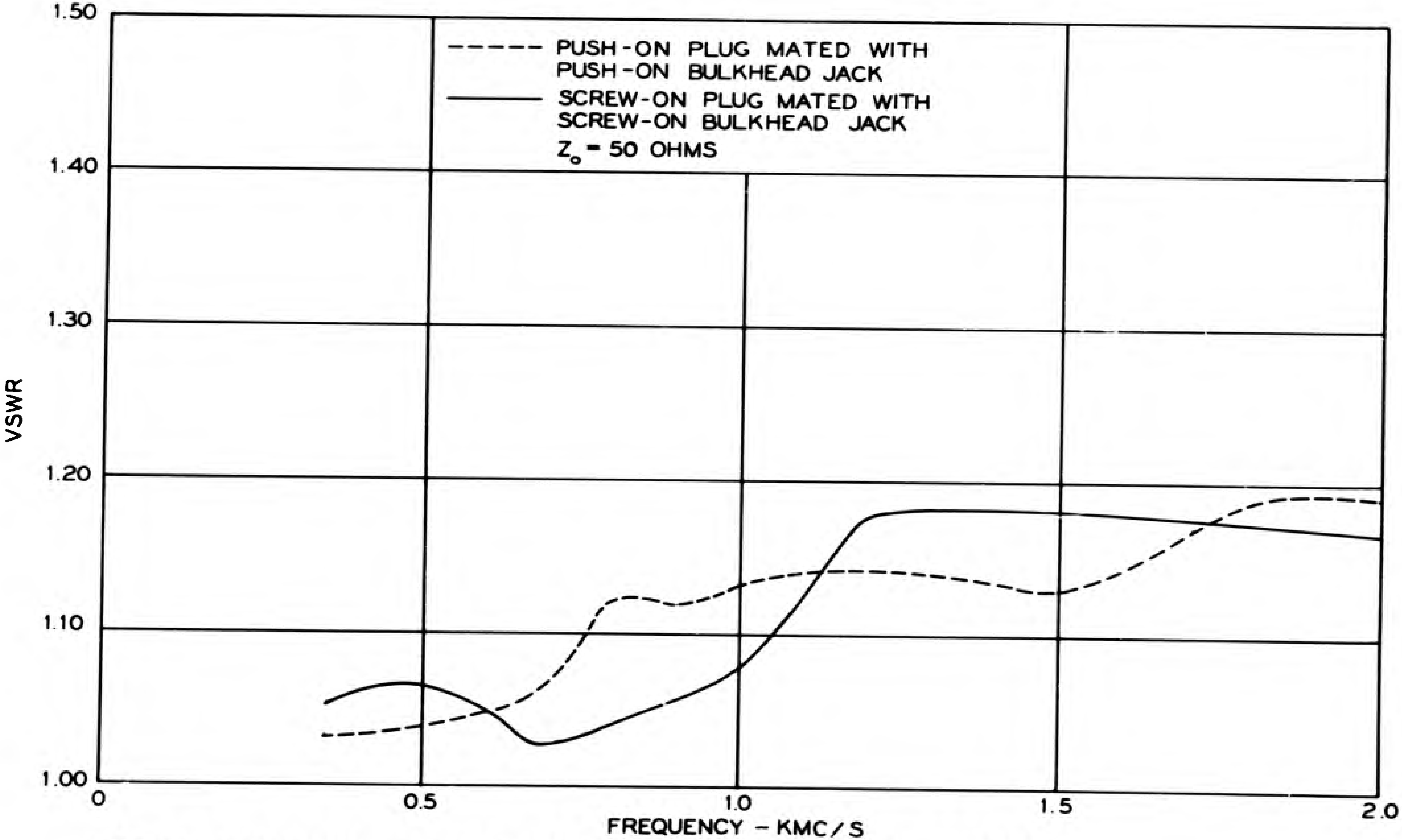


FIG.11 VSWR VS. FREQUENCY – SUBMINAX CONNECTORS

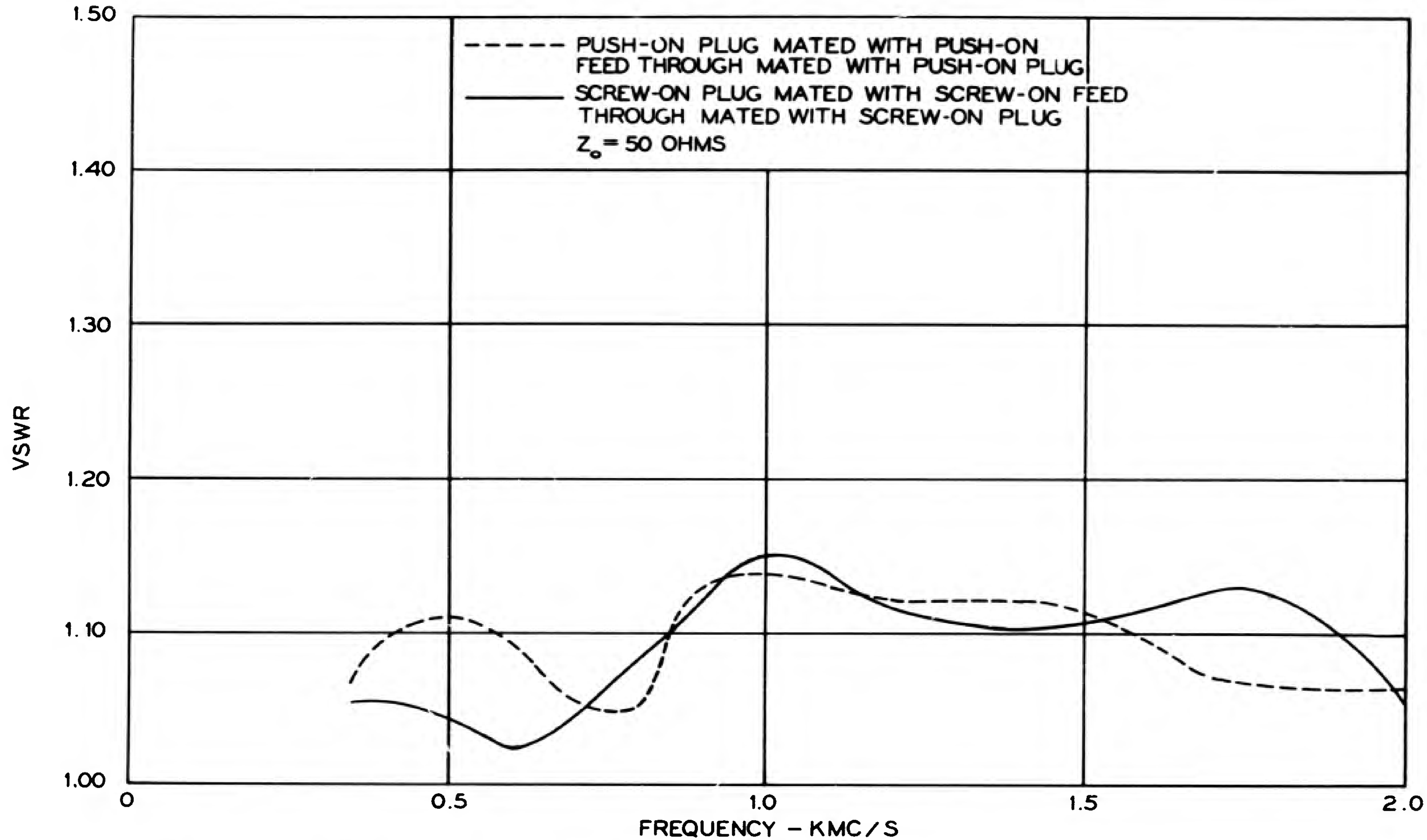


FIG. 12 VSWR VS. FREQUENCY – SUBMINAX CONNECTORS

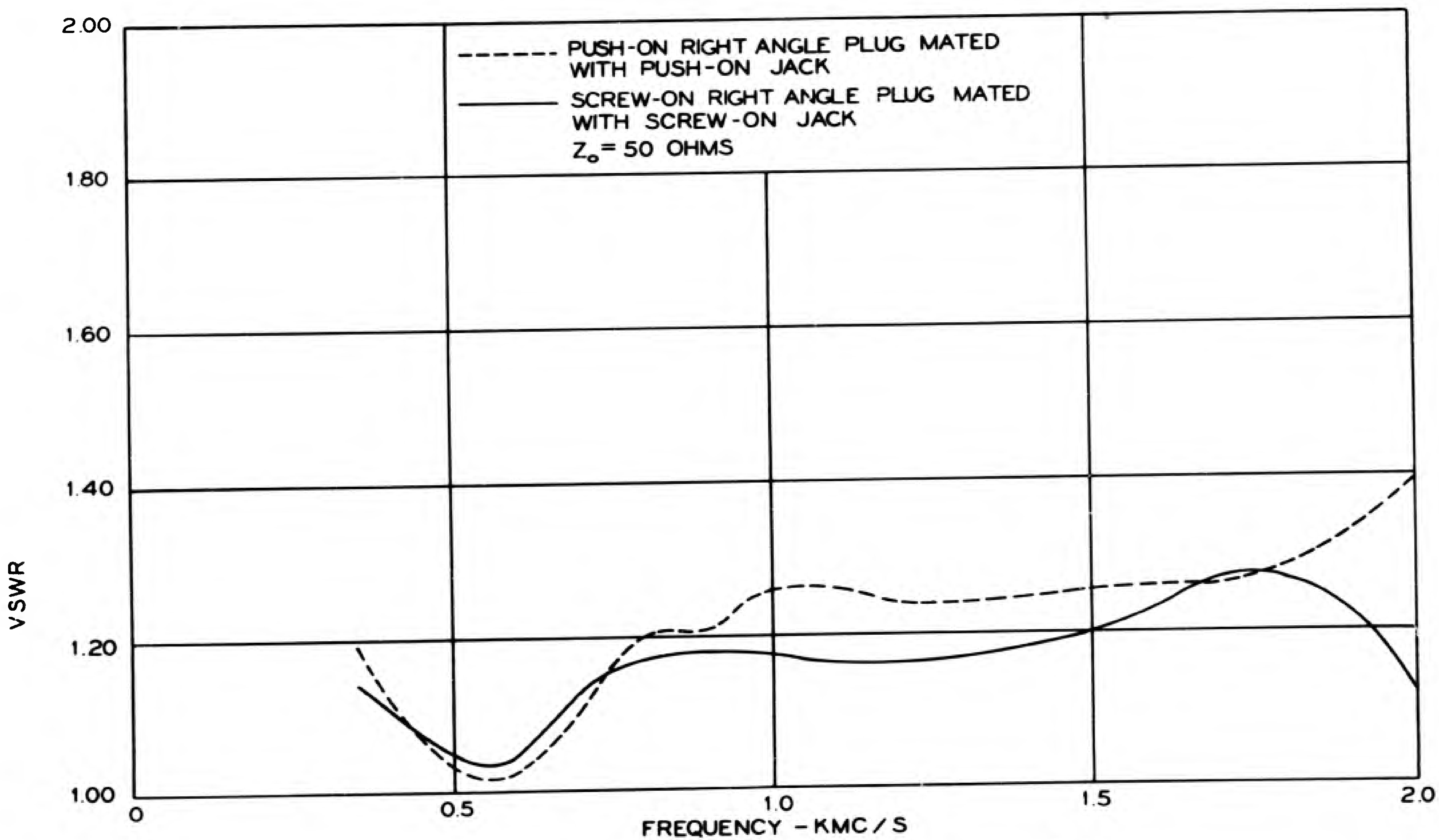


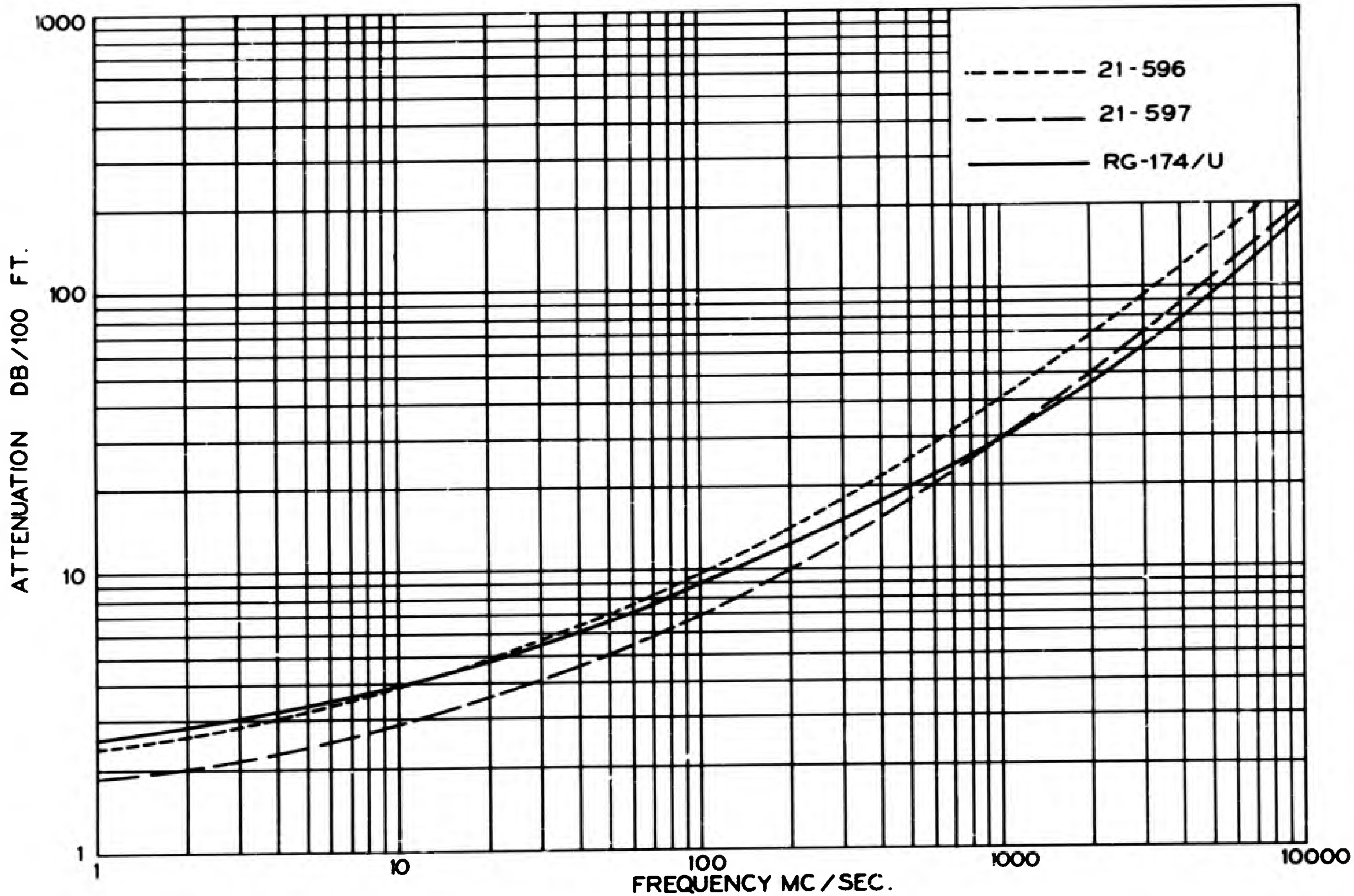
FIG.13 VSWR VS. FREQUENCY - SUBMINAX CONNECTORS

APPENDIX

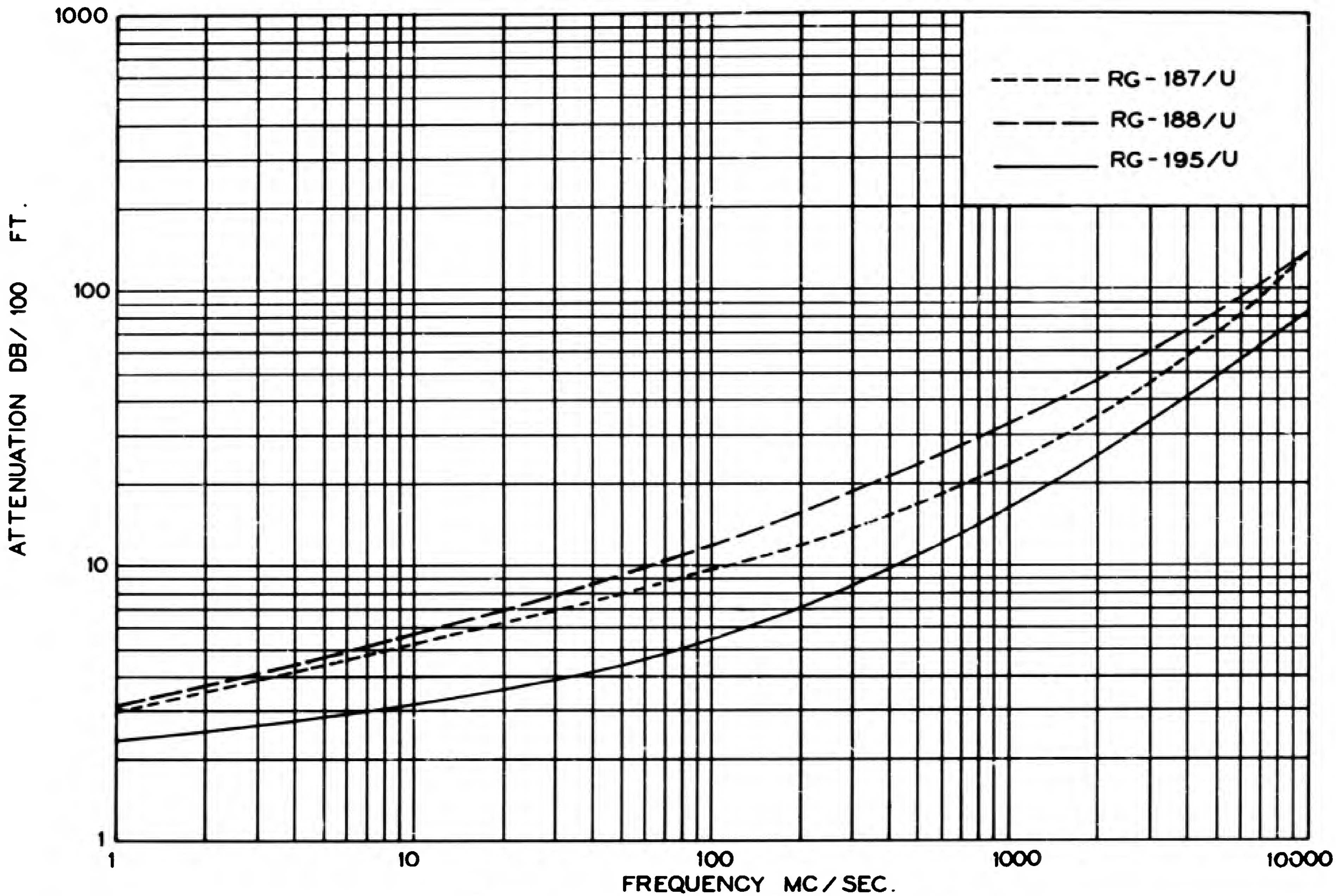
ATTENUATION VS. FREQUENCY CURVES

of

SUBMINIATURE POLYFLUORON, POLYETHYLENE AND TEFLON DIELECTRIC COAXIAL CABLES



ATTENUATION VS. FREQUENCY - SUB-MINIATURE POLYETHYLENE CABLES



ATTENUATION VS. FREQUENCY -SUB-MINIATURE TEFLON CABLES

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