IQ Based Direct Sequence Spread Spectrum Spatial Data Focusing implemented over a 6 Ray Urban Canyon Channel Model

Michael Odhiambo, Guylian Molineaux, Sidney Golstein, Philippe de Doncker, Julien Sarrazin

JS 20

FUTURE NETWORKS: 5G AND BEYOND

IQ Based Direct Sequence Spread Spectrum Spatial Data Focusing implemented over a 6 Ray Urban Canyon Channel Model

***Odhiambo M*[1,2]*, Molineaux G*[2,1]*, Golstein S*[1,2]*, De Doncker P*[1]*, and Sarrazin J*[1]**

[1] *L2E, Sorbonne Université, France, michael.odhiambo@sorbonne-universite.fr*
[2] *Opera Wireless, ULB, Belgium, guylian.paul.molineaux@vub.be*

Keywords: Spatial Data Focusing, Geocasting, Spread Spectrum Modulation, Beamforming, Antenna Arrays, Multipath Channel models

Abstract:
Spatial Data Focusing is implemented using Direct Sequence Spread Spectrum technique with orthogonal Gold code sequences forming the orthogonal transmit signal basis. IQ Spatial Channel Orthogonalisation (SCO) is implemented for an additional degree of freedom to enhance performance over multipath channel environment. With a four element antenna array, it is demonstrated that this scheme attains a beam-width of less than 4°. The robustness of this schemes' performance is assessed using a 6-ray urban canyon multipath micro-cell channel model simulation. (In SDF, the beamwidth is defined as the region within which transmitted signals can be decoded)

1 Introduction

The ability to carry out wireless broadcast of data to narrow predefined spatial locations, geocasting, is a concept that is being widely researched in the advent of 5G and IoT technologies. If done well, geocasting may significantly enhance performance of modern technologies in the sectors of Intelligent Transport Systems, tourist guide systems, and enhancement of daily activities of physically challenged persons in smart city environments. Spatial Data Focusing (SDF) is proposed as a candidate scheme to be used in geocasting environments [1, 2]. SDF will enable data focusing at the physical layer level to predefined locations and receivers can only decode the transmitted data if they locate themselves within those locations. Moving away from the location results in inability to decode the data. Localisation techniques are not employed as the transmitter constantly geocasts data to the predefined location unassuming of the presence or not of the receiver, thus preserving receiver privacy. It is envisaged that SDF may serve as an alternative to classical power focusing techniques like beamforming

2 Principle of IQ Based Direct Sequence Spread Spectrum Spatial Data Focusing

The left part of figure 1 shows the block diagram of the DSSS-SDF transmit architecture. The incoming symbol stream $A[n]$ are mapped into an N-dimensional signal space, $A_i[n]$, $i : 1, 2, ..., N$. A set of $N/2$ Orthogonal Gold codes $C_G[j]$, $G : 1, ..., N/2$ with $C_G[j] \in [-1, 1]$ are subsequently generated. The first $N/2$ symbol mapped coefficients spread spectrum modulate the first $N/2$ orthogonal Gold codes sequences, similar case for the second $N/2$ mapped coefficients with the second $N/2$ orthogonal code sequences. The $N/2$ spread sets above are multiplied by I and Q components respectively for subsequent spatial IQ channel modulation exploiting the additional degree of freedom due to IQ orthogonal property. The spread signal is also pulse shaped with a Square Root Raised Cosine (SRRC) pulse filter, $g(t)$. The signals transmitted via individual antenna elements are expressed as:

$$s_i(t) = \sum_{n=0}^{\infty} A_i[n] C_G(t) = \sum_{n=0}^{\infty} A_i[n] \sum_{j=1}^{L_c} C_G[j] g(t - nT - jT_c) \quad \text{where} \quad s_i(t) \in s_i^I(t), s_i^Q(t) \tag{1}$$

T_c, T, and j represent the chip duration, symbol duration and chip index respectively and L_c is the length of the applied orthogonal sequences. Orthogonal Gold codes are preferred because they are completely orthogonal at zero delay and have really bad cross correlation properties for other delays leading to significant distortion at unwanted delays, in addition their autocorrelation are fairly low compared to Walsh codes which guards against cases of falsely registering the main peak of the autocorrelation function. DSSS-SDF enables the control of phase (time delays) of each channels coding from the base station and orthogonal Gold codes properties make it possible to achieve a zero cross correlation with respect to the phase between the channels. A 6-ray street canyon channel model was implemented for this application with the goal of analysing the influence of the

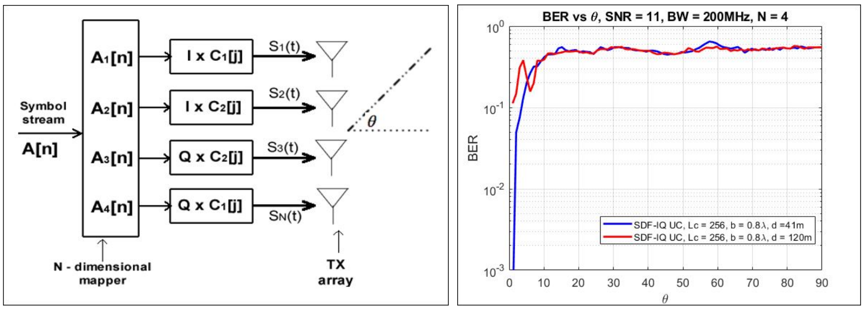

Figure 1 – DSSS-SDF transmit archtecture(left), BER vs θ Plots (right)

multipath propagation scenario on the DSSS-SDF. The channel output, $r(t) = \sum_{l=0}^{L-1} s_i^o * h_i(t) + z(t)$, $z(t)$ is AWGN. $r(t)$ is passed through a chip matched filter with an impulse response similar to the pulse shaping in the transmitter. The matched filter output signal, $y(t) = r(t) * g^*(-t)$, exhibits minimal inter symbol interference and is sampled at chip rate. The sampled matched filter output is represented as shown in (2):

$$\hat{y}_i(l_c T_c) = \sum_{i=0}^{N-1} \sum_{n=0}^{\infty} A_i[n] \left\{ \alpha_i^{LOS} \sum_{j=0}^{L_c-1} C_G[j] f(\psi_L) e^{-j\omega\tau_i^{LOS}} + \sum_{l=0}^{L^{MP}-1} R_{il}^{MP} \alpha_{il}^{MP} \sum_{j=0}^{L_c-1} C_G[j] f(\psi_{MP}) e^{-j\omega\tau_{il}^{MP}} \right\} \tag{2}$$

where $A_i[n] \in (A_i^I[n], A_i^Q[n])$, $\psi_L = (l_c - j)T_c - nT - \tau_i^{LOS}$ and $\psi_{MP} = (l_c - j)T_c - nT - \tau_{il}^{MP}$. τ_i^{LOS}, τ_{il}^{MP} and L^{MP} are the propagation delay due to the LOS, NLOS paths and the number of multipath components (MPC) respectively. N is the number of applied dimensions and R_{il}^{MP} is the reflection coefficient due to each MPC. The correlated output at the receiver is a function of the sampled matched filter output $y[l_c T_c]$ correlated with the orthogonal sequences generated at the receiver (despreading). DSSS-SDF carries out initial acquisition (phase synchronization) using only one reference dimensions' orthogonal sequence codes, say the first dimension, the rest of the dimension codes are synchronized based on this initial acquisition results. The mth estimated symbol is derived from the above samples as:

$$\hat{s}_i(m) = \hat{y}_i(l_c T_c) \sum_{z=mLc+1}^{m+1} \left\{ C_G[z - mLc] + \sum_{y=0, y\neq i}^{N-1} C_G[z - mLc] \right\} \tag{3}$$

(3) describes despreading involving the sampled matched filter outputs with the synchronized replica of the orthogonal Gold sequence used in the transmitter. Based on Orthogonal Gold code properties, the likeness of the signal time spaced copies rapidly diminishes with the delay mismatch, this can attributed to the receiver moving away from the targeted geographical location if a perfectly synchronized scenario is considered.
Results : The right part of figure 1 outlines the BER vs θ plot. It is noted that BER quickly increases from zero as the receiver moves away from broadside leading to increased symbol error rate. It also shows that the scheme can attain focused beamwidths lower than 4° in classical street canyon multipath environments.

3 Conclusion

The operating principle of this scheme is that if the receiver is located outside the predefined receive location the orthogonality of the respective dimensions making up the constellation is lost, this impacts the SNR leading deterioration of the received signal symbol estimation thus increased Symbol Error Rate. Further this scheme takes advantage of the inherent multipath mitigating capacity of spread sectrum systems to enabled successful Spatial Data Focusing over a classical urban canyon multipath environment.

4 References

[1] J. Sarrazin, M. Odhiambo S Golstein, P. De Doncker and F. Horlin. "Spatial Data Focusing: an alternative to Beamforming for geocasting scenarios". In: IEEE Antennas and Propagation Symposium conference (2018).

[2] Guylian Molineaux, M. Odhiambo, S Golstein, P. De Doncker and J. Sarrazin. "Spatial Data Focusing using Time and IQ Resources for Wireless Geocasting", (accepted for presentation at IEEE Globecom 2019)