Preliminary Scintillation Data Analysis of measurements done in CASPER West

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***Abstract*—In this paper, the measurement done pertaining to scintillation in CASPER West experimental campaign is described and preliminary data analysis of the measured data is presented. The variation of the signal due to scattering from the rough ocean is shown to match with previous predictions.**

I. Introduction

Small-scale fluctuation of the refractive index of the atmosphere leads to the amplitude variation of the signal received, a phenomenon termed as scintillation. Such scintillation, especially at high frequencies, may cause fast fading of the signals which becomes a major hindrance for low margin systems. Hence, it is essential to predict the worst case fading possible, given the atmospheric properties of a region.

The fade depth can be obtained through simulations. Large Eddy Simulations (LES) is a computational fluid dynamics tool which provides a 3D refractive index profile with the turbulence effects over a region. 2D parabolic equation (PE) based EM propagation models, like Advanced Propagation Model (APM), uses these refractivity profiles to obtain the propagation loss of a signal at a desired range and height. Several 2D realizations can be obtained from the 3D profile to perform a Monte-Carlo analysis, providing a distribution of propagation loss from which the fade depth can be obtained.

The Coupled Air-Sea Processes and Electromagnetic (EM) wave ducting Research (CASPER) [1] is a multi-university research initiative to better understand the propagation of radar and communication signals in marine environments. The CASPER West is the second of the two planned field campaigns, conducted on the month of October 2017, offshore of Pt. Mugu, California. One of the goals of CASPER West was to make extensive scintillation measurement so that the simulation model developed can be validated. In this work, we describe the experimental methodology for the CASPER West scintillation measurement and preliminary analysis of the obtained data.

II. Scintillation Measurement Setup

CASPER West leveraged the research platform R/P FLIP and the research vessel R/V Sally Ride on the Pacific Ocean for various measurements conducted during the one month period. The R/P FLIP was the stable platform and the R/V Sally Ride was the mobile platform moving between the shore and the R/P FLIP. The scintillation measurement was done with the transmitter placed on the R/P FLIP, while the receiver was placed on the shore. The transmitter system consisted of a signal generator (Agilent model no. E8257D) which generates continuous wave (CW) signals with frequencies ranging from 2-40 GHz, power amplifiers and two horn antennas: one operating from 2-18 GHz and the other one operating from 18-40 GHz. The receiver system had high gain wide band dishes, low noise amplifiers, and a signal analyzer (Agilent model no. N9060). The received signal power was measured at the frequencies of 2.02 GHz, 5.25 GHz, 10.01 GHz and 17.31 GHz and all the signals were vertically polarized. The two antennas used for the measurement were placed at a height of 12.74 m and 13.63 m respectively and were separated by a distance of 49.76 km. Each measurement involved measuring the power continuously for a time interval of 15 minutes at one of the four selected frequencies. The decorrelation time of the random process describing the atmospheric fluctuation and that of the rough ocean surface is less than 100 sec [2], [3]. Hence, an interval of 15 minutes (900 sec) was chosen for the measurement since it is much longer than the time scale of the decorrelation. The measurement was repeated multiple times a day for the entire one-month long experimental campaign.

In this paper, we present the measurements done on October 20 2017, for a CW signal at 10.01 GHz, as shown in Fig. 1(a). The blue dashed line in Fig. 1(a) is the power of a direct beam propagating in free space, which is calculated from the Friis transmission formula. The variation of the gain of the signal level over the free-space power level in Fig. 1(a) is due to the combined effects of ducting, interference of multiple rays reflecting of the rough ocean and scintillation.

III. Data Analysis

As discussed in the previous section, the measured power variation is influenced by multiple factors for which a detailed analysis needs to be done to isolate these effects from the measurement. Here, we present preliminary data analysis. The spectrum due to atmospheric fluctuation is expected to have a dominant region within 0.01 to 0.1 Hz (10-100 sec) [2]. Also, the power spectrum of the propagation gain F, defined as $F = \frac{E_d+E_s}{E_d}$, where E_d is the direct field which is obtained in free space without the presence of any surface, and E_s is the scattered field which is radiated from the induced currents on the ocean surface, with a dominant region within 0.22 to

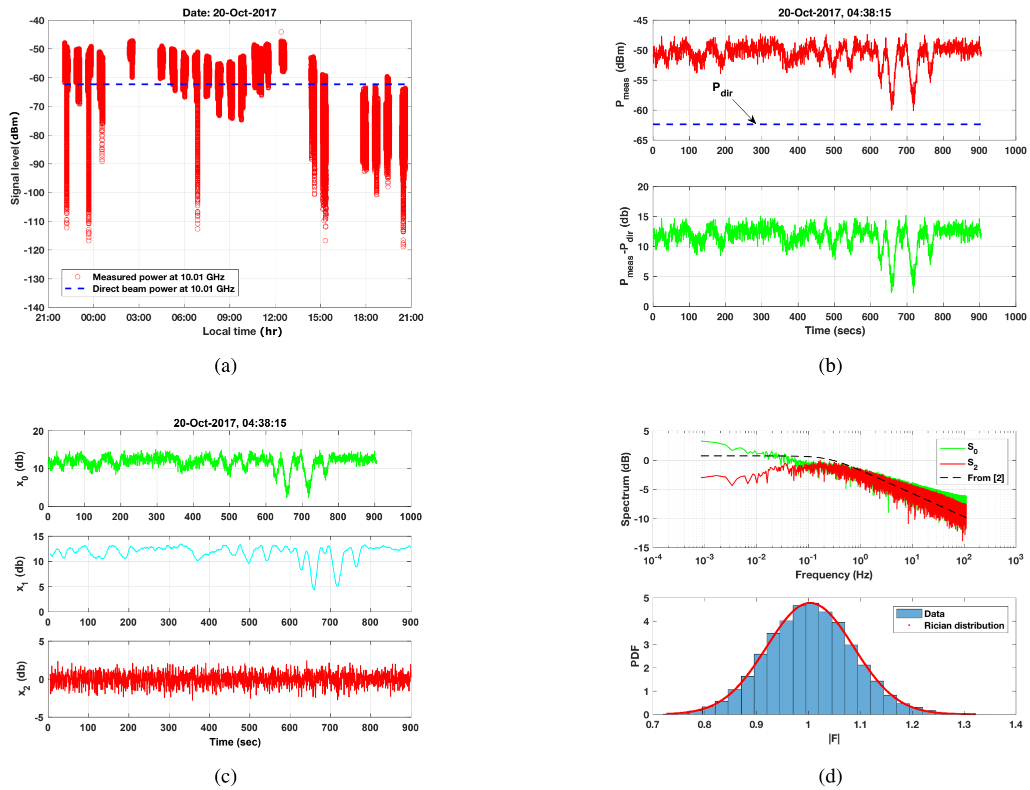

Fig. 1: Plot of (a) Measured signal with local time on Oct 20, 2017, (b) Measured signal with time on Oct 20, 2017, zoomed at 04:38:15, (c) Propagation factors, x_0, x_1 and x_2, with time, (d) Spectrum of x_0 and x_2, S_0 and S_2 respectively, and fitted spectrum in [3] and PDF of $10^{(x_2/20)}$.

0.09 Hz (5-10 sec) for wave velocities varying from 5 m/s to 15 m/s [3]. The power corresponding to the field E_d is $P_{dir} = 20\log_{10}(|E_d|)$, which is calculated from the Friis transmission formula. The received power measured (P_{meas}) is $20\log_{10}(|E_d + E_s|)$. The propagation factor in dB which is expressed as $x_0 = 20\log_{10}(|F|)$ is obtained by subtracting P_{dir} from P_{meas}, and is shown in Fig. 1(c).

Considering the difference in decorrelation time scales of the random process describing the ocean surface and the atmosphere fluctuations, the slow scale variations due to the atmosphere in the received power is filtered out with a moving average low pass filter of length 10 sec. The moving average filter applied on x_0 results in x_1, which when subtracted from x_0 yields x_2. x_2 represents the propagation factor with fluctuations due to scattering of the ocean surface and has a decorrelation time scale of less than 10 sec. The propagation factors x_0 to x_2 have been plotted in Fig. 1c. The spectra of x_0 and x_2 are plotted in Fig. 1(d) and the spectrum of x_2 matches well with the fitted spectrum expression in [3]. Moreover, the fitted distribution of $|F|$ turns out to be Rician as mentioned in [3].

The fluctuations of the heading of the stationary platform R/P Flip might have affected the signal fluctuations presented in this preliminary analysis. Future work will include the corrections due to the heading fluctuation of R/P Flip and the variation of the antenna gain. Further processing also needs to be done to obtain the distribution of signal variation due to atmospheric turbulence.

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