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I^2SP_{hybrid} pulse shape: Modified I^2SP pulse by using weighting technique and it's impact on SC-FDMA system

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Abstract— Pulse shaping plays a crucial role in spectral shaping in the modern wireless communication to reduce the spectral bandwidth. Pulse shaping is a spectral processing technique by which fractional out of band power is reduced for low cost, reliable, power and spectrally efficient mobile radio communication systems. The Multipath channel has two main considerations spectral efficient transmission and reduced ISI both these requirement of Spectral efficient transmission and reduced ISI are satisfied by pulse shaping the transmitted signal. I^2SP_{hybrid} pulse shape introduced in this research work by using weighting techniques has better spectral characteristics and shows improved OBR performance when used with SC-FDMA system.

Keywords—pulse shape, ISP, OBR, SC-FDMA, companding

I. INTRODUCTION

For every Communication system (Out Band Radiation) OBR is always being the concern for the system design engineers as it leads to adjacent channel interference and worsens the interference level. This OBR will provide the interfering signal to the adjacent users hence degrading the system performance. In Engineering, communication system design is based on requirement, if in a scenario where there are already so many noise sources and interfering power, an increased OBR will be more devastating for the system performance. Pulse shaping is a spectral processing technique by which fractional out of band power is reduced for low cost, reliable, power and spectrally efficient mobile radio communication systems**.** The more compact we make the signalling spectrum the higher is the allowable data rate or the greater is the number that can simultaneously be served; this has important implications to communication service providers, since greater utilization of the available bandwidth translates into greater revenue. This research paper is organized as follows section II discuss the SC-FDMA system model. Section III discusses the pulse shaping basics. Section IV discusses the methodology used. Section V discusses the results. Section VI discusses the conclusion and future scope.

II. SC-FDMA SYSTEM MODEL

The system model for Single Carrier Frequency division multiple access (SC-FDMA)[1] [2] system is as shown in Fig. 1.

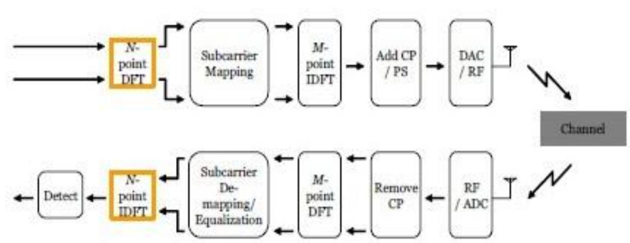

Figure 1. SC-FDMA System model

SC-FDMA is used as multiple access schemes for high data rate system in the uplink section. The main feature of the SC-FDMA is the precoding prior to subcarrier mapping. Several precoding techniques has been mentioned in the literature like Walsh Hadamard transform (WHT) [3], Discrete Wavelet Transform (DWT) [4], Discrete Cosine transform (DCT) [5]. Subcarrier mapping in SC-FDMA based system can either be distributed subcarrier mapping or localized subcarrier mapping. In the distributed subcarrier mapping mode, DFT outputs of the input data are allocated over the entire bandwidth with zeros occupying the unused subcarriers, whereas consecutive subcarriers are occupied by the DFT outputs of the input data in the localized subcarrier mapping mode. The localized subcarrier mapping mode used in SC-FDMA is coined as localized FDMA (LFDMA)[6] and distributed subcarrier mapping mode used in SC-FDMA is coined distributed FDMA (DFDMA), Interleaved frequency divison multiple access IFDMA[7] is a type of DFDMA.

The parameter of system used for the research work is as given in Table 1.

Table 1 Simulation Parameter

Parameters	Value
FFT size	1024
Modulation technique	16 QAM
Subcarrier mapping	IFDMA
Precoding	FFT

III. Pulse Shaping Basics

The two important parameters for design of telecommunication system are bandwidth efficiency and reducing the spectral leakage. These requirements are fulfilled by pulse shaping [8] [9] [10] the signal before transmission. Various pulse shaping techniques have been discussed in the literature which improves spectral efficiency and supports high data rate. Various pulse shapes provides trade-off between mainlobe width and the sidelobe attenuation.

Improved Sinc power pulse (ISP) is given as:

$$P(f) = \exp(-a(fT)^2)\, Sinc^n(fT)$$

a, is design parameter to control the amplitude
n, is the degree of sinc function

IV. Methodology

In [11] we have proposed a technique to improve the response of ISP pulse and named it as I^2SP pulse. In this research paper we are proposing a new pulse and named it as I^2SP_{hybrid} pulse, this new pulse is obtained after improving the response of ISP pulse using hybrid window (hybrid window are obtained by weighting technique). The new pulse shape we proposed is represented as:

$$I^2SP_{hybrid}\,(w_1^{p1}, w_2^{p2}) = ISP * W_W$$

$I^2SP_{hybrid}\,(w_1^{p1}, w_2^{p2})$ = impulse response of the proposed pulse.

ISP=impulse response of ISP pulse.
W_W=Hybrid window obtained by weighting technique.
I^2SP_{hybrid} pulse proposed in this research work shows better response then the ISP and I^2SP.

Where, w_1 is the 1st window function, p1 is the power to which 1st window function is raised, w_2 is the 2nd window function, p2 is the power to which 2nd window function is raised. Window w_1 is weighted with window w_2. Hybrid window function is obtained using mapping technique to generate a new window function by weighting 1st window coefficients with the 2nd window coefficients, by choosing suitable parent windows function power.

In this research work we have taken
Window (w_1)= Blackman window
Window (w_2)=Kaiser window

$$Hybrid\ Window(W_W) = blackman^{power1}\ X\ Kaiser^{power\ 2}$$
$$where,\quad power1 + power2 = 1$$

In this research work $power1 = power2 = .5$

hence
$Hybrid\ Window\ (W_W) = blackman^{.5} X\ Kaiser^{.5}$, for different shape parameter (β) for Kaiser window.

The proposed pulse shape I^2SP_{hybrid} in combination with A law companding transform is applied to SC-FDMA system and it's impact on the out band radiation is analyzed. The SC-FDMA system transmitter combining A law companding (A=3), with I^2SP_{hybrid} pulse shape is as shown in Figure 2.

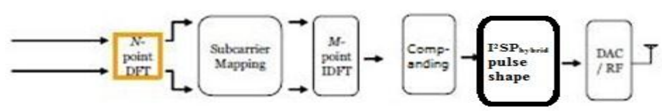

Figure 2. SC-FDMA transmitter with I^2SP_{hybrid} pulse in conjunction with A law companding

Impulse response, magnitude response and group delay of I^2SP_{hybrid} (blackman$^{.5}$,Kaiser$^{.5}$), β=.5 are shown in Figure 3 and Figure 4 respectively.

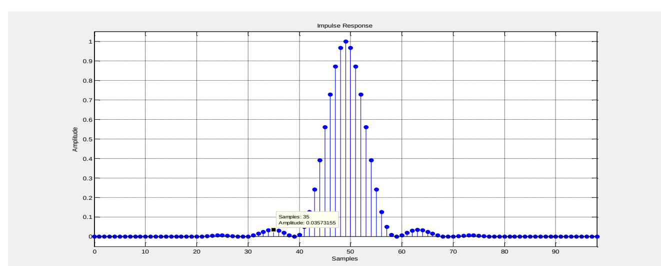

Figure 3. impulse response of I^2SP_{hybrid} (blackman$^{.5}$,Kaiser$^{.5}$), β=.5

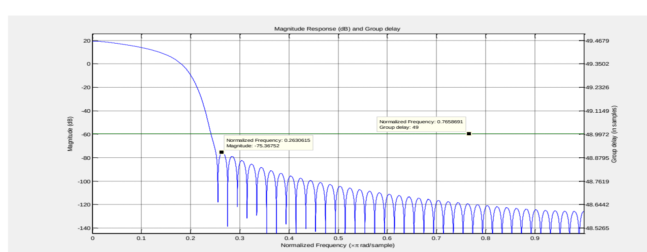

Figure 4. magnitude response and group delay of I^2SP_{hybrid} (blackman$^{.5}$,Kaiser$^{.5}$), β=.5

Impulse response, magnitude response and group delay of I^2SP_{hybrid} (blackman$^{.5}$,Kaiser), β=.8 are shown in Figure 5 and Figure 6 respectively.

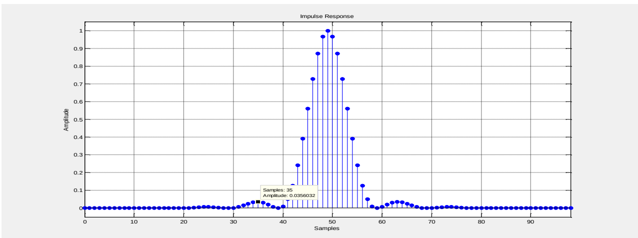

Figure 5. impulse response of I^2SP_{hybrid} (blackman$^{.5}$,Kaiser$^{.5}$), β=.8

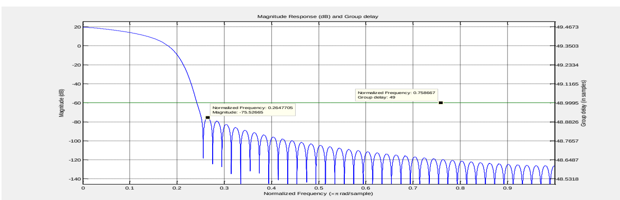

Figure 6. magnitude response and group delay of I^2SP_{hybrid} (blackman$^{.5}$,Kaiser$^{.5}$), β=.8

Impulse response, magnitude response and group delay of I^2SP_{hybrid} (blackman$^{.5}$,Kaiser$^{.5}$), β=.95 are shown in Figure 7 and Figure 8 respectively.

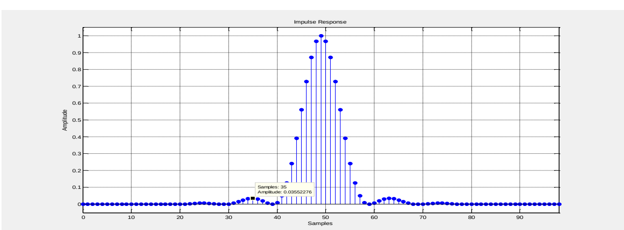

Figure 7. impulse response of I^2SP_{hybrid} (blackman$^{.5}$,Kaiser$^{.5}$), β=.95

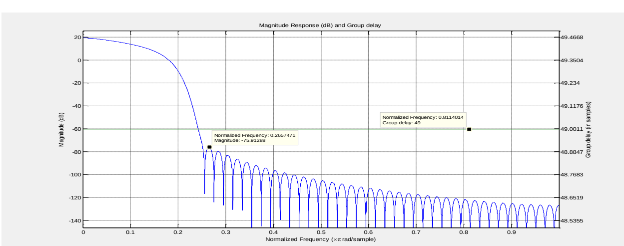

Figure 8. magnitude response and group delay of I^2SP_{hybrid} (blackman$^{.5}$,Kaiser$^{.5}$), β=.95

The data obtained from the various proposed pulse shape I^2SP_{hybrid}(blackman$^{.5}$,Kaiser$^{.5}$) with varying value of shape parameter (β) is presented in Table 2. The corresponding value for $I^2SP(w^{.5})$ are obtained from [11]

Table 2 Analysis of various proposed pulse shape

Proposed pulse shape	Impulse response (tail)	Magnitude response	Group delay
$I^2SP(w^{.5})$	0.03582018	-74.94 dB	49
I^2SP_{hybrid}(blackman$^{.5}$,Kaiser$^{.5}$), β=.5	0.03573155	-75.36752 dB	49
I^2SP_{hybrid}(blackman$^{.5}$,Kaiser$^{.5}$), β=.8	0.0356032	-75.52665 dB	49
I^2SP_{hybrid}(blackman$^{.5}$,Kaiser$^{.5}$), β=.95	0.03552276	-75.91288 dB	49

V. RESULTS AND DISCUSSION

The proposed I^2SP_{hybrid} (blackman$^{.5}$, Kaiser$^{.5}$), β=.5 pulse shape in conjunction with A law companding with A=3, is applied to SC-FDMA based cellular system, and the power spectral density (PSD) of the signal, PAPR and the data statistics of PSD is obtained using MATLAB Simulation and the result obtained is as shown in Figure 9, Figure 10 and Figure 11 respectively.

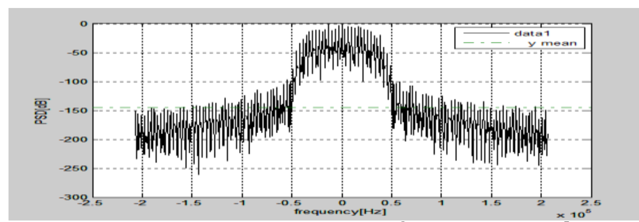

Figure 9. PSD of SC-FDMA system with I^2SP_{hybrid} (blackman$^{.5}$, Kaiser$^{.5}$), β=.5

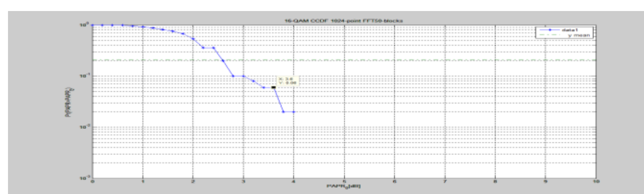

Figure 10 PAPR of SC-FDMA system using I^2SP_{hybrid} (blackman$^{.5}$, Kaiser$^{.5}$), β=.5

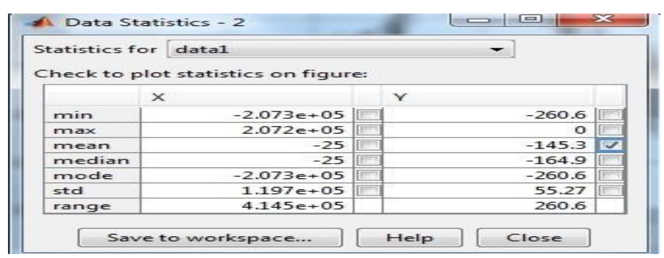

Fig 11 data statistics for PSD of SC-FDMA system using I^2SP_{hybrid} (blackman$^{.5}$, Kaiser$^{.5}$), β=.5

The proposed I^2SP_{hybrid} (blackman$^{.5}$, Kaiser$^{.5}$), β=.8 pulse shape in conjunction with A law companding with A=3, is applied to SC-FDMA based cellular system, and the power spectral density (PSD) of the signal, PAPR and the data statistics of PSD is obtained using MATLAB Simulation and the result obtained is as shown in Figure 12, Figure 13 and Figure 14 respectively.

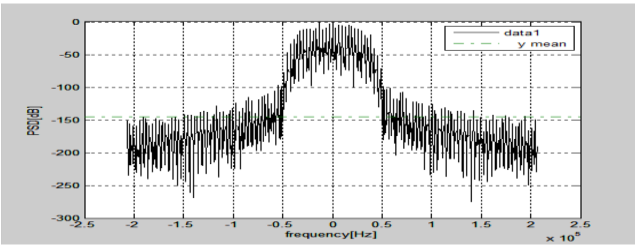

Figure 12. PSD of SC-FDMA system with I^{2}SP$_{hybrid}$ (blackman$^{.5}$, Kaiser$^{.5}$), β=.8

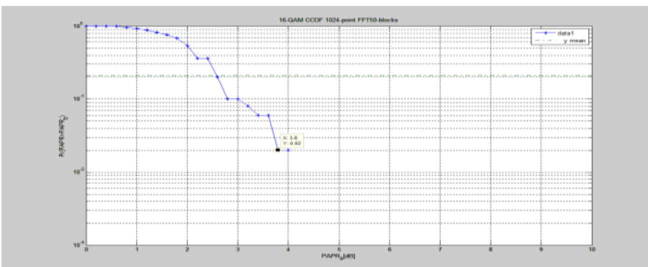

Figure 13 PAPR of SC-FDMA system using I^{2}SP$_{hybrid}$ (blackman$^{.5}$, Kaiser$^{.5}$), β=.8

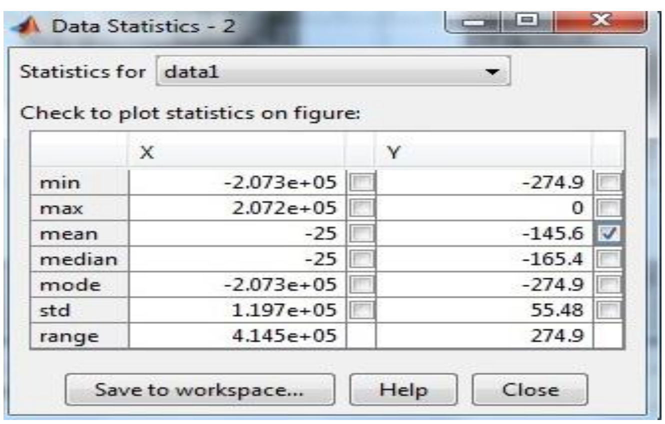

Figure 14 data statistics for PSD of SC-FDMA system using I^{2}SP$_{hybrid}$ (blackman$^{.5}$, Kaiser$^{.5}$), β=.8

The proposed I^{2}SP$_{hybrid}$ (blackman$^{.5}$, Kaiser$^{.5}$), β=.95 pulse shape in conjunction with A law companding with A=3, is applied to SC-FDMA based cellular system, and the power spectral density (PSD) of the signal, PAPR and the data statistics of PSD is obtained using MATLAB Simulation and the result obtained is as shown in Figure 15, Figure 16 and Figure 17 respectively.

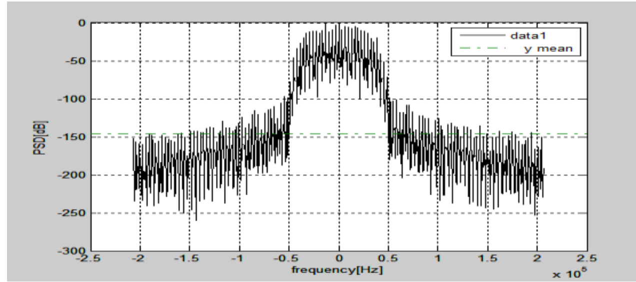

Figure 15. PSD of SC-FDMA system with I^{2}SP$_{hybrid}$ (blackman$^{.5}$, Kaiser$^{.5}$), β=.95

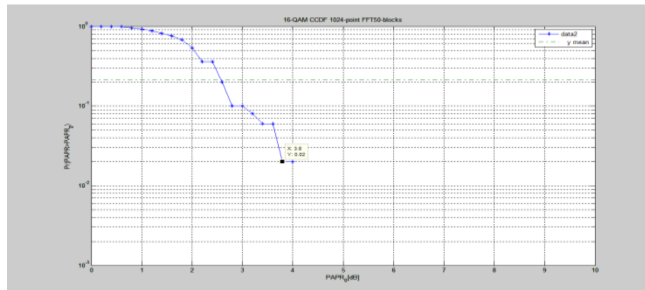

Figure 16 PAPR of SC-FDMA system using I^{2}SP$_{hybrid}$ (blackman$^{.5}$, Kaiser$^{.5}$), β=.95

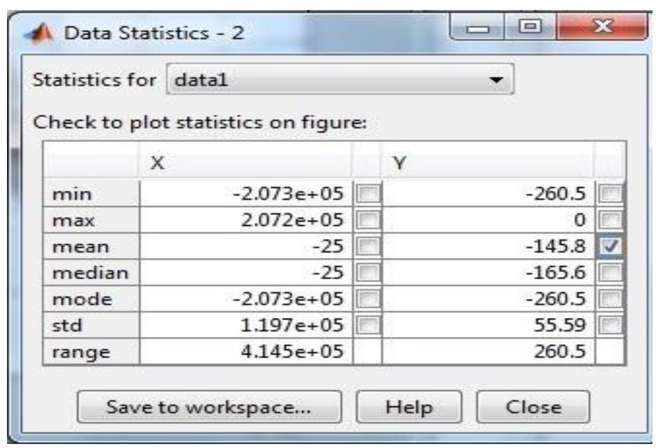

Figure 17 data statistics for PSD of SC-FDMA system using I^{2}SP$_{hybrid}$ (blackman$^{.5}$, Kaiser$^{.5}$), β=.95

Table 3 presents the comparative analysis for the performance of SC-FDMA system with proposed I^{2}SP and I^{2}SP$_{hybrid}$ (blackman$^{.5}$, Kaiser$^{.5}$) pulses using Blackman window weighted with Kaiser window (with different shape parameter value as .5, .8 and .95) in conjunction with A law companding. The corresponding value for I^{2}SP(w$^{.5}$) are obtained from [11]

Table 3. comparative analysis for the performance of SC-FDMA system with I^2SP and I^2SP_{hybrid} (w_1^{p1}, w_2^{p2}) pulse

Proposed Pulseshape	$PAPR_O$ 2.2 Db	$PAPR_O$ 2.2 Db	$PAPR_O$ 2.2 Db	$PAPR_O$ 2.2 Db	$PAPR_O$ 2.2 Db	$PAPR_O$ 2.2 Db	Mean PSD (From Data Statistics)
$I^2SP(w^{.5})$	0.36	0.36	0.1	0.08	0.06	0.02	-145.1 db
$I^2SP_{hybrid}(blackman^{.5}, Kaiser^{.5})$, β=.5	0.36	0.36	0.1	0.08	0.06	0.02	-145.3 db
$I^2SP_{hybrid}(blackman^{.5}, Kaiser^{.5})$, β=.8	0.36	0.36	0.1	0.08	0.06	0.02	-145.6 db
$I^2SP_{hybrid}(blackman^{.5}, Kaiser^{.5})$, β=.95	0.36	0.36	0.1	0.08	0.06	0.02	-145.8 db

VI. CONCLUSION AND FUTURE SCOPE

From Table 2 it is observed that, $I^2SP_{hybrid}(blackman^{.5}, Kaiser^{.5})$ pulse shape designed using Blackman window weighted with Kaiser window, gives better response in time domain and frequency domain by varying Kaiser window shape parameter (β), and from table 3. It is observed that, when $I^2SP_{hybrid}(blackman^{.5}, Kaiser^{.5})$ is used with SC-FDMA system it shows improved OBR performance, with decreasing OBR (mean PSD value is decreased), while maintaining the same PAPR.

In general the new proposed pulse shape I^2SP_{hybrid} (w_1^{p1}, w_2^{p2}) gives lesser OBR for SC-FDMA based cellular system while maintain the same peak PAPR.

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