Provisional Application for United States Patent

TITLE: Unified Quantum Electro Dynamic Field Effect Option Model

INVENTOR(S): John Wang, Chris Pei, Teresa M. Pak

U.S. Patent Application Number 6213 5187 7777

BACKGROUND

In the financial world, option trading makes up a large part of the opportunities to make money. Determining the future market value of these securities and options in an efficient manner is important to all the entities involved buying, selling, and holding these options and securities. Traders, trustees, investment bankers, fund managers, broker-dealers, investors all need tools to determine the implied value the options and securities they are trading or holding.

There are many approaches to modeling the financial behavior of securities. Most have shortcomings for a variety of reasons. Earlier option pricing models such as the 1973 Black Scholes approach with brownian motion and diffusion process as described by the second law of thermodynamics are sufficient for near-the-money or at-the-money trades but not for out-the money trades.

The understanding that financial systems interactions can be modeled in the same manner as physical systems leads to the use of the laws of physics, mathematics and statistics, to create financial models that use the similarities to physical interactions in our universe.

Some of the ways this modeling invention addresses the shortcomings of earlier models is by:

Unifying many of the classical modeling methods

Brownian motion extended to quantum propagation

Classical Heat diffusion extended to quantum wave diffusion

The introduction of asymmetric quantum diffusion to account for investor psychology of asymmetric biases for positive and negative outcome

It uses concepts from the unified field theory of physics and mathematics including:

Weak and Strong Interactions (Short Range)

Electromagnetic Field (Long Range)

Gravitational Field (Long Range)

Differentiable Manifold Deconvolution

Space Time Energy Momentum Tensors

Dark Matter Dark Energy

The Quantum Electro Dynamic (QED) field effect option model describes the quantum behavior of volatility evolution, unlike what has ever been done in the market before. This gives it the ability to accurately predict when short-term volatility inefficiencies occur in the market, and thereby profit from the high-probability mean reversion strategy on volatility-based trades.

Unlike the classic Black Scholes model the QED Model provides five pieces of information:

Positive implied volatility (good)

Negative implied volatility (bad)

Upward movement speed

Downward movement speed

Deviation of risk neutral condition (ugly)

BRIEF SUMMARY OF THE INVENTION

This option model is based on quantum electrodynamics (QED) field effect. The classical random walks are extended to quantum walks. The quantized option price states are modeled along one-dimensional tight-binding quantum chain. The wave function of such a quantum chain is described by the Schrodinger equation and the probability density function is governed by the generalized master equation of quantum diffusion. Numerical solutions can be obtained via Monte-Carlo simulations. The resulting density distribution has well defined front shape. One key feature of the model is the introduction of asymmetric quantum diffusion along positive and negative states to account for investor asymmetric risk preference. Our QED-based model unifies many classical option models (BS, VG, DE) as special cases but most importantly extends to other endless possibilities from quantum ballistic limit to quantum super-diffusive regime.

DETAILED DESCRIPTION AND BEST MODE OF IMPLEMENTATION

The model is implemented as a set of computer programs running on a massively parallel, memory based, ubiquitous computing system that use a large heterogeneous data base of securities data going back several decades along with real time trading data. The model can also be used for other types of financial or other modeling using the appropriate data and factors.

Options Formula

$V_p(t|S, K, T)$
$- put\ price\ at\ time\ t\ for\ stock\ S, strike\ K, maturity\ T$
$V_c(t|S, K, T) - call\ option\ price\ at\ time\ t$

$$V_p = K_d p_0 \rho \nu \left[e^{-x_*} \sum_{n=0}^{\infty} \frac{\rho^n}{n!} \Gamma(\nu + n\nu, y) - \Gamma(\nu, y) \right] + (K_d - S_d)\theta(x_*) (1)$$

$$V_c = S_d - K_d + V_p \quad (2)$$

Confidence Formula

$P_p - probability\ of\ exercising\ a\ put\ option$
$P_c - probability\ of\ exercising\ a\ call\ option$

$$P_p = \theta(x_*) - p_0 \rho \nu \Gamma(\nu, y) \quad (3)$$

$$P_c = 1 - P_p \quad (4)$$

$Confidence\ of\ Success\ (for\ Short\ Put\ Strategy)$
$Confidence - likelihood\ of\ not\ exercising\ the\ put$
$Confidence = 1 - P_p$

Model Calibration Formula

$$\chi_\nu^2(\nu_\pm, \sigma_\pm, \alpha_\pm, \epsilon_\pm, \delta) = \frac{1}{N_{KT}} \sum_{i,j} \left[\frac{V_{OTM}(K_{ij}, T_j) - V_{QED}(K_{ij}, T_j)}{\langle Spread \rangle (T_j)} \right]^2 \quad (5)$$

$$\langle Spread \rangle (T_j) = \frac{1}{N_T} \sum_i (Ask_i - Bid_i) \quad (6)$$

$N_{KT} - number\ of\ data\ points\ for\ all\ option\ series\ in\ (K, T)$
$N_T - number\ of\ data\ points\ for\ a\ given\ option\ series\ in\ K$
$V_{OTM}(K_{ij}, T_j) - market\ mid\ price\ for\ the\ (i, j)th\ point$
$V_{QED}(K_{ij}, T_j) - model\ price\ evaluated\ at\ the\ (i, j)th\ point$

$$V_{OTM}(K_{ij}, T_j) = \begin{cases} Put\ Mid\ Price & for\ K_{ij} < S \\ Call\ Mid\ Price & for\ K_{ij} \geq S \end{cases} \quad (7a)$$

$$V_{QED}(K_{ij}, T_j) = \begin{cases} V_p(0 | S, K_{ij}, T_j) & for\ K_{ij} < S \\ V_c(0 | S, K_{ij}, T_j) & for\ K_{ij} \geq S \end{cases} \quad (7b)$$

Definitions

$$S_d = Se^{-(q+\delta)(T-t)} \quad (8)$$

$$K_d = Ke^{-r(T-t)} \quad (9)$$

$$\rho = \rho_+ \theta(x_*) - \rho_- \theta(-x_*) \quad (10)$$

$$\nu = \nu_+ \theta(x_*) + \nu_- \theta(-x_*) \quad (11)$$

$$\theta(x_*) = \begin{cases} 1 & x_* \geq 0 \\ 0 & x_* < 0 \end{cases} \quad (12)$$

$$y = (x_*/\rho)^{1/\nu} \qquad (13)$$
$$x_* = \ln(K/S) - (r - q - \delta)(T - t) + \ln R \qquad (14)$$

$$R = p_0 \sum_{n=1}^{\infty} \left[\frac{\rho_+^n}{n!}\Gamma(1 + n\nu_+) - (-1)^n \frac{\rho_-^n}{n!}\Gamma(1 + n\nu_-)\right] \qquad (15)$$
$$p_0 = [\rho_+\Gamma(1 + \nu_+) + \rho_-\Gamma(1 + \nu_-)]^{-1} \qquad (16)$$

$t - future\ time\ in\ years\ (0 \leq t \leq T)$
$S - stock\ price\ at\ t$
$K - strike\ price\ of\ an\ option$
$T - maturity\ in\ years$

$r - risk\ free\ annual\ interest\ rate$
$q - annual\ divident\ yield$
$R - risk\ neutral\ normalization$

$$\Gamma(\nu) = \int_0^{\infty} u^{\nu-1}\, e^{-u} du - gamma\ function \qquad (17)$$
$$\Gamma(\nu, y) = \int_y^{\infty} u^{\nu-1}\, e^{-u} du - incomplete\ gamma\ function \qquad (18)$$

Volatility Evolution

$$\rho_\pm = \sqrt{\tau}\, \sigma_\pm \tau_\pm [\Gamma(\nu_\pm)/\Gamma(3\nu_\pm)]^{1/2} \qquad (19)$$

$$\tau = T - t \qquad (20)$$

$$\tau_\pm = \exp\{\alpha_\pm\, ln\, \tau + \epsilon_\pm ln[\gamma(0.75{,}100\tau)/\gamma(0.75{,}100)]\} \qquad (21)$$

$$\gamma(\nu, y) = \Gamma(\nu) - \Gamma(\nu, y) \qquad (22)$$

Implied Volatility

$$\sigma = [f_+\sigma_+^2 + f_-\sigma_-^2 + 2g_+g_-\sigma_+\sigma_-]^{1/2} \tag{23}$$

$$p_\pm = p_0\rho_\pm\Gamma(1+\nu_\pm) \tag{24}$$

$$w_\pm = \Gamma(2\nu_\pm)[\Gamma(\nu_\pm)\Gamma(3\nu_\pm)]^{-1/2} \tag{25}$$

$$f_\pm = p_\pm\tau_\pm^2\left[1 - p_\pm w_\pm^2\right] \tag{26}$$

$$g_\pm = p_\pm\tau_\pm w_\pm \tag{27}$$

Option Greeks

Delta	Vega	Theta	Rho	Gamma
$\Delta \equiv \frac{\partial V}{\partial S}$	$\nu \equiv 1\% \frac{\partial V}{\partial \sigma}$	$\Theta \equiv \frac{1}{252}\frac{\partial V}{\partial t}$	$\rho \equiv 1\% \frac{\partial V}{\partial r}$	$\Gamma \equiv \frac{\partial^2 V}{\partial S^2}$

Parallel-Shock Vega

$$\nu = \frac{1\%}{\sigma}\left(\sigma_+\frac{\partial V}{\partial \sigma_+} + \sigma_-\frac{\partial V}{\partial \sigma_-}\right) \tag{28}$$

$$\nu = 1\% \lim_{\lambda\to 0}\frac{V[\sigma_+(1+\lambda), \sigma_+(1+\lambda)]}{\lambda\sigma} \tag{29}$$

Model Parameters

$(\sigma_\pm, \nu_\pm, \alpha_\pm, \epsilon_\pm, \delta) - model\ parameters$

$\sigma_\pm - model\ parameters\ for\ up\ (+)\ or\ down\ (-)\ volatility$
$\nu_\pm - model\ parameters\ for\ up\ (+)\ or\ down\ (-)\ diffusion$
$\alpha_\pm - model\ parameters\ for\ long\text{-}range\ time\ evolution$
$\epsilon_\pm - model\ parameters\ for\ short\text{-}range\ time\ evolution$
$\delta - model\ parameter\ for\ center\ corrections$

$\nu_{\pm} - related\ to\ diffusion\ exponent\ and\ potential\ energy$

$\nu_{\pm} = 0$ $\quad balistic\ limit\ (box\ distribution)$

$\nu_{\pm} = 1/2$ $\quad classical\ case\ (normal\ distribution)$

$\nu_{\pm} > 1/2$ $\quad superdiffusive\ (wedge\ distribution)$

$(\sigma_{\pm}, \nu_{\pm})\ introduces\ asymmetric\ risk\ perference$

$TNA\ (\sigma_{-} > \sigma_{+})$ $\quad left\ skewed\ distribution$

$TZA\ (\sigma_{+} > \sigma_{-})$ $\quad right\ skewed\ distribution$

Limiting Cases

$$V_p \to (K_d - S_d)\theta(K_d - S_d) \qquad \sigma \to 0 \tag{30}$$

$$V_c \to (S_d - K_d)\theta(S_d - K_d) \qquad \sigma \to 0 \tag{31}$$

$$P_p \to \theta(K_d - S_d) \qquad \sigma \to 0 \tag{32}$$

$$P_c \to \theta(S_d - K_d) \qquad \sigma \to 0 \tag{33}$$

Black-Scholes

$$\sigma_{\pm} = \sigma, \nu_{\pm} = 1/2\,, \alpha_{\pm} = \epsilon_{\pm} = \delta = 0$$

Initial Values

$$Set\ initial\ values\ of\ the\ model\ parameters\ (\sigma_{\pm}, \nu_{\pm}, \alpha_{\pm}, \epsilon_{\pm}, \delta)$$

$$\nu_{\pm} = 1$$

$$\alpha_{\pm} = 0$$

$$\epsilon_{\pm} = 0$$

$$\delta = 0$$

$$\sigma_- = \frac{1}{N_T}\sum_j \sqrt{\frac{2}{T_j}}\left[\frac{\langle(lnV_p)(lnK)\rangle_j - \langle lnK\rangle_j\langle lnV_p\rangle_j}{\langle(lnK)(lnK)\rangle_j - \langle lnK\rangle_j\langle lnK\rangle_j} - 1\right]^{-1} \quad K < S \quad (34)$$

$$\sigma_+ = \frac{1}{N_T}\sum_j \sqrt{\frac{2}{T_j}}\left[1 - \frac{\langle(lnV_c)(lnK)\rangle_j - \langle lnK\rangle_j\langle lnV_c\rangle_j}{\langle(lnK)(lnK)\rangle_j - \langle lnK\rangle_j\langle lnK\rangle_j}\right]^{-1} \quad K > S \quad (35)$$

$where\ the\ subscript\ j\ refers\ to\ maturity\ T_j\ and\ \langle x\rangle_j\ denotes\ the\ average\ of\ x\ over\ strikes\ for\ a\ given\ maturity\ T_j$

Accuracy – Standard Error

$$\mathcal{E} = \left\{\frac{1}{N_{KT}}\sum_{i,j}\left[V_{OTM}(K_{ij},T_j) - V_{QED}(K_{ij},T_j)\right]^2\right\}^{1/2} \quad (36)$$

Notes on Calibration Method I

$Set\ \delta_j\ for\ each\ maturity\ T_j$
$Set\ V_{QED} = 0.015\ if\ V_{QED} < 0.015\ to\ avoid\ data\ flooring\ issue$

$Approximate\ boundaries\ on\ model\ parameters$

$$0 < \sigma_{\pm} \lesssim 3$$
$$0 < \nu_{+} \lesssim 1$$
$$0 < \nu_{-} \lesssim 3$$
$$-1 \lesssim \alpha_{\pm} \lesssim +1$$
$$-3 \lesssim \epsilon_{\pm} \lesssim +3$$
$$-0.03 \lesssim \delta_j \lesssim +0.03$$

$Set\ \alpha_{\pm} = 0\ and\ \epsilon_{\pm} = 0\ \ if\ there\ is\ only\ one\ maturity$
$Set\ \epsilon_{\pm} = 0\ \ if\ there\ is\ only\ two\ maturities$

Notes on Calibration Method II

$Set\ \delta_j\ for\ each\ maturity\ T_j$
$Set\ \alpha_{\pm} = \epsilon_{\pm} = 0\ and\ set\ \sigma_{\pm j}\ for\ each\ maturity\ T_j$
$Set\ V_{QED} = 0.015\ if\ V_{QED} < 0.015\ to\ avoid\ data\ flooring\ issue$

$Approximate\ boundaries\ on\ model\ parameters$

$$0 < \sigma_{\pm j} \lesssim 3$$
$$0 < \nu_{+} \lesssim 1$$
$$0 < \nu_{-} \lesssim 3$$
$$-0.03 \lesssim \delta_j \lesssim +0.03$$

Greeks Formula (I)

Delta

$$\Delta_p \equiv \frac{\partial V_p}{\partial S} = \frac{K_d}{S} p_0 \rho \nu Z(\nu, y) - \frac{S_d}{S} \theta(+x_*) \quad (37)$$

$$\Delta_c \equiv \frac{\partial V_c}{\partial S} = \frac{K_d}{S} p_0 \rho \nu Z(\nu, y) + \frac{S_d}{S} \theta(-x_*) \quad (38)$$

Gamma

$$\Gamma_p \equiv \frac{\partial \Delta_p}{\partial S} = \frac{1}{SR} \frac{e^{x_* - y - q(T-t) - \delta}}{[\rho_+ \nu_+ \Gamma(\nu_+) + \rho_- \nu_- \Gamma(\nu_-)]} \quad (39)$$

$$\Gamma_c \equiv \frac{\partial \Delta_c}{\partial S} = \frac{1}{SR} \frac{e^{x_* - y - q(T-t) - \delta}}{[\rho_+ \nu_+ \Gamma(\nu_+) + \rho_- \nu_- \Gamma(\nu_-)]} \quad (40)$$

Vega

$$\nu_p \equiv \frac{1\%}{\sigma} \left(\sigma_+ \frac{\partial V_p}{\partial \sigma_+} + \sigma_- \frac{\partial V_p}{\partial \sigma_-} \right) = \frac{1\%}{\sigma} V_\sigma \quad (41)$$

$$\nu_c \equiv \frac{1\%}{\sigma} \left(\sigma_+ \frac{\partial V_c}{\partial \sigma_+} + \sigma_- \frac{\partial V_c}{\partial \sigma_-} \right) = \frac{1\%}{\sigma} V_\sigma \quad (42)$$

$$V_\sigma = K_d p_0 \rho \nu \left[Z_\sigma(\nu, y) + \left(1 - \frac{R_\sigma}{R} \right) Z(\nu, y) \right] \quad (43)$$

Greeks Formula (II)

Theta

$$\Theta_p \equiv \frac{1}{252}\frac{\partial V_p}{\partial t} = \frac{1}{252}\left(V_{p,t} + V_{\lambda,t}\right) \tag{44}$$

$$\Theta_c \equiv \frac{1}{252}\frac{\partial V_c}{\partial t} = \frac{1}{252}\left(V_{c,t} + V_{\lambda,t}\right) \tag{45}$$

$$V_{p,t} = (rK_d - qS_d)\theta(+x_*) - K_d p_0 \rho \nu [\mathrm{r}\Gamma(\nu, y) - q\mathrm{Z}(\nu, y)] - \frac{V_\sigma}{2\tau} \tag{46}$$

$$V_{c,t} = (qS_d - rK_d)\theta(-x_*) - K_d p_0 \rho \nu [\mathrm{r}\Gamma(\nu, y) - q\mathrm{Z}(\nu, y)] - \frac{V_\sigma}{2\tau} \tag{47}$$

$$V_{\lambda,t} = K_d p_0 \rho \nu [\mathrm{Z}(\nu, y) - \Gamma(\nu, y)] \frac{\lambda - \bar{\lambda}}{\tau} - \frac{V_\lambda}{\tau} \tag{48}$$

$$V_\lambda = K_d p_0 \rho \nu \left[\lambda Z_\sigma(\nu, y) + \left(\bar{\lambda} - \frac{R_\lambda}{R}\right) Z(\nu, y)\right] \tag{49}$$

$$V_{\lambda,t} = 0 \qquad if \;\; \alpha_\pm = \epsilon_\pm = 0 \tag{50}$$

Rho

$$\rho_p \equiv 1\% \frac{\partial V_p}{\partial r} = -1\% \tau K_d [\theta(+x_*) - p_0 \rho \nu \Gamma(\nu, y)] \tag{51}$$

$$\rho_c \equiv 1\% \frac{\partial V_c}{\partial r} = +1\% \tau K_d [\theta(-x_*) + p_0 \rho \nu \Gamma(\nu, y)] \tag{52}$$

Greeks Formula (III)

Definitions

$$Z(\nu, y) \equiv e^{-x_*} \sum_{n=0}^{\infty} \frac{\rho^n}{n!} \Gamma(\nu + n\nu, y) \tag{53}$$

$$Z_\sigma(\nu, y) \equiv e^{-x_*} \sum_{n=1}^{\infty} \frac{\rho^n}{\Gamma(n)} \Gamma(\nu + n\nu, y) \tag{54}$$

$$R_\sigma \equiv p_0 \sum_{n=1}^{\infty} \left[\frac{\rho_+^n}{\Gamma(n)} \Gamma(1 + n\nu_+) - (-1)^n \frac{\rho_-^n}{\Gamma(n)} \Gamma(1 + n\nu_-) \right] \tag{55}$$

$$\lambda_\pm \equiv \alpha_\pm + \epsilon_\pm [(100\tau)^{0.75} e^{-100\tau} / \gamma(0.75, 100\tau)] \tag{56}$$

$$\lambda \equiv \lambda_+ \theta(x_*) + \lambda_- \theta(-x_*) \tag{57}$$

$$\bar{\lambda} \equiv \lambda_+ p_+ + \lambda_- p_- \tag{58}$$

$$R_\lambda \equiv p_0 \sum_{n=1}^{\infty} \left[\frac{\lambda_+ \rho_+^n}{\Gamma(n)} \Gamma(1 + n\nu_+) - (-1)^n \frac{\lambda_- \rho_-^n}{\Gamma(n)} \Gamma(1 + n\nu_-) \right] \tag{59}$$

Derivatives Formula

$$\partial/\partial\delta$$

$$V_{p,\delta} \equiv \frac{\partial \mathrm{V}_p}{\partial \delta} = K_d P_p - V_p \tag{60}$$

$$V_{c,\delta} \equiv \frac{\partial \mathrm{V}_c}{\partial \delta} = -K_d P_c - V_c \tag{61}$$

$$\partial/\partial\sigma_{\pm}$$

$$V_{p,\sigma_{\pm}} \equiv \frac{\partial \mathrm{V}_p}{\partial \sigma_{\pm}} = V_{c,\sigma_{\pm}} \equiv \frac{\partial \mathrm{V}_c}{\partial \sigma_{\pm}} \tag{62}$$

$$V_{p,\sigma_{+}} = \frac{1}{\sigma_{+}}\left[V_a\left(\theta_{+} - \frac{p_0}{R}R_{\sigma}^{+}\right)Z - V_a(\theta_{+} - p_{+})\Gamma(\nu, y) + \theta_{+}V_a Z_{\sigma}\right] \tag{63}$$

$$V_{p,\sigma_{-}} = \frac{1}{\sigma_{\pm}}\left[V_a\left(\theta_{-} + \frac{p_0}{R}R_{\sigma}^{-}\right)Z - V_a(\theta_{-} - p_{-})\Gamma(\nu, y) + \theta_{-}V_a Z_{\sigma}\right] \tag{64}$$

$$V_a \equiv K_d p_0 \rho \nu \tag{65}$$

$$\theta_{\pm} = \theta(\pm x_{*}) \tag{66}$$

$$R_{\sigma}^{\pm} \equiv \sum_{n=1}^{\infty} \frac{(\pm\rho_{\pm})^n}{\Gamma(n)}\Gamma(1 + n\nu_{\pm}) \tag{67}$$

$$\partial/\partial\nu_{\pm}$$

$$V_{p,\nu_{\pm}} \equiv \frac{\partial \mathrm{V}_p}{\partial \nu_{\pm}} = V_{c,\nu_{\pm}} \equiv \frac{\partial \mathrm{V}_c}{\partial \nu_{\pm}} \quad \text{(Use Numerical Calculations)} \tag{68}$$

CLAIMS

A model for forecasting option price movement for option trading.

A model that generates: Positive implied volatility, Negative implied volatility, Upward movement speed, Downward movement speed, Deviation of risk neutral condition.

A Pricing model that is continuously calibrated using real-time market data using:
Monte-Carlo Simulation Based: Monte-Carlo simulations of 100,000 paths in tick by tick time steps are performed in our massive parallel computing environment to generate option prices on the fly.
Option trading volume and bid-ask spread data are taken into account in the calibration process.
Using the entire spectrum of ATM to far OTM strikes within the calibration process to account for the entire Full Volatility Skew exhibited in the market prices and bid-ask data, and thereby allow accurate modeling of stochastic volatility.
Advanced nonlinear techniques and maximum-likelihood optimization are used to estimate model parameters to ensure Global Minimum Solution.

ABSTRACT

Unlike earlier option trading models, the Quantum Electrodynamic (QED) Field Effect Option Model provides five pieces of information:

Positive implied volatility (good)
Negative implied volatility (bad)
Upward movement speed
Downward movement speed
Deviation of risk neutral condition (ugly)

The Quantum ElectroDynamic (QED) field effect option model describes the quantum behavior of volatility evolution, unlike what has ever been done in the market before. This gives it the ability to accurately predict when short-term volatility inefficiencies occur in the market, and thereby profit from the high-probability mean reversion strategy on volatility-based trades.