

In considering the modulator and demodulator structure for the new modulations, Figures 1 and 2 illustrate the structure of staggered quadrature-overlapped modulation systems. Fig. 1 shows a modulator in a transmitter and Fig. 2 shows a demodulator in a receiver.

The modulator in Fig. 1 comprises a serial/parallel converter block 1, an offset delay block 2, Waveform Shaping Filters 3 and 4, two multiplication units 5 and 6, a carrier generator 7, a phase shifter block 8, an addition unit 9, and a transmitter filter 10. The demodulator in Fig. 2 comprises a receiver filter 11, two multiplication units 12 and 13, a carrier generator 14, a phase shifter 15, two match filters 16 and 17, two decision threshold blocks 18 and 19, a delay block 20, and a parallel/serial converter 21. The modulator and demodulator comprises two channels, I channel and Q channel.

The modulation systems of Figures 1 and 2 are quite normal, but according to this invention, their Waveform Shaping Filters are unique.

In this modulation method, the word "staggered" means that the data sequence in the Q channel is delayed for the time duration $\tau=T$ relative to that in the I channel. One single-shaped pulse from the "waveform shaping filter" (WSF) 3 or 4 is $g(t)$, which is defined in the duration $(0, 4T)$.

The original input data sequence a is first separated into even b and odd b' subsequences at the "serial/parallel converter" 1, and the b' subsequence will be delayed in the delay block 2 for the time duration $\tau=T$ because of the staggering requirement. It is assumed that the data bit rate in the original input a is $1/T$. Therefore, the bit duration in either I or Q channel will be $2T$. The output of one single pulse $g(t)$

from the WSF has a duration $4T$. The sign of $g(t)$ depends on the sign of the corresponding input data bit to WSF. The overlapping pulses are fed into quadrature carrier modulator or multiplication units 5 and 6 for the carrier modulation. After the carrier modulation and later on, the signal is fed to the bandpass filtering in block 10 to limit out-of-band power emission. An inverse process exists in the demodulator unit as shown in Fig. 2 in blocks 11-21.

In Figures 1 and 2, the most important part is the Waveform Shaping Filter (WSF) 3 and 4, the transfer function of which is $H_{WSF}(w)$, because $H_{WSF}(w)$ uniquely determines the Power Spectral Density (PSD) of the modulated signal. The superiority of the new modulation techniques is also based on its special WSF design, which can generate particularly shaped waveforms $g(t)$ in Fig. 1 and 2, which in turn make the modulated signals efficient in the bandwidth.

The normalized PSW for the QOTC modulation is given as follows:

$$g(t) = \begin{cases} \frac{t}{2T} - \frac{1}{2\pi} \sin \frac{\pi t}{T} & (0 \leq t \leq 2T) \\ (2 - \frac{t}{2T}) + \frac{1}{2\pi} \sin \frac{\pi t}{T} & (2T \leq t \leq 4T) \end{cases} \quad (1)$$

where we can see that it consists of two components, a triangular function

$$g_1(t) = \begin{cases} \frac{t}{2T} & (0 \leq t \leq 2T) \\ 2 - \frac{t}{2T} & (2T \leq t \leq 4T) \end{cases} \quad (2)$$

and a cosine function