Influence of Fractal and SRR on Moore Antenna for Multiband Applications

Chintapanti Murali Krishna, Mallela Mamatha and Dola Sanjay S

October 6, 2019

Influence of Fractal and SRR on Moore Antenna for Multiband Applications

Ch Murali Krishna
Department of ECE,
Ramachandra College of Engineering,
Eluru, India,
krishnasri780@gmail.com

M Mamatha
Department of ECE,
Ramachandra College of Engineering,
Eluru, India,
mallela.mamatha59@gmail.com

Dola Sanjay.S
Department of ECE,
Ramachandra College of Engineering,
Eluru, India,
dicedola@gmail.com

***Abstract*— A Compact miniaturized asymmetric fed Moore curve with fractal, DGS and SRR are designed for several wireless applications. The compact size of proposed antenna is 25mm x 25mm x 1.6mm. By the proper alignment of fractal shapes, this Moore curve obtains multiple resonances. To improve the several performance characteristic of proposed antenna like bandwidth, gain and radiation efficiency, defected ground structure (DGS) and split ring resonator (SRR) are loaded. The maximum peak gains at the center frequencies are 2.67dBi at 2.32GHz, 2.82dBi at 4.84GHz, 3.60dBi at 5.14GHz, 2.62dBi at 5.58GHz, 3.41dBi at 6.66GHz, 1.87dBi at 7.22GHz, 2.37dBi at 7.66GHz, 1.11dBi at 8.36GHz and 2.41dBi at 9.78GHz.**

Keywords*— *Moore curve, Koch fractal,Quad fractal, Hybrid fractal, SRR, Multiband.

I. Introduction

In the last two decades, wireless communication systems have tremendous demand with high data rate, smaller in size, low profile, and light weight and easily integrated with other microwave components. The crucial factors like miniaturization, multiple resonances, impedance matching, high gain, good radiation efficiency and versatility affects the importance of future wireless devices. Due to these inherent properties, fractal antennas are developed. These antennas operated due to mainly two properties such as self-similar & space filling structure. This type of antennas mainly gives multiple resonances [1-3].

A Koch fractal printed monopole antenna was developed by A.Ismahayati et al. [4]. A planar printed monopole antenna with small ground has been investigated. This antenna saved 20% of its electrical length. In [5], larger bandwidth can be obtained by varying the shape of circular structure into elliptical shape. This parany antenna resonates at five frequencies. In [6], Adding and Subtracting Circles to the Circumference of a Circle modeled antenna designed to enhance the bandwidth and radiation efficiency. The main advantage of this proposed structure is 40% of size reduced and it covers LTE band2 & LTE band13. These multibands have narrow bandwidths. In order to avoid the interference with the nearest communication systems, the authors introduced split ring resonators (SRR) in a single antenna that can operate at multiple bands. Generally, metamaterials are designed by creating modifications in fabricated structures. The SRRs were initially designed for size reduction and were used for improving gains [7]. In [8], the authors presented a dual band antenna for wireless applications. This proposed antenna has less gain of 1.68dBi and 2.32dBi for lower and upper bands respectively. Metamaterials exhibits negative permeability property and it can used for bandwidth enhancement in an antenna. Different types of SRRs are investigated by various authors like multiple SRRs, complimentary SRRs and broadside coupled SRRs [9].

In this paper, moore curve with hybrid fractal antenna designed for multiband applications, which can cover the L-, S-, C- & X- band applications. Along with this structure, split ring resonator also included in this structure for improving the bandwidth & gains of each band. The electrical & far field characteristics, surface current distributions, measured results and its design summary are presented in various sections.

II. ANTENNA DESIGN AND METHODOLOGY

Hilbert curve is self-similar & space filling structure. It is a continuous and non-smooth that close to every point in space and it is also mapping from one dimensional to two dimensional spaces.

These space filling curves are derived from hybrid fractal antenna; fractal is nothing but a structure which supports space filling and self-similarity properties. The geometries of this type of structures can easily derived using Iterative Function System (IFS). The fractal dimension (D) and length of fractal curve can be derived from following equations [10]:

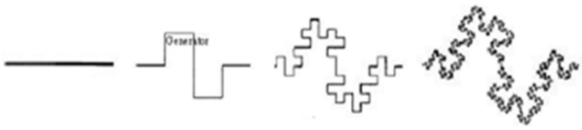
$$D = \frac{\log N}{\log r} \quad (1)$$

$$\& \quad l = h\left(\frac{N}{r}\right)^{n} \quad (2)$$

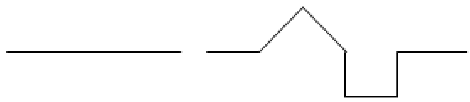
Where 'N' denotes the number of segments, 'r' represents the number of each segment is divided on iteration, 'h' is height of curve and 'n' denotes number of iterations.

The initiator, generator of various fractal models and further implementations are shown in figure 1.

(a) Triangular Koch fractal (TKF)

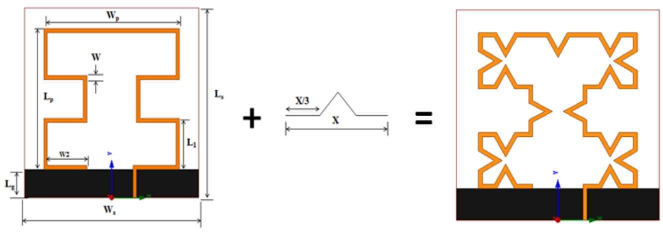


(b) Quadratic Koch fractal (QKF)



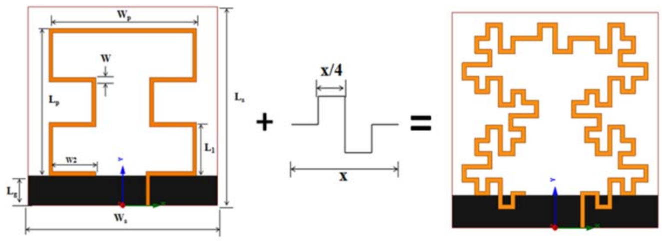
(c) Triangular-Quad Koch fractal (TQKF)
Fig 1: Iterations of various Koch fractals

The authors proposed a Moore curve Koch fractal antenna for wireless applications. This antenna has multiple resonances at 2.93GHz, 5.06GHz, 6.9GHz and 8.37GHz frequencies. This model is shown in figure 2. The dimensions represented on figure 2 are depicted in table 4. The thickness of printed monopole antenna is 0.5mm. Initially it is the generator to this work.



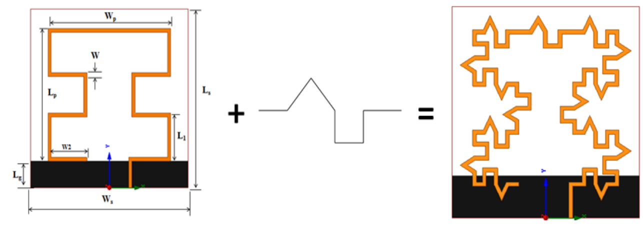
(a) Moore curve (b) Triangular Koch fractal (c) MTKFA
Fig 2: Proposed model MKHFA in existing systems

To improve the bandwidth characteristics of MTKFA, QKF implemented on Moore curve that is MQKFA as shown in figure 3. The proposed Moore Quadratic Koch Fractal Antenna (MQKFA) is a creation of two multidisciplinary structures, Moore and quadratic Koch functions. Figure 3(a) is Moore curve and figure 3(b) is quadratic Koch fractal. The proposed structure is generated by superimposing these two structures as shown in figure 3(c).



(a) Moore curve (b) Quadratic Koch fractal (c) MQKFA
Fig 3: Design implementation of proposed MQKFA antenna

Also a hybrid fractal that is combination of triangular Koch with quadratic Koch is developed on Moore curve as shown in figure 4. This proposed antenna is named as MTQKFA.

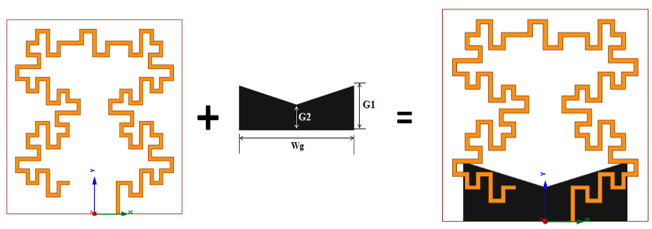


(a) Moore curve (b) Triangular - Quadratic Koch fractal (c) MTQKFA
Fig 4: Design implementation of proposed MTQKFA antenna

A defected ground structure (DGS) introduced for MQKFA as shown in figure 5 to increase the number of resonances. V-slot structure developed from this partial ground. The dimensions of this structure are shown in figure 5(b). The parameters shown on figure 5(b) are represented in table 4. The proposed MQKFA with DGS named as MQKFDGA as shown in figure 5(c).

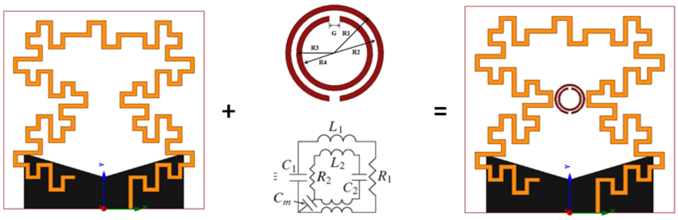
Table 4: Parameters represented on antenna models (All units are in mm)

L_s	W_s	L_p	W_p	L_g	L_1	W_2	W
25	25	18.5	19.5	3.75	6.67	5.67	0.5
W_g	G_1	G_2	R_1	R_2	R_3	R_4	G
20	7	4	1.8	1.6	1.4	1.2	0.4



(a) MQKFA (b) DGS (c) MQKFDGA
Fig 5: Design implementation of proposed MQKFDGA antenna

Till now, hybrid fractal antennas developed along with DGS methods to achieve the multibands and to obtain maximum impedance bandwidths. To improve the various parameters of proposed antenna (MQKFDGA), Split Ring Resonators (SRR) are loaded on it. In general, SRR is an artificially generated structure to create the necessary strong magnetic coupling to electromagnetic (EM) fields and these are useful to improve the antenna performance. SRR having two concentric rings with slits etched in opposite directions as shown in figure 6(b). The negative permeability characteristics of SRR have been validated by using waveguide method. The equivalent circuit of SRR is also shown in figure 6(b). The dimensions of SRR are tabulated in table 4. The proposed MQKFDGA loaded with SRR is shown in figure 6(c).



(a) MQKFDGA (b) SRR (c) MQKFDGA with SRR

Fig 6: Design implementation of proposed MQKFDGA loaded with SRR

III. SIMULATED RESULTS AND DISCUSSIONS

The proposed antennas has been simulated using High Frequency Structure Simulator (HFSS) on Flame Retardant – 4 glass epoxy material with dielectric constant 4.4 and dielectric loss tangent is 0.02.

a) Scattering parameters (S_{11}) of proposed designs

Figure 7 shows the electrical characteristics of Moore curve antennas Moore curve antenna resonates at two frequencies such as 3.12GHz and 8.62GHz with their corresponding impedance bandwidths are 750MHz and 770MHz respectively.

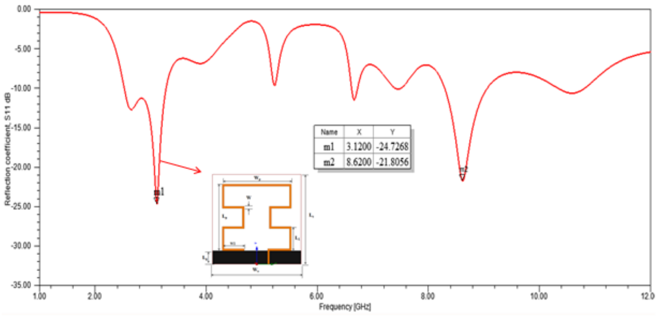


Fig 7: Reflection coefficient characteristics of Moore curve antenna

The existed model MTKFA has five multiple resonances at 2.74GHz, 5.66GHz, 6.36GHz, 8.04GHz and 9.36GHz with impedance bandwidths 180MHz, 120MHz, 260MHz, 960MHz and 360MHz respectively as shown in figure 8. This quadratic hybrid fractal achieves six multiple resonances at 5.58GHz, 6.78GHz, 7.34GHz, 7.82GHz, 8.32GHz and 9.76GHz with impedance bandwidths are 150MHz, 270MHz, 150MHz, 150MHz, 260MHz and 280MHz respectively as shown in figure 8. The electrical behavior of superimposition of triangular Koch and quadratic Koch fractal antenna with Moore curve as shown in figure 8. This novel hybrid fractal antenna has number of multibands with bandwidths are 240MHz, 80MHz, 200MHz, 400MHz, 190MHz, 150MHz and 440MHz at their center frequencies are 2.42GHz, 5.20GHz, 5.92GHz, 7.12GHz, 7.66GHz, 8.34GHz and 10.66GHz respectively. The design summary of Moore curve antenna, MTKFA, MQKFA and MQTKFA antenna results are tabulated in table 5.

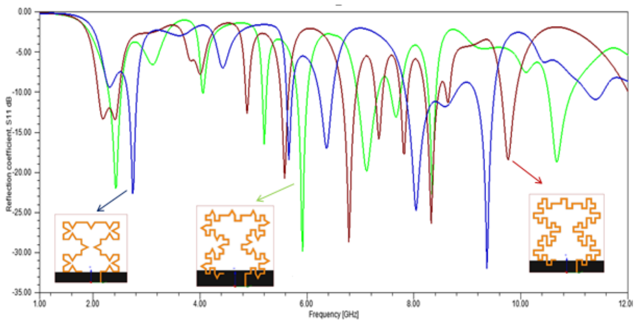


Fig 8: Reflection coefficient characteristics of Moore curve antenna with triangular, quadratic & hybrid fractals

Table 5: Comparison of simulated results of various antennas

Designed Antenna	Center frequency, f_c	Impedance bandwidth, $BW=f_U-f_L$	Peak gain
Moore curve antenna	3.12GHz	750MHz	3dBi
	8.62GHz	770MHz	3.74dBi
MTKFA	2.74GHz	180MHz	1.97dBi
	5.66GHz	120MHz	2.48dBi
	6.36GHz	260MHz	3.88dBi
	8.04GHz	960MHz	3.86dBi
	9.36GHz	360MHz	3.51dBi
MQKFA	5.58GHz	150MHz	3.98dBi
	6.78GHz	270MHz	3.30dBi
	7.34GHz	150MHz	3.76dBi
	7.82GHz	150MHz	1.59dBi
	8.32GHz	260MHz	1.94dBi
	9.76GHz	280MHz	1.97dBi
MQTKFA	2.42GHz	240MHz	2.16dBi
	5.20GHz	80MHz	3.8dBi
	5.92GHz	200MHz	4.14dBi
	7.12GHz	400MHz	3.58dBi
	7.66GHz	190MHz	3.25dBi
	8.34GHz	150MHz	3.57dBi
	10.66GHz	440MHz	3.44dBi

Figure 9 shows the MQKFA with DGS design has multiple resonances at 2.32GHz, 4.86GHz, 5.56GHz, 6.72GHz, 7.30GHz, 7.74GHz, 8.38GHz and 9.88GHz. The main moto of DGS is used for antenna miniaturization, enhancing the impedance bandwidth and gain, higher order modes suppressed. Sometimes this DGS produces notch band characteristics to reduce interference with some other applications. The proposed antenna MQKFDGA loaded with SRR achieves nine multibands at 2.32GHZ, 4.84GHz, 5.14GHz, 5.58GHz, 6.66GHz, 7.22GHz, 7.66GHz, 8.36GHz and 9.78GHz with their corresponding impedance bandwidths are 140MHz, 80MHz, 60MHz, 140MHz, 270MHz, 150MHz, 120MHz, 170MHz and 240MHz respectively as shown in figure 9. The proposed antenna has small frequency ratios 2.086, 1.061, 1.085, 1.193, 1.084, 1.06, 1.091 and 1.169 between two consecutive resonant frequencies. The design summary of proposed antenna is given in table 6.

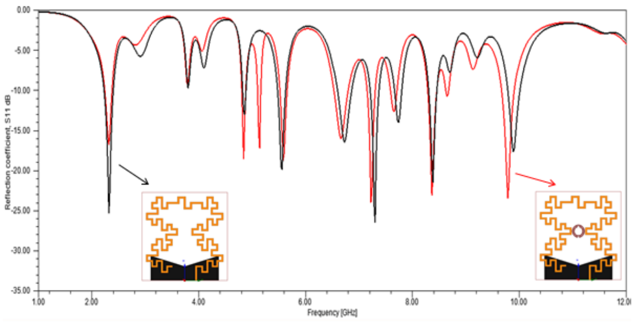


Fig 9: Reflection coefficient characteristics of proposed antenna with and without SRR

Table 6: Summary of MQKFA with DGS & SRR Simulation results

Designed Antenna	Center frequency, fc	Impedance bandwidth, BW=fU-fL	Peak gain
MQKFDGA (MQKFA with DGS)	2.32GHz	170MHz	2.89dBi
	4.86GHz	70MHz	3.14dBi
	5.56GHz	160MHz	3.38dBi
	6.72GHz	260MHz	3.45dBi
	7.30GHz	160MHz	4.92dBi
	7.74GHz	140MHz	2.33dBi
	8.38GHz	150MHz	1.92dBi
	9.88GHz	230MHz	1.43dBi
MQKFDGA loaded with SRR	2.32GHz	140MHz	2.67dBi
	4.84GHz	80MHz	2.82dBi
	5.14GHz	60MHz	3.60dBi
	5.58GHz	140MHz	2.62dBi
	6.66GHz	270MHz	3.41dBi
	7.22GHz	150MHz	1.87dBi
	7.66GHz	120MHz	2.37dBi
	8.36GHz	170MHz	1.11dBii
	9.78GHz	240MHz	2.41dBi

b) Surface current distributions of proposed design

The current distribution at center frequencies of proposed antenna is shown in figure 10. Due to the more discontinuities in the radiating element, it produces multiple resonances so mainly the current distribution concentrated on fractal curve.

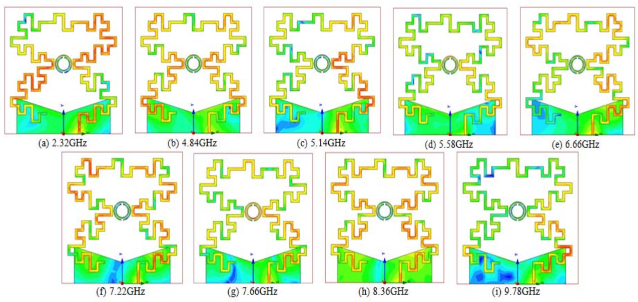
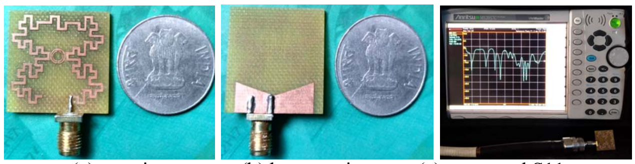


Fig 10: Magnitude surface current distribution of proposed antenna

c) Prototype designs & its results

Figure 11 shows the top view & bottom view of fabricated antenna. Figure 12 & 13 shows the behavior of simulated & measured S11 and VSWR characteristics.



(a) top view (b) bottom view (c) measured S11

Fig 11: Fabricated designs

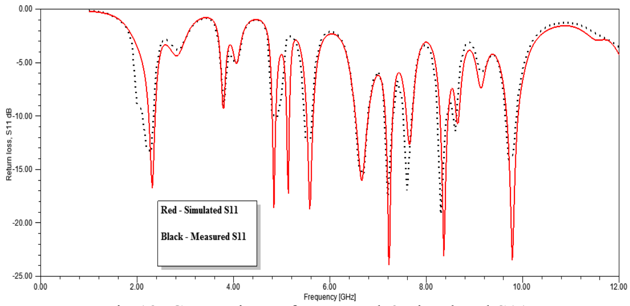


Fig 12: Comparison of measured & simulated S11

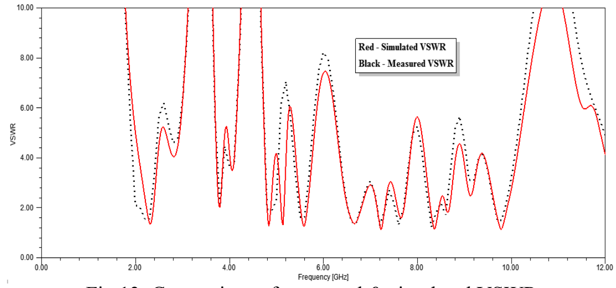


Fig 13: Comparison of measured & simulated VSWR

d) Far field characteristics of proposed antenna

Figure 14 shows the radiation patterns of the proposed antenna at the centered frequencies. At phi = 0° represents the E-plane and phi = 90° represents the H-plane pattern. There is a good agreement between the simulated & measured results.

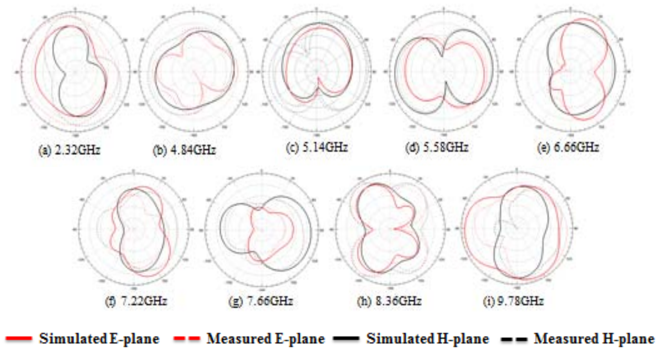


Fig 14: Radiation patterns of the proposed antenna

IV. CONCLUSION

In this paper, a Moore curve with triangular koch, quadratic Koch, triangular-quadratic Koch fractal antennas are designed on FR-4 epoxy dielectric material. To enhance the antenna performance characteristics, DGS and SRR are loaded on Moore quadratic Koch fractal antenna (MQKFA). This proposed antenna achieved nine multibands. The resonant frequencies and its corresponding applications are

2.32GHz for mobile systems, 4.84GHz for defense systems, 5.14GHz for radio navigation, 5.58GHz for weapon system radars and tactical radar systems, 6.66GHz for high capacity fixed link systems, 7.22GHz for fixed links based in ITU-T systems, 7.66GHz for defense systems, 8.36GHz for earth exploration satellite systems and 9.78GHz for civil and non-civil aeronautical radio navigation systems. This antenna has good impedance matching characteristics and small frequency ratios.

REFERENCES

[1] Gianvittorio, J. P., et al., "Fractal antennas: A novel antenna miniaturization technique and applications," IEEE Antennas and Propagation Magazine, Vol. 44, 20–36, 2002.

[2] Mehdipour A, Sebak AR, Trueman CW and Denidni TA, "Compact multiband planar antenna for 2.4/3.5/5.2/5.8-GHz wireless applications", IEEE Antennas Wireless Propag Letters 11, 144–147.

[3] Wang H and Zheng M, "An internal triple-band WLAN antenna", IEEE Antennas Wireless Propag Letters 10, 569–572

[4] Ismahayati, A., Soh, P. ., Hadibah, R., & Vandenbosch, G. A. "Design and analysis of a multiband koch fractal monopole antenna", 2011 IEEE International RF & Microwave Conference. doi:10.1109/rfm.2011.6168695.

[5] Song, C. T. P., Hall, P. S., & Ghafouri-Shiraz, H. (2003). Multiband multiple ring monopole antennas. IEEE Transactions on Antennas and Propagation, 51(4), 722–729. doi:10.1109/tap.2003.811097.

[6] Eskandari, Z., Keshtkar, A., Ahmadi-Shokoh, J., & Ghanbari, L. (2015). A novel fractal for improving efficiency and its application in LTE mobile antennas. Microwave and Optical Technology Letters, 57(10), 2429–2434. doi:10.1002/mop.29346.

[7] N.Haider, D.Caratelli, and A.G.Yarovoy "Recent developments in Reconfigurable and Multiband antenna technology", International Journal of Antennas and Propagation, January 2013.

[8] M.Z.M.Nor, S.K.A,Rahim,M.I.Sabran & F.Malek,"Dual- Band, parabolic, slotted ground plane directive antenna for WLAN Applications", Journal of Electromagnetic waves and Applications, Vol .27.No2, 2013.

[9] Baena, J. D., J. Bonache, F. Martin, R. M. Sillero, F. Falcone, T. Lopetegi, M. A. G. Laso, J. Garcfa-Farcfa, I. Gil, M. F. Portillo, and M. Sorolla, "Equivalent-circuit models for split-ring resonators and complementary split-ring resonators coupled to planar transmission lines," IEEE Transac ti ons on M i c rowav e Theory and Tec hniques, Vol. 53, 1451–1461, 2005.

[10] Kumar Y, Singh S. A compact multiband hybrid fractal antenna for multistandard mobile wireless application. Wire Pers Comm 2015; doi:10.1007/S11277-015-2593-X.