CTU Presents

“All Coaxial Cables are not Created Equal”

Selection parameters while shopping the flea market

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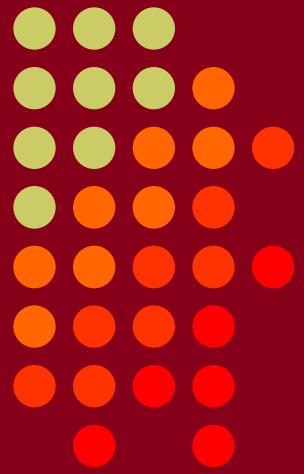


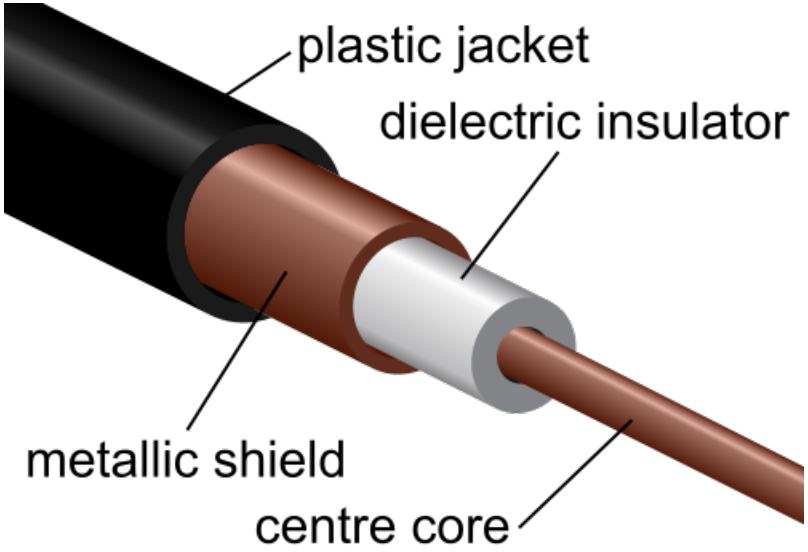
Value – The tradeoff between price and specifications.

- Lowest price may not be the best choice.
- Highest price is likely also not be best choice.
- Somewhere in between usually lies a product that meets the needs.
- One needs to define the requirements and understand the specifications.

What is coaxial cable?

- Coaxial cable or “Coax” is a type of cable that has an inner conductor surrounded by an insulating layer, surrounded by a tubular conducting shield. The term coaxial comes from the inner conductor and the outer shield sharing a geometric axis.

Coaxial cable



Applications

- Coaxial cable is used as a transmission line for radio frequency (RF) signals. The primary use is in connecting transmitters and receivers with antennas or other RF components.

Main Parameters - electrical

- Shunt capacitance.
- Series inductance.
- Characteristic impedance.
- VSWR
- Voltage breakdown.
- Power handling.
- Loss / Attenuation - efficiency.
- Velocity factor.
- Phase stability.
- Shielding effectiveness.
- IMD products.

Physical parameters – variables

- Length of the cable: h
- Outside diameter of inner conductor: d
- Inside diameter of outer conductor: D
- Dielectric constant of the dielectric insulator: Є
- Magnetic permeability of dielectric insulator: μ

Shunt capacitance & series inductance

- Shunt capacitance: $\frac{C}{h} = \frac{2\pi\epsilon}{\ln(D/d)}$
- Series Inductance: $\frac{L}{h} = \frac{\mu}{2\pi}\ln(D/d)$

Characteristic Impedance

- For frequencies above about 1MHz, the characteristic impedance of a coaxial cable line depends only on the dielectric constant of the inner insulator and the ratio of the diameter of the inner conductor to the inner diameter of the outer conductor.

- Characteristic Impedance = $Z_0 = \sqrt{L/C}$

VSWR (Voltage Standing Wave Ratio)

- VSWR is a function of how well the cable maintains its characteristic impedance (Zo) over its length.
- Function of how well the geometry of the cable is maintained over its length.
- Function of how consistent the dielectric material is maintained over its length.

Voltage Breakdown

- Generally a function of:
  - Dielectric material
  - Environmental conditions – Moisture or contaminants.
- Often limited by choice of connectors.
- Instantaneous issue with possible carbon tracking = permanent damage.

Power Handling

- Limited by:
  - Breakdown Voltage.
  - Thermal dissipation capability of the cable.

- Directly related to size of cable (surface area).
- Directly related to attenuation per unit length.
- Frequency dependant.
- Time rather than instantaneous problem.
- Specifications need to be de-rated for temperature and VSWR.

Loss & Attenuation

- Conductor losses
  - Type of metal
    - Copper
    - Aluminum
    - Copper clad
  - Size – surface area of inner and outer.
  - Skin effect at RF – currents travel on surface only.

Loss & Attenuation (cont …)

- Dielectric losses
  - Type of material (In order of increasing loss)
    - Air (*Nitrogen*) with polyethylene spiral. HJ5-50
    - PTFE (*Teflon*). RG142
    - PF (*polyethylene foam*). RG6
    - PE (*Polyethylene*). – RG213

Power/Voltage/Efficiency tradoffs

- Why are 50 Ohm cables in such common use?
- It's a tradeoff between power, voltage and attenuation.
- Bell Laboratories (1929) testing showed:
  - 30 Ohms best for power handling.
  - 60 Ohms best for voltage rating.
  - 77 Ohms best for attenuation.
  - 50 Ohms best overall compromise.

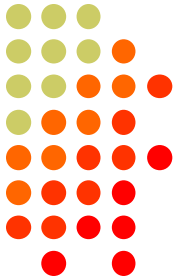
Velocity Factor

- The velocity factor (**Vf**) is the speed an electromagnetic wave travels along a coax cable relative to the speed in a vacuum.
- **Vf** is directly related to the dielectric material of the cable.
- Denser dielectric material = lower **Vf**.
- A cable with a lower **Vf** is physically shorter than a cable with a higher **Vf** for the same electrical length.
- Important consideration for phased applications.

Phase stability

- Length or phase variation with temperature.
- Thermal expansion or contraction rates.
- Important for phasing – especially as frequency rises.
- Cable types should not be mixed for phased applications.

Shielding effectiveness



- Signal leakage from cable to outside world.
- Signal ingress from outside world. (It's a two way issue)
- Function of continuity and bonding of outer conductor.
- Solid (or corrugated copper) best.
- Braided shield percentage coverage is largest factor.
- Continuity at connectors very important.

IMD Products (Inter Modulation Distortion)

- IMD is the generation of undesirable signals as a result of two or more desired signal mixing together through some medium.
- IMD products occur when two or more signals cross a non linear junction and are rectified.
- IMD products most often occur across ferromagnetic or oxidized surfaces.
- Poor cable to connector or connector to connector connections are the most likely sources.
- Connectors with greater surface areas are desired.

IMD Products (Inter Modulation Distortion) cont …

- Properly soldered connections are essential.
- Proper connector torque is essential.
- Moisture free connections are essential.
- IMD issues very important in Multi transmitter. environments – including SO2R.
- IMD issues can be the source of TVI or other interference situations.

Main parameters - Mechanical

- Conductor materials.
- Jacket material.
- Dielectric material.
- Air vs solid dielectric.
- Size.
- Weight.
- Bending radius.
- Crush strength.

Conductor Materials

- Outer conductor
  - Copper braid (Single or double)
  - Aluminum braid (Single or double)
  - Aluminum foil (Often with braid)
  - Corrugated copper (annular or spiral)
  - Corrugated aluminum (annular or spiral)
  - Solid copper
  - Solid aluminum

Conductor Material

- Inner conductor material:
  - Braided copper.
  - Solid copper wire.
  - Solid copper heavy gauge.
  - Hollow copper (straight) cylinder.
  - Hollow copper spiral cylinder.
  - Copper clad aluminum.

Jacket Material

- Cable jacketing designed to protect from environmental factors – moisture, chemical, solar as well as abrasion.
- Jacket materials:
  - Polyvinyl-chloride
  - Polyethylene
  - Polyurethane
  - Teflon
  - Neoprene
  - EPDM
  - Silicone rubber
  - Natural rubber
  - Bare – no jacket

Fire retardant and plenum rated cables generally have blue or white jackets and are made of non-halogenated materials to reduce smoke and production of toxic gases.

Dielectric Material

- Air (*Nitrogen*) with polyethylene spiral. HJ5-50
- PTFE (*Teflon*). RG142
- PF (*polyethylene foam*). RG6
- PE (*Polyethylene*). – RG213

Air vs. solid dielectric

- Air cables have large voids in dielectric material.
- Air cables need to be pressurized at all times with positive dry air (dehydrator) or Nitrogen source.
- Failure to pressurize will lead to condensation within the cable = water accumulation.
- From outside it is difficult to determine if cable is foam or air dielectric. Be careful unless pressurization requirements can be met.

Cable Size

- Large range of sizes to meet large set of applications.
- Smallest cables – approximately 1/8 inch diameter.
- Largest cables – approximately 6 inch diameter for “flexible” – 9 inch for rigid.
- Size generally refers to inside diameter of outer conductor – not outside dimension over jacket.

Sample of different cable types

Cable Weight

- Sample weights:
  - RG 213 - .13 lbs/foot
  - LDF4-50A (1/2” foam dielectric) - .15 lbs/foot
  - LDF5-50A (7/8” foam dielectric) - .54 lbs/foot
  - HJ9-50 (5” air dielectric) – 3.3 lbs/foot

Bending Radius

- Two issues:
  - One time – installation issue only - cable left in place.
  - Repeated – cables that are allowed to move like jumpers and rotation loops on antennas.
- Exceeding specified bending radius can kink outer conductor or deform the dielectric material. Both cases result in VSWR and power handling issues as well as decreased mechanical strength of the cable.

Crush Strength

- Rating of cable that identifies force required to deform the outer jacket and outer conductor.
- Exceeding crush force results in deformation of cable with resulting VSWR and Voltage breakdown issues.
- Damage can result from traffic over buried cables, falling ice or other material from higher elevations or from other issues at time of installation.

The real world – practical objectives for Amateur Radio.

- Power handling:
  - 1.5 kW + head room for VSWR and temperature compensation = 2.0 kW.

- Cable attenuation – efficiency:
  - Rule of thumb – 1dB or less of attenuation TX to antenna = 80% efficiency.

Cable Attenuation charts (W3LPL data)

CABLE ATTENUATION (dB per 100 ft)

	1.8	3.5	7.0	14.0	21.0	28.0	50.0	144	440	1296
LDF7-50A	.03	.04	.06	.08	.10	.12	.16	.27	0.5	0.9
FHJ-7	.03	.05	.07	.10	.12	.15	.20	.37	0.8	1.7
LDF5-50A	.04	.06	.09	.14	.17	.19	.26	.45	0.8	1.5
FXA78-50J	.06	.08	.13	.17	.23	.27	.39	.77	1.4	2.8
3/4" CATV	.06	.08	.13	.17	.23	.26	.38	.62	1.7	3.0
LDF4-50A	.09	.13	.17	.25	.31	.36	.48	.84	1.4	2.5
RG-17	.10	.13	.18	.27	.34	.40	.50	1.3	2.5	5.0
SLA12-50J	.11	.15	.20	.28	.35	.42	.56	1.0	1.9	3.0
FXA12-50J	.12	.16	.22	.33	.40	.47	.65	1.2	2.1	4.0
FXA38-50J	.16	.23	.31	.45	.53	.64	.85	1.5	2.7	4.9
9913	.16	.23	.31	.45	.53	.64	.92	1.6	2.7	5.0
RG-213	.25	.37	.55	.75	1.0	1.2	1.6	2.8	5.1	10.0
RG-8X	.49	.68	1.0	1.4	1.7	1.9	2.5	4.5	8.4	

CABLE ATTENUATION (Ft per dB)

	1.8	3.5	7.0	14.0	21.0	28.0	50.0	144	440	1296
LDF7-50A	3333	2500	1666	1250	1000	833	625	370	200	110
FHJ-7	2775	2080	1390	1040	833	667	520	310	165	92
LDF5-50A	2500	1666	1111	714	588	526	385	222	125	67
FXA78-50J	1666	1250	769	588	435	370	256	130	71	36
3/4" CATV	1666	1250	769	588	435	385	275	161	59	33
LDF4-50A	1111	769	588	400	323	266	208	119	71	40
RG-17	1000	769	556	370	294	250	200	77	40	20
SLA12-50J	909	667	500	355	285	235	175	100	53	34
FXA12-50J	834	625	455	300	250	210	150	83	48	25
FXA38-50J	625	435	320	220	190	155	115	67	37	20
9913	625	435	320	220	190	155	110	62	37	20
RG-213	400	270	180	130	100	83	62	36	20	10
RG-8X	204	147	100	71	59	53	40	22	12	

FEET REQUIRED FOR 1 DB ADVANTAGE LDF5-50A VS:

	1.8	3.5	7.0	14.0	21.0	28.0	50.0	144	440	1296
LDF4-50A	2000	1430	1250	910	715	625	435	250	165	100
RG-17	1666	1430	1110	770	560	475	420	120	60	30
FXA12-50J	1250	1000	770	525	435	355	255	120	75	40
9913	835	590	455	320	280	220	150	85	53	29

FEET REQUIRED FOR 1 DB ADVANTAGE LDF4-50A VS:

	1.8	3.5	7.0	14.0	21.0	28.0	50.0	144	440	1296
RG-17	-	-	-	-	-	-	-	220	90	40
FXA12-50J	-	-	2000	1250	1100	835	625	250	145	65
9913	1430	1000	715	500	455	345	235	135	75	40
RG-213	910	600	285	200	150	120	85	45	20	12

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CABLE ATTENUATION (dB per 100 ft)

	1.8	3.5	7.0	14.0	21.0	28.0	50.0	144	440	1296
LDF7-50A	.03	.04	.06	.08	.10	.12	.16	.27	0.5	0.9
FHJ-7	.03	.05	.07	.10	.12	.15	.20	.37	0.8	1.7
LDF5-50A	.04	.06	.09	.14	.17	.19	.26	.45	0.8	1.5
FXA78-50J	.06	.08	.13	.17	.23	.27	.39	.77	1.4	2.8
3/4" CATV	.06	.08	.13	.17	.23	.26	.38	.62	1.7	3.0
LDF4-50A	.09	.13	.17	.25	.31	.36	.48	.84	1.4	2.5
RG-17	.10	.13	.18	.27	.34	.40	.50	1.3	2.5	5.0
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RG-213	.25	.37	.55	.75	1.0	1.2	1.6	2.8	5.1	10.0
RG-8X	.49	.68	1.0	1.4	1.7	1.9	2.5	4.5	8.4	

LDF7-50A : 1 5/8 inch foam dielectric
LDF5-50A : 7/8 inch foam dielectric
LDF4-50A : 1/2 inch foam dielectric

CABLE ATTENUATION (Ft per dB)

	1.8	3.5	7.0	14.0	21.0	28.0	50.0	144	440	1296
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FHJ-7	2775	2080	1390	1040	833	667	520	310	165	92
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FEET REQUIRED FOR 1 DB ADVANTAGE LDF5-50A VS:

	1.8	3.5	7.0	14.0	21.0	28.0	50.0	144	440	1296
LDF4-50A	2000	1430	1250	910	715	625	435	250	165	100
RG-17	1666	1430	1110	770	560	475	420	120	60	30
FXA12-50J	1250	1000	770	525	435	355	255	120	75	40
9913	835	590	455	320	280	220	150	85	53	29

FEET REQUIRED FOR 1 DB ADVANTAGE LDF4-50A VS:

	1.8	3.5	7.0	14.0	21.0	28.0	50.0	144	440	1296
RG-17	-	-	-	-	-	-	-	220	90	40
FXA12-50J	-	-	2000	1250	1100	835	625	250	145	65
9913	1430	1000	715	500	455	345	235	135	75	40
RG-213	910	600	285	200	150	120	85	45	20	12

Power Handling

Maximum power in Watts at:

MHz:	10	30	50	100	145	200	400	435	500	1296	2320	3000	5000
Cable type													
RG8X	350												
RG-11 AU						420	300					95	
RG-58 CU	550			240	125	100	90		49	31	30		20
RG-142 AU	3200			1500			850		460	320			175
RG-174 U	200			95	57	42			30	18	13		
RG-188 AU	550			380			260		130	90			75
RG-196 AU					85	57						18	
RG-213 U	2000			800	420	300	290			100	95		65
RG-213 US-100	2000			800	440	420	400		220	140			70
RG-214 US	2000			800	440	420	400		220	140			70
RG-223 U	950			300			200		100	68			40
RG-316 U	550			380			260		130	90			75
H100	2100			1000			530		300				
Aircell-7	2960		850						190				
CF1/4"Cu2Y	2700			1200			750		400				
CF3/8"Cu2Y	4700			2800			1200		680	520			
CF1/2"Cu2Y	6400			2800			1600		850				
CF5/8"Cu2Y	9000			4000			2300		1350	950			
TU-165					170	110						32	
TU-300					660	450						150	
TU-545					1700	1200						370	
LDF4-50	6400												
LDF5-50	14100												

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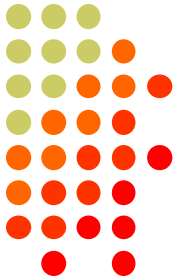
Cable size conclusions

- For HF work, RG 213 type cables are adequate for 1.5 kW power levels.
- For HF work with cable runs up to 100 feet – RG213 type OK.
- For HF work with cable runs up to approximately 300 feet – 1/2 inch LDF4 cable OK.
- For HF work and cable runs over 300 feet, 7/8 inch LDF5 or larger cables should be considered.
- For all VHF and UHF work, nothing less than ½ inch cable should be used even for short runs.

Connectors

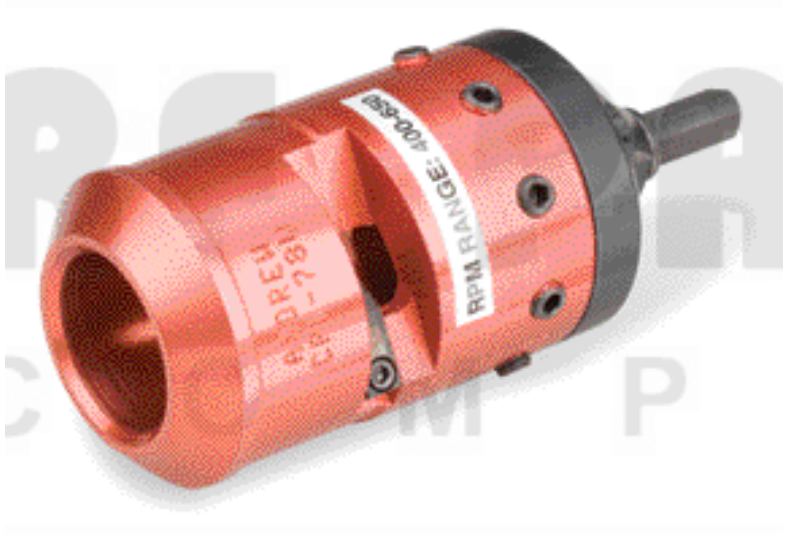
- Single biggest failure point in most RF systems.
  - Installation issues
  - Weatherproofing
  - Connector type
  - Connector series

Connector installation issues



- Proper connector for cable type.
- Proper cut back dimensions.
- Use prep tools where available.
- Follow installation instructions.
- Keep all parts including cable clean and dry.
- For solder connections – lots of heat for short time. Make sure solder flows to connector and cable.

Prep Tools



Connector weatherproofing

- Connections must stay dry.
- Use conformable rubber splicing tape like 3M type 130C (or equiv) as weather seal.
- Protect from UV and hold in place using 3M type 88 vinyl tape (or equiv).
- Cut – do not stretch final tape wrap.
- For large connectors use butyl rubber tape as gap filler before taping.
- In hard to reach locations use UV rated heat shrink.

Connector types

- Use proper connector for cable type.
- Be aware that there are different manufacturers of various cable sizes and that connectors are not interchangeable. (exception MIL spec cables)
- For a given manufacturer there are different generations of cable and connectors will not be interchangeable.
- Avoid home made connectors. They are not long term solutions.

Connector Series

- Choose the right connector series for the application. (Power rating, VSWR and impedance)
  - UHF (PL 259 series)
  - Type “N”
  - 7/16 DIN
  - BNC
  - “F” series
  - EIA Flanged connectors (7/8, 1 5/8, 3 1/8 etc…)
- Avoid inter-series adaptors where possible.
- Avoid “cheap” Elbows and “Tees” – they have power issues and can be sources for IMD.

Installation

- Cable support.
  - Cable hangers or Ty wraps – avoid tape.
  - Use UV resistant Ty wraps – never use white nylon.
  - Hoisting grips for larger cables.
  - Leave a little extra at the top.
  - Drip loop at bottom.

Installation cont ....

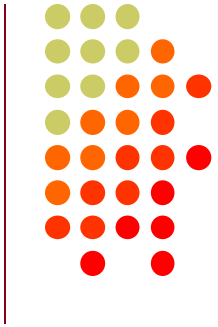
- Be careful not to nick cable jacket – source of water entry.
- Make sure no cable rub locations – future sources of water.
- Plan rotator loop – sufficient clearance and length.
- Ground kits – top, middle (for long runs), bottom and entry point to radio room.
- Bury horizontal runs for cables so rated or use overhead centenary wire for support.
- Do not bury connectors or splices.
- Bury below frost line.
- Weatherproof all connections.

Inspections and maintenance

- Benchmark performance at time of installation. VSWR or swept VSWR – TDR + photograph installation.
- Keep records.
- Regularly re-test – changes are signs of trouble.
- Physically inspect on regular interval.
- Photograph and compare pictures.
- Deal with the problems promptly – they rarely fix themselves!

Bottom Line

- Understand your needs and objectives.
- Understand the specifications for what you are proposing to buy.
- View coax runs as systems – cable, connectors and jumpers. It's a series circuit and any single component failure is a system failure. All components are equally important.
- Make sure the products meet or exceed your needs.
- Apply your best negotiating techniques to obtain best value.



Thank you for your attention!

73, John, VE3EJ

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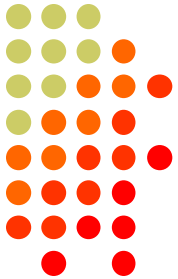
Sources and credits



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