

The present invention relates to a method and a device for on-line test, that is to say test while operating, of an antenna consisting of a plurality of radiating sources.

5 A particular field of application of the invention relates to monopulse-type secondary radar antennae, making it possible to radiate into space the pulses produced by an IFF (Identification Friend or Foe) interrogator, and to pick up the possible responses from
10 interrogated aeroplanes. Such antennae consist of a plurality of radiating elements, called columns. It is very difficult, on site, to identify whether one or more of these columns is unserviceable, and, in the event of a loss of performance of the antenna, the column or
15 columns which are the cause thereof cannot be located precisely.

 A known practical method of locating unserviceable columns consists in placing a detector successively in front of each column in order to verify whether their
20 radiation really is that expected. The drawback of such a method lies in the interaction of the radiation patterns of the columns adjacent to the column tested, which makes the measurements taken imprecise. Moreover, this method requires the temporary stopping of the antenna in
25 its functions of interrogation and of reception of responses from aeroplanes.

 There also exist various methods working directly on the radiation pattern of the antenna and based on the following principles:

- 30 - the mean level of the side lobes may make it possible to detect an unserviceability. In fact, this method is discarded as it does not make it possible to extract reliable information concerning the end columns for which the variations in the mean level on the side lobes are
35 too slight;
- the characteristic function of the alignment of the dipoles cancels out as many times as there are radiating elements in the alignment. Observation of the number of zeros should therefore allow failures to be detected.

However, this is an unreliable method in the sense that, in practice, reflections on obstacles may cause zeros to disappear;

- the radiation pattern of an antenna is deduced from the Fourier Transform of the illumination from this antenna. By calculating the inverse Fourier Transform, it should thus be possible to reconstitute the appearance of the illumination from the antenna, and thus to detect holes at the site of the unserviceable columns. In fact, this method cannot be exploited as it is not possible to recover the essential information of the signal, namely its phase.

The inverse Fourier Transform is used, for example, in the document IEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, Vol. 36, No. 6, June 1988, pages 884-889, New York, US, J. J. LEE et al.: "Near-Field Probe Used as a Diagnostic Tool to Locate Defective Elements in an Array Antenna."

The object of the invention is to overcome the preceding drawbacks by proposing a method and a device for on-site test of the operation of a multi-source antenna which make it possible precisely to locate the radiating source or sources which are unserviceable, without the prime function of this antenna being disturbed.

Although the description of the method and of the device according to the invention is given in the context of the application to a secondary radar antenna, it is important at the outset to note that the invention is not limited to this specific application, as we will see in what follows.

More precisely the subject of the invention is a method for on-site test of an antenna including a plurality of radiating sources, characterized in that it consists in:

- compiling a library of radiation patterns of the antenna on the one hand, when all the radiating sources are operating normally and, on the other hand, when at least one of the said sources is deliberately made

unserviceable;

- plotting the radiation pattern of the antenna when it is operating on site;

- calculating the coefficient of correlation of the said radiation pattern with each of the radiation patterns contained in the said library;

- calculating the maximum value of the coefficient of correlation, so as to detect a possible failure of one or more of the said radiating sources.

10 The invention also relates to a device for on-site test of an antenna consisting of a plurality of radiating sources, characterized in that it includes:

- first means for measurement and memory storage in a library of the radiation patterns of the antenna on the one hand, when all the radiating sources are operating, and, on the other hand, when at least one of the said sources is deliberately made unserviceable;

- second means for measuring the radiation pattern of the antenna when it is operating on site;

- means of calculating the coefficient of correlation of the radiation pattern of the antenna and of each pattern contained in the said library;

- means of calculating the maximum value of the coefficient of correlation in order to detect a possible failure.

25 The test device and method will be better understood during the description which follows, relating to the following figures:

- Figure 1 is a representation of the front face of a secondary-radar antenna;

- Figure 2 is a representation of the rear face of this same antenna;

- Figure 3 represents the three radiation patterns of the preceding antenna;

- Figure 4 is a block structure representative of the steps to be carried out for the test according to the invention.

Figures 1 and 2 respectively represent the front face and the rear face of a monopulse-type secondary

radar antenna. This antenna includes a beam 1 on which radiating columns (2, 3) are fixed, numbering thirty-six for example, the thirty-five columns 2 being placed to the front of the antenna, and the column 3 being placed to the rear. Radiation can be obtained, for example, by a plurality of radiating dipoles placed on each column. The antenna is intended, on the one hand, to radiate into space the signals derived by an interrogator (not represented) and, on the other hand, to pick up the responses emanating from transponders mounted on aeroplanes. To this end, it possesses three radiation patterns shown diagrammatically in Figure 3, which are obtained by different distributions of the energy, in amplitude and in phase, among the thirty-six radiating columns. The antenna first of all radiates a pattern (Σ), 3 exhibiting a directional main lobe 4 surrounded by side lobes 5, by virtue of which it sends out a pair of interrogation pulses. In order to avoid a transponder on board a nearby aircraft responding to the pulses sent out by the side lobes 5, a third pulse interposed on the preceding ones is sent out according to the quasi-omnidirectional radiation pattern (Ω) 6, which completely covers the side lobes 5. Thus, only the aeroplanes situated in the area of coverage of the main lobe 4 are caused to respond to the interrogations from the antenna. The latter diagram 7, or (Δ) diagram, makes it possible to refine the position of the aeroplane which sends out a response.

Figure 4 explains the various steps of the method according to the invention.

A first step, referenced 11, consists in memory-storage, in a library, of the three patterns Σ_i , Ω_i and Δ_i , measured, for example, at the site of the antenna (i representing the column index) in the particular configuration in which column i is deliberately made unserviceable. Index 0 corresponds to the case in which no column is unserviceable.

The necessity of using the triplet (Σ , Δ , Ω) of the radiation patterns is justified by the fact that a single pattern is insufficient for exact location of an

unserviceable column. In effect, the energy applied to the input of the (Σ) channel of the antenna is distributed among the thirty-five front columns with the same phase and amplitudes decreasing from the centre of the antenna towards the ends. Thus, the (Σ) pattern makes it possible to detect only the unserviceabilities of the columns close to the centre of the antenna, with ambiguity, moreover, as to the relative position of these columns with respect to this centre. For the radiation pattern (Δ), the seventeen columns situated to the left of the central column are fed in phase opposition with respect to the seventeen columns situated to the right. This makes it possible to remove the above ambiguity. Moreover, the amplitude distribution of the Δ pattern makes it possible more specifically to deal with the columns placed on either side of the centre of each half of the antenna. Finally, the (Ω) pattern, for which only the rear central column is fed in phase opposition with respect to the other thirty-five columns, makes it possible to detect the unserviceability of this rear column.

The second step of the method according to the invention, referenced 22, consists in measuring, on site at predetermined times, the three radiation patterns Σ , Ω , Δ of the antenna while it is operating in IFF interrogation.

The third step, denoted 44, is the calculation of the coefficient of correlation for each pair of signals (E_1 , Σ), (Δ_1 , Δ), (Ω_1 , Ω), knowing that this coefficient of correlation for a pair of signals ($x_1(t)$, ($x(t)$) is given by the relation:

$$\rho_{x_1} = \frac{x_1(t) x(t)}{\sqrt{x_1^2(t) \cdot x^2(t)}}$$

This coefficient ρ_{x_1} makes it possible to evaluate the resemblance in the two signals $x(t)$ and $x_1(t)$, knowing that the maximum resemblance theoretically

achieved for $\rho_{x_i} = 1$, and the total decorrelation for $\rho_{x_i} = 0$.

Steps 44 and 55 thus allow detection of the unserviceable column i . More precisely, step 44 makes it possible to calculate the maximum values of the coefficients ρ_{Σ_i} , ρ_{Δ_i} and ρ_{Ω_i} , these values not necessarily being 1 in practice as the resemblance is never perfect. The column i identified as probably unserviceable by step 55 corresponds to the highest coefficient of correlation. In the case in which several columns are unserviceable, the operation is repeated from step 33 so as to examine all of the columns. Instead of proceeding by iteration, it would be equally possible to design a larger library than the preceding one, containing unserviceability configurations over more than one column.

The invention also proposes a device for implementing the method as previously described.

Steps 11 and 22 of the method are on-site plots of radiation patterns. To be done [sic], a ground beacon placed within the optical range of the radar (typically between 1 km and 50 km) is used, this beacon operating like an aeroplane transponder, with the difference that it responds to all the interrogations sent out by the antenna. The plot of the three (Σ), (Δ) and (Ω) patterns is done by measuring the peak amplitudes of the three pulses constituting the response from the beacon. This plot is done over several antenna revolutions, which makes it possible to obtain very precise radiation patterns. The idea is based on the fact that the position of the antenna is generally known, by virtue of an optical coder, for example, comprising n bits, and the resolution of which is $360^\circ/2^n$. It is possible to obtain very precise radiation patterns by plotting the peak amplitudes of the responses of the beacon for a position of the antenna varying from 0° to 360° by a pitch which approaches as close as possible to the resolution of the coder. To obtain all the points, it is necessary to take measurements over several antenna revolutions. However, this does not represent a constraint, as the antenna

continues to carry out its function of IFF interrogator.

Thus this device makes it possible very precisely to measure, on the one hand, the triplets (Σ_1 , Δ_1 , Ω_1) which it is subsequently necessary to store in a library and, on the other hand, the triplet (Σ , Δ , Ω) for the purpose of detecting one or more possible unserviceabilities. The remainder of the test device can be represented by any means making it possible to calculate the three coefficients of correlation ρ_{Σ_1} , ρ_{Δ_1} and ρ_{Ω_1} , to search for their maximum, and thus to determine the column probably unserviceable.

As we have already pointed out above, the invention is absolutely not limited to monopulse-type secondary radar antennae, and can be extended to all cases of antennae possessing at least two radiating sources.

Moreover, the library can also be compiled by simple mathematical calculation.

CLAIMS

1. Method for on-site test of an antenna including a plurality of radiating sources, characterized in that it consists in:
 - 5 - compiling a library of radiation patterns of the antenna on the one hand, when all the radiating sources are operating normally and, on the other hand, when at least one of the said sources is deliberately made unserviceable (11);
 - 10 - plotting the radiation pattern of the antenna when it is operating on site (22);
 - calculating the coefficient of correlation of the said radiation pattern with each of the radiation patterns contained in the said library (33);
 - 15 - calculating the maximum value of the coefficient of correlation (44), so as to detect a possible failure of one or more of the said radiating sources (55).
2. Test method according to Claim 1, characterized in that the library includes the radiation patterns of
20 the antenna when each of the radiating sources is made unserviceable in turn.
3. Test method according to one of the preceding claims, characterized in that the radiation patterns contained in the said library are plotted on site.
- 25 4. Test method according to any one of the preceding claims, characterized in that the said antenna is a monopulse-type secondary radar antenna, and in that its operation is represented by a triplet of radiation patterns.
- 30 5. Test method according to Claim 4, characterized in that the said triplet consists of a sum (Σ) pattern, of a difference (Δ) pattern and of a quasi-omnidirectional (Ω) pattern.
- 35 6. Test method according to any one of Claims 4 and 5, characterized in that the calculation of the coefficient of the correlation is done for each radiation pattern constituting the said triplet.
7. Device for on-site test of an antenna consisting of a plurality of radiating sources, characterized



in that it includes:

- first means for measurement and memory storage in a library of the radiation patterns of the antenna on the one hand, when all the radiating sources are operating, and, on the other hand, when at least one of the said sources is deliberately made unserviceable;
- second means for measuring the radiation pattern of the antenna when it is operating on site;
- means of calculating the coefficient of correlation of the radiation pattern of the antenna and of each pattern contained in the said library;
- means of calculating the maximum value of the coefficient of correlation in order to detect a possible failure.

8. Test device according to Claim 7, characterized in that the said first means perform the radiation pattern measurements on site.

9. Test device according to any one of Claims 7 or 8, characterized in that the said antenna is a monopulse-type secondary radar antenna and in that the said means for on-site measurement of the radiation patterns consist of a ground beacon placed within the optical range of the radar, and responding to all the interrogations from the antenna, and of means for measuring the peak amplitude of the responses from the said beacon over several antenna revolutions.

