

Fig. 2 Pareto curve for three bit digital phase shifter design of array of 80 isotropic elements and responses for the two designs highlighted

As a second demonstration, we design a symmetric linear array of 80 isotropic elements with three bit phase shifters separated by one half wavelength. The Pareto curve for this problem, along with patterns of two of the Pareto optima, are shown in Fig. 2. The GA was run with a population of 1000 chromosomes, and a mutation rate varying between 2.5 and 10% for 100 generations.

Finally, the technique is demonstrated for the design of a  $16 \times 16$  element array of isotropic radiators with three bit phase shifters. The Pareto curve, as well as the maximum reduced sidelobe level design are shown in Fig. 3.

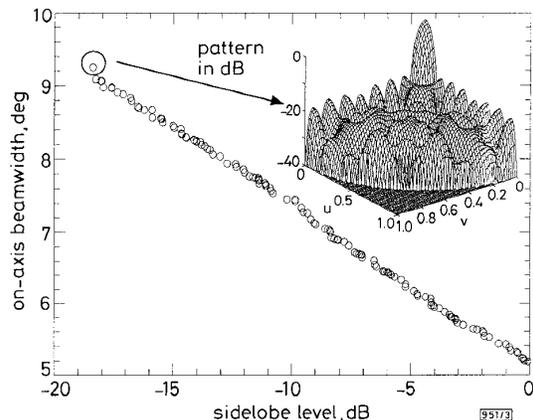


Fig. 3 Pareto curve for  $16 \times 16$  isotropic element array fed with digital phase shifters along with lowest sidelobe level design's response

**Conclusions:** Pareto genetic algorithms provide the designer with both thinned and digitally phase shifted antenna arrays, with many achievable tradeoffs between beamwidth and sidelobe levels. The algorithm used incorporates two changes to the simple genetic algorithm described in [3]: one which makes the GA amenable to Pareto optimisation, and another which incorporates problem specific knowledge into the coding. The algorithm is seen to be an improvement over the standard GA, as it always returns more information, and may even perform better on single objective optimisation problems. The algorithm can further be extended to more difficult array problems, such as those involving elements radiating in the presence of a complicated body.

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## References

- 1 SHIMIZU, M.: 'Determining the excitation coefficients of an array using genetic algorithms'. IEEE Antennas Propag. Soc. Int. Symp., Seattle, WA, 1994, (1), pp. 530-533
- 2 FLAAPT, R.L.: 'Thinned arrays using genetic algorithms', IEEE Trans. Antennas Propag., 1994, 42, (7), pp. 993-999
- 3 GOLDBERG, D.E.: 'Genetic algorithms in search, optimisation and machine learning' (Addison-Wesley, Reading, MA, 1989)
- 4 SRINIVAS, N., and DEB, K.: 'Multiobjective optimization using nondominated sorting in genetic algorithms', Evolutionary Computation, 1995, 2, (3), pp. 221-248
- 5 WEILE, D.S., MICHELSEN, E., and GOLDBERG, D.E.: 'Genetic algorithm design of Pareto optimal broad band microwave absorbers', IEEE Trans. Electromagnetic Compatibility, 1996, 38, (4)
- 6 HAUPT, R.L.: 'Speeding convergence of genetic algorithms for optimizing antenna arrays'. 12th Annual Review of Progress in Appl. Comput. Electromagnetics, 1996, Monterey, CA, pp. 742-749

## Sensitivity analysis of capacity enhancement with adaptive multibeam antennas for DCS1800

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Indexing terms: Adaptive antenna arrays, Time division multiple access, Mobile radio systems

The authors present results for the likely capacity improvement when an adaptive multibeam antenna is used in conjunction with air interface parameters, as with the DCS1800 system. An analysis is made of the possible capacity enhancement while taking into account parameters such as power control, radio channel characteristics and different frequency reuse patterns. The results show that a substantial capacity improvement can be achieved with adaptive antennas, and also highlight the sensitivity of the capacity to operational parameters.

**Introduction:** With the deployment of spatial signal processing at the cell sites of wireless networks, the available capacity and quality of service can be greatly enhanced [1-3]. This approach is usually referred to as space division multiple access (SDMA), and enables multiple users within the same cell to be accommodated on the same frequency and time slot. This Letter reports new results from a capacity sensitivity analysis performed for an adaptive multibeam antenna system.

**Simulation method:** Based on the techniques originally discussed in [4] and subsequently used for CDMA and adaptive antennas analysis in [1], a similar set of tools was employed in this analysis. For the uplink, the simulation generates a random deployment of uniformly distributed users and then steers the main beam towards the desired user. For each new user, the carrier-to-interference ratio (CIR) is calculated and compared with a predefined threshold value. If this value is exceeded, then the user is assigned to another channel, otherwise the user is accepted on the same channel (SDMA mode). This process stops when the number of available channels has been exceeded. Since a TDMA-FDMA system is considered here, this effectively happens when there is no other frequency carrier or time slot channel available. These calculations are repeated  $10^4$  times and then the probability density function and the outage probability of the number of co-channel users are calculated. The model includes the effects of: network topology; path loss models; log-normal shadowing; power control imperfections; different number of physical channels; radiation patterns; frequency reuse patterns. Initial parameters used for the simulations include: 9dB CIR threshold; a radiation pattern with  $\sim 30^\circ$  beamwidth,  $-14$ dB first sidelobe level and  $-60$ dB maximum null depth; frequency reuse pattern 3; single slope pathloss model with exponent 4; eight handover channels, unless otherwise stated.