I. 1:1:1 triplet CD

II. 1:2:3:2:1 quartet CD₂

III. 90° rotation

IV. 180° rotation

V. ωₐ = -ωₑ = \frac{2πJ}{\alpha} \text{ rad/sec}

\frac{1}{\text{sec}} \cdot \frac{2π \text{ rad/sec}}{\text{sec}} = \frac{T}{\alpha} \text{ rad}

\frac{1}{\text{sec}} \cdot \frac{2π \text{ rad/sec}}{\text{sec}} = π \text{ rad}
\[ \omega_B = -\omega_D = 2\pi(5) \text{ rad/sec} \quad \text{same as } A \text{ in } CD \text{ case above} \]

\[ \omega_A = -\omega_E = 2\pi(25) = 4\pi \text{ rad/sec} \]

\[ \left(\frac{1}{48} \text{ sec}\right) \left(4\pi \text{ rad/sec}\right) = \pi \text{ rad} \]

\[ \left(\frac{1}{30} \text{ sec}\right) \left(4\pi \text{ rad/sec}\right) = \frac{2}{3} \pi \text{ rad} \]
II

By symmetry, four equivalent sets of carbon nuclei:

- $147\text{ ppm}$ $2$ - equivalent coupling to $19\text{ F}$, i.e. triplet
- $165$, $1, 3$ - doublet of doublets - see below.
- $112$, $4, 6$ - doublet of doublets
- $132$, $5$ - equivalent coupling to $19\text{ F}$, i.e. triplet, but smaller than for $C_2$

III. A

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>35 ppm $(\sim 2 \text{ ppm})(^{25}\text{H} \text{Hz}) \cong 50 \text{ Hz}$</td>
</tr>
<tr>
<td>B</td>
<td>33.2 $(\sim 1 \text{ ppm})(^{25}\text{H} \text{Hz}) \cong 25 \text{ Hz}$</td>
</tr>
<tr>
<td>C</td>
<td>33 $(\sim 14 \text{ ppm})(^{25}\text{H} \text{Hz}) \cong 350 \text{ Hz}$</td>
</tr>
<tr>
<td>D</td>
<td>32 $(0.5 \text{ ppm})(^{25}\text{H} \text{Hz}) \cong 12 \text{ Hz}$</td>
</tr>
<tr>
<td>E</td>
<td>14 $(0 \text{ ppm})(^{25}\text{H} \text{Hz}) \cong 50 \text{ Hz}$</td>
</tr>
<tr>
<td>F</td>
<td>$\sim 10$</td>
</tr>
<tr>
<td>G</td>
<td>$\sim 10$</td>
</tr>
</tbody>
</table>

II

Sn has two NMR active isotopes, $^{117}\text{Sn}$ and $^{119}\text{Sn}$. Both are spin $\frac{1}{2}$ nuclei. They both have very similar magnetic gyromagnetic ratios, leading to similar coupling to carbon. There is only enough resolution (i.e. difference in the coupling) to see both satellites when the coupling is large.

C

Dihedral angle between 1-2 & 3-Sn is $\sim 180^\circ$ - i.e. large coupling, while dihedral angle between 6-2 & 3-Sn is much smaller. ii C-1 is the more downfield of the two closely spaced peaks at $\sim 10 \text{ ppm}$. 