



# **NOVEL PERFORMANCE EVALUATION STUDIES OVER EXTENDED GENERALIZED-K COMPOSITE FADING CHANNELS**

By

Husam Rafiq Mahmoud Alhennawi

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**  
in  
Electronics and Communications Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
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**Title of Thesis:**

Novel Performance Evaluation Studies over Extended Generalized-K Composite Fading Channels

**Key Words:**

Extended Generalized-K; Symbol error rate; Cognitive radio; Probability of detection; Fox's  $H$ -function

**Summary:**

In this thesis, the performance of EGK is studied by offering unified and generic closed-form exact expressions for the symbol error rate of the EGK composite fading channels. In this context, the single as well as the maximal-ratio combining and equal-gain combining receivers are considered over most of the commonly used modulation schemes. Furthermore, a novel general expression for the average probability of detection of energy detection spectrum sensing is derived over the EGK fading. The new expression provides a unified form, which can handle several of the well-known fading environments.

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Finally, I would like to express my gratitude and respect to my great family for giving me unequivocal supports throughout my life. Without their support it might be impossible to complete this work to the end.

# **Dedication**

This Master thesis is dedicated to my parents, my brother and my sister who have supported me all the way in my life and my study.

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# List of Abbreviations

|         |                                             |
|---------|---------------------------------------------|
| AAF     | Amplify-and-Forward                         |
| ABEP    | Average Bit Error Probability               |
| AC      | Average Capacity                            |
| AF      | Amount of Fading                            |
| AFD     | Average Fade Duration                       |
| ASEP    | Average Symbol Error Probability            |
| ASK     | Amplitude Shift Keying                      |
| AUP     | Average Unified Performance                 |
| AWGGN   | Additive White Generalized Gaussian Noise   |
| AWGN    | Additive White Gaussian Noise               |
| BER     | Bit Error Rate                              |
| BPSK    | Binary Phase Shift Keying                   |
| CAF     | Cyclic Autocorrelation Function             |
| CBFSK   | Coherent Binary Frequency Shift Keying      |
| CDF     | Cumulative Distribution Function            |
| CFD     | Cyclostationary Feature Detection           |
| CR      | Cognitive Radio                             |
| CSD     | Cyclic Spectral Density                     |
| CSS     | Cooperative Spectrum Sensing                |
| DBPSK   | Differentially Binary Phase shift keying    |
| DF      | Decode-and-Forward                          |
| DPSK    | Differentially coherent Phase shift keying  |
| DSA     | Dynamic Spectrum Access                     |
| ED      | Energy detection                            |
| EGC     | Equal Gain Combining                        |
| EGK     | Extended Generalized-K                      |
| FC      | Fusion Center                               |
| FCC     | Federal Communications Commission           |
| GG      | Generalized Gamma                           |
| GNM     | Generalized Nakagami-m                      |
| i.i.d   | Independent and identically distributed     |
| i.n.i.d | Independent and non-identically distributed |
| LOS     | Line-Of-Side                                |
| MF      | Matched Filtering                           |
| MGF     | Moment Generating Function                  |
| MIMO    | Multiple-input Multiple-output              |
| MISO    | Multiple-input Single-output                |
| MRC     | Maximal-Ratio Combining                     |
| NCBFSK  | Non-Coherent Binary Frequency Shift Keying  |
| NC-FSK  | Non-Coherent Frequency Shift Keying         |

|      |                                   |
|------|-----------------------------------|
| NLOS | Non Line-Of-Side                  |
| PAM  | Pulse Amplitude Modulation        |
| PDF  | Probability Density Function      |
| PSK  | Phase Shift Keying                |
| PU   | Primary User                      |
| QAM  | Quadrature Amplitude Modulation   |
| QoS  | Quality of Serves                 |
| QPSK | Quadrature Phase shift keying     |
| RMSC | Root Mean Square Combining        |
| ROC  | Receiver Operating Characteristic |
| RV   | Random Variable                   |
| SC   | Selective Combining               |
| SDR  | Software Defied Radio             |
| SER  | Symbol Error Rate                 |
| SLC  | Square-Law Combining              |
| SLS  | Square-Law Selection              |
| SNR  | Signal-to-Noise Ratio             |
| SS   | Spectrum Sensing                  |
| SSC  | Switch and Stay Combining         |
| SSK  | Space Shift Keying                |
| SU   | Secondary User                    |

# List of Symbols

|                                                                                        |                                                                                      |
|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| $A, B$ and $g$                                                                         | The modulation schemes parameters                                                    |
| $c$                                                                                    | The real constant that lies in the strip of definition of the Mellin-transform       |
| $E[.]$                                                                                 | Expected value                                                                       |
| $f^*(s)$                                                                               | The Mellin transform of function $f(.)$                                              |
| $f_{\gamma_l}(\gamma_l)$                                                               | The PDF of the $l$ i.n.i.d instantaneous SNR, $\gamma_l$ where $l = 1, \dots, L$     |
| $f_{\gamma}(\gamma)$                                                                   | The PDF of the instantaneous SNR                                                     |
| $f_{\gamma}^*(\gamma)$                                                                 | The Mellin transform of $f_{\gamma}(\gamma)$                                         |
| $F_{\gamma}(\gamma)$                                                                   | The CDF of the instantaneous SNR                                                     |
| $F_{\gamma_l}(\gamma_l)$                                                               | The CDF of the $l$ i.n.i.d instantaneous SNR $\gamma_l$                              |
| $F_{\gamma}^*(\gamma)$                                                                 | The Mellin transform of $F_{\gamma}(\gamma)$                                         |
| ${}_pF_q$                                                                              | The generalized hypergeometric function                                              |
| $g^*(z)$                                                                               | The Mellin transform of $g(\gamma) \equiv -\gamma \frac{d}{d\gamma} P(error \gamma)$ |
| $G_{p,q}^{m,n}(\cdot)$                                                                 | Meiger's $G$ -Function                                                               |
| $G_{p,q;p_1,q_1;p_2,q_2}^{0,n;m_1,n_1;m_2,n_2}(\gamma_1, \gamma_2)$                    | Bivariate $G$ -Function                                                              |
| $h$                                                                                    | Channel gain                                                                         |
| $h^*(z)$                                                                               | The Mellin transform of $h(\gamma) \equiv P(error \gamma)$                           |
| $h^*(\mathbf{z})$                                                                      | $L$ -dimensional Mellin-transform of conditional SER                                 |
| $H_0$                                                                                  | Primary user absence                                                                 |
| $H_1$                                                                                  | Primary user presence                                                                |
| $H_{p,q}^{m,n}(\cdot)$                                                                 | Fox's $H$ -Function                                                                  |
| $H_{p,q;p_1,q_1;\dots;p_r,q_r}^{0,n;m_1,n_1;\dots;m_r,n_r}(\gamma_1, \dots, \gamma_r)$ | Multivariable $H$ -function                                                          |
| $I_{\nu}(\cdot)$                                                                       | Modified Bessel function of the first kind order                                     |
| $K_G$                                                                                  | Generalized-K distribution                                                           |
| $L$                                                                                    | Number of branches in diversity reception                                            |
| $m$                                                                                    | Fading figure(diversity severity/order) of EGK distribution                          |
| $m_l$                                                                                  | Fading figure(diversity severity/order) of $l$ -branch in EGK distribution           |
| $m_s$                                                                                  | Fading shaping factor of EGK distribution                                            |
| $m_{s,l}$                                                                              | Fading shaping factor of $l$ -branch in EGK distribution                             |
| $M[.]$                                                                                 | The Mellin transform                                                                 |
| $M^{-1}\{.\}$                                                                          | The inverse Mellin transform                                                         |
| $n$                                                                                    | The number of collaborative users in CSS scenario                                    |
| $n(t)$                                                                                 | zero-mean AWGN                                                                       |