Interoffice

National Radio Astronomy Observatory

Very Large Array

February 11, 1982

To: H. Hvatum, J. Findlay

From: W. Horne

12 METER MILLIMETER WAVE TELESCOPE
MEMO No. 132

Subject: 12 Meter Panel Support Analysis

Transmitted attached is an analysis of 3 possible support configurations for the 12 meter panel supports. Condition 1 showing fixed connection at the panel with a pin (ball) at the back-up structure, condition 3 with both ends of the bolt fixed and condition 4 with the fixed end at the BUS and the pin at the panel. As can be seen from the summary on sheet 5 any configuration chosen will be a compromise of what we would like to produce. For example condition 3 produces the best results in terms of panel translation due to pointing the antenna at horizon but unfortunately due to the higher restraint imposed also produces under temperature change the greatest distortion of the panel. Condition 4 which appears to be the best choice and which I used in Memo 37 has the distasteful requirement that we will have to drill attachment holes for the ball bushing in the panel. I am presently working on a sketch to accomplish this.

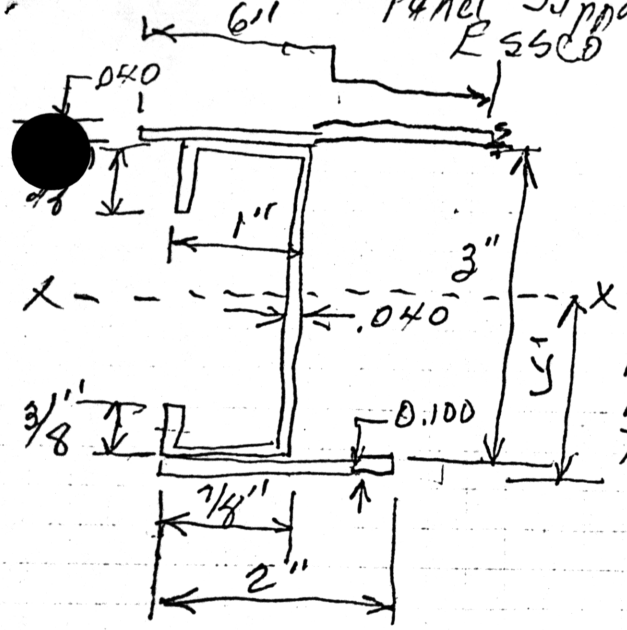
In either condition 1 or 4 one of the undesirable features is the panel translation due to gravity influence as the antenna is tilted to horizon - remember this is a translation of the entire surface in the direction of gravity and cannot be compensated for by John Paynes alignment system which only measures the movement of the apex. The following table shows the effect of an increase in bolt diameter (stiffness of bolts) which, while it would decrease the panel translation under gravity, produces for all three conditions the following results:

A. Temp Change
   1. Panel Translation - unchanged
   2. Moment to Panel - increase by ratio of bolt dias. to the 4th power.
   3. Panel Defl. - increase same as moment

B. Gravity
   1. Panel Translation - decreased
   2. Moment to panel - unchanged
   3. Panel Deflection - unchanged

Feb 2, 1982

Panel Support Bolts for Essco Panels



Calculate I find N.A.

	A	y	Ay	I_o	Ad^2
B.A.	.200	.050	.0100	.00017	0.54081
[Web	0.120	1.6	.1920	.09000	.00110
Fl. 1	0.0318	0.120	.0038	—	.06294
Fl. 2	0.0368	3.080	.1133	—	.05460
Web 1	0.0150	0.2875	.0043	.00018	.03718
Web 2	0.0150	2.9125	.0437	.00018	.02880
Top Pl	0.240	3.120	.7488	.00003	.48776
	Σ=0.6586		ΣAy=1.1159	.09056	1.21319

$$\bar{y} = \frac{\Sigma Ay}{A} = \frac{1.1159}{.6586} = 1.6942''$$

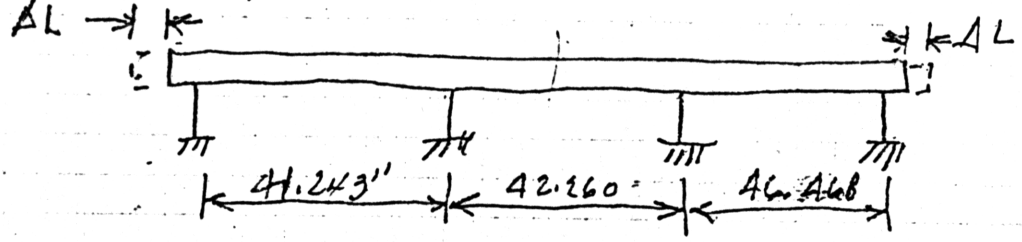
I_{xx} = 1.21319
+ .09056
1.30375 in^4

length of inner panel 132.452 inches

For 3/4" bolt dia $A = 0.11045$ $I = \frac{\pi d^4}{64} = .00097\ in^4$

For 1/4" bolt $A = 0.04909$ $I = .00019\ in^4$

Panel has four supports; assume expansion takes place from mid-point of panel in both directions



Assume temp. change of 30°F

$\epsilon_t = \epsilon_t(\Delta L) - \epsilon_t(St\ l)$
$= 6.5 \times 10^{-6}\ in/in/F°$

$$\Delta l = \frac{132.452}{2} \times 30° \times \frac{6.5}{10^6} = 0.012914 \text{ inches}$$

(1) Assume bolt has one end fixed, one end free to rotate
Calculate force to produce necessary deflection (Δl) in bolt

$M = Pl$ $\Delta max = \frac{Pl^3}{3EI}$

for simplification use $I = \frac{.00097 + .00019}{2} = .00058\ In^4$

$$.012914 = \frac{Pl^3}{3(30)10^6[5.8\times10^{-4}]}$$

$Pl^3 = 12.914(10^{-3})\ 3(30)10^6(5.8)10^{-4}$
$= 12.914(90)5.8(10^{-1})$
$= 674.110$

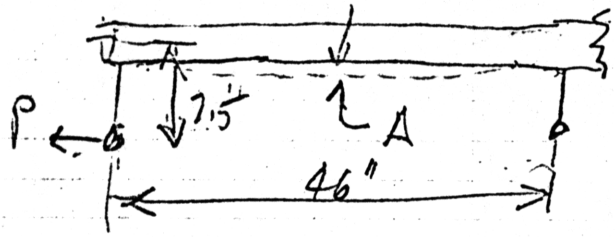
If bolt is 6" long then
force $P = \frac{674.110}{6^3} = 3.1209$ lbs, $M_1 = 6 \times P = 18.72$ ft. lbs

(1)

Panel Support Bolts — Feb 3, 1982
12m panels

1(a) With Pinorball at top of BUS eccentricity = 1.5 + 6 = 7.5"

Moment on Panel = 7.5 × 3.1209# = 23.4066 in lbs.



$$\Delta = \frac{M}{EI} \times \frac{l}{2} \times \frac{l}{4} = \frac{23.4066}{10(10^6)(1.30375)} \times \frac{46}{2} \times \frac{46}{4} = 0.000475"$$

$$\doteq 0.0121\ mm = 12.1\ \mu m = \text{max. defl}$$

Est. RMS = $\frac{12.1}{3}$ = 4.0 microns ∴ actual deflection and RMS will be less because of continuity in the support rib, and because the top plate of the panel will exert more restraining effort than I have allowed for.

(2) Gravity Effect

wt. of panel: inner panels 39# (1.75#/ft²)
outer panels 20#

wt. to each bolt of inner panels = $\frac{39}{8}$ = 4.875 lbs

Deflection of bolt (translation of panel @ 90° zenith angle)

$$\Delta = \frac{Pl^3}{3EI} = \frac{4.875(6^3)}{3(30)(10^6)\,5.8(10^{-4})} = 0.0202 \text{ inches}$$

$$= 512\ \mu$$

$M = 4.875(6) = 29.25$ inch lbs.

Twisting moment to N.A. Panel = 29.25 + 4.875(1.64) = 37.48 inch lbs

$$\text{Panel deflection} = \frac{37.48}{10(10^6)1.30375} \times \frac{46}{2} \times \frac{46}{4} = .000760 \text{ inches}$$

$$= 0.0193\ mm$$

$$= 19.3\ \mu m$$

$$RMS = \frac{19.3}{3} = 16.4\ \mu$$

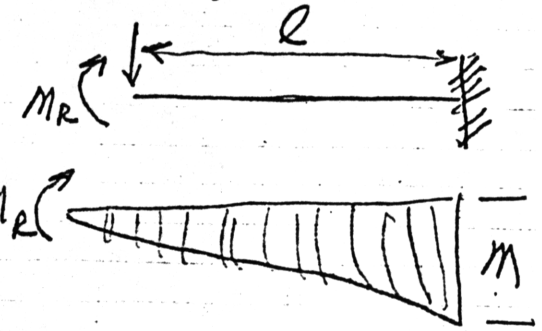
Panel Support System
12M Panels

Feb 5, 1982

1) Analyze with moment connection at both ends of bolt (Beam fixed at one end, free to deflect laterally but not rotate at other - concentrated load at deflected end)

M_{max} (each end) $= \frac{Pl}{2} =$

$\Delta_{max} = \frac{Pl^3}{12EI}$



3a For temperature Exp.

$\Delta = 0.012514$ inches (From 5f.1)

$P = \frac{\Delta(12EI)}{l^3} = \frac{1.2514(10^{-2})}{0.012514(12)30(10^6)5.8(10^{-4})}$

$= 12.48$ lbs

Bolt $M = \frac{Pl}{2} = \frac{12.48(6)}{2} = 37.45$ in. lbs. (versus 18.72 ft lbs for a pin ended bolt)

→ Moment applied to Panel Neutral Axis
$= 37.45 + 12.48(1.69) = 58.54$ inch lbs
Panel Deflection (ctr) $= .00119$ in $= 30.2$ μm

3B Check for Gravity effects
wt. of panel = 39 lbs assume $\frac{1}{8}$ to each bolt

$P = \frac{39}{8} = 4.875$ lbs

Defl. (Panel Translation) $\Delta_{max} = \frac{Pl^3}{12EI} = \frac{4.875(6)^3}{12(30)10^6(5.8)10^{-4}} = 0.005$ inches
$= 127$ μm

Mom $M = M_{Res} = \frac{Pl}{2} = \frac{4.875(6)}{2} = 14.625$ in lbs

Twisting Moment to N.A. Panel $= 14.625 + 4.875(1.69) = 22.863$ in. lbs.

Panel Deflection (ctr) $= \frac{22.863}{10(10^6)1.30375} \times \frac{46}{2} \times \frac{46}{4} = 0.000464$ in
$= 11.8$ μm

Feb. 5, 1982

(4) Analyze with pin (ball) at bottom of panel and fixed end at BUS

4a Temperature effects

Bolt deflection rad'l (sheet 1) = 0.012914

Force P = 3.1209 lbs (at bottom of panel)

Bending M at N.A. of Panel = 3.1209 (1.69) = 5.274 in. lbs

Panel Distortion $\Delta = \frac{M}{EI} \times \frac{l}{2} \times \frac{l}{4} = \frac{5.274}{10(6)(1.30375)} \times \frac{46}{2} \times \frac{46}{4} = .00011$

$= .0027$ mm $= 2.7\mu$

Rot RMS $= \frac{2.7}{3} = 0.9\mu$

4b Gravity Effects

Actual Gravity effect on bolt same as with pin at bottom of bolt but panel moment is less since restraining moment of bolt is now on BUS.

Translation of panel $= \frac{Pl^3}{3EI} = 0.0202$ inches

$= 512\mu$

Moment to panel $= 4.875 (1.69) = 8.239$ in. lbs

Δ = Panel deflection $= \frac{8.239}{10(10^6)1.30375} \times \frac{46}{2} \times \frac{46}{4} = 0.000167$ inches

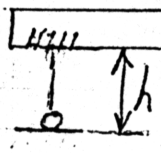
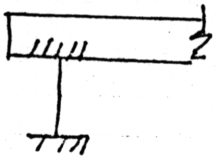
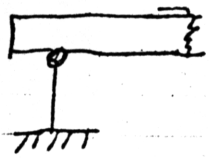
$= 4.2$ mm

RMS $= \frac{4.2}{3} = 1.4\mu$

H. Huston
L. King

Sheet 5
Feb. 8, 1982
W.G.H.

Summary of Results
Panel Support Analysis

	(1)	(3)	(4)
			
A. Temp. change of 30°			
Panel Translation	0.012914 in.	0.012914 in	0.012914 inch.
Moment to Panel	23.407 in lbs.	58.54 in. lbs.	3.27 in. lbs.
Panel Defl. (center span)	0.000475 in (12.1 μ	0.00119 in (30.2 μ)	0.000169 (4.3 μ)
		12 μm for 30°	
B. Gravity @ 90°			
Panel Translation	0.0202 inches	0.005 inches	0.0202 in
Moment to Panel	37.48 in. lbs.	22.863 in. lbs	8.239 in. lbs
Panel Deflection	0.00076 inches (19.3 μ)	.000464 in. (11.8 μ)	0.000167 inches 4.2 μ

C) Note that for a change in Bolt diameter (increase) we would reduce the panel translation due to gravity influence; the translation due to temp. change would remain the same; the moment to the panel (and deflection) would increase for the temp. change while the moment to the panel for gravity would be unchanged