A SURVAYS ON FADING CHANNEL OVER WEST - JAVA AREA FOR FLIGHT TEST RADIO TELEMETERING PURPOSES

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ABSTRACT

This paper discusses one approach to determine a characteristic of West - Java's air and ground segment as a block-box to accomodate radio waves propagation, especially in L-band ranges, by evaluating both the topographical data and radio reception pattern as measured from ground based telemetry receiving-end system. All the measured signals are random and assumed to be stationair and ergodic. In order to characterize the channel for polarization diversity reception, some statistical analysis are applied to the signal strength measured of both - RHCP and LHCP components of 1531 MHz propagated waves as transmitted fr om NC212-200 PK-NZJ-aircraft.

Some computer calculated correlograms of measured data are shown herewith, it is focused for a certain radio corridor at radial 265° relative to the ground based receiving antenna. More over some curves of predicted multipath gain factor are also presented to gain more theoretical back ground.

When this paper is written, a further field experiments on the matter concerned is beeing conducted.

KEY WORDS: Airborne data relay system, correlogram, fading environment, radio corridor, radio reception pattern, statistical approach.

INTRODUCTION

Back ground

In the early 1987's, the whole IPTN's engineering flight test activities at the Kemayoran Flight Test Center (KFTC) had to be moved from Kemayoran Civil Airport (situated at the northern coast of West Java) to IPTN's industrial complex at Bandung (situated at the inland of West Java) after two years served the CN235 prototype aircraft type certification flight test program. Its regard to the clossing down of the Kemayoran airport as one the civil airfield in Jakarta from the beginning of October 1986.

As a new flight test base, the IPTN's industrial complex is more managerialy convenient and more time effective than the previous. But due to the mountainous land profiles exist in between Bandung and test areas (see Figure 1) it is almost impossible to get a good transmitted signal from test vehicle without any other additional supporting system. For illustration, the height of surrounding obstacles within radius of ± 47 Sta.Mi from test base are at ranges of about 1400 feets up to 5500 feets as measured from NUSANTARA plane (IPTN ground as the plane of reference).

Figure 2 gives a good diagramatical impression on the environment situation by radio line of sight profiles as observed from test base for varous angles of azimuth from 58° up to 352°. Based on the above reasons, such a highly movable flying radio relay system had been decided to be established to support the whole flight test activities which are conducted over all the possible flight test areas at West Java. By making use of NC212-200 commuter aircraft, the ADReS, a short for airborne data relay system, had been configured and tested in an experimental status since May 1987 [*].

However, some major telemetering problems come to the surface which could be comprehended from the following constraints : 1. The relay aircraft has to be flown near the test aircraft is a chaser, and it has to be able to cover a certain test configuration over the ocean as low as 100 feets a.s.1 ; 2. The relay aircraft has to be able to maintain data transmission to the ground based telemetry system during the mission conducted in interuption free status.

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[*] See Adi Dharma S., Fauzi E.R., THE ITPN'S AIRBORNE DATA RELAY SYSTEM (ADReS). A SYSTEM CONCEPT AND THE PHASE ONE SYSTEM CONFIGURATION, - Proceedings of ITC/USA/88, Las Vegas, N.V., Oct. 1988.

link (betwen relay aircraf and ground based receiving antenna), the link reliability was seems predominantly affected by the wave propagation anomalies which might caused by the ground multipath interference and waves diffraction. Therefore to see deeper the above phenomena quantitatively, especialy for air to ground link, the West Java area is observed further and it is consider as a black-box exist in between aircraft mounted transmitting and ground based receiving antenna. This research is a portion of the flyght test radio telemetering network establishment program conducted since June 1988.

When this paper is written, a further survays is being performed and the method involved in this research is continously verified and developed. It is the reasons that some conclussions included in this paper is the subject might to be revised in the future.

Objective

The objective of the paper is to describe one approach to determine a characteristic of the West Java area by both topographical and statistical analysis for flight test radio telemetering aims, in conduction with the IPTN's telemetry network supported by ADReS. The analysis is focused to characterize the transmission medium (the space in between where the waves is propagate) in conjunction with the utilization of polarization diversity techniques radio reception at frequency range of 1531 MHz.

APPROACH

The concept.

The signal as received by ground based receiving antenna could be expressed mathematicaly as the following :

$$y(t) = x(t) + n(t) \qquad (1)$$

Where x(t) is the signal which is perturbed by the noise free environment, and n(t) is assumed to be zero mean white Gaussion random process with two sided spectral density of $N_0/2$ Watt/Hz Further related to the transmission medium, the perturbed signal could be expressed as follow :

$$x(t) = \int_{\infty}^{\infty} c(A,f,t)\ s(f)\ df \qquad (2)$$

Where c(A,f,t) is time variant transfer function of the channel and s(f) is spectrum of the signal. Equation 2 is the expression of x(t) in frequency domain. As the derivative of input signal s(t) (it means the waves transmitted from aircraft mounted antenna and "supplied" to the medium), x(t) could be written in the other expression :

$$x(t) = \left[c(A,f,t) \right] s(t) \tag{3}$$

where :

$$\begin{aligned} s(t) &= A_0 \sin(\omega_0 t + \theta_0 + \psi) \\ \omega_0 &= 2\pi f_0 , \quad 0 \leq t \leq T \\ \psi &= 0, \pi \end{aligned} \tag{4}$$

In our discussion, C is the parameter what we are concern to, whic is contributed by a sever factors, those are :

(1) Multipath fading due to the ground reflection. It is depending on the relative position between the aircraft and ground based receiving antenna.
(2) Edge scattering and diffraction effects due to the dynamic motion/ movement of the aircraft which will generate such a dynamic obstacles (by aircraft stuctures) in the direction of ground based receiving antenna.
(3) Time varian losses due to the atmospheric and cloud absorptions.

The third factors is difficult to be predicted. It is also depend on the aircraft slant range from receiving antenna.

In order to minimize the influence of this factors, it has to be convinced that the aircraft will fly in such a good weather and "clear" space.

In our case, the first and the second factors are seems to be the dominant parameters. They will give a negative fading deeps in signal reception during inflight data transmission. The edge diffraction effects caused by the aircraft structures could be calculated and predicted by computer simulation using geometrical theory of diffraction (GTD). When this paper is written, the simulated edge diffraction effects is beeing examined and evaluated.

To have illustration on the influence cf ground reflected signal, the multipath gain effect could be predicted over a real land profiles according to the following expression :

$$E_r^c = E_{max} P(\theta - \theta_t) G_M(P1, D, |\vec{\Gamma}|) \tag{5}$$

where :

E_r^C : total signal power at receiving antenna
$P(\theta - \theta_t)$: antenna power pattern
$G_M(P1, D, |\vec{\Gamma}|)$: gain of reflecting ground

By single reflecting point model, the gain of reflecting ground could be expressed by :

$$G_M = 10 \log_{10} \left[1 + (P1\ D |\vec{\Gamma}|)^2 + 2\ P1 D |\vec{\Gamma}| \cos(\alpha - \phi) \right] \qquad (6)$$

where :

P1 : antenna gain
D : spherical earth dispersion factor
$\vec{\Gamma}$: ground reflecting coeficient
α : phase difference of the waves
ϕ : phase of reflection coeficient

G_M could be calculated for either horizontal (H) or vertical (V) polari ze d waves following reflection coeficient calculations. For rough surfaces :

$$\vec{\Gamma} = \vec{\Gamma}_{eff\ V,H} = \vec{\Gamma}_{V,H}\, e^{-\check{X}^2/2} = |\vec{\Gamma}_{V,H}|\, e^{-(\check{X}^2/2 - j\ \ V,H)} \qquad (7)$$

$$\check{X} = \frac{4\pi}{\lambda_o} \Delta h \sin \psi_i$$

where :

$$\check{X} = \frac{4\pi}{\lambda_o} \Delta h \sin \psi_i \qquad (8)$$

Δh is standart deviation (from its mean value) of the reflecting ground e levation, ψ_i is grazing angle of the wave.

The multipath fading prediction will give a sufficient explanation on where the aircraft could fly over (at a certain altitude) whithout any “fading trap” will occur. The combined analysis over topographical data, multipath gain prediction and field experiment data will give a rough figure on the characteristic of observed areas.

The Evaluated data.

Study and analysis are performed over the three kinds of data, those are : 1. Data on the topographical landprofiles of the West Java area, 2. Data on the multipath gain effect as computer calculated, 3. Data on the received signal strength got from the field experiments. The first kind of data is needed to derive such a radio line of sight profiles of the area observed from test base, as depicted in Figure 2. From the diagram we could find further a suitable test area which has possibility to link the data to the test base either directly or indirectly. As shown in Figure 1, there are three test areas available, and only one area as condidate, whereas three radio corridors are available to link the test area with test base. The radio corridors are exist in the radial of 111°, 260° and 280°, relative from the test base.

As previously mentioned, the second kind of data will give illustration on the expected areas which has no negative fading trap. After evaluating the first data, then the predicted gains of reflecting ground are computed over dry reflecting surfaces (ε_{r2} = 3.5 ; σ = 0.0001 mho. m/m^2) for each radio corridors for various slant ranges and various aircraft altitudes. Those G_M are diagramaticaly illustrated as depicted in Figure 3, 4 and 5 respectively. For first approximation, calculations polarized waves. From Figure 3 (a, b, c and d), negative fading trap are gradualy occur at slant range of 5 Sta. Mi up to 13 Sta. Mi for horizontaly polarized waves. The negative fading deep as high as -62 dB is occur at slant range of 11 - 12 Sta. Mi. Radial 265° (see Figure 4) gives more fluctuation in G_M for both polarized waves. Slant ranges in between 15 Sta.Mi and 35 Sta.Mi gives the best choice for the aircraft will hold over, whereas slant range of 50 - 55 Sta.mi will be the other choices.

The third data got from the field measurements is required in this survay to see quantitatively the influences of the environment (both air and ground segment) to the transmitted signal in relation with reception with reception reliability. The signal of 1531 MHz is transmitted from the NC212-200 PK NZJ/ ADReS aircraft over a certain radio corridor for various altitudes and various slant ranges. The signal is received by L-band parabolic tracking antenna in both left handed and right handed circularly polarized (LHCP and RHCP). The variation of signal strength received will be represented by the variation of AGC signal of the L-band receiver and then recorded by strip chart recorder. In order to get stationair data during measurement, the aircraft will fly in a circle pattern and perform both clock wise (CW) and counter clock wise (CCW) flight movements. Figure 6 show the structure of the above mentioned measured data which should be got from the field experiments, For data analys is purposes, those field strength data (in analog form) then will be extracted in a numerical quantities to be staticaly computed for finding both its auto and cross correlation functions, according to the following approximation formulas :

$$\hat{R}_x(k) = \hat{C}_x(k) + \bar{X}^2 \quad , k = 0,1,2,\ldots, N/2 \tag{9}$$

for autocorrelation function, where:

$$\hat{C}_x(k) = \frac{1}{N}\sum_{n=0}^{N-|k|-1} (X_n - \bar{X})\,(X_{n+k} - \bar{X}),\ k=0,1,2,\ldots, N/2 \tag{10}$$

$$\bar{X} = \frac{1}{N}\sum_{n=0}^{N-1} X_n \quad ,n = 0,1,2,\ldots, N-1 \tag{11}$$

are approximation of the autocovariance function and estimate of mean value μ_x respectively; and

$$\hat{R}_{xy}(k) = \hat{C}_{xy}(k) + \bar{X}\bar{Y} \tag{12}$$

for approximation cross corelation function, where :

$$\hat{C}_{xy}(k) = \frac{1}{N}\sum_{n=0}^{N-|k|-1} (X_n - \bar{X})(Y_{n+k} - \bar{Y}) \tag{13}$$

$$\bar{Y} = \frac{1}{N}\sum_{n=0}^{N-1} Y_n \tag{14}$$

are approximation of the crosscovariance function and estimate of mean value μ_y respectively.

FIELD EXPERIMENTS

The field experiments are pointing to the following main objective s : 1. Observing a telemetry coverage distances for both air to air (from test aircraft to relay aircraft) and air to ground (from relay aircraft to ground based receiving antenna) telemetry link, 2. Observing the reception pattern as influenced by the environment, for a certain aircraft position, 3. Observing reliability of the data received as transmitted from test aircraft and then relayed by relay aircraft (ADReS) to ground station.

Figure 8 show the configuration of the system field experiments. Moreover to have more illustration on the ADReS hardware involved in this test, a hardware layout of the ADReS inside NC212-200 PK-NZJ aircraft shown in Figure 7.

In thsi test, a simulated PCM data is modulate 1531 MHz carrier and transmitted from test aircraft (IPTN's CN235-20X) and then relayed by NC212-200 PK-NZJ/ADReS aircraft to ground station. A signal strength are recorded both on board of relay aircraft and at ground station. Reliability of PCM data received, which is represented lock and loss status of PCM decommutator is also recorded on ground. Figure 9 show a typical data recorded as previously mentioned. From Figure 1 and 2, and refere to the flight test requirements, it could be concluded that the test area No. II is the best area available. From this area, the data could be linked to ground station (flight test base) via relay aircraft. The last mentioned aircraft will fly (in a circle pattern) over radio corridor No. II (radial of 265°), at distances of about 80 Sta. Mi (HS_1 see Figure 1) from test base and of about 40 Sta. Mi from test aircraft.

For the above reasons, the most inflight measurements were conducted over radio corridor No.II.

TEST RESULTS.

It could be concluded from the field experiments, as the followings :

* Reception reliability due to the fading environment :

  From link test obtained that ± 265° radial/ ± 69 Sta. Mi, ± 111° radial/± 75 Sta. Mi and 280° radial/ ± 23 Sta. mi are the most suitable holding space for relay air craft to cover the second and the third test area, includsboth northern and southern region emergency airports. Due to the existance of the northern obstacles (± 6800 - 7300 feets a.s.l. height at 12 Sta. Mi from test base), it is impossible for relay aircraft to link the first test aircraft to link the first test area with test base.

  From link test conducted over the second radio corridor (radial 265°, as the best choise to link the second test area with flight test base), the max. distance for air to air TM link was only ± 23 Sta. Mi, whereas for air to ground link the maximum link distance was ± 82 Sta. Mi. Reliability of the data reception was very sensitive with the relative position between aircraft (transmission antenna) and ground based receiving antenna which might caused by aircraft edgr diffraction. The multipath effect is might the other reasons to reduce the reception reliability. During test aircraft - relay aircraft - ground station TM link experiments, it was detected such a kind of r.f. coupling from transmitting to receiving antenna of the relay aircraft in order between 25 up tp 35 dB which depend upon the aircraft position relative to the ground surfaces, and occured when the aircraft flown below 4000 feets.

  This coupling cause receiver's sensitivity degradation.

* Phase diversity techniques applied.

  From analysis through both autocorrelation and cross correlation function of both LHCP and RHCP (received) signal (see Figure 10, 11 and 12), phase diversity techniques is not proper to be used in this such a transmission medium. It was not give such an "overlay effect" between LHCP and RHCP signal. It could be comprehended from Figure 12, that there is meaningless improvement by using of circularly polarized phase diversity technique in the system. The pattern of autocorrelograms, as depicted by both Figure 10 and 11, are not much differ with their cross correlogram as shown by Figure 12.

From Figure 13 and 14 it also could be summarized the influence of the above factors (i.e. edge diffraction, multipath) to the reception pattern of ground based receiving system for various aircraft heading, is very evident especialy when the aircraft fly over a radio corridor No II.

CONCLUSION

The concept, field experiments and the test results on the Western Java area as a fading channel are discussed. From the test results, it is temporary concluded that the radial of 265° is the sufficient radio corridor available to link the second test area (over the Indonesian Ocean) with the IPTN fligth test Base. However, due to the fading environment exist in between relay aircraft and ground based receiving antenna, signal reception using polarization diversity techniques is not sufficient for the systems. The utilitation of frequency diversity techniques has to be considered. To have the optimal solution for the telemetry system as a whole, it has to be examined further.

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(ii) To the pilot team of Flight Operation Division for their earnestness to support the program during on ground and flight measurements by handling the NC212-200 PK NZJ aircraft.
(iii) To the Fixed Wing technicians of Aircraft Service Devision for their help to take care the NC212 - 200 PK NZJ aircraft during field experiments.

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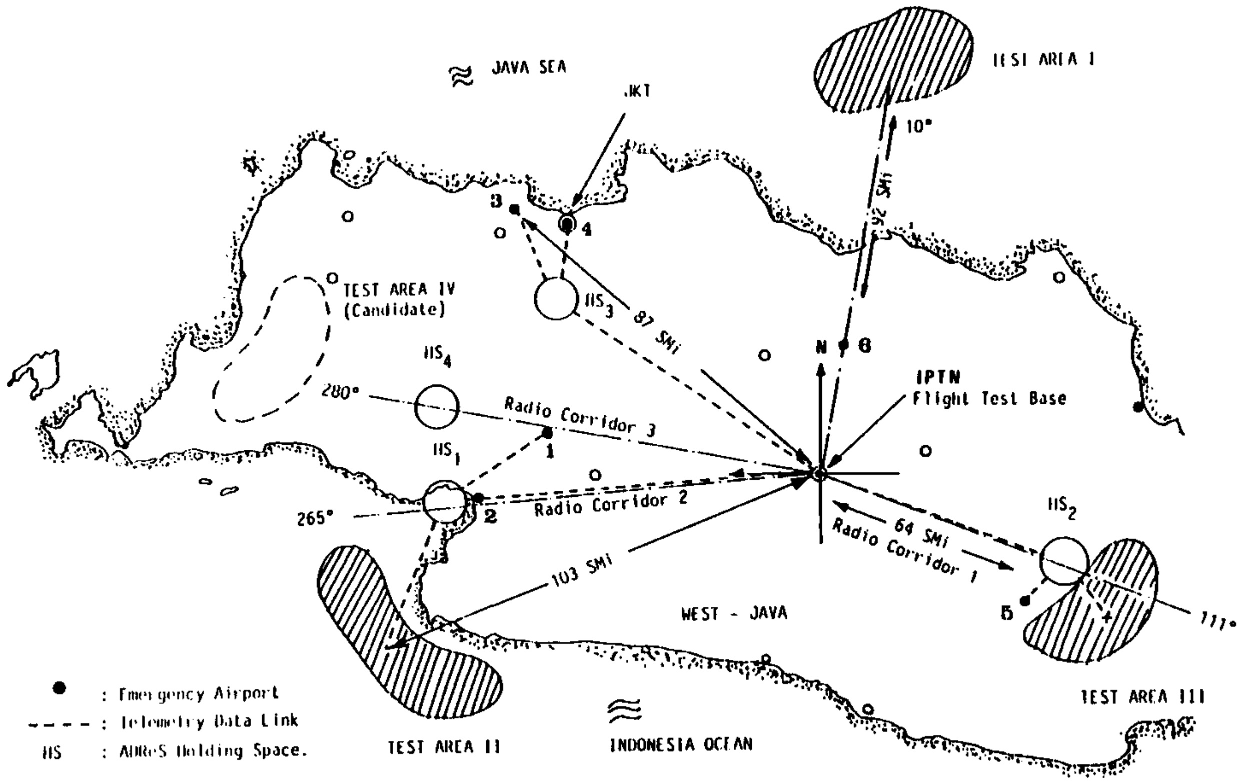

Figure 1 - A situation of Western Java as a flight test area. IPTN flight test base is located at the center of iland.

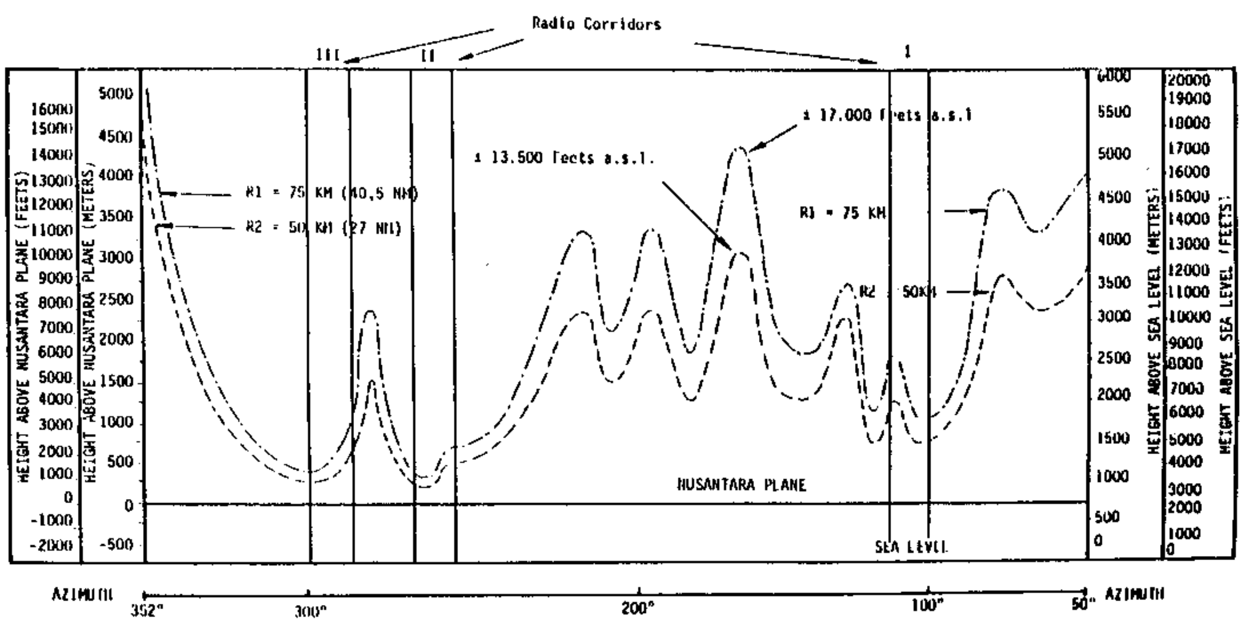

Figure 2 - Radio line of sight profiles of Western Java as observed from IPTN flight test base.

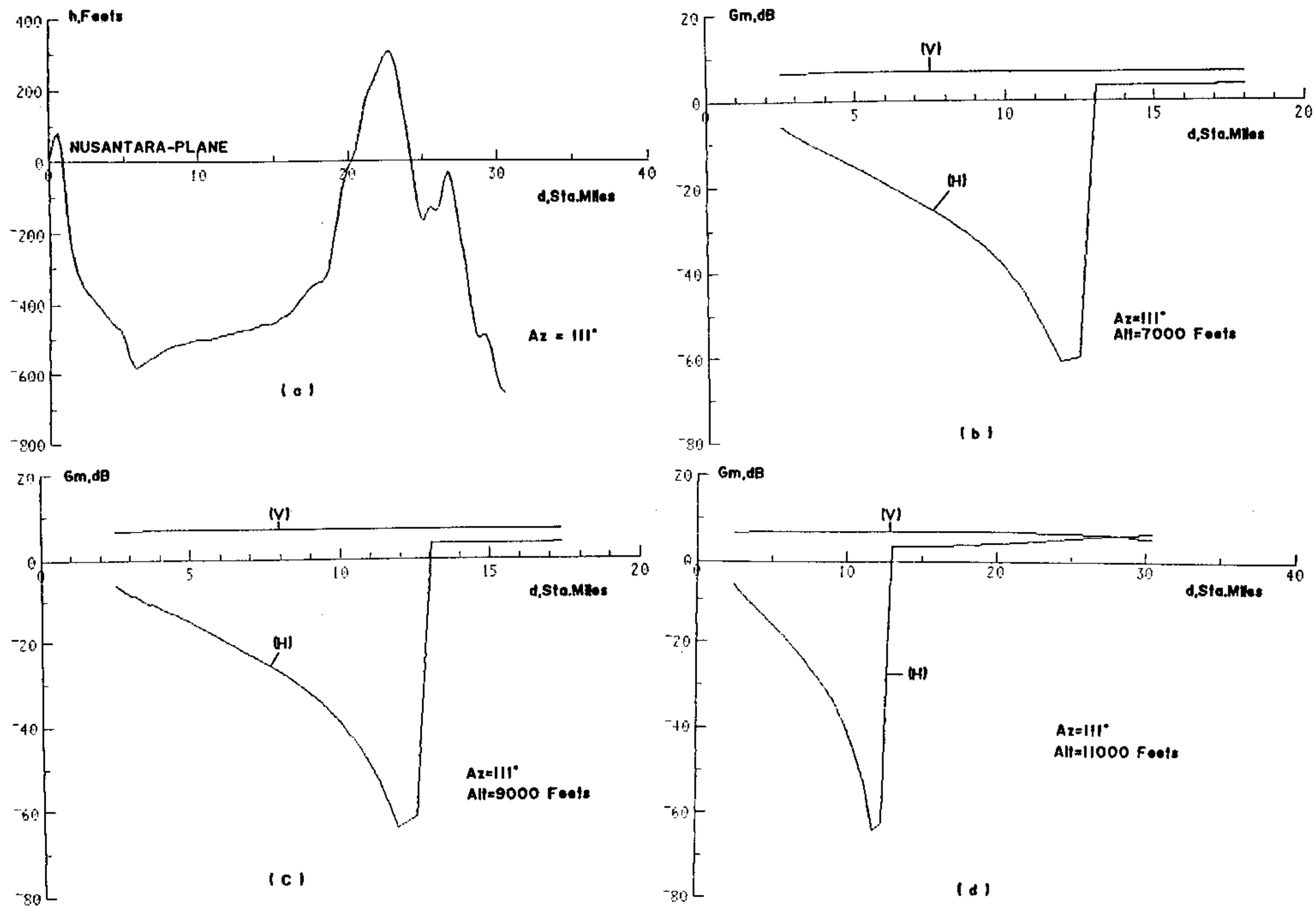

Figure 3 - Multipath fading estimation due to dry earth reflection, relative to the ground based receiving antenna, at f_0 = 1531 MHz for azimuth 111°. (a) Surface profile; $G_{MV,H}$ for (b) 7000 feets (c) 9000 feets altitudes. (d) 11000 feets altitudes.

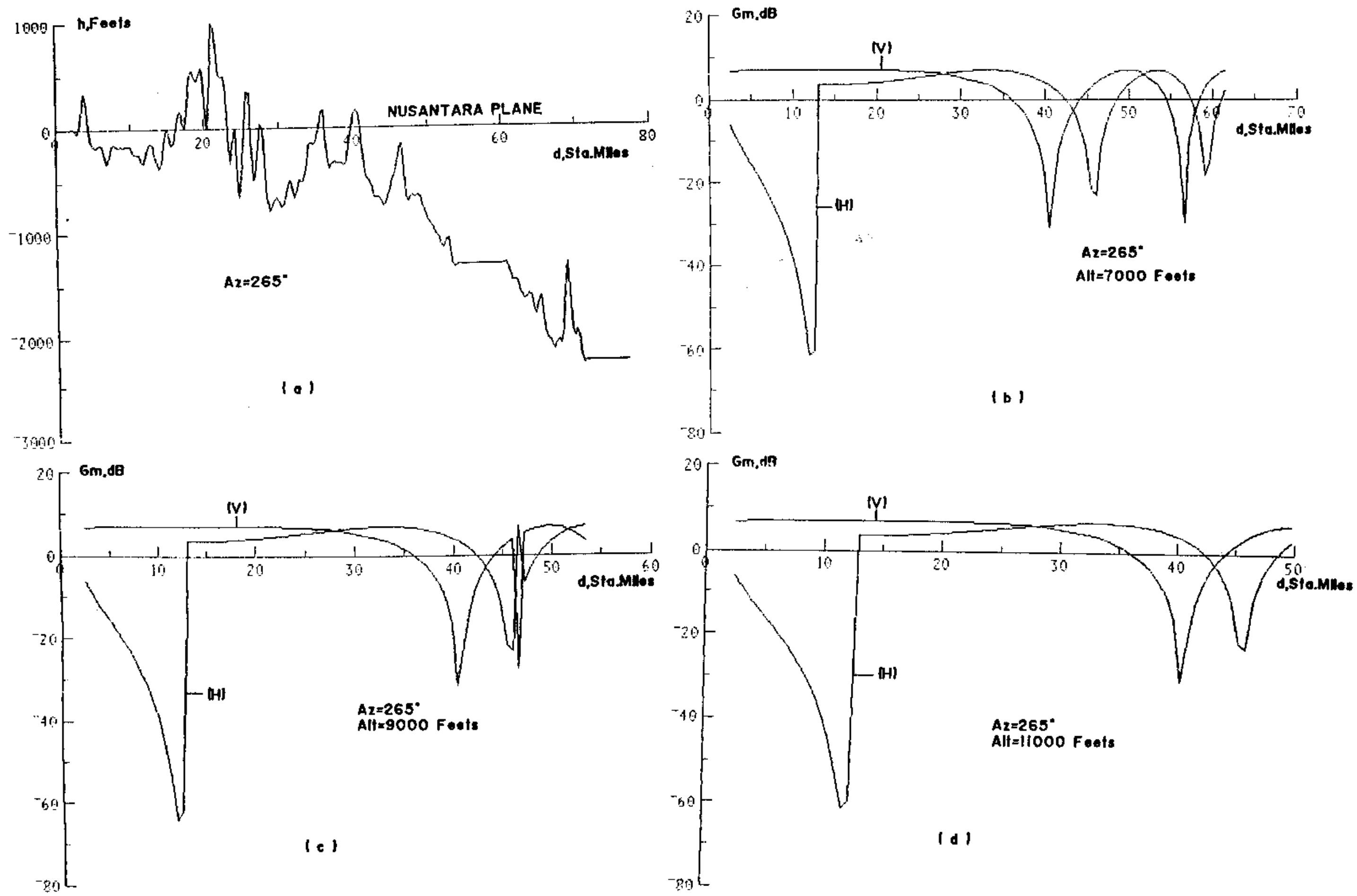

Figure 4 - Multipath fading estimation due to dry earth reflection, relative to the ground based receiving antenna at f_0 = 1531 MHz for azimuth 265°. (a) Surface profiles; $G_{MV,H}$ for (b) 7000 feets, (c) 9000 feets and (d) 11000 feets altitudes.

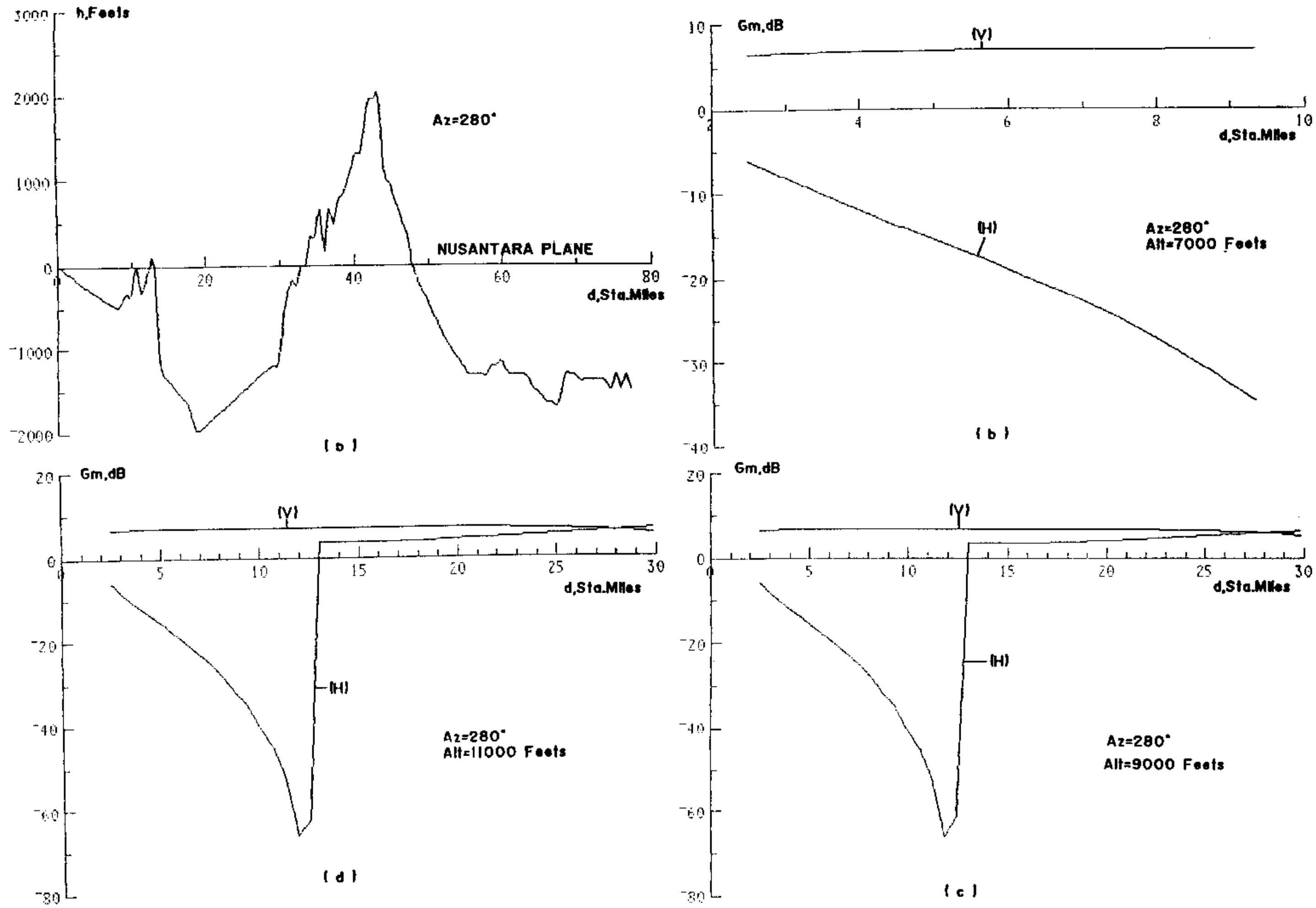

Figure 5-- Multipath fading estimation due to dry earth reflection, relative to the ground based receiving antenna, at f_0 1531 MHz for azimuth 280° (a) Surface profiles; $G_{MV,H}$ for (b) 7000 feets, (c) 9000 feets and (d) 11000 feets altitudes.

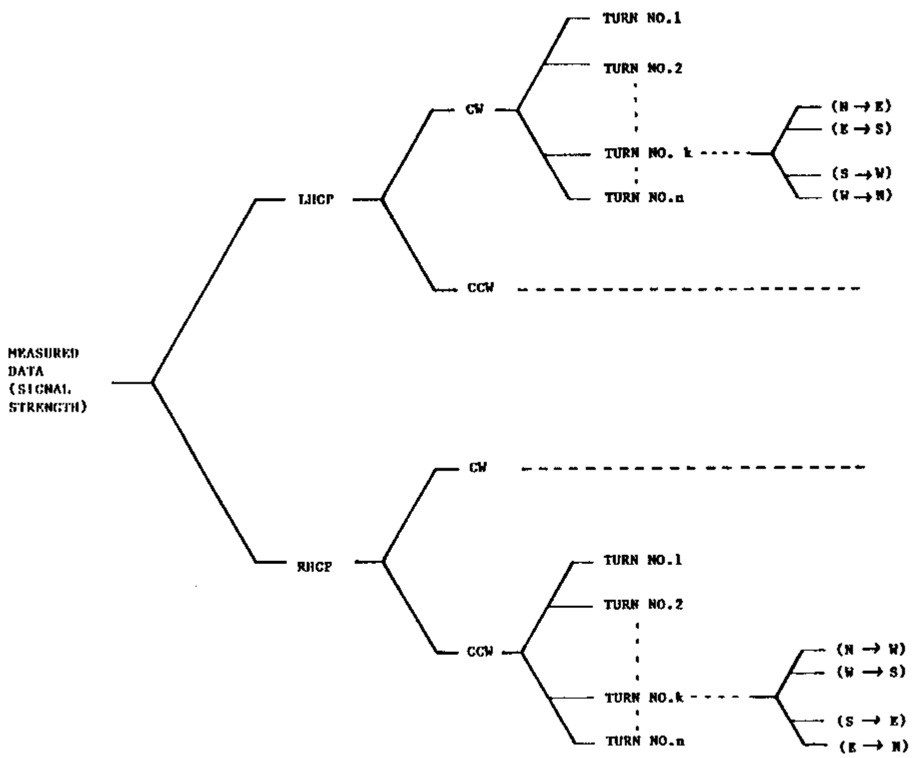

Figure 6 - Data structures as collected from the field experiments.

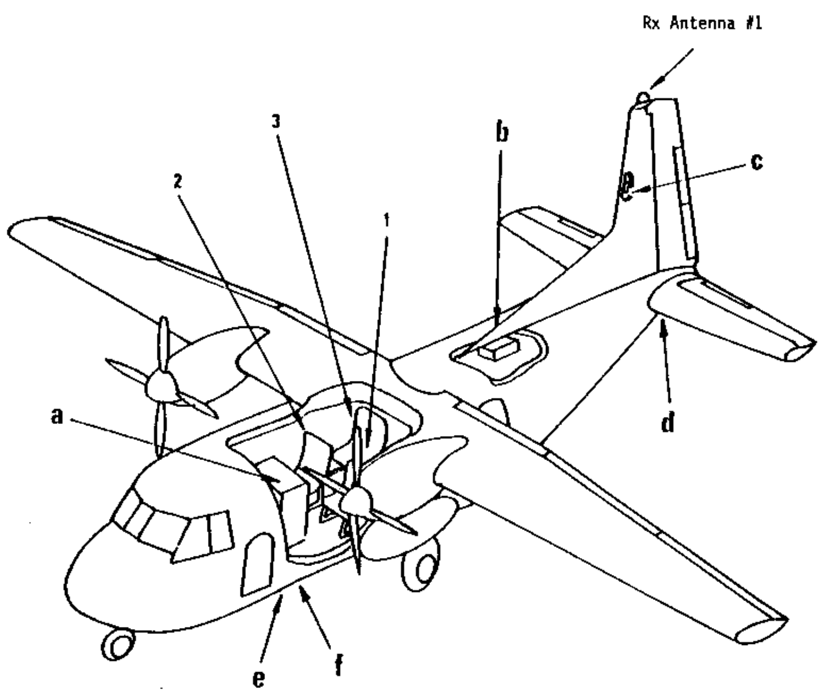

Figure 7 - Instrumented NC212-200 PK NZJ aircraft as ADReS. (a) Telemetry front end system, (b) L-band amplifilter unit, (c) L-band am -plifier #1, (d) R_x antenna #2 (bottom of tail cone, (e) L-band Tx antena (bottom of fuselage).

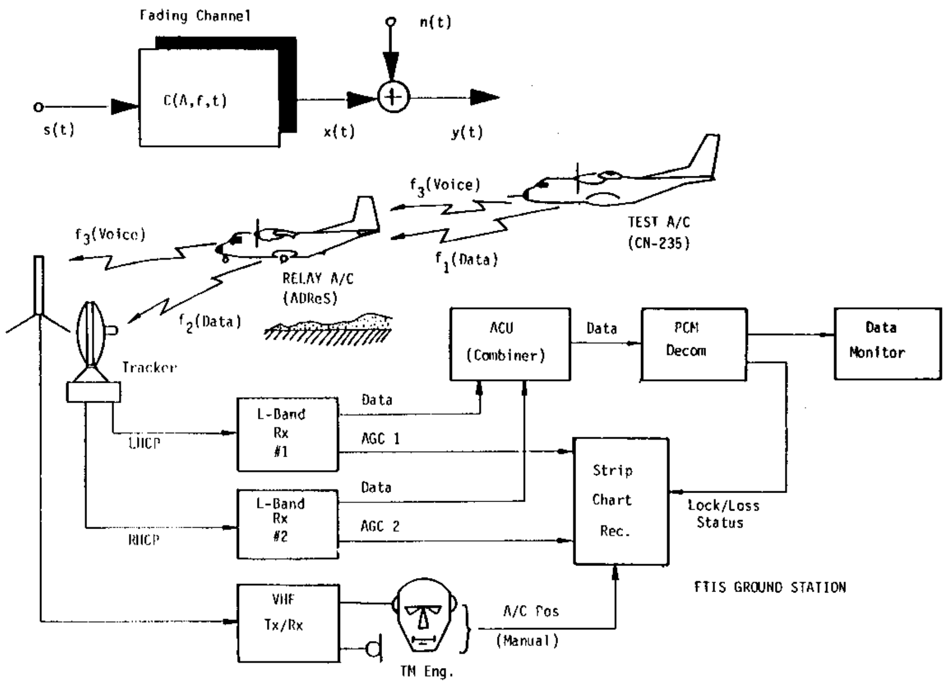

Figure 8 - The field experiment system configuration.

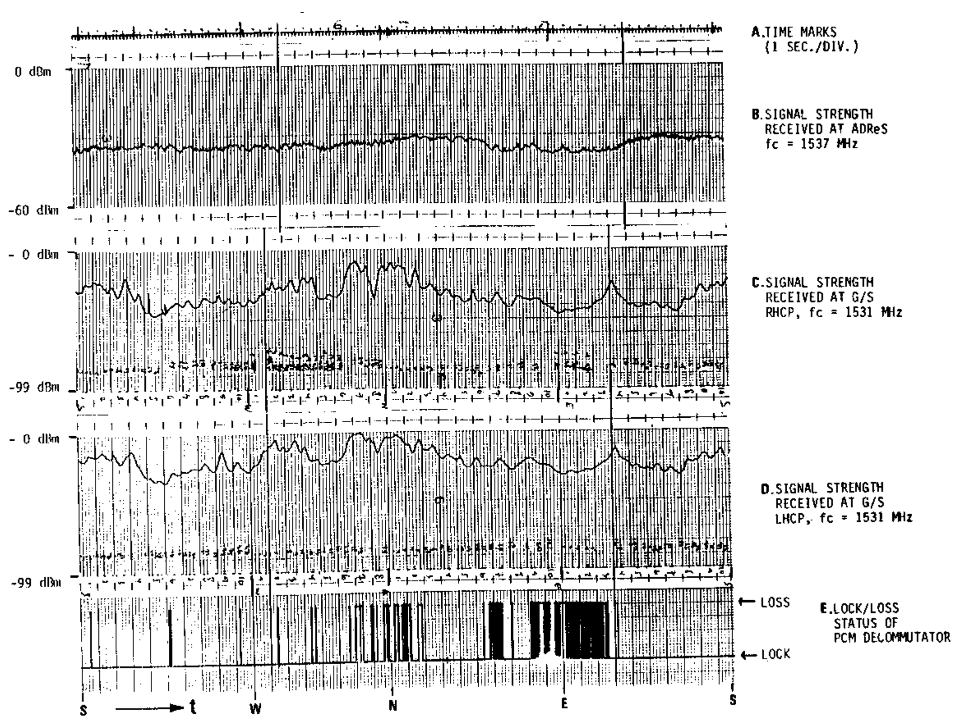

Figure 9 - The typical pattern of signal strength received at both reley aircraft and ground station during inflight experiments. This data was catched up when the relay air craft flown at altitude 10000 feets at azimuth 265° relative to the Bandung VOR and 64 SLa. Mi . slant range from the base station, whereas the test aircraft flown over Indonesian Ocean at 2000 feets and 23 Sta. Mi from relay aircraft.

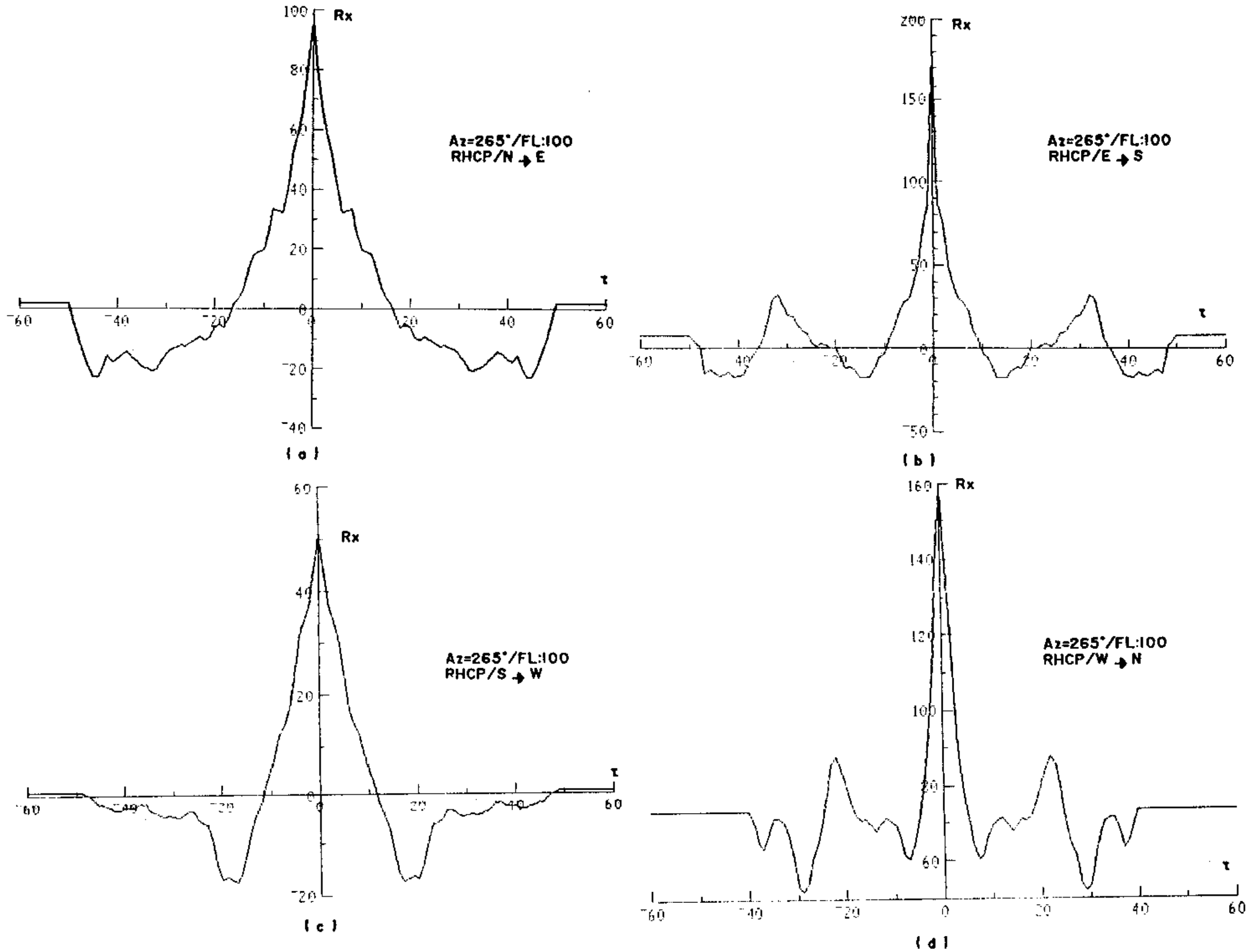

Figure 10 - Autocorrelograms of received RHCP signals at f_0 = 1531 MHz, for various aircraff headings at azimuth 265° and 10000 feets altitude. (a) heading N E, (b) heading E S, (c) heading S W, (d) heading W N.

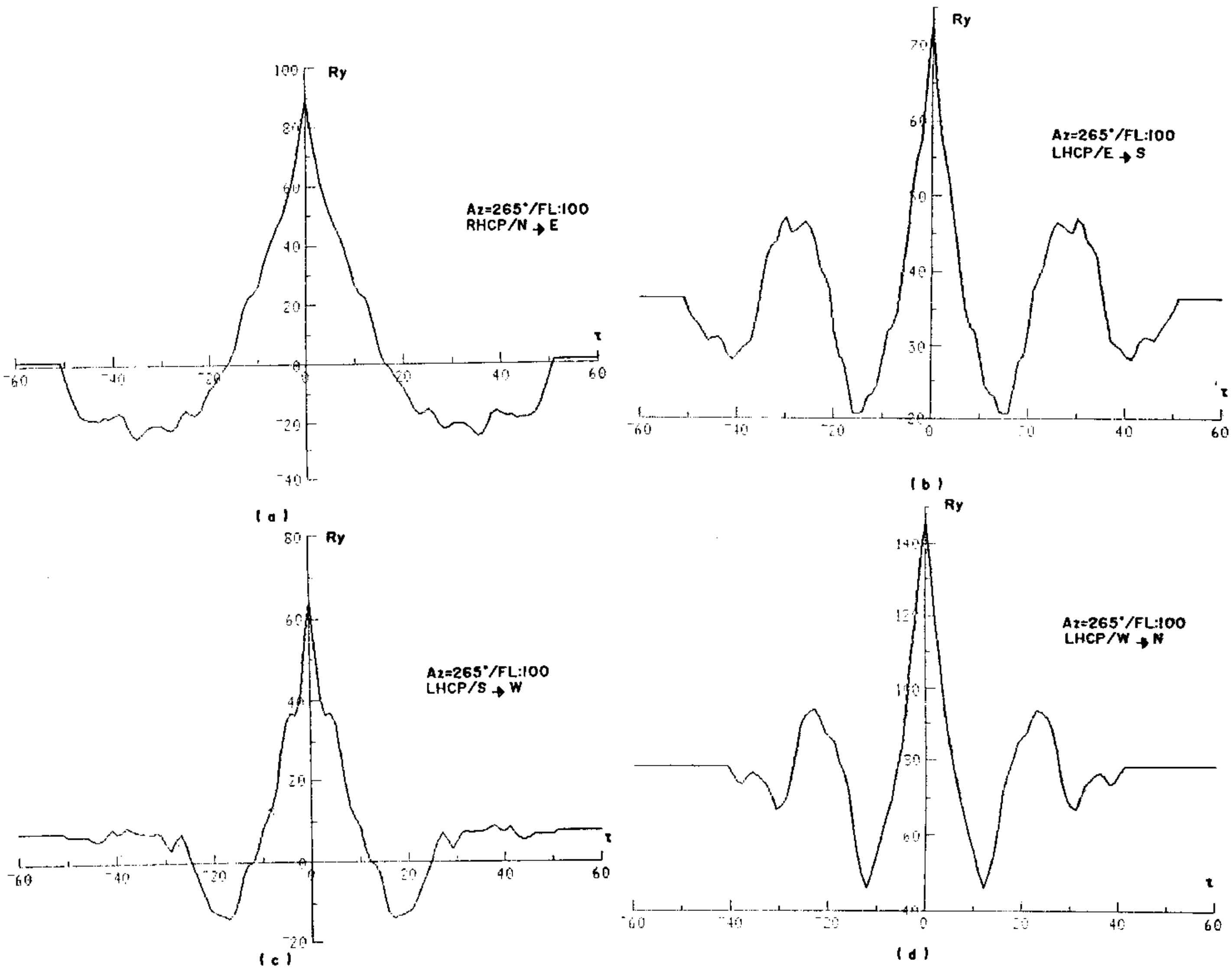

Figure 11 - Autocorrelograms of received LHCP signals at f_0 1531 MHz, for various aircraft headings at azimuth 265° and 10000feets altitude. (a) heading N   E, (b) heading E   S, (c) heading S   W, (d) heading W   N.

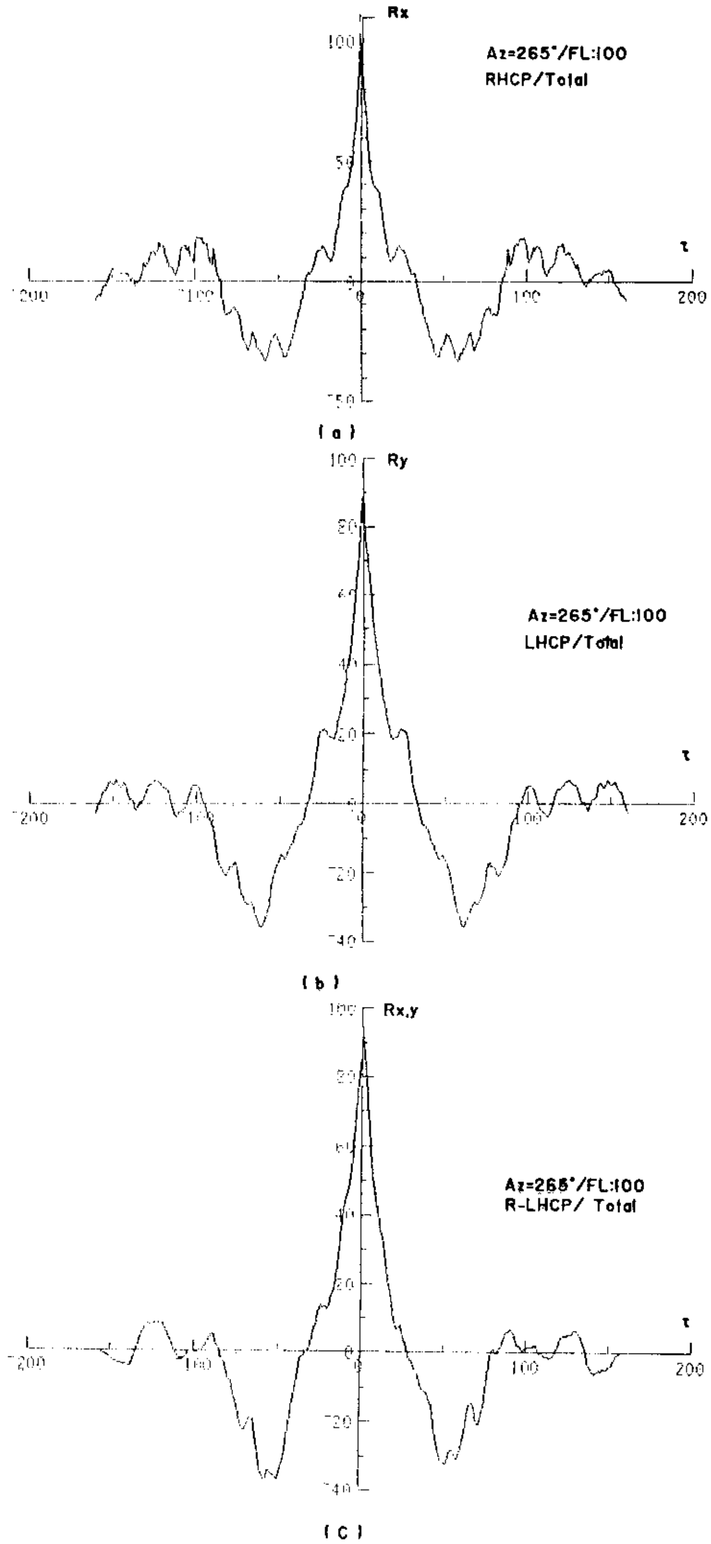

Figure 12 - Total auto and crosscorrelograms of both RHCP and LHCP signals at f_0 = 1531 MHz, for various aircraft heading at azimuth 265° and 10000 feets altitude. (a) R_x/RHCP, (b) R_x/LHCP, (c) Cross R_x/R-LHCP.

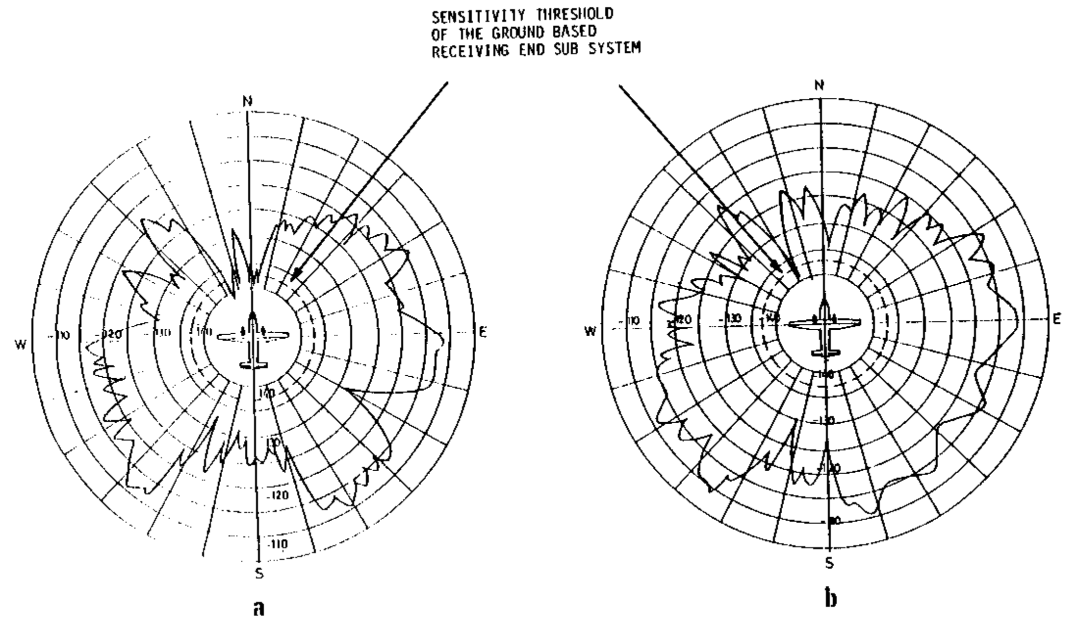

Figure 13 - A horizontal reception pattern diagram of ADReS transmitting antenna as measured by ground based receiving end system; relative aircraft position from base station " 265° azimuth, 64 Sta.Mi slant range and 10000 feets altitude : (a) 360° turn right, (b) 36° turn left.

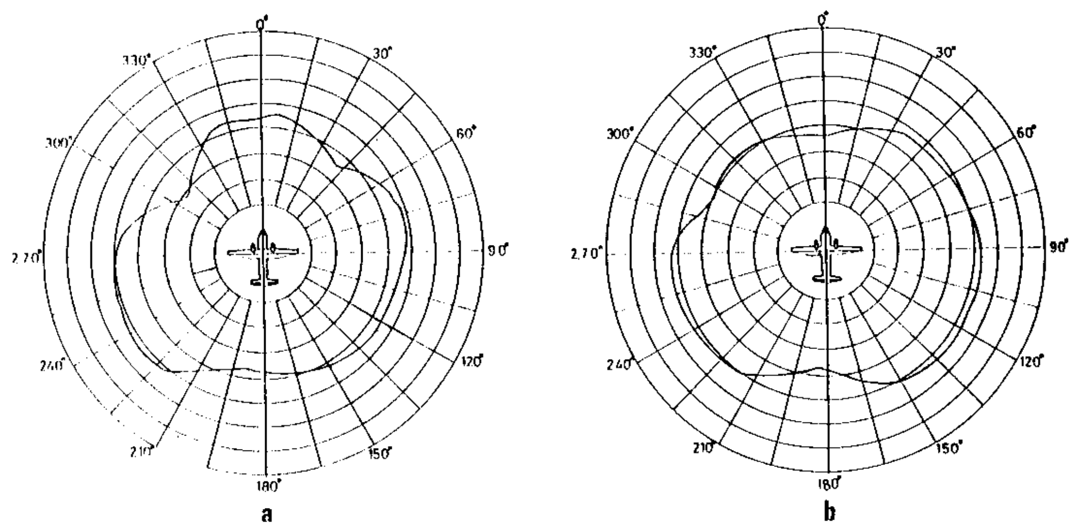

Figure 14 - A horizontal reception pattern diagram of ADReS transmitting ntenna as measured on ground; test location : runway 07 - 25, Soekarno-Hatta International airport. (a) 360° turn right, (b) 360° turn left.