E I G H T   E U R O P E A N   R O T O R C R A F T   F O R U M

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STRAPDOWN INERTIAL NAVIGATION SYSTEMS FOR HELICOPTERS

prepared by "Departement Pilotage Navigation Integration"

du Service Technique des Télécommunications et Equipements Aéronautiques

presented by I.C. MOREAU

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STRAPDOWN INERTIAL NAVIGATION SYSTEMS

FOR HELICOPTERS

I - INTRODUCTION

To meet operational specifications issued by GALAT for handing his new PUMA and GAZELLE helicopters, STTE started on 1977 the development of a self-contained Navigation System.

The system, fitted for good navigation performances, is composed with :

- Doppler radar RDN 80 from ESD.
- Gyromagnetic compass CG 512 from SFIM.
- Vertical detector :
  GV 76 from SFIM (PUMA)
  H 140 from SFENA (GAZELLE)
- Anemometric unit type 51 from CROUZET, delivering Vc and Ti.
- Navigation computer type NADIR from CROUZET.
- Horizontal Situation Indicator IP 152 from CROUZET.

See figure 1

This self-contained navigation system has been worked out and tested at CEV center. ALAT performed an evaluation on it to demonstrate requested performances (2 % flight distances, 2 σ apart).

The navigation system is now on production. PUMA and GAZELLE helicopters are being equipped.

II - HAC - HAP PROGRAMS

D.T.C.A. (Air Armement Technical Services) started studies of syst design in first for HAC helicopter, then for HAP helicopter.

Navigation subsystem studies had to deal with :

- fire system facilities (Gun, rockets, missiles),
- autopilot services,
- navigation performances :
  - Cruise flight - 1,5 % distance, 2 σ
  - Tactical flight - 300 m / 1/4 H, 2σ

Then navigation subsystem specifications could be issued.

Studied solutions were :

- self-contained navigation system, discribed in paragraph I.
- Inertial - Doppler system.
- Complete Inertial system.

Self-contained navigation system

ALAT navigation system could meet position performance with an impro ved magnetic unit (compensation of magnetic errors and disturbances, neces sary). Needs of weapon system added gyrometer and accelerometer componer to the basic system (air to air fight - angular speeds : few degres per seconc required - accelaration : few 10^{-2}).

Specifications were then completely assumed. Higher performances, i required in the next future, will be limited to inertial components improve ments.

Inertial systems

- Inertial - Doppler System
- Complète Inertial System

Complete Inertial solution seems less to meet helicopter navigation because of low speeds in tactical missions.

Inertial - Doppler system, non regarding cost aspect, must satisfy all specifications.

Two ways have then been engaged :

- solution based on Inertial plateform unit with relative poor performances - error of few nautics in an hour.

- strapdown unit of same class performances.

The first alternative is well known in aircraft applications, so it shouldn't present difficult helicopters adaptations.

III - STRAPDOWN SYSTEM

The second one, strapdown based solution, is less known but presents sure advantages :

1) slighter acquiring cost,
2) weapon - system integration easier : parameters directly delivered in helicopter references,
3) better reliability,
4) lighter weight,
5) easy maintenance in operation.

In order to valid inertial systems nw concept, and overview specific helicopter in use problems as :

- alignment delay (stopped and turning rotor operations),

- navigation performances (navigation in route and tactical flights).

S.T.T.E. decided an evaluation of such an hybrid system strapdown based solution.

Standard architecture system is showed in figure 2 .

Principaly composed of :

- strapdown unit,
- doppler navigation radar,
- pressures box unit,
- gyromagnetic reference,
- navigation display indicator,
- commands and displays box unit..

Basically, the navigation system has the following characteristics :

- self vertical alignment,
- heading alignment by copying magnetic direction,
- hybridization of inertial and doppler speeds,
- hybridization of inertial an barometric informations (Vz),
- manual keying of the system on the true map position,
- delivery of calculated parameters on a data bus.

Several new sensors technologies appeared and started on productior by 1977 - first 1978.

In order to minimize development costs of these new helicopters navigation systems, S.T.T.E. services rested on previons studies in components and systems :

1) S.T.En (a D.T.En service) reached out an inertial guidance unit for missiles from SFENA and CROUZET industries :

   - a 21 cm perimeter laser gyrometer (G III), few 0,1°/h class, was developped.
   - inertial subsystem grouping those 3 laser gyrometers, plus 3 MICRACC accelerometers was assembled.
   - calculation soft (virtual plateform) found place in a standard SFENA computer (UMP).

2) S.T.E.T. (a D.T.En service) conducted in 1977, SFIM industrie realisations :

   - a harmonized suspending gyrometer (GAM III), few 0,1°/h class.
   - a guidance unit for tactical missiles composed with those 2 gyrometers, 3 Q flex accelerometers, a specific calculator. The syster is called SIL 3.

Heading source : magneticmeter 3 axis with self compensation of magne tic interferences (hard and soft irons)

Alignment : 65 s delay, heading precision 0,25° average.

Navigation : in directionnal mode.

2) <u>26 SH (SFIM)</u>

Heading source : blocked flux-valve, self compensation of magneti interferences, magnetic earth field mathematic model

Alignment : 65 s delay, maximum error 0,9°.

Navigation : in a gyromagnetic mode (hybridization of inertial and magne tic headings).

<u>Comments</u> : Today, SFIM constructor proposes a new system derived fro 26 SH : 28 SH unit, lighter, more economic with optimise performances, for HAP helicopter.

3) <u>MSD (SAGEM)</u>

Alignment : 1 minute when copying magnetic heading
9 minutes with gyrocompass reaching geographic north.
precision : 1,7°, 2 σ apart.

Navigation : in directionnal mode.

<u>Comments</u> : more studies to reduce alignment delay are in course 4,5 minutes - precision 0,4°, 2 σ apart.

V - <u>CONCLUSION</u>

Tests andd evaluations conducted by CEV center on S.T.T.E. demand showed that the "trapdown navigation concept" suits to the specific helicopte environment (linear and angular short and quick motions).

3) S.T.T.E. services resting on a self conducted SAGEM study on mini harmonized suspending gyrometer (GSD), few 0,1°/h class, launched in 1978 the realisation of a strapdown unit prototype meeting ARINC 705 recommandations.

Thus keeping on results of studies rapidly discribed above, S.T.T.E. launched an helicopter strapdown navigation unit development. Main adding subsystems to former realisation are :

- commands an displays box unit,
- necessary calculator inputs for doppler radar and pressures box unit,
- output according to ARINC 429,
- calculation soft of the virtual plateform suited to vibrations helicopters environment,
- hybridization calculations of doppler and anemometric informations,
- navigation calculation soft (flight plan, input - output gestion).

3 prototypes systems were developped :

- SEXTAN I unit from CROUZET - SFENA association,
- 26 SH unit from SFIM,
- MSD 01 unit from SAGEM.

They have been tested and evaluated at CEV center from early 1980 to mi 1982. After a short put in order period, tests were conducted on :

- alignment performances,
- in route performances,
- tactical flight performances.

The 3 new systems meet to S.T.T.E. service specifications

IV - PERFORMANCES ISSUED FROM EVALUATIONS (see table 1).

1) SEXTAN I (SFENA - CROUZET)

First strapdown gyrolaser system wich has flown in FRANCE

- alignment performances reached with non rotating or rotating helicopter.
- parameters performances according specifications for military helicopter missions.
- weapon system integration made easier (out put datas in helicopter references).

This concept will be taken on consideration in new military helicopter navigation system definitions.

FIGURE 1

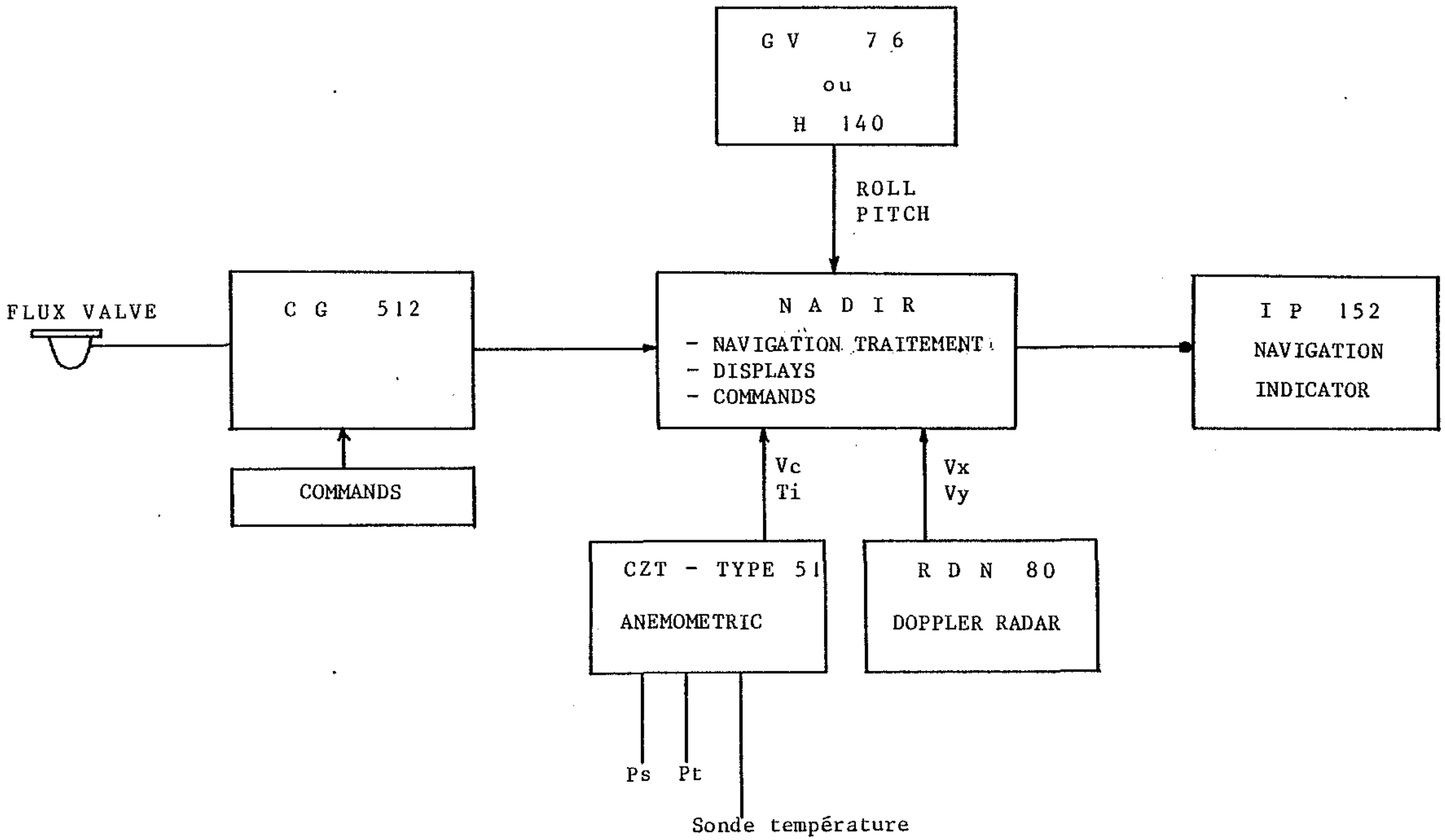
G V 7 6
ou
H 140
ROLL
PITCH
FLUX VALVE
C G 512
COMMANDS
N A D I R
- NAVIGATION TRAITEMENT
- DISPLAYS
- COMMANDS
I P 152
NAVIGATION
INDICATOR
Vc
Ti
Vx
Vy
CZT - TYPE 51
ANEMOMETRIC
R D N 80
DOPPLER RADAR
Ps
Pt
Sonde température

FIGURE 2

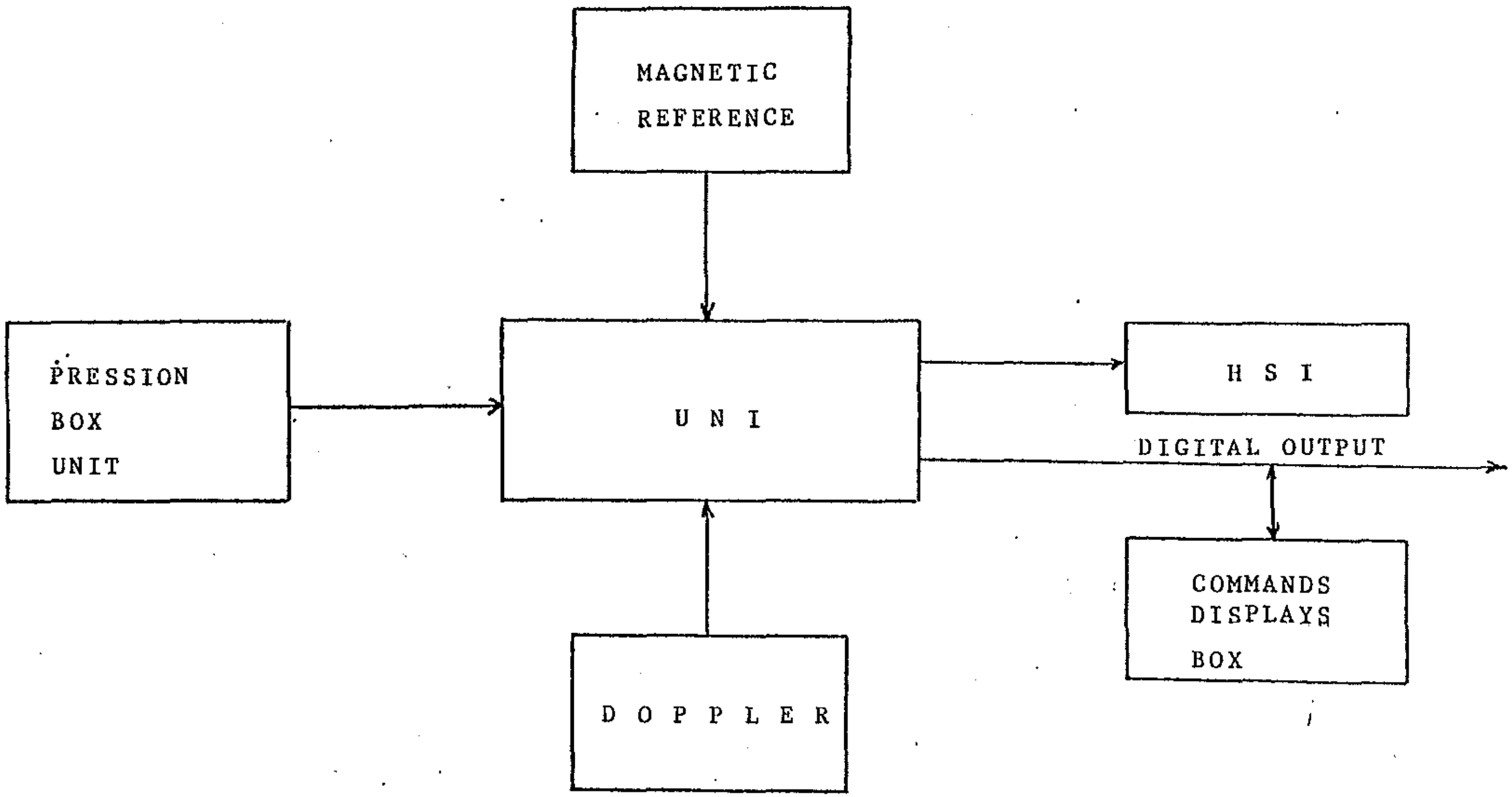
MAGNETIC
REFERENCE
PRESSION
BOX
UNIT
U N I
H S I
DIGITAL OUTPUT
COMMANDS
DISPLAYS
BOX
D O P P L E R

TABLE I

PERFORMANCES ISSUED FROM CEV CENTER EVALUATIONS

SYSTEM	CONSTRUCTOR	ALIGNMENT DELAY	LEADING ERROR	POSITION ERROR, 2σ APART	
				IN ROUTE FLIGHT	TACTICAL FLIGHT
SEXTAN 1	CROUZET	65 s self compensated magnetic heading	0,25° average	1,3 % of flight distance	≤ 270 m for 1/4 h
26 SH	SFIM	65 s self compensated magnetic heading	≤ 0,9° maximal error	1,45 %	≤ 444 m for 1/4 h
MSD 01	SAGEM	9 mn gyrocompas alignment	1,7° 2σ apart	1,7 %	340 m for 1/4 h