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Fast orbital quantum modulation using Orbital Angular Momentum wave emitter based on N-PSK modulators

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Abstract

Based on Phase Shift Keying modulators architecture and annular array radiating antenna, an efficient OAM emitter is proposed and built with Q-PSK at 2.45 GHz. Once characterized, it exhibits 100 MHz data rate modulation capability. The encoded orbital quantum (or index modulation) only uses three states (for Q-PSK) and four array elements. The received signals also suffer from conventional OAM line of sight links drawbacks, especially OAM "cross-talk" which comes from OAM states non ideal orthogonality in the realized setup.

1. Introduction

In the last decade, and after the pioneering work of B. Thidé and Al. [1], Orbital Angular Momentum waves have been widely investigated as a possible way to increase data rates in point to point wireless communications. Firstly in a controversial mode, it now appears to be generally admitted that it represents a subset of the more general MIMO class systems. The paper's authors have already studied some new questions that raised with such vortex waves [2]. Recent developments in the millimeter range have been investigated in line of sight links [3]. They provide new multiplexing capabilities.

In the present paper, we focus on a new emitter circuit structure, based on usual components. We demonstrate the feasibility of that circuits which provide high-speed orbital quantum modulation. One has to note that each OAM vortex radiated wave only lasts few tens of nanoseconds. A recent discussion of the system advantages can be found in [4].

The paper is organized as follows: first, an original circuit layout is found from conventional OAM annular arrays specifications; second, the generated signals are measured and commented; last, a global OAM, very short distance, link is built, with a simple Butler matrix receiver, in order to show that the orbital quantum encoded information can be recovered.

2. Layout

It has been previously introduced that annular arrays were able to generate OAM waves [5]. As an elementary demonstration, we will further use the four elements array depicted in figure 1. It is fed the way described in table 1.

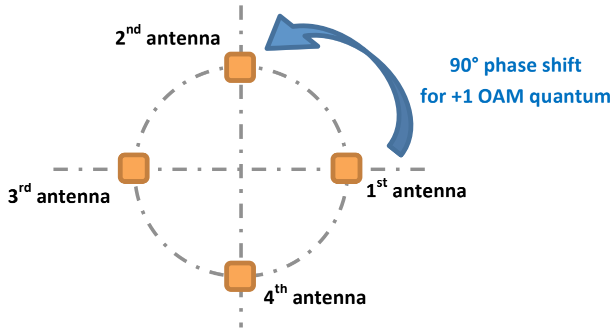

Figure 1. OAM Annular array configuration.

OAM Quantum	Antenna index 1	2	3	4	IQ Modulation I_1Q_1	I_2Q_2	I_3Q_3	I_4Q_4	Symbol
0	0°	0°	0°	0°	00	00	00	00	A
	90°	90°	90°	90°	01	01	01	01	B
	180°	180°	180°	180°	11	11	11	11	C
	270°	270°	270°	270°	10	10	10	10	D
+1	0°	90°	180°	270°	00	01	11	10	E
	90°	180°	270°	0°	01	11	10	00	F
	180°	270°	0°	90°	11	10	00	01	G
	270°	0°	90°	180°	10	00	01	11	H
-1	0°	270°	180°	90°	00	10	11	01	I
	90°	0°	270°	180°	01	00	10	11	J
	180°	90°	0°	270°	11	01	00	10	K
	270°	180°	90°	0°	10	11	01	00	L

Table 1. exhaustive list of the Q-PSK architecture states and related symbols.

Based on QM-2326A Polyphase Microwave modulators and a CY8C586AXI-LP032, PSoC, from Cypress Semiconductor to drive the logical circuits (Field-Programmable Gate Arrays : Altera MAX10), a PC-controlled emitter has been realized. It allows data rate flows (i.e. IQ command rates) from 2MHz to 200MHz, while the modulators are specified with 275MHz IQ bandwith. A special attention has been paid to lines supporting high frequency signals to avoid differential phase errors by the use of Low Voltage Differential Signals. The result is depicted in figure 2.

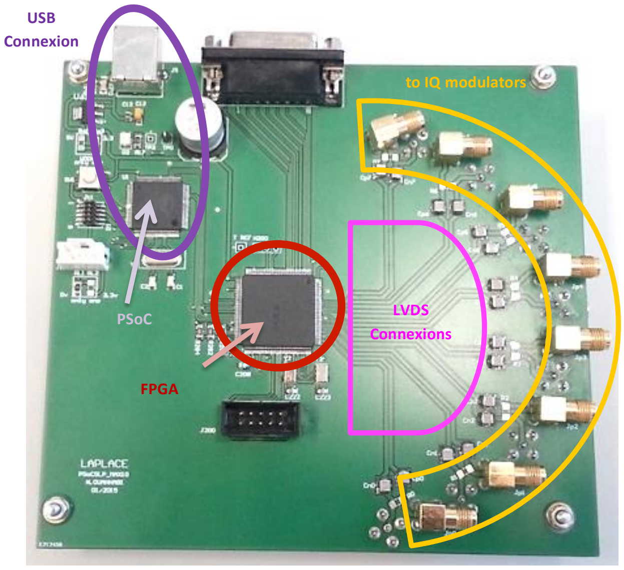

Figure 2. Main PCB (8 others "to IQ modulators" SMA connectors on back).

A home developed software is used to drive the emitter which only requires a standard CW source (6dBm typ).

3. Emitter qualification

Looking with an oscilloscope at the four feeding signals that can be produced with this circuit for several symbols, the data of figure 3 can be obtained for a 10MHz clock frequency. They clearly show the in-phase or quadrature correct behaviors related to OAM quantum 0, +1 and -1. Neither phase nor amplitude mismatches appears to be significant until a modulation frequency of 50MHz. From 100MHz and especially 200MHz, the bandwidth of the modulators for square signals is then not enough: peak voltage levels decrease.

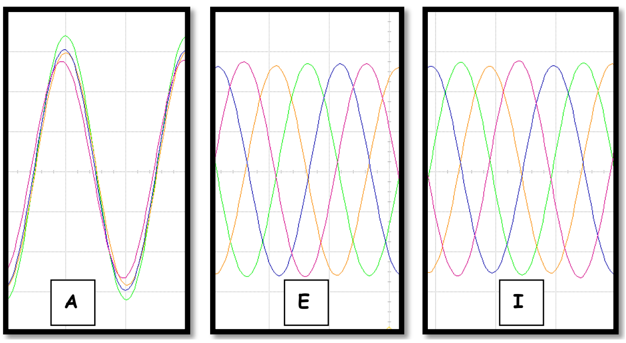

Figure 3. Time Signals related to symbols A, E and I that will further feed radiating annular array elements.

Focusing on symbol transitions, we achieve the chronograms of figure 4 for a 10MHz clock. The global transition time has been evaluated around 2ns (arrow).

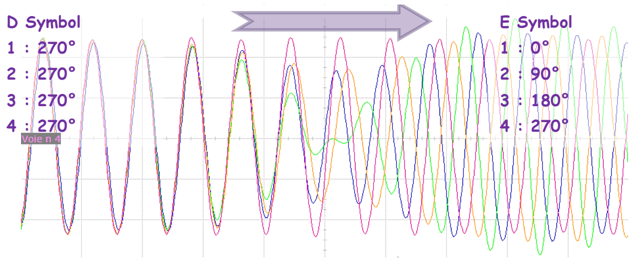

Figure 4. Transition from symbol D to symbol E.

4. Global OAM link results

The OAM symbols are radiated by an array (on the right, figure 5) connected to the modulators' outputs of the active box described earlier. The carrier frequency (2.45GHz) is provided by an additional generator. A very simple receiving network, placed at 2.8m, is connected to a Butler matrix [6] to discriminate 8 OAM quantums including 0, +1 and -1. Unused outputs are loaded on 50 Ohms. Although this Butler matrix exhibits almost 10° max phase errors, which lead to significant crosstalk, it was the straightest path available to discriminate OAM quantum states and prove the OAM quantum modulation capability.

Figure 5. Emitting (4 active antennas) and receiving (8 act. ant.) arrays facing each other in the semi anechoïc room.

The Butler matrix outputs, related to orbital quantums -1, 0 and +1, are used and plotted in figure 6. The three chronograms are showing that the I, E and A symbols, sequentially encoded in the emitter, are found at the corresponding outputs, with a higher voltage level. The fourth pink plot is only the trigging signal (clock). Two sets are printed corresponding to 2MHz and 100MHz clocks. Although some crosstalk is clearly visible on adjacent modes, the symbols are sorted with respect to the specific OAM quantum and a threshold scheme could discriminate these datas. We consider that these results prove the capability of such an emitter and make it a valuable candidate for OAM emitting devices.

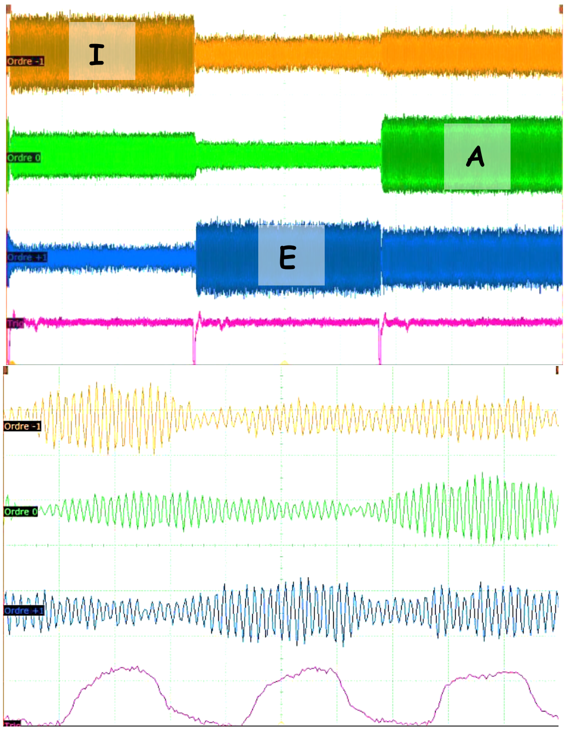

Figure 6. Butler matrix outputs for -1, 0 and +1 OAM quantums (resp. orange, green and blue) and clock (pink) for 2MHz and 100MHz clocks.

5. Conclusion

A new and basic configuration for OAM radiation and modulation, using Q-PSK modulators, is proposed, built and measured. It exhibits high speed OAM quantum modulation capability till 100MHz, though a poor phase accuracy receiver is used and the differential mode link budgets are not balanced.
Furthermore, it allows standard PSK modulation for the zero order mode using only A, B, C and D symbols.

6. Acknowledgements

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7. References

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