ARMA MODEL OF THE SPERM WHALE SOUND PRODUCTION SYSTEM

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Processing sperm whale signals for individual localisation or classification is an attractive scientific challenge for which modelling the sound production system can help achieve an optimal solution. We start from the most accepted hypothesis that a broadband pulse is produced at the 'monkey lips'. From there, a realistic approach is to consider that this pulse propagates by different physical processes depending on the ratio (wavelength [lambda] / organs size [d]). We focus on low lambda/d ratios for which the pulse energy propagates back to the frontal sac and part of it is ducted through the junk to the water (main click). Meanwhile, part of the higher frequency (low lambda/d) vibrations would also propagate back through the spermaceti organ to the distal sac producing a series of reverberant clicks. With this hypothesis we formulate an autoregressive moving average (ARMA) model for individual clicks. Our experiments show that the clicks' spectrum reflects the existence of resonances and antiresonances in accordance with the tube-like structure of the spermaceti organ and the cone-shaped junk. This is reflected in the model where the AR and MA parameters model resonances and antiresonances, respectively. We adopt an input-output approach for the estimation of the ARMA parameters where the input is a broadband pulse and the output is a given click signal. This approach also allows an elegant reformulation to include clicks from several series in the estimation of their common parameters. Our experiments are carried out with click series from several sperm whales. The results lead to three main conclusions. Firstly, the sperm whale click propagation hypothesis is plausible. Secondly, an ARMA model is appropriate for the sperm whale sound production system. And, thirdly, an input-output approach seems to be a proper choice when we try to estimate the common parameters of several clicks.