Array pattern nulling by element position perturbations using a genetic algorithm

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Indexing terms: Antenna arrays, Antenna phased arrays, Genetic algorithms

A genetic algorithm has been used for null steering in phased and adaptive arrays. It has been shown that it is possible to steer the array nulls precisely to the required interference directions and to achieve any prescribed null depths. A comparison with the results obtained from the analytic solution shows the advatages of using the genetic algorithm for null steering in linear array patterns.

Introduction: Null steering in adaptive arrays can be achieved by element position perturbations [1–3]. This technique is based on the assumption of relatively small element position perturbations so that an analytic solution can be formulated. Results were given for displacements of the elements both along, and normal to, the axis of the array. In this Letter, we report the use of a genetic algorithm [4] in the realisation of adaptive nulling by element position perturbations. The use of a genetic algorithm removes the restrictions imposed on the array element displacements in order to obtain the linear analytic solution. The results presented show that it is possible to steer the array nulls precisely to the required interference directions and to achieve prescribed null depths.

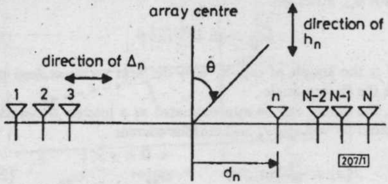

Fig. 1 *Linear array geometry*

Null steering by element position perturbations (the analytic solution): The derivation of the required element position perturbations starts from the array factor of a linear array of N equispaced elements, which is given by

$$F_0(u) = \sum_{n=1}^{N} a_n e^{jd_n(u-u_s)} \tag{1}$$

where d_n is the distance from the array centre to element n, $u = k \sin\theta$ where $k = 2\pi/\lambda$ is the wave number, and θ is the angle measbols X and Y. $gx_i = 0$ (respectively, $gy_i = 0$) if the the generator of X (Y) has no connection with the encoder register at level i; $gx_i = 1$ ($gy_i = 1$) otherwise. In practice, we have $gx_0 = gx_\nu = gy_0 = gy_\nu = 1$. If the decoder is in the in-sync state and if X_{k+1} and Y_{k+1} are not erroneous, the parity relation to be verified between S_k, X_{k+1} and Y_{k+1} for a hard decision, is

$$PS_k = X_{k+1} \oplus Y_{k+1} \oplus \sum_{i=4}^{\nu-1}(gx_i \oplus gy_i)S_{\nu-i,k} = 0 \quad (1)$$

where $\oplus$ represents the sum modulo 2 and PS_k is the pseudo-syndrome at time k. Unlike the syndrome, calculating the pseudo-syndrome involves running the decoder. In the in-sync condition and in the presence of noise, PS_k may be equal to 1 if X_{k+1} or Y_{k+1} is erroneous or if S_k is not the maximum likelihood state. Because analysis of the latter case is not straightforward, the probability for $PS_k = 1$, lower than 0.5, will be determined by a Monte Carlo simulation. In the out-of-sync condition, because X_{k+1} and Y_{k+1} have not been used by the decoder to establish S_k, the probability of having $PS_k = 1$ is exactly 0.5. So discrimination between in-sync and out-of-sync conditions will be possible above a certain signal to noise ratio, which will be given by simulation.

Of course, the pseudo-syndrome can only be calculated if the couple (X_{k+1}, Y_{k+1}) is available, that is to say for a punctured code of rate $(n-1)/n$, every $n-1$ periods. Therefore the synchronisation time will be proportional to $n-1$.

The pseudo-syndrome calculation assumes that the maximum likelihood state is known, which requires some more or less complex circuitry, depending on the number of states in the decoder. In most Viterbi decoders, processing codes with various rates, this circuit is already available. In particular, with turbo codes [4,5], the number of states is low (8 or 16), and the circuit for searching for the maximum likelihood path or state is not cumbersome.

Supervision principle:

(i) if X_{k+1} and Y_{k+1} are available at the decoder input, increment a counter C of periodicity L

(ii) if C is incremented and if the pseudo-syndrome has value 1, increment a second counter CS

(iii) when counter C reaches 0 (mod L), compare the content NS of CS with threshold $Th < L/2$; if $NS < Th$, the decoder is assumed to be in the in-sync state; reset C and CS.

The choice of L and Th answers to a tradeoff between synchronisation time, false synchronisation and false alarm probabilities.

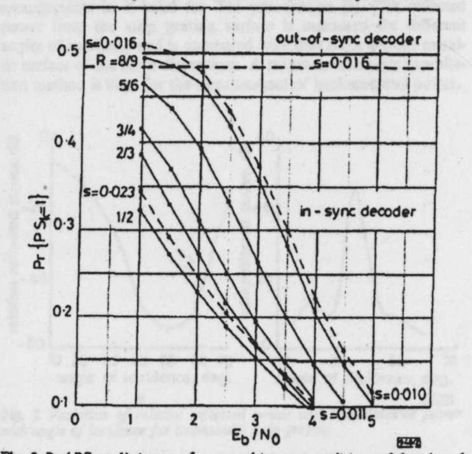

Fig. 2 *Pr {$PS_k = 1$} in out-of-sync and in-sync conditions of decoder of $K = 7$ (133, 171) code for rates $R = 1/2$, 2/3, 3/4, 5/6 and 8/9*

Quantisation of 4 bits
——— mean value
- - - - mean value minus (out-of-sync) or plus (in-sync, $R = 1/2$ and 8/9) standard deviation s for $L = 1024$

Pseudo-syndrome method applied to K = 7 (polynomials 133, 171) encoder/decoder: PS_k is calculated as $X_{k+1} \oplus Y_{k+1} \oplus S_{3,k} \oplus S_{1,k}$. Fig. 2 shows the probability of having PS_k equal to 1, as a function of the signal to noise ratio E_b/N_0, for rates R = 1/2, 2/3, 3/4, 5/6 and 8/9. In the out-of-sync situation, Pr $\{PS_k = 1\} = 0.5$; the dashed line represents the probability minus the standard deviation s of the measure when L is 1024, for a large number of measures. In the in-sync case, the dashed line, for the extreme rates, represents probability plus standard deviation. From these curves, we can see that very reliable discrimination may be achieved at low E_b/N_0. Moreover, it happens that the gaps between these curves are close to the gaps between the curves yielding the binary error rate (BER). This means it is quite possible to adopt the same threshold for all coding rates, corresponding roughly to the same BER.

Conclusion: A very simple supervision/synchronisation method has been proposed for Viterbi decoders which already possess the ability to search for the maximum likelihood path or state. This method, based on the calculation of the so-called pseudo-syndrome, offers very reliable discrimination between in-sync and out-of-sync cases. The associated circuit and its parameters can be independent of the coding rate. It has been implemented successfully in the first turbo encoder/decoder [6] for supervision needs.

Acknowledgments: The authors thank A. Glavieux for his relevant remarks on the presentation of this Letter, and COMATLAS for their support.

27 April 1994
Electronics Letters Online No: 19940737

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