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(54) Beam steering.

(57) Apparatus for steering the beam from an antenna element array (1) includes two feedback loops (4,5) for analysing respectively a first signal representative of the total output of the array, which includes noise and unwanted information and a second signal representative of the wanted information. The two signals are used by a computer (6) to adjust each element step-wise until a desired ratio between the signals is maximised and hence the beam is steered to a desired position.

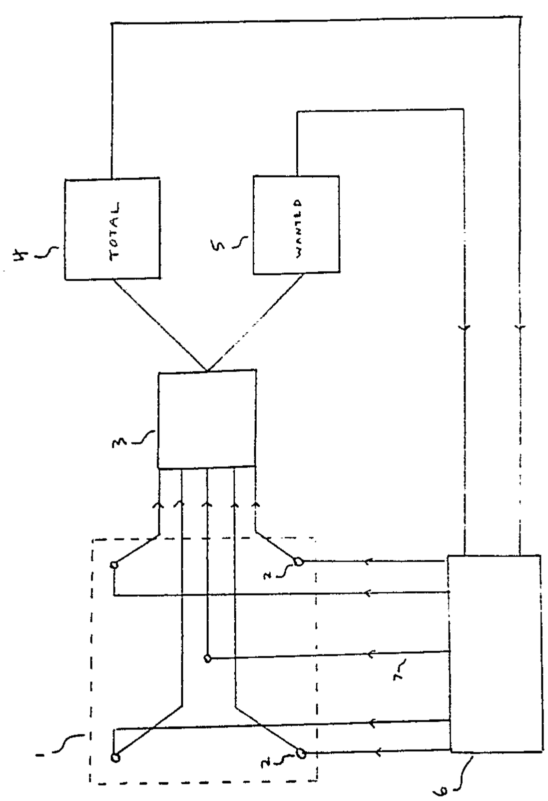

FIG 1

EP 0 305 099 A2

Beam Steering

This invention relates to beam steering, and in particular it relates to apparatus for steering the beam of electromagnetic radiation associated with an array of antenna elements.

It is of course well known that the combined output from an array of antenna elements generally has a lobed structure with the output greater in some directions than others. It is useful to be able to control the exact nature of this structure; either to rotate the beam for directionality or to maximise the reception or transmission in some directions and minimise it from other directions where unwanted signals may occur or in which direction signals are not to be transmitted. Several methods are available to achieve such beam steering although all are heavily processing intensive. One such method involves knowing in advance the precise gains and phase shifts that must be applied to the signals associated with each element within the array to achieve any particular beam configuration and direction. When a chosen configuration is desired, signals with the appropriate amplitudes and phases are then automatically fed to all the elements within the array to achieve that desired radiation pattern. As will be appreciated, many different combinations are possible even with a relatively small array and hence the apparatus requires a large and costly processing and/or memory capability. There is also a degree of inflexibility associated with such a system.

Perturbation methods also exist in which a desired result is achieved basically by a trial and error process by sequentially altering the gain and phase of the signals from each array element until the desired beam configuration is achieved. Although this method would seem to take a long time to achieve any desired beam direction, in fact it is not significantly slower than in the previously described method since the speed of response depends mainly upon the processing speed, i.e. the data rate of the processing computer. Inevitably, a feed-back loop is required in such an arrangement although all systems up to now have only required the use of one feedback loop.

The present invention represents an improved apparatus for achieving such a perturbation method which is more flexible in terms of achieving any particular desired result.

According to the present invention there is provided apparatus for steering the beam from an array of antenna elements, comprising: a first and a second feedback loop including respective means for obtaining a first signal representative of a first chosen parameter of the total output of the array and a second signal representative of a second chosen parameter of the total output of the array; and processing means for increasing or decreasing the output of each element in turn by discrete steps, the first and second signals being used as inputs to the processing means which is adapted to alter the outputs of each element in a way that maximises a chosen relationship between the first and second signals.

Preferably, the first signal is representative of the total output, including any noise or unwanted information, from the entire antenna array, and the second signal is representative of the useful or wanted information which has been extracted from the outputs of the array.

The chosen relationship may be the ratio between the wanted and unwanted signals.

The apparatus may further include means for varying the step size used for increasing or decreasing the output of each element in accordance with the past history of the process; such that if, for instance, the ratio between the wanted and unwanted signals is poor then large steps can be used to more quickly reach an optimum but coarsely defined relationship and if the ratio of the wanted to unwanted signals is good, i.e. in most instances is high, then smaller steps can be used to finely adjust and maximise the relationship.

In a preferred embodiment the steps may range from 1/8 to 1/256 of the total available control output of each element.

The apparatus may be adapted to operate on one particular element in turn until the chosen relationship is maximised for that element and then proceed to adjust a second element, until all elements have been adjusted and the relationship is maximised. Various elements can be used as reference elements if desired, in a manner which will become clear.

The apparatus may include means for applying weightings to the wanted and unwanted signals to reflect the relative importance of each of these at any stage. These weightings may adaptively change as the relative importance varies throughout the use of a system. This means that although at some point during the processing it might be desirable to maximise the signal to noise ratio, at other times it may be desirable merely to minimise the unwanted signal without worrying too much about the signal to noise ratio, i.e. without being concerned about useful information being obtained. The criteria affecting these choices can of course vary throughout the use of a system and hence the control perameters may be adaptively altered. The control parameters may, for example, be phase or amplitude values.

The use of the apparatus with a given antenna array may be schematically described as follows: firstly a start condition is set in which for example the output of one element may be set at its maximum and the output of all other elements set at their minimum. The output signals from the array are then fed via the two feedback loops to the processing means which adjust the output of the elements in firstly coarse and then in fine steps to attempt to find an acceptable solution to any given problem. If no acceptable solution can be found, perhaps because the start condition was wrong, then the start condition can be changed, perhaps by setting a different element as the 'reference' or fully on element and setting all other elements to zero. The feedback process is then repeated until an acceptable solution is found. Note that the reference element need not be held at maximum during the adjustment process. Generally, an acceptable value for the ratio of wanted to total signal will be 25dB although of course this will vary depending upon the circumstances. Weightings can be applied to the wanted and total signals, as described above, to reflect the relative importance of each of these.

An embodiment of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 shows schematically a control arrangement according to the present invention, and

Figure 2 shows some initial start conditions for the antenna array.

Referring to Figure 1 there is shown an antenna array 1 which is shown, by way of example only, as having five regularly spaced elements 2. The spacing and number of these elements may of course vary depending upon the particular application. Outputs are taken from each of the antenna elements 2 to a first processing unit 3. This analyses the output signals and produces two respective outputs, the first of which is representative of the total output of the array, and hence includes unwanted signals and noise as well as the useful data. This signal is output to a unit which may be called the total signal analyser 4. A second signal from unit 3 which is representative only of the useful or wanted data is fed to a wanted data analyser 5. Outputs from the total and wanted analysers, 4 and 5 respectively are fed to a second or main processing unit 6, which will generally be a computer. This computer 6 is used to control the signals applied to the antenna elements over control lines 7.

The use of the apparatus will now be described.

Firstly, an initial start condition is set on the array. This may be for instance the condition shown in Figure 2A where the output of the central element is set at its maximum value 1 and the outputs of all other elements are set at 0. Initial weightings are also given at this stage to the wanted and total signals, where the terms wanted and total are as hereinbefore described. These ratings will depend upon whether it is merely the ratio between the wanted and total signals that is to be maximised for the particular application or whether some other application is desired, such as to reduce totally the output from, or sensitivity of, the array in a given direction to suppress the effect of deliberate signal jamming from that direction for instance, in which case in that direction the total or unwanted signal is to be minimised and the level of the actual wanted signal is unimportant. The weightings given to the two signals will reflect this and thus may perhaps be termed 'relative importance values'.

Having set the desired condition in processing computer 6 and decided what the final beam is to look like, the total output signal from the array is analysed in unit 3 which functions, in known manner, to produce a signal representative of the total signal to unit 4 and of the total wanted or desirable signal to unit 5. These units then analyse the data received and output may be taken from them to further processing units (not shown) if required. Outputs from units 4 and 5 are used as feedback loops into the computer 6 which applies the previously determined weightings to the respective outputs and then compares them. If a desired ratio is not adequate then the unit serves to change the gain and phase of the signal applied to one of the array elements step wise, initially with steps of the largest step size, which in this embodiment is 1/8 of the total output of that element. Some form of attenuator network may be used to alter gain and phase, such an PIN diode attenuators. After an element, which may be for example element 8 in Figure 2A has been adjusted once by one discrete step then naturally the total array output will change. This is analysed by units 3, 4 and 5 and the resulting ratio is measured in computer 6 which determines whether or not the ratio has been improved by altering the output of the one particular array element. By measuring the change in ratio after each stepwise alteration in an array element control line 7, it is seen that the total output of the array will gradually be shifted towards that which gives the desired result or beam configuration. After the output of one element has been adjusted through its entire usable range then this element will be held at its value which maximises the ratio and a second element will begin to be varied. Alternatively, after the first element has been adjusted by one step a second element may be adjusted by one step and so on. In either case after all the elements have been varied to maximise the ratio it is seen that the desired result is likely to be achieved.

The elements are initially adjusted in coarse steps in order that the system may rapidly be brought to a state as close as possible to the desired one. As it approaches the desired beam configuration then smaller steps may be used to finely tune the system. The exact size of these steps and the time when the steps are reduced will be determined by the processing computer 6 dependent upon the past history of the system. Factors such as the number of previous attempts to reach a desired state, the particular element being varied, and whether or not the ratio of the wanted to unwanted ratio is low or high (i.e. poor or good) will all be used to determine the exact step size at any instant. The smallest step size envisaged in the present embodiment is 1/256 of the total output of any element, although of course this will vary depending upon the particular application.

There may however be circumstances in which given the initial start conditions set up in the array, the ratio of the unwanted to wanted signals will never be adequately maximised for any chosen desired application. A typical criterion for this is that the wanted to unwanted signal ratio should be better than 25dB. If this is not achieved after step-wise varying of the array elements then a second start condition may be selected, for instance that in Figure 2b where it is seen that a different element to that of Figure 2a is set at its maximum output and all other elements are set at their minimum output as the start condition. This start condition could automatically be selected if a chosen number of attempts have been made to maximise the wanted to unwanted ratio without success. The method described above is then repeated from this new start condition. Any other desired start condition may of course be applied if the second one is not successful.

Claims

1. Apparatus for steering the beam from an array of antenna elements (1), characterised by; a first and a second feedback loop including respective means (4,5) for obtaining, a first signal representative of a first chosen parameter of the total output of the array and a second signal representative of a second chosen parameter of the total output of the array; and processing means (6) for increasing or decreasing the output of each element in turn by discrete steps, the first and second signals being used as inputs to the processing means which is adapted to alter the outputs of each element in a way that maximises a chosen relationship between the first and second signals.

2. Apparatus as claimed in claim 1 wherein the first signal is representative of the total output from the entire antenna array and the second signal is representative of the useful or wanted information which has been extracted from the outputs of the array.

3. Apparatus as claimed in claim 1 or claim 2 wherein the chosen relationship in the ratio between the second and first signals.

4. Apparatus as claimed in any of the preceding claims, including means for varying the step size in accordance with the past history of the process.

5. Apparatus as claimed in claim 4 wherein the step size is variable between 1/8 to 1/256 of the total available control output of each element.

6. Apparatus as claimed in any of the preceding claims further including means for applying weightings to the first and second signals to reflect the relative importance of the signals.

7. Apparatus as claimed in claim 6 wherein the weighting means are arranged to adaptively alter the weightings to reflect any variation of the relative importance of the signals with time.

8. An antenna system, including beam steering apparatus as claimed in any one of the preceding claims.

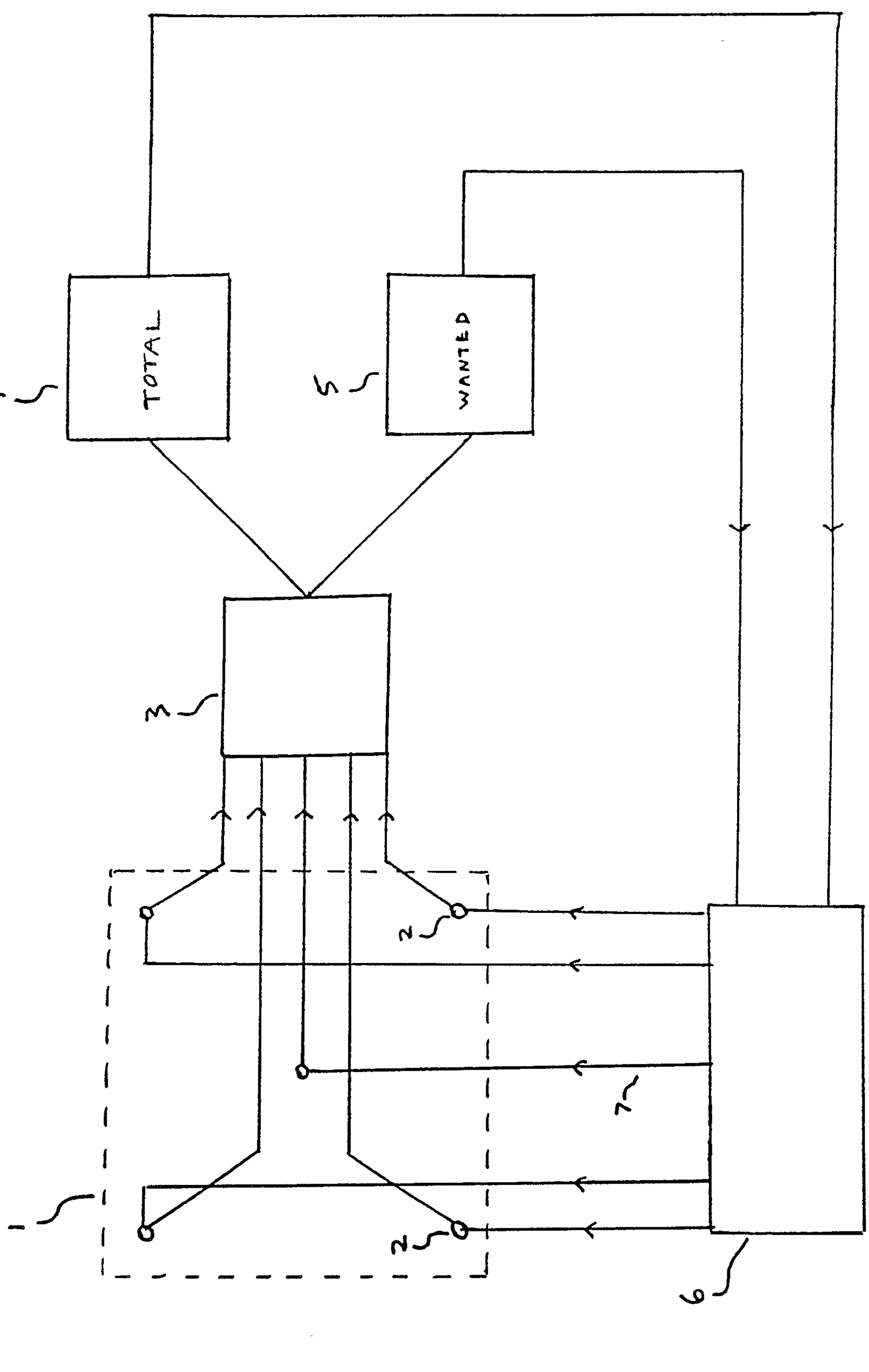

FIG 1

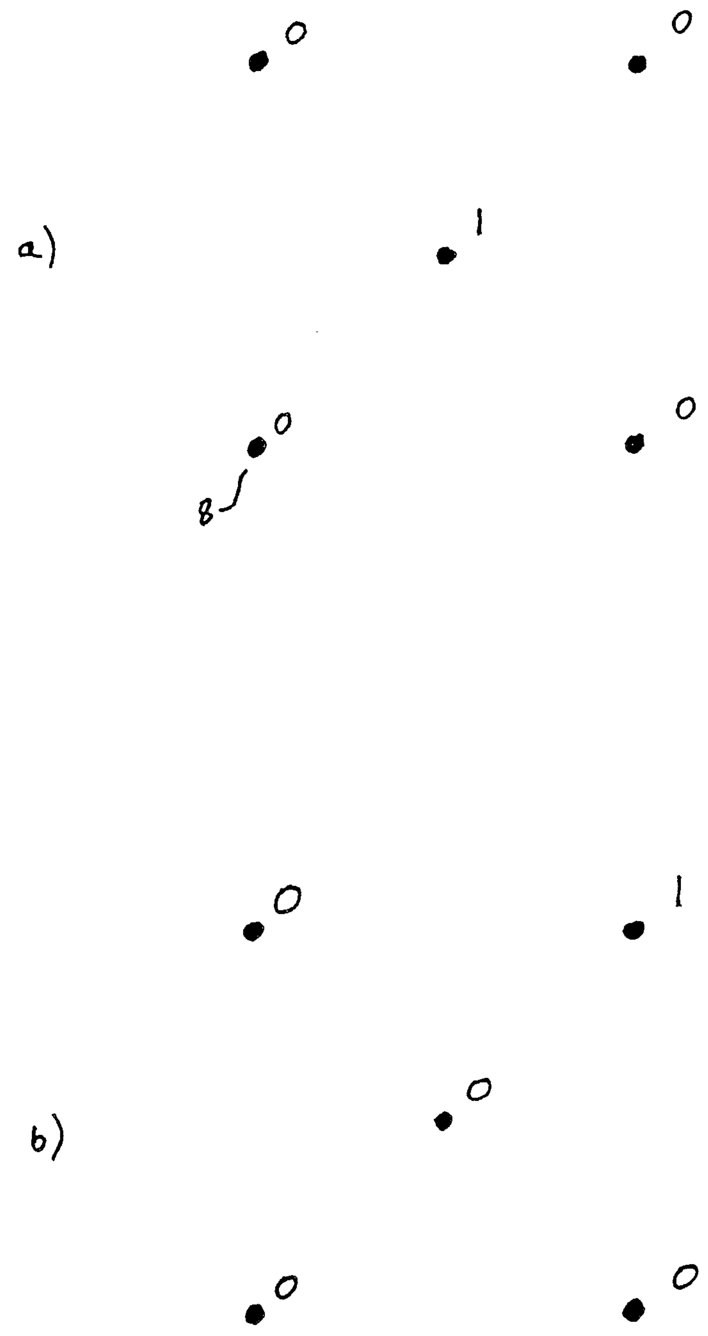

FIG 2