Cable Cost for LWA Stations

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1 Summary

The LWA is currently envisioned to consist of 52 stations, each consisting of 256 antenna stands, with each stand mounting 2 dipole-like antennas providing orthogonal linear polarizations. Signals from all stands within a station must be combined at some physical location before transmission to a central site. One possible architecture for this is bring the entire 30-90 MHz passband of each antenna to a central location at the station site – henceforth referred to as the "electronics bunker" – and at that point perform all other processing such as digitization and beamforming. This requires a separate RF connection between each antenna and the bunker. This report attempts to estimate the cost of the cables required to do this. It is found that this cost varies dramatically depending on design choices, but is lower bounded at about \$2K/station and upper bounded at about \$46K/station, with a cost of about \$10K/station being achievable for an attractive direct burial approach.

2 Analysis

LWA stations are envisioned to approximately circular, with all antennas positioned within a circle of $R \sim 25$ m radius. To simplify the analysis, let us assume that the electronics bunker is located a distance L_1 from the center of this circle, with L_1 possibly, but not necessarily, being greater than R. In this case, all cables run a length L_1 from the bunker to the geometrical center of the station, and then travel some additional distance from that point to the antenna stands. It is noted that this is probably not the optimal method for routing cables; for example, some reduction in the overall amount of cable required may be acheived by distributing the cables from multiple points within the station perimeter. However, the assumed geometry is useful in that it should yield conservative estimates.

Since the area enclosed by the station perimeter is about πR^2, we find that we have on average $N/(\pi R^2)$ antenna stands per unit area, where $N = 256$ is the number of stands. Assuming that this density is approximately uniform over the station, the total amount of cable required to connect all antenna stands to the center of the station is

$$\int_{station} M \left(\frac{N}{\pi R^2} \right) \rho \; dS \; , \tag{1}$$

where $M = 2$ is the number of cables per antenna stand (one per polarization), ρ is the distance from the center of the station to any other point within the station perimeter, and the integration is over the area of the station. Thus, we have

$$\int_{\rho=0}^{R} \int_{\phi=0}^{2\pi} M \left(\frac{N}{\pi R^2} \right) \rho \left(\rho \; d\rho \; d\phi \right) = \frac{2}{3} MNR \; . \tag{2}$$

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Cable cost	$L_1 = 0$ (8.4 km/station)	$L_1 = \frac{3}{2}R$ (27.8 km/station)	Remarks
\$0.13/m	\$1.0K	\$3.6K	+ cost of conduit
\$0.33/m	\$2.8K	\$9.2K	direct burial
\$1.64/m	\$13.8K	\$45.6K	estimated upper bound

Figure 1: Estimated costs of cable for a complete station under various assumptions concerning cost/length and the location of the electronics bunker.

Thus the total length of cable required to connect all the antenna stands to the electronics bunker is approximately

$$MN(L_1 + \frac{2}{3}R) \ . \tag{3}$$

For example, assuming $M = 2$, $N = 256$, $R = 25$ m, and $L_1 = \frac{3}{2}R = 37.5$ m (to put the electronics hut well outside the station perimeter) we find that 27.8 km of cable are required for the station, and the longest run is 62.5 m. If we were to reduce L_1 to zero (say, by putting the electronics bunker directly underneath the center of the station), then only 8.4 km are required for the station, and the longest run is a little more than 25 m.

The cost of cable per unit length varies dramatically depending on the type of cable selected. After a few minutes surfing the internet, the lowest cost that was identified for a type of cable that could conceivably be used was \$0.04/ft (\$0.13/m) for RG-59. RG-59 is 75-ohm cable which has a loss of $\sim$0.09 dB/m at 100 MHz, so the longest cable would have an insertion loss of about 6 dB, which is acceptable. However, this cable would not be rated for direct burial, and so would need to be either run within a conduit under the ground, or perhaps suspended above ground. The lowest cost encountered in the quick internet search for coaxial cable which was rated for direct burial was \$0.10/ft (\$0.33/m) for RG-6. RG-6 is also 75 ohm cable, but has an insertion loss of about 0.07 dB/m (i.e., somewhat better than RG-59). At the other end of the scale, most types of coaxial cable which are both relatively low-loss and rated for direct burial were found at costs of \$0.50/ft (\$1.64/m) or less in bulk, and so this is used as an extreme upper bound on the cost. In summary, costs for types of cables which are reasonable for this application range seem to range from about \$0.13/m to about \$1.64/m, with a good candidate being identified at a cost of \$0.33/m. Additional research is likely to yield even lower costs.

The results of the above analysis are summarized in Figure 1. We see that the total cost per station varies dramatically depending on design choices, but it seems safe to assume that the cable cost can be on the order of \$10K, and perhaps much less.

A remaining issue is, of course, the cost of connectors required for each end of each cable. The cost of connectors will be very small compared to the cost of a station and perhaps even compared to the costs of the cables themselves. To see this, consider that $2MN$ connectors are needed; i.e., 1024 connectors according to the current station design parameters. It should be possible to find suitable connectors for \$1 or less; in this case the total cost for connectors will be on the order of \$1K.