induces a mixing of signal and noise, the phase-to-amplitude noise is additionally enhanced for two amplitude level signals compared to the PSK formats with the same average energy, see Fig. 5(c). However, the enhancement is incremental and saturates to a constant value as the number of regenerators is increased.

Finally, we have extended the analysis to modulation formats of higher complexity by considering 16-symbol constellations of different geometry and evaluating their performance in systems of cascaded phase regenerators. The performance of the single ring 16-PSK constellation has been benchmarked against the dual ring diagrams of 2-ASK/8-PSK and 2-ASK/8-PSK shifted, the four-ring 4-ASK/4-PSK shifted format, and finally the 16-star QAM. Figure 6 depicts the corresponding constellation diagrams at the input of the link, as well as, at the receiver after different numbers of cascaded regenerators. For the formats presented here, the effects of phase regeneration discussed above become more pronounced, in particular the trade-off between the efficiency of phase squeezing and the impact of phase-to-amplitude conversion.

The SER performance as a function of the SNR of the 16 point constellations of Fig. 6 is depicted in Fig. 7. Though amplitude modulated formats surpass densely-packed PSK for linear transmission, as the number of PSAs increases the SER associated with 16-PSK is gradually improved, and eventually the 16-PSK outperforms all other examined formats. Therefore, PSK signal modulation proves to be the most beneficial for transmission in PSA based regenerative links as it experiences the best SER improvement. As with the 8-symbol example, this is attributed to the intrinsic robustness of the PSK format against the amplitude noise, whereas, the multi-ring constellations are more vulnerable to this effect. Applying phase shift on the different rings of the constellations does not bring major improvement in their SER performance.

4. Conclusions

We have investigated the transmission performance of non-linear regenerative channels based on cascaded PSAs and we have explored the impact of the phase and amplitude noise accumulation mechanisms in the selection of the optimum modulation format. The results demonstrate that densely packed PSK formats are highly favored by the phase squeezing properties of the channel for high capacity transmission. On the other hand, the use of multi-amplitude level ring constellations brings minor improvements in SER performance as the benefits of phase regeneration are counterbalanced by the enhancement of the amplitude noise imposed by the phase to amplitude conversion in the PSAs. In particular, we find that the use of PSA regeneration with a 16-PSK signal outperforms the linear transmission performance of the 8-QAM system by 2 orders of magnitude in SER at an SNR of 16dB, suggesting that a system employing phase regenerators has the potential to offer higher point to point capacities than conventional dual quadrature transmission systems. We anticipate that the addition of a small level of amplitude regeneration to resist the phase to amplitude noise conversion process will further enhance the performance of the regenerative channel with respect to the conventional nonlinear channel.

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