Note 143

Note

General Principles for the Design of

ATLAS I and II

Part I:

ATLAS: Electromagnetic Design Considerations

for Horizontal Version

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ATLAS:

Electromagnetic Design Considerations for Horizontal Version

1. Plate spacing

- enough to avoid more than some desired fractional change of current and charge parameters of largest aircraft - ignore earth presence for the moment.

- also specifies pulser voltage for field spec. - note some field nonuniformity.

2. Plate width

- choose from a width to spacing ration based on a desired field variation over the working volume - earth not yet included.

3. Impedance of simulator

- from width to spacing ratio without earth.

4. Length of the input double transition

- enough to meet a planarity specification (in meters or ns) over the cross section of the transmission line (say between plates) or equivalently over the working volume.

- keeping the simulator symmetrical the two transition sections might meet before the plane where the transition conductors attach to the transmission line.

- this length is out to two apexes and the generators need not be that far back if a distributed generator is used.

5. Connection of pulser design with double transition section

- two pulsers or pulser arrays

- design each to work against an infinite ground plane

- each drives an impedance (forward) equal to the impedance of one of the transitions which is half the basic simulator impedance

- for early times this impedance is halved for a pulser array for a time of order of the transit time across the array

- for pulser array the plate spacing at the array is spcified by pulser design (electrical stress) - this affects the transition length in that the effective apex is behind the pulser array but for flexibility one might put the arrays at the effective apexes and have a better planarity but go back to the original planarity spec. when the pulser array is replaced by a low voltage source with a corresponding change in the small width pos. or neg. plate - alternately the low voltage transition (including ground plane extensions) might just go farther back to the design apexes.

6. Central ground planes in double input transition

- initially consider them as infinitely wide compared to pos. and neg. plates which connect to the transmission line.

- for finite width look at the fractional impedance change from the infinite width case - make this change (an increase in impedance) small in a relative sense.

- it is easy to make the ground planes comparatively wide back at the pulsers - at the transition output it is more difficult - it is not necessary to maintain a constant ground plane width to spacing ratio - the idea is to make the impedance change and thereby the fringe fields at the ground plane edge unimportant and some change in an unimportant quantity is allowed.

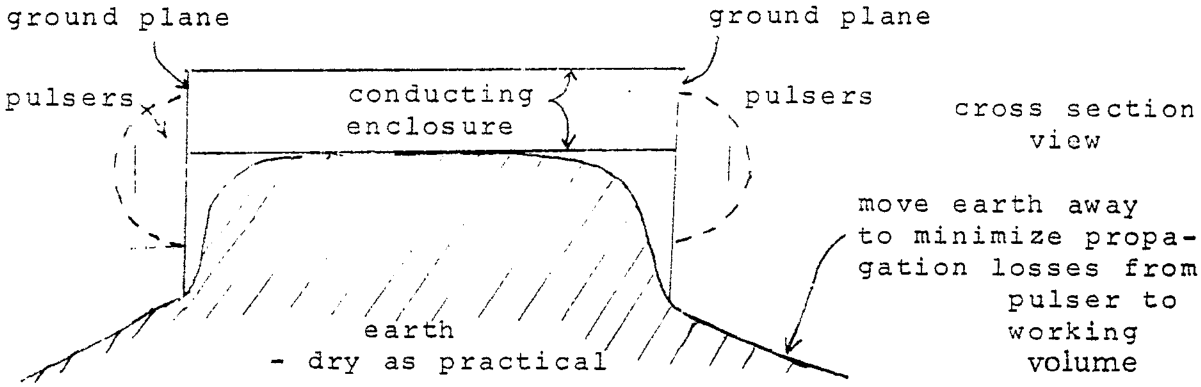
- the ground planes extend down to earth and the earth between the ground planes is covered with a conducting surface.

- the top edges of the ground planes are connected by a conducting surface which also connects to the conducting surface on the earth back at the pulsers thereby forming a large enclosed shielded volume.

- the shilded volume so formed contains pulser control and recording facilities for environment monitors and perhaps telemetered data.

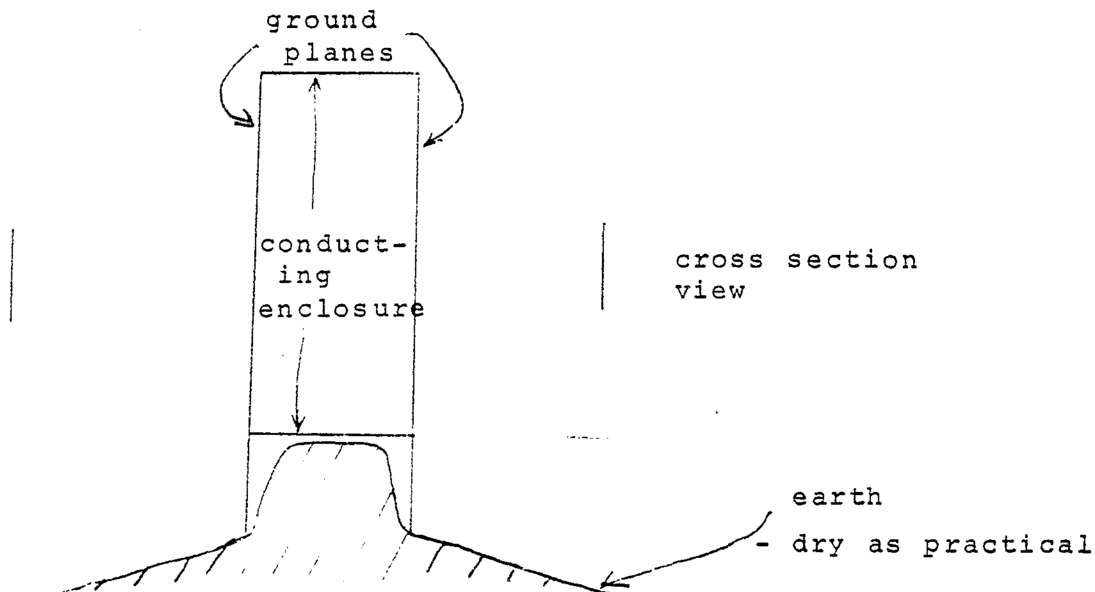
7. Earth shaping around input transitions and pulsers

- the pulser ground planes look like

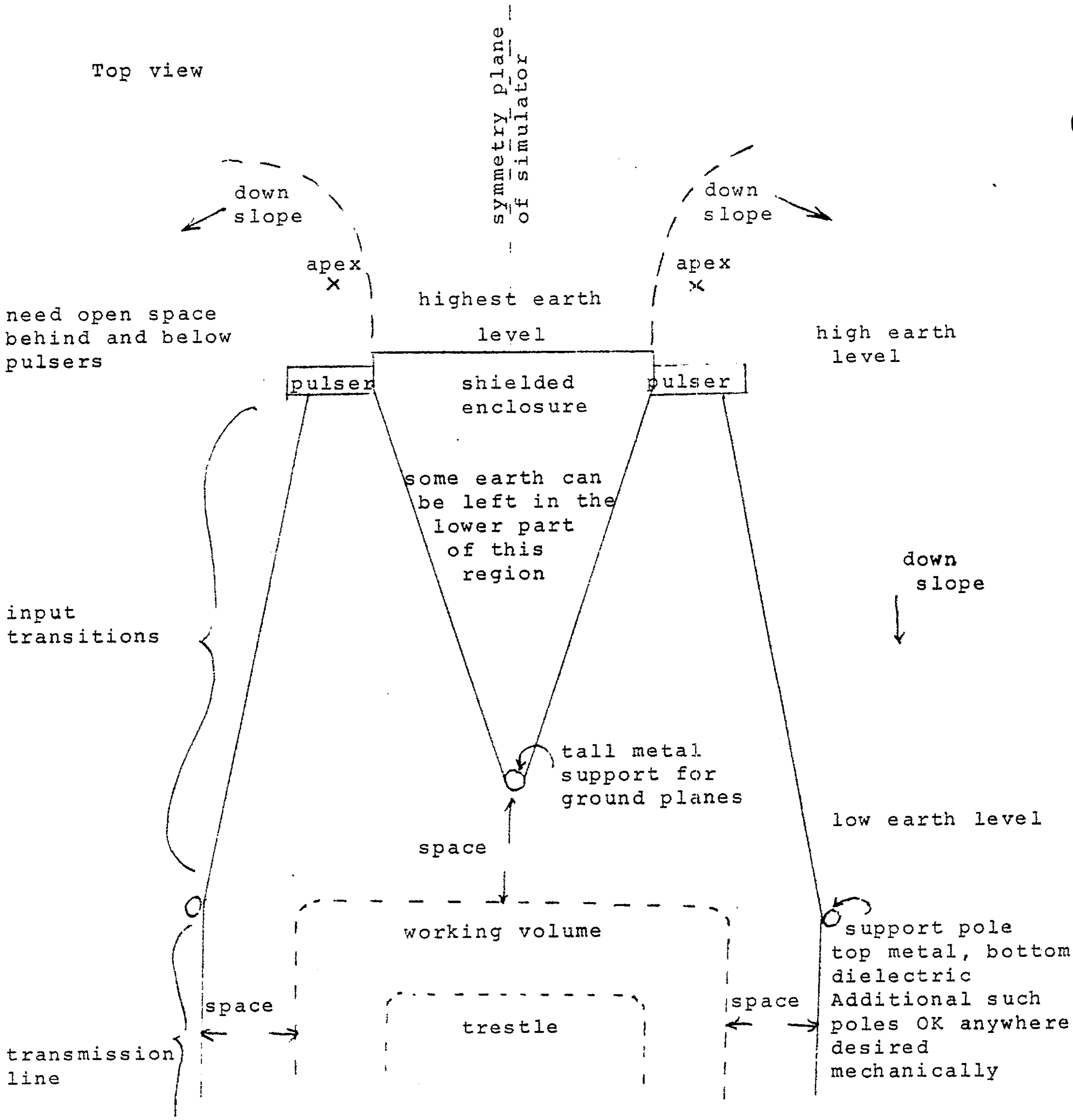


- on field side of ground plane earth must be away from the pulsers a distance associated with the ground plane width.

- near the output of the transitions this is like



- note that any high frequency propagation loss for what gets to the working volume must occur in the input transitions - if the ground planes are wide enough coupling to the earth can be made sufficiently small so that losses are small enough - note that transit time delay of a wave from pulser to earth to working volume also helps here

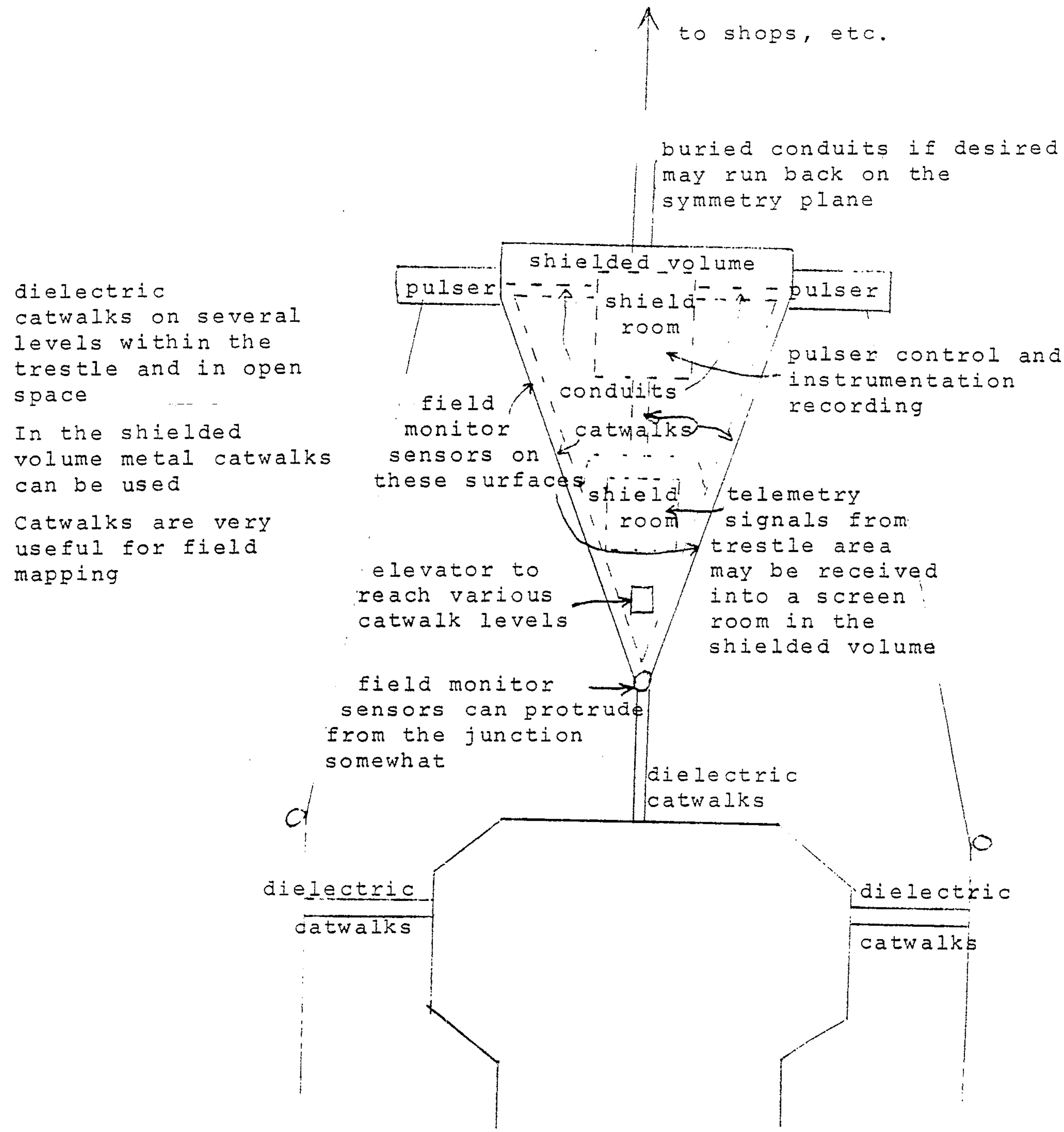


8. Working volume relative to transitions

- working volume includes aircraft overhang beyond trestle.

- aircraft should be far enough back from ground plane intersection to not couple to the dual ground plane structure.

9. Facility instrumentation layout



Some fields will go into the coarsely shielded volume because it is mostly wire grid.
Resulting low level resonances induced inside this volume can be severely damped by connecting strategic points together by a wire through space with damping resistors in it.

10. Earth shaping under trestle

- two options

A. taller trestle over bascially flat earth

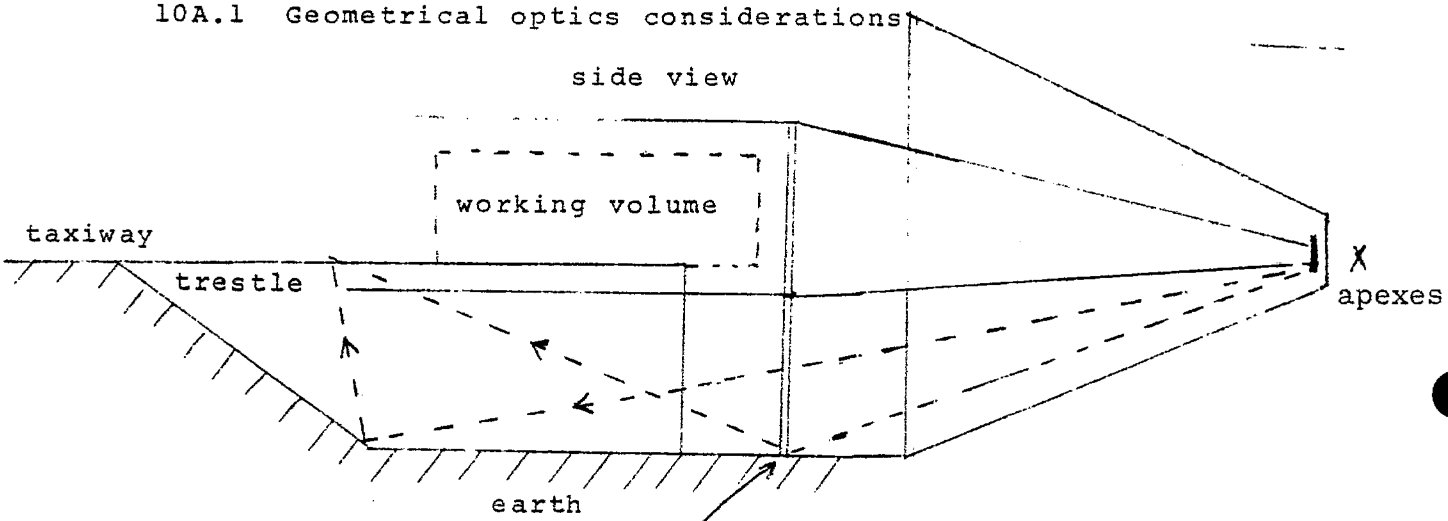
- simplifies electromagnetic considerations with simpler earth shaping - allows various aircraft entry directions.

B. shorter trestle over earth mound

- more complex earth shaping and more complex electromagnetic design considerations

10A.1 Geometrical optics considerations

side view



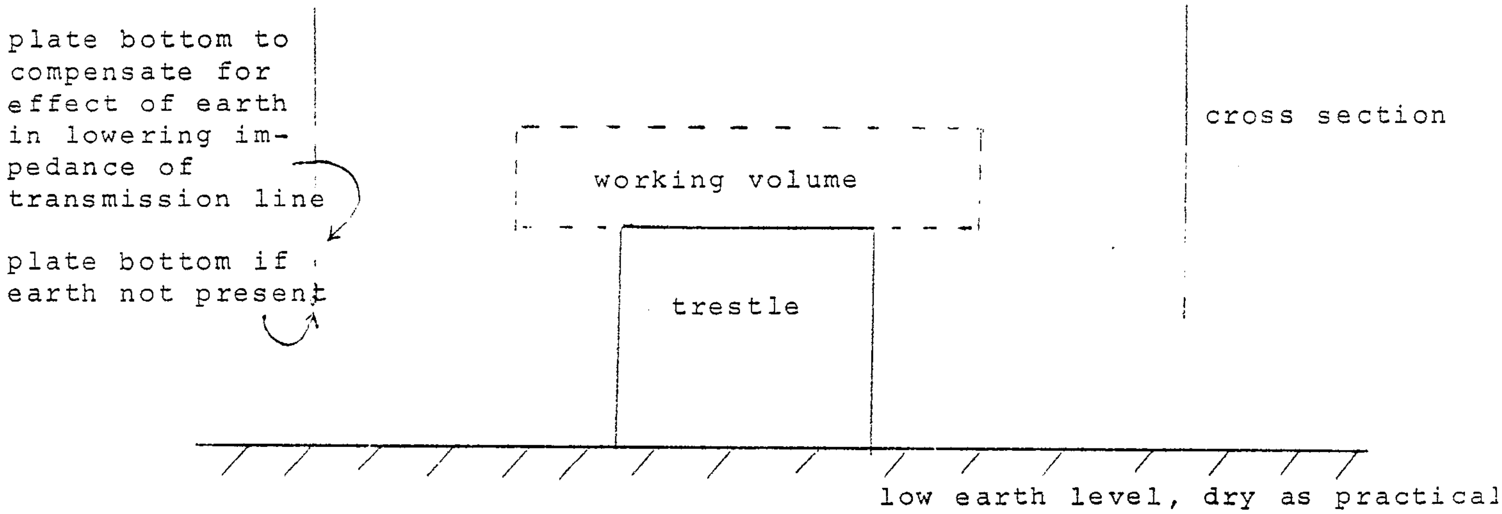
make sure the relections off the earth pass below and behind the working volume with some room to spare.

This removes all direct ground reflections.

It makes the trestle at least some height based on the transition length and working volume.

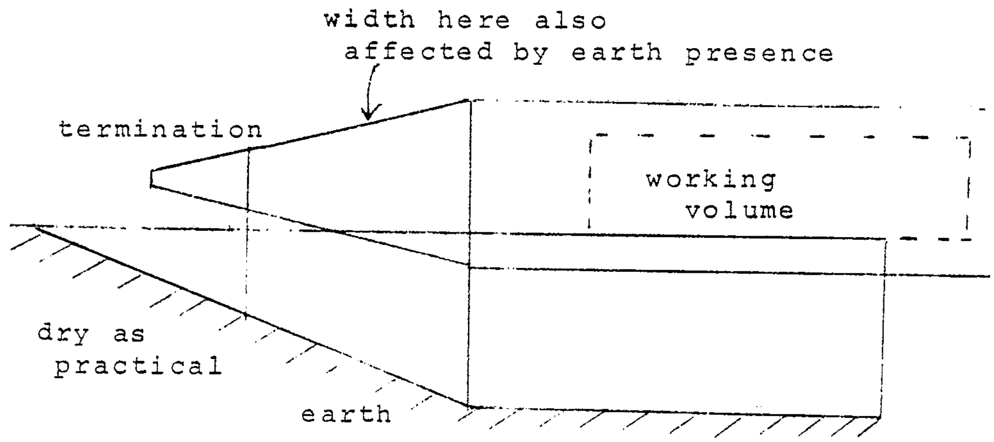
The slope up to the taxiway must also not be so steep as to directly reflect from the apex back to the working volume.

10A.2 Low frequency impedance change



Keep level low to like a spacing away from the transmission line conductors.

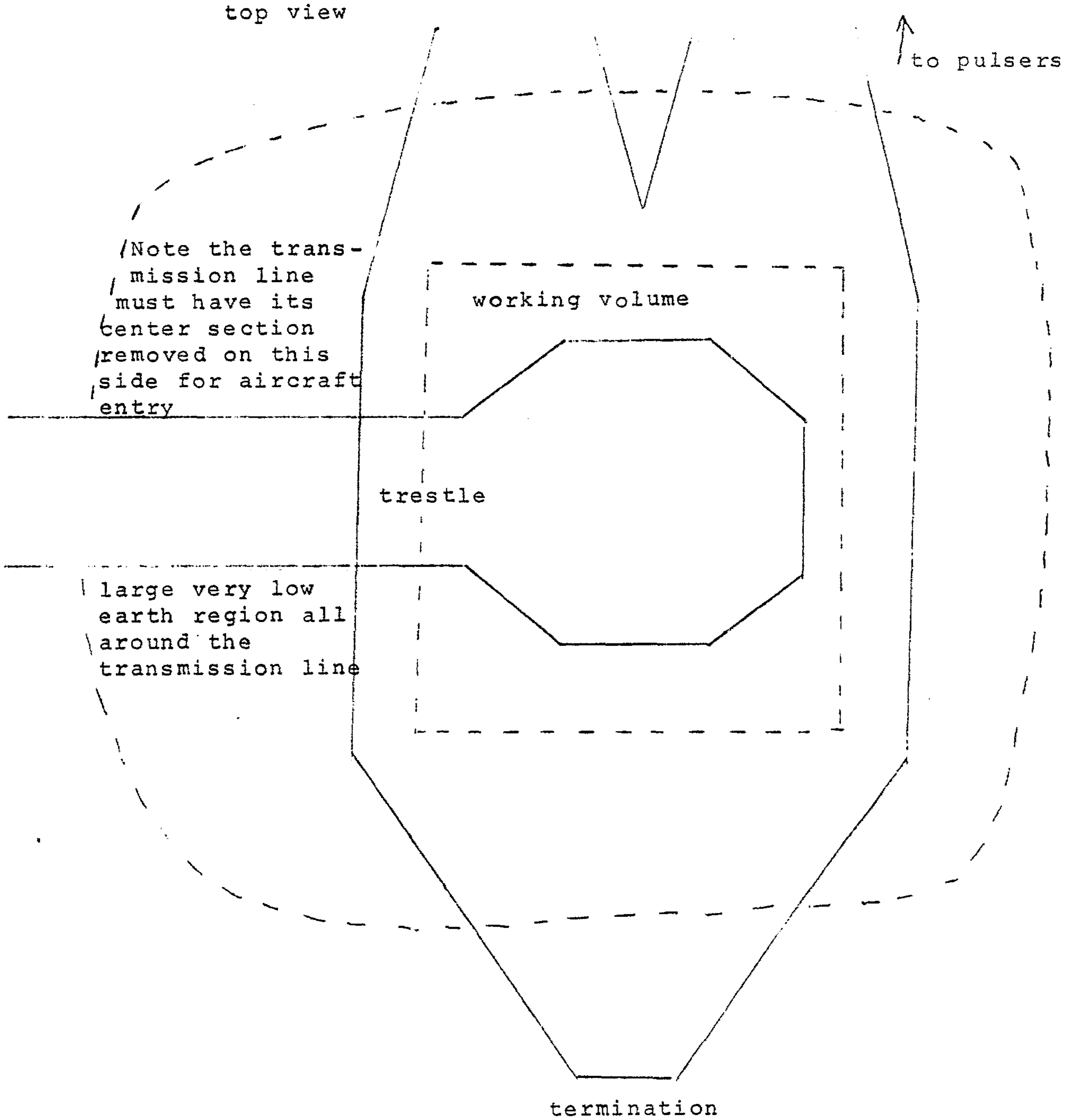
side view with entrance through termination



Make the impedance change a small number and compensate for it by raising the bottom of the conducting plates.

10A.3 Side entry of aircraft for option A

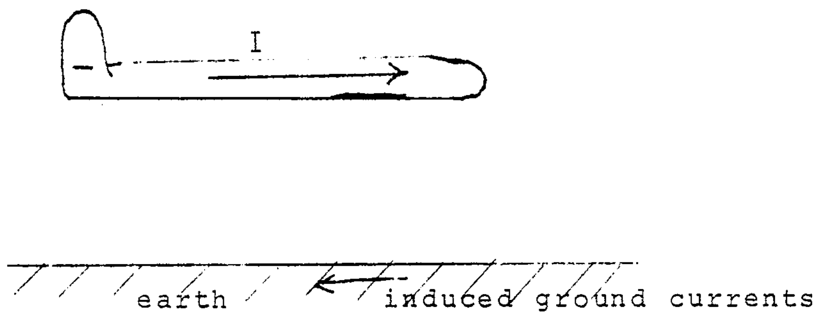
- this option allows side entry of the trestle if desired.



10A.4 Distortion of currents and charges on aircraft by coupling from aircraft to ground

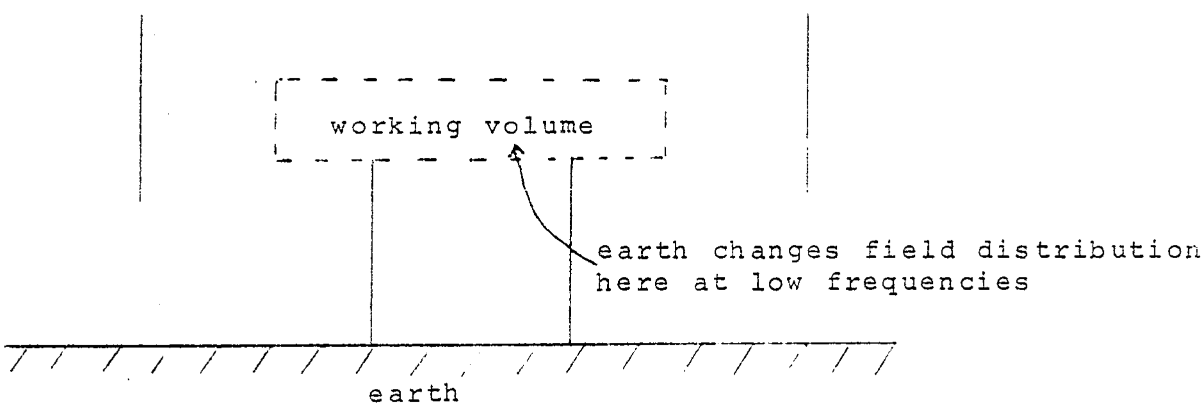
- the plate spacing was chosen so as to be a certain factor times the working volume size to minimize coupling to the plates.

- for same reason aircraft must be some factor times its largest dimension above the earth surface.



These influence resonances, etc. on aircraft

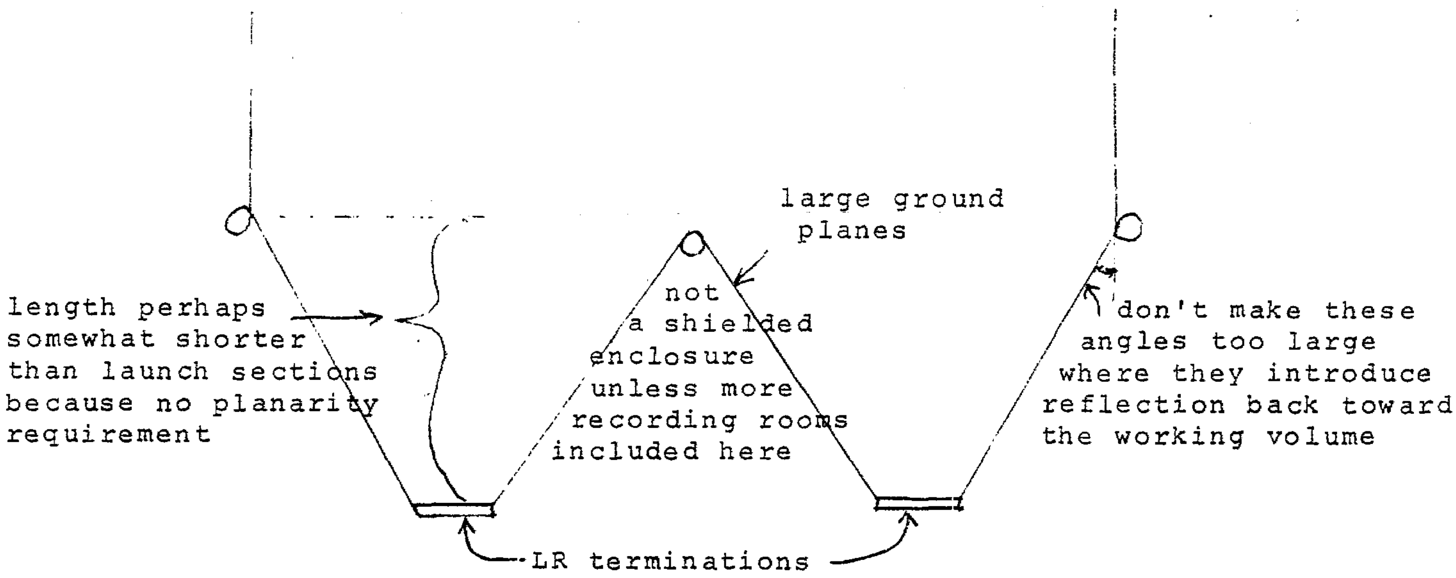
10A.5 Change of field uniformity in working volume at low frequencies due to presence of earth



This should be quantified and made an acceptably small number.

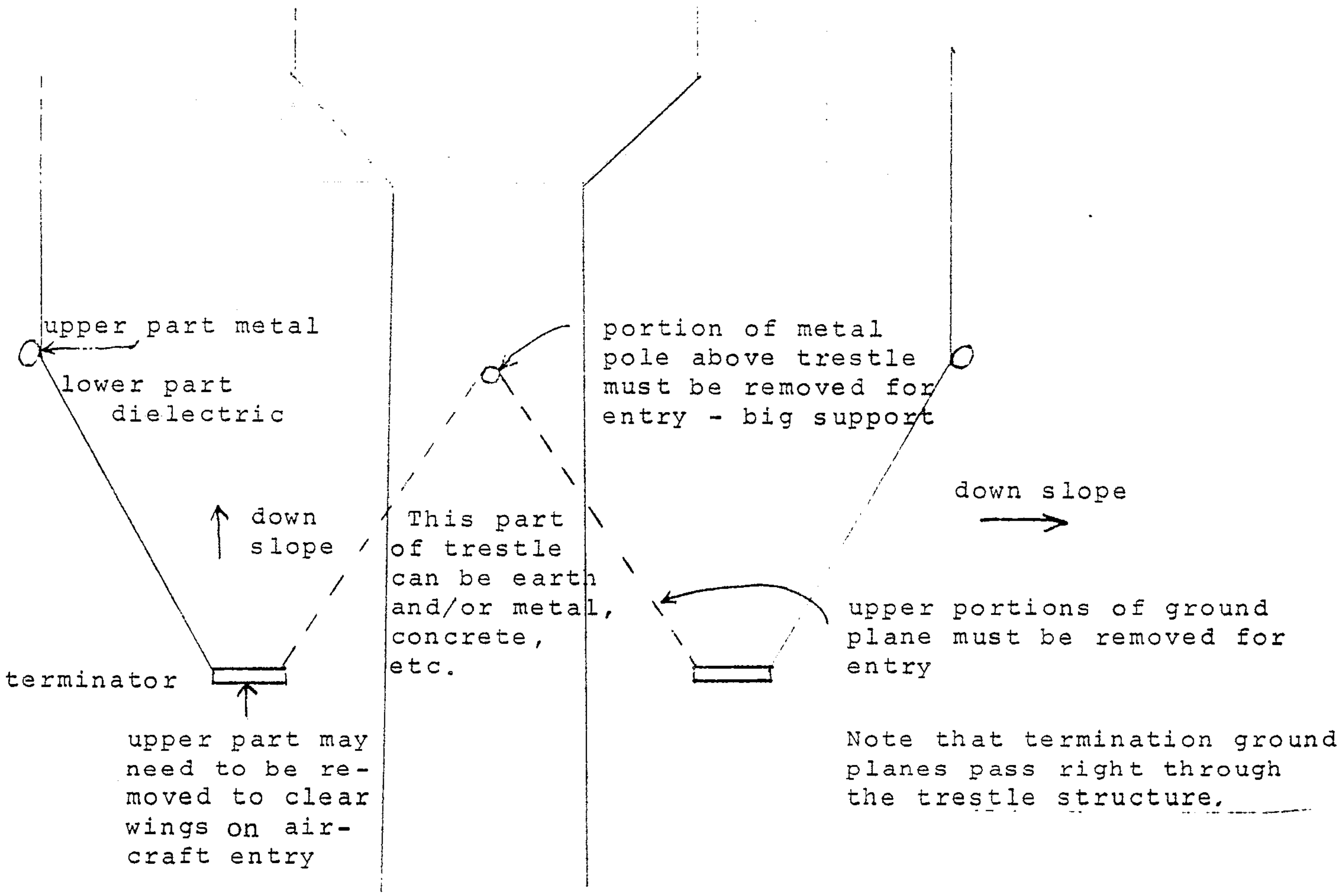
10A.6 Double termination transition - for side entry case

- one design would use two conical transmission lines just like the double launcher with large central ground planes.

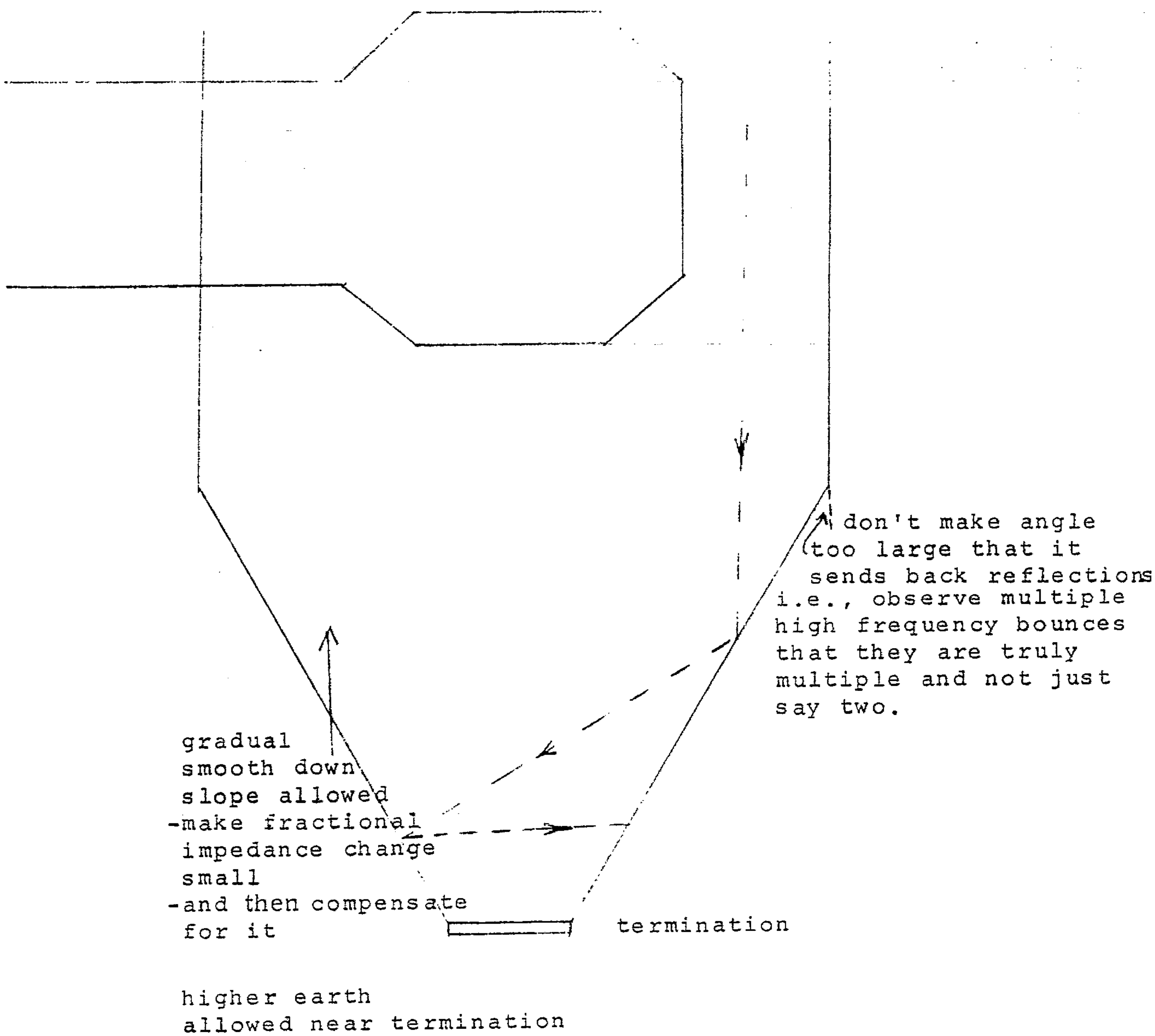


Of course if the termination section is intended for a future set of pulsers then the double termination transitions would be identical to the double launch transitions.

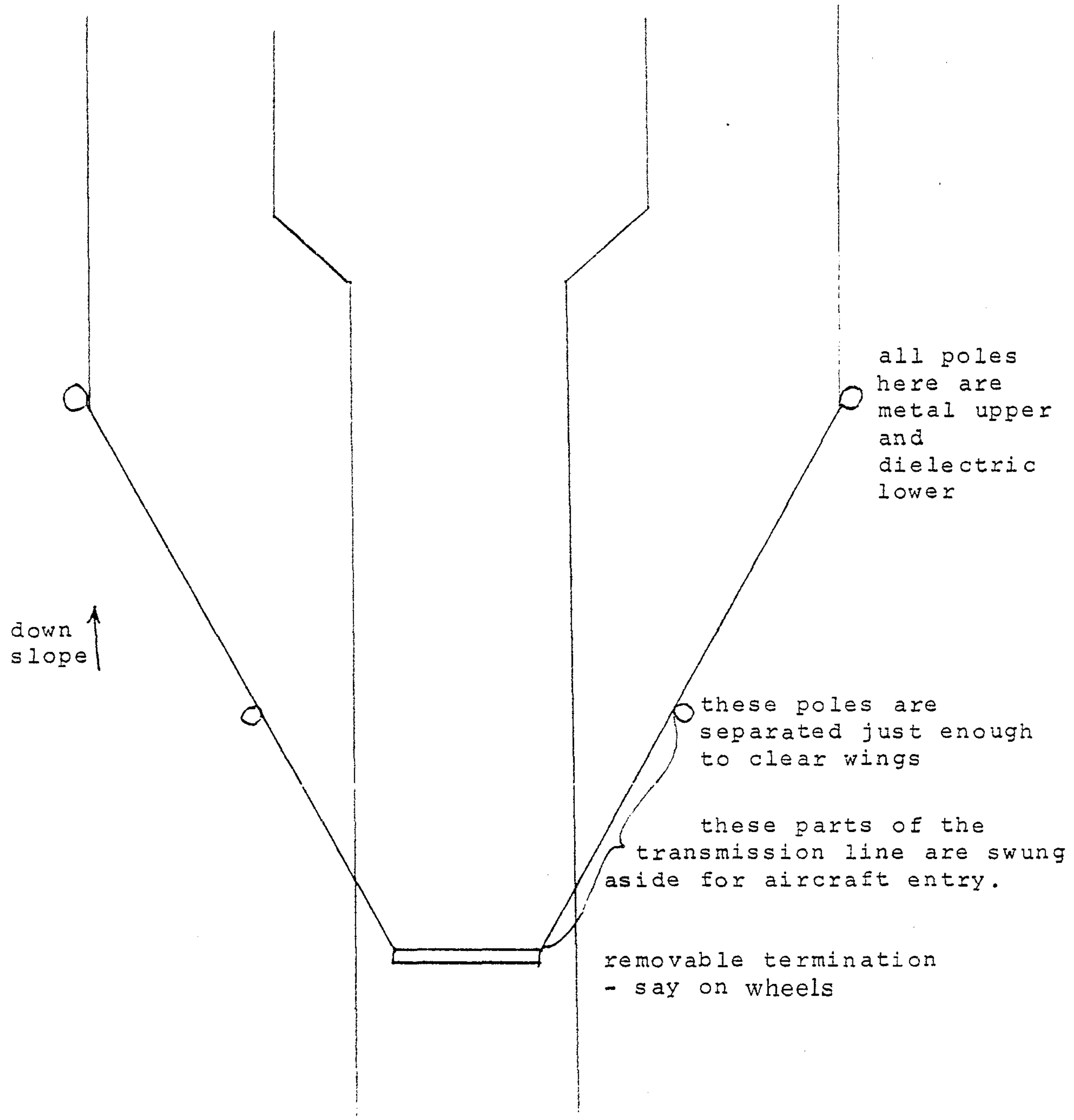
10A.7 Double termination transition - for rear entry case



10A.8 Single termination transition for side entry case



10A.9 Single termination transition for rear entry case

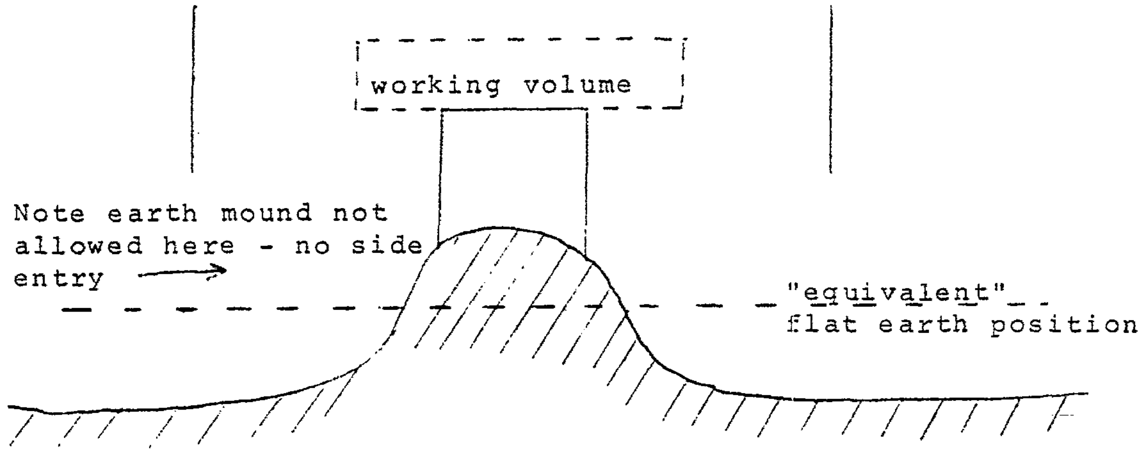


10B.1 Curved earth mound under the trestle

- only entrance through the termination is allowed in this option.

- earth mound is to be symmetrical with respect to the symmetry plane of transmission line and launchers.

- basic concept is to raise earth level directly under the trestle while lowering it on both sides of the trestle thereby having about the same electrical effects at low freq. for impedance change and coupling to aircraft resonances while allowing the trestle to be shorter.

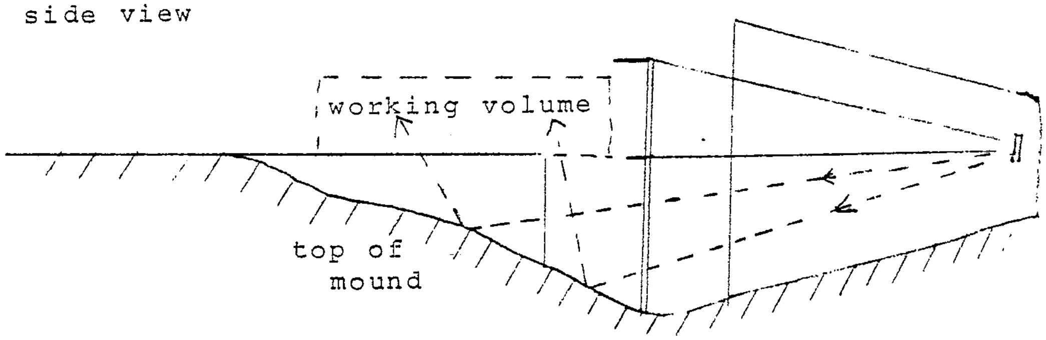


Note "equivalent" has several possible definitions based on different types of distortion. Consider impedance change as in 10A.2 - also coupling of aircraft with ground as in 10A.4 - also consider change of field uniformity (could be degradation or improvement associated with combination of mound together with lower earth further away, including under the transmission line conductors) - also just consider in this design how much the field in the working volume is changed by the earth and earth mound.

10B.2 Geometrical optics considerations

- with higher earth in center underneath the working volume high frequency waves can reflect off the earth in straight line paths from the apexes, off the earth surface by simple reflection and up into the working volume.

side view



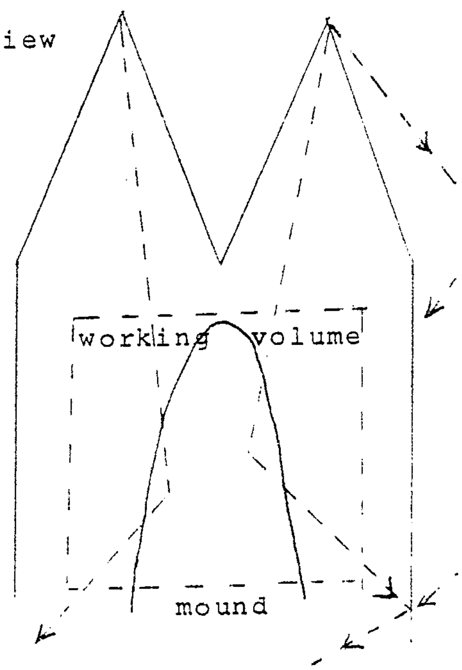
- thus make the earth be very dry to minimize the high frequency reflection coefficient.

- minimize the radius of curvature of the mound as a convex surface in any region which reflects the primary wave into the working volume.

- scatter the wave outward away from the symmetry plane of the simulator.

- make the combined curvature reduction of reflected field amplitude with the earth reflection coefficient less than some small fraction of the peak field throughout the working volume.

top view



It should be obvious from these considerations why a mound can't run out through the side of such a simulator - the high frequency reflections are not scattered out of the working volume as well.

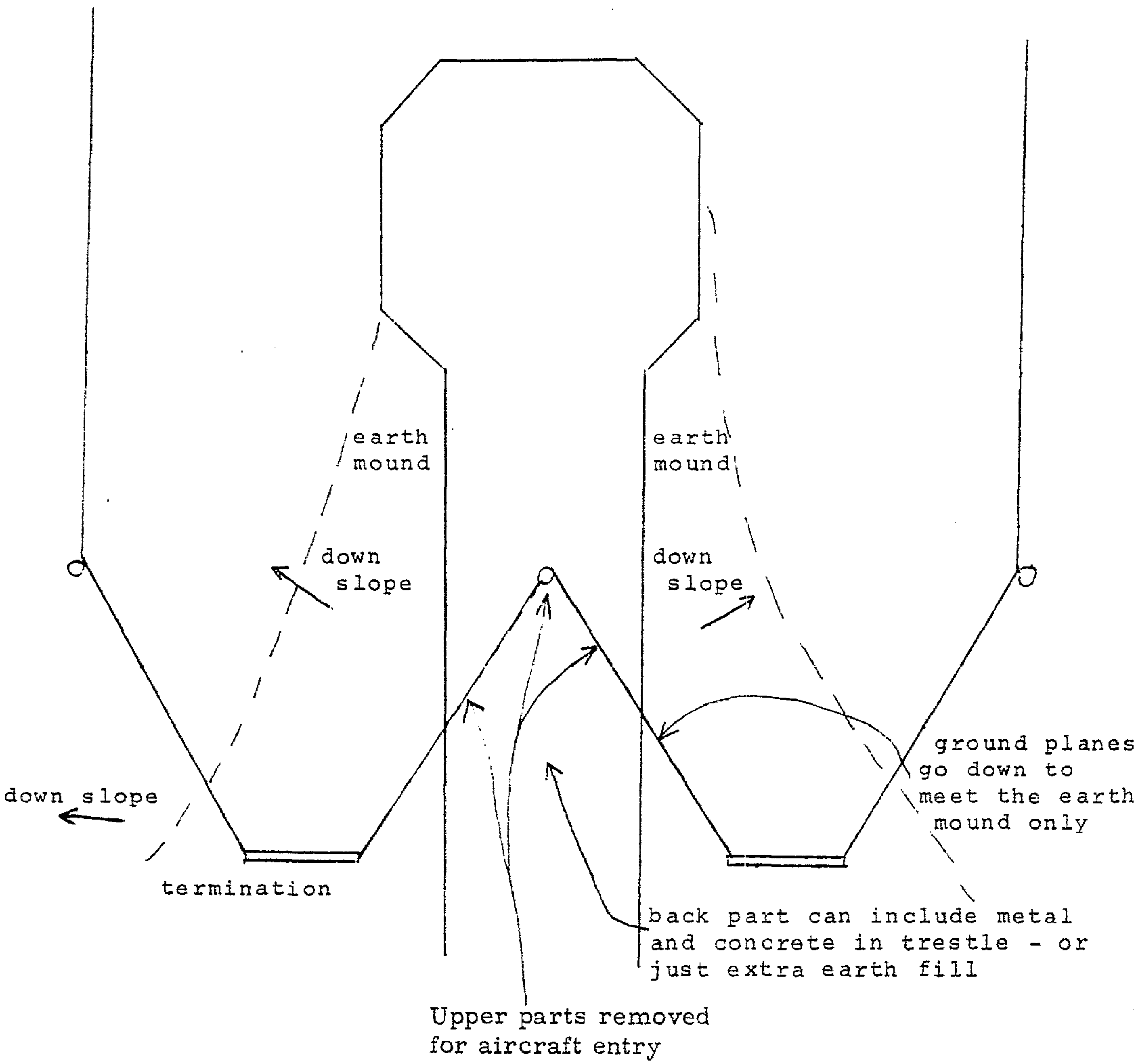
watch for any bounce from the earth outside the simulator plates toward the working value - the plates can provide some shielding here

watch for any second bounce off the conducting plates that might be going back into the working volume

10B.3 Double termination transition

- rear entry only

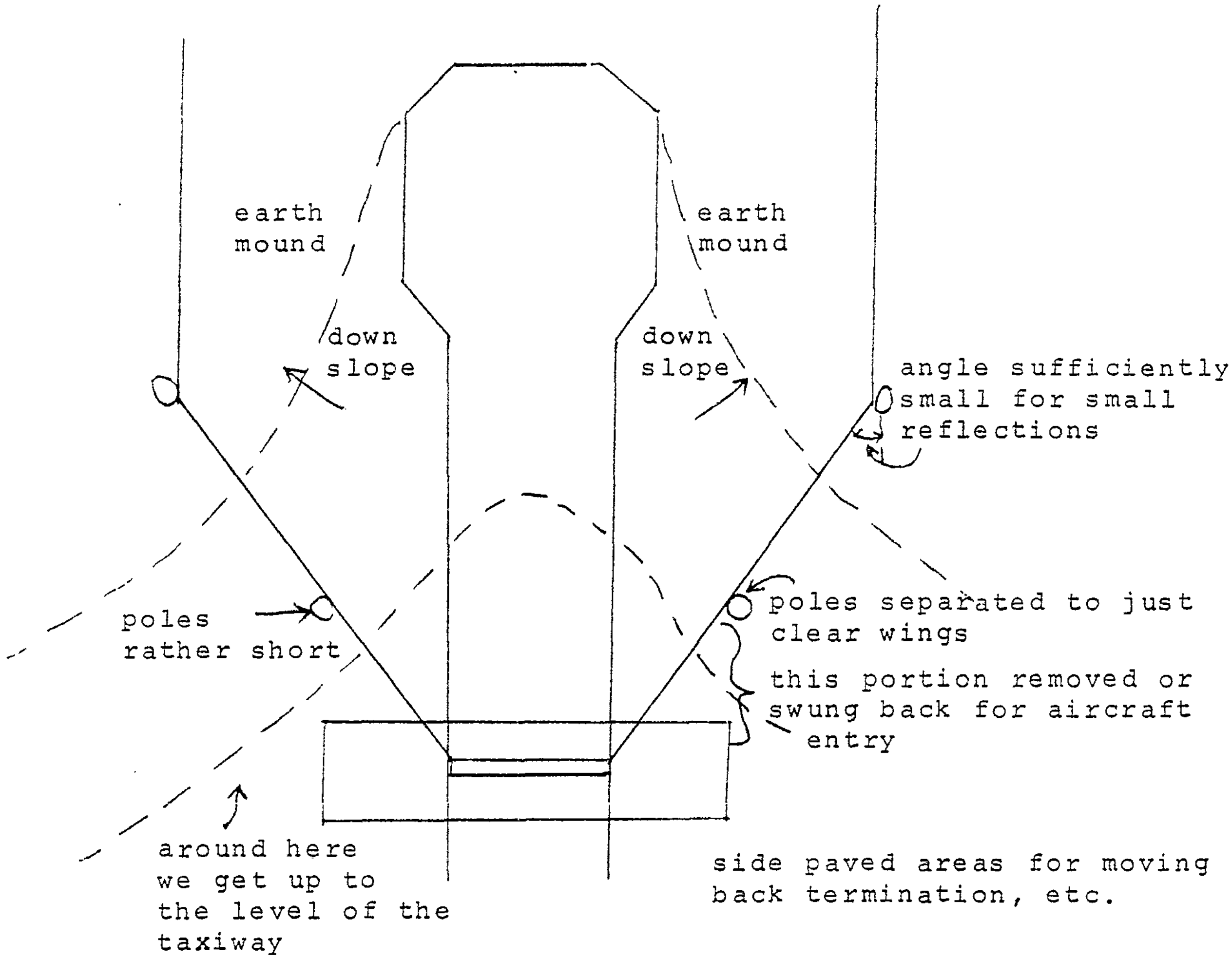
- like in 10A.7 except now we have an earth mound to mechanically help us



10B.4 Single termination transition

- rear entry only

- like in 10A.9 except with an earth mound under the trestle and sloping out a bit



Since for the earth mound option the earth near the termination is coming up quickly the poles near the termination get shorter and the earth may significantly decrease the transmission line impedance. In this case we again compensate the impedance back toward the design numbers without earth effects by removing plate material along the bottom edge, where it has the most effect. This applies in the transition section as well as the transmission line. The termination has to be somewhat above the taxiway so the output transition has to be slanted slightly upwards to move its effective apex sufficiently above the taxiway.

11. Terminations

- for either single or double terminations

- peak volts are given by pulser voltage - this is worst case

- plate spacing at termination made adequate to hold peak volts in air including presence of termination resistors

- use LR terminator - distributed - right amount of inductance to minimize high frequency reflections

12. Transmission line and transitions for launch and termination; structure of conductors

- metal beams, bailey trusses, etc. can be used as part of the mechanical structure for any piece which can be made an integral part of these conducting sheets, including in the case of the ground planes

- avoid large resonant loops of conductors - small loops means perimeters equal to or less than wavelengths at the highest frequencies of concern - this is another simulator spec.

- if a sparse wire structure is used then cross-shorting wires should be added with spacing of order half wavelength at highest frequency - spacing of these shorts should vary in frequency - spacing of these shorts should vary in somewhat random fashion to avoid looking like a diffraction grating - also vary the angle of crossing the main wires (or tubes, etc.) for the same reason.

- wire, tube, etc., spacing for wires in direction of main current flow should be small fraction of spacing between crossing shorts.

- presence of earth changes propagation constant differently on each wire making crossing shorts more important.

- near pulsers and termination fields are very high so electrical breakdown (streamers) are important - use continuous metal sheets here with rollups on edges and perhaps high dielectric strength insulation on edges.

13. Ground planes and shielding for volumes

- quality of ground planes depends on whether or not they are used for shielding enclosed volumes for instrumentation purposes - if such shielding is not intended make ground planes as in 12.

- if ground planes or other surfaces are intended be shields then much closer wire spacing is desirable - such surfaces might use expanded metal, rolls of fence or ribar type material with crossing welded wires, or even continuous metal sheets in some cases (say where the external fields are largest)

14. Poles for holding up transition sections and transmission lines

- use metal for portions laying along the conducting wire grids, sheets, etc. - be sure to make electrical contact at many places if metal used here so as to avoid resonant structures as discussed in 12.

- use dielectric for all parts of poles or other structural supports leading away from conductor arrays into regions of fields and this applies in most cases.

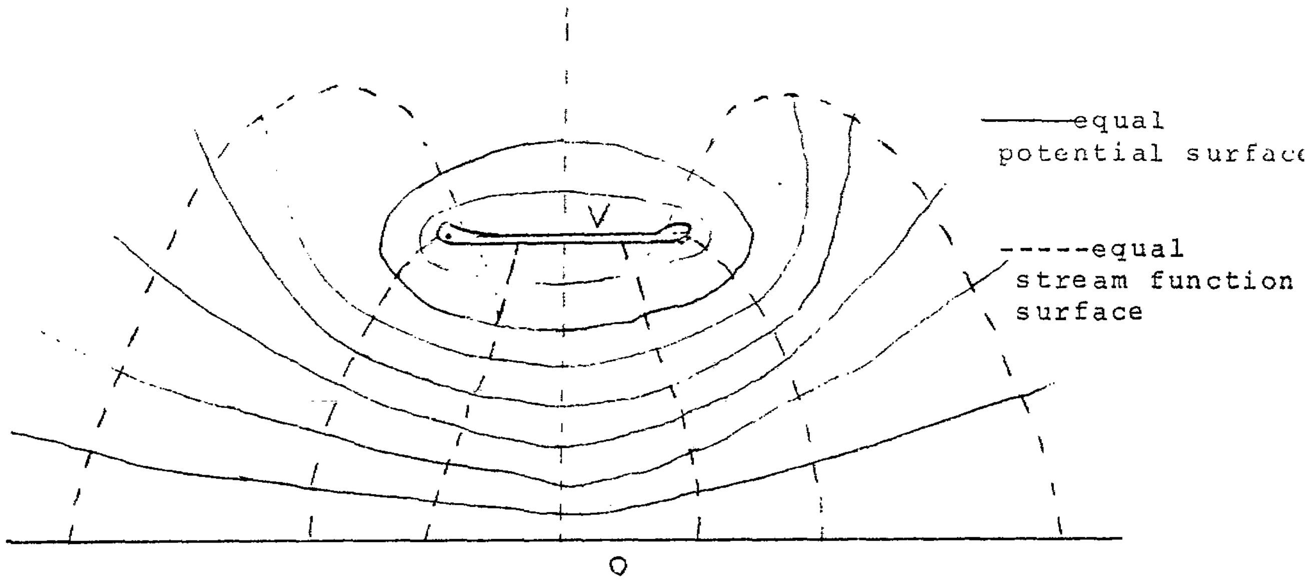
- use dielectric for any auxiliary mechanical structures of any significant size in field containing regions where the fields are designed to be there - this doesn't apply, for example, in shielded enclosures.

15. Design of the dual pulser array if arrays instead of single point sources are used

- given the plate spacing to width ratio then electrical stress (including pulse width) determines the minimum spacing in air - the pulser arrays go here provided the internal stress in the pulsers (which will be larger due to the presence of conducting objects) can be met using adquate insulating dielectric

- knowing a spacing we have a cross section to fill - we also know the volts we want - the impedance is half the simulator impedance and so the current is also known

- make a plot of static potential and stream functions for the transition section near the pulser array



- assuming n modules in series and m in parallel with n x m identical modules, each module has volts V/n and drives low frequency current I/m, except at early times the back wave from the array requires twice as much current

- the late time impedance is $\frac{m}{n}\frac{Z_s}{2}$ where Z_s is the simulator impedance - the early time impedance for proper array distribution is 1/2 this to account for the backwave or $\frac{m}{n}\frac{Z_s}{4}$

- basically the proper array distribution is determined for differential generators (symmetric output) by making 2n equipotentials separated by V/2n and 2n stream functions symetrically spaced and corresponding to equal changes in the stream function - note one stream function contour has two values O and I corresponding to integral of H around the finite width plate.

- put on pulser at each intersection of every other potential line with every other stream line - at least roughly so

- pulser inductance gives an L/R type of limit on wave rise time where R is $\frac{m}{n}\frac{Z_s}{4}$.

- If pulsers are basically flat and confined to source plane then the transit time from the output switch(es) of each pulser to the farthest position in an area bounded by the adjacent potential and stream functions on 4 "sides" is another rise time limitation for launching a TEM wave.

- there is a significant amount of energy in the fringe fields and it is important to the wave launch - but not all positions on the source plane are equally important - define some part of the source plane which has some large fraction (approaching 1) of the integral of E^2 in the TEM mode - this includes the part between the plates and part of the fringe fields, neglecting some of the region behind the finite width plate - fill this part of the source plane with pulsers as discussed above

- conductors and/or resistors (small values probably) can be used to link pulsers on equipotentials if desired

- large value resistors can be placed along stream functions (or actually anywhere else) if desired

- note that actually a spherical TEM wave is being launched so a planar array should have its timing modified to account for this

- the potential and stream functions on a conical tansmission line are slightly different from those on a cylindrical transmission line with the same cross section (on a plane) - this can be accounted for more accurately if desired

- the pulsers need not be planar but might include some builtin conical transmission line characteristics to make them launch basically forward and minimize back radiation for very early times (comparable to pulser trans times) - this minimizes the differences in arrival time of the wave over the source plane over an area between the 2 adjacent potential lines and 2 adjacent stream lines that bound the area fed by the individual pulser.