Course: Leaky Feeder System

Module 4.1: Cost models

RFI
TECHNOLOGY SOLUTIONS

Leaky Feeder Solution Offerings

Digital Drift leaky feeder systems are available to meet a variety of usage scenarios. The appropriate solution for each mine depends on its requirements & budget.

	Offering	2-way radio	Ethernet outlets along the LCX	Continuous Wi-Fi *(or LTE)*
1	• VHF radio on **Yellow LCX**	☑	-	-
2	• VHF radio + Ethernet, on **Yellow LCX**	☑	☑	-
3	• VHF radio + Ethernet + radiating Wi-Fi on **Premium Broadband LCX** *($1/2$″ dia.)*	☑	☑	☑
4	• Ethernet + radiating Wi-Fi on **Standard Broadband LCX** *($7/8$″ dia.)*	-	☑	☑
5	Offering 1 + 4: • VHF radio on **Yellow LCX** • Ethernet + radiating Wi-Fi on **Standard Broadband LCX** *($7/8$″ dia.)*	☑	☑	☑

RFI TECHNOLOGY SOLUTIONS

Offering 1: VHF Radio on Yellow LCX – **Design rules**

Device spacing is determined by the RF insertion loss between LineAmps.

VHF DESIGN RULES:

- ***VHF Rule 1:*** Maximum 23 dB loss between LineAmps, in the downlink band *(150 MHz)*
- ***VHF Rule 2:*** Minimum 10 dB insertion loss between LineAmps, in the downlink band *(150 MHz)*

VHF LOSSES:

- ***Yellow LCX cable:*** 4.2 dB / 100m at 150 MHz
- ***2-way splitter (GCS):*** 3.5 dB insertion loss
- ***2-way splitter (RFI):*** 5.0 dB insertion loss
- ***Power Coupler:*** 1.2 dB insertion loss

DC POWER DESIGN RULES:

- Use the online modelling tool: https://adodd.net/tools/voltagedrop-tool/

- ***Yellow LCX loop resistance:*** 8.6 Ω / km
- ***LineAmp power draw:*** 2.5 W

DESIGN TIP:

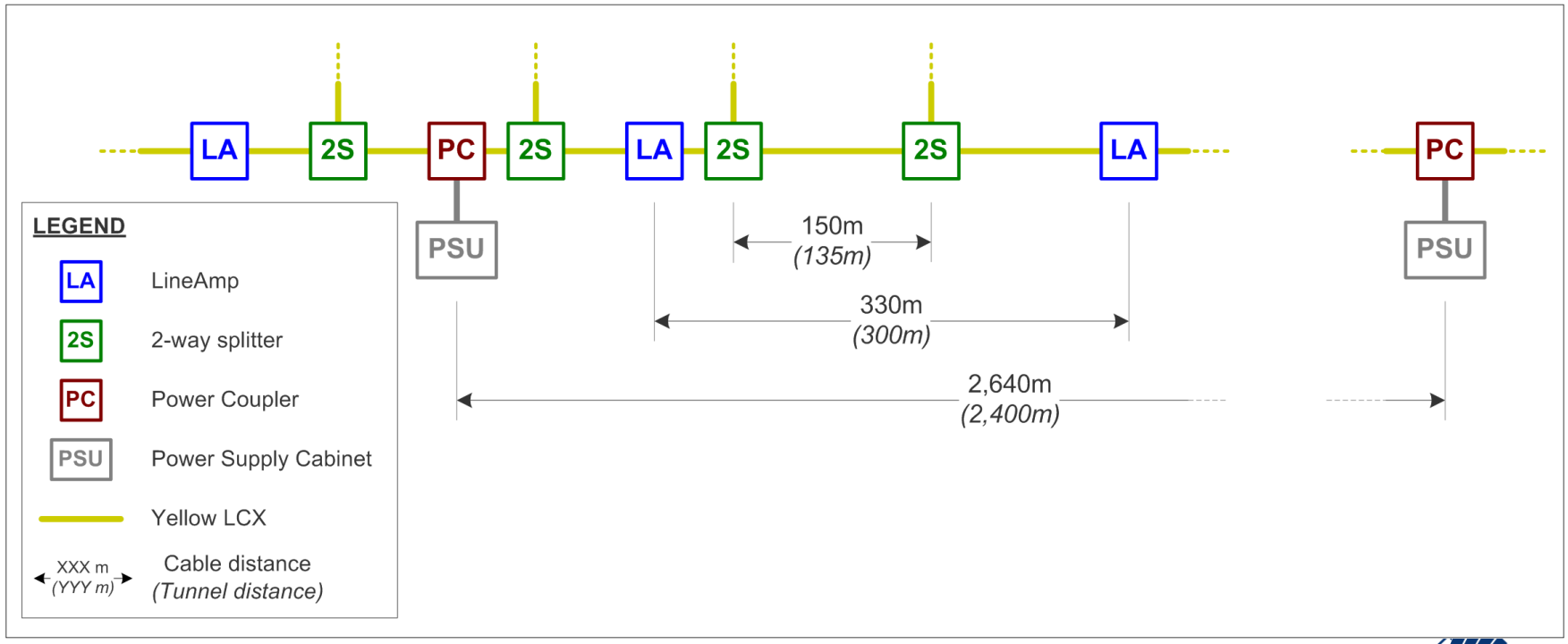
- Max. cable length between LineAmps = 550m $\left[{}^{23\ dB} / {}_{(0.042\ dB\ /\ m)} \right]$
- Subtract 85m for each 2-way splitter (GCS)
- Subtract 30m for each power coupler

RFI TECHNOLOGY SOLUTIONS

Offering 1: VHF Radio on Yellow LCX – **Typical layout**

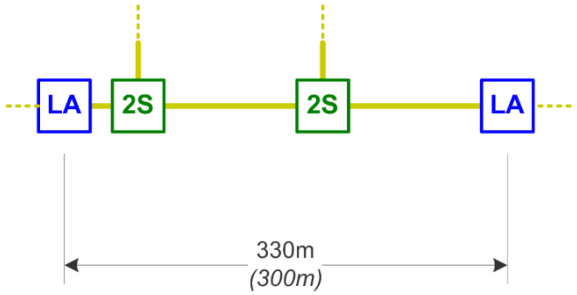
ASSUMPTIONS:

- ***2-way Splitters:*** Located every 135m *(tunnel distance).*
  Affordable splitters designed for yellow LCX are used (e.g. GCS)
- ***Line voltage:*** 36 VDC
- ***Power Strategy:*** Each LCX segment is powered from both ends, with each PSU able to take the complete load of the segment if the adjacent PSU fails.



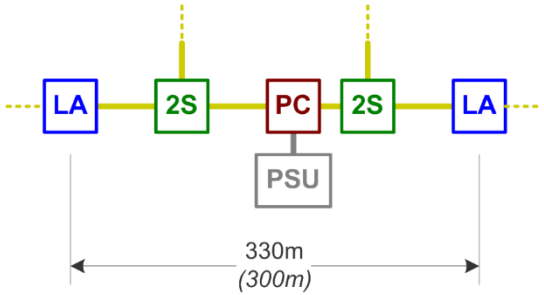
RFI TECHNOLOGY SOLUTIONS

Offering 1: VHF Radio on Yellow LCX – **VHF design check**



	Insertion loss (dB)	Calculation basis
Cable	13.9	0.042 dB/m * 330 m
2-way splitters	7.0	3.5 dB * 2 splitters
TOTAL	**20.9**	

- ***VHF Rule 1:*** insertion loss < 23 dB. ✓
- ***VHF Rule 2:*** insertion loss > 10 dB. ✓



	Insertion loss (dB)	Calculation basis
Cable	13.9	0.042 dB/m * 270 m
2-way splitters	7.0	3.5 dB * 2 splitters
Power Coupler	1.2	1.2 dB * 1 power coupler
TOTAL	**22.1**	

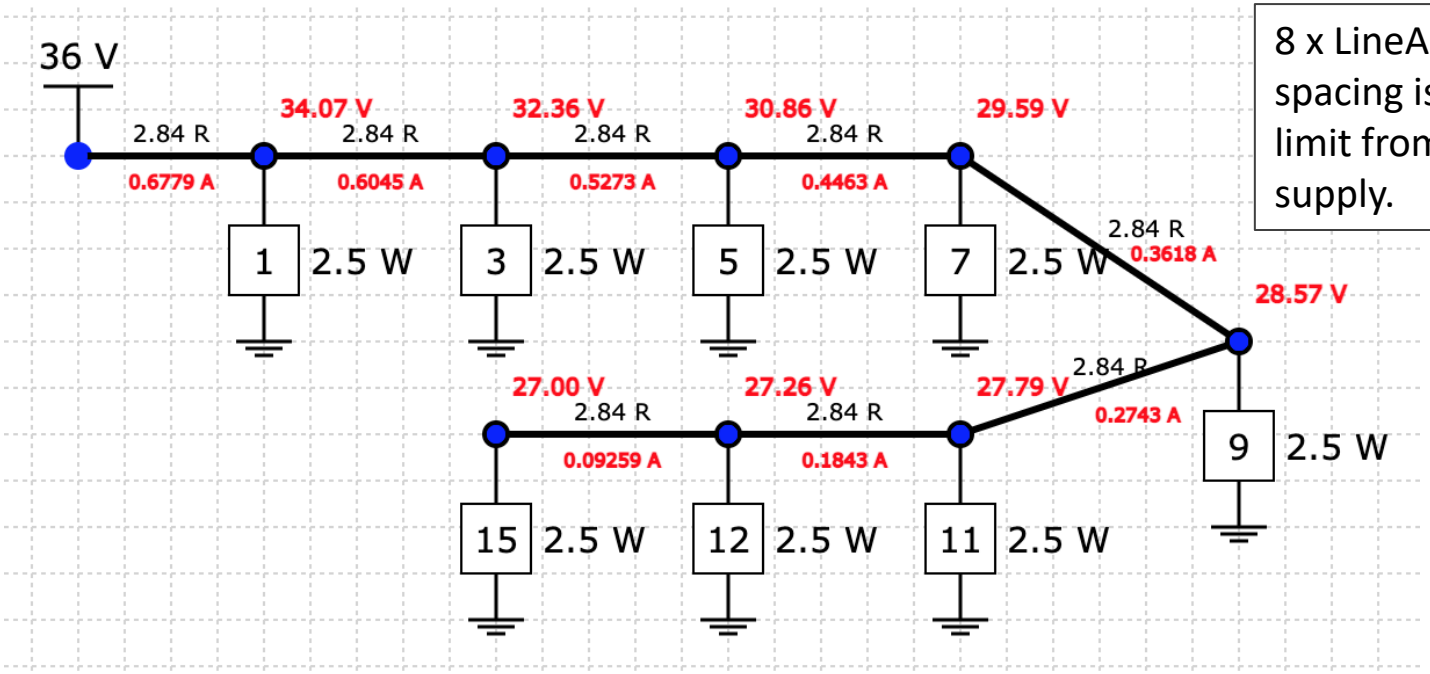
- ***VHF Rule 1:*** insertion loss < 23 dB. ✓
- ***VHF Rule 2:*** insertion loss > 10 dB. ✓

RFI TECHNOLOGY SOLUTIONS

Offering 1: VHF Radio on Yellow LCX – **Power design check**

Parameters for the model:

- Supply voltage = 36 VDC
- LineAmp power consumption = 2.5 W
- Loop resistance between LineAmps = 2.84 Ω (8.6 Ω/km * 0.33 km)



8 x LineAmps at 330m spacing is the upper limit from a 36 VDC supply.

Max. PSU spacing: 2,640 m *(cable distance)*

2,400 m *(tunnel distance, assuming 10% cable slack)*

RFI TECHNOLOGY SOLUTIONS

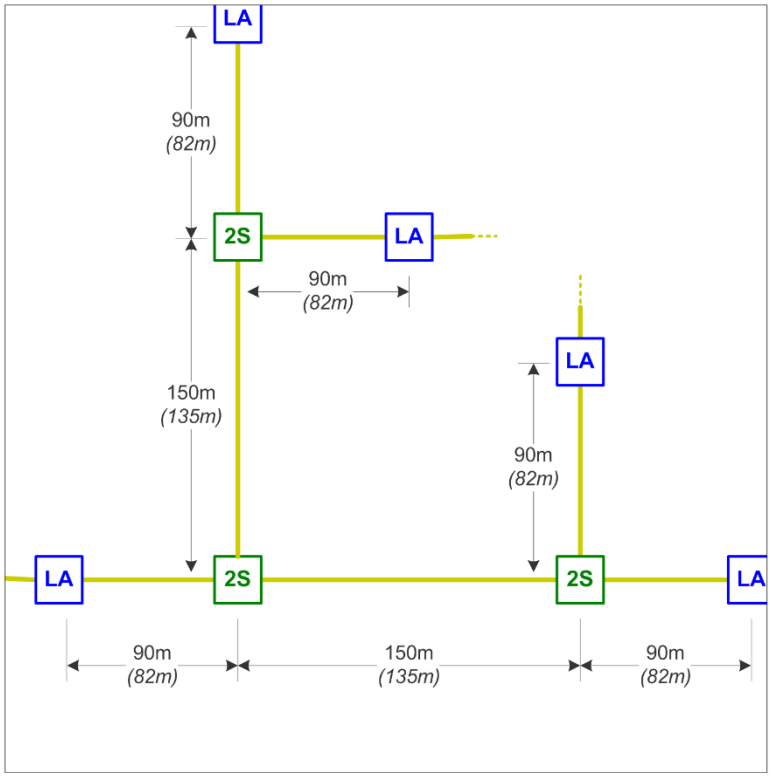
Offering 1: VHF Radio on Yellow LCX – **Cost model basis**

EXCLUSIONS(*):

- Radio headend and RF over Fibre (RFoF) equipment.
- Line terminations and stope antennas.
- Installation, commissioning & support labour.

NOTES:

- Tunnel distances (rather than cable distances) are used since this is more useful for mine planning.
- 36 VDC line voltage has been assumed for the power coupler & power cabinet spacing, placing them every 2.4km on average.
- Splitters (GCS) are located every 135m (tunnel distance)
- Based on this splitter density, if each LineAmp is optimally spaced it will cover 680m (tunnel distance), as shown in the image to the right. In reality, LineAmps are not optimally spaced. However, 500m of tunnel coverage can be comfortably assumed.



RFI TECHNOLOGY SOLUTIONS

Offering 1: VHF Radio on Yellow LCX – **Cost model**

VHF 2-way radio on yellow LCX costs $##/m(*)

Part	Name	Qty / km	Calculation basis	Unit price	Ext. price (per km)
DDLFS-LA-V75	LineAmp	2.0	Located every 500m	$#,###.##	$#,###.##
-	2-way splitter	7.4	Located every 135m	$###.##	$#,###.##
DD-LFC-350	350m roll yellow LCX	3.1	1000m / (350m / 1.1)	$#,###.##	$#,###.##
DDLFS-PC-V75	Power Coupler	0.4	Located every 2,400m	$###.##	$###.##
-	Power supply cabinet	0.4	*<As above>*	$#,###.##	$#,###.##
TOTAL					**$##,###.##**

RFI TECHNOLOGY SOLUTIONS

Offering 2: VHF Radio + Ethernet on Yellow LCX – **Design rules**

Design based on the VHF losses, then use a LineAmp+Ethernet on every second LineAmp.

VHF DESIGN RULES:

- ***VHF Rule 1:*** Maximum 23 dB loss between LineAmps, in the downlink band *(150 MHz)*
- ***VHF Rule 2:*** Minimum 10 dB insertion loss between LineAmps, in the downlink band *(150 MHz)*

VHF LOSSES:

- ***Yellow LCX cable:*** 4.2 dB / 100m at 150 MHz
- ***2-way splitter (GCS):*** 3.5 dB insertion loss
- ***2-way splitter (RFI):*** 5.0 dB insertion loss
- ***Power Coupler:*** 1.2 dB insertion loss
- ***QuadPort2:*** 3.0 dB insertion loss

EoC DESIGN RULES:

- ***EoC Rule 1:*** Maximum 45 dB insertion loss between LineAmp+Ethernet units, at 75 MHz

EoC LOSSES:

- ***Yellow LCX cable:*** 3.3 dB / 100m at 75 MHz
- ***LineAmp:*** 2.3 dB insertion loss
- ***QuadPort2:*** 5.5 dB insertion loss
- ***2-way splitter (GCS):*** 3.5 dB insertion loss
- ***2-way splitter (RFI):*** 8.0 dB insertion loss
- ***Power Coupler:*** 1.2 dB insertion loss

DC POWER DESIGN RULES:

- Use the online modelling tool: https://adodd.net/tools/voltagedrop-tool/

- ***Yellow LCX loop resistance:*** 8.6 Ω / km
- ***LineAmp power draw:*** 2.5 W
- ***LineAmp+Ethernet power draw:*** 6.0 W
- ***QuadPort2 power draw:*** 7.5 W + (PoE load * 1.2)

DESIGN TIP:

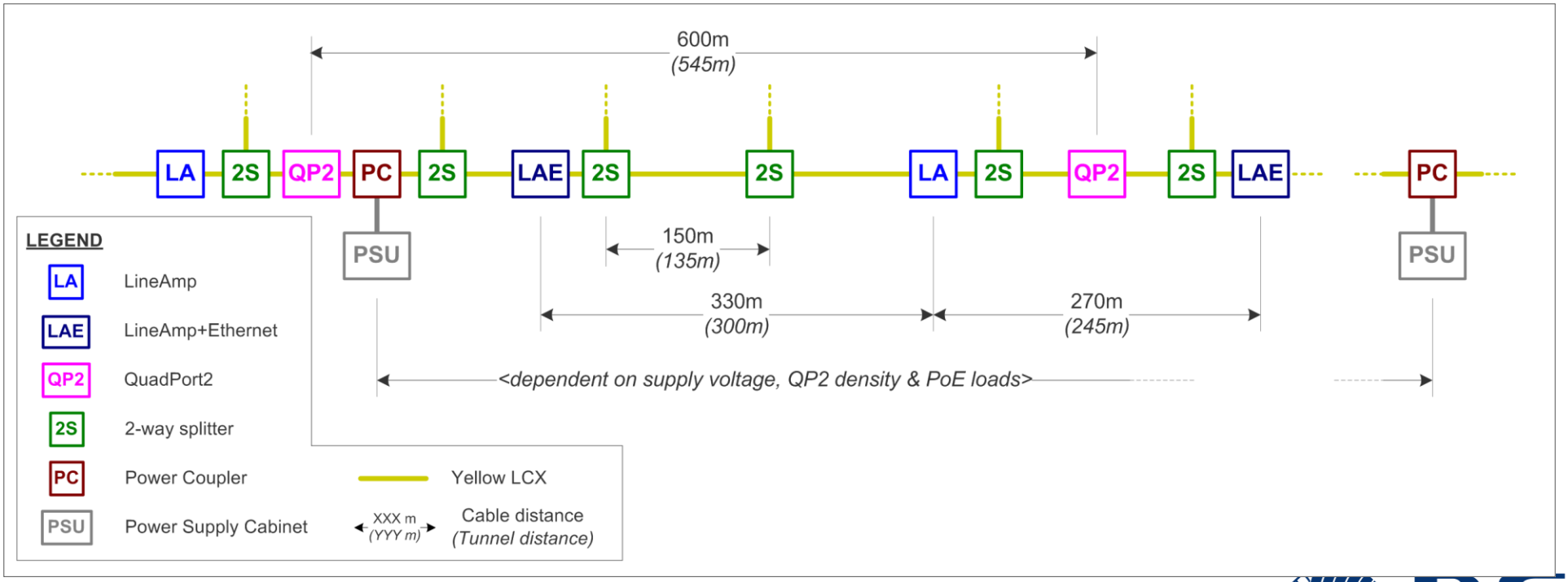
- Set LineAmp spacing based on the VHF losses (taking account of QP2 losses)
- Make every second LineAmp into a LineAmp+Ethernet, and the EoC usually works out fine.

RFI TECHNOLOGY SOLUTIONS

Offering 2: VHF Radio + Ethernet on Yellow LCX – **Typical layout**

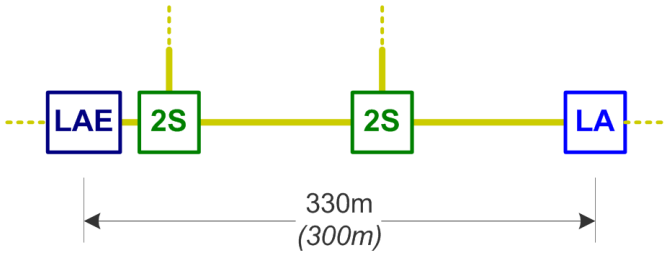
ASSUMPTIONS:

- ***2-way Splitters:*** Located every 135m *(tunnel distance).*
  Affordable splitters designed for yellow LCX are used (e.g. GCS)
- ***QuadPorts:*** Located every 545m (tunnel distance)
  17 W PoE load connected to each QuadPort
- ***Power Strategy:*** Each LCX segment is powered from both ends, with each PSU able to take the complete load of the segment if the adjacent PSU fails.



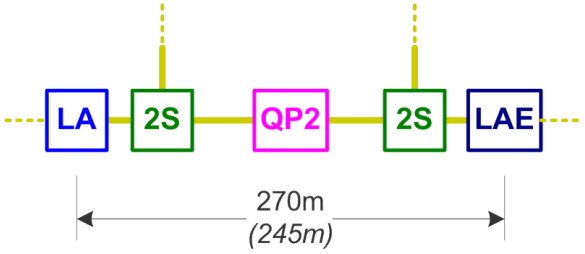
RFI TECHNOLOGY SOLUTIONS

Offering 2: VHF Radio + Ethernet on Yellow LCX – **VHF design check**



	Insertion loss (dB)	Calculation basis
Cable	13.9	0.042 dB/m * 330 m
2-way splitters (GCS)	7.0	3.5 dB * 2 splitters
TOTAL	**20.9**	

- ***VHF Rule 1:*** insertion loss < 23 dB. ✓
- ***VHF Rule 2:*** insertion loss > 10 dB. ✓

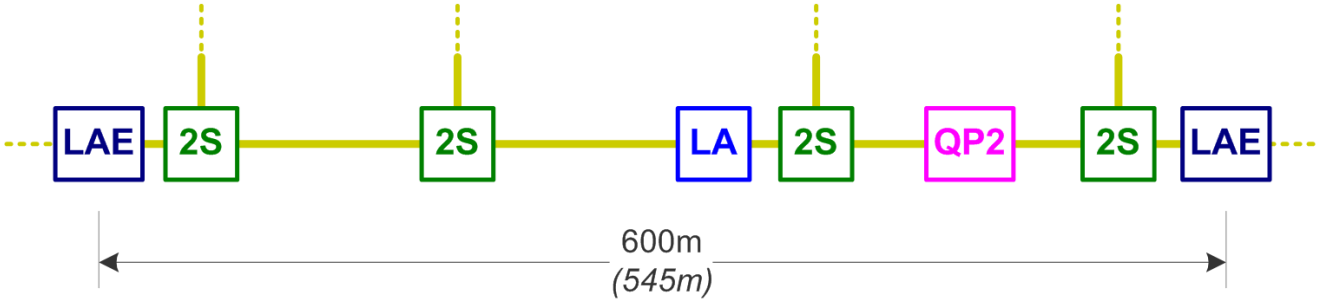


	Insertion loss (dB)	Calculation basis
Cable	11.3	0.042 dB/m * 270 m
2-way splitters (GCS)	7.0	3.5 dB * 2 splitters
QuadPort2	3.0	3.0 dB * 1 QuadPort2
TOTAL	**21.3**	

- ***VHF Rule 1:*** insertion loss < 23 dB. ✓
- ***VHF Rule 2:*** insertion loss > 10 dB. ✓

RFI TECHNOLOGY SOLUTIONS

Offering 2: VHF Radio + Ethernet on Yellow LCX – **EoC design check**



	Insertion loss (dB)	Calculation basis
Cable	19.8	0.033 dB/m * 600 m
2-way splitters (GCS)	14.0	3.5 dB * 4 splitters
QuadPort2	5.5	5.5 dB * 1 QuadPort2
TOTAL	**39.3**	

- ***Eoc Rule 1:*** insertion loss between LAEs < 45 dB. ☑

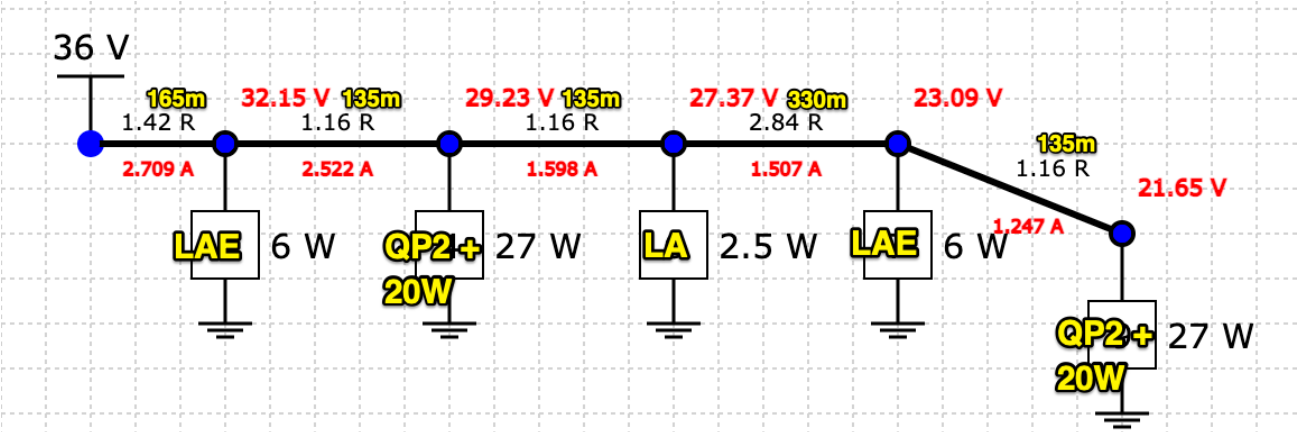
RFI TECHNOLOGY SOLUTIONS

Offering 2: VHF Radio + Ethernet on Yellow LCX – **Power design check**

Model 1 (36V supply):

A PSU is required every 900m.

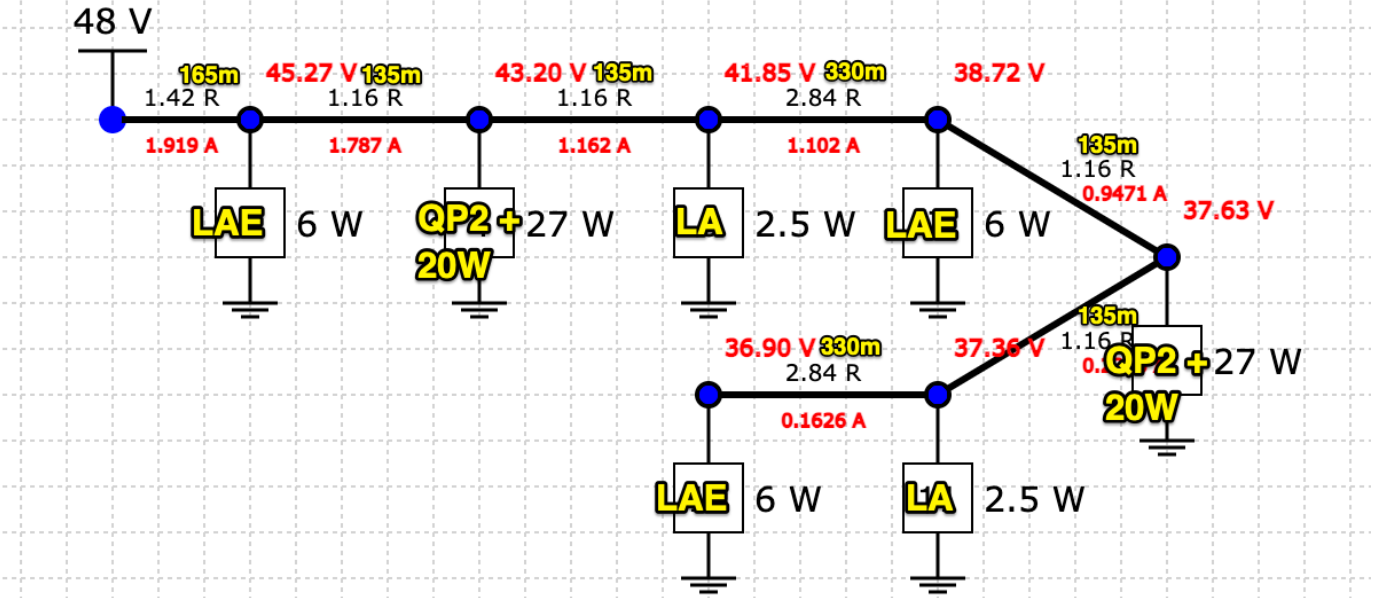
(for the assumed QP2 spacing and PoE loads).



Model 2 (48V supply):

PSU spacing extends out to 1,400m.

(for the assumed QP2 spacing and PoE loads).



TECHNOLOGY SOLUTIONS

Offering 2: VHF Radio + Ethernet on Yellow LCX – **Cost model basis**

EXCLUSIONS(*):

- Radio headend and RF over Fibre (RFoF) equipment.
- Line terminations and stope antennas.
- Installation, commissioning & support labour.

NOTES:

- Tunnel distances (rather than cable distances) are used since this is more useful for mine planning.
- (+) 48 VDC line voltage has been assumed for the power coupler & power cabinet spacing, placing them every 1.4km on average.
- Splitters (GCS) are located every 135m (tunnel distance)
- Based on this splitter density, amplifiers are required at the same spacing as for Offering 1 (VHF Radio on yellow LCX).
- Since every second amplifier must be a LineAmp+Ethernet, this drives the average spacing of LA & LAE devices to be 1,000m each.

Offering 2: VHF Radio + Ethernet on Yellow LCX – **Cost model**

VHF 2-way radio + Ethernet on yellow LCX costs $##/m(*)

Part	Name	Qty / km	Calculation basis	Unit price	Ext. price (per km)
DDLFS-LA-V75	LineAmp	1.0	Located every 1,000m	$#,###.##	$#,###.##
DDLFS-LAE-V75	LineAmp+Ethernet	1.0	Located every 1,000m	$#,###.##	$#,###.##
DDLFS-QP2-V75	QuadPort2 with VHF	1.8	Located every 545m	$#,###.##	$#,###.##
-	2-way splitter	7.4	Located every 135m	$###.##	$#,###.##
DD-LFC-350	350m roll yellow LCX	3.1	1000m / (350m / 1.1)	$#,###.##	$#,###.##
DDLFS-PC-V75	Power Coupler	0.7	Located every 1,400m(+)	$###.##	$###.##
-	Power supply cabinet	0.7	*<As above>*	$#,###.##	$#,###.##
TOTAL					**$##,###.##**

RFI TECHNOLOGY SOLUTIONS

Offering 3: VHF Radio + Ethernet + radiating Wi-Fi on Premium Broadband LCX
Design Rules

Segment lengths are defined by the Wi-Fi losses, with alternate LAE and QP2 devices at the head of each.

VHF DESIGN RULES:

- ***VHF Rule 1:*** Maximum 23 dB loss between LineAmps, in the downlink band *(150 MHz)*
- ***VHF Rule 2:*** Minimum 10 dB insertion loss between LineAmps, in the downlink band *(150 MHz)*

VHF LOSSES:

- ***Premium Broadband LCX cable:*** 2.8 dB / 100m at 150 MHz
- ***2-way splitter:*** 3.5 dB insertion loss
- ***Power Coupler:*** 1.2 dB insertion loss
- ***QuadPort2:*** 3.0 dB insertion loss

EoC DESIGN RULES:

- ***EoC Rule 1:*** Maximum 45 dB insertion loss between LineAmp+Ethernet units, at 75 MHz

EoC LOSSES:

- ***Premium Broadband LCX cable:*** 1.9 dB / 100m at 75 MHz
- ***QuadPort2:*** 5.5 dB insertion loss
- ***2-way splitter:*** 3.5 dB insertion loss
- ***Power Coupler:*** 1.2 dB insertion loss

Wi-Fi DESIGN RULES:

- ***Wi-Fi Rule 1:*** Maximum 30 dB loss per segment, at 2,450 MHz

Wi-Fi LOSSES:

- ***Premium Broadband LCX cable:*** 14.9 dB / 100m at 2,450 MHz
- ***Wi-Fi Coupler:*** 3.0 dB insertion loss
- ***2-way splitter:*** 3.2 dB insertion loss

DC POWER DESIGN RULES:

- Use the online modelling tool.

- ***Premium Broadband LCX loop resistance:*** 4.3 Ω / km
- ***LineAmp+Ethernet power draw:*** 6.0 W
- ***QuadPort2 power draw:*** 7.5 W + (PoE load * 1.2)

DESIGN TIPS:

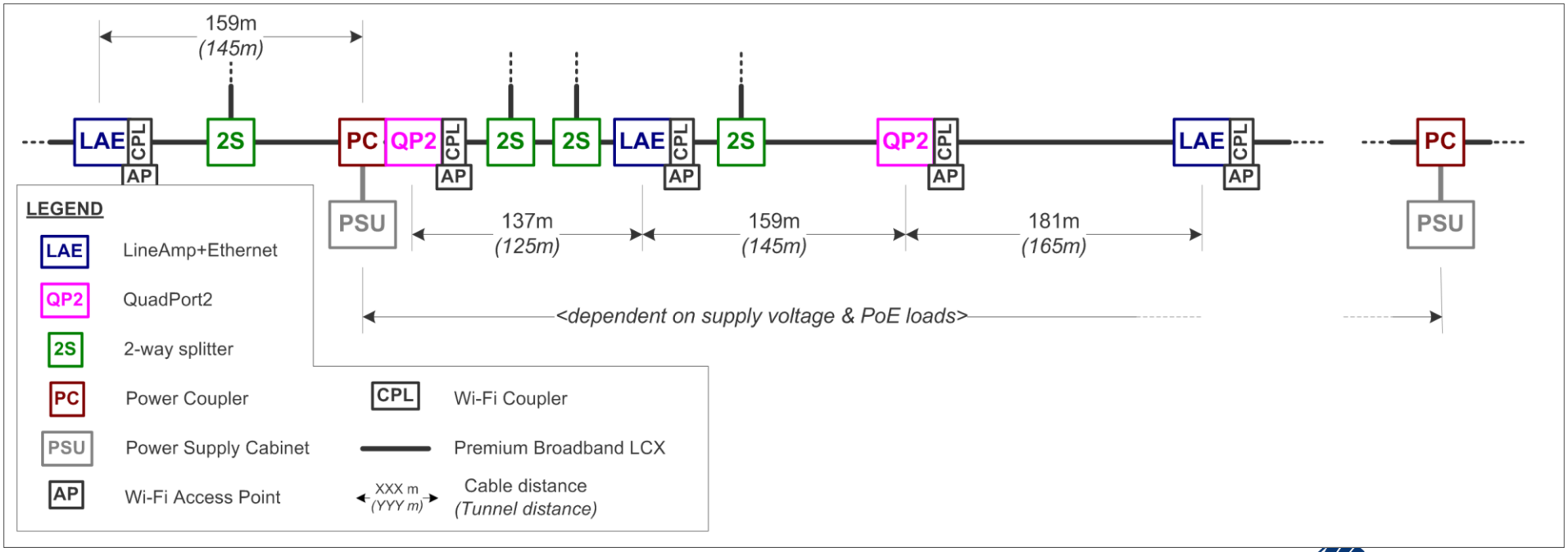
- Max. W-Fi segment length = 181m $\left[{}^{(30-3)\ \mathrm{dB}} / {}_{(0.149\ \mathrm{dB/m})} \right]$
- Subtract 22m for each 2-way splitter
- Alternate LAE & QP2 devices at the head of each segment
- Wi-Fi does not pass-through Power Couplers or QuadPorts.

RFI TECHNOLOGY SOLUTIONS

Offering 3: VHF Radio + Ethernet + radiating Wi-Fi on Premium Broadband LCX
Typical layout

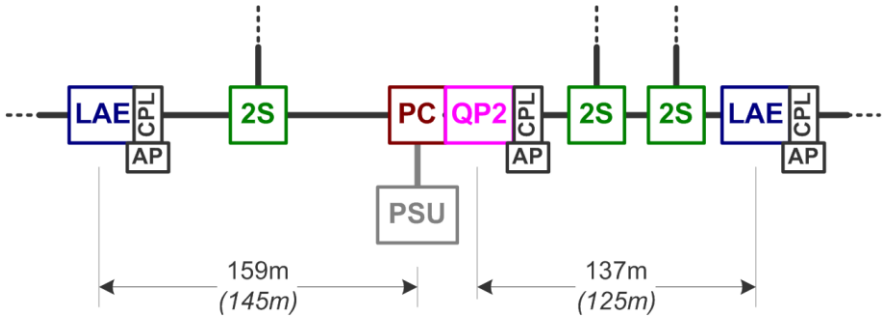
ASSUMPTIONS:

- ***2-way Splitters:*** Located every 135m *(tunnel distance).*
  Broadband Wilkinson dividers are used (RFI)
- ***LineAmp+Ethernet:*** 10 W passive PoE load connected to each (Microtik Metal)
- ***QuadPorts:*** 10 W IEEE PoE load connected to each (Microtik Metal)
- ***Power Strategy:*** Each LCX segment is powered from both ends, with each PSU able to take the complete load of the segment if the adjacent PSU fails.



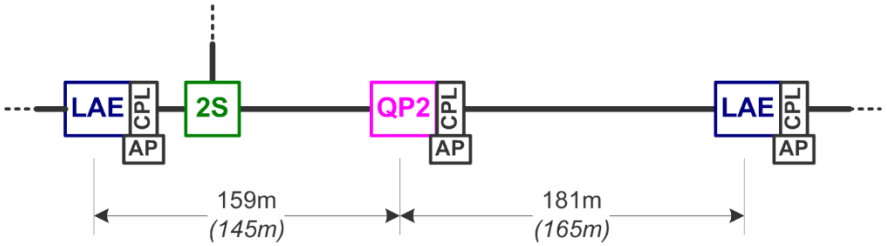
RFI TECHNOLOGY SOLUTIONS

Offering 3: VHF Radio + Ethernet + radiating Wi-Fi on Premium Broadband LCX
VHF design check



	Insertion loss (dB)	Calculation basis
Cable	8.3	0.028 dB/m * 296 m
2-way splitters	10.5	3.5 dB * 3 splitters
QuadPort2	3.0	3.0 dB * 1 QuadPort2
Power Coupler	1.2	1.2 dB * 1 Power Coupler
TOTAL	**23.0**	

- ***VHF Rule 1:*** insertion loss < 23 dB. ✓
- ***VHF Rule 2:*** insertion loss > 10 dB. ✓

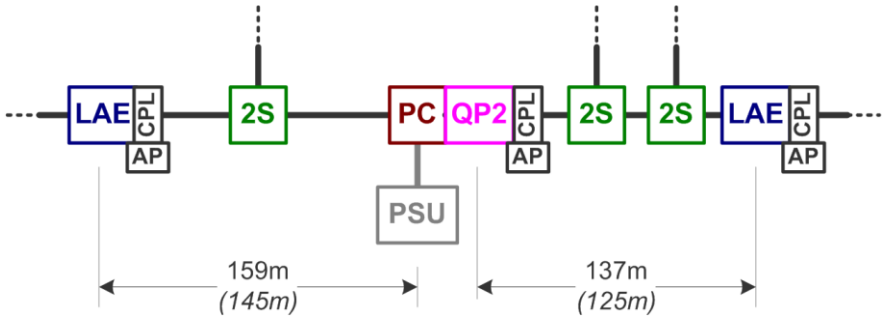


	Insertion loss (dB)	Calculation basis
Cable	9.5	0.028 dB/m * 340 m
2-way splitter	3.5	3.5 dB * 1 splitter
QuadPort2	3.0	3.0 dB * 1 QuadPort2
TOTAL	**16.0**	

- ***VHF Rule 1:*** insertion loss < 23 dB. ✓
- ***VHF Rule 2:*** insertion loss > 10 dB. ✓

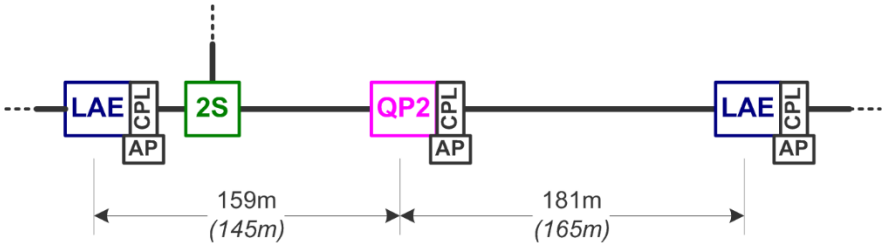
RFI TECHNOLOGY SOLUTIONS

Offering 3: VHF Radio + Ethernet + radiating Wi-Fi on Premium Broadband LCX
EoC design check



	Insertion loss (dB)	Calculation basis
Cable	5.6	0.019 dB/m * 296 m
2-way splitters	10.5	3.5 dB * 3 splitters
QuadPort2	5.5	5.5 dB * 1 QuadPort2
Power Coupler	1.2	1.2 dB * 1 Power Coupler
TOTAL	**22.8**	

Eoc Rule 1: insertion loss between LAEs < 45 dB. ✓



	Insertion loss (dB)	Calculation basis
Cable	6.5	0.019 dB/m * 340 m
2-way splitter	3.5	3.5 dB * 1 splitter
QuadPort2	5.5	3.0 dB * 1 QuadPort2
TOTAL	**15.5**	

Eoc Rule 1: insertion loss between LAEs < 45 dB. ✓

RFI TECHNOLOGY SOLUTIONS

Offering 3: VHF Radio + Ethernet + radiating Wi-Fi on Premium Broadband LCX

Power design check

TO DO

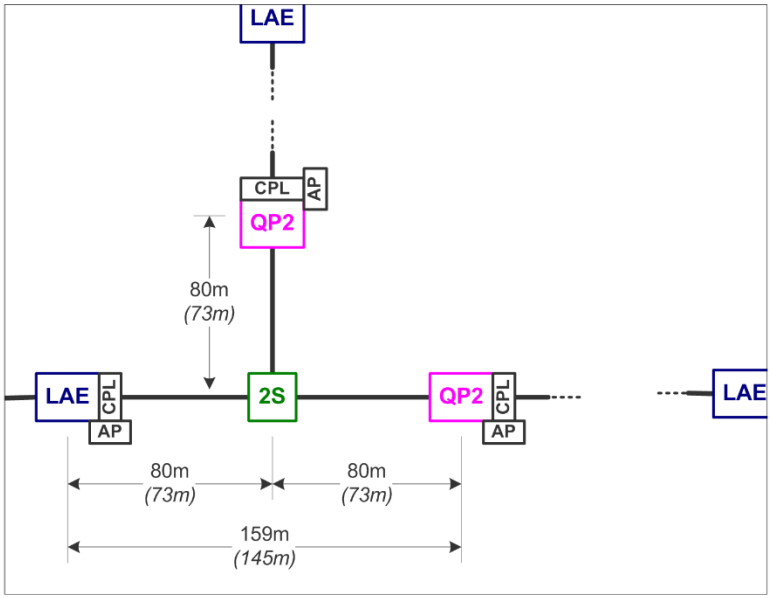
Offering 3: VHF Radio + Ethernet + radiating Wi-Fi on Premium Broadband LCX
Cost model basis

EXCLUSIONS(*):

- Radio headend and RF over Fibre (RFoF) equipment.
- Line terminations and stope antennas.
- Installation, commissioning & support labour.

NOTES:

- Tunnel distances (rather than cable distances) are used since this is more useful for mine planning.
- (+) 48 VDC line voltage has been assumed for the power coupler & power cabinet spacing.
- Each Wi-Fi segment covers 218m (tunnel distance), as shown in the image to the right. This drives the average spacing of LAE and QP2 devices to be 436m (because LAE & QP2 devices alternate at the head of each Wi-Fi segment).



RFI TECHNOLOGY SOLUTIONS

Offering 3: VHF Radio + Ethernet + radiating Wi-Fi on Premium Broadband LCX
Cost model

VHF 2-way radio + Ethernet + radiating Wi-Fi on premium broadband LCX costs $##/m(*)

Part	Name	Qty / km	Calculation basis	Unit price	Ext. price (per km)
DDLFS-LAE-V75 + DD-24V-POE-INJ-Q48	LineAmp+Ethernet 24V passive PoE injector	2.3	Avg. spacing = 436m	$#,###.##	$#,###.##
DDLFS-QP2-V75 + INS-3AF-O-G	QuadPort2 with VHF IEEE to passive PoE converter	2.3	Avg. spacing = 436m	$#,###.##	$#,###.##
DD-CPLR-7026-NF + CSM700-N + SP0000-7230-00	Wi-Fi coupler Compact Wi-Fi antenna 30dB NM to NF atten.	4.6	Avg. spacing = 218m	$###.##	$#,###.##
-	Microtik Metal AP	4.6	Avg. spacing = 218m	$###.##	$#,###.##
DDLFS-NF50-ADPTR	50 Ohm NF for DDLFS	9.2	2 req'd every 218m (LAE/QP2)	$##.##	$###.##
PSP6927-5302-N	2-way splitter (Wilkinson)	7.4	Located every 135m	$##.##	$###.##
DD-LFC-RMC12-1025-500	500m roll premium broadband LCX	2.2	1000m / (500m / 1.1)	$#,###.##	$##,###.##
DD-CONN-RMC12-1025-NF50	N-Female connectors for premium broadband LCX	31.4	2 req'd every 218m (LAE/QP2) 3 req'd every 135m (2S)	$##.##	$#,###.##
-	NM to NM jumper	36.0	3 req'd every 218m (LAE/QP2) 3 req'd every 135m (2S)	$##.##	$###.##
DDLFS-PC-V75	Power Coupler	TODO	Located every TODO (+)	$###.##	$###.##
-	Power supply cabinet	TODO	*<As above>*	$#,###.##	$#,###.##
TOTAL					**$##,###.##**