

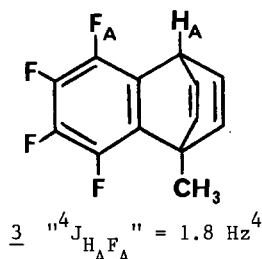
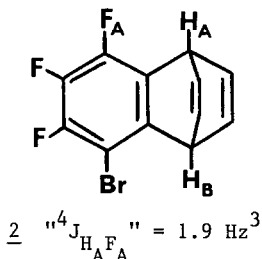
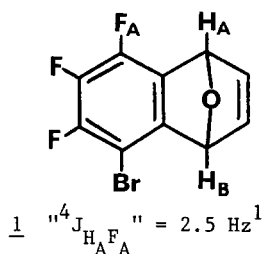
REINTERPRETATION OF LONG-RANGE ^1H - ^{19}F SPIN-SPIN COUPLING
 IN 1,4-DIHYDRO-1,4-EPOXYNAPHTHALENES AND RELATED SYSTEMS

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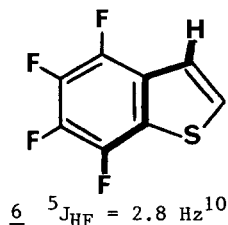
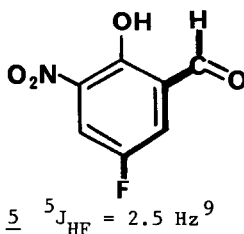
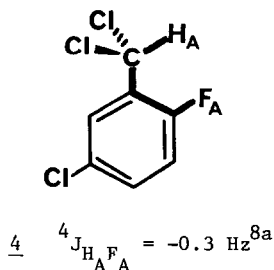
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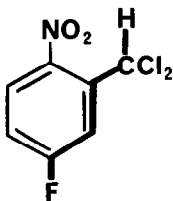
Summary: The long-range ^1H - ^{19}F coupling reported earlier for the bridgehead proton(s) in 1,4-dihydro-1,4-epoxynaphthalenes (e.g., 1) is shown unequivocally to involve the distal fluorine by a five-bond zig-zag coupling pathway.

The long-range ^1H - ^{19}F spin-spin coupling frequently observed in 1,4-dihydro-1,4-epoxynaphthalenes (e.g., 1), 1,2 1,4-dihydro-1,4-ethenonaphthalenes (e.g., 2, 3), 3,4 and 1,4-dihydronaphthalen-1,4-imines 5 has been reported 1,3,4 and generally assumed 6 to involve a four-bond benzylic coupling between a bridgehead proton and the proximal fluorine as shown below.

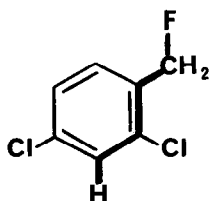


However, it seemed to us that the H_AF_A internuclear distance in 1 - 3 is too great for a "through-space" contribution 7 to the coupling mechanism. Furthermore, the planar cisoid arrangement of F_ACCCH_A in 1 - 3 is known not to be ideal for a σ - or π -electron coupling mechanism. 8 For example, $^4J_{\text{H}_A\text{F}_A} = -0.3 \text{ Hz}$ in 4 8a , where the H_AF_A internuclear separation (2.35\AA) is less than that in 1 - 3. In our opinion, a more likely H-F coupling mechanism in 1 - 3 is a five-bond zig-zag coupling between a bridgehead proton and the distal fluorine (e.g., H_BF_A in 1), several examples of which are known (5 - 9).

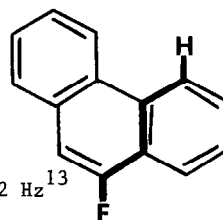




$$\underline{7} \quad {}^5J_{\text{HF}} = 1.2 \text{ Hz}^{11}$$

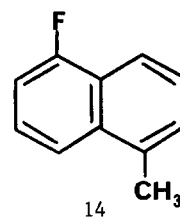
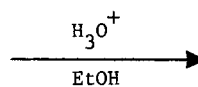
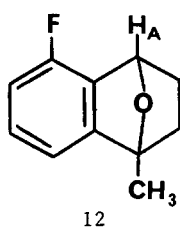
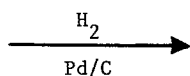
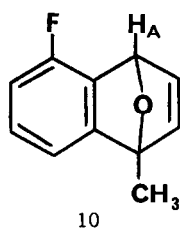
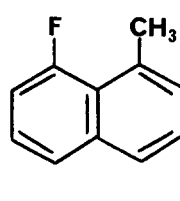
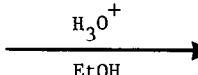
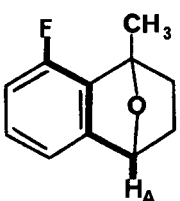
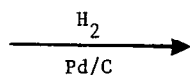
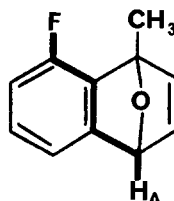


$$\underline{8} \quad {}^5J_{\text{HF}} = 1.35 \text{ Hz}^{12}$$



$$\underline{9} \quad {}^5J_{\text{HF}} = 2 \text{ Hz}^{13}$$

To decide which of the two coupling pathways operates in systems such as 1 - 3, we prepared 1-methyl-5-fluoro-1,4-dihydro-1,4-epoxynaphthalene (10) and 1-methyl-8-fluoro-1,4-dihydro-1,4-epoxynaphthalene (11) and examined their $^1\text{H-NMR}$ spectra. Compounds 10 and 11 were prepared¹⁴ as a mixture from 1,3-difluorobenzene and 2-methylfuran using standard aryne/Diels-Alder methodology^{2b,5c} and separated by medium pressure liquid chromatography.¹⁵ Their identity was proved by conversion^{2b,16} into their respective naphthalenes, 14 and 15,¹⁷ both of which are known¹⁸ and easily distinguishable by the large through-space $\text{CH}_3\text{-F}$ coupling constant in 15^{18b} but not in 14.

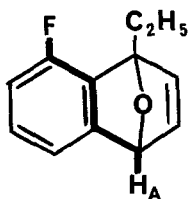
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$$\underline{11} \quad {}^5J_{\text{H}_A\text{F}} = 2.0 \text{ Hz}$$

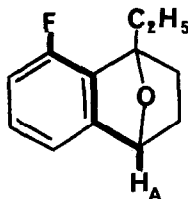
$$\underline{13} \quad {}^5J_{\text{H}_A\text{F}} = 1.8 \text{ Hz}$$

$$\underline{15} \quad {}^5J_{\text{CH}_3\text{F}} = 7.5 \text{ Hz}$$

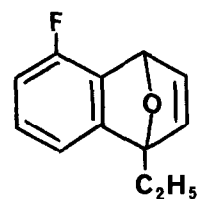
The $^1\text{H-NMR}$ spectrum of 10 revealed H_A as a doublet, ${}^3J_{\text{HH}} = 1.8 \text{ Hz}$, split by the adjacent vinyl proton.¹⁹ Irradiation of the vinyl region collapsed H_A to a singlet, indicating unresolvable or no coupling to fluorine. In contrast, the $^1\text{H-NMR}$ spectrum of 11 revealed H_A as a triplet ($J = 2.0 \text{ Hz}$) which, upon irradiation of the vinyl region, collapsed to a doublet, ${}^5J_{\text{H}_A\text{F}} = 2.0 \text{ Hz}$. We observe similar long-range coupling in 1-ethyl-8-fluoro-1,4-dihydro-1,4-epoxynaphthalene (16) (${}^5J_{\text{HF}} = 2.0 \text{ Hz}$), 1-methyl-8-fluoro-1,2,3,4-tetrahydro-1,4-epoxynaphthalene (13) (${}^5J_{\text{H}_A\text{F}} = 1.8 \text{ Hz}$), and 1-ethyl-8-fluoro-1,2,3,4-tetrahydro-1,4-epoxynaphthalene (17) (${}^5J_{\text{HF}} = 2.0 \text{ Hz}$), but no observable bridgehead proton-proximal fluorine coupling in the corresponding 1-alkyl-5-fluoro isomers (e.g., 12, 18). The bridgehead proton H_A in 13 and 17 appears as a doublet of doublets prior to decoupling because of a larger coupling to the adjacent exo-proton, ${}^3J_{\text{HH}} = 5.5 \text{ Hz}$, than to the distal fluorine. The ethyl compounds (16 - 18) were synthesized in a similar fashion to the methyl compounds (10 - 13) (*vide supra*), utilizing 3-fluorobenzynes and 2-ethylfuran.²⁰



$$\underline{16} \quad {}^5J_{\text{H}_A\text{F}} = 2.0 \text{ Hz}$$



$$\underline{17} \quad {}^5J_{\text{H}_A\text{F}} = 2.0 \text{ Hz}$$



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These results demonstrate unequivocally that a five-bond zig-zag pathway rather than a four-bond benzylic pathway accounts for the long-range H-F coupling in the 1,4-dihydro-1,4-epoxynaphthalene system. We would also conclude that a comparable five-bond zig-zag coupling exists in 1,4-dihydro-1,4-ethenonaphthalenes (e.g., 2, 3) and 1,4-dihydronaphthalen-1,4-imines⁵, which are structurally related to the 1,4-dihydro-1,4-epoxynaphthalenes, although this point remains to be rigorously established.

Preparation of 1-methyl-5-(and 8-)fluoro-1,4-dihydro-1,4-epoxynaphthalene (10 and 11). To a magnetically stirred solution of 1,3-difluorobenzene (7.50 g, 0.0657 mol) in dry Et₂O (100 mL) under N₂ at -78° was added dropwise *n*-butyllithium (1.5 M in hexane; 44 mL, 0.066 mol). The mixture was stirred for 1 h at -78°, treated at -78° dropwise with 2-methylfuran (10 g, 0.12 mol), and then allowed slowly to warm to room temperature (over 18 h). The mixture was poured into water and extracted with Et₂O. The extracts were washed, dried (MgSO₄), and concentrated *in vacuo* to give 7.27 g (63%) of a yellow oil. Medium pressure liquid chromatography¹⁵ using hexane/Et₂O (90/10) afforded 3.70 g (32%) of 11 as a solid and 2.61 g (23%) of 10 as an oil. Recrystallization of the former from Et₂O gave pure 11, mp 68-69°, and distillation of the latter gave pure 10, bp 54-58°/0.35 torr.¹⁴

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7. From Dreiding models, $H_{AF} \approx 2.9\text{\AA}$ in 1 and $\sim 2.6\text{\AA}$ in 2 and 3. Since these distances are larger than the sum of the van der Waals radii of hydrogen and fluorine ($\sim 2.5\text{\AA}$), one does not expect orbital overlap and through-space coupling should be negligible. For examples of the distance dependence on through-space H-F coupling, see (a) P. C. Myhre, J. W. Edmonds, and J. D. Kruger, J. Am. Chem. Soc., **88**, 2459 (1966); (b) G. W. Gribble and J. R. Douglas, J. Am. Chem. Soc., **92**, 5764 (1970); (c) K. L. Servis and F. R. Jerome, J. Am. Chem. Soc., **93**, 1535 (1971).
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14. 10: (23%) bp 54-58°/0.35 torr; $^1\text{H-NMR}$ (CDCl_3) δ 7.00-6.40 (m, 5H), 5.85 (d, $J=1.8$, 1H), 1.85 (s, 3H); ms m/e 176.0620 (M^+ , calcd 176.0637). 11: (32%) mp 68-69° (ether); $^1\text{H-NMR}$ (CDCl_3) δ 7.00 (m, 3H), 6.85 (m, 2H), 5.65 (t, $J=2.0$, 1H), 2.08 (s, 3H); ms m/e 176.0627 (M^+ , calcd 176.0637).
15. Patterned after the design by A. I. Meyers, J. Slade, R. K. Smith, E. D. Mihelich, F. M. Hershenson, and C. D. Liang, J. Org. Chem., **44**, 2247 (1979).
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17. 14: (60% from 10) bp 74-78°/1.5 torr (lit.^{18a} bp 64°/0.7); $^1\text{H NMR}$ (CDCl_3) δ 7.75-6.80 (m, 6H), 2.43 (s, 3H). 15: (63% from 11) bp 50-51°/0.1 torr (lit.^{18b} bp 54-58°/3.5); $^1\text{H NMR}$ (CDCl_3) δ 7.50 (m, 6H), 2.76 (d, $J=7.5$, 3H); 13: mp 57-58° (ether/hexane); $^1\text{H NMR}$ (CDCl_3) δ 7.20 (m, 3H), 5.39 (d of d, $J=5.5$, 1.8, 1H), 1.96 (s, 3H), 1.5 (m, 4H).
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19. We have prepared 1-methyl-1,4-dihydro-1,4-epoxynaphthalene (benzynes + 2-methylfuran) and observe a $^3\text{J}_{\text{H}_3\text{H}_4} = 1.8$ Hz coupling between the bridgehead proton and the adjacent vinyl proton. For comparison, norbornene has $^3\text{J}_{\text{H}_1\text{H}_2} = 2.0$ Hz: A. P. Marchand and J. E. Rose, J. Am. Chem. Soc., **90**, 3724 (1968).
20. 16: bp 54-58°/0.08 torr; $^1\text{H NMR}$ (CDCl_3) δ 7.20-6.45 (m, 5H), 5.70 (t, $J=2.0$, 1H), 2.55 (q, $J=7.3$, 2H), 1.20 (t, $J=7.3$, 3H). 17: bp 72-78°/0.25 torr; $^1\text{H NMR}$ (CDCl_3) δ 7.20 (m, 3H), 5.25 (d of d, $J=5.5$, 2.0, 1H), 2.32 (q, $J=7.3$, 2H), 1.20 (t, 7.3, 3H). 18: bp 57-60°/0.15 torr; $^1\text{H NMR}$ (CDCl_3) δ 7.25-6.45 (m, 5H), 5.94 (d, $J=1.8$, 1H), 2.30 (q, $J=7.3$, 2H), 1.21 (t, $J=7.3$, 3H).

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