Selecting a Transmission Line for Your Broadcast System

Introduction
This Bulletin presents the procedures broadcasters need for calculating attenuation and power handling parameters to properly design a broadcast transmission line system.

Three types of transmission lines are available for broadcast systems:

• **Semi-flexible Coaxial Transmission Lines** have two concentric conductors and are available with foam or air as a dielectric media.

• **Rigid Coaxial Transmission Lines** also have two concentric conductors and use air as a dielectric media.

• **Waveguides** are transmission lines which incorporate a single hollow conductor. Waveguides may be configured with a rectangular or circular cross section and also use air as a dielectric media.

Air-dielectric transmission lines have been generally accepted as the primary choice for broadcast applications because broadcast systems to this point have required high average power handling requirements. As the change is made to digital broadcast, foam cable may become more widely used, as specifications for systems may need modification.

Pressurization
Air-dielectric transmission lines should be maintained under positive pressure using dry air or dry nitrogen to prevent moisture condensation inside the line. If a positive dry pressure is not maintained inside the lines, "breathing" can occur, allowing moist air and dust to enter the line through the joints. The presence of moisture can lead to corrosion of the copper inner and outer conductors and can seriously degrade electrical performance. Pressurization values must not exceed the lowest component pressure rating in the transmission system (usually the antenna).

HELIAX® foam-dielectric coaxial cables have a closed-cell, foam dielectric that prevents water migration and pressurization is not required.

Transmission Line Characteristics
Table 1 shows the general characteristics of the most commonly used broadcast transmission line types with layout considerations.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Semi-flexible Coaxial Cable</th>
<th>Rigid Coaxial Line</th>
<th>Waveguide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Application</td>
<td>AM, HF, FM, LPTV</td>
<td>AM, HF, FM, LPTV, UHF-TV</td>
<td>UHF-TV</td>
</tr>
<tr>
<td>Pecise Layout Required</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Channelized Lengths</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Power Handling</td>
<td>Good</td>
<td>Better</td>
<td>Best</td>
</tr>
<tr>
<td>Attenuation</td>
<td>Good</td>
<td>Good/Lower</td>
<td>Lowest</td>
</tr>
<tr>
<td>Power Loading</td>
<td>Low/Medium</td>
<td>Low/Medium</td>
<td>Higher</td>
</tr>
<tr>
<td>Typical Hanger Type</td>
<td>SST Band</td>
<td>Spring Hanger</td>
<td>Spring Hanger</td>
</tr>
<tr>
<td>Typical Hanger Spacing</td>
<td>3-6 feet</td>
<td>10 feet</td>
<td>10-12 feet</td>
</tr>
<tr>
<td>Pressurization Required</td>
<td>Foam, No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Recommended Maintenance</td>
<td>Annual Inspection</td>
<td>Annual Inspection</td>
<td>Annual Inspection</td>
</tr>
<tr>
<td>Initial Material Cost</td>
<td>Most Economical</td>
<td>More Expensive</td>
<td>More Expensive</td>
</tr>
<tr>
<td>Initial Installation Cost</td>
<td>Lower</td>
<td>Higher</td>
<td>Higher</td>
</tr>
</tbody>
</table>
Coaxial Selection Criteria

Criteria used in the selection of broadcast transmission lines are:

- Operating frequency and bandwidth (single or multiple channel)
- Impedance
- Power handling capability
- Transmission efficiency (attenuation)

Careful review of each of these factors is necessary to make the best choice.

Frequency

Maximum frequency of operation in a transmission line is primarily a function of the diameter. Semi-flexible coaxial lines typically range in size from 1/4" to 9" diameter, rigid lines from 7/8" to 9-3/16" diameter, rectangular waveguide for UHF-TV frequencies from 5.25" x 11.5" (WR1150) to 9.0" x 18.0" (WR1800), and circular waveguides from 13" to 18" nominal diameter. The table shows that waveguide for broadcast applications is practical only for UHF applications, based on size considerations.

Impedance

Characteristic impedance for coaxial lines is a function of the ratio of the inner diameter of the outer conductor and the outer diameter of the inner conductor and the dielectric constant. The following equation expresses the relationship:

\[ Z_c = \left( \frac{60}{\sqrt{\varepsilon'}} \right) \ln \left( \frac{D}{d} \right) \]

where:
- \( Z_c \) = Characteristic impedance, ohms
- \( \varepsilon' \) = Dielectric constant = relative permittivity of dielectric (\( \varepsilon' = 1.0 \) for air dielectric)
- \( D \) = Inner electrical diameter of outer conductor, inches
- \( d \) = Outer electrical diameter of inner conductor, inches

Power Handling

Power handling in a broadcast transmission line is limited by the safe long term operating temperature of the dielectric support material and the heat produced by resistivity losses on the surface of the inner conductor and dielectric losses. This heat can cause the dielectric to soften and allow the inner conductor to move relative to the outer conductor. The result is a change in the impedance of the transmission line creating a mismatch, higher reflected power (increased VSWR), and degraded performance.

Attenuation

The corrugated construction of semi-flexible cable presents a curved path for the signal to travel, compared with a shorter, straight path for rigid line. For this reason, rigid line has slightly lower attenuation than semi-flexible cable. Also, more dielectric material is needed to maintain concentricity of the inner conductor of semi-flexible transmission line.

Attenuation and power performance of transmission line are affected by various external factors which should be taken into consideration. These factors include ambient temperature, load VSWR, line pressure, line VSWR, and modulation scheme.

Connector insertion loss is negligible for the connectors and frequencies used for broadcast and can, therefore, be ignored.

Attenuation and Power Ratings

Detailed attenuation and power ratings for HELIAX® air-dielectric coaxial cables, rigid coaxial lines, and GUIDELine® Waveguides, at broadcast frequencies, are tabulated in Bulletin SP50177.
Calculation Guide

Attenuation and power ratings should be adjusted for actual environmental conditions to obtain accurate system operating specifications. Mathematical procedures are provided below. Special attention should be given when comparing data from different manufacturers. The conditions chosen as standards may vary slightly and the published numbers may not be comparable. Each manufacturer also factors in a value for safe operation of its products. That factor may also vary from manufacturer to manufacturer based on material type, manufacturing technique, and component design.

Attenuation Rating and Efficiency

Attenuation expresses the ratio of output power to input power in decibels. It is determined by material properties and construction of the line:

\[ \alpha = \left( \frac{0.433}{Z_c} \right) \left[ \left( \frac{1}{D} \right) + \left( \frac{1}{d} \right) \right] \sqrt{T} \]

where:

- \( \alpha \) = Attenuation, dB/100 ft
- \( Z_c \) = Characteristic impedance, ohms
- \( f \) = Frequency, MHz
- \( D \) = Inner electrical diameter of outer conductor, inches
- \( d \) = Outer electrical diameter of inner conductor, inches

Note that attenuation is a minimum when \( D/d \) is equal to 3.59 resulting in an impedance of 77 ohms.

Line attenuation will vary with ambient temperature as shown in Figure 1.

Efficiency is a convenient expression for power loss of a transmission line. By definition, efficiency is the ratio of power which reaches the antenna to the transmission line input power, in percent:

\[ \text{Efficiency in percent} = \left( \frac{\text{Power Out}}{\text{Power In}} \right) \times 100\% \]

or:

\[ \text{Efficiency in percent} = \frac{100\%}{10^{-\left( \frac{\alpha}{10} \right)}} \]

where:

- \( \alpha \) = Total line attenuation in dB

The graph in Figure 2 is a convenient method for determining transmission line efficiency.
Load VSWR Effect on Total Transmission Loss
When the transmission line is attached to a load, such as an antenna, the VSWR of the load increases the total transmission loss of the system. This effect is quite small for normal conditions. Figure 3 shows the minimum increase in loss with load VSWR, assuming a VSWR of 1.0 at the input of the transmission line. This requires use of an input matching device.

Peak Power Rating
There are two power ratings for coaxial line, peak and average. The peak power rating is based on voltage breakdown considerations, and the average power rating is based on the maximum heating that the line construction can safely withstand. At VHF, FM, and UHF frequencies, coaxial transmission lines are average power limited, while the peak power rating is usually the limiting factor in amplitude modulation (AM) applications at medium frequency (MF). For AM high frequency (HF) applications, the line may be either average or peak power limited depending on the conditions.

Peak power is the maximum RF power which can be reached in a short interval (a few RF cycles). Note that this is not the instantaneous power when the RF voltage is at a maximum. It is actually the power averaged over an RF cycle. Therefore, peak refers to the peak amplitude of modulation. In a continuous wave carrier (including FM), peak power equals average power.

A conservative method of determining peak power ratings is to use the following equation:

\[ P_{PK} = \left( \frac{E_p \times 0.707 \times 0.7}{1.4} \right)^2 \frac{1}{Z_c} \]

where:
- \( P_{PK} \) = Cable peak power rating, standard conditions, kW
- \( E_p \) = DC production test voltage, volts
- 0.707 = RMS factor
- 0.7 = DC to RF factor (empirically verified)
- 1.4 = Safety factor on voltage
- \( Z_c \) = Characteristic impedance, ohms

An adequate safety factor on peak power is necessary to safeguard against voltage breakdown, which can result in permanent damage to the cable. Manufacturers of coaxial cables may use different safety factors for published peak power ratings, so this should be taken into account when comparing catalog values.

Peak power ratings can be increased by pressurization above atmospheric pressure levels, by using high density gases with high dielectric strength, or by combining these two methods. See Figure 4 for the effects.

⚠️ Caution. Insure that antenna and transmission line system can safely withstand any increased pressure applied. If system operation depends on increased pressurization, loss of pressure may destroy both antenna and transmission line. Operation of transmission line at higher than rated power without compensating pressure will void warranty.

Figure 3 - Effect of Load VSWR on Transmission Loss
Figure 4 - Pressurization Factors
Peak power ratings for semi-flexible cable must be derated for VSWR and modulation technique. Rated transmitter power must be less than the calculated derated peak power of the semi-flexible coaxial cable for safe operation. The table below shows methods for derating peak power for modulation and VSWR:

**Peak Power Derating for Modulation and VSWR**

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Peak Power Derating Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>$P_t &lt; \frac{P_{PK}}{(1+M)^2} VSWR$</td>
</tr>
<tr>
<td>FM and DTV</td>
<td>$P_t &lt; \frac{P_{PK}}{VSWR}$</td>
</tr>
<tr>
<td>Analog TV</td>
<td>$P_t &lt; \frac{P_{PK}}{(1+AU+2\sqrt{AU}) VSWR} = \frac{P_{PK}}{(2.09) VSWR}$</td>
</tr>
</tbody>
</table>

where:

- $P_t$ = Rated transmitter power
- $P_{PK}$ = Peak power rating of cable
- $M$ = Amplitude modulation index
- $AU$ = Aural to visual ratio (example, 20% Aural: $AU = 0.2$)
- 2.09 = Modulation derating factor for TV for $AU = 0.2$

**Average Power Rating**

Average power is the power in the signal capable of creating heat. Average power ratings of transmission lines are based on the maximum inner conductor temperature which will permit safe, long-term performance for the particular dielectric material used. Since the average power rating is limited by heating, which is created by line losses, it decreases with increasing frequency.

The average power applied to a transmission line is dependent on the nominal continuous wave power of the transmitter and the type of modulation. The table below shows the different modulation schemes:

**Transmitter Average Power Calculations**

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Average Power Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF, AM</td>
<td>$P_{AVE} = P_C \cdot [1+(M^2/2)]$</td>
</tr>
<tr>
<td>FM and DTV</td>
<td>$P_{AVE} = P_t$</td>
</tr>
<tr>
<td>Analog TV</td>
<td>$P_{AVE} = 0.80 P_{TV}$ *</td>
</tr>
</tbody>
</table>

where:

- $P_{AVE}$ = Average transmitter power (visual & aural)
- $P_C$ = Carrier power
- $M$ = Amplitude Modulation index
- $P_t$ = FM transmitted power
- $P_{TV}$ = TV peak of sync power

Commercial AM (530-1610 kHz) is usually peak power limited.

* For TV average power the factor of 0.80 is based on a totally black picture where 60% of the peak power is for the visual carrier and 20% of the peak power is for the aural carrier. A more typical value is 0.70 where 10% is for the aural carrier.

Average power must be derated for ambient temperature, VSWR, and solar radiation. Cable attenuation and average power ratings are given for particular operating conditions that are not likely to be representative of typical applications. The average power rating should be adjusted according to the actual ambient temperature condition relative to the location of the installation. See Figure 5.
Average power should also be derated for VSWR. The derating factor (D.F.) is calculated from the formula given below where \( F' \) is a factor that varies with frequency and line size.

\[
D.F. = \frac{(VSWR^2 + 1)}{2(VSWR)} + \frac{F'(VSWR^2 - 1)}{2(VSWR)}
\]

This calculation of derating factor is conservative in that it assumes that all reflected power is re-reflected at the transmitter and absorption of the reflected signal by line attenuation is small. See Figure 6.

Finally, solar radiation reduces the average power handling capability of transmission line. Derating factors are shown in Figure 7.

The average radiation intensity for moderate climates is 300 W/m² or less. Hot, dry climates give solar radiation intensities which at the hottest time of day can be 1000 W/m² or higher. The mean value over the day, which is applicable to average power derating calculations provided absolute maximum temperatures are not exceeded, is about 400 W/m². Hot, dry locations are also subject to elevated ambient temperatures, which must be considered as well.

Waveguide Selection Criteria

Waveguide “guides” the electric and magnetic fields of the traveling wave within its conducting surface. The following forms of waveguide for UHF broadcast applications are typical:

- **Rectangular Waveguide**: generally aluminum construction, with a width to height ratio of 2:1, ranging in size from 11.5” x 5.75” (WR1150) to 18” x 9” (WR1800).

- **Circular Waveguide**: also aluminum construction, with diameters ranging from approximately 13” to 18”.

- **Truncated Waveguide**: an aluminum hybrid of rectangular and circular consisting of a special interior shape (between circular and rectangular) surrounded by a cylindrical cover to reduce wind loading on the tower.

Other than UHF television, waveguide is rarely used for broadcast applications because it is larger in size than coaxial transmission line. The main criteria for selection, then are the power handling capability and transmission efficiency (attenuation) required for a particular system.

Power Handling

The single tube construction of waveguide provides high power handling capacity. There is no inner conductor to heat up, no dielectric support material to soften, and a large surface area over which the I²R losses can be dissipated. Applications of up to 360 kW are possible, and waveguide is the only practical way to deliver such power levels to the antenna.

Attenuation

The absence of dielectric support materials together with propagation at waveguide modes reduces attenuation to values well below that of large rigid coaxial line. The lower attenuation of waveguide translates to high efficiency according to the formula previously cited:

\[
\text{Efficiency in percent} = 100\% \left(\frac{\alpha}{10}\right)
\]

where:

- \( \alpha \) = Total line attenuation in dB

The power lost in the line is dissipated as heat.
Example 1

A class B FM station has the following design parameters:

- Frequency: 98.1 MHz
- ERP: 50 kW
- Tower height: 517 ft
- Coaxial cable length: 486 ft
- Temperature: 86°F (30°C)
- VSWR, Antenna: 1.5
- Connectors: 3-1/8” EIA

The antenna manufacturer specifies that the input power to the antenna should be 15.16 kW to achieve the desired ERP.

Calculate attenuation, peak power rating, average power rating and efficiency for both Types HJ8-50B and HJ12-50.

**Calculations for HJ8-50B**

Obtain the following specifications from Bulletin SP50177:

- Attenuation at 98.1 MHz, dB/100ft: 0.140
- Peak Power, kW: 640
- Average Power @ 98.1 MHz, kW: 42.88

**Attenuation**

1. Total attenuation of transmission line run based on standard conditions at given frequency.
   \[ \alpha_{TOT} = \alpha \times L \]
   \[ \alpha_{TOT} = 0.140 \text{ dB/100 ft} \times 486 = 0.6804 = 0.68 \text{ dB} \]

2. Adjust for ambient temperature.
   Note: Andrew specifications for air-dielectric cable and rigid line are given for 68°F (20°C). Other manufacturers may rate their products at different standard conditions. This is important to remember when comparing products from different manufacturers.
   Ambient temperature = 86°F (30°C), correction factor from table = 1.015
   \[ \alpha_{TOT} \times \text{correction factor} = 0.68 \text{ dB} \times 1.015 = 0.6902 = 0.69 \text{ dB} \]

3. Derate for load VSWR. The effect of load VSWR is slight. From Figure 3 the added loss is approximately 0.04 dB.

4. Effect of connectors. For 3-1/8” EIA flanges the effect is negligible. Assume 0.

5. Adjust attenuation rating.
   \[ 0.69 \text{ dB} + 0.04 \text{ dB} = 0.73 \text{ dB} \]

**Peak Power**

For FM broadcast frequencies coaxial transmission lines are typically average power limited, so it is not necessary to adjust peak power ratings for pressurization effects. Verify this to insure that there are no problems.

1. The peak power based on standard conditions is 640 kW.

2. Derate for modulation techniques and load VSWR.
   \[ P_{MAX} = \frac{P_{PK}}{VSWR} = \frac{640}{1.5} = 426.67 \text{ kW} \]

3. Connector effects. 3-1/8” EIA connectors are rated for 902 kW, significantly greater than required.

**Average Power**

1. Average power based on standard conditions at operating frequency: 42.88 kW

2. Derate for modulation technique. The derating factor to convert rated transmitter power to average power for FM radio is 1.0. Therefore it is not necessary to correct for modulation technique.

3. Adjust for ambient temperature.
   The ambient temperature factor from Figure 5 is 1.15
   \[ 42.88 \times 1.15 = 49.312 \text{ kW} \]

4. Derate for load VSWR.
   \[ D.F. = \frac{VSWR^2 + 1}{2(VSWR)} + \frac{F' (VSWR^2 - 1)}{2(VSWR)} \]

   From Figure 6, \( F' = 0.35 \) for 3” cable @98.1MHz.
   \[ \therefore D.F. = 1.23 \]

   Average power rating @1.5 VSWR and 30°C = 49.312/1.23 = 40.09 kW

5. The effect of the 3-1/8” EIA brass connectors is negligible.
**Efficiency**

From Figure 2, 0.7 dB attenuation is equivalent to 84.5% efficiency.

Efficiency is the percent of transmitter power which reaches the antenna. At 84.5% efficiency, the transmitter output power would need to be:

\[
\frac{15.16}{0.845} = 17.9 \text{ kW}
\]

The average power rating, calculated above, is higher than the required 17.9 kW. The 3" cable is, therefore, acceptable on the basis of power handling.

**Calculations for HJ12-50**

Obtain the following specifications from Bulletin SP50177:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attenuation at 98.1 MHz, dB/100 ft</td>
<td>0.167</td>
</tr>
<tr>
<td>Peak Power, kW</td>
<td>425</td>
</tr>
<tr>
<td>Average Power @98.1 MHz, kW</td>
<td>23.33</td>
</tr>
</tbody>
</table>

**Attenuation**

1. Total attenuation of transmission line run based on standard conditions at given frequency.

\[
\alpha_{\text{TOT}} = \alpha \times L
\]

\[
\alpha_{\text{TOT}} = 0.167 \text{ dB/100 ft} \times 486 = 0.8116 = 0.81 \text{ dB}
\]

2. Adjust for ambient temperature.

Note: Andrew specifications for air-dielectric cable and rigid coaxial lines are given for 75°F (24°C). Other manufacturers may rate their products at different standard conditions. This is important to remember when comparing products from different manufacturers.

Ambient temperature = 86°F (30°C), correction factor from table = 1.015

\[
\alpha_{\text{TOT}} \times \text{correction factor} = 0.81 \text{ dB} \times 1.015 = 0.8222 = 0.82 \text{ dB}
\]

3. Derate for load VSWR. The effect of load VSWR is slight. From Figure 3 the added loss is approximately 0.04 dB.

4. Effect of connectors. For 3-1/8" EIA flanges the effect is negligible. Assume 0.

5. Adjust attenuation rating.

\[
0.82 \text{ dB} + 0.04 \text{ dB} = 0.86 \text{ dB}
\]

**Peak Power**

For FM broadcast frequencies coaxial transmission lines are typically average power limited, so it is not necessary to adjust peak power ratings for pressurization effects. Verify this to insure that there are no problems.

1. The peak power based on standard conditions is 425 kW.

2. Derate for modulation techniques and load VSWR.

\[
P_{\text{max}} = \frac{P_{\text{pk}}}{\text{VSWR}} = \frac{425}{1.5} = 283.33 \text{ kW}
\]

3. Connector effects. 3-1/8" EIA connectors are rated for 902 kW, significantly greater than required.

**Average Power**

1. Average power based on standard conditions at operating frequency: 23.33 kW

2. Derate for modulation technique. The derating factor to convert rated transmitter power to average power for FM radio is 1.0. Therefore it is not necessary to correct for modulation technique.

3. Adjust for ambient temperature.

The ambient temperature factor from Figure 5 is 1.15

\[
23.33 \times 1.15 = 26.83 \text{ kW}
\]

4. Derate for load VSWR.

\[
\text{D.F.} = \frac{(\text{VSWR}^2+1) + F' (\text{VSWR}^2-1)}{2(VSWR)}
\]

From Figure 6, \(F' = 0.37\) for 2-1/4" cable @98.1 MHz.

\[
\therefore \text{D.F.} = 1.24
\]

Average power rating @1.5 VSWR and 30°C = 26.83/1.24 = 21.64 kW

5. The effect of the 3-1/8" EIA brass connectors is negligible.
Efficiency
From Figure 2, 0.9 dB attenuation is equivalent to 81% efficiency.

Efficiency is the percent of transmitter power which reaches the antenna. At 81% efficiency the transmitter output power would need to be:

\[ 15.16/0.81 = 18.72 \text{ kW} \]

The average power rating, calculated above, is higher than the required 18.72 kW. The 2-1/4” cable is, therefore acceptable on the basis of power handling.

Example 2
A TV Station currently operates a channel 20, Andrew TRASAR® antenna for its analog channel. The maximum ERP is 2421 kW visual + 10% (242.1 kW) aural. The peak gain of the antenna is 47.00 and the maximum VSWR = 1.10. The transmission line is a 1250 foot run of HRL875, 8-3/16”, 75-ohm, rigid line. In the next five years the station will begin operating an Andrew ALP24M3-HSER-21 for its DTV channel 21. The FCC has assigned a 78.2 kW ERP for the DTV channel. The engineer intends to use HJ12-50 to feed the antenna. The ambient temperature, where the station is located, is 86 °F (30°C).

For both channels, calculate the antenna input power, attenuation, average power, and efficiency. Neglecting the cost of power from the power company, is HJ7-50A an appropriate choice of transmission line?

Antenna
Before looking at the transmission lines, let’s consider the input power to each antenna. We are given that the TRASAR® antenna peak power gain is 47.00 and the ERP is 2421 kW peak of sync visual + 242.1 kW for aural. The power input to the antenna is then obtained in the following manner:

\[ P_{IN} = \text{ERP}/\text{Gain}_{PK} = 2421/47.00 = 51.5106 = 51.5 \text{ kW} \]

peak of sync visual

And, 242.1/47.00 = 5.1511 = 5.15 kW aural

where \( P_{IN} \) = input power

\( \text{Gain}_{PK} \) = Peak Gain

Therefore, the input power is 51.5 kW peak of sync visual + 5.15 kW aural for the analog power.

We also know, from the manufacturer’s catalog, that the ALP24M3-HSER-21 antenna has a peak power gain of 48.66. The ERP assigned is 78.2 kW, and this is based on DTV average power. Again, the power input to the antenna is obtained in the following manner:

\[ P_{IN} = \text{ERP}/\text{Gain}_{PK} = 78.2/48.66 = 1.6071 = 1.61 \text{ kW} \]

(DTV) average power

Therefore, the input power is 1.61 kW.

This information will be important when judging the power ratings of the transmission line.

Calculations for HRL875, 8-3/16” HRLLine

<table>
<thead>
<tr>
<th>Attenuation @ 507.25 MHz, dB/100ft</th>
<th>0.100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Power, kW</td>
<td>1800.00</td>
</tr>
<tr>
<td>Peak of Sync Power, kW</td>
<td>122.00</td>
</tr>
<tr>
<td>Average Power @ 507.25 MHz, kW</td>
<td>85.20</td>
</tr>
</tbody>
</table>

Attenuation
1. Total attenuation of transmission line run based on standard conditions at given frequency.

\[ \alpha_{TOT} = \alpha \times L \]

\[ \alpha_{TOT} = 0.100 \text{ dB/100 ft} \times 1250 = 1.25 \text{ dB} \]

2. Adjust for ambient temperature.

Note: Andrew specifications for Air Dielectric HELIAX® and Rigid Transmission lines are given for 68°F (20°C). Other manufacturers may rate their products at different standard conditions. This is important to remember when comparing products from different manufacturers.

Ambient temperature = 86°F (30°C), correction factor from table = 1.015

\[ \alpha_{TOT} \times \text{correction factor} = 0.68 \text{ dB} \times 1.015 = 1.2688 = 1.27 \text{ dB} \]

3. Derate for load VSWR.

The effect of load VSWR is negligible. From Figure 3 the added loss is negligible.

4. Connector effects are negligible.

5. Adjust attenuation rating.

Therefore, the attenuation is 1.27 dB
Peak Power
1. The peak power based on standard conditions is 1800 kW.

2. Derate for modulation techniques and load VSWR.
   \[ P_{\text{MAX}} = \frac{P_{\text{PK}}}{(1 + \alpha_U + 2\sqrt{\alpha_U})VSWR} \]
   \[ = \frac{1800}{(1.7325) \times 1.1} = 1142.8571 = 1143 \text{ kW} \]

In this example the aural to visual ratio (AU) is 0.1 because we are given that the aural is 10% of the visual.

3. Connector effects are, again, negligible.

Average Power
1. The TV peak of sync power, or \( P_{TV} \), based on standard conditions at operating frequency:
   \[ 122.00 \text{ kW} \]

2. Derate for modulation technique.
   The derating factor to convert rated transmitter power to average power for analog television in this case is 0.7 because we are using only 10% aural power.
   \[ P_{AVG} = 0.7P_{TV} = 0.7(123.50) = 85.20 \text{ kW} \]

3. Adjust for ambient temperature.
   Once again, the ambient temperature factor from Figure 5 is 1.15.
   \[ 85.20 \times 1.15 = 97.98 \text{ kW} = 98.0 \text{ kW} \]

4. Derate for load VSWR.
   \[ \text{D.F.} = \left( \frac{VSWR^2 + 1}{2VSWR} \right) + \frac{F'(VSWR^2 - 1)}{2(VSWR)} \]
   From Figure 6, \( F' = 0.02 \) for 8-3/16" rigid line @507.25 MHz.
   \[ \therefore \text{D.F.} = 1.0065 = 1.01 \]

   Average power rating @1.1 VSWR and 30°C = 98/1.01 = 97.0297 kW = 97.0 kW

Efficiency
From Figure 2, 1.27 dB attenuation is equivalent to 74.5% efficiency. Let's see what the average transmitter power is.

Continuing, the peak of sync visual is 51.5 kW. Recall that efficiency determines the percent of transmitter power which reaches the antenna. At 84.5% efficiency the transmitter output power would need to be:

\[ 51.5/0.745 = 69.1275 = 69.1 \text{ kW} \]

The average power rating, calculated previously, is greater than the required 69.1 kW. The HRL875 is, therefore, acceptable on the basis of power handling.

Calculations for HJ12-50
Obtain the following specifications from the table:

- Attenuation @513.25 MHz, dB/100ft: 0.406
- Peak Power, kW: 425
- Average Power @513.25 MHz, kW: 9.62

Attenuation
1. Total attenuation of transmission line run based on standard conditions at given frequency.
   \[ \alpha_{\text{TOT}} = \alpha x L \]
   \[ \alpha_{\text{TOT}} = 0.406\text{dB/100} \times 1200 = 4.8720 = 4.87 \text{ dB} \]

2. Adjust for ambient temperature.
   Note: Andrew specifications for air-dielectric cable and rigid coaxial lines are given for 68°F (20°C). Other manufacturers may rate their products at different standard conditions. This is important to remember when comparing products from different manufacturers.
   \[ \text{Ambient temperature} = 86°F (30°C), \text{correction factor from table} = 1.015 \]
   \[ \alpha_{\text{TOT}} \times \text{correction factor} = 4.87 \text{ dB} \times 1.015 = 4.9431 \]
   \[ = 4.94 \text{ dB} \]

3. Derate for load VSWR. The effect of load VSWR is slight. From Figure 3, the added loss is approximately 0.04 dB.

4. Effect of connectors. For 3-1/8" EIA flanges, the effect is negligible. Assume 0.

5. Adjust attenuation rating.
   \[ 4.94 \text{ dB} + 0.04 \text{ dB} = 4.98 \text{ dB} \]

Peak Power
For DTV, like FM broadcast frequencies, coaxial transmission lines are typically average power limited, so it is
not necessary to adjust peak power ratings for pressurization effects. Verify this to insure that there are no problems.

1. The peak power based on standard conditions is 425 kW.

2. Derate for modulation techniques and load VSWR.

\[ P_{\text{MAX}} = \frac{P_{\text{PK}}}{\text{VSWR}} = \frac{425}{1.5} = 283.33 \text{ kW} \]

3. Connector effects. 3-1/8" EIA connectors are rated for 902 kW, significantly greater than required.

Average Power

1. Average power based on standard conditions at operating frequency: 9.62 kW

2. Derate for modulation technique. The derating factor to convert rated transmitter power to average power for DTV is 1.0. Therefore, it is not necessary to correct for modulation technique.

3. Adjust for ambient temperature.
   The ambient temperature factor from Figure 5 is 1.15.

\[ 9.62 \times 1.15 = 11.06 = 11.1 \text{ kW} \]

4. Derate for load VSWR.

D.F. = \( \frac{(\text{VSWR}^2+1)}{2(\text{VSWR})} + \frac{F'(\text{VSWR}^2-1)}{2(\text{VSWR})} \)

From Figure 6, \( F' = 0.04 \) for 2-1/4" cable @513.25 MHz.
\[ \therefore \text{D.F.} = 1.01 \]

Average power rating @1.1 VSWR and 30°C =
\[ 11.1/1.01 = 10.99 = 11.0 \text{ kW} \]

5. The effect of the 3-1/8" EIA brass connectors is negligible.

Efficiency

Using the equations for Efficiency, 4.98 dB attenuation is equivalent to 34.59% efficiency.

Efficiency determines the percent of transmitter power which reaches the antenna. At 31.8% efficiency, the transmitter output power would need to be:

\[ 11.0/0.318 = 34.59 \text{ kW} \]

The average power rating, calculated above, is significantly lower than the required 34.59 kW. The 2-1/4" cable is, therefore, not acceptable on the basis of power handling. Also, the transmission line is highly inefficient for this application.