STUDY OF AIRCRAFTSHADOWING EFFECTS DURING MANUEVERS FOR AERONAUTICAL TELEMETRY

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ABSTRACT

Typical aeronautical telemetry instrumentation for a fighter aircraft comprises of multiple antennas on the aircraft, with typical placement of one antenna on the spine of the aircraft and the other on the aircraft belly. Complimentary to the aircraft instrumentation, is the fixed ground station equipped with a tracking antenna. Air to ground channel for this telemetry link is considered as line of sight propagation. But there is a link loss observed at the ground station for a certain instant of time. Possible causes of link loss/attenuation in the case are due to aircraft manoeuvring. The main objective of this paper is to study and analyze masking patterns of the aircraft instrumentation scheme. Polarization diversity combining at the RF receiver and frequency diversity combining at the tracking receiver were explored at the ground station to mitigate the effect of RF fading due to antenna masking. The RF signal levels at the ground station are analyzed with respect to different aircraft attitudes. This paper also brings out the possible causes of the RF level drop and the solutions which can be explored to overcome it.

I INTRODUCTION

Aeronautical telemetry Flight Testing is carried out for health and performance monitoring of the developmental aircraft. In this scenario, the quality of the telemetry data is important as it is critical for ensuring flight safety. The air to ground telemetry link is a key component of test and evaluation of airborne systems such as aircrafts and missiles. Historically, aircraft links were comprised of a transmit antenna mounted on the underside of the fuselage and fixed ground station equipped with a tracking antenna but certain manoeuvres of the aircraft might block the required line of sight propagation path. The traditional solution has been to use two antennas on the aircraft radiating same signal, with typical placement of one antenna on spine and the other on the aircraft belly. The shadowing effect is discussed with coordinates (pitch, roll and yaw) related to aircraft manoeuvring as shown in **Fig 1(a).**

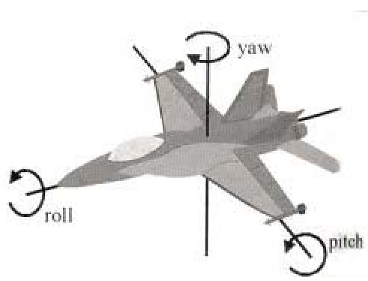

Fig 1(a)

This paper investigates the shadowing effect induced by a fighter aircraft during manoeuvring for air to ground communication at L- Band for Aeronautical Telemetry. A typical variation of RF level w.r.t aircraft coordinates is shown in **Fig 1 (b)**. The red colour in the flight path indicates an RF level below -60dBm, blue indicates RF level between -59 dBm and -50 dBm and green indicates an RF level above -39dBm. Measurements were carried out across multiple flights across various flight paths and the results were analyzed. It is found that the communication link can be easily shadowed by the aircraft body and the transmitted signal undergoes significant attenuation due to shadowing.

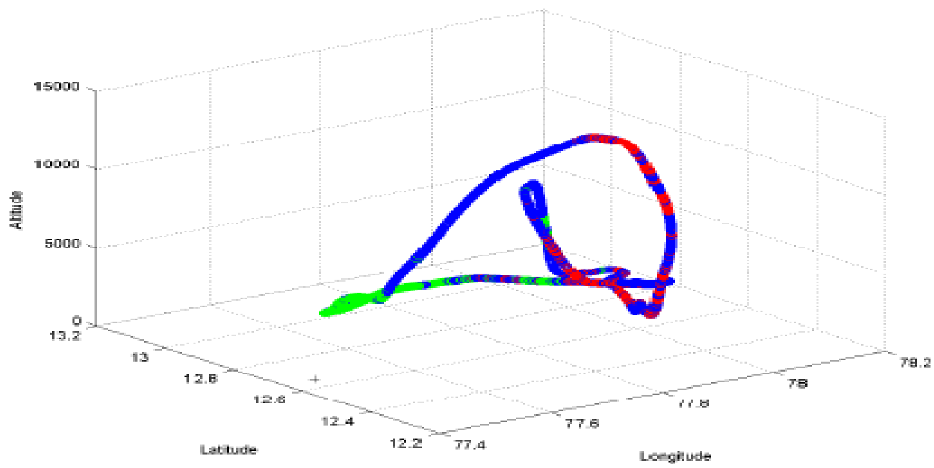

Fig 1(b)

II INSTRUMENTATION SCHEME

The typical RF transmission chain on the aircraft is as shown in Fig. 2(a). L Band FM transmitter with 12W transmitted power is used for modulating the data signal on designated L Band carrier. Two vertically polarized omni-directional blade antennas are used on the aircraft. Blade Antenna 1 is located on the aircraft belly and blade antenna 2 is located on spine of the aircraft. The output from the transmitter is fed to the two antennae through a power divider and power amplifier. As given in **Fig 2(a).**

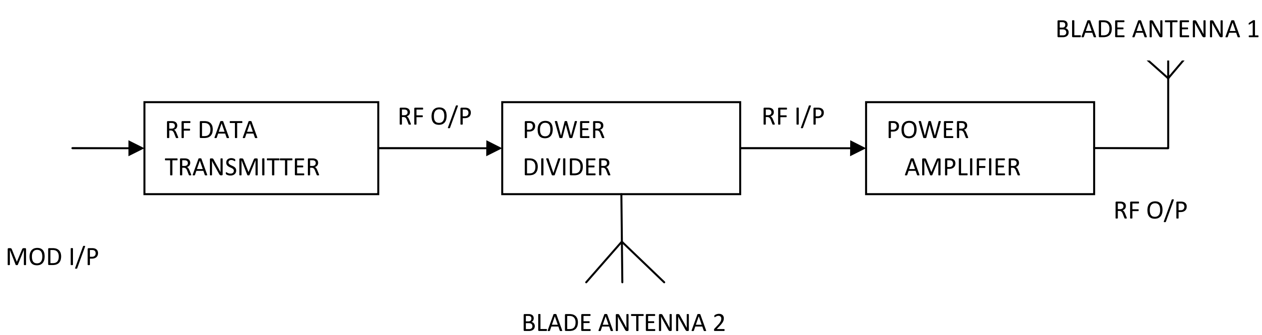

Fig.2 (a)

The power split between the antennas is typically 10 to 20 percent on the spine and 90 to 80 percent on the aircraft belly to reflect the fact that ground based telemetry receiving stations are generally looking at the belly of the aircraft during level flight. The top antenna comes into play when the aircraft is rolling or banking, causing the bottom antenna to be masked by the fuselage or the wings of the aircraft. In certain attitudes of the aircraft, both the antennas will be in line of sight of the ground station antenna. For this reason 50/50 power split is avoided in order to lessen the likelihood of having signal cancellation caused by both signals combining 180 degree out of phase at the ground station.

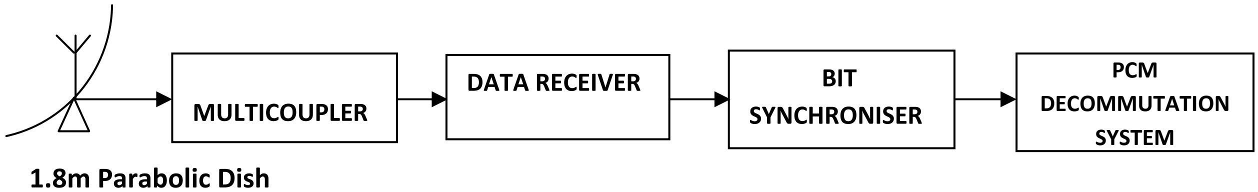

Fig 2 (b)

The typical ground instrumentation scheme is as shown in Fig. 2(b). It comprises of an auto track antenna system, L band FM Receiver and PCM Decommutation system. The antenna used for the measurement is 1.8 meter parabolic reflector antenna, whose gain is 24dbi with a beam width of 4.7 X 4.7. The RF signal is demodulated at the L band receiver and de-commuted, processed and acquired at the PCM decommutation system. To eliminate possible multipath effects and ground reflections E-Scan technique was used to track the aircraft and the tracking antenna was placed 50 feet above the ground level for the measurement. Detailed instrumentation scheme is given in [1].

MEASUREMENT SETUP

To study the shadowing effect by the aircraft at the ground station, during manoeuvring, data was collected from 25 flight sorties of the airborne platform.The data from the aircraft which includes aircraft parameters like pitch, roll, yaw, distance, pressure altitude, aircraft coordinates were acquired. Also antenna parameters throughout the flight were acquired from Antenna Control Unit (ACU) like received RF- levels, azimuth and elevation position of the tracking antenna. The data from the PCM Decommutation system and the ACU were combined to study and analyze the shadowing effect from the aircraft.

III RESULTS AND DISCUSSIONS

The data collected from different flights were analyzed and the behaviour of the RF signal levels at ground station based on the position and attitude of the aircraft were broadly classified into the following:

Aircraft heading (yaw) matching with ground station antenna azimuth-
When aircraft heading and the tracking antenna azimuth are matching, it indicates that the aircraft is moving away from the ground station. The acquired data was plotted and analysed. From the plot it was observed that, as the aircraft roll varies from 0 to -180and -180 to 180 degree, no significant variation was observed on the RF-Level. But when the aircraft does a positive pitching a RF level drop of 14 to 16dB was observed,while negative pitching does not

have anysignificant effect in RF level. Also it was observed that there was no significant variation in RF-Level with the aircraft heading. Hence, pitch up of the aircraft effects the RF level when the aircraft heading matching with antenna azimuth. Atthis condition aircraft was at a distance of 25km and altitude of 2000ft. As given in **Fig 3(a)**

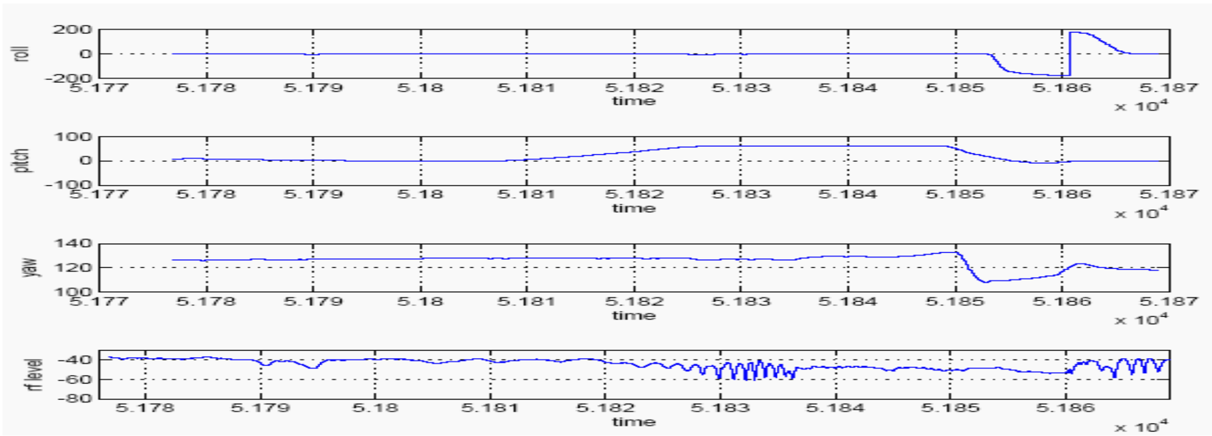

Fig 3(a)

Aircraft manoeuvring flight path-

1. Under this flight condition aircraft moving clockwise w.r.t the ground station is considered first. The aircraft yaw varies from 180 to 100 degree and roll varies from 0 to -60 degree simultaneously. The aircraft pitch is not a factor of RF-Level variation as observed in the plot. Under this condition RF-Level drop of 18 to 20dB is observed. As given in **Fig 3(b).**

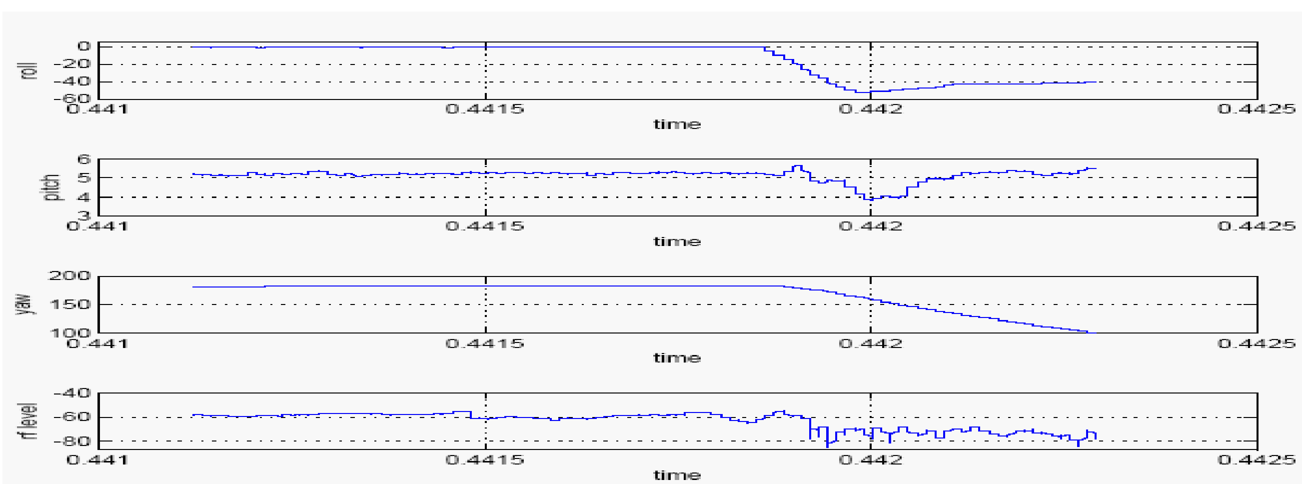

Fig 3(b)

2. Under this flight condition aircraft moving in anti-clockwise w.r.t the ground station is considered. The aircraft yaw varies from 355 to 180 degree and the roll varies from 0 to 55 degree simultaneously. . The aircraft pitch is not a factor of RF-Level variation as observed in the plot. At this condition aircraft was at a distance 75km and altitude 20000ft. As given in **Fig 3(c).**

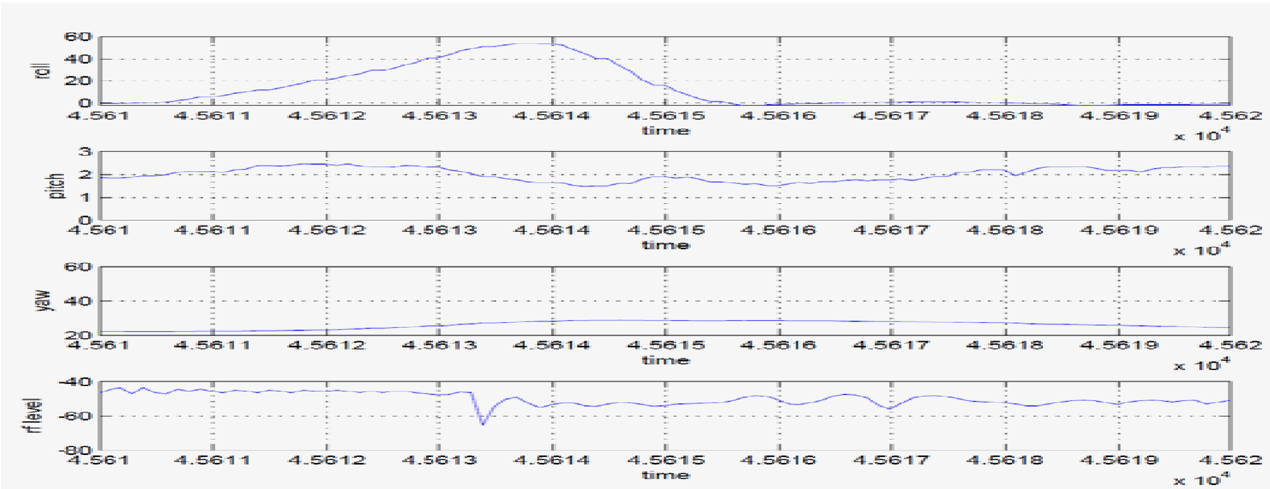

Fig 3(c)

Aircraft Roll Factor-

As the aircraft roll varies from 0 to 180 degree and from 180 to 360 degree the RF-level drop of 14 to 16dB is observed. Also it was observed that there was no significant variation in RF-level with the variation in aircraft heading and pitch. Hence roll factor affects the RF-Level in this flight condition. At this condition aircraft was at a distance of 50kms and altitude of 25000ft. As given in **Fig 3(d).**

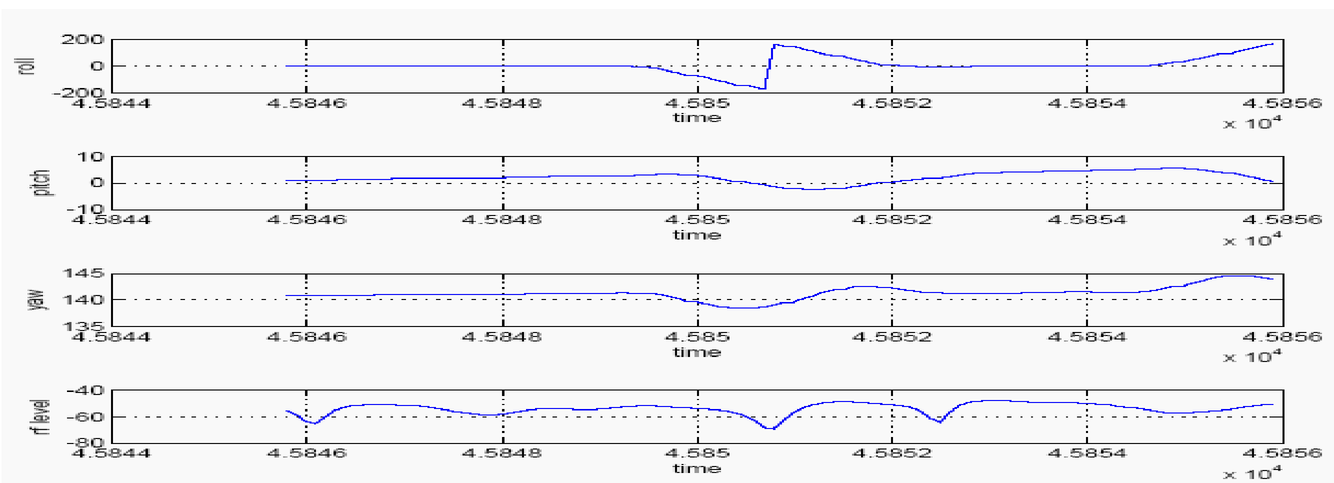

Fig 3(d)

The impact of RF-Level drop out is also observed using the analysis and is listed below:

- Video signal degradation- The Signal to Noise Ratio required for a good quality analog video is approximately 20 dB. The decrease in received RF level causes decrease in the SNR, there by degrading the overall video quality.
- Data intermittency-The Eb/No threshold value for PCM BiΦ-L signal as per IRIG 106 standards to maintain the bit error to $1x10e^{-5}$ is 14 dB. The decrease in RF level results in reduction in Eb/No from 14 dB thus increasing the BER.
- Link margin effect-The decrease in the received RF level will reduce the effective available link margin.
- Tracking Loss-The autotrack tracking antenna controller at the ground station tracks the aircraft from the tracking errors generated from the received signal. When the aircraft antenna gets masked completely the signal level reaches close to noise floor and the generated tracking errors will be noisy resulting in tracking loss. Fig.4(a) show a Noisy AM error and perfectly formed AM error during the aircraft tracking. As given in **Fig 4(a).**

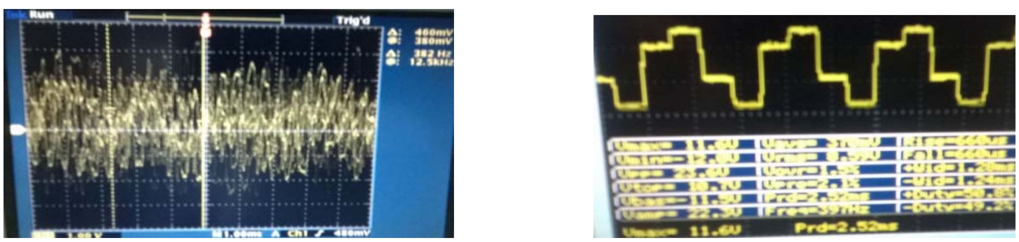

Fig 4(a)

CONCLUSION

The study indicated that when aircraft is moving away or towards the ground station antennae at right angles, the pitch of the aircraft plays a key role in the RF level drop. While the roll factor of the aircraft is the main cause of RF drop in a manoeuvring flight path when the aircraft moves in clockwise or anticlockwise direction from the ground station antenna. At a distance of more than 25 km from the ground station, the masking of the belly antenna causes a significant RF level variation. The impacts of this decrease in the RF signal strength on the video signal, the PCM data, the decrease in the link margin and the resultant tracking signal lose has been brought out. This problem can be mitigated by the following:

1. Modification of the antenna mounting scheme on the aircraft
   The relocation of the vertically polarized omni directional antenna on the spine of the aircraft to the fin may lead to significant improvement in the RF signal strength during manoeuvres. Theoretically the placement of the antennas on the fin will avoid

the masking irrespective of aircraft movement and may thus lead to increased RF signal.

2. Polarization diversity combining at the ground station
   Fig. shows the received RF signal at RHCP and LHCP with respect to the aircraft attitudes. It is observed that in certain conditions of the flight, when there is a considerable decrease in signal strength in one polarization, the signal strength in the other polarization is upto 15 db higher. Thus by using polarization diversity combining at the ground station, the overall RF level at the ground station can be increased thus mitigating the effects due to the same. As given in **Fig. 5(a).**

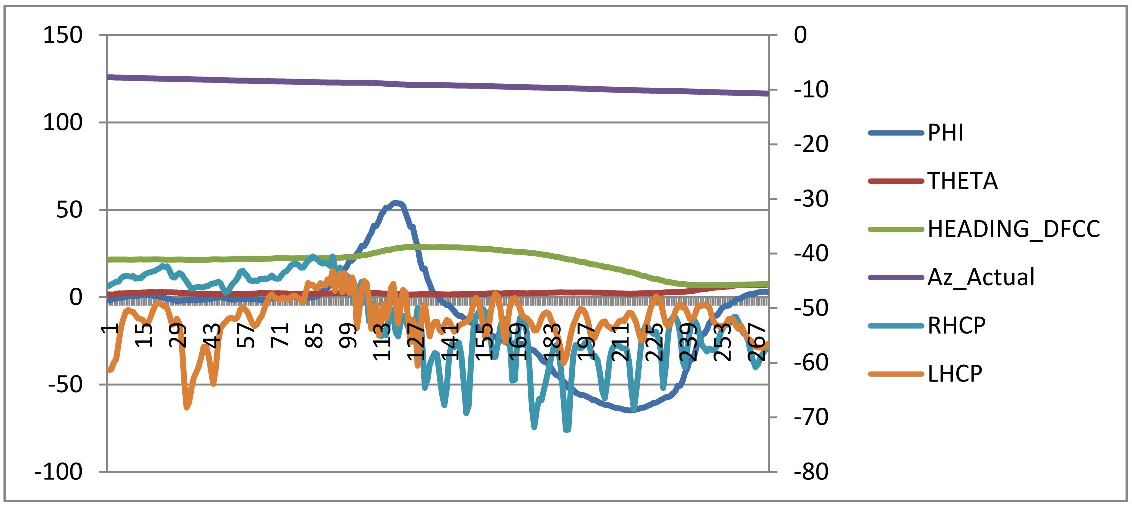

Fig.5 (a) RF level Plots with polarization diversity

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