Supporting Information

General Access to Furan-Substituted *gem*-Difuoroalkenes Enabled by PFTB-Promoted Cross-Coupling of Ene-yne-ketones and Difluorocarbene

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I. General

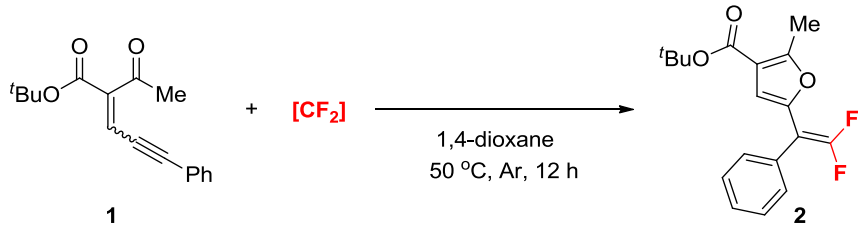
Unless otherwise noted, proton (^{1}H), proton-decoupled carbon [^{13}C{^{1}H}] and proton-decoupled fluorine ^{19}F NMR spectra were recorded on Bruker Avance 400 MHz, 500MHz or 600 MHz spectrometers. ^{1}H NMR spectra were referenced to tetramethylsilane (s, 0.00 ppm) using $CDCl_3$ as solvent, ^{13}C NMR spectra were referenced to solvent carbons (δ = 77.16 ppm for $CDCl_3$). ^{19}F NMR spectra were referenced to 2 % perfluorobenzene (s, -164.90 ppm) in $CDCl_3$. DCM, CPME, Dioxane, THF, Toluene, EtOAc, DMF, MeCN and DMSO were dried and freshly distilled prior to use. Unless otherwise indicated, all reagents were obtained from commercial supplier and used without prior purification. Glassware was dried at 120 ^{o}C for at least 3 hours and cooled under an argon atmosphere before used. Flash chromatography was performed on silica gel (200–300 mesh) by standard techniques eluting with EtOAc/petroleum ether (PE, 60–90 ^{o}C). High-resolution mass spectrometry (HRMS) were recorded on a Thermo Fisher Scientific Q Exactive. Crystal was measured on a XtaLAB PRO MM007HF diffractometer.

Ene-yne-ketones were synthesized according to the literature procedure, used as mixtures of *E*- and *Z*-isomers in an approximately 1:1 ratio.[1-4]

II. Condition optimization

In an argon-filled glovebox, a dry reaction tube was charged with ene-yne-ketone **1** (0.1 mmol, 1.0 equiv), $Ph_3P^+CF_2CO_2^-$ (0.2 mmol, 2.0 equiv) and indicated solvent (1.0 mL). Then catalyst (0.01 mmol, 10 mol%) was added to the solution above. The mixture kept stirring at the 50 °C for 12 hours. The NMR yields of the product were determined by ^{19}F NMR analysis of the crude reaction solution using $PhCF_3$ as an internal standard.

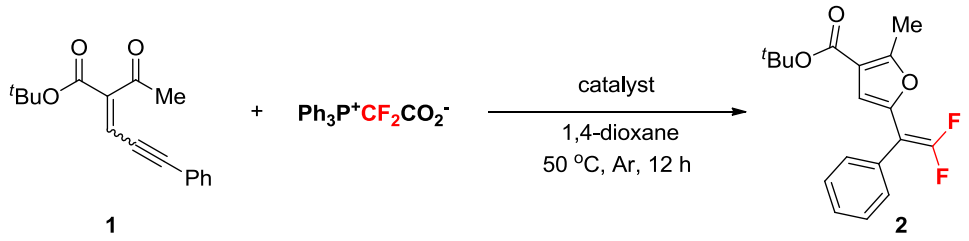
Table S1. Effect of [CF_2].



Entry	CF_2 reagent	**2** (%)
1	$TMSCF_2Br$/TBAF	trace
2	$BrCF_2COOEt/Cs_2CO_3$	N.D.
3	$BrCF_2COOK/ Cs_2CO_3$	N.D.
4	HCF_2Cl/Cs_2CO_3	N.D.
5	$TMSCF_3$/NaI	N.D.
6	$PPh_3^+CF_2CO_2^-$	45

Reaction condition: **1** (0.1 mmol) and $\mathbf{CF_2}$ reagent (2.0 equiv) in dioxane (1.0 mL) at 50 °C for 12 h. Yields determined by ^{19}F NMR spectroscopy using trifluorotoluene as an internal standard.

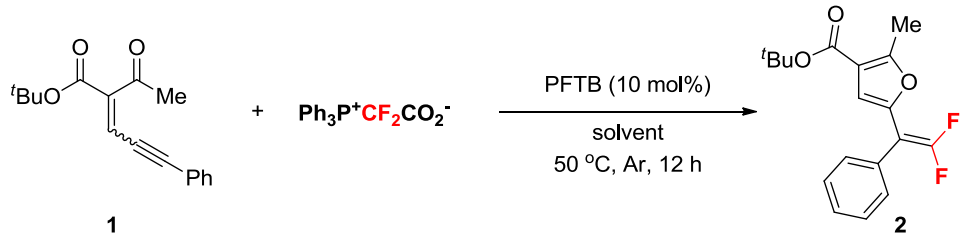
Table S2. Effect of catalyst.



Entry	Catalyst	**2** (%)
1	CuI	3
2	$FeCl_2$	48
3	$NiCl_2$	39
4	$PdCl_2$	39
5	$AlCl_3$	45
6	$Zn(OTf)_2$	39
7	$Sc(OTf)_3$	60
8	$Fe(OTf)_2$	33
9	BF_3 OEt_2	45
10	HFIP	51
11	PFTB	63
12	PPh_3	30
13	PhOH	16
14	HCOOH	N.D.
15	CH_3COOH	21
16	PhCOOH	36
17	CF_3COOH	30

Reaction condition: **1** (0.1 mmol), $PPh_3^+CF_2CO_2^-$ (2.0 equiv), and catalyst (10 mol%) in dioxane (1.0 mL) at 50 °C for 12 h. Yields determined by ^{19}F NMR spectroscopy using trifluorotoluene as an internal standard.

Table S3. Effect of solvent.

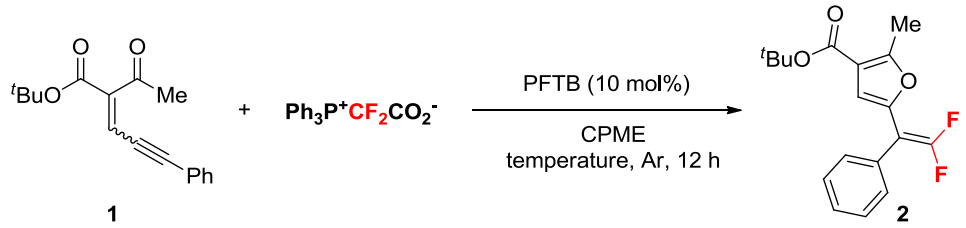


1 2

Entry	Solvent	**2** (%)
1	dioxane	63
2	THF	51
3	CPME	84
4	TBME	63
5	EA	54
6	hexane	66
7	DCM	27
8	DMF	trace
9	DMSO	N.D.
10	MeCN	N.D.
11	MeOH	N.D.

Reaction condition: **1a** (0.1 mmol), $PPh_3^+CF_2CO_2^-$ (2.0 equiv), and PFTB (10 mol%) in solvent (1.0 mL) at 50 °C for 12 h. Yields determined by ^{19}F NMR spectroscopy using trifluorotoluene as an internal standard.

Table S4. Effect of temperature



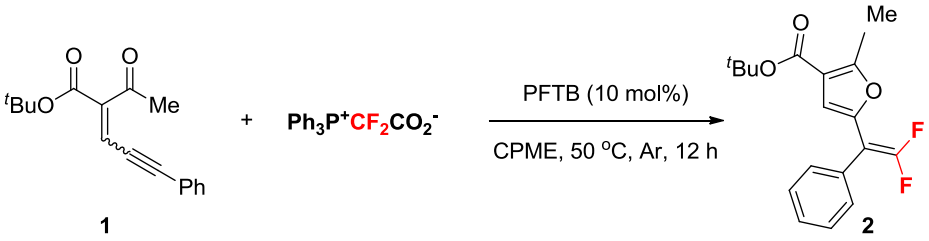
1 2

Entry	Temperature	**2** (%)
1	rt	N.D.
2	50	84
3	80	84
4	110	81

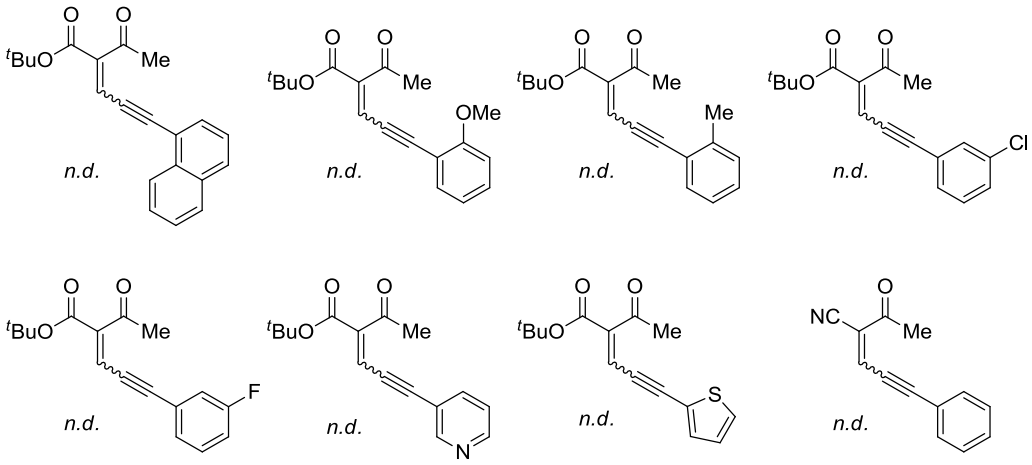
Reaction condition: **1a** (0.1 mmol), $PPh_3^+CF_2CO_2^-$ (2.0 equiv), PFTB (10 mol%) in solvent (1.0 mL) at temperature for 12 h. Yields determined by ^{19}F NMR spectroscopy using trifluorotoluene as an internal standard.

III. Isolation of products

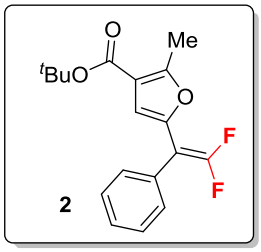
General procedure (**2a** as an example)



In an argon-filled glovebox, a dry reaction tube was charged with ene-yne-ketone **1** (0.5 mmol, 1.0 equiv), $Ph_3P^+CF_2CO_2^-$ (1.0 mmol, 2.0 equiv) and CPME (5.0 mL). Then PFTB (0.05 mmol, 10 mol%) was added to the solution above. The mixture kept stirring at the 50 °C for 12 hours. After the reaction completion, the residue was purified by flash column chromatography on silica gel to afford the compound **2** (134.4 mg, 84% yield) as a colorless oil.

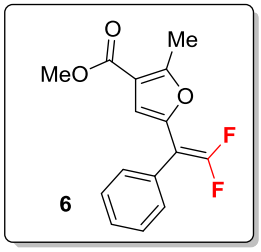


Scheme S1. List of unsuccessful substrates

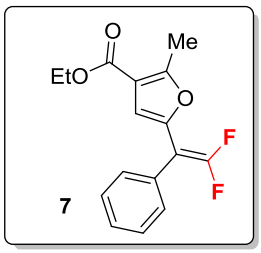


***tert*-butyl 5-(2,2-difluoro-1-phenylvinyl)-2-methylfuran-3-carboxylate(2)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (134.4 mg, 84%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.41 – 7.35 (m, 3H), 7.34 – 7.29 (m, 2H), 6.41 (s, 1H), 2.54 (s, 3H), 1.53 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.0 (d, J = 22.3 Hz, 1F), -90.6 (d, J = 22.0 Hz, 1F). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 163.3, 158.5, 153.9 (dd, J = 300.1, 292.1 Hz), 145.0 (dd, J = 6.2, 4.6 Hz), 130.9 (t, J = 3.3 Hz), 129.8 (t, J = 2.7 Hz), 128.6, 128.4, 116.5, 111.2 (t, J = 5.5 Hz),

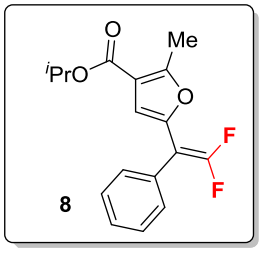
89.3 (dd, J = 26.3, 16.7 Hz), 80.9, 28.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{18}H_{19}F_2O_3^+$ 321.1297, found 321.1302.



methyl 5-(2,2-difluoro-1-phenylvinyl)-2-methylfuran-3-carboxylate(6) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (83.5 mg, 60%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.41 – 7.37 (m, 3H), 7.35 – 7.31 (m, 2H), 6.44 (s, 1H), 3.80 (s, 3H), 2.57 (s, 3H). **^{19}F NMR** (753 MHz, $CDCl_3$) δ -85.8 (d, J = 22.0 Hz, 1F), -90.3 (d, J = 21.9 Hz, 1F). **^{13}C NMR** (201 MHz, $CDCl_3$) δ 164.4, 159.3, 153.9 (dd, J = 300.7, 291.9 Hz), 145.7 – 145.4 (m), 130.8 (t, J = 3.6 Hz), 129.9 (t, J = 2.7 Hz), 128.7, 128.5, 114.8, 110.8 (t, J = 5.7 Hz), 89.2 (dd, J = 26.6, 16.4 Hz), 51.5, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{15}H_{13}F_2O_3^+$ 279.0827, found 279.0839.

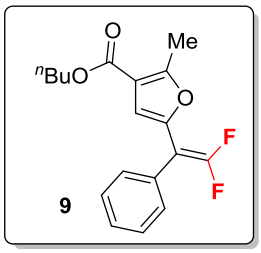


ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-methylfuran-3-carboxylate(7) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a pale yellow oil (98.0 mg, 67%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.40 – 7.36 (m, 3H), 7.34 – 7.31 (m, 2H), 6.45 (s, 1H), 4.27 (q, J = 7.1 Hz, 2H), 2.57 (s, 3H), 1.32 (t, J = 7.1 Hz, 3H). **^{19}F NMR** (471 MHz, $CDCl_3$) δ -85.8 (d, J = 24.0 Hz, 1F), -90.3 (d, J = 23.1 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.9, 159.2, 153.9 (dd, J = 300.6, 292.0 Hz), 145.4 (dd, J = 6.3, 4.5 Hz), 130.8 (t, J = 3.3 Hz), 129.8 (t, J = 2.7 Hz), 128.7, 128.4, 115.1, 110.8 (t, J = 5.7 Hz), 89.2 (dd, J = 26.4, 16.4 Hz), 60.3, 14.4, 13.9. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{16}H_{15}F_2O_3^+$ 293.0984, found 293.0988.

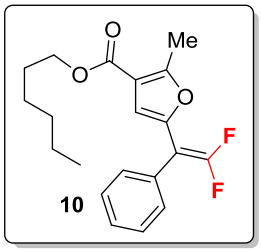


isopropyl 5-(2,2-difluoro-1-phenylvinyl)-2-methylfuran-3-carboxylate(8) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a pale yellow oil (105.7 mg, 69%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.41 – 7.37 (m, 3H), 7.34 – 7.31 (m, 2H), 6.45 (s, 1H), 5.18 – 5.08 (m, 1H),

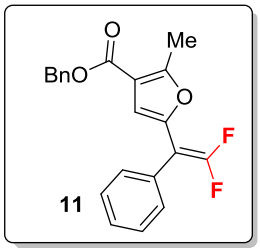
2.56 (s, 3H), 1.31 (s, 3H), 1.29 (s, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.0 (d, *J* = 22.2 Hz, 1F), -90.6 (d, *J* = 22.0 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.5, 159.0, 153.9 (dd, *J* = 300.6, 292.0 Hz), 145.2 (dd, *J* = 6.3, 4.5 Hz), 131.0 – 130.4 (m), 129.8 (t, *J* = 2.7 Hz), 128.6, 128.4, 115.4, 111.0 – 110.8 (m), 89.2 (dd, *J* = 26.1, 16.6 Hz), 67.8, 22.1, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{17}H_{17}F_2O_3^+$ 307.1140, found 307.1146.



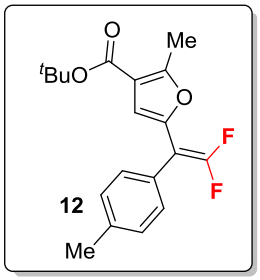
butyl 5-(2,2-difluoro-1-phenylvinyl)-2-methylfuran-3-carboxylate(9) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (85.8 mg, 56%). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.42 – 7.37 (m, 3H), 7.33 (dt, *J* = 6.8, 1.4 Hz, 2H), 6.45 (s, 1H), 4.22 (t, *J* = 6.7 Hz, 2H), 2.57 (s, 3H), 1.74 – 1.64 (m, 2H), 1.48 – 1.38 (m, 2H), 0.95 (t, *J* = 7.4 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.8 (d, *J* = 21.3 Hz, 1F), -90.4 (d, *J* = 21.8 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 164.0, 159.4 – 158.8 (m), 154.0 (dd, *J* = 300.3, 292.1 Hz), 145.4 (dd, *J* = 6.3, 4.5 Hz), 130.8, 129.8 (t, *J* = 2.7 Hz), 128.7, 128.5, 115.1, 110.9 (d, *J* = 5.5 Hz), 89.3 (dd, *J* = 26.3, 16.5 Hz), 64.3, 30.9, 19.4, 14.0 (d, *J* = 20.9 Hz). **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{18}H_{19}F_2O_3^+$ 321.1297, found 321.1307.



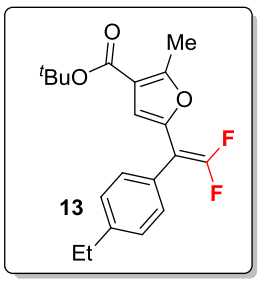
hexyl 5-(2,2-difluoro-1-phenylvinyl)-2-methylfuran-3-carboxylate(10) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (111.5 mg, 64%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.45 – 7.35 (m, 3H), 7.39 – 7.29 (m, 2H), 6.45 (s, 1H), 4.21 (t, *J* = 6.7 Hz, 2H), 2.57 (s, 3H), 1.69 (dq, *J* = 8.1, 6.7 Hz, 2H), 1.45 – 1.36 (m, 2H), 1.33 – 1.28 (m, 4H), 0.93 – 0.85 (m, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.9 (d, *J* = 21.3 Hz, 1F), -90.4 (d, *J* = 21.7 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 164.0, 159.1 (t, *J* = 2.4 Hz), 154.0 (dd, *J* = 300.4, 292.1 Hz), 145.4 (dd, *J* = 6.2, 4.4 Hz), 130.8 (t, *J* = 3.4 Hz), 129.8 (t, *J* = 2.7 Hz), 128.7, 128.5, 115.1, 110.9 (t, *J* = 5.6 Hz), 89.3 (dd, *J* = 26.4, 16.4 Hz), 64.6, 31.6, 28.8, 25.8, 22.7, 14.1, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{20}H_{23}F_2O_3^+$ 349.1610, found 349.1619.



2-(2-phenoxyethoxy)ethyl 5-(2,2-difluoro-1-phenyl vinyl)-2-methylfuran-3-carboxylate(11) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (120.5 mg, 68%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.40 – 7.35 (m, 7H), 7.34 – 7.30 (m, 3H), 6.48 (s, 1H), 5.26 (s, 2H), 2.57 (s, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.7 (d, *J* = 20.9 Hz, 1F), -90.3 (d, *J* = 21.5 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.6, 157.3 (t, *J* = 2.7 Hz), 154.1 (dd, *J* = 301.7, 292.4 Hz), 145.6 (dd, *J* = 6.5, 4.1 Hz), 130.7 (t, *J* = 3.3 Hz), 130.0 (d, *J* = 2.3 Hz), 128.7, 128.6, 122.3, 114.0, 113.7, 113.3 – 112.7 (m), 89.4 (dd, *J* = 26.6, 16.0 Hz), 60.7, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{21}H_{17}F_2O_3^+$ 355.1140, found 355.1142.

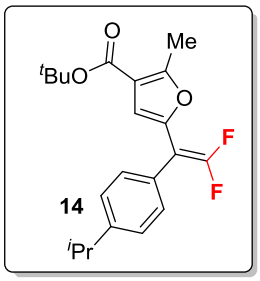


***tert*-butyl 5-(2,2-difluoro-1-(p-tolyl)vinyl)-2-methylfuran-3-carboxylate(12)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a pale solid (125.4 mg, 75%). **Melting point** : 81.2-81.5 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.21 (d, *J* = 1.7 Hz, 4H), 6.41 (s, 1H), 2.53 (s, 3H), 2.37 (s, 3H), 1.53 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.4 (d, *J* = 23.6 Hz, 1F), -90.9 (d, *J* = 23.2 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.4, 153.9 (dd, *J* = 299.9, 291.6 Hz), 145.2 (dd, *J* = 6.3, 4.6 Hz), 138.2, 129.6 (t, *J* = 2.7 Hz), 129.4, 127.9 (t, *J* = 3.3 Hz), 116.5, 111.1 (t, *J* = 5.6 Hz), 89.1 (dd, *J* = 26.2, 16.4 Hz), 80.8, 28.4, 21.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{19}H_{21}F_2O_3^+$ 335.1453, found 335.1461.

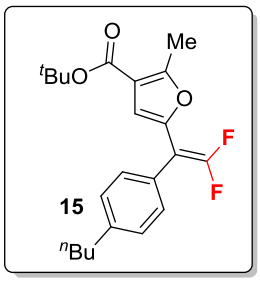


***tert*-butyl 5-(1-(4-ethylphenyl)-2,2-difluorovinyl)-2-methyl furan-3-carboxylate(13)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (139.4 mg, 80%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.28 – 7.12 (m, 4H), 6.43 (s, 1H), 2.67 (q, *J* = 7.6 Hz, 2H), 2.54 (s, 3H), 1.53 (s, 9H), 1.26 (t, *J* = 7.6 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.3 (d, *J* = 23.0 Hz, 1F), -90.9 (d, *J* = 23.0 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.4 (t, *J* = 2.6 Hz), 153.9 (dd, *J* = 300.1, 291.6 Hz), 145.2 (dd, *J* = 6.6, 4.8 Hz), 144.5, 129.7 (t, *J* = 3.0 Hz),

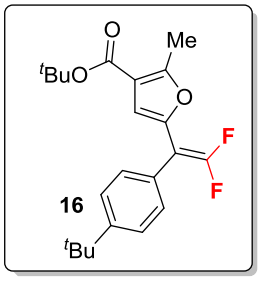
128.1, 116.5, 111.1 (t, J = 5.9 Hz), 89.1 (dd, J = 26.4, 16.5 Hz), 80.8, 28.7, 28.4, 15.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{20}H_{23}F_2O_3^+$ 349.1610, found 349.1620.



***tert*-butyl 5-(2,2-difluoro-1-(4-isopropylphenyl)vinyl)-2-methyl furan-3-carboxylate(14)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (116.0 mg, 64%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.25 (s, 4H), 6.43 (s, 1H), 2.93 (hept, J = 6.9 Hz, 1H), 2.54 (s, 3H), 1.54 (s, 9H), 1.28 (s, 3H), 1.26 (s, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.3 (d, J = 22.8 Hz, 1F), -90.9 (d, J = 22.9 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.4, 153.9 (dd, J = 299.8, 291.9 Hz), 149.1, 145.2 (dd, J = 6.1, 4.6 Hz), 129.7 (t, J = 2.8 Hz), 128.2 (t, J = 3.3 Hz), 126.7, 116.5, 111.2 (t, J = 5.5 Hz), 89.1 (dd, J = 26.1, 16.5 Hz), 80.8, 34.0, 28.4, 24.0, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{21}H_{25}F_2O_3^+$ 363.1766, found 363.1771.

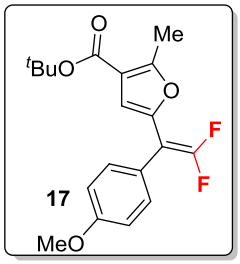


***tert*-butyl 5-(1-(4-butylphenyl)-2,2-difluorovinyl)-2-methyl furan-3-carboxylate(15)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (120.4 mg, 64%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.36 – 7.14 (m, 4H), 6.42 (s, 1H), 2.70 – 2.59 (m, 2H), 2.54 (s, 3H), 1.66 – 1.58 (m, 2H), 1.53 (s, 9H), 1.37 (h, J = 7.4 Hz, 2H), 0.94 (t, J = 7.4 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.3 (d, J = 22.1 Hz, 1F), -90.9 (d, J = 22.4 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.4 (t, J = 2.3 Hz), 153.9 (dd, J = 299.9, 291.8 Hz), 146.1 – 144.3 (m), 143.2, 129.6 (t, J = 2.7 Hz), 128.7, 128.1 (t, J = 3.4 Hz), 116.5, 111.1 (t, J = 5.5 Hz), 89.1 (dd, J = 26.2, 16.5 Hz), 80.8, 35.5, 33.6, 28.4, 22.5, 14.0 (d, J = 7.2 Hz). **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{22}H_{27}F_2O_3^+$ 377.1923, found 377.1930.

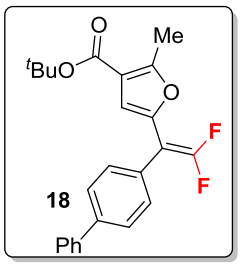


***tert*-butyl 5-(1-(4-(*tert*-butyl)phenyl)-2,2-difluorovinyl)-2-methyl furan-3-carboxylate(16)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (109.2 mg, 58%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.50 –

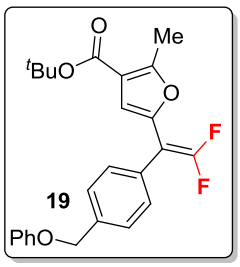
7.32 (m, 4H), 6.93 (s, 1H), 2.49 (s, 3H), 1.52 (s, 9H), 1.31 (s, 9H).**^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.2 (d, *J* = 22.9 Hz, 1F), -90.8 (d, *J* = 22.9 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.4, 158.4, 154.0 (dd, *J* = 299.8, 292.0 Hz), 151.3, 145.5 – 144.8 (m), 129.4 (t, *J* = 2.9 Hz), 127.9 (t, *J* = 3.3 Hz), 125.6, 116.5, 111.2 (t, *J* = 5.5 Hz), 89.0 (dd, *J* = 25.9, 16.5 Hz), 80.8, 34.8, 31.4, 28.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{22}H_{27}F_2O_3^+$ 377.1923, found 377.1926.



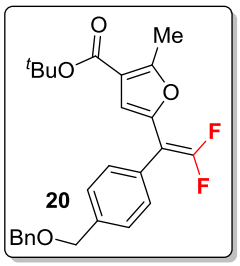
***tert*-butyl 5-(2,2-difluoro-1-(4-methoxyphenyl)vinyl)-2-methyl furan-3-carboxylate(17)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (129.6 mg, 74%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.51 – 7.06 (m, 2H), 6.92 (d, *J* = 8.8 Hz, 2H), 6.40 (s, 1H), 3.83 (s, 3H), 2.54 (s, 3H), 1.54 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.7 (d, *J* = 24.1 Hz, 1F), -91.3 (d, *J* = 24.1 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 159.6, 158.4 (t, *J* = 2.3 Hz), 153.8 (dd, *J* = 299.9, 291.0 Hz), 145.3 (dd, *J* = 6.3, 4.5 Hz), 131.0 (t, *J* = 2.8 Hz), 122.9 (t, *J* = 3.2 Hz), 116.5, 114.1, 111.0 (t, *J* = 5.6 Hz), 88.8 (dd, *J* = 26.3, 16.8 Hz), 80.8, 55.4, 28.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{19}H_{21}F_2O_4^+$ 351.1402, found 351.1395.



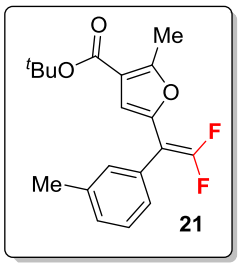
***tert*-butyl 5-(1-([1,1'-biphenyl]-4-yl)-2,2-difluorovinyl)-2-methyl furan-3-carboxylate(18)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a pale yellow solid (196.4 mg, 99%). **Melting point** : 62.5-63.0 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.61 (dd, *J* = 8.1, 2.2 Hz, 4H), 7.47 – 7.42 (m, 2H), 7.41 – 7.32 (m, 3H), 6.48 (s, 1H), 2.55 (s, 3H), 1.54 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.6 (d, *J* = 21.6 Hz, 1F), -90.3 (d, *J* = 20.7 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.6 (t, *J* = 2.3 Hz), 154.0 (dd, *J* = 300.2, 292.7 Hz), 144.9 – 144.5 (m), 141.2, 140.5, 130.1 (t, *J* = 2.9 Hz), 129.8 (t, *J* = 3.4 Hz), 129.0, 127.7, 127.3, 127.2, 116.2, 111.3 (t, *J* = 5.4 Hz), 89.0 (dd, *J* = 25.8, 16.8 Hz), 80.9, 28.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{24}H_{23}F_2O_3^+$ 397.1610, found 397.1617.



***tert*-butyl 5-(2,2-difluoro-1-(4-(phenoxymethyl)phenyl)vinyl)-2-methylfuran-3-carboxylate(19)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (170.6 mg, 80%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.47 (d, *J* = 8.0 Hz, 2H), 7.35 (d, *J* = 7.9 Hz, 2H), 7.33 – 7.29 (m, 2H), 7.03 – 6.97 (m, 3H), 6.43 (s, 1H), 5.09 (s, 2H), 2.53 (s, 3H), 1.54 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.7 (d, *J* = 21.9 Hz, 1F), -90.3 (d, *J* = 21.8 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.8, 158.6 – 158.5 (m), 154.0 (dd, *J* = 300.3, 292.6 Hz), 144.8 (d, *J* = 4.8 Hz), 137.3, 130.6 (t, *J* = 3.4 Hz), 130.0 (t, *J* = 2.9 Hz), 129.7, 127.7, 121.2, 116.5, 115.0, 111.2 (t, *J* = 5.5 Hz), 89.0 (dd, *J* = 25.9, 16.9 Hz), 80.9, 69.7, 28.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{25}H_{25}F_2O_4^+$ 427.1715, found 427.1723

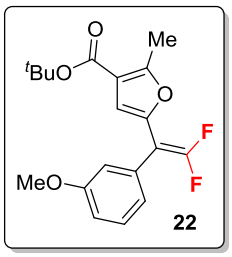


***tert*-butyl 5-(1-(4-((benzyloxy)methyl)phenyl)-2,2-difluo rovinyl)-2-methylfuran-3-carboxylate(20)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (150.0 mg, 68%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.42 – 7.36 (m, 6H), 7.31 (d, *J* = 8.0 Hz, 3H), 6.42 (s, 1H), 4.60 (s, 2H), 4.58 (s, 2H), 2.53 (s, 3H), 1.53 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.9 (d, *J* = 21.7 Hz, 1F), -90.5 (d, *J* = 21.7 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 167.9, 163.3, 158.5 (t, *J* = 2.3 Hz), 153.9 (dd, *J* = 300.2, 292.4 Hz), 144.9 (d, *J* = 10.6 Hz), 138.6, 138.2, 130.2 (t, *J* = 3.3 Hz), 129.8 (t, *J* = 2.8 Hz), 128.6, 127.9, 127.8, 116.5, 111.1 (t, *J* = 5.5 Hz), 89.1 (dd, *J* = 26.0, 16.7 Hz), 80.8, 72.6, 71.8, 28.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{26}H_{27}F_2O_4^+$ 441.1872, found 441.1868.

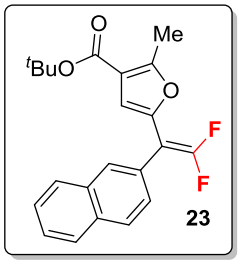


***tert*-butyl 5-(2,2-difluoro-1-(m-tolyl)vinyl)-2-methyl furan-3-carboxylate(21)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (105.3 mg, 63%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.32 – 7.24 (m, 1H), 7.17 (d, *J* = 7.7 Hz, 1H), 7.12 (d, *J* = 8.4 Hz, 2H), 6.41 (s, 1H), 2.54 (s, 3H), 2.37 (s, 3H), 1.54 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.3 (d, *J* = 21.8 Hz,

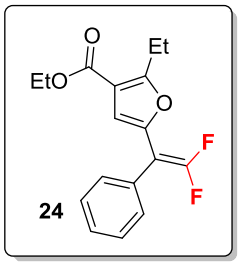
1F), -90.6 (d, J = 22.1 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.4 (t, J = 2.3 Hz), 153.9 (dd, J = 300.0, 291.8 Hz), 145.1 (dd, J = 6.3, 4.6 Hz), 138.3, 130.8 (t, J = 3.3 Hz), 130.4, 129.2, 128.5, 126.9 (t, J = 2.8 Hz), 116.5, 111.1 (t, J = 5.5 Hz), 89.3 (dd, J = 26.3, 16.3 Hz), 80.8, 28.4, 21.5, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{19}H_{21}F_2O_3^+$ 335.1453, found 335.1463.



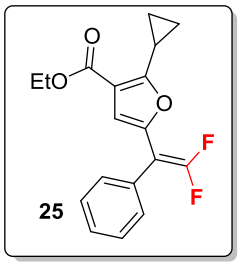
***tert*-butyl 5-(2,2-difluoro-1-(3-methoxyphenyl)vinyl)-2-methyl furan-3-carboxylate(22)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (126.1 mg, 72%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.34 (t, J = 7.9 Hz, 1H), 6.97 – 6.91 (m, 2H), 6.89 (q, J = 1.5 Hz, 1H), 6.44 (s, 1H), 3.84 (s, 3H), 2.56 (s, 3H), 1.56 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.9 (d, J = 21.6 Hz, 1F), -89.9 (d, J = 21.5 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.2, 159.6, 154.2 (dd, J = 300.2, 292.7 Hz), 144.9 – 144.4 (m), 132.0 (t, J = 2.8 Hz), 122.1(t, J = 2.8 Hz), 116.4, 115.4, 113.8, 111.1 (t, J = 5.5 Hz), 89.3 (dd, J = 26.3, 16.3 Hz), 80.8, 55.3, 28.3, 13.9. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{19}H_{21}F_2O_4^+$ 351.1402, found 351.1411.



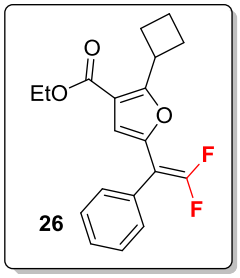
***tert*-butyl 5-(2,2-difluoro-1-(naphthalen-2-yl)vinyl)-2-methyl furan -3-carboxylate(23)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (113.0 mg, 61%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.88 – 7.75 (m, 4H), 7.54 – 7.46 (m, 2H), 7.40 (dt, J = 8.5, 1.5 Hz, 1H), 6.46 (s, 1H), 2.54 (s, 3H), 1.53 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.5 (d, J = 21.6 Hz, 1F), -90.4 (d, J = 21.6 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.6, 154.2 (dd, J = 300.5, 292.3 Hz), 145.0 (dd, J = 6.2, 4.5 Hz), 133.3, 133.1, 129.3 (t, J = 2.9 Hz), 128.3, 128.2, 127.8, 127.2 (t, J = 2.7 Hz), 126.7, 126.5, 116.5, 111.3 (t, J = 5.5 Hz), 89.4 (dd, J = 26.0, 16.8 Hz), 80.9, 28.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{22}H_{21}F_2O_3^+$ 371.1453, found 371.1462.



ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-ethylfuran-3-carboxylate (24) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (99.5 mg, 65%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.42 – 7.35 (m, 3H), 7.37 – 7.31 (m, 2H), 6.43 (s, 1H), 4.27 (t, *J* = 7.2 Hz, 2H), 3.01 (q, *J* = 7.5 Hz, 2H), 1.32 (t, *J* = 7.3 Hz, 3H), 1.24 (t, *J* = 7.5 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.9 (d, *J* = 21.8 Hz, 1F), -90.5 (d, *J* = 21.8 Hz, 1F). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 163.8, 153.9 (dd, *J* = 300.9, 291.9 Hz), 145.4 (dd, *J* = 6.4, 4.3 Hz), 130.8 (t, *J* = 3.3 Hz), 129.9 (t, *J* = 2.7 Hz), 128.7, 128.4, 114.1, 110.8 (dd, *J* = 6.4, 5.1 Hz), 89.3 (dd, *J* = 26.3, 16.4 Hz), 60.3, 21.4, 14.5, 12.3. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{17}H_{17}F_2O_3^+$ 307.1140, found 307.1150.

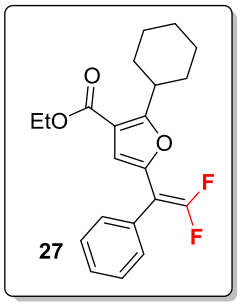


ethyl 2-cyclopropyl-5-(2,2-difluoro-1-phenylvinyl) furan-3-carboxylate(25) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a white solid (100.3 mg, 63%). **Melting point** : 34.9-35.1 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.37 (ddt, *J* = 7.0, 5.0, 3.5 Hz, 3H), 7.33 – 7.28 (m, 2H), 6.38 (s, 1H), 4.28 (q, *J* = 7.2 Hz, 2H), 2.78 (p, *J* = 6.8 Hz, 1H), 1.32 (t, *J* = 7.1 Hz, 3H), 1.04 (s, 2H), 1.02 (s, 2H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.4 (d, *J* = 22.5 Hz, 1F), -90.7 (d, *J* = 22.7 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 164.2, 163.2 (t, *J* = 2.5 Hz), 153.8 (dd, *J* = 300.9, 291.8 Hz), 144.1 (dd, *J* = 6.4, 4.0 Hz), 130.7 (t, *J* = 3.4 Hz), 129.8 (t, *J* = 2.7 Hz), 128.6, 128.4, 114.5, 111.0 (dd, *J* = 6.8, 4.8 Hz), 89.2 (dd, *J* = 26.6, 16.2 Hz), 60.3, 14.5, 9.4, 8.8. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{18}H_{17}F_2O_3^+$ 319.1140, found 319.1150.

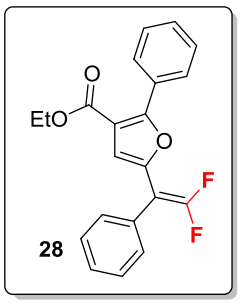


ethyl 2-cyclobutyl-5-(2,2-difluoro-1-phenylvinyl)furan-3-carboxylate(26) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (108.0 mg, 65%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.42 – 7.39 (m, 2H), 7.38 – 7.32 (m, 3H), 6.40 (s, 1H), 4.25 (q, *J* = 6.8 Hz, 3H), 2.43 – 2.27 (m, 4H), 2.07 – 1.92 (m, 1H), 1.88 (ddt, *J* = 11.9, 6.2, 2.2 Hz, 1H), 1.32 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.9 (d, *J* = 21.8 Hz, 1F), -90.4 (d, *J* = 21.5 Hz, 1F). **^{13}C**

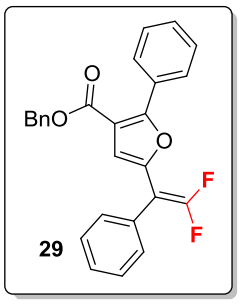
NMR (126 MHz, $CDCl_3$) δ 164.1 (t, *J* = 2.6 Hz), 163.8, 153.9 (dd, *J* = 301.1, 291.7 Hz), 145.4 (dd, *J* = 6.4, 4.1 Hz), 130.8 (t, *J* = 3.3 Hz), 129.9 (t, *J* = 2.7 Hz), 128.7, 128.4, 113.5, 110.9 (dd, *J* = 6.7, 4.7 Hz), 89.4 (dd, *J* = 26.4, 16.3 Hz), 60.3, 32.9, 27.7, 18.5, 14.5. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{19}H_{19}F_2O_3^+$ 333.1297, found 333.1304.



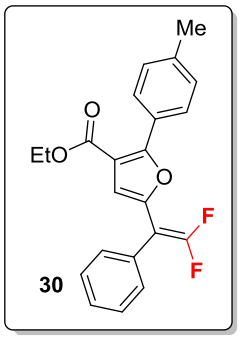
ethyl 2-cyclohexyl-5-(2,2-difluoro-1-phenylvinyl) furan-3-carboxylate(27) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a yellow solid (140.6 mg, 78%). **Melting point** : 69.1-69.5 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.38 (q, *J* = 6.5, 6.0 Hz, 3H), 7.33 (d, *J* = 7.6 Hz, 2H), 6.40 (s, 1H), 4.25 (q, *J* = 7.1 Hz, 2H), 3.44 (tq, *J* = 11.9, 4.3, 3.5 Hz, 1H), 1.90 – 1.84 (m, 2H), 1.80 (dt, *J* = 12.9, 3.4 Hz, 2H), 1.70 (dt, *J* = 12.8, 3.6 Hz, 2H), 1.55 (qd, *J* = 12.5, 3.4 Hz, 2H), 1.39 (tt, *J* = 13.0, 3.4 Hz, 2H), 1.31 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (471 MHz, $CDCl_3$) δ -86.0 (d, *J* = 23.6 Hz, 1F), -90.5 (d, *J* = 24.1 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 166.7 (t, *J* = 2.5 Hz), 163.8, 153.8 (dd, *J* = 301.0, 291.7 Hz), 145.2 (dd, *J* = 6.4, 4.1 Hz), 130.8 (t, *J* = 3.4 Hz), 129.8 (d, *J* = 2.9 Hz), 128.6, 128.4, 113.2, 110.6 (dd, *J* = 6.7, 4.8 Hz), 89.4 (dd, *J* = 26.3, 16.0 Hz), 60.2, 37.1, 30.9, 26.2, 25.9, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{21}H_{23}F_2O_3^+$ 361.1610, found 361.1615.



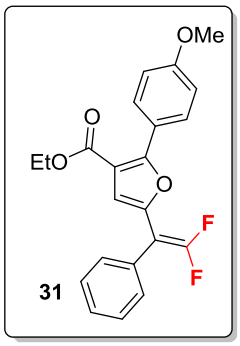
ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-phenylfuran-3-carboxylate (28) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (106.3 mg, 60%). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.01 – 7.93 (m, 2H), 7.43 – 7.37 (m, 8H), 6.63 (s, 1H), 4.28 (q, *J* = 7.1 Hz, 2H), 1.30 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -84.9 (d, *J* = 18.8 Hz, 1F), -89.3 (d, *J* = 19.3 Hz, 1F). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 163.4, 156.9 (t, *J* = 2.8 Hz), 154.2 (dd, *J* = 302.0, 292.6 Hz), 146.3 (dd, *J* = 6.6, 4.3 Hz), 130.5 (t, *J* = 3.3 Hz), 130.0 (t, *J* = 2.7 Hz), 130.0, 128.8, 128.6, 128.4, 128.2, 115.3, 113.0 (t, *J* = 5.8 Hz), 89.3 (dd, *J* = 26.8, 16.0 Hz), 60.8, 14.3. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{21}H_{17}F_2O_3^+$ 355.1140, found 355.1146.



benzyl 5-(2,2-difluoro-1-phenylvinyl)-2-phenylfuran-3-carboxylate(29) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (110.3 mg, 53%). **^{1}H NMR (500 MHz, $CDCl_3$)** δ 8.01 – 7.98 (m, 2H), 7.47 – 7.39 (m, 13H), 6.72 (s, 1H), 5.33 (s, 2H). **^{19}F NMR (376 MHz, $CDCl_3$)** δ -84.7 (d, *J* = 18.5 Hz, 1F), -89.2 (d, *J* = 18.6 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.2, 157.3 (t, *J* = 2.6 Hz), 154.2 (dd, *J* = 301.8, 292.9 Hz), 146.4 (dd, *J* = 6.5, 4.4 Hz), 136.0, 130.5 (t, *J* = 3.3 Hz), 129.6, 129.5, 128.8, 128.7, 128.5, 128.5, 128.4, 128.3, 115.0 113.0 (t, *J* = 5.8 Hz), 89.3 (dd, *J* = 26.6, 16.1 Hz), 66.5. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{26}H_{19}F_2O_3^+$ 417.1297, found 417.1291.

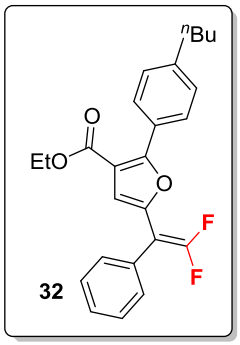


ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(p-tolyl)furan-3-carboxylate(30) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a pale yellow solid (116.0 mg, 63%). **Melting point** : 81.9-82.2 °C. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.91 – 7.84 (m, 2H), 7.47 – 7.31 (m, 6H), 7.21 (d, *J* = 8.0 Hz, 2H), 6.60 (s, 1H), 4.27 (q, *J* = 7.1 Hz, 2H), 2.37 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (565 MHz, $CDCl_3$) δ -85.1 (d, *J* = 19.4 Hz, 1F), -89.5 (d, *J* = 19.5 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.5, 157.3, 154.1 (dd, *J* = 301.9, 292.5 Hz), 145.9 (dd, *J* = 6.5, 4.2 Hz), 139.8, 130.6 (t, *J* = 3.3 Hz), 1 (t, *J* = 2.6 H30.0z), 129.0, 128.7, 128.6, 128.3, 126.8, 114.8, 113.6 – 112.5 (m), 89.4 (dd, *J* = 26.8, 15.9 Hz), 60.7, 21.6, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{22}H_{19}F_2O_3^+$ 369.1297, found 369.1305.

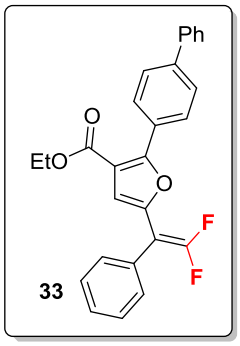


ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(4-methoxyphenyl) furan -3-carboxylate(31) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a white solid (142.2 mg, 74%). **Melting point** : 57.3-57.6 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.02 – 7.92 (m, 2H), 7.47 – 7.34 (m, 5H), 6.98 – 6.89 (m, 2H), 6.59 (s, 1H), 4.27 (q, *J* = 7.1 Hz, 2H), 3.82 (s, 3H), 1.31 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.3 (d, *J* = 20.0 Hz, 1F), -89.7 (d, *J* = 20.0

Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.6, 160.6, 157.2 (t, *J* = 2.7 Hz), 154.0 (dd, *J* = 301.7, 292.3 Hz), 145.5 (dd, *J* = 6.5, 4.2 Hz), 130.6 (t, *J* = 3.3 Hz), 130.0, 128.7, 128.5, 122.2, 114.0, 113.7, 112.9 (t, *J* = 5.8 Hz), 89.3 (dd, *J* = 26.6, 16.0 Hz), 60.6, 55.4, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{22}H_{19}F_2O_4^+$ 385.1246, found 385.1254.

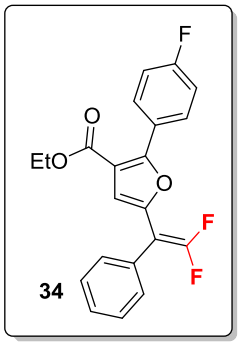


ethyl 2-(4-butylphenyl)-5-(2,2-difluoro-1-phenylvinyl)furan -3-carboxylate(32) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (119.0 mg, 58%). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.89 (d, *J* = 8.3 Hz, 2H), 7.42 (dd, *J* = 6.7, 1.2 Hz, 2H), 7.39 (dd, *J* = 7.5, 1.2 Hz, 3H), 7.22 (d, *J* = 8.4 Hz, 2H), 6.61 (s, 1H), 4.28 (q, *J* = 7.1 Hz, 2H), 2.86 – 2.12 (m, 2H), 1.70 – 1.57 (m, 2H), 1.44 – 1.33 (m, 2H), 1.31 (t, *J* = 7.1 Hz, 3H), 0.92 (t, *J* = 7.3 Hz, 3H). **^{19}F NMR** (565 MHz, $CDCl_3$) δ -85.1 (d, *J* = 19.5 Hz, 1F), -89.5 (d, *J* = 19.4 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.5, 157.3 (t, *J* = 2.7 Hz), 154.1 (dd, *J* = 301.7, 292.5 Hz), 145.9 (dd, *J* = 6.6, 4.2 Hz), 144.8, 130.6 (t, *J* = 3.2 Hz), 130.0 (t, *J* = 2.7 Hz), 128.7, 128.6, 128.4, 128.3, 127.0, 114.7, 113.0 (t, *J* = 5.9 Hz), 89.4 (dd, *J* = 26.7, 16.0 Hz), 60.7, 35.7, 33.5, 22.5, 14.4, 14.1. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{25}H_{25}F_2O_3^+$ 411.1766, found 411.1775.

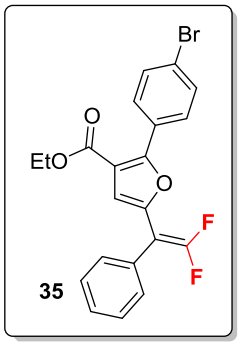


ethyl 2-([1,1'-biphenyl]-4-yl)-5-(2,2-difluoro-1-phenyl vinyl) furan-3-carboxylate(33) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a pale yellow solid (288.4 mg, 67%). **Melting point** : 68.4-68.9 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 8.3 Hz, 2H), 7.63 (dd, *J* = 10.9, 8.0 Hz, 4H), 7.47 – 7.38 (m, 7H), 7.35 (d, *J* = 7.5 Hz, 1H), 6.64 (s, 1H), 4.29 (q, *J* = 7.2 Hz, 2H), 1.32 (t, *J* = 7.2 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -84.8 (d, *J* = 18.5 Hz, 1F), -89.2 (d, *J* = 18.8 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.4, 156.7, 154.2 (dd, *J* = 302.1, 292.7 Hz), 146.3 (dd, *J* = 6.7, 4.2 Hz), 142.1, 140.5, 130.5 (t, *J* = 3.3 Hz), 130.0 (t, *J* = 2.6 Hz), 120.0, 128.7, 128.7, 128.6, 128.4, 127.8, 127.2, 126.9, 115.4, 113.1 (t, *J* = 5.9 Hz), 89.4 (dd, *J* = 26.8, 15.9 Hz), 60.8, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for

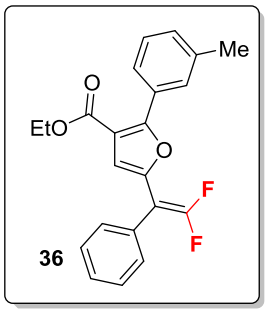
$C_{27}H_{21}F_2O_3^+$ 431.1453, found 431.1457.



ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(4-fluorophenyl) furan-3-carboxylate(34) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (128.5 mg, 69%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.07 – 7.95 (m, 2H), 7.49 – 7.31 (m, 5H), 7.15 – 7.04 (m, 2H), 6.61 (s, 1H), 4.28 (q, *J* = 7.2 Hz, 2H), 1.31 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -84.9 (d, *J* = 18.8 Hz, 1F), -89.2 (d, *J* = 18.7 Hz, 1F), -113.70 – -113.91 (m, 1F) **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.4 (d, *J* = 250.3 Hz) , 163.4, 156.1 (t, *J* = 2.7 Hz), 154.2 (dd, *J* = 300.4, 292.1 Hz), 146.3 (dd, *J* = 6.6, 4.3 Hz), 130.5, 130.5, 129.9 (t, *J* = 2.6 Hz), 128.8, 128.7, 125.8 (d, *J* = 3.4 Hz), 115.4 (d, *J* = 21.8 Hz), 113.0 (t, *J* = 5.8 Hz), 89.3 (dd, *J* = 26.9, 16.0 Hz), 60.9, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{21}H_{16}F_3O_3^+$ 373.1046, found 373.1053.

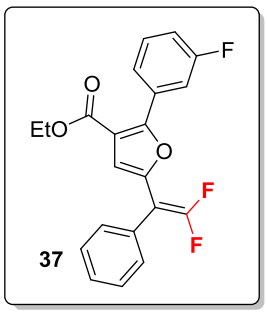


ethyl 2-(4-bromophenyl)-5-(2,2-difluoro-1-phenylvinyl) furan-3-carboxylate(35) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (117.0 mg, 54%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.93 – 7.84 (m, 2H), 7.60 – 7.50 (m, 2H), 7.44 – 7.36 (m, 5H), 6.61 (s, 1H), 4.29 (q, *J* = 7.2 Hz, 2H), 1.32 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -84.6 (d, *J* = 18.3 Hz, 1F), -88.9 (d, *J* = 18.3 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 155.7, 154.2 (dd, *J* = 302.1, 293.0 Hz), 146.6 (dd, *J* = 6.6, 4.4 Hz), 131.5, 130.4 (t, *J* = 3.2 Hz), 130.0 (t, *J* = 2.6 Hz), 129.8, 128.8, 128.7, 128.4, 123.9, 115.8, 113.1 (t, *J* = 5.9 Hz), 89.3 (dd, *J* = 26.9, 15.9 Hz), 61.0, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{21}H_{15}BrF_2O_3^+$ 433.0245, found 433.0297.

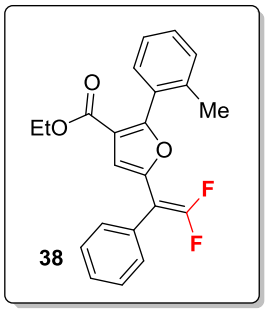


ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(m-tolyl)furan-3-carboxylate(36) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (141.8 mg, 77%). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.80 –

7.71 (m, 2H), 7.46 – 7.35 (m, 5H), 7.30 (t, *J* = 7.7 Hz, 1H), 7.20 (d, *J* = 7.6 Hz, 1H), 6.61 (s, 1H), 4.28 (q, *J* = 7.2 Hz, 2H), 2.38 (d, *J* = 8.4 Hz, 3H), 1.31 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (565 MHz, $CDCl_3$) δ -84.9 (d, *J* = 19.1 Hz, 1F), -89.3 (d, *J* = 19.1 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.5, 157.1, 154.1 (dd, *J* = 301.9, 292.5 Hz), 146.2 (dd, *J* = 7.0, 4.5 Hz), 137.8, 130.6 (d, *J* = 3.5 Hz), 130.4, 130.0 (t, *J* = 3.1 Hz), 129.0, 128.7, 128.6, 128.2, 125.6, 115.2, 113.1 (t, *J* = 6.2 Hz), 89.3 (dd, *J* = 27.0, 16.2 Hz), 60.8, 21.6, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{22}H_{19}F_2O_3^+$ 369.1297, found 369.1304.

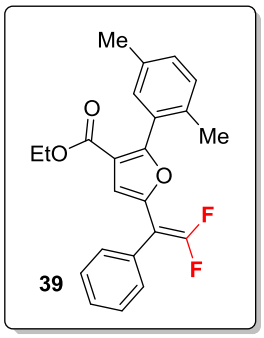


ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(3-fluorophenyl) furan-3-carboxylate(37) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (109.8 mg, 59%).**^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.82 – 7.70 (m, 2H), 7.45 – 7.36 (m, 6H), 7.13 – 7.03 (m, 1H), 6.63 (s, 1H), 4.30 (q, *J* = 7.2 Hz, 2H), 1.32 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (565 MHz, $CDCl_3$) δ -84.5 (d, *J* = 18.5 Hz, 1F), -88.7 (d, *J* = 18.6 Hz, 1F), -116.01 (ddd, *J* = 11.6, 9.3, 6.6 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ, 163.2, 162.6 (d, *J* = 244.8 Hz), 155.2, 154.2 (dd, *J* = 302.2, 292.9 Hz), 146.7 (dd, *J* = 6.7, 4.4 Hz), 130.3 (t, *J* = 3.3 Hz), 129.9 (t, *J* = 2.7 Hz), 129.9, 129.8, 128.8, 128.7, 123.9 (d, *J* = 2.8 Hz), 116.3, 115.2 (d, *J* = 24.3 Hz), 113.2 (t, *J* = 5.9 Hz), 89.3 (dd, *J* = 26.9, 15.9 Hz), 61.0, 14.3. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{21}H_{16}F_3O_3^+$ 373.1046, found 373.1051.

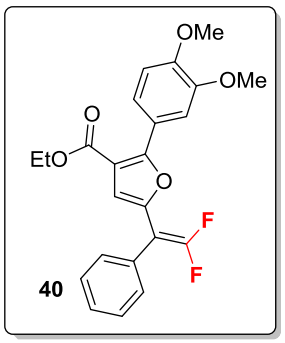


ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(o-tolyl)furan-3-carboxylate(38) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (143.7 mg, 78%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.48 – 7.41 (m, 1H), 7.43 – 7.35 (m, 5H), 7.32 (td, *J* = 7.5, 1.5 Hz, 1H), 7.27 – 7.18 (m, 2H), 6.65 (s, 1H), 4.17 (q, *J* = 7.1 Hz, 2H), 2.26 (s, 3H), 1.18 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.0 (d, *J* = 19.5 Hz, 1F), -89.6 (d, *J* = 19.2 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.2, 158.2, 154.1 (dd, *J* = 301.2, 292.4 Hz), 146.8 (dd, *J* = 6.4, 4.5 Hz), 138.0, 131.2, 130.6 (t, *J* = 3.3 Hz), 129.9, 129.8, 129.5,

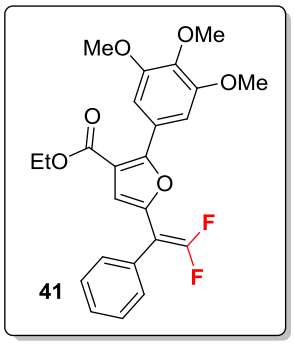
128.7, 125.2, 116.7, 111.4, 89.4 (dd, J = 26.8, 16.3 Hz), 60.5, 20.3, 14.2. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{22}H_{19}F_2O_3^+$ 369.1297, found 369.1305.



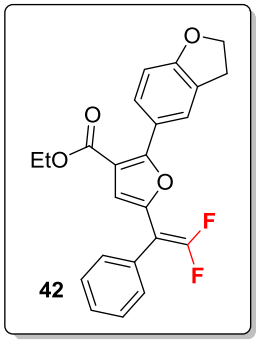
ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(2,5-dimethyl phenyl)furan -3-carboxylate(39) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (147.2 mg, 77%). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.39 – 7.34 (m, 5H), 7.25 (s, 1H), 7.12 (d, J = 1.3 Hz, 2H), 6.65 (s, 1H), 4.17 (q, J = 7.1 Hz, 2H), 2.32 (s, 3H), 2.20 (s, 3H), 1.17 (t, J = 7.1 Hz, 3H). **^{19}F NMR** (565 MHz, $CDCl_3$) δ -85.0 (d, J = 20.2 Hz, 1F), -89.6 (d, J = 20.3 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.1, 158.4 (t, J = 2.6 Hz), 154.1 (dd, J = 301.4, 292.3 Hz), 146.7 (dd, J = 6.4, 4.4 Hz), 134.9, 134.5, 131.6, 130.6 (t, J = 3.2 Hz), 130.5, 130.2, 129.9 (t, J = 2.7 Hz), 129.3, 128.7, 128.5, 116.5, 111.5 (d, J = 5.6 Hz), 89.4 (dd, J = 26.6, 16.1 Hz), 60.4, 20.9, 19.7, 14.1. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{23}H_{21}F_2O_3^+$ 383.1453, found 383.1460.



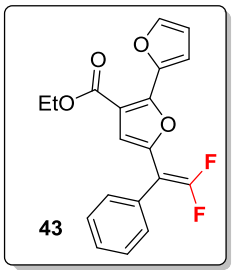
ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(3,4-dimeth oxyphenyl) furan-3-carboxylate(40) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (159.5 mg, 77%).**^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.75 (d, J = 2.1 Hz, 1H), 7.67 (dd, J = 8.5, 2.1 Hz, 1H), 7.46 – 7.37 (m, 5H), 6.90 (d, J = 8.5 Hz, 1H), 6.60 (s, 1H), 4.28 (q, J = 7.1 Hz, 2H), 3.91 (d, J = 3.0 Hz, 6H), 1.32 (t, J = 7.1 Hz, 3H). **^{19}F NMR** (565 MHz, $CDCl_3$) δ -85.2 (d, J = 20.3 Hz, 1F), -89.6 (d, J = 20.4 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.6, 156.9, 154.0 (dd, J = 301.6, 292.4 Hz), 150.2, 148.5, 145.4 (dd, J = 6.6, 4.1 Hz), 130.6 (t, J = 3.3 Hz), 128.7, 128.5, 122.4, 121.5, 114.2, 113.0 (t, J = 5.9 Hz), 111.4, 110.7, 89.4 (dd, J = 26.8, 16.0 Hz), 60.7, 56.0, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{23}H_{21}F_2O_5^+$ 415.1352, found 415.1360.



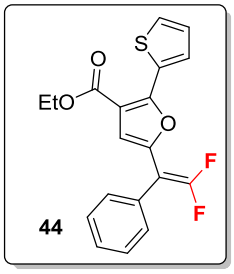
ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(3,4,5-trimeth oxyphenyl) furan-3-carboxylate(41) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a white solid (166.6 mg, 75%).**Melting point** : 82.6-83.1 ^{o}C. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.45 (s, 2H), 7.41 (qd, *J* = 7.1, 2.2 Hz, 5H), 6.62 (s, 1H), 4.29 (d, *J* = 7.1 Hz, 2H), 3.89 (d, *J* = 1.1 Hz, 9H), 1.33 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (565 MHz, $CDCl_3$) δ -84.9 (d, *J* = 19.8 Hz, 1F), -89.3 (d, *J* = 19.9 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.4, 156.4 (t, *J* = 3.1 Hz), 154.1 (dd, *J* = 302.1, 292.7 Hz), 153.0, 145.6 (dd, *J* = 7.1, 4.4 Hz), 139.3, 130.4 (t, *J* = 3.6 Hz), 130.0 (t, *J* = 2.8 Hz), 128.7, 124.8, 115.0, 113.1 (t, *J* = 6.4 Hz), 105.6, 89.3 (dd, *J* = 27.2, 16.0 Hz), 61.0, 60.8, 56.2, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{24}H_{23}F_2O_6^+$ 445.1457, found 445.1464.



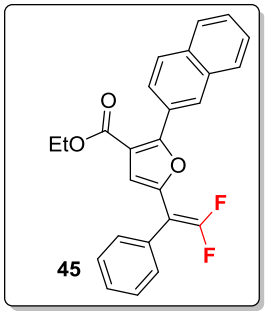
ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(2,3-dihydroben zofuran-6-yl)furan-3-carboxylate(42) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (136.8 mg, 69%). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.90 (t, *J* = 1.7 Hz, 1H), 7.80 – 7.76 (m, 1H), 7.44 – 7.41 (m, 2H), 7.39 (d, *J* = 7.6 Hz, 3H), 6.81 (d, *J* = 1.1 Hz, 1H), 6.58 (d, *J* = 1.8 Hz, 1H), 4.61 (t, *J* = 8.7 Hz, 2H), 4.27 (qd, *J* = 7.1, 1.1 Hz, 2H), 3.24 (t, *J* = 8.7 Hz, 2H), 1.31 (td, *J* = 7.1, 0.9 Hz, 3H). **^{19}F NMR** (565 MHz, $CDCl_3$) δ -85.3 (d, *J* = 20.0 Hz, 1F), -89.7 (d, *J* = 20.2 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.6, 161.4, 157.7 (t, *J* = 2.7 Hz), 154.0 (dd, *J* = 301.6, 292.4 Hz), 145.3 (dd, *J* = 6.4, 4.1 Hz), 130.7 (t, *J* = 3.4 Hz), 129.9 (t, *J* = 2.7 Hz), 129.2, 128.7, 128.5, 127.1, 125.3, 122.2, 113.6, 113.0 (dd, *J* = 6.5, 5.1 Hz), 109.1, 89.3 (dd, *J* = 26.5, 16.0 Hz), 71.8, 60.6, 29.6, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{23}H_{19}F_2O_4^+$ 397.1246, found 397.1251.



ethyl 5-(2,2-difluoro-1-phenylvinyl)-[2,2'-bifuran]-3-carboxylate (43) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a white solid (122.2 mg, 71%). **Melting point** : 70.6-71.1 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.59 – 7.44 (m, 2H), 7.44 – 7.29 (m, 5H), 6.57 (s, 1H), 6.56 – 6.46 (m, 1H), 4.30 (q, *J* = 7.2 Hz, 2H), 1.33 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (471 MHz, $CDCl_3$) δ -84.3 (d, *J* = 17.7 Hz, 1F), -88.7 (d, *J* = 18.4 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 162.7, 154.2 (dd, *J* = 302.1, 293.0 Hz), 148.5 (t, *J* = 2.7 Hz), 146.2 (dd, *J* = 6.5, 4.3 Hz), 144.3, 143.7, 129.9 (t, *J* = 2.7 Hz), 128.7, 128.6, 114.0, 113.7, 112.4 (dd, *J* = 6.3, 5.0 Hz), 112.0, 89.2 (dd, *J* = 26.9, 16.0 Hz), 60.7, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{19}H_{15}F_2O_4^+$ 345.0933, found 345.0938.

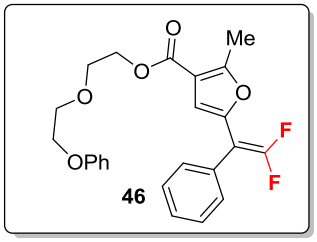


ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(thiophen-2-yl) furan-3-carboxylate(44) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (99.1 mg, 55%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.00 (dd, *J* = 3.8, 1.2 Hz, 1H), 7.40 (tq, *J* = 4.9, 3.4, 2.8 Hz, 6H), 7.08 (dd, *J* = 5.1, 3.8 Hz, 1H), 6.55 (s, 1H), 4.32 (q, *J* = 7.2 Hz, 2H), 1.34 (t, *J* = 7.2 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -84.6 (d, *J* = 18.4 Hz, 1F), -89.0 (d, *J* = 18.4 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.2, 154.1 (dd, *J* = 302.5, 292.5 Hz), 152.5 (t, *J* = 2.7 Hz), 145.6 (dd, *J* = 6.8, 4.1 Hz), 131.4, 130.0 (t, *J* = 2.7 Hz), 129.0, 128.7, 128.6, 128.3, 127.5, 113.5, 112.4 (dd, *J* = 6.8, 5.3 Hz), 89.2 (dd, *J* = 27.2, 15.9 Hz), 60.8, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{19}H_{15}F_2O_3S^+$ 361.0704, found 361.0693.

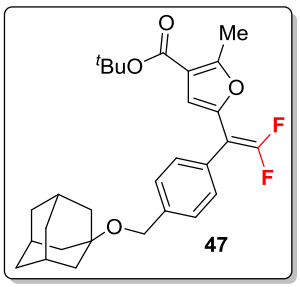


ethyl 5-(2,2-difluoro-1-phenylvinyl)-2-(naphthalen-2-yl) furan-3-carboxylate(45) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (143.6 mg, 71%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.58 (d, *J* = 1.7 Hz, 1H), 8.03 (dd, *J* = 8.7, 1.8 Hz, 1H), 7.94 – 7.85 (m,

1H), 7.85 – 7.73 (m, 2H), 7.57 – 7.44 (m, 2H), 7.42 (s, 5H), 6.67 (s, 1H), 4.30 (q, *J* = 7.1 Hz, 2H), 1.31 (t, *J* = 7.1 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -84.7 (d, *J* = 18.5 Hz, 1F), -89.1 (d, *J* = 19.2 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.5, 156.9, 154.2 (dd, *J* = 302.0, 292.6 Hz), 146.5 (dd, *J* = 6.7, 4.2 Hz), 133.7, 133.0, 130.5 (t, *J* = 3.3 Hz), 130.0 (t, *J* = 2.7 Hz), 129.0, 128.8, 128.6, 128.4, 127.8, 127.7, 127.1, 126.9, 126.5, 125.3, 115.7, 113.8 – 112.9 (m), 89.4 (dd, *J* = 26.8, 15.9 Hz), 60.8, 14.4. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{25}H_{19}F_2O_3^+$ 405.1297, found 405.1303.

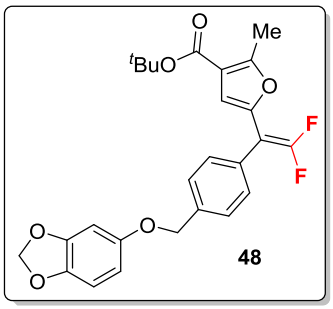


2-(2-phenoxyethoxy)ethyl 5-(2,2-difluoro-1-phenyl vinyl)-2-methylfuran-3-carboxylate(46) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (128.5 mg, 60%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.38 (td, *J* = 6.8, 6.4, 3.0 Hz, 3H), 7.35 – 7.30 (m, 2H), 7.26 (dd, *J* = 6.1, 2.5 Hz, 2H), 6.98 – 6.93 (m, 1H), 6.91 – 6.88 (m, 2H), 6.47 (s, 1H), 4.56 – 4.33 (m, 2H), 4.25 – 4.04 (m, 2H), 3.98 – 3.74 (m, 4H), 2.56 (s, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.8 (d, *J* = 20.7 Hz, 1F), -90.3 (d, *J* = 21.1 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.8, 159.5 (t, *J* = 2.3 Hz), 158.8, 156.6 – 151.0 (m), 145.7 – 145.0 (m), 130.8 (t, *J* = 3.4 Hz), 129.8 (t, *J* = 2.8 Hz), 129.6, 128.5, 121.1, 114.7, 110.9 (t, *J* = 5.5 Hz), 89.2 (dd, *J* = 26.4, 16.4 Hz), 69.5, 67.5, 63.4, 14.1. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{24}H_{23}F_2O_5^+$ 429.1508, found 429.1516.

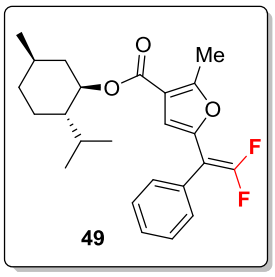


***tert*-butyl 5-(1-(4-((((3s,5s,7s)-adamantan-1-yl)oxy)methyl) phenyl)-2,2-difluorovinyl)-2-methylfuran-3-carboxylate(47)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (77.1 mg, 66%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.39 (d, *J* = 7.9 Hz, 2H), 7.28 (d, *J* = 7.9 Hz, 2H), 6.39 (s, 1H), 4.53 (s, 2H), 2.53 (s, 3H), 2.21 – 2.17 (m, 3H), 1.87 (d, *J* = 3.0 Hz, 6H), 1.71 – 1.61 (m, 6H), 1.53 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.2 (d, *J* = 22.7 Hz, 1F), -90.8 (d, *J* = 22.3 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.5 (t, *J* = 2.3 Hz), 153.9 (dd, *J* = 300.1, 291.8 Hz), 145.1 (dd, *J* = 6.2, 4.4 Hz), 140.4, 129.8 (t, *J* = 2.7 Hz), 129.6 (t, *J* = 3.4 Hz), 127.8, 116.4, 111.1 (t, *J* = 5.5 Hz), 89.2 (dd, *J* =

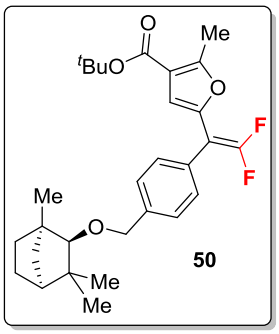
26.3, 16.5 Hz), 80.8, 73.0, 62.1, 41.8, 36.6, 30.7, 28.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{29}H_{35}F_2O_4^+$ 485.2498, found 485.2509.



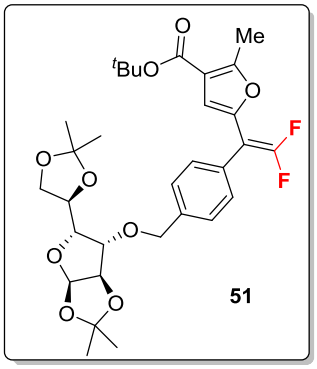
***tert*-butyl 5-(1-(4-((benzo[d][1,3]dioxol-5-yloxy)methyl) phenyl)-2,2-difluorovinyl)-2-methylfuran-3-carboxylate(48)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (74.8 mg, 53%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.45 (d, *J* = 8.1 Hz, 2H), 7.39 – 7.32 (m, 2H), 6.72 (d, *J* = 8.4 Hz, 1H), 6.58 (d, *J* = 2.5 Hz, 1H), 6.42 (d, *J* = 8.2 Hz, 2H), 5.93 (s, 2H), 5.01 (s, 2H), 2.54 (s, 3H), 1.54 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.6 (d, *J* = 21.7 Hz, 1F), -90.3 (d, *J* = 21.4 Hz, 1F). **^{13}C NMR** (126 MHz, CDCl3) δ 163.3, 158.5, 154.4, 154.1 (*J* = 300.1, 292.1 Hz), 148.5, 144.8, 142.2, 137.4, 130.9 – 129.3 (m), 127.7, 116.6, 111.3 (t, *J* = 5.5 Hz), 108.1, 106.4, 101.4, 98.7, 89.1 (dd, *J* = 26.3, 16.4 Hz), 80.9, 70.9, 28.5, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{26}H_{25}F_2O_6^+$ 471.1614, found 471.1612.



(1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl 5-(2,2-difluoro-1-phenylvinyl)-2-methylfuran-3-carboxylate(49) The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a yellow oil (138.7 mg, 69%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.45 – 7.35 (m, 3H), 7.34 (dt, *J* = 7.9, 1.2 Hz, 2H), 6.46 (s, 1H), 4.85 (td, *J* = 10.9, 4.4 Hz, 1H), 2.56 (s, 3H), 2.10 – 2.03 (m, 1H), 1.90 (pd, *J* = 7.0, 2.7 Hz, 1H), 1.74 – 1.66 (m, 2H), 1.51 (ddq, *J* = 13.9, 8.4, 3.0 Hz, 2H), 1.44 (dt, *J* = 10.9, 3.0 Hz, 1H), 1.11 – 1.02 (m, 2H), 0.90 (t, *J* = 6.5 Hz, 6H), 0.78 (d, *J* = 6.9 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.9 (d, *J* = 21.6 Hz, 1F), -90.5 (d, *J* = 21.6 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.6, 159.0 (d, *J* = 2.6 Hz), 154.0 (dd, *J* = 300.4, 292.2 Hz), 145.3 – 145.2 (m), 130.9 (t, *J* = 3.4 Hz), 129.8 (t, *J* = 2.7 Hz), 128.7, 128.4, 115.4, 110.9 (t, *J* = 5.7 Hz), 89.3 (dd, *J* = 26.2, 16.6 Hz), 74.2, 47.3, 41.3, 34.4, 31.6, 26.6, 23.7, 22.2, 20.9, 16.6, 14.1. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{24}H_{29}F_2O_3^+$ 403.2079, found 403.2085.

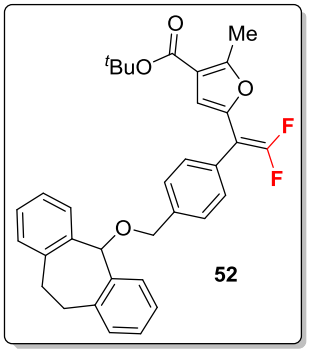


***tert*-butyl 5-(2,2-difluoro-1-(4-((((1*R*,2*R*,4*S*)-1,3,3-tri methyl bicyclo[2.2.1]heptan-2-yl)oxy)methyl)phenyl)vinyl)-2-methylfuran-3-carboxylate(50)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (113.9 mg, 78%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.39 (d, *J* = 8.2 Hz, 2H), 7.29 (d, *J* = 7.9 Hz, 2H), 6.41 (s, 1H), 4.63 (d, *J* = 12.3 Hz, 1H), 4.47 (d, *J* = 12.3 Hz, 1H), 3.04 (d, *J* = 1.8 Hz, 1H), 2.54 (s, 3H), 1.81 (ddd, *J* = 11.7, 5.8, 2.4 Hz, 1H), 1.75 – 1.68 (m, 1H), 1.65 (d, *J* = 3.8 Hz, 1H), 1.53 (s, 10H), 1.50 – 1.37 (m, 3H), 1.11 (s, 3H), 1.04 (s, 3H), 0.99 (s, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.1 (d, *J* = 22.7 Hz, 1F), -90.7 (d, *J* = 22.1 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.5, 153.9 (dd, *J* = 300.1, 292.0 Hz), 145.0 (dd, *J* = 6.2, 4.6 Hz), 139.9, 129.7 (t, *J* = 3.3 Hz), 129.6 (t, *J* = 2.8 Hz), 127.5, 116.5, 111.2 (t, *J* = 5.6 Hz), 93.0, 89.1 (dd, *J* = 26.1, 16.6 Hz), 80.8, 73.2, 49.4, 49.0, 41.6, 39.7, 31.8, 28.4, 26.3, 26.2, 21.0, 20.3, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{29}H_{37}F_2O_4^+$ 487.2654, found 487.2655.

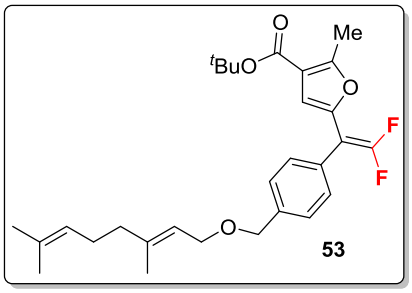


***tert*-butyl 5-(1-(4-((((3a*R*,5*R*,6*S*,6a*S*)-5-((*R*)-2,2-di methyl-1,3-dioxolan-4-yl)tetrahydrofuro[2,3-d][1,3]dioxol-6-yl)oxy)methyl)phenyl)-2,2-difluorovinyl)-2-methylfuran-3-carboxylate(51)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a pale yellow solid (103.3 mg, 61%). **Melting point** : 100.2-100.6 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.39 (d, *J* = 8.0 Hz, 2H), 7.32 – 7.29 (m, 2H), 6.42 (s, 1H), 5.92 (d, *J* = 3.7 Hz, 1H), 4.78 – 4.58 (m, 3H), 4.39 (dt, *J* = 8.0, 5.9 Hz, 1H), 4.17 – 4.12 (m, 2H), 4.08 – 3.98 (m, 2H), 2.54 (s, 3H), 1.54 (s, 9H), 1.44 (s, 3H), 1.38 (s, 3H), 1.33 (s, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.7 (d, *J* = 21.9 Hz, 1F), -90.5 (d, *J* = 21.8 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.5 (d, *J* = 2.5 Hz), 154.0 (dd, *J* = 300.3, 292.6 Hz), 144.7 (dd, *J* = 11.8, 6.1 Hz), 137.5, 130.1 (t, *J* = 2.8 Hz), 127.8, 116.5 (d, *J* = 2.9 Hz), 112.0 (d, *J* = 2.1 Hz), 111.2 (dd, *J* = 8.8, 5.2 Hz), 109.2, 105.3, 89.5 – 88.5 (m), 82.8, 82.4, 82.2, 82.0, 81.5, 80.9, 80.9, 80.2, 72.6, 72.1, 71.9, 69.4, 67.7, 64.6, 31.0, 28.4, 27.0, 27.0, 26.9, 26.4, 25.6, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{31}H_{39}F_2O_9^+$ 593.2557,

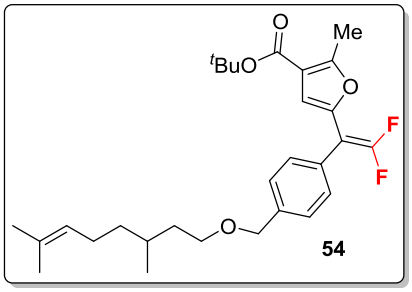
found 593.2563.



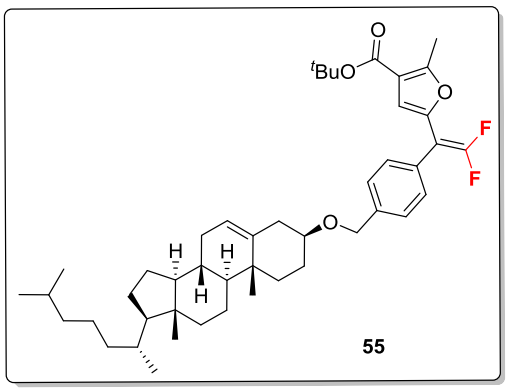
***tert*-butyl 5-(1-(4-(((10,11-dihydro-5H-dibenzo[a,d][7] annulen-5-yl)oxy)methyl)phenyl)-2,2-difluorovinyl)-2-methylfuran-3-carboxylate(52)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (99.3 mg, 61%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.36 (t, *J* = 7.8 Hz, 4H), 7.29 (d, *J* = 7.9 Hz, 2H), 7.22 – 7.15 (m, 6H), 6.42 (s, 1H), 5.45 (s, 1H), 4.53 (s, 2H), 3.59 (dt, *J* = 15.2, 6.3 Hz, 2H), 3.02 (td, *J* = 10.0, 9.3, 4.1 Hz, 2H), 2.53 (s, 3H), 1.53 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -85.9 (d, *J* = 21.8 Hz, 1F), -90.5 (d, *J* = 21.7 Hz, 1F). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 163.3, 158.5 (t, *J* = 2.3 Hz), 154.0 (dd, *J* = 300.2, 292.2 Hz), 145.0 – 144.9 (m), 139.7, 138.8, 138.5, 130.51, 129.8 (t, *J* = 2.7 Hz), 128.3, 127.9, 126.1, 116.5, 111.16 (t, *J* = 5.5 Hz), 89.1 (dd, *J* = 25.9, 16.8 Hz), 80.9, 70.3, 32.4, 28.4, 14.0. **HRMS-ESI** m/z : $[M+Na]^+$ calcd for $C_{34}H_{32}F_2O_4Na^+$ 565.2161, found 565.2162.



***tert*-butyl 5-(1-(4-(((3,7-dimethylocta-2,6-dien-1-yl) oxy)methyl)phenyl)-2,2-difluorovinyl)-2-methylfuran-3-carboxylate(53)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (119.7 mg, 69%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.38 (d, *J* = 8.2 Hz, 2H), 7.33 – 7.28 (m, 2H), 6.40 (s, 1H), 5.42 (tq, *J* = 6.8, 1.3 Hz, 1H), 5.11 (tt, *J* = 6.8, 1.4 Hz, 1H), 4.52 (s, 2H), 4.08 (d, *J* = 6.8 Hz, 2H), 2.53 (s, 3H), 2.10 (d, *J* = 6.3 Hz, 2H), 2.09 – 2.01 (m, 2H), 1.68 (s, 3H), 1.67 (s, 3H), 1.61 (s, 3H), 1.53 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.0 (d, *J* = 22.1 Hz, 1F), -90.5 (d, *J* = 22.0 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.2, 158.5 (t, *J* = 2.4 Hz), 153.9 (dd, *J* = 300.2, 292.0 Hz), 144.9 (d, *J* = 10.7 Hz), 140.7, 138.9, 131.7, 130.0 (t, *J* = 3.3 Hz), 129.8 (t, *J* = 2.8 Hz), 128.0, 124.1, 120.8, 116.4, 111.1 (t, *J* = 5.5 Hz), 89.1 (dd, *J* = 26.1, 16.6 Hz), 80.8, 71.7, 67.0, 39.7, 28.4, 26.5, 25.8, 17.8, 16.6, 13.9. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{29}H_{37}F_2O_4^+$ 487.2654, found 487.2656.

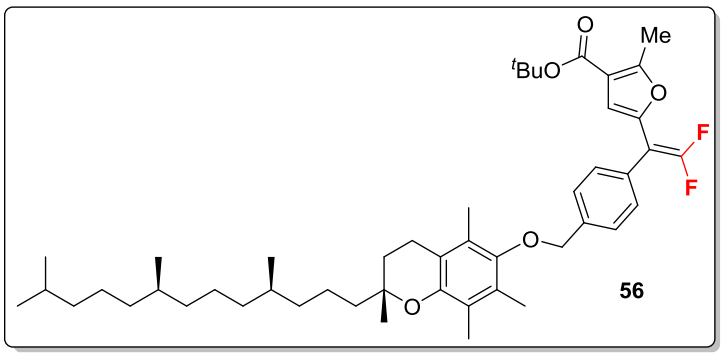


***tert*-butyl 5-(1-(4-(((3,7-dimethyloct-6-en-1-yl)oxy) methyl)phenyl)-2,2-difluorovinyl)-2-methylfuran-3-carboxylate(54)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (81.7 mg, 56%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.37 (d, *J* = 7.9 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 6.41 (s, 1H), 5.10 (t, *J* = 7.3 Hz, 1H), 4.52 (s, 2H), 3.54 (ddt, *J* = 9.1, 7.1, 3.2 Hz, 2H), 2.53 (s, 3H), 1.99 (tq, *J* = 15.2, 7.4 Hz, 2H), 1.68 (s, 4H), 1.60 (s, 4H), 1.53 (s, 9H), 1.50 – 1.37 (m, 1H), 1.40 – 1.29 (m, 1H), 1.17 (dddd, *J* = 13.6, 9.7, 7.7, 5.9 Hz, 1H), 0.90 (d, *J* = 6.6 Hz, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.0 (d, *J* = 21.2 Hz, 1F), -90.6 (d, *J* = 21.8 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.5 (t, *J* = 2.3 Hz), 153.9 (dd, *J* = 300.1, 292.1 Hz), 145.0 (dd, *J* = 6.2, 4.5 Hz), 139.0, 131.3, 130.0 (t, *J* = 3.3 Hz), 129.8 (t, *J* = 2.9 Hz), 127.8, 124.9, 116.5, 111.1 (t, *J* = 5.5 Hz), 89.1 (dd, *J* = 26.1, 16.7 Hz), 80.8, 72.7, 69.2, 37.4, 36.8, 29.7, 28.4, 25.9, 25.6, 19.7, 17.8, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{29}H_{39}F_2O_4^+$ 489.2811, found 489.2813



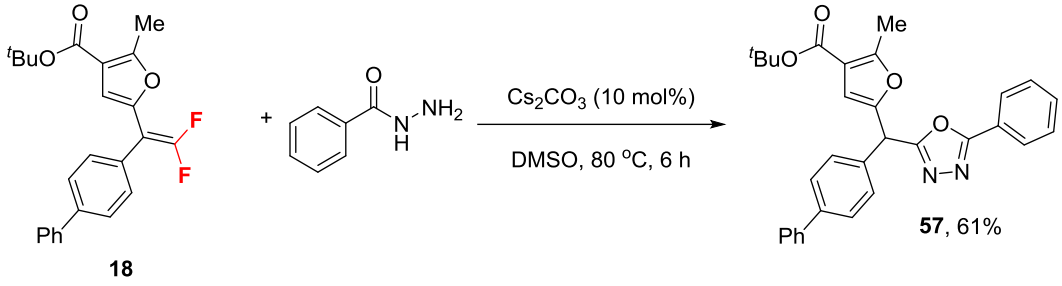
***tert*-butyl 5-(1-(4-((((3*S*,8*S*,9*S*,10*R*,13*R*,14*S*, 17*R*)-10,13-dimethyl-17-((*R*)-6-methylheptan-2-yl)-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1H-cyclopenta[a] phenanthren-3-yl)oxy)methyl)phenyl) -2,2-difluorovinyl)-2-methylfuran-3-carboxylate(55)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (132.3 mg, 69%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.38 (d, *J* = 8.1 Hz, 2H), 7.29 (d, *J* = 8.2 Hz, 2H), 6.40 (s, 1H), 5.39 – 5.34 (m, 1H), 4.58 (s, 2H), 3.32 (tt, *J* = 11.2, 4.5 Hz, 1H), 2.53 (s, 3H), 2.45 (ddd, *J* = 13.2, 4.7, 2.2 Hz, 1H), 2.36 – 2.25 (m, 1H), 2.05 – 1.95 (m, 3H), 1.92 – 1.77 (m, 2H), 1.59 – 1.56 (m, 2H), 1.53 (s, 9H), 1.51 – 1.46 (m, 4H), 1.43 (q, *J* = 4.6 Hz, 2H), 1.40 – 1.21 (m, 6H), 1.17 – 1.05 (m, 7H), 1.02 (s, 3H), 0.92 (d, *J* = 6.5 Hz, 3H), 0.87 (d, *J* = 1.8 Hz, 3H), 0.86 (d, *J* = 1.8 Hz, 3H), 0.68 (s, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.0 (d, *J* = 21.8 Hz, 1F), -90.6 (d, *J* = 21.8 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.5, 153.9 (dd, *J*

= 300.2, 292.0 Hz), 145.0(d, *J* = 10.8 Hz), 141.0, 139.4, 130.0 (t, *J* = 3.2 Hz), 129.8 (t, *J* = 2.7 Hz), 127.8, 121.8, 116.5, 111.1 (t, *J* = 5.5 Hz), 89.1 (dd, *J* = 26.2, 16.7 Hz), 80.9, 79.1, 69.7, 56.9, 56.3, 50.3, 42.5, 39.9, 39.7, 39.3, 37.4, 37.1, 36.3, 35.9, 32.1, 32.1, 28.6, 28.5, 28.4, 28.2, 27.1, 24.4, 24.0, 23.0, 22.7, 21.2, 19.5, 18.9, 12.0. **HRMS-ESI** m/z : $[M+K]^+$ calcd for $C_{46}H_{64}F_2O_4K^+$ 757.4404, found 757.4396.



***tert*-butyl 5-(2,2-difluoro-1-(4-((((*R*)-2,5,7,8-tetramethyl-2-((4*R*,8*R*)-4,8,12-tri methyl tridecyl)chroman-6-yl)oxy)methyl)phenyl)vinyl)-2-methylfuran-3-carboxylate(56)** The product was purified with silica gel chromatography (petroleum ether/ethyl acetate = 100/1) as a colorless oil (158.0 mg, 69%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.40 (d, *J* = 8.2 Hz, 2H), 7.32 (d, *J* = 7.9 Hz, 2H), 6.42 (s, 1H), 4.67 – 4.55 (m, 2H), 4.46 – 4.37 (m, 1H), 3.50 (ddd, *J* = 11.0, 4.6, 1.9 Hz, 1H), 3.44 – 3.36 (m, 2H), 2.56 (s, 3H), 2.04 – 1.94 (m, 2H), 1.89 (t, *J* = 6.9 Hz, 1H), 1.84 – 1.73 (m, 4H), 1.72 – 1.65 (m, 4H), 1.62 (d, *J* = 5.1 Hz, 3H), 1.56 (s, 9H), 1.55 – 1.39 (m, 5H), 1.38 – 1.22 (m, 7H), 1.21 – 1.04 (m, 4H), 0.99 (d, *J* = 7.0 Hz, 3H), 0.97 – 0.87 (m, 3H), 0.86 (s, 3H), 0.81 (d, *J* = 6.3 Hz, 3H), 0.79 (s, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -86.1 (d, *J* = 22.1 Hz, 1F), -90.7 (d, *J* = 22.2 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.3, 158.5, 153.9 (dd, *J* = 300.1, 292.0 Hz), 145.1 – 145.0 (m), 139.5, 132.4 (d, *J* = 10.8 Hz), 129.9 (t, *J* = 3.4 Hz), 129.8 (t, *J* = 2.8 Hz), 127.8, 116.5, 111.1 (t, *J* = 5.5 Hz), 109.4, 89.1 (dd, *J* = 26.2, 16.7 Hz), 81.0, 80.9, 78.5, 69.6, 67.0, 62.4, 56.5, 54.5, 45.0, 41.8, 40.7, 40.2, 37.1, 36.1, 35.3, 35.0, 32.4, 31.9, 31.5, 30.5, 28.9, 28.9, 28.4, 21.2, 17.3, 16.6, 14.6, 14.0, 12.5. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{48}H_{69}F_2O_5^+$ 763.5108, found 763.5096.

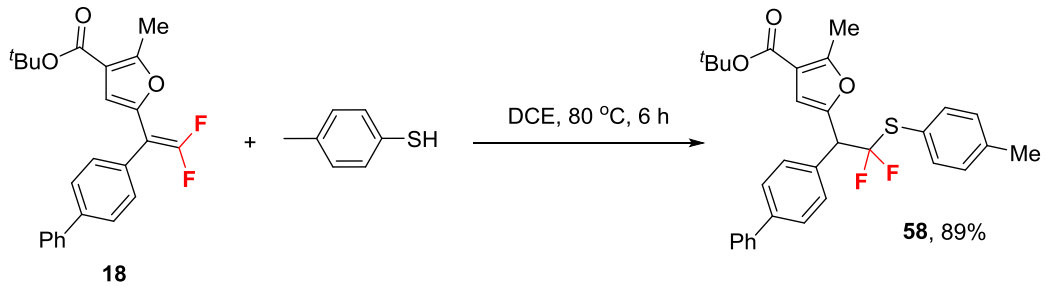
IV. Transformation of the product



***tert*-butyl 5-([1,1'-biphenyl]-4-yl(5-phenyl-1,3,4-oxadiazol -2-yl)methyl)-2-methylfuran-3-carboxylate(57)**

A 25 mL of dried round-bottom flask was charged with *gem*-difluoroalkene **18** (0.1 mmol, 1.0 equiv.), benzoyl hydrazide (0.12 mmol, 1.2 equiv.), Cs_2CO_3 (0.2 mmol, 2 equiv.), and dry DMSO (1 mL) under Ar atmosphere. The mixture was stirred at 80 °C for 6 h (monitored by TLC). After the reaction completed, the reaction mixture was quenched with H_2O (20 mL) and extracted with EtOAc (3 × 10 mL). The combined organic layer was washed with brine (3 × 10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel to afford product **57** as a colorless oil. (30.2 mg, 61% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 – 7.96 (m, 2H), 7.63 – 7.56 (m, 4H), 7.54 – 7.47 (m, 5H), 7.44 (t, *J* = 7.5 Hz, 2H), 7.38 – 7.33 (m, 1H), 6.52 (s, 1H), 5.78 (s, 1H), 2.53 (s, 3H), 1.53 (s, 9H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 165.5, 164.9, 163.3, 159.0, 148.3, 141.4, 140.5, 134.6, 132.0, 129.2, 129.0, 128.9, 127.9, 127.7, 127.3, 127.1, 123.9, 116.1, 110.2, 80.9, 42.6, 28.4, 14.0. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{31}H_{29}N_2O_4^+$ 493.2122, found 493.2132.

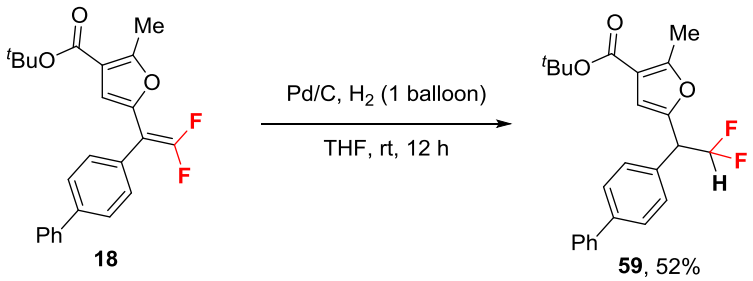


***tert*-butyl 5-(1-([1,1'-biphenyl]-4-yl)-2,2-difluoro-2-(p-tolylthio)ethyl)-2-methylfuran-3-carboxylate (58)**

To a 10 mL Schlenk tube was charged with *gem*-difluoroalkene **18** (0.1 mmol, 1.0 equiv.), 4-

methylbenzenethiol (0.12 mmol, 1.2 equiv.), and dry DCE (500 μL). The reaction mixture was placed in a preheated metal block and stirred at 80 °C for 6 h. The solvent was evaporated under reduced pressure and the residue was purified by column chromatography on silica gel to afford product **58** as a colorless oil. (48.3 mg, 89% yield).

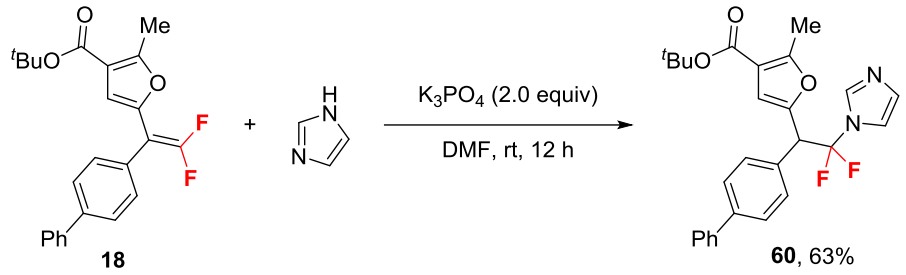
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (dd, *J* = 7.9, 4.2 Hz, 4H), 7.45 (dt, *J* = 16.0, 8.0 Hz, 6H), 7.34 (t, *J* = 7.3 Hz, 1H), 7.17 (d, *J* = 7.8 Hz, 2H), 6.66 (s, 1H), 4.66 (t, *J* = 13.7 Hz, 1H), 2.52 (s, 3H), 2.36 (s, 3H), 1.54 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.1 (dd, *J* = 13.7, 6.2 Hz, 2F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.4, 158.5, 147.6, 141.3, 140.7, 140.4, 136.6, 133.3, 130.3, 130.0, 128.9, 128.5 (t, *J* = 284.8 Hz), 127.6, 127.4, 127.3, 123.1, 116.0, 110.7, 80.8, 53.5 (t, *J* = 24.3 Hz), 28.5, 21.4, 14.0. **HRMS-ESI** m/z : $[M+K]^+$ calcd for $C_{31}H_{30}F_2O_3SK^+$ 559.1515, found 559.1523.



***tert*-butyl 5-(1-([1,1'-biphenyl]-4-yl)-2,2-difluoroethyl)-2-methylfuran-3-carboxylate (59)**

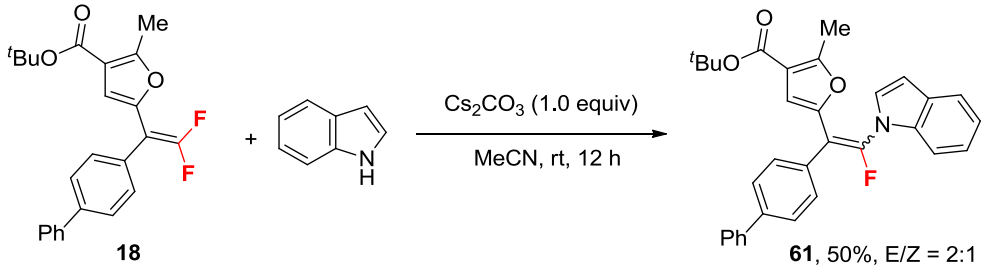
Under an atmosphere of H_2, a mixture of compound **18** (0.1 mmol, 1.0 equiv.) and Pd/C (10% Pd on carbon, 0.02 mmol, 0.2 equiv) in dry THF (2 mL) was stirred at rt overnight. The mixture was filtrated through a pad of Celite, and the filtrate was concentrated. The crude product was purified by column chromatography on silica gel to give **59** as a colorless oil (20.7 mg, 52% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 – 7.55 (m, 4H), 7.48 – 7.34 (m, 5H), 6.55 (s, 1H), 6.21 (td, *J* = 55.8, 4.3 Hz, 1H), 4.48 – 4.36 (m, 1H), 2.53 (s, 3H), 1.54 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -121.05 – -123.74 (m, 2F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.4, 158.6, 147.8 (t, *J* = 5.0 Hz), 141.3, 140.6, 133.0 (t, *J* = 2.9 Hz), 129.7, 129.0, 127.6 (d, *J* = 2.4 Hz), 127.3, 115.9, 115.5 (t, *J* = 245.8 Hz), 109.8, 80.8, 49.4 (t, *J* = 22.3 Hz), 28.5, 13.9. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{24}H_{25}F_2O_3^+$ 399.1766, found 399.1778.



***tert*-butyl 5-(1-([1,1'-biphenyl]-4-yl)-2,2-difluoro-2-(1H-imidazol-1-yl)ethyl)-2-methyl furan-3-carboxylate (60)**

A solution of imidazole (0.1 mmol, 1.0 equiv.) in DMF (0.5 mL) was added dropwise to a mixture of *gem*-difluoroalkene **18** (0.12 mmol, 1.2 equiv.) and K_3PO_4 (0.2 mmol, 2 equiv.) in DMF (0.5 mL) via syring and then stirred at room temperature for 12 h (monitored by TLC). After completion of the reaction, the mixture was quenched with H_2O (20 mL). The aqueous phase was extracted with CH_2Cl_2 (3 × 10 mL). The organic layer was dried over $MgSO_4$ and filtered, and the filtrate was concentrated in vacuo. The crude product was purified by column chromatography on silica gel to afford product **60** as a colorless oil. (29.2 mg, 63% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.66 – 7.56 (m, 6H), 7.45 (dd, J = 8.1, 6.4 Hz, 5H), 7.39 – 7.34 (m, 1H), 6.63 (s, 1H), 4.70 (q, J = 9.0 Hz, 1H), 2.53 (s, 3H), 1.55 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -71.1 (d, J = 9.1 Hz, 2F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.0, 158.6, 141.5, 140.2, 131.2, 129.6, 128.7, 127.5, 127.4, 127.0, 124.8 (t, J = 280.5 Hz), 115.8, 110.2, 80.7, 49.5 (d, J = 29.9 Hz), 28.2, 13.7. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{27}H_{27}F_2N_2O_3^+$ 465.1984, found 465.1988.

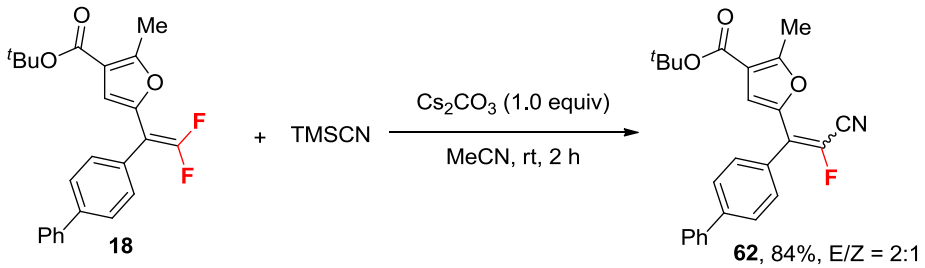


***tert*-butyl 5-(1-([1,1'-biphenyl]-4-yl)-2-fluoro-2-(1H-indol-1-yl)vinyl)-2-methylfuran-3-carboxylate (61)**

An dried 10 mL Schlenk tube was charged with Cs_2CO_3 (0.1 mmol, 1.0 equiv.), indol (0.3 mmol, 3.0 equiv.), **18** (0.1 mmol, 1.0 equiv.), and dry MeCN (1.0 mL). The reaction mixture

was stirred at room temperature for 2 h. The solvent was evaporated under reduced pressure and the residue was purified by column chromatography on silica gel to give **61** as a colorless oil (24.7 mg, 50% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 – 7.44 (m, 6H), 7.40 (d, *J* = 7.9 Hz, 3H), 7.38 (m, 1H×0.33), 7.34 – 7.29 (m, 1H×0.67), 7.24 – 7.11 (m, 3H), 7.11 (d, *J* = 3.4 Hz, 1H×0.33), 6.77 (d, *J* = 3.5 Hz, 1H×0.67), 6.71 (s, 1H×0.67), 6.66 (d, *J* = 3.5 Hz, 1H×0.33), 6.40 (d, *J* = 3.4 Hz, 1H×0.67), 6.15 (s, 1H×0.33), 2.60 (s, 2H), 2.15 (s, 1H), 1.56 (s, 6H), 1.46 (s, 3H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -88.04 (s, 1F×0.67), -90.11 (s, 1F×0.33). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.4, 158.7 (d, *J* = 2.6 Hz), 158.6 (d, *J* = 1.9 Hz), 146.9 (d, *J* = 6.8 Hz), 145.3(d, *J* = 273.3 Hz), 145.1 (d, *J* = 266.7 Hz), 140.8, 140.4, 132.4 (d, *J* = 3.4 Hz), 132.1 (d, *J* = 3.7 Hz), 130.3 (d, *J* = 3.5 Hz), 130.0 (d, *J* = 2.8 Hz), 129.0, 128.9, 128.8, 127.7, 127.6, 127.3, 127.3, 127.1, 127.1, 123.4, 121.8, 121.7, 121.1, 116.8, 112.8 (d, *J* = 7.6 Hz), 112.6 (d, *J* = 6.4 Hz), 111.8 (d, *J* = 3.1 Hz), 107.2 (d, *J* = 23.6 Hz), 106.0, 105.9 (d, *J* = 2.1 Hz), 81.0, 80.8, 28.5, 28.4, 14.2, 13.7. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{32}H_{29}FNO_3^+$ 494.2126, found 494.2119.

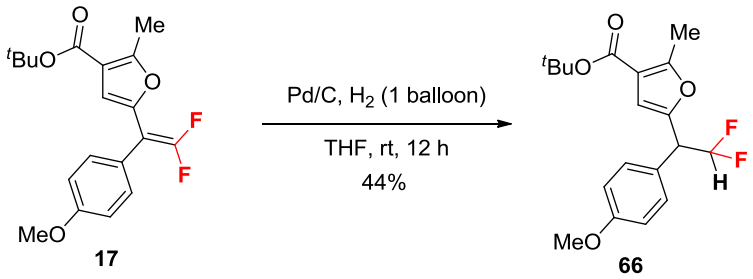


***tert*-butyl 5-(1-([1,1'-biphenyl]-4-yl)-2-cyano-2-fluorovinyl)-2-methylfuran-3-carboxylate (62)**

An dried 10 mL Schlenk tube was charged with Cs_2CO_3 (0.1 mmol, 1.0 equiv.), TMSCN (0.3 mmol, 3.0 equiv.), **18** (0.1 mmol, 1.0 equiv.), and dry MeCN (1.0 mL). The reaction mixture was stirred at room temperature for 2 h. The solvent was evaporated under reduced pressure and the residue was purified by column chromatography on silica gel to give **62** as a colorless oil (33.8 mg, 84% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (dt, *J* = 19.0, 6.4 Hz, 4H), 7.43 – 7.29 (m, 5H), 6.76 (s, 1H×0.67), 6.63 (s, 1H×0.33), 2.57 (s, 1H), 2.51 (s, 2H), 1.47 (s, 9H). **^{19}F NMR** (376 MHz,

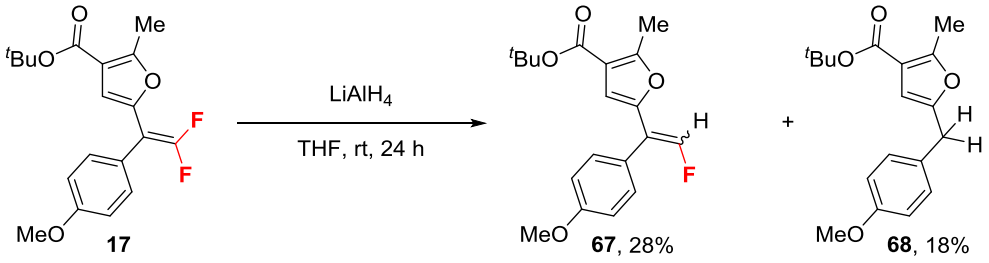
$CDCl_3$) δ -126.1 (s, 1F×0.67), -131.9 (s, 1F×0.33). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 162.5, 161.5 (d, *J* = 4.4 Hz), 145.2 (d, *J* = 7.2 Hz), 143.3, 140.1, 140.1, 130.6 (d, *J* = 2.7 Hz), 130.2 (d, *J* = 3.2 Hz), 129.1, 128.1, 128.2 (d, *J* = 248.9 Hz), 127.7, 127.5 (d, *J* = 241.0 Hz), 127.4, 127.3, 127.3, 118.7 (d, *J* = 9.9 Hz), 117.9, 113.3 (d, *J* = 45.1 Hz), 113.3 (d, *J* = 44.0 Hz), 81.6, 81.5, 28.4, 14.3, 14.3. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{25}H_{23}F_2NO_3^+$ 404.1656, found 404.1664.



***tert*-butyl 5-(2,2-difluoro-1-(4-methoxyphenyl)ethyl)-2-methylfuran-3-carboxylate (66)**

Under an atmosphere of H_2, a mixture of compound **17** (0.1 mmol, 1.0 equiv.) and Pd/C (10% Pd on carbon, 0.02 mmol, 0.2 equiv) in dry THF (2 mL) was stirred at rt overnight. The mixture was filtrated through a pad of Celite, and the filtrate was concentrated. The crude product was purified by column chromatography on silica gel to give **66** as colorless oil (15.4 mg, 44% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (d, *J* = 8.7 Hz, 2H), 6.89 (d, *J* = 8.8 Hz, 2H), 6.48 (s, 1H), 6.13 (td, *J* = 56.0, 4.3 Hz, 1H), 4.36 – 4.26 (m, 1H), 3.80 (s, 3H), 2.51 (s, 3H), 1.54 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -121.5 – -123.9 (m, 2F). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 163.4, 159.5, 158.5, 148.2 (t, *J* = 4.9 Hz), 130.4, 126.0 (t, *J* = 3.0 Hz), 115.8, 115.6 (t, *J* = 245.5 Hz), 114.3, 109.5, 80.8, 55.4, 48.9 (t, *J* = 22.1 Hz), 28.4, 13.9. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{19}H_{23}F_2O_4^+$ 353.1559, found 353.1444.



A 25 mL of dried round-bottom flask was charged with *gem*-difluoroalkene **17** (0.1 mmol, 1.0 equiv.), $LiAlH_4$ (0.1 mmol, 1.0 equiv.) and dry THF (1 mL) under Ar atmosphere. The mixture was stirred at room temperature for 24 h. After the reaction completed, the reaction mixture was quenched with H_2O (20 mL) and extracted with EtOAc (3 × 10 mL). The combined organic layer was washed with brine (3 × 10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel to afford products **67** as a yellow oil (9.3 mg, 28% yield) and **68** as a colorless oil (5.4 mg, 18% yield).

***tert*-butyl (*E*)-5-(2-fluoro-1-(4-methoxyphenyl)vinyl)-2-methylfuran-3-carboxylate (67)**

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 – 7.23 (m, 2H), 6.91 (d, *J* = 8.8 Hz, 2H), 6.69 (d, *J* = 81.2 Hz, 1H), 6.63 (s, 1H), 3.84 (s, 3H), 2.55 (s, 3H), 1.54 (s, 9H). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -126.1 (d, *J* = 80.5 Hz, 1F). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.5, 159.9, 158.4 (d, *J* = 3.2 Hz), 146.6 (d, *J* = 1.7 Hz), 144.4, 130.5 (d, *J* = 2.8 Hz), 125.6 (d, *J* = 8.2 Hz), 125.6 (d, *J* = 369.5 Hz), 116.5, 114.1, 112.3 (d, *J* = 8.5 Hz), 80.8, 55.5, 28.5, 14.1. **HRMS-ESI** m/z : $[M+H]^+$ calcd for $C_{19}H_{22}FO_4^+$ 333.1497, found 333.1517.

***tert*-butyl 5-(4-methoxybenzyl)-2-methylfuran-3-carboxylate (68)**

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.14 (d, *J* = 8.6 Hz, 2H), 6.84 (d, *J* = 8.6 Hz, 2H), 6.17 (s, 1H), 3.82 (s, 2H), 3.79 (s, 3H), 2.49 (s, 3H), 1.52 (s, 9H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 163.8, 158.5, 157.6, 152.7, 129.9, 129.8, 115.6, 114.1, 107.2, 80.4, 55.4, 33.5, 28.5, 13.9. **HRMS-ESI** m/z : $[M+Na]^+$ calcd for $C_{18}H_{22}NaO_4^+$ 325.1410, found 325.1393.

V. Cell viability assay

The *in vitro* cytotoxicity of synthesized compound was determined using a CCK-8 cell viability kit assay. Hela, 4T1 and HepG2 were used to test the cytotoxicity of the compounds. Cells were plated at a density of 3-15 $\times 10^3$ cells/well into 96-well plates and cultured in DMEM media supplemented with 10% fetal bovine serum. The cells were allowed to attach to the wells for 24 h at 37 ^oC, 5% CO_2. Then the cells were incubated with different concentrations of the compounds (100 μL) for 48 h. After that, each well was added 100 μL of 10% CKK-8 reagent. After incubation for another 1 h at 37 ℃, the absorbance at 450 nm was determined using a microplate reader (MULTISKAN FC). The results presented are the average of three independent experiments.

Table S5. Cell viability percentage of compounds **2**, **6-60** against HeLa cell line at 100 μM

Compound	cell viability (%)	Compound	cell viability (%)
2	97.20±0.67	**33**	65.08±0.24
6	89.51±3.21	**34**	92.34±0.63
7	88.63±2.22	**35**	53.65±0.63
8	82.69±2.52	**36**	89.11±1.65
9	88.12±1.30	**37**	78.31±1.02
10	95.62±1.47	**38**	**15.20±0.48**
11	**22.86±0.75**	**39**	34.72±6.75
12	33.20±1.44	**40**	90.68±2.98
13	79.49±1.07	**41**	**7.20±0.44**
14	84.24±1.00	**42**	**19.52±1.82**
15	86.35±3.88	**43**	76.38±4.35
16	89.13±1.20	**44**	**10.46±2.14**
17	**7.43±0.12**	**45**	25.61±1.50
18	53.22±0.86	**46**	83.72±1.24
19	68.83±1.25	**47**	98.68±4.63
20	78.13±0.50	**48**	74.59±1.25
21	72.81±0.98	**49**	97.61±3.75
22	87.50±0.53	**50**	77.56±1.06

23	86.24±1.19	**51**	57.32±2.13
24	78.31±2.33	**52**	67.23±1.23
25	85.57±4.23	**53**	71.93±1.38
26	61.59±0.63	**54**	67.20±2.57
27	94.31±1.30	**55**	81.19±3.82
28	95.67±5.34	**56**	95.71±0.06
29	92.10±1.73	**57**	85.76±1.08
30	73.31±1.96	**58**	94.90±0.78
31	56.13±1.92	**59**	87.29±2.09
32	86.35±3.88	**60**	62.11±0.91

Cells were incubated with compounds for 48 h, and cell viability was measured by the CCK-8 assay. All the data was the average of three replications

VI. Cellular ROS assay

A fluorescent probe, DCFH-DA was used to measure the intracellular generation of ROS by **5-FU**, **17** and **41**. Briefly, the cells were seeded in 12-well plates and allowed to stabilize for 24 h and then incubated with medium containing compound **5-FU**, **17** or **41** (25 μM) for 24 h at 37 ℃. After washing with PBS, the cells were stained with 0.1 μM DCFH-DA in PBS for 15 min at 37 ℃ in the dark. The fluorescence signals of DCF were measured using a fluorescence microscope (OLYMPUS IX73).

VII. References

(1) González, J.; González, J.; Pérez-Calleja, C.; López, L. A.; Vicente, R. Zinc-Catalyzed Synthesis of Functionalized Furans and Triarylmethanes from Enynones and Alcohols or Azoles: Dual X─H Bond Activation by Zinc. *Angew. Chem. Int. Ed.* **2013**, *52*, 5853-5857.

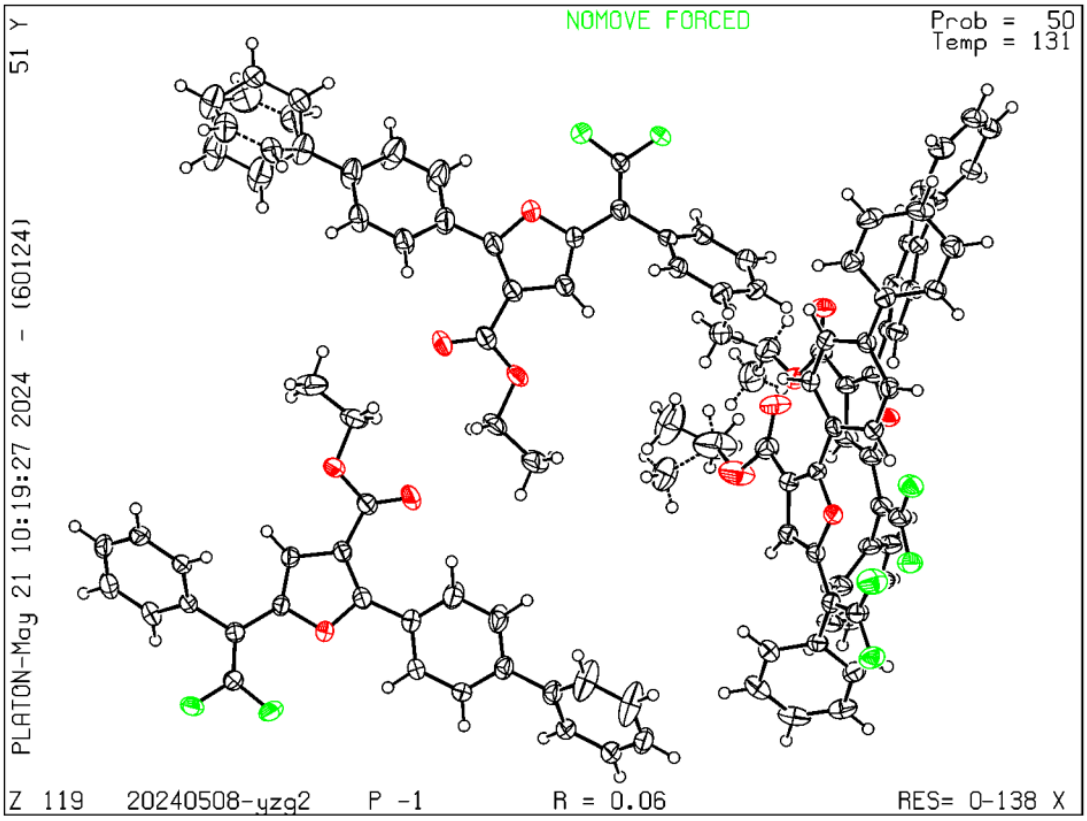
(2) Ma, J.; Jiang, H.; Zhu, S. NHC–AuCl/Selectfluor: A Highly Efficient Catalytic System for Carbene-Transfer Reactions. *Org. Lett.* **2014**, *16*, 4472–4475.

(3) Yu, Y.; Yi, S.; Zhu, C.; Hu, W.; Gao, B.; Chen, Y.; Wu, W.; Jiang, H. Csp^3─P versus Csp^2─P Bond Formation: Catalyst-Controlled Highly Regioselective Tandem Reaction of Ene-Yne-Ketones with *H*-Phosphonates. *Org. Lett.* **2016**, *18*, 400–403.

(4) Wu, W.; Chen, Y.; Li, M.; Hu, W.; Lin, X. Access to Polysubstituted (Furyl)methylthioethers via a Base-Promoted S─H Insertion Reaction of Conjugated Enynones. *J. Org. Chem.* **2019**, *84*, 14529–14539.

VIII. X-ray crystallographic data

X-ray sample was crystaled from liquid-liquid diffusion in ethyl acetate and petroleum ether (1:10) as the anti-solvent at 25 °C and acquired using CuKα (λ = 1.54184 Å) radiation.

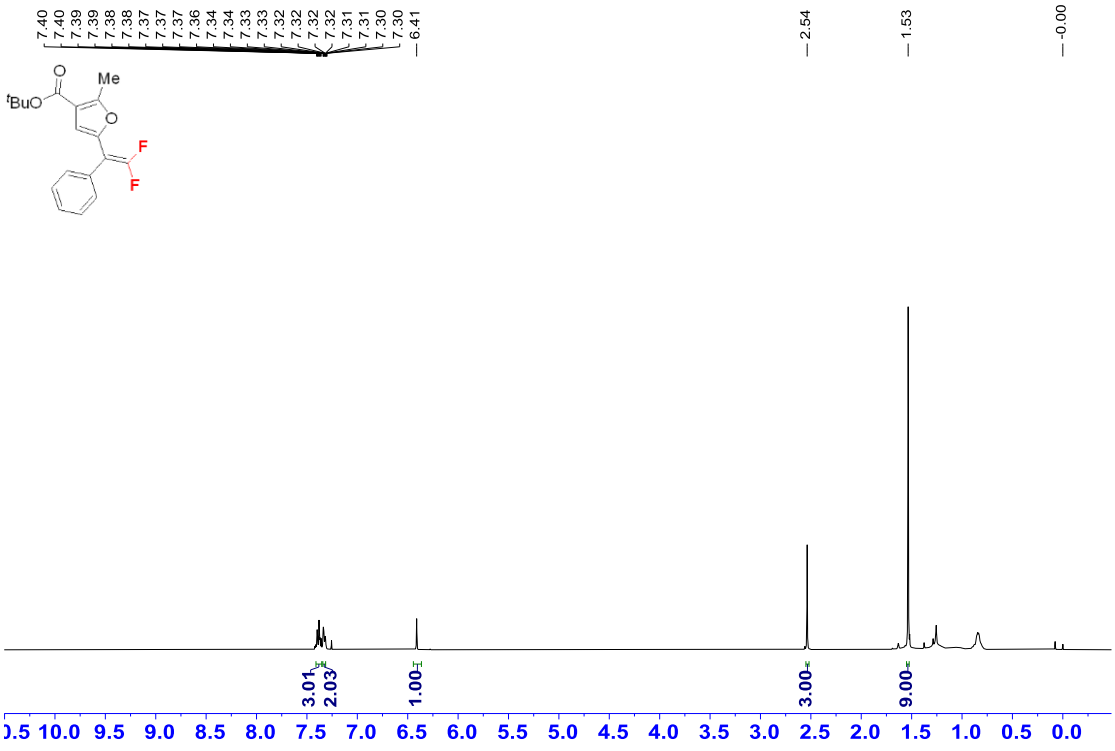


Crystal Data for $C_{27}H_{20}F_2O_3$ (*M* = 430.43 g/mol): Crystal size = 0.1 × 0.05 × 0.04 nm^3, Bond precision: C-C = 0.0044 Å, Wavelength = 1.54184, a=9.86943(17) Å, b=17.5275(3) Å, c=26.1199(5) Å, α = 95.7908(14)°, β = 99.8803(15)°, γ =106.3386(16)°, Temperature = 141(19) K, Volume = 4218.11(13) $Å^3$, Space group P-1, Hall group -P1, Moiety formula $C_{27}H_{20}F_2O_3$, Sum formula $C_{27}H_{20}F_2O_3$, Mr = 430.43 g/mol, D_{calc} = 1.356 g/cm3 , Z = 8, μ(MuKα) = 0.825 mm^{-1} , F000 = 1792.0, (h,k,lmax) = (11,20,31), Nref = 14903, Tmin = 0.827, Tmax = 1.000, Data completeness = 0.980, Theta(max) = 66.599, R(reflections) = 0.0645(10576), wR_2(reflections) = 0.2588(14603), S = 1.128, Npar = 1203.

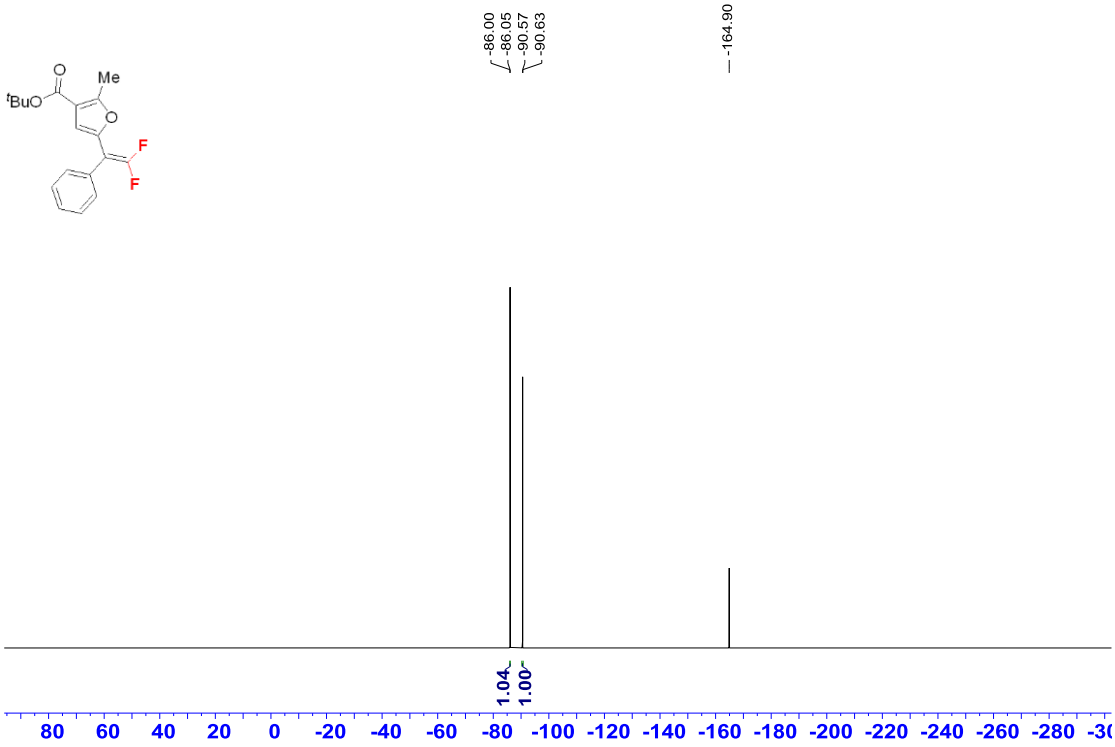
The crystal structure is deposited in the Cambridge Crystallographic Data Centre (CCDC Code: 2356931).

IX. Copies of the NMR spectra

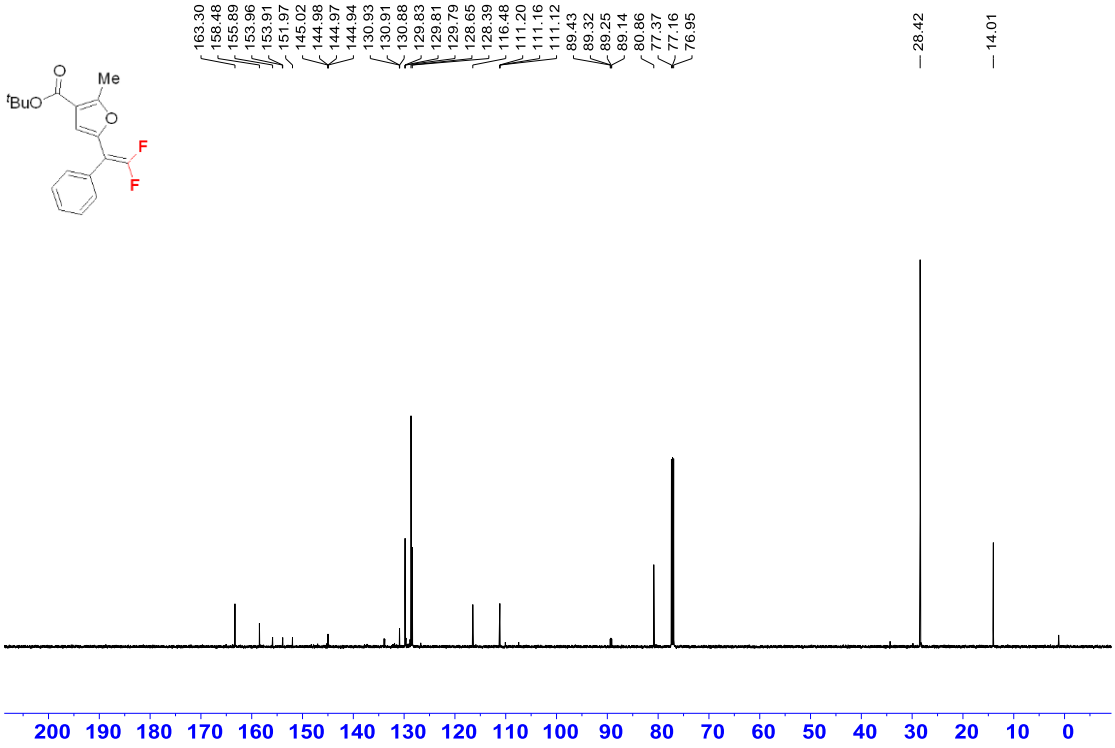
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **2**.



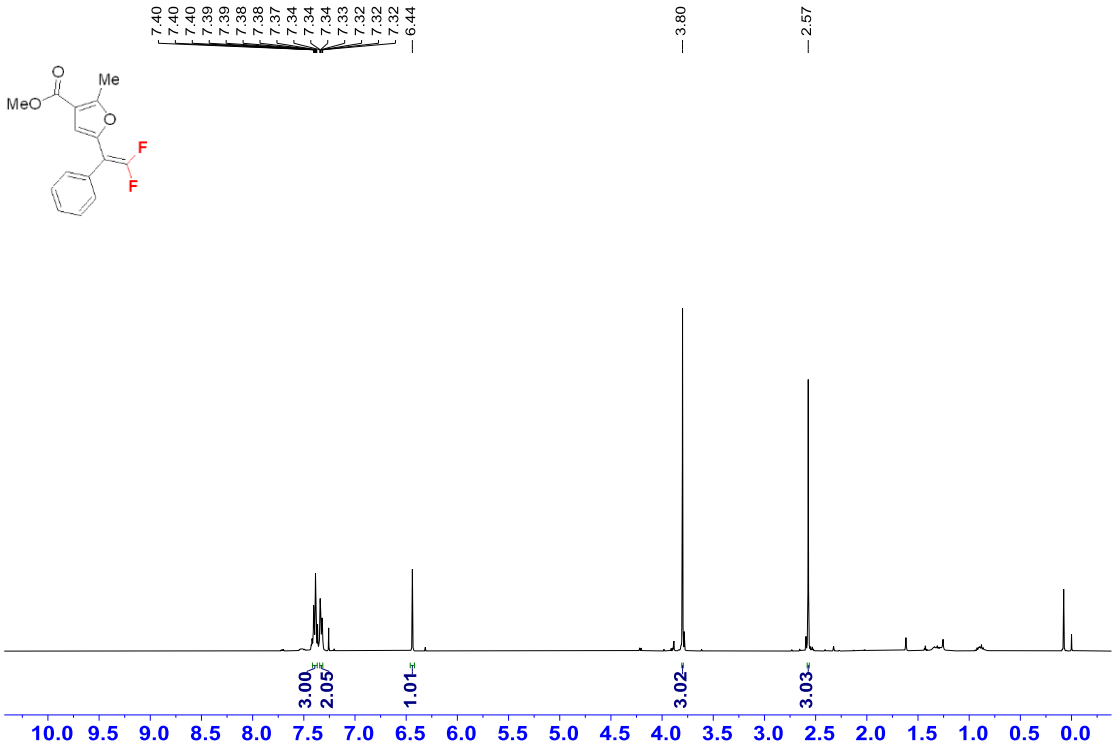
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **2**.



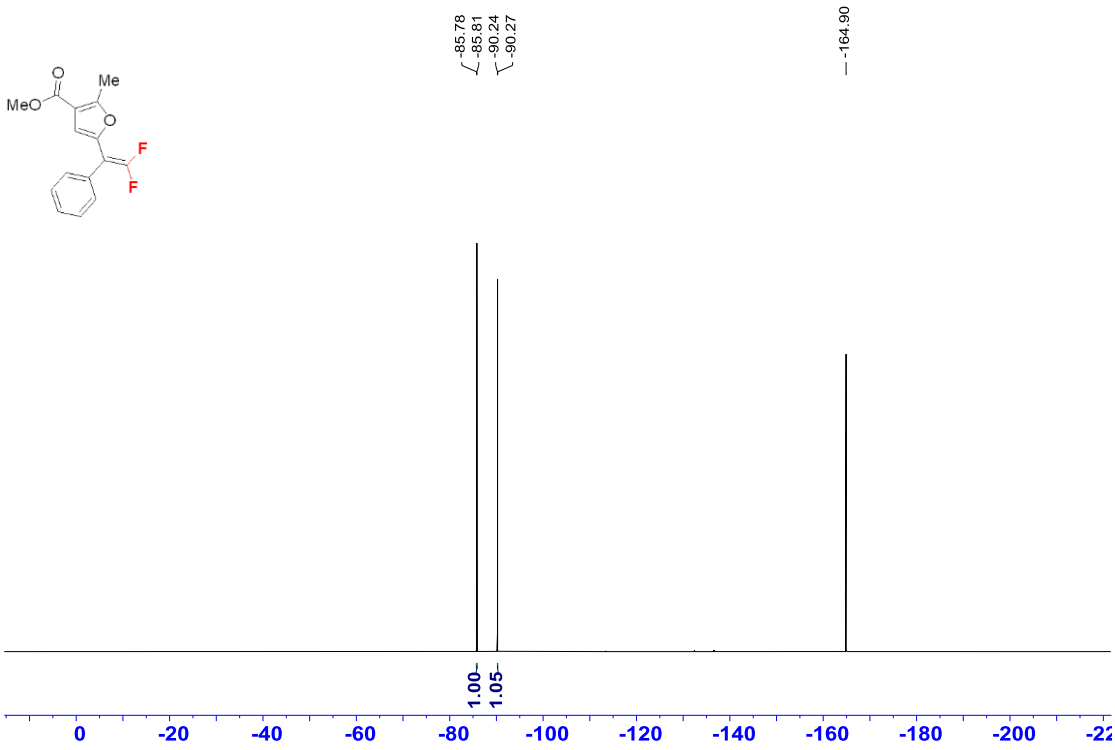
^{13}C NMR (151 MHz, $CDCl_3$) spectrum of compound **2**.



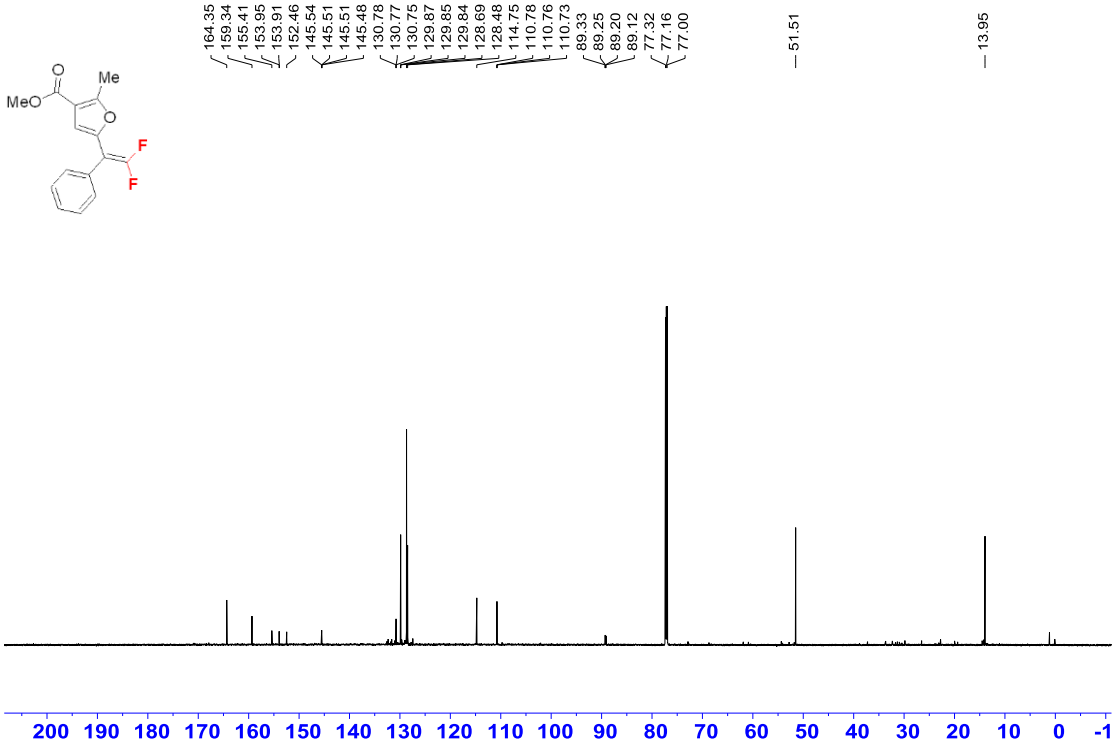
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **6**.



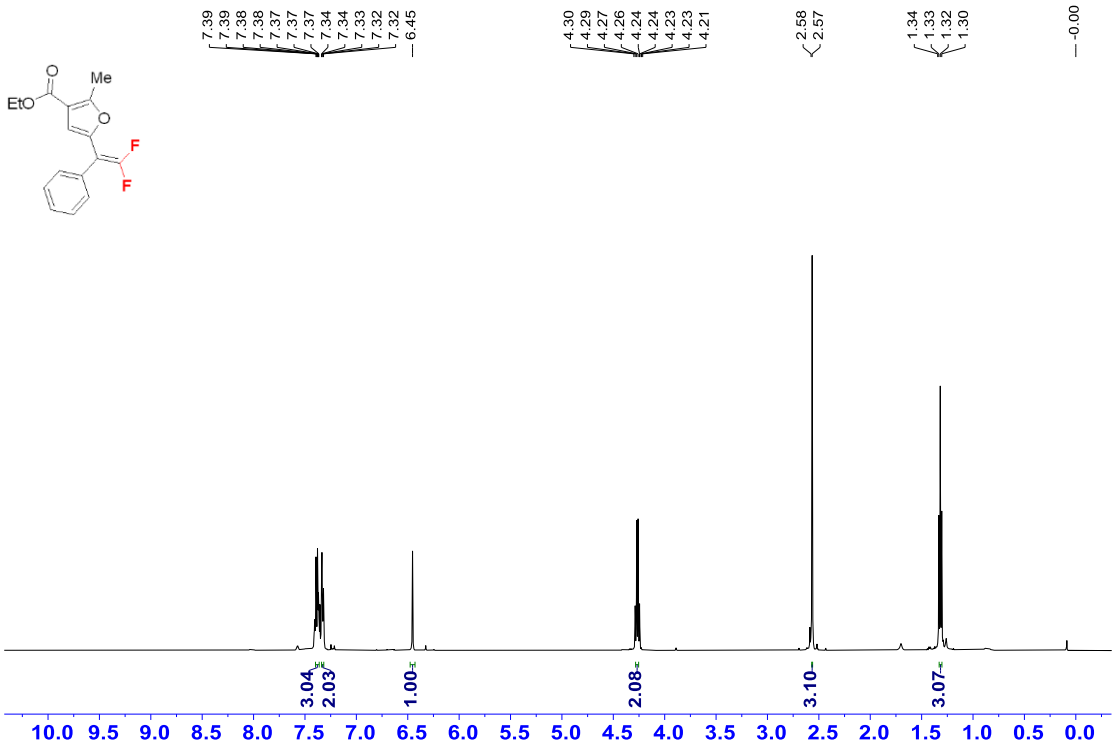
^{19}F NMR (753 MHz, $CDCl_3$) spectrum of compound **6**.



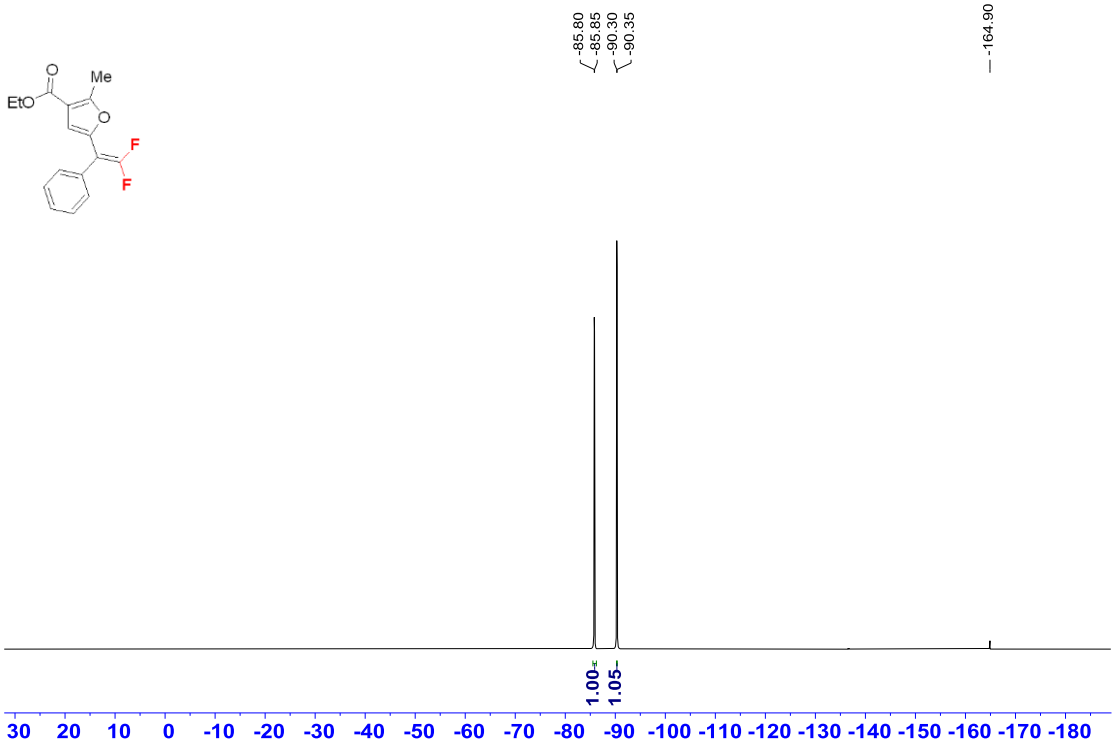
^{13}C NMR (201 MHz, $CDCl_3$) spectrum of compound **6**.



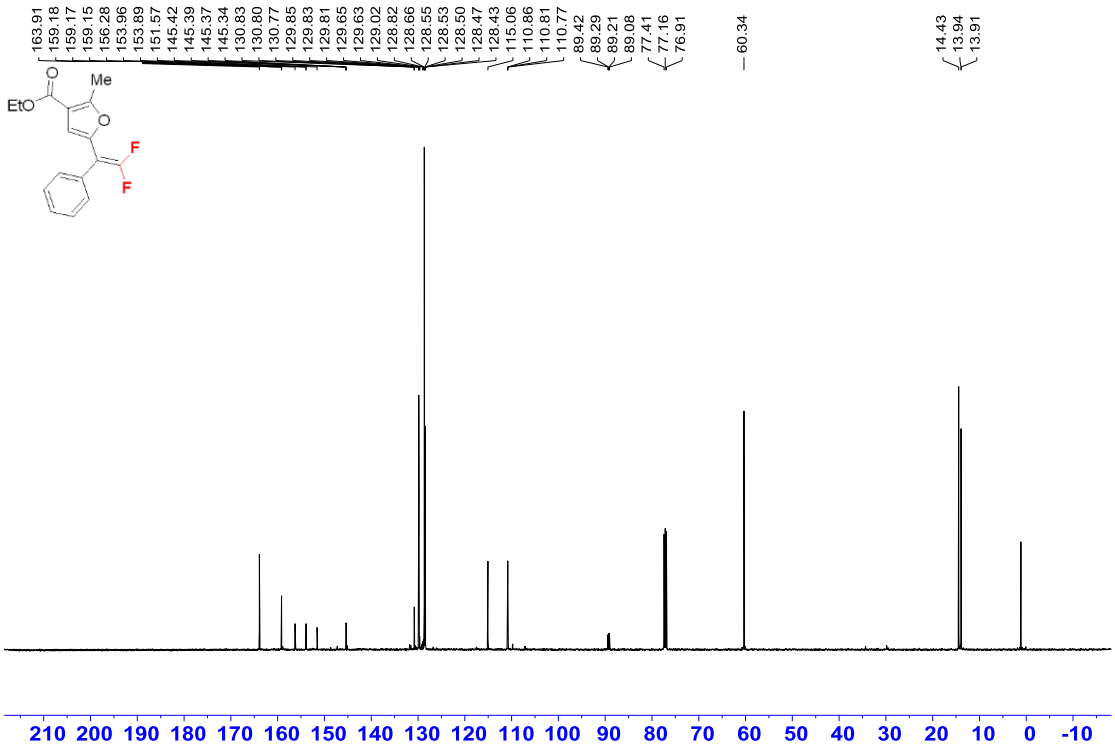
^{1}H NMR (500 MHz, $CDCl_3$) spectrum of compound **7**.



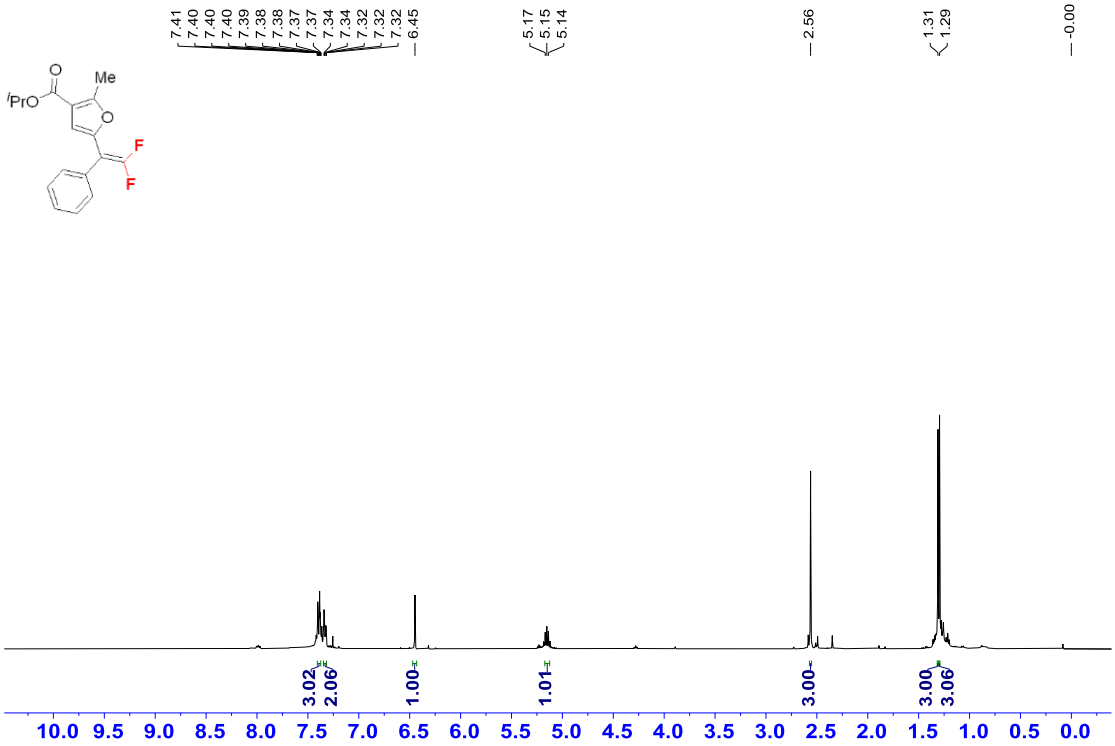
^{19}F NMR (471 MHz, $CDCl_3$) spectrum of compound **7**.



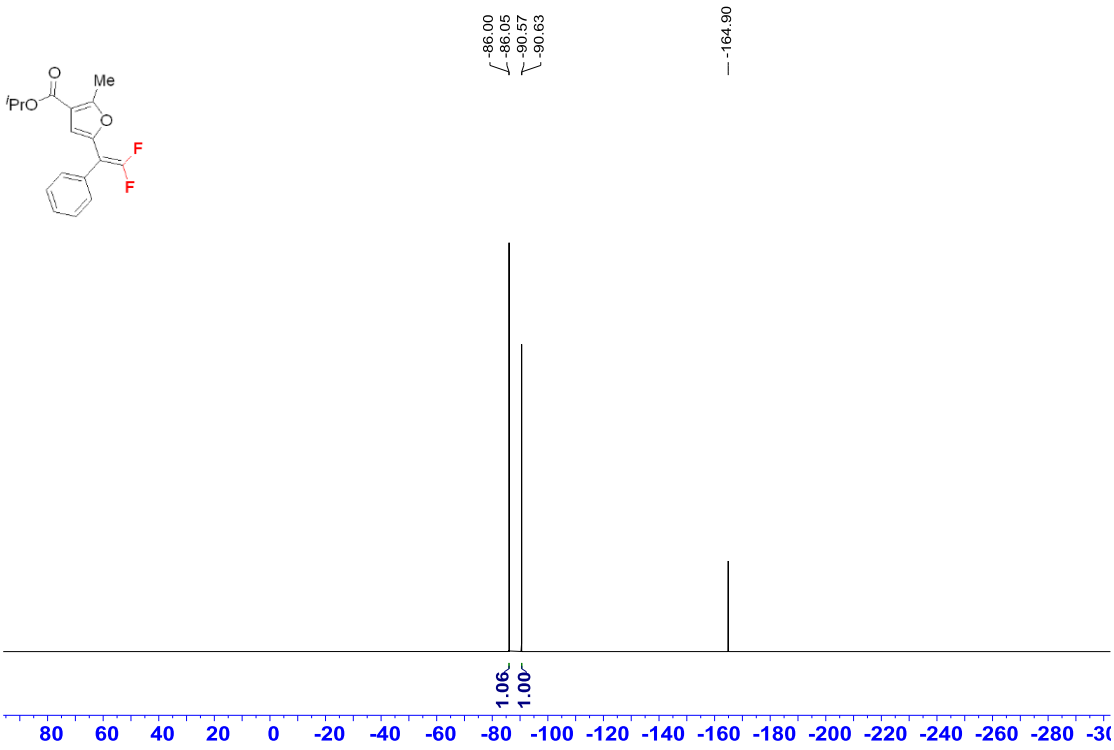
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **7**.



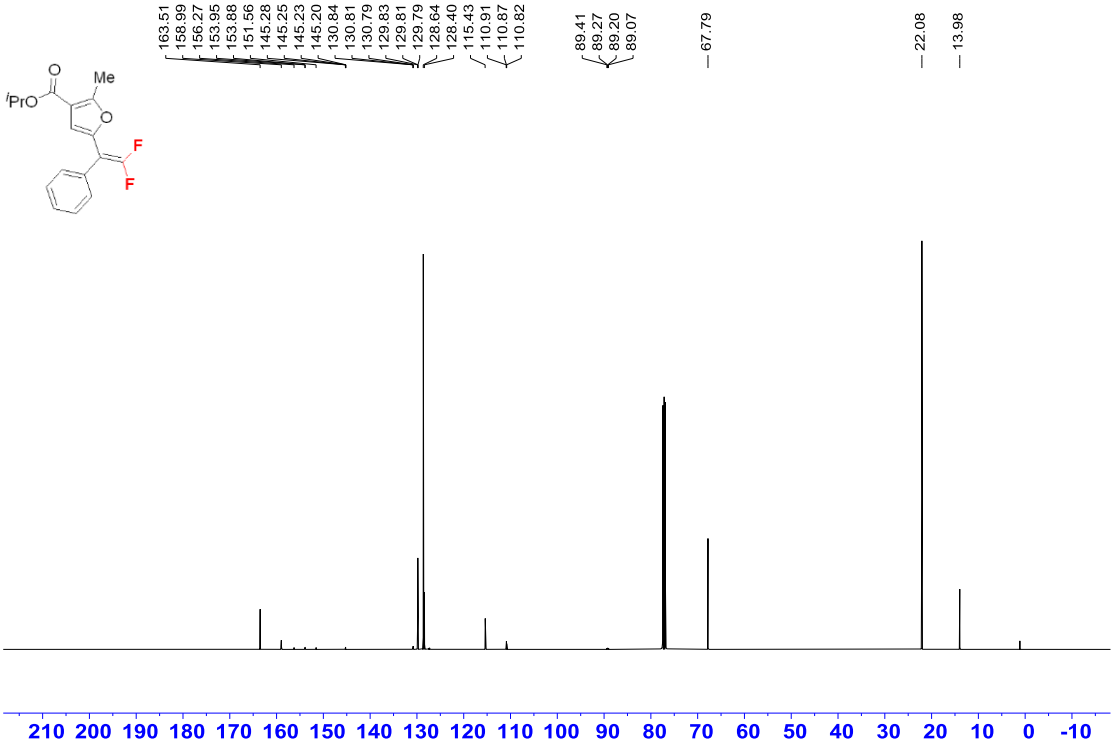
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **8**.



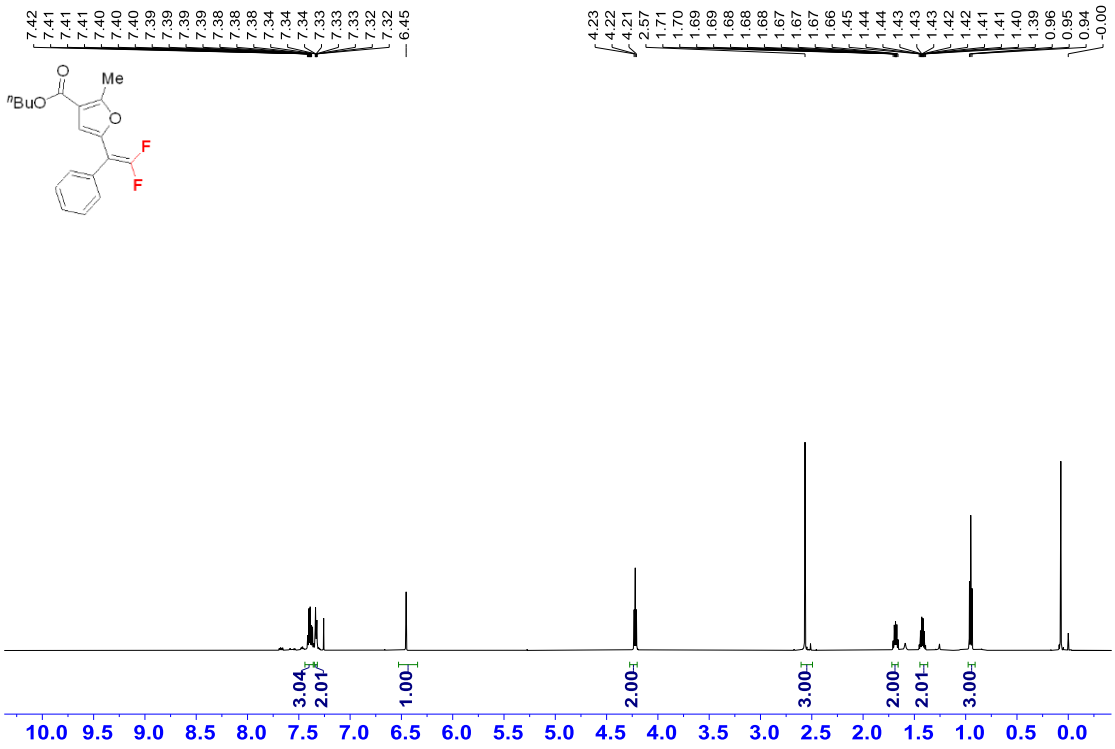
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **8**.



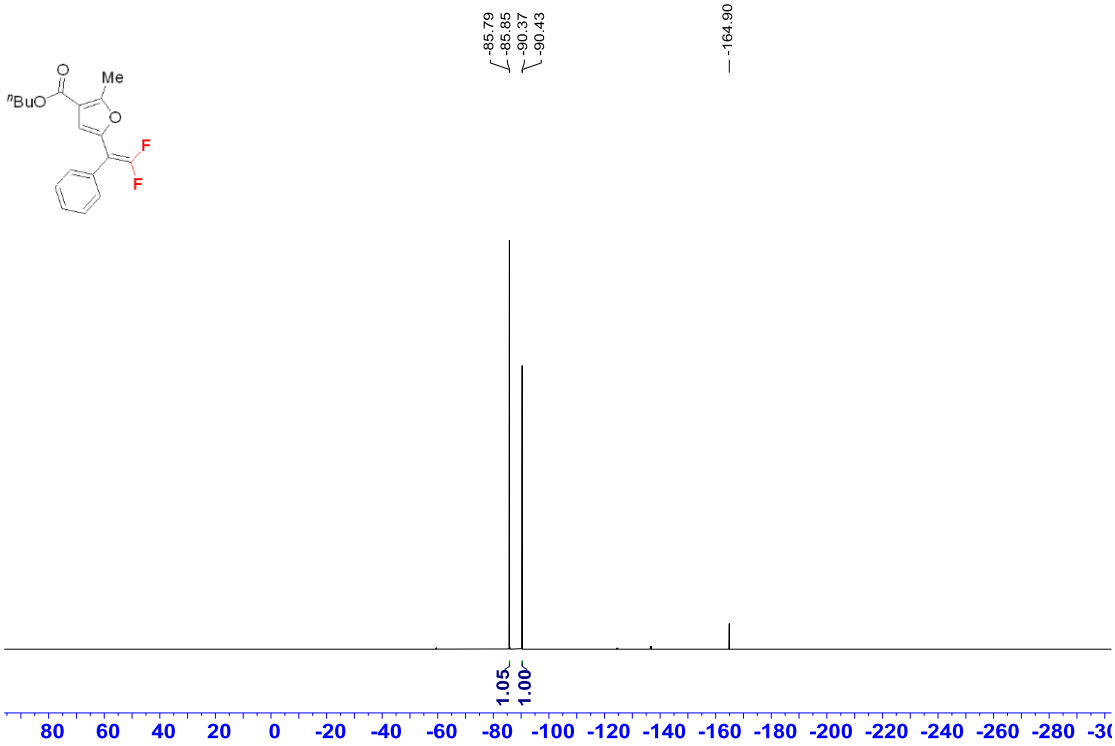
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **8**.



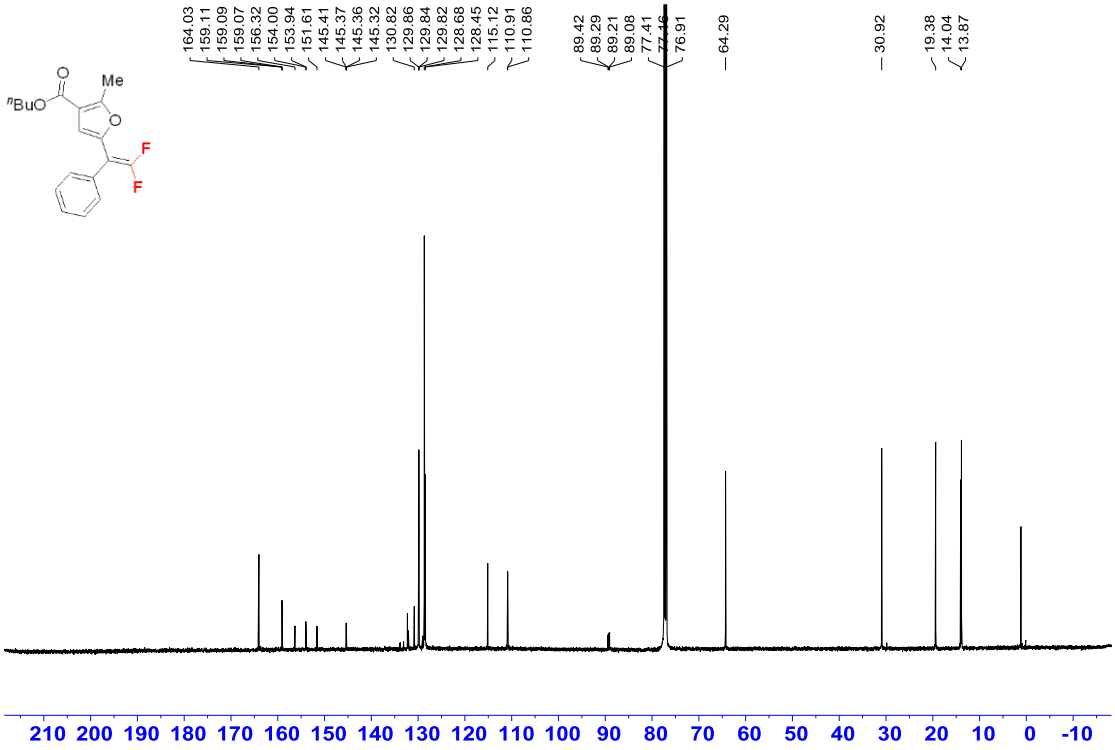
^{1}H NMR (600 MHz, $CDCl_3$) spectrum of compound **9**.



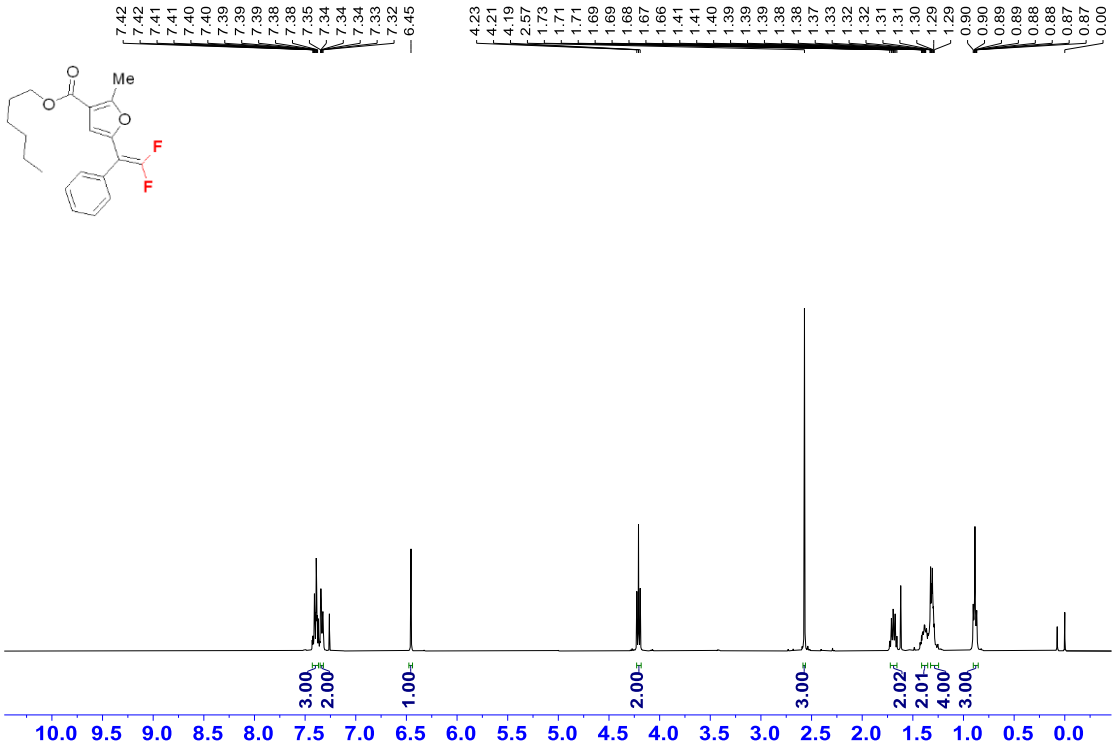
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **9**.



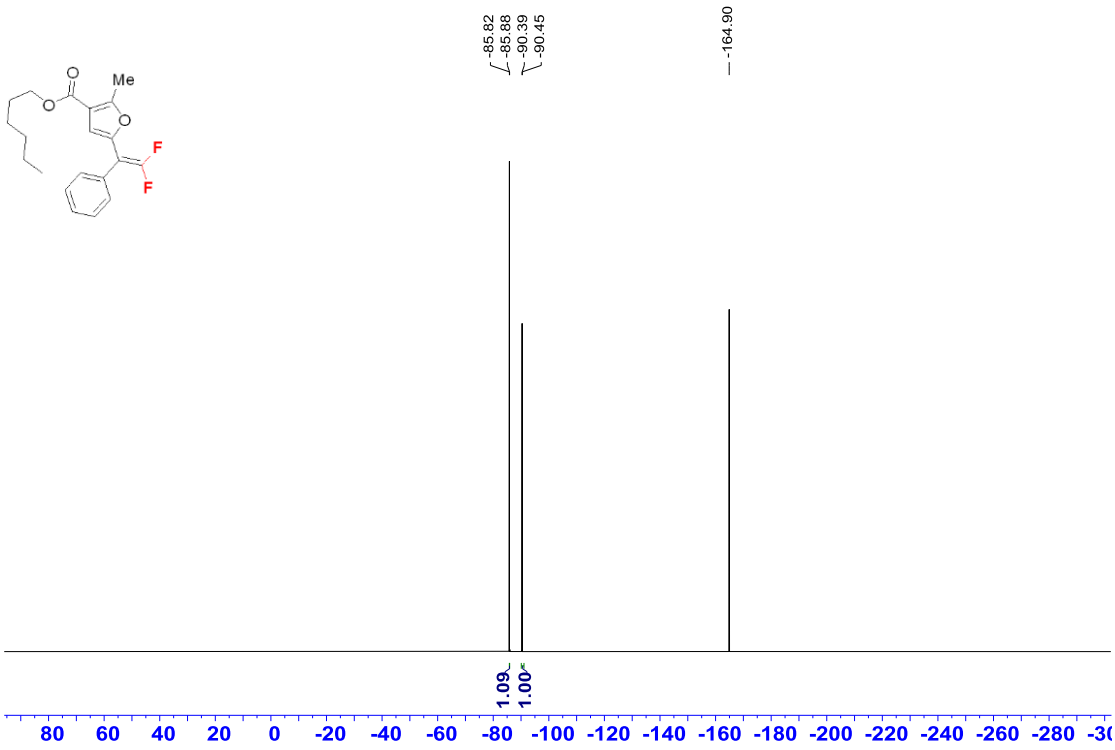
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **9.**



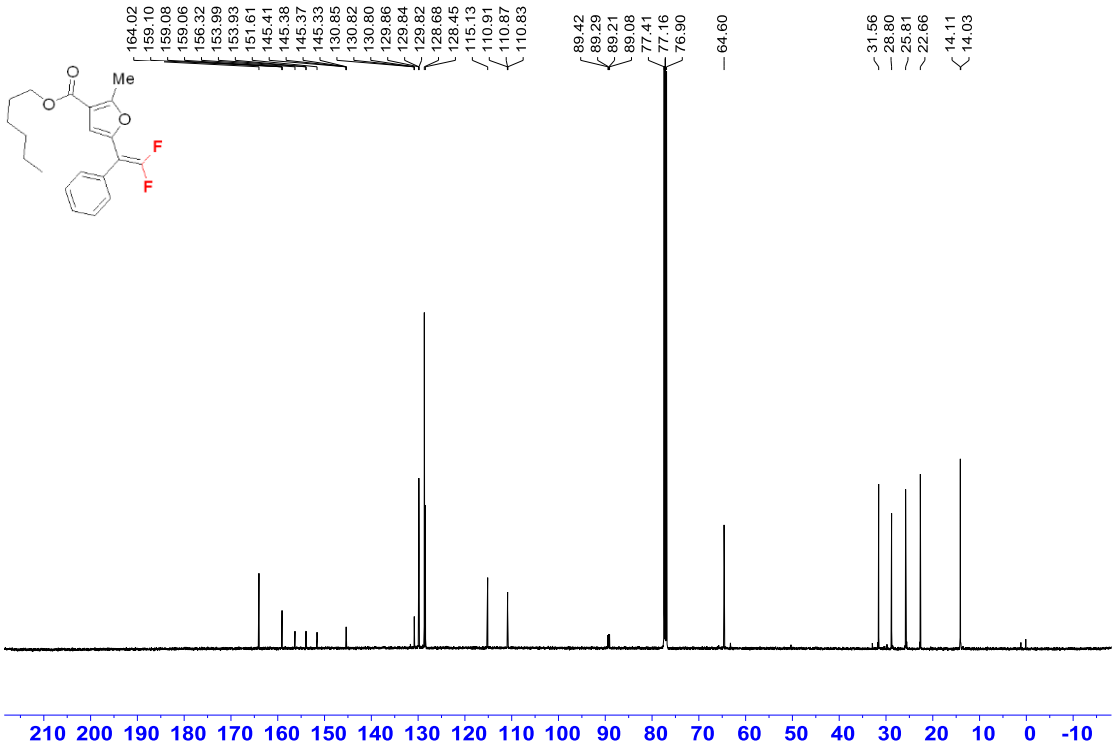
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **10.**



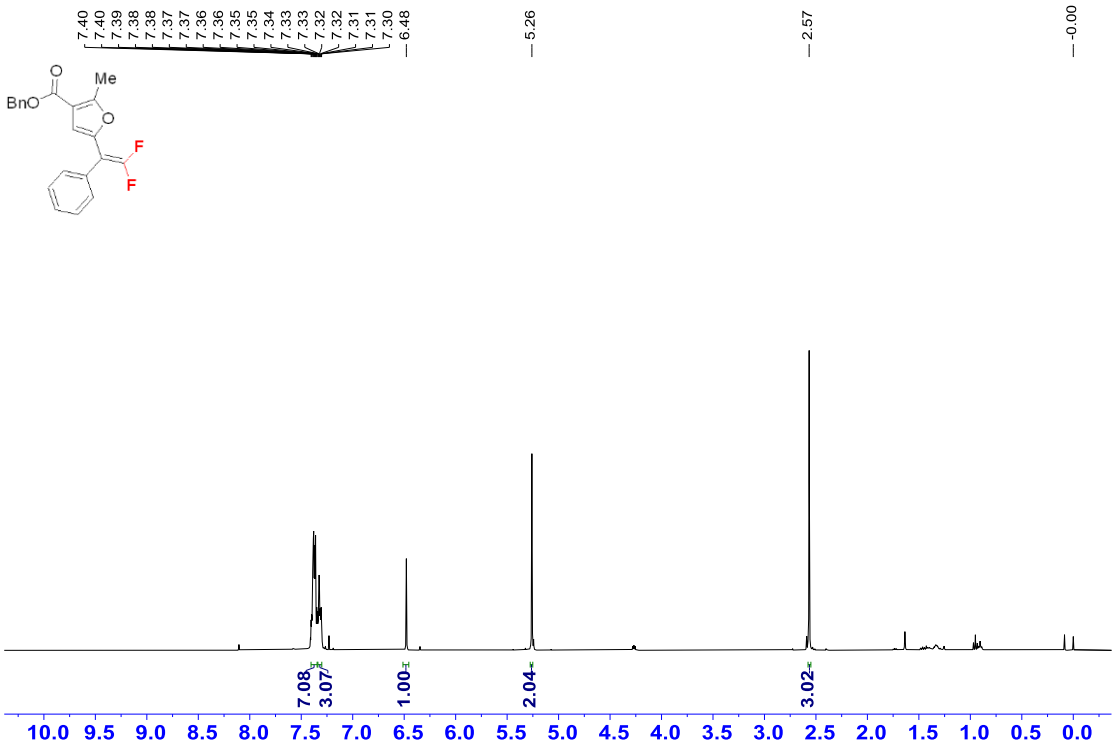
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **10**.



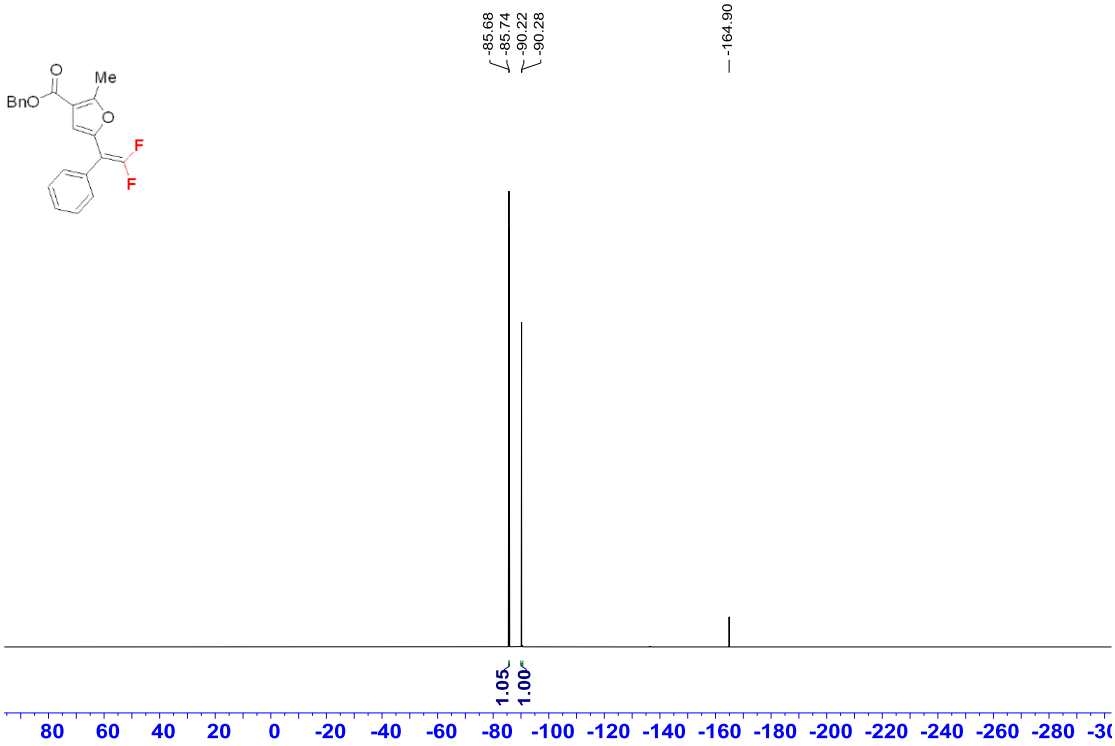
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **10.**



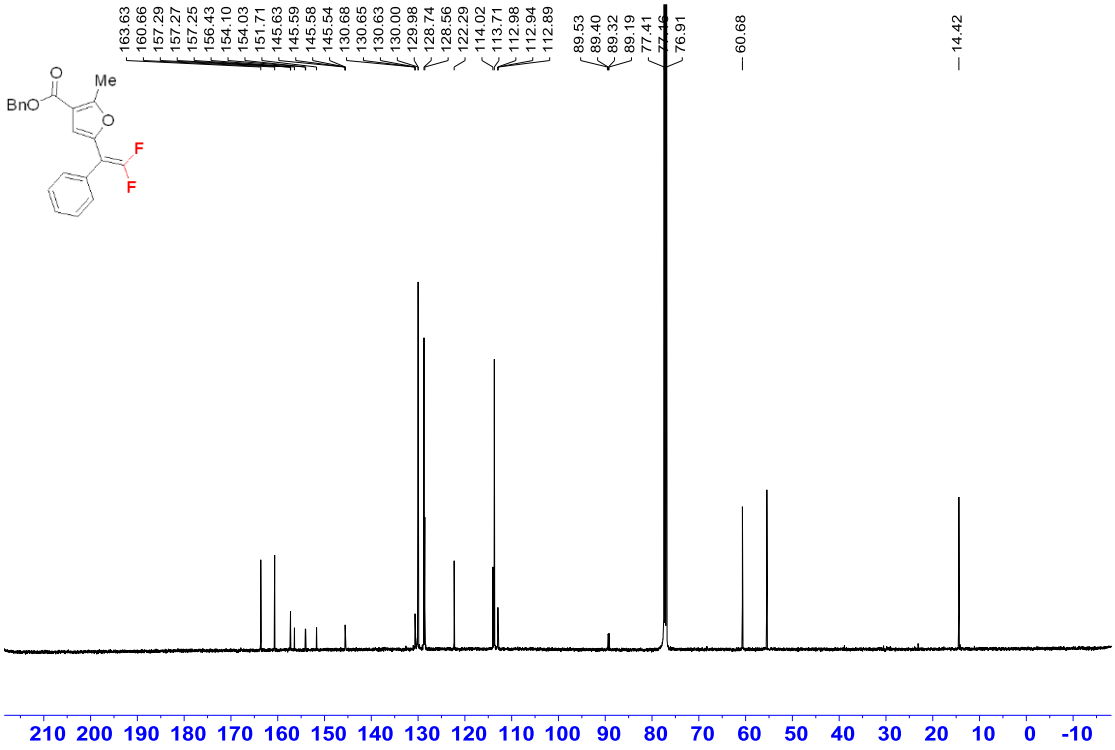
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **11.**



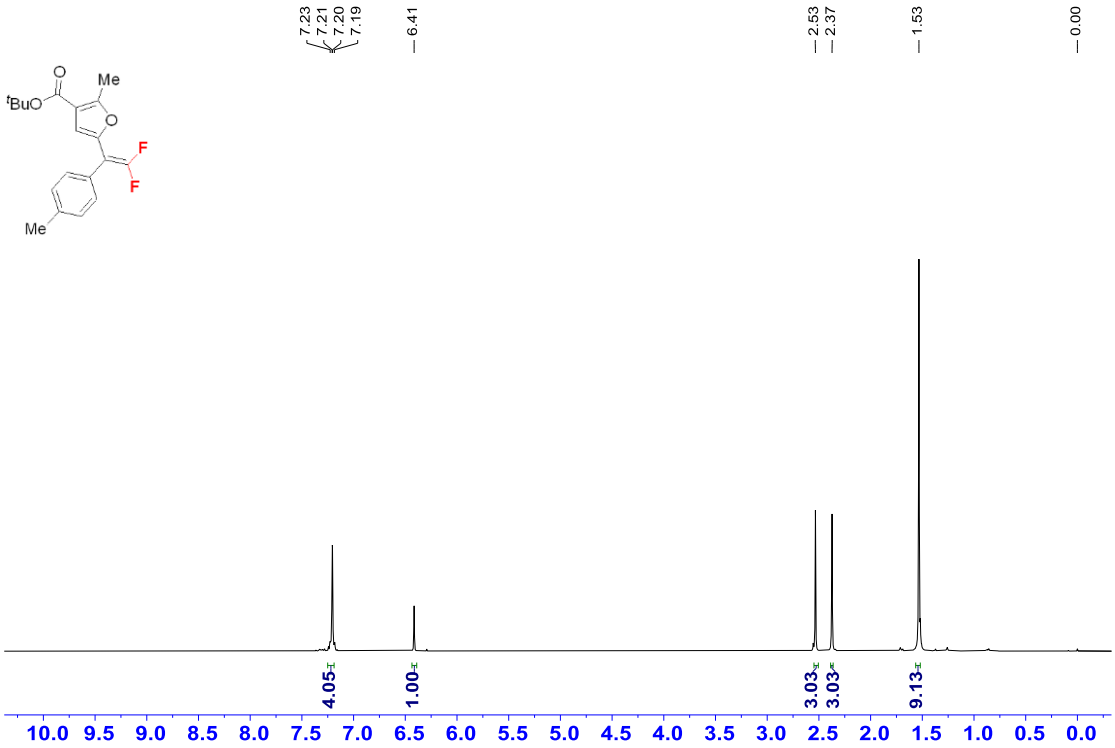
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **11.**



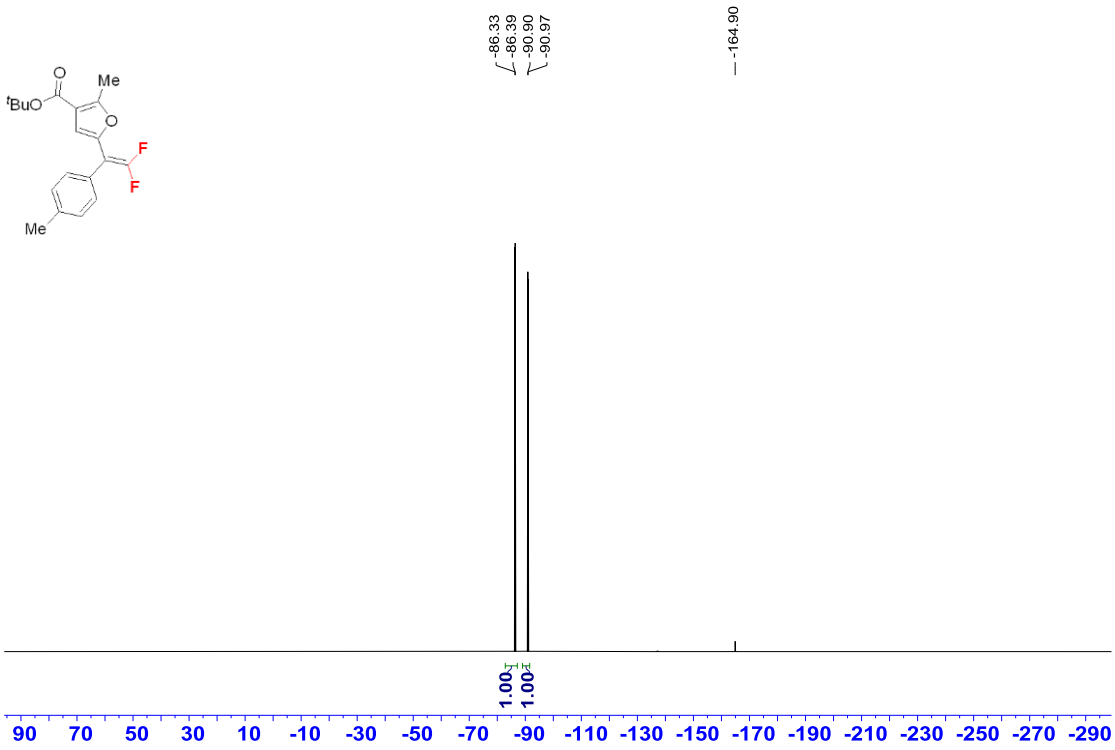
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **11.**



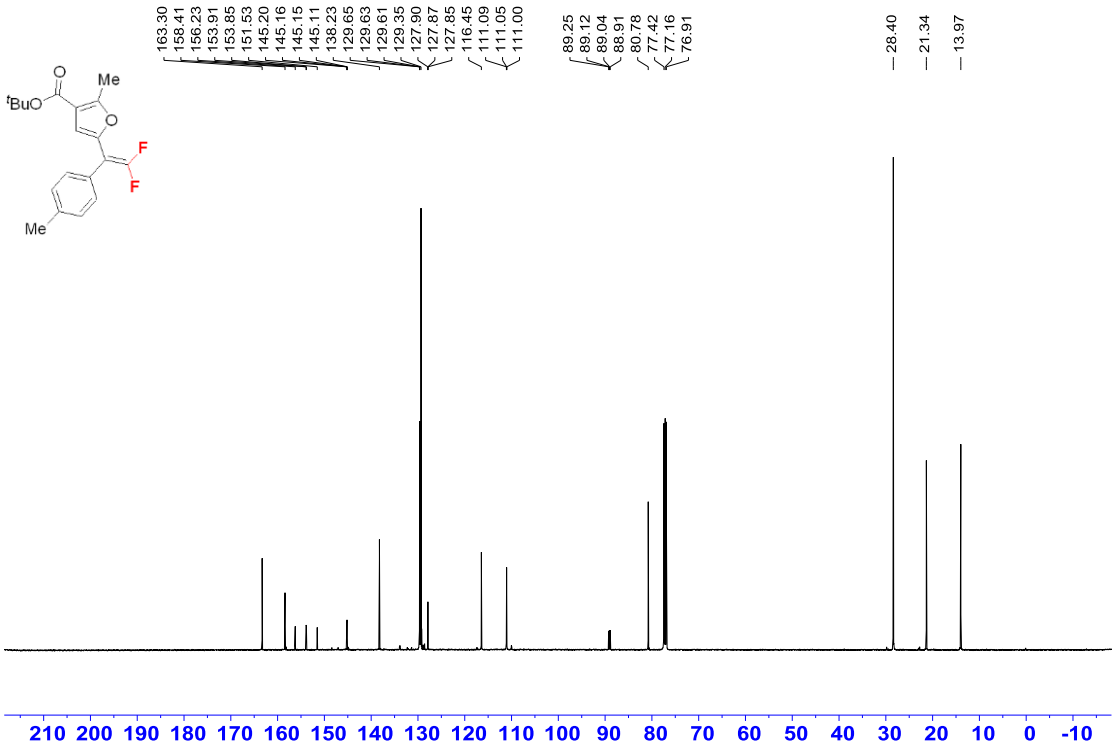
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **12.**



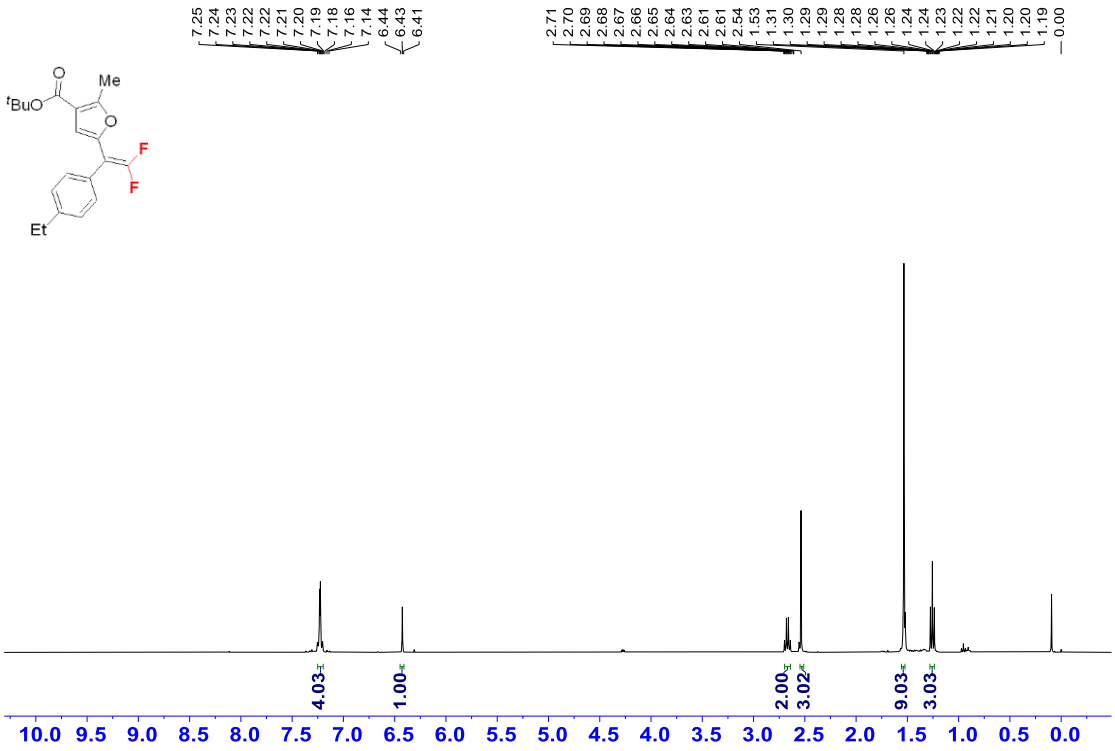
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **12.**



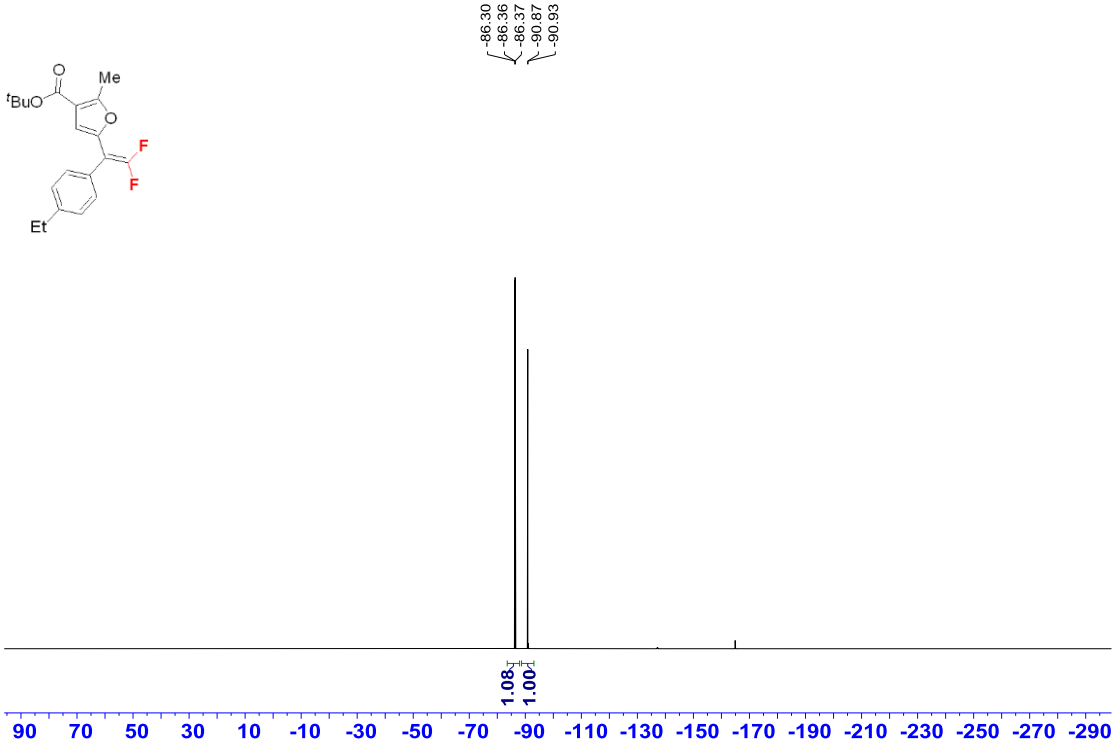
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **12.**



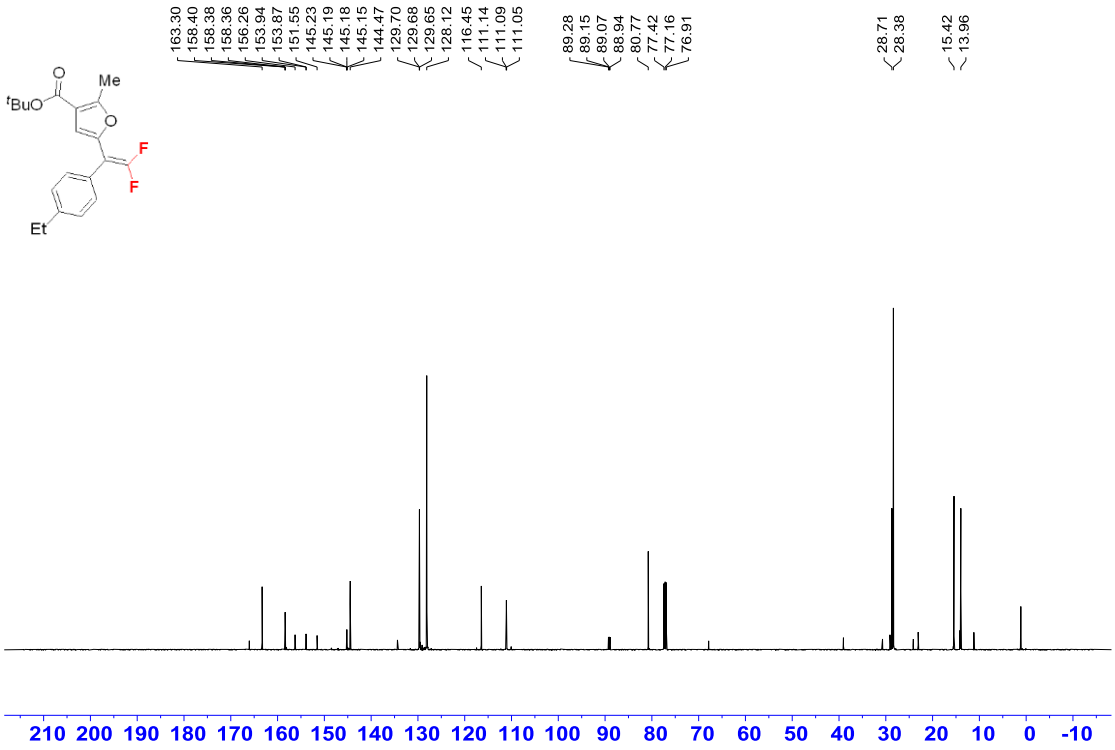
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **13.**



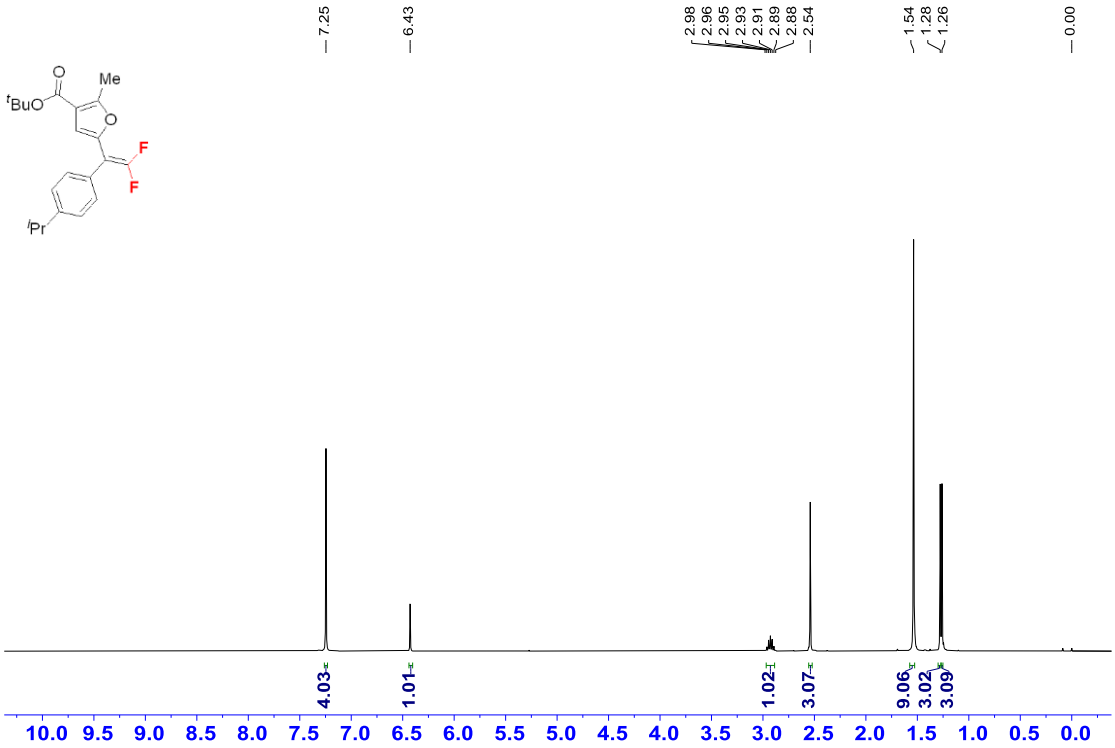
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **13.**



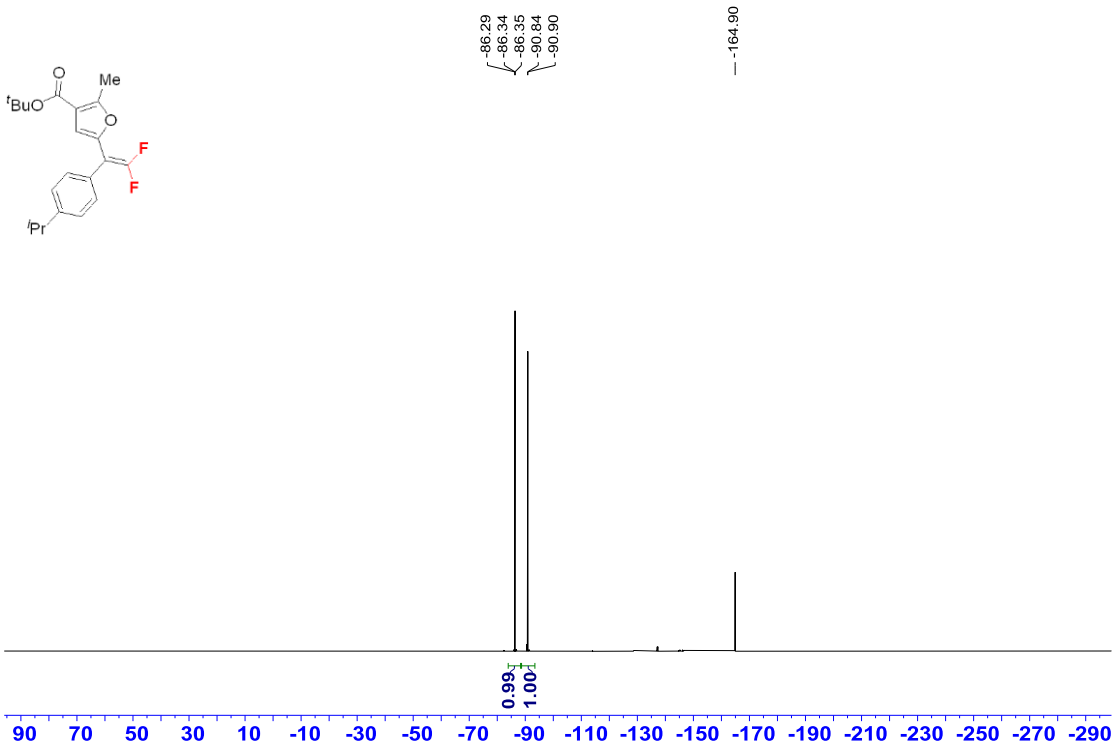
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **13.**



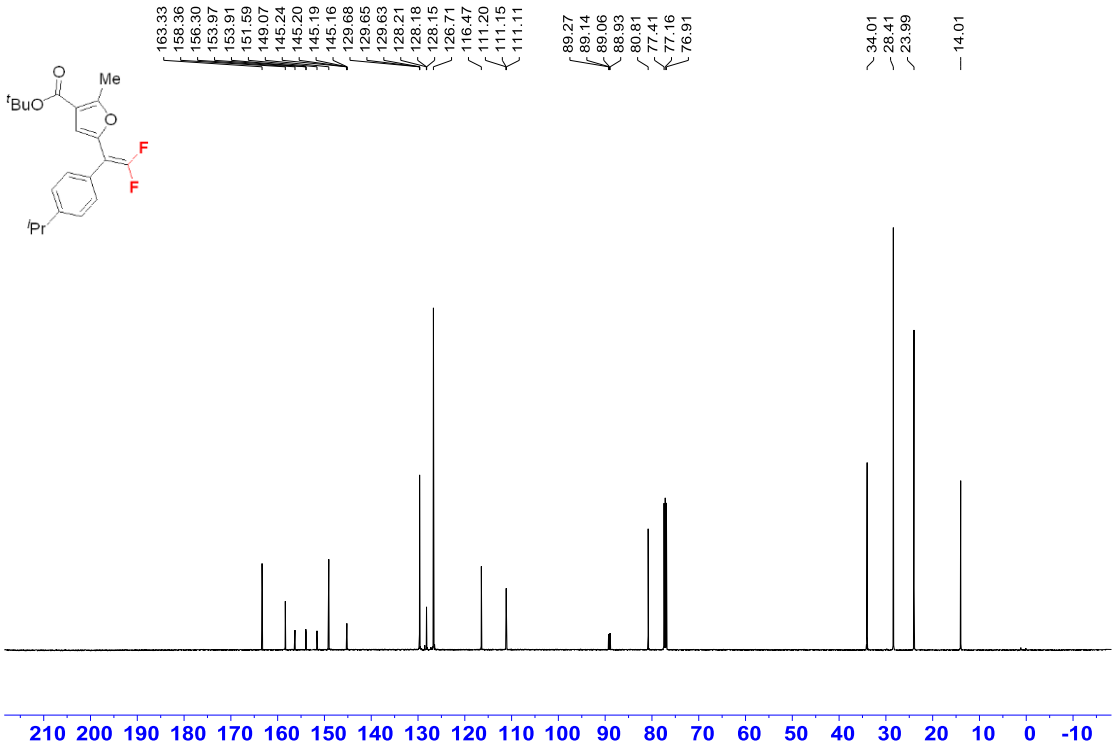
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **14.**



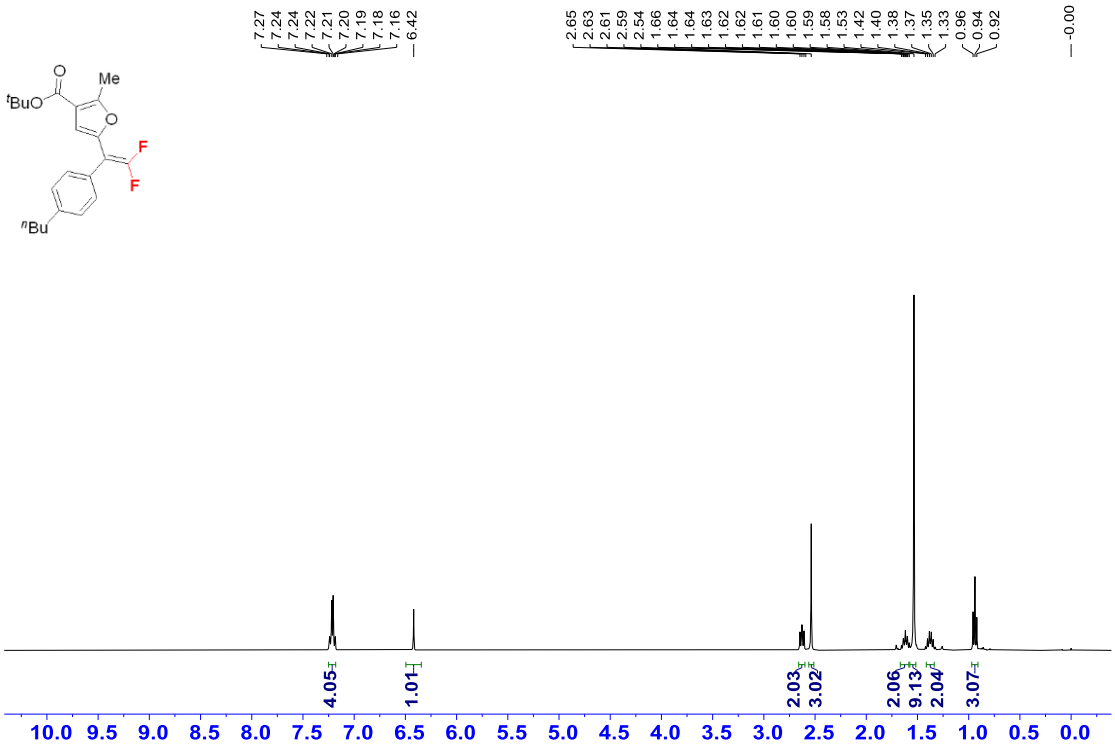
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **14.**



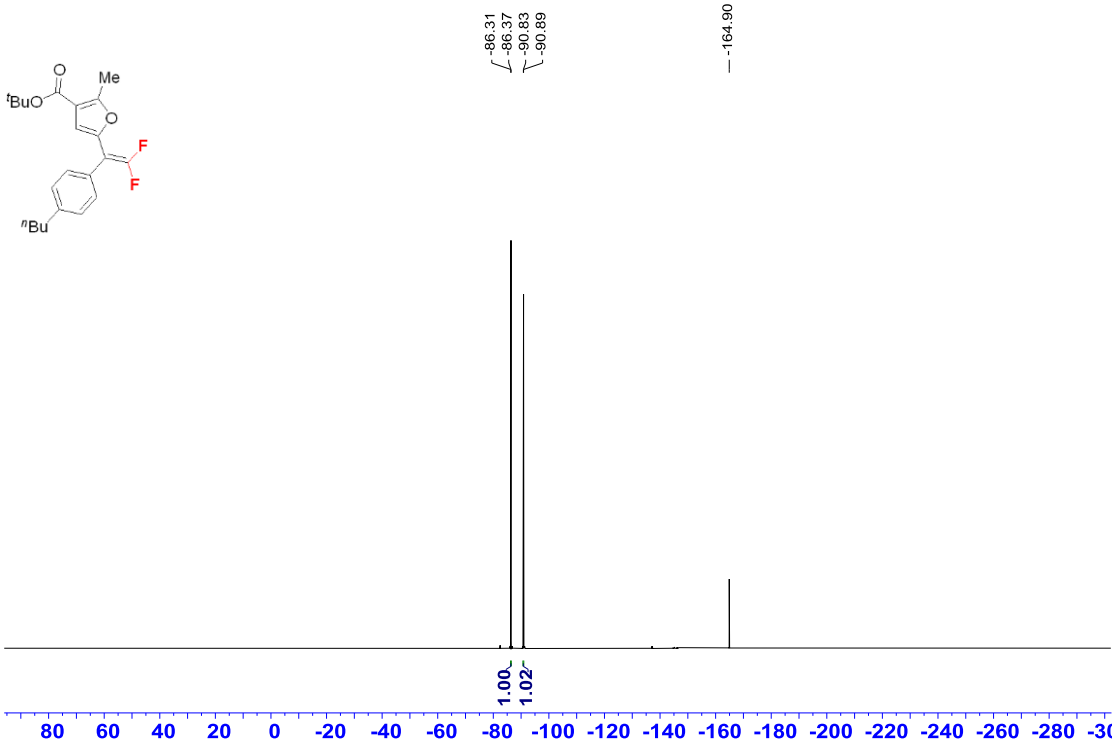
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **14.**



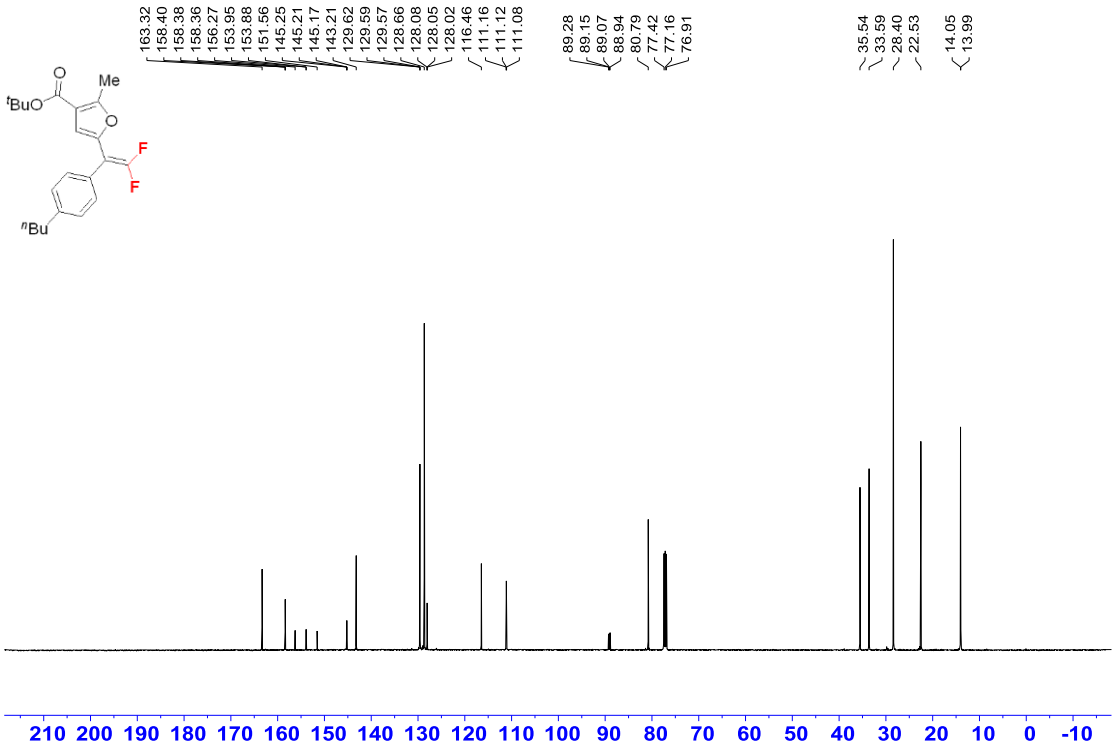
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **15.**



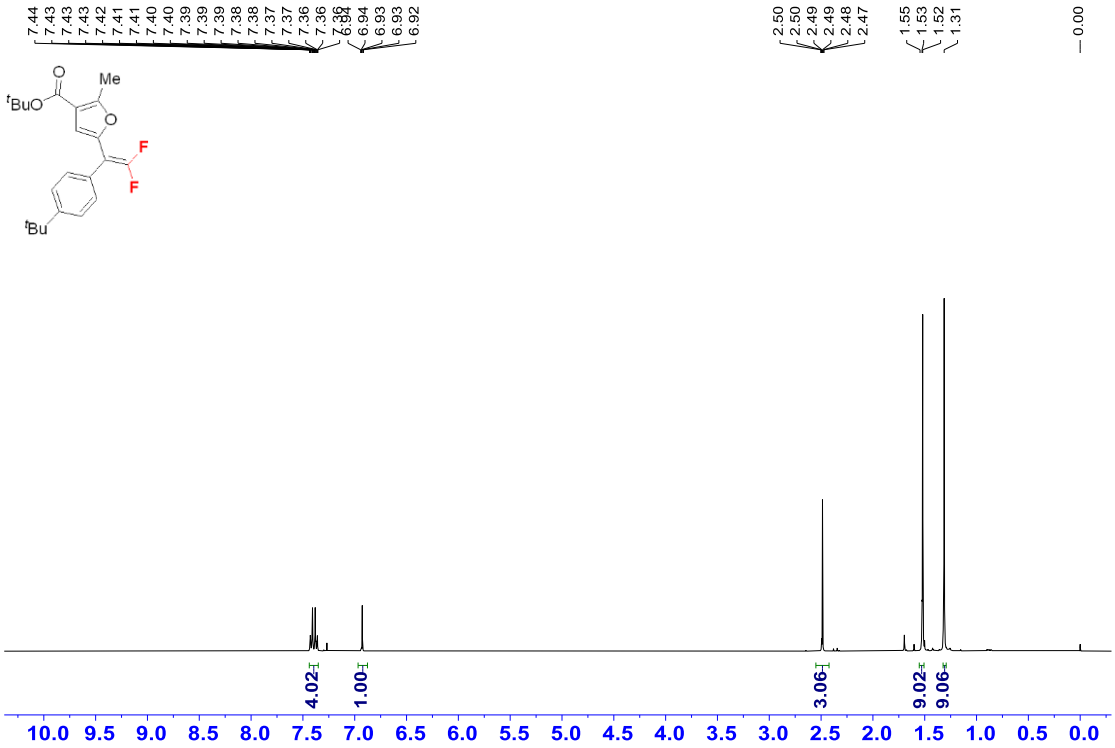
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **15.**



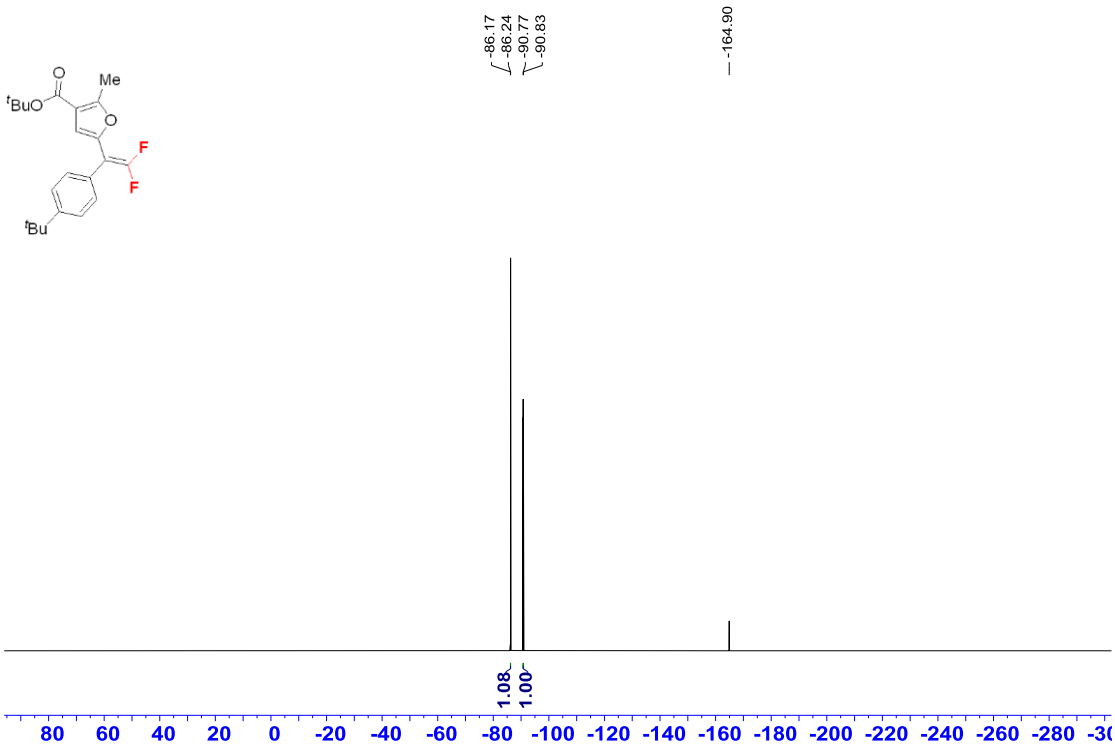
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **15.**



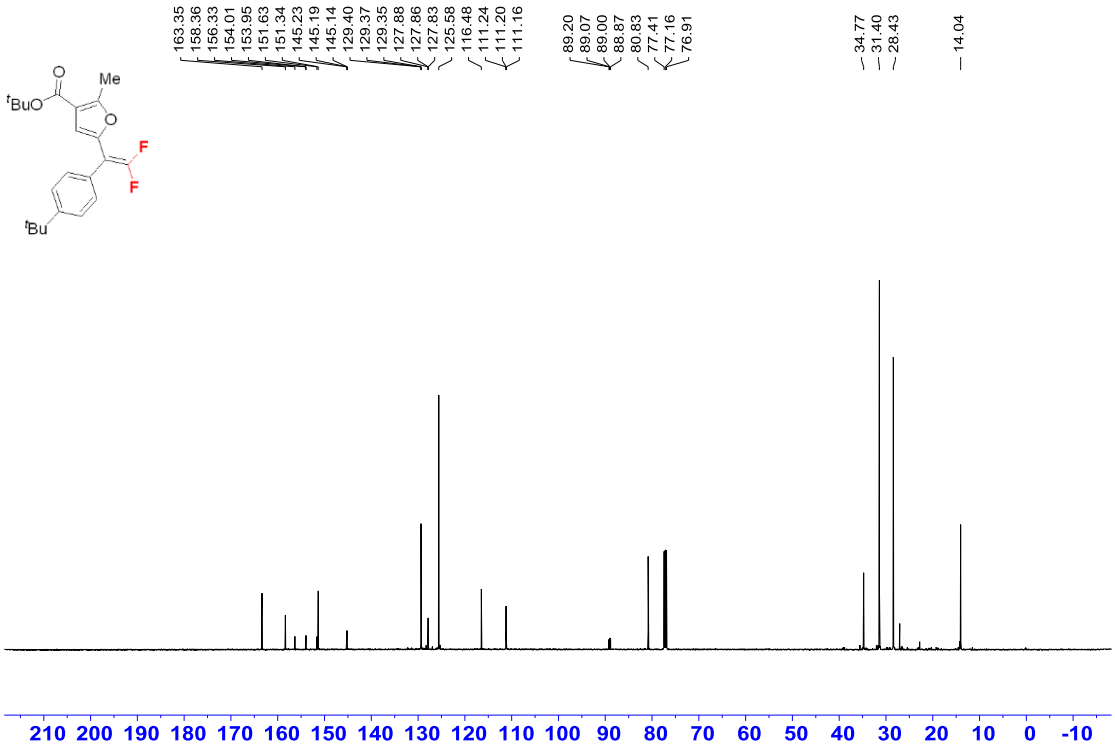
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **16.**



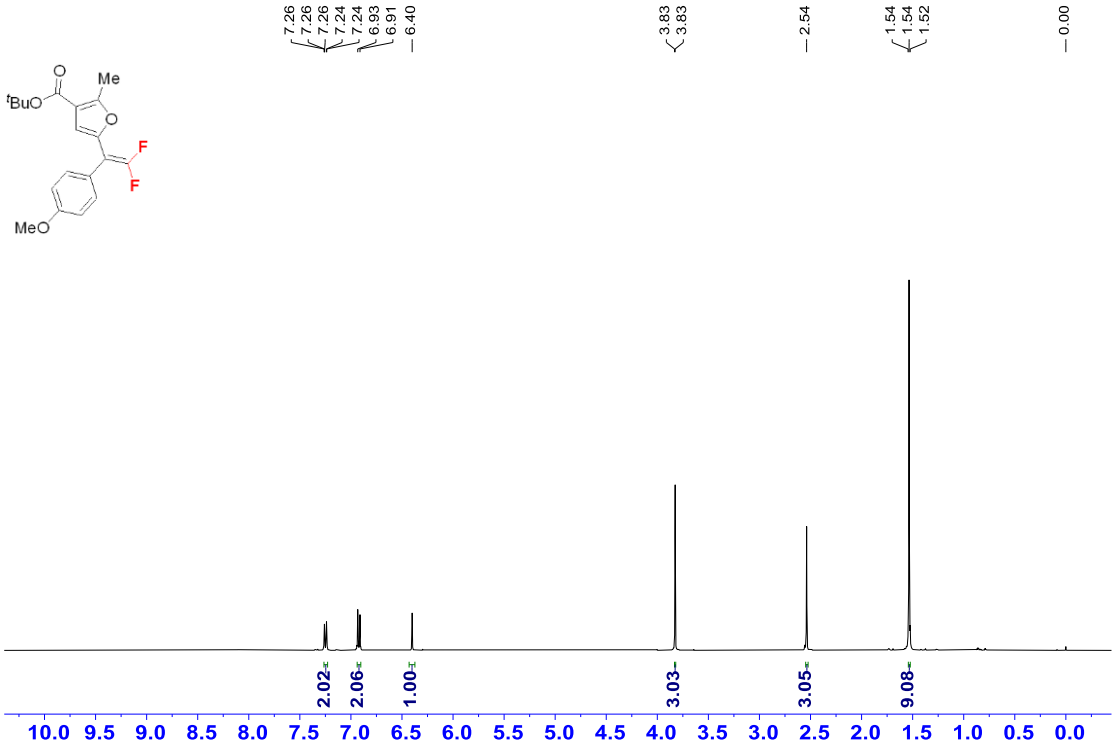
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **16.**



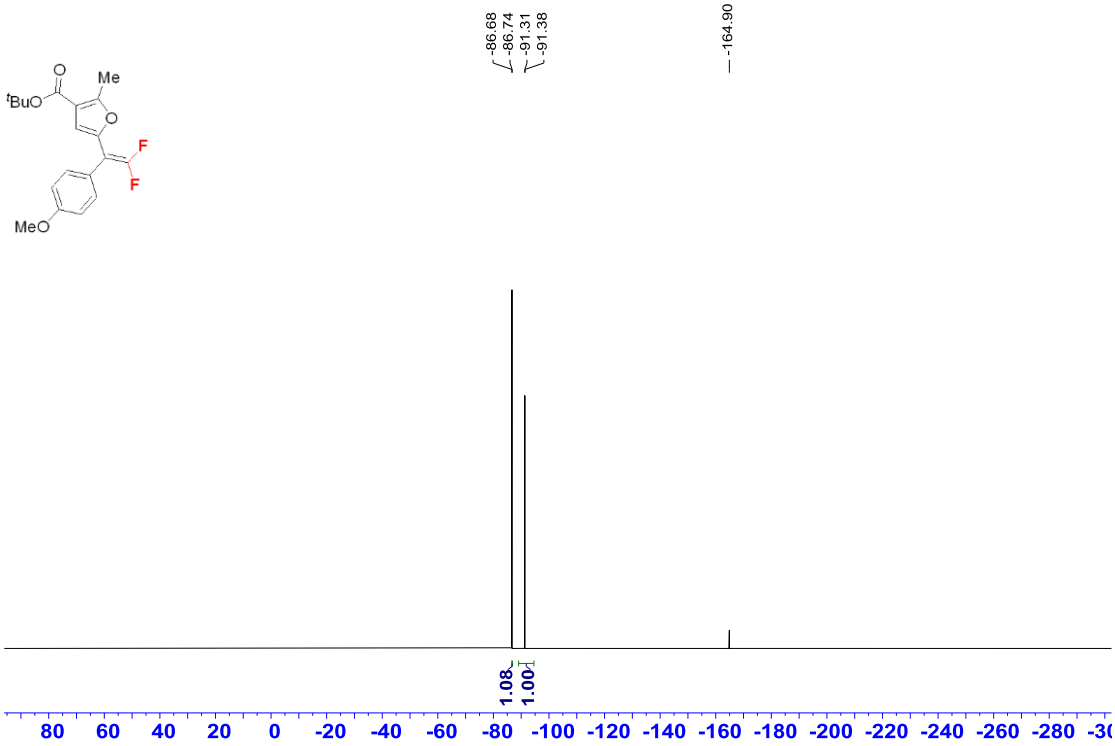
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **16.**



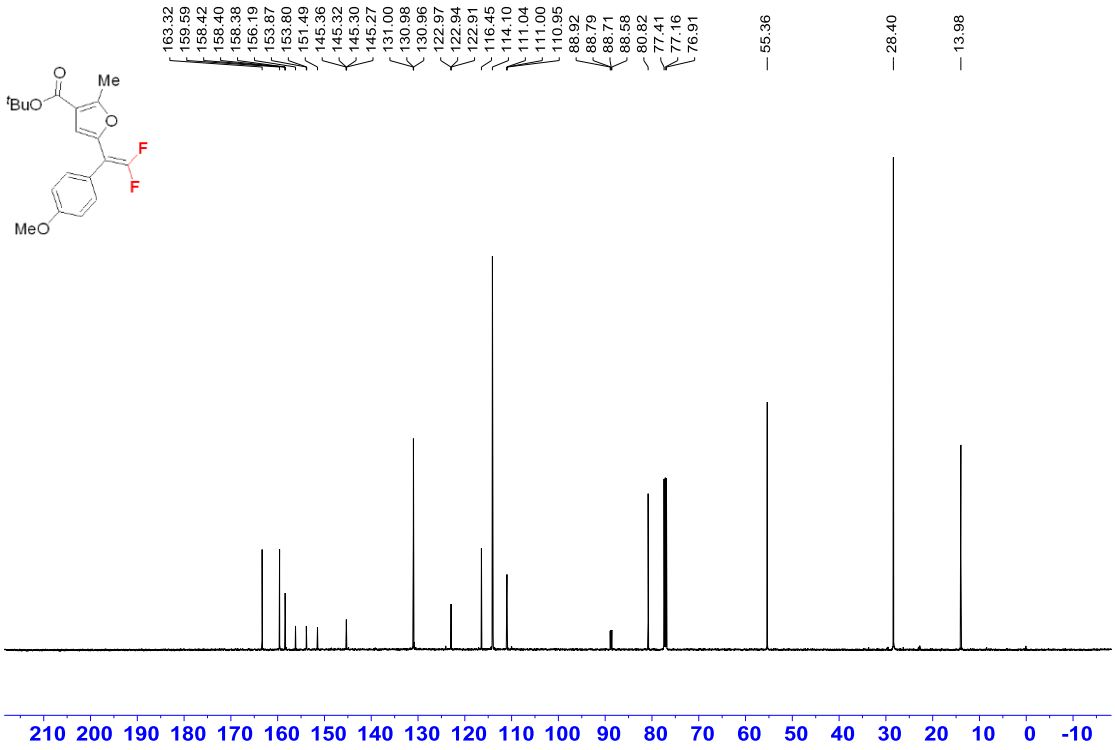
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **17.**



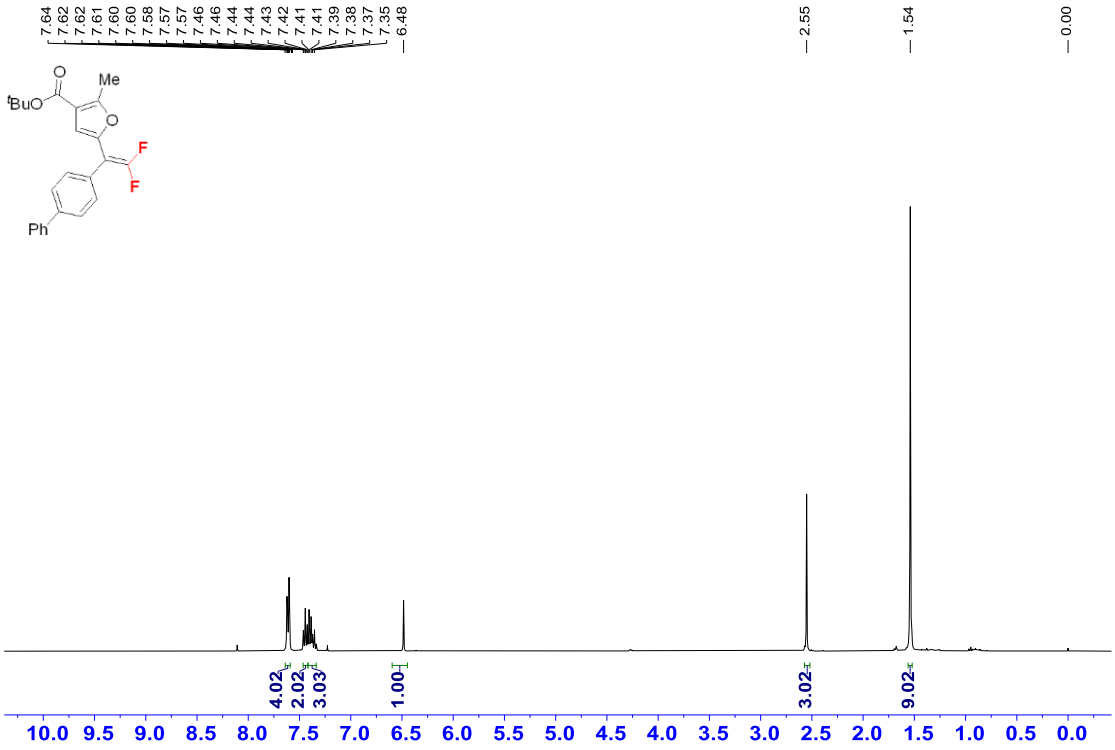
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **17.**



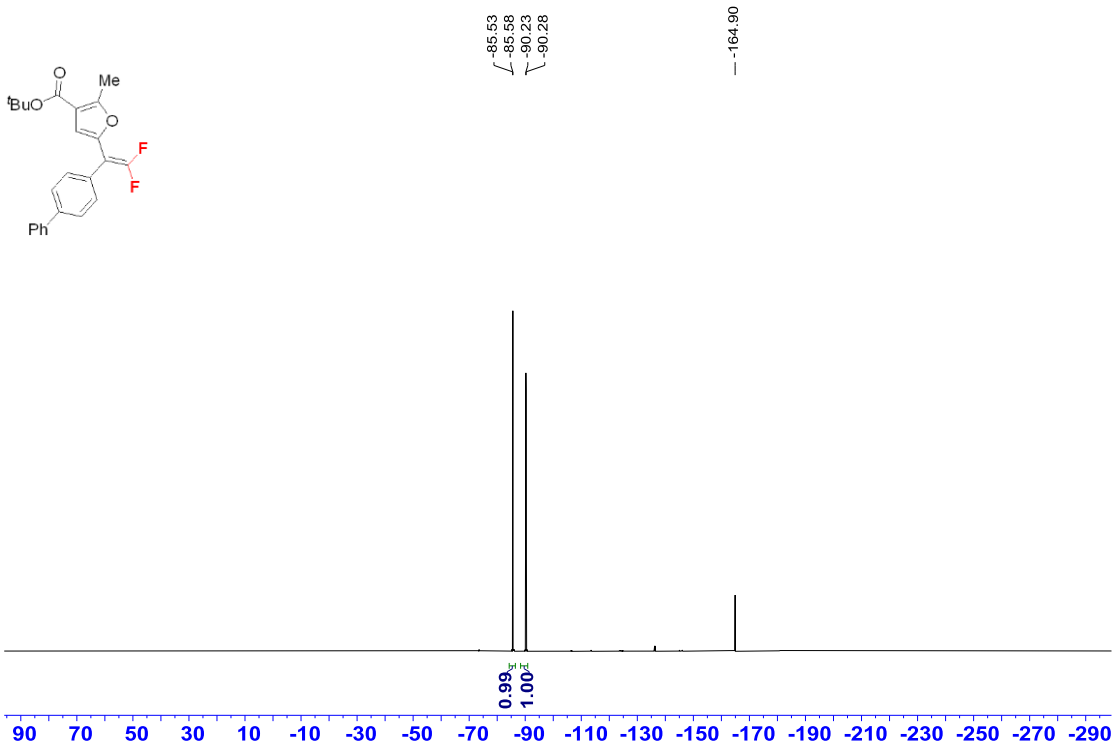
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **17.**



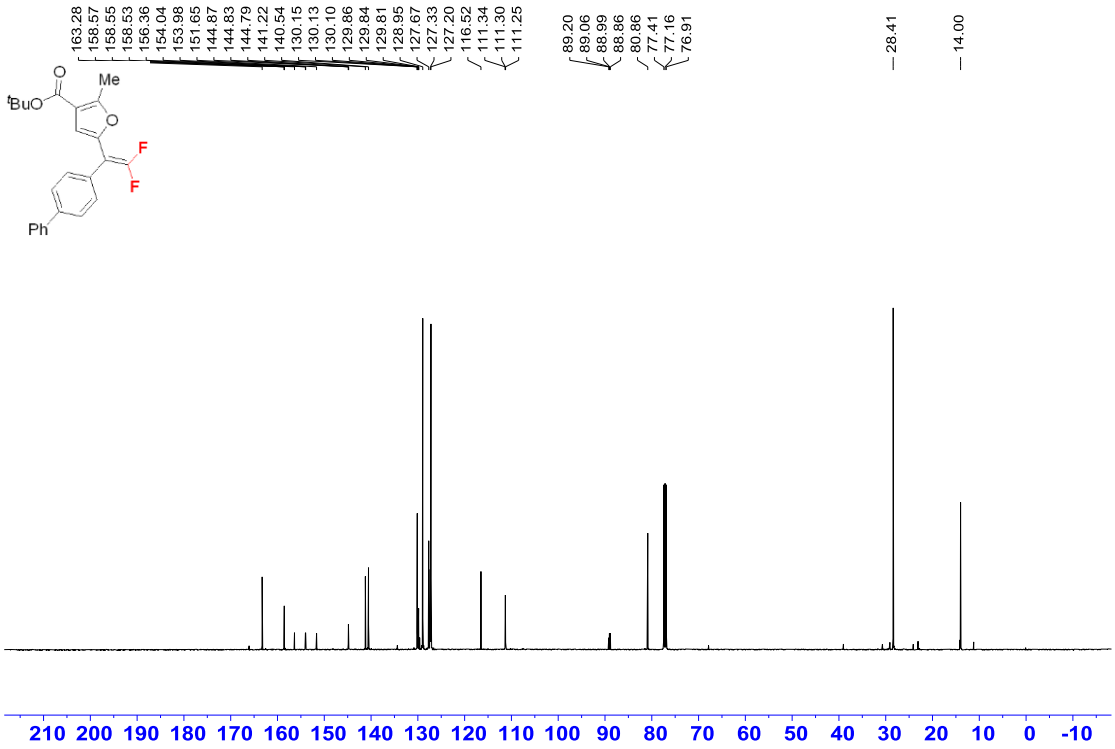
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **18.**



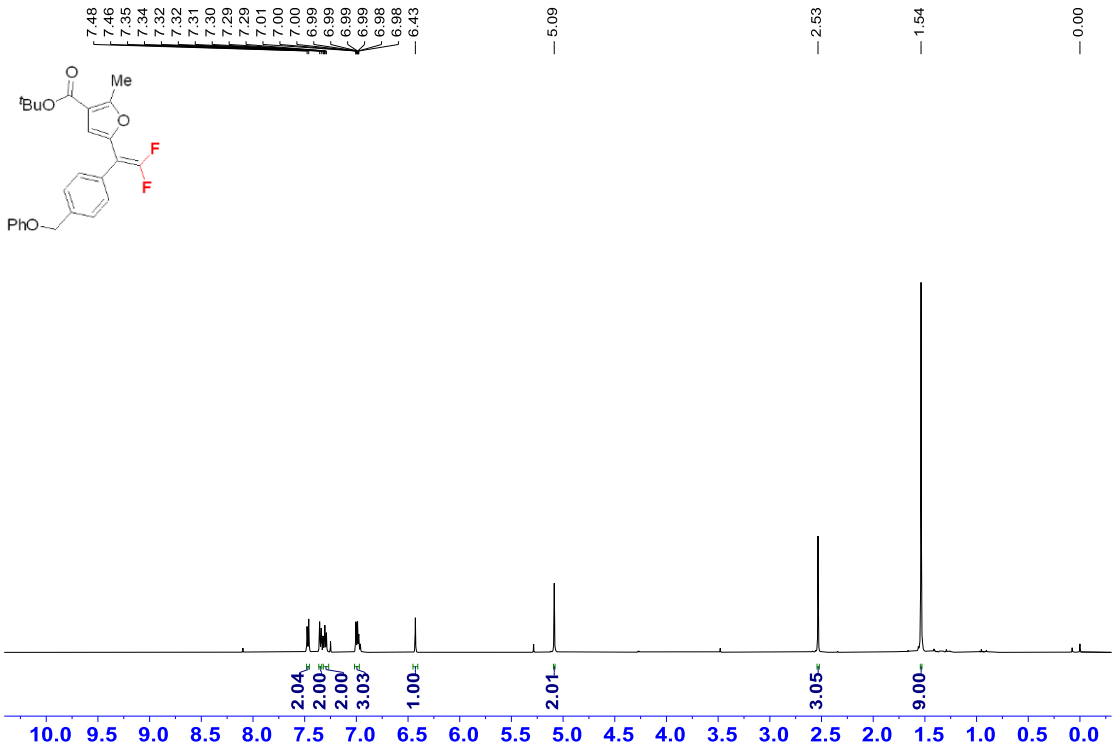
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **18.**



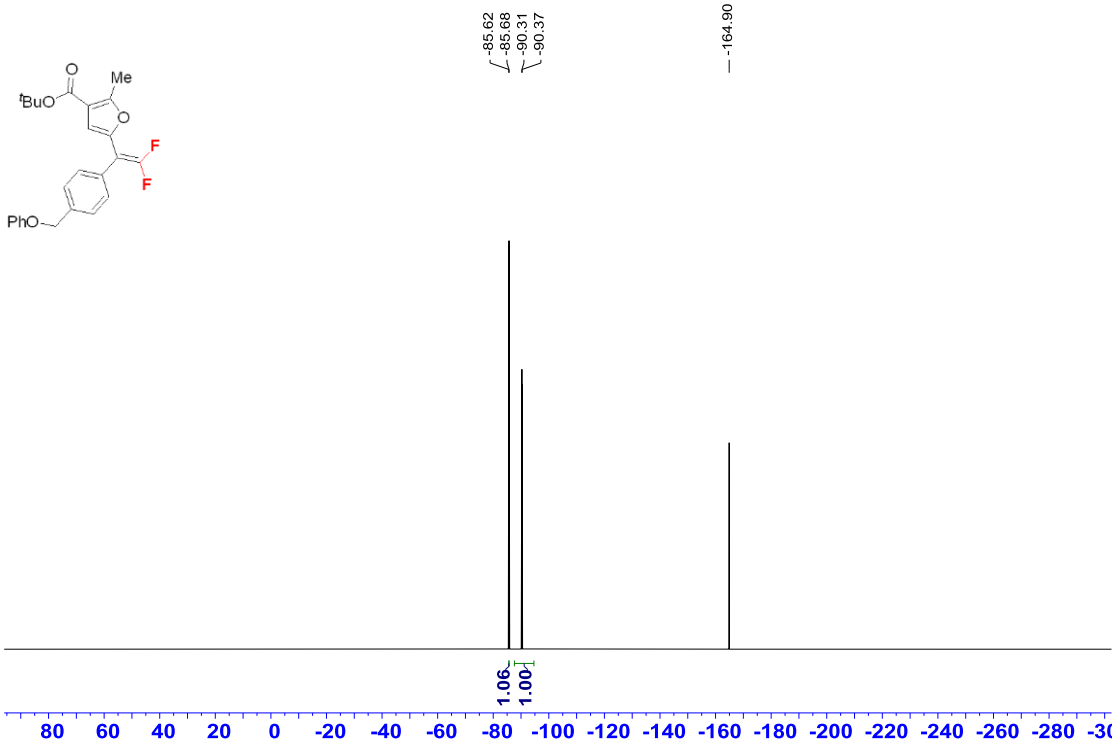
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **18.**



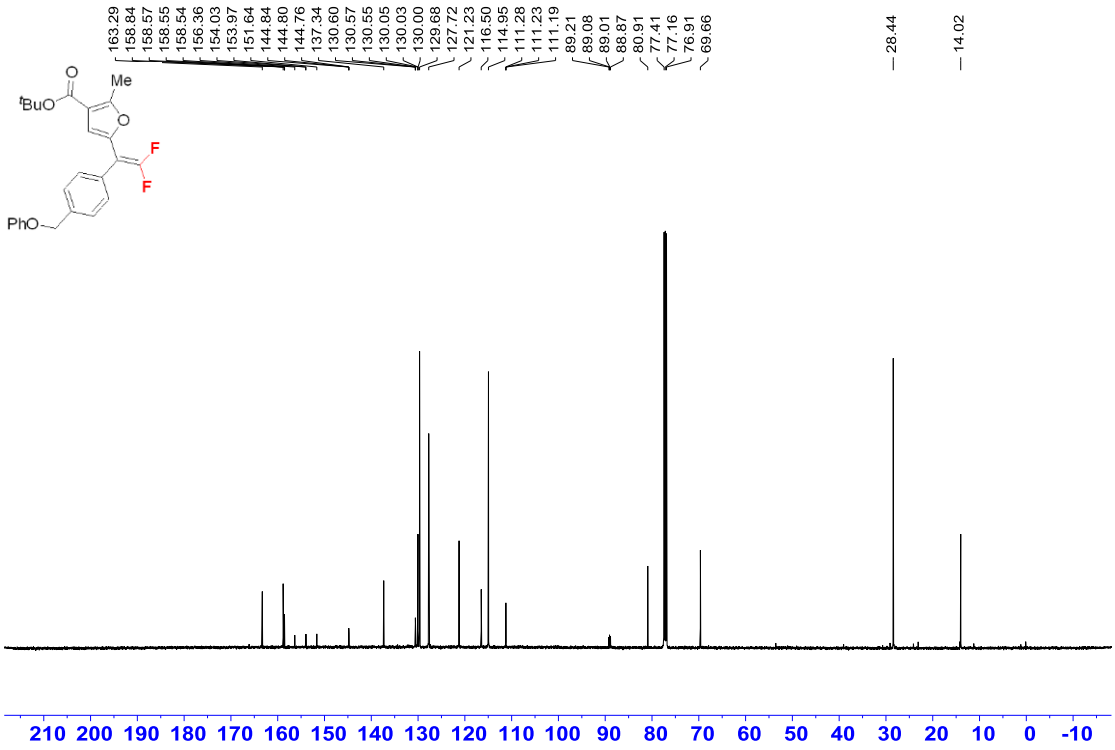
^{1}H NMR (500 MHz, $CDCl_3$) spectrum of compound **19.**



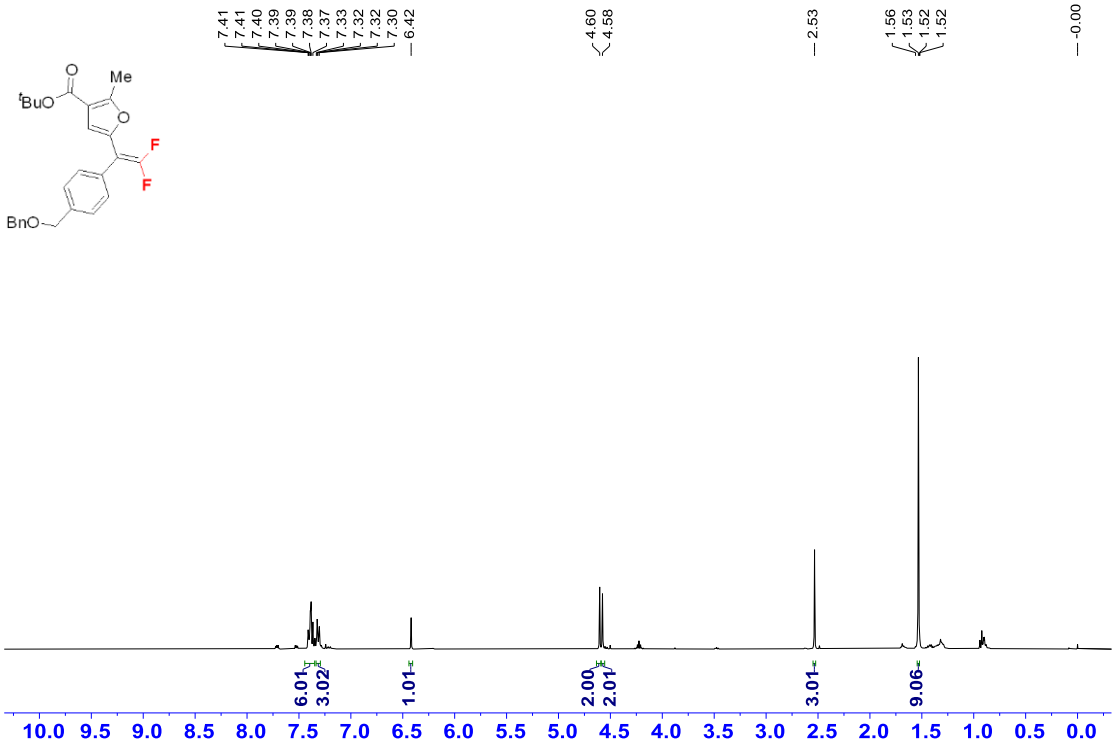
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **19.**



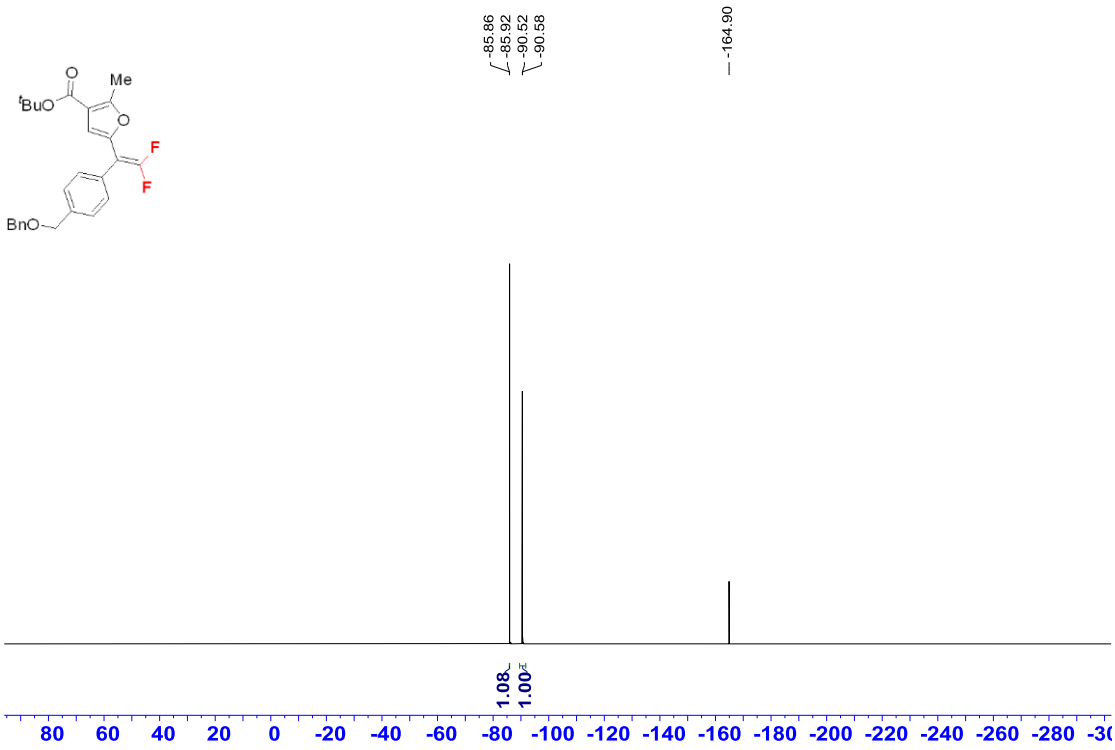
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **19.**



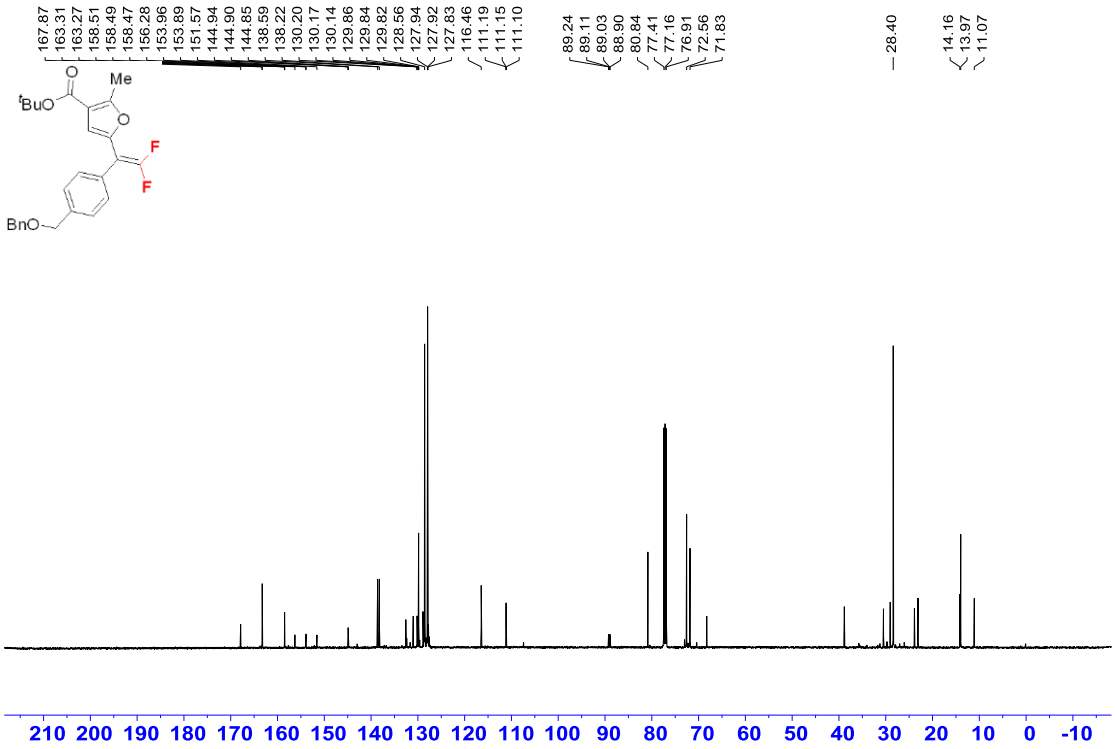
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **20.**



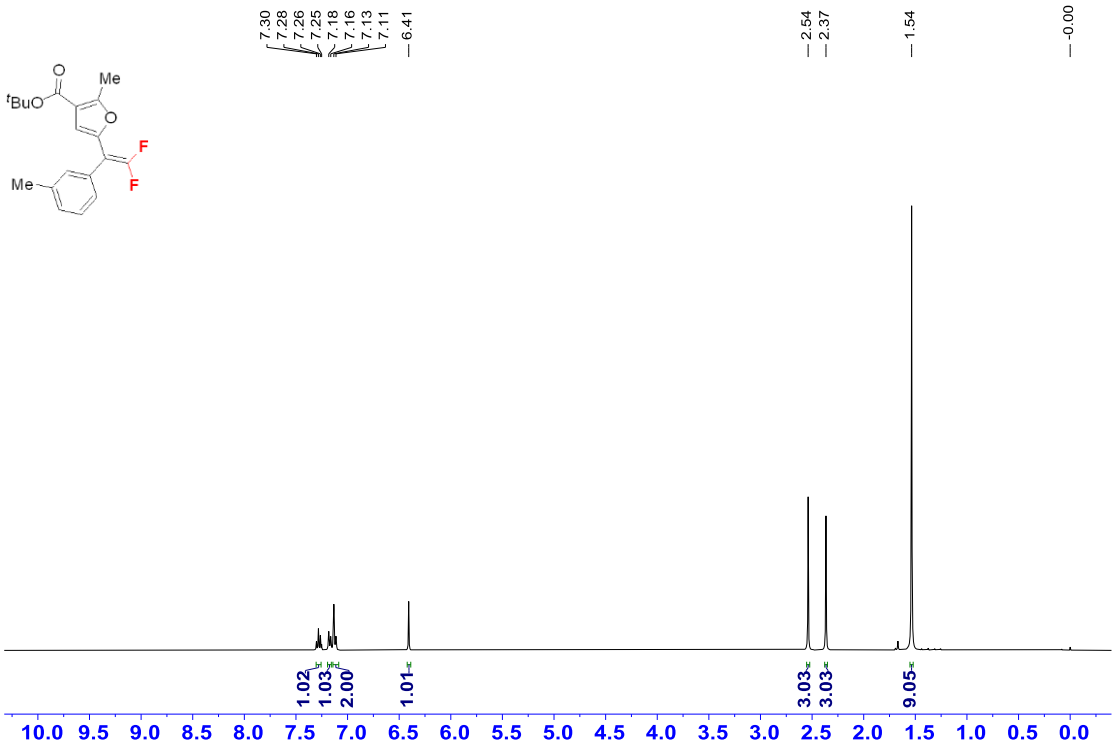
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **20.**



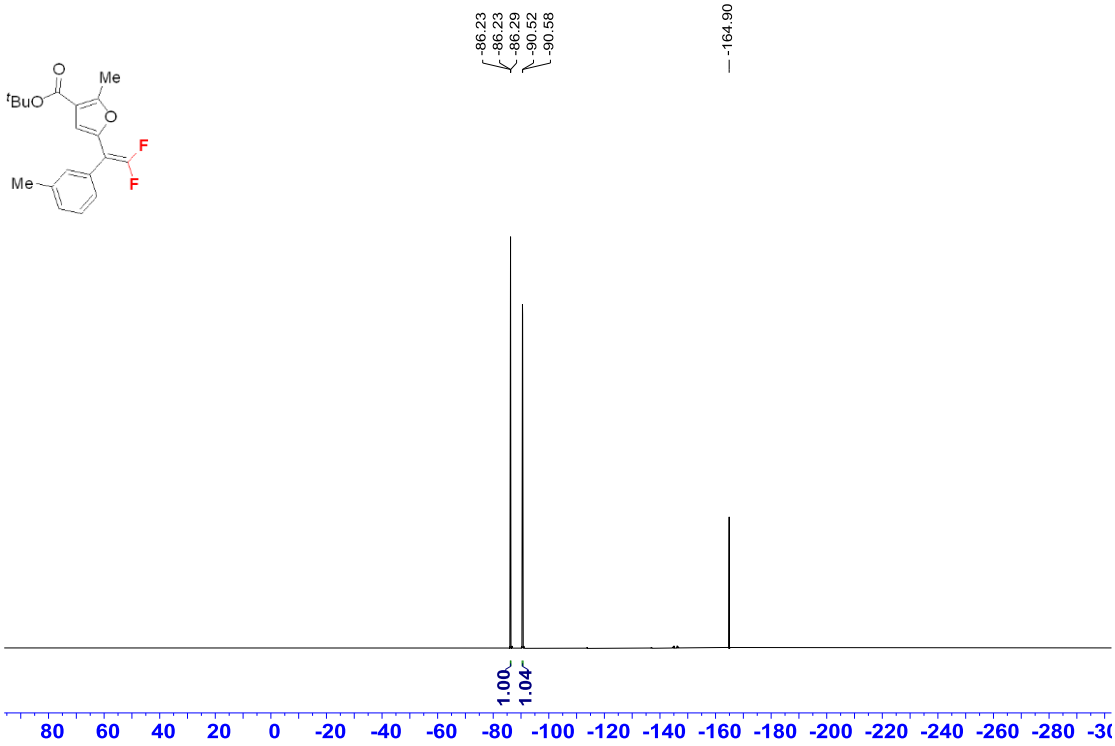
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **20.**



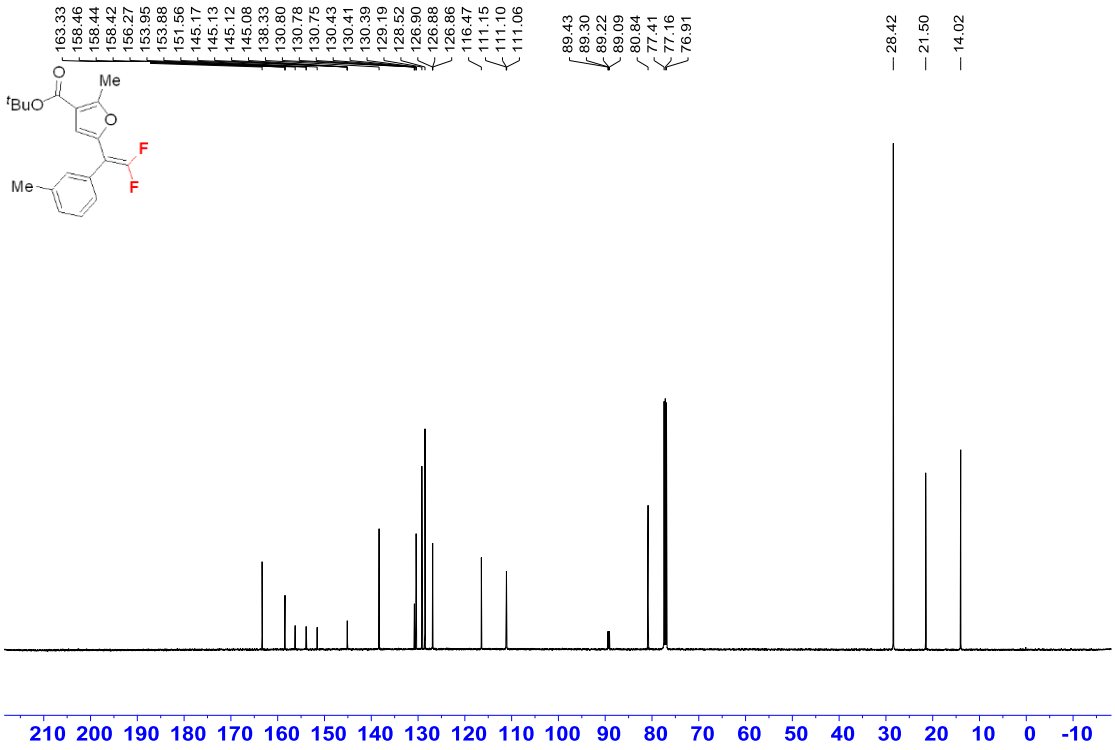
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **21.**



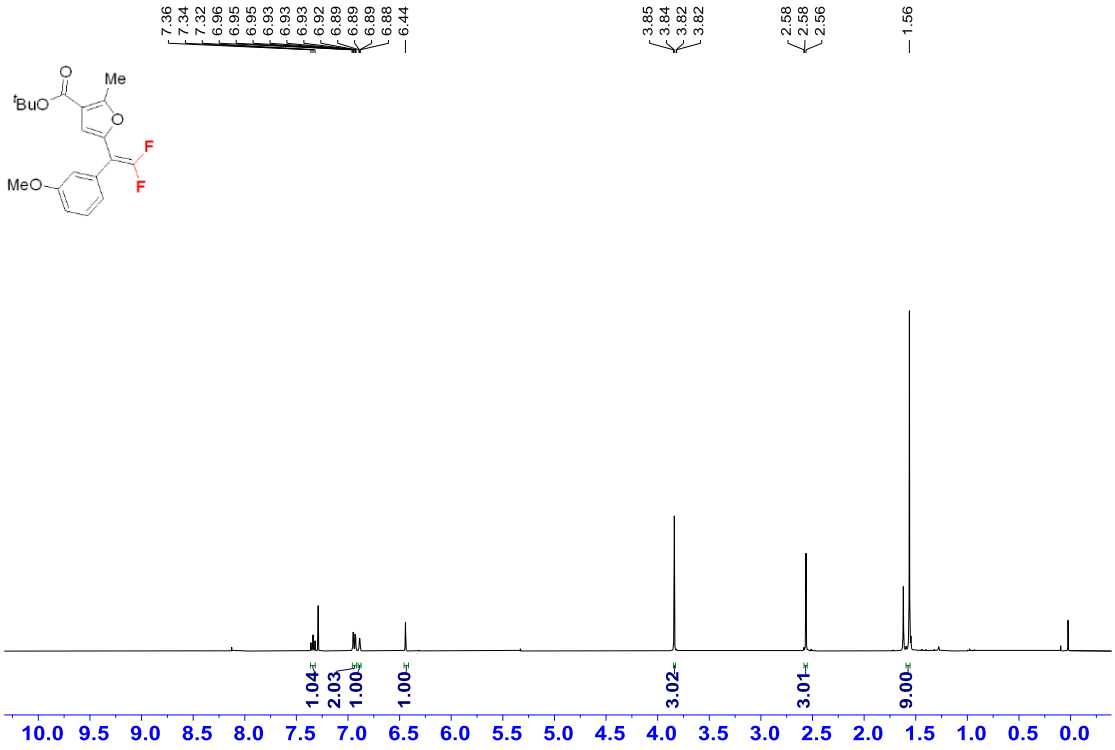
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **21.**



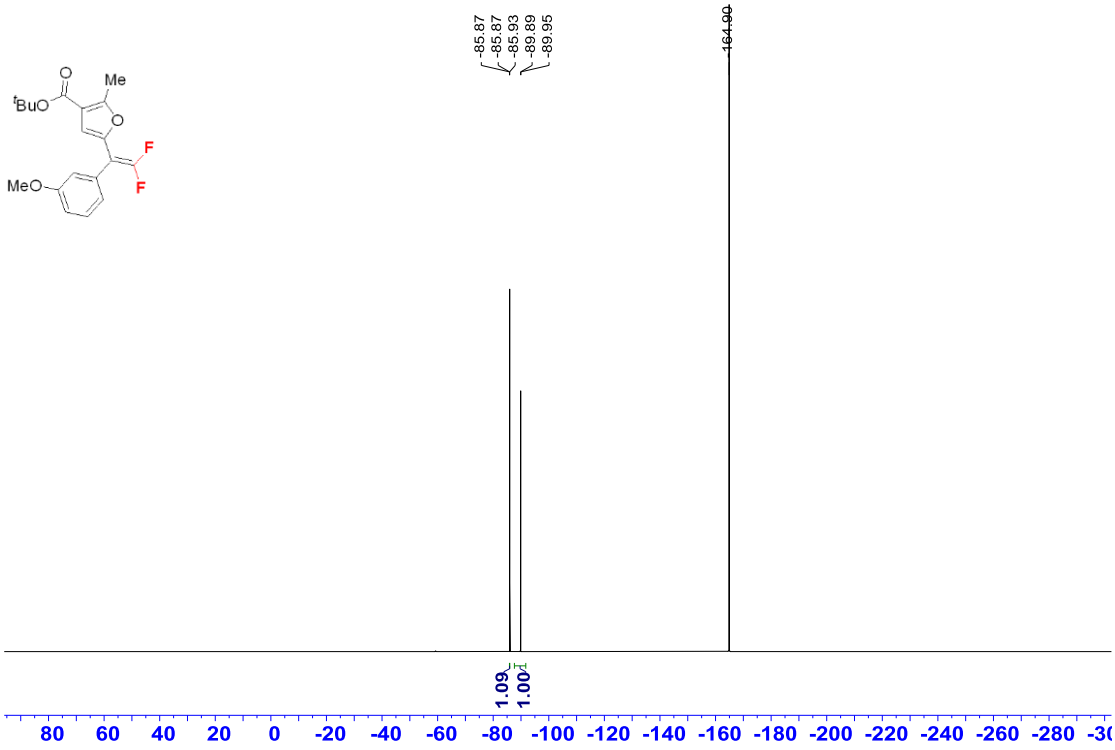
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **21.**



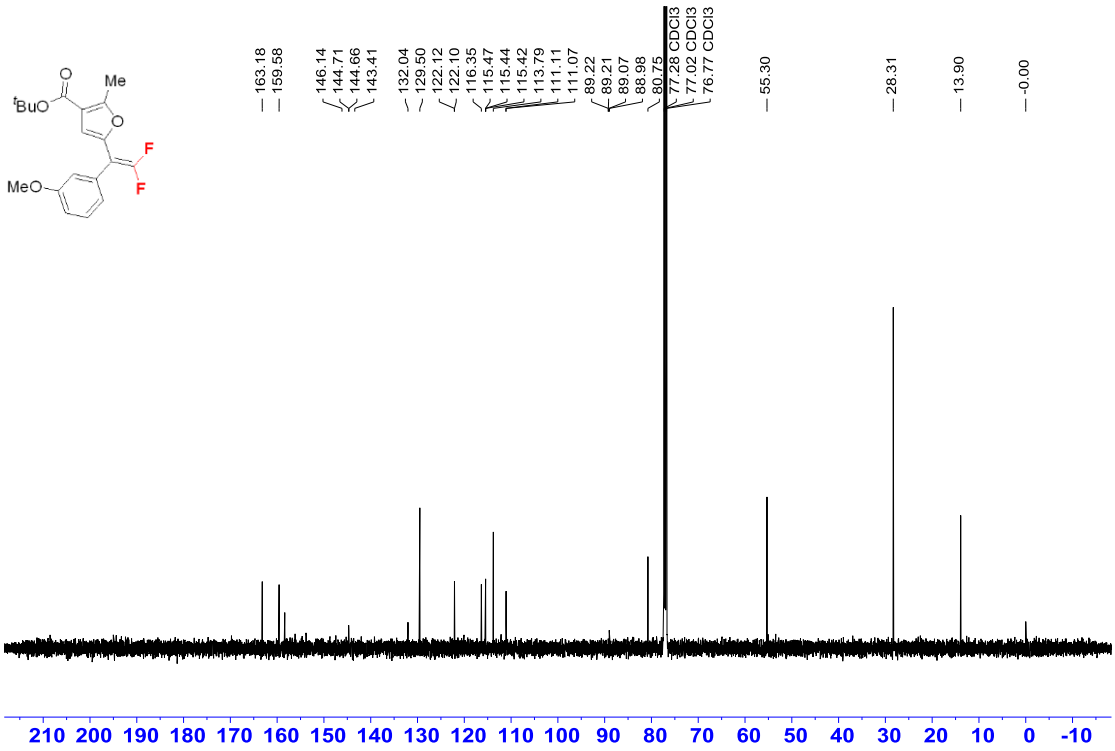
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **22.**



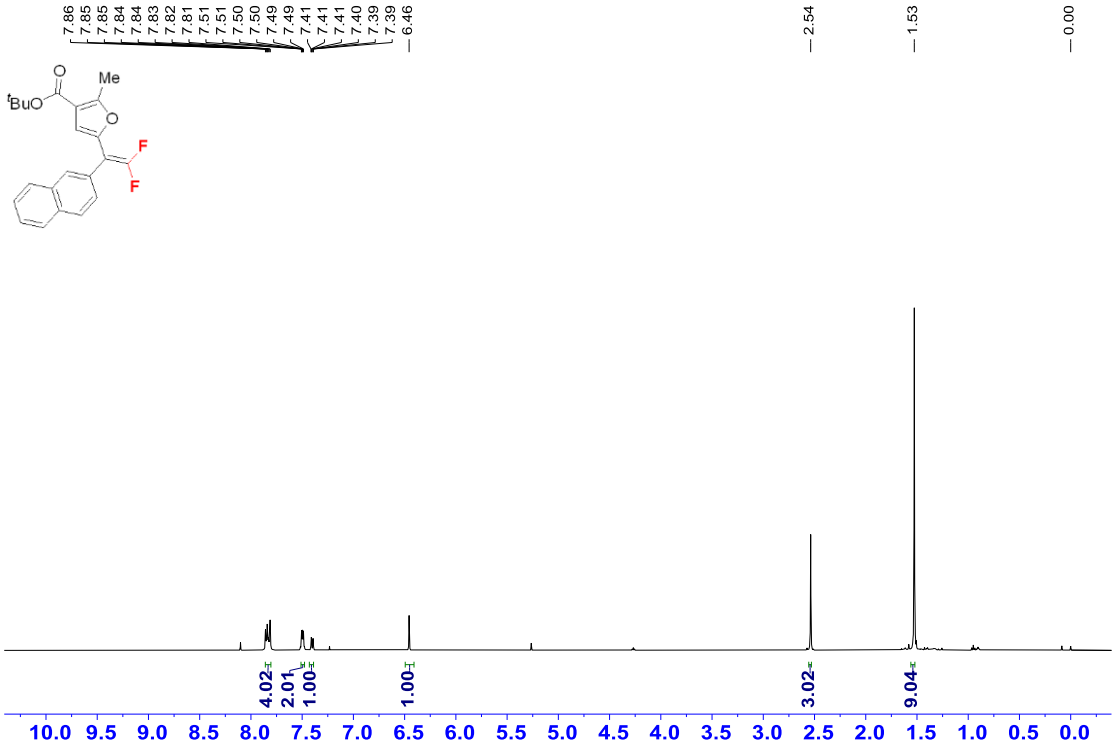
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **22.**



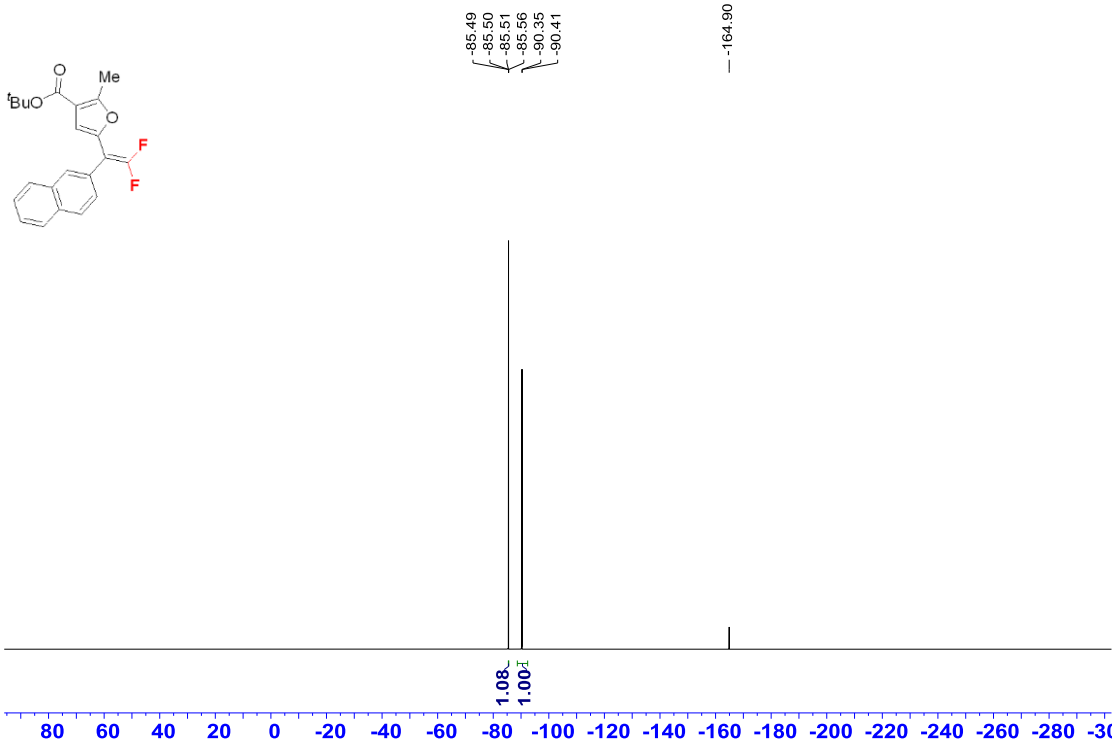
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **22.**



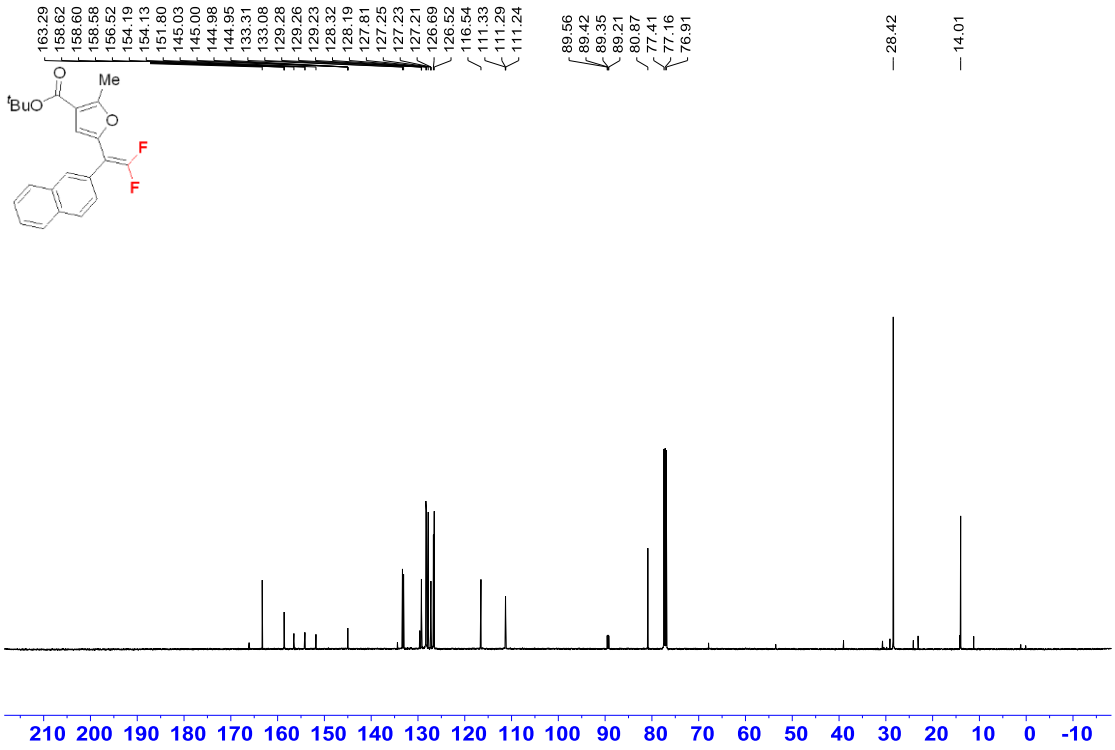
^{1}H NMR (500 MHz, $CDCl_3$) spectrum of compound **23.**



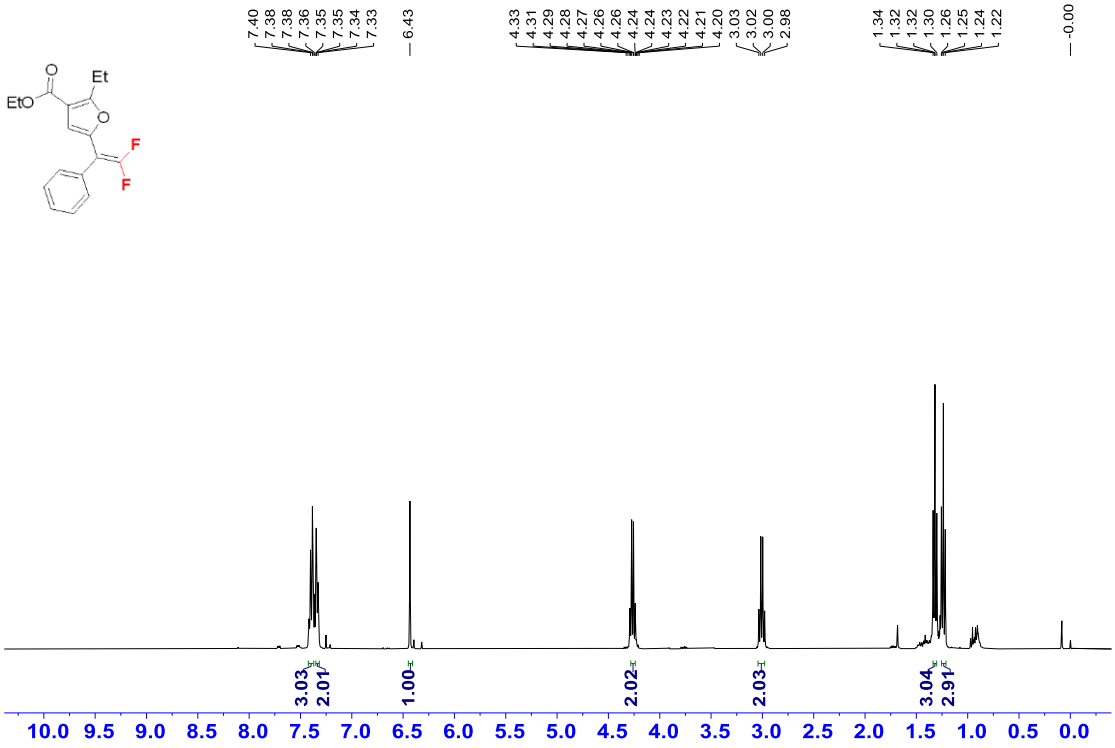
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **23.**



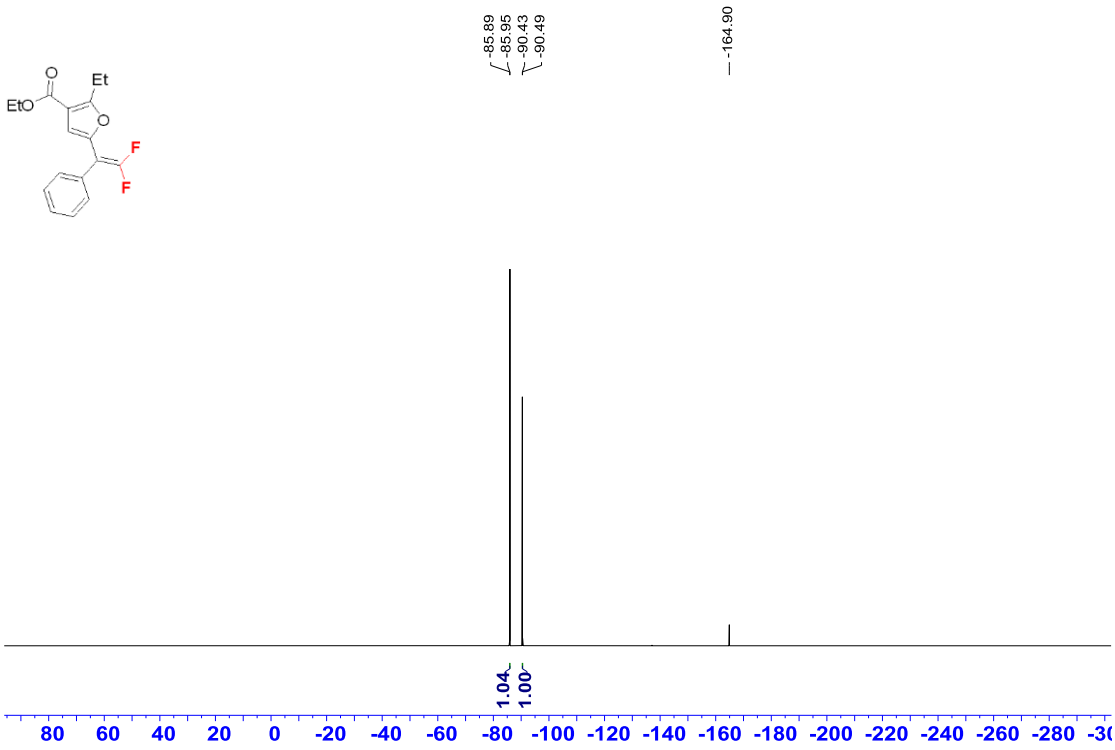
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **23.**



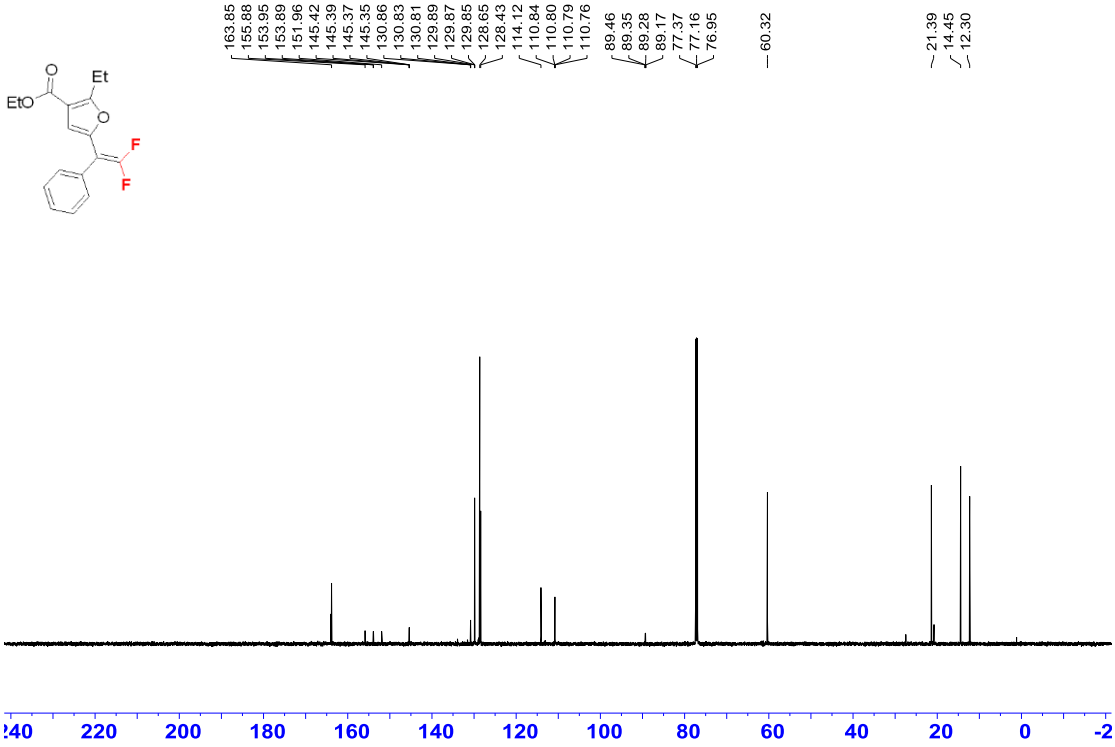
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **24.**



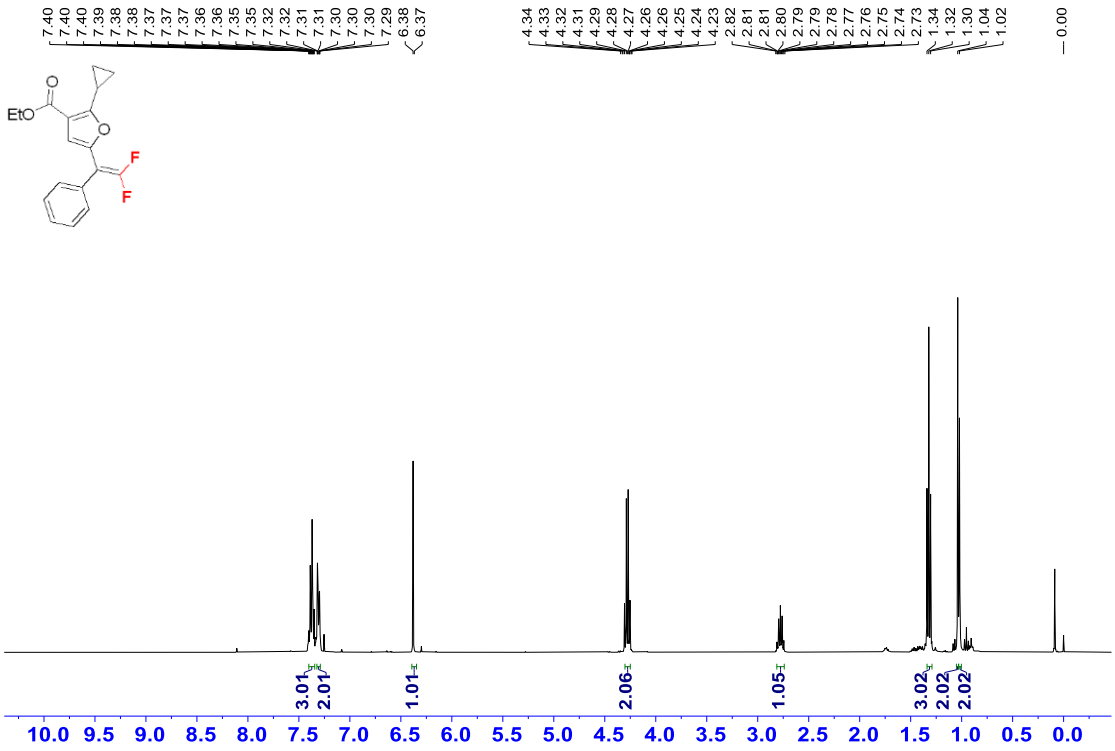
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **24.**



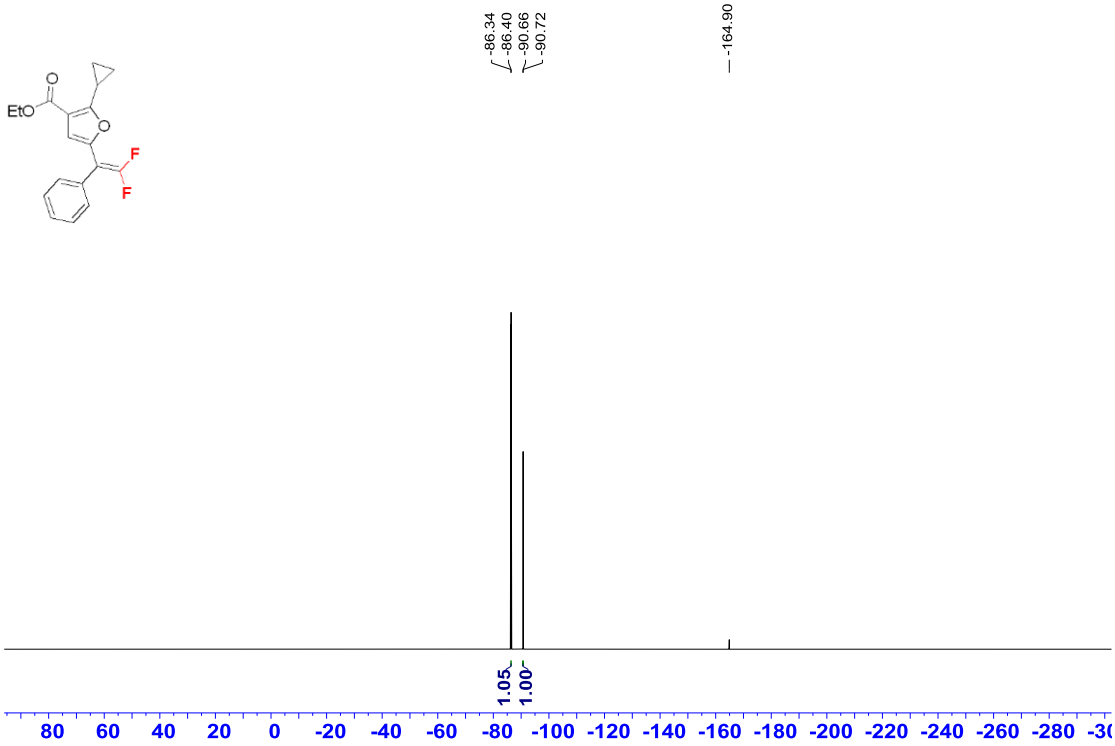
^{13}C NMR (151 MHz, $CDCl_3$) spectrum of compound **24.**



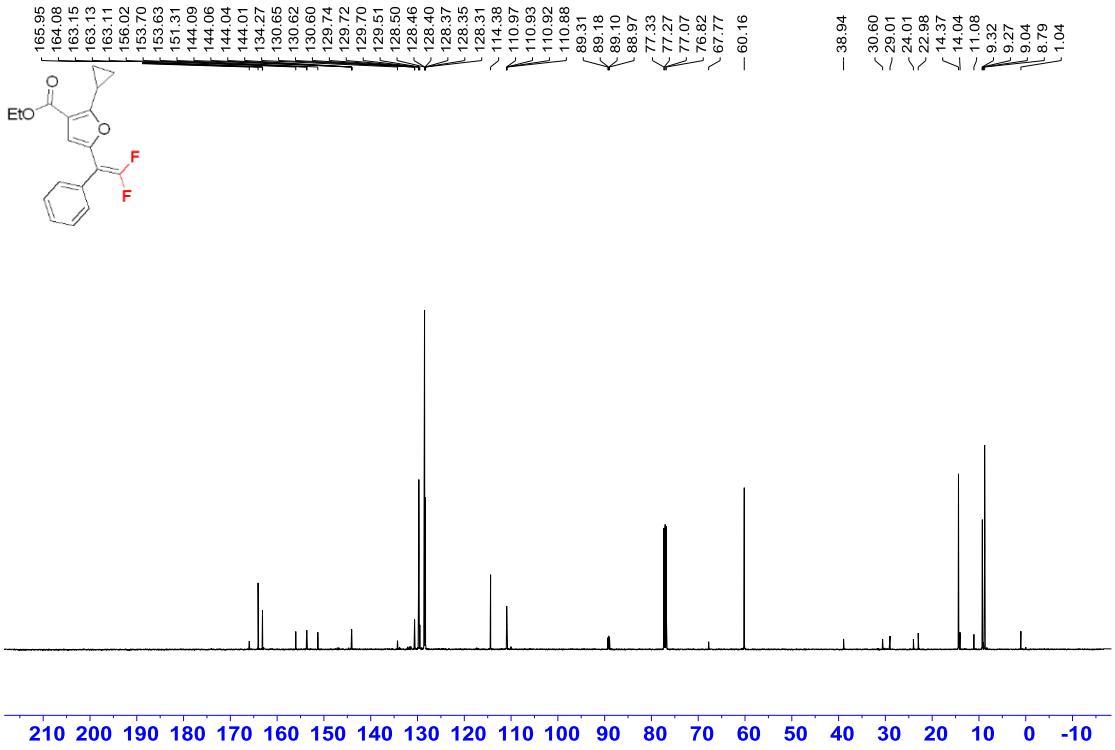
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **25.**



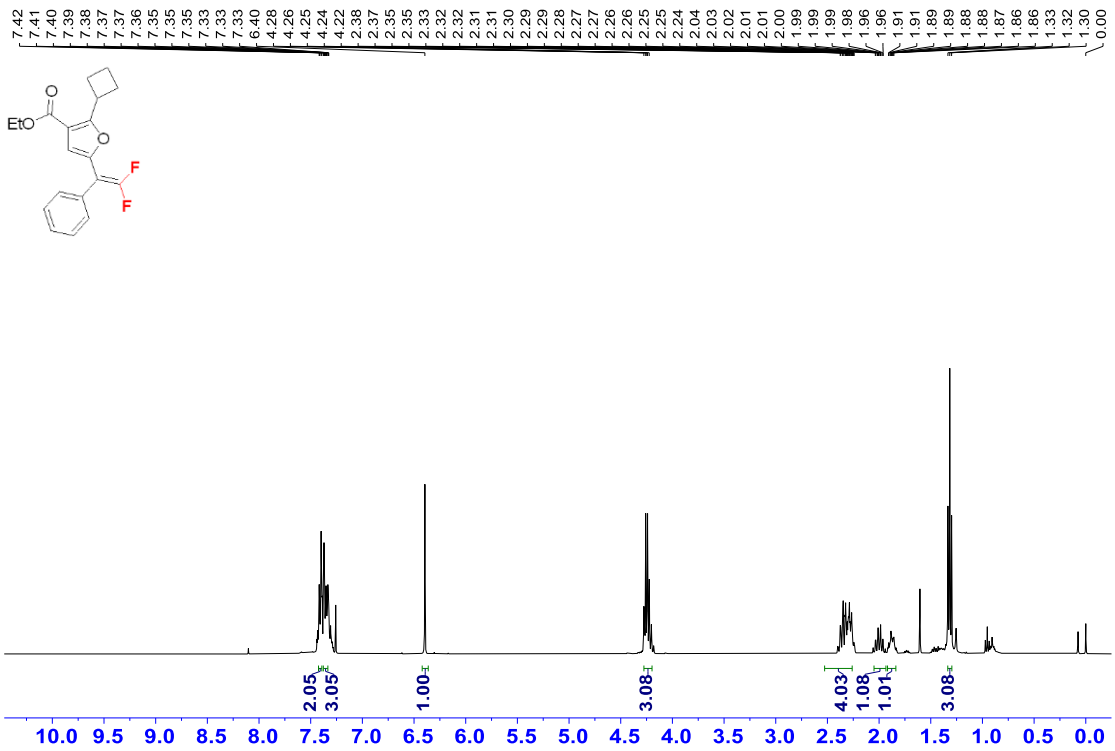
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **25.**



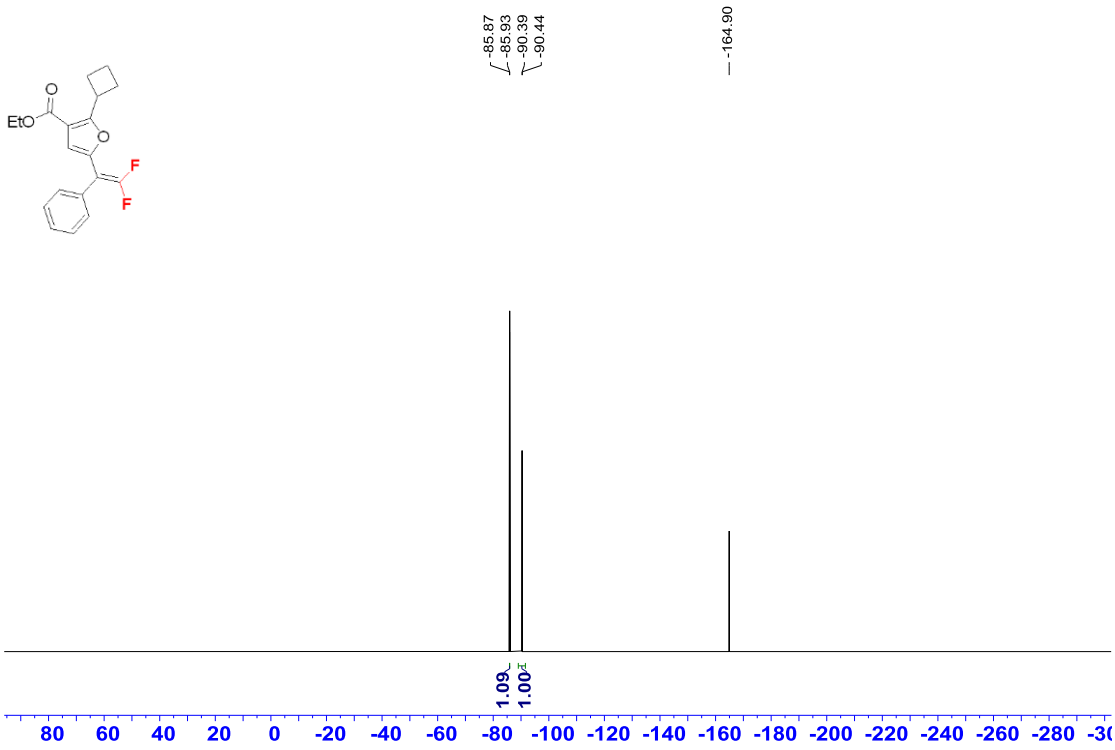
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **25.**



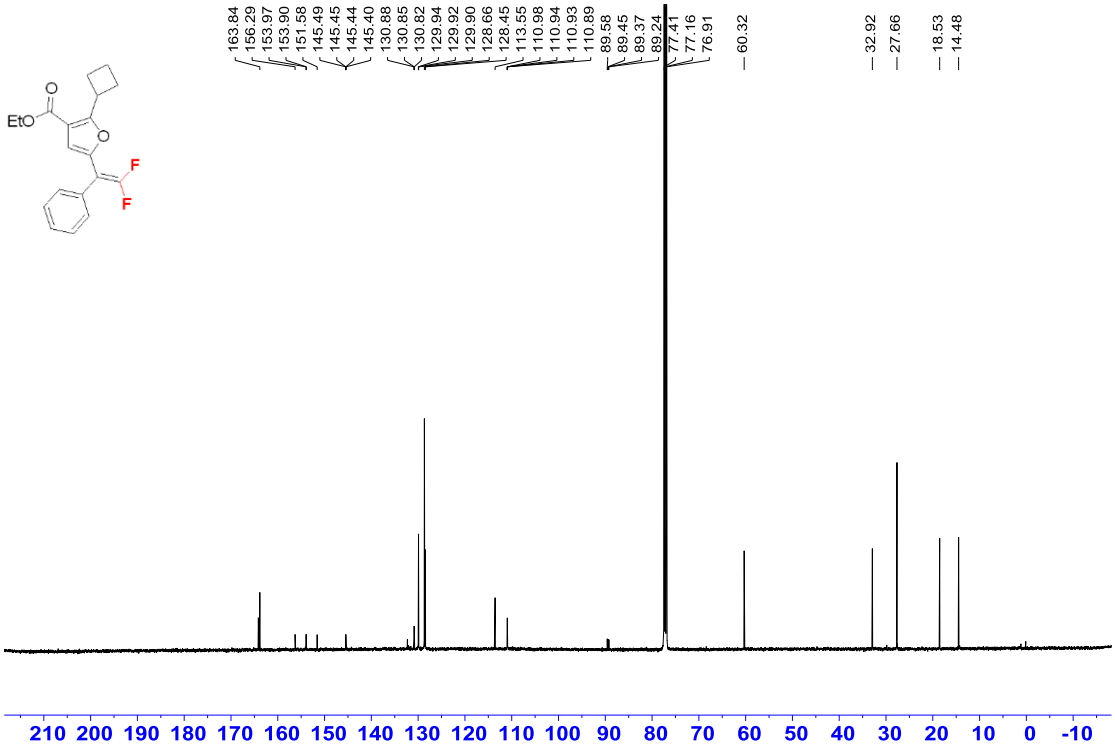
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **26.**



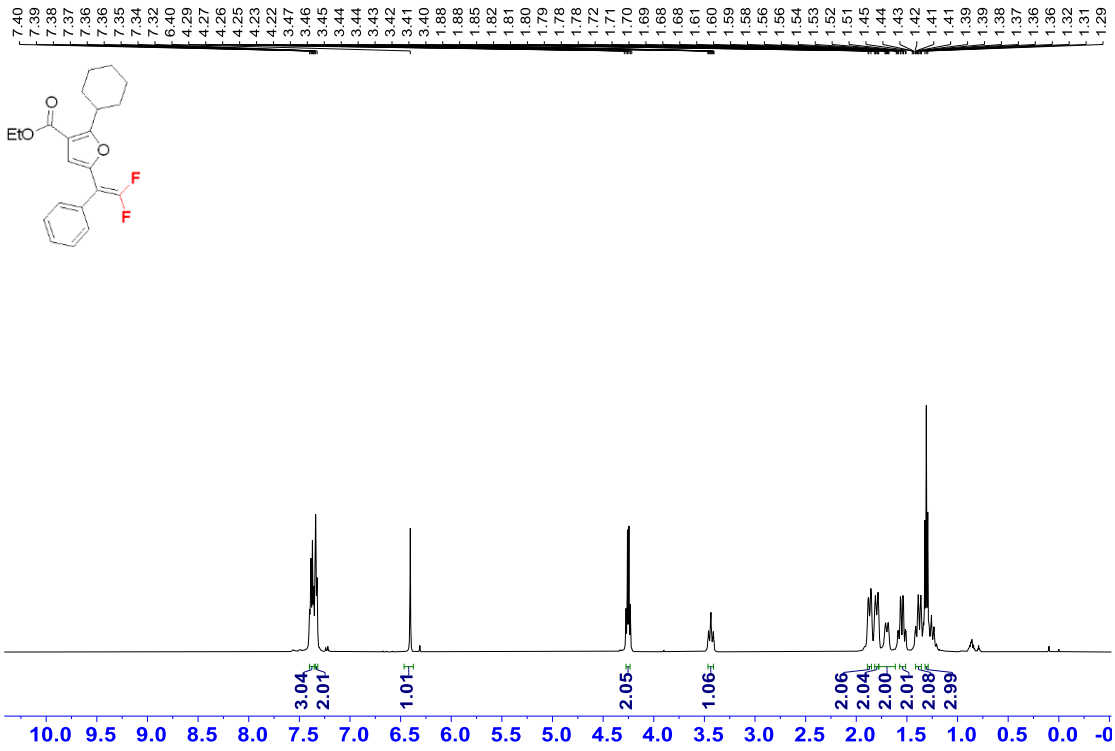
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **26.**



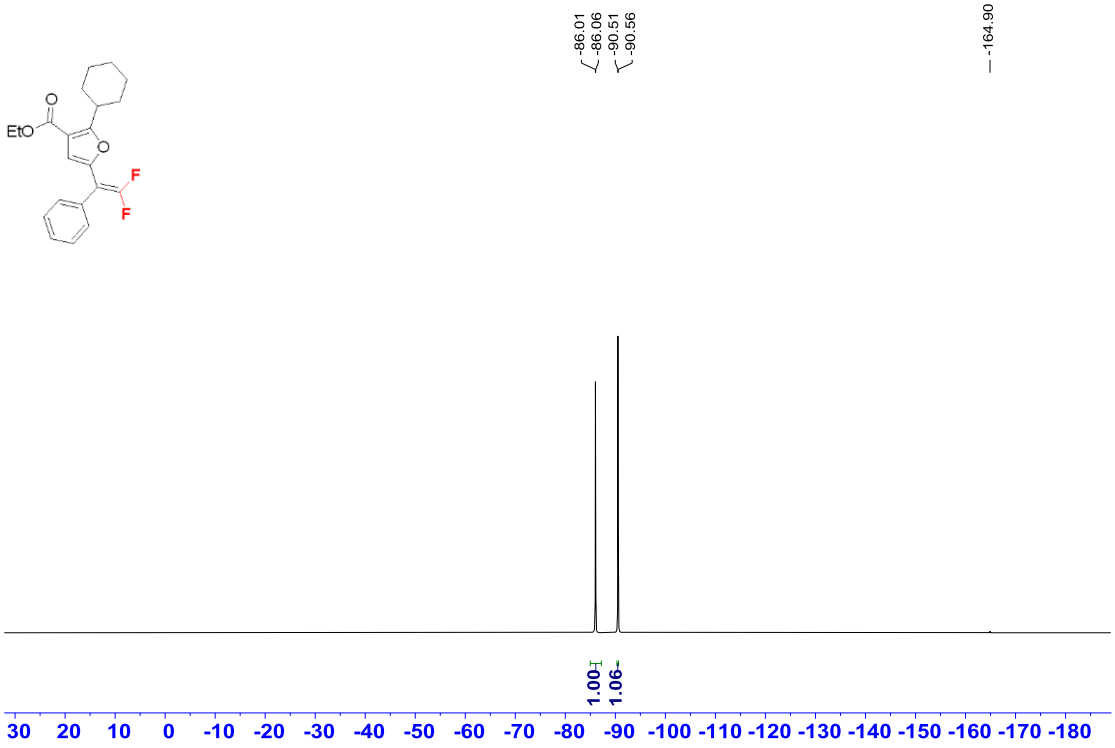
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **26.**



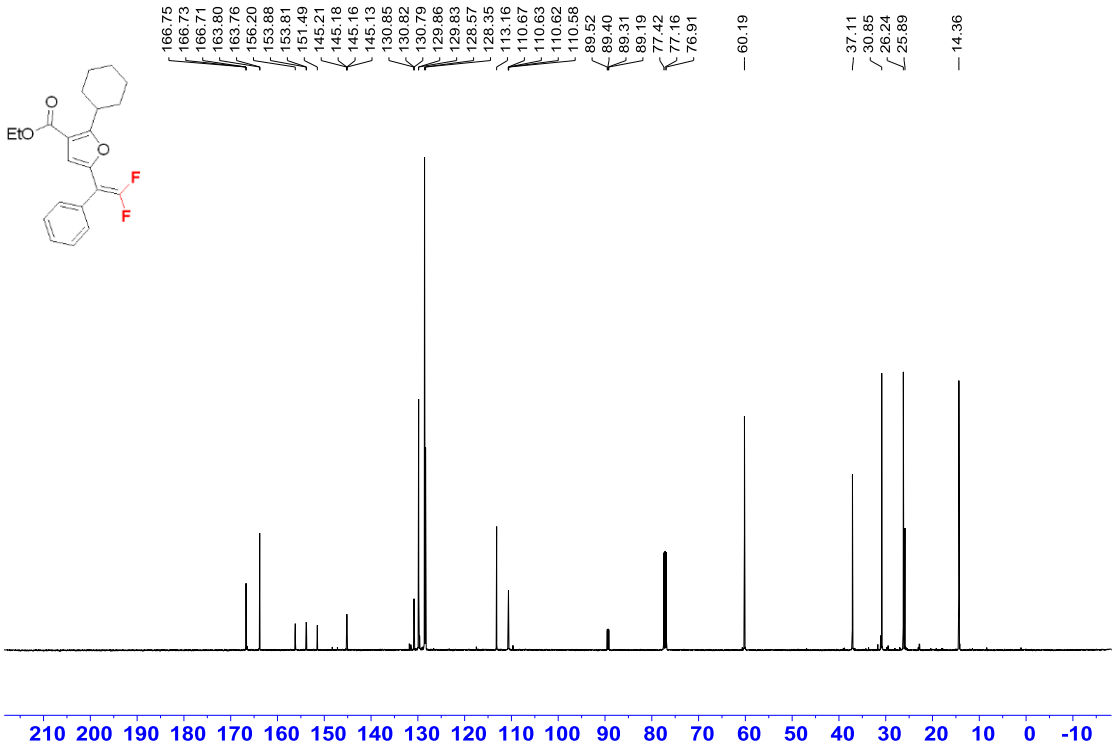
^{1}H NMR (500 MHz, $CDCl_3$) spectrum of compound **27.**



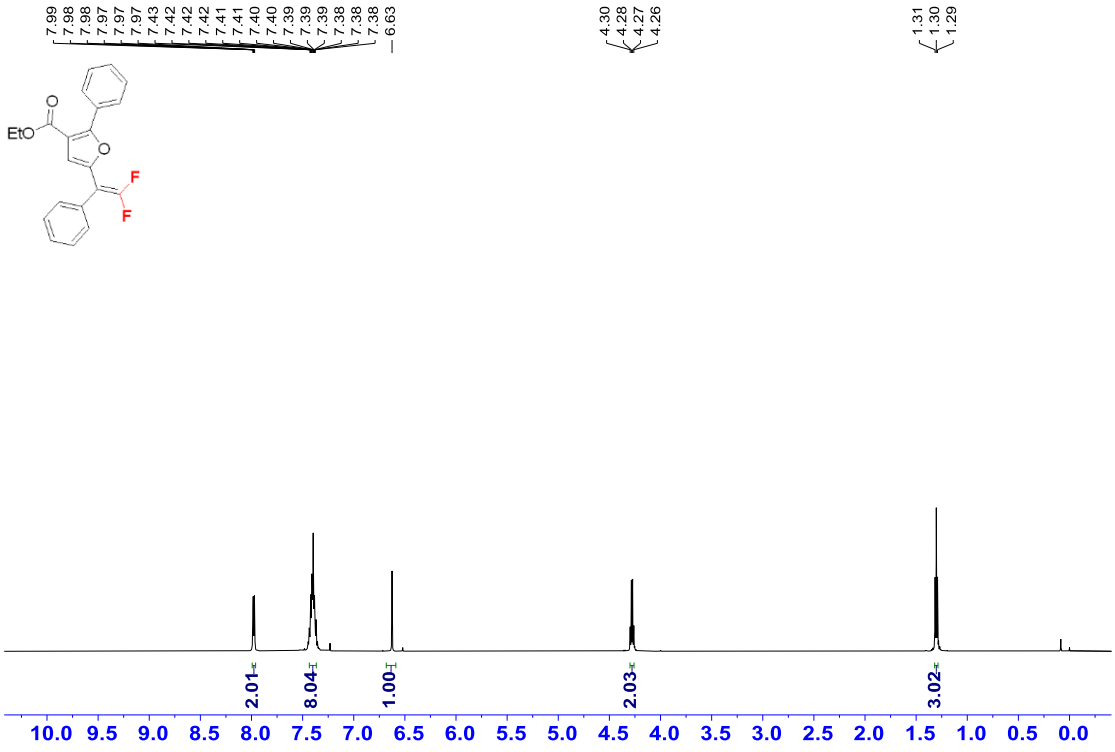
^{19}F NMR (471 MHz, $CDCl_3$) spectrum of compound **27.**



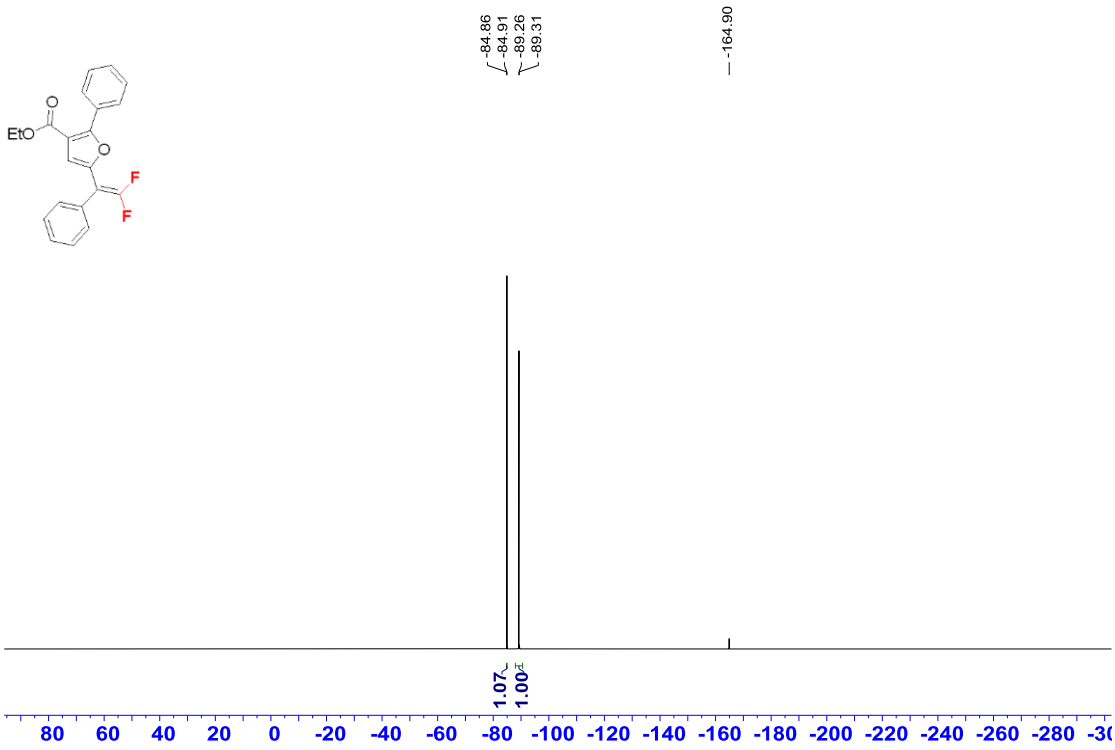
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **27.**



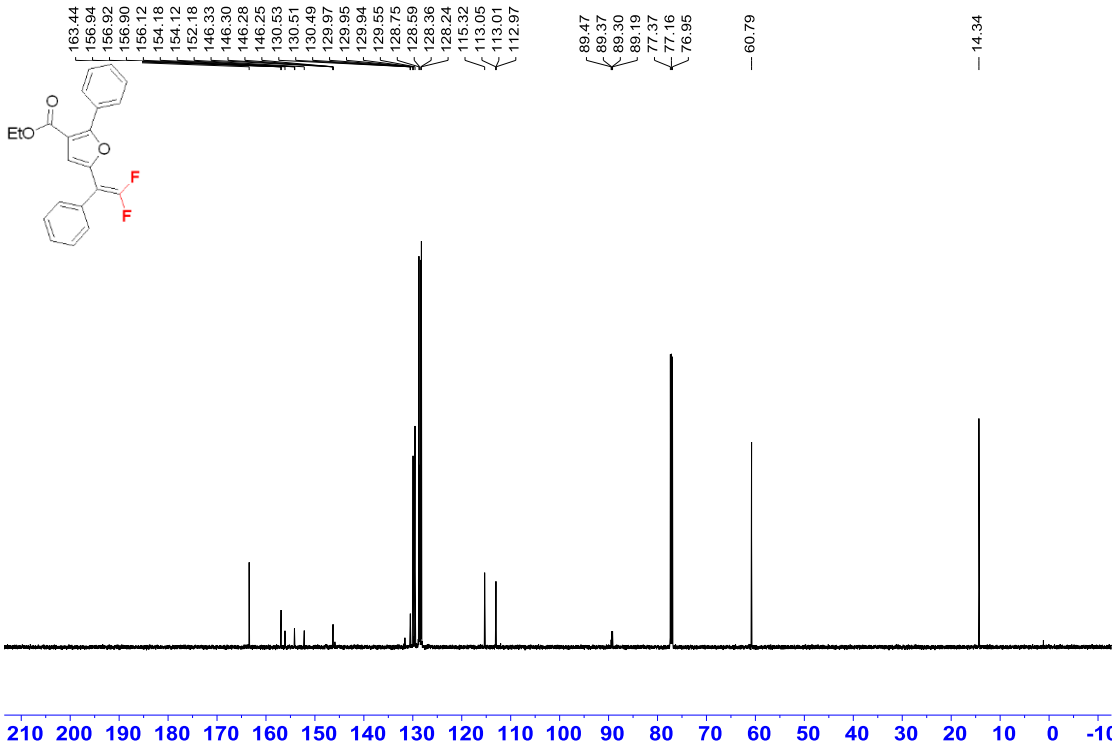
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **28.**



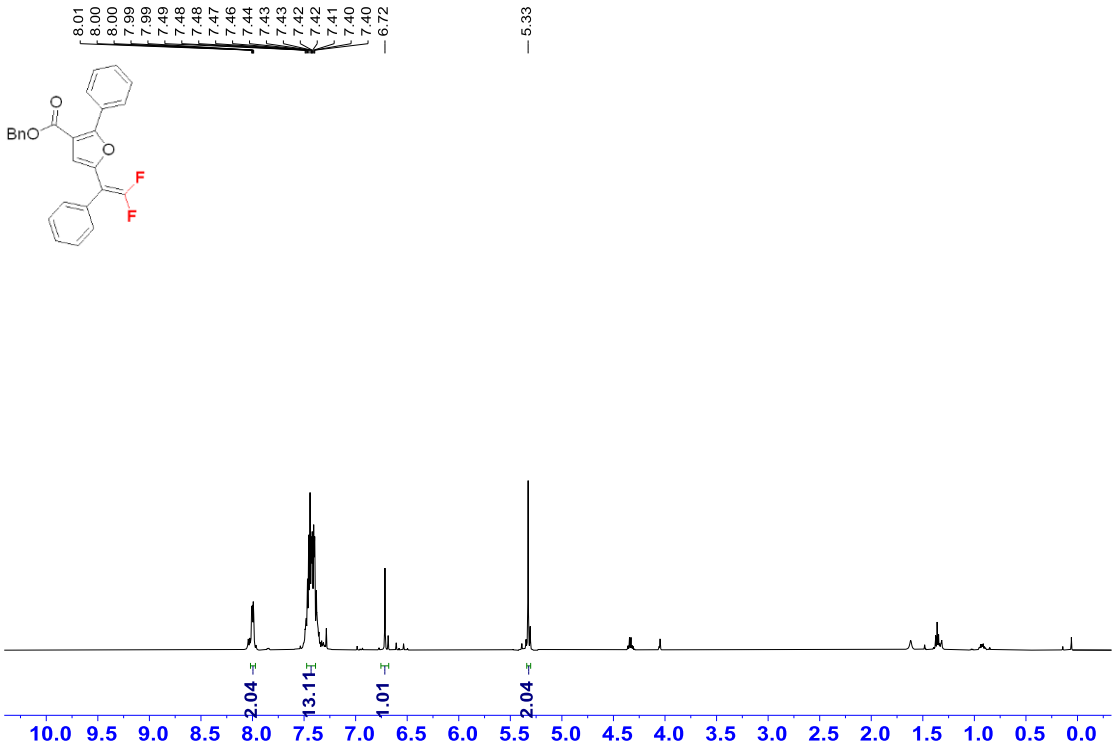
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **28.**



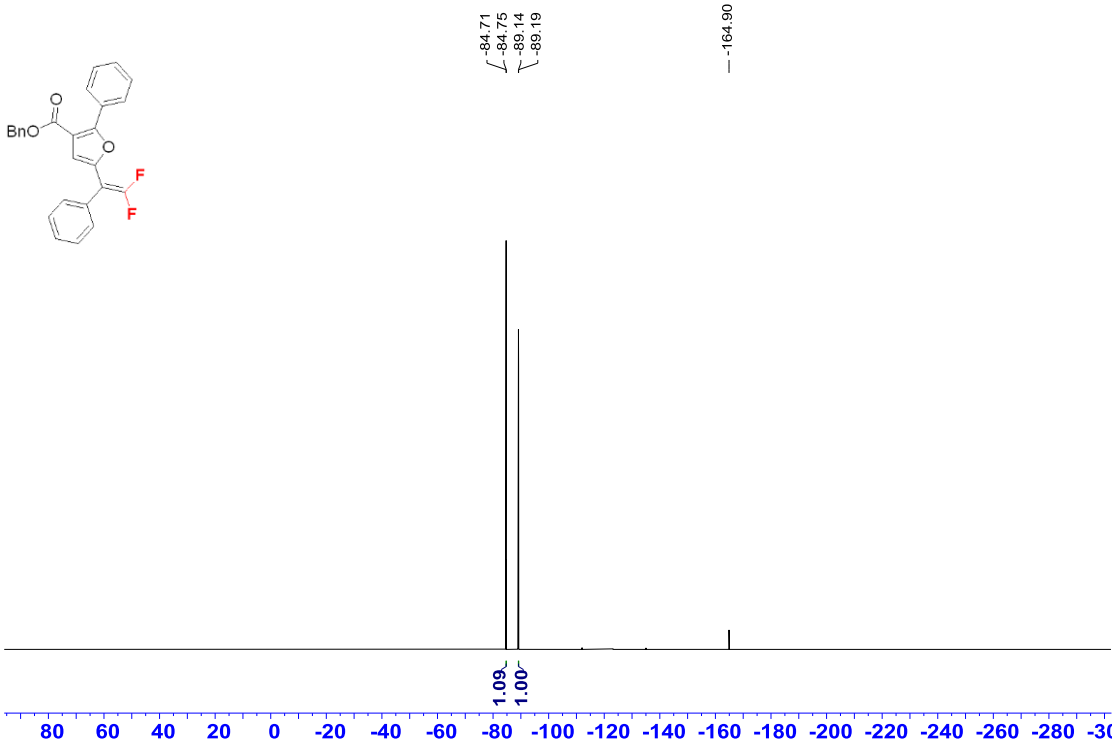
^{13}C NMR (151 MHz, $CDCl_3$) spectrum of compound **28.**



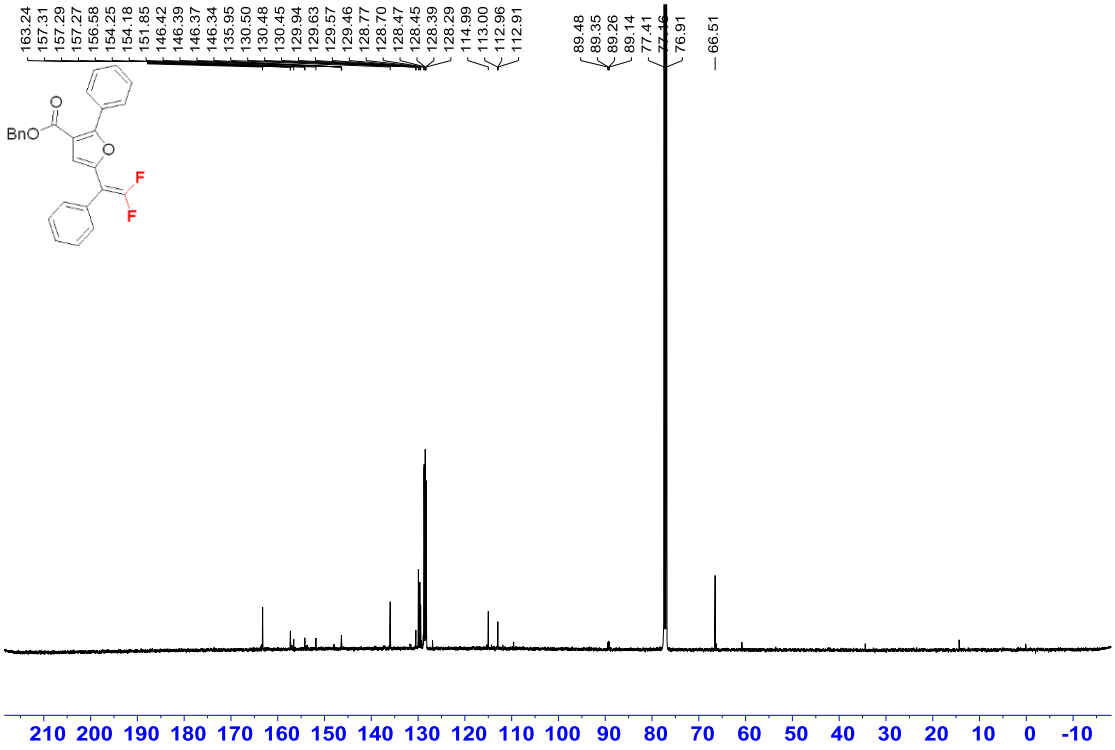
^{1}H NMR (500 MHz, $CDCl_3$) spectrum of compound **29**.



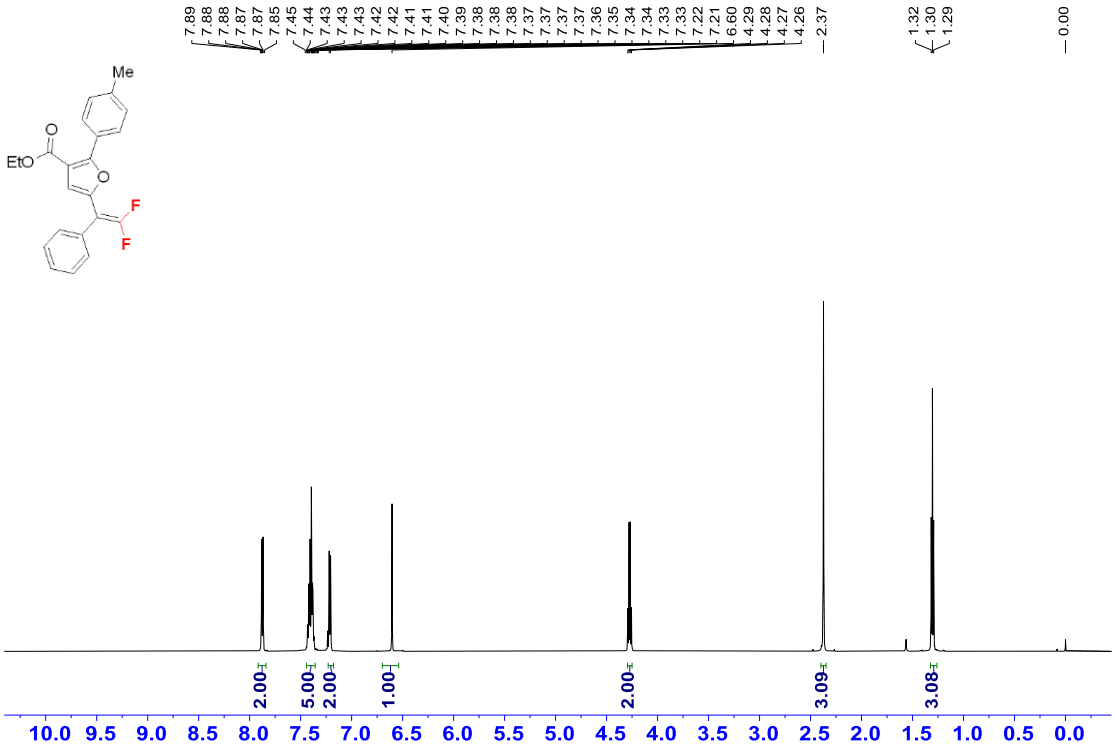
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **29**.



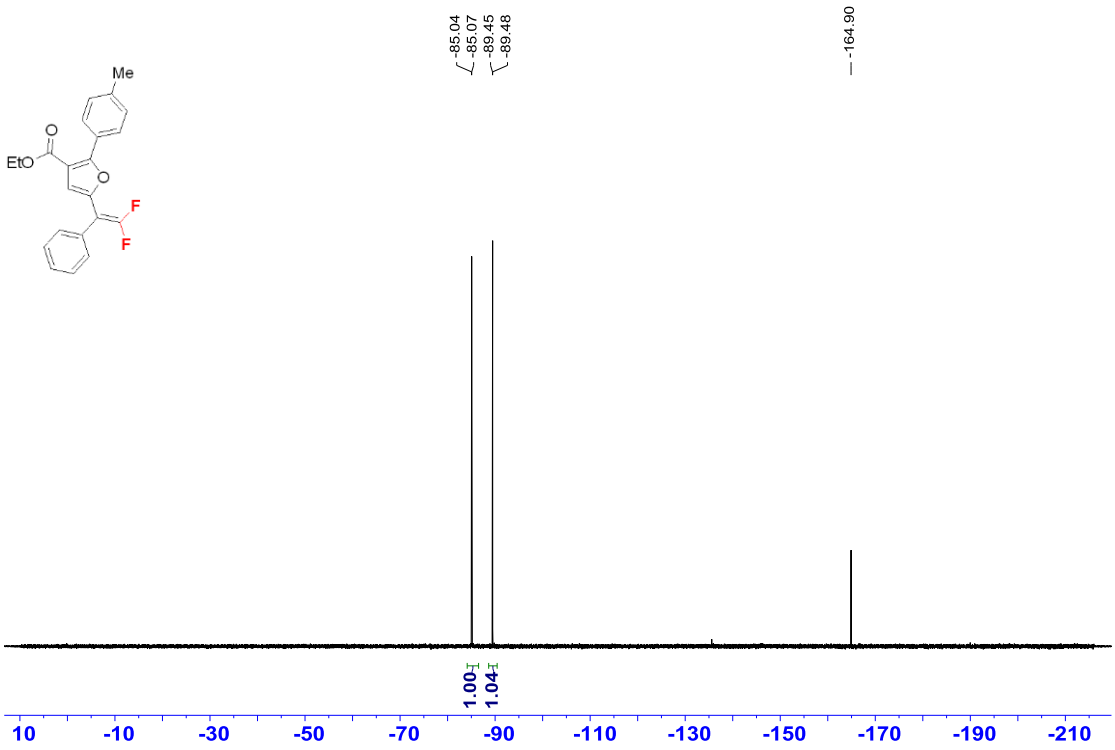
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **29**.



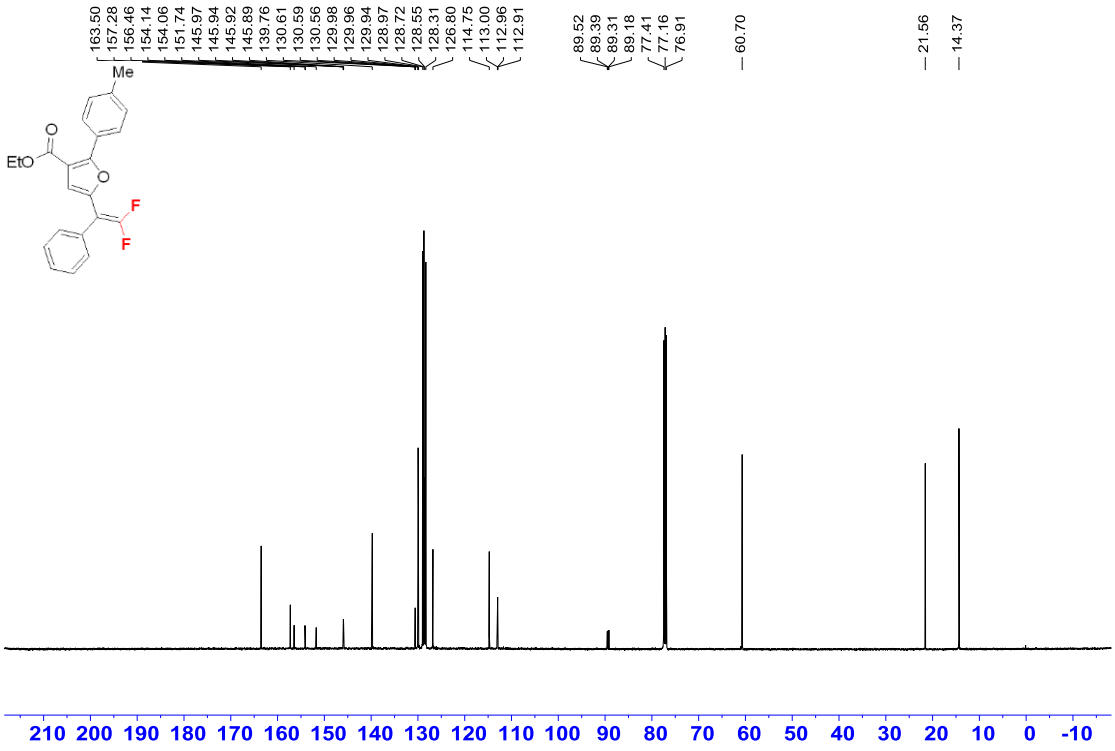
^{1}H NMR (600 MHz, $CDCl_3$) spectrum of compound **30.**



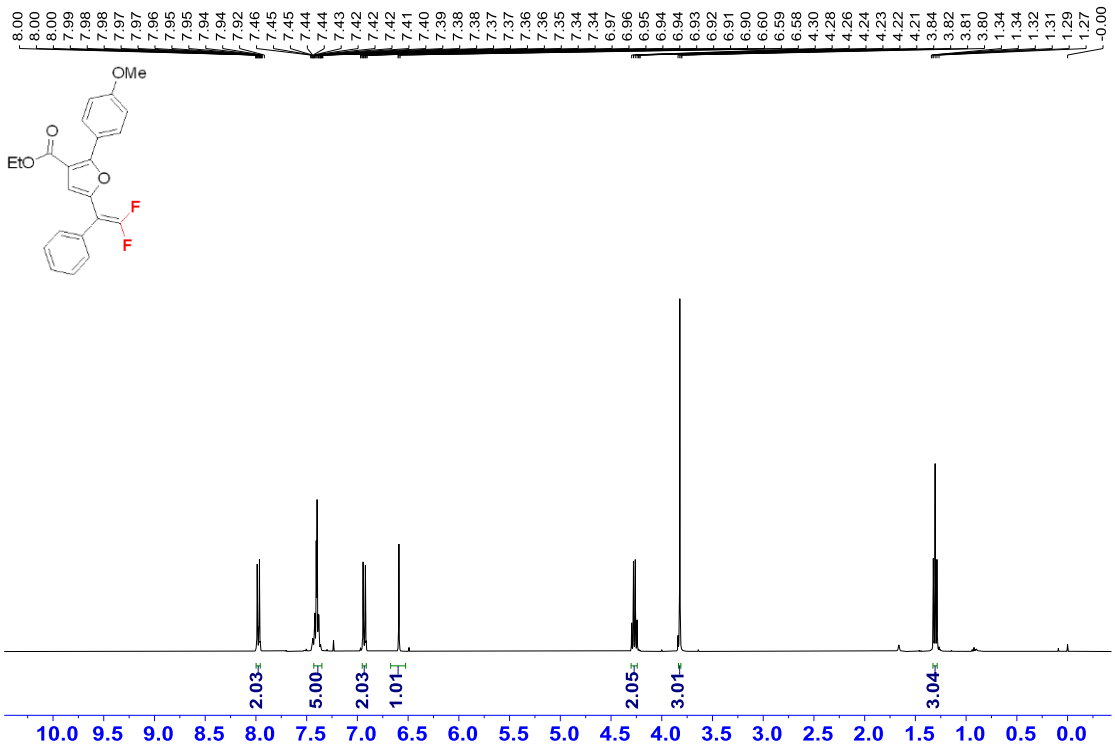
^{19}F NMR (565 MHz, $CDCl_3$) spectrum of compound **30**.



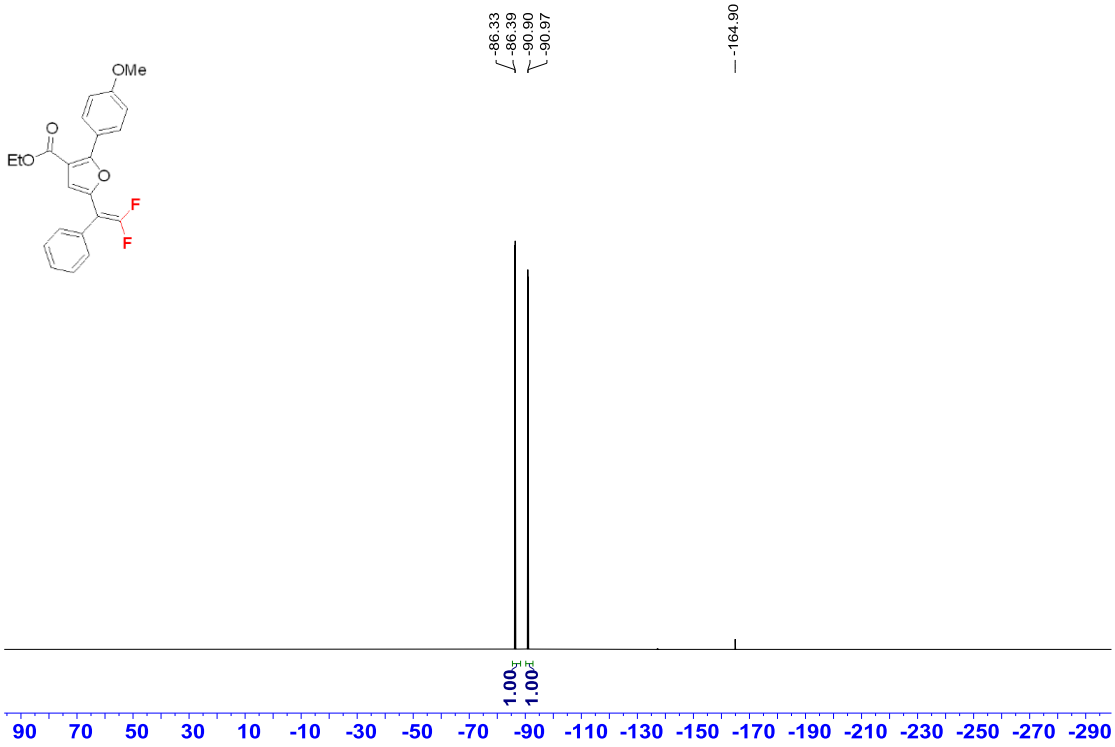
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **30**.



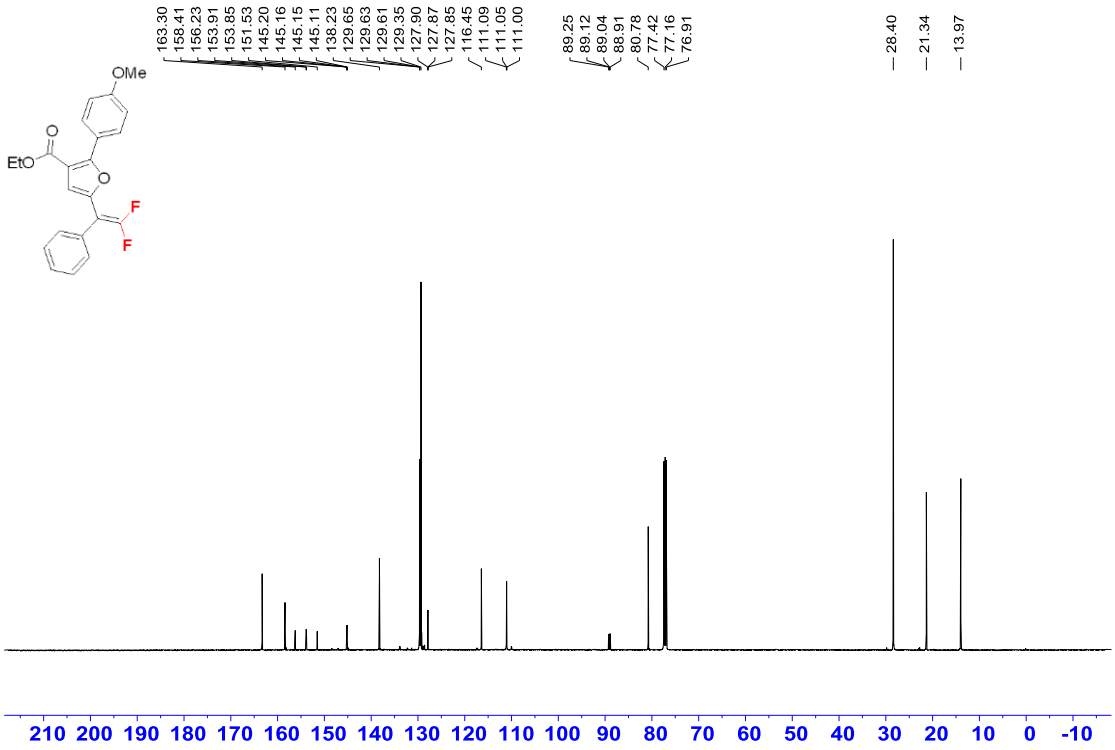
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **31**.



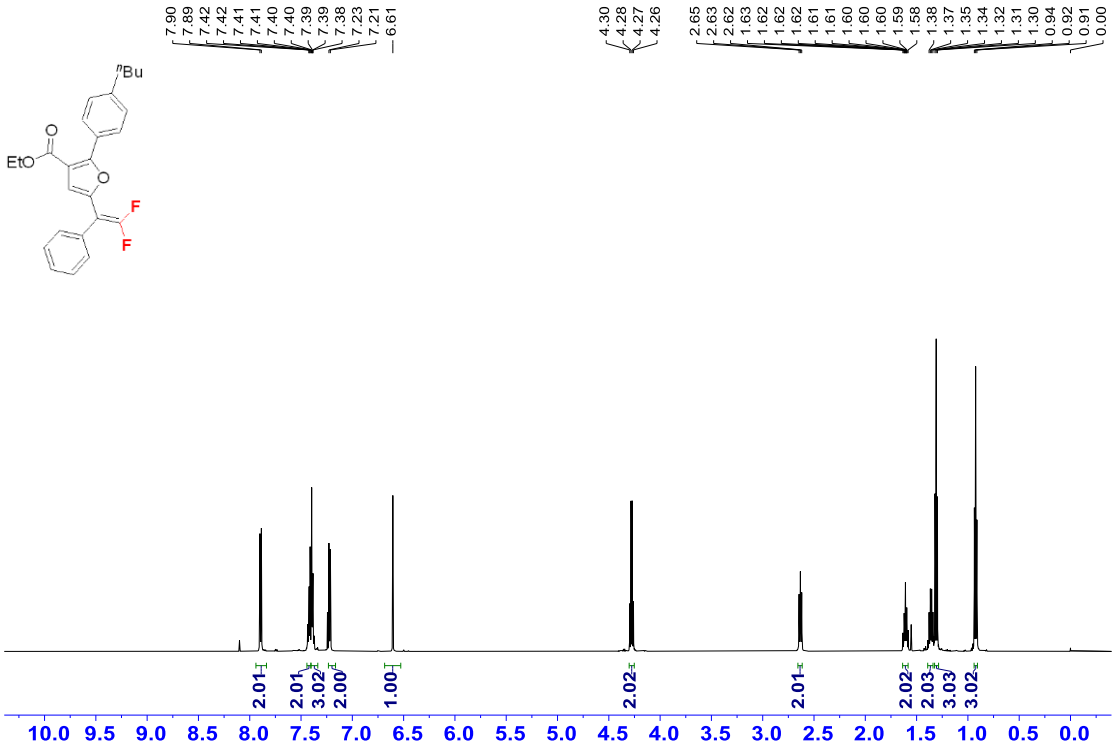
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **31**.



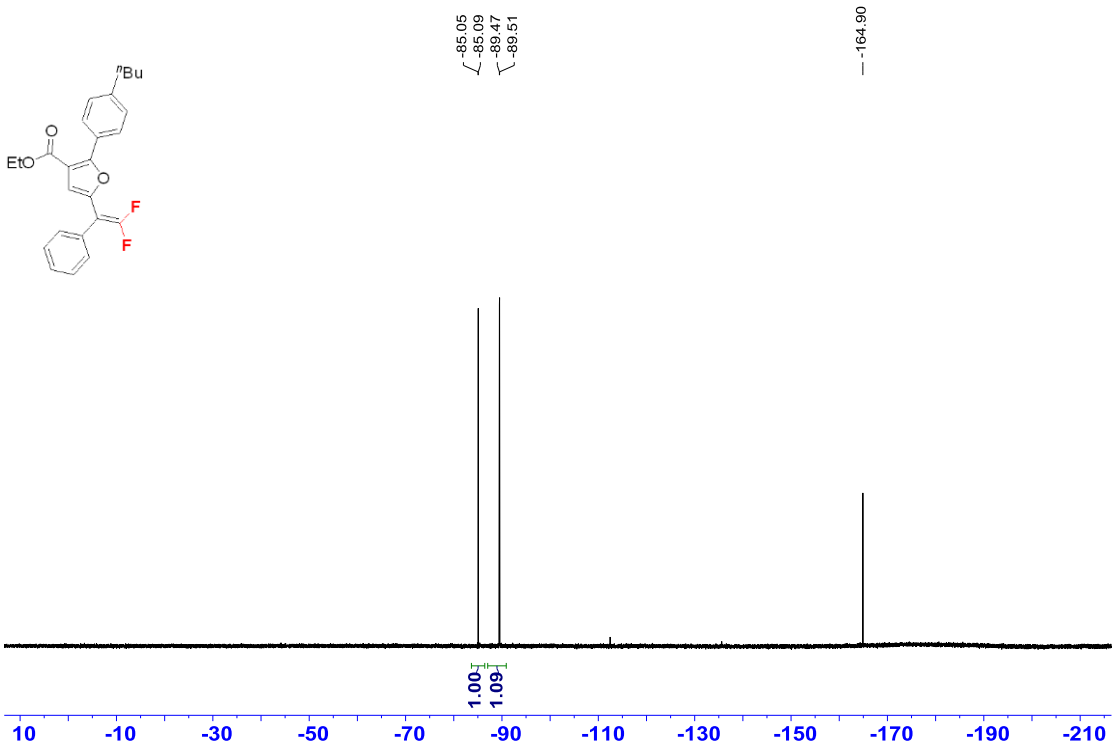
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **31**.



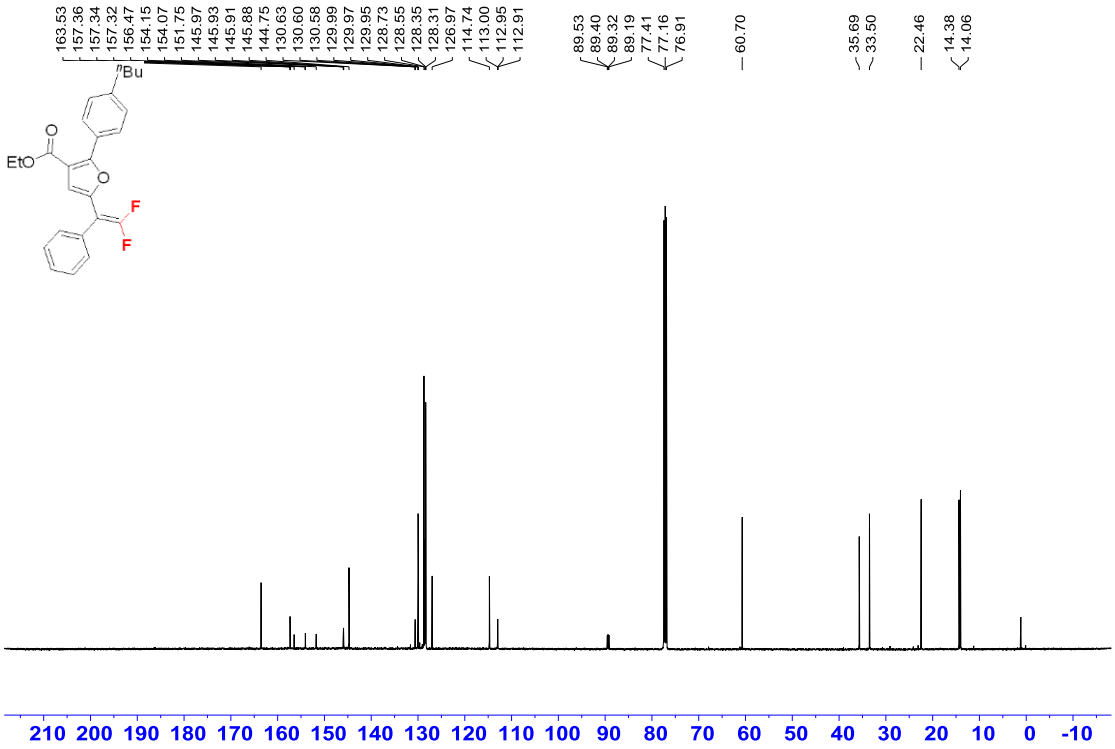
^{1}H NMR (600 MHz, $CDCl_3$) spectrum of compound **32**.



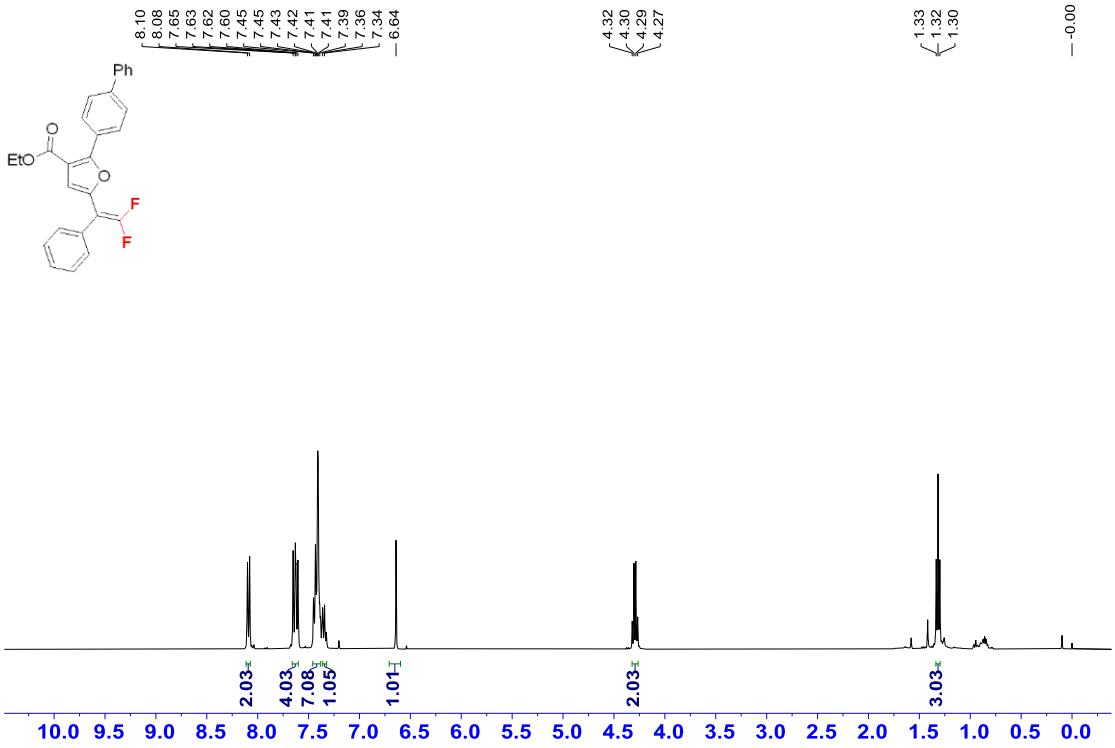
^{19}F NMR (565 MHz, $CDCl_3$) spectrum of compound **32**.



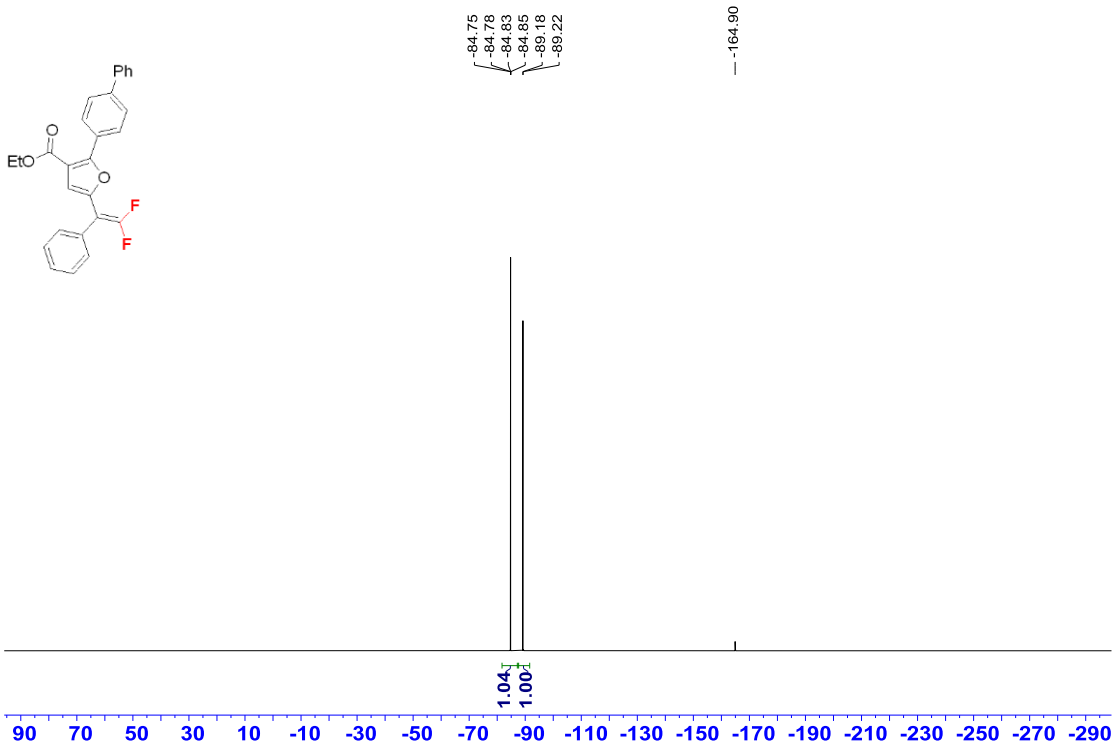
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **32**.



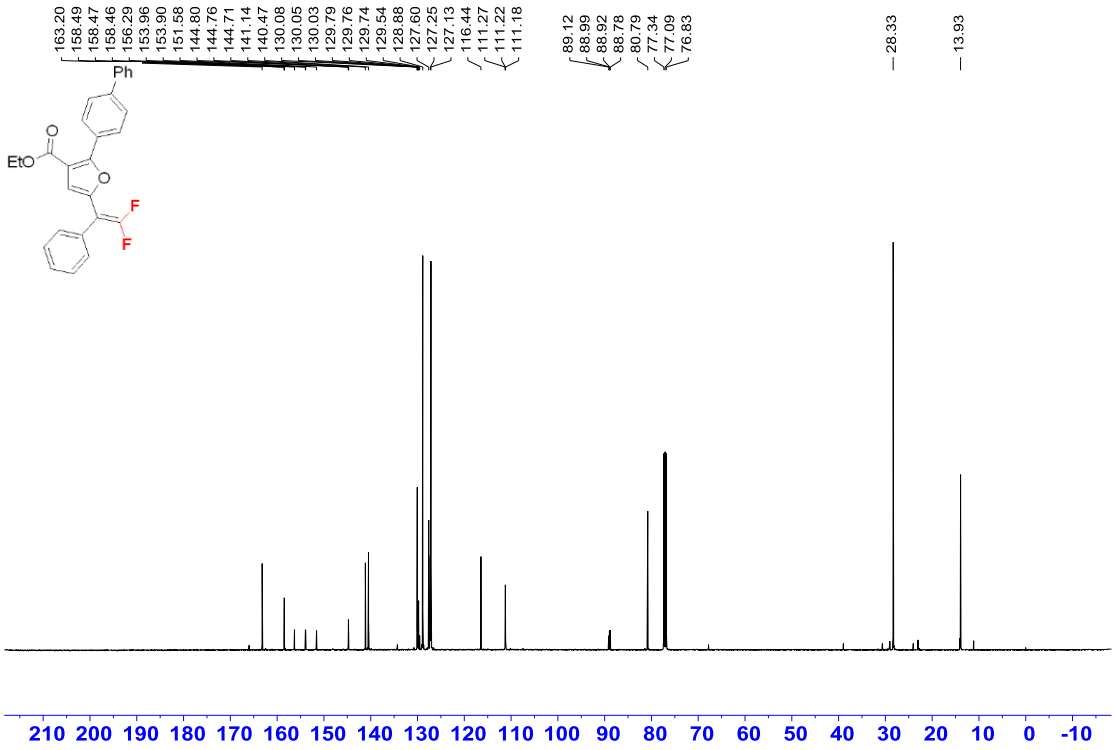
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **33**.



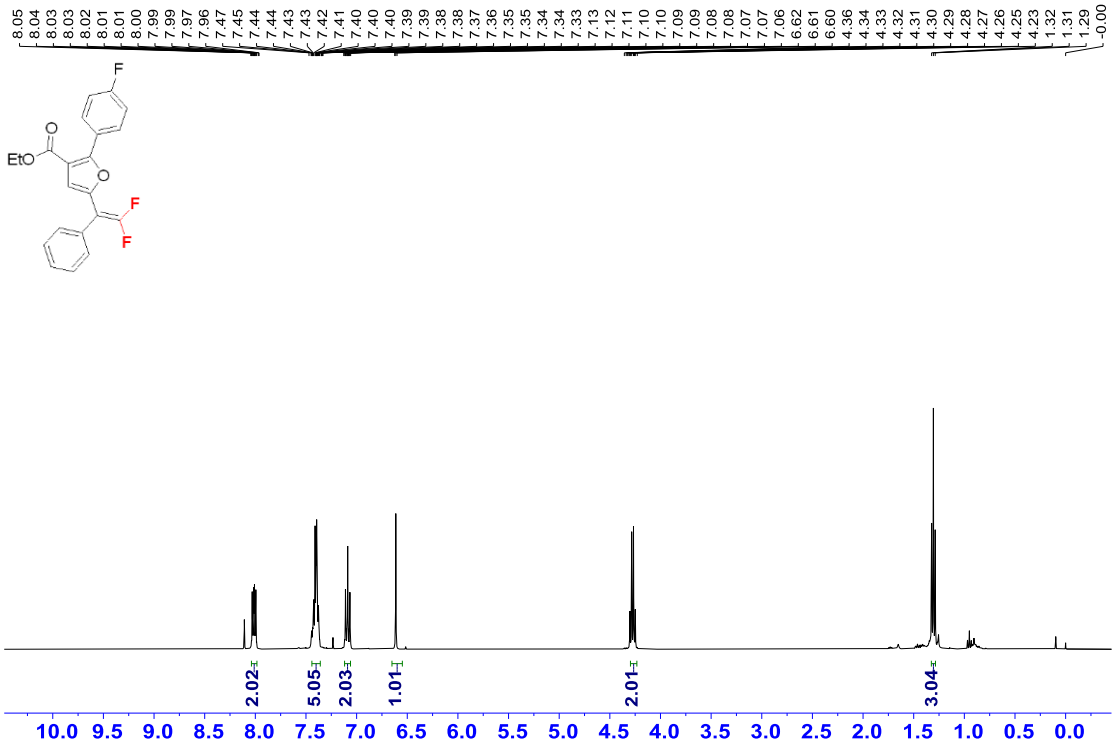
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **33**.



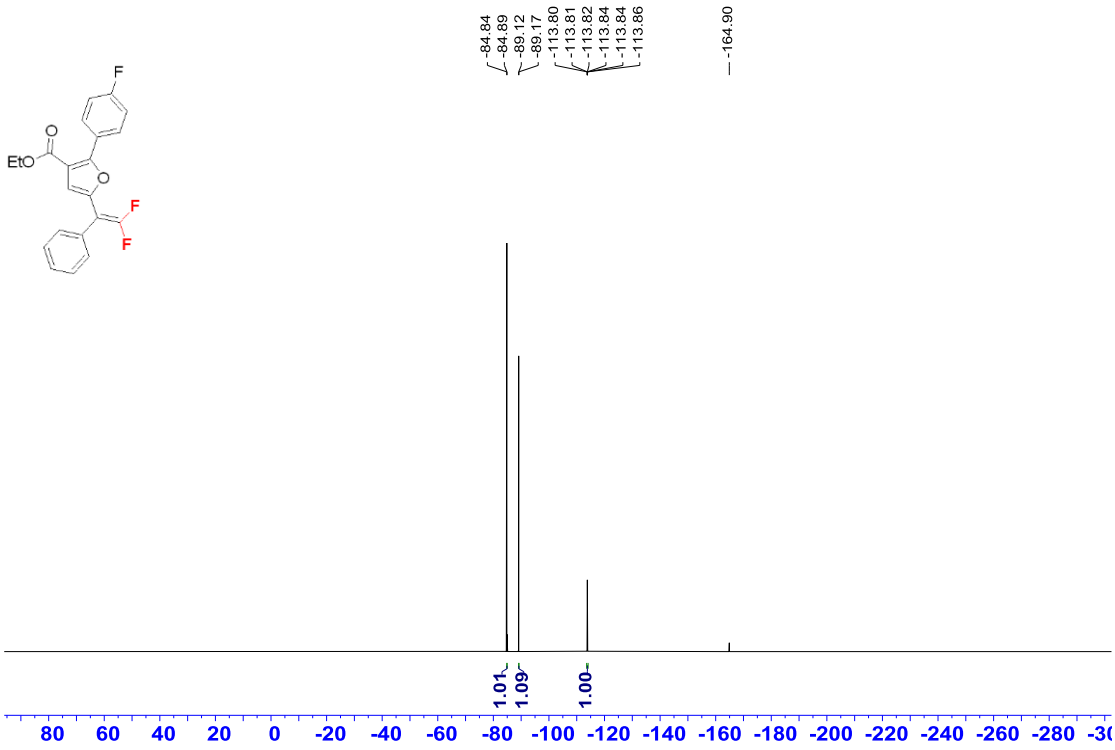
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **33**.



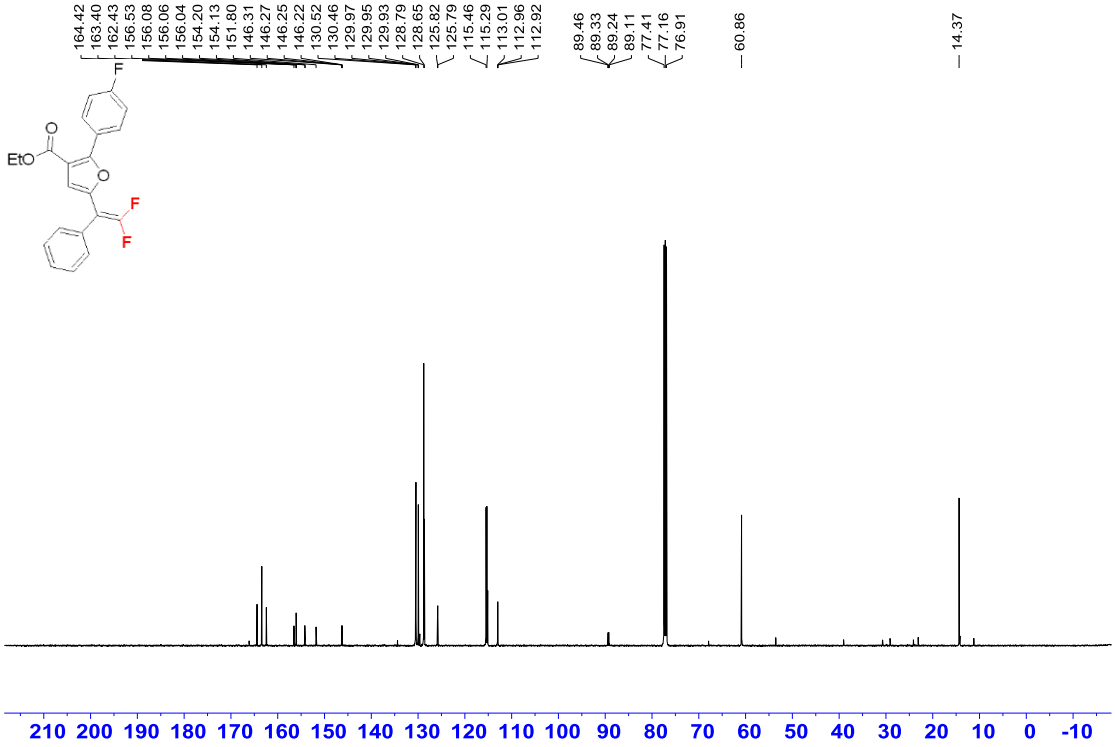
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **34**.



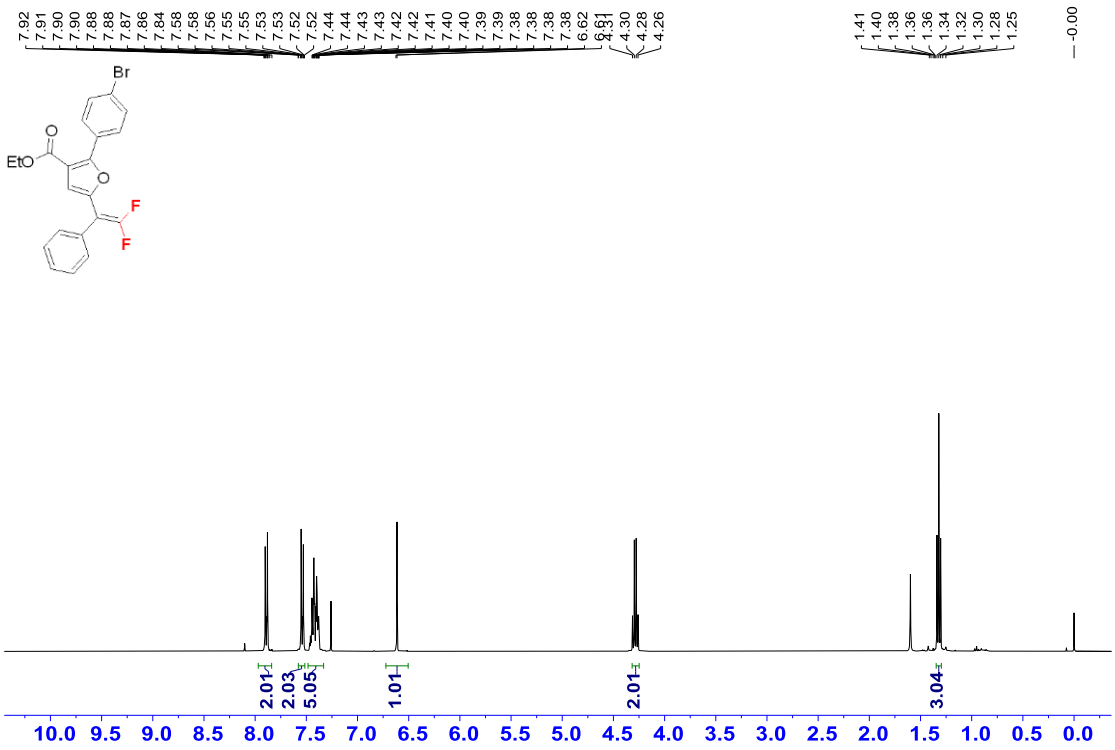
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **34**.



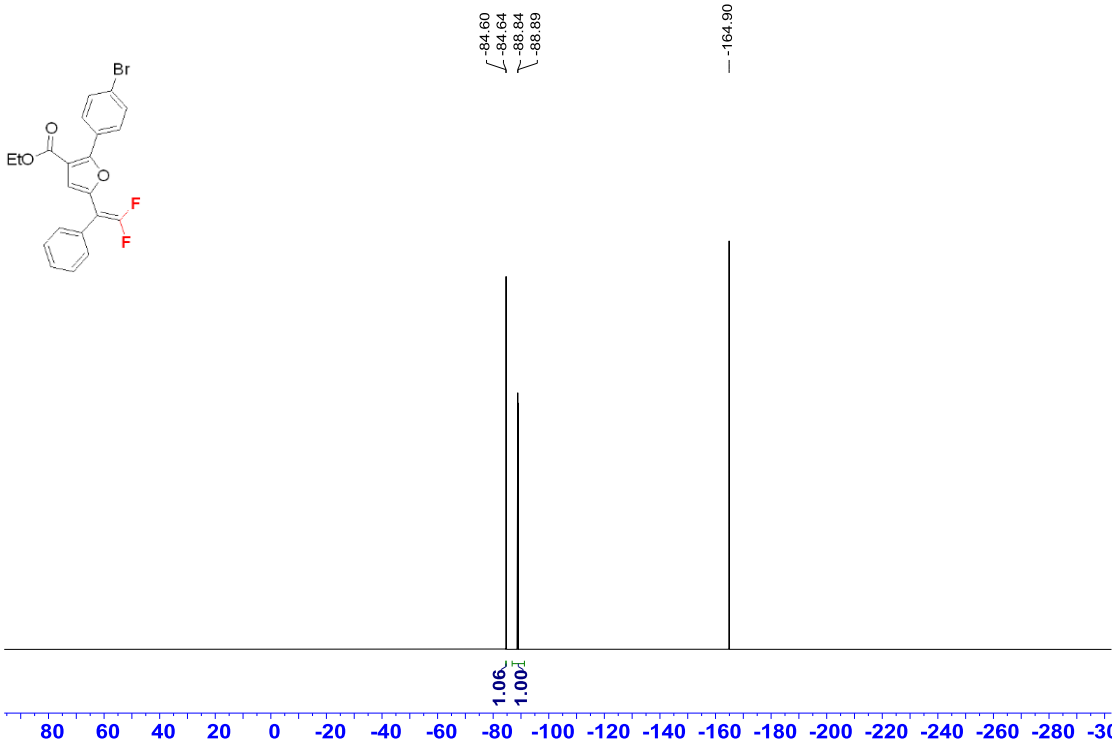
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **34.**



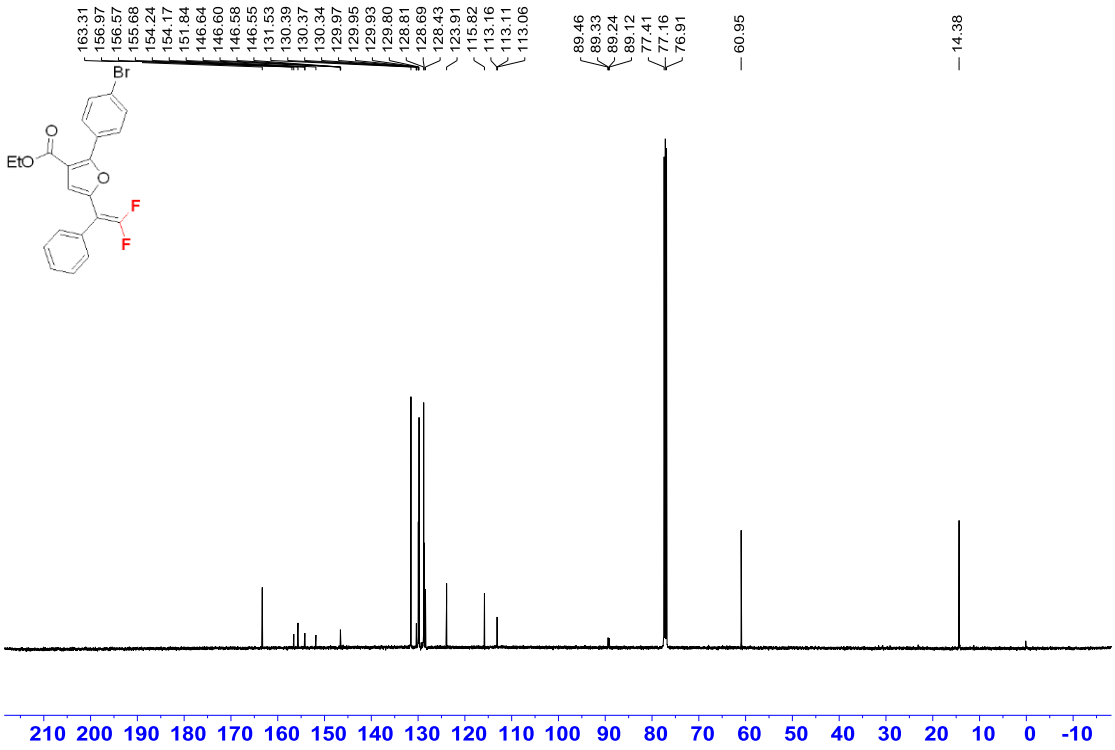
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **35.**



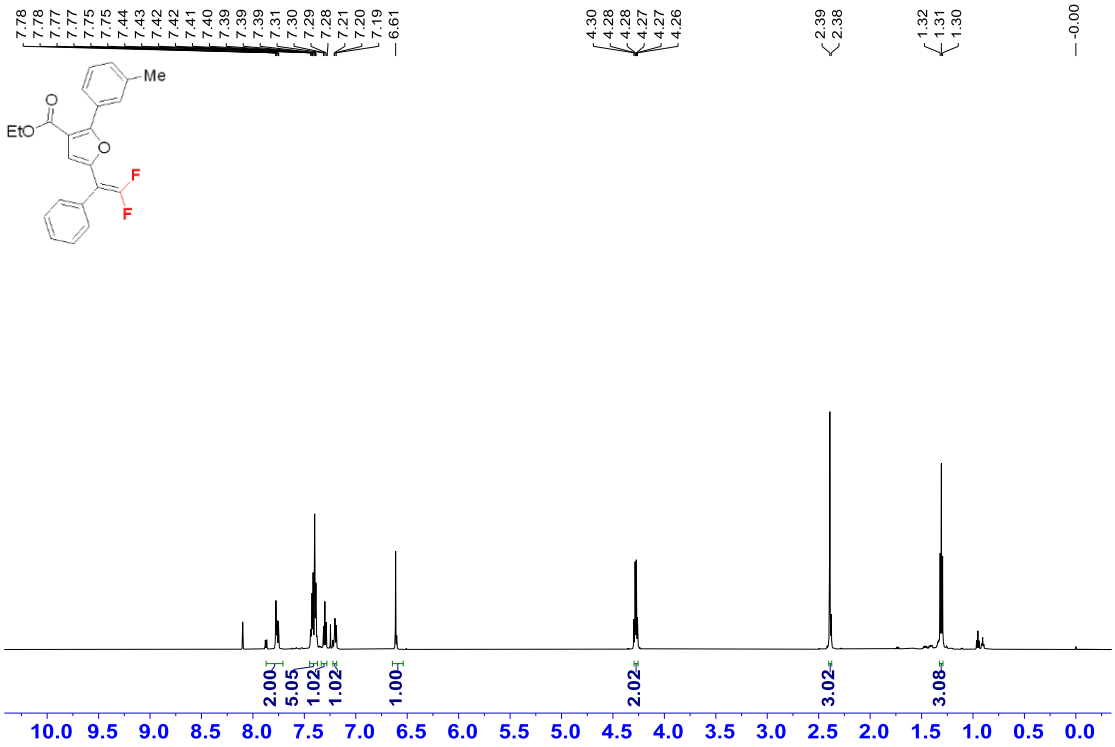
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **35**.



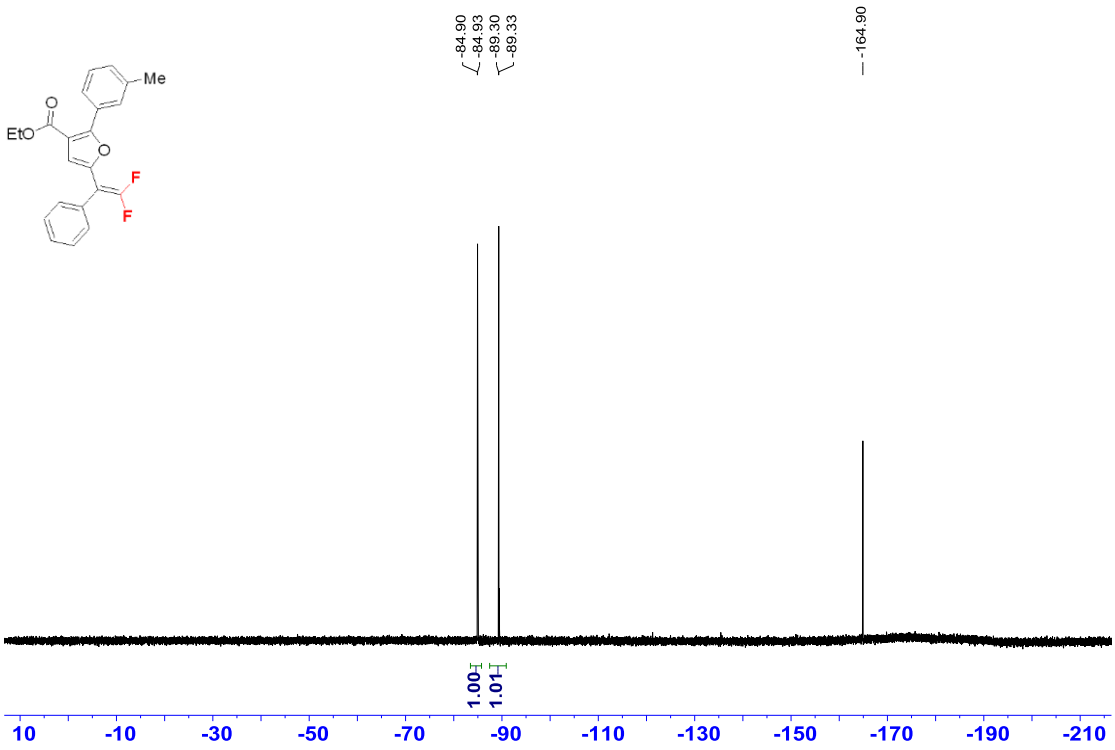
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **35.**



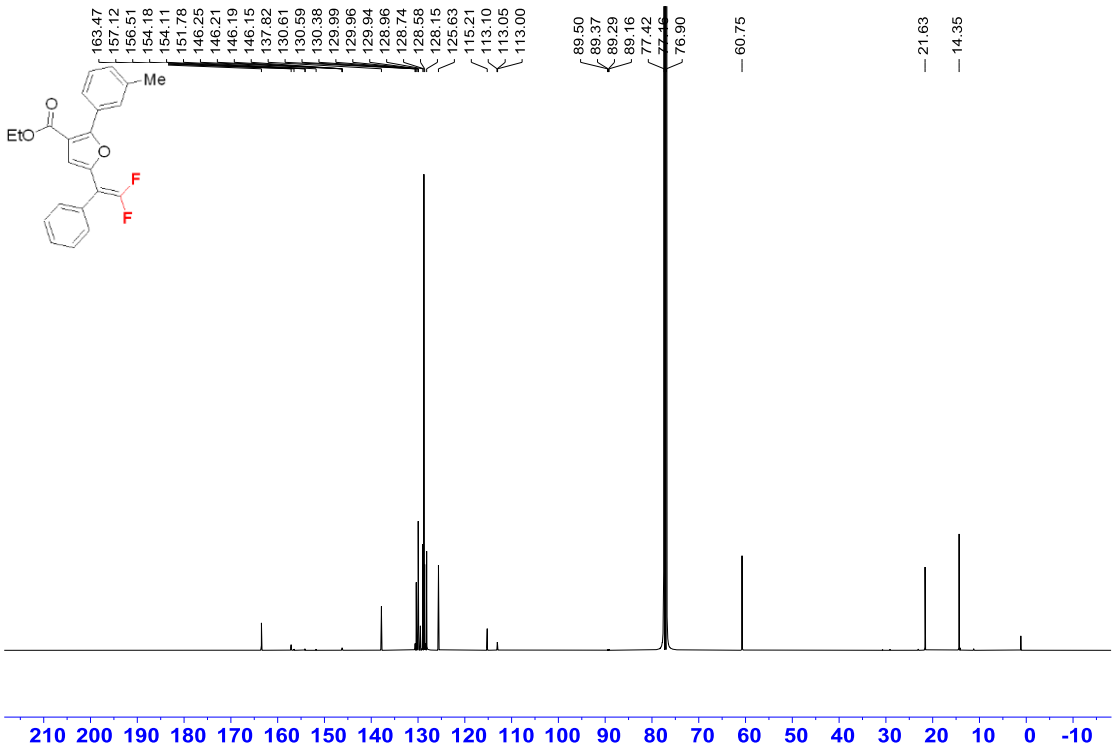
^{1}H NMR (600 MHz, $CDCl_3$) spectrum of compound **36.**



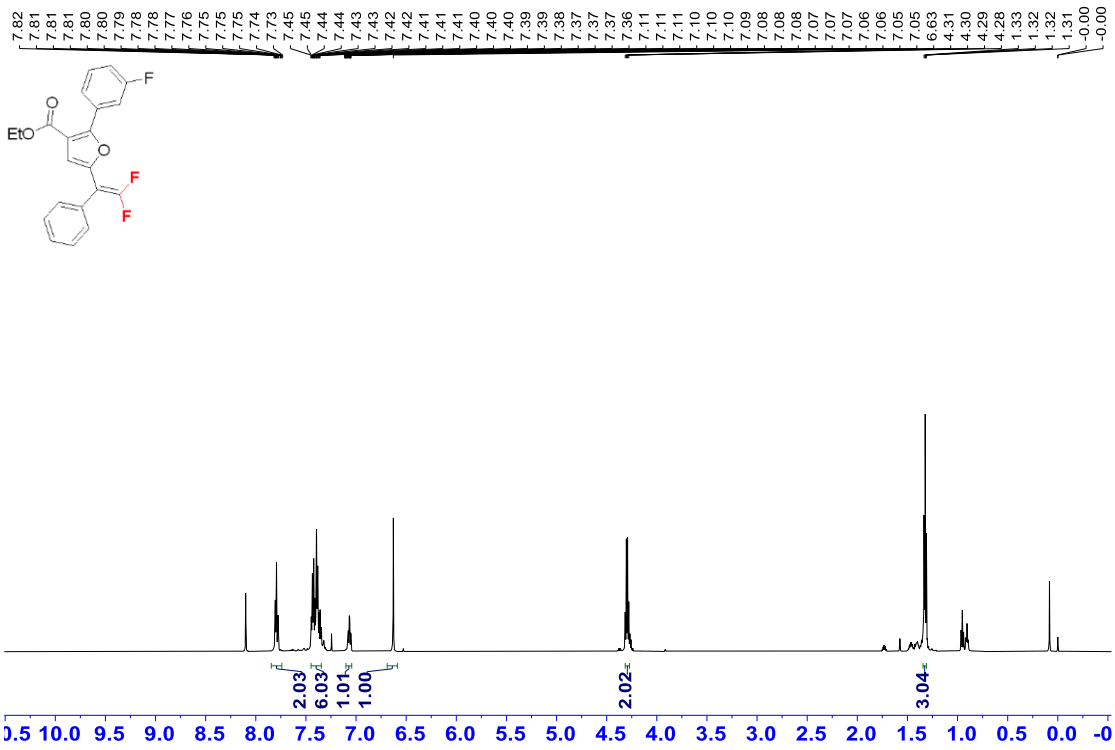
^{19}F NMR (565 MHz, $CDCl_3$) spectrum of compound **36.**



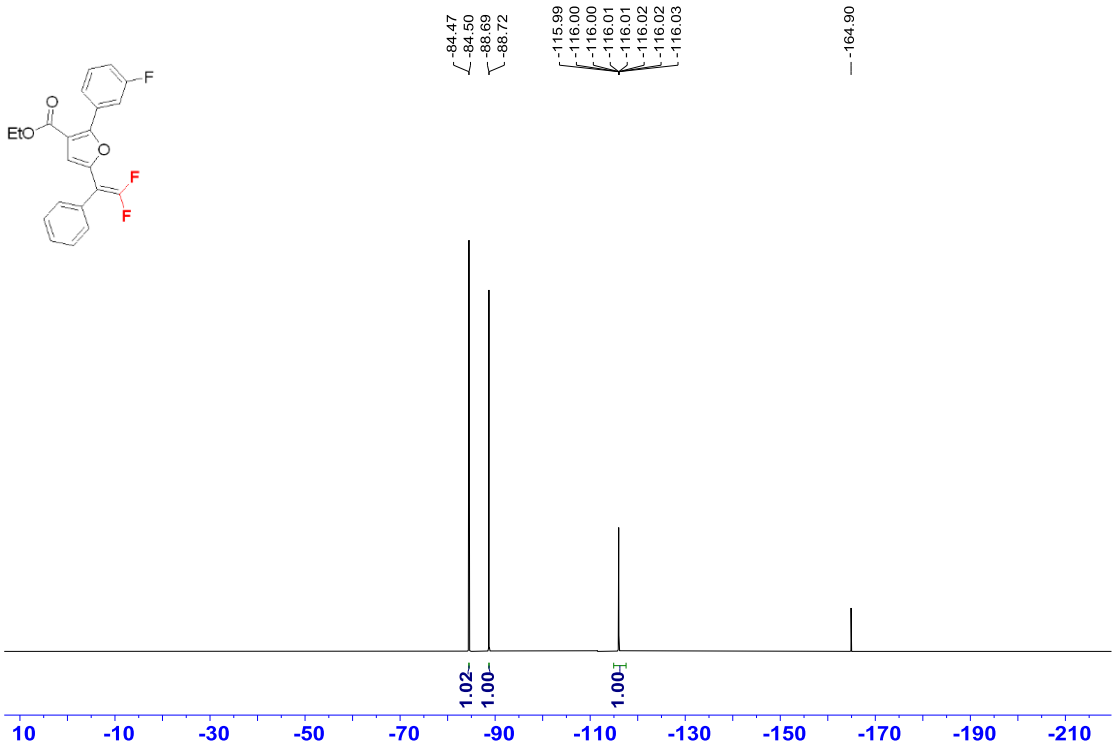
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **36.**



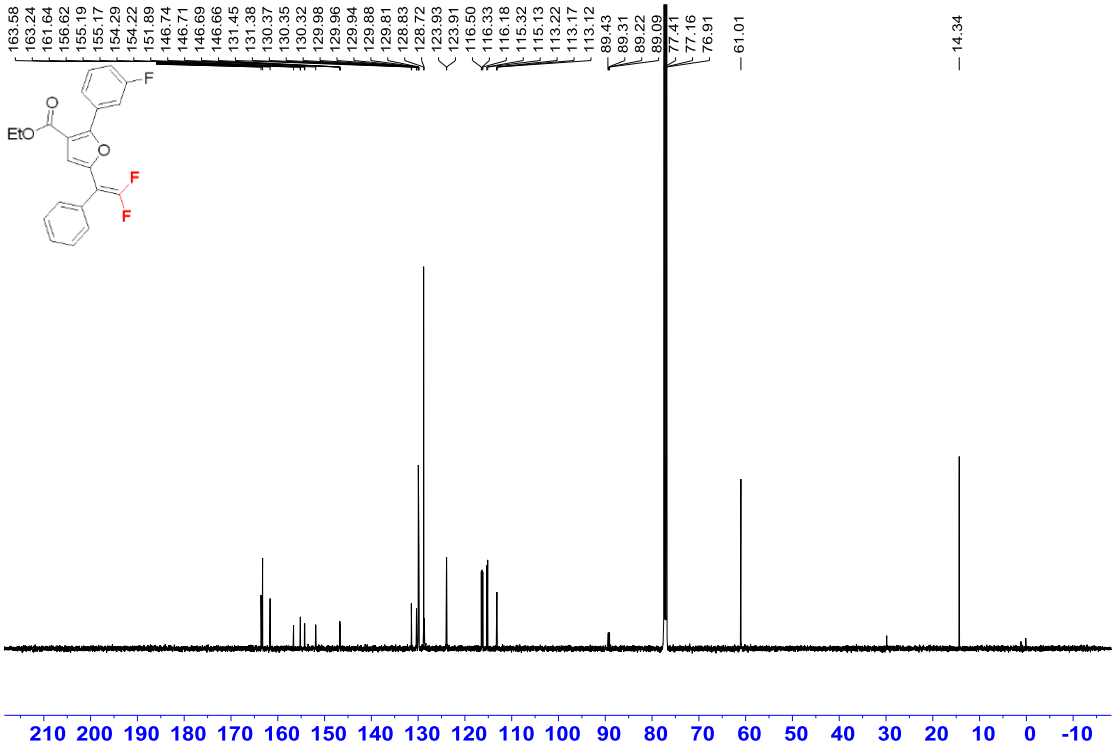
^{1}H NMR (600 MHz, $CDCl_3$) spectrum of compound **37.**



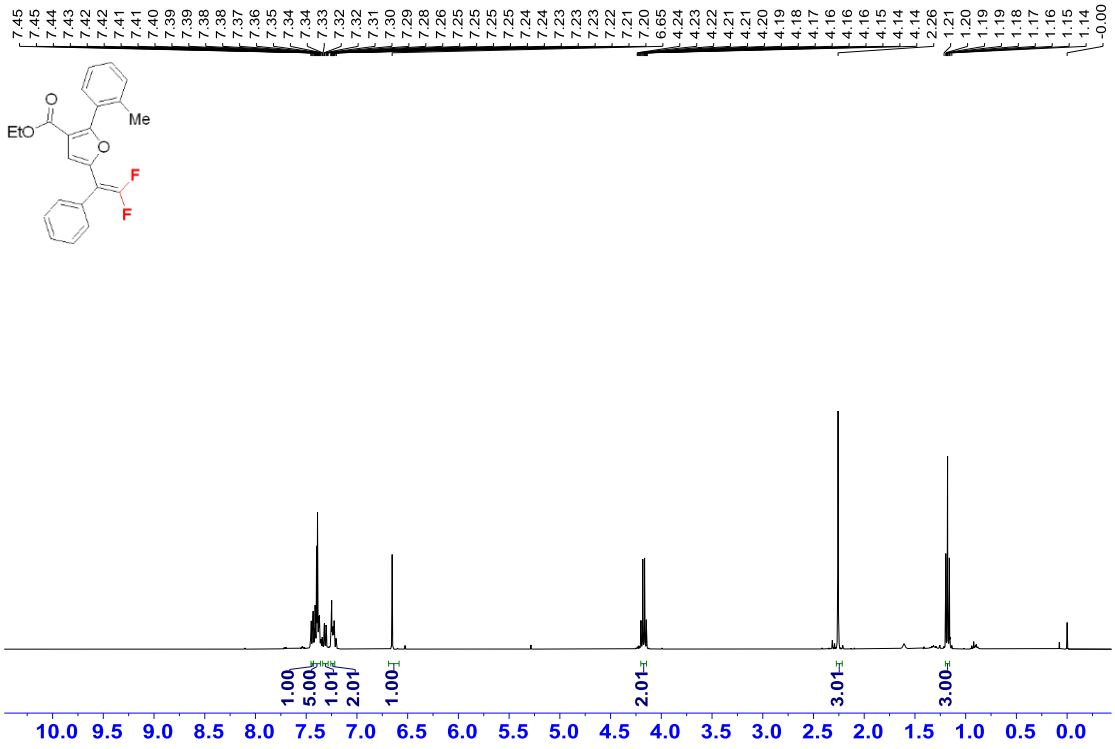
^{19}F NMR (565 MHz, $CDCl_3$) spectrum of compound **37.**



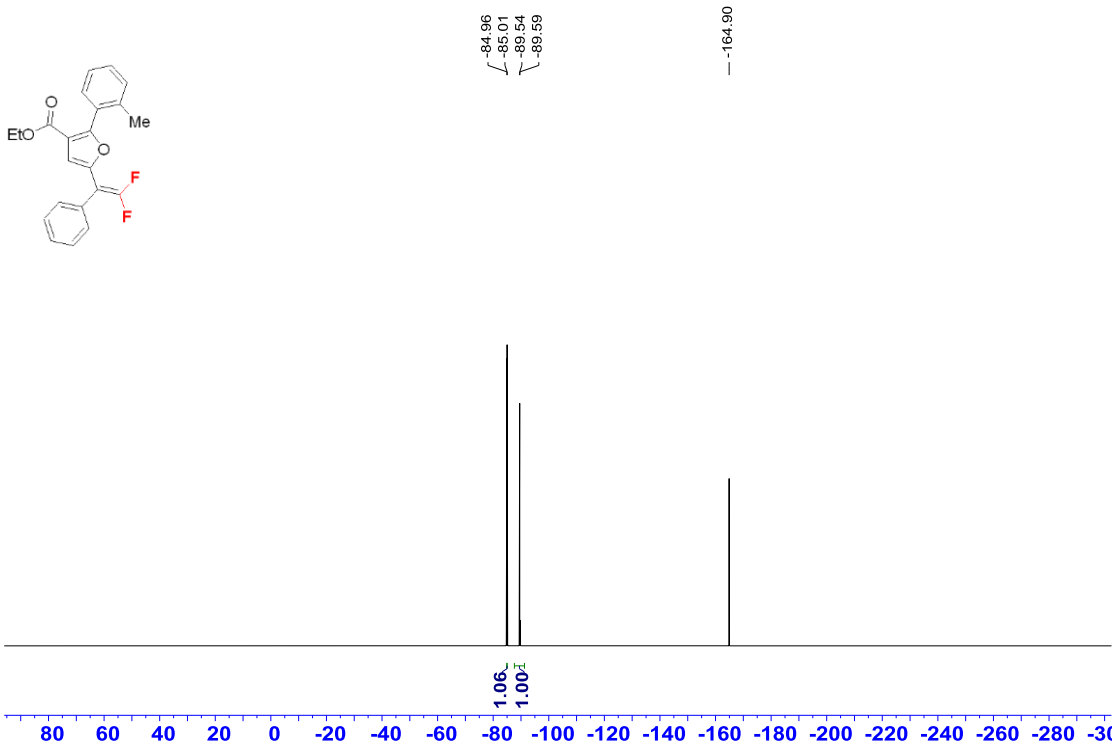
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **37.**



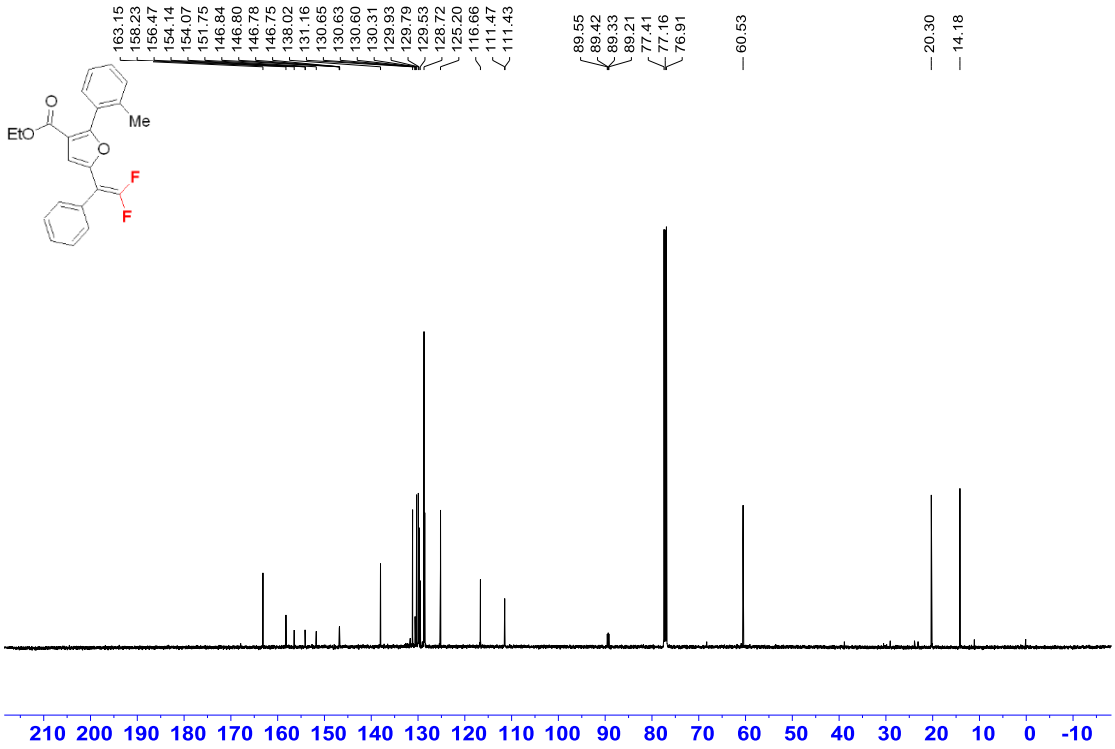
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **38.**



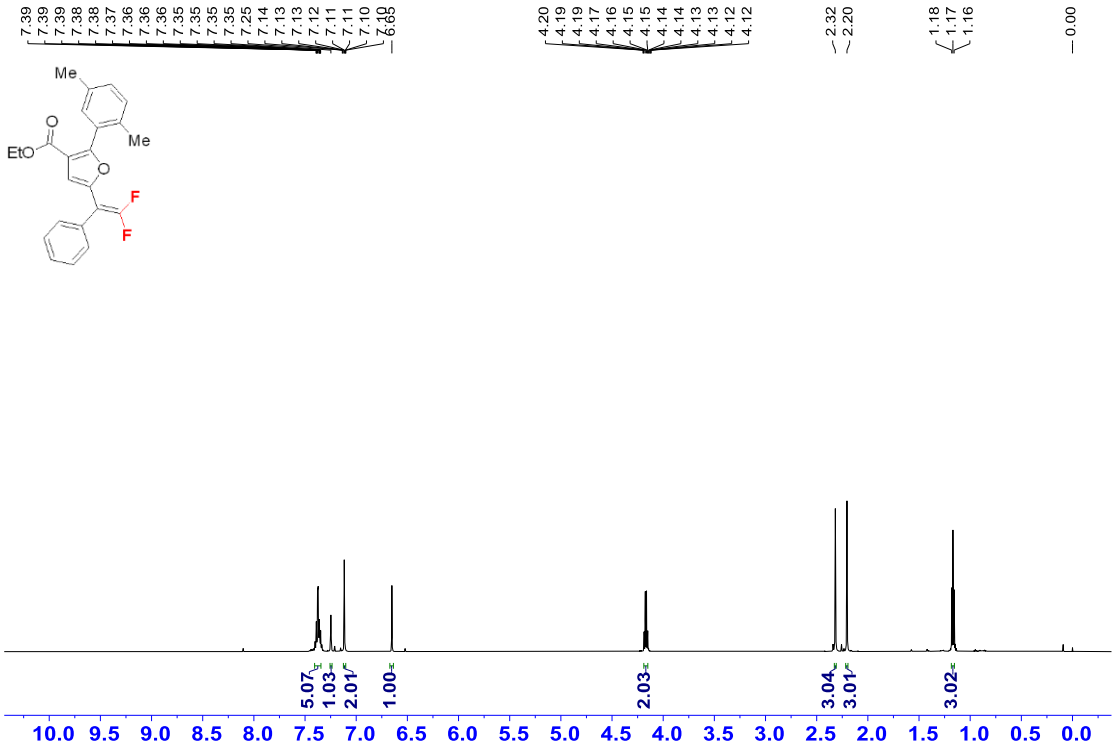
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **38.**



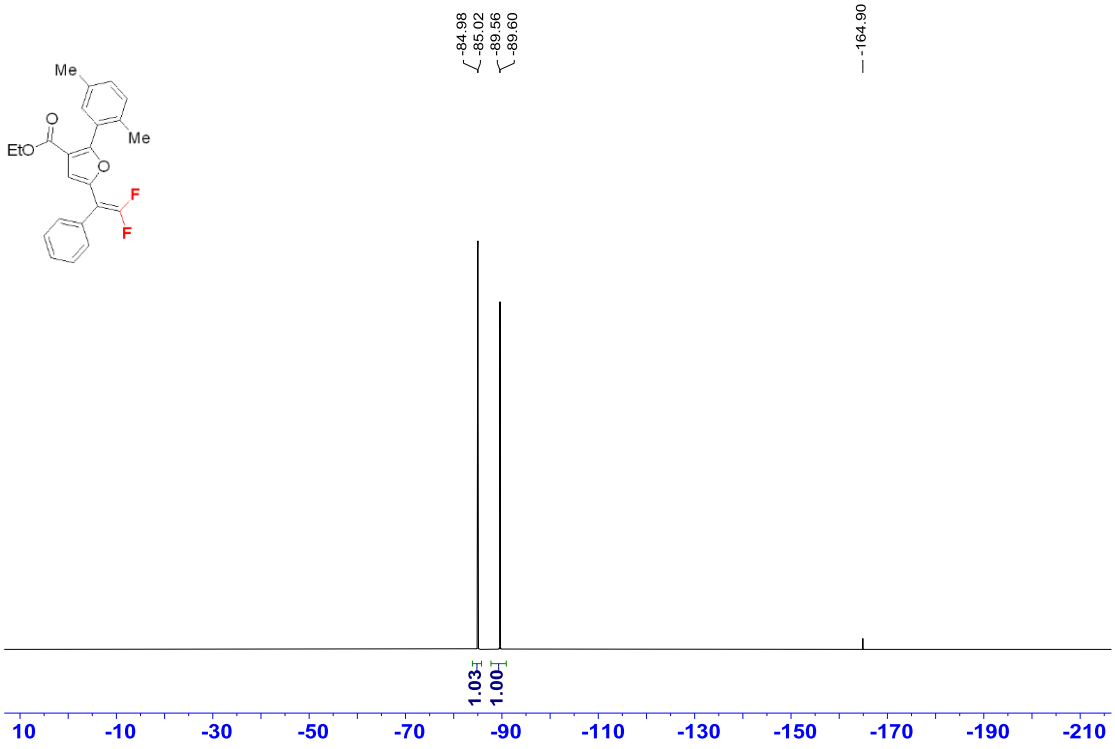
^{13}C NMR (101 MHz, $CDCl_3$) spectrum of compound **38.**



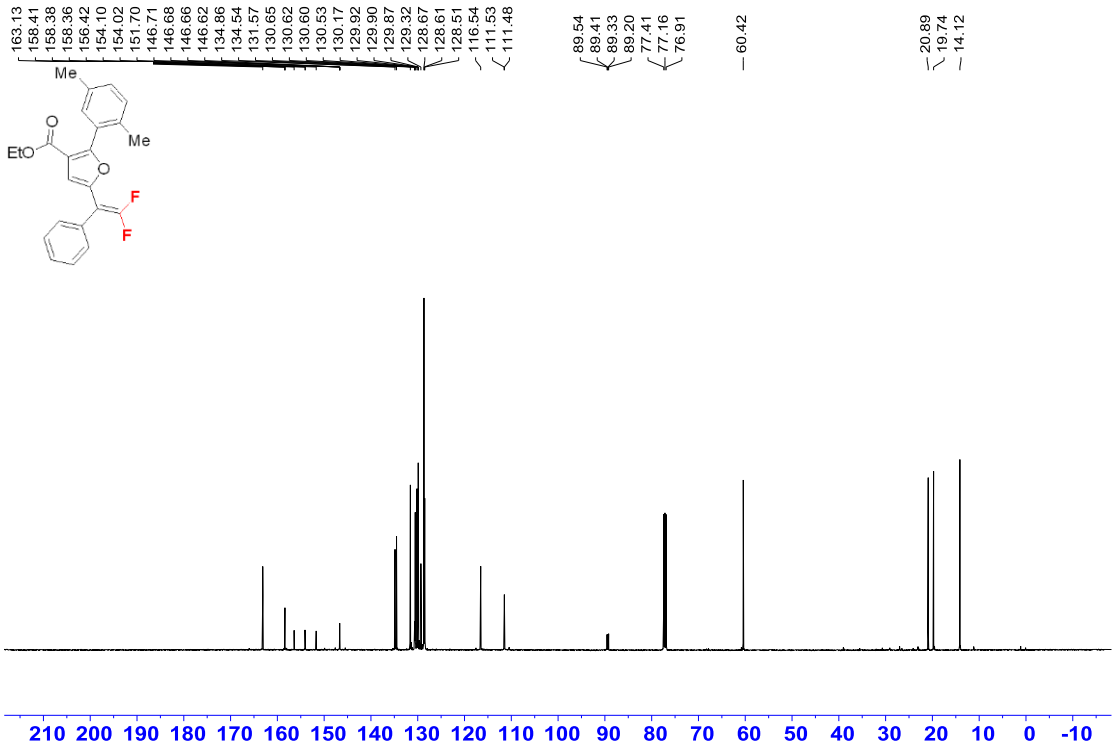
^{1}H NMR (600 MHz, $CDCl_3$) spectrum of compound **39.**



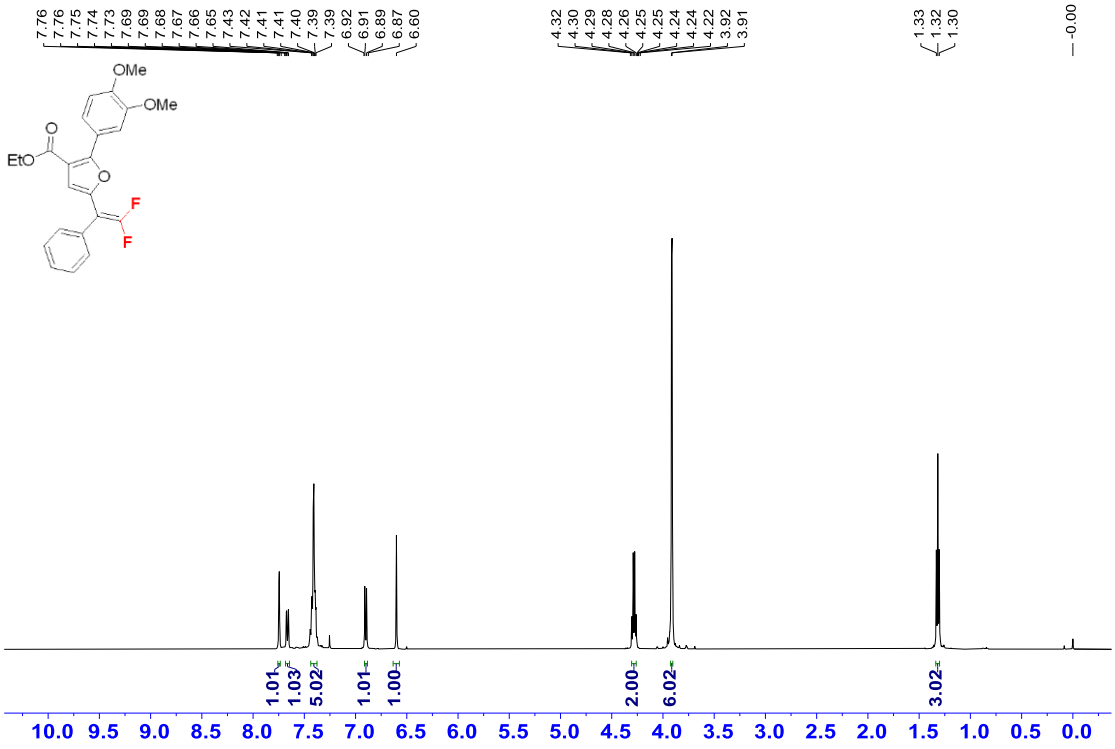
^{19}F NMR (565 MHz, $CDCl_3$) spectrum of compound **39.**



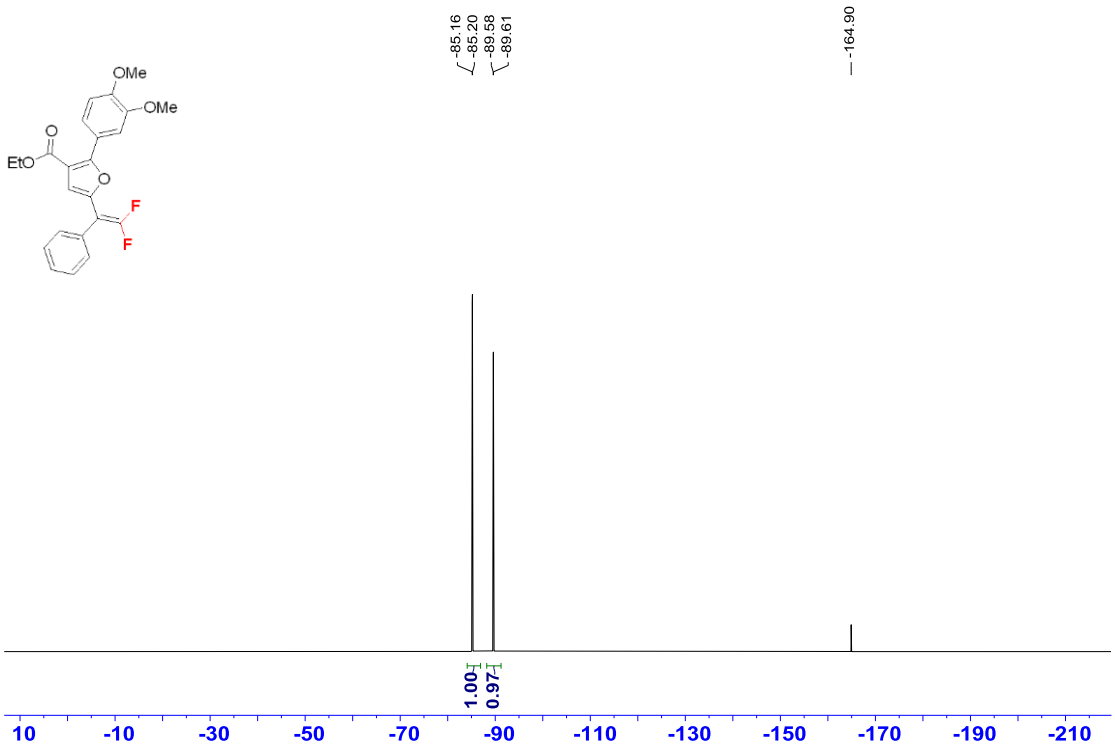
^{13}C NMR (101 MHz, $CDCl_3$) spectrum of compound **39.**



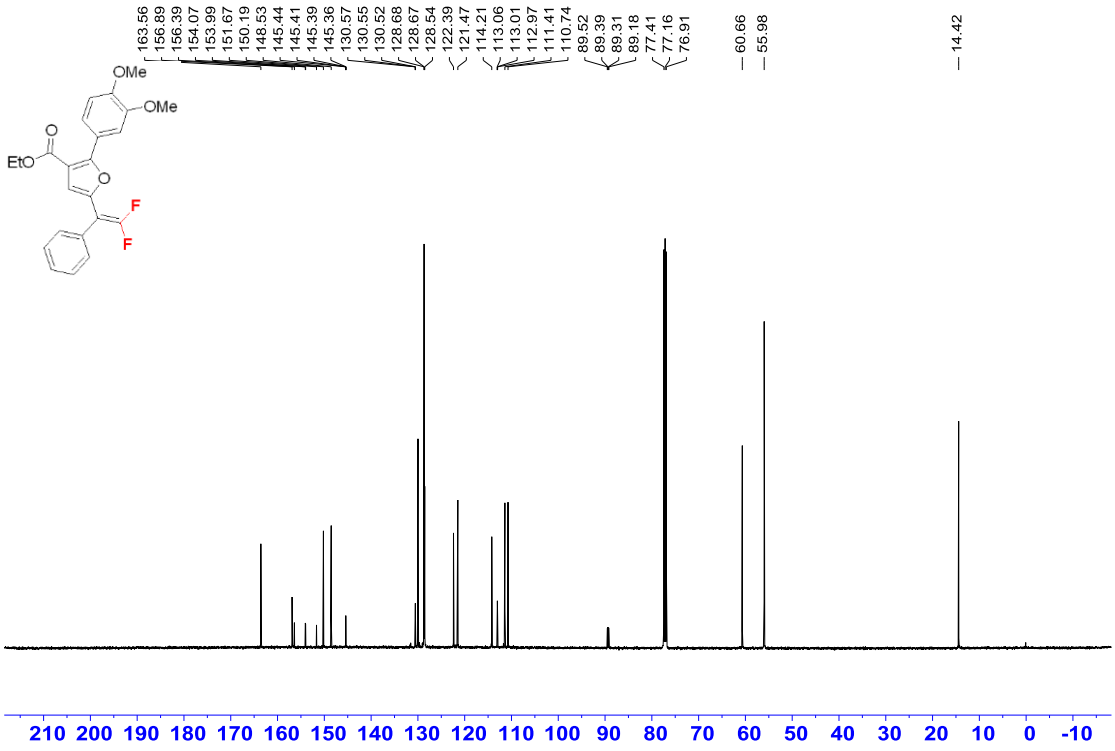
^{1}H NMR (500 MHz, $CDCl_3$) spectrum of compound **40.**



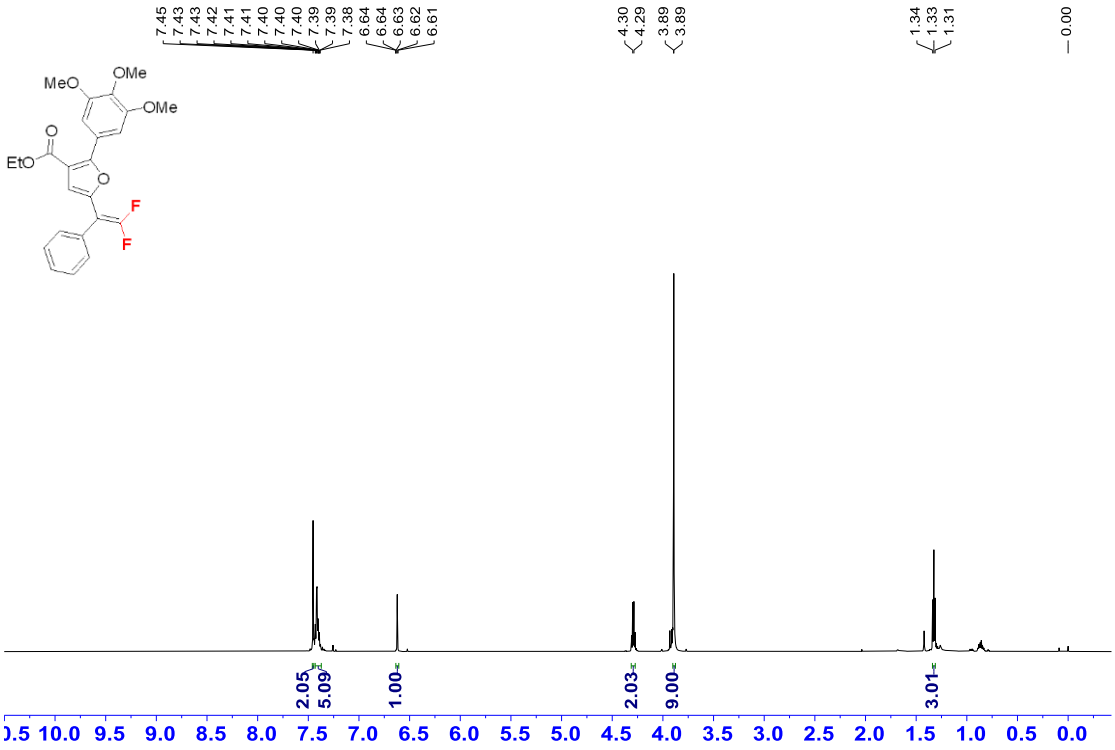
^{19}F NMR (565 MHz, $CDCl_3$) spectrum of compound **40.**



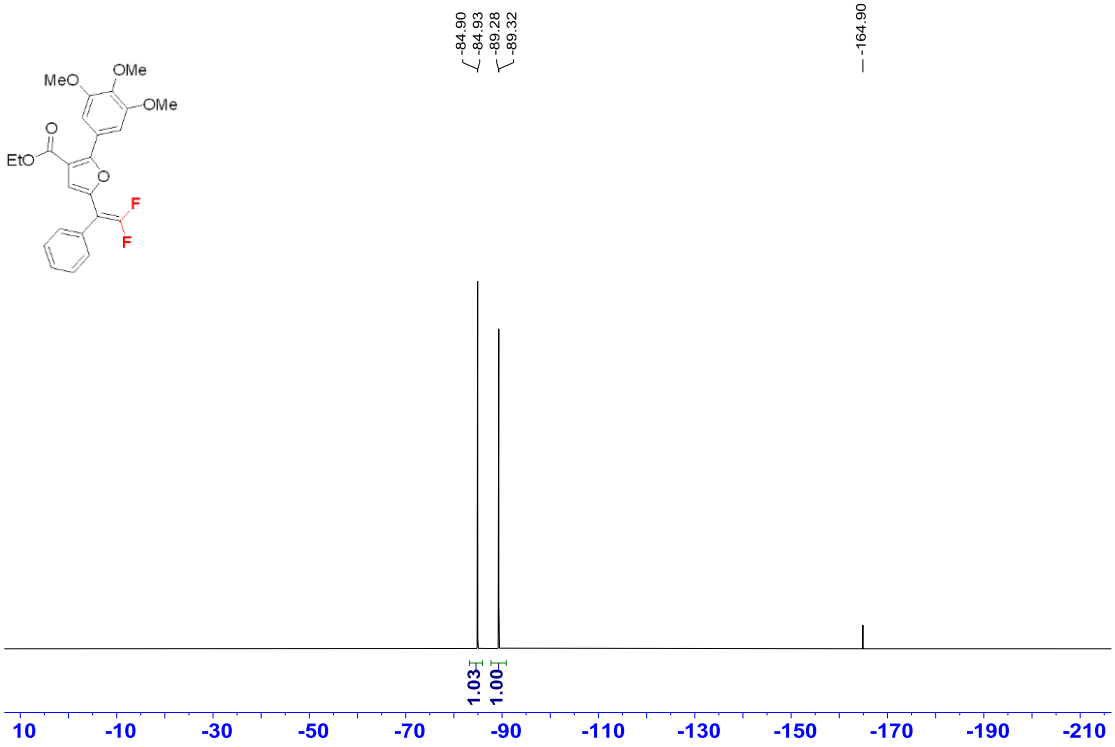
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **40.**



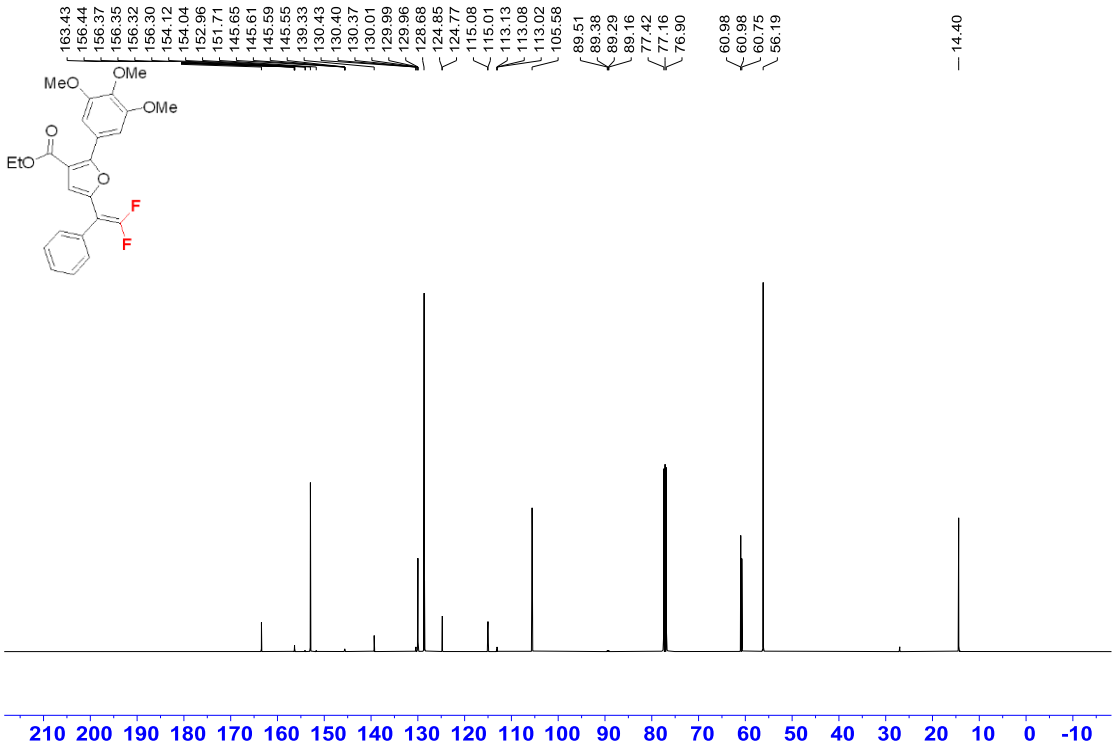
^{1}H NMR (600 MHz, $CDCl_3$) spectrum of compound **41.**



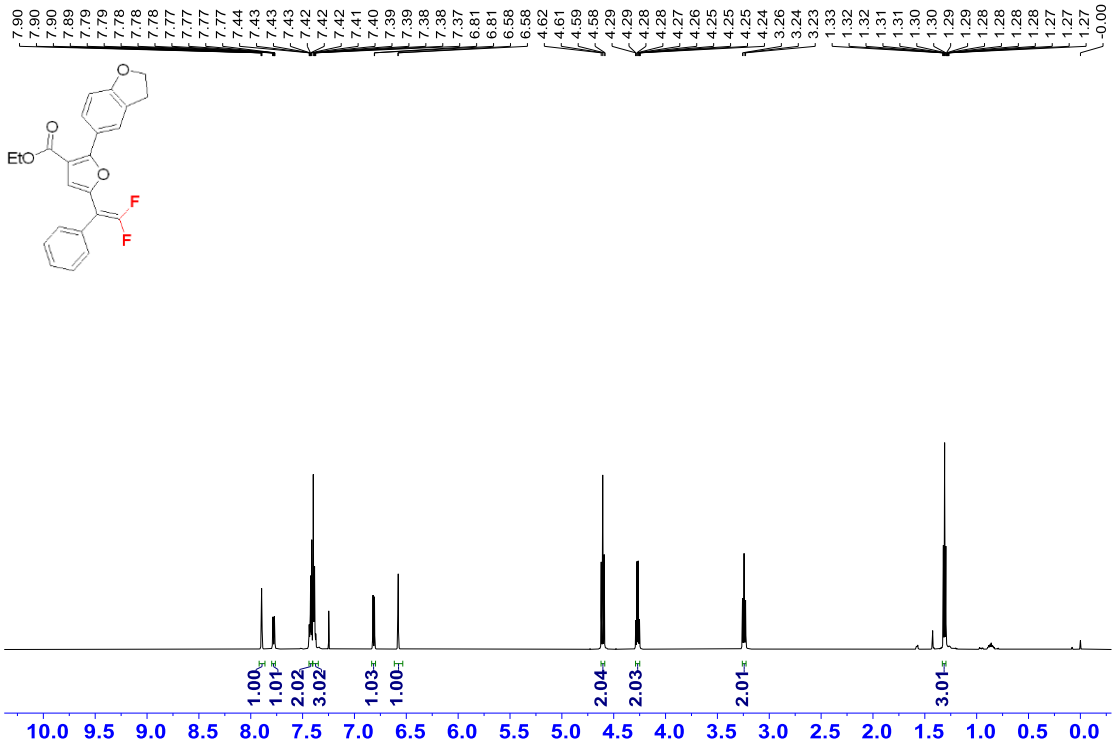
^{19}F NMR (565 MHz, $CDCl_3$) spectrum of compound **41.**



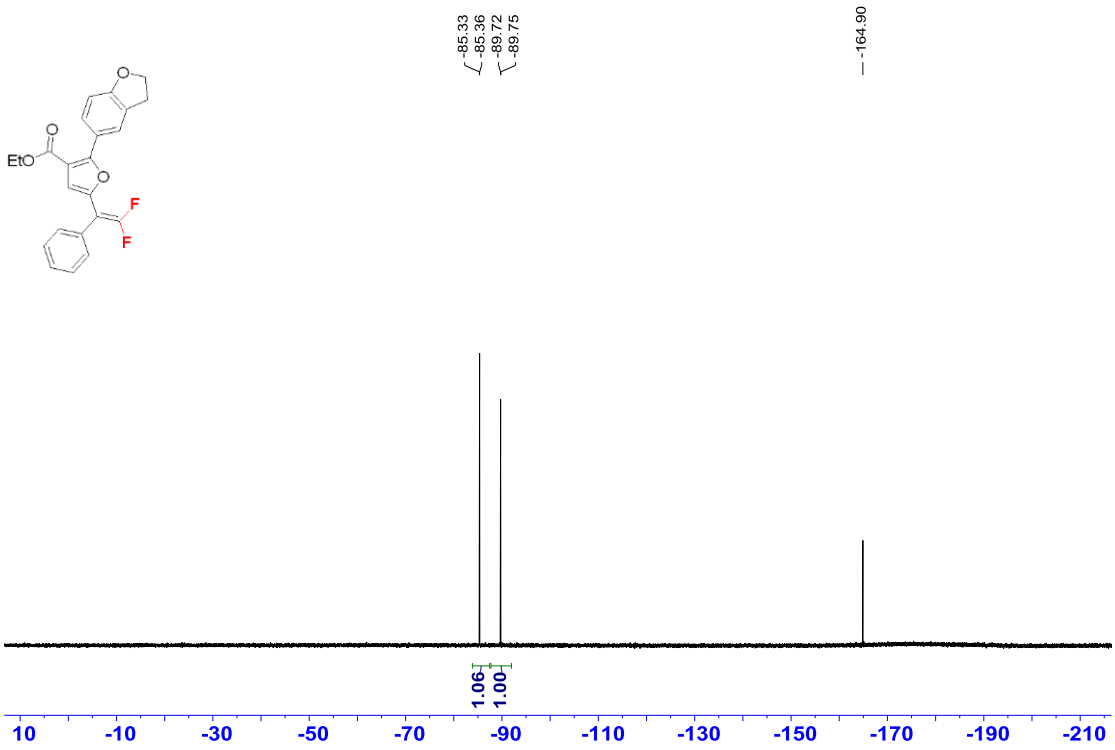
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **41.**



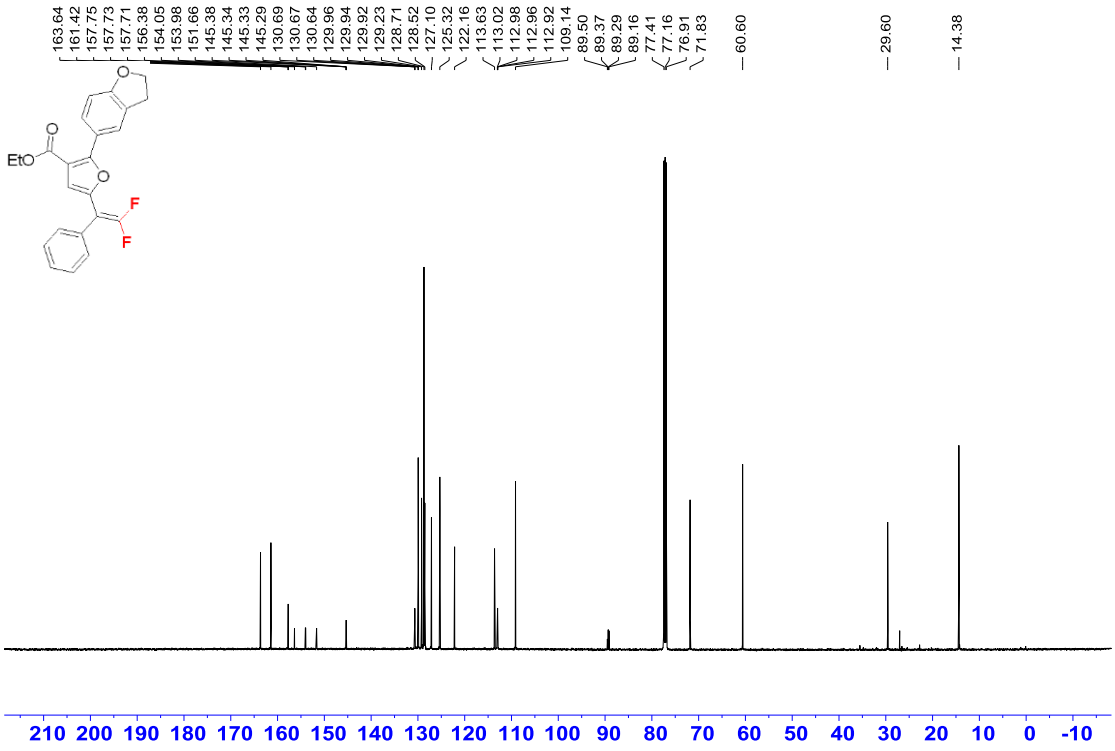
^{1}H NMR (600 MHz, $CDCl_3$) spectrum of compound **42.**



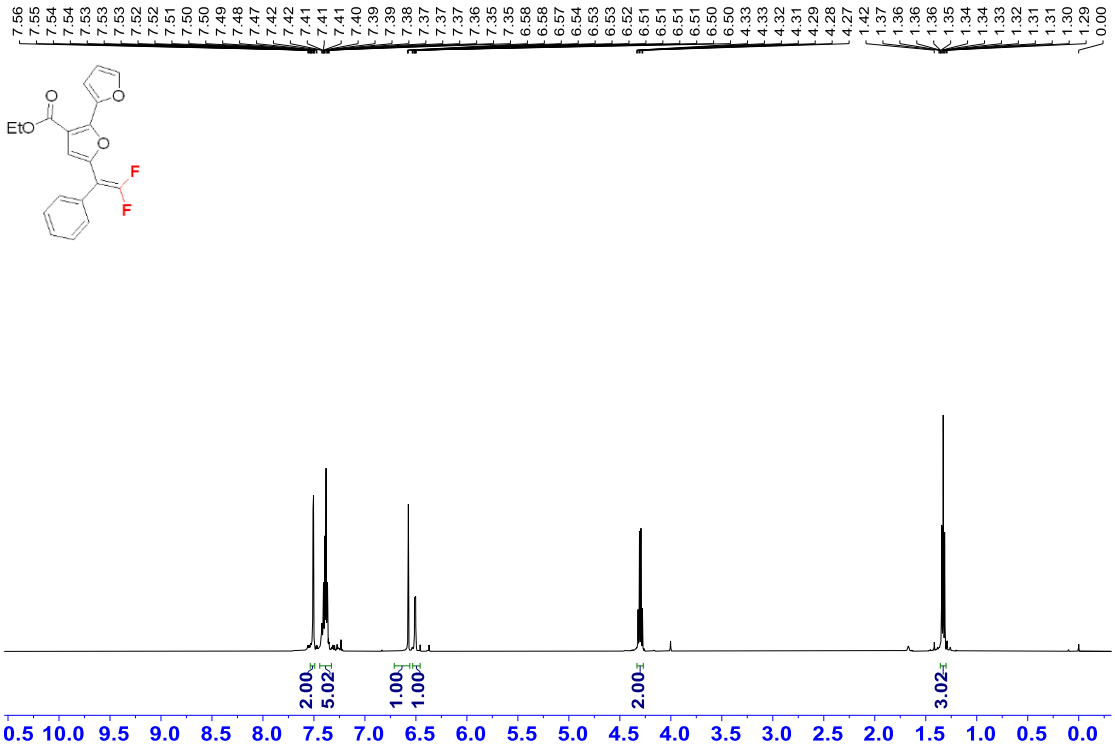
^{19}F NMR (565 MHz, $CDCl_3$) spectrum of compound **42.**



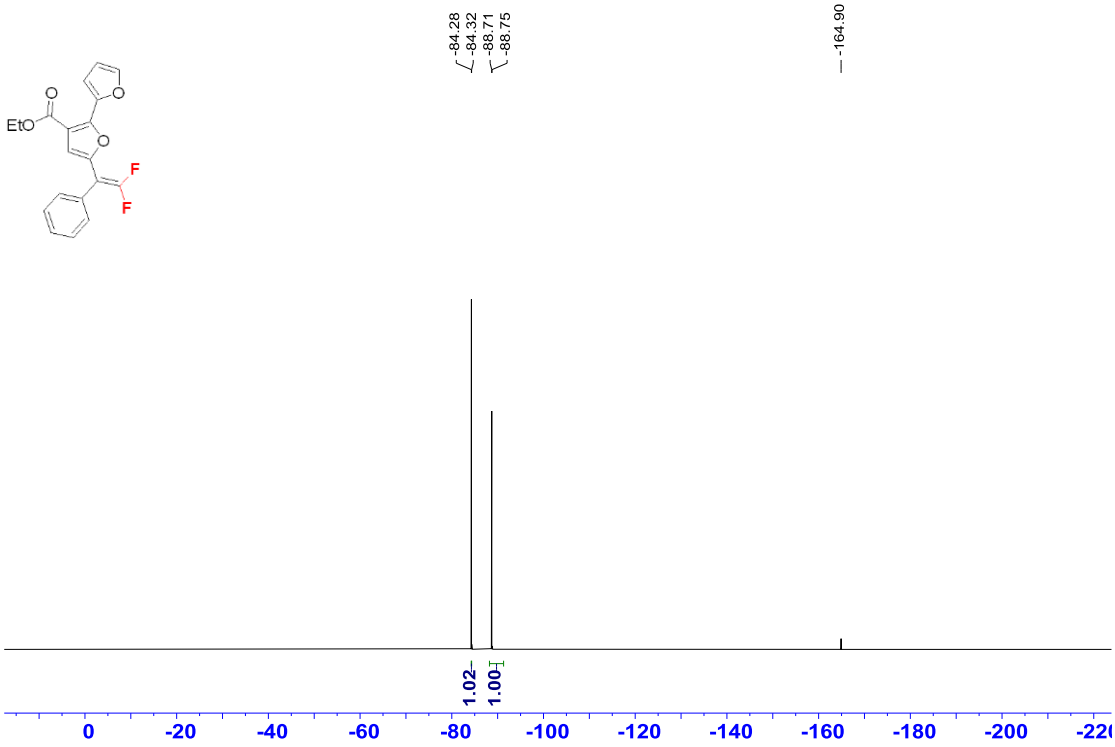
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **42.**



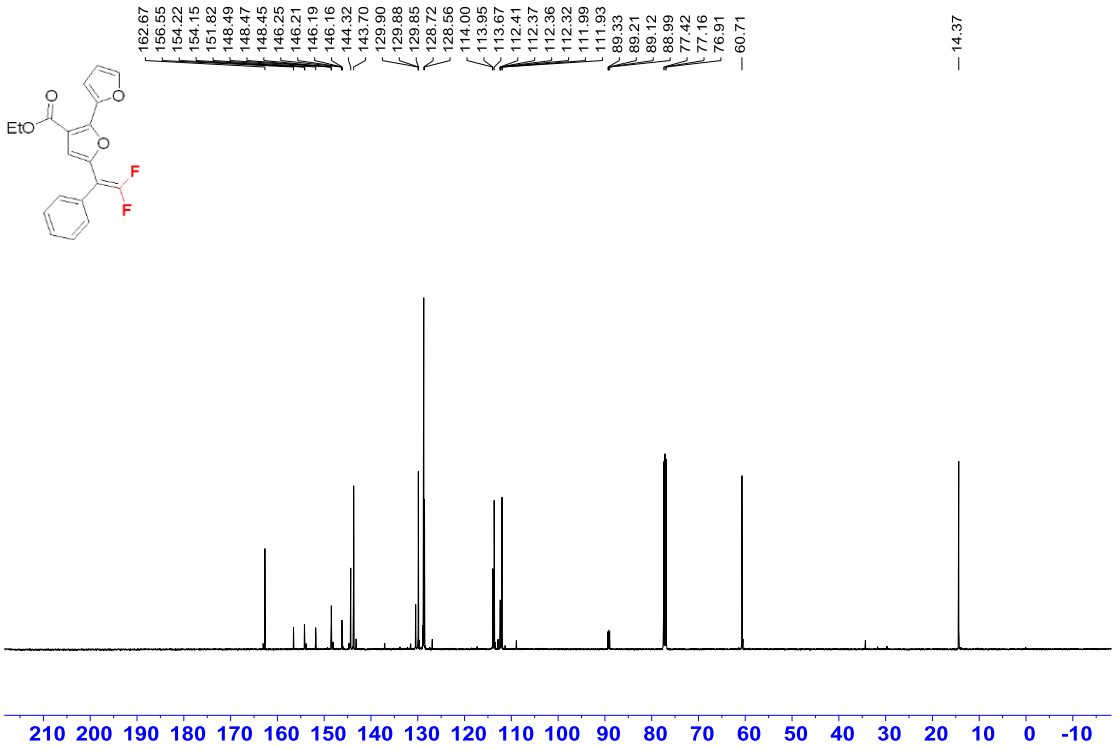
^{1}H NMR (500 MHz, $CDCl_3$) spectrum of compound **43.**



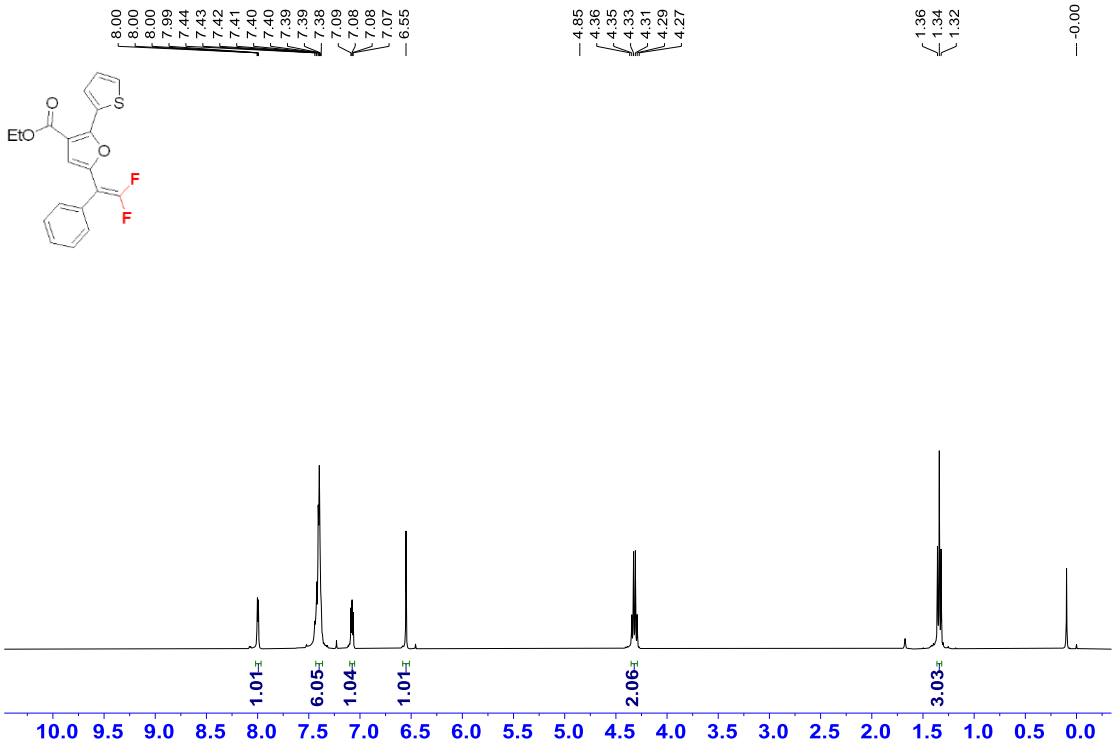
^{19}F NMR (471 MHz, $CDCl_3$) spectrum of compound **43.**



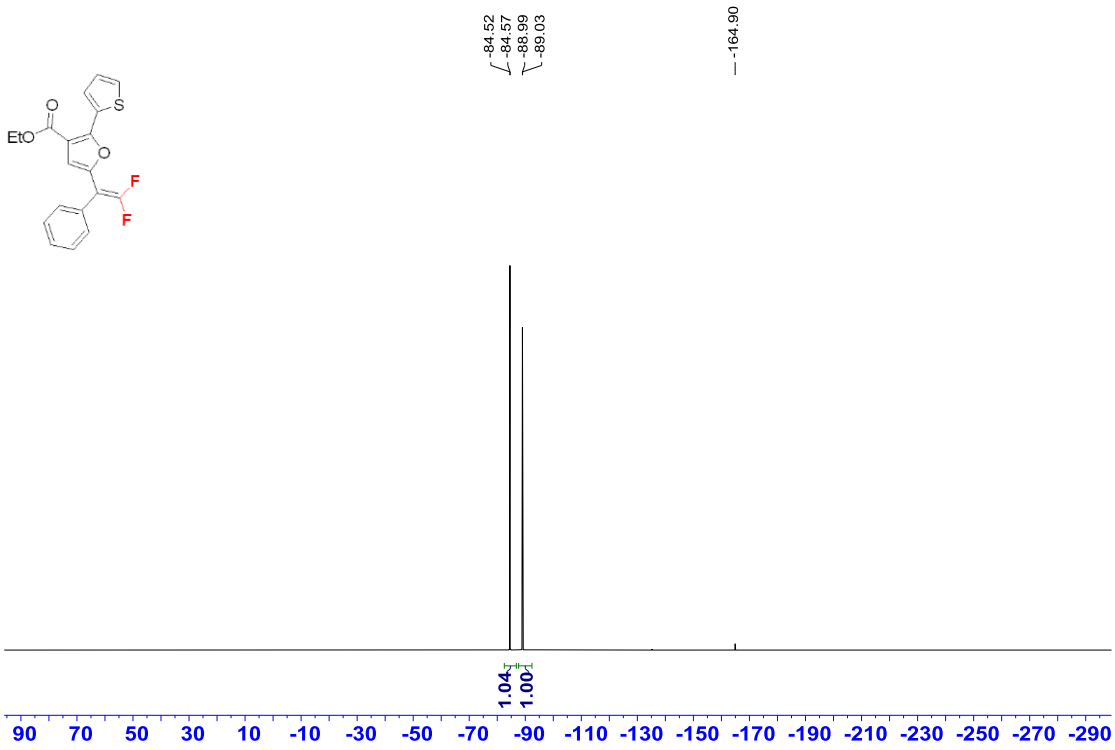
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **43.**



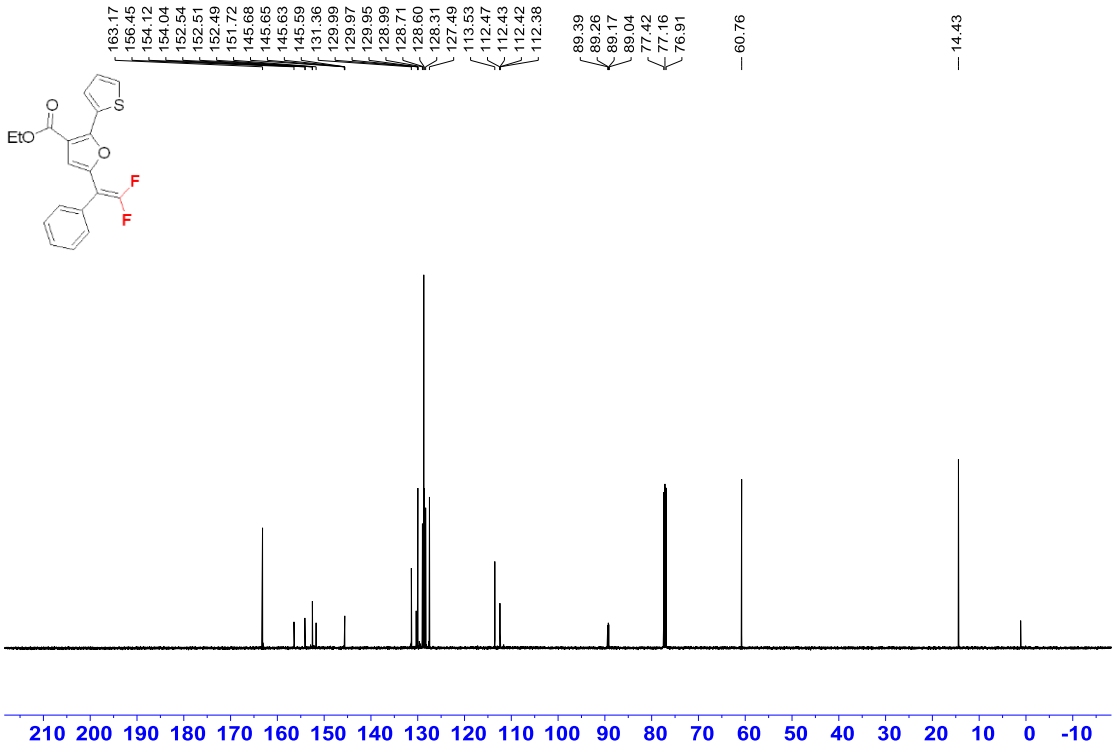
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **44.**



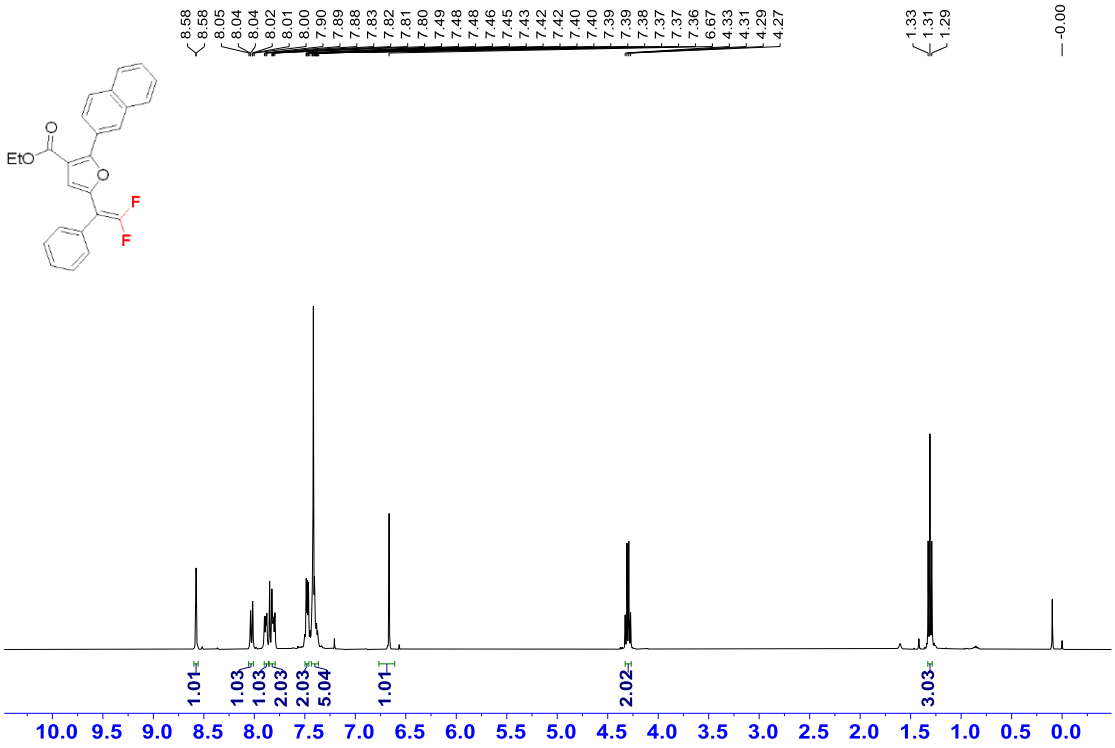
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **44.**



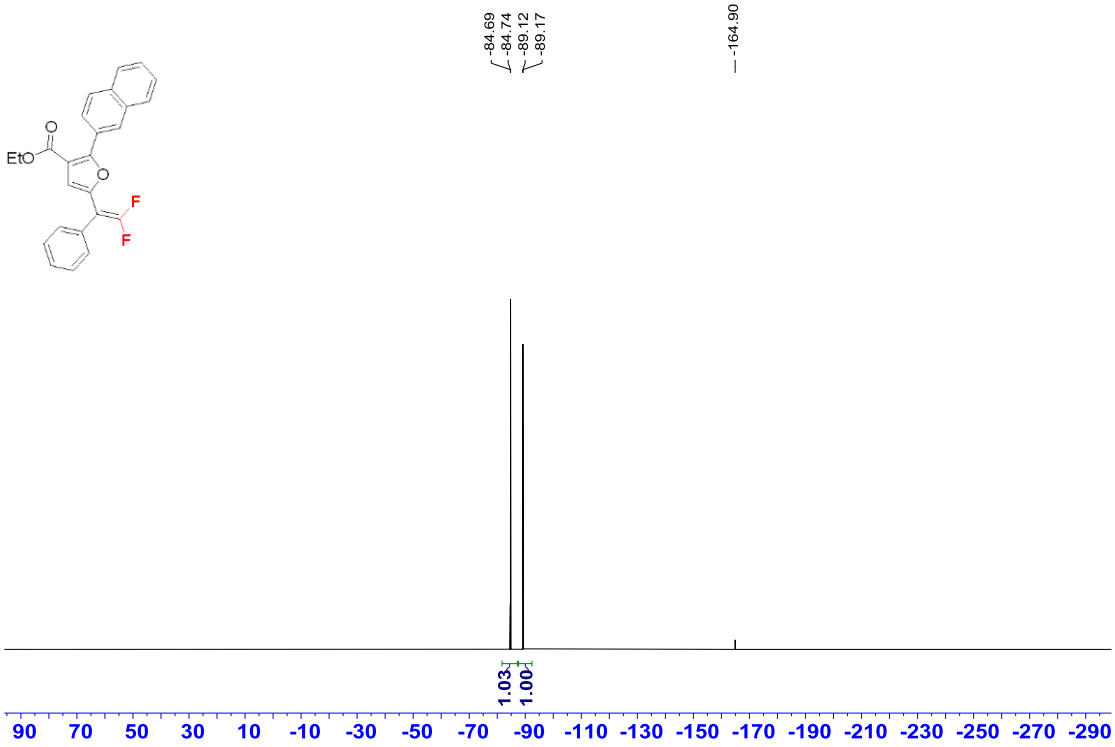
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **44.**



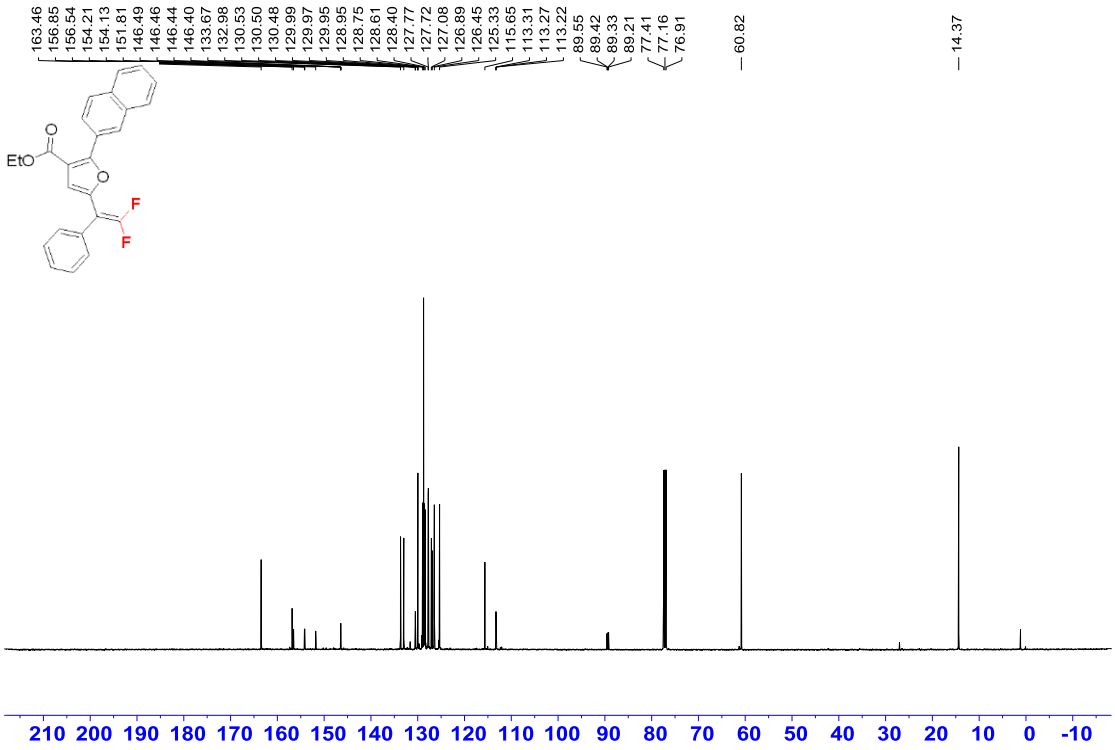
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **45.**



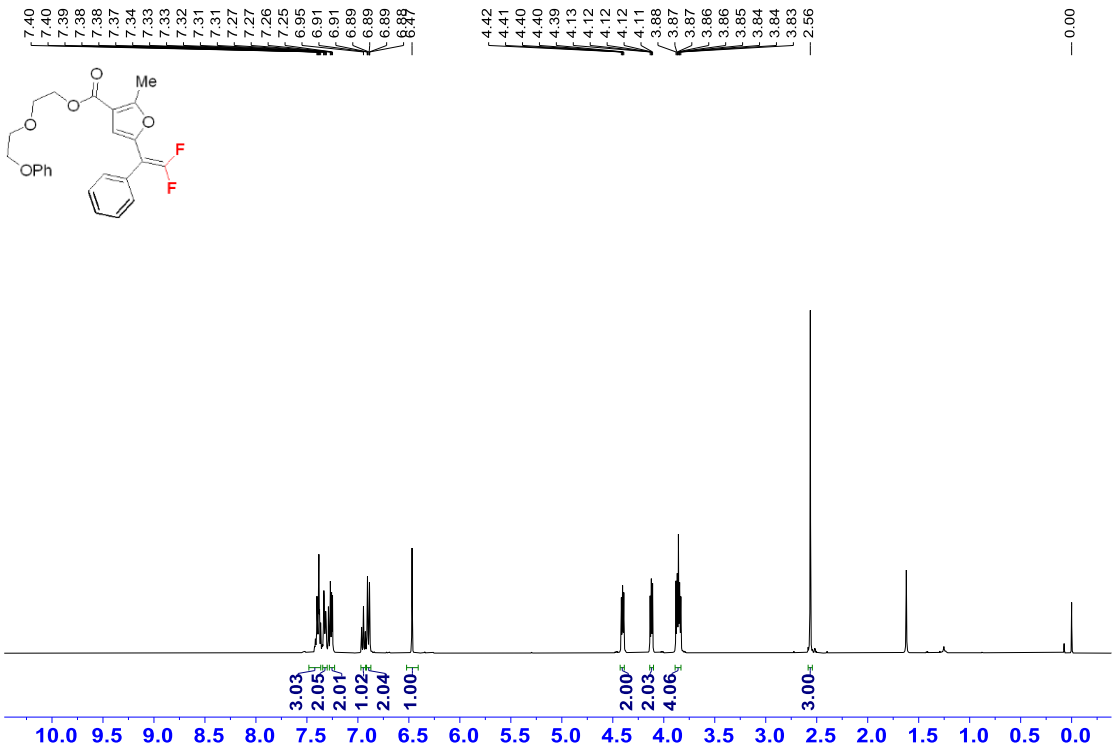
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **45.**



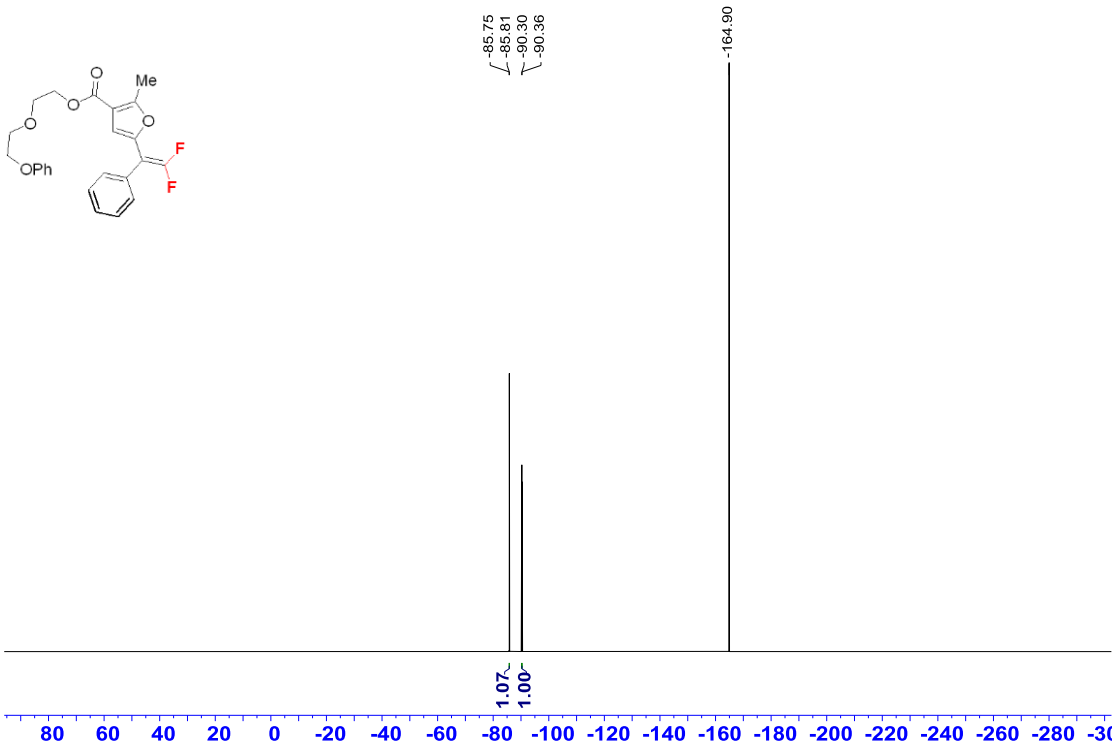
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **45.**



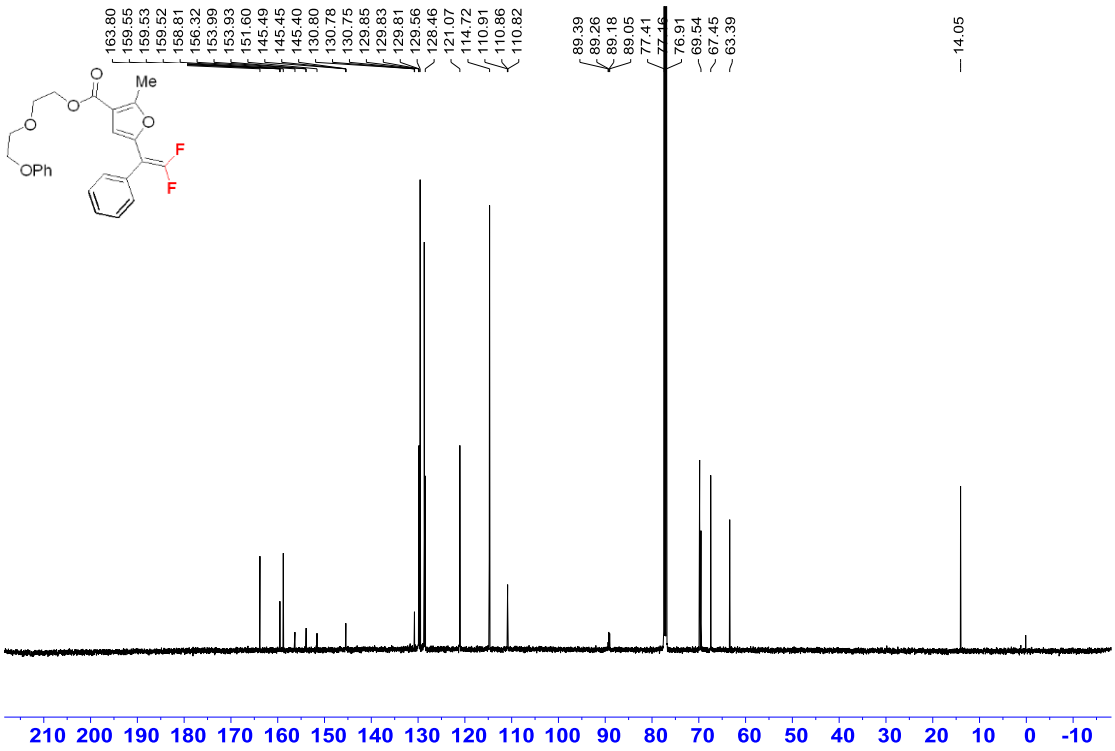
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **46.**



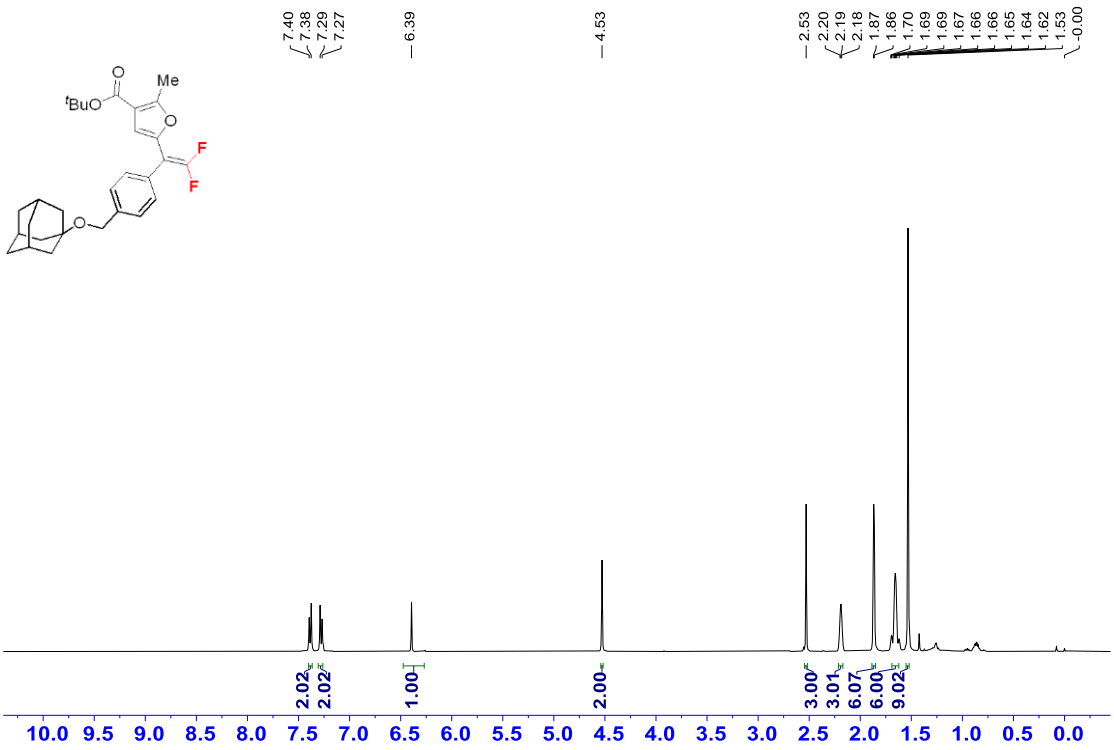
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **46.**



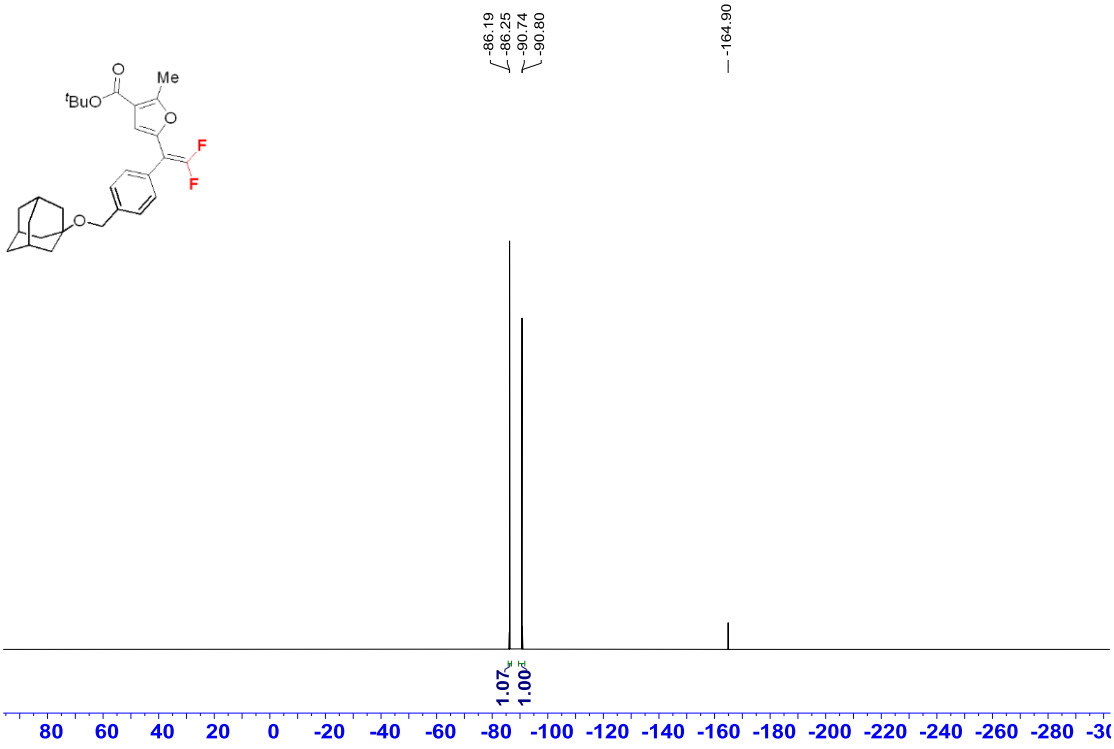
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **46.**



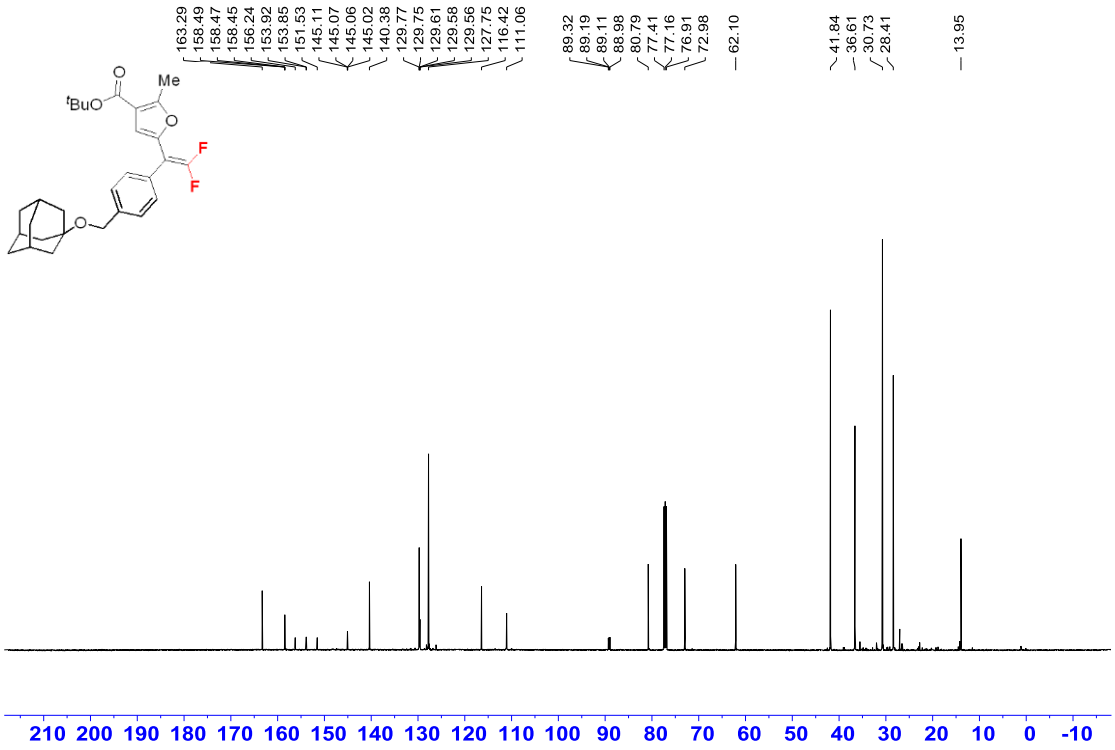
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **47.**



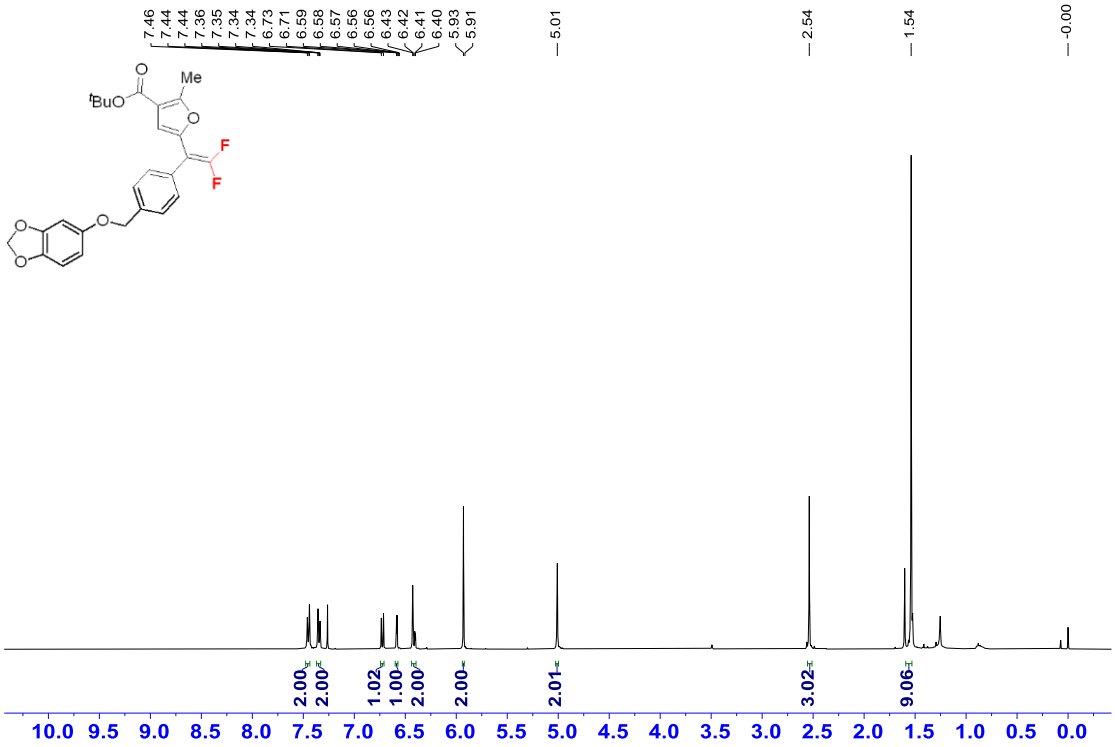
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **47.**



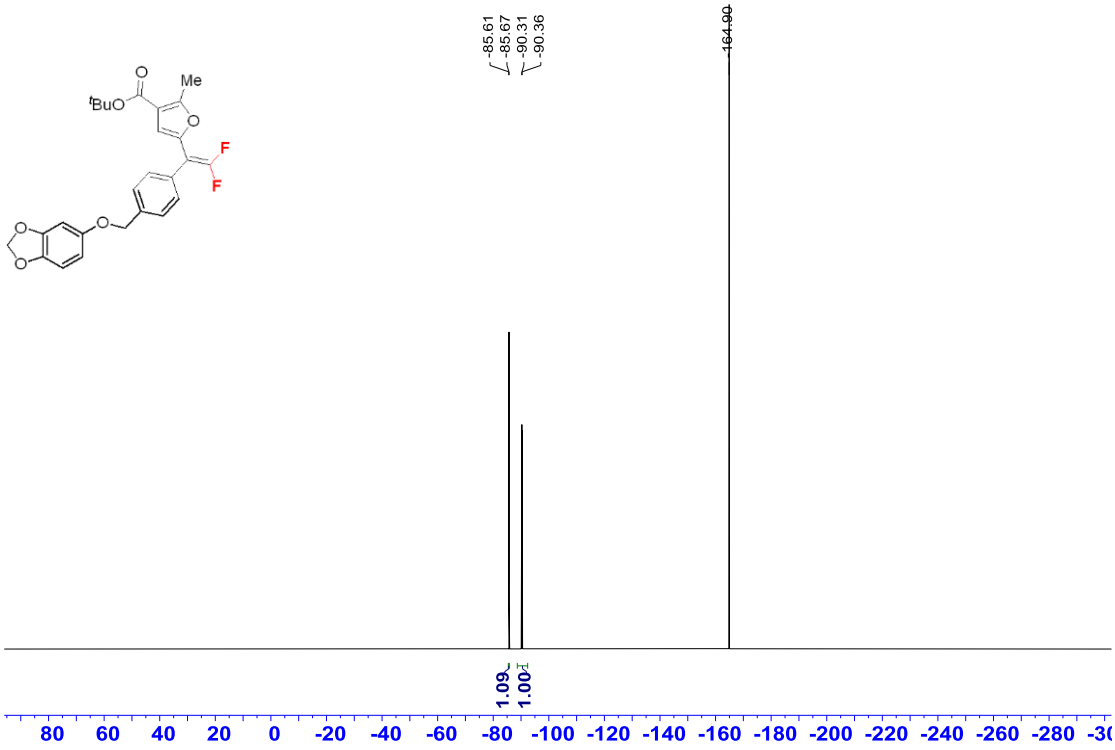
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **47.**



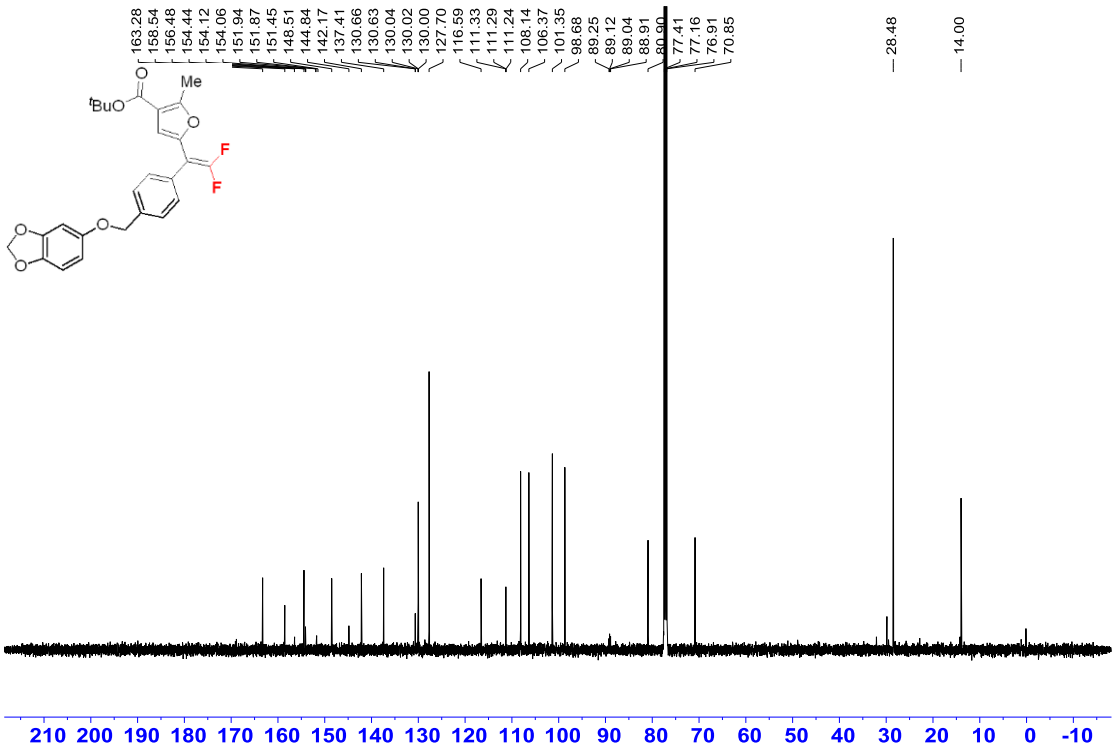
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **48.**



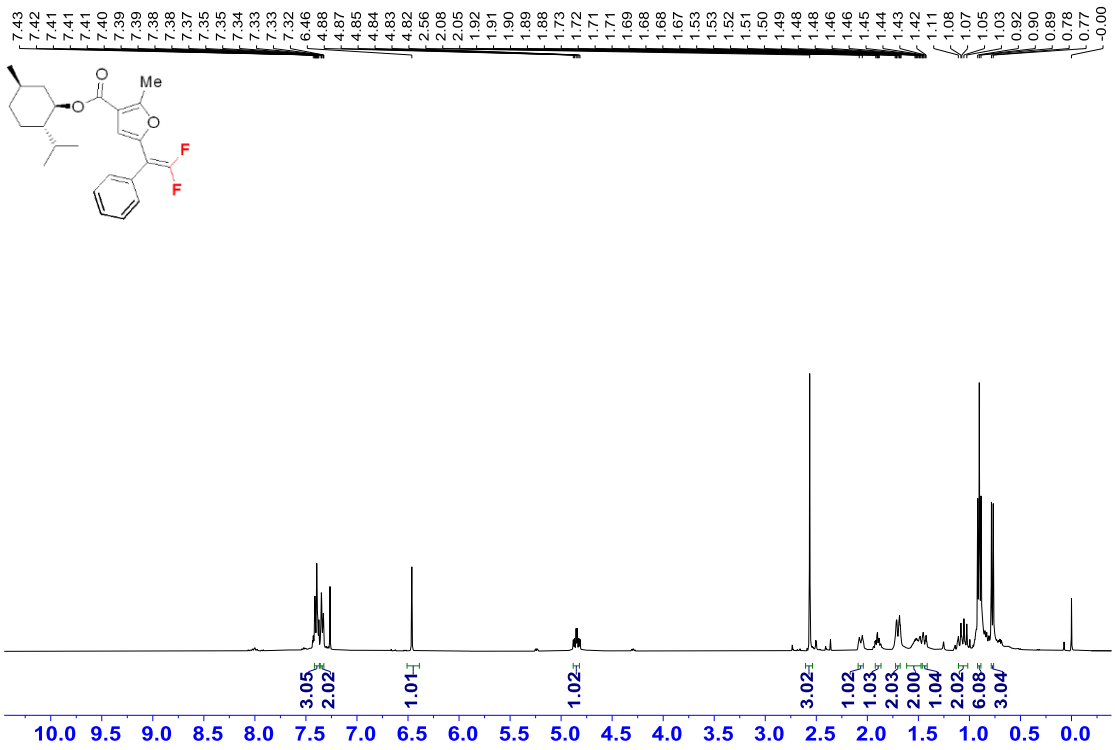
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **48.**



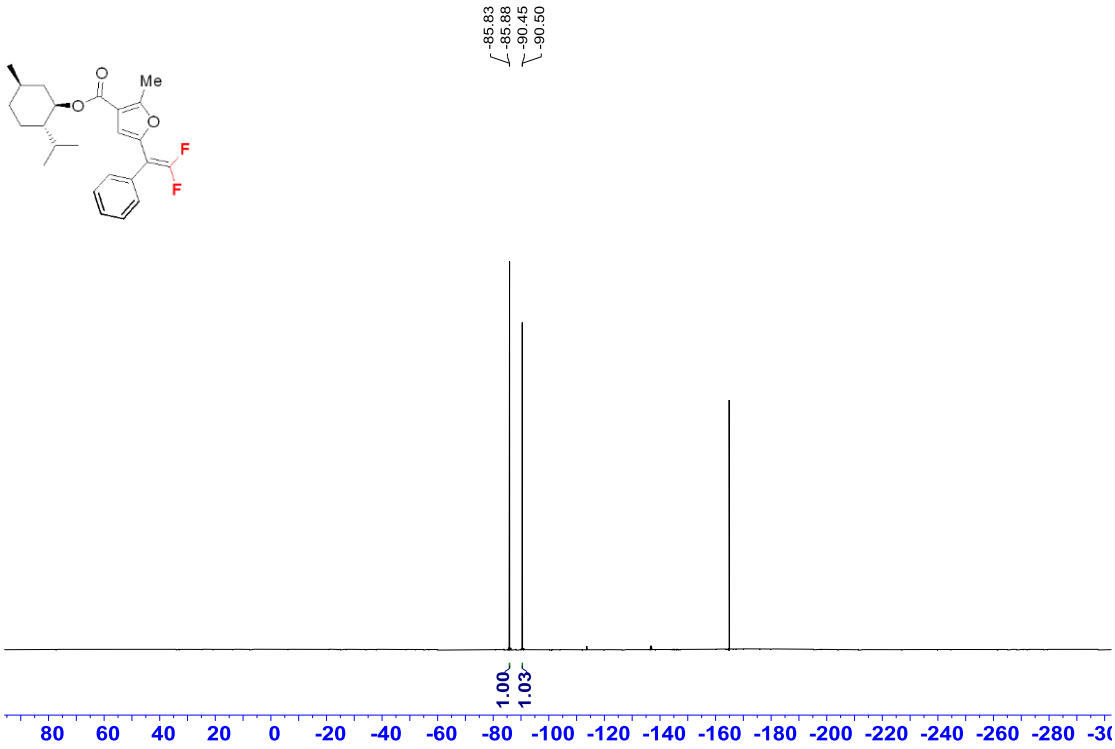
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **48.**



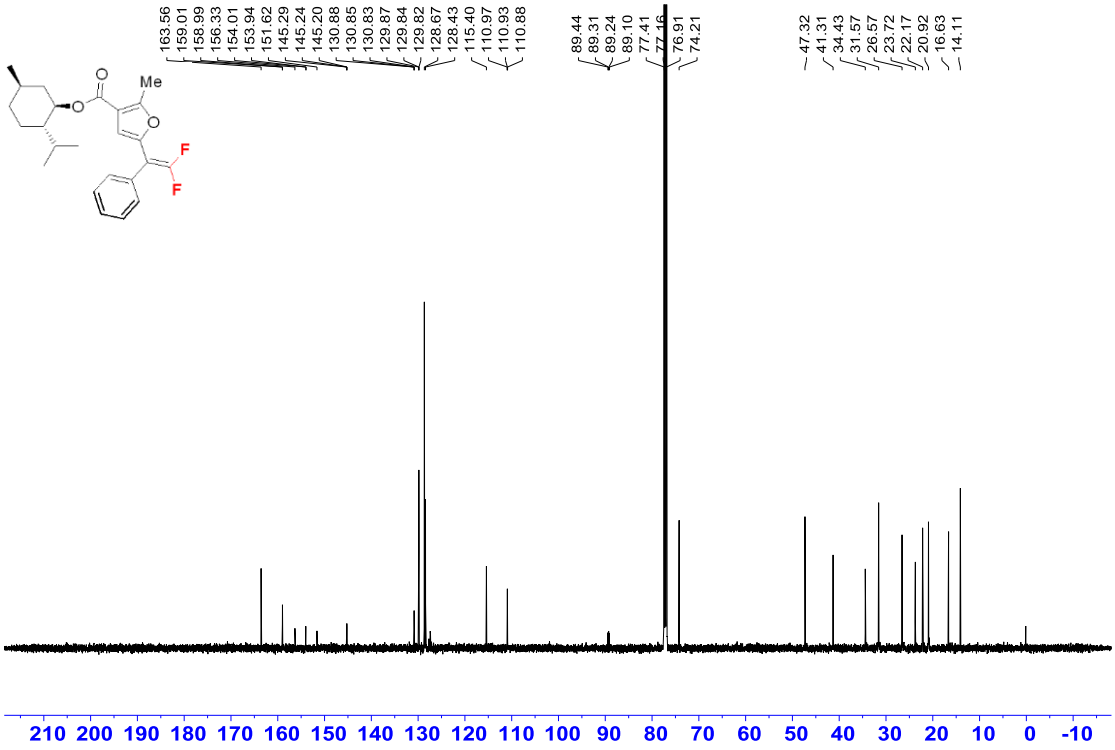
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **49.**



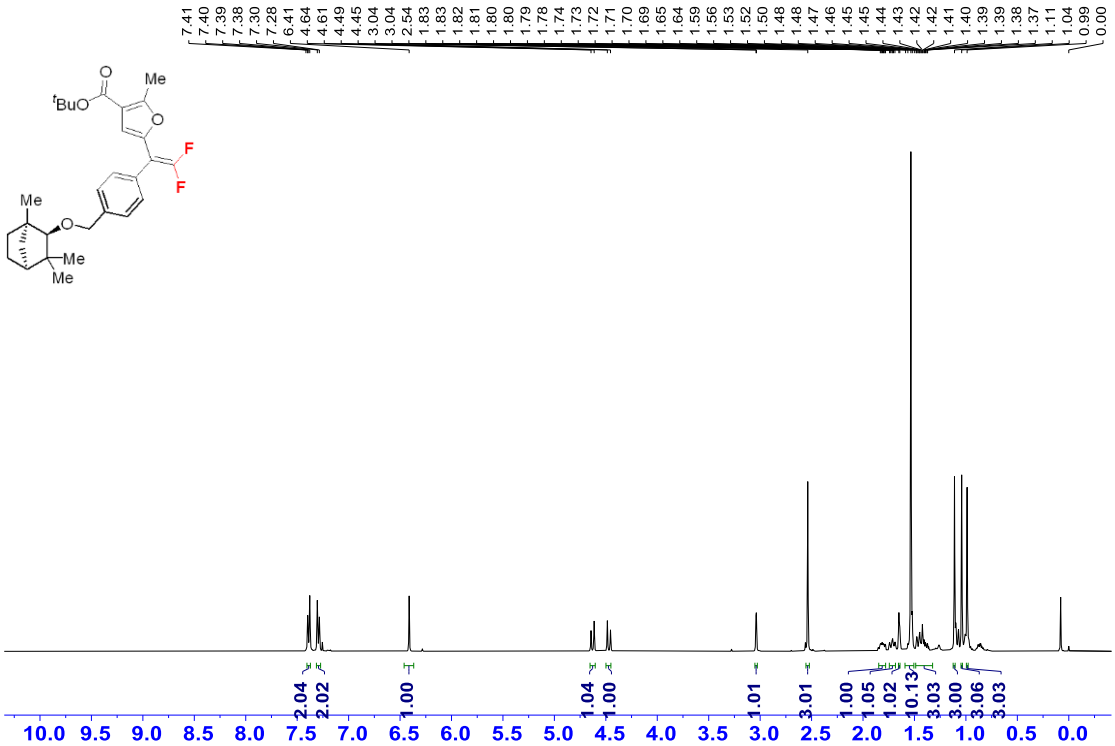
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **49.**



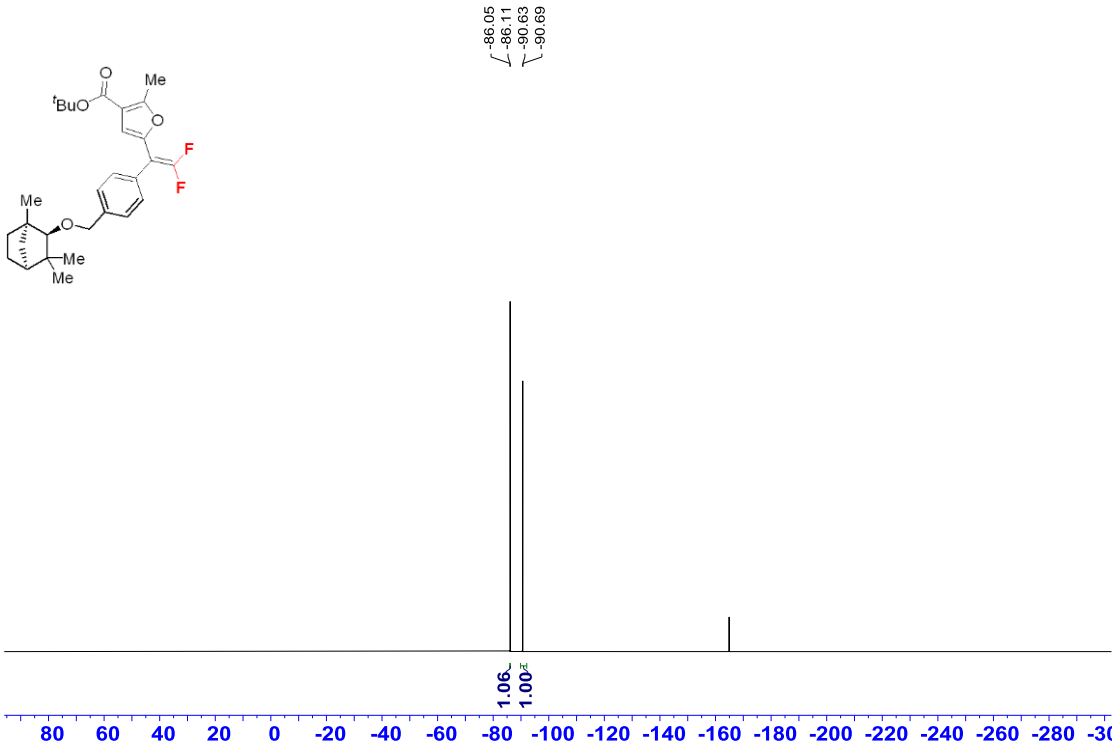
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **49.**



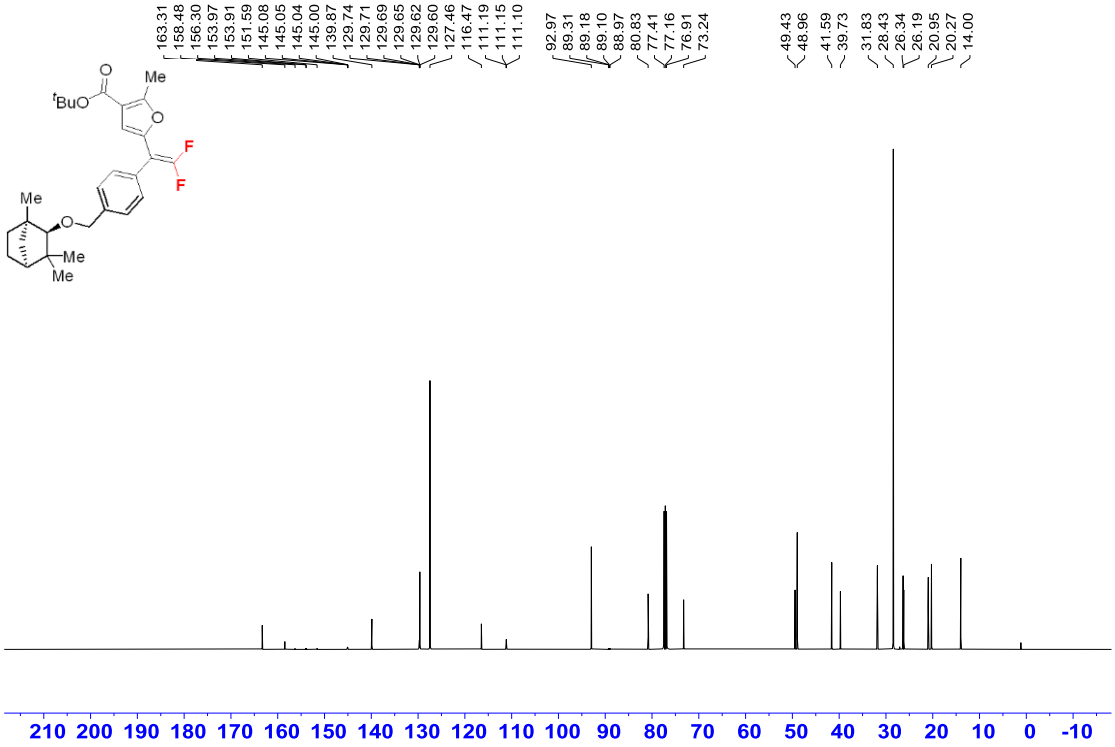
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **50.**



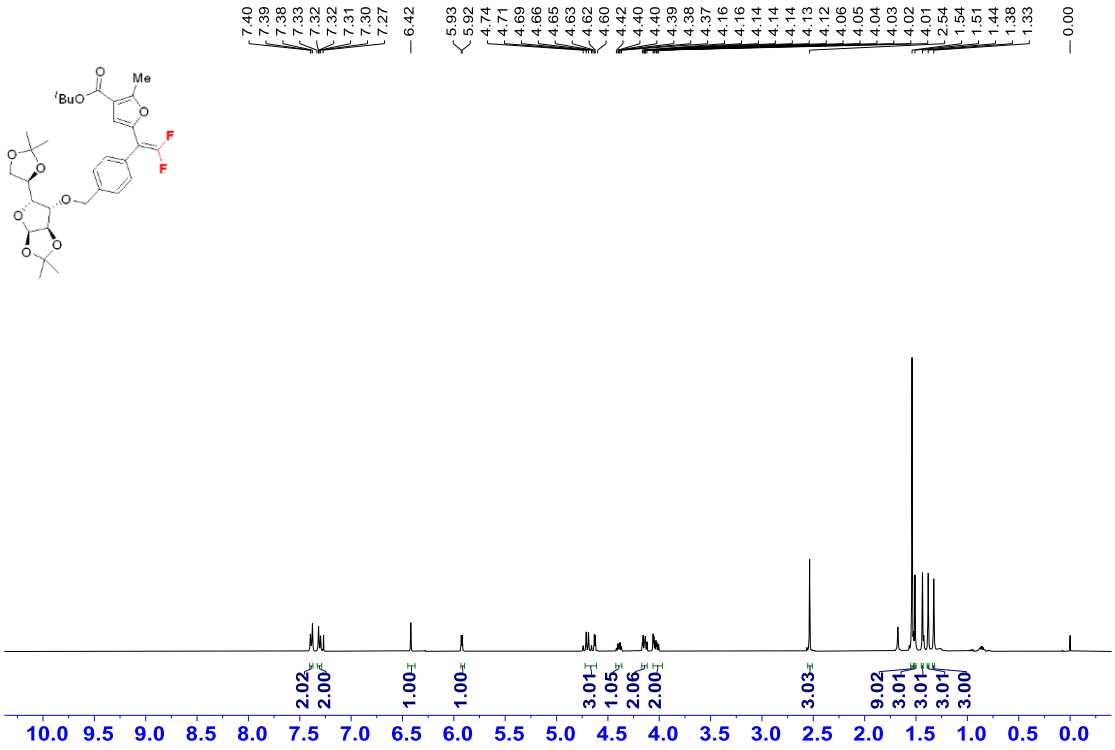
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **50.**



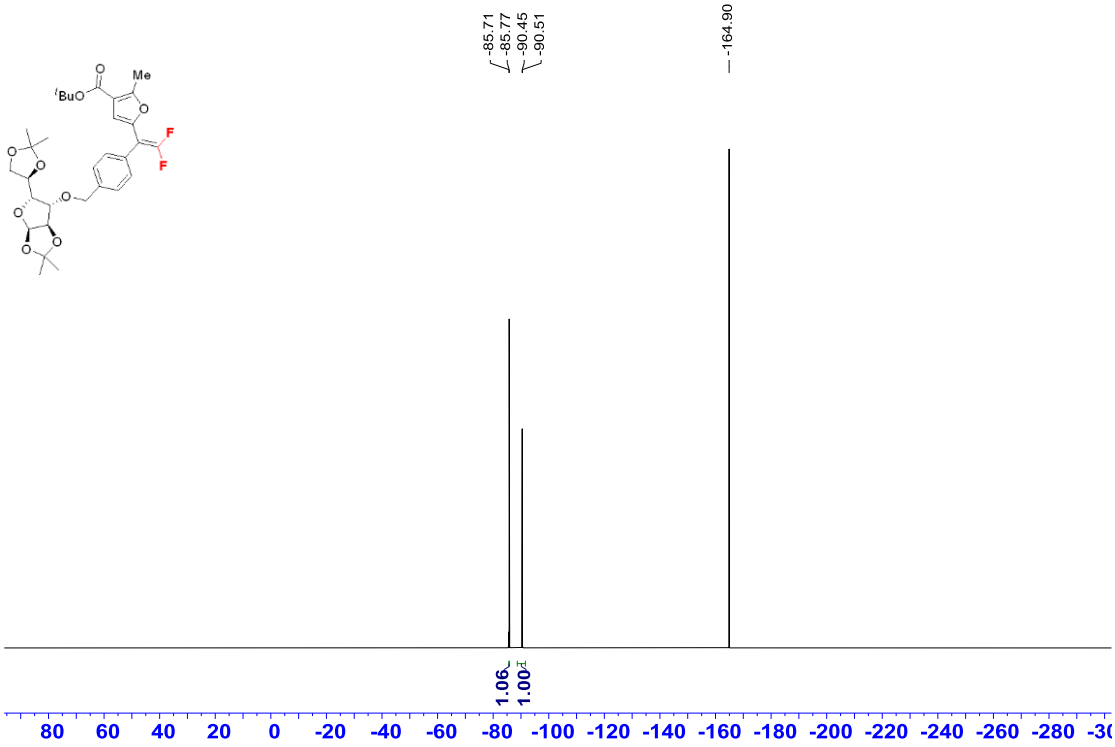
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **50.**



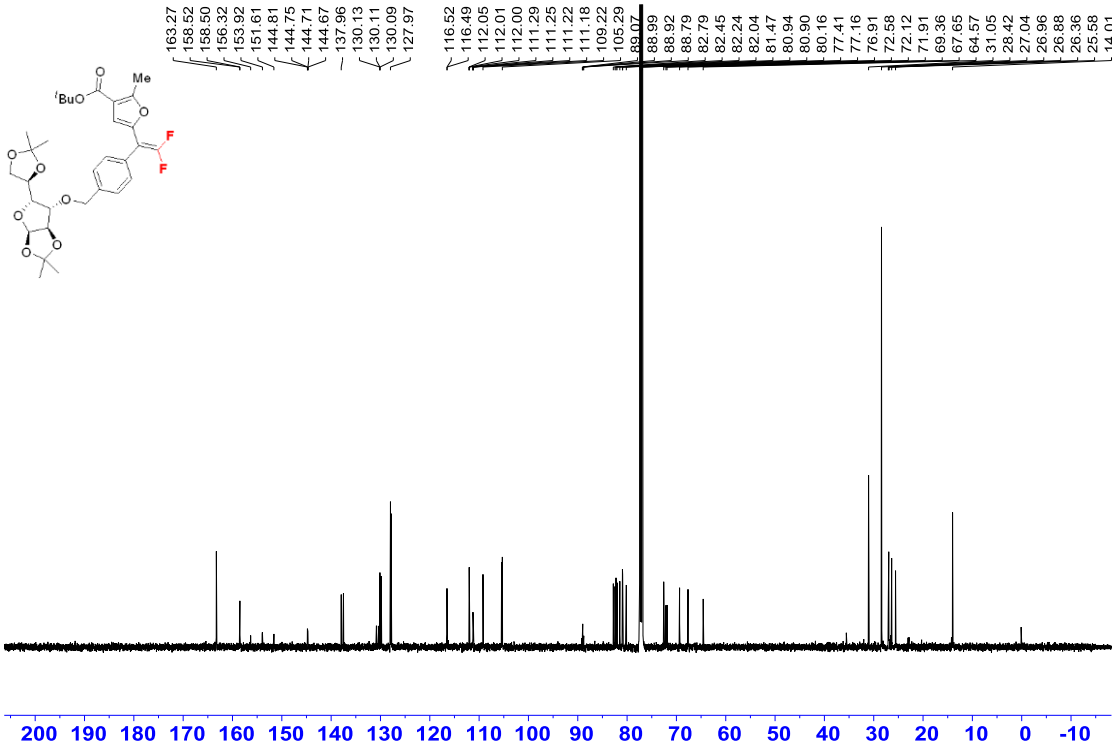
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **51.**



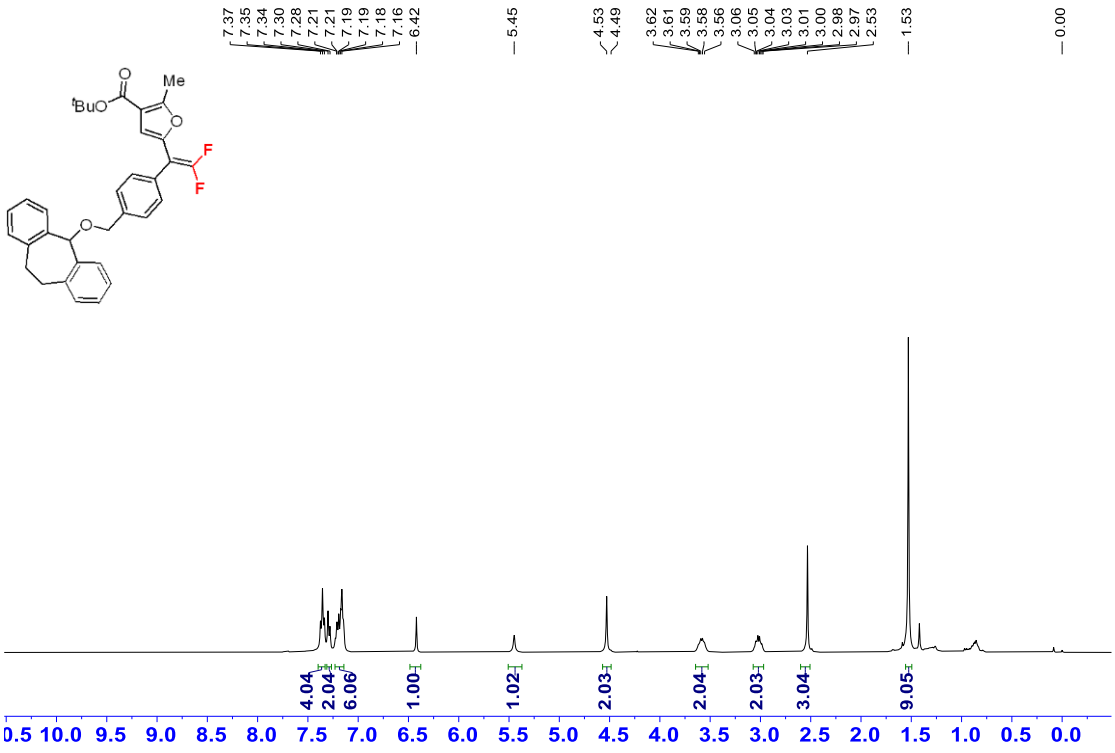
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **51.**



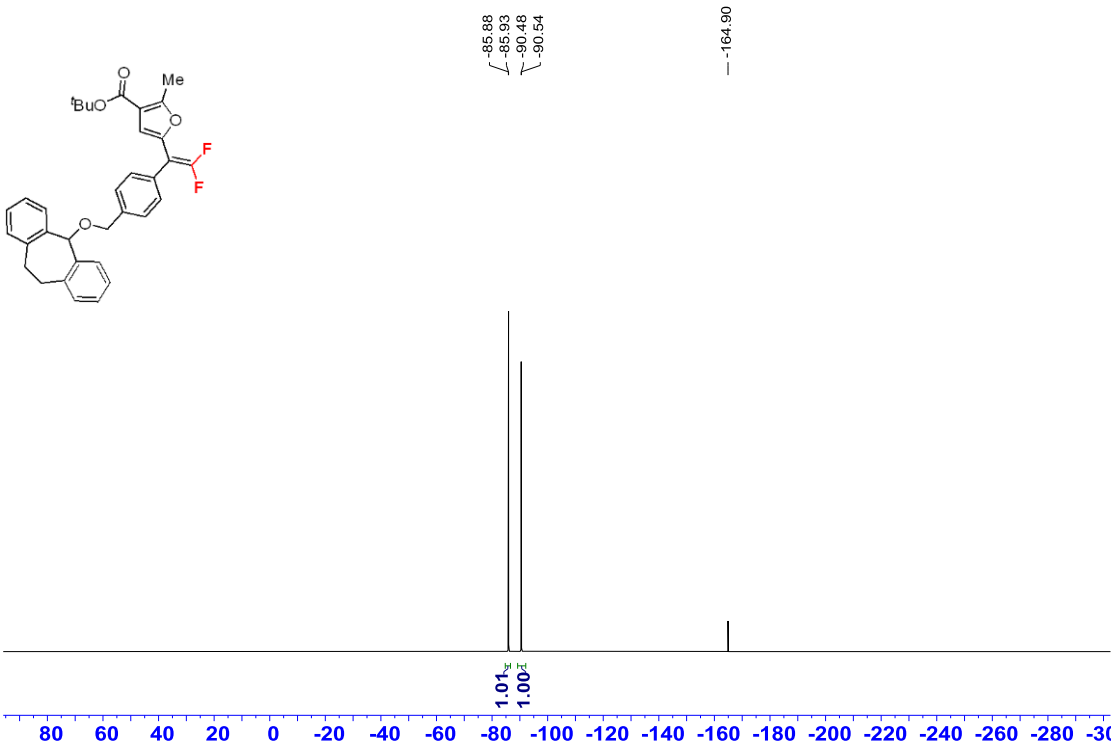
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **51.**



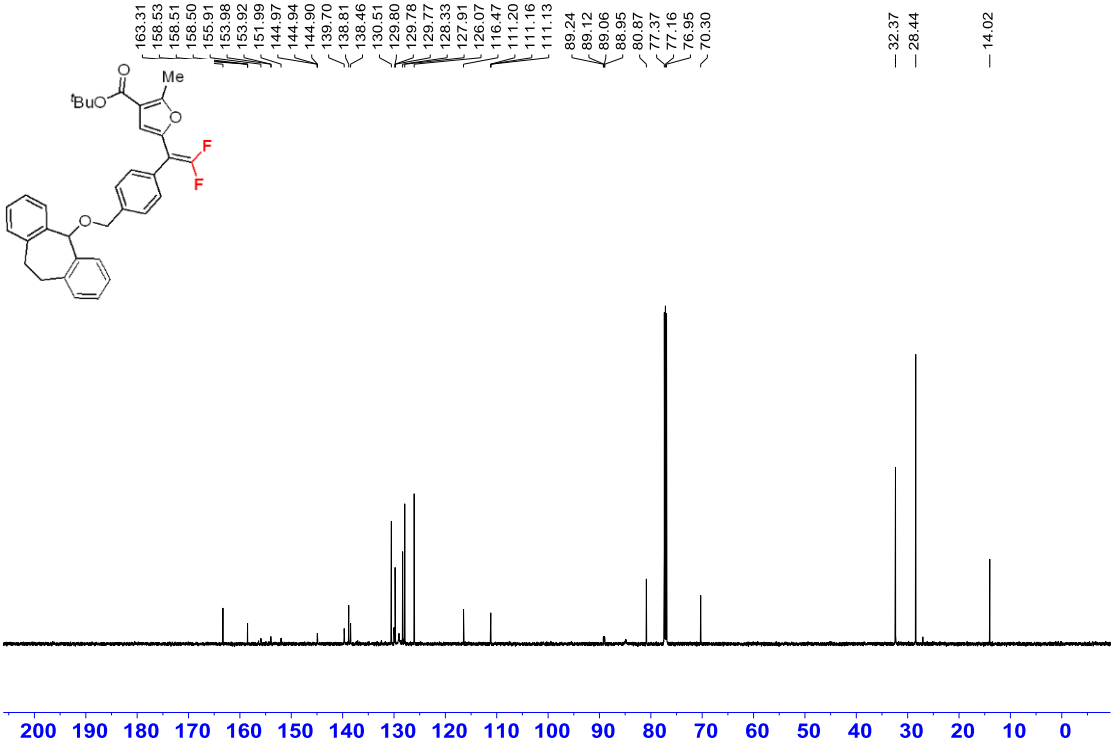
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **52.**



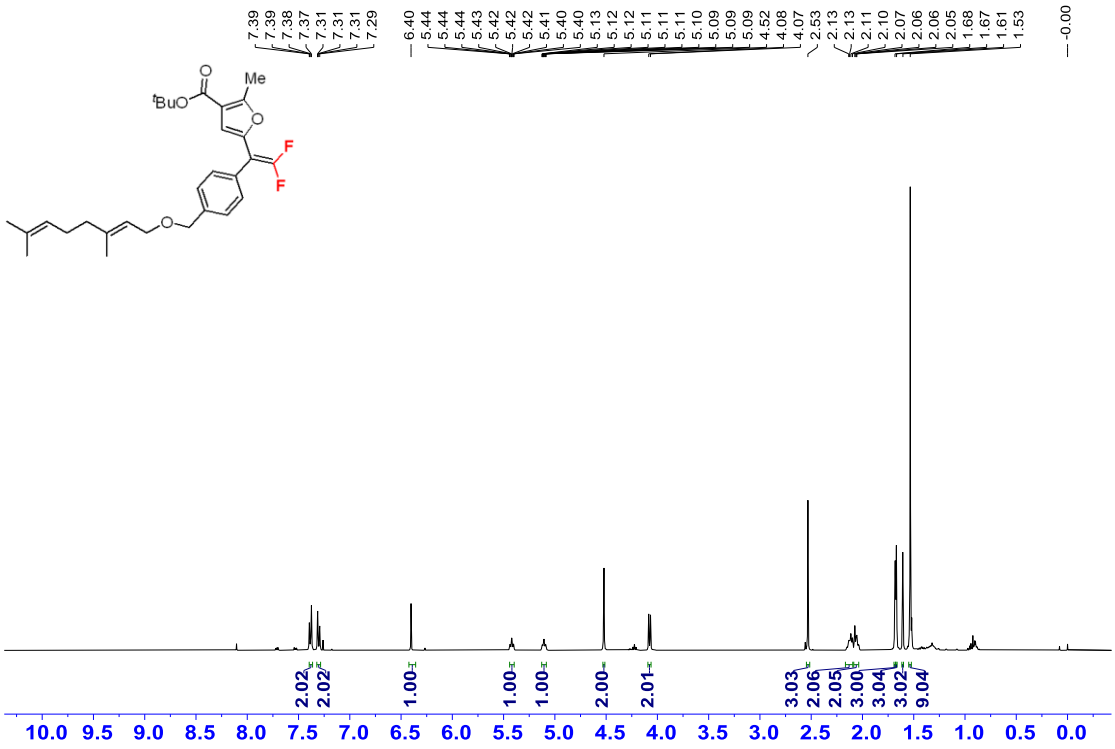
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **52.**



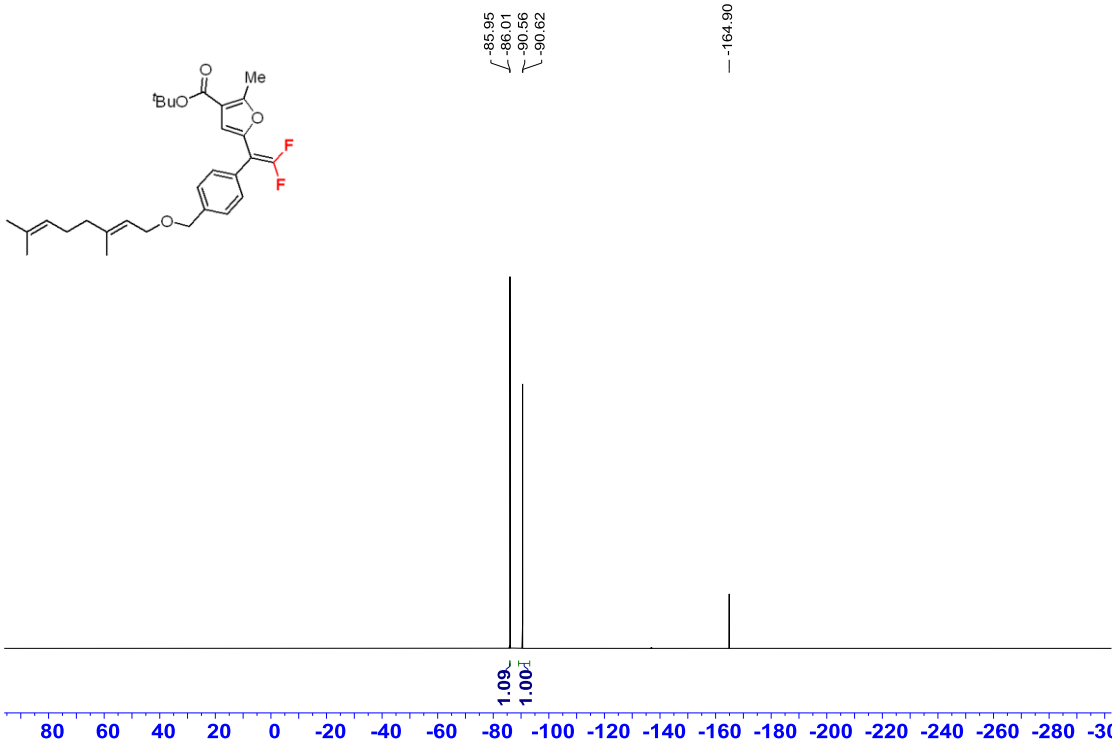
^{13}C NMR (151 MHz, $CDCl_3$) spectrum of compound **52.**



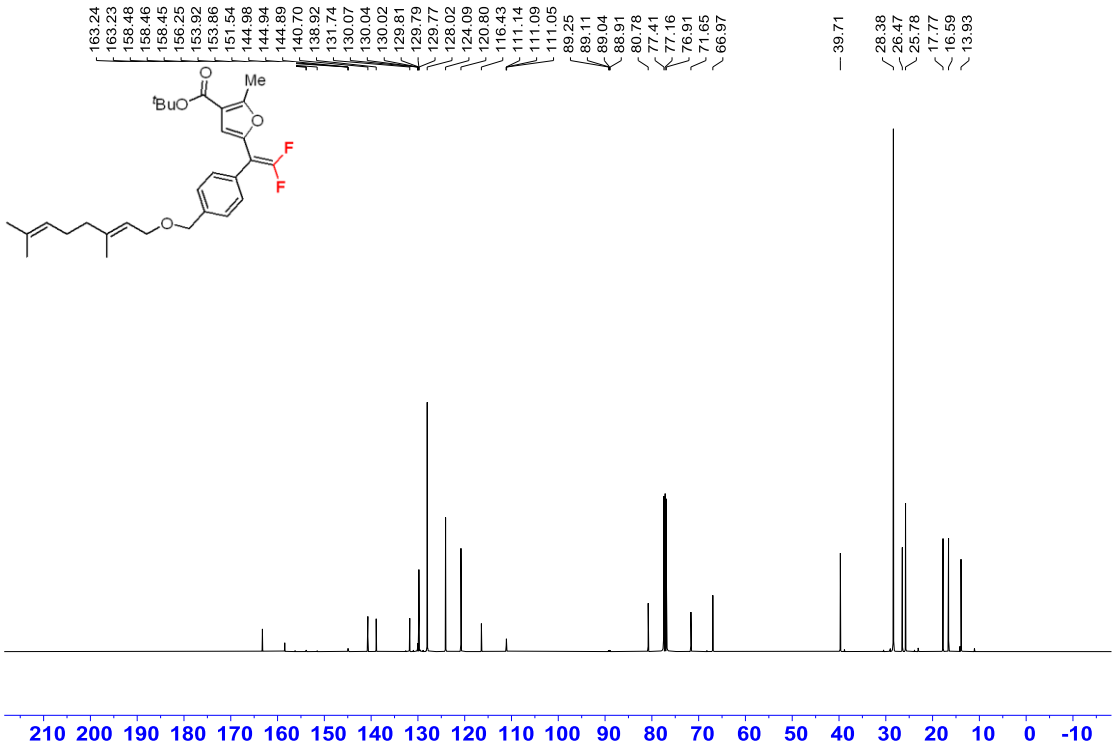
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **53.**



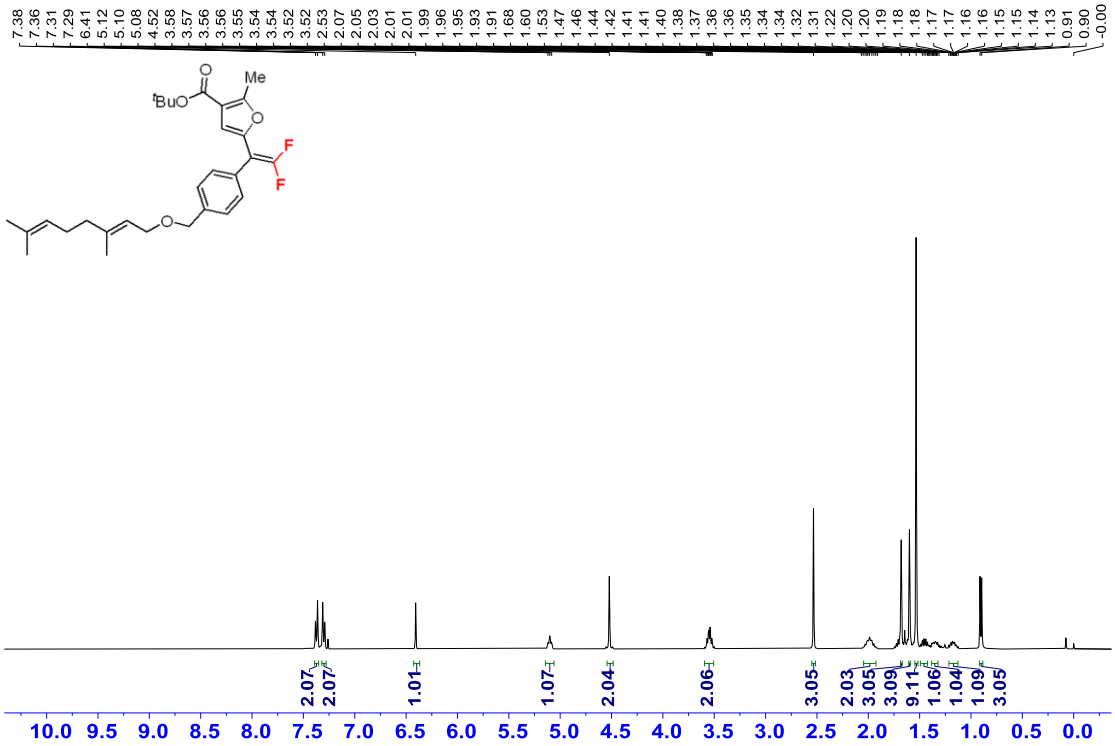
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **53.**



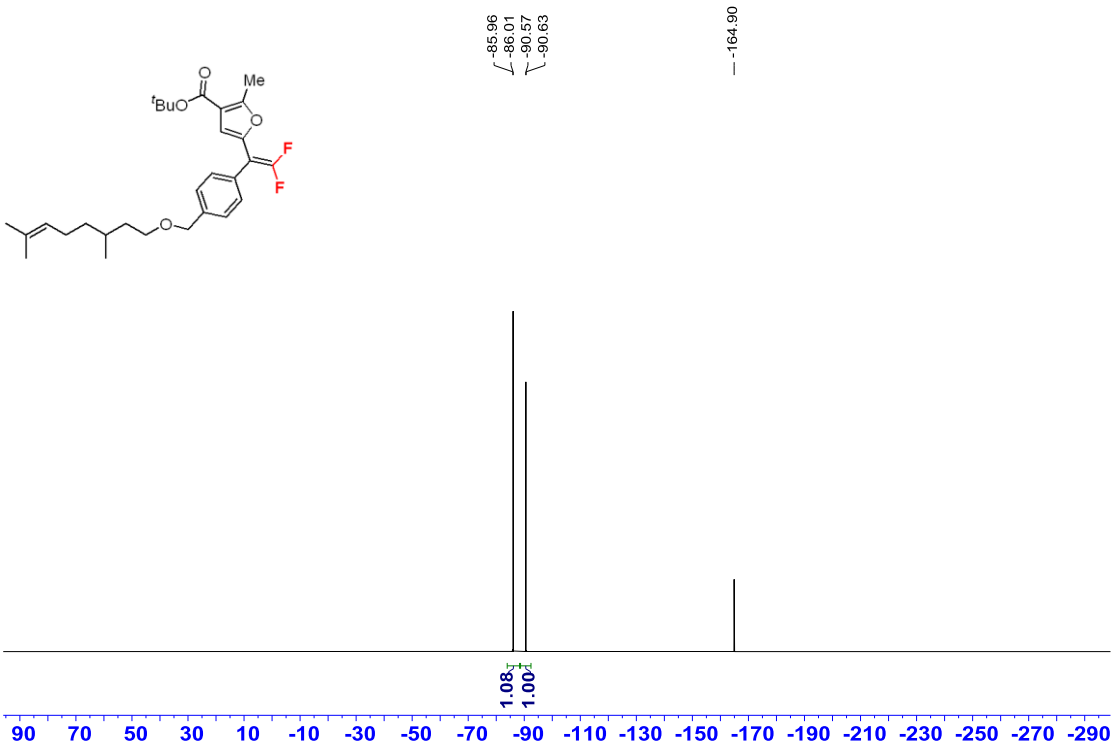
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **53.**



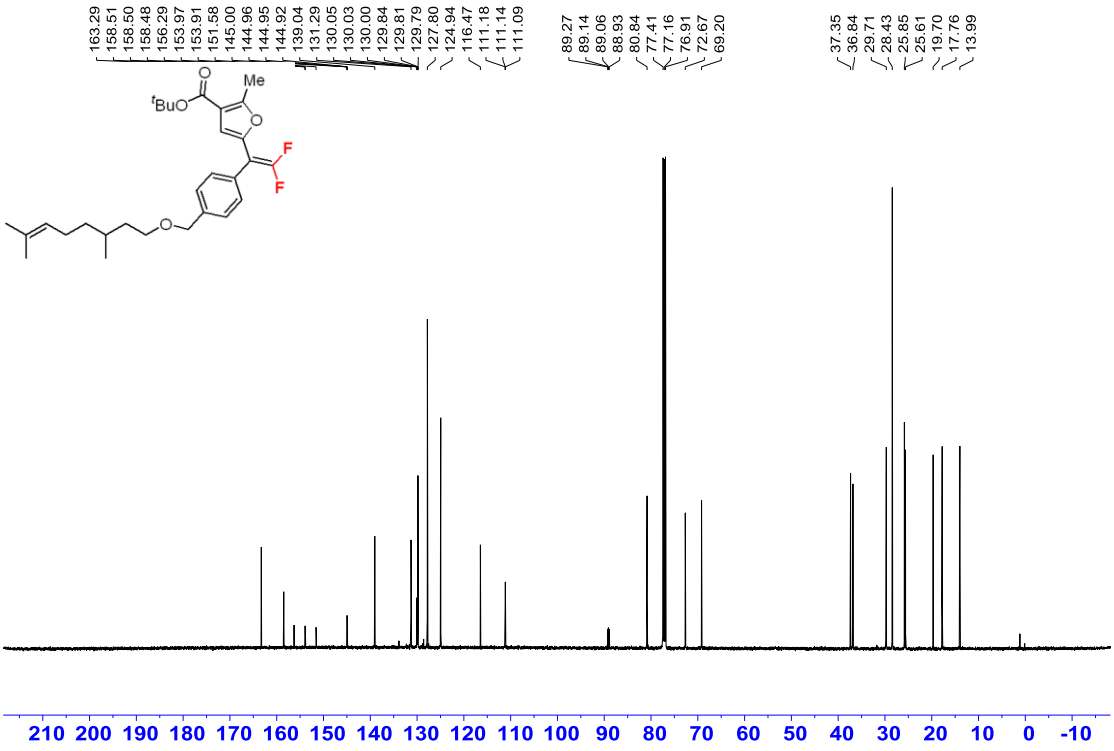
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **54.**



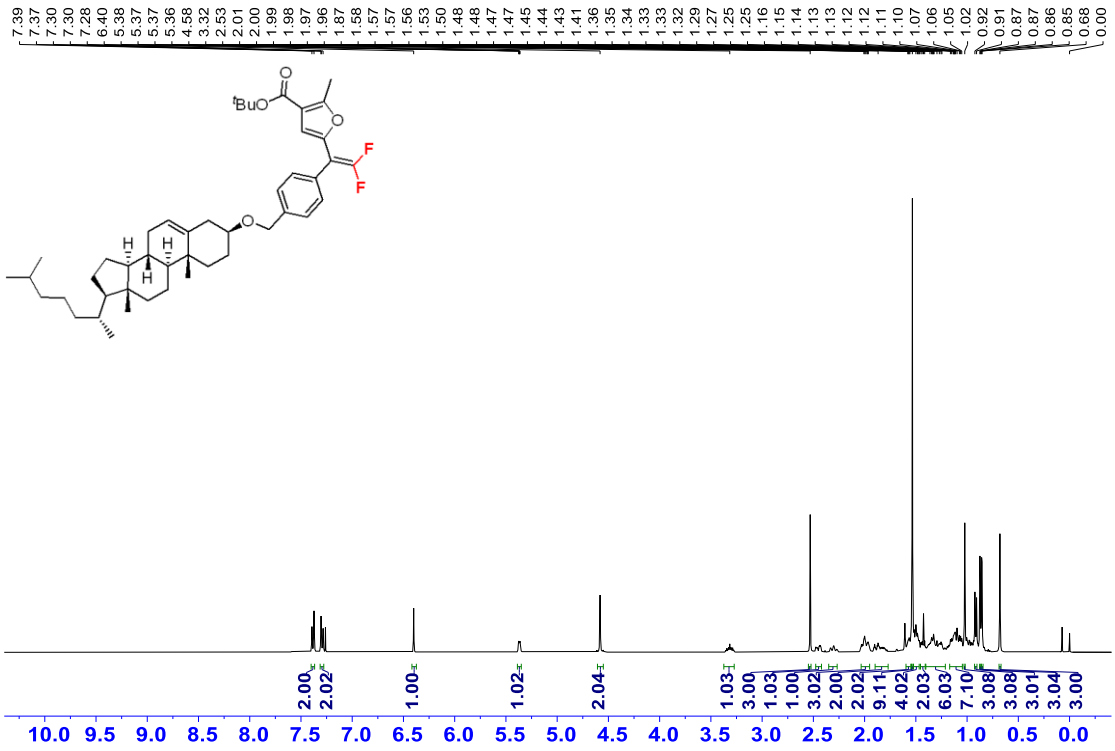
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **54.**



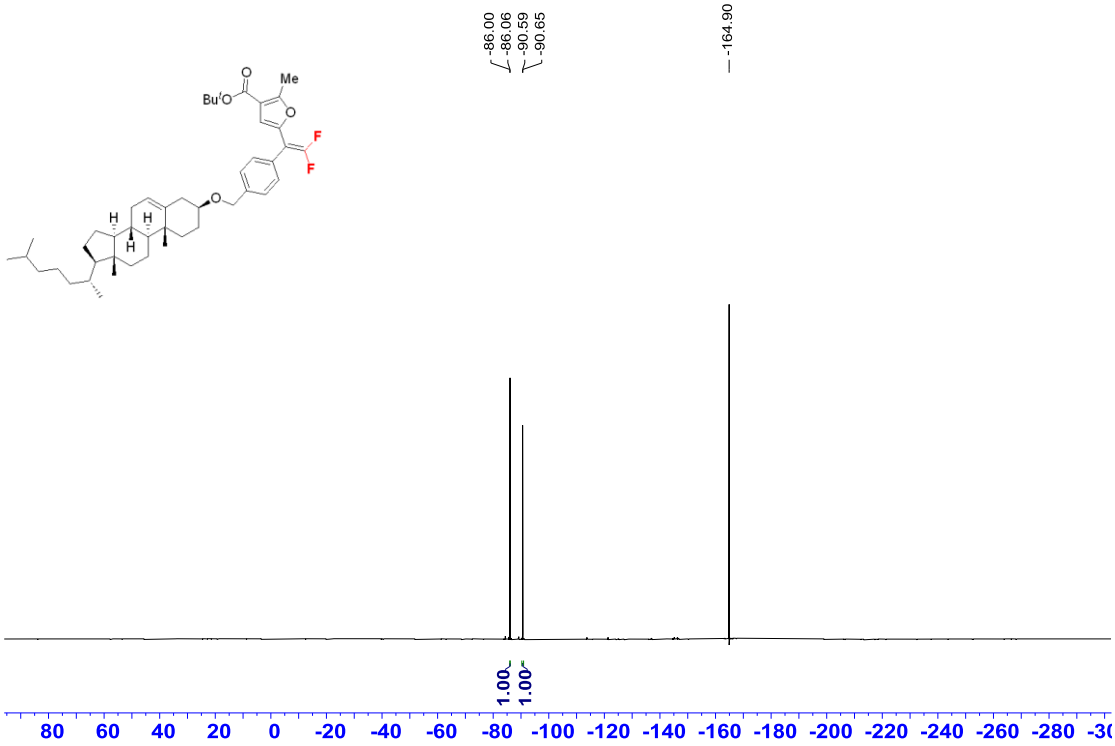
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **54.**



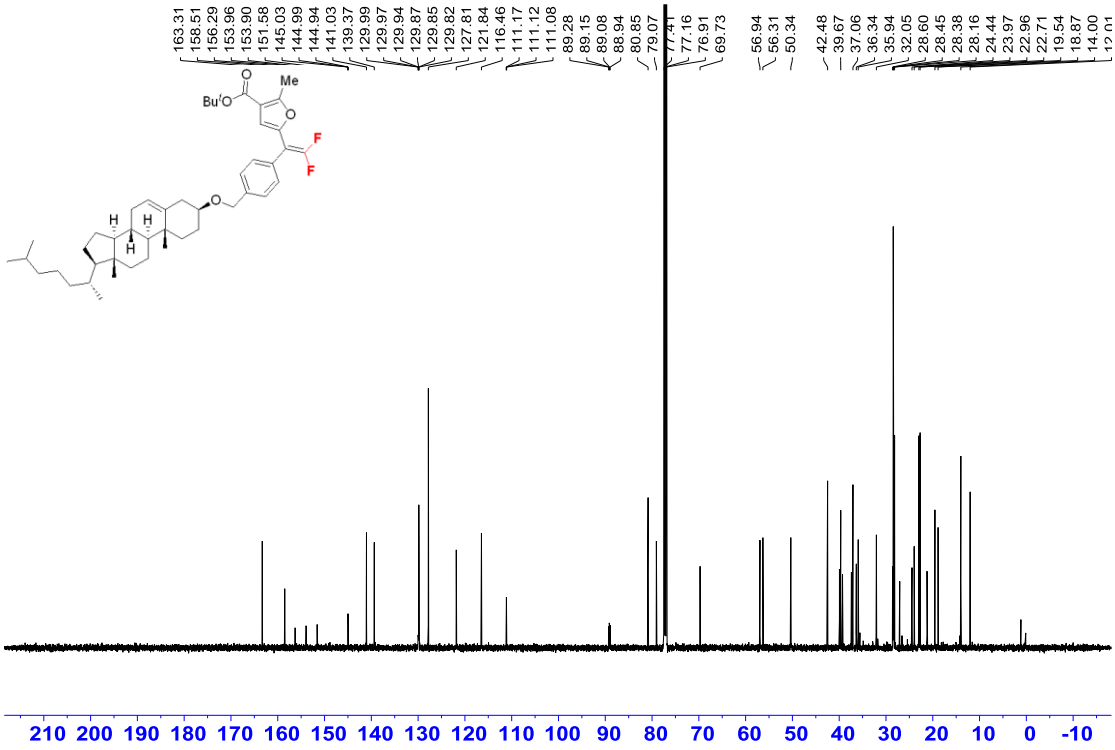
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **55.**



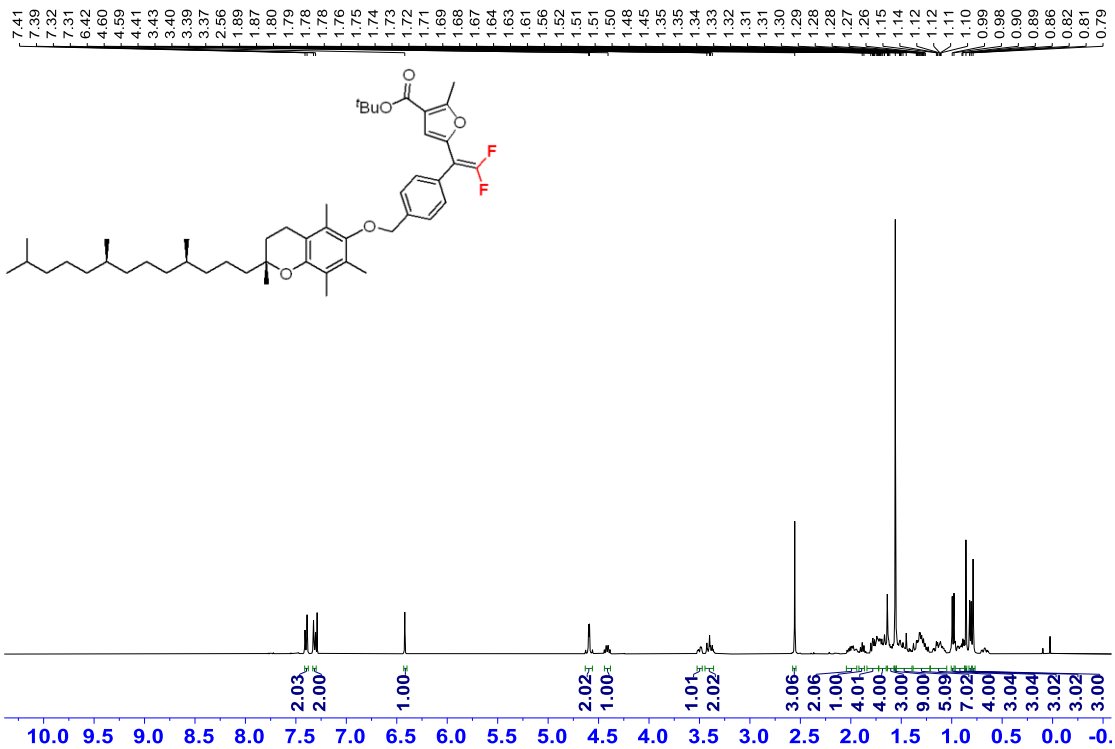
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **55.**



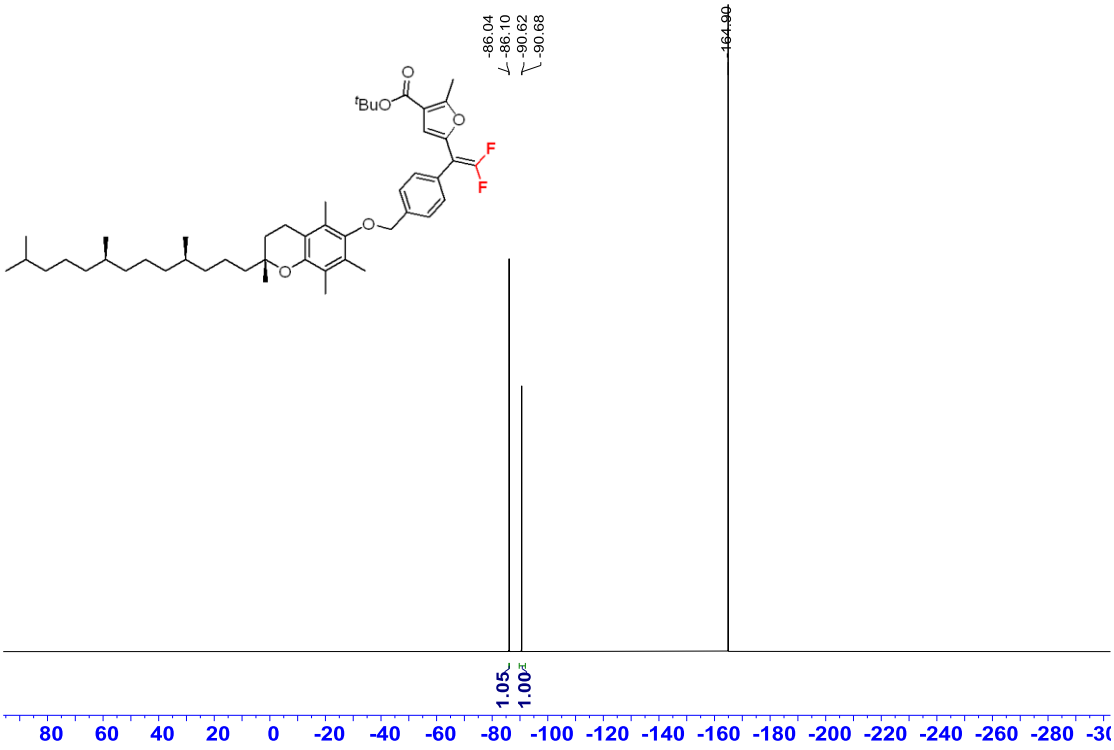
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **55.**



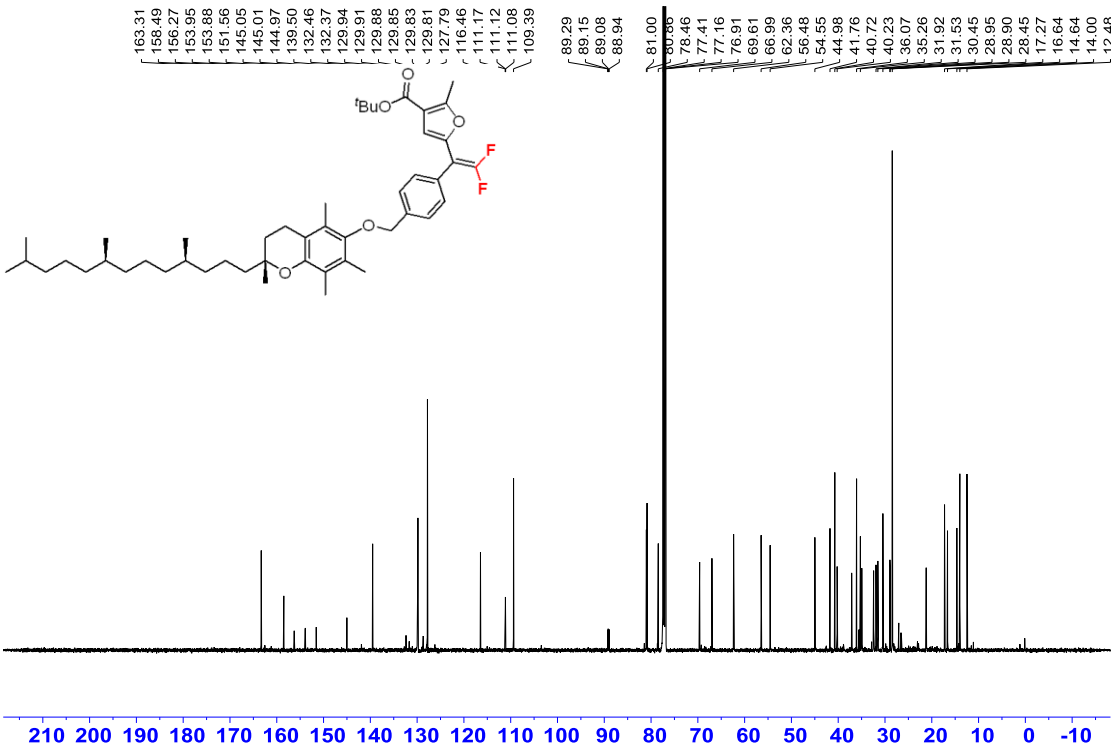
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **56.**



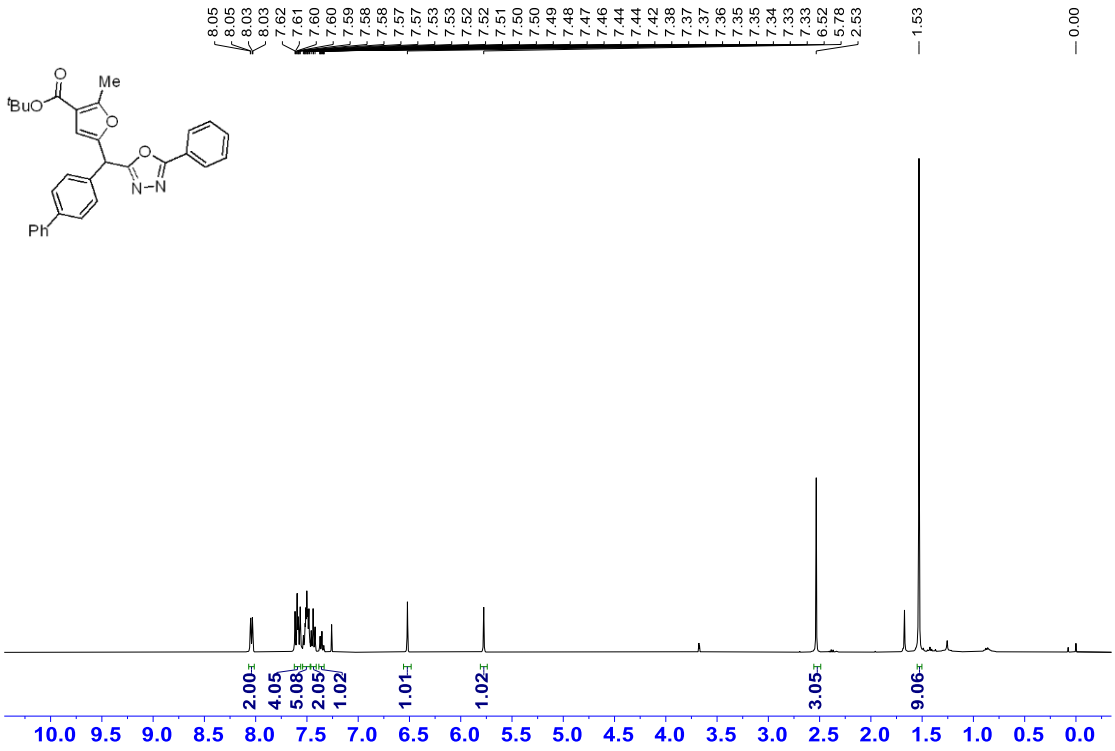
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **56.**



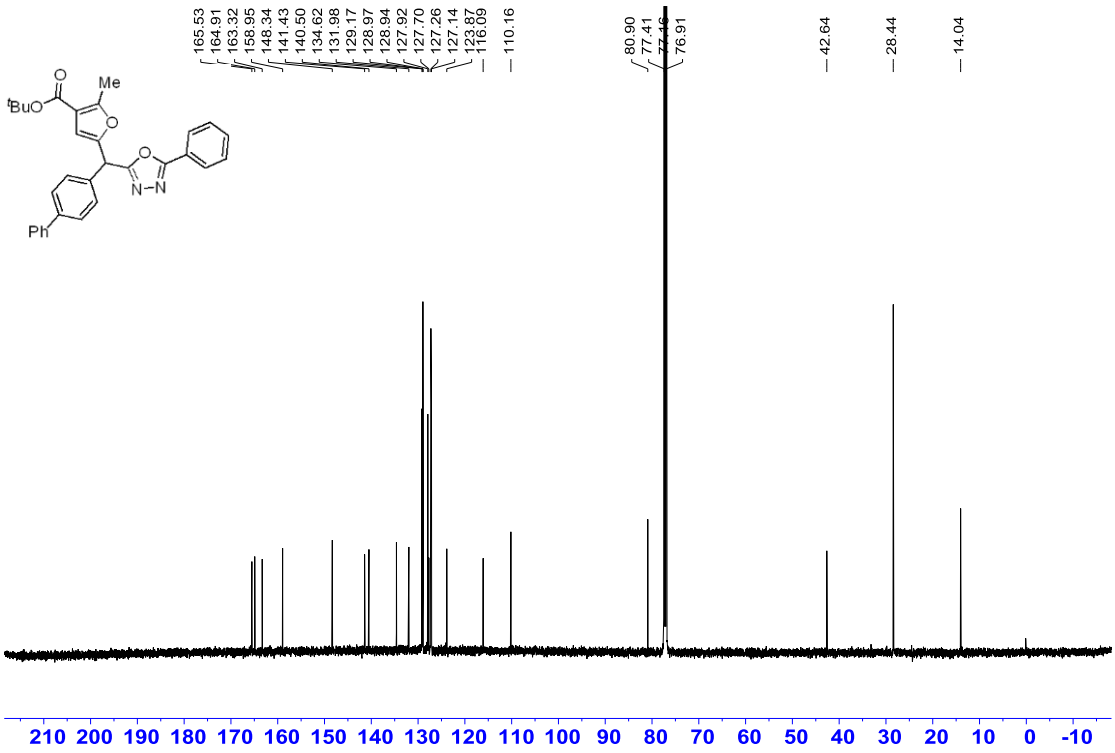
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **56.**



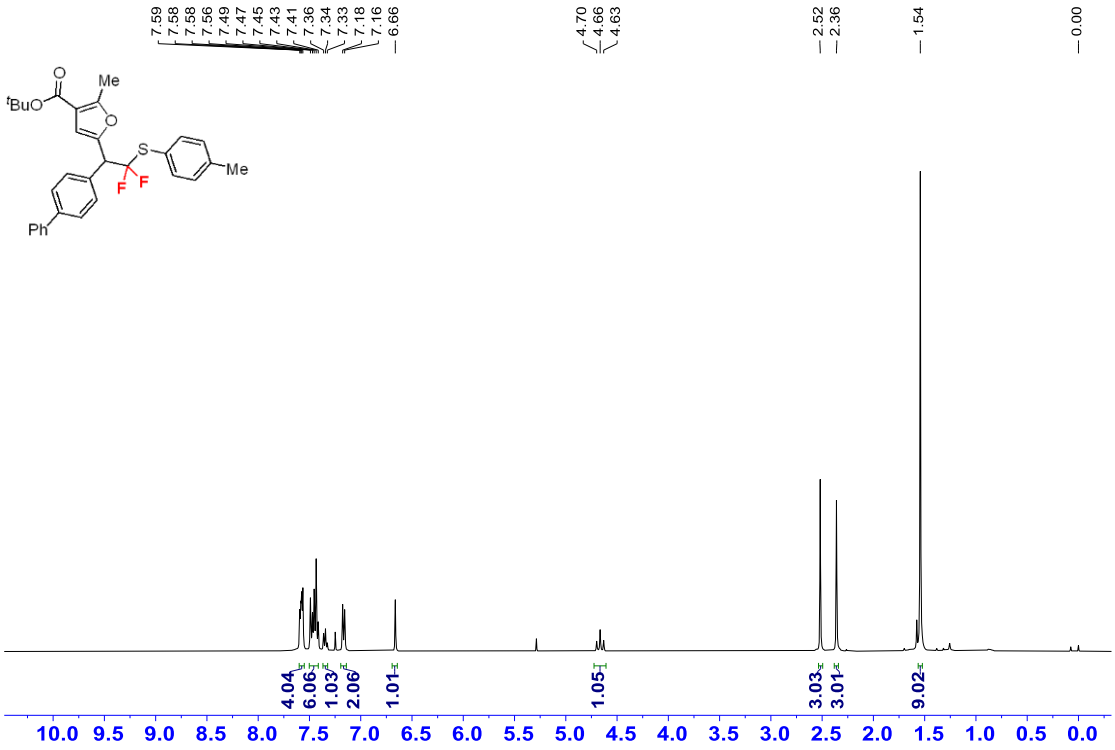
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **57.**



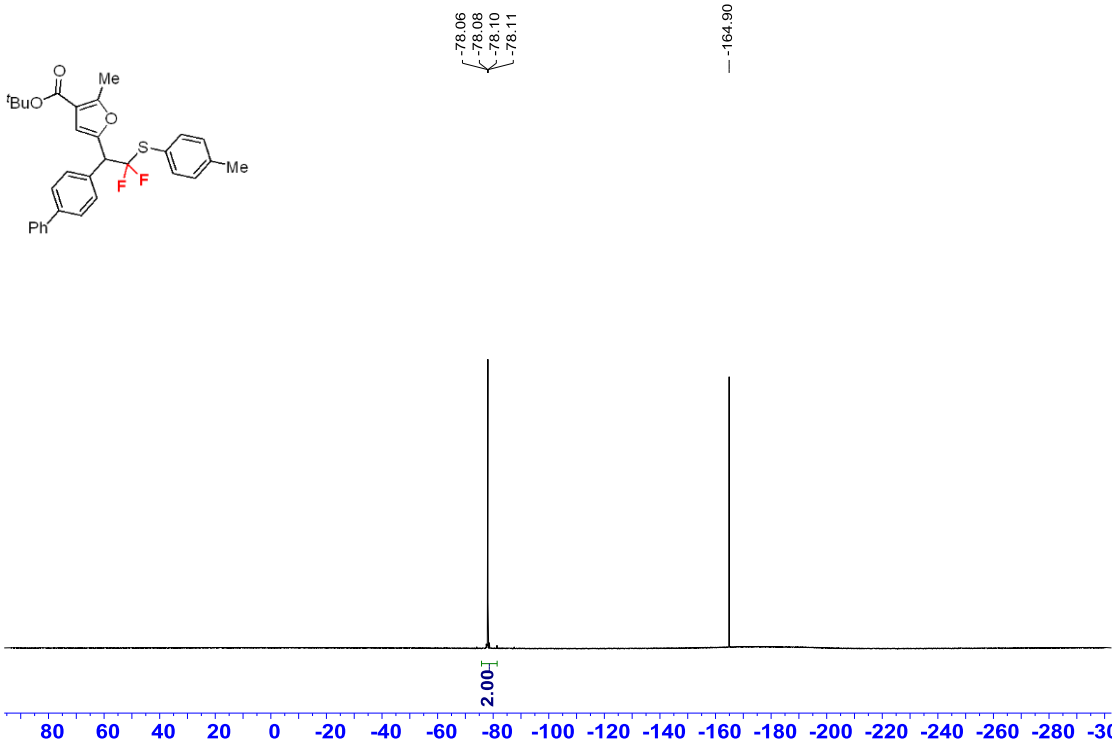
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **57.**



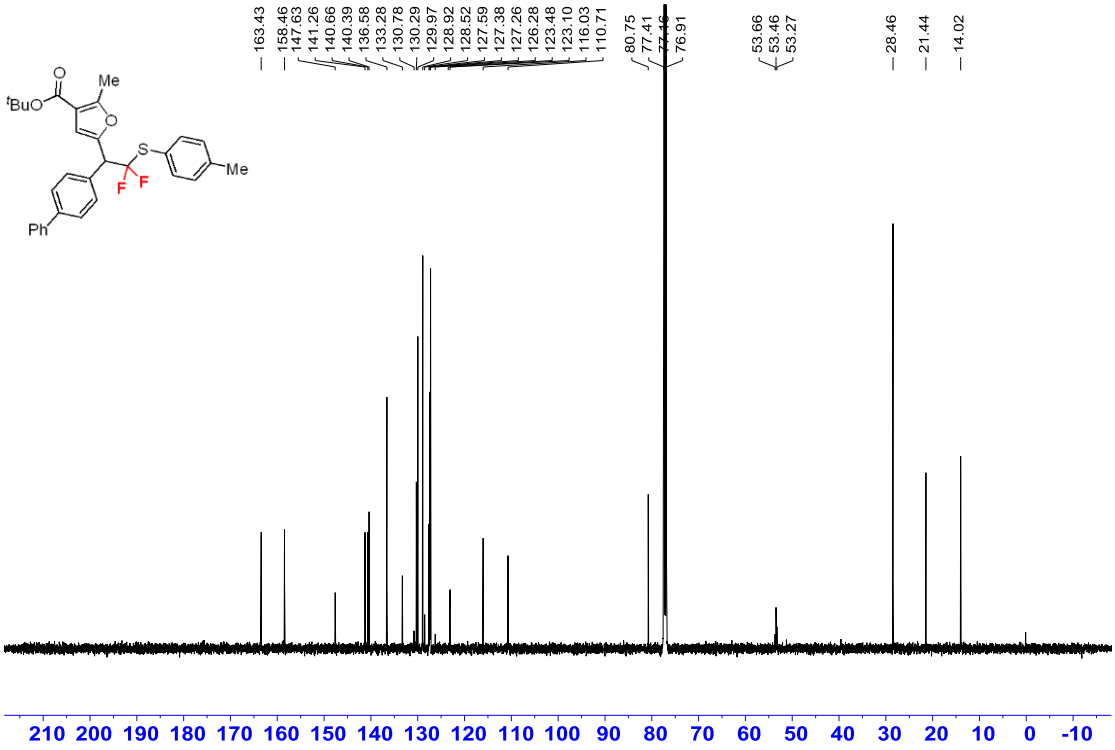
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **58.**



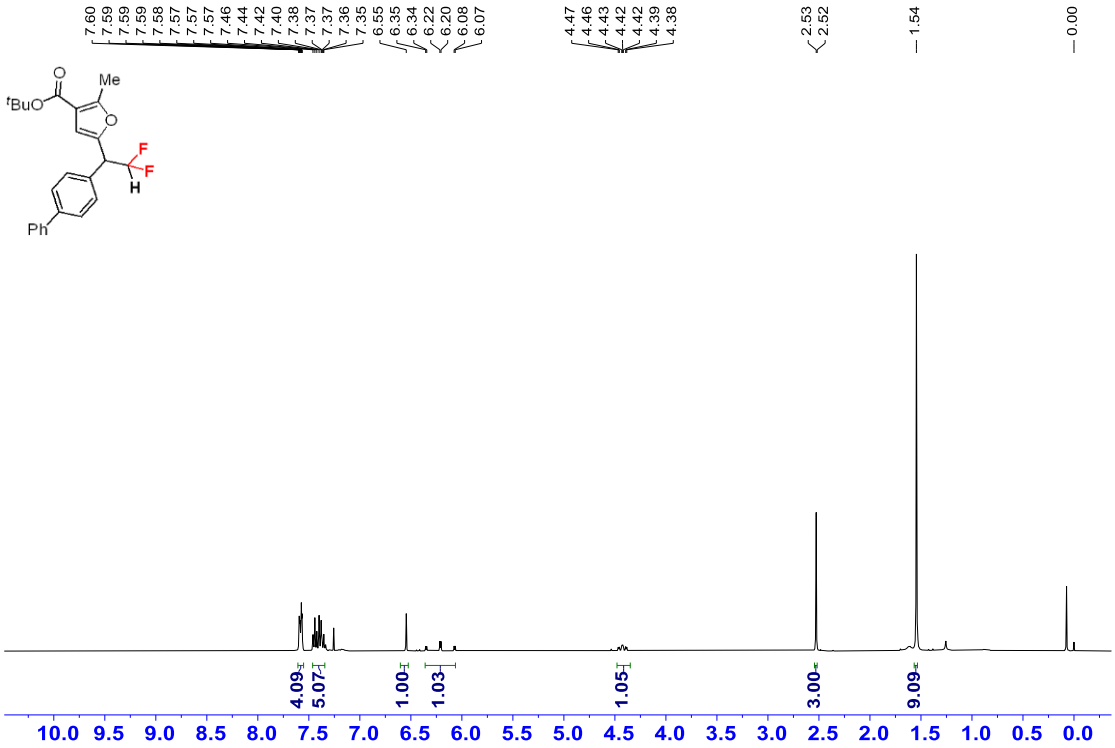
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **58**



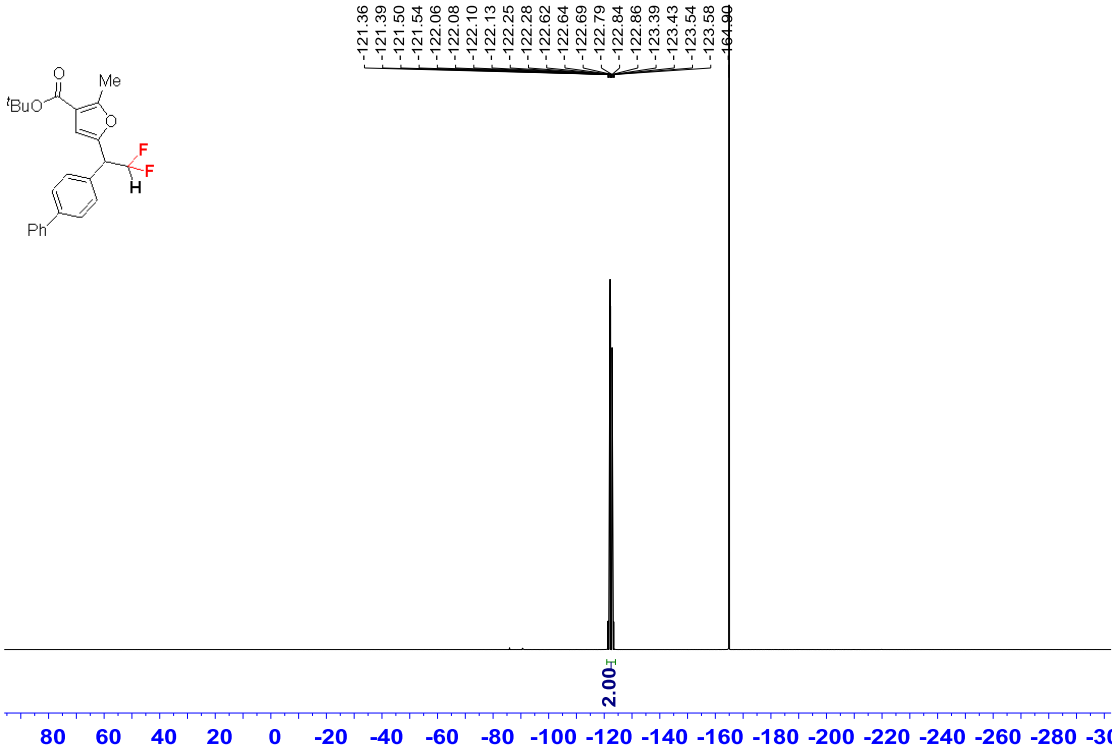
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **58.**



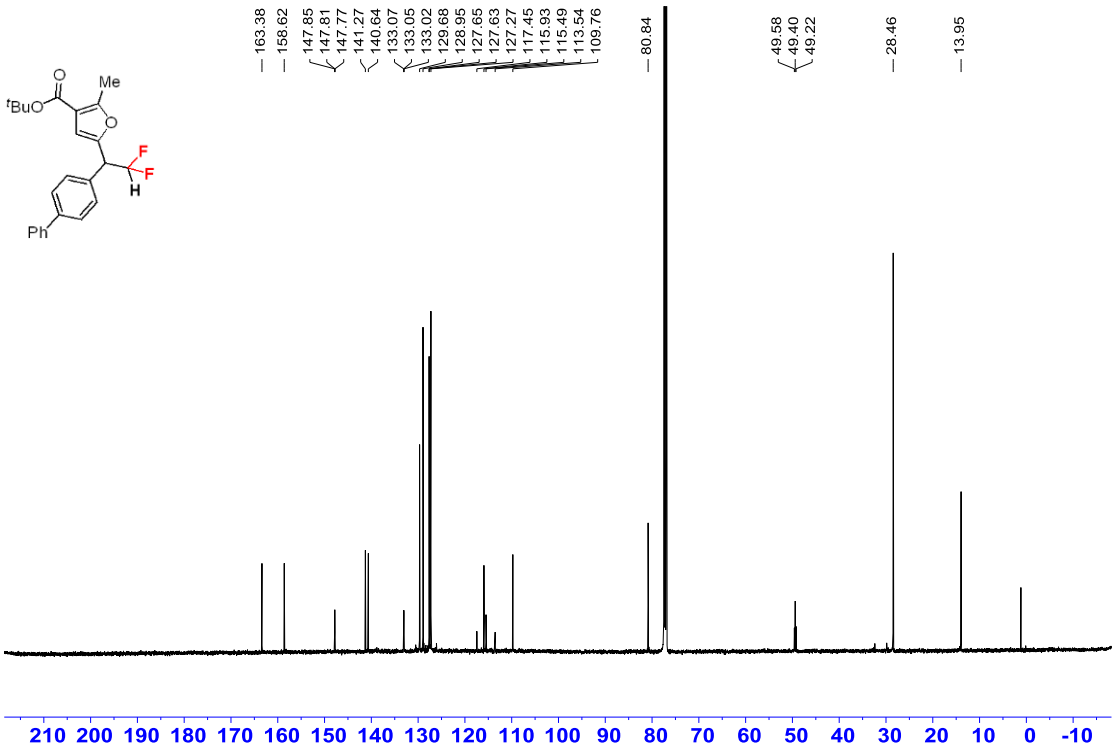
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **59**.



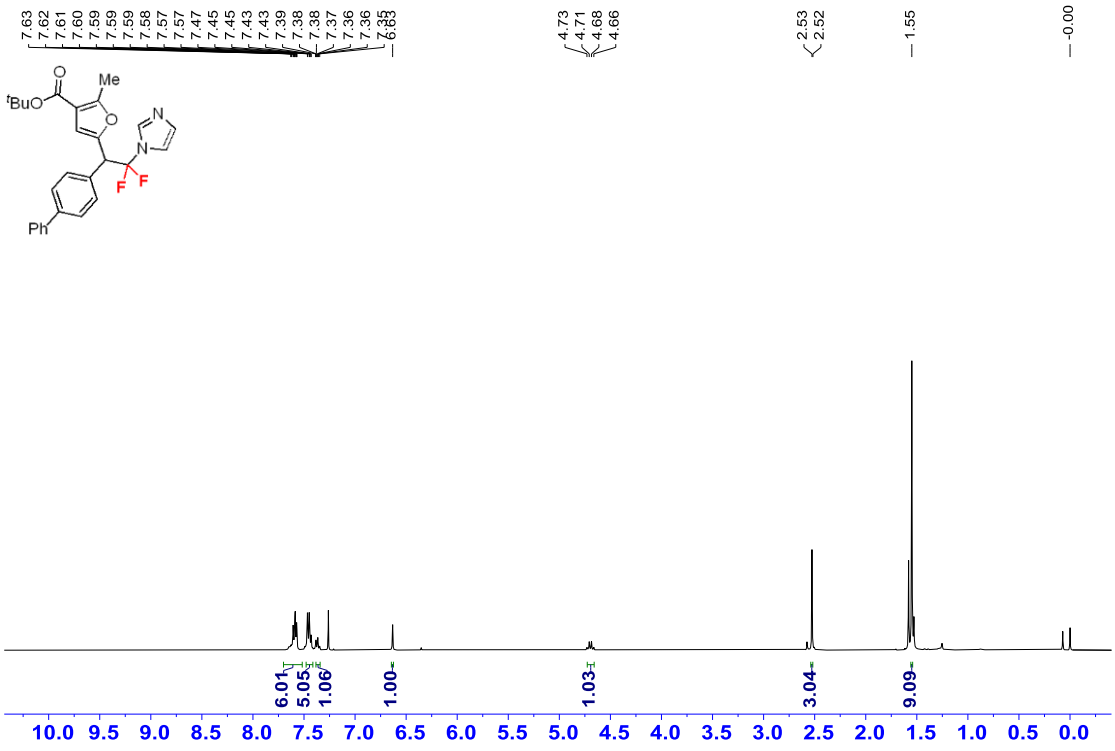
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **59**.



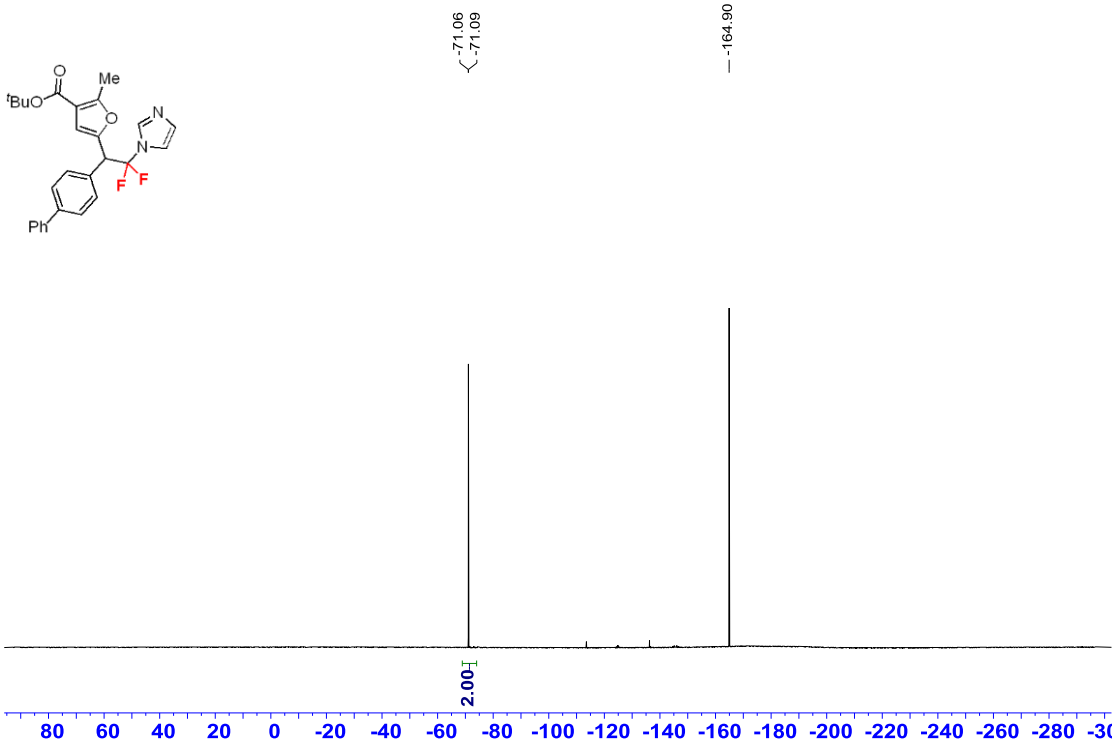
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **59**.



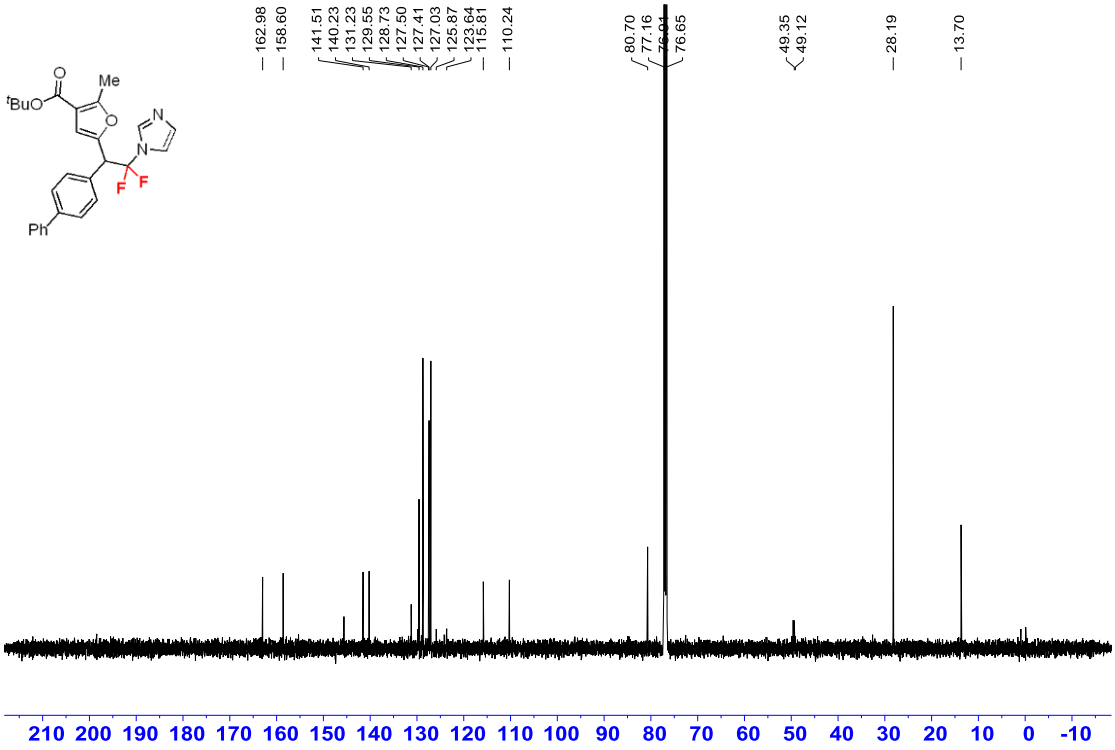
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **60**.



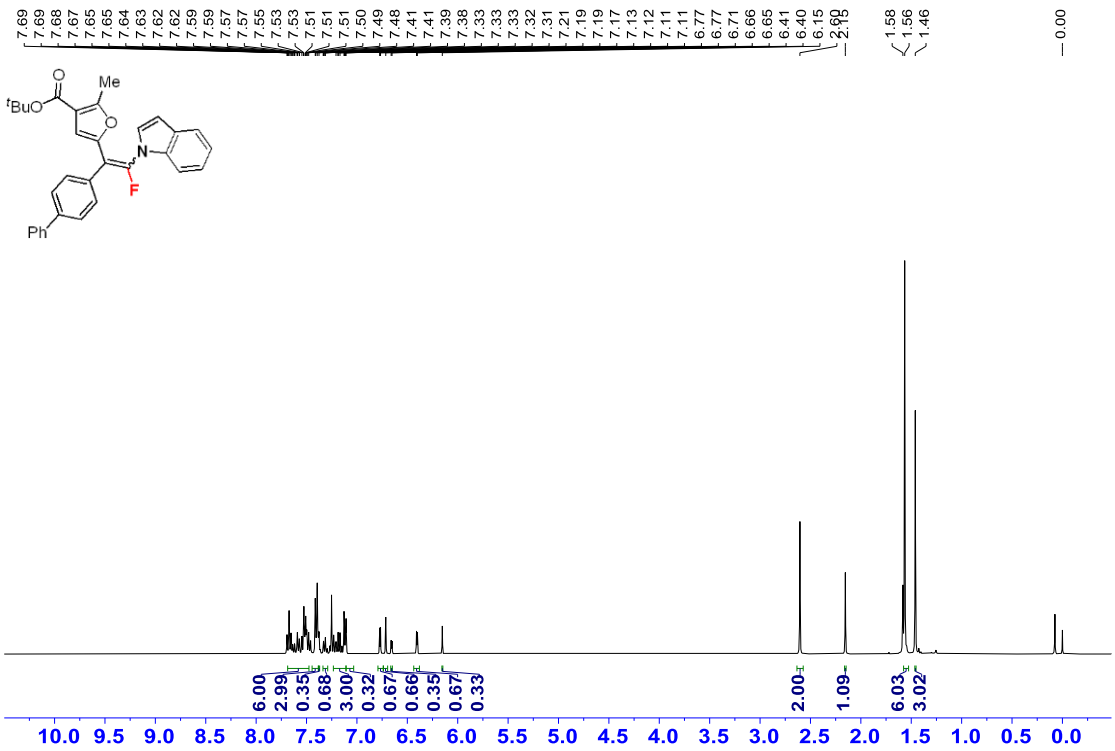
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **60**.



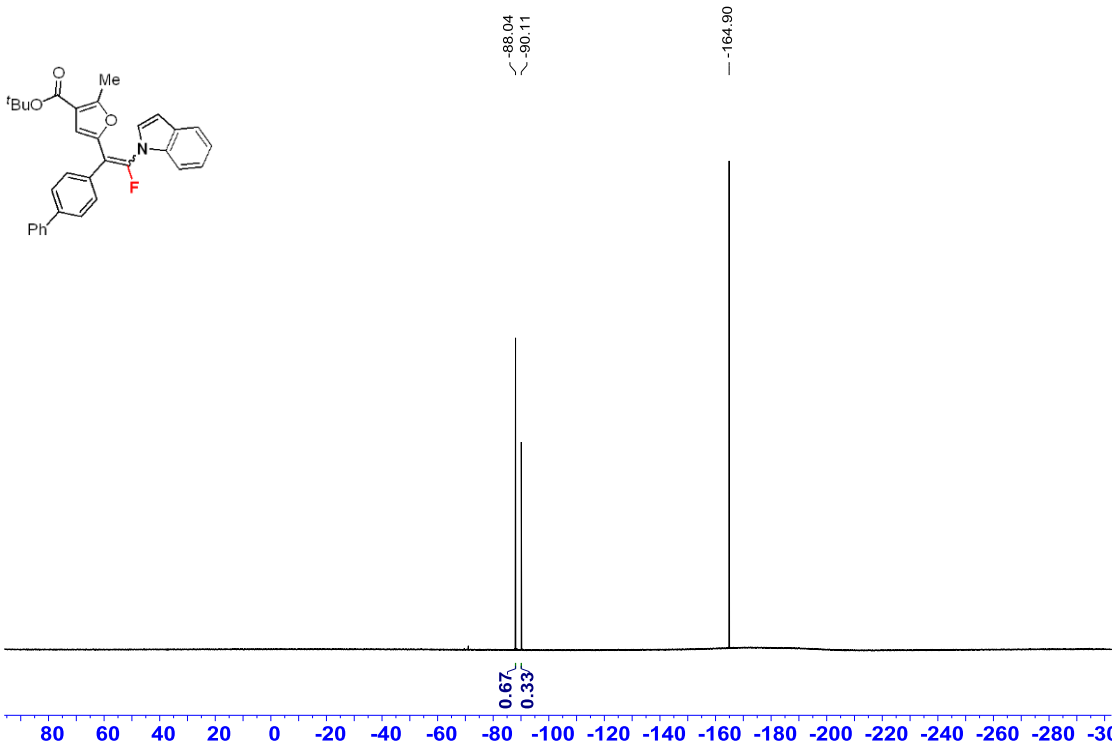
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **60**.



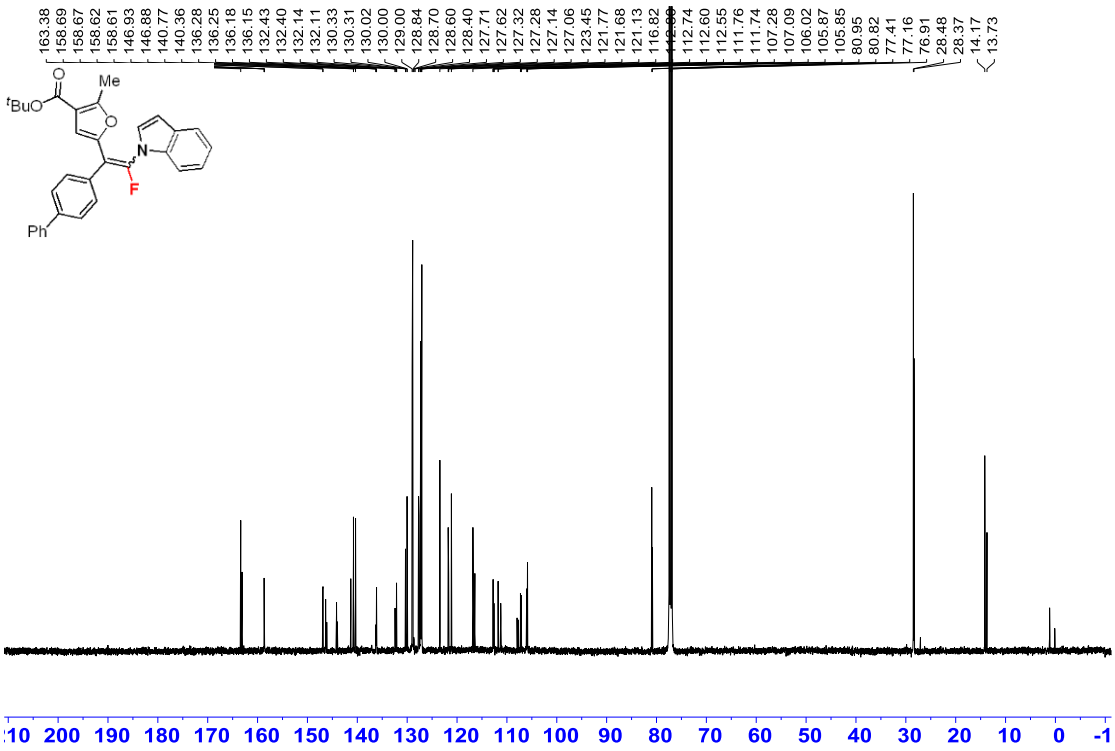
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **61**.



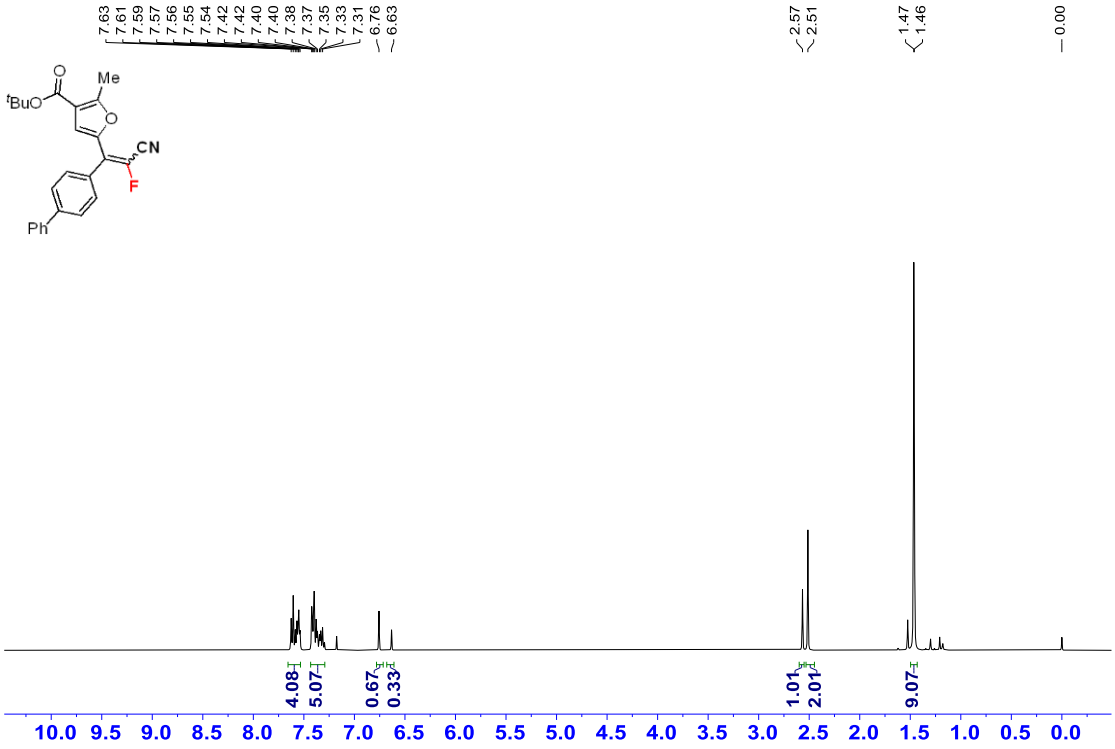
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **61**.



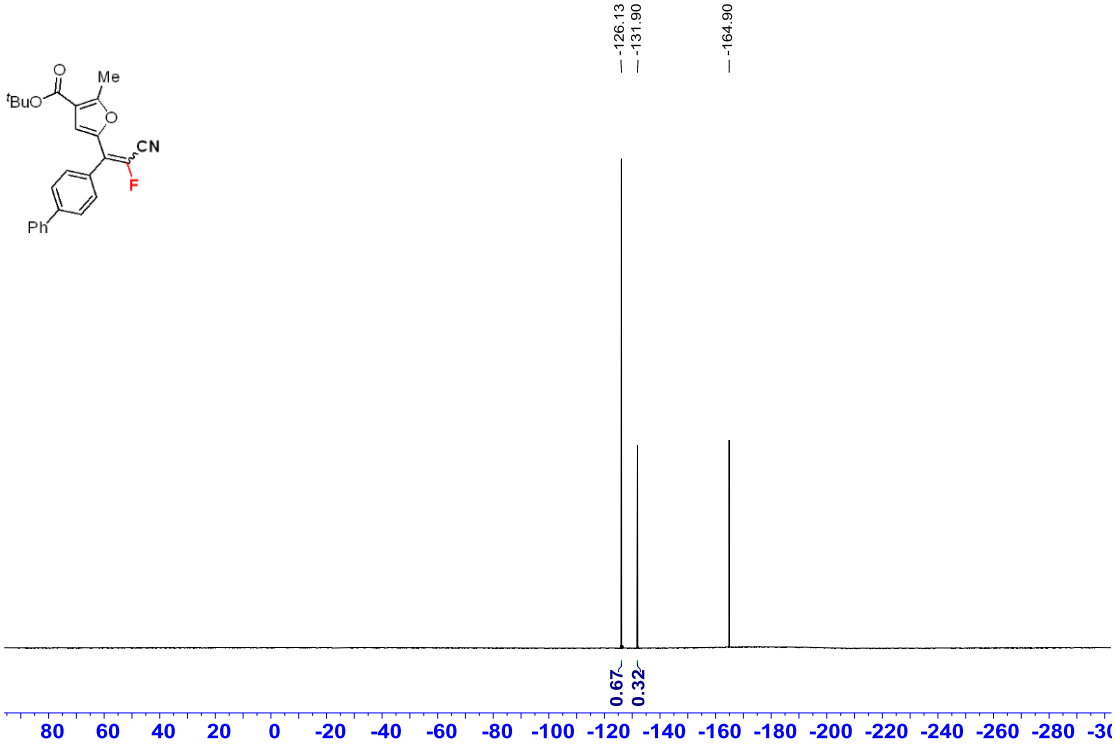
^{13}C NMR (151 MHz, $CDCl_3$) spectrum of compound **61**.



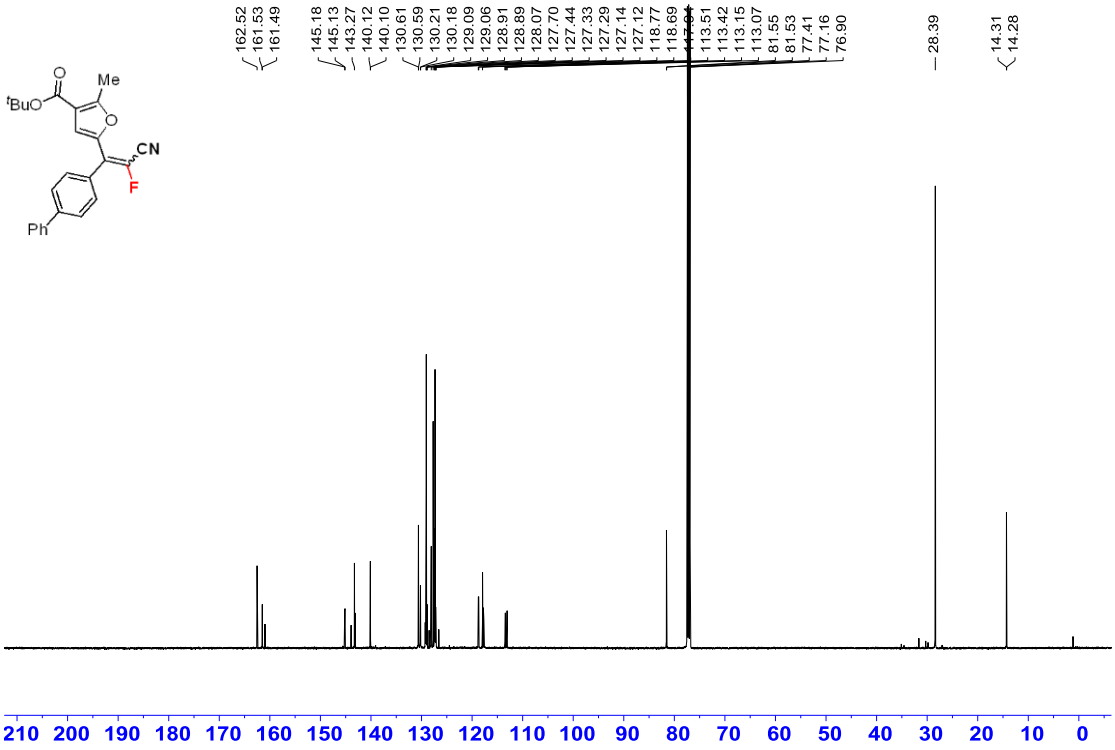
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **62**.



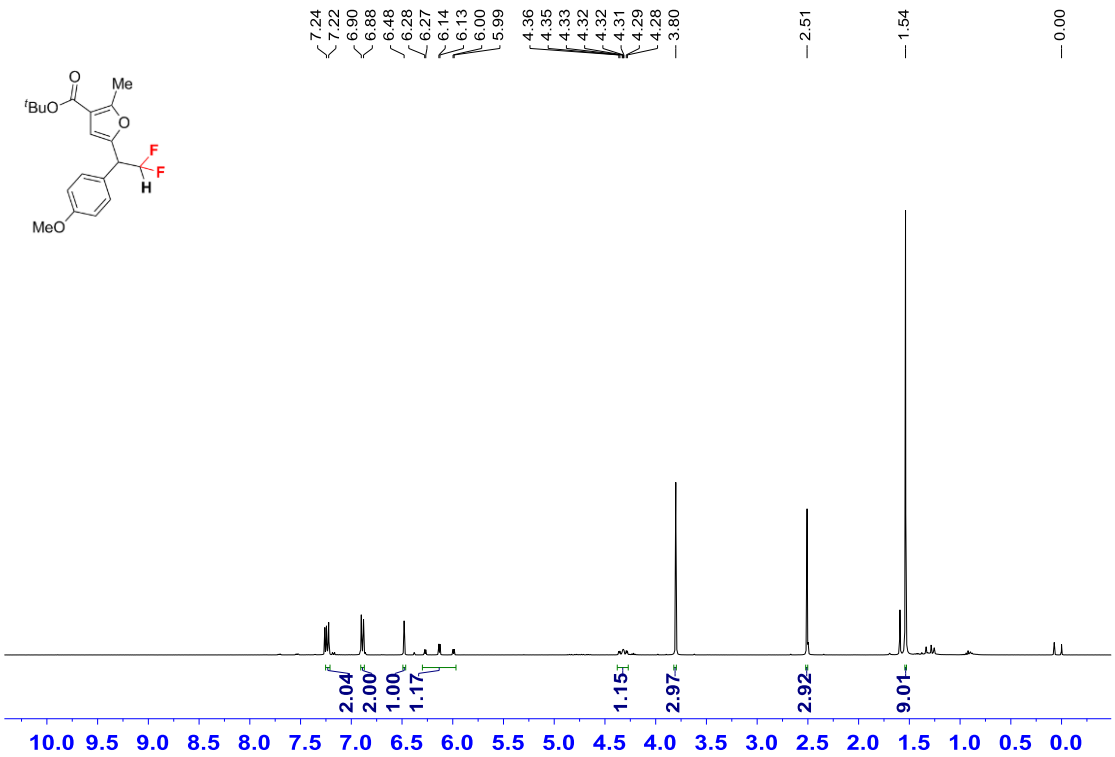
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **62**.



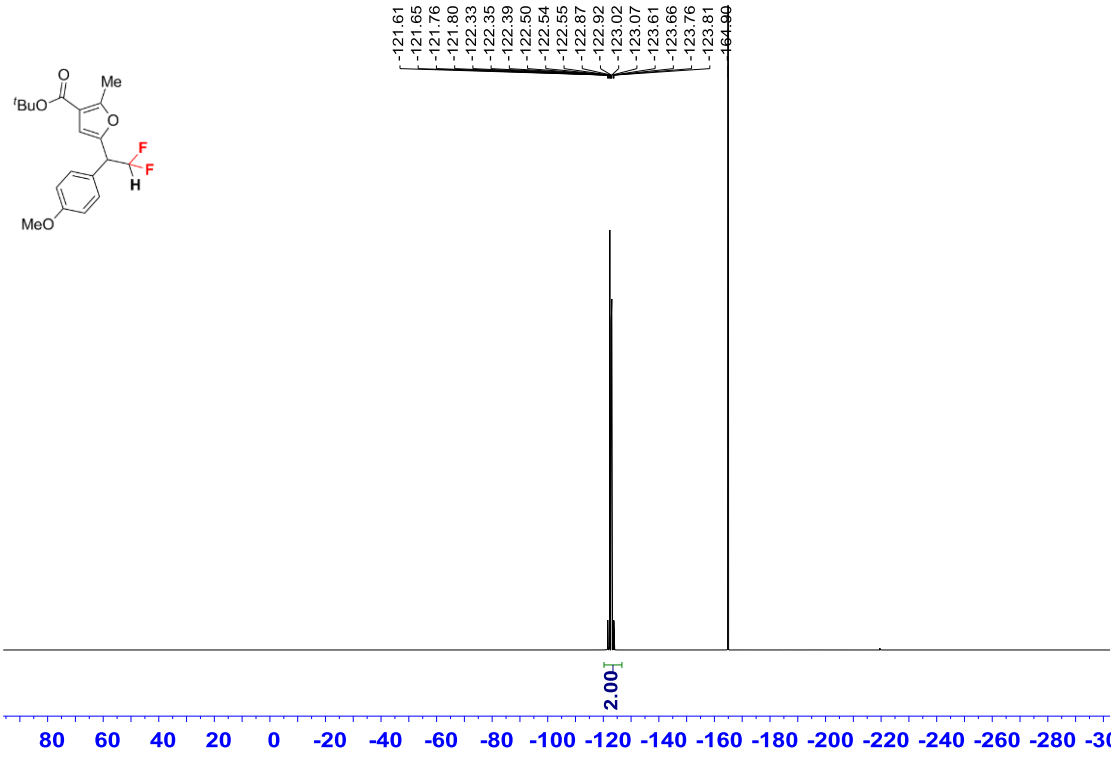
^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **62**.



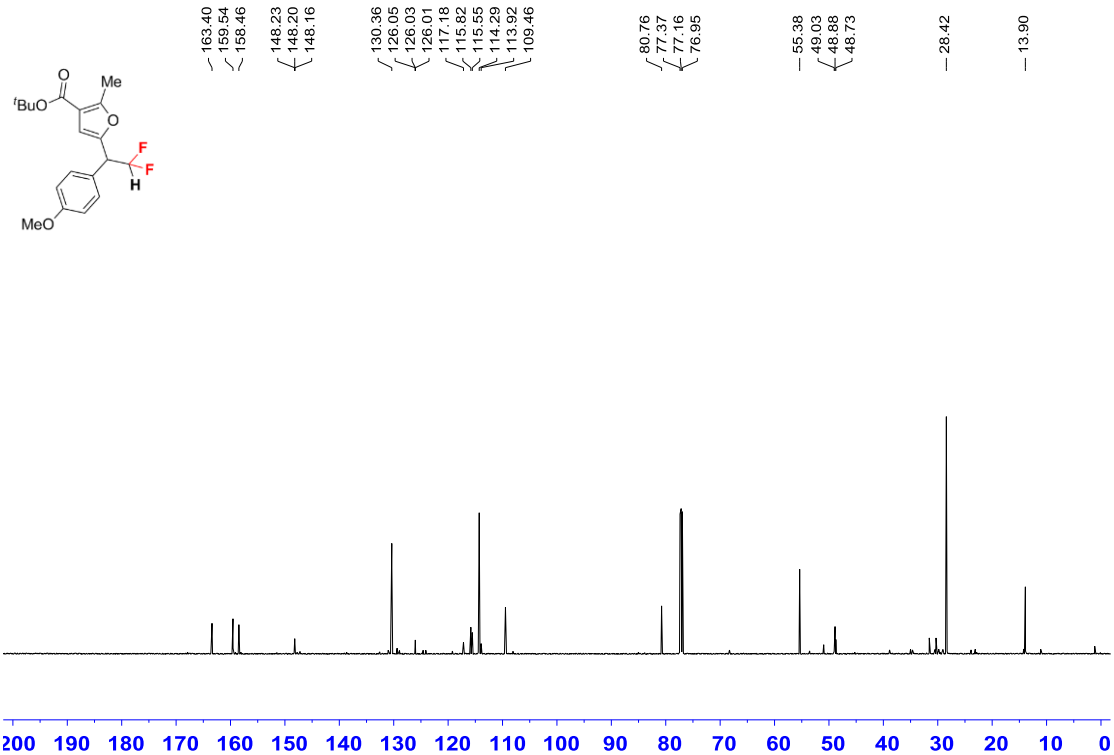
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **66**.



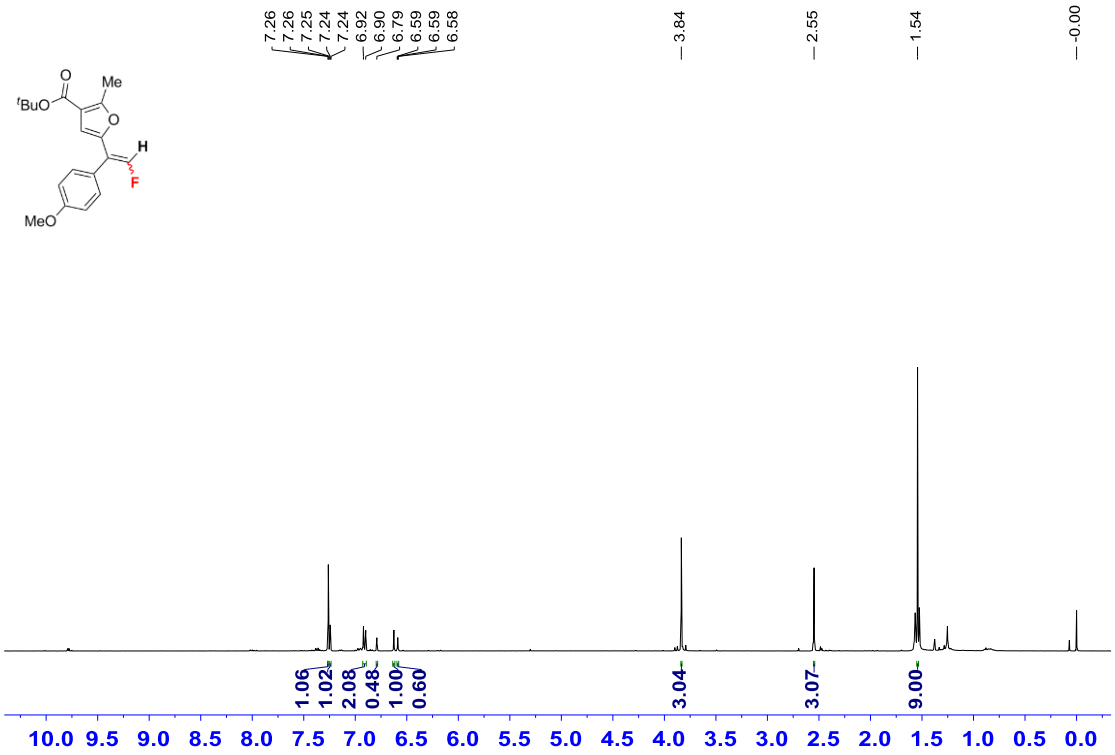
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **66**.



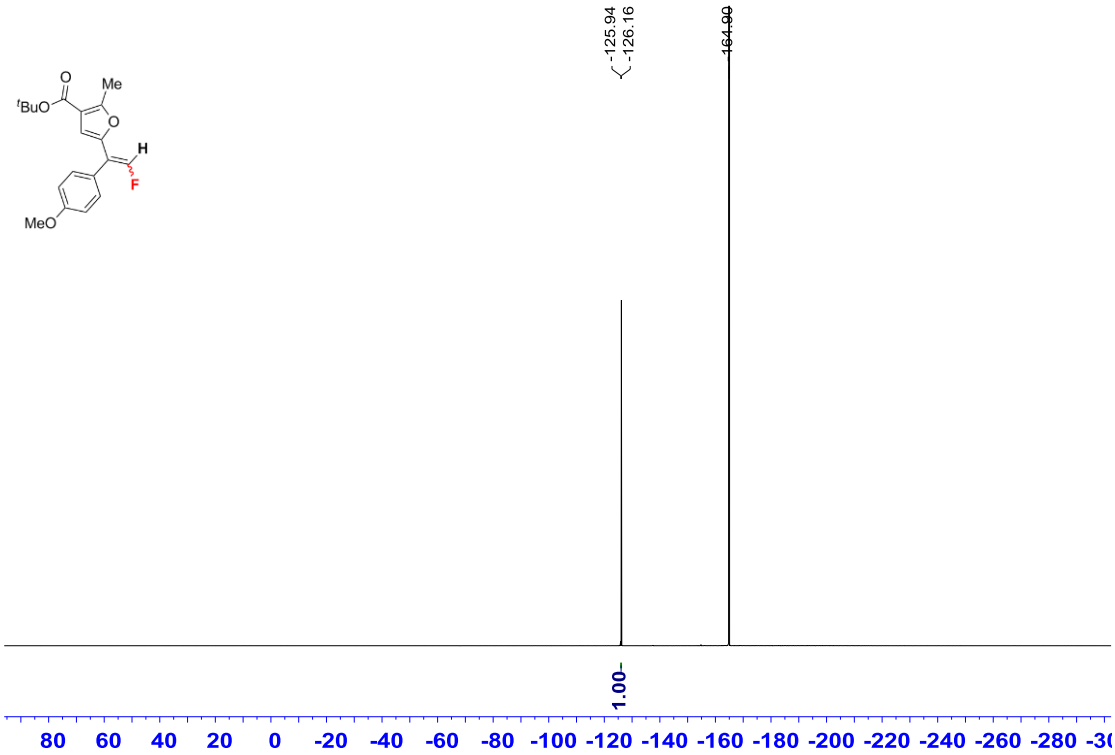
^{13}C NMR (151 MHz, $CDCl_3$) spectrum of compound **66**.



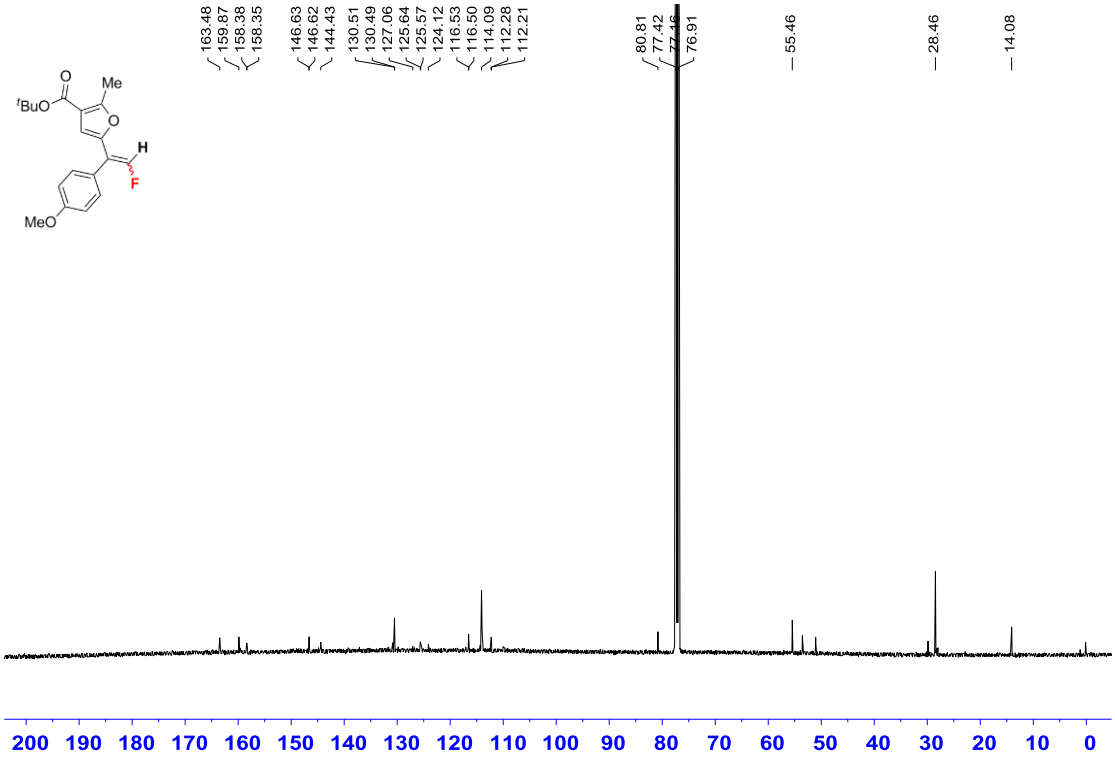
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **67**.



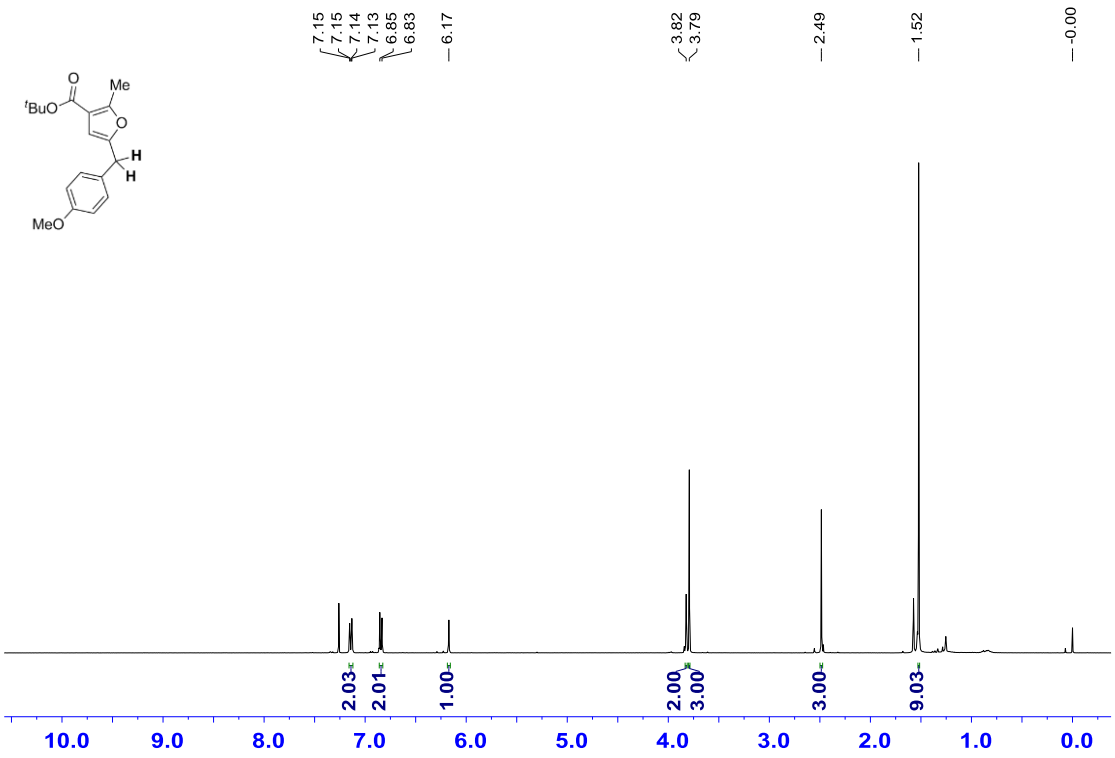
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound **67**.



^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **67**.



^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound **68**.



^{13}C NMR (126 MHz, $CDCl_3$) spectrum of compound **68**.