Numerical modelling of the Blackstone radar antenna array

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Objective

This work forms part of a study of the results from the newly constructed Blackstone SuperDARN radar which employs the antenna design developed by Ray Greenwald and colleagues. This is an improved version of the earlier Wallops design which has an antenna separation of 12.9m rather than the earlier 15.24m, due to site limitations. The aim was to characterise the antenna performance by means of a numerical model in order to understand the radar echoes now being measured.

Limitations of previous models

Previous antenna models, at least those in the UK, considered a single antenna and the associated reflectors behind the antenna and extending horizontally for a distance equal to the antenna separation. This antenna was then cloned to form the array of 16 antennas. Whilst this realisation provided a simplification in the construction of the model, it fails to take account of the fact that in the actual antenna the reflectors stretch the entire length of the array. This simplification was found to have a marked effect on the model results, particularly as the antenna separation is decreased.

Blackstone antenna array

The current model

This study is based on results from EZNEC and a rigorously correct geometric model of the Blackstone antenna with realistic ground conductivity. Results have been computed for the boresite direction i.e. for equal phase signals applied to each antenna. To allow the performance to be compared to earlier radars, results have also been calculated for this antenna but with the more usual antenna spacing of 15.24m, as well as for an array of SABRE log periodic antenna with the conventional antenna spacing of 15.24m. Note that the phasing for the Blackstone antenna with 12.9m antenna separation is the same as that for the other antenna arrays and represents the configuration of the Blackstone radar. Results have been calculated at 0.5 MHz intervals from 8.5 to 16 MHz.

CUTLASS Finland log-periodic array

From the 3-dimensional antenna patterns for each antenna and at each frequency, we have extracted the most important parameters and these are shown opposite. Results are those conventionally used for antenna patterns and represent one way paths, to obtain results for the complete radar system they should be considered for both receive and transmit.

Results

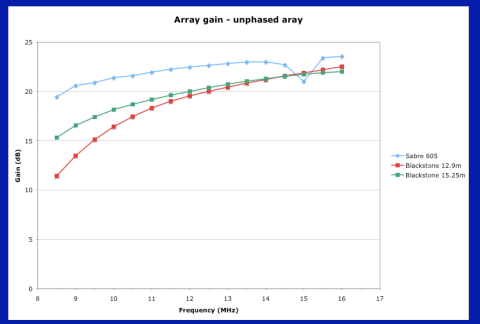
Comparison of Blackstone and SABRE antenna arrays:

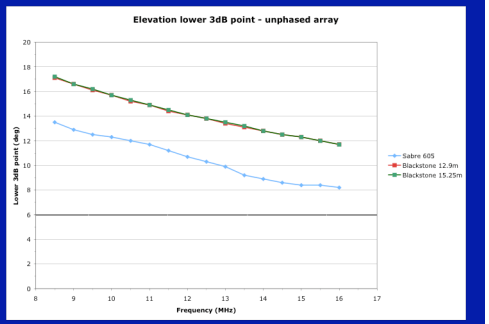
- The array of log periodic antennas has greater gain particularly at lower frequencies
- The elevation angle of the main beam is lower for the log periodic antennas - because they are physically higher
- The vertical beamwidth of the log periodic antennas is smaller as a consequence of the higher gain, but
- The lower 3dB point of the Blackstone array is only 4 degrees higher than that of the log periodic antenna array

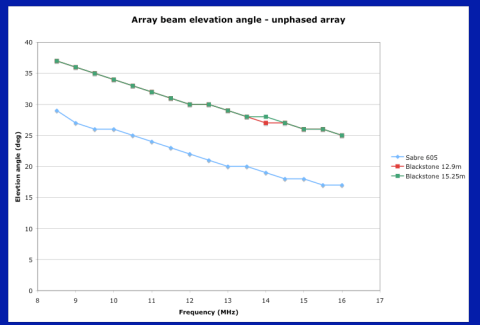
Comparison of Blackstone array with 12.9m and 15.24m antenna spacing:

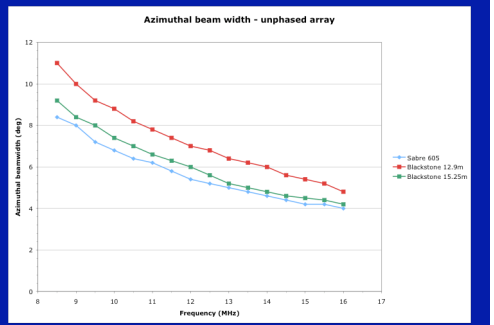
- Array gain is decreased at the smaller separation at frequencies below 12 MHz
- As would be expected the azimuthal beam width (and the beam separation) is increased by the smaller antenna spacing
- The azimuthal coverage is, however, increased from 50 to 60 degrees and the azimuthal sidelobes at higher frequencies significantly reduced by the smaller antenna separation.

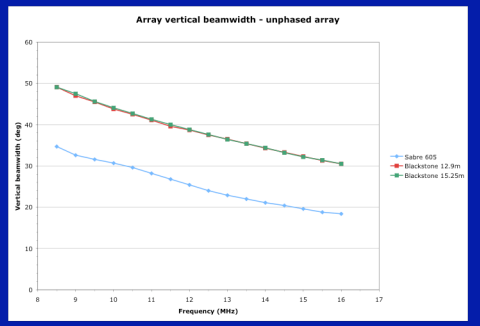
Overall, the performance of the Blackstone antenna array, at least according to the model results, is fairly similar to that of the SABRE array. The Blackstone antenna gain is slightly less, but the mainnlobe to largest sidelobe ratio is significantly improved.

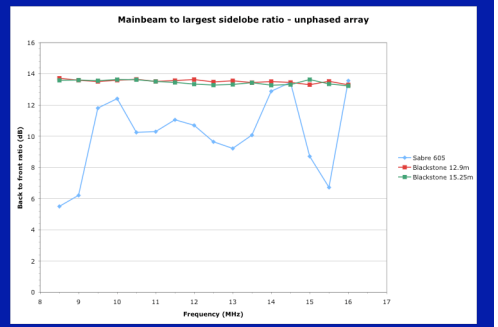












Concluding remarks

We should point out that the model does not take into account the efficiency of coupling the transmitters to the antenna and note that in general the VSWRs measured at the transmitter outputs at Blackstone are worse than those measured at the CUTLASS radars (same transmitters but with log periodic antennas). This might suggest more efficient coupling with the SABRE antennas which would not be accounted for in these results.

In addition, it should be noted that modelling the SABRE antenna is complex and the model described here does not include the inductive element of the three longest elements or the transmission line loading coil.