Lightning, Grounding, and DOC Circuitry

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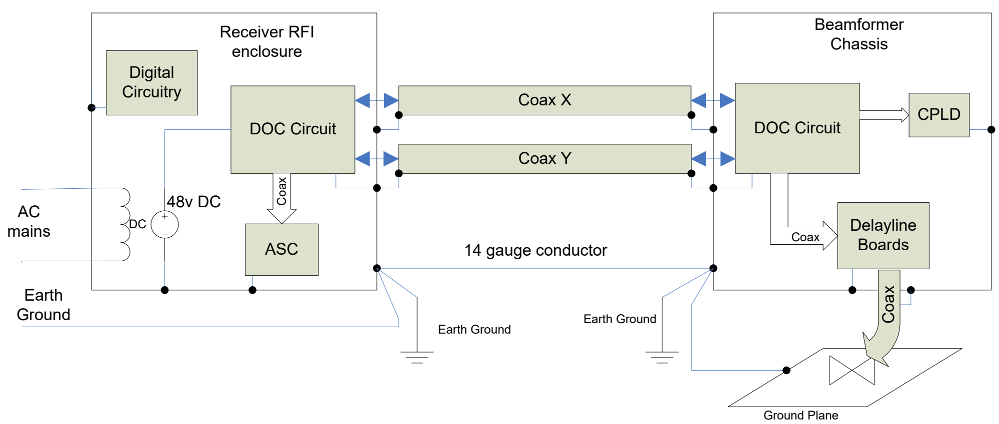
Introduction

The Data over Coax (DOC) circuitry is intended to minimize the number of conductors that must run between the beamformer and the receiver of the MWA telescope. Integral to the DOC circuitry is the RF signal, 48v power, digital control signaling, and lightning protection. To properly implement the DOC circuitry as well as maintaining safety, an appropriate grounding scheme must be employed.

System Diagram

The basic diagram of the DOC circuitry with its grounding scheme is shown below. The RF and digital control signals are AC coupled and the 48v power and lighting protection are DC coupled. Reference [1] shows a similar sort of earth connection.



DC Power

The Receiver has a 220AC to 48vDC power supply in it and the 48vDC is fed to the Beamformer in the center conductors of the coax cables. The 48vDC return is through the coax shields which is connected to the chassis of the Receiver on one end and the chassis of the Beamformer on the other end . An additional conductor is added between the Receiver and Beamformer to help discharge any voltage buildup between them.

Since DC power is used there will a nominal chassis potential difference between the Receiver and the Beamformer of 1.8v, and a maximum of 3.1v based on the fuse values for a point failure, for a 200m cable. Some amount of DC power will be sent through the earth due to the chassis potential difference, but the resistance of the earth should be high enough that it will not create noise that will be received by the RF circuitry. The digital control signals and RF signals are unaffected by any chassis DC potential differences since they are AC coupled. Since 48vDC is used, all voltages present at the beamformer/tile are within the guidelines of the IEC 60950 codes for TNV-2 and TNV-3 systems, which consider DC voltages under 60v as low voltage.

Lightning

The MWA Antenna tile is unlikely to survive a direct lightning strike due to the proximity of the LNA to the antenna element arms, and is considered expendable. However, some lightning protection is employed in front of each LNA. Each antenna arm on both polarizations are grounded through a 470uH inductor, to dissipate static charges, as well as having back to back low capacitance diodes from each element to ground. The peak surge current the diodes can handle are 2amps, above which they will break down and allow the gate voltage on the LNA to rise. The LNA will suffer permanent damage when the gate to source voltage rises above 2v. The use of larger diodes usually implies a greater capacitance at the input and that rapidly degrades the noise performance of the LNA.

The RG-6 cable connecting the beamformer to the receiver has an additional ground conductor which is intended to reduce the resistance of the dc power return path. This wire is not intended to provide a conduction path (counterpoise) for lightning and will likely be damaged in a direct lightning strike.

The receiver is significantly more expensive and should have more lightning protection. The diagram shown above indicates a ground rod at both the beamformer and the receiver, and while it may be argued that it is not necessary at the beamformer end, it is required at the receiver end to adequately discharge lightning strikes. The DOC circuitry at the receiver end includes a 500 amp gas discharge tube from the center conductor to the shield as well as back to back diodes. The shield and the additional ground wire are directly connected to the chassis. All the other penetrations in the receiver should also have a low impedance path to ground during a strike.

The probability of a lightning strike is given in [2] as

$$Ng*(s+4*h)^2$$

Where

Ng = Number of strikes/km^2/yr
s = length of sides of object
h = height of object

For the MWA we can use Ng=2strikes/km^2/yr, s=5m, h=.6m, to find a probability of a lightning strike on a single tile to be1.09e-4strikes/yr. Assuming independence between tiles, for the 512 tile system the probability of a lightning strike is 0.056strikes/yr.

Assuming there is 20km of RG-6 cabling between the tiles, and that its height above the ground is negligible, the probability is;

Ng*(w*L)

Where

Ng = 2 strikes/km^2/yr
w = width of the cable, 1.75cm
L = length of the cable, 20km

Which gives a probability of 7.0e-4 strikes/yr. This neglects the effect of surrounding shrubbery and variations in cable height above the ground.

From the above analysis the probability of a lightning strike on the MWA antenna system is once in 17.6years. This does not take into account the receiver and any other outbuildings used to house electronic equipment. All structures should be earth grounded according to local building codes. More detailed information is found in the following standards;

NFPA 780:2004
IEC62305-1:2006
IEEE998:1996

References

[1] ARRL Antenna Handbook, 16th edition, Ch1, Figure 16.
[2] Uman, Martin, "The Art and Science of Lightning Protection," Cambridge University Press, 2008.