Investigation of Low Altitude Air-to-Ground Channel over a Tropical Sea Surface at C Band

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Abstract—This paper investigates a low altitude air-to-ground channel over a sea surface in the tropical region at C band. It is found that, compared to a high altitude air-to-ground channel where a free space propagation condition can be assumed, the sea surface reflection and other multipath propagation phenomena for lower altitude air-to-ground channel can readily be observed. Therefore, for low altitude flight paths, spatial diversity at the ground station can be used to overcome signal degradation.

1. INTRODUCTION
Due to the rapid increase in aircraft density, the current air traffic control (ATC) system that operates at VHF band is fast becoming saturated. Therefore, an alternative frequency band is introduced for traffic control communication systems in order to satisfy this increasing demand. At present, C band is assigned for Microwave Landing System (MLS) in aviation navigation. In order to optimize the MLS performance at C band, thorough air-to-ground channel measurement in order to perform characterization is important.

Matolak et al. [1] started an interesting piece of research work on wireless channel characterization for the 5 GHz MLS system in 2007. They covered the characterization of both small and large size airports, mainly using wideband characterization. In addition to this work, Tu et al. [2] conducted a comparative study of the conventional VHF system and the MLS C band system. The focus of both studies [1, 2] concentrates on the propagation over land environments. However, little research work is done on the study of the air-to-ground link over a sea surface at C band. The evaporation duct is a well recognized form of propagation mechanism that can result in a substantial increase in signal strength when signals of frequencies above 3 GHz propagate over-water paths [3]. Therefore, there is interest in the investigation of the air-to-ground link near to a tropical ocean. These results are important to modern military and commercial applications for a seashore country such as Singapore.

As a continued work of our previous studies [4, 5]; C band channel characterization at a small airport [4], and air-to-ground channel investigation over a sea surface at high airborne altitude (20 kft to 40 kft) [5], in this study, a series of air-to-ground channel measurements at low airborne altitudes (1.2 kft to 6 kft) are conducted over the sea surface in the tropical region. The main objective of this paper is to report on the preliminary study of the spatial diversity at the ground station for the improvement of signal quality of the communication links. This is helpful for future research work in this area.

2. MEASUREMENT CAMPAIGNS
Wideband channel measurements with low airborne altitudes were conducted at 5.69 GHz over the South China Sea in February, 2009. The system hardware is upgraded and improved as compared to the previous one in [4, 5]. A vertically polarized, omni-directional blade antenna is mounted on an aircraft. The Effective Radiated Power (ERP) from the blade antenna is 40 dBm. One of popular spread spectrum techniques, maximal-length pseudo-noise (PN) sequences (“m-sequences”) is implemented at the transmitter as in [1] and [6]. In our measurement, a 511-bit PN sequence is transmitted at 20 Mchips/s data rate and modulated with Binary Phase Shift keying (BPSK). This allows for a spatial resolution of 15 m and a high processing gain relative to the sounding in [1, 6]. During the flight, GPS data was logged continuously through GPS modem installed on the aircraft throughout the experiment so as to obtain instantaneous altitude, longitude, latitude, pitch and roll coordinates of the moving aircraft.

At the receiver, two identical directional antennas with a beamwidth of 20° in azimuth and 25° in elevation as shown in Figure 1(a) are used to create diverse receptor as shown in Figure 1(b). The received signals are amplified and down-converted to an intermediate frequency (IF) of 22 MHz,
and then recorded by a GPS time-stamped data logger at 100 Msample/s. Details of the data logger and its performance can be obtained in [7]. The total gain of each front end of the receiver is 84.5 dB. All the data recorded are time stamped with the GPS time in order to synchronize the data collected with the aircraft location.

The reception site ($1^\circ20'07''N$, $104^\circ01'16''E$), as shown in Figure 1(c) is directly at the coast. The site is selected in order to ensure that the propagation is mainly over the sea surface and there is no blockage of the propagation signal. During the measurements, the on-site weather condition is recorded by a portable weather station, WeatherHawk, as shown in Figure 1(d).

3. RESULTS ANALYSIS

3.1. Sea Surface Reflection

The measured signal is down-converted to its baseband signal via a software program. The baseband signal then undergoes cross-correlation with a copy of the known original 511-bit PN sequence. This will produce the complex channel impulse response $h(\tau)$ as

$$h(\tau) = \sum_{k=0}^{M} a_k \exp(j\varphi_k) \delta(\tau - \tau_k)$$

where $a_k$, $\tau_k$, and $\varphi_k$ are the signal strength, the propagation delay and the phase shift of the $k$th multipath component. $M$ is the number of multipath clusters. The power delay profile is the envelope of the received power and is proportional to $|h(\tau)|^2$. Examples of the measured power delay profile are shown in Figure 2.

From Figure 2, there is several multipath components in the air-to-ground channel at lower flight altitude (1.2 kft) as compared to results at the higher flight altitude (10 kft). This might be due to the sea surface induced reflection. Our experimental results show that, as the flight altitude is low, there is a higher probability for the appearance of multipath components. This multipath component can degrade the signal quality.
3.2. Diversity at Reception

In order to improve the quality of the communication link for the air-to-ground channel, spatial diversity at the reception as in Figure 1(b) is examined. Figure 3(a) shows the typical results for the synchronized signal to noise ratio (SNR) at the two branches when the flight altitude is about 1.2 kft, where there is a high probability of the signal degradation due to the multipath component. The results in Figure 3(a) show that the diversity effect is obvious at the diverse receptors. A selective combining is implemented and the results shown in Figure 3(b). As shown in Figure 3(b), selective combination can improve the link performance for the air-to-ground channel at lower flight altitude.

4. CONCLUSIONS

This paper presents a preliminary study of the air-to-ground channel over the sea surface at low flight altitude. A measurement campaign conducted in February 2009 over the South China Sea is presented. From the results, it is observed that, sea surface reflection can occur especially when the flight altitude is low. This multipath component can degrade the quality of the propagating signal. Therefore, a popular fading mitigation technique, spatial diversity is applied at the receiver side, and found to improve the communication link significantly.

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REFERENCES


