

Detection of aeronautical frequencies jamming

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ABSTRACT

DTI uses, for 5 years now, an aircraft specifically equipped for detection and localization of jamming and disturbances affecting the aeronautical frequencies.

This equipment has shown, on several occasions, its effectiveness against these phenomena affecting, sometimes in a critical way, air traffic safety and regularity.

The aircraft and its equipment exploitation are an integral part of the DGAC policy. The aim is to reduce the impact of frequencies jamming. The presentation following will explain the stakes, the material used, the characteristics and the operational and technical constraints of a search for jamming carried out on board an aircraft. Several examples of solved cases will illustrate the description of this activity.

CONTEXT

Since 1997, the struggle against frequencies jamming has been taken more seriously and more actively. This is a result of the important impact that this phenomena can have on the air traffic safety and on the regularity and quality of services due to air users.

15 years ago these frequencies disturbances were considered in a passive way, as a fatality. Today the approach is totally different, getting more aggressive. Different working groups and the experience of a great number of solved problems have led us to establish an organization with a high reactivity and a high technical level.

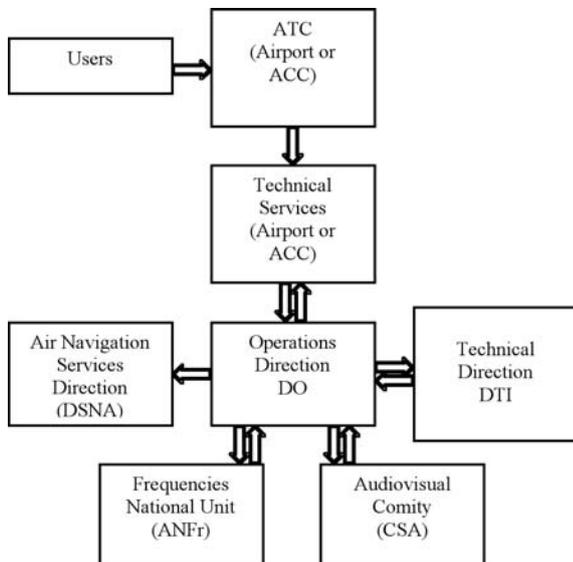


Figure 1 : Services taking part in the struggle against frequencies jamming

Figure 1 schematically describes this organization.

In most of the situations, air users and Air Traffic Controllers are the first ones to notice.

For many years ATC have been made sensitive to the different aspects of these problems through different actions, initial training at school, professional training, specialized internal publications, working groups. When such a disturbance occurs, they rapidly inform the technical services. Depending on the situation, of the human resources, the local technical service will be able or not to solve the problem.

It's important to notice that most of the local technical services or maintenances are equipped for detection and localization of jammings (receivers, antenna, specific software,...).

At the same time, specific training was organized at ENAC (Civil Aviation National School in charge of the training of all the employees of civil aviation, engineers, ATC, technicians) for both students and professionals to present the basics of the detection of jammings.

In France, many actors contribute to an efficient struggle against frequency jamming.

In the core of the organization, is the DO (Operations Direction). They centralize and coordinate the different actions. Especially the DO will classify the cases, set priorities and decide any air operation.

DSNA (Direction of the Services of Air Navigation, French Operator for Air Navigation) will intervene on a regulation and juridical scope. Important efforts have been made to create a legal ground for the different interventions and from now, DGAC systematically ask for lawyers' advice to instigate legal proceedings against jammers.

DTI (Technical Direction, French Technical Operator for DSNA) brings assistance and a technical expertise function of the seriousness of the problem.

DTI has different ways to solve the most delicate and tricky cases:

- For a couple of month, DTI has acquired a car and a trailer specifically equipped for detection of jamming and localization. They have been equipped with a wide band direction finder and a synthesized receiver.



The two systems are regularly used on sites (airports for example) by local maintenance or DTI operators.

- As specific aircraft.

When the jamming source is identified, the DO systematically lodge at ANFr (Frequencies National Unit). ANFr is the body in France in charge of the spectrum regulation. Only their agents can deal with the owner of the station. If necessary they can ask for police assistance.

Interventions of the Civil Aviation are only detection and localization ; the solving of the problem will need other bodies.

Aircraft of the DTI is a part of the organization. The equipment definition of the aircraft has been designed as part of this scope.

Now we will describe the equipment of our specific aircraft for detection and localization of jammings and the associated operating modes.

AIRCRAFT EQUIPMENT

The Beech 90 F-ASFA is dedicated to detect and localize jammings and disturbances affecting the aeronautical frequencies.

In this aircraft is, in particular, implemented a VHF and UHF direction finder for localization.

The architecture of the interference search bench is based on this DF and on a measurement receiver.

We will describe these two systems :



Figure 2 : F-ASFA : « JAMMING ZERO ONE »

The MDF-124F and its installation on the aircraft

The MDF-124 direction finder was, of course, not initially designed to search for interference. Its main function was to find SAR emergency beacons. The first version of the MDF only gave access to the classical SAR frequencies of 121.5MHz, 243MHz and the COSPAS/SARSAT frequency of 406MHz. The addition of a frequency synthesizer in later versions enabled other frequencies to be envisaged between 108MHz and 406MHz. The main reason to use the MDF-124F is the fact that it was originally designed for use on board an aircraft. This is one of the main advantages that lead to this equipment being chosen. The various certification processes for equipment needing to be assembled onto an aircraft are indeed extremely long and complex, and the lengthy process would have ruled out any instruments initially designed for use on the ground.

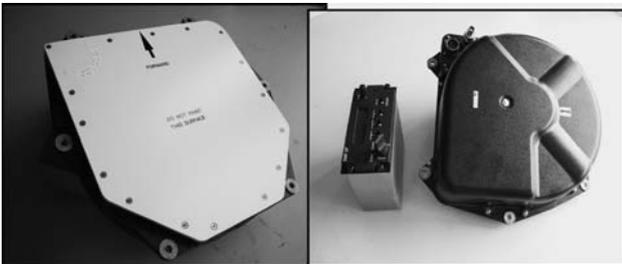


Figure 3 : MDF-124F(V2) antenna and its control unit

In order to fit the equipment onto the aircraft, a limit had to be made on the size and bulk of the antennae which were only compatible with the Doppler direction finder principle. Unfortunately, this principle is not the best in terms of precision and sensitivity. The precision is decreased due to the smaller size of the aerial and the resulting sensitivity is weak. This defect is inherent to the Doppler system, which requires the incident signal to be processed in order to extract the relative bearing. However, the first tests carried out using the TB-20 showed that even the basic version of the MDF-124 was able to satisfy the requirements. These tests generally showed up a certain number of points that needed to be improved.

DTI therefore requested Rockwell Collins France to make certain modifications, which resulted in a new version of the MDF-124F, specific to DTI; this version, named MDF-124F (V2), is now fitted in the Beechcraft 90. The sensitivity was improved by adopting a new reception stage with double frequency change. The rejection of adjacent channels was also increased, in order to prevent signals that are close in frequency from disturbing the measured signal. This parameter is essential since, by definition, we are working on weak signals in a band where there are many "legitimate" transmissions (at least, seen from an aircraft in upper airspace). It is therefore important to be able to separate correctly the signal to follow from signals which are close in frequency. The other improvements concerned the width of the intermediate frequency filter that can now be switched between different values, and on the frequency selection increment, which was changed from 25kHz to 12.5kHz. This might seem high compared to laboratory instruments, but it must not be forgotten that this direction finder was initially designed for use on regularly spaced aeronautical frequencies, and was never designed as a measuring device or as research equipment. The technology used did not allow smaller spacing than this.

The MDF-124 is designed in such a way that once it is installed; the antenna is flush with the skin of the aircraft. The exposed part outside the aircraft is therefore reduced to a minimum. However, this requires major piercing that is incompatible with the structural resistance needed for a pressurised aircraft such as the Be-90. Fitting it under the radome was therefore the only viable solution. The assembly kit was made by SOCATA and installed by the SEFA workshops in Castelnaudary during the aircraft modification works. The various tests carried out before the aircraft was put into operational service showed that this type of installation did not in any way detract from the direction finder operation, or alter the flight qualities or performance of the aircraft either.



Figure 4 : The direction finder antenna fitted under the aircraft

An aircraft used as a carrier for a measurement direction finder is far from being the ideal environment. Indeed, the propellers create large masks on either side of the lubber line. The various antennae tuned on VHF frequencies are also potential disturbances. In addition, the VHF transmissions of Air/Ground communications risk saturating the reception stages of the direction finder. The antenna associated with the second on-board VHF therefore had to be moved as it was too close to the place planned for the MDF-124. This type of change systematically requires submission of a modification file and its approval by the appropriate authorities, which inevitably leads to delays.

The first tests using the newly equipped Be-90 were carried out in October 2002 and showed that the aircraft and its interference search bench could begin without any delay. The sensitivity of the MDF-124 was measured to be -100dBm . At this sensitivity threshold, the precision is calculated to be $\pm 20^{\text{RMS}}$ (RMS: Round Mean Square). Of course, the quality of the measurements obtained increases with the level received. The error curve recordings showed correct operation enabling coherent vertical searches to be made in particular. More specifically, on the error curve shown in Figure 5, a dip can be observed in the area located between $\pm 30^\circ$, which characterises a slow reaction of the direction finder. This "over-stable" behaviour is characterised by variations of the indicated relative bearing which are lower than the variations of the real relative bearing. This distinctive feature, partly linked to the antenna installation, is a sort of integration of the information on the relative bearing, which makes it easier to read and exploit. The validation tests of the MDF-124/Be-90 couple also enabled a methodology for use during

operational searches to be defined. Due to the functional characteristics of the system, the search for the origin of a disturbance is facilitated by tracking the direction finder measurements as closely as possible and adapting the trajectory to make one or more vertical passes over the site of emission. This pass is then confirmed by a sharp change in the direction finder bearing. Nevertheless, it remains possible to make abeam measurements of the bearing, although without the precision of a vertical measurement.

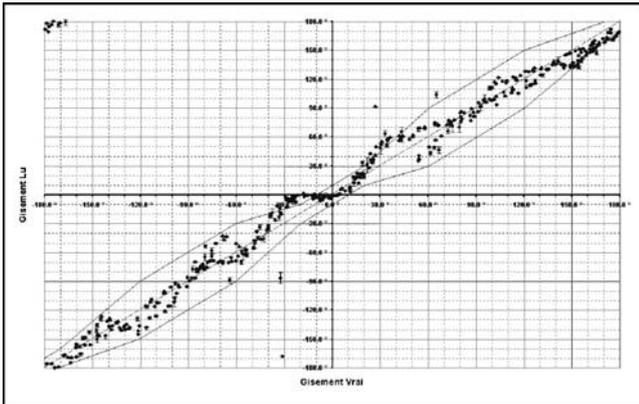


Figure 5 : MDF-124 Error Curve Measured Bearing =f(Real Bearing)

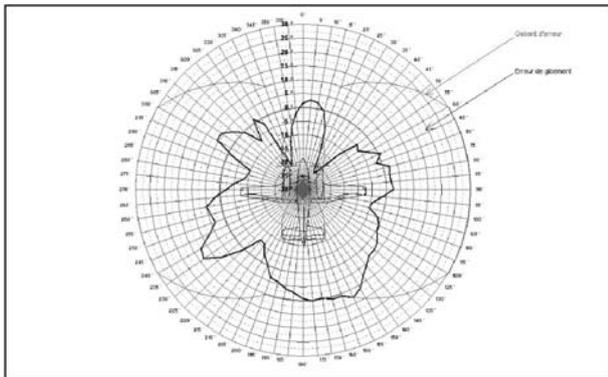


Figure 6 : Same Curve in polar form

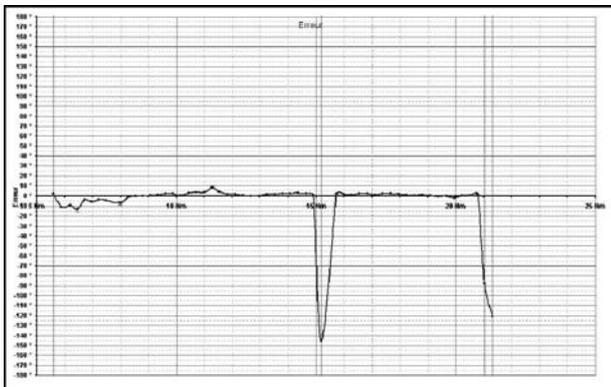


Figure 7 : Inbound Bearing Example

The interference search bench

The MDF-124 by itself is not enough to correctly carry out an interference search of VHF interference. A conventional measurement receiver needs to be added to it, which can provide far better reception in a weak field, finer demodulations and a good resistance to parasite radiation: briefly speaking, everything that can be expected from a device of this type.

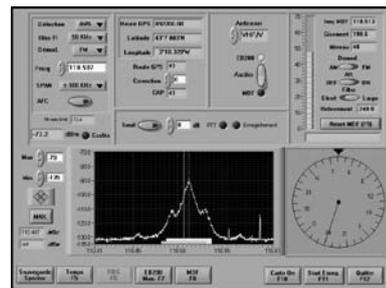
A "frequency interference" technical working group, set up within the DGAC in the context of the strategy to fight against these phenomena, defined the standard equipment to be provided to the various technical services in order to manage ground research efficiently. The Rohde & Schwarz EB-200 receiver was chosen to be the kingpin of this equipment. After this choice was made, DTI/SO obtained three of these receivers that have many advantages; amongst others they are light, compact and work on 28V direct current. All these features are necessary for use on an aircraft such as the Be-90 that has a light allowable load and only has a direct current power source.

The Be 90 interference search bench is based on these two means, the MDF-124F for localization and the EB-200 for detection and listening. Associated with this equipment are tunable filters enabling perfect protection of the EB-200 against the appearance of non-linear phenomenon in the entrance stages in the presence of strong fields, a GPS/GLONASS receiver for geographical localizing, a control and switching unit, and a ruggedized PC enabling central control of the various pieces of equipment. These are connected to the aircraft by a junction box which acts as an interface between the antennae (VHF and UHF for the EB-200 and the direction finder antenna for the MDF-124). This junction box also provides the power supply and the necessary parameters (synchronisation of heading and "push to talk" of the on-board VHF radios). All the equipment is conditioned to fit into 19" standard racks, enabling fast assembly and disassembly and the addition of specific devices in certain cases of specific interference on frequencies other than VHF. Most of the time these various pieces of equipment work on the PC with very user-friendly software that was developed by DTI.

Specific Softwares

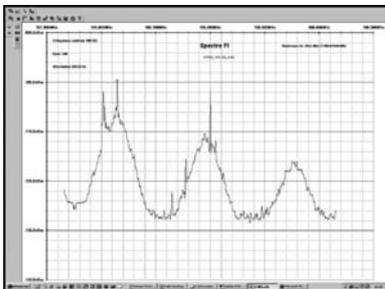
The DTI developed two specific softwares to get the best of the couple EB200 / MDF 124 :

- The first one MELBA is designed for the control/command of the receivers and the acquisition of the different parameters and in particular to link GPS positions with goniometric plottings and signal level measurements. Integrated cartographic function makes operator job easier during the searching phase and the guidance phase to the source.



- The second software CARL is a complement of MELBA and is in charge of operating, replaying and processing of the different data recorded during the searching flights. These raw data are ponderated, the quality and the power level of the signal are processed and this allows to obtain from the different measures through a triangulation a localization area of the jammer. If the source of the jamming is a FM station, we can compare

directly this area of localization to a data base of more than 7200 FM stations and antenna in France to get a more accurate positioning and to reduce the investigation area for the final ground search.



All the data are automatically plotted on a cartographic background which scale is matched to the flight area.



Figure 8 : Interference search bench installed on board the F-ASFA

PROCEDURE AND RESULTS

Methods

The equipped Be-90 was put into operational service in October 2002. The first searches were immediately fruitful and showed the importance of this means in the fight against frequency interference. DO played a central role in the action plan that was set up: it is the empowering body that decides to start a search. When the information on the interference is sufficient, this is transmitted to DTI which organizes a search flight as quickly as possible, depending of course on the availability of the aircraft and crew (in-flight controller from DTI and pilots from SEFA). When all these elements are available the operation can take place very quickly, and in certain critical cases the search flight takes place just three hours after it has been triggered by DO. Every effort is made so that the operation takes place within 24 hours of the interference being reported to DTI. The Beech 90 is also regularly used for systematic control campaigns over the country by sweeping the aeronautical band. During these campaigns we record a maximum of interferences and set priority taking into account the potential risk for an operational frequency.

Typical search course

DTI Operations are in charge of filing the flight plan that is established as far as possible to pass through the area where the interference is perceived. Depending on the results, this flight plan is of course adjusted in real time with air traffic control. ATC is warned in advance by Operations staff

concerning the specific nature of the flight and the planned course of operations. DTI also asks that the disturbed frequency be liberated during the search in order to avoid misleading direction finder readings on legitimate transmissions from an aircraft or air traffic control. This requirement does not usually create any problems, but can sometimes necessitate sector groupings, which in some cases, can lead to regulations being laid down. In order to reduce the impact that the search flight can have on air traffic, the preliminary information is essential since it allows the area of operation to be well defined.

Once the flight arrives in the area, the aircraft follows the filed flight plan until a first signal is detected, which is always on the EB-200 as it is more sensitive than the direction finder. If it is possible to obtain readings and if the listening quality is not good enough to identify the interference with certainty, the operator then instructs the flight crew to look for a first switchover, therefore a first "abeam station". It is during this approach that care must be taken to correctly interpret the direction finder information that can sometimes be rather erratic according to the nature of the interference signal and/or the electromagnetic environment in the area. This first pass usually occurs at cruising level (between flight levels 170 and 240 usually). After that, in order to be as certain as possible regarding the position of the source and to give pertinent information to the ground team (Regional Technical Service or National Frequency Agency ANFr) who will finalize the search, one or more low passes are necessary. This is done depending on the terrain, the safety altitude in the sector and the weather conditions. When these elements are favorable, it is sometimes possible to identify visually the origin of the interference.

When a vertical pass is difficult or impossible because of fluctuating bearings for example, software is used to calculate a position by triangulation from the various measurements recorded (direction finder readings, GPS position and EB-200 field levels). The final search on the ground is then made from the latitude/longitude coordinates obtained. When the flight is completed, the operator produces a document that will be transmitted to the DO. This will initialize the legal proceeding for jamming.

It gives all the information concerning the identification and the localization of the disturbance. Generally we give:

- One or more spectrum analyses of the jammers.
- A cartography of the trajectory,
- Accurate geographical coordinates,
- An audio recording and identification of the station when a FM station is the source,
- A list of the transmitting positions (antenna) of this FM station close to the measured position.

Results

Since 1998, the operations using DTI aircraft were able to resolve 70 cases of interference that were either reported or simply observed during systematic search campaigns. The origin of 89% of the cases treated was an FM radio broadcasting service in the 88-108MHz band, and 34% of the cases were of foreign origin. Among these 70 cases, some of them required an operation using the Be-90. The following examples explain some of the most symptomatic interferences.

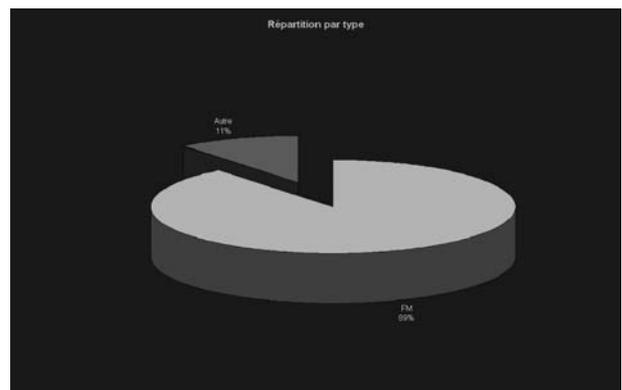


Figure 9 : Distribution by origin

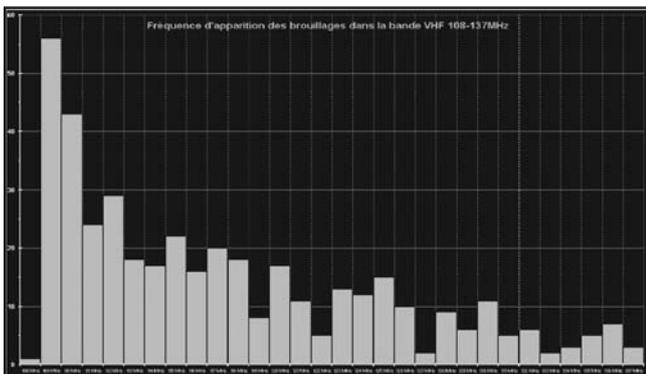
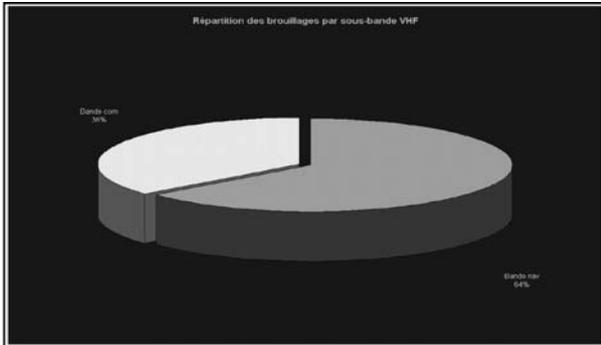


Figure 10 : Occurrences of interference in the Civil Aviation VHF band

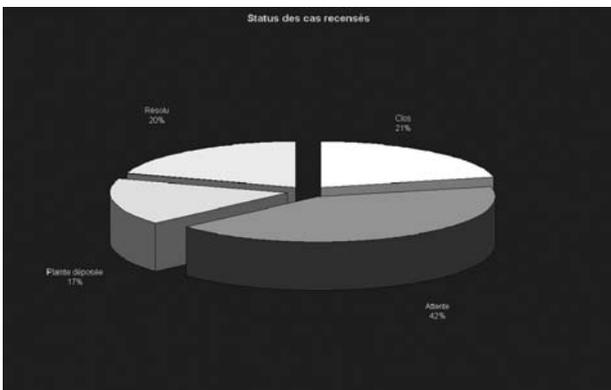


Figure 11 : Known cases status

EXAMPLES

ACC/Southwest: Sector N

This case is one of the most critical ones that occurred in 2003. UIR sector N is operated by Area Control Centre (ACC) Southwest and covers an area extending from the south of Toulouse as far as the Spanish border where the traffic is then under control of the Madrid ACC. This sector channels a large quantity of north/south traffic; closing the sector and grouping the frequency with the adjacent sectors means that many regulations need to be laid down.

This is what happened on several occasions during the year 2003 due to an audible disturbance on frequency 135.205MHz described by crews as background noise or humming. As is often the case, the controllers did not perceive this interference. In addition, this phenomenon seemed to appear randomly at any time of the day. This case needed two operations using the Be-90. The first search took place on 9 April 2003 and was not successful due to the limits imposed by the dedicated permit to fly issued before the final airworthiness certificate was obtained after the modifications made to the aircraft. In fact, this first search showed that the source of the disturbance was located in Spain. It was not possible to

perform a vertical search as the permit to fly limited the aircraft's maneuvers over French territory. Nevertheless, the specific character of this interference could be shown which, for once, was not caused by an FM radio, but by a parasite signal randomly moving on a band of 2MHz. This particularity explained the temporary aspect described by the pilots who had been confronted with this phenomenon.

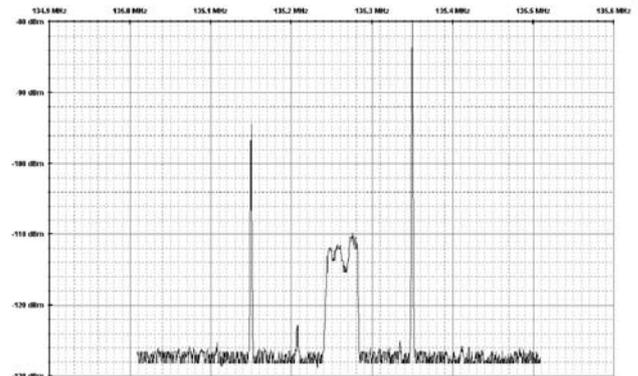


Figure 12 : Sector N ACC/SW Interference Spectra

On 30 July 2003, the second search, this time with a normal airworthiness certificate, found the source located northwest of Gerona (Spain). The search was quite delicate, however, due to the mobility of this signal that needed many frequency changes on the EB-200 and direction finder to continue the measurement, which in addition, was quite disturbed due to the mountainous environment of the site. These different points prevented a good vertical pass over the site being made in spite of many attempts at different altitudes and from different angles of approach. The data recorded was nevertheless sufficient to calculate a reliable and precise triangulation of the interference. This position was confirmed later (within a range of 600m) by a team on the ground. The origin of this disturbance turned out to be an electrical drying system used by a manufacturer of conductor cables.

It is noteworthy that although the operation identified the source, it also caused some delays as sector N had to be closed during the whole duration of the search.

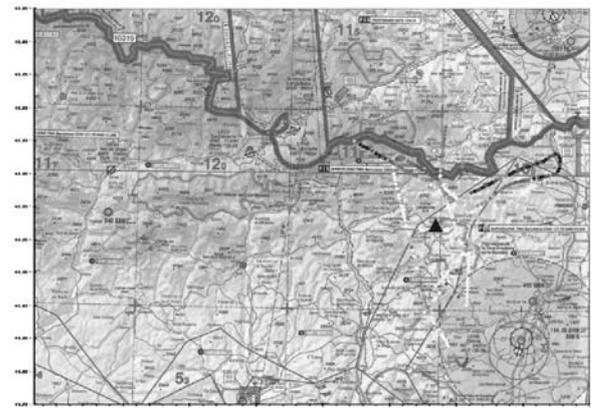


Figure 13 : Trajectories of interference search flights on 135.205MHz.

Trajectories of interference search flights on 135.205MHz.

This case could have had more serious consequences if the jamming had lasted. It had been reported by three aerodromes using the same TWR frequency, 123.20MHz. The complaints mentioned a permanent background noise above a certain altitude, which varied depending on the place where the interference was perceived. The probable area where the source of interference was located was quite easy to determine because of the geographical distance separating the three aerodromes. The search flight plan was therefore defined in a triangle: Toulouse, Montpellier and

Perpignan. As expected, the interference was picked up quickly after taking off from Toulouse Blagnac and was immediately tracked by the direction finder. The first abeam station pass took place at FL170, then two vertical passes at 6000ft and 3000ft enabled visual identification of the source located at a military airfield close to Narbonne. As shown by the spectra recorded during this search (see Figure 14) it was a continuous wave emitted by some military VHF equipment, on which the push-to-talk automatic test system had remained stuck on transmission.

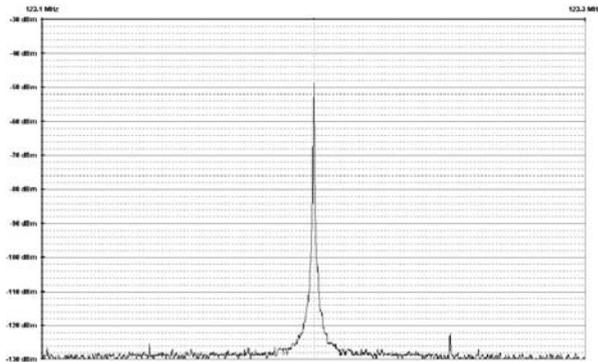


Figure 14: Muret, Nimes and Calvi TWR frequency interference



Figure 15 : Search flight trajectory on 123.20MHz

CRNA/O : ACC/West: 127.86MHz

A search to solve this case took place in August 2003 after complaints from ACC/West reported severe disturbances on 127.86MHz. As some crews had reported hearing music, it was fairly certain that the source would be an FM radio. This hypothesis, together with the experience of interference affecting the ACC/West's sectors of south Brittany/Bay of Biscay, led to a flight plan being filed to pass over Biarritz and continue to Bilbao (BLV VOR). Indeed, shortly after Pau, the interference was easily identified. The signal and its spectra confirmed that the phenomenon was in fact due to a fault in a Spanish FM station. The search continued until an excellent vertical pass was made, which enabled the site of the transmitting pylon to be located very precisely.

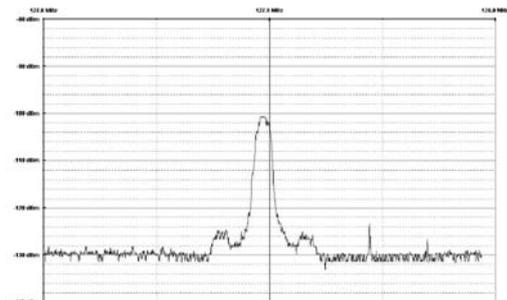


Figure 16 : Spectra of interference from a Spanish radio on an ACC/West frequency



Figure 17 : Site of emission



Figure 18 : Search trajectory on 127.86MHz

Clermont Ferrand aerodrome: Approach frequency

This example is typical of operations carried out the most frequently with the Beech 90. This assignment took place on 23 October 2003 and enabled identification of an FM radio beaming signals on 128.83MHz, a Clermont Ferrand approach frequency. The complaints at the origin of this search reported crackling and background noise on the approach frequency in the whole of the West/Northwest sector of its area of use. The initial flight plan was designed to cover this fairly large area. Very quickly after take-off, the disturbing signal was identified and easily tracked thanks to the co-operation of Clermont Ferrand air traffic control that had liberated the frequency. A vertical pass was made at very low altitude, which allowed a visit by the ANFr the very next day. It turned out to be a transmitter of the "Vallée de Vézère" radio station in Dordogne, emitting 1kW on 104.40MHz. This radio could not be identified during the search, as the parasite signal more like a continuous wave than an FM modulation. Apparently the fault originated in a frequency synthesizer generating parasite rays with very little FM modulation.

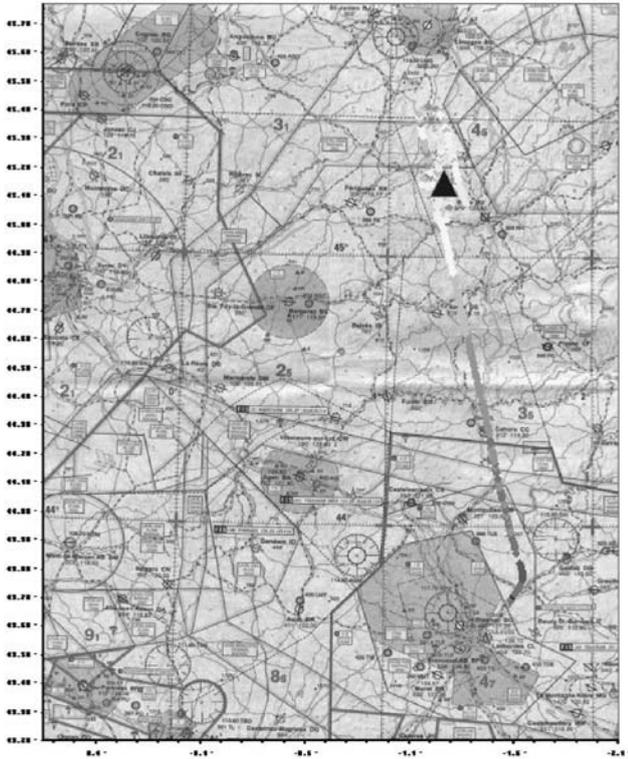


Figure 19 : Search on Clermont Ferrand APP frequency.

ACC/Southwest LG Sector

This last case illustrates the added value of the Be-90/MDF-124 system. During the month of May 2004, ACC/Southwest had been subject to many disturbances on band 135.96MHz. The pilots had described these phenomena as noises like a "machine gun", which seemed to indicate that for once the troublemaker was not an FM radio, but rather a parasite coming from a factory or some kind of electrical equipment. The first operations planned by DO were unfruitful since the phenomenon had disappeared before the aircraft took off. It was only during the third attempt that the signal could be followed as far as the vertical over the Chinon nuclear power plant. This interference, the cause of which has been identified later as a non authorized monitoring system functioning on the 136-137MHz band, would have been difficult to locate without the capabilities of the direction finder. Furthermore, with a longer operation time, the aircraft could not have been airborne during the periods when the ACC/Southwest was disturbed due to the random occurrence of the phenomenon over a period of time.

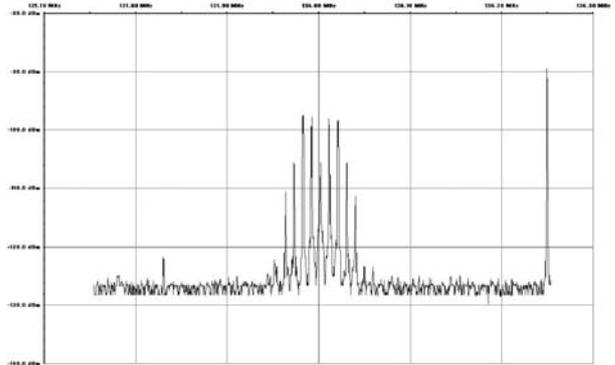


Figure 20 : Interference on ACC/Southwest's frequency sector LG



Figure 21 : The site emitting the disturbance

FUTURE

Today this equipment is only implemented on the Beech 90. We plan to equip our two flight inspection planes, the ATR 42 and a new Beech 200 to be delivered in 2007, with a Collins MDF 124 direction finder. We will add a second DF in order to increase our detection capacity to the GNSS L band. Moreover, DTI continues to develop and improve the two softwares dedicated to jamming research in order to increase reactivity and efficiency.