APPLICATION NOTE

Three Key Cabling Decisions to Optimize RF System Performance

Introduction

Cable selection for optimal RF system performance must take into account cable type as well as length. Connector type is a third significant consideration. This application note provides background, guidelines, and resources to enable you to make the best choice for your system and avoid common problems resulting from improper cable selection.

Background

The RF cable, also called the *transmission line*, transports energy from the RF power supply to the matching network. The goal in cable selection is to reduce loss as much as possible and to match the impedances that the cable connects. Coaxial cable (*coax*), readily available at 50 Ω, is commonly used with RF power supplies. Cable construction, length, and connector type are key factors to consider when choosing cabling in an RF system.

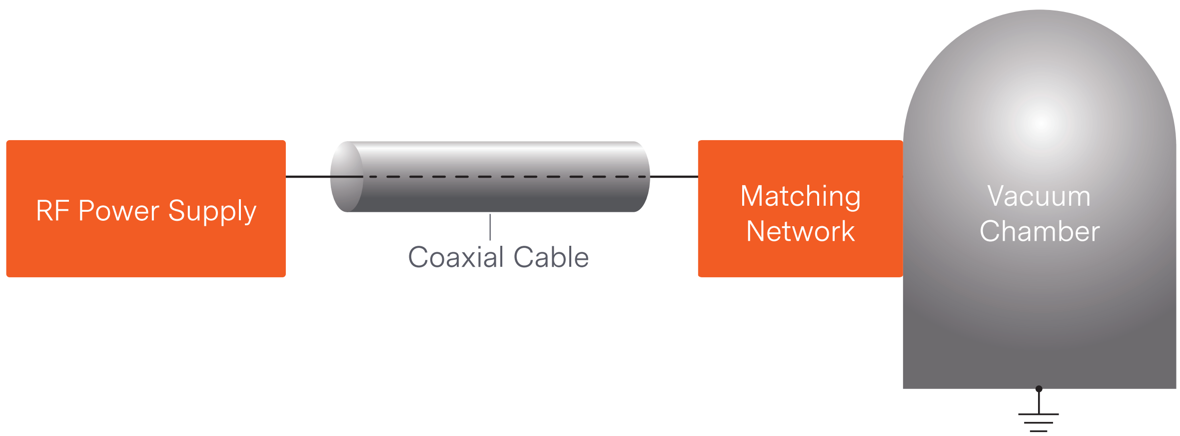

Figure 1. Ideal RF system setup.

Arcing, Interference, and Reflected Power: Potential Problems of Improper Cabling

Interference with control signals, EMI, reflected power, arcing, and even fire are problems that can occur when inappropriate cabling is used in an RF system. Choosing a cable type with inadequate shielding for your application can allow RF interference with signals in the control system or other equipment. Reflected power at the power supply is a possible result when connectors cause variation in impedance in the transmission line. Furthermore, arcing between the conductors in the cables may occur when cables of inadequate voltage or power rating are used. Excessive heat then may degrade cable shielding and even cause the insulator material to melt, enabling the center conductor to encroach into this softened material and come into proximity with the shield. When this happens at low power, arcing is likely. At high power, arcing may lead to flame.

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Anatomy of Coaxial Cable

Coax is composed of two conductors that are coaxially oriented—that is, the outer conductor (shield) encircles the center conductor. The inner conductor and shield both carry current, but only the shield is grounded. It acts as a return path and minimizes external radiation. A layer of dielectric insulation separates the two conductors from one another. An outer protective "jacket" holds the layers together and keeps out moisture and impurities.

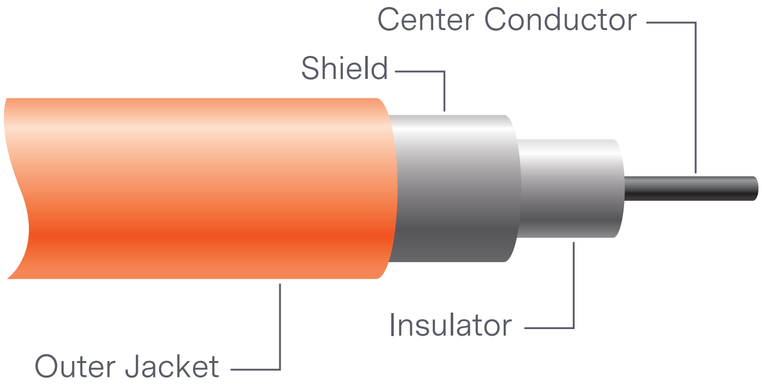

Figure 2. Anatomy of a single-shield coaxial cable.

CABLE CONSTRUCTION AND PERFORMANCE

Coax type (ex. RG-217, RG-393) is determined by the physical configuration of the cable. This section generally describes key materials and cable performance parameters. RF cable manufacturers typically provide detailed descriptions of cable types, materials, and performance characteristics.

Center Conductor Material

The center conductor may be solid, stranded, or multi-stranded. This choice affects cable attenuation and signal distortion.

Dielectric Material

Propagation velocity and time delay are key properties affected by dielectric material choice (Table 1, below). Temperature tolerance is another consideration. Coaxial cable with a PE dielectric layer can operate at temperatures up to 80°C (176°F). Cable with a Teflon® dielectric layer can handle higher RF powers for the given diameters due to its ability to operate at temperatures up to 220°C (428°F).

Shield Material

The shield may be constructed as solid/single braid or double braid. Cable with shield material that is composed of two single braids with a layer of insulation between them is known as triaxial (triax) cable. It is used where there is significant risk of RF emissions interfering with control signals. Double braid also reduces RF interference, though to a lesser degree.

Jacket Material

PVC, mesh braid, FEP, or corrugated are common jacket types. Material choice affects the cable's flexibility, temperature tolerance, moisture resistance, flammability, and durability.

Table 1. Effect of dielectric material type on cable properties

Dielectric Type	Propagation Velocity (% of C)	Time Delay (nsec/m)
Solid Polyethylene (PE) RG-217, RG-214	65.9	5.08
Foam Polyethylene (FE)	80	4.16
Foam Polystyrene (FS)	91	3.66
Air Space Polyethylene (ASP)	84 to 88	3.96 to 3.78
Solid Teflon (ST) RG-393	69.4	4.80
Air Space Teflon (AST)	85 to 90	3.92 to 3.70
Speed of Light	100	3.33

Determining Cable Type, Length, and Connectors

Cable is available either in bulk or as pre-cut lengths. Pre-cut cable typically comes with connectors already attached and comes with a specific length tolerance (consult the manufacturer for specification). Bulk cable typically comes on a reel. It can be cut to any length and assembled with appropriate connectors.

1. CHOOSING CABLE TYPE

RF cable manufacturers can provide detailed information on available cable types and properties. The section below describes general performance characteristics and recommendations.

Cable Power Ratings

Generally, cable carries less power at higher frequencies; as RF frequency increases, cable power transmission decreases. Check the cable manufacturer's website or contact the manufacturer directly for recommendations on cable power ratings for your given power and frequency. If you have a specialized application, please contact AE® Global Support at technical.support@aei.com.

Cable Impedance

Coax is readily available at 50 Ω. Cable impedance must match load impedance. This key characteristic governs power transfer, as well as the amount of reflected power in the transmission line.

2. DETERMINING CABLE LENGTH

Generally, to minimize reflected power in the RF system, the system needs to be investigated/scanned within the cable length interval that coincides with ½ wavelength.

Calculate wavelength with the following equation:

$$\lambda = (c/f) \cdot vp$$

vp = velocity of propagation (velocity factor) – expressed as percentage of speed of light
f = frequency
c = 3.0×10^8 m/sec

Please note that velocity factor varies depending on the dielectric type. Consult the cable manufacturer to determine the specification for your cable type.

RG-217 coax cable is the most common type used in RF systems. If the velocity factor for this type of cable is 0.659 c, then its wavelength for 13.56 MHz is about 48' (14.6 m), and cable length should be a multiple of 24' (7.3 m).

Between the matching network and the chamber, a direct connection is best, with the matching network mounted on the chamber. See Figure 1 for a graphical representation of an ideal RF system setup.

3. CHOOSING CONNECTOR TYPE

Connector choice depends on your requirements for power and voltage rating, compatibility with your selected cable type, and your power supply's connector specification.

Any given connector type comes in many different configurations to accommodate different cable sizes and varieties. Consult the manufacturer for information on connector ratings and cable/connector compatibility.

Also, your AE product may come with a specific requirement for connector style, or you may have chosen a specific connector style when you purchased your power supply. Consult your user manual or contact AE Global Services (technical.support@aei.com) to determine the type of connector required by your power supply.

Note that if you have limited clearance, use of a 90 degree (right angle or elbow) connector is acceptable.

Resources

For more information on AE's catalog of RF cables and connectors, contact sales.support@aei.com.

For additional assistance selecting cabling for your application, contact AE Global Services at technical.support@aei.com.

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