RESULTS OF A RADAR IMAGING EXPERIMENT BY ISAR TECHNIQUE

RESULTATS D'UNE EXPERIENCE DE RECONSTRUCTION D'IMAGINE OBTENUS PAR LA TECHNIQUE ISAR

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RÉSUME

Dans ce travail on expose et on examine les resultats d'une expérience de reconstruction d'imagine obtenus par la technique ISAR. Le profil monodimensionel d'une avion qui se déplace suivant une trajectoire rectiligne a eté tracé à le mite de une élaboration cohérente du signal réçu par un radar conventionel de traçage.

SUMMARY

In this paper the results of a radar imaging experiment by Inverse Synthetic Aperture Radar (ISAR) technique are presented and discussed. A one dimensional profile of an airplane in motion along a rectilinear trajectory is obtained by means of a coherent processing of the received signal collected by a conventional tracking radar.

1 INTRODUCTION

Radar Imaging through Inverse Synthetic Aperture Radar (ISAR) is a technique which allows a radar systems to obtain an electromagnetic image of the illuminated object, by means of a suitable coherent signal processing [1]. The relevance of the applications, both civil and military, lead to a great theoretical development in recent years, so that the theory of ISAR is now well assessed (see for example [2] and references therein). At the same time different experiments were performed and the results were so encouraging, that it is expected that radars of the next future will embody an imaging capability.

The Institute of Electronics and Telecommunications of the University of Pisa and Selenia Company cooperated to develop the capabilities in order to perform an ISAR experiment. This experiment was made by using a conventional tracking radar in order to test the feasibility of the developed azimuthal compression technique: to this purpose a one dimensional ISAR experiment was performed. In this paper some results derived from the experimental data processing are reported.

2 THE EXPERIMENTAL SET-UP

The sensor employed in the experiment was a tracking radar of Selenia Company. A general purpose equipment was used in order to acquire radar echoes, while the aircraft was flying a pre-programmed path. The acquisition set-up is reported in Fig. 1. According to the flight plan, the aircraft is expected to fly a straight path AB with uniform speed v_a=130-150 m/s. Both the trajectory length AB and the distance R_0 are about 10 Km. When a trajectory is run along, the aircraft turns, flies back the same trajectory, and so on for about 15 times, corresponding to twenty minutes of recording time. The radar transmits a pulse with wavelength λ=3 cm. The baseband converted echoes are acquired by the W.R. (Waveform Recorder) HP 5180A. The W.R. works in the following way: the input signal is sampled at the clock frequency (internal or external). When a trigger (internal or external) is present at the input, each sample is sequentially stored, as a ten bits word, in a record whose storage capability is 16 K word. Data recording ends when the record is full. At this time the record may be transferred to a buffer of the HP 9000/300 HP P.C. (Personal Computer). The acquisition of a new record begins later with the next trigger, and so on. In the experiment the W.R. was set up with the greatest storage capability of 16 K words. External clock and external trigger were generated by means of the timing circuitry, which consists of a pulse generator and a burst generator. When the buffer is full, it is stored in the hard disk. As this transfer ends, the computer controls the acquisition of a new buffer, and so on. During the flight of the target, the data of azimuth, elevation, range, doppler and speed were recorded by the operator at the radar-console. Target trajectory was automatically plotted by means of the data available from the data-processor of the tracking radar.

Let us now see in detail the timing for the acquisition of the radar pulses. The radar trigger coincides with the beginning of the tracking gate. The I (In phase) and Q (Quadrature) components of the received signal are present on channel A and B respectively. The burst generator, as triggered by the pulse generator, sends a burst of 32 pulses to the W.R. as external clock. 16 samples are acquired in every sweep, 8 for channel I, and 8 for channel Q. So one record contains the samples relative to 1024 sweeps. It is so possible to make a rough evaluation of the resolution obtained by the coherent processing of one record. In fact the observation time T_0 is given by $T_0=1024 \cdot PRT \cong 0.26$ s. According to the flight-plan, target velocity v_a and target range R_0 are roughly given by: $R_0=10$ Km and $v_t=150$ m/s. Assuming that during the observation interval T_0 the target flight is approximately orthogonal with respect to the line of sight, we have that $\theta_{el} \cong v_t T_0/R_0=39 \times 10^{-4}$ rad. The cross range resolution is then roughly given by: $r_x \cong \lambda/2\vartheta_{el}=3.8$ m.

The transfer of one record from the W.R. to the P.C. is carried out by means of a DMA cable which connects the DMA port of the W.R. to the G.P.I.O. (General Purpose Input Output) interface of the P.C. After this transfer the P.C. controls the acquisition of a new record, and so on until 8 records are transferred in the buffer. Because a record transfer takes about 0.25 s, two consecutive records are separated by about 0.5 s. When the record is full, it is stored in the hard disk as a file. Then the computer controls the acquisition of a new file.

3 SIGNAL PROCESSING

The experimetal data recorded as described in section 2, were processed at the Institute of Electronics and Telecommunications of the University of Pisa according to the following steps:

3.1 Raw data preprocessing.

This step was performed in order to obtain data useful for image reconstruction. A single complex sample was obtained from the eight complex available samples for each echo, and the 1024 so obtained samples relevant to the observation time were arranged for successive processing.

3.2 Frequency analysis.

This step corresponds to an FFT on the preprocessed data, and while it was not strictly necessary for profile recovery, it was important for data validation and data extraction purposes. In particular, from this analysis it was possible to associate data with actual trajectories and to obtain an estimate of the radial velocity of the aircraft, which was used later in the motion compensation algorithm. The results of the analysis performed in this step were used to single out the data records to be used in the subsequent analysis.

3.3 Motion compensation.

This step is necessary in order to remove the phase component due to motion of a reference point on the target. This step was realised by means of the autofocusing technique [3]. Basically, it estimates parameters relevant to the phase history of the reference point by maximizing a suitable functional of the received signal. The maximation algorithm used in this step was developed in [4].

3.4 Profile reconstruction.

This step is basically an inverse Fourier Transform. Because of the high value of the transmitted frequency (10 GHz) and the short observation time corresponding to a small variation of the aspect angle, the actual polar distribution of the available samples in the Fourier domain (arc of circumference) can be conveniently approximated by a rectangular distribution (straight line). Based on the above discussion the reconstruction algorithm was implemented by an FFT algorithm. The scale of the resulting profile was obtained from the resolution derived from the motion parameters estimated in the motion compensation step.

3.5 Data weighting.

In order to reduce the sidelobes arising from the profile reconstruction algorithm and to highlight different peaks of the reconstructed profile a data weighting was performed in order to compare results obtained without data weighting. The used windows are those of Hamming, Hanning and Blackman-Harris [5].

4 DISCUSSION OF RESULTS.

As an example of the results obtained by applying the processing procedure illustrated in sect. 3, we will discuss Figs. 2-6.

Fig. 2 shows the spectral analysis of a record of data. The significant part of the spectrum has a width of about 40 Hz. The same record was processed by the described motion compensation technique and the result is presented in Fig. 3. It is easy to see that the spectrum is compressed and the resulting bandwidth is about 8 Hz. The motion parameters inferred by the motion compensation algorithm determine the scale of the reconstructed airplane profile; in this case it is estimated that 1 Hz corresponds to 1.15 m and then the width of the main lobe of the compressed spectrum is about 9.2 m. In this condition it is very difficult to make the meaning of the reconstructed profile clear. In fact the aircraft dimension along the cross-range direction is about 10 m and corresponds to the width of the main lobe. This is to say that the resolution of the system is too poor to resolve single scatterers. Moreover, the effect of the spread of the spectrum were enhanced by the presence of the staggering of the pulse repetition frequency and of the AGC of the receiver, even if, at a preliminary analysis, these two phenomena seem to have little effect on the reconstructed profile.

Fig. 4 shows the result of a spectral analysis of another record of data relevant to the same target trajectory. The significant part of the spectrum has the same width of the previous case. The result obtained by using the motion compensation algorithm is shown in Fig. 5. In this case, it is possible to note a secondary lobe with an amplitude of 7 dB below the main lobe. The distance between these lobes is about 9 m and it reveals the possible presence of a second scatterer. For a better interpretation of the result a weighting of the data with the Hamming window (see Fig.6) and woth the Hanning window (see Fig. 7) was performed in order to reduce the effects of the sidelobes. Figs. 6-7 show the profile obtained with the afore mentioned processing techniques. As it is clearly shown in the figures, a second peak is present in the reconstructed profile. Its amplitude is about -18 dB which corresponds to an amplitude of an hypothetical second scatterer 0.12 times that of the main scatterer.

For a better comprehension of the experimental results a simulation program has been developed. This program permits to generate samples of the received signal from a target in motion along an assigned trajectory. The target is modelled by means of a finite collection of ideal scatterers. The simulation results are in good agreement with the experimental ones and suggest to improve the capability of the acquisition system in order to obtain a better resolution.

5 CONCLUSION

The results of an imaging experiment by ISAR techniques are presented and discussed. A one dimensional profile of an airplane moving along a rectilinear trajectory was obtained by a coherent processing technique of the echoes collected by a conventional tracking radar. An estimated cross-range resolution of about 4 m was obtained. The images are difficult to interpret because the dimension of the airplane is about two resolution cells. However the obtained cross-range compression of the signal spectrum is encouraging and it is expected that, if the acquisition capability of the system are improved and the object is observed for a longer time, high resolution images can be produced.

6 REFERENCES

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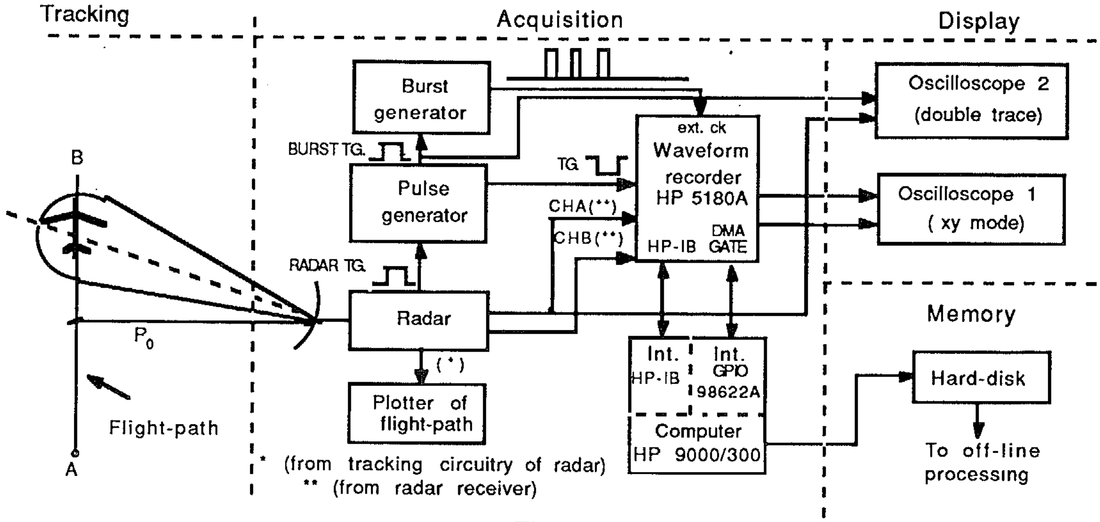

Fig. 1

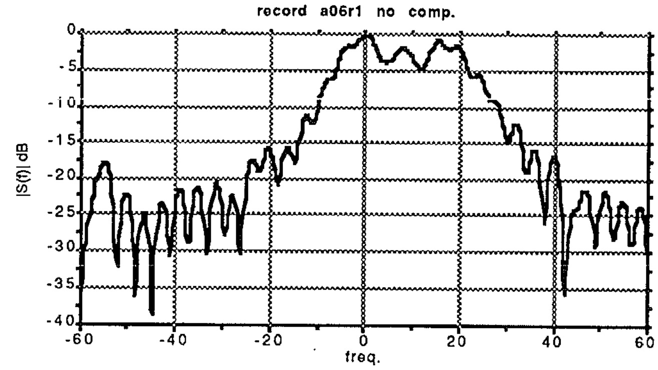

Fig. 2

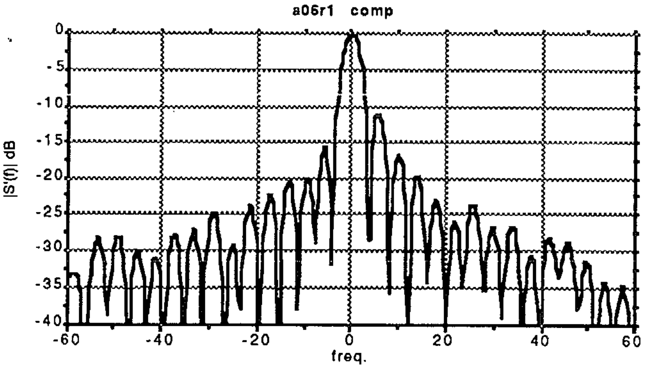

Fig. 3

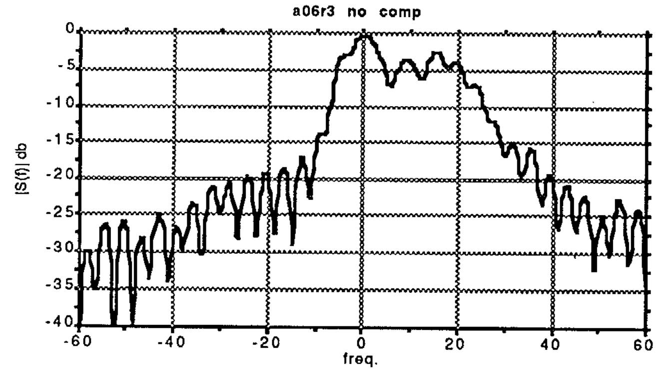

Fig. 4

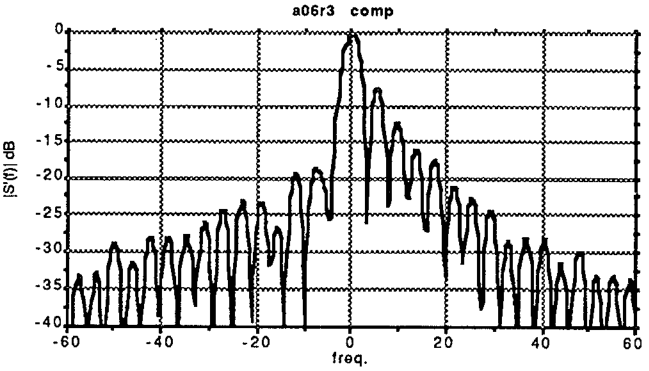

Fig. 5

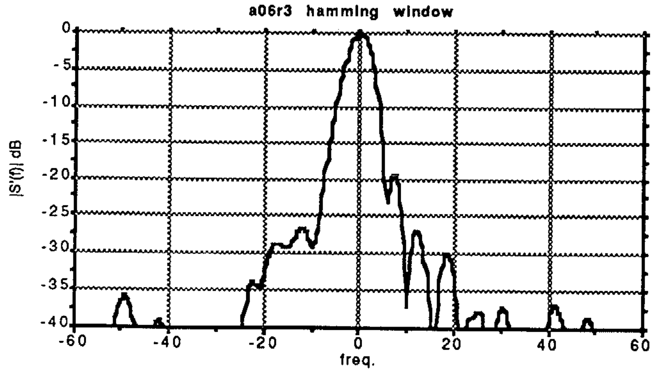

Fig. 6

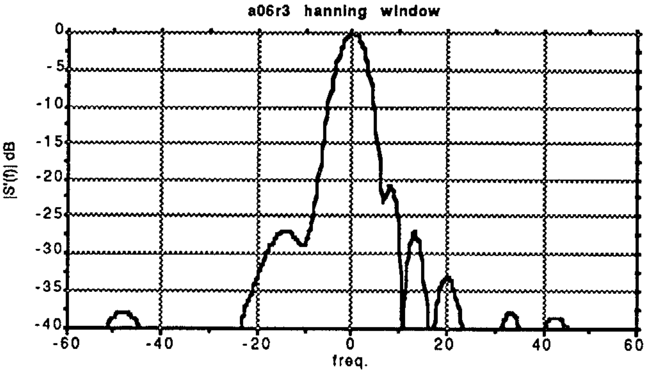

Fig. 7