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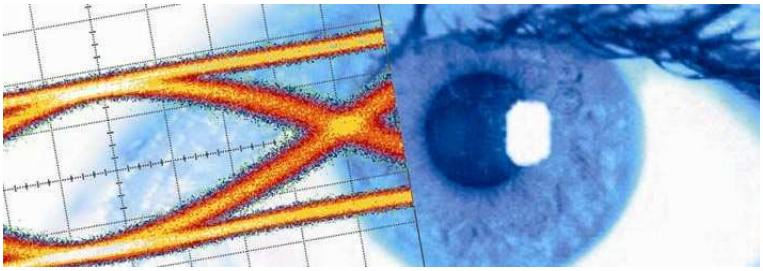
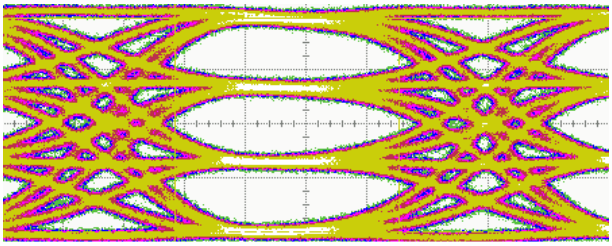
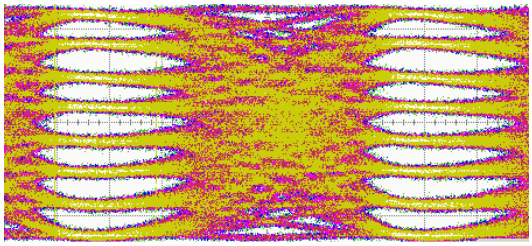


Application Note

Multi-Level Signal Generation for QAM using the Multi-Channel SHF 12103 A





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Introduction

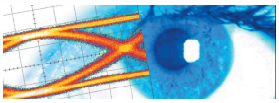
As the development of 100 Gbps system products based on Dual Polarisation (DP) QPSK and coherent detection matures, and system deployment anticipated shortly, QAM could become a key technology for future developments towards even higher spectral efficiency. The SHF 12103 A multi-channel bit pattern generator is developed specifically, though not exclusively, having in mind for such advanced optical system developments.

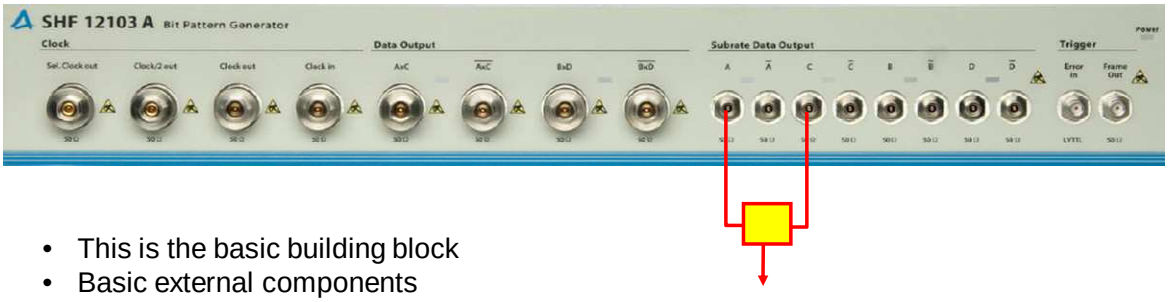
The objective of this note is to provide a simple guide on how to make the best use of the SHF 12103 A Quad-32, 4-channel 32 Gbps BPG, as a multi-bit data source, to realize 4-level electrical signals when used in conjunction with an external broadband power combiner. The resultant multi-level analogue electrical signal could be used to modulate, when used in conjunction with a suitable drive amplifier, a commercial I-Q optical modulator for the generation of 16QAM signal. This basic implementation may conceptually be further expanded to at least a three-bit structure for 8-level signal generation for 64QAM applications.

The Basic Idea

Figure 1 illustrates how a 4-level signal can be generated using the SHF 12103 A Quad-32 BPG and minimal external components. The basic external components are: two RF cables to connect the sub-rate outputs of the SHF 12103 A to a broad band power combiner. Two important features within the BPG are used. These are the output amplitude adjustment control, and the skew control which allows fine adjustment of the timing delay of each output data stream, with a step size of 0.1 ps and a range of ± 25 ps, as illustrated in figure 2. Additionally, for de-correlation purpose, the sub-rate outputs can be set to different patterns (prbs or user-defined). If the same pattern is preferred, the integer bit delay function can be activated to set the number of integer bits of delay. Figure 3 shows how these are set in the control software.

Signal Generation Concept





- This is the basic building block
- Basic external components
  - Matched cables
  - Power divider
- Timing and amplitude adjustment performed internally with the BPG
- Scalable concept towards higher number of effective bits (3,perhaps 4)

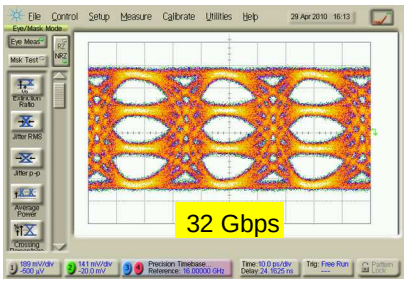


Figure 1

Control of Binary Signal for Performace

BCC Software control of the 4 Level parameters

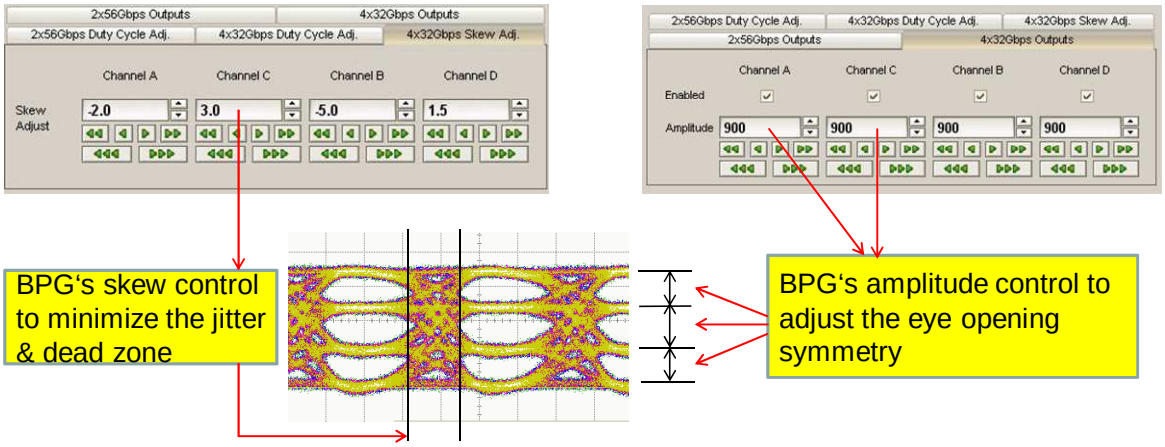


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Figure 2

Signal De-correlation

Different PRBS pattern lengths

Same PRBS pattern lengths
Bit delays activated

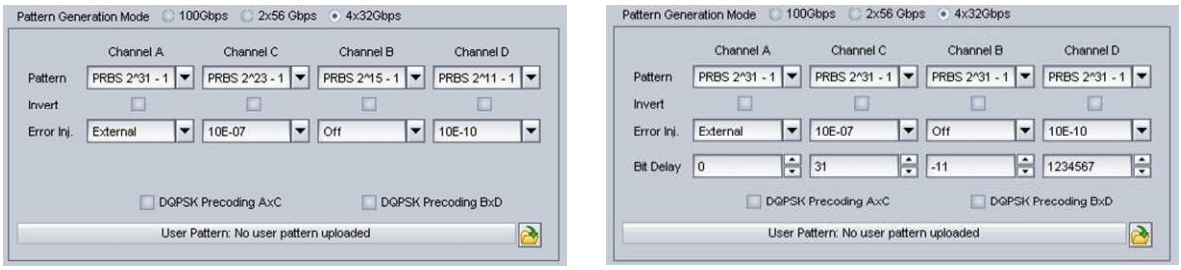

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Figure 3

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Optimization for Signal Quality

Figure 4 shows how the 4-level signal quality may be further improved by using additional attenuation to minimise the manifestation of RF reflections within the hybrid power combining structure. However, a small reduction in the over-all amplitude of the resultant 4-level signal is incurred due to the additional attenuation. However, the resultant 400 mV amplitude, in conjunction with a suitable linear driver, such as the SHF 807, should be sufficient to drive a commercial I-Q modulator.

By choosing the right amplitude ratio between the two sub-rate outputs from the SHF 12103 A, it is also possible to define (within a limited range) the amplitudes of the inner and the two outer 'eye' of the 4-level signal. This is illustrated ion figure 5.

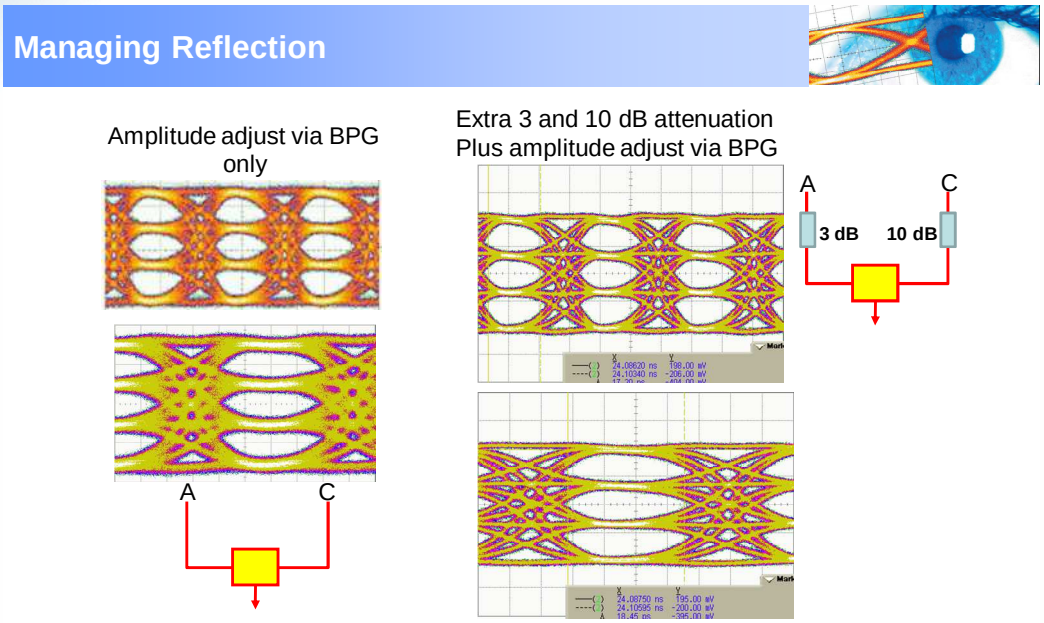

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Figure 4

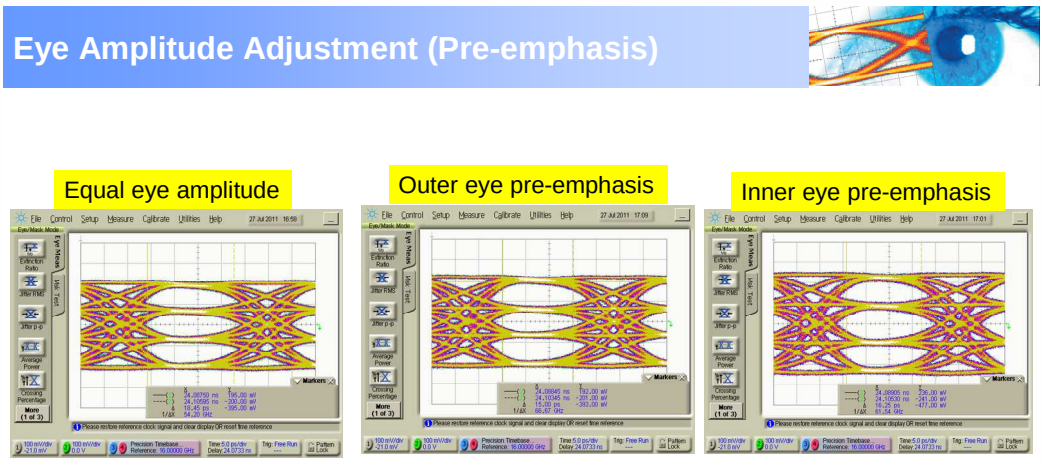

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Figure 5

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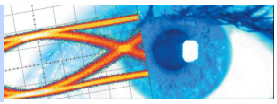
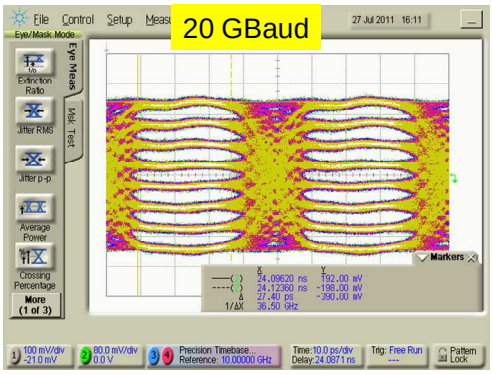
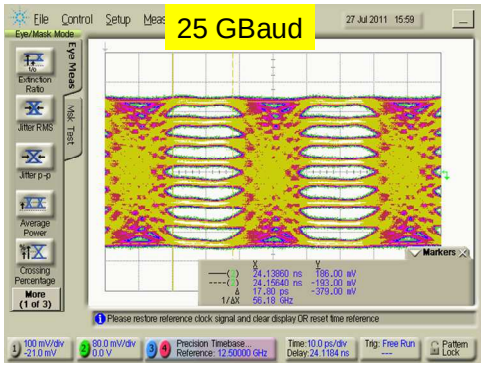
Scaling for 3-bit, 8-level

To further illustrate the versatility of combining the SHF 12103 A and the passive combiner approach for multi-level signal generation, figure 6 shows how using three binary data channels of the SHF 12103 A, and a suitable augmentation of the power combining structure, an 8-level signal could be generated for 64QAM. In this case, an additional 6 dB attenuator is added to the 3rd bit before the 2nd power combiner. Again, the amplitude and individual channel skew control are crucial in achieving the right delay and amplitude combinations in order to realise a good quality multi-level signal.

3-Bit 8-Level for 64QAM







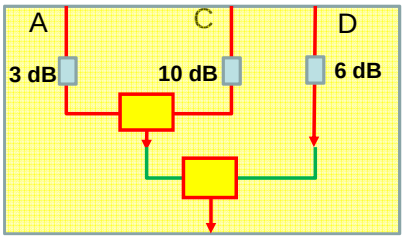


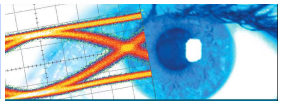
Figure 6

Two-channel implementation for 4-level I-Q modulation

Figure 7 shows the actual implementation of two 4-level signals suitable I-Q modulation. Here, all four sub-rate channels of the SHF 12103 A are used.

In the event that only two sub-rate channels are available (Dual-32 option), the inverted data outputs (data_bar) may be used to form the second 4-level signal. However, care should be exercised to ensure correct timing delay(s) is realised. For de-correlation purpose, a suitable external delay, which could be a suitable piece of high quality coaxial cable (with pre-determined delay value) or an adjustable delay line, should be used.

Dual 4-level Implementation for 32 Gbaud 16QAM



Potential choice of components:

- Coaxial cables
  - E.g. CA 185 or 292 series
- Attenuators
  - 1.85, 2.92 mm or equivalent
- Combiners
  - 1.85, 2.92 mm or equivalent
- Linear amplifiers
  - SHF 807

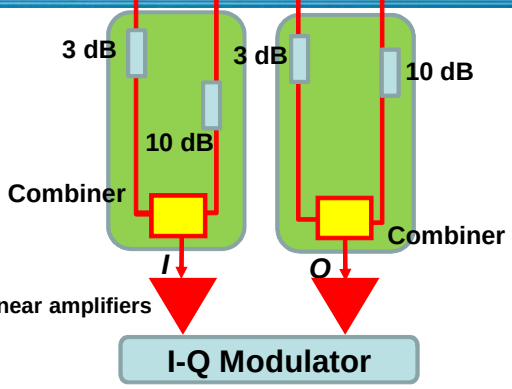


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Figure 7

A practical realization of one attenuator-combiner structure to match the sub-rate outputs of the SHF 12103 A BPG is shown in Figure 8. The structure comprises the 1.85 mm (or equivalent) components as described in Figure 7 to maximize the over-all bandwidth. The two semi-rigid cables are designed to match the physical spacing of the sub-rate outputs A & C, and B & D. Two additional 1.85 to 2.92 mm adaptors are used to interface to the SHF 12103 A sub-rate outputs.

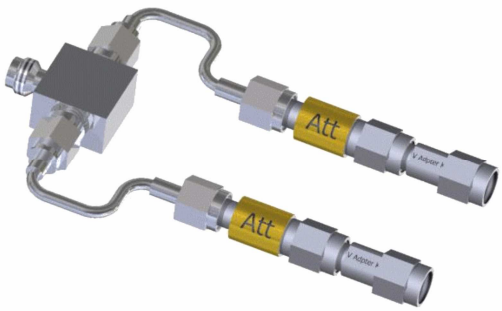

Figure 8 1.85 mm realization of attenuator-combiner structure

The complete structure or specifically the custom-designed semi-rigid cables are available on request.

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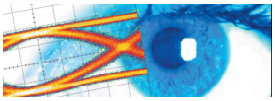
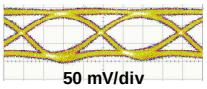
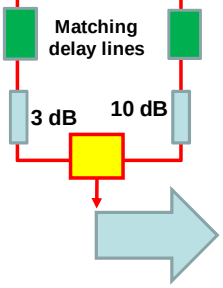
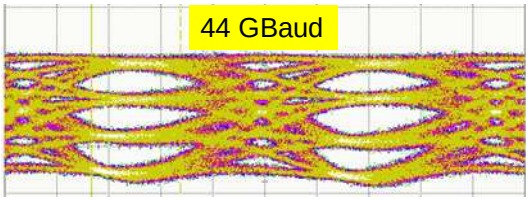
It should also be pointed out that by removing the 1.85 to 2.92 mm adaptors, the remainder can be used for generating high baud rate (>32 GBaud) 4-level signals if the dual-56G configuration of the SHF 12103 A is also available. Figure 9 shows 4-level signals at 44 and 50 GBaud generated by using the same 1.85 mm attenuator-combiner structure. However, two additional delay lines may be required for skew control adjustment.

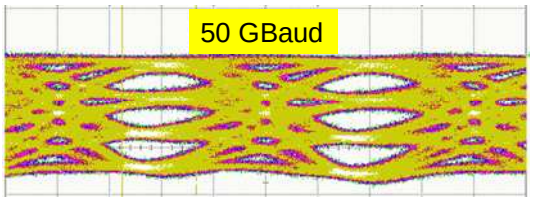
Beyond 32 GBaud











- Scaling to higher baud rates
- Additional timing delay adjustment would be necessary
- Requires linear driver development for high baud rate

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Figure 9

11

Matching linear driver amplifiers

Since the peak-to-peak amplitude level of the 4-level signal is typically less than 1V, a suitable choice of linear amplifier with the right bandwidth, phase linearity and linear output power level amicable for commercial I-Q modulators is a pre-requisite. Please refer to the SHF home page for New Amplifiers, link http://www.shf.de/en/.

For baud rates up to 32 GBaud, the SHF 807 could be considered for I-Q modulators with 2 V□ of up to 6 V. However, for baud rates in excess of 40 GBaud, the ultra-broad band amplifiers SHF 824 potentially offers the least distortion. Although a moderate small signal gain of 11 dB will limit the maximum available output drive level, thus restricting the modulation excursion to the linear regime of the modulator and increased optical attenuation.