A Feasibility Study on Quantum Illumination Radar

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In a paper titled "Quantum Illumination with Gaussian States" published in 2008, Si-Hui Tan et al [1], determined that a Quantum radar based on Gaussian State illumination (also termed Quantum Illumination Radar) theoretically has a 6dB improvement in SNR compared to Conventional Radar at low signal powers. Following this paper, there have been a number of recent claims that such a Quantum Radar has been built and demonstrated to have unprecedented performance – capable of detecting stealth bombers at distances of 100km away [2].

Such claims were further bolstered in 2019 when Sandbo Chang [3] and David Luong [4][5] from the University of Waterloo and Defence Research and Development Canada (DRDC) demonstrated an experimental Quantum Illumination Radar prototype which has 8 times more SNR than its classical counterpart – even more than Si-Hui Tan's theoretical 6dB estimate. Moreover, the Waterloo Quantum Radar can directly generate entangled microwave photons (at ~7GHz) and operate without any joint measurements of the signal and idler, making it very attractive as a practical Radar.

In view of the above, we shall therefore examine in this report the claimed advantages of the Quantum Illumination Radar, reconcile the differences between Si-Hui Tan's theoretical results and the Waterloo Quantum Radars, and determine just how practical and feasible Quantum Illumination Radars are compared to an optimized Classical Radar.

We develop a framework that builds on Si-Hui Tan's analysis to include noise introduced from the Waterloo experiment, and show that their results are not at odds with each other. Finally, we shall demonstrate that while small scale results may appear promising, we show that the SNR enhancement vanishes in the high power limit even if a hypothetical high-power entangled source were to exist, making the quantum radar impractical for realistic distances (*Figure 1*)

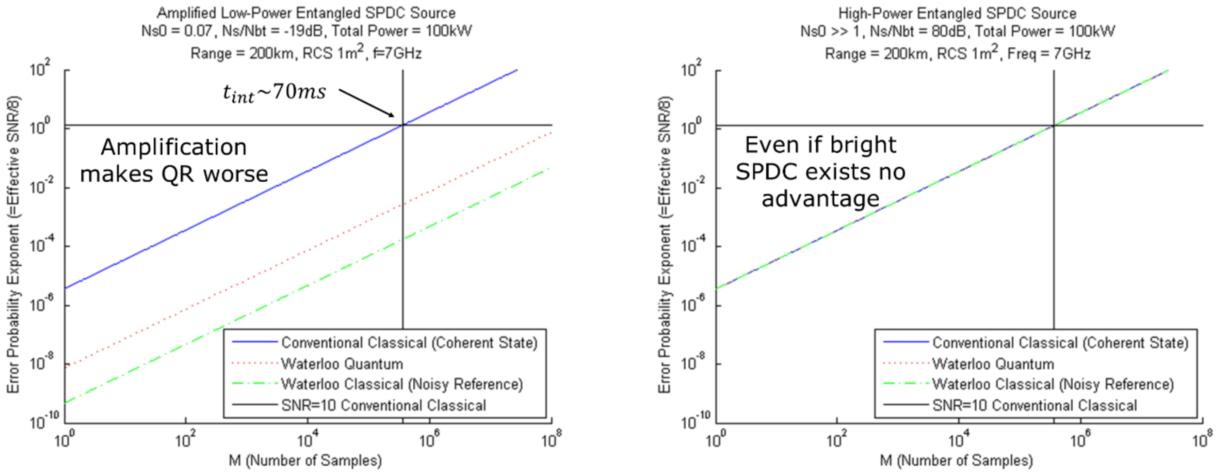

Figure 1: Plots of the Effective Received SNR for varying number of samples (at a typical sampling rate of $10MHz$) for practical radar target detection scenarios (target at 200km, with typical losses and noise). The Waterloo Quantum (red dotted) and Waterloo Classical (green dashed) Radars are compared to Conventional Classical radar (blue) when operating at typical $100kW$ powers ($N_s \gg 1$). Left: Waterloo Radars

when amplified to $100kW$. Right: hypothetical High power Spontaneous Parametric Down Converted (SPDC) Waterloo Radar, which outputs entangled photons without need of amplification. For a typical sampling interval ($M \sim 10^5$ or integration time $t_{int} \sim 70ms$), it can be shown that the Amplified Waterloo radars has an SNR much smaller than 1 – much worse than Conventional Radar. While for the Hypothetical High power Waterloo Quantum Radar, it has the same SNR as a Conventional Radar – implying no advantage when applied to practical situations.

1 REFERENCES

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