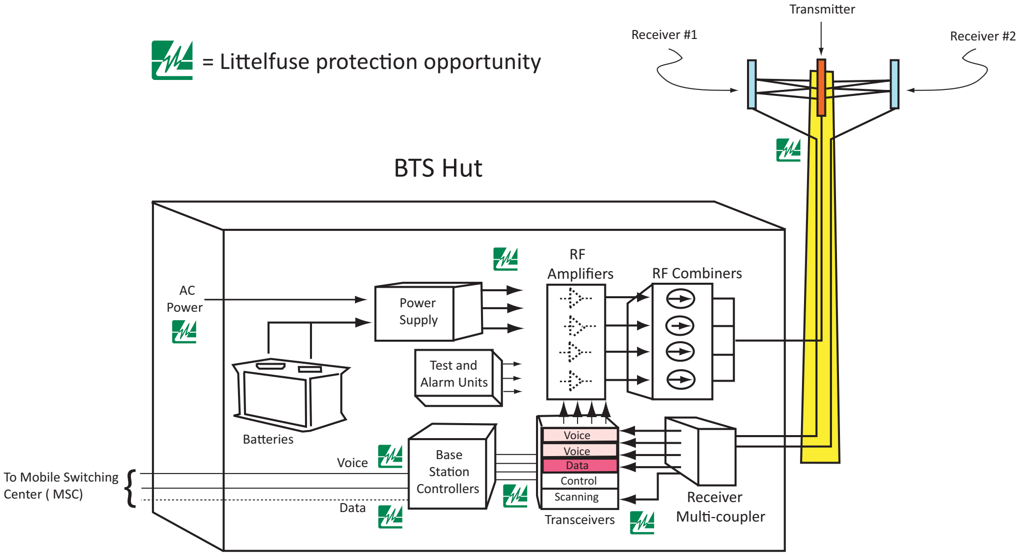
Application Note:
Distributed Base Stations

The most popular type of Wireless Base Station deployment (cell site) consists of a Base Transceiver Station (BTS) located in close proximity to the antenna tower. This BTS connects to both the Mobile Switching Center (MSC), which directs hand-off between towers for mobile users, and the Radio Frequency (RF) transmitters/receivers antenna located on the tower structure. The "hut" at the base of the tower or in the basement of a tall building is configured with the RF transceivers and RF amplifiers, along with the baseband processing unit, test and alarm unit, ac power, battery back-up systems, and a backhaul transport unit (MSC connection), all of which are typically installed in a single rack enclosure. The RF amplifiers drive through the cables to the antenna located at the top of the elevated tower. This typical setup requires climate controls for the entire building structure, a large building site footprint, and a hefty back-up system (large, bulky batteries); it also is subject to high signal and power losses in the cable due to the length of the cable between the RF amplifiers and the transmitter/receiver antennas mounted at the top of the tower. Tower Mounted Amplifiers (TMAs) are sometimes required to boost this RF signal when the distance between the tower-mounted antenna and the BTS location is too great. Some architecture changes are being implemented to correct some of these long-standing drawbacks.

Five basic Base Station architectures are in use today:

1. Legacy architecture, with all of the equipment located inside the BTS hut, with a coax connection to the top of the tower and a fiber/copper connection to the MSC (illustrated in **Figure 1**).
2. Split architecture design, with the BaseBand Unit (BBU) located indoors and a Remote Radio Unit (RRU) located on the tower (illustrated in **Figure 2**).
3. "Hoteling" approach that uses a single BTS hut but connects to multiple towers (illustrated in **Figure 3**).
4. All-outdoor, zero-footprint BTS, with all components located on the tower (essentially multiple boxes on the tower that travel via a combination of coax to the antennas and fiber/copper to the MSC without a BTS hut in between, as illustrated in **Figure 4**).
5. Capacity Transfer System (wireless BTS repeater concept) (illustrated in **Figure 6**).



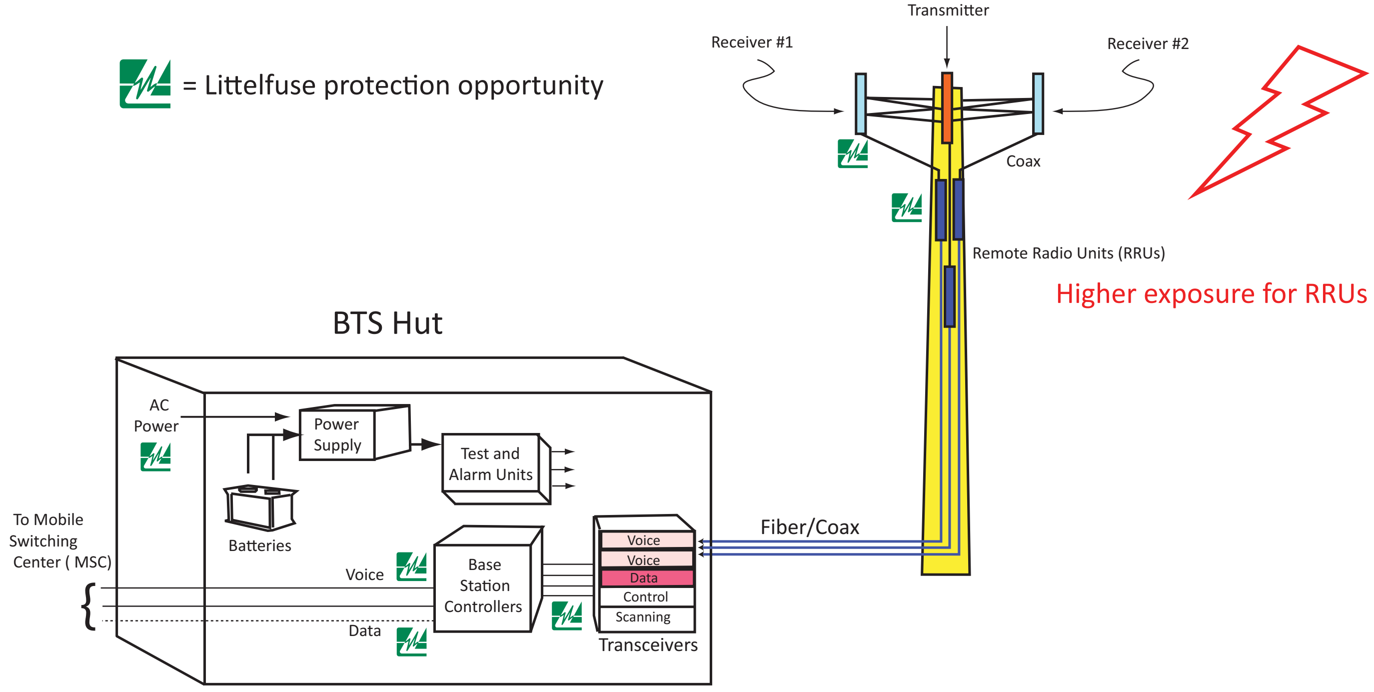
Radio tower and BTS equipment used in a typical cell site location.

Figure 1. Legacy BTS (cell site). Radio tower and BTS equipment used in a typical cell site location.

Legacy BTS drawbacks:

- BTS hut must be physically close to the tower to avoid the need for Tower Mounted Amplifiers (TMAs)
- Large footprint requirement
- Structurally reinforced rooftops needed to support BTS hut
- Lack of suitable size location in highly populated areas
- Parameter security requirements
- Nuisance appearance in local neighborhoods

The Distributed Base Station architecture illustrated in **Figure 2** places the RF transceivers on the tower. This arrangement requires an optical fiber to connect the digital baseband signals inside the BST hut with the tower mounted RRU. This allows making a much shorter coax connection between the RRU and the transmitters and receivers on the top of the tower. This arrangement consumes much less RF power due to the reduced losses that result from using the shorter coaxial cable and the optical fiber. It also allows greater flexibility in selecting the location of the BTS hut with respect to the tower. The BTS hut and the tower currently may be up to 20 km (12 miles) apart; in the near future, this may be as much as 40 km (25 miles).



Radio tower and Distributed BTS equipment

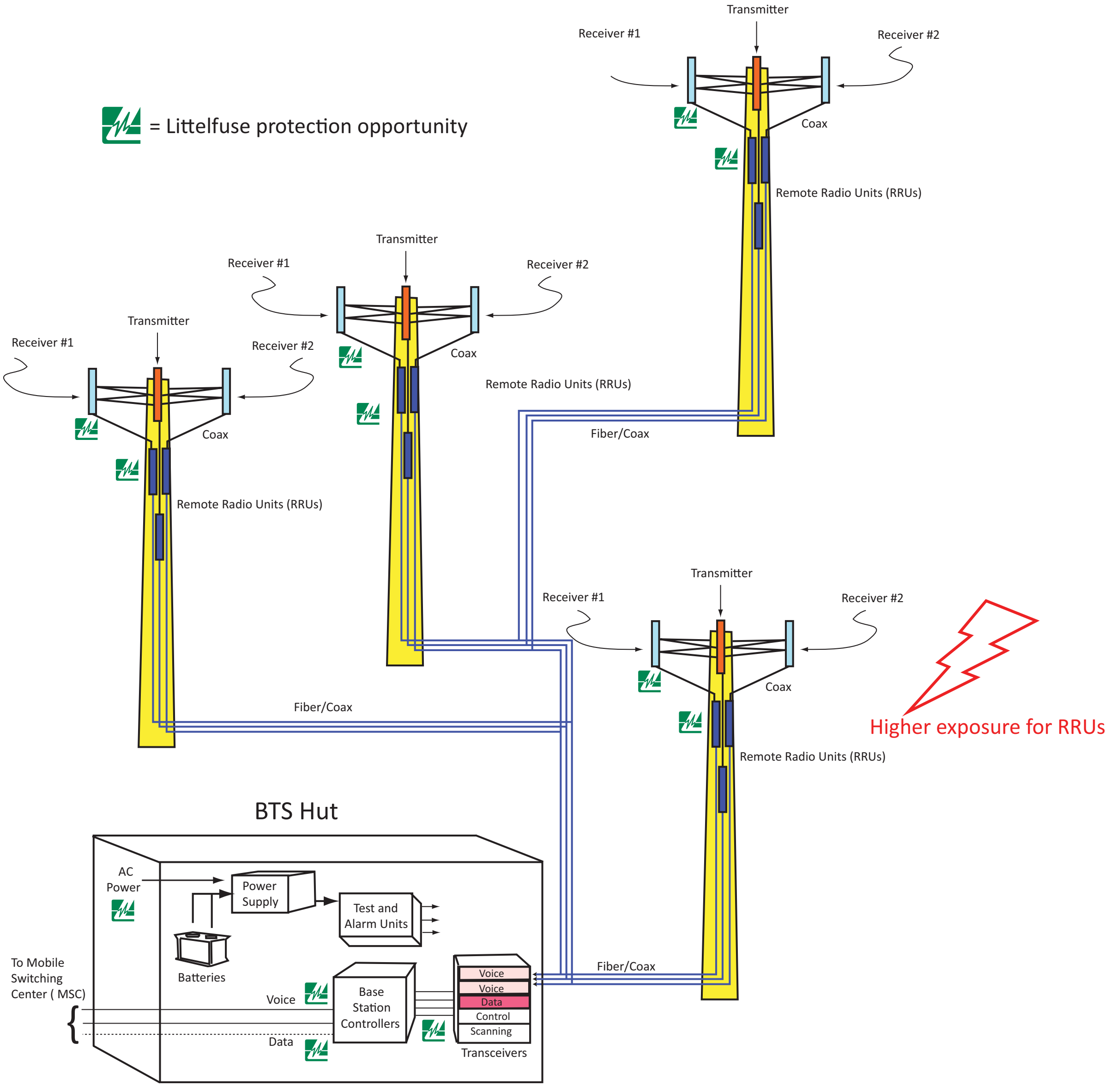
Figure 2. Distributed BTS Architecture

Distributed BTS architecture advantages:

- Hut can be physically remote from antenna site; no TMAs required, more flexibility on hut placement
- Smaller footprint requirements (lower power requirements): no special reinforced rooftops, reduced parameter security measures, reduced nuisance appearance

There are no RF amplifiers contained within the BTS hut or TMAs because the RRU performs this function in this architecture. However, because this function is now located on the tower, it has increased exposure to lightning induced surges.

This Distributed Base Station concept can be further expanded by using a central remote "hotel" for multiple tower sites (see **Figure 3**). This approach dramatically reduces the required footprint, which allows for an easier expansion of the new 3G and 4G Base Stations in densely populated downtown districts. Placing all of the hardware on the tower (see Figures 4 and 5) makes a zero-footprint design possible.



Radio tower and Distributed Base Station equipment

Figure 3. "Hoteling" Distributed BTS Architecture

"Hoteling" Distributed Base Station Architecture advantages:

- Single hut can be physically remote from multiple antenna sites
- No TMAs required because RRUs substitute for this feature
- More flexibility on hut placement due to smaller footprint
- Lower power requirements
- No special reinforced rooftops requirements
- Reduced parameter security measures
- Reduced nuisance appearance

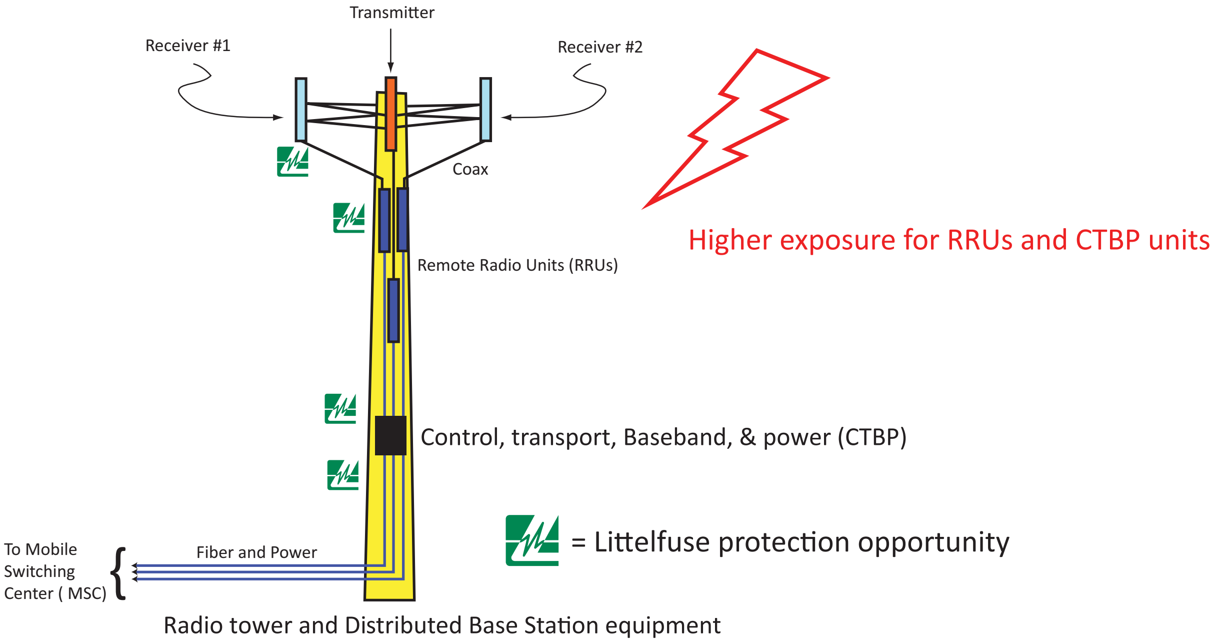


Figure 4. Zero-footprint BTS Architecture

Zero-footprint Architecture advantages:

- No TMAs required, most flexibility
- No footprint requirements except for tower (this equipment may be installed on the top floor of a parking garage without need of a tower)
- Lowest power requirements
- No special reinforced rooftops
- No physical security measures (depending on specific location of equipment)
- Minimized nuisance appearance

Figure 5 shows a zero-footprint BTS installed on the top floor of the parking garage at the Littelfuse, Inc. headquarters building in Chicago, Illinois, USA.

Figure 5: Zero-footprint BTS installed on the top floor of a parking garage.

Another variation on the Distributed BTS concept is the capacity transfer system, in which a single BTS with a digital connection to the BSC (Base Station Controller) is connected to additional tower sites via microwave frequency carriers to extend its footprint coverage (see **Figure 6**).

The RRUs are powered by either a shielded or unshielded dc power cable. Because they are now located on the tower, their exposure to nearby lightning strikes is greatly increased. Therefore, appropriate overvoltage protection must be considered for these new architectures. ITU K.56 provides some basic recommendations for the BTS hut; however, it was issued before the concept of Distributed BTSs started. New efforts are underway in ITU Study Group 5 to define the lightning protection needs of this new architecture.

The power supplies and the tower mounted equipment require both over-voltage and over-current protection. **Figure 7** illustrates the recommendation for protecting the power supply interface as a block diagram. Given that this dc supply is most likely a 48-volt supply, the stand-off voltage for the protection

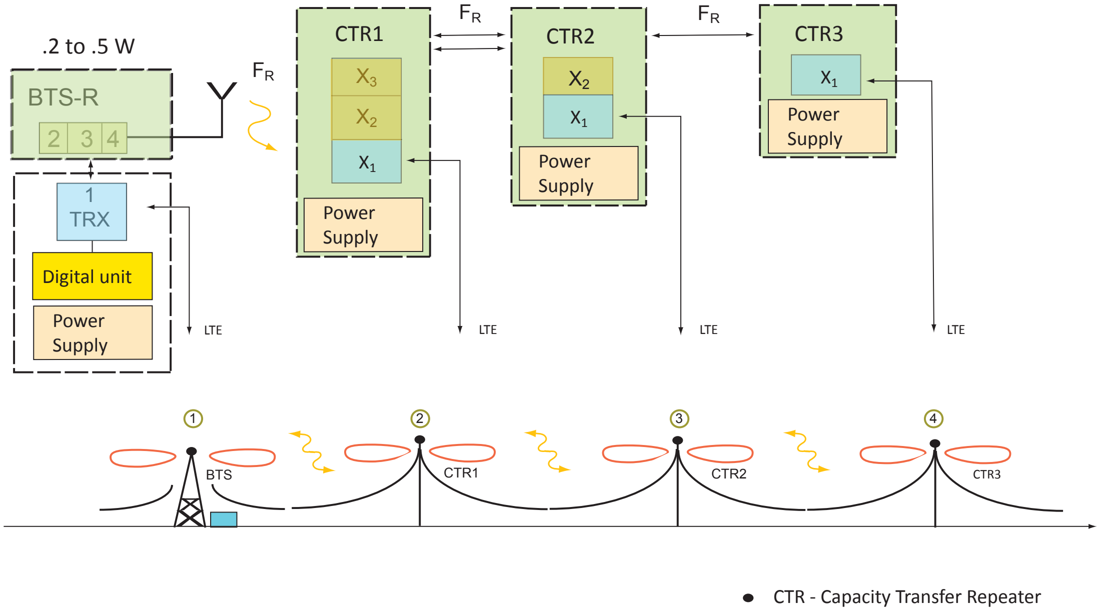


Figure 6. BTS repeater concept (Capacity Transfer System)

BTS system with a single connection to the central BTS-R (digital unit) and then RF connections between the BTS-R and CTR1, CTR2, and CTR3 (repeaters).

is easily defined. The worst-case surge resistibility may be defined as a 40 kA 8/20 event for an unshielded system and 20 kA for a shielded cable (**Table 1**).

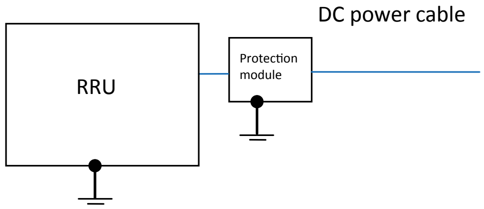


Figure 7: Recommendation for protecting the power supply interface.

This protection module has three possible solutions as illustrated in **Figure 8**.

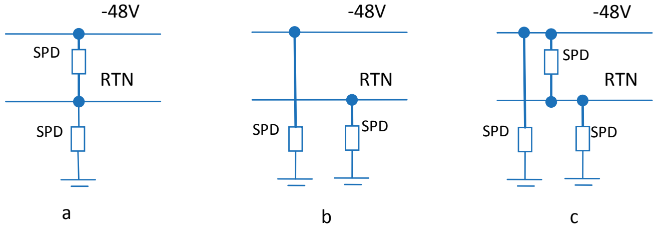


Figure 8: Protection module implementations.

Table 1: Lightning Protection Levels (LPLs).

Lightning Protection Level		I	II	III-IV
Current (kA)	Unshielded cable	40	30	20
	Shielded cable	20	15	10

8/20 µs peak current

To meet the worst-case situation for the unshielded cable, each individual SPD shown in **Figure 8** would have to consist of three (3) AK15-058C devices, but to meet the minimum case for a shielded cable (10kA), a single AK10-058C could be used for each SPD position. **Table 2** shows the various surge rated AK devices available with a 58-volt stand-off parameter.

Table 2: AKxx-058 Series Electrical Characteristics.

Part Number	V_{SO}	I_R	VBR		I_T	V_{CL} @ I_{PP} (8/20µs)		Max Temp Coefficient	Max Cap @ 0 V bias 10 kHz
	V	µA	Min	Max		V_{CL}	I_{PP}	%/°C	(nF)
AK15-058C	58	20	64	70	10	110	15000	0.1	12
AK10-058C							10000		6.5
AK6-058C							6000		8
AK3-058C							3000		6

For over-current protection of these over-voltage devices, the LVSP20/30/40 power fuses would be appropriate for the 20 kA/30kA/40 kA categories of the LPL classes from **Table 1** so that excessive lightning induced events nor excessive power fault events do not cause a safety-related issue with the AK devices (this fuse is placed in series with the AK device, NOT in series on the power supply line). However, the design engineer must be aware of the I^{2}t rating for each fuse because the "lightning rating" is so high. For example, the LSVP20 has a nominal I^{2}t of 4,940A^{2}S. See **Table 3** for a list of available Littelfuse options.

Table 3: LVSP fuse

Part Number	8/20 Rating	I^{2}t melting (A^2 s)	I^{2}t clearing (A^2 s)
LVSP 5	5,000	359	981
LVSP10	10,000	1,300	3,210
LVSP15	15,000	3,267	8,235
LVSP20	20,000	4,940	11,710
LVSP30	30,000	11,950	35,325
LVSP40	40,000	20,550	61,700

The rectifier located within the hut that is supplying this dc power should also be protected and comply with ITU K.56. The protection module illustrated in **Figure 9** would use the same options as shown in **Figure 7** and **Figure 8** (a single SPD, two SPDs, or three SPDs). Refer to the Littelfuse *Radio Base Station Protection Summary* article for full details.

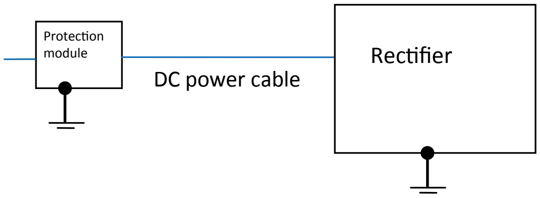


Figure 9: Protection module.

The dc voltage feeder cable between the RRU and the transmitter/receiver located at the top of the tower should not require an additional protection module if the RRU dc voltage feeder has been protected sufficiently and there is sufficient distance between the RRU and the top of the tower.

One can quickly see from Equation 1 that the $Z_T l$ factor must be a significant value to result in a peak surge voltage of concern (such as non-Distributed BTS architectures where the distance between the tower top and the radio unit is significant). If this feeder uses the same conductor as the RF feed between these two points, then a low capacitance solution would have to be used to prevent any negative impacts on the high frequency content. If this feeder carries the dc power feed only, then the protection choice may include the AK series.

Equation 1 is useful in determining the peak voltage on this dc voltage feeder cable.

$$V_T = I_{LPL}\alpha_T\alpha_F Z_T l \qquad \textit{Eq. 1}$$

where:

I_{LPL} is the peak lightning current associated with the application. The lightning protection level rating as given in **Table 4** based on the 10/350 waveshape.

l is the length of the feeder cable.

The value of α_T is determined by the tower and feeder geometry. Typical values are:

Tubular tower (mast): $\alpha_T = 0.30$
Three legs tower: $\alpha_T = 0.20$
Four legs tower: $\alpha_T = 0.15$

Equation 2 provides an approximate value of α_F, where n is the number of cables in the feeder tray.

$$\alpha_F = \frac{1}{n + 3.5} \qquad \text{Eq. 2}$$

Table 4: Lightning flash parameters from [IEC 62305-1] are based on a 10/350 mS waveshape

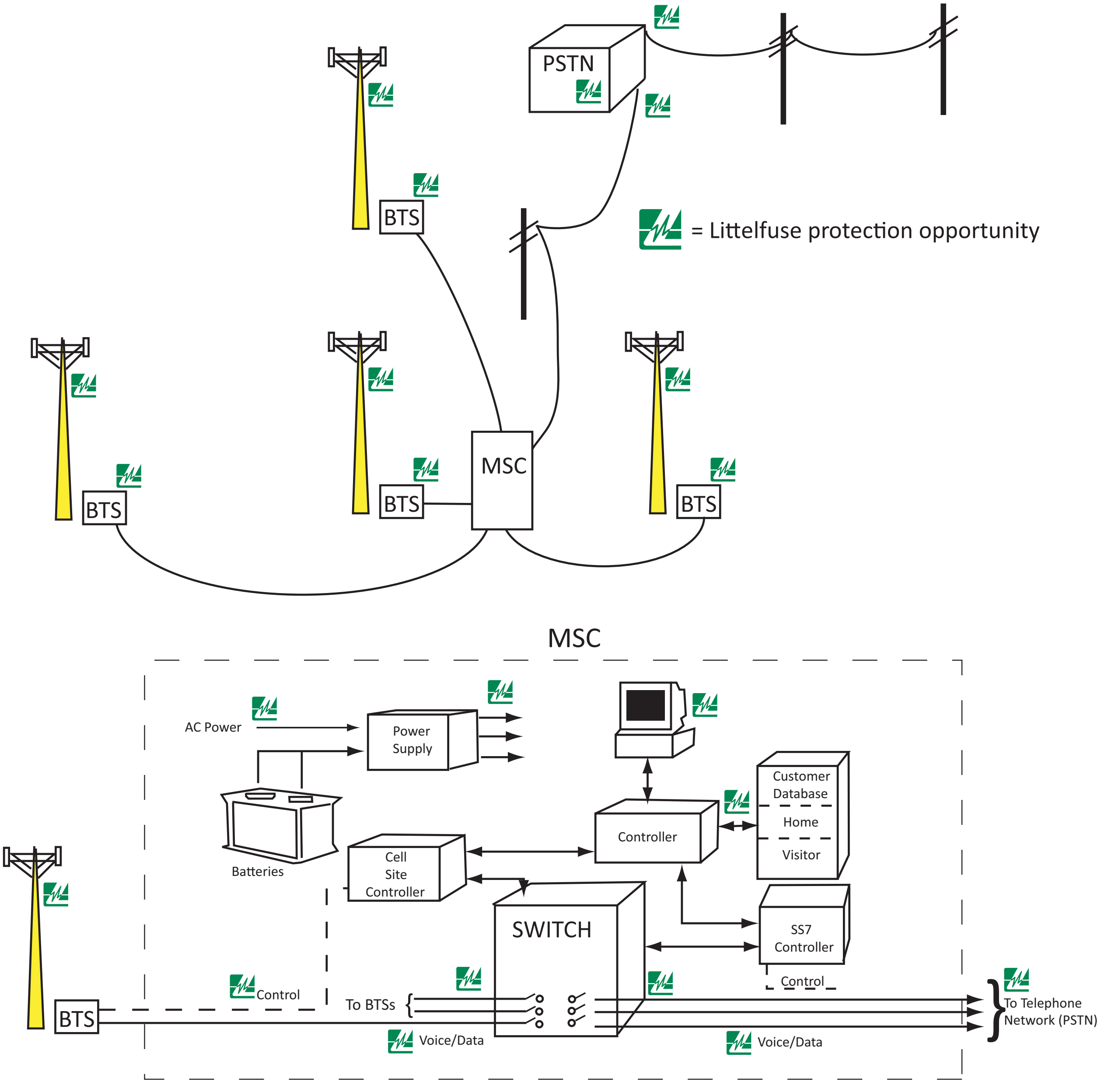
Parameter	Units	Lightning Protection Level (LPL)			
		I	II	III	IV
Max peak current	kA	200	150	100	100

Table 5: Typical values of DC resistance of the external conductor of coaxial feeder cables (ZT).

External diameter (mm)	7.8	10.2	13.7	27.5	39.0	50.3	59.9
DC resistance (Ω/km)	6.6	5.3	3.4	1.04	0.62	0.47	0.31

The various data communication and long haul ports located inside the Base Station hut or on the tower such as Ethernet ports, T1/E1 ports, or xDSL ports should also be protected accordingly. Refer to the Littelfuse *Ethernet Protection Design Guide* for more details on the Ethernet port protection recommendations and the "Reference Designs" section of the Littelfuse *SIDACtor Product Catalog and Design Guide* for other port protection recommendations.

Figure 10 provides an overview of how the BTS connects to the MSC.



Radio tower and Distributed BTS equipment

Figure 10. This MSC (Mobile Switching Center) connects mobile users to mobile users or mobile users to wireline users.

Littelfuse, Inc.
8755 West Higgins Road, Suite 500
Chicago, IL 60631 USA
Phone: (773) 628-1000
www.littelfuse.com