Technical Bulletin

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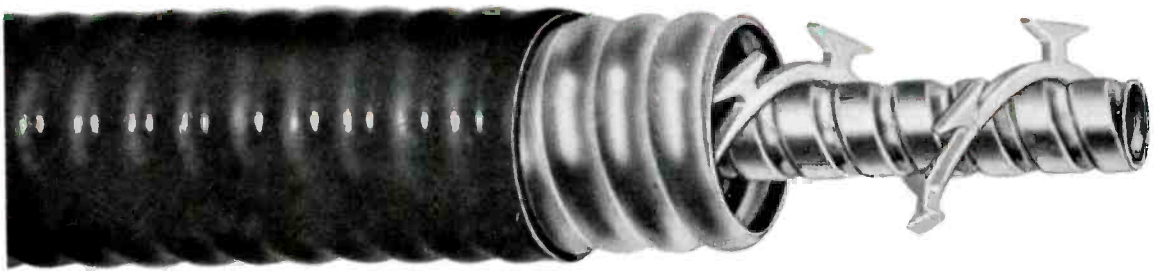
The Broadcasters Guide To Transmission Line Systems



CONTENTS

This Technical Bulletin has been prepared to assist the broadcast engineer in the selection, installation and maintenance of his transmission line system. It is our intention to consolidate in this single document, all the necessary basic information required for the broadcaster to purchase and maintain a transmission line system which yields maximum performance per investment dollar.

Cablewave Systems Inc.

60 Dodge Avenue, North Haven, Connecticut 06473

203-239-3311 • TWX: 710-465-0244

Cablewave Systems

SECTION 1

Selection

As a broadband device, D.C. to cut-off, a transmission line is the simplest, most versatile and most popular means of transferring R.F. energy. Whether it is used as a link between transmitter and antenna, receiving antenna to receiver, or sampling loop to phasor, the basic consideration remains the same; How efficiently can it be accomplished?

In selecting the proper transmission line, the broadcaster must consider its specific application. In AM, FM, and TV applications, the operating characteristics vary considerably. For example, FM and TV stations require a transmission line system which exhibits a very low VSWR not only to assure maximum transfer of R.F. energy, but to also maintain optimum signal quality in picture and sound. For AM broadcast, maximum power transfer is the primary consideration. Of course, there is universal interest in total cost which not only includes the transmission line and accessories, but the installation as well.

Additional considerations in selecting the proper transmission line should be based on the operating frequency, power handling capabilities and the attenuation. High power stations require larger diameter cables than low power stations. However, there are instances, such as long cable runs, where a low or medium power station can efficiently increase its effective radiating power (ERP) by using a larger diameter cable. Therefore, efficiency should merit primary consideration.

Attenuation

The efficiency of the transmission line system is dependent on the total attenuation exhibited from the transmitter to the antenna. It can easily be calculated by the following formulas:

$$\text{Efficiency } \% = \frac{100}{\text{Antilog}} \left(\frac{\alpha \ell}{1000}\right)$$

α = Attenuation in dB/100 feet at operating frequency

ℓ = Length of line in feet/100

or:

$$\text{Efficiency } \% = 100 \, \frac{\text{Power Output}}{\text{Power Input}}$$

For example, the efficiency of an 800 foot length of Cablewave Systems Inc.'s 3" Air Dielectric Wellflex (HCC300-50J) at 100 MHz is:

ℓ = 800 feet/100

Attenuation dB/100 feet = 0.126

$$\text{Efficiency\%} = \frac{100}{\text{Antilog}}\left(\frac{1.008}{1000}\right)$$

$$\text{Efficiency (\%)} = \frac{100}{1.26} = 79.3\%$$

Thus, a transmission line system with 79.3% efficiency means that, with a power input of 20kw, 15.86kw will reach the antenna. The remaining 4.14kw will be dissipated as heat. See Figure 1 for a conversion chart of dB loss vs. efficiency (percent). Since attenuation changes with both frequency and temperature, the loss of a transmission line system, used at its full rated power, increases approximately 13%. Figure 2 shows the correction factor which can be applied for variations in attenuation with ambient temperature. In addition, the load VSWR effects on attenuation must be considered. See Figure 3.

Power

The peak power ratings are dependent on the maximum voltage withstand capability. Peak power ratings are constant with frequency and expressed in the following relationships:

$$Ppk = \frac{Ep^2}{2\ Z_o} \quad \text{or} \quad Ppk = \frac{Ep^2}{2\ Z_o\ (1+M)^2 VSWR} \quad \text{or} \quad \frac{(Erf)^2}{2\ Z_o\ (1+M)^2 VSWR} \text{ watts}$$

Where:
- Ep = RMS voltage at breakdown with a safety factor added
- VSWR = Voltage standing wave ratio
- M = Modulation percentage, as a decimal
- Z_o = Characteristic impedance
- Erf = Ep (RMS) x .7 (correction factor)

Average power is determined by the safe temperature limits of the materials and the thermal dissipation characteristics of the line.

NOTE: At a certain frequency where the peak power curve intersects the average power curve, the voltage flash-over becomes the limiting factor.

Average power curves with peak power ratings for all Cablewave Systems Inc. copper corrugated cables are included in the back section of this bulletin.

In broadcast applications, the actual average power of the modulated signal is not necessarily the same as that of the unmodulated signal. Thus, a modulation multiplying factor must be applied to the transmitter carrier power for derating.

Type of Signal	Modulation Factor
Continuous Wave (CW)	1.0
Frequency Modulation (FM)	1.0
TV (includes effects of audio carrier)	1.1
Amplitude Modulation	1.5

Example: A 5.0 kw AM transmitter at 90% efficiency will effectively have an input power to the transmission line system of 5.0 x 0.9 x 1.5 = 6.75 kw.

There are various ways of increasing the power ratings of Air Dielectric cables. The most practical way is by increasing the air pressure (dry air or dry nitrogen) or replacing air with an inert gas such as sulfur-hexafluoride or freon. The use of a heavier gas increases the heat transfer from the center to outer conductor so that greater power can be carried while remaining at the lower operating temperature. The following tabulation shows the effective increase on average power ratings for various popular gases.

Gas	0 psig	10 psig	15 psig
Air or Nitrogen	1.0	1.15	1.20
SF_6 (Sulfur-Hexafluoride)	1.30		1.60
Freon 12	1.15		1.30
Freon 16	1.37		1.62
Freon 13	1.20		1.40

The average power rating is dependent upon the ambient temperature. Figure 4 shows the variations of average power ratings with change in ambient temperature.

For the effects of pressure on peak power ratings, a good rule of thumb to follow is:

Dry Nitrogen or Air

An increase of one atmosphere of pressure (15 psig) increases the power rating by a factor of 2.

An increase of two atmospheres of pressure (30 psig) increases the power rating by a factor of 4.

Sulfur Hexafluoride (SF_6)

For higher power handling capabilities, sulfur hexafluoride may be used. An increase of one atmosphere of SF_6 (15 psig) increases the peak power rating by a factor of 4.

An increase of two atmospheres of SF_6 (30 psig) increases the peak power rating by a factor of 10. See figure 5.

Caution: When using SF_6, any electrical discharge within the cable produces toxic oxides of fluorine. Therefore, do not attempt to investigate peak power failure in a transmission line system without proper ventilation.

Voltage Standing Wave Ratio

The final major consideration in the selection of a transmission line system is derating the power handling capabilities due to system voltage standing wave ratio commonly abbreviated VSWR. VSWR is caused by an impedance mismatch which results in reflections back to the R.F. source (transmitter, etc.) from the load (antenna, etc.) resulting in a standing wave of current and voltage. These standing waves effect the average and peak power of the transmission line system.

Typical VSWR exhibited by Wellflex Air Dielectric cable assemblies are 1.05:1 at 50-250 MHz (VHF-TV) and 1.10:1 at 450-900 MHz (UHF-TV).

If the value of the VSWR exhibited by the transmission line is known, the line should be derated so that it can safely operate without fear of burn-out. The following formula can be used to determine the derated power value:

$$\text{Derated peak (or average power)} = \frac{P}{D}$$

P = Power rating from curves

$$D = \frac{(VSWR)^2 + 1}{2\ VSWR}$$

Note: For a VSWR of less than 1.2:1,

$$\text{Derated Power} = \frac{P}{(VSWR)}$$

For example: At 100 MHz, 3.0" Wellflex Air Dielectric cable is rated at 35.9 kw. With a system VSWR of 1.10, the derated power rating is:

$$\frac{35.9\ kw}{1.10} = 32.64\ kw$$

(Based on 0 psig and ambient temperature 40°C)

A more exact figure for derating average power can be calculated for any frequency from the following relationship:

$$DF = \frac{(VSWR)^2 + 1}{2\ VSWR} + \frac{F'\ VSWR^2 - 1}{2\ VSWR}$$

Where F' is a factor that varies with frequency and line size, see Figure 6.

Thus far the basic parameters of consideration for a transmission line system involving AM-FM and TV have been covered. These considerations have essentially been for standard transmission line applications. But in an AM directional station where the array has been installed, tuned and fixed, the stability of the transmission line system over wide environmental variations must also be considered. The directional station's pattern must remain constant within narrow limits of time and temperature as well as varying weather conditions. The FCC imposes a plus or minus 4° phase angle limit. This $\pm 4°$ or 8° phase angle window is for the entire system, from the transmitter to the antenna and whatever is in between. The transmission line system is, therefore, only part of the possible problems of phase angle shift. Transmission lines change in electrical length with varying temperature. This variation is caused by the expansion or contraction of the outer and inner conductor and the change in dielectric constant of the insulator material. The temperature rises, the conductors expand and the dielectric constant of the polyethylene insulation lowers, producing a coefficient called "Phase Temperature Coefficient"; usually expressed in parts per million per degree Fahrenheit (PPM/°F). The use of phase stabilized transmission line reduces the change in electrical length over varying temperature ranges.

Phase stabilized cables are standard cables which have undergone extensive temperature cycling until such time as they exhibit their minimum phase temperature coefficient. Phase compensated cables are those that have been specially designed by controlling the volume of dielectric and outer/inner conductor to keep the electrical length change to a minimum.

Typical phase/temperature coefficients of phase stabilized as well as phase compensated cables are listed on the next page.

TYPICAL PHASE TEMPERATURE CHARACTERISTICS (70-110°F) FOR COAXIAL CABLES AND TRANSMISSION LINES

Cable/Line Type	Coefficient
Flexible, Braided Outer Conductor, Solid Polyethylene Dielectric	-50 to -250 PPM/°F
Flexible, Braided Outer Conductor, Foam Polyethylene Dielectric	-50 to -100 PPM/°F
Flexible, Braided Outer Conductor, Teflon Dielectric	-100 to -300 PPM/°F
Foamflex and Foam Wellflex Cables	-15 to -40 PPM/°F
Copper Rigid Coaxial Line	+8 PPM/°F
Air Dielectric Spirafil and Wellflex Coaxial Cable	+2 to +7 PPM/°F
Phase Compensated, Air Dielectric Spirafil and Wellflex Coaxial Cable	+1 to +2 PPM/°F

The phase temperature coefficient chart clearly shows that using flexible braided solid polyethylene or braided foam polyethylene to feed an AM directional array, can result in a sizeable portion of the allowable deviation in relative phase angle being taken up by the coaxial lines. Therefore, the phase temperature coefficient of the line being considered should be as low as possible since other parts of the system, such as phase networks, VSWR mismatches, etc., also contribute to the overall phase shift. If as much as one half the total phase error is allotted to the coaxial cables, the phase change in cables must be held to ±2°. Thus, the only acceptable cables are air or foam Dielectric cables such as air dielectric Spirafil and Wellflex, or Foamflex and Foam Wellflex.

Consideration of the phase temperature coefficient is also most important to the broadcast engineer in designing an AM array where feed lines can be of different lengths. Typical AM directional arrays utilize transmission line systems such as 1-5/8" or 3.0" Air Wellflex phase stabilized, and 1/2" Foam Wellflex, phase stabilized, for sampling lines.

All standard Cablewave Systems Inc. air and foam dielectric cables are available phase stabilized upon request.

SECTION II

Installation

This portion covers the recommended installation procedures for Cablewave Systems Inc. air and foam dielectric, jacketed, semi-flexible cables. Both air and foam dielectric cables are offered in bulk quantities or as a complete cable assembly system with factory attached connectors. Foam dielectric cables in bulk are shipped with cable ends sealed from environmental moisture by means of plastic end caps. When shipped as assemblies, the end terminations are protected to avoid damage during transit.

All air dielectric cable is shipped pressurized at 5 psi, after a 24 hour pressure test.

When shipped in bulk the inside coil end is sealed with a blank rubber end cap and the outside coil end with a rubber end cap containing an inlet valve for pressurization or monitoring with a tire gauge.

Receiving Inspection

When cable is received, on a reel or in a carton, inspect carefully for possible shipping damage. If damage is visible, contact carrier immediately. After inspection remove reel lagging or carton cover carefully and again inspect cable carefully for possible hidden shipping damage.

With air dielectric cables, check the pressure by means of a pressure gauge or tire gauge. Although end caps or connectors are pressure tight, they are not hermetically sealed. If there is no evidence of pressure, especially after lengthy shipment or storage, re-pressurize the cable to 5 psi and monitor for 24 hours. If more than one pound is lost, check for pressure leaks. Pressure leaks can usually be traced by employing a mixer of water and soap, or a commercial leak detection solution that will bubble when brushed over a pressure leak.

Cable assemblies of one or two EIA connectors installed at the factory are shipped with a protective cover plate attached to the outside end, or both ends in the case of two gas passing types, to maintain pressure during shipment. Do not remove the cover plate until the cable assembly has been hoisted and bound to tower since it provides protection to connector face during hoisting.

Installation

Hoisting the cable up the tower can be accomplished by means of a pulley situated at the top of the tower to make easy connection to the antenna. Most cables can be raised manually; however, with lengths of several hundred feet of 1-5/8" or 3" cable, a winch should be employed. Where cable is on a reel, place the reel at the base of the tower and allow the cable to pay off from the bottom toward the tower. Cable reel should be supported on tripods, with axle, to allow freedom of rotation. As the cable unreels, an even pull should be maintained on the cable as it is being hoisted. Where cables are in short lengths, uncoil on the ground away from base of tower until completely uncoiled in a straight length.

Before raising cable, place a protective covering over the connector. This will prevent damage during hoisting. If the cable is ordered with a cable hoist, position hoist approximately 2 feet from connector end and attach hoist line. If no cable hoist is provided, a rope sling may be attached by first wrapping friction tape securely around cable in sections approximately 8" wide and situated approximately 2 feet from connector. Then fashion a rope sling from which the hoist line is attached. With cable lengths in excess of 200 feet, additional cable grips are recommended at 150 to 200 foot intervals. Additional cable hoist ties are left to discretion of the installer. Naturally, the more ties to the hoist line, the less the chances of strain on the cable. Hoist the cable slowly, allow the payoff from the reel to retard evenly with the pull of the hoist line. Controlled cable payoff will prevent possible kinking or unnecessary straining. With short length stretched out away from the base of the tower, caution must be taken so the cable is not dragged over sharp edges along the ground. Hoist cable in an even pull to avoid any unnecessary strain on cable.

Attachment To Tower

Insulated hangers are required on hot AM towers. When cable has been raised to correct height, anchor to the tower leg nearest the antenna by means of cable hoist. It is important that only the cable hoist support the weight of the cable. The purpose of the hangers is to prevent the cable from "swaying" and to "dress" along the tower members. Space hangers 1 foot apart for the first 5 hangers from the antenna and 3 feet apart thereafter.

Be sure to maintain hoist line pressure until cable hanger is at least 25% completed down the tower.

A variety of cable hangers, associated mounting adaptors, and Straptite are available from Cablewave Systems Inc. to accommodate just about every tower member arrangement.

Caution should be taken during the installation of hangers or Wraplock to avoid excessive tightening which may deform the cable or cut the jacket. Repair of a cut jacket is easily accomplished by applying a close layer of No. 33 all weather vinyl tape, a coating of 3M Scotchkote and an additional layer of vinyl tape.

Grounding of the cable is usually done at the top and bottom of the tower and at the point where it enters the transmitter building, especially when there is a long horizontal run. With tower installations in excess of 300 feet of vertical run, it is advisable to ground the cable at approximately the 150 foot level as well. Grounding instructions are detailed in Cablewave Systems Inc. Grounding Kits. See Figure 7 for typical Wellflex transmission line installation.

Routing Cable

Routing the cable from the base of the tower to the transmitter house is relatively easy. The cable can be buried or supported above ground. The above ground installation usually requires a messenger cable to prevent cable sag. Attachment to the messenger cable can be made with the same hanger arrangement as in the tower run at three foot intervals. Exposed horizontal runs must be protected from falling tower ice by means of an ice shield.

Buried cables should be installed with a ditch at least 3 feet deep and surrounded by 6 inches of sand to prevent damage from rock movement, frost heave, or from heavy vehicle traffic.

When routing the cable through the transmitter building, a wall feed-through is recommended. For horizontal above ground installations, a moisture loop is recommended prior to building entry to prevent rain "rolling" down the cable into the building.

Cable Testing Prior To Connecting To Antenna

Remove all connector protective coverings. Air dielectric EIA connectors will have blank covers. Prior to connecting to antenna, a continuity check is recommended. A short should be fashioned between inner conductor and outer conductor of the connector. With the cable shorted, a good quality ohmmeter at the other end of the cable should read zero or nearly zero. When short is removed, the meter should read at least 1000 megohms.

Antenna Connection

Install anchor assembly to the antenna interface. If connector is an EIA type, seat "O" ring in gasket groove of cable connector. Caution: Be certain that all connector interfaces, ("O" ringe etc.) are perfectly clean. Use acetone, carbontetrachloride, or denatured alcohol if cleaning is necessary. A thin coat of silicon grease, (DC-4) will keep "O" ring seated properly in gasket groove of connector. Position and engage cable connector to antenna input, being certain that the "O" ring gasket remains in place and the inner anchor assembly seats properly. Rotate swivel flange on cable so that the alignment pin is engaged to the antenna input flange and then secure cable to antenna with appropriate hardware.

For foam dielectric cables, the procedure is essentially the same, however, other type connectors such as a type N, LC, or UHF, may be used at the antenna input. Remove the factory-provided dust cap and be sure interface is perfectly clean. Make connections to antenna. Apply a light coat of silicon grease (DC-4) to inside surfaces of connector to prevent moisture formation. Protect back end of connection by applying several layers of all weather vinyl electrical tape over connector body.

Repeat connecting process on transmitter end.

Pressurization

Air dielectric cables should always be pressurized to avoid moisture build-up in the cable, which will impair its electrical characteristics. If, under some unusual circumstance, the cable is to be used without pressure, a notch can be filed through the outer conductor at the underside of the cable to allow condensation to drain. Do not punch a hole through the outer conductor since this will leave burrs inside and possibly cause an arc gap from inner conductor to outer conductor, permanently damaging the cable. A convenient location for a notch would be at the lower ebb of the moisture loop.

After cable has been installed at the antenna and before connection of the gas barrier connector to transmitter end, the cable should be purged to remove any particles of moisture acquired within the cable during installation. Purging is accomplished by removing the gas port plug of the connector at the antenna end and allowing air to flow through the cable with air pressure being applied at the transmitter connector end. Set the pressure regulator to 10 psi and allow air to escape at the antenna end for a minimum of 1.0 hours. Repeat this process three times concluding each process with the connector gas port plug installed while gas is still escaping to prevent moisture from being pulled back into the cable.

Pressurization is accomplished by means of an automatic dehydrator, a dry nitrogen tank, or a dry air hand pump. The pressurization system selected is dependent on the amount of cable to be pressurized.

CSI AIR DIELECTRIC CABLES
VOLUME $ft.^3/ft.$

Diameter	Volume/$ft.^3$
1/2"	0.0008
7/8"	0.0035
1-5/8"	0.014
3.0"	0.038

Pressurizing equipment is usually attached to the transmitter end (gas barrier) connector and normally set at 5-10 psi. A manifold system is used to provide a number of pressure outlets for more than two transmission line systems. Each outlet should provide a needle valve and pressure gauge for individual readings.

After installation of cable and pressurizing equipment is completed, a thorough inspection of all joints, connections and threaded sections should be made to assure a completely sealed system. Although Cablewave Systems Inc. connectors are not hermetically sealed, careful attention to the initial installation should yield a transmission line system with an extremely low or insignificant leak rate.

Your Cablewave Systems Application Engineer will be pleased to assist you in the selection of the proper pressurization system for your specific needs.

SECTION III

Maintenance

The broadcast engineer does not often consider the transmission line system as equipment that requires periodic maintenance. Although coaxial cable is sometimes thought of as a passive device, it nevertheless, requires a certain degree of vigilance by the user to assure continual service. Physical inspection of the transmission line at frequent intervals is recommended, checking terminating connectors, hangers and clamps, and maintaining pressure on gassed lines. Antenna and equipment (transmitter, phasor, etc.) connections should be occasionally disconnected and examined for developing high resistance arcing. If a "burn spot" is discovered, clean thoroughly and apply a light coat of silicon grease (DC-4) prior to installation. Check all interface "O" rings for dryness and apply a liberal coat of silicon grease if necessary.

Gas pressure should be observed on a daily basis. With a dry nitrogen gas cylinder, the capacity gauge and the output pressure gauge should be noted for replacement of the tank. Monitoring the gas tank capacity gauge will give a good indication of a developing air leak. With an automatic dehydrator, the cycling rate (on-off) is also a good indication of a developed leak. Whichever pressurization system is employed, an air leak in the transmission line should be repaired immediately.

The first step in locating a leak in the transmission line is to increase the line pressure to approximately 20 psi and listen for an audible "hiss" from the equipment or antenna connector. If this method is not successful, then dab both connectors with a soapy solution. A pressure leak will blow a bubble. Common points of pressure leaks on connectors are the back end, the pipe plugs, and the interfaces. However, the obvious should never be overlooked; perhaps a stray or vindictive bullet puncturing the line.

An air dielectric line should always be pressurized. If such a line is left unpressurized, moisture and dirt can accumulate within the line in a very short period of time, especially during the summer months. Moisture and dirt can cause voltage breakdown seriously damaging the line. During the winter months, moisture can freeze causing the efficiency to deteriorate, possibly resulting in serious damage or a fatal blow out.

During annual inspection, careful examination of the hangers and hanger adaptors should be conducted and tightened or replaced if necessary.

Caution: Do not overtighten hangers. It is not the responsibility of the hangers to support the weight of the cable; that is the responsibility of the cable hoisting grips. Hangers prevent the cable from swaying away from the tower. Overtightening can result in cutting through the jacket and possibly deforming the cable. The transmission line should also be periodically checked electrically to assure continued optimum performance. FM and lower channel TV stations can be checked by means of a generator and slotted line. The resultant readings can be checked with the manufacturer for typical readings. A D.C. resistance bridge is also a useful tool. The resistance should be less than 1.0 ohm. Higher resistance could mean the line is developing contact resistance at its terminating points.

Transmission line maintenance can be simply summed up by giving it the minimum care it requires. Daily and annual checks made conscientiously will yield many years of service with a minimum of problems. Correct small problems as they occur and the line will give good service with little or no downtime.

SECTION IV

TECHNICAL DATA

Figure 1
Conversion Chart Showing The Relation Between DB Loss And Efficiency Of Transmission

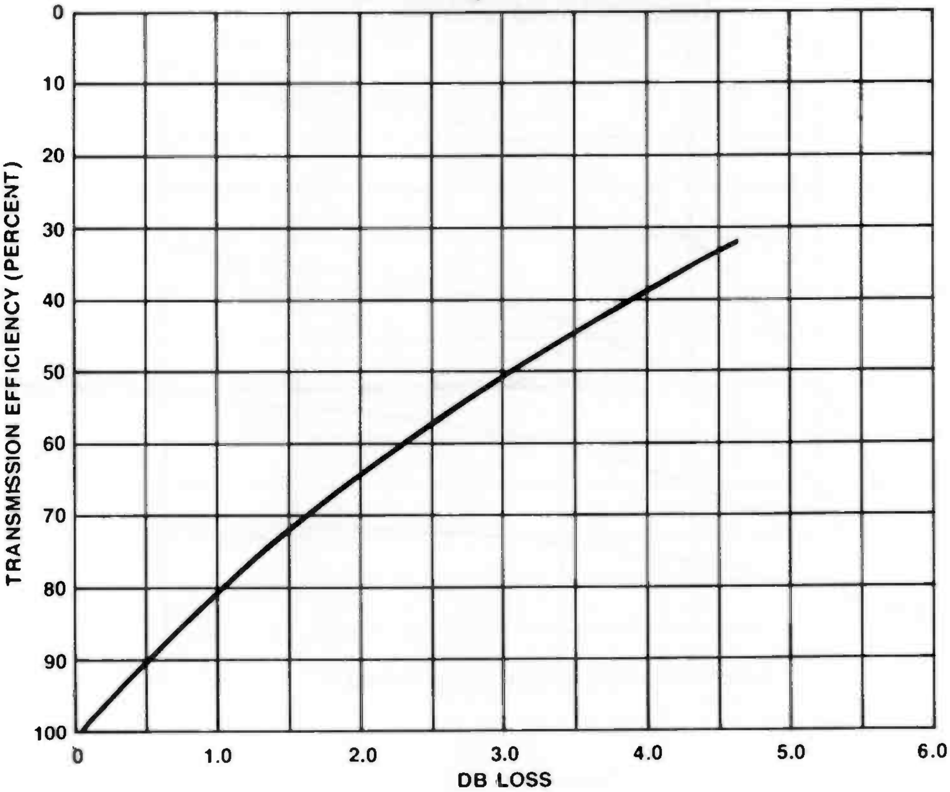


Figure 2
Attenuation Changes Due To Ambient Temperature

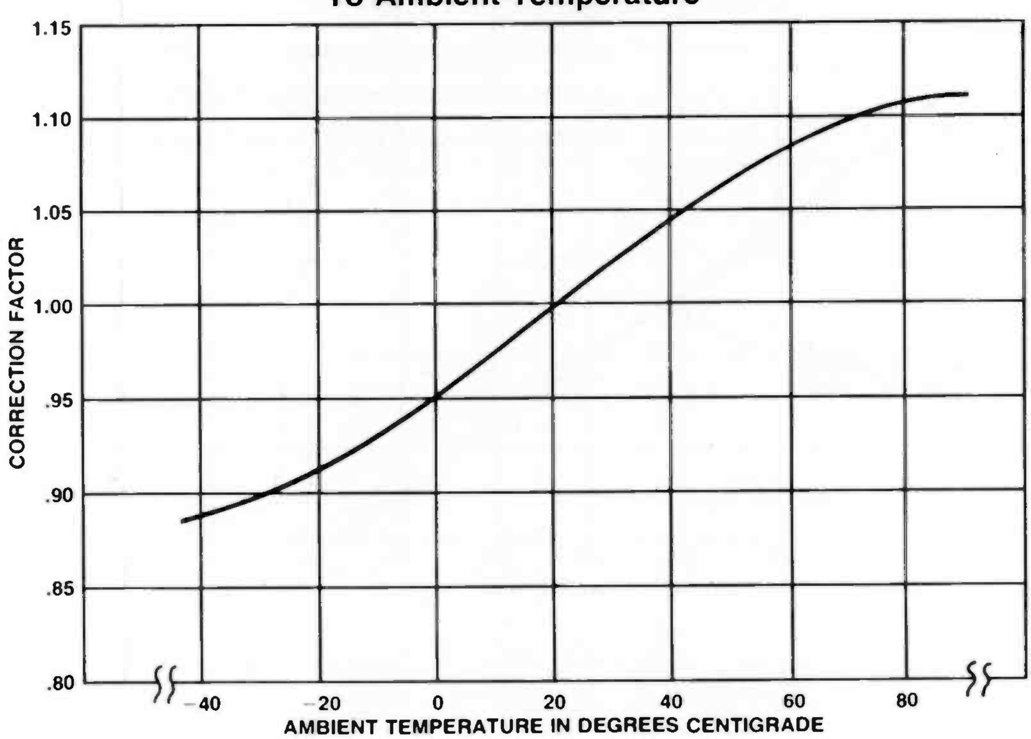


Figure 3
Insertion Loss Correction Due To Load VSWR

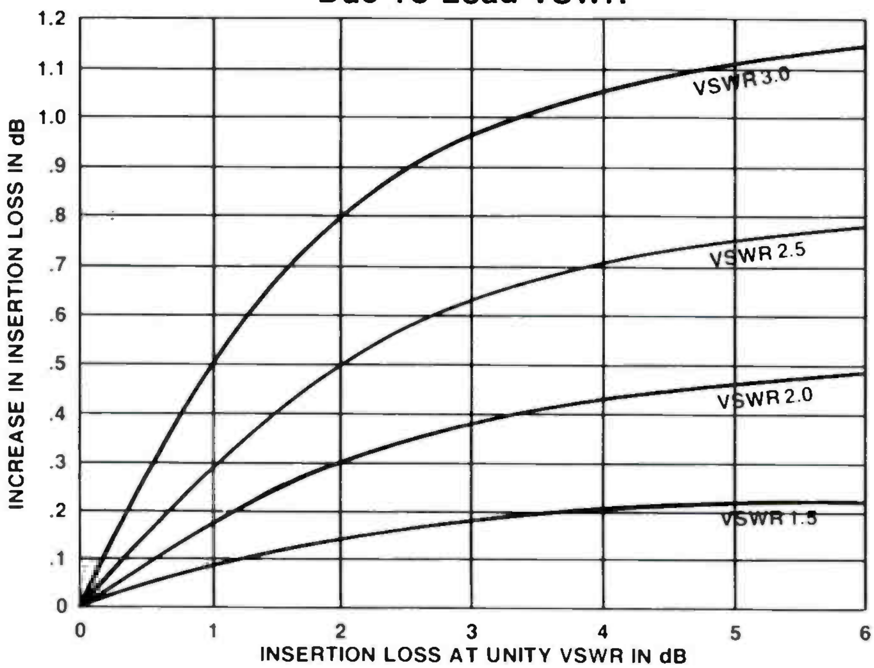


Figure 4
Variation Of Average Power Rating With Changes In Ambient Temperature

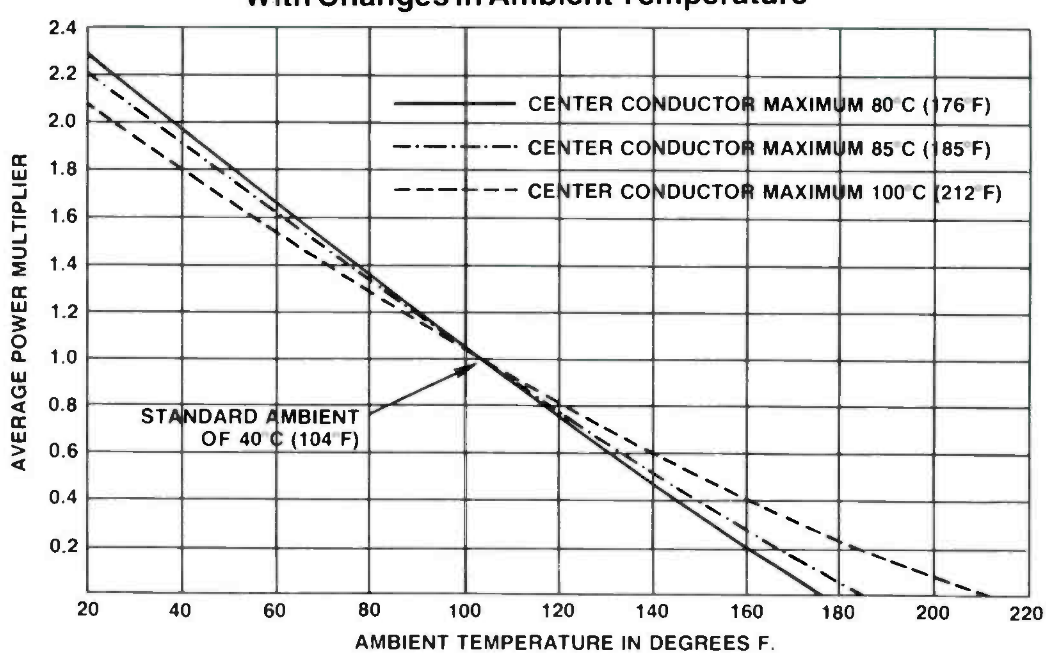


Figure 6
VSWR Derating Factor K_1 Versus Frequency

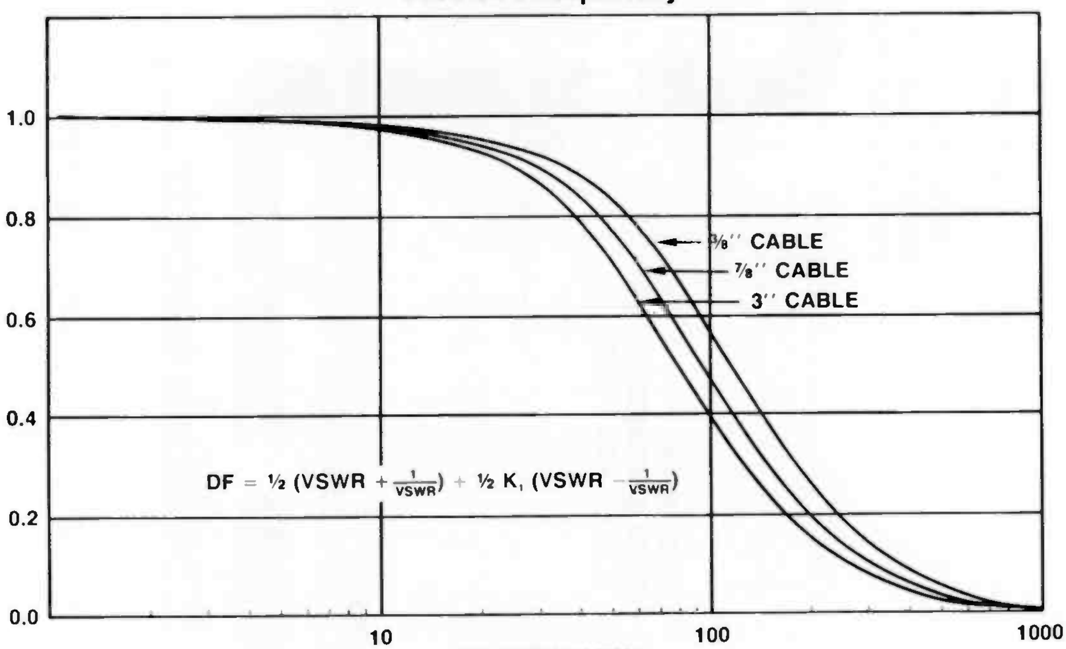


Figure 5
Peak Power Rating Improvement Due To Pressurization

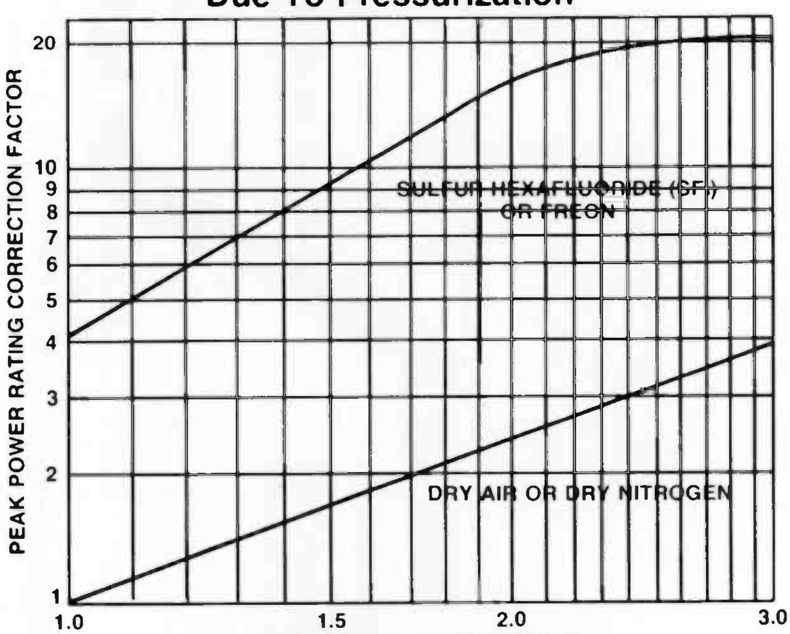
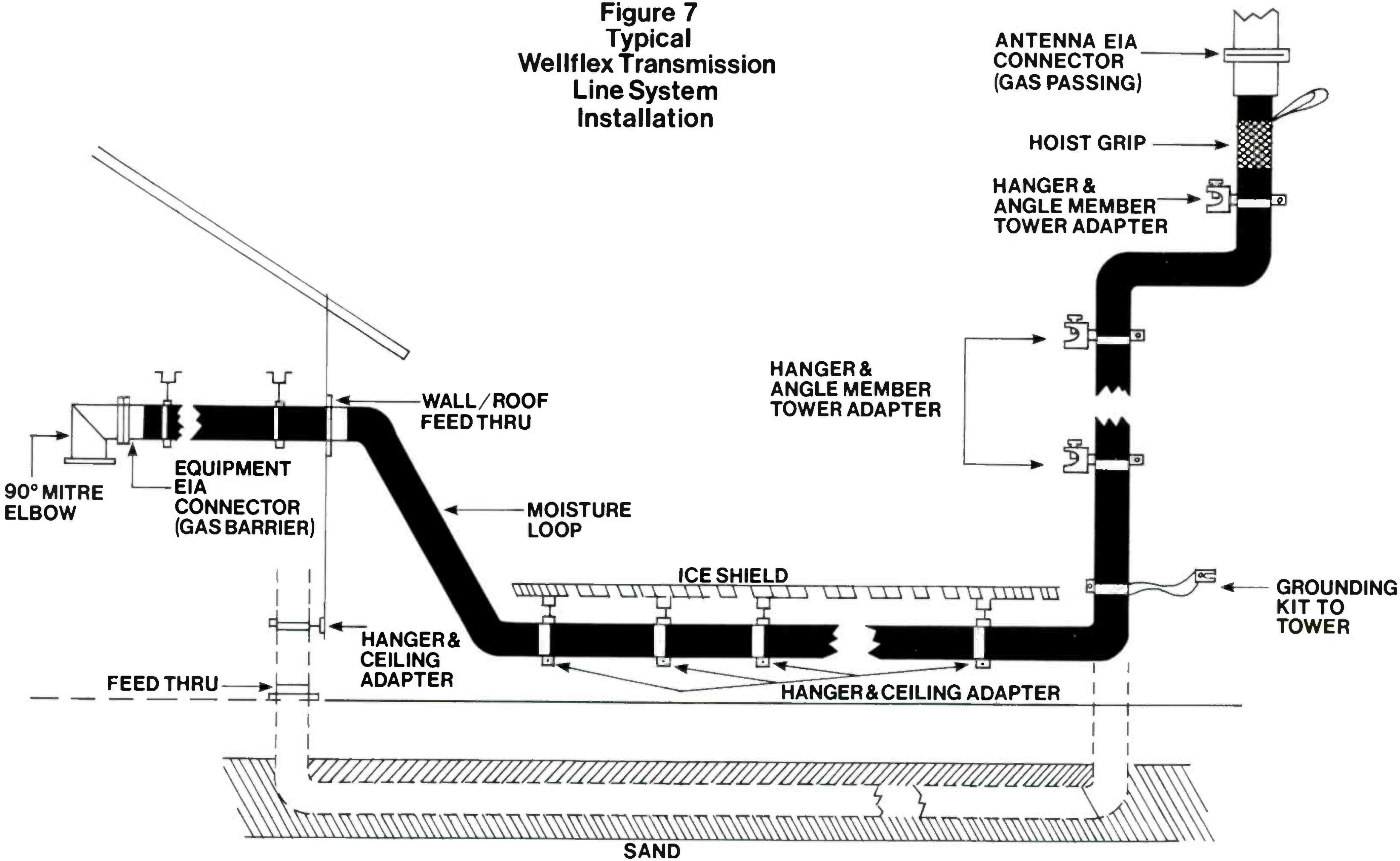


Figure 7
Typical
Wellflex Transmission
Line System
Installation



USEFUL COAXIAL FORMULAS

Characteristic Impedance

$$Zo = 60 \; Vp \; Ln \frac{D}{d} \quad \text{(or)} \quad \frac{60}{\sqrt{e}} \; Ln \frac{D}{d}$$

Velocity of Propagation

$$Vp \; (\%) = \frac{100}{\sqrt{e}}$$

Attenuation (dB/100 feet)

$$at = am + ad$$

$$am = \frac{0.0174}{Ln \frac{D}{d}} \left[\frac{\rho}{d} \; \& \; \frac{\rho}{D} \right] \sqrt{e} \; \sqrt{F \; (MHz)}$$

$$ad = 2.78 \sqrt{e} \quad Tan \; \delta \; r \quad F \; (MHz)$$

NOTE: ρ = 0.414 for copper
= 0.525 for aluminum

$Tan \; \delta \; r = 0.0003$

$$\text{Wavelength (ft)} = \frac{984}{F \; (MHz)}$$

$$\text{inches} = \frac{11801}{F \; (MHz)}$$

$$\text{Cutoff Frequency} = 90\% \; Fco = \frac{6760}{\sqrt{e} \; (D+d)} \; MHz$$

$$\text{Capacitance (picofarads/ft)} = \frac{16.9e}{\text{Ln}\ \frac{D}{d}}$$

$$\text{Inductance (microhenries/ft)} = 0.059\ \text{Ln}\ \frac{D}{d}$$

$$\text{Time Delay} = 1.016 \sqrt{e}\ \text{nanoseconds/ft}$$

D.C. Peak Voltage

$$Ep\ (kv) = \frac{G}{S}\ (.5)\ d\ \text{Logn}\ \frac{D}{d}$$

G = Air Dielectric 70 volts/mil
Foam Dielectric 60 volts/mil

S = Safety Factor = 1.75 Max. Test
4.0 Max. Operate

$$\text{Peak Power} = Ppk = \frac{Ep^2}{2\ Zo\ (1\ \&\ M)^2\ VSWR}\ \text{or}\ \frac{(Erf)^2}{2\ Z_o\ (1+M)^2 VSWR}\ \text{watts}$$

Ep = D.C. Test Voltage

Size	Air Cables	Foam Cables
1/2"	3,000	10,000
7/8"	6,000	15,000
1-5/8"	11,000	20,000
3.0"	16,000	

SYMBOL KEY

Zo = Characteristic Impedance

D = Inner Diameter of Outer Conductor (inches)

d = Outer Diameter of Inner Conductor (inches)

Vp = Velocity of Propagation

e = Dielectric Constant

F = Frequency in MHz

at = Total Loss (dB/100 ft)

am = Metal Losses (dB/100 ft)

ad = Dielectric Losses (dB/100 ft)

Tan r = Dissipation Factor (power factor)

G = Maximum Voltage Gradient of the Cable Insulation in Volts/Mil.

S = Safety Factor

VSWR = Standing Wave Ratio

M = Modulation Percentage in Decimal

Ln = Natural Log

Ep = Peak Voltage (DC)

Erf = Test Voltage X RMS X Correction Factor RMS .707 X Test Voltage to convert D.C. to R.F. Correction Factor = .7 (70% of Ep X RMS)

SECTION V

Product Information

Standard cables offered to the broadcast engineer by Cablewave Systems Inc. have been designed to provide the most efficient transfer of R.F. energy at broadcast frequencies. Wellflex air dielectric cables are available in outside diameters of 1/2", 7/8", 1-5/8" and 3.0". Wellflex foam dielectric cables are available in 3/8", 1/2", 7/8" and 1-5/8" O.D.

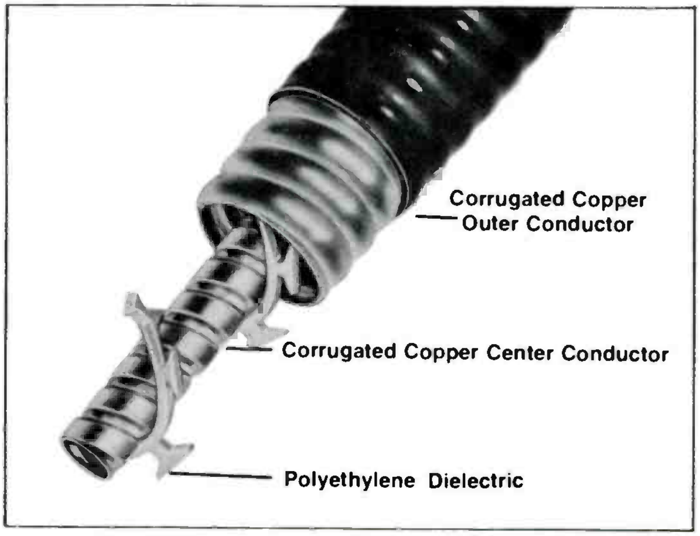
The unique design of CSI's copper corrugated outer conductor, special helix, or foam insulator, and copper inner conductor, results in a cable of low loss and excellent mechanical stability. Installation is extremely economical since the corrugated design is truly flexible with less fear of kinking or crushing.

Typical transmission line characteristics for Cablewave Systems Inc. air and foam Wellflex cable are tabulated on the next two pages. For complete details, send for Cablewave Systems Inc. Catalog No. 401 by telephoning or writing:

CABLEWAVE SYSTEMS INC.
60 Dodge Avenue
North Haven, Connecticut 06473
Telephone: 203 239-3311
TWX: 710-465-0244

WELLFLEX CABLES

7/8", 1-5/8" And 3" Air Dielectric Wellflex Coaxial Cable



Cablewave Systems air dielectric Wellflex coaxial cables achieve a combination of remarkable flexibility, rugged strength, and superior electrical performance. The cable design includes a corrugated tubular copper center conductor for 3.0" and 1-5/8", and solid copper clad aluminum for 7/8", spiral polyethylene dielectric, corrugated outer conductor, and a black polyethylene jacket. The special helix insulator construction contributes to low dielectric loss and excellent mechanical stability.

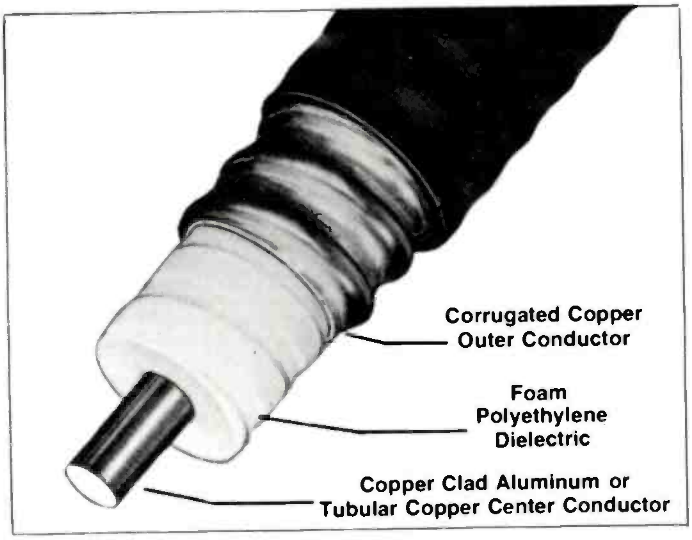
Air Dielectric	Characteristics		
Size	7/8"	1-5/8"	3.0"
Type No. Jacketed	HCC78-50J	HCC158-50J	HCC300-50J
Impedance - Ohms	50	50	50
Attenuation at 100 MHz — db/100 Feet	.36	.19	.13
Velocity %	91.5	95	96
Average Power at 100 MHz-kw	6.2	14.5	35.9
Bend Radius (Minimum-Inches)	10	20	30
Net Weight-Pounds Per Foot	.16	.915	1.75

All standard connectors available. EIA (Gas Passing or Gas Barrier), Splice. LCM, LCF, NM, NF, End Terminal, Reducers.*

*NOTE: See Cablewave Systems Inc. Catalog No. 401 for complete listing.

WELLFLEX CABLES

1/2", 7/8" And 1-5/8" Foam Wellflex Coaxial Cable



Cablewave Systems Foam Wellflex coaxial cables offer a combination of remarkable flexibility, high strength, and superior electrical performance. The designs include a copper clad aluminum (for 1/2" and 7/8") or a corrugated copper tube center conductor (for the 1-5/8" size), a low loss cellular polyethylene foam dielectric, corrugated copper outer conductor, and a protective black polyethylene jacket. Foam Wellflex is used widely in communications systems in the HF through microwave frequency range.

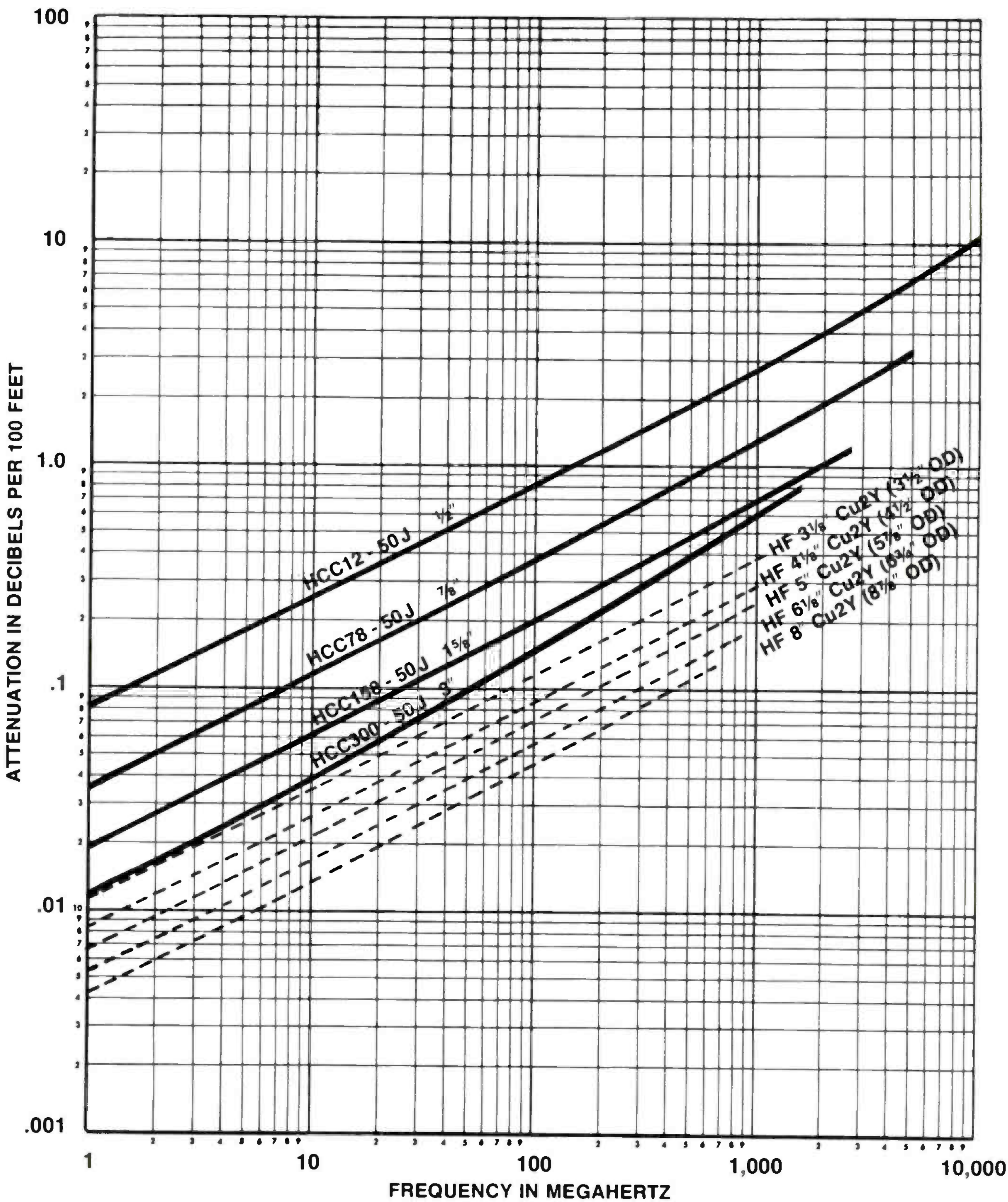
Foam Dielectric	Characteristics		
Size	1/2"	7/8"	1-5/8"
Type No. Jacketed	FCC12-50J	FCC78-50J	FCC158-50J
Impedance	50	50	50
Attenuation at 100 MHz — dB/100 Feet	.780	.458	.296
Velocity %	81	81	80
Average Power at 100 MHz-kw	2.24	4.88	10.2
Bend Radius (Minimum-Inches)	5	10	15
Net Weight-Pounds Per Foot	.157	.476	1.20

All standard connectors available. EIA, Splices, LCM, LCF, NM, NF, End Terminal, Reducers.*

*NOTE: See Cablewave Systems Inc. Catalog No. 401 for complete listing.

Air Wellflex Cable Attenuation

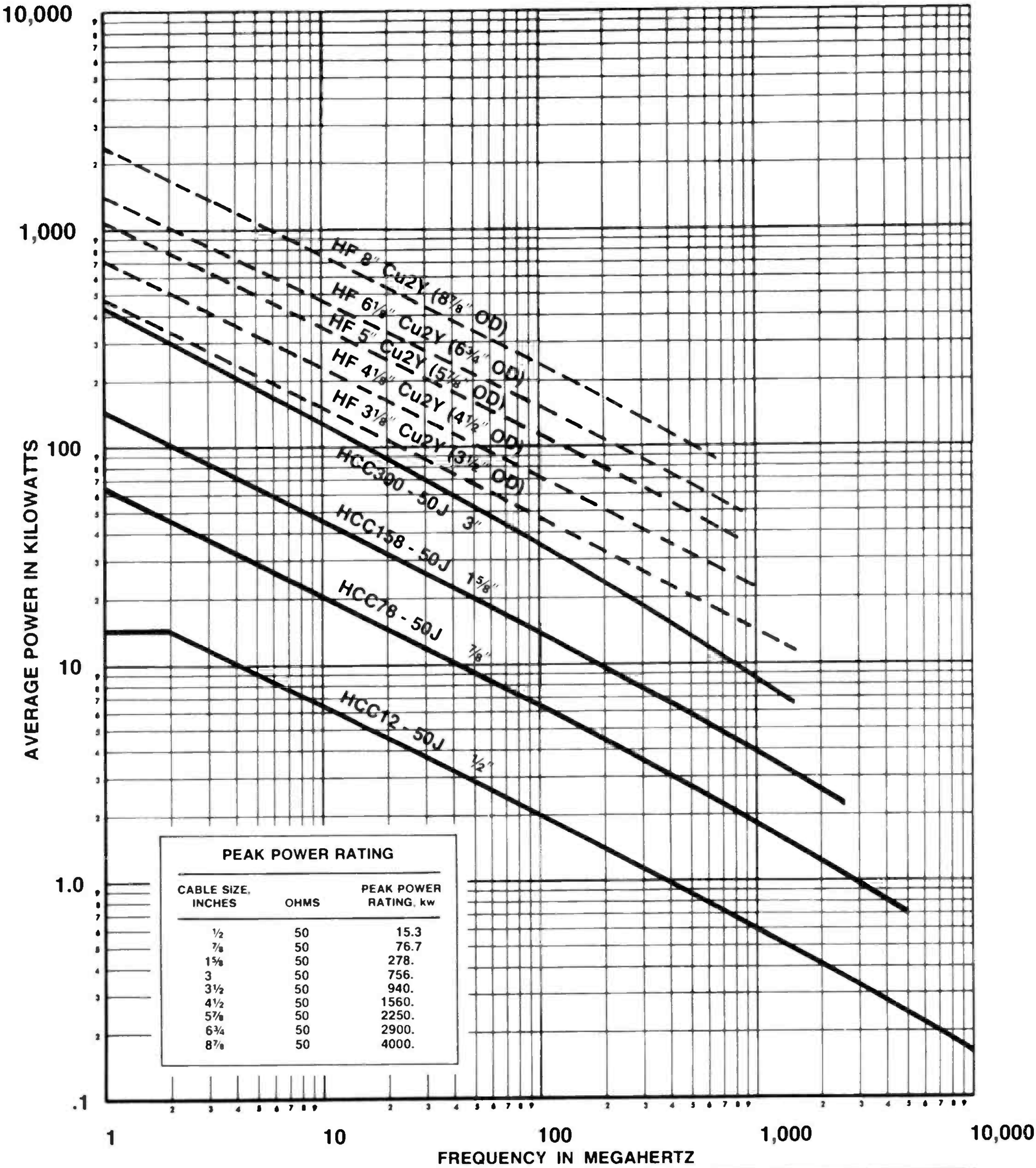
CORRUGATED COPPER/50 OHM/AIR DIELECTRIC



Attenuation curves based on:	Conversion Data:
Ambient Temperature 20°C (68°F)	1 db/100 feet = 3.28 db/100 meters
Unpressurized dry air (0 psig)	For 75 ohm cables, multiply by .94

Air Wellflex Average Power Rating

CORRUGATED COPPER/50 OHM/AIR DIELECTRIC



PEAK POWER RATING

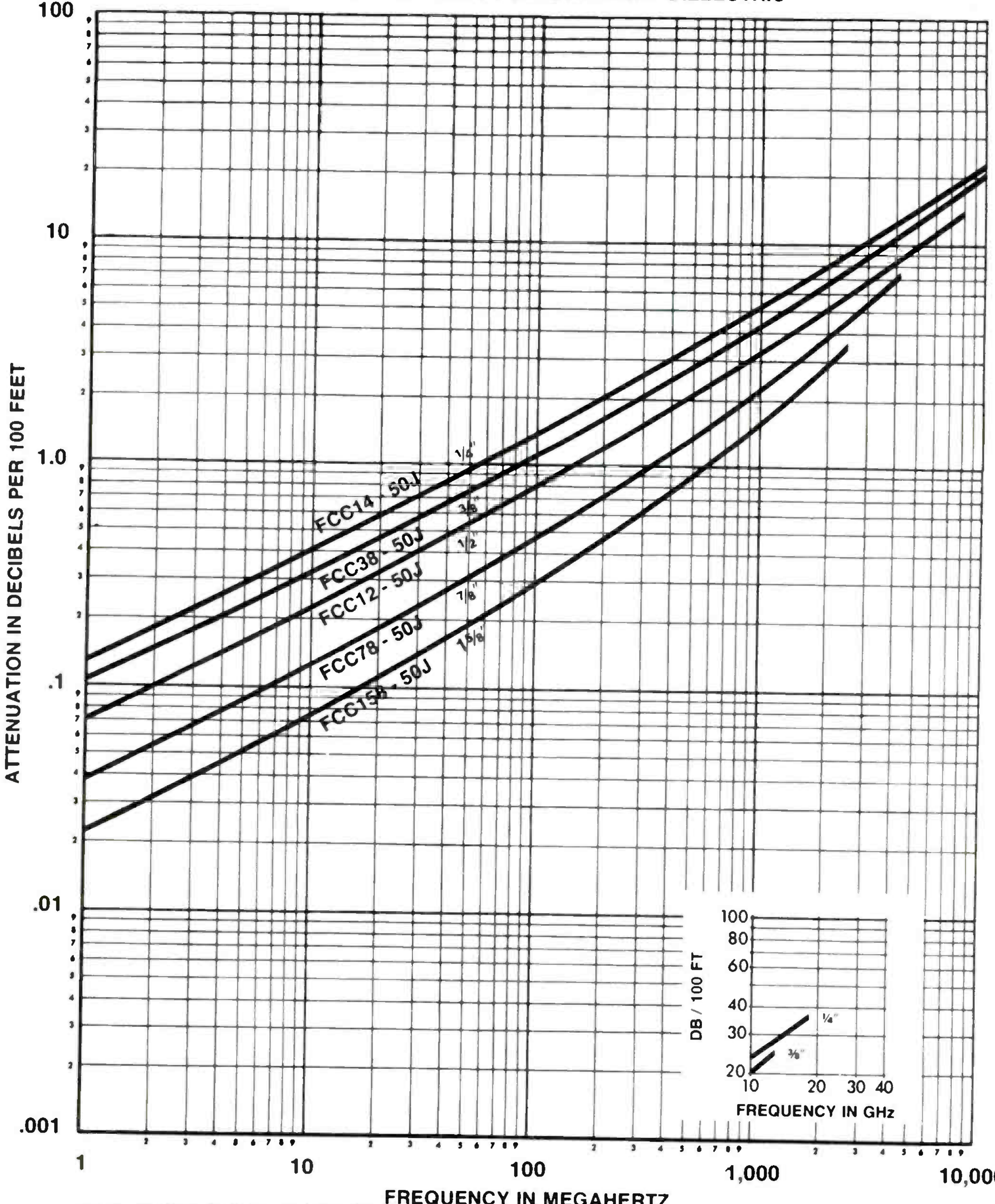
CABLE SIZE, INCHES	OHMS	PEAK POWER RATING, kw
½	50	15.3
⅞	50	76.7
1⅝	50	278.
3	50	756.
3½	50	940.
4½	50	1560.
5⅞	50	2250.
6¾	50	2900.
8⅞	50	4000.

Power ratings based on:
VSWR 1.0
Ambient Temperature 40°C(104F)
Unpressurized dry air (0 psig)

Conversion Data:
Ambient temperature 50°C(122F), multiply by .78 to .80
For 5 psig dry air pressure, multiply by 1.07
For 15 psig dry air pressure, multiply by 1.2

Foam Wellflex Cable Attenuation

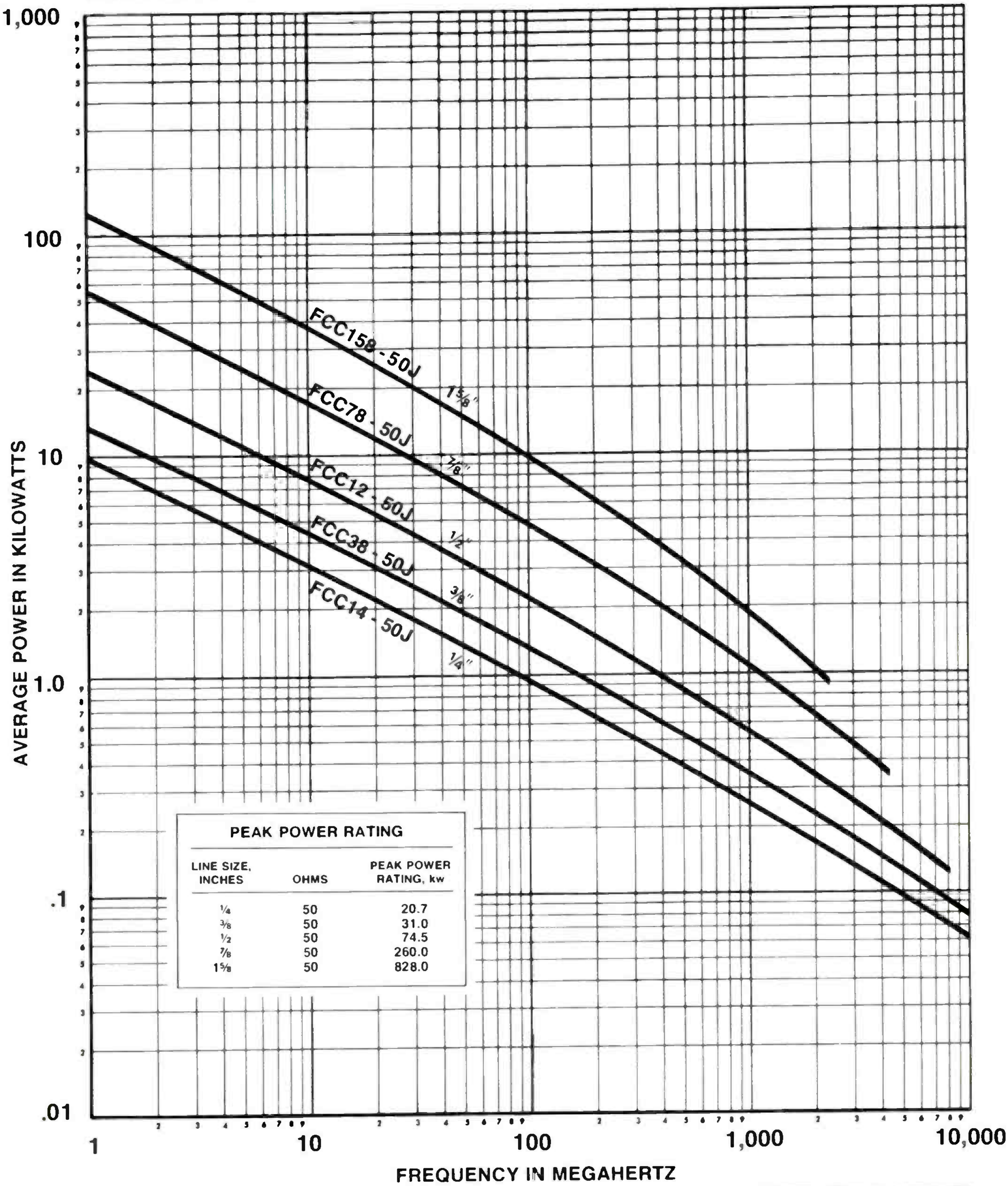
CORRUGATED COPPER/50 OHM/FOAM POLYETHYLENE DIELECTRIC



Attenuation curves based on: Ambient Temperature 20°C (68°F)	Conversion Data: 1 dB/100 feet = 3.28 dB/100 meters For aluminum outer conductors multiply by 1.06 For 75 ohm cables, multiply by .99

Foam Wellflex Average Power Rating

CORRUGATED COPPER/50 OHM/FOAM POLYETHYLENE DIELECTRIC



PEAK POWER RATING

LINE SIZE, INCHES	OHMS	PEAK POWER RATING, kw
¼	50	20.7
⅜	50	31.0
½	50	74.5
⅞	50	260.0
1⅝	50	828.0

Power ratings based on:
VSWR 1.0
Ambient Temperature 40°C (104°F)
Inner conductor temperature 80°C (176°F)

Conversion Data:
For ambient temperature 50°C (122°F), multiply by .75
For 75 ohm cables multiply by .71
For aluminum outer conductors multiply by .71

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Cablewave Systems Inc.

60 Dodge Avenue, North Haven, Connecticut 06473

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