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Acquisition and Use of Orlando, Florida and Continental Airbus Radar Flight Test Data

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*Acquisition and Use
of
Orlando, Fla. and Continental Airbus
Radar Flight Test Data*

by

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Abstract

Westinghouse is developing a lookdown pulse Doppler radar for production as the sensor and processor of a forward looking hazardous windshear detection and avoidance system. A data collection prototype of that product was ready for flight testing in Orlando to encounter low level windshear in corroboration with the FAA-Terminal Doppler Weather Radar (TDWR). Airborne real-time processing and display of the hazard factor were demonstrated with TDWR facilitated intercepts and penetrations of over 80 microbursts in a three day period, including microbursts with hazard factors in excess of .16 (with 500 ft. PIREP altitude loss) and the hazard factor display at 6 n.mi. of a visually transparent ("dry") microburst with TDWR corroborated outflow reflectivities of +5 dBz. Range gated Doppler spectrum (I,Q,FFT) data was recorded for subsequent development and refinement of hazard factor detection and urban clutter rejection algorithms.

Following Orlando, the data collection radar was supplemental type certified for in revenue service on a Continental Airlines Airbus in an automatic and non-interfering basis with its ARINC 708 radar to allow Westinghouse to confirm its understanding of commercial aircraft installation, interface realities, and urban airport clutter. A number of software upgrades, all of which were verified at the Receiver-Transmitter-Processor (RTP) hardware bench with Orlando microburst data to produce desired advanced warning hazard factor detection, included some preliminary loads with automatic (sliding window average hazard factor) detection and annunciation recording. The current (14-APR-92) configured software is free from false and/or nuisance alerts (CAUTIONS, WARNINGS, etc.) for all take-off and landing approaches, under 2500 ft. altitude to weight-on-wheels, into all encountered airports, including Newark (NJ), LAX, Denver, Houston, Cleveland, etc.

Using the Orlando data collected on hazardous microbursts, Westinghouse has developed a lookdown pulse Doppler radar product with signal and data processing algorithms which detect realistic microburst hazards and has demonstrated those algorithms produce no false alerts (or nuisance alerts) in urban airport ground moving vehicle (GMTI) and/or clutter environments.

Introduction

The Westinghouse Technical Direction is to provide a forward looking detection and avoidance system of low level windshear based upon a pulse-Doppler lookdown radar sensor to the commercial air transport market. The design of this system is for a "quiet, dark cockpit" with low false alert and nuisance alert rates. To be used, its warnings must be trusted and its hardware performance reliable.

Detection of microbursts employs an X-Band radar sensor designed to criteria which has made Westinghouse a leader in reliable lookdown airborne radar. Specific for this application are the demands of operating in an urban clutter environment and its attendant moving vehicle background. Our design approach is to temper initial, analytic designs based on experience with data from encounters with both microbursts and airport urban clutter.

However, it is difficult to obtain simultaneously interesting/stressing microbursts and appropriate clutter. These two series of flight tests have been respectively concerned to record radar data for microburst detection algorithm refinement and to observe and develop clutter rejection processing into a robust variety of urban airports with an in-revenue service aircraft reality. Signal and data processing algorithms subjected to input data collected in flight against actual microburst hazards verifies the detection capability of software upgrades to a radar in revenue service and demonstrate by superposition both hazard detection and low false alert criteria.

Overview

The Westinghouse involvement with airborne forward looking windshear detection radar (see figure 1) began in 1989. After talks with NASA LaRC, a flight test into nearby urban airports was conducted using a modified APG-68 (F-16) radar [1]. Data was collected along approach glideslopes using NASA "typical" waveforms. A number of antenna lookdown angles were examined to establish a baseline on antenna sidelobe rejection and appearance of ground moving discrete_n and traffic. Airport selection excluded stressing second time around urban clutter.

Westinghouse initiated a major development program. Receiver/transmitter/processor (RTP) units were designed, assembled, and software equipped to gather microburst data at the tailend of the microburst season. The design included pre-prototype component and design techniques. RTP configuration conformed to ARINC 708. The design included an FFT based signal processor and real time data processor.

The data collection radar was delivered to the Westinghouse owned and operated BAC-1-11 at the end of August with signal processing algorithms installed. Vectored by TDWR to areas of evolving or potential microburst activity, pilot decisions about fly-through utilized a realtime hazard factor display. Pre-processed radar data (FFT) was collected on over 100 microbursts over a 3 day period, including a run which produced 500 ft. loss in altitude.

The Orlando flights served as a checkout for installing the R/T into a Continental Airbus. Unlike Orlando, only VCR format data would be collected on the Airbus. The radar operated in an autonomous, non-interfering basis with the installed ARINC 708 type antenna system. VCR format data has been collected on 682 flight (1682 flight hours from 4-SEP-91 thru 8-APR-92) for take-off and approaches over altitudes from weight-on-wheels to 2500 ft. into a variety of urban airports including Cleveland, Denver, Newark, L.A., San Fransisco, Houston.

The initial software configuration on the Continental Airbus included only the signal processing algorithms as configured in the Orlando flights. These included neither complete clutter rejection nor total hazard factor algorithms. The software has been recently updated to include (1) refinement in the signal processing designed to reject GMTI-clutter while not impairing windshear detection, (2) computation of a total (vertical plus horizontal) hazard factor and (3) detection logic for total hazard factor. Effectively, the equipment is nominally configured for false alert scoring.

Radar and Instrumentation Design Considerations

Hazard factor accuracy may seem like an abstract and inaccessible quantity, but first order estimates of hazard factor accuracy can be controlled in sensor design by examining the sensitivity of the hazard factor to various measurement accuracies, particularly the accuracy of measuring outflow radial velocity and the distance over which the change in outflow velocities take place.

In fact, once these sensitivities are recognized, budgets for controlling the contribution from any single source can be allocated into the design. While the effects of sidelobe clutter, GMTI discrettes, and other "clutter residue" contributions may be analytically elusive, accuracy limits of the hardware, the algorithmic processes, and/or waveform design may be established early in the design process.

In general, there may be several contributors to the Doppler velocity accuracy budget besides the signal-to-noise limitation, but the signal-to-noise limitation on Doppler velocity accuracy is most fundamental to when (at what range) the radar algorithmic processes can be expected to produce good velocity maps which produce good hazard factor maps. Minimal outflow reflectivities (and Doppler velocities) which produce marginally accurate hazard factors can be small if larger amplitude sidelobe/mainlobe ground moving vehicles or sidelobe discrettes are inhibited from entering the velocity map.

~~range~~

Imperfect accuracy in the dimension over which the winds change will produce errors. Over-resolving sensors like radar will cut the microburst outflow into several pixels on a fine range grid, making the measurement of the outflow diameter relatively accurate in comparison to non-resolving sensors (e.g. infrared).

When the microburst is well resolved in range, a series of velocity measurements for the range pixels along an azimuth line may be used to construct an approximation to the horizontal windshear. Least mean square type approximations will be accurate over linear regions of shear (i.e. hazards) if the velocity measurements for each pixel are accurate.

Limits on velocity accuracy are usually set by the Doppler filter 3 dB bandwidth. Non-resolving (i.e. pulse pair) Doppler sensors must resort to large signal-to-noise ratios to maintain accurate velocity measurements. Resolving (i.e. FFT spectrum analyzer) Doppler sensors can provide accurate Doppler velocity measurements at low signal-to-noise ratios.

The importance of low signal-to-noise ratio velocity accuracy is that the reflectivity of the outflow may be correspondingly less reflective, i.e. "dry".

According to NASA-LaRC, a minimally small, hazardous microburst will have the hazard area extend over about $D_{\mu} = 1000$ meters. Allowing some overlap by the approximating ensemble, the least mean square type slope estimator may begin to operate when diameter of the microburst hazard is subtended by the LMS window (population) of n_e points,

$$D_{\mu} \sim n_e \Delta R$$

$$\Delta R \sim D_{\mu}/n_e$$

Substituting for the range gate ΔR , with $(V/g) = (80/9.81) = 8.15$ sec, a 10% hazard factor accuracy on a nominal hazard factor of .105 yields [2],

$$\delta F/F = .10 \sim [(8.15)/[2(1000)(.105)]] [n_e \delta v / (n_e - 2)^{.5}]$$

Re-arranging, the velocity accuracy (δv) per point must be small,

$$\delta v \sim 2.58 (n_e - 2)^{.5} / n_e$$

For signal-to-noise limits, the velocity resolution Δv contributes to defining the velocity accuracy, $\delta v \sim \Delta v / (2 S/N)^{.5}$. Squaring both sides of the equation, the relationship between Doppler resolution and signal-to-noise becomes, approximately :

$$(\Delta v)^2 / (S/N) \sim 2(2.58)^2 (n_e - 2) / n_e^2$$

Consequently, range gated FFT spectrum analyzers can furnish fine Doppler resolution and, hence, accurate hazard factors at low S/N ratios due to minimal outflow reflectivities.

Accurate hazard factor processes at low S/N must avoid larger S/N returns, e.g. mainbeam clutter, sidelobe clutter, ground moving traffic, spurious, etc. The RTP assembly contains a stable oscillator (STALO), Receiver, Signal Processor, Solid State Transmitter, and Low Voltage Power Supplies. The STALO and receiver provide stability and spurious free operation in the presence of large mainbeam clutter. The receiver and STALO are departures for their attention to minimum detectable velocity and interference. The transmitter is solid state, based upon GaAs MMIC power amplifiers. A powerful signal processor is provided. This furnishes the numerical signal processing engine to accomplish an FFT spectrum analysis with proprietary algorithms to reject/sort clutter and GMTI with no consequence to windshear. Such algorithms are demanding because they must be executed at input data rates.

The signal processing effectively furnishes velocity (range x azimuth arrayed pixel) maps of the horizontal wind fields before and along the glideslope of the aircraft. Map data is available at a reduced rate. Data processing of these maps furnishes total hazard factor estimates along the aircraft approach or departure altitude profile. The final output stages of the warning system utilize a graphic processor to transform the radar coordinate maps into PPI formatted data as well as colour code the VCR displays. The processor design also supports high speed porting of the I&Q input data, the FFT data, etc. for instrumenting/data collection purposes.

"The Name of the Game" (see figure 2) for low level windshear warning is to sort windblown rain return ~~for~~ other returns, including mainbeam urban (STAE) clutter, sidelobe distributed clutter, sidelobe and/or mainlobe GMTI. "Conditioning" preserves the signal integrity and minimizes spreading of mainbeam clutter through the downconversion process to analog-to-digital (ADC) conversion. "Signal Processing" includes those algorithms which are accomplished at the coherent processing interval (input data rate). With FFT spectrum analysis processing, there is a whole filterbank of Doppler candidates to describe the Doppler of the wind in a single range x azimuth beam (velocity map) pixel. The signal processor chore must smartly reduce the data entering the subsequent data processing stages by orders of magnitude. Pulse-pair and spectral averaging processes are simple and less demanding largely because they accept/include as eligible many Doppler returns which may not be windshear. "Data Processing" means the processing of the wind velocity maps to produce a total (i.e. both horizontal and vertical component) hazard factor map. It also may include the detection of average hazard factor areas. These different levels of radar data become the principal intermediate stages for observing radar performance and recording/instrumenting/displaying data.

Prior to the Orlando flights, Westinghouse assembled and delivered the data collection radar hardware to the software/systems integration bench. Real beam map and supporting modes were first developed and checked out at the bench and in local flight tests. Windshear mode development proceeded with several local flights through August. Initial development of the windshear signal processing utilized NASA-LaRC FORTRAN computer models of microbursts [3] and glideslope geometry, modified by Westinghouse to include its own models of multiple time around echo (MTAE, STAE) and distributed sidelobe clutter.

The objectives of the ORLANDO flights were to collect data on microbursts and to demonstrate airborne real-time processing and hazard factor display. The Orlando flights were conducted with signal and data processing operating (loading the timeline) but with ~~some~~ cursory signal processing enabled only. In general, the many thresholds and adjustable processing parameters in the signal processing algorithm were "de-sensitized" to insure that any and all Doppler reports would be passed to the VCR map displays. The objective was to unhinderedly collect any available data on microbursts. Real time processing of the wind blown rain return into velocity maps and hazard factor maps would allow the pilot and test crew to penetrate the microbursts, collect *in situ* (SUNDSTRAND) data, and otherwise corroborate the airborne displayed and recorded data with TDWR.

The installation on the BAC-1-11 (see figure 3) utilized a configuration in anticipation of the Continental Airbus installation to follow. A typical ARINC 708 (i.e. retrofittable) 30 inch flat plate phased array antenna was controlled through the sequencer. Data collection would include I&Q pulse and gated FFT radar data, INU, and air data input to the SUNDSTRAND reactive device in addition to the VCR formatted displays.

The BAC-1-11 operated in a fashion with the air traffic controllers and TDWR radar operators not unlike the preceding NASA flights. Safety of flight considerations included minimum altitude limitations and air space restrictions. Using the voice and data link established by NASA earlier, the TDWR operators would vector the aircraft to the vicinity of the microburst. Based on pilot observations and TDWR radar reflectivity, Doppler, and/or hazard factor, the aircraft might penetrate the microbursts.

The Westinghouse flights were greatly aided by the fact of the real time airborne radar instrumentation display (see figure 4). The aircraft was directed to the vicinity of microburst activity by the TDWR, and the pilot used the radar display to locate a particular cell, assess the flight safety, and navigate through with little problem. As the data collection proceeded and the radar demonstrated its abilities to locate microbursts at long range, Westinghouse could approach general areas of activity and pick among evolving events. The VCR display format for both the Orlando and the Continental flight tests was constructed to the arguable convenience of engineers, and crowded a lot of instrumentation into a small space. Range (out to 8 n.mi. in range gates of 300 m.) x Azimuth ($\pm 23^\circ$) (B Scope) maps were provided for two bars of azimuth data, one bar at a lower elevation angle than the other. Each pixel on the screen represents a range gated angle cell of 16 colour shade coded data.

The maps at the top of the VCR format are unscaled amplitude (i.e. S/N). The "bland" colour palette employs red as a large amplitude signal and blue-green as minimal (near noise). The upper bar is on the right and the lower bar is on the left. Below these amplitude maps are the velocity maps for the respective bars. Green indicates zero velocity, yellow-red indicate tailwinds of increasing magnitude and blue indicates increasing headwinds (± 24 m/s or 3 m/s per colour shade). The odd rectangular window on the left is a B-scope lower bar horizontal hazard display. Most

people will find the PPI format of "total" hazard factor in the lower right corner most assessible. Hazard factor colour quantization spanned ± 2 (0.025 per shade). The space not used by the colour coded maps allows numerical discrete data. Activity of the signal processing numeric words provides engineers indications of proper activity of critical stages of the process. Along the bottom are indications of azimuth and elevation antenna position, aircraft location (lat.-long.), altitude, etc. Space was also allocated for SUNDSTRAND reactive hazard factor display and alphabetic annunciation.

The BAC-1-11 was vectored to some 80 different microburst events by the TDWR operators. Many of those events included multiple "isolated" cells and complex "line" events. In all, the radar collected data on over 100 microbursts in three afternoons of flight.

VCR tapes of the instrumented VCR format and views of the intercepts out the windshield will be shown.

The first video begins with a full screen display of the VCR instrumentation format. The amplitude, velocity, and hazard factor maps at the start of this run are full of activity in progress at near and very far (8 n.mi.) ranges. The cells of interest are being discussed by the pilot and TDWR. The airborne radar operator begins directing the pilot's attention to a beginning event. The audio contains conversation between the pilot and crew over the intercom and with the air traffic rf communication including the TDWR. The video transitions to a view out the pilot's windscreen with the instrumentation shrinking into the lower left corner of the screen. Subsequently, only the total hazard factor PPI map (true perspective) is shown. The visual shows little sign of outflow in the rain cell. As the penetration evolves, the microburst develops hazard factor displays portraying many shades of colours, including nearly .2 (top red). TDWR corroboration (post-flight de-briefing) placed the hazard factor along the flight path at .16, and the audio includes a pilot report of 500 ft. altitude loss for a penetration which began at an altitude under 2000 ft.

The second video segment begins as the plane (windscreen visual) emerges from a prior run on a rain core. The plane maneuvers slightly under TDWR direction, approaching a lake. Careful visual inspection of the lake surface will reveal an outflow. The air volume above the lake is clear. The radar display picks up indicated outflow activity in both the upper and lower bars of its scan patterns, and the hazard display shows a weak hazard factor at about 6 n.mi. as the aircraft turns and steadys under radar operator/radar display direction. Post flight de-briefing with TDWR corroborated a microburst forming with an outflow of +5 dBz. reflectivity. As the BAC-1-11 approaches, pilot comments indicate little or no visual ~~appearance~~ of a reflective rain core. The final audio remarks indicate the physical encounter with the windshear.

An outflow reflectivity of +5 dBz. at 6 n.mi. offers a rough calibration of the minimum detectable outflow reflectivity performance of the Westinghouse radar. As we introduced earlier, the RTP was installed aft of the pilot cockpit with additional waveguide run losses. We should expect to see lower reflectivities at shorter ranges, so, together with the range scaling and the ~~additional~~ ^{reflected} losses of a typical air transport installation, we may interpret an equivalent detectable reflectivity at 1.5 n.mi. (30 seconds of warning) of -5 dBz. **This particular microburst happens to be the least reflective outflow which we encountered, and the minimum detectable outflow reflectivity the Westinghouse radar system may expect is considerably smaller (better) than -5 dBz.**

Continental Airlines Airbus Flight Testing

The Continental Airbus installation has given Westinghouse a opportunity to collect data and observe radar operation in the commercial airframe environment. The object of the Continental flight test was to place a radar of expected performance into a typical airline installation environment and observe its performance in the clutter and ground moving target/traffic environments as provided by the approaches and take-offs of its schedule. This objective was not in principle concerned with encountering microbursts and verifying/evaluating equipment detection performance. The salient design reasons for the flight test addressed the false alert and accuracy aspects of the radar design. Certainly, the interest was to perceive how and to what extent clutter, including mainbeam clutter, sidelobe clutter, ground moving ~~vehicle~~ ^{service} traffic, etc. and any other phenomena encountered within the operational conditions of the aircraft approach and/or departure, including rf interference, will be evident to the radar. Such perceptions may allow some assessment of the false alert potential, but more likely, they furnish opportunities to Westinghouse to refine or add to its design.

Radar systems are dependent upon other systems on the aircraft for their satisfactory operation. Radomes and radome maintenance, mounting, vertical reference, altitude, etc. are furnished by the aircraft. Independent of any urban clutter - false alert concerns, there is much to be observed to insure a sensitive pulse-Doppler radar can properly operate, come what may with clutter.

Given that suitable hosting is provided, the regular flight patterns of an in-revenue service aircraft expose the radar to a variety of mainlobe, sidelobe, and second time around (STAE) urban and airport vicinity ground moving vehicular clutter.

The data collection radar system was supplied to Continental for installation. After supplemental type certification [4], the radar began supplying VCR display formatted video tapes at regular intervals. The installation of the Westinghouse equipment allowed non-interfering operation of the data collection radar with the on-board radar transparent to the pilot/crew. Whenever the radar was not being used, the Westinghouse radar would turn on automatically at altitude or takeoff using supplied aircraft discrettes and altitude data. The installation is largely an exploitation of the dual RTP operation expected for ARINC 708 equipment.

After returning to Baltimore, a different, more vivid colour palette was introduced to highlight activity. In general, the velocities of the outflows did not begin to approach 24 m/sec, so the velocity scale was reapportioned to ± 16 m/sec. The I and Q data recorded during the BAC-1-11 Orlando flights could be re-played through the RTP to produce new VCR displays and maps. The new palette uses a black background for zero activity. The amplitude scale indicates max (saturating) amplitudes by white decreasing to red, yellow, blue, green. The new velocity scale uses black for zero doppler with yellow, red as increasing magnitude tailwinds and green, blue, purple as increasing magnitude headwinds. The hazard factor uses black as zero, with yellow, red, magenta as increasing hazardous windshear and green to blue as increasing performance enhancing windshear.

The Orlando flights collected a mountain of radar data on microbursts. In general the clutter background was not worst case urban clutter, but some data was collected in/over the Orlando airport when it was closed to air traffic by the storms. This data allowed empirical studies of signal processing thresholds to reject non-windshear and ensure that windshear-like returns are retained without apparent loss. *In situ* data collection was limited. Air data collection was included at the last moment and its quality/collection is under examination and is questionable. TDWR radar data, available each day immediately after the respective flights, was used to "calibrate" the reflectivity/sensitivity of the radar, Doppler, and horizontal hazard processes of the data collection hardware and signal processing algorithms. Given their often differing perspectives on the events, the airborne and ground based radars produced excellent agreement in velocity and hazard factor and time and physical registration.

The Continental installation was initially equipped with unmodified Orlando signal processing algorithms. These algorithms were tailored to ensure that windshear would not be inadvertently edited/rejected, etc. Hence, the initial installed software configuration furnished only the simplest of mainbeam clutter processing as a means of rejection. Subsequent software updates included total hazard factor construction and a sliding window detection (400 m. range window with an window average $F=.105$ threshold) and optimized signal processing. All subsequent software loads were developed in the signal processing lab using the spare RTP unit as a test bed. The range gated in-phase and quadrature A/D data recorded during the flights for particular (i.e. hazardous) cases was played through the unit to check the performance of the PROMS (programmable read only memory chips) ~~which~~ destined for the Continental Airbus. Hence, the signal and data processing algorithms updating the Continental were verified to produce hazard factors, cautions, and warning alerts in correspondence to the corroborated Orlando microbursts. ***The software updates retain detection performance during periods of urban airport approach clutter false alert rejection algorithm observation, experimentation, and refinement.***

The latest software load included parameters and thresholds for the signal processing algorithms as determined empirically from reprocessing the Orlando flight test data.

The video segment shows a sample in-revenue service landing approach for two different software loads in side-by-side comparison into the same (Newark) airport. Although the PPI total hazard factor display of the earlier (incomplete) software load shows some caution and hazard factor activity (from the spurious returns entering the velocity map from sidelobe leakage of discrete targets), it might well be considered remarkably "clean" were it not for the other PPI display being absolutely free of any such false cautions and/or alerts, even down to minimum altitude (weight on wheels). This video short indicates the power of the combined signal and data processing of the final configuration.

The map/instrumentation displays of these two runs were not, of course, collected simultaneously. However, the results portrayed are representative of the false alert performance to be viewed on all the landing approaches and takeoffs of the respective configurations.

The Continental flight tests have allowed Westinghouse to observe the commercial air transport operating and clutter environments. The equipment has performed largely as expected. Software loads have demonstrated by superposition the power of signal processing in rejecting sidelobe/vehicle traffic leakage while fully retaining microbursts, i.e. the signal processing algorithms and data processing algorithms operated satisfactory on the collected microburst data without any detection losses. The thresholds for sidelobe/GMTI rejection were empirically determined to retain microburst windshear by training with the Orlando microburst data. The Continental flight test data argues that a combination of modern signal and data processing algorithms can eliminate false alerts without compromising necessary detection performance..

Summary

1. Westinghouse has provided a new design pulse-Doppler lookdown radar for the air transport market.
2. With the help of the FAA and TDWR and the procedures established with them during the NASA LaRC flights, unprocessed quantitative (FFT) airborne data was collected in Orlando on over 100 separate microbursts, including real time hazard factor maps.
3. Westinghouse demonstrated the first airborne real-time detection of microburst windshear using airborne radar signal, data and hazard factor processing.
4. With the help of Continental Airlines, clutter data on many urban airports has been sampled within the context of the Westinghouse design.
5. Westinghouse has used the raw (I,Q,FFT) data collected in Orlando on hazardous microbursts to verify that its subsequent software loads have retained the necessary hazard detection performance. [False alert suppression has not been achieved at the expense of detection performance.]
6. Westinghouse has demonstrated airborne real time sidelobe/GMTI clutter rejection and a potential for satisfactory false alert operation. [Demonstration of 100,000 flight hour false alert times takes a long time.]

*Demonstrated
Detection and Avoidance Range Sensing of Hazardous Windshear
AND
Low False Alert Techniques in Urban Airport Clutter*

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Success by Empirical Refinement

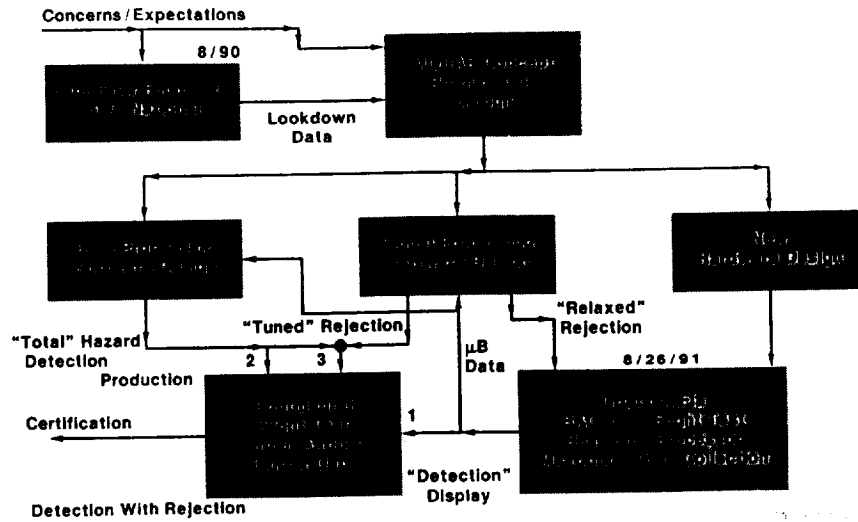


fig. 1 Overview of Approach

Low false alarm rate radar design must address mainbeam and sidelobe realities, particularly for sensitive detection near urban airports. Westinghouse has stressed the empirical detailed understanding of both microburst and urban airport clutter radar return in its design approach.

The Name of the Game ... Separate the Wind Return from Clutter

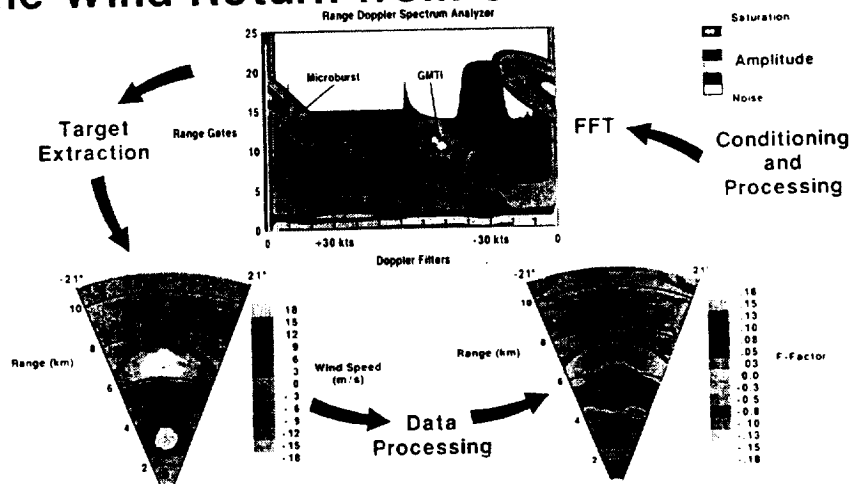


fig. 2 the Name of the Game... Separate the Wind Return from Clutter

Clutter and ground moving vehicular traffic returns must be separated from microburst outflow returns. This begins with a hardware design attendant of pulse Doppler realities and continues through digital algorithms to keep the wind blown rain and disregard non-windblown rain-like returns.

BAC1-11 Data Collection Configuration

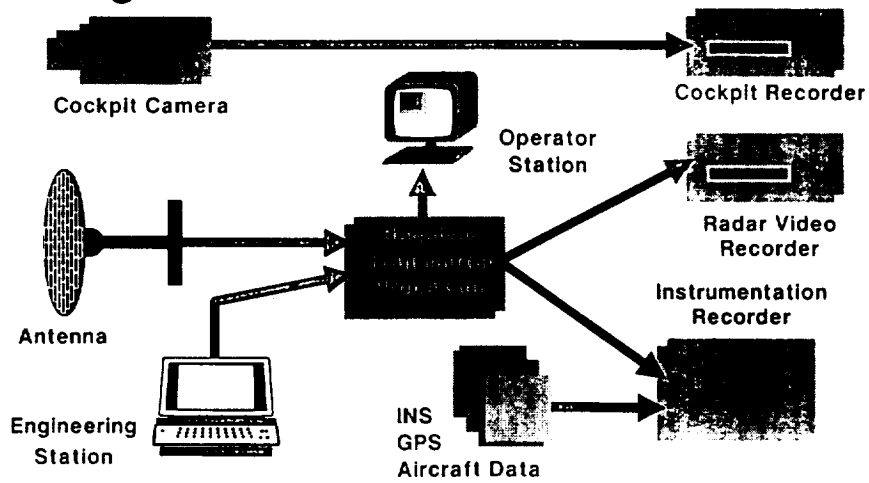
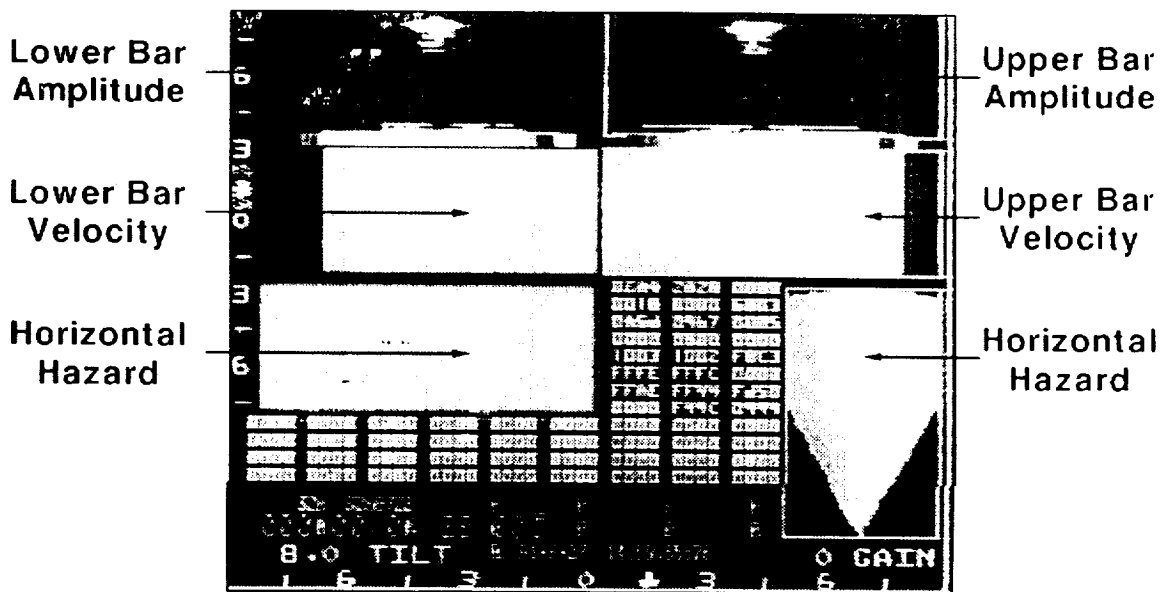


fig. 3 BAC-1-11 Installation

The BAC-1-11 installation includes ports for recording a variety of radar instrumentation and aircraft data.



G420909 (2) BD311

fig. 4 VCR Instrumentation Format

The VCR format allowed collection of a great quantity of data of differing types. The discrete words included aircraft data and general processor health/activity parameters. The velocity display covered ± 24 m/s in Orlando with 16 colour shades (± 16 m/s on Continental Airbus). The hazard factor map covered $-0.2 \leq f \leq +0.2$

**Acquisition and Use of Orlando, FL and Continental Airbus Radar Flight Test Data
Questions and Answers**

Q: Roland Bowles (NASA Langley) - Do you consider the ground clutter problem, both fixed and ground moving, solved?

A: Bruce Mathews (Westinghouse) - Yes, I do. The only thing I see remaining is a demonstration of the hazard factor accuracy in the presence of competing clutter.

Q: Roland Bowles (NASA Langley) - On a couple of the charts I saw the words "proven performance." On what kind of scientific basis do you claim proven performance, and would that be admissible in your certification initiative?

A: Bruce Mathews (Westinghouse) - I am not sure what is admissible to certification. We are engineers we are not scientist, we are not doing science. We have a great deal of faith and understanding in the principles of radar. We believe what we see, and it correlates very well with the TDWR. When they say they have an outflow reflectivity and velocity and we get the same thing, that is what we expect, and we are getting it. We do have a limited amount of In Situ data that we collected. We do not have a great deal of faith in it and there is not much we can do because it is limited.

Q: Roland Bowles (NASA Langley) - Do you plan to get it?

A: Bruce Mathews (Westinghouse) - We plan to get it this summer.

Q: Roland Bowles (NASA Langley) - Can you show us how your radar correlated, in your one hundred events, with the TDWR data?

A: Bruce Mathews (Westinghouse) - I think we can show that, yes. But, I don't have a viewgraph to show it right now.

Q: Roland Bowles (NASA Langley) - Dave Hinton talked about this yesterday, and I think Steve Campbell will further elaborate on it. Depending on how you flew and where you were relative to the divergent center, the TDWR could be viewed as significantly overestimating. We went through a very careful selection criteria to pull out the microburst encounters that really warranted detailed inspection. I would appreciate it if you could show us sometime what you have done, maybe later in the conference.

A: Bruce Mathews (Westinghouse) - Well, we are hoping to get that data. We do not have In Situ data, so we can't give you that kind of analysis. That is all there is to it. The data we have from our Sundstrand is very unsatisfactory.

Q: Jim Evans (MIT) - First, I would like to make a comment on the value of In Situ data. One of the key issues is the altitude dependence of the outflows, and where you are measuring versus where you should be measuring. We are flying our tests up at 1000 feet or above and we think the threat is a lot worse at lower altitudes. I think that is the first point we ought to recognize.

The value of In Situ is somewhat limited here because in fact you are not totally realistic as to where you should be flying. But that leads to another question. At what altitude where you attempting to measure in the measurements that we saw here? That is a very important issue in terms of your overall system performance and it has important implications. You did not really say at what altitude your antenna measures?

A: Bruce Mathews (Westinghouse) - We showed a two bar scan. We have one bar which we call an upper bar which points up and its principle purpose is to look at the reflective core and to make a higher altitude measurement of the outflow. As you can see in some of the displays, there was a stronger outflow in that upper bar than in that lower bar. The lower bar looks as near to the glide slope as a function of altitude as we dare. We tend to pick the beam up to keep the receiver from saturating, to stay in linear operation and to avoid unwanted clutter and saturation effects in the receiver. We picked the beam up as we come down in altitude. Now for these flight test in Orlando that beam was probably not doing a lot because we were flying fairly level at 1000 feet. When we land into Newark we are picking the beam up as a function of altitude controlling the beam with aircraft data. That is why the Continental Air Bus flight is important, to see how well that algorithm works. Some of the adjustments we wave made were to pick that up a little bit faster, because we saw a little bit more three sigma chatter in the elevation accuracy of the antenna than we had anticipated. Summarizing, we seek to make an estimate or a statement of the hazard factor along the glide slope that the pilot is flying. We look with two beams, one well above the glide slope and one very near to the glide slope to make that estimate.

Q: Pete Sinclair (Colorado State University) - How was the vertical motion determined?

A: Bruce Mathews (Westinghouse) - Westinghouse determines the vertical hazard factor using an algorithm which we would say is an extension of the NASA work that Dan Vicroy has reported. Because we have a two elevation bar scan, we measure the outflow velocities at two altitudes. Now, if you have two points you can draw a line between them. If you have a linear polynomial and you integrate it like you would for a conservation of mass principle, like Dan uses in his treatment of vertical estimation, you would get a quadratic polynomial, and that is what we do.

Q: Pete Sinclair (Colorado State University) - Was aircraft data or radar data used in this calculation?

A: Bruce Mathews (Westinghouse) - It is all radar data.

Q: Pete Sinclair (Colorado State University) - At what altitude is the calculation valid?

A: Bruce Mathews (Westinghouse) - The altitude is the altitude along the glide slope, that is what the calculation is made for. It is for every range gate along the glide slope. There is a separate vertical hazard factor calculated for each one of those range gates.

Session V. Doppler Related Research

